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This fourth volume in the history of the Navy at China Lake is a "must read" for Navy Military and civilian leadership today. The Station Comes of Age examines the years between 1959 and 1967, a critical era in the China Lake Story. Interestingly, this timeframe is also pivotal in our nation's history, encompassing the Cold War, the space race, and the Vietnam conflict.
This fourth volume of our history meets the high standards established in the first three volumes, and it candidly captures China Lake's contributions to this interval in history.

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> "With lucid descriptions of technical innovations and bureaucratic entanglements, Cliff Lawson brings a decade of the creative programs and people at the Naval Ordnance Test Station, China Lake, to vivid life in *The Station Comes of Age*. Readers interested in military history will relish learning about some of the world's most effective weaponry; all readers will enjoy the dozens of tales told in the participants' own words."
>
> *— Elizabeth Babcock*
> *Author of Magnificent Mavericks*

Bill Stephenson created the cover art for *The Station Comes of Age*, which depicts several of the people and programs that contributed to the success of the Naval Ordnance Test Station in its final decade of existence. Bill is a design artist for the Technical Communication and Library Office at the Naval Air Warfare Center Weapons Division, China Lake.

At left is Dr. William B. McLean, the legendary Technical Director who inspired and developed the Sidewinder missile and shaped China Lake's technical programs from 1954 to 1967. His far-reaching genius encompassed development efforts ranging from submarines to satellites. Next to McLean is Dr. Pierre Saint-Amand, a Fulbright scholar, teacher, inventor, and world-renowned geologist. Saint-Amand pioneered the use of weather modification as a tool of peace as well as a weapon of war. At top center is Frank Knemeyer, an engineer and one of the most successful managers in NOTS history; his career at China Lake ranged from project engineer for Elsie (the Mk 91 nuclear penetrator) to head of the Weapons Department, Weapons Planning Group, and Systems Acquisition Group. He was a strong and effective proponent of the Chine Lake's "Smart Buyer" role. Dr. Peggy Rogers, at right, was a trailblazer. As a physicist, college professor, and China Lake's first woman department head (Weapons Development) and Laboratory Director, she oversaw the development of some of NOTS' most important weapons, including Snakeye and Rockeye.

At upper left, launched from an F4D "first stage" is NOTSNIK, China Lake's first foray into space. To the right is an A-4, the principal Navy attack aircraft of the Vietnam War, launching a China Lake-developed Shrike antiradiation homing missile. Below the A-4 is a stick of four Snakeye retarded bombs, developed by NOTS for close-air support of ground troops. At lower right is an AD-1, the workhorse prop-driven aircraft that served in Vietnam as a launch platform for most of China Lake's air-to-surface weapons. At lower left, wet-suited engineers test the two-man submarine Moray, Dr. McLean's concept for an "underwater fighter plane." At center is Sidewinder, which, from its first combat use in 1958 to the present day, has been the Free World's premier short-range air-to-air missile.

The Station Comes of Age

History of the Navy at China Lake, California
Volume 4

THE STATION COMES OF AGE

Satellites, Submarines, and Special Operations in the Final Years of the Naval Ordnance Test Station, 1959-1967

By

CLIFF LAWSON

With an Introduction by

DR. JAMES E. COLVARD

Published by NAWCWD
China Lake, CA, 2017

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Naval Air Warfare Center Weapons Division.

UNITED STATES NAVY
NAVAL AIR WARFARE CENTER
WEAPONS DIVISION
CHINA LAKE, CALIFORNIA
2017

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Foreword

This fourth volume in the history of the Navy at China Lake is a "must-read" for Navy military and civilian leadership today. *The Station Comes of Age* examines the years between 1959 and 1967, a critical era in the China Lake story. Interestingly, this timeframe is also pivotal in our nation's history, encompassing the Cold War, the space race, and the Vietnam conflict.

This fourth volume of our history meets the high standards established in the first three, and it candidly captures China Lake's contributions to this interval in history.

Of equal importance is Cliff Lawson's portrayal of the significance of the Navy's in-house research, development, test, and evaluation capabilities in the transition and fielding of new, innovative weapons and technology.

The Navy has a tradition of being an early adopter of new technology; during these years the tradition was embraced to an even higher degree. China Lake's technical agenda during this period was amazingly broad, spanning from space to underseas, weapons to weather modification, military actions to humanitarian assistance, and booby traps to nuclear warfare.

This was an era when technology was exploding, the importance of the military and scientist linkage (that grew out of the early California Institute of Technology days) was greatly reinforced, and the Navy's role was expanding to include land warfare.

Most significantly, Navy leaders recognized these areas of growth and took action. They continued to emphasize the importance of supporting and managing technology development as an element of a naval officer's career, and they reorganized to establish a laboratory structure that would underpin and facilitate the Navy's movement into the technological era. These stories are all astutely captured in *The Station Comes of Age*.

Lawson keenly describes the contributions of innovation, technology, organization, and freedom, from the lashings of bureaucracy to China Lake's substantial success in executing its mission, which was to develop and rapidly field new weapons and air warfare systems to the Fleet.

The scientist-military relationship that evolved during this period was also a significant contributor to China Lake's achievements. This relationship led to the realization of the quick improvements needed to hone the military utility and effectiveness of our weapons systems in Vietnam.

Beyond the Station's security fence, China Lake's engineers rode ships, were assigned to theaters of operation, staffed desks in Washington, DC, and traveled to all corners of the earth to ensure the effective execution of the Naval Ordnance Test Station's mission for the Navy.

NOTS employees invented new weaponry through the application of technology as demonstrated in Polaris, Shrike, Walleye, and other "Eye" weapons. These workers organized to nurture innovation through competition, both internally and externally, and had a willingness to take risks. NOTSNIK, the Station's response to Sputnik, is a key example.

China Lakers routinely asked "Why not?" instead of "Why?" when faced with new ideas and often shunted the bureaucracy aside when it became a barrier, as was the case in efforts in weather modification technology and uses. This volume clearly exposes the contributions of each in the Station's efforts to ensure that our sailors had an advantage in the wars they fought.

Lastly, this history captures what the radio broadcaster, Paul Harvey, affectionately called "the rest of the story."

Specifically, the successes of China Lake during this period were supported by the resources made available through its continuing relationships with the California Institute of Technology, the military leadership that was initially located at the Station but moved to higher-level assignments in the Navy, and the isolated community inside the fence of the Station. All these were important factors. The former set the values: innovation, can-do attitude, technical competence, and the freedom to think differently. Supportive Navy leadership enabled and embraced action. The Station community provided a neighborhood, unity of purpose, encouragement, and a strong sense of pride.

All these factors make China Lake a crucial naval asset when *The Station Comes of Age* in the 1960s.

SCOTT M. O'NEIL
Executive Director and Director of Research and Engineering
Naval Air Warfare Center
Weapons Division

MICHAEL MORAN
Rear Admiral, U.S. Navy
Commander
Naval Air Warfare Center
Weapons Division

Preface

The Station Comes of Age is a partial history of the Navy's presence at China Lake. The story begins in 1959, 16 years after the Naval Ordnance Test Station (NOTS) was established, and concludes in 1967. More than four decades later the organization is still going strong. The rich slice this book takes out of China Lake's past is not presented as a straight-ahead chronological narration of events. To maintain focus and continuity, I have discussed sequentially threads that, in real life, ran in parallel.

Volumes 1, 2, and 3 of this series recount the first 15 years of NOTS history. Those volumes total 1,344 pages. The depth of treatment for the 10-year span covered in this fourth volume is, perforce, influenced by length constraints.[1]

Volume 4 intends to capture the major players and the important projects of NOTS and to contextualize them in the Navy, the nation, and the world. While China Lakers have historically taken a perverse pride in their isolation, the base has been a dependent variable in a complex equation of national defense, economics, politics, and culture. To understand a weapon system, one should consider its sponsors, its manufacturers, its competitors, its users, and its victims, as well as its designers.

A phenomenon affecting any examination of the Station's history is security classification. Certain NOTS scientists, engineers, analysts, and technicians spent long periods of time, some nearly their entire careers, working on so-called "black" projects; activities whose level of security classification precludes mention of their name or nature. Even at a 50-year remove, there is a small but significant amount of work that remains classified. This necessary cloak of

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1 Albert B. Christman. *History of the Naval Weapons Center, China Lake, California, Volume 1. Sailors, Scientists, and Rockets. Origins of the Navy Rocket program and of the Naval Ordnance Test Station, Inyokern, Naval History Division, Washington, DC, 1971*; J.D. Gerrard-Gough and Albert B. Christman, *History of the Naval Weapons Center, China Lake, California, Volume 2. The Grand Experiment at Inyokern. Narrative of the Naval Ordnance Test Station During the Second World War and the Immediate Postwar Years*, Naval History Division, Washington, DC, 1978; Elizabeth Babcock, *History of the Naval Weapons Center, China Lake, California, Volume 3. Magnificent Mavericks. Transition of the Naval Ordnance Test Station From Rocket Station to Research, Development, Test, and Evaluation Center, 1948–58*. Naval History Division and Naval Air Systems Command, Washington, DC, 2009.

secrecy has only a minor redacting effect on the historical narrative; however, operating behind that cloak does take a toll on the individuals whose work cannot be discussed even with their families. Silence does not diminish the importance of their efforts, nor the magnitude of their contributions.

Source material impacts the comprehensiveness and accuracy of this history; in some cases, there is too much, in others, far too little. For relatively minor programs, reams of documentation may be available. For other efforts, many of which were quite significant, documentation was the last thing on anybody's mind.

The 1960s were a heady time at China Lake, and people, programs, and money moved with great speed. The principals didn't realize that the work they were doing on a day-to-day basis was unique and might have lessons for the future. One engineer, interviewed after his retirement, said:

> In retrospect, I wish I had realized how important it was to write down what we did. But so often, when you are young and doing things, you just think that GE and all these great big corporations have already done this. It turned out that's not true.[2]

Mark Twain's *Huckleberry Finn* begins, "You don't know about me without you have read a book by the name of *The Adventures of Tom Sawyer;* but that ain't no matter." It "ain't no matter" here, either. But "without you have read" the first three volumes in this series, I'll set the stage with a brief sketch of the Station's history prior to the period covered in this volume.

The following excerpt is from a summary prepared by China Lake Command Historian Leroy L. Doig III for the 50th-anniversary edition of the *Rocketeer*, China Lake's in-house newspaper, in November 1993.

> In 1943, adequate facilities were needed for test and evaluation of rockets being developed for the Navy by the California Institute of Technology (Caltech); at the same time, the Navy also needed a new proving ground for all aviation ordnance. The Naval Ordnance Test Station (NOTS) was established in response to those needs in November 1943 . . . . The NOTS mission was defined in a letter by the Secretary of the Navy dated 8 November 1943:
>
>> . . . A station having for its primary function the research, development and testing of weapons, and having additional function of furnishing primary training in the use of such weapons.[3]

2 S-185, Donald K. Moore interview, 11 Oct 1990, 35.

3 Memo Op13C-jc, 4 Nov, Ser. 232213, Secretary of the Navy Frank Knox to All Ships and Stations, "Naval Ordnance Test Station, Inyokern, California, Establishment of," 8 Nov 1943.

> Harvey Field was commissioned at the auxiliary landing field at Inyokern, and the first facilities of the fledgling NOTS were established there while the building of the actual NOTS base at China Lake commenced. Testing began within less than a month of the Station's formal establishment, and by mid-1945 NOTS' aviation assets were transferred to the new Armitage Field at the China Lake site.
>
> The vast, sparsely populated desert around China Lake and Inyokern, with near-perfect flying weather year-round and practically unlimited visibility, proved an ideal location not only for test-and-evaluation (T&E) activities, but also for a complete research-and-development (R&D) establishment. The early Navy-Caltech partnership established a pattern of cooperative interaction between civilian scientists and experienced military personnel that in the ensuing five decades has made China Lake one of the preeminent RDT&E institutions in the world.
>
> Air-launched rockets, solid propellants, fire-control systems, and rocket- and guided-missile T&E were NOTS' primary areas of effort in the 1940s. During World War II, the Station played a role in the Manhattan Project as the site of Project Camel, which developed non-nuclear explosive bomb components—a role that continued into the 1950s. Holy Moses, Tiny Tim, and a family of spin-stabilized barrage rockets were fielded while the Station was built.
>
> After the war, the Pasadena Annex was added to NOTS, bringing with it the torpedo-development program and other underwater-ordnance RDT&E efforts. In the late 1940s, NOTS began research on fire-control systems that evolved into the concept of the Sidewinder guided missile.
>
> With the advent of the Korean War, NOTS rapidly gained cognizance over an even more extensive catalogue of rockets, missiles, and torpedoes and an array of guns, bombs, and fuzes. The Station sent the 6.5-inch tank-killing Ram rocket to the combat forces in Korea after only about 28 days in development and testing.
>
> The ensuing years saw the development and deployment of some of China Lake's most noted products, including the Weapon A, Mighty Mouse, and BOAR rockets; a series of torpedoes; new aircraft fire-control systems ("avionics" now); and, of course, Sidewinder.[4]

Leroy Doig is only one of the many people at China Lake who made this book possible. Scott O'Neil, executive director of the Naval Air Warfare Center Weapons Division (NAWCWD), invited me to assume the task, and I had splendid support from others at NAWCWD, particularly from the Technical Library and the Technical Communications Office (TCO).

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4 Leroy L. Doig III, "A Brief History of China Lake's First 50 Years," *The Rocketeer,* 4 Nov 1993, commemorative insert, 4.

My principal (and patient) contacts in the TCO were Deanna Ripley-Lotee, Antonella Thompson, and Shaleen Lambert.

Others from NAWCWD who helped in the effort were Stephanie Baca, Patricia Backes, Duane Blue, John Daly, Michael Giroux, Mike Johnson, Sam Miller, Mark Pahuta, Mary Ray, Mike Ripley-Lotee, Peggy Shoaf, Stacy Sechrist, John Trowbridge, Vinnie Vargas, Robert Voigt, Amy Wyatt, and Pamela Wheelock. Jacobs Technology Naval Systems Group. New Directions Technology, Inc., and Systems Applications and Technologies, Inc., provided support throughout the project.

Also contributing time, effort, information, and counsel were the editors and staff of the *Daily Independent*; Will Forman, author and submersibles pilot; John Greco of the Naval History and Heritage Command; Maryrose Grossman and Stephen Plotkin, reference archivists at the John F. Kennedy Presidential Library; Tom LaPuzza, former Public Affairs Officer for the Navy Marine Mammal Program; Scott Pedersen, military aviation historian; Peter Pesavento, historian and author; Carol Porter of the Historical Society of the Upper Mojave Desert; and Gary Verver, creator and owner of *chinalakealumni.org*. Mr. Verver provided several of the photographs for this book. The Maturango Museum was also generous in locating and sharing photographs from its collection. (Unless otherwise stipulated, all photos used in this book were taken by the U.S. Navy or another branch of the U.S. Government.)

Many people who were interviewed for the history program and whose recollections form a substantial part of this document—including Phil Arnold, James Colvard, Frank Knemeyer, Ray Powell, and Bud Sewell, to name but a few—kindly responded to scores of emails and phone calls requesting additional information and elucidation.

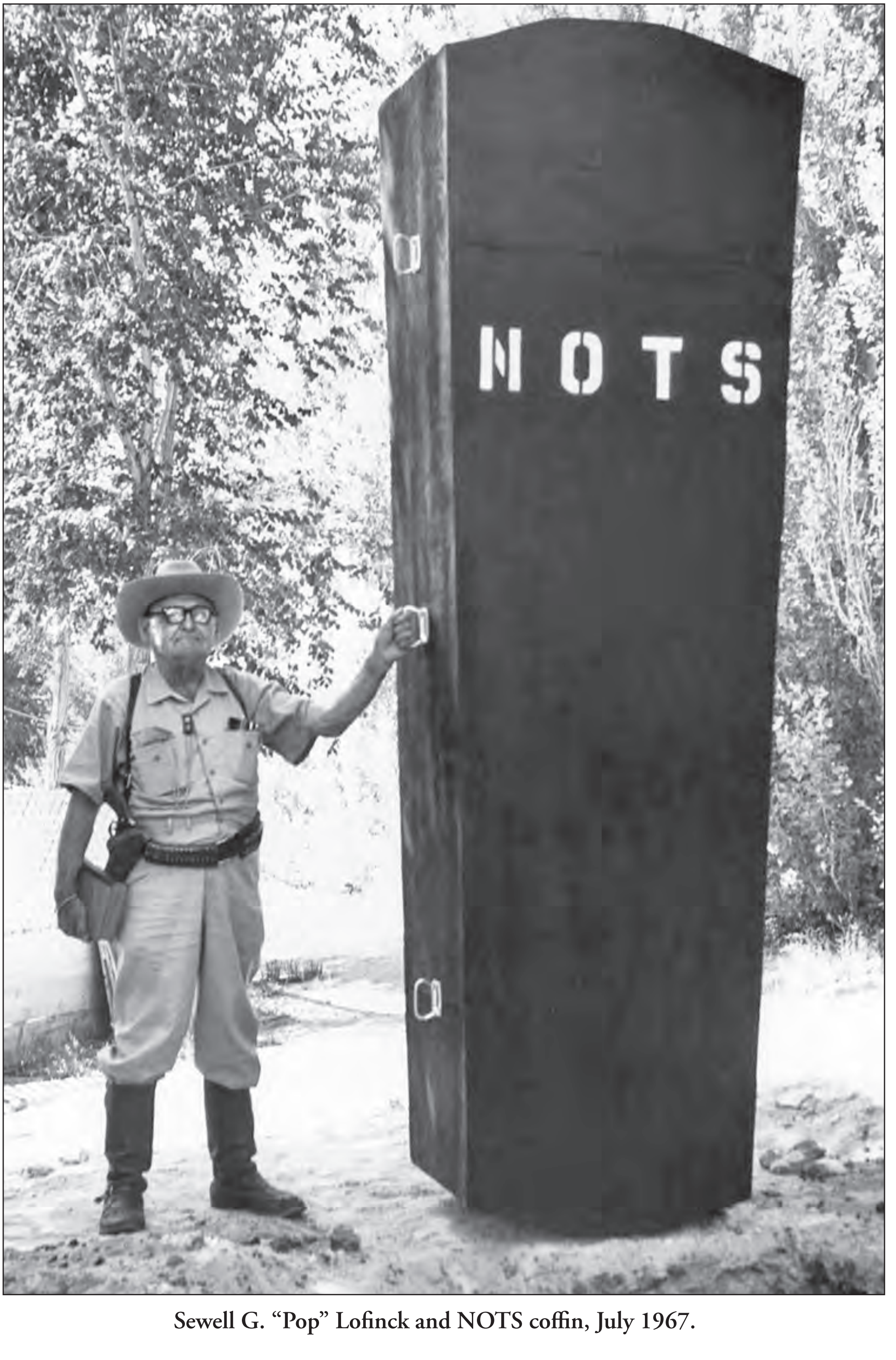
Liz Babcock, who wrote Volume 3 of this series was a source of inspiration as well as practical advice. More than 20 subject-matter experts, current and former China Lakers as well as others with first-hand experience of the events related here, reviewed the draft manuscript or portions thereof. All offered corrections and helpful suggestions.

I would never have tackled this job, and could not have finished it, were it not for the continuous encouragement of my wife, Ramona Bernard.

Such invaluable assistance notwithstanding, I am solely responsible for errors, omissions, and inconsistencies in the text as well as for the opinions not specifically attributed to others and for the biases that must inevitably creep in—I did, after all, work at China Lake for 24 years.

What follows is a story of Shrike and Polaris and Walleye and countless other systems that changed naval warfare. It is a tale of ordinary (and some not-so-ordinary) people, living in an out-of-the-ordinary place—"the middle of the desert," most China Lakers call it, although it's actually much closer to the edge—and producing extraordinary tools for the nation's warriors. It is a recounting of what was, in my opinion, the most productive decade in China Lake's history, before or since.

CLIFF LAWSON



Sewell G. "Pop" Lofinck and NOTS coffin, July 1967.

Introduction

When NOTS—the official acronym for the Naval Ordnance Test Station at China Lake—came to an end in July 1967, a funeral was held in the back yard of Dr. Ivar Highberg, head of the Systems Development Department. The Ground Range crew constructed a 10-foot-tall coffin, to indicate that NOTS really was 10 feet tall, and NOTS was formally interred, with Highberg among the pallbearers. Legendary range guard Sewell G. "Pop" Lofinck was the presiding minister. The epitaph on the grave marker read "Born in adversity. Died in bureaucracy."

In fact, NOTS never died. The concepts embodied in NOTS live on: cooperative military and civilian leadership of a group of "magnificent mavericks" who fuse a knowledge of physical science with the understanding of the art and craft of war to meet the needs of those who fight from the sea. The Navy's base at China Lake has since operated under several acronyms and has survived the bureaucratic onslaughts of drawdowns, pay freezes, Base Realignment and Closure (BRAC) actions, and one cycle of dictatorial military leadership that threatened to destroy the military-civilian team concept.

Yet the base continues. As Vice Adm. Frederick L. Ashworth wrote in his introduction to Volume 3 of the China Lake history, the organization is known simply as China Lake. It survives because while individuals come and go, an institution will continue as long as it has value to those it serves. China Lake has such value; it is the consummate prototype for Navy research and development activities.

The principles that define China Lake, those that Admiral Ashworth and Dr. L. T. E. Thompson learned during the Manhattan Project when they worked with General Leslie Groves and Dr. Robert Oppenheimer, begin with the military-civilian leadership team and include scientists who understand theories, engineers who translate theories into reality, and military personnel who judge the operational worth of a system.

China Lake is an institution that can "conceive," "construct," and "confirm" weapon systems. It does so in a single remote desert location with a workforce whose skills seamlessly span the spectrum of capabilities necessary to solve the problems encountered at each stage in the weapons development process.

Cliff Lawson's book, the fourth in a series chronicling the ongoing history of China Lake, treats a critical period in which the institution was transitioning from being staffed at the leadership level by former Caltech professors who chose to stay with the Navy after World War II to being led by professional scientists and engineers who had chosen careers at China Lake. During this period the Navy was engaged in a shooting war in Southeast Asia, and the country was in the midst of the Cold War with the Soviet Union. The central principles of China Lake, those shaped by Ashworth and Thompson and their contemporaries, had to be transferred to the new leadership—an ongoing process, and one that tends to have generational peaks. That process continues today.

China Lake's current leadership effects cultural transfer through such activities as the Legends Dinners, where recently hired professionals commingle with "old hands" for cocktails, dinner, and a lecture, and the "Have I Got a Story for You!" program, where former leaders are invited to speak informally to the workforce about programs that shaped the history of China Lake.

The best mechanism for developing a sound leadership philosophy is to observe, understand, and emulate successful leaders. During the era covered in this volume, Dr. Bill McLean provided the successful technical leadership that defined China Lake, and his skills were reflected in those who later assumed positions of leadership. Dr. McLean's impact on China Lake was profound. His principles, like his weapon designs, were simple. He insisted on technical competence, allowed people freedom to try wild ideas, and had a high tolerance for failure. Those "profound simplicity" principles created and sustained an effective technical institution, and they are equally applicable to the Navy Laboratory of today.

Dr. McLean's disdain for formal management was legendary. He once told me that if I ever took a course in management he would fire me. But he also recognized the need to accommodate radical management concepts—such as his "absolute right of transfer" by personnel across division and department lines—with a reasonable amount of organizational stability. This led him to select Haskell G. "Hack" Wilson as his Deputy Technical Director. Wilson's management skills and political finesse combined with McLean's technical genius to expand China Lake's reputation as the preeminent technical institution in the Navy, one that produced effective weapons for the Fleet in a time of great need for such weapons.

Since those days, the Navy has subjected its activities to a myriad of management fads, such as Quality Circles, Lean Six Sigma, and Competency-Aligned Organizations. None of these have been as effective as the "profound simplicity" of China Lake: hire good people, give them challenging work and room to operate, and create management boundaries rather than barriers. The Navy benefitted from the weapons designed at China Lake. It could benefit even more by learning China Lake's management approach.

Another characteristic of China Lake worthy of emulation is the co-location of the scientists, engineers, technicians, and military personnel with the laboratories, ranges, and specialized facilities in which the weapon systems are created and tested. The technical insights of a John Boyle were transformed into hardware by technicians like Bill Grady and confirmed on the ranges by a team led by Duane Mack, all of them in the same department headed by Newt Ward. Assigned project pilots (experienced combat veterans) flew from Armitage Field, midway between the laboratory complex and the ranges, all within the NOTS fence line, all under NOTS controlled airspace.

This ability to communicate in person, rather than by paper across organizational walls, makes the development process more efficient and effective. This continuous communication was part of the institutional genius of China Lake. For example, if a group in the Range Department needed assistance with the construction of a large target complex, the Public Works Department was there to help shoulder the load. That lesson was lost on the Navy when, following the 1990 BRAC, it formed Installation Commands to independently manage the facilities at laboratories like China Lake. This approach shattered the integral nature of the affected commands and created institutional barriers that slow communications, increase costs, and generally result in poorer performance.

Simple concepts in the hands of extraordinary people result in success in any endeavor. Cliff's book highlights this fact with its review of the accomplishments of China Lake as it matured from a test station to a preeminent research, development, and test institution. The Navy's continued success in conducting war from the sea depends on sustaining such institutions.

DR. JAMES E. COLVARD

Former Deputy Chief, Naval Material Command

Sailor raising the flag over China Lake, 0800.

1

A Winter's Day

It marks the beginning of an era of expansion . . . .

— NOTS Commander Captain William W. Hollister,
at the groundbreaking ceremony for Hangar 3[1]

January 1, 1959, dawned cold on the western edge of California's Mojave Desert. The temperature had dipped to 28° in the early hours of the morning. In the small town of Ridgecrest and on the adjoining Naval Ordnance Test Station (NOTS) at China Lake, frost obscured car windshields and whitened the bent blades of withered lawns.

Shortly after 7 a.m., the sun's rays began to filter over the Slate Range and the Spangler Hills to the east and south. Sunlight first touched the high points of the Sierra Nevada, which runs along the western edge of the Mojave Desert. A weak winter light (the sun had reached its southernmost point just 11 days earlier) illuminated the rocky prominences in the Sierra foothills known to local residents as Five Fingers, then gradually moved down into the Indian Wells Valley. A waning moon faded in the brightening sky. Winter-morning quietness lay over the sere brown desert and the sprawling Navy base.

Precisely at 0800 hours (military terminology for 8 a.m.) in front of the NOTS Administration Building, two sailors conducted the time-honored Navy ceremony of morning colors, raising the national ensign to the top of the 42-foot flagpole. Although Hawaii had been admitted to the union less than five months earlier, the 50-star American flag raised that day was already nearing time for replacement. Wind in the Mojave Desert is strong and persistent.

On that chill Thursday morning, many of the Station's civilian employees and military personnel were taking advantage of the New Year's Day holiday (and the second week of the Christmas school vacation) to sleep in after a night of partying. So, too, were residents of Ridgecrest, the unincorporated town just southwest of China Lake's "Mainside"—the unofficial name for the portion

1 *The Rocketeer*, 10 Jan 1958, 1. The Station's in-house newspaper was published weekly.

of the base where the main laboratory, administrative, and housing facilities were located, distinguishing it from China Lake's far-flung ranges and facilities scattered over hundreds of square miles to the north and southeast. Only a thin wire fence and the occasional "Warning—U.S. Government Property" sign demarked the line between town and base.

Revelers in Ridgecrest danced and drank the New Year in at the Starlite Room, the Village, the Desert Inn, and Duke's Tavern. On the base, the Community Center, just south of the Administration Building, had been the site of a "Ring in the New, Ring out the Old" party (adults only, dancing to the music of Pug Pilcher, coats and ties required for men). The Officers' Club—formally the Commissioned Officers' Mess (Open)— was a 10-minute walk to the east on Blandy Avenue and had seen its share of more informal socializing—as in fact it did on most nights.

Despite the partying, the final evening of 1958 had been "… a very quiet New Year's Eve," according to Ridgecrest's weekly newspaper, *The Indian Wells Valley Independent and Times-Herald* (predecessor of the current *Daily Independent*). "Law enforcement personnel were on duty in full force to handle any overzealousness on the part of persons seeing out the old and welcoming in the New Year. . . . Just one arrest of a drunk driver suspect by Naval Station Security Police marred an otherwise perfect record."[2]

For the Naval Ordnance Test Station, barely 15 years old, 1958 was a year worth celebrating, a year of progress and growth. The Station's achievements spanned land, sea, air, and space.

Progress

Weapons development had been spurred by the ongoing Cold War between the U.S. and Russia. Tensions were running high. In March Nikita Khrushchev had been named Premier of the Soviet Union, and NOTS Commander Captain William W. Hollister, addressing the Bakersfield Rotary Club in May 1958, struck an alarmist note. "Security can be measured only in terms of the threat—and the threat is great," he was quoted in the *Bakersfield Californian*. Remarking on the rapid pace of technological change since the end of WWII, he said:

> We find ourselves working with only two kinds of weapons systems—the obsolete and the experimental. No sooner is a new weapon made operational than new developments begin pushing it into obsolescence. . . . The peacetime

2 *Indian Wells Valley Independent and Times-Herald*, 8 Jan 1958, A1. Hereinafter cited as *IWV Independent and Times-Herald*.

> Soviet war machine is unprecedented in magnitude. . . . Today the Soviet Union has more than 475 submarines. The magnitude of this threat to our vital sea lanes cannot be overemphasized.[3]

The formal mission of the U.S. Naval Ordnance Test Station—the official charter from the Bureau of Ordnance (its parent organization) that delineated what the base could, and by extension could not, do—was stated in a single brief paragraph:

> Conduct research, design, development, limited production, testing, and technical evaluation of ordnance materials, components, assemblies, and systems . . . principally in the field of rockets, guided missiles, underwater ordnance and aircraft fire control.

NOTS was earning a reputation within the Navy and the Department of Defense for interpreting that mission as broadly as possible.[4]

Most notable of the Station's accomplishments in 1958 was the aerial shoot-down, by Chinese Nationalist forces, of four MiG-17s over the Formosa Strait on 24 September. The Sidewinder 1A (AIM-9B) missiles that sent the Red Chinese fighters into the ocean were conceived and developed at China Lake and, for that particular operation, code named Black Magic, assembled at

Aviation ordnanceman checking Sidewinder missile mounted on F/A-18C aircraft, Strike Fighter Squadron 146 aboard *USS John C. Stennis* (CVN-74) in the Persian Gulf, May 2007—more than half a century after the NOTS-developed missile's first successes.

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3 "Commander of Kern Base Warns of Complacency," *The Bakersfield Californian*, 30 May 1958, 19.

4 NOTS TP 2127, *Technical Program Review 1958*, China Lake, California, 1 Jan 1959, ii. That mission statement, with minor changes, would remain constant for the remainder of NOTS' existence (through 1 July 1967).

China Lake. The Formosa Strait engagement was the first time air-to-air guided missiles were used in combat.[5]

North American Treaty Organization (NATO) units also began using Sidewinder in 1958; the missile would eventually become one of the most widely used weapon systems in the world. Sidewinder, much modified and refined but still fundamentally the same China Lake-developed weapon, remains the United States' principal short-range air-to-air missile more than half a century after its first combat victories.

Other events boosted China Lakers' pride in the work they carried out during 1958. In April *The New York Times* reported that a NOTS rocket sled had set a new speed record of 2,825 miles per hour, eclipsing a record set by the Air Force at Holloman Air Force Base, New Mexico, the previous month.[6]

In August, high above the NOTS north ranges, a Tartar surface-to-air missile intercepted and destroyed an F6F drone in the missile's first successful firing.[7]

At NOTS' San Clemente Island facility, 60 miles off the Southern California coast, the Marine Corps spent part of the year evaluating the Demolition Line Charge. The line charge, in development since 1950, employed a NOTS-developed 5-inch rocket motor to throw an explosive train from a boat or amphibious vehicle onto a beach to explosively clear mines and obstacles. The rocket motor passed the rigid evaluation tests and was accepted for Marine Corps use.[8]

Not all accomplishments that year were exclusively related to weaponry. At a Los Angeles press conference in September, NOTS announced the development of an "explosive press," a new technique for using the power of explosives to form and bond metals. The press had been developed by John Pearson, head of the Warhead Research Branch, and Edward W. LaRocca, who believed that widespread adoption of their technique in military production could save $30 million per year.[9]

5 A more detailed description of the event is in Babcock, *Magnificent Mavericks*, 468-472.

6 "Rocket Sled Mark Set," *The New York Times*, 25 April 1958. During that year 365 runs were conducted on NOTS' three supersonic tracks—SNORT, B-4, and G-4. The runs ranged from tests of ejection seats, fuzes, missile components, and guidance systems, to tests with animal subjects, the latter part of an Air Force study to determine if humans could survive aerodynamic loadings above 3,000 pounds per square foot.

7 *Technical Program Review 1958*, 116-117. China Lake was involved in test, training, and component development for the Tartar, Talos, and Terrier missiles, all descendents of the Bumblebee missile, which had begun testing at China Lake in 1945.

8 NWC TP 6413, Part 1, *Major Accomplishments of the Naval Weapons Center*, 1982, 15. Hereinafter cited as *Major Accomplishments*.

9 *Rocketeer*, 19 Sept 1958, 1.

Articles on the new process began to appear immediately in the trade press. Over the next three months, in a phenomenon that would years later come to be known as "technology transfer," more than 30 industrial companies contacted Pearson for additional information on explosive-forming techniques. Pearson's and LaRocca's methods would come to be used throughout the world, and Pearson's books, *Explosive Forming of Materials*, and *The Behavior of Metals Under Impulsive Loads*, both coauthored with NOTS physicist Dr. John S. Rinehart, remain standard references in the field.[10]

In October 1958 NOTS had publicly unveiled the Rocket Assisted Personnel Ejection Catapult (RAPEC), which had just begun high-speed testing on NOTS' Supersonic Naval Ordnance Research Track (SNORT). RAPEC employed a rocket propellant to fire an ejection seat 200 feet or more above the aircraft's fuselage, allowing a pilot to safely eject on or near the ground (or even 35 feet under water), thereby greatly increasing the chance of survival. The NOTS-designed, -developed, and -tested system was released to production in November and was responsible for saving the lives of many A-4 Skyhawk pilots in the years to come.[11]

SNORT would be heavily used by China Lake and other organizations, with the types of testing limited only by an engineer's imagination. For example a novel Picatinny Arsenal-sponsored program called Catshell would begin in 1959. Over 5 years, more than 40 155-mm howitzer shells would be fired at maximum accelerations and chamber pressures and caught in the back of a SNORT test sled traveling at 1,600 feet per second. Shells would then be retrieved from the sled's Ensolite-filled catch box for analysis of the fuzing components.[12]

The most ambitious of the Station's undertakings in 1958 was NOTSNIK, the in-house nickname for a crash program established in response to the launch of Sputnik by the Soviet Union in October 1957. (It would be nearly four months after Sputnik's launch before the embarrassed U.S. finally put Explorer 1, its first satellite, into orbit.) NOTSNIK was a China Lake-conceived plan to launch a NOTS-designed satellite into orbit on a NOTS-built rocket launched from a NOTS-based jet aircraft.

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10 *Rocketeer*, 9 Jan 1959, 1.

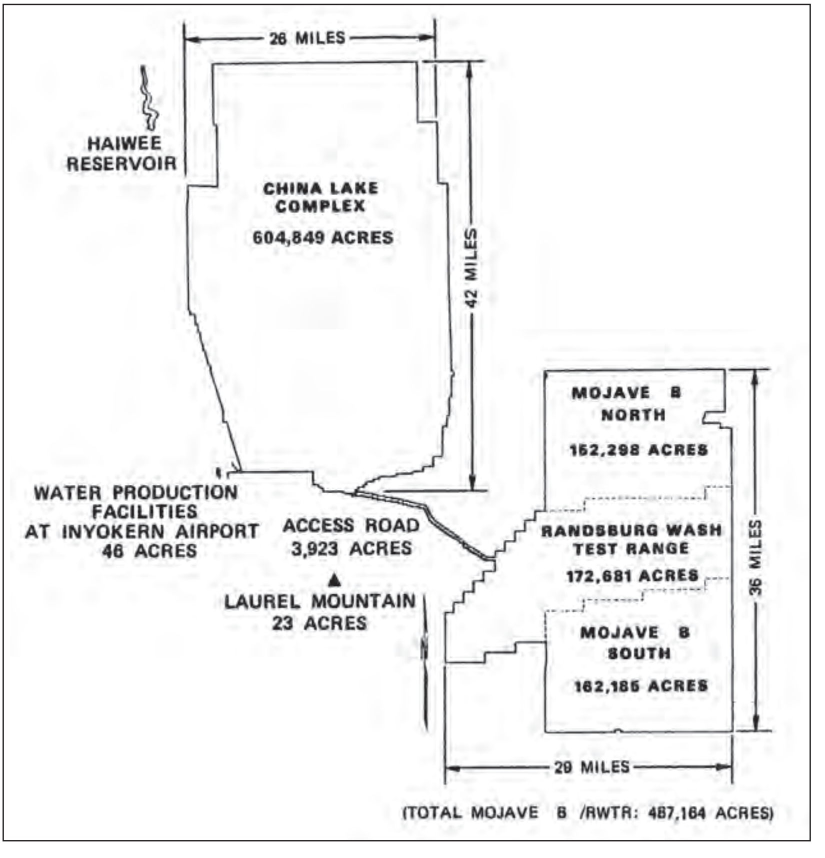
11 OPNAV Report 5750-5, *Command History of U.S. Naval Ordnance Test Station, China Lake, California*, 1959, 23 (hereinafter cited as *NOTS Command History*); *Major Accomplishments*, 83. RAPEC technology became the basis for many subsequent aircrew ejection systems.

12 NOTS TP 3726, *Technical History, U.S. Naval Ordnance Test Station, 1964*, April 1965, 8-54 (hereinafter cited as *NOTS Tech History*).

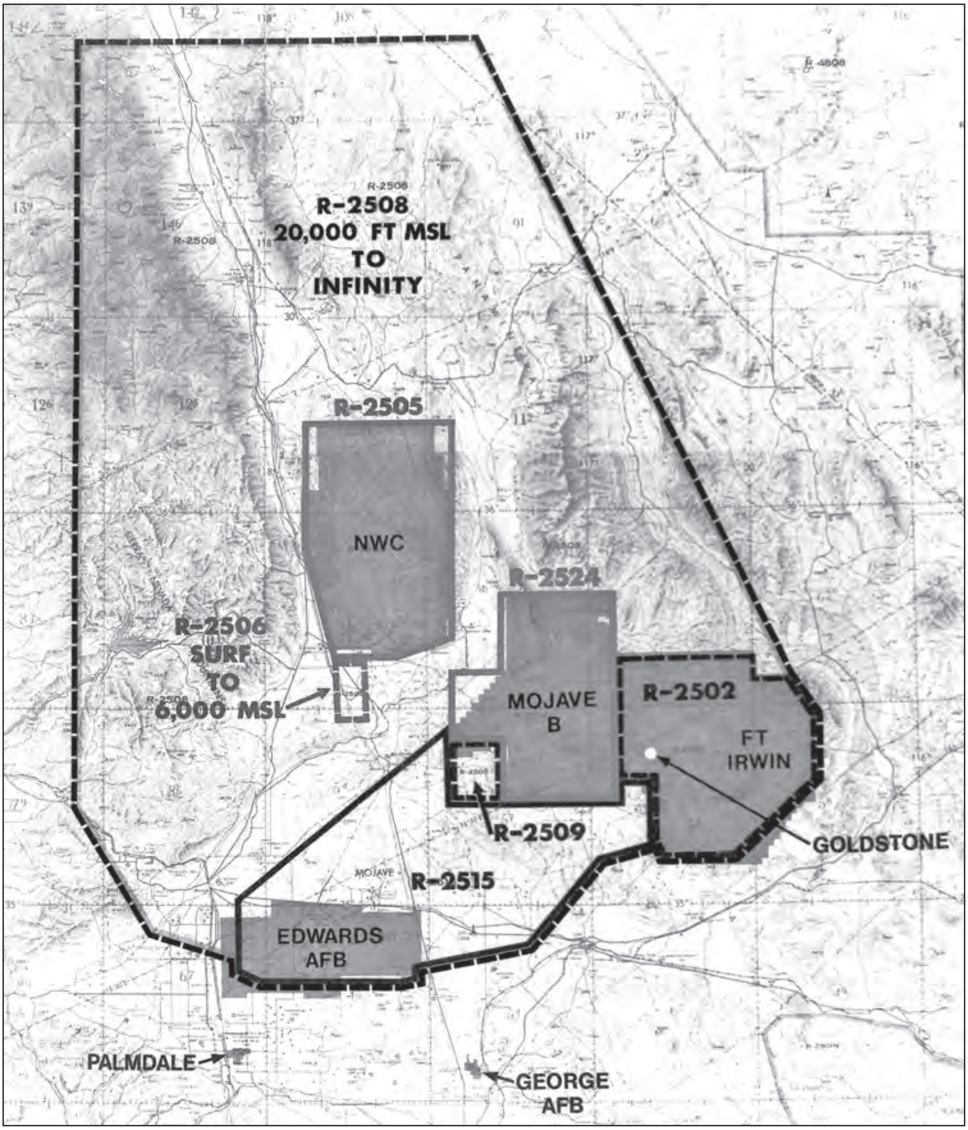
During 1958, the NOTSNIK project (also called Project Pilot and NOTS 1) attempted six launches. Whether any of the payloads actually attained orbit has never been conclusively determined; however, the effort did develop technologies that would be incorporated in future U.S. satellite programs. And NOTSNIK firmly established the Station as a player in the "space game."

Growth

With success came growth. As China Lake entered the final year of the 1950s, its physical infrastructure of research, development, test, and evaluation (RDT&E) was expanding rapidly. Across the base, new ranges, laboratories, and specialized facilities were under construction or in the planning stages. While none would rival in scope Michelson Laboratory—that massive complex of laboratories, machine shops, and office spaces completed in 1948 with more than 10 acres of floor space and a price tag of $10.4 million ($96 million in 2011 dollars)—each new capital investment at China Lake enhanced the Station's ability to prosecute its mission.

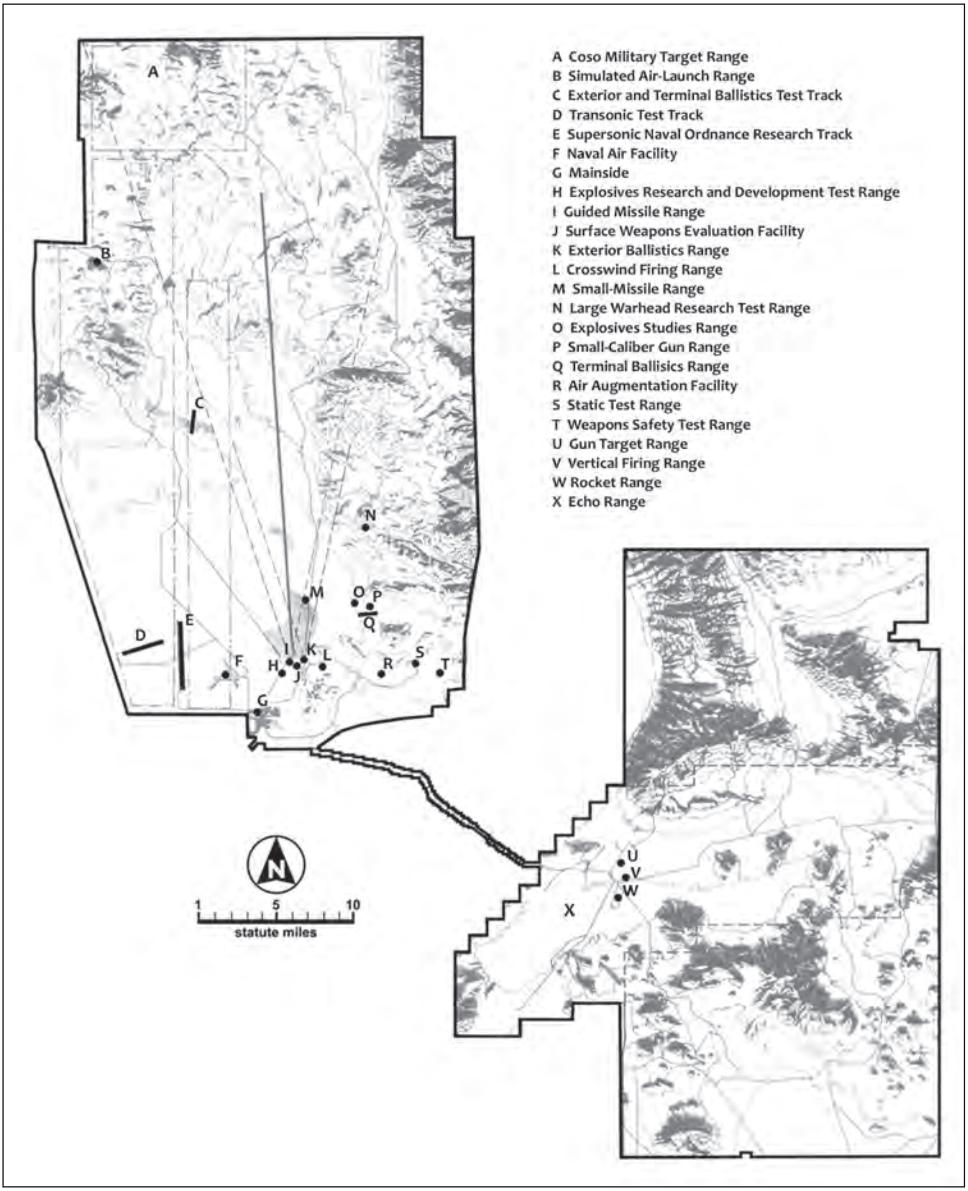


China Lake range areas, 1.1 million acres in all.



Restricted airspace R-2508, with military land areas shown as gray shapes. The configuration, shown in 1974, has remained substantially the same since R-2508's establishment in 1955.

NOTS had no shortage of room for expansion—the Navy's base at China Lake is huge. In 1959 it represented ⅓ of the Navy's total worldwide land holdings. It was—and is today—the Navy's largest single collection of land (1,700 square miles), lying under the largest military-restricted airspace in the nation. China Lake's land area is larger than Rhode Island and about 25 times as big as the District of Columbia.



Major ranges and facilities on China Lake land.

The R-2508 Military Restricted Airspace Complex (reserved exclusively for military use from 20,000 feet to infinity and in certain areas from ground level to infinity), which was formally approved by the Civil Aeronautics Administration in 1955, covers 18,000 square miles, an area greater than Vermont and New Hampshire combined.

However, NOTS did not seem as large in 1959 as it had when it was established. Back in 1943 a Navy F4U Corsair fighter flying at top speed could cross the widest part of China Lake's North Range Complex (just over 21 miles) in about 3½ minutes. By 1959 an F8U Crusader could make the same transit in less than a minute and a half—although such a flight would be followed by telephoned complaints from Indian Wells Valley residents as the sonic boom rattled and shattered windows.

The shadows of encroachment, external limits on China Lake's RDT&E activities, were just beginning to fall across the desert base. In the earliest days of the Station, the focus of NOTS' work had been on relatively short-range air-to-surface weapons. As air-to-air weapons became a larger part of China Lake's effort, more land and sky were necessary for safe and secure testing as well as tactics development.

The phenomenon of "shrinking ranges" would continue as the footprint of naval air-launched weapons increased and the era of long-range standoff weapons dawned. The NOTS-developed nuclear weapon, the Bombardment Aircraft Rocket (BOAR), the Navy's principal standoff weapon in 1959, had a maximum range of only 7½ miles.

By the 1990s thorough testing of a long-range standoff weapon like the Tomahawk cruise missile required that it be launched on the Sea Range off Point Mugu and maneuver a dogleg stretch of specially cleared FAA restricted airspace before entering the R-2508 Complex west of Edwards Air Force Base and continuing north to China Lake's ranges—a journey of more than 300 miles.

Shrinking ranges notwithstanding, NOTS at the end of the 1950s was spacious enough to accommodate any new facility the Department of Defense required and funded.

The largest of the building projects under way on 1 January 1959 was a $4.3-million aircraft hangar, on which construction had begun a year earlier. Sited at Armitage Field, about a mile north of Mainside, Hangar 3 would be the home of the Naval Air Facility (NAF) and of the Aviation Ordnance Department (AOD, Code 35).

The new facility would allow Hangar 1 to be used by Air Development Squadron Five (VX-5), which had transferred to China Lake from Moffett Field in 1956, as well as by visiting Fleet squadrons. In a sign of things to come, AOD's removal from Hangar 2 would "provide limited facilities for private contractors whose mission requires their location near areas of development and test performance."[13]

13 *Rocketeer*, 5 Sept 1958, 1, 4.

Armitage Field after construction of Hangar 3, the large two-bay building at center left. Hangar 2 is at left, with Hangar 1 at right. The view is west toward the Sierra Nevada.

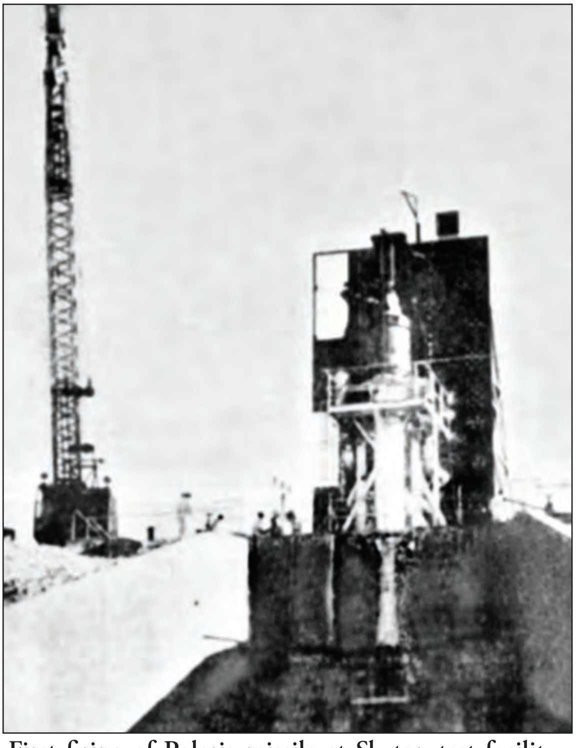
For NOTS, the new hangar symbolized progress. *The Rocketeer* (China Lake's official weekly newspaper since 1945) waxed poetic in describing the groundbreaking ceremony on 30 December 1957: "A 'golden era of expansion' for NOTS was symbolized by the reflection of a desert afternoon sun from gold-painted shovels wielded in the recent ground breaking."

Addressing the group of 100 gathered for the occasion, Captain Hollister called construction of the hangar "the beginning of an era of expansion, . . . just one of the plans for the largest and most important research and development center in the United States."[14]

New construction was also under way to support the Polaris nuclear ballistic-missile program, which had been ramping up throughout 1958. In response to the Sputnik launch, the program had been dramatically accelerated. The deadline for an interim capability had been pushed forward 2 years (to June 1961) and for an operational system 18 months (to April 1962).[15]

14 *Rocketeer*, 10 Jan 1958, 1.
15 "The Origin of the APL Strategic Systems Department," *Johns Hopkins Applied Physics Laboratory Technical Digest*, Vol. 19, No. 4 (1998), 381.

China Lake had a big piece of the Polaris action—which was only fitting, since the concept for that submarine-launched solid-fueled nuclear-tipped missile system was developed at China Lake. The Station's growing responsibilities in the program required extensive new facilities both at China Lake and at San Clemente Island.[16]



First firing of Polaris missile at Skytop test facility, 15 November 1961.

East of China Lake's Mainside and behind Lone Butte (known locally as B Mountain because of its large white-painted "B," which Burroughs High School seniors refresh each year), site preparation was under way for Skytop, a complex designed specifically for live testing of Polaris rocket motors and capable of handling motors with a peak thrust of 10 million pounds. Completed in November 1959 at a cost of $650,000, Skytop (formally, the Static Test Facility, and later, as it expanded, the Static Test Range) became the Navy's go-to site for testing large solid-propellant rocket motors. The facility's role subsequently expanded to support a number of national and international large solid-propellant motor programs.

The Navy's Special Projects Office—the nerve center of the Polaris program—had also selected NOTS to design the underwater launching technique for Polaris.

Initial planning for underwater-launch equipment and support facilities on San Clemente Island began in 1958, and NOTS' 1959 budget earmarked $1.55 million for construction.

The new facilities would include an underwater pop-up launcher and an ingenious barge-mounted crane called "Fishhook" that snagged the expensive

16 James Baar and William Howard, *Polaris!*, Harcourt, Brace and Co., 1960, 68–69; S-117, Frank Knemeyer interview, 20 Feb 1981, 27.

Fishhook barge with Polaris on tether at San Clemente Island, April 1959.

prototype missiles at the apogee of their pop-up, more than 100 feet above the ocean's surface, and then gently braked their descent to avoid damage on water impact.[17]

The pace of Polaris work at SCI, as the island was often called, had increased to the point that the NOTS Test Department set up a new Test Division at Pasadena just to manage the underwater test range.

Operations at SCI were gaining interest nationally. In early December 1958, three members of the Defense Subcommittee of the House Appropriations Committee visited the island. The group included Gerald R. Ford, who was in his 10th year as a Michigan congressman and who would 16 years later become the 38th President of the United States.

On China Lake's north ranges, construction on the final phase of the High Altitude Bombing Range had began in early 1958 and would be completed in

17 *NOTS Command History* 1959, 10.

1959. The range allowed a high-altitude (15,000 to 60,000 feet) bombing run to be analyzed with more than 30 miles of continuous 10-frames-per-second photographic coverage. The specialized cameras used in this process, called flight-line recorders, were designed by the Station's Applied Optics Branch.

New Directions

Other expansions in the NOTS workload were not measured in concrete, steel, or military construction (MILCON) dollars. They were expansions driven by the curiosity of engineers and laboratory researchers pursuing promising leads. One of the attractions that NOTS employment held for highly talented scientists and engineers was that fact that NOTS management encouraged investigation of new ideas and supported researchers who wished to look in novel directions.

This encouragement was often manifested through a locally controlled discretionary funding source called Exploratory and Foundational (E&F) funding, later renamed Bid and Proposal (B&P) funding. E&F-funded investigations into automatic-tracking TV-guided weapons at NOTS during the late 1950s, for example, led to the development of the Walleye glide weapon. Walleye would become a staple of U.S. air strikes from Vietnam to Desert Storm, and its "amazing accuracy" was even lauded by President Lyndon B. Johnson in a 1964 press conference.[18]

In Michelson Laboratory, known by China Lakers as Mich (pronounced "Mike") Lab, researchers in the Optics Division had developed a new reflectometer for measuring fundamental optical constants in the ultraviolet, visible, and near-infrared regions of the electromagnetic spectrum. In conjunction with another NOTS-developed reflectometer, it provided "an improvement in accuracy of 50 times that commonly quoted for reflectance measurements."[19]

Support for new directions and unusual ideas was not limited to the research laboratory or the engineer's drafting table. Midway through 1959, for example, the Weapons Planning Group at NOTS hosted the Inyokern Meeting, a "top-drawer symposium on methods of deterring strategic wars."[20] The meeting's 15 attendees included leading experts in psychology, political science, anthropology, sociology, economics, physics, mathematics, and chemistry.

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18 "Transcript of the President's News Conference on Foreign and Domestic Matters," *New York Times*, 2 Feb 1964.

19 NOTS TP 2374, *Technical Program Review 1959*, China Lake, CA, 1 Jan 1960, 50.

20 *IWV Independent and Times-Herald*, 9 July 1959, B1. Although the attendees flew into Inyokern, the meetings were actually held at China Lake.

"This is not a policy making group," Weapons Planning Group psychologist Thomas W. Milburn told a reporter. "We seek to achieve our objective of preventing and suppressing war through scientific research. Our findings are then presented to the military policy makers."[21]

Today, such a symposium would be sponsored by a university or a think tank rather than a military base. But China Lake was the bold 16-year-old offspring of the California Institute of Technology and boasted the academic and intellectual horsepower to make such an excursion from physical science into social science a plausible effort.[22]

Deterrence had first been studied at China Lake in the mid-1950s as part of the Station's work on nuclear targeting consequences. The Inyokern Meeting joined physical and behavioral scientists from academia with China Lake analysts and weapons experts. Several research projects recommended at the meeting became the basis for Project Michelson, through which NOTS "coordinated the political scientists of the nation in a study of the strategy of deterrence."[23]

The methodology of the project was "to predict what actions various world leaders would pursue under given future circumstances. Such future predicted actions were based upon past writings and speeches of world leaders indicating their stand on polemical issues at that time and what course they actually took when the specific issue became a reality."[24]

Funded by the Polaris program and the Secretary of Defense's International Security Affairs Office, and managed by the Weapons Planning Group, Project Michelson eventually included more than 50 studies at various universities. This was heady stuff for a naval base that focused primarily on developing and testing weapons.[25]

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21 *Rocketeer*, 2 July 1959, 1.

22 China Lake's Central Evaluation Group in the early 1950s gave NOTS its first formal operations analysis capability. The group eventually became the Weapons Planning Group (Code 12). Carl Schaniel, head of the group, wrote shortly after establishment of the Naval Weapons Center in 1967, "The onset of organized operations analysis activity within the Navy laboratories represented a fundamental recognition that detailed study of military operations and requirements had to be a continuing part of the R&D cycle." Carl L. Schaniel, "Operations Analysis and the Naval Weapons Center," *News and Views, Points of View and Information on Management Matters*, China Lake, Aug-Sept 1967, 1.

23 John Piña Craven, *The Silent War: The Cold War Battle Beneath the Sea*, Simon & Schuster, 2001, 62. Craven served, among his senior Navy posts, as chief scientist of the Special Projects Office.

24 Memo, 6002/WWS ref Ser. 4821, Commander, NWC to CNO (OP-092D3), "Requests for Security Review and Clearance of Project Michelson Reports for Release to Universities," 7 Nov 1969 .

25 Louis D. Higgs and Robert G. Weinland, *Project Michelson Preliminary Report*, NOTS

Finding the Right People

As NOTS' workload and facilities grew, so too did the need for qualified personnel to staff new and expanding programs. Adventuresome men and women continued to be drawn to this remote military base in the sun-drenched Mojave Desert, as they had since NOTS' creation in the waning days of WWII. But they seldom found it on their own. Recruitment was necessary. And of course China Lake had its own way of going about that.

"We didn't necessarily go for the ones with the best grades," recalled Robert G. S. "Bud" Sewell. "These were mostly guys who had been to war, were going through college on the GI bill, had families, responsibilities."[26]

Nor did the Station use professional recruiters. Scientists and engineers who were engaged in China Lake's everyday work, it was reasoned, were better able to communicate the nature of that work to prospective employees as well as to judge an individual's potential to contribute to the Station's projects. China Lakers were encouraged to get people they knew to come and see the base and its facilities. In fall 1958 a coordinated recruiting drive sent 32 NOTS employees to visit 49 colleges and universities in 14 states to find new talent and extol the benefits of working at China Lake.[27]

NOTS' recruiting was carried out under the leadership of Robert C. Nelligan, head of the Personnel Department's Recruitment Branch. In a back-door approach to recruitment, the Station would invite selected professors to spend the summer at China Lake, working in the ever-growing collection of laboratories and specialized facilities. When the professors returned to their classrooms in the fall, they brought with them tales of exciting work being done at a mysterious science and engineering complex in the Mojave Desert.

Sometimes convincing a candidate to move to the desert could be a hard sell, particularly if the prospective employee came from an urban background. The harsh term "desert" invokes images of parched and delirious wanderers, circling buzzards, and sun-bleached bones in a flat, endless field of eye-blinding whiteness. In literature and religion, desert is usually the metaphor for emptiness, barrenness, hopelessness, and desolation.

For the Mojave Desert, those connotations are misleading. On average, the Mojave—also known as the High Desert, to distinguish it from the Sonoran Desert (the Low Desert), which lies to the south and east—receives about

TP 3154, China Lake, March 1963.

26 Conversation with Bud Sewell, 28 Oct 2009.

27 *Rocketeer*, 10 Oct 1958, 2.

Wild (feral) horses standing amidst Joshua trees in China Lake's North Range Complex.

10 inches of rain per year. China Lake averages somewhat less than half that amount, primarily because it is in the rain shadow of the Sierra Nevada. That's not a lot of precipitation, compared to Sacramento (18 inches) or Los Angeles (15 inches) or even San Diego (12 inches), but adequate to support abundant plant and animal life.

The Mojave Desert encompasses a staggering variety of topography, flora, and fauna, and China Lake's 1.1 million acres are a microcosm of this variety.

On the North Range Complex, piñon pines, junipers, and scattered Joshua trees cover the high mesas (6,000 feet plus). These uplands are home to deer, mountain lions, badgers, golden eagles, and free-roaming herds of wild horses. To the south and east—the lower half of the North Range Complex and the entire Mojave B Range—a more traditional desert picture prevails; creosote bush and rabbitbrush provide cover for jackrabbits, coyotes, sidewinder rattlesnakes, desert tortoises, kangaroo rats, and myriad other heat-tolerant water-conserving species of plants and animals (including feral burros, descendants of the early miners' pack animals).

China Lake promoters learned how to put a positive spin on the arid desert environment, touting "More than 300 days per year of perfect flying weather!" and "360 days of sunshine!" They seldom mentioned the harsh winds that regularly rip across the Mojave Desert, bitterly cold in the winter and blast-furnace hot during the long, dry summer.[28]

New hires and their families soon learned that the isolated Navy base and its neighboring communities formed a small oasis of civilization in a thinly populated region that stretched to the horizon and far beyond. Some people fled after months or even weeks at their new posting—tales of "termination winds" are foundational to the folklore of China Lake.[29] But a surprisingly large number of new employees did not leave. It wasn't the pay that kept them, which was significantly less than industry scale, even with the 10-percent pay raise for civil servants that President Dwight D. Eisenhower signed in June 1958.[30]

NOTS' primary attraction to new professionals was the technically challenging nature of the work, the willingness of management to give young scientists and engineers as much responsibility as they could handle, and the ability to see a job through from start to finish. An idea sketched on a bar napkin at the Officers' Club on Friday night could be discussed with a battle-tested Navy pilot over a backyard barbeque on Saturday, then could be on the drafting table Monday, in the machine shop the following week, and flown in a live range test the next.

James E. Colvard, who joined the NOTS workforce in 1958, fresh from graduate school, described the work environment he encountered:

> When I first came into Code 40 [the Weapons Development Department], I didn't have an office—I had a bench like all other engineers—and right next

28 The peak monthly wind speed, measured over a 34-year period at China Lake's Instrumentation Operations Building (IOB), ranged from a low of 47 knots (54 miles per hour) in September 1986 to 60 knots (69 miles per hour) in March 1961 and August 1984. Data at *http://www.navair.navy.mil/nawcwd/weather/chinalake/PUBS/TM77.10.html,* accessed 11 July 2009. The average rainfall at China Lake's Armitage Field (elevation 2,283 feet) is about 4.5 inches per year, less than half the Mojave Desert average. However, averages are deceptive; in August 1984 a storm dumped 4 inches of rain on the Indian Wells Valley in one day, causing massive flooding.

29 Al Boyack, who came to work at NOTS in 1945 and retired 61 years later recalled, "They always talked about the termination winds, and people would come in and go to work, and the wind would blow, and they'd leave and not even come back for their pay or anything. They'd terminate by mail." S-235, Robert A. "Al" and Darlene Boyack interview, 6 July 1994.

30 *Rocketeer*, 27 June 1958, 1. According to the *Rocketeer*, that raise (which was retroactive to January 1958) translated to a $1.7-million annual increase in NOTS paychecks.

> to us was a machine shop run by three or four grizzled old machinists who we knew well and they'd take us wet-behind-the-ears college graduates and teach us reality. And we also had former university professors like [Dr. William R.] Duke Haseltine (an internationally renowned ballistician and NOTS senior research scientist) and others who were people of sufficient scientific depth we could go consult with and talk to when we had problems. So that ability to traffic back and forth between abstract knowledge and practical reality was great.[31]

One attraction used by China Lake to draw new talent was the Junior Professional (JP) Program. New hires fresh from college divided their first year at NOTS into 3-month tours in various departments. The idea—and it worked well—was to let the young scientists and engineers train with experienced professionals, trying different types of work to see which the JP was best suited for and found most interesting. Responsibility was given commensurate with the JP's ability to accept it. In 1958 nearly 80 new graduates from more than 35 colleges and universities joined the NOTS workforce as JPs.

Despite the discrepancy between salaries in industry and those in government laboratories, China Lakers were hardly poverty stricken. Government-subsidized housing was a bargain, and the prices at the commissary store and the Navy Exchange, where civilians shopped side by side with the military, were far below those in the urban areas where most contractors were situated. One China Laker recalled:

> You could make $8,000 or $9,000 a year here and bank $2,000 of it with that beautiful low-rent housing . . . and the other breaks—the commissary, the exchange, the Officers' Club, and the Chiefs' Club . . . no Joneses to keep up with. If I bought a new Cadillac, why, instead of being impressed by my prosperity you'd wonder how I could afford it on my salary because everybody knew what everybody else made. There was no status symbolism.[32]

For many of these bright young men and women, fresh from school and operating at the cutting edge of their professional disciplines, the idea of working with NOTS' advanced computing capabilities must have been a draw. Why, in 1959 the Station boasted a state-of-the-art IBM 709 computer that output data to magnetic tape at a rattling 2,500 numbers per second.[33]

The new hires who went on to spend three decades at China Lake, as many did, would in the course of their careers see computational speeds increase several thousandfold as computers mushroomed in capability, dwindled in size, migrated from a centralized facility into every office and laboratory, and entrenched

31 S-272, Dr. James Colvard interview, 11 Dec 2008, 13.

32 S-132, Dr. Richard E. Kistler interview, 24 Feb 1982, 3.

33 *NOTS Command History* 1959, 9.

A few of the tape decks for NOTS' mainframe computer in the 1960s.

themselves as ubiquitous and essential desktop tools, replacing not only slide rules and drawing boards but in many cases range firings and flight tests as well.

These young scientists and engineers, along with their older peers, would soon have to reeducate themselves to the capabilities of the integrated circuit. Invented in 1958, "ICs" would have a stunning impact on the Station's work. In air-to-air weapons, where volume and weight are the limiting parameters, ICs would allow previously unimagined capabilities to be crammed into the tiniest spaces. And as Moore's Law reliably predicted, the number of transistors that could be put on an IC would double every 2 years.

At the end of 1958, NOTS' civilian workforce—including both the technical workforce of scientists, engineers, and technicians, and the support workforce, or so-called "wage grade" employees—was just over 4,600 (despite a small, about 0.5-percent, reduction in force early in the year). Military personnel increased this number to about 5,000, with the total on-base population more than 10,000.[34]

The growth in NOTS' infrastructure and personnel was paralleled by an increase in funding; the Station's technical-project budget for 1959 was $53.6 million (topping 1958's by $10.5 million). The figure would increase to $61 million for 1960.[35]

34 *Rocketeer*, 16 May 1959, 2; *Rocketeer*, 17 May 1958, 2.

35 NOTS TP 1875, *Technical Program Review 1957*, 1 Jan 1958, 6; *Technical Program*

"We were hiring people like mad at that time," said Colvard. "It was right after Sputnik and scientists and engineers were in great demand. . . . There didn't seem to be a problem getting people or money."[36]

New families also meant more children in school. In spring 1958 work had started on the new $1.1-million Burroughs High School. Formal cornerstone-laying ceremonies—complete with time capsule—were conducted by Masonic officials in September.[37] Nearly 900 students would begin classes at the new building in September 1959. At the same time, the new Desert Park Elementary School would open in the Wherry housing area, bringing the number of elementary schools in the China Lake School District to six and the total school enrollment to more than 3,100.[38]

As might be expected in a community with a disproportionately high number of advanced-degreed residents, China Lakers were almost obsessively active in their children's schools. In November 1958 educators and PTA officials attended a conference on the base to learn about the Gifted Child Program, which focused on the educational, social, and psychiatric well-being of intellectually gifted children. Unlike many gifted-child programs that were popping up nationally at the end of the 1950s, China Lake's had been created well before the launch of Sputnik.[39]

Increased activity at NOTS had ripple effects beyond the borders of the base. The local newspaper trumpeted the "Continued Growth of Kern County Population," anticipating that the population of about 303,000 would increase to 480,000 by 1980 (in fact, it reached just over 400,000 in 1980).[40]

Base and Town

Within the Indian Wells Valley, tension existed between China Lakers and residents of Ridgecrest, the little town outside the gate. NOTS, largely self contained, provided its own services. Ridgecrest was as yet unincorporated at the start of 1959 and would remain so until November 1963. Most of the

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Review 1958, 7; *Technical Program Review 1959*, 7.

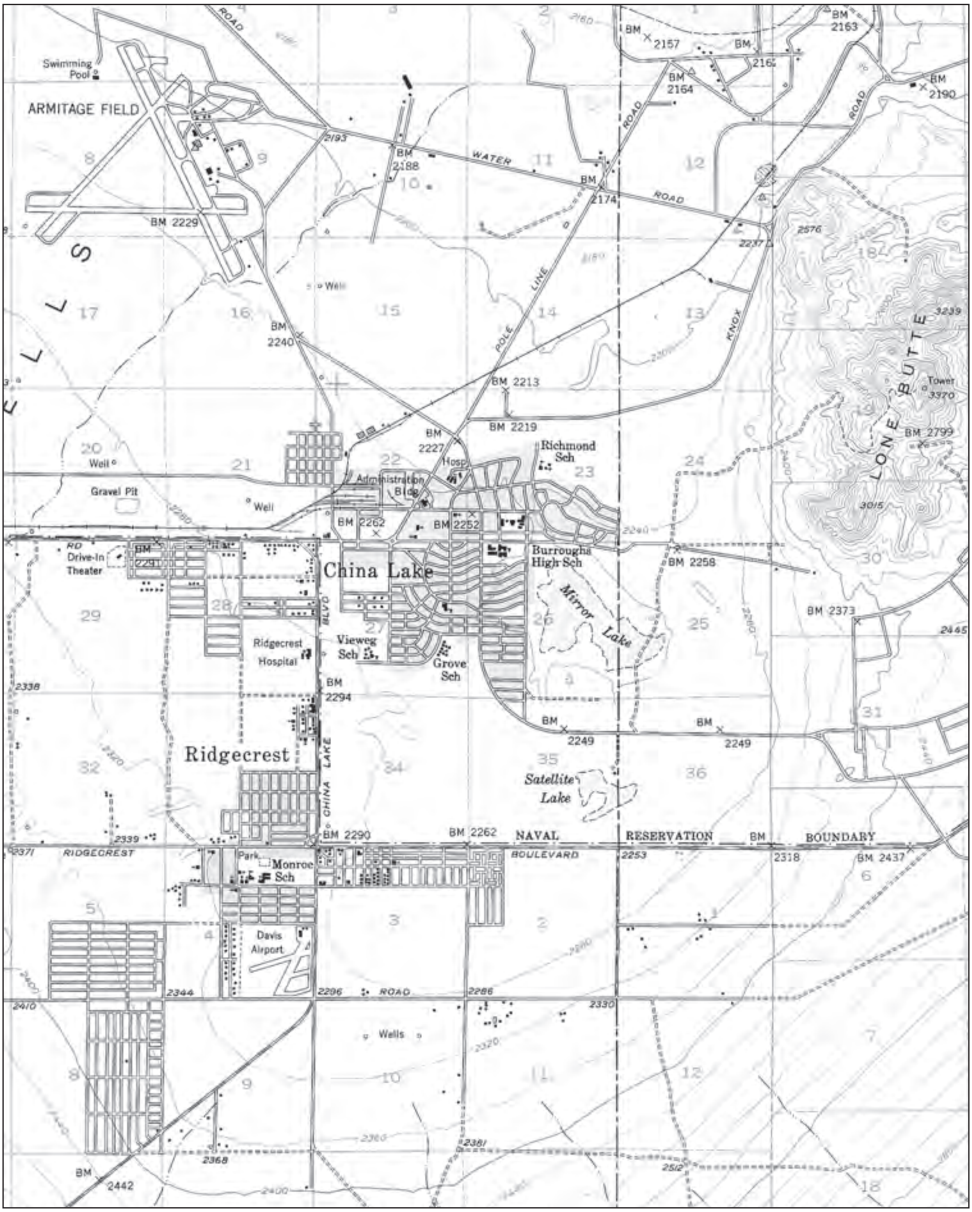
36 NL-T28, Dr. James Colvard interview, Navy Laboratories Oral History Program interview, 3 Nov 1980.

37 *Rocketeer*, 12 Sept 1958, 1.

38 Ellis L. Tiffany, *Public Education on the United States Naval Ordnance Test Station of California. A Brief History*, China Lake School District, 1966; *NOTS Command History* 1959, 13.

39 *Rocketeer*, 21 Nov 1958, 4.

40 *IWV Independent and Times-Herald*, 8 Jan 1958, B1; U.S. Department of Commerce, *1980 Census of Population*, Vol. 1, Chap. A, Part 6, Table 2, March, 1982.



Housing areas, Ridgecrest and China Lake. The China Lake main gate is located at the intersection just above and to the left of the words China Lake. The little town of Inyokern (not shown) is 8 miles to the west (left on this map). Burroughs High School, shown in this 1953 map by the U.S. Geological Service, was relocated to Ridgecrest in 1959, and the former Burroughs campus became Murray Middle School.

town's services—fire, police, ambulance, and so forth—were supplied by Kern County. The county seat, Bakersfield, was more than 100 twisting road miles away across the Sierra Nevada.[41]

The demographic line between the China Lake community and surrounding settlements was as distinct as the fence line that marked the geographic boundaries. Those who lived within the fence were civilian or military employees of the base (with very few exceptions, including teachers and medical people who worked in town but lived on the base), while most of the people who lived in the adjacent community did not work on the base.[42]

Thus many residents of Ridgecrest, and nearby Inyokern, had less allegiance to NOTS than did the China Lake residents. The divide between the two communities was also based on economics. China Lakers not only lived in government rental housing, which was maintained by a government workforce, but also enjoyed government-supported shopping and services that were unavailable to those not employed by NOTS. These benefits were

Balsam Street, Ridgecrest's main shopping street, circa 1959.

41 The base encompasses parts of three counties: Kern, Inyo, and San Bernardino.
42 The notable exceptions to this demographic division in 1958 were some 575 families who resided in town but were eligible for base housing. This was viewed at the time as an indication of the severe housing shortage on the base, rather than the start of an exodus. That shortage—along with a disparity in the quality of housing for higher-paid technical employees and lower-end wage-grade and clerical employees—was a continuing source of disharmony between employees and Station management. *Rocketeer,* 25 April 1958, 3; *Rocketeer*, 6 June 1958, 2.

perceived by some townspeople as undercutting Ridgecrest's fragile commercial infrastructure and adversely affecting the town's nascent business community. Leroy L. Doig III (whose father was a leading ballistician and later head of Acquisition Management at China Lake) said:

> I can remember in the '60s when folks who lived on base tended, to a certain extent, to think of people who lived off base as somehow second-class citizens. These were people who couldn't use the commissary and exchange.[43]

Indeed, in the early 1950s, the tension between base and town had erupted into a brief, bitter boycott of the town's businesses after Ridgecrest merchants tried to persuade Washington officials to end civilian shopping privileges at China Lake.[44]

Although these distinctions between off-base and on-base interests would change drastically in later years, they prevailed throughout the 1950s and 1960s. The rifts would not heal until the 1970s and 1980s, when, in a Navy-encouraged exodus, nearly all the civil servants left their homes in China Lake to reside in Ridgecrest and other nearby communities. Still, at the start of 1959, the town of Ridgecrest was doggedly forging its future. In January the local newspaper reported that the Ridgecrest Property Owners and Taxpayers Association, under the leadership of its new president Terri Hughes, would focus on "rekindling public interest in the establishment of a state college in Ridgecrest."[45]

At the end of the 1950s, contractors were helping to bridge the gap between town and base, foreshadowing what would become a lucrative industry in Ridgecrest: technical service contracts. Los Angeles-based DuWes Engineering Co. had opened an 11-man office in Ridgecrest in 1957. The venture was based, according to a newspaper account, on a simple question: "Would it be possible for a small engineering company to succeed in a place much larger companies did not think worthwhile enough to investigate?" The answer was yes. By the end of 1958 more than 50 DuWes employees in Ridgecrest were working on a NOTS contract worth more than $300,000, and the company was expanding its facilities from 1,000 to 8,000 square feet.[46]

By 1967 three technical service contractors (Gordon M. Genge Industries; Associated Aero Science Laboratories, Inc.; and ARINC Research Corp.) would employ 444 people in their Ridgecrest facilities.[47]

43 Leroy L. Doig III interview for video, "Somewhere on the Edge of Nowhere," 4 April 2004, Maturango Museum, Ridgecrest, CA.
44 *Magnificent Mavericks*, 278–281.
45 *IWV Independent and Times-Herald*, 8 Jan 1959, A5.
46 *IWV Independent and Times-Herald*, 30 July 1959, A7.
47 *News and Views*, Oct 1967, 5.

Trouble and Tragedy

As positive and promising as 1958 had been for NOTS, the year also had its setbacks. It began with a reduction in force (RIF), the Civil Service equivalent of a round of layoffs, in which 26 individuals were separated, or, in the local vernacular, "went out the gate." Another 16 people were reassigned to different jobs and 29 positions were changed to lower pay grades.[48]

Disappointment on the technical side of the house included the Rocket-Assisted Torpedo (RAT). The weapon had been under development at China Lake and at NOTS' Pasadena Annex since 1950 and was declared operational in February 1958—then suddenly cancelled at year's end, just months before it was to have been sent into the Fleet.[49]

The year, like those before and since at China Lake, also brought tragic reminders that developing and testing weapons is dangerous. Just 3 weeks before Christmas, two ordnancemen from the Chemistry Division were injured by a flash explosion while they were mixing igniter compositions in Michelson Laboratory. One sustained third-degree burns on the arms and face with "involvement of the corneas of the eyes."[50]

In separate incidents in May, two aircraft from NAF crashed when their pilots ejected after in-flight problems. A search-and-rescue helicopter crashed while attempting to rescue one of the pilots.[51]

The following month, VX-5 pilot Lieutenant Commander Richard M. Hopfinger, a WWII Pacific air combat veteran, was killed when his FJ-4B Fury crashed during refueling operations. Between 1958 and 1967, 23 people, both military and civilian, would die while carrying out China Lake's mission, and many more would be injured.[52]

The Larger Picture

For every failure in the laboratory or on the range—and failures in the research-and-development business often outnumber successes—China Lake was nevertheless accumulating a record of achievement that continued to

48 *Rocketeer*, 21 Feb 1958, 4.

49 *Basic Information About NOTS*, TS 62-168, NOTS, 21 Sept 1962.

50 *Rocketeer*, 12 Dec 1958, 4.

51 *NOTS Station Journal*, 1 May–31 May 1958, 4, 8–9.

52 *The China Laker*, newsletter of the China Lake Museum Foundation, Fall 2004. See also China Lake Alumni website *http://www.chinalakealumni.org/index.htm*, Gary Verver, owner and webmaster. Since 2002 Verver has operated this website, which contains a wealth of information about China Lake's history.

NOTS officials unveiling a model of RAT. From left are Douglas J. Wilcox, head, Underwater Ordnance Department, Pasadena Annex; Captain William W. Hollister, NOTS Commander; Commander J. J. O'Brien, Officer in Charge, Pasadena Annex; and Dr. William B. McLean, NOTS Technical Director.

bring in new tasks from Department of Defense and other customers and to open new areas of scientific and technological development from deep-diving undersea vehicles to military satellites. With success following upon success, it seemed that no task was beyond the capabilities of China Lake's military and civilian team.

NOTS, despite its physical isolation, geographic remoteness, and self-cultivated image of go-it-alone independence, operated neither autonomously nor in a vacuum. The base was affected tremendously by the outside world, and the Station's effectiveness had always been dependent on the active engagement of NOTS executives (military and civilian) in both Navy and national politics.

Events far beyond the California desert directly and substantially influenced the nature and amount of work performed at China Lake and the lives of the people who lived there. One center of such influence was, of course, Washington DC

President Eisenhower, since his 1952 election, had railed against duplication of effort among the military services, as well as their inefficiency and interservice rivalries. His determination to remedy these problems was spurred on by the Soviet success with Sputnik, and in 1958 he proposed a sweeping reorganization of the Department of Defense.

"Since [Sputnik] was in the main a technological shock, the President and the rest of the American body politic demanded a technological reply. . .," wrote Dr. Herbert F. York and G. Allen Greb in 1977. The Defense Reorganization Act of 1958, signed into law by Eisenhower in August, not only streamlined the Department of Defense and gave the Secretary of Defense greater powers, but also reshaped the manner in which the department's scientific and technological development programs were conducted by creating the office of Director of Defense Research and Engineering (DDR&E).[53]

The first DDR&E (the above-quoted Dr. York, a gifted physicist who 5 years earlier, at age 32, had been the first director of the Lawrence Radiation Laboratory at Livermore) was DOD's third-ranking civilian, below only the Secretary and Deputy Secretary of Defense. As well as holding a higher rank than the Assistant Secretary of Defense (Research and Development), who had formerly overseen military science and technology programs, the new director had the expanded authority to approve, disapprove, or modify any R&D program in the Department of Defense. Creation of DDR&E was a milestone in centralization of control within DOD, a trend that would increase over the next decade. In the continual reorganization of the Navy's R&D program through the 1960s, DDR&E would be the principal driver.[54]

Early in 1959, Howard A. "Howie" Wilcox, a China Lake department head and former Sidewinder program manager who had known York while working and teaching at Berkeley, left China Lake to become York's deputy. Wilcox once described a perception of China Lakers that, while not wholly inaccurate, would plague China Lake well beyond the period covered by this book:

53 Herbert F. York and G. Allen Greb, "Military Research and Development: a Postwar History," *Bulletin of the Atomic Scientists*, Jan 1977, 22.

54 Shortly after the creation of DDR&E, the Navy followed suit, creating the position of Assistant Secretary of the Navy for Research and Development (ASN(R&D)) with full control over all Navy R&D including management of the R&D appropriation. Centralization begets centralization.

> They thought of us as being the Huns descending on Washington out of the West to run off with all the plums. I think there was a certain "robber-baron character" to the way NOTS operated, because our philosophy basically was: if you can run faster than the next guy, then you get the job. So we ran just as fast as we knew how to run, and that wasn't the way that a lot of people in the East and the other laboratories operated.[55]

Eisenhower's Defense Reorganization Act also created the Advanced Research Projects Agency (ARPA), reflecting the administration's concern for Russia's ability to exploit space for military ends. ARPA operated under DDR&E and allowed special projects—initially space projects—to be undertaken without all the traditional service-specific red tape.

The technology and techniques that China Lake's technical workforce had developed for NOTSNIK, as well as the Station's record of upper-atmosphere research dating to 1946, positioned NOTS to be an important participant in several ARPA programs including Project Defender, a satellite-borne ballistic-missile defense system, and antisatellite projects.

Over the next few years, ARPA would be a prime source of funding and direction for China Lake and would support much of the weapons and technology developed by NOTS for use in the Vietnam War. ARPA-funded work at the Station ranged from satellite-launch programs to microrocket projectiles and even to a so-called "exploding rock," an antipersonnel mine designed to "defy visual detection because of its close resemblance to indigenous materials"[56]

A Changing Navy

Within the Navy, other forces were at work that would help shape China Lake's future. As 1958 rolled into 1959, a review board under the direction of Navy Undersecretary William B. Franke (who would become the Secretary of the Navy in June 1959) was formulating the Navy's response to the Defense Reorganization Act of 1958.

The Franke Board recommended that the Bureau of Ordnance and the Bureau of Aeronautics (BuAer) be combined. The recommendation was implemented, and in 1959 NOTS became part of a new Bureau of Naval Weapons (BuWeps).[57]

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55 S-196, Dr. Howard A. Wilcox interview, 22 Nov 1991, 26.

56 Advanced Research Projects Agency, *Project AGILE, Remote Area Conflict Research and Engineering, Semiannual Report, 1 July – 31 December 1963*, by Remote Area Conflict Information Center (RACIC), Battelle Memorial Institute, 1 Feb 1964.

57 Thomas C. Hone, *Power and Change. The Administrative History of the Office of the Chief*

Continuing problems with the bureau system would culminate, in 1967, with the creation of the Naval Weapons Center and the concomitant demise of the Naval Ordnance Test Station.

Two other events in early 1959, both in Virginia, also affected China Lake, though perhaps more psychologically than operationally. First, flight testing was discontinued at the Naval Aviation Ordnance Test Station (NAOTS), Chincoteague, Virginia. As a consequence, the NAOTS bomb and fuze evaluation work was assigned to NOTS. At about the same time, the restricted airspace over the Naval Proving Ground Aeroballistics Range at Dahlgren was reduced, thereby limiting Dahlgren's drop-test capability for bombs and air-delivered mines. Shortly thereafter the Mk 76 bomb ballistics program was transferred from Dahlgren to NOTS.[58]

These transfers briefly lent credence to a dream that many China Lakers have harbored throughout the history of the base. In a perhaps overly simplistic scenario, encroachment pressures exerted by the expanding population in urbanized areas of the country—primarily "back East"—force DOD to reduce noisy and hazardous activities at various laboratories and facilities.

The powers-that-be then assign those still-necessary activities, along with the personnel and dollars supporting them, to that vast, unencroached base way out there in the desert at China Lake, where noise and risk are a routine part of the job and where a population almost entirely dependent on the base for its sustenance (either directly or indirectly) has a higher tolerance (some even an affection) for the "sound of freedom"—loud engines at low altitudes and earth-shaking explosions at odd hours.

In 1959 the audio track of that dream may have been overlain with the "ka-ching" of local cash registers as transfers of personnel and funds from Virginia to NOTS were nearly completed by year's end. It would be another 50 years, however, before the dream began to be realized in any significant manner.

Still further from NOTS, beyond Washington, outside the nation's boundaries, changes were taking place that would dramatically shape the future of the Station—and the country.

Global Influences

In July 1958 President Eisenhower had sent U.S. Marines into Lebanon at the request of a Lebanese government threatened by civil strife. That same

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of Naval Operations, 1946–1986, Naval Historical Center, 1989, 46.

58 *NOTS Command History* 1959, 1.

month an assassination and revolutionary coup in Iraq ended the country's Western-aligned monarchy and brought a military junta into power. These incidents were symptomatic of a spreading destabilization of the world's political balance. Fires of nationalistic fervor, fanned in many countries by the revolutionary rhetoric of Communism, were eating at the traditional structures of imperial order.

Vietnam, since its 1955 partitioning into North and South Vietnam, was viewed by American military and political leaders as a front line of the war on Communism. Lack of effective resistance by the U.S.-backed forces in the south against Communist-backed forces from the north was a growing concern to America's senior military and political leaders.

The Vietnam War was edging up on America in 1959. Halfway through the year, before most Americans were even aware that the U.S. had a military presence in Vietnam, two American servicemen died in combat northeast of Saigon. During the next 16 years, more than 58,000 Americans would die in Southeast Asia. The Vietnam War would be the largest single factor shaping the direction of NOTS through the 1960s.[59]

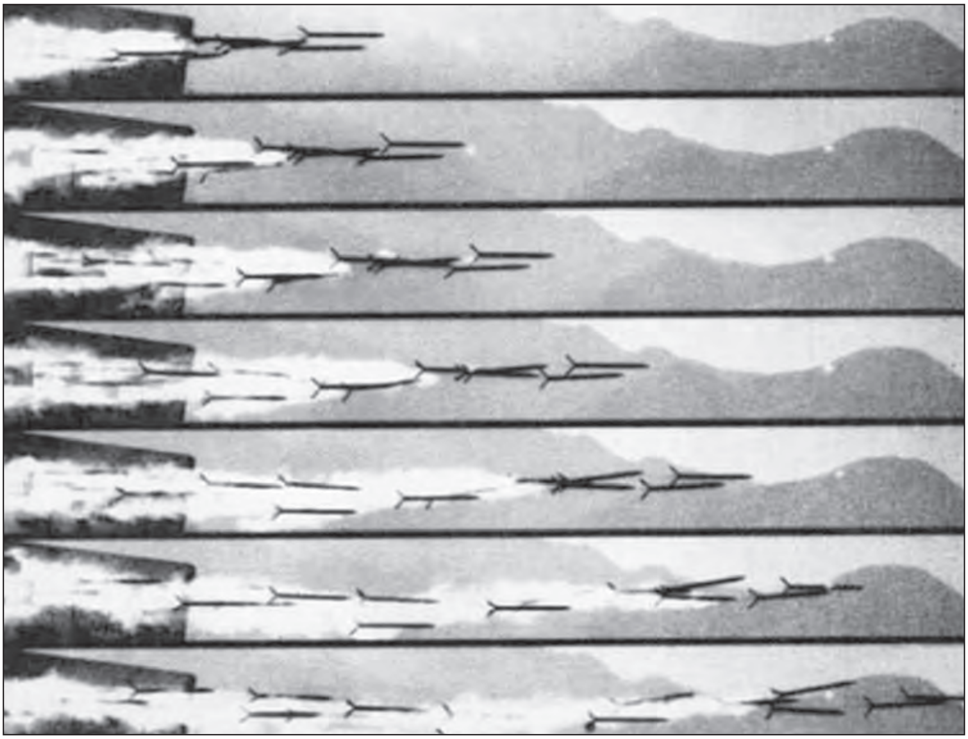
But Vietnam was only one influence on China Lake's future. In the early morning of that cold New Year's Day, 1959, just after champagne corks popped at midnight in the Mojave Desert, a portentous event occurred more than 2,000 miles away, on the outskirts of Havana, Cuba. The American-supported dictator Fulgencio Batista, pressed by a rebel army, boarded a plane to flee his country. Later that New Year's Day, 32-year-old Fidel Castro, head of the rebels, celebrated Batista's flight with a victory speech in Santiago de Cuba.

Within a year, Castro would be warning of a U.S.-supported invasion of his island. His warnings would be validated by the April 1961 Bay of Pigs invasion followed by the brink-of-nuclear-war Cuban Missile Crisis in 1962.

Certainly no one at China Lake would have imagined on January 1, 1959, that less than 5 years hence a NOTS A-4 aircraft carrying NOTS-developed Shrike radar-homing missiles would be flying through Cuban airspace, the chirp of Russian fire-control radars sounding loud in the pilot's headset.

Equally unlikely was the possibility that anyone at China Lake could have envisioned what the future held for the Mighty Mouse 2.75-inch Folding-Fin Aircraft Rocket (FFAR), a weapon developed at China Lake beginning in the late 1940s, used intensively in Korea in the early 1950s, and taken out of

59 The first mention of Vietnam ("Viet-Nam") in the NOTS *Command Histories* is a brief reference to a group of foreign naval attachés who toured China Lake in 1960. The term does not appear again in a *Command History* until 1965.



Mighty Mouse 2.75-Inch FFAR firing sequence, 1956. ***Naval Aviation News*** **photo.**

production in 1957. By 1967 the Secretary of Defense would be demanding a production rate of 800,000 rounds *per month* of the "bread-and-butter" round in South Vietnam.[60]

Nor in January 1959 had any China Laker yet heard of the "Eye Series," more than a dozen weapon systems with names like Rockeye, Deadeye, and Snakeye, that NOTS would develop over the next several years. At the height of the Vietnam War, the traditional radio call for close-air support, sent by Marines under intense ground attack, would be for "snakes and nape!" (also "shake and bake"), grunt shorthand for Snakeye retarded-delivery bombs and napalm.

Stability and Optimism

All that still lay ahead. New Year's Day 1959 was generally an unhurried day at China Lake. The Navy and Marine Exchanges, commissary store, and Station Library were all closed. So was the Community Center Snack Bar. The

60 "Navy Meeting Need for 2.75-In. Rocket," *Missiles and Rockets*, 22 Nov 1965; "Shortages Slow 2.75-in. Rocket Effort," *Missiles and Rockets*, 18 April 1967.

weather had warmed to the low 60s by mid afternoon, and children were outside playing with still-new Christmas toys. Base personnel carried out the minimum holiday level of routine duties and mundane details. Police and Public Works Department personnel responded to infrequent emergency calls, and Marine sentries checked cars as they entered China Lake from Inyokern Road.

The beginning of 1959 was a stable time in terms of Station leadership. Dr. William Burdette McLean was in his fourth year as NOTS Technical Director, the highest civilian position on the Station. Bill McLean was less than one-third of the way to what would ultimately prove to be a 13-year tenure—the longest of any China Lake Technical Director before or since.

McLean's career was already marked by extraordinary achievement: in January 1958 President Eisenhower had personally presented him with a gold medal for Exceptionally Meritorious Civilian Service for "conceiving and directing development of the Sidewinder Guided Missile Weapon System," a service ". . . of incalculable value to the defense of the nation and the free world." The Presidential award was highest honor the U.S. government could bestow on a federal career employee. (Among the four fellow recipients of the award that year was FBI Director J. Edgar Hoover.)

Two years earlier Chief of Naval Operations Admiral Arleigh Burke had presented McLean with a cash award of $25,000 under the Incentives Award Program, at the time, the program's largest monetary award ever made to a civil service employee.[61]

Captain William W. Hollister, NOTS Commander, was nearly halfway through the final tour of his 30-year career. He would retire in June 1961. Hollister was a longtime aviator who had flown bombers over the North Atlantic during WWII and had come to NOTS from a posting as commanding officer of USS *Hornet* (CVS-12). He had a less ambitious approach to his tour at China Lake than did many who had preceded and would follow him.[62]

Hollister and McLean "got along very well," said Haskell G. "Hack" Wilson, McLean's Associate Technical Director and the man who managed much of the day-to-day operations at China Lake. "There were no arguments about 'that's my cognizance, this is yours.'"[63]

Dr. Newton E. "Newt" Ward, who was head of the Aviation Ordnance Department when Hollister arrived at NOTS in 1957 and was later double-

61 Starla Hall, *William B. McLean, Man Scientist, and Administrator* (unpublished manuscript), Naval Ocean Systems Center, 10 Oct 1980.

62 For biographies of NOTS/NWC Commanders from 1958 to 1967, see Appendix A.

63 Haskell G. Wilson interview S-96, 9 July 1975, 40.

hatted as Associate Technical Director for Development (Weapons Systems), ascribed Hollister's effectiveness to the fact that he knew his China Lake tour would be his last. Said Ward:

> We had a bunch of lame-duck COs up there, guys who knew they were going to be passed over while they were there. Bill Hollister was one that knew when he came there that he could not make it [admiral] and that made him a better CO because he didn't worry about it. He was very relaxed.[64]

The spring semester of UCLA evening classes would soon begin at China Lake. A few scientists and engineers no doubt took advantage of the New Year's holiday to consider the list of course offerings. These included not only specialized subjects of interest to NOTS' weapons-development professionals—Mechanics of Continua and Advanced Analysis of Shell Structures—but also at least one course—Scientific Russian—that reflected the new, if grudging, respect that the Soviet launch of Sputnik had sparked in the U.S. scientific community.

January 1 was chosen by members of WACOM (Women's Auxiliary of the Commissioned Officers' Mess) to officially kick off the theme contest for the 1959 Desert Wildflower Show. The show had been held every spring since 1945, the year of WACOM's establishment; 2,000 guests had attended in 1958. Just as the "termination winds" were an unexpected shock to newcomers in the high desert, so was the extraordinarily brilliant display of wildflowers that transformed the desert into a gorgeous vista of color for a few all-too-brief weeks in later March or early April. The theme for 1959, contributed by Genevieve Allen, would be "Awakening Desert."[65]

Official sunset that day was at 4:48 p.m., though the sun had slipped below the edge of the Sierra Nevada nearly an hour earlier, dropping the base into the shadow of the mountains. At about 4:40 p.m. the loudspeaker on the Administration Building sounded First Call, and 5 minutes later the Call to Attention crackled over the speaker. Traffic, light on that holiday afternoon, halted on Blandy Avenue and Knox Street. A few people walking to their cars in the Michelson Laboratory parking lots stopped and faced the flag. The strains of the National Anthem floated over Mainside.

Although it was a holiday, many cars remained in the laboratory parking lot well into the night. China Lakers had a well-earned reputation for working long hours. In an R&D activities survey 2 years later, the Station would be asked about its policy on flexible working hours. Command's official response would read in part:

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64 S-94, Dr. Newton E. Ward interview, 23 Oct 1974, 19.

65 *Rocketeer*, Jan 30, 1959, 4.

> The majority of our employees reside not more than 10 minutes from their offices in an integrated work-community situation; and they have great personal involvement in their work. As a consequence, it is usual to find professional and scientific employees working, without compensation, at nights, on weekends and holidays. In a real sense, their vocation is their avocation. . . . strict adherence to normal working hours would penalize the laboratory many man-years of effort.[66]

China Lake legend Bud Sewell, whose contributions to China Lake's mission ranged from work on satellites and warheads to counterinsurgency weapons and field support in Vietnam, phrased it well: "NOTS was not so much a place to work as a state of mind."[67]

Lee Jagiello, a Sidewinder expert who had designed the critical torque-balance canard-control system for the missile and who would be one of the principal architects of the Shrike antiradiation missile, said, "Smartest thing the Navy did was put NOTS way the hell out there in the desert, build that beautiful lab, put the guys in there with nothing else to do. So you worked."[68]

For some employees, Thursday's work would continue into the evening over drinks at the Officers' Club, though perhaps not so many as the night before. A few NOTS residents would take in an evening show at the Station Theater—Van Johnson in "The Last Blitzkrieg" and a Mr. Magoo cartoon—or work on projects at the newly opened Hobby Shop on Halsey Avenue, a low-key finish to a quiet midwinter's holiday in the desert.[69]

As NOTS moved into the final year of the 1950s, the community shared a buoyant optimism that had been growing throughout the decade and across America. A holiday greeting, jointly issued by China Lake's civilian and military leadership, said in part, "With the advent of the coming year, the opportunity for achievement in the service of the Nation is outstanding."[70]

Franklin H. "Frank" Knemeyer, former Deputy Technical Director for Strike Systems and head of the Systems Acquisitions Office, identified the era

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66 *Reply to Questionnaire for In-House Research and Development Activities*, NOTS IDP 1447, Nov 1961, 34, 35.

67 S-106, Robert G. S. "Bud" Sewell interview, 26 Aug 1975, 1. Sewell spent 35 years at China Lake, earning an international reputation as an expert in detonation physics.

68 Leonard T. "Lee" Jagiello and Vice Adm. William J. Moran interview by Dr. Ron Westrum, 18 July 1988, 33.

69 *Rocketeer*, 26 Jan 1962, 1. The Officers' Club had been the social hub of the base since October 1944. It was open to military officers and to NOTS professional employees in grades GS-5 and above, nonprofessionals in grades GS-9 and above, and members of many support activities.

70 *Rocketeer*, 19 Dec 1958, 1.

just ahead as a time "when China Lake really came of age. . . . We weren't afraid to tackle anything. We had the expertise here. We had the basic capability to do whatever we wanted."[71]

"We can do it" was the prevailing attitude at NOTS. The Station would spend the rest of its days working to prove that it could, in fact, accomplish anything it set its collective mind to do.

71 S-200, Franklin H. Knemeyer interview, 20 Nov and 13 Dec 1991, 42, 76. Knemeyer's illustrious 34-year career at China Lake included 6 years as head of the Weapons Planning Group as well as leadership of the Weapons Development Department during the most productive years of the 1960s, At his retirement ceremony in 1982, he received the Distinguished Civilian Service Award, the Navy's highest civilian honorary award. NWC Technical Director Robert M. Hillyer said at the time, "He is one of those most responsible for the success of China Lake, and there is no one in the R&D business today who has had a greater impact on weapons development." *Rocketeer,* 26 March 1982.

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Reaching Skyward

We ought to go shoot the damned thing down!

— Lee Jagiello, speaking of Sputnik, 1957[1]

On Monday, 14 October 1957, just 10 days after the Soviet Union had launched Sputnik into orbit, 15 men crowded into the Technical Director's office in the second floor of the NOTS Administration Building. One was a Mr. Cowgill, a visitor from the Army's Office of the Chief of Ordnance. The others were all China Lakers: Dr. William B. McLean, the Technical Director, was joined by the Commander, Captain Hollister, the Executive Officer Captain Frederick A. Chenault, the Experimental Officer Lieutenant Commander Donald E. Bruce, and 10 civilian technical experts (including three department heads) from across the Station.

McLean's summary of the meeting, in the form of a memo to files (classified Secret at the time), began, "A meeting was held on the possibilities of NOTS developing a cheap, lightweight television satellite." Later in the memorandum, he referred to the payload as a "reconnaissance satellite." Considerable discussion was given to the relative merits of aircraft, balloon, and ground launching, with the conclusion that aircraft launching would be the preferred method.[2]

The two-page memorandum makes no mention of Sputnik, nor of the Soviet Union. Yet given the subject of the meeting, it's hard to imagine that Sputnik was not a large presence in the room.

Sputnik's launch on 4 October had been a slap in the face to American scientists and engineers. The U.S. and foreign press took the Sputnik story and ran with it, creating the impression of a disparity—variously known as the "space gap," the "missile gap" the "satellite gap," and the "technology

1 "Secret City. A History of the Navy at China Lake," China Lake Video Projects Branch, Nov 1993, Disk 2. Jagiello recalled that he addressed this remark to Haskell G. Wilson.
2 Memo, Doc. No. 01-45, "Meeting in Dr. McLean's Office," Wm. B. McLean to files, 14 Oct 1957.

gap"—between the U.S. and the Soviet Union. If the Soviets had the rocket power to put a 184-pound satellite into orbit, went the reasoning—Sputnik's steady "beep beep" signal was played repeatedly over U.S. radio and television stations—how difficult would it be for "the Russkies" to lob a nuclear weapon at North America?

The thought of an orbiting nuclear weapon, a perpetual Damoclean sword over the United States, was frightening to contemplate. Although President Dwight D. Eisenhower was one of the most famous Army generals in U.S. history, the public's faith in American military strength and, indeed, in American technological competence was deeply shaken by the Soviet accomplishment.

That faith was further shaken when, on 6 December 1957, the attempt by the Naval Research Laboratory (NRL) to launch the first U.S. satellite failed spectacularly. The launch vehicle, Vanguard TV3, blew up before it cleared the launch gantry. As reported in *Time* magazine, "The U.S.'s tiny, grounded satellite got rechristened stallnik, flopnik, dudnik, puffnik, phutnik, oopsnik, goofnik, kaputnik, and—closer to the Soviet original—sputternik."[3]

The Los Angeles Times, under the headline "Vanguard Fiasco Deals Heavy New Blow to American World Prestige," reported that "News from Cape Canaveral, Fla., about the rocket failure hit the State Department with a kind of sickening thud." Referring to the "injury suffered" by the U.S. when Sputnik had been launched two months earlier, reporter John Hightower wrote, "Allied and neutral nations alike realized then that the Soviet Union had flashed ahead of the powerful United States, with all of its scientific resources and productive capacity, as well as its political doctrine of scientific freedom."[4]

There was no shortage of excuses for America's apparent second-place status. Lockheed Aircraft executive Louis Polk, speaking at a conference at China Lake, said, "The big difference between this country's space efforts and those of Russia lies in the two attitudes after Word War II. While the United States worked hard for disarmament, Russia kept right on with her military and rocket programs."[5]

At the time of the Sputnik launch, Dr. Ivar Highberg was head of NOTS' Test Department. Highberg had earned his PhD in mathematics from Caltech and taught for a dozen years at Whitman College, Washington, before coming to China Lake in 1947. Looking back from 1981, he recalled the reaction Sputnik evoked at NOTS:

3 "The Death of TV-3," *Time*, Vol. LXX, No. 25, 16 Dec 1957, 9, 10.
4 *Los Angeles Times*, 7 Dec 1957, 2.
5 *Rocketeer*, 16 Jan 1959, 1.

> We immediately set out to hunt up apparatus so that we could listen to Sputnik, and with the JPL [the Caltech-managed Jet Propulsion Laboratory] being given the responsibility to produce an immediate answer to Sputnik . . . we joined with Caltech to develop a tracking station for the satellite that they were going to put up.[6]

Highberg had been one of the attendees at McLean's 14 October meeting.

NOTS 1—NOTSNIK

As the shadows lengthened on 1957, China Lake was doing more than just devising a way to monitor signals sent from a JPL satellite. In November 1957, while Sputnik was still circling the earth (though mercifully its irritating beep-beep had ceased late in October, 3 weeks after launch, when the batteries died), NOTS pitched its own plan for the first U.S. satellite to the chiefs of the Bureau of Aeronautics and Bureau of Ordnance as well as to the NOTS Advisory Board, a high-level group that both advised the Station and acted as a liaison between the Station and industry, academia, and government. The plan had been hatched at the 14 October meeting in McLean's office.

The payload would be dubbed the Naval Observational Television Satellite (NOTS 1). As Howie Wilcox recalled in an interview nearly 18 years later, the original thought behind the project had been a suborbital rocket that could be used for ocean surveillance ahead of a fleet, but it didn't take long for the proposal to evolve into an orbiting satellite launched with a six-stage rocket.[7]

Advisory Board endorsement was quick in coming. At the conclusion of the meeting, the board praised the Station "for the excellent study of a simple earth scanning system largely comprising existing components, and for ingenuity and invention in simplifying the methods of achieving satellite orbits." It further stated, "If the promise indicated to the Board is borne out by further study, the Board recommends the authorization and vigorous pursuit of a development phase."[8]

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6 S-121, Dr. Ivar E. Highberg interview 1 April 1981, 9–10. Highberg retired from China Lake in 1975. Along with many honors from China Lake and the Navy, he received an honorary Doctor of Science degree from Whitman College in 1977. He died in 2009 at the age of 97.

7 Minchen Strang notes on a telephone interview with Dr. Howard Wilcox, 2 May 1976, National Museum of Air and Space, Space History Technical File ON-21000-01.

8 Advisory Board recommendations, 14–16 Nov 1957, 17-3–17-4. Among the members of the board that year were Dr. Norris E. Bradbury, director of Los Alamos Scientific Laboratory; E. H. Heinemann, chief engineer of Douglas Aircraft Corp.; Rear Adm. C. M. Bolster, USN (Ret.), head of R&D for General Tire and Rubber Co.; W. Kenneth Davis, director of Reactor Development for the AEC; Dr. William Shockley, director of Shockley Semiconductor Laboratory (and recipient of the Nobel Prize in Physics in 1956); Carleton

Technical Director Bill McLean and Associate Technical Director Hack Wilson hit the road to Washington and eventually briefed NOTS 1 all the way to President Eisenhower.[9]

With a positive response in Washington, the original idea of a $200,000 project to demonstrate the air-launched concept soon expanded to an $860,000 ground-launched-satellite project. BuOrd approved and funded that proposal. In mid-December, however, funding for the rocket motors and launch facility was halted. (In a 1993 paper, Dr. John D. Nicolaides, former Technical Director for Astronautics for the Navy, attributed the funding halt to the Navy's fear of embarrassment if the ground-launched version should suffer the same fate as the Vanguard TV3.)

China Lake then brought forth a new (or a revision of the old) proposal: an infrared-scanning satellite to be launched not from the ground but from a Douglas F4D Skyray fighter aircraft. That project quickly became known as NOTSNIK.[10] This air-launch concept had actually been the one agreed on by the attendees at the 14 October meeting in McLean's office. His memo noted:

> The relative merits of ground launching, balloon launching, and launching from a high-speed aircraft were discussed. It appears that a suitable propulsion system can be made light enough for installation on the F8U, the F-104, or the B-58. Launching from the aircraft has a large factor in its favor over launching from the ground. It is preferable to the balloon in that the initial launch direction is much easier to control and is closer to the direction required for orbiting.[11]

Later in 1958, the Station's IBM 704 digital computer (referred to in the annual *Technical Program Review* as a "calculator") was used to analyze the feasibility of an air-breathing ramjet engine-powered air vehicle that could be accelerated to Mach 2 on SNORT (or on a supersonic aircraft). The winged vehicle would then accelerate to Mach 4 and climb to 75,000 feet or higher, where rocket stages would kick in to lift a satellite into orbit. Although this "flying start" approach showed the possibility of lowered cost and major weight reduction in the first stage, it was not pursued beyond the analysis stage.[12]

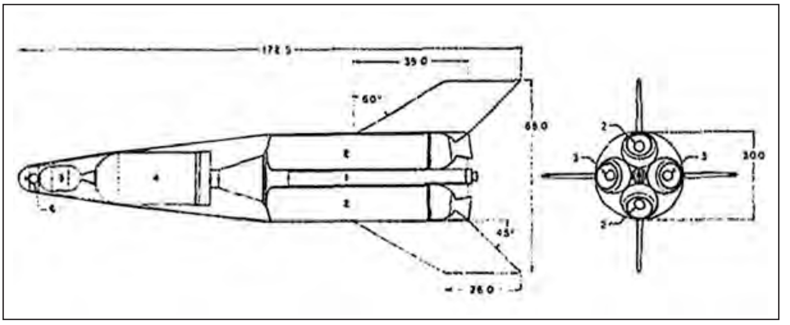
Shugg, general manager of General Dynamics Electric Boats Division; and Professor Kenneth S. Pitzer, dean of Berkeley's College of Chemistry. The Advisory Board was established by Dr. L. T. E. Thompson in 1949 and continued until the mid 1970s.

9 AdPub 107, *Basic Information on the U.S. Naval Ordnance Test Station China Lake, California*, Encl. (1), "In Reply to Secretary McNamara's Task No. 97," Aug 1961, 23.

10 The history of NOTSNIK is described in detail in Babcock, *Magnificent Mavericks*, 434–442. An excellent account is also in Matt Bille and Erika Lishock, *The First Space Race*, Texas A&M University Press, 2004, 140 ff. In some documents, NOTSNIK is called Project Pilot..

11 Memo, Doc. No. 01-45, "Meeting in Dr. McLean's Office," 1.

12 *Technical Program Review 1958*, 87–88.



NOTS vehicle configuration. Figure from *Status Report on the Naval Observational Television Satellite Project*, **April 1958.**

In those early space-race days, when an IBM computer would still be called a calculator, NOTSNIK had a wonderful simplicity of design. For example, the fins on the third-stage propulsion motor, which was timed to fire at 69,000 feet above sea level, were canted just enough to impart a spin to the missile of 5 revolutions per second. This spin allowed the onboard IR telescope to begin sensing the earth horizon on each revolution, once the missile had reached a certain angle. That “horizon trigger” fired the fourth-stage motor and imparted additional velocity to the missile. Following burnout of Stage 4, the Stage 5 motor fired, adding an additional 8,900 feet per second of velocity.

Only the Stage 6 motor remained, a tiny China Lake-designed solid-propellant spherical motor, 5.5 inches long and 3.5 inches in diameter, with a 1-second burn time and a total thrust of 172 pounds. The motor, weighing a scant 1½ pounds, was mounted in the center of the IR scanning payload. At 200 seconds into the flight, a timer on the motor caused the fourth stage to drop away; then at 3,200 second (about 53 minutes later), the timer fired the final motor.

While all the other motors had their nozzles facing the aft end of the missile (as is traditional in rockets), the final motor’s nozzle faced forward, in the direction of flight. Because the missile was spinning (from the fourth-stage motors fins), its orientation in space was fixed, through the gyroscopic effect. During the 53 minutes between Stage 5 separation and Stage 6 firing, the missile had coasted halfway around the world, 180 degrees. The motor was now pointing not away from the earth but toward it. When it fired, it provided what JPL Director Dr. William H. Pickering termed a “kick in the apogee,” the final push that propelled the little payload into its final orbit. Still spinning, the IR telescope could now capture sequential strip views of the earth below and transmit them back to receiving stations on the ground, a so-called “flying spot scan and raster picture.”

The “flying spot” hardware was designed and built by Aviation Ordnance Department electronics technician John “Mel” Brawn. Prior to coming to

China Lake in 1956, Brawn had owned his own television-repair business in San Diego for 7 years.[13]

On 31 January 1958, as NOTS was scrambling for funds to continue NOTSNIK, the U.S. finally managed to launch a satellite. Explorer 1, designed and fabricated by JPL, was put into orbit with an Army Jupiter-C rocket The satellite weighed 31 pounds, less than half of which was actual payload. The successful launch took place nearly four months after Sputnik, and three months after Sputnik 2, which weighed 1,100 pounds and carried a dog, Laika.

NOTS' partnership with JPL in the development of tracking stations paid off. The *Rocketeer* reported, "The minute signal radiated from the United States' first man-made satellite was received at NOTS Microlock station at 9:41 p.m. last Friday, as the baby-moon began its repeating 115.2-minute orbit."[14]

Six weeks after Explorer 1's launch, Vanguard 1, the first Navy satellite, reached orbit. NRL's satellite measured just over 6 inches in diameter and weighed 3.2 pounds and was derided by then-Soviet Premier Nikita Khrushchev as "the grapefruit satellite."[15]

Compared to the two Soviet Sputniks, the Explorer 1 and Vanguard 1 were indeed diminutive. But greater accomplishments lay ahead for the U.S. Though starting late out of the gate, the nation threw itself wholeheartedly into the "space race" with the Soviets and quickly began to catch up.

By January 1959 a Ridgecrest newspaper would be able to report that the U.S. had 8,900 pounds of satellites in orbit—twice as much as the Soviets.[16]

In typical China Lake fashion, work had begun on NOTSNIK as soon as Station management decided it was a good idea. Financing for the effort came from in-house exploratory development funds, augmented as necessary by monies on the Station for other projects. Still, by mid March 1958, the funding situation was becoming desperate. Then came a welcome turnaround from the Advanced Research Projects Agency (ARPA).

ARPA head Dr. Herbert York—who had initially looked askance at the NOTSNIK proposal—decided to support the program, a change in position brought about because China Lake's project coincided with a super-secret Navy-led program to detonate three nuclear devices outside the atmosphere

13 NOTS 2000 Rev. 1, *Status Report on the Naval Observational Television Satellite Project*, China Lake, CA, April 1958; *Rocketeer*, 2 July 1971, 7.

14 *Rocketeer*, 7 Feb 1958, 1.

15 Naval Research Laboratory Press Release 21-03r, 10 March 2003, "Vanguard Satellite Marks 45 Years in Space," *http://www.nrl.navy.mil/pressRelease.php?Y=2003&R=21-03r,* accessed 19 Oct 2009. As of 2009, Vanguard 1 was still the longest-orbiting man-made satellite.

16 *IWV Independent and Times-Herald*, 1 Jan 1959, A2.

over the South Atlantic Ocean. York realized that the NOTS satellite launch vehicle could be used to place radiation sensors in orbit to monitor the effects of the explosions. Thus China Lake became a player in Operation Argus.[17]

The Argus exo-atmospheric explosions were scheduled for August 1958. Around April, according to official Operation Argus records:

> . . . an additional project was added: the launching of small satellites into polar orbits from naval fighter aircraft under the cognizance of the Naval Ordnance Test Station . . . to provide additional Earth satellite instrumentation as a backup to Explorer IV [a U.S. satellite launched in July 1958] for measuring the ARGUS effect.[18]

Although there was now money for NOTSNIK—according to one 1961 report, by July 1958 NOTS had received more than $1.3 million for the project from ARPA, BuOrd, and the Armed Forces Special Weapons Projects Agency—there was simply not enough time to properly carry out the enormous amount of work that needed to be done.[19]

Propulsion engineer Crill Maples, fresh from Oklahoma State University, was immediately put to work on NOTSNIK. As he recalled in 1974:

> Charlie Bernard . . . came to get me at 5 a.m. on my very first day on the job, and I never got home again for a week. That was in conjunction with work on the NOTS 1. I was indoctrinated right away on the crash methods of NWC, famous all over the world at that time.[20]

According to the records of the Defense Nuclear Agency (DNA):

> In the 5 months prior to ARGUS, NOTS personnel designed, fabricated, tested, and attempted to launch a new kind of satellite. The launch vehicle and satellite were to be carried aloft by a Navy F4D-1 aircraft that would then launch the rocket intended to place the satellite package in orbit. Each satellite instrument package contained radiation-sensing and -counting equipment, plus a transmitter. NOTS-built/JPL-designed Microlock stations, manned by NOTS personnel, were shipped to New Zealand, Alaska, Greenland, the Azores, and Hawaii to track the satellites and to receive telemetered data.[21]

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17 Defense Nuclear Agency (DNA) 6039F, *Operation Argus 1958,* 30 April 1982, 1. According to this report, "The ARGUS shots were conducted to test the Christofilos theory, which argued that high-altitude nuclear detonations would create a radiation belt in the upper regions of the Earth's atmosphere. It was theorized that the radiation belt would have military implications . . . ."

18 Ibid., 23.

19 AdPub 107, Encl. (1), "In Reply to Secretary McNamara's Task No. 97, Aug 1961," 39.

20 *Rocketeer*, 20 Sept 1974, 7.

21 DNA 6039F, *Operation Argus*, 46. The Station constructed five of these portable stations (3,500-pound shipping weight) each consisting of three 6-foot racks of electronics

The television satellite concept was on standby, at least temporarily.

To add to the complexity of the task, the nature of the payload and frequency constraints required the designers—all products of the electron-tube school of design—to use transistors. Phil Arnold, who had arrived in China Lake in 1955 to stay until his retirement as head of the Weapons Planning Group almost 40 years later, designed the transmitter for NOTSNIK while working in Bud Sewell's Long Range Missile Branch. Arnold noted that he "had zero experience designing transistor circuitry, let alone state-of-the-art radio transmitters."[22]

There were to be two different payloads. The first vehicles would carry FM/FM diagnostic payloads: a wet-cell battery, the low-wattage 108-MHz transmitter designed by Arnold, and a subcarrier oscillator designed by Richard V. Boyd. Leo Kielman made the fiberglass skin and foam packaging structure. The diagnostic payloads were intended to demonstrate that the satellites could actually transmit data from orbit.

The final three vehicles would carry the Operation Argus radiation sensors, designed and built by Mel Brawn of NOTS Aviation Ordnance Department's Development Division No. 3 (Instrumentation). The operational specifications and the circuitry for the Argus payload came from famed American space scientist James Van Allen, then head of the Department of Physics and Astronomy at the University of Iowa.[23]

Security was tight for Operation Argus. Even the then-classified *Technical Program Review* described the payloads as "cosmic-ray satellite probes."[24]

Developing the NOTSNIK launch vehicle, designated NOTS-EV-I (EV for experimental vehicle), and its payloads in only five months required superhuman effort. Arnold recalled a work schedule of "14-15 hours a day, 6 days a week," and the occasional working Sunday. His team worked in China Lake's celebrated Building X, a precise replica of the atomic bomb assembly building on Tinian Island. Building X had been constructed for NOTS' work on the Fat Man bomb, which had undergone flight and aerodynamic testing at NOTS late in WWII.[25]

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and a five-turn knockdown helix receiving antenna. For satellite observation, NOTS also developed a satellite tracking capability for cinetheodolites as well as ballistic streak cameras for satellite photography.

22 S-275, Phil Arnold interview, 28 April 2009, 7.

23 S-188, Rod McClung interview, 22 and 26 March 1991, 40, 41; WT-1667, *Project Operation Argus, Satellite Launching from Aircraft*, Defense Atomic Support Agency, Washington, DC, 25 May 1960, 20.

24 *Technical Program Review 1958*, 60.

25 S-275, Arnold interview, 8; Babcock, *Magnificent Mavericks*, 435. NOTS also manufactured the non-nuclear explosive components for the first atomic bombs at the Salt

In a review of the NOTSNIK project's management, published 2 years later, Dr. Eugene Walton of Central Staff quoted an unnamed member of the NOTS team:

> I feel that the time schedule was set up in either a very optimistic or an opium-smoking atmosphere, or else it had to be set (that way) in order to get any support at all. Certainly they were not set up on any sound technical considerations . . . .[26]

At some point during the hectic process of design and test, the launch vehicle was reduced from the original six stages (not counting the launch aircraft), to five, through the elimination of the 5-inch-diameter Zuni motor designed to kick the vehicle up and away from the launch aircraft. A study of flight and guidance tolerances showed that ballistic performance, using pre-set timed ignition of the five stages would be nearly—but not quite—reliable enough to put the payload in orbit. Therefore "a scheme was designed to ignite the important third-stage rocket at the precisely correct trajectory-elevation angle by using a telescope, rigidly mounted in the vehicle, to sense the earth's distant horizon." Total number of moving parts in the launch vehicle: zero.[27]

Forces far from NOTS were driving the time schedule. The United States had committed to a voluntary cessation of nuclear tests starting on 31 October 1958, and that was the clock against which all Argus participants were racing.

Operation Argus was managed by the fledgling ARPA organization and required the coordinated efforts of the Atomic Energy Commission (the nuclear devices), the Army (the three Explorer rockets that launched the nukes), the Navy (China Lake and the Naval Research Laboratory), the Air Force (high-altitude sounding rockets to study the "lower fringes of the expected effect" at an altitude of 500 miles), as well as the Smithsonian Institution, the University of Iowa, and various contractors. The heart of the operation was Task Force 88, a fleet of nine ships and some 4,500 sailors commanded by Captain (later Vice Admiral) Arthur R. Gralla aboard USS *Norton Sound* (AVM-1), from which the rockets carrying nuclear devices were launched.[28]

Between 25 July and 28 August, NOTS tried six times to launch a satellite. For each launch attempt, the F4D "first stage" carrying EV-1 would take off

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Wells Pilot Plant. These explosive "lenses" were precisely designed to crush the nuclear core material of the bomb to initiate the nuclear reaction.

26 Eugene Walton, *A Review of the Management of the NOTS I Project*, NOTS IDP 1092, Aug 1960, 20.

27 *Technical Program Review 1958*, 60.

28 James R. Killian, Jr., *Sputnik, Scientists, and Eisenhower*, Cambridge, London, MIT Press, 1977, 188; DNA 6039F, *Operation Argus 1958*.

Ordnance technicians loading NOTSNIK on F4D-1 Skyray aircraft, 19 July 1958.

from China Lake's Armitage Field and fly to the Pacific Missile Range, over the Pacific Ocean near Point Mugu, California. The pilot would launch the rocket from a 57-degree climb at 35,000 feet over the range. The missions were flown by NOTS project pilots Commander Hal Lang and Lieutenant Commanders Joel Premselaar and Bill West.[29]

At least four of the EV-1 launches failed. The primary problem was the first- and second-stage rocket motors. These HOTROCs, as they were called, were specially modified versions of the China Lake-developed Antisubmarine Rocket (ASROC). China Lake engineers had thinned the cases and added extra propellant to give a better thrust-to-weight ratio. NOTS-EV-1's designers had wanted to use Sergeant motors, designed for the Army's new surface-to-surface missile, for the first and second stage, but this request had been nixed back East, perhaps for reasons of Navy pride.

Two of the NOTS-EV-I rockets may have achieved their goals. According to military historian Norman Friedman:

> It appears that the rocket orbited a short lived satellite on its first attempt on 25 July 1958 (a Minitrack [Microlock] station at Christchurch, New Zealand, detected a sign; the rest of the network had shut down after the launch pilot thought—apparently incorrectly—that he saw the rocket explode after

29 Joel Premselaar, quoted on China Lake Alumni website, *http://www.chinalakealumni.org/1958.htm*, accessed 15 Sept 2009.

> launch). After a failure, there was another apparent success on 22 August of the same year, the New Zealand station picking up signals on the expected first and third orbits. In both cases, probably the last stage failed to ignite, the fourth stage having given the satellite too low a perigee (60 miles) to last for very long.[30]

The two possible successes Friedman refers to would have been the first and third diagnostic payloads. According to Sewell and Knemeyer, all three of the rockets carrying the radiation payloads fell into the ocean when the first stage—the HOTROCs that China Lake had been pressured into hastily developing in lieu of the Sergeant motors—failed to ignite.[31]

A 1994 *Los Angeles Times* article also reported that two of the satellites reached orbit, citing John Nicolaides. At the time of the NOTSNIK program, he was Systems Director, Aviation Ordnance, the senior civilian position in the BuOrd Planning, Coordination, and Analysis Branch. It was this office—later titled the Technical Director for Astronautics—that coordinated the Navy's nascent space program. Nicolaides reiterated the two-satellites claim in a 1996 interview.[32] Whether or not any NOTS satellites launched reached orbit, the program was unsuccessful in delivering the goods for Operation Argus. According to a DNA account:

> On 25, 26, and 28 August NOTS attempted to launch the satellite with the radiation counting payload on board. All three of these attempts also failed. Consequently, the NOTS project was not operational during any of the ARGUS shots.[33]

Nicolaides stated in a 1996 interview with Peter Pesavento, a writer on space and military history, that news of the possible success of two launches was relayed to President Eisenhower, but the decision was made not to publicly acknowledge the success, if success it was. Politics may have played a role—the Air Force's launch methods were far more expensive than China Lake's, but the

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30 Norman Friedman, *Seapower and Space*: *From the Dawn of the Missile Age to Net-Centric Warfare,* London, Chatham Publishing, 2000, 33.

31 S-297, Knemeyer, Sewell, Doig, and Lincicum interview, 7.

32 Ralph Vartabedian, "One Last Transmission From Satellite Old-Timers," *Los Angeles Times*, 2 Oct 1994, D1; Peter Pesavento, "US Navy's Untold Story of Space-Related Firsts," *Spaceflight, the International Magazine of Space and Astronautics*, 38, No. 7 (July 1996): 239. In a 1996 interview by Pesavento, Nicolaides stated that the actual name of the project was NOTSNIC: "The name NOTSNIC was "NOTS" for the Naval Ordnance Test Station, and the "NIC" was for the first part of my last name . . ."

33 DNA 6039F, *Operation Argus 1958*, 46. The Argus report did note that "The NOTS microlock ground receiver stations, however, did assist in tracking Explorer IV and monitoring its telemetry signals. Explorer IV, which had been launched in July 1958, collected radiation data from the Argus tests.

last thing the President needed at that point in the space race was a fragmented and incoherent program.[34]

After the failure of the Station's first guided missile, the NOTS AM (NOTS Air Missile), which had been cancelled in 1949, McLean had decried the project's "easy looking and seductive approach of welding 'off-the-shelf' components into a system," as well as the project's "design by committee," which he believed resulted in "the final product clearly showing the lumpy structure representing individual enthusiasms."[35]

"Design by committee" and "off-the-shelf" seem to have played a role in the failure of NOTSNIK as well. Not a week after the last NOTSNIK had gone in the drink, Bud Sewell wrote a memo to Bernard "Barney" Smith, head of the Weapons Development Department. Sewell's memo began, "Approximately ten months and four million dollars ago, the NOTS Project was started . . ." [36]

Obviously rankled by the NOTSNIK experience, Sewell called it "a prime example of how not to run a project" and described the task as:

> . . . undermanned in the skills and techniques required and undersupplied with the material required for such a project. It was limited continually by supply and facilities and faced such other hardships as unrealistic time scales; unrealistic cost estimates; panic at all times; uncoordinated activity; conflicting information from various sources connected with the project; lack of clear-cut lines of responsibility, with the resultant lack of knowledge of whom to see to correct an obvious fault; and, perhaps the most important, lack of a true project engineer for the first six months or more of operation.

He zeroed in on the key technical weakness:

> Forced by a political situation at much higher levels, the Station had to use a system of motors which were not those desired for this project. . . . the

34 Pesavento, "US Navy's Untold Story," *Spaceflight*, 241.

35 "Air-to-Air Interception," NOTS 2068, *Weapons: Journal of Research, Development, and Test*, 1, No. 1, NOTS, 1 Jan 1959; "Research and Development of Military Equipment," 17 April 1959, Retrievable Manuscript (RM) 24, *Collected Speeches of Dr. William B. McLean*, China Lake: NWC, 1993, 12.

36 Memo, 4053/RGSS:ch Reg. 4053-42, "Informal thoughts on the NOTS Project," Head, Long-Range Missile Branch, to Head, Weapons Development Department, 2 Sept 1958. Smith would leave NOTS in 1960 to become chief engineer for the Bureau of Naval Weapons and later Technical Director of the Naval Weapons Laboratory, Dahlgren, VA. He said in his autobiography that he left China Lake because McLean "was asking me to divert money from other projects to a continuation of the space work and he honestly felt he had the right to do so as Technical Director. He had absolutely no faith in our masters in Washington and he was certain they were incompetent drones. I could share some of those views, but I could not in good conscience agree to diverting the money for which I had made personal promises in the Bureau." Bernard Smith, *Looking Ahead from Way Back*, Richmond, IN, Prinit Press, 1999.

> Station had to develop the HOTROC cluster to use as the first two stages of the missile system. These motors are extremely thin-walled, high performance motors and in this capacity perform admirably; however, in addition, they are forced in this system to serve as principal parts of the structure, making their marginal wall thickness, which while adequate as motors alone, inadequate as both motor and structure.

Positive results were also noted: "excellent motors have been developed" (referring particularly to the 8-inch and 3-inch motors) and "considerable expertise has been gained by many groups on the Station in transistor circuitry and radio frequency design."

Finally, Sewell made several recommendations for future projects ("Avoid unrealistic time scales and the resultant panic which they entail.") Perhaps most interesting was his final piece of advice:

> Make realistic cost estimates and do not try to sell the efforts of this Station as being cheap. Good work will be bought regardless of cost and realistic cost and time estimates are certainly appreciated by the Bureau more than unrealistic ones.[37]

The allusion to cost is significant; NOTSNIK's paper trail is cluttered with conflicting estimates of the magnitude of cost and the sources of funding. Apparently, a significant portion of the money for NOTSNIK came from Sidewinder missile development funds. Dr. W. F. "Frank" Cartwright, head of the Air-to-Air Weapons Division (home of Sidewinder development), was called east to justify the extensive expenditures that had gone to into the Station's satellite program. He explained that the money had been used for a project called "HAIRS," a High-Altitude Infrared (Background) Survey. Years later he commented "How else than measuring from space? Sidewinder is, in fact, an IR guided weapon."[38]

As with Sidewinder and numerous other programs, the Station's ability and willingness to quickly reallocate assets had allowed NOTSNIK to proceed full-bore, even as the money came in fits and starts.

In one sense NOTSNIK was a failure, but in others it was a success. The program forced the Station to develop rudimentary expertise in new technologies that were essential to satellites. Experience with NOTSNIK also pointed up the need for new, better-instrumented propulsion-development facilities. One technological innovation employed in NOTSNIK and used in countless man-made satellites since, is the nutation damper. This device controls a rotating

37 Ibid.

38 Frank Cartwright emails to the author, 8 and 13 Nov 2009.

body's precession (wobbling, like a spinning top). NOTSNIK's mercury-thallium filled nutation damper was based on one developed by NOTS to control precession in the Sidewinder missile gyroscope.

Perhaps coincidentally, and certainly ironically, in that same week in August 1958 that the final NOTSNIK launch failed to put the Argus radiation sensor into orbit, Addison M. Rothrock, administrator of the then-month-old National Aeronautics and Space Administration (NASA), and three representatives from ARPA toured the Station's facilities "for the specific purpose of determining the capability of NOTS to assist in the national space program."[39]

Although ARPA pulled the plug on NOTSNIK's funding after the radiation sensors failed to reach orbit, China Lake did not get out of the satellite launching business. By year's end, the Station had submitted a proposal to BuOrd for

> . . . an aircraft-launched missile assembly capable of placing a small satellite payload into orbit. The special characteristics of this proposal were that the missile should be an ordnance item that could be handled by the Fleet and be sufficiently simple and inexpensive so that reconnaissance, navigation, communication, and similar types of small satellite payloads could be used readily whenever they were needed.[40]

The Station had developed a corps of experts and a body of expertise in the technologies associated with satellite delivery. The NOTSNIK development team had met and solved innumerable technical problems, and despite the dismay that went with failure, there was an upbeat "we came so close!" attitude. NOTS was not about to bow out of the space venue. Next would come Transit and NOTS' first "official" orbiting payload. But first there was a little matter of moon photography to take care of.

Lunar Scanner

While much of China Lake's scientific and engineering staff worked madly on the NOTSNIK project, work was continuing on that original idea cooked up in McLean's office in October 1957—a television satellite "based on the utilization of spin of the last stage for gyro stability, as well as to provide the scanning necessary for a television picture." McLean had done some calculations. Using a spin rate of 500 revolutions per second (which he calculated as the bursting strength limit of the final stage) and an orbital velocity of approximately 22,000 feet per second, he concluded that "the distance between scan lines on the ground could be as small as 50 feet."[41]

39 *Rocketeer*, 29 Aug 1958, 1.
40 *Technical Program Review 1958*, 5–6.
41 Memo, Doc. No. 01-45, "Meeting in Dr. McLean's Office," 14 Oct 1957.

The TV scanner had been displaced by the diagnostic and radiation-sensor payloads for the NOTSNIK/Argus shots, but engineers continued to refine the concept, and an opportunity to use it came from an unlikely quarter: the Air Force.

By mid 1958, the Air Force had still not yet entered space. Earlier in the year the Army had orbited Explorer 1, and the Navy had followed with Vanguard. The Air Force was eager to join in the space exploration and exploitation effort. Its first attempt would be in support of NASA's Pioneer series of space probes launched in conjunction with the International Geophysical Year (IGY), which by international agreement lasted from 1 July 1957 through the end of 1958. Pioneer's mission was to gather information on the outer-space environment as well as to orbit and survey the moon. To this end the probe's payload included a magnetometer and micrometeorite detector and a NOTS-developed TV camera (called the Lunar Scanner in NOTS technical literature) designed to take pictures of the side of the moon that always faces away from the earth.

Pioneer 0 was launched in July 1958 but was destroyed shortly after takeoff when a Thor rocket motor failed. Pioneer 1 was launched that October. Both Pioneers (also designated Able-1 and Able-2) carried the NOTS camera. The camera's principle of operation reflected the spin-scanning design described in McLean's 1957 memo, but it had been tailored for the lunar mission by a group of China Lake engineers led by R. Gordon McCarty, with funding from ARPA.

McCarty had received his MS in physics from Wayne State University in 1951. Between that time and joining the China Lake team in 1955, he had worked for NRL on radar, spent a yearlong fellowship at Vanderbilt University courtesy of the Institute of Nuclear Studies, undertaken additional studies at Illinois Institute of Technology, and worked for Armour Research Foundation as a nuclear physicist. By 1958 he was head of the Countermeasures Branch of the Weapons Development Department, and he and his team designed and built the IR-sensitive optical telescope scanning system for Pioneer. As he wrote in 1959:

> One of the first space payload tasks undertaken at NOTS was the development of a scanner for the Air Force's lunar probes which would generate a picture of the back side of the moon. The terminal stages of the AF vehicles were spun to between two and three revolutions per second to achieve spin stabilization of the vehicle above the atmosphere. It seemed worthwhile to incorporate the spin and resultant gyroscopic stability into the design of the experiment. Hence the optical telescope was mounted perpendicular to the spin axis and allowed to sweep out a narrow circular strip scan.

Here again the Sidewinder-based NOTSNIK-designed nutation damper was employed for payload stability.

> The damper . . . consists of a ring partially filled with mercury and placed concentric with the spin axis and above the center of mass. The mercury revolves at a rate different than the spinning body while nutation exists but remains fixed relative to the body after damping the nutation. The damper, although quite simple, has been found to be extremely effective and works rapidly.[42]

A 2½-inch convex mirror focused light in a lead sulfide photocell detector with a 0.003-inch-square sensitive area. When the scanner was 10,000 miles from the moon, the mirror would focus light from an area of about 100 square miles so that as the device rotated it would see the moon's surface as a series of lines each 10 miles wide. The signals from the detector would be transmitted at a frequency of 108 MHz to an Air Force receiving station in the Hawaiian Islands.[43]

McCarty's team, like most NOTS project teams, was anything but insular. When the members needed something outside their collective expertise, they reached out and found it.

One problem arose in trying to bond and hermetically seal the lunar scanner's wet cell batteries—the cases were made of acrylonitrile styrene copolymer, and none of the commercially available solvents could adequately seal the material. Plastics scientists in Michelson Laboratory's research wing used a polyester styrene copolymer to develop a block polymer that had exceptional strength and proved satisfactory for the application.

To maximize the life of the camera's 5-pound battery, the scanner's design incorporated an ingenious power-saving scheme. First, the entire system would remain deactivated until the final-stage motor fired to slow the payload as it neared the moon. That firing would close a switch to activate the transistorized video amplifier, which would operate continuously.

> If light pulses are detected, the signal-present sensor (a condenser-charging circuit) will cause a relay to close which will supply . . . power to the vacuum tube circuitry of the oscillator modulator and power stages of the transmitter. When light pulses cease to be detected, the condenser discharges, the relay falls open, and the battery power is conserved until the next occasion for picture transmission. . . . The [payload] is spinning in a circular or elliptical orbit around the moon. The light sensor is alternately looking at black space and light from the sun reflected from the surface of the moon.[44]

A simple, elegant solution.

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42 R. G. McCarty, "Designing Small Space Payloads," *Astronautics*, May 1959, 24–25.
43 China Lake History Program Document 7522/MS-46, *Information on NOTS Lunar Probe Equipments* (undated).
44 *1958 NASA/USAF Space Probes (Able-1) Final Report, Vol. 2, Payload and Experiments,* Los Angeles, Space Technology Laboratories, Inc., prepared for Air Force Ballistic Missile Headquarters, 18 Feb 1959, 121.

Pioneer 1's launch on 11 October 1958 was flawless. However, the first stage of the Douglas Thor-Able launch vehicle burned for 3 seconds longer that it should have. The result, rather than a trip around the moon, was a 43-hour flight that carried the vehicle and its payload more than 79,000 miles above the earth.

Because the final-stage retrorocket was never fired, the TV camera was not activated during the flight. It would be another year before the Soviet Luna 3 satellite sent back to earth the first images of the far side of the moon.[45]

Undaunted, McCarty's group continued work on satellite payloads. Much like NOTS itself, the team was looking in all directions and working on meteorological satellites to scan the earth as TV systems, simultaneously in the ultraviolet, visible, and infrared; radiation satellites to explore the local visible, ultraviolet, X-ray, visible, infrared, and cosmic-ray regions; and astronomical satellites to yield stellar-radiation data and pictures in the ultraviolet, infrared, and radio regions.[46]

Transit

Another Navy space program jump-started by the Soviet's launch of Sputnik was Transit, also called the Navy Navigational Satellite System (NAVSAT). Transit was designed to provide accurate positional information for the Navy's Polaris ballistic missile submarine.

The first Transit satellite was launched in April 1960, and the system went into service in 1964. It remained operational until 1996, when it was rendered obsolete by the Global Positioning System (GPS).

The Station's primary involvement in the Transit program was development and operation of the ground tracking stations known as Navy Correlation Detection and Receiving Stations (NACODE), the same system NOTS had developed jointly with JPL in 1958 for tracking Explorer 1, adapted now by NOTS to track the Transit satellites.

As Highberg explained:

> The work that we had done on this program [tracking Explorer] then got us into the Navy's Transit Program, and we developed the tracking stations for the Transit Satellite and built and operated, eventually, 10 tracking stations for the Transit all over the globe.[47]

45 William O. Miller, "AF Alters Pioneer for Third Moon Try," *Missiles and Rockets*, 4, No. 16, 20 Oct 1958, 13–14.
46 *Technical Program Review 1958*, 61.
47 S-121, Highberg interview, 10.

Colvard, who worked on NACODE as a Junior Professional in 1959, remembered that:

> We were building [NACODE], which was a Doppler tracker, a scheme that got the location of the satellite from measuring the Doppler shift. I helped build those and we took them all over the world, to Australia, Turkey, Brazil, Newfoundland, Puerto Rico. I wound up taking one to Puerto Rico.[48]

China Lake also took a big step into digital electronics with the development of the Naval Ordnance Data Automation Center (NODAC). The system converted analog data into digital data at rates up to 33,000 conversions per second, and then fed the data to the Station's state-of-the-art IBM 709 computer.

"The NODAC had been developed out of our desire, and my demand, that we no longer photograph Doppler radar records and measure them by hand laboriously, but that we count electronically the Doppler waves," said Highberg.[49]

The greater significance of the Transit program for NOTS was that it unequivocally placed the Station's first payload into orbit. In the course of developing Transit, several "demonstrator" satellites were orbited (and in some cases were attempted unsuccessfully to be orbited). Not all of the demonstrators contained payloads related to the positional-location mission of the Transit system.

The first successful Transit satellite launch (Transit 1B) occurred on 13 April 1960 and carried a NOTS-developed IR scanner (as had an earlier unsuccessful attempt, Transit 1A, in September 1959).

On 22 June 1960, the second successful launch (Transit 2A) carried twin payloads into orbit: a Naval Research Laboratory solar-radiation measurement satellite and the NOTS IR scanner. Three of the NACODE receiving stations were modified with increased bandwidth to receive data telemetered from the IR scanners.

The Station's *Tech History* reported that:

> . . . quantitative data were obtained on the intensity and distribution of infrared radiation radiated by the earth, and an infrared picture of the earth as seen from a satellite 600 miles up was obtained by tape recording and analysis of radio signals from the Transit satellite.[50]

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48 NL-T28, Colvard interview, 2.

49 *NOTS Command History* 1960, 7 ; S-121, Highberg interview, 11.

50 NOTS TP 2598, *NOTS Tech History 1960*, Jan 1961, 15.

By July 1959 McCarty had become head of the Special Projects Branch of the Weapons Development Department, and from there he led the successful development of the IR camera system flown in the Transit program.

This version of the camera was substantially larger than that which had flown on the Pioneer mission. The IR-sensitive telescope, batteries, transmitter, and associated electronics weighed a hefty 18 pounds. McCarty's development team included Frank St. George, Jim Lee, Ray Francis, Jim Hurtt, and Wade Abbot.[51]

Transit 2A's camera system operated like the one developed for Pioneer, scanning strips of the earth and its cloud coverage with each revolution of the satellite. The signals from the IR detector were transmitted to two tracking stations, one at Walla Walla, Washington, and the other at China Lake. At each site a 28-foot-diameter mobile parabolic antenna (built from scrap by Station personnel) picked up the signals, which were then recorded on tape for display and analysis. The Test Department's Telerecording Section, under Bob Merriam, handled the setup and operation of the ground tracking stations.

By the time of the June 1960 launch, McCarty had left the Special Projects Branch to work on the manned submersible *Moray*, and Donald K. Moore had taken over the branch. Moore described the images from Transit 2A as "what surely would have to be the first infrared pictures from space."[52]

The successful launch of Transit 2A and the transmission of IR pictures from space back to earth was a technical milestone for the U.S. space program. Rear Admiral Thomas F. Connolly, who headed the Bureau of Naval Weapons' Astronautics Department (and who as a captain had been the NOTS Experimental Officer from 1952 to 1954) remarked that the launch of Transit 2A meant the United States was "moving into the space age for real—now that we can get devices up there and use them."[53]

In late July Moore's group put together an article about the Transit 2 payload for the *Rocketeer*. The article took up about half of page 4, complete with a detailed photograph of the IR-scanner components, a sample scan display, and a map of the satellite's path. Moore recalled that he "then right quickly found, 'Hey, you better not talk about that, that may be confidential.'"[54]

51 *Rocketeer*, 29 July 1960, 4.

52 S-185, Moore interview, 37. Moore, an engineer, worked at China Lake from 1954 to 1967, when he followed McLean to the newly formed Naval Undersea Warfare Center. Another Don Moore, Donald W. Moore, a noted chemist, conservationist, and ornithologist, also served at China Lake, working there from 1951 to 1984.

53 *Rocketeer*, 29 July 1960, 4.

54 S-185, Moore interview, 37.

Although no one at NOTS was speaking publicly of the potential of an IR-camera-carrying military reconnaissance satellite, that application must have been considered. Since the early 1950s the U.S. had been engaged in strategic reconnaissance of its Cold War adversary, first with converted bombers, then, from 1955 on, with the U-2 high-altitude surveillance aircraft. The shoot-down of Major Francis Gary Powers' U-2 over the Soviet Union in May 1960, showed that even the most sophisticated winged aircraft did not provide a safe enough vantage point for observation, and the next logical step was straight up.

There is no debate that the U.S., since the mid 1950s, planned to launch reconnaissance satellites that would gather intelligence as they overflew the Soviet Union. The biggest problem was the technical challenge, but another stiff barrier was international law. Nations had long recognized the concept of territorial waters wherein a nation might seize an intruding country's ships, and territorial airspace where the nation might legally shoot down foreign aircraft.

The United States did not want that concept of territoriality extended into space. Above the atmosphere, the Eisenhower administration claimed, satellites should not be subject to the sovereignty of the nations they overflew. The U.S. called this policy "freedom of space" and argued for it to be codified in international law. The Soviets balked at the principle.

In 1954 Eisenhower had appointed a group—originally called the Surprise Attack Panel, but later retitled with the more innocuous Technological Capabilities Panel (TCP)—under the leadership of MIT President James R. Killian, Jr., who would later become Eisenhower's Science Advisor. The TCP's task had been to inform the President of new technologies that could prevent a surprise attack on the U.S. The TCP's final report in February 1955 had recommended that the U.S. institute a nonmilitary artificial satellite program to establish the "freedom-of-space" principle and pave the way for subsequent military missions.

The International Geophysical Year, scheduled for 1957–1958, had seemed to provide the ideal opportunity to implement that recommendation. What better time for the U.S. to launch a scientific satellite? By mid 1955, the nation had embarked on two space projects: one a purely scientific effort to launch a scientific satellite that would demonstrate the idea of "freedom of space," and the other a military satellite project known as WS-117 that would eventually become Corona. It is not without irony that freedom of space was de facto established by the Soviets themselves when Sputnik overflew many countries, crossing international boundaries without any diplomatic controversy. The day after Sputnik's launch, Eisenhower's Deputy Secretary of Defense

Donald Quarles had reportedly told the President that the Soviet Union had unintentionally done the U.S. a "good turn" in establishing the freedom-of-space concept.[55]

Between 1960 and 1972, the Air Force and CIA launched a series of more than 100 reconnaissance satellites, aptly named the Keyhole series, under the Corona program, authorized by President Eisenhower in 1958. The imagery, which was used for both intelligence and mapping, had a resolution of 25 feet, later improved to 6 feet. Each Corona satellite used a rotating stereo panoramic camera to capture visible imagery on 21,500 feet of 70mm film. When each Keyhole satellite completed its mission it would be "de-orbited" and recovered by an Air Force C-119 as it parachuted toward Earth.[56]

The approach used by NOTS on Transit 2A was significantly different from that used on Corona. NOTS' Transit used real-time transmission of the imagery and did not rely on the complex, expensive, and occasionally unsuccessful air-snatch film-recovery technique used for Corona.

Another distinction between the two program had to do with the nature of IR imagery, such as that being developed by NOTS. IR imagery is responsive to temperature variations in the object being observed and is therefore well suited to meteorological applications. It also offers advantages over visible spectrum imagery in certain military reconnaissance applications. Using temperature variations that can be detected by IR imagery, according to military experts, "it is possible to determine if oil is running through a pipeline, if a nuclear reactor is active, or if a vehicle is operating or not."[57]

Military reconnaissance satellites and NOTS seemed to be a good match, given the Station's IR imaging expertise as well as the lessons learned from the 1958 NOTSNIK development.

China Lake engineers were also working on a precessible (steerable) telescope for space applications. In his 1959 article, McCarty said that "an attempt will be made to include a precession system that can be controlled from the ground" using high-pressure gas emitted from a nozzle.[58]

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55 Dwayne A. Day, "Cover Stories and Hidden Agendas: Early American Space and National Security Policy," *Quest, the History of Spaceflight Quarterly*, *http://history.spacebusiness.com/sputnik/files/sputnik56.pdf,* accessed 3 Jan 2010.

56 National Reconnaissance Office, Corona, *http://www.nro.gov/corona/facts.html,* accessed 22 Nov 2009.

57 *AU-18 Space Primer*, prepared by Air Command and Staff College Space Research Electives Seminars (Maxwell Air Force Base, AL: Air University Press), 173; *http://space.au-18-2009/au-18_chap13.pdf,* accessed 22 Nov 2009; *http://www.foia.cia.gov/SovietandWarsawPact/1962/1962-08-27a.pdf*, accessed 23 Nov 2009.

58 McCarty, "Designing Small Space Payloads," 24–25.

The combination of an ability to air-launch satellites "at any place and any time" and the technology to point a state-of-the-art IR camera using controlled precession would have made NOTS a strong candidate for military reconnaissance missions. But beginning in late 1959, a series of high-level events ended whatever role NOTS might have had in the military reconnaissance satellite business.

First, after complaints from the military services, Secretary of Defense Neil McElroy, before leaving his government position in December 1959 and returning to Proctor & Gamble as CEO, removed control of military space programs from ARPA and parceled them out among the services. The Army got communications satellites, the Navy navigation satellites, and the Air Force reconnaissance and surveillance satellites.

NASA, created in July 1958, already had the corner on meteorological satellite. Its Television and Infrared Observation Satellite (TIROS) system, which had begun development in May 1958 under the U.S. Committee on Meteorological Satellites, had its first successful launch in April 1960. Succeeding that system was Nimbus, which provided data not only on weather but also on the earth's oceanographic, environmental, and geophysical structure.

In fall 1960 John F. Kennedy, newly elected as President but not yet inaugurated, appointed a committee to study space policy and programs; it was chaired by Jerome Wiesner, president of MIT, who would later become Kennedy's science advisor. The Wiesner Committee report, issued the following January, was critical of the nation's proliferation of space programs:

> Each of the military services has begun to create its own independent space program. This presents the problem of overlapping programs and duplication of the work of NASA. If the responsibility of all military space developments were to be assigned to one agency or military service within the Department of Defense, the Secretary of Defense would then be able to maintain control of the scope and direction of the program and the Space Council would have the responsibility for settling conflicts of interest between NASA and the Department of Defense.[59]

Interestingly, the Soviet Union had recognized that weakness in the U.S. space program. In a top-secret journal article, Major General P. Vysotskiy wrote:

> The present lack of powerful carrier-missiles, capable of putting large payloads into space, makes the Americans quite feverish and impedes their general progress in the mastery of space and the development of carrier-missiles. It is no coincidence, therefore, that governmental scientific centers and a number

59 Jerome B. Wiesner, *Report to the President Elect of the Ad Hoc Committee on Space*, NASA,10 Jan 1961, 5, *http://www.hq.nasa.gov/office/pao/History/report61.html,* accessed 28 Feb 2013.

> of the larger aircraft and missile construction firms are proposing the most varied designs, which, to a significant degree, encumbers the development of space means of combat.[60]

China Lake was one of those "governmental scientific centers."

On 6 March 1961, DOD Directive 5160.32 assigned the Air Force responsibility for developing and acquiring future military space systems. The Air Force was also given responsibility 3 weeks later for "research, development, and operation" of future DOD imaging reconnaissance satellite systems, except those of the Central Intelligence Agency. That effectively ended any ambitions NOTS might have had to become a lead activity for military reconnaissance from space.[61]

Dr. Robert Frosch put it bluntly in a 1981 interview:

> The Air Force was hell-bent to make sure the Navy did nothing whatever in space. That is, having been given the mission, they wanted to have it totally and exclusively, and just not have anybody else in the business of building anything that went into space.[62]

Captain Frank Ault (best known for his study that led to the creation of Topgun, the Navy Fighter Weapons School), wrote in a 1967 report:

> There is no gainsaying that the Navy's enthusiasm for space systems development was seriously crippled by the SECDEF Space Directive (5160.32) of 7 March 1961. Here the question of military space capability was decided by fiat—essentially unrelated to need, competence, or excellence of concepts.[63]

NOTS was still trying to find its niche in the space program, but the range of options was narrowing. Navigation? The Navy's Transit system, with satellites designed, built, and launched by Johns Hopkins University Applied Physics Laboratory (JHU/APL) filled the Navy's navigation needs. Communications? The earliest communications satellite, SCORE, launched in December 1958 was primarily an Army effort.

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60 Maj. Gen. P. Vysotskiy, "American Military Technological Means of Combat in Space," *Voyennaya Mysl* [Military Thought], Dec 1961, 8. Released by the CIA, Dec 2004.

61 Gary Federici, "From the Sea to the Stars: A History of U.S. Navy Space and Space-Related Activities," June 1997, Chap. 2, Sec. 2.1.1, *http://www.history.navy.mil/books/space/Chapter2.htm*, accessed 28 Feb 2013.

62 Dr. Robert Frosch, interview by Dr. David DeVorkin, National Air & Space Museum, 15 Sept 1981, *http://www.aip.org/history/ohilist/28066_4.html,* accessed 3 Feb 2011. Frosch served with ARPA from 1963 until his appointment as ASN (R&D) in 1966. He held high-level positions with the Navy, United Nations, Woods Hole Oceanographic Institution, NASA, General Motors Corp., and Harvard University (Senior Research Fellow).

63 Capt. Frank Ault, "Navy Planning in the Space Age" handout for NWC Technical Planning Board, 27 Sept 1967, 9.

Carrying a tape recorder that picked up a radio transmission from one point on the planet and then rebroadcasting it when the satellite passed over another point, SCORE was of limited practical utility, but NASA soon took the lead in communications satellites, establishing a network that went international in 1962 with Telstar, followed by the Communications Satellite Corp. (COMSAT) system and the worldwide International Telecommunications Satellite Consortium (INTELSAT) system.[64]

TERASCA, TASCAN, Viperscan

NOTS, however, was not to be kept out of the space race. About the same time that McCarty's group began development of the IR scanner, China Lake engineers and propulsion experts were entering the field of high-altitude sounding rockets.

A sounding rocket, also called a research rocket, is generally a disposable rocket-powered vehicle designed to carry an experimental payload to altitudes ranging from a few tens of miles to several hundreds of miles. Typically, the payload separates from the expended rocket and continues toward space as the rocket falls back to earth—or in most cases involving NOTS' missiles, falls into the ocean. Payloads may transmit data earthward by telemetry or a parachute may be used to bring the payloads safely back to earth.

In February 1959 Eugene Rutkowski and Wayne Howard of China Lake's Propulsion Development Department (Code 45) proposed a research vehicle called TERASCA, a vehicle "for high altitude studies" that was simple and inexpensive. TERASCA would couple three off-the-shelf rocket motors (Terrier for the first stage, ASROC for the second, and Cajun for the third—thus the project's name) into a 30-foot-long 2,200-pound missile capable of lofting a payload of more than 25 pounds to altitudes of 250 miles. McLean approved the discretionary-funded experiment, and Dennis Haluza was assigned as project engineer.[65]

TERASCA's payload was an ultraviolet "celestial mapper," designed to map the stars and detect the ultraviolet radiation that is absorbed by atmospheric ozone. Successful testing of the motors and airframe was completed less than 2 months from the project start.[66]

In June 1959, less than 5 months after project conception, a TERASCA carrying a 28.5-pound payload was launched from the Pacific Missile Range

64 Another unique naval satellite program was NRL's Communication Moon Relay (CMR) system, operational from 1959 through the mid 1960s, which used the moon as a passive reflector satellite to bounce radio signals between Washington and the Pacific Fleet.
65 *Rocketeer*, 18 Sept 1959, 1.
66 S-185, Moore interview, 36.

(PMR) at Point Mugu. The missile reached a velocity of 5,000 miles per hour and soared 110 miles into space before impacting the ocean 240 miles downrange after a flight of 7 minutes and 25 seconds. The entire cost of the TERASCA development program was less than $20,000.

Douglas D. Ordahl, head of the Missile Propulsion Division, noted the "astoundingly small cost in time and effort compared to any other known work in space research" and observed that a "vast amount of exploratory research" would be needed to "design and develop practical instrumented satellites for such significant objectives as greatly improved weather predictions and world communications." He said that such research could be accomplished "expeditiously, simply, and at a very low cost if extensive use is made of reliable rocket engines already in existence." The lesson of reliable engines had been learned from the NOTSNIK experience the year before.[67]

Like any complex development program, TERASCA had its setbacks, including one of the earlier diagnostic shots. Jack Crawford (who with Bill Woodworth had built the timers that sequenced the firing stages of NOTSNIK) designed the timer that controlled the firing of TERASCA's second and third stages. About 2 seconds before launch, the timer was sent a commitment signal that would start a counter running.

As Crawford recalled in a 1991 interview:

> A hold-fire signal was received one second before launch. That stopped firing of the first stage but the timer controlling the second and third stages was committed. Right on time, at 20-some seconds, the second and third stages took off leaving the first stage behind on the launcher. In retrospect the logic flaw was obvious, but no one had caught it previously.
>
> As a personal aside, I think the impact of going through some of these real hardware mishaps is something missing in the computer simulation world. When you are in a firing bunker and a rocket takes off unexpectedly, you are a changed person. You realize the importance of considering all the possible scenarios even if some of them "can't happen."[68]

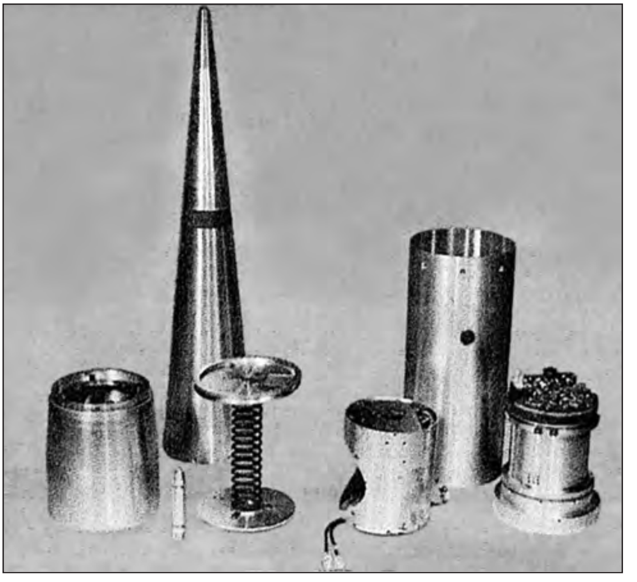
A more advanced version of the TERASCA scanner called the Ultraviolet Star Survey Payload was developed in 1960. It used a rapidly spinning collecting dish that precessed by means of its interaction with Earth's magnetic field.

At the focal plane of the dish was a 2,500- to 2,800-Angstrom photomultiplier, the output of which was transmitted to a ground receiving station. Two attempts to launch the probe were made that year; in one the payload

67 *Rocketeer*, Ibid.

68 S-171, Jack Crawford interview, addendums 13 Dec 1990 and 17 Jan 1991, 74.

failed, in the second, the launch vehicle failed. A third was scheduled for February 1961, but there is no evidence that the launch took place.



Ultraviolet Star Survey Payload components.

It was inevitable that the IR-scanning technologies demonstrated in the Pioneer and Transit 2 programs would be joined with the air-launched rocketry skills developed for NOTSNIK. In the TASCAN project, late in 1960, NOTS engineers coupled the strip-mapping techniques, originally proposed by McLean and then developed for the Pioneer and Transit 2 satellites, with a two-stage Terrier-ASP 1 sounding rocket.

The rocket ejected a spin-stabilized payload that flew a long horizontal trajectory with the spin axis of the payload aligned with the trajectory. A telescope, aimed perpendicular to the spin axis, scanned the earth from horizon to horizon on each revolution. With the right relationship of spin rate to payload velocity, the telescope would scan contiguous strips thereby creating a strip map. Between June and October 1960, four firings were made. The fourth completed all the test objectives and provided data in the 0.2 to 0.6-micron region from which NOTS researchers constructed a picture of the earth's cloud cover from an altitude of 50 miles.[69]

Viperscan begun in 1960 as a joint NASA-NOTS-PMR program and culminated with a launch in January 1961. The 8-foot 6½-inch-diameter rocket was air-launched from an Edwards Air Force Base F-104 Starfighter over the PMR. On ignition the rocket developed 6,000 pounds of thrust for 5½ seconds, propelling the vehicle to an altitude of 50 miles. At that point, about 50 miles downrange, Viperscan's IR-scanning terrain-mapping payload was ejected and continued another 200 miles down range while imagery was transmitted to receiving stations at Point Mugu. Two channels of telemetry data—one for the temperature of the IR cell and the other carrying the IR

69 *NOTS Tech History 1960*, 72–73.

telescope signal—were received for about 210 seconds. The project engineers, Norm Osborne and John Sichra of the Weapons Development Department (Code 40), credited John Johnson of AOD with the design and fabrication of the payload. Johnson would later become head of AOD's Radar Systems Branch.[70]

An improved Viperscan payload, called the Viper-Palmer Scan was developed in 1961. Among other changes it incorporated a solid-state transmitter with about 20 times the power output of Viperscan.[71]

The mating of IR scanner payloads with high-altitude sounding rockets capable of both air and ground launch gave NOTS a product that needed only a customer. That came in the form of ARPA and Project Defender.

Project Defender

One of ARPA's first projects after its creation in 1958 was Project Defender. The goal was to defend the United States from intercontinental ballistic missiles (ICBMs). Defender, which lasted into the mid 1960s, explored various methods of destroying an enemy ICBM as soon after launch as was technologically possible.

The chances of eliminating a threat missile would be increased if it could be detected in the very first moments after launch. To understand the science involved in early detection, a subproject of Project Defender was established in 1961 and named TABSTONE (Target and Background Signal-to-Noise Experiments). The goal of the program was "to provide a detailed understanding of the optical and ER [electromagnetic radiation] phenomena associated with the launch phase and also the expected background conditions against which detection and tracking equipments . . . will have to operate."

TABSTONE was estimated to cost more than $9 million over 2 years, but that was the tip of the iceberg in ballistic-missile defense (BMD) spending; in fiscal 1962 an astonishing $2.4 billion was spent in BMD programs, half of that on early-warning systems.[72]

As part of TABSTONE, ARPA's Ralph Zirkind, who would later become the agency's deputy director and chief scientist, contacted China Lake about conducting an infrared survey to assess the feasibility of detecting missiles on their way up.

70 *Rocketeer*, 27 Jan 1961, 1.

71 NOTS TP 2906, *NOTS Tech History 1961,* Jan 1962, 71.

72 PPD 61-33, *ODDR&E Assessment of Ballistic Missile Defense Program*, April 1961, *http://www.dod.mil/pubs/foi/reading_room/308.pdf.*

The Weapons Development Department selected Don Moore to head the effort under the China Lake project name HITAB (High-Altitude Target and Background measurement). Specifically, the purpose of HITAB was to measure, from an observation point in space, the infrared and ultraviolet radiation from sunlit-cloud backgrounds and the exhaust plumes of launched missiles. Suddenly, money for China Lake's space efforts was not a problem. According to Moore, ARPA and the Air Force "inundated us with money to build new things for infrared measurements from high altitude."[73]

Knemeyer said "We did spend maybe 5, 10 million dollars a year on it, which was a lot at that time for this kind of work."[74]

During the next few years, NOTS carried out several different projects under HITAB, all involving the use of sounding rockets and IR measurement devices. One of the earliest efforts was T-BIRD (Terrestrial Background Infrared Detection), sponsored by the Air Force and conducted from 1961 to 1963. T-BIRD used sounding rockets to measure radiation reflected from high-altitude sunlit clouds, gathering data at altitudes up to 60 miles.

Various phases of HITAB investigated various aspects of the background radiance phenomenon. For example, HITAB-BWSS collected Wiener spectrum data (statistical descriptions of the spatial distribution of the background radiance) in the 2.2-, 2.7-, 3.8-, and 4.3-micron regions. The project involved three launches of Terrier-Viper combination rockets from the Gulf Test Range at Eglin Air Force Base, Florida, in 1962 and 1963. The first two shots had problems with telemetry and radar tracking, but the third sent good quality data for 120 seconds and was tracked throughout most of its flight. That flight successfully generated Wiener spectra of the earth's infrared background.[75]

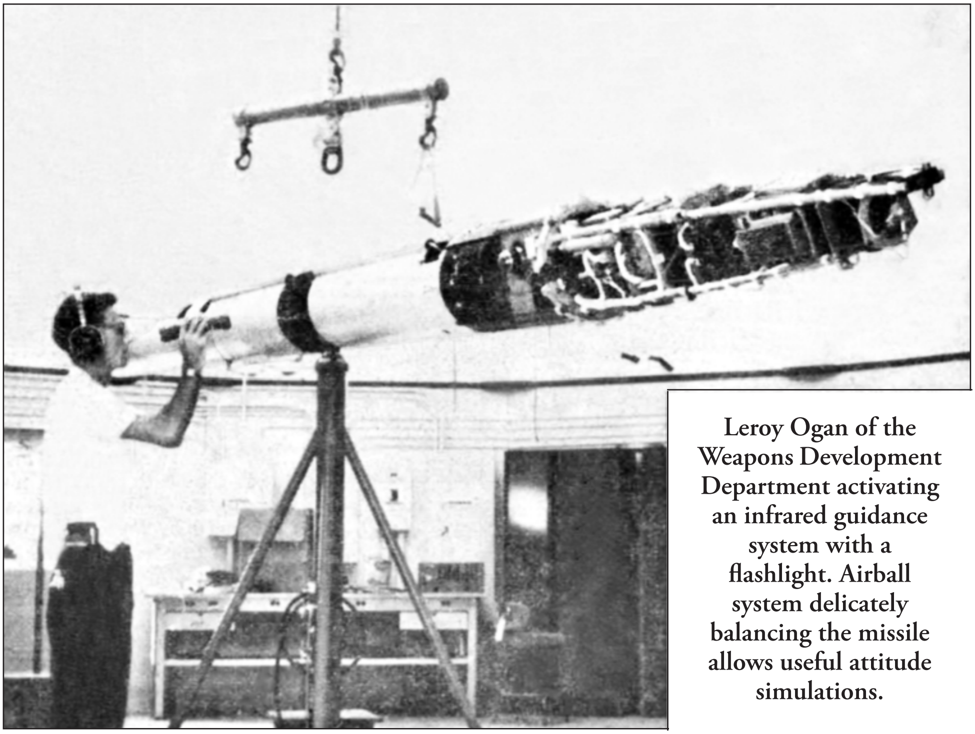
NOTS-developed precession-control systems were key to the success of many of the HITAB projects, which continued through the end of 1966. As the HITAB projects became more ambitious, the necessity for accuracy and extreme precision in dynamically orienting the payload orientation (via the reaction-jet control system) increased. To help meet the stringent standards, an Air Bearing Facility was built in a geodesic dome behind Michelson Laboratory.

In the facility, engineers would essentially cut a missile in half and insert a stainless-steel sphere between the two segments. The sphere was tooled to a tolerance of 2 millionths of an inch and rested "on a Pyrex cup with a bearing

73 S-185, Moore interview, 35; NOTS TP 3119, *NOTS Tech History 1962*, July 1963, 61.

74 S-200, Knemeyer interview, 84.

75 John A. Hoyem, James E. Hurtt, and Larry N. Pace, *HITAB-BWSS Payloads*, China Lake, Astrometrics Division, Weapons Development Department, NOTS TP 3799, Aug 1965.



Leroy Ogan of the Weapons Development Department activating an infrared guidance system with a flashlight. Airball system delicately balancing the missile allows useful attitude simulations.

surface as perfect as a man can produce." The cup was at the top of a hollow steel column through which air was pumped to maintain a pressure of 220 pounds per square inch, a pressure that created a virtually frictionless air bearing between the sphere and the cup. The missile under test (weighing more than half a ton) was so delicately balanced that "the weight of two flies on the nose cone is sufficient to dip the missile downward."[76]

With the test missile thus freed to move much like a sounding rocket in free space after motor burnout, engineers could dynamically check the attitude-control system and measure such parameters as transient response times, overshoots, and damping characteristics. Payload responses could also be measured (as depicted in a *Rocketeer* photo showing Leroy Ogan using a flashlight to activate an IR guidance system on a test article). The aim was to yield data that would provide accurate tracking of a moving target.

Construction of the frictionless Air Bearing Facility typified China Lake's approach to technical challenges. If the right component (or tool) doesn't exist, design it and build it. Ingenuity and elegance of design were not reserved for weapon systems—creating a necessary test fixture would be approached with the same purposeful design, attention to detail, and craftsmanlike fabrication.

76 *Rocketeer*, 9 Oct 1964, 4.

Frank Knemeyer recalled that "The air bearing test facility was very useful and successful."[77]

Controllable IR imaging devices proved valuable for more than just investigating background imagery of the earth. As NOTS involvement with Project Defender deepened, the Station began to launch rockets from Point Mugu and Navy ships to parallel the course of large rockets launched from Vandenberg Air Force Base. Since the rockets were on a parallel course and climbing nearly vertically, the sidescanning payload measured the spectral signature not of the earth but of the rocket exhaust.

In a phase called TRIS (Target Radiant Intensity Measurements from a Spin-Stabilized Vehicle), a dozen vehicles were launched between April 1962 and August 1963, primarily from Navy ships. The TRIS payloads gathered data from Thor, Titan, Jupiter, Atlas, and Minutemen missile targets.[78]

Ray Francis, a NOTS technician in the Weapons Development Department (and later *Moray* project engineer) was assigned to coordinate the TRIS Aerobee launches from Navy guided missile frigates off the California coast. According to George A. Wilkins, who worked with Francis for many years at China Lake and later Hawaii:

> . . . he was able to achieve a fantastic level of support from shipboard gunner's mates by convincing them that we were in the earliest phases of developing an antimissile rocket. After each fly-by "miss," he would tell them that "we almost got it right this time."[79]

Using TABSTONE funds, China Lake built a complete rocket launching facility at Walker Cay in the Bahamas. Construction was completed in 1963. From there, WAC Corporal and Aerobee sounding rockets carrying NOTS IR-imaging payloads were fired. The launches were coordinated with launches of large rockets from Cape Canaveral in Florida. For example, on 11 December 1964, a HITAB-TSRA (Target Spectral Radiance) payload on an Aerobee 150 launched from Walker Cay followed an Atlas Centaur launched from Cape Canaveral. The NOTS rocket reached an apogee of 120 miles.[80]

Don Moore described one such effort:

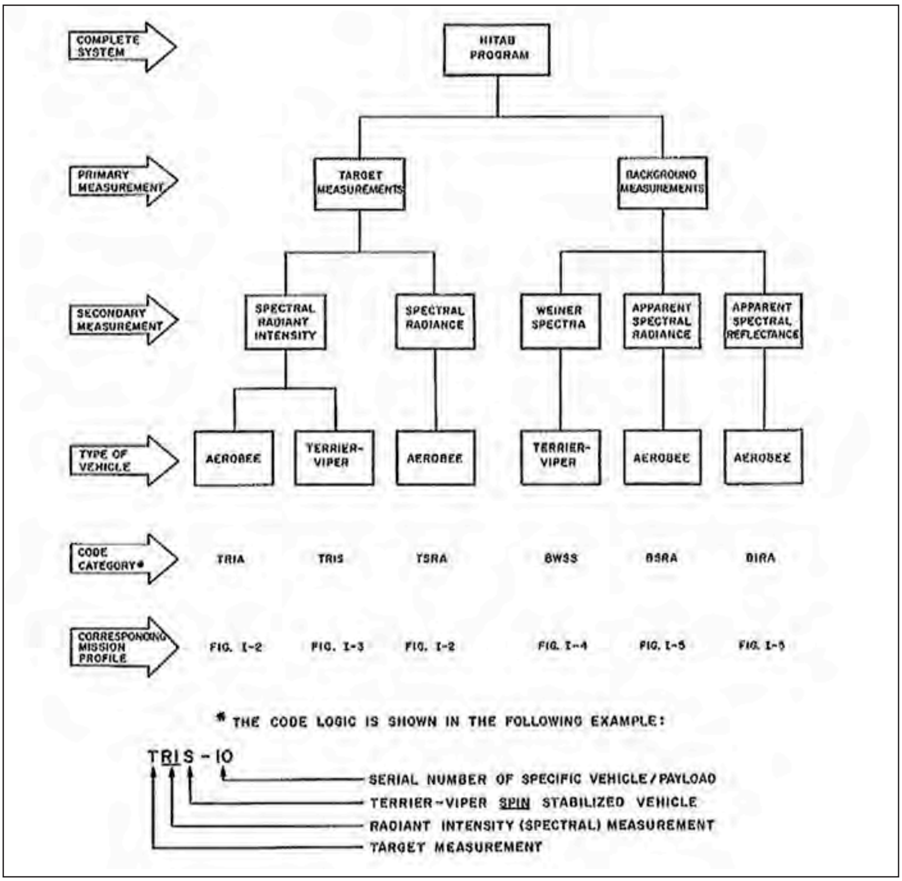
> We took a Sidewinder seeker with a spiral scan on it, and then they would fire the Aerobee up next to an ICBM, well, 90 miles south of it [Walker Cay], if you will. And so the ICBM was coming up on a predicted trajectory, and we had

77 Frank Knemeyer, email to the author, 2 Dec 2009.
78 NOTS TP 3726, *NOTS Tech History 1964*, 1 April 1965, 2-36–2-37.
79 George Wilkins, email to the author, 2 Sept 2011.
80 *Encyclopedia Astronautica*, *http://www.astronautix.com/thisday/decber11.htm*.

> a predicted trajectory. And so we would figure out what the attitude control system should tell the Aerobee, to point, and then the Sidewinder would do a scan, lock onto the ICBM, then take over the control of the pointing system on the Aerobee, and point the radiometers and interferometers that we had at the ICBM. We built three of those payloads, and it turned out between our failures and failures of ICBMs, none of them ever worked. . . . They were very expensive. Those payloads averaged $600,000 apiece[81]

Six vehicle-payload combinations were used to obtain HITAB measurements. The purposes and functional elements of these probes are shown below.[82]

The firing phase of HITAB concluded with six Aerobee/HITAB launches in 1964 (although data reduction would continue into 1965). In January 1964, Moore's Special Projects Branch was combined with the Servo Development



HITAB primary and secondary measurement categories and vehicle types.

81 S-185, Moore interview, 39–40.

82 NOTS TP 3275, *Third Technical Summary Report HITAB (TABSTONE) Rocket Probe Program, 25 June 1962–1 March 1963*, China Lake, June 1963, 3–7.

Branch and renamed the Astrometrics Division, with four branches. Moore was selected to head the division, and Dick Boyd was brought in as assistant division head to help handle the expanding work load associated with Project Defender.

By July 1965 (the last year of existence for the Astrometrics Division), the number of branches had grown to seven: Physics, Electronics, Guidance, Control, Projects, Structures and Materials, and Sensors Systems.

George Wilkins, who headed the Physics Branch, recalled an incident that captured the spirit of NOTS workers during the period. His group was trying to complete the radiometric calibration of an IR scanner payload that would monitor an Atlas launch from Cape Canaveral (then known as Cape Kennedy). They had been working nonstop and suddenly ran into the federal personal-leave situation known as "use or lose." This policy decreed that any earned leave in excess of 240 hours could not be carried over from one year to the next; it must be used or it would be forfeited. Wilkins wrote:

> As their magic dates approached, I tried to order each branch member to take his or her leave time. The response was unanimous: "We're going to take our leave any damned way we want!" and they continued to work until the job was done. I have never been so proud of any group as I was that Christmas. (We made our deadline.)[83]

Several launch sites were used, and there were many launches. Although authenticated, detailed records are not available, the pace of activity was frenetic. According to Moore:

> We fired 41 rockets, six different payloads, fired on all of the national ranges. We fired from six guided missile frigates . . . we fired from Point Mugu, San Nicolas Island, Eglin Air Force Base. We built a launch complex down in the Bahamas, fired Aerobees there, and we fired at Wallops Island [Virginia], White Sands [New Mexico]. We did the work for Fort Churchill [sounding rocket launch facility] up in Canada . . . So we did an awful lot of work. We had successes and we had spectacular failures.[84]

By the end of 1966, the division, with largely the same personnel, would be renamed the Undersea Systems Division—a dramatic shift in direction for the edge-of-the-envelope scientists and engineers.[85]

Through the ICBM detection programs, NOTS made important advances in IR-imaging techniques and payload control. For some of the scientists,

83 George Wilkins, email to the author, 2 Sept 2011.
84 S-185, Moore interview, 38.
85 RM-17, *NOTS-NWC Code Directories*, Vol. 1, 1949–1965, China Lake, NWC, Jan 1982; and Vol. 2, 1966–1980, China Lake, NWC, Aug 1982.

engineers, and technicians in China Lake's space program, however, Project Defender and other paying customers were just the bread-and-butter jobs. The Holy Grail was an antisatellite weapon—an ASAT.

Antisatellite Projects

One night in October 1957, Leo Jagiello looked into the desert sky and watched Sputnik cut its northeast-southwest track across the heavens. As he recalled 35 years later, he promptly found Hack Wilson and said, "Hey, I just saw Sputnik, and you know what we ought to do Hack? We ought to go shoot the damned thing down." Wilson "didn't cotton to that idea," Jagiello recalled, but the seed had been planted.[86]

McLean's record of his 14 October 1957 meeting with the Station's top military and scientific leadership does not mention an antisatellite application for the proposed NOTS satellite (nor, as noted earlier, did it mention Sputnik). Aircraft launching, however, was proposed in that meeting, and that approach is entirely consistent with an antisatellite weapon, since aircraft-launched ASATs have a singular advantage over their ground-launched counterparts.

Although it is possible for one satellite to change its orbit to intersect the orbit of another satellite, the process is time consuming and expensive, requiring large amounts of energy and thus extra fuel and weight. The most efficient way to intersect a target satellite's orbit is to launch the killer satellite when the target satellite is passing overhead and headed in the same direction as the launch vehicle.

"For ground-launched vehicles, the wait between successive passes of the target satellite could be as much as several days, depending on the target orbit," wrote Dale Fenn, a scientist at Orbital Sciences Corp. "Mobile assets, however, can eliminate the wait by essentially choosing a launch point that is ideally suited for a rendezvous."[87]

In mid 1959, NOTS received an Operational Requirement (OR) for an antisatellite-missile system. That OR meant that the Navy had recognized the need for a new system to accomplish a military goal. In response, the Station completed a Technical Development Plan (TDP) for an antisatellite system

86 "Secret City," Disk 2. Jagiello was a gifted aerodynamicist. Among the programs he contributed to were Sidewinder, Shrike, Sparrow, *Moray*, Polaris, North Star, Walleye, Osprey, Chaparral, ASROC, SUBROC, and Caleb.

87 Dale Fenn, "Air and Ship-Based Space Launch Vehicles," Orbital Sciences Corp., Dulles, VA, *http://media.wiley.com/product_data/excerpt/86/04713240/ 0471324086.pdf*, accessed 14 Dec 2009.

and forwarded the plan to BuOrd. The TDP called for a 300- to 500-pound homing missile that would be launched from an aircraft to intercept targets up to 1,000 miles in altitude. The TDP was prepared nearly a year after the NOTSNIK program had concluded. Not surprisingly, China Lake's proposed ASAT launch vehicle looked very much like the NOTSNIK launch vehicle, EV-1. The ASAT proposal included "coordination with associated military and civilian systems for target detection, identification, and position prediction, and for permission to fire."[88]

In April 1959 Frank Cartwright authored a NOTS publication called *Design of an Antisatellite Missile*. Three months later, Horace L. Newkirk, formerly a branch head in the Ballistics Division, published a companion document, *Design Study for an Antisatellite Missile*. Cartwright's report had outlined three concepts for an antisatellite system, and Newkirk's concentrated on the most promising, the Zero Velocity Homer. Its target, Newkirk wrote, "could be a scientific satellite that had, in some way, become objectionable (for example, by broadcasting radio noise), or it could be an enemy surveillance, or otherwise menacing, satellite." Newkirk's study summarized the TDP that NOTS had submitted to the Bureau of Ordnance. The proposed missile would be air-launched in the direction of the target satellite's orbit and employ a sensor that would receive reflected sunlight from the satellite: a system similar to Sidewinder. Newkirk wrote that:

> It is estimated that the sensitivity of such a seeker would have to be increased by at least one order of magnitude over Sidewinder, and this may not be unreasonable to expect. . . . This should permit detecting a reasonably large satellite at a distance of about 500 mi.[89]

Propulsion was a critical subsystem of the weapon. The recommendation was a four-stage missile booster launched from an aircraft, with a weight about half that of a ground-launched version.

Detection would be the biggest problem, and Newkirk proposed that the detector be developed in three stages, each "employing progressively more advanced test vehicles." The first would employ a "Background and Stellar Intensity Scanner," the second a "Precessible Scanning Telescope" with a compressed-gas vector motor, and the third a "Precessible and Maneuverable Telescope," including a liquid-propellant propulsion motor "to translate the unit as in a homing maneuver."

88 *Technical Program Review 1959*, 60, 61.

89 W. F. Cartwright, *Design of an Antisatellite Missile*, NOTS 2001, April 1959; H. L. Newkirk, *Design Study for an Antisatellite Missile*, NAVORD Report 6571, July 1959, 6, 28.

Newkirk did not describe the kill mechanism for the Zero Velocity Homer, though in discussing one of Cartwright's alternate approaches to the satellite-kill problem he wrote:

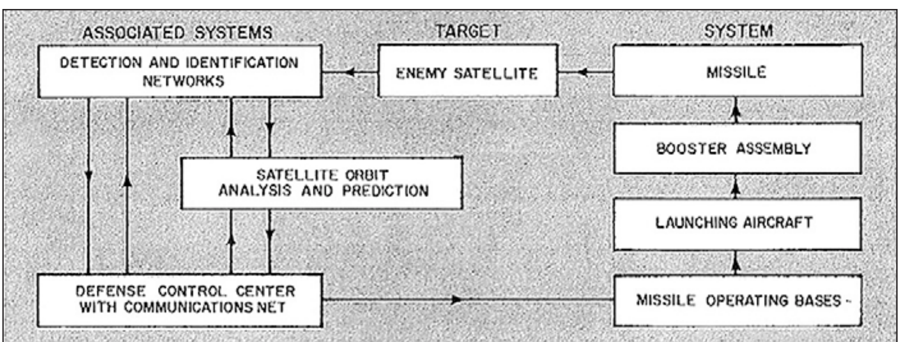
> The most economical approach to the problem of satellite interception would appear to be that of projecting a mass of material vertically from the earth into the vicinity of the orbit and let the satellite run into it.

For such an application he suggested a ballistic warhead that:

> . . . would consist entirely of warhead material; that is, only fuzing, explosive, and a maximum of fragment mass.
>
> The fuze would function some time before summit is reached in order that at the expected intercept time the warhead material would have expanded to occupy a sufficiently large volume or present a cross-sectional area large enough to provide for probable orbit prediction uncertainties, launching errors, and projectile dispersion.[90]

Development of an ASAT was not a frivolous venture. Soviet satellites did pose a potential threat to the United States. In an August 1961 speech celebrating Gherman Titov's becoming the second Russian cosmonaut to orbit the earth (Yuri Gagarin had performed the feat four months earlier), Premier Nikita Khrushchev threatened the West:

> You do not have fifty- or one-hundred-megaton bombs. We have bombs more powerful than 100 megatons. We placed Gagarin and Titov in space, and we can replace them with other loads that can be directed to any place on earth.[91]



Block diagram of antisatellite weapon system proposed by NOTS in 1959.

90 Ibid., 3.

91 "Outer Space: The Next Battlefield?" by Stewart Alsop, *Saturday Evening Post*, 28 July 1962, 18. In the article, Alsop posited "a sort of limited warfare in space, with both sides trying to knock out the other side's 'eyes in the sky' and other space devices."

There is also no question that the Navy did get into the antisatellite business. In April 1961 the House Committee on Science and Astronautics released testimony from Captain Robert F. Freitag, astronautics officer in the Bureau of Naval Weapons, who spoke of "a minimum-energy missile." The *New York Times* reported, "The missile, built around the Navy's proposed solid-fueled Sea Scout space rocket, would be 'launched vertically with just enough power to arrive at the altitude of the satellite at zero velocity.'" Freitag testified that:

> At that point, it can hover and wait for the satellite to come and then by terminal guidance seek out the satellite and kill it with some mechanism. We believe within a year and a half, for example, we could destroy one of our own satellites as a demonstration of this capability.[92]

Unfortunately for China Lake's ASAT aficionados, official funding for the ASAT proposed by NOTS in 1959 was not forthcoming. The Station reported to the Department of Defense in August 1961 that "Anti-satellite Missile development was proposed by NOTS in 1958, but the decision to proceed with the development has not been made."[93]

NOTS nevertheless pressed forward with its ASAT goal. Don Moore explained how the apparent hodgepodge of China Lake's early space-related programs were all working toward an antisatellite weapon. Referring to China Lake's rocket-borne-scanner development work Moore said:

> . . . that was part of the grand scheme that we had of getting into the antisatellite business. The way that we went about structuring our organization and our marketing—what type of work we were trying to get—is that we went through and said, 'What are all the components that you'd have to have to make an antisatellite system?' So that's rockets and telemetry and sensors and gyros and, you know, how to put all this stuff together and fire it either from the ground or from airplanes and communicate with the controls and all that kind of stuff, computers and the whole nine yards. So we started making proposals any place we saw some money that would let us learn about one of those things.[94]

An example of this "grand scheme" in action can be found in the 1961 *Technical History*. Under the mantle of the DOD-funded HITAB-TRIS program discussed previously, NOTS engineers attempted to gather data on more than just the launch signatures of ballistic missiles. The history reported:

92 John W. Finney, "Fuel Cells to Run Some Submarines," *New York Times*, 7 April 1961, 7. Captain Freitag, as a lieutenant commander, had spent a week at China Lake in 1952 as part of an industrial survey team for the Naval Inspector General.
93 AdPub 107, Encl. (1), 5.
94 S-185, Moore interview, 36

> A target radiant-intensity payload will be fired at Pacific Missile Range. The Terrier-Viper vehicle will be launched at San Nicolas Island at a polar-orbiting body fired from Vandenberg Air Force Base.

Knowledge of the spectral signature of an orbiting satellite would be essential to the development of a satellite-seeking and -tracking ASAT payload.[95]

Caleb

EV-2, son of the NOTSNIK launch vehicle EV-1, continued development under the project name of Caleb. The first Caleb launch was on 28 July 1960, from an F4D at a 63-degree launch angle. Ignition took place 4.9 seconds later and the motor burned for 50 seconds. Telemetry signals were received from the vehicle for 90 seconds.[96]

The project went public in October 1960 when the *Rocketeer* published a front-page article, "Caleb Pioneers Satellite Air-Launching," with a photo of Caleb loaded on the centerline station of an F4H Phantom II model. Caleb was described as "an extrapolation of work done at NOTS several years ago." With surprising frankness, the article admitted that:

> Caleb is a new name for an old project—a project that seemed to end suddenly but went under wraps two years ago when the Navy confirmed that they had tried to orbit a satellite from an F4D jet and were unsuccessful.
>
> The four-stage solid propellant rocket is a far cry from the cluster of rockets hastily put together for the first air launching attempts. In its new configuration, designed at NOTS, it is a masterpiece of simplicity. Depending upon the mission, it uses one, two or three solid propellant stages. For satellite missions a fourth stage is added.
>
> . . . As a vertical probe where high altitude is desired, Caleb can be launched at 85 degrees, nearly straight up. The vehicle will travel at a maximum speed of approximately 18,000 miles per hour. It is 16½ feet long, 2 feet in diameter, and weighs 3,000 pounds at launch.[97]

The launch vehicle was a joint product of the Propulsion Development, Weapons Development, Test, and Engineering Departments.

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95 *NOTS Tech History 1961*, 72.

96 Research Board minutes, 9 Aug 1960.

97 *Rocketeer*, 7 Oct 1960, 1. The final stage included a NOTS-designed spherical rocket motor (variously recalled as 3-inch, 3½-inch, and 5-inch), sometimes called the "baseball motor." Contrary to logic, the nozzle of the small motor in the nose of the final stage was pointed forward in the direction of flight. When the spin-stabilized final stage had traveled 180 degrees around the earth, the motor would then be pointed earthward and, when fired, would give the payload a final nudge into orbit: the "kick in the apogee."

A significant difference between Caleb and its predecessor, EV-1, was that the troublesome HOTROC motors, probable contributors to the demise of NOTSNIK, were replaced by the China Lake-developed 24-inch-diameter NOTS 500 rocket motor that could generate 8,560 pounds of thrust. The motor featured a six-point star perforation that ran the length of the motor, a graphite/plastic composite nozzle, and a magnesium-Teflon pyrogen igniter that was unaffected by environmental conditions. The second-stage ABL-241 motor used on EV-1 was replaced with an ABL X-248. Jesse F. "Jess" Osier and other members of the Propulsion Systems Division were responsible for the improved propulsion system used on Caleb and its variants.[98]

Naval Aviation News reported that "Attainable altitudes for an almost vertical [Caleb] probe launched at 85 degrees are: 85 pounds to 1000 miles with a two-stage vehicle, and 13 pounds to 2,000 miles with a three-stage vehicle."[99]

Crill Maples recalled that the Caleb EV-2 launch vehicle was built from "space metal," a welded 301 stainless steel sandwich material. The material had been fabricated by North American Aviation for the Air Force's Navaho intercontinental cruise-missile program; when that program was cancelled in favor of the Thor and Atlas ballistic missiles, NOTS managed to obtain the surplus. The Navaho material demonstrated excellent strength-to-weight characteristics and could withstand the large bending moment incurred when the F-4 "first stage" launched the rocket from the plane's belly.[100]

Several versions of Caleb were developed between 1960 and 1962, each tailored to the needs of whomever was providing the funding. Most were air-launched although at least one ground-launched version was also developed and tested.

HIHOE

Caleb was used in a NOTS program called HIHOE (also found in documents as Hi Hoe, Hi-Hoe, Hi Ho, and Hi-Ho). The whimsical sounding name was actually an initialism for exospheric composition studies of hydrogen (H), helium (HE), and oxygen (O) ions.[101]

On 25 July 1962, a Caleb vehicle dropped from the belly of an F4H-II 38,000 feet above the Pacific Missile Range and carried a 120-pound payload

98 *NOTS Tech History 1960*, 102–103; Crill Maples, email to the author, 10 Dec 2009.

99 Marie Pfeiffer, "Rockets Probe Mysteries of Upper Air," *Naval Aviation News*, BuWeps, Sept 1962, 18.

100 S-324, Crill Maples interview, 10 Oct 2009, 3.

101 Raymond Dickinson, *Glossary of Project Titles*, IDP 1607 Rev. 1, March 1967, 36.

Lieutenant Al Newman with HIHOE on a Caleb vehicle mounted on a YF4H-1 Phantom, Naval Air Facility, China Lake, July 1962.

of scientific instruments 1,000 miles into space. Lieutenant Al Newman, fighter weapons systems project officer at China Lake's Naval Air Facility, flew the Phantom II that launched the rocket. Charles M. "Chuck" Dye, head of the Weapons Development Department's Advanced Systems Branch and project director for HIHOE, described the mission as "completely successful."[102]

Naval Aviation News reported that HIHOE used a "Caleb II" vehicle, a "two stage, high-performance air-launched probe" with "structural stiffening" and that "Nominal altitude performance is 600 nautical miles for a payload weight of 200 lbs. when launched from a Navy F4H-1 aircraft."[103]

HIHOE, one of a series of high-altitude probes under NOTS development, carried an NRL-built payload designed to measure the ion composition of the earth's upper atmosphere. (HIHOE has nevertheless been characterized as an ASAT by the Federation of American Scientists and as either an ASAT or an air-launched ballistic missile attempt, by an Air Force study of U.S. antisatellite policy.)[104]

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102 *Rocketeer*, 27 July 1962, 1. Dickinson, *Glossary of Project Titles*, 13, reported that HIHOE reached "an altitude in excess of 800 miles."

103 "Rockets Probe Mysteries," *Naval Aviation News*, 18.

104 Federation of American Scientists, *http://www.fas.org/spp/military/program/asat/overview.htm*, accessed 21 Dec 2009; Johnson-Freese, "Viability of US ASAT Policy," USAF Institute for National Security Studies, Jan 2000 *http://www.usafa.af.mil/df/inss/OCP/ocp30.pdf*, 15,

To adapt Caleb for the payload, NOTS designed several mission-unique features including a nitrogen-actuated separation device that separated the payload from the second stage, thereby avoiding contamination of the immediate ionosphere around the payload that could occur with a traditional explosive-actuated separator; and a yo-yo-type "de-spin" device to slow the payload from 9 to 1 revolution per second.[105]

Frank Knemeyer related that the method of recovery for the HIHOE payload involved a Sound Fixing and Ranging (SOFAR) bomb. When the payload landed in the ocean, the bomb would drop to a specified depth, known as the deep sound channel, where the pressure would initiate an exploder. Several stations of the SOSUS (Sound Surveillance System) network would receive the sound of the explosion underwater and, by calculating the differences in time of arrival, the location could be pinpointed.

In keeping with Station safety requirements, the Ammunition Safety Committee had to review the use of the device. "Chuck [Charles W.] Bernard was the guy that was pretty big into this," said Knemeyer.

> He was kind of a honcho for this whole thing. We had an Ammunition Safety Committee meeting, and he brought in this SOFAR bomb which was marked 'inert' on the side. Many months later he admitted to me that that was a lie. He couldn't find an inert one, so he just printed the word 'inert.' This was the kind of thing that people have got to understand. You've got to take chances to cause things to happen.[106]

Satellite Interceptor—SIP

The next use of Caleb was in SIP. Depending on the source consulted, SIP stands for either Satellite Interceptor Program or the more innocuous Solar Instrument Probe. The 1960 *Technical History* discussed "the satellite interceptor program (Project SIP)" but then the 1961 *Tech History* reported, under the heading "Precessible Telescope," the test of a "solar instrumented probe (SIP), carried by a Caleb–type vehicle." The latter article related that "The Solar Instrumented Probe project terminated with a single firing" and went on to describe the results with uncharacteristic detail:

> A burn-through of the head end of the first-stage motor caused the second

accessed 21 Dec 2009. The FAS article notes that the ABL-248 second-stage motor of HIHOE was also used as the final stage motor of the USAF Miniature Homing Vehicle, the only U.S. air-launched ASAT acknowledged to have successfully killed a satellite.

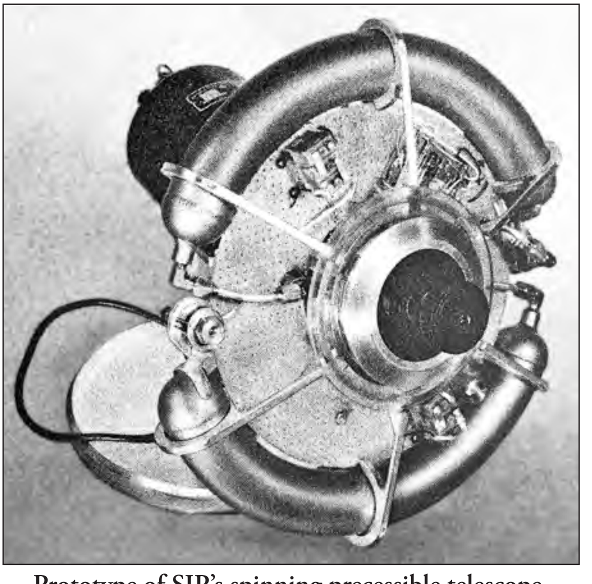
105 *NOTS Tech History 1961*, 69.

106 S-200, Knemeyer interview, 63. Such behavior, while indicative of China Lake's can-do attitude, was not condoned then nor is it today.

> stage to ignite prematurely, blasting the first-stage structure, which then separated from the second stage. The first stage experienced a series of chuffs during the remainder of the flight. Fire emitted from both ends. The second stage, with the structure intact and telemetry functional, burned out before impact.[107]

Use of the term Solar Instrumented Probe to define SIP appears to have been a bit of a red herring, probably for security purposes. The evidence indicates that SIP was one step in a multiyear attempt to develop an antisatellite payload and launch vehicle. A formerly classified glossary of project titles published by the Station in 1967 defined SIP as “a NOTS Exploratory and Foundational Research project conducted in 1960 and directed toward demonstrating the feasibility of a simple terminal navigation system with only two moving parts capable of acquiring, tracking and maneuvering to intercept a target satellite.” Don Moore was listed as the cognizant engineer for SIP.[108]

A spinning payload built around a precessible telescope (a modified Sidewinder seeker) was at the core of the SIP homing system, and its description makes clear that the satellite wasn’t looking for the sun. “When the image of the target satellite is off the optical axis, it is chopped by a fixed reticle,” said the 1960 *Tech History*. The amount and phase of the output signal controlled “fingerlike reaction jets” that “result in a precession of the optical axis to the desired attitude.” When the signal reaches zero and does not change, “a collision course has been obtained.”[109]



Prototype of SIP’s spinning precessible telescope.

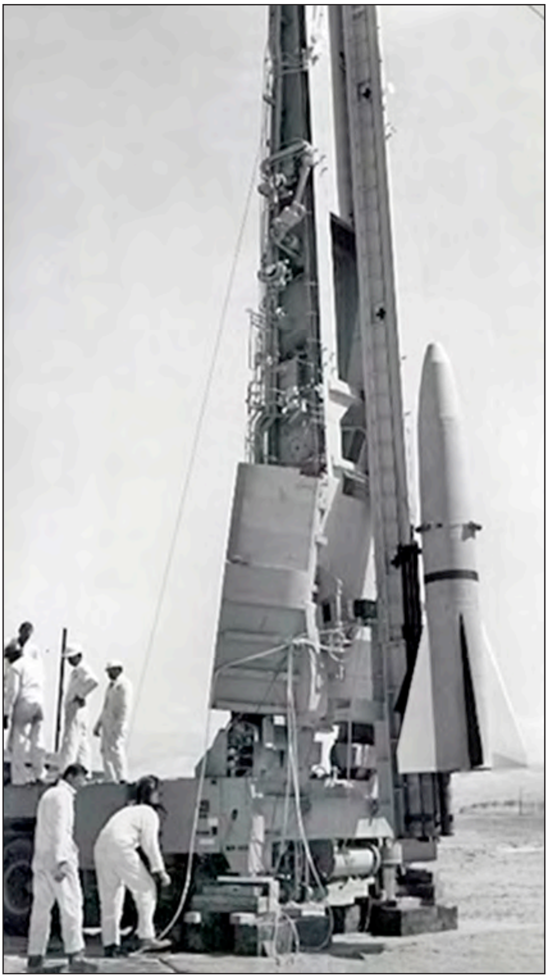
The SIP version of Caleb was ground launched and thus presented unique technical challenges. Caleb, like EV-1, had been designed for launch from a supersonic jet fighter flying at more than 30,000 feet. For ground launching, the plan in 1960 was to attach the Caleb launch vehicle to a rocket-powered sled riding on a hy–

107 *NOTS Tech History 1960*, 76-77; *NOTS Tech History 1961*, 76.
108 Dickinson, *Glossary of Project Title*s, 79.
109 *NOTS Tech History 1960*, 77.

draulically operated near-vertical rail launcher (another leftover from the Navaho program). The rocket-pow-ered sled would give SIP the initial thrust to carry it to a height where the powerful NOTS-500 motor would fire.

Crill Maples was assigned to develop the ground-launch system for SIP. Duke Haseltine, China Lake's premier ballistician, told Maples, "There's no way on God's green earth to launch that from the ground." Haseltine claimed that for the payload to have a chance for reaching orbit, the launch vehicle would have to reach a speed of at least 120 miles per hour by the time it reached the end of the Navaho launch arm.[110]

China Lake engineers and machinists extended the length of the launch arm. To power the launch sled, which was designed by John Ward and built in NOTS' main machine shop, eight NOTS 124-C motors were selected. These were motors normally used for sled boosters at China Lake's Supersonic Naval Ordnance Research Track (SNORT). The motors were modified by machining the propellant grain down, as Maples recalled, "to about the size of gunpowder" so that the motors would burn for only 0.6 second, putting out 10,000 pounds of thrust each. The sled was fitted with unstretched nylon ropes to retard it at the end of the rail so that the SIP vehicle would separate from the sled. SIP was further fitted with an external harness to which three small rockets (M7 "spin motors" from the Army's Honest John missile) were attached; when these were fired, they would start Caleb spinning about its longitudinal



Dummy SIP vehicle on launcher, China Lake, August 1961.

110 S-324, Maples interview, 4.

axis to impart stability. Then the harness and spin rockets would be jettisoned.

In August 1961 a dummy SIP vehicle was ground launched at China Lake using the launcher sled and rocket harness. The vehicle reached the 120-mile-per-hour threshold as it separated from the sled at the end of the launch rail. Maples recalled that when the vehicle successfully cleared the launcher, Frank Knemeyer (head of Code 40, which was responsible for SIP development) turned to him and said "You're now a GS-12"—a significant promotion in the civil service pay system.[111]

The launcher, barely fitting in the cargo bay of its host C-133, was flown to San Nicolas Island. The SIP test vehicle itself traveled on a C-124. After setup and launch preparations on the island, the SIP was launched on October 1. The first stage operated properly, but the second stage ignited prematurely, causing the vehicle to go unstable and resulting in loss of the rocket and payload.

Maples would later become head of Code 453, the Quality Assurance Division of the Propulsion Development Department. He would hold that position for 22 years—one of the longest serving division heads in China Lake history—until his retirement in 1986. It was not until 1993 that China Lake publicly mentioned "the early-'60s demonstration of concept and hardware for SIP, a developmental satellite-killer."[112]

Guided Flight Vehicle

According to Maples, China Lake project people used the term Cerberus—the three-headed dog of Greek and Roman mythology—to refer to a constellation of three programs: HIHOE, SIP, and the Guided Flight Vehicle (GFV).

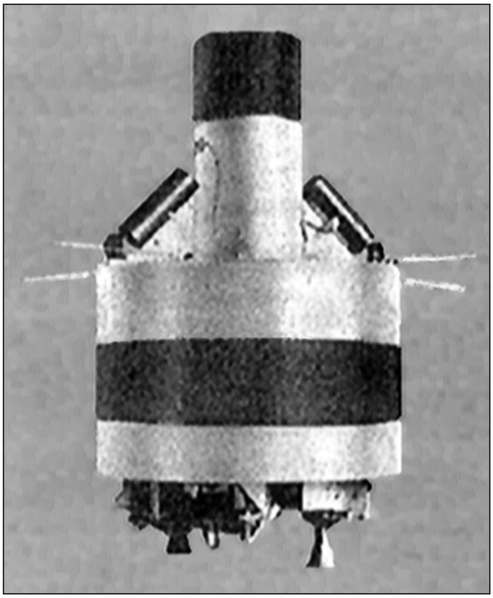
GFV was a continuation of the earlier SIP work and was designed to place a homing device near an orbiting body on a collision course. The GFV project included the launch vehicle, the ground-launch system, and the interceptor payload prototype, and its technical objective was phrased broadly—"to explore the concept of a spin-stabilized satellite interceptor."[113]

Although GFV, like SIP, employed solid-fuel rockets as the primary propulsion source (as did all Caleb variants), GFV carried a more advanced payload. Designated "Payload A," it contained an axial-mounted optical seeker and associated equipment, a telemetry system, and a propulsion package consisting of a pair of 7½-pound-thrust liquid-fueled precessional-pulse

111 Ibid., 4.

112 *Rocketeer*, 4 Nov 1993, 28.

113 S-324, Maples interview, 5; *NOTS Tech History 1961*, 17. 42.



Guided Flight Vehicle Payload Type A

motors, all packed into a 17-inch-diameter payload.[114]

A planned Payload B would be similar to A but would also have a larger (0- to 2,500-pound-thrust) liquid-fueled rocket motor for maneuvering the payload in space (the smaller precessional motor merely reoriented the payload to keep the axis fixed on the target). "The interception problem is solved," reported the *Technical History*, "by accelerating the body normal to its spin axis by fast-response liquid-propellant rockets in compliance with commands from a homing tracker whose null axis coincides with the body spin axis."[115]

NOTS had carved out a niche in the variable-thrust liquid-fueled rocket arena. Ron Dettling, who had a fruitful 31-year career at China Lake as a mechanical engineer and designer, recalled that the first project he was put in charge of at China Lake in late 1958 or 1959 was:

> . . . the combustion chamber and injector for a maximum 10-pound thrust, variable-thrust [hypergolic liquid] motor. . . . That was considered to be something that could be used to control the position and attitude of satellites. So, in fact, this was called a Satellite Position Adjust Rocket, SPAR.[116]

At the core of the variable-thrust motor was the variable-area injector patented by D. Marshall Klein. The motor's uniqueness was that "it could run the entire range from zero to whatever the maximum thrust was, so it was, basically, utterly simple," Dettling recalled. "There was one [engine] designed and built, and I don't believe we ever tested it, as large as 20,000 pounds of thrust."

Klein and co-researchers Douglas D. Ordahl and Eugene V. Rutkowski

114 *NOTS Tech History 1961*, 73, 101.

115 Ibid., 72.

116 S-218, Ron Dettling interview, 12 Nov 1992, 7. Dettling and fellow engineers Tom Zulkoski and John Bush would later invent and patent a "flying saucer," an "Omni-Directional Liquid-Fueled, Saucer-Shaped Attack Weapon for Aircraft," U.S. Patent No. 3,827,656.

had unveiled the "rocket controller" at a public demonstration in January 1959. Roy Johnson, head of the Advanced Research Projects Agency, witnessed a test of the system, and NOTS produced films on the controller that were shown on the three major television networks.[117]

While one group of engineers worked on the precessional and maneuvering (also called "translational") motors, another pursued the precessible-telescope homing system, and yet another experimented with a radio-homing version of the Payload A. The intent was to use this homing system in an "intercept experiment" with the Explorer VII, which the U.S. had launched on a 2-year mission in October 1959. However, before technical problems were resolved, the Explorer VII batteries began to fail, degrading the signal to below that required for radio tracking. (As of this writing, Explorer VII was still in orbit.)[118]

Meanwhile, launch vehicles capable of putting an antisatellite payload into orbit were being refined. NOTS' Propulsion Development Department developed a solid-rocket propulsion system for GFV vehicles designed to carry the satellite interceptor to orbit. Two styles were fabricated, both employing five modified 5-inch HVAR rockets as the initial kick to propel the launch sled the length of the SIP rail launcher.

The first launch vehicle used a NOTS 500 motor (with modified nozzle and igniter) for the first stage and a NOTS-designed NOTS 505 near-spherical motor (capable of generating 4,000 pounds of thrust for 33.5 seconds) for the second stage. The Honest John motors that had imparted stabilizing spin on SIP were replaced with a NOTS-designed spin motor that was small (3.5 by 13.5 inches) but developed 1,900 pounds of thrust for ⅓ of a second.

This launch vehicle was also designed to test the concept of directing the rocket exhaust plume of a NOTS 500 motor by injecting Freon 114B directly into the plume in an early form of thrust-vector control. Four injectors were spaced 90 degrees apart in the rocket nozzle, and the injection system was controlled by an autopilot, designed by Nick Schneider, in the rocket. The Freon fluid was pressurized from a tank of nitrogen gas, which was controlled by a pyrotechnic valve. The system was first successfully demonstrated in September 1961, and ground tests at the Skyline B facility in December 1961 showed that vectoring forces greater than 10 percent of axial thrust could be achieved without degrading axial thrust.[119]

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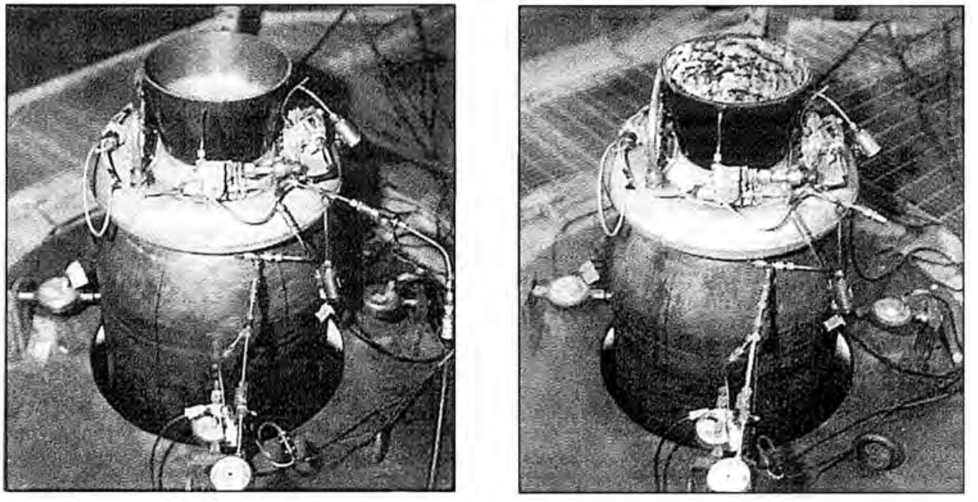
117 *Rocketeer*, 23 Jan 1959, 1.

118 *NOTS Tech History 1961*, 75; United Nations Office for Outer Space Affairs, Register of Space Objects, *http://www.unoosa.org/oosa/search.do*, accessed 13 Aug 2011.

119 *NOTS Tech History 1961*, 118.



NOTS 500 rocket motor with flight-weight thrust-vector-control system, before static firing (left) and after static firing.

When the vehicle was launched from San Nicolas Island, it was "the first surface launching of a vehicle with secondary injection thrust-vector control, and it significantly demonstrated early flight control." However, 8 seconds after launch the nitrogen-control valve vibrated shut. With no pressure, there was no Freon injection and thus no further control. The vehicle, Maples remembers, made a large outside loop and crashed on the island.[120]

The second type of GFV launch vehicle used a fin-stabilized first stage propelled by a NOTS 500 motor and a spin-stabilized second stage employing the ABL X-248-A6 motor. Two of these were launched from San Nicolas Island in 1962. In the first, on 5 May, the payload did not eject. Engineers determined the cause and modified the ejection mechanism. The next GFV launch—and from all available records, the final one—was made on 30 November 1962.

A December 1962 *Rocketeer* article, erroneously headlined "SIP Launch," is the only issue of the base newspaper to talk, albeit guardedly, about an antisatellite test launch. In that article, the acronym SIP is not spelled out—an unusual omission for the generally well-edited *Rocketeer* under the guidance of editor Budd Gott. In fact, the vehicle reported on in the article was not SIP but rather the GFV, that used the SIP rail launcher. The launch took place on 30 November.[121]

The *Rocketeer* article reported a ground launch from San Nicolas Island that carried the payload to an altitude of 200 miles. Tantalizingly vague as to the

120 *NOTS Tech History 1962*, 85; S-324, Maples interview, 3; *Rocketeer*, 25 Oct 1963, 3.
121 *NOTS Tech History 1962*, 84.

purpose of the launch, the writer merely mentioned "payload experiments of which the details are classified" and that "the payload concept and development was taken care of by Mel Creusere of the Armament Control Systems Branch of the Aviation Ordnance Department and Earl Yim of the Liquid Propulsion Systems Branch, Propulsion Department."[122]

Both Yim and Creusere were developing systems to control and maneuver a body in space. Yim, a chemical engineer, was head of the Liquid Propulsion Systems Branch and one of the developers of the Soft-Landing Vehicle, which used variable-thrust liquid-fuel rockets to control its rate of descent. Creusere had long recognized the need for an effective precessing system: "A precisely controlled attitude appears essential in an operational scanner," he had written in a 1958 memo. He estimated the weight of such a "precession mechanism" as 5 pounds for a 23.5-pound payload.[123]

The purpose of the flight was to determine the applicability of guided spin-stabilized bodies as satellite interceptors. Both May and November payloads were steerable in sightline but not in coordinate position. The payload separated successfully on the second flight. About 19 second later, a heavy object, possibly the nose cone, struck and partially damaged the probe.

That ended the test flight and, so far as can be determined, the GFV program. As when any program disappears from the official record, one can assume that it either "went black" or—as was more commonly the case—ran out of money or technical promise and was no longer pursued.[124]

Dixie Pixie

Almost no official documentation of the Dixie Pixie project has been found in the China Lake records. It appears that sometime between 1960 and 1962 a Caleb launch was undertaken, in partnership with the Franklin Institute, to put a rat into orbit. Maples recollected that the intent of the mission was to recover the rat by parachute, but that the effort was unsuccessful.

Space historian Matt Bille characterized Dixie Pixie as "a biomedical satellite carrying two rats."[125]

A 1967 glossary of project titles described the project as one "conducted

122 *Rocketeer*, 21 Dec 1962, 7.

123 Memo, Head, Branch 3 [Creusere], to Head, Aviation Ordnance Department [Ward], via Head, Development Division 4 [Amlie], "Considerations for a 'TV' Weather Satellite (Tentative Thinking)," 3543/MCC:drq, Ser. 7, 26 June 1958.

124 *NOTS Tech History 1962*, 19, 64.

125 S-324, Maples interview, 2; Bille and Lishock, *The First Space Race*, 149.

by the Naval Missile Center (NMC), Pt. Mugu, to provide a recovery system to be compatible with Naval Air Development Center (NADC), Johnsville-developed payload and NOTS-developed CALEB booster," and listed Chuck Dye as the point of contact.[126]

Kill Mechanisms

Little official material is available concerning the kill mechanisms for Navy ASATs. For a *Los Angeles Times* article on a patent dispute between Hughes Aircraft Co. and the Navy over satellite-related patents, Ralph Vartabedian interviewed Nicolaides, then 71.[127]

Vartabedian wrote:

> Ultimately, the Navy hoped to use the Notsnick [*sic*] rocket to launch a reconnaissance satellite and an anti-satellite satellite, using the same type of precession as Hughes outlined in its later patent application, according to Nicolaides. Though the devices were not sent into orbit, they were built and tested at China Lake between 1958 and 1960, he said.

Vartabedian also interviewed Leo Kielman, a former Navy enlisted man who attended school on the G.I. Bill after the war, received a mechanical engineering degree, and went to work at NOTS. In the early 1960s, Kielman worked as a mechanical engineer in the Weapons Development Department. Vartabedian wrote that Kielman:

> . . . said he built the anti-satellite model himself in about 1958. It was prepared for launch at a Pacific Ocean test range but was destroyed by an explosion in the rocket motor; no physical evidence of the device exists today, he said. "It nearly landed on my head," Keilman [*sic*] recalled, referring to the wreckage raining from the sky.[128]

In 1996 Nicolaides reiterated the antisatellite claim and expanded on it:

> I went ahead and authorized NOTS to go forward with both of these projects: a project to put a satellite into orbit (a reconnaissance satellite) and other satellites into orbit; and two, to come up with an anti-satellite system.

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126 Dickinson, *Glossary of Project Titles*, 24.

127 Vartabedian, "One Last Transmission From Satellite Old-Timers Aerospace," *Los Angeles Times*, 2 Oct 1994, D1.

128 Ibid. The article also states that "Leroy Doig, a Navy historian at China Lake, said his research confirms the accounts by Nicolaides and the others, although formal reports, blueprints and drawings of the devices cannot be found. 'A lot of stuff here wasn't documented well or the documents were packed off to a federal documents center' and lost, Doig said."

> We performed our programme like an ordnance program—there were many tests, a lot of tests. I can tell you we were well on our way—with the appropriate ground complexes to send them into space, the computer systems, the viewing systems for intercept, and the destruction system (which was a particle system that would throw particle into the path of the target and destroy it.) But we had a very methodical series of tests. We made sure it would work. There were a number of launches in this programme.

Nicolaides also confirmed Kielman's account as reported in the *Times*:

> He witnessed that launch from a boat. And Keilman [*sic*] had nothing to do with the rocket failure. . . . He built the working model, he built the satellites, and he built the anti-satellite demonstrator.[129]

Bud Sewell remembered Kielman's warhead design:

> They called it the Zero Velocity Homer. Well it turns out from the studies that I remember doing on the thing it wound up going 25,000 miles per hour if you were going to make the intercept which was hardly a zero velocity. . . . You put it up in the right spot out there and then you detect it coming in and then it just sits there and just shifts over slightly.[130]

For Pesavento's *Spaceflight* article, he spent 10 hours interviewing Nicolaides at his San Luis Obispo home, where Nicolaides showed him many photographs, documents, and artifacts. Pesavento later said:

> They tested two sizes of industrial marbles (the kind that they use to break up rust scale inside pipes, is what he [Nicolaides] told me). Larger blue colored ones, and smaller green colored ones. He had examples of both that I was shown. They weren't dull in color, but were metallic . . . iridescent.[131]

In an addendum to the Pesavento article, published in the same issue of *Spaceflight*, Nicolaides also affirmed Moore's recollection of many programs all working toward one end.

> According to Dr. Nicolaides, the main reason why the programme had so many different names was the attempt to continue to get money to continue the project—different project names meant new and different sources of funding. A secondary effect was the confusion created if anyone outside a few Navy personnel would attempt to track any of the efforts.[132]

When Pesavento asked how China Lake equipment had wound up in the Transit satellite, when the equipment had nothing to do with the Transit

129 Pesavento, "US Navy's Untold Story," *Spaceflight*, 242.
130 S-297, Knemeyer, Sewell, Doig, and Lincicum interview, 19.
131 Pesavento, emails to the author, 20 Aug and 10 Sept 2009.
132 Pesavento, "US Navy's Untold Story," *Spaceflight*, 245.

mission, Nicolaides replied:

> You must remember we did not have the bureaucracy that space flight operations have today. I was the bureaucracy. If I made a decision to have something tested, it got tested. If I said it had to go up on a specific mission, it did so. . . . Things were done well, and done quickly.

After leaving the Navy, Nicolaides held senior positions at NASA, chaired the Aerospace Engineering Departments at Notre Dame University and California Polytechnic State University, and patented, among other things, the parafoil. He died in 1999.[133]

The antisatellite weapon with Kielman's warhead sounds very much like the system described by Captain Freitag in his testimony to Congress. The ability to "hover and wait for the satellite" that Freitag had spoken of was also being developed under two other China Lake projects: the Soft Landing Vehicle and the Hovering Rocket System. In 1967 China Lake propulsion engineers, working to requirements set by the NWC Corona Laboratories (formerly NOL Corona), developed an experimental spin-stabilized motor called Teeny Rocket. This ⅜-inch-diameter 4-inch-long motor/projectile was intended for "an antisatellite weapon that launched hundreds of these at 1,000 ft/s into the path of an oncoming satellite."[134]

Soft-Landing Vehicle

The Soft-Landing Vehicle was a follow-on to the breakthrough "rocket controller," or variable thrust liquid-fueled engine, that had been announced in 1959. Klein and Rutkowski had boldly stated that "this engine, with proper guidance, could land a space vehicle on the moon without damage, " and they proceeded to work toward that end .[135]

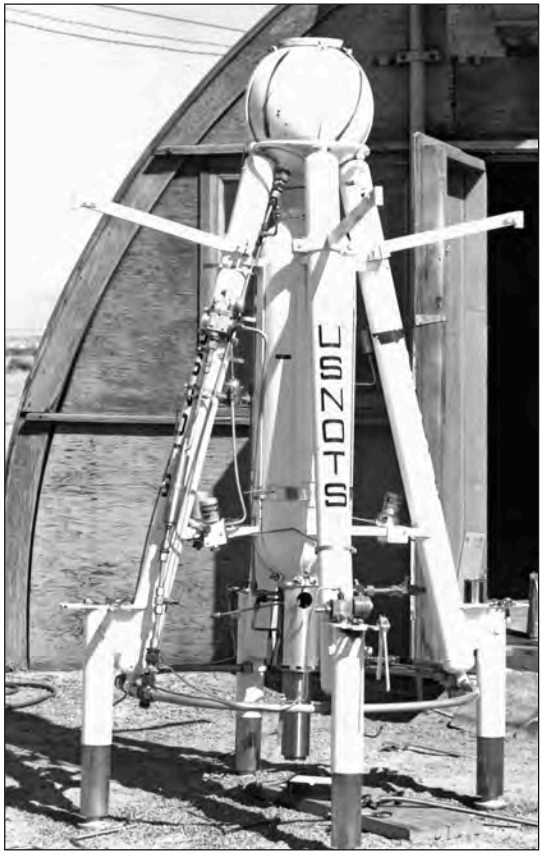
In May 1961 the *Rocketeer* boasted that:

> NOTS has designed, developed and tested a rocket-propelled soft-landing vehicle (SLV) which has risen off the ground, hovered in mid-air, and landed under complete control. This is the first rocket-powered vehicle to take off and land gently—a feat vital for putting men and instruments on the moon and planets—under its own power.[136]

This early experimental SLV was 8 feet high and 5 feet wide and weighed

133 Ibid., 240.
134 J. M. Robbins and R. W. Feist, "The China Lake Propulsion Laboratories," July 1992, 7; *NWC Tech History 1967*, 4-11.
135 *Rocketeer*, 23 Jan 1959, 1.
136 *Rocketeer*, 20 May 1961, B-2.

700 pounds fully loaded. A 300-pound fuel load—unsymmetrical dimethylhydrazine (UDMH) and an oxidizer, inhibited red fuming nitric acid (IRFNA) —powered the vehicle for 75 seconds. Using a NOTS-designed optical guidance system with no pilot in the loop, the vehicle successfully demonstrated the ability to lower itself safely to the ground from test-stand heights of up to 146 feet with touchdown velocities as low as 3.8 feet per second.[137]



NOTS Soft-Landing Vehicle, 1961.

In April 1962 NOTS published *Preliminary Systems Analysis for Hovering Vehicle*, by Ron Dettling, which addressed systems analysis techniques "for missions requiring rocket motor thrust variation, and specifically for vehicles hovering both in and out of the atmosphere."[138]

Three months later, in July 1962, the SLV—more formally the "VT 1105 R Test Vehicle" and less formally the Ugly Duckling—was featured in *Astronaut* magazine in an article by Earl Yim and Project Engineer Felton "Toby" Williamson.

Earlier that year, Don Cooper of the Test Department was commended for his outstanding contributions to the program. "The reliability and general high quality of the electronic and electrical aspects of the SLV program were due largely to his superior efforts," said the *Rocketeer*.[139]

Williamson went on to enjoy a varied and colorful career in engineering and private business and eventually became a political gadfly and author of *21st*

137 *NOTS Tech History 1961*, 103–104.

138 Ronald F. Dettling, *Preliminary Systems Analysis for Hovering Vehicles*, NOTS TP 2829, China Lake, 2 April 1962.

139 "Astronaut Mag Features Station Artist and Authors," by Phillys Wair, *Rocketeer*, 20 July 1962, 4; *Rocketeer*, 23 Feb 1962, 1.

Century Common Sense. On his website he said of his days at China Lake:

> They let me build and test all those rocket engines and it didn't cost me a dime. They even paid me a salary."[140]

It took a little longer to achieve the "proper guidance" mentioned by the developers in 1959, but in 1964 three China Lakers—Paul Driver, Charles E. Hendricks, and Donald D. Stevenson—were granted a patent for a device that could autonomously control the thrusters during a descent to the moon's surface. The "TV Top Hat," so called for its placement at the very top of the landing vehicle, used an electro-optical sensor that measured the angular rate of a line-of-sight sensor. From this device the derived signal was proportional to the ratio of lander's descent velocity to the distance from the terrain. The signal was converted to retro-thrust controllers such that the vehicle's velocity and height both became zero at the instant of touchdown. The approach was cutting-edge technology for the early 1960s.[141]

Hovering Rocket System

Meanwhile, a separate program using the hovering-rocket technology was under way at the Station. The Hovering Rocket System (HRS) was funded by the U.S. Army Ballistics Research Laboratories and later supported by the Defense Atomic Support Agency. According to a summary report on the program, the system was designed to "deliver a large payload to a predetermined point in the upper atmosphere at zero velocity, and then hover the payload until all propellant has been expended, or move it in any direction to a new position, and then release the payload to fulfill its mission." The program was an outgrowth of a feasibility analysis for a Hovering Instrumentation Platform (HIP) conducted in 1961.[142]

Specifically, HRS design requirements were as follows:

> . . . to place a 600-pound payload at target altitudes ranging from 65,000 to 165,000 feet with a ground range of approximately 115,000 feet; (2) to achieve positioning within a spherical radius of approximately 1,000 feet with reference to the aimpoint; (3) to provide a stabilized hover time of 120 seconds if possible, but no less than 30 seconds; and (4) to provide the vehicle with the capability of being repositioned after launching." The payload would employ four variable-thrust liquid-fuel rocket engines to provide pitch, yaw,

140 *http://www.commonsense21c.com/AUTHOR.html,* accessed 22 Sept 2009.

141 "NOTS' SLV Scanner May Go in Moon Project," *Rocketeer*, Dec 1964, 1.

142 NOTS TP 3652, *Hovering Rocket System: Volume 1: Summary Report on the Preliminary Design*, by Engineering Technology Division, Propulsion Development Department, China Lake, NOTS, 30 Nov 1964, i.

and axial thrust control.[143]

In a *Rocketeer* article on HRS in early 1964, program manager Foy McCullough, Jr., commented with carefully phrased lack of specificity:

> The vehicle has many potential scientific values. Its missions could include direct observation of natural and man-made phenomena of both space and earth origin, which might not be observable in any other manner.

McCullough was assisted in the program by Project Engineer Chuck Green and a 16-man team that included Ron Dettling, Fred Zarlingo, Ben Glatt (who designed the guidance system), and Don Moore as a consultant.[144]

As much as HRS sounds like the antisatellite system that Freitag was describing to the House committee, it was actually intended for a different purpose. James A. Bowen, who took over the HRS program in mid 1964, recalled:

> [McCullough] became aware of the requirement for instrumenting the detonation aspects of nuclear weapons. Well, to do that, you had to measure it very close, like within a quarter of a mile, or half a mile of the detonation itself, at 50 kilometers [165,000 feet] high. . . . What they wanted to do is . . . fire a Minuteman [an ICBM] from a western test site and have it go over Johnston Island and detonate at 50 kilometers altitude, and, at the time they detonated it, have a device hovering in the sky, 50 kilometers high, at a precise location, the precise location being determined by radars knowing when the missile was coming . . .
>
> We'd fire the variable-thrust rocket engine, it would go up, and then at a certain height, it would do a 180-degree turn in flight, like the Apollo did, and then slow down to zero velocity, and then a stable platform would cause it to hover there for a long period of time. The warhead would detonate and then the HRS payload would obtain the data and then sometime later a parachute was deployed and would be recovered at Johnston Island.[145]

The program was cancelled in November 1964—U.S. ratification of the Partial Test Ban Treaty the year before had made the likelihood of the HRS's actual employment in a nuclear test unlikely—but not before China Lake had completed, as Bowen recalled, "a complete system design, demonstration firing of the actual rocket engines, and buying all the components for almost everything."

Bowen's assertion that the HRS was intended to support nuclear testing—despite the similarity to the ASAT system described by Freitag—is borne out in part by the 165,000-foot altitude requirements for the HRS. An ASAT would

143 Ibid., 1; NWC TP 4456, *Naval Weapons Center Technical History 1967, Part 3, Bibliography*, April 1968, 26. Hereinafter cited as *NWC Tech History*.

144 *Rocketeer*, 17 Jan 1964, 1, 3.

145 S-175, James A. Bowen interview, 14 April 1989, 30–31.

have to operate at a substantially higher altitude than 31 miles.

Nevertheless, the Hovering Rocket System fits nicely with Moore's "grand scheme that we had of getting into the antisatellite business . . . making proposals any place we saw some money that would let us learn about one of those things."

Other Navy, Army, and Air Force Variants

One system mentioned often in connection with Navy ASAT efforts is Sea Scout. The *United States Civilian Space Program 1958–1978* (a Library of Congress report for Congress) stated that:

> . . . the Navy considered in 1960 and 1961 building for certain military missions a rocket combination they called Sea Scout which was to be launched from either a surface ship or a modified submarine. These missions included Yo Yo (later Albatross), a one-orbit reconnaissance satellite; Skipper (later Early Spring), a satellite destroyer which would loft debris in the path of an approaching vehicle; and Renae, a tactical weather satellite. As a study project, Early Spring was still active until 1964.

The report went on to describe in some detail the components of four possible variants of Sea Scout and concludes :

> The Sea Scout was not built and the Navy lost the authority to continue further work on launch vehicles under the doctrines which passed such responsibility to the Department of Defense with the Air Force as executive agent of the department.[146]

The author found no evidence that China Lake was involved in the Sea Scout variants side except for a single allusion by Nicolaides in a 1960 open literature article, "Examples of this approach [cheaper and more versatile launching vehicles] exist in the Naval Ordnance Tracking [*sic*] Station (NOTS) aircraft-launched satellite vehicles, Scout, Sea Scout, and Hydra."

One parenthetical reference in the 1960 *Technical History* also indicates SIP work was being conducted under a BuWeps Task Assignment titled "Antireconnaissance System (Skipper)."[147]

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146 *United States Civilian Space Program 1958–1978* (prepared for the Subcommittee on Space Science Application, Committee on Science and Technology, U.S. House of Representative Ninety-Seventh Congress, First Session), by Science Policy Research Division, Congressional Research Service, Library of Congress, Ser. D, Vol. 1, Jan 1981, 197–198.

147 John D. Nicolaides, "A New Frontier in Astronautics?" *Signal*, Dec 1960, 15; *NOTS Tech History 1960*, 245. The Naval Missile Center, Point Mugu, did experiment with the Hydra rocket fired from floating launchers in 1960.

The Navy did pursue a research program into sea-launched rockets beginning in 1961. Named Hydra, the effort investigated the feasibility of launching various types of rockets from floating vertical launch assemblies.

The first water-launch tests were conducted by Aerojet-General Corp. using first a 5-foot-long wooden dummy rocket powered by a 2.25-inch motors and later a 10-ton boilerplate rocket powered by surplus Genie solid booster motors. A test series at the Pacific Missile Range in 1962 employed POGO-HI target rockets obtained from NOTS and launched from a recoverable floating open-rail launcher.[148]

In the long run, the Army and the Air Force captured the nation's antisatellite mission. The Air Force had been in on ASAT work from the ground floor. During 1958 and 1959, while China Lake was working on NOTSNIK and Caleb, the Air Force was developing, through its contractors, Bold Orion and High Virgo, air-launched ballistic missiles (ALBMs) capable of antisatellite missions.[149]

The Army was developing its own antisatellite-capable system using ground-launched missiles. In 1962, Secretary of Defense Robert S. McNamara approved the Army's Program 505 to modify Nike Zeus ABMs with nuclear warheads that could kill satellites in low earth orbit.[150]

On 23 May 1963, a Program 505 Nike Zeus intercepted a satellite at 100 nautical miles altitude, with a simulated detonation occurring approximately 290 meters from the satellite. The Office of the Secretary of Defense claimed that the system was capable of engaging threats at altitudes to 200 nautical miles, and that of 35 Soviet satellites examined, approximately half of them passed through the Kwajalein-based area of Nike Zeus coverage.[151]

Not to be outdone, the Air Force then proposed a longer-range nuclear-kill-mechanism ASAT system. The White House Diary has the following entry for 6 August 1963:

148 Bill Wilks, "Pogo-Hi Boosts Sea-Launch Stock," *Missiles and Rockets*, 12 Feb 1962, 24–25.

149 Andreas Parsch, *Directory of U.S. Military Rockets and Missiles*, Appendix 4: "Undesignated Vehicle, 'WS-199,'" *http://designation-systems.net/dusrm/app4/ws-199.html*, accessed 24 Aug 2009.

150 Lt. Col. Bruce M. DeBlois, USAF, "Space Sanctuary, A Viable National Strategy," *Airpower Journal*, Winter 1968, *http://www.airpower.maxwell.af.mil/airchronicles/apj/apj98/win98/deblois.html*, accessed 24 Aug 2009.

151 Memo, Secretary of Defense Assistant for Atomic Energy (W. J. Howard) to Charles E. Johnson, Office of the Special Assistant to the President for National Security Affairs, 18 Jan 1984, Johnson Library, National Security File, Subj. File, Nuclear Weapons, Vol. I, Box 32. Top Secret, Sanitized E. O. 13526, Sec. 3.5, NLJ 10075, NARA, 12 May 2011.

> President Kennedy assigns the highest national priority to Program 437, an anti-satellite ballistic missile system using Thor rockets equipped with nuclear warheads to cause electromagnetic pulses to damage space satellites.[152]

By January 1964, the Secretary of Defense had either spent or approved about $85 million for Programs 505 and 437—and this was before Program 437 had a successful launch demonstration.[153]

Programs 505 and 437 won the day. On 17 September 1964, President Johnson spoke on the steps of the California capitol building in Sacramento. Citing the "danger that an aggressor might some day use armed satellites to try to terrorize the entire population of the world," he said:

> To insure that no nation will be tempted to use the reaches of space as a platform for weapons of mass destruction, we began in 1962 and 1963 to develop systems capable of destroying bomb-carrying satellites. We have now developed and tested two systems with the ability to intercept and destroy armed satellites circling the earth in space. I can tell you today that these systems are in place, that these systems are operationally ready, that these systems are on alert to protect this Nation and to protect the free world.[154]

Program 505 was later phased out in favor of the longer reach of Program 437, which was itself cancelled in 1972.

It wasn't until the mid 1970s that the U.S. military revisited the idea of an air-launched antisatellite missile. The Air Force Space Systems Command worked with LTV Aerospace to develop the ASM-135, which carried an inertial/IR-homing kinetic-energy warhead and was designed for launch from an F-15 in a supersonic climb. The efforts culminated with the September 1985 launch of the weapon against the U.S. Solwind P78-1 satellite, destroying the target. According to the manufacturer, intercept occurred at a closing velocity of 15,000 miles per hour, and the weapon hit the target within 6 inches of the aim point.[155]

Further testing against satellite targets was halted almost immediately by a Congressional ban, and the program was terminated in March 1988.[156]

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152 John F. Kennedy Presidential Library and Museum, White House Diary, *http://www.jfklibrary.org/Asset-Viewer/KDpRULS3kEyvCS2x5v6MQQ.aspx,* accessed 21 Jan 2011.

153 Memo, Secretary of Defense Assistant for Atomic Energy (W. J. Howard) to Charles E. Johnson.

154 Lyndon B. Johnson, Remarks in Sacramento on the steps of the State Capitol, 17 Sept 1964, American Presidency Project, University of California Santa Barbara, *http://www.presidency.ucsb.edu/ws/index.php?pid=26508*, accessed 24 Nov 2009.

155 Vought Aircraft Corp. product brochure, "ASAT Missile," *http://www.voughtaircraft.com/heritage/products/html/asat.html,* accessed 3 Sept 2009.

156 Peter L. Hays, *United States Military Space: Into the Twenty-First Century,* INSS

Through the 1960s and 1970s, as satellites became more common and more essential to the world's infrastructure of commerce, communication, and navigation, the earlier urgency of an antisatellite capability diminished. It seemed that world leaders came around to the feeling expressed by Harold Brown, who as Director of Defense Research and Engineering had expressed his antipathy to antisatellites in 1964:

> It is more advantageous to the United States to have our satellites and the Soviet satellites up there, than it is to have neither ours nor theirs.[157]

NOTS did not develop a successful antisatellite system. In a variety of programs and through a maze of different sponsors and funding sources, many of the complex technical problems inherent in satellite and antisatellite systems had been solved, but China Lake does not appear to have ever actually tested an ASAT against an orbiting satellite.

China Lake was involved in other projects on the 1960s that supported the nation's expansion into space. Although none was as dramatic as the satellite and anti-satellite work, these projects did showcase a broad range of NOTS capabilities.

Contributions to Space Exploration

A watershed event in American space exploration occurred on 25 May 1961, when President Kennedy, in his second State of the Union address, said:

> I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth.[158]

By the end of the year, NASA had expanded its man-in-space efforts from the Mercury program of one-man capsules to the development of a two-man program, dubbed Gemini. Gemini was an intermediate step between Mercury and the three-man Apollo missions, which would realize the commitment that

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Occasional Paper 42, USAF Institute for National Security Studies, Maxwell Air Force Base, AL, 2002, 93.

157 Harold Brown interview, May 6, 1964, 23, John F. Kennedy Library Oral History Program. Brown, who later served as Secretary of Defense under Jimmy Carter, also noted the inherent flaw in the ground-launch approach to ASATS. "If the Soviets do put up a satellite that we for some reason think we have to knock down, or to kill, rather, and the kill, by the way, takes a nuclear explosion which is against the nuclear test ban treaty—we may have to wait up to a week or so before the satellite comes over the right place. It eventually will, but we may have to wait a week," 26.

158 John F. Kennedy Presidential Library and Museum, *http://www.jfklibrary.org/JFK/JFK-Legacy/NASA-Moon-Landing.aspx*, accessed 20 June 2013.

Kennedy had made for America.

Blowing up a rocket early in flight, as America had done so many times since 1957, was a major expense and embarrassment when the payload was scientific instrumentation. With a human payload, the potential cost was much greater. Project Mercury employed a launch escape system that consisted of rockets mounted on a tower atop the manned capsule that would pull the capsule up and away from a malfunctioning launch vehicle. The capsule would then descend by parachute. The system was awkward, and doubts were expressed as to the survivability of the astronaut if the system ever had to be used. Operation of the separation mechanism between the booster motor and Mercury capsule had been tested at SNORT in the summer of 1961, under the oversight of NOTS Project Engineer Bill Moore.[159]

Gemini was the only U.S. spacecraft until the Space Shuttle to employ a true ejection system for its astronauts. NASA selected NOTS to test the system, which used aircraft ejection seats built by Weber Aircraft Co. According to a 1963 *Rocketeer* article, "Nearly 300 aircraft pilots belong to an exclusive club of those who have safely ejected from a jet in a Weber ejection seat."[160]

Ejection would be possible only while the Gemini's Titan II rocket was on the launch pad or during the earliest stage of powered flight. This early launch phase, however, was considered most critical; memories of Vanguard rockets collapsing on the launch pad were still fresh in the public's mind. China Lake's program used the 150-foot launching tower at Randsburg Wash to simulate "on the pad" ejections and employed the SNORT facility to simulate ejections made after Gemini liftoff.

On-the-pad testing began in June 1963 when an anthropomorphic dummy was successfully ejected from atop the launch tower. More than 30 technicians, engineers, and company representative watched as an explosive shell ejected the seat with the dummy from the test bed. A rocket motor carried the seat a safe distance from the "launch vehicle," and another explosive charge deployed the parachute.

Among the crowd were Bob Vorwerk, project engineer; Jim Keosky, "seat" range engineer; and Oscar Perkins, ground range engineer. Also on hand was former China Lake Test Department employee Ken Hecht, the NASA representative for the recovery system; and Gordon Cress, Weber's project engineer.

"The idea," reported the *Rocketeer*, "is to shoot a man as far away from an

159 *Rocketeer*, 27 July 1962, 4.
160 *Rocketeer*, 21 June 1963, 1, 4.

exploding launch vehicle as is necessary and as fast as possible without harming him." Max Peterson, Weber's senior man at the tests, noted that "escape for astronauts becomes a rocketry problem in itself."[161]

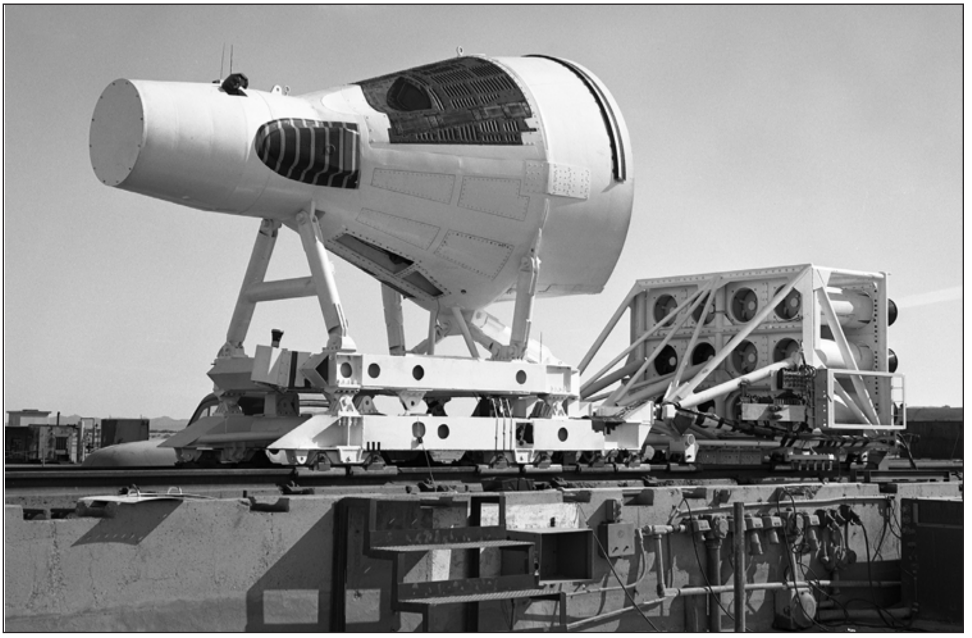
Single dummy tests at Randsburg Wash were followed by tests in which two dummies (Castor and Pollux) were ejected. One was a 15th-percentile dummy (taller and heavier than all but 15 percent of the population) and the other a 75th-percentile dummy. Each was fitted with accelerometers and gyros to obtain acceleration, roll, pitch, and yaw data. The ejection system for the initial tower tests was not enclosed in a Gemini capsule.

Developmental testing of the seats at SNORT had begun in July 1962. The 4.1-mile track, opened in 1953, was more than adequate to the task. It was capable of sustained runs with heavy carriage weights at velocities up to 3,700 feet per second—several times faster than the subsonic speeds required to simulate the dynamic environment that the Gemini capsule would encounter during the first moments after launch. The developmental tests at SNORT, using a mockup or "boilerplate" model of the Gemini capsule, were designed to "make sure all the 'bugs' are eliminated" before the actual seat qualification tests.[162]

Dual-seat testing on SNORT began in July 1963, under the direction of Project Engineer Mario Falbo of the Test Department's Supersonic Track Division, and continued through 1964. In November 1964 seven astronauts visited to Station to watch one of the tests: John Young, Ed White, Wally Schirra (a former NOTS Sidewinder project pilot), Tom Stafford, Gus Grissom, Frank Borman, and Jim McDivitt.[163]

The two final qualifying tests for the Gemini ejection system were conducted in February 1965, with the first Gemini launch scheduled for April. One of the February tests was held at SNORT under dynamic conditions (near-supersonic speed at ejection). In the other, witnessed by astronaut Lieutenant Commander Alan Bean, a Gemini boilerplate capsule with seats and dummies installed and hatches closed was tested at the top of a Randsburg Wash tower. The test simulated a launch abort and ejection from atop the Titan II launch vehicle on the launch pad at Cape Canaveral. At T-minus-zero, the capsule hatch was blown off, Castor and Pollux were successfully ejected and rocketed away from the tower, the parachutes opened, and the two dummies touched down 850 feet from the launch tower in "perfect shape."[164]

161 Ibid., 4.
162 *Rocketeer*, 7 Dec 1962, 1.
163 *Rocketeer*, 13 Nov 1964, 5.
164 *Rocketeer*, 19 Feb 1965, 4.



Gemini capsule at SNORT (above) and atop Randsburg Wash Tower (at right).

Ten manned Gemini flights were conducted in 1965 and 1966. All of the Titan II launches with manned capsules were successful (although at least two preliminary unmanned test launches failed), and the ejection system was never used.[165]

In 1964 NASA called into the nation's service a tracking device conceived at China Lake 14 years earlier. When the Test Department's Jack Clemente began development of the Tracking Instrument Mount (TIM) in 1950, he envisioned it as a successor to Askania and Mk-45 tracking mounts, which he felt would not be adequate for tracking high-performance aircraft.

After Clemente left China Lake, Lyman Van Buskirk continued the work on TIM. When NASA learned about TIM at an Optical Systems Working Group meeting in early 1963, it funded the project and asked for an early 1964 delivery. TIM was to be used in Project FIRE (Flight Investigation Reentry Environment) to study the effects of re-entry heating on materials used in spacecraft.[166]

With only 10 months of lead time, Art Bittel (head of the Opto-Mechanical Branch) was put in charge. Phil Roper was assigned as project engineer and Van Buskirk was the technical advisor. The task was completed on time and the 39,000-pound 105-inch-diameter mount (carrying a 36-inch telespectrograph) was airlifted via C-124 to Ascension Island in the South Atlantic, where it tracked the re-entry of "an Apollo-shaped vehicle."

Said Bittel of this typical NOTS team effort:

> I don't know we could have made it without the cooperation of the Engineering Department's Machine Shop personnel, NOTS Pasadena Supply Department, I. [Irving] R. Stone [contract specialist], and the Public Works riggers.[167]

Another Station contribution to the nation's space mastery came later in the Apollo era. NASA researchers had devised the Active Seismic Experiment to measure lunar seismology by using a mortar to launch grenades that would explode on the moon's surface. Geophones would record the resultant seismic shocks and the data would be used to profile the sublunar geological structure. Contamination of the moon's surface with biological material was a concern to NASA scientists who contacted China Lake about the possibility of developing a sterile propellant to use in the mortar. Ray Miller, former head of the Propulsion

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165 Barton C. Hacker and James M. Grimwood, *On the Shoulders of Titans: A History of Project Gemini,* NASA Special Publication 4203, NASA History Series, 1977, *http://www.hq.nasa.gov/office/pao/History/SP-4203/ch7-2.htm,* accessed 4 Jan 2010.
166 *Rocketeer*, 24 Jan 1964, 1, 4, 8.
167 Ibid., 8.

Systems Division, Propulsion Development Department, recalled:

> They needed a propellant that was sterilizable. And of course, that takes extremely high temperatures to sterilize anything. . . . So Ron Vetter and I worked up a formulation, and it used an oxidizer that was very stable thermally so that it could be sterilized. And those went to the moon.

The mortars were used during the Apollo 16 mission in 1972, and the experiment was officially declared a success.[168]

Engineering technician Jud Eldridge worked with Vetter and Miller in developing the formulation, PL 6670, which would also be used in the parachute ejection mortar of the Viking Mars Lander and in the F-14A aircraft's emergency escape system. "The propellant's stability in extreme environments makes it useful for a wide variety of applications," Vetter said.[169]

Three other NOTS ventures into space are worth noting. In December 1962 NOTS astronomer Bill White accompanied Air Force Captain (later Colonel) Joseph W. Kittinger II, on an 18½-hour balloon flight over New Mexico. In an observation gondola named Stargazer, the pair reached an altitude of 82,000 feet, where they photographed stars and performed various other scientific experiments. The two wore space suits to protect them against outside temperatures of -82°F and to monitor their physiological state.

"The doctors told me that my reactions, as measured on Earth, were quite normal throughout our trip," White told the *Rocketeer*. "But in my own mind, I know how excited I was."[170]

The following summer, in August 1963, a NOTS-designed ozonesonde ascended to 145,000 feet (more than 27 miles) above North Dakota on a balloon. The device measured the vertical distribution of ozone as it passed through the ozonosphere (which extends from about 6 to 30 miles above the earth) and telemetered the results back to a ground crew for further processing in the NOTS IBM 7090 computer. The results were compared with a chemical ozonesonde, produced by Parametrics, Inc., which was also on board. (At 70,000 feet on the ascent, well above the ozonosphere, the chemical ozonesonde failed.)[171]

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168 S-262, Ray Miller interview, 4 Sept 2008, 13; Sec. 3.2.10, "Active Seismic Experiment," *Apollo Program Summary Report*, JCS-09423, April 1975; "Apollo 16 Final Lunar Surface Procedures," March 16, 1972, *http://ares.jsc.nasa.gov/HumanExplore/Exploration/EXLibrary/docs/ApolloCat/Part1/ASE.htm* accessed 31 Dec 2009. Elmer Rhyn also assisted in the development.
169 *Rocketeer*, 11 Feb 1972, 3.
170 *Rocketeer*, 25 Jan 1963, 1, 3.
171 *NOTS Tech History 1962*, 2–26.

The project, led by Arlin J. Krueger of the Earth and Planetary Sciences Division and supported by the Office of Naval Research, was part of China Lake's development of a new rocket-borne ozonesonde (ROCOZ) for use with the Arcas sounding rocket.[172]

Several other members of the division (headed by Dr. Pierre Saint-Amand) assisted Krueger, as did James Lee and Larry Pace of the Weapons Development Department and Dr. William R. McBride of the Research Department's Chemistry Division. In 1969 Krueger would leave China Lake for NASA, which later awarded him its Exceptional Scientific Achievement Medal and Exceptional Service Medal.

Finally, a China Lake space project that did not reach such a rarified altitude as White's Stargazer or Krueger's ozonesonde offers insight into the enthusiasm that China Lake scientists and engineers brought to their chosen field of rocket science.

In 1960 Marshall Kriesel was a 20-year-old sophomore at the University of Minnesota, majoring in aeronautical engineering. In his spare time he worked on a liquid-fueled rocket that had begun as a high-school science project 5 years earlier. He contacted local naval officials, was put in touch with NOTS, and soon was on his way to China Lake with a rocket named Labor of Love on which he'd spent $3,500 of his summer job earnings.

Another institution might have smiled at the young man and presented him with an Official Rocket Scientist pin, but not China Lake. The NOTS scientists and engineers took the young man and his 11-foot-long, 5-inch-diameter missile seriously, with a reported 70 people helping with launch preparations.[173]

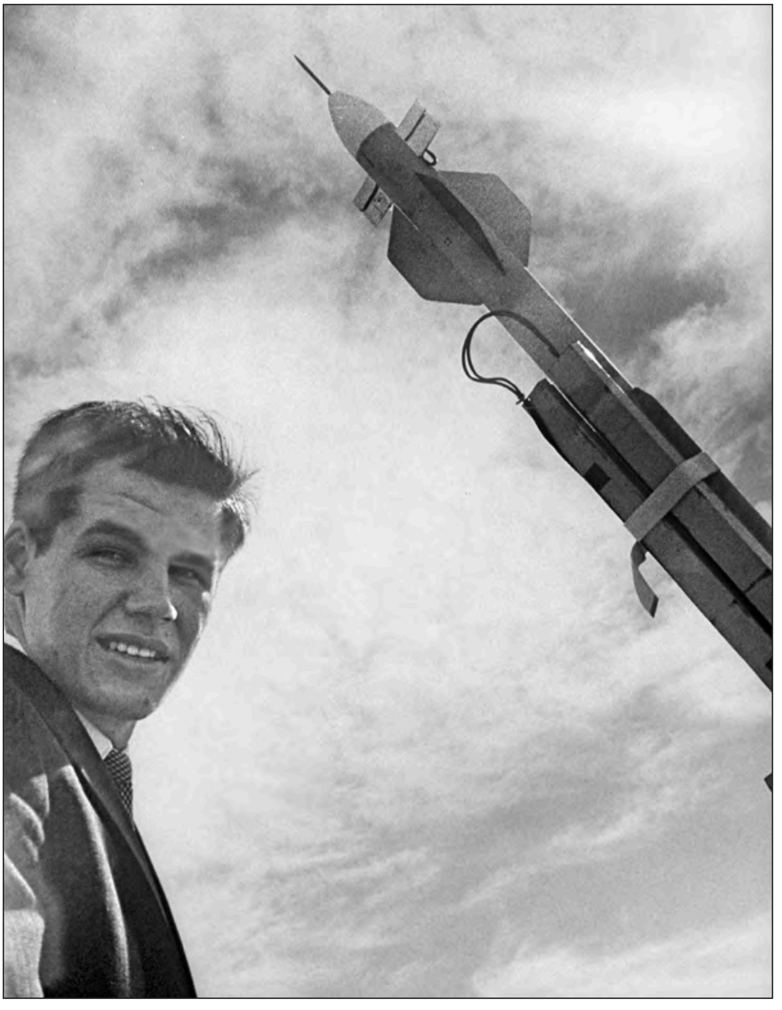
The *Rocketeer* reported:

> Kriesel conceived the rocket according to his own design which included a 1,000 lb. thrust rocket engine, using highly volatile red fuming nitric acid and aniline as the propellant, guidance and control systems, telemetry, and a destruction mechanism. It passed the rigid scrutiny of Navy scientists, who shattered precedent by permitting the firing, and by scientists at the Minneapolis-Honeywell Regulator Co., who assisted Kriesel throughout his project.[174]

172 *Rocketeer*, 20 Sept 1963, 1, 4.

173 Gene Handsaker, "Spends Fourth of Life on Missile; It Works! Navy Helps with Test," Associated Press, dateline China Lake, Benton Harbor, Michigan *News-Palladium*, 22 Dec 1960, Sec. 2, 9.

174 *Rocketeer*, 30 Sept 1960, 1.



Marshall Kriesel and his rocket at China Lake. Grey Villet photo courtesy of *LIFE* magazine.

The first launch, in September 1960, failed when a "10-cent item" (a pressurization valve) malfunctioned. Among the disappointed attendees were national news media including ABC, CBS, AP, UPI, the *Los Angeles Times,* and many newspapers and magazines. Kriesel returned to China Lake on his Christmas vacation that year and tried again.

The story had attracted such wide national attention that this time *LIFE* magazine sent famed photojournalist Grey Villet to capture the event in a two-page three-photo story.[175]

The rocket was designed to reach an altitude of about 1¼ miles but ascended only about 1,000 feet and traveled about 300 yards downrange in a 7-second

175 "A Rising Young Rocketeer," *LIFE,* 15 Sept 1961, 19, 21.

flight. According to China Lake Project Engineer Dick Harris, a misaligned control fin probably caused a right-down maneuver, thus terminating the flight prematurely. Nevertheless, the *Rocketeer* reported, "The exuberant Kriesel considered the launch a success."[176]

After the flight, but before the 10 days of post-flight data reduction and high-speed film analysis that would fill his Christmas-vacation time at China Lake, Kriesel said "I'm the happiest boy on earth."

He worked the following year as a China Lake summer hire and would go on to become a prolific inventor with more than 200 patents. In December 1960, when he was interviewed for the AP story, Kriesel said, "I'm proud to be an American, proud to demonstrate to other kids that this can happen to them, too; that our government will cooperate."[177]

Asked 39 years later if he still felt that way, Kriesel responded, "I only wish that the kids of today—and especially the ones who are interested in science—could have the same opportunity that I had."[178]

Summing Up

Considerable mystery—and confusion—still surrounds the true purpose of China Lake's many ventures into space, if indeed there was a single purpose. Part of the discontinuity is attributable to the erratic starting, stopping, and redirecting of programs and projects. The helter-skelter approach reflects the coming and goings of many different sponsors, each bringing its own space agenda—as well as its much-needed funds.

McLean and his managers could smooth these perturbations to some degree by reprogramming project funds within the organization and judiciously distributing the limited in-house funding sources, but that process, coupled with the hectic pace of events during the first years of the space race, left an incomplete and convoluted paper trail as well as conflicting recollections from the participants.

NOTS management, in an August 1961 report to the Secretary of Defense, lamented the variety of funding sources and the procedures necessary to finance any given China Lake project. To illustrate the issue, the report's authors selected "NOTS Caleb" and constructed a table showing that between 1958 and 1961 funding for Caleb came from Station E&F, the BuOrd Research Division, the

176 *Rocketeer*, 6 Jan 1961, 1. Kriesel recalled the altitude as "about 1000 feet." Other reports ranged from 300 feet (*Rocketeer*) to 2,000 feet (*News-Palladium*).

177 Handsaker, "Spends Fourth of Life on Missile," Sec. 2, 9.

178 Marshall Kriesel, email to the author, 7 Feb 2010.

BuOrd Material Division, ARPA, NASA, the Armed Forces Special Weapons Projects Agency, the Bureau of Naval Weapons RDT&E Group, Pacific Missile Range, and the Naval Research Laboratory. And that was in 1961, at the very start of the SIP project and before HIHOE.[179]

That patchwork of funding sources was both a curse and a blessing. On one hand, Station management had some extraordinary juggling to keep people working productively on real projects and to maintain stability and direction in the efforts of the technical workforce. Also needed were intense marketing efforts and a near-continuous presence of China Lakers "back East" dealing with sponsors.

On the other hand, as Don Moore pointed out, the large number of potential sponsors with money let the Station make "proposals any place we saw some money that would let us learn about one of those things." And as Nicolaides noted, the plethora of programs created confusion "if anyone outside a few Navy personnel would attempt to track any of the efforts."

The question remains as to whether there was an overall purpose in the collective efforts of the base, and, if so, what it was. Moore saw the various manifestations of China Lake's air-launched satellite-delivery vehicles—NOTSNIK, Caleb, SIP, HIHOE, Guided Flight Vehicle—as steps toward an antisatellite capability.

A broader interpretation is that China Lake was pursuing and refining the larger vision of an inexpensive, reliable, flexible method for launching earth satellites. In McLean's memorandum of the October 1957 meeting that started the Station's space efforts, he wrote:

> The question of what would be accomplished by the development of an inexpensive reconnaissance satellite was discussed with the following items being listed: (1) weather, (2) radio survey and location, (3) ship location, (4) damage assessment, (5) target location (6) political influence, (7) research data on the upper atmosphere, and (8) *demonstrate that a low cost satellite is feasible and thus exert pressures for reduction in government costs.*[180]

Demonstration of a relatively inexpensive means to put a satellite in orbit is a common thread through many of NOTS' space programs. McLean believed that if a device could be made to accomplish its intended purpose well and reliably and it could be produced cheaply, it would be widely used. This approach had worked with Sidewinder, and there was no reason to believe it would not also work on systems designed for outer space or for the ocean deeps.

179 AdPub 107, Encl. (1), "In Reply to Secretary McNamara's Task No. 97," 37.
180 Memo, Doc. No. 01-45, "Meeting in Dr. McLean's Office," 2. Emphasis added.

In a 1969 interview with *Astronautics & Aeronautics* McLean articulated this philosophy in the context of undersea vehicles:

> I think it's very important to be working toward the creation of a vehicle as reliable and as economical as the private automobile or airplane. . . The first such units will probably sell for $100,000. As they get produced in larger quantities, I would hope and expect the price to drop by an order of magnitude or more.[181]

McLean also believed that the initial design and experimentation of radically new systems should be done with only minimal oversight from those who didn't understand the technologies involved or the risks inherent in new development:

> Any new development brings a certain degree of risk, and it has to be individual risk. If the FAA regulations had been in effect at the time of the Wright Brothers' first flight, we never would have gotten any aviation going.

He was keenly aware that the less understanding there was in Washington about the details of what China Lake was doing, the less likelihood that the Station would be told to stop doing it, or to do it differently.[182]

NOTS' efforts to take command of space were a manifestation of the Station's holistic approach to warfare: the Fleet must be capable of carrying the fight to the enemy anywhere, from the sea bottoms to space, and China Lake must be there to support them with systems that were cheap, effective, simple, and dependable. McLean's vision of the future of naval warfare was of far broader reach than that of most of his contemporaries, civilian and military.

Space programs were never the largest part of the Station's technical effort. The *Command History* for 1961 reported that "support of astronautics and space programs continued to the extent that 10 percent of the Station's technical effort was expended in this area."Space programs did, however, support a broad range of scientific and military programs and developed essential new technologies for outer space exploitation, most notably the nutation control and platform precessing techniques and the variable thrust controller for liquid-fueled rockets.[183]

The space programs also reveal two recurring themes in China Lake weapon- and system-development philosophy. One is the reliance on technical cross-fertilization that was encouraged by co-locating distinct and unrelated science and engineering disciplines. In any given NOTS project, a team could

181 "A Bedrock View of Ocean Engineering," Dr. William B. McLean interview, *Astronautics & Aeronautics*, April 1969, 33.

182 Ibid., 35.

183 *NOTS Command History* 1961, 1.

be assembled at the drop of a slide-rule that would include experts in electronics, chemistry, propulsion, ballistics, sensors, material properties, or whatever other disciplines might be required, as well as experienced military personnel.

While leaders like McLean, Wilcox, and Wilson ran interference, these in-house subject-matter experts were free to address the technical issues and test their approaches in China Lake's laboratories, machine shops, and specialized ranges and test facilities. Ideas formulated in solitude could be spun out in noisy argument at the Officers' Club.

While occasional personality mismatches occurred among the large egos of the China Lake workforce, teams were generally close knit. The fact that team members lived cheek-by-jowl far from the diversions of cities, knew one another socially as well as professionally, and could (and did) go back to the office or laboratory or hangar at virtually any hour of any day, all helped to cement team bonds and provide a disincentive for giving anything less than a 100-percent effort.

A second theme is the emphasis on adapting earlier developments to new technological challenges; for example, the evolution of the NOTS EV-1 launch vehicle to carry payloads of various sizes and weights, the adaptation of a Sidewinder seeker to the ballistic missile plume-characterization projects, the application of nuclear weapon air-delivery techniques (anytime, anywhere) to satellite air launches, the refinement of a Sidewinder-based nutation device for satellite stability, the application of IR scanning technology to earth and cloud mapping, the use of variable-thrust control techniques in the soft-landing vehicle and the hovering rocket system, and the adaptation of NOTS-developed sled-track-booster rockets for the SIP ground-launch variant.

Don't reinvent the wheel, but rather invent new uses for wheels. Or borrow the spokes and go start another project.

3

Back to Basics

The marriage of imagination and science with the hard facts of life . . . .

— Secretary of the Navy John B. Connally Jr., 1961,
speaking of the NOTS weapons-development process[1]

During the 1950s, two roads diverged in the course of U.S. military preparedness. One road followed nuclear weaponry. The other, less traveled in those days, pointed toward conventional weaponry. China Lake, not surprisingly, took both.

Military planners draw a distinction between "strategic" operations (those that have a long-range effect on the enemy and influence his policy) and "tactical" operations (those undertaken to accomplish a specific military goal during an active conflict). With some few exceptions, nuclear weapons are considered strategic tools, while tactical weapons employ non-nuclear conventional-explosive warheads.

Under President Eisenhower, the U.S. defense posture emphasized nuclear weapons. The administration embraced a strategic nuclear policy called the New Look, which was based on the doctrine of massive retaliation. Any attack on the U.S. or its allies would be met by a massive and disproportionate response. Everyone was aware that if the initial attack was by a nuclear power, then an all-out nuclear war would quickly ensue. Eisenhower was convinced that by threatening massive retaliation (often described by critics as "suicide or surrender") he could meet his defense obligations while sustaining the nation's long-term economic health. He thought that the New Look would avoid the crushing financial burden of protracted conventional warfare, such as that imposed on the nation by the Korean War. The administration's policy was publicly proclaimed in a speech by Secretary of State John Foster Dulles in 1954 in which he referred to the "deterrent of massive retaliatory power."[2]

1 *Rocketeer*, 20 May 1961, A-3.

2 "Text of Dulles' Statement on Foreign Policy of Eisenhower Administration," *New York Times*, 13 Jan 1954. Dulles referred to the policy as "getting maximum protection at a

Charles E. Wilson, who served as Secretary of Defense from 1953 to 1957, said that the United States "can't afford to fight limited wars. We can only afford to fight a big war, and if there is one, that is the kind it will be."[3]

The Air Force was content with the New Look scenario. That junior service—not created until 1947—had embraced nuclear technology more closely than either the Army or the Navy. Emphasis on strategic nuclear armaments meant a bigger Air Force share of the defense pie.

Even those who opposed the idea of all-out nuclear war as the only alternative to peace were not necessarily thinking in terms of conventional weaponry. In 1958, when General James Gavin announced his retirement from the Army, where he had been Chief of Research and Development, he contended that the Army had been hurt by the heavy concentration of investment in the Air Force. Gavin's version of "limited war," however, involved tactical atomic weapons. "I had become convinced that nuclear weapons had a tremendous field for tactical application, in fact, in the long run, probably the most promising field of all." As early as 1949 he advocated changing the then-current policy of allocating all fissionable material to strategic use. The issue of nuclear versus conventional forces was as much a battle for service dominance as it was an argument over the efficacy of particular types of weapons.[4]

Nuclear Programs

NOTS management saw opportunity in the development of conventional weapons for limited warfare—opportunity to provide the Navy with the kind of weapons needed to defend the nation in a rapidly changing world as well as opportunity to bring more work to the desert. This perception did not, however, mean that the Station was about to give up its nuclear work. The NOTS tent was large enough to hold many programs, and nuclear weapons were firmly entrenched in the organization.

In 1945, the Station had been a key player in the Manhattan Project, which produced the world's first nuclear weapons. Under the code name Project Camel, China Lake developed, cast, machined, and tested the high-explosive lens blocks that were used to bring the nuclear material together with sufficient force to achieve critical mass: the sine qua non of weaponizing nuclear energy. Case designs for nuclear weapons were also developed at the

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bearable cost."

3 Official biography of Charles E. Wilson, *http://www.defense.gov/specials/secdef_histories/bios/wilson.htm*, accessed 5 Jan 2010.

4 James Gavin, *War and Peace in the Space Age*, 1958, 114.

VX-5 A4D-2 Skyhawk in flight with a Mk-7 nuclear shape (T-63) on the centerline, circa 1959.

Station and nuclear bomb shapes were tested in drops from Army B-29s on the Station's ranges. After the two nuclear bombs, Little Boy and Fat Man, ended the war with Japan, China Lake remained active in the nuclear weaponry field. Frank Knemeyer headed a nuclear-weapon development project known as Project Elsie (L. C. for "light case," also called Little Child, harkening back to Little Boy). Elsie was based on the TX-8 nuclear weapon, which was further developed into the TX-11 and released to the Fleet as the Mk 91 nuclear penetrator bomb.

Beginning in 1952, NOTS developed the rocket-propelled nuclear Bombardment Aircraft Rocket (BOAR) and a release computer for weapon delivery. Stan Marcus was the project engineer. VX-5 developed the loft-bombing technique that would ensure launch aircraft survivability when the nuclear device detonated. BOAR was deployed on aircraft carriers in 1956 as an air-to-surface standoff weapon.[5]

During the late 1950s, NOTS Special Weapons Division developed kits to adopt the Regulus I and II missiles to a nuclear warhead. The division also worked on warhead designs for Diamondback (a nuclear warhead version of Sidewinder) and Thunderbird (a long-range nuclear-armed guided missile).

5 *Major Accomplishments*, 59. BOAR is translated by some as Bureau of Ordnance Atomic Rocket.

The division was renamed the Nuclear Weapons Evaluation Division in 1957 and relocated to Kirtland Air Force Base, New Mexico, where the following year it was separated from NOTS and reassigned to the Naval Air Special Weapons Facility.

NASWF later became the Naval Weapons Evaluation Facility (NWEF), affectionately known to its Navy and civilian workforce as "the Rio Grande Navy." In 1991 NWEF was reassigned to China Lake (under the newly organized Naval Air Warfare Center Weapons Division), only to be closed in 1993 pursuant to a Base Realignment and Closure (BRAC) action.

With the obsession on "all things nuclear" that prevailed during the 1950s, the Station also developed Big Stoop, a surface-launched nuclear weapon that stood 51 feet tall (it was tested to ranges of 20 miles). Later NOTS demonstrated the feasibility of a submarine-launched shore-bombardment nuclear weapon called Marlin.

VX-5 was devoted almost exclusively to nuclear weaponry during the postwar years. "In 1958 as it had been for perhaps 10 years, all the flying in VX-5 was connected with nuclear weapons delivery whether it was low-level navigation, aerial refueling, mission profiles, loft bombing, or dive bombing. When I joined VX-5 in March 1958, we did every kind of nuclear weapons delivery that there was," said Marine Captain William H. Fitch who came to VX-5 straight out of Test Pilot School at Patuxent River.[6]

Polaris

The most significant contribution China Lake made to the nation's nuclear program was in the development of the Polaris fleet ballistic missile system. NOTS' involvement began with the earliest theoretical studies and included participation in design development (particularly the underwater launching system), propellant development and testing, full-scale motor testing, and development of motor radiological inspection techniques. Polaris would eventually become the third leg of a nuclear triad—bombers, intercontinental ballistic missiles, and submarine-launched ballistic missiles. Collectively, these would ensure survivability of a U.S. counterstrike capability after an enemy first strike: the foundation of nuclear deterrence.

Beginning about 1955 there was growing recognition in the defense establishment that truly sustainable nuclear dominance for the U.S. would require a submarine-launched nuclear weapon. The first weapon proposed by

6 Lt. Gen. William Fitch interview, Marine Corps Oral History Program, McLean, VA, 2006, 129.

the National Security Council was the Jupiter missile, far too big to fit in a Navy submarine. A new submarine large enough to carry Jupiter would need to be on the order of 8,000 tons displacement, more than twice that of *Nautilus*, the nation's first nuclear submarine, launched in 1954. Plus Jupiter was liquid fueled, anathema to the Navy because of the potential for disaster in the storage and handling of the fuel components at sea.

Back to the drawing board went the planners; the next iteration of a sub-launched nuke was a solid fueled missile, Jupiter S, which would weigh in at a whopping 160,000 pounds. An even larger submarine would be needed to accommodate that system and the submarine would have to come to the surface to fire its missiles—a disadvantage if the launching submarine was to avoid detection.[7]

In a study begun in 1956 called Project Mercury, China Lake's Weapons Planning Group (Code 12) showed that by taking advantage of technologies then in the pipeline, a much smaller, lighter missile could be developed. Frank Knemeyer, Don Witcher, Charles Arney, Peter Kim, and M. Duncan Insley proposed the concept of a far lighter missile, reducing the warhead, guidance unit, and controls in size and integrating the warhead case with a lightweight beryllium heat shield for a substantial weight savings. They backed up the recommendation with a flight test of a proposed reentry configuration on the NOTS Ballistic Firing Range. "As a result, we came up with the Polaris missile to be 30,000 pounds," said Knemeyer. "In reality it ended up being 33,000 pounds, but that breathed life into the whole Fleet missile business."[8]

Two members of Code 12, Dr. Glover S. "Dud" Colladay and David Bloom, conducted a study that explored targeting strategies and the amount of damage that would need to be inflicted by U.S. ballistic missiles to preclude a counterstrike from the enemy. They came up with the "Rule of Three": maximum disruption would be achieved by killing one third and injuring one third of the people in the target cities. Further, government control could be effectively destroyed by using a 1-megaton warhead on each of 25 Soviet cities. These numbers were considerably smaller than those recommended by earlier studies.[9]

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7 Baar and Howard, *Polaris!* , Chap. 4–5.

8 S-117, Knemeyer interview, 27. The results of Project Mercury were published in February 1957. During this period NOTS also developed competing ballistic-missile concepts such as North Star, a liquid-fueled submarine-launched boost-glide vehicle. Except for the launch mode, North Star was similar to the Air Force's X-20 Dyna-Soar, which began development in 1957 and was cancelled 6 years and $600+ million later.

9 In a subsequent study, Knemeyer, Kim, and Insley proposed a Polaris missile follow-on with vastly extended range that would reduce detection threats as well as submarine-transit

Dr. Frank E. Bothwell and Witcher participated in Project Nobska, held at Woods Hole, Massachusetts, in summer 1956. This study, ordered by CNO Arleigh Burke and conducted by the National Academy of Sciences' Committee on Undersea Warfare, considered the effect of nuclear submarines on national security. The "Panel on the Strategic Use of the Undersea" recommended that a small solid-fueled ballistic missile be developed (after nuclear physicist Edward Teller assured the participants that a nuclear warhead small enough to be launched from a submarine was indeed possible). According to nuclear historian Chuck Hansen, "Dr. Teller asked a simple and vital question: 'Why are you designing a 1965 weapon system with 1958 technology?'" The concept of inserting projected technology into an ongoing development program was revolutionary.[10]

In October 1956 CNO Burke endorsed the Nobska group's final report, and in December DOD approved the plan to shift from the Army's Jupiter to the Navy's solid-propellant concept, Polaris. The Navy set up the Special Projects Office (SPO) under Rear Admiral William F. "Red" Raborn, Jr., specifically to run the Polaris program. Raborn's office had Brickbat 01 status, the Navy's highest procurement priority rating, and unlimited funding to make Polaris a reality. SPO accepted the NOTS studies, which were fundamental to the final design of the Polaris submarine-based missile system and to the Navy's nuclear strategy.

The Army and the Air Force had come narrowly close to edging the Navy out of the country's strategic force structure, but Polaris made the sea service an essential part of that structure. W. Stuart Symington, a former Secretary of the Air Force and a senator from Missouri for 23 years, said years later that "what saved the Navy and much of its combat mission was the Polaris submarine."[11]

In 1961 Bothwell, head of Code 12 from 1954 to 1959, received the Station's highest honor, the L. T. E. Thompson Award for

> . . . his vital contribution to the currently accepted concepts of a submarine-launched ballistic missile system. His work as head of the Weapons Planning Group at NOTS was eminently instrumental in emphasizing the Polaris concept, including a great amount of detail on warhead and weapons requirements for strategic targeting.[12]

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times to in-range launch sites. That missile was called Atlantis (a missile of Atlas range in Polaris size). Frank E. Bothwell, *The Origin of Atlantis*, NOTS Weapons Planning Group, 13 Jan 1958.

10 Chuck Hansen, *U.S. Nuclear Weapons, The Secret History*, Aerofax, Inc., Arlington, TX, 1988, 203.

11 W. Stuart Symington interview, U.S. Air Force Historical Research Agency, Maxwell Air Force Base, AL, 2 May 1978, 199.

12 *NOTS Command History* 1961, 21.

In 1957 SPO assigned NOTS responsibility for the Polaris underwater-launch system. The Station investigated both a capsule-launch and a "bare missile" system.[13]

To develop launch techniques, the NOTS engineers had to use more than slide rules and drafting tables. James A. Bowen was design engineer for the system that would separate the missile from the underwater launch capsule. He recalled:

> We built full-scale models and devised all different kinds of techniques for separation. We used the Randsburg Wash facility, the big 300-foot towers out there, to actually demonstrate the opening of the capsule with special rocket motors that were fixed to the nose section. I had a system built in Area R where I had a 100-foot by 100-foot fish net built up. When one-fifth-scale devices were fired, when they'd open, the components would not be destroyed.[14]

Many tests during the capsule-launch concept development phase had to be conducted under water. Navy divers were available at San Clemente Island, but they were not trained for inspecting and verifying the underwater test arrangements. China Lake's Explosive Ordnance Disposal (EOD) officer set up a diver training program for NOTS engineers: 2 weeks at the Station pool, and another 2 weeks in open-ocean training at San Clemente Island. Bowen and about another dozen China Lake engineers were trained through the program. "Very rugged, and very interesting," said Bowen.

Underwater work was new to most China Lake engineers. Bowen explained that:

> As time went on, there was a cadre of personnel who became more involved with the underwater world, a world to itself. In other words, involved with keeping water out, preventing leaks, preventing rust, and things that were much more severe—that were different environmentally than the things that we normally were working on.[15]

This experience would prove invaluable in later years as NOTS became more involved with underwater systems such as *Moray*, *Deep Jeep*, and Rock-Site.

McLean preferred the capsule launch approach, on which development continued through 1957 and 1958. The obvious advantage was that the depth

13 NOTS had already investigated underwater missile launching. Capt. Levering Smith, the SPO technical director, was fully aware of NOTS' technical capabilities, having served at NOTS from 1947 to 1954.

14 S-175, Bowen interview, 15. "You don't buy fishnets ready made," said Bowen. "You have fishnets made to order. So the Supply Department had the job of having a fishnet maker make it."

15 Ibid, 16.

of launch could be vastly increased beyond the maximum sustainable by a "bare missile." NOTS' capsule launch program included full-scale buoyant launching tests at Morris Dam and culminated in a successful demonstration of the capsule and a Polaris test vehicle firing at the San Francisco Naval Shipyard's Peashooter test facility.[16]

Positive results of the capsule launch approach notwithstanding, Lockheed Missile Systems Division and Westinghouse Electric Corp., the prime contractors, preferred the bare-missile approach. According to Bowen, it was believed that opting for the bare-missile approach would shorten the time required to make Polaris operational. SPO Technical Director Captain Levering Smith also opposed the capsule system because "I wanted to have not only the ability to launch surfaced at sea but also surfaced in port or in water too shallow to submerge."[17]

One serious accident marred the capsule-launch program. An assembled capsule was attached to the side of a work barge at San Clemente Island when *USS Butternut* (AN-9, a tow ship assigned to NOTS) approached. The ship had its radars operating and the radio frequency (RF) energy caused the rocket motor inside the capsule to fire, nearly swamping the barge and badly burning two workers. As Bowen recalled:

> It turns out that prior to that time there had been a number of rocket motor firings, accidental firings onboard ship. As I understand it, it was always attributed to sailor error. No one knew about the radar problem at that time but as a result of this and the investigations on this accident, we started the first RadHaz [Radiation Frequency Hazards] program, which became a very important thing for the Navy.[18]

Several options were available for bare missile launch. "One choice would be to fire rocket motors in the submarine to project it out. Well, that leads to all kinds of consternation," said Bowen. So the Station's Polaris launch team conducted "research and development on compressed air techniques and gas generator techniques to create a motive force of firing through the water and into the air at sufficient velocity so you can then light off the rocket motor."[19]

Aside from early model tests in the swimming pool at China Lake's Naval Air Facility, most of the testing took place at San Clemente Island, beginning

16 *Major Accomplishments*, 67.

17 S-177, Levering Smith interview, 15 June 1989, 41.

18 S-304, Jim Bowen interview, 23 Feb and 2 March 2010, 7. NOTS' Hazards of Electromagnetic Radiation to Ordnance (HERO) Program was merged with the Navy's RadHaz Program in 1958, and the Station was assigned responsibility for solving radiation and ordnance problems for several major weapon systems, including Zuni and Sidewinder.

19 S-175, Bowen interview, 14.

late in 1957. The test program, dubbed Operation Pop-Up, was based at a launch facility on the island. Construction of the facility and conduct of the test program was carried out by NOTS' Pasadena Annex, under the direction of Douglas J. "Doug" Wilcox, head of the Underwater Ordnance Department, and DeVirl A. "Bud" Kunz, Polaris project manager for NOTS. Sixteen successful launches were made at the new facility in 1958.[20]

Ocean testing the Polaris launch system posed unique challenges. There were no precedents for such specialized pieces of test equipment as the Submerged Tactical Launcher Facility (Pop-Up Facility). In developing the facility, which was located at Wilson Cove on San Clemente Island, NOTS engineers fired hundreds of redwood logs and then steel cylinders filled with concrete before actual dummy Polaris missiles were attempted.[21]

By April 1960 the first pop-up tests using a Lockheed-designed Launch and Training Vehicle (LTV) nicknamed Dolphin were under way at San Clemente Island.[22]

In August 1959 the Pasadena Annex had completed construction of the Variable Atmosphere Tank (VAT) for characterizing cavitation (partial vacuums formed in a liquid by the passage of a solid body) of Polaris models. The highly instrumented 41-foot-tall pressure tank was enclosed in a light-tight room and used ultraviolet radiation and continuous filtration to eliminate algae in the water. Engineers could control atmospheric pressure and launching pressure. Crossflow was simulated by lateral motion of the launch tube, and the missile models were caught by a fallback net. By summer 1963 VAT had logged more than 800 launches, many in support of the Polaris development program.[23]

NOTS Pasadena personnel proved ready for every new challenge the program brought, and Operation Pop-Up maintained an already accelerated schedule. Ingenuity was the order of the day as SPO continually presented new test requirements. For example, to simulate the heavy seas that a Polaris submarine would face in the operational environment, Navy heavy cruisers would run close in-shore at top speed, generating 8-foot waves at the facility.[24]

The most novel piece of test equipment used in Operation Pop-Up was the Fishhook barge, which became operational in April 1959. Like so many systems that bore the NOTS touch, Fishhook was elegant in its simplicity. Its

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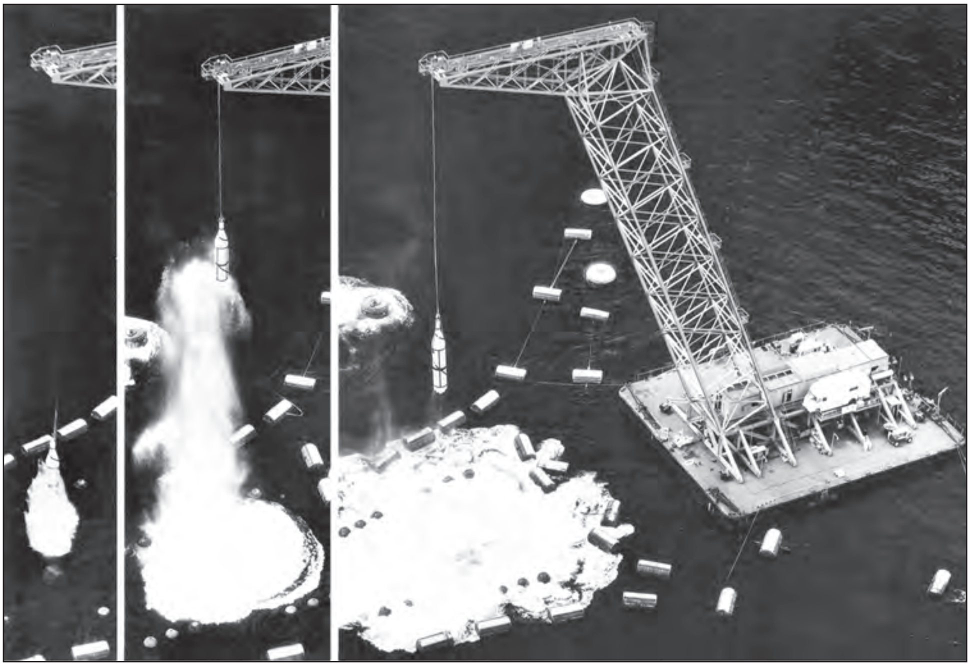
20 *Technical Program Review 1958*, 110 ff.

21 NOSC TD 1940, *Fifty Years of Research and Development on Point Loma 1940–1990*, Naval Ocean Systems Center, San Diego, Sept 1990, 54.

22 *Rocketeer*, 1 April 1960, 1.

23 *NOTS Command History* 1959, 10; *Rocketeer*, 30 Aug 1963, 10.

24 *Rocketeer*, 10 April 1964, 6.



Three stages of Polaris firing on Fishhook barge, San Clemente Island, 29 May 1959.

industrial demeanor belied its highly technical function. Fishhook measured 186 feet from water surface to cranetop.

For a test, Fishhook would be floated so that the tip of the crane arm was directly above the dummy test missile, resting in its launcher 50 feet or more below the surface. A sturdy line ran from the tip of the missile up to the top of the crane and then to a servo motor on the Fishhook barge.

When the missile was launched with compressed air, it would shoot up through the water and then pop up to about 100 feet above the surface. The servo motor would take up the slack in the line as the missile flew upward and would then snub the line just as the missile reached zero velocity at the apex of its flight. The fragile and expensive missile could then be lowered gently to the surface for refurbishment in anticipation of another test.[25]

In a congratulatory message after a successful April 1959 demonstration of Fishhook, Rear Admiral P. D. Stroop, Chief of BuOrd, wrote that:

> . . . many bystanders stated that "The fishook barge monstrosity can't float and won't work." . . .This floating monument of the impossible will expedite

25 The Fishhook barge had its origin, ironically, with a WWII adversary. The "German Crane," as it was known was originally used to lift U-boats out of the water.

> and assist the Polaris development with resultant savings of many millions of dollars.[26]

Tests of the 28-foot-long thin-skinned dummy Polaris ballistic missiles were complex and expensive, and recording and instrumenting subsurface and in-flight events was tricky in the open-ocean environment. NOTS instrumentation engineers worked closely with the Polaris contracting team to ensure that the maximum amount of data was wrung from each test.

Polaris launch, Wilson Cove, San Clemente Island, 14 April 1960.

26 Chief, BuOrd, Msg. 272036Z, *NOTS Station Journal, 1 April–30 April 1959*, 16.

Operation Pop-Up culminated in a spectacular launch with a live rocket motor at San Clemente Island on 14 April 1960, witnessed by more than 80 members of the media.

In an article entitled "Polaris Launching Makes Headlines Coast to Coast," the *Rocketeer* reported that:

> . . . the 28-foot bottle-shaped missile hurtled from the ocean's depths and zoomed up to 1800 feet. Then, its 5 seconds of solid fuel expended, the missile arched gracefully to a splash landing about 500 feet from its launch point.[27]

Demonstrating the transition from underwater launch to controlled powered flight was a major milestone in Polaris development. Less than three months later, *USS George Washington* (SSB(N)-598) made the first launch of Polaris from a submerged submarine. As one China Lake engineer noted, "They fired them from underwater, and that shook up every admiral around the world. The U.S. now had the capability of firing missiles from a submarine underwater. My God, they could be right next to your shore!"[28]

Polaris testing continued at San Clemente Island. The Pasadena Annex designed and installed the Variable Depth Launch Facility (including telescoping camera towers equipped with a dozen high-speed underwater cameras and television cameras) in the summer of 1961. Built for less than a million dollars, the 120,000-pound launch tower was set in place by ships that were moored to previously installed 20-inch piles to minimize the ships' movement and ensure precision placement of the facility components. With the new facility, Polaris could be launched from depths more representational of its intended operational environment.[29]

In 1963 an underwater translator launcher was built at San Clemente Island, adding the capability to launch Polaris at horizontal velocities. The translator structure alone, sans launcher, weighed 90 tons. Installation was handled by NOTS divers—professional Navy underwater construction divers from the NOTS Diving Division, not cross-trained engineers—who made 724 SCUBA dives plus 80 dives in full 190-pound deep-sea hard-hat suits, at depths of over 150 feet, in the course of the 47-day project.[30]

More than 100 tests over a 4-year period demonstrated the integrity of the Polaris launching system. In a ceremony at Pasadena in April 1964, Captain J. J. Hammerstone, representing the Director of Special Projects, presented a

27 *Rocketeer*, 22 April 1960, 1.
28 S-248, Richard J. DeMarco interview, 22 and 28 May 2008, 30.
29 *Rocketeer*, 28 July 1961, 1.
30 *Rocketeer*, 13 Dec 1963, 1, 4.

Polaris submarine flag to the Pasadena employees who had worked on Polaris. Captain Grady H. Lowe, Officer in Charge, NOTS Pasadena, accepted the honor. "This flag represents a badge of membership in a unique and vital team dedicated to defense of our country and preservation of peace," Hammerstone told more than 100 employees at the ceremony.[31]

While NOTS Pasadena concentrated on the underwater launch testing, NOTS China Lake was making other contributions to the Polaris program. As early as 1958, China Lake had been called in to assist when problems developed for Aerojet-General, the Polaris solid-propellant motor contractor. Propellant mixers at the contractor's facility were exploding during mixing of the polyurethane propellant.

The Propulsion Development Department set up a program led by Tom Hayes to produce the solid-propellant motors at China Lake. The task of designing the facility was assigned to Richard J. DeMarco, a mechanical engineer who had come to China Lake after graduating from the University of Illinois in 1954. DeMarco's facility incorporated an underground chamber for vacuum-pouring the propellants into the motor cases, a vibration unit for properly settling the mix, and heating elements to cure the propellant. The finished motor would be extracted by means of a gantry crane.[32]

Over time, China Lake developed process controls that resolved the Aerojet-General production problem. As part of the propellant evaluation program, the Station also studied burning-rate, cook-off characteristics, accelerated curing, and the deflagration-to-detonation ("burn to bang") transition.[33]

In a separate project, China Lake investigated the attenuation of radio-frequency signals in the exhaust plume of the Polaris rocket motor. This was necessary, explained propulsion engineer Ray Miller, "so that system designers could tell what signals they might be able to send to the missile during flight."[34]

In 1960 Dr. Joseph I. Bujes, China Lake's resident radiological testing expert (who had studied under Dr. Wilhelm Roentgen, the discoverer of X-rays), set up a facility for nondestructive testing of Polaris first- and second-stage propulsion units. Because the cost of X-ray pictures in the Station's 25-million-volt betatron was, according to the *Rocketeer*, "extremely high (about $1,300 to X-ray first-stage Polaris)," Bujes developed a unique method using ion chambers

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31 *Rocketeer*, 10 April 1964, 6.

32 The facility is still in use today producing motors for current missile systems.

33 *Technical Program Review 1958*, 94 ff. Solving process-control issues was one of the reasons that pilot plants had been built at China Lake in the 1940s.

34 S-262, Miller interview, 8, 9. Miller spent the last 25 years of his 34-year career at China Lake as head of the Propulsion Systems Division. He retired in 1990.

or scintillators that resulted in a $1,000 savings per first stage or an estimated $1.5 million for the Navy Polaris and Air Force Minuteman programs.[35]

As the Polaris program gathered momentum and the Navy began to build its Polaris-equipped fleet (40 ballistic missile submarines (SSBNs), each carrying 16 Polaris missiles, would be launched between 1960 and 1966), the need for a systematized test program for Polaris rocket motors became apparent. China Lake was selected as site of the Navy's largest and most completely instrumented propulsion static-test installation for all-up testing of developmental and production motors.

Construction of Skytop began in 1958 under the leadership of Edwin G. Swann, Jr., head of the Medium Range Missile Branch in the Weapons Development Department. DeMarco designed the facility, and Ralph M. Parsons Co. of Los Angeles constructed it. The project was completed in November 1959 at a cost of $650,000.

Bay 1, where the first firing of a Polaris motor took place in February 1959, could accommodate rockets with an average thrust of a million pounds and a peak thrust of 10 million pounds. At 35 feet long and 30 feet wide, the test bay accommodated motors up to 6 feet in diameter and weighing up to 100,000 pounds. Support structures included the Preparation and Conditioning Building (where motors could be conditioned in temperatures from +70°F to +110°F) and, a quarter mile away from the firing bay, the Fire Control and Instrumentation Building, where the 40 channels of test data initially obtainable during a firing were later expanded to 200 channels. All the structures were massive, built of reinforced concrete and covered with earth. By the end of 1961, 20 full-scale Polaris motors, both first and second stages, had been fired at Skytop.[36]

Even with Skytop I on line, the demand for full-scale test facilities still exceeded capability. In June 1960 construction began on Skytop II, which gave the Navy the capability to test a giant motor in a nozzle-down orientation and under simulated high-altitude (up to 100,000 feet) conditions. The initial firing at Skytop II took place in November 1961, with the successful test of a Polaris second-stage motor.[37]

Still more was needed. Construction began on Skytop III in July 1960 for high-hazard testing of the big motors, including test of those suspected of being

35 *Rocketeer*, 23 Sept 1960, 1, 4. Many years later China Lake's Jon Rogerson would develop a facility capable of X-raying full-size rocket motors (up to the size of the Space Shuttle boosters) during static firing.

36 *NOTS Command History* 1959, 7–8; *NOTS Command History* 1961, 9.

37 *NOTS Command History* 1961, 10.

Skytop static firing test of large composite-propellant motor.

defective. Early tests included firing a .30-caliber armor-piercing round into a Jupiter Junior rocket motor and testing a Polaris motor flight-termination device (to be used to destroy a missile if something went awry during flight).

By the time the Skytop Complex was dedicated in November 1961, the Navy had invested $2 million in the facility. In his remarks at the dedication, NOTS Commander Captain Charles Blenman, Jr., praised the Propulsion Development Department, which had spearheaded the Skytop construction effort, as well as groups in the Test, Engineering, Supply, and Public Works Departments. He added that:

> The Skytop Facility provides the Station not only with an excellent ballistic performance evaluation capability but also with the capability for testing the performance of thrust-vectoring systems of the Polaris weapon.[38]

In 1962 China Lake would construct a microwave link between Skytop and the IBM 7090 mainframe computer in Michelson Laboratory, thus allowing the 7090 to perform high-speed, real-time control of test firings at Skytop.[39]

The "thrust-vectoring systems" to which Blenman alluded in his dedication speech at Skytop were another important China Lake contribution to the Navy's strategic capability. When the Special Projects Office requested in 1960 that NOTS attain a vertical testing capability, it was "to be used for testing Polaris A-3 thrust-vector-control schemes under development by several agencies."[40]

38 *Rocketeer*, 24 Nov 1961, 1.
39 *NOTS Command History* 1962, 11.
40 *NOTS Command History* 1961, 9.

The Polaris A-3, which started development in 1960, was the third and final generation of Polaris. The original jetavator system for thrust-vector control (a solid surface that moved within the propulsion stream to control steering) of the A-1's second stage had been replaced in the A-2 with rotatable nozzles. Something new was needed to withstand the more powerful propellants and the increased thrust temperatures in the A-3 motors.

NOTS began development of a Freon fluid-injection system for the A-3 in 1961. The idea was that injecting Freon 114-B2, a very dense liquid, into the rocket exhaust, would create shock waves to redirect the exhaust and thus give directional control of the rocket. This could be accomplished at a weight savings over the rotatable-nozzle system and with less vulnerability to high velocity, high-temperature gas flow than a jet-vane system. Although Lockheed had been working toward that goal (with a far larger budget), it had not made the progress expected by the Special Projects Office.

In thrust-vector-control development, SPO borrowed a page from McLean's playbook. He liked to employ a management technique that came to be known as "the carrot and the needle." *LIFE* magazine described this "unique incentive system" in a 1967 article about McLean:

> On the one hand he will launch an expertly organized, well-funded program complete with a time schedule . . . At the same time he selects a smaller creative team whose goal is to beat the larger group to a solution—on about 10 percent of the first team's budget.[41]

McLean articulated the idea in a speech to the National Advanced-Technology Management Conference, Seattle, Washington, in September 1962:

> In essence, my proposal for the management of military programs is to attack each objective with both a large program, which will provide a safe, scheduled and well funded route toward the objectives, and a more risky venture funded at 10 percent of the cost where we can try out the talents of our creative designers without forcing them to risk the political safety of the nation while they are taking chances.[42]

In developing the A-3 thrust-vector control, it was the SPO that used the carrot-and-needle technique, and China Lake was the needle. According to Jim Bowen, who was head of the Astro-Propulsion Branch in Code 45 during the development process:

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41 "The Navy's Top Handyman," *LIFE*, 6 Jan 1967, 31.

42 RM-24, *Collected Speeches of McLean*, 30. McLean added "If such a management tool is ever accepted, I personally hope that I can always find an opportunity to work on the 10 percent end . . . ."

> Lockheed was charged with implementing fluid injection thrust-vector control, and they were dragging their feet, so [SPO] says, "OK, China Lake, do it yourself, build the complete system." In six months we built the complete system, and conducted a static firing at Skytop, and demonstrated the whole damn thing successfully.[43]

A significant firing on 29 September 1961 successfully demonstrated a NOTS-developed fluid-injection thrust-vectoring system.[44] China Lake also assisted the Polaris program with drop testing of the re-entry bodies. To check the functioning of the target-detecting device (TDD), Polaris re-entry bodies were dropped from an AD-5 aircraft at altitudes between 10,000 and 12,000 feet. The TDD output was connected to flashbulbs on the exterior of the body, and the TDD function—which in operational use would detonate the nuclear warhead—was observed visually and photographed.[45]

Deterrence and Other Nuclear Studies

Not all of NOTS' strategic-weapons-related work in the early 1960s involved design or testing. Various studies were conducted, including an investigation of torpedo-tube size missiles. This work resulted in a report by James T. Bartling of the Pasadena Annex, "Submarine Nuclear Bombardment Weapons of Torpedo Size." The studies indicated feasibility of a such a weapon with a range of about 900 nautical miles.[46]

Project Michelson, which Code 12 began in 1960 and continued through 1965, was an outgrowth of the earlier Mercury and Atlantis studies. Whereas Mercury and Atlantis had dealt with vulnerabilities and damage effects, Michelson took a more academic, big-picture view of the concept of deterrence.

"Project Michelson grew out of the NOTS work on Polaris," explained Dr. Robert Rowntree, who was hired by Code 12 out of graduate school to be a consultant for Project Michelson and then remained at China Lake for 28 years. He continued:

> Bill McLean became interested in the ideas of deterrence and what would make deterrence work. He concluded, correctly, that we did not know much about what really influenced national decision makers, particularly those in foreign countries like Russia and China who we wanted to deter. There wasn't much scholarly literature on what influenced these guys' decisions and

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43 S-175, Bowen interview, 66. The demonstration was done as part of NOTS' Guided Flight Vehicle program.
44 *NOTS Command History* 1961, 9.
45 *NOTS Tech History 1961*, 222.
46 Research Board minutes, 9 Aug 1960; *NOTS Tech History 1960*, 6.

> particularly what kind of possible military capabilities might influence them. Project Michelson was set up . . . to undertake a rather expensive program of scholarly research in what influenced foreign decision makers and particularly what characteristics of military programs might influence them.[47]

More than 50 studies were conducted and documented by universities around the country and included contributions by such intellectual giants as Dr. Ithiel de Sola Pool, founder and chair of the MIT Political Science Department. The flavor of the writings is distressingly academic—in an essay titled "Design for the Study of Deterrence," Project Michelson Director Tom Milburn wrote:

> "Design for the Study of Deterrence" explicates a heuristic model of strategic deterrence seen as hardware-related influence attempts upon certain kinds of choices (those related to a war-peace continuum) of to-be-deterred decision-makers in a multilateral deterrence situation.[48]

Milburn's Behavioral Sciences Group (Code 014) established the analytical framework for the project. Individual studies were grouped in terms of variables—independent, situational, structural, perceptual, etc.—and bore such titles as "A Comparison of the Values of Soviet and American Elites," "Factor Analysis of Concepts of Stability and Deterrence in Soviet Writings," and "Empirical Foundations of Deterrence Propositions." Participants focused on the period 1965 through 1980. According to the group, "The concept of military deterrence developed in Project Michelson is connectable to more general psychological data on motivation, learning, and communication."[49]

"Through Project Michelson," wrote Harlan K. Ullman, "the academic community was challenged and commissioned to examine the fundamental questions of war and peace in the Nuclear Age."[50]

If Project Michelson was ever successful in integrating the various studies into a usable tool for military and political decision makers, and if so, whether that tool was ever exercised, and if further so, with what results, evidence was not found in researching this book. The project's preliminary report in 1963 states in its introduction that "Program results have already been used by American policy-

47 S-176, Robert and Esther Rowntree interview, 7 and 21 June 1989, 26.

48 Higgs and Weinland, *Project Michelson Preliminary Report,* 69.

49 *NOTS Tech History 1964*, 3–8.

50 Richard L. Kugler and Ellen L. Frost, Ed., *The Global Century, Globalization and National Security*, Vol. 1, Part III, Chap. 22, "Influencing Events Ashore," 494, *http://www.ndu.edu/inss/books/Books_2001/Global_percent20Century_percent20-percent20June_percent202001/C22Ullma.pdf,* accessed 10 Sept 2009. Ullman is known as the co-developer with James P. Wade of the Doctrine of Shock and Awe.

makers as a basis for choices among weapon systems," but additional information is not forthcoming, perhaps because of the classification levels involved.[51]

It is noteworthy, however, that in 1965 the sponsorship of Project Michelson was transferred from the Navy Special Projects Office to the Office of the Chief of Naval Operations (OPNAV). By that time, approximately 150 study reports had been completed through Project Michelson. OPNAV began a new strategic study program, including all five specific Project Michelson studies that NOTS had recommended for extension.[52]

The Navy's strategic nuclear program was running all-ahead-full in the early and mid 1960s. Polaris would be replaced with Poseidon and Trident in the late 1960s and 1970s, and NOTS would continue to support and assist these weapon systems, particularly in the area of propulsion and testing.

Though nuclear programs would play a smaller part of NOTS work in later years, the Station would maintain a level of expertise. In 1964, under the direction of Nick Schneider, China Lake completed a survey of current and projected (1970) technology of gyroscopes, accelerometers, inertial platforms, and airborne digital computers for advanced sea-based deterrent systems.[53]

Seek-Bang nuclear Walleye on Air Force F-4 aircraft.

51 Higgs and Weinland, *Project Michelson Preliminary Report*, 1.
52 Dickinson, *Glossary of Project Titles*, 50; *NOTS Tech History 1965*, NOTS TP 4001, April 1966, 3–11. The five programs were Analysis of European Elite, Chinese Communist Value, The Chinese Communist Operational Code, Chinese Communist Risk-Taking, and The Decision to Attack Pearl Harbor.
53 Dickinson, *Glossary of Project Titles,* 4.

NOTS also developed the BDU-20C and -24C nuclear weapon simulators to assess the effectiveness of B-57 weapon-loading crews and pilots. SM-2(N), the nuclear version of the Standard Missile Type 2, would rely on China Lake for fuzing and flight-termination systems. In the late 1960s and early 1970s, China Lake would join with the Air Force in the Seek-Bang Program, which developed a nuclear Walleye that used a China Lake-designed and -developed data link.[54]

Conventional Weapons

Even in the face of the nation's overwhelming dependence on nuclear weapons as the massive-retaliation cornerstone of defense policy, a body of evidence was growing throughout the 1950s and into the 1960s that indicated a new kind of war developing in the world, a type of conflict for which nuclear weapons might not be the most effective. Historian and political scientist Bernard B. Fall examined the concept of "small wars" (also known as limited wars or small-scale conflicts):

> If we look at the 20th Century alone, we are now in Viet-Nam faced with the forty-eighth "small war." Let me just cite a few: Algeria, Angola, Arabia, Burma, Cameroons, China, Colombia, Cuba, East Germany, France, Haiti, Hungary, Indochina, Indonesia, Kashmir, Laos, Morocco, Mongolia, Nagaland [an Indian state on the Burmese border], Palestine, Yemen, Poland, South Africa, South Tyrol, Tibet, Yugoslavia, Venezuela, West Irian [West Papua, New Guinea], etc. . . . if a survey were made of the number of people involved, or killed, in these 48 small wars it would be found that these wars, in toto, involved as many people as either one of the two world wars, and caused as many casualties.[55]

Some U.S. leaders believed that relying exclusively on atomic weaponry for the nation's defense—whether strategic or tactical—was not the prudent or practical course. One of these was General Maxwell D. Taylor, Eisenhower's Army Chief of Staff, who became convinced that dealing with the various levels of conflict in the world would require a multi-tooled, flexible approach. In 1959 General Taylor retired from active service and wrote a book, *The Uncertain Trumpet*, in which he articulated this political/military position. The following year he spoke to the University Club in New York City and summarized his view on the issue of nuclear and conventional forces:

> Should we concern ourselves exclusively or almost so over the waging of general atomic warfare with missiles and bombers carrying megaton weapons

54 *Major Accomplishments*, 54.

55 Bernard B. Fall, "The Theory and Practice of Insurgency and Counterinsurgency," *Naval War College Review*, April 1965, reprinted in *Naval War College Review*, Winter 1998, *http://www.au.af.mil/au/awc/awcgate/navy/art5-w98.htm#author,* accessed 7 July 2008.

> of indiscriminate destruction? If you answer yes, then you become a proponent of a strategy of Massive Retaliation. But in a period when the USSR has similar weapons of great destruction, should we not give equal attention to the requirements of so-called limited war to which the megaton weapons have no application? If you accept this view, then you are inclining to a strategy of Flexible Response and to a repudiation of Massive Retaliation . . . .[56]

Taylor's book caught John F. Kennedy's attention, and in the Presidential campaign of 1960 it helped Kennedy coalesce his defense policy around the "flexible response" model. At a campaign speech in September 1960, he spoke of Eisenhower's policy of massive retaliation, saying that the people of the world "are not interested in a fire department that can put out a fire only by blowing up their house."[57] In 1961 Kennedy recalled Taylor to active service to become the President's chief military advisor and, in 1962, Chairman of the Joint Chiefs of Staff.

While Taylor strode large on the national stage, others within the military R&D community were also advocating a second look at the merits of conventional weapons. McLean was among this group. Although he supported the Station's continuing work on nuclear weapons, he spoke often of the need for a broad range of weaponry that would be suited for the political situations as well as the specific targets that might face military planners. Korea, he believed, had shown that a protracted conflict could be engaged in without resorting to nuclear weapons. "My personal philosophy," he once said, "is that there is no stopping point after you start using nuclear weapons."[58]

Propulsion Development Department Head Francis M. "Frank" Fulton asked the rhetorical question "Can it be that the great weapons forged from the most advanced of man's technology to preserve a bastion America are almost useless in dealing with these local, internal conflicts?"[59]

Times were tough in the conventional weapons business. Vice Admiral William J. Moran, who was a lieutenant commander and the assistant experimental officer at NOTS in the mid 1950s, recalled that:

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56 Gen. Maxwell D. Taylor, USA (Ret.), "A More Certain Trumpet," summary of remarks at University Club, New York City, March 12, 1960. National Defense University, Ft. McNair, Washington DC, *http://www.ndu.edu/library/taylor/mdt-0125.pdf,* accessed 9 Sept 2009.

57 Sen. John F. Kennedy, excerpts from a speech at Civic Auditorium, Portland, OR, 7 Sept 1960. The American Presidency Project, *http://www.presidency.ucsb.edu/ws/index.php?pid=25678*, accessed 16 Sept 2009.

58 S-97, Dr. William B. McLean interview, July 1975, 30.

59 Francis M. Fulton, *Limited War Weapons for Indigenous Forces and Covert Operations*, TS 61-134, NOTS, May 1961, 2.

> . . . we got down to the point where the conventional warhead office decided to close up shop. It had gotten down to about two guys, and there was no money, no conventional warhead of any kind working. I took some alarm at that and went over and talked to Admiral Ashworth [then a captain and the NOTS Commander]. . . He ended up getting some money from BuOrd, enough to keep a couple of guys in the office, keep the files open and somebody answering the phone, and staying in touch with all of the other activities in the Department of Defense that were working with warheads.[60]

In 1955 NOTS developed a variety of proposals for new weapons of limited warfare, and over the next 2 years McLean, Ashworth, and other China Lakers peddled the ideas in Washington.[61]

Phil Arnold recalled that when he joined NOTS in 1955, "China Lake was up to its ears in nuclear weapon development or concept development; e.g., BOAR, Elsie, and Diamondback." Shortly after his arrival, however:

> I attended a presentation by someone from the [Weapons Planning] Group commenting on the Navy's system-acquisition agenda. The presentation was highly critical of the focus in weapons development at the time, on weapons employing tactical nuclear warheads. Everything had a nuke in its belly—air-to-air missiles, air-to-surface weapons, depth charges, you name it, it had to have a nuke. As a newbie just out of college, I was impressed that someone from China Lake was thinking about national policy rather than the nuts and bolts engineering I was seeing every day. As it turned out, by 1960 the national leadership came to the same conclusion.[62]

Through the last half of the 1950s, weapons development and acquisition leaders were beginning to turn away from nuclear weaponry and toward the development of conventional weapons. The arguments made by Taylor, Gavin, Ashworth, McLean, Knemeyer, and others—that conventional weapons would give the nation a flexible response option in limited war—gained traction. The trend became stronger as the 1950s rolled into the 1960s, the Eisenhower administration was replaced by the Kennedy administration, and the rumbles of conflict in Southeast Asia grew louder.

Even Eisenhower's Secretary of Defense Thomas Gates, in his final month in office before turning over the DOD helm to Robert S. McNamara in January 1961, allowed that one of the two principal defense objectives for the

60 S-187, Vice Adm. William J. Moran interview, 5 Dec 1990, 5. Moran was a Navy fighter pilot in WWII; he was aboard the USS *Hornet* (CV-8) when it was sunk at Santa Cruz. He served two tours at China Lake in the 1950s before returning as Commander from 1970 to 1972. He retired from the Navy at the rank of vice admiral in 1975 as Director of Research, Development, Test, and Evaluation.

61 Babcock, *Magnificent Mavericks*, 377–378.

62 S-275, Arnold interview, 65.

nation was "to maintain, together with our allies, a capability to apply to local situations the degree of force necessary to deter local wars, or to win or contain them promptly if they do break out."[63]

In January 1958 the Navy—seemingly content that its piece of the nuclear pie and the commensurately large share of the defense budget would be secured by the Polaris system and its successors—released a statement of long-term objectives for the 1970s. In the document, the Navy proposed that carrier forces be tailored "for limited war, to be the nation's primary cutting tool for that purpose."[64]

July 1958 brought a letter from the Office of the Chief of Naval Operations forwarding Operational Requirement No. CA-13501 for the development of free-fall conventional ordnance for use with modern high-performance attack aircraft. That fall China Lake's Advisory Board met at the Station for 3 days. The six-member board that year included among its distinguished members Dr. Charles C. Lauritsen, head of Caltech's Kellogg Radiation Laboratory and the man who had both discovered the site for NOTS and run its wartime rocket programs for Caltech; Dr. Kenneth S. Pitzer, former Director of Research for the Atomic Energy Commission and later president of both Rice and Stanford Universities; and Dr. William Shockley, who 2 years previously had won the Nobel Prize as co-inventor of the transistor. Among the board's recommendations was a strong statement of support:

> The Board commends the Station for the emphasis being given to weapons useful in limited war and for its recognition of the importance of non-nuclear as well as nuclear warheads for various weapons systems, including the need of greater accuracy of delivery when non-nuclear warheads are employed.

The board's primary recommendation in November 1958, one that it considered "of overriding importance not only to the Station and the Bureau of Ordnance but to the entire Navy Department," was the need for "getting adequate weapons into the ordnance system of this country." The board believed the Station to be "uniquely equipped to do some of the major exploratory work necessary for the selection of a few best approaches to hardware elements" and added that "those setting the direction of this center's work [presumably including leaders not only of the Station but also of BuOrd, whose Commander,

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63 Official Biography of Thomas S. Gates, *http://www.defenselink.mil/specials/secdef_histories/bios/gates.htm*, accessed 15 Oct 2009.

64 Col. Alfred F. Hurley, USAF, and Maj. Robert C. Ehrhart, USAF, eds., "American Postwar Air Doctrine and Organization: The Navy Experience, in Air Power and Warfare," *Proceedings of the 8th Military History Symposium*, U.S. Air Force Academy, 18–20 Oct 1978, 269.

Rear Admiral P. D. Stroop, was in attendance at the meetings] should frankly recognize the urgent need for making this class of work its primary mission."[65]

Not an organization to waste time, NOTS submitted a preliminary Technical Development Plan for non-nuclear free-fall ordnance in January 1959. The TDP outlined a general weapons R&D program but did not delineate specific weapons to be developed.

When James H. Wakelin, Assistant Secretary of the Navy for Research and Development, visited NOTS in October 1959, McLean expressed his belief that:

> We can . . . expect a continuing series of international situations in which the United States will be faced with the choice of yielding to pressure, resisting with conventional weapons, or initiating the use of nuclear attack. We would like to assume that the United States will resist these pressures by the use of conventional weapons.

McLean went on to point out specific areas of needed improvement in conventional weaponry, including the need for "weapons for air-to-ground attack which are capable of being released from our existing aircraft. These weapons are needed to destroy tanks, troops, and supplies. For this purpose, the Bureau of Ordnance has initiated a program at the Station for the study of free-fall weapons."[66]

China Lake under McLean's leadership was determined to be the source for as many of the limited-war conventional weapons as possible. As Frank Knemeyer recalled:

> . . . we recognized that the Navy was deeply involved in the application of the development of nuclear weapons; we recognized that the pendulum had to swing the other way and it would in due time. Therefore, projecting this, we got busy to see what we ought to do about conventional air-delivered weapons. Hence, we got a head start on everybody. So when the recognition finally came, we were prepared with the kind of weapons that needed to be worked on.
>
> . . . I think that is a key to what the Center has done in just about everything; that with our association with the Fleet, our understanding of what the Navy should be doing, we project ideas and initiate them and eventually we are able to get a lot of them sold to the Navy. Ninety percent of the weapons that we have developed, been responsible for the development of here, were initiated here, they were not something that was asked of us from outside.[67]

65 Advisory Board recommendations, Nov 1958, 4.

66 "Comments on Trends in Weapons Requirements," 2 Oct 1959, RM-24, *Collected Speeches of McLean*, 135.

67 S-124, Franklin H. Knemeyer interview, 3 June 1981, 10.

Lillian Regelson came to China Lake in 1951 with her husband Raim (Ephraim). Raim was a meteorologist by profession but would eventually become one of China Lake's top specialists in the infrared spectrum and its military applications. Lillian was not typical of the China Lake civilian wives of that era, most of whom did not join the Station's professional workforce. Lillian—a Phi Beta Kappa with a BA in mathematics from Hunter College, an MA in mathematics from UCLA, and experience as an analyst with Hughes Aircraft—took a job with the Aviation Ordnance Department, and by 1954 she was head of the Computer Branch, developing the Mk 8 Fire Control System. ("Lillian owned the Mk 8 Fire Control System," recalled Frank Cartwright.) In 1957 she transferred to Code 12 where she later became the associate for weapons analysis.[68]

Regelson later commented on the free-fall weapons study that McLean had mentioned to Secretary Wakelin. Assigned to Dr. Pauline Rolf, who held a doctorate in physics from Bryn Mawr and was a noted physicist listed in *American Men of Science*, Regelson recalled that:

> Pauline asked me to take a look at what was known about air-launched conventional weapons. I couldn't find anything after a report written right after World War II by a group which surveyed the effects of weapons dropped on Europe during the war.

Regelson traveled to Rand Corp., which was doing research work for the Air Force. "They told me that there was nothing being done because all future wars would be fought with nuclear weapons." She then plowed into the WWII data.

> I spent about a year reading everything I could find, organizing and analyzing the data, incorporating what I knew about accuracy, and writing up the results." She recalled that in about 1958 "an engineer in the Bureau of Ordnance sent us some money to write a report describing as many ideas for new air-launched non-nuclear weapons as we could find.[69]

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68 S-194, W. F. "Frank" Cartwright interview, 28 Aug 1991, 36; *Rocketeer*, 28 Sept 1962, 5. In June 1964 Regelson would be appointed as the first special assistant to the Technical Director. "The reason we went to NOTS is that I couldn't get a professional job in the L.A. area because I'm a woman. At that time it was legal for companies to tell women that they didn't hire women for professional jobs. Raim wanted me to have an opportunity to get interesting work; even though he could get a job many places, we went to NOTS to give me a chance," she said in an email to the author, 21 July 2011.

69 *Rocketeer*, 19 Feb 1965, 3; Lillian Regelson, emails to the author, 26 Aug 2008–8 July 2009. Rolf, Regelson, Dr. Marguerite M. "Peggy" Rogers, Dr. Marian E. Hills, and Dr. Jean M. Bennett are generally credited as being "icebreakers" for women in top technical positions in the China Lake workforce. A 3 Aug 1956 *Rocketeer* column, "The Distaff Side," noted that Rolf, who came to NOTS in 1946, "holds the distinction of being the

That engineer was George Spangenberg, director of the Evaluation Division of the Bureau of Aeronautics (which in 1959 was combined with the Bureau of Ordnance to become the Bureau of Naval Weapons). Ray Powell, a Marine aviator who served two tours at China Lake, remembered Spangenberg as "the NAVAIR No. 1 Fighter/Attack Engineer in the Navy for so many years that I can't remember." Spangenberg was known for his willingness to take on a fight—he worked side by side with former China Laker Vice Admiral Thomas F. Connolly in the late 1960s for cancellation of the F-111B aircraft and approval of the F-14.[70]

In response to Spangenberg's request, Regelson "discussed this [conventional weapons] with everyone at NOTS I could think of, added my own ideas, and wrote the report. . . ." In June 1959, the Weapons Planning Group published the seminal document that was the foundation for the next decade of free-fall weapons work. That long-range (10-year) survey of air weapons for research and development is still classified Secret. Regelson recalled that:

> [Spangenberg] was very pleased and said he would incorporate the report into the budget. He said that if he put the weapons in individually, they would be deemed too small to include so he put them in as a family, with the 'eye' name identifying them as a group. He made up all the names.

Frank Marquardt, an influential up-and-coming engineer at BuWeps, was assigned as the Bureau's project engineer for the new family of weapons. Thus was born the Eye series.[71]

In July 1959 the Free-Fall Weapons Program (the overall program under which the Eye series was developed) began in the NOTS Weapons Development Department. By year's end, the program was reporting progress on Hawkeye, Bigeye, and Gladeye, and BuWeps had requested feasibility studies of several additional free-fall weapons.[72]

In mid 1959 Knemeyer moved from the Weapons Planning Group to become assistant head of the Weapons Development Department under Barney

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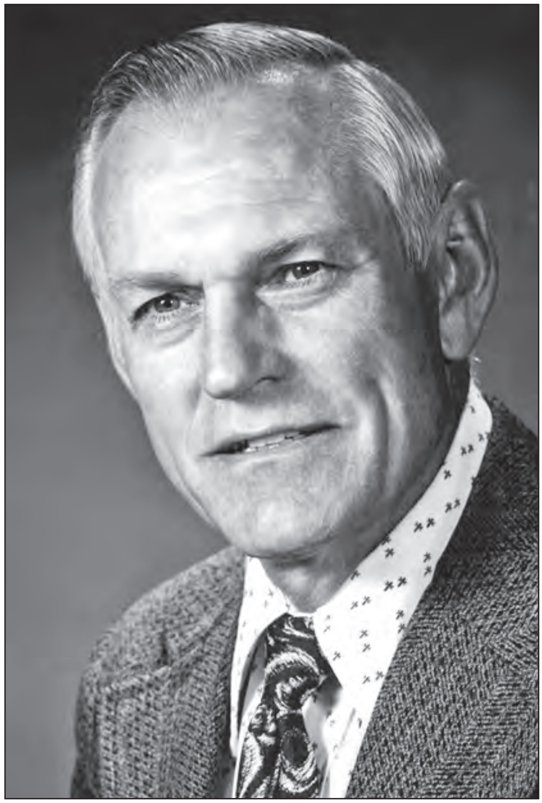
highest salaried woman employed on the Station." Not until 1998 was a woman, Dr. Karen Higgins, selected for the position of China Lake Executive Director (formerly Technical Director).

70 Ray Powell, email to the author, 14 Nov 2008. Another former China Lake Marine aviator, Lt. Gen. William Fitch, referred to Spangenberg in a 2006 interview as "a genius for aircraft design" and a "giant in the R&D world." Spangenberg was one of a small number of civilians inducted into the exclusive Early and Pioneer Naval Aviators Association (Golden Eagles). In his official Golden Eagles biography under "Combat Tours" is listed "USN vs. Office of the Secretary of Defense, 1960–1973."

71 Regelson email to the author, 12 Nov 2008.

72 *Technical Program Review 1959*, 111.

Smith. By fall 1960, when Smith left to become Chief Engineer for the Bureau of Naval Weapons, Knemeyer took over Code 40. Meanwhile, approval for funding of the Eye series was percolating through the Navy bureaucracy in the Pentagon, and money for the new weapons was arriving on Station.



Franklin H. Knemeyer.

In September 1960 BuWeps published a plan for its Free-Fall Nonnuclear Ordnance RDT&E Program, a "revision of the initial Technical Development Plan submitted in 1959."[73]

The document justified the need for NOTS' new line of air-dropped weapons by listing the shortcomings of those in the current stockpile—mostly leftovers from WWII:

> Almost without exception, all of the bomb stockpile represent designs which are inefficient in terminal effectiveness, incompatible with jet aircraft, of doubtful ability to withstand ejection forces, dimensionally incompatible for efficient magazine stowage and handling aboard modern aircraft carriers, and their current condition is that resulting from years of outdoor storage. The explosive fillers are TNT or one of the older compositions.
>
> The fuzes are air arming and utilize distances of air travel to provide arming. Since they are designed for aircraft in the 200–300-knot category, they do not provide sufficient separation from aircraft on completion of arming at release speeds of modern jet attack aircraft. Further, they seldom have the safety feature of out-of-line detonator trains and the pyrotechnic elements are generally overage and thereby unreliable. Mechanical design of the fuzes is such that some will not withstand the torque loads imposed by the arming at high release speeds.

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73 Bureau of Naval Weapons, *Free-Fall Nonnuclear Ordnance RDT&E Program*, 9 Sept 1960. The document also mentions an aerial-emplaced landmine program involving "self-camouflaging ideas" that was referred to as a Gravel Weapon—perhaps the precursor of China Lake's "exploding rocks," discussed herein in Chapters 5 and 6.

Having defined the problem, the report then went on to outline the dimensions of the new free-fall development program, specifically discussing several of the new "eye" weapons that were already under development at NOTS.

In alphabetical order, the Eye systems proposed or devised at the Station over the years were Bigeye, Briteye, Bugeye, Chaffeye, Deadeye, Deneye, Evileye, Fakeye, Fireye, Gladeye, Hawkeye, Marceye, Misteye, Padeye, Rockeye, Sadeye, Smokeye, Snakeye, Walleye, and Weteye.

Not all of the Eye series became operational. Some never got past the feasibility study stage. Others stayed in the Fleet inventory for decades. The series ranged from cluster weapons (Rockeye, Sadeye) to biological and chemical weapons (Bigeye, Misteye, Padeye, and Weteye) to flares (Briteye) to a target-marking system (Marceye). All of them, however, were new approaches to conventional—as opposed to nuclear—weapons, and all benefited from China Lake's combination of Fleet-experienced military personnel working with scientists and engineers versed in state-of-the-art technologies. Descendents of some of these weapons would also serve the Fleet under other names: Gator, for example, and APAM.

In the 1960 revision of the TDP, another major technological shortcoming was noted that related to the entire program: warhead research for surface targets. The report commented:

> This area has been inadequately supported to the extent that virtually no significant technological advances have been made during the past many years. This situation, as indicated earlier, is the result of inadequate planning coupled with the complacency developed from the emphasis on nuclear weapons since World War II.[74]

Knemeyer set up a Warhead Supporting Research program operating out of the Weapons Development Department (Code 40) under the leadership of Bud Sewell. The program would continue for some 16 years, and Sewell would later serve as head of China Lake's Warhead Supporting Research Steering Committee.

As NOTS began to translate the new weapon concepts into reality, Station management worked to solidify a lead role in Navy conventional weapons development. In May 1961 Secretary of the Navy John B. Connally Jr. visited the Station for a whirlwind 4-hour tour. He watched two NOTS-produced films, "Expanding Frontiers in Ordnance" and "Weapons for Limited War," viewed a display of NOTS weaponry, and was briefed by Code 40's Commander

74 Ibid., 2, 17.

Irving A. Robinson on "Light Attack Aircraft Requirements." In remarks at the end of his visit, Connally said, "The marriage of imagination and science with the hard facts of life are producing here ideas and weapon systems which the Navy needs and can use."[75]

Knemeyer set up the Eye series in his department as the Free-Fall Weapons Program, headed by Roy Compton of the Air-to-Surface Weapons Division's Mechanics Branch. The division would grow from two branches in 1960 to four branches in 1961. Dr. Marguerite M. "Peggy" Rogers, a physicist, was selected in 1962 to lead the division, which grew to seven branches by January 1964.

One of the most successful weapons of the Eye series, Snakeye, was not strictly speaking a weapon at all. It was instead a retrofit kit that applied to existing weapons, specifically the large DOD inventory of Mk 81 (250-pound) and Mk 82 (500-pound) general-purpose bombs. Snakeye addressed a problem of concern to Navy and Marine pilots who flew close-air support (CAS) for ground troops. To accurately deliver bombs in close proximity to friendly forces, an aircraft had to come in low and slow. This increased not only the susceptibility to enemy ground fire but also the likelihood that fragments from the bombs would strike the aircraft that delivered them.

Snakeye was not the first solution ever proposed for this problem. In 1942 Lauritsen, who was then Division Vice Chairman in the National Defense Research Committee, wrote to Chairman Richard C. Tolman, "A hedgehopper [a pilot who flies very close to the ground] is comparatively safe from attack, even over a battlefield, but he cannot drop ordinary bombs because the bombs follow him and blow him up. The vertical bomb on the other hand gives him time to get away."

The vertical bomb Lauritsen referred to was launched tail first and fired a retro-rocket on release from the aircraft. Several tests were conducted and, according to Lauritsen, "These experiments were entirely successful, the bombs were stopped in mid-air and dropped vertically like dead ducks."[76]

The Snakeye modification was simpler: a folding "dive brake" that would catch the air and immediately slow the bomb after it was released from the aircraft so that by the time of ground impact, the aircraft was well away from

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75 *Rocketeer*, 20 May 1961, B-2. Connally was later elected governor of Texas. He was in the car with President Kennedy and was seriously wounded when the President was assassinated in Dallas in 1963. Connally also served as Secretary of the Treasury under President Nixon.

76 Memo, C. C. Lauritsen to R. C. Tolman, 7 July 1942, "Vertical Bombing." Encl. 3 to Memo Reg. H-152-67, Code 75201, "Evolution of the Concept of Operating NOTS and Other Scientific Organizations Within the Military Structure," May 1967.

Snakeye drop from A-4 (from data film).

the danger area. An additional benefit is that the retarding fins acted as a "land anchor," digging into the ground and reducing the tendency of the weapon to skip or ricochet.[77]

Snakeye had a further advantage; the pilot made the final decision before flight whether or not to use the retarded mode of the weapon. If a mission was a high-altitude strike, then the retardation feature was not activated and the weapon followed a normal free-fall ballistic trajectory to its target. If a last-minute change of missions called for close-air-support operations, the retardation feature was activated before takeoff. Snakeye was also compatible with virtually every U.S. attack aircraft without aircraft or launcher retrofit.

Roy Compton, assisted by Anthony J. Simshauser, managed the Snakeye program within Peggy Rogers' division. The weapon went into production in 1964. A photograph of the project crew in a 1965 *Rocketeer* article conveys the magnitude of the development effort; it includes "engineers, technicians, ordnancemen, technical assistants and secretaries, loading and scheduling groups, B-1 range crew, engineering drawings, packaging, inspection, contracts, supply [personnel], NAF and VX-5 pilots, plane crewmen."

Dr. Robert Rockwell, early in his 35-year career at China Lake, developed the ballistic models for Snakeye's retarded delivery mode.[78]

77 *Rocketeer*, 5 March 1965, 1.
78 S-254, Dr. Robert Rockwell interview, 2 July 2008, 13.

Years later at the height of the Vietnam War, as Navy and Marine attack pilots supported Marine, Navy, Army, and South Vietnamese ground units, the radio call for "snakes and nape" frequently crackled over the airways. A well-executed drop of retarded Snakeye bombs and napalm gelled-gasoline incendiary canisters, often targeted only a few tens of meters from friendly forces, determined the outcome of many engagements.

Marine Captain (later Major General) Richard A. Gustafson served at VX-5 as the project officer for Conventional Weapons Delivery from 1964 to 1967. The following year he flew 427 combat missions in the Republic of Vietnam flying the A-4 with Marine Attack Squadron 211. Gustafson characterized Snakeye as "the weapon of choice for close-air-support missions" in Vietnam and noted that "NOTS deserves the greatest kudos for its inception." He added:

> The Snakeye was a "don't fire 'til you see the whites of their eyes" type of weapon by modern aircraft standards. The retarding fins allowed release as low as 400 feet above the target in a 10-degree dive, slightly higher for the Mk 82 500-pound version because of its greater fragmentation pattern. The troops on the ground preferred the Mk 81 250-pound version because we could drop it closer to them.[79]

Snakeye was a major success for the Station, but it was only one of the growing Eye family. Gladeye, for example, was completed in 1962. It carried a variety of payloads in seven canisters that could be released singly, in sequence, or in salvo. The canister contents varied from chaff, leaflets, smoke, or CS gas to

Gladeye canisters loaded with Lazy Dog projectiles, leaflets, and munitions.

79 S-269, Maj. Gen. Richard A. Gustafson USMC (Ret.), interview, 13 Sept 2008, 3.

Lazy Dog projectiles (inert .41-caliber steel projectiles fitted with tiny tailfins) and Mk 83 butterfly bomblets.

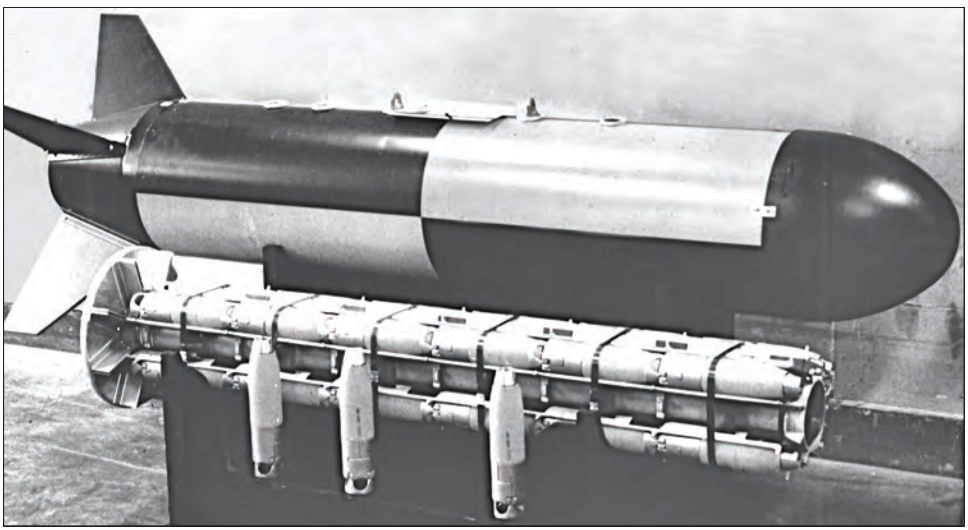
Another weapon that came to be used in large numbers and with great effectiveness during the 1960s and 1970s was Rockeye, a cluster bomb that began life under the name Hawkeye in 1959.

A lengthy poem in the Naval Air Facility's official log book for 1 January 1961, penned by Lieutenant Commander R. P. McArdle, read in part:

> We'll keep up on the Hawkeye
> or Sadie [Sadeye], say a few.
> To name them is a far cry
> from what they aim to do.[80]

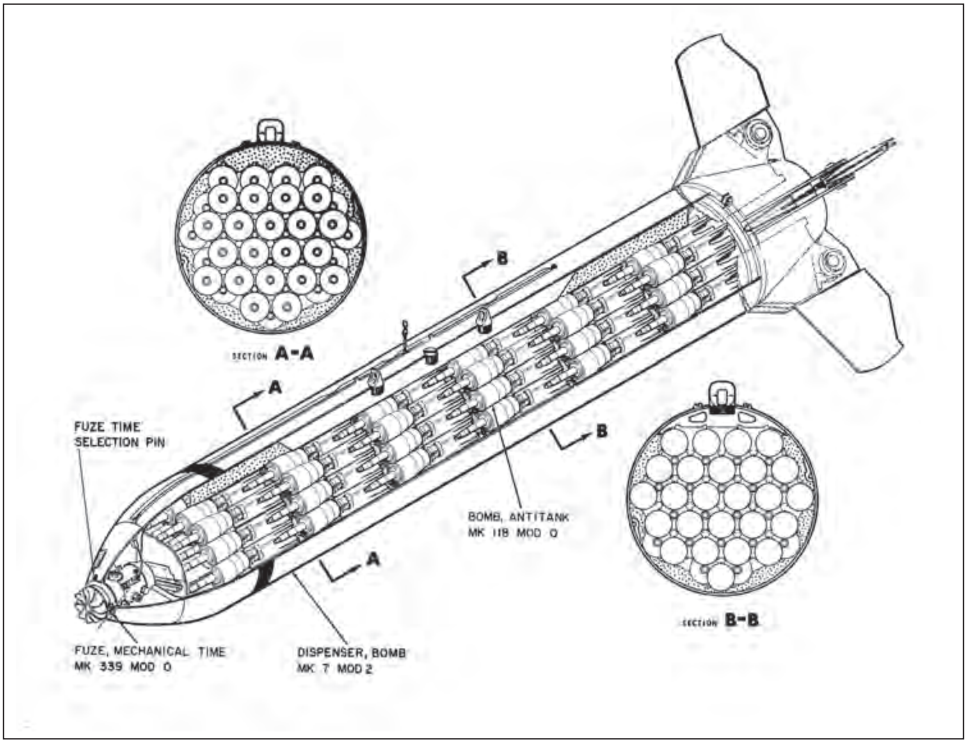
What Hawkeye aimed to do was kill tanks—or any other target that got in its way, ranging from trucks to people. The 96 submunitions contained within the tubular dispenser were modified 2.75-inch rocket warheads, which led the developers to soon rename the weapon Rockeye. Rockeye I was an interim weapon that used a backward-facing Zuni rocket to blow the casing apart and scatter the submunitions. The design was complicated and, in the words of Ray Powell, "a disaster."[81]

Rockeye I was soon replaced by Rockeye II. Designed for delivery from a high-speed jet aircraft, Rockeye II would fall to a predetermined altitude



Hawkeye and partial submunition load.

80 *Rocketeer,* 20 Jan 1961, 3. The use of clustered warheads to clear a target area was suggested to China Lake engineers by Frank Marquardt of BuWeps. See *Rocketeer*, 9 Feb 1973, 1.
81 S-270, Col. Ray Powell, USMC (Ret.), interview, 13 Sept 2008, 41.



Rockeye II cutaway diagram.

where a linear shaped charge would split the dispenser in two, releasing 247 submunitions, or bomblets. Moyle Braithwaite developed the shaped charge for the Mk 118 bomblet, and Mike Aley oversaw development of the Mk 7 dispenser. The weapon's Mk 339 target-discriminating (hard or soft) fuze was developed by the Naval Ordnance Laboratory (NOL) White Oak.

When a submunition, stabilized in its nose-down orientation by four folding fins, struck a hard target such as a tank, the shaped charge would activate. The resultant blast of molten metal was capable of piercing 7.5 inches of armor. If a softer target was struck, an alternate warhead initiation system would create a blast that sent metal fragments in every direction. A single Rockeye canister's dispersion pattern covered roughly the size of a football field.

Used extensively in Vietnam, Rockeye was employed against "targets such as trucks, convoys, antiaircraft sites, parked aircraft, radar installations, and personnel; tanks were not common targets during that conflict."[82]

At one point during the Vietnam War, antiwar groups circulated the story that the fins of the Mk 118 bomblet—which were made of glass filled nylon—

82 *Major Accomplishments*, 23.

were designed so that when people were wounded by the bomblets, the fin fragments would be invisible to X-rays.

When Frank Knemeyer, first saw the fins, he had questions too. According to Braithwaite, Knemeyer said:

> "I don't really like that idea very well, using plastic. It would be better with metal." I told him. "If it is metal, and you bend it, then [the bomblet's flight] is unstable. If it breaks, then it is still probably stable." And we found, working with Honeywell, that glass-filled nylon absorbs a lot of energy before it will break, and so that is the choice we made. And he said, "I want you to bring me one of those. I'm going to put it into my dishwasher and see if it survives [the environment of heat and water]." So, sure enough, he did, and it survived OK.[83]

Mk 118 Rockeye bomblet cutaway diagram showing glass-filled-nylon fin assembly.

Rockeye II had its problems. As Powell explained, the Marines had some hesitancy about using it. The bomblets "had a very high dud rate [because of swampy ground conditions]. So you're basically laying a minefield for your own troops." Even when operating behind enemy lines, that was a problem. "There's the humane thing that comes in there. You might kill some kids."[84]

Rockeye II was released for pilot production in 1967, and production was continuous well into the 1970s. In 1971 a second-source contract was awarded to the Marquardt Corp.

Briteye was a new concept for night combat illumination. Flares, ranging from small hand-held pop-ups to 30-pound aircraft-dropped pyrotechnics,

83 Moyle Braithwaite comments recorded during tour of U.S. Naval Museum of Armament and Technology (subsequently redesignated a Heritage Center), 2009, 6.
84 S-270, Powell interview, 52.

are indispensable tools for night warfare. They are particularly important for defense of an established position under attack, as was frequently the situation with U.S. forces in Vietnam. Flares are also used by pilots to illuminate ground targets and in search-and-rescue missions. As the Vietnam War heated up during the 1960s, calls increased for a flare that would stay up longer than the standard aircraft-launched parachute-borne flare.

China Lake engineers worked to design an air-launched flare that would produce about 5 million candlepower for 5 minutes. (The existing standard was 2 million candle power for 2 minutes). The chief problem was that for a parachute-borne flare, the heavier payload necessary to achieve the higher candlepower increased the parachute's rate of descent. The choice seemed to be brighter and shorter or dimmer and longer.

Jimmie M. Craig, the project engineer for Briteye, was also a hot-air balloon pilot with three national records. Not surprisingly, the suspension system that Craig and his team designed for Briteye used a small hot-air balloon, rather than a parachute. The principle was sound, but there were obstacles. Briteye project manager Vernon D. Burklund remembered:

> One of the problems that we had during testing was that, as the flare itself was losing weight because of burning, the balloon would then tend to climb up into the smoke and interfere with the light output of the flare. So then it was necessary to provide a mechanism for venting the balloon, to keep it from rising up into the smoke.[85]

A second problem was that with a sink rate of only 4 to 5 feet per second, Briteye was essentially a hovering flare and could remain in the air after burnout long enough to endanger aircraft. To solve this problem, the flare emitted a red light during the last 30 second of burnout to alert the pilot that burnout was imminent; at burnout, a destruct system consisting of strands of pyrotechnic material threaded into the balloon's seams deflated the balloon, thus clearing the air of hazards to aircraft.[86]

The biggest problem with Briteye was that manufacturing costs proved to be higher than those for a competing, though lesser-performing, parachute flare produced by Thiokol. Given the enormous quantities of flares that would need to be produced for operations in Vietnam, the contractor's design won out, although the Air Force did have a number of Briteyes manufactured.

An interesting, and characteristically China Lake, aspect of the Briteye program was that instead of using a fixed-wing aircraft or helicopter for the

85 S-271 Vernon D. "Vern" Burklund interview, 15 Oct 2008, 7.
86 *NWC Tech History 1967,* April 1968, NWC TP 4456, 1–16.

many design-and-development-phase drop tests, the program used a full-size hot air balloon. The balloon was much cheaper to operate—and no doubt more fun for Craig and his assistants Dick Zinke, Bob Willard, and Jim Andrews.

John H. "Jack" Lyons, who shared an office with Craig, recalled that the initial request by the Briteye engineers to purchase a hot-air balloon for the test was turned down by the department:

> That's "No, we can't have any toys in our department." So they regrouped and figured out "Well why don't we just buy a thermal aerostat [the technical name for a hot-air balloon] in pieces?" So they ordered a thermal aerostat burner, OK, they got that. Then they ordered a thermal aerostat basket or something. Little by little they had all the components and so they put them all together, went out on the range—next thing you know there's a big hot-air balloon testing a flare.[87]

Once inflated, the 62,000-cubic-foot balloon could stay aloft with two passengers for up to 5 hours at a cost of about $1.75 per hour in propane. Plus it provided a more stable platform for test drops than did a hovering helicopter. During the course of the project, Craig piloted the balloon to an altitude of 20,000 feet and on a nonstop flight of over 50 miles.[88]

Lyons observed that:

> When it proved very valuable, everybody wanted to use the platform for testing; maybe a sensor, where you could suspend it over the range and do something with transmission, receiving or whatever. So it became a very popular test bed for other things. That was the can-do attitude.[89]

Fakeye was a system of dispenser-released aerially emplaced decoys that, to enemy search and surveillance radar, would appear as Fleet surface vessels. The system appears not to have gone beyond the study and analysis phase, which was completed in 1963.

Walleye

Walleye, one of China Lake's must successful weapons, was part of the Eye series in name only. One might say that the Free-Fall Weapons Program bought the naming rights to the weapon.

According to Jack Crawford, "It was pretty much local for a long time. And we finally got $95,000 . . . from the office that was doing the Eye series of weapons, and they're the ones who gave it the Walleye name." It had formerly been known as Snoopy and Fetch.

87 S-282, Jack Lyons interview, 22 Oct 2008, 69–70.
88 *Rocketeer*, 23 Sept 1966, 1, 3.
89 S-282, Lyons interview, 70.

Walleye's conception far predated Spangenberg's 1959 solicitation of "new air-launched non-nuclear weapons" that led to the Eye series. Volume 3 of this series traces Walleye's roots to a 1934 memorandum by Radio Corp. of America's Vladimir Zworykin in which he proposed a "flying torpedo with an electric eye." In 1957 Crawford (then head of the Systems Design Branch in the Aviation Ordnance Department) and fellow engineer William H. Woodworth had sought the support of AOD Department Head Newt Ward to begin exploratory-development work on an automatic television tracking system that would guide an air-to-surface weapon—despite McLean's reservations.[90]

Walleye co-inventors Jack Crawford (above) and Bill Woodworth (below).

"The Walleye program was a problem of trying to get a missile to work air to ground," McLean said, "and I didn't think it would work. Jack Crawford and Newt Ward said it would."[91]

"He was unconvinced," said Crawford, "but in another organization, if the Technical Director thinks it won't work, it gets killed. Bill was smart enough to realize that you don't always know whether things will work and so you ought to let people give it a try."[92]

Crawford's partner in the Walleye endeavor, Bill Woodworth commented:

> There were two geniuses I've known in my life: one was McLean and the other was Crawford. Jack was and is always the one that had the ability to unify aerodynamics and guidance laws and electronics . . . I would say I was always the one who probably had a more detailed capability of system design. That's kind of the synergy.[93]

90 Babcock, *Magnificent Mavericks*, 455–459.
91 S-87, Dr. William B. McLean interview, 16 Nov 1973, 6.
92 S-171, Crawford interview, 20 Sept 1988, 17.
93 S-215, William H. Woodworth interview, 20 Aug 1992, 82.

Walleye AGM-62 glide weapon on A-4 Skyhawk aircraft.

When Lillian Regelson's list of candidate weapon concepts went back to Spangenberg in 1959, it included Walleye. As Frank Knemeyer, explained "Though it was actually started beforehand . . . it helped to sustain the funding for Walleye because we had included it in this conventional package."[94]

Neither a guided missile, nor a true bomb, nor a rocket, Walleye was a TV-guided glide weapon. A fair summary of the weapon's function was given by President Lyndon B. Johnson at a press conference less than three months after he had taken office following President Kennedy's assassination in November 1963.

> . . . the Navy has recently demonstrated the Walleye, a guide [*sic*] bomb to be launched from an airplane and guided to its target by television.
>
> The bomb has a television camera which is focused through remote control by the pilot in the airplane. Once the pilot has focused the camera on the target, the mechanism in the bomb takes over, watches the television screen inside the bomb, and then guides it until it reaches the target.
>
> The Walleye has been demonstrated and it has shown amazing accuracy at a range of several miles. It is being developed by the Naval Ordnance Test

94 S-200, Knemeyer interview, 27.

> Station at China Lake, California, where the now famous Sidewinder missile was developed.[95]

Crawford explained part of the reasoning behind the Station's investment in Walleye:

> Before we started Walleye, we had looked at some bomb damage assessment pictures from Korea. And, you can see a bridge standing there and the whole countryside around is pockmarked with bomb craters in an attempt to take the bridge out. And, from a military standpoint, you've subjected to pilots to risk over and over again, and you don't like to do that. . . . That was part of what led to "we really ought to be able to do something better."[96]

"Something better" meant something more accurate. The WWII tactic of carpet bombing population centers with the hopes of destroying some industrial capability had become distasteful to the nation. It would become more so through the 1960s, as the same technology that guided Walleye also brought pictures of combat carnage from Vietnam into people's living rooms.

As early as 1943, both the Army and the Navy had looked into television as a means of guiding a bomb to its target. The earliest attempts were command guided. These included Robin, a glider missile that carried a TV camera in the nose and a TV transmitter and radio-command system in the tail. An operator had to hang around after weapon release and watch the television screen while guiding the weapon to the target. Advances in radar-guided antiaircraft guns would make this launch-and-loiter tactic an increasingly high-risk operation.

Another inherent weakness of the earliest TV weapon concepts was enemy jamming of the bidirectional signals (TV signals to the aircraft and control signals back to the weapon). The ultimate goal of the air-to-surface-weapons community was an autonomous, unjammable, highly accurate "launch and leave" weapon.

WWII television technology was still rudimentary, unsuited by size, weight, and reliability to the rigors of combat. With a booming post-war economy came a surge in demand for home TV viewing. TV technology became more mature, and military designers were watching. By the end of the 1940s, the invention of the transistor (rugged, tiny, cool running) provided the key that would weaponize television.

In 1951 Frederick C. Alpers and a team at NOL Corona developed an automatic contrast-tracking TV guidance system called AVOSET (Automatic

95 "Transcript of the President's New Conference on Foreign and Domestic Matters," *New York Times*, 2 Feb 1964.
96 S-241, Jack Crawford interview, 4 March 2005, 34.

Video Optical System of Edge Tracking). According to Alpers, "No AVOSET missile was ever actually built and flown; we couldn't really sell it."[97]

Six years later Woodworth, Crawford, and their group picked up where Alpers had left off.

Using discretionary funds from Station overhead, as well as some informal funding support from other programs, such as Sidewinder, team members built a TV guidance system that could go into a bomb. They introduced a gimbaled mount for the seeker, gyro stabilized it, and narrowed the field of view so the seeker could see more clearly. They built a small, compact, entirely solid-state camera system that worked on a standard U.S. commercial signal (AVOSET had employed a nonstandard scan) and developed new video-processing techniques and the first practical electronic light-level control. The engineers had a free hand to try any approach that showed promise.

"That's why it was the best place in the world to be," commented Earl Donaldson, who designed the Walleye gyro. "I had my hobby, gyros; I had the free hand to do the gyro as long as I could make it work for them."[98]

Marc Moulton, who arrived at the Station in 1967, was just in time to start designing what would be the second-generation Walleye seeker. He concurred.

> We had freedom to pursue ideas. . . . If I needed a brand new integrated circuit that just came out on the market . . . I would simply call up a guy named Bob Greene in procurement on the telephone and say, "Bob I need one of these," and it would be on my desk within 2 weeks. . . . At the time, solid-state technology was advancing so rapidly that if you didn't do that, your design would be obsolete before you ever got it finished.[99]

As with the early satellite-launching efforts at NOTS, China Lake's designers had no compunctions about borrowing ideas and concepts from other local programs. The gyro stabilization of Walleye's seeker was a page straight out of Sidewinder, and indeed many of the Sidewinder technical personnel helped with the nuts and bolts of the early Walleye design efforts.

One of the trickiest aspects of Walleye's development was figuring out the algorithms to process the video image, translating the contrast of light and

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97 S-118, Frederick C. Alpers interview, 27 and 28 Jan 1981, 21. The Corona lab was merged with China Lake in 1967, and Alpers transferred to China Lake in 1971 when the Corona facility was closed. Alpers was the recipient of the Arthur S. Flemming Award as one of the outstanding young men in government service (1960), as well as of the L. T. E. Thompson Award (1967).

98 VP 07-82, "The Pursuit of Precision. Walleye, the TV-Guided Glide Bomb," China Lake Video Projects, 2007.

99 S-245, Marc Moulton interview, 14 June 2007, 7–8.

dark into a meaningful tracking guidance scheme. The weapon's view had to be visually displayed on a cockpit monitor, so that the pilot could see what the weapon was locked onto.

The breakthrough was Crawford's concept of a two-loop tracker. The television electronically tracked the target by itself, independently moving the tracking crosshairs. "It's not smart enough to know that a bridge is a bridge or a car is a car or a tank is a tank," Moulton explained, "But it can know an edge is an edge and try to stay stuck on that edge."[100]

Then the gimbal, with the seeker, would electronically track the position of the tracking gate. "And it formed a dynamically stable system from which error signals could be taken easily and used to control the aerodynamic fins," Woodworth explained.[101]

The guidance system was shaping up, and by 1960 wind tunnel and sled testing of the aerodynamic configurations for the Walleye airframe were under way at China Lake. David Livingston, head of AOD's Missile Development Branch B—Crawford headed Branch A—took over as Walleye program scientist in 1960 and continued as program manager for the next 12 years. (He was recognized for his leadership of the Walleye effort with the L. T. E. Thompson Award in 1967.) The first tactical airframe configuration of Walleye was drop tested in 1961.

Weapon power, to run the onboard electronics and the actuators that moved Walleye's control surfaces, posed another challenge. Batteries were rejected because of weight concerns. The next option was a hot-gas generator, but designing one that could last for perhaps a minute and a half of flight proved difficult. The Walleye design team abandoned that and instead selected a ram-air-turbine generator, the RAT, that used an airstream-driven propeller to provide both electrical and hydraulic power.

Dale Knutsen, the Walleye flight-test engineer, called the RAT solution a:

> . . . very clever arrangement, because you didn't have to carry batteries. And you only have that thing operating when it's in the air so . . . you're not wearing anything out, or you're not having to check battery leads after a period of time. However, those blades operated at a very high speed and they make quite a noise. And probably very few Americans have ever heard a Walleye—quite of few of our enemies have. They are a screamer.[102]

100 Ibid., 29.
101 S-215, Woodworth interview, 32.
102 S-259, Dale Knutsen interview, 17 Sept 2008, 40.

That noise was not a concern to the Walleye designers. "As one Marine aviator put it, the scream simply allowed the enemy to die all tensed up."[103]

The first air launch of a self-guided Walleye in 1962 was a failure. A control loop had been hooked up backwards, and the weapon plummeted to earth out of control. On the second test, 27 November 1962, the weapon successfully guided to a target on Baker range. It was not until April 1963 that NOTS submitted a Technical Development Plan for Walleye to BuWeps. The TDP was approved. The proposed weapon would be a standoff (16-mile range when launched from 30,000 feet) TV-guided precision munition with a 750-pound warhead.

NOTS was instructed to farm out the production engineering to the Naval Avionics Facility, Indianapolis (NAFI), and the fuzing to NOL, Corona. Bud Sewell assigned Mel McCubbin the warhead-design task. Harry Potts and his crew from Public Works constructed specialized targets in Burro Canyon for warhead development testing. (The resulting linear-shaped-charge warhead, despite containing only 500 pounds of high explosives, proved far more effective than many larger traditional-design warheads.) Even as the weapon evolved to a level of Fleet readiness, China Lake engineers were developing refinements and upgrades for the system. Pilot production of Walleye began in 1965.

On 11 June 1965, Lieutenant Commander Francis "Frank" Pesenti was flying a Walleye test against a trailer target on Baker Range. The weapon was guided but contained no warhead. Lieutenant Douglas S. "Doug" Mayfield was flying photo chase on the mission in an A-4C, assigned to follow the weapon, photographing its flight from launch to impact. The Walleye flew unerringly to its target, struck the target, and knocked the wheel and axle assembly into the air where it ripped a wing off Mayfield's aircraft. Mayfield was killed in the crash.

Walleye testing continued in 1966, with launches being made by the Air Force, VX-5, Naval Missile Center, and NOTS. Zero miss-distance was achieved in 31 of 50 launches. In April 1966, the first live-warhead Walleye round was launched at China Lake, totally destroying its 18-inch-thick concrete-reinforced target. The following month, VX-5 began Operational Evaluation of the system. A $24-million Walleye production contract was let to Martin Marietta Orlando Aerospace Division.[104]

On 12 January 1967, Walleye was declared ready for Fleet use and was immediately deployed with Attack Squadron (VA)-212, the "Rampant Raiders," in *USS Bon Homme Richard* (CVA-31) to Vietnam. Since operational

103 Dale Knutsen, "Walleye Notes, a Few Rambling Remembrances," comments for China Lake Museum Foundation, July 2007.
104 NOTS TP 4237, *NOTS Tech History 1966*, April 1967, 1-22.

evaluation at China Lake had not been entirely completed, the operations from the "Bonnie Dick" were classified as "combat operational evaluation."

Six of the VA-212 pilots, flying the Navy's new and more powerful A-4Es, were selected to fly Walleyes against targets in Vietnam. Group members called themselves the "Succulent Six" and "Smart Bombers."

Ironically, to properly evaluate Walleye's effectiveness against real-world targets, the pilots opted to fly in tandem, one pilot dropping the weapon and the second aircraft, fitted with both video cameras and gun cameras, following the Walleye to the target. This was precisely the scenario in which Mayfield had been killed, with the added dangers of a live warhead (and commensurately larger aerial debris field) and enemy ground fire.

The VA 212 pilots were well aware of the danger of that maneuver. Nevertheless, as Lieutenant Commander Mike Cater explained:

> . . . we thought it was necessary. . . . and the only way you could get data was to watch it hit. . . . that was stupid and we all admitted that, but it, you know it was also essentially a requirement, so we did it. The data went back, the photos went back, everybody did what they did, and that was the end of it."[105]

The data that came back to China Lake was used by NOTS pilots, analysts, and engineers to refine the weapon and its launch and delivery techniques.

On 19 May 1967 (Ho Chi Minh's 77th birthday), VA-212 and its Walleyes took out the Hanoi power plant. In Cater's words, "It was proven at that point." The weapon was also used against bridges, railroad trains, military barracks, and high-value targets in urban settings where accuracy was essential. In the Air Force's own combat operational evaluation of Walleye on the F-4 aircraft, the weapon had eight direct hits in nine combat launches.[106]

During its 1967 tour, VA-212 launched more than 43 Walleyes against targets in North Vietnam with 39 on-target hits. Of the pilots who carried out those missions, five of the Succulent Six made it back to the States. The sixth, Commander Homer Smith, VA-212's commanding officer, was shot down during a raid on the Bac Giang power plant in North Vietnam and died in a North Vietnamese prisoner of war camp. He was posthumously awarded the Navy Cross, the highest award for valor in combat that the Navy can bestow.[107]

Walleye was the first air-launched weapon to deliver on the promise of high accuracy, high pilot survivability, and minimal collateral damage. It was also

105 S-243, Cdr. Mike Cater, USN (Ret.), interview, 12 Oct 2007, 19.
106 VP 07-082, "The Pursuit of Precision."
107 *NWC Tech History 1967, Part 2,* April 1968, NWC TP 4456, 1.

Walleyes ready for their first flight over Vietnam, 11 March 1967. On the deck of *Bon Homme Richard* with a pair of Walleyes on an A-4E Skyhawk are Tom Taylor (left), on temporary duty from China Lake, and VA-212 CO Commander Homer Smith.

the first modular weapon system—different weapon sections, such as wings or warheads, could be interchanged to suit the needs of a particular mission.

China Lake, never content to rest on its laurels, would go on to develop Walleye II, which was released to the Fleet in 1974. Walleye II boasted nearly triple the warhead weight of the original Walleye. An extended-range data-link (ERDL) version of Walleye II, fielded about 1975, stretched the weapon's range to 45 miles and allowed the pilot to update the weapon's aim point after launch.

Although Walleye was the Station's primary electro-optically guided weapon, two similar programs were under way during the same period. Development of Condor, which was essentially a Walleye with a rocket motor (originally liquid fueled and later solid fueled), began in 1961. Although Condor development under China Lake's technical management was completed in 1975, the weapon was never fielded.

Snipe, which Station engineers conceived in 1962, was a small (72-pound) optically guided missile designed for ground attack from helicopters and small fixed-wing aircraft. The Army supported Snipe development for several years, but when that funding ceased, in 1969, the program was terminated.

Through Walleye, the Station expanded its core expertise in electro-optical guidance technologies. NOTS would apply this expertise to the development of fire-control systems (such as the Angular Rate Bombing System), sophisticated range instrumentation (for data collection and test control), and control systems for targets and remotely piloted vehicles.

Later, China Lake would develop charge-coupled devices (CCDs) for air-to-air-missile imaging, shuttered video technology (the basis of today's TV slow-motion-replay technology), low-light all-weather seeker technology, the guidance system for the first Standoff Land Attack Missile (SLAM) version of Harpoon, and, in the 21st century, Spike, the world's smallest precision "fire-and-forget" missile.

Weapons Requirements Studies

The Eye series was indicative of a sea change in U.S. weapons policy. As China Lake (and, to a lesser degree, other DOD laboratories) continued to conceive and develop new weapons, against the backdrop of a widening conflict in Southeast Asia, it was clear that the focus of U.S. weapons acquisition was shifting from nukes to weapons of limited war.

By 1962 the Department of Defense under Secretary Robert Strange McNamara was already beginning to have concerns about the variety of conventional ordnance used by the three services. The proliferation of specialized weaponry generated to meet specific services' needs ran contrary to McNamara's penchant for efficient organization and systematization.

Carl L. Schaniel came to China Lake in June 1962 as an associate for operations analysis in Code 12, where he was assigned responsibility for the group's mathematical tools.[108]

One of his first assignments at China Lake was the Non-Nuclear Ordnance Requirements (NNOR) Study. Annually each service submitted its budget requirements for non-nuclear (conventional) ordnance. DOD had discovered that there was no agreement between the services on the effectiveness of their non-nuclear ordnance across the spectrum of limited-war scenarios.

Schaniel pointed out a pertinent example:

> . . . for a Russian MiG aircraft, the Air Force kill criteria was a hole in the aircraft. The Navy kill criteria were a hole in the engine block, the electronics,

108 Schaniel, who had worked for 11 years at the Naval Electronics Laboratory, was recruited to China Lake by then Weapons Planning Group Head Dud Colladay. Schaniel would take over Code 12 in 1965, when Colladay left NOTS for the Center for Naval Analyses, and would lead the group for the next 12 years.

> or the fuel tank. It is easy to see that these criteria would lead to widely different ordnance requirements. The annual weapons procurement budgets were in the billions of dollars. So this was not a trivial issue. [109]

DOD directed the services to clarify and resolve the differences. Schaniel opted to let others concentrate on the details of the 1962 requirements (there was never enough money in the DOD budget to fill everyone's "requirements," anyway) and instead to focus his efforts on creating a sound base for future computations—and in the process to more firmly establish China Lake's expertise within DOD's increasingly competitive ordnance-development community. Schaniel recalled:

> I had the China Lake leaders in the effectiveness computations develop briefing materials displaying each element of the effectiveness comparisons. I then integrated all of this into a single briefing so the process was transparent to the Washington offices. When the procurement budgets were sent in to the Washington offices, we had in hand this briefing on the computational process.

He and others gave a well-received "detailed one-hour briefing (the short version)" to all interested parties. As a result, Deputy Secretary of Defense Roswell Gilpatric, McNamara's right-hand man, sent a commendatory memorandum to Secretary of the Navy Fred Korth. It said in part:

> The Navy study of non-nuclear ordnance is, in Mr. McNamara's and my considered opinion, one of the finest accomplishments to date in this area. The Navy's application of war models and the use of operational analysis represent a breakthrough in logistics planning and the rational development of material requirements. . . . You should implement the recommendations contained in the Study. Of particular importance is 'the assignment to a permanent OPNAV organization the continuing task of analyzing weapon systems effectiveness so that it may be used as a basis for determining further requirements, new weapons introduction, and procurement budgets.'[110]

China Lake had always been known as the place that could build a better weapon. Now the NNOR bolstered a parallel reputation that had been established with Atlantis, Mercury, and other important Code 12 studies. The NNOR study demonstrated that NOTS, foremost among DOD laboratories, understood the theoretical and mathematical framework for assessing weapons effectiveness—and used that understanding to build the necessary tools for carrying out national defense policies.

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109 Carl Schaniel, "Carl's Career Chronology," Aug 2007, 58. Provided by the Schaniel family.

110 Ibid., 60.

Additional Eye Weapons

Even as Schaniel was hammering out the NNOR study, new weapons were added to the Eye series. Deneye, an air-launched dispenser for mines, began development in 1962. Deneye 1 dispensed antitank mines and Deneye II dispensed antipersonnel mines (which could be set to self-destruct at preset times from 6 hours to 7 days) or a mix of antipersonnel/antitank mines. These were among the earliest of "self-sanitizing" mines.[111]

Although later cancelled, the weapon points up an advantage of China Lake's full-spectrum capability. When Weapons Development Department engineers were designing Deneye's antitank submunition, they called on the Public Works Department, which maintained a Soils and Materials Testing Laboratory.

The lab was routinely used for such mundane but essential tasks as evaluating candidate resurfacing materials for the Station's 400 miles of road. To determine the behavior of the Deneye submunition when it impacted various soil types, Public Works engineers performed in-place density, grain-size analysis, soil classification, and moisture determinations.[112]

Fireye was a gelled-fuel "close-support flame weapon," not unlike napalm. With its clearly defined edge effects (unlike fragmentation weapons) the weapon was safer to use than was conventional ordnance in close proximity to friendly troops. NOTS developed the aerodynamic shell, fuses, and an effective fuel-gelling agent. Both Powell and Gustafson flew development tests for Fireye. Although the weapon itself was not fielded, the portable fuel-gelling unit was used extensively by the Marines in Vietnam. The gelled fuel burned longer and hotter than napalm and could be made with available fuel supplies.

In 1965, the Station was assigned Deputy Assistant Program Manager (DAPM) status for the weapons in the Free-Fall Weapons Program, which gave China Lake responsibility for the direction and funding of related efforts by contractors and by other laboratories that had previously been funded by BuWeps. (Rockeye II was the first weapon to be developed with NOTS as DAPM, and at one point the Station had responsibility for managing 13 other field activities involved with Rockeye.)[113]

Cracking the management whip over the Eye series was Peggy Rogers. In July 1966 she was presented the Navy Superior Civilian Service Award—the Navy's second highest civilian award—by Richard A. Beaumont, Deputy

111 Dickinson, *Glossary of Project Titles*, 23.
112 *Rocketeer*, 3 July 1970, 1.
113 *Rocketeer*, 9 Feb 1973, 1.


Dr. Marguerite "Peggy" Rogers

Under Secretary of the Navy for Manpower. The award citation noted Rogers' "strong leadership and management in the development of the free-fall weapons as represented by Snakeye I (Mk 81 and Mk 82), Snakeye II, Sadeye, Gladeye, Rockeye I and Rockeye II, Weteye, Bigeye, Padeye, Misteye, Fireye, Deneye, Briteye, and the Walleye warhead."[114]

The previous year, Rogers had received the L. T. E. Thompson Award "for outstanding technical leadership and effectiveness in managing and directing the development of a large portion of this country's conventional warfare arsenal, the Free Fall Weapons System Program."[115]

Rogers was loved by her employees, and she was fiercely protective of them. Edwin V. "Ed" Alden, who specialized in warhead detonation physics in Rogers' group, said "I've seen her make a three-star admiral cringe."[116]

While some of the Eye weapons reached the Fleet and were used successfully in combat and others barely got off the drawing board, each benefited from the same "make-it-work" attitude that characterized China Lake's approach to every new weapon or system. For example during the development of Sadeye—a multipurpose dispenser weapon for bomblets and submissiles—an extended cook-off test was needed. The test would show how the weapon would react if it were exposed to a prolonged fire on a ship or at a storage area. Jack Lyons—an aeronautical engineer and former Navy pilot—was the Sadeye project manager.

114 *Rocketeer*, 5 Aug 1966, 1. In 1974 Rogers would become the first woman to head a technical department at China Lake: Code 40, the Weapons Development Department. Her sons, Alexander "Sandy" Rogers, Fred Terry, and Robert, worked on base as civil servants (Sandy retired as head of the Naval Air Warfare Center Weapons Division Range Department in 2002), and her daughter Alison worked there as a contractor. Sandy's son James is employed at China Lake as a computer scientist.
115 *NOTS Command History* 1965, 28. Rogers was the first woman to receive the award.
116 Ed Alden, telephone interview, 16 June 2011.

He remembered that:

> They needed to run some more wires out to the cook-off area and they needed another chart recorder and they needed this and they needed that . . . I just couldn't afford to expend that kind of money. So I took the equipment up there with my sleeping bag. . . . I had some food and water. And I stayed there until it cooked off in the middle of the night, wrote everything down, turned off the chart recorder and then when the sun came up I had finished up, packed up what I needed to, came back. . . . I got the test done and it didn't cost hardly anything to get the results because I needed them. But lots of things like that were expected. We were expected to be resourceful, get the job done, don't look for excuses how you can't do it—find a way where you can do it.[117]

Sadeye—titled rather grandly the Sadeye Universal Weapons Dispenser—went into production in 1964 and was available for Fleet use in 1965. Five loaded versions, varying in their bomblet types, were produced.

The Eye series was a large part of the Station's activities. Although Eye programs touched every department at China Lake, most of the work was managed from Frank Knemeyer's Weapons Development Department and the majority of those programs were located in Peggy Rogers' Air-to-Surface

Four Sadeyes during development, on A-4 aircraft, Armitage Field, 1962.

117 S-282, Lyons interview, 27.

Waldo Born in January 1964, shortly after he learned the truth about Fisheye.

Weapons Division.

By 1963 Code 40 was the "largest organization at the Naval Ordnance Test Station in terms of project dollars assigned and spent annually," according to the *Rocketeer*. The department controlled the expenditure of nearly $25 million (about $175 million in 2009 dollars), and its programs represented "a Station-wide effort involving 650 persons" (about 13 percent of the total civilian complement).[118]

The prevalence of Eye weapons provided the inspiration for a practical joke at Armitage Field. One day Ray Powell told his friend and fellow test pilot, Lieutenant Commander Waldo Born, about a new weapon concept called Fisheye. Top Secret. Very hush hush. But Powell might be able to get Born in on it. Born was excited—the Eye weapons were usually flown on newer A-4 jets and his qualification was in the older A-1H propeller aircraft.

In truth there was no Fisheye weapon, but over the next few weeks the

118 *Rocketeer*, 28 Feb 1964, 5, 8; *NOTS Command History* 1963, 18.

entire squadron, from VX-5's skipper, Commander Harry N. O'Connor, to Aviation Ordnanceman Petty Officer Third Class R. F. Lacey, who had come up with the name Fisheye, got into the act. Born was given intentionally abstruse "briefings" on Fisheye and was cautioned about the weapon's very sensitive fuze. On 2 successive days, Fisheye's maiden flight was cancelled because of high winds. When finally the very keyed-up pilot went to his plane on the third day, he found hung on the starboard wing a yellow bathtub, complete with six goldfish, and the sensitive fuze—a release lanyard running from the plug up to the cockpit.

A *Rocketeer* photographer was there (along with most of VX-5), and a good laugh was had by all. The photo and story were picked up by *Naval Aviation News* and one must assume that the story followed Born throughout the remainder of his 30-year Navy career.[119]

The Military Edge

Essential to the success of the Eye series—and every other weapon-development program at the Station—was the military. Civilian-military cooperation in the weapons-development process was not a new phenomenon; it had been growing steadily since the First World War. Al Christman wrote that during the period from WWI to the end of the Korean War:

> The relationship between American science and the military changed from indifference to collaboration. The result was a weapons revolution that perfected radar and created the first mass-produced smart weapons, modern military rockets, guided missiles, and the atomic bomb.[120]

China Lake, from its founding in 1943 until the 1970s, was unique among military laboratories in the nature of the relationship between the Station's military and civilian components. Part of this was circumstance: the base was remote and isolated. China Lake's employees, unlike their counterparts in more urban work settings, did not spend the day at work and then scatter to farflung neighborhoods to enjoy their private social lives after work and on weekends. China Lakers, military and civilian, not only worked together, but also lived together and played together. The familiarity bred a mutual respect.

"The people who came to work here were not only a part of a company, but they were also part of a community, and a very close-knit community at that," observed C. John Di Pol, who culminated his 31-year career at China Lake as

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119 *Rocketeer*, 25 Oct 1963, 1, 4; Ray Powell, email to the author, Oct 2008.

120 Al Christman, *Target Hiroshima: Deak Parsons and the Creation of the Atomic Bomb,* Naval Institute Press, Annapolis, 1998, 5.

head of the Range Department.

> The fact that your next-door neighbor or the guy behind you was the person who was in the next department or at Armitage Field . . . went a long way in helping to solve the problems which are inherently created in any large organization; the interpersonal relationship problem, the jurisdictional problems, etc. And the fact that we lived and played together was a principal force in our ability to get along in our business relationships and to solve problems that might come up between us.[121]

The bright line between work and leisure that later became the norm was absent at China Lake in the 1940s and '50s and '60s. That absence was often a shock for newcomers, but they soon got over it. "One had to adjust," said Lee Jagiello. "Actually, everybody enjoyed that. It was kind of funny. You could see a party break up, and everybody would go down to the laboratory. And go to work. Everybody got ideas."[122]

The Officers' Club was the watering hole of choice for scientist and officer alike. This unusual mixture on occasion caused consternation for an officer newly assigned to the Station. Ashworth related in a 1969 interview:

> I remember that we had some new people arrive, some new aviator types, and I guess they were in the air facility there. One of these characters got pretty well loaded up with beer one day and said, "I don't see what all these God damned civilians are doing up here in our Officers' Club." He said, "Somebody ought to do something about it." So you get him over in the corner and hit him over the head a few times and straighten him out and tell him the facts of life, and tell him to shut up and go about his business. "This is not an Officers' Club in the normal sense; this is the Naval Ordnance Test Station Club and it's as much civilian as it is military, and now shut up!"[123]

"Every project was assigned a Navy officer, usually a pilot," Frank Knemeyer recalled. "When briefings were given to Fleet personnel aboard ship, the officer gave the briefing, with the civilians as backup. Military to military was very effective."[124]

The relationship between the military personnel and civilians at China Lake was complex and multifaceted—disparate cultures of scientist and warrior interfacing in the management, social, and political spheres. Commanding Officers argued with Technical Directors, scientists gave presentations to Pentagon admirals and generals, sailors' wives joined with engineers' wives to

121 S-119, John Di Pol interview, 9 Feb 1981, 21.

122 Jagiello and Moran interview by Westrum, 33.

123 S-61, Vice Adm. Frederick L. Ashworth interview, 9 April 1969, 94–95. Civilians were also welcome at the Chiefs' Club (enlisted rates E-7 through E-9), Acey Deucy Club (E-5 and E-6), and Jolly Roger (E-4 and below).

124 Frank Knemeyer review comment, 16 Aug 2011.

set up Girl Scout troops. There was no end of association between military and nonmilitary personnel. This close relationship was foreign to the leaders back East. "People back in Washington and other places would say 'Well, you're unique? What's unique?'" Knemeyer said. "They didn't understand how good it could be from a technical standpoint, social standpoint, because they'd never really experienced it."[125]

The most productive point of contact between the two cultures, in terms of the quality of China Lake's weapons, was during a weapon's design, test, and evaluation phases. Designs formulated by scientists and engineers were tempered with the operational experience of the sailors and aircrews who would ultimately use the weapons.

This process of tempering desire with realism worked both ways. "Sorry, Captain, you can't have a death ray mounted in the nose of your aircraft, the technology's not there yet." But more often it was the experienced military user who might observe "Looks good, Doc, but on a pitching deck at night in the rain, I don't think it'll work. Unless of course you . . ."

Captain John I. Hardy put it this way:

> The chance for the people dealing directly with hardware and making the technical decisions to have a feel for what goes on on a flight deck or down in the magazines . . . you can't get any other way than by dealing directly with the Fleet people, and it is the key I think to the success or failure of the average weapon.[126]

It was not unusual to find engineers at Armitage Field watching sailors assemble and load ordnance, and asking, "Why do you do this or that?" The answers could make a difference in how a part was built, or a tolerance specced, or a process implemented in a new weapon system. It was more than "human engineering." It was "Navy engineering." The Fleet was the focus. John Lamb, a central figure in the development of the Chaparral system, emphasized the practicality of the relationship:

> We'll put together a team of military people. We may or may not have any of our civilians with them. But that team will go out ride a carrier, ride an airplane, a boat, whatever it takes to talk to the people today, right now, doing that job and they'll be at the right level. And they'll come back and tell us here's what the problem is, here's what we're doing, here's what we need to do.
>
> It's an immediate ability to step into the world today of what's going on out there and bring that information back into the very, very front of the design

125 S-200, Knemeyer interview, 143.

126 S-34, Capt. John I. Hardy interview, 13 Feb 1967, 2. Hardy was NOTS Commander from August 1964 to February 1967.

process. That's not in industry. I don't think you could put it in industry.[127]

Ray Powell recalled being invited by Peggy Rogers to briefings on new weapon concepts in the early 1960s:

> She wanted an operational pilot up there to listen to the brief and the concept for the weapon that they were going to do . . . they had every damn thing you could think of—some of the wildest things. Some of them were good, some of them were bad. So Peggy Rogers would get operational people in there and listen to it and see if there was anything really stupid in it. . . . The scientific part of it she didn't need me, believe me. . . you sit in there and then you wouldn't understand 10 percent of what they were saying. But then you get to the bottom line of what you do when you get ready to drop the S.O.B. . . ."[128]

Military aviators at China Lake had two separate organizational homes. One group was the NOTS project pilots, both Navy and Marine, who worked exclusively for the development projects. This group was in the Station's military chain of command, part of the Naval Air Facility, a subcommand of NOTS located at Armitage Field. The second group was the VX-5 pilots. These Navy and Marine flyers were assigned to Air Development Squadron Five (known as the "Vampires), also located at Armitage Field. VX-5 was a tenant command at China Lake and answered to Commander, Naval Operational Test and Evaluation Force (COMOPTEVFOR), in Norfolk, Virginia. The Vampires concentrated on Operational Evaluation (OPEVAL) of new weapons—testing how well they would really work in operational use, in peace and war, and how effective they were—as well as the development of delivery tactics.[129]

The organizational distinction reflected a two-tiered system of military influence in the weapon design process. NOTS project pilots worked directly with scientists, engineers, and technicians in the development of a new weapon: inspecting it, strapping it on a plane, and flying a few or sometimes hundreds of test flights, all according to carefully crafted test plans. The project pilot's subjective evaluations complemented the data obtained from telemetry and range cameras as well as instrumentation on the project aircraft and the test item itself. VX-5 pilots conducted the Operational Evaluation of a weapon system and developed the tactics for its use after the system had completed development at NOTS and flight clearance at Patuxent River.

Late in 1960 the Projects Department was established at NAF under the

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127 S-313, John Lamb interview, 20 and 22 July 2010, 124.

128 S-270, Powell interview, 44.

129 Operational Evaluation assignments for weapon systems were based on the type of weapon: VX-1 (Key West, FL) for antisubmarine warfare systems, VX-4 (Point Mugu, CA) for air-to-air weapons, and VX-5 for air-to-surface weapons.

leadership of Commander R. L. "Larry" Walker. During a 22-year Navy career, Walker accumulated 7,825 hours in 62 different aircraft types. A combat pilot with four air-to-air kills to his credit, he was a graduate of the first Navy test pilot class in 1948 and had previously served as chief test pilot at NOTS in 1950.

Prior to NAF's establishment of the Projects Department, the relationship between the Navy and Marine aviators who flew for the various technical programs at NOTS and the civilian engineers who worked on those programs had "been on a pretty loose and informal basis," said retired Navy Commander Anthony L. Tambini II, a NOTS project pilot from 1961 to 1965.

> Typically, the engineers would tell the [NAF] Operations Department that they needed a plane and pilot for a test, and the Operations Department provided it. When the engineer was ready to fly, he would tell the pilot what it was that the program people wanted the pilot to do, and he did it if he could. This was an accident waiting to happen, and sometimes it did.[130]

Under Walker and his successor, Commander John A. "Jack" Sickel, the Projects Department formalized the procedures for the pilot-project interface. Projects Department pilots were assigned to the individual test programs and reviewed each proposed test before it was approved for flight.

"The work demands a special type of individual," said Sickel, a 1946 Annapolis grad. "One out of every 10 aviators has the makings of a successful project pilot. . . . We represent the airborne eyes, ears, and senses of reaction to the scientists and engineers on the ground."[131]

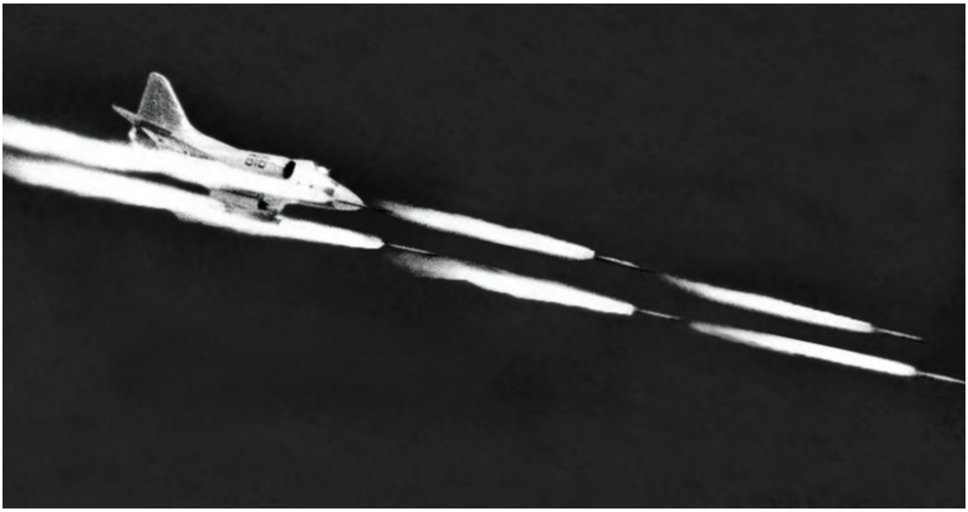
The benefits of formalizing the roles of project pilots were several. First, a clear understanding of roles enhanced the safety of the flight-test process. Second, by bringing pilots into the test-plan-development process, some redundant testing could be eliminated. A third benefit was that it helped the pilots better understand the problems in developmental testing.

Speaking of the "scientist-pilot relationship," project pilot Lieutenant Jim Kistler said "There's a kinship between us that welds us together. Their problems are ours, too."[132]

For a pilot, "flight test can be a frustrating business," said Tambini.

> On average, pilots are scheduled for, and man up, five airplanes for every one that actually gets into the air. I've spent day after day going from briefing to preflight, to taxi maybe, and back to the hangar, only to repeat the process

130 *The Flying Tambinis*, unpublished autobiographical manuscript by Tony and Angie Tambini, circa 1988, Ch. 9, 19. Excerpts provided by Tony Tambini, Oct 2008.
131 *Rocketeer*, 2 Aug 1963, 4.
132 Ibid., 5.



A4D-2N aircraft firing salvo of 5-inch Zuni air-to-ground rockets over China Lake ranges.

> several more times without getting a minute of flight time. It's just the nature of the job.

But the frustrations paled beside the excitement and satisfaction of the job. "China Lake is as close to heaven as a pilot can get," Tambini wrote.[133]

With the pilot more intimately involved in the test design—and by extension in the development process—the inevitable delays and gear malfunctions were more a shared burden between the pilots, who were now part of the team, and the project personnel. "It made a major difference when the 'big picture' was known by all hands involved," Tambini observed.[134]

The Civil Service project engineers often flew as aircrew during testing, particularly when the aircraft involved was a (two-seat) TF-10, TA-4F, or F-4. "Their knowledge, experience, and ability to assess system performance were invaluable to mission completion," wrote Ernest Mares, who as a lieutenant commander served as Shrike project pilot in the mid 1960s.[135]

While China Lake was "as close to heaven as an aviator could get," it was even closer in another sense; the work was dangerous. Decisions made in a split second could make the difference between life and death for a pilot, and often whether the decision was right or wrong was simply a matter of luck.

133 *The Flying Tambinis*, Ch. 9, 19, 2.
134 Ibid., Ch. 9, 19
135 Ernie Mares, email to the author, 11 July 2011.

Although everyone agreed that the weather at China Lake was ideal for flying, there was one down side to it—the wind. Flight operations were normally suspended if the wind reached 35 knots (about 40 miles) per hour. The problem wasn't the aircraft, which were designed to fly in all weather at nearly all wind speeds, but rather safety if a pilot had to eject over the desert.

Many people who have never visited the desert envision it as soft sand and gentle sweeping dunes. While the Mojave Desert has isolated examples of that type of topography, most of the high-desert terrain is hard-packed caliche, coarse dirt, and rock, covered sparsely with low brush (primarily creosote bush and rabbit brush) and networked with shallow washes and ravines. A 35-knot wind pushing an emergency parachute across that unforgiving desert floor would almost certainly result in death or serious injury to an aircrew member.

The standards for pilots participating in the weapons-development process at China Lake were exceptionally rigorous, even for seasoned military aviators. Captain Marco Renella told of one of his first assignments at China Lake:

> They sent me out to the Bravo-2 instrumented range with a slick-wing A-4E loaded with 24 Mk 76 practice bombs. I flew three hops that day, performing 72 individual bombing runs.

Renella was satisfied with his accuracy and "suspected the engineers would be happy with the results." But at the debrief, the lead engineer:

> . . . proceeded to go through each run and tell me where I had not met their requirements. My 30-degree runs ran between 28½ and 31 degrees. "When we ask for 30 degrees, we mean 30 degrees." Also, my delivery speeds were between 442 and 457 knots. "When we ask for 450 knots, we mean 450 knots."

Embarrassed, Renella turned to leave. The engineer "put his hand on my shoulder and shared with me that the fellow I was replacing was the best they had ever seen, but he was sure I would measure up with a little sharpening of the flying skills. (That pilot had been killed on the range about a month earlier.)"[136]

The work was difficult and dangerous because the pilots were working with new unproven technology and with engineers who would make frequent, even daily, changes to systems. Even with the greatest safety precautions every flight had the potential for disaster, and the days were long and tiring. Tambini recalled a test of Rockeye I:

> The whole Rube Goldberg looked flimsy, and I said so. My mouth earned me a trip to the range with one of these little dudes attached to my centerline

136 Capt. Marco Renalla, USN (Ret.), "Naval Weapons Center China Lake," *Skyhawk Quarterly*, Spring 2006, 11.

> bomb rack. At about fifteen thousand feet over the range in a programmed unbalanced flight condition, the entire weapon disintegrated. All of those little warheads, they were dummies, thank God, went bouncing along the underside of the airplane wiping out a good portion of the wings, the landing flaps, and most of the underside of the tail section of the airplane as well. Another A4 was sent to the scrap heap.[137]

Pilots, of course, did not fly their aircraft single-handedly. They were supported by a highly trained workforce of primarily enlisted personnel who maintained the aircraft, loaded and unloaded weapons, guided the pilots through crowded airspace via the air-traffic-control system, provided daily weather reports, processed intelligence and naval communications, and carried out the myriad other tasks necessary to keep the aircraft operating safely. The inputs of these sailors, particularly the observations of the "ordies" or ordnance handlers, were essential to the weapon development process.

A weapon had to not only achieve its combat goal of destroying the target but also fit seamlessly into a complex system of transportation, training, maintenance, and documentation, to mention only a few categories. While one engineer might be designing the fragmentation pattern of a warhead, another would be ensuring that the weapon would fit a standard launch rack—the ordies would be the first to know if it didn't—or that the weapon canister's seals were impervious to the salt spray on a carrier deck.

Overseeing every major weapon's development was the Station's Design Review Committee. Composed of senior scientists, engineers, and managers, the DRC scrutinized the development program at key milestones to ensure that rigorous standards and controls were maintained throughout the development process.

When a new weapon reached a sufficient level of maturity in its development at China Lake, it was transferred to Naval Air Test Center, Patuxent River, Maryland, for testing to ensure aircraft compatibility. Following a positive outcome at "Pax River," the weapon was turned over to VX-5 for Operational Evaluation. The Vampires' job in OPEVAL was to "wring the weapon out," exercise it throughout its entire operational envelope and to develop delivery techniques and ordnance-handling procedures for the weapon. Until it had passed OPEVAL, a weapon was not ready for Fleet introduction.

When Ray Powell came to VX-5 as a Marine captain in 1962, he was assigned to Project OV28, the Conventional Weapons Project. Previously, under COMOPTEVFOR guidelines, each individual weapon project was

137 *The Flying Tambinis,* Ch. 9, 20.

required to get special permission to modify aircraft, transfer funds, etc., putting a heavy administrative burden on the pilots who were doing the flight testing. Project OV28 was a "multiple-aircraft, multi-task, multi-weapon" project, which allowed pilots to concentrate on the more essential tasks of evaluating the weapon with the aircraft.[138]

Powell explained the process:

> When you would get a particular aircraft assigned to carry Zuni rockets for instance, you'd write out a test plan for that—you write out the parameters of the test, what you're going to do, and program so many flights doing 10 degrees, 20 degrees, 30 degrees, 45 degrees, whatever,. You come up with the best altitudes, airspeeds . . . and you put out a handbook [an Advanced Evaluation Note, AEN] and you put out all of the stuff necessary to release it: air sensitivity analysis, fuzing options and all. . . . There's a section in there tells you how to load it and how to wire it and the fuzing options to use on it, what kind of fuze, and whether you use an electrical fuze or a mechanical fuze, and then it gives you the delivery parameters . . . .[139]

As with developmental testing (conducted during the concept development and engineering development phases of a weapon system's life), OPEVAL was hazardous and demanding, even when conducted according to carefully designed test plans that incorporated every conceivable safety protocol. "Mishaps" were not uncommon for VX-5 and project aircrews, and fatalities were all too frequent.

But each test flight produced a bit more information about the performance of the system under test, and this information was fed back into the system's specifications, part of a production package that, after thorough testing at the Station, was turned over to a contractor for limited production and subsequent full-rate production (all under the watchful eye of China Lake's technical specialists). Once full-rate production was under way, "article acceptance testing" continued to ensure that the manufacturer was following the production specifications package to the letter.

Even after the weapons had been released to the Fleet and were being used in combat, feedback from the operational community played a big role in refining both the weapon itself and delivery tactics.

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138 Powell, who was assigned to VX-5 in 1962-1965, typified the quality of the aviators, both Marine and Navy, who were selected for duty at China Lake. Nearly all were graduates of the Air Force or Naval Test Pilot School. Powell, who was an infantry platoon leader prior to attending flight school, was awarded the Cunningham Trophy as Marine Aviator of the Year in 1966. He retired as a colonel in 1982.

139 S-270, Powell interview, 41, 43. The AEN is an interim publication; it is formalized in a tactical manual (TACMAN), which provides all the information necessary for the pilot to accurately deliver ordnance.

When Powell returned in January 1967 from his 115-mission combat tour in Vietnam, he spent a month at China Lake debriefing the civilian and military weapons-development teams. Commander (later Captain) Gary H. Palmer served with Powell at China Lake, and the two pilots flew the Snakeye portion of the weapons demonstration for President Kennedy in June 1963.

Later Palmer served in Southeast Asia as a commander of Attack Squadron 144 (VA-144) aboard *USS Kitty Hawk* (CV-63). He regularly sent letters to NOTS describing both successes and problems with China Lake-developed weapons and equipment.

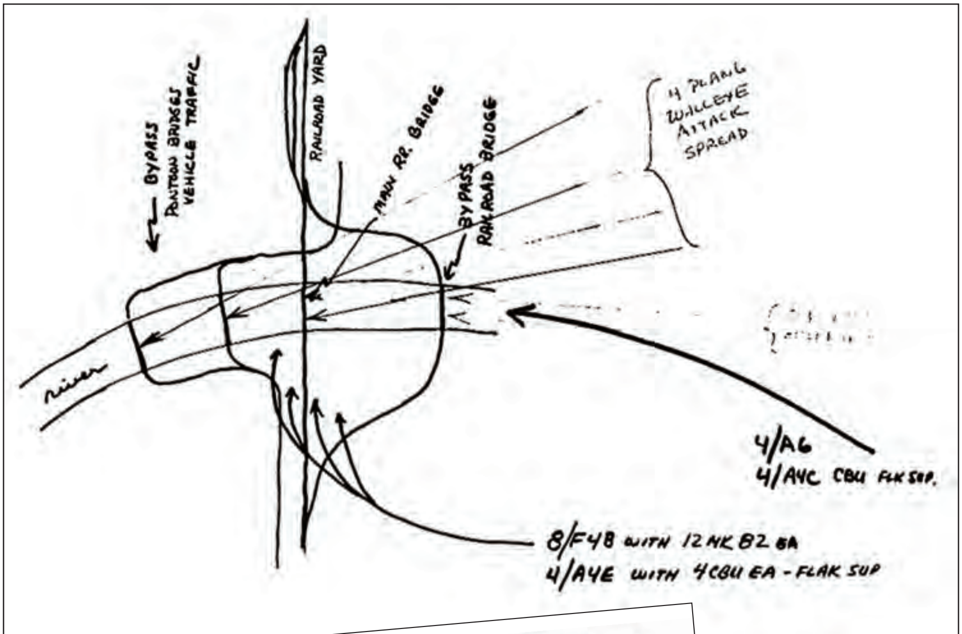
The de-emphasis on nuclear weaponry and re-emphasis on conventional weaponry in the late 1950s and early 1960s required major adjustments for the entire naval aviation community. Aircraft carriers were oriented to the delivery of nuclear weapons. The Navy's newest jet aircraft, the A4D, was designed to carry nuclear weapons.

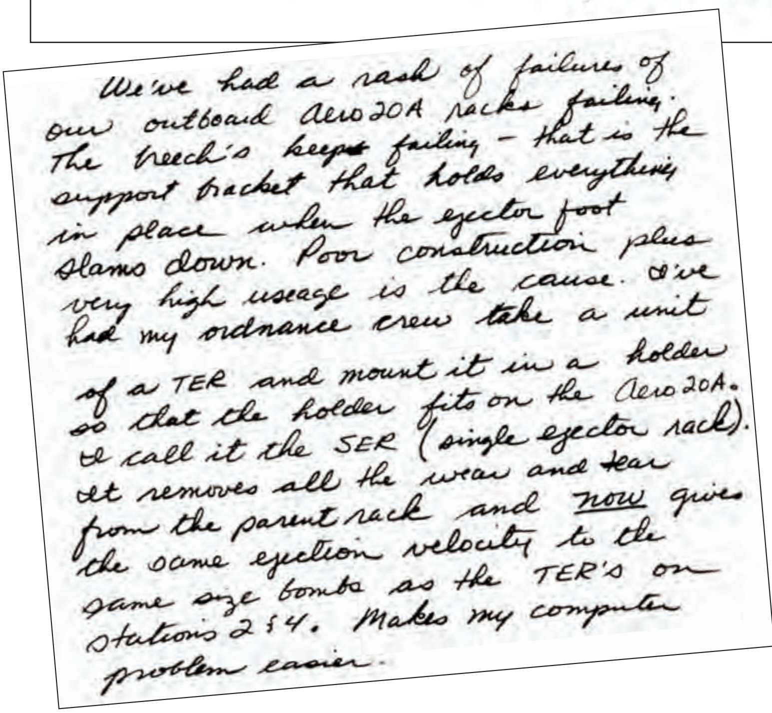
VX-5, until 1959, had been almost exclusively concerned with developing delivery tactics for nuclear ordnance. Captain Bill Fitch and other China Lake pilots saw the writing on the wall, particularly in terms of the incompatibility of conventional weapons designed for limited war with high-speed attack aircraft designed for nuclear weapons delivery.

As a result, two systems were developed at China Lake that sprang not from the fertile minds of China Lake's scientists and engineers nor from the conference rooms at the Bureau of Naval Weapons nor from the hallways and admiral's offices in the Pentagon. These systems—the Banded Bomb System and the Multiple Carriage Bomb Rack—were conceived and developed by the military personnel at Armitage Field.

One obvious shortcoming of the early jets (to the pilots) was the ordnance-carrying capacity. The aircraft had been designed to carry heavy nuclear bombs or large air-to-surface missiles, such as the AGM-12 Bullpup, so each weapon pylon—the points of attachment for a weapon to the aircraft, usually on the center fuselage and under the wings, also called hard points—could accommodate only a single weapon. The FJ-4B, for example, could carry 6,000 pounds of ordnance but had only four underwing pylons. The A4D had three external storage points, but one had to be used for carrying fuel. Banded bombs were as simple as the name implies. Three Mk 80-series conventional bombs were locked together with two metal straps, and these straps were attached to the pylons with pylon-lugs.[140]

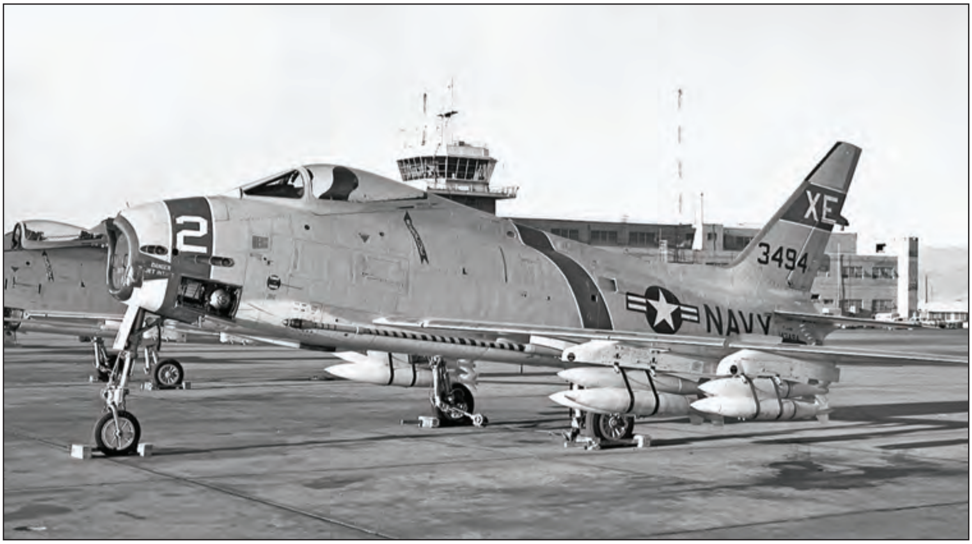
140 The Mark 80 bombs are GP (general-purpose) blast/fragmentation bombs. They include the Mk 81 through 84 with nominal weights of 250, 500, 1,000, and 2,000




We've had a rash of failures of our outboard Aero 20A racks failing. The breech's keeps failing - that is the support bracket that holds everything in place when the ejector foot slams down. Poor construction plus very high useage is the cause. I've had my ordnance crew take a unit of a TER and mount it in a holder so that the holder fits on the Aero 20A. I call it the SER (single ejector rack). It removes all the wear and tear from the parent rack and now gives the same ejection velocity to the same size bombs as the TER's on stations 2 & 4. Makes my computer problem easier.

Excerpts from Commander Gary Palmer's letters from Yankee Station discussing tactics and problems encountered in operational use of China Lake-developed systems.

pounds. About half of the bomb weight is explosive filler. GP bombs are distinguished from special-purpose bombs such as cluster bombs, fire bombs, fuel-air-explosive bombs, penetrator bombs, etc.



FJ-4B aircraft carrying banded bombs, NAF Tower in the background, 1959.

"Where the FJ-4B could carry a maximum of four bombs without the strap arrangement, with the metal strap concept we would increase that total to twelve," said Fitch.

> That banded bomb solution was accomplished by the NOTS ordnance shop [Ordnance Department, NAF], them alone, but I did the test flying to prove that it worked. The NOTS folks were fabricating the steel bands, banding the bombs, putting three banded bombs on each pylon of the FJ-4B.[141]

The bands were designed to separate from the bombs on release, so that the bombs would fall individually. In one low-altitude test using three 250-pound bombs, the bomb impact points formed an isosceles triangle 40 feet across the base and 70 feet to the apex.[142]

Major Knowlton P. "K. P." Rice came to VX-5 at about the same time as Fitch. The two Marines, with the support of VX-5 Executive Officer Commander Dale Cox, invented a device that turned the A-4B aircraft (at that time designated the A4D-2) into a close-air-support system that fairly bristled with conventional ordnance and that would become the Navy's workhorse light bomber in the early years of the Vietnam War.[143]

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141 Fitch interview, Marine Corps Oral History Program, 141.

142 *Technical Program Review 1958*, 114.

143 Rice, who Fitch characterized in his 2006 interview as "an absolutely brilliant man" also developed a rear-view mirror for the A-4 (to observe contrails, which would make the aircraft more detectable). He and another Marine, W. H. Beckett, developed the concept for the OV-10A Counter Insurgency Aircraft, which later became the OV-10 Bronco.

The A-4, according to Fitch:

> . . . was not much of an aircraft when it came to thinking about conventional weapons delivery. The A4D-2 in 1958 had three bomb stations, which were a centerline Aero 7A pylon, and an Aero 20 pylon on each wing. A pilot had his choice, where he could carry a high-explosive bomb on each of the three pylons on the A4D-2 (A4B) for a grand total of three bombs for close air support or he could carry a centerline 150 or 300 gallon external fuel tank along with one bomb on each wing station for two HE bombs, or he could carry two 150 or 300 gallon drop tanks on the wings for deep strike and have a one bomb delivery. As a conventional bomber in 1959, the A4D-2 was pathetic.[144]

Fitch and Rice conceived of the Multiple Carriage Bomb Rack (MCBR), which would fit on the existing single-bomb pylons of the A-4. They scrounged Aero 15 bomb racks from a wrecked AD Skyraider propeller aircraft at "the

VX-5 A-4 aircraft with Multiple Carriage Bomb Racks loaded.

Following a tour in Vietnam during which Rice earned a Distinguished Flying Cross and several other decorations, he would serve another tour at China Lake as USMC Liaison Officer, 1967–1969. He currently heads Volante Aircraft Co.

144 William Fitch, "Development of the Multiple Carriage Bomb Rack," 11 Nov 2006, *www.skyhawk.org/2c/a4parts/mcbr.html,* accessed 30 July 2009.

junk yard dump where they parked the wrecked aircraft at China Lake" and requisitioned channel iron and steel tubing. As Fitch recalled:

> The squadron metal-smiths then got busy, assembling the first MCBR which would go on the centerline of the A4B. With torches they would cut the channel iron and then they would weld the pieces in the right place, according to the scheme K. P. and I had given them.

Stepper switches allowed the pilot to select which bombs would be released from the rack: singles or salvo. On 30 September 1959 Fitch made the first flight with the MCBR.[145]

A Marine weapons meet was scheduled for Marine Corps Air Station, Yuma, in December 1959. This was a high-visibility competition of naval and Marine aviators. Among the visitors would be Vice Admiral Robert Pirie, Assistant CNO for Air Warfare.[146]

The meet would also include a fire-power demonstration. Fitch talked with the meet coordinators and got on the schedule.

> When I flew by the stands and turned the belly up to the crowd [displaying not 3 but 16 bombs on his MCBRs] Vice Admiral Pirie was reported to have said (by the Weapons Meet coordinator) words to the effect of "We are going to buy that." After the fly-by the stands, I did the low-angle loft maneuver as planned, with ten bombs in the air, and then I delivered the six Mk 81 off the centerline MCBR in a skip bombing run. Everything worked to perfection.[147]

The following year, Douglas Aircraft Corp. was given a contract for 2,000 bomb racks based on the MCBR. On 25 February 1964, Fitch, Rice, and Cox were awarded U.S. Patent No. 3,122,056, "Multiple Carriage Bomb Rack." When Fitch left China Lake in 1960, he was replaced by Captain Hal W. Vincent. One of Vincent's projects was to demonstrate the capability of the F-4 to deliver a single Mk 28 (later B28) nuclear bomb. He was soon assigned Project OV5 (the predecessor of Powell's Project OV28) for "development of tactics and delivery for conventional weapons."

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145 Ibid.

146 Interestingly, the Light Jet Attack competition at the Weapons Meet that year was won by a team from VA-56: Cdr. Larry Walker, Lt. (j.g.) Tony Tambini, and alternate Lt. (j.g.) Edward E. Luetschwager. All three would later serve in the NAF Projects Department.

147 Fitch interview, Marine Corps Oral History Program, 150. Fitch would eventually rise to the rank of lieutenant general. His career accomplishments included serving as the Commanding General of the First Marine Air Wing and as the Marine Corps' Deputy Chief of Staff for Aviation. Among his numerous decorations were the Silver Star Medal awarded for a single-plane A-6A night-attack mission against a target in Hanoi, North Vietnam. Fitch said China Lake offered "one of the best tours in my Marine Corps career."

Lieutenant Colonel Thomas H. Miller, Jr., in his F-4 aircraft with VX-5's MCBRs carrying 5½ tons of bombs, 1961.

One day, as a joke, he hung one of the A-4's MCBRs on the centerline of the nuclear-weapon-capable F-4. A photograph was taken, it began to circulate, and the next thing Vincent knew queries were coming in about the new "capability." The machine shop got busy and soon an MCBR was cut in half, wiring was installed, and a triple ejector rack for the F-4 was the result.

Vincent soon received a call from a fellow graduate of the Air Force Fighter Weapons School who wanted to "borrow" some of the racks to show off the Air Force's conventional capability. Vincent checked with his boss, VX-5 skipper Captain Karl S. VanMeter, and the question was rapidly escalated to Vice Admiral Pirie's level. Pirie said no and explained, as Vincent recalled, that "the Naval Service was going to put on a show with the new conventional weapons and racks that would show the world who had the conventional weapons capability."[148]

Lieutenant Colonel (later Lieutenant General) Thomas H. Miller, Jr., R&D project officer for the F4H-1 (later the F-4B) picked up the story:

> I received a call from Admiral Pirie to go to Edwards and pick up F4H-1F (Bu. No. 145310) which had been fitted with some unconventional bomb rack mounts, and fly it first to St. Louis so the MAC plant could check over the installation, and then fly it to Cherry Point to put on a maximum bomb drop demonstration for the Air Force TAC Commander. I arrived at Cherry

148 Maj. Gen. Hal Vincent, USMC (Ret.), email to the author, 7 May 2008.

> Point on 21 April 1961. The plan called for a maximum bomb load drop of 22 500-pound bombs on the Camp Lejeune target range on 25 April 1961.

That flight and a subsequent demonstration the next day "went off without a hitch."[149]

Tactical air power demonstrations such as these, before audiences that included congressional representatives and dignitaries such as General Curtis LeMay, helped to convince Washington and Pentagon decisionmakers of the utility of conventional weapons and the potency of the weapons systems—and delivery techniques—being developed at China Lake.

The value that NAF and VX-5 pilots and aircrews added to the weapons created at China Lake cannot be overstated. By risking their lives in the sky over China Lake, the aviators refined weapon designs, suggested improvements, detected flaws, developed effective delivery techniques, and, when a weapon was proven ready, finally gave the stamp of approval for its use in combat.

Their work was no less dangerous than that of their fellow pilots who flew in combat—and through the 1960s, most of the NAF and VX-5 aircrews saw combat before or after their tours at China Lake.

Military and civilian teamwork at NOTS had a collateral benefit for the Station's programs—any naval officer or enlisted person who served at NOTS learned first-hand the unique culture and capabilities of the Station and carried this knowledge back to the operational forces. The Station's reputation for having a Fleet-first attitude and a practical approach to solving Fleet problems was reinforced through frequent visits by NOTS technical personnel to operational units stateside, on the ocean, and overseas.

Another important military link between NOTS and the operating forces was the Experimental Officer (later Technical Officer), a military position born of a relationship that predated NOTS' establishment. When Dr. L. T. E. Thompson, NOTS' first Technical Director, was Chief Scientist at the Naval Proving Ground, Dahlgren, from 1923 to 1942, he worked closely with young naval officers who had been assigned there for postgraduate ordnance training. From 1939 until he left Dahlgren, Thompson reported to Commander (later Rear Admiral) William S. "Deke" Parsons, Dahlgren's Experimental Officer. Rear Admiral Sherman E. Burroughs, NOTS' first Commanding Officer, said of Thompson and Parsons, "They were both pioneers in developing a good military-civilian relationship based on mutual respect."[150]

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149 Lt. Gen. Tom Miller, quoted on the website of Lt. Col. Donald Edward Cathcart, USMC (Ret.), *http://www.mofak.com/Jet_Air_to_Mud_Arms.htm,* accessed 30 Jan 2010.

150 TMP 366, "The Founding of NWC," China Lake documentary film, 1973, excerpted

Parsons was not only a military officer but also a gifted scientist—he had worked with Dr. Vannevar Bush in development of the radar proximity fuze and headed the Ordnance Division at Los Alamos during the Manhattan Project. He had also been the weaponeer and bomb commander on the Enola Gay when it dropped the atomic bomb on Hiroshima on 6 August 1945.

Based largely on the success of their working relationship at Dahlgren, both Parsons and Thompson believed that their model of a military scientist acting as liaison with civilian scientists could be similarly effective at the new Station in the desert. The relationship was enshrined in the NOTS Principles of Operation, approved by Admiral George F. Hussey, Jr., Chief of the Bureau of Ordnance, in 1946. Commander John T. "Chick" Hayward was selected as the Station's first Experimental Officer, serving in that capacity from 1944 to 1947.[151]

The Experimental Officer, located organizationally on the Commander's staff, had a staff, usually of commanders and lieutenant commanders. In 1961 the position of Experimental Officer was disestablished, and its primary function of providing liaison between the Station and the Fleet, as well as between the Station and Washington policy makers, was divided between the two newly established military advisory functions of Plans and Operations Officer and Technical Officer.[152]

A comprehensive 1981 study of the Experimental Officer/Technical Officer position observed that:

> The role [of the Experimental/Technical Officer] clearly is to be the NWC interface between operations in the Fleet and the scientist developing weapons at NWC. Execution of this role varies with the personality and aggressiveness of each individual officer.[153]

As the years passed, the influence of the position was eroded, its power became more circumscribed, and its mission grew less specific and more cluttered with ancillary duties. Indeed, when the title of Technical Officer was changed to Deputy Laboratory Director in 1977, no functional statement for the position was included in the Organizational Manual. As the importance of the position waned, those selected in Washington to fill the slot were not of

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in "Pictures of Us II, Episode 1. A Station Having For Its Primary Function . . .," China Lake, Video Projects, 2007. In 1948 the title of NOTS' senior military officer changed from Commanding Officer to Commander.

151 "NOTS Principles of Operation" as approved by BuOrd, 21 Oct 1946, reproduced as Appendix F, *Grand Experiment at Inyokern*, 403–404.

152 *NOTS Command History* 1961, 4.

153 Frances Matthews and Mary McIntire, *History of the Experimental/Plans & Operations/Technical Officers/Deputy Laboratory Directors at the Naval Ordnance Test Station/Naval Weapons Center (NOTS/NWC)*, TS 85-38 (Draft), Oct 1981, 8.

the caliber of the earliest NOTS Experimental Officers. Dr. Richard E. Kistler, head of NOTS' Office of Finance and Management, summed it up:

> In earlier years they were just about always Annapolis graduates and five of the first six made admiral. In later years, they are seldom Annapolis graduates and they don't make admiral.[154]

Several of the men who held the slot advanced to positions of power and influence in the Navy. Foremost was four-star Admiral Thomas H. Moorer (Experimental Officer from 1950 to 1952), China Lake's highest ranking military alumnus. He served as commander of both Atlantic and Pacific Fleets, as Chief of Naval Operations, and, from 1970 to 1974, as Chairman of the Joint Chiefs of Staff, the nation's senior military officer.

Four other Experimental Officers reached the three-star rank: Vice Admirals John T. Hayward (1944-1947), Jack P. Monroe (1949-1950), Thomas F. Connolly (1952 to 1954), and Thomas J. Walker III (1954 to 1955). Captain Carl O. Holmquist (1961 to 1963) attained the rank of rear admiral and served as Chief of Naval Research in the early 1970s. (Captain Vincent P. dePoix, a NOTS project pilot, went on to become a vice admiral and to direct the Defense Intelligence Agency.)

Although NOTS was a military base, most of the Station Commanders were wise enough not to try to impose the same level of "militaryness" found on most military bases—even those with a large civilian component. Fred Nathan, a Central Staff administrator, was for many years NOTS' organizational communications officer. On several occasions he was invited to speak at the Army Management Engineering Training Agency in Illinois, a management school for both military and civilian employees. He recalled:

> I was always struck with the fact that these were middle and senior managers attending the seminars—almost all from military activities—and they seemed really astounded that an activity, a military activity, would countenance the kind of openness, the kind of bottom-up communication, the kind of permissiveness—in a constructive way, I think—that was permitted here.[155]

NOTS Commanding Officers were also in a position to support the Station during their later careers. While for certain officers, NOTS was their final tour—"lame duck COs," Newt Ward called them—others went on to hold influential positions in the Navy years after their NOTS tours.[156]

154 Memo 08/REK:rs/58a, 08-0296-82, R. E. Kistler, Head, Office of Finance and Management (Code 08) to Technical Director, "Role of Technical Officer," 12 Nov 1981, in Matthews and McIntire, TS 85-38, 8.

155 S-192, Frederick M. Nathan interview, 17 July 1991, 6.

156 S-94, Ward interview, 19.

Captain P. D. Stroop, for example, who commanded NOTS from 1952 to 1953, was the first head of the Bureau of Naval Weapons when it was formed in 1959 and commanded Naval Air Forces, Pacific Fleet, from 1962 to 1965. He retired as a vice admiral. Captain Frederick L. Ashworth, Commander of NOTS from 1955 to 1957, also made three-star rank and commanded the Sixth Fleet from 1966 to 1967.[157]

Not to be overlooked in the group of military alumni who helped NOTS is Levering Smith, who came to NOTS as a commander in 1947. He served in various positions, including department head and Associate Technical Director, until 1954, then went on to lead the Polaris Missile Program and to become a vice admiral. It is to him that the Station owed many of its assignments in support of the Special Projects Office, as well as funding to support numerous projects and facilities.[158]

The senior NOTS military alumni maintained their knowledge of what was going on at the Station through both formal and informal contacts with China Lakers. Lillian Regelson wrote that on one visit to Washington:

> I ran into Tom Connolly (then Deputy Chief of Naval Operations (Air Warfare)) in the hall in the Pentagon. He asked me to make a presentation to his staff. He introduced me by saying, "Just because she's wearing a skirt, don't assume she doesn't know a lot more about this than you do, because she does."[159]

Operations Evaluation Group

Another reason for the success of China Lake's weapon-development programs was a little-known organization called the Operations Evaluation Group (OEG), later the Center for Naval Analyses. In the dark days of 1942 when German U-boats were decimating Allied shipping in the Atlantic, OEG was established as the Anti-Submarine Warfare Operations Research Group. OEG comprised civilian scientists, most from MIT, who pioneered a field called operations research and analysis, which has since become one of the

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157 In a 1975 interview, McLean observed that the officers who "moved up best are the ones who came as Experimental Officers at China Lake. See, the Experimental Officer comes in without having to take the responsibility for the laboratory, whereas the Commanding Officer has to take the credit for both the progress and the mistakes." S-97, 38–39.

158 In *Magnificent Mavericks*, 479-480, Babcock wrote, "Throughout his distinguished naval career, he sent work to China Lake and supported that work with the necessary funding. As technical director of the Polaris Missile Program, he also sponsored underwater-launch test facilities at San Clemente Island and the Skytop propulsion-test stand, the nation's largest static test facility, at China Lake."

159 Regelson email to the author, 13 Nov 2008.

central disciplines used in military planning and complex problem solving. While arcane definitions of "operations research" abound, Kistler explained it simply:

> A major part of most practical operations research studies consists of identifying the real problem (as contrasted with what the problem is initially believed to be), describing the problem in a logical context, and collecting information needed to put the description in quantitative form. Once these steps are completed, the actual solution may often be straightforward.[160]

OEG not only provided analytical assistance to the field units but also furnished the Secretary of the Navy, the Chief of Naval Operations, and the Marine Corps with information that was critical to top-level decisions as well as for planning the weapons, tactics, and capabilities to meet mission requirements.

Phil E. DePoy, after completing a master's degrees in nuclear engineering at MIT, joined OEG in 1959. At that time, OEG had representatives serving one- and two-year tours with all Fleet commands as well as with each of the air development squadrons. In 1960 DePoy was assigned to VX-5, working directly for the squadron's commanding officer while keeping OEG apprised of the analyses he was doing. When DePoy arrived at China Lake, the Station had been working on its new conventional weapons programs for about a year, and Lillian Regelson soon briefed him on the Eye series. He shared an office with Major K. P. Rice and worked closely with Captain Bill Fitch, who was running VX-5's conventional weapons project.

DePoy's job was essentially to be an analytical "hired gun." Sometimes the commanding officer would assign him a task, other times he would identify an issue in development or testing that required his skills and would offer his services.

For example, in 1960 VX-5 was still focusing most of its efforts on nuclear delivery tactics. One big question was the likelihood of flash blindness. "In nuclear delivery, if other weapons are going off in the area while you're delivering, you'd be blinded for a long enough period that you would probably not be able to control the plane," said DePoy.

He tackled the problem, which involved a computer model of the likelihood of an attack pilot getting flash blindness while delivering nuclear ordnance in various areas of the Soviet Union. Rice, who subsequently developed a "buggy top" thermal shield for the A-4 aircraft that would prevent flash blindness, was an engineering genius, according to DePoy.[161]

160 Dr. Richard E. Kistler, "On Operations Research," *News and Views*, July 1967, 7.

161 S-278, Phil E. DePoy interview, 24 Nov 2008, 10; DePoy review comments, 10 Aug

NOTS' hectic pace of conventional weapons development entailed a lot of flight testing, so another task that occupied DePoy's time was designing tests to extract the maximum amount of information from each event. In the process, he developed a familiarity with conventional weapons that was probably unique among his OEG peers and that would stand him in good stead later in his career.

In 1961 DePoy left China Lake for a yearlong tour in Washington. The next year OEG was merged with two other Navy analysis groups to form the Center for Naval Analyses (CNA). In 1963 DePoy was assigned to the 7th Fleet to work for Commander, Task Force 77, in the Western Pacific. He remembered that:

> They were making a transition at that time from nuclear delivery to conventional and of course there was the buildup in Southeast Asia. So almost immediately I got involved in planning strikes and of course I was with them when we started making attacks in Laos in late 1963 and in Vietnam after the Tonkin Gulf incident.[162]

It was on that tour that DePoy saw unanticipated ramifications of the Navy's increasing emphasis on conventional weapons. Aboard *Kitty Hawk* he ran into a warrant officer named Max Gunn, whom he'd known at China Lake.

Gunn was concerned about the ship ordnancemen's lack of skill with loading conventional weapons on aircraft, after years of working almost exclusively with nuclear ordnance. Compounding the problem was a safety restriction for aircraft carriers that forbade the loading of conventional ordnance (except the Sidewinder air-to-air missile) unless it was fired or dropped; training opportunities for ordies were nonexistent.

Rear Admiral Tom South, commanding CTF 77, agreed to submit a request for waiver to the BuWeps to allow the crews to load and unload conventional ordnance. The waiver was granted, and the first training exercise for loading, fuzing, and unloading live conventional ordnance was scheduled. DePoy recalled that:

> The word got out on the ship and created a terrible turmoil, as often happens on ships. I remember a rumor got started that Jeane Dixon, a well-known psychic, had predicted that a major U.S. ship was going to have a terrible explosion that day in the Far East. These types of rumors arise frequently on ships, they get around. So I went to the admiral and I told him about the rumor and I asked 'Do you think we should delay it?' and he said, 'No.' He said, 'You never pay attention to these things,' so we went ahead with it.

2011.

162 S-278, DePoy interview, 12; and review comments.

The exercise did not go smoothly.

> Even with relatively few numbers of aircraft we were loading, it took us probably 4 or 5 hours, and it was a mess . . . I watched ordnancemen who didn't remember ever putting a fuze into a conventional weapon and they would be assuming right-hand threads and of course they were left-hand threads, and oh, it was just a mess.

But the ship's crew persevered.

> We started doing this regularly. We started having these drills, not daily but probably two or three times a week, and we gradually worked it up and were doing more types of ordnance and more planes at a time. Then the admiral ordered the other two carriers in his command to start doing the same thing. It was a real blessing because a month or two later we were launching actual strikes. And the credit goes entirely to Max Gunn![163]

The use of conventional weapons continued through 1964 and escalated sharply after the Gulf of Tonkin Resolution in August. With the increased usage, problems began to arise with some weapon systems that had been neither foreseen in development nor noted in operational testing.

To resolve these problems, Admiral Moorer, then Commander in Chief, Pacific Fleet, and his staff visited China Lake on 4 September 1964. At about 4 p.m., after a day of briefings and discussions, one of Moorer's staff suggested they should wrap up discussions because they went "wheels in the well" at 5 p.m. The admiral responded that "he didn't think the plane would leave without him," so the discussions continued. Once a course of action had been outlined, Knemeyer assigned Peggy Rogers carry out the task.[164]

The following month, Rogers and McLean flew to Hawaii where they met with Moorer's staff. Also in attendance were Lillian Regelson, Captain Ray Powell from VX-5, DePoy and a Seventh Fleet officer, and representatives from BuWeps. After a week of meetings during which problems were presented—"We had a list, pages of items that we came back with," DePoy recalled—and solutions were proposed, the China Lakers returned to the Station with their marching orders. "China Lake followed up and got a lot of these things corrected for us," said DePoy.[165]

Another purpose of the meeting, according to Ray Powell, was to help Moorer's staff write a 20-page message to CNO "establishing Fleet weapons development and improvement requirements and priorities." The CNA analysts,

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163 S-278, DePoy interview, 14-15; and review comments.
164 Frank Knemeyer review comments, 16 Aug 2011.
165 S-278, DePoy interview, 17.

China Lake scientists and engineers, CINCPACFLT military planners, and a VX-5 project pilot represented a powerful combination of disciplines and perspectives to bring to bear on that task.[166]

CNA and China Lake maintained close ties, unsurprising considering that CNA's work was similar to that of the Station's Weapons Planning Group. Frank Bothwell, who as head of Code 12 played a prominent role in developing the Polaris concept, left China Lake to serve as CNA Chief Scientist in 1963. In 1965, when the offices of Chief Scientist and CNA Director were merged, Bothwell was chosen for the post.[167]

Don Witcher, who became Code 12's program director for antiair studies in 1969, had previously spent 5 years as director of CNA's Systems Evaluation Group. Robert A. Blaise, assistant head of the Propulsion Development Department and technical assistant to Hack Wilson, left China Lake to join CNA in 1964. Dud Colladay, who headed Code 12 from 1959 to 1965, also left China Lake for a position with CNA. Captain Frederick A Chenault, NOTS Executive Officer from 1955 to 1958, spent his final military tour as CNO project officer for CNA's Fleet Anti-Air Warfare Study. He returned to China Lake as a civilian employee in 1966 and retired in 1973 as the head of the Systems Development Department.

DePoy would go on to become president and chief executive officer of CNA from 1984 to 1990. He has been a CNA trustee since 1992. Although little publicized, the analysis work of OEG and CNA enhanced the suitability and quality of China Lake products.

Today CNA's mission statement echoes China Lake's principles of Fleet support:

> At CNA we analyze and solve problems by getting as close as possible to the people, the data, and the problems themselves in order to find the answers of greatest clarity and credibility—all to help government leaders choose the best course of action.[168]

Through the 1960s, as today, the quality of China Lake's products could not be ascribed solely to the experience and courage of the Station's military

166 Ray Powell, email to the author, 28 May 2008. Powell also noted, "It was a career highlight for a young Marine captain to have the opportunity to work and be associated with these legends 8-10 hours a day for an entire week. Having dinner at Hawaiian Bar with Peggy Rogers was most enjoyable and highly entertaining . . . With her super intellect, great sense of humor and hot temper, she was truly one of a kind."

167 Keith R. Tidman, *The Operations Evaluation Group*, Naval Institute Press, 1984, 250–251.

168 CNA website *http://www.cna.org/about/cna/*, accessed 30 March 2010.

contingent nor solely to the technical acumen of scientists, engineers, and analysts. It was rather the orderly fusion of the two complementary yet dramatically different military and civilian cultures—the coming together of what Colvard called "the vision of the art and craft of war and the knowledge of the laws of physics"—that resulted in weapons that have been the mainstay of naval aviation for more than 70 years.[169]

169 Dr. James Colvard, "Heritage and Horizons," keynote speech at the China Lake Legends Dinner, NAWS China Lake, 11 March 2009.

4

Cooperative Targets

Here we had a naked Navy; they didn't have much of anything.

Frank Knemeyer, on the need for an antiradiation weapon[1]

Naval warfare is a game of one-upmanship. Increases in the range and accuracy of naval guns in the late 1800s led to the development of superior armor. Germany's use of submarines in WWI led the British to develop the depth charge. Axis mines and barbed-wire beach obstacles intended to deter Allied amphibious attacks during WWII were countered with Bangalore torpedoes. And beginning in the late 1940s, the proliferation of radar-directed guns and missiles among adversaries and potential adversaries led NOTS to begin development of technology pertinent to the Shrike antiradiation missile.

Shrike Missile AGM-45A on VX-5 A-4E aircraft, Armitage Field, China Lake, 1965.

1 S-124, Knemeyer interview, 11.

When the ability to detect metallic objects by bouncing radio waves off them was demonstrated experimentally in 1904, it seemed a technology perfectly suited for naval applications. After all, ships were metallic objects, often colliding at sea or running aground on rockbound coasts, particularly at night.

In 1922 the Naval Aircraft Radio Laboratory (forerunner of NOTS' sister lab, the Naval Research Laboratory), demonstrated the first primitive radar system in the U.S. (The word "radar" comes from a 1940 Navy acronym for Radio Direction and Ranging.)

By the early 1930s, radar was moving out of the laboratories and into practical applications, and at the start of the Second World War, every major combatant had some capability for radio detecting, locating, and ranging.

Because of the extraordinary military potential in radar, staggering amounts of resources were expended to improve and refine radar and radar countermeasures during WWII. Among the radar systems introduced during the war were search radars, tracking radars, fire-control radars, antiaircraft gun-laying radars, and that marvel of technology, the tiny radar-proximity fuze.

In 1942, the National Defense Research Committee began development of the United States' first air-launched radar-guided weapon, an antishipping glide bomb conceived at the National Bureau of Standards. Called Pelican (official designation Special Weapons Ordnance Device (SWOD) Mk 7), the weapon could be fitted with a variety of bombs and was designed to be dropped from a launch aircraft carrying AN/APS-2 radar. The plane's radar would illuminate the ship target and Pelican would home on the reflected signal. The program was terminated in 1944.[2]

Radar-guided weapons fall into one of three categories: passive, which home on an enemy radar's signal; active, which home on a signal that has been transmitted from the attacking weapon itself and reflected back to the weapon from the target; and semi-active, which home on a radar signal reflected from the target by a third-party radar (often from the launch aircraft). Pelican was a semi-active weapon.

A later version of SWOD, the SWOD Mk 9 (called Bat because its active radar homing capability was analogous to a bat's sonar homing), saw use in the Pacific against both ship targets and land targets in 1945. It was designated ASM-2 and later ASM-N-2 but was abandoned not long after the war.

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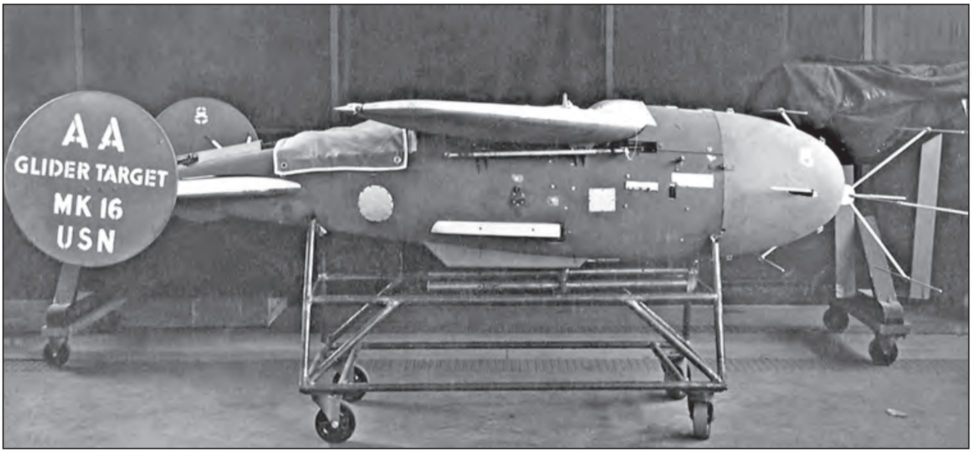
2 Parsch, *Directory of U.S. Military Rockets and Missiles*, *http://www.designation-systems.net/dusrm/app1/swod.html#_SWOD7*, accessed 24 Sept 2009.



Moth, a 650-pound antiradar homing bomb, circa 1945. This Pelican airframe has been converted to a Vulture antiaircraft target. Many of these targets were subsequently converted to Moths by installing antenna and radar receivers tunable to the frequency of a threat radar emitter.

Moth, the nation's first radar-guided defense-suppression weapon, was also developed during WWII, initially by the Navy and later by the Army Air Corps, using airframes left over from the cancelled Pelican program. Designed to guide on the radio-frequency (RF) signal emitted by the German antiaircraft radars, Moth was a passive-homing weapon. It required the cooperation of the target to achieve a kill—but not necessarily to achieve success.

True, if the target radar shut down, Moth had no signal to guide it. However, by shutting down, the radar could no longer supply directional information to the antiaircraft guns, so in that sense the weapon satisfied its defense-suppression mission even though it caused no damage. Like Pelican, Moth was terminated by the Navy before reaching operational capability.

In tandem with the development of offensive radar weapons, defensive systems were strongly supported as well. Frederick Emmons Terman left his faculty position at Stanford in 1942 and relocated to Harvard University where he organized and led the 800-person Radio Research Laboratory. The RRL's job was to develop radar countermeasures, and according to one report, the 150 countermeasures developed at RRL (including chaff, metallic strips that return a decoy signal to radar) saved more than 800 Allied bombers. By the end of WWII, the radar game of cat and mouse, of measure and countermeasure, was well under way.[3]

3 Dawn Levy, "Biography revisits Fred Terman's roles in engineering, Stanford, Silicon Valley" (review of *Fred Terman at Stanford: Building a Discipline, a University, and Silicon Valley*, by C. Stewart Gillmor), *http://news-service.stanford.edu/news/2004/november3/*

Commander William J. Moran arguing his case to Haskell G. Wilson, circa 1955.

In the Korean War, radar-directed antiaircraft guns were a serious threat, taking their toll on United Nations (primarily U.S.) air forces. In early 1952, *Time* magazine reported:

> The enemy has large numbers of big, radar-directed AA guns, 88- or 85-mm. (and possibly a few long-range 120s or 155s; U.S. Sabre jets have occasionally reported flak bursts above 30,000 ft.). . . . and he has radar-directed searchlights, which can hold a night-flying U.N. plane transfixed.[4]

Bill Moran, before returning to China Lake in 1955 for his second tour (as senior experimental officer for air-to-air weapons), had been assigned to a carrier-borne jet night-fighter squadron. The squadron flew the F2H-3 Banshee, which carried a single nuclear weapon and which had eight rocket rails on its wings. The F2H-3, known as a penetrator, was assigned to penetrate the Soviet Union's air defense network in very-low-level flight and carry a nuclear payload to its target. Moran recalled that:

> We used to do quite a little pre-planning and "what if" planning to know what the problems would be, and I began to be impressed with the number of air-defense radars that were to be found in any parts of the world where the Soviet Union had interests. Something like 3,000 of them in the whole inventory. . . . If you had just a Sidewinder-size missile with the radar-homing seeker, it would hear and sense a radar—and in those days all the penetration flights were right on the ground—if you heard something that tracked you and locked on, you could pull your nose up a few degrees and release a weapon in that general direction and just keep right on going because you were going to keep on going anyway, and you may drive him off the air or damage or

Terman-1103.html, accessed 9 Feb 2010.

4 "Battle of Korea: Deadly Flak," *Time*, 11 Feb 1952, 36.

> even destroy the radar. And the principal function that I saw with that was as a penetration aid.[5]

He talked to the “guys in the radar business” at China Lake who were then working on the SARAH, the Semi-Active Radar Alternate Head model of Sidewinder, but they were too busy to devote much attention to developing Moran’s concept. In 1958 he brought the idea to Barney Smith, who had just become head of the Weapons Development Department (Code 40) when Howie Wilcox took over the Research Department.

Moran told Smith, “Even though there’s no requirement for it in Washington, if we’re going to get into this nuclear-delivery business in the future, you’re just going to have to have some kind of help to increase the probability of getting there and kind of hold your attrition during the penetration phase down to something acceptable.” Smith agreed, then, according to Moran, said, “Well, Bill, if you really want to do that, why don’t we do it in my department?” Moran hesitated. The radar missile work (SARAH) was being done in Dr. Thomas S. Amlie’s division in the Aviation Ordnance Department (Code 35).[6]

“I know how I’m going to start,” Moran continued. “I’m going to go over and talk to the Technical Director and tell him that we’ve been talking about starting a guided-missile development program in the Weapons Department. That’s going to get all the people in the organization charts upset, but I’d kind of like to do it.” Moran got the green light. As he recalled:

> McLean was tickled to death. He just loved to work that way. If there was a thing worth doing, he’d like to have four or five people working on it separately. Competition meant that you were combing through the best of the lot of the brains, and you’re going to get slightly or substantially different answers, and you may end up getting the best answer to pick out of several.

Leonard T. “Lee” Jagiello, head of Code 40’s Aeromechanics Division, was selected to head the technical team that would develop Moran’s concept. When he and Moran went back to BuOrd to seek funding, they were in luck. In 1957 Leroy Riggs, a branch head in Jagiello’s division, had gone back to Washington on a temporary assignment to BuOrd as assistant for engineering (air weapons).

With Riggs’ help, Moran and Jagiello persuaded Captain Stanley W. “Swede” Vejtasa, head of Air Weapons, and Captain Edward A. “Count” Ruckner, BuOrd’s Assistant Chief of R&D, to fund an antiradar missile

5 S-187, Moran interview, 17.

6 Ibid, 18–19. Amlie, who had come to the Station in 1952, would become China Lake’s fourth Technical Director (1968–1970).

feasibility program for a year, to the tune of $250,000. When Riggs returned to China Lake in 1958, he took over as ARM program manager.[7]

Comparing the ease of acquiring funding for what would become Shrike with the difficulties of funding the High-Speed Antiradiation Missile (HARM) in the 1970s, Frank Knemeyer commented, "It was a lot easier to sell Shrike because there was a total void for that kind of a weapon system . . . . Here we had a naked Navy; they didn't have much of anything."[8]

Competing Antiradar-Missile Programs

At the earliest stage of its existence, China Lake's antiradar program—then known simply as ARM, for antiradar missile—faced two competing programs. One, in the Air Force, was called Rascal. The other, funded by the Navy, was known as Corvus.

Rascal, developed in the 1940s for the Air Force by Bell Aircraft Corp., used a command-guidance control system (with the weapon's flight controlled by an operator in the launching bomber via an RF link with the weapon). In its original version Rascal was 32 feet long and 12 feet wide, a size too big to fit in the bomb bay of any operational, experimental, or planned bombardment aircraft.[9]

Bell's Rascal was plagued with technical problems. It could not meet the Air Force's requirement of a 300-mile range, so the range requirement was reduced to 100 miles. Rascal carried a nuclear warhead, which always meant increased complexity and expense. It was powered by a liquid-fueled rocket and by virtue of its size had to be carried externally on a large bomber. After dismal test results, Rascal was cancelled in September 1958.

Since 1953 NOL Corona had been working on a passive air-launched weapon (threat-radar-guided) based on the WWII Bat glide bomb. NOL's weapon Bat II (pronounced "Battu") was flown several times between 1953 and 1956, with promising results. "We hit some targets with that," said Fred Alpers. "Those were the first successful flights, flights that actually hit the target with an antiradar missile." About 1956, when the Corona team began to write specifications for the weapon, the name changed to Corvus.[10]

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7 When Sputnik went up in October 1957, Riggs was double-hatted as the first technical director of the quickly formed Astronautics Office. John Nicolaides would follow him in that office when Riggs returned to China Lake.

8 S-124, Knemeyer interview, 11.

9 Rear Adm. D. S. Fahrney, *The History of Pilotless Aircraft and Guided Missiles*, unpublished manuscript, circa 1958, 1308. Coincidentally, a small-scale Rascal test vehicle, used to resolve aerodynamic and other problems with Rascal, was designated Shrike.

10 S-118, Alpers interview, 19.

The Naval Ordnance Laboratory's XASM-N-8 Corvus being prepared for test, circa 1958.

In 1957 NOL's work was incorporated into a much larger air-to-surface missile, which the Navy contracted with Temco Aircraft Company (later Ling-Temco-Vought Corp.) to design. (NOL also transferred some seeker hardware to China Lake.) The Temco Corvus was more ambitious than NOL's original concept. Like Rascal, Corvus had a nuclear warhead. As well as being a passive radar weapon, guiding on the emissions from a threat radar, it was also an antiship missile that could be guided in a semi-active mode by an illuminator radar on the launch aircraft. The weapon incorporated a data link through which it could receive mid-course guidance commands during the semi-active mode until it was close enough to detect the target's radar signals and switch to passive mode.

Corvus also contained a simple inertial navigation system that was a safety backup for the nuclear warhead. Alpers explained:

> You could shoot it in a confined area and set the inertial system as a backup and it would confine the missile. It was a pretty big box, 8 miles or something like that, but it kept the missile from going completely off in another country.

The first test version of Temco's Corvus was launched from an A-4D Skyhawk at Point Mugu in July 1959. In its early tests, the missile showed promise. "It flew actually on a successful flight test against a radar 165 miles off. That's never been equaled since then" said Alpers.[11]

Considerable infighting was taking place in the naval aviation community over Corvus because other missiles—notably the Typhon surface-to-air weapon system (forerunner of the Aegis system) and the Eagle air-to-air missile (forerunner of Phoenix)—were also vying for funding. Weighing against

11 S-141, Frederick C. Alpers interview, 16 Nov 1982, 21.

Corvus was the fact that it was complicated and very expensive. It was also powered by a liquid-fueled engine, a characteristic looked on unfavorably in weapons carried aboard aircraft carriers.

In 1959, in the words of an official Navy history, "The Navy terminated the Corvus air-to-surface missile program in order to permit increased emphasis upon other weapons systems offering a wider scope of employment."[12]

NOTS' First Antiradar Missile

When Jagiello set up the ARM program in 1958, he had already lined up some people with relevant expertise. Radio frequency technologists Robert Etcheverry and Langthorne Sykes had worked on advanced nuclear fuzing for the BOAR project. When BOAR began to wind down, Jagiello took the two men into the Aeromechanics Division. Using the parts from NOL's Corvus, they started developing an antiradiation seeker.

Also in Jagiello's original crew was Steve Carter and Leroy Doig, Jr., who worked the weapon system's aerodynamics, and Albin Fojt and Jud Smith, who ran simulations on the Reeves Electronic Analog Computer (REAC) and performed weapon system analysis.[13]

Carter, Doig, Fojt, Smith, and William B. Porter, who became Shrike program manager in 1964, were all survivors from disestablishment of the Station's Ballistics Division. Years later Porter noted a difference between the developmental approach with Shrike and that taken with the earlier in-house-developed Sidewinder missile:

> We were beginning to develop good simulation, hardware-in-the-loop simulation . . . I think Shrike benefited from having more simulation work done than had been done on the early Sidewinders.[14]

The original idea for ARM was to have a guidance system less sophisticated in design than Sidewinder's. "A very simple passive radar seeker and control system was possible. Lock on their gun or missile-directing radars and get close enough to damage the antenna, that's all you had to do," said Jagiello.[15]

12 *United States Naval Aviation 1910-1995*, Part 9, "The Sixth Decade," 239, *http://www.history.navy.mil/avh-1910/PART09.PDF*, accessed 12 Sept 2009.

13 REAC, purchased by China Lake in 1951, was the Station's first computer for running flight simulations and calculating aerodynamic characteristics. It contained some 3,000 vacuum tubes. Work with REAC was the foundation for China Lake's later development of sophisticated hardware-in-the-loop simulation facilities.

14 S-216, William B. Porter interview, Dec 1992 and March 1993, 30. Porter would go on to be China Lake's 12th Technical Director (1989-1992).

15 S-168, Leonard T. "Lee" Jagiello interview, 15 Jan 1988, 29.

As McLean may have foreseen, Code 35 and Code 40 had conflicting opinions about the best method of guidance for the new weapon. Amlie's group in Code 35 submitted a proposal for an ARM seeker using a free gyro and proportional navigation (in which the external control surfaces that guide the missile's flight move a precise amount proportional to the degree of course correction needed), a system similar to Sidewinder and SARAH. However, using a gimbaled gyro meant moving parts in the seeker, which equated to additional cost and complexity.

Code 40 opted for a simpler approach. Riggs recalled that he told Jagiello (who had been the chief aerodynamicist for Sidewinder):

> You did Sidewinder and for a maneuvering target where you have to really pull all of these *g*s, Sidewinder is a beautiful airframe. But that damn radar's sitting down there stationary, or at most it's going to be on a ship at 20 knots. Why do I want to have all this maneuverability and high-*g* capability? . . . I can almost hit that radar down there, if I knew where it was, with an unguided rocket, and you're trying to guide all the way and you're laying on requirements of the seeker people of this high sensitivity in order to pick this thing up miles and miles away to home on it . . . .

Moran had suggested a weapon in the Sidewinder size (5-inch diameter). Instead, an 8-inch-diameter missile body was selected, because state-of-the-art RF technology required at least 8 inches for the antenna. Four moveable cruciform wings were mounted about midway on the missile, near its center of gravity. Beefed-up Sidewinder servos controlled the wings, but instead of proportional control, the new ARM weapon's servos worked on a more rudimentary "bang-bang" principle. Riggs explained:

> I'm not going to feed in a signal to the solenoid as a proportional control like Sidewinder has to have. I'm just going to give it either a plus or minus signal . . . and no matter how far off axis the target is, say to the right, that's going to be plus and I don't care how much it is, you just 'bang' and hold it until it goes to zero.[16]

Robert G. Corzine, who reported for work at NOTS on Valentine's Day, 1958, had his first permanent assignment with the ARM program, where he worked on the guidance antennas. He was soon joined by another newcomer, Joseph A. Mosko. The two would become fast friends over the years and would develop and patent several antennas, but at this point they were just youngsters with their hands full of responsibility. As Corzine remembered:

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16 S-136, Leroy Riggs interview, 18 and 19 June 1982, 58–59. In the course of his 27-year career at China Lake, Riggs received the Navy Meritorious Civilian Service Award—the highest civilian award the Commander can bestow—not once but twice.

> We really did not have the necessary lab equipment to do everything we wanted to do, and the people that were also doing RF work were Tom Amlie and his SARAH group up in the tower at the north end of Michelson Lab. They had a radar range, which I think was about the only one on base, that went across the rooftop, and they would let me use their antenna facility whenever they weren't using it. . . . There was that kind of mutual thing that really made an impression on me, how everybody wanted to help. And everybody would take time; Tom Amlie was very interested in our project, and when I was up there making measurements, he would sit down and discuss it with me if he was not too busy.

Corzine soon became the head of the RF Section. "Really too much responsibility for my background and experience at that time, but we had lots of enthusiasm, and as I mentioned, lots of help from other people." The first antennas were helices. "Everybody called them 'bedsprings,' because they were kind of a twisted coil that stuck out the front. Of course, they worked, but not very well," Corzine said.[17]

Initially the weapon was designed to attack radars operating in the S-band (S for short, 2- to 4-gigahertz wavelength), a frequency range that covered most of the Soviet antiaircraft (AA) and surface-to-air-missile (SAM) radars in use at the start of the 1960s. As Moran had noted, the greatest threat was posed by the Soviet radars, operating in Korea and Vietnam and elsewhere. Most of the Soviet systems were copies of U.S. radars, dating back to the MIT-developed SCR-584 aircraft-tracking radars that Russia had obtained from the U.S. under the WWII lend-lease program.

In 1959 the feasibility study for the ARM weapon was completed when the first two ARM proof-of-concept rounds were fired from an F3D Skyknight aircraft against an SCR-584 S-band target. The ARMs were hybrid weapons: Corvus seekers, Sidewinder hot-gas servos, Sparrow-based airframe, and four Mighty Mouse 2.75-inch rocket motors clustered in an 8-inch-diameter tube. The first round malfunctioned, but the second round struck close enough to the target to prove that the missile had indeed been tracking the radar signal.[18]

Phil Arnold pointed out that the Sparrow airframe was particularly appropriate for Shrike:

> In addition to the cost and logistic advantages from common motors and wings, the wing-controlled airframe (as opposed to canard control for Sidewinder and tail control for Falcon, and later Walleye) can maneuver without the need

17 S-283, Robert G. Corzine interview, 9 Oct 2008, 3, 4, 6. Corzine spent 30 years at China Lake, retiring as head of the Electronic Warfare Department's RF Development Division.

18 *Technical Program Review 1959*, 107.

> for pulling high angles of attack. The forward-firing warhead fragments can then be impelled in a cone more directly forward of the missile's terminal flight path, increasing the lethality of the spread against a radar antenna.[19]

By the end of 1959, ARM was ready to move into engineering development. At this point the name Cobra was attached to the weapon, a snake on a par with the Sidewinder in terms of lethality. China Lake management was able to convince the Bureau of Naval Weapons (formed in December 1959 by a merger of the Bureau of Ordnance and the Bureau of Aeronautics) to make a small but significant change to the traditional method of weapons development: the Station was assigned the responsibility and delegated the authority for the complete weapon system. Previously a separate task for each component of the system would be issued by the responsible technical branch within the Bureau.

NOTS' responsibilities for ARM's technical direction were carefully laid out in a three-page memo from Ashworth (by then BuWeps Assistant Chief for RDT&E) to the NOTS commander in June 1961. The memo included such details as "Carry out [your] responsibility of review and direction not only with the prime but also with sub-contractors and other team members who are providing other parts of the missile." This shifting of responsibility and authority to the laboratory would come to be called the Deputy Assistant Program Manager (DAPM) concept and, when used, proved far more effective in integrating the efforts required for a complex weapon system than were the fragmented lines of authority and responsibility that characterized non-DAPM programs.[20]

China Lake's successful launches were enough to secure funding for further development work, to the great relief of the weapon's design team. Duane J. "Jack" Russell, who took over management of the guidance-section design from Etcheverry, remembered:

> We saw all kinds of problems in trying to approach the task we were doing. Using that Corvus guidance system was a monstrosity, a lot of problems in the servo, we had to get going on the design of a warhead and fuzing system, we had to come up with a better rocket motor . . . .[21]

19 Phil Arnold, email to the author, 20 July 2011.

20 Memo RMGA-3:JLB, Chief, BuWeps, to Commander, NOTS, "Technical Direction of the ARM Missile Program," 15 June 1961.

21 TS 84-14-4. Duane J. "Jack" Russell interview, ARM History Project, circa 1984, 4. In 1965 Russell would become head of the Guided Missile Division. He would head both the Electronic Warfare Department and the Engineering Department before retiring as head of the Land Range Directorate in 1994. In 1967 he was one of the first recipients of the Michelson Laboratories Award for "vital contributions . . . that contributed directly to the design of the highly successful Shrike missile." *Rocketeer*, 12 May 1967, 1, 3.

Shrike

In 1961 Cobra was renamed Shrike. According to Leroy Riggs, the team had a naming contest and his wife, Ditty, contributed Shrike, a desert bird. Another story has it that the name was based on the Shrike of folklore, which pecks out the eyes of its prey—precisely what the Shrike missile was designed to do by blinding the enemy radars that controlled the AA and SAM systems. The overall weapon system, including support equipment, was now known as Shrike Weapon System W-115. The Shrike missile itself was now designated XASM-N-10. In 1963 this was changed to AGM-45 (often seen with a "Y" prefix during development), a designation which Shrike retained until the weapon's phase-out in the early 1990s.[22]

NOTS' overall Shrike plan called for a competitively selected contractor to provide engineering support, pilot production, and first full-scale production. Following pilot production, a competition would be held to select a second production source. After the second source was qualified, all out-year procurements would be competitive. This plan was followed. Texas Instruments, Inc., (TI) of Dallas, Texas, was awarded an engineering support contract in October 1961 through competitive bidding. The initial contract called for 32 guidance-and-control sections to be delivered between March 1962 and March 1963. Several people from TI were detailed to China Lake where they shared workspace with the NOTS team, facilitating the efforts in Dallas.[23]

The contractual vehicle selected was called Cost Plus Fixed Fee with a Task Award Fee contract. As Frank Knemeyer described the advantages for this type of contract:

> . . . it provided for the sharing of the engineering effort but left China Lake with technical and financial control. This approach guaranteed the contractor his legitimate cost plus fee with an additional award fee for competent work. It also provided for continuous correlation of detailed technical milestones with related financial expenditures.[24]

In a 1961 test, Shrike was launched in a loft maneuver from an FJ4 at a horizontal range of more than 15 miles. It impacted within 11 feet of the target.

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22 S-136, Riggs interview, 59–60. One of Secretary McNamara's standardization measures was the Joint Designation System, a naming system for unmanned aerospace vehicles (including missiles) that became effective on 27 June 1963 and that followed the conventions of the new aircraft designation system that had gone into effect the previous year. The new designations were based loosely on a weapon's mission (i.e., AGM is air-to-ground missile, AIM is air-intercept missile, etc.).

23 *NOTS Tech History 1961*, 132.

24 Frank Knemeyer, "Shrike's Forgotten Lessons," *The China Laker,* newsletter of the China Lake Museum Foundation, Fall 2004, 9–10.

The following year, the program moved from the Aeromechanics Division into the newly formed Guided Missile Division (Code 402), headed by George F. Cleary and located in Hangar 1 at Armitage Field.[25]

Paul E. Cordle and others in Bud Sewell's Warheads Branch designed a warhead tailored to the target and designated EX 52. The 145-pound warhead had a kill probability of 0.85 at a miss distance of 40 feet. Commander Tony Tambini, who became the Shrike project pilot in 1961, described the details:

> The warhead was composed of a high explosive charge around which were stacked thousands [22,000 to 23,000] of three-sixteenth-inch steel cubes in such a way that when detonated by the target detecting device, there would be a distribution of steel cubes such that at least one cube would penetrate every square foot within the target effective range. It was a relatively small warhead [150 pounds with 50 pounds of explosive filler]. There wasn't a great big boom, but inspection of a target afterwards revealed that the target had been thoroughly perforated with little steel cubes, cutting virtually every wire and cable in the target radar van, rendering it useless and unrepairable." [26]

Extensive analysis of the potential targets as well as of the various endgame-encounter geometries (the spatial relationship of target and weapon in the microseconds before warhead detonation) resulted in the incorporation of five different charge-to-mass ratios into a single warhead. This design yielded five distinct fragment velocities that would work most effectively for the expected range of warhead-target encounters. The fragment size was optimized for doing maximum damage to the threat-radar elements—most obviously the antenna—that the enemy could not protect with armor and still maintain a functioning radar system. The explosive powering the fragments was the China Lake-developed PBXC-104, the very first castable plastic-bonded explosive (PBX), which was replaced in 1964 by the China Lake-developed PBXN-101.[27]

The Shrike team also drew on NOL Corona's fuzing expertise to design a fuze that would detonate the warhead in front of the antenna; the 70-degree cone of fragments projected by the warhead proved to be devastating against antennas, electronic components, and operators. The dual-mode fuze would also detonate on impact. Cordle commented:

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25 *NOTS Tech History 1961*, 5. In 1963 Cleary took over the Shrike program's management from Riggs, and a year later Porter (who was head of the Analysis Branch under Cleary) was assigned as program manager. In April 1965 the Shrike Program Office under Porter would be elevated to a staff position in Code 40, and Porter would remain as program manager until Charles B. May took over the position in 1970.

26 *NOTS Tech History 1962*, 115; *The Flying Tambinis*, 3.

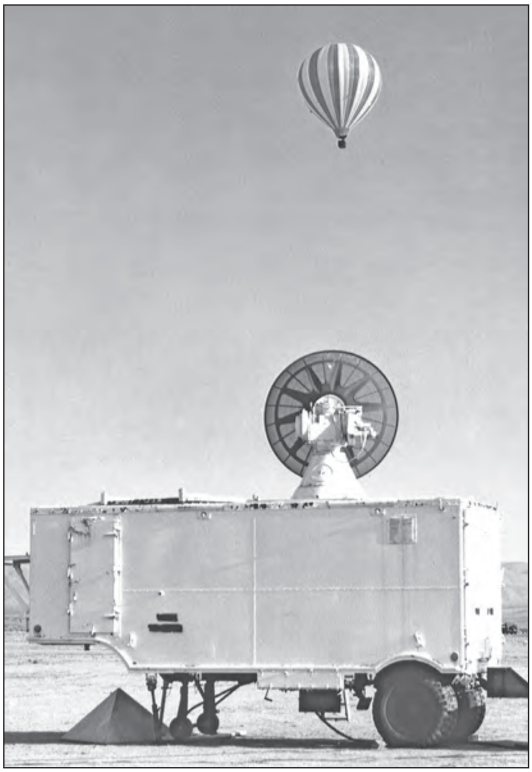
27 *Major Accomplishments*, 105; *NOTS Tech History 1964*, 4-26. China Lake has long been the Navy's principal developer of pressed, extruded, and cast PBXs.

> The true measure of a weapon of this nature is not so much its terminal effectiveness as it is the survivability of the strike force. It's a deterrent weapon. Ideally, if it were 100-percent effective, you'd never have to use it. Because if the radars stay shut down, then they pose no problem to the strike force, which is the principal objective of the missile to start with.[28]

In essence, the enemy radar, by performing its normal function, was complicit in its own demise. Without its active cooperation, there would be no signal to guide the Shrike to the radar's antenna.

Initially, the Shrike team planned to develop a rocket motor specifically for Shrike. However, a study by the Ballistics Division showed that a Sparrow motor would meet the system requirements. Therefore the four 2.75-inch motors that had been used in the proof-of-concept demonstrations were replaced by a modified Sparrow motor under development by Rocketdyne. That decision, which did not anticipate the problems that would surface in Rocketdyne's motor development program, would later be revisited.

The biggest difficulty was replacing the "monstrosity," the Corvus-based seeker. Charles B. "Charlie" May came to China Lake in 1960 and, after his Junior Professional tour, joined the Shrike program as an RF design engineer. He, Mosko, and Corzine tackled the guidance problems. They scrapped the helical antennas and concentrated on a new single four-arm spiral antenna using microstrip technology implemented in a broadband monopulse network. That, coupled with a rugged solid-state guidance computer (designed by Richard Hughes and Robert Atkinson), allowed them to fit far more detection and guidance capability into a small area than had hitherto been possible.



Shrike seeker test incorporating a hot-air balloon and an SCR-584 radar.

28 VP 04-154, "Origins of ARM," 2004.

One of the test platforms used in the seeker development was Jimmie Craig's hot-air balloon that had been acquired for the Briteye project. Moored at various distance and elevations from a simulated threat radar, the balloon provided a stable platform for testing seeker performance. (Helicopters were more expensive and their rotating blades caused glint that would interfere with the testing.) Shrike's developers also used an A-4 "nosey" aircraft with a Shrike seeker installed in the nose for dynamic testing against targets.

More successful tests of the S-band Shrike followed as the design matured. When tests against multiple radiating targets showed that the missile had difficulty picking out a single target, the designers incorporated an improvement called "angle gating." This allowed the missile to narrow its focus to a single threat emitter when operating in an environment crowded with enemy radars.

Despite the demise of Rascal, the Air Force hadn't given up its desire for an in-house antiradiation weapon development program. In 1962, as recalled by project pilot Tony Tambini:

> China Lake was involved in a battle to get funding from DOD. As part of the team, I went back and forth to Washington to participate in hearings with Department of Defense DDR&E Dr. Harold Brown's office. It seems that the Air Force had a different idea about how to go after surface-to-air missile sites. The Air Force Systems Command had joined up with Martin Marietta in proposing a version of the Bullpup missile [designated GAM-83, later AGM-12] for the job. They had no hardware and had never built even the first component, but their 'brochuremanship' came close to doing us in.[29]

The threat was serious. Since the Defense Reorganization Act of 1958, DDR&E had the authority to approve, modify, or disapprove all R&E programs within the military departments, and DDR&E was now considering the adoption of a single antiradar missile system for both services. The Navy did not want the Air Force candidate as the two services had different damage criteria for destruction of radar targets. Frank Knemeyer advised the NOTS Research Board:

> If the Navy were directed to accept GAM-83, the system would not meet the Navy operational requirement. The high altitude mission would require costly and complex detection and acquisition equipment to be incorporated.[30]

As Bill Porter told it:

> The Air Force described that the toughest situation would be two targets 100 feet apart and having a missile which could guide and hit one of the targets

29 Tambini, email to the author, 26 Oct 2008.

30 Research Board minutes, 11 Sept 1962.

> . . . so between a couple of meetings, we went out and fired a Shrike at two targets that were 100 feet apart, and we impacted 10 or 15 feet from one target and took the data back and said, "That's not a problem. We've already demonstrated it." We had hardware. We were further along. We had a better concept. And we won the competition.[31]

Response to a Crisis—Project ESE

By summer 1962 Shrike was well on its way to becoming a weapon of war. The program was proceeding with energy and enthusiasm, if not a great sense of urgency—after all, Korea was long past, and American air involvement in Vietnam was a few years in the future.

The pace changed that summer with the detection of Soviet SAM air-defense sites in Cuba, 90 miles off the coast of Florida. The SAM sites were followed by the introduction of Soviet SS-4 nuclear missiles. The so-called Cuban Missile Crisis in October that year brought the nation to the brink of nuclear war with the Soviet Union. Escalating tensions throughout the late summer and fall of 1962 gripped the nation—and China Lake.

Tambini was called back to Washington, where top officials had decided that any invasion of Cuba would require a way to counter the SAMs the Soviets had surreptitiously introduced to the island nation. The seriousness of that SAM threat was underscored on 27 October 1962 when a U-2 spy plane overflying the island was shot down by a Lavochkin OKB S-75 missile (NATO code name Guideline, DOD designation SA-2) guided by a Fansong S-band radar. The incident spotlighted a critical absence in the U.S. defensive arsenal: an effective antiradiation (i.e., antiradar) weapon.

The nation and the world weathered that crisis; the Soviets removed the SS-4s, but the SAMs remained. Such a close brush with open warfare had been a wake-up call for the defense establishment. Now the need for an antiradiation weapon to counter Soviet-built air defenses was not just a China Lake or a Navy concern, but also a top national security issue. Washington officials took seven months to decide what to do, and then they turned to China Lake and Shrike.

May 1963 marked the beginning of the Emergency Shrike Effort (also called Early Shrike Effort or Project ESE, pronounced "Easy"). According to Ernest G. Cozzens, head of the Weapons Systems Office of the Engineering Department (Code 55):

> President Kennedy asked Secretary McNamara what he had to combat the threat. He said the only thing we had was some people out at NOTS, China

31 S-216, Porter interview, 28.

> Lake, that have this thing that might work. So there was a brief prepared and . . . the word came back from him, "Give them anything and everything they need to expedite the development of that weapon." And that was what initiated the ESE program.[32]

The Station was given nine months to have Shrike ready for the operational forces. China Lake agreed to prepare the missiles. Since a new version of the Fansong radar operating in C-band had been detected, the project team would build 50 complete missiles operating in S-band and 50 C-band alternate seekers. The estimated cost of the project was $10 million, and Project ESE was given "Brickbat" priority.

TI was already on board as the engineering support contractor; however, ESE began while Shrike was still in its development stage—well before it was ready for production. Changes to the weapon (and concomitant changes to the specification package) were being made on a daily basis. The decision was made to build the guidance sections entirely in house at China Lake.

"We did all the manufacturing, the quality assurance, the whole thing in-house and then shipped those to TI, which mated it with the control section and the rest of the airframe," said Corzine.[33]

Knemeyer set up a war room next to his office with a detailed technical schedule for every component of the missile. Assistant Department Head Richard T. Carlisle kept the schedule up to date on an hourly basis. Communications and travel between China Lake and Dallas were continuous, and every Saturday morning the key players at China Lake met in the war room to review progress and problems. One item of concern was the new C-band seeker, which, late out of the gate, was far behind the S-band seeker in the development process.

China Lake's traditionally flexible policy of letting personnel find their own comfortable homes in the organization went temporarily by the board. In May 1963 Associate Technical Director Hack Wilson issued a memo with a list of people to be detailed to "Shrike Program, Plan C," the administrative name for Project ESE. The directive swept up technical experts from Codes 30, 35, 40, 45, 55, and even 75 (TID, the Technical Information Department) and added them to the existing program staff. As the memo explained:

> It is of utmost urgency that maximum assistance be given to the Shrike program. There will be a requirement for the assignment of additional personnel to support this program even though effort on other programs may have to be curtailed. Your full cooperation in meeting Shrike requirements is requested.[34]

32 S-126, Ernest G. Cozzens interview, 25 June 1981, 11.

33 S-283, Corzine interview, 21.

34 Memo 1501/LSL:abf, Reg. No. 15-1703, Hack Wilson, "Personnel Designated to be

Phil Arnold, then a branch head in the Air-to-Air Weapons Division, and several members of his branch were assigned to ESE with responsibility for the missile test equipment and the bomb director that would become the CP-741/A computer. He recalled:

> I, for one, was not happy at the time. I wasn't aware of the urgent need for the project or, for that matter, of the project itself. It hadn't occurred to me that I, or anyone, could arbitrarily be reassigned without at least being offered a choice, but reassigned we were.[35]

According to Gerald R. "Gerry" Schiefer, who designed the Shrike test set:

> "Easy" was a misnomer . . . it was anything but easy. I remember Jack Russell [by then head of the Missile Branch] coming to me at one time and saying "Schiefer, I would like to have you put out a little bit more." He said "I do not mean that you are not pulling your weight in the time that you are here because you do that very well but we would like to have 12 hours instead of just 10."[36]

In June 1963, less than a month after Wilson's memo, President Kennedy visited China Lake. He asked NOTS Commander Captain Charles Blenman,

President John F. Kennedy receiving a Shrike model from NOTS Commander Captain Charles Blenman, with Technical Director Dr. William B. McLean looking on. In the background is a portrait of Albert A. Michelson hanging in the lobby of Michelson Laboratory.

Detailed to Shrike Program, Plan C," 14 May 1963.

35 S-275, Arnold interview, 16; email to the author, 20 July 2011.

36 TS 84-14-7, Gerald Schiefer interview, ARM History Project, 24 Jan 1984, 6–7. Schiefer would become NWC's 11th Technical Director (1986–1989) and eventually the Director of Navy Laboratories.

Jr., what the Station's most important projects were. In a memo to BuWeps, Blenman, writing of himself in the third person, responded:

> Commander, NOTS, told him that Shrike was NOTS number one project and we were expending every effort in order to get a limited operational capability by the first of October. He appeared to be familiar with this emergency program and he asked how we were getting along. He was told that we would have an S-band capability on schedule and that we hoped our C-band capability would work out, although there might be the possibility of some unforeseen developmental problems. . . .
>
> He asked if we needed any more money for this emergency program. . . Commander, NOTS, responded that, in his opinion, we did not, that NOTS has all the money needed to employ the number of people we have, and that money was not the answer at this time to our problem.[37]

China Lake had not seen such hectic activity since the days of NOTSNIK in 1958. Corzine recalled, "Those were 6 days a week, 10-hour days that we worked for several months. I remember by the time we got through, I was real happy to go back to 5 days a week." He remembered that the tight schedule occasionally called for cutting corners on technical niceties:

> Charlie May was the person that was in charge of the actual production of the antenna systems. I can remember one day, he brought me in an antenna that was just built, and it was all wet. I think he put it in the toilet and flushed it three times and then tested it, and it still worked, so he said, 'Well, it passed the humidity test.' . . . We had a lot of confidence. We tested in our anechoic chambers and did bore-sight tests and ran all the usual full-up systems tests in the laboratory. So we had great confidence in the system, but they still wanted to fly it against the actual radars.[38]

That desire to fly Shrike against the actual radars is why in early July 1963 Tambini and Commander Jack Sickel, his boss, lifted off from Armitage Field in an A4-C and an A4-E en route to Naval Air Station, Key West, Florida, for "temporary additional duty with regards to Classified project #10."[39]

The two Navy pilots were to fly their aircraft along the coast of Cuba in hopes that the SAM radars would "paint" the aircraft so that the signal could be recorded. The aircraft had no defensive armaments. "Every nook was taken up with recording devices and various types of instrumentation." They did,

37 Memo 14/DLR/lae Ser. 0080, Commander NOTS, to Chief, BuWeps (Code R), "Presidential visit to NOTS, 7 June 1963," 21 June 1963, 1. The Kennedy visit marked the first public display and first public firing of Shrike.

38 S-283, Corzine interview, 21.

39 Travel Orders 18/DGH:pa, 1320, Ser. T-001-64, Commander, NOTS, to Commander John A. Sickel, 1 July 1963.

Project Pilot Tony Tambini firing Shrike from an A-4C aircraft in a test at China Lake, 12 June 1964.

however, have "fighter air cover stationed five miles out and five thousand feet above our altitude."

During a 2-week period, Tambini and Sickel made 14 flights and captured signal data that was invaluable to the Shrike developers back at China Lake.[40]

While the on-board instruments could sort out the different signals, discriminating among them was not so easy for the pilots. As Knemeyer, at that time head of Code 40, said:

> . . . we took our military pilot and put him in an A-4 and sent it down to Florida with a captive Shrike head on it . . . to fly along the Cuban coast to find out how well he might be able to distinguish different kinds of radars. . . . But it turned out that he said, "I'm in a bird cage." There were so many radars coming up and all of the different tones coming in that it was very difficult for him to single out any particular targets.[41]

Schiefer recalled that:

> . . . we put together a recording system to record all of the signals from the Russian missile guiding radars—the SA-2, et cetera—because you can't refute what you record. So [Tambini] would go up there and "troll." He'd fly in the A-4, and when they'd come on the air, why, we'd record all of that.

40 *The Flying Tambinis*, 30.
41 S-200, Knemeyer interview, 92.

> Interviewer: So you sent somebody to Cuba to ask the Russians to shoot at him?
>
> Schiefer: Well, no. Well, yeah. Yeah, we did. We said, "Here's this fish up here; take a shot." Yeah, we trolled.
>
> Interviewer: But it's scary, things like that.
>
> Schiefer: Well, yeah! But it's scary to land aboard a carrier at night!

Schiefer knew that China Lake's project pilots brought courage to the table, along with their operational expertise.[42]

Project ESE continued at a hectic pace through the end of 1963 and was completed in January 1964 when the missiles and alternate guidance sections were delivered to the Marine Corps Air Station, Cherry Point, North Carolina. The program had been completed within the agreed-on time and budgetary constraints. As Arnold pointed out:

> TI tried to convince the Systems Command that they were better equipped than China Lake to not only produce weapons, but to manage the program. They fell on their face in ESE, China Lake delivered its product on schedule, and China Lake continued to be in charge.[43]

The year 1964 also saw the completion of a NOTS study of a proposed version of Shrike containing a nuclear warhead. The weapon was intended to "destroy radar sites, antiaircraft artillery batteries, and ships, which might be only moderately damaged by a conventional warhead." Although the study recommended that further effort be made to develop a nuclear Shrike, there is no evidence that the program was pursued past the study stage.[44]

Shrike Production

By mid 1964 Navy Technical Evaluation and Operational Evaluation had been completed, and Shrike was ready for pilot production. The weapon had became a balance of the tried and true (wings, fins, bang-bang control section, Sparrow airframe) and new cutting-edge technology (fuzing, warhead, and guidance), and its evolution had been exhaustively documented in a production data package.

The production version of the missile was about 10 feet long and 8 inches in diameter and weighed about 390 pounds. It could reach Mach 2 (approximately 1,500 miles per hour) and strike targets at a nominal range of 10 miles (actually 15 to 17 miles, later extended to 25 miles or more with the dual-thrust motor).

42 S-305, Gerald Schiefer interview, 9 March 2010, 23.
43 S-275, Arnold interview, 17.
44 *NOTS Tech History 1964*, 1-7.

Pilot production went well, and the first missiles from the Fleet-introduction lot were delivered to USS *Midway* (CVA 41) in January 1965.[45]

Texas Instruments also won the first full-scale production contract, and several people from TI were detailed to China Lake to work with the NOTS team in shared workspaces to facilitate the transition to production. Although China Lake had been closely managing the TI contracts through the pilot-production phase, BuWeps decided that China Lake did not need to be in the loop for production changes during full-scale production. Shrikes soon began to roll off the line in Dallas, and there were problems. Knemeyer recalled:

> There were something like 650 changes that TI wanted to put into the missile. They were Class One [major, affecting the weapon's "form, fit, or function"], Two or Three [minor] changes. The DCAS [Defense Contract Administrative Services representative] down there didn't really know the difference, so they let TI put a lot of changes in there that caused the missile not to perform the way it should.[46]

The situation caused, in Knemeyer's words, "a real rhubarb with BuWeps." When the smoke had cleared, China Lake conducted a comprehensive test program on the TI missiles. Missiles that had already been deployed were recalled from the Fleet. The Bureau of Naval Weapons also put China Lake back in the documentation-control loop.

Meanwhile, NOTS was in contract negotiations with a second production source, Sperry-Farragut, in Bristol, Tennessee. To smooth the process, China Lake gave Sperry a research contract that, according to Knemeyer, said in essence:

> "You go and make three of these guidance units. Do it in your model shop." We brought their engineers here, and we showed them how we went about it. We gave them everything that we knew about it and helped them make these. Then they brought the units here, and we tested them, and they worked the way they should. Now they had all that knowledge in their own production plant so they could troubleshoot their own problems. And we were able to actually get the Sperry-Farragut Shrikes over into Vietnam before we effectively got the TI ones over there.[47]

"From that point on as we went out each year for the production of Shrike missiles, it was a competitive procurement between Texas Instruments and Sperry," said Porter, adding that:

45 *NOTS Tech History 1965*, 1-16, 1-17.

46 S-200, Knemeyer interview, 40.

47 Ibid., 41. The first second-source Shrike was fired in combat in Vietnam in January 1966.

> The Navy would say we want to buy so many thousand Shrikes and the contractor would come back in with proposals and each contractor would have options. If he built 1,000, 2,000, 3,000, 4,000 they would have the options broken out. And then the Navy was in the position to decide how to split the buy and they would give maybe 60 percent of the buy to Texas Instruments and 40 percent to Sperry or vice versa depending on which one had the lowest cost. So it was a very competitive situation and the cost actually went down over time.[48]

An important factor in Shrike's success was documentation. Building a reliable component in China Lake's state-of-the-art laboratories with highly motivated professionals was only a first step. Even the minutest details of the fabrication and assembly processes had to be translated into technical specifications that minimized room for error at the production facility. The art of ensuring that parts will function as designed without requiring unreasonable cost and time to manufacture is called producibility.

Military Specification MIL-Q-9858A, first released in 1963, required every government contractor to establish a quality program. According to Burrell W. Hays, who worked in the Shrike program during the mid-1960s and was a central figure in qualifying the second-source contractor:

> One of the fallacies of 9858A is that it's invoked almost by the interpretation of the local government guy and the contractor, and how much tenacity they have. That turns out to be a two-edged sword because if the guy isn't on the ball, you can have no quality, and if he happens to be a zealot, he can close every factory down in the world.[49]

Instead, beginning with Sidewinder, China Lake had begun to write quality into the specifications that dictated how a contractor would produce a weapon. These were not arbitrary—during the pilot-production phase of a weapon the government and contractor often agreed on Class 1, 2, and 3 changes that were shown to be necessary to accommodate the design to the production environment. However, the specifications were exhaustive and ensured consistent reliability in the performance of items coming off the production line. Reliability was designed in by China Lake during development and then maintained through quality control in production. Hays explained:

> We essentially tailored the quality assurance standard by writing a weapons requirement. We wrote a whole thing, and we called it a requirement for interpreting 9858A because nobody would allow us to write a spec for quality

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48 TS 84-14-5, William B. Porter interview, ARM History Project, circa 1984, 12.

49 S-221, Burrell W. Hays interview, 6 Jan 1993, 9. Hays would become China Lake's 10th Technical Director (1982-1986).

> without getting through the DOD and a bunch of problems. . . . We wrote our own solder spec . . . We wrote specs for configuration control. We wrote them for classification of defects . . . And we started to impose them.[50]

The imposition of rigorous technical discipline worked. According to Schiefer, Sperry-Farragut, Shrike's second source:

> . . . didn't have the technology that TI had. All he had was the prints. So he religiously designed to the prints, brought [the Shrikes] out here, and fired them. And they worked just exactly the way they were advertised.[51]

The Shrike second-source experience showed that documentation and quality control were not only essential to effective, producible weaponry but also key elements in obtaining cost-reducing multisource production contracts. Prior to the Sperry second-source contract, Shrikes had been costing about $18,000 each. Knemeyer observed:

> When we got Sperry-Farragut in, it dropped down to less than a quarter of that. So that shows that if you've got a good documentation package, you know what you're doing, and you've got somebody that understands it, with competition you can really get the cost down and still get effective systems out of it.[52]

As reported in the *Rocketeer* in 1973—when more than 17,000 Shrikes had been produced—"Because Shrike was designed and developed by a government laboratory, which provided a complete documentation package for bid between competitive contractors, a cost savings exceeding 100 million dollars over that normally experienced in sole-source procurement was realized."[53]

One problem with Shrike was the fixed frequency range of its seeker. The first Shrike models (AGM-45A-1 and -2) were designed to combat the widely used Soviet-built Fan Song (SAM fire-control and tracking) and Fire Can (AA gun director) radars. But in what became a cat-and-mouse game, the enemy would deploy radars operating on new frequencies. Then the Shrike development team would quickly develop another "dash version" that would work in that frequency. This technical issue proved also to be an intelligence issue, as mission planners had to determine before a mission the type of radars that were anticipated in the target area so that the proper Shrikes could be loaded on the defense-suppression aircraft. It was a cost and logistical issue as well.

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50 Ron Westrum, in *Sidewinder: Creative Missile Development at China Lake*, calls Hays "the apostle of production quality." Naval Institute Press, 1999, 178.

51 TS 84-14-7, Schiefer interview, 24.

52 S-200, Knemeyer interview, 41.

53 *Rocketeer*, 12 Jan 1973, 4.

Eventually, the AGM-45A/B-9 and -10 models of Shrike achieved the bandwidth capability to cover most of the threat radars. Between new bandwidth capabilities and other improvements to Shrike's seeker, warhead, and motor, about 20 subvariants of the missile were produced. More than 16,000 units of the most commonly used version—the AGM-45A-3 and -B-3 or "dash threes"—were produced beginning in 1966.

Equipment and Support for the Fleet

There was more to the Shrike weapon system than just the antiradiation missile itself. As with any new missile, specialized equipment was needed to integrate the weapon with the aircraft and its sensors and to allow a pilot to locate the target and fire the missile within acceptable launch parameters. Early in Shrike's development, the need became apparent for a fire-control system to assist the pilot in determining the proper launch point. Said Knemeyer:

> We came up with the idea we had to put something on the nose of the airplane in order to present a scope presentation to him to tell him, based on the frequency of the target, what kind of a target it was and where was it located, so he could look at his scope and really determine it. Then he could decide which one to go after.[54]

Fire control was not a new area of work for NOTS; the Station's experience in the development of such system dated back to the 1940s. For Shrike, an existing bomb director, Mk 9 Mod 0, in production since 1956 and used with BOAR, was modified by Code 35 and Code 40 under Project ESE.

In 1964 the system was designated the Weapons Delivery Computer CP-741/A, a magnetic-amplifier analog computer that gave warnings and alerting signals to a pilot delivering a free-fall weapon (bomb) or terminally guided air-to-ground missile (e.g., Shrike), and automatically released the weapon at the correct point. The system employed four modes of delivery—stick, toss, loft, and over-the-shoulder—and used the aircraft's radar range-to-target and barometric altitude data as primary inputs.

Development continued until 1966, when the CP-741/A was released to the Fleet for use in the A-4 and A-7. Reliable, easily maintainable, and relatively inexpensive, the –741/A could be adapted for any aircraft (by selecting an appropriate aircraft-characteristic module), and for any two weapons on a given mission (by selecting the appropriate weapon-ballistics module).[55]

Ray Powell, who flew at China Lake during CP-741/A development, recalled:

54 S-200, Knemeyer interview, 93.
55 NOTS TP 3428, *NOTS Tech History 1963*, June 1964, 4-20.

> We'd go out and do contests with it—we'd go out to an unfamiliar target and drop a bomb by eyeball and then drop a bomb using the CP-741. We used to beat it, but the average Fleet pilot couldn't beat it because he didn't get to bomb every day on the same range.[56]

Gary Palmer, who made three tours as an attack pilot during the Vietnam War, confirmed Powell's assessment. "I had that system in my airplanes when I was a squadron commander on *Kitty Haw*k and I made sure the damn thing worked because it was better than my young pilots. . . . you had to have command influence there to make sure the damn thing was maintained and worked on and used."[57]

Knemeyer made a similar observation based on a visit to the Fleet in the late 1960s:

> There was one squadron commander who said, "O.K., I've got this fire-control system, and I'm going to make it work." So he put effort on it and did what turned out to be normal maintenance on it, and it performed just the way it should. What happens to many of these squadrons that go out and try to use it, maybe it wasn't properly maintained and it wouldn't work, so they just totally disregard it.[58]

In the same vein, Tony Tambini, who deployed in 1969 with VA-37 as weapons officer, observed:

> In our squadron, a down weapons-delivery system was a down airplane. We never lost a combat sortie to a down weapons-delivery system, and we had a reputation of hitting anything that we pointed our noses at. [Robert J.] Bob Freedman [NOTS' CP-741/A flight test engineer] showed up regularly with CP741 modules for our Weapons Delivery Computers and we were always glad to see him.[59]

The CP-741/A initiated a chain of NOTS developments that would lead to China Lake's Weapon System Support Activities (WSSAs) of the 1980s and 1990s. These aircraft-specific facilities (A-7, A-6, AV-8B, F/A-18 and others) would ensure the interoperability of systems, sensors, and computers on the Navy's ever-more-complicated fighter and attack aircraft.

After Tambini's and Sickel's "birdcage" experience off the coast of Cuba, aural cues were investigated as a means of differentiating threat radars. "But that's when we found out that pilots are basically tone deaf, so our concept of listening to the frequency of the radar wasn't too good because they were

56 S-270, Powell interview, 47.
57 S-280, Capt. Gary H. Palmer, USN (Ret.), interview, 18 Nov 2008, 22.
58 S-200, Knemeyer interview, 91.
59 Tony Tambini, email to the author, 17 July 2011.

around jets so much that particularly if you go to the higher frequencies, it just didn't work for them any more," said Knemeyer.[60]

Nevertheless, the Shrike team would develop a simplified tonal indicator that was coupled with the visual aiming cues. The cockpit display would show the direction to the strongest signal and the pilot's earphones would carry a tone indicating the type of signal the Shrike was receiving. Commander George M. "Bud" Biery II, a Navy Iron Hand (defense-suppression) pilot in Vietnam explained:

> You had aural tones in your headset so you were listening to your GCI [ground control intercept], your early warning radars, which would be a sweep back and forth. You'd hear your fire-control radars which would be sort of like a buzz, and then you'd hear your SAM radar, you'd hear a low chirp, a low warble we always called it, and then you'd go to a high warble which meant they were locked and were tracking. And then you'd get another tone which would be a deedle deedle deedle, which is the best way I can describe it, and your big red light which would say, "Launch," and that would mean that they were now sending commands to a missile that was after somebody.[61]

Shrike entered the Fleet with Navy and Marine A-4 squadrons in 1965, after the problems with TI's first production run had been resolved. It was the year after the Gulf of Tonkin Resolution and the first year of America's overt combat role in Vietnam. Shrike came along not a moment too soon for U.S. aircrews who suddenly found themselves operating against Soviet air-defense threats. On 24 July 1965, an F-4C piloted by Air Force Lieutenant Colonel Richard P. Keirn became the

Shrike detonating above target, frame from G Range test film.

60 S-200, Knemeyer interview, 93.

61 VP 04-154, "Origins of ARM." Biery served two tours at VX-5: as Operations Officer from 1979 to 1982 and as Executive Officer from 1985 until his retirement in 1988. He flew more than 200 combat missions during the Vietnam War.

first U.S. aircraft shot down over North Vietnam by a SAM. (Keirn's radar intercept officer was killed, and Keirn spent 7 years and 7 months as a prisoner of war.) The following year, the first Shrike was fired from an Air Force F-105 Thunderchief (aka "Thud") at China Lake, foreshadowing the Air Force's Wild Weasel program.[62]

Back when Moran had conceived of his simple antiradiation missile, he'd envisioned an equally simple method for using it against the enemy: "Pull your nose up a few degrees and release a weapon in that general direction and just keep right on going." This was the initial delivery tactic that was developed for Shrike. An attack pilot would be briefed before flight on the location of the target, perhaps a Fan Song radar that had been identified by aerial reconnaissance imagery or by aircrews who had run afoul of it on a bombing raid.

The attack pilot would approach on a straight line to the target, pitch the aircraft nose up to about 30 degrees, and launch Shrike before the missile acquired the radar signal. Shrike would follow a long loft pattern and then descend into the "basket" where it would pick up the threat radar's signal and begin homing on it.

The success of this fire-and-forget mode depended on accurate intelligence, good target-location information, and of course a radiating target. The percentage of failures with the blind "basket" shot was higher than desired. While cheaper by far than Standard ARM, which would be fielded in 1968, and cheaper by even farther than HARM, which after 15 years of development was fielded in the mid 1980s, Shrike was still not an inexpensive weapon.

The next approach was the dip and pull up, which required the pilot to triangulate the pitch-up angle necessary to launch the missile. With the aircraft in level flight, the pilot picked up the active emitter signal and aligned the axis of the aircraft toward the emitter. He then lowered the nose of the aircraft to point Shrike directly at the radar and calculated the "dip" angle (which was greater the closer the aircraft was to the target). Based on that angle, he could calculate the pullup angle necessary to launch the missile with enough loft to ensure a high probability of reaching the target. The closer the target, the shallower the pullup angle; the farther away the target, the greater the angle.

According to Biery, the method that Iron Hand pilots used the most was a "down the throat."

62 From 24 July 1965 to 27 Jan 1973, the U.S. lost 205 fixed-wing aircraft to North Vietnamese SAMs. Chris Hobson, *Vietnam Air Losses: United States Air Force, Navy, and Marine Corps Fixed-Wing Aircraft Losses in Southeast Asia 1961-1973*, Midland Publishing, Hinckley, England, 2001, 271.

> You centered your needles [the AJB-3 needle display used with the A-4 Low Altitude Bombing System] and you just fired. Typically, the sites would not be any great distance away, so if you just centered the needles and shot you were probably going to be pretty accurate.[63]

The operational forces developed other methods for using Shrike. One example was a tactic adopted by the Air Force Wild Weasel program in the late 1960s. Wild Weasels were specially outfitted Air Force F-105s used to provide protection—defense suppression—for larger flights of Air Force bombers going after tactical targets in North Vietnam. Four groups of four Wild Weasels each might be assigned to protect a 64-plane attack force of F-105s armed with iron bombs. The bombing flights would also be accompanied by B-66 jammer aircraft (the Air Force version of the Navy's A-3).

In industrial centers such as Hanoi literally hundreds of radar-directed AA and SAM sites surrounding high-value targets—bridges, power houses, railroad yards—waited for the attackers. The North Vietnamese defenders, using their long-range warning radars, knew exactly where the bombers were coming from and when they would arrive. Before the Wild Weasel program was developed, the North Vietnamese air-defense sites took a heavy toll on the bombers, which had to dive directly into their targets to guarantee accurate delivery of their ordnance.

Pilots faced a triple threat: AA fire, SAMs, and MiG aircraft. Flying low, the biggest danger was the AA fire. "The sky was absolutely full of lead below 5000 feet," said Major Robert Huntley, USAF (Ret.), a Wild Weasel pilot in Vietnam in the late 1960s. Above that were the SA-2s with a speed of Mach 3.5 (about 2,600 miles per hour), altitude of up to 65,000 feet, and a range over 25 miles. MiGs could be anywhere.[64]

Huntley and his fellow Wild Weasel pilots realized that for their missions, Shrike's capability to destroy a particular radar site was not particularly important. They were keenly aware of the more important defense-suppression capability of the weapon. The Weasels' job was to give the bomber pilots a window of electronic silence, temporarily shutting down the AA and SAM radars so that the bombers could dive low and put their bombs on target.

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63 VP 04-154, "Origins of ARM."

64 Robert Huntley, "Have I Got a Story for You! 100 Wild Weasel Missions in Vietnam," Technical Library presentation, Video Projects, China Lake, 8 Sept 2004. Most of Huntley's missions were flown against Hanoi, the most heavily defended location in North Vietnam. Among the decorations Huntley earned in his Vietnam tour were two Silver Stars and six Distinguished Flying Crosses. He was nominated for a Congressional Medal of Honor for his actions on a solo mission in North Vietnam on 19 Dec 1967. During the late 1980s, Huntley served as China Lake's technical and program manager for the Sidearm antiradiation missile.

To do that job, they developed the Pinwheel tactic. About 2 minutes were required for the Air Force bombers to roll in, dive on their targets, release their bombs, and get out. Each Wild Weasel would carry two Shrikes. As the main flight commenced its bombing sequence, a Wild Weasel pilot would fly in, pitch up, loft the Shrike into the emitter-rich target area, and then circle back out.

Fifteen seconds later, a second Wild Weasel would do the same maneuver, and so on through the four aircraft. Then they would repeat the sequence, lobbing a Shrike as high as 35,000 feet before the missile would nose over and home on an emitter, even as the Air Force bombers continued to dive and bomb their targets.

"We never hit an F-105 [bomber]," Huntley said. "That's a big sky. It's a calculated risk." But the continuous rain of Shrikes had the desired effect. The enemy quickly learned that "if they kept tracking people in the dive bomb run, they were going to eat a Shrike. So they'd turn off their radar."

Huntley opted for the white-phosphorous marker warhead version of Shrike. As he recalled:

> I never carried high-explosive warheads . . . It was accurate enough that when they saw them coming into their target area they shut the radar off. So the name of the game was not hunter-killer, it was point-defense suppression.

Throughout the war in Vietnam, the advantage shifted from attacker to defender and back. Radar operating in a new frequency band would be introduced into battle, impervious to the existing Shrikes. Then a new "dash version" of Shrike would be hurriedly developed and sent to the U.S. forces.

Creativity in the laboratories of China Lake was matched by that in the ready rooms of the Fleet. On occasion a pilot would fake a Shrike shot. The radio call a pilot used to let other aircrews know there was a Shrike in the air was "Shotgun" (alluding to those 22,000+ steel cubes). The North Vietnamese SAM and AA crews eventually correlated the incoming dip-and-pull-up approach of an aircraft and the radio signal "Shotgun" with the launch of a Shrike.

According to Captain J. David Janiec, USN (Ret.):

> . . . the enemy operators soon picked up this distinctive maneuver that the aircraft were making and if they heard 'shotgun' they would shut down. Well, in the evolution of tactics and counter tactics, as they began to shut down even before we launched the missile we had a counter tactic. We could actually go out without a Shrike aboard. We would actually go through the dip maneuver, shout 'Shotgun,' and in some case launch a Zuni missile, which

> was substantially cheaper than the Shrikes were, and they would shut down. So we had achieved our objective of suppressing them.[65]

That worked for a time. But as Biery noted, "The North Vietnamese aren't any dumb guys." Eventually they figured out this tactic (Zuni traveled much faster than did Shrike) and would continue to radiate. "It was a little game of cat and mouse . . . we had to shoot a Shrike every once in awhile just to keep 'em honest and get 'em to shut down," said Biery.[66]

Continuous Fleet support was an integral part of Shrike's success. China Lake engineers, technicians, project pilots, and ground crews traveled to the ships off Vietnam to assist with Shrike operations and to solicit feedback from the aircrews. Support took the form of maintenance and repair of the missiles and supporting systems, training pilots and aircrews in the use of new Shrike subvariants, and whatever else needed doing to make the system work as intended. As early as 1964, NOTS was bringing Fleet personnel to the Station, schooling them in the operation and maintenance of the Shrike system, and providing them with operational manuals.[67]

This support of the Shrike-armed squadrons began before they even left the country. As the squadrons were being formed in Replacement Air Wings on the east and west coasts, overhaul facilities would reconfigure the aircraft to Shrike capability. According to Knemeyer:

> The overhaul places would put the airplanes together. The avionics [were] in a sorry state—[they] didn't work. We got interested because we were going to put Shrike on those things, and other equipment. The avionics had to work or our systems wouldn't work. So what we finally did was to bring those airplanes out here to NAF [Naval Air Facility at Armitage Field] before they would deploy, and try to get them put into shape out here. We actually helped train the pilots, and then, because of the short time, things could be done on the carrier, so they'd fly them on the carrier. . . .
>
> Guys from the Air Facility would ride the carriers from here to Hawaii, finishing up getting all that stuff done. So it evolved into doing those kinds of things, as well as bringing them here out on the range. . . . We had a lot of people that were constantly going out, helping them. That way, we knew what their problems were. We'd come back and come in with ideas.[68]

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65 VP 04-154, "Origins of ARM." In 2009 Janiec was NAWCWD's director for Weapons and Energetics.
66 VP 04-154 ,"Origins of ARM."
67 Memo 17/RWB:is, Ser. 0586, Commander, NOTS, to Chief, BuWeps, "Visit to the U.S. Naval Ordnance Test Station, China Lake, by the Honorable Paul H. Nitze, Secretary of the Navy, on 2 April 1964," 13 April 1964.
68 S-200, Knemeyer interview, 76, 89.

"In the years 1965 through 1969, while I was aboard USS *Coral Sea* and later, USS *Kitty Hawk*, it was not at all uncommon to find China Lakers crawling around under aircraft on Yankee Station or sipping a cup of coffee in a ready room," Tambini wrote.[69]

Some Fleet problems could be anticipated—wear and tear from repeated "cats and traps" (aircraft catapult launches and arrested landings on a carrier), corrosion, slip-shod maintenance from overworked support personnel too long at sea. When NOTS received reports that Shrikes were breaking loose from A-4s when the aircraft would land on a carrier, the Station sent an engineer out to investigate the problem. It turned out to be caused by improper maintenance on a launch rack—a part for which NOTS was not responsible but a failure that was obvious to a China Laker familiar with the entire weapon system and weapon-platform interface.

Other problems encountered by the operational forces were unanticipated. Bill Porter related an example:

> You know, the original Shrike radomes [the dome at the very front of the missile that must be both transparent to the threat radar signals and sufficiently strong to withstand Mach 2+ flight speeds] were black. They were simply black because the material used gave a black radome. We got back these reports that radomes were being broken in the Fleet, a high number of them. Well, the problem was that they're moving hardware around on a crowded carrier deck at night, and you couldn't see the black radome, so we changed the radome so it would be white. You know, a real simple thing. Nobody had thought of it.[70]

Shrike was also involved in a bizarre incident later in the Vietnam War. As reported in *Time*:

> During the Haiphong raid [in April 1972], an anti-radar missile that was intended to strike a Communist antenna accidentally homed in on the guided missile frigate USS *Worden* (DLG-18). The ship was so heavily damaged that it had to be towed to the Philippines for repairs.

The official Navy history says the damage was inflicted by two missiles. One sailor was killed and nine seriously injured. Remarked Knemeyer, "We got a good evaluation of the Shrike warhead." The incident would lead to China Lake's crash program to install Sea Chaparral (dubbed Austere Sea Chaparral) systems on Navy ships assigned to coastal gunfire support in Vietnam.[71]

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69 Tambini, email to the author, 17 July 2011.

70 S-216, Porter interview, 36.

71 "The Nation: The Harrowing War in the Air," *Time*, 1 May 1972; *Dictionary of American Naval Fighting Ships*, Department of the Navy, Naval Historical Center, *http://www.history.navy.mil/danfs/w11/worden-iv.htm*, accessed 21 July 2010; S-200, Knemeyer interview, 67.

Even as it was fielded, Shrike kept evolving. In 1965 the Commander in Chief Pacific Fleet established an urgent need for a marker round for Shrike to aid in identifying the point of warhead detonation. The marker would need to be visible for 3 minutes to allow follow-up attacks on the radar site by aircraft armed with other conventional weapons. The marker should detonate with the proximity fuzing function, and not on impact (in case of a miss).

China Lake engineers, at the suggestion of the Bureau of Naval Weapons, experimented briefly with a small marker charge that replaced counterweights in the motor section. As NOTS chemist George S. Handler recalled, the BuWeps approach "resulted in a pitiful puff unsuitable for the intended effect." Handler, noted weapon designer Milton K. Burford, and pyrotechnics engineer Kenneth R. Foote then developed a white-phosphorous warhead that replaced the standard warhead. The successful Quick-Reaction Capability (QRC) development met the Navy and Air Force requirements and earned a patent for Burford, Handler, and Foote.[72]

In Fleet use, the modified Sparrow motor that had replaced the four 2.75-inch rockets was erratic and expensive—the opposite of the Shrike design philosophy of high reliability and low cost. China Lake prepared performance specifications for a new motor to be used for both Shrike and Sparrow.

After competing procurement contracts were let to Aerojet and Rocketdyne, both Shrike and Sparrow wound up with motors that were reliable and far less expensive. Ray Miller recalled that:

> We had the cost of the rocket motor down well below $3,000, where before, they were costing up around $15,000. . . . So that turned out to be a real advantage to Sparrow and Shrike both, to have that competition going.[73]

A subsequent propulsion improvement in the early 1970s replaced the all-boost propellant with a boost-sustain propellant combination, an improvement that extended Shrike's range by increasing motor burn time from 3 seconds to about 20 seconds.

An additional benefit was that the sustain-phase propellant did not produce a telltale smoke trail. Enemy radar crews in Vietnam had learned to detect that trail and use it as a cue to shut down their radars. The boost-sustain motor effort led to development of a variety of reduced-smoke propellants.

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72 NOTS TP 4020, *Pyrotechnic Research and Development, Propulsion Development Department Review, July 1965–December 1965,* Dec 1965; George Handler, email to Bill Porter, 12 Aug 2004.

73 S-262, Miller interview, 20.

NAF Plane Captain ADJ3 J. R. Upton with Vice Admiral Tom Connolly and Lieutenant Commander Ernest Mares in a TF-10 aircraft prior to a Shrike test flight.

Shrike's success reflected well on the Station and helped enhance its reputation as a laboratory that could accomplish any task assigned to it (and quite a few that were not assigned to it). Top-level military and civilian visitors continually visited the Station, and were accorded presentations and tours commensurate with their rank and interests.

In July 1966, Vice Admiral Tom Connolly, former NOTS experimental officer (1952-54) who had become COMNAVAIRPAC (Commander, Naval Air Forces, U.S. Pacific Fleet), arrived at the Station to learn more about the Shrike program and to fire a Shrike missile. The aircraft chosen for the admiral's Shrike launch was a TF-10, a two-seater with flight controls available only on the pilot's side.

Shrike project pilot Lieutenant Commander Ernest Mares was selected to accompany the admiral. The plan was that Mares would take off, he and Connolly would switch seats at 15,000 feet, Connolly (not qualified in that particular aircraft) would make the Shrike run against the SCR-584 target radar, then they would switch seats again, and Mares would land the aircraft. NAF's skipper and the technical officer were blunt with Mares, who recalled, "I was given direct orders that under no circumstances could I let that old man land the aircraft."

All went as planned. The Shrike struck the target dead on. "Admiral Connolly was absolutely euphoric!" Mares remembered. "We made a couple of turns over what was left of the target and he could hardly stop talking." They returned to Armitage Field, with Connolly still in the pilot's seat. As Mares tells it, he said, "'Admiral, enter the pattern downwind at 90 knots and shoot for 85 on final!' His landing was absolutely perfect."

As they taxied back into the chocks, the NAF skipper and technical officer were shocked when they saw who was in the pilot's seat. Recalled Mares:

> Apparently their facial expressions did not go unnoticed because just before he shut down the engines, the seasoned naval aviator told me, "Son, if either of those two four-stripers give you any crap about letting me land this plane, call me and I'll shitcan both of them!"[74]

Shrike became the most used guided missile in history. During the missile's service life, some 22,000 missile systems were manufactured, with more than 9,000 Shrikes fired in combat, and approximately 1,000 fired in development, testing, and training.[75]

Shrike was adopted by many U.S. allies and was used by the Israelis in two wars and by the British in the Falkland Islands conflict. In Operation Desert Storm, Shrikes were launched by Navy and Marine pilots who were not yet school age when the Shrike was first flown in combat.

Other Antiradiation Contributions

NOTS' contributions to the nation's antiradiation capabilities continued beyond Shrike's successful introduction. China Lake started a research-and-development effort in 1965 called the Electromagnetic Radiating Source Elimination (ERASE) program. Through ERASE, engineers like Mosko and Corzine would develop new antiradiation technologies—both for missiles and for aircraft avionics—that would culminate in the design of HARM (originally called Shrike-73) in the 1970s.

Using technology developed at China Lake in a short-lived program for the Army known as ARP (Antiradiation Projectile), HARM put the capabilities of all the AGM-45 "dash versions" in a single seeker and added greatly increased range and lethality in a very small package. By that time, however, the power of the defense industry in the acquisition process had greatly increased, and the

74 Lt. Cdr. Ernest Mares, USN (Ret.), "Shooting Stars," submitted to *The Skyhawk Assoc. Quarterly,* 2011.

75 Knemeyer, "Shrike's Forgotten Lessons," *The China Laker.* "Air-Launched Anti-Radiation Missiles" in *Jane's Defence Weekly*, 23 June 1984 1032, claims "24,000 plus."

primary difficulties faced by China Lake were less those of technology than of Washington politics and defense industry economics.

Another antiradiation missile of the day was Standard ARM (AGM-78, also called STARM), which began development by NOL Corona and General Dynamics in 1967. This weapon was basically a Standard missile—a large ship-launched air-defense weapon—fitted with a Shrike seeker on a gimbal and attachments for aircraft carriage. Later versions replaced the Shrike seeker with a wideband superheterodyne system. One of the justifications for Standard ARM's development was that the warhead was substantially larger than Shrike's. In the ongoing back-and-forth contest between Shrike shooters and air-defense emplacements, the enemy had taken to hardening its equipment and placing it behind revetments. U.S. fliers complained that a site would be shut down by Shrikes one day, but would be up and operating again the next, presumably after having the exposed radar antenna replaced. Standard ARM also had a range of over 30 miles, which was, barely, outside the effective range of the SAMs.

The Standard ARM program would move to China Lake organizationally with the realignment of Navy labs in 1967. Standard ARM would be fielded with the Navy and Air Force the same year. Although it was an effective weapon, its size and weight precluded it from being carried on some aircraft that could carry the Shrike. Standard ARM's size and high cost would leave Shrike as the preferred antiradar weapon through the remainder of the Vietnam War.

In 1967 China Lake completed development of the Shrike Improved Display System (SIDS), developed by the Special Projects Branch of Jack Russell's Antiradiation Division. This quick-fix program replaced the earlier Shrike display that had difficulty distinguishing individual targets in a dense threat-radar environment. SIDS used the nine-inch APG-53 radarscope on the A-4E to display light spots representing the emitting radars. The Shrike would go for the center dot. For this project, electronics engineer Robert A. Vargus was named a China Lake Fellow in Ordnance Science.

Instrumental in the SIDS design was Gerald O. Miller, in whose honor "GOM Box" became the pilots' pet name for the SIDS package. Recalled Miller:

> What we were doing was time sharing the radar system in the A-4 airplane, and we adapted an interface box which allowed us to use it as a Shrike display system when it was not in the radar mode . . . In that plane, you did not have the luxury of adding more equipment.

In 1967, China Lake sent 288 SIDS units to the Fleet.[76]

76 Mares, "Shooting Stars"; TS 84-14-2, Gerald O. Miller interview, ARM History Project, circa 1984, 10–11; *NWC Tech History 1967, Part 1,* 5-22.

The Special Projects Branch was also responsible for development of the Target Identification and Acquisition System (TIAS), designated the AN/APS-117, which gave pilots even better delivery capabilities in highly dense radar environments. Begun in 1965, Shrike TIAS employed a dedicated aircraft-mounted receiver and signal processor. By 1967 the new system had met all its performance specifications, including rear-lobe detections of threat radars at range of 20 to 30 nautical miles and handling multiple tracking and heavy-density radar environments without ambiguities or false alarms. TIAS was fielded in 1969. In the 1970s China Lake would execute Shrike on Board (SOB), a successful quick-reaction program to mount Shrike on Navy ships to counter shore-based fire-control radar. Just 104 days would elapse between SOB program initiation and its first successful combat use.[77]

Later would come HARM and still later Sidearm (AGM-122), a China Lake-developed radiation-homing Sidewinder missile for helicopter launch. All these weapons would trace their lineage to Moth, Corvus, ARM, Cobra—and to Shrike, the world's first operational antiradiation missile and most fired guided missile in history.

Nowhere is the difference between government laboratory development and contractor development more starkly drawn than with Shrike. Developing Shrike took managers—Riggs, Cleary, Porter, May—who could listen to a sound idea and say, "Let's do it," without quibbling over precisely where in the organization the program should properly go. China Lake's leaders had faith in the judgment of those managers and backed them with the Station's full range of resources. Early in its conceptual stage, the program's originators had access to and communication with people in the Navy hierarchy who recognized the potential value of the effort and provided funding. Throughout the program the originators also had access to the Fleet operators and maintenance personnel who would use the weapon. Importantly, the Bureau assigned responsibility for the complete weapon system to the Station, along with delegation of the authority to carry out that responsibility.

To actually prove the antiradiation missile concept and design a workable weapon system required the coordinated efforts of experts, in many case nationally and internationally recognized leaders, in such diverse disciplines as RF technology, aerodynamics, mathematics, chemistry, metallurgy, warhead design, rocket-motor design, and flight simulation. The program could not succeed without highly trained military test pilots and aircrews. It also required the co-located resources of controlled airspaces, instrumented indoor and

77 NWC TP 7088, R. E. Kistler and R. M. Glen, *Notable Achievements of the Naval Weapons Center*, August 1990, 35.

outdoor ranges of several types, supersonic test tracks, machine shops, explosives casting facilities, specialized RF test facilities, simulated threat environments, and computer facilities.

This extraordinary community of people and capabilities was all directed by the same employer, all working toward the same end, and all motivated by the goal of producing the best possible weapon at the most affordable price. There has never been a contractor or consortium of contractors that could bring those resources to bear on the from-scratch development of a single relatively inexpensive but vitally needed weapon. And by virtue of the fact that private industry has an obligation to shareholders to maximize profits, there never could be.

In a weapons-development model that has yet to be improved on, China Lake created Shrike with an in-house program and in-house design, using contractor support as necessary in the design, testing, and proofing. Once the design was complete, a comprehensive and thoroughly proven data package was turned over to the contractor for production, with NOTS assistance, oversight, and data control. With full design responsibility residing in the government laboratory, the most advantageous balance of effectiveness and cost was achieved. With a comprehensive specification developed at China Lake, the government had control of the program. When technical problems arose in operational use, an in-house team could be quickly assembled to solve them. And since the government "owned the documentation package," second-sourcing was carried out efficiently and with dramatic cost reductions

Phil Sprankle, a Shrike design engineer, understood the foundation of Shrike's success:

> Throughout the program, the government took responsibility for the system. It was not something that we passed off to the contractor for a large lump-sum fee and a promise to deliver a total package at a future date. Throughout the life of the program, it was China Lake that took responsibility for it.[78]

From the point of view of the warfighter, the payoff was simpler. "Thank God for Shrike," Bob Huntley said, "And thank God that we've got engineers who can put their head down and figure out weapons and give them to us to do the job with."[79]

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78 TS 84-14-9, Robert Corzine and Phillip Sprankle interview, ARM History Project, circa 1984, 10. Sprankle completed a 31-year career at China Lake as the advanced program analysis consultant in the Electronic Warfare Department. Among his career awards was the Navy Superior Civilian Service Award, presented for his work as China Lake's representative to the Naval Strike Warfare Center.

79 Huntley, "Have I Got a Story for You! 100 Wild Weasel Missions in Vietnam."

5

Command Performance

I cannot think of a prouder statement when asked what our occupation may be than to say "I serve the United States of America."

— President John F. Kennedy, speaking
at China Lake, 11 June 1963[1]

Every generation has at least one moment, an incident or event, that is universally shared and long remembered. These moments usually involve calamity—Pearl Harbor, President Kennedy's assassination, 9/11—or celebration—VE-Day, Neil Armstrong's walk on the moon. For the residents of the Indian Wells Valley in the 1960s, the unforgettable moment was 7 June 1963—the day President John F. Kennedy visited China Lake.

ROCKETEER
NOTS
FROM UNDER THE SEA TO THE STARS

Vol. XVIII, No. 21 Naval Ordnance Test Station, China Lake, California Fri., May 31, 1963

IT'S OFFICIAL!

PRESIDENT KENNEDY TO VISIT HERE FRIDAY

First President to Tour NOTS

Front page of the *Rocketeer*, 31 May 1963, giving China Lakers the news of the President's upcoming visit.

1 *IWV Independent and Times-Herald*, 13 June 1963, A7.

U.S. Presidents have a long tradition of "reviewing the Fleet." In 1962 Kennedy (a former naval officer) had conducted his review of the Atlantic Fleet. On 14 April that year he toured the latest Polaris submarine, USS *Thomas A. Edison* (SSBN-610), in Norfolk, Virginia, and then went aboard USS *Northampton* (CC-1) for a sail-by review of 48 ships of the Second Fleet. As *Northampton* sailed westward, it passed between two 6½-mile-long lines of eastward sailing ships. All the Fleet ships equipped with gun batteries fired the traditional Presidential 21-gun salute. The President transferred to USS *Enterprise* (CVN-65) where, accompanied by diplomats from 56 countries, he watched naval maneuvers and operations, including an Antisubmarine Rocket (ASROC) demonstration, and the firing of two Terrier missiles at a drone (which they missed).[2]

That afternoon at Camp Lejeune, North Carolina, with the Shah of Iran seated to his right, and Commandant of the Marine Corps (and Medal of Honor recipient) General David M. Shoup to his left, Kennedy watched as 9,000 Marines conducted an amphibious assault at Onslow Beach, North Carolina. Later that day he watched an air show at nearby Bogue Field. The Atlantic Fleet's military demonstrations were massive and impressive, and when a visit to the West Coast was scheduled for June 1963, Pacific Fleet command was determined to put on at least as good a show for the President as had their eastern counterparts.

On 31 May 1963 the *Rocketeer* announced the impending visit of the President, carrying a bold "It's Official!" banner across the top of the front page. This news was a surprise to few, since no Presidential visit is spontaneous, and 6 weeks of feverish planning and scheduling preceded the announcement. The event was considered of such importance that it was assigned the Navy code name, NOTS Project 1-63. As the *Rocketeer* explained:

> The code name refers to NOTS first operational designation of the year. But then too, it can be construed as saying that Mr. Kennedy is the first President ever to visit the Station. The visit was carried as "classified" information until this week. All references were made to the short-term code.[3]

NOTS' director for Project 1-63 was Special Military Assistant/Plans and Operations Officer Captain Floyd Reck, a 22-year Navy veteran. His assistant director was Lieutenant Colonel D. L. "Tex" Ritter, the Marine liaison officer, whose qualification for the position was that he had helped with a Presidential

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2 MN-9928, "An Answer," documentary film on the President's review of the Atlantic Fleet, U.S. Naval Photographic Center, Atlantic Fleet Mobile Photographic Center, and Seneca Productions, 1963.

3 *Rocketeer*, 31 May 1963, 5.

visit in Hawaii several years before. Assisting them in project-coordination capacities were Commander J. A. Sickel, Commander R. B. Speaker, Lieutenant Commander R. C. Clasen, Albert B. Christman, Robert A. Appleton, William N. Sorbo, Henry H. Wair, William H. Hampton, and J. T. Bibby—and a supporting cast of hundreds.

China Lake was largely a restricted area; most of the base, including Michelson Laboratory, Armitage Field, and the million acres of ranges, was accessible only to those who needed to be there. Access was through gates guarded by armed Marines. To enter these areas, individuals had to display the correct area designators on their badges.

Despite the rigid security, the concept of an "open house" had developed at the Station over the years. Around Armed Forces Day (mid May) and Christmas, parts of the Mich Lab complex, the airfield, the China Lake Pilot Plant ("the hill"), and the golf course were open to the public.[4]

Open houses were opportunities for Indian Wells Valley residents to glimpse what went on at the base and to gawk at displays of weaponry. Family members could see where their spouses or parents worked. An Armed Forces Day open house was accompanied by an air show—sometimes featuring the Blue Angels—and firepower demonstrations that included, since 1957, a Sidewinder firing.

NOTS Commander Capt. Charles Blenman ordered an open house for 7 June. It would encompass, in the words of the *Rocketeer*, "A three-fold celebration: that of the President's visit, the 20th anniversary of NOTS, and Armed Forces Day." (The traditional Armed Forces Day open house in May had been deferred because of 1-63).

On Wednesday, 5 June 1963, the President began a tour of western military bases by flying from Washington to Colorado Springs, where he visited the North American Air Defense Command headquarters and addressed the graduating class of the Air Force Academy. He next stopped at White Sands Missile Range in New Mexico.

After spending the night in El Paso, Texas, he flew to San Diego on Thursday morning and delivered the commencement address at San Diego State College, where he also received the first honorary doctorate of laws presented by that institution.

4 The China Lake Pilot Plant (CLPP, pronounced "clip") entrance gate is referred to as the "clip gate." Everything behind the gate (to the east) is known informally as "the hill." People who work "on the hill" are primarily involved in propulsion-related activities and are one of several subcultures within the China Lake community.

He was then helicoptered to the Marine Corps Recruit Depot in San Diego for a recruit-training demonstration and an inspection of the troops and from there to the attack aircraft carrier USS *Oriskany* (CVA-34) to begin his Fleet visit. En route to *Oriskany* he watched an anti-mine-warfare operation by SEAL (Sea, Air, Land) and underwater demolition teams in the waters off Silver Strand, south of Coronado.

Aboard *Oriskany* the President observed an antiair-warfare demonstration. Next he was flown to USS *Kitty Hawk* (CV-63), where he watched an impressive display of firepower including Fleet air firings of Sidewinders and Sparrows, and ship launches of Terrier and Tartar missiles against a Firebee drone (which the missiles destroyed). He also witnessed an antisubmarine warfare exercise in which the nuclear submarine USS *Permit* (SSN-594) played the target submarine. The Fleet was demonstrating its ability to move through a hostile air and submarine environment to project Navy and Marine Corps power to any trouble spot in the world. Addressing the assembled crew of *Kitty Hawk*, the President spoke on the subject of control of the seas:

> All of us have been impressed by how vigorously and successfully the United States Navy has applied all of the modern advances in science and technology to this age-old struggle for maintenance and control of the seas.[5]

On Friday at 10 a.m., after a night aboard *Kitty Hawk* that included a demonstration of night carrier operations, the President helicoptered to Point Mugu for a brief tour. He then boarded Air Force One (the Presidential Boeing 707) for the flight from Point Mugu to China Lake, where he was scheduled to land at 10:55 a.m.

Logistics and scheduling for the Presidential visit were intimidating. There were issues of security; not only the President but also a significant number of top military and civilian leaders would be in attendance. Secret Service agents from Los Angeles had made an advance inspection of the site, and the advance shift of agents arrived well before the Presidential party.

According to Agent Toby Chandler, a member of the President's Secret Service detail at the time, NOTS security officials initially balked when told that the President's agents planned to accompany him at all times, even in the most sensitive classified briefings and private meetings. It was made clear to the base security officials that the agents were "with him, everywhere, always." Appropriate badges were quickly issued.[6]

5 MN-9928, "United States Arriving," documentary film on the President's review of the Pacific Fleet, part of the "Sea Power for Security" series, U.S. Naval Photographic Center, 1963.

6 Toby Chandler, email to the author, 31 Aug 2011.

Crowd control was a potential problem for the visit; no one knew how many civilians would show up for a chance to see the President, nor from how far away. (The final official total was 27,000, in addition to the 10,000 base residents.)[7]

Firepower Demonstration

The firepower demonstration—the centerpiece of the NOTS visit—presented its own challenges. It would be much larger than anything the Station had done before, and many of the weapons were still in their developmental stages.

To ensure that the show went off smoothly, three full-scale practices were held, on 20 May, 29 May, and 3 June. These practice runs required coordination not only of the VX-5 and project aircraft based at Armitage Field but also of the participating fighter and attack squadrons, Carrier Air Group (CAG) 16 operating from *Oriskany* and CAG 11 from *Kitty Hawk*.

Base employees were allowed to park near the golf course and Lark ramp to watch the rehearsals, but not for the actual demonstration. Command's memo to all hands announcing the rehearsals simply referred to them as "demonstration firings of fleet and developmental weapons" and stated that "Department Heads may grant excused time to NOTS employees who can be spared."[8]

Weapons need targets, and Public Works and Range Division crews were experienced at building them. In the actual demonstration, 20 different targets were used, not counting the flares and the drone targets employed in the Sidewinder firings. Newt Ward recalled:

> We spent a hell of a lot of good taxpayers' money building a ship out on the desert and having all the guys who were going to drop bombs or shoot rockets or anything practice on that. We knocked it down, then we'd build another one. It was out of plywood, lots of plywood, lots of carpenters' time putting it together, lots of bullets and rockets being fired.[9]

Thousands of details required attention: signage, displays, camera crew assignments, meals for guests, crowd control, and accommodations for some

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7 Memo 14/DLR/lae, Ser. 0080, Commander, NOTS, to Chief, Bureau of Naval Weapons, "Presidential visit to NOTS, 7 June 1963, report of," 21 June 1963. All of Capt. Blenman's subsequent comments in this chapter are also quoted from this memorandum.

8 Memo 11/JAQ:mja, Commander, NOTS, "Demonstration Firings 22 and 29 May," 20 May 1963.

9 S-211, Dr. Newton E. and Maryon Ward interview, 11 June 1992, 100.

275 members of the U.S. and foreign press. "Prettification" of the base was an issue, and both Public Works and China Lake residents stepped up, mowing lawns and printing or refurbishing anything on which the distinguished guests might set their eyes.

When someone raised the question of what to do if weather forced cancellation of the firepower demonstration, Al Christman, who had been tapped as static display coordinator, assigned the Technical Information Department to make a film. He reported that:

> This complete film was produced in an amazingly short time using mainly film shot during the 29 May dry run. A week later the film was ready in the event foul weather caused cancellation of the weapon demonstration that could be shown to the President in Michelson Laboratory.[10]

It seemed that everyone at China Lake was swept up in the preparations. Rod McClung remembered that:

> The amount of work and effort that went into that was beyond belief. They built a huge grandstand out there for Kennedy and other parties to sit in and view a live demonstration of our ordnance, and they even brought in septic tanks and . . . a complete restroom just in case the President wanted to go while he was there, which I understand he didn't.
>
> Those of us who lived near the Commander, of which I was one, were told that we had to take care and get our dogs out of the neighborhood because the President was going to take a nap. There would be no barking dogs in the neighborhood.
>
> We had to have a forest [for the Helicopter Trap Weapon demonstration] so they cut down all the trees on the way to the air facility. The road used to be lined with trees, so they cut all the trees off at almost the ground level to build an artificial forest out there. As time went on, year after year, these stumps that were left would start growing new trunks . . . so we could watch the "Kennedy forest" reestablish itself.[11]

Static weapon displays were set up for the President's viewing at Mich Lab; unclassified weapons outside, classified ones in the first wing of the lab. "They painted that first entryway, then down to the first bathroom. In case he had to go to the bathroom, that was all redone," Dick DeMarco recalled. "So this is all the things that they were doing for Kennedy's visit that he had no clue about."[12]

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10 Memo 75201/ABC:hmt, Reg. 75-20825, Al Christman to Plans and Operations Officer (Code 14), "Nominations for Special Recognition on Project NOTS 1-63," 17 June 1963.

11 S-188, McClung interview, 67. The "forest" is clearly visible in the film *United States Arriving*, cited above.

12 S-248, DeMarco interview, 92.

Page Four THE ROCKETEER Friday, June 7, 1963

Department Heads of NOTS

Capt J. A. Quense, Executive Officer
H. G. Wilson, Assoc. Tech. Dir.
Dr. G. S. Colladay, Weapons Planning
Dr. I. E. Highberg, Test
Dr. N. E. Ward, Aviation Ordnance
F. H. Knemeyer, Weapons Dev.
J. T. Bartling, Propulsion Dev.
Dr. T. E. Phipps, Research
D. J. Wilcox, Underwater Ordnance
R. J. Bjorklund, Central Staff
K. S. Skaar, Safety
K. H. Booty, Engineering
R. W. Anderson, Personnel
K. H. Robinson, Technical Information

NOTS leaders as published in the 7 June 1963 souvenir edition of the *Rocketeer*.

That Friday morning began early at the Station. At 4 a.m., 28 members of China Lake Civil Air Patrol Squadron 84 assembled at the *Rocketeer* office then fanned out across the base and town to deliver 8,000 copies of Friday's *Rocketeer*, which contained the program of events and guidelines for visitors. The souvenir edition was replete with photographs of visiting dignitaries, NOTS leaders, and past NOTS Commanders, and included an illustrated review of the Station's "Twenty Years of Research and Development," as well as an article about three "NOTS Women Scientists" (Marian E. Hills, Marguerite M. Rogers, and Jean M. Bennett, all PhDs).[13]

Pat Burke, who ran a milk-delivery route in Ridgecrest, had been up since 2 that morning, hoping to complete his route in time to see the President's motorcade. "I was at the China Lake Trailer Court in Ridgecrest and I saw Air Force One come over. I can remember getting choked up just watching it," he said.[14]

Air Force One landed at 11:20 a.m., 25 minutes behind schedule. The moment the wheels touched the runway, Blenman's flag was lowered at the Station's headquarters, two miles from Armitage Field, and the Presidential flag was run up the staff. It was the first and, as of this writing, the last time the flag of the President of the United States flew over China Lake.

13 *Rocketeer*, 7 June 1963.
14 S-279, Pat Burke interview, 7 Oct 2008, 3.

Air Force One shortly after landing at Armitage Field, China Lake.

Gary Verver, then a sailor at NAF, was part of the line crew that rolled the stairs up to the aircraft. The sailors wore special uniforms that included heavy white coveralls worn over the regular working dungarees and white tight-fitting skull caps that snapped under the chin. They didn't wear ear protectors because "it didn't look good," recalled Verver. The outfits, hot under the mid-day desert sun, were worn only for visiting dignitaries and were "universally despised at China Lake."[15]

If ever China Lake had visiting dignitaries, the group that arrived that Friday morning fit the title. Accompanying the President on the civilian side were Secretary of the Navy Fred Korth, Under Secretary of the Navy Paul Fay, California Governor Edmund G. Brown, California Senators Clair Engle and Thomas Kuchell, Georgia Senator Richard Russell, California Congressman Harlan Hagen, and White House Press Secretary Pierre Salinger.

The military was represented by Chairman of the Joint Chiefs of Staff General Maxwell Taylor; Chief of Naval Operations Admiral George W.

15 Gary Verver, email to the author, 10 Oct 2008.

Anderson, Jr.; Commander in Chief of the Pacific Fleet Admiral John Sides; Commander of Naval Air Forces Pacific Fleet Vice Admiral P. D. Stroop; Commander of the First Fleet Vice Admiral R. T. S. Keith; Commandant of the Marine Corps David M. Shoup; Medical Aide to the President Rear Admiral G. G. Burkley; Naval Aide to the President Captain Tazewell Shepard; and Rear Admiral William Blenman, USN (Ret), Captain Blenman's brother. Add various and sundry White House aides and assistants, a full Secret Service contingent, and a horde of curious journalists, and China Lake was hosting as powerful a group of visitors as the base had ever seen.

Welcoming formalities were conducted quickly. Though the high temperature that day was only 79°, the sun was fierce (the airfield sits at 2,283 feet above sea level), and the civilians wore dark business suits. Each guest was given an official program and a briefing booklet.

NOTS leaders were well aware of Kennedy's (and General Taylor's) commitment to the doctrine of "flexible response"and to the need for military

Presidential greeting at Armitage Field. From left are California Governor Edmund G. Brown (in rear); President John F. Kennedy, NOTS Commander Capt. Charles Blenman, Jr.; Capt. Tazewell Shepard (Kennedy's naval aide); unknown captain; and NOTS Technical Director Dr. William B. McLean in front of Hangar 2.

technologies suitable for limited warfare. Indeed, despite the Station's heavy involvement in nuclear weapons—development, strategy, and delivery tactics—the firepower demonstration and exhibits on 7 June were focused almost exclusively on the type of weaponry that was already being used, or would be suitable for use, in Southeast Asia. The briefing booklet stated:

> Presented will be the capabilities of naval aviation today against targets likely to be encountered in limited war situations. The demonstration will also include, by way of contrast, improved weapons and devices now under development, which will soon give our Navy, its sister services, and our allies a greater capability to prosecute limited war.

In a section titled Philosophy of Operation the brochure noted that "For almost 10 years NOTS has recognized the crucial need for better means of prosecuting limited wars." Now the Station had the opportunity to show the President—and top Navy and Marine Corps brass—what it was talking about.

Five minutes after the guests debarked Air Force One, the motorcade left the Naval Air Facility for the demonstration area, about 3 miles east of the airfield and 1½ mile north of B Mountain. (The President's limo and other support vehicles had been flown in on a C-130 the previous day, and Secret Service agents had spent the night with them in a hangar).[16]

People had been pouring into the base since 9 a.m. and, as the motorcade got under way, crowds were packed six deep behind a line of barricades stretched across the Armitage Field tarmac. As his car drove slowly past, paralleling the barricades and about 50 feet away, the President stood and waved to the cheering crowd.

On the drive to the demonstration site, Captain Blenman rode with the President, Governor Brown, Senator Engle, and Secretary Korth in the President's limousine. Kennedy peppered Blenman with questions. According to Blenman's after-action report to the Bureau of Naval Weapons, the President asked about the history of the base, its mission, and its population characteristics. When he asked what the most important projects on the base were, Blenman responded that Shrike (Project ESE) was the No. 1 project, and there ensued the conversation related in Chapter 4.

The President next asked Blenman the difference between the Sidewinder 1A (the AIM-9B, which the Nationalist Chinese had used successfully against

16 The film of the visit clearly shows the limousine's license plate as District of Columbia plate GG300. The Secret Service has verified that this is the limousine known as X-100, a customized 1961 Lincoln Continental with a removable top—the same vehicle in which President Kennedy was riding when he was shot in Dallas on 23 November (Mike Sampson, Secret Service historian, telephone conversation and emails with the author, 27 July 2009).

the Communist Chinese in 1958 and with which the U.S. Air Force and NATO were equipped) and the new Sidewinder 1C (with a larger operational envelope and interchangeable radar and infrared seekers). After receiving the explanation, the President asked:

> . . . why Dr. McLean (who receives only $20,000 a year) was still working for the Navy, in view of the fact that his scientific eminence and particular genius would be most attractive to industry. Commander, NOTS, responded that, in his opinion Dr. McLean was tremendously loyal to the Navy and was also given a great deal of latitude or freedom in being allowed to pursue programs he thought best, and he probably would not enjoy this freedom to the same extent if he were to work for industry.

The drive in the open limo from Armitage Field to the demonstration area took only 10 minutes, but to Blenman it may have seemed longer. With a diversified Navy career and 2 years under his belt as Commander, NOTS, he was well qualified to answer the Kennedy party's questions.[17]

The Secretary of the Navy must have been satisfied with Blenman's comments during the short trip, because he asked the NOTS Commander to sit between himself and the President during the demonstration.

At the demonstration area were two viewing grandstands—one for the President's party and another for the press, which had arrived at the site moments before in eight chartered buses.

The stands faced northeast, with a clear view of a wide, flat expanse of G Range. Scattered across the range were more than a score of targets, ranging from simple plywood panels and structures to vehicle convoys and two giant wooden ships. Several targets were painted with large letters so the audience would know where to look for a particular event. Behind the targets the mountains shimmered in a haze of heat waves rising from the desert floor.

"Although it would never be allowed today," wrote Tony Tambini, who flew the Shrike portion of the demonstration, "the reviewing stand was placed so close to the targets, you could feel the blast from the larger weapons."[18]

Bill McEwan, one of the fortunate NOTS employees to be seated in the President's stand, recalled that "he was very nice. He came up and shook hands and said, 'I'm Jack Kennedy.'"[19]

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17 Blenman was both a naval aviator (he had earned the Distinguished Flying Cross in WWII) and, as former Commanding Officer of USS *Windham Bay* (CVE-92), a "black shoe" (the traditional name for members of the surface Navy).

18 *The Flying Tambinis*, 11.

19 S-249, Dr. William S. McEwan interview, 12 May 2008, 30.

Ingenious engineers had designed, and Public Works had constructed, a special addition to the President's grandstand: a "miniature carrier deck-edge elevator," about 8 feet wide, that could be run up to Kennedy's eye level with models and displays of various weapons as they were demonstrated. A smaller elevator to the right carried photographs of aircraft and weapons. Directly in front of the President at knee level was a television monitor.

During the two rehearsals, the script for the demonstration had been painstakingly refined and revised. Selected to narrate the show for the guests were two naval officers well-suited for the task. Captain Carl O. Holmquist, NOTS Technical Officer, who presented an unclassified narration of the events to the press viewing stands, was a decorated combat veteran and a Naval Academy graduate with a PhD in aeronautics from Caltech.

Presenting the more detailed, classified narration for the President and his party was VX-5 Executive Officer Commander Joseph E. Schwager, also a Naval Academy graduate and the holder of a master's degree in physics from MIT and two doctorates (physics and nuclear engineering) from the University of California, Berkeley. In addition to the two narrators, Navy Chief Journalist Ronald Sweig carried live coverage of the demonstration via telephone to listeners of a Los Angeles radio station.

According to Blenman's report, the demonstration started at 11:34 a.m. Schwager opened the show with brief introductory comments, including:

> Most of the weapons you will see today were born at this Station. They were conceived in Michelson Laboratory which you will visit later and developed and tested on these ranges. . . . The purpose of this demonstration is to contrast our stockpiled limited war weapons, their tactics, and their effects, with some of the more effective limited war weapons now under development.[20]

Schwager included some "housekeeping" details: "All aircraft will approach from your right and will generally be difficult to see until close in—a disadvantage which we sincerely hope will be shared by defense units on actual strikes."

The firepower demonstration comprised 30 discrete events divided into two segments (a 31st event, a demonstration of the Weteye chemical-weapon dispenser spraying colored water on a mock troop convoy, was cancelled after the second rehearsal.) The first nine events, flown by pilots from *Oriskany*'s CAG 16, were designed to showcase the current conventional air-strike capabilities of carrier-based aircraft. The remainder of the show highlighted systems being developed and tested at NOTS.

20 *Commentary for NOTS 1-63*, typed manuscript, 3 June 1963, in archives of the China Lake History Program.

Four A-4 Skyhawks dropping napalm bombs for the Kennedy demonstration.

An RF-8 Crusader flying a simulated "reconnaissance" mission opened the show with a bang, flying a huge loop while it deployed 21 photoflash bombs over the target area in a salute to the President. Next came four piston-engined A-1 Skyraiders, each carrying a dozen 250-pound bombs, rolling in on their targets from 9,000 feet for a 30-degree glide attack. The "Spads," as pilots called the A-1s, were followed by four A-4 Skyhawks, each with 18 250-pound bombs. Flying near ground level, the Skyhawks closed in and then pulled up to loft their combined 9 tons of bombs more than 3 miles onto the target. Next in was a pair of A-4s carrying Bullpup liquid-fueled air-to-surface missiles, which the pilots launched from a 7,000-foot altitude, then radio-guided to the target.

The NOTS–developed 5-inch High-Velocity Aircraft Rockets (HVARs) were next up, launched in a simulated close-air-support operation from four A-1s. Ratcheting the firepower up a notch, four more A-1s came in with 2.75-inch Folding-Fin Aircraft Rockets (FFARs); with 84 rockets per aircraft, the barrage carried twice the destructive power of the HVARs. (The narrator noted that the shelf price for FFARs was less than $55 per copy.)

The final rocket deliveries came from four A-4s firing 32 NOTS-developed 5-inch Zunis on the target. Before the smoke from the Zunis had cleared, four more A-4s flying at 500 knots just above the deck dropped three napalm bombs each, engulfing the target area in burning gelled gasoline and creating a towering black mushroom-shaped cloud. The segment ended with a high-low pass of two RF-8s taking post-strike photo reconnaissance. "The pictures they take will be processed for your review," said Schwager.

Up to this point, both the dignitaries' stands and the press stands had been receiving the briefing from Schwager. Beginning with Event 10, Holmquist delivered the unclassified narration for the press, while Schwager presented President Kennedy's stand with more detailed classified information about the capability of the new weapons. There was actually little difference between the two narrations: for example, in the Sidewinder 1C demonstration, Schwager mentioned a maximum altitude capability of 80,000 feet, while Holmquist merely noted "extreme altitudes."

Before the demonstration of new weaponry began, Schwager commented:

> May I emphasize that the events to follow illustrate weapons in various stages of development and test. Like parents bracing themselves for the possible embarrassments of a child's first recital, we continue.

Event 10 was a strafing run by a T-28 trainer carrying two .50-caliber machine guns of WWII vintage, each firing about 750 rounds per minute. Event 11 took the pace up a notch: two F-8A Crusaders, each mounting four 20-mm cannons, with each cannon firing at 1,000 rounds per minute. As the planes attacked, Holmquist told his audience "it is very difficult for a pilot to miss—he simply walks his tracers on to the target, much like playing a garden hose."

Dramatically concluding the strafing demonstration was Event 12, a single A-4 carrying the High-Performance External Gun (HIPEG) system, which was still in development. The three externally mounted 20-mm cannon pods laid down a withering 12,000 rounds per minute. In 1963, HIPEG fired faster per barrel than any automatic weapon ever developed.

The Walleye glide weapon was not far enough along in development to be demonstrated as a complete system, so it was presented in two stages. First was a captive carry of a Walleye with an active seeker. The television camera on the President's viewing stand was hooked up to a nearby telemetry van connected through a data link to an airborne A-4 carrying a Walleye. As Schwager narrated:

> We will illustrate the Walleye guidance system with a live telecast relayed from a captive Walleye in flight so you may see on your television monitor exactly what the Walleye sees as it homes on Target J.

As Bill Woodworth recalled:

> . . . lo and behold, it all worked. It even tracked the stand that Kennedy was on, flew at it, and so forth, which may have caused the Secret Service some consternation . . . It occupied probably way more time and effort than it was worth because, as I understand it from people who were with Kennedy, he

> couldn't figure out what the hell he was seeing on the TV screen, which is understandable.[21]

Following the Walleye seeker demonstration, a Walleye static warhead was detonated against a Public-Works-built bridge structure flanked by a tank and truck. The warhead successfully demolished the targets as Schwager told the President:

> The warhead is of a unique design. When it detonates, the gaseous jets created by the explosion are focused outward. They travel at such extremely high velocity that hard targets are literally ripped apart at close ranges.

Kennedy, according to Blenman:

> . . . appeared to be very interested in Walleye. . . . He made the observation that in these days of fast airplanes, with relatively limited endurance that had to hit a target in a highly defended area, the pilots had to hit on the first pass as they would probably never have another opportunity. He observed that this requirement meant that we had to develop fine weapons and good fire control systems, and that we had to have highly skilled pilots.

The President's remarks were prescient: the search for the right combination of weapon, fire-control system, and pilot would be a long one. The Thanh Hoa Bridge in North Vietnam, for example, would be the site of hundreds of unsuccessful U.S. missions, with great loss of aircraft and aircrews, from 1965 until the bridge was finally brought down in 1972.

By now the demonstration was about half over. The next event was Gladeye, a dispenser weapon containing seven canisters that could be deployed individually or in ripple firing. The canisters could be loaded with chaff, leaflets, or fragmentation bomblets. For this demonstration, an A-4 carried two dispensers, each loaded with 35,000 Lazy Dog steel projectiles. The target was a field of red balloons, simulating enemy soldiers.

As balloon breakers, the Lazy Dogs were a success. However, Ray Powell, who tested them at China Lake, did not think highly of them. "When it hit terminal velocity, it would start tumbling and most of it didn't even break that plastic [target] panel. It hit flat on it." Commander Gary Palmer, who also flew at China Lake (and, like Powell, in Vietnam) said:

> We had an idiot concept called Lazy Dog that had 45-caliber slugs with little fins on them. . . . The place we were working [Vietnam] was a jungle. There's lots of tree branches and stuff. I like things that go 'boom' instead of just drop and rain down.[22]

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21 S-215, Woodworth interview, 84–85.

22 S-270, Powell interview, 51; S-280, Palmer interview, 11–12.

Next was Sadeye, another NOTS-developed dispenser weapon. The *Rocketeer* described the weapon as the "Sadeye dispenser which during its trajectory spews anti-personnel grenades over a large target area." The grenades themselves were highly classified because of their novel kill mechanisms. They were intended, Project Manager Jack Lyons said, to take care of "the situation where you've got hordes of Chinese, wave after wave of people on the ground, [where] you need to drop something that would take care of a large group of people." The battlefields of Korea were still fresh in the memories of many weapon designers.[23]

Out of deference to safety, the bomblets used for the demonstration, while explosive, were not the actual bomblets that would be used in the weapon. An A-4 Skyhawk delivered the bomblets, and a platoon of what Schwager described as "200 brightly colored balloons, designed to simulate troops in tactical deployment," was wiped out.

Events 17 and 18 were the Sidewinder shots. In the first event, two F-8 Crusaders launched target rockets—yet another NOTS innovation to save money in developmental testing and training—and a few seconds later launched their heat-seeking Sidewinder 1As at the rockets. Both shots were successful. The narrator stated that the weapons used in the event were "NATO Sidewinder[s] assembled from components recently shipped here from nine NATO countries." The display elevator rose to the President's level, festooned with the flags of the participating allies.

For the Sidewinder 1C firings, a QF-9 drone was launched. Trailing it were two DF-1D Fury chase planes, in case the drone control malfunctioned. Two F-8 Crusaders closed on the target and from 3 miles away fired their Sidewinders, sending the burning drone tumbling 5,000 feet to the desert floor.

Both Sidewinder demonstrations drew Presidential comments. Blenman reported:

> The President seemed to be very interested in the Sidewinder 1A program in NATO and seemed impressed that they had this weapon. He questioned why NATO nations did not buy the weapon from U.S. manufacturers instead of it being manufactured in various parts of Europe. Mr. Korth [Secretary of the Navy] indicated that this decision had been made by the previous Administration.

After the dramatic drone kill, the President asked Korth:

> . . . whether or not we were going to make this missile available to NATO; he also said that he did not think we should, not only because of the tremendously

23 *Rocketeer*, 31 May 1963, 3; S-282, Lyons interview, 28.

> increased capability (the demonstration kill was made at a slant range of 17,000 feet), but that it would be compromised soon after it went to NATO. Mr. Korth assured him that there were no plans to do this.

Snakeye, the NOTS-developed retarded-delivery bomb, was up next. Gary Palmer and Ray Powell flew the event in A-4s in section formation. With a pilot's attention to detail, Powell recalled 45 years later:

> We flew into the target at about 100 feet to a pop-up point abeam Bravo Mountain, popped up to about 2,000 feet AGL [above ground level], did a roll-ahead maneuver and pulled into about a 20-degree dive, released 4 bombs each in a retarded mode at 450 knots at about 800 feet and made a flat recovery, leveling off at about 100 feet AGL.

For more than four decades Powell would rib Palmer (the flight leader) because instead of giving the ordnance-release command "drop" that they'd practiced, Palmer instead radioed a drawn out "reeeeeelease." Nevertheless their 250-pound bombs landed square on target.[24]

Next Rockeye I cluster weapons, each encompassing 96 2.75-inch shaped-charge warheads clustered around a Zuni rocket motor, were delivered by two A-4Es, the Navy's newest Skyhawks (the other Skyhawks in the demonstration were A-4As, Bs, and Cs) to decimate a truck convoy target.

Shrike was demonstrated in Event 21. According to Blenman, the Shrike shot was one of only two "obvious failures" in the show, impacting 353 feet left of the target. "The target was so far downrange that they had no way of knowing whether it hit the target, and we didn't hit the target, but the President didn't know that, as I recall," said Bill Porter, who would become Shrike program manager the following year. Another year and a half of intense developmental work would be required before the weapon was released to the Fleet and used, effectively and in great numbers, against North Vietnam's Soviet-supplied fire-control radars.[25]

Following the Shrike event was a massive bombing display by a pair of Phantom II F-4B fighters, flown by Marine Captain Hal Vincent and Navy Lieutenant Paul McCarthy. The sequencing of the events simulated a tactical operation; Shrike-equipped aircraft would knock out the SAM defenses so the strike aircraft could blast the primary target that the SAMs were defending. Prior to the development of the Multiple Carriage Bomb Rack by Captain Bill Fitch and Major K. P. Rice at China Lake in 1959 and 1960, the F-4 (then designated F4H) was limited to one bomb for each of its five external

24 Ray Powell, email to the author, 13 Oct 2008; S-280, Palmer interview, 3.

25 S-216, Porter interview, 35.

weapon stations (four partially recessed fuselage stations could accommodate only Sparrow missiles). But by 1963, a single Phantom with multiple carriage racks could carry 24 500-pound bombs, and still carry a fuel tank on the center station, which is exactly what the demonstration aircraft did. Vincent, who had served 2 years with VX-5 before returning to the Fleet, recalled that the 12 tons of bombs dropped by the two aircraft turned the wooden ship target "into splinters."[26]

Meanwhile, on Blandy Avenue, crowds were building. All the local schools were closed for the day, and whole families were hoping to get a glimpse of the very popular young President. The following week's *Rocketeer* would report:

> To the thousands who waited for hours along the Blandy St. parade route, it seemed as though the President would never get there. But they knew the schedule of events and waited as patiently as they could. Some used binoculars to watch the planes zoom in on their aerial demonstration runs to see the explosions rise up from the desert floor.[27]

On G Range, the demonstration now took a turn from weapons to weather control (although as NOTS would one day show, control of the weather could be an effective weapon). A single A-3 Skywarrior approached the demonstration area at 15,000 feet and released 160 pounds of silver iodide smoke comprising, in Schwager's words, "10 million billion particles." Schwager explained that this cloud seeding technique would normally be done from 45,000 feet.

President Kennedy asked Blenman what the applications were for weather modification "to which it was replied that there were many tactical situations where weather modification capability would be quite useful and, of course, the peacetime applications for weather modification were many indeed." Blenman pointed out that NOTS was collaborating with the Department of Commerce in Project Stormfury, which was investigating the effectiveness of weather modification techniques to affect hurricanes. Schwager noted in his commentary that "these same techniques could be used for such applications as closing mountain passes with snow or clearing cold ground fog in the Arctic."

Following the weather modification event, the severed tree tops from the Kennedy forest had their brief moment of Presidential attention. The narrators explained the problem of insurgents using bamboo poles to damage helicopters attempting to deploy troops in the jungle. They then described the NOTS solution: a Zuni continuous-rod warhead, dropped from a helicopter to detonate perpendicular to the ground.

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26 Vincent email to the author, 18 Oct 2008. Vincent would eventually retire from the Marine Corps as a major general. McCarthy would attain the rank of vice admiral.

27 *Rocketeer*, 14 June 1963, 9.

"Upon detonation," said Schwager, "the Zuni sterilizer deploys a rapidly expanding ring of steel rod, in a horizontal plane, cutting the poles. Result: Instant heliport!" The previously planted warhead was then detonated remotely, with a close-up of the explosion shown on the President's TV monitor.

After WWII, China Lake had received a great many B-29 Superfortresses that were no longer needed by the Air Force. To the regret of current aircraft preservationists, most of these venerable aircraft were used for targets, and one of them was the test object for the next demonstration event: fuel-air explosive. Called FAX at this stage of its development (later FAE), the weapon consisted of a container of fuel that was vaporized by an initial explosion. After a moment's delay the resulting aerosol cloud was detonated. The detonated fuel-air mixture produced extremely high overpressures. As President Kennedy watched (he was advised by Schwager that the television would provide a better look at the effect), the FAX bomb was triggered and the B-29 destroyed.

At this point the demonstration had been going on for 45 minutes, but NOTS still had plenty to show the President, his high-level guests, and the 275 members of the U.S. and foreign press.

The next event was intended to demonstrate for the watchers the use of plastic-bonded explosives, or PBX, a product of NOTS explosives and chemical research. The plan was to tow a truck through a minefield—but not your standard WWII minefield. As Schwager described it:

> As an illustration of the fiendish potentialities for PBX, one nasty trick is to make disguised land mines by molding PBX in the shape and color of rocks common to an area. Dropped along roads or paths these rocks will detonate upon future disturbance. A mechanism is provided which will make them inoperative after a stipulated period of time.

Meanwhile, Holmquist could only tell his audience that the event involved a land mine made of PBX and that "because of the nature of this particular event, I am afraid I cannot discuss it further."

At this point occurred the second "obvious failure" that Blenman noted. The vehicle that was being towed toward the PBX mine failed to contact the mine. There was no explosion. Contingency planning paid off, however, and Blenman reported that "a film clip of the successful land mine detonation [filmed during one of the rehearsals] was promptly shown to the President on his TV monitor."

Event 27 was a demonstration of the NOTS-developed Rocket Assisted Personnel Ejection Catapult (RAPEC), a device that since its fielding in 1960 had saved the lives of scores of Navy and Air Force pilots. RAPEC allowed a pilot to safely eject near or at ground level by propelling the ejection seat 200 feet from the aircraft, giving sufficient altitude for the parachute to deploy and lower the pilot to earth safely.

A TF-9J Cougar trainer approached the demonstration area at 150 knots, 50 feet off the deck. In front of the stands the pilot ejected the standard RAPEC test dummy, "Sierra Sam," from the rear cockpit. The system worked as advertised and the dummy descended to the desert floor under full parachute.

To end the show as it had started—with a bang—the NOTS demonstration turned to the NOTS-developed rocket-thrown line charge, a string of explosive charges built into a flexible line that, when detonated, caused sympathetic detonation of any pressure-sensitive mines in the area. Just before the charge was fired, Schwager warned, "Some overpressure from the blast will be felt at the viewing stand. Steady yourselves as we trigger the explosion."

The next event was a salute to the President: the air was filled with the roar of jet engines as 60 aircraft—a dozen each F-4s, F-8s, and F-3s and two dozen A-4s—thundered past the reviewing stands. These were the fighter and attack squadrons of CAG 11, which had recently returned from a tour of duty with *Kitty Hawk* in the Western Pacific.

On the heels of the flyby, two A-4s with Mk 12 smoke tanks laid down a curtain of smoke between the reviewing stands and the targets, in the words of Schwager "to draw a curtain over our demonstration area and to close our program."

"The entire weapons demonstration was magnificent," Blenman wrote enthusiastically in his memo to BuWeps. Gary Palmer took a slightly more jaundiced view of the event 45 years later:

> You've got to remember it's a demonstration and a permissive environment. It's like going to the circus and everything works well. That isn't real life with somebody shooting at you.[28]

Exhibits at Michelson Lab

Before the smoke curtain had completely cleared G Range, the President and his entourage were back in their vehicles and on the way to Michelson Laboratory. As they arrived at the main entrance, they drove slowly by an unclassified display of the weaponry NOTS had developed over the previous two decades: bombs, rockets, and torpedoes, many mounted on a custom-built 40-foot-long display stand that flanked the entrance.

28 S-280, Palmer interview, 8.

"We had all the different weapons that we had worked on lined up on both sides of the parking lot," recalled Bill Porter, "and I had the privilege of standing by the Shrike weapon which was on display. The President walked past. He was very friendly, but we did not talk."[29]

According to Newt Ward, "We were lined up like a bunch of kindergarten kids for him to pass by . . . he looked like he was tired, wished he didn't have to do this, and wanted a good beer or a shot of whiskey or something."[30]

The President was whisked inside and taken down the main hallway, where, out of public view, a display of classified weapons had been set up. McLean escorted him through the 15 major exhibits that had been designed and developed for the visit, ranging from a seven-by-two foot printing of a space probe to a "three dimensional panel display on Value Engineering."[31]

The presentations at Michelson Laboratory were designed to show the immense breadth of China Lake's work, not just to the President but also to his coterie of senior military and civilian advisors. In a display of guerilla-warfare products developed under Project AGILE, several items bore signs that said "Sent to Vietnam, 1962." Sea Chaparral was shown as a shipboard antimissile defense system. Caleb was touted as being a future satellite killer.

Kennedy limousine driving by weapons exhibit outside Michelson Lab. Among those lined up to answer question are (from left) Steve Little, Loretta King (now McKinney), Ted Lotee (smoking a pipe), and (at right in front of sign) Leroy Riggs.

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29 S-216, Porter interview, 36. After the visit, the unclassified display was moved to a Weapons Exhibit Center adjacent to the Maturango Museum, which had been established the previous year. The Maturango Museum moved off the base in October 1986, and today the weapons display is part of the U.S. Naval Heritage Center of Armament and Technology, housed in what was formerly the Officers' Club at China Lake.

30 S-211, Newt and Maryon Ward interview, 100.

31 Christman memo, "Nominations for Special Recognition," 17 June 1963.

With so little emphasis on past nuclear contributions, and so much on the Station's new sea-floor-to-space capabilities and its capacity to design weapons for limited and unconventional warfare, it was as if NOTS was making a statement: don't pigeonhole us with the fast-closing atomic age—we are already major players in the future of warfare.

Moray, a deep-diving two-man prototype for an undersea "fighter plane," was on display. It was one of McLean's favorite projects. A ramp and viewing area had been constructed so that the President could walk up and look into the interior of the 33-foot-long vehicle. Dick DeMarco, the *Moray* program manager at the time, recalled:

> Al Christman wanted me to bring the boat . . . out in front of Michelson Lab. And I said, "We can't do that." And he was upset. I said, "The boat's confidential! . . . . It's not open to the public!" He finally got it. I said, "Don't argue with me, go argue with the Skipper! This is a classified boat!" So that's why it wasn't out in front.[32]

DeMarco believed that the classification stemmed from the nature of the *Moray* display; various first-of-a-kind technologies were shown, including the shape of the hull and tail assembly, the odd and even number of blades on the counter-rotating propellers, and the syntactic buoyancy material.

In Blenman's report to BuWeps he wrote:

> The President asked about the purpose of *Moray*. Dr. McLean stated that we were conducting *Moray* as a feasibility study, using it in the context of a manned torpedo to study its capability of target identification, of verification of kills, and of countermeasure avoidance. . . .The President asked "How fast and deep will the vehicle go?" On receiving the answer (maximum speed of 15 knots and a design depth of 6,000 feet) . . . The President appeared very impressed at this.

Kennedy and his entourage trooped back down the hall for the obligatory "grip and grin" shots in the Mich Lab lobby. Blenman presented the President with a small model of a Shrike missile. NOTS' "First Ladies," LaV McLean and Rhea Blenman, introduced Kennedy to 13-year-old Mark McLean and 12-year-old twins Chip and Bing Blenman. The young Blenmans wore their Boy Scout uniforms, and the President asked the boys about their scouting activities.

The party was still well behind schedule. The Michelson Laboratory visit had been scheduled to end at 12:55 p.m., but in a photo of the President talking with the boys, the wall clock shows 1:14 p.m. It had been a long day,

32 S-248, DeMarco interview, 95.

President Kennedy and Senator Clair Engel (D-CA) (right) chatting in the Michelson Lab lobby with Mark McLean (in suit) and twin Boy Scouts Chip and Bing Blenman. The boys' proud mothers, LaV McLean (left) and Rhea Blenman stand behind them.

and Blenman reported, "After a few minutes the President appeared to be quite tired and, at his request, the time spent in the Laboratory was considerably shortened." The visitors returned to their vehicles and were soon on their way to a scheduled luncheon in the residential area behind the Officers' Club.

The President and the Public

Now came the portion of the visit that the Secret Service probably dreaded more than the bullets and bombs of the firepower demonstration: Blandy Avenue, the route that the motorcade would travel from Michelson Laboratory to its luncheon destination. It was midafternoon, and crowds had been building since early morning. As the dignitaries exited the lab, the President briefly left his car "to walk over and personally greet a few of the sizeable crowd that had collected."[33]

The people who had gathered to see the President's arrival at Armitage Field 2 hours earlier had been enthusiastic. But the crowd on Blandy, when the President's limousine came into view, "exploded with delirious enthusiasm—it was like New Year's, Fourth of July and V Day all in one."[34]

33 *IWV Independent and Times-Herald*, 13 June 1963, A-7.

34 "Bedlam on Blandy" by Sewell "Pop" Lofinck, *Rocketeer*, 14 June 1963, 10. "V Day" was the term used prior to the end of WWII, in anticipation of V-E Day (victory in Europe)

Nearly everyone in the crowd had a copy of the souvenir paper passed out to all hands and visitors that morning which proclaimed in bold all-capital letters:

> **IT IS IMPORTANT THAT ALL SPECTATORS LINING BLANDY STREET FOR THE PROCESSION REMAIN BEHIND THE CURB**.

The admonition was largely ignored. Pat Burke was one of those who ran out in the street toward the Presidential limo. As Burke remembered:

> There were security all around him . . there were quite a few of them and they were jogging alongside the vehicle and in front of it . . . I don't know what possessed me to do it but I just run out of the crowd and onto the street, ran to the vehicle—my timing was perfect—because as I got to the car he'd seen me coming and he leaned way over to shake my hand. . . and we did shake hands and then two of those guys grabbed me . . .

The cars were rolling and the Secret Service didn't have time to deal further with Burke, who "went back to the crowd back to the sideline where people were just waiting to shake the hand that shook the hand of President Kennedy."[35]

Enthusiastic crowds greeting the President on Blandy Avenue. AP Wirephoto as printed in the *Rocketeer*, 14 June 1963.

and V-J Day (victory over Japan).

35 S-279, Burke interview, 3–4.

Others also were unexpectedly carried away. The normally dignified Maryon Ward, Station librarian and wife of the head of the Aviation Ordnance Department, admitted:

> When he got into a limousine, I turned and just ran along, following the limousine until it was out of sight. Afterwards, I thought, "Good grief, you might have run into somebody and injured them or yourself!"[36]

The Secret Service was fighting a losing battle. In photographic as well as moving-picture footage of the event, it is clear that the President was on the side of the people, not the Secret Service. Even as tall, dark-suited agents in sunglasses tried to run interference, the President stretched out his hand to the people and grinned broadly. The *Rocketeer* reported:

> Secret Service and Station Security officers, aided by newly arrived Seamen Guardsmen, found the task of containing the crowd's enthusiasm one of the biggest problems of the day. By early afternoon, the effort became pointless. The handclasp, symbol of brotherhood and friendship down through the ages, served as a prime objective for thousands of spectators who tore through police lines to touch the President's hand.
>
> They found a willing one awaiting theirs. At 46, one of America's youngest Chief Executives displayed a genuine willingness and earnest desire to shake hands with as many people as humanly possible during his visit here.[37]

Luncheon was a three-venue affair. The press ate at the Officers' Club (where Tambini's wife Angie was one of the hostesses). Most of the dignitaries lunched at the home of the Public Works Officer. The President and Governor Pat Brown were to dine at Blenman's home, 1 Enterprise Drive.

Tina Knemeyer recalled:

> We were asked to take over the Public Works Officer's quarters, which were just opposite the Commanding Officer's quarters, and transform it into a lovely luncheon setting. So they moved out most of the furniture there and repainted it . . . and then I went out in town and asked to borrow plants at the nursery out there. . . each of us was assigned a person to be host or hostess . . . and Frank and I happened to be assigned to Maxwell Taylor. . . We of course flanked him at lunchtime, and he was just very social and chatted with us and couldn't have been more charming.[38]

By all accounts the President did not eat but took the opportunity—an hour and a quarter—to nap at a Capehart military home on Bogue Circle that

36 S-211, Newt and Maryon Ward interview, 21.
37 *Rocketeer*, 14 June 1963, 4.
38 S-204, Cecilia "Tina" Knemeyer interview, 20 Feb 1992, 35–36.

had been renovated and partially furnished for that contingency. Then it was back in the motorcade for the 10-minute ride to the airfield.

Concluding Ceremonies

Since the conclusion of the firepower demonstration, the pilots and aircrews had been waiting at the airfield. When the President arrived, they were lined up on the west side of Hangar 1, in front of their aircraft, in the order of their events. Many were still in their orange flight suits; others had changed into dress uniforms. The President walked the line, shaking hands and thanking the crews. When he reached Tony Tambini, whom he had met in connection with the Cuban missile crisis of the previous year, “he recognized me and stopped to chat . . . he had several new questions about the Shrike Program,” Tambini wrote.[39]

Further along the line the President greeted Hal Vincent, who remembered the conversation:

> He asked me what my participation was in the show . . . I told him my RIO [radar intercept officer] and I dropped the 24 500-pound bombs off the F-4 and ruined a ship. He said he was impressed and thanked me for the work. . . . He was a young, stalwart, and impressive figure.[40]

Commander Robert B. Baldwin was commanding CAG 16, which had played a large part in the show for Kennedy. Years later he recalled:

> Our sailors had gotten a bunch of white Bekins Moving Co. coveralls. They ripped off the Bekins logos and sewed on their squadron patches. They looked a lot different than the guys from other units, who were in their dungarees. Kennedy noticed this and as he passed behind me he asked one of the sailors why they had different “uniforms” than the guys in other units. The kid blurted out, “Cuz we’re the BEST, sir!” [41]

According to Blenman’s account, Kennedy shook hands with every pilot in the event. He stepped to a microphone and briefly addressed the officers and men “congratulating them on their skill and dedication to their work.” He then climbed the stairs to a platform that had been erected for the occasion of his closing remarks.

From behind four microphones and a Presidential seal, he faced the assembled military personnel and a larger crowd of civilian employees and

39 *The Flying Tambinis*, 12.

40 Vincent, email to the author, 20 July 2008.

41 Robert Baldwin email to Hal Vincent, 27 Aug 2008. As a vice admiral, Baldwin would later command the Naval Air Forces, Pacific Fleet.

visitors gathered behind wooden barricades. Blenman introduced the President, and the crowd applauded, cheered, and whistled.

Kennedy spoke for 1 minute and 51 seconds. He noted first how impressed he was with the youth of California. "I have never seen any healthier looking children, which is the best advertisement that I have heard for this state, and I want to express commendation to all of the mothers and fathers who are bringing up what looks like some of our best future citizens." He next thanked the people "who work for our country in this decade: those of you who fly, those of you who maintain the planes, those of you who may be the wives or the children of those who serve our country, those of you who may work in research, those who may work in Civil Service."[42]

From left, pilots Tony Tambini and Gus Jones chatting with President Kennedy at Armitage Field. Photo courtesy of Kennedy Library

He spoke of pride in serving the country and concluded:

> This is the last, best hope, and I think in 1963 I cannot think of a prouder statement, when asked what our occupation may be, than to say, "I serve the United States of America." We want to thank all of you.[43]

Marine One, the Presidential helicopter, was now waiting to ferry the President back to Los Angeles (Air Force One would leave later that day). But there was one more task for Kennedy before he left China Lake. The Marine Barracks, the Corps' official presence at China Lake, was being disestablished after 18 years. A 55-member Seaman Guard was taking over sentry and

42 BuWeps 11-63, "The Presidential Visit," documentary film, U.S. NOTS, Nov 1963.
43 Interestingly, the official version of the President's remarks, as reported in the *Rocketeer* and *Valley Independent* and included in Blenman's report to BuWeps, omits the phrase "those of you who may be the wives or the children of those who serve our country."

guard duties. The last official act of the Marines under Major Maurice Rose, commanding officer, had been to provide the President's honor guard during his visit. As a band from the El Toro Marine Base played the Marine Corps Hymn, the President reviewed and inspected the Marine honor guard. President Kennedy then boarded his helicopter in a flurry of salutes and was gone.[44]

While NOTS heaved a collective sigh of satisfaction and relief, the President's work day was not over. Back in the Southland, he headlined a $1,000-a-plate President's Club fundraising dinner that evening at the Beverly Hilton and the next morning, Saturday, spoke at a $10-a-plate public breakfast at the Hollywood Palladium hosted by the Woman's Division of the Democratic State Committee.

Undoubtedly President Kennedy had more on his mind that weekend than Navy readiness and fundraising. Within a week, NAACP Field Secretary Medgar Evers would be murdered in Jackson, Mississippi; the National Guard would be sent into Alabama; the government of Greece would resign; and the USSR would put the first woman into space.

Project 1-63 was now officially history, and NOTS quickly returned to its everyday routines. The *Valley Independent* held a "best photo of the Kennedy visit" contest. Fay Couch of China Lake won the $15 first prize with her color picture of the President standing in his limousine. TID's Charles Nardone, Lynn Nowels, William S. Spafford, and Richard Johnsen designed a 38-mm brass-alloy medallion to commemorate Project 1-63; 6,500 coins were struck and distributed to Station employees. In August, a second run was made available to the public for $1 each. In a 17 June memo to the Plans and Operations Office, Al Christman nominated 66 individuals for "Special Recognition on Project NOTS 1-63," and those were just folks who had worked on displays, documents, and films.[45]

The President sent Blenman a thank-you note expressing his delight with the "handsomely designed replica of the Shrike." He wrote that the model, some photographs, and his briefing book "will be excellent mementos of my most enjoyable visit to your facility."[46]

44 At a goodbye party for the Marines on 28 June, Maj. Rose announced, "Gentlemen, the main gate [barricade] to the Naval Ordnance Test Station and the sign at the Naval Air Facility have been missing since six o'clock this morning. It is appropriate, before my departure, that I return these articles to you on behalf of the Marine Barracks. They were taken from under the noses of our new Navy sentries." That was in retaliation, he explained, for an infamous incident years before when sailors swiped the gate from under the noses of the Marine sentries. *Rocketeer*, 5 July 1963, 5.

45 Christman memo, "Nominations for Special Recognition," 17 June 1963.

46 *Rocketeer*, 28 June 1963, 1.

Two months after the Presidential visit, Anderson was relieved from his position as CNO by Secretary of Defense McNamara. On 1 November Korth resigned his position as Secretary of the Navy in a conflict-of-interest scandal involving the Tactical Experimental Fighter (TFX). On 23 November President Kennedy was killed by an assassin in Dallas. Lyndon Johnson assumed a presidency in which the war in Vietnam would play a growing role that would finally drive him from office in 1968.

How much did the Kennedy visit cost the Station? China Lake resident Charles C. Devalon, Jr., had the same question. In a letter to Blenman he wrote:

> By this time you probably have received a report on how much the President's visit cost the Station. I would like to know approximately what the cost was. I would also like to get a general idea of how and why the money was spent.[47]

Blenman replied cordially, saying in part, "I believe that any attempt to estimate the cost of the President's visit would not be worth the time and cost involved in the undertaking, for the following reasons." One reason given was that the costs would have "been incurred in any event—only a matter of timing was involved. (For example, the test and demonstration of our R and D project, necessary maintenance and repair, and cleanup of certain areas.)" Also, the captain explained, "All equipment and materials used in the presentations will have continuing value for similar purposes in the future. It would be improper, therefore, to ascribe such costs to the President's visit."

Although financial records associated with the visit are fragmentary, Al Christman reported at the end of April, more than a month before the event, that more than $22,000 had been expended for "Exhibits, films, and medallions." An unsigned document, "NOTS 1-63," dated 22 June 1963, sets out a "Grand Total Labor & Materials" for exhibits as $84,291.97.[48]

Significance of the Visit

The 1963 visit of President Kennedy to China Lake was the most memorable event ever to occur at NOTS. The Station staged the biggest firepower demonstration in its history, showcasing the newest weapons and technologies to a captive-audience of powerful civilian and military leaders—a group such as has not been seen in the Mojave Desert before or since.

47 Letter from Charles Devalon to Commander, NOTS, 19 June 1963. Devalon lived on North Richmond Road in China Lake. There is no indication that he worked for the Station, although a Judith Devalon was employed by NOTS at the time.

48 Memo, Christman to Associate Head of Staff for Finance, "Revised Cost Estimates of NOTS 1-63 Exhibits, Films, and Medallions," 30 April 1963; Kennedy Visit collection, China Lake History Program archives.

Throughout the visit, the Station emphasized the importance of new limited-war weapons and of the laboratories, ranges, and highly trained personnel (military and civilian) necessary to bring these weapons into being. The official program carried on its back the acronym NOTS spelled out as "Naval Ordnance Through Science" (a re-acronymizing that had first been used on a NOTS float in the Tehachapi Lilac Festival in 1958). The message was plain—despite the Station's official name, this was far more than just a test station. Rather it was—as then-Secretary of the Navy John B. Connally Jr. had described it during his visit 2 years earlier— a facility for the "marriage of imagination and science with the hard facts of life."[49]

Implicit in the firepower demonstration was the concept that weapons development is an evolutionary process: the early HVAR leading to Zuni, the rattling twin .50 calibers guns evolving into the withering blanket laid down by HIPEG, the early 1950s technology of Sidewinder 1A developing into the vastly more capable 1C. The narration, as well as the static displays at Mich Lab, made it clear that China Lake had the laboratories, the test facilities, bright scientists (e.g. weather modification breakthroughs) and clever engineers (the adaptation of a Zuni warhead to the Helicopter Trap Weapon) to keep the Navy out in front of the competition. The competition in NOTS' view was not just the current and potential enemies of the United States but also the other laboratories and industrial entities that vied for DOD development dollars.

As a public-relations exercise, Project 1-63 was an unparalleled success, putting NOTS and its weaponry on the national and even the international map. The *New York Times* gave the visit four somewhat condescending paragraphs:

> Among the experimental weapons demonstrated for the President at China Lake were the HIPEG three-barrel gun mount, which the Navy says is "faster per barrel" than any gun in the West; a Zuni warhead for clearing helicopter landing areas in jungle terrain; an explosive that tears apart buildings and vehicles while scarcely damaging the ground beneath them, and a land mine that today failed to work.[50]

As a personal experience, the Kennedy visit remains fresh even today in the memories of those who experienced it. Pat Burke still recalls Air Force One flying over as he delivered milk in China Lake Acres. "It's in my head," he said. "I can see it right now."[51]

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49 *Rocketeer*, 20 May 1961, B2. Throughout NOTS' existence there were many, including McLean, who questioned the appropriateness of the Station's name.
50 *New York Times*, 8 June 1963, 8.
51 S-279, Burke interview, 11.

6

Fueling the Fire

Eighty percent of the weapons dropped in Vietnam were developed at China Lake.

— Attributed to Secretary of Defense Robert S. McNamara[1]

Two events took place on 2 September 1945 that would affect the Navy's base at China Lake. The first was the formal surrender of Japan to Allied forces in ceremonies aboard USS *Missouri* (BB-63) in Tokyo Harbor (the actual surrender had taken place nearly 3 weeks earlier). The end of the war, coming less than 2 years after NOTS' founding, would alter the pace of activity and the mix of programs at the Station.

The second event that day occurred at Ba Dinh Square in Hanoi, Vietnam, when Ho Chi Minh, the 55-year-old leader of the Viet Minh independence movement, stood before a cheering crowd and declared the independence of the Democratic Republic of Vietnam after 80 years of French colonial rule. His speech that day began, "All men are created equal. They are endowed by their creator with certain unalienable rights; among these are life, liberty, and the pursuit of happiness."[2]

Twenty years later, Ho's country—the northern half, that is, as the new nation was partitioned at the 17th parallel by the Geneva Accords in 1954—would be at war with the country from whose Declaration of Independence Ho had quoted. NOTS would be one of the principal providers of the weapons used by the U.S. in a protracted conflict that left more than 58,000 Americans and approximately 1,000,000 North and South Vietnamese dead.[3]

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1 Ralph Vartabedian, "Lab Opposed 'Gold Plated' Systems, China Lake Weapons Center Battling With the Navy Brass," *The Los Angeles Times*, 1 May 1986, 1.

2 William J. Duiker, *Ho Chi Minh: A Life*, New York, Hyperion, 2000, 323.

3 "Statistical Information about Casualties of the Vietnam War," Electronic and Special Media Records Services Division of the National Archives and Records Administration, *http://www.archives.gov/research/vietnam-war/casualty-statistics.html*, accessed 5 March 2010; Charles Hirschman, Samuel Preston, and Vu Manh Loi, "Vietnamese Casualties During the

For nearly 15 years, from about 1960 until the war's end, the jungles, rivers, mountains, swamps, and skies of Vietnam would become, in a way, an extension of China Lake's laboratories and ranges.

The open use of America's conventional forces against North Vietnam did not begin until after the Gulf of Tonkin Resolution (formally the Southeast Asia Resolution, Public Law 88-408) was passed by the U.S. Congress in August 1964, following a naval engagement between U.S. and North Vietnamese forces (the details of that incident and the motives on both sides are still in dispute). The resolution gave the U.S. President the authority to use conventional forces in Vietnam without an official declaration of war by Congress.

However, the U.S. had been supporting the South Vietnamese in their fight against the Communist-controlled, North Vietnamese-supported Vietcong (also known as the National Liberation Front for Southern Vietnam) since the early 1950s. In 1962, President Kennedy sent 4,000 advisors to South Vietnam, and success seemed always just over the horizon. According to an October 1963 record of the National Security Council, "Secretary McNamara and General [Maxwell] Taylor reported their judgment that the major part of the U.S. military task can be completed by the end of 1965, although there may be a continuing requirement for a limited number of U.S. training personnel."[4]

That was not to be so. By early 1964 nearly 17,000 U.S. troops were in South Vietnam, and by the end of 1965 that number had increased to about 184,000. In April 1969 U.S. troop strength would reach its peak of 543,000.[5]

China Lake's active involvement in the conflict started well before the Kennedy administration. In February 1958, the Department of Defense created the Advanced Research Projects Agency (ARPA), a product of the immediate-post-Sputnik anguish over the perceived inadequacy of America's scientific and technological capabilities. The new agency "became in effect an operating arm in the office of the Secretary of Defense by means of which various special projects (most originally in the space and missile defense areas) could be accomplished without having to cope with service red tape."[6]

American War: A New Estimate," *Population and Development Review*, Vol. 21, No. 4. (Dec., 1995), 783-812, abstract at *http://www.jstor.org/pss/2137774,* accessed 5 March 2010.

4 "Record of Action No. 2472, Taken at the 519th Meeting of the National Security Council. Washington, 2 October 1963," Foreign Relations of the United States, 1961-1963, Vol. IV, Vietnam, Aug–Dec 1963, Document 170, Office of the Historian, U.S. Department of State, *http://history.state.gov/historicaldocuments/frus1961-63v04/d170,* accessed 18 March 2010.

5 Vietnam War, *http://www.globalsecurity.org/military/ops/vietnam.htm*, accessed 13 April 2010.

6 York and Greb, "Military Research and Development: a Postwar History," 24. York was

According to the Armed Forces Press Service (AFPS) press release announcing ARPA's establishment, it was formed "to direct advanced research in the development of antimissile missiles and the application of satellites and outer space projects to military purposes." The thrust of ARPA's work was indeed space related, and the agency was soon funding China Lake's work on the NOTSNIK satellite and later on the anti-ICBM effort Project Defender.[7]

Not all of the agency's work, however, was directed toward space. The ability to avoid service red tape, and presumably much of the oversight and questioning that went along with operating in traditional bureaucratic channels, appealed to those in the Department of Defense and elsewhere in the government who were concerned about counterinsurgency. According to the official DARPA history (the D was added when ARPA's name was changed to the Defense Advanced Research Projects Agency in 1972), "By 1960, a counter-insurgency project (AGILE) was started as the Vietnam War heated up."[8]

Project AGILE

At half a century's remove, it is difficult to appreciate the pervasive fear in the U.S. during the middle of the Cold War. The threat of nuclear annihilation was primary—"duck and cover" atomic bomb drills were common in schools, and home bomb-shelter plans were sold in bookstores. In 1960 the *Valley Independent*'s conservative columnist Joe Fox was among 300 civilians and 200 field-grade officers statewide attending a 2-week National Defense Resources Conference in Bakersfield. Fox reported that "up to 100 million Americans is the estimate that may die 'unknelled, unhonored, and uncoffined' in a sudden nuclear aggression. The only alternative is 'atomic shelters,' according to the best information, if casualties are to be restricted."[9]

But another specter was abroad in the land—the fear of a vast Communist conspiracy to take over the world, one country at a time. Although pillorying and black-listing suspected Communists had declined after the death of Senator

the first Chief Scientist of ARPA as well as DOD's first Director of Defense Research and Engineering.

7 *Rocketeer*, 28 Feb 1958, 1.

8 Dr. Richard Van Atta, "Fifty Years of Innovation and Discovery," *DARPA: 50 Years of Bridging the Gap*, Defense Advanced Research Projects Agency, April 2008, 21.

9 *IWV Independent and Times-Herald*, 28 Jan 1960, C1. In a 22 Aug 1961 meeting of the NOTS Research Board, Capt. Blenman reported on disaster-control shortfalls: "No single plan now exists which would meet the requirements for China Lake in the event of an all-out nuclear war. . . . There are numerous facets to this problem, such as the evacuation of China Lake to safe areas, or remaining in a fall-out shelter for a specified period of time, to handling an influx of people from the Los Angeles area . . . ."

Joseph R. McCarthy in 1957, the so-called Domino Effect—the idea that one country would fall to Communism, and then a neighboring country, and so on—was a basic principle of U.S. foreign policy.

Insurgent groups in countries throughout the world, whether motivated by anti-colonialism or nationalism or ancient schisms, were all seen by the U.S. as part of a Communist conspiracy—and in fact Communists were quick to seize on any nation's internal strife that offered fertile ground to spread their philosophy.

Thus battles between the two great powers of the world were often fought in a framework of armed rebellion in small or unstable countries, the Communists (including Russia and China) siding with the insurgents, and the U.S. and its allies supporting the established (and often shaky and/or totalitarian) governments.

Counterinsurgency was a new type of warfare for America, and there was an urgency associated with learning its tools, techniques, and tactics. That urgency gave rise to the ARPA effort known as Project AGILE.

AGILE's mission statement, as set out in a 1964 report, was clear in its purpose, drawing a distinction between the general U.S. armed forces (the beneficiaries of traditional military research and development organizations like NOTS) and the AGILE customer base:

> Project AGILE performs research and engineering support for the military and paramilitary forces engaged in or threatened by conflict in remote areas of the world. Its activities are oriented toward the requirements of the local forces in these areas, whereas the Service research and development agencies are primarily concerned with the requirements of the U.S. forces.

Project AGILE was, at that time, "providing research and engineering support for the forces engaged in Vietnam and to the Ministry of Defense in Thailand."[10]

The authors of the report were candid in their description of the requirement for their work:

> There are several forms of conflict which lie below the threshold of that categorized by the term "limited war, and there are many remote areas of the world where discretely different environmental conditions affect the nature of any level of conflict that can or does exist. The counterinsurgency conflict in Vietnam and the border war between India and Red China are two current examples of quite different types of warfare— each of which has some discrete materiel requirements.

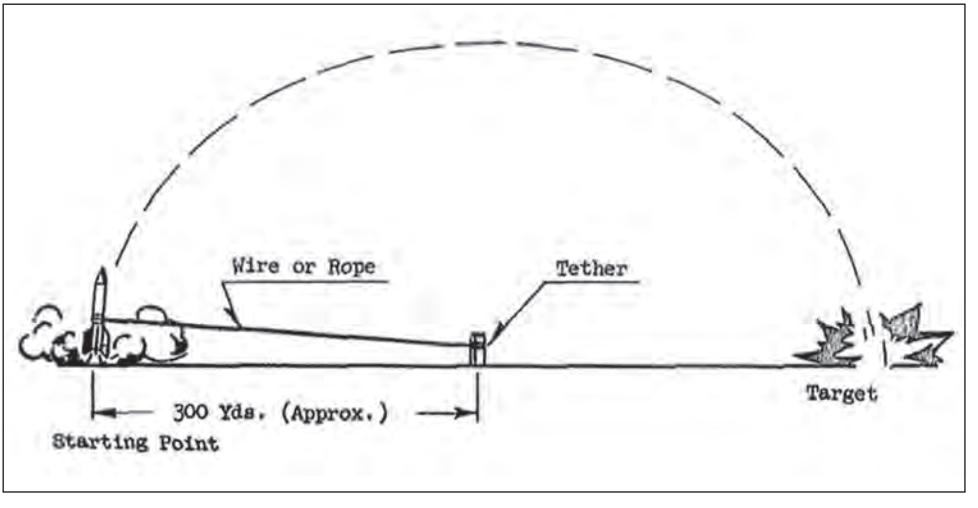
10 ARPA, *Project AGILE, Advanced Research Projects Agency, Semiannual Report,* 1964, 1.

AGILE's goal was to meet those requirements, and ARPA used China Lake to help do it.

NOTS' earliest creations for use by indigenous forces and in covert operations predate the Station's association with Project AGILE and seem slightly bizarre in their conception, something one might expect from a brainstorming session in which the participants were encouraged to suggest ideas no matter how impractical they might sound.

Several of these devices were documented by Frank Fulton, head of the Propulsion Development Department, in a then-classified 1961 NOTS publication.

There is, for example, the tethered rocket, which brings to mind cartoons of Wile E. Coyote and the Roadrunner. The counterinsurgent fighter finds a suitable rocket-launching location within 600 yards of an enemy target. He then places a stake firmly in the ground halfway between the target and the launch site and connects the launch stake and the rocket by a stout cord. When the rocket is fired, it follows a semi-circular course, constrained by the cord, and smacks down in the center of the target. China Lake's Command Historian, Leroy L. Doig III, said that this concept was actually tested, but that technical problems occurred at the conceptual level.[11]



Tethered rocket concept as shown in the NOTS *Handbook on Limited War Weapons*, 1961.

11 Fulton, *Limited War Weapons*, 21; Leroy Doig review comments, December 2011. Fulton received the L. T. E. Thompson Award in 1961 for "outstanding leadership in directing Naval Ordnance Test Station efforts in new areas of propulsion applied research and his initiative in exploring potentials in the field of limited warfare weaponry."

Another novel idea was "Project Eight-Ball," a poor-man's bazooka consisting of an expendable launcher and three rounds of ammunition. Each round consisted of two attached spheres, which fit in the barrel of the launcher. One sphere contained a rear-facing rocket motor, and the other was a forward-facing Armor Piercing Explosive Sphere (APES) containing a small shaped charge within a fragmenting case. The line-of-sight range was 200 yards. A feasibility study of the Eight-Ball was carried out in 1959, including experimental firings, but there is no evidence that it was ever actually fielded.[12]

For "indigenous or undercover personnel" a standard .22-caliber Sturm-Ruger automatic pistol was modified with a .128-caliber barrel and concentric silencer. The weapon fired a 15-grain projectile from a necked-down .22 cartridge. The designers commented that "the use of projectiles in this weapon which are soluble in body fluids would add the possibility of injecting drugs for nonlethal effects."[13]

Other concepts included rocket-powered flechettes, a gasoline-fueled gun called GO-TEC (Gasoline Operated, Total Energy Conversion), and sand-and-binder bullets that could be made in the field. "Poisons could be incorporated in the sand before molding, hence, fatality could be assured with each hit."[14]

FAX/FAE

NOTS' first task for Project AGILE began in 1960 with work on a fuel-air explosive or FAX as it was then called (the acronym was later changed to FAE). In a fuel-air explosive, a canister of gas or liquid (or even superfine aluminum particles) is explosively dispersed to form an aerosol cloud. Ambient oxygen provides the oxidizer. When the cloud has reached a certain dimension, an initiating charge (or charges) ignites the aerosol particles. The resulting explosion generates high overpressures but damage is largely confined to the area of the blast—a so-called "cookie-cutter effect"—unlike a conventional bomb, whose fragments carry far beyond the area of the blast itself.

AGILE's goal for the NOTS project was to develop "a munition which will be effective against area targets concealed and shielded by heavy vegetation or protected by earthworks and tunnels." In January 1961 NOTS demonstrated the first FAE, "an ethylene oxide cloud disbursed by a burster charge and detonated by a high-explosive booster." China Lake was tasked in January 1963 to develop an air-drop version. Under AGILE funding, the Station also

12 Ibid., 12.
13 Ibid., 34.
14 Ibid., 17.

Two phases of FAE weapon test on China Lake North Range.

developed and let a manufacturing contract for 66 fiberglass launchers for use with the 10-pound, 7-inch-diameter FAE weapon under development.[15]

During this period FAE was also considered for a land-mine and a bazooka-type round. FAE's advantage in smaller-size applications was the fact that the "blast from a FAE warhead covered 445 percent more area than an equivalent weight of conventional explosives."[16]

William A. Gey, who had worked for DuPont as a chemist during WWII, led the initial FAE development efforts, working with Jack Sherman, Arnie Nygaard, and Cecil A. Glass in the Explosives and Pyrotechnics Division of Frank Fulton's Propulsion Development Department (Code 45).

In 1964 Fulton brought in Dr. Richard J. Zabelka, who had joined the China Lake workforce as a mechanical engineer in 1956, to lead the weaponization process. Zabelka set up a successful advanced-development program and sold the idea to BuWeps.

Development of FAE posed several technical challenges. The selection of fuel was critical: it needed to be relatively benign in the liquid state, capable of producing the desired effect in the aerosol state, and functional over a broad range of temperatures. Cloud formation had to be initiated at a specific distance above the target, which required precisely timed fuzing of the burster charge that created the aerosol cloud.

Equally critical was ensuring that the initiating charges were located at the right point in the expanding cloud and were detonated at exactly the right moment (if they fired too soon, the mixture was too rich; too late, and the cloud was too lean).

Ray Powell became involved with FAE during his tour at China Lake. At that time it was being considered for clearing landing zones (LZs) in the jungles of Vietnam, rather than as an antipersonnel weapon. Powell recalled:

> A weapon like that has fantastic capabilities of killing people. But because of the rules of engagement and the rules of war and I guess the close similarity to nuclear bombs, for some reason they didn't use it that way.

FAE was not very successful in the LZ-clearing role, Powell said.

> You could blow the trees out, there was no question. But what you had was stubs and sticks and tree trunks sticking up about 3 to 4 feet. So however thick the trees were, that's how many of those you had sticking up. So now the helicopter can't land.

15 ARPA, *Project AGILE*, 33.
16 *NOTS Tech History 1963*, 5-23.

In theory, the helicopters might get low enough for the troops to jump out, but getting tired soldiers and their wounded and gear back into the helicopters under such conditions would be impossible.[17]

In 1966 FAE was again considered for a combat role, this time as an anti-booby trap device. Jim Bowen, who took over as project coordinator for FAE weapons systems across the Navy in May 1966, described the problem:

> [Enemy forces] design a device that when a helicopter comes into an area to land, the down wash from the helicopter, a very strong wind, can blow a bush. [The bush is wired to a propulsive charge that throws armed hand grenades into the air.] So a simple landing of a helicopter . . . throws large numbers of hand grenades into the air [that] can do significant damage to a helicopter. Not only that, but the psychological effect makes [the pilot] very suspicious of landing again in an area he doesn't really know about.[18]

It was apparent to U.S. planners that if the Vietcong forces knew how effective the technique was, they could very quickly deny helicopter operations throughout Vietnam. The threat was sufficient for the Joint Chiefs of Staff to sponsor a study to find a solution, and 32 different munitions were examined as candidates for the role. A wide variety of techniques were explored "from machines guns firing in the area to low-altitude supersonic flights over the area to clear out these devices," said Bowen. According to China Lake's *Tech History*, the study "indicated that the FAE munitions were ideally suited."[19]

DOD assigned an urgent Rapid Development Capability (RDC) priority to a FAE weapon. Development was tricky; the weapon used new technologies including plastic-bonded explosives. "We had all kinds of technical problems during development, but for each one of them, we put teams together and then solved it," Bowen said. Two versions of the weapon—the 500-pound CBU-55 for slow-aircraft delivery in close-air-support functions and the CBU-72 for high-speed aircraft—were developed concurrently. China Lake designed, manufactured, and tested the prototype weapons entirely in-house. Honeywell Inc., was the FAE prime contractor.

Field testing was conducted in the swamps and forests of Louisiana, and the weapon was on track for 1969 deployment to Vietnam. The Secretary of Defense, however, ordered another test series in the triple-canopy jungles of Panama. The outcome of those tests led to the requirement for a self-destruct device to prevent the enemy from using any duds or weapons that might hang up in trees (since the weapon descended under a small parachute).

17 S-270, Powell interview, 44-45.
18 S-175, Bowen interview, 39.
19 *NWC Tech History 1967, Part 1*, 5-66–5-67.

Weapon development centered in Norman L. Rumpp's Explosives and Pyrotechnics Division (Code 454) and was carried out by Dr. C. Douglas Lind, Dr. Harold J. Gryting, Dr. Alvin Gordon, Charles Falterman, and Walt LaDassor.

Among those contributing to the successful design of the weapon itself were engineers Bryant Ferguson, Charles Martin, and Al Lopez, test engineer Bill Bessee, project analyst Larry Josephson, and technician Tom Short. NOL White Oak designed the self-detonating self-destruct fuzes for the dispenser and the detonator.[20]

Finally, in 1970, 70 production CBU-55s were delivered to Vietnam. Accompanying the weapons was an introduction team composed of Lieutenant Colonel Bob Oliver from DDR&E; Jim Bowen; Michael Aley, the program chief engineer; and Larry V. Zabel, a Technical Information Department filmmaker and combat artist. The team spent 2½ months in-country, training officers and enlisted personnel in the use of the weapon.

China Lake also provided 20 weapons to Light Attack Squadron Four (VAL-4), which operated at Binh Thuy and was the Navy's only close-air-support squadron in Vietnam.

The Black Ponies used the weapons with good effect from their OV-10A Broncos, said William E. Shaw, who in 1971 was in the back seat of a Black Pony OV-10A carrying CBU-55Bs during a mission in the "Wagon Wheel," a section of the Mekong Delta northeast of Binh Thuy where several canals converged. The target was a Vietcong force that had engaged a South Vietnamese Army (ARVN) unit and its U.S. advisors. The friendlies were on one side of a canal, the enemy on the other. As Shaw recalled:

> We went in at about 40 degrees rotation. Used [machine guns] to mark the target followed by a Zuni to keep their heads down, then wings level for the CBU delivery. We then broke right and climbing. Our wingman followed suit. A pair of CBUs, then the final one on centerline.

Shaw noted that prior to the target run:

> Charlie was coming up on the [communications net] with [derogatory comments], never to be heard from after the first two CBUs went off Stations 2 and 6 . . . I watched 'em go . . . checked the chutes and impact areas . . . It wasn't a "Hollywood" explosion. . . The flash, which was of short duration . . . a dark reddish orange under the trees. This turned to a muddy brown (irregular) cloud.

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20 *Rocketeer*, 10 March 1972, 1, 3.

Shaw later met with a U.S. Army captain who had accompanied the ARVN unit. "It was hell on earth on the other side of the river," he told Shaw.[21]

Zabel took many opportunities to fly combat missions while in Vietnam (eventually making four trips there). At China Lake he was a friend of the NOTS Dispensary's senior medical officer, Dr. Elmo Russell Zumwalt, Sr., who was the father of Vice Admiral Elmo Zumwalt, the commander of U.S. naval forces in South Vietnam. Once this relationship was known in Vietnam, Zabel's access to people and places increased.[22]

"I could get back into the back end of an OV-10 and film," Zabel recalled. "I can film that thing from 6 feet away clear to impact and see what it does. So I did a lot of that."[23]

Within 2 weeks of the team's return, Zabel had produced the 9-minute color film "CBU-55 Combat Introduction"—which Bowen took back to Washington to show at the Pentagon. Soon the Air Force was using CBU-72s as well, dropping them from the Douglas A-1 Skyraider and the Cessna A-37 Dragonfly.

Meanwhile another specialized type of FAE unit had been deployed to Vietnam in 1968.

For years, South Vietnamese forces had been employing land mines in defensive positions around Da Nang, but the locations of the fields had not been properly marked and recorded. As a result American forces were walking into these fields and being killed. Bob Rowntree described the problem:

> The conventional ways of going out with a metal detector were hard, particularly in the jungle and you couldn't very well use vehicular-based systems with a flail or something because of the soft ground and the vegetation. What you really wanted was something that would generate a great pressure pulse and trigger all the mines around that might be armed. So I think it was Bud [Sewell] who came up with the suggestion of, "Gee, why don't we use the fuel-air explosive?"[24]

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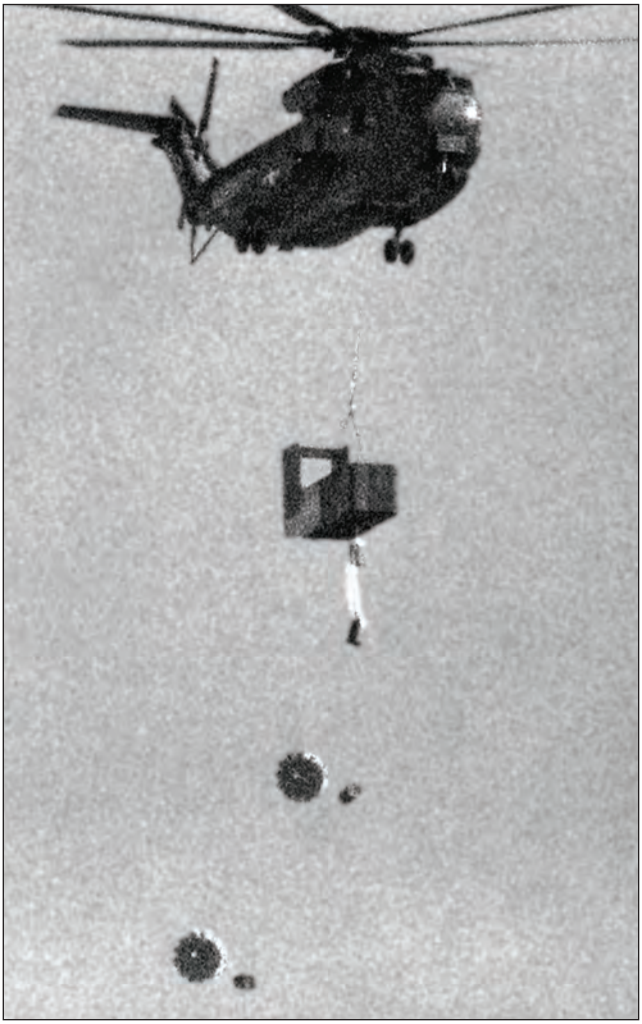
21 AO1 William E. Shaw (VAL-4 AO/AQR, 1971–72), emails to the author, 1 July 2010 and 26, 27, and 28 March 2011. Shaw also wrote that among the massive armament load carried by the OV-10A was "a single Mk 12 20-mm cannon, originally from the port gun station on A-4s. This thing was cobbled together at China Lake. (It worked.)"

22 In one 30-day combat photography tour in 1967, Zabel logged 48 flights in 19 different types of aircraft including 23 combat flights; enough, noted a local newspaper article, to earn two Air Medals if he were in the military. *IWV Independent and Times-Herald*, 27 July 1967, A-1.

23 S-307, Larry Zabel interview, 29 May 2010, 13. Zabel, who became a noted Western artist, died in 2012.

24 S-176, Rowntree interview, 33. Rowntree came to China Lake in 1963, retiring as the



Helicopter deploying MADFAE.

FAE program engineer Lloyd Smith took smaller FAE units to the Marine Amphibious Force located at Da Nang. When a suspected minefield was located, one of the units would be hand emplaced on a stand at the edge of the field and detonated, activating the pressure-sensitive land mines.

Later, China Lake would develop Surface-Launched Unit (SLU)-FAE, an FAE warhead launched by rocket from a tracked vehicle to clear a lane through a minefield or beach obstacle, and Catapult-Launched Unit (CAT)-FAE, a similar FAE weapon designed for mine clearing. SLU-FAE was developed for the Army, and CAT-FAE for the Marines. For the weapon designers, air-delivery was the preferred method for mine clearing with FAE; however, other factors were at play. As Bowen explained, the only people interested in clearing mine fields were:

> . . . the grunts, the guys on the ground. They want it for themselves. They don't want to depend on the airplane drivers to come through. The airplane drivers, if you really got the honest output, you'd find out they don't really

technology base coordinator in 1988. Under the Vietnam Laboratory Assistance Program, beginning in 1967, he worked in Code 12, coordinating NOTS technical efforts with other government and private laboratories. Rowntree was instantly recognizable by his colorful attire and bright bow ties.

> want to drop bombs over a mine field, which is protected by covering fire. They'd rather the grunts would do it.[25]

FAE was used by Marine forces for mine clearing as recently as Operation Desert Storm.

Bowen's group also developed Mass-Area-Delivery FAE (MAD-FAE) for the Marines. Milt Burford, who was later Bowen's division head (Warhead Division, Code 456) described the weapon as:

> . . . a large canister that contained several of the CBU-55 bomblets, which were basically 80 pounds of ethylene oxide fuel in a canister. . . . Several of these things were carried underneath a helicopter and thrown over an area, and you could sprinkle an area with quite a number of these fuel–air explosive devices.[26]

In 1972 Bowen received the Harvey C. Knowles award from the American Ordnance Association for the development of the CBU-55. At the award ceremony, NWC Technical Director Haskell G. Wilson said, "Mr. Bowen, more than any other individual, has provided the military services with a new fuel-air weapon technology."[27]

Other AGILE Projects

FAE was the first weapon produced under Project AGILE, but many more items were requested as the fighting (and the U.S. presence) in Southeast Asia expanded. Late in 1961 ARPA tasked China Lake to develop an antipersonnel mine that could be either air dropped or hand emplaced "and will defy visual detection because of its close resemblance to indigenous materials."[28]

NOTS studied the feasibility of "casting PBX (plastic-bonded explosives) into the form of indigenous materials, such as rocks, logs, or common household articles, for antipersonnel devices. Initial development was concerned with casting explosive rocks to deny area access." The resulting PBX mine was shaped like a common rock; to ensure visual fidelity, Code 45 used actual rocks from Vietnam as models. A requirement for the mine was that, once armed, it would explode if it were disturbed, and that it would also fire after a pre-determined

25 S-175, Bowen interview, 56.

26 S-263, Milton K. Burford interview, 26 June 2008, 60.

27 *Rocketeer*, 19 May 1972, 1. In his acceptance speech, Bowen, who in his 32-year career at China Lake worked on such diverse programs as Polaris, *Moray*, HRS, Zuni, and the rocket-powered Pogo Stick, said "The most important thing, I think, is to not be afraid to do what you know nothing about."

28 ARPA, *Project AGILE*, 31.

period so that the area would be sanitized and not pose a threat to civilians or friendly forces.[29]

Designing the mine's fuze proved to be the most complex technical challenge. China Lake shipped two hundred mines to the ARPA R&D Field Unit in Vietnam in September 1962, but the fuzes were inadequate: many did not properly fit the fuze wells and some mines exploded spontaneously after being armed. The rest of the mines were disposed of.

The following year, again under AGILE sponsorship, the Station investigated the idea of hollowing out "indigenous brittle materials," such as rocks or bricks, and filling them with explosives and a triggering device. Engineers studied fragment sizes, velocities, and distribution patterns with devices made of diorite, limestone, basalt, mud-gravel mixtures, and brick. "Indications are," they reported, "that casualties will result primarily from contact detonation with associated blast- and fragment-produced serious wounds, or from skin penetration with accompanying overwhelming infection." Designs for effective camouflaged explosive items would continue to be pursued as the war escalated.[30]

Under Operation AGILE China Lake developed several other technologies for the U.S. forces in Vietnam. One was a grenade that could be launched from an M-1, M-14, or AR-15 rifle using standard ball ammunition (rather than the special grenade-launching cartridges). The design involved a momentum-transfer device consisting of a stack of alternating aluminum and titanium washers which was located behind the grenade. This "bullet trap" transferred the momentum of the bullet to the grenade.

Two other AGILE-funded projects sought to improve the lethality of firearms. The first was the investigation of "strip bullets." Short lengths of lead were pressed together to form the core of a bullet that was then clad in thin copper foil. Centrifugal force imparted by the weapon's rifling caused separation of the strips, producing a shotgun-like effect and increasing the probability of striking the target. Tests at China Lake demonstrated the feasibility of the strip-bullet concept in .45, .30, and 9-mm calibers. In 1966 inventors Ottow W. Schneider and Hubert M. Ross, Jr., both of the Propulsion Department, were awarded a patent for the invention.[31]

A second project, driven by a perceived need for low-cost defensive hand-held weapons for paramilitary or civilian forces, looked into "microrocket"

29 *NOTS Tech History 1962*, 134, 136.

30 *NOTS Tech History 1963*, 5-23–5-24.

31 *NOTS Tech History 1964*, 7-22; *Rocketeer*, 13 May 1966, 1.

projectiles. Working under contract to the Station, MB Associates developed a 0.49-caliber microrocket pistol. The projectile was actually a tiny dual-nozzle rocket that was spin-stabilized (3,000-5,000 revolutions per second) for accuracy. Nozzle erosion was a problem, with propellant flame temperatures reaching 6,500°F, and the researchers concluded that the state of the art for microrocket projectiles was not sufficiently advanced to warrant further investigation. (MB Associates briefly marketed a 13-mm Gyrojet pistol to the public in the late1960s.)[32]

Despite the fact that most of this work was classified at the time, the ever-vigilant U.S. press got wind of it. An August 1961 article in *Newsweek* discussed the microjets, small boats, and night-vision devices. "We've got some wild ideas we're working on. Nothing is too fantastic for us,'" said an unnamed official. The article may have been referring to FAE when it described "an explosive gas that could be released over the enemy. Hugging the ground, the gas is set off by any spark-in the same way that dust in a grain elevator sometimes ignites. 'In a fraction of a second,' says a researcher, 'the stuff goes boom and it pulverizes everything in sight.'"

The article quoted an unnamed military source as saying "We are really getting support from the top, including money. It may not sound very big in a $47 billion defense budget, but the total may run into tens of millions. And that's certainly not peanuts in what, after all, is a peanut-size war. But this is a peanut war we cannot afford to lose." NOTS was not mentioned in the article. The text was read into the minutes of the NOTS Research Board meeting, however, without recorded comment.[33]

Project Loudmouth

More was requested from NOTS under Project AGILE than just destructive devices. The importance of psychological warfare had been learned by the U.S. in WWII and Korea, and military planners realized that it would play an even more important role in counterinsurgency operations. "Winning the hearts and minds of the people" became an important—and later, as civilian losses mounted, much-mocked—theme of the Vietnam War.

ARPA wanted a man-portable self-contained public-address system for carrying out psychological warfare operations in remote areas. Standard portable PA systems of the day ran off car batteries and were unacceptable.

32 *NOTS Tech History 1964*, 5-22.

33 "Weapons: For the 'Peanut War,'" *Newsweek*, 21 Aug 1961, 21; Research Board minutes, 12 Sept 1961.

Project Loudmouth, as it came to be known, was assigned to John M. Boyle, an electrical engineer in Tom Amlie's division in Code 35, who had come to China Lake in 1951 after working for Honeywell.

Boyle fabricated a system that fit into a cube 19 inches on a side. He recalled that:

> I put in there a little tiny engine like the engines you have in a weed whacker. Little tiny, goes, "Weeaaww!" And I put a muffler on it to make it quiet, and I put a little generator on it, which was kind of like the generator in the Sidewinder missile, and I put this audio amplifier in there and a tape recorder, and we had this box that was watertight, very rugged, and you could carry it easily. . . . We got ARPA to sponsor it because ARPA would fund anything at that time. And we sent one over to Bangkok, Thailand, and had it evaluated and got back a glowing endorsement of the idea.[34]

A test report from the Combat Development and Test Center in Thailand confirms Boyle's recollection—"the unit was found to be compact, powerful, easy-to-operate, and reliable"— and also conveyed the informality of operations in Southeast Asia at the time:

> Before taking the speaker to the field, preliminary testing was conducted at Lumpini Park, Bangkok. On opening the case, it was found that a screwdriver was required to dismount certain components. After mangling a 10-satang piece [coin] in attempting to turn the screws, a screwdriver was borrowed from a taxi-driver standing in the crowd which had gathered to watch the tests. . . It is recommended that the following tools be included with the speaker, possibly chained, so that they stay with the speaker . . . .[35]

Helicopter Trap Weapon

One quick-reaction project carried out under AGILE was the Helicopter Trap Weapon (HTW). Early in the 1960s, as U.S. helicopter assistance to the South Vietnamese Army increased, the Communist forces developed a simple but very effective technique to hinder the effectiveness of rotary-wing aircraft. The Vietcong would plant long bamboo poles vertically in open areas that otherwise appeared suitable for a helicopter landing zone. If a helicopter dropped down into these slender poles (which were not readily visible from the air against the vegetative background) the rotors would be damaged by the poles.

34 S-180, John M. Boyle interview, 31 Aug 1989, 76.

35 Capt. Joseph P. Martino, USAF, *Test of Naval Ordnance Test Station Portable Public Address System*, Combat Development and Test Center, Thailand, May 1963. NAWCWD Technical Library Number 136711, C.1, 2, 37.

To counter this threat, Paul Cordle's Warhead Branch in Code 40 built the EX115 Mod 0, a weapon based on the Zuni unguided 5-inch rocket, developed at NOTS in the 1950s for air-to-air and air-to-surface applications. E. D. "Dall" Hughes was the project engineer.

The HTW was essentially a Zuni warhead falling nose down under a parachute that was deployed in a low-level, low-speed drop from either a fixed-wing aircraft or helicopter. The Zuni in its air-to-air configuration employed a continuous-rod warhead (invented at New Mexico Institute of Mining and Technology), a bundle of 3/16-inch square steel rods welded together at alternate ends. When detonated, the bundle became a single ring of steel expanding outwards at more than 4,500 feet per second. Although the warhead was originally designed to rip through an enemy aircraft or vehicle, the theory was that, when fuzed to go off at the proper height, the expanding rods would slice the Vietcong's bamboo poles like a scythe.

And it worked. The weapon achieved the required specification of a 90-percent continuous cut at a 28-foot radius (which meant that multiple weapons would have to be used to clear an area greater than 50 feet in diameter). The HTW was demonstrated for President Kennedy as part of the confidential segment of the weapons demonstration at China Lake in June, 1963, and was shipped to Vietnam shortly thereafter. In 1963, 200 HTWs were produced and released to ARPA (Project AGILE). Improvements were made to the weapon, and in 1967 a production contract for another 500 weapons was awarded.[36]

Project AGILE illustrates a dynamic that helped NOTS provide superior weapons to the U.S. and allied forces in Vietnam. Station personnel did not merely sit in the desert waiting for work to come their way. For all its remoteness, China Lake was well connected in many of the Washington offices that mattered (recall for example that Howie Wilcox left his job as head of China Lake's Research Department in 1959 to work as the deputy for Herbert York, DDR&E, who became ARPA's chief scientist).

Because of these relationships, as well as close connection with the operational forces and insight into new technologies—many originally developed in NOTS laboratories—Station scientists, engineers, and managers could approach sponsor offices, offering suggestions for programs that would benefit the fighting forces.

Before any such approach was made, China Lake had generally done enough homework on its own nickel to convince a potential sponsor of the likelihood of success.

36 *NOTS Tech History 1963*, 5–22; *NWC Tech History 1967, Part 1,* 5-70.

Often NOTS would make a parallel and contemporaneous effort to demonstrate the viability of a proposed system to the operating forces, which then could approach the same Washington offices with a "wouldn't it be great if we had this" proposal.[37]

TIARA and Chemlight

One example of NOTS' synergistic product development is the Target Illumination and Rescue/Recovery Aid (TIARA), the NOTS product funded by Project AGILE that has perhaps had the most lasting impact.

In 1961 the China Lake Research Department (Code 50) began to study and improve PR-155, a compound manufactured by DuPont Corp. The compound had the novel property of producing light when exposed to air, and the Station saw great military potential for chemiluminescence, as that property is known. In 1962, NOTS was assigned the responsibility "to develop chemiluminescent substances into workable systems to enhance nighttime vision."[38]

Rod McClung's division in Code 35 immediately began the TIARA project to improve and weaponize the material, using ARPA funds provided through Project AGILE. Early work was done in Steve Little's branch, with help from chemists Herb Richter and Carl Heller in Code 50's Chemistry Division. When the Advisory Board convened at China Lake in November that year, it cited TIARA as an example of "continued ingenuity and productivity" at the Station.[39]

In April 1962 the Station demonstrated TIARA capabilities at the Marine Corps schools, Quantico, Virginia, and in August 1962 BuWeps delegated to NOTS the authority for technical direction and administration of the Bureau's program for research and development in the field of chemiluminescent materials.[40]

Progress was rapid, and more and more uses were found for these chemical compounds that emitted a dull, green-blue light. By the end of 1963, "hand grenades, rifle grenades, marking sticks, 81-mm mortar shells and land mines [had] been packaged and tested; quantities of grenades and marking sticks

37 This give and take between operational forces, Washington headquarters, and the laboratory would be seriously curtailed later in the 1960s as Secretary McNamara formalized, centralized, and bureaucratized the process of introducing weapons to the fighting forces.

38 *Project Tiara—Status Report 1*, NAVWEPS Report 8676, NOTS TP 3729, Feb 1966, ii.

39 Advisory Board meeting, 15, 16, and 17 Nov 1961, Dr. Ithiel de Sola Pool, chairman, NOTS CL 1167, April 1962, 75, 2.

40 *NOTS Command History* 1962, 6; *Major Accomplishments*, 119.

were shipped to Vietnam for field evaluation." AGILE also provided funds for packaging TIARA in drop-zone panel markers and parachute signal flares.[41]

Although ARPA terminated support for TIARA under Project AGILE in 1964, new sponsors would continue to fund the program for the next decade. By 1967 NOTS researchers were developing two TIARA devices for air-to-ground marking. One was the EX 60, a modified Zuni rocket warhead, designed for use with all fixed-wing tactical aircraft, and the other was Marceye, a chemiluminescent-filled 100-pound general-purpose bomb restricted to propeller-driven aircraft. The EX 60 provided sufficient light for strike aircraft to deliver ordnance on target for 5 minutes; Marceye lasted about 50 percent longer.[42]

An improved formulation called Chemiluminescent Light from Oxalate Ester (CHLOE), developed in conjunction with American Cyanamid Corp., produced light up to 1,000 times more intense than the early TIARA material. In the 1970s chemists Herb Richter and Ruth Tedrick would invent Chemlite, in which two chemicals were stored separately in the same container; when the chemicals were mixed, light would be emitted for up to 12 hours. This development would lead to a multimillion-dollar commercial industry in light sticks with applications including everything from Halloween safety lights to commercial deep-sea fishing.

The first employment of chemiluminescence in combat was by SEALs using Marsticks (roll-on markers), aerosol spray cans, and beer-can style grenades. This description of one of the early combat uses of TIARA came from Robert H. Forster, NOTS' primary contact with Special Operations units during the 1960s:

> A number of SEALs were ambushed while on patrol at night in enemy territory and were completely surrounded and in an extremely hazardous position. By radio they contacted close air support in the form of Sea Wolf helicopters, which were the Navy version of the UH-1B helicopter and which were equipped with M-60 machine guns and rockets. The SEALS identified their position by throwing TIARA grenades out on each side of their flanks and the Sea Wolfs immediately provided fire support against the enemy. A very strange thing happened following the burst of the two TIARA grenades in that the enemy immediately directed their weapons fire at the two light patterns produced by the TIARA material on the ground and on the foliage. Evidently the Vietcong were surprised by this phenomenon, not having seen it before and being somewhat superstitious, recognized it as some sort of a threat and expended a great amount of their firepower just at these glowing patterns. Because of the diversion of enemy fire, the SEALs were able to escape

41 ARPA, *Project AGILE*, 140.

42 *NWC Tech History 1967, Part 1*, 5-75.

> this ambush and suffered no casualties whatsoever. We got glowing feedback on that particular action from the SEALs involved who, to this day, claim that those TIARA grenades saved their lives.[43]

TIARA light sources had the additional benefit of being visible to both photopic (light-adapted) or scotopic (night-adapted) vision. During nighttime use, at the ranges that TIARA would be used for target illumination, it would not interfere with scotopic vision (once the eye's photopic sensors have been activated, nearly 30 minutes of scotopic conditions are required for the eye to re-adapt to night vision).[44]

Special Ops Forces

Early involvement in the Southeast Asian conflict led to China Lake's first associations with what are today called Special Operations Forces: small units of specially trained individuals who carry out high-risk nonstandard military missions. These forces were descendants of such WWII organizations as the Army Rangers, Marine Reconnaissance Battalions, Navy Underwater Demolition Teams (UDTs), and the Office of Strategic Services (OSS).

The Navy's SEAL (Sea, Air, Land) teams, formed in 1962, were the chief beneficiary of China Lake's special operations technology and were usually the first to try out the China Lake-developed special weapons and devices in combat. Later, as word of NOTS counterinsurgency systems spread, Army Special Forces, Marine Recon, and other units used China Lake's wares.

Then, as now, special operations units were characterized by rigorous physical conditioning, highly intensive and technically specialized training, nonstandard and often custom-developed equipment tailored to mission needs, and extremely high levels of esprit de corps. Often too they exhibited individuality and confidence bordering on arrogance that touched a responsive chord in the independent mavericks who worked at China Lake.

Robert Henry Forster, a native of Los Angeles, was stationed at NOTS as a sailor from 1950 to 1952 and returned to the base in 1956 with a BS from Berkeley. In 1960 he was made head of the newly formed Computer Branch in the Aviation Ordnance Department; later he headed the Navigation Branch. In 1967 AOD created the Special Operations Branch with Forster as its head. Although Forster was an electrical engineer by training, his forte was ordnance in any shape or form; in 1968 China Lake named him a Fellow in Ordnance Science.

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43 S-163, Robert H. Forster self-interview, circa 1980. Much of the information in this section was obtained from this transcript.

44 *Project Tiara—Status Report 1*, 47.

In 1964 Forster was requested to support naval special warfare groups operating with the South Vietnamese Navy. The initial requests, he recalled, were for "a remote-controlled radio-fired device used to remotely detonate explosive charges, a system for remotely controlling a drone boat, two types of rocket launchers, and a self-destructing two-man rubber life raft."

Forster later recalled an incident that gave him some insight into the nature of the people with whom he was working. His group had developed a test model of the remote-detonating device, and one evening at China Lake he had given it to his SEAL/UDT contact, Lieutenant Craig Dorman to test.[45]

The next morning, Dorman told Forster that an antenna had broken when he and an associate had climbed a tall tree and tied the unit to the trunk. Forster related:

> I asked where he had taken his people to find big trees and why big trees. He told me that big trees were common to Southeast Asia and were used frequently by SEAL personnel to hide in and to locate explosives, claymore mines, and that sort of ambush device when out on patrol.
>
> Again, I asked where he had found the big trees, and it turned out that at approximately 2 or 3 o'clock in the morning he and his six SEALs had conducted a series of tests in the residential area on the hill east of the Officers' Club. I asked if they had been seen, or had any trouble with, the tenants and he said, no, they were accustomed to operating quietly in the dark in that type of environment. That incident alerted me to the fact that it would probably be well in the future to discuss with those people in a bit of detail just where they intended to operate and under what circumstances.
>
> It was beginning to dawn on some of us at China Lake that these people were unique in that they required risk and daring and maybe danger to satisfy some sort of unique need in their personalities. It became obvious later that they had very little respect for authority, they had very little fear of the consequences of breaking rules and regulations, that their superiors in the chain of command pretty much expected them to operate and behave in that fashion, and that their superiors were very much out of the same mold.

The first project—the remote-detonating device—was a mutual learning experience for Forster's people and the SEALs, both groups learning the ways of folks from different professional cultures. But a satisfactory device was developed, chiefly by Daryl Beman, Don Quist, Gaylon West, and Bemis Jones. After the detonating device, the self-destructing rafts were a relative piece of cake. These

45 After retiring from the Navy as a rear admiral, Dr. Dorman would serve as director of the Woods Hole Oceanographic Institution and vice president for research at the University of Alaska.

were used for a one-way transit of up to 5 miles from an offshore boat at night. NOTS purchased 50 rafts from Sears Roebuck, painted them with dark-blue lacquer, and supplied them to the SEALs in rubberized bags along with simple plywood paddles, an air pump, and containers of bromine and bromoform which, when mixed and poured into a raft's floatation chamber, would render it unusable in 3 hours.

Behind the drone-boat controller was a plan to load an indigenous vessel with explosives and then steer it into an enemy harbor or anchorage where it would be remotely detonated. The Mine Defense Laboratory at Panama City, Florida, was responsible for the propulsion system and actuators, and China Lake was tasked with the remote-control system. Engineers at the Naval Air Facility had some surplus drone-control equipment, which was adapted to the task. Elvy Hopkins coordinated the project with Panama City.

The system was successfully tested in San Diego, and China Lake turned over transmitter-receiver and safe-arm systems to the Naval Special Warfare Group at Coronado, along with cabling and instruction manuals.

SEAL teams still wanted their exploding rocks, so Code 35 obtained BuWeps funding to develop a new fuze. The new design used a commercially patented component called an electrolyte cell or "E cell." The E-cell container was prone to leakage, which caused the circuit to fire prematurely. Forster reported that:

> In all fuzing development, the attempt is to design a fail-safe concept. In other words, if you have a failure, the device fails in a safe mode rather than a fire mode. The failure of E cells was the opposite to that. When it failed, it would fire rather than render itself safe. And the failure of that one component caused the entire development of that rock mine fuze on our part to fail.

The exploding rocks never saw service. However, the castable explosive capability had opened up a whole field of booby traps to Forster's team, with the applications limited only by their ingenuity.

Booby Traps

Booby traps were not simply a way to inflict casualties on enemy troops; the weapons had a sensible place in the larger scheme of prosecuting the war. As Forster explained:

> One of the problems encountered in Vietnam was the fact that the Vietcong guerrillas early in the war were sustaining their operation primarily with captured equipment. That equipment was generally captured from the

> South Vietnamese forces who were putting up a very minimal resistance to the Vietcong and were usually overrun and their equipment captured. Their equipment, however, was all U.S.-supplied and was very similar to what our own troops were using themselves.
>
> One of the means to defeat this use of captured equipment was to discredit that equipment by salting captured supplies with booby-trapped items unidentifiable from the valid article. Items of primary concern were weapons, ammunition, food supplies, and medical supplies. So the SEALs were anxious to obtain booby-trapped articles in these different categories.

The booby traps might be considered a force multiplier in that a single incident caused by a booby-trapped item could render a whole class of items suspect in the eyes of the Vietcong, leading to morale issues and a hesitation to use such items. At the time, the only available standard-issue booby traps in the U.S. arsenal were unsophisticated mechanical trip-wire-released units. The enemy, by contrast, had a great variety of simple and ingenious booby traps (although they were short on safety features). One SEAL had been killed early in the conflict trying to fashion his own booby trap, and that had been a driving force in the special warfare community's decision to contact NOTS. Forster and his small team turned to and began to produce booby traps.

A NOTS request to the CIA for information on booby traps brought no help, so the NOTS engineers started from scratch. They opted for systems built around electronic blasting caps and capacitors. For test, training, and demonstration purposes, blasting caps were replaced by flashbulbs. The capacitors were very small, with low leakage, and could be used to incorporate a timing sequence in the booby trap. Some units that required variable pressures for effective use (a pressure switch that would be concealed by debris, for example) incorporated a tiny light that would allow the operator in the field to set up the booby trap and test that the sensitivity was properly set before hooking up the blasting cap leads.

Many of the booby traps were modular: China Lake developed a variety of fuzes, clock mechanisms, antidisturbance/antitampering devices, and explosive units with which the SEALs could exercise their own inventiveness in a specific tactical situation. Components were ruggedized and waterproofed to afford greater latitude of emplacement conditions (muddy roads, railroad tracks, submerged bridge supports, etc.). For the field operative who was not a do-it-yourselfer, a 1968 publication prepared by Forster's group lists a menu of "Prepared Pre-Loaded Booby Traps" for field personnel.[46]

46 *Naval Special Warfare Projects*, NWC IDP 2927, Oct 1968, 11.

Booby traps were designed for M-79 grenade launchers, .45-caliber pistols, M-16 and AK-47 rifles, their ammunition magazines—items that might appear to have been "abandoned" at the site of a firefight, for example—and the fuel tanks of boats and vehicles. Booby-trapped items would be left at the scene of combat operations.

Remembering the early problems with the exploding rocks that had been made under Project AGILE, the Code 35 group put quality and safety first in their designs. Forster reported:

> It with a little bit of pride that I can say that there never was an accident with any of our booby traps that was ever reported back to us. You always get feedback on bad operations, accidents, malfunctions, and so forth, and, in the case of booby traps, we never received one adverse report in their usage in training or in combat.
>
> . . . because the SEAL operations were conducted in enemy territory, but in the vicinity of heavily populated agricultural areas and villages which were considered friendly by day and enemy by night, very close control of the employment of booby traps was required, and each employment of such a device was catalogued such that these devices were not eventually to inflict death or injury on friendly forces. This was strictly adhered to, as was reported to us.

Small Arms

Vietnam drew NOTS into the small-arms business as well. One of the earliest examples was the "Five-Foot Rifle," reported by the Station to be "the best lightweight rifle to fill the need for small arms for people of small stature (5 feet or less)." Built around a standard .30-caliber M-2 carbine, the weapon had "adequate power to produce lethal wound in jungle fighting, moderate recoil, and excellent firepower" and could be used in both semi- and full-automatic modes. The 28-inch-long weapon, complete with 90 rounds of ammunition, weighed the same as a standard M1 rifle without ammunition.[47]

Special Operations Units needed very high firepower at minimal weight, because their operations were often far from regular supply channels. Since the SEALs (unlike the Army and Marine forces) were not constrained to use "approved" U.S. weaponry, like the M-14 and M-16 rifles and regulation-issue sidearms, SEALs obtained a variety of foreign weapons for particular mission needs. China Lake engineers, gunsmiths, and machinists learned to modify existing military weapons to lighten their weight and improve their flexibility.

47 *NOTS Tech History 1962*, 133.

This trend grew into the development of custom weaponry, such as a .50-caliber sniper rifle built by Al Kermode of the Engineering Department (Code 55). The rifle's design was based on an 1850s-vintage rolling-block lever-action rifle, updated with a modified lightweight aircraft machine-gun barrel and a muzzle brake to cut down recoil. The weapon was accurate; one story, unverified, is that at the old Marine Corps rifle range east of B Mountain, Kermode fired a three-shot, six-inch group at 1,600 yards.[48]

It is unclear if the .50-caliber ever made it to combat—Forster himself said that at 23 pounds it was too heavy for the SEALs, although they loved to fire it on their China Lake visits.

Regardless, it proved a popular demonstration piece for visitors to the Station. Forster related that when then-retired Air Force General Curtis LeMay visited China Lake in 1977 he was so taken with the rifle that he obtained a set of the drawings and had one of the weapons built at a friend's machine shop in Costa Mesa.

Other weapons rolled out of China Lake and into the jungles of Vietnam. "Big Shot" and "Little Shot" were provided to SEAL units. The weapons were set up to remotely fire rockets into a target area—a 4.5-inch artillery rocket for Big Shot and three 3.5-inch bazooka-type rockets for Little Shot—according a preset timer. Both contained antidisturbance devices and would self-destruct after firing.

Napalm grenades (with a 20-foot-diameter burst area) came in a kit form—just add gasoline. A three-barrel triangular configuration 40-mm grenade launcher was designed to mount in place of the forestock on the M-16 rifle, and a four-round pump-action 40-mm grenade launcher designed and built by Kermode, Herb Swader, Ron Gonder, and others, dramatically outshot the existing M-79 grenade launcher in speed and accuracy.

China Lake's Swader (a Pearl Harbor survivor) modified about 50 Ithaca Model 37 Featherlight shotguns for SEAL use. The modifications consisted of expanding the magazine capacity from four to seven rounds and adding a duckbilled spreader choke that produced a pattern 8 feet wide by 2 feet high at 25 yards. After a shootoff by SEALs of the China Lake choke against a commercial spreader choke, the SEALs opted for the China Lake model.

A carbine version of the M-16 (30 were custom built for the Station by Colt) was designed for parachute operations, where minimizing weapon length

48 In his spare time, working in his home workshop, Kermode designed and built from scratch such weapons as a .45-caliber automatic pistol, with no external moving parts, that fired a 300-grain bullet at 2,000 feet per second. *Rocketeer*, 11 March 1966, 3.

and weight were critical. The weapon had a folding stock and was so small that "it fit in a Samsonite slim briefcase."[49]

At the SEALs' request the Station also developed a secondary selector switch for the M-16 that prevented more than three rounds in a burst, as a means to limit ammunition expenditure. A NOTS-developed blank firing adapter that permitted semi- and full-auto firing of blanks—and would not harm the weapon or operator if a ball round were fired through it—added a greater dimension of realism to SEAL training exercises.

During the Vietnam War, the Station also designed and manufactured a "pipe gun" for another government agency. Forster described this as a "9-mm submachine gun that was designed in the form of a cylinder about 20 inches long and 2½ inches in diameter. It was black anodized and from external appearance looked nondescript and completely unidentifiable as a weapon." The pipe gun was created by Hubert Ross and Robert A. "Al" Boyack working under Dr. Guy W. "Bill" Leonard, head of Code 45.

Other Special Operations Items

Outside the realm of weapons, NOTS developed a variety of items that increased the safety and effectiveness of the Special Operations combatants. The SEALs requested a fluid-filled wrist compass (as opposed to an air-filled compass, which would collapse and leak at relatively shallow depths in SCUBA operations). Station engineers modified a Silva compass and added an extra-large strap that would fit around a wetsuit. The compass was a hit with the SEALs. Forster observed:

> This was such a popular item and we supplied these in such very large numbers that we believe that it was a highly prized trade item used by the SEALs in Vietnam to obtain whatever their hearts desired. It's otherwise hard to explain how a platoon of 15 SEALs could require upwards of a hundred wrist compasses for a 6-month tour in Vietnam.

Beacons and signaling devices were especially important to the SEALs. Much of their work was done at night and in jungles. Insertion and extraction of teams required pinpoint timing and dead-on accurate positional information. The need to communicate among team members and between teams and their support units (aircraft, vessels) by means that the enemy couldn't detect is self evident.

Again, China Lake's approach to many of the needs shows the characteristics of a government laboratory solution—make it as quickly, simply, and cheaply as possible. While certain of the products developed at the Lake would eventually

49 S-259, Knutsen interview, 50.

become more refined and be made available to the general military forces through large-scale commercial production, most of the early requests from the field were of the "we need it yesterday" variety and did not involve large numbers of units.

One sorely needed device was a marker light that could be used to signal for a seaborne or helicopter pickup. China Lake engineers started with the standard "Light, Distress Marker, SDU-5/E," a battery powered Xenon strobe light used as a rescue marker by downed naval aviators. (Advertisers claimed that these commercially available devices were visible for up to 50 miles in daylight; however, nighttime tests at G Range road indicated a more realistic nighttime range of about 3 miles.)

Each marker light was sent to Vietnam with a movable shroud fitted to the omnidirectional strobe to make the strobe a directional signaling device. Unfortunately, the Vietcong had taken strobe lights from downed pilots and on at least one occasion tried to decoy a Patrol Torpedo, Fast (PTF) boat (also called a "Nasty" boat) that was attempting to pick up a shore party.

That particular situation was resolved by radio communications without mishap, but it led NOTS to order a special manufacturing run of the Xenon strobes that flashed at 120 pulses per minute, twice the rate of the normal-issue marker.

NOTS designed an IR filter for the strobe light that made it visible only to an observer using an IR scope. (Special operations units were already equipped with the Army Signal Corps metascope—a flashlight that passed only infrared light and a receiver that allowed viewing in the IR range.) The filter could be used either with the directional shroud or, in a "bathtub" configuration, omnidirectionally. Colored filters were also designed for the strobe light so that various elements of a unit could identify one another. Finally, the units were waterproofed to a 200-foot depth.

Later testing at China Lake showed that the Xenon strobe with an IR filter actually had a dramatically shorter range than a standard flashlight with an IR filter (a function of the low average-power output of the strobe and the physiology of the human eye). Thereafter the Station procured a variety of colored and IR flashlight lenses.

A domed rotating flashlight beacon was also produced with interchangeable color and IR filters. Hundreds of beacons and signaling devices were provided to SEAL and UDT teams operating in Southeast Asia and, after the Marine landing in Chu Lai in 1965, to the Third Marine Amphibious Force (III

MAF). Army 82nd Airborne headquarters requested the flashlights for use in rendezvousing ground forces after mass parachute jumps.

Not every requirement needed a design solution. For example, a serious problem with the early M-16 rifles was that a rifle could malfunction if mud got into the muzzle, which was a common occurrence in Vietnam. Forster's group located a commercially available plastic cap from Cap Plug Manufacturing Co. (a company that made plugs for electrical connectors). Tests showed that the plug fit the muzzle, stayed on during normal usage, would keep out the elements, and—if the shooter didn't have time to remove it—could be fired through without damaging the weapon.

The only problem was that the company manufactured them only in bright colors: green, red, orange, etc. NOTS made a special procurement in black plastic (on the order of 5 cents per unit in quantities of 1,000) and shipped them off to Vietnam.

The mud plug contrasts NOTS' goal-oriented, get-the-job done approach with that of more bureaucratic organizations. Forster's group notified the Army, which was also using the M-16 in Vietnam, of the mud plug and were requested to send several dozen for testing to the Rifle Project Office at Rock Island, Illinois, which had cognizance for the Army's M-16 rifle.

Forster recollected that:

> Instead of running immediate tests like we did at China Lake on the M-16, satisfying themselves that it was a solution to some of the problem, they immediately launched into a full-blown test program to determine the effect of this type of plastic on the carbonized finish of the M-16 flash suppressor and the effect of storing this mud plug in the muzzle of an M-16 for extended periods of time.
>
> They could tell you at the end of the program what the effect would be after 1 year, 2 years, 5 years, 10 years, in 40 degrees relative humidity, 60 degrees relative humidity, 80 degrees relative humidity, etc. This would seem to be an overkill of what their immediate objective was, since these were available for approximately 5 or 6 cents each in large quantities.
>
> How many accidents, failures, unreliabilities, and so forth could have been prevented in Army usage of the M-16 had Rock Island immediately procured these . . . .

China Lake also developed the Dry Atmosphere Maintenance Unit, or "dry box," a container with attached compressor and reusable desiccant cells designed to create an environment for maintenance of metascopes and starlight scopes. The scopes were indispensable for night operations but contained high-voltage transistorized power supplies that were notorious for their susceptibility to moisture. A glass window and reach-through gloves in the dry box let technicians perform maintenance and repairs.

"This unit proved to be very, very effective," reported Forster. "We manufactured approximately 20 of these."

Sometimes the solution to a tactical problem was as simple as waterproofing. SEALs were continually having China Lake waterproof manufacturers' lots of equipment ranging from binoculars and signaling devices to metascopes and AN/PRC-25 tactical radio handsets.

Metascopes in particular were a problem; the manufacturing specs required only a pass-through exposure to 1 inch of water, and the molded plastic cases were prone to develop cracks. NOTS set up an overhaul line to waterproof scopes and add O-rings and high-vacuum grease. The Station treated five or six hundred scopes for both Navy and Marine units in Vietnam.

When metascopes came to NOTS that were beyond local capability to fix, they were sent to Army specialists. Said Forster:

> We developed an excellent rapport with the Army overhaul depots at Rock Island, Illinois, and Sacramento, California, and enjoyed this excellent working relationship and cooperation with these people for considerable period of time. They were more than eager to help us. The charges that they required were minimal, the turnaround time was excellent, and a better spirit of cooperation could not be found anywhere.

Many of the contributions that NOTS made to the Special Operations Forces seem almost trivial in their simplicity, but they were not thought trivial by those who requested and used them. A partial list includes plastic caps to keep dirt out of M-16 magazines, a waterproof plastic mount-out locker for carrying weapons and operational gear, and rolls of vinyl waterproofing material that could be cut to fit for making waterproof bags for equipment.

Republic Tool and Manufacturing Co. of Los Angeles was one of the chief contractors for Forster's group. The company's owner was an officer in the naval reserves and highly supportive of the Station's efforts. When he would visit China Lake, Forster recalled:

> We would take him out on the range and let him fire the various weapons, throw grenades, initiate explosives, whatever, that normal people never had the opportunity to do. In return he was very enthusiastic about supporting us and supplied us at very reasonable cost in a time frame compatible with our quick-reaction work.

Spin-Stabilized Aircraft Rocket—SSAR

NOTS began work in 1963 on a Spin-Stabilized Aircraft Rocket (SSAR) to provide a quick-burning, high-acceleration air-to-ground weapon for light aircraft to use against troops. This 3.5- by 14-inch rocket employed a high-density fluorocarbon propellant firing through canted nozzles to impart spin and a wrap-around warhead.

Spin-stabilized rockets were not a new concept for the Station, but the SSAR was unique in that it was designed to be fired sideward and rearwards, as well as in the conventional forward-firing configuration. Rearward firing gave the attacking aircraft a first-pass close-range firing capability. Sideward firing—with the aircraft in a "pylon turn," the lower wing pointed at the target—had the advantage of extending time on target, maintaining constant range, and offering a crossing target for return fire.

The feasibility of the sideward firing was demonstrated by mounting two M-2 automatic carbines on the wing of an L-19 aircraft and analyzing bullet-impact data.[50]

Patrol Boat, River—PBR

In 1964 Code 12 addressed another need of the U.S. forces in Vietnam. Dale Knutsen, who joined the Station in 1963, and other analysts developed the requirements definition for the Patrol Boat, River (PBR), a Navy vessel used for delivering personnel and supplies as well as patrolling the waterways of Vietnam. Knutsen recalled:

> There was an argument going on as there often is when you get into requirements about which choice of several do you want to make. And there was one contingent that felt that a floating tank was the ideal thing to go into harm's way. There were others that had a different view, and this particular group as a result of the analysis we did indicated that they felt strongly that it should be a very lightweight, fast, maneuverable, heavily armed patrol boat that could get into tight places but have enough firepower and enough speed to get out. And that led to the PBR.[51]

The Code 12 group also included Alex Lee (who would later head the 3rd Marine Force Recon Company in Vietnam and write the book *Force Recon*

50 *NOTS Tech History 1963*, 3-10.

51 S-259, Knutsen interview, 6. Knutsen retired in 1996 after having made numerous important contributions to the Navy's strike warfare capabilities. He is the recipient of the Technical Director Award (1987), the L. T. E. Thompson Award (1995), and the Navy Meritorious Civilian Service Award (1996).

Command based on his experiences) and Franklin M. Osanka. Prior to coming to China Lake, Osanka had served in a Marine Force Recon Company working with Vietnamese Special Force Paratroopers; his book *Modern Guerrilla Warfare* was published in 1962, and he was considered "one of the world's foremost authorities on guerrilla warfare."[52]

Project Michelson notwithstanding, the Weapons Planning Group was not a collection of ivory-tower academics.

Project SWAB

No department had a monopoly on cooking up new technology for the forces in Vietnam. In 1963 AOD's John Boyle approached McLean with an idea for an attack boat. "I got fascinated by small boats," Boyle said. He worked for 2 years designing and building a 31-foot boat, built on a Bertram Yachts hull, that he called the Shallow Water Attack Boat (SWAB).[53]

After the first year of development, the boat came to the attention of the prestigious NOTS Advisory Board, which reported in the minutes of its May 1964 meeting:

> The Board was shown a 31-foot Bertram fiberglass hull driven by two 320 HP Chrysler engines configured as a low-cost weapon carrier. It has a crew of three and a maximum speed of approximately 50 knots. It is recommended that this project be completed at relatively high priority and be put through appropriate sea trials. In the mean time it is suggested that this concept be studied further to determine optimum design configurations. This work should also include cost effectiveness studies.[54]

SWAB also caught the attention of the NOTS Technical Board; in a secret vote taken at the board's 1 October 1964 meeting, the project was selected as one of a dozen to be given first priority for Independent Exploratory Development funding.[55]

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52 *Rocketeer*, 6 March 1964, 3.

53 S-180, Boyle interview, 4–6. Originally his boat was called the Sheltered Water Attack Boat. Before he built SWAB, Boyle, who had arrived at NOTS in 1951, worked on radar projects including the Sidewinder-based antiradiation missile Raywinder, the concept of which was successfully demonstrated in 1957; SARAH, the semiactive radar version of Sidewinder; and Project Loudmouth.

54 Advisory Board meeting, 18-19 May 1964, F. G. Jameson, chairman, Appendix I, Recommendations, 2.

55 NOTS Technical Board meeting, 1-2 Oct 1964, 11. The Technical Board was composed of the Commander, Technical Director, heads of the technical departments, and other invitees as appropriate for the topics under discussion.

SWAB carrying original 2.75-inch rocket canisters, with Raymond Laidler (standing by the boat) and John Boyle (looking through a scope at right), at SNORT Reservoir.

SWAB used a hydraulic steering unit (in place of a standard cable drive) that, coupled with its speed and hull design, gave it extreme maneuverability. At 25 knots, the boat could complete a 180-degree turn in less than 8 seconds.

But SWAB had a couple of other things going for it beyond being small, fast, and maneuverable. First, it had powerful stabilized armament. Originally the forward-firing armament consisted of twin canisters of 2.75-inch aircraft rockets. However, the rocket dispersal pattern and cross-wind sensitivity were greater than desired, and so the 2.75s were replaced by two stabilized gun packages, each containing seven 57-mm recoilless rifles.

Eugene Baker, from Code 35's Development Division Four, assisted Boyle with the mathematical analysis of the servo system used for stabilizing the guns. Augmenting the big guns were a 20-mm stern machine gun and two .50-caliber forward-firing machine guns.[56]

SWAB was also, according to Boyle, the Navy's first radar-camouflaged vessel. He recalled:

56 *NOTS Tech History 1965*, 7-33–7-35.

> In conjunction with the SWAB project, I got into the development of very-high-resolution laboratory radars specifically designed to assist in the reduction of radar signatures. This first radar I built was in 1963. I remember the first crude model of it. I set it up in Dr. McLean's office, in his conference room, and showed him how it worked, and he supported me. He gave me three hundred thousand dollars for 3 years' work. Three hundred thousand dollars went a long ways in those days.

This incident illustrates a management principle McLean discussed in a 1959 conference presentation when he set forth a list of nine ways to "rapidly change a creative organization into one doing only routine productive work." The fifth item was "Insist that all plans go through at least three review levels before starting work. Review weeds out and filters innovation . . ."[57]

Radar signature reduction for small boats was a new area of effort for NOTS. Unfortunately—in terms of obtaining long-term development funding—the technology was not driven by the needs of the Vietnam War. SWAB never caught on with the Navy; there were other more suitable boats with which to wage war on the rivers of Vietnam. Boyle himself described the boat as:

> . . . an absolute miserable failure in spite of the fact at that time, the U.S. Navy was right in the middle of extensive small-boat operations in Vietnam . . . this thing didn't sell because I wasn't thinking of the Vietnam War. I was thinking of us fighting Third World navies or possibly the Russian Navy, in coastal waters, not in rivers . . . and these small boats being able to protect and screen our bigger ships.[58]

SWAB's capabilities were impressive. In tests at the Long Beach Sea Range the boat reached speeds of 33 knots and demonstrated "excellent seaworthiness, stability, and maneuverability. Most remarkably, through the use of nonvertical surfaces and radar-absorbing materials, the head-on radar cross section of the boat was reduced to "less than 0.1 square meter."[59]

Although the Soviets had been working on antiship missiles since the late 1950s—notably the P-15 Termit (NATO reporting name Styx)—little thought was given to reducing the radar signature of U.S. Navy ships—even after the Israeli destroyer INS *Eilat* was sunk in 1967 by three or four Styx missiles launched from small Egyptian *Komar*-class missile boats. The first serious reductions in the radar signature of Navy ships (angled rather than vertical surfaces) were not made until the *Arleigh Burke*-class destroyers were built in the 1990s.

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57 RM-24, *Collected Speeches of McLean*, 103. The list is reproduced in Appendix B.
58 S-180, Boyle interview, 92, 6–7.
59 *NOTS Tech History 1965*, 7-33.

Jesus said that a prophet has no honor in his own country. Boyle felt strongly that the Navy was misdirected in its emphasis on large carriers to the exclusion of serious antiship missile defenses, and he spoke often and openly about it:

> I'll never forget one time when I was giving a big lecture on what was wrong with the Navy and how we should fix it and getting all worked up, and everybody in the audience was sitting there with vast disinterest . . . Newt Ward afterwards said in comment—he's the only one that made a comment—he says, "You know, Boyle, the only thing you need is a white robe and a repent sign." And it really kind of shattered me.[60]

In 1965 SWAB was transferred to the Naval Operational Support Group, Coronado, California, to evaluate its potential for coastal operations.

Project Salty and Other Support to Special Warfare

Before the Gulf of Tonkin Resolution put the U.S. officially in the war in 1965, NOTS assistance to the war effort already encompassed several efforts unrelated to the Special Operations units. One such project addressed a problem with the Douglas A-1 Skyraider aircraft (known also as the Spad or AD), which the South Vietnamese Air Force had used to battle Communist insurgents since 1962. South Vietnamese pilots were trained by U.S. Navy and Air Force advisors.

A powerful and rugged propeller plane, the Skyraider mounted 20-mm cannons and carried a hefty ordnance load. It became a workhorse of the Vietnam War, for both U.S. and allied forces; 40 Navy and 104 Air Force men were killed flying Skyraiders during the Southeast Asia conflict.[61]

One shortcoming was the plane's acoustical signature—it was loud. Maurice Hamm, who had been in AOD since 1956, was assigned to a project called Salty in 1963. Hamm described the problem that Salty addressed:

> ADs . . . are these hogs that go along relatively strong. You can hear them for miles coming, and they carry more than their own weight. They are a fabulous machine, but over Vietnam [the Vietcong] could hear them coming, so they would hide in the huts, and as soon as the AD got over the village, then they would look over the side and here all these guys were scrambling out and you'd see little white puffs, shooting rifles at them. A lot of times they could knock an airplane out of the sky.[62]

The Project Salty team was led by Joseph M. Seibold from Code 35's Missile Development Branch. Tests in 1962, using an F-10 with a rear-facing

60 S-180, Boyle interview, 5.

61 A-1 Skyraider Assoc., *http://www.skyraider.org/skyassn/menlost.htm,* accessed 15 March 2010.

62 S-166, Part 1, Don Hart, Maurice Hamm, and Howard Schafer interview, Dec 1985, 58.

TV camera, had shown the feasibility of tracking a target after the aircraft had flown over it by watching the TV monitor in the cockpit, "a technique similar to flying with a rearview mirror."

In 1964 an M-2 .30-caliber carbine was mounted facing aft on the fuselage of a Cessna 0-1A, and a successful demonstration showed the ability of a pilot to hit targets with the weapon—shooting backwards. The pilot used a rearview mirror with crosshairs that was attached to the fuselage and with a rod on the horizontal stabilizer that functioned as a "front" sight. During eight firing flights against an 8- by 8-foot target, 267 rounds were fired: "59 percent made a direct hit on the target and 73 percent impacted the target."[63]

The group next installed a television camera in the tail of an NAF A1-G Skyraider and mounted a TV screen in the cockpit. The camera was boresighted with a rear-facing .50-caliber machine gun on a wing station. Seibold remembered testing the system on Baker Range.

> Oh, it worked! Merle Gurkey, the technician, had loaded the gun with tracer rounds. We burned the target down.

No records have been found indicating whether the system was actually deployed to Vietnam.[64]

Why the name Salty? "Remember back in the Bible when Lot's wife turned into a pillar of salt?" Hamm asked rhetorically. "OK, we called this Project Salty, because this was looking back."[65]

NOTS support to the special warfare community during the Vietnam War highlights an important need in the nation's defense program that government laboratories are well suited to fill—the rapid development of items that are effective, inexpensive, and will only be produced in limited quantities. For a defense contractor, the cost to research and develop a specialized item—particularly on an urgent quick-reaction schedule—is not warranted for a small-scale production run. Most of the items that NOTS shipped to Vietnam were produced in quantities ranging from one to several hundred units. Some items were never entered into the formal Navy acquisition process because of the small size of the procurement and the necessity for expeditious delivery.

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63 NOTS TP 3119, *NOTS Tech History 1962*, 157; *NOTS Tech History 1964*, 7-27. The difference was presumably caused by ground ricochets.

64 Joe Seibold, telephone interview, 15 March 2010.

65 S-166, Part 1, Don Hart, Maurice Hamm, and Howard Schafer interview, Dec 1985, 58. Project Salty should not be confused with Project Salty Dog, which developed and tested 13-gallon drums of pyrotechnic cloud-seeding material that could be suspended below a helicopter or parachuted from an aircraft. *NWC Tech History 1967, Part 1*, 2-44.

Bob Rowntree decried the problem of "the lack of a way to insert anything in the logistic system." He added that:

> You didn't have a Navy stock number and you've got to have gone through all the rigmarole of approval and acceptances by OPTEVFOR and everybody else. . . . any kind of bureaucracy has a real problem with trying to get things inserted other than at the very input side of the system.[66]

Throughout the early 1960s—through the entire Kennedy administration, which was cut short by the assassination in Dallas in November 1963, and into President Johnson's administration—China Lake was kept busy by the nation's military activities in Southeast Asia: solving problems for the relatively small Navy combatant force while at the same time developing a variety of new conventional weapons including the Eye series, which were suitable for limited war. However, after the nation's official entry into the conflict in August 1964, the size of the force committed to Vietnam increased rapidly and so did their needs. If this was indeed a brushfire war, as some contended, it was not going to be quickly brought under control.

The stepped-up pace of hostilities had brought out problems with the conventional weaponry, particularly air-launched weapons, that the Navy and Marines were using in Vietnam. Resolving those problems had been the focus of the meetings described in Chapter 3 between CNA reps, NOTS personnel, and Admiral Moorer's staff in Hawaii in late 1964.

Navy laboratory support for the ground-based fighters—the SEALs, the UDTs, and the Marines—also suffered growing pains as the war escalated. The numbers of forces increased on both sides of the fight, and the enemy grew increasingly savvy. The relatively informal relationship between the Navy combatants and the laboratories that had characterized the early 1960s was not well suited for a full-scale war. Navy officials decided to establish a more structured framework for the laboratory support activities.

Vietnam Laboratory Assistance Program

NOTS had begun sending its technical staff into combat zones during the Korean War. The Station had developed the 6.5-inch Antitank Aircraft Rocket (ATAR) in a crash program for use against Soviet-built heavy tanks. In less than a month, ATAR had been designed and tested at China Lake, and 600 rounds were hand-built by NOTS personnel. When four NOTS employees arrived in the theater of operations in 1950—ostensibly to introduce ATAR to the Air Force and Navy aircrews—they encountered so many technical problems

66 S-176, Rowntree interview, 35.

with existing weaponry that soon they were providing training and advising the combatants on the proper selection, handling, loading, and delivery of the entire arsenal of bombs and rockets. The ATAR team's experience emphasized the need for the laboratories to work directly with the end users of their products.[67]

In 1965—the year in which U.S. troop strength in Vietnam reached 184,000—the Navy established the Navy Research and Development Unit, Vietnam (NRDU-V). Its mission was to do officially what NOTS had been doing informally: identify problems that required RDT&E. NRDU-V was also tasked with reaching out for assistance to solve those problems; evaluating new materials and tactics in a combat environment; and providing a test environment for new weapons, equipment, and techniques. Less than a year after the establishment of NRDU-V, the Director of Navy Laboratories (DNL) created the Vietnam Laboratory Assistance Program (VLAP).

VLAP was a true outreach program. Its purpose was to provide not only advice and support but also scientific and technical advisors to the Navy and Marine units in Southeast Asia—lab shoes on the ground, as it were. This was not a new concept. In WWII, the Army Signal Corps had assembled a unit called the New Equipment Introductory Detachment (NEID), an all-military unit that sent teams on temporary duty throughout the combat theaters to introduce new signal-corps equipment and report on its performance.[68]

VLAP's purpose was to attack the troops' problems with quick-response, short-term solutions. Specifically, the ground rules set by DNL were:

> (1) tasks should be only those to which prototype solutions could be available for field evaluation in a relatively short time (3 to 6 months), (2) tasks should be small-scale (not over $50,000), and (3) no large-volume production procurement should be undertaken.[69]

At any given time there might be six representatives from the laboratories operating in Vietnam. NOTS, as the West Coast VLAP Coordinator, oversaw the VLAP activities of the Naval Electronics Laboratory Center, San Diego; the Naval Undersea Research and Development Center, San Diego; the Naval Civil Engineering Laboratory, Port Hueneme; and the Naval Radiological Defense Laboratory, San Francisco. The first NOTS employee to serve in Vietnam under VLAP was Frederick H. Davis, a Harvard-trained physicist who headed the mysteriously named Techniques and Devices Group on the staff of the Research

67 Babcock, *Magnificent Mavericks*, 184–188. See also 196–198 for a discussion of the establishment of NOTS' first formal fleet-support organization.
68 Rebecca Robbins Raines, *Getting the Message Through: A Branch History of the U.S. Army Signal Corps*, Center of Military History, United States Army, Washington, DC 1996, 302.
69 *Major Accomplishments*, 167.

Department. Davis had worked in radar with the Navy during WWII, as a telemetry engineer with the Jet Propulsion Laboratory in Pasadena, in missile and torpedo technology at NOTS Pasadena, and as head of the Guidance and Control Branch in AOD at China Lake.

After another stint in private industry, he'd returned to China Lake as a "consultant in applied research, advanced development, technical advisor in physics, electronics, missiles, and weapons system" in the Weapons Department before moving to the Research Department. With a hobby of growing orchids and exotic plants, Davis was a technically well-rounded individual.[70]

When he arrived in Vietnam in April 1967, he began his four-month tour at NRDU-V in Saigon (VLAP representatives' chain of command ran through NRDU-V). Soon after his arrival, he was transferred north to the Third Marine Amphibious Force (IIIMAF) at Da Nang. Operating from this sprawling base at the edge of the Bay of Da Nang, Davis traveled to Marine outposts throughout the northern part of the country, making personal contacts and "getting first-hand information from privates to generals."

Fred Davis on the job in Vietnam, 1967. *Rocketeer* photo.

70 *Rocketeer*, 18 Aug 1972, 7.

When he identified a problem he would first try to work out an immediate solution in-country, writing up his suggestions and recommendations and submitting them to NRDU-V. He transmitted copies of these reports to Bob Rowntree, his contact at China Lake, for evaluation by a laboratory team.[71]

Although most of Davis' work was ordnance related (later in the war he would serve on the DNL Committee on Mines and Booby Traps, as well as the Committee on Vietnamization), the Marines did not hesitate to bring him any technical problems they encountered.

For example, the five-gallon WWII-vintage "jerrycans" the Marines used for hauling water were difficult to handle and too heavy to haul through the rugged jungle-covered terrain. Foremost Milk Co. had a Navy contract in Vietnam and ran a milk reconstituting operation that used disposable plastic bags in corrugated cardboard boxes. With a little modification and redesign (courtesy of the laboratory backup team), the containers proved ideal for the water-hauling and distribution task and were soon being distributed to the Marines by the thousands.

China Lake developed a filling station for these containers that could fill three 6-gallon disposable plastic bags with water every minute. The station was sent to Vietnam and was set up at Camp Evans and then moved to Dong Ha. Not long after operations began there, all the equipment and about 8,000 containers were "destroyed by enemy action."[72]

After Davis' return, Bud Sewell was tapped to be NOTS' next VLAP representative. Sewell, chosen when the scheduled selectee had a stroke, did not want to go. Frank Knemeyer had first suggested the possibility in 1966. Sewell recalled:

> He called me at home and asked if it would represent a personal inconvenience to me to spend four to six months in Vietnam. I let him know that it would represent a large inconvenience to me, but that it was not such an inconvenience that if I were ordered to go that I would not.[73]

Sewell relented (though he claims he never signed the "volunteer" papers). Like Davis, he had a broad range of experience in the types of problem-solving the Marines in Vietnam might need. A physicist by education, having studied at Harvard, Yale, MIT, and Berkeley, he wears white shoes in honor of Enrico Fermi, from whom he took a quantum physics course at Berkeley. His background before VLAP included being an Air Force communications officer,

71 *Rocketeer*, 8 Sept 1967, 1, 3.
72 *NWC Tech History 1967, Part 1*, 1-8.
73 S-105, Robert G. S. Sewell interview, 14 Oct 1975, 2.

and in his 17 years at China Lake (which would eventually stretch to 35), he worked in ballistics, explosives, warheads, satellite launch vehicles, detonation physics, and passive detection systems. He was described by Phil Arnold as "a professional enthusiast."[74]

Sewell would eventually make six trips to Vietnam for the Station. While he was in-country, his primary contact at China Lake was engineer Albert S. Gould, Sr., a NOTS pioneer.

In December 1967, a month before the massive Vietcong/NVA campaign known as the Tet Offensive, Sewell was called into the office of Gen. Robert E. Cushman, IIIMAF Commander. As Sewell recalled it, Cushman said "Mr. Sewell, I am holding you personally responsible for the two main bridges at Da Nang." When Sewell subsequently asked the G-3 officers what the general meant by that, he was told, "We don't know, but if they go down, you better be on them."[75]

Like the Shrike program—which kept developing new "dash models" as the enemy employed new operating frequencies—the VLAP advisors had to revisit problems that they had solved, but which the enemy had then "unsolved."For example, Sewell recounted the story of how, during Davis' tour, the Vietcong were destroying bridges by using 200-pound explosives charges that swimmers would attach to a bridge. A NOTS-designed preventive device was sent to Vietnam and installed. Said Sewell:

> It worked. . . . and that's part of the problem. It was a partial solution. All it did was change the ante. Now they had to use 2,000-pound charges to blow the bridges.[76]

VLAP representatives were kept busy. In 1967 alone, VLAP projects included "a radar beacon for the A-6 aircraft, a field-portable filling station for drinking water, strobe lights and filters, a passive S-band radar tracker, a portable low-frequency radio set, a directional listening device, and a lead-computing gun sight for aircraft; evaluation of wet-suit material, life preservers, and flak suppression devices; and a feasibility determination of the use of a fuel-air explosive (FAE) warhead as a minefield-clearing device."[77]

74 S-275, Arnold interview, 8.
75 Robert G. S. "Bud" Sewell, "Have I Got a Story for You! Vietnam Laboratory Assistance Program," VP 07-032, Technical Library presentation, Video Projects, China Lake, 2007.
76 Ibid. When the author was in Vietnam in 1966, he occasionally crossed the Nam-O bridge over the Song Cu De River on Highway 1, just north of Da Nang. The Marine infantry unit guarding the bridge had a Marine assigned to sit on the west side of the bridge with an M-14 and shoot anything suspicious floating downriver toward the structure.
77 *Major Accomplishments*, 167–168.

Robert G. S. "Bud" Sewell at his desk, 1976. Photo courtesy of Larry and Patti Cosner

Often, the solution to a problem didn't require an expert in R&D but rather someone who could find the right item in a catalog—as Bob Forster had done with the mud plugs for the M-16. Sewell recalled ordering items for the Marines from a Herter's catalog. "Newt Ward always used to question why we sent engineers and scientists there," Sewell commented. "It appeared at times that it would have been better if we'd sent a supply clerk because that's what most of the problems needed."

One fundamental problem with VLAP, in Sewell's view, was that it used civilians instead of military personnel. The Marines had an almost reflexive mistrust of civilians trying to solve their problems, a mistrust that Sewell said was exacerbated by the fact that some civilians in Vietnam were there primarily for the bonus money paid by civilian contractors and for the very generous Post Exchange (PX) privileges. He remembered:

> Entering as a civilian being assigned to headquarters, it was a bad show. It took at least two months for me to convince the Marines that I was not one more God-damned civilian. And, after being there for a while I had the same feeling towards the rest of the civilians that the Marines had.

A factor in his acceptance by the Marines, Sewell said, was that he took their side when he was called back to the U.S., and Director of Navy Laboratories Dr. Gerald W. Johnson came to China Lake and chewed him out. "I went with the Marines and against the Navy. I know they are part of the naval service but there is still a difference,"said Sewell. Johnson threatened to prevent him from returning to Vietnam, and Sewell said that was fine with him, that he didn't want to go back anyway. He was soon on his way back.

A second problem with VLAP was the bureaucracy. When a problem was identified that seemed suitable for a laboratory quick fix, according to Sewell:

> . . . the approved method was that the problem was proposed; a preliminary study done; then it was to be sent through channels, we'll say through III MAF; it was to be completely staffed through III MAF, and then forwarded to NRDU-V for its endorsement, and then directed back to the laboratory. The Marines did not appreciate having to send things down for a chop to NRDU-V. I must admit I violated it. I went directly to the lab, bypassing NRDU-V, and the lab responded and we got complaints back through VLAP channels, but we got there.

Yet another problem was the organizational location of VLAP. Since it was under DNL, it was not tied to the systems commands, which had the money and power to implement positive solutions on a large scale.

According to Sewell, the only two items to make it into the official Navy inventory (out of some 500 VLAP projects) were a loading lever assist that allowed the Vietnamese to cock the .50-caliber machine guns on the riverine patrol boats and the lightweight 20-mm gun pod for the OV-10 light-attack/observation aircraft.

The assist device had been introduced into VLAP by the Naval Ordnance Systems Command and funded entirely with NAVORD money. The OV-10 gun pod had started in VLAP, but only six of the required 26 pods were produced through VLAP. When the order for the additional 20 came up to the Naval Air Systems Command, the order was almost killed before Sewell talked with the OV-10 gun program manager, Frank Marquardt, explained the need for the program, and secured funding.

"The VLAP effort suffered continually from not being tied to the Systems Command," said Sewell.

When Sewell returned from his first tour, it was still early in the war. The U.S. military would continue to fight for another 5 years. However, low morale was already becoming a factor among the troops on the ground. Frustration was also widespread among the officer corps in both the air and ground war because of what was seen as meddling and micromanagement of the war by politicians and by military leaders far removed from the day-to-day realities of a new kind of war.

VLAP would continue through 1972, with varying degrees of success and failure. (NOTS was the West Coast coordinator until 1970, when overall coordination was assigned to NOL White Oak.) VLAP was followed by the Navy Science Assistance Program (NSAP) in 1972.[78]

In an interview given in 1975, a few months after Marines evacuated the U.S. embassy in Saigon and the Vietcong raised their flag over the Presidential palace, Sewell observed:

> Unfortunately, this was not a war that could be won with R&D. It was not even a war that could be won. Many of the problems which became R&D problems were not R&D problems. They were problems imposed by restrictions that had been placed on the operating men to the point that they could not use the tactics which they knew how to use to solve the problem.
>
> . . . [VLAP] was very much . . . a token program. We did get some good out of it and the amazing thing, in spite of all the errors and the management, organization and everything else, we did come out with a better record than any other R&D group in Vietnam. Which doesn't really speak well for the R&D groups in Vietnam.
>
> . . . I have the feeling that in our operation in Vietnam, the VLAP effort was the best, and yet it wasn't good. . . . as far as actual R&D saving the day, winning the war with twentieth-century technology, we really didn't do it.[79]

Whatever the overall benefit of VLAP, the program followed a model, tracing back to the Signal Corps' NEID and NOTS' ATAR introduction team, of bringing technical expertise directly into the combat theater to provide faster and more efficient service to the people who were actually fighting the war. This model would be revived in the 1990s, as the U.S. went to war in the Middle East, and it continues, with China Lake participation, to this day.

RAP and BOMROC

Efforts to help the naval forces on the ground in Vietnam—initially SEALs and UDT, and later tens of thousands of Marines—extended to the seagoing Navy.

78 NSAP has since evolved into the Office of Naval Research Global program, which maintains a staff of science advisors and associate directors (primarily from the Navy laboratories) at various commands throughout the world.

79 S-105, Sewell interview, 10–11, 18.

Two programs to increase the range of the Fleet's guns, the Rocket-Assisted Projectile (RAP) and the Bombardment Rocket (BOMROC) were begun in 1962 and 1963, respectively. Like many other weapon-development programs of the 1960s, these two acquired increased urgency as the minor conflict in Southeast Asia developed into a major one.

The RAP project sought to remedy a problem that the Navy had brought on itself. During WWII and Korea, the Navy operated *Iowa*-class battleships whose mighty 16-inch guns could fire shells weighing nearly 1½ tons more than 20 miles, a formidable weapon system for coastal fire missions. However, the battleships were decommissioned after the Korean War. That left the Navy with destroyers whose 5-inch guns could fire 55-pound projectiles a relatively modest 9 miles.

RAP, as the name implies, was designed to add a booster-type rocket motor to a 5-inch gun projectile and thus increase the effective range of the gun by a third to a half. The extended range allowed U.S. destroyers to engage targets further inland (supply lines, fuel depots, SAM sites, and fire-support of U.S. and RVN land operations) while staying out of range of enemy shore batteries. RAP was produced as both a 38- and a 54-caliber round.[80]

BuWeps assigned NOTS the role of System Integrator for RAP, and the Propulsion Development Department got the job. Crill Maples was the first NOTS Project Manager. Later the project was taken over by Irvin F. Witcosky (who in 1969 would receive the Michelson Laboratories Award making him an Ordnance Fellow for development and Fleet introduction of RAP).[81]

Working with the Naval Weapons Laboratory, Dahlgren, which made the blast-fragmentation warhead, and NOL White Oak, which developed the proximity fuze, NOTS engineers developed the rocket motor and igniter and integrated the RAP components. Howard Payne was in charge of developing the RAP motor, which used dense fluorocarbon-based propellants. William R. "Duke" Haseltine, senior scientist in the Research Department, assisted with analysis and flight-characteristics-determination for the projectile.

Test Department personnel—including Joe Rice (head of the Test Design and Evaluation Branch), Dick Murphy, Cliff Reinholt, Chuck Woods, and Lynn Lyon—assisted with technical issues related to fire control and gun-mount modifications. Other contributors to the management and execution of

80 Caliber in this context is a measure of the barrel length for which a round is designed. The number is a multiple of the projectile's diameter. Thus a 5"/54-caliber round is fired from a 270 (5 x 54)-inch-long barrel.

81 *Rocketeer*, 13 March 1964, 5; 8 Dec 1967, 1; and 3 Oct 1969, 3.

the project were Dr. George Rice, Charlie Rodgers and Bob Dow (propellant), Ken Thorsted and Tom Preston (rocket motor), and Bob Dillinger and Louis Renner (engineering design). Bill Thielbahr in the Propulsion Development Department conducted thermal investigations for the project.

Two NOTS innovations were key to RAP's success. One was a high-density, high-impulse fluorocarbon propellant employing Teflon and Viton as binders. The propellant proved tough enough to withstand 18,000 *g*s of acceleration from the gun firing and 12,000 *g*s of radial acceleration (250 revolutions per second) from the rifling in the gun barrel. The other was the igniter: the gun's high-pressure chamber fired a percussion primer that ignited a 23-second pyrotechnic delay column, which in turn actuated the rocket motor for a 2-second burn.

The RAP rounds were tested in 5-inch guns on the NOTS Gun Target Range in the Mojave B Range area and at the West Cove Range on San Clemente Island. In the 5"/38 version, the projectile increased the gun's range by 58 percent compared to standard projectiles. The range increase with the 5"/54 RAP round was 30 percent. Each round carried a high-explosive, brittle-steel warhead, and proximity fuzing was backed-up by a point-detonation capability.[82]

Full-rate production began in 1967 and, ironically, first Fleet use was from the newly recommissioned battleship USS *New Jersey* (BB-62) in 1968—which, in addition to her 20 5"/38 guns carried nine 16"/50 guns.[83]

BOMROC began in 1963 after NOTS studies indicated that the use of dual-thrust propulsion and new warhead materials could extend both the range and the warhead effectiveness of Spin-Stabilized Bombardment Rockets (SSBRs). The state of the art at the time was a range of about 10,000 yards for a 30-pound proximity-fuzed SSBR.[84]

Bombardment rockets were not new to the Navy, nor to NOTS. Many Marine and Army landings in the Pacific during WWII had been preceded by devastating barrages of rockets launched from converted LSTs and LCTs (Navy amphibious assault vehicles). What the rockets lacked in accuracy, they

82 *NWC Tech History 1967, Part 1*, 1-26.

83 During her service in Vietnam, *New Jersey* would fire almost 6,000 16-inch shells (compared with only 771 fired between her commissioning in 1943 and her first decommissioning in 1948) and nearly 15,000 5-inch shells at enemy targets in the coastal region of Vietnam, both north and south of the Demilitarized Zone. Norman Polmar, *The Naval Institute Guide to the Ships and Aircraft of the US Fleet*. 2001, Naval Institute Press, 129.

84 *Major Accomplishments*, 9.

made up for in quantity; a single converted landing craft might fire as many as 5,000 rockets in support of a landing operation. The first 5-inch spin-stabilized rockets (often called "spinners") were developed during the war by Caltech and tested at NOTS before seeing action. They were fired from the IFSs (Inshore Fire Support Ships) and from LSMRs (Landing Ships, Medium (Rocket)). The latter used automatic launcher/feeder systems and could fire a withering barrage of 380 rockets per minute. SSBRs were also used in the Korean War, when the NOTS-developed Mk 7 General Purpose Spinner Rocket (GPSR) was used during the landing at Incheon in September 1950.[85]

Like RAP, BOMROC was carried out in partnership with Dahlgren (final range firing and safety testing) and White Oak (fuzing), and, again as with RAP, BuWeps named NOTS the System Integrator. The project was run from the Propulsion Development Department, where Earl Love was the team leader. Dr. Ray Morrow, Dr. George Rice, and Elmo Julian of the Propellants Division developed the new propellant used in the weapon. Over in Code 40, the warhead was developed by Paul Cordle, Ed O'Connor, Larry Boyer, and Fred Brandt, while Billy Dotson and Fred Scheberies from the Test Department oversaw modifications of, respectively, the fire-control system and the launcher.[86]

With the development of a more powerful (and more reliable) rocket motor, NOTS was able to increase the range of BOMROC to 18,000 yards. The momentum of the project increased with growing military involvement in Vietnam; by 1968 BOMROC was in limited production as a result of an accelerated program in support of the needs in Southeast Asia.[87]

A problem common to RAP and BOMROC resulted from the high rate of spin while the rocket motors were burning. The spin caused a whirlpool effect in which the burning propellant bored a hole in the forward wall of the case. Improper burning was causing problems ranging from bad ballistics to ruptured motor cases. A private contractor was hired to X-ray the burning motors while they were spinning at 300 revolutions per second on a specially constructed static firing stand. The X-rays revealed that a gas vortex caused by the spinning was drilling through the propellant.

The owner of the X-ray equipment was offered a job at China Lake, and he declined. However, his operator, Donald Jon Rogerson, accepted a position with the base. According to Ray Miller, who was head of Code 45's Development

85 *Rocketeer*, 24 Sept 1965, 1.
86 *Rocketeer*, 1 Nov 1963, 1, 4.
87 NWC TS 67-259, *Naval Weapons Center Silver Anniversary*, Publishing Division, Technical Information Department, Oct 1968, 11.

Engineering Branch at that period, "Jon Rogerson stayed on and developed that capability for the Skytop people, many times improved over that original system."[88]

Once engineers understood the nature of the gas vortex problem, they could devise a solution. Raymond W. Feist, David W. Carpenter, Ron Vetter, Bill Thielbahr, Jack Yeakey, Lonnie Pauls, and Danny Meraz, all from the Propulsion Development Department, developed an ingenious diffuser system that drained burned propellant gasses (at temperatures of 6,000°F) to two centrally located nozzles. "The drain system, or diffuser, is pretty well destroyed after the sustainer propellant has finished burning," Carpenter reported, "but by that time it has done its job."[89]

Another problem common to both RAP and BOMROC was managerial, not technical. BuWeps assigned NOTS the System Integrator role but did not give the Station Deputy Assistant Program Manager (DAPM) status, as it had with the Shrike and Free Fall Weapons programs.[90]

In 1968 *News and Views* discussed the experience of Earl Love, head of Code 45's Program Management and Integration Group, which had been established in February 1965 in part to "plan, coordinate, and direct all research and development phases" of the two projects.

The newsletter reported that:

> Without clear authority for controlling funds used by outside groups, for determining "who does what" and for making daily management decisions, misunderstanding and conflicts have arisen. Lacking a clear-cut notion of what authority is held, Love's project people have had to use persuasion to achieve cooperation by other activities that were tasked and funded directly by [the Naval Ordnance Systems Command].
>
> Love also made the case for extending DAPM authority to the laboratory through pilot production and Fleet introduction.

Quoting Love directly, the article continued:

> "When the hardware enters first production runs, virtually as many new problems arise as did during development. Fleet introduction brings its own set of problems. When new activities take over a system, they often lack the concern and personal interest of the development. They also lack

88 S-262, Miller interview, 34.

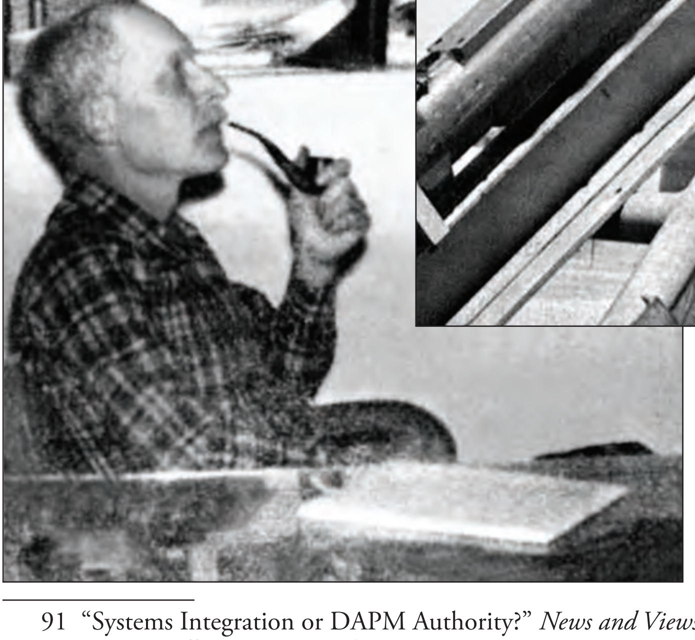
89 *Rocketeer*, 24 Sept 1965, 1, 4. Ray Feist was a successful manager of rocket-motor propulsion programs at China Lake. The Raymond W. Feist Solid Propulsion Building was named in honor of his contributions to the Navy.

90 *NOTS Command History* 1965, 10

the background to modify the item when problems affecting performance inevitably arise."[91]

Despite technical and management problems, RAP and BOMROC were used extensively in combat. According to Miller, "Ultimately, tens of thousands of each of these were introduced to the Fleet and used in Vietnam."[92]

The Station's experience in spin-stabilized rockets, rocket motors, rocket propellants, rocket test and evaluation, aerodynamics and ballistics, and warheads had paid off once again. Nearly all the technical departments contributed to the projects, covering the full spectrum of NOTS expertise, from the cerebral trajectory calculations of Duke Haseltine at his desk in the Research Department to the hands-on loading of test rounds on G-2 Range



Dr. Duke Haseltine pondering BOMROC trajectory at his desk in Michelson Lab and Clyde Hienzig loading the weapon into a tube on G Range.

91 "Systems Integration or DAPM Authority?" *News and Views,* May 1968.
92 S-262, Miller interview, 34.

by Experimental Ordnance Equipment Mechanic Clyde Hienzig of the Test Department.

Nonlethal Weapons

By 1965, the first full year of U.S. combat in Vietnam, it was becoming clear that Vietnam was not warfare as usual and that traditional methods of waging war would not—or could not, for political reasons—carry the day. Beginning late in 1965, the Weapons Planning Group conducted an investigation into nonlethal warfare. In March 1966, Bob Rowntree produced a memo titled "Non-Lethal Warfare; final report (hopefully) on." With characteristic wit, Rowntree illuminated some of the problems involved in a more humane approach to warfare:

> A consideration of non-lethal warfare reveals that it is an influencing process. (Actually, of course, *all* warfare is an influencing process.)[93]

Rowntree's report examined issues of the effectiveness and lethality of supposedly nonlethal weapons:

> The question of "how non-lethal must a non-lethal weapon be" is clearly also a very difficult one. If it is non-lethal to a healthy, 6-ft., 200-lb., 25 year-old, must it also be non-lethal to a 75-year-old cardiac case? A 3-day-old baby? An 8-1/2 months pregnant woman? Do we worry about the munition carrier as well as the primary agent? (Must the air-delivered incapacitating bomblet be non-lethal if it hits someone on the way down? How about the bomblet dispenser?) How about secondary effects? (We douse a man with CS [tear gas]; he can't see and so falls down some steps and breaks his neck.)

To those questions, as with so many surrounding the war in Vietnam, there were no simple answers.

Rowntree also recognized that military decisions in the Vietnam War were made with a keen awareness of their political consequences. No-fire zones and bombing restrictions and inconsistent rules of engagement seemed often designed more to make the war palatable to TV audiences back home and in foreign capitals rather than to hasten victory. He wrote that:

> . . . the requirement for non-lethality originates from political reasons and from organizations like the State Department. Almost certainly the only standard the State Department could supply for "how non-lethally should we be able to control riots?" would be "such that, we have no significant repercussions afterward."

93 Memo 1201A/RFR:pfd, Bob Rowntree to Frank Knemeyer, 11 March 1966. The succeeding Rowntree quotes are also from this memo.


Dr. Bob Rowntree.

Fear of repercussions—from foreign governments, from war protestors, from the electorate—would be one of the primary forces shaping U.S. prosecution of the Vietnam War until the fall of Saigon in 1975. But perhaps worse than fear of repercussions was a lack of purpose and of clear objectives.

In a 1975 interview, McLean said:

> The first thing that has to happen in any technical organization is for its management to decide where they are going to work and what it is they want to accomplish. That is 'A'-number-one priority. Till you get that, you can't go anywhere. . . . the problem of Vietnam was not one that the laboratory could do much about because it was not a technical problem. Nobody decided what our objectives in Vietnam were before we started. We wouldn't have known if we had won or not because we didn't know what it was that we wanted to accomplish.[94]

94 S-97, McLean interview, 30.

7

Tightening the Reins

We tend as a nation to meet any new situation by reorganizing; and a wonderful method it can be for creating the illusion of progress while producing confusion, inefficiency, and demoralization.

— Charlton Ogburn, Jr., writing of his days with Merrill's Marauders in 1943[1]

After the Gulf of Tonkin Resolution, the Vietnam War—in those days referred to as "conflict," "hostilities," "military involvement," and similar euphemisms—injected money and vitality into the government laboratories. The presence of an enemy brought to the laboratory employees a heightened feeling of patriotism as well as the sense that their jobs were worth doing.

The war also presented specific technical challenges to stimulate the scientific and engineering workforce. With mushrooming defense budgets—between 1964 and 1968, the DOD budget increased from $52.5 billion to $80.3 billion, and NOTS/NWC's from $90 million to $158 million—anyone with a worthwhile idea had a good chance of finding the money to pursue it. This was particularly true at NOTS where the measure of "worthwhile" was often the enthusiasm of the proponent.[2]

The war also brought pressure on the Navy to remedy longstanding conflicts within the research-and-development organizations and between those organizations and the rest of Navy. This pressure increased at a time when there was also a growing tendency to centralize authority within the Department of Defense and, within the Navy, to reduce the traditional autonomy of individual commands.

These trends had their genesis in the massive military reorganization of 1947, when the Office of Secretary of Defense was established to head the

1 Charlton Ogburn, Jr., "Merrill's Marauders," *Harper's Magazine*, Jan 1957, 32–33.
2 Office of Management and Budget, Table 4.1, Outlays by Agency: 1962 to 2016, *http://www.whitehouse.gov/omb/budget/Historicals/*, accessed 30 March 2011. *NOTS Tech History 1963*, 1–5; *NWC Tech History 1967*, Part 1, 1–40.

new National Military Establishment (renamed the Department of Defense in 1949).

Centralization was already manifest in the late 1950s when Captain Edward A. "Count" Ruckner (Assistant Chief for R&D, BuOrd) wrote to NOTS Commander Captain Hollister, shortly after the announcement of the BuOrd-BuAer merger:

> Of greatest concern to me is the increasing centralization all the way through the setup from DOD down. This is evidenced by the increased load of justification and rejustification and tighter and tighter financial controls. We have been forced into even tighter control than before in the new Bureau of [Naval] Weapons.[3]

One authoritative study of Navy R&D commented that:

> The trend toward centralized control of the material organization rapidly accelerated in the 1960s. Contributing to the momentum for centralization were a new round of cognizance disputes, the designation of a second special designated project [the Surface Missiles Systems Project Office, with the first the Special Projects Office, for Polaris], and a growing popularity of the use of program/project management tools.[4]

A key part of that statement is "program/project management tools." With the proliferation of new technologies since WWII, the products of American industry—consumer goods, military weapons, public infrastructure—were becoming ever more complicated.

Since the capabilities of the human mind had not expanded appreciably during the same period, new techniques and tools were needed to maintain control of the design, manufacturing, and distribution processes and to track and control the acquisition and expenditure of necessary resources—material, labor, and money.

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3 Memo EAR:mw, Capt. E. A. Ruckner to Capt. W. W. Hollister, 18 Sept 1959, 1. The trend toward centralization of authority in the Navy is recounted in "U.S. Navy Research and Development Since World War II," by David K. Allison, *Military Enterprise and Technological Change: Perspectives on the American Experience*, Merritt Roe Smith, ed., MIT, 1985, 299–302.

4 Booz, Allen & Hamilton, *Review of Navy R&D Management 1946–1973*, Department of the Navy, 1 June 1976, 107. The evolution of the Navy's and DOD's administrative and management structure is covered exhaustively in this 493-page document. That evolution is also well summarized in Robert V. Gates, *Strategic Management of Navy R&D Laboratories; An Application of Complexity Theory*, PhD dissertation, Virginia Polytechnic Institute and State University, 18 Nov 2003, *http://scholar.lib.vt.edu/theses/available/etd-12022003-195802/unrestricted/GatesDiss112003C.pdf*, accessed July 2008. Gates is the former Technical Director of the Naval Surface Warfare Center, Indian Head Division.

An early and successful example of these tools was the Program Evaluation and Review Technique (PERT) system, developed to help manage the enormously complex Polaris system development. PERT allowed a user to visualize and analyze the various tasks in a project and the time needed to complete them. It was a true systems management breakthrough because it correlated expenditures with technical progress, thus offering more control over cost and schedule.

PERT later became mandatory in smaller DOD programs and was first used at China Lake in 1961 for the Shrike program.[5]

Beginning in 1965, PERT was replaced at China Lake by a more complex and capable tool called the Mark III Management System. Leroy L. Doig Jr., who as technical plans coordinator for Code 40, was responsible for implementing the system, noted in 1967 that "experience at NWC to date indicates that while the Mark III system is not a panacea for all management ills, it can be an extremely useful and powerful tool when used intelligently."[6]

PERT, Mark III, the Work Breakdown Structure, and other "program/ project management tools" had strong supporters at NOTS. One was Frank Knemeyer, who headed Code 40 (NOTS' largest department) from 1960 to 1974 with the philosophy that:

> Engineers do not appreciate a management system until they have worked with it and they find out how much it relieves them of certain kinds of management and administrative things in their operation. It keeps them organized. And a lot of technical people don't appreciate that they need to be organized. They just go off and do what they want, and then pretty soon they lose control of it.[7]

Knemeyer's disciplined attitude toward process also was also behind the traditional China Lake drive to control system documentation, which made possible successful second-sourcing, as in Shrike.

As management tools proliferated, there was a growing sense among the Station's leaders that they were spending more time working on the management tools than on the project. Doig noted that:

> In some instances at least, significantly more effort was expended in the formulation of plans utilizing Mark III than had been expected, Evidence

5 *NOTS Tech History 1961*, 10. While government programs are seldom cited as examples of good management practices, Polaris is perhaps the most famous exception.
6 Leroy L. Doig, Jr., "Mark III Management System," *News and Views,* Nov 1967, 7.
7 S-200, Knemeyer interview, 108. The Weapons Development Department grew from 350 to nearly 500 people during Knemeyer's tenure as department head.

> available points to deficiencies in content and/or logic of the original planning data and the consequent necessity for revision as the underlying reasons for the greater expenditure of effort.[8]

In the 1960s computers and high-speed communication systems were becoming ubiquitous, and as their capabilities expanded exponentially, they facilitated the trend toward centralization. Levels of detail that would never have been asked for (although they might have been desired) by NOTS' sponsors in earlier days could now be assembled readily—so why not do so?

This trend applied not only to tracking technical progress but also to monitoring financial data. Typed reports delivered by first-class mail were no longer detailed or timely enough for managers "back East." As in battlefield intelligence, the goal of the information recipients became to obtain more information and to get it in as close to real time as possible.

Valid arguments were made both for and against this increased scrutiny. Access by Washington sponsors to extremely detailed project information from the laboratories provided the people who controlled the purse strings with an accurate, up-to-date picture of how funds were being spent and what progress was being made.

On the other hand, the system begged for micromanagement. It allowed distant military officers and "bean counters" (as bureaucrats were routinely called) to second-guess technical and management decisions made by the experts at the laboratories.

There were, of course, ways around this scrutiny. Knemeyer's Weapons Development Department simply raised its cost-center overhead charges to bring in about $1 million per year, an amount the department used to finance its in-house projects and investigations. Knemeyer recalled:

> That gave me the flexibility to do things that we cannot do today. For instance, the HARM missile—I initiated it in my department and at that time I spent over $600,000 of overhead money just getting that thing started. You can't do that today."[9]

He and other managers would borrow or redirect funds from one program to another to match the immediate needs of system developers with the more measured pace of off-Station funding. At the end of the day, said Knemeyer, "everyone got their money's worth."[10]

8 Doig, "Mark III Management System," 6.
9 Knemeyer review comments, 16 Aug 2011; S-117, Knemeyer interview, 11.
10 Knemeyer telephone conversation, 26 Aug 2011.

Organizational Realignment

Robert Strange McNamara was an intelligent and successful executive who in 1962 left his position as the first non-Ford president of Ford Motor Co. to become Secretary of Defense. McNamara was a strong believer in centralization and maximally efficient management. As he wrote in his autobiography:

> Most of my predecessors. . . ended up deferring to the old-line bureaucrats and to generals and admirals on matters of budgeting, procurement, strategy, and sometimes even policy—without understanding the issues—because the military establishment had grown so complex. . . . My team and I were determined to guide the department in such a way as to achieve the objective the president had set: security for the nation at the lowest possible cost.[11]

Some in the old-school Navy felt quite the opposite. "We believe in command, not staff," Chief of Naval Operations Admiral Arleigh Burke wrote to an associate in 1958, continuing that:

> We believe we have "real" things to do. The Navy believes in putting a man in a position with a job to do, and let him do it—give him hell if he does not perform—but be a man in his own name. We decentralize and capitalize on the capabilities of our individual people rather than centralize and make automatons of them. This builds that essential pride of service and sense of

Secretary of Defense Robert S. McNamara at work at his desk in the Pentagon, March 17, 1961. Photo by Frank Hall, U.S. Army

11 Robert S. McNamara with Brian VanDeMark, *In Retrospect: The Tragedy and Lessons of Vietnam*, New York, Random House, 1995, 22–23.

> accomplishment. If it results in a certain amount of cockiness, I am for it. But this is the direction in which we should move.

On the issue of centralization, the old school lost to the new school, and Burke retired from his third term as CNO in 1961, seven months after McNamara took office.[12]

Inefficiency was anathema to McNamara and his followers, and that posed a problem for the McLean school of management. McLean believed that a certain amount of inefficiency was good, was even necessary, to maximize the creative forces of the laboratory's scientific and technical workforce. In his often-reproduced paper sometimes called "Nine Ways To Ruin a Laboratory," included here as Appendix B, he writes that the number-one way to curtail creativity is "Coordinate work carefully to avoid duplication."[13]

McLean, like Ruckner, saw the dangers of centralization and its handmaiden, efficiency, as a real threat to the creative design process. In an address to the American Ordnance Association in May 1960 he pleaded with the ordnance engineers and the industrialists to "find some way to rescue the design of our military equipment from the morass of integration, coordination, centralization, and detailed specifications to which it is sinking."[14]

One example of inefficiency that McNamara eschewed was duplication of effort and overlap of mission between branches of the armed services. This led to the concept of "lead service," and, within the laboratories, of "lead laboratory." Tom Amlie believed that the end of duplication meant the end of competition. With Amlie-esque enthusiasm, he explained:

> McNamara was at fault….the OSD has this knee-jerk reaction, lead service and so forth. As soon as whoever's doing it, whichever service is doing it has the franchise, they don't have to excel. There's nobody breathing on their shoulder, or running behind them, and I think they should be allowed, I think they should be forced to compete.[15]

Rigid adherence to form, clearly proscribed roles for each organizational element (and individual), and lack of competition were not the China Lake way of doing business. The Station's "loose-reins" style always riled the more

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12 David Alan Rosenberg, *Arleigh Burke: The Last CNO*, Naval Historical Center Biographies in Naval History, *http://www.history.navy.mil/bios/burke_rosen2.htm# fn36http:// www.history.navy.mil/bios/burke_rosen2.htm#fn36*, accessed 17 March 2010.

13 "Management and the Creative Scientist," Sept 1959, RM-24, *Collected Speeches of McLean*, 103. NOTS work on the Sidewinder missile in the 1950s was painted by the Station's critics as duplicative of guided missile work that was under the purview of other laboratories.

14 Ibid., 146.

15 S-150, Amlie interview, 1983, 20.

formalized managers in Washington—despite the fact that products like Sidewinder, Walleye, Shrike, and numerous other successes would never have seen the light of day in an "efficient" organization, one in which every penny was spent precisely as the Washington managers had ordered.

The quest for increased efficiency in an organization frequently leads to reorganization. From the late 1950s through the 1960s the very process of reorganizing became a tool for centralizing authority at the highest levels of DOD (and, in a mirror effect, centralizing authority within the services themselves).

A key step in the process was the 1958 creation of the Director of Defense Research and Engineering (DDR&E), who was assigned virtually complete control over DOD research and development programs. Looking back on the legislative battles that led to the Defense Reorganization Act of 1958, President Eisenhower wrote several years later that:

> I insisted that we should reorganize Defense research and development to strengthen the Defense Secretary's control over it. To this end, I recommended the establishment of a new position of Director of Defense Research and Engineering at a salary equal to those of the service Secretaries. . . . This new official [would] supervise all research and engineering activities in the Department and direct all research and development requiring centralized management. He would thus minimize duplication and rivalry among the three services in their work in science and engineering.[16]

Over the next decade, the various DDR&Es—Herbert F. York, 1958–1961; Harold Brown (later President Carter's Secretary of Defense), 1961–1965; and John S. Foster, Jr., 1965–1973—were the instigators of many organizational studies and reviews, as well as the arbiters of which recommendations and plans would be implemented and which would not.

Two areas of the Navy ripe for organizational readjustment were the service's so-called "bilinear structure" and its bureau system. Since the 1840s the material procurement side of the Navy (the side that dealt with obtaining the wherewithal of naval combat, the ships, guns, equipment, medicine, food, etc.) had been separate from the operational side (the warfighters, the users of the material procured). The operational side reported to the Navy's highest-ranking officer, the Chief of Naval Operations (CNO), who in turn reported to

16 Dwight D. Eisenhower, *The White House Years. Waging Peace 1956–1961*, Doubleday & Co., Inc., Garden City, NY, 1965, 248. He also noted, "I have always believed that a nation's defense would be most efficiently conducted by a single administrative service, comprising elements of land, sea, and air. . . . Successful defense cannot be conducted under a debating society."

the Secretary of the Navy. The material side—which also contained the majority of the Navy's civilian employees—reported to the Secretary through the civilian Under Secretary and Assistant Secretary of the Navy. Thus the providers of the Navy's material needs were not in the chain of command of the person who commanded the operational forces. This way of doing business was known as the bilinear structure. The Navy laboratories were on the material side of the Navy, under the Bureaus of Aeronautics, Ordnance, and Ships. NOTS operated, since its inception, under BuOrd.

In the days when a cannon factory cast a cannon and a shipyard built a ship, the bureau system had worked reasonably well. As weapons and platforms became more integrated, however, the lines between bureau responsibilities grew fuzzy. Disputes between the bureaus grew more frequent—for example, was the fire-control system for an air-launched guided missile the responsibility of the weapon designer (BuOrd) or was it part of the launch platform (under the purview of BuAer)?

The Navy hierarchy realized that a systems approach to development was more appropriate for new, complex weaponry. The Booz, Allen & Hamilton study of Navy management reported that:

> The problems were particularly acute in aircraft and guided missile development where allowances for weight, space, and aerodynamic drag required close control and where incompatibilities among subsystems could lead to undesirable compromises in performance or time-consuming redesign with attendant cost overruns.

A bureau review board ordered by CNO Burke in 1956 considered consolidation of BuAer and BuOrd, but finally suggested instead a "lead bureau" concept. One bureau would have overall responsibility for direction of a weapons system project that spanned multiple bureaus.[17]

A 1959 study led by Undersecretary of the Navy William Franke recommended continuance of the Navy's bilinear structure but, like Burke's 1956 review, recommended the consolidation of BuAer and BuOrd into the Bureau of Naval Weapons (BuWeps). The Franke Board recommendation was implemented, and in December 1959 NOTS became part of the new Bureau of Naval Weapons.

Consolidation of the two bureaus generated much apprehension at NOTS. Size, for one thing, was an issue. A December 1959 *New York Times* article titled "Navy's Weapon Chief, Paul David Stroop" began:

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17 Booz, Allen, *Review of Navy R&D Management 1946–1973*. 346–347.

> Rear Admiral Paul David Stroop's new job, in his own words, is to merge the Navy's Bureaus of Ordnance and Aeronautics and "keep the final products from smelling too much like an elephant." The elephant in this case is the Bureau of Aeronautics, with an annual expenditure of more than $3,000,000,000.[18]

Even more fundamental than the disparity in size were the two bureaus' divergent philosophies regarding the role of the laboratories. As the *Times* article put it, "The Bureau of Ordnance has developed its weapons in its own installation, while the Aeronautics Bureau, along with the Air Force, frequently uses private manufacturers."[19]

As Captain John Hardy explained:

> BuAer looked mainly to industry for their research and development because this is where their big research and development was, mainly in airframes. BuOrd was looking toward a complete weapon system as such, everything you required along with the guided missile or whatever it might be, the fire control, the launcher, the sway braces, the whole works that went with this right down to the pilot's control of the thing. So BuOrd looked mainly to laboratories for this development whereas BuAer was looking towards industry. . . .[BuOrd] essentially said, "We need in-house laboratories to run this whole gamut." BuAer said, "We should go essentially out-of-house to industry to do all this."[20]

Beyond the philosophical arguments as to who should control which portions of the acquisition process, very large amounts of money were at stake. Industry bridled at having to shape its actions to accord with the views of the vastly smaller laboratories. Stories are legion of "gold plating" by industrial weapons developers; the $600 toilet seat would become a rallying point for acquisition reform in the 1970s, and the term "beltway bandits" would enter the national lexicon. The conflict regarding the proper roles of contractors and government laboratories in acquiring military weapons and platforms has never been resolved.

On the plus side of the bureau consolidation for NOTS was the fact that BuWeps' new leader, Rear Admiral Stroop, was a former NOTS commander. As a captain he had been assigned to NOTS in 1952 because, as he described it:

> I'd introduced the Norden bomb sight into the Fleet, and I'd had some spectacular luck in bombing . . . they wanted an officer who was an aviator

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18 "Navy's Weapon Chief, Paul David Stroop," *New York Times*, 1 Dec 1959. McLean referred to the consolidation with a similar animal metaphor: "It's a case of where you're trying to make horse and rabbit stew with one horse and one rabbit." DNA Oral History Collection interview BA-1-75, Dr. William B. McLean, 1975, 7.

19 Ibid., *New York Times.*

20 S-34, Hardy interview, 18–19.

> because it was concerned with aviation. They wanted an officer who had been associated with ordnance because it was aviation ordnance, and I had had both experiences.[21]

This combination of expertise was also a factor in his selection to head the new bureau. Although he'd served only 10 months at NOTS before he was selected for rear admiral and reassigned, Stroop was a firm NOTS supporter. He later wrote:

> It was a place where the best the Navy had in scientific talent was gathered together, and it was a place where very competent operating naval aviators were ordered. And you brought these two skills together, and as a result you developed weapons that were practical, simple, and useful. It was probably one of the finest scientific-technical arrangements the Navy's ever had.[22]

Vice Admiral Paul D. Stroop (a rear admiral when he became the first head of the Bureau of Naval Weapons).

Still, China Lakers were concerned about how the consolidation would affect the Station's business.

In anticipation of the changeover, Executive Officer Captain Harry B. Hahn and Associate Technical Director Hack Wilson spent a week in Washington in October 1959 on an assignment:

> . . . to familiarize themselves with the current status

21 Reminiscences of Vice Adm. Paul D. Stroop, USN (Ret.), U.S. Naval Institute, Annapolis, MD, 1970, 253, 256.
22 S-191, Vice Adm. Paul D. Stroop, USN (Ret.), interview, 11 June 1991, 3.

> of the merger of BuAer and BuOrd into the Bureau of Naval Weapons and to discuss with BuOrd personnel, and particularly with NOTS "alumni," the feasibility of giving a presentation which would explain NOTS . . .especially to the BuAer personnel who are not familiar with the mission and operation of the Station.

The consensus of those interviewed by Wilson and Hahn was that any such presentation should "stress the economy of using the Government's in-house capability."[23]

When McNamara took over, he posed 120 questions on ways to improve strengthen the in-house laboratory system. Question 97 was "Advise me ways in which to improve the operations of the in-house laboratories." Eugene G. Fubini (later Assistant Secretary of Defense and Deputy DDR&E) headed a task force to answer this question in 1961. The Fubini Report (also called Task 97) noted low morale and low salaries at the laboratories, as well as an inability to obtain the necessary military-construction funds for laboratories and equipment.

The Task 97 force visited many of the laboratories within the Department of Defense. Collectively, the labs were large. E. M. Glass, executive director of the Task 97 Action Group, stated that the approximately 140 laboratories had a replacement value of $8 billion, employed 30,000 professionals, and had an annual operating budget of $1.5 billion.[24]

The Naval Ocean Systems Center in a history published on the 50th anniversary of the Center and its predecessor organizations (including the NOTS Pasadena Annex) summarized the general discord unearthed by the study:

> Funding was just one area cited for improvement. The Task 97 Action Group reported that technical directors wanted more discretionary funding. Navy laboratories depended too much on bureau sponsors, were losing touch with the cutting edge of science, and were having troubles attracting top scientists. Obtaining sponsor support required excessive time from technical personnel. Managers complained that laboratories were being turned into 'job shops' and were spending more time managing contracted work rather than researching challenging and broadly defined assignments.[25]

23 NOTS Research Board minutes, 27 Oct 1959.

24 E. M. Glass, "Findings from Recent Studies of the Defense Laboratories by the Task 97 Action Group," presented at "Panel on Inflexibilities in the Federal System—Inherent or Management's Choice?" Symposium on the Environment of the Federal Laboratory, Federal Council for Science and Technology, 7–8 Dec 1964, Office of DDR&E, Washington, DC, Management Analysis Memo 64-1, 1.

25 *Fifty Years … Point Loma, 1940–1990*, Sept 1990, 59.

Harold Brown, DDR&E in 1961, vigorously supported the Fubini Report, noting that "too many high-level review teams have reported similar problems over too long a period of time, and that the rate of progress in providing relief has been too slow." McNamara, in what has become known as the October Memorandum, firmly endorsed the report, instructing Brown "to formulate and carry out a program of strengthening the in-house laboratories."[26]

The 1962 Bell Report, produced under the leadership of David E. Bell, then director of the Bureau of the Budget, likewise commented on the low salaries at the laboratories and noted that this factor, coupled with the strong competition for talent by the private sector, was eroding the quality of the laboratory technical workforce. The report recommended delegating greater authority to laboratory directors. It also found that, although some 80 percent of federally funded R&D was done by industry or academe, the government should maintain in-house laboratory competence, both to accomplish innately government research tasks and to manage nongovernment R&D.

In 1963, the Naval Material Support Establishment (NMSE) was created under the leadership of the Chief of Naval Material (CNM) Vice Admiral William A. Schoech. It was responsible for coordinating the activities of BuWeps and BuShips—since so many new major systems acquisition programs (e.g. aircraft carriers) involved both organizations—as well as the Bureau of Yards and Docks (BuDocks) and the Bureau of Supplies and Accounts (BuSandA). While the new structure put the bureaus for the first time under a single military commander, the CNM still reported through a civilian chain to the Secretary of the Navy, while the operating forces continued to report to the Chief of Naval Operations, maintaining the bilinear structure.

And even 4 years down the line there were still those who were not satisfied with the 1959 bureau consolidation. If BuAer had been the "elephant" in the BuWeps consolidation, BuWeps was now the elephant among the bureaus, controlling 60 percent of the NMSE budget. As the Booz, Allen report pointed out:

> . . . while the merger of the Bureaus of Ordnance and Aeronautics simplified the aircraft-weapons interface, it further complicated the ships-weapons interface. There was also concern that the bureau management subordinated the non-air ordnance programs [e.g., ships' weapons] to the point that the ordnance capability was seriously lagging.[27]

Meanwhile, the deteriorating situation at the Navy's laboratories was still a concern. The Sherwin Plan, in November 1964, was based on the findings

26 Booz, Allen, *Review of Navy R&D Management 1946–1973*, 137–138.

27 Ibid., 85.

of a study conducted under the leadership of Dr. Chalmers Sherwin (Deputy DDR&E for Research and Technology). The plan recommended that the Army, Navy, and Air Force each establish a civilian director for their laboratories.

Dr. William P. Raney, special assistant to the Assistant Secretary of the Navy for Research and Development (ASN R&D) during that period, has opined that Sherwin's plan was an attempt to avoid wasteful practices in the R&D system and to more effectively use the vast resources available in the DOD laboratories. However, the plan was also seen by many in the defense hierarchy as a step to centralizing management of the laboratories at a high level, and centralized high-level management was very much in line with McNamara's leadership philosophy. As soon as Sherwin completed the plan, Raney recalled, it "was then fired off by McNamara to the service secretaries for implementation."[28]

Raney subsequently reviewed all Navy in-house RDT&E activities and made several suggestions for consolidating and rearranging them.

In May 1965 the Naval Material Support Establishment was replaced with the Naval Material Command (NAVMAT). The new Chief of Naval Material, Vice Admiral Ignatius J. Galantin, no longer reported through civilians to the Secretary of the Navy but instead reported to the Chief of Naval Operations. That reorganization ended the traditional bilinear organizational structure of the Navy. The bureaus, which had largely controlled research and development, were now under the direction of the Navy's senior military officer, the CNO.

To the civilians in the laboratories, the organizational change was important in a symbolic sense as well. As Dr. James Colvard observed:

> For the first time in its history, the chain of command within the Navy shore establishment went from the CNO to the people in the field. Until 1966, it had been a bilinear system. There was talk about a Navy in which military and civilians were treated equally, and we put that into organizational effect—although we never put it into practice.[29]

In December 1965 the Secretary of the Navy established the civilian office of Director of Navy Laboratories (DNL). The title "Director" was somewhat misleading; DNL was responsible only for in-house Independent Research (formerly Foundational Research) and Independent Exploratory Development (IR/IED) programs, which represented about 5 percent of the laboratories'

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28 NL-T31, Dr. William P. Raney interview, 29 Nov 1980. Dr. Raney also served as chief scientist of ONR and scientific advisor to the President.

29 Dr. James Colvard, "Cooperative R&D: Getting Technology to the Fleet," luncheon address to the Flagship Section's R&D Symposium, JHU/APL 25 Oct 1990.

budgets. (The balance came from the systems commands.) Still, from the perspective of the laboratories' research community, this reorganization was an improvement; for years, funds originally intended for research had wound up being diverted into systems development. DNL was also given control of the RDT&E Military Construction (MILCON) program and directed long-range planning for the Navy's RDT&E resources. The new DNL reported to both the Chief of Naval Material and the ASN (R&D).[30]

Colvard noted that:

> This arrangement recognized the special nature of the Navy's scientific institutions and treated them differently than shipyards and other in-service support activities. Naval officers resented the special treatment of laboratories and felt they should be "commanded" just like all other naval activities.

However, he observed, "The 'command' philosophy will control, but it will not motivate."[31]

The next phase of the reorganization occurred in April 1966, when command and management control of the Navy's 15 major R&D laboratories—including NOTS—was officially transferred to CNM Galantin. The following month, the four bureaus were disestablished and were replaced with six systems commands, or SYSCOMs, under the direction of the CNM: Naval Air (NAVAIR), Naval Electronic (NAVELEX), Naval Ordnance (NAVORD), Naval Ship (NAVSHIPS), Naval Supply (NAVSUP), and Naval Facilities Engineering (NAVFAC). After 126 years, the bureau system was over.

The SYSCOMs did not have direct control of the laboratories, as the bureaus had. Instead, the laboratories reported directly to the CNM and thus were on the same reporting echelon as their former bosses (the bureaus) and their present customers (the SYSCOMs). The Booz, Allen report stated that the SYSCOMs referred to this aspect of the reorganization as "the great lab grab," although it noted that the SYSCOMs still retained de facto control of the labs through control of most of the R&D funding.

While all the SYCOMs were on the same level on the organization chart—directly below the CNM—there were significant size differences among them. Largest, in terms of manpower, was NAVAIR (169,000, according to China Lake Central Staff figures), next was NAVSHIPS (107,000), and, a distant third,

30 Dr. Gerald Johnson was the first Director of Navy Laboratories (March 1966 to Aug 1968) and Dr. Joel S. Lawson, Jr., was the second (Sept 1968 to June 1974). The office would later be held by two former China Lake Technical Directors: Robert M. Hillyer (TD in 1977–1982) and Gerald R. Schiefer (TD in 1986–1989).

31 Dr. James Colvard, "Navy Technical Structure in Disarray," unpublished manuscript provided by Colvard, 8 Dec 2008.

NAVORD (41,000). Next came NAVSUP (31,000) and NAVFAC (23,000) with NAVELEX at the bottom (4,000, of which 1/4 were headquarters staff).[32]

Some were unhappy with the new SYSCOMs. Captain Hardy, commander of NOTS at the time, thought that the separation of NAVAIR and NAVORD was regressive (BuWeps had been established from BuAer and BuOrd in 1959 in an attempt to better integrate the air and ordnance communities). "I don't care who you are," Hardy observed in February 1967, "it's going to be a whale of a lot more difficult to [pull together projects] with a separate ordnance and a separate air than when you had the two together. It just is going to be a lot tougher because you have more interfaces, two bosses instead of one"[33]

Less than a year before the SYSCOMs were established, the Navy had ratcheted up the centralization of authority within the service, when the Secretary of the Navy gave the CNM responsibility for designated projects throughout the Navy. The CNM established Project Managers (PMs) at the bureau level (subsequently the SYSCOM level) or, in special cases, at the CNM level. (BuAer had previously established PM positions for the E2/ATDS, A-6, and A-7 in 1963.)

The breadth of authority of the new PMs at the CNM level was reflected in their titles; e.g., Antisubmarine Warfare (PM-4), Deep Submergence Systems Programs (PM-11), Inshore Warfare (PM-12), and 17 others. One notch down at the SYSCOM-level, PMs were assigned an added letter reflecting the parent SYSCOM (Ships, PMS; Air, PMA; Ordnance, PMO; etc.). NOTS now answered to PMs from the various SYSCOMs (e.g., PMS-378, Anti-air Warfare, and PMA-242, Anti-Radiation Missiles).

A further impact on NOTS caused by the centralization of authority in the PMs was subtler. The new system increased the share of the RDT&E pie that went to contractors. As the Booz, Allen report observed, "Project managers were much less inclined to be influenced by either traditional bureaus patterns or laboratory prerogatives in deciding where work would be assigned."[34]

While change has continued—each reorganization leading to further studies and further reorganizations—to the present day, the final significant step in the reorganization process, for the period covered by this volume, was the conversion of the laboratories into weapons centers. In 1966, Dr. John S. Foster, Jr., Director of Defense Research and Engineering (DDR&E), requested a Defense Science Board study of the in-house laboratories. The board proposed

32 K. W. Heyhoe, "The Navy's Reorganization," *News and Views,* July 1966, 1.
33 S-34, Hardy interview, 20.
34 Booz, Allen, *Review of Navy R&D Management 1946–1973*, 360.

Naval Ordnance Test Station and Naval Weapons Center logos.

that the laboratories be organized into weapons centers, and Foster concurred. By the end of 1966, Foster was asking what progress the Navy had made toward meeting his goals. Recognizing that the parochial air-versus-ordnance attitudes of the bureau system had been a hindrance to effective systems development, Foster was particularly concerned with the Navy's progress in strengthening its capability to manage integrated systems development.

In response, CNM Galantin in January 1967 set out a reorganization plan that called for reorganizing the laboratories into "Centers of Excellence," each oriented toward a different aspect of naval warfare. It was approved.

On 7 July 1967, the *Rocketeer* ran a double banner headline that read "Naval Ordnance Test Station Now Naval Weapons Center." A subhead read "Navy Establishing Several New 'Centers of Excellence.'" The lead article reported that "The Naval Ordnance Test Station officially came to an end on Navy organization charts Saturday, July 1, and became a new center for Navy research and development, according to announcements for Galantin:

> China Lake is now the nucleus for a new organization called the Naval Weapons Center (NWC). The Center will include the former Naval Ordnance Laboratory at Corona, now called Naval Weapons Center, Corona Laboratories.
>
> The Pasadena Laboratories become the headquarters for the new Naval Undersea Warfare Center (NUWC), and will include undersea technology people from both the former NOTS and the former Naval Electronics Laboratory at San Diego. . .[35]

35 *Rocketeer*, 7 July 1967, 1.

Over the next 7 years, the Navy's 15 principal laboratories would be consolidated into nine weapons centers.

As might be expected, trying to dovetail the new Centers of Excellence with the also new SYSCOMs brought headaches. One problem, for the centers, was more paperwork—not so much a new problem as a dramatic increase in an old one. Reporting requirements (financial, personnel, planning, progress, etc.) had steadily increased since 1960. "Each year there seemed to be more oversight, more paperwork, more things that actually didn't necessarily work towards the end product," remarked Mel McCubbin, who arrived at China Lake in 1959.[36]

In 1964 Hack Wilson and Captain Donald C. Campbell (head of the Naval Radiological Defense Laboratory and a former NOTS Pasadena officer) co-authored a paper that they submitted to Special Assistant to ASN (R&D) Raney.

Noting in their introduction that SecNav Instruction 3900.13A "emphasizes that the primary function of the administrative functions associated with the research and development program is to assist the laboratories in carrying out their technical activities to the maximum extent possible," the two senior managers went on to explain in detail (26 pages) how these administrative functions were not assisting but rather deterring the labs. They wrote:

> The authority and responsibility of research and development managers is fractionated. Non-program administrative areas [personnel, financial, facilities, and procurement management] . . .are controlled and managed in detail by specialist organizations in the Navy Department and in OSD who have no overall responsibility for the accomplishment of the objectives of the research and development program. . . . From these specialist organizations, multiple vertical lines of control extraneous to the line of research and development management focus on the in-house research and development laboratories. This chain of command, operating under administrative specialist procedures, introduces delays and harassment into the research and development program.

The paper's authors proposed instead that the Navy institute a management structure in which the Navy's R&D managers would "exercise vigorous and dynamic executive control of the Navy research and development program including all administrative and support functions and services."

Wilson and Campbell then spent 21 pages enumerating instance after instance of "Major Problems Which Require Improvements" (e.g., streamlining the

36 S-258, Melvin J. McCubbin interview, 1 Oct 2008, 23. McCubbin retired as head of the Process Systems Division, Ordnance Systems Department, in 1992.

Haskell G. Wilson.

MILCON process, raising contractual authority). They even included a section called "Minor Irritations," stating, for example, that because of printing regulations, "a pilot's handbook could not include statements printed in red for emphasis. This detracted from the attention-getting quality of vital instructions."[37]

No record is available of Raney's response to the paper. However, the trend of increasing paperwork was inexorable, and the establishment of the SYSCOMs in 1966 laid on a whole new layer of reporting requirements.

In 1968 China Lake, in response to a NAVMAT request, published a list of "recurring" reports sent to the SYSCOMs. These ranged from the mundane ("Report of Collections: Unofficial Users of Telephone Service" and "Navy-owned Type II Demountable Household Goods Boxes Report") to the mysterious ("Status of Special Projects" and "Current Requirements for Helium"). The list of 83 reports did not include those required exclusively by other Navy and DOD agencies or by individual program sponsors.[38]

The Chief of Naval Material (nominally the office controlling the laboratories) recognized the problem. A May 1968 NAVMAT Notice signed by the Deputy CNM stated that:

37 H. G. Wilson and Capt. Donald C. Campbell, "Integration of Non-Program Administrative Functions with Technical Programs in Research and Development," NOTS, Dec 1964, 2, 5, 16, 17.

38 Memo, 1711/BC:gs, Ser. 3056, Commander, NWC, to CNM (MAT 0332), "Support of RDT&E shore (field) activities under direct command of CNM," Encl. 2, "List of Recurring Reports Required by or Distributed to the Naval Systems Commands," 15 July 1968.

> Systems Commander will not unilaterally place administrative constraints on RDT&E activities under direct command of the CNM. . . . Further, the Systems Commanders will not request routine or repetitive administrative information from these activities except insofar as it is required by higher authority and is within an assigned support function.[39]

A second problem in integrating the centers and SYSCOMs stemmed from the imbalance of the relationship between the laboratories and the SYSCOMs. Near the end of fiscal year 1966, Kenneth W. Heyhoe, associate head of China Lake's Central Staff, estimated that in the following fiscal year "about one-half of the project support for NOTS will come from the Air Systems Command, while about one-fourth will come from the Ordnance Systems Command."[40]

Based presumably on this primacy of sponsorship, the CNM issued Naval Material Instruction (NAVMATINST) 5450.8, in June 1967, assigning NAVAIR responsibility for "Primary Support Functions" at China Lake. The memorandum enumerated various primary support functions—general-management, military personnel, and facilities—and included an "other" category that read in part:

> In addition, the Systems Commanders will be consulted in matters involving plans to change the mission, tasks and functions, and organizational structure of the laboratories where they are assigned support, or other factors which might affect program responsiveness.[41]

This "primary support" relationship was not viewed kindly by Rear Admiral Arthur R. Gralla, the first head of NAVORD. Ivar Highberg, was at the time in his 11th year as head the Systems Development Department (formerly the Test Department). Over the years, the department had done a lot of work for BuOrd and later for the ordnance programs within BuWeps. That, however, was to change.

Highberg recalled:

> Admiral Gralla who was to head the ordnance side . . . was a month late in getting to Washington to assume his command. By the time Gralla got to Washington, the AIR people had stolen all of the good men in BuWeps and, in particular, had taken the Naval Ordnance Test Station—underline Ordnance—and the Naval Ordnance Laboratory, Corona—underline Ordnance. They had stolen Admiral Gralla's nuggets, and, to make a long

39 NAVMAT NOTICE 5450, "Support of RDT&E Shored (field) activities under direct command of CNM," 15 May 1968.

40 Heyhoe, "The Navy's Reorganization," *News and Views*, 9.

41 Memo MAT 033:BHA, Chief of Naval Material to Navy R&D Laboratories, "Navy R&D Laboratories; command relationships and management policies for," Encl. 1, NAVMATINST 5450.8, 27 June 1967.

> story short, I was unable to convince Admiral Gralla that he should leave his projects at China Lake.
>
> I offered to sign a contract and give him 40 percent of the Station or whatever he wanted, and he said, "Oh, no, no, as long as that belongs to those guys in AIR, they will be the boss; their projects take precedence," and every time he found, no matter what it was, whether we had a 5-inch lightweight gun or whatever it was, he would say, "Get it out of China Lake; send it to Louisville or send it to Dahlgren."[42]

Colvard, then working on a digital fire-control program, recalled that:

> Admiral Gralla came out, reviewed the program which I was in charge of, went up to the [Technical Director] in the Commander's Office and said, I quote, "This is the best program I've ever reviewed in my career." And I continue to quote, "but I'm transferring it all to [Naval Ordnance Station] Louisville." I said, "Admiral, if you said it was a terrible program I would have been hurt because I think it's a good program. I was flattered when you said it was the best program you've ever reviewed but your second statement that you're going to transfer it doesn't follow logically."
>
> He said, "Son, you don't understand, I no longer sign your Commander's fitness report."[43]

Such an attitude ran counter to the relationship of laboratories and SYSCOMs that had been envisioned by those who planned the reorganization and it was certainly the enemy of efficiency. In a memorandum to Gralla in June 1968, CNM Galantin (by then a full admiral) admitted that "resource control and, hence, effective control of activities, devolved on the primary support agency [the SYSCOM] rather than the command agency [CNM]."

Galantin assured Gralla, however, that the "primary support" concept was on its way out and that new instructions were being prepared that would "delete all reference to 'primary support.'" Galantin also observed that:

> Close identification with individual Systems Commands inhibit[s] cross servicing by one laboratory of multiple SYSCOMs and Project Managers. . . . In order to exercise direct command authority the CNM is now and will continue to exercise direct control of R&D activity, workload, and resources.[44]

Each step toward centralization and toward divesting the laboratories of their traditional roles of leadership and self-governance was keenly felt at NOTS.

42 S-121, Highberg interview, 13.
43 S-285, Dr. James Colvard interview, 11 March 2009, 23. Gralla subsequently changed his mind when he found that Louisville didn't have a digital computer capability.
44 Memo, CNM to Commander, Naval Ordnance Systems Command, "Support of shore (field) activities directly commanded by the Chief of Naval Material," 17 June 1968.

Lee E. Lakin Jr., who was head of the Test Department's Assessment Division when McNamara took over in 1963, reported in a 1981 interview that:

> Up until the McNamara era, China Lake was allowed to try a lot of new ideas. After McNamara, the way you ran the Defense Department is by program managers and many paper analytical studies. . . .
>
> Up until that period, we had decentralization and more hardware experiments. McNamara's era was a major turning [point] in the way that DOD was run. His way of running the war in Vietnam, his way of counting bodies to say we are winning or losing, his way of quantifying things, his way of doing operational analysis, his way of more paperwork reporting and planning—all of these things DOD said were great management techniques to control things from the very top. I feel that NWC's trend toward centralization followed DOD's trend toward centralization.[45]

Indisputably, there were benefits to centralization, both at the DOD level and, writ small, at China Lake.

Bill Porter, who served as China Lake's 12th Technical Director, gave the example of machine shops on the base:

> You've got the work close to the customers, et cetera, but then maybe the middle ground is where there's enough work to justify a machine shop like out in Salt Wells or out at CLPP [China Lake Pilot Plant] or at the airfield . . . when you own your own machine shop, you can come up with all the reasons why you need to keep it. But then when you look across the Center, and you see that we've got machine shops all over the place, and they operate under different ground rules and policies and so on, then you can ask yourself does that make sense."[46]

Booz, Allen's review of Navy R&D management included interviews with more than 75 senior military and civilian figures who had been directly involved in the R&D management process. The authors, in their commentary, noted that:

> Many [interviewees] accepted the creation of the Office of Secretary of Defense and a measure of centralized control as necessary in view of complex inter-service issues and the magnitude of resource commitments. What they found troubling was the proliferation of staffs and reviewing authorities at virtually all levels who were able to insert themselves in the decision-making process with little or no accountability for the success or failure of an endeavor.

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45 S-122, Lee E. Lakin interview, 17 Feb 1981, 27. In McNamara's autobiography, he wrote, "The monitoring of progress—which I still consider a bedrock principle of good management—was very poorly handled in Vietnam. Both the chiefs [Joint Chiefs of Staff] and I bear responsibility for that failure." McNamara, *In Retrospect*, 48.

46 S-216, Porter interview, 12.

> The interviewees also noted that the removal of statutory constraints to organizational change accelerated the tendency to seek organizational solutions to virtually all problems. Each change traded one organization interface for another and disrupted the continuity of purpose so essential to effective R&D management. Moreover, the syndrome appeared to be self-perpetuating.[47]

The tension between centralized control on the one hand, and decentralized decision making and resource management on the other, continues, as do the arguments over the roles of industry and in-house laboratories in the systems-development and -acquisition process. These issues have still not been resolved.

Planning Systems

Planning, particularly long-range planning, was another process that changed greatly in the 1960s and generated additional turmoil for NOTS. Among the milestones—critics called them millstones—that most affected the laboratories was the establishment of the Planning, Programming, and Budgeting System (PPBS). The system was the centerpiece of McNamara's planning efforts, and the concept that many felt encapsulated all that was wrong with the McNamara approach to running DOD.

While McNamara is most closely identified with PPBS, the actual architect was a brilliant manager named Charles J. Hitch. He was the first American Rhodes scholar to become a don at Oxford, had been the head of Rand Corp.'s Economics Division, and was later appointed 13th president of the University of California.

Charles J. Hitch.

In 1961 Hitch was appointed by Kennedy as Assistant Secretary of Defense and Comptroller for DOD, and in that capacity, he developed PPBS, which was introduced in July 1961.

The new system was designed to solve some of the disconnects within the nation's defense establishment. For example, while planning looked several years ahead—overall system development time might take 5 to 10 years or longer—budgeting was

47 *Review of Navy R&D Management 1946–1973*, 107.

done a year at a time. "According to Hitch, planning was carried out, on the one hand, without regard to costs; budgeting was accomplished, on the other hand, without reference to implications for military capability."[48]

Programming, the second P in the acronym, was key to the new system. In Hitch's words, "Since the military planning function and the budget function were already well established, the role of programming was to provide a bridge between the two."[49]

PPBS leaned heavily on systems analysis, which had been developed at Rand. "Rand researchers envisioned systems analysis as a rigorous, 'rational' means of comparing the expected costs, benefits, and risks of alternative future systems—such as weapons systems—characterized by complex environments, large degrees of freedom, and considerable uncertainty."[50]

PPBS cut across service lines, aggregating programs and activities into program elements which were further aggregated into forces structures and finally Program Packages. These packages looked ahead 5 years and were incorporated into the Five Year Defense Plan (FYDP, originally the Five Year Force Structure and Finance Program). PPBS was continually updated through a Program Change Control System. Significant changes to the FYDP required approval by the Secretary. And mere inclusion in the FYDP did not guarantee program funding. One slight hiccup in the program was that the budget categories that Congress used in its appropriations process did not match up with the program categories used by DOD to develop the Program Packages. This mismatch, however, served OSD's purposes. Hitch wrote that:

> . . . this division of the budget by broad input or resource categories also provides needed flexibility for the adjustments in the program that are inevitably required in the course of the budget year. . . . It is important not to freeze programs in appropriation bills.

As to the problem of translating between budget categories and programming categories, Hitch blithely stated, "This is the sort of disadvantage that modern high-speed computers are well designed to overcome."[51]

Far more advanced than previous planning tools, PPBS integrated systems analysis and traditional requirements studies with long-range plans and budgets and a myriad of decisions points and reviews. It was a system by which the

48 Ibid., 297.

49 Charles J. Hitch, *Decision-Making for Defense*, University of California Press, 1967, 29.

50 David R. Jardini, "Out of the Blue Yonder, How RAND Diversified into Social Welfare Research," *http://www.rand.org/pubs/corporate_pubs/2007/RAND_CP22-1998–08.pdf,* accessed 1 April 2011.

51 Hitch, *Decision-Making for Defense*, 29–30.

Secretary could direct and control the defense effort. At a symposium in 2004, OSD's Program Evaluation and Analysis group delivered a presentation on the PPBS in which it stated flatly, "The PPBS was *designed* to establish the Secretary's control over the Department of Defense." And establish control it did.[52]

Dr. Howard J. White, Jr., special assistant for research to ASN (R&D) Wakelin, said that PPBS:

> . . . was inevitable . . . In the 1950s and 1960s, it was becoming clear that science and our technology could think of more things to do that were logical, and apparently reasonable, and probably useful, than could be funded at any one time, so that there was a priority-manufacturing technique in the works.

Perhaps an element of paranoia was also driving PPBS and its ancillary documentation requirements. If there was one thing that PPBS did well, it was generate paper, and White noted that:

> . . . the paper trail is important because people didn't trust everybody anymore. In other words, you need a paper trail when you're liable to have to come back on yourself, when people are openly challenging your judgment in some way or another. This was, of course, happening, with McNamara, Congress, and others.[53]

Colvard made a similar observation:

> A congressman can understand numbers; he may not understand decibels, he may not understand Mach numbers, he may not understand the jargon of the scientist, the jargon of the militarist, but he says, "This number is bigger than that number and I can tell my constituents I bought the best for their dollars."[54]

McLean was as rankled by McNamara's strong emphasis on detailed long-range planning as he was by the Secretary's resolute commitment to efficiency. NOTS' top civilian believed that such planning was more suitable to an industrial organization than a laboratory. He wrote in 1963 that:

> The more concretely the organization can plan and schedule its future, the more reasonable will be the rationale for avoiding anything that will have the chance of changing the future. I am not against plans, but the government tends to be production-oriented. The planning process, which is very necessary for production, tends to be carried over into research, much to the discouragement of inventors.[55]

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52 Vance Gordon, "DOD's Planning, Programming and Budgeting System (PPBS)—A Historical Perspective," presented at the Military Operations Research Society workshop, Institute for Defense Analyses, Arlington, VA, 18 Oct 2004. Emphasis in the original.

53 NL-T32, Dr. Howard J. White interview, 4 Dec 1980, 31, 33.

54 NL-T28, Colvard interview, 28.

55 "Paper on Invention," presented 20 June 1963 at George Washington University,

Fascination with systems analysis did not stop at the DOD level. Whether because of the perceived value of the discipline, or as an adapt-or-die defensive measure, the discipline spread downward. As one historian put it:

> McNamara's approach to PPBS had a domino effect. The concept of systems analysis cascaded down the levels of the Navy's organization. Studies, once a luxury, became essential. As the CNO's deputies acquired analytic support, either directly from the Center for Naval Analyses, or indirectly from outside contractors (the so-called beltway bandits), a "shadow" OPNAV [Office of the CNO] staff grew.[56]

To further subdivide (and track) R&D efforts for PPBS, a six-category system was established in 1961 to replace the former three category system of Research (the programs under the Chief of Naval Research), Exploratory Development, and Systems. The new categories were Research (6.1), Exploratory Development (6.2), Advanced Development (6.3), Engineering Development (6.4), Management and Support (6.5), and Operational Systems Development (6.6).[57]

This subdivision was accompanied by a blizzard of new reporting requirements emanating from DDR&E. Among them was the requirement that Technical Development Plans (TDPs), which had been a required Navy internal reporting document since 1957, would now be submitted to DDR&E—20 copies, thank you—for each project in the 6.3, 6.4, and 6.6 categories. The flexibility in allocating funds internally that China Lake had exercised so successfully over the years was disappearing.

In 1963 the requirement for a Program Definition Phase (later changed to Project Definition Phase, so as not to be confused with Hitch's top-level programs) was instituted for any project whose total RDT&E cost was estimated to exceed $25 million (or production cost exceeding $100 million). The authorizing directive stated that "the most important objective of Project Definition is to provide an adequate basis to assure that management decisions to proceed with, cancel or change development projects are made on a total system and total cost basis." Requests to initiate a PDP had to be submitted, with extensive documentation, to DDR&E.[58]

Coupled with the PDP was a revision of the processes for DOD contracting. The 1950s had been marked by cost overruns, slipped schedules,

Washington, DC, RM-24,*Collected Speeches of McLean*, 126.

56 Hone, *Power and Change*, 72.

57 Subsequently these categories were further divided (e.g., 6.3A, Advanced Technology Demonstration).

58 DOD Directive 3200.9, "Project Definition Phase, 26 Feb 1964, cited in Raymond Dickinson, *Synopsis of Navy Research, Development, Test and Evaluation Formal Planning Procedures*, Central Staff, NOTS IDP 2337, June 1964, 13.

and contractor-developed systems that didn't perform as they should. In response to this problem (which grew in proportion to the complexity of the systems being developed), McNamara and his advisors decided that all major development projects—systems expected to run $25 million or more in R&D or $100 million lifetime cost—should have Contract Formulation and Definition Phases that would carefully identify the risks involved in the project and lay out the technical approach to be taken. This process, implemented by SecNav Instruction 3900.3 of 20 August 1965, emphasized competitive contracting as the preferred method of doing business:

> In [Contract Definition], generally, two or more competitive contractors, working closely with the Navy, develop concept, design approach, trade-off solution, management plans, schedule, and overall cost.[59]

The PDP and the Contract Definition Phase were not well received at NOTS. Said Chuck Bernard:

> They had invented something they called the contract definition phase, a fairly innocuous title for screwing around with the kind of contracts people have had. . . . this contract definition phase was interpreted by [the Bureau of Naval Weapons] to say that there has to be a competitive phase. You can't compete government with contractors; therefore, the government had to drop out.

The requirement to essentially cede development work to the contractors was enough to make Bernard quit his job as head of the Propulsion Systems Division in Code 45.[60]

Jack Crawford related that Walleye was hit by the PDP late in the development game:

> We completed the development, it was fed to the Naval Avionics Facility to do a product design and a pilot run and then send the design out to industry to be built. They would develop and prove the documentation, and out it goes.
>
> Well, we were well into that process when the requirement for the Project Definition Phase came along from DOD. This was the latest management scheme to ensure successful economical development and production. The

59 *Navy Systems Performance Effectiveness Manual*, NAVMAT P3941-A, HQNAVMAT, Washington, 1 July 1968.

60 S-189, Charles W. Bernard interview, 3 May 1991, 93. After leaving China Lake, Bernard worked for Lockheed for 6 years then went to work at Naval Weapons Laboratory, Dahlgren, where former China Laker Barney Smith was Technical Director. When Jim Colvard took over from Smith as Technical Director at Dahlgren, he appointed Bernard Technical Director at NOL White Oak when it was combined with Dahlgren. Bernard concluded his government service as Director of Land Warfare on the staff of the Under Secretary of Defense for Research, Development and Acquisition.

> process was to get two competing industrial sources in. They would take over the design and make competitive bids to complete development and do production. . . .
>
> Walleye was nearly ready to release for full production but PDP put a kink in the process, and we now had to deal with both Hughes and Martin and go through a series of formal management hoops that slowed down the process. And I think it cost us a lot of money.[61]

Commenting on that development, McLean said:

> Walleye was allowed to go ahead, because the program was so far down the line when that [PDP requirement] was instituted. It was contractor-modified. Walleye was almost the last system that escaped. . . . Walleye came out ahead of the change to the PDP. Condor [a powered version of Walleye with a 60-mile range] came out afterwards, and so the development time on Condor was much longer than on Walleye. There's no question that Condor and Walleye could have come out practically simultaneously.[62]

So intense was NOTS' concern about the PDP that when Secretary of the Navy Paul H. Nitze visited the Station on 2 April 1964, Station managers broached the subject to him during an informal discussion. As NOTS' report of the meeting to BuWeps stated:

> Secretary Nitze noted the concern expressed by Station representatives relative to current interpretations of the Project Definition Phase policies which might adversely affect the in-house laboratories. . . . He expressed the view that the aim of DDR&E [Harold Brown] is to reduce the time required to move from the advanced development stage to Fleet-issue hardware; that *DDR&E seemed to feel that retention of design cognizance in the hands of in-house laboratories through the Project Definition Phase and Engineering Development might tend to discourage creativity on the part of industrial contractors*; and thus extend the time required for complete development." That response provided little solace to the attendees.[63]

In an attempt to clarify the maze of new requirements, Raymond Dickinson in Central Staff (Code 17) prepared a synopsis of "formal planning procedures." In the document's summary, Dickinson wrote:

> The one outstanding conclusion that may be deduced from the foregoing outline and brief description of RDT&E planning processes is the enormity of the many procedures and requirements involved. . . .

61 S-171, Crawford interview, 30.

62 S-87, McLean interview, 15–16.

63 Memo 17/RWB:ia, Ser. 0586, Commander, NOTS, to Chief, BuWeps, "Visit to U.S. Naval Ordnance Test Station, China Lake, by the Honorable Paul H. Nitze, Secretary of the Navy, on 2 April 1964," 13 April 1964, 4. Emphasis added.

> However, this is as it should be in an environment of changing technology that dictates a dynamic state-of-the-art in the blending of the Nation's resources and capabilities into a modern arsenal of weapons for the future.[64]

With the very large increase in planning and paperwork requirements came a similar explosion in the processes required for planning and justifying programs. The Booz, Allen report stated in 1976 that:

> In a little over a decade, the number of steps in this process had increased by a factor of five. The "user-producer" dialogue, with OPNAV representing the "users" and the material bureaus and offices representing the "producers,"had been transformed into a highly formalized documentation system to serve the accelerated trend toward centralized control of the R&D program.[65]

The Funding Process

One of the key tools for centralizing control over the laboratories was the funding process. In the post-WWII years, the bureaus had controlled RDT&E funding, but in 1956, Congress established a single "R&D, Navy" appropriation, with the Office of Naval Research (ONR) responsible to the Secretary of the Navy for coordinating and administering the funds. This category was expanded in 1959 to include test-and-evaluation funds ("RDT&E, Navy").

Appropriation of money by Congress was now made to the DOD level (not to the individual services), ostensibly to allow DOD flexibility in shifting funds and programs between services.

ASN (R&D) was assigned to be the interface point with the DDR&E. While this assignment was made "to give the Navy maximum effectiveness in dealing with the DDR&E (who had authority over the Defense Department's total RDT&E budget)," it nevertheless further complicated an already convoluted budgeting process. Navy budgeting became "more complex, time consuming, and subject to reviews."[66]

In the 1963 *Command History (*China Lake's annual report to CNO), the Station explicitly addressed the growing restrictions on its financial operations:

> The Station's FY 1964 RDT&E funds have been further compartmented into an increasing number of administrative and statutory limitations. The Station's FY 1964 funds are provided under approximately 40 different subheads, compared to 27 in FY 1963. This compartmenting puts increasing strain on both the

64 Dickinson, *Synopsis of Navy Research, Development, Test and Evaluation Formal Planning Procedures*, Central Staff, NOTS IDP 2337, 18.
65 *Review of Navy R&D Management 1946–1973*, 215–216.
66 Ibid., 291, 283.

> Station and the Bureau in achieving the degree of fund flexibility needed to meet constantly changing research and development program needs.[67]

John Boyle remembered that:

> McLean was great for stealing money. That was his genius. And at that time [under the bureaus] it was easy to do. The downfall of China Lake occurred at the point at which they lost control of their discretionary funding. In the early days they were block-funded. They got so much for air-to-air weapon systems, so much for air-to-ground, so much for ASW, so much for rocket development. Chunks of money.[68]

Wilson and Campbell, in their paper for Raney, cited the example of one laboratory (presumably NOTS), in 1965, performing 275 different tasks and problem assignments for a single bureau from that bureau's share of the Navy's RDT&E appropriation.

> The management bureau involved in this illustration acknowledges that, as the grantor of allotments, it has authority to pass on to an allottee [the laboratory] the same flexibility permitted by the allocation from which the allotment was issued. In practice, however, this bureau has imposed 44 separate statutory funding limitations upon the laboratory rather than a single one, effectively eliminating flexibility of funding at the laboratory.

The letter further noted that the number of funding limitations was 28 in 1963 and only 2 in 1962.[69]

Whether the proper term is Boyle's "stealing" or the *Command History*'s "achieving the degree of fund flexibility needed," it was clear that both the Department of Defense and the Department of the Navy were tightening the reins in a manner that would affect the Station's ability to maintain its autonomy.

Hone has observed of McNamara that he "understood the difference between data collection as a means of tracking expenditures and data collection as a means of discovering what an organization is doing and of controlling that organization."[70]

Conflict of Cultures

Increased centralization of authority within the Department of Defense was brought sharply before the public's eye with the resignations of Rear Admiral William A. Brockett, chief of BuShips, and Rear Admiral Charles A. Curtze, his

67 *NOTS Command History* 1963, 2.
68 S-180, Boyle interview, 8–9.
69 Wilson and Campbell, "Integration of Non-Program Administrative Functions," 11.
70 Hone, *Power and Change*, 79.

deputy, in October 1965. Readers of the 29 October *New York Times* article had only to read the headline "Admiral Explains Why He Resigned, Tells Superiors He Opposes Pentagon Centralization," to get the gist of the complaint.

Another factor cited for the resignations was "the plan to procure two newly authorized cargo ships . . .by going to private contractors for 'conception formulation and design.'" Both admirals were engineers and lifelong friends, and each had more than 30 years of service.

The article also reported that CNO Admiral David L. McDonald was asked "whether he, personally, believed that there had been too much centralization at the Pentagon. 'In many ways, yes,' he replied, paused, then added: 'In some ways, no.' 'Let's leave me out of it.'"[71]

Admirals resigning so publicly was symptomatic of a deeper cultural rift between the defense establishment's uniformed, combat-seasoned military leaders and McNamara's progressive, academically trained so-called "whiz kids." The (mostly) young statisticians and computer scientists, who wielded their analytical tools in the PPBS venue as effectively as the military used its guns and bombs on the battlefield, spoke a language that was unfamiliar to many of the senior officers.

As historian James E. Hewes, Jr., observed:

> . . . cost effectiveness and systems analysis introduced the jargon of statistics and computer technology into military planning. When 'the standard economic model of efficient allocation" employed in cost effectiveness studies was defined as "the maximization of a quasi-concave ordinal function of variables constrained to lie within a convex region," a communications gap opened between the systems analysts and those combat veteran officers unfamiliar with the language.[72]

A dramatic example of this conflict of cultures occurred during the Cuban Missile Crisis of 1962. McNamara was exercising close control over the delicate and ever-changing situation between the Navy and the Soviet ships that were approaching the naval blockade of Cuba. The blockade was being coordinated by a Pentagon admiral; however, when the admiral did not satisfactorily answer McNamara's questions, Admiral George W. Anderson, Jr., Chief of Naval Operations, was summoned. At one particularly tense session in the Pentagon's Navy Flag Plot, Anderson finally had all he could take of the Secretary's persis-

71 Jack Raymond, "Admiral Explains Why He Resigned, Tells Superiors He Opposes Pentagon Centralization," *New York Times,* 29 Oct 1965.
72 James E. Hewes, *From Root to McNamara: Army Organization and Administration, 1900–1963*, U.S. Army Center of Military History, 310.

tent questioning of the Navy's procedures. According to *Washington Post* reporter and author Michael Dobbs:

> "This is none of your goddamn business," [Anderson] finally exploded. "We know how to do this. We've been doing it ever since the days of John Paul Jones, and if you'll just go back to your quarters, Mr. Secretary, we'll take care of this."

Admiral Anderson was relieved of his office by the Secretary in August 1963 and retired soon thereafter.[73]

Although McNamara wanted power centralized in the Department of Defense, he did not want to share that power with the military side of the department. According to one study, "McNamara centralized only the managerial or business side of Defense; he was content with patronage appointments over the services as long as they facilitated his control on a divide and conquer principle."[74]

In 1961 the new Secretary of Defense was concerned that disgruntled naval leaders might find a sympathetic reception in the White House (President Kennedy had been a lieutenant in the Navy during WWII and had been wounded in combat and decorated for heroism). McNamara—who had insisted on selecting his own service secretaries—chose John Connally as his first Secretary of the Navy.

In the heated 1960 campaign for the Democratic nomination for President, Connally had been Lyndon Johnson's campaign manager. After Johnson's loss to Kennedy (although he was given the VP slot), Connally was "the least enthusiastic Kennedy supporter in government."[75]

There was an irony to the centralization of power under McNamara. Before the reorganization of the defense establishment in 1958, there had been serious consideration of eliminating the individual services (an idea called "service unification," which President Truman had proposed in 1945 and which President Eisenhower purportedly favored). Indeed, elimination of the individual services was recommended by a panel, led by Missouri Senator Stuart Symington, that President-elect Kennedy commissioned in 1960 to study DOD.

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73 Michael Dobbs, *One Minute to Midnight: Kennedy, Khrushchev, and Castro on the Brink of Nuclear War*, Alfred A. Knopf, 2008, 72. McNamara later told an interviewer, "What Admiral Anderson didn't understand was that the quarantine was not just a blockade. It was a line of communication from President Kennedy to Premier Khrushchev." Brock Brower, "McNamara Seen Now, Full Length," *LIFE*, 10 May 1968, 78.

74 Paul R. Schratz, "John B. Connally," in *American Secretaries of the Navy*, Vol. 2, Paolo E. Coletta, ed., Naval Institute Press, 1980, 914.

75 Hone, *Power and Change*, 57, quoted from Schratz, *American Secretaries of the Navy,* 914.

CNO Arleigh Burke, in a 1959 letter to retired Vice Admiral Walter G. Schindler wrote that among his reasons for opposing the single-service concept was that:

> . . . a single Service would give effective control of the power of over $40 billion-plus a year into the hands of a single man, or a group of disciplined men all oriented in exactly the same direction, and this power would directly threaten the government of the country.[76]

Although Symington's recommendation was not taken, McNamara's centralization efforts appear to have achieved the end that Burke predicted. In 1967 Hitch himself wrote of Symington's unification proposal that "the management innovations introduced in the Department of Defense during 1961–62 made unnecessary so drastic an overhaul of the existing organizational structure."[77]

Military historian Paul Y. Hammond wrote in 1961 that:

> . . . the significance of new weapons development to service interests is almost impossible to overestimate. It is indisputable now that the crucial decisions about weapons research and development, such as the final elimination of weapons for development and production, must be made by the Secretary of Defense. . . . Gradually, and with a finesse which demands respect, the services are being dismembered and disemboweled, so that the question of their utility is decided continually in decrements. Since we cannot reasonably expect to turn the clock back, the only relevant question is whether the process is too fast or too slow.[78]

Change, we are told, is stressful. The barrage of organizational and procedural changes thrust on NOTS and the other government laboratories during the 1960s was not all bad—as Howard White pointed out, a "priority manufacturing technique" was necessary, given the balance of needs and resources within the Defense Department—nor all good, but at NOTS as elsewhere throughout the DOD that barrage caused turmoil and negatively affected morale.[79]

Change also, of course, elicits change in response. According to Jim Bowen:

> At that time we were coping with McNamara's Programming, Planning, Budgeting System. It was obvious that the world was changing, and we had to operate differently. We were trying to determine the best way of operating.[80]

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76 Ibid., 18, also quoted from Schratz, 914.

77 Hitch, *Decision-Making for Defense*, 18.

78 Paul Y. Hammond, *Organizing for Defense: The American Military Establishment in the Twentieth Century*, Princeton University Press, 1961, 373–374.

79 NL-T32, White interview, 31.

80 S-175, Bowen interview, 33.

NOTS leaders did change; they became better at paperwork and at operating the management tools that their predecessors had eschewed. Fred Alpers believed that the laboratories began to spend too much time on management and not enough on the technical work.

Alpers concluded that:

> It's a tendency that came in with McNamara and all his analyses, and all his planning, endless revisions, and whatnot. The pendulum just swung all the way over. I think you needed some of that. McNamara was right, but it swung much too far over that way.[81]

In an interview near the end of Robert M. Hillyer's tenure as China Lake Technical Director, he said that the significant change in nature of China Lake's work

> . . . started with McNamara [in] 1962 when he redesigned the systems acquisition process of the Defense Department and built more structure into the system than was probably good. We used to do more design in-house and control in-house and then rely on industry for production. I believe that's the way to do business. When McNamara put the chink in the armor of doing business that way, the industrial lobbyists put a pick in that chink and broke it open, and we got policies passed which relied more and more on the private sector.[82]

Changes to the old ways of doing business were already taking their toll, and the level of dissatisfaction was building between the mavericks out west and the bureaucrats back east.

The momentum of work driven by the war in Vietnam would mask some of the effects that the changes of centralization had wrought, but as control of the Station's direction drifted further and further away from China Lake and as the war wound down in the early 1970s, the conflict between the old and the new would become more apparent. It would reach the crisis level in the mid 1970s under the reign of Rear Admiral Rowland G. "Doc" Freeman, III, and again in the battle between China Lake Technical Director Burrell Hays and Assistant Secretary of the Navy Melvyn R. Paisley in 1986.

To many China Lakers, it seemed that the decision makers in Washington had read one of McLean's maxims from the "Nine Ways to Ruin a Laboratory" and were taking it literally: "Keep the check reins tight, define missions clearly, follow regulations. (Nothing new will get a chance to be inserted.)"[83]

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81 S-118, Alpers interview, 75–76.
82 S-134, Robert M. Hillyer interview, 14 and 27 May 1982, 65.
83 "Management and the Creative Scientist," RM-24, *Collected Speeches of McLean*, 103.

At NOTS in the 1960s, the signs of a new order were clear for those who chose to look—or for those who chose to listen. As a 22-year-old songwriter put it in 1963:

> As the present now
> will later be last
> the order is rapidly fadin'
> and the first one now will later be last
> for the times, they are a-changin'.[84]

84 Bob Dylan, "The Times They Are A-changin'," 1963, copyright Special Rider Music.

8

Control of the Air

Prior to the Southeast Asia war, the pilot reasonably had the skies to himself, but they challenged him in Vietnam.

— Captain William B. Haff, Commander,
Naval Weapons Center, 1979–1981[1]

Beginning with an Air Force C-47B that was shot down during an intelligence mission over Soviet-built air bases in Laos on 23 March 1961, and ending with an Air Force F-4D that crashed landed at Udorn, Thailand, on 29 June 1973, the United States lost 3,332 fixed-wing aircraft during the hostilities in Southeast Asia. The Navy and Marine Corps accounted for about a third of that number.[2]

While many of those aircraft were lost in routine (for a war zone) air operations—bombing runs against enemy personnel and material, close-air support of ground operations, reconnaissance missions, ferrying troops and supplies—a large number were sacrificed in an attempt to gain what military strategists call "air superiority." The Department of Defense defines air superiority as:

> That degree of dominance in the air battle of one force over another that permits the conduct of operations by the former and its related land, sea, and air forces at a given time and place without prohibitive interference by the opposing force.[3]

1 S-125, Capt. William B. Haff interview, 24 June 1981, 2. Haff also served as Assistant Technical Officer, Technical Officer, and Deputy Laboratory Director at China Lake in the 1970s. An Annapolis graduate, he is a combat veteran of Vietnam (two Distinguished Flying Crosses, Bronze Star with V, 21 air medals), and holds additional degrees from the Naval Postgraduate School and MIT.

2 Hobson, *Vietnam Air Losses*, 268. The Vietnam Helicopter Pilots Assoc. states that 5,086 U.S. helicopters were destroyed during the war. *http://www.vhpa.org/heliloss.pdf,* accessed 16 June 2011.

3 *Department of Defense Dictionary of Military and Associated Terms*, Joint Publication 1-02, 12 April 2001.

Cornell University's Air War Study Group elaborates that "Air superiority is the first-priority mission; if air superiority is not established none of the other missions can be performed without severe interference from enemy aircraft."[4]

WWII had proved beyond a doubt—and Korea had reinforced the lesson—that in modern warfare, control of the air is essential to success on the ground and ocean. NOTS took that lesson to heart. Because the Station's mission included RDT&E of "rockets, guided missiles . . . and aircraft fire-control systems," and the great majority of NOTS' products, particularly those from the China Lake site, involved aircraft. The Station assumed an early position of leadership in ensuring that U.S. forces would have the technology to control the air war.

Sidewinder

September 1958 had provided a stunning example of the effectiveness of NOTS-developed air weaponry and of the strategic, as well as tactical, importance of controlling the skies. The Station's *Technical Program Review* that year noted:

> Because of the Station's active interest and leadership in the Sidewinder development program since its inception, the final combat proof of this air-to-air guided missile in 1958 was of particular significance. The action of 24 September 1958 over the Formosa Strait, in which Chinese Nationalist aircraft scored four kills out of six Sidewinder missiles fired, further demonstrated the effectiveness of this weapon.[5]

The review did not add that the F-86 Sabrejets flown by the Nationalist Chinese were no match for the Communists' Soviet-built MiG-17s, and that without Sidewinder a very different outcome to the Formosa engagement might well have occurred.

"Deterrent weapon" is a term that generally brings to mind nuclear or biological weapons—devices so terribly effective that their mere existence is sufficient to deter action against those who possess them. In the Formosa Strait, however, it was Sidewinder that became a deterrent.

Prior to the incident, after months of bellicose pronouncements by the Communists and continuous shelling of the islands of Quemoy and Matsu, it had seemed that a cross-straits attack by mainland China against the Nationalists was imminent. Yet the lopsided aerial battle over the strait helped

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4 Raphael Littauer and Norman Uphof, eds., *The Air War in Indochina*, 1972, 17.

5 *Technical Program Review 1958*, 4. Details of NOTS' contributions to the Formosa Strait confrontation are in Babcock, *Magnificent Mavericks*, 468–472.

convince that Communists to rethink their plans. China Lake Command Historian Doig put it succinctly:

> Sidewinder was a deterrent. The Chicoms didn't come back across the Strait after the shoot-downs by Sidewinders.[6]

Aircraft are vulnerable to air, sea, and land-based threats. The missile used by the Nationalist Chinese, the Sidewinder 1A, had been developed to combat the first of these threats—enemy aircraft. Sidewinder was not the only air-to-air weapon in the U.S. arsenal—there were longer-range missiles like Sparrow, and, for close-in work, guns—but within its envelope the 1A was the weapon of choice for the U.S. and its allies (and later, in its purloined form as the Soviet-built Atoll, by its adversaries as well).

Dr. William B. McLean and his Sidewinder missile, November 1966. Bill Ray photo courtesy of *LIFE* magazine.

Sidewinder was an important milestone in modern weapon development. It was significant not just because of the effectiveness of the weapon itself but also because of its larger lesson in how to create an environment for quantum breakthroughs in the application of technology to military needs. The $25,000 Incentive Award that McLean received in 1956 and the Gold Medal presented by President Eisenhower in 1958 for developing Sidewinder somewhat missed the point. They should have been given to him for developing a culture and a system that encouraged the development of

6 Leroy Doig III, discussion with the author, 11 Dec 2007.

Sidewinder (and Walleye and Zuni and Tiara and Shrike and scores of other weapons and systems). Sidewinder was as much a testament to McLean's bold and visionary leadership style as it was to his technical genius.

But a research-and-development laboratory cannot rest on its past successes; one truism of weapon design is that for every measure there is a countermeasure, and for every countermeasure, a counter-countermeasure. That is why air-to-air missile designers are always working to expand the envelope of their missiles. Envelope, in its narrowest sense, is the missile's "tactical firing envelope . . . a volume in space, relative to the target, from which the missile may be launched to secure a hit."[7]

More generally, expanding the envelope means increasing a weapon's effectiveness in each of its engagement parameters. Some aspects of the envelope are intuitive: maximum range of the weapon, for example, or its speed, or altitude. Others are less obvious; temperatures at which the weapon can operate, or degree off boresight (a straight line through the missile axis to the target) at which the missile can be fired, or the aspect angle of the target (head on, tail on), or the maximum speed at which the weapon can be safely carried on a maneuvering aircraft. Maximizing the envelope also involves anticipating enemy defensive measures against the weapon (both tactical and technological) and developing countermeasures to defeat them. The process never ceases over the life of the weapon system—which in the case of Sidewinder, at the time of this writing, is 54 years and counting.[8]

Envelope expansion is the reason that, even though Sidewinder 1A was the most advanced air-to-air guided missile in the world when it downed the Soviet-built, Chinese-piloted MiGs in 1958, NOTS had already been at work for 2 years on an even more capable version of the missile—Sidewinder 1C.

Sidewinder 1C was actually two weapons with completely different types of guidance systems. The Sidewinder 1C Mk 29, like the original Sidewinder, carried an infrared seeker. The developers called it IRAH (Infrared Alternate Head). The other variant of the 1C was the radar-guided Mk 30, called SARAH (Semiactive Radar Alternate Head). The two nicknames were later officially dropped because of potential copyright issues, although the developers continued to use them.

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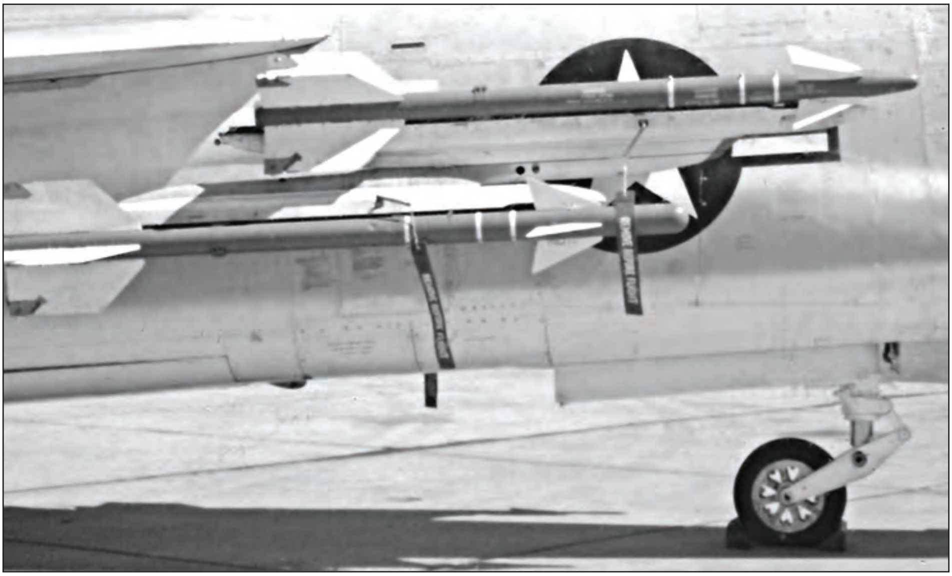
7 Gaye Ritter, "Sidewinder in the Fleet," NOTS 2068, *Weapons,* 34. Ritter was a NOTS physicist who conducted simulation studies for Sidewinder.

8 Frank Cartwright quoted China Lake engineer Gene Younkin as saying, "That fellow McLean was really smart. He designed the missile, Sidewinder, and it's so well designed that five generations of engineers haven't been able to screw it up yet." S-112, AOD Group interview, 14 March 1980, 76.



Sidewinder AIM-9C (SARAH, bottom) and AIM-9D (IRAH, top).

With the advent of the Joint Designation System in 1963, the original Sidewinder 1 became the Air-Intercept Missile (AIM)-9A. The Sidewinder 1A of Formosa-shootdown fame became the AIM-9B. (Sidewinder 1B, a folding-wing model designed for internal carriage, never made it to the Fleet, although the seeker portion of it became the seeker for the Redeye shoulder-launched missile.) Of the two variants that NOTS had been calling Sidewinder 1C, SARAH became AIM-9C, and IRAH became AIM-9D. The mishmash of alphanumerics causes confusion to this day.

With either of its two seeker heads, the new Sidewinder—with improved rocket motor, wings, fuze, and warhead—promised a large improvement over the combat-proven AIM-9B. The tactical firing envelope of the new weapon would be twice the tactical firing range of the 9-B at altitudes from sea level to 80,000 feet.

AIM-9C

SARAH, or Sidewinder AIM-9C, was Tom Amlie's baby. Unlike the other Sidewinders, it was a semiactive homing missile; that is, the seeker tracked a signal that was transmitted by the launching aircraft's radar and reflected from the target aircraft (or, alternatively, the seeker could track a jamming signal sent out by the target aircraft). The -9C, being radar-guided rather than infrared-homing, had two advantages over the IR-based AIM-9B and -9D. First, the -9C could operate in any weather (clouds block infrared radiation but not radar signals). Second, because the seeker tracked a radar signal reflected from the target, it allowed nose-on shots (the IR seekers of the day homed on the heat signature from the jet engine exhaust at the aft end of the aircraft, so early IR weapons were least effective when launched from directly in front of the aircraft).

In a 1980 paper, Amlie wrote that "the AIM-9C was designed to be launched from the F-8D/E [Crusader] aircraft and its purpose was Fleet air defense; i.e., head-on attacks against incoming bombers." The F-8s would fly not from the newer carriers but from older WWII-vintage carriers that under a project designated SCB-27C had been converted to handle jet aircraft. As Amlie explained, "The smaller 27C carriers of that era could not accommodate the heavy and fast F-4 [Phantom] which carried Sparrow [the radar-guided medium-range AIM-7]."[9]

Radar guidance for Sidewinder had been investigated by John Boyle in the Raywinder program, which began as an Exploratory and Foundational (E&F) research program in 1955. E&F money—typically about 5 percent of project-designated funding—was not earmarked for any specific project and Station management had wide discretion in its use. L. T. E. Thompson described the essence of E&F money as:

> . . . to stimulate new-approach exploratory work at NOTS. . . . In my opinion this provision meant as much as anything ever done in the effort to attract and hold good R&D people.[10]

"Good R&D people" included Boyle, whose far-ranging interests and interdisciplinary acumen pushed the envelope of weapons development in several different areas during his 32-year career at China Lake and later at the Naval Weapons Laboratory, Dahlgren. Boyle's Raywinder concept was a Sidewinder with a passive radar seeker that could be used to track radar sources, such as a bomber's radar tail-turret.

The Station's leaders believed that development of Boyle's concept could lead to a semiactive radar missile, a combination IR-RF missile, or an air-to-surface passive radar-homing missile. According to Boyle, a Raywinder test firing in August 1957 missed the target by 9 inches, prompting a congratulatory

9 Tom Amlie, "AIM-9C," unpublished paper, 1980, 1. The SCB-27C carriers were USS *Hancock* (CVA-19), *Intrepid* (CVA-11), *Ticonderoga* (CVA-14), *Shangri-La* (CVA-38), *Lexington* (CVA-16), and *Bon Homme Richard* (CVA-31).

10 S-5, Vice Adm. George F. Hussey and Dr. L. T. E. Thompson interview, April 1966, 106. In 1961 Station leaders said that E&F funding was approximately $2 million "during each of the past several years." *Reply to Questionnaire for In-House Research and Development Activities*, NOTS IDP 1447, 56.

message from Rear Admiral Frederick S. Withington, Chief of the Bureau of Ordnance.[11]

The Aviation Ordnance Department (Code 35), headed by Newt Ward, was the home of Sidewinder. Specifically, the program was located in the Development Division (Missiles) run by Dr. Walter B. "Walt" LaBerge. In 1956 Amlie, at the suggestion of LaBerge, transferred from Development Division (Missiles) to Development Division (All-Weather Fire Control), run by John Gregory. Amlie recalled that LaBerge told him:

> "Those people . . . are starting to fiddle around with a radar version of the Sidewinder and I want you to watch what they are doing." So I did. I came up to see what they were doing, kept tabs on them. Because we were essentially in charge of the Sidewinder down there.[12]

Early in 1957 LaBerge left China Lake to work for Philco. The Sidewinder program, then under Charles P. Smith, was moved to Code 40, the Weapons Development Department. Smith became head of the Interceptor Missile Branch in Frank Cartwright's Air-to-Air Weapons Division. According to Peggy Rogers, part of the reason for this move may have been because Smith and Amlie "fought like cats and dogs."[13]

Amlie claimed that the reason for the Sidewinder move was money. Code 40 "had no jobs, no projects. There had been pretty bad mismanagement. So it was decided to give the whole Sidewinder program, lock, stock, and barrel, to [that code]." By all accounts, including his own, Amlie flatly refused to leave Code 35.

> This outraged me, because I thought Newt Ward was a genius, and I just was damned if I was going to leave AOD.
>
> So everybody said, "OK, cool it. You don't have to go to Code 40. You can go upstairs [the third floor of Mich Lab] and work with those radar nuts."[14]

Amlie stayed in AOD with the "radar nuts," leading the SARAH project as a branch head under John Gregory while the rest of Sidewinder and IRAH moved over to Code 40. (At that point, Sidewinder 1B production support was

11 S-180, Boyle interview, 36.
12 S-109, Dr. Thomas S. Amlie interview, 24 Aug 1976, 14. "Down there" refers to Michelson Laboratory's second floor; the radar Sidewinder folks were situated on the third floor.
13 Dr. Marguerite Rogers interview, 22 July 1976, 1, in "Biography, NWC Technical Directors, March 1968–March 1970, Thomas Strong Amlie," unpublished data package compiled by Michelle Ballinger, Summer 1976.
14 S-199, Dr. Thomas S. Amlie interview, 1 June 1992, 39–40; S-109, Amlie interview, 14.

Dr. Thomas S. Amlie.

being handled out of Code 55 (the Engineering Department) In 1958 Amlie took over the division, which had been renamed Development Division 4 (Weapon Systems), and led it until his selection for Technical Director in 1968. Rogers commented of the SARAH-IRAH split that "the leaders didn't get along worth a hoot and the different teams didn't communicate very well."[15]

"He was made a division head partly because he had a PhD in electrical engineering. No one else even had a master's," said Jim McLane, who served as head of the of the Systems Projects Engineering Branch under Amlie. "Also, he understood SARAH, a project that the division worked exclusively on for about 10 years, better than anyone else."[16]

Progress on SARAH was rapid, albeit with a few bumps. Designed before integrated circuits were available, the -9C contained many discrete components (transistors, resistors, capacitors) as well as three vacuum tubes, including a klystron local oscillator. Packaging was a challenge. As the 1958 *Technical Program Review* quaintly described it, "…the packaging problem is that of putting a very sensitive radar receiver, guidance subassemblies, and all the necessary power supplies in a volume equivalent to that of a two-pound coffee can."[17]

NOTS let a contract to Texas Instruments for a dozen electronics packages. When problems arose with the original packaging design, the NOTS team

15 Dr. Marguerite Rogers interview in "Biography, NWC Technical Directors," 1.
16 Jim McLane, "Casual interview," 15 July 1975, "Biography, NWC Technical Directors," 178.
17 *Technical Program Review 1958*, 108.

redesigned it to make it more production friendly, and in August 1958 let a contract to Motorola, Inc., for 30 prototype production units.

Packaging was only one problem. Because of radar noise, the gyro for the semi-active seeker had to spin three times as fast as an IR Sidewinder gyro. In knee-bone-connected-to-the-thigh-bone fashion, the faster-spinning gyro had greater stiffness than its predecessor, requiring five times the torque to move the gyro. This in turn required the addition of a torquer system.

Throughout the design and development process, the -9C team stressed simplicity, which they knew translated into reliability. In a 1980 interview, Amlie would comment “Another thing about Sidewinder is, even your early one with seven vacuum tubes was a very sophisticated design. It’s just that the sophistication stayed in the mind of the designer and never got into hardware, which is exactly opposite to the way we do things now.”[18]

Earl J. Donaldson, who was the lead electronics technician on the AIM-9C, concurred. He recalled that:

> We tried to stay away from sophistication, which brings in complexity and failures. In talking to Dr. McLean about this many years ago, we strived here at China Lake to build an expendable round of ammunition so we didn’t have to require a battery of Navy technicians and half a deck of test equipment to check it out before you put it on an aircraft. This was the philosophy behind the Sidewinder.[19]

Despite the packaging and gyro difficulties and the third of a year spent solving a noise problem in the receiver, before the end of 1958 a SARAH flight-test vehicle fired at a slant range of 8,000 feet passed within 3 feet of the target emitter.[20]

With a two-stage (booster and sustainer) propulsion unit, and a continuous-rod warhead (an expanding ring of steel traveling at a velocity of more than 3,000 feet per second), AIM-9C was shaping up to be a formidable weapon. While work at NOTS progressed, researchers and engineers at Corona were developing sophisticated fuzes suitable for the more complex “end-game geometries” that both the -9C and -9D would encounter. Jess Lamar, head of the Special Projects Branch in Amlie’s division, developed an active optical fuze based on a xenon flash tube. Though it was thoroughly tested at SNORT (in the only air-to-air firing test, the missile made a contact hit on the target

18 S-112, AOD Group interview, Dr. Thomas S. Amlie, 11.

19 Ibid., Earl Donaldson, 16. When Donaldson reported to China Lake in 1952 with his wife and three children, he was assigned to a trailer, with shared bathroom and shower facilities, on a dirt street.

20 *Technical Program Review 1958*, 107.

aircraft), Lamar's fuze was never fully developed; Corona had the responsibility for fuzing. (Throughout its existence, NOTS China Lake repeatedly had its hand slapped for working in areas that were assigned to other laboratories.) Several years would pass before the advent of laser diodes made the active optical fuze practical. The fuze was incorporated in the AIM-9L in 1976.

AIM-9C used the same airframe as the IR-guided AIM-9D except that the -9C needed an additional 5 inches of length to accommodate the seeker hardware. Unwanted flight oscillations in early flight tests were resolved by replacing the cast-aluminum wings with a stiffer honeycomb material and redesigning the rollerons and their dampers.[21]

Amlie's team tackled each technical challenge enthusiastically. Earl Donaldson translated Amlie's gyro-platform concept into hardware, and Donald J. Stewart made improvements in the gimbaling and detector mounting. Lowell Smith and Richard D. Rohret developed a "ruggedized" crystal oscillator, and Conrad "Connie" Neal resolved a problem with generator gas that was shorting out the guidance system. Norman F. "Norm" deGroot, head of the Missile Guidance and Control Branch, developed the -9C antenna, and Gene Robertson was responsible for the receiver and signal processing. Douglas C. Deyoe and Jim McLane oversaw the manufacturing by Motorola, the -9C prime contractor. Coors Brewing Co. of Golden, Colorado, manufactured -9C's radome using a ceramic material that Coors had developed to line beer vats.

A host of more mundane but no less important items were necessary for a functioning weapon system. These included test sets, Fleet handling equipment, launcher power supplies, training rounds, containers, documentation, and a great deal more. These items were no less essential to the success of the -9C—or to any guided missile—than were the motor, guidance section, and warhead. The contributions of the engineers and technicians who developed, tested, refined, and perfected the less glamorous elements of the weapon system were essential to the overall success of Sidewinder.

In 1963 and 1964, AIM-9C underwent a rigorous VX-4 Operational Evaluation and passed with flying colors.

21 The rolleron is a classic example of a simple, elegant solution to a technical problem—how to reduce the rate at which Sidewinder rolled around its own longitudinal axis, an undesired behavior that occurred at high altitudes and that increased the demands on the GCU. With the rolleron, the airstream causes a small notched wheel set into a hinged tab (one on each of the four tail fins) to spin at high speed, establishing gyroscopic torque (resistance to moving outside the plane of rotation). When the missile begins to roll, the torque is transferred to the hinged tab, which then deflects into the air stream. That deflection exerts a force counter to the direction of roll. The idea was devised by Sydney R. "Sid" Crockett, a high-school-educated shop foreman on the original Sidewinder team.

Amlie said that during OPEVAL at Point Mugu:

> We knocked down 11 drones . . . with contact hits. Finally the drone officer said, "You can't shoot my drones anymore. They are too expensive; we don't have enough and they are hard to get. You just can't do that." I said, "That's a chicken thing to do."[22]

AIM-9C entered the Fleet in 1964. Amlie was a member of the Fleet introduction team for three of the aircraft carriers. As Ron Westrum observed in his history of Sidewinder, "Having a PhD leading the program onboard ship sent the unmistakable message that China Lake stood behind its weapons."[23]

The missile had some problems. Because of limitations of the airborne-intercept radars in the F-8s, performance was poor at low altitudes and in look-down situations, where ground clutter confused the seeker. Whether AIM-9C would have performed as well in combat as it did in OPEVAL is a moot question. Amlie wrote:

> The AIM-9C was not used in combat in Vietnam because nobody attacked the Fleet, and the dogfights over land usually ended up at very low altitude where the AIM-9D was a much better choice and did in fact produce excellent results.[24]

Also the "head-on" aspect of the short-range missile's performance was a fundamentally flawed concept. Amlie would later say that:

> . . . it turns out that the whole thing was a mistake because head-on shots don't occur in nature. Hardly ever. They're almost all tail shots, and the infrared missile's cheaper and more accurate, certainly.[25]

Another disadvantage was that AIM-9C was restricted to the F-8 Crusader as a launch platform, rather than the newer, more capable F-4 Phantom. Said Amlie:

> There was a political problem. I personally designed it so it would have fit the F-4 even better than it fit the F-8. I would bring that up to the Navy, and of course the Sparrow was the naval aviation sacred cow, and so I wasn't ever even allowed to look at the F-4, although the missile was certainly compatible with it.[26]

Some questioned the practicality of a semiactive-radar short-range missile in a dogfight. Peggy Rogers commented that:

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22 S-109, Amlie interview, 25–26. *NOTS Tech History 1964,* 1-30, reports 13 contact hits.
23 Westrum, *Sidewinder: Creative Missile Development at China Lake*, 184.
24 Amlie, *AIM-9C*, 1–2.
25 S-199, Amlie interview, 44.
26 Ibid., 44.

> The basic problem was that it required the pilot to look inside the cockpit on a scope to acquire the target. When a guy is in a dogfight he's going to keep his head up and look off and keep his eye on that target every moment. He doesn't like to look down into a small scope to see the radar return and his missile locked on that target.

Rogers, who had as much weapons-development experience as anyone on the Station, added, "This frequently happens to weapons. They are very fine in concept, but there's some little hooker in the way you have to use them."[27]

As the 1960s wore on, the need for a short-range missile to be used in Fleet air defense against incoming Soviet bombers seemed less pressing than it had in the 1950s. About 1,000 -9Cs were produced between 1965 and 1967. The 1967 *Technical History* reported that "during 1967 the Navy expended an AIM-9C for the first time in combat," but no other evidence of combat use was found during research for this book. The same issue of the *Tech History* mentions the missile's "limited use in the Fleet because of the requirement for use of the radar by the combat pilot."[28]

Many of the AIM-9Cs were later remanufactured by Motorola as Sidearm, the AGM-122 air-to-surface antiradar missile. Sidearm was developed by China Lake beginning in 1980 under Dick Mello's direction as a lightweight radar-suppression weapon for fixed-wing aircraft and helicopters.

A lesson about weapon systems can be taken from the Sidewinder AIM-9C. When McLean developed the original Sidewinder concept, it masqueraded for a time (for political, bureaucratic, and financial purposes) as a fire-control system. However, McLean believed that the solution to the air-superiority problem was not an aircraft-borne fire-control system, but rather a fire-control system that was incorporated within the missile itself. Once the missile was launched, the launch aircraft was extraneous to the missile's success. This relative autonomy for the IR Sidewinders allowed them to be used on the widest variety of U.S. and foreign aircraft with relatively minimal adaptation.

Guidance for the AIM-9C, by contrast, was dependent on the F-8 Crusader's Magnavox AN/APQ-83 and -94 airborne-intercept radars. When the smaller 27C aircraft carriers were replaced in the Fleet, the Crusaders (and their AIM-9Cs) were replaced with the F-4 Phantom (and its Sparrows and its AIM-9D IR Sidewinders). The AIM-9C had tied its fate to an aircraft that was on the way out.

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27 Rogers interview, "Biography, NWC Technical Directors," 1–2, The Ault Report (1969) would refer to this phenomenon, in the context of the Sparrow semiactive missile, as fighting "in a 'heads-up' environment with 'heads-down' cockpit displays."

28 *NWC Tech History 1967, Part 1,* 5-3, 5-45.

AIM-9D

The Sidewinder team (save for Amlie's -9C "radar nuts" and Sidewinder 1B production support folks in the Engineering Department) settled into Code 40 where Chuck Smith took the lead for IRAH development. Babcock relates of Smith that in the early days of Sidewinder development "his schedule of day-and-night work earned him legendary status even on McLean's industrious team."

Phil Arnold, who served as a branch head under Smith beginning in 1962, remembers that Smith "worked incredible hours and slept at odd moments during the day and night." Arnold recalled incidents of visiting Smith's office to talk with him "on some matter I thought important . . . I would notice the pupils of his eyes had changed diameter and realize he was sound asleep with his eyes open, sitting bolt upright in his chair."[29]

Some of the Station's best talent was working on Sidewinder. Dr. Edward E. "Mickie" Benton joined the team in January 1962 as head of the Optical Design Branch. Benton had come to China Lake in 1953—his son was born the day of the first Sidewinder direct hit on 9 January 1954—but had left on a fellowship in 1958 to earn his doctorate at the University of Texas.

In January 1963, Burrell Hays, who would become China Lake's Technical Director in 1982, helped set up the Sidewinder Production Office in the Engineering Department.

W. G. "Gene" Younkin, who had been with the Sidewinder program since the early days, headed the Systems Analysis Branch during -9D development. Younkin recalled that the original -9D design incorporated a Sidewinder Acquisition and Track (SWAT) capability, designed by Magnavox, for off-boresight target acquisition. The circuitry would drive the seeker in a spiral scan pattern searching a 20-degree-diameter angle in front of the missile until a target was encountered. SWAT "was dropped from the design for economy prior to deployment."[30]

Kenneth J. "Ken" Powers, who had previously worked on Sidewinder as a lieutenant (j.g.) in the early 1950s, served as assistant division head for the Sidewinder group. Powers recalled that the new rocket motor—which was to

29 Babcock, *Magnificent Mavericks*, 105; S-275, Arnold interview, 18. Arnold also said of Smith, "Though he was educated as a physicist, he was the best electronics engineer I ever saw, and I've seen some pretty good ones."

30 Gene Younkin, "The Clan Sidewinder," informal paper, unnumbered pages, 1 May 1979. Phil Arnold believes SWAT was cancelled because its host aircraft, the F8U-2N (F-8D), ceased production in 1962. (It was soon replaced by the F-8E.)

be common to both the IR and RF versions—became an issue early in the -9C and -9D development. Code 45, the Propulsion Development Department, had Bureau backing to develop a complex five-segmented sustainer motor that would control the speed of motor burn according to the launch velocity of the missile. According to Powers:

> On paper that motor was fantastic. Frank Cartwright felt that it would never work. Frank was right. Frank felt we had to have a credible motor or the whole Sidewinder 1C program [both -9C and -9D] would have a black mark and might even be cancelled. … Frank essentially took one million dollars and gave it to [general engineer] Nadim Totah, and said, "Totah, you go develop a rocket motor as follows: aluminum tube, single-stage, internal burning, etc."
>
> … The important thing is . . . the division head diverted approximately a million dollars without telling the Bureau about it . . . but he got the motor developed that has become the Sidewinder 1C rocket motor, and when the segmented thing fell on its face, Cartwright said, "Hey, look what we happen to have from the back room." … The Totah motor became the mainline Sidewinder 1C rocket motor.[31]

As Frank Knemeyer described it, "Code 45 failed to do a good job on the Sidewinder rocket motor . . . Nadim Totah, Ed Creer, and Roland Baker then developed the actual Sidewinder motor in Code 40."[32]

The issue was summed up most diplomatically in the NOTS annual technical overview for 1958:

> More detailed studies of the propulsion requirements for the advanced missile indicated that the sustainer motor will not be required to provide the degree of velocity control that was originally planned. Accordingly, the 5-segment propellant grain in the sustainer stage has been replaced with a single internally burning charge, resulting in a much simplified and more reliable propulsion unit.[33]

The -9D's designers wanted to extend the wavelength at which the seeker operated in the infrared. Mickie Benton said that group members "wanted to go to out past 4 microns but it turned out that the infrared detectors at the time just weren't quite good enough to do it." Nevertheless they achieved the desired result by "cooling . . .the same type of detector material that we had in the original Sidewinder that gave it a lot more range and gave it more sensitivity. It was cooled with liquid nitrogen." The nitrogen cooling also allowed the seeker better discriminate the target against IR-saturated background—background

31 S-123, Ken Powers interview, 18 May 1981, 8–9.
32 S-200, Knemeyer interview, 84–85.
33 *Technical Program Review 1958*, 109–110.

with a high degree of IR radiation, which made for minimal contrast between background and target. Integral to the cooled seeker were a novel refrigerated detector unit (RDU) and a very small regenerative cooler designed by Santa Barbara Research Center.[34]

An added benefit of the increased seeker sensitivity using the cooled detector was that it permitted a smaller IR window in the front of the missile thus allowing the high-drag blunt nose of the earlier Sidewinders to be replaced by a more aerodynamic ogival (egg-shaped) nose section, with a resulting extension of the weapon's range.

NOTS contracted with Philco to assist in developing the Sidewinder guidance-and-control units (GCUs), but the relationship was not a smooth one. Poor quality work at the contractor repeatedly delayed the program. In the words of Ken Powers:

> Philco was running an out-of-control "garage operation" on a large scale; they didn't build the missile according to the drawings; they only made the drawings in order to satisfy the Bureau requirements; they made the missile based upon their internal paperwork; and they did not convert their paperwork into drawings.
>
> . . . I looked at their internal records; one missile had gotten into final test 30 times, and every time had failed because of reliability problems, cold solder joints, burned-out resistor, open connection on the circuit boards, etc. I asked . . . the NOTS main contact at Philco, "How can you possibly expect us to use this once we get it, because obviously it's very unreliable?" He said, "That's not my problem. I'm only trying to get it through final test. I don't care what you do with it once you get it." Now with a team member like that, you don't need enemies.
>
> . . . At one time we had a crew of about 20 people back there to inspect, review, modify, and certify their internal test equipment calibration system. We also required them to have a form to fill out every time they had a failure. They fought that very strongly, but they finally had to do it, and the results convinced the Bureau, I believe, that there was a significant problem, and Philco then had to shape up some. Philco personnel were shifted and things did improve.[35]

Navy Technical Evaluation of the AIM-9D began in October 1962 and was completed in 1963, with a 74-percent firing success rate. VX-4 then conducted Operational Evaluation and completed it in early 1964. In one test a missile

34 S-286, Dr. Mickie Benton interview, 8 April 2008, 4. A version of the RDU was also used in the Target Radiant Intensity-Aerobee (TRIA) sensors developed by NOTS as part of the HITAB program described in Chapter 2.

35 S-123, Powers interview, 3–5.

fired in June 1963 from an F-4B at an altitude of 83,000 feet passed within kill distance of a target rocket, making it, at that time, "the highest altitude on record in the Free World at which a missile launched from an aircraft has successfully intercepted a target."[36]

In 1964 the production contract for the AIM-9D GCUs went out for bids. The Bureau saw no need for China Lake's further involvement. Raytheon Co., the Sparrow III missile contractor, submitted a bid less than half that of Philco's. Raytheon was given the contract to produce the GCUs using the design-disclosure package that NOTS had developed. According to Arnold:

> The bid was low, and Raytheon had a great deal of trouble producing seekers. Chuck Smith was sent by [Technical Director of the Missile Development Office, BuWeps] John Rexroth, to work with Raytheon to fix the problem.
>
> . . . Chuck and Jim Foust, a technician in charge of the clean room in the Infrared Systems Division, showed up at the Raytheon plant and went to work. Jim worked over the company's cleanroom procedures and lectured them on calibrating their test equipment. Chuck went through the company specifications and procedures and worked with Raytheon to either change the company procedures or adapt China Lake procedures to fit the company system. At the end of the visit, Raytheon was producing seekers that met spec and earned a profit.[37]

Dick Meeker and Mike Kamimoto designed a launcher for the -9D incorporating a bottle of nitrogen to cool the lead sulfide detector prior to launch.[38]

As with the -9C, myriad specialized pieces of support equipment were designed, tested, and incorporated into the overall weapon system. For example, NOTS worked with Air Dry Co. to design and develop a passive filtration unit (PFU) that provided clean gas under high pressure to charge the launcher cooling bottles.

In 1964 China Lake engineers developed SEWHAT (Sidewinder Exercise and Warhead Telemetry) for the AIM-9C and -9D. Employing an all-solid-state nonproprietary FM/FM telemetry system, SEWHAT Mk 6 evolved into

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36 *NOTS Tech History 1963*, 1-29.

37 S-275, Arnold interview, 19. Knemeyer in a review comment noted that "Nothing came off the Raytheon production line for over a year."

38 Meeker and Kamimoto were veterans, along with Lee Jagiello, of the famous Sidewinder airframe test series, circa 1952, in which they drove a Navy truck across Mirror Lake (a playa in the China Lake housing area) with a Sidewinder model airframe suspended on a long metal pole that Kamimoto stuck out the window. When Kamimoto received static electricity shocks, they switched to a bamboo pole.

three models: one for pilot training, another for production monitoring, and a third (monitoring all main missile functions) for R&D applications. The R&D model was also repackaged for AIM-9B carriage.[39]

Compared to its IR predecessors (the -9A and -9B), the -9D had a larger aerodynamic launch envelope, greater seeker acquisition range, and improved fuzing. It shared many components with the contemporaneous -9C including the new continuous-rod warhead and the new motor. AIM-9D, like the -9C, was introduced into the Fleet in 1964.

The first Fleet firings of the tactical missiles were carried out late in 1964 by VF-211 pilots flying F-8Es from USS *Hancock* (CVA-19) off Hawaii. The 9-C scored a direct hit at 5.5 miles in a head-on shot against an unaugmented Regulus I drone, and the 9-D destroyed another Regulus drone at 2.8 miles. Military pilots continued to train with the -9Bs; the -9Ds went straight to Vietnam, where they accounted for the majority of the air-to-air kills made during the Vietnam War.[40]

Between them, the -9C and -9D brought a huge infusion of funds to the Station in the late 1950s and early 1960s. In the peak year, 1960, their combined budgets were about $16 million dollars. This level of funding for Sidewinder would not be seen again at China Lake until 1972, when the AIM -9L development program hit its stride.[41]

As each new Sidewinder missile segued into full contractor production, the importance of documentation and productionizing was underscored. Items that had been handbuilt by the ones and twos in a NOTS laboratory by dedicated engineers and technicians now had to be capable of replication in large quantities, at reasonable cost, and with through processes and procedures suitable to a contractor's assembly line and spelled out precisely in drawings and instructions that—ideally—left no room for error.

Pilot production—the phase between prototype production at NOTS and full production at the contractor's facility—was a "one foot in the boat and the other on the dock" transition that was seldom without perturbations. NOTS engineers and technicians were constantly in cars or on planes traveling to and from far-flung contractors to iron out production issues.

One means that NOTS employed to ease the process was to bring potential contractors into the game early, through small contracts that let them

39 *NOTS Tech History 1965*, 5-7.

40 *NOTS Tech History 1964*, 1-31.

41 *Sidewinder Program Information*, no author given, Naval Weapons Center, Nov 1964, Attachment 3, "Sidewinder Programs Funding Chart," 5.

gain familiarity with the system they'd be producing. In most cases this early contractor participation and the relatively harmonious relationship between government laboratory (with its mission to keep weapons as inexpensive as possible) and private contractor (with a legal obligation to maximize returns to the shareholders) worked surprisingly well. Moreover, by exercising close control of the documentation and specifications that formed the basis for every manufactured part, the laboratory opened the option of second-sourcing (hiring a second contractor to manufacture the item). Second-sourcing brought competition into the picture and thereby reduced cost.

Sidewinder 1A (AIM-9B)—the weapon that had brought down the Chinese MiGs over the Formosa Strait and that was also used by the Air Force and NATO—was an excellent example of the value of competition in the weapons acquisition process. Philco was the original contractor. In 1956 the Navy solicited bids for a second production source. Eight contractors were finalists in the competition, and the winner was General Electric's Light Military Electronics Department.

As soon as GE was brought into the picture with a small initial production run (in fiscal year 1956), Philco dropped its price by ⅓ from its previous year's contract. The competition intensified, with the two companies vying to streamline their production processes and minimize their rejection rates.[42]

Quality improved and price plummeted. By 1962, *Aviation Week and Space Technology*, citing Captain Charles D. Mott, chief of BuWeps Missile, Astronautics, and Ammunition Division, reported that:

> Today, the going price of Sidewinder guidance and control units is only one-seventh the original Fiscal 1955 pilot quantity figure. Compared with the initial Fiscal 1956 high-production quantity cost, which is the more logical reference, today's price is only one-third.[43]

Even the possibility of a second-source competition was sometimes sufficient to reduce the Navy's costs. In the 1980s Texas Instruments was having production problems with the High-Speed Antiradiation Missile (HARM). Gerry Schiefer, who had been China Lake's HARM program manager in the 1970s, commented, "I think just the threat of second source has . . . caused TI to sharpen the pencil and really work at it, and there is that threat hanging over them." A comprehensive documentation package for a production-engineered

42 When GE started production it had a final-test rejection rate of 120 percent—units rejected and returned for repair often failed the final test again and sometime even a third time. Philip J. Klass, "Competition Slashes Sidewinder 1-A Price," *Aviation Week and Space Technology*, 9 April 1962, 89.

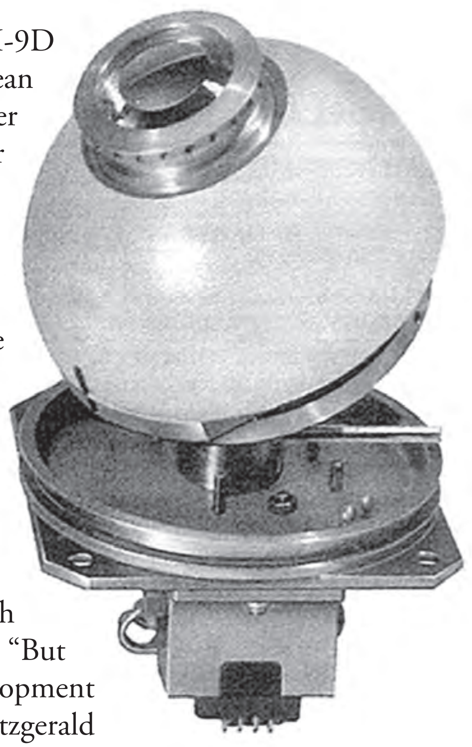
43 Ibid.

item is both a carrot—it makes the contractor's work easier—and a stick—it permits competing contractors to be more easily brought on board.[44]

With the Shrike weapon system, NOTS learned the disastrous consequences of letting a documentation package get out of government control. Not only did the incident lead to increased costs and contentious relationships between NOTS, Washington, and the contractor, but it also delayed the delivery of a much needed weapon to the forces fighting in Vietnam.

Dual-Mode Seeker

Even as the AIM-9C and AIM-9D progressed through development, McLean was supporting a third Sidewinder guidance approach. The dual-mode seeker was assigned to Bud Sewell's Long Range Missile Branch in Code 40. The plan was to incorporate both the -9C radar and -9D IR capabilities in a single seeker head. This combination would "provide in one missile the ability to home semiactively by radar during foul weather, and passively and more accurately on infrared radiation when such radiation from the target can be received."[45]



Dual-mode seeker hardware.

"None of us, with the possible exception of Bud Sewell, knew much about radar systems," said Phil Arnold. "But we took it on in an advanced development project." Bob Lawrence and Bill Fitzgerald tackled the basic design of the seeker, while Arnold worked on the range-gate system (a technique whereby once the radar signal reflected from the target is detected, signals from outside that range—as measured by the time between signal transmission and reception—are ignored). Like the AIM-9C, the radar portion of the dual-mode seeker would home on a radar signal transmitted by the launching aircraft and reflected from the target aircraft.[46]

44 TS 84-14-7, Schiefer interview, 38.
45 *Technical Program Review 1958*, 109.
46 S-275, Arnold interview, 10.

In April 1959 Admiral Arleigh Burke visited NOTS for a familiarization tour of the Station's activities. The dual-mode seeker was chosen as one of the projects to be displayed in Mich Lab, and Phil Arnold was selected to explain the display model. Just before Burke's visit, BuOrd Chief Stroop and McLean held a dry run. Arnold was disappointed when, after he had finished his presentation, McLean "turned to Stroop and remarked that he was thinking about training dolphins for naval operations."[47]

After a few unsuccessful test flights of the dual-mode seeker in the IR mode, the program was ended. Sewell later reported that:

> We never finished it, no. It was at that time a little bit ahead. Realize we were still having to use vacuum tubes for IF strips at that time. We didn't have a good transistorized IF strip.

The concept was revisited again in the late 1960s. However, as Sewell observed, the "changes [in available technology] that occurred from 1958 to 1965 were tremendous."[48]

AIM-9E, -9F, and -9G

After the AIM-9C and -9D went to the Fleet, the 1960s would see further Sidewinder development work in the form of the AIM-9E and the AIM-9G. The AIM-9F designation was assigned to a German version of the AIM-9B produced by Bodenseewerke Gerätetechnik (BGT) that was upgraded with a silicon seeker dome, a CO^2-cooled detector, and some semiconductor electronics.

AIM-9E was a Philco-designed Air Force upgrade of the AIM-9B (the service had not participated in the -9C and -9D program). Five thousand AIM-9Bs were given a new seeker with Peltier thermoelectric cooling (which allowed unlimited cooling time on the launch rail), enhanced low-altitude capability against maneuvering targets, a wider search angle, and better target-tracking speed. The nose was conical (rather than ogival), and the swept delta wings were located further back on the missile. The -9E entered service in 1967. In a variant designated AIM-9E2, the original Mk 17 rocket motor was replaced with a reduced-smoke version (SR-116). The -9E lacked the range and seeker

47 Ibid., 11. Both Arnold and Sewell recall that Burke, in a management pep talk, said words to the effect that "We don't know just what you're doing out here, but it's obviously right so keep on doing it." S-106, Sewell interview, 12; S-275, Arnold interview, 11.
48 Robert G. S. "Bud" Sewell interview by Dr. Ron Westrum, 23 Feb 1993, 20. In 1974 Guenter H. Winkler and Robert P. Moore of NWC's Electronic Systems Department would receive notices of allowability on their patent application for a dual-mode seeker.

discrimination of the -9D and the Air Force replaced it with an improved version in 1972.

Legendary Air Force triple ace General Robin Olds summarized the feeling of many Air Force personnel toward Sidewinder:

> It occurred to me that we were the warrior victims of an ongoing battle between the Air Force and Navy. Our Sidewinder was a Navy missile that had been thoroughly tested and proven in actual combat. That meant the Air Force procurement people had to go hat in hand to obtain a share of the production, and it also meant the operators had little or no control over any future changes and improvements. Bureaucracy![49]

The AIM-9G was an improved AIM-9D that offered an expanded off-axis target-acquisition mode called the Sidewinder Expanded Acquisition Mode (SEAM). Developed by the Magnavox SWAT team, SEAM slaved the seeker to the scan pattern of the aircraft's radar. The -9G went to the Fleet in 1968, and 2,120 missiles were manufactured by the prime contractor, Raytheon.

Sidewinder performance in the early years of the Vietnam War was not particularly auspicious, for a number of reasons. The weapons employed old tube technology; until the solid-state Sidewinder AIM-9H came along in 1973, the missile's electronics, particularly its vacuum tubes, took a harsh beating from the repeated shocks of shipboard catapult launches and arrested landings. Sparrow, a longer-range air-to-air missile (22 miles versus the -9D's maximum of about 11 miles), was available to both Navy and Air Force pilots. If a MiG—for that was the only real airborne threat—could be detected early enough, Sparrow was the weapon of choice. Dogfight training, too, was not all it should have been. The techniques used in WWII and even those of the Korean War did not fully exploit the capabilities of the newest aircraft and weapons.

By 1967, performance was improving. Raytheon's production rate for the -9D Mk 18 Mod 1 GCU was up to a high of 275 acceptable units per month. The *Tech History* reported that:

> Increased availability of all AIM-9D missile components resulted in expanded Fleet distribution and operational expenditures in the Southeast Asia conflict. The ratio of hits to valid firings (missiles fired from within the prescribed launch envelope) is approximately 70 percent against MiG aircraft.[50]

The total number of Vietnam War kills for the various versions of Sidewinder (-9B through -9H) is widely reported as 82. Nearly all of the kills occurred during the two major U.S. air campaigns of the war: Rolling Thunder

49 Robin Olds, *Fighter Pilot,* St. Martin's Press, New York, 2010, 306.

50 *NWC Tech History 1967, Part 1*, 5-41.

(1965 to 1968) and Linebacker I and II (1972). The number of U.S. aircraft lost to MiG-17s, -19s, and -21s, by comparison, was 90.[51]

Overall, making no allowance for in- or out-of-envelope launches, Sidewinder's success rate in Vietnam combat was 18 percent kills, 35 percent misses, and 47 percent failures. Comparable performance for the AIM-7 Sparrow was 9 percent kills, 25 percent misses, and 66 percent failures.[52]

Sidewinder's combat performance was considerably better for the Navy than for the Air Force. Many factors contributed to the disparity including differences in the aircraft types, mix of Sidewinder types used (kill rate for the AIM-9E, used by the Air Force but not the Navy, was only 8 percent), training, tactics, and mission profiles. Another significant factor was targets: 68 percent of the Air Force engagements were with the newer MiG-21s, versus 42 percent for the Navy.[53]

The Albuquerque Incident

Back in 1957 a group of Air Force reservists from Fresno had been invited to China Lake to learn about the new weapons being developed by NOTS. Although a Sidewinder test scheduled for the day of their visit was cancelled, they did watch a film about the new missile.

Following the presentation, Commander Glenn A. Tierney, (commanding officer of China Lake's Guided Missile Unit 61 and the principal Sidewinder project pilot) spoke to the reservists.

As member of the audience remembered the event:

> "As you have seen on the film," said Cmdr. Tierney, "The Sidewinder really has a 'brain' and once it is launched nothing can stop it from hitting its target. It's very close to the 'ultimate ultimate,' I would say."
>
> "Suppose," asked a reservist, an ex-fighter pilot who probably (as did a great many others) had reason to recall such an incident during his war experience, "suppose a pilot, during the excitement of battle, inadvertently launched that thing at one of his own planes? Could he stop it, or turn it?"

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51 James F. Dunnigan, *How To Make War: A Comprehensive Guide to Modern Warfare in the 21st Century*, Fourth Edition, 2003, William Morrow and Co., New York, 191. Marshall Michel reports 81 Sidewinder kills; however, his book covers the war from 1965 through 1972, and the final U.S. MiG kill of the war took place on 12 Jan 1973. Marshall L. Michel III, *Clashes: Air Combat over North Vietnam*, 1997, 287; Robert K. Wilcox, *Scream of Eagles*, Simon and Schuster, 1990, 283; Hobson, *Vietnam Air Losses*, 271.

52 Michel, *Clashes*, 287.

53 Ibid., 278.

> "There is only one answer to that," smiled Cmdr. Tierney. "You get on your radio and yell to the pilot of the plane you shot at: 'Sam, you've got 4 seconds to bail out!'"[54]

Tierney's joking comment foreshadowed a deadly accident in the skies over New Mexico on 7 April 1961. The tragedy pointed up the danger associated with training missions as well as the critical importance of attention to detail when dealing with live ordnance.

The incident began as a routine training mission when the B-52B *Ciudad Juarez* took off from Biggs Air Force Base in Texas and flew into New Mexico airspace. A pair of F-100A Super Sabres from the New Mexico National Guard approached the bomber near Albuquerque for an interception exercise. Each F-100 carried two Sidewinder AIM-9Bs on its left wing pylon. After verifying that the switches for the 20-millimeter cannons and Sidewinders were in the "off" position, the interceptor pilots made several runs against the B-52. The F-100s were on "strip alert," as part of the nation's primary air-defense system, and thus were carrying live missiles and live ordnance.

On the sixth and final run, one of the F-100 pilots was making an approach from the rear of the bomber, so that the B-52 tail gunner could practice tracking him, when one of the Sidewinders fired. The missile homed on the bomber's left inboard engine pod, exploded, and severed the wing.

"I heard [the F-100 pilot] call 'Look out! My missile's fired.' We were on autopilot and I grabbed the controls just as the missile hit," the B-52 pilot recalled.[55]

High *g* forces made escape from the falling aircraft difficult. Three of the crewmembers were killed (two by fragments from the Sidewinder's warhead), and five others were seriously injured.

Bud Sewell and fellow NOTS engineer Wayne Zellmer were part of the post-accident investigation team. The conclusion that some local papers had jumped to—that the missile switches had actually been "on" and the F-100 pilot had fired the missile—was ruled out. The cause of the accidental launch eventually turned out to be a crushed plug in the wing of the F-100 that carried wiring from the power and control signals to the launcher. This connector had been battered by the wing flight-control hydraulic line that made a right-angle bend next to the connector. The connector, when it was impacted by the

54 Bud Nelson, "Air Reservists from Fresno Watch the Navy's Mojave Mission," *The Air Reservist*, May 1957, 9.

55 Aviation Safety Network Flight Safety Foundation, *http://aviation-safety.net/wikibase/wiki.php?id=48341*, accessed 8 July 2010.

hydraulic line, was able to complete the firing circuit. Damage to the connector was found in five out of five of the unit's F-100s that were examined.

Ironically, this problem had been first identified in 1956, and a corrective change had been developed. But somehow that change had not been carried into all the production drawings and was not implemented in the Air Force. A contributing factor was that the Air Force at that time, unlike the Navy, did not use training rounds but rather carried out its training exercises with live missiles.

Sons of Sidewinder

Sidewinder was a monumental advancement in weaponry. No sooner had it proved its ability to track and kill an enemy aircraft then the innovative minds at NOTS began to wonder, "Why limit this technology to an air-to-air weapon?"

In a locally funded project in 1958, NOTS engineers in the Weapons Development Department investigated the possibility of a submarine-launched Sidewinder called, naturally, Subwinder. (A concurrent program, Manta, considered the feasibility of a submarine-launched encapsulated antiaircraft missile.) Subwinder was initiated by Commander, Submarine Flotilla One, and was intended as an off-the-shelf anti-escort weapon; that is, a means to defend against surface boats (escorts) pursuing the submarine. The work was carried out in Sewell's Long Range Missile Branch in the Air-to-Air Weapons Division.

Tests conducted against destroyers and smaller craft with an IR tracking device had results that, according to the official report, were "inconclusive." The three live firings made, one against a target vessel fitted with an IR emitter, had varying degrees of success.[56]

Irving K. "Irv" Sheffield, Jr., was the project engineer for Subwinder. Don Moore—an engineer who had his hand in nearly every oddball project in the Weapons Department—also worked on the project.

Moore recalled:

> We went out to San Clemente Island, fired some rockets off [at the surface], then we lowered it down about 150 feet deep, and it was supposed to come out in front of you. Some of them came up, some of them never did. . . .What happens on a fixed body like that is that it gets up enough speed, and the cavitation from the nose removes the water from the fins, so it doesn't have any way to stabilize the missile. . . later we were able to make some of them fly stably underwater.

56 *Technical Program Review 1958*, 118.

No records indicate that Subwinder ever went beyond initial feasibility testing.[57]

Also in 1958, NOTS looked at a surface-launched version of Sidewinder. Its official name was Project Hamburger ("ground round") although some people referred to it as "Small Sam" (for Short-Range Surface-to-Air Missile, SSAM). John W. Lamb, who had come to the Station as a physicist in 1959, was one of the principal investigators. The goal of this BuOrd-funded study was to assess the feasibility of a short-range (50-foot to beyond 10,000-foot) ship-to-air weapon, "a simple one for adaptation to all types of craft and small ships, providing them with an independent antiaircraft defense with a minimum encumbrance."[58]

Project Hamburger investigators concluded that the Sidewinder could not be readily adapted to the task because of seeker shortcomings; low-altitude interception injected high noise levels from background radiation and surface reflections into both IR and semi-active radar seekers. Also the then-available Sidewinder motor lacked sufficient energy for an effective ground-launched version. Hamburger was terminated; however, a low level of effort continued, with the next attempt, begun in 1960, called Osprey.

In 1960 when Frank Knemeyer took over the Weapons Development Department, Cartwright, who had moved from division head to department staff with the title of senior scientist, was thinking of leaving NOTS. Knemeyer recalled he had a talk with Cartwright:

> I said, "Well, what's it going to take to keep you here?" He said, "Well, I'd like to work on . . ." what we eventually called Osprey, so it turned out that I needed about 200,000 dollars of overhead to keep Cartwright here, so I went down to Hack's office one afternoon and said, "Hack, he wants to leave, and it's going to cost us 200,000 to keep him." And he said, "O.K., you've got it." That's the way you worked with Hack [Wilson].[59]

As Chuck Bernard recalled it, McLean gave Cartwright the money. Bernard said:

> McLean said, "I'll give you some money." In those days it was a big lump of money. "Do anything you want. I want you to stick around." So Frank said, "What do you think, Chuck, shall we make a ground-launched Sidewinder?" And so I said, "Right on!"[60]

57 S-185, Moore interview, 16.
58 *Technical Program Review 1958*, 118.
59 S-200, Knemeyer interview, 65.
60 S-189, Bernard interview, 77.

Jeep in SNORT area towing Ospreys with 5-inch motors on Mk-45 tracking-camera mount, 4 June 1962.

Osprey's development goal was an IR- and radar-homing missile that would fit on a 5"/38 naval gun mount. Bernard and John Lamb were both active in the development program, as was Bob Lawrence, who was also working on the dual-mode seeker in Sewell's group. A system was put together using an old Mk-45 tracking-camera mount (a converted quad .50-caliber machine-gun mount) on which Sidewinder launch rails replaced the camera mounts.

According to Cartwright, Lawrence was given an unusual task—determining what the effects would be on the operator of the Osprey system (who would be sitting in the front of the launcher) when a missile or a salvo of missiles was launched.

> "How bad is it going to be if we put a guy in a plastic bubble [a P-2 tail turret bubble] in between these two camera rails, which will now be Sidewinder launchers, and what about the noise and the blast?" So he did a bunch of research, literature research, on how close can you get, and what's the danger of physiological stuff, and he ended up looking into what do lobsters feel when you throw them in boiling water. And he decided, I think, he will never again have a lobster.[61]

The effects of the blast were greater than those of a regular Sidewinder because the Osprey developers had replaced the 5-inch Sidewinder motor with an 8-inch dual-thrust motor and more or less, in Cartwright's words, "screwed the front end of a Sidewinder on it." They later went back to a 5-inch motor.

61 S-194, Cartwright interview, 47.

A technical development plan was completed for Osprey. Commander Robert H. Wertheim, who had been assigned as a military assistant to Code 40 and worked on Osprey, tried to sell the program back East. However, according to Bernard:

> . . . the Navy didn't want it—the surface Navy wanted a Talos kind of a missile. They wanted to reach outside of the range of the bad guy's ordnance hundreds of miles. This was a short-range system. It made a lot of sense, but we had a real bunch of dunderheads in . . . BuWeps.

The program ran until 1963 and was cancelled before development. Undeterred, NOTS continued to work on a surface-to-air version of Sidewinder, drawing on the knowledge gained from Hamburger and Osprey.[62]

Chaparral

The Army, since 1959, had been heavily investing in a forward-area air-defense program called Mauler. The new weapon was designed to counter the threat posed by low-flying high-performance fighter aircraft as well as short-range ballistic missiles, but development was plagued with problems. Difficulties ranged from the rocket motors to missile aerodynamics to launch containers but lay primarily with the Mauler's seeker and guidance system. Mauler was designed as a beam-riding system, with continuous guidance from a radar on the launch vehicle that was tracking the target, augmented by IR terminal guidance. For field mobility, the entire system of missiles, radar, launcher, and crew would be mounted on an M113 tracked vehicle.

It became apparent that the Mauler's problems were insurmountable; the program was scaled back in 1963 and then cancelled in 1965. Still, the Army was desperate for an alternative because an embedded mobile antiair capability was essential to the Army's strategic posture for the 1960s.

At NOTS the IR/RF approach of Hamburger and Osprey had been abandoned. Efforts concentrated on an IR-only weapon based on the AIM-9D. Dick Boyd, a branch head in Code 40's Air-to-Air Weapons Division, took over the program, with John Lamb as his assistant. Wertheim, who hailed from New Mexico, suggested that the developmental weapon be named after the New Mexico state bird, the chaparral (also known as the roadrunner).[63]

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62 S-189, Bernard interview, 77–78. The RIM-8 Talos was a ship-launched semiactive-radar-homing SAM with a range of about 100 miles. It was in the Fleet from 1959 until 1979.

63 Like many other naval personnel who served at NOTS, Wertheim went on to a distinguished career. An Annapolis graduate, he retired as a rear admiral after playing a central role in the development of Fleet ballistic missile systems as Director of Strategic

Overcoming Service pride, the Army realized—even while the Mauler program was still grappling with its problems—that another approach was needed for a mobile surface-to-air intercept weapon. Two weapons were looked at: NOTS' Chaparral and the Air Force's Falcon missile (AIM-4) built by Hughes Aircraft.

NOTS and Hughes had competed head to head before. In a famous "shoot out" at Holloman Air Force Base in 1955, Sidewinder had demonstrated its superiority over Falcon, convincing the Air Force to buy Sidewinder. The Air Force eventually procured the AIM-9B for seven types of aircraft.

The second NOTS-versus-Hughes face-off was held on China Lake ranges. Arnold's Advanced Design Branch was responsible for the side-by-side test. "As branch head I rated a certain amount of humoring by the crew I guess," said Arnold, "so I got to operate the turret [a gun turret from a P2V Neptune] through many of the tests."

On the turret were mounted a Sidewinder AIM-9D (the seeker being used for Chaparral), an AIM-4 Falcon, and a camera boresighted to the missiles. The test was a straightforward comparison of the detection, lock-on, and track ranges for the two missiles. For the Sidewinder, the turret operator announced visual detection, missile audio detection, and lock-up (the last two provided by the audio signal from the missile that the pilot normally received); his announcements were recorded. The Falcon had no audio signal, so the Falcon's automatic gain control (AGC) signal, which indicated target acquisition and lock, was recorded. After the test runs, performance of the two missiles was compared.

According to Arnold:

> Bill Irby did the data assessment with the Hughes guys looking over his shoulder. The AGC signal would be flat, not a wiggle, but a Hughes man would cry, "There it is, the missile is tracking." Irby would point out that he would give the missile credit for acquisition when he saw an indication on the AGC and not before, and then go to the next data set.[64]

The test was a win for the Sidewinder seeker. Falcon, despite its poor performance, remained in the Air Force inventory. It was used in Vietnam in 1967 (on an Air Force F-4 Phantom weapon station that was not wired for Sidewinder) but its performance was so poor, and Air Force pilots so unhappy

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Systems Projects. During his post-military career in business and public service he has received numerous awards including the Joint Chiefs of Staff Distinguished Public Service Award.

64 S-275, Arnold interview, 15.

with it, that it was withdrawn in 1969. General Olds wrote of his experiences with Falcon in 1967 as commanding officer of the 8th Tactical Fighter Wing (the Wolf Pack). After one particularly disheartening mission in which yet another Falcon failed him in an air-to-air engagement, he landed and told his maintenance chief, Ernie Timm:

> Ernie, I want you take those goddamn AIM-4s off all the [Phantom F-4]D models and replace 'em with Sidewinders. I don't give a rat's ass what you do with those pieces of junk, but I don't want to see another one on this ramp, ever![65]

NOTS continued its work on Chaparral, aware of the Army interest in the program (for short-range air defense in Germany's Fulda Gap) as well as the potential for a shipboard point defense weapon. A major technical challenge of converting Sidewinder from an air-to-air missile to a ground-launched missile was to make the missile function properly in a zero-velocity launch condition.

A 2005 article described the primary technical modifications to turn Sidewinder into Chaparral:

> A slow enable circuit was incorporated in the guidance unit to prevent overshoot . . . Without this modification, the missile would determine that it had to fly a divergent path [leading the target] immediately after launch, causing an unacceptable trajectory excursion. [The new circuit limited the turning rate until the missile was up to speed.] The launch hangers on the motor were reduced in size to minimize aerodynamic drag and to accommodate the launch rail on the tracking mount. The rollerons on one pair of opposite wings were removed to further reduce drag and were replaced by flat plate wings. These two rollerons were not required because of the low-altitude flight of the missile.[66]

Connie Neal's Electronic Design Branch modified the missile electronics, Mickie Benton's Optical Design Branch assisted with missile checkout, and Gene Younkin's Systems Analysis Branch evaluated the interplay of design change with performance. Airframe engineer Ed Creer bolstered Army confidence in the safety of the developing weapon by collecting information on more than 1,000 rocket-motor firings.

From January to October 1965, the Chaparral team under Boyd's leadership conducted a thorough military potential program and an engineering design evaluation that culminated in the Army's decision late in the year to proceed with acquisition of the Chaparral system.

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65 Olds, *Fighter Pilot,* 315.

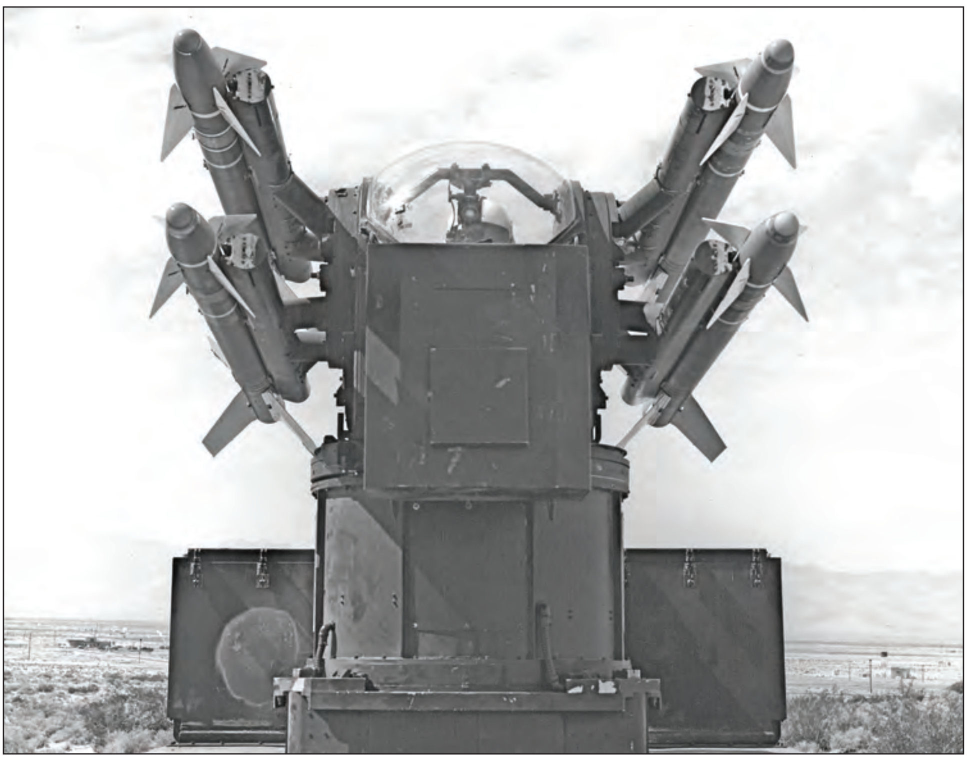
66 Roland Baker and Frank Knemeyer, "The Evolution of Chaparral," *The China Laker, Newsletter of the China Lake Museum Foundation*, Vol. 11, No. 4, Fall 2005.

As the *Rocketeer* described it:

> U.S. Army officials . . . witnessed the military potential and engineering design evaluation being conducted [at NOTS] . . .and were deeply impressed with the Chaparral missile's performance, fast reaction and launch time, and excellent capability against low-flying targets. Perhaps the most impressive part of the Military Potential program was the ability of [NOTS] to conduct such an extensive project in such a short time frame (9 months). During this period, the prototype design was established; the Sidewinder missile was modified in accordance with the new design, utilizing hardware manufactured in [NOTS] shops; and a flight evaluation program was conducted.[67]

Engineers at China Lake also developed a version of the Sidewinder telemetry system, dubbed SEWHAT Jr., for use in the Chaparral test program at Fort Bliss.[68]

After Army acceptance of the program, Boyd was transferred to assist Don Moore in managing the far-flung space-exploration efforts of the Astrometrics Division. "Dick Boyd had a good way of organizing things and getting them



Chaparrals on launcher for China Lake test.

67 *Rocketeer*, 12 Sept 1969, 4.
68 *NWC Tech History 1967, Part 1,* 5-48–5-49.

done," said Knemeyer, his former boss. "And then I made John Lamb the head of Chaparral"[69]

Lamb selected Roland Baker as his project engineer. At that point, China Lake was responsible for Chaparral both to the Army (the Army Missile Command, MICOM, at Redstone Arsenal, Alabama) and to the Aeronutronic Division of Philco (the Chaparral system integrator and ground-support-system contractor for the Army). Over the next 32 months, Chaparral would undergo a development and qualification testing program that would culminate with the Army releasing the system to full production in August 1967.

Although most of the development work was done within Code 40, Lamb and Baker reached out across the Station for help. Howard C. Cook in the Engineering Department's Servomechanics Branch (Code 5521) was responsible for the Chaparral servo unit. Don Herigstad in the Test Department's Range Engineering Branch handled range issues. George Harrigal of the Engineering Department's Destructive Test Section helped determine (by means of an environmental simulation chamber) whether the Chaparral guidance-and-control section could stand up to 50-knot winds at -50°F.

The Fuze Department in Corona contributed fuzing data that, when combined with lethality data, yielded measures of missile effectiveness.

James R. Bowen, in the Engineering Department (not to be confused with James A. Bowen the FAE developer) was tapped to direct engineering development of the guidance and control systems, based on his long experience with production support of Sidewinder. Under the direction of Don Winters, Engineering Department personnel also developed the test equipment for the missile.

Paul King oversaw the flight testing against a wide selection of target drones. Target flight parameters were designed to test the Chaparral missile to the limits of its seeker capabilities and flight performance range. King traveled to Alaska, Panama, Greece, Italy, and Germany while assisting the Army in the Chaparral qualification tests.

Charles "Chuck" Frederickson oversaw the complex task of the interface between the vehicle and the missile. Neither piece of equipment, of course, had originally been designed with any consideration of the other. Frederickson worked closely with the Aeronutronic Division of Philco to list and collect all of the required interface data and, where data didn't exist, to conduct tests and measurements.

69 S-200, Knemeyer interview, 66.

Another challenge in adapting Sidewinder to Chaparral was the nature of the weapon's operational environment. Sidewinder had been designed for an aerial and maritime environment characterized by well-understood influences; e.g., the shock of cats and traps, exposure to salt air, manual uploading and downloading, shipboard electromagnetic radiation. Chaparral, by contrast, would be carried on launch rails or in containers on a tracked vehicle through some of the world's harshest climates and terrains. The physical beating the system could take in a battleground environment needed to be determined before the system was turned over to the operational forces.

The test program was divided into two phases. First was the component-level testing, in which the guidance and control group, warhead, motor, etc., were tested individually. Contributing to this effort were Ed Creer, Jerry Halpin, and Peter Bouclin. Following this phase came the ready-to-fire-level testing, "road tests" with missiles mounted on the vehicle's launch rails.

"The most grueling and definitive of the Chaparral road tests was the 4,000-mile test which was conducted at Aberdeen Proving Ground," reported the *Rocketeer*. These tests included a full spectrum of terrain including "unpaved road, ramps, rough open country, swamps, streams and watercourses, steep grades, and side slopes." By the time the test ended, the test mileage totaled 5,800 miles. Barney Kinkennon, Ben Tidwell, and Roy Eisenhower monitored the test and provided field support.[70]

"That whole mount and launcher system survived, but the M113 tracked vehicle did not. It had problems," said Knemeyer. "So we did our job."[71]

When the Army wanted tropical testing, Chaparral was taken to Panama in the summer. A *Rocketeer* photo from the trip shows Baker atop a Chaparral vehicle that has just returned from a test run; jungle foliage hangs from the missile's canards (front steering fins). Arctic tests were conducted at Fort Greely, Alaska, in the winter.

During testing a number of flaws and design inadequacies came to light—which is the purpose of thorough testing. The issues were systematically addressed by the Army, Navy, and contractor team and did not delay overall system progress. General Electric was the contractor for the missile guidance unit, but the first production units did not work satisfactorily. A NOTS team visited the contractor and found insufficient quality control in the procurement and the acceptance inspections of electronic components, and the problem was resolved.

70 *Rocketeer*, 12 Sept 1969, 5, 7.
71 S-200, Knemeyer interview, 67.

The first Chaparral units, designated MIM-72 (mobile intercept missile), were delivered to Army troops in October 1967. In May 1969 the Army activated its first tactical Chaparral battalion. In 1971 the weapon system was classified Standard A—fully operational. China Lake continued to support the Chaparral system until 1975.

While the early Chaparral had several limitations (a tail-on-only firing aspect and susceptibility to relatively simple IR jamming systems), later models incorporated all-aspect capabilities, new seekers, improved fuzing and warheads, and smokeless motors. The roots, however, were at NOTS. Beginning with Sidewinder and continuing through Project Hamburger and Osprey, the Station established the foundation for a surface-to-air weapon system that would see nearly 30 years of service with U.S. forces and with a number of allies.[72]

After the Army accepted Chaparral, the system's developers began looking for an opportunity install it aboard a Navy ship. That opportunity came in 1972, when the Navy instituted a program called Hip Pocket that encouraged early shipboard evaluation of experimental systems. In August NOTS formed an Anti-Ship Missile Defense Group under Roland Baker, and the group began work on CHIMP II (an acronym contrived from Surface to Air Improved Chaparral). In six months the program had succeeded in using components from the AIM-9D and AIM-9H to create the new weapon system, installing it in USS *Lawrence* (DDG-4) and successfully testing it against a pair of low-flying targets. In a follow-on program, Hip Pocket Two, Baker oversaw installation of a more complex ship-defense system in USS *Hoel* (DDG-13), augmenting Chaparral with Dual-Mode Redeye and Hornet. For his leadership of the program, which involved not only the 18-member Chaparral team but also elements from the Fuze and Engineering Departments, Baker received the first NWC Technical Director Award, presented by Walt LaBerge in 1973.[73]

Another event in 1972 intensified the Navy's interest in Chaparral as a potential ship-defense system. On 15 April, during the first major air strike on the North Vietnamese port of Haiphong since 1968, two Shrike missiles were accidentally fired at the U.S. guided missile frigate *Worden*. Assessment of the damage inflicted on the ship by the missile pointed up the vulnerability of Navy vessels to air attack or attack by antiship missiles. (The late-1950s-vintage Soviet-built P-15 Termit (Styx) had already demonstrated its ability to sink a destroyer during the 1967 Egypt-Israel Six-Day War.)

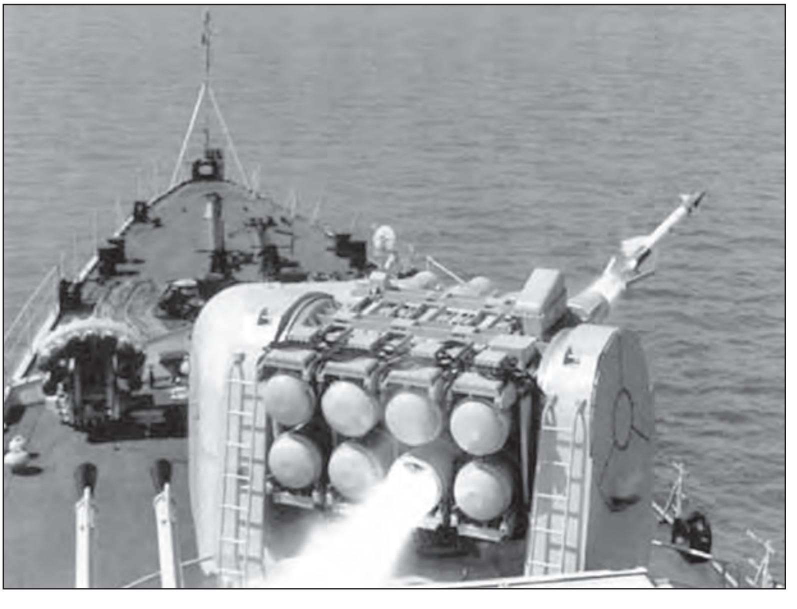
72 Chaparral outlasted two short-range air defense systems—Divad and Roland—that were intended to replace it.

73 Roland Baker, "Hip Pocket," *The China Laker,* Vol. 10, No. 3, Summer 2004; *Rocketeer*, 25 May 1973, 1, 3.

Navy leaders were alarmed by the air threat to their ships. China Lake suggested installing Chaparral systems aboard several Navy ships as part of a Navy Laboratories quick-response program. The OK was given, and John Lamb was assigned the task. An immediate problem was that the Navy did not have any Chaparral systems of its own. Baker and Knemeyer recalled that:

> . . . to expedite the effort, John Lamb, . . . not to be deterred by bureaucracy, directly called the appropriate Undersecretary of the Army in the Pentagon (since he had contacts through the Army with Chaparral) and was able to broker a deal whereby the Army would bail [five Chaparral] systems to the Navy with the stipulation that they would be returned to the Army in the same condition after the conclusion of the Vietnam conflict.[74]

Sea Chaparral, or Gun Line Sea Chaparral as it was also called, was a "slimmed down" version of the CHIMP II and was manufactured by Philco-Ford's Aeronutronic Division. Chaparral launcher units were removed from the M113 vehicles, mounted on a steel bases, and welded to the ships' decks. Five ships received the Sea Chaparral system, designated RIM (Ship-launched Intercept Missile) -72D, and all were deployed to Southeast Asia. The first was USS *Floyd B. Parks* (DD-884), which served as plane guard for carriers operating from Yankee Station in the Gulf of Tonkin. China Lake also set up a 3-week course of instruction for Navy operators and maintenance personnel and graduated the first sailors who would accompany the systems on board.[75]



Sea Chaparral firing from its shipboard launcher.

74 Baker and Knemeyer, "The Evolution of Chaparral," *The China Laker*.

75 Philco was acquired by Ford in 1961; the name change to Philco-Ford was in 1966.

In October 1972 Moran (by then Commander, Naval Weapons Center) presented Lamb with the Group Award of Merit for Special Achievement in recognition of his team's outstanding work. Sharing the award were Roland Baker, Ed Creer, Richard C. Harmon, Roy F. Eisenhower, Roy W. Martin, Harold J. Schlarman, Stewart L. Thorne, and Army Specialist 5 Richard R. "Rick" Brodeur (the China Lake representative of the Army's Chaparral program manager in Washington).[76]

There's a punch line. According to Baker and Knemeyer, "At the end of the Vietnam conflict, the China Lake team was able to retrieve all of the Sea Chaparral systems, restore them to their original operational condition, and return them intact to the Army."

North Vietnamese aircraft did not attack Navy ships, and so Sea Chaparral was never tested in combat. The system was later exported to Taiwan where it is still in service on *Kang Ding*-class frigates.

FOCUS

Sidewinder was an air-to-air weapon. Subwinder was subsurface-to-surface. Chaparral was surface-to-air. About all that was left to try was air-to-surface. Enter FOCUS, the Fixed Aperture Optical Contrast Universal Spectra seeker.

According to Mickie Benton, McLean had the idea for FOCUS, "a simple single detector scanning in a conical fashion." Benton and Bob Lawrence worked on the concept under local funding. There were at least three versions: near IR, mid-IR, and visible spectra. "We took old AIM-9B missile hardware that was obsolete . . . We were always trying to find some mod we could put on AIM-9B and make it into a newer cheap weapon, and this one worked out pretty good."[77]

Working with General Dynamics, the NOTS engineers developed a seeker with the lead sulfide IR cell replaced by a selenium crystal tuned to the visible light frequency. Installed in a Sidewinder airframe, the seeker could operate at night, tracking visible light sources—for example, a truck's headlights—on the ground. "We tested them out here on the range, and they were very successful," said Frank Knemeyer. "We had one picture of a truck out there

76 *Rocketeer*, 13 Oct 1972, 1, 3; and 24 March 1972, 5.

77 S-193, Edward E. (Mickie) Benton, Jr. interview, 26 Aug 1991, 38. Arnold recalled in a 20 July 2011 email to the author that "Bill [McLean] kept searching for ways to adapt the AIM-9B. I remember calls from the front office for Chuck Smith to walk across the street to the Administration Building for a session with McLean to go over McLean's latest idea on adapting the AIM-9B for the Vietnam arena."

with two headlights. It shows the missile went right through the radiator, right between them."[78]

According to the *Tech History*, "Once the seeker has sufficient signal for tracking, the missile can be expected to guide within 2 feet of the light source. The AIM-9B warhead can be expected to destroy searchlights and to severely damage trucks." In 1967, forty -9B seekers were modified to FOCUS seekers and tested, both on the China Lake ranges and in Southeast Asia.[79]

In 1969 FOCUS, with the designation AGM -87A, was used experimentally in combat in Vietnam. The pilot need only fly with the weapon scanning until he heard a signal, indicating it had locked on a light source, and then fire. Knemeyer recalled that:

> They misused the visible one over there. Instead of shooting it at a very discrete target, they started using it along the shoreline, and the thing would travel along a contrast point. The way it was implemented and deployed did not work out very well.[80]

A FOCUS seeker, FOCUS-4, was tested as a replacement seeker for the Chaparral. At White Sands Missile Range, it demonstrated the ability to track head-on targets at ranges in excess of 25,000 feet. In multiple-target presentations, with 100-foot separation between aircraft, "the seekers always chose to track one of the targets when their separation became greater than the field of view and well outside the minimum range necessary for proper intercept performance"—approximately 4,000 feet.[81]

Another version of FOCUS, investigated for the Marines, featured a four-quadrant detector operating in the 1.06-micron range, for use with a laser target designator. This version does not appear to have gone beyond the concept-formulation stage.

Bullwinder and Bombwinder

Other air-to-surface variants of the Sidewinder were investigated, but none ever reached full development. Bullwinder, fabricated in early 1967, was based on the 1950s-vintage Martin Marietta Bullpup (AGM-12A/B). The original rocket-powered Bullpup was designed to be steered toward a ground target by radio controls from the launch-aircraft pilot, who would have visual assistance from flares located on the back end of the weapon.

78 S-200, Knemeyer interview, 29.
79 *NWC Tech History 1967, Part 1,* 5-76.
80 S-200, Knemeyer interview, 29.
81 *NOTS Tech History 1965*, 5-42.

Bullwinder's developers proposed to eliminate the pilot-control function and instead add an IR seeker from the AIM-9B, coupled with larger steering canards from an AIM-9C. Shrike Project Pilot Ernie Mares, who flew the first launch just after dawn on 8 April 1967, picked up the story:

> The target was a 25-pound bag of charcoal that was ignited on the Baker Range impact area. To deliver, the A-4 was pointed toward the target to acquire guidance tone. With a solid tone the missile was launched by depressing the bomb button.
>
> During the first test, the missile flew a big corkscrew path and totally missed the target. It took the engineers just a few minutes to determine that an obvious scaling error caused the failure and the problem was quickly fixed.
>
> Five days later we tried again and Bullwinder drilled through the center of the charcoal fire. No question about it, the Sidewinder [GCU] worked perfectly to control the missile.[82]

"The major advantage of Bullwinder is that it has a very high probability of putting a payload on a target," noted the minutes of a NOTS Technical Board meeting.[83]

Bombwinder, assembled in the summer of 1967, worked on the same principle as Bullwinder but with a far larger payload—an Air Force Mk 118 3,000 pound bomb.

Mares wrote that:

> The obvious next step was to strap a Sidewinder to the nose of a bomb to see if we could also hit an IR target on the ground à la Bullwinder. This was intended as a low-cost quick-and-dirty smart-bomb experiment to precede development of a strap-on guidance unit.
>
> We could have easily used any Mk-80 series bomb for these tests; however, it was just as important to show that this concept would support a much larger bomb. NWC's Technical Officer Captain [Robert E.] Bob Moore, USN (former CAG-2), and I felt that a bigger bomb would get more attention. We hoped that we could demonstrate that this guided bomb could be used against targets like the Thanh Hoa Bridge.
>
> The Air Force had the Mk 118—a 3,000 lb. bomb with fairly low drag. With a little imagination and if we ignored a few normal safety issues, it would just fit on an A-4. Turns out that the bomb was almost a quarter of the size of an A-4. Not really, but it sure seemed like it. The large oversize tail fins required

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82 Ernie Mares, email to the author, 4 Nov 2008.

83 NOTS Technical Board meeting, 19–21 April 1967, 4. In the 1970s, NOTS would develop a laser-guidance kit for Bullpup and call the resultant hybrid Bulldog; it was approved for service use in 1974 but later cancelled in favor of the Air Force Maverick.

Bombwinder on A-4C Skyhawk, Armitage Field, 28 July 1967.

> for additional lift made ground clearance a major concern. Once airborne, the bomb needed to be dropped or jettisoned because the A-4 could not be landed safely with the store on board.
>
> On September 21, 1967, we flew the "Built-In Guided M-118 Under Terminal Homing for Accuracy" or BIG MUTHA. The drop was conducted on Baker Range and like the Bullwinder, the weapon drilled through the center of the hot charcoal target.

Mares added to his recollection of those tests that "Both Bombwinder and Bullwinder were inspired by Dr. Tom Amlie and Captain Bob Moore. These two visionaries knew that laser guidance was just a short time away from reality and a demonstrated strap-on weapon capability could be available and waiting."[84]

Neither Bullwinder nor Bombwinder was pursued beyond the proof-of-concept stage. The Air Force and Rockwell International were already into development of an electro-optical guided bomb that would see service in Vietnam: the Homing Bomb System (HOBOS). Laser-guided bombs were in

84 Ernie Mares, email to the author, 4 Nov 2008.

development as well, and Walleye was already in use in Vietnam. Simple and inexpensive weapons of NOTS devising (such as Bullwinder and Bombwinder and, in the 1980s, Skipper) were not well received when higher levels of the DOD had already committed to larger and more expensive alternatives.

Sidewinder Support

With Sidewinder, as with all NOTS weapons, the work didn't stop once the weapon was released to the operational forces. Support services continued throughout the life of each model until it was phased out of the Fleet inventory. Fleet support included investigating any malfunctions reported by the weapon users and determining the cause. If the problem was due to a handling or operational error, an Air Weapons Bulletin would be issued to Fleet users, updating them on the proper procedures.

If the problem was a design deficiency, NOTS engineers developed a "fix" or design change that solved the problem and integrated that change into the production process. This back-and-forth communication between the Fleet operators and the China Lake engineers was facilitated by Navy and Marine pilots visiting the Station as they returned from overseas tours and by NOTS engineers and technicians going aboard vessels and serving temporary duty at Navy and Marine bases stateside and overseas.

Cradle-to-grave care was not limited to the Navy Sidewinders. When problems arose with foreign military sales (FMS) users, NOTS technical teams visited the countries and assisted the users in resolving the issues. Assistance might take the form of troubleshooting, technical consultation, training personnel, assisting with aircraft installations, advising on logistical issues, providing direct technical aid—in short, anything within NOTS' capabilities that was required to rectify the problems.

The Ault Report

A pivotal event in U.S. efforts to achieve air superiority in the Vietnam War was a study conducted in 1968 by Captain Frank W. Ault, a WWII Navy combat veteran who in 1966 and 1967 had commanded USS *Coral Sea* (CVA-43) deployed off Vietnam. The study was commissioned by Chief of Naval Operations (and NOTS alumnus) Admiral Thomas H. Moorer to examine the Navy's air-to-air missile capabilities from end to end. Moorer and others were concerned with the poor showing that naval aviation was making in air-to-air combat in Vietnam.

Report of the Air-to-Air Missile System Capability Review, more commonly referred to as the Ault Report, was published in 1969. All quoted material in the next nine paragraphs is from that report.[85]

Ault's incisive report came to grips with the problem of air superiority from the very first paragraph:

> Almost 600 air-to-air missiles have been fired by Navy and Air Force pilots in about 360 hostile engagements in Southeast Asia between 17 June 1965 and 17 September 1968 (date of last hostile engagement). Performance in combat indicates a probability of achieving about one kill for every ten firing attempts.

Between July and November 1968, Ault's team "examine[d] concurrently the complete spectrum of influences on weapon system characteristics and performance." These influences included design, production, aircrew training, Fleet support, weapon system capabilities, and repair and rework. China Lake's Burrell Hays was one of five task leaders selected to coordinate and direct the review and was specifically tasked to answer the question "Is industry delivering to the Navy a high quality product, designed and built to specifications?"

A sense of urgency comes across in the pages of the report:

> As a final note, the Review Team could have had no greater incentive to press its efforts to conclusion than by observing that between the first meeting of the Team (on 8 August) and the last (on 8 November) the Navy fired an additional 12 Sparrows (AIM-7Es) and 12 Sidewinders (AIM-9Ds) in combat with a net yield of 2 MiG kills: both to Sidewinders.

Ault's report was direct in its criticism, and there was plenty to go around:

> The performance of shipboard missile assembly, handling, and loading crews suffers from lack of command emphasis on training as well as dilution of attention . . . problems with Sidewinder do, of course, exist as exemplified by the current AIM-9D breakup problem. . . . despite continuing emphasis on performance improvements to the semiactive radar missile system [Sparrow] over the years, overall system reliability has remained relatively constant at an unacceptably low level.

In terms of missile performance, however, the findings were clear. "Analyses of combat encounters in Southeast Asia clearly establish Sparrow performance as the primary problem."[86]

85 *Report of the Air-to-Air Missile System Capability Review*, *July–Nov 1968,* Naval Air Systems Command, 1 Jan 1969.

86 The Sidewinder breakup problem was solved by Herbert T. "Ted" Lotee and his group after they watched sailors assemble an AIM-9D aboard a carrier. The group designed a simple device that installed between the motor and warhead and eliminated the problem. S-181, Ted and Eleanor Lotee interview, 13 March 1990, 31.

As a result of the report, many steps were taken, including major revisions of Fleet-support procedures—storage, test, maintenance, repair, assembly, handling, and loading. Observations were far ranging, covering tactics, training, contracting, management, and more.

Among many other recommendations, the report urged that "CNO strongly support the solid-state Sidewinder development" and that "CNO reexamine the requirement for the AIM-9C and either provide necessary support or drop from the inventory." (The authors noted bluntly that "The AIM-9C (SARAH) is providing only marginal Fleet capability at present because of performance limitations at altitudes below 10,000 feet, lack of user confidence and interest, and deteriorating logistic support.")

One of the most far-reaching effects of the report was in aircrew training, which the report sharply criticized:

> [Air Combat Maneuvering] exercises conducted on an instrumented range at [the Naval Missile Center, Point Mugu,] by experienced fighter pilots in VX-4 revealed that about half of the simulated missile shots were being made out of envelope.

Recall that the Sidewinder was originally designed for attacking inbound enemy bombers, and thus Sidewinder shooters were trained more for intercepts than for dogfights.

> Past major reliance on R&D ranges for missile training exercises has exacted its toll no less than the unavailability of missile training allowances and suitable airborne targets. Realization of improved aircrew performance should be possible through increased missile and target allowances, better range facilities, more realistic air combat maneuvering training, a concentrated effort on aircraft missile system qualification (as well as aircrew firing qualification), and improved tactics and doctrine.

The Ault report's recommendation that "CNO and ComNavAirPac establish, as early as possible, an Advanced Fighter Weapons School . . . at NAS Miramar for both the F-8 and the F-4" was the basis for the creation of the Navy Fighter Weapons School (Topgun, also called Top Gun) in March 1969.

The report was also a vindication of the quality efforts that China Lake had been espousing for years—but that had often encountered resistance from industry and the Bureaus.

Two cases in point were BuWeps' removing NOTS from production-change control during the original Shrike full-production contract with Texas Instruments and allowing Raytheon to carry out the first AIM-9D Sidewinder production run without NOTS oversight.

Apropos of contractors the report stated that:

> While protection of his reputation is a prime motivation for a responsible contractor, his stock holders insist that he hew a line which provides an acceptable (but not an exceptional) design and, during the production process, holds expenditures on quality control/assurance to a nominal minimum required to 'sell' the product to the Government representative at the plant. . . . The Navy must be more specific . . . in defining systems performance requirements and in stating quality *requirements*, not quality *goals*."

Regarding another theme close to the heart of NOTS engineers—the thoroughness and integrity of the production data package—the report observed, "The lack of a complete data package for the Sparrow missile requires considerable improvisation in the [Naval Air Rework Facilities] from time to time in order to respond to problem uncovered in the missile rework process," and recommended that NAVAIR "require Raytheon to produce and submit a complete data package for the Sparrow missile."

The impact of the Ault Report would be felt in the Navy for years to follow, and its recommendations would have a lasting positive affect on naval aviation. Robert Wilcox stated that the Navy and Air Force kill ratio against enemy aircraft over North Vietnam was 2 to 1 in 1968. (During Korea and WWII, it had averaged about 10 to 1.) The Navy's kill ratio following the institution of Topgun training jumped to 12 to 1. "The Air Force, which had made no significant changes in its air-to-air training since the Vietnam War's beginning, ended the war with the same 2 to 1 ratio with which it had started."[87]

Ground-Based Threats

In Vietnam, as in the two major U.S. conflicts before it, groundfire was as great an obstacle to U.S. control of the air as were the enemy's air forces. During WWII, the nemesis of Allied aircraft had been flak or ack-ack. In Korea, it was the Communists' radar-directed guns that played havoc with UN (which usually meant U.S.) fliers.

By the time U.S. forces carried the air war into North Vietnam with Operation Rolling Thunder in 1965, Navy and Air Force pilots faced a Soviet-supplied air-defense system that was extremely dangerous. The threat systems were superior to their Korean counterparts in target acquisition and tracking, velocity, range, fuzing, and warhead lethality. At high altitudes the threat was SAMs; down lower, it was antiaircraft guns, usually radar directed.

87 Wilcox, *Scream of Eagles*, xi, 284. Emphasis added.

North Vietnamese SAM crew in front of SA-2 launcher.

U.S. Air Force photo.

Two distinct air wars were going on in Vietnam. The demilitarized zone divided the Republic of Vietnam (south) from the Democratic Republic of Vietnam (north). In the south Navy and Marine aviation supported ground operations with bombing and attack missions. Here the antiair threat was less developed than in the north because the targets themselves were more transient—convoys and troop concentrations and temporary fuel or ammunition storage facilities. Nevertheless, the aviators' missions, particularly close-air-support of ground troops (CAS missions), required pilots to bring their planes in dangerously low.

In the north Navy and Air Force missions encountered threats at all altitudes (SAMs could reach 65,000 feet). Targets tended to be fixed—dams, railroad yards, port facilities, electric generating stations, and the like—and were usually surrounded by a dense and well-coordinated network of antiair weaponry that sometimes extended for many miles around a target.

NOTS made a major contribution to countering the radar-directed gun and SAM threat with the development of the Shrike weapon system, which homed on enemy radar emitters. Still, despite Shrike and many other air-to-surface weapons—bombs, guns, rockets (millions, literally, of China Lake-developed 2.75-inch and 5-inch rockets were expended during the war), U.S. aircraft were taking a beating from surface fire.[88]

88 One of the most unusual shoot-downs of the Vietnam War occurred on 1 May 1967 when Lt. Cdr. Theodore "T. R." Swartz, flying his A-4C from USS *Bon Homme Richard* (CVA-31) was on a ground-attack mission over North Vietnam, carrying China Lake-developed Zuni 5-inch rockets. When Swartz was jumped by two MiG 17s, he salvoed his

In the earliest days of the air war, U.S aircraft losses were particularly high. One China Lake engineer commented that "in warfare the curve of mortality is extremely high at the beginning of a battle. It falls after pilots get to be wary and know what they are getting into. Some of the old heads manage to survive and become squadron leaders and pass the information along to others."[89]

Coso Military Target Range

An essential element in reducing aircrew mortality was to train pilots to know what they were getting into before they got into it. Two NOTS facilities were established in the 1960s that would help pilots increase their effectiveness and survivability in the skies over Vietnam. The first was the Coso Military Target Range.

One handicap for U.S. aerial combatants in Vietnam was, ironically, that their aircraft were far superior to those used a decade previously in Korea. The newer planes' higher speeds and greater agility made target acquisition much tougher, particularly with the abundant natural cover provided by the jungles of Southeast Asia. The problem, according to China Lake mathematician-turned-analyst Lillian Regelson was "the difficulty of finding a small target (especially one trying to hide) when flying past it at a high speed and a high enough altitude not to be vulnerable to small arms fire." Missing a target on the first pass meant coming in for a second run, which increased the risk to the aircraft exponentially.[90]

In the early days of the Vietnam War, ground-attack training was little changed from that for the previous two wars. Regelson wrote:

> We had many squadrons practicing bombing on our ranges. The ranges had a bull's-eye target, which made it easy to find the target. Among other reasons, something like this was necessary to protect range personnel from harm.

Regelson's position in the Weapons Planning Group made her privy to the intelligence reports concerning the effectiveness—and ineffectiveness—of U.S. air strikes in Vietnam. In early 1962 she was approached by Commander Robert F. Doss from Lemoore who was looking for a range where his squadron could train against unfamiliar targets.[91]

Zunis at the attackers, destroying one of the enemy aircraft.

89 S-129, Robert F. Barling interview, 16 Jan 1982, 13.

90 Lillian Regelson, email to the author, 13 Nov 2008.

91 Doss had earlier served at China Lake as lieutenant in VX-5 and would later be instrumental in the introduction of Shrike to the Fleet. After a successful if controversial career in the Navy, Doss went on to found Farnsworth Cannon, Inc.

Simulated Vietnamese trestle bridge at Coso Military Target Range.

She discussed the target-recognition problem with Dr. William Simecka, also of Code 12; Phil DePoy, the Operations Evaluation Group's former representative at China Lake; and range engineers Ray Schreiber and Anthony J. Bachinski and highly respected range boss Duane W. Mack, all from AOD.

Mack recalled years later that:

> Simecka . . . asked me if I knew of an area where they could plan a typical combat environment,and I knew about the Cosos [the Coso mountain range], which is up in piñon country . . . and I said, "Yes, I know of an ideal location" because I'd been up hunting Indian artifacts up in that area.[92]

By June 1962 the new range had been established, 40 air miles (80 road miles) north of the Mainside area, yet still within the perimeter of the 1,700-square-mile base. "We tried to typify a combat environment, with targets and bridges, railroads, tanks, convoys, helicopter landing sites, guns, howitzers, . . . radar vans," said Mack.

After the Cuban Missile Crisis in 1963, a star-shaped SAM site, modeled after those in Cuba, was added to the range. In 1965, in anticipation of Walleye

92 S-228, Part 2, Duane Mack interview, circa 1993, 45. Mack led the way in opening up the highly instrumented Charlie Range (C-Range) to Fleet attack squadrons for training, an accomplishment that earned him the L. T. E. Thompson Award in 1962. He served on the China Lake ranges from 1943 (starting as a Caltech employee for the very first test on 3 December) until his retirement in 1972.

Operational Evaluation, new targets were added at Coso Range, including a 250-foot-long highway bridge; a railroad tunnel built into a mountainside, with about 1,000 feet of track leading into the tunnel; and a military supply dump.

Since tests might run over several days, a crew of range personnel would convoy over the winding rutted dirt roads to the area and stay in the “Coso Hilton,” an old Quonset hut with bunk beds. “It was a very popular place for people to go, and most of the crew enjoyed being up in the high country in the summer months, that is, at the 7,000-foot level,” recalled Mack.

Learning how to pick out a target vehicle parked under trees, while at the same time maneuvering at high speed through mountains, was difficult and came only with repetition. “Pilots flew over the range and practiced spotting the targets,” Regelson recalled, “This worked very well.” As word spread within the naval aviation community, more and more pilots found their way to China Lake and the range grew in popularity.

Spotting targets, however, was only the first part of the problem. The second part was killing them. VX-5 was charged with developing tactics for the Navy’s new weapons (many of which were coming out of the laboratories and machine shops of China Lake) and the same tactic that worked against a bull’s-eye on the flat desert floor of Charlie Range wouldn’t necessarily work at Coso.

Ray Powell, a VX-5 project pilot from 1962 to 1965, observed that:

> . . . the Fleet pilots would come in there and after a couple of ops on China Lake they’d get some pretty good hits on . . . Charlie Range because you fly over the swimming pool at 7,500 feet and your target’s going to be on one side or the other of the walls and if you’ve got the right horizontal distance and the right dive angle, shoot, you can’t miss it very far! But you go up in the Cosos and everything’s different—different elevation, different terrain, different everything—and you’ve got target identification problems.[93]

Traditional tactics had to be adapted, sometimes drastically, to fit the new weapons and their higher-performance launch platforms to real-word topography and target placement. Said analyst DePoy:

> The altitudes were going to be a lot higher for similar types of tactics and of course the speeds were greater and we didn’t know in the tactical development what we could get away with—what kinds of altitude and speeds.

In mid January 1964, in the largest joint exercise of its type ever conducted at China Lake, VX-5 and 11 other Navy and Marine Corps units fielded more than 100 aircraft for 2 days of nonstop air operations over the Coso target

93 S-270, Powell interview, 66.

range. Mack's 12-person crew operated and maintained the tracking and control instrumentation (including radios facilities, M-33 radars, and spotting stations) during the exercise, the purpose of which was "to evaluate newly developed tactics under realistic circumstance and the compatibility of these tactics with planes now in operational use."[94]

Mack, with justifiable pride, told an interviewer, "Pilot after pilot after pilot has told me the best training they ever got has been the training in the Cosos." As of this writing, Coso Military Target Range is still regularly used by the Navy and other agencies. Only inert ordnance is used against the Coso targets to minimize damage to resources, to preserve the natural appearance of the terrain, and to reduce hazards associated with unexploded ordnance.[95]

"In the long term," the *Rocketeer* reported in a 1973 range retrospective, "the greatest value of Coso Range will be derived from simulated operational employment of new weapons and tactics."[96]

Echo Range

Echo Range—officially the Electronic Warfare Threat Environment Simulation (EWTES) Range—served a different purpose than Coso Range, one more suited to the pilots who flew against the heavily defended targets of North Vietnam. Echo Range taught pilots how to operate in the dense electronic environment associated with threat antiaircraft guns and SAM systems. SAMs were the big killers in the skies over North Vietnam; during the course of the war they would account for 205 U.S. fixed-wing aircraft losses.[97]

When an SA-2 missile shot down Lieutenant Colonel Richard P. Keirn's F-4 on 24 July 1965—the first SAM kill of the war—it was a wakeup call for U.S. military aviators. It shouldn't have been; the SA-2 had been operational with Soviet forces for more than 10 years. As the SAMs took an increasing toll on the Navy and Air Force—both direct, by destroying aircraft, and indirect, by degrading the ability of the fliers to perform their bombing missions—the U.S. began, belatedly, to take remedial action.

In 1966, the Navy asked the Applied Physics Laboratory (APL) at Johns Hopkins University to develop electronic countermeasures (ECM) and tactics to counter the antiair threat. Initially, APL set up a program to test aircraft in

94 *Rocketeer*, 24 Jan 1964, 1.
95 S-60, Duane W. Mack interview, Jan 1969, 51.
96 Jack Lindsey, "Air Operations Ranges Play Vital Role in Weapon Test, Evaluation," *Rocketeer*, 2 March 1973, 3.
97 Hobson, *Vietnam Air Losses*, 270.

a simulated threat environment in Nashua, New Hampshire, where Sanders Corp. had built an SA-2B fire-control-radar emissions simulator. VX-5 sent a pair of A-4s with their pilots and crews from NOTS to the Manchester Airport in New Hampshire to assist.

In the words of APL writer Arthur Williamson, "It became immediately apparent . . .that testing airplanes in the presence of threat simulators could provide many answers to tactical problems, as well as enhance and complement countermeasure system design and development." NOTS was selected as the site of the new threat-simulator range for several reasons:

> It had unrestricted airspace usage within its boundaries, the weather was generally good for flight operations and employment of optical instruments, and VX-5 was stationed there. Furthermore, it was easily accessible by air from Edwards Air Force Base and Point Mugu.[98]

Because of the secretive nature of the work and the need to avoid spurious electromagnet radiation from other sources, considerable attention was given

Fuze Test Facility in Randsburg Wash area, Mojave B Complex.

98 Arthur C. Williamson, "The EWTES (Echo Range) Story," *Johns Hopkins APL Technical Digest*, Vol. 21, No. 4, 2000, 582.

Typical threat radar installation at Echo Range, circa 1968.

to where within the confines of the NWC landmass the new range would be located. The Randsburg Wash area of the 800-square-mile Mojave B Complex, southeast of Mainside, was selected. At the time, the principal use for that area was proximity fuze testing against aircraft suspended from wooden towers on nylon ropes, an activity that would not interfere with the new mission.

Echo Range was built from scratch in the open desert. APL was the technical director and engineering design agency, and NOTS was responsible for the site's operation, maintenance, and management. The work was assigned to the Systems Development Department. Lieutenant Commander August M. "Marty" Wildberger, Highberg's military assistant, was assigned as the project officer, assisted by Roger P. Bock and William W. Baer.

Jim Colvard's Range Operations Division was responsible for putting the range together. Recalling Echo Range, Colvard still gets irritated when people bring up the stereotype of the lazy civil servant:

> We were working 14-hour days, 7 days a week, not paid overtime, you couldn't tell your spouse what you were doing, and, Christ, people would get so tired I'd have to send them home because it was unsafe for them to be around the high voltage of the Fan Song radar. So don't tell me that civil servants won't work![99]

99 S-272, Colvard interview, 17.

Initially the range sported Fan Song B and Fan Song C radar simulators (the SA-2 SAM's fire-control and tracking radars) built by Tasker Industries, and a single captured Son-9 Fire Can (the radar director for the North Vietnamese 57- and 100-mm antiaircraft guns). NOTS engineers converted four SCR-584 radars to simulate additional Fire Can radars and built Puazo 6 antiaircraft artillery directors using components from the Navy Mk 28 and Mk 63 gun-fire-control systems. Soon there were simulators for the Soviet Spoon Rest early-warning radar and Flat Face target-acquisition radar. The threat simulators, which were arrayed to simulate shipborne radar complexes, were augmented by a host of support equipment: control and instrumentation vans, target reference radars, surveillance radars, and tracking radars with boresighted TV cameras.

Payoff from the new range came quickly. In November 1967 Project F/O-210 was assigned to Echo Range with A-1 priority. The goal was to develop aircraft tactics against SAMs. In run after run against the "threat" radars, pilots and system developers worked the bugs out of new electronic countermeasures (ECM) equipment, refined methods of use, and developed maneuver-based countermeasures that were incorporated into the NATOPS.[100]

New systems would follow. In the early 1970s, Fan Song E, built by Tasker, went on line, soon joined by Low Blow (the fire-control radar for the advanced SA-3 SAM, with which Egypt took out five Israeli F-4Es in 1970), built by Georgia Technological Research Institute and Johns Hopkins University Applied Physics Laboratory. The Echo Range Operations Branch under L. D. "Duane" Burton handled day-to-day operations.

Low Blow simulator at Echo Range, August 1972.

Photo reprinted with permission © Johns Hopkins University Applied Physics Laboratory

100 NATOPS is the Naval Training and Operating Procedures Standardization Program, the Navy's official guide to flight doctrine and operating procedures.

Establishment of Echo Range began a significant expansion of China Lake's work in the new field of electronic warfare. Haff remembered the Vietnam conflict as:

> . . . the first time we've ever encountered true electronic warfare in the skies. Prior to the Southeast Asia war, the pilot reasonably had the skies to himself, but they challenged him in Vietnam, that field has come on strong. And from what we see here at Echo, we may enter the next fracas and find in a matter of a few days that the skies are effectively denied to the pilots unless you just want to accept tremendous losses.[101]

The term "electronic warfare" first shows up in a China Lake code directory on 1 November 1967 as the Electronic Warfare Branch, originally headed by R. E. Boyer and later by Charles B. Campbell and part of Colvard's division. Pockets of related expertise began to develop across China Lake, for example in the Countermeasures Division (set up under Colvard in March 1969) and the Technology Development Division (established in 1971 under Leroy D. Marquardt).

As a result of the Naval Weapons Center's expanding expertise in electronic warfare, in July 1971 China Lake was assigned full responsibility for the design, fabrication, maintenance, and operation of the hardware and software at Echo Range (with APL as a technical consultant), and in 1972 China Lake assumed full technical-direction responsibility for the range. By 1973 Echo Range would be supporting 70 billets (up from 22 in 1967), and in 1975 China Lake would establish the Electronic Warfare Department under the leadership of Jack Russell. Eventually Echo Range would become a collection of specialized sites simulating several land- and sea-based threat radar environments. As the threat evolved, so did Echo Range.

Echo was created as a tool in the development of systems and tactics to counter threat air-defense systems. However, it also was—and is—used for training, to assist pilots in learning the arcane art of airborne electronic warfare and survival in high-threat environments. As Bob Barling wryly observed:

> After the pilots have gone through all their primary and basic training and advanced training, they go to the carriers and they come back hot pilots. Then they are dispatched from carriers and sent through one of our electronic warfare ranges where they get shot down in 2 minutes.[102]

It is a testimony to the foresight of the range planners of nearly half a century ago that both Coso Military Target Range and Echo Range are still

101 S-125, Haff interview, 2.
102 S-129, Barling interview, 12.

being actively used by weapons and tactics developers and for the training of U.S. and allied military pilots.

Work Hard, Play Hard

The air war in Vietnam led to several milestones in naval aviation, including development of Shrike for use against fire-control radars, development of new Sidewinders and their variants, establishment of ranges that increased both aircraft lethality and aircrew survivability, inception and development of the new field called electronic warfare, and recognition of the importance of an independent, technically astute government laboratory to oversee contractor behavior in the weapon-development and -production process.

Of the technologies developed for the air war, Sidewinder best illustrates the unique NOTS approach to military matters. This simple and inexpensive missile has been called NOTS' signature weapon, and it is without a doubt the most famous weapon created by the organization. Government employees who were associated to any degree with the Sidewinder program have found that the mention of that weapon brings recognition even from laypersons.

The Sidewinder program was so large, and has continued for so long, that as Bertha Ryan once wrote, "Just about everyone who has worked at China Lake has worked on Sidewinder." There was a kernel of truth to the wry 1967 remark by Walt LaBerge (then a vice president at Philco-Ford), "I feel honored to be one of the over 4,000 people I have met who single-handedly invented Sidewinder."[103]

Sidewinder development over the years was always fast-paced, even frenetic, and that pace sometimes took its toll.

Phil Arnold commented that:

> Chuck Smith maintained a work routine that's legendary, but other leaders also worked long hours as well, placing pressure on wives and families. It's no coincidence that two wives of the [Sidewinder] management team underwent treatment for nervous breakdowns during that period.[104]

103 Bertha M. Ryan, "Wuzwinder event lives again!" *News Review*, 30 Oct 02, 9; Walter B. LaBerge, "The Mongol Horde," *News and Views,* Nov 1967, 11. The peripatetic LaBerge (who stood a towering 6' 4") left NOTS in 1957 for employment as a senior manager for Philco-Ford. He would return to China Lake in 1970 as Assistant Technical Director, was named Technical Director in 1973, and three months later left to become Deputy Secretary of the Air Force for Research. He later held top management positions in NATO, the Army, DOD, and Lockheed. See *http://www.walterlaberge.com/*.
104 S-275, Arnold interview, 18.

Anne "Nancy" Carter, who joined the Sidewinder team as a physicist in 1953, remembered "a lot of enthusiasm, a lot of paid overtime, a lot of overtime that was not paid, too." She recalled one engineer who "apparently died of a heart attack, and people said it was because of the tremendous number of overtime hours he put in."[105]

McLean himself, in a presentation on the Sidewinder program given in 1962, commented "The wives tend to be less enthusiastic about continuous attention to the work than the men."[106]

On the other hand, the program was characterized by an astonishing amount of esprit. Preston Lerner in *Air & Space Smithsonian* refers to "McLean and his merry band of missileers."[107]

One manifestation of this enthusiasm was the Sidewinder party, a tradition that began on 9 January 1954 when Sidewinder made its first direct hit on a B-17 target. China Lake always was a partying place, but Sidewinder parties, and beginning in 1979, the annual Wuzwinder party hosted by former Sidewinder program leaders, held a special place in the China Lake culture. Sidewinder

AOD party featuring Peggy Rogers as emcee, with serenade by (from left) Walt LaBerge, Frank Cartwright, Peter Nicol, and Howie Wilcox.

105 S-135, Ann (Nancy) Carter interview, 1 May 1975, 21.

106 "The Sidewinder Missile Program," presented at the National Advanced-Technology Management Conference, 5 Sept 1962, Seattle, Washington, RM-24, *Collected Speeches of McLean*, 25.

107 Preston Lerner, "Sidewinder, The Missile That Has Rattled Enemy Pilots Since 1958," *Air & Space Smithsonian*, 1 Nov 2010, 56.

parties—as well as parties by AOD and other China Lake departments—were characterized by skits and songs specially written for the occasion and the presentation of tongue-in-cheek "awards." The festivities would sometimes go on until breakfast.

Chuck Smith commented that:

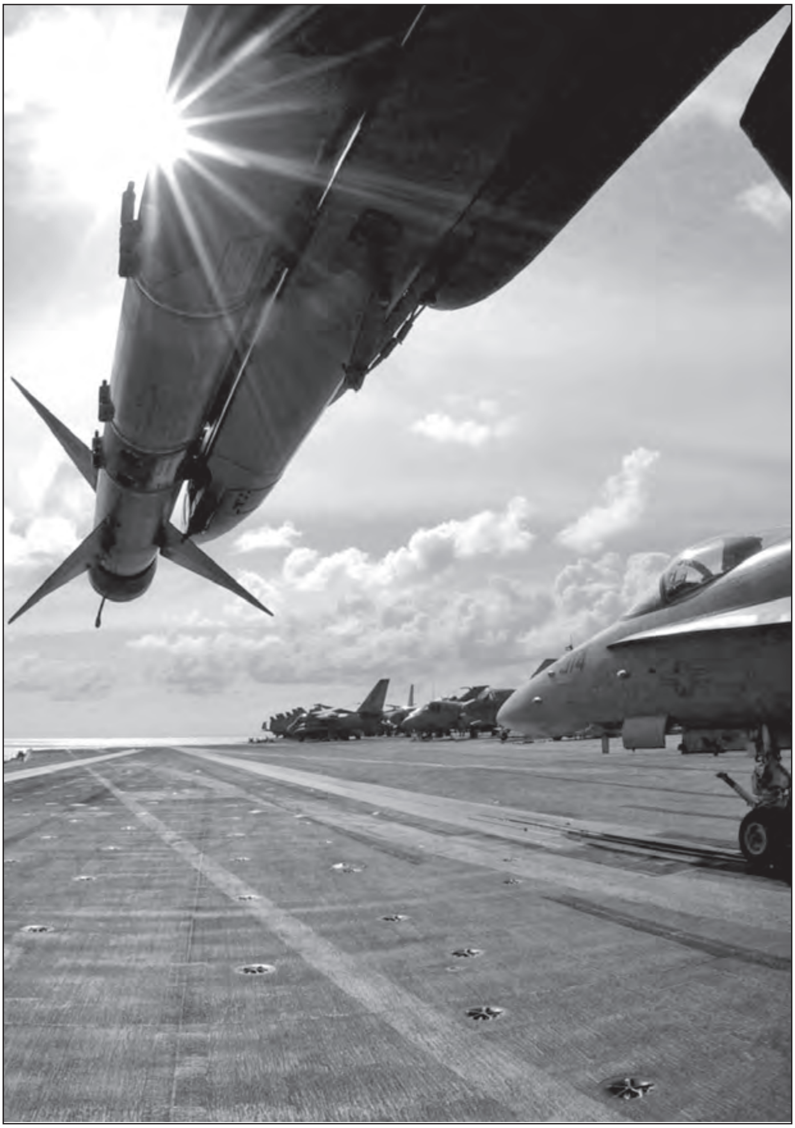
> Reflecting back on it, I think we have to admit that the families paid a price for all of those long hours. But I think it was ameliorated by the fact that we were a close community. What I mean is that we would have paid a much higher price had we been structured like—well, I look at the company I'm working for now, and once the day is over at the plant the people go out in every direction about 10 or 15 miles.
>
> And if today, in that organization, we were working the kind of hours we were working then, the wives would feel completely isolated. It would be much tougher for a family to survive under those conditions. So I think some of the unique conditions under which we worked here at the Station had a lot to do with the fact that the families had a sense of participation, and so you didn't quite have the kind of sacrifice you would normally associate with those long hours.[108]

One reason that Sidewinder holds such a central place in the NOTS culture is its unparalleled success as a weapon system. Military analyst James Dunnigan wrote that "the cheapest missile has proven to be the most lethal. The Sidewinder has been in service for over 40 years. It has knocked down more warplanes (at least 270) than any other air-to-air missile." After tallying the missile's successes throughout the world Dunnigan concluded, "It will be a long time, if ever, that one missile matches the record of the Sidewinder."[109]

A second reason for Sidewinder's iconic status is that the weapon epitomized the NOTS way of doing business. Though sparked by the genius of one man, Dr. William B. McLean, the weapon was nurtured by the heroic efforts of many individuals who could exhibit fierce competitiveness when seeking a solution to a particular technical problem and symphonic teamwork when working toward a common end.

Sidewinder took advantage of a set of circumstances—co-located laboratories, ranges, restricted airspace, machine shops, propulsion and explosives facilities, specialized test complexes, an airfield—that could not, and had not, been duplicated anywhere. Sidewinder was zealously protected by China Lake management—not infrequently, in the case of military officers, at the expense

108 S-112, AOD Group interview, Charles P. Smith, 28.
109 Dunnigan, *How To Make War*, 190–191.



Sidewinder AIM-9M on an F/A-18C Hornet aircraft, flight deck of USS *Kitty Hawk* (CV 63), 17 February 2003.

of further career advancement—from a Washington bureaucracy that often lacked vision, abhorred independent action by field activities, and resented the Station's ability to juggle its finances to support worthwhile projects.

Sidewinder's parentage was as much the practical, tactical, unforgiving reality represented by the Station's combat-experienced military pilots and technical officers as it was the esoteric, theoretical, cutting-edge science—optics, electronics, materials science, energetics, aeroballistics, and many other disciplines—of the Station's technical workforce.

In the words of Will Haff:

> That was something that comes along perhaps once in 100 years, to develop a weapon like that. It's given us a reputation here. We have made Sidewinder model improvements that perhaps really overshadow the effect of the initial Sidewinder, but they'll never gain the visibility that initially came to China Lake when they said, "Here's the Sidewinder; use this instead of a bullet."[110]

Clear-cut victory in the skies over Vietnam was never achieved. Despite massive amounts of firepower available to U.S. forces and the disparity of military might between the adversaries, U.S. air losses continued to the end of hostilities. The last U.S. aircraft lost to enemy fire was an Air Force F-4E shot down on a strike mission in Cambodia on 16 June 1973.[111]

America's failure to win a military victory in Vietnam owed less to deficiencies in military technology than it did to national policies that restrained the U.S. military from prosecuting the war more energetically. That constitutionally mandated authority of elected government officials over appointed military leaders—regardless of how well or poorly the government officials may direct a particular war—is the benefit, some would say, or the price, others would argue, of living in America.

In Vietnam, as in two wars before it and others that would follow, NOTS (and its descendant organizations) kept the focus simple: devise the technology, training, and tactics to inflict maximum damage on the enemy and bring the friendly forces safely home.

110 S-125, Haff interview, 22.
111 Hobson, *Vietnam Air Losses*, 249.

9

Exploiting the Invisible

I will find a way or make one.

— William A. Arriola, NOTS photo-optical technician[1]

In the earliest days of World War I, nearly 100 years ago, the principal weapon for air-to air-combat was the pilot's handgun (although there are stories of pilots throwing bricks and hand grenades at enemy aircraft and even throwing lengths of rope in hopes of tangling propellers and stalling motors). The handgun evolved to a rifle, and then a machine gun, and the race for technical superiority in air weapons was on.

Today a missile with an infrared seeker is a pilot's principal weapon for visual-range engagements—generally called dogfights. Radar-guided missiles and those with inertial guidance systems are certainly part of the air weapons mix, particularly for beyond-visual-range engagements (although those weapons often use IR homing in the final, terminal phase of flight). Guns and cannons also continue to play a role for close-in work. But the linchpin technology of modern aerial combat is IR detection—and its counterpart, avoidance of IR detection. The foundational work in understanding and exploiting IR for military purposes took place at NOTS.

In WWI the British developed a rudimentary IR-based aircraft-detection system, and late in WWII Germany fielded an IR sniper system, the Zielgerät. Toward the end of the war, the U.S. Army tested a heat-guided free-fall bomb, the VB-6 Felix, designed for use against strong heat emitting targets such as blast furnaces. The Navy began work on a similar weapon called Dove (eventually designated XASM-N-4) and transferred the work after the war to Eastman Kodak. The Dove program continued into the 1950s, but never progressed beyond the prototype stage.

1 "Employee in the Spotlight," *Rocketeer*, 26 July 1974, 7.

In 1948 China Lake began to work on the technologies that would lead to the Sidewinder air-to-air missile and to a host of other military systems. McLean established a program to develop a capability to detect and track an aircraft by its infrared radiation—its heat signature. (Aircraft engines were powerful heat sources even before the advent of jet aircraft with their super-hot exhausts.) This detecting and tracking capability was at the heart of McLean's vision of "A Heat Homing Rocket," the title of his first formal proposal for support from the Bureau of Ordnance in 1949.

Before they could design an IR detection and tracking system, the Sidewinder developers needed to understand the IR radiation emitted by its target—military aircraft. Fortunately, a nascent IR-characterization capability existed at NOTS. As part of one of China Lake's early failures, the NOTS Air Missile, IR target studies had been undertaken by Dr. Roger S. Estey, head of the Applied Science Division of the Research Department (originally Code 75, after 1950 Code 50). The studies continued even after NOTS AM was terminated in 1949.

Lawrence W. "Larry" Nichols, who came to the Station in 1946, worked with members of the Optics Branch (part of Estey's division) to design an IR detection system. They used a lead sulfide (PbS) cell that received radiation through a disk with a slit in it (a reticle) that rotated in front of the cell. They built a rudimentary IR detection device, and in 1949 Nichols, using primitive data-recording techniques, tested it against jet aircraft flying out of Edwards Air Force Base. As he recalled:

> We were real naive, hopeless. We built these [detectors] and in our first real tests we put them in a TBM torpedo bomber, left over from WWII. . . we cut a hole in this Plexiglas turret and stuck this thing out of it. . . .And at that time there weren't any jets around here . . . So we'd get in this TBM and fly down to Edwards . . . . With our homemade little seekers, why, we'd fly alongside of these Air Force jets, and I can remember we'd be about 200 meters away from them, no signal at all, so we'd have to ask them to move in a little closer. . . .We had an oscilloscope and a camera to photograph the oscilloscope, and when we'd see signals, we'd run the camera and photograph this oscilloscope. We also had a camera looking alongside the seeker that would photograph the airplane, and we'd come home, and we could measure the airplane's dimensions on the film and get its range and measure the size of our signal.

Nichols recalled that the lead sulfide cells were also crude:

> They were little films of lead sulfide inside of a glass envelope, a little like a light bulb. Very insensitive and noisy. But we'd actually get signals from the tailpipes 100 meters away. We measured the signals, and in turn we could then

> measure how strong the radiation from the aircraft were and get some idea of the strength of the jet tailpipe signal.[2]

"After many different kinds of aircraft were surveyed," Nichols wrote in 1959, " it became apparent that the shape and magnitude of the radiation patterns could be correlated with engine types, operating temperatures, and the position of the engine within the fuselage. When these three things were known, it was possible for us to predict accurately what kind of a target a particular aircraft would make."

Thus the same lead sulfide photoconductive cell that would be at the heart of the Sidewinder seeker was also a tool for characterizing the IR signature—the nature and intensity of the IR radiation—of both friendly and enemy aircraft.[3]

Along with Estey and Nichols, early pioneers in IR technology at China Lake included Dr. Lucien M. "Luc" Biberman, Ed Swann, John J. Miyata, Raim Regelson, and Theodore R. "Ted" Whitney. Their work on the IR detector progressed steadily, through the shaky period in Sidewinder's early development when the weapon's continuing existence was so tenuous that the program was reclassified from a rocket project to a fuze project and then to a mere feasibility study—FS-567. Sidewinder survived the political and financial turmoil.

Rod McClung, Dave Simmons, and Jon Mathews coupled Nichols' detector with an SCR-584 radar tracking pedestal so that the pedestal would follow the IR target seen by the detector. This odd hybrid was a dramatic visual demonstration of the military potential of IR detection. Whether tracking an aircraft passing overhead or slewing to follow the motion of a lit cigarette (often held by McLean or a visiting VIP), the mount was a primary marketing tool for the emerging Sidewinder's capabilities.

As awareness of the military potential of infrared technology increased, so too did the Defense Department's IR research and development programs. By the mid 1950s, Convair was developing the Redeye man-portable missile for the Army and Marine Corps, though it would not become operational until 1968. The Air Force studied a 1954 Rand Corp. report on IR countermeasures and began development of the Balls of Fire decoy flare designed to protect B-47s, B-52s, and B-58s from lead-sulfide-detector-based IR threats (1.8 to 2.8 microns).

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2 S-198F, Lawrence W. Nichols interview, week of 12 Jan 1971, F2–F3. A more detailed technical description of the early NOTS radiometers is found in RM-8, *History of Pyrotechnics at NWC/NOTS*, by B. A. Breslow, partial copy, 30 April 1982.

3 Lawrence W. Nichols, "Infrared Research for Development of Sidewinder," NOTS 2068, *Weapons*, 38.

As NOTS IR countermeasures specialist Raim Regelson observed, "Sidewinder put the fear of IR into the world."[4]

In 1956 NOTS' growing expertise in IR technology led to the establishment of an IR-fuze evaluation program at the Fuze Evaluation Range at Randsburg Wash. The test arena consisted of multiple heat sources (targets) that could be set up in various configurations on 50-foot-tall poles located along a rocket's flight path. The fuze to be tested was mounted in the rocket and fired past the arrayed heat sources while high-speed Bowen cameras recorded the flight to determine the point at which the fuze functioned. (Originally the heat sources were electric hot plates, but when test team members found that a gust of wind could reduce the radiant field by as much as 40 percent, they replaced the plates with quartz lights with power levels adjustable from 1 to 21 kilowatts.)[5]

Sidewinder was the driving force behind the Station's IR exploitation work in the early years. Targets were one area of effort. Since simulation technology was relatively primitive in the early days of Sidewinder's development, the only sure way to tell if something worked—a circuit modification, a new seeker component, refined processing electronics, or any of the hundreds of missile subcomponents whose design had to mature in concert with all the other subcomponents—was to take a missile out and shoot it.

Leftover WWII B-17 Flying Fortress (QB-17) bombers that had been converted to drones were reliable targets. Their large, supercharged piston engines were adequate heat sources for the early Sidewinder's IR detection system. QF6F-5Ks—Grumman F6F Hellcats converted to drones at $150,000 each—made excellent targets as well, but the IR signature of the Hellcat's Pratt & Whitney radial engine was not intense enough for the early Sidewinder to dependably track.

In 1954, NOTS completed development of the T-131 tracking flare. Several of these flares affixed to the tail of a QF6F-5K provided a trackable IR source for the Sidewinder seeker.

Flares were also attached to NOTS-modified 3.25-inch target rockets (which simulated targets below 15,000 feet) and to NOTS-developed 5-inch High-Velocity Aircraft Rockets (HVAR), modified for use above 20,000 feet. Looking for more and cheaper targets, NOTS engineers designed (and, when funds were tight, built locally) an all-wood towed target called Dart. According

4 Ephraim Regelson, telephone interview by the author, 22 June 2009.

5 Richard D. Finch, "Infrared Evaluation and Test Facilities at the Naval Ordnance Test Station," *Proceedings of Infrared Information Symposia*, Vol. 4, No. 4, ONR, Oct 1959, 32–40.

to Babcock, "Dart was initially configured to carry 16 T-131 flares, but after the ejecta and the smoke from the flares caused early functioning of the Sidewinder proximity fuze, improved flares were devised."[6]

Shooting down actual aircraft targets is not a cost-effective way to test weapons, gratifying though it may be to the weapon developers. When the first drone unit was established at NAF China Lake, it was assigned only 10 of the WWII-vintage Hellcat drones. Each aircraft was expected to carry out as many test flights as possible, including those for programs other than Sidewinder.

Here too IR flares offered a solution. The Sidewinder team reasoned that if an appropriate heat source could be attached to a drone's wingtips, the incoming missile, particularly when fitted with an inert warhead, would stand a smaller chance of downing a drone than if it were guiding on the drone's engines.

Robert A. Blaise (head of the Sidewinder Branch in the Test Department and later assistant head of the Propulsion Development Department) explained in a memo to his division head that:

> Because of drone losses, the next step taken was to mount the flares on brackets on the wingtips of the drones where the possibility of contact with the drone would be considerably reduced. . . . This resulted in substantial reduction in test-cost-per-missile-firing as well as speeding-up the missile development program.[7]

The T-131 had originally been designed as a visible tracking flare. Test Department engineer James H. Pennington wrote that:

> . . . availability, probably more than any other consideration, established the T-131 tracking flare as the first IR source for drone use. However, 6 to 16 such flares had to be ignited simultaneously to provide a suitable target. . . . Needless to say, something a little more efficient was desirable.[8]

What was needed for the QF6F-5K and for other potential targets was a reliable, inexpensive IR augmentation source, and NOTS set to work on its development. The Station had long been in the business of developing flares and tracers, but IR sources required specialized formulations to maximize the IR (rather than visible) output from the burning materials. Although the IR flare was an entirely new pyrotechnic item, the Station had the requisite expertise

6 Babcock, *Magnificent Mavericks*, 416.

7 Memo 3-11/RAB wa A1-1/S-23 Ser. 21, from Head, Sidewinder Branch, Code 3011, to Head, Project Engineering Division, Code 301, "IR Target Source for Sidewinder, History and Recommendation for Extended Use of," 17 May 1957.

8 James H. Pennington, "Pyrotechnic Target Augmentation at the U.S. Naval Ordnance Test Station," *Third Semiannual Interstation Pyrotechnics Conference at the U.S. Naval Ordnance Test Station, 5-7 April 1960*, NOTS, June 1960, 41.

F6F-5K drone rigged with thermic pots, 2 May 1957.

in chemistry, as well as years of experience developing igniters for rocket propellants. Early research by Frank G. Crescenzo, Elmo C. Julian, and Robert C. Meyers investigated compositions that included "magnesium, aluminum, boron, thorium, zirconium, molybdenum, and titanium as the fuels; Teflon, lithium perchlorate, potassium perchlorate, sodium fluoride, and potassium chromate as the oxidizers; and Kel-F oil #10 as a fluorine carrier and binder."[9]

The T-131 flare was soon replaced by thermite-filled carbon crucibles called "thermic pots," developed by China Lake and fabricated by Cooper Development Co. One such pot provided the necessary augmentation for a missile test, although the drones were usually rigged with several to allow multiple passes.

Bob Blaise led the effort for IR augmentation of the Sidewinder targets as IR flare work took off in earnest in the late 1950s. Most of the actual development was done by the Pyrotechnics Branch, which was set up in 1957 under B. Arthur "Art" Breslow in the Propellants and Explosives Department (Code 45). (Breslow had headed the Explosives Systems Branch in Code 45 since 1952.) Breslow's branch developed the NOTS 702 infrared flare, the forerunner of modern IR flares. It used a new composition made up of 54

9 Dr. Bernard Douda, *Genesis of Infrared Decoy Flares*, Naval Surface Warfare Center, Crane, Indiana, 2009, 28.

percent magnesium, 30 percent Teflon, and 16 percent Kel-F wax. By 1959 the Kel-F wax, which had been used only for molding purposes, was eliminated from the mix by molding the magnesium-Teflon mixture at 700°F.[10]

The need for Sidewinder high-altitude targets led NOTS engineers in 1957 to develop POGO-HI IR targets, modifications of the POGO-HI target, first developed for the Navy in 1953 by the Physical Science Laboratory of New Mexico State University. Engineers at the Naval Ordnance Missile Test Facility, White Sands, modified POGO into two versions for Talos testing: POGO-HI (50,000- to 60,000-foot altitude) and POGO VERY-HI (50,000-90,000 feet). The original missiles released a radar target at altitude that descended under a parachute. At NOTS they were modified to carry an IR source that consisted of a thermite mixture in a carbon crucible that, upon ignition, brought the crucible "to a yellow heat."[11]

In 1958, Code 45's Paul G. Rivette, Rodney G. Weldon, and George T. Hahn applied for a patent on an "Infrared Tracking Flare" designed to be affixed to a rocket. (The notice of allowability was granted in 1961 but the patent was not issued until 1997.) The patent description reads in part that "the object is to provide a flare which will produce infra-red radiation of 0.8 to 3.5 microns in wave length in greater quantities than previous flares."[12]

An incident in March 1961 illustrated the value of the IR wing-decoy flares. When an F9F-6K drone was sent up as a missile target over G Range, the wingtip flares on the drone ignited, but through some malfunction they were carried away shortly after the drone was launched.

Lieutenant A. S. Newman, flying an F8U Crusader with a pair of Sidewinders, approached the target at 500 miles per hour. According to a *Rocketeer* article the following week:

> Newman closed in and fired one missile. With the wingtip flare gone, the missile, lacking a better source of heat to seek, homed in on the jet engine of the drone, ripping a hole eight inches wide and eight feet long on the tail section and fuselage.

Although the missile carried an inert warhead, the impact damaged the aircraft's rudder. Lieutenant Commander Walt Henning, who was flying chase and controlling the drone, brought it down from 26,000 feet to 10,000 feet before handing over control to the ground crew. Skillful handling by drone controllers Lieutenant Commanders Andy Berthelson and John McIlmoil at

10 *Technical Program Review 1959*, 92.

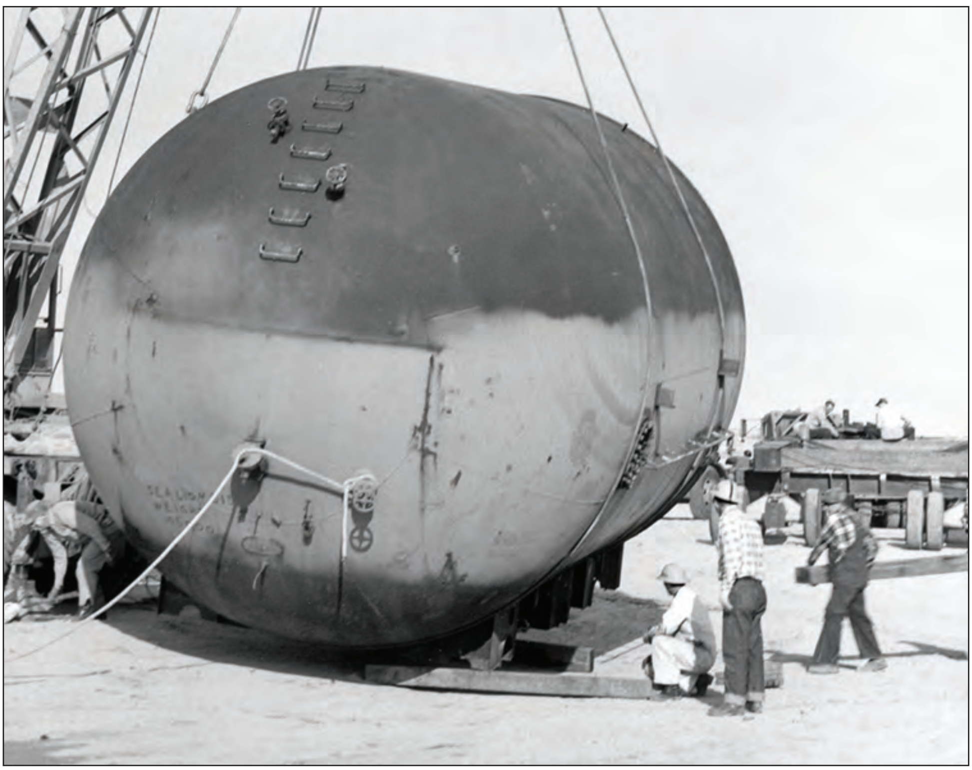
11 *Technical Program Review 1958*, 203.

12 U.S. Patent No. 5,679,921, "Infra-Red Tracking Flare," 21 Oct 1997.

NAF managed to land the drone intact on their second attempt. The drone fliers "saved the taxpayer and the Navy an estimated $100,000 by their quick thinking and skill."[13]

High-altitude ignition was a continuing problem with IR flares. Engineers Kenneth R. "Ken" Foote and Armin T. Wiebke studied the use of hot bridge-wire initiation of a magnesium-fluorocarbon composition to increase ignition reliability. In 1957 Breslow got wind of an odd item that might help resolve some of the issues of pyrotechnics' high-altitude performance. The WWII-era submarine USS *Sealion* (LPSS-315) had her on-deck hangar removed during remodeling. The cylindrical hangar, measuring 34 feet long and 16 feet wide and weighing 52 tons, was available for the cost of transport. The hangar had been used aboard *Sealion* to house a tracked landing vehicle (LVT) and was capable of withstanding the immense pressures of the deep ocean.

At Breslow's urging, the Station had the hangar shipped by way of the Panama Canal to Long Beach, California, and from there by a specially permitted and circuitously routed doublewide truck to China Lake's Camel T



***Sealion* hangar being unloaded at Camel T Range.**

13 *Rocketeer*, 17 March 1961, 1.

Range, eight miles east of the China Lake Pilot Plant and close to Pyrotechnics Branch facilities.[14]

Christened the High Altitude Test Chamber, the hangar was refitted with a 40-horsepower vacuum pump and associated equipment that could reduce the air pressure inside the chamber to that existing at an altitude of 200,000 feet. A 100-*g* centrifuge was added to test items under high-speed conditions. (In 1963 Dr. George S. Handler had a rapid scanning IR spectrograph installed at the chamber.) For many years the facility was used to test propellant mixtures and pyrotechnic devices at simulated high altitudes.

At the request of the Air Force, NOTS began development in 1958 of the Model 711A electrically initiated IR target flare that had "defined characteristics in terms of size, radiant energy and altitude performance." (The Air Force designation was the TAU-15/B.) Development was completed the following year.[15]

In 1959 Charles Falterman, and Horace Stanton developed the shock-gel process for mixing the IR compositions. The process resulted in safer, more stable mixes and, according to Dr. Bernard Douda, remains in use today. By the end of 1959, IR sources (flares or thermite crucibles) had been used on nine different types of Sidewinder aerial targets, ranging from helium-filled balloons and POGO-HI rocket-launched parachute targets to Ryan AQM-34 Firebee (KDA) drones and, of course, QF6F-5Ks.[16]

From missile target flares and wing-decoy flares to IR countermeasures is a short logical step—it stands to reason that if an IR flare can attract a missile to a target, even to a specific point on the target, the same flare can also draw that missile away from the target. If a target flare is designed so that its IR signature simulates that of a threat aircraft, why not make a flare with a signature as close as possible to a friendly aircraft, and then eject that flare when the enemy fires on the friendly?

The NOTS Model 704A flare, developed around 1960, was jettisonable (it was ejected by an explosive squib and fell aerodynamically by virtue of fins and a weighted nose section) and may have been the first actual "countermeasure" (versus tracking) flare. More than 60 models in the NOTS 700 series followed,

14 *Rocketeer*, 14 Feb 1958, 4. The China Lake Pilot Plant (CLPP) had been constructed a few miles east of Mainside during WWII to produce propellants for the Caltech rocket program. The several hundred buildings were later designated the China Lake Propulsion Laboratories, but the entry gate for the area is still referred to as the "Clip Gate."

15 Douda, *Genesis of Infrared Decoy Flares*, 38.

16 J. R. Deal, R. D. Finch, and L. E. Lakin, Jr., "Sidewinder Test Program," NOTS 2068, *Weapons,* 34.

continuing well into the 1970s. Varying in chemical and binder composition, luminosity and radiance, target type simulated, intended altitude of operation, burn time, ignition type, size, case material and design, etc., these devices were used by both the Navy and its sister services.[17]

Flares originally developed for tracking were refined and repackaged as decoys. For example, to protect the next-generation Ryan BQM-34A targets, Eddie Allen and Michael Mamula began development of the Model 733A flare in 1962. This flare not only had to function at very high altitudes but needed to be compatible with the AN/ALE-33 chaff dispensers installed in the wings of the BQM drone. The 733A was released to the Fleet as the Mk 42 Mod O Decoy Flare. This could be released at Mach 0.9 and could function at an altitude of 70,000 feet. Its specifications called for a burn time of at least 2 seconds at 50,000 feet.[18]

The Mk 42 was followed by the Mk 43 Mod 0 Decoy Flare. This flare was unique in that it could be deployed from the pneumatic chaff dispenser (AN/ALE-18) of the A-6A Intruder. The value of confusing enemy radars had long been recognized by aircraft designers—chaff was used by both Germany and the Allies in WWII—so chaff dispensers were standard equipment on most military aircraft.

One problem in development of flares that accurately simulated tactical IR sources was the rudimentary nature of the IR characterization process. The technology had advanced well beyond Nichols' early primitive detector; in 1960 IR cameras conceived in NOTS' Weapons Development Department orbited the earth in two Transit satellites, transmitting data on the intensity and distribution of the earth's IR radiation. But the lack of sophistication in IR detectors was still a limiting factor in how precisely the developers of IR tracking flares and countermeasures could characterize their targets and tune their products. Armin Wiebke described his laboratory IR instrumentation circa 1960 as "very simple, consisting of a lead sulfide cell in series with a resistor, mounted behind an interference filter. . . . the cell is mounted on an aluminum block that is held at a constant temperature by an ice-cube and water bath." Better devices were needed.[19]

Raim Regelson had moved to NOTS in 1951 with his wife Lillian, after receiving a degree in meteorology from UCLA. Regelson got his feet wet in

17 Douda, *Genesis of Infrared Decoy Flares*, 33-45. The 700 series flares are described in some detail in this report.

18 Ibid., 59.

19 Armin T. Wiebke, "Instrumentation Employed by the Pyrotechnics Branch for Pyrotechnics Measurements," *Third Semiannual Interstation Pyrotechnics Conference*, 41.

infrared research at AOD while working in the Sidewinder program designing reticles, filters, IR sources, and calibration devices. Being able to pick out a jet exhaust through different haze conditions, at varying distances against rapidly changing backgrounds of earth and sky, was an immense technical challenge. Radiation varies to the fourth power of the temperature, so even minor changes in aircraft power settings caused a large change to the radiation received by the detector. A missile could be distracted by something as simple as the sun glinting off the skin of a wing or off a body of water on the ground. "The sun," Regelson observed, "is a fierce enemy."[20]

NOTS needed an accurate radiation source to check the detectors that Philco was producing for the early Sidewinder seekers. At the time, Bureau of Standards accuracy requirements for radiation sources were 10 to 20 percent; Regelson wanted 1 percent. "Everything radiates, all around you, all the time," Regelson said. "We were trying to measure a rubber band with a rubber ruler."

Working with Nichols, Regelson began to develop his own radiation sources: coils of tungsten wire with a heat-resistant glue, which proved adequate to the task of monitoring the contractor's detector performance. In 1961 the two men developed an even more accurate airborne radiometer using a liquid-nitrogen-cooled lead selenide detector cell for measuring the IR output of aerial flares.[21]

Rapid expansion of flare development brought the need for a dedicated flare test facility. As Jim Pennington noted:

> . . . it is unfortunate for those of us concerned with augmenting targets that source measurements from different groups are often confusing. In some instances, measurements vary in magnitude by a factor of four or five. . . . Reliable data that could be used in comparing a new source with a familiar one would be most advantageous to the test planner."[22]

In 1963 the Skyhook Flare Facility opened at the CT Range. Art Breslow, senior design engineer Herb Neuhaus (who had designed RAPEC, the rocket-assisted personnel ejection capsule), and mechanical engineer Joe Hanzel came up with the idea. The three had done most of the conversion of the submarine

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20 Regelson telephone interview by the author, 22 June 2009. Trial and error played a major role in the early IR work; Regelson said the reticle used in the first production Sidewinder was "Type 93"—the 93rd reticle design that the developers conceived, built, and tested.

21 Regelson, telephone interview by the author, 3 July 2009. Regelson's "Infrared Calibration Lamp" was granted U.S. Patent No. 3,225,242 on 21 Dec 1965.

22 Pennington, "Pyrotechnic Target Augmentation," *Third Semiannual Interstation Pyrotechnics Conference*, 43.

hangar to a high-altitude test chamber in 1958. According to the *Rocketeer*, the maxim of the Pyrotechnics Branch was "One test is worth a thousand opinions."

Skyhook consisted of three 120-foot-high poles set in an equilateral triangle 86 feet on a side. The poles were fitted with rigging that allowed objects up to 1,000 pounds to be lifted up to the 100-foot working height. By elevating the objects being tested, the test crew minimized ground influence and developers could obtain "more accurate measurements of the candle-power output and infrared intensity of pyrotechnic items." The geometry of the facility also eased the tasks of cross-wind testing and testing against different sun and cloud backgrounds.[23]

As the variety and sophistication of IR flares increased, the Sidewinder missile developers were keenly aware that their IR-guided missile could be diverted from its course by a nontarget IR source; that is, by an enemy countermeasure flare. Therefore two parallel paths of engineering development began. One was the effort by the Sidewinder seeker engineers to anticipate how an enemy might try to confuse Sidewinder using IR countermeasures, and then to develop a capability in Sidewinder that would discriminate between the real target and the decoy—a counter-countermeasure.[24]

The second path mirrored the first, with developers working on an in-house IR countermeasure capability to fool Soviet IR air-to-air missiles such as the Vympel K-13, NATO designation AA-2 Atoll—a reverse-engineered AIM-9B, which entered service with Soviet air forces in around 1960. Soon Don Moore's group was working on a missile launch detector operating in the IR, and countermeasures research expanded into obscuration techniques and the fabrication of decoys from pyrophoric materials (those that ignite spontaneously on contact with air).

A modification to the Sidewinder AIM-9C/D by Breslow and Richard A. Breitengross in 1961 resulted in a dramatic reduction in the IR radiation of the motor plume, making the missile less likely to be detected by an IR-based missile-warning system on an enemy aircraft.

That year's *Tech History* reported that:

> Infrared measurements . . . showed a reduction in radiation intensity from the suppressed rounds by factors of 2-to-1 and greater. . . . Motion pictures of the

23 *Rocketeer*, 5 April 1963, 5.

24 The process of understanding enemy countermeasures occasionally received a boost when actual threat hardware was acquired, through purchase, capture, or theft, and was subjected to analysis by a team of experts—sometimes in the form of super-secretive In Country Exploitation (ICE) teams, several of which included NOTS/NWC personnel.

> firings showed drastic reduction of visible radiation . . . Motor performance was not noticeably affected by the suppressor system.[25]

Given the penchant of Station employees to blend the lines between work and play, it is no surprise that on the 4th of July 1964, Breslow, Allen, Foote, Mamula, and Breitengross comprised the volunteer crew that put on the spectacular fireworks display for the Station's Independence Day program.

In 1966 Dr. George Handler, Joseph W. Hanzel, and Rosemary Whitman began development of the Mk 46 Mod 0 Decoy Flare. An outgrowth of the earlier NOTS Model 400A flare, the Mk 46 used an improved composition to give a shorter rise time and higher average output. The Mk 46 and its subsequent Mods (1, 1A, 1B, and 1C) were used with the Tracor, Inc., AN/ALE-29 countermeasures dispenser (flares and chaff) installed on all Navy fixed-wing fighter and attack aircraft. Later in the war, China Lake developed a kit for mounting the AN/ALE-29 on Marine and Army helicopters.

Cheaper and better performing than its contractor-developed counterpart (the Mk 47, manufactured by Unidynamics Division of UMC Industries) the Mk 46 decoy was released for limited production in December 1967 and went to the operational forces in 1971. During VX-4 testing at Point Mugu, Sidewinder AIM-9Bs were used as simulated Atoll air-to-air missiles against the Mk 46. In Vietnam, the flare was "credited with saving many U.S. aircraft."[26]

One novel IR decoy developed by NOTS was the Mk 48 Ship's Ordnance Infrared Decoy (SOID). The impetus for this decoy was the possibility that an enemy antiship missile might guide on the IR signature of a naval vessel (the same fear that, after the *Worden* incident in 1972, would lead to the Sea Chaparral program). SOID was a quick, inexpensive countermeasure, a hand-launched IR decoy that could be shot sufficiently far from the ship, and create a sufficiently strong IR signature, that it would draw the heat-seeking missile away from its intended target. The decoy consisted of a foot-long cylinder containing the flare material. In the floating base was a seawater-activated battery that fired an electrical squib to ignite the flare.

In initial tests, the reliability of the flare, as Howard Auld recalled, "was terrible." He remembered that as engineers scratched their heads, someone came forward and said:

> All you need to do is where you have your solid flare. . . drill a hole like 2 inches down into the center of the flare and then draw a horizontal hole that intersects, put your squib right there at the opening, and that will give you

25 *NOTS Tech History 1961*, 109.
26 *Major Accomplishments*, 71.

> . . . a chimney effect. . . . it was tried and . . . brought the reliability up over 99 percent. It was a simple solution to a really difficult, at least to most of us, a difficult problem.[27]

SOID completed development and went to the Fleet in 1971.

IR Characterization Studies

The evolving technologies of IR-based missile guidance systems initiated a related development in the aircraft design community. After the MiG shootdown over the Formosa Strait, aircraft designers were suddenly aware of the vulnerability of their aircraft to IR-guided weapons and realized that steps could be taken in the design and manufacturing processes to minimize the IR signature.

At China Lake Regelson was put in charge of AOD's Radiometry Branch when it was formed in 1958. (It would become the IR Countermeasures Branch in 1964). He would remain in charge of this group until leaving in 1969 to head NAVAIR's Countermeasures and Weapons Control Section. Regelson's group specialized in radiometric measurement, offering the capability to gather data on the IR vulnerability of virtually any type of aircraft.[28]

An F3D equipped with fixed nose and tail radiometers was the branch's original test platform. (The nose radiometer allowed quantitative data to be gathered on another aircraft from its "six," the most vulnerable region directly behind the aircraft, where the IR radiation was greatest.)

Regelson didn't like the Barnes and Perkin-Elmer radiometers that his peers in industry and other laboratories were using, so he and Paul Mutchlechner built their own, using optical filters and a modulator. It took a year to get the F3D operational with the new gear.

The F3D flew more than 50 missions in 1958, measuring jet and flare targets and, according to the Station's *Technical Program Review*, "contributed materially to the understanding of the radiation characteristics of both afterburning and nonafterburning jets. Also, certain types of flares were found to be valuable for both target-simulation and countermeasure applications."[29]

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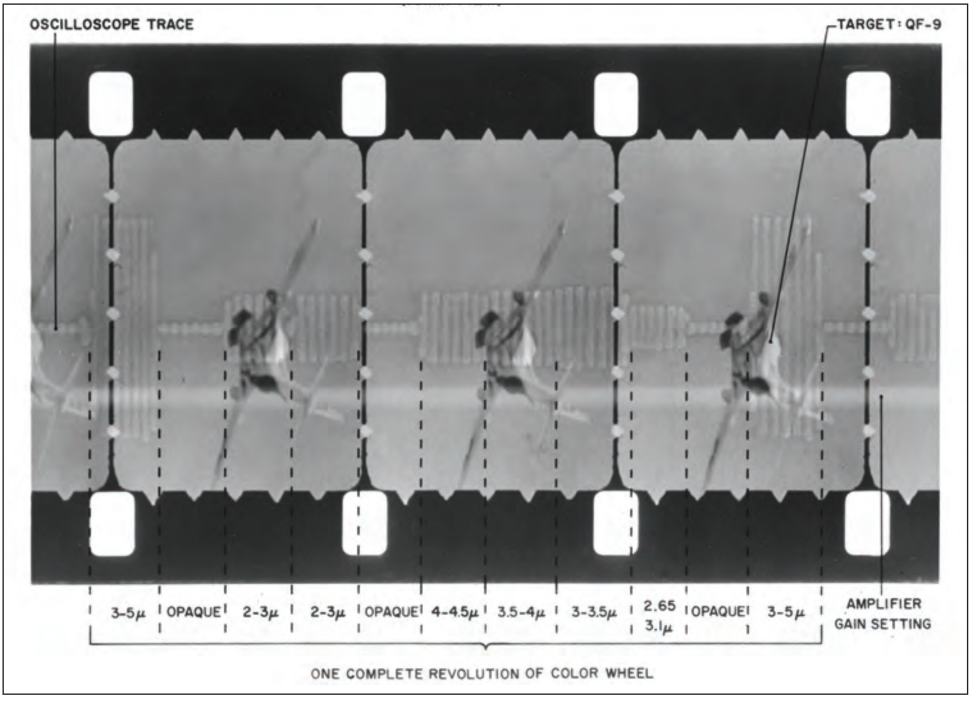
27 S-273, Howard Auld interview, 4–5 June 2008. 39. Auld, who was in the Propulsion Development Department at the time, spent a 35-year career as an engineer and supervisor at China Lake. In 1977 he received the Technical Director Award for his direction of the Vertical Launch Standard Missile prototyping program. He died on Dec. 29, 2013.

28 Regelson was also responsible for establishing the influential IR Countermeasures Specialty Group of the Infrared Information Symposia (IRIS).

29 *Technical Program Review 1958*, 133.



NOTS radiometer data log, 16mm film.

Size and space limitations in the F3D restricted its use as a radiometric test bed, so the NOTS team sought a more suitable platform. The first candidate was a P-3 Orion, but the Air Force offered a B-52 for the group's work. Boeing modified the bomber by adding gimbal-mounted measurement stations in the tail turret and at the bombardier-navigator position as well as a fixed radiometer station in the nose.

The Radiometry Branch installed color-wheel radiometers with half a dozen optical filters that split the IR radiation into half-micrometer intervals. The devices were pointable, and photo-optical recorders overlaid the output signal from an oscilloscope and the target image on the same picture.

Starting with measurements for the Air Force and Navy, the program soon expanded to include aircraft manufacturers. A *Rocketeer* from 1959 shows Regelson with Boeing representatives and the crew of a B-52 that landed at Armitage Field for a 15-minute stop. The aircraft was there for a joint program involving the Station, the Air Force, and the Boeing Airplane Co. in high-altitude measurements.[30]

30 *Rocketeer* 16 May 1959, 4. Not all was work at NOTS; the same *Rocketeer* issue carried a photograph of a smiling 26-year-old Jayne Mansfield who visited China Lake to formally open the new patio at the Enlisted Men's Club.

IR applications seemed to be everywhere. In 1960 NOTS engineers repackaged a radiometer to fit in a 5-inch-diameter tube so that it could be used on any aircraft equipped with a Sidewinder launcher. That same year NOTS used its radiometers to measure the IR emissions of small, propeller-driven civilian aircraft, in connection with proposals to develop collision-warning devices.[31]

At about the same time, the Station was working on Project Stone, a BuWeps-funded project to develop a fixed-platform radiometer for detecting the IR signature generated by the wake of an enemy submarine. An ocean range for this project, the Stone Range, was established at San Clemente Island in 1961. The range was used in conjunction with a promontory called Station Stone, elevation 1,500 feet, the site of a 100-inch-diameter radiometer. The site was used to define the ocean-surface effects created by the passage of a submerged submarine.[32]

Stone was an outgrowth of NRL's Project Clinker in which a ZPM-4 airship was outfitted with a large radiometer. Little documentation is available on Project Stone, although McLean, in a then-classified 1963 presentation, alluded to work on the detection of submarines by the Kelvin wave patterns that their subsurface passage leaves on the surface, and an appropriations memo for fiscal year 1963 lists a $475,000 limit for "Submarine Surface Effects."[33]

NOTS set up an Infrared Detector Evaluation Laboratory (IDEL) in 1961. At the facility, researchers could evaluate cooled and uncooled infrared detectors, infrared sources, infrared filters, and associated optical elements in any spectral region from 0.125 to 16 microns and could measure sensitivity, noise, microphonics, infrared energy distribution, and optical efficiency under a range of environmental conditions.[34]

In 1963 the Air Force assigned NOTS a T-39 Sabreliner, which proved an even better platform than the B-52 for IR testing against high-performance targets. Bill Arriola, John Crecelius, and Jim Mills designed and built the tracking equipment and mounts. Wayne Claunch designed a miniaturized

31 *NOTS Tech History 1960*, 22.

32 Dickinson, *Glossary of Project Titles*, 84; *NOTS Tech History 1960*, 235.

33 "NOTS Presentation—BuWeps R&D Planning Conference," 17 April 1959, RM-24, *Collected Speeches of McLean*, 171; "Notes from Informal Discussion with Dr. Harold Brown, Dr. James H. Wakelin, Admiral Chas. B. Martell and Captain Wm. J. Moran with Representatives of Station Management on 12 October 1962," no author given, Attachment 1, "Complete Listing of Statutory Limitations in RDT&E Appropriations at NOTS for FY-1963." The Station also investigated the use of the AN/APQ-56 radar to detect surface manifestations of submerged submarines.

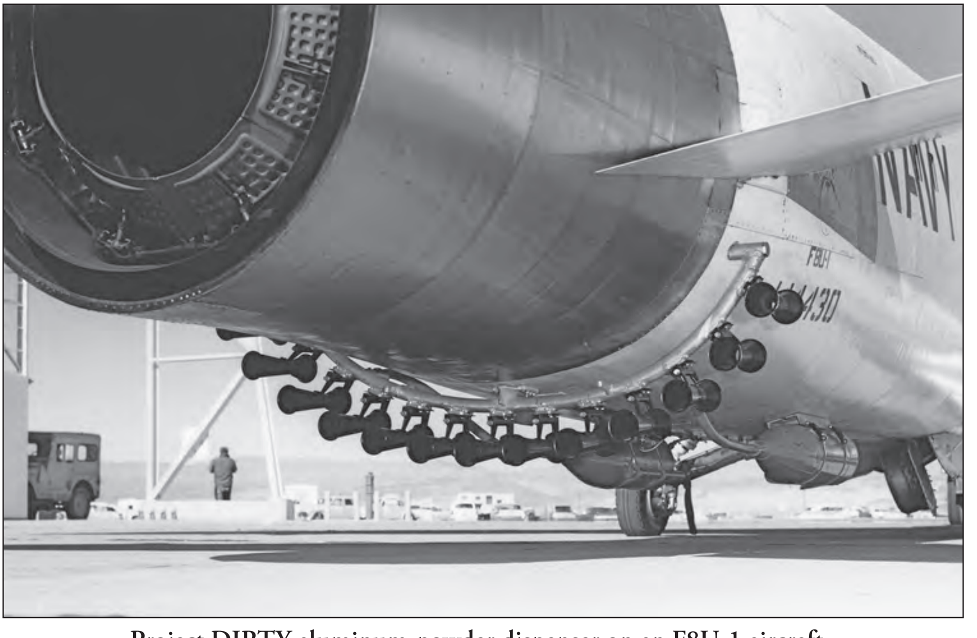
34 *NOTS Command History* 1961, 12.

radiometer to fit behind a 5-inch-diameter synthetic sapphire window in a tracking turret (the largest synthetic sapphire in the world at that time).

Arriola, a photo-optical technician and amateur photographer, was the Radiometry Branch's jack-of-all-trades, operating by the motto of his alma mater, San Diego High School: "I will find a way or make one." In a complex joint IR exercise with Point Mugu in February 1963 that involved several aircraft from both sites, he served as test coordinator, equipment builder, and in-flight radiometer operator. [35]

As the Station's IR detection capabilities expanded, IR vulnerability measurements drew an increasing number of customers, and the Station used the T-39 in many IR characterization and signature-reduction programs for the Navy, Air Force, Marines, and contractors.

In 1963 and 1964, NOTS supported an IR reduction program known as Project DIRTY (Dispensing Items Reducing Thermal Yield). Extensions and deflectors were added to the exhausts of A-4As, -4Bs, and -4Es (and the Army UH-1B Iroquois helicopter), and the aircraft were flown in tandem with the T-39 while IR data were collected at different ranges and aspect angles and against various backgrounds. The data were compared with baseline data



Project DIRTY aluminum-powder dispenser on an F8U-1 aircraft.

35 *Rocketeer*, 1 Feb 1963, 1. Arriola later served as head of administrative operations for the Systems Development Department.

from unshielded exhaust systems. Other aircraft were fitted with dispensing mechanisms by which various additives were released into the jet exhaust to alter its IR characteristics.

NOTS was making a substantial investment in IR research, not only for continuing Sidewinder development and related applications (decoys, targets, and warning systems) and aircraft IR-signature measurements but also for satellite and ballistic-missile defense applications. As the Station's expertise and reputation expanded and its IR detection capabilities became more robust, NOTS, and particularly the IR Countermeasures Branch, became the go-to place for aircraft manufacturers seeking comprehensive IR characterization—vulnerability assessments—of their products. These included civilian as well as military aircraft, propeller-driven planes as well as jets.

The Army, Air Force, and Marines also relied on NOTS for IR characterization of their aircraft. Even the CIA availed itself of the branch's expertise, asking for a full IR-signature-reduction modification of a Lockheed Electra aircraft. "We made many, many modifications over a short period of time, and they were very successful," said Regelson. "The whole science of camouflage had to be reopened in the context of infrared."

He also recalled that his group worked for at least 20 different sponsors. "We were never short of money. I could go to any wing of the Bureau . . . and get all the money I could possibly spend."[36]

Business was almost too good. Demand for the services of the group, which operated out of a trailer behind Michelson Laboratory, expanded to the point that by 1967 members could barely keep up with the work. The task of correlating photographic views of the targets with the instrument readings and of calculating the range and aspect angle of the target was extremely tedious, with a film reader having "to view successive film images using a light box and an eyepiece magnifier with a scale engraved on the lens. Back and eye strain caused accuracy to fall off severely during the day."[37]

A better method was needed. A team including Regelson, Crecelius, Arriola, and physicists Howard Sumnicht and George Silberberg examined the problem and came up with the Film and Television Correlation Assessment Technique—FATCAT. Silberberg was the system's chief inventor.

By introducing highly detailed scale models and television into the data-reduction process FATCAT dramatically sped up the work. According to *Rocketeer* reporter John R. McCabe:

36 Regelson telephone interviews, 3 July 2009, 22 June 2009.

37 *Rocketeer*, 24 March 1967, 1.

> In a nutshell, FATCAT combines on a TV screen the film image of an aircraft in actual operation—range and attitude unknown—and the televised image of an exact scale model of the same aircraft—range and attitude exactly known. When FATCAT's operator matches the two images by adjusting the scale model [which was mounted on a 60-foot-long rail] and the TV camera trained on it, with the film image, he gets a "fix" on the actual aircraft.

At that point, it was quick work to evaluate the dynamic target's range and aspect as well as the IR characteristics and the performance of countermeasures.[38]

As countermeasures and counter-countermeasures became big business in DOD, everybody, it seemed, wanted a piece of the action. The Radiometry Branch developed a program for evaluating the inevitable proliferation of new devices and technologies from laboratories and contractors. The methodology included ground testing at SNORT before the equipment was ever installed on an aircraft. The branch would also assess the degree of difficulty that an enemy might have in defeating the countermeasure device. There is no way to assess the amount of money that this "smart buyer" service saved the Department of Defense.

In spring 1965 Regelson and AOD Head Newt Ward had a difference of opinion concerning the future of the Radiometry Branch. As a result, Regelson approached Test Department head Highberg, seeking a new home for his team. Regelson was made head of the Infrared Countermeasures Group, on the department staff. "AOD was very reluctant to lose the projects," Regelson recalled, "but 100 percent of my people moved despite offers made to stay in AOD."[39]

Through the 1960s NOTS integrated its IR-characterization efforts into a more holistic approach aimed at improving aircraft survivability. The program combined IR-, radar-, and acoustic-signature reduction techniques, a forerunner of later stealth technology programs. Aircraft body and engine designers could bring prototypes to NOTS and come away with data that, when incorporated in an evolving design, reduced the likelihood of detection by the enemy.

In a 1966 meeting of the NOTS Technical Board, Highberg observed that:

> . . . the other Services have come to NOTS to get information on countermeasures . . . one of the main portions of effort is working directly with manufacturers of aircraft engines in an attempt to have built-in passive countermeasures.[40]

38 Ibid.

39 Regelson telephone interview, 22 June 2009. The Test Department was redesignated the Systems Development Department in October 1965.

40 NOTS Technical Board meeting, 16–18 March 1966, 13.

Since IR detectors in missiles were dependent on radiation emitted by the target, the simplest defense for an aircraft manufacturer was to reduce the amount of radiated energy; for example, by using more efficient exhaust nozzles that not only reduced IR radiation but improved engine performance. Regelson pointed out that "energy radiated is, in fact, energy wasted." He also observed in 1967 that "some of our present-day aircraft usage might be compared to the sending of a soldier into combat wearing a red hunting jacket."[41]

Through open-literature publications and such venues as the IR Countermeasures Specialty Group, Station experts shared information with their academic and industrial counterparts to help develop in-house IR exploitation and vulnerability reduction capabilities within the aerospace industry.

Missile Warning Technology

Timing is of the essence in the deployment of IR countermeasures. Too early, and the decoys are wasted; too late, and . . . well, they're too late. The pilot (or an automatic decoy deployment system) needs a cue that an antiair missile has been launched, either from the ground (a SAM) or from another aircraft (an AIM). Missile warning systems provide that cue.

When the threat is a radar-guided missile, the pilot's radar-warning-receiver gives a heads-up that the aircraft is being "painted" or "illuminated" by an enemy radar. Since an IR missile is passive (guiding on the friendly aircraft's IR radiation), the only way to detect its launch—short of seeing it being launched, as was often the case with the 33-foot-long SAMs in North Vietnam—is to detect the heat signature from the missile's rocket motor when it is launched against the friendly aircraft. Here again, IR detection technology is the key.

By the mid 1960s, NOTS was working on several approaches to tactical missile-launch warning systems. In 1967, responding to the serious threat posed to U.S. ships and aircraft by enemy gunfire, this work was expanded to include gunfire detection—a particularly difficult task because of the highly transient nature of the spectral signature from a gun flash.

Night Attack FLIR, ADAM, NOGS

Another major technological advancement that grew directly from the Station's accumulated IR expertise was the first true night-attack capability for aircraft.

41 E. Regelson, "Impact of IR Devices on Aircraft Design Trends," *Astronautics & Aeronautics*, Aug 1967, 62.

Night attack had always been a risky and inefficient business. In WWII, aerial night-attack operations often took the form of massive carpet-bombing missions that were both indiscriminate in target damage and expensive. Achieving higher accuracy depended on visually identifying the targets, which in turn required a light source. NOTS developed many different illumination flares, and they were used with some success in Korea, where Navy PB4Y-2 Privateers flew "firefly" missions to illuminate targets for U.N. night-attack aircraft. But flares, being spot sources, provided limited light, and their use warned the enemy of imminent attack. Additionally, even crudely camouflaged targets that remained still for the duration of a flare's burn were unlikely to be detected by a fast-moving attack aircraft. This was particularly true in the jungles of Southeast Asia. Something new was needed, and that proved to be forward-looking infrared (FLIR).[42]

FLIR grew out of NOTS work on the Sidewinder AIM-9D, the IR-guided version of the Sidewinder 1C program. In 1962, with the end of development work on the AIM-9D in sight, Chuck Smith's Air-to-Air Weapons Division (Code 405) was looking about for new work that would use the group's capabilities in electro-optical technologies. During a retreat division members decided to develop an IR air-to-surface weapon system called the Advanced Development Attack Missile (ADAM). Integral to the system would be an IR-sensor-based "search set" that, from an airborne platform, would scan the ground for targets and display them in the aircraft. From 1962 to 1964, a requirements analysis was carried out under IED funding.

NOTS' earliest uncooled lead sulfide IR detectors had operated in the near-infrared region of the electromagnetic spectrum (radiation with a wavelength of about 0.4 to 2.6 microns). To expand the detection range further into the IR required cooling the detector. The designers of the ADAM search set believed that optimum performance would be in the 8- to 13-micrometer range (also known as long wavelength infrared or LWIR), which required cooling the detector to around 10° Kelvin (-441°F). This was cold, considerably colder than the -321°F required for the AIM-9D's detector, which operated at around the 4-micrometer range.

ADAM was developed by Phil Arnold's Advanced Design Branch (later Weapons Control Branch) which was responsible for the electronics, and Mickie Benton's Optical Design Branch, which handled the optics, cryogenics and detector array, mechanical scanning mechanism, and box that held the

42 The term FLIR was chosen to distinguish the system from previous IR aerial-mapping systems that looked straight down from the aircraft and were called Downward-Looking Infrared (DLIR). S-275, Arnold interview, 21.

device. Bill Fitzgerald designed the optics; Eddie Allen and Larry Jeffris designed the mechanical system; and the electronics design effort was led by Floyd S. Hall, who had recently come to NOTS from Missouri School of Mines and Metallurgy and who would later head the Infrared Weapons Systems Branch.

Initially, funding was a problem. There were competent technical people at China Lake who opposed the project, believing among other things that the cryogenics-detector arrangement wouldn't operate reliably. In Washington, potential sponsors had concerns about whether targets could be recognized and acquired from an aircraft by means of a TV-type display. However, after successful feasibility flights with a pod-mounted TV camera on an AD aircraft, funding was provided—"reluctantly," Arnold recalled—to design and build demonstration hardware.

Several technical challenges had to be surmounted if the ADAM search set were to work. First was cooling; a cryostat (refrigeration unit) was required that would hold an extremely hard vacuum, and that necessitated an ion pump that would trap any particles in the cooling chamber. Voltage for the ion pump would need to be maintained 24 hours a day—permanently and in a rugged military environment.

Second was optics. Coated (gold-doped) germanium was chosen for the optical components. Germanium was not a problem for the multiple lenses internal to the system; however, as Arnold recalled, a "very large, flat chunk of polished and coated germanium" was required for the window through which the scanner would look.

Frank Knemeyer, then head of Code 40, stated that:

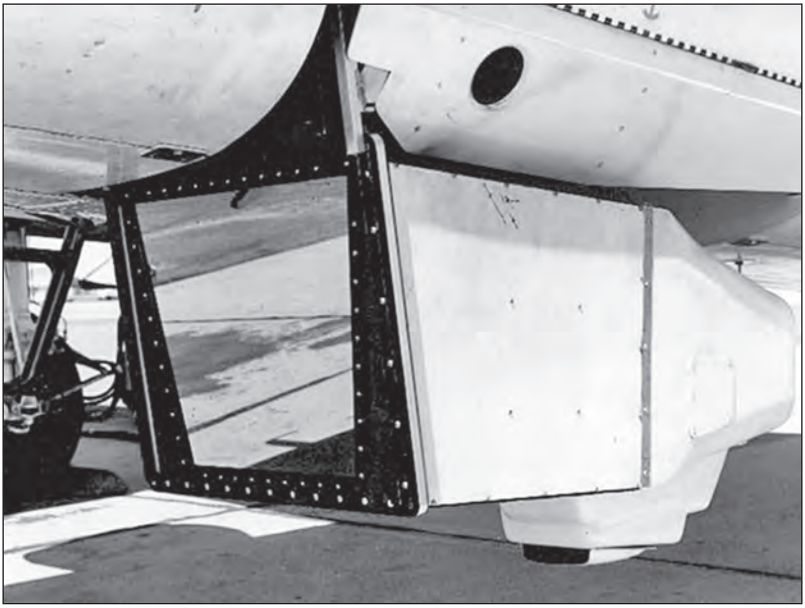
> . . . they conned me into buying a window for the thing. . . . A germanium crystal. It was about so big, so thick, and it cost 25 thousand dollars of overhead money just for that one window. That's the advantage of having overhead to do what we wanted.[43]

A third challenge was the scanner. Arnold reported that:

> We had wanted to build a mechanical scanner using a linear array of gold-doped germanium detectors in sufficient number to generate a usable field of view. But in a compromise over cost and risk with NAVAIR and Hack [Wilson], we finally settled on a 36-detector array.[44]

Since a field of view of 36 lines, each about 1 milliradian, was too small, the ADAM team designed a 6-to-1 interlaced scan that would yield a picture 216

43 S-200, Knemeyer interview, 69.
44 S-275, Arnold interview, 20.



S-2A tracker, ADAM FLIR search set, at China Lake, 23 August 1967.

lines high. Allen and Hall designed the mirrored optical system that produced the interlaced picture.

To reduce weight, the large hexagonal scanning mirror was made of beryllium (a third the weight of aluminum), which posed its own challenges in casting and machining because of the metal's toxicity. Despite the weight-saving efforts, the detector ultimately weighed in at over 700 pounds.

The completed ADAM FLIR was tested, first on the roof of Mich Lab and then on B Mountain, looking west toward the Sierra Nevada. Sponsors from back East were treated to a demonstration and recommended ADAM FLIR as the basis for a quick-reaction program to field a FLIR for use in Vietnam.

At its original size, ADAM FLIR was too clumsy for tactical use. Mickie Benton recalled that:

> It worked, gave us a good picture, we flew it, but it was a real kluge, and as we were getting it through into the development stage, we began to find Hughes and other companies were coming in with concepts to do essentially the same—to give a real-time IR picture.[45]

Eliahu "Ely" Reuben had worked at China Lake on the AIM-9D before leaving to join Hughes Aircraft Co. in Culver City, California. In 1969 he proposed to his management, which in turn proposed to China Lake, that the two organizations work jointly on a FLIR that could be used with the Trails/

45 S-193, Benton interview, 59.

Roads Interdiction Multisensor (TRIM), a unit that would contain FLIR, low-light television, and other sensors (including a magnetic-anomaly detector that could pinpoint truck ignition coils) to identify targets during night-attack missions in Vietnam. Since early in the war, the U.S. had been attempting unsuccessfully to stop the flow of war materials from North Vietnam into South Vietnam, primarily along a network of roads, trails, and rivers (mostly in the Laotian panhandle) known informally as the Ho Chi Minh trail.

In an unusual contractor-laboratory arrangement, Hughes and China Lake partnered cooperatively to develop the new system—dubbed EVE (because it sprang from ADAM). China Lakers Larry Jeffris and Eddie Allen did mechanical design work at the Hughes facility. A government program manager funded China Lake and Hughes independently, and no money was exchanged between the partners. In place of China Lake's large beryllium mirror, EVE used a system of Hughes-conceived counter-rotating germanium wedges that scanned the area ahead of the aircraft, "an effective and much smaller concept," according to Arnold. "Hughes was a very competent house, and success required the utmost in engineering capability."[46]

TRIM was initially installed in a P-2H and later P-3s for use in Vietnam. It was subsequently incorporated in the "C" model of the A-6 Intruder, which was released in 1970. These aircraft were used successfully for night-attack missions along the Ho Chi Minh trail.

Totally passive and undetectable by the enemy, FLIR could be used anywhere and would give no warning to the enemy. Because the system imaged heat, rather than the reflection of visible light, it was far less vulnerable to deception by target camouflage.

The Station's seminal work on FLIR would lead, in the 1970s, to the Night Observation Gunship (NOGS), a YOV-10D Bronco aircraft equipped with FLIR and a three-barrel 20-mm cannon in a rotating turret, what Knemeyer called "a perfect weapon" for the Vietnam War.[47]

China Lake was assigned management authority for the NOGS development project at the suggestion of Luc Biberman, who had left China Lake to work for the Institute for Defense Analyses, an advisory group to the Secretary of Defense.

46 Phil Arnold, email to the author, 20 July 2011.

47 S-200, Knemeyer interview, 69. The original concept for the OV-10 was developed at China Lake by K. P. Rice and W. H. Beckett. Lillian Regelson and Cdr. W. R. "Robbie" Robertson also performed studies and analysis that influenced the design of the OV-10—despite an official reprimand for "improperly establishing an operational requirement." Lillian Regelson email to the author, 13 Nov 2008.

Phil Arnold.

Arnold was the program manager for this quick-reaction-capability (QRC) project, which oversaw the efforts of Hughes (the FLIR contractor), North American Rockwell (the aircraft), and General Electric (the guns). The project also fielded the system on time and within budget. Arnold accompanied the Marine Corps' NOGS unit to Vietnam. During the NOGS deployment, which lasted several months, a member of the China Lake NOGS team—Bill Irby, Orin Gilbertson, Ron Jones—was always with the detachment.

Later in the 1970s came the Night Observation Surveillance (NOS) aircraft similar to the NOGS but with a surveillance, rather than interdiction mission; the A-6E Intruder Target Recognition and Attack Multisensor (TRAM) system; and the A-7E Corsair's FLIR system. Today, FLIR technology is standard on ships, fixed- and rotary-wing aircraft, and fighting vehicles. Civilian applications of the technology range from firefighting to wildlife monitoring to electrical-transmission-line inspection. The rapid expansion of FLIR research in industry after NOTS' trailblazing work points up the value of a government laboratory as the pioneer in developing high-risk technologies to pave the way for commercial exploitation.[48]

One reason that NOTS was so prolific in generating new weapons and new technologies during the 1960s was the interconnected nature of its technical workforce. Ideas and inspiration, like ripples on a pond, would spread in all directions from a single new advance. IR detection is an excellent example of diverse applications spreading from a common point. The seminal "heat homing" work on Sidewinder led to the development of new IR sensors and new controlled sources of IR radiation, which in turn gave rise to IR flares for

48 A comprehensive discussion of NOGS development may be found in S-275, Arnold interview.

use in weapons development applications and IR decoys to enhance aircraft survivability. This work generated advances in IR detection and radiometry that were used to characterize U.S. platforms, so that ship and aircraft IR susceptibility could be addressed in the design stage. That advanced radiometric technology—coupled with NOTS-built rockets and stabilized platforms—was flown to the edge of space to characterize the earth's IR signature and that of friendly and threat ballistic missiles.

Each effort was propelled from concept to reality by the can-do attitude of the Station's eclectic mix of employees—physicists and technicians, gate guards and bean-counters, pilots and plane captains—who would "find a way or make one." NOTS' dogged but enthusiastic tenacity—as invisible to the human eye as infrared radiation, but no less real in its effects—was the animating force behind the Station's extraordinary success in weapons development.

10

Antisubmarine Warfare

Even if a submarine should work by a miracle, it will never be used. No country in this world would ever use such a vicious and petty form of warfare!

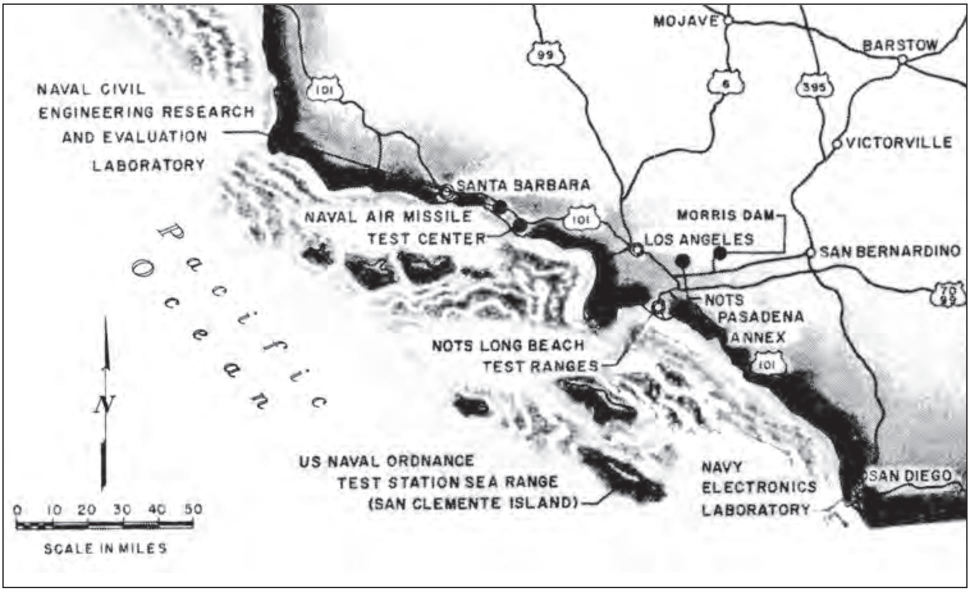
— Attributed to Vice Admiral Sir William Hannam Henderson, British Royal Navy (1845-1931)

On 17 May 1958, China Lake opened the gates for its traditional Armed Forces Day open house. The event included an air show and two rocket-sled firings at SNORT. According to the *Rocketeer*, 15,000 visitors watched a display of military strength that included rocket firings, bombing, in-flight refueling, and—the greatest crowd pleaser of all—a Sidewinder firing from an FJ-4 Fury at a target drone. (The missile, with an inert warhead, knocked the wingtip-mounted flare off the drone, which the controllers nevertheless managed to land safely.) A souvenir copy of the *Rocketeer* was printed for the occasion, chock-a-block with pictures of weapons and historical accounts of the Station's various departments and attached activities. NOTS Pasadena Annex was on the back page.[1]

Being relegated to the back page was, in the minds of some, an apt metaphor for Pasadena's relationship with China Lake. While the two sites were both under the military authority of the NOTS Commander and the technical leadership of the NOTS Technical Director, they were far apart physically (155 miles) and culturally.

China Lake was, to oversimplify, introverted: life in the isolated desert community was centered on work, socializing took place among co-workers, and people lived and entertained on the base. At Pasadena, there was no base housing; the workforce was more integrated into the larger Pasadena community, physically and socially. And whereas China Lakers tended to deal with defense

1 *Rocketeer Souvenir Edition*, Armed Forces Day, 17 May 1958. As a piece of editorial minutia, that back page was the only page with the wrong date printed on it—24 May 1957.



Pasadena Annex and other naval facilities in Southern California, November 1961 map.

contractors circumspectly, and on occasion adversarially, the employees at Pasadena Annex, most of whom had at one time worked for General Tire and Rubber Co. (GT&R), were much more comfortable in delegating work to contractors, as well as local academic institutions, in the earliest stages of the weapons research and development process.

The China Lake-Pasadena relationship began in WWII, when both sites were part of the California Institute of Technology's war effort. After the war, Caltech withdrew from the weapons-development business and NOTS, headquartered at Inyokern and later China Lake, was assigned the responsibility for rocket and torpedo development. Caltech's torpedo group in Pasadena was also assigned to NOTS. Initially, the Station contracted with GT&R (which had been producing rockets for the Caltech program) to run most of the Pasadena operations.

On 1 July 1948, the employees who had been working for GT&R transferred to the Civil Service, and by 1951 about 1,300 NOTS employees were working at facilities on Green Street, Foothill Boulevard, Thompson Laboratory (the former Vista Del Arroyo Hotel), and Eaton Canyon (in the foothills of the San Gabriel Mountains), all in Pasadena, and at Morris Dam, 20 miles east of Pasadena and five miles north of Azusa on the San Gabriel River. The Annex also operated the Long Beach Ranges and the Sea Range at San Clemente Island, 60 miles off the coast.

The overall focus of NOTS Pasadena's work was antisubmarine warfare (ASW), specifically the development of new technologies, submarine-detection, torpedoes, and fire-control and weapon-delivery systems. Russian submarines were seen as a major threat in the years following WWII, and in a study headed by then-Captain (later Admiral and CNO) Arleigh Burke in 1948, antisubmarine warfare was identified as the first mission of a carrier task force (an aircraft carrier and its associated support vessels, the Navy's primary surface combatant group). Professor David Rosenberg asserts that from 1948 until at least 1950, "submarine technology and anti-submarine warfare development were the Navy's top research and development priorities."[2]

Drawdowns began at Pasadena in the early 1950s, and Green Street was vacated in 1952. In a NOTS-wide reorganization in the spring of 1954, many of the functions at Pasadena—and 109 of its employees—were moved to China Lake, and Pasadena's Thompson Laboratory was closed (another Thompson Laboratory, also named for Dr. L.T. E. Thompson, NOTS' first Technical Director, was built at China Lake in 1953 and continued in use for more than 50 years).

There was talk in the following years of relocating the Pasadena operation. San Diego was a potential site, as was Seal Beach. One suggestion, nixed in a 1959 relocation study, was to move the Pasadena operations to the Naval Hospital at Corona, California. Among the reasons given for rejecting that plan was that "many key personnel . . . would not be willing to relocate unless a genuine improvement over present location were offered."

And the "present location" did have problems. As the study commented:

> Numerous inspection teams have agreed that the present Pasadena laboratory is inadequate. The Pasadena facilities consist of a miscellaneous group of old warehouse-type buildings converted to laboratory and office space. They are overcrowded and have no potential for expansion beyond the present level of effort. The makeshift character of the buildings and building layouts is not conducive to efficient use of space, efficient operations, or economical maintenance.[3]

Pasadena Facilities

However makeshift its buildings might be, the Pasadena Annex operated unique facilities that were essential to its mission "To plan and conduct a

2 David Alan Rosenberg, "American Postwar Air Doctrine and Organization: The Navy Experience," *Air Power and Warfare,* 257, 250. In 1988 Rosenberg became the first military historian to be awarded a five-year MacArthur Foundation Scholarship.

3 "Study for Relocation of NOTS Pasadena Annex at Facilities of NAVHOSP, Corona," 23 March 1959, *NOTS Station Journal 1959*, March, 2–3.

Variable-Angle Launcher at Morris Dam.

program of research and development in the field of underwater ordnance, including complete torpedo and missile weapons systems for the Fleet."[4]

Largest and most impressive of the Pasadena facilities was the Variable-Angle Launcher (VAL) at Morris Dam. Completed in 1948 at a cost of $2 million, the VAL simulated aerial launching of torpedoes by firing them with compressed air through either a 22.5-inch-diameter or 32-inch-diameter tube into the reservoir behind Morris Dam. The twin launch tubes were fastened to a 22-foot-wide, 35-foot-high, 300-foot-long steel bridge (which in 1950 was the largest all-welded structure in the country), the bottom of which was supported by a floating dock.

Developers used the VAL to manipulate the two principal variables affecting water entry for an air-launched weapon: angle of water impact and speed of water impact. The angle could be varied from 0 degrees (horizontal)

4 NOTS Pasadena Annex Mission Statement, *Station Journal 1959*, Jan–June, 183.

to 40 degrees. Speeds of entry could be as high as 1,000 feet per second. Underwater instrumentation recorded not only the details of water entry but also underwater trajectory characteristics. Engineers could determine, among other useful data, at what speed and angle combinations the torpedo would "broach," or rise to the surface of the water.[5]

Numerous other specialized laboratories and facilities run by the Pasadena Annex included the Hydrodynamic Simulator, used to test torpedoes and other ASW weapons in the same pitch, yaw, and roll conditions that would be encountered at sea; the Variable Atmospheric Tank for testing ⅕th-scale models of missiles; the Propulsion Laboratory for research into chemical propulsion, high-energy batteries, and various thrust-producing mechanisms; the Vertical Drop Launcher, for dropping torpedoes and other items weighing up to 2,000 pounds from heights up to 160 feet; and the Sonic Barge, for measuring the sound signatures of torpedoes.

In 1963 Pasadena added a new facility; the Vertical Water Tunnel. Standing nearly 25 feet high and capable of flow rates of over 14,000 gallons per minute, the tunnel was used to study the effects of fluid flow on bodies (torpedoes, rockets, hydrofoils, etc.). Attached to the Variable Atmosphere Tank, which had been completed for the Polaris program in 1959, the new tunnel complemented a horizontal water tunnel belonging to Caltech that NOTS used extensively in modeling underwater shapes.

The value of such exotic research facilities was only as good as the expertise of the scientists and engineers who used them, and the Pasadena Annex had some of the top specialists in the nation. Pasadena's expert on water-tunnel phenomena, for example, was Dr. John G. Waugh, who had joined Pasadena's staff in 1945 armed with BA, BS, and MA degrees from University of Missouri and a PhD from Cornell. An expert in the problems associated with the water entry and exit of missiles, Waugh was also chair of the BuWeps Hydroballistics Advisory Committee (BOWHAC). In 1972 the Naval Undersea Center published the authoritative *Hydroballistic Modeling* by Waugh and fellow hydrodynamicist Genevieve M. Stubstad; the book is still frequently cited in technical proceedings.

Other facilities, while not as complex as the Hydrodynamic Simulator or the Variable Atmosphere Tank, were equally essential to developing and testing ASW weapons. One of these was the Underwater Cableway Facility at Morris Dam. The cableway—designed by Dr. Robert C. Brumfield, head of Pasadena's

5 The Fixed-Angle Launcher, heavily used during WWII, launched torpedoes at 19 degrees from the horizontal.

Propulsion Division, and built in 1950—consisted of a pair of parallel ¾-inch steel cables anchored to two land masses on either side of the lake and stretched between (at a tension of about 15,000 pounds) in a catenary curve, with a maximum water depth of 60 feet. The cables' underwater span was 1,000 yards.[6]

The cableway, functionally an underwater version of the SNORT high-speed track, was used to test complete underwater vehicles at operational speeds with the certainty that they would be recovered. Although underwater testing in the controlled conditions of a laboratory was necessary during a weapon's development phase, such static testing had limitations. The Cableway Facility allowed realistic measurement of acceleration, thrust, noise radiation, and interactions between a weapon's power plant and its thrust producer (propeller, water jet, etc.).

In operation, the test vehicle was affixed to a pair of runners that were attached to the 45,000-pound-test cable—the type used for aerial cable cars—and the runners slid along the cables as the test-item moved under its own propulsion. Permanent acoustic and photographic instrumentation at the site was augmented by instrumentation on-board the test items. In 1963, the facility celebrated its 1,000th run.

Pasadena Ranges

Pasadena operated two range complexes that were fundamental to the development of systems at both the China Lake and Pasadena sites: the San Clemente Island Range Complex and the Long Beach Ranges. The San Clemente Island Range Complex, containing both deep and shallow water ranges, lay in the area of San Clemente Island, 60 miles off the Southern California coast. These ranges were used for developmental and operational testing as well as for Fleet training exercises.

The cornerstone of this range complex was the island itself, a 36,300-acre Navy-owned property that rises to nearly 2,000 feet at the top of Mount Thirst and is surrounded by generally calm waters. The high cliffs and the steep drop-off to deep water close to the island allowed good shore coverage of testing from camera sites at locations on the cliffs. The island's isolation from the public

6 *Rocketeer*, 17 May 1963, 6. It was Brumfield who, in a Research Board meeting in 1951, suggested that a classified volume be prepared to record the growth and achievements of the Station, both for historical purposes and to indoctrinate new personnel. The board expanded this idea into a running narrative of technical accomplishments, which became the *Technical Program Review* and *Technical History* series and eventually the *Annual Report of Technical Progress*. Unfortunately, because of budget cuts, this invaluable yearly overview of the Station ceased publication with the 1987 issue and has never been resurrected.

San Clemente Island, showing the Auxiliary Landing Field. Wilson Cove is at left.

enhanced the security of weapons testing, yet the facilities there were easily accessed by Fleet and laboratory personnel.

For the Navy military personnel stationed there, San Clemente Island was good duty. As a sailor said in 1959, "This island is tops. The liberty is good, the recreation is about the greatest, and there is never any boredom. It's truly the answer to a sailor's dream of a duty paradise."[7]

Civilians were transported to and from the island by a contracted airline with morning and evening flights from Long Beach Airport. Howard Auld, who oversaw several projects on the island, recalled that in the early days:

> . . . oftentimes the island would be shrouded in fog. The pilot would make the determination to fly out anyway. [The San Clemente Island] air controller was . . . a security person with a radio who was undoubtedly in contact with the pilot and saying, "Let's say you have a couple of hundred feet clearance between the ground and the bottom of the fog." . . . there was no ground approach equipment or anything like that."[8]

7 BU1 T. Hutton in *The North Islander*, 4 Dec 1959, quoted in W. J. Sturgeon, *SCI–A Chronological Military History (1932-2000)*, Buena Vista Assoc., San Diego, CA, 2002, 25.
8 S-273, Auld interview, 47.

Since the late 1940s, the facilities on the island had been used and maintained by NOTS, while the Station used the test ranges under contract with the Eleventh Naval District. As testing increased through the 1950s, the investment at the island grew; in 1959 NOTS spent more than $1.5 million on additions and improvements there. As well as piers, roads, power, dormitories, machine shops, and other support infrastructure, the island had a 9,350-foot-long concrete runway known as the Auxiliary Landing Field built in 1957 to replace the older airstrip. The island was a busy place and kept getting busier; 27,736 takeoffs and landings were logged at the Auxiliary Landing Field in 1965, an increase of 6,276 over 1964. (The field was often used for practicing carrier landings—the pilot came in over water and went out over water—and touch-and-go landings.) Operations at the field were the responsibility of NAF, and project pilots rotated to the island for weeklong tours as operations duty officers.[9]

Beginning with the East Shore Range, established in 1953 for shore- and underwater-launched missiles with ranges of up to 15 miles, more facilities were added as new weapons and systems were developed with specialized test requirements. These facilities included the Eel Point Shallow Water Range (1956); the Pop-Up and Fishhook facilities for Polaris testing (1957–1958, deactivated in 1964); the SUBROC facility and Fixed Platform Airborne Instrumentation Facility (1959); the Deeptrack Range (Project Star) and West Cove Range (1960); the Variable Depth Launch Facility, the Acoustic Range, and the Stone Range (1961); the Basic Underwater Demolition School (BUDS) Complex (1962); and a control tower and a helicopter maintenance building (1965).

The accelerated pace of testing at San Clemente Island through the late 1950s led the Station to establish, in 1960, a dedicated SCI Range Division of the Public Works Department; the new division was run from the Public Works Office in Pasadena. In 1961 CNO approved a NOTS request that administrative command of the island be transferred from Naval Air Station, North Island, to NOTS.

The ever-present danger of the weapons-development process was brought home tragically in an incident at San Clemente Island in 1961, when premature ignition of a rocket motor in a magazine assembly building took the lives of two NOTS civilian employees and injured two others. Three members of the SCI Range Division, Howard Lynch, Charles V. Bradley, and Luke R. Osborn, risked their lives to pull the men from the burning building and received Navy Meritorious Civilian Service Awards in recognition of their heroic actions.[10]

9 *NOTS Command History* 1959, 10; *NOTS Command History* 1965, Enc. 1, 2.

10 *Rocketeer*, 31 March 1961, 1. The victims were Ordnancemen Hubert J. Stanfill, who

Other than rain catchments there is no fresh water on the island, no potable groundwater, and no perennial streams. According to one author, a desalination plant that had been procured for the island in 1963 was on a barge being prepared for transport to the island. However, when the Cuban government cut off water to the Navy base at Guantanamo Bay in 1964, the barge was diverted to Guantanamo. As of 2008 the Navy was still barging drinking water to the island—about a quarter-million gallons weekly.[11]

The Long Beach Ranges were administered from facilities at Terminal Island in Los Angeles Harbor. These ranges encompassed 467 square miles of ocean between the mainland and Catalina Island and were used for open-ocean torpedo testing.

One feature of the ranges was a Navy Landing Craft Tank (LCT-1398) that had been extensively modified for deep-water work in 1956, redesignated a Harbor Utility Craft (YFU-44) in 1958. It was officially named the Deep-Depth Launching and Test Facility, and unofficially called *Trygon*. An instrumented platform could be lowered to a depth of 600 feet through a well in *Trygon*, and torpedoes could be launched (and rockets fired) from the platform. The platform was also used as an equipment test bed for measuring noise and vibration of underwater missiles and for ocean acoustics studies.[12]

China Lake and the Pasadena Annex operated smoothly enough as a technical team; there was little duplication of effort between the two sites and most programs benefited from the complementary facilities. However, resentment existed between the two organizations from the start. "China Lake was the favored child of BuOrd," said George Pollak, who was deputy for administration at Pasadena during the 1960s, "and they didn't really feel the hardship that some other emerging Navy laboratories were feeling because the Bureau of Ordnance really went to bat for NOTS."[13]

James H. Jennison, engineer and longtime Pasadena manager, spoke of

> . . . the struggle between China Lake and Pasadena. . . a group that often thought it should be independent, there should be a separate laboratory. Many of us recognized that there were some benefits to being attached to the larger center at China Lake but there were also many restrictions that we did not

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left a wife and daughter; and Robert B. Hughes, who left a wife and three children.

11 W. J. Sturgeon, *SCI—A Chronological Military History*, 29; Naval Facilities Engineering Command, *Southern California Range Complex Environmental Statement*, 2009, 3.4-15.

12 *Trygon* replaced a barge-mounted collection of deep-water test equipment, also called *Trygon* (the ancient Greek name for the common stingray), that had served on the ranges since 1951.

13 S-100, George Pollak interview, 24 Oct 1975, 2.

> like. We felt that the people at China Lake didn't understand our problems, our needs, and I guess this was true at times. We often thought that their viewpoint, their attitude was that they shouldn't let us be too successful or we might secede from the union, and we had thoughts of doing that.[14]

One of the benefits of being under the wing of China Lake was the clout that the larger entity had with Washington and the Navy. Jennison observed that when management at Pasadena wanted to do something that required Washington approval, an internal reorganization for example:

> Dr. Thompson [NOTS' first Technical Director] and later Dr. McLean had tremendous influence. And their endorsement of something like that was very important and very essential to getting approval of it. Washington people could prevent it almost as easily by ignoring us as they could by vetoing it or disapproving it.

Even the name Pasadena Annex rankled the Pasadenans. Jennison recalled that:

> We asked many times that we be called the Pasadena Laboratory and were successful in getting a building, the Thompson Laboratory, named for Dr. L. T. E. Thompson. So for a time they would speak of going to Thompson Laboratory rather than the Pasadena Annex. So on an informal basis we made some progress. But officially it was named Pasadena Annex.[15]

In 1956, Douglas John "Doug" Wilcox, who had been hired by NOTS as a mechanical engineer in 1948, was assigned to head the Underwater Ordnance Department (UOD, Code P80) at Pasadena, a group of more than 500 scientists, engineers, and technicians. Wilcox recalled years later that:

> . . . up until my appointment . . . there had been nothing but problems between the Pasadena Annex and China Lake. . . . Dr. McLean, Technical Director at NOTS, called me into his office and said that one of the conditions of my being the head of that department was that I mend the relationship between the Pasadena Laboratory and China Lake. In other words, that was a condition of employment . . . to cure the problem. And I said, "I welcome that, the opportunity to build that bridge," and took the job with that understanding.[16]

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14 S-99, James Jennison interview, 23 Oct 1975, 21. Jennison headed the Product Engineering Division at Pasadena from the division's creation in 1954 until the disestablishment of NOTS in 1967. He was the lead designer and construction manager of the VAL.

15 Ibid., 17–18.

16 S-103, Douglas Wilcox interview, 23 Oct 1975, 2. Wilcox had a spectacular career at Pasadena, rising from entry-level engineer to become the Annex's senior civilian and NOTS Assistant Technical Director for Development. After the disestablishment of NOTS in 1967, he served under McLean as Associate Technical Director at the Naval Undersea Warfare Center, San Diego. Among Wilcox's many honors were the L. T. E. Thompson

RAT and ASROC

Not all the resentment was on the Pasadena side of the divide. RAT was a case in point. In the early 1950s, Barney Smith's group in the Rocket Development Department (Code 40, forerunner of the Weapons Development Department) had been developing an ASW weapon with the cumbersome official name of "Rocket-Thrown Torpedo Weapon System" but called RAT, for Rocket-Assisted Torpedo.[17]

RAT was the first of an entirely new line of weapons. It was made possible because sonar technology had progressed to the point where detection of a submarine was possible well beyond the range of traditional torpedoes and traditional ASW weapons. RAT would allow escort ships—which still relied on the WWII tactic of chasing enemy submarines and dropping depth charges in an attempt to sink them—to attack subs quickly, at long ranges (without leaving their escort positions), while still out of range of enemy torpedoes, and with less warning to the target.

When the range requirement for RAT was changed from 3,000 yards to 5,000 yards in 1954, the developers nicknamed the improved version Super RAT. The payload was changed from the Mk 24 passive acoustic mine to the improved (but more delicate) Mk 43 Mod 3 torpedo.

Shortly before Super RAT was to enter the Fleet, the Bureau of Ordnance again increased the range requirement—doubled it, actually, from 5,000 to 10,000 yards. Smith's group was working on the ensuing suite of technical issues when the Bureau decided that it wanted the new Super RAT (the 5,000-yard Mk 43 model was now back to being called just plain RAT) equipped with a nuclear depth charge instead of a torpedo, and BuOrd prepared to assign the weapon development program to the Naval Ordnance Laboratory (NOL), White Oak.

McLean presented the case to the Bureau that a more flexible approach would be to develop a new rocket-launched ASW weapon with both nuclear and torpedo payloads. The Bureau's leaders were persuaded; however, they assigned the non-nuclear version of the new weapon—now called the Antisubmarine Rocket, or ASROC—to NOL.

In a Washington meeting, Barney Smith learned that NOL was leaning toward a liquid-fueled version of ASROC as the only practical way to control

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Award, the Arthur S. Flemming Award, and the Navy Superior Civilian Service Award.

17 The weapon was named RAT by Smith's group because since it didn't just swim and didn't just fly and thus was not a fish or a bird . . . "then it must be a beast." *Rocketeer*, 14 March 1958, B1.

the weapon's water entry. (Supersonic velocity was needed to get the payload to the area quickly, but termination of thrust and a retarded velocity were essential for safe water entry.) Smith telephoned the news to Don Moore, who called in Chuck Bernard and Orville J. "Jerry" Saholt. In the never-say-die fashion typical of NOTS, the three men designed, built, and tested a crude but workable solid-rocket-motor termination device in the span of 4 days. Smith returned to China Lake, carried film of the test back to Washington, and used it to persuade the Bureau that NOTS had the technical expertise to build a solid-fueled ASROC.[18]

Officials at the Bureau approved the development of ASROC (later designated RUR-5), an antisubmarine rocket that would be launched from Navy cruisers and destroyers and would carry either a Mk 44 acoustic-homing torpedo or the W-44 nuclear depth charge.

But was the project assigned to Smith's group? As Smith wrote in 1999:

> Not too far from the desert resided the Pasadena Annex to NOTS, an appendage devoted to ASW but otherwise not sufficiently cherished by Washington to receive assignments of stirring importance. The Annex immediately laid claim to the new RAT, soon to be called ASROC. I was dismayed to find the minuscule weight given to my new position as head of the Anti-Submarine Division and overwhelmingly appalled at the short shrift given to my impregnable arguments for keeping the project within the organization of proven competence.[19]

And to whom should the ASROC project be assigned but Doug Wilcox—in the same month that he accepted McLean's charge to "build that bridge" between the two NOTS sites.

In June 1956 when the ASROC program began, Wilcox already had his hands full managing RAT, which was less capable but further along in the development process. The development of RAT was a genuine team effort, with significant contributions from eight departments at China Lake, nearly everyone in Wilcox's UOD at Pasadena, a number of other Navy organizations (including six naval ships involved in various phases of development and testing), and a raft of contractors. Military input also played an essential role. As the *Rocketeer* noted, "Line officers, well aware of the limitations of World War II ordnance . . . provided the communications link from the Fleet to the drafting board."[20]

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18 Saholt earned a patent based on that concept: U.S. Patent No. 3,867,893, "Rocket Thrown Missile."

19 Bernard Smith, *Looking Ahead From Way Back,* 51. Smith was actually head of the Surface Weapons Division that contained the Anti-Submarine Weapons Branch.

20 *Rocketeer*, 14 March 1958, 1.

When RAT was trotted out before the press at Pasadena in February 1958—it had already passed Fleet evaluation testing and was in production—the event was carried in newspapers all over the country. "Navy Rocket May Block Russ Submarine Threat" shouted a Page 1 headline in the *Los Angeles Times*. The story was accompanied by a diagram showing RAT's mode of operation. The caption read like a Rube Goldberg invention:

> (1) Search equipment detects and tracks sub; (2) fire control system aims launcher; (3) rocket propels RAT from launcher; (4) airframe separates and first parachute opens; (5) second chute opens; (6) the torpedo enters water; (7) torpedo begins search pattern; (8) its homing device finds the target and (9) warhead explodes near the sub.[21]

According to the article, the weapon was described in the press conference as "the greatest advancement in antisubmarine warfare since World War II." The event was great publicity for the Station. "It made all three wire services," noted the *Rocketeer*, "and several hundred stations on network TV."[22]

Despite the hoopla, the deficiencies of RAT were quickly apparent, particularly when it was compared to the fast-developing ASROC. RAT, for example, was built around the Mk 43 Mod 3 torpedo. With that payload, it could defeat a submarine traveling at 15 knots, at depths up to 1,000 feet, and at a maximum range from the launch ship of 5,000 yards.

ASROC, by contrast, could reach out 10,000 yards (almost 6 miles) and with the Mk 44 torpedo (which was already in production) defeat subs traveling at 25 knots at depths of up to 1,000 feet. ASROC equipped with the Mk 46 torpedo, which had transitioned from a feasibility study into full-scale development in 1958, would extend the attack depth to 1,500 feet and would kill subs traveling up to 33 knots.[23]

At the end of 1958, therefore, the Bureau pulled the plug on RAT. The event was not as newsworthy as the rollout: the *Times* had no bold headlines, no photographs, merely a 2-column-inch piece on page B2 noting that "Navy spokesmen said the program was dropped because other secret anti-submarine weapons are superior."[24]

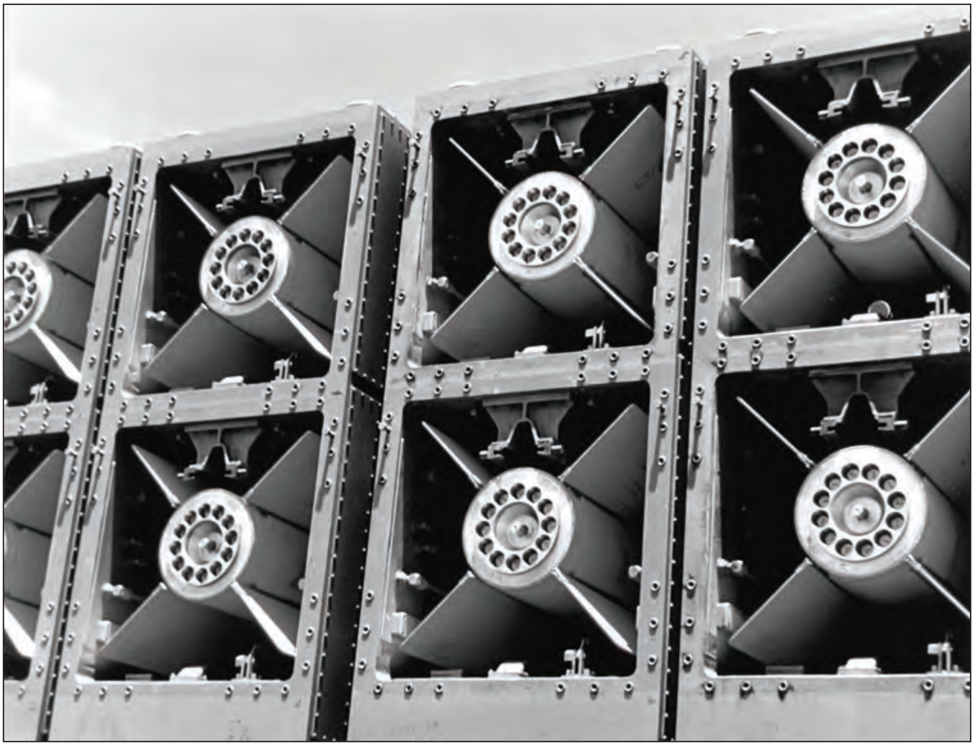
When RAT was terminated, ASROC had just completed full-scale development and was ready for BuWeps evaluation. In a 1960 NOTS film, "ASROC, An Anti-Submarine Weapon," ASROC is shown during that evaluation process

21 "Navy Rocket May Block Russ Submarine Threat," *Los Angeles Times*, 11 Feb 1958, 1.

22 *Rocketeer*, 14 March 1958, A4.

23 *Technical Program Review 1958*, 21.

24 "Anti-Sub Torpedo Work Dropped," *Los Angeles Times*, 8 Jan 1959, B2.



ASROCs in matchbox launcher.

in field trials in USS *Norfolk* (DF-1) off Key West. For the trials—actually a concurrent evaluation by BuWeps and the Operational Test and Evaluation Force—*Norfolk* was fitted with the new eight-cell "matchbox" launcher developed by the Universal Match Corp.

Underway replenishment is also shown in the film as the ASROC "coffins" are lined from a supply ship to the *Norfolk*. The coffins were lightweight, airtight, waterproof containers that carried the ready-to-fire ASROC round. The round (the rocket-torpedo combination) was considered "fixed ammunition," that is, no special handling or check-out procedures were required once it was on board. It was loaded directly from the coffin into the launcher and was ready to fire. Today, this configuration is known as an "all-up round." The elimination of extra handling and preparation aboard ship increased the weapon's reliability. [25]

ASROC was an integrated weapon system. As well as the rocket/torpedo round, the system included a sonar detecting and ranging set, with the sonar transducer mounted on the hull of the ship; a digital fire-control system; and

25 TMP 93, "ASROC, An Anti-Submarine Weapon," NOTS Documentary Film Section, China Lake and Pasadena, 1960.

a launcher group, which included the launcher captain's control panel and the eight-cell launcher. These were augmented by standard on-board hardware such as the ship's fire-control system, plan position indicator, and meteorological equipment.[26]

Operationally, ASROC was very similar to RAT. When a target was detected, the launcher slewed to the computed angle and azimuth and, on command, fired the round (singly or in salvos of two or four). Thrust was terminated at a calculated point based on the target's range. With the acoustic homing torpedo payload, a parachute deployed when the airframe reached the separation point and the torpedo's speed was reduced during descent. After water entry the torpedo circled in search mode until it locked on the target, then pursued it to destruction. With a depth-charge (nuclear) payload, no parachute was used. The charge plunged into the water and detonated at a predetermined depth.[27]

ASROC had extensive contractor involvement (though not to the scale of Polaris). Minneapolis-Honeywell was the prime contractor for ASROC. The principal subcontractors were Librascope Division of General Precision, Inc. (fire-control and attack console), and Universal Match (launcher). Other government laboratories were involved as well, among them NOL, White Oak, which did analysis of the depth-charge fuzing function, and the Naval Weapons Laboratory, Dahlgren, which worked on the ballistics. Ultimately, nearly 40 contractors and government agencies or activities were involved. The development process also had to be coordinated with the Atomic Energy Commission and with ship-building schedules. Virtually everyone at Pasadena was involved in the program, right down to the dive crews who recovered test units at Morris Dam, San Clemente Island, and Walker Lake, Nevada (where the nuclear-depth-charge version of ASROC was tested).

By no means was all of the development work done by the contractors. Barney Smith directed development of the rocket motor as well as the depth-charge fuze. China Lake's Jack Crawford and Bill Woodworth designed the critically important weapon controller—the Range and Airframe Separation Programmer (RASP)—that determined the timing of thrust cutoff and the opening of the clamshell airframe to release the torpedo. Project Engineer

26 The Fire Control Group Mk 111, developed under the direction of NOTS Pasadena's Thomas L. Cloer, Jr., and Ronald D. Thuleen, was the first digital computer system to control a major weapon system on a surface ship.

27 As the Federation of American Scientists put it, "The resulting shockwave did the rest—water doesn't compress, sub hulls do." ***http://www.fas.org/man/dod-101/sys/missile/vla.htm***, accessed 10 Oct 2010.

Rodney Beran was assisted in the assembly, testing, and packaging of RASP by technicians Robert Franks, Paul Payne, and Earl Norman.

With so many different entities working on various aspects of the ASROC system, extensive in-house testing was essential to ensure that everything worked, individually and together. Testing—laboratory and field—was carried out continuously throughout the project, including more than 70 ASROC firings on China Lake ranges. The weapon was tested at SNORT and the K-3 Range (a 2.8-mile crosswind track that simulated a ship in motion), on the Long Beach Range, at Walker Lake, and at San Clemente Island. During summer 1960, ASROC-launched Mk 44 torpedoes hit the target submarine, the former USS *Burrfish* (SSR-312), at ranges of 2,500 and 4,000 yards.[28]

As the *Rocketeer* reported:

> It is difficult for someone who was not a member of the team to imagine the amount of work involved in the preparation and execution of even a single test series. It all begins with logistics: missiles and associated instrumentation, ships, aircraft, spare parts and the men who must fly, sail, plot, calculate, fire. Before and during the tests scores of engineers and technicians from Pasadena, China Lake and various cooperating activities had to be coordinated. And then the tests themselves—highly complex operations requiring missile assembly, equipment check-out, firing at a target, data recording, and subsequent data analysis.[29]

With the able assistance of Assistant Project Manager Donald Cozen, Wallace E. "Wally" Hicks (Wilcox's associate department head, who assumed responsibility for systems analysis), and a seven-man core team that included two China Lakers, Wilcox orchestrated the development, which was completed (including Technical Evaluation) in a respectable 48 months.

Just as the Bill McLean-Hack Wilson team at China Lake joined a visionary genius with a technically gifted administrator, so too did the Doug Wilcox-Wally Hicks relationship pair men with different but complementary skill sets. As Shelby Sullivan said of Wilcox:

> "He was a mechanical engineer, and he knew that he was better in management, even though he was no dummy. He'd been fooling with technical things, but he wasn't a technical guru, so he hired Wally Hicks to be his technical guy to help him. So they had a management team. [Wilcox] was able to motivate people and provide the environment where they could grow and prosper and he set priorities on the problems that they'd work on.[30]

28 *Fifty Years … Point Loma, 1940–1990*, 53.

29 *Rocketeer*, 8 July 1960, B2.

30 S-173, Shelby Sullivan interview, May 1989, 57–58. Sullivan joined Pasadena as an electronics engineer in 1956.

ASROC missile streaking skyward from USS *Norfolk* during a test firing.
***Naval Aviation News* photo.**

And problems there were, from the task of building new ranges at San Clemente Island and Walker Lake to a plethora of scientific and engineering problems associated with the complex weapon system itself. An account of many of ASROC's technical challenges and their resolution is contained in Volume 3 of this series.[31]

The unveiling of ASROC was even bigger than that of RAT. On 21 June 1960 the press was taken aboard *Norfolk* at Key West and treated to three firings at short, intermediate, and long ranges. The submarine USS *Skate* (SSN-578) served as the target, as she had during the two months of sea trials.

31 Babcock, *Magnificent Mavericks*, 450–455.

This time the *Los Angeles Times* (perhaps regretting having gone overboard on the unveiling of the ill-fated RAT) was silent. The *New York Times*, however, carried an Associated Press story under the title "New U.S. Weapon Kills Submarines." It quoted Rear Admiral P. D. Stroop, Chief of BuWeps, as saying that the weapon system represented "a significant advance in the anti-submarine warfare program." Although the article stated that the exact range and speed of the weapon were classified, the writer accurately estimated the ranges as from 3 to 6 miles.[32]

Initial Operational Capability with the Fleet came in 1961 (for the depth-charge payload; the torpedo payload was accepted for service use in 1962). By April 1961, nine systems were installed in the Fleet with 88 more scheduled and another 40 planned. By the late 1960s, ASROC was also in use by the navies of Germany, Greece, Italy, Japan, Republic of China, Spain, and Turkey.[33]

In 1961 Wilcox received the L. T. E. Thompson Award ". . . for his leadership and technical contributions to the field of underwater weapon systems and especially for the ability displayed in the integration of a Navy-wide and industrial team for the successful accomplishment of the ASROC program."[34]

Pursuant to a 1961 CNO request, NOTS conducted a feasibility study for an Extended Range ASROC in 1961. In 1962 the Station submitted a proposed technical approach for the weapon, and the Preliminary Technical Development Plan was approved by OPNAV in 1963. Key to the range extension was the development, by Ray Miller's Propulsion Systems Division, of a larger rocket motor (13½–inch-diameter versus 11¼ inches) that would still fit in the ASROC launcher. The first test vehicle was fired from a standard ASROC launcher in 1965, and advanced engineering work on an 18,000-yard-plus version continued through 1967.[35]

In the 1980s, development of Vertical Launch ASROC (VLA) would start at China Lake, reaching full-rate production in the early 1990s. ASROC (VLA) is still in service with the Fleet today.

The original ASROC program was the first major program at NOTS Pasadena where the contractor was brought in early in the development phase. This approach was also taken with the Mk 46 torpedo. In Booz, Allen's 1976 review of Navy R&D, the authors noted the two distinct approaches to contractor involvement among Navy laboratories:

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32 "New U.S. Weapon Kills Submarines," *New York Times*, 22 June 1960.
33 Research Board minutes, 25 April 1961, 2.
34 *NOTS Command History* 1961, 10.
35 Dickinson, *Glossary of Project Titles*, 26.

> Not only did the involvement of Navy contractors in innovative R&D increase substantially during the 1940s and 1950s but many of the laboratories were sometimes deeply involved in full-scale development of Fleet hardware. Arrangements varied among individual projects . . .
>
> For example, the Sidewinder air-to-air guided missile was an outgrowth of research and exploratory development performed at NOTS, China Lake, in the years immediately following World War II. Management and technical direction of the development remained at NOTS with relatively little industrial participation until the missile approached production in 1954 at which time the Philco Corporation was selected as the initial production contractor for the major sections of the missile. . . .
>
> A different approach was followed with the MK 46 torpedo which was developed under a prime contract initiated in 1958 with Aerojet-General Corporation. In this case, NOTS, Pasadena exercised technical direction . . .Other BuOrd projects during the period followed similar patterns. For example, ASROC was developed with Minneapolis-Honeywell as the prime contractor and NOTS, Pasadena as the Technical Director. . . . In all of the above cases in which prime contracts were involved, [the Bureau] retained both fiscal and contract management responsibility.[36]

This model of control through funding was also carried out at the Naval Electronics Laboratory (NEL), San Diego, a predecessor of the Naval Ocean Systems Center (NOSC). A 1990 history of NOSC observed:

> The TD [Technical Director] acted as senior staff adviser to the CO. However, the most detailed supervision of the work underway at the laboratory came from BuShips project officers and civilian program managers in Washington.[37]

There was no question about the locus of control in the ASROC program. While NOTS Pasadena was the Technical Direction Agent for the weapon system, overall direction and management of the program came from BuOrd and its successor, BuWeps.

In a four-page ASROC insert to the *Rocketeer* that followed the June 1960 rollout, the key players at the Bureau level were spelled out:

> Over-all program coordination was under the direction of Captain E. A. ["Count"] Ruckner . . .The program was directed by Captain W. C. Abhau . . . assisted by Commander L. H. Keator. . . . Effective program management was provided by . . . Commander H. H. Scales, assisted by R. S. Johnson, H. Stone, H. Silk . . . and G. G. Beall. . . .[38]

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36 Booz, Allen, *Review of Navy R&D Management 1946–1973*, 349.

37 *Fifty Years … Point Loma, 1940–1990*, 38.

38 *Rocketeer*, 8 July 1960, B1.

Coordination . . . direction . . . effective program management . . . these translated into fiscal and contract management responsibility, a way of doing business about which McLean was extremely wary.

As he said in 1975:

> If you are really going to do the technical monitoring at the laboratory, you have to have control of the funds. Technical monitoring without control of the funds is just asking for trouble, as we have demonstrated many times.[39]

The two different approaches to weapons development taken at China Lake and Pasadena reflected those taken by the Bureaus of Ordnance and Aeronautics. China Lake, like BuOrd, tended to maximize the use of in-house resources right up to the point of production. Pasadena, like BuAer, had earlier and deeper dependency on the services of the private sector.

Recognizing the difficulties inherent in assigning authority and responsibility among the bureaus, laboratories, and contractors, Stroop requested in 1959 that NOTS develop a "statement of management philosophy on the Bureau-Laboratory-Contractor relationship." The resulting document was prepared by R. W. Bjorklund, head of Central Staff, working with the heads of the three development departments at China Lake, Newt Ward for Aviation Ordnance, Barney Smith for Weapons Development, and Frank Fulton for Propulsion Development. If inputs from the Underwater Ordnance Department (Doug Wilcox) were solicited or considered, there is no record in the group's final report. The report was released under the authority of McLean and no doubt reflected his and Hack Wilson's opinions.[40]

The six-page report, acknowledging that there was no one-size-fits-all model for the relationship among bureau, laboratory, and contractor, identified the crucial problem as:

> . . . determining the ratios in which the Bureau of Naval Weapons' in-house capacities can best be applied to the various stages of the conception-to-evaluation continuum. This requires a continuous examination and appraisal of the special competences of government and industry. These fluctuate widely between organizations and within organizations.

It noted that BuWeps RDT&E included "a wide range of governmental and industrial effort with differing degrees of all-round capability," and warned that "altering this complex quickly or severely is not feasible without risking

39 S-97, McLean interview, 29.

40 NOTS Central Staff, "The NOTS Concept of How to Achieve Effective Bureau-Laboratory-Contractor Relationships on Weapon Development Program," China Lake, Jan 1960.

serious disruption to present effort." The report did, however, urge greatest laboratory involvement "from conception through technical evaluation" and "maximum disengagement of Navy personnel and facilities from classical large scale production." It stated that a little less than half of BuWeps RDT&E funds went to government laboratories, and that NOTS allocated about a third of its project funding to outside procurement.

"It appears desirable to utilize the limited resources of the government's scientific laboratories as extensively as possible in a high-risk effort," the report suggested, defining high-risk development as "when a substantial advance in the state of the art is required for success and that the risk disappears when feasibility has been demonstrated." Several justifications for that approach were given, among them:

> It would utilize and motivate the available talent to their highest potential . . . it would provide a positive stimulus to attract and retain high-caliber personnel in the government's laboratories . . . [and] it would provide the Bureau with a source of information unbiased by the profit motive on which to base technical judgment.

The report suggested a set of guidelines for action, including feasibility studies:

> It is considered imperative that each proposed development be subjected to an analytical and experimental evaluation of its concept and possible performance (including the building of feasibility hardware) before full-scale development is undertaken. . . it is considered desirable that governmental competence be used to the fullest in this area and that this be considered the most important role of the government laboratory. . . .it is vital that the organization selected to head the development be granted substantial operating leeway in conducting the program . . . [including] cognizance and administration of funds and contracts for the program.

Barney Smith (then head of Code 40), who had barely saved ASROC from being assigned to NOL, would certainly have agreed with the cautionary note toward the end of the report:

> . . . technical knowledge, rather than authority, is the only valid medium of exchange in research and development. The organization with greatest technical competence ordinarily does, and should, exert the greatest influence. Without such competence, the authority implied by technical direction and design cognizance has an empty ring.

To what extent this report affected future apportionment of resources and responsibility among the three groups is not known. However, the report did make a cogent case for heavy laboratory involvement in the preproduction phases, and bureau assignment of authority commensurate with responsibility. Its reasoning is sound, and its philosophy makes sense today.

Achieving the most effective balance of authority and leadership among the laboratories, bureaus, and contractors also depended on the personalities and management styles of the major players. Whereas McLean acted almost intuitively in his technical management role, unpredictably and sometimes unorthodoxly, the much younger Doug Wilcox was more suited to the new world of systems engineering, systems analysis, and PERT charts. Each man's approach worked . . . for him.

"I think Doug Wilcox would be the first to say that he never understood one word that Bill McLean ever said," said Howie Wilcox, who headed the Rocket Development Department (Code 40) when Doug Wilcox became head of the Underwater Ordnance Department.

> He just couldn't understand what Bill McLean was saying. And I think that irritated Bill deeply. Yet Doug Wilcox not only continued to be the Technical Director of the Annex down there, but Bill McLean took a big interest in the work of the Annex; and later they both joined the Naval Undersea [Warfare] Center, and Bill was Technical Director and Doug Wilcox was his Associate. The fact that Doug Wilcox could never understand Bill McLean didn't make it impossible for them to work together.[41]

SUBROC

The next logical step for ASROC was to make it capable of launch from submarines, and when ASROC was about midway through development, work started on the Submarine Rocket (SUBROC) a submarine-launched rocket with a nuclear depth charge. As with the early plan for an NOL-developed nuclear-only ASROC, engineers and managers at NOTS felt that the proposed SUBROC should have more flexibility—and that it should be developed at China Lake.

After NOL's proposal for a liquid-fueled ASROC in 1956, "we had developed . . . some disdain for their systems engineering ability," said China Lake's Don Moore. Plus NOTS had already done feasibility studies and engineering work on a submarine-launched weapon called North Star, a boost-glide vehicle that was an early potential competitor for Polaris.[42]

As a counterproposal to SUBROC, a team comprising Moore, Chuck Bernard, and Bill Simecka put together the concept they called Marlin—also

41 S-112, AOD Group interview, Dr. Howard A. Wilcox, 88.
42 S-185, Moore interview, 18.

known as Torpedo-Tube Ballistic Missile (TTBM)—"a proposed weapon for delivery from a submarine at shallow depths . . . capable of delivery of large warheads from a distance of 25 to 100 miles against shore targets with launching from standard torpedo tubes."[43]

The critical difference between Marlin (so named because, Bernard said, "the marlin jumps up out of the water") and SUBROC was that Marlin was not just a nuclear ASW weapon. It was envisioned as having a nuclear depth charge payload, a torpedo payload, and a land-attack payload.

At NOTS, putting together a "concept" was usually not enough. You also had to show that it had a high likelihood of working. So in 1957 a small team of engineers got to work. As Don Moore recalled:

> [We] got some old torpedoes and took the propellers off, and put canards that were made from Sidewinder parts. We took two Sidewinder servos and put the canards on that would stabilize the missile roll and control it in pitch. And then we took gyros from the B-29s [retired WWII bombers that NOTS used as targets] and from torpedoes and made an autopilot for it, and we took parachutes out of the old Ryan Firebee drones. And then back where the warhead of the torpedo is, we put fins on that—cut off the round nose of the warhead and put fins on it—and then stuffed the rocket motor from the BOAR missile up in it. Then we put all that stuff on rails that could be lowered underwater from an LCV [landing craft]. Then by hooking up [two] reduced-impulse Sidewinder boosters, we could simulate a launching from a torpedo tube.[44]

As simple as that. They built three, took them to San Clemente Island, and fired them. Two of them worked. For one test, McLean had brought some visitors from Washington and he, Doug Wilcox, and the guests were on the island watching. According to Moore:

> One of the rocket motors flooded, and the one that pushed it off didn't produce sufficient velocity for it to achieve the [correct flight] angle, so it rolled back down, tumbled the gyro, and fired off and went out sideways . . . . straight toward the island. The payload section separated, the parachute bloomed out, the rocket motor was still booming, and it had gone end over end. Ha-woomp, ha-woomp, ha-woomp! It went right over the heads of the people, landed on the island, and set it on fire. They couldn't get back until they helped fight the fire. That was the most memorable Marlin test.[45]

Bernard recalled the NOTS team going into the mess hall on the island the next morning for breakfast. Several Air Force enlisted men who had spent all night fighting the fire were there. Said Bernard:

43 *NOTS Command History* 1958, 41.
44 S-185, Moore interview, 19.
45 Ibid., 21.

> There were these poor devils who were all blackened and really dirty, eating breakfast, and there we were in our white suits [coveralls], and they knew we'd set the island on fire. . . We thought that we were not going to finish breakfast without being attacked."[46]

At about the same time, NOTS was considering a proposal called Wet ASROC Missile, or WAM, an ASROC modified for submarine launch. The Station expected the system to have somewhat greater effectiveness than ASROC because the submarine would make a better sonar platform than the surface ship.[47]

The idea for WAM was to tube-launch the ASROC with a JATO bottle booster. A system was soon cobbled together to see if the concept would work. Four consecutive firings from a submerged torpedo tube off San Clemente Island were unsuccessful, because, according to Shelby Sullivan, "It just went places it wasn't supposed to go." Sullivan, still a relatively junior engineer, was working on the WAM program in UOD.

A meeting was convened in a conference room in Pasadena to discuss the problem. Sullivan recalled that:

> It was really a brainstorming session to try to find out why wasn't this thing working. They went through and they described each of the tests, what they tried to do, and then they described the results of the tests, then these four shots, and then they had a discussion about what they were going to do about it.
>
> Pretty soon it just dawned on me what the problem was. The way they were doing it was they were turning through gimbal lock on the gyro, and once you go to gimbal lock, the gyro tumbles, and then it doesn't know where anything is. So after this meeting—it was just about to break up—they did say, "Has anybody out there got any ideas?" because they hadn't come to any conclusions. I raised my hand and they asked me, "What do you think?" I was scared to talk, it was such an impressive group up there, and I suggested that maybe it was going into gimbal lock, and then there was dead silence. And everybody started thinking then and the meeting broke up very quickly, because that was the answer. . . . Well, the next day I got a call and McLean wanted me to take over the program.[48]

But despite four subsequent successful WAM firings at Morris Dam, it was all for naught. According to Moore, McLean took a "conciliatory view" on NOL White Oak's SUBROC approach, perhaps out of concern for the lack of project work at NOL, and he decided not to pursue the competing programs.

46 S-189, Bernard interview, 50.
47 *Technical Program Review 1958*, 6.
48 S-173, Sullivan interview, 24–25.

SUBROC missile leaving the water after a test launch from a submerged submarine, September 1963.

Naval Aviation News **photo.**

The Navy chose to go ahead with SUBROC, and that was the end of both Marlin and WAM.

NOL was assigned technical responsibility for SUBROC and oversaw development by the prime contractor, Goodyear Aircraft Corp. (changed to Goodyear Aerospace in 1963), and a variety of subcontractors. NOTS was, however, assigned the SUBROC test program. Ivar Highberg, at the time head of the Test Department, recalled that:

> . . . we persuaded NOL, White Oak, with a little help from P. D. Stroop, that we would not steal SUBROC from them the way we had ASROC, and so the developmental firings of SUBROC also took place here on the Station, the land firings. And I set up a division in Pasadena [in 1958] to carry out the underwater firings of SUBROC at San Clemente Island.[49]

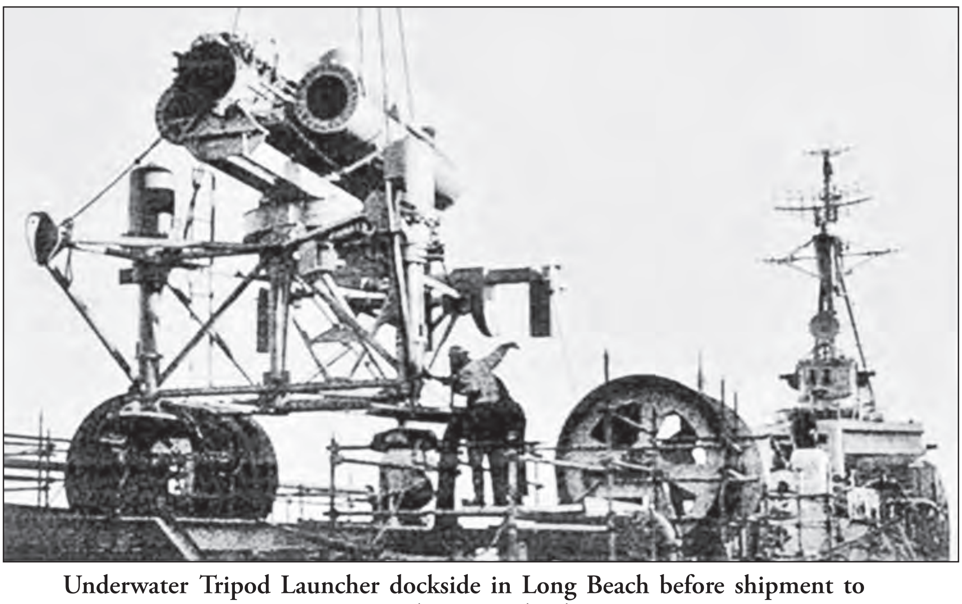
NOTS worked closely with NOL to develop a comprehensive test program and identify requirements for instrumentation and modified facilities, a complex task that required the development of new test procedures as well as specialized range facilities. Consider the sequence of events in a SUBROC attack: the 21-foot-long, 21-inch-diameter, 4,000-pound weapon is launched

49 S-121, Highberg interview, 12. The new division was the Test Division, Pasadena, Code P309, under Thomas C. Mico, former assistant head of UOD.

horizontally from a submarine's torpedo tube. The rocket motor ignites under water and the weapon transitions to a steeper angle of attack, exiting the water at an angle of about 45 degrees. Once sufficiently clear of the water, SUBROC returns to more or less horizontal flight at supersonic speeds for approximately 30 miles, steered by jetavators that deflect the thrust of the exhaust gases. At a predetermined velocity, the thrust-reversal system separates the depth charge from the rocket motor. The payload continues its flight, guided by an inertial guidance system that controls aerodynamic fins and determines the point and angle of water reentry. The payload reenters the water, still at supersonic speed, sinks to a predetermined level, and detonates.

Motor and payload separation tests for SUBROC were carried out at SNORT. The track was also used to obtain data on the performance of the inertial guidance and control system under sustained acceleration and vibration. Full-scale flight tests were on G-1 Range at China Lake, with an impact site some 26 miles downrange in the Cole Flats Area.

Howard R. Talkington managed the SUBROC test program at San Clemente Island. He was assisted by Project Engineer Frank N. Brady, Range Engineer Ray Musgrave, and a large contingent of engineers, technicians, divers, and other support personnel. Assembly and checkout facilities were set up at Long Beach and Seal Beach. A new range was added to the Eel Point Range for water-impact testing, and a portable underwater launch facility dubbed the Underwater Tripod Launcher was constructed, consisting of a launch tube, an



Underwater Tripod Launcher dockside in Long Beach before shipment to San Clemente Island.

adjustable stand with an azimuth orientation system, and attached photographic and TV cameras and other instrumentation.[50]

Pasadena craftsmen modified a Landing Craft, Utility (LCU) for use as a SUBROC launch-control vessel. The boat carried a pneumatic launcher that could be lowered through a central well and launch test articles at various depths. SUBROC testing at the island and its adjacent waters shared much of the specialized test equipment and instrumentation—shore control, telemetry ground station, radar installations, camera pads, etc.—that had been developed for Polaris.

The Propulsion Development Department demonstrated that the weapon's weight could be reduced (and thus range increased) by pre-pressuring the motor case. The department designed a modified propulsion system that would still carry the nuclear depth charge to a range of 70 nautical miles but that had a volume sufficiently reduced to allow the Mk 46 torpedo as an alternate payload. At the China Lake Pilot Plant, high-energy nitrasol propellants were mixed and SUBROC test motors were loaded with up to 500 pounds of the propellant. The Skyline Facility, set up for running tests on the SUBROC development motors, was isolated to minimize the damage produced by malfunctions. China Lake also provided consulting services in combustion instability problems.[51]

NOTS developed a command flight interrupter system, consisting of destruct charges, a command-destruct receiver, and a timer firing device to increase the safety of live flight testing. The system proved its value during a 1961 test from the underwater launcher:

> The B-4 [test item], for which a 12-mile flight had been planned, made a right turn after emergence, failed to make a corrective left turn, and was destructed approximately 2,500 feet down-range and 2,500 feet off-range.[52]

The pace of SUBROC testing was hot and heavy. During 1961, for example, NOTS conducted 5 ground-launched free-flight firings, 6 inertial-guidance sled-test runs, 5 underwater hydrodynamic firings, 2 underwater-launched free-flight tests, and 13 air-drop tests.[53]

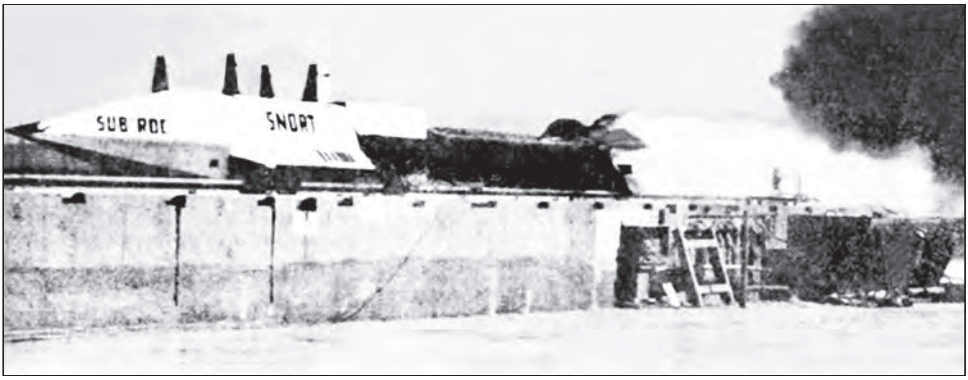
With its inertial guidance system and jetavator steering, SUBROC was a complicated weapon that encountered numerous technical problems in

50 Talkington was a highly respected engineer who would eventually head the Engineering and Computer Science Department at NOSC. Dr. Robert Wernli calls Talkington the father of deep ocean robotics.

51 *Technical Program Review 1958*, 70.

52 *NOTS Tech History 1961*, 224.

53 Ibid., 223.



SUBROC sled test, one of a series at SNORT to test the weapon's inertial-guidance platform, liquid-propellant rocket engine, and rocket-motor/depth-charge separation.

its development. Many of these problems stemmed from the environmental extremes the weapon encountered in its operational envelope—icy waters in the flooded torpedo tube, launch acceleration, water-to-air transition and acceleration, thrust reversal, and water reentry.

One major challenge was development of a shock-mitigation device that allowed the nuclear depth charge—a W-55 device with an underwater kill radius of about 5 miles—to survive supersonic impact with the surface of the water on reentry.

Each technical difficulty was overcome, and the first successful submerged firing, from USS *Permit* (SSN-594), occurred in March 1963. The first submarine to be fitted with SUBROC was *Permit*'s sister ship, the ill-fated USS *Thresher* (SSN-593).[54]

The official roll-out of SUBROC for the press came at a New York City press conference on 4 December 1963. The *Los Angeles Times* front-page story by Marvin Miles, the *Times* aerospace editor, began, "Deadly SUBROC, the Navy's long-awaited breakthrough in antisubmarine weaponry, was officially disclosed Wednesday after five years of development and test." The article also noted that "much of the development work on the new weapon was carried out at the Naval Ordnance Test Station, China Lake," but curiously did not mention Pasadena's role as Technical Direction Agent.[55]

54 *Thresher* sank during a deep dive test off the coast of Massachusetts on 10 April 1963. Everyone aboard was lost: 16 officers, 96 enlisted men, and 17 civilians. The *Thresher/Permit* class of submarines was the first to incorporate some of the advanced capabilities recommended by the Nobska study, notably a large bow-mounted sonar, angled torpedo tubes located amidships, new stronger alloy steel, and a smaller sail.

55 "Navy Unveils New Weapon to Fight Subs," *Los Angeles Times*, 5 Dec 1963, A1.

At the roll-out, Rear Admiral W. T. Hines, Deputy Chief, BuWeps, explained the importance of a strong ASW arsenal:

> It is no secret that the Soviet Union has approximately 500 submarines. You may recall that Hitler began World War II with 57 subs and during the course of the war built 1000 more. He never had more than 325 operational at any one time, but, the submarines sank nearly 3,000 Allied merchantmen, many of them off the East coast of this country.
>
> Enemy submarines are a definite challenge to the free world's use of vital shipping lanes, especially when you consider that the United States imports and exports over 99 percent of all materials by ship. In addition, with the advent of missile firing submarines, the protection of our coastal cities becomes a problem of the highest priority. [SUBROC] promises to be of the utmost importance in combating the submarine menace.[56]

SUBROC's official designation originally was Mk 28. With the advent of the Joint Designation System in June 1963, it was designated UUM-44A (underwater launch mode, underwater target, missile). The SUBROC system was declared fully operational in 1965 and remained in the Fleet throughout the Cold War, with the last missiles being removed from naval service in 1992.[57]

RETORC and the MK 46 Torpedo

In 1954 NOTS initiated a program at UOD called the Research Torpedo Configuration (RETORC). Pasadena researchers working in this program looked at electric propulsion systems for torpedoes and proposed a torpedo called the EX-2. This lightweight (420-pound) torpedo with salt-water-activated batteries could run at 30 knots for about 6 minutes, and its sonar seeker could pick up a target at about 800 yards.

Developed by General Electric Co., Pittsfield, Massachusetts, under NOTS technical direction, the EX-2 was redesignated the Mk 44 and released to the Fleet in 1956.

Based on the work done under RETORC, NOTS researchers believed that electric propulsion for torpedoes had reached its zenith with the Mk 44. RETORC researchers and engineers turned to liquid fuel and hot-gas propulsion. The result was the EX-8, which was powered by a hot-gas engine (using a solid rocket fuel) and propelled by a pump jet. The EX-8 was half again faster than the Mk 44 and had an acoustic range of 1,500 yards.

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56 *Rocketeer*, 6 Dec 1963, 6.

57 From January 1964 to April 1974, about 285 W-55 nuclear depth charges were produced for SUBROC. Chuck Hansen, *U.S. Nuclear Weapons: The Secret History*, 209.

There was an urgency to the RETORC work. In 1958 the Soviet Union fielded its first nuclear-powered submarine. Nuclear subs could go faster and stay submerged longer than their diesel kin, and new hull designs were increasing the submarines' maneuverability and depth capabilities.

Two years later USS *George Washington* (SSBN-598) launched the first 12,000-mile-range ballistic missile while submerged. There was no overlooking the growing threat posed by rapidly advancing submarine technology. As Howie Wilcox, then NOTS' Assistant Technical Director for Research, told a China Lake audience in January 1959:

> Today the U.S. is the world's most powerful maritime power—or at least we still tell ourselves so—but perhaps our greatest military problem comes from the sea. Russian cities lie far from the sea, in the main, but ours lie close. Communist lines lie over land; the free world's lines lie over water. All together, the free world operates over 90 percent of the world's surface ships—the targets—while Russia operates over 70 percent of the worlds' ship-killers—the submarines.[58]

Delivery of torpedoes against surface ships was the initial driving factor in submarine development, but as the Naval Underwater Systems Center's E. W. Jolie pointed out:

> With rapid advances in submarine development, the roles were reversed. The high-speed, deep-diving, quiet, highly-maneuverable submarine as a potential threat provided the impetus for the development of another generation of the lightweight ASW torpedo, the Mk 46 Mod 0.[59]

NOTS submitted a proposal to BuOrd in 1957 to move the EX-8 into full development. The proposal was accepted and funded in 1958.

NOTS was assigned as technical director, as it had been with ASROC, but the bulk of the development was to be done by Aerojet-General Corp. of Azusa, California, as the prime contractor, with Bendix Corp. as the principal subcontractor for the guidance-and-control system and Clevite Corp. of Cleveland, Ohio, as the principal subcontractor for the propulsion system. Charles G. "Chuck" Beatty, who had been head of UOD's Torpedo Development Division since 1956, was assigned to lead the project with Morton O. "Mort" Heinrich as project engineer. (Heinrich had been program manager for the Mk 32, the Navy's first active acoustic torpedo.)

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58 *Rocketeer*, 16 Jan 1959, 1.

59 E. W. Jolie, *A Brief History of U.S. Navy Torpedo Development*, Naval Underwater Systems Center, Newport Laboratory, 1978, 51, *http://www.history.navy.mil/museums/keyport/html/part1.htm,* accessed 19 Oct 2010.

Jim Campbell, a Pasadena Annex engineer who worked on the Mk 46, said of Beatty:

> He was very concerned about getting things into the Fleet. That was his number-one priority. "Let's get our stuff into the Fleet. That's what we're in business for." And everybody understood that. And he would back that to the hilt.[60]

RETORC's EX-8 was designated the Mk 46 Mod 0 torpedo. The new weapon was designed to be versatile, capable of submarine launch, shipboard launch, air launch (fixed, rotary wing, lighter than air), and rocket launch (as a payload for ASROC).

The torpedo's long acoustic range was ensured by the two different types of acoustic panels (sonar processing systems) that had been under development at Pasadena. LANA was a transistorized panel that used a frequency modulated pulse. REVEL (reverberation elimination) used a narrow frequency system and filtering to eliminate reverberation (echoing) and thus increase the sonar's range of detection.

Jack H. Slaton, a NOTS Pasadena electrical engineer, was the principal architect of REVEL. In 1962 he received the L. T. E. Thompson Award "for outstanding leadership and technical contribution to the field of aircraft antisubmarine torpedoes, and especially for the brilliant achievement of synthesizing, developing and guiding through initial production an advanced acoustic-homing system of greatly increased search and target acquisition capability" In 1965 he also received BuWeps' highest award—the Superior Civilian Service Award—for that work.[61]

The Mk 46 was 8 feet 5 inches long, 12¾ inches in diameter, and with a weight of about 570 pounds. It incorporated a modular design that made possible the replacement of any of the four major component sections—guidance and control, explosive, propulsion, and accessory (gas pressure generator)—as an entire unit.

In operation the torpedo would enter the water and within ½ second a seawater-activated battery would initiate the propulsion system. After power diving to a predetermined depth, the torpedo would begin a pre-programmed search for the enemy submarine, either an active echo-ranging "snake" mode or a passive/active circle mode. When the target was located, the attack/pursuit program began, using the torpedo's high speed and maneuverability to zero in on the sub. If target contact was lost, the torpedo went back into search mode.

60 S-174, Jim Campbell interview, 25 Jan 1989, 33.
61 *NOTS Command History* 1962, 21.

The hunt continued until either the target was destroyed or the torpedo ran out of fuel (about 6 minutes).

NOTS' unique test facilities were brought into play to find any weaknesses in the system and wring the best performance out of the new torpedo. At Pasadena's Slingshot Facility, a giant bungee cord propelled the torpedo test units into the water at high speeds, at angles from 50 to 90 degrees, to simulate the crushing forces encountered by the torpedo's water entry following an air launch. The Variable-Angle Launcher was used for high-speed water-entry tests at shallower angles (10 to 40 degrees). The fielded weapon had to be capable of launch from an aircraft at speeds of up to 400 knots.

At China Lake's K-3 Range crosswind track, a cart-mounted ASROC launcher with a dummy Mk 46 was propelled down the track at speeds that simulated a destroyer in full pursuit of a submarine. When the ASROC was fired, cameras and radar tracked the flight and desert impact, with the resulting data used to compute ballistic tables for the weapon system.

Much of the Mk 46 testing took place at sea, not only on the San Clemente Island and Long Beach ranges but also off Seal Beach and San Nicolas Island, in the Caribbean, in Puget Sound, and off Vancouver Island, Canada.

An unusual test series took place off Long Beach. A Mk 46 was suspended inside a custom-made steel cage with a system of springs. The propellers were replaced with circular drag disks that simulated the propellers but caused no forward motion. The caged and instrumented torpedo was lowered over the side of the tug to the required depth. "Shorn of its propellers," reported the *Rocketeer*, "the torpedo stood still while 'running at full speed.' In this way its performance at operational depth was studied." The Long Beach Range was also the site of Mk 46 drops from the QH-50 drone antisubmarine helicopter (DASH) and the UH-34 Seahorse helicopter.[62]

In October 1961 the first launch of an ASROC with Mk 46 as payload demonstrated the torpedo's ability to survive the harsh ASROC operating regime. USS *Butternut* (AN-9), a former submarine-net-laying vessel assigned to NOTS, launched more than 150 Mk 46 torpedoes in 1964 alone.[63]

Contractor cost overruns plagued the Mk 46 development. On Friday, 12 October 1962, three top Pentagon officials were visiting NOTS: Harold Brown,

62 *Rocketeer*, 18 Dec 1964, 5.

63 USS *Butternut* was one of 32 ships in the *Aloe* class named after trees, ranging from USS *Aloe* (AN-6), commissioned June 1941, to USS *Yew* (AN-37), commissioned July 1942. *Butternut* was the cornerstone of the "NOTS Navy," a collection of boats, barges, underwater vehicles, and other small craft that served NOTS' Pasadena and Long Beach operations.

Torpedo Mk 46 rigged for an instrumented air drop from a UH-34 helicopter.

DDR&E; James Wakelin, ASN; and Vice Admiral Charles B . Martell, OSD. Also on board was Captain William J. Moran, who would become China Lake's Commander in 1970. In a discussion between these gentlemen and Station management, the talk turned to cost overruns and the role of the laboratory in controlling contractor costs.

According to notes of that meeting, "The Mk 46 torpedo program was cited as an illustration of how significant cost over-runs may develop when the ongoing expenses of industry amount to even as little as $1-$1½ million per month."[64]

Again, as in the ASROC program, the problem could be attributed to technical monitoring without control of the funds. In McLean's 1975 interview, he specifically cited the Mk 46 as an example of the problems associated with assigning a laboratory technical control without funding control.[65]

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64 "Notes from Informal Discussion with Dr. Harold Brown, Dr. James H. Wakelin, Admiral Chas. B. Martell and Captain Wm. J. Moran with Representatives of Station Management on 12 October 1962," no author given, 5 pages plus 1-page attachment, 4.
65 S-97, McLean interview, 29.

Cost overruns weren't the only problem with Mk 46. Aerojet and its subcontractors introduced changes during the development process, unbeknownst to the NOTS monitors. For example, part of the power plant that ran the torpedo's sonar transducer was an output transformer that was designed with three ferrite-core toroids (doughnut shapes) wrapped in wire.

As Shelby Sullivan recounted:

> Some cost person at Bendix decided that he could save the company some money and take one of those things out. You didn't need three of those things in there; two was good enough. So they built the transformers with two of them. Well, when you only had two of them in there, the transformer would saturate, and it would burn out the transistors. So the first production runs of these things would work for a while, and then they'd burn up. It was really a mess.

The transformer task was soon taken away from Bendix and given to another contractor.[66]

Pasadena also had problems with Aerojet-General's "tinkering" with the torpedo's design. Vice Admiral Frederick L. Ashworth, who had been NOTS Commander from 1955 to 1957, was the assistant chief of BuWeps for RDT&E during the Mk 46 development program. He recalled that:

> We had a terrible time with [Aerojet] because they wanted to fix everything all the time. They wanted to change this and change that and change the other thing. And the people down at Pasadena knew more about torpedoes than Aerojet-General had ever heard of. I think Pasadena's forgotten more than they ever knew. . . Finally I got to the point where I went out there. I said, "Look, if you don't do it our way, we're going to take this contract away from you." I don't know whether I had power enough to do it or not, but that's typical of my experience in dealing with industry.[67]

Cost and technical problems notwithstanding, the program forged ahead, with Pasadena much more actively in the loop than Aerojet preferred. An integrated Technical Evaluation and developmental sea-run program was completed in August 1963. In a series of 13 sea runs programmed not to hit high-speed nuclear submarines, Mk 46 Mod 0 showed a potential capability of closing to hit 70 percent of the time. When it was permitted to close all the way, it hit a 25-knot target.[68]

Mk 46 completed its Fleet evaluations in the Caribbean late in 1964, and on 18 December the Secretary of the Navy announced the successful completion

66 S-173, Sullivan interview, 44.
67 S-226, Vice Adm. Frederick L. Ashworth interview, 16–17 April 1993, 136.
68 *NOTS Tech History 1963*, 1-30.

of the development program. The new weapon was unveiled to the public by Vice Admiral Stroop (then Commander, Naval Air Force, U.S. Pacific Fleet) at a press conference in Pasadena. Among those attending were Aerojet-General's vice president, Vice Admiral William F. Raborn, USN (Ret.); and Aerojet's Chairman of the Board, the Honorable Dan A. Kimball.[69]

In November 1964 Chuck Beatty received the L. T. E. Thompson Award "for outstanding creative foresight and technical contributions in the field of antisubmarine torpedoes, and especially for his perceptive guidance of the supporting research and system integration which culminated in the outstanding performance demonstrated by the torpedo Mark 46, a significant advancement in the Navy's antisubmarine capability."[70]

Aerojet was awarded a $40-million fixed-price-incentive production contract in August 1964. Production models began to reach the Fleet in 1965, and the weapon was officially released to the Fleet in 1966. By 1962, it had become apparent that Mk 46's solid-propellant motor created maintenance problems. Studies to define a new propulsion system began in 1962, and a liquid-monopropellant cam engine, developed by Clevite Corp., became the Mk 46 Mod 1, which had its first successful in-water runs early in 1964.

Mort Heinrich, who had been project engineer for the Mk 46 Mod 0, also led the Mod 1 effort. The Mod 1's propulsion change, as well as electrically actuated control fins, made it lighter (and thus faster and of longer range) and more reliable. NOTS management described the Mod 1 as "vastly superior from the standpoints of reliability, cost, and ease of manufacture."[71]

Late in 1965, however, NOTS' distinguished Advisory Board spoke out against the Navy's plans for initial production of the Mod 1, with the following advice:

> The Board views with grave concern the allocation of production of the Mk 46 Mod 1 torpedo to contractors without experience in the development of this item. A contractor, after completion of a development, should continue to make the developed item at least until another source has demonstrated acceptable performance. Within one organization it is difficult to transfer the know-how built up during development phases to production. When the

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69 *Rocketeer*, 8 Jan 1965, 6. Raborn had headed the Special Projects Office during the initial development of Polaris. In 1965 President Johnson appointed him Director of Central Intelligence. Kimball served as Secretary of the Navy from 1951 to 1953.

70 *NOTS Command History* 1964, 20.

71 Advisory Board recommendations, 6–7 May 1965, 6-3. Heinrich was later program manager for the Advanced Light-Weight Torpedo and eventually headed the Torpedo Systems Division at NOSC. At his retirement in 1984 he received NOSC's highest honor: the Lauritsen-Bennett Award.

> transfer must cross a boundary between contractors, there is almost sure to be more delay than can be tolerated in a weapons program.[72]

In 1966 NOTS engineers developed a dynamic real-time simulation to support Mk 46 system evaluation and obtained excellent correlation between the first 500 simulation runs and 33 sea runs. The Advisory Board's production concerns notwithstanding, Mod 1 production was relatively free of trouble, and the weapon entered service with the Fleet in 1967.

The timing was good, because Aerojet's Mod 0 torpedoes were having problems; in January 1967 Rear Admiral Gralla (then head of the Naval Ordnance Systems Command) had sent back 700 Mod 0s for rework. Problems included bad gas-generator casings, engine leaks, ineffective exploders (fuzes, initiators), and "a tendency for the torpedo to drift downward more than planned."[73]

Eventually, more than 25,000 Mk 46 torpedoes went to the Fleet, and the weapon has since been used by more than 25 foreign navies. The Mk 46 Mod 1 was the Navy's standard lightweight torpedo for 20 years, and the Mk 46 Mod 5A, with a search range of over 3,000 yards, is the current Navy standard lightweight torpedo for destroyers and aircraft as well as the NATO standard torpedo. The Mod 5A is also the payload for the Vertical-Launch ASROC (VLA).[74]

As with ASROC, there was no question where the real control of the Mk 46 program resided. The NOSC history cites both ASROC and the Mk 46 as examples of programs where

> . . . as the pace of technological change accelerated, the laboratories had to contract for more of their R&D work, not simply for the production of the finished article whose prototype had been fabricated in-house. . . . Under these arrangements, overall control remained with the R&D Division of BuOrd (the sponsor), but NOTS was responsible to the Bureau for the performance of the new torpedo and its compatibility with related weapons systems. Since the ability to dispense or withhold money was the foundation

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72 Advisory Board recommendations, 4–5 Nov 1965. 1. The board's membership at that time was Dr. W. Albert Noyes, Jr., Chairman; Dr. Luis W. Alvarez; Dr. Paul M. Fye; Dr. Joseph E. Henderson; Frank Gard Jameson; Dr. Charles C. Lauritsen; Dr. J. C. R. Licklider; Adm. John H. Sides, USN (Ret); Dr. L. T. E. Thompson; and Dr. James H. Wakelin, Jr.
73 NOTS Technical Board meeting, 18–20 Jan 1967, 7.
74 Russell Thomas, *The History of the Torpedo and the Relevance to Today's U.S. Navy*, Naval Undersea Museum, Keyport, WA, *http://www.history.navy.mil/museums/keyport/History_of_the_Torpedo_and_the_Relevance_to_Todays_Navy.pdf,* accessed 19 Oct 2010; "Torpedo – Mk 46," *United States Navy Fact File*, *http://www.navy.mil/navydata/fact_display.asp?cid=2100&tid=900&ct=2,* accessed 21 Oct 2010.

> of authority over the contracting partners, the Station had essentially been assigned responsibility without the commensurate authority.[75]

Aircraft Nuclear Standoff ASW Weapon

In the late 1950s, nukes were never far from any weapon designer's mind. Knemeyer said of the period, "We were in the process of looking at putting nuclear warheads in everything." It is not surprising therefore that in 1958 NOTS developed preliminary specifications for the Aircraft Nuclear Standoff ASW Weapon.[76]

The design goal was a nuclear weapon that could be launched from a helicopter while it maintained sonar contact on an enemy submarine. For the payload, the designers looked beyond the then-current Mk 101 Lulu and Mk 90 Betty nuclear depth bombs to a next-generation warhead weighing just over 200 pounds. The weapon was to be a scant 76 inches long with a 12-inch-diameter body and overall weight of 520 pounds.[77]

As with any NOTS-designed weapon, the operational context and support requirements were given careful consideration. The weapon would be deployed with a team of several helicopters, to maximize the probability of target detection, and could be launched from either the helicopter making the sonar contact or a sister aircraft that was closer to the target.

Bearing-to-target and range-to-dive data would be loaded into the autopilot just before launch. After being launched near sea level, the weapon would climb to 500 feet, powered by its solid-propellant rocket motor, covering the distance from launch point to its maximum range (10,000 yards) in about 40 seconds. In the last 600 yards of flight, it would dive toward the water and, on water impact, the frangible nose section (containing the autopilot-controlled steering canards) would break away, leaving the weapon to sink to target depth (up to 1,000 feet) where the warhead would detonate. There is no evidence that this weapon ever was taken beyond the study stage.

Sonaray

As Soviet submarines increased in capability, the Navy redoubled its efforts to detect, classify, and track these deep-sea threats. One program, conceived in the early 1960s, was dubbed Sonaray. It consisted of an unmanned autopilot-controlled free-running sonar transmitter-receiver platform and a surface ship

75 *Fifty Years … Point Loma, 1940–1990*, 38.
76 S-200, Knemeyer interview, 26.
77 *Technical Program Review 1958*, 147.

Sonaray Deep Dunk sonar test unit.

that would direct the Sonaray vehicle and carry out the sonar signal processing. The Sonaray vehicle's design goals were 10 hours endurance at 15 knots to depths of 6,000 feet. It would be acoustically linked to the parent ship.

Wally Hicks was assigned the task of managing the program, which began with preliminary design studies in 1964. Ivor Lemaire and later Bob Hearn ran the project for Hicks. Thomas G. Lang worked the hydrodynamics of the subsurface platform—a sphere that used boundary-layer control techniques to reduce drag—and Horace E. "Ed" Karig and Gerrit DeVries built the propulsion system, which was designed around a molten-salt boiler using lithium hydroxide and lithium fluoride. Construction of the steam-powered dynamic test vehicle that would carry the sonar equipment and acoustic telemetry gear began in 1965.78

In 1966 an 18-inch-diameter water-tunnel model of the Sonaray vehicle was sent to David Taylor Model Basin for testing. Encountering flow problems, the design engineers made changes to the duct-inlet and after-body contour. Tests in 1967 at Caltech's GALCIT wind tunnel in Pasadena showed the flow problems to be significantly reduced.[79]

A subproject of Sonaray development, dubbed Deep Dunk, would test the Sonaray sonar from a barge-mounted winch. In 1967 the specially designed winch was installed on NOTS' Underwater Operations Vessel YFU-53 (ex-LCT 1446), which was used primarily for deep-salvage operations (having recovered a SUBROC test vehicle from 2,500 feet of water in 1964).

The winch had the capability of raising and lowering the vehicle at high speed with automatic tension control and could compensate for boat motion by moving the cable to stabilize the load, providing 100:1 attenuation of ocean surface effects at the payload depth. (At the heart of the system was a pressure sensor that rode on the cable at depth and was known by the developers as the "climbing monkey.") The winch demonstrated the ability to hold the payload stationary in ocean conditions up to Sea State 4, the worst conditions encountered during the testing.[80]

In 1967, Hicks was made a Michelson Laboratories Fellow, cited particularly "for the exploratory research and concept formulation of the Sonaray system." The program moved NUWC with the July 1967 reorganization that created NUWC and NWC. Pasadena employees Guy Andrews, John McCool, and Shelby Sullivan applied for a patent for the Sonoray system, and the patent (U.S. Patent No. 5,029,147, assigned to the Secretary of the Navy) was granted in July 1991.[81]

78 Karig and DeVries received U.S. Patent No. 3,722,445 in 1973 for their "Underwater Molten Salt Heat Storage Boiler."

79 *NWC Tech History 1967, Part 1,* 8-4.

80 NOTS Technical Board meeting, 18–20 Jan 1967, 5.

81 *Rocketeer*, 12 May 1967, 1.

Sonaray's operational concept—a semiautonomous vehicle that would travel with a naval convoy to protect it from enemy submarines—was its undoing (and perhaps ahead of its time). Convoys were falling into disfavor in naval strategy. Sonaray became, in the words of Norm Estabrook, who worked on the project, "a solution that no longer had a problem." Although Sonaray ended with the prototype phase, it produced technological advances in acoustics and hydrodynamics.[82]

Supercavitating Propeller

Pasadena made many technical contributions to the Navy's ASW programs beyond the weapons systems discussed here. For example, RETORC, which continued as a NOTS program until the Station's disestablishment in 1967, served as the test bed for a supercavitating propeller designed and manufactured by David Taylor Model Basin.

The propeller was designed to break the "cavitation barrier" (the point at which the speed of a rotating propeller causes bubbles and cavities of water vapor to form behind the blade, affecting propeller efficiency and creating noise and erosion of blade surfaces) by "ventilating," which involved injecting high-pressure gas through passageways in the propeller blade.

Working with Office of Naval Research funding, Jack Hoyt (head of UOD's Propulsion Division) and his senior engineer Paul C. Roberts designed and carried out a program that tested the supercavitating propeller under far more realistic load, speed, and depth conditions than did the towing basin and water tunnel experiments previously used. The torpedo configuration used, called RETORC-I, was powered by decomposed hydrogen peroxide, which also produced ample oxygen for the ventilation process. Testing at the Morris Dam Underwater Cableway Facility generated much-needed performance and acoustics data and also demonstrated that the supercavitating propeller was a serious contender for service in future underwater vehicles.

Project Swish

Basic and applied research played an important role at the Pasadena Annex. Subjects ranged from the nature of the ocean itself to the extremely complex interactions of water on moving objects, and vice versa. Anything that might conceivably lead to a technological edge in underwater warfare was

82 Norm Estabrook, telephone interview, 6 July 2011. An aeronautical engineer, Estabrook began his Navy career at NOTS Pasadena and eventually headed the Ocean Engineering Division at the Naval Ocean Systems Center, San Diego.

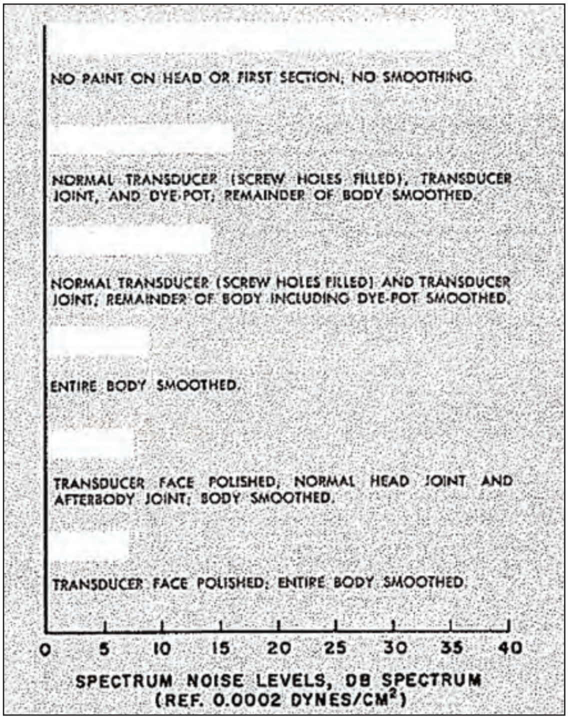


Chart showing variations in hydronamic noise with variations in torpedo parameters.

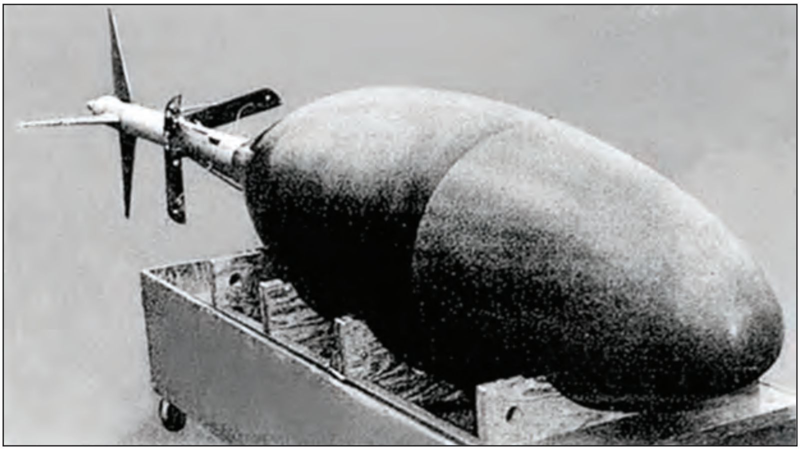
scrutinized—boundary-layer control, motion studies of fish propulsion, water entry and exit phenomena, the ability of sea animals to generate and detect sounds, human biological response, silent gears for propulsion systems, ducted and wake-adapted torpedo propellers, biological polymers for drag reduction, gravitational gradients, vented hydrofoils for high-speed operations, explosives specially designed for underwater operation—all these and more received the attention of the NOTS researchers at Pasadena and, to a lesser degree, at the desert site.[83]

One example is UOD's Project Swish, which began in 1956. The purpose of this onomatopoeically named effort was to gain an insight into the nature of the hydrodynamic noise produced by a body as it moved through the water.

Buoyancy-propelled RETORC bodies were used in the Swish studies. The test objects would be taken down to 500 feet or more beneath the surface and released. A complex instrumentation array including super-sensitive sound recorders collected the sonic signature of the body, which could be correlated with its speed of ascent. Researchers examined the variations of noise with body surface roughness, materials, nose shape, speed, and structural design.

During summers the project brought the Pasadena scientists and engineers to Lake Pend Oreille in northern Idaho, where the deep, quiet water remained at a nearly constant 39°F and test bodies could be released at depths up to 1,000 feet. Among the employees participating in these summer studies were the Propulsion Division's Carl Nisewanger, Wally Magnuson, Jr., and Artie Daniels, and the Guidance and Control Division's Jim Campbell, Dick

83 The NOSC history reported that "in the mid-1960s, about 10 percent of the annual budget of NOTS Pasadena went toward basic research." *Fifty Years … Point Loma, 1940–1990*, 87.



Project Swish research vehicle.

Allman, and Nick Saines. In their off-hours, the men would fish for cutthroat and Kamloops trout.[84]

By 1967 Project Swish had produced a buoyancy-propelled laminar-flow research torpedo that, released at 500-foot depth, could reach a speed of 90 feet per second. In one test, carrying 150 pounds of ballast and 50 pounds of instrumentation, the torpedo reached a speed of 73 feet per second. Drag brakes deployed automatically at 160 feet below the surface to reduce the water-exit speed to 15 feet per second.[85]

Information generated through Project Swish proved useful not only to designers of boat hulls and torpedoes but also to designers of underwater detection equipment and intelligence analysts. These were flip sides of the same ASW coin: minimize the noise of our weapons; maximize the ability to detect, decipher, and defeat the enemy's.

Quality Engineering

An essential activity carried out by the Pasadena Annex was quality engineering; the assurance that the weapons and associated equipment manufactured both by and for the Station were of satisfactory quality and conformed to the intent of the designers. This responsibility was assigned to the Quality Engineering Division, the only division in NOTS Engineering Department that was headquartered at Pasadena. Heading the division was Robert M. Leard, who'd begun his career at Pasadena with Caltech in 1943. He transferred to GT&R in 1945 and was converted to civil service in 1948.

84 *Rocketeer*, 8 April 1960, 3.
85 *NWC Tech History 1967, Part 1,* 8-26.

When the 1954 NOTS reorganization transferred most of Pasadena's Design and Production Department to China Lake and renamed it the Engineering Department, under Kelvin H. Booty, Leard remained behind with 30 people to serve as liaison with contractors.[86]

One of the reasons that the division remained in Pasadena was the need for physical interaction with contractor facilities throughout the Los Angeles area. NOTS inspectors were a constant presence in plants and factories, monitoring operations and reporting to management on the quality of experimental manufacturing and pilot production. Leard's group also directed and operated environmental simulation, mechanical, packaging, chemical, metallurgical, and nondestructive testing laboratories and facilities.

Members of the division's Source Inspection Branch, headed by Clarence V. "Mike" Heath from 1949 to 1964, ranged across the Southland, and indeed across the nation, inspecting the materials obtained from vendors for use in the Station's R&D work. (In one 2-week period, the inspectors showed up at contractor facilities in Cleveland, Ohio; Buffalo, New York; Washington, DC; Macon, Georgia; and Long Island, New York.)

"Members of this branch lead an exciting, problem-filled life," the *Rocketeer* reported. "On their judgment may depend the success or failure of many Station projects, and sometimes the life or death of many small industries."[87]

Leard himself was an expert in all facets of the manufacturing process and served as the production manager for the Mk 46 torpedo. He taught classes at the Pasadena Annex, including a lecture series on the methods by which Station-developed items were prepared for and introduced into quantity production. In 1962 he was named president of the Metrology Division of the Los Angeles Chapter of the American Society for Quality Control.[88]

Analysis

Along with basic and applied research, hardware development, and contract oversight, NOTS was also involved in ASW theory and analysis. In the early 1960s, China Lake management became uncomfortable with the fact that nearly all the antisubmarine expertise at NOTS resided at Pasadena. McLean instructed Carl Schaniel, then head of the Weapons Analysis Group

86 Booty, who led the Engineering Department from 1954 until his retirement in 1964, had the distinction of being the only NOTS department head who did not hold a college degree. He arrived at NOTS in 1945 and set up the Station's first machine shop.

87 *Rocketeer*, 5 Aug 1960, 3.

88 *Rocketeer*, 16 March 1962, 3.

(Code 122), to establish a group of analysts that could provide the NOTS community and the Navy with expertise in the larger issues and theoretical aspects of undersea warfare.

With the help of Richard A. Nagelhout, the group was assembled and began preparing reports on various aspects of underwater warfare. One of the first steps was the transfer, on 1 July 1961, of the entire Pasadena Weapons Planning Group to China Lake. The *Rocketeer*, citing Code 12 head Dud Colladay, reported that "the transfer will provide greater integration of the group's antisubmarine warfare analysis work into the over-all weapons planning field."[89]

Schaniel recollected that:

> There was much to be done. We were surprised when we found a void in documented information on how a submarine carried out an attack on surface ships. We began going to exercise reconstructions and collecting submarine logs that detailed the steps they took in carrying out an attack on ships. We built attack scenarios based on actual exercise events. This procedure really built up the credibility of our attack scenarios.[90]

In the early 1960s, the Navy was considering a new class of ship called *Sea Hawk*, an advanced ASW escort vessel that would run quietly on gas turbine propulsion and would feature an integrated state-of-the-art sonar suite with a variable-depth sonar capability. In 1963 NOTS was assigned technical direction for development of *Sea Hawk*'s fire-control and weapon systems and for their integration into the ship.[91]

Schaniel (then associate for operations analysis in the Weapons Planning Group at China Lake) and his group discovered in the course of their research that the operating manuals for the proposed sonar system had not yet been written. As well as completing a comprehensive report on the adequacies of the proposed ship's weapons and fire-control system, the group created, as an appendix to the report, an operating manual for the sonar system. For their work, they received a commendatory letter from Vice Admiral Charles Martell (OP-95), the Navy's chief advisor for ASW.[92]

In ASW, as in most technical fields, McLean seemed to be always a step or two ahead of everyone else. Two years before Schaniel's group began its analysis of *Sea Hawk*, McLean had already reviewed the *Sea Hawk* concept—and dismissed it. "My first reaction, personally, to the *Sea Hawk* proposal was

89 *Rocketeer*, 10 Feb 1961, 3.
90 Schaniel, "Carl's Career Chronology," 63–64.
91 *NOTS Tech History 1963*, 1-2.
92 The Sea Hawk program was cancelled in 1965.

that the Navy needed more [large and expensive] surface ships to defend like it needed a hole in the head," he told the Undersea Warfare Research and Development Planning Council, of which he was a member.[93]

He proposed that instead of the expensive (and thus necessarily few in number) *Sea Hawk* vessels, the Navy investigate the practicality of a large group of high-speed, low-value, small-crewed, wind-powered catamarans (the traditional sails replaced with rigid airfoils). The boats would carry auxiliary power units, would have sophisticated sensors and inter-craft communication gear, and would be capable of "a high burst speed, in perhaps the 60-70 knots category, for sufficient period to carry out effective attacks."

McLean told his fellow council members that this approach:

> . . . will provide the Navy with a large number of small, long-range patrol craft which can serve the purpose of challenging shipping on the high seas, acting as a police force on the high seas, and carry out attacks on submarines in the event that they make the mistake of disclosing their position. . . . I believe that such a ship can be used to apply high political pressure with a minimum risk of loss by the fact that they will be available in large number. The loss of such a ship in a police-type action is much less likely to provoke nuclear retaliation than would be the loss of an aircraft carrier, such as the *Enterprise*.

McLean's vessels would be equipped with a vertical-takeoff-and-landing aircraft for air defense, and a "cruise type missile, utilizing wing and fuselage structures molded from cast plastic bonded explosives" for antiship and shore bombardment capability. To prosecute the ASW mission, *Moray*, then under development at NOTS, would be used.

Separation

On 1 July 1967, the Pasadena Annex, along with San Clemente Island and the Long Beach Ranges, was severed from China Lake in a major reorganization of the Navy's research and development laboratories and facilities. Pasadena merged with elements of the Naval Electronics Laboratory to become the Naval Undersea Warfare Center (NUWC), with its headquarters at Pasadena (the other two NUWC sites were the San Diego Division and the Hawaii Division).

The new Center was commanded by Captain Grady H. Lowe (then serving as NOTS' interim Commander and before that Pasadena Officer-in-Charge) and was led on the civilian side by McLean, with Doug Wilcox as his associate technical director. Wilcox's longtime right-hand man, Wally Hicks, became

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93 "NOTS Concept of Future ASW Weapons Systems," 11-13 Dec 1962, RM-24, *Collected Speeches of McLean*, 200.

assistant technical director. McLean's longtime right-hand man, Hack Wilson, remained at China Lake as Acting Technical Director.

NUWC was headquartered at Pasadena, as were five of the new organization's eight technical departments.

While there was little immediate change in the Pasadena workload or mission, there was the sense of a new beginning for employees who had long felt that they were considered subordinate to China Lake. Never again to be relegated to the back page of the *Rocketeer*, Pasadena established its own newspaper, the *Seascope*.

And finally, Pasadena received the name change it had sought for more than 20 years. No longer called the Pasadena Annex, it was now, officially, the Pasadena Laboratory. "Which," according to James Jennison, "made everybody there much happier."[94]

94 The bloom was taken off the rose of independence when, in July 1968, the official headquarters of NUWC was transferred to San Diego. In 1969 the name was changed to Naval Undersea Research and Development Center (NURDC, later simply NUC), because the word "Warfare" in NUWC's title was causing problems with recruiting and was reducing the number of invitations of NUWC professionals to conferences. For a summary of Pasadena's history from 1968 to 1990, see *Fifty Years … Point Loma, 1940–1990*.

11

The World Beneath the Surface

In my mind, the first indication that the Navy intends to survive and win a limited-war conflict at sea using non-nuclear weapons will be when they start the research on submarine tankers and submarine transport. Without this capability I see no possibility for long-term survival of naval forces.

— Dr. William B. McLean, NOTS Technical Director[1]

Bill McLean spent the most successful and productive years of his life in the Mojave Desert. Yet, ironically, his great passion was the ocean, the antithesis of the arid landscape that was his desert domain. McLean's need to be on the water, and in the water, went beyond the fact that he worked for the Navy and that he believed—based on careful analysis of people, technology, and politics—that the future of the Navy lay under the sea. William Burdette McLean, personally, loved the ocean.

Don McLean, one of his three sons, recalled vacations from his childhood:

> My dad has made his scuba gear . . . and wet suits, homemade wet suits . . . You actually glue them; you don't sew them. . . . and we used the base pool for testing out the equipment. . . . we went out to Catalina and had scuba gear back before you had to have any kind of license.[2]

McLean would craft his own scuba regulators for aqualungs in the days before they were widely available commercially. "He did have a nylon mold injector arrangement [in Michelson Laboratory] where we could mold nylon valves for making these regulators," said Bill Woodworth, who used to dive with McLean in Mexico. In 1956, when a Station employee drowned while fishing at Lake Isabella, NOTS engineer Ken Powers located the body using special skin diving equipment invented and designed by McLean.[3]

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1 "Survival of the Navy at Sea" presentation, 8 Jan 1975, RM-24, *Collected Speeches of McLean*, 223.

2 S-308, Don McLean interview, 29 May 2010, 4.

3 S-215, Woodworth interview, 18; *Rocketeer*, 5 Oct 1956, 1.

McLean's wife, Edith LaVerne (universally known as LaV), told an interviewer:

> He made wet suits for us just out of Sears Roebuck rubber, just cut me out the pants and cut me out the top and then used a little rubber hose around there, and then we used longjohn underwear. Then he took me down to Mexico and put me in the ocean [laughter], and I had a tank on me. Then we used to go over to Catalina and go diving. I loved that scuba diving.[4]

Another time LaV remembered when her husband made a Rogallo wing:

> He put his waterskiing equipment on, and hung himself on big huge wing he designed. He got behind the boat and was going to ski and try to have the wind raise him up in the air over Lake Isabella. For some reason or another, the boat didn't go fast enough and the wing got caught underneath the water. We were dragging him underneath the water, and we nearly drowned him.[5]

Every August the McLeans would vacation at their cabin on Lake Chelan in Washington state. The site was accessible only by boat. Bill McLean, his two brothers, and his father (a Presbyterian minister) had built the cabin, barging material in from road's end at Stehekin. Long-time friend Polly Nicol said:

> I remember from the first, his real love was the water and the ocean. . . . He taught us to water ski in that cold, cold lake at Chelan, cold as only a glacier lake can be.

The McLeans' 21-foot fiberglass boat was named *C'est LaV*.[6]

Perhaps a clue to McLean's attraction to the water can be found in an autobiography he prepared for the National Academy of Sciences in 1974:

> About 1927 when I was just starting high school, my father bought a 25-foot lot on the beachfront at Newport Beach between 36th and 37th Streets. At that time the whole block was vacant and the family and friends built a two-story beach house for a total materials cost of $950. We spent our next four summers in Newport Beach with my father commuting to Los Angeles by the Red Electric cars. We built surfboards, canoes, and rafts, learned about the power of the waves and that sucking air through a hose from the surface is not possible.[7]

Whatever the source of McLean's affinity for the ocean, his position as NOTS Technical Director put him in a position to indulge his passion. He did

4 S-210, NOTS South interview, LaV McLean, 10 June 1992, 21.

5 DNL-T-23-80, Edith Laverne McLean interview, DNL Oral History Collection, 17 June 1980, 30.

6 S-225, Peter and Polly Nicol interview, 31 March 1993, 59.

7 "Autobiography of Dr. William B. McLean for National Academy of Sciences," June 1974, LaV McLean papers, provided by Elizabeth Babcock, 2008.

McLean family at Newport Beach, late 1920s. From left are Robert N. Jr., Robert N. Sr., John G., William B., and Clara McLean. The unidentified woman at right is probably the boys' grandmother. Photo courtesy of Don McLean

so, and in the process contributed to the Navy's mission of maritime security, to the scientific understanding of matters oceanic, and to the unveiling—for those who chose to look—of the enormous potential that the ocean held for human discovery and exploitation.

Moray

Next to the Sidewinder missile, *Moray* may have been the NOTS development program closest to McLean's heart. He believed, and argued persuasively, that the future of the Navy lay not on top of the ocean but under it. He looked beyond the traditional view of submarines as underwater versions of destroyers and envisioned a more complex undersea infrastructure involving submarine tankers, submarine transports, marine mammals as undersea assistants, and submarine/subterranean bases. He was convinced that the world's ocean depths offered endless possibilities for the Navy as well as for civilian habitation, recreation, and commerce.

Frank Knemeyer, who for many years headed the Station's largest department, said of his boss:

> He had plans, philosophical plans, of putting the whole Navy underwater. He wanted to put carriers underwater and everything. He was even looking

> at how to come to the surface, launch planes, recover them, and then go back under. He wanted all the transports and things like that to be underwater.[8]

Moray—at least in its initial proposal stage in 1959—was an undersea weapon, a two-man, high-speed submersible vehicle that would carry underwater rockets with shaped-charge warheads. Launched from a ship or a submarine, *Moray* would seek out and destroy enemy submarines.

Small manned submersibles were not a new idea. During WWII the Japanese had employed both midget submarines and manned torpedoes against allied warships and merchantmen. But while most midget submarines were scaled-down versions of regular submarines, McLean's idea was to come at it from the other direction, scaling up a torpedo.

"We started the thinking process on this vehicle using the data available for the aircraft torpedo Mk 46," McLean told a National Academy of Sciences panel in 1960. He described the vehicle as:

> . . . 1 foot in diameter and . . . designed to travel at 45 knots. If we scale it up in linear dimensions by a factor of 5, we arrive at some of the characteristics which we would like to build into the *Moray* vehicle. For the Mk 46 we have demonstrated active sonar ranges out to 2,000 yards in the water. If we assume that the sonar range might scale proportional to the dimension, we should then have an active range for *Moray* of the order of 10,000 yards. We can assume that the drag will go as the square of the linear dimensions, but the volume available for fuel will go as the cube of the linear dimensions. At a 45-knot speed [unheard of for submarines at that time], *Moray* might therefore be expected to run for the order of an hour and a quarter. If we can shift gears, by either using a piston engine or multiple turbines, so that the fuel consumption will vary as the velocity cubed, then we should have 28 hours at 15 knots, which we believe is an adequate cruising speed and time for most of the applications which we have in mind.[9]

At the outset of the project, it was unclear just what those "applications which we have in mind" were. In a 1959 presentation to James H. Wakelin, ASNR&D, McLean called *Moray* a "two man torpedo." This was safe, since torpedoes were within NOTS' mission; submarines and other seagoing vessels were not. In his presentation to the National Academy McLean said, *"Moray* is a weapon," and the 1960 *Technical History* he called it an "interceptor."

8 S-200, Knemeyer interview, 42. The idea of launching aircraft from submarines was not far-fetched. The Japanese built three submarine aircraft carriers during WWII. See for example *http://www.combinedfleet.com/ships/i-400* accessed 5 Nov 2010.

9 *Moray* presentation to Panel on Deep Submersibles, Committee on Undersea Warfare National Research Council, National Academy of Sciences, 13 Sept 1960, RM-24, *Collected Speeches of McLean*, 196.

Generically, in the NOTS technical literature, *Moray* was described as a "two-man, deep-diving submarine" or "submersible vehicle," which was still arguably within NOTS mission as a support tool for the Station's ASW work.[10]

A justification for this ambiguity of purpose—other than the obvious need to be able to claim the project as within the Station's scope of responsibility and not within that of some other organization—is provided in McLean's National Academy presentation:

> We find that one of our difficult problems in presenting *Moray* is to define the tactical functions. This difficulty probably arises because there are so many uses for *Moray* that everybody seems to be discussing a different possible use. We believe that it is true that the *Moray* vehicle could replace all of the functions which are now carried out by homing torpedoes. In addition, it has the ability to classify and challenge in peacetime. In the case of war, it can verify the target before killing and can remain to verify the kill after firing its weapons.[11]

Early in 1960, the Station formally decided "to broaden the capability of the first *Moray* test vehicle by giving it greater scope and flexibility as a research tool as well as having it perform the necessary experiments to prove the feasibility of the *Moray* [weapon] design concept." The original design goal had called for a maximum dive depth of 6,000 feet, but for the first test vehicle (*Moray* 1A) that maximum was modified to 2,000 feet.[12]

During *Moray*'s initial formulation stage, Jim Bowen (who had earlier worked on alternative underwater-launch options for Polaris) and William P. Deavers, Jr., met with pioneering deep-ocean experts such as Dr. Andreas Rechnitzer, Jacques Piccard, and Navy Lieutenant (later Captain) Don Walsh. In 1960 Piccard and Walsh set the record, still unbroken, for the deepest descent of men into the ocean (35,798 feet), a depth they reached in the bathyscaphe *Trieste*. The Navy-owned vessel, designed by Piccard's father, Auguste, had carried them to the bottom of the Challenger Deep in the Mariana Trench, nearly 7 miles below the surface, and returned them safely to the surface.

The *Moray* team members also studied the state of the art in underwater vehicles and submersibles and met with subject-matter experts at the Pasadena Annex and the Naval Electronics Laboratory in San Diego.

Moray development was assigned to Knemeyer's Weapons Department in 1960. As Knemeyer recalled:

10 "China Lake Products Digest," *Rocketeer*, 4 Nov 1993 (50th Anniversary Edition), 30; *NOTS Tech History 1960*, 161.

11 *Moray* presentation to Panel on Deep Submersibles, RM-24, 197.

12 *NOTS Tech History 1960*, 161–162.

> I took over in [Code] 40, and we got into this conventional "free-fall" business [the Eye series of free-fall weapons for limited war] and McLean got interested in underseas. McLean eventually had very little to do with what I was doing in the department, except for *Moray*. . . I took one branch, and that was devoted strictly to McLean, and I'd go to Hack [Wilson] and tell him how much money I needed to do what McLean wanted, and that's how we kept it going. And, in fact, Hack told McLean, he said, "Knemeyer has given you one full branch to be your hobby shop."[13]

That branch, the group established to carry out the *Moray* project, was the Underwater Weapons Systems Branch (Code 4064) in the Aeromechanics Division. The branch, initially headed by Bill Deavers, was taken over 3 months later by R. Gordon "Gordy" McCarty. Charles E. "Charlie" Jenkins became the branch head in 1962, followed by Dick DeMarco in 1963.

Leroy Riggs, who headed the Aeromechanics Division from the early 1960s until the 1967 disestablishment of NOTS, said, "Bill McLean looked at the old [Code] 406 [Aeromechanics Division] as kind of his playground to a certain extent because we had a lot of the old Sidewinder people."[14]

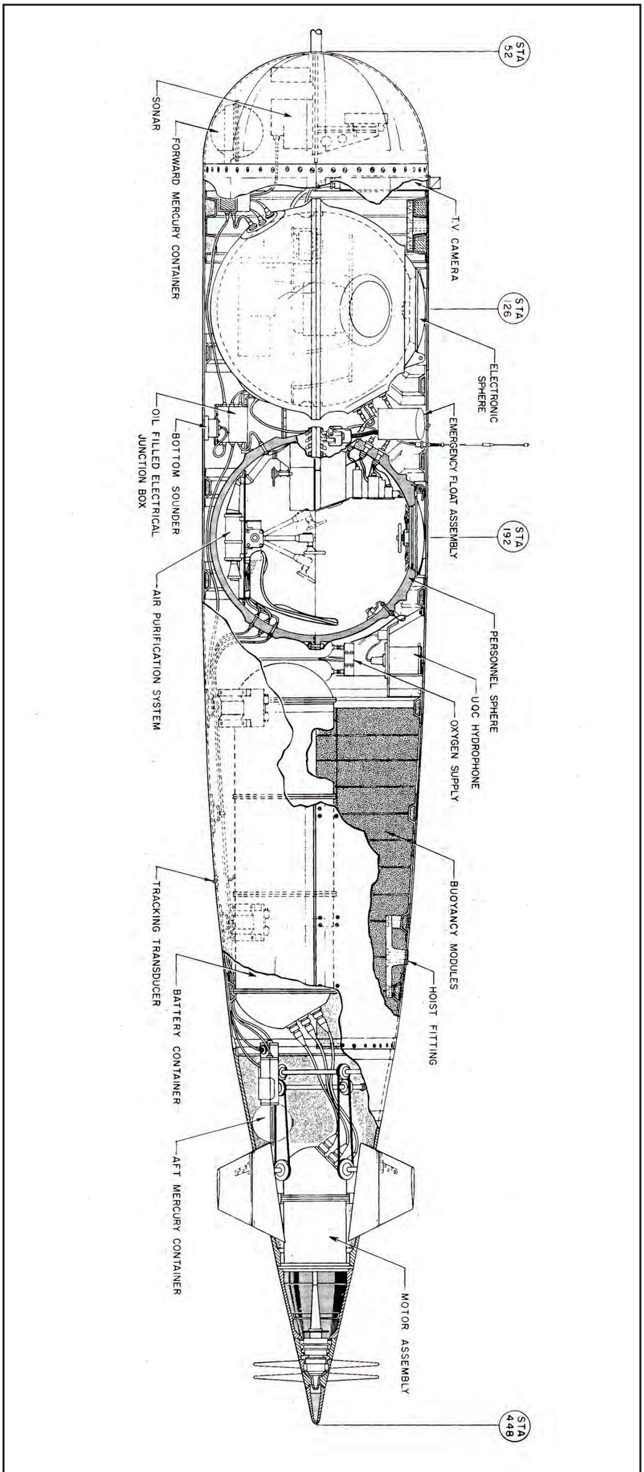
DeMarco remembered McLean's intense interest in *Moray*:

> When you got involved in the *Moray* program, he was down there like one of your workers. He was down there practically on a daily basis. In fact, your department head was no longer your department head; the guy running the program was McLean. And he was just such a down-to-earth person. I mean, he'd come in, and he'd ask how's this going, how's that going, and he was there listening.[15]

Moray did bear some resemblance to the Mk 46 torpedo. *Moray* was 33 feet long and 64 inches in diameter. An external flooded hull was constructed in two pieces (upper and lower) of layered fiberglass and foam. Inside the hull were two windowless, pressure-resistant cast-aluminum spheres that, along with the foam and a dry battery compartment toward the stern, provided about 500 pounds of positive buoyancy for the craft. In the aft sphere, two operators controlled the vessel by instruments, primarily sonar (at the surface a TV periscope was used). The 5-foot-diameter pilots' sphere had about as much interior space as a Volkswagen Beetle of the era.

The forward sphere contained the electronic control systems and instrumentation. Mounted forward of that sphere was a continuous-transmission frequency-modulated (CTFM) sonar built by the Applied Physics Laboratory,

13 S-200, Knemeyer interview, 61.
14 S-136, Riggs interview, 9.
15 S-248, DeMarco interview, 31.



Line drawing, *Moray* Test Vehicle 1A.

University of Washington (and adapted to *Moray* by electrical engineer Burrell Hays, who would become Technical Director of the Naval Weapons Center in 1982). This state-of-the-art sonar remained the standard for submersibles well into the 1980s, when time-pulse sonars and digital processing became prevalent.

A battery-powered 90-horsepower motor turned two counter-rotating propellers, one with four blades and one with three. The designers also investigated other more exotic modes of locomotion, including a hydrogen-decomposition motor, a thermal propulsion engine, and even a tiny nuclear reactor, inspired by NASA's SNAP (Systems for Nuclear Auxiliary Power) reactors of the period.

For communication, a unique frequency-shift keying (FSK) technique was used to modulate the vehicle's sonar when submerged, and a UHF radio link was used when the vehicle was surfaced. *Moray* also included a mercury system to control the pitch trim and provide ballast. Through a system of pumps, valves, and storage flasks, hydraulic fluid was used to move mercury forward or backward to maintain an even keel—although technically *Moray* had no keel. A mechanism was incorporated for the crew to jettison the mercury (approximately 1,000 pounds), in *Moray* operator Al Berryman's words, "just in case."

One of the most common ways that *Moray* was described was as an underwater fighter plane, and the new vessel did have much in common with Navy fighter aircraft. It was designed to be launched from a mother ship (either a surface vessel or a submarine), complete its mission, and return to the mother ship. It would have a two-man crew, as was more and more the tendency in Navy fighter and attack aircraft. "We believe that the surface ship now needs *Moray* to fight its battles below the interface in exactly the same manner in which it needed the aircraft in the last war to fight its battles above the air-water interface," McLean said.[16]

Don Moore, who was *Moray*'s final project manager at NOTS before the program (and Moore) left China Lake in 1967, said:

> So he just kind of made the underwater analog of a fighter plane. What would you end up with? An airplane is reasonably safe, e.g., if you're flying around and you run out of fuel, you'll come back to the surface because it's heavier than air. That says, well, if you're going to be underwater, you want it to be fail-safe, so it'll come back to the surface if you ran out of fuel or whatever, so that means it has to be lighter than water.[17]

16 *Moray* presentation to Panel on Deep Submersibles, RM-24, 198.

17 S-185, Moore interview, 1990, 8.

Thus because of the vehicle's positive buoyancy, it required motion to submerge and maneuver; if it stopped moving, it would rise toward the surface. While moving, it would dive, climb, and turn much like an aircraft, albeit far more slowly, with the pilot controlling pitch, roll, and yaw.

Allyn R. "Al" Berryman came to work at China Lake as an electronics technician in 1952. "I thought, well, it looked like the work might be reasonable, and I would just take a job until I could get another job someplace where it was more civilized," he recalled 57 years later and still a Ridgecrest resident. Soon after he arrived, he learned to fly.[18]

Berryman soon became an accomplished aviator; in 1959 he flew his Cessna 170B to an altitude of 11,000 feet over Inyokern, cut the engine, and glided the Sierra Wave (a meteorological phenomenon of rising air on the east side of the Sierra Nevada) to Lone Pine and back, a distance of 140 miles. He remained airborne with the motor off for 5 hours and 15 minutes.[19]

As the years went by, he taught soaring to a few fellow workers, one of whom happened to be working on *Moray*. Soon thereafter, Berryman was recruited to "fly" *Moray* during its development.

The large, rechargeable zinc-silver batteries that powered the engine of the *Moray* text vehicle were troublesome and were the cause of an incident that in 1965 sank *Moray* and nearly sank the whole program. Berryman was flying *Moray* that day with Lieutenant Commander Robert W. Montross as co-pilot. The two were running a series of exercises near San Clemente Island.[20]

One of the batteries went bad and released enough gas to cause an explosion. Berryman related that:

> We got maybe about a third of the way into the run when the battery compartment exploded. The battery compartment is a cylinder, maybe 2½ or 3 feet in diameter, maybe 10 or 12 feet long. And it's of course dry, and of course when it exploded, we lost all that buoyancy and immediately started tail-first toward the bottom and went right all the way to the bottom, which was about 220 feet, and hit bottom in almost a near-vertical attitude.[21]

The only option was to dump the mercury ballast and hope to achieve buoyancy. "We should have known—but neither one of us knew—whether

18 S-277, Allyn R. Berryman interview, 11 May 2009, 2.

19 *IWV Independent and Times-Herald*, 5 Feb 1959, A-1.

20 Naval officers, many of them submariners, were trained as *Moray* operators. These included Montross, Cdr. Lincoln H. Lippincott, Lt. Jack Phelps, CWO Robert B. McLaughlin, Lt. j.g. Wayne Rouse, and Lt. Robert D. Blaine.

21 S-277, Berryman interview, 9.

dumping the mercury would compensate for the loss of that buoyancy of that battery pack," Berryman said.

So they dumped the mercury. "Well, what we found is when you're sitting in sand, the mercury doesn't pour out too fast," said Knemeyer. "So it gave us a little cause for worry there."[22]

Said Berryman:

> It wiggled around a little more, and finally it wiggled and we gained about a foot or two and sat there for quite a while, and then it wiggled some more, broke loose, and drifted to the surface very, very slowly. Got to the surface—we were about at an 80-degree angle with the nose up.[23]

For a deep-diving vessel, even matters as fundamental as buoyancy had to be revisited and re-engineered. Up to the time of the NOTS submersibles, gasoline was used to provide buoyancy for deep-diving bathyscaphes (bathy*spheres* are generally suspended by a cable from a surface ship; bathy*scaphes* are independent of a surface connection, suspended instead from their own attached float, much like a gondola under a dirigible). The use of gasoline required that large amounts of steel shot be carried to counteract the buoyancy and let the bathyscaphe descend. As the gasoline compressed at extreme depths, shot would be released to counteract the reduced buoyancy. More shot would be released to allow ascent.

Moray's developers, principally Ray F. Hinton, came up with a simpler and more efficient source of buoyancy—syntactic foam, which is still in use today. Syntactic foam consists of minute glass spheres embedded in an epoxy base. The spheres are not compressible and thus do not lose buoyancy under the great pressures at extreme depths. The initial formulation created in 1961 "fulfills all requirements for a buoyant material for use in deep-sea submersibles," and "loses less than 1 percent of its buoyancy when subjected to a hydrostatic pressure of 1,500 psi for 24 hours."[24]

DeMarco remembered that:

> . . . we came up with a formulation [that] weighed about 40.1 pounds per cubic foot. That gives you about 24 pounds of buoyancy in sea water [which weighs 64 pounds per square foot]. So every cubic foot of that material we put into our boat in all the interstices, all the voids, would give us buoyancy. When we came to mix it, we could use our mixers out at Salt Wells, the explosive mixers. We could make this, and we could pour it into any form we

22 S-200, Knemeyer interview, 44.
23 S-277, Berryman interview, 11. .
24 *NOTS Tech History 1960*, 55.

> wanted, and when it set up, we could machine it like a block of wood. It was very easy to work with, but once it was hardened and put in place, it had the same compressibility as sea water, so that when we went down in depth we didn't lose our buoyancy.[25]

The large spheres that would form the electronics and crew compartments were a challenge. *Trieste* used a steel sphere for the crew compartment but the weight of a steel sphere was prohibitive for the *Moray* design. Titanium was considered, but after talking to Mallory-Sharon Titanium Corp., the titanium-fabrication experts, the *Moray* team found that the cost of a titanium sphere would equal the project's budget for an entire year. The next choice was aluminum, and Modern Pattern and Foundry Co. in Los Angeles agreed to build the two spheres (cast as four hemispheres), an inch and a half thick and 60 inches in diameter, for $25,000. "They even made the hatch," DeMarco said.

Moray's life-support system was originally designed with a pure oxygen environment, similar to that being concurrently used in the Mercury space-flight program. In tests conducted in summer 1961 under the direction of Lieutenant (Dr.) Steven L. Tope, VX-5 flight surgeon, members of the *Moray* team simulated routine operations in the crew's sphere during shifts ranging from 3 to 10 hours. Several of the team reported not feeling well after continuously breathing the oxygen, and someone also pointed out the danger of pure oxygen in an environment where an electric spark was always possible (this was more than 5 years before the Apollo 1 oxygen-fueled fire that killed three astronauts).

The engineers then designed a life-support system using a 20/80-percent oxygen and nitrogen mix. Scrubbers absorbed the crew's exhalents (carbon dioxide and moisture); when pressure in the sphere fell below 14.0 pounds, a regulator would allow oxygen to flow into the sphere from an external source. Backup individual rebreather systems were kept inside the sphere in case the primary oxygen supply failed, and as a last resort the sphere carried two Steinke Hoods, which would provide them with air during an emergency submerged exit from the vehicle.[26]

Supersonic tracks are not often associated with submarines, but *Moray* was an exception. China Lake's Supersonic Naval Ordnance Research Track (SNORT, one of three supersonic tracks at the Station) runs straight as a laser beam for 4 miles near the southwest corner of the China Lake North Range Complex. SNORT has been used to test many things, from space capsules to

25 S-248, DeMarco interview, 32.
26 DeMarco review comments, 26 Aug 2011.

Moray **at SNORT Reservoir, 1962.**

aircraft wings to SUBROC, and its rocket-powered sleds have achieved speeds of over 4,500 feet per second.[27]

What brought the *Moray* team to SNORT in March 1963 was not the track itself but rather the water-brake system. In most track tests, the rocket-powered sled carrying a test item is decelerated by an onboard probe that extends down into a water-filled trough between the rails. The trough runs the length of the track (although for most tests only the last 2 miles of trough are used). To supply water for the braking system, a reservoir near the north end of the track is filled from a dedicated well. The size of the reservoir, 120 feet long, 80 feet wide, and 12 feet deep, made it ideal for *Moray*'s initial water tests.[28]

Using a specially constructed hoist and bale, the 16-ton vessel was lowered into the reservoir. DeMarco said that the riggers first trained with a crude mockup of *Moray* called "Barrelcuda," which was constructed from seven clusters of seven water-filled barrels each secured to a 10-inch steel channel beam.

27 NWC AdPub 332, *Range Users' Guide*, Technical Information Department, July 1988, 21..

28 NWC TP 5120, *NWC Supersonic Research Tracks*, May 1972, 9–10. The rate of deceleration can be precisely controlled by altering the flow rate of water through the trough or by establishing pools of various depths, separated by frangible weirs (easily breakable dams) along the length of the trough.

For the tests, *Moray*'s propellers had been replaced with dynamometer disks to simulate system loading. The test team found that, as calculated, the internal heat load of 4,000 Btu per hour was dissipated through the aluminum spheres into the water. In 3 days of testing the team checked about everything that could be checked, given the size of the reservoir. The centers of balance and of buoyancy were determined, the mercury-transfer trim system was exercised, and the ease of handling the vessel by a support crew was assessed. *Moray* was oriented to various transit-aligned points to ensure that the onboard compass functioned accurately in the water.

Funding for *Moray* was primarily from in-house discretionary sources. Because the project was large for an in-house effort, minimizing the cost of development was always a priority. One example of the program's parsimony was the *Moray* support vehicle. When *Moray* was put in the ocean, a surface vessel would be required to support the submersible during travel from the dock site to the test-dive areas and to provide a stable surface platform and an area for test personnel, instrumentation, and supplies.

According to Berryman:

> We needed a mother ship of some kind. McLean's idea was to go ahead and see what is available. And so they had several people looking at all the different possibilities of how to solve this problem, most of which, if not all of which, were either getting Navy ships or commercial ships of one kind or another, which were all amounted to budgets that far, far exceeded *Moray*'s.

When this information was presented to McLean, according to Berryman:

> . . . he says, "Well, my first reaction to all of this is—and it's probably been in your minds too— but none of these are going to work. So what should we do? Shall we cancel work on *Moray* because we don't have any means of supporting it in the water, or do we look at other possibilities? . . . Keep your minds open. We don't have to do things the way things were done before. All of these vessels that you're looking at are nice, seaworthy vessels. For a support vehicle for *Moray*, do you need a real, ocean-going, seaworthy something, or do [we] just need a raft or something?"

And that was the genesis of *CataMoray*, a home-built catamaran that filled the bill perfectly. Under the direction of Sam Holliday at Salt Wells, Berryman continued:

> They [the Engineering Department's Components Section at China Lake] just bought this bulk foam, sawed it up in blocks, reinforced it with fiberglass, screwed all these pieces together, built a boat with a couple of big outboard motors—it wasn't pretty, but it was totally functional. And there was no crew. The crew was whoever was available on the *Moray* staff.

CataMoray **in sea trials, 1964.**

Later, during sea trials off San Clemente Island in 1964, a three-man naval crew was assigned to operate *CataMoray*.[29]

In his presentation to the National Academy of Sciences in 1960, McLean made a comment that said as much about himself, his management philosophy, and the confidence in which he held his employees as it did about his proposed "weapon."

He told the panel members that:

> [A] question which we are quite often asked is why a weapons laboratory, such as the Naval Ordnance Test Station, should try to do this particular job in place of some other activity. I believe that the only answer here lies in the fact that this job looks easy to us and that it would utilize the particular skills we have available, and, finally, that we think it would be lots of fun to try to carry it out.[30]

And fun it was. One day during test dives, the design team asked Berryman if he could surface with a little more speed and angle than normal. *Moray*'s speed on the surface was a mere 6 knots, but underwater, straight and level, it had reached speeds of up to 20 knots, 4 knots higher than the design goal for TV-1A. As Berryman recalled:

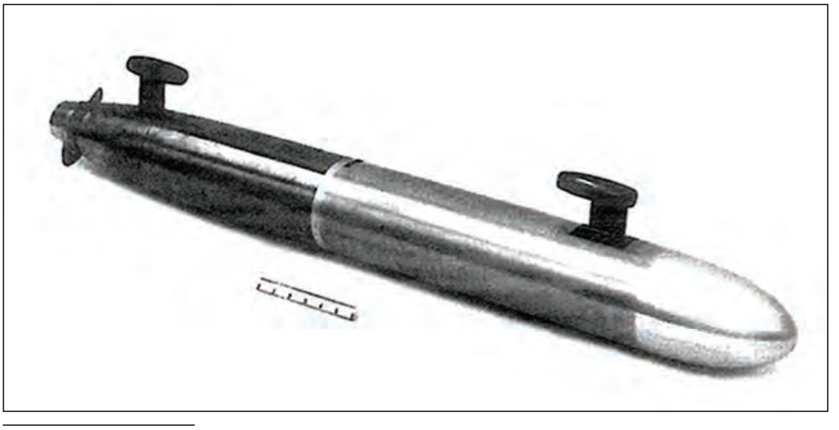
29 S-277, Berryman interview, 15.

30 *Moray* presentation to Panel on Deep Submersibles, RM-24, 198.

> And I said, "Oh, we [Berryman and Montross] could do that." So we turned around, made another run, and got it at kind of low speed, but it was under power, and then from about 20 feet down, I just kind of picked it up to where it had a significant angle. And the nose came out of the water—sploosh!—and everybody was just tickled with that; they were taking pictures of all that.
>
> "And anyway, they said, "How exaggerated could you do that maneuver?" And I says, "Well, we can hit the surface vertically at full speed if you want." They said, "No, no, something less than that, but something that would make a nice picture." . . . And so we made another run, and stayed down about 30 feet, a little bit deeper, and then just pulled it up at about a 45-degree angle and left the power on right to the point to where we broke the surface. And that boat came out of the water, about two-thirds of the hull came clear out of the water, and then went "sploosh!" back down in the drink.[31]

Willis R. "Will" Forman, NOTS' foremost submersibles engineer, was there that day, and he recalls that the sub approached the surface in a 60-degree climb at close to full speed. "The sub came down like a breaching whale with a horrendous splash, which messed up the sonar in the nose of the sub," he wrote. "Operations of that kind were forbidden thereafter."[32]

As work continued on the vehicle itself, other engineers pursued possible armament. One novel idea was the turbine-integrated propeller (TIP)-jet round. This 5-inch-diameter hybrid rocket/torpedo was fueled by a solid propellant that burned at pressures up to 4,000 psi. The gasses were expelled through tangential nozzles in a propeller hub containing two 1-inch-span supercavitating propeller blades, driving it like a pinwheel at speeds up to a phenomenal 30,000 rpm, which translated into a vehicle speed of 80 knots (135



TIP-jet round for *Moray*, 1963.

31 S-277, Berryman interview, 16.

32 Will Forman, *History of American Deep Submersible Operations, 1775–1995*, Best Publishing Co., Flagstaff, Arizona, 1999, 262.

feet per second). The design proved to have a higher propulsion efficiency than an axial rocket motor. Tests in 1964 were "moderately successful"—although internal instrumentation failed, the run was completed in the predicted time, as measured by hydrophones.[33]

Moray's name had been mentioned on several occasions in the *Rocketeer*, beginning in 1960, though only in connection with such matters as personnel transfers or briefing notifications. The project was not openly discussed in the paper until the 12 November 1965 issue. At that time the paper wrote that " *Moray* is designed to operate as an undersea laboratory device," and is "designed, built and tested for manned deep-sea oceanographic operations." Its mission was described as "the location, identification and classification of underwater objects, with the aid of development[s] in underwater television, radio communication, sonar, and sound localization techniques." The article noted that *Moray* had already been tested to a 2,000-foot depth. [34]

There was no mention in that article of *Moray*'s original intent as a weapon although, according to DeMarco, the Station had gone to great lengths to convince the Navy of the submersible's value as a fighting vehicle. In February 1962 Vice Chief of Naval Operations Vice Admiral Claude V. Ricketts and CNO Deputy Chief for Fleet Operations and Readiness Vice Admiral C. D. Griffin had actually climbed into *Moray*'s operators' sphere in the course of a briefing, and President Kennedy himself had been briefed on the "manned torpedo" during his visit in 1963.

DeMarco recalled that:

> . . . if [Ricketts and Griffin] were pleased with you, you thought every base was covered, that upper command back in Washington would approve this for what Dr. McLean intended it to be, an underwater fighter.
>
> When we got to that point where we needed Washington's approval to build the final version, the actual underwater fighter, different propulsion system with weapons, we had a meeting with [Vice] Admiral [Lawson P.] Ramage, "Red" Ramage, in Washington. And that's where we found out that the road ahead wasn't filled with roses. He had somehow felt that, by having a small submarine where you had to train the operators to be pilots, flyers, this would necessitate . . . another command in the Navy, another career pattern, another

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33 *NOTS Tech History 1964*, 6-9.

34 *Rocketeer*, 12 Nov 1965, 1, 4. Page 1 of that same issue of the *Rocketeer* announced McLean's receipt of the Rockefeller Public Service Award for Science, Technology, and Engineering and reported that "McLean revealed this week that he would use the $10,000 award to explore his personal interest and ideas in undersea technology. He believes that exploration of the ocean is of great national importance for both political and economic reasons."

Vice Admiral C. D. Griffin entering *Moray* with (from left) Frank Knemeyer, Dick DeMarco, and Vice Admiral Claude V. Ricketts looking on, February 1962.

> school pattern, et cetera. And he didn't want to bring that into the Navy . . . . So that's why the program went from becoming an underwater fighter just to an underwater research vehicle.

It was at that point, in January 1965, that *Moray* was reassigned from DeMarco, in Leroy Riggs' Aeromechanics Division, to Ray Francis in Don Moore's Astrometrics Division (which would become the Undersea Systems Division in January 1967). When NOTS was disestablished in July 1967, *Moray*, along with the Undersea Systems Division, was transferred to NUWC. DeMarco said that:

> Some of the men that were in the program had the option of going with *Moray* or staying behind and doing something else, and there were people

> who were put in charge that were not of the same frame of mind that the original team was in. And that discouraged quite a few of the original team from continuing to work with the program, especially when it was just going to become a research vessel and not be used for its intended purpose. So quite a few of us stayed and went into other areas of work on the base.[35]

Before *Moray* left NOTS, however, the project had demonstrated that small, lightweight, relatively inexpensive vessels could operate freely under the surface at reasonable speeds and with almost no limit on depth. It had shown its capabilities as a test vehicle for numerous communication and acoustical developments as well as developing improved information-display systems and craft-control methods. But, because of upper-level naval decisions made in Washington, *Moray* had not been allowed to achieve its original goal: demonstrating the value of a small, fast, inexpensive deep-diving weapon to counter the growing undersea threat posed by Soviet submarines.

George Wilkins, who spent most of his career working at the cutting edge of naval undersea technology research, believes *Moray* had a fatal flaw. "It was a high energy consumer," he said. For it to be a true underwater fighter, operating in the range and depth envelopes that McLean had envisioned, it needed levels of speed and endurance that could be obtained only through one power source: nuclear energy. When the Navy's support for development of the tiny (basketball-sized) nuclear reactor was withdrawn, the fate of *Moray* was sealed.[36]

What eventually became of *Moray* after it went to NUWC? According to Will Forman, "Once the feasibility of the concept had been proven and demonstrated, the project was discontinued." *Moray* was shipped to Hawaii, where McLean, with the assistance of Don Moore, George Wilkins, Bill Powell, Dan Hightower, and others, had set up a laboratory— NUWC Hawaii. A photo of the opening ceremonies for the laboratory in September 1968 shows what appears to be *Moray* in the background of a publicity shot. Norm Estabrook, who worked at the Hawaii laboratory from 1968 to 1972, recalled that:

> . . . it languished in a scrapyard, with its mercury containers laying around open and raw mercury just puddled in the dirt. A sad end for a fascinating project. When the "boneyard" was cleaned up, it disappeared, and I have no further knowledge of what happened to it.[37]

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35 S-248, DeMarco interview, 42–43.

36 George Wilkins, telephone interview, 2 Aug 2011; email to the author, 2 Sept 2011. Wilkins, a nuclear physicist, worked at China Lake from 1959 to 1968. He transferred to Hawaii to assist in setting up NUWC Hawaii, where he served until his 1987 retirement as senior scientist in the Underwater Technology Division.

37 Forman, *History of American Deep Submersible Operations,* 262. When the Hawaii

But that wasn't quite the end for *Moray*. A scrap company in Hawaii bought the weathering remains and resold them to Dr. Phil Nuytten, a pioneer in deep-water exploration and undersea technology development. *Moray*'s fairing was missing, but the tail section was intact. The spheres had been separated into their original hemispheres and gutted. Today the components (minus one hemisphere that was stolen, sold to a scrap dealer, and melted into ingots) are at Nuytten's Nuytco Research Ltd. facility in Vancouver, destined to become part of a museum chronicling the development of modern submersibles.[38]

Undersea Research

Project Nobska, the 1956 CNO-directed study of undersea warfare that led to the acceptance of the NOTS concept for the Polaris weapon system, was also a boon to the study of oceanography. The Nobska panelists included not only military and civilian Navy experts but also such noted oceanographers as Columbus O'Donnell Iselin, Carl Eckart, and Roger Revelle. According to Dr. Gary E. Weir, historian for the National Geospatial Intelligence Agency:

> Oceanography came of age with Nobska. . . . the CNO himself had publicly sanctioned oceanography as the most comprehensive way of effectively appreciating the Navy's natural medium.[39]

Red Ramage, then a rear admiral and a special assistant to CNO Burke, observed that

> . . . what did begin to emerge from [Project Nobska] was more and more money directed toward oceanographic research. . . . I doubt very much there was much, together with both private and public monies, more than 10 million dollars going into oceanographic research at that particular moment in time. But within the next 5 or 10 years this thing was up to 100 million and 400 million . . it certainly opened the floodgates for that.[40]

Given McLean's love of the ocean, and the fact that the ASW mission of NOTS Pasadena was dependent on an understanding of the ocean as it affected

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laboratory was formally opened in September 1968, McLean announced his intention "to make Hawaii the oceanographic center of the Pacific." *Seascope*, 27 Sept 1968, 1; Norm Estabrook email to Deanna Ripley-Lotee, 10 Feb 2011.

38 Phil Nuytten, telephone conversation with the author, 13 Sept 2011.

39 Gary E. Weir, *An Ocean in Common, American Naval Officers, Scientists, and the Ocean Environment*, Texas A&M University Press, College Station, 2001, 278.

40 Vice Admiral Lawson P. Ramage, USN (Ret.), interview by John T. Mason, Jr., U.S. Naval Institute, Annapolis, MD, June 1975, 285. For his actions as a submariner during WWII, Ramage was awarded the Congressional Medal of Honor, two Navy Crosses, the Silver Star, and other decorations. He retired as commander of the Military Sea Transportation Service.

weapons, targets, and strategies, it was no surprise that the Station was quick to climb aboard the oceanographic research bandwagon.

One of the first steps was to find someone to lead the research, and McLean needed look no further than Wofford Heights, a rustic little community overlooking Lake Isabella some 60 miles west of NOTS.

Dr. Pierre Saint-Amand, head of the Research Department's Optics Branch at the time and later head of the Earth and Planetary Sciences Division, related that:

> Bill McLean . . . brought into my office one day an old man, who was then close to 70 years old and wanted to find some work for him, and it turned out the fellow wanted to put up a sort of program in oceanography. So we found out, indeed, that he was a very famous scientist in his own right. He had retired several times before, but wanted something to do, so we took him on. This was Dr. René Engel and he had a doctor's degree from the Sorbonne and another one from Caltech and had a very distinguished career.[41]

In 1958 NOTS set out on a program of what the *Technical Program Review* described as "Deep Sea Research." During that first year, "work was begun on the study of the physicochemical structure of the ocean and its floor. The design of deep sea research vessels and the hydrodynamics of sea-animal locomotion were investigated."

Four working groups were established "for the purpose of conducting research in underwater phenomena and their relationship to major naval problems. . . . Under way or planned were laboratory calibrations of equipment and field measurements of principal oceanic variables such as underwater temperature, sound velocity and propagation, currents, pressures, salinity, light propagation, and other deep sea phenomena."[42]

To carry out this ambitious agenda, the Oceanic Research Division (Code 508) was created in the Research Department in early 1959, and Engel was appointed its head. Saint-Amand said that:

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41 S-120, Dr. Pierre Saint-Amand interview, 27 March 1981, 6. During WWII Engel, who had been working as a consultant in the Philippines, was held as a prisoner of war in the Japanese internment camp at the University of Santo Tomas. His wife-to-be Marcelle, a fashion designer, was interned there as well. After a career as a geologist and professor of geochemistry at Caltech, and as the curator of mineralogy and petrology at the Los Angeles County Museum, Engel retired; he and his wife moved to Wofford Heights where he had once operated a tungsten mine. (Other China Lakers who had been interned at Santo Tomas were Leroy L. Doig, Jr.; Robert T. Merriam; E. Graham Westmorland; Tom and Delores Chapman; and Ray and Jeanne Schreiber.)

42 *Technical Program Review 1958*, 13, 57.

> [The division] flourished for about 10 years until the administrative decision was made to move it to San Diego. This group would send expeditions all around the world; they measured the depth of the ocean and the various trenches, were instrumental in bringing over Piccard's deep-diving submersible, the *Trieste*, and then bringing over Cousteau's diving saucer, and set to work designing small submarines for exploration and search and rescue purposes. This work culminated in the building of several submarines, small ones, some of which have subsequently been used in recovering atom bombs and things that have been dropped into the ocean. That all started here with that work.[43]

Engel's group would also become involved in marine gravimetry, biochemical studies of marine microorganisms, and bioluminescence studies. In 1959 he traveled to Monaco to visit Jacques-Yves Cousteau's Oceanographic Institute and to meet the famous French underwater explorer.

In 1960, at Engel's invitation, Cousteau visited the Station and gave a public talk on underwater exploration. Addressing an overflow audience including "enthusiastic aqua-lungers and skin divers"—McLean's passion for the ocean had caught on with many NOTS employees—Cousteau spoke at length of his underwater projects and showed three films about his research program. He commented, "I've spent 26 years in French navy ships, always disgusted by the surface of the sea."[44]

McLean and Cousteau shared a vision of expanding the human presence under the oceans, and Cousteau would return to NOTS in 1964 with his

Famed underwater explorer Jacques-Yves Cousteau (left) and his son Jean-Michel Cousteau, also an ocean explorer, conferring with Dr. William B. McLean (center).

Photo courtesy of Don McLean

43 S-120, Saint-Amand interview, 6. Several years later Engel would transfer to Saint-Amand's Earth and Planetary Sciences Division as senior research scientist, where he remained until his retirement in 1964. He died in 1980 at the age of 93.

44 *Rocketeer*, 9 Dec 1960, 1.

undersea diving saucer *Soucoupe* for joint diving operations with NOTS submersibles off San Clemente Island.

Marine Mammal Projects

For an "old man," as Saint-Amand referred to him, Engel hit the deck running. Besides his travel to Monaco to lay the groundwork for what would prove to be a world-class submersibles program at the Station and his hiring of hard-science researchers in oceanographic disciplines to staff his division, Engel also initiated a marine mammals program at the Station. Today, marine mammals such as dolphins and sea lions are routinely used by U.S. naval forces for mine detection, swimmer defense, underwater surveillance, and other specialized tasks. In the 1950s, however, their extraordinary skills were showcased primarily at amusement parks, where they performed "aquabatics" for the public.[45]

Engel, McLean, and others saw the value in studying marine mammals for several purposes. One was the animals' extraordinary efficiency in the water. Their speed, diving ability, and underwater detection skills were, to naval underwater weaponeers, enviable. The NOTS researchers hoped to understand how these feats were achieved and perhaps to apply lessons learned to benefit the Navy, for example by developing more effective propulsion methods.

A second reason for studying dolphins was their demonstrated intelligence and their communication capabilities. If they could be taught to work for and with Navy personnel, the potential advantages were obvious. And if their underwater communication techniques could be understood and replicated, there were direct applications in naval undersea warfare.

In the earliest days of the NOTS communication studies, the researchers worked with show animals at Pacific Ocean Park (locally called POP), a nautically themed amusement park on a pier in Santa Monica with the motto "More Fun Than Anything." In 1960 NOTS acquired the Navy's first marine mammal, a female Pacific white-sided dolphin named Notty. She was boarded at Marineland of the Pacific, on the Palos Verdes Peninsula west of Long Beach. Dr. Irving Rehman, a consultant to the Research Department in anatomy and physiology, was the principal investigator in Project Notty. Ralph Penner, from Marineland of the Pacific, was contracted to train the dolphin.

To better understand the ability of the 4-year-old, 200-pound animal to reach speeds approaching 30 miles per hour, researchers applied colored dyes

45 Marine mammals include the cetaceans (whales, porpoises, and dolphins), sirenians (manatees and dugongs), and pinnepeds (seals, sea lions, and walruses). By some definitions, the term also includes the polar bear and the sea otter.

Graduate student (later UCLA professor) Ronald N. Turner with Notty at Marineland, 1960.

to her skin and filmed her with a wide-angle 400-frame-per-second camera. They attached sensors to her with rubber suction cups to measure heartbeat, respiration, and temperature. One theory of the dolphin's ability to move quickly through the water was that the animal used blood vessels under its skin to affect the water layer next to the skin and thereby reduce drag; it was observed that dolphins had a progressively greater number of subcutaneous blood vessels toward the tail end, the areas most susceptible to turbulence and drag.[46]

Hydrodynamics, the interaction of bodies and fluids, was of great interest to the Navy, since a more thorough knowledge of this science could translate into faster and more efficient ships and torpedoes. Dr. William C. Shaw, a NOTS research physicist, told the *Valley Independent*, "If a porpoise's fuel conversion were as inefficient as that of our ships, he would have to eat continuously. You might picture him swimming through a school of herring, and eating all the way."[47]

Notty's observers also studied her ability to communicate. This work had three goals: to develop techniques of voice communication with Notty, to determine whether standard educational techniques worked with her, and to

46 *Rocketeer*, 27 Jan 1961, 1.

47 *IWV Independent and Times-Herald*, 16 April 1959, A5. The term porpoise is sometimes used to distinguish the dolphin mammal (*Delphinidae*) from the dolphin fish (*Coryphaenidae*).

rate her intelligence as compared to human children. A filmed technical report on the project from 1961 commented that "the man selected to conduct the test has 12 years' teaching experience with elementary students."[48]

The researchers found that Notty could be taught to understand simple commands and could differentiate between named objects in her tank—a ball, a ring, a hat, a stick—when the researcher called out their names. After seven 20-minute training sessions, she recognized the words for the objects and achieved a 70-percent correct response by swimming to the named item. The examiner adjudged her learning rate to be equivalent to a normal 6- to 8-year-old child.

In March 1961 Notty, along with Rehman, appeared on KTLA TV's "City by Night." The show, taped at Marineland of the Pacific, discussed NOTS' contributions to oceanic animal research.

As interesting as the marine mammal studies were for their own sake, however, the researchers did not lose sight of the fact that the ultimate goal of the work was to enhance the Navy's military capability. Pasadena torpedo designer Jim Campbell said that:

> We had instrumentation that we hauled in trucks and cars. Listening devices were put in the water and then we could hear what the porpoise was doing acoustically under various situations, such as going to get a fish, or coming up to get scratched under his chin, or whatever. We were trying to relate those signals to what they meant. What's his language? How does he do what he does? How does he know? His eyes aren't very good. How does he find your hand or how does he find a fish? Well, he does it acoustically, and that's exactly what we want to do with a torpedo.[49]

By 1962, the NOTS researchers had gathered enough data on the capability of dolphins and the potential for training them that a new program of study was established. Tom Lang of the Research Department's Hydrodynamics Group was assigned as coordinator for the NOTS Dolphin Research Program, which concentrated on communication, hydrodynamics, and man-animal team operations.[50]The program was a joint effort with the Naval Missile Center,

48 TMP 103, "Project Notty (Dolphin Research) Conducted by U.S. Naval Ordnance Test Station, A Preliminary Study of Dolphin Training by Voice Command," BUWEPS No. 28-61, filmed technical report, 1961.

49 S-174, Campbell interview, 15–16. Notty died in late 1961 and was taken to the University of Southern California for anatomy research by Rehman.

50 Lang, who received his first mechanical engineering degree from Caltech at the age of 19, was a specialist in boundary layer control, hydrofoils, and sea animal locomotion. In 1964 he received a Navy Patent Award for "a new method for stabilizing and controlling torpedoes" (*Rocketeer*, 9 Nov 1964, 6). After moving to NUWC in the 1967 reorganization,

Point Mugu. Lang was in charge of the research program, and NMC was in charge of facilities and animal care. Dr. Sam H. Ridgway, a military veterinarian specializing in marine mammals, was appointed Animal Health Officer and tended to the care and well being of the Navy dolphins, then kept at POP.[51]

In early 1962, with NOTS support, NMC had started construction of a $130,000 Marine Bioscience Facility for the dolphins. It was not finished when the first dolphins arrived at Point Mugu in September 1962 after a flight from Gulfport, Mississippi, so the animals were taken to POP until the facility was ready in spring 1963. At that time the dolphins were transferred to the new facility where in May 1963 they were joined by more dolphins from Marineland of Florida. NMC hired Forrest G. Wood to head its Marine Sciences Division and run the new facility.

At the Bioscience Facility, the mammals were kept in concrete pools and above-ground tanks (one of redwood and three of plastic) adjacent to the facility's offices and laboratories. The dolphins could also be put through their paces in the mile-long Mugu Lagoon adjacent to the facility. As many as a dozen marine mammals at a time were in residence at the facility.

NOTS also contracted in 1963 with Dr. Keller Breland of Animal Behavior Enterprises, Hot Springs, Arkansas, to help Station researchers learn how to train marine mammals. (Breland had worked with Dr. B. F. Skinner in WWII in a program to teach pigeons to guide weapons.) Of Breland, McLean once told an audience:

> It is his experience . . . that negative pressures, or punishment, are useful only for the purpose of making an animal stop doing something. If one wants an animal to try something new or be creative, it is necessary to use reward and approval . . . The contrast between training animals through a series of rewarding situations, and some of the negative processes which go into the training of our children, struck me as highly interesting. Is it possible that in our desire to see everyone educated we are introducing negative pressures which tend to make them resist education? And more important, perhaps

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he headed the new Center's Hydrodynamic Division. Lang was responsible for the Navy's first SWATH (small waterplane-area twin-hull) ship, *Kaimalino*, in the early 1970s. According to Don McLean, Lang visited the McLeans at Lake Chelan and brought his homemade hydrofoil boat, which, at speed, would lift out of the water and ride on barely submerged thin foils, much to the amazement of the Washington locals (S-308, Don McLean interview, 21; see also *Rocketeer,* 16 Nov 1956, 3).

51 Ridgway is a professor in the Department of Pathology, University of California School of Medicine, where he oversees animal care for the U.S. Navy Marine Mammal Program. His book *The Dolphin Doctor: A Pioneering Veterinarian and Scientist Remembers the Extraordinary Dolphin that Inspired His Career* (Ballantine, 1987) discusses the early days of the Navy's marine mammal work.

> we are also only producing a minimum response, rather than establishing an environment which will encourage the creativity needed to branch off into new types of learning and behavior.[52]

Although the dolphin research program was physically relocated to the Mugu site (and retitled "Porpoise Studies" in the annual *Technical Reports*), it remained under the direction of NOTS, and more specifically under the watchful eye of McLean, who had high interest in—and high hopes for—the work. Communication was seen as a key to understanding and working with the dolphins. Robert E. Bailey, a NOTS biologist and animal trainer, began a multiyear project, working with a dolphin named Buzz Buzz, to remotely control dolphins by using acoustic devices that could transmit signals over long distances.

Dr. Dwight W. "Wayne" Batteau, working under contract to NOTS, began work on man-dolphin communication at the Bioscience Facility. He developed an electronic "translator" which converted the unintelligible dolphin sounds—variously described as whistles, clicks, creaks, barks, squeals, yelps, and grunts—into a language pattern. His device translated dolphin sounds into sound patterns more recognizable to humans and vice versa. Human speech could be fed into the machine and converted into dolphin sounds to command specific actions, which, when completed would bring the dolphin a fish reward.[53]

The concept of direct communication with dolphins held great potential for antisubmarine warfare. If these mammals, which could travel at 25 miles per hour and dive to 1,000 feet, could be trained in large numbers to scout out enemy subs and report the intelligence back to their handlers, or relay it to airborne receivers, the U.S. Navy would gain a big advantage in the ASW arena. McLean told the Technical Board in 1964 that NOTS needed to see how far it could push direct communication. "So far," he said, "everything that has been tried has worked, but all that needs to be tried has not been done. The rate of success has been higher than expected."[54]

In another series of experiments by Batteau, two dolphins, Doris and Dash, were placed in separate tanks that were connected with a hydrophone. When the hydrophone was disconnected the dolphins could not communicate. When the hydrophone was activated, however, in the words of the *Rocketeer,* "they

52 Presentation to the Conference on Education for Creativity in Sciences, New York University, June 1963, RM-24, *Collected Speeches of McLean*, 119–120.
53 Dwight W. Batteau and Peter R. Markey, *Man/Dolphin Communication, Final Report, 15 December 1966-12 December 1967*, prepared for NOTS, Contract No. N00123-67-C-1103, Dec 1967, 6.
54 NOTS Technical Board meeting, 1–2 Oct 1964, 20.

'chat' via the man-made communications hookup as might a pair of housewives on the telephone."[55]

By 1964, the joint NOTS-NMC Marine Bioscience Facility at Point Mugu housed 11 dolphins, four sea lions, and one seal. One program at the facility, which NOTS management felt might have application for SEAL and UDT operations, was called Porpoise Tow. Dolphins were trained to wear a harness and allow a swimmer to hang on and trail behind them. The minutes of a 1964 Technical Board meeting contained the cryptic comment, "allows swimmer to control direction by flappers; have not controlled speed."[56]

NOTS nuclear physicist C. Scott Johnson decided to study marine mammals and sharks instead of following a more traditional career path. He used an Atlantic bottlenose dolphin named Salty for his studies of echolocation at the Point Mugu facility. In 1965 he demonstrated for the press Salty's ability to retrieve articles while the dolphin's eyes were covered by rubber suction cups. The dolphin was able to locate and discriminate between various items, some as small as vitamin pills, using what the *Rocketeer* called his "sonic abilities." A series of experiments to measure dolphins' hearing capabilities showed an upper auditory limit of 150 KHz; the upper limit of human hearing is between 15 and 20 KHz.[57]

While the sea mammals' capabilities to exploit acoustic energy had been considered a possibility among marine scientists since the 1940s, Johnson was the first to prove it. His work, according to Tom LaPuzza, longtime spokesman for the Navy Marine Mammal Program, "was the springboard for all the later work with dolphins and whales."[58]

In 1965 NOTS released a half-hour documentary film, "The Dolphins Who Joined the Navy." The film was directed by Otto Lange and narrated onscreen by noted Hollywood actor Glenn Ford, who was also a Navy Reserve lieutenant commander and public affairs officer. Filmed at Point Mugu and aboard ships at sea, the movie explains the rationale for the Marine Mammal Program. As Ford put it early in the film, "The dolphin is an expert on sonar, high-speed water travel, underwater communications, and maybe a number of things that the Navy is quite interested in." Copies were distributed nationally to Naval Reserve units. McLean appeared on Los Angeles TV show to discuss the Navy's marine mammal studies in conjunction with the premiere of the movie.[59]

55 *Rocketeer*, 19 March 1965, 5.

56 NOTS Technical Board meeting, 1–2 Oct 1964, 17.

57 *Rocketeer*, 19 March 1965, 1; *NOTS Tech History 1965*, 2-39.

58 Tom LaPuzza, email to the author, 19 July 2011.

59 With the Glenn Ford movie, the Navy was capitalizing on the public's interest in dolphins that had been inspired by the 1963 movie "Flipper." The heartwarming story of

By 1965 it was clear that dolphin research was not going to revolutionize torpedo propulsion or physical design. NOTS researchers had concluded that "dolphins do not have exceptional hydrodynamic ability" and that their drag coefficient "was about the same as an equivalent torpedo-like body." The top average speed for a Pacific bottlenose dolphin was 16.1 knots for 7 seconds, and sustained speed for a 50-second period was "only 11.8 knots." Top burst speed for a Pacific spotted dolphin was 21.4 knots. (By comparison, a current Mk 46 NATO torpedo runs at about 45 knots.)[60]

The first use of a trained marine mammal in an operational environment occurred in 1965 as part of a Navy-sponsored series of physiological and psychological experiments known as SEALAB, which involved people living and working under the ocean for extended periods using saturation diving techniques in which divers breath gasses under high pressure to saturate their tissues, thus allowing them to spend long periods of time operating at water depths that correspond to the pressure of the gasses. Decompression is required before returning to the surface, although the divers can exit the water into dry containers that are pressurized to the depth at which they are working.

SEALAB I was held for 11 days off the coast of Bermuda in 1964. SEALAB II took place off La Jolla in 1965, and during the program astronaut-aquanaut Scott Carpenter stayed submerged for a then-record 30 days, living in a 57-foot by 12-foot cylindrical metal structure at a depth of 200 feet. "The sea is a tough adversary—much more hostile an environment than space," Carpenter told reporters after his return to the surface.[61]

During SEALAB II, Tuffy, a Bottlenose dolphin that had been trained for 18 months at the Marine Bioscience Facility, assisted the aquanauts. He was taught to deep dive to a fixed point with a "deep diving device," which carried an acoustic buzzer that could be remotely activated.

When Tuffy swam to the device and touched a switch, the buzzer stopped. When he returned to the surface, he was given fish. (In 1969 Tuffy dove to

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a boy and his dolphin, Flipper was followed by a sequel in 1964 and spun off a television show of the same name that ran through 1967.

60 *NOTS Tech History 1965*, 2-39–2-40.

61 *Los Angeles Times*, 29 Sept 1965, 3. The SEALAB II cylinder's 12-foot-diameter end-bell was fabricated using explosive-forming technology pioneered by John Pearson at NOTS. A single sheet of inch-thick steel was placed over a die and 100 pounds of C4 propellant were distributed over the opposite side. Die, plate, and explosives were lowered 30 feet under water where the explosives were detonated. The end-bell was formed in the space of about 0.004 second.

Puka at Coconut Island Lagoon. Original photo, in *Man/Dolphin Communication, Final Report,* 1967, 14, had the caption, "Puka executing the command 'Puka IMUA YUMP OK.'"

990 feet—the maximum length of cable on the deep-diving device—with no indication that he had reached his maximum depth.)[62]

Free swimming (with no tether), Tuffy carried tools, mail, and soft drinks from the surface to the divers in SEALAB II. He even carried plastic bags of fish to the aquanauts, who used them as rewards for his successful performances. He also practiced rescue techniques, carrying rescue lines from the surface to the divers. That phase of the SEALAB II, called Project Arion (after a seventh-century B.C. Greek poet who was supposedly captured by pirates and rescued by a dolphin), set the stage for the Navy's man-dolphin operational programs, which today are under way across the globe.[63]

Like so many other undersea projects that NOTS began in the late 1950s and early 1960s, this tale of man and marine mammal is interrupted. In 1965 the operation and ownership of the facility were transferred to the Naval Missile Center. Bill A. Powell stayed on to coordinate the work of four NOTS researchers—C. Scott Johnson, Robert E. Bailey, Ralph H. Penner, and William E. Evans—who continued to engage in Station-sponsored tests. In 1966, still operating under a NOTS contract, Batteau and his colleague, Peter R. Markey,

62 Forrest G. Wood, *Marine Mammals and Man, The Navy's Porpoises and Sea Lions*, Robert B. Luce, Inc., 1973, 174–175.

63 For a detailed discussion of Tuffy and Project Arion, see Ridgway, *The Dolphin Doctor*.

moved the dolphin communication program to Hawaii, where participants operated from the Oceanic Institute at Makapuu Point and worked with two dolphins (Dash, renamed Maui, and Puka) in Coconut Island Lagoon, a large artificial lagoon in Kaneohe Bay, Oahu.[64]

Results of efforts to develop an interspecies language were initially promising. Unfortunately, Batteau died in a swimming accident in Hawaii in 1967. Efforts by Navy researchers in Hawaii to replicate his early results were unsuccessful, and the Navy abandoned that avenue of research in February 1968.

In the 1967 reorganization that created NWC and NUWC, the NOTS portion of the sea mammal work was transferred to NUWC. There it continued and eventually became what is officially known as the U.S. Navy Marine Mammal Program—not merely a research program, but an integral part of today's operational Navy.[65]

Underwater Camera

Dr. René Engel's early undersea research programs faced daunting challenges. The marine environment is harsh—a fact known to surface navies since time immemorial. However, just as very high altitudes compound the problems faced by air-weapons designers, so do increased depths bring new technical obstacles to the weapons designer. As the depths of undersea operations increased, instrumentation had to be invented or adapted to the deep-ocean environment. Underwater photography posed particular difficulties. "In the deep we have problems in color," Test Department employee George Silberberg told the *Valley Independent* in 1959. "The greens and blues come through, but the reds are filtered out on the way down. They just don't show."[66]

In addition to the color issues there was a problem with "fog": light scattering off microscopic algae, plankton, and mineral dust in the water. Contrast between light and dark also suffered at depth. Silberberg, along with Albert M. Pezzuto, Wesley Lambert, and Carl Kolner, consulted with Station scientists and engineers to develop a set of requirements and specifications for an instrument that would meet NOTS' deep-water photography needs. The Test Department's Opto-Mechanical Branch, under C. John Di Pol developed the actual hardware.[67]

64 Batteau and Markey, *Man/Dolphin Communication,* 5.

65 An overview of the use of marine mammals in the Navy today can be found at the Space and Naval Warfare Command's marine mammal website, *http://www.spawar.navy.mil/sandiego/technology/mammals/*, accessed 17 Dec 2010.

66 *IWV Independent and Times Herald*, 20 Aug 1959, A8.

67 During Di Pol's 30-year career at NOTS and NWC he became a national expert in

The new instrument, known as a Mitchell Bell because it was built around a 35mm Mitchell motion-picture camera, had a hardened steel case, 4 feet long and 3 feet in diameter, in which two custom lenses, spaced 4 inches apart, compensated for the refractive and chromatic aberrations of deep water. The Bell also contained heating and humidity-control equipment and a leak detector and was augmented by an externally mounted pair of NOTS-designed photometers that transmitted real-time information on vertical and horizontal light to project engineers. A dozen Mitchell Bells were installed on towers along a 1,000-foot stretch of the Sea Range. Each unit weighed half a ton out of water but was buoyancy compensated to weigh only 10 pounds in the water. Cables connected the units into a system that, using ambient light, provided high-speed film coverage (originally 1,000 frames per second, later increased to 2,500 frames per second) for underwater weapons testing.

A problem that the new cases did not solve was fish interference. Silberberg described the problem:

> The fish come right up and look into the lens. That kills the photography right now. We can't chase them away with electricity because of the divers working under the water. If we use chemical, it will cloud the water, and that's just as bad as the fish.[68]

Acoustical R&D

An understanding of underwater acoustics was essential for many undersea projects, ranging from weapon homing systems and the detection of threat vessels and weapons to accurate missile-impact measurements on the Sea Range. Since 1953 NOTS had been a partner in the Acoustics of the Medium (ACMED) program, which gathered data on the acoustic signatures of submarines. The REVEL guidance system for the Mk 46 torpedo was an outgrowth of this work.

T&E range management and operation. His career concluded with a three-year stint as head of the Range Department, during which he oversaw a major modernization of the China Lake ranges and was a strong and effective advocate against encroachment threats to the ranges. Di Pol received the L. T. E. Thompson Award in 1975. At his 1981 retirement ceremony, where he was presented the Navy Distinguished Civilian Service Award, he described China Lake as "a mysterious blend of work, play, friends, a place, and a style." *Rocketeer*, 10 April 1981, 4.

68 *Rocketeer*, 14 Aug 1959, 1. Silberberg later adapted television to range data collection and invented (with help from fellow China Lakers Pat Keller and Richard White) a television shutter that is the basis for clear stop-action video. His contributions to optical instrumentation during his 35-year career at China Lake earned him many honors, including the Alan Gordon Memorial Award, shared with Dr. Edwin Land (of Polaroid renown), from the Society of Photo-Optical Instrumentation Engineers.

In the early 1960s, based on earlier work by James M. Snodgrass at Scripps Institution of Oceanography, NOTS oceanographer Jack R. Lovett of the Research Department developed an instrument called the SVTP, for the continuous measurement of sound velocity, temperature, and pressure. The data were transmitted via FM signal to either a surface vessel or a remote recording station. The device was accurate to ±0.01°C for temperature, to ±0.025 meter/second for sound velocity, and to ±1 meter for depth.[69]

Although initially intended primarily for sound-velocity measurements, the device also proved useful for measuring microstructure fluctuations on the sea floor and thus assessing the relative stability of underwater sites. Several permanent SVTP stations were installed around San Clemente Island as part of the survey work for the Rock-Site project.

In 1965, Lovett joined other NOTS and NEL oceanographers on a voyage aboard the USNS *Charles H. Davis* (an oceanography vessel) to waters off Alaska, where they measured the stability of the sea floor a year after a Richter magnitude 9.2 earthquake that devastated parts of that state.[70]

NOTS researchers in 1961 joined with United Research Inc. (Batteau) to study the role of the human pinna (external ear) in localizing and classifying sound. The results indicated that the pinna performed a function in the perceived location of sound that was distinct from the well-known stereophonic effect.

From 1959 through the 1960s, Pasadena conducted extensive acoustical research and development work under a joint program with the Ordnance Research Laboratory at Pennsylvania State University. The program, called Acoustics of the Target (ACTAR), was an outgrowth of ACMED and studied target classification for active acoustic torpedoes as well as the acoustic characteristics of submarine targets.

Recovery Vehicles and Systems

What goes down—particularly when it is an expensive and highly classified developmental torpedo—must come up. Cost and security were not the only considerations in recovering undersea ordnance; test items often contained onboard data-recording systems. (Developmental air weapons generally transmitted onboard data to ground stations by means of telemetry, which does not work undersea.)

The launching of hundreds of torpedoes and other underwater weapons in the waters around San Clemente Island and on the Long Beach Ranges had

69 *NOTS Tech History 1962*, 59.
70 *Rocketeer*, 11 June 1965, 1.

prompted, over the years, substantial investment of time, attention, ingenuity, and new technology for recovering objects from the ocean floor.

On the San Clemente Island ranges, the work of post-test recovery of newer antisubmarine weapons, such as SUBROC—weapons that traveled farther, faster, and deeper than their predecessors—was increasing. Thus when the surge of interest in oceanography loosened purse strings in Washington, NOTS had good justification for pursuing the development of deep-diving equipment.

Deep Jeep

In late summer 1960 McLean solicited proposals from NOTS engineers for a two-man deep submersible that could operate to depths of 2,000 feet. One proposal came from Will Forman, an engineer in Code 55's Production Engineering Branch who had joined NOTS just six months earlier. Forman was assigned the job of developing *Deep Jeep* based on his proposal.

Forman, an ex-naval aviator, holds an engineering degree from University of Portland and has studied oceanography at UCLA. Before joining NOTS he was the main shop engineer for a 200-man manufacturing job shop in Vancouver, Washington. In the introduction to Forman's authoritative book on deep ocean submersibles, Don Walsh—of *Trieste* fame and one of America's leaders in ocean science and engineering—wrote:

> Will was fortunate enough to land in a Navy research laboratory that understood, and exploited, that peculiar breed of non-conformist. His first Navy lab employer was just as unorthodox as his career: the Naval Ordnance Test Station at China Lake in the Southern California Desert. The Laboratory's mission was aircraft weapons. Will's was to build submersibles. And that's what he did.[71]

Early in their project the *Deep Jeep* developers spent a day with Don Walsh and the *Trieste* team in San Diego, a meeting that "saved a lot of lost effort besides contributing to safer operations." For example, based on their experience in the Marianas Trench, the *Trieste* people recommended that the electric lights in the front of the vehicle be placed as far out in front as possible, to minimize backscattering from detritus and biological particles in the water.

Forman requested that top NOTS machinist John W. Ball be assigned to his project. When Forman asked Ball if he had ever machined a submarine before, "He indicated that he had not, but said he was sure he could do it OK. Later, when he saw my name on the fabrication drawings, he asked if I'd ever

71 Walsh, introduction to Forman, *History of American Deep Submersible Operation*, v.

designed a submarine before. I told him I had not, but that I was sure I could—and since I was to be the test pilot, we'd better both do it right!"[72]

Deep Jeep was built around a 5-foot-diameter steel sphere and was propelled and maneuvered by two external outboard electric motors (running in oil) and powered by eight deep-charge golf-cart batteries. The motors could be pivoted simultaneously about the vehicle's lateral axis. By altering the speed and angle of the propellers, the pilot could maneuver *Deep Jeep* much like an underwater helicopter. Pilot and copilot saw the ocean in front of the vessel through individual optical systems that shared a common acrylic view port. The systems corrected for the distortion and enlargement usually characteristic of faceplates and view ports.

Syntactic foam provided *Deep Jeep*'s buoyancy. If a power failure or other emergency required rapid ascent, the batteries could be jettisoned to provide an unpowered rate of ascent of 3 knots. In addition, a floatation ring, normally filled with colored water, could be blown out with compressed air (with the colored water alerting the surface support team) to force the vessel to the surface.

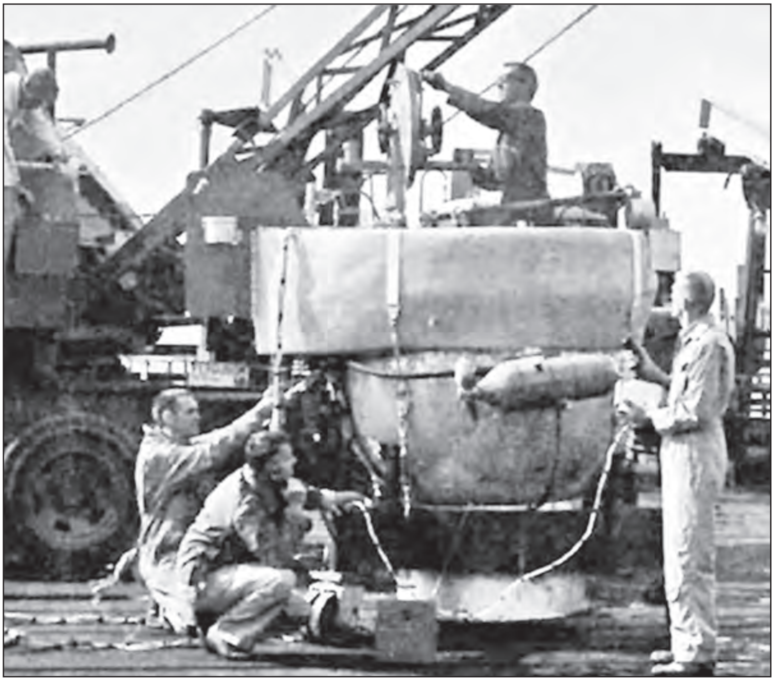
Entrance and egress were through a topside hatch. An air-scrubber system provided acceptable air quality for 4 to 6 hours but could be stretched to 60 hours in an emergency. The developers eventually settled on a normal operating time of 4 hours, "based on aircraft pilot's effectiveness over extended periods of high stress and concentrated effort."[73]

Once fabrication of the pressure hull was completed—the most expensive and time-consuming aspect of *Deep Jeep*'s construction—the hull was pressure tested by Southwest Research Institute. At the highest stress areas, a collapse depth of 5,000 feet was calculated. A proof pressure, equal to a depth of 2,700 feet below the surface, was held for 15 hours, after which cyclic pressure testing was conducted. The hull more than met specifications.

When *Deep Jeep* was launched on 21 January 1964 from Rincon Pier near Santa Barbara, it was the first American-made deep submersible. Forman and his co-pilot, Lieutenant Commander Philip Johnson, made the first manned dive off San Clemente Island, and 22 hours of manned and unmanned dives were logged that year.[74]

In 1964 Cousteau's *Soucoupe* (from *soucoupe plongeante* or diving saucer) visited the Station for a cooperative diving program off San Clemente Island. *Soucoupe* carried a crew of two and could dive to 1,000 feet. *Moray* and *Deep*

72 Forman, *History of American Deep Submersible Operation,* 36–37.
73 *NOTS Tech History 1961*, 202, 33.
74 *NOTS Tech History 1964*, 2-33.



***Deep Jeep* pre-dive testing at Rincon Pier just prior to the deep submersible's first launch, 21 January 1964.**

Jeep spent 2 weeks diving with the French submersible, practicing various underwater-location and -recovery techniques. The exercise was supported by the NOTS Underwater Operations Vessel (YFU-53, ex-LCT 1446), which like *Trygon* (YFU-44), was a converted Navy landing craft.

In a manned dive in April 1965, *Deep Jeep* descended to 2,010 feet, which at that time was the deepest descent made by an American-built submersible. The craft demonstrated the ability to cruise at 2 knots and to maneuver and hover with precision.[75]

CURV

In 1960 NOTS made efforts to increase the effectiveness of San Clemente Island's sea-test range operations by establishing a capability for underwater observation, search, and recovery beyond diver depths. Studies showed that the facility would need a maneuverable, unmanned vehicle controlled from the surface with closed-circuit television.[76]

The Station ordered such a vehicle from Vare Industries, Roselle, New Jersey, that year and set about modifying the vehicle for range operations. (Forman recalled that it was the Vare submersible's $100,000 price tag that prompted

75 *NOTS Tech History 1965*, 1-20.
76 *NOTS Tech History 1960*, 224.

McLean to seek a two-man deep submersible, which he thought—and Forman agreed—could do the underwater recovery task more inexpensively.)[77]

After less than fully successful attempts to modify the new vehicle at China Lake, it was sent to Pasadena where Richard K. Heller, a physicist who had joined UOD in 1956, was assigned as program manager. The Sea Range was flush with money at the time, because of the Polaris program. According to Norm Estabrook, Bud Kunz "kind of detoured a little bit of that money to the side over a period of a few years, into a back room where his technicians were trying to figure out how to make this Vare vehicle work."[78] The goal was an unmanned vessel that could recover torpedoes from the ocean floor.

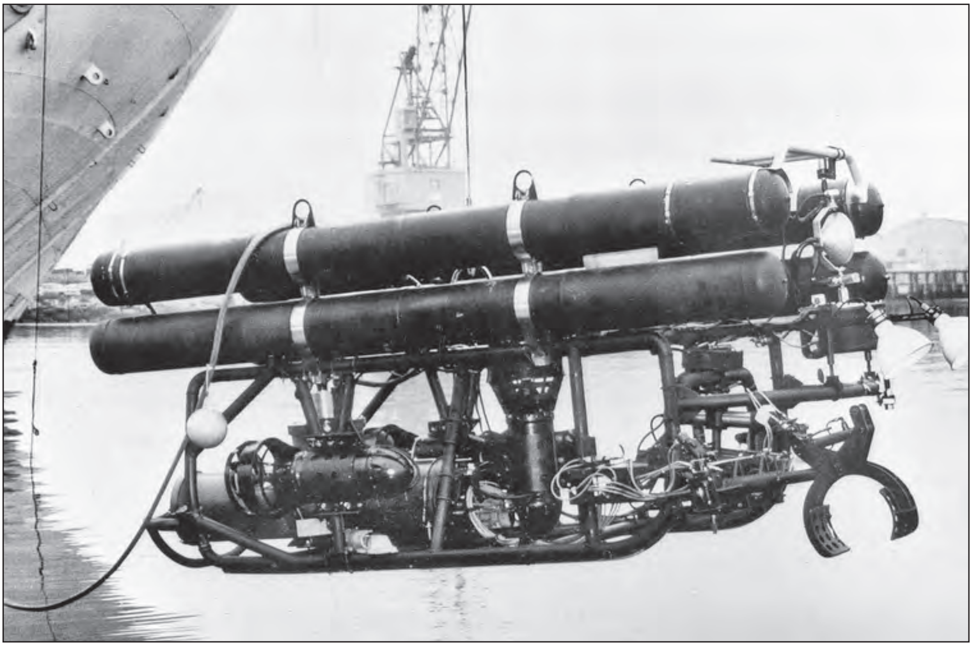
The new vehicle was named the *Cable-Controlled Underwater Recovery Vehicle* (*CURV*). There was nothing curvaceous about *CURV*. A 2008 China Lake technical film described it as "an unlikely accretion of canisters, cables, and claws." One newspaper reported, "It looks like a compact portable machine shop, with small motors, canisters, lights and other equipment slung on a tubular frame and topped by four cigar-shaped pontoons."[79]

CURV was built on an aluminum frame 4 feet high, 4 feet wide, and 11 feet long. The "pontoons" were actually ballast tanks. Three propulsion motors attached to screw propellers (port, starboard, and vertical) allowed movement at the end of the 1½-inch-diameter umbilical cable that connected the submersible to the operators aboard a support vessel on the surface.

From the Army's Transportation Material Command at Rio Vista, California, NOTS procured a 100-foot-long surplus tugboat (LT-2077), which was redesignated YTM-759. With 40 feet of clear deck space, this would be the "mother ship" for *CURV*, carrying the submersible to and from its operation sites, lowering and raising the umbilical cable, and containing the control console from which the submersible was operated. A five-man crew launched, operated, and recovered the submersible.

Hydraulics onboard *CURV* controlled the sonar tilt pan, lights, cameras, and mechanical claw. Fully loaded with instrumentation (acoustics, cameras, lights), recovery buoy, and a mechanical claw for grasping the item to be recovered, *CURV* weighed about one ton. Final acceptance tests were conducted in 1961, and the vehicle was rated to perform to a maximum depth of 2,000 feet.[80]

77 Forman, *History of American Deep Submersible Operation*, 33.
78 S-320, Norm Estabrook interview, 9 Aug 2011, 9.
79 "Pictures of Us II, Episode 6. From Submarines to Satellites: Science and Cetaceans," China Lake, Video Projects, 2008; *Star-News*, Pasadena, 8 April 1966, 3.
80 *NOTS Tech History 1960*, 253.



***CURV* hanging above the water at Long Beach Naval Shipyard, March 1966.**

By using its own propulsion units, *CURV* could bring items weighing up to 200 pounds to the surface. Heavier loads could be brought up by winching in the umbilical cable or by having *CURV* attach lifting lines to the object. In 1964 the vehicle's capabilities were expanded with the installation of a new sonar, acoustic locator, altimeter, depthometer (SLAD) system; the latter three functions were used to locate *CURV* in relationship to its support ship and the ocean bottom.[81]

CURV was operated and maintained by personnel from the Pasadena Annex and was used extensively on NOTS Sea Range. During the Western Electronic Show and Convention (WESCON) in San Francisco, August 1965, more than 35,000 people saw *CURV* demonstrated. "*CURV* has extended man's hand deep into the sea, provided it with intelligent direction and Herculean strength," said a 1965 NOTS technical film. During the last 5 months that year, *CURV* recovered 24 torpedoes from depths to 1,750 feet, with an average in-water time of 3 hours.[82]

A July 1965 *Rocketeer* article extolling the benefits of *CURV* concluded that "with the development of *CURV*, an important milestone has been reached in

81 *NOTS Tech History 1964*, 6-24; *NOTS Tech History 1965*, 6-19.

82 TMP 209, "A Deep Sea Retriever Called CURV," D-A-LHL-67-01, Pasadena Film Branch, Technical Information Department, 1967; *NOTS Tech History 1965*, 6-19.

recovery of research ordinance [*sic*] components. Navy personnel believe that it may be expanded to even broader use in the future." They didn't have to wait long.[83]

Palomares Incident

On 17 January 1966, a U.S. Air Force B-52 bomber collided with a KC-135 tanker during refueling operations over the fishing village of Palomares, Spain. The four crew members of the tanker were killed, as were three members of the B-52's seven-man crew. Four B28R1 hydrogen bombs fell from the sky. Three landed on land. Two of those suffered low-order (non-nuclear) detonations and burned, scattering plutonium widely. One bomb landed in the ocean.

The bombs on land were recovered quickly, but the one that fell in the ocean was not. Several U.S. Navy vessels in the vicinity and an explosive ordnance disposal team searched without success. Five days after the incident the Air Force formally requested Navy assistance in locating and recovering the bomb, and 2 days later the Chief of Naval Operations requested help from all available deep submersible projects. The Navy assembled a fleet of more than 20 ships and vessels under the command of Rear Admiral William S. Guest.[84]

Included in the hastily assembled task force was *Deep Jeep*. Despite the fact that it had been in a nonoperational status for several months, it was prepped and en route to Madrid in a C-130 less than 36 hours after the CNO's message was received.

From Madrid the bright-yellow submersible was flown to Torrejon and thence carried by truck to Cartagena, to await its support ship, USS *Kiowa* (ATS-72), a Fleet tug. Traveling with *Deep Jeep* were Forman, Berryman, Commander Phil Johnson, and a support crew including machinist John Ball and retired Chief Warrant Officer 2 Glenn Minard. Serving as the team's safety officer was Lieutenant Commander James P. Crowder, a Code 40 military assistant.

Deep Jeep was the first of the submersibles to arrive. Later it was joined by *Alvin* (DSV-2), a Navy-owned manned deep-ocean submersible operated by Woods Hole Oceanographic Institution; *Aluminaut*, owned and operated by Reynolds Metal Corp.; and *Cubmarine*, also operated by Woods Hole.

Dr. John Piña Craven, then chief scientist of the Special Projects Office (and later manager of the Navy's Deep Submergence Systems Project), assisted in the search. He recalled that:

83 *Rocketeer*, 9 July 1965, 6.
84 *Rocketeer*, 10 June 1966, 3.

> Admiral Guest had expected a flotilla of advanced submarine search and recovery equipment to be at his disposal. Instead he was confronted with an array of small, uncoordinated research and development teams whose expertise was limited to their individual equipment. The disciplined conduct of a well-organized search was impossible and the equipment needed for search in the high-probability area was slow in arriving. Like the proverbial drunk looking for his car keys under the streetlight because that was the only place he could see, the only coordinated military activities at the site took place nine to twelve miles out at sea where the bomb almost certainly would not be.[85]

Guest's concern was that if the bomb were in international waters, 12 miles off the coast, the Russians could possibly recover it. The U.S.'s Cold War archenemy could save billions of research and development dollars by reverse engineering the U.S. nuclear-weapon technology.

The initial search was fruitless, although portions of the aircraft were recovered by EOD divers near shore. Craven then led a new search pattern based on Bayesian search theory, a mathematically derived pattern based on known probabilities. Still, the bomb was not located, and on 2 March, more than 6 weeks after the incident, the U.S. finally admitted publicly that a hydrogen bomb was missing—a fact that had been widely reported in the press since shortly after the incident (*LIFE* had published in its 25 February issue a three-page special article, "The Case of the Missing H-Bomb," with photographs of the sea-search operation).[86]

On the day of the incident, a local fisherman, Francisco Simo-Orts, had helped rescue the bomber pilots when they parachuted into the sea. He reported to Navy officials that he had seen something else enter the water under a parachute, which he believed to be the upper half of a man's torso with intestines hanging from it. Experts believed it might have been the bomb with one of its two parachutes deployed and the other hanging by the shroud lines. On two occasions Simo-Orts was taken on Navy vessels (once by Forman) to identify the spot where he thought the parachute had entered the water. Both times, using his knowledge of local waters and landmarks, he located the identical point.

As the search continued, targets on the sea floor were identified by sonar and other means, and then assigned for identification. For 2 weeks *Deep Jeep* made dives to the assigned targets. Working from the *Kiowa*, the submersible averaged 4 hours of submerged time per day. Forman recalled that after countless hours searching in, what was for *Deep Jeep*, shallow waters—often 200 feet or

85 Craven, *The Silent War*, 170.
86 Craven's Bayesian theory was also used in the successful search for the remains of the U.S. nuclear submarine USS *Scorpion* (SSN-589) in 1968.

less for a vehicle certified to go to 2,000 feet—the crew members' frustration level was high. Then they were assigned to search in deeper water, as deep as 1,900 feet, but the frustration remained. Said Forman:

> The useless dives went on in hazardous seas in very deep and very shallow water far from the fisherman's spot with dispatches sent every night [by Forman to the Task Force Commander] asking to dive at the "Fisherman's Spot." We were often miles from shore in an experimental submarine in rough seas with no other submersible for rescue in the area.[87]

According to Berryman, he and Forman took it upon themselves to maneuver *Deep Jeep* to a location closer to the one identified by the fisherman. On a steep slope they discovered the start of a long downward track, as if

> . . . a shovel or trench-maker or something, a plow had just plowed a hole in the rocks. The bottom was very heavily sedimented, but also a lot of rocks, so this plow-thing would kind of bounce over these rocks or whatever; it would keep going down deeper. And anyway, we both thought we had it. And so we just followed it right straight down and got as deep as we dared to go, but we never found anything. But we went to the surface and reported our find, and the admiral was furious. I mean, absolutely furious.[88]

Eventually, electrical cables began to be flooded out and then one of the motors became unrepairable, so a dispatch was sent to the Task Force Commander requesting that *Deep Jeep* be detached and sent back to the States. By then *Alvin* had arrived. Forman briefed its chief pilot, Bill Rainnie, and chief scientist Dr. Earl Hays on the situation, left what equipment and spares might help the *Alvin* team, and *Deep Jeep* returned to NOTS.

Later, the search officially shifted to the area in which Simo-Orts reported seeing the object descend. On 17 March *Alvin* located the bomb in about 2,500 feet of water. An attempt was made to secure lines to its parachute, but only one line could be attached. The USNS *Mizar* (T-AGOR-11), an oceanographic research vessel, attempted to retrieve the bomb, but the single line parted, sending the bomb and parachute sliding back down the steep slope. How far, no one knew.

Knowledgeable members of the recovery team were aware of *CURV* and requested that it be sent to the search site. Back at the *CURV* facility at Long Beach, the submersible was modified to reach a depth of 3,000 feet. The modification required splicing an additional 1,000 feet into the cable that

87 Forman, *History of American Deep Submersible Operation*, 49.

88 S-277, Berryman interview, 23. Asked to comment on Berryman's memories, Forman wrote "Al's recollections are close enough." Will Forman, email to the author, 10 July 2009.

carried commands to the *CURV* and sonar and TV signals back from *CURV* to the controllers. Based on interviews with Larry K. Brady, *CURV*'s principal operator, and *CURV* project engineer Robert Pace, science journalist Barbara Moran wrote:

> The splicing was tedious work. The cable contained fifty-five separate conductors, each of which had to be spliced individually. The team [Brady and fellow CURV operator George Stephenson] staggered the splices over about four feet of cable, then covered the wounded area with a gray, pliable goo used for sealing air ducts. . . . Then they wrapped the area in black electrical tape, sealing the splices as well as they could.[89]

After a few test dives on the Sea Range, *CURV* was picked up, loaded on a plane, and on 24 March flown to Spain. Accompanying the submersible were personnel from the Pasadena Annex, the Long Beach Naval Shipyard, and Photo-Sonics, Inc., working under contract to NOTS.

The *CURV* team consisted of Commander Henry H. Schleuning, Jr. (NOTS Pasadena's Technical Officer); Howard Talkington; Bud Kunz; Joe Vetter; Robert Pace; Keith Maxwell; Bill "Shorty" Matill; George Stephenson; Andy Nielson; Larry Brady; and Leslie Campbell. Also assisting in the operation were Joe Berkich, Dick Lapp, Ernie Ostic, Olin Smith, Carl Halsey, and Vernon Hayes.[90]

CURV went to sea aboard *USS Petrel* (ASR-14), which would serve as the submersible's launch and control center. The *Petrel*, under command of Lieutenant Commander Max A. Harrell, carried several 3,000-foot spools of braided 3-inch nylon line that could be fitted to its winches. While *Alvin* frantically searched to find the bomb again, *CURV* practiced: it recovered a dummy bomb the size of the actual weapon at over 1,000 feet and then recovered an acoustic pinger in a barrel at 2,400 feet.

Nine days after the first failed recovery attempt, *Alvin* again located the bomb, this time covered in its parachute at a depth of 2,850 feet. *Alvin* marked the location with acoustic pingers and strobe lights. Onboard *Petrel*, *CURV*'s mechanical claw was replaced with a device that could attach a specially constructed grappling hook with spring-loaded prongs designed to snare the bomb's parachute.

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89 Barbara Moran, *The Day We Lost the H-Bomb*, Ballantine Books, 2009, 195.

90 According to Larry Brady, when the search for the bomb began, Kunz, head of UOD's Systems Operations Division, sent over "every person in his organization including contractors that had anything to do with any recovery operation." Carl Halsey, Brady wrote, "had a reputation as a can-do guy that could think outside the box." Larry Brady, email to the author, 21 Dec 2010.

On 7 April Brady was at *CURV*'s controls, on the deck of *Petrel*. According to an official report on the recovery, "the launching and retrieving operation of *CURV* from the tending ship was extremely hazardous as the *CURV* frame and ballast tanks are pressure structures and susceptible to damage." Brady later responded that "The launch and retrieval WAS NOT extremely hazardous. A gross exaggeration."[91]

On two dives, *CURV* attached a pair of lines to the bomb's parachute with the grapples. On the dive to attach a third line, *CURV*'s horizontal-propulsion propellers became entangled in the parachute. The decision was made to attempt a lift, with the knowledge that if something failed, the bomb might fall back and slide into a 4,200-foot abyss where it would be difficult or impossible to recover. Rear Admiral Guest had transferred to *Petrel* for the recovery operation. According to one participant, the atmosphere in the wardroom of *Petrel* was so tense that Howard Talkington, *CURV*'s on-site manager, fainted from the stress.[92]

More than half a mile above the bomb, *Petrel* began to lift the entire entangled mass: bomb, parachute, and *CURV*, by the lines that *CURV* had placed. The submersible's vertical-propulsion propeller continued to operate on the ascent, as did its TV and still cameras, recording the event.[93]

When the bomb came into view, about 100 feet below the surface, two EOD divers attached wire straps to it so that it would clear the water in a horizontal orientation. The bomb was hoisted onboard the *Petrel* at 0845 and "rendered safe" by the EOD team.

A *LIFE* magazine photo taken shortly after the recovery shows the battered bomb in the foreground with *CURV* and members of the NOTS team behind it. Even the *LIFE* caption writer commented on *CURV*'s distinctive appearance, noting that it was "a far more lethal looking apparatus" than the H-bomb itself.[94]

A week after the successful operation, the *Rocketeer* carried photos of the Pasadena team aboard *Petrel*, as well as a photo of a grinning Kunz (head of

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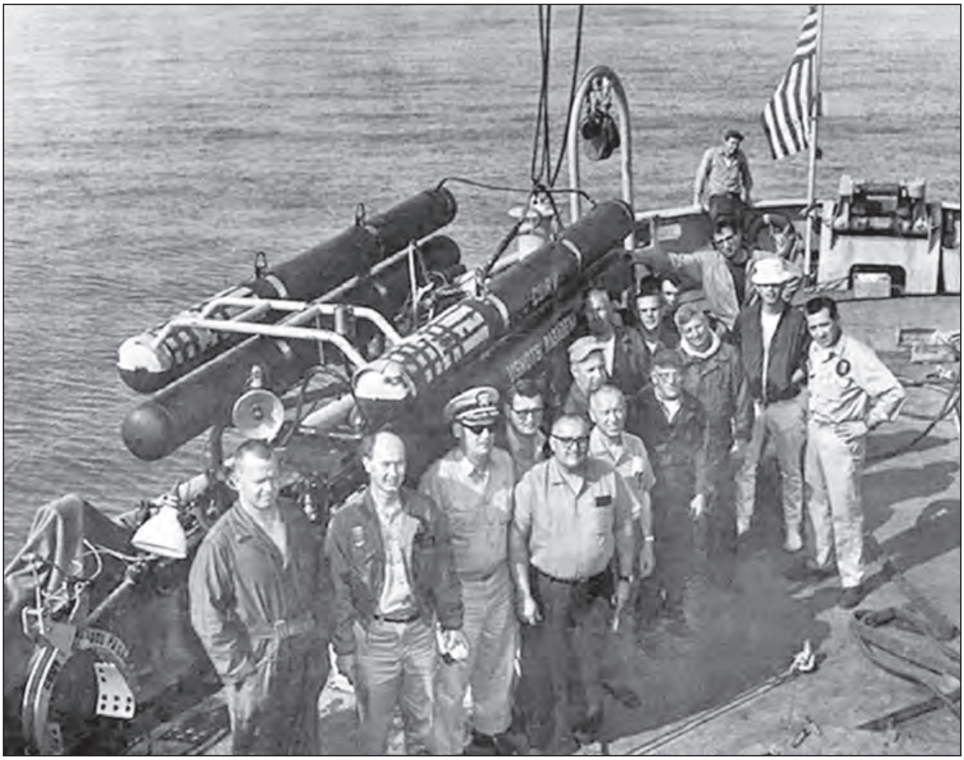
91 *Aircraft SALVOPS Med, Sea Search and Recovery of an Unarmed Nuclear Weapon*, Interim Report, prepared by Summary Group Sponsored by Director, Deep Submergence Systems Project and Supervisor of Salvage, U.S. Navy, 15 July 1966, 86; Larry Brady, email to the author, 12 Jan 2011. Emphasis in the original.

92 Cdr. D. H. Moody, USN (Ret.), "40th Anniversary of Palomares," *Faceplate. The Official Newsletter for the Divers and Salvors of the United States Navy*, Vol. 10, No. 2, Sept 2006, 19, *http://www.supsalv.org/pdf/FACEPLATESept06.pdf*, accessed 6 Dec 2010.

93 "Bomb Recovery," *Current Technical Events Memorandum*, newsletter in memorandum format from Technical Director to Commander, 15 April 1966.

94 *LIFE*, 22 April 1966, 38.



NOTS Pasadena H-bomb recovery team in front of *CURV* aboard *USS Petrel* off Palomares Beach. From left are Leslie Campbell, Howard Talkington, Commander Henry H. Schleuning Jr., Joe Berkich, Bob Pace (with cap), Bud Kunz in front of Berkich, and Joe Vetter. Others are not named. *Rocketeer* photo

UOD's Systems Operations Division) showing his boss, Doug Wilcox, a piece of the recovered bomb's parachute. Before the year's end, Kunz and Talkington would receive the Navy Superior Civilian Service Award for their role in the H-bomb recovery, while Ball, Forman, and Berryman would be awarded the Navy Meritorious Civilian Service Award.[95]

CURV was the first of the Navy's remotely controlled underwater vehicles. Later generations would be used for exploring shipwrecks, recovering aircraft flight recorders, and in at least one case, rescuing the crew of a stranded submersible (the Canadian *Pisces III*, in 1973, in 1,575 feet of water).The Navy's latest version, *CURV-III*, can conduct operations to a depth of 20,000 feet.[96]

95 *Rocketeer*, 15 April 1966, 1, 3; *NWC Tech History 1967, Part 1*, 1-35.
96 Space and Naval Systems Command (SPAWAR) website, *http://www.spawar.navy.mil/robots/undersea/CURV/CURV.html,* accessed 6 Dec 2010; Roger Chapman, *No Time on Our Side*, W. W. Norton & Co., New York, 1975, 62.

Perhaps more significantly, *CURV* demonstrated the feasibility of using a remotely operated vehicle to do practical work in the deep ocean. It laid the groundwork for industrial-grade underwater remotely operated vehicles that today are used in applications ranging from oil exploration and extraction to underwater-communications-cable maintenance.

Two months after the H-bomb recovery, *Deep Jeep* was transferred to Scripps Institution of Oceanography at La Jolla on indefinite loan through an ONR contract. Previously, Scripps had leased Cousteau's diving saucer for marine-life observation and data collection off the continental shelf and in a submarine canyon west of La Jolla. According to Dr. Fred N. Spiess, director of Scripps' Marine Physical Laboratory, *Deep Jeep* had twice the speed of the saucer and could be operated at a fraction of the cost. As Forman told the *Rocketeer*, "NOTS has reaped all the development information it was looking for in *Deep Jeep*, and Scripps will now be able to get a great deal of use from it."[97]

Buoyancy Bag

Deep Jeep and *CURV* were not the only NOTS systems at the Palomares H-bomb rescue site. Since 1964, engineers in the Propulsion Development Department had been working on the Deep Submergence Buoyant Recovery Program to develop a hydrazine-powered buoyant recovery system—basically a flexible bag with a gas generator that could be attached to an object at depth (a spent torpedo, for example) and, when filled with gas, would carry it to the surface.

Jay Witcher managed the program from the Engineering Applications Branch of the Liquid Propulsion Division. His team included engineer David Oliver, James O. Dake (project engineer for the hydrazine generator), and technician Bert Andreasen.

Gas generation was based on an easily controlled catalytic decomposition of hydrazine-based fuels. In addition to deep ocean recovery (to a depth of 20,000 feet, the developers believed), the gas generator showed promise for propelling deep submersibles or swimmers, blowing emergency ballast in submersibles, and powering underwater tools. [98]

In a December 1964 operation conducted with *Soucoupe* off San Clemente Island, *Soucoupe* descended to 1,000 feet with the NOTS device and attached

97 *Rocketeer*, 10 June 1966, 1, 3. When the first Michelson Laboratories Awards were presented in May 1967, Forman was one of eight NOTS employees to be honored with the title of Fellow in Ordnance Science.
98 *Rocketeer*, 19 Aug 1966, 1.

it to a 200-pound torpedo. When activated, the buoyancy system lifted the torpedo to the surface. The system also demonstrated its capabilities with a test-recovery of *CURV* on the Sea Range from 2,100 feet, as well as with a lift of 10 tons from a submerged depth of 40 feet.

After the hydrogen bomb was lost at Palomares, Witcher's program moved into high gear. In a demonstration for the Navy's Supervisor of Salvage, the system was used to lift objects weighing 4,000 pounds from 2,800 feet below the surface. Witcher and Oliver were then flown with the recovery equipment to Spain; however, with *CURV*'s success in recovering the bomb, the buoyancy system was not required.

Cycloidal Propellers

In 1965 Leonard Seeley, a hydrodynamicist in the Astrometrics Division, demonstrated a remote-controlled ¼-scale model of a submersible. The demonstration was held at the Station swimming pool, the usual first stop for concept testing of any underwater vehicle designs, and was attended by Captain John Hardy, NOTS commander; McLean; Knemeyer, then the Assistant Technical Director for Development, Weapons Systems; Dr. Gilbert Plain, associate head of the Research Department; and Saint-Amand, head of the Earth and Planetary Sciences Division.

The model submersible had two distinct features. One was its shape, an oblate spheroid. It looked like two soup bowls fastened bottoms outward, oriented vertically. The other feature was the means of locomotion: a pair of cycloidal propellers.

Each propeller consisted of a rotating disk from which extended a group of parallel winglike blades. The blades provided propulsion by changing pitch. The blades moving backwards pushed flatwise against the water while those on the opposite side of the disk moved edgewise to the water. By varying the pitch on the blades, thrust could be changed through a full 360 degrees, so stops, reverses, and quick turns could be accomplished without changing the speed or direction of the drive shaft that turned the disk (and without requiring a rudder).

Cycloidal propellers, also called cycloidal thrusters, had been around at that time for more than 20 years, but their only application was in a few river tugs (although a variation had been used in German minesweepers during WWII). Seeley's interest stemmed from the fact that he had studied under the inventor of the cycloidal propeller, Dr. Frederick K. Kirsten, at the University of Washington.

Speaking of the cycloidal propeller, Seeley's division head, Don Moore, called it "a unique and highly useful device which we hope to use in a full-scale submersible under development in the Department," and Knemeyer commented, "It could have important applications in submersibles eventually."[99]

Hikino

In 1963 H. A. Perry at NOL lamented that "after millennia of time, humanity is still crowded up on a relatively narrow beach, while over two thirds of the Earth's terrain has never even been seen."

Perry calculated that a transparent vitreous-silicate spherical hull "offers a potential for an all-depth capability, while metal hulls of the same weight do not." Of a general class of transparent materials, he wrote:

> The bridgmanites are immensely strong in compression and shear . . . They are lightweight, transparent . . . They cannot be oxidized further and can be inert and insoluble. They are quite impervious to gasses and liquid. They can be very resistant to salt solution, enzymes and other constituents of sea water. They offer very little nutrient, if any, for the growth of marine organisms. They are hard and impervious to marine borers.[100]

The following year, Perry and Craven conducted a series of conceptually simple tests of the strength of glass spheres. Test spheres were lowered into the ocean from the USNS *James M. Gilliss* (T-AGOR-4) above the Puerto Rico Trench off San Juan. One-pound charges of the explosive Pentolite were set off at fixed distances from the 10-inch glass spheres. At a 300-foot depth, the explosion cracked the sphere from a distance of 18 feet. At 7,200 feet the explosion did not crack the sphere until the distance between the two was reduced to 5½ feet—a concussive force of greater than 13,000 pounds per square inch. The sphere was stronger at the lower depth.[101]

McLean, fascinated with the concept of submersibles based on transparent spheres, began to experiment with various materials including glass and acrylics. Will Forman credited Tom Lang with being "the first one to come up with a reasonable proposal for an acrylic hulled deep submersible at China Lake." Called the Utility Submarine, it featured a transparent sphere for the operators and pivotal mounting of the entire outer structure.[102]

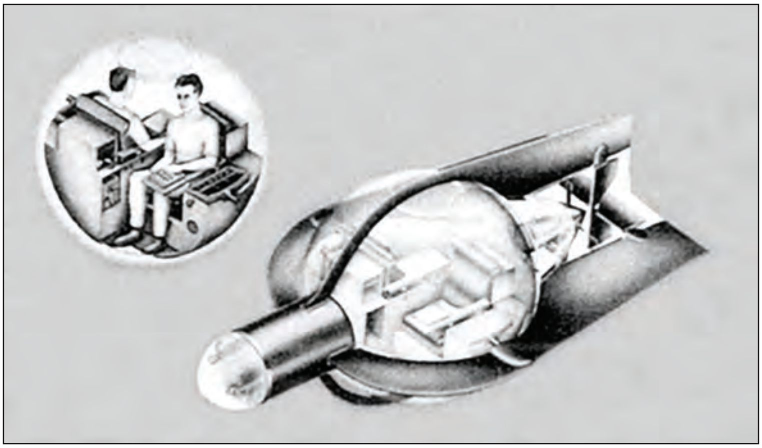
99 *Rocketeer*, 19 Nov 1965, 1.

100 H. A. Perry, *Feasibility of Transparent Hulls for Deep-Running Vehicles*, American Society of Mechanical Engineers (ASME) Paper No. 63-WA-219, 1963, 8.

101 *Rocketeer*, 24 June 1966, 1.

102 Will Forman, *History of American Deep Submersible Operations, 1775–1995*, Best Publishing Co., 1999, 207; *NOTS Tech History 1961*, 16. The Utility Submarine evolved

Artist's concept of the Utility Submarine.



Of those early days of experimentation, Berryman remembered:

> They had this plastic sphere, which was good size, about maybe 4 or 5 feet in diameter. They had some big wide straps that went around this thing to the bottom, and then put it in the [Station] swimming pool. . . . and pulled this thing down underwater, right down to the bottom. . . . many of us were in the pool with scuba gear. . . and one of the people went over and put their finger on that surface, that plastic surface. It looked like he just touched it, but when he touched, it started moving, and moving and moving and pow! The whole thing just imploded! And this was perfectly clear stuff, and we had to clean that up afterwards, the little tiny pieces all over the pool.
>
> [McLean] had a lot of experiments going to where they had glass hemispheres, from relatively small to substantially bigger, that they would hook together so that they were quite well sealed, and then they'd drop them down into the ocean to extreme depths, with strain gauges on the glass there, and then bring them back up and see what was happening. And the results were somewhat astounding. The glass was just—the fact that it was being compressed all the way around, nice and even—just made it stronger.[103]

When Pierre Saint-Amand was being interviewed in 1981, he pointed out an object in his office:

> That little glass sphere over there was part of one of our experiments; that was taken down to the bottom of the Milwaukee Deep several times and released and found its way back up again and didn't crush. It has fresh water inside of it now that got forced through the pores in the glass.[104]

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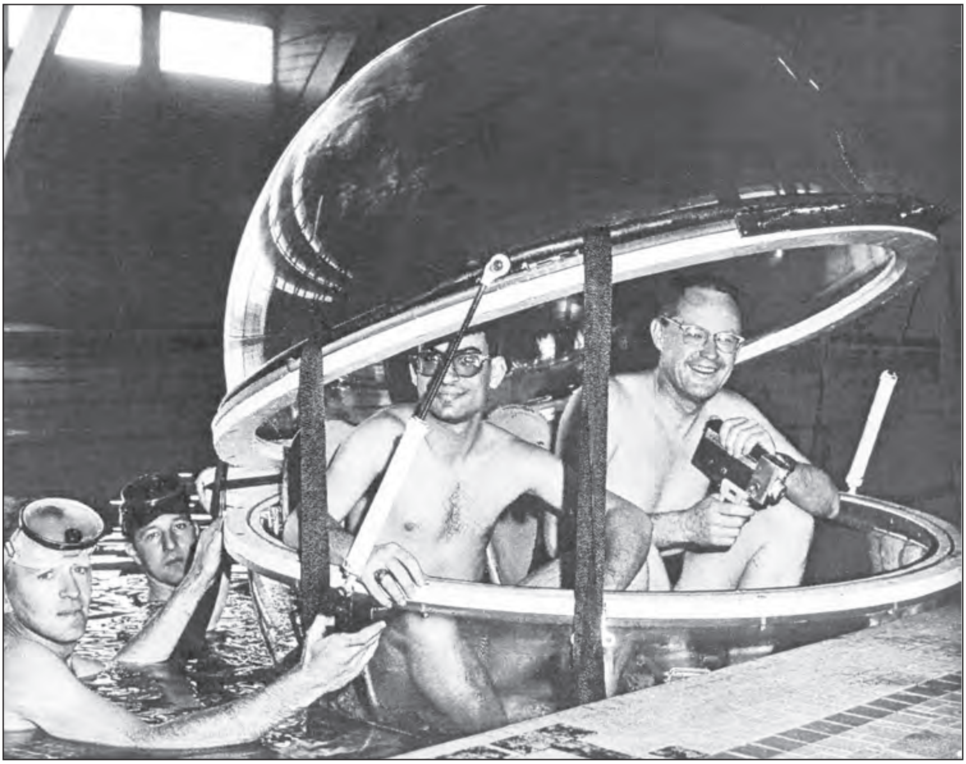
into Kumukahi (Hawaiian for "delectable little fish"), which appeared in a *LIFE* magazine story on undersea exploration. According to the story, "The sub can move at 3 knots and turn like a top." "A New Wave in Aqua Gear," *LIFE*, 6 March 1970, 72.

103 S-277, Berryman interview,, 13.

104 S-120, Saint-Amand interview, 7.



Bill McLean (with camera) and Ron Cohn, a Junior Professional mechanical engineer, ready for a plastic-sphere test in the deep end of the Station pool, June 1966. Steadying the sphere are (from left) Bob Flood, project technician, and Larry McKinley, project engineer.

McLean's interest in glass was based on more than its innate strength under pressure. He believed that opening the ocean up to commerce and recreation would require full visibility for the undersea operators. As he said:

> The number of people who would submit to a dark, minimum-volume "can" is considerably smaller than the number of people who would like to dive enclosed in a transparent hull, and therefore the market for a transparent vehicle will be much greater than for a non-transparent one with windows. Also, the ability to see all around you allows you to estimate your relative motions to avoid danger . . . From a safety viewpoint, the ability to see out from all directions from an undersea vehicle is very important. I think the transparent hull is essential to the acceptance of undersea operations by the general public.[105]

In the mid 1960s McLean began the development of a submersible that consisted of a glass sphere and little else. The *Rocketeer* observed that McLean's "glass bubble concept for the protective and life supporting enclosure for a

105 McLean interview, "A Bedrock View," April 1969, 33.

submarine is a radical departure from the heavy, multi-jointed, and view-restricting metal submersibles that have carried the burden of search and research so far."[106]

McLean said in 1965 that he would use the $10,000 that accompanied his Rockefeller award to pursue his own ocean research. Development of a transparent-sphere-based submersible was just the opportunity he wanted.

The *Rocketeer* article explained that:

> Actually, two separate projects are being conducted here to build twin-hulled, catamaran-type submersibles using the glass sphere cockpit. One is being undertaken by Dr. McLean on his own time and with his own private funds, which he envisions as an eventual private pleasure craft. It would be sold commercially and would serve to introduce to a wide section of the public the absorbing interests to be found beneath the sea's surface.[107]

The argument could be made that, privately funded or not, a military laboratory had no business designing a private pleasure craft (the government version was described as a vehicle for "researchers" and "aquanaut-scientists"). However, the pleasure craft was merely a step in McLean's larger plan to develop the oceans for human commerce, industry, habitation, and recreation. As he told a symposium audience in 1966:

> Last year the citizens of the United States spent something between $2 and $4 billion dollars for recreational use of the ocean. We also have in this country, according to figures from *Skin Diver Magazine*, 3 million people interested in diving and about 1 million active divers who purchased skin diving equipment for the purpose of exploring the ocean to the first 100 meters of depth.[108]

He elaborated on that view in 1969, telling an interviewer that "it seems to me that the primary commercial hope for undersea exploration lies in the recreational area. This is the only source of funds of sufficient magnitude to really get undersea operations going." He also expressed his skepticism of too much "government" in the exploitation of the ocean.

> The urgent requirement . . . is the design of a low-cost submersible that can be operated in large quantities by large numbers of people. My worry relative to this ever being accomplished primarily concerns the regulatory area, rather than the technical. I can see the government establishing regulations relative to the operation of undersea vehicles which will prevent the construction of

106 *Rocketeer*, 24 June 1966, 1.

107 Ibid.

108 "Future Exploration of the Ocean," Symposium on Modern Developments in Marine Sciences, American Institute of Aeronautics & Astronautics, RM-24, *Collected Speeches of McLean*, 210.

> anything that has widespread application, and establishing requirements for design of civil vehicles that can't be met simply.[109]

Hikino was an extension of the work done in the Utility Submarine project. Officially, the purpose of the *Hikino* prototype was "to furnish information and incentive to develop a submersible to fill an existing need for an inexpensive, unlimited depth, high visibility, safe, self-sufficient vehicle for research and military applications that individuals from governmental agencies as well as college professors could afford to operate."[110]

On the government side of the *Hikino* project, Don Moore, head of the Astrometrics Division, took the lead, with assistance from Larry McKinley as project engineer and Elmer Slates. Mike Sanitate's Structures and Materials Branch provided engineering and technical support.

As with every project of consequence at NOTS, the core team reached out, without regard for divisional and departmental lines, to tap the expertise of interested individuals across the Station. McLean viewed formal organizational groupings as necessary evils. "McLean's approach," Bud Sewell once observed, "was never to compartmentalize people or projects."[111]

To some, this lack of respect for structured organization was anathema. But others saw it as organizational brilliance. According to Tom Amlie:

> [McLean] had the absolute right of transfer. If you were an engineer working somewhere and someone else on the base offered you a job, you could transfer no matter what your boss said, no matter what anyone said, you could transfer. What this meant was that branch heads and supervisors tended to try to treat their people well or otherwise they would lose them. It was a very simple thing, but it was genius because it turned out that people were treated very well and good people got recognized because everybody was trying to steal everybody else's people. It worked fine. It really did. He recognized very early that there had to be competition, so he would never allow a single department or group to be assigned the sole responsibility for something because he knew that they would get lazy.[112]

Hikino's pilot and passenger sat in a 56-inch-diameter sphere fabricated of two hemispheres hinged at the aft end. (For the prototype version, called the "mock-up" in the NOTS literature, acrylic was used, although by mid

109 McLean interview, "A Bedrock View," 32, 34.

110 E. F. Slates, "Hikino Mock-Up, an Operational Two-Man, Catamaran Submersible," Weapons Development Department, China Lake, March 1968, Technical Note 404-65-68, 8. The term "Hiki No" is an interjection in the Hawaiian language meaning "it can be done" or "can do."

111 S-106, Sewell interview, 7.

112 S-109, Amlie interview, 4.

1966 Corning Glass Works had delivered the first 1½-inch-thick glass sphere.) Propulsion and steering were achieved by means of a pair of belt-driven cycloidal propellers, similar to those that Seeley had tested on his ¼-size submersible model in 1965, mounted forward of the sphere.

The Weapons Development Department's Elmer Slates, who developed *Hikino*'s propeller system, was awarded a patent for his propeller in 1972. The propellers were driven by two 1.4-horsepower DC motors powered by 20 6-volt lead-acid batteries (installed on tracks, so that with an electric screw motor they could be used to fine tune the vessels trim fore and aft).[113]

Onboard air was purified with an oxygen and CO^2 scrubber system, and the air in the sphere was good for two people for 24 hours. To maintain the integrity of the two perfectly mated hemispheres that formed the passenger compartment, all the support equipment and batteries would be contained in the hulls. The sphere would contain only the passengers, the air filtration system, and the controls. McLean proposed an ingenious system by which control signals generated inside the sphere would be transmitted through the transparent sphere material to photoelectric-cell receivers in the hull. As a safety precaution, the sphere could be released from the hull in an emergency and would rise to the surface by its own buoyancy.

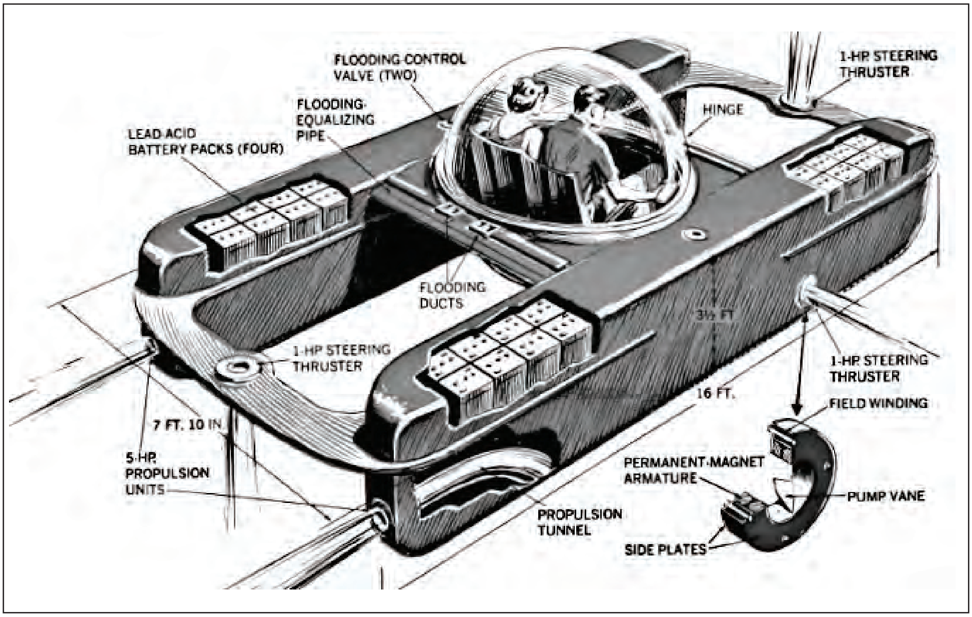
One of the design constraints, probably proposed by McLean, was that "the vehicle was to be highway trailerable and capable of being launched from a trailer by 2 men," so *Hikino* was 16 feet long, 8 feet wide, and 5½ feet high, with a dry weight of 5,700 pounds. The sphere was mounted between two catamaran-type hulls that were partially flooded to dive. With 1,750 pounds of ballast, the vessel was neutrally buoyant at launch. Cruise speed was 0.9 knot, although *Hikino* could move at a maximum speed of 3.5 knots for 45 minutes.[114]

A 1966 *Popular Science* cover story on *Hikino* contained a series of photos of McLean testing the acrylic sphere in the Station pool. Also accompanying the article were two drawings by illustrator Ray Pioch. In these the sporty-looking craft is piloted by a gentleman in a short-sleeved shirt accompanied by a woman in a sundress and high heels. In the cover artwork by Pierre Mion, the man is shirtless and the woman wears a halter top as they cruise beneath the sea.

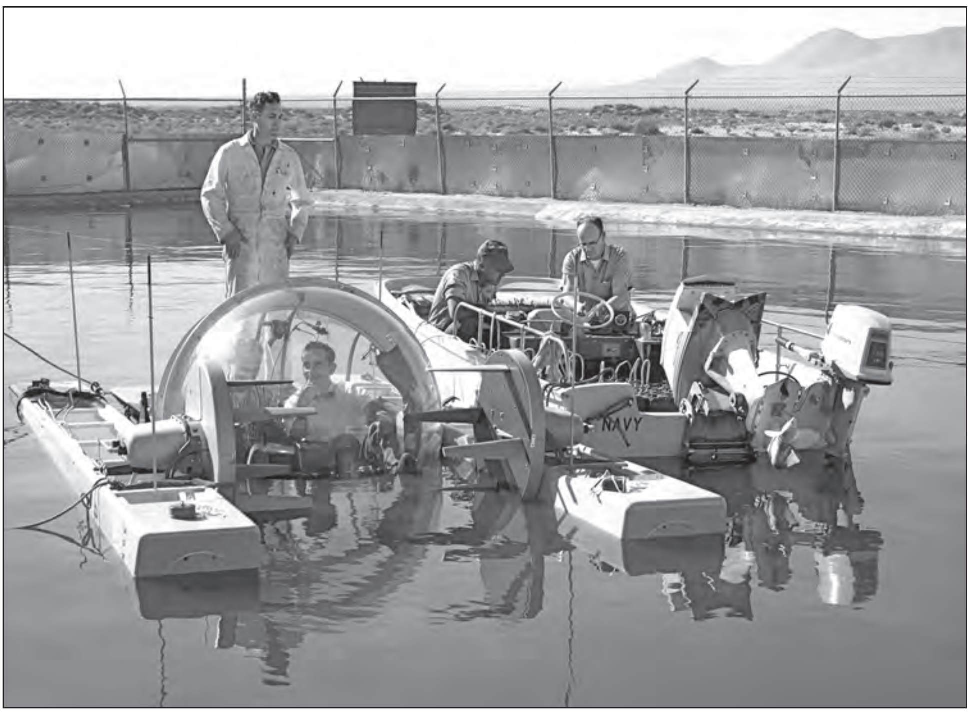
"And what a craft it will be!" enthused the *Popular Science* writer. "Because it will be made of glass, it will be the safest, most economical submersible

113 U.S. Patent No. 3,639,077, "Belt-Driven Pi-Pitch Cycloidal Propeller," 1 Feb 1972.

114 R. Frank Busby, *Manned Submersibles*, Office of the Oceanographer of the Navy, 1976, 139.



Artist's concept of *Hikino*, *Popular Science*, July 1966



***Hikino* test in SNORT Reservoir, 1967.**

(under $10,000) ever constructed. Transparent, it will offer its two occupants the most spectacular, fascinating panorama of the ocean ever seen."[115]

Bowlus Engineering Corp. was awarded a $15,000 contract to fabricate the *Hikino* mock-up in June 1966. The craft was delivered in December 1966, and testing began in January 1967 at the SNORT Reservoir.

Maximum visibility of 1 to 2 feet in the reservoir—even after draining it, cleaning it, and chemically treating and filtering the water—hampered testing. Slates reported that "dropped tools, divers' safety, and visual feedback are problems aggravated by or visibility. Hover maneuvers are done by the 'seat of the pants' and the operator knowledge and skill is hindered by lack of visual feedback."

In September 1967 *Hikino* was towed on its trailer to Shaver Lake, about 50 miles from Fresno, California. Visibility in the lake was 18 to 24 feet. *Hikino* used its cycloidal propellers to vary the depth of operation and, when the craft hovered near the bottom, the downwash caused large clouds of sediment to cloud the water. "This points out the need of a good variable buoyancy control on submersibles," Slates noted.

The acrylic sphere, which furnished about 3,160 pounds of buoyancy to the craft, worked perfectly. It had been tested to a 30-foot-depth at Morris Dam, but during the test series at Shaver Lake it was never taken below 20 feet. The team discovered that while the craft was floating on the surface, the pilot became hot (or in the *Hikino* report's technical lingo, "Adverse personnel comfort was also noted when the sun's rays penetrated the sphere").

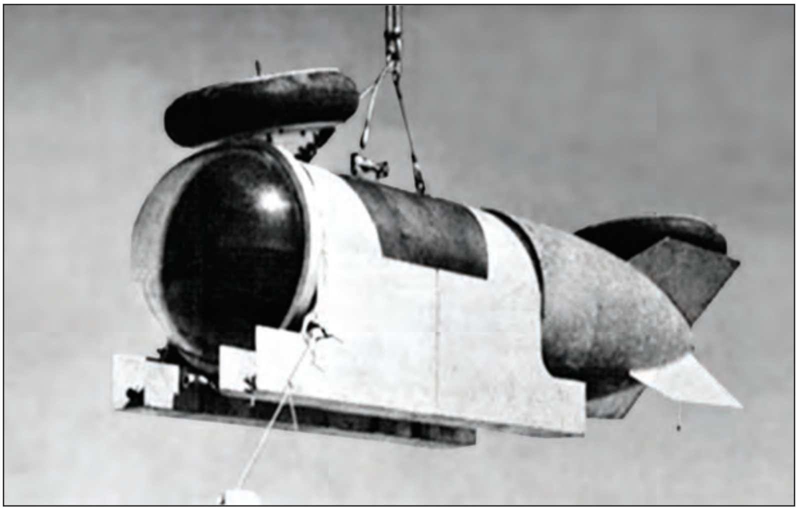
Aside from one motor burning out, the cycloidal propellers performed well. Each propeller had four 15-inch detachable blades of plastic over an aluminum core and was powered by a 2¼-horsepower electric motor. The two propellers moved the craft through the water at 3.5 knots (a brisk walking speed). Slates' report observed that "it is possible to make a submersible go fore and aft, sideways, up and down and to turn on axis with only 2 propellers."[116]

As for the glass version, Ernie Cozzens, who headed the Engineering Department's Weapons Systems Office, recalled "we actually got two glass spheres made in hemispheres, and our problem was to mount little electric motors to them, drive it to make it steer up and down, then pumps for buoyancy, lights, and all kinds of stuff. It was kind of a fun project."[117]

115 W. Stevenson Bacon, "Low-Cost Glass-Bubble Sub for Undersea Adventure," *Popular Science*, July 1966, 61–64.

116 Slates, "Hikino Mock-Up," Tech Note 404-65-68,25, 22, 13.

117 S-126, Cozzens interview, 3.



***Deep View* ready to enter SNORT Reservoir, January 1968.**

Glass hemispheres would be used in *Deep View*, the development of which began at China Lake in late 1966. A *LIFE* magazine article about McLean in 1967 showed him standing by *Deep View*, with its 44-inch-diameter glass viewing hemisphere. The writer characterized it as "a low-budget counterpart" of the 56-inch acrylic sphere used for *Hikino*.[118]

Deep View was another of Will Forman's babies. It was the first vessel to use a combined glass and steel pressure hull designed for operation at depths of 5,000 feet. When cracking problems at the interface between the glass hemisphere and the steel hull developed, Forman again sought out a craftsman with the specialized knowledge to translate the engineer's design solution—changing the flat-edge seal between glass and metal to one with a turned radius—into a testable real-world solution. According to Forman:

> *Deep View* is an example of the capabilities of the Engineering Department. . . .The machinist who ground the round edge on our glass hemispheres, Jack Herbstreit, had to develop his own tools for the job. He got his own grinder motor and wheels, developed his own grinding wheel and work fixture, revolving speed and feeds, and then did a beautiful job.[119]

After the reorganization of the Navy laboratories in July 1967, the *Hikino* project went to NUWC. It is unclear what ultimately became of the *Hikino* prototype. Cozzens' recollection was that "it was used and tested off San

118 "The Navy's Top Handyman," *LIFE*, 6 Jan 1967, 32. Forman reported that the hemispheres were "available ready-made 44-inch-diameter Corning hemispheres that were left over from the AT&T transatlantic cable crossing project to buoy the cables up where they crossed over canyons." Forman, *History of American Deep Submersible Operations*, 252.
119 *Rocketeer*, 12 Jan 1968, 6.

Clemente, but as far as I know it never went beyond that." In April 1968 NBC newsman Frank McGee was filmed in it at San Diego for the documentary "Man and the Sea."

Five months later *Hikino* was in Hawaii, on display to the public at the September opening of NUWC's Hawaii laboratory. The *Seascope* photo caption reads, "Here, visitors look over, around, and through *Hikino* pressure hull, to be made of glass, the strongest material in compression."[120]

As for *Deep View*, development continued at NUWC. The craft was launched at Point Loma in December 1972, with Will Forman's 18-year-old daughter, Susan, doing the christening honors. It was certified as a submersible during 2 weeks of testing on Catalina Island and was later used in Hawaii in connection with a classified marine mammal program related to the Vietnam War.[121]

Rock-Site

In a 1965 NOTS technical movie produced at Pasadena, the narrator explained how submersibles offered the tools people would need to operate freely under the sea:

> Ideally, man would like to do on the seafloor what he does on land; tarry in some selected locale, or move rapidly to some distant area of interest. Submersibles like *Deep Jeep* and *Soucoupe* will enable man to familiarize himself with a particular area, while submersibles like *Moray* will provide him a long-range exploration capability.[122]

Add to that mix *CURV*, which could do the heavy lifting, and about the only other thing needed for exploiting the undersea world was a place to live down there on the ocean floor. And so there was Project Rock-Site.[123]

"The ocean is large, covering 71 percent of the planet's surface." With this basic fact of geography, McLean opened a slide-show presentation to the American Institute of Aeronautics & Astronautics in Los Angeles on 21 April 1966. He added a less widely known fact:

> Most of our interest will lie either at depths less than 300 meters [about 1,000 feet], or at a depth lying near 6 kilometers [3.7 miles]. The depths less than

120 *Seascope*, 27 Sept 1968, 2.

121 Forman, *History of American Deep Submersible Operations*, 257.

122 TMP 186, "Footprints in the Sea," D-A-LHL-65-05, Film Branch Pasadena, Technical Information Department, 1965.

123 The project is variously referred to as Rock-Site, Rocksite, and Rock Site. This volume follows the spelling used in Dr. Carl Austin's technical publications.

> 300 meters include all of the continental shelves. Most of the ocean depth is near 6 kilometers and only a few trenches reach depths greater than this value.

He then pointed out to his audience that the bathyscaphe *Trieste*, had "demonstrated the feasibility of exploring at any depth."[124]

For McLean, feasibility demonstrations carried a lot of weight. Once the feasibility of a concept was demonstrated (even such a far-fetched concept as guiding a missile to intercept an airborne target, using only the infrared signature of the aircraft as information) then the rest—development, refinement, putting the concept to productive use—was merely a matter of engineering. So if *Trieste* could take people safely to the deepest part of the ocean, the ocean was, in essence, conquered. Rock-Site was just the next step in implementing long-term exploration and exploitation.

Rock-Site was the brainchild of Dr. Carl F. Austin, who in 1966 set out the steps necessary "to establish permanent manned installations within the sea floor that do not have any air, umbilical, or other connection with the land or water surface, yet maintain a normal one-atmosphere environment within." Moreover, he contended, this technical marvel could be accomplished "using off-the-shelf petroleum, mining, submarine, and nuclear equipment."[125]

Austin emphasized that his proposal—save perhaps for the nuclear part—was not new. Citing technical papers dating back to 1875, he chronicled the history of undersea industrial operations and pointed out that the technology for tunneling under the ocean floor was widely used in mining. (In fact, the earliest undersea mines were established in England, beneath the Firth of Forth, in the early 1600s.) He noted Dominion Coal's undersea workings adjacent to Cape Breton in Canada:

> The Dominion Coal operations are a complex of many consolidated undersea mines ranging in depth from 200 to 2,700 feet below the sea floor, with a water cover of 60 to 100 feet. These mines span an area of approximately 75 square miles and presently employ some 4,100 men in the undersea workings. . . . the best examples of mine floodings and, in particular, of mine operations within zones of high water pressures are to be found on land.[126]

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124 McLean, "Future Exploration of the Ocean," 209–210.

125 C. F. Austin, *Manned Undersea Structures—the Rock-Site Concept*, NOTS TP 4162, Oct 1966. Austin was an internationally recognized expert in geology and mining who received his PhD from the University of Utah in 1958 and came to NOTS in 1961. He was the person most responsible for the development of China Lake's geothermal capabilities, which led to NWC being assigned the lead role for all Navy geothermal efforts. He retired in 1991 and died in September 2011.

126 One photograph in the report shows a pressure lock and bulkhead assembly used in a mine at Ruby Hill, Nevada, operating against a 1,200-foot head of water at a pressure

Austin distinguished his approach from two other methods the Navy was exploring. The first of these was saturation diving, which was the subject of DOD's Man-in-the-Sea program and the SEALAB studies. The second approach was bottom-sitting structures, in which pressure-proof buildings are constructed on the ocean floor, directly accessible to the water. At the time of Austin's report, the Naval Civil Engineering Laboratory at Port Hueneme was conducting research into spherical concrete hulls for ocean-floor installations.

While acknowledging that these two approaches had some practical use for small-scale installations, Austin set out to show that his concept had virtually no limit on the size of habitation and work structures and connecting tunnels that could be constructed. He explained the various methods of entry into the sea floor and the technologies and techniques that would be used to construct a Rock-Site base.

In a discussion of Austin's concept, McLean observed that:

> . . . to me the thing that made access to an undersea environment practical is the fact that, in an underwater environment, we can design locks in such a way that they always stay filled with water. Thus the amount of energy necessary to open and close a lock will be relatively small. . . . This requires the locks being put on the bottom of the structure, rather than at the top. . . . a submarine can sail into a water-filled lock, change the pressure, and then sail into a water compartment—into a one-atmosphere environment—in a very short transit-time.

The one-atmosphere aspect was particularly important. It required no special gasses to be breathed and no tedious pressurizing and depressurizing sessions as people and vessels came and went from the underwater site.[127]

Austin enumerated the advantages of his design, introducing that section of the report with an optimistically philosophical comment that could be applied to many of NOTS out-of-the-mainstream projects:

> As soon as someone proposes to do something differently, a flurry of argument breaks forth as to "why," and "what good is it," and "obviously, it is impossible or it would have been done already." These discussions are healthy for all concerned as they take some of the shine off of new ideas and they get other persons besides the original idea-formers involved in contributing thoughts, problems, and solutions in support of the original concept.

He explained that with the Rock-Site concept (unlike sea-floor exploration from oceangoing barges or platforms):

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of 520 psi.

127 McLean interview, "A Bedrock View," 31.

> 1. Weather and waves are not a hazard, 2. All equipment is accessible to ordinary technicians and laborers [read land lubbers], 3. The working volume or space can be expanded cheaply . . . 4. The Rock-Site installations can be placed at great depth beneath the sea floor; their openings can be numerous and scattered; and access to the installation is absolutely controlled by the base occupants . . . 5. Surface hazards such as accidental ship-caused damage and floating hazards are avoided.

Comparing his concept to what he derisively termed "bottom-squatting structures," he noted that Rock-Site would not be subject to "water mass 'weather'" such as shear and current. Likewise damage from "accidental ship activities would be less" and Rock-Site would have fewer problems with catastrophic flooding and high-leakage rates than would a "thin-skinned" structure. Lastly he reiterated the volume argument: "Structures within the sea floor can easily be made large and comfortable enough to permit the quartering of crews and their families for extended periods of time."

Austin proposed that his concept be evaluated in three phases: Rock-Site I, a laboratory connected to the land; Rock-Site II, a laboratory in an isolated shelf or sea-mount; and Rock-Site III, an isolated deep-sea or under-ice laboratory.[128]

When McLean was asked years later if the undersea base design had been his idea, he responded:

> No, Dr. Austin suggested the Rock-Site idea . . . at NOTS, we funded his visiting existing undersea installations to bring back data on what techniques they were using. . . . Most of the funds that pinned down Rock-Site as a concept—some $50,000—[of in-house discretionary funds] went simply for his travel . . . I was very skeptical that there was any sense in building an undersea cavern because it looked like it might be of limited utility and mobility. . . But data on the size of the undersea cavities showed that, once you have established yourself in a base, you can use atomic power and rock-drilling equipment to increase the cavity as much as you think necessary.[129]

The initial distribution for Austin's *Manned Undersea Structures* included the Chief of Naval Material, the chief scientist of the Office of Naval Research, the Navy Chief of Engineers, the Central Intelligence Agency's oceanographer, the Atomic Energy Commission (four copies), the Manned Spacecraft Center (Attn: Scott Carpenter, one of the SEALAB study participants), NASA, the National Science Foundation, and 85 other recipients. By the time his report hit the street in September 1966, work was under way on surveying San Clemente Island and the surrounding waters for a suitable location for the first Rock-Site installation.

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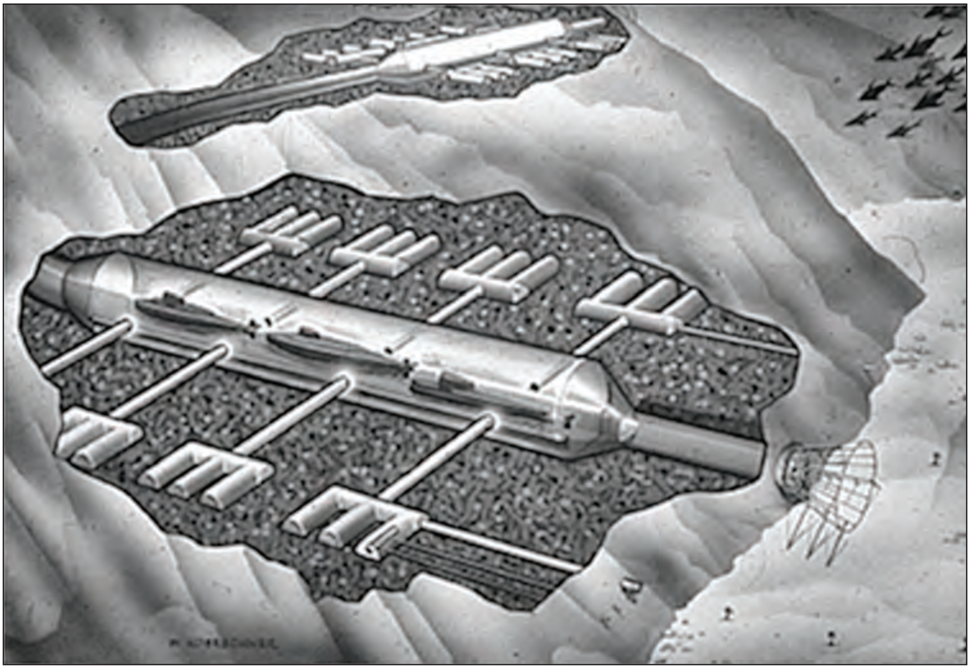
128 Austin, *Manned Undersea Structures*, 32-33.

129 McLean interview, "A Bedrock View," 31.



Artist's concept of Rock-Site.

In December 1966 Knemeyer, acting by direction of NOTS Commander Captain John Hardy, sent a memo to the Commander, NAVFAC, requesting an engineering study for a nuclear power and desalination plant for undersea use. The equipment would be used for a program called Oceanus "to demonstrate that military-man can occupy and effectively use large, one-atmosphere volumes excavated under the floor of the sea," and the initial prototype installation was to be Rock-Site.

The memo described the features of the prototype as follows:

> This sub-bottom prototype would be constructed a short distance offshore, would be permanently linked by a tunnel/shaft to the surface, and would be connected via watertight locks to the ocean volume. The land link could be sealed for long periods of time to allow realistic simulation of isolated operation under the seabed.
>
> For this prototype to be meaningfully extrapolated in terms of military use of a truly isolated installation, it is necessary that it be self-sufficient in power, water, and air. Specifically, the on-site power system must not be an air breather, in fact, must produce the power necessary for distillation of water and electrolysis of oxygen from water. Technically, only nuclear power appears to satisfy this criterion.

The memo requested that NAVFAC determine the characteristics of a nuclear power plant that would suit the project's needs, specifying a desired output of 5 megawatts and a 50,000- to 80,000-gallon-per-day water distillation capacity. As official contacts the memo listed Don Moore and George Wilkins (a member of Moore's Astrometrics Division staff who worked with Austin on Rock-Site and who was the memo's actual author).[130]

The following month, January 1967, the Chief of Naval Material promised $150,000 to the Rock-Site project, and NAVFAC advised NOTS of the availability of a "surplus" 2-megawatt portable nuclear reactor at Edgewood Arsenal that could be made available to NOTS for installation at San Clemente Island within 2 years at a cost of $3 million.

None of it—not the nuclear power plant, nor the desalination capability, nor Rock-Site itself—was to be.

Six months after the NAVFAC offer, NOTS was disestablished and simultaneously reborn (merged with the Naval Ordnance Laboratory, Corona) as the Naval Weapons Center. The personnel and facilities at Pasadena, plus McLean and the bulk of NOTS' underwater work, became the core of the newly established Naval Undersea Warfare Center.

Rock-Site did not end abruptly but rather tapered down. In January 1968 James B. Ridlon (a member of the Earth and Planetary Sciences Division who had taken his PhD in oceanography at Oregon State on a NOTS Fellowship) published the results of a detailed geophysical and geological survey of the ocean area off Eel and Lost Points at San Clemente Island. Ridlon published additional work, including residual magnetic anomaly mapping and seismicity studies, in 1969, by which time he was working for McLean in San Diego.[131]

In March 1968 Austin published his final Rock-Site report, which contained the results of a geologic evaluation of San Clemente Island for a Rock-Site I installation. It concluded that a candidate site on the ocean (west) side of San Clemente Island in the vicinity of Mail Point and Lost Point was "a technically feasible but difficult location."[132]

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130 Memo 40403/GAW:pl, Ser. 4188, Commander, U.S. NOTS (Frank Knemeyer, by direction) to Commander, Naval Facilities Engineering Command, "Nuclear Power and Desalination Plant for Undersea Use; request for engineering study of," 14 Dec 1966. NAVFAC plans, designs, builds, and maintains the Navy's shore structure.

131 J. B. Ridlon, *San Clemente Island Rocksite Project: Offshore Geology, Part 1. Detailed Survey Off Eel and Lost Points Area*, NWC TP 4442, Part 1, Jan 1968; J. B. Ridlon, *San Clemente Island Rocksite Project: Offshore Geology, Part 2. Reconnaissance Survey Around the Island*, NUC TP 156, Aug 1969.

132 C. F. Austin, *Geologic Evaluation of San Clemente Island as a Location For a Rock-Site I*

One of the aspects of Rock-Site that appealed to McLean was its isolation. He believed in the value of isolation—had indeed seen its effects first-hand at China Lake. In a 1975 interview, he said:

> The society at NOTS had a unique capability for interorganizational communication because the people don't just meet during the working hours. They also get together on skiing trips, boating trips, camping trips, social hours, meetings at the club. . . I think the random getting together of the people who were all living in one location was very effective. . . . I have proposed as one of the things that the Navy ought to be doing, but I'm sure they won't, is to build a floating island as an integrated research community. The objective would be to figure out how you can recycle all your materials in an isolated environment, and that would be a good lead-in, first, to an undersea city and, second, to the city that someday we will establish on the moon.[133]

In the space of two sentences, McLean had traveled from a floating island, to an undersea city, to the moon. Asked if an idea like that had just popped into his head or had started with a problem, McLean responded:

> Yes, it starts with a problem. I guess the first thing that started it was reading *On the Beach*, which is the story of how the civilization ends because regulations won't permit you to take women on submarines. And it was so clear that what you need to do in order to insure survival of mankind is to start developing cities that are isolated from the surface environment, can be recycling and self-contained. We have the technology now with the nuclear power plants of being able to do that.[134]

McLean's mind did not seem to function as linearly as most; many people reported that keeping up with him in a conversation was difficult because he would jump around from subject to subject. However, there was logic in his connection of seemingly disparate ideas. In regard to establishing a community on the moon, for example, he commented:

> It seemed to me the undersea community was a much easier job, energy wise, cost wise, and would solve a lot of the problems which would otherwise undoubtedly doom to failure the first two or three moon colonies. So you ought to try the things you can do easily before you try the things that are hard.[135]

Asked years later what had happened to Rock-Site, Don Moore replied:

Installation, NWC TP 4501, Feb 1968, 23.

133 S-97, McLean interview, 33.

134 Ibid., 34. Nevil Shute, *On the Beach*, William Morrow, New York, 1957, was a bestselling novel that was made into a 1959 movie starring Gregory Peck and Ava Gardner.

135 S-97, McLean interview, 34-35.

> Rock-Site. . . there's no reason to do that. Yet. Whether there ever will be or not, I don't know. . . . I hope that we don't chew our environment up enough so that it is necessary.[136]

Closer Ties with the Underwater Navy

The Navy's Deep Submergence Systems Project (DSSP) was created in 1964 as a group under the Special Projects Office—the organization that had developed Polaris and was then developing Poseidon, the Navy's follow-on ballistic missile system. DSSP's primary and public purpose was to develop methods for locating and rescuing submariners; USS *Thresher* had sunk in 8,400 feet of water the previous year, with the loss of all 129 people on board. DSSP would eventually also carry out covert projects such as tapping Soviet subsurface communication cables and recovering undersea debris from lost Soviet weapons.

In September 1966, Craven, DSSP's project manager, opened the organization's principal offices at the Submarine Support Facility, Ballast Point, San Diego. Two months later DSSP was in discussions with NOTS for a DSSP test range, and the Station had begun to acquire equipment for supporting the Deep Submergence Rescue Vehicle, one of the first DSSP major efforts.

At that point, according to Craven, the undersea Navy was moving in three directions: deterrence, attack, and intelligence. DSSP was, he wrote, "the embryo of the intelligence Navy."[137]

DSSP was well funded, but initially unfocused. In recognition of NOTS' leadership role in undersea research and technology, Don Moore's group was tasked to put together a road map—a Technical Development Plan (TDP)—for Deep Ocean Technology. The task was difficult and the time short; on the eve of the deadline for the DOT-DTP presentation, the principal players—George Wilkins from China Lake, Ivor Lemaire from Pasadena, and John Freund from NAVSEA (Moore was away in Hawaii)—pulled a marathon overnight session to hammer together the final plan. It was multi-tiered: major demonstration projects, like Rock-Site, were at the top level; the next level described the components needed for each project; the third level specified the subsystems necessary for those components; and the bottom level described the technologies that would have to be developed to create those subsystems.

The next morning the plan, in the form of a set of table charts, was presented to the sponsors. According to Wilkins, "They were overwhelmed, praised everything we had done, and promised future funding." The plan was

136 S-185, Moore interview, 46.
137 Craven, *The Silent War*, 110.

accepted as a framework for deep-ocean-technology development and guided research and funding within DSSP for many years.[138]

Estabrook analogized these undersea demonstration projects to the nation's efforts to put a man on the moon in the 1960s:

> There's absolutely no value in putting a man on the moon, if you think about it. You walk around—it's a very expensive trip. But in order to do that, you had to develop miniaturized electronics, advanced rocketry, life support systems, and the list is endless of all these different technologies that had to be developed to be well beyond where the current state of the art was. So they developed a series of demonstration projects that would cause you to have to create advanced technologies in order to make it happen.[139]

In January 1967 Captain William M. Nicholson was assigned as the DSSP director. He met with NOTS Pasadena personnel to discuss the Station's involvement with DSSP and specifically with the SEALAB program. That same month the site for SEALAB III was selected near the Pop Up Launcher at San Clemente Island. Pasadena Annex personnel were also working on DSSP's optical sensors program, the Large Object Salvage System (LOSS), and the DSSP test range.

As NOTS' disestablishment approached, with the accompanying transfer of the Pasadena Annex to NUWC, DSSP increased its involvement with the Annex and its use of the NOTS facilities on the California coast.

When the undersea work was assigned to the new Naval Undersea Warfare Center in July 1967, McLean was senior enough in the laboratory community that he could have remained as Technical Director of the Naval Weapons Center, China Lake, if he so chose, but he did not. His belief that the future of the Navy lay below the ocean's surface, and that the future of the entire nation would be revolutionized by the exploitation of the undersea world, left him little choice as to which laboratory to lead.

In October 1967, three months after the schism, NUWC hosted the Navy Deep Submergence Ocean Engineering Program Planning Group meeting. McLean's new organization had become the focal point of the Navy's deep ocean work. China Lake did not get entirely out of the submersibles business. In 1972, as the war in Vietnam dragged on, NWC was tasked to develop an underwater two-person Swimmer Delivery Vehicle for use by special operations personnel. The craft was not completed, however, until after the U.S. military actions in Southeast Asia were terminated.

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138 George Wilkins email to the author, 2 Sept 2011.

139 S-320, Estabrook interview, 11.

China Lake lost more than the undersea work when McLean left; a great deal of the spirit that was NOTS left with him. In the following 2 years, many of the old timers retired, early China Lakers who had come NOTS in the mid 1940s and had stayed beyond their initial retirement opportunities simply because it was still fun to work on the base.

Those who remained put the best face on the situation. Slates' report on *Hikino* was published just 8 months after the reorganization. It concluded with this hopeful statement:

> Much valuable knowledge was gained by all the personnel involved. This knowledge is not lost by reorganization as it will continue to exist. Procedures, training, design experience, etc., will be utilized by those who acquired them wherever they work.[140]

140 Slates, "Hikino Mock-Up," Tech Note 404-65-68, 9.

12

Controlling the Weather

If I had the management of such affairs, I would rain softly and sweetly on the just, but if I caught a sample of the unjust out doors I would drown him.

— Mark Twain, American novelist[1]

On 20 November 1963, 2 days before President Kennedy was shot, Dr. William B. McLean, NOTS Technical Director, was back East addressing an R&D planning conference hosted by the Bureau of Naval Weapons. He loosened up the crowd with a little humor:

> I began to worry a great deal about my speech, particularly when I made the quick calculation that the manpower and travel money represented in the room was probably spending our resources at the rate of about $10,000 per hour. I was afraid that I could not make a speech that would be worth that amount of money.[2]

He cautioned the attendees that "the rate of development of technology is so fast at present that the Navy is continually faced with the problem of making choices from the among the many opportunities that are open to it," and, accompanied by slides, he began to discuss some of those opportunities.

By the time he reached Slide 10, he was talking about limited wars, which, he said prophetically, "require skills more closely related to police activity than to the destruction which we normally associate with warfare" and he noted that "many of the limited warfare goals must be accomplished by influence, rather than force."

He spoke of nonlethal agents and of economic, political, and educational programs, and then he said:

1 Mark Twain (Samuel Clemens), quoted in *My Father Mark Twain*, by Clara Clemens, Harper and Brothers, New York, 1931, 276.
2 "NOTS Presentation," BuWeps R&D Planning Conference, 20 Nov 1963, RM-24, *Collected Speeches of McLean,* 169.

> Another interesting possibility for exerting influence is through the use of tactical weather modifications. . . . Many societies we want to influence still express their control of environment through the influence of the witch doctor. If we could have a real positive display of weather control which is easy to recognize, we provide a tool by which the authority of the witch doctor can at least be challenged by a mechanism which people can understand.[3]

McLean's interests ranged broadly. When he connected weather modification with witch doctors, he may well have been thinking of the Native American rock art found on the walls of remote canyons in the Coso Range at NOTS. Many of these petroglyphs—figures chipped into rock, as opposed to pictographs which are figures painted on rock—have been interpreted by archaeologists as early attempts at weather control, iconic tools used by weather shamans to summon rain.[4]

McLean realized that the potential impact of weather modification was far greater than the ability to impress primitive cultures. He had been supporting weather modification research and testing for more than 2 years, and would continue to do so through the remainder of his tenure as NOTS Technical Director. The potential it offered both as a weapon of war and as a benefactor to humanity was on a par with that of nuclear energy.

His speech did not go into the specifics of NOTS ventures into weather modification. But it could have. Two years previously, in a project called Cyclops, the Station had demonstrated the ability to change the internal dynamics of a hurricane. That was only one of many successes of the Station's weather modification team, whose work ranged from hurricane abatement and fog control to rainmaking and rain unmaking.

To understand weather modification requires a basic understanding of how rain is formed. As water vapor in the air cools, it condenses and forms clouds containing droplets of moisture about 1⁄100th of a millimeter in diameter. Under the right conditions of air movement and temperature, these droplets collide and merge, becoming sufficiently heavy to fall as rain. As the raindrops fall, they strike other raindrops and the coalescence process spreads.

This process can be hastened. If the air is supercooled, that is, below 0°C, adding fine particles to the air will form the nuclei of ice crystals. (Water can be

3 Ibid., 176–177.

4 See for example David S. Whitley, "Finding Rain in the Desert: Landscape, Gender, and Far Western North American Rock Art," in *The Archaeology of Rock Art*, edited by Christopher Chippendale and Paul S. C. Taçon, Cambridge, Cambridge University Press, 1998, 11–29. Two China Lake rock-art sites, Big and Little Petroglyph Canyons, were designated as National Historic Landmarks by the Department of Interior in 1964.

Rock art of Little Petroglyph Canyon, Coso Range, China Lake. The central figure with what appears to be raindrops over its head is frequently referred to as a "rain shaman." Photo by Liz Babcock

cooled to far below zero without freezing, unless it contacts a foreign particle or an ice crystal.) As the water freezes, heat is released—heat of fusion—and the air rises, expands, and causes clouds to rise rapidly. As they do so, more air gets sucked in with more moisture. At the same time, the ice crystals become nuclei around which the tiny droplets of moisture condense and start to produce rain.

Different sized drops fall faster or slower, causing collisions, which in turn produce larger drops.

As early as the 1890s, both the government and private industry had investigated methods to generate rain. The science behind raindrop formation was not well understood, but people had long observed that smoke, from fires or military battles, was sometimes associated with precipitation. Therefore, these early efforts to make rain usually involved creating smoke that, with luck, would enter the cloud and provide the nuclei for moisture to condense into rain particles.

Luck, though, was the operant word in these early efforts. Isaac Pitman Noyes, writing in 1892, disparaged the Department of Agriculture's unsuccessful attempt to create rain in West Texas by setting off hundreds of charges of dynamite atop Mt. Franklin, near El Paso. He wrote of "men who seem to think that there is enough moisture always present in the upper strata of the atmosphere to produce rain, and all they have to do is to contrive some mechanical device whereby they can tap this great reservoir, as one might tap some high cistern, and down the water will come in copious showers."[5]

One of the chief difficulties in measuring the effectiveness of any rainmaking attempts was the lack of controlled experiments. With so little technical understanding of the actual physical mechanisms of rain formation, it was hard to determine whether, in the occasional confluence of rainmaking activities and rainfall, there was a causal relationship or just coincidence.

In the late 1940s, NOTS began to investigate rainmaking, initially by seeding clouds with dry ice (a process discovered by General Electric researcher Vincent Schaefer in 1946). The Station was ideally suited to the new field of research; it had the expertise in chemistry and other relevant technical disciplines, extensive experience in pyrotechnics (generating heat, gases, and smoke by burning or detonating), the capability to devise mechanisms for dissemination and distribution of candidate rainmaking materials, and the tools and facilities—radar, camera-equipped aircraft, aerial photography, data analysis—to empirically evaluate the results of weather-modification experiments. As Dr. Pierre Saint-Amand put it many years later:

> No place else in the country could have done it but this place, because here we had chemists who understood how to make pyrotechnics, and we had aviators who weren't afraid to drop the things, and a number of scientists who were just looking for something interesting to do.[6]

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5 Isaac P. Noyes, *Meteorology, the Weather Map and the "Rain Makers*," Joseph L. Pearson, Washington, DC, 1892, 6.

6 Pierre Saint-Amand, "Have I Got a Story for You! Doing Something About the Weather," VP 06-054, Technical Library presentation, Video Projects, China Lake, 26 Jan 2006.

Saint-Amand was one of those scientists. He had joined NOTS' Pasadena Annex in 1950, received his PhD in geophysics and geology from Caltech in 1953, and came to China Lake in 1954 to conduct research into the night sky. By 1961 (after a year in Paris on a Fulbright Scholarship and 3 years with the International Cooperation Agency setting up a school of geology at the University of Chile), he was head of the Aeronautical Sciences Division, which later that year was renamed the Earth and Planetary Sciences Division. From that position, which he would hold for 20 years, Saint-Amand oversaw China Lake's worldwide efforts in both military and civilian applications of weather modification.[7]

The big breakthrough in weather modification at NOTS came in the late 1950s, when the Station was working on screening smokes for military use. Screening smokes, as the name implies, are laid down from a vehicle or an airplane to hide friendly activities, such as troop advances, from visual observation by the enemy. (In 1963 when President Kennedy witnessed a firepower demonstration at China Lake, the show concluded with A-4s laying down a smoke screen between the President's reviewing stand and the targets.)

The best screening smokes were found to be those made of hygroscopic (water-absorbing) materials, because they attracted moisture in the air and created a smog (smoke and fog) effect that had more obscurant value than smoke alone.

In the course of the screening-smoke research, in about 1957, Dr. Lohr A. Burkardt and Dr. William G. Finnegan of the Research Department's Chemistry Division were investigating colored smokes.[8]

Meanwhile, McLean had asked Saint-Amand to find a material that could be released from a rocket in outer space and leave a tracer trail visible from the earth (at that time NOTSNIK, the Station's first venture into space, was just beginning). McLean stipulated that the material used for the tracer trail could weigh no more than 500 grams (just over a pound). Saint-Amand investigated fluorescent materials, then television phosphors, but none were bright enough. He remembered that:

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7 An internationally recognized authority in weather modification and water management, Saint-Amand is a legend at China Lake. His L. T. E. Thompson Award cited "his outstanding scientific and entrepreneurial accomplishments." He was also the recipient of the Distinguished Civilian Service Award. Saint-Amand died in 2011.

8 In a distinguished 28-year career at China Lake, Finnegan would receive, among other honors, the L. T. E. Thompson Award and the Navy Meritorious Civilian Service Award. He published 65 papers, was granted 21 patents, and served as a director of the Weather Modification Association.

> I went over to the chemists to see if they had anything that would do . . . and I found Dr. Burkardt and Bill Finnegan over there who were trying to make colored smoke . . . and they tried to make an orange smoke by making lead iodide . . and they used a reaction to change the valence of the lead so that it released iodine, and they had this lovely orangish-purple cloud.[9]

Saint-Amand was aware of the work of GE scientist Bernard Vonnegut (older brother of novelist Kurt Vonnegut) who in 1946, just a month after his colleague Schaefer had discovered the principle of cloud seeding with dry ice, had found that silver iodide could also be used as a cloud-seeding agent. (According to a 2008 interview with Dr. William S. McEwan, he and Saint-Amand had visited Vonnegut in New York.)[10]

"About that time, of course, people were talking about seeding clouds," Saint-Amand continued. "I asked [Burkardt and Finnegan] if they could make silver iodide for me, and they did, a short time later."

The beauty of using pyrotechnics was that a few ounces of material could generate very large amounts of aerosolized material. Saint-Amand obtained silver iodate, which the chemists used as an oxidizer to make silver iodide and which had the desired effect of creating ice crystals in supercooled water. Assisted by Dr. Frederick Kirk Odencrantz, who oversaw testing of the compounds, and chemical technician Charles D. Stanifer, the chemists succeeded in creating silver iodide crystals in an aerosol suitable for rain making. Saint-Amand remembered that:

> I wrote a long letter to the Bureau of Naval Weapons, pointing out this might be a useful thing to be able to do, and never got an answer. So then I went off and taught school in South America for a couple of years and came back and nothing had been done, so I just appropriated some money to myself and started working on the subject.[11]

Saint-Amand's knack for taking charge and getting things done was the force behind nearly a decade and a half of weather modification work at China Lake.

Project ACE

Saint-Amand's first program was called Project ACE, for Atmospheric Control Experiment. Since Vonnegut's work more than a decade earlier, many researchers had used silver iodide in attempts to make rain. However, they had used one of Vonnegut's later formulations that employed an alkali iodide as

9 S-120, Saint-Amand interview, 8.
10 S-249, McEwan interview, 53.
11 S-120, Saint-Amand interview, 8–9.

the soluble agent. The results were "indeterminate." Work at NOTS showed that the use of the alkali iodide-silver iodide complexes yielded water-soluble products that did not function as ice nuclei; as a result, the techniques used in these experiments to seed clouds should have been ineffective. With a return to the earlier technique using ammonium iodide-silver iodide complexes, seeding efforts were strikingly effective.[12]

Understanding the chemistry was only the first step. Using a theory for the growth of droplets developed by Dr. D. T. Gillespie from the University of Nevada, Dr. Larry Mathews, a NOTS chemical engineer, applied his knowledge of thermodynamics to develop a sound theoretical basis to guide the program. Using Mathews' framework, Saint-Amand's team developed a procedure to deploy the silver iodide into the target clouds. The complicated procedure required many hours of testing to perfect. Most cloud-seeding researchers before Saint-Amand and company had not actually done much flying within the clouds. "Our people here were only too happy to go riding in airplanes," Saint-Amand recalled years later.[13]

The dispersal team had to know what types of clouds to enter and in what sequence, where and at what speed and altitude (the last determined from the external temperature) and from what direction to enter them, and when to fire the cartridges that generated the silver iodide aerosol. Different types of clouds, different temperatures, and different wind conditions required different seeding techniques. The success of seeding also depended on the wind flow within the cloud. As one China Lake technical film put it, "the secret of successful weather modification is putting the proper seed in the exact place at the correct time."[14]

The technique developed at NOTS (and used today throughout the world) is known as dynamic cloud seeding, which causes clouds to yield up to 10 times their normal rainfall. According to the American Meteorological Society, "The goal of dynamic cloud seeding is to stimulate or enhance vertical air motions in the cloud through increased buoyancy derived from the release of latent heat of freezing."[15]

Military-grade hardware was developed that was compatible with DOD aircraft. The very large nuclei-generators used in the early projects were replaced

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12 "Technique Development," *Current Technical Events Memorandum*, 23 Sept 1977.

13 VP 06-054, Saint-Amand, "Doing Something About the Weather."

14 D-A-LHL-71-01, "Military Applications of Weather Modification," Technical Film Report, China Lake, 1971. (At the time this film was made, the very title was classified Secret.)

15 *Glossary of Meteorology*, 2nd edition, Todd S. Glickman, ed., American Meteorological Society, Boston, 2000, 150.

with smaller (about 10 grams) generators that, as delivery techniques became more refined, proved to be more efficient.

In a program called Thunderbird (not to be confused with the earlier NOTS nuclear weapon program of the same name), NOTS developed the WMU-1/B, -2/B, and 6/B catalyst generators (which contained the pyrotechnics that actually generated the silver iodide aerosol) and then the SUU-53/A dispenser, which could carry 52 aerosol generators and shoot them into the clouds. All the devices were approved for Fleet use. These were "ordnance items" as NOTS defined the term: devices that were not only effective but also safe, reliable, and economically producible on a large scale.

New chemical formulations with different effects were continuously being developed. After computer modeling the effects of a new formulation and running controlled experiments in the laboratory, the developers would go to airborne testing, removing the combustible charges from standard photoflash cartridges and refilling them with seeding agents.

In all the weather-modification programs, the researchers rigorously examined the results of their experimentation using the most sophisticated instrumentation available and applying the most exacting methodologies to assess results. They logged thousands of hours in a variety of aircraft, often using multiple instrumented aircraft simultaneously to gather data on a single experiment.

The weather-modification team participated in numerous humanitarian projects and was continually active with the Fleet in operations that ranged from Alaska to Antarctica. Much of that work involved the elimination of fog, which hampers naval operations, particularly flight operations.

Project Cyclops

Project ACE soon gave way to other specialized projects. The 1961 *Technical History* reported that:

> Cloud seeding has been tried for some years, but with negligible results. In 1961, NOTS scientists and engineers developed a new method of generating silver iodide nuclei and a new means of dissemination. The new device, called Cyclops, was used for the first time in a seeding operation on Hurricane Esther in September 1961. The operation was carried out, in cooperation with the U.S. Weather Bureau, from the U.S. Naval Station, Roosevelt Roads, Puerto Rico.[16]

16 *NOTS Tech History 1961*, 14.

Commander William R. Eason, NOTS Assistant Experimental Officer, was the Navy coordinator for Project Cyclops, and Saint-Amand was project director. Even the NOTS Commander participated. A *Rocketeer* article noted that "Captain Charles Blenman, Jr. not only gave full support and cooperation; he additionally made several valuable operational suggestions."[17]

Tackling a hurricane required a larger dissemination device than had previously been used. Mechanical engineer Otho Hart and other members of the Earth and Planetary Sciences team developed a piece of ordnance about 4 feet long and 6 inches in diameter designated by the project name, Cyclops. Argentasol 5052, a propellant composition consisting of 70-percent silver iodate as the oxidizer and 30-percent Nitrasol binder, was the nucleating agent. When ground tests on the NOTS ranges showed that the mixture did not burn with enough heat, 5-percent aluminum was added. The composition was cast as an end-burning grain by China Lake's propellants experts and installed in a bomblike container. When jettisoned, the tail section opened to deploy a parachute, and a fuze ignited the Argentasol mixture, which burned for 160 seconds, generating silver iodide crystals.[18]

Naval Air Facility machinists at Armitage Field fabricated an adapter for the A3D-2's bomb bay to carry nine of the Cyclops ordnance units. NOTS assigned NAF Lieutenant Frank O. Baty as the bombardier-navigator to see the test series through. When an all-up test was conducted 40,000 feet above G-1 range in 29 August 1961, the unit failed to fire (fuzes are difficult to ignite at 40,000 feet). The fuze was beefed up with a little ammonium potassium perchlorate and tested successfully in the High Altitude Test Chamber at 50,000 feet. On 11 September 1961, a second all-up test was held over G Range and the unit operated properly. After three more successful all-up tests, the team was off to Florida, for a planning session with the other agencies involved and then to Roosevelt Roads, Puerto Rico, to wait for the storm.

On 16 September, with Hurricane Esther 400 miles from Puerto Rico, Hurricane Reconnaissance Squadron VW-4 sent a control aircraft into the hurricane to guide the A3D-2 to the drop point. The Weather Bureau put up a B-57, two DC-6s, and a B-26 to gather data. An Air Force U-2 reconnaissance plane took photos from overhead. Loaded and fueled, the NOTS A3D-2 took off to fly into the hurricane. As a *Los Angeles Times* article on the Station's hurricane abatement efforts described this phase of the operation:

17 *Rocketeer*, 31 Aug 1962, 1.

18 This and other details of the operation are taken from TMP 100, "Cyclops 1," a technical film report prepared by the NOTS Technical Information Department, BuWeps No. 25-61, 1961.

> This is not an easy task. The eye of the storm is deathly calm, but near the eye a plane is buffeted by crosswinds so strong a pilot has to hold his ship at 45 degrees in order to stay on course. The noise of the heavy rain beating on the fuselage drowns out all other sound.[19]

As the A3D-2 approached the storm, it had to dump 6,000 pounds of fuel to climb to the optimum drop altitude of 44,000 feet. The Cyclops units were dropped into the northeast quadrant of the storm. The area was seeded with the silver iodide which, when it mixed with the clouds, caused the supercooled water to freeze. Four hundred cubic miles of cloud, from about 45,000 feet down to 20,000 feet, were converted to ice and snow, and the hurricane's eye started to fall away and open up. Having expended all the Cyclops units and short on fuel, the A3D-2 returned to base while the other aircraft stayed to observe the storm.

As the *Rocketeer* reported, "Wind velocity decreased from a 130 knot force to 100 knots. Turbulence decreased. The eye of the hurricane widened, thus diminishing its force." The Weather Bureau consultant, who had been aboard the control ship during the operation, gave the debriefing back at Roosevelt Roads. Asked whether the eye-deformation phenomenon was "definitely due to the seeding operation," he replied, "There's no doubt in my mind."[20]

The *Technical History* entry concluded:

> Had more Cyclops units been available to continue the attack, far more conclusive results would undoubtedly have been achieved.[21]

Project Skagit

In 1962, the weather modification team traveled to the state of Washington to help the Department of Conservation with Project Skagit (named for the Skagit Mountains near Seattle). The objective was to increase the mountain snowpack. Silver iodide combined with magnesium Teflon rocket fuel was used to seed the clouds and resulted in a snowpack increase of 10 to 20 percent.[22]

Project Stormfury

The early success of Project Cyclops led to its expansion under the name Project Stormfury. An Advisory Board was established that included Dr. Joan

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19 Irving Bengelsdorf, "New Experiments Due in Hurricane Control," *Los Angeles Times*, 4 Nov 1963, C3.

20 TMP 100, "Cyclops 1."

21 *Rocketeer,* 31 Aug 1962, 1; *NOTS Tech History* 1961, 62.

22 *Major Accomplishments*, 116.

Malkus, Professor of Meteorology at UCLA, and Dr. Robert W. Simpson of the U.S. Weather Bureau. Saint-Amand was director of the project, and his assistant was Captain Max A. Eaton, Officer in Charge of the Navy's Fleet Weather Facility in Miami. The joint project was organized by Dr. Simpson, who would go on to head the National Hurricane Center from 1967 to 1974.

The plan was to go the Caribbean during the hurricane season of 1963 when it looked like a hurricane might form, meanwhile seeding cumulus clouds over the ocean to demonstrate the capabilities of NOTS' weather-modification equipment and techniques.

"The Project Stormfury experiment," explained a *Rocketeer* article, "is designed to alter cloud conditions in the eye wall band and, by upsetting the balance of forces near the eye, to cause a redistribution of the energy concentrated there. Theoretically, injection of silver iodide particles into the eye wall upstream from the primary energy cell—or chimney—could transform supercooled water droplets to ice crystals, releasing heat energy into the storm system near the warm core, and lessen the storm's violence."[23]

Cloud seeding would be carried out by two A-3B (formerly A3D-2) aircraft carrying two types of seeding devices: Cyclops II was an improved version of the dispenser used in the 1961 experiments. While Cyclops 1 had deployed

Cyclops II dispensers in bomb bay of A-3B aircraft.

23 *Rocketeer*, 23 Aug 1968, 1.

under a parachute, Cyclops II was free falling, with three high-drag unbalanced folding fins. This design made the delivery unit fall in an open spiral. Cyclops II could dispense 60 pounds of silver iodide smoke in 35 to 60 seconds, while falling in the wall cloud of a hurricane at a rate of 250 to 350 feet per second. The smaller Alecto (a NOTS-designed and fabricated dispenser, named for one of the three furies of Greek mythology) generated about 5 pounds of smoke and was designed to seed large thunderstorms and the spiral rain clouds of hurricanes.[24]

At the core of both generators was the silver iodide mixture invented by Burkardt and Finnegan, which was generated with a propellant formulation of silver iodate, powdered aluminum or magnesium, and a binder of complex organic compounds. The formulation was developed by Dr. Ron Vetter, a chemist in the Propulsion Development Department. Glen Binns designed the Cyclops II canister and John Burmeister designed the Alecto canister; both men were from the Engineering Department.

As the Stormfury team waited and hoped for a hurricane, they seeded cumulus clouds for several days, using as few as two and as many as 26 Alectos per cloud. "The reaction of the cumulus clouds to the seeding," according to the *Technical History*, "was immediate, violent, and dramatic."[25]

One of the clouds they seeded was about 300 miles south of San Juan. The top of the cloud was at an altitude of about 19,000 feet, and the aircraft flew into the cloud at about 17,000 feet. "Within 5 minutes, the cloud rose spectacularly to at least 35,000 feet," said Dr. John A. "Jack" Donnan of the Earth and Planetary Sciences Division.[26]

On the verge of packing up and going home, the team received word that the Tiros satellite had spotted a disturbance 900 miles east of Puerto Rico. It was a tropical depression that developed quickly into Hurricane Beulah. On Friday 23 August, the go-ahead was received and a flight of 10 aircraft approached the storm. The two A3-Bs penetrated the storm at 35,000 feet and dropped eight Cyclops II canisters and 47 Alectos, to dispense a total of 715 pounds of silver iodide smoke.

Almost immediately the north wall of the storm disappeared from radar, an observation that was confirmed visually by several of the participating aircraft.

The next day the team laid down another 775 pounds of smoke along a course 30 to 35 miles long. The results were the same as the previous day. "The

24 *NOTS Tech History 1962*, 15, 99.
25 *NOTS Tech History 1963*, 116.
26 *Rocketeer*, 30 Aug 1963, 1.

seeding simply knocked a hole in the wall," said Donnan. The Weather Bureau used two DC-6s, a B-57, and a B-26 to gather data for later analysis.

Opportunities to seed Beulah were dependent on the ever-changing condition and location of the storm; therefore, the NOTS team was kept jumping with the uploading and downloading of ordnance (the pyrotechnics that generated the silver iodide smoke) on the aircraft operating out of Roosevelt Roads, Puerto Rico.

AOD's Maurice Hamm and Jack Depew, who had helped design the ordnance release systems for the Cyclops and Alecto hardware, kept the systems operating properly. William L. Burson of Saint-Amand's staff and Ronald "R. C." Noles of the Engineering Department were in charge of the nonstop ordnance handling, loading, and unloading. "These four men were the hardest working, most dependable and conscientious group I have ever been privileged to work with," commented Donnan.[27]

The *Los Angeles Times* ran a front-page story titled "Science Bests Nature, Hurricane Stopped by New Technique." Despite the exuberant title, *Times* Science Editor Irving S. Bengelsdorf wrote, "Both Dr. Saint-Amand and Donnan cautioned that while the experiment apparently was a success, much more research is needed to really see if the method will work to control hurricanes."[28]

For the next few years, opportunities to seed hurricanes were limited. Out of an abundance of caution—lest the experimenters' efforts increase rather than reduce storm intensity—tight controls were placed on the Stormfury experiments. They were restricted to an area of the Atlantic from which no hurricane on record had, within 36 hours, made landfall on a highly populated area. No storms met that criterion in 1965 or 1966. The area was expanded in 1968, but the Stormfury experimenters could go into storms only when there was a less than 10-percent probability that the storm would come within 50 miles of a populated area during the following 24 hours.

Although most observers at the time considered Project Stormfury a success (a front-page *Rocketeer* headline on 30 August 1963 read "Call Project Stormfury an Unqualified Success"), Saint-Amand was less enthusiastic. He recalled candidly that:

> That program didn't get along very well because of the inter-service rivalry between the Department of Commerce [the U.S. Weather Bureau], the Navy, and the Air Force; and the State Department eventually led it astray and

27 *Rocketeer*, 30 Aug 1963, 3.
28 *Los Angeles Times*, 31 Aug 1963, A1.

> nothing ever came of it. That was a damned shame—the safety requirements placed on it were so severe that it was impossible to get enough storms to get any definitive information out of it, although the three or four that we had worked on were markedly changed.[29]

In 1969 the Stormfury team tackled Hurricane Debbie. By this time, control of the program was far from the hands of the China Lake originators. The joint announcement of the results was made by no less than Secretary of Commerce Maurice Stans and Secretary of the Navy John H. Chaffee. In that announcement was the first public indication that the Stormfury project may have been on the wrong track in its attempts to defuse hurricanes.

Under a damn-with-faint-praise front-page headline that read "'Debbie' Seeding Mildly Successful," the *Rocketeer* reported that "Hurricane Debbie weakened significantly on 18 August and moderately on 20 August following seeding operations over the Atlantic." However, the paper also noted, "the Secretaries said that scientists cannot now be certain whether the dramatic changes occurred as a result of the seedings." When Stormfury flew its last hurricane-modification mission into Hurricane Ginger in 1971, there was no mention of it in the *Rocketeer*.[30]

Stormfury spanned almost 20 years, although the last field experiments were conducted in 1971. Researchers eventually determined that the hypothesis on which Stormfury's hurricane abatement efforts were built was incorrect. Observations in the 1980s found that eye-wall changes similar to those seen in Esther, Beulah, and Debbie occurred naturally in hurricanes, and that tropical hurricanes contained little supercooled water, the presence of which had been the theoretical foundation of the seeding experiments.[31]

Nevertheless the results of Stormfury led to a greater scientific knowledge of hurricanes, in large measure because those early apparent successes of Stormfury generated increased funding for the Weather Bureau's National Hurricane Research Laboratory, which continues today as the Hurricane Research Division.

GROMET II: Philippines Drought Relief

"The Philippine Islands, jewels of green in a calm blue sea, have been famous for the bounteous climate that furnished all the water needed for

29 *Rocketeer*, 30 Aug 1963, 1; S-120, Saint-Amand interview, 11.
30 *Rocketeer*, 9 Jan 1970, 1.
31 In 2005 a Florida company was pursuing the same line of research that Stormfury had, with initially positive results. See Michael Behar, "Can We Stop Storms?" *Popular Science*, Dec 2005, 17–18.

domestic and agricultural purposes and for the growing of some of the world's finest hardwood forests." So begins the background section of Saint-Amand's 1971 report on Project GROMET II, a campaign to augment rainfall in the Philippines during the drought of 1968-1969.[32]

At the start of 1969, the Philippine economy was in dangerous shape. As described in the GROMET II report:

> . . . the availability of domestic and irrigation water was reduced. Operations at some mines were in danger of curtailment because of lack of water for milling and processing. As the season wore on and little or no rain fell between January and the end of April 1969, crops in the fields turned brown and died, and the soil became too hard to plow.

Private contractors had been hired to seed clouds and the Philippine Air Force had also assisted. Although 196 flights (using brine solution, crystalline salt, or powdered urea as the nucleating material) did produce rain, "it was early recognized that locally available resources were inadequate to meet the widespread water requirements." At the request of President Ferdinand Marcos, the U.S. sent the NOTS weather-modification specialists.

From April through mid-June 1969, using two U.S. Air Force WC-130 Lockheed Hercules aircraft of the 54th Weather Reconnaissance Squadron, flying from Clark Air Force Base, the GROMET team seeded clouds throughout the archipelago. Standard photoflash racks on the aircraft were used to deploy three different types of pyrotechnic seeding agents which differed in their rate of dispersion, speed of fall, and other physical properties.

Each aircraft also had on board a Very pistol (flare gun) that was used to fire pyrotechnic units from the flight deck. The aircraft were fitted with forward- and side-looking X-band radars. They also carried instrumentation for gathering cloud data, including a National Center for Atmospheric Research Bollay-type continuous ice-nucleus counter. Most missions included the deployment of dropsondes (air-launched miniature weather stations that descend through the weather by parachute, transmitting information on humidity, pressure, and temperature to ground stations).

Saint-Amand was scientific director of the team, whose China Lake members included physicist Dr. Sheldon D. "Doug" Elliott, Jr., meteorologist T. L. "Tommy" Wright, Ordnanceman Charles Cordell, and Army Reserve

32 P. Saint-Amand, D. W. Reed, T. L. Wright, and S. D. Elliot, *GROMET II: Rainfall Augmentation in the Philippine Islands*, NWC TP 5097, TID, May 1971. The name GROMET is derived from the terms agronomy and meteorology. GROMET I was conducted in India in 1966-1967.

Officer Captain David Reed. Bud Sewell of the Weapons Development Department and R. C. Noles of the Aviation Ordnance Department later joined the group in the Philippines.

AOD's Rod McClung supported the group stateside, procuring needed materials, and L. Lee Wilson Engineering of Hollister, California, produced the ordnance under McClung's direction.

The U.S. Air Force flew the NOTS team to the targeted areas throughout the Philippines, and Saint-Amand and his team taught the Air Force crews the proper techniques for seeding, as well as for diminishing rainfall. By flying into the bottom of clouds that are about to rain and then seeding heavily, the weathermakers could cause the lower column of rain to rise so fast that it sucked in drier air from the sides and the cloud pinched off, thus extinguishing the cloud as a rain threat. "When they saw what they could do they kept changing the crews on us every couple of days, because they wanted to teach the whole Air Force how to do it," said Saint-Amand. The NOTS team was kept busy training new personnel in the theory and practice of cloud seeding, ordnance handling, and flight procedures.[33]

Although the U.S. Air Force was flying the actual missions (with NOTS teams aboard), the Philippine Air Force, the Weather Bureau, and the Civil Aviation Authority were very much a part of the program.

> During GROMET II every opportunity was taken to teach the local people how to seed clouds for rain augmentation. Fifty Philippine officials, Air Force pilots, and Weather Bureau personnel were given instruction in cloud physics and cloud seeding theory and techniques and were taken aloft on operational missions . . . Both Air Force and Weather Bureau personnel developed a keen interest in the processes, and the basis for further training in case of need was firmly laid. As it happened, a number of the trainees were participants in the 1970 follow-on program financed by the Philippines. Thus, the technology was transferred to the host country for them to use if needed and desired.

This pattern of sharing and teaching was followed in NOTS weather operations throughout the United States and the world.[34]

During GROMET II, 58 seeding missions were conducted. Target clouds were seeded at their -5°C level, usually at about 19,000 feet. "We succeeded in wetting down every island in the archipelago, repeatedly," said Saint-Amand.[35]

The results, according to a China Lake film report, were:

33 VP 06-054, Saint-Amand, "Doing Something About the Weather."
34 Saint-Amand, et al., *GROMET II*, NWC TP 5097, 9.
35 VP 06-054, Saint-Amand, "Doing Something About the Weather."

> . . . immediate and impressive. For instance, one seeded cloud system released 50,000 acre feet of water in 6 hours. Another, on Sabu Island, released 12 inches of rain in an afternoon, filling a depleted reservoir. On average, however, rainfall from seeded clouds was ½ to 3 inches, enough to return the agrarian economy to normal.[36]

Although the amount of total rainfall attributable to the operation could not be precisely calculated, the impact on the economy could. According to the project's final report:

> Benefits derived, at least in part, from the project included marked improvement in the agriculture, increased sugar production amounting to 43 million U.S. dollars, and augmented crops of rice and corn sufficient to make anticipated importation unnecessary.[37]

Philippine Vice President Fernando Lopez commented, "This is probably one of the few projects jointly undertaken by the two governments whose benefits slipped down from the large-scale agricultural producers to the smallest farmer in the field." Based on the success of GROMET II, the Philippine government conducted its own cloud seeding programs in the following years.[38]

Plaque of appreciation being presented to Pierre Saint-Amand by Philippines Vice President Fernando Lopez, U.S. Embassy, Manila, 18 June 1989. At center is an Air Force participant, Lieutenant Colonel Dempster.

36 D-A-LHL-71-01, "Military Applications of Weather Modification."
37 Saint-Amand et al., *GROMET II*, NWC TP 5097, ii.
38 Ibid., 72.

Among those writing letters in praise of the success of GROMET II were CNO Admiral Moorer, Chairman of the Joint Chiefs of Staff Gen. Earle G. Wheeler, Secretary of Defense Melvin R. Laird, and Secretary of State William P. Rogers.[39]

NOTS team of rainmakers plied their trade throughout the world, taking their expertise and equipment on humanitarian missions to India (1966-67), Midway (1969), Okinawa (1971), and the Azores (1972), as well as providing pyrotechnics for drought relief in Niger and Texas. They also provided cloud-seeding consultation services to numerous states including Texas, California, and Florida. They trained or advised contractors, cloud-seeding operators, and program managers in South Africa, Rhodesia, Australia, Chile, Taiwan, Mexico, Canada, and Italy. These activities were, of course, in addition to the team's primary responsibility: supporting the Navy's military needs, a task which also spanned the globe.[40]

Project Foggy Cloud

Most of the Station's weather modification programs addressed aspects of weather control that had both military and civilian components. Fog, while not as dramatic a threat as hurricane, thunderstorm, or hailstorm, is responsible for major economic losses in the civilian sector (think socked-in airports, slowed maritime operations, rerouted airline flights, not to mention miles-long traffic tie-ups and multi-car accidents). For the military, fog—a cloud lying on the ground—not only obscures the battlefield but also can inhibit or at least complicate nearly all sea, land, and air operations.[41]

There are basically two types of fogs: cold fog (below 0°C) and warm fog (above 0°C). Cold fog was not particularly difficult to dissipate; it could be "snowed out" by seeding with a variety of substances. But warm fog, which accounts for about 95 percent of the fogs in the world's inhabited areas, does not respond to icing nuclei and is considered the more difficult to dissipate. For the Navy alone, it was estimated that between 1970 and 1975, $113 million in ship and aircraft accidents were attributed to warm fogs, with a loss of 74 lives. It was this warm fog that Foggy Cloud was targeting.[42]

39 *Rocketeer*, 10 Oct 1969, 4.
40 "Technique Development," *Current Technical Events Memorandum,* 23 Sept 1977.
41 Fog was the primary cause of the worst airline disaster in history when two aircraft collided in 1977 at Tenerife Airport, Canary Islands, resulting in 583 fatalities.
42 *Rocketeer*, 26 March 1971, 5; 7 Feb 1975, 1. The Air Force—notably the Meteorology Laboratory at the Air Force Cambridge Research Laboratories in Bedford, Mssachusetts—was the leader in DOD cold-fog research.

Foggy Cloud began in 1968. The overall director of the project was Dr. Richard S. Clark. From 1963 to 1967, Clark, a lieutenant colonel, had been the Army Liaison Officer at China Lake. He retired from the Army in December 1967 and was hired by Saint-Amand in January 1968 as a contractor. (Clark, who held a PhD in chemistry from Purdue, would later serve as China Lake's representative to Project Cloudpuff, a tri-service investigation of cloud growth and rain formation conducted at White Sands Missile Range.) Clark's assistant project leader was David H. Dickson, a physicist with the Army's Atmospheric Sciences Laboratory at White Sands Missile Range.

The first of what would eventually become seven Foggy Cloud exercises was conducted in 1968. The objective was to disperse coastal fog (also called advection fog) at Arcata Airport, near McKinleyville, in Humboldt County, California. Like so many of the projects with which the Earth and Planetary Sciences Division was involved, Foggy Cloud 1 was a multi-player operation. Besides NOTS the project involved the White Sands Missile Range, the Navy Weather Research Facility, the Air Force Cambridge Research Laboratory, Cornell University Aeronautical Laboratory, the Federal Aeronautics Administration, the Bureau of Standards, the City of Arcata, and the Humboldt County Department of Aviation.[43]

Experiments were carried out during the summer and fall, the fog season at Arcata. The Earth and Planetary Sciences Division's Cessna 337, with a compact meteorological laboratory installed—the so called Minilab aircraft—was the control and data-collection aircraft. Seeding was done by a WWII-vintage B-26 Marauder (leased from McDonnell Enterprises) with a 1,000-gallon agent-dispersal tank, and a DC-7 with a 3,000-gallon tank. A second Cessna provided photo coverage, and by 1970 a third Cessna was added to the project.

Various agents were used on the fog. Although silver iodide was the chemical agent of choice in NOTS' rainmaking and hurricane-busting efforts, it wouldn't work for Foggy Cloud I, since the warm fog could not create ice crystals. Instead, hygroscopic powders including sodium chloride and calcium chloride were tried, and the best formulation for the task turned out to be a solution of ammonium nitrate and urea (two common fertilizers with a high degree of hygroscopy) in water.

In the initial experiments with the formulation, results began to be seen within 15 minutes of seeding an area directly over the airport. After an hour, conditions had changed from IFR to VFR (instrument to visual flying rules).

43 "Progress in Fog Study by NWC Described," *Bakersfield Californian*, 29 March 1971, 11.

Though the results were not spectacular, they showed that the fog could be dissipated sufficiently to allow aircraft operations if the fog bank were less than 100 feet thick and the wind were at 10 knots or less.

As with any large project, there was the occasional glitch. On 29 September 1969, the pilot of one of the spray aircraft "miscalculated his position," Clark told a local newspaper, and dumped the sticky fog-clearing solution on 15 cars parked at the Arcata Redwood Co. The Navy paid for the car washes.[44]

As Foggy Cloud exercises progressed, a variety of different flight patterns and seeding altitudes were tried. Eventually, the team was able to make significant reductions in fog banks up to 500 feet thick by flying a "dog bone" pattern at 500 feet and with a subsequent on-top seeding when the cloud bank was thicker. Each flight was preceded by the launch of a balloon-borne radiosonde to give the researchers a vertical profile of the fog properties (temperature, humidity, and pressure) and the winds aloft. Airborne data collection continued for an hour after the seeding concluded. Seeding times averaged 30 minutes, during which the seeder aircraft might make 8 to 10 treatments of the fog.

In 1970, the third year of the project, experiments were conducted with a giant Army CH-54 Tarhe helicopter (the military version of the S-64 Skycrane). The downwash from the helicopter's 72-foot-diameter rotor was powerful enough to disperse shallow (200- to 300-foot-thick) fog at the airport. The dispersal was a combination of two phenomena; one was actually pushing the fog aside and replacing it with clear air from above the fog bank. The second was mixing of the dryer air from above the fog with the befogged air, causing the latter to become subsaturated and thereby evaporating the fog droplets. With helicopter downwash mixing, according to Air Force researchers, "the dimensions of the clearings created by the helicopter wake are much larger than the helicopter itself, usually by a factor of 10 to 20."[45]

To augment these two phenomena, the China Lake researchers added a third—a fog-dispersal mechanism. A large tank fitted below the helicopter had been fitted with spray fixtures that allowed liquid (pure water or a hygroscopic mix) to be released into the downwash.

Project Foggy Cloud continued intermittently into the mid 1970s. In 1972 the weather modification team conducted field operations at the Gaillard

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44 "Autos Get Doused by Fog Spray," *The Times-Standard* (Eureka, CA), 1 Oct 1969, 3.

45 Bernard A. Silverman and Alan I. Weinstein, "Fog," in *Weather and Climate Modification*, W. N. Hess ed., John Wiley & Sons, New York, 1974, 369. Saint-Amand reported that this technique had been used to clear fog from the Marine base at Khe Sanh in Vietnam, and Silverman and Weinstein also said (371) that the process was used in military operations in Southeast Asia.

Project Foggy Cloud principals posing with a specially equipped Army CH-54 Skycrane helicopter used in the tests. From left are Colonel Richard Chabot, director of the Army's Atmospheric Sciences Laboratory, White Sands; Dr. Vincent Hanoman of the Army Scientific Advisory Committee; Alex Blomerth, head of the Atmospheric Physics Division, White Sands Missile Range; Dr. Pierre Saint-Amand, head of the Earth and Planetary Sciences Division, NWC; and Dr. Richard Clark, project director, NWC.

Cut of the Panama Canal. This exercise, Foggy Cloud V, was conducted jointly with the Army Atmospheric Science Laboratory, the FAA, and the Panama Canal Co. The Gaillard Cut was chosen for the test site because during the rainy season (generally from May to November), fog in that area causes the canal to be closed to navigation three or four times a week for several hours at a time. Between 1968 and 1971, the canal was closed down by fog an average of 236 hours per year.[46]

Various techniques and devices were tested, including two systems developed by contractors for the FAA. One was a ground-mounted machine that sprayed electrically charged droplets into the fog. (The electrical charge attracts fog droplets, causing collisions and coalescence.) The second FAA item was a ground-based laser nephelometer to measure the size and number of fog droplets.

The helicopter downdraft technique was used in Panama as well. An Army CH-54 from Fort Sill, Oklahoma, was flown to New Orleans where it

46 R. S. Clark, et al., *Project Foggy Cloud V, Panama Canal Warm Fog Dispersal Program*, NWC TP 5542, Dec 1973, 9.

was loaded on a ship and transported to Balboa, Panama, for outfitting with spraying equipment.[47]

This time the researchers used a "9:1 solution" (not actually a solution but a mixture of ammonium nitrate and urea solids with water in a 9-to-1 ratio by weight). Lithium chloride was tested as a dispersal agent both by spraying from a boat and by burning. The dispersal effect of aircraft wingtip vortices (the "wake" of aircraft flying through the fog) was also investigated, as were the fog-dissipation characteristics of electrically charged spheres (initially plastic, later gas-filled bubbles) dispensed from a ground-based machine.

While at first flush the concept of a "bubble machine" to clear fog might sound far fetched, the approach actually had significant advantages over other methods. First, being ground based, it was cheaper and safer than air-disseminated dispersants. Being filled with either lighter-than-air or heated gas, the bubbles were buoyant (or in scientific jargon, had "negative fallspeed") and rose into the fog bank. Second, the material was inexpensive (in the Panama tests automobile exhaust was used with satisfactory results). Third, a bubble requires only about 1/100th the amount of material required to obtain the same surface area as a droplet (the electrical charge is carried on the surface of the liquid). Finally, this method cleared fog from the ground up, which was of value in airport and canal clearing because operations could start once fog had cleared to a sufficient height to achieve visibility, rather than waiting for an entire fog bank to be dispersed from top to ground level.

Evaporation suppression testing (fog prevention, as opposed to dispersion) was also carried out. An aircraft laid down long-chain fatty alcohols in a 5-percent water/alcohol emulsion to form a monomolecular film that coated the Canal water surface, minimizing contact between the water and the air.

A B-26 aircraft was used for seeding with various agents including heated glycerin, a Cessna U-3 provided aerial photo coverage, and the Cessna Minilab aircraft and a Cessna 401 gathered meteorological data. Surface equipment included two instrumented vans (one with a 50-foot high observation tower) and a 73-foot-long modified Landing Craft, Medium (LCM) as a mobile platform for the vans on the canal surface. China Lakers participating in the program included Richard Clark, Tommy Wright, and airborne laboratory operator Richard W. Evert.

Bureaucratic snags delayed the program a month, so there was not enough time left in the foggy season to complete all the tests. Nevertheless, the majority

47 "Sill Fliers To Take Part in Fog Test," *The Lawton Constitution* (Lawton, OK), 28 Aug 1972, 2.

of the objectives were accomplished. The researchers concluded that while large helicopters could clear fog up to 500 feet in depth, the method was not economically feasible for situations such as the Gaillard Cut. Electrically charged ground-dispersed droplets and spheres both showed sufficient promise to warrant a recommendation for further testing.

Evaporation suppression tests showed potential, and further testing was recommended. Dissemination of glycerin (nearly as hygroscopic as the ammonium-urea mixture but nontoxic, noncorrosive, and biodegradable) demonstrated effectiveness in clearing sizable openings through the fog; here too additional testing was recommended. Wingtip vortices showed the capability of cutting through "thin" fog (300 feet thick in the only test conducted). The lithium-chloride tests resulted in a recommendation against further testing; the lithium chloride showed some promise as an obscurant, but "as far as fog dispersal is concerned, better agents are available."[48]

The Panama Canal Co. was interested in the evaporation-suppression approach. The company funded a follow-up program at China Lake the following year in which members of the Polymer Sciences Branch of the Research Department developed a mixture of hexadecyl and octadecyl fatty alcohol that was stable enough for shipping and that could be diluted and applied on site. In 1973, 30,000 pounds of the emulsion were manufactured and sent to the Canal Zone.[49]

In experiments conducted with the emulsion in 1973, difficulties with data acquisition prevented conclusive results from being obtained. However, the researchers stated, "It seems reasonable to conclude that with proper engineering, evaporation suppression by the long-chain alcohol technique may well solve the fog problem in the Panama Canal."[50]

Foggy Cloud VI returned to Arcata Airport in 1974 to conduct more extensive tests on electrically charged water droplets and bubbles and to refine the equipment and techniques used to produce and disseminate the clearing agents. Over the course of 13 test flights, "results . . . were variable, even when the fog or stratus conditions were very good for testing. However, some positive indication that dispersal effects were induced [were] evident from the data."

Reflecting a host of complications encountered with the bubble-generation technology, the researchers recommended that:

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48 R. S. Clark, et al., *Project Foggy Cloud V*, NWC TP 5542, 69.

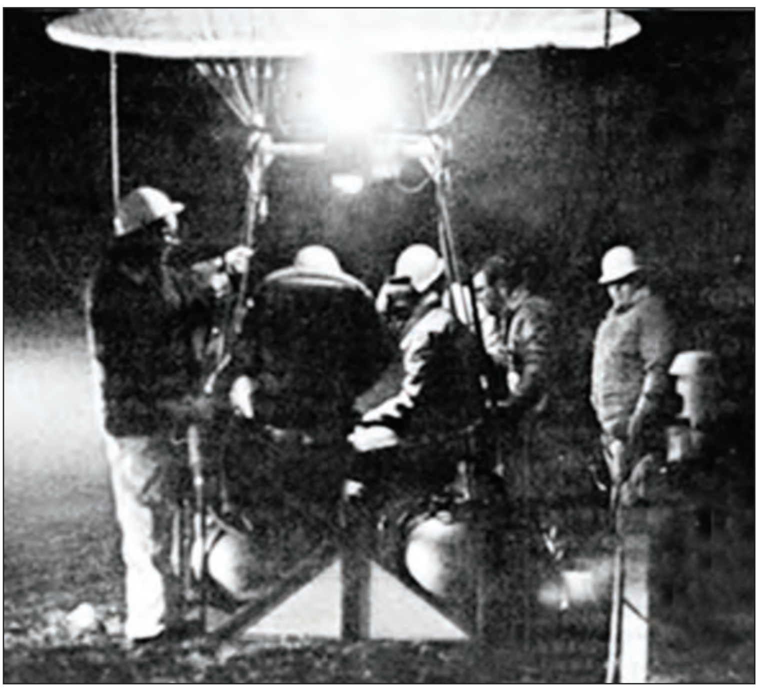
49 "Fog Clearing," *Current Technical Events Memorandum,* 23 Sept 1977.

50 R. F. Reinking et al, *Project Foggy Cloud VI: Design and Evaluation of Warm-Fog Dispersal Techniques*, NWC TP 5824, May 1977, 70.

> . . . since the airborne electrostatic charging system is in a more advanced state of design and gives promise for a more immediate and portable fog dispersal system, it is recommended that further work on the surface dispensing charged-bubble system be held in abeyance until the airborne electrostatic charging system is finalized.[51]

The final phase of the project, Foggy Cloud VII, took place at California's Visalia Airport. By then Clark, who had led the previous Foggy Cloud operations, had retired. He was replaced by Dr. Roger F. Reinking. In these efforts to disperse the so-called Tule fog, characteristic of California's San Joaquin, Sacramento, and Central Valleys, the researchers seeded the fog with lithium chloride as well as with electrostatically charged water droplets. Larry Mathews, Kirk Odencrantz, Jerry Ennis, Chuck Cordell, Richard Evert, and Jack Vanskike also participated in the project.

A B-26 was fitted with an electrostatic induction system that charged the water droplets sprayed into the cloud, causing "rain out" of the cloud's moisture. A second ingenious method of countering the Tule fog was demonstrated at Visalia. Prior to fog formation, the air over the airport was seeded with hygroscopic lithium chloride, forming stratus clouds. The stratus clouds absorbed and then re-radiated some of the terrestrial infrared (heat)



Predawn preparation of hot-air balloon at Visalia Airport. NOTS Foggy Cloud VII participants (from left) are Dr. Roger Reinking, Jimmie Craig, Chuck Cordell, Richard Evert, and Jack Vanskike.

51 Ibid.

radiation, thus reducing the temperature difference between the cool ground and the warm air and inhibiting fog formation.

China Lake's tethered hot-air balloon, piloted by Jimmie Craig, was also a player in the Visalia operation. The balloon carried instruments into the fog to measure such phenomena as heat and energy exchanges and the composition of natural particles that serve as fog-droplet nuclei. The balloon had been used at Arcata in 1971, as a chemical spray vehicle, but had suffered a minor accident and had to be returned to China Lake. (The local newspaper's report of that incident began, "What is red and white striped, carries four men on its underside, is filled with hot air and goes 'fsss' when speared by a redwood?")[52]

Other Experiments and Events

In concert with a private contractor, North American Weather Consultants, NOTS carried out a program to increase rainfall from the Pacific winter storm systems passing over Santa Barbara, California. The program began in 1967, and the early efforts used silver-iodide-sodium iodide acetone burners to generate nuclei, with only marginal results.[53]

In 1968, the researchers used a pure silver-iodide aerosol. It was successful and, "significantly, the increased rainfall in the Santa Barbara area was accompanied by increased rainfall in adjacent regions."[54]

In the words of Doug Elliott, a Yale PhD physicist who spent most of his career in the Earth and Planetary Science Division and who managed the Santa Barbara work, the experiments resulted in "statistically significant and controlled increases in rainfall."[55]

One issue that concerned those in the weather modification business was legal liability. For a December 1964 meeting of the Weather Control Research Association, 24 representatives of government and industry gathered at China Lake to hear presentations on different aspects of weather modification. One speaker was Edward A. Morris, president of the San Francisco-based law firm Bronson, Bronson & McKinnon, who noted the absence of legislation governing weather control. The *Rocketeer* captured the essence of weather-modification liability concerns when it wrote, "It is not hard to envision Farmer John firing

52 "Up, Up and Pop," *The Times-Standard* ,Eureka, CA, 1 Oct 1971, 1.
53 "Weather Modification as a Tactic, Monsoon Enhancement," *Current Technical Events Memorandum*, 23 Sept 1977.
54 *Major Accomplishments*, 116.
55 *Rocketeer*, 23 April 1976, 7. Elliott also directed NOTS' successful drought-relief program in the Azores in 1971. Asked about artificial snow, Elliott, an avid skier, quipped, "My rain is not synthetic, it's artificially enhanced natural rain."

a silver iodide cartridge into the friendly cloud over the back forty—and the irate building contractor on the adjoining tract . . . suing him for costly work interruption." On the scale that the NOTS weather-modification team was operating, the potential liability issues were orders of magnitude higher.[56]

In 1967 the China Lake weather-modification team participated in Projects Hailswath and Cloudpuff. In the former, conducted in South Dakota in cooperation with the South Dakota School of Mines, "considerable success was reported using pyrotechnically generated AgI [silver iodide] to suppress formation of hail in Midwestern thunderstorms." Cloudpuff was a joint operation with the Air Force at Patrick Air Force Base, Florida, to measure cloud parameters and test pyrotechnic mixes "designed for clouds found at the land-ocean interface."[57]

The year 1968 was exceptionally busy for the weather-modification researchers. As well as Foggy Cloud, continuing efforts in Stormfury, the Santa Barbara experiments, and activities in Southeast Asia, the division broke ground for a new building located a few hundred yards south of the intersection of Pole Line and Water Roads, north of Mainside. The $729,000 building consolidated the division's several work sites. One justification for the new structure was to serve as the home for the Joint Environmental Research Unit (JERU), an activity of the division that formalized the many strands of interservice and interagency work.

A photograph with the *Rocketeer* article on the groundbreaking shows an enthusiastic Saint-Amand digging in with his shovel while Hack Wilson and several Navy and Air Force officers look on with smiles. The building was notable for a huge vault in the basement and a glassed-in "penthouse" type structure atop the building, which afforded a splendid view of the Sierra Nevada and the Coso Range.

Over time, the building became known as "Pierre's Palace," and for years a live rattlesnake lived in a glass cage in the lobby.[58]

With all the publicity that China Lake's peaceful uses of weather modification received, one might loose sight of the fact that the primary purpose of the Station's work in weather modification was to serve the military. In some cases—fog abatement, for example—the military-civilian distinction

56 *Rocketeer*, 18 Dec 1964, 10.

57 *NWC Tech History 1967, Part 1,* 2-43.

58 Rocketeer, 31 May 1968, 1. Saint-Amand had a reputation for unconventionality. Former Rocketeer editor Minchen "Mickey" Strang said, "Who else do you know that dyes his goatee green for St. Patrick's Day?" S-170, Minchen Strang interview, 24 May 1988, 3.

made little difference. But Saint-Amand and his colleagues were able go beyond merely facilitating military operations by making airfields and sea lanes safer. They could turn the weather into a weapon of war.

In 1972 testimony to the Senate Commerce Committee, Saint-Amand stated:

> A good deal of the work of the Naval Ordnance Test Station is aimed at giving the U.S. Navy and other armed forces, if they should care to use it, the capability of modifying the environment to their own advantage, or to the disadvantage of the enemy. We would regard the weather as a weapon. Anything one can use his way is a weapon, and weather is as good a one as any.[59]

Fertile minds at NOTS came up with clever concepts. One was a gelling agent that, when dumped into an enemy's water reservoirs, would cause the water to turn to jelly. While this was not properly weather modification, Saint-Amand reported that the technique was actually used in North Vietnam. He added:

> Every time somebody got a bizarre idea they would come to us with it and we would try to make it work. I think that if you're involved in a war, you ought to win or you ought to get out.[60]

Operation Popeye

The only weather-modification program used as an offensive weapon in the Vietnam War was Operation Popeye, in which rainfall was used to disrupt enemy supply lines in Southeast Asia. Popeye may, for better or worse, have had greater consequences for the world than any other program NOTS was ever involved in, except for the Manhattan Project.

Dr. Leonard Sullivan, Assistant Director for Defense Research and Engineering, SEA Affairs, conceived of Popeye in early summer 1966 and suggested it to his boss, Dr. John Foster, who recognized the potential military value of rainmaking. Foster proposed Operation Popeye (also known by the

59 Hearings Before the U.S. Senate Subcommittee on Oceans and International Environment of the Committee on Foreign Relations, *The Need for an International Agreement Prohibiting the use of Environmental and Geophysical Modification as Weapons of War and Department of Defense Weather Modification Activity,* Ninety-Third Congress, Second Session, 25 Jan and 20 March 1974, U.S. Government Printing Office, Washington, DC, 42 (hereinafter referred to as Senate weather modification hearings). Senator Pell referred to the 1972 Commerce Committee hearing and prefaced his restatement of Saint-Amand's comment with "you said, and I quote…."

60 S-301, Dr. Pierre Saint-Amand interview, 27 Jan 2010, 36.

code names Compatriot and Intermediary). The chain of approval went directly from Foster to Secretary of Defense McNamara and thence to the President Johnson.

NOTS was approached with the concept in August 1966. Saint-Amand's team, assisted by NOTS Air Weapons Officer Commander Francis R. Walsh, Jr., immediately set to work.[61]

The principal military target for Operation Popeye was the Ho Chi Minh trail. In a top-secret briefing to Senators Claiborne Pell and Clifford Case in 1974, Colonel Harry "Ed" Soyster stated the program's objectives:

> . . . to increase rainfall sufficiently in carefully selected target areas to further soften the road surfaces, cause landslides along roadways, and to wash out river crossings. These events normally and naturally occur anyway during the height of the rainy season. By seeding it was intended to extend the period of occurrence beyond the normal rainy season and to supplement the natural rainfall as required to maintain the resultant poor traffic conditions.[62]

Initial field trials—dubbed Project (rather than Operation) Popeye—were held in October 1966 over the Laos Panhandle. At the time, Saint-Amand and his Earth and Planetary Sciences Division were in the Research Department. His boss was the department head, Dr. Hugh Hunter. According to Saint-Amand, while the aircraft was being loaded with rainmaking gear at Armitage Field to go to Thailand, he turned to Hunter and said "Hey, you see, something does come of research!" Hunter replied simply, "That's not research."[63]

Research or not, it worked. Saint-Amand's interim report on the project to Dr. Leonard Sullivan (Assistant DDR&E, Southeast Asia Affairs), read:

> Using operational aircraft and units in actual operational situations, Project Popeye was successful, under scientifically controlled conditions, in over 80 percent of the more than 50 tests conducted. Feasibility of project techniques was proven; effectiveness of materials and equipment was demonstrated; tactical value is obvious.[64]

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61 Cdr. Walsh would later receive the Legion of Merit for his work with Popeye.

62 Senate weather modification hearings, 20 March 1974, 89. Senator Case was co-sponsor of the bill less than a year earlier that prohibited further U.S. military activity in Southeast Asia. Soyster rose to the rank of lieutenant general and became Director of the Defense Intelligence Agency.

63 VP 06-054, Saint-Amand, "Doing Something About the Weather."

64 Memo 502/PStA:rr, Reg. No. 50-000315, Pierre Saint-Amand, Test Director Project Popeye, to Dr. Leonard Sullivan, Assistant Director for Defense Research and Engineering, SEA Affairs, "Project Popeye," 18 Nov 1966. Saint-Amand also noted, "In addition to realization of the test objectives, Project Popeye demonstrated the excellent and prompt results which can be achieved by an operationally oriented-interservice-military-civilian experimental team."

The final report on Project Popeye, running 366 pages with appendixes, carefully documented every phase of the complicated and rigorous test program. The logistics were daunting, involving elements of seven different military units besides China Lake, operating from three bases (Da Nang and Pleiku, Republic of Vietnam, and Udorn, Thailand) as well as pyrotechnic-fabrication support from L. Lee Wilson Engineering. The aircraft dedicated to the project were an Air Force WC-130E Hercules, two Air Force A-1E Skyraiders, and two Marine Corps F-4B Phantoms.

China Lake personnel participated in all the operations. Four types of pyrotechnic generators were used, and each ordnance type and ejector had a code name in keeping with the Popeye theme: Sweetpea, Wimpy, Grumper, Olive Oyl, Goongirl, and Bluto. Some sense of the danger and difficulty of the project is captured in the report:

> Only one who has actually engaged in such activity can fully appreciate the problems involved in initially locating and identifying the target cloud on the basis of a minimum of information from the command aircraft and then in maintaining subsequent orientation on the same cloud at levels too low to permit the use of radio navigation aids, often under terrain-avoidance conditions.[65]

"This experiment worked out extremely well," recalled Saint-Amand, "and during that time, in fact, the extra water that we produced was enough to bring the streams up to the point where people couldn't ford them anymore, and it stopped infiltration very effectively."[66]

Again from Colonel Soyster's testimony:

> On November 9, 1966, the Commander in Chief, Pacific, reported the test completed and concluded that cloud-seeding to induce additional rain over infiltration routes in Laos could be used as a valuable tactical weapon. . . . Intelligence analysis of the area indicated that there would be no significant danger to life, health, or sanitation in the target areas. The sparsely populated areas over which seeding was to occur had a population very experienced in coping with the seasonal heavy rainfall conditions. Houses in the area are built on stilts, and about everyone owns a small boat.[67]

Project Popeye became Operation Popeye when the operational phase began in March, 1967. Operation Popeye was conducted during the southwest

65 Capt. James T. Cobb, Jr., USAR; Sheldon D. Elliot, Jr.; et al.; *Project Popeye Final Report*, NWC Doc. No. 50-319, Dec 1967, 70. The document's introduction states that "Project Popeye was the first use of weather modification as an aggressive element in warfare."
66 S S-120, Saint-Amand interview, 10.
67 Senate weather modification hearings, 20 March 1974, 92–93.

monsoon season (extending from March to November) every year for the next 5 years. Using Air Force WC-30 and RF-4C aircraft from Thailand, the project flew 2,602 sorties and expended 47,409 units of cloud-seeding material at a cost about $3.6 million per year. In a takeoff on a popular antiwar sentiment of the day, Air Force meteorologists sometimes called the program "make mud, not war."

Jack Lyons, an aeronautical engineer who had been a Navy fighter pilot in the 1950s, was assigned to Saint-Amand's group during Popeye. Lyons recalled that:

> The Air Force pilots learned about my background with the Navy. I got invited to sit in the driver's seat in the C-130 going through the actual mission. We'd brief in the mornings. It was still dark in a big briefing room. It was wartime situation. . . . the Air Force would drop bombs on the Ho Chi Minh trail, actually just make big craters, they didn't care if anybody was there or not. They just wanted to make a big crater and our job was to come along and fill them with water.[68]

Not a terribly sophisticated technique, but effective.

Research unpublished, goes an old adage, is research wasted. Since the Station's first technical report (*Standardization of Aircraft Metric Photography Technique Using F-46 Torpedo Camera*, by R. V. Adams, Jr.) was published on 14 April 1945, NOTS was a prolific publisher of scientific papers. In 1966, for example, the Station's scientists and engineers published 114 open-literature articles, along with hundreds of technical publications and reports. But when it came to weather modification, there were a couple of problems.

The first problem arose in the earliest days of the Station's weather modification work. Because the Navy researchers were not credentialed meteorologists, but merely physicists, chemists, mathematicians, and engineers, the professional meteorological journals turned up their noses at NOTS' submissions. Undaunted, China Lakers participated in 1950 in the formation of the Weather Control Research Association, an organization that published its own journal. The weather-modification user community—the commercial operators and industrial researchers in the business of trying to fill reservoirs, bring rain to farmers, make snow for ski resorts, and bust fog that socked in airports—eagerly embraced the knowledge of products and techniques that flowed from China Lake.[69]

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68 S-282, Lyons interview, 37.

69 The Weather Control Research Association changed its name to the Weather Modification Association in 1967; it is still active today.

The second problem with disseminating the results of the Station's weather-modification work began with Popeye and the activities in Southeast Asia. Aware that "fooling with Mother Nature" was a potential hot-button issue of great political sensitivity as well as potential international ramifications, the Department of Defense slapped the entire program with the classification Top Secret, Special Category. That meant that even if people had Top Secret clearances, they could not know anything about the program unless they were on a carefully controlled list. The Project Popeye Final Report (the report of the experimental phase of Popeye only, not the operational work) published in 1967, besides being restricted as Top Secret, Limited Distribution, and Not Releasable to Foreign Nationals, contained the following admonition in the foreword:

> The international implications of the work done in Project Popeye are extremely grave because of the possible public reaction to the use of geophysical warfare in what is theoretically neutral territory. Readers are therefore cautioned to observe the rather strict secrecy control imposed on this work.[70]

"We couldn't publish anything about it at all and that went on for years," said Saint-Amand in a 2010 interview. "This led all the wise-asses in the scientific community to claim that we were doing nothing because we hadn't published anything."[71]

Saint-Amand and company couldn't publish, but Jack Anderson could. Anderson was a Pulitzer Prize winning columnist—a muckraker or an investigative journalist, depending on one's point of view. His "Washington Merry-Go-Round" column, which he had taken over from the legendary Drew Pearson, was syndicated in hundreds of newspapers.

On 18 March 1971, Anderson ran a column, "Air Force Turns Rainmaker in Laos," which opened with "Air Force rainmakers, operating secretly in the skies over the Ho Chi Minh trail network, have succeeded in turning the weather against the North Vietnamese." He went on to give a fairly accurate accounting of Popeye (which he called by the Air Force code name Intermediary-Compatriot) and concluded the story with:

> The only trouble with rain, as Jesus Christ pointed out, is that it falls on the just and the unjust alike. The same cloudbursts that have flooded the Ho Chi Minh trails reportedly have also washed out some Laotian villages. This is the reason, presumably, that the Air Force has kept its weathermaking triumphs in Indochina so secret.[72]

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70 Cobb, et al., *Project Popeye Final Report*, iii.

71 S-301, Saint-Amand interview, 10.

72 Jack Anderson, "Air Force Turns Rainmaker in Laos," *Washington Post,* 18 March 1971, F7.

The environmental movement as a political entity was then beginning to gain strength (The National Resources Defense Council was founded in 1970), and there was already a growing public outcry against the U.S. military's use of Agent Orange and other herbicides to defoliate large areas of Vietnam.[73]

When Anderson's column on Popeye was printed, the sleet hit the fan. Senator Claiborne Pell (D) of Rhode Island took up the cause of those who opposed weather modification, stating that:

> Rainmaking as a weapon of war can only lead to the development of vastly more dangerous environmental techniques whose consequences may be unknown and may cause irreparable damage to our global environment. This is why the United States must move quickly to ban all environmental or geophysical modification techniques from the arsenals of war.[74]

On 11 July 1973 Pell introduced Senate Resolution 71 calling for an international treaty to ban "environmental and geophysical modification activity as a weapon of war." The resolution defined such activity in part as activity "which has as a purpose or has as one of its principal effects, a change in the atmospheric conditions over any part of the earth's surface, including, but not limited to, *any activity designed to increase or decrease precipitation. . . .*" [75]

By the time of the 1974 hearings on Operation Popeye, Pell had moderated his stance, but only slightly. He said:

> The thing that concerns me is not rainmaking per se, but when you open that Pandora's box what comes out with it? Will we achieve a technique to be able to both create and point a hurricane or typhoon? Will we be able to do geophysical modification, put a charge under the surface and let the earthquake follow?[76]

Although using weather modification as a weapon of war elicited strong moral reactions, they were not all on one side. Dennis J. Doolin, Deputy

73 The toxic effects of Agent Orange on humans were made public in 1969; by 1971, 20 million gallons had been sprayed in South Vietnam, defoliating 12 percent of the country.
74 Hearings Before U.S. Senate Subcommittee on Oceans and International Environment of the Committee on Foreign Relations, Ninety-Second Congress, Second Session, *S. Res. 281 . . . Proposed Treaty Prohibiting the Use of Any Environmental or Geophysical Modification Activity as a Weapon of War, or the Carrying Out of any Research or Experimentation With Respect Thereto*, U.S. Government Printing Office, Washington, DC, 26–27 July 1972, 4.
75 Senate Resolution 71 (Report No. 93-270), 93rd Congress, 1st Session, 5. Congressional Information Service (CIS) Card S381-18. Emphasis added.
76 Senate weather modification hearings, 20 March 1974, 112. One can assume that the staff at Pierre's Palace considered these more than rhetorical questions. It is possible that Pell or a staffer had read the *Los Angeles Times* article of 26 July 1957 datelined "China Lake" and titled "'Artificial Earthquakes' Set Off in Navy Tests."

Assistant Secretary of Defense (East Asia and Pacific Affairs) commented to Pell's committee:

> If an adversary wanted to stop me from getting from point A to point B so I could do something at point B, I would rather he stopped me with a rainstorm than stopped me with a bunch of bombs.[77]

Saint-Amand, speaking before Pell's subcommittee early in 1974, went to great lengths to point out the positive and beneficial side of weather modification, chronicling the Station's work at fog-control and drought-breaking throughout the world (at one point Pell told him, ""I don't mean to hurry you but it would be about 40 minutes if you read the whole statement").

When the questions turned to the military use of weather modification, the going got trickier. At that time Popeye was still Top Secret, despite Anderson's earlier column, and Pell would not be briefed on it for another two months. Pell asked, "Did your laboratory have any relationship with the weather modification in Southeast Asia that was reported in the press?" to which Saint-Amand replied:

> I am appearing here as a private citizen. I am not authorized to express any opinions whatsoever one way or the other on the subject, gentlemen. I must decline to answer.

He went on to say, however, "To my mind anyone who does anything in support of his government, or economy, in a time of war is a member of the fighting team and is participating in the war," verbalizing what was no doubt the feeling of many at China Lake and, indeed, many employees throughout the government laboratory community.

World opinion was on the side of Pell. In 1977 a treaty titled "Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques" (more commonly known as the Environmental Modification Convention, or ENMOD) was signed in Geneva. Among the 49 signatories were the U.S., USSR, and China. The treaty went into effect in 1978.

On the path to international consensus, ENMOD was weakened from the version that Pell had envisioned. It banned only the use of environmental modification techniques that met at least one of three criteria (known as the

77 Senate weather modification hearings, 20 March 1974, 121. At the urging of Senator Pell, the full 37-page transcript of the 1974 hearing on weather modification, including the detailed briefing on Operation Popeye, was fully declassified within 2 months of the testimony. Today, China Lake's final report on Project Popeye is also declassified and publicly released.

Weather modification research.

"troika")—widespread, long lasting, or severe. Significantly, it banned only the use, and not the development, of such techniques. ENMOD left some wiggle room for smallscale weather operations, what Saint-Amand in testimony before Congress in 1974 had described as "tactical" as opposed to "strategic" uses of weather modification.

But the wind was out of weather modification's sails, so to speak. The end of the Vietnam War and enactment of ENMOD dried up the DOD's research into military applications of weather modifications and thus drew to a conclusion one of the most effective programs in China Lake's history.

Over the decades, many people have questioned why those who worked at China Lake would want to do so. It certainly wasn't for the money; wages in private industry have always been higher. It wasn't for an easy job with the "Silly Service" as the Civil Service was sometimes disparagingly called; the culture of China Lake demanded long hours and total commitment. And it surely wasn't for the location; China Lake, beloved though it may be to those who live there, has never been considered a garden spot, nor does it have the amenities of San Diego, Seattle, Phoenix, Boston, or the Washington Beltway communities.

What would prompt Saint-Amand an his colleagues to work at wages below those of their industry counterparts, sharing their knowledge and techniques not merely through the pages of journal articles but through driving rain, stinging hail, knock-down winds, and slogging mud in countries across the entire globe?

In his statement to Pell's committee, Saint-Amand said:

> The main thrust of my professional work has been oriented toward the safe and profitable use of the environment for human benefit. You may find it odd that one interested in such things is employed at the Naval Weapons Center. The answer is that it has been the policy of the Navy to encourage and support science of use to the country as a whole as well as to the Navy itself. The opportunity to do good and useful work there is at least as great and probably greater than anywhere else in the federal system.[78]

Because of the public, political, and ultimately international response to Operation Popeye, the pursuit of weather modification as a weapon of war was terminated throughout the world, or at least so the ENMOD signatory nations agreed. To Saint-Amand and others this termination was unfortunate because the greatest gains in understanding and mastery of weather control came directly from those DOD-funded efforts at China Lake. Probably no other field of development at NOTS had greater potential than weather modification to make real the metaphor of beating swords into plowshares. While several government agencies and industrial players continued to investigate weather modification for peaceful and humanitarian purposes, the gains made in the 35 years since ENMOD have been less than those made at China Lake in the dozen years preceding it.[79]

And that is not surprising. The constellation of qualities and capabilities that gave the nation Sidewinder and Shrike and Walleye and Popeye—an

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78 Senate weather modification hearings, 1974, 43.

79 According to the Weather Modification Association, weather-modification "research in the U.S. peaked at about $20 million per year in the 1970s, but has dwindled to around $500,000 today." *Weather Modification in the United States*, undated publication of the Weather Modification Association, P.O. Box 26926, Fresno, CA 93729-6926, provided by the organization, Sept 2010.

encyclopedic assemblage of scientific and engineering expertise; co-located laboratories, machine shops, ranges, and aircraft; access to the larger suite of sister-service military resources; disciplined and visionary leadership; and, yes, now and then some financial sleight-of-hand—such a combination could not be duplicated at any government laboratory or private corporation dedicated solely to weather research.

In 1975, Finnegan, Burkardt, Odencrantz, Saint-Amand, and Stanifer were granted U.S. Patent No. 3,915,379 for their work. The title was simple. But it nicely summarized the bold and ambitious goal of their work: "Method of Controlling Weather."

13

Frontiers of Research

. . . the lunatic fringe, the congenital nonconformists, the people to whom any regulations are unacceptable.

— Dr. William B. McLean on NOTS' creative scientists[1]

Charles E. Wilson, Secretary of Defense from 1953 to 1957 under President Eisenhower, was asked by a Senate subcommittee about the amount of money the Department of Defense allocated to research. He responded:

> If we want to go ahead and have pure research, let us let somebody else subsidize it. Let us not put the burden of it on the Defense Department. I am not much interested, as a military project, why potatoes turn brown when they are fried.[2]

Wilson's response reflected the Eisenhower administration's attitude on research at the DOD laboratories as well as the attitude among many military leaders. True, the nation's most ambitious research project had developed the two bombs that won the war in the Pacific. But as Robert Gates put it, "The military officers praised the contribution of science to the war effort, but were usually talking about technology when they said that."[3]

Apparently, Wilson had been referring to a study at the Army's research facility at Natick, Massachusetts. Dr. Robert Frosch, a theoretical physicist and later Assistant Secretary of the Navy for Research and Development, once commented on Wilson's dismissive observation:

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1 "Management and the Creative Scientist," Sept 1959, RM-24, *Collected Speeches of McLean*, 1993, 101.

2 *Pharos Tribune,* Logansport, IN, 29 July 1953, 4. Wilson had formerly been CEO of General Motors. He left his position as Secretary of Defense 4 days after the launch of Sputnik.

3 Robert V. Gates, *Strategic Management of Navy R&D Laboratories; An Application of Complexity Theory*, PhD Dissertation, Virginia Polytechnic Institute and State University, 18 Nov 2003, *http://scholar.lib.vt.edu/theses/available/etd-12022003-195802/unrestricted/GatesDiss112003C.pdf,* accessed July 2008.

> The right answer is: the U.S. Army feeds a million people a day, feeds them potatoes three times a day, and you have to allocate something like, I don't know, half a pound of potatoes per man per day. That's 500,000 pounds of potatoes a day, and potatoes cost ten cents a pound, that's $50,000 a day. My estimate is that we're throwing away potatoes because they turn brown in the process to the tune of 5 percent; that's $2,500 a day. You think I shouldn't spend $50,000 on the possibility of finding out how to save $2,500 a day. You don't believe in saving money.[4]

Skepticism from government and military leaders notwithstanding, one of the principal activities of the Naval Ordnance Test Station from its very founding was research. In early 1943, months before the first spade of dirt had been turned for the facilities at NOTS, BuOrd Chief Rear Admiral William H. P. Blandy said:

> The Station shall be adequate to conduct research and development of all naval ordnance; particularly the application of new and novel scientific developments to naval ordnance.[5]

The Station's establishing document signed by Secretary of the Navy Frank Knox on 8 November 1943 was equally explicit:

> A station having for its primary function the research, development and testing of weapons, and having additional function of furnishing primary training in the use of such weapons.[6]

The roots of NOTS' research mandate reached back nearly 100 years before Knox's memo. On 28 February 1844, President John Tyler, Jr.; Secretary of State Abel P. Upshur; and Secretary of the Navy Thomas W. Gilmer joined other dignitaries aboard USS *Princeton* near Washington, DC, for a demonstration cruise. *Princeton*, pride of the Fleet, was fitted with the Navy's two biggest guns. The larger of these, the 12-inch cannon "Peacemaker," weighed 27,000 pounds.

As the ship cruised the Potomac River below Washington, the Peacemaker was fired twice, each shot bringing a round of applause from the guests. Secretary Gilmer requested a third firing. On that shot, the cannon exploded, killing Gilmer, Upshur, and several bystanders. President Tyler avoided injury only because he had paused momentarily below decks to listen to a champagne-inspired ditty sung by a guest.[7]

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4 Dr. Robert Frosch interview, National Air & Space Museum, *http://www.aip.org/history/ohilist/28066_4.html*, accessed 3 Feb 2011.

5 Christman, *Sailors, Scientists, and Rockets*, citing a 1944 BuOrd internal memorandum.

6 Knox memo, "Naval Ordnance Test Station, Inyokern, California, Establishment of," 8 Nov 1943.

7 Ann Blackman, "Fatal Cruise of the Princeton," *Naval History*, Oct 2005, 37.

Lithograph, "Awful Explosion of the 'Peace-Maker' on board the U.S. Steam Frigate *Princeton*, on Wednesday, 28th Feby. 1844." Published by N. Currier, New York, 1844, now in the U.S. Navy Art Collection, Naval History and Heritage Command.

This incident, later determined to have been caused by the poor quality of the steel used in the construction of the giant cannon, was a seminal event in the creation of the Navy's first test and engineering station at Washington Navy Yard in the 1850s and spurred extensive research into the science of iron gun manufacturing. From that beginning evolved the Navy laboratory system. By 1966, when the position of Director of Navy Laboratories was created, 15 Navy laboratories were operating across the country.

The Problems With Research

Research is a necessary function of the DOD laboratories, but the word "research" comes with many definitions and nuances. For NOTS, and in fact for the entire American military establishment, the word has caused problems. It is seldom found by itself but is usually paired with any of a broad range of adjectives—pure, basic, fundamental, exploratory, supporting, applied, directed—that place the function somewhere along a continuum.

That continuum begins with basic (or fundamental or pure) research, which seeks only to advance science, without regard to the possible applications of the work, and emphasizes theory formulation and validation. At the other end of the continuum is applied (or directed) research, aimed at solving a particular problem for a specific system: for example, determining what seeker-dome material best meets the transmissivity requirements for a specific missile in a defined range of environmental conditions.

In the community of scientists, a certain cachet adheres to the conduct of pure research, where a scientist follows his or her own path of inquiry with no regard for the degree to which that work will benefit the mission of the employer (be it university, manufacturer, or government laboratory). To scientists of that persuasion at NOTS, the mission statement was less ambiguous than they might have chosen. Secretary Knox mandated not simply "research," but research of weapons. Would that include the study of the night sky, which was a focus of NOTS research physicists in the 1950s? Because research was expensive, arguments as to the nature of research and the degree of control that should be placed on it, spilled into the competition for funds.

NOTS Technical Directors continually faced the problem of ensuring that the research paid for with defense dollars was, at least arguably, providing a return in military readiness. Babcock notes that L. T. E. Thompson, the first NOTS Technical Director, "was especially interested in fostering basic research *within the context of a pragmatic technical organization*."[8]

In an interview with *LIFE* (then the nation's top-circulation magazine), McLean summarized both the problem with DOD-sponsored research and what he considered the solution:

> How do you program research? How do you make sure that the research people are working on projects the Navy will be interested in? Well, you select people who will do *good* research. I think any organization as big and as varied as the Navy can't help but use any due result of such people's work. . . . If the guy who is doing the research is any good, he's going to be way ahead of anybody who could review his proposal. And if you've got to pass his proposal through several committees, each of whom understands it less than he did, you can almost be sure that no worthwhile research project will ever get funded.[9]

When the Office of Naval Research was created in 1946, it was assigned the responsibility for basic research in the Navy. However, in order to make the bill that created ONR palatable to the bureaus—Ordnance, Aeronautics, etc.—the actual authority of the new office outside its own organization was greatly diminished. The Senate Naval Affairs Committee, at the behest of the material bureaus, dropped the clause giving ONR authority to control bureau research and substituted a more innocuous provision giving the scientific organization coordinating authority over bureau research programs.

8 Babcock, *Magnificent Mavericks*, 16. Emphasis added.

9 "The Navy's Top Handyman," *LIFE*, 6 Jan 1967, 31. Emphasis in the original.

In 1955 that coordination effort was delegated to a Deputy Science Director for Coordination whose methods included "the creation of formal committees; informal gathering of laboratory and bureau personnel; and study groups, conferences, and seminars." There was no serious external threat to each bureau's control of its own research program.[10]

In the late 1940s, the Station closely examined its research policies and attempted to establish guidelines for the nature and extent of research at NOTS. The locus of the debate was the NOTS Research Board, which had been established in 1946 to review technical programs and advise the Technical Director "with regard to their establishment and conduct." The Board comprised the Technical Director, Experimental Officer, heads of the technical departments, "and such other members as the Technical Director shall designate."[11]

By 1950 the issue of just how "basic" research should be had been thrashed out and was presented in a Research Board paper stating that Station scientists "must have freedom to do a limited amount of basic research" but adding that "the person doing basic research at a developmental center will normally be stimulated along those lines likely to influence the course of development programs." Basic, in other words, but not too basic.[12]

The upshot was, as Babcock writes, that:

> . . . the emphasis at NOTS would be on foundational research, studies undertaken with tangible goals in mind, a category somewhere along the fuzzy border between basic research, with its emphasis on formulating and validating theory, and applied research, with its applications to specific practical problems.[13]

Hack Wilson, McLean's longtime Associate Technical Director and himself Technical Director from 1970 to 1973, told an interviewer in 1982 that:

> . . . we did once have a kind of rule of thumb which we were trying to get the technical organization to about 1,500 people, and from 100 to 150 of those people would be doing research and applied research and probably twice that

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10 Booz, Allen, *Review of Navy R&D Management 1946–1973*, 13, 49. The difficulties ONR faced in straddling the military and scientific communities are examined in Harvey M. Sapolsky's *Science and the Navy: The History of the Office of Naval Research*. See especially Chap. 5, "Managing Naval Science."

11 "NOTS Principles of Operation," 21 Oct 1946, reproduced as Appendix F, *Grand Experiment at Inyokern*.

12 NOTS Research Board, *Summary of the Technical Program*, 21 Jan 1950, 17. Cited in Babcock, *Magnificent Mavericks*, 38.

13 *Magnificent Mavericks*, 13.

> many doing exploratory and advanced development. We were close to that at one time, but the Vietnamese War came along.

The war put the emphasis strongly on the "D" in "R&D" at the expense of the "R"; the 1960s and early 1970s were called by some the "weapon a week" period. By the end of the war, Wilson said, "Probably under the best of circumstances [it] would have taken you 5 years to get back to where it was." And the circumstances for China Lake research at the end of the Vietnam War were not the best.[14]

The Ballistics Division Controversy

Questions about the nature and value of research at NOTS had come to a head in the late 1950s in the context of a nearly decade-long organizational conflict tinged with personal elements. Evelyn Glatt, a member of NOTS' Management Research Division, studied that conflict in 1959 and 1960, then published her results in *The Demise of the Ballistics Division*.[15]

Although NOTS was not mentioned by name in Glatt's book, the Station was described with a level of detail that left no room for confusion. And while the names of the principal players were changed, the guises were thin: Dr. McLean became Dr. Mackay, Dr. Ivar Highberg was Dr. Lindberg, Dr. Duke Haseltine was Dr. Henderson, Dr. Howie Wilcox was Dr. Warner, Lee Jagiello was Lee Jackson, and so forth.

The Ballistics Division, part of the Research Department, was one of the elite organizations at the Station. A disproportionately large number of the Station's finest scientists, engineers, and leaders—Highberg, Haseltine, Jagiello, Doig, Knemeyer, Newkirk, Riggs, Porter, Fojt, Sewell, Rogers—had either started in that division or spent portions of their careers there, and the ballisticians had been involved in virtually all of the Station's major projects. Leroy Riggs once told an interviewer, "We always said that to get places at China Lake you have to have been ex-Ballistics Division or from Idaho."[16]

Many members of the division, which in the early 1950s was run by Highberg, and from 1955 by Haseltine, viewed themselves as research scientists at the "basic research" end of the spectrum. However, some of the work that was being done in the Ballistics Division was directly in support of Sidewinder missile development. Howie Wilcox, however, was not satisfied with the quality

14 S-138, Haskell G. Wilson interview, 10 Aug 1982, 14.

15 Evelyn Glatt, *The Demise of the Ballistics Division*, Institute of Governmental Studies, University of California, Berkeley, Nov 1964.

16 S-136, Riggs interview, 38.

of the results Sidewinder was receiving from the Ballistics Division scientists in the early 1950s, except for those of a young aerodynamicist named Lee Jagiello.

In 1952 the Aviation Ordnance Department (under McLean) set up Jagiello as a consultant, and in 1954 McLean established an Aero Mechanics Branch with Jagiello as its head. In December 1956 Jagiello and his team moved over to the Weapons Development Department under Wilcox, where they were elevated to division status (the Aeromechanics Division).

There was tension between aeromechanics and the ballistics groups from the outset. One source was competition for work; funding for research was limited and precarious. It was difficult enough to "sell" a Washington sponsor on funding some of the more esoteric projects, let alone on supporting two groups that seemed to be doing the same type of work.

Then there was the background of the two division heads involved. When Jagiello came to China Lake he didn't have a college degree (though he later earned a BS in aeronautical engineering and an MS in aeronautics and astronautics). He was a hands-on kind of person with industrial experience.

Haseltine had arrived at the Station at about the same time as Jagiello but with a PhD in physics from MIT. He had begun at a much higher pay grade. Glatt noted that "the Research Department was still regarded by most of its members as an organization of higher prestige than any one of the development departments." There was the flavor of class warfare in this clash between the developers and the theorists.[17]

Dr. John H. Shenk, head of the Research Department since 1949, ignored the conflict. However, Shenk and McLean did not see eye to eye on many matters, and Shenk left for ONR in 1958. As recalled by Dr. Gilbert "Gil" Plain, who served as associate head of the Research Department during Shenk's last 3 years at the Station, "Dr. McLean kind of squeezed him out."[18]

McLean selected Wilcox, who had been running the Weapons Development Department for more than 2 years, to replace Shenk as head of the Research Department. Wilcox was a research scientist. A veteran of the WWII Manhattan Project (working at Los Alamos), he had a PhD in nuclear physics from the University of Chicago and had been a research physicist and instructor of physics at Berkeley. At NOTS, however, he had spent most of his career in the developmental departments. Soon after his appointment to head the Research Department, he added an ominous variant to the already confusing lexicon of research: "trivial research."

17 Glatt, *Demise of the Ballistics Division*, 19.
18 S-108, Dr. Gilbert Plain interview, 9 Dec 1975, 13.

In a paper that Wilcox issued shortly after taking over the department, he elaborated on what he meant by trivial research:

> I suppose one could find, perhaps, examples of research individuals and groups who have frittered away their time and efforts on problems which, even if solved, would not advance man's knowledge in a worthwhile degree.

He gave three categories of such inconsequential problems, the third category being the type of problems that:

> . . . spotlight small islands of slight uncertainty in the midst of a sea of certainty, so that, when answered, they promise to advance our general structure of knowledge not at all. [Such problems are] truly unworthy of the whole efforts of a professional research individual or group, in my opinion, and are better left to be cleaned up by any individuals or groups who may find it necessary in the course of solving their special problems.

Glatt commented, "It was no secret that [Wilcox] considered much of the work of the Ballistics Division to fall in category three."

Jagiello had been arguing to have the Ballistics Division dissolved and its members incorporated into his Aeromechanics Division. Wilcox wasted no time in making that happen. Glatt quoted Wilcox as saying, "As soon as I got over into the Research Department, I had the necessary authority to carry out the change. I made it my first major decision."[19]

Incorporating the former Ballistics Division employees in the Aeromechanics Division was messy. In the March 1959 performance-rating period, seven "letters of warning" (the preliminary step to an unsatisfactory rating) were issued, mostly to former Ballistics Division personnel. Problems with morale, productivity, and sponsor satisfaction in the affected area lingered long after the reorganization.

The elimination of the Ballistics Division pointed up the conflicting views concerning the purpose of research and the difficulty of measuring, in the short term, the value of research—and indeed the value of the researchers themselves. It also symbolized changing times and evolving technology.

With the advent of onboard missile guidance and high-speed computational devices, the need for ballisticians became less critical in the weapons design process.

As Wilcox put it, "They were experts in a vanishing field."[20]

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19 Glatt, *Demise of the Ballistics Division*, 21.
20 S-196, Wilcox interview, 15.

Project Hindsight

Research at the government laboratories was better supported by the Kennedy and Johnson administrations than it had been by the Eisenhower administration. Both DDR&E Harold Brown and McNamara strongly endorsed the findings of the Fubini Commission in 1961, which recommended strengthening the laboratories.

Defense management specifically examined the value of research to DOD in a mid 1960s study called Project Hindsight. The goals were twofold: to identify the management factors important to ensure that research and technology programs were productive and that their results were used, and to measure how much of the increase in cost effectiveness of current programs over their predecessors was attributable to DOD's investment in science and technology. Dr. Chalmers W. Sherwin carried out the project under the direction of Army Colonel Raymond S. Isenson. At the time a lot of money was involved in DOD research. Sherwin and Isenson wrote that:

> . . . in recent years, the Department has been spending $300 to $400 million a year for "research." Of this sum, we estimate that about 25 percent is committed to basic or undirected science, although concentrated in areas generally relevant to the DOD missions, and about 75 percent to applied science more directly related to defined DOD needs. The Department has been spending an additional billion dollars a year for "exploratory development" . . .[21]

Beginning in 1964 teams of technical specialists spent 3 months studying 20 recent successful weapon-system or major-military-equipment programs. The study included government laboratories as well as private companies such as Lockheed and Raytheon. The teams analyzed these programs for "research or exploratory development events," or RXDs, applications of science and technology that had not been used in predecessor systems and that contributed to the increased cost-effectiveness of new systems.

The next step was to trace the science involved in each RXD and categorize it as either "directed" (research done to solve a specific problem) or "undirected" (in the words of the study's final report, "basic research done to expand the frontiers of scientific knowledge").

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21 Chalmers W. Sherwin and Raymond S. Isenson, "Project Hindsight. A Defense Department Study of the Utility of Research," *Science*, Vol. 156, 23 June 1967, 1571. By 1978 the amount spent on basic research had remained level in dollars but had shrunk to about half its size in purchasing power, according to *Report of the Working Group on Basic Research in the Department of Defense*, Office of Science and Technology Policy, 22 June 1978, iv.

From there it was a short step to the principal conclusion. Directed research events paid off in approximately 9 years from their conception, "while it took 20 or more years for some events from the undirected category to impact on development." The report hastened to note that:

> The Hindsight report and other subsequent analyses of the interaction between science and technology have not altered the strong *philosophical* commitment of the DOD to an aggressive, high-quality program of research in the basic science.[22]

There were attempts to "spin" the results of Project Hindsight, which had enough detailed findings to support arguments both for and against research in DOD.

Sherwin and Isenson themselves summarized the Project Hindsight results in a 1967 article in *Science*. Among other things, they noted that:

> What the Hindsight study has done . . . on a scale previously not attempted, is to develop a strong, factual demonstration that recent, mission-oriented science and technology are a good investment in the short term. . . . What we have not been able to do is to demonstrate value for recent undirected science. . . .
>
> It is clear that, on the 50-year or more time scale, undirected science has been of immense value. . . . None of our science Events could have occurred without the use of one or more of the great systematic theories . . . We feel, however, that entirely aside from the research results themselves . . . a laboratory carrying on undirected research, co-located with and skillfully related to an applied research and development organization, more than pays its way. . . . Undirected research serves as a form of postdoctoral training . . . it provides intellectual stimulation and a link between the research frontier and the applied activities; and it provides a body of in-house expert consultants to help on unusually difficult applied technical problems.
>
> In the strongest and most productive mission-oriented laboratories undirected research generally amounts to about 15 percent of the total research effort.

The authors identified 10 organizations as being "prolific contributors of the science and technology upon which the examined weapon systems were based." Among these was NOTS.[23]

One observation not made by the authors was that for-profit industrial organizations—the defense contractors—were unlikely to finance substantial

22 Col. Raymond S. Isenson, *Project Hindsight Final Report*, Office of DDR&E, Oct 1969, iii, iv. Emphasis in the original. Interestingly, the study also found that 95 percent of the RXDs came from DOD-supported S&T activities.

23 Sherwin and Isenson, "Project Hindsight," 1577.

amounts of "undirected research," because the "immense value" of out-year returns—20 to 50 years distant—added nothing to a company's per-share value or positioning in the marketplace. And, unlike the government laboratories, the contractors did not have to permit freedom of research in lieu of competitive wages. To certain creative and talented scientists who were entering the workforce fresh from colleges and universities, opportunities to continue their research projects were as attractive as high salaries. The government and, to a degree, the universities were in the best position to make investments in esoteric fields of research with virtually no short-term payoff, but without which the frontiers of science could not advance.

Managing Research

Management of what McLean called "creative scientists" was no easy task. Many of these were strong-willed characters, and the laboratory research community had more than its fair share of "characters" and "prima donnas."

McLean called the creative people the "lunatic fringe." Elizabeth Babcock titled the third volume of the China Lake History *Magnificent Mavericks* in homage to these individuals. Lieutenant Commander Tony Tambini, a NOTS project pilot, wrote of the civilian scientists and engineers he worked with, "You really never knew what one of these screwballs would come up with next."[24]

McLean looked not at the spectrum of research but rather at the spectrum of researchers. "The creative scientist," he said, "views management in a manner which I believe is different than that of the productive scientist." Of the former, McLean said—perhaps only half with tongue in cheek, since he had been on both sides of the divide:

> . . . these people tend to be a nuisance, or worse, in any smooth-running organization. They want change just to be different. They question even the most obvious actions and take deep delight in finding discrepancies. If they could only learn that such things as company policy might just as well be accepted on faith, life would be so much easier for all of us.[25]

Then-Rear Admiral Dick Ashworth, who, as a captain, had taken command of NOTS the year after McLean was appointed Technical Director, also commented on the management issue. In a 1962 paper on laboratory management, Ashworth—by then BuWeps Assistant Chief for RDT&E—wrote:

24 *The Flying Tambinis*, 8.
25 RM-24, *Collected Speeches of McLean*, 101.

> When we take the trouble to look back at the source of our most effective long strides in weaponry, we find some strange and fearful things. For example, we find the breakthroughs coming with impressive frequency from the people who are very often classified as rebels, dissenters and non-conformists. We in the military, by training and tradition, have been trying to stamp out this kind of mutiny from time immemorial. Yet it is the kind of present day goose that seems to be laying the golden eggs we need for military surprises. This sort of trait is so strong in some of our better laboratory people that, often enough, they do their best work—head and shoulders above the work formally supported—only when they're forbidden to do it. It's a kind of challenge they can't seem to resist. It would be unthinkable to try to manage these people from Washington.[26]

Twenty years later, Bob Hillyer, NWC Technical Director, would observe that:

> Really creative people are almost always, by the standards of the rest of us, characters. Those people that have gotten things out the door and have been inventive—and have been successful at that—are . . . people that largely are willing to take the system on a bit and get something done in spite of it.[27]

And while politicians and senior brass and theoreticians argued and ranted and fretted about what, really, *is* research, and how *do* we measure our return, indeed if any, on our research dollars, NOTS scientists continued to do what government laboratory scientists had always done. Ignore the fray as best they could, find some funding, and get on with the real work.

NOTS Research in the 1960s

When Howie Wilcox moved on to become Deputy DDR&E in 1959, Dr. William S. McEwan, a chemist, took over as the acting head of the Research Department. (McEwan was ably assisted in his new task by his head of staff Harold Turner, whose wife, Nona, was McLean's secretary.)

McEwan would brook no aloofness separating his department from problems on the development side of the house. "The Research Department should be able to help and solve particular problems," he said. But he had a couple of rules. "You got to one, first, find out what the real problem is." Which was not necessarily the problem the engineer might think he had. McEwan's second rule was that the engineer soliciting assistance "must be assured that you're not going to take all the credit for everything. . . . They won't come down

26 Rear Adm. F. L. Ashworth, "Some Thoughts on Better Laboratory Management," 12-page typewritten manuscript, 8 Jan 1962, 4, China Lake History Program archives.

27 S-134, Hillyer interview, 73.

Dr. William S. McEwan.

if they think that you're going to take all the credit."[28]

Although research continued across the board under McEwan—mathematics, chemistry, explosives, ceramics and plastics, physics, oceanography, optics, aeroballistics, and space studies—combustion studies received particular attention.

Unstable burning of rocket motors—combustion instability—had been a problem for the U.S. military since WWII, and as rocket motors became larger, the consequences of combustion instability (unexpected erratic and uneven burning, deflagration, and even explosion of rocket-motor propellants) became more severe. In the late 1950s, Project Vanguard rocket explosions had been a too-frequent embarrassment for the nation. With a multimillion-dollar satellite or a nuclear warhead or a human being atop a rocket, a higher degree of certainty in the launch-vehicle performance was called for than had hitherto been required.

To the lay person, the very nature of the combustion studies conducted by NOTS research scientists was beyond comprehension. Even in such reports as the *Technical Program Review* and its successor the *Technical History*, both of which were aimed at a general technical audience, the descriptions of accomplishments beggared understanding. Typical is an excerpt from a summary of a study of cyclohexal and cycloheptal free radicals in 1959:

> At higher temperatures [than 300°C], these radicals open the ring and intramolecularly form a methyl cyclic radical with one carbon atom less in

28 S-249, McEwan interview. When McEwan was a boy, his family became homeless during the Great Depression and lived in a tent by the Salmon River. He earned money by sculpting animals out of chalk for a nearby fishing lodge. He went on to graduate from Utah State College, become a Rhodes Scholar at Oxford, travel across Europe by motorcycle in 1939, earn a PhD from Harvard, and command an ordnance company in the European Theater in WWII. In 1947 he began a brilliant 29-year career at NOTS, He became a world-renowned propellant chemist. After retirement, he remained in Ridgecrest and had a successful second career as a sculptor for more than 30 years. He died in August 2008.

> the ring; thus a cyclohexyl radical forms a methyl cyclopentyl radical, and a cycloheptyl radical forms a methyl cyclohexyl radical.[29]

To the researchers' peers, however, these studies were perfectly comprehensible. The products created in the Station's laboratories evolved into propellants that delivered better performance and did so more dependably.

NOTS leaders recognized McEwan's contributions in shaping the goals of the Research Department to harmonize with those of the Station and in 1961 presented him with the L. T. E. Thompson Award "for his outstanding role in organizing the Station's program in chemical research, his maintenance of top-level productivity within that organization, and his directing of that research toward the Station's mission in regard to propellant systems for missiles."[30]

In summer 1960 McEwan returned to his former position as head of the Chemistry Division. McLean and Hack Wilson took over the Research Department as joint acting heads, but the leadership was more nominal than directional.

Dr. Gil Plain, who provided stability at the top through eight different Research Department heads in a period of 6 years, recalled that period of joint leadership:

> They said, "We'll share it. As long as Gil is down there, you see, we won't really worry about it . . . if he wants to see either one of us about something, OK." . . . I didn't see them for weeks at a time. . . . but on paper they were "Acting." They said, "We'll assume the responsibility in case something goes wrong."[31]

Early in 1961, Dr. Charles E "Chick" Waring, a physical chemist, was selected to head the Research Department. For the previous 6 years, Waring had chaired the Chemistry Department at the University of Connecticut and had consulted extensively for DOD (including for NOTS).

Waring, a stylish man, was somewhat taken aback by the workaday appearance of the China Lake facilities. Highberg recalled that:

> Michelson Lab sort of looked like an overgrown Quonset hut when he came in. The first thing that he did was to produce a sign for his office that was not a handwritten memo saying who was inside and stuck to the door by a secretary with tape. The next thing was to get some office furniture that looked as if it came out of a newly furnished dentist's office.

McLean caught the spirit of the changes.

29 *Technical Program Review 1958*, 42.
30 *Rocketeer*, 17 Nov 1961, 1.
31 S-108, Plain interview, 13.

> Bill McLean essentially says, "We gotta smarten up the lobby [of Michelson Laboratory], and the present lobby that you see is the result of that effort. Then even my secretary finally says, "We're not gonna let the rest of these guys get ahead," and that's the way it goes.[32]

McLean introduced Waring to the Research Department on 6 February 1961 at a department all-hands meeting held at the NOTS Community Center. McLean took the opportunity to share with the audience "some personal comments concerning my beliefs with respect to the future orientation of the Station's work and the importance of research with respect to achieving the over-all objectives of the Station."

Addressing the ever-sticky issue of precisely how useful research in a military laboratory should be, he was somewhat vague, a vagueness that may have been intentional in light of his intellect and lucidity.

> It would seem to me that the proper climate for good research is an organization equipped with good tools, free communication between various members of the group (including the rest of the Station), mutual respect, and an interest in new ideas. In such conditions, it is very difficult to imagine that the research will not be useful, particularly to an organization whose objectives are as broad as those represented at NOTS. I don't intend to imply by this that the research man should plan his work so that it will obviously be useful, but I do believe that any really new information which comes out of the research work will, without doubt, open many new avenues of approach to the imaginative development man. We should not try to make research work useless.

In speaking of the responsibility of the researcher, McLean expressed his strong belief that "we should give our research people the maximum freedom possible to prosecute those things which they believe important." But he then echoed, though with more restraint, the triviality standard that Wilcox had articulated in his caustic memorandum 2 years before. Said McLean:

> A large measure of freedom, however, does imply some definite responsibilities which the research man must assume. The first of these, I think, is the responsibility to avoid things that are in some sense trivial.[33]

Fourteen months later, in March 1962, Dr. Thomas E. Phipps, Jr., replaced Waring, who returned to the University of Connecticut. Phipps had been acting head of the Physics Division since November 1961, while also holding the position of consultant to the Technical Director and representing McLean to the Special Projects Office in Washington. Phipps had received his doctorate in

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32 S-121, Highberg interview, 19.

33 Remarks at a Research Department all-hands meeting, 6 Feb 1961, RM-24, *Collected Speeches of McLean*, 105–106.

physics in 1951 from Harvard, where he was Phi Beta Kappa and had worked with the Operations Evaluation Group (forerunner of the Center for Naval Analyses).

Phipps was a man of wit. He once described his position at NOTS as a "Supervisory Research Ziontist," citing Nobel laureate Dr. I. I. Rabi's definition: "One who spends all his time proselyting other people in an effort to get them to go to the Promised Land but never goes himself." Years later, in a letter critical of the increasing use of contractors versus laboratories in weapons development, Phipps wrote:

> In my opinion sovereign national military forces will continue to exist and will continue to need in-house laboratories in a world of burgeoning technology and fakery—in much the same way the Tin Woodsman needed an in-head brain. However, the Tin Woodsman was wise enough to sense his need, while our present military services seem perfectly happy to buy their brains on contract.[34]

During Phipps' tenure as department head, the tension between purity of research and contribution to the mission continued. He later wrote that:

> NOTS was a mission-oriented organization, and everything, including basic research, had to be given a coloration of mission relatedness. I always viewed this as somewhat regrettable, because in some cases it failed to exploit the academic training of the "real" researchers. Fortunately, there were enough non-real ones in the department to keep alive a non-faked concept of mission-related work. The non-real ones, incidentally, somewhat resented the real ones, because the former knew they were keeping the bean-counters off the latter's backs. But the latter never showed any appreciation.[35]

Phipps left the Station in September 1964 to work in the office of Dr. Eugene Fubini, Assistant DDR&E, as an assistant to Dr. Chalmers Sherwin (who was then conducting Project Hindsight). Phipps held several research and administrative positions in the Navy and DOD before retiring in 1980. After retirement he returned to his physics roots, publishing two books and dozens of articles that critique the classical approach to physics.[36]

After Phipps' departure, Gil Plain again ran the Research Department until March 1965, when Dr. Hugh W. Hunter returned to the Station to assume leadership of the department.

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34 T. E. Phipps, "A Pilgrim's Progress Report," *News and Views,* March 1967, 7; T. E. Phipps, Jr., "Whither In-House Laboratories?," guest editorial, *News and Views,* Nov–Dec 1968, 6. Actually, in *The Wizard of Oz*, it was the Scarecrow who needed the brain.

35 Dr. T. E. Phipps, Jr., email to the author, 3 Jan 2011.

36 See for example Thomas E. Phipps, *Old Physics for New: A Worldview Alternative to Einstein's Relativity Theory*, Montreal, C. Roy Keys Inc., 2006.

Dr. Hugh W. Hunter.

Hugh Hunter was a veteran NOTS manager. He had received an AB in chemistry (1932) and a PhD in physics (1937) from Indiana University—where in 1929 and 1931 he was a member of the national championship cross-country track team—and had taught there and at the University of Connecticut for 6 years before being caught up in wartime research at the University of California. L. T. E. Thompson had recognized Hunter's potential and, in 1946, lured him to NOTS from a teaching position at the University of Colorado.

By 1959 Hunter had served as head of two divisions, associate head of the Research Department, head of Central Staff, head of the Propellants and Explosives Department, and head of the Propulsion Development Department. He was intimately familiar with the various viewpoints regarding the role of the Research Department, having been the executive secretary for the Research Board beginning under Thompson.

In 1959, Hunter had left the Station to serve as vice president of research at the Research Triangle Institute in North Carolina. Today the organization is known as RTI International, one of the world's leading research institutes, with 3,800 employees working in more than 40 countries. But in 1959 it was in its first year of operation and needed a man of Hunter's skill, experience, and stature to shape its initial research efforts.

What brought Hunter back to China Lake in 1965 was a difference in basic philosophies. He explained that:

> . . . a not-for-profit organization of that sort [RTI] ends up very simply having to meet the payroll. So you start looking for anybody that has money, it doesn't matter too much what he wants done. First you find out if he has money, then you find out what he wants done, then if you can possibly talk him into thinking that you can do it, you get his money.

He contrasted that approach with China Lake's, where "we don't look for somebody with money and then find out what his problem is, we look for someone who has a problem that matches what we think is worth doing. Then, if he has money, we are in luck."[37]

Hunter's pragmatism and experience served him well in balancing the freedom of research with the practical requirements of supporting the Station's larger mission. He recalled that:

> When I got here [in 1965] there had been, for some five or six years, an in and out process in this office with four or five people acting as department head. None of them stayed terribly long and each had his own ideas. And the one thing they all had in common was a fairly complete appreciation of the fact that the research man himself, in his selected field of research, knows what are the important things to do and they kept their hands off pretty thoroughly. I've tried to do that too, and have found more and more difficulty in the last few years in letting the research man call his own shots, simply because we have to demonstrate relevance.[38]

He remained at the helm of the Research Department from 1965 until his retirement in 1976. At his retirement ceremony, he received the Navy Meritorious Civilian Service Award (he had received the L. T. E. Thompson Award in 1971) and was commended "for his outstanding role in the integration and application of fundamental and applied research to the timely solution of complex weapons development problems."[39]

Not all research was coordinated from the Research Department. After NOTS had established a comprehensive conventional weapons program in the early 1960s, the Station received a large increase in funding for applied research in warheads and explosives. Most of this work was administered from Code 40's Warhead Branch, which Bud Sewell had taken over in early 1960.

In the Warhead Supporting Research Program, NOTS researchers from various departments delved into not only warheads but also targets and target analysis, terminal ballistics, explosive formulations, instrumentation, and feasibility studies of new warhead types and kill mechanisms. Topics investigated ranged from fire bombs to focused-energy devices, detonation mechanics to blast damage.

The program, which Sewell coordinated for 16 years, made major contributions to DOD understanding of warhead design and fabrication. Even as the researchers developed more effective warheads for the new weapons being developed at NOTS they also produced hundreds of papers, presentations, and reports, many with esoteric titles such as "Application of Nonlinear Elasticity

37 S-95, Dr. Hugh Hunter interview, 30 May 1975, 25–26.

38 Ibid., 10.

39 *Rocketeer*, 11 June 1976, 1.

and a Flow Law of Plasticity to Plane-Wave Propagation in Metals," that became the technical foundation for advanced warhead designs.[40]

The creation of the Warhead Supporting Research Program provides an insight into McLean's leadership style. Prior to the program, McLean would invariably come to Sewell when a problem arose that involved warheads. But after the program was set up, Sewell recalled:

> . . . the next warhead problem I found Bill had, he didn't bring to me. He took it to somebody else who was off in an area that was away from me, and I felt hurt, and I went to him, and I said, "What's the matter, Bill? What did I do wrong?" He said, "You got funded." I said, "That's what we were trying for!"And he said, "Yes, but I don't want you to think that you have a monopoly." He hated monopolies with a passion. Because in Bill's view, any time any laboratory or any part of a laboratory got a monopoly, they fell behind one year per year in technology.[41]

It may not have been a distaste for monopolies that drove McLean to seek other sources of expertise in warheads. Discretionary funding was precious. Judiciously allocated, it was one tool McLean used to maintain competition and discourage complacency in the NOTS workforce. Discretionary funding of Sewell's early work had resulted in Bureau funding; now it was time to look for new ideas in which to invest.

The Paper Trail

NOTS scientists, at whatever point they were operating on that range of "pure" to "applied" research, were productive during the 1960s. They amassed a wealth of patents, contributed to scientific journals, published books, and worked hand in hand with engineers and end-users to resolve the inevitable technical problems that could not be engineered away.

NOTS' primary in-house vehicle for recording technical progress was the *Technical Progress Report*, which began in 1950. In 1955 the title changed to the *Technical Program Review*, changed again to the *Technical History* in 1960, to the *Command and Technical History* in 1976, and to the *Annual Report of Technical Progress* in 1980. They were all essentially the same annual compendium of the Station's/Center's accomplishments.

While every Navy command is required to publish a *Command History* each year, the requirement for the annual *Technical History* was internal. Most

40 "Application of Nonlinear Elasticity and a Flow Law of Plasticity to Plane-Wave Propagation in Metals," presented to the American Physical Society at the University of California, Los Angeles, Dec 1961, cited in *NOTS Tech History 1961,* 156.

41 Sewell interview by Westrum, 27.

Navy laboratories did not have such a publication; perhaps the academic heritage of the California Institute of Technology underlay the Station's culture of documentation (the product of research, in those predigital days, was paper).

Following a call for submissions early in the year, projects across the Station (except for the most highly classified) reported their progress for the previous year. The submissions were reviewed at the branch, division, and department levels. A bevy of technical editors, illustrators, and photographers in the Technical Information Department edited the submissions and cast them into a uniform format and style.

The resulting document, released in the spring at the Confidential level (sometimes with a Secret supplement), was widely distributed to sponsors, potential sponsors, DOD laboratories, selected contractors, and top brass throughout the Navy. Each issue ran about 250 pages.

The *Technical History* had six or seven chapters, each covering a major area of effort: "The Year at NOTS" (a programmatic and technical summary), "Propellants and Explosives," "Ordnance for Air and Surface Warfare," "Combat Air Weapons Systems," "Exploratory and Foundational Research," etc.

In one randomly selected year—1962—more than 125 separate research projects were reported in the Exploratory and Foundational Research chapter alone, projects in mathematics, chemistry, explosives, materials, physics, oceanography, and space studies. This work was separate from applied or supporting research, which was reported under the appropriate project chapter. For example, the Underwater Weapons chapter in 1962 listed five weapons under development—Torpedoes Mk 44, Mk 46 Mod 0, Mk 46 Mod 1, ASROC, and SUBROC—and 23 supporting research projects, ranging from "Acoustics of Target and Medium" to "Water-Reactive Warhead."[42]

The *Technical History* was only the most visible tip of the paperwork iceberg. A project that submitted a single paragraph for the *Tech History* might have shipped hundreds of pages of reports and documentation to its sponsors and generated thousands of pages of raw data.

The official NOTS publications (formal Technical Publications, or TPs, and interim Technical Memoranda, or TMs) for every project reported in the *Technical History* were listed in a companion volume, the *Bibliography of NOTS Technical Publications*, commonly known as "the Bib." (Not listed but vitally important at the working level were informal Technical Notes, TNs.) The *Technical History* and *Bibliography* series were valuable on several levels.

42 *NOTS Tech History 1962*, ix.

For a sponsor—or a historical researcher—who wanted to trace the history of a specific project, the documents reported a chronological well-indexed summary of important events. For a new Junior Professional employee, the histories were an education, a map of where the Station's technical efforts had been directed and where they were headed.

For the more senior scientist or engineer interested in a new area of endeavor, the books were a quick reference of what had been done at NOTS in that area, by whom, and when. For sponsors and potential sponsors, and for senior military leaders with problems in need of technical solutions, each annual volume summarized the continuously expanding capabilities of the Station and enumerated specific concrete accomplishments that strengthened the Navy's ability to carry out its mission.

For researchers, the Bib was a detailed year-by-year key to the literature produced by NOTS scientists and engineers. In 1967, for example, it presented detailed bibliographic information and abstracts for 224 technical publications, 5 administrative publications, 110 open-literature articles, 17 technical motion pictures, and 56 patents.

World-Class Researchers

The important advances made by NOTS researchers in the 1960s are manifold, far too many to list individually.

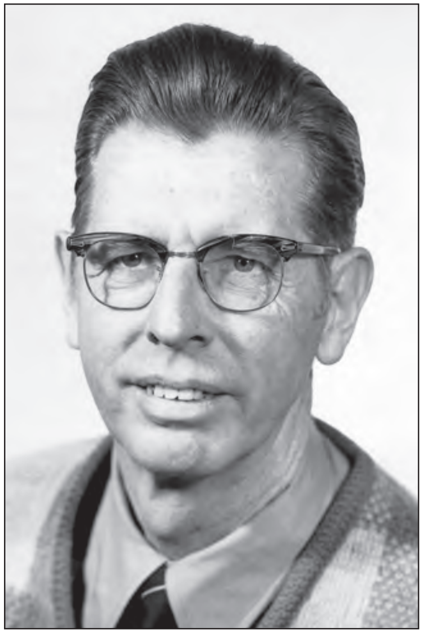
Some have been discussed in earlier chapters: establishment of weather modification as a scientific process; a deeper scientific understanding of the oceans and marine mammals; comprehension and exploitation of the vast potential of the infrared segment of the electromagnetic spectrum; creation of new chemiluminescent compounds that would find applications far beyond their military uses; and fundamental and applied research in explosives, propellants, and pyrotechnics that formed the basis for NOTS' ventures into space as well as for weapons that still serve the nation's military.

NOTS scientists conducted seminal work in many fields. Generally, a single person or a small group at the Station would make a breakthrough and then continue to forge ahead on the new path, establishing a reputation that attracted more work and more funds, which led to even greater advances. McLean and his original Sidewinder team are paradigmatic of this phenomenon, and it was repeated many times in the 1960s.

A few other examples follow.

Combustion Instability

Physicist Edward W. Price was the first to point out the critical importance of understanding combustion instability, a phenomenon that led to the disastrous missile failures that plagued not only weapons designers but also, far more publicly, the U.S. space program. In a seminal paper, "Analysis of Experimental Research on Combustion Instability in Solid Propellant Rockets," presented at Princeton in 1960, Price noted that although some missile and rocket programs had circumvented the instability problem by lowering power output or tweaking the design of the firing chamber—Price himself in the 1940s had demonstrated a method for reducing combustion instability by using noncircular perforations in tubular propellant charges—such engineering approaches were "black magic . . . Success without understanding furnishes little protection from recurrence of the same trouble in future motor designs."[43]



Edward W. Price, 1971.

In 1961 BuWeps officially assigned NOTS the Navywide leadership role in missile propulsion ignition and named Price the technical coordinator for the program. Price would hold several leadership positions in the Research Department, including head of the Aerothermochemistry Division, before retiring to take a position as a professor at Georgia Institute of Technology in 1974—30 years after coming to China Lake in WWII as a Navy enlisted man. Throughout his career he was consulted by the other armed services for his combustion instability expertise, and he helped the Air Force set up an in-house combustion instability capability. At his retirement party, Price was awarded the Navy Superior Civilian Service Award by NWC Commander Rear Admiral Rowland G. Freeman, III.

Price, who had only a bachelor's degree in a department where most of the scientists held masters or doctorates, authored more than 100 papers, articles, and books (including the seminal textbook, *Theory of Propulsion*) during his career at China Lake and invented or co-invented seven devices related to rocket

43 *Rocketeer*, 5 Feb 1960, 1.

motor combustion. He was founder and first chair of the China Lake American Institute of Aeronautics and Astronautics (AIAA) Chapter and an AIAA Fellow.

Among his other honors are NOTS' L. T. E. Thompson Award (1960), several awards from AIAA including the Goddard Award (1974, AIAA's highest honor, given only to a person "who has made a brilliant discovery or series of outstanding contributions … in the engineering science of propulsion or energy conversion"), the JANNAF Combustion Subcommittee Certificate of Recognition (1983), the NASA Public Service Medal (1988), and the NASA Astronauts' Personal Achievement Award (1989).[44]

Detonation Physics

On Christmas Eve 1968, the U.S. Patent Office granted a patent that had been filed nearly 7 years earlier. The patent's title was simply "Explosive Welding." The inventor was listed as "John Pearson, China Lake, Calif., assignor to the United States of America as represented by the Secretary of the Navy."

Explosive welding is the process of bonding two often dissimilar metals by accelerating one into the other using the force of an explosion—the same process used to produce blanks for the nation's first clad (sandwich) coinage in the 1970s. By the 1980s explosive welding was being used in U.S. naval shipbuilding to weld transition joints between steel hulls and aluminum superstructures.[45]

Pearson's explosive welding patent was one of nine that he received during his 32-year career at China Lake. He was the author or co-author of more than 140 technical publications and was one of the few people to have buildings at China Lake named after them (others include Raymond Feist, Dr. Charles C. Lauritsen, McLean, Thompson, Dr. Albert A. Michelson, Dr. Jon Wunderlich, and Carl Schaniel). The Pearson R&D Laboratory (Building 31600, sometimes called "the warhead building") honors the work of a man who was known as the father of explosive welding and who was a pioneer in warhead fragmentation control.[46]

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44 Price was an undergraduate at the California Institute of Technology when he was hired as an hourly employee to work on the Caltech rocket program under Dr. Bruce Sage. In August 1944 Price entered the Navy as an enlisted man; the instant he was discharged in January 1946, NOTS hired him as a physicist in the Rocket Department. He later took educational leave to earn his bachelor's degree in math and physics from UCLA in 1948. He died in Atlanta on June 11, 2012.

45 *Major Accomplishments*, 103.

46 When the decision was made to name the building for Pearson, a problem came to light: China Lake policy did not allow a building to be named for a living individual. Thom Boggs, head of the Research Department's Engineering Sciences Division, which was located in the building, chose to ignore the policy—or as he phrased it, "to hell with

John Pearson at his desk, China Lake, 1976.

Pearson's official biography describes his areas of expertise as "scientist and engineer in the general area of detonation physics [including] the behavior of explosive-metal systems, physical and metallurgical properties of impulsively loaded materials, stress waves and fracture, terminal ballistics, and dynamics of warhead behavior, and the initiation and detonation processes of explosives." Because of his breadth of knowledge in explosives-related matters, he assisted in post-event investigations for not only the Navy but also for NATO, the National Transportation Safety Board, and the Los Angeles Police Department.[47]

As head of the Warhead Research Branch in the late 1950s, Pearson, with NOTS metallurgist Edward W. LaRocca, discovered a process called the

regulations"—and had the Public Works Department paint the sign and fabricate the lettering proclaiming the building the Pearson R&D Laboratory. Pearson retired from China Lake in 1980 but continued to work as a rehired annuitant for many years thereafter. He died on 31 Oct. 2011.

47 John Pearson official NWC biography, circa 1990. China Lake History Program archives.

"explosive press" while engaged in a program, begun by NOTS in 1951, to study the application of explosives to other than destructive purposes. When Pearson announced the breakthrough in a 1958 press conference, he unleashed a flurry of excitement in manufacturing circles.[48]

Pearson also investigated the use of explosives for other metalworking applications, such as explosive extrusion and explosive forming (see the description of forming the SEALAB end-bell in Chapter 11). His research was a major advancement in the field of metallurgy and created a new set of tools for industries around the world.

He further advanced the Navy's mission through his expertise in the design of shaped charges and fragmentation warheads. In 1965 he earned the L. T. E. Thompson Award "for outstanding basic and applied research in the fields of impulsive loading, explosive metal working, and warhead behavior, which has contributed highly to the advancement of ordnance, the fulfillment of the Station's mission, and the defense establishment as a whole."[49]

In the late 1960s, he invented the so-called Pearson Notch, a means for controlling the size, shape, and mass of warhead fragments. His patent "Improved Means for Controlled Fragmentation," filed in 1970, was granted in 1978. This discovery greatly improved the effectiveness of antipersonnel and antimaterial fragmentation warheads, and it was cost effective. In 1985 then-Technical Director Burrell Hays estimated that this invention had saved the Navy in excess of $4.3 million.[50]

When Pearson was presented with the Navy Superior Civilian Service Award in 1984, Dr. Edwin B. Royce, then head of the Research Department, said, "John and the work of his division have had a profound affect on the ordnance work of the U.S. and her allies." In 1989 Pearson was made the first Distinguished Fellow of the Naval Weapons Center.[51]

Optical Properties

Dr. Harold E. "Hal" Bennett and Dr. Jean M. Bennett came to NOTS in 1956. Hal had earned a double-major (mathematics and physics) BA, with honors, at Montana State University. Jean had received her BA in physics and

48 The Warhead Research Branch moved from the Weapons Development Department to the Research Department in 1958. It became the Dynamics of Solids Branch in 1959, Detonation Physics Group in 1960, and the Detonation Physics Division in 1966. Pearson headed the organization from 1955 to 1979.

49 *NOTS Command History* 1965, 28.

50 *Rocketeer*, 28 June 1985, 7.

51 *Rocketeer*, 29 June 1984, 1.

Hal and Jean Bennett with a fairy shrimp specimen, 1963. Maturango Museum photomontage.

chemistry (*summa cum laude*) from Mount Holyoke College. They met and married as graduate students at Penn State, where both received their master's degrees and doctorates. (Jean was the first woman to receive a PhD in physics at Penn State.)

The Bennetts' first positions outside of academia were as physicists at the Air Force's Wright Air Development Center. Jean recalled that:

> The lab was full of Civil Service people who were technically incompetent. They represented the worst of Civil Service, and they were not fun to work with. The laboratory was not set up to do research because in order to even have something as simple as a screwdriver, you had to fill out a nine-part stub and wait 6 months.[52]

As one would expect, Jean approached the search for a new job scientifically:

> I went through the current issues and back issues of optics journals . . . I looked at the affiliations and the locations of the people that were doing what I considered was interesting work.

52 S-184, Dr. Jean M. Bennett interview, 19 July 1990, 3.

One such person was Dr. Wilfred F. "Rick" Koehler at NOTS, whom Jean had met at Penn State. She contacted him, and Koehler agreed to look for billets at the Station. While participating in an IR measurement program at Pike's Peak, the Bennetts met Raim Regelson, one of NOTS' leading innovators in the field of IR measurement and exploitation. He assured them that they would find the work at the Navy's desert lab exciting and challenging.

The following month, October 1956, the Bennetts went to work at China Lake.

By 1960 Hal was head of the Physical Optics Branch. He took on the additional duty of associate division head in mid 1971, and in 1982 he became head of the Optical Components Technical Program Office. Jean eschewed a line-management position and devoted herself to research in pursuit of super-smooth optical surfaces and an understanding of the optical properties of solids until her retirement in 1995.

Although, as the Project Hindsight report observed, pure or fundamental research has the slowest payback time, the work the Bennetts were engaged in coincided with a rapid integration of lasers and optical technology into new weapon systems. Hunter, their department head, said:

> The net result is that we've got about 25 people in the Physics Division working in related subjects tying in pretty closely with the questions of high-energy laser systems. In that case the world hunted us up.[53]

In much the same way that Koehler's work drew the Bennetts to the base, so did the Bennetts' work attract national and international attention. Both Bennetts were Fellows of the Optical Society of America (OSA). Jean served as the first woman president of OSA (1986) and received OSA's David Richardson Medal for distinguished contributions to applied optics (1990). Her research generated more than 100 papers that defined the expanding boundaries of her discipline, as well her book *Introduction to Surface Roughness and Scattering* (co-authored with friend and colleague, Dr. Lars Mattson of Sweden), and three patents.[54]

Both Bennetts received China Lake's highest honors, including designations as NWC Fellows and L. T. E. Thompson Awards. Both were invited to address

53 S-95, Hunter interview, 12.

54 In a tribute to Jean Bennett on the OSA website (*http://www.osa.org/en-us/about_osa/newsroom/obituaries/bennettjean/*) after her death in 2008, Boris Stoicheff, 1976 OSA president, wrote, "Jean Bennett was a pioneering figure in optics, not least in being the first woman to be president of OSA (after a long line of some seventy-odd more or less elderly white males)."

prestigious gatherings throughout the world. And as a recruiting tool—starting salaries aside—few organizations or other government laboratories could offer a newly degreed optics professional anything as enticing as the opportunity to work with the Bennetts.

Broad-Spectrum Researchers

It is notable that researchers themselves were divided on the need for compartmentalizing research into discrete categories; many carried out basic and applied research and followed on into exploratory development.

Ed Price noted that Physics Division Head Rick Koehler's "insistence on basic research" led Price, Saint-Amand, and Pearson to become "escapees" from Koehler's division: Price to the Aerothermochemistry Division, Saint-Amand to the Earth and Planetary Sciences Division, and Pearson to the Detonation Physics Group. Price observed that "a 'broad spectrum researcher' will select relevant basic research and carry it through to application fast, and it helps if management knows this and at least does not get in the way."[55]

Plain, Pearson, the Bennetts, Alpers, Saint-Amand, Austin, Engel, McEwan, Lang, and others mentioned in this book are representative of a larger group of NOTS scientists whose expertise ranged from astronautics to zoology. These researchers, from the ones who never left the laboratory to those who had the grease of projects ingrained beneath their nails, made an impact on the world. They served the nation not only by contributing to the weapons that preserved U.S. military dominance but also by opening doors to new possibilities—from balancing satellites in outer space to tunneling the bedrock beneath the ocean's bottom.

They did not hesitate to tackle the most difficult problems, measured in angstroms or in the span of a South Atlantic hurricane. The technologies whose foundations they built—with endless experiments, journal articles, technical presentations, books, and, of course, pleading for continued funding of their specialized projects—spread from the military into the wider world of commerce and industry.

Asked what China Lake's most important contributions had been over the years, Pierre Saint-Amand did not talk about rockets and bombs and missiles. Instead he spoke at length about chemistry, both applied and theoretical, and computer programs for predicting combustion processes, and optical polishing, and nonsteady-state thermodynamics theory, and topology, and statistical validation.

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55 Edward Price email to the author, 21 July 2011.

He offered his opinion that:

> These things go unnoticed because they just appear in the scientific literature or are used elsewhere, they don't have a name and they're not a product, and you can't take a picture of it exploding . . . But that is the sort of thing that was really valuable.[56]

What IS in a Name?

Although "research" appears before "test" in the NOTS charter—as it has in every China Lake mission statement to the present day—the use of the term "Test Station" in the organization's name was a source of dismay for some NOTS military and civilian managers from the very founding of the Station. The implications of the term chafed on them, much as did the word "Annex" for those who worked at NOTS' Pasadena Annex.

The Station's first Technical Director, L. T. E. Thompson, summarized the problem:

> Quite well back during the crystallizing of the essential concepts in which this center was to grow, there was some discussion that the name was a handicap. It seemed to imply that all of the research and development work and much of the supporting analytic work would be done in some other place and that this is a very well equipped center for going down and "trying something out." Now that was not the kind of a place we started off with in late '45, never has been, but by the time a concerted effort was developed to get the name changed, and there was some correspondence about it, it had become fixed.
>
> . . . in the early days the thought was quite generally held that the name of the Station should be Naval Ordnance Development Center or something of that kind."[57]

Even before the Station was established, then-Commander Sherman E. Burroughs, (who as a captain would be NOTS' first Commanding Officer), expressed his views on the Station's name to his superiors in the Bureau of Ordnance:

> I offer no objection to designating this Station as now proposed "Naval Ordnance Station" provided that it is understood by all concerned that no test or proof work of any nature will be placed on this Station that will in any way interfere with the primary purpose of this facility; namely, the test and development of air weapons and their evaluation.[58]

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56 S-120, Saint-Amand interview, 35.

57 S-15, Dr. L. T. E. Thompson interview, May 1966, 13-14.

58 NWC TS 67-259. *Naval Weapons Center Silver Anniversary*, 1.

The name "Naval Ordnance Test Station" was accurate insofar as it reflected what had been a major wartime mission of NOTS, which was to test rockets for Caltech. But the name did not conjure up the far broader mission that was anticipated for NOTS' post-WWII service. Al Christman, who authored Volume 1 and co-authored Volume 2 of this history, thought that the somewhat misleading nature of the name might be intentional. He related a conversation with Burroughs on the subject, more than 20 years after the Station's establishment:

> [Burroughs] felt that there was at some early period a feeling, well why, if we have something like a Peenemünde here, why put a big tag up here and say that this is the Navy's biggest research and development center. . . . Maybe it's best we continue this Test Station name as a kind of cover.[59]

The cover would be less from foreign enemies than from other Navy laboratories back East, where the political power of the Navy's research and development community resided.

McLean, who abhorred compartmentalization of organizations, whether branches or government laboratories, thought the name was inappropriate. He explained his view in a 1961 presentation:

> We find ourselves continually faced with the problem of explaining why a "Test Station" should be heavily concerned with everything from basic research through the time when the equipment we have conceived is being used in Fleet operation. Because of this confusion, we have been anxious for many years to change the name from "Test" to a term which would have broader and more all-inclusive connotations. These attempts at name change have for various reasons been unsuccessful.[60]

Before the dedication of Michelson Laboratory in 1948, BuOrd had nixed the idea of renaming NOTS the Michelson Laboratories. Over the years, other names had also been suggested, as detailed in preceding volumes, but not adopted.

For physicist and senior NOTS manager Howie Wilcox, the Station's name was a nonissue. In 1991, he contrasted his view with that of Dr. Frederick W. Brown, NOTS' second Technical Director, who wanted the name changed to the Naval Ordnance Research and Development Center:

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59 S-15, Thompson interview, 16. Peenemünde was the German Army's research center where the V-2 rocket was developed and produced. Dr. Wernher von Braun was the Technical Director.

60 "The Mission of NOTS," presented to the Kern, Inyo, and San Bernardino County Supervisors and Members of the Death Valley Forty-Niners, Commissioned Officers' Mess, 20 Jan 1961, RM-24, *Collected Speeches of McLean*, 63.

> He [Brown] put his time in on problems that didn't seem to me to be problems. . . . for example, what should be the name of the Station. See, the 'Naval Ordnance Test Station'—it just didn't convey the prestige that the Navy's foremost research and development center should have had. You shouldn't have had this name Naval Ordnance Test Station. That was a very mediocre name. . . . Of course, from where I sat, who cares what the name of the Station is? We've got the job, let's go do it, and that's it.[61]

In May 1958 NOTS entered a float in the Tehachapi Lilac Festival, an annual event in the little mountain city about an hour and a half's drive southwest of the Indian Wells Valley. On the side of the float (which carried RAT, Zuni, Sidewinder, Mighty Mouse, and a 12-foot-tall mechanical man) was the acronym NOTS spelled out as "Naval Ordnance Through Science." That same translation of the acronym was displayed on the back cover of the souvenir brochure produced for President Kennedy's visit in 1963.[62]

The "Michelson Laboratories" faction persisted, and during the mid 1960s several films and publications were produced under the name of "The Michelson Laboratories at China Lake."

In 1966, a new award, the Michelson Laboratories Award, was instituted to complement the L. T. E. Thompson Award, the Station's highest.[63]

All internally generated efforts to change the Station's name proved unsuccessful. Captain John Hardy, NOTS Commander from 1964 to February 1967, asked about the issue during the last month of his tenure, answered that:

> This is just a question of growing up. The name, even though test is in the name, no longer has the same connotation to people anymore because you can point to so many things that have come out of NOTS that are products that have started with concepts and gone all the way through. Without any change in the name, people realize at this stage in history what the Station really is.

When Hardy was asked what he thought of "getting people to think more in terms of Michelson Laboratories" he responded:

> I think our emphasis on the Michelson Laboratories is a good one. I think it's real nice to have the laboratory, as such, involved in all of this. . . . this business

61 S-196 ,Wilcox interview, 24-25.

62 "Naval Ordnance Through Science" shows up again as a banner head on a 1987 *Rocketeer* special edition celebrating the Navy's 212th birthday and the 44th anniversary of the Station's founding. By then—after two decades as the Naval Weapons Center—the naming controversy was long past.

63 Over time, the award has come to be known as the "Michelson Laboratory Award" (singular), and so reads the certificate that accompanies it. However, the plaque presented to each recipient, as of this writing, still uses the plural "Laboratories."

> of tying ourselves to products basically from the concept all the way up to fruition, and following them right on into the Fleet . . . Now this 'laboratory' is not quite the right connotation for that. So the laboratory kind of offsets the test operation and you have some of both, but I don't know how you get in this whole cradle-to-grave concept, as far as the name is concerned.[64]

Ironically, less than five months later, the question of "how you get in this whole cradle-to-grave concept" was answered when a more encompassing, less compartmentalizing name was formally announced. With the disestablishment of NOTS on 1 July 1967, the Navy's premier cradle-to-grave weapons development facility became officially known as the Naval Weapons Center.

64 S-34, Hardy interview, 13–15.

14

Growing Pains

When your lawn dries up in the summer, mine does too.

Dorothy Fettar, *Valley Independent* columnist[1]

Long before the term "corporate culture" came into vogue in the early 1980s, China Lakers knew they were different. Nearly everyone lived, worked, and played on the base (although they generally went to Drummond Hospital in Ridgecrest to have babies or to die).

Folks had the clear sense that their way of life was different from that of their government and industrial partners, and they were correct; China Lake's isolation had created a culture that was sometimes jarring to visitors and often an irritant to those steeped in the more traditional culture of the government laboratories and bureaucracies "back East."

China Lakers didn't play the game like everyone else did. They looked to results, they valued functional solutions to Navy problems above commendations, and their single-minded approach to serving the Fleet often put them at odds with the Navy establishment. As an editorial in *Defense News* put it:

> China Lake long has been the prickly pear of the Navy's R&D bureaucracy. The intelligence, innovation, and, yes, the guile that are necessary to score a few victories in a hierarchy as large as the Defense Department's are the very same qualities that make for lousy bureaucrats.[2]

Visitors expecting to see the same sort of bureaucratic caste system at China Lake that they found at other government laboratories were disappointed. Rod McClung observed that:

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1 Dorothy Fettar, "Small World (News and Views of the Indian Wells Valley)," inaugural column, *IWV Independent and Times Herald*, 8 Jan 1959, B1.

2 "Sneak Attack at China Lake," *Defense News*, 10 March 1986, 3. The editorial discussed the ouster of China Lake's Technical Director Burrell Hays by Melvyn Paisley, Assistant Secretary of the Navy (Research, Engineering, and Systems). Five years later Paisley was convicted, fined, and sentenced to 4 years in prison for taking hundreds of thousands of dollars in bribes while in office.

> Nobody ever called anybody "Doctor." In fact, someone came through my lab from Washington one time and commented, "It's absolutely inconceivable that you're doing the caliber of work here and having nobody but technicians." Where he came from, the professionals all wore suits.[3]

James Colvard observed, "When you're out drinking beer, you're all equal. You're beer drinkers. . . .You play together, work together, and you don't take yourself too seriously." The informality was deceptive. What China Lake employees did take very seriously was their work. Many outsiders had difficulty harmonizing the ability of a workforce—Technical Director included—to accomplish tremendously difficult technical feats while treating organizational structure, administrative procedures, and traditional lines of authority as, at best, necessary evils.[4]

Uniqueness notwithstanding, China Lake and the people who lived there were not impervious to change, and the 1960s was a period in which the outside world began to exert a strong influence on life in the Indian Wells Valley. The isolation of the remote desert, that long drive required to get just about anywhere worth going, continued to nurture a sense of life in an oasis—or on a desert island, depending on one's attitude. But from the end of the 1950s on, the larger national culture began to have a telling impact on behavior and attitudes.

Television's proliferation and its insinuation into the fabric of the family was a principal contributor to those inroads. As the '60s progressed, the nightly news carried gritty footage of blood-spattered Medevac helicopters in Vietnam and of marijuana-smoking hippies in the Haight. Children of NOTS employees, the postwar baby boom now turned teenagers, began to question their parents' attitudes on subjects as diverse as consumerism, sex, war, music, drugs, competition, and race relations. The Beatles—"the mop-top group from England," as the *Rocketeer* called them—seduced the youth of China Lake and Ridgecrest as effectively they did youngsters throughout the country. Popular movies like *Dr. Strangelove* and *Lilies of the Field* and *Easy Rider* gave people pause to reexamine old presumptions and stereotypes. As Bob Dylan said, the times were a-changin', although, at China Lake, maybe not quite as rapidly or dramatically as on the coasts.[5]

One of the changes that began in the 1960s and that would have a profound and permanent impact on China Lake culture, however, had nothing to do with national or international influences. It was based in the fulfillment of a

3 S-188, McClung interview, 20.
4 S-285, Colvard interview, 27.
5 *Rocketeer*, 11 Sept 1964, 3.

fundamental human need that had not been adequately addressed in the Indian Wells Valley since the base's founding. It was a revolution in housing.

Housing

Finding adequate homes for China Lake's civilian employees had been a problem at NOTS since the base was established in 1943. A 1945 *Los Angeles Times* article reported that 1,300 people were living in dormitories at China Lake while some 14,000 others—Station employees, construction workers and their families, local merchants—lived outside the gate, primarily in Inyokern, a few miles down the road to the west. (Inyokern boasted 18 restaurants at the time, 15 more than in 2011.)

The *Times* article, colorfully headlined "War-Born Boom Town of Inyokern, Where Residents Clamor for Meat," reported an interview with NOTS Chief Commissary Steward James Duncan, who urged an Office of Price Administration inquiry into local rents. "A friend of mine rented a two-room cabin the other day for $40 a month, unfurnished. It has one room 8 x 12 and another 10 x 12, with no bath or toilet and only one light," said Duncan. A front-page photo accompanying the article shows a sea of shacks and tiny trailers that seems to spread to the horizon.[6]

Calvin J. "Cal" Fallgatter was a Navy dive bomber pilot during WWII. He had visited NOTS to train in the use of Caltech-developed air-to-surface rockets and had subsequently fired those weapons against Japanese forces at Rabaul, New Guinea. After his plane ran out of fuel on a carrier approach and crashed, near the end of the war, Fallgatter spent time in a hospital in Washington and then followed his wife's parents to China Lake. He became housing administrator (later head of the Housing Division) in 1946 and stayed in that position until 1976. Fallgatter recalled that:

> At one time, in 1946, there were approximately 1,200 bunks in use [at China Lake]. And some of those could have been married couples in different buildings. That wasn't unusual. There were many families that didn't even come up here initially. Just the husband would come and he would live in single quarters.[7]

Added to the other hardships of desert life, the housing situation was hardly conducive to recruiting scientists and engineers who wanted a normal family life and a place to raise their kids.

6 *Los Angeles Times*, 27 Feb 1945, A-1, A-6.
7 S-110, Calvin J. Fallgatter interview, 6 Dec 1976, 15.

Over the years the situation improved somewhat through piecemeal acquisition of dormitories and housing units at China Lake—200 prefabs were trucked in at the war's end; a few score woodframe units that had been built during the war for the Vanadium Mining Co. at Pine Creek, near Bishop, were transported to the Station; 300 Hawthornes (named after a style of home built in Hawthorne, Nevada) were built in 1947; 150 Normac duplexes were constructed in 1950; and 300 Wherry units (so named for Senator Kenneth Wherry, the sponsor of the 1949 legislation that allowed them to be constructed by private developers with government-insured loans) were built at the southeast end of the Mainside area in 1953. Still, demand far outstripped supply; there was never enough adequate housing to go around. As newer homes were constructed, some (not all) of the older substandard housing was demolished. Fallgatter explained that:

> The basic requirement [established by DOD] was that you are never supposed to have more than 90 percent of your needs. So technically, you would always be short 10 percent. You'd say, "Well, where are all those people supposed to be, in substandard houses?" Well, there weren't that many substandard units. Were they supposed to be out walking the streets or where? So we had that hurdle to always overcome.[8]

Inadequate housing was a focal point for discontent. In 1951 a letter from a China Lake resident to the NOTS Commander, Captain Walter V. R. Vieweg was printed in the *Rocketeer*. The writer complained that "The sight of house trailers parked like a shantytown instead of neat housekeeping apartment units does not give a pleasant effect to the Station" and observed that "FHA housing off the Station would be, in the long run, more satisfactory, as then employees could own their own homes and enlarge as required."

Vieweg replied that the Station was trying everything it could to improve the situation:

> Your belief that FHA housing off the base would be more satisfactory is concurred in by the Commander. The Command has done everything possible to encourage development of communities in the Ridgecrest area where employees may become home owners.[9]

As in any situation of limited resources and growing demand, there was competition, and grumbling, over the housing assignments at China Lake. At first, allocations were controlled by the individual NOTS departments (which led people to transfer from one department to another if they could obtain better accommodations). In 1950 the community manager was assigned to

8 S-110, Fallgatter interview, 21.

9 *Rocketeer*, 24 Jan 1951, 1, 5.

Deteriorating 1940s-era prefabricated housing units off Richmond Road, 1960. B Mountain, complete with painted "B," is in the background.

manage the housing situation, and a system was established in which eligibility was based on seniority and family size.

Captain Frederick L. Ashworth, NOTS' Commander from 1955 to 1957, realized how important adequate and affordable housing was in attracting and retaining professional employees. He spent considerable time and energy during his tour trying to convince the bureaucracy in Washington to recognize the exceptional circumstances of life in the remote desert, to increase the allocations for housing and related infrastructural improvements, and to keep rental rates lower than the rates established by standard DOD formulas for civilian on-base housing.

In 1962 Ashworth (by then a rear admiral) wrote of the housing problem in a paper on laboratory management:

> One of our laboratories was established in a remote area of the great American desert. The technical staff was recruited by appeals to their patriotism and compensatory benefits for the sacrifice of living in huts and enduring the hardships of the desert environment. Then a parasite community grew up just outside the reservation. Now the poor citizens trying to earn a living in competition with governmental support inside the fence became the "good guys" and the sheltered and pampered civil servants feeding at the public trough became the bad guys. . . . Every two years . . . the rents are re-appraised

> and inevitably raised. At this particular Station there are no houses available for purchase, so year after year our Civil Service scientists have nothing to show for their money and inevitably receive the equivalent of a biannual pay cut, as they dig deeper for the rent. At the same time, with decreasing Station support funds, our rent-paying scientists see less and less maintenance, the usual manifestation of taxes paid. In response to reclama [a request for reconsideration], we are quoted a federal statute of 1871, which states that Civil Service employees shall not be given subsidies by way of preferential rental standards."[10]

Of his efforts to promote better housing during his tour at China Lake, Ashworth later said, "I suppose people felt that I was kind of a Judas amongst the military hierarchy, the way I would be back there fighting for the civilian side of the fence."[11]

Under Section 809 of the National Housing Act, the Federal Housing Administration operated a program to assist civilian employees of the armed services in buying homes. The so-called 809 program was limited to areas near military R&D installations where the additional housing was, by FHA standards, in excess of that needed for normal growth of the local community. Such areas did not measure up to FHA standards for economic soundness in granting traditional FHA Title II mortgage loans. Under the 809 program, FHA would fund a mortgage, but DOD had to guarantee the loan. That way, if the base should be closed or go through a reduction in force, FHA wouldn't be left holding the bag with a bad mortgage.

The 809 program had limitations. The Station had to apply for individual certificates and thoroughly justify the need, and individual applicants had to be certified as engaging in essential R&D work. Justification was particularly difficult because DOD did not officially consider NOTS a "permanent installation." Still, some success came from the 809 program. In June 1957 NOTS was granted 100 certificates, which could be used not only for China Lake employees who wanted to build outside the gate but also for the employees of contractors—Continental Telephone, Genge Industries, Texas Instruments, and others—that did business on the base. The 1959 *Technical Program Review* reported that 72 families had moved out of Station housing that year and that a Los Angeles construction company was trying to use the financing authorized under Section 809, "with the result that construction of 40 additional houses appeared imminent at the end of the year." Housing at China Lake, though, was still a problem.[12]

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10 Ashworth, "Some Thoughts on Better Laboratory Management," 11.

11 S-61, Ashworth interview, 96.

12 *Technical Program Review 1958*, 11.

A comprehensive set of administrative regulations governed the behavior of those who lived at China Lake. These regulations, issued by the NOTS Commander, covered housing, recreation, health, fire, sanitation, safety, motor vehicle operation, child care—all the concerns that any moderate-size city faced (by the end of 1966 about 12,000 people lived on the base). The *Rocketeer*s of the period tell of dogs running loose, or littered yards, or children playing with unexploded ordnance, or drivers speeding in residential area.

Regulations were meaningless if not fairly enforced, so in 1961 NOTS management established a Community Hearing Board to review citations issued by base authorities for violations of the regulations and to determine penalties. Two of the three board members were elected by the China Lake community. The *Command History* that year noted that "this is a significant delegation of the Commander's controls over community life."[13]

The year 1961 marked the start of construction of 500 Capehart houses (named after Homer Capehart, co-sponsor of the WWII-vintage federal legislation that authorized such housing) at China Lake. The work was done by the J. W. Bateson Co., a Dallas, Texas, construction firm, under a contract worth $8,183,794, or about $16,000 per unit. More than half the units (270) were duplexes for military and civilian personnel at the GS-7 level, 58 were duplexes for junior officers and civilians at the GS-7 to GS-10 level, and 172 were single-family dwellings for officers and civilians in the GS-11 to GS-14 range. All the houses were built on concrete slabs and had attached garages.

NOTS' Advisory Board, meeting in November 1961 under the chairmanship of Dr. Ithiel de Sola Pool, addressed the issue of base housing:

> It is one thing to isolate a man in a desert community, relying on the fact that his dedication to his work will make his surroundings unimportant; however, the majority of the inhabitants at China Lake are married, and one can hardly expect the wives to be as dedicated. These women spend much of their time in their homes, and they must be content with the surroundings for themselves and their children."[14]

The board then launched into a critical review of the new Capehart housing:

> It is obvious that *too much has been spent on the facade* and *too little on the function*. The false fronts of applied decoration will not last physically or esthetically. . . . space between the new houses is insufficient and deplorable . . . Station personnel are consulted only on insignificant details. *Houses* are made into *homes* only if the people who live in them are content and happy and secure. . . . while a green oasis in the desert is often a welcome relief, it

13 *NOTS Command History* 1961, 17. Captain Blenman was then the NOTS Commander.
14 Advisory Board recommendations, Nov 1961, 2.

> is expensive and unnecessary to attempt to make the entire California desert bloom like a town in New Jersey.

Foreshadowing the trend of xeriscaping that would come to the Indian Wells Valley in the 1970s, the board recommended that the Station seek expert direction to create an example of "how handsome, how rewarding, how *maintenance* free, native planting and local rock arrangements can be."[15]

The Capeharts were the last military housing construction at China Lake. Although they largely eliminated the housing shortage, they did not solve the housing problem. Because many of the units in the Station's housing inventory were inadequate in size and quality, a long, piecemeal program of rehabilitation and refurbishment followed. Add to that the continuing dissatisfaction with housing assignments (a 1966 NOTS Instruction intended to clarify the housing-assignment system runs a numbing 22 pages), and the free-market system was looking more and more attractive.[16]

Fallgatter recalled that:

> The orientation shifted to the private community. The idea became, "Why don't we encourage more building in Ridgecrest?" . . . We still needed housing after that, but we said we'd rely on the private community.[17]

Moving off the base was not an easy sell for many China Lake residents. Most had reasonably decent homes, by local standards, and affordable, if not bargain, rents. Life was good on the Station, with its shopping, theater, restaurants, bars, golf course, bowling alley, hobby shop, swimming pools, even its own taxi fleet with uniformed drivers. Kids had places to go and lots to do—and miles of desert back yard, all inside a fence.

China Lakers had fabricated their own world of diversions there on the base. Scores of clubs and civic associations, ranging from the Alkali Angels (model airplanes) to Sage Sharks (skin and SCUBA diving) to Women of the Moose, served the residents. As LaV McLean said:

> No matter what you did, when we got some new people and they had a new idea, we just started a new club. At one time, I remember about 200 clubs like the Gem and Mineral Club, the Rockhounds, and Square Dancing. . . You name it, we had a lot of different things to do. We had art clubs, music groups, drama, etcetera. It only took a few members to start a club. And it was so easy for us because we all lived so close and were close neighbors.[18]

15 Ibid., 4. Emphasis in the original.

16 NOTS INST 11101.1E, *Housing Assignment Policy and Procedures*, 1132/CJF:gs, 3 Aug 1966.

17 S-110, Fallgatter interview, 24.

18 LaV McLean interview by Billie Hise, Historical Society of the Upper Mojave Desert,

LaV McLean pouring tea at home on Lexington Avenue, China Lake.

There were sports: golf and bowling; military, intramural, and interdepartmental basketball and baseball; and for the kids, Little League baseball and Pop Warner football.

It wasn't all "desert casual." Tina Knemeyer recalled that:

> . . . there were just a lot of visiting people who needed to be entertained, and so that was done in the homes. People did use the china and the crystal and silver, you know, and did a lot of that kind of entertaining. Dinner parties, that type of thing.[19]

Margaret Marie Fitch, whose husband Bill co-invented the Multiple Carriage Bomb Rack, told an interviewer:

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20 Sept 1988, 5.

19 S-204, Tina Knemeyer interview, 11.

> It was some years later that I learned from Patty Barrow, when her husband was [Marine Corps] Commandant, that in planning for food it helped if you counted a captain and his wife as six people, a major and his wife as four, and a colonel and his wife as two.[20]

The Station Theater and the clubs were venues for frequent shows by out-of-town talent. Artur Rubenstein, Jayne Mansfield, the Vienna Boys Choir, Hal Holbrook, Dick Powell, Robert Cummings, Robert Young, Count Basie, the Beach Boys, Bob Hope, Peggy Lee, Yehudi Menuhin, Joe E. Brown, Hugh O'Brian, Frank Sinatra Jr., Connie Stevens, Marian Anderson, Vincent Price, Andres Segovia, and Charles Laughton were among the stars and near-stars who performed at China Lake over the years.

In 1962 a new dimension of culture was added to the China Lake experience when the Maturango Museum of the Indian Wells Valley was formed. Hundreds of people attended the opening ceremonies in December in a converted Quonset hut on Halsey Avenue, just east of Switzer Circle. Leftover exhibits from the Kennedy visit in 1963 would later form the core of the Weapons Exhibit Center (formally opened in November 1964 as the Weapon Exhibit Center) in an adjoining building.[21]

Original Maturango Museum near Switzer Circle, China Lake.

20 Fitch interview, Marine Corps Oral History Program, 555.

21 The Maturango Museum would remain there until 1986, when it moved to its present location in downtown Ridgecrest. Founder Rhea Blenman (wife of the NOTS Commander), artist and founding curator Sylvia Winslow, Technical Information Department Head Ken Robinson, and safety specialist and indefatigable volunteer Billie Hise were among the driving forces behind establishment of the museum. The Weapons Exhibit Center would move to the old Officers' Club building in 1991.

Beginning in summer 1962, NOTS even had its own full-time air carrier representative—essentially a travel agent—"to provide expeditious handling of the Station's commercial air travel needs at the most reasonable cost." These services were for personal, as well as official, travel.[22]

While homeowners in Ridgecrest might spend the weekend repairing a garage door or replacing shingles that had blown away, China Lakers left those tasks for the Public Works Department by just calling the Public Works Trouble Desk, extension 7177. Life was comfortable, even though the enclave-like situation contributed to the obsession with work, which characterized most employees. Ken Powers remembered that:

> None of us owned our homes. We didn't feel a responsibility to do painting and fixing up things, and during essentially all off-work activities, we would talk about NOTS programs. We had good information on what was going on not only on our own programs, but also on programs that might in the future contribute to our programs. Our morale was high, we knew the people, we knew where to go to get help, we had more of a feeling for the total program; the informal communication was fantastic.

When Powers later left China Lake and moved to NOSC in San Diego, "the change was phenomenal. I think once in the first three months after I got there I saw one person from work outside of the work environment."[23]

The self-contained world of the China Lake community couldn't last forever. In 1961 the authority to set rents, which had been the responsibility of NOTS, was transferred to the Naval Facilities Engineering Command (NAVFAC). To determine the new rental rates, NAVFAC relied on Bureau of the Budget Circular A-45, which was based in part on a June 1874 federal statute that forbade supplementing of federal employees' salaries through unreasonably low rental rates. Soon rents went up.

As the *Rocketeer* summarized the subsequent series of events:

> . . . it was directed that rents at China Lake be set on the basis of comparability with nearby year-around communities. A firm of private appraisers made a study which resulted in significant rent increases being proposed. The Station appealed this proposed increase to the Secretary of the Navy . . . as a result, a new survey was ordered which resulted in proposed increases which were again appealed. The Secretary of the Navy directed that these increases be effected over a one year period beginning July 1, 1963. . . .Further, the Secretary . . . directed the immediate initiation of a study of various alternatives for private home ownership for NOTS personnel.[24]

22 *NOTS Command History* 1962, 16.
23 S-123, Powers interview, 10–11.
24 *Rocketeer*, 26 July 1963, 4.

It was clear to everyone that issues connected with housing, maintenance, and rents were taking up too much of China Lake's time and resources. Station management, pursuant to the Secretary's direction, tackled the issue of private ownership in concert with the China Lake Community Council.

Founded in 1945 as the Employees Welfare Association, the Community Council was the primary link between China Lake residents and NOTS command and management. Bill Hattabaugh, who would eventually become China Lake's T&E director, was president of the council in 1963. "It had no budget," he recalled, "but it had a civic voice with Command, with Public Works, with recreation programs, and that was its real role. It represented the residents of China Lake, primarily the civilian residents."[25]

In July 1963 the council held closed session to address a specific type of private home ownership known as the Open Community. This concept was modeled on the Atomic Energy Commission's actions at Oak Ridge, Tennessee; Richland, Washington; and White Sands, New Mexico. In those communities, the agency had sold government housing units back to the residents who already lived in them, effectively transferring the community (and the responsibility for maintenance, utilities, etc.) to private control. Fallgatter explained that:

> Los Alamos was twin-like to us here in their employment make-up, scientific make-up, the isolation—even more isolation than we have. When they sold to the employees, they did appraise the houses, but they had a 15-percent reduction in the appraisal price for those that wanted to purchase the unit they occupied."[26]

Months of study by a council committee had preceded the meeting. The NOTS community had been surveyed, and residents of the AEC open communities had been interviewed. When the meeting opened, Council member Robert P. Biller (a NOTS administrator who would later become dean of USC's School of Public Administration) reiterated the context of the study for the council members and for Captain Blenman, Executive Officer Captain John A. Quensé, McLean, and Hack Wilson, who were also in attendance. Biller told the attendees that:

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25 S-127, William R. Hattabaugh interview, 9 July 1981, 22.

26 S-110, Fallgatter interview, 33. According to McLean, the houses were offered at a 25-percent discount if the buyer agreed to assume total responsibility for the payments and at a 15-percent discount with the provision that the owner could sell it back to the government in the event of a RIF or certain other circumstances. All but one person took the 25-percent reduction. Minutes of the Community Council closed session, 2 July 1963, in "U.S.NOTS. China Lake California Community Study, Supplemental Information" transcript, 13.

> A wide variety of community problems has been increasingly felt by the Station's management, which now sees itself spending a disproportionate amount of time, effort, and resources on community matters, which is detracting from the accomplishment of the technical programs.[27]

After a lengthy debate and discussion, the sense of the attendees was that about half the people on the base were for the Open Community solution and about half were against it. But nearly everyone agreed that something needed to be done to change the status quo. As Hack Wilson told the group:

> The first consideration should be whether or not we want to live in a normal community. We have lost a lot of employees through the years that wanted to buy houses and could not. Trying to be landlord, mayor, and employer is a real knotty set of problems.[28]

Several further studies were conducted on the subject of the Open Community solution. However, the idea died for lack of a strong champion. But the goal of moving civilians off base, one way or another, had become firmly established.

There had always been a few people who chose, for whatever reason, to live off the base. Gil Plain decided in the late 1940s that he was tired of paying the modest $900-per-year rent for his home on base. He spent 5 years building a house that he would occupy for nearly 50 years.

The Drummond Tract, just north of the hospital and west of China Lake Boulevard and a stone's throw from the base, was the first of the well-built housing tracts to lure meaningful numbers of people out into town. Construction of the tract began in 1961, and Drummond houses are home to many China Lakers and former China Lakers today.

Soon after the Drummond Tract came the Deeter Tract. Both areas offered buyers a level of home quality that was unusually high for off-Station housing. John Deeter, who had built hundreds of homes in Bakersfield, sensed the potential of the Ridgecrest market and bought and developed with an eye to the future. LeRoy Jackson recalled that:

> He was a first-class builder, and all the time I was on the Board of Supervisors, many builders would show up to the board with exceptions [requests for variances] and things of that nature. Not once did John Deeter ever show up, not once.[29]

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27 Ibid., 13.

28 Ibid., Tape 2, 15.

29 S-186, LeRoy Jackson interview, 16 Nov 1990, 53. Jackson headed the NOTS Community Relations Office before being elected Kern County 1st District Supervisor in 1964.

Families who moved off base before 1968 were the pioneers. The process was more difficult than simply hauling one's household goods a couple of miles outside the gate. Many who made the move felt initially as if they were venturing into foreign land.

Ted and Eleanor Lotee and their daughters moved to a new home in the Drummond Tract in 1963. Ted recalled that:

> When we moved out here, my friends said, "Why?" And they said, "You know, this is only temporary." And I said, "17 years is temporary?" I said, "I want a house for my children. If I'm going to have anything, I want it now. I don't want it when I'm ready to retire." . . . And so that was why we moved. But they thought we were crazy. We wondered if we were. But we never regretted it."[30]

Ted's daughter Deanna was in grade school at the time and transferred to Las Flores Elementary School, about a mile southwest of the China Lake main gate. She recalled that:

> It was traumatic in the beginning because all the friends I'd known were going on to Murray [the middle school on the base]. . . . I knew absolutely no one in Ridgecrest, nor did my sister. . . . I was probably the last person to surrender my community pass and hated doing so because that really meant I didn't belong.

The Ridgecrest schools were not as well funded as those on the base. "Even Monroe [middle school] didn't have the amenities that base schools had. For physical education we very often played in our school clothes, which for us girls were our dresses."[31]

Money was central to any solution for NOTS' housing problems. Except for the FHA 809 certificates, no easy financing was available for people who wanted to move off the base. As engineer and longtime Community Council member Harry Bearman had told the Open Community meeting:

> The Bank of America will not make a loan longer than 7½ years in this area. Their policy is . . . that the base represents a one-industry town and that they don't want to make these loans.[32]

Bank of America, of course, was only following the lead of the Federal Housing Administration. The major roadblock to FHA financing for housing off the base was the issue of the Navy's "permanency" at China Lake; the FHA was stubborn in its unwillingness to recognize that permanency. As far back as

30 S-181. Ted and Eleanor Lotee interview, 18.

31 Deanna Ripley-Lotee, email to the author, 4 April 2011.

32 Minutes of the Community Council closed session, 2 July 1963, "Community Study, Supplemental Information" transcript, 8.

1956, during Ashworth's tenure, the Assistant Secretary of the Navy (Material) had written to the FHA stating that:

> The Naval Ordnance Test Station is classified unconditionally as a permanent installation of the National Defense Establishment, and the activities of the Station are to be maintained generally at their present level.

Ashworth had released that quotation to the Board of Directors of the Ridgecrest County Water District (later the Indian Wells Valley Water District), to assist the board with a prospectus for water revenue bonds. That letter had not been enough to change FHA policy.[33]

When NOTS became NWC in July 1967, the reorganization brought more people to the desert, which increased the need for housing. James McGlothlin, head of NOTS' Community Relations Office, spoke about the issue at a Town Hall meeting at China Lake that November:

> A new mission has been assigned to the Center, and 85 additional housing units are needed to support the program. But to discuss housing, you should discuss housing for the Indian Wells Valley. Hopefully, progress on private housing will develop very soon.[34]

In May 1968 the NWC Advisory Board reported that:

> The Chief of Naval Material has recently stated that "It is recognized that a long-range solution to the problems associated with civilian housing and community resources must be pursued without further delay." He also stated "The continued excellence of output of the Center must not be interrupted or reduced by degradation of the community environment. *The affirmation of the need for the Naval Weapons Center as a permanent installation at its present or increased size cannot be overemphasized*."[35]

Finally, in August 1968, Secretary of the Navy Paul R. Ignatius issued a formal "Statement of Permanency, Naval Weapons Center, China Lake, California." Shortly thereafter, FHA mortgages became available for those base residents wishing to buy or build in Ridgecrest. The stage was set for a generation-long demographic revolution that would change not only the housing patterns of China Lake's civilian employees but also their social customs and the very culture of the workforce.[36]

Ready availability of financing did not lead to an immediate exodus. FHA financing simply made the process easier. With the influx of Corona Annex

33 *IWV Independent and Times-Herald*, 8 March 1956, 8.
34 *Rocketeer*, 17 Nov 1967, 3.
35 NWC Advisory Board meeting, 15-17 May 1968, 1-7. Emphasis added.
36 Babcock, *Magnificent Mavericks*, 521.

personnel beginning around 1970, the pressure on base housing, and the attractiveness of off-base housing alternatives, increased. As more people moved from the base and new neighborhoods grew up in and around Ridgecrest, the option of living "out in town" became more viable and more often exercised.

The improved quality of off-base housing and access to the financial tools to purchase that housing was part of the "pull" for movement off the base. The "push" components were the ever increasing rent on base, the diminishment of government-subsidized services, and the Navy's desire to get out of the housing business. This "push" would increase through the 1970s and into the 1980s.

Base Meets Town

Migration of government employees from the base into the larger Indian Wells Valley diminished China Lake's insularity. The fence that surrounded the Mainside portion of NOTS had been, in effect, a moat. Beyond the fence's role as a physical barrier, it symbolized a cultural divide between those who lived on the base and those people who lived outside—the townies, the locals, the inhabitants of what one irate China Laker described in 1960 as "the village of Ridgecrest, which would, except for NOTS, revert to a filling station, general store, wide spot off the highway."[37]

China Lake was a "gated community" long before the term came into popular use. Like other gated communities it engendered a degree of envy and mistrust from those who lived outside the gate, and a corresponding attitude of snobbery, even xenophobia, from those on the inside.

Since the inception of the Station, there had been tension between people who lived on it and those who lived off it. Ken Smith, a former mayor of Ridgecrest who had begun the practice of law there in 1955, remarked:

> We used to love to have jury trials here in Ridgecrest, and my people asked, "Why?" Well, about half the people were from China Lake, and about half of them were from Ridgecrest, and they never could agree, so it was usually a hung jury.[38]

Relationships had reached a low point in 1953, when the Ridgecrest Chamber of Commerce had supported a legislative attempt to eliminate Navy Exchange and commissary privileges for civil servants at China Lake. Base civilians had retaliated with a brief boycott of the town's businesses. That crisis passed, but in the Ridgecrest community there continued to be ambivalence

37 Janet L. DeBejar, letter to the editor, *IWV Independent and Times-Herald*, 20 Oct 1960.
38 S-227, Ken Smith interview, 16 March 1993, 3.

toward China Lake and those who lived there. In 1959, for example, local merchants announced a gala "NOTS Appreciation Day," with nearly 100 stores participating. In a gesture of cooperation that would be shocking in the security atmosphere of the 21st century, base security officials provided the Indian Wells Valley Merchants Association with a list of all base pass holders, so that people could be randomly selected for 200 free gifts.[39]

On the very same page of the *Valley Independent and Times-Herald*, the Desert Empire Board of Realtors (headquartered in Ridgecrest) expressed its opposition to the Navy's planned acquisition of the 500 Capehart houses for China Lake. The board formally resolved that:

> . . . the Desert Empire Board of Realtors hereby goes on record as being opposed to any and all types of direct government subsidized or owned housing projects, except in cases of emergency such as existed in the Indian Wells Valley area in 1944-45, said period of emergency now being over.[40]

As the years passed, the tension between the two camps lessened, and people on both sides tried to reach across the divide. In her inaugural column "Small World," in the *Valley Independent*, Dorothy Fettar stressed the two communities' commonality of interests. "One storm produces rain in both communities," she wrote, "and when your lawn dries up in the summer, mine does too."[41]

The China Lake Community Council and the Ridgecrest Chamber of Commerce established a position of liaison director. China Lake engineer David A. Colpitts initially held the position; Neal Webb replaced him in 1959. Webb, an administrative assistant in the Research Department, also lived in Ridgecrest and owned several motel apartments. By 1960 he was able to report. "As Liaison Director between the Council and the Ridgecrest Chamber of Commerce, I have been impressed with the manner in which the relationship and cooperation between the two organizations have improved in recent years."[42]

When a tea was held in May 1962, to generate support for the nascent Maturango Museum of the Indian Wells Valley, President-elect Clarence A. Willey emphasized that "representatives from Trona, Inyokern, and other desert communities as well as workers from China Lake and Ridgecrest attending this tea reflect the widespread interest of the museum." A larger sense of community was beginning to develop. NOTS Commander Blenman said of the museum,

39 *IWV Independent and Times-Herald*, 9 April 1959, A1.
40 Ibid.
41 *IWV Independent and Times-Herald*, 8 Jan 1959, B1.
42 *Rocketeer*, 1 July 1960, 4.

"There's no question that projects of this nature do much in unifying the cultural interests within our community and strengthen ties between our Navy employees and the adjoining City of Ridgecrest."

Unifying cultural interests was one thing; unifying economic and commercial interests would prove to be quite a different matter.[43]

Integrating Commerce

Prior to 1966 two distinct economies operated in the Indian Wells Valley. The first included Ridgecrest and Inyokern and the rest of the valley outside the confines of NOTS. It was as close to a traditional free-market capitalist system as one would find in rural America in the 1960s; prices for goods and housing and service fluctuated with supply and demand. People either owned their homes through traditional mortgage financing structures, built and financed their own homes, or rented from local landlords.

Aboard the base, residents participated in a second economy that had been established in the mid 1940s. China Lake residents lived in government-owned housing and paid rents that were low in comparison to the average NOTS income. Instead of shopping at the markets in Ridgecrest, China Lake civilians shopped side by side with their military neighbors at the commissary store and Navy Exchange, paying artificially low prices that were subsidized by the government. Bennington Plaza included not only the Navy Exchange and the commissary but also a government-subsidized gas station, barber shop, beauty shop, cobbler shop, laundry, and dry cleaners. The plaza was also the site of the Station's Child Care Center as well as the gymnasium and swimming pool.

Driving the dual economies was the fact that salaries for government scientists and engineers were lower than for their industrial counterparts. It was widely believed, and reflected in congressional legislation, that very few of the professional technical workers who were the lifeblood of NOTS would agree to come to this isolated corner of the Mojave Desert without the added benefit of discounted housing, inexpensive food and staples, and heavily subsidized incidental services such as a barbershop and a movie theater.

LeRoy Jackson quoted his high-school-age son, who later became city manager of Torrance, California, as observing, "This is the first place that I've ever seen [where people are] willing to sell their souls for a two-bit movie."[44]

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43 *Rocketeer*, 19 May 1962, 11; *Rocketeer*, 30 Nov 1962, 3. In fact, Ridgecrest would not become an incorporated city for another year.
44 S-186, Jackson interview, 52.

Above: The All Faith Chapel, Bennington Plaza, and the community of China Lake, early 1960s.

Below: The community of Ridgecrest, late 1950s. The intersection of Ridgecrest and China Lake Boulevards is at lower right, with China Lake land holdings out of frame at right.

China Lake civilian access to the Navy Exchange and commissary had been authorized under the Emergency Powers Continuation Act during WWII and had been reaffirmed by Congress in 1953. Ridgecrest merchants, of course, had always resented having to compete with the federal government when it came to providing goods and services, although a few understood the need for some sort of subsidy to encourage people to work at China Lake. A large-scale study of Navy Exchange and commissary services on the base was undertaken in 1960 and included representatives of the Ridgecrest Chamber of Commerce. "The principal result was the agreement of on-Station and off-Station interests that current service should be continued, with no expansion of Station facilities."[45]

But the little community outside the gate, Ridgecrest, formerly Crumville, had been growing rapidly—not surprising when one considers that a good percentage of China Lake's multimillion-dollar civilian payroll was being spent there.[46]

The town began to assert its own identity, while acknowledging its dependence on the base. In 1960 the last vestige of Crumville, Crumville Road, had its name changed to Church Street. Trona Road was renamed Ridgecrest Boulevard, and Ridgecrest Road renamed China Lake Boulevard. As the town grew, more businesses moved in to support the activities on the base. Others came to cater to the needs of the China Lakers—car dealers, carpet stores, insurance agencies, sporting goods stores, women's fashions, radio and TV repair, purveyors of good and services that were not available on the base, or stores that offered a greater variety of goods.[47]

More medical services were becoming available in town. On 2 April 1963, Drummond Hospital, which had been built by the pioneering Dr. Thomas A. Drummond in 1945, announced that, after several months of preparation and paperwork, the facility was converting from a proprietary hospital to a community nonprofit medical facility, to be known as the Ridgecrest Community Hospital. Dr. Drummond was elected chairman of the board of the new organization. Dr. Thomas V. Reese, speaking at the opening press conference, bemoaned the increasing costs and decreased length of hospital stays in recent years. He commented that "now the obstetrics patient barely warms the bed after having her baby."[48]

45 *NOTS Command History* 1960, 11.

46 In 1960 the civilian labor costs for the Station—China Lake and Pasadena—were $32.7 million. In 1963, the year of Ridgecrest's incorporation, the figure was $37.6 million. *NOTS Tech History* 1960, 7; *NOTS Tech History 1963*, 1-6.

47 *IWV Independent and Times-Herald*, 28 Jan 1960, 1.

48 *IWV Independent and Times-Herald*, 4 April 1963, A-1, A-7.

On 18 November 1963, the community voted to incorporate as the City of Ridgecrest. "We extend our congratulations to the newly incorporated City of Ridgecrest which, as a result of the expressed will of the majority of its citizens, has assumed local control of its civic affairs," wrote Acting Commander Captain Jack Hough on a front-page article of that Friday's *Rocketeer*, overshadowed by a banner headline reading "President Kennedy Slain."[49]

As a city, Ridgecrest would now be receiving part of the 4-percent sales tax that had been going to Kern County. The first Ridgecrest City Council was seated, and among the priority matters of business were the hiring of a city attorney (Graham Richie of Los Angeles) and passage of an ordinance relating to building, plumbing, and electrical regulations.

As the national economy and the economy of the Indian Wells Valley both grew, the necessity for government subsidies to the China Lake civilian workforce became less apparent to Navy higher-ups back East (and to many Ridgecrest business owners as well). In January 1966 the Navy announced a major change in the way that services would be provided at China Lake. Beginning within the year, Navy Exchange and commissary privileges would be limited to China Lake's military personnel—as they were on almost every other stateside base. The extension of those privileges to civil servants, which had begun in 1943, would be discontinued. Captain John Hardy, who was NOTS Commander at the time, recalled that:

> There were many hard feelings by a lot of the civilians in [BuWeps] because at China Lake the civilians had everything. They went to the commissary. They went to the Navy Exchange. Everything that the officers had, they had. Well, in Washington, the civilians couldn't go in the Navy Exchange and couldn't go to the commissary, and you'd be surprised how many people in Washington really resented it and worked hard to get those privileges taken away.

While Hardy was in Washington fighting unsuccessfully to reverse the Navy's decision, he was struck by the plethora of recreational services available to DOD civilians.

> I went over to the Pentagon and talked to their recreation people over there and said, "How does the Pentagon have all these squash ball courts and exercise facilities and everything else? How do you support that?" Oh, all the shops over there give a certain percentage, 1 percent or whatever it was, of their gross to the recreation department in the Pentagon. So I went right back to [BuWeps] and talked to the Deputy Chief and said, "If we have to go this way, I want the authority to contract for supermarkets on the base."[50]

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49 *Rocketeer*, 22 Nov 1963, 1.

50 S-238, Capt. John I. Hardy, USN (Ret.), interview, 13 June 1995, 13–14.

Under the new plan, shopping and commercial services for China Lake civilians would be converted to free enterprise, "opened to competitive bidding by any interested private businessman." NOTS was authorized to conduct the negotiations with private enterprise and the Station assigned that task, and the management of the commercial activities, to the Employee Services Board (ESB).[51]

Since 1962 the ESB had been managing the Station Restaurant and the Michelson Laboratory Cafeteria. In 1963 the board negotiated concessionaire agreements with a dentist and pharmacist, who had previously operated at China Lake under a lease agreement, and also set up a Malt Shop. Six members were appointed by Command for two-year terms on the board, with their ESB work as a collateral duty to their regular civil service jobs.

The target date to complete the transition to civilian services was scheduled for 31 December 1966. Von's Grocery Co. won the bid to provide supermarket services—the largest of the commercial activities on base—and on 31 August 1966, after a $400,000 investment by the company, an 18,000-square-foot store officially opened at Bennington Plaza. On that same day, commissary and Navy Exchange privileges ended for civilians.[52]

By the year's end, all the remaining government-supplied services, except the gas station, had been successfully converted to civilian operations. The Station Beauty Shop became Senn's Coiffures. Henry Thompson, of Thompson's Shoe Repair Shop in Ridgecrest, operated the cobbler shop. R. H. McKeon, owner of Fashion Dry Cleaners and Laundry in Lancaster, contracted to provide laundry and dry cleaning services.

Veteran China Lake barber Joe Perry took over the barber shop. "He has some very definite ideas in mind, designed to promote good customer relations and provide the Station with the highest quality tonsorial service in most pleasant surroundings," the *Rocketeer* reported.[53]

The ESB's workload was greatly increased with the rapid expansion of commercial activities on the base. In September the board hired its first professional business manager, Arthur W. Rutherford, to run the operation. Contractors paid fees to the board for the privilege of providing commercial services to China Lake civilians. Rent for buildings was based on a commercial scale, and utilities were charged at Ridgecrest rates. Most of the funds generated

51 *Rocketeer*, 12 May 1967, 1.

52 In 1967 the supermarket was renamed Shopping Bag following a Supreme Court decision that forced the sale of 40 Vons markets, including the China Lake store.

53 *Rocketeer*, 10 Oct 1966, 4; 16 Dec 1966, 3; 13 Jan 1967, 3.

by ESB operations were used to improve the quality of the service; excess funds supported recreational programs, including the public library in Bennington Plaza, the golf course, the bowling alley, the gymnasium, and even the TV relay program. Funds for those programs had primarily been generated through the civilian patronage of the Navy Exchange facilities.[54]

"Suddenly we had a lot more money for the Recreation Department on the Station, for everybody, for the civilians and the military," said Hardy. "So it wasn't as nice as having the commissary, but it was the best deal we could make, and then we wound up getting some pluses out of it too."[55]

Generally, the intermingling of on- and off-base business interests went smoothly. In March 1966 the Ridgecrest Chamber of Commerce invited the China Lake Community Council to participate in the first "Congress for Community Progress," billed as "a multi-faceted study of the Valley's living and development problems and potential." The following year, the council accepted the chamber's offer to act as co-host of the event.[56]

Still, it didn't take much to put both sides on the defensive. Such a conflict arose over the gas station at Bennington Plaza. Traditionally, civilians on base used this government-run gas station because it was cheaper than gas out in town. As LeRoy Jackson observed "the gas stations [outside the base] couldn't buy gas as cheap as the Exchange was selling it on base."[57]

Pursuant to the commercial services directives managed by the ESB, NOTS planned to put in a new commercially run gas station on the base. The successful bidder for this project would have to build the new gas station and would receive a five-year lease to operate it. Since an agreement had not been negotiated by the initial December 1966 target date, Navy higher-ups granted NOTS a six-month extension on civilian use of the Bennington Plaza gas station. At a public hearing on the matter January 1967, several Ridgecrest residents spoke out against the proposed station on base, among them Chamber of Commerce vice president (and service station operator) Ed McLean, and Jim Wheeler, operator of the Ridgecrest Western Auto shop.

"You're getting a nice shopping complex on the Naval Station and it's hard for little businesses on the outside to compete," Wheeler said. "This thing can gain a lot of momentum, and I think it can stalemate free enterprise."

54 TV signals from Los Angeles were received at a station on Laurel Peak, south of the Indian Wells Valley, and transmitted by microwave to B Mountain, where they were retransmitted across the valley.

55 S-238, Hardy interview, 17–18.

56 *Rocketeer*, 11 March 1966, 1; 5 May 1967, 4.

57 S-186, Jackson interview, 29.

Regarding the proposed gas station, the *Valley Independent* article pointed out that Ridgecrest already had 14 similar businesses in operation.[58]

At the request of several Ridgecrest residents, KABC-TV Channel 7 from Los Angeles sent a team of reporters and cameramen to the Indian Wells Valley, where they interviewed city residents as well as NOTS Community Relations Officer Jim McGlothlin for a news story on the budding conflict. Don Yockey editorialized in the *Valley Independent* that "ample tinder is available for an inter-community conflagration—now it remains to be seen who, if anyone, elects to play with matches."[59]

When Ridgecrest officials tried to use congressional pull to have the gas station plan squelched, the China Lake Community Council fired back with a letter to Congressman Bob Mathias, a copy of which was printed in the *Valley Independent*. In the letter Council President Kenneth Miller noted pointedly that his China Lake group "is the only representative body in a community that represents two-thirds of the population of the entire area." Speaking for the council, he stated its "firm opinion that the proposed service station, operated by a private businessman on a free enterprise competitive basis is essential to the well being of our community."

On a more conciliatory note, the council's letter concluded that "the community of China Lake would welcome and patronize any and all expanded merchandising and service outlets in the City of Ridgecrest."[60]

In this stare-down, probably mindful of the 1953 boycott, Ridgecrest blinked. In April the Ridgecrest City Council proposed a resolution "urging the Naval Ordnance Test Station to prevent a possible rupture of community relations." Under a series of "Whereas"s, it noted that "Ridgecrest, with its population of 7,221, and [NOTS] with its population of 11,500 civilians are for economic, social, and cultural purposes one community." It noted that the city had already presented two awards to NOTS "in appreciation of the Command's enlightened policy of maintaining a spirit of healthy community relations," and acknowledged the "need for a gasoline service station on the test station." Finally, it urged the Command to establish "only such a service station as will be privately owned or privately leased and operated in the American competitive way, and shall be comparable with similar stations now in operation in the Ridgecrest area." The resolution passed unanimously, although according

58 *IWV Independent and Times-Herald*, Jan 1967, A-1.

59 *IWV Independent and Times-Herald*, 23 March 1967. Yockey was editor of the *Rocketeer* from 1950 to 1954, the *Valley Independent* from 1955 to 1971, then the *Rocketeer* again from 1971 to 1985.

60 *IWV Independent and Times-Herald*, 13 April 1967, A-1, A-3.

to the *Valley Independent* one citizen (Pat Leibert) "exploded with the remark 'We're being sold down the river.'"[61]

In 30 June 1967, the gas station, operated by Fedco Inc., of Los Angeles, opened at the southwest corner of the Bank of America parking lot, adjacent to Bennington Plaza. The transition to civilian services at China Lake was complete. Civil servants and their families now had less in common with their military associates on base and more in common with their civilian counterparts in town.

Civil Rights

Full equality for minorities was late coming to the Indian Wells Valley, as it was to the rest of the nation. The awakening to the social problems of racism (both institutionalized and individual) largely paralleled that process elsewhere in America. While the valley never suffered the turmoil associated with larger urban areas—Los Angeles, for example, and Newark—the journey to full integration was more difficult for some than for others. At China Lake in the 1960s, the Navy—specifically, China Lake's command and management team, implementing higher-level regulations—took the lead in guaranteeing equal opportunity to all citizens under its authority, and setting an example for those who were not. It hadn't always been that way.

Prior to the Second World War, segregation was as deeply entrenched in the military services as it was in the larger American experience. Under Navy regulations, African Americans were permitted to serve only as mess attendants. By 1942 the need for wartime manpower opened the enlisted rates to "all qualified personnel." In 1944 the first group of African Americans to complete naval officer training—the so called Golden Thirteen—was commissioned, although it would be another 17 years before an African American (Commander, later Vice Admiral, Samuel L. Gravely, Jr.) would command a regular Navy warship.

President Truman, in July 1948, signed Executive Order 9981, which stated: "It is hereby declared to be the policy of the President that there shall be equality of treatment and opportunity for all persons in the armed services without regard to race, color, religion, or national origin."

The order contained a major loophole—"This policy shall be put into effect as rapidly as possible, *having due regard to the time required to effectuate any necessary changes without impairing efficiency or morale*."[62]

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61 Ibid., A-1, A-2.

62 Harry S. Truman Library and Museum, *http://www.trumanlibrary.org/9981.htm*, accessed 11 Sept 2013. Emphasis added.

But by 1950, a report from the President's Committee on Equality of Treatment and Opportunity in the Armed Services stated that "All jobs and ratings in the naval general service now are open to all enlisted men without regard to race or color. Negroes are currently serving in every job classification in general service."[63]

In the Station's earliest days, NOTS reflected prevailing segregationist practices. Cal Fallgatter, discussing the inadequacy of 1940s housing at the base, said:

> The poorest units were some Quonset huts and contractor buildings. . . . We have an old map here that shows the area. This map actually showed some of the huts marked for Negro employees. . . . the Negro men, the Blacks, had their own hut and we condoned that.[64]

Rod McClung, who arrived at China Lake in 1946, remembered racial discrimination as a problem. He recalled that:

> The Navy was officially opposed to it, but we had practically no minority-group employees and no supervisors, no professionals in the real early days. And so it was thought that we could at least get started in that direction by opening up our apprentice program and trying to recruit in the L.A. area. The mainly Black recruits that came up to be apprentices for our shop work weren't staying too well because they were having to live in their cars, because nobody in Ridgecrest would rent to them. Cal Fallgatter managed to find people who owned mobile homes who would rent to the Black people if the Navy would agree to move the homes onto the base. That's how the mobile home park that was over south of the Public Works area was started. These were the mobile homes that Cal Fallgatter brought in so that our Black apprentices wouldn't have to live in their cars. I can remember well that restaurant across from the old county building had a good sized sign in the window that said "White Trade Only."[65]

China Lake management, which had enough problems with managing and housing its thousands of civilian employees, hewed to Navy regulations. Through the 1950s and '60s, the federal government took the lead in expanding and enforcing the civil rights of minorities, and under the cooperative leadership of military commanders and civilian technical directors, the Station followed the letter of the law in its employment and housing policies. For example, the President's Committee on Government Policy in 1955 issued governmentwide

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63 *Freedom To Serve. Equality of Treatment and Opportunity in the Armed Services,* a report by the President's Committee, U.S. Government Printing Office, Washington: 1950, *http://www.trumanlibrary.org/civilrights/freeserv.htm*, accessed 27 April 2011.

64 S-110, Fallgatter interview, 17.

65 S-188, McClung interview, 70, 71.

regulations barring discrimination based on race, color, religion, or national origin, and established policies for handling complaints of discrimination.

NOTS Commander Captain Ashworth designated Executive Officer Captain Frederick. A. Chenault, the NOTS Deputy Employment Policy Officer, to whom complaints of discrimination could be directed. (The Navy had 90 days to make a decision on the merits of a discrimination claim.)[66]

President Kennedy's Equal Employment Opportunity Policy (Executive Order 10925) of March 1961 reaffirmed "the plain and positive obligation of the United States Government to promote and ensure equal opportunity for all qualified persons, without regard to race, color, creed or national origin, employed or seeking employment with the Federal Government." Subsequent Commander, Charles Blenman, set up an Equal Employment Opportunity Committee with engineer John L. Cox as chairman.

In 1964 DOD banned the use of racial designations in personnel forms, and China Lake complied. Later that year, LeRoy Jackson, then head of the NOTS Community Relations Office, received a request from California Congressman Harlan F. Hagen, whose district included the Indian Wells Valley. The letter began, as Jackson recalled, "'I talked with one of my constituents, and I am disturbed at the amount of discrimination taking place at the Naval Ordnance Test Station.'"

Jackson responded quickly. As he remembered:

> I wrote back and told him that unfortunately for his question that we kept no record of the race or nationality of the person at the time we hired them, that in fact we were prohibited by law from making any indications on their personnel folders, and that the only means by which we could give him an answer to his question would be if we went through and, contrary to law, interviewed each of our employees. And so he considered the matter settled.[67]

State law also affected the civil rights of minorities living in the Indian Wells Valley. In 1963 William Byron Rumford, an African American member of the California Assembly, introduced the Fair Housing Bill, which would outlaw discrimination in housing throughout the state.

In the same issue of the *Valley Independent* that announced the impending visit of President Kennedy to China Lake, Milton H. Ritchie (a China Lake chemist and legislative chairman of the Indian Wells Valley NAACP Branch) urged people to support Rumford's bill. He wrote in part, "I have every

66 *Rocketeer*, 16 March 1956, 8.
67 S-186, Jackson interview, 18.

confidence that the American dream of a truly democratic society will reach full fruition soon, despite the obstructionist tactics of bigots."[68]

Rumford's bill did pass the Assembly and Senate and was signed into law by Governor Pat Brown, despite opposition from the California Real Estate Association and the California Chamber of Commerce. Undeterred, the bill's opponents put California Proposition 14, which would nullify the Fair Housing Act, on the state ballot. The proposition passed, with a 65-percent majority, but was declared unconstitutional by the California Supreme Court the same year. (That holding was affirmed by the U.S. Supreme Court in 1967.)

An occasion that the *Valley Independent* billed as "a major achievement in better race relations in the Indian Wells Valley" took place in October 1966 when Ridgecrest trailer court operators signed an agreement to make their accommodations "available to Negroes on the same basis as for other applicants."[69]

The signing event was hosted by the local branch of the NAACP, which had some leverage to use against those who discriminated against African Americans in housing matters; California's 1959 Unruh Civil Rights Act and Title II (Public Accommodation) of the 1964 U.S. Civil Rights Act both prohibited racial (among other forms of) discrimination. In return for the operators' non-discrimination agreement, the NAACP "gave the trailer court people assurance that the NAACP would not initiate or support legal action on behalf of person evicted for failure to maintain proper standards of conduct and upkeep of the premises."

It was a less than complete victory, however. Owners of 10 trailer courts had been invited to the signing ceremony. Only five attended.

When one trailer park proprietor asked during the meeting "what he should do if all the white tenants moved out if he rented to a Negro," he was answered by Wash Nichols, former president of the local NAACP branch and chairman of the branch's Housing Committee. Said Nichols:

> By definition, tolerance signifies purity of soul and mind, therefore any really worthwhile person would not be guilty of such an act. And certainly you wouldn't want such an individual in your park to begin with, as you have already said that you are only interested in your tenants' characters.[70]

The 1966 nondiscrimination agreement between Ridgecrest trailer court operators and the NAACP appears to have had little impact on either the

68 *IWV Independent and Times-Herald*, 6 June 1963, C-5.
69 *IWV Independent and Times-Herald*, 13 Oct 1966, A-1.
70 Ibid., A-5.

housing situation or the integration issue. Eight months after the signing, China Lake sent a memo to the Commandant, Eleventh Naval District. It stated in part "There are presently no Negro military families occupying mobile homes in this area."[71]

Many urban areas of America were the scene of so-called "race riots" in the 1960s. One of the earliest was in Oxford, Mississippi, in 1962 when Southern segregationist civilians battled federal troops over the admission of an African American, James Meredith, to the University of Mississippi. Two people died in the riot.

As the decade progressed, the riots increased in number and intensity; the Watts Riots in Los Angeles in 1965 left more than 30 dead. In August 1967 the cover of *LIFE* showed federal troops silhouetted against burning buildings in Detroit under the headline "Negro Revolt: The Flames Spread." The *LIFE* editorial began:

> Not for 102 years—not, that is, since Appomattox—has the essential fabric of this republic been so cruelly strained. . . . The sites of 1967's Negro riots are numerous and varied enough to define a national crisis: Omaha, Chicago, Boston, Tampa, Cincinnati, Atlanta, Kansas City, Buffalo, Minneapolis, Plainfield [N. J.]. The five days of horror at Newark seemed at the time to be a climax. But soon Newark was overshadowed by Detroit, the riot of a thousand arsonous fires. Nor is there any reason to suppose that Detroit marks the end of the line, the worst that can happen . . .[72]

Even in the Indian Wells Valley, the riots focused attention on the wide racial divide and fueled racial stereotypes. Just two months after the Detroit and Newark riots, James R. Jefferson, president of the IWV Branch of the NAACP, wrote in a letter to the editor:

> If one looks upon every Negro as a [Stokely] Carmichael or a [H.] Rap Brown, then he must also regard every white person as a [George] Wallace, a Castro, or a Hitler. Nothing is further from the truth, of course, and this holds true for Negroes as well.[73]

Against the background of national racial turmoil, the Department of Defense had in April 1967 announced a policy for eliminating racial discrimination in off-base housing for military personnel. Secretary McNamara, according to his Assistant Secretary for Manpower, Alfred B. Fitt, believed that:

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71 Memo 1131/RLR:mac, 11101, Ser. 2411, Commander, U.S. Naval Ordnance Test Station, to Commandant, Eleventh Naval District, San Diego, "Equal Opportunity for Military Personnel in Rental of Off-Base Housing," 23 June 1967.

72 George P. Hunt, "Quench Riots—and Look Beyond," editorial, *LIFE*, 4 Aug 1967, 4.

73 *IWV Independent and Times-Herald*, 14 Sept 1967, A-6.

> . . . any department which administers 10 percent of the gross national product, with influence over the lives of 10 million people, is bound to have an impact. . . . McNamara wanted to marshal that impact by committing defense resources to social goals that were still compatible with the primary mission of security. . . . He felt this was wholly justified by the military situation; that, for instance, there was a requirement for open housing because, in this man's Army, the least of these was entitled to the same as the most of these.[74]

When the Ridgecrest City Council proposed a resolution to support that antidiscrimination policy, there was grumbling. Ridgecrest citizen Ed Harris stated that "as long as this attitude exists that the federal government can tell me who I can rent or sell my property to, I don't like this kind of law."[75]

Surprisingly the strongest opposition to a resolution supporting the DOD policy came from Weldon Jules, a teacher at Las Flores School and the lone African American member of the Ridgecrest City Council. Accusing the community of having a "head in the sand" attitude toward equal opportunity housing, Jules said that the DOD policy didn't go far enough. He said the DOD proposal, in only addressing discrimination as it applied to military personnel, did not go to the root of the problem:

> I think it's time the city council was put on the spot to support open housing. . . . [under the DOD policy] the rights of all individuals are not protected. If the federal government wanted to, by simply supporting the Constitution, everyone's rights would be protected.[76]

Nevertheless, after some further debate, Jules voted for the resolution of support, ensuring that it passed unanimously.

When an African American businesswoman, Christine Stephenson, applied for a license to run a "beer parlor, card room" at 224 Kern Street in August, 1967, the chief opponent speaking publicly at the license hearing was the NAACP's Wash Nichols, who told the city council:

> Now you want to set up a recreation area for Negroes from China Lake to come out here and talk bad language. . . . You can help these people by enforcing the law. . . You claim you're their friends, but you're their enemies if you put this in.

74 Brock Brower, "McNamara Seen Now, Full Length," *LIFE*, 10 May 1968, 89.

75 *IWV Independent and Times-Herald*, 14 Sept 1967, A-1, A-6.

76 *IWV Independent and Times-Herald*, 14 Sept 1967, A-1. Jules was Deanna Ripley-Lotee's 6th grade teacher in 1963, "a teacher I count as one of my best." When President Kennedy was assassinated, "Mr. Jules was so engrossed in listening to the radio to hear and understand all that was happening. I never knew until years later . . . that he, along with so many others, had pinned their civil rights hopes upon this President." Deanna Ripley-Lotee, e-mail to the author, 4 April 2011.

Despite Nichols' warning, the license was granted.[77]

As the new Naval Weapons Center moved into the 1970s, it continued to implement DOD and Navy policies and regulations for the civil rights of minority groups and also for evolving federal policy on gender equality, age discrimination, and rights for the handicapped.

Conservation and environmentalism also were areas where strong government action played a major role in changing the way that the citizens of the Indian Wells Valley looked at the world. (As late as 1959, Kern County spread poison bait on stock trails west of China Lake in midwinter "to kill off predator animals [primarily coyotes] who would otherwise prey on flocks of sheep brought in to graze in the spring.")[78]

That the Indian Wells Valley took these social evolutions in stride, with little apparent controversy or strong opposition, lends credence to an observation that Milt Ritchie made in his statement of support of the Rumford Bill in 1963:

> The implementation of the law changes community patterns. And community patterns change attitudes.[79]

Flower Children

Youngsters at China Lake in the 1960s were little different from their peers nationwide. They joined Brownies and Cub Scouts, Girl Scouts and Boy Scouts, 4-H, Little League, youth bowling leagues, church summer camps, and numerous other youth-focused organizations. They hunted lizards. When the wind was calm enough, they flew kites—and by the end of the decade, model rockets. They went to school and went off to college. Some returned to work on the base or in family businesses, most did not.

The youth of the valley were caught up in the same trends as their counterparts, and one of these was juvenile delinquency, which became a major concern of adults in the valley, as elsewhere, in the late 1950s. The topic had been presented to a broad popular audience in the movies *Rebel Without a Cause* and *The Blackboard Jungle*, both released in 1955, and the life of New York City gangs was romanticized in the 1962 film *West Side Story*.

The so-called "epidemic" of juvenile delinquency was ascribed variously to children watching the above-noted movies, poor parenting, an excess of affluence, too much comic-book reading, and the interactions of various more

77 *IWV Independent and Times-Herald*, Aug 1967, A-2, A-3.
78 *IWV Independent and Times-Herald*, 8 Jan 1959, A-1.
79 *IWV Independent and Times-Herald*, 6 June 1963, C-5.

complex social phenomena. Whatever the cause, isolation did not prevent the Indian Wells Valley from being affected.

Some of the "juvenile crime" was what might be expected from the 1950s. "Five teenagers charged by sheriff's deputies with stealing watermelons from a local field entered pleas of guilty July 27 and were fined $10 each and lectured by the court on respect for property and the rights of others," the *Valley Independent* reported in July 1959. The next month, however, was an eye opener for the valley.[80]

On 27 August 1959, the *Valley Independent* published a photo of a police officer standing by an assortment of lethal weapons. The caption read:

> A potential outburst of gang violence was nipped in the bud over the past weekend by the arrest of 41 local youths on a charge of unlawful assembly. Sgt. Curtis Bell, officer-in-charge of the Ridgecrest substation of the Kern County Sheriff's Office, looks over a collection of the various items that were confiscated before they could be put into use. These include several clubs, a weighted rubber hose, a heavy length of chain, a switchblade knife, and beer can openers that had been readied for use as weapons. Six youths arrested have pleaded guilty and were sentenced Tuesday by Judge [Robert L.] Pruett.

The accompanying article noted that 12 of the suspects were juveniles, and the suspects were "military and civilian residents of the Navy Station as well as Ridgecrest youths."[81]

But aside from that brush with mass mayhem in 1959, most of the juvenile delinquency incidents of the period seem, by 21st-century standards, relatively mild. In April 1962 new Station Police Chief Robert Groth announced that existing Kern County curfew laws would be enforced "following several minor incidents in which China Lake youths were involved."

The *Rocketeer* reported 10 offenses involving juveniles in October 1962 including "malicious mischief, petty theft, vandalism and two cases of runaway juveniles." In 1963, under the title "End of School Spawns Malicious Mischief Spree," the *Valley Independent* reported 20 incidents of punctured automobile tires over just a weekend.[82]

Lieutenant Commander Joseph A. Costa, NOTS chaplain, addressed his "Chaplain's Message" *Rocketeer* column to teenagers in August 1963, observing:

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80 *IWV Independent and Times-Herald*, 30 July 1959, A-2.

81 *IWV Independent and Times-Herald*, 27 Aug 1959, A-1.

82 *Rocketeer*, 27 April 1962, 1, and 1 Dec 1961, 4; *IWV Independent and Times-Herald*, 13 June 1963, A-2.

> There is another gripe of teenagers that is heard constantly. It is: "My parents don't understand that times have changed." . . . There is some truth in the statement, times do change; but basic problems do not.

He advised teens to listen to their parents, but added "You need not follow them blindly. If their advice proves wrong for some reason, you can adopt a mode of action which conforms more closely to your own experience."[83]

China Lake and Ridgecrest teenagers did in fact adopt modes of action conforming more closely to their own experience. By the mid 1960s, parents' fear of their children slipping into juvenile delinquency changed to a fear of losing their kids to illegal drugs. Marijuana and LSD began to make the local papers. During the first six months of 1967, 19 children younger than 18 were arrested for drug offenses. In one 2-week period during the summer, Ridgecrest police arrested 11 local people for possession of the "hallucinogenic drug" marijuana. Five were Navy enlisted men.[84]

The drug war was on. Shortly before Captain Melvin R. Etheridge arrived to take command of NWC in September 1967, a survey taken of students at Burroughs High School indicated that marijuana was used by 50 percent of the students. Etheridge later said that:

> The evidence that was being used to say that there was a drug problem was based largely upon a survey that had been done in the high school here. And if you read the survey, and looked in detail at how the survey was structured, the only conclusion you could come up with was that the place was nothing more than a mass of drugs and drug users. And I refused to accept that. So I was accused by the local press in town of looking through the world with rose-colored glasses and other things.[85]

By October the community was highly alarmed. More than 300 people packed the James Monroe School Auditorium on the base to hear a lecture titled "Hippies, LSD, Sex, the Youth Quake That Is Destroying Your Children." The presentation was sponsored by the China Lake Chapter of Truth About Civil Turmoil (TACT), according to a *Rocketeer* article that invited all interested persons from China Lake and the surrounding area to attend. What the article did not mention was that TACT was a committee of the John Birch Society.[86]

As if the inflammatory title of his presentation were not enough, the lecturer, Ken Granger, a newspaper photographer and collector of psychedelic

83 Rock*eteer*, 16 Aug 1963, 2.

84 *IWV Independent and Times-Herald*, 19 Nov 1967; 3 July 1967;14 Sept 1967.

85 S-152, Capt. Melvin R. Etheridge, USN (Ret.), interview, 23 Sept 1983, 26, 27.

86 *Rocketeer*, 6 Oct 1967, 8; John Birch Society website, *http://www.jbs.org/component/content/article/962-from-the-ceo/4230*, accessed 12 May 2011.

posters, inundated the audience with a barrage of "facts": in Los Angeles "dope usage has increased 600 percent in the first quarter of 1967," in Rolling Hills School of Palos Verdes, "70 percent of the teenage students had taken LSD or marijuana this year." He added that Bob Dylan's *Rainy Day Woman* (with the repeating chorus "But I would not feel so all alone, everybody must get stoned") refers to a marijuana cigarette."[87]

He claimed that the drug problem in Ridgecrest was "far more serious than the public knows . . .because an effort is made to protect the parent's job, and thus the story doesn't always get into print." He claimed that "teenagers are being duped into dope and an illicit communal sex conduct that has overnight created a national canker of crime and disease." And of course he blamed "the Communists."

Granger even told the *Valley Independent* reporter in a post-meeting interview that "some of the long-haired unwashed, barefoot 'hippies' in the audience, who came up later to talk to him, showed obvious signs of drug hallucinations. They 'saw' imaginary worms, and 'heard' imaginary cats meowing, he said." One wonders how many of the "hippies" had difficulty maintaining straight faces during the encounters.[88]

Unfortunately, Granger, like many commentators of the day, conflated music, clothing, hair length, sexual experimentation, antiwar sentiment, and drugs into a single monolithic Communist-inspired plot against America. And a lot of people bought the package, furthering a rift between the young ("don't trust anybody over 30") and their parents' generation.

By 1968 Etheridge was up to speed on the drug problems. He ordered a series of articles to be prepared for publication in the *Rocketeer* to get the relevant facts before the public. The first of these five articles, a full two-page spread, was the most informative: a round-table interview by a *Rocketeer* staff writer with the chiefs of the China Lake and Ridgecrest Police Departments, an investigator from the Kern County Sheriff's Department, and the China Lake legal officer.

The interviewer asked the participants about "the rumor that China Lake-Ridgecrest area produces the largest number of narcotics users per capita in this part of the United States." China Lake's Chief V. A. "Slim" Cummins responded that, on the base, "over a 2 year period only 14 people have been involved in some sort of narcotics arrest."

87 *Valley Independent and Times-Herald*, 5 Oct 1967, A-8; 19 Oct 1967, A-4.
88 *Valley Independent and Times-Herald*, 19 Oct 1967, A-4.

Sheriff Don Glennon summarized the problem statistically:

> For the year 1966, in Kern County, there was a total of 46,247 felony and misdemeanor arrests. That was out of a total population of some 330,000 people. Narcotics arrests were 40. In 1967 there were 44,765 felony and misdemeanor arrests . . . and a total of 104 narcotics arrests, or almost three times as many as the previous year. So far this year for the first quarter there have been 68 narcotics arrests in Kern County. This indicates there is a growing problem. It's a moral and social problem stemming from the family and the family not knowing what's going on or instilling good old-fashioned ideals in their kids.

Ridgecrest Police Chief George Whaley pointed out the statistical rise in drug use across the nation (e.g., "in 1967, throughout the State of California felony drug law violations increased 68.9 percent") and then commented:

> There has been a lot of publicity given to the use of drugs, the amphetamines, barbiturates, LSD, marijuana, etc., and I think the publicity, at times, may have worked to our disadvantage by making enough young people curious to try and see if the drug did what the publicity said it would do for them.

The officers were united in placing the blame for the drug problem on parents. In addition to Glennon's comment above, Commander H. E. Byrd, the base legal officer, said:

> If he, the parent, is going to tie this up in his bosom for fear the Joneses might talk about him; if he's concerned with his own image rather than the welfare of the child; and he is, if he fails to surrender the information to the police, then he is hampering, directly, law enforcement and has no right in a sense to talk about the problem in the valley.

"Parents have to accept their parental responsibilities; they have to know where their children are at all times; they have to know who they are associating with and they have to know what they are doing," said Whaley.

Cummins added, "I feel without the parents' help we are in trouble. I'm not going to baby-sit these kids living on the Center and the parents should know this. If they don't know where their kids are, what they are doing, then, I say, we're really in trouble."

Byrd closed the interview with "When we speak of educating the child, children, minors, we think the of parents . . . it's their responsibility."[89]

In a conference with Capt. Etheridge and 10 Burroughs High School students in April 1968, a reporter interviewed the youngsters at length about drug use in the community. They had a more nuanced view of the factors

89 *Rocketeer*, 12 April 1968, 5–6.

leading to the decision to use drugs than did the law-enforcement officials. The students assigned some responsibility to parents and to "home problems," but they also blamed peer pressure, rebellion, "spiritual revelation," "free thinkers," and of course the perennial complaint of youngsters in the Indian Wells Valley, a lack of better things to do.[90]

In 1968, then-Deputy Technical Director Hack Wilson and his wife Jane were increasingly concerned with the growing drug problem in the community. According to Thomas L. "Thom" Boggs, Wilson turned to him, giving him a job order number and telling him to "do what needed to be done."[91]

While Boggs is a renowned research scientist in the field of propellant combustion, he is also well-known in the Indian Wells Valley for his extensive work with local youth and for his leadership roles in community service organizations. Late in 1969 Boggs and Marty Denkin, director of the China Lake Youth Center, set up a program called Reality. While most efforts nationally were concentrating on the supply side of the problem—the "pusher"—the Reality program dealt with the demand side, specifically with young people addicted to drugs. It offered them counseling, support, and, when needed, medical assistance. The program helped many young people turn their lives around.

In 1970 a young sailor at the Naval Air Facility told NAF Commanding Officer Captain Robert E. McCall about Reality. McCall, like Etheridge, Wilson, and other China Lake leaders, was concerned about the growing drug problem, and he asked Boggs to bring his message to NAF. Boggs prepared two drug-education presentations: one for NAF's enlisted men, stressing individual responsibility, and another for the officers, emphasizing leadership and accountability. Word of the Reality program spread, and it was featured nationally in an August 1970 ABC News special, "The Kid Next Door Smokes Pot."

But despite efforts by civilian and military leaders, the problems associated with drug use would continue as China Lake moved through the 1970s. During that decade, drug use became a major concern for all of the armed services, as it did for most American communities.

By the 1980s, China Lake Command would be using drug-sniffing dogs in so-called "health and welfare" inspections of all base housing, military and civilian.[92]

90 *Rocketeer*, 24 May 1968, 4–5.
91 Thom Boggs, telephone interview with the author, 13 July 2011.
92 *Rocketeer*, 17 Dec 1982, 3.

The Antiwar Movement

Throughout the nation, and indeed throughout the world, sentiment against the U.S. military's role in Southeast Asia during the 1960s and 1970s was greater than in any other 20th Century American war. As the number of U.S. troops increased and operations intensified, so too did the size and vehemence of the opposition.

China Lake had been actively supporting U.S. military efforts against the Communist-backed forces in Southeast Asia since 1960, but the efforts were given little publicity in the press. A 1962 article in the *Rocketeer* reported a presentation at the Station by the Marine Corps Educational Center. The Marines discussed the Corps' amphibious warfare techniques in the context of a hypothetical 1965 scenario: "the violation of boundary agreements of a democratic, western-oriented nation by regular and irregular forces of a northern, Communist-oriented nation."[93]

In 1963 the *Rocketeer* first wrote of a China Lake project intended for use in Vietnam: the Helicopter Trap Weapon or "sterilizer" as the *Rocketeer* called it. The weapon was demonstrated for President Kennedy during his June visit to China Lake.[94]

By 1965 there was no ignoring the Vietnam War, nor NOTS involvement. One article in the *Rocketeer* contained excerpts of a letter from Lieutenant Commander Charles H. McNeil, a Navy attack pilot in Vietnam whose exploits had been featured in *Time* magazine. "I would like to convey my thanks to all the people, both civilian and military, at China Lake for the weapons they have developed in the past few years," McNeil wrote.[95]

While 1965 marked the beginning of the big buildup in U.S. troop strength (184,000 American military personnel were on the ground in Southeast Asia by year's end), a realization was already dawning in some quarters that the war could not be won by military force alone. Bernard Fall, writing in *Naval War College Review*, observed that Vietnam was a "revolutionary war," which he defined as:

> . . . guerilla warfare plus political action . . . the insurgency problem is military only in a secondary sense, and political, ideological, and administrative in a primary sense. Once we understand this, we will understand more of what is actually going on in Viet-Nam.[96]

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93 *Rocketeer*, 9 Feb 1962, 1. The hypothetical amphibious force also included "a South Vietnam Marine Battalion."

94 *Rocketeer*, 9 Feb 1962, 1; 31 May 1963.

95 *Rocketeer*, 23 April 1965, 1.

96 Bernard B. Fall, "The Theory and Practice of Insurgency and Counterinsurgency," *Naval*

As early as 1963, a former South Vietnam ambassador to the U.S., Tran Van Chuong, speaking about U.S. Secretary of Defense Robert McNamara and Gen. Maxwell Taylor, said, "I do not think such clear-minded men can separate the military from the political in a war they know above all to be political . . a war to win the hearts and minds of the people." China Lake, however, was not in the business of winning the hearts and the minds of the people, but rather in developing better ways to achieve military victory. [97]

While antiwar sentiment undoubtedly existed in the Indian Wells Valley in the 1960s, it did not reach the level of expression that it did elsewhere in the country—not surprising in a community where most everyone's job was directly or indirectly dependent on developing systems to prosecute the war. The view of Don Yockey may have been typical of many:

> I started out believing that we should be there, that it was necessary to have the South Vietnamese have some protection while they were trying to set up a government of their own, but then the government of their own turned out to be so graft-ridden, and [I] heard about the different things that were happening there, that I just decided that I couldn't support it any longer from my own point of view. But I didn't do anything about it. I just said, "Gee, that's sure is a rotten way to fight a war, that you don't go in with the object of really winning, you just sort of want a stalemate."[98]

Asked if he was aware of any focused opposition to the war, Yockey—a decorated WWII veteran who throughout the entire Vietnam War was editor of either the *Rocketeer* or the V*alley Independent*—replied that "no concrete group came forward and said, 'This is our stand. We want you to put this in the paper because we believe it's all wrong.' Nobody. No one like that."[99]

Naturally there was interest in the war, and in the conflicting views about U.S. participation. In February 1968, several organizations, including the local chapter of the American Society for Public Administration, the Bakersfield College Annex Student Council, and a few local churches, joined to sponsor a public forum on the Vietnam War. Two speakers were invited to represent the opposing views. Representing the Johnson administration's position was William H. Marsh, a U.S. State Department political officer who had served in that position for 3 years in Vietnam. Speaking "in favor of disengagement"

War College Review, April 1965, reprinted in *Naval War College Review*, Winter 1998, *http://www.au.af.mil/au/awc/awcgate/navy/art5-w98.htm#author,* accessed 7 July 2008. Professor Fall was killed by a mine while on patrol with U.S. Marines in Hue, Vietnam, in 1967.

97 "Can't Win Under Diem, Mme. Nhu's Father Says," *Los Angeles Times*, 14 Oct 1963, 15.

98 S-214, Don R. Yockey interview, 11 Aug 1992, 37.

99 Ibid., 39.

was Dr. Fred W. Neal, chairman of the international relations faculty at the Claremont Graduate School (and a WWII veteran of the U.S. Naval Air Corps).

Advertising community events on base was common practice, and Fred Nathan, NOTS' organizational communications officer, worked with the dean of the Desert Division, Bakersfield College, on publicity for the forum. Nathan recalled that the dean brought in a draft of the poster to show Captain Robert Williamson II, NOTS Executive Officer

> . . . who had asked to see it before it was permitted to be put up on the base. So [the dean] showed it to me and then took it up to Captain Williamson. When he came back down, he was shaking his head. Captain Williamson was going to go along with it, but Captain Etheridge said, "No way." So, we didn't have any publicity on the base.[100]

The absence of on-base advertising notwithstanding, the debate attracted a crowd of 360 to Burroughs High School's multi-use room on 21 February. Both speakers were well prepared and clearly laid out the principal opposing philosophies. Marsh asked, "What are our objective in Vietnam? It's so simple it seems transparent. It is to preserve the right of the Vietnamese people to express their nationalism in their own way. . . I would regard it as a gross immorality for the U.S. to abandon South Vietnam to the tender mercies of North Vietnam."

Neal pointed out that "the Geneva Agreement clearly called for a unified Vietnam. . . . every international law is being violated by the U.S. in Vietnam. . . . Either the U.S. negotiates its way out of the Vietnam War, or there will be a thermonuclear holocaust. . . . The Chinese don't like this any more than U.S. citizens would if there was a large Chinese army in Mexico."

Dr. Edward J. Jones, a consultant in China Lake's Organizational Behavior Group, moderated the debate, which was heated but civil. At one point, when an audience member asked Neal "How many professors teaching in our colleges are aiding and abetting the Communists as you are?" Marsh reacted immediately, according to the *Valley Independent*:

> Stepping to the microphone he said: "I regret the remark that was just made by the questioner, and I feel Professor Neal is owed an apology. If the meeting is going to resort to name-calling, then I must leave." This accomplished the desired result of squelching any further inquiries involving personal attacks against either of the speakers.

Two hours of well-reasoned debate may have served only to harden the audience in their opinions. "At the conclusion of the public forum," the paper reported, "no one in the audience was ready to admit, in response to a query by

100 S-192, Nathan interview, 4.

Dr. Neal, that anything either of the principal speakers had said had changed the views of the dilemma in Vietnam which they had held before the meeting began." A post-debate poll of the audience (157 out of 360 responded) showed 45.8 percent opposed to bombing North Vietnam, 49.1 percent in favor of continued or escalated war policies, and 5.1 percent undecided.[101]

In a subsequent letter to the editor, Neal clarified a statement he had made: during the debate:

> What I did suggest was that it may be difficult for some of those whose livelihood is involved with the military efforts to appreciate fully the possibilities of diplomatic as against military solutions.[102]

The lack of strong antiwar sentiment at China Lake may have reflected a more complex view of the war, rather than either wholehearted endorsement of it or a hesitation to speak out publicly against it. In 1969, the Public Works Department installed an A-4 aircraft on pillars at Switzer Circle, complete with six Snakeye bombs and a pair of Rockeyes. That prompted the Research Department's Roger Peck to speak up, in the form of a letter to the widely read management newsletter *News and Views*.

Peck wrote:

> Why has management chosen to adorn the peaceful green of Switzer Circle with a military aircraft—now complete with bombs? I admit that it is representative of the Navy's immediate task and, more specifically, of the NWC task, but why not use the area for a symbol of Navy's ultimate goal—peace. It would at least seem more appropriate to display some noncombatant "thing" that is important historically to IWV—or maybe a memorial to local men who died while fighting to protect the freedoms we're supposed to be thinking about preserving—but in any case, not an instrument of war.[103]

Nathan, editor of *News and Views*, recalled his reaction to the letter**:**

> I thought, well, the better part of valor might be to check this out first, and I brought it to [Etheridge] and he swallowed hard and said 'OK, go ahead and publish it.' . . . We published it and invited feedback and feedback, as I recall, was like 3-to-1 patting Roger on the back instead of taking exception. That kind of thing would astound outsiders that—"They actually let you publish something like that? In a military community?"[104]

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101 *IWV Independent and Times-Herald*, 29 Feb 1968, A-1–A-2, A-4.

102 *IWV Independent and Times-Herald*, 14 March 1968.

103 *News and Views*, July-Aug 1969, 10.

104 S-190, John L. Cox and Frederick M. Nathan interview, 24 and 29 March 1991, 83. According to the *News and Views* fall 1969 issue, 7 respondents opposed Peck's position, 15 favored it, and 3 had mixed reactions.

The reaction of physicist Dr. Bernard Seraphin was representative:

> I strongly support Roger Peck's protest against setting up a military aircraft, complete with bombs, in a place and in a manner so prominent that it acquires the status of a symbol. True, the products of this Center are methods of destruction. As long as we must have weapons, they must be superior to anything a potential enemy can devise. . . . However, we must draw a line between a "showcase" and a "symbol." Professional pride notwithstanding, should we elevate our product to the status of a symbol? Shouldn't we rather symbolize the values we are prepared to defend by using these means of destruction? Or the men, traits, or events that in past history have upheld these values?[105]

But the protests were for naught. As of this book's publication, the A-4 still stands at Switzer Circle.

Elsewhere in California, the attitudes were far more polarized. While there were a few pro-Vietnam War rallies, the more spectacular protests were in support of the burgeoning antiwar movement. Jack Lyons recalled one recruiting trip to University of California at Berkeley. He was on the top floor of a building with two other recruiters: one from Dow Chemical (the makers of napalm) and the other from the CIA. At one point the noise level outside rose and Lyons went to a window and looked out.

> The noise came from a helicopter hovering over the building . . . they were shooting tear gas into a crowd of angry students who didn't want the CIA, China Lake, or Dow Chemical interviewing on campus . . . There were police arm-in-arm cordoned off, holding back this huge throng of shouting students.[106]

Generally though, through the 1960s, antiwar sentiment in the Indian Wells Valley was an undercurrent in public discourse. It never reached the level of a strong disruptive force, as it did in so many other American cities.

The View Ahead

At the end of 1967, major upheavals were still ahead for the country and the residents of the Indian Wells Valley. Among these were the My Lai massacre; the antiwar marches on Washington; the assassinations of Dr. Martin Luther King, Jr., and Robert F. Kennedy; the Kent State shootings; the first OPEC oil crisis; and a phenomenal upsurge in the use of illegal drugs. Next to the cessation of the Vietnam War in 1975, however, the change that had the

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105 *News and Views*, Sept-Oct 1969, 10.
106 S-282, Lyons interview, 50.

greatest impact on China Lake over the next decade was that same homegrown issue that simmered through the 1960s: housing.

Once financing became available for off-Station housing, and the on-Station perks of government-subsidized food and services had been removed, more and more people—old hands who had been at the base since WWII as well as newly hired employees—opted for life outside the gate. The trickle became a flow and then a torrent in the 1970s, when the Navy decided that on-base housing should be used exclusively for military personnel. As more people moved off the base, more builders and developers moved into the valley. No precise moment can be found when China Lake became a community of commuters—if one can call a drive of a mile or less a commute—but the centroid of Civil Service residency moved outside the gate at some point in the 1970s.

The migration had a direct impact on China Lake's culture. As the balance shifted from nearly all the civilian employees living on base at the start of the 1960s to nearly all living off base by the 1980s, the obsession with work—and its influence on every aspect of people's lives—dwindled. Civil servants established relationships with citizens who did not live on base, they found their entertainment at off-base facilities, they saw their military counterparts, by and large, only at work. In most respects, for better and for worse, the China Lake of the 1970s and beyond was a far different place than the China Lake of the 1960s.

15

In With the New

For decades there were thousands of employees who were proud to say they worked at China Lake; to be a China Laker was to be associated with success. Success breeds pride.

Jim Colvard, former China Laker[1]

January 1, 1967, fell on a Sunday. The day was seasonably cold and, according to the *Valley Independent*, followed a New Year's Eve celebration on Saturday night that had been relatively quiet.

At China Lake, old traditions continued—the All Faith Chapel hosted the year's first Protestant, Catholic, Jewish, Christian Science, and Unitarian services. The first baby of the year, Lee Allen Shepherd, was born to the wife of a NOTS sailor at the Station Hospital at 9:15 a.m. on New Year's Day and was featured on the front page of the *Rocketeer*. New traditions began—the *Rocketeer* announced that Indian Wells Valley residents would be able to watch the first annual Super Bowl on their televisions, courtesy of Station KERO, Channel 23, in Bakersfield.[2]

On that chill, windy, New Year's day, some residents of NOTS and Ridgecrest may have taken part of their leisure time to read the latest issue of *LIFE* magazine, which had just been delivered in the mail. It featured an article about Dr. William B. McLean, "The Navy's Top Handyman." Back in November, *LIFE* writer John Riley and photographer Bill Ray had spent a week at NOTS, accompanying McLean as he carried out his duties at China Lake as well as at Pasadena, Point Mugu (a visit to the marine mammal facility), San Clemente Island, and Morris Dam.

It was a laudatory article, although given to artistic embellishment ("Tinkering in his home garage in the 1950s, he invented the Sidewinder

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1 James. E. Colvard, "Why Navy Laboratories?" presentation to National Defense University, Washington, DC, 1 Sept 2004.

2 *Rocketeer*, 6 Jan 1967, 1; 13 Jan 1967, 2.

Bill McLean and his son Mark tinkering in the family garage, November 1966.
Bill Ray photo courtesy of *LIFE* magazine.

target-seeking missile"), and it made clear that McLean's first passion was the ocean. The piece was subtitled "Dr. McLean, Sidewinder's Inventor, Tackles the Depths," and the four-page story began with a 9- by 8-inch color photograph of McLean and Don Moore in a 56-inch transparent bathysphere in the Station pool.

The article concluded with a quotation from McLean that captured an important part of his philosophy of leadership:

> We have 4,800 civilian employees, and the ones in the technical organization work for me—as much as anyone ever works for anyone in a technical organization. Let's say I can protect them from being directed.[3]

McLean's laissez-faire attitude toward his workers was tempered by the realities of the weapons development process. In research projects or discretionary funding ventures, in which no Fleet customer was anxiously awaiting a product, a well-presented, carefully thought-out idea was often rewarded with additional resources—money and, often more importantly, time.

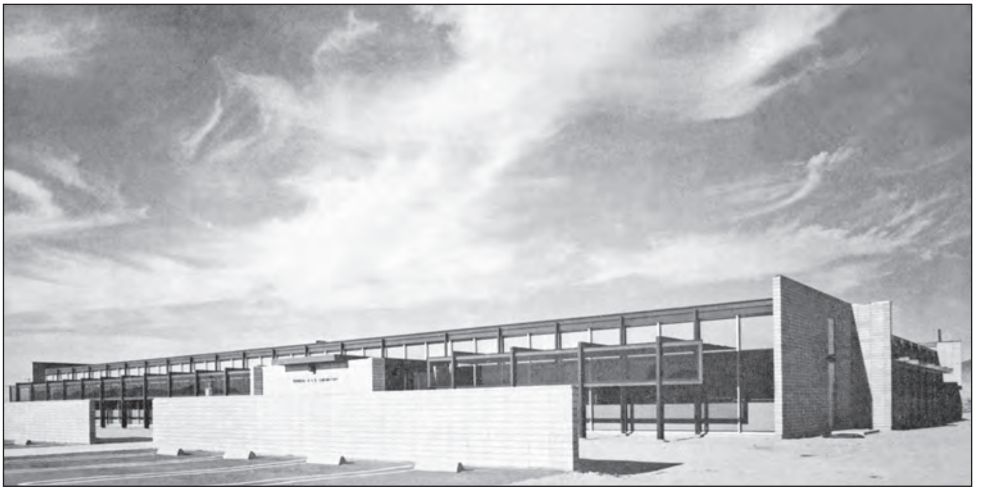
However, as new concepts moved into the development process, they became constrained by calendars and budgets. People and organizations outside the Station, including sponsors, other government agencies, contractors, and end users, depended on adherence to those constraints. It was in this area of the Station's work that seasoned managers like Hack Wilson, Doug Wilcox, Frank Knemeyer, Carl Schaniel, Barney Smith, Dick Boyd, Bud Sewell, and others brought to bear the management discipline and leadership skills necessary to bring projects in on time and on budget.

Standing on the edge of 1967, the Station had a promising road ahead. The growth that begun at the end of the 1950s had continued steadily, and new facilities and capabilities were flourishing across the Station.

At Skytop, the $1.3-million Liquid Propulsion Testing Facility, 2 years in construction, had just opened. It consolidated farflung facilities in Area R to a single site on "the hill." The new test bay was capable of handing sustained thrusts of 0.25 million pounds and instantaneous thrust of 1.25 mllion pounds.[4]

Two months earlier, the 10,071-square-foot Warhead Research and Development Laboratory, with a nearby 2,600-square-foot test-firing chamber, opened for business. Located at the southwest corner of the intersection of Pole Line and Water Roads, north of Mainside, the new facility co-located elements of three departments: the Weapons Development Department's Weapons

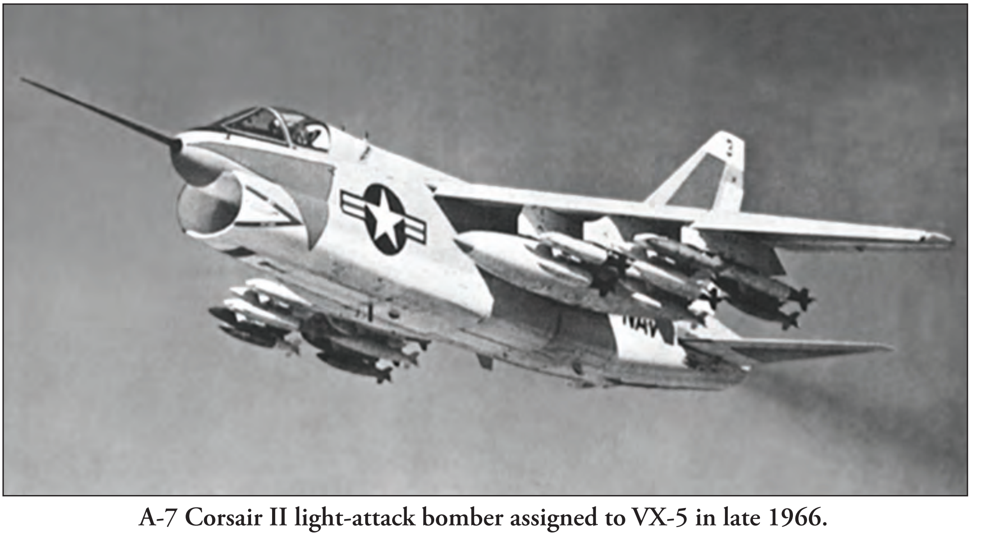
3 "The Navy's Top Handyman," *LIFE*, 6 Jan 1967, 31.
4 *Rocketeer*, 6 Jan 1967, 1.



Warhead Research and Development Laboratory.

Systems Analysis Division; the Propulsion Development Department's Warhead Development, Warhead Analysis, and Explosive Ordnance Development Branches; and the Research Department's Detonation Physics Division.[5]

Shortly before the New Year's holiday, the Station's first A-7A Corsair II light-attack bomber had arrived at VX-5. The aircraft joined the squadron's stable of project aircraft, including A-4s, A-6s, and F-4s, whose sister aircraft were seeing heavy action in the Vietnam War.[6]



A-7 Corsair II light-attack bomber assigned to VX-5 in late 1966.

5 *Rocketeer*, 4 Nov 1966, 8. The facility was renamed the Pearson R&D Laboratory to honor pioneering China Lake explosives expert John Pearson.
6 *Rocketeer*, 6 Jan 1967, 4–5.

The pace of that war was steadily increasing. U.S. troops in South Vietnam, had numbered 184,000 at the start of 1966. The number reached 389,000 by the start of 1967 and would grow by an additional 97,000 during the year. The average number of U.S. personnel killed in action each month—412 in 1966—would jump to 770 per month in 1967. The number of Americans who thought America's entry into the war was a mistake would rise during 1967 from 32 percent in January to 45 percent, in December, according to the Gallup Poll.[7]

To the NOTS families, the cost of war was more than statistics or Secretary McNamara's infamous "body counts." At the start of 1967, a favorite China Lake chaplain, Father Edward F. Kane, Lieutenant CHC, who had served at the Station from 1964 to 1966, lay in the Oakland Naval Hospital. His spine had been severed by a sniper's bullet while he was on patrol with the Marines. It was Father Kane's second tour in South Vietnam.[8] By war's end, four young men who called Ridgecrest or China Lake home—Ernest Frederic Davidove, Ralph Eugene Foulks, John Scott Pinney, and Timothy Joseph Rizzardini—would die in Vietnam.

References to local servicemen serving in Vietnam had been steadily increasing as U.S. involvement grew. Sometimes the news was inspiring. Marine Corporal John Oakley, 20, whose parents lived on Robertson Road in Ridgecrest, was awarded the Navy Cross for extreme heroism. While he was on a search-and-destroy mission, his unit came under fire from a Vietcong machine gun, which killed two men next to Oakley. He single-handedly attacked the position, overrunning it and killing 13 enemy soldiers despite being twice wounded himself. Of receiving his orders to Vietnam, Oakley told a reporter, "I was real happy when my orders read Vietnam. That's why I joined the Marines."[9]

In 1967, as in most years before and since, the danger inherent in the weapon-development business was brought forcefully home. Commander William L. "Mike" Reardon (executive officer of the Naval Air Facility), Lieutenant Commander Robert R. Kornegay, and ADJ-1 Vernon K. Whipkey would die in March when one of NAF's A-3Bs came down short of the runway at Lockbourne Air Force Base, Ohio. In August a VX-5 A-7A Corsair II and a civilian Cessna 210B would collide near Owens Peak, west of China Lake, killing Lieutenant Commander Thomas H. Ewell of VX-5 and three members

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7 Gallup Poll, *http://www.gallup.com/poll/2299/americans-look-back-vietnam-war.aspx*, accessed 6 Sept 2013.

8 *Rocketeer*, 27 Jan 1967, 2.

9 *IWV Independent and Times-Herald*, 6 April 1967, A-1, A-2.

of the Giroux family flying out of Reno, Nevada. In December Richard L. Kiliz would die in an oven accident at Salt Wells.

Overseas, NOTS-developed weapons were bringing the war to the enemy, from Mighty Mouse and Snakeye in the jungles of South Vietnam to Shrike and Sidewinder in the SAM- and MiG-infested skies of North Vietnam. Walleye was introduced into the Fleet in January, and made its combat debut in May, scoring a direct hit on the thermal power plant at Hanoi. The same month, a MiG-17 was shot down by an A-4C—the only enemy aircraft shot down by an A-4 during the entire Vietnam War—with, of all things, a China Lake-developed Zuni rocket. For an organization whose primary products were the tools of war, business at NOTS was good and the outlook for 1967 was auspicious.

The previous 2 years, however, had seen the foundations laid for organizational changes that would have a major impact on both China Lake and Pasadena. The bilinear structure of the Navy had ended on 1 May 1965 when the Naval Material Support Establishment was replaced with the Naval Material Command (NAVMAT), the head of which, Vice Admiral Ignatius J. Galantin, reported to the Chief of Naval Operations. From that point on, both the operational and material sides of the Navy reported to the Navy's senior military officer. (In the past, under the bilinear system, the four parent bureaus of the 15 Navy laboratories had reported through a civilian channel to the Secretary of the Navy).

December 1965 had seen the creation of the office of Director of Navy Laboratories, although the director in fact directed only a small portion of the laboratories' work. He was primarily responsible for IR/IED funds and for MILCON planning. Dr. Gerald W. Johnson, a DOD physicist with a background in nuclear weapons issues, was assigned the job. In April 1966 command and management control of the Navy laboratories had been officially transferred to Vice Admiral Galantin. The admiral and Johnson together visited NOTS in July 1966 for a briefing which, according to the *Rocketeer*, "leaned heavily toward work in ocean studies and submersibles."[10]

In May 1966 the four bureaus, which had existed since 1840, were replaced with six Systems Commands (SYSCOMs), which collectively constituted the Naval Material Command. On the organization chart, the SYSCOMs were on the same level as the laboratories. However, the SYSCOMs controlled the money and the assets (aircraft, fuel, etc.)—and thus, de facto, the laboratories.

Complicating the structure was a newly instituted system of project managers, established in May 1965 by Deputy Secretary of Defense Cyrus

10 *Rocketeer*, 22 July 1966, 5.

Vance (later Secretary of State under President Carter). The goal of the system was to focus management responsibility for the growing number of increasingly large projects. For those projects extending across SYSCOM boundaries, the managers reported to Galantin. For those within a single SYSCOM, the manager reported to the SYSCOM commander. By the end of 1965, there were 46 project managers. Between 1966 and 1969, the number would nearly triple.[11]

Changing from bureaus to SYSCOMs was a major reorganization, but its rationale made sense. Electronics, for example, which had became essential to military operations long after the original Bureau system was established, was now recognized with its own SYSCOM. The internal structures of the SYSCOMs were also standardized and reflected the structure of the Naval Material Command. Rear Admiral Frank L. Pinney, Jr., then Galantin's deputy for development, was quoted in a China Lake report as saying of the reorganization:

> Frankly, I don't think you will notice any difference. The laboratories are the same, as are their Commanding Officers and Technical Directors.[12]

In retrospect, there was irony in Pinney's remark, because a second effort had been under way in parallel with the bureaus-to-SYSCOMs reorganization. When complete, that effort would have a striking effect on the entire Navy laboratory community.

Centers of Excellence

While the Navy was trying to adjust to the 1965-1966 reorganization that had birthed the SYSCOMs, higher levels of the Department of Defense were still looking at ways to increase efficiency. Increasing efficiency was one of the touchstones of Secretary McNamara's DOD, as was the elimination of waste and redundancy; steps taken to achieve these goals usually had the effect of consolidating control at higher levels.

The Sherwin Plan—"A Plan for the Operation and Management of the Principal DOD In-House Laboratories"—in 1964 had suggested among other things the grouping of laboratories into functional centers. In 1966 Dr. John Foster, the Director of Defense Research and Engineering (DDR&E), had asked Dr. Leonard S. Sheingold (a member of the Defense Science Board and former chief scientist of the Air Force) to study the DOD in-house laboratories. The board's report, published in August 1966, recommended that the laboratories

11 Booz, Allen, *Review of Navy R&D Management 1946–1973*, 83, 91.

12 K. W. Heyhoe, "The Navy's Reorganization," *News and Views,* July 1967, 11.

be reorganized into weapon systems development centers, with discrete warfare areas assigned to individual laboratories. It further recommended that the Navy come up with a plan for that reorganization by November 1966. Foster duly directed the Navy to plan for the establishment of these centers, and when November rolled around, he sent a memo requesting that the status of the plan be reported to him by 1 January 1967.[13]

"Centers of Excellence" was a term borrowed from an ongoing federal program in which funds were provided to colleges and universities to establish themselves as centers for federal research and development. In 1964 the National Science Foundation had proposed to give any single institution $5 million over 3 years to implement self-designed 5-year plans to upgrade academic science activities. In November 1964 the House Subcommittee on Science, Research, and Development issued a report describing the potential of Centers of Excellence for more evenly distributing federal R&D funds. "Around these centers may then grow private companies capable of doing high quality R&D work, and both the institutions and the companies would attract federal funds," the subcommittee stated.[14]

The Navy's Centers of Excellence were to be "self contained organizations oriented toward the identification and solution of specific and related military problems." Centers were expected to have greater capability for managing the development of increasingly complex and interrelated systems. As well as maintaining and expanding existing technical capabilities, the centers were to develop broader systems-analysis capabilities with which they could better assess the relative merits of alternative development approaches and conduct more thorough program planning.[15]

When the Navy's plan for the new warfare centers was floated in late 1966—it appears to have originated in the office of Dr. Robert Frosch, Assistant Secretary of the Navy (R&D)—NOTS leaders discussed it with the NOTS Advisory Board during the board's bi-annual meeting at China Lake in November 1966.

Advisory Board membership had varied over the years. In November 1966 it included Admiral John H. Sides (USN, Ret.), (former Commander-in-Chief of the Pacific Fleet); Vice Admiral Paul D. Stroop (former Commander of Naval Air Force Pacific, BuWeps, and NOTS); Dr. James H. Wakelin, Jr. (former ASN

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13 Defense Science Board, "Report of the Committee on In-House Laboratories, 19 Aug 1966," cited in Booz, Allen, *Review of Navy R&D Management 1946–1973*, 157.
14 Robert C. Toth, "U.S. Begins Scientific Development Program," *Los Angeles Times*, 31 March 1964, 5; Toth, "Plan Urges Better R&D Distribution," *Los Angeles Times*, 9 Nov 1964, Business Sec., 9.
15 *NWC Tech History 1967, Part 1*, 1-43.

Members of the NOTS Advisory Board, their hosts, and a guest at China Lake, 3–4 November 1966. Seated from left are Rear Admiral F. L. Pinney; Vice Admiral Paul D. Stroop; Dr. William B. McLean; Captain John I. Hardy; Dr. W. Albert Noyes, ,Jr.; and Dr. L. T. E. Thompson. Standing from left are Admiral John H. Sides; Dr. James H. Wakelin, Jr.; Dr. Luis W. Alvarez; Dr. Frederick C. Lindvall; Dr. Joseph E. Henderson; and Dr. Paul M. Fye.

R&D and head of Research Analysis Corp.); Dr. Luis W. Alvarez (physicist who would win the Nobel Prize in 1968); Dr. Frederick W. Lindvall (Caltech engineering professor); Dr. Joseph E. Henderson (founder of the University of Washington Applied Physics Laboratory); Dr. W. Albert Noyes, Jr. (professor of chemistry at the University of Texas and former president of the American Chemical Society); and Dr. L. T. E. Thompson. The board was headed by Dr. Paul M. Fye, director of the Woods Hole Oceanographic Institution. A guest at the meeting was Rear Admiral Frank L. Pinney, Jr., Deputy Chief of Naval Material (Development).

The new plan for consolidating the laboratories into more narrowly tasked "Centers of Excellence" did not sit well with the board. Its recommendations included a statement that:

> With constantly changing environmental conditions, and constantly developing new technologies, it would appear not in the best interests of the Navy to implement any general organizational scheme which might involve such strict compartmentalization that certain warfare areas were assigned exclusively to specific laboratories. With the background of the NOTS success pattern over the past twenty years, the Board feels strongly that this organization should be kept intact as a Center in order to preserve the flexibility of operation and program diversity in many overlapping warfare areas which are the essence of its strength and effectiveness.[16]

16 Advisory Board meeting, 3–4 Nov 1966, Recommendations, 1.

Now that the plan for Centers of Excellence had taken form, the clock was ticking toward the plan's execution. On 18 January 1967, the NOTS Technical Board convened a two-day meeting in San Diego. McLean presided over the meeting of 20 men representing NOTS military and civilian technical leaders (the sole woman, Irma Agnew, was the recording secretary).

The group's discussion was wide ranging. Members talked about community issues, range testing, ocean engineering, the urgent need to get Walleye to the Fleet, and the status of the Extended Range ASROC program (Doug Wilcox reported that the Aerojet Mk 46 Mod 0 torpedoes were "not acceptable" and that Gralla, head of the Naval Ordnance Systems Command, was sending 700 of them back for rework). They discussed staffing of the NOTS Liaison Office in the Munitions Building in Washington, DC, and a "State of the Union" address that Captain Hardy was preparing for senior personnel.

They next turned to a subject that the recording secretary called "Techniques for Minimizing Adverse Effects on Laboratory Morale of Unsettled Conditions in Washington." The record noted that "Uneasiness at the working level is evident both at NOTS and in the Systems Commands." The sources of the uneasiness were identified as technical conflicts with the Naval Ocean Systems Center (NOSC) over Extended Range ASROC and the Spinner Rocket, and CNO (Admiral David L. McDonald) attempts to bypass Vice Admiral Galantin and the SYSCOMs to deal directly with the laboratories. Agnew wrote:

> It appears that each Systems Command wants to "own the labs" and this makes things particularly difficult for NOTS since a large portion of our effort comes from Commands other than [the Naval Air Systems Command]. (The reorganization emphasized the incompetence of certain people at Headquarters. Headquarters people don't act like they are at war, but they seem to expect us to act like we are.)[17]

The "Consensus and Conclusions" of the discussion were that:

> Each project requires a considerable amount of salesmanship and NOTS personnel should continue to negotiate with the appropriate sponsor. We need to continuously emphasize that NOTS desires to work for all Systems Commands and to continue business as usual. We need to remember that funding is still in the hands of the respective [Systems] Commands and to treat them as customers, therefore. Discussion with Dr. [Gerald W.] Johnson [Director of Navy Laboratories] by Top Management might help.

It was clear that despite Admiral Pinney's predictions, the previous year's reorganization had created its own set of problems.

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17 NOTS Technical Board meeting, 18–20 Jan 1967, 10.

After a status report from Carl Schaniel on warfare areas, and a presentation from Hack Wilson on advanced concepts for air weapon systems, Frosch's proposal for a "West Coast Complex of Laboratories and Associated Missions" was taken up. The proposal would establish six R&D centers, three on each coast. "All laboratories are opposed to that approach," the secretary recorded, "but they have not been able to change it."

NOTS, the Naval Electronics Laboratory, and the Naval Ordnance Laboratory Corona had submitted a plan for a single "Naval Warfare Center, Pacific." However, the record noted that the plan "probably is not agreeable to either Dr. Frosch or the Systems Commands." The proposal had been submitted to both Johnson and Pinney, and Pinney's response, according to the board minutes, had been that "it does not solve anything."

The discussion's concluding paragraph (echoing the sentiments of the NOTS Advisory Board) noted that "because of NOTS' varied mission as compared to other laboratories, we [NOTS] have the most to lose from reorganizing along the line of narrow or single warfare missions (e.g., air-launched weapons)."

Following a discussion of new efforts for Southeast Asia, including "use of FAX [fuel-air explosive] as an anti-mine or field clearance device," and Hack Wilson's suggestion of "a sales pitch to Marine generals and scientific advisor for close support and helicopter projects,"the meeting concluded. The news of the impending establishment of the centers had still not been made public.

The following month, *News and Views* published a curious exchange of letters. One had been submitted by Ed Price, head of the Aerothermochemistry Division, and was according to the editor "intended for attention at a higher level." Price's letter suggested that research in such military applied sciences as warheads, propellant combustion, etc.:

> . . . "belong" by their nature to DOD rather than to individual services. The motivational needs of these particular areas dictate that the research be carried out in chosen "centers of excellence," either in government laboratories or under close collaboration with them.

News and Views printed the following response from Edward M. Reilley, Assistant Director of Defense for Research and Engineering (Research):

> I do think I can do something along the lines suggested by Ed Price. It is a worthwhile suggestion and, as a matter of fact, has been partially implemented by a number of discrete, unconnected decisions which have not been coupled together and announced.[18]

18 "Letters," *News and Views*, Feb 1967, 12.

The decisions to which Reilley referred were not long in being coupled together. Despite the antipathy of NOTS management and its Advisory Board to Frosch's plan, progress toward it was inexorable. A letter from Frosch to the Chief of Naval Material on 27 March formally proposed reorganizing the West Coast laboratories into three "Centers of Excellence," and the plan was approved. A last-ditch attempt by McLean to dissuade Johnson, Frosch, and Foster from that course was unsuccessful.[19]

Frosch's plan—at this point, Galantin's mandate—was going to happen. It involved carving up three West Coast laboratories—NOTS, the Naval Ordnance Laboratory (NOL) Corona, and the Naval Electronics Laboratory (NEL) San Diego—and reassembling them into three new Centers—the Naval Weapons Center (NWC), the Naval Undersea Warfare Center (NUWC), and (a name that smacks of authorship by committee) the Naval Command Control Communications Laboratory Center (NCCCLC).

NOTS would be split in two. China Lake would form the core of NWC, and the former Pasadena Annex the core of NUWC. NOL Corona would be absorbed into NWC. NEL San Diego would have some elements transferred to NUWC—primarily those associated with sonar work—and what remained would constitute NCCCLC.

NOTS Commander Captain Grady H. Lowe (just 5 weeks into his command) and McLean sent a jointly signed letter to Captain Edward B. Jarman, Commanding Officer, and Dr. F. Stanley Atchison, Technical Director, NOL Corona. The letter suggested that "In view of the reorganizations proposed by Dr. Frosch's letter of 21 March 1967 to Chief of Naval Material, it is suggested that you might like to attend the NOTS Technical Board meeting" on 19-21 April at the Half Moon Inn in San Diego.[20]

The first public announcement of the impending reorganization was surprisingly low key. A Page 3 story in the 14 April *Rocketeer*, "NOTS Requested to Submit Plans for New Centers," spoke of the Centers of Excellence and accurately described the recombination of China Lake, Pasadena, and Corona (though omitting any mention of NEL and NCCCLC). While the *Rocketeer* referred to the reorganization as only a "proposal," the article did state that "since it is desired to form these new Centers by July 1 1967, the Station has been asked by CNM to submit implementation plans by May 1."[21]

19 NOTS Technical Board meeting, 19–21 April 1967, 1.

20 Memo, G. H. Lowe, Commander, and Wm. B. McLean, Technical Director, NOTS, to Capt. E. G. Jarman, Commanding Officer, and Dr. F. S. Atchison, Technical Director, NOL Corona, 5 April 1967.

21 Rock*eteer*, 14 April 1967, 3.

Less than a week after that article, the NOTS Technical Board held a meeting, with Captain Jarman and Dr. Atchison in attendance. The overwhelming task of figuring out how to make the change work was beginning.

The first item on the meeting agenda was titled "Where Are We Going?" McLean led the discussion. He related his lack of success in trying to convince Johnson, Frosch, and Foster to consider an alternative to the three-laboratory complex. He added that the mission statements were not yet set and that the currently suggested name "Naval Air Weapons Center" might be changed. The recorder noted that "there was a feeling that 'air' in the title implied a too restrictive mission and some object to 'weapons' in the title also."[22]

A draft merger plan that would be transmitted to Vice Admiral Galantin to meet his 1 May deadline was reviewed "paragraph by paragraph, sentence by sentence, with the items having the least disagreement being handled first." Consensus was reached on the mission and task statements.

Jarman suggested that the functions of program management and planning, facility planning, public affairs, and systems management for Corona should reside at China Lake, and that a military Deputy Commander should be appointed for Corona. He then announced that he would retire in December. There was argument over the need for any military representative at Corona, and "the Corona people decided to caucus separately at this point."

Discussions continued on the mechanics of the separation. The Auxiliary Landing Field at San Clemente Island, it was agreed, would become part of NUWC and no longer a subordinate activity of NAF, China Lake. The heads of the technical codes were asked to identify the number of billets at China Lake that were engaged in "undersea" programs (which would be moved to NUWC). "There was general reluctance to identify specific people by name," the secretary reported, "but the number of billets was generally agreed upon." Surprisingly, it totaled only 60, of which 29 (from the Engineering Department) were already located at Pasadena.

On Friday, the final day of the three-day event, Director of Navy Laboratories Johnson joined the meeting and spoke to the NOTS and NOLC leaders. He suggested that if NOTS and NOLC had differences that could not be resolved, they could write a "joint letter nevertheless," specifying the areas of concern. He then made it clear that this was not just an organizational redrawing but rather a true integration of formerly independent units into a single center.

22 NOTS Technical Board meeting, 19–21 April 1967, 1.

At that point Jarman balked. He "indicated that NOLC's reply would take a different form [than the joint letter]; his earlier discussions with representatives in the Washington area indicated that integration was not intended."

Johnson urged that the merger be conducted expeditiously, and "he hopes there will be no interruption to on-going work and that there will be a minimum adverse effect on morale."

But what was perhaps the biggest bombshell of the April 1967 Technical Board meeting had come on the first day:

> Dr. McLean was queried as to his intentions. The Board was advised that Dr. McLean had decided to take the Technical Director's position at the Undersea Warfare Center.[23]

After 22 years at NOTS, 13 as Technical Director, McLean was leaving China Lake.

Frank Knemeyer, head of the Weapons Development Department, thought the reason for McLean's decision had to do with programs like *Moray*, which for several years had been carried out in the department's Astrometrics Division (which had become the Undersea Systems Division in January 1967). Said Knemeyer:

> All these manned submersibles, they were strictly because of McLean's interest in this. And you see, he became the Technical Director of [NUWC], and he wanted to go there because that gave him a chance to exploit these things with . . . a whole laboratory rather than [a single division].[24]

Research Department head Hugh Hunter said of McLean's leaving:

> Oh it was bad for the Center, at least I think it was, and I know it was for me. Some of us tried to persuade Bill to stay on but his reasons for leaving were good ones, solid ones, they had to do essentially with what the Navy is all about. Bill philosophically disagreed with the idea that it was worthwhile to try to defend capital ships on the surface. I think he was right. Any persistent enemy can sink them if he wants to. He wasn't willing to spend his professional life trying to keep them afloat if the enemy did want to sink them. That's an awfully simplified statement of what he believed, but he just felt that the Navy had to learn to use the part of the ocean that was under the surface and he wanted to work on that.[25]

Pierre Saint-Amand identified other factors in play:

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23 NOTS Technical Board Meeting, 19-21 April 1967, 1–3.

24 S-124, Knemeyer interview, 21.

25 S-95, Hunter interview, 5

> Towards the end of his stay here, the pressures to reverse his style of operating were becoming quite pronounced, because bookkeepers, with the aid of computers, were able to keep track of the money that he was using for things other than what he was supposed to be using them for, and this was regarded as a heinous sin. These guys never realized that, had they really wanted production out of the organization, that would have been the best way to fund it and operate it. But the pressure on McLean was getting pretty bad the last few years he was here.[26]

Lynn Nowells, an illustrator-animator in the Technical Information Department, had designed a new masthead for the *Rocketeer* in June 1962. The graphic showed a globe of the world. An arrow led from NOTS' location on the globe to the word "NOTS" encircled in the "O" of *Rocketeer*.

Joe Paiement and Wilbur Beard of Public Works taking down the NOTS sign from the Administration Building, July 1967.

"I tried to project the international importance that our command represents," Nowells said. She credited TID Editor Graham Henderson with the subhead that appeared under the word *Rocketeer*: "From Under the Sea to the Stars."[27]

That masthead ran on some 150 issues of the *Rocketeer* until the first issue of July 1967 with the double banner headline reading "Naval Ordnance Test Station Now Naval Weapons Center." Most people probably did not notice that the masthead that day had two slight changes. The acronym NOTS now read NWC. The editor also removed the subhead "From Under the Sea to the Stars," which was no longer quite accurate.

Similarly, the famous NOTS "screaming eagle" logo was changed. Previously the eagle's claws had held a Sidewinder and a torpedo, reflecting the air-warfare and underwater-ordnance missions of the Station; in the new logo,

26 S-120, Saint-Amand interview, 28.

27 *Rocketeer*, 6 July 1962, 3.

Pop Lofinck presiding at the NOTS burial ceremony as Ken Robinson (left) and Newt Ward wield the shovels.

the eagle held a Sidewinder and a Shrike (Corona was responsible for Shrike fuzing), and the Corona name was added (see page 310).[28]

A mock funeral for NOTS was held just outside Ivar Highberg's back yard in the housing area behind the Officers' Club. Jim Colvard organized the event and had a range crew build a 10-foot-long coffin. The coffin had three handles on each side, was painted black, and had the word NOTS painted in white letters on lid.

Sewell "Pop" Lofinck officiated. Lofinck, known as the Law of Wild Horse Mesa because of his 15 years as a guard on China Lake's remote north ranges, dressed for the occasion in his traditional range uniform: baggy khaki trousers tucked into knee-high leather boots, short-sleeved shirt, and white Stetson hat. A pair of suspenders supported a gun belt full of bullets, and on his right hip was a heavy .45 caliber revolver in a leather holster.

28 *Rocketeer*, 7 July 1967, 1. Since the Pasadena facilities had no newspaper of their own, the *Rocketeer* continued to devote one page a week to Pasadena news and to distribute the paper there.

Photographs of the event showed Lofinck reading from the Bible. A yellow sign with blue letters was secured to a large tree stump that served as a makeshift pulpit. The sign read “Here Lies NOTS. 8 Nov 1943—30 June 1967. Born in Adversity. Died in Bureaucracy.”

The six pallbearers wore traditional dark suits. This was not a group of low-level malcontents. All six were current or former department heads: Dr. Ivar Highberg (Systems Development), Dr. Hugh Hunter (Research), Dr. Newt Ward (Aviation Ordnance), Ken Robinson (Technical Information), Ray Harrison (Personnel), and Dr. Wallace Brode (Science, forerunner of Research). [29]

One could make the case that there should have been an air of celebration at China Lake. While the organization had lost most of its undersea warfare work, it had gained a wealth of expertise and specialized facilities relating to fuzes, which were more closely related to the Station’s primary products—air-launched weapons—then were the torpedoes and submersibles and sonar systems of Pasadena. NWC transferred 866 billets to NUWC (representing the bulk of the Pasadena workforce) but gained 967 billets from the merger with Corona. For the first time since the Salt Wells Pilot Plant was closed in 1954, the civilian billet ceiling surpassed 5,000.[30]

A month to the day after NWC was established, Admiral Tom Moorer took over as Chief of Naval Operations. Moorer was a China Lake alumnus who had a deep appreciation of the laboratory’s contributions and understood how business was done at China Lake. Center management was well aware that as control became more centralized in the DOD, it helped to have friends in high places.

Military and civilian DOD employees had also received hefty pay raises in 1967. At the White House bill-signing ceremony in December 1966, President Johnson had said “Patriotism can be its own reward—and thank God we have so many gallant men and women willing to live and die by that belief. But that is no excuse for making patriotism a penalty.” The civil service annual salaries now ranged from a GS-1, Step 1 ($3,776) to a GS-15, Step 10 ($23,921).[31]

Captain Jarman’s question about the extent of integration between Corona and China Lake was answered when Corona’s new mission statement was

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29 A similar though less solemn celebration dubbed a “funeral/wedding” was held in January 1992, when NWC was merged with the Pacific Missile Test Center, Point Mugu, and naval units at Albuquerque and White Sands, NM, to form the Naval Air Warfare Center Weapons Division. At that time the physical plant at China Lake, a subcommand of the Weapons Division, was designated the Naval Air Weapons Station.

30 *NWC Tech History 1967*, *Part 1,* 1-34.

31 *Rocketeer*, 19 Jan 1967, 4.

announced. It made the fuze organization's subsidiary level indelibly clear. Pre-consolidation, Corona's mission had been "conduct research, analysis, feasibility studies, development, design, engineering, testing, evaluation, inspection and surveillance relating to materials, assemblies, and systems principally in the field of guided missiles, guided missile fuzes, and related electronic devices." After the consolidation it was "support the mission of the Naval Weapons Center in selected weapons systems, components and investigations."[32]

Over the next 3 years, some 500 employees would be relocated from Corona to China Lake, exacerbating an already serious housing shortage at NWC. The Naval Weapons Center Corona Laboratories closed in 1971. Carl Schaniel wrote of that period, "The fuze and sensors people came to the desert kicking and screaming."[33]

With McLean assigned as Technical Director of NUWC, Hack Wilson, McLean's right-hand man, was appointed acting NWC Technical Director (although McLean and his family remained at China Lake until January 1968). Wilson would be replaced as Technical Director in early 1968 by Tom Amlie.

NOTS' Commander Captain Grady Lowe, who had been assigned as Commander, NUWC, in the reorganization, was double hatted over NWC and NUWC for two months after the reorganization. Then Captain Melvin R. Etheridge took over as Commander, NWC, in September 1967 for his last tour; he was not selected for rear admiral and retired in 1970.

The consolidation that created the Naval Weapons Center, Naval Undersea Warfare Center, and Naval Command Control Communications Laboratory Center was just one part of the sweeping Centers-of-Excellence reorganization. The next 7 years would see the Navy's 15 principal laboratories devolve, through consolidation and closure, into nine centers.

The Year at China Lake

The people at China Lake most concerned with the reorganization were those tasked to make it work: to integrate the Corona fuzing work into NWC's ordnance programs; to find housing for people who, willingly or unwillingly, were giving up their life "down below" and all the amenities of urban living and moving to the high desert; and to close out accounts and process the thousands of paperwork details necessary to transfer the Pasadena activities to NUWC.

32 OPNAV Report 5750-1, *Command History, Naval Weapons Center Corona Laboratories*, Corona, CA, calendar year 1967, 3.

33 Schaniel, "Carl's Career Chronology," 153.

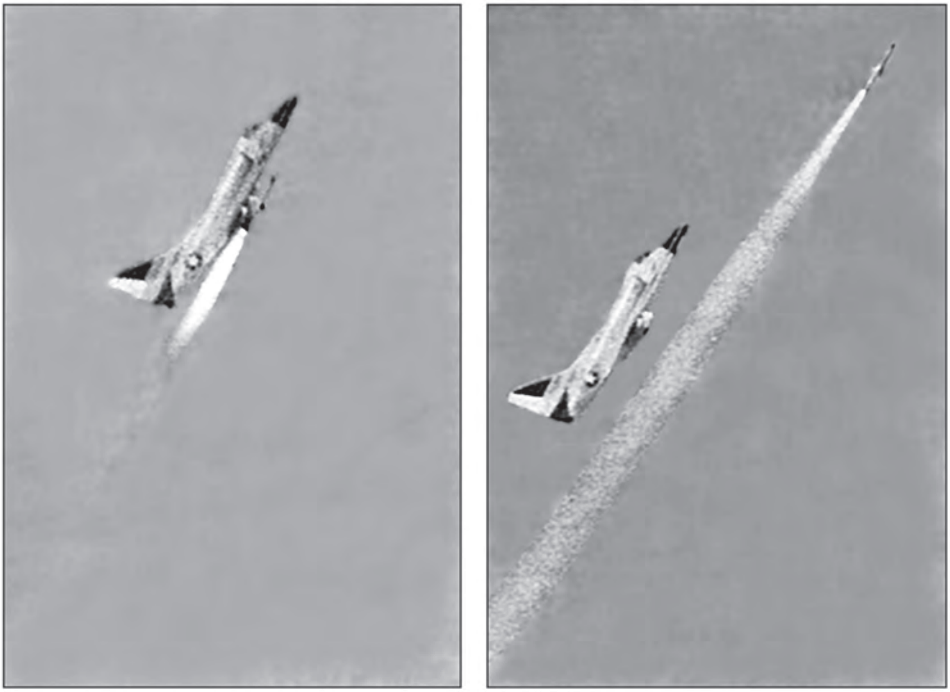
For many NOTS employees, however, probably the biggest impact of the reorganization was seeing new Naval Weapons Center signs at the front gate and on the Admin Building and ordering new business cards. Whether this place was called NOTS or NWC, there was work to be done, important work. A war was going on, and China Lake weapons and systems were in the fray. Big projects were under way, and new programs were planned. McLean was gone, but longtime leader Hack Wilson was still pulling most of the strings from the Administration Building. *Le roi est mort, vive le roi.*

McLean was gone from the organization chart, but he was not, and would not be, forgotten. More than 40 years after he left China Lake and 34 years after his death, he is still at the heart of China Lake's culture and value system. When a spectacular $60-million, 177,000-square-foot building was constructed at China Lake in 2010, it was inconceivable that it be named anything other than the Dr. William B. McLean Laboratory. The remarks by China Lake Executive Director Scott O'Neil, delivered at the laboratory's dedication and reproduced here as Appendix C, capture China Lake's continuing fascination with McLean. They also reflect the high esteem that China Lakers share for the man who created Sidewinder and who was the longest serving Technical Director in the installation's history.

Regardless of the reorganizational pluses (gaining Corona) and minuses (losing Pasadena and McLean), 1967 was a year of accomplishment. China Lake's home-grown Shrike (AGM-45A) was a top wartime priority as Navy, Marine, and Air Force pilots faced the radar-guided guns and missiles of the North Vietnamese. About 4,300 Shrike missiles were delivered for operational use in 1967, nearly half of them to the Air Force.

Responding to changes in the threat radars, the Center deferred work on the AGM-45A-5 ("dash-5," combined S- and C-band) to concentrate on the dash-6 (X-band) and dash-7 (L-band). Work on the Shrike Target Identification and Acquisition System (TIAS)—designed to increase radar detection capability and delivery accuracy—was accelerated, with a goal of Fleet delivery in 1969. Meanwhile, Project ERASE (Electromagnetic Radiating Source Elimination) was set up to explore guidance technologies for post-1972 antiradiation missiles. Among the design objectives were the ability to home on non-emitting radars. Electronic warfare was coming into its own.

A feasibility study of Misteye, successfully concluded in 1967, showed that Gladeye (a NOTS-developed universal dispenser system) and Sadeye (an antipersonnel cluster weapon) could also be used for disseminating stockpiled biological and chemical munitions—if the use of these deterrent weapons ever



Sequence of Shrike missile launch from A-4 aircraft in loft maneuver.

became U.S. policy, which it did not. Development of Weteye (Mk 116), a dispenser of lethal chemical agents, was completed, and production began at Harvey Aluminum Co. Weteye went into the Fleet inventory, but the last of the weapons were transferred to the Tooele Army Depot in 1981. As Frank Knemeyer told an interviewer in 1981:

> This Center was the only laboratory within the Navy that had a capability to develop biological and chemical weapons, and we did.[34]

China Lake's close working relationship with the operational forces in Vietnam was recognized when NOTS was made West Coast Coordinator of the Vietnam Laboratory Assistance Program. In September 1967 NWC received $1.5 million to operate the program during fiscal year 1968. Assistance provided by China Lake ranged from the mundane—buying 30 commercial life preservers for evaluation "because of complaints that the standard life preservers were too bulky and hot"—to the formidable—effectiveness testing of a large white phosphorous bomb (using a Weteye bomb case) as a suppressor for flak fired from visually directed guns.[35]

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34 *Major Accomplishments*, 24; "Last of Nerve Gas Bombs Put in Bunkers at Utah Site," *The Stars and Stripes*, 31 Aug 1981, 27; S-117, Knemeyer interview, 11.

35 *NWC Tech History 1967, Part 1,* 1-9.

The first real-time IR night display of targets was demonstrated with the China Lake-designed ADAM forward-looking infrared (FLIR). This milestone led to a joint development effort with Hughes Aircraft Co. of an advanced system called EVE, and would eventually culminate in such weapon systems as the Night Attack System, the Marine Corps' Night Observation Surveillance (NOS) System, the OV-10 Night Observation Gunship (NOGS), the A-6E TRAM, and the A-7E FLIR.

Events in Vietnam were ratcheting up project schedules. In July, the Commander in Chief, Pacific Fleet, requested accelerated delivery of the 5"/38 Rocket-Assisted Projectile so that the Navy could outrange the North Vietnamese coastal defenses. NWC released the design to limited productions (51,000 rounds) to be conducted concurrently with the Technical Evaluation program. Similarly, the Bombardment Rocket (BOMROC) development program was stepped up as another means to increase the range and effectiveness of ship-to-shore fire.

In August 1966 the Fleet had asked NOTS to develop a shipboard chaff decoy rocket to confuse enemy radars and homing missiles. China Lake engineers developed CHAFFROC—a Zuni rocket fitted with a chaff warhead that delivered a cloud of aluminum dipoles to a predetermined point, creating a false radar image. The system—fuze, warhead, launcher, fire-control system, and ready-service locker—was developed and tested at China Lake, and the first CHAFFROC launcher was installed on a Navy ship in November 1967, just 14 months after the requirement was received. In December 1967, NWC initiated procurement of 100 CHAFFROC launchers and 5,500 rounds.[36]

Chaparral, a system for which the Army was desperate, was undergoing a rugged environmental qualification program. An infamous 5,800-mile road trip completed in 1967 proved the ruggedness of the Sidewinder-based system, and live firings by Army enlisted personnel at White Sands Missile Range tested the weapon to the edges of its intercept envelope.

In April 1967 NWC undertook the Navy's first major experiment in remote computing and computer time sharing, using a centralized computer to serve a remote large-volume scientific user. NWC's UNIVAC 1108 computer began processing more than 1,200 jobs each month for the Naval Radiological Defense Laboratory (NRDL) in San Francisco. The scientists at NRDL used a UNIVAC 1005 as a remote batch terminal. During the year, the original 2,400-baud leased circuit was upgraded to broadband (50,000 bits per second). Three other 1005 terminals were set up locally at China Lake as part of the "digital

36 Ibid., 1-23, 1-24, 5-74.

computing facility network," and the 1108 processed more than 76,000 jobs during the year. The computer revolution was well under way at China Lake.[37]

White-smocked scientists in China Lake's specialized laboratories not only contributed to the body of basic knowledge but also applied their skills to specific problems with existing and developing weapons. Dr. R. L. Conger of the Corona Laboratories, for example, drew on optical-lens principles from the 19th century to propose a directional warhead. Live firing tests demonstrated that varying the point of initiation of the spherical warhead changed the focus of the blast.[38]

And while only fellow mathematicians could truly appreciate the successful expression of the average of ellipsoidal normal distributions with respect to a distribution of ellipsoidal orientations (expressed in terms of classical functions), engineers, managers, and sponsors alike could appreciate the fact that the mathematical feat had applications to detection of submarines.

Operations research and systems analysis were parts of a major and expanding work area. Between China Lake and Corona, approximately 120 man-years of effort were devoted to such analytical work in 1967, and all of the technical departments were involved. The products included special studies (e.g., the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME)) as well as weapons planning studies, enemy capabilities studies, air-to-air weapon studies, air-to-surface weapon system analyses, surface-launched-weapon analyses, warhead analyses, fuze analyses, propulsion and propellant studies, and aircraft system studies.

Ranges are the locations at China Lake where theory comes face to face with reality—often with unexpected and sometimes spectacular results, frequently accompanied by an engineer muttering some variation of the expression "back to the drawing board." Expansion and upgrading of range facilities has been an ongoing process throughout the history of the base, and 1967 was notable in that it witnessed the start of construction of Echo Range, a major new facility at Randsburg Wash for real-world testing of electronic warfare systems and tactics. This range, which would prove to be one of the most valuable assets at China Lake, continues to draw customers from all the services and from U.S. allies around the world.

Why the name Echo Range? China Lake has always had a confusing system for referring to its scores of specialized ranges. Generally a formal, descriptive name is used in reports (Transonic Test Track, Large Warhead Research Test

37 *NWC Tech History 1967, Part 1*, 1-25, 1-47, 1-48.

38 Ibid., 6-44, 6-45.

Range, Air Augmentation Facility, Weapons Safety Test Range, and Static Test Facility, for example). Then there are the names by which these assets are known to everyone on the base (respectively, for those just listed, B-4 Range, Burro Canyon, T Range, CT-4, and Skytop). The connection between the two names is seldom intuitive.

At its inception, the new range at Randsburg Wash area was referred to as "E" (for electronic warfare) Range, which quickly became Echo Range, from the radio phonetic alphabet. Although the range was named the Electronic Warfare Threat Environment Simulation (EWTES) Facility, it is still more commonly referred to as Echo Range.

One event that occurred in summer 1967 sent shock waves through the Navy and would have an impact on China Lake's work for decades. On 29 July aircraft carrier USS *Forrestal* (CVA-59) was preparing to launch an air strike against North Vietnam. A Zuni rocket on an F-4 Phantom fired and struck an A-4, igniting the Skyhawk's 400-gallon external fuel tank. Flames swept the ship's fantail and the fire spread below decks, setting off bombs and ammunition. The cost was 134 dead and 161 injured, as well as 10s of millions of dollars in damage to the ship and aircraft.

Less than 3 weeks later, the Aircraft Carrier Safety Review Panel was convened, chaired by retired Admiral James S. Russell. Knemeyer briefed the committee on the safety characteristics engineered into China Lake-developed weapon systems. The panel's recommendations led to the establishment of China Lake's Aircraft Carrier Conflagration Control Test Facility (locally known as Minideck). The *Forrestal* fire, as well as a similar horrendous fire on USS *Enterprise* (CVN-65) in 1969, also created a demand for munitions that were less subject to accidental detonation or deflagration (rapid violent burning). Beginning in the 1970s, China Lake would become a national leader in the study and development of insensitive munitions (although its work on Hazards of Electromagnetic Radiation to Ordnance (HERO) dated back to the 1950s).

Fleet support has been central to China Lake's business since 1943. Every action taken in every department is intended, ultimately, to help the operational forces—the Fleet—wage war or maintain peace. The most visible of these Fleet support actions were direct Fleet services; the presence of China Lake engineers and technicians and scientists aboard U.S. vessels and at Navy outposts throughout the world. Complementing these Fleet visits were the deployments of operational units to the training ranges at China Lake, where Navy, Marine, and Army pilots learned to use the weapons created at China Lake and to employ the weapons-delivery tactics developed by VX-5.

In 1967, in addition to the Vietnam Laboratory Assistance Program, a new Fleet support service was added: the weapon system predeployment review. Performed jointly by NWC and the Naval Missile Center, Point Mugu, these informal evaluations of ships' and squadrons' readiness were held prior to deployment to inform commanding officers of any major problems that would impact operational effectiveness.

The largest Fleet support effort in 1967 was called Brushup. VA-147, the first A-7A squadron scheduled to deploy to Yankee Station, off North Vietnam, brought 18 aircraft and their aircrews and support personnel to China Lake. After complete ground checks of all weapon systems and electronics countermeasures gear, the aircraft were boresighted and flight tested. Pilot training was provided by NWC experts with assistance from Point Mugu and Patuxent River personnel and specialists from Vought Aeronautics Division. More than 100 sorties were flown at China Lake and the Pacific Missile Range and included Sidewinder, Shrike, and Bullpup firings. As a result of Brushup, VA-147 deployed aboard USS *Ranger* (CVA-61) on schedule and in a combat-ready condition.[39]

Lessons Learned

When George Santayana wrote, "Those who cannot remember the past are condemned to repeat it," he was not merely creating a line with which old timers could preface their anecdotes about "how we did it in the good old days."[40]

In an organizational context, remembering the past is more than a way to avoid making the same mistakes; equally important is remembering the techniques, often developed with great investments of time and money, for facing problems that will surely arise again and again.

The NOTS way of doing business—of developing revolutionary weapons and of being a smart, even shrewd, guardian of the taxpayer's weapons-acquisition dollar—worked well in the 1950s and 1960s. It did not work perfectly, nor all the time, but on balance it worked better than the many government and industry alternatives. The approach—generally referred to as "the China Lake way"—was not so much a recipe for success, or a formula, or a specific methodology as it was a general approach to work, a positive mind-set, and a collection of proven business practices and management techniques.

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39 *NWC Tech History 1967, Part 1,* 1-10.

40 George Santayana, *The Life of Reason*, London, Archibald Constable & Co. Ltd, 1906, 284.

In the same paragraph in which Santayana set down his famous maxim about remembering the past, he also wrote "In a moving world, readaptation is the price of longevity."[41]

The 1960s cannot be recaptured, but the lessons of NOTS' success can still be applied to the serious threats that face the nation. These threats come not only from enemies foreign and domestic but also from an acquisition system that can lose sight of the ultimate goal of weapon development—to cost-effectively provide the nation's military forces with the tools to win the wars and keep the peace.

Use Whatever Works

NOTS scientists and engineers did not always operate by the book. Since so much of what was done at NOTS had never been done before, it was often more productive to say "what if we . . ." and then, if nobody could come up with a good reason why not, go ahead and try it. This practice, in a later generation, would be called "thinking outside the box." When Jimmie Craig was testing the Briteye flare, for example, he used a hot-air balloon for a drop-test vehicle rather than a helicopter or fixed-wing aircraft. Why not? As a result, the program saved thousands of dollars in flight-testing costs.

Not operating by the book did not mean operating in an undisciplined manner. With a little prodding in the early '60s, NOTS managers embraced the new project-management tools like PERT, Mark III, and the WBS—"It keeps them organized," Knemeyer said. And when safety was involved, NOTS engineers and technicians could methodically work through exhaustive pre-test and post-test checklists with the best of them. But when it came to striking out in new directions to solve a Fleet problem, as Tony Tambini observed, "You really never knew what one of these screwballs would come up with next."

Assume Anyone Can Be Brilliant

Certain people at NOTS were, by any objective standards, geniuses. McLean is perhaps the best example, although Pearson, Rice, Saint-Amand, and others qualify. They came up with the sorts of brilliant design, discovery, or engineering breakthroughs that are expected of geniuses. But it was a high-school educated shop foreman named Sydney R. "Sid" Crockett who proposed the idea for the rolleron, one of the simplest and most revolutionary design innovations of the Sidewinder missile.

McLean recognized that great ideas could come from anywhere, and created a management culture in which people could try their ideas out, even when—

41 Ibid., 285.

as with Walleye—he himself thought they wouldn't work. As Jack Crawford said, "Bill was smart enough to realize that you don't always know whether things will work and so you ought to let people give it a try."

This belief filtered through the organization. Junior engineers may have been nervous about speaking up, but when they did, they were listened to. When young Shelby Sullivan recognized the gimbal-lock problem on the Wet ASROC Missile, it was after a roomful of senior engineers had tried and failed to identify it.

Take Risks

McLean's quiet manner and unassuming demeanor belied the fact that he was a bold risk taker. That trait showed in his personal life (as when he nearly drowned testing his homemade Rogallo wing) and it was manifest in his technical and managerial actions. In an era when a mighty aircraft-carrier force was central to the Navy's sense of self, McLean believed, and argued—and spent money on the premise—that surface ships were targets and that the future of the Navy lay beneath the ocean surface. Tom Word, who worked directly for McLean as an operations analyst for 2 years, said:

> I've described Bill as an engineer. I also called him a visionary. There is a difference . . . . A visionary engineer will build a bridge that falls down a few years after he builds it. With a little bit of luck, he won't be there when it lands on whoever happens to be underneath. All right, there will be a little juggling and that will end up being the bridge that everybody builds. Visionaries take chances.[42]

McLean encouraged his people to take chances. Not foolish risks, not abandonment of the principles of safe operation that were built into the Station's RDT&E processes, but intellectual risks, engineering risks, and funding risks. If the potential payoff was high, he reasoned, it warranted a high risk of failure. As he told a magazine interviewer:

> Any new development brings a certain degree of risk, and it has to be individual risk. If the FAA regulations had been in effect at the time of the Wright Brothers' first flight, we never would have gotten any aviation going. . . . Unfortunately, there is a great deal of evidence that concern with safety in the undersea environment is going to get ahead of the actual developments and so may prevent the introduction of new equipment.[43]

Looking back, there is a great deal of evidence that McLean was correct.

42 S-142, Thomas J. Word interview, 27 Nov 1982, 72.
43 McLean interview, "A Bedrock View," April 1969, 33.

Co-locate Capabilities

The antithesis of compartmentalization, co-location was manifested physically, culturally, and organizationally. It worked on several levels. At NOTS, scientists, engineers, technicians, and military personnel worked within hailing distance of one another. Machine shops were co-located with laboratories. Test ranges were moments away from the airfield, and military and civilian employees had mixed housing.

One obvious benefit of co-location is synergy. Saint-Amand said that no place in the country could have made the advances in weather modification that NOTS did because "here we had chemists who understood how to make pyrotechnics, and we had aviators who weren't afraid to drop the things, and a number of scientists who were just looking for something interesting to do."[44]

Investigations into IR detection and tracking were the basis for developing IR seekers. The technologies and techniques also fed into the parallel development of active and passive IR countermeasures, and a few scientists and engineers—Raim Regelson, for example, and Larry Nichols—collaborated on both seekers and countermeasures.

Co-location also meant greater efficiency. For many of the weapon systems developed during the 1960s, the entire process of conception, design, fabrication, test, and productionizing could be accomplished within the secure confines of the base. The more geographically concentrated the process is, the smaller the transactional costs (in terms of communication as well as dollars) to move a developing system through the process.

A less obvious but nevertheless important benefit of co-locating resources was morale. When an idea was conceived locally and stayed local as it was carried through to service use, everyone on the base felt a sense of proprietorship. This was the phenomenon to which Walt LaBerge referred when he wrote, "I feel honored to be one of the over four thousand people I have met who single-handedly invented Sidewinder." It was the feeling that Colvard referred to when he said, "Success breeds pride."

Develop Full-Spectrum Capabilities

Very few undertakings were beyond the scope of NOTS/NWC in the 1960s, given the variety of experience and disciplines in the workforce coupled with the immense infrastructure of ranges, laboratories, and specialized facilities. Full spectrum was a multidimensional concept.

44 "Pictures of Us II, Episode 11, Everyone Complains About the Weather . . . " China Lake Video Projects, 2010.

Bob Hillyer captured the essence of the term as it applied to China Lake:

> This is the only place in the free world where you can go and find experts in propulsion, warheads, fuzing, guidance control, aerodynamics, interface to the launch aircraft, fire-control systems, the threat, kill mechanisms. . . .
>
> We're also full spectrum across the systems-acquisition process. We work from basic research through exploratory and advanced development, support the Navy in engineering development, do test and evaluation, and provide production assistance and Fleet support.[45]

Breadth of capability and the self-assuredness born of successful systems development were behind Frank Knemeyer's assertion that the 1960s were the period of China Lake's maturity, the era "when China Lake really came of age. . . . We weren't afraid to tackle anything."

Use Teamwork

Almost nothing at NOTS was done single-handedly. Starting from the top—the team of the military Commander and the civilian Technical Director—down to the lowest levels of the organization, people worked together, contractors with civil servants, civilians with military, scientists with engineers. Teams were put together for every project with, more often than not, the membership slicing across organizational boundaries. An individual or small group might be part of several teams, each supporting a different weapon or system with different sponsors and schedules.

Simplicity of design is a hallmark of China Lake products. (The entire NOTSNIK vehicle that may or may not have put a satellite into orbit had zero moving parts.) But simplicity is a relative term. As Einstein is said to have remarked, "Make things as simple as possible—but no simpler."

By the 1960s, the staggering complexity inherent in a single weapon system called for larger teams as individuals from scores of specialized disciplines joined together in pursuit of a common goal. Some project managers were more egalitarian than others, some more authoritarian. The inevitable clashes of personalities occurred, and spirited debate, even argument, frequently accompanied team meetings.

But overall, the quality, effectiveness, and timeliness of the systems developed by NOTS testify to the success of the Station's team approach.

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45 S-134, Hillyer interview, 72. Hillyer worked with China Lake from NOL Corona beginning in 1957 until his transfer to the Naval Weapons Center in 1970. He served as China Lake's Technical Director 1978-1982. He died in San Diego on 28 Oct 2013.

Compete Internally and Externally

Teamwork had a cohesive influence on China Lake's employees, but often, and intentionally, the Station's leaders fostered competition. McLean demonstrated that setting two groups to work toward a single goal would not only generate alternative methods for meeting that goal but also spur the members of each group to outdo the other by putting maximum effort into their own project. His "carrot-and-needle" approach was to take 10 percent of a group's funding and give it to another group that would work toward the same goal.

McLean's belief in competition extended beyond his own organization. He felt that no area should be off limits for a government laboratory that was serving the needs of the military or even (as with underwater vehicle research) the larger best interests of the nation. If that meant getting into someone else's bailiwick, so be it. The first two items on McLean's "Nine Ways to Ruin a Laboratory" (see Appendix B) are "1. Coordinate work carefully to avoid duplication" and "2. Keep the check reins tight; define missions clearly; follow regulations."

During the tenure of Secretary of Defense McNamara (1961-1968), efficiency was king. DOD's philosophy was that there be no overlap of missions, because overlap means duplication, and duplication equates to waste. McLean's approach ran contrary to that, based on the premise that competition toward the same goal, both within organizations and between organizations, led to better products. Other managers at NOTS shared McLean's view. As Tom Amlie put it, railing against the "lead service" and "lead laboratory" concepts of the McNamara era, "We used to compete with the Air Force, and of course we beat them bloody . . . you can get all the Blue Ribbon panels that call it duplication of effort' and all that. Hell, it's healthy competition."[46]

Others outside the Station also fought the encroaching compartmentalization of effort (and the stifling of competition) that marked DOD of the 1960s. As noted earlier in this chapter, the NOTS Advisory Board praised NOTS' flexibility of operation and program diversity as "the essence of strength and effectiveness."

The brilliant scientist Dr. L. T. E. Thompson, NOTS' first civilian leader, pointed out the fallacy of DOD's duplication-of-effort proscription. While Thompson agreed that duplication of effort in a production environment or in the carrying out of routine tasks could be wasteful, he believed that in the early stages of weapons development, it was essential to have multiple individuals, or groups, or laboratories, working toward the same goal. As he said:

46 S-150, Amlie interview, 20.

> You can't have too much duplication. You can't have what really is duplication of effort in idea productiveness. This isn't the way the world works. The more people you can get trying to generate new approach ideas, the more likely you are to have the results that you hope to get.[47]

At some point, of course, the duplicative approaches need to go up against one another to determine which is best in terms of the military's needs and budget and schedule constraints. Examples are the famous Holloman Air Force Base shootout between Falcon and Sidewinder in 1955, and the side-by-side test of the AIM-9D seeker and the AIM-4 Falcon seeker on the China Lake ranges at the start of the Chaparral program. In both events the China Lake product was victorious.

Encourage Creativity

Hand in hand with encouraging competition was encouragement and nurturing of the oddballs, the folks Hillyer dubbed "characters," the ones Babcock calls "the magnificent mavericks," those to whom McLean referred as "the lunatic fringe, the congenital non-conformists," and whom Rear Admiral Ashworth described as "rebels, dissenters, and non-conformists." For these were the people who most often came up with the revolutionary concepts, with the insights that broke through technical logjams, and with the new technologies that swept through the Navy and the DOD and into national and world-wide use.

Both Thompson and McLean spent more time than they should have had to protecting people who roamed outside of NOTS' mission area. Sidewinder was the most obvious example (the Station hid the program during its early stages under a variety of false covers). McLean believed that an important part of his job was to let people pursue good ideas, whether those ideas were properly within the "assigned mission area" or not. As noted earlier in this chapter, he said "I can protect them from being directed." *Moray* was one example, as was John Boyle's Shallow Water Attack Boat. As John Cox observed, "If a guy had an idea, he could run with it"[48]

Form Internal Partnerships

Shared leadership on the civilian side of NOTS was an extension of the team philosophy. Individuals with complementary strengths—McLean and Hack Wilson at China Lake, and Doug Wilcox and Wally Hicks at Pasadena—essentially double-teamed the top management role at the two sites. While in each case one person was ultimately responsible for the decisions, that

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47 S-15, Thompson interview, 15.

48 S-190, Cox interview, 57. Cox was a mechanical engineer who spent the first 6 years of his 39-year federal civil service career at Pasadena before moving to China Lake in 1952.

person did not make all the decisions, even the top-level ones. It was no more reasonable to expect a visionary scientist to unravel the complex administrative issues involved in heading a large organization than it was to expect a gifted administrator to reliably anticipate the direction of technological development for a 5 or 10 year period. Each party in these relationships did what he did best, and thereby freed up the other to do the same.

This complementarity of capabilities was found lower in the organization as well. Will Forman could design a submersible like no one else, but he sought out the best machinists on the Station to actually build his structures. Jack Crawford and Bill Woodworth collaborated on NOTSNIK, Walleye, ASROC, and other projects. Crawford, Woodworth explained, had "the ability to unify aerodynamics and guidance laws and electronics" while Woodworth had "a more detailed capability of system design." In these relationships, it was less important who received the credit than that the job got done right, and it usually did.

Work Directly With End Users

Through the 1940s, '50s, and '60s, China Lake was always in close touch with the operational Navy: civilian engineers went aboard carriers, scientists worked in the jungles of Vietnam, Navy aircrews flew missions over the North Ranges and loaded ordnance at Armitage Field. Fleet problems became China Lake problems, with the fewest levels of intermediaries to revise, interpret, modify, and gloss those problems. The result was that many weapon systems developed at NOTS and NWC were originated in-house—direct responses to Fleet needs devised by people who understood the capabilities, and the limitations, of technology. While China Lake's premier weapons—Sidewinder and Shrike—both solved serious Fleet problems, neither had its genesis in a formal Operational Requirement, a multi-authored document that framed the Fleet need in bureaucratic jargon and drew a tight box around potential solutions. The China Lake weapons were born, rather, in the minds of the Station's scientists and engineers—people with a perspective different both from the Fleet personnel, who faced the threats, and from the Washington bureaucrats, who redefined the needs into Operational Requirements.

The difference between the two approaches could not be more starkly drawn than by contrasting the Falcon and Sidewinder air-to-air missiles. Falcon, the result of an Air Force Operational Requirement, was an expensive failure. Its designers were constrained from the start by an exhaustive list or "must meet" requirements. Sidewinder, the result of Bill McLean's quest to find the Fleet a weapon that was lethal, reliable, inexpensive, and easy to maintain and use in a combat environment was, and is, the world's premier dogfight missile. China Lake experience has shown that as the lines of communication are shortened (and the layers of bureaucracy reduced) between the operational forces and the laboratory technologists who serve them, the resulting products are more useful, reliable, and cost-effective.

Localize Funding Control

Everything accomplished at NOTS required money, a lot of money. Beyond the organization's basic payroll, millions of dollars each year went for supplies, equipment, travel, shipping, utilities, maintenance, and infrastructure improvements. Prior to the McNamara years, it was relatively easy for NOTS to manage its budget at the local level. Some discretionary funds were available, but they were not adequate for what were seen as necessary investments in new ideas. When Station management saw promise in a project that had little chance of survival, funds could be diverted from other projects or other areas to support the fledgling effort, at least until it had established its feasibility (and thereby enhanced its chances for funding in the more competitive environment for sponsor dollars) or had shown that the avenue was not worth further investment.

McLean felt that such determination could often be better made at the local level, by people who understood the needs of the Fleet and the capabilities of both current technology and the NOTS technical workforce, than by those officials back East who controlled the purse strings. Prior to the nearly instantaneous "looking over your shoulder" capabilities that were afforded by high-speed computing and high-bandwidth data transmission capabilities, redirecting funds to where they were needed was a relatively simple task, though it sometimes required creative interpretation of regulations and terminology. Sidewinder funds had been used during the NOTSNIK program, and Frank Cartwright was called back East to justify the expenditures. He claimed, one assumes with a straight face, that the money was used for a project called High-Altitude Infrared Survey (HAIRS) and gamely offered "How else than measuring [infrared] from space? Sidewinder is, in fact, an IR guided weapon."

Value Isolation and Hard Work

While the term "isolation" often carries a negative connotation, the geographic isolation of the Mojave Desert created a vibrant and thriving "homemade" culture impossible to duplicate in more densely populated regions, and proved to be a boon to employee retention and job dedication. Though some China Lake employees saw a trip to L.A. or Bakersfield as a rare treat, most viewed it as a necessary evil. (To this day, China Lakers complain about having to drive "down below" for some perceived essential.) Despite the complaints, most of what was needed was available on the base and much of what wasn't was simply done without.

On the base—which is where most China Lake employees lived until the 1970s—everyone's neighbor, whether military or civilian, worked for the same employer. School kids had at least one parent (usually dad) working for that employer. For people who liked to party (anecdotal evidence indicates a disproportionately large number of China Lakers liked to party), there were two options: one's home, or the military clubs, which welcomed their civilian counterparts. (Teenagers had a few secluded spots in the desert, such as the Haystack and the Circle, where they would congregate and party away from the eyes of their parents.) Membership in the scores of cultural and recreational organizations comprised employees and their families. Until September 1966, civilians and military alike shopped at the Navy Exchange and commissary. The result of this forced fusion was that the line between military and civilian, and between work and nonwork, was blurred. Work, and the mission of the base, extended far deeper into people's personal and private lives than it did in areas less isolated.

In an interview for China Lake's 40th anniversary, Leroy Doig, Jr., who came to NOTS in 1945, spoke of the Station's ambiance in the early days:

> "Relationships among people were closer," he says. "Work groups also tended to play together, and you got to know those people a lot better than you do now." He muses for a moment, and adds, "That, of course, sometimes wasn't all that great an idea."[49]

In the shops and laboratories of China Lake, as in most workplaces, there were incentives and peer pressure to work hard and to do one's best. But at China Lake, those influences permeated the entire community. It was common to see cars parked at Michelson Laboratory into the wee hours of the morning, and old timers recall leaving an evening party to return to the laboratory and work on a new idea that had been proposed over drinks. Phil Arnold's story of Chuck Smith falling asleep with his eyes open epitomizes the extremes to which the work fixation could be taken.

The old saying that "hard work never killed anybody" is not accurate What is often called a "can do" attitude became in some cases a "can't stop" attitude, and over the years NOTS had its share of heart attacks and nervous breakdowns and failed marriages and suicides. In some of these, the pace of

49 *Rocketeer*, 4 Nov 1983, 5.

work was probably a factor. As McLean commented, "The wives tend to be less enthusiastic about continuous attention to the work than the men." But most people seemed to thrive in the hard-charging environment and to take pride and satisfaction in the results of their efforts.

China Lake leaders encouraged hard and challenging work. They were supported by a Station-wide management philosophy that gave people responsibility based on their ability to handle it, rather than on their seniority. Barney Smith, who came to NOTS straight out of college, observed that "from the day I arrived at the Station until the day I left, my supervisors always managed to over-commit me by precisely the correct amount; more than enough to keep me from becoming complacent, but not so much as to discourage hope of ever completing the assignments. For 12 years I was kept too busy to look for another job."[50]

Bill Arriola's motto "I will find a way or make one" summarized the attitude of the employees. As NOTS management said of its workers in response to a 1961 survey of R&D activities, "it is usual to find professional and scientific employees working, without compensation, at nights, on weekends and holidays. In a real sense, their vocation is their avocation. . . . strict adherence to normal working hours would penalize the laboratory many man-years of effort." Unrelenting persistence in the face of obstacles usually paid off, as when the Sidewinder development team designed, built, and tested 92 seeker reticles before they came up with Type 93, the one used in the first production missile.

Control the Data

Astute managers at NOTS learned early on that whoever controls the data controls the product. In cases where the Station's control of the data package was taken away—as with the first Texas Instruments production contract on Shrike—disaster followed. Leaders like Frank Knemeyer, Kelvin Booty, Burrell Hays, and Gerry Schiefer insisted that the NOTS maintain control over the specifications and documentation, the paperwork that decreed how every part of a weapon system was constructed, from the nature of the materials used, to the precise processes by which items were fabricated and assembled, to the tests that verified functionality and quality.

Data control had to be backed up by inspection; if a contractor was substituting a cheaper material for the more expensive one required in the specs, that fact was not likely to be self-reported. The Source Inspection Branch of NOTS' Quality Engineering Department, operating out of Pasadena, helped enforce the specifications.

50 *New and Views,* Aug-Sept 1967, 10. When Smith did leave, it was to become chief engineer at the Bureau of Naval Weapons.

Close data control not only ensured the quality of the product but also allowed the government, at its option, to bring in another industrial partner and, using the data package as an exhaustingly detailed guide, set up a second source for production, as was done with Sidewinder and Shrike. The second-source capability not only effected huge savings (even the threat of a second source effort would be enough to reduce HARM costs in the 1970s) but also provided a safety net. In the complex contracting and subcontracting network on which a weapon system was dependent, single-source acquisition at any point was a potential trouble spot. If the supplier of a single critical component ran into problems (bankruptcy, labor disputes, natural disaster, etc.) the ripple effect could stall an entire program for days or months and cost the taxpayer appalling amounts of money.

Tightly controlled data packages also helped Fleet support. When problems cropped up in operational use, NOTS scientists and engineers could readily determine if the manufactured system conformed to the official system specifications or if some deviation from the specs during manufacture was causing a problem—as for example when Bendix decided on its own to pull one of the transformer toroids from the Mk 46 torpedo, resulting in burnouts of the sonar transducers.

Buy Smart

Being a smart buyer meant seeing that the taxpayers' systems-acquisition dollars were spent on systems that were needed, effective, and affordable. Bob Hillyer termed it, "being the conscience and the technical watchdog of the Navy as it acquires its systems." NOTS/NWC's decades of experience in weapons acquisition and development and internationally recognized expertise in a wide range of scientific and engineering disciplines, allowed it to critically evaluate the strengths and weaknesses of, for example, contractor-suggested Engineering Change Proposals, or proposed "silver bullet" solutions for complex technical problems.

In the days of Sidewinder and Shrike and Walleye, that job was accomplished with NOTS as the designer and controller of a new system through its entire development process and into operational use. Through the decades beyond the 1960s, as an increasingly more powerful industrial sector took on more of the systems development work, China Lake would fulfill its smart-buyer obligation primarily through an advisory role. Over the years, the base waged a struggle against being sidelined into the role of contract monitors.

Today, it is more important than ever that the government have the in-house technical capability to work with industry and ensure that the taxpayers receive maximum value for each defense dollar spent.

The Future

The *Rocketeer*'s final issue of 1967 was filled with the usual pre-holiday fare—articles on fire safety and sober driving, the Christmas Dinner menu for the enlisted personnel mess, a message from the chaplain on the significance of Christ's birth, and a characteristically offbeat article by Pop Lofinck titled "Quarreling is Healthy." On the inside back cover—the page dedicated to the activities of the Naval Undersea Warfare Center—was an announcement:

> With the reluctance of old friends to part, but with the enthusiasm of youth to seek new adventures, NUWC bids a fond adieu to the "*Rocketeer*" with the current issue of this excellent newspaper. NUWC now will enter a new phase of its public life with the publication of its very own newspaper, devoted exclusively to news about its activities and achievements.

After more than 1,000 issues of the paper, that last link between China Lake and Pasadena was severed.

Page 3 carried a Christmas message from Captain Etheridge and Hack Wilson that read in part:

> This is a fitting time to compliment members of the military and civilian NWC team on the success of their numerous projects during the past year. Such projects are playing no small part in maintaining the freedom of many peace-loving nations throughout the world today.[51]

That tribute would be well deserved by China Lake at the end of any year, from 1943 to the present day. NOTS and its descendant organizations have for seven decades developed weapons, technologies, and tactics that ensure America's military preeminence in a dangerous world. If George Santayana was correct in another of his remarks—"only the dead have seen the end of war"—the future of the Navy's base at China Lake seems secure.

More generations of China Lakers will undertake the difficult and often unappreciated task of ensuring the technological supremacy of our nation's military. These young men and women should take heart in the words of the nation's 35th President, who, at the conclusion of his visit to China Lake in June 1963, stood before an enthusiastic audience at Armitage Field and said, "I cannot think of a prouder statement, when asked what our occupation may be, than to say 'I serve the United States of America.'"

51 *Rocketeer*, 15 Dec 1967, 3, 11.

Appendixes

A. Biographies of NOTS Commanders, 1959 to 1967

Captain William W. Hollister

Commander, U.S. Naval Ordnance Test Station

6 September 1957 to 1 June 1961

William Wallace Hollister was born in Florence, Wisconsin, on 25 October 1907. He graduated from the U.S. Naval Academy in 1931. His early naval service included sea duty on the battleships USS *Nevada* (BB-36) and *New Mexico* (BB-40).

After flight training at Naval Air Station, Pensacola, Captain Hollister became a naval aviator in 1933. He joined Fighting Squadron Six based aboard USS *Saratoga* (CV-3) and later joined Patrol Squadron Five, based at Coco Solo, Canal Zone.

After receiving an aeronautical engineering degree from the California Institute of Technology in 1941, he was assigned as Executive Officer and later as Commanding Officer of Patrol Bombing Squadron 82, based in Newfoundland. In 1943 he was named Commanding Officer of Multi-Engine Aircraft Refresher Flight Training and was next transferred to the Bureau of Aeronautics as torpedo-plane design officer. At the end of WWII, he was assigned duty as Executive Officer aboard USS *Belleau Wood* (CVL-24) and subsequently aboard USS *Boxer* (CV-21). He was next selected as Officer in Charge of the aeronautical engineering curriculum at the Naval Postgraduate School, Annapolis, from 1947 to 1950.

He also served as Commanding Officer of Transport Squadron Three, Military Air Transport Service; Director of Naval Aviation Armament and

Test, Naval Air Test Center, Patuxent River; and Commanding Officer of USS *Kenneth Whiting* (AV-14). He also attended the Naval War College.

After a tour on the staff, Commander, Naval Air Forces, U.S. Pacific Fleet, Captain Hollister served as the Commanding Officer of USS *Hornet* (CVA-12) from August 1956 to August 1957. In September 1957 he succeeded Captain Frederick L. Ashworth as Commander, Naval Ordnance Test Station.

During his tour as Commander, NOTS, Captain Hollister guided China Lake and Pasadena through a period of rapid growth, both in infrastructure (the completion of Hangar 3 and the Propulsion Research Laboratory, the building of Skytop, the installation of underwater launchers at San Clemente Island, the start of the 500-unit Capehart project) and in mission (NOTSNIK and the space vehicles, underwater exploration and exploitation, the conventional weapons program).

Speaking at his final change-of-command ceremony in 1961, Captain Hollister said, "First, I want to commend all of you enlisted men of the Navy and the Marine Corps. I am proud of your ability to adjust to the type of life required here in the desert—without your help we could not accomplish our mission. To the officers here at NOTS I extend my highest commendation for your loyalty, dependability, and the highest standards of performance. To all Civil Service employees, both at China Lake and Pasadena, who make NOTS the important Naval Laboratory it is, I offer my honest praise."

Dr. William B. McLean, in a tribute to Captain Hollister, said, "Captain Hollister's sympathetic and determined support of essential measures, both in the technical operations and in the community, has been a decisive factor during the past three and one-half years. I desire to record what I know to be the sincere appreciation and gratitude of every department head, every Station employee, and the community residents to Captain Hollister for a difficult job splendidly done."

Captain Hollister's decorations consisted of the Legion of Merit, Air Medal and a Gold Star in lieu of a second Air Medal, Presidential Unit Citation, and Navy Unit Commendation.

Captain Hollister and his wife, the former Norma M. Morris of Pasadena, had three daughters: Holly, Patrice, and Wilma.

Upon completion of his tour at NOTS in June 1961, Captain Hollister, with 30 years of active commissioned service in the Navy, retired. He and his family moved to Pasadena where he died on 30 July 1994.

Captain Charles Blenman, Jr.

Commander, U.S. Naval Ordnance Test Station

1 June 1961 to 30 June 1964

Charles Blenman, Jr., was born on 23 June 1911 in Los Angeles and raised in Tucson, Arizona. He attended the University of Arizona before his appointment to the U.S. Naval Academy, where he graduated in 1934.

Captain Blenman served aboard USS *Chester* (CA-27) until 1937, then reported to Naval Air Station, Pensacola, for flight training. The following year he joined Scouting Squadron 41 aboard USS *Ranger* (CV-4). He later attended the Army Air Corps School of Aviation Ordnance and supervised the Atlantic Fleet Aircraft Gunnery School. (During this period he invented and developed an electronic flight-training device for which he was awarded a U.S. Patent in 1944.)

In 1940 he returned to Pensacola as a flight instructor and subsequently was transferred to the Naval Air Station, Jacksonville. Late in 1941, he was assigned duty as Executive Officer of a scouting squadron in the Philippines and was reassigned to Scouting Squadron l, Detachment 14. In 1942 he became Executive Officer of the Navy's first long-range photographic squadron. He was assigned as Officer in Charge of the Photographic Training Unit, San Diego, and later Jacksonville, in 1944. In 1945 he was named Multi-Engine Training Officer on the Staff of Commander, Naval Air Operational Training, and then Commanding Officer of Air Evacuation Squadron One on Guam.

Following an assignment as an instructor in ordnance and gunnery at the General Line School, Monterey, he joined the Staff, Commander Air Force Pacific Fleet, as Administrative Officer. In 1951 he became Executive Officer of USS *Valley Forge* (CV/CVA-45) and saw duty in the Korean War.

In addition to attending the National War College, Captain Blenman served as Chief of the Operational and Training Division, Headquarters of the Chief, Armed Forces Special Weapons Projects; Assistant Director of Plans, Offensive Operations, Staff, Supreme Allied Commander Atlantic; Commanding Officer, USS *Windham Bay* (CVE-92); Deputy Chief of Staff to the Commander, Operational Development Force; and Chief of Staff to the Commander, Operational Test and Evaluation Force, before assuming command of the Naval Ordnance Test Station in June 1961.

While serving as Commander, NOTS, Captain Blenman oversaw continued expansion of the facilities and mission of the Station, and he pushed for greater technical authority for the Station in its major program areas.

In 1963 he hosted the only Presidential visit to China Lake before or since. He was very active in the community and was recognized for his efforts to bring China Lake, Ridgecrest, and Kern County into closer harmony. He and his wife, the former Rhea Loomis of St. Petersburg, Florida, were instrumental in the establishment of the Maturango Museum in 1963.

In his remarks upon assuming command of NOTS, Captain Blenman said, "The outstanding record of NOTS in the fields of weaponry and science is no accident. It is because a brilliant and dedicated group of men and women have been provided a fertile place in which to work, live, and play; a place where their ideas and dreams can be transformed into useful substance. NOTS is a unique Station. It is one of the very few in the Navy where the philosophy has been that it is primarily a civilian operation, which we in the military support. I assure you that this philosophy will be continued."

Captain Blenman's decorations, earned both in WWII and Korea, consisted of the Distinguished Flying Cross, Air Medal and two gold stars in lieu of a second and third Air Medal, Letter of Commendation Pendant and gold star in lieu of a second Letter of Commendation Pendant, and Navy Unit Citation and a gold star in lieu of a second Navy Unit Citation.

Captain and Mrs. Blenman had twin sons, Charles III (Chip) and William (Bing). At the completion of his tour as Commander, NOTS, on 30 June 1964, Captain Blenman retired, concluding 30 years of active commissioned service. He moved to Tucson where he died on 29 November 1991.

Captain Leon Grabowsky

Commander, U.S. Naval Ordnance Test Station

30 June 1964 to 4 August 1964

Leon Grabowsky was born in Paris, France, on 18 September 1917. He enlisted in the Navy in 1936, received an appointment to the U.S. Naval Academy, and was graduated and commissioned in 1941.

He was assigned to USS *Arizona* (BB-39), which was sunk at Pearl Harbor. He served as Gunnery Officer aboard USS *Gillespie* (DD-609) and then as Gunnery Officer and Executive Officer aboard USS *Leutze* (DD-481). When the Commanding Officer was seriously wounded in a kamikaze attack, Captain Grabowsky assumed command of *Leutze*; he received the Navy's highest decoration for valor for his actions in that engagement. He was the youngest commander of a U.S. destroyer during WWII.

Captain Grabowsky was assigned command of USS *Porter* (DD-800) and later returned to the Naval Academy for postgraduate studies. In 1949 he was awarded an MS in electrical engineering from the University of Pennsylvania. Following assignments aboard USS *Franklin D. Roosevelt* (CV-42) and USS *Oriskany* (CV-34), he served on the staff of Commander in Chief, Naval Forces Eastern Atlantic and Mediterranean, in Italy and the United Kingdom; and on the staff of Commander in Chief, European Command, in Germany.

While performing technical and executive duties at the Naval Ordnance Laboratory, White Oak, Captain Grabowsky earned an MBA at the University of Maryland. He next served aboard USS *Ranger* (CVA-61) and then commanded USS *Catamount* (LSD-17). Following an assignment as Chief, Techniques and Devices Branch, Ballistics Missile Defense Division, Advanced Research

Projects Agency in the Office of the Secretary of Defense, he was Commanding Officer of USS *Hector* (AR-7).

He was assigned to NOTS as Executive Officer in November 1963 and became interim Commander in June 1964.

In August 1964 Captain Grabowsky returned to his position as NOTS Executive Officer, and in 1966 he was assigned as Commander, Service Squadron Five, Pearl Harbor, and Commander, Task Group 73.5/Underway Replenishment Group Two, during combat operations in Southeast Asia.

After another tour in the Office of Secretary of Defense, Captain Grabowsky took command of the Naval Weapons Station, Concord. He retired from the Navy in 1971 with 35 years of service.

Although his tour as Commander, NOTS, was brief, Captain Grabowsky did manage to convince Washington authorities to delay by one year the elimination of commissary privileges for China Lake civilians.

Captain Grabowsky's decorations included the Navy Cross, Bronze Star, Navy Commendation Medal with combat V and gold star in lieu of a second Navy Commendation Medal, and area service awards for Pacific and Atlantic duty with stars for seven major campaigns.

Captain Grabowsky and his wife, the former Joanne Karpen of Hastings, Minnesota, were the parents of five children: Kari, Lori, Paul, Jeanne, and Steven.

Following his retirement from the Navy, Captain Grabowsky taught business classes at Diablo Valley College in Pleasant Hill, California. He died on 28 July 2000 in Danville, California.

Captain John I. Hardy

Commander, U.S. Naval Ordnance Test Station

4 August 1964 to 28 February 1967

John Ingolf Hardy was born in Mahnomen, Minnesota, on 21 January 1919. He studied at St. Olaf College in Northfield, Minnesota, before attending the U.S. Naval Academy, where he graduated in 1940. Following his commissioning he was assigned to USS *Pensacola* (CA-24) and was aboard her when she was torpedoed in November 1942 during the Battle of Tassafaronga. He participated in the Guadalcanal, Coral Sea, Midway, Solomons, Santa Cruz, and Cape Esperance campaigns.

In 1943 Captain Hardy reported to NAS Pensacola for flight training. Following his designation as a naval aviator in 1944, he became a flight instructor in PV aircraft. He next studied aeronautical engineering as a postgraduate student at the Naval Academy and then at the Massachusetts Institute of Technology, where he received his MS in 1947. He then was assigned to the office of the Chief of Naval Operations (Guided Missile Section) and then Patrol Squadron 1 as Executive Officer from 1949 to 1951, where he saw service in Korea.

After a tour as head of the Installations Branch, Armament Division, in the Bureau of Aeronautics, Captain Hardy served as Commanding Officer, Patrol Squadron 22, in Hawaii and Alaska during 1953 and 1954.

Captain Hardy was assigned to the Naval Ordnance Test Station in 1954 as Assistant Experimental Officer and became Experimental Officer in July 1955. Following his tour at NOTS, he served as Executive Officer of USS *Princeton* (CVS-37) from 1957 to 1958, when he assumed the duties of naval aide to the Assistant Secretary of the Navy (Research and Development). After attending the Industrial College of the Armed Forces in 1961 and 1962, he joined USS *Taluga* (AO-62) as Commanding Officer.

In 1963 he was given command of USS *Hornet* (CVS-12). In August 1964 he assumed the duties of Commander, NOTS.

While serving at NOTS as Experimental Officer, Captain Hardy was intimately involved in the test program for Sidewinder. As Commander he oversaw the rapid expansion of new weapon systems and Fleet support activities in connection with the escalating war in Vietnam (he assumed command just 3 days before the Gulf of Tonkin Resolution was passed).

Speaking to NOTS senior personnel a month before his retirement he said, "I am more convinced than ever of the Station's extreme importance to our country. The tremendous scope of resources, talents, and abilities here at the Naval Ordnance Test Station is one of the most valuable assets the country has."

A letter from Vice Admiral Galantin, Chief of Naval Material, read at Captain Hardy's final change-of-command ceremony said in part that Captain Hardy had "marshaled the resources of NOTS to effectively pursue the problems created by the Southeast Asian conflict." He called Captain Hardy's retirement "a significant loss to the Navy and to me, personally."

Captain Hardy's decorations included the Air Medal and various campaign and service medals. He and his wife, the former Dolores Webster of Stillwater, Minnesota, had two children: Randall and Janet.

Following Captain Hardy's retirement after 30 years of active commissioned service, he became Assistant to the President of Case Institute of Technology (where he oversaw the integration of Case Institute and Western Reserve), and subsequently worked as Director of Engineering for Honeywell Inc.

Captain Hardy died in Rancho Santa Fe, California, on 16 July 2010.

Captain Grady H. Lowe

Commander, U.S. Naval Ordnance Test Station

28 February 1967 to 15 September 1967

Grady Howard Lowe was born in Gastonia, North Carolina, on 23 May 1916. He enlisted in the Navy in 1940 and served aboard USS *Quincy* (CA-39). He completed midshipman training and was commissioned ensign in June 1941.

During WWII he served aboard USS *Indiana* (BB-48) in the Atlantic and South Pacific and, while attached to Landing Ship Flotilla Twelve, he participated in amphibious landings in the Mediterranean and at Normandy on D-Day, 1944.

Other tours of duty include Executive Officer of USS *McCaffery* (DD-860), Force CIC Officer on the staff of Commander, Task Force 90, and Commanding Officer of USS *Hollister* (DD-788) from 1953 to 1955.

Captain Lowe was a graduate of the General Line School and the Naval Warfare Course at the Naval War College, Newport. He also attended Catawba College, the University of North Carolina, and the University of Rhode Island, and was awarded a BA in chemistry from San Diego State College.

He completed graduate courses for a PhD in nuclear physics. From 1955 to 1958 he served as Officer in Charge of the Nuclear Weapons Courses at the Nuclear Weapons Training Center Pacific and was the Principal Instructor in Nuclear Physics.

From 1959 until 1962, Captain Lowe served on the staff of Commander in Chief, U.S. Pacific Fleet, as CINCPACFLT Representative for the Pacific Missile Range. After duty as Commanding Officer of USS *Renville* (APA-227) he reported to NOTS Pasadena in July 1963 as Officer in Charge, NOTS Pasadena Annex. He became Commander, NOTS, in February 1967.

In July 1967, when the Naval Undersea Warfare Center was established, Captain Lowe was selected as NUWC's first Commander and served in that position until 31 July 1969 when he retired after 29 years of active service. (He was double-hatted as Commander of NUWC and Commander of NWC from 1 July through 15 September 1967).

Following his retirement, Captain Lowe played an active role in Navy League and Pasadena civic affairs for 20 years.

Captain Lowe's greatest contribution while at China Lake was managing the wrenching transition that separated Pasadena from the organization and added the Corona Laboratories.

The citation of his Legion of Merit, signed by Secretary of the Navy Paul R. Ignatius, noted in part, "Working within an extremely short time-period, Captain Lowe exercised dynamic leadership, outstanding administrative ability, and diplomatic finesse in producing effective plans [for the reorganization]. He has represented the Navy in varied and delicate situations with great distinction."

In addition to the Legion of Merit, Captain Lowe held the Navy Commendation Medal; American Defense, Asiatic Pacific, American Theater, WWII Victory, National Defense, and Korean Service Medals; United Nations Medal; WWII Occupation Medal; China Service (Extended) Medal; and Korean Unit Citation.

Captain Lowe and his wife, the former Daisy "Dee" Martin of Plymouth, Florida, had two children: Linda Jean and Gary Howard.

Captain Lowe died in Pasadena on 4 August 1990.

Captain Melvin R. Etheridge

Commander, U.S. Naval Ordnance Test Station

15 September 1967 to 22 October 1970

Melvin Rheul Etheridge was born on 26 January 1923 in Birmingham, Alabama. At age 16, he entered the U.S. Naval Academy (the youngest member of his class) in the first three-year class at the Academy. He graduated and was commissioned in 1942. He served on submarines during WWII, including USS *S-18* (SS-123) and USS *Drum* (SS-228).

In 1947 Captain Etheridge was designated a naval aviator. From 1949 to 1952 he attended the Naval Postgraduate School and the University of California, earning a master's degree in nuclear engineering and bioradiology. In 1952 he participated in the first thermonuclear device test at Eniwetok Atoll.

Captain Etheridge served with Squadrons VS-22 and VA-42; on the staff of Commander, Naval Air Force, U.S. Atlantic Fleet; at the Nuclear Weapons Training Center, Pacific; and with Armed Forces Special Weapons Projects. He joined USS *Independence* (CVA-62) as Weapons Coordinator and was selected as Executive Officer.

From 1962 to 1964 he was assigned to the Joint Chiefs of Staff, and from 1964 to 1965 he commanded USS *Caliente* (AO-53). Following a year at the National War College, he was assigned command of USS *Wasp* (CVS-18) in 1966, and then reported as Commander, NOTS, in 1967. He completed his tour in 1970 and retired with 28 years of active commissioned service.

One of Captain Etheridge's chief contributions to the Naval Weapons Center was to facilitate the technical and organizational flexibility that was necessary to cope with the increasing demands and accelerated developmental timelines caused by the Vietnam War.

He also oversaw the move of hundreds of employees and their families from the Corona Laboratories to the high desert. Although the move put heavy pressure on the laboratory infrastructure and on China Lake's housing resources, the integration went smoothly and added essential expertise and experience in weapon-system fuzing to the Center's in-house technical capabilities.

Captain Etheridge's decorations include the Legion of Merit and various campaign and theater medals.

Following his retirement Captain Etheridge worked in the U.S. and abroad for Combustion Engineering Co. He and his wife, the former Margaret Anne Ennis of Annapolis, Maryland, had two children: Melvin Jr. and Maggie. Captain Etheridge died in Simsbury, Connecticut, on 18 May 2010.

B. Nine Ways to Ruin a Laboratory

From "Management and the Creative Scientist," presented by Dr. William B. McLean at the Thirteenth National Conference on the Administration of Research, hosted by Rensselaer Polytechnic Institute at the Equinox House, Manchester, Vermont, 28-30 September 1959[1]

We can rapidly change a creative organization into one doing only routine productive work if we

1. Coordinate work carefully to avoid duplication. (Everything new can be made to look like something we have done before, or are now doing.)

2 Keep the check reigns tight; define missions clearly; follow regulations. (Nothing very new will get a chance to be inserted.)

3. Concentrate on planning and scheduling, and insist on meeting time scales. (New, interesting ideas may not work and always need extra time.)

4. Ensure full output by rigorous adherence to the scheduled workday. (Don't be late. The creative man sometimes remembers his new ideas, but delay in working on them helps to dissipate them.)

5. Insist that all plans go through at least three review levels before starting work.(Review weeds out and filters innovations. More levels will do it faster, but three is adequate, particularly if they are protected from exposure to the enthusiasm of the innovator. Insist on only written proposals.)

6. Optimize each component to ensure that each, separately, be as near perfect as possible. (This leads to a wealth of "sacred" specifications, which will be supported in the mind of the creative man by the early "believe teacher" training. He will then reject any pressures to depart from his specifications.)

7. Centralize as many functions as possible. (This creates more review levels and cuts down on direct contact between people)

8. Strive to avoid mistakes. (This increases the filter action of review.)

9. Strive for a stable, successful, productive organization. (This decreases the need for change and justifies the opposition to it.)

1 Reprinted in RM-24, *Collected Speeches of McLean*, NWC, 1993, 103.

C. William B. McLean Laboratory Dedication Speech

From a speech given by NAWCWD Executive Director Scott O'Neil at the dedication of the Dr. William B. McLean Laboratory at China Lake, California, 8 October 2010.

This facility is named in honor of Dr. William B. McLean. In his service Dr. McLean made enormous and lasting impacts on our Navy and our nation. He personified all of the core values that this NAWCWD stands for. It is right to name this facility after him.

I remember back when I was a kid in Bremerton, Washington, in the late '50s there was a TV show on Saturday afternoon I loved to watch. It was called "You Asked For It." The format was for kids from around the country to write in questions, and if [a question was] selected the show would answer that question. One episode I distinctly remember was a response to a question about a heat-homing rocket. I watched that episode with great amazement … imagine an airplane shooting down another airplane with a rocket that homes on heat generated from the target … wow!

Fast forward about 14 years. It was 1973, I was a Junior Professional here at China Lake on my third tour, working on the Sidewinder servo-control system in Salt Wells. One of the engineers I was working for asked me if I wanted to watch a test of AIM-9L Sidewinder, the newest version of that heat-homing rocket. Of course I did, and with the enthusiasm of an 8-year-old I went with him outside and looked to where he pointed in the sky. It seemed right overhead, two airplanes engaged in battle, a white streak across the sky, a ball of fire . . . double wow! I thought to myself, I can work here forever!

Who would have thought that one day that kid, inspired by what he saw on a TV show, would be dedicating a building to the man who not only invented that heat-homing rocket but also the whole concept of guided weaponry? All of the weapons we have in our nation's arsenal, for sure all of the guided weapons that are displayed here, owe their roots to Dr. McLean.

Immediately after WWII, many organizations were working on ways to improve our weaponry, primarily to defend our cities from attacks by Soviet bombers. The main approach was to do what we were doing only to do it better—to improve the fire-control systems that would more accurately direct our unguided rockets.

At the time, 1945, Dr. McLean was the head of the Fire Control Section at China Lake. He was charged to develop those improved fire-control techniques for Navy aircraft. Dr. McLean's analysis to develop requirements for such fire-control systems unveiled the impracticality of this approach. Even with increased accuracy, to be effective very large numbers of rockets would need to be launched against a threat bomber. Rockets were effective against ground targets, but in the air-to-air role against a maneuverable aircraft they were just not acceptable.

In this work he became convinced that the only way to solve the problem was to put the fire-control system in the missile, instead of the aircraft. And the rest is history. Dr. McLean did not set out to design a guided missile—rather this idea erupted from his frustration in trying to develop reliable, accurate aiming techniques for unguided air-to-air rockets.

Earlier during WWII, his work at the Bureau of Standards made him aware of lead sulfide photocells that could detect infrared radiation (heat). It was while on travel to Boston in 1947 with some other China Lake engineers that Dr. McLean first sketched out his idea for a "target seeker." He bounced the idea off of his cohorts, and back at the Lake he pursued his idea with his peers.

Nine year later, after conquering many technical challenges and overcoming even bigger problems—the Navy bureaucracy—Sidewinder became operational. Today, after many upgrades, Sidewinder is still the free world's preeminent short-range air-to-air weapon. Dr. McLean saw the opportunity enabled by then-day technology. He fought doggedly to change the paradigm, to do something different, and he changed the world.

Bill McLean was soft spoken, modest, humorous, technically competent, and very persistent in solving difficult problems. Such problems drove him and he pursued their solutions without rest. As, one of his colleagues (W. H. Pickering) said, "As an engineer and scientist, he had the curiosity needed to ferret out the key factors in a problem, the wisdom to know what were the important elements in the solution, and the tenacity to stay with the problem until it was solved."

He threw away paradigms that did not support his needs. He was an innovator at heart. His technical instincts were excellent, and he was driven by simplicity. In short, Dr. McLean was a good engineer, but he was also a good leader. He very rarely gave direct orders. He respected his peers and he had their respect in return, he listened and provided clear direction when needed, he led by good example both personally and professionally. He loved a challenge and he was extremely stubborn if he thought he was right.

I want to talk briefly about simplicity as one of Dr. McLean's engineering tenets. Bill knew that a guided missile had to be reliable. Its role in defending our nation against Soviet bombers demanded this. Reliability follows simplicity in design, which in turn stems from understanding. Dr. McLean spent 3 years considering possibilities, trading off the merits of various approaches, trying to determine methods of arrangement which would make the final design more acceptable to the user. From this pondering the answer slowly emerged: Dr. McLean reasoned the ability to self-guide toward a target must be combined with the simplicity and reliability associated with rockets. Only a missile so designed would meet the needs of the user and also the objections of the critics.

Today, our weapons designers must rededicate their efforts to this tenet. In a digital world, with electronics and sensors getting smaller and more capable, it is easy to be trapped into seemingly elegant, complex designs. Instead, we need to listen to Dr. McLean; we need to take the time to ponder, to deeply understand the issues and approach, and then deliberately design solutions that are direct and simple. Elegance in design is not founded in complexity but rather in simplicity.

I have high hopes for this building; having it at the center of our China Lake campus is a persistent reminder of Dr. McLean and all he stood for. And I have high hopes for our future at Weapons Division. I truly believe and I see that the spirit of Dr. McLean is alive and well. We continue to put high value on many of his tenets: creativity and innovation, technical competence without arrogance, and persistence in the face of adversity while remaining humble.

Like Dr. McLean, we are forward leaning for the Navy. This is keenly demonstrated by our many products that give the warfighters advantage on today's battlefields. In many ways, these products have revolutionized how we prosecute war. I am certain that Dr. McLean is smiling today.

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