REPORT DOCUMENTATION PAGE

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED (DD-MM-YYYY) START DATE	END DATE
09-01-2022	History Book	01-01-1968	12-31-1979

4. TITLE AND SUBTITLE

Holding the Course, History of the Navy at China Lake, California, Volume 5
Challenge and Change at the Naval Weapons Center, 1968-1979

5a. CONTRACT NUMBER	5b. GRANT NUMBER	5c. PROGRAM ELEMENT NUMBER
N/A	N/A	N/A
5d. PROJECT NUMBER	**5e. TASK NUMBER**	**5f. WORK UNIT NUMBER**
N/A	N/A	N/A

6. AUTHOR(S) *(Last Name, First Name, MI)*

Lawson, Cliff

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
Naval Air Warfare Center Weapons Division 1 Administration Circle China Lake, California 93555-6100	ISBN 978-0-9676977-7-2

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)	11. SPONSOR/MONITOR'S REPORT NUMBER(S)
Naval Air Warfare Center Weapons Division 1 Administration Circle China Lake, California 93555-6100	NAWCWD	N/A

12. DISTRIBUTION/AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A. Approved for public release: distribution is unlimited.

13. SUPPLEMENTARY NOTES

None.

14. ABSTRACT

In this latest volume in the China Lake history series, Cliff Lawson delves into the struggles facing the men and women dedicated to supporting our nation's Warfighters, their resolve to overcome, and their enduring accomplishments that continue to improve America's defense posture, even today. These steadfast scientists, engineers, support personnel, and numerous others, many of whom uprooted themselves and their families to move to a rural naval base in the middle of nowhere, have much to teach us on persevering through times of trials and uncertainty. Holding the Course takes readers on a 12-year journey through the turbulent Vietnam War era and the myriad of cultural and political changes shaping one of the Navy's—and the nation's—most valuable RDT&E bases. Holding the Course is the fifth volume in the China Lake History series. Volumes 1 through 4 (published respectively in 1971, 1978, 2009, and 2013) record the first 24 years of the Navy's history at China Lake.

15. SUBJECT TERMS

Advanced Antiradiation Guided Missile (AARGM), Advanced Propulsion Technology, Agile, China Lake, Electronic Warfare, Evolved SeaSparrow Missile (ESSM), Fuel-Air Explosives, Harpoon, High-Speed Antiradiation Missile (HARM), Naval Ordnance Test Station (NOTS), Naval Weapons Center (NWC), Point Mugu, Polaris, Rockets, Rolling Airframe Missile (RAM), Shrike, Sidearm, Sidewinder, Sparrow, Standard Missile, Standoff Land-Attack Missile (SLAM), Technology Transfer, Tomahawk, Trident, Vietnam War

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR	696

19a. NAME OF RESPONSIBLE PERSON	19b. PHONE NUMBER (Include area code)
Travis Ball	(760) 939-7009

PREVIOUS EDITION IS OBSOLETE.

STANDARD FORM 298 (REV. 5/2020)
Prescribed by ANSI Std. Z39.18

"For over 75 years, China Lake has contributed to the security of the nation and defense of freedom. Volumes 1 through 5 of the China Lake History series cover 36 of those 75 years. In Volume 5, Cliff Lawson provides insight into the challenges and changes faced by the Naval Weapons Center from 1968–1979. For Holding the Course, he adroitly scoured the available resources to bring 12 years of accomplishments to life. The people, the teams, and the innovations are revealed and preserved, providing an invaluable education to the public on the significance of China Lake."

— Robert Campbell

Former Deputy, Weapons Department, Naval Air Warfare Center Weapons Division
Current President, China Lake Museum Foundation

The cover illustration by Bill Stephenson depicts some of the most influential leaders who shaped the Naval Weapons Center (NWC) during one of its most tumultuous decades. From 1968 to 1979, these men guided the Center through turbulent cultural and political upheavals to develop game-changing weapons that continue to make their mark in naval defense today.

At left is Rear Admiral Rowland G. Freeman III, the legendary NWC Commander whose dramatic restructuring of the Center's culture and organization became known as the "Freeman Era." Next to Freeman is Robert M. Hillyer, who played a crucial role in the development of the Agile missile and whose tenure as Technical Director restored balance and morale to the base. In the center is Hack Wilson, who, as Assistant, Acting, and Technical Director, smoothed the transition from Naval Ordnance Test Station to NWC and buffered the tempestuous years during and after the Corona consolidation. To the right of Wilson is Jack Russell, the first and well-respected head of the Electronic Warfare Department and a vital contributor to the successful design of antiradiation missile technology. At far right is NWC Commander Rear Admiral William B. Haff, who, alongside Hillyer, brought a decade of tumult to a close.

The late 60s and 70s saw major innovations in NWC's signature weapons programs, including, at top, the evolution of Sidewinder. AIM-9H, pictured at upper right, was the first solid-state Sidewinder and the most effective U.S. missile in the Vietnam War. Illustrated below Sidewinder is the advancement of AGM-45 Shrike, the world's first effective antiradiation missile and the precursor to the AGM-88 High-Speed Antiradiation Missile, which became the primary defense-suppression weapon used by the United States military. Below Shrike, at left, is the A-7 Corsair, a progressive aircraft for its time and one of the first to integrate platform and weapon. Next to it is the AIM-95 Agile, which, although it never became operational, was the most advanced air-to-air-missile of its era and one that boasted an infrared seeker with all-aspect capability. To the right of Agile is the QF-86H target, the first full-scale, all-attitude drone that was capable of being operated remotely with unlimited maneuvers. At lower left is the Vertical-Launch Antisubmarine Rocket, a novel weapon that remains one of the Navy's foremost antisubmarine missiles. To the right is the Night Observation Gunship System, an innovation in night attack capability that was used to great effect in Vietnam.

Lawson

HOLDING THE COURSE

HISTORY OF THE NAVY AT CHINA LAKE, CALIFORNIA

VOLUME 5

HOLDING THE COURSE

HISTORY OF THE NAVY AT CHINA LAKE, CALIFORNIA • VOLUME 5

Cliff Lawson

Holding the Course

History of the Navy at China Lake, California
Volume 5

HOLDING THE COURSE

Challenge and Change at the
Naval Weapons Center, 1968-1979

By

CLIFF LAWSON

With an Introduction by

VICE ADMIRAL DAVID J. VENLET
USN (RETIRED)

Published by NAWCWD
China Lake, CA
2022

This authorized history was supported by
Naval Air Warfare Center Weapons Division.

UNITED STATES NAVY
NAVAL AIR WARFARE CENTER
WEAPONS DIVISION
CHINA LAKE, CALIFORNIA
2022

Contents

Figures

Foreword

"Grit is that 'extra something' that separates the most successful people from the rest. It's the passion, perseverance, and stamina that we must channel in order to stick with our dreams until they become a reality." These words, penned by author and entrepreneur Travis Bradberry, reflect the ideology on which the Naval Ordnance Test Station was founded in 1943 and that has fueled the Center's state-of-the-art advances in research, development, test, and evaluation (RDT&E) through present day.[1]

In this latest volume in the China Lake history series, Cliff Lawson delves into the struggles facing the men and women dedicated to supporting our nation's Warfighters, their resolve to overcome, and their enduring accomplishments that continue to improve America's defense posture, even today. These steadfast scientists, engineers, support personnel, and numerous others, many of whom uprooted themselves and their families to move to a rural naval base in the middle of nowhere, have much to teach us on persevering through times of trials and uncertainty. *Holding the Course* takes readers on a 12-year journey through the turbulent Vietnam War era and the myriad of cultural and political changes shaping one of the Navy's—and the nation's—most valuable RDT&E bases. The years 1968 to 1979 are a crucial time period in China Lake's history, embodying the many challenges inherent in rapidly developing weapons and their associated technologies in the midst of cultural and organizational upheaval and bolstering a foundation of tenacious innovation for the many creative minds and unshakable spirits still yet to come. Through many conflicts, reorganizations, restructurings, policy transitions, and other periods of unrest, the China Lake spirit of ingenuity and grit endured. What would have broken creative, curious minds elsewhere only strengthened China Lakers' determination to press on in pursuit of the Center's predominant goal of equipping the nation's servicemen and -women with the cutting-edge weapons systems needed to defeat its enemies.

---

[1]Travis Bradberry, "11 Signs You Have the Grit You Need to Succeed," accessed 4 May 2022, https://www.forbes.com/sites/travisbradberry/2016/01/05/11-signs-you-have-the-grit-you-need-to-succeed/?sh=598caa853bf8.

This fortitude produced the innovations that characterized China Lake in the 20th century and that continue to make their mark in naval defense today. The late 60s and 70s ushered in not only incessant waves of change that altered every facet of the Center's culture and operations but unprecedented technological breakthroughs. Weapons technology was shifting from analog-based systems to more progressive, computer-centered systems, and avionics, advanced electronic-warfare systems, and simulation efforts were gaining speed. During this era, the Center fielded avionics software and hardware for a wide variety of defense applications, including weapons integration and advanced self-protection techniques. The Center also continued to develop vital defense capabilities such as the Rolling Airframe Missile, Standard Missile, Sidewinder, Harpoon, SeaSparrow, the original High-Speed Antiradiation Missile program, night attack capabilities, automated fire-control, fuel-air explosives, computer-centered weapons, optical and laser systems, advanced propulsion technologies, and antiradiation guidance. Far from being relegated to decades past, many of these weapons and technologies have continued to evolve and remain at the forefront of current defense tactics.

Moreover, technology transfer—sharing the knowledge, facilities, or capabilities developed with federal research and development funds with industry, academia, or civil government institutions—picked up momentum in the early 70s, resulting in hundreds of scientific and medical advances for society. The hard-working men and women at China Lake were behind influential developments that included an air-operated bone mill for tissue banks, chemical-biological techniques for the study of valley fever, a fire-line-clearing device for the U.S. Forest Service, a cataract detector, a laser for medical research, a pilot study on using infrared thermography to detect hearing in newborns, a mathematical model of the human circulatory system for diagnosing cardiovascular diseases, weather-modification work for the *Federal Aviation Administration*, chemiluminescent light sticks, and stop-action video.

As former Navy SEAL Jeff Boss so aptly stated, “Success comes to those stubborn few that choose to ignore the temporary discomfort of setback for the long-term strategy of delivering value.” The grit and innovation that marked the earliest days of the Station’s establishment and that continued to shape it in the 60s and 70s are alive and well today, a legacy of the many men and women who had the courage and resolve to persevere during times of intense challenges and changes. Their stories of endurance and fortitude are as relevant today as they were 50 years ago, a testament to what the combination of persistence and passion can achieve.[2]

DANIEL A. CARREÑO
Executive Director
Naval Air Warfare Center
Weapons Division

---

[2]Jeff Boss, “10 Inspirational Quotes From Navy SEAL Training,” accessed 4 May 2022, https://www.entrepreneur.com/slideshow/232209#:~:text=You%20Don’t%20Have%20to,and%20run%20into%20the%20fray.

Preface

At 2200 on Saturday, 16 April 2011, as a large crowd cheered and clapped and fireworks flashed in the night sky, the Navy's newest cargo and ammunition ship, the 45,000-ton USNS *William McLean*, champagne dripping from its bow, slid down the ways into San Diego harbor. The ship had just been christened by Margaret Taylor, niece of Dr. William Burdette McLean, for whom the ship was named.

Bill McLean, as he was known to his contemporaries at China Lake, is a legend in the Navy laboratory community. Beginning in 1954, he served for 13 years as the Technical Director of the Naval Ordnance Test Station (NOTS) at China Lake, California—the third Technical Director since the base's inception in 1943. He left in 1967 to head the newly formed Naval Undersea Warfare Center at Pasadena and San Diego. As part of the same Navy laboratory reorganization that created McLean's new organization, his former one, NOTS, became the Naval Weapons Center (NWC), a designation it would retain for the next two and a half decades.

McLean had a tremendous impact on the character of the China Lake workforce. The father of the Sidewinder air-to-air missile, he earned nearly every accolade the Department of Defense (DoD) had to offer its civilian employees. Chief of Naval Operations Arleigh Burke presented him with a $25,000 cash incentive award in 1956. In 1958, President Eisenhower personally decorated him with a gold medal for exceptionally meritorious civilian service, and in 1965, Vice President Humphrey presented him with the Rockefeller Public Service Award for Science, Technology, and Engineering and an accompanying $10,000 stipend. *LIFE* magazine, the most widely read periodical of the time, featured him in a 1967 article titled "The Nation's Handyman."[3]

Success for McLean was not built merely on the Sidewinder. Under his leadership, NOTS' contributions to the nation's arsenal solidified his reputation as a genius not only in weapon design but in managing a Navy laboratory: steering a workforce of 5,000 individuals, most of them educated professionals with a strong streak of individualism. (It took a certain type of personality to accept a position at a secretive military base located in the Mojave Desert, several

[3]Riley, "The Navy's Top Handyman," 16.

hours away from major urban centers.) Liz Babcock dubbed these people who worked for McLean "magnificent mavericks" in her book by the same name, the third volume in the China Lake History series.

Few, if any, leaders of government laboratories receive the same level of honor as McLean. With that honor came power, of a sort. In Washington, McLean had access to the highest levels of decision makers, and his track record at "the Lake" ensured that his opinions were listened to with respect, if not always agreement. He ran interference for his technical workforce at NOTS so that they could concentrate on what they did best—finding technical solutions for Fleet problems and devising more effective weapons from rapidly evolving technology. He had friends in high places, some of them long-time scientific associates, others former NOTS Commanders or Experimental Officers who had moved into the top levels of Navy leadership.

When McLean left China Lake in 1967, he turned over the reins to his long-time assistant, Deputy Technical Director Haskell G. "Hack" Wilson. At the time, Gerald R. Schiefer was in his seventh year at China Lake, running a program called Shrike, the world's first effective antiradiation (antiradar) weapon. Years later, Schiefer would himself become Technical Director at China Lake and subsequently Director of Navy Laboratories (DNL). In a 1985 interview, Schiefer said, "One of the jobs of a TD [Technical Director] is to be the buffer, and to go back there and take the hard licks, so people out here can do what they needed to do for the country and for the Fleet. I spent a lot of time back there; so did every other TD."[4]

But none of the Technical Directors in the 12 years after McLean's departure—the span covered in this volume—had his success in buffering their charges from the turmoil in Washington. During this period, NWC had six Technical Directors (one served twice), with an average tenure of less than 2 years. During the same period, NWC was commanded by eight men—five rear admirals and three captains.

After 13 years of relative stability under McLean, the China Lake workforce was barraged with change, and not just management change. The Vietnam War ended, and with it much of the demand for China Lake's bread-and-butter weaponry. The war's end brought a redefinition of the Navy's mission, and China Lake had to redefine its own mission to keep pace. The national culture changed, and the base—leaders and rank-and-file employees alike—had to cope with issues of racial justice and women's rights. Washington continued to tighten the screws of control and extend its micromanagement, following a pattern established in the early 1960s under Secretary of Defense Robert W.

[4]S-305, Schiefer interview, 17.

McNamara. Inadequacy of housing and a shift in the Navy's policy toward civilians living on base drove people from the insular security of life within the China Lake perimeter to the autonomy of home ownership in Ridgecrest and the surrounding area. With that change, the homogenous culture of China Lake—working, playing, and socializing with the same people in the same fenced enclave—was dismembered.

Against that backdrop of multidimensional and unrelenting change, this volume chronicles the technical progress and evolution of China Lake, which managed to retain and even enhance, during those tumultuous years, its preeminence among the DoD laboratories. The laboratory's experience is a real-world illustration of Friedrich Nietzsche's maxim "What does not destroy me makes me stronger."

Holding the Course is the fifth volume in the China Lake History series. Volumes 1 through 4 (published respectively in 1971, 1978, 2009, and 2013) record the first 24 years of the Navy's history at China Lake.

When I was asked to write Volume 5 close on the heels of Volume 4, I was taken aback. First, I would be writing about the same base, in the same place, with many of the same people and facilities and ranges, and the principal line that separates the two volumes is a name change: Naval Ordnance Test Station (NOTS) to Naval Weapons Center (NWC). How many ways, I asked myself, can I say the same thing about the same place in the same general time frame?

Turns out it wasn't the same place. Geographically, yes it was (with the absence of the Pasadena Annex, which was lopped off in 1967). But the differences between, for example, Captain John Hardy (NOTS) and Rear Admiral Rowland G. Freeman III (NWC), were huge. NWC Technical Director Dr. Tom Amlie was as unlike NWC Technical Director Bob Hillyer as both were unlike NOTS Technical Director William B. McLean.

NOTS never saw a weapon system that caused problems like those that Agile caused NWC, and NOTS management never had to deal with the task of transferring hundreds of people "kicking and screaming" from their lovely Corona home to the harsh Mojave Desert. NOTS and NWC were each the Navy's finest research, development, test, and evaluation laboratory—but they were different in as many ways as individuals are from each other.

Time constraints were tighter with Volume 5 than with Volume 4, and so it was written with greater haste than Volume 4. And since I was appalled, as I imagine some readers were, with the staggering page count of Volume 4, I strove this time to write a shorter, more concise history of the sprawling, heterogeneous base—even though the period covered is one third longer than Volume 4: 12 versus 9 years.

As a consequence, I have elided, or omitted entirely, many projects, people, and incidents that, if time and length were not barriers, would have made this a richer and more valuable volume. Maybe every writer of history believes that.

Another factor shaping this book, as well as Volume 4, is that while I was writing Volume 4, there was considerable uncertainty as to whether Volume 5 would ever be undertaken. Therefore, in a few areas of Volume 4 I ran well over the nominal cutoff date of 1967 to give fuller treatment.

Thus notably absent from this volume is an in-depth accounting of the landmark weather-modification efforts of Dr. Pierre Saint-Amand and his Earth and Planetary Sciences Division. The accomplishments of Saint-Amand's group include the development of a potent weapon of war (Project Popeye) and the development and application of tools and techniques for fighting drought and clearing fog. These efforts, which continued well into the period covered by this volume, are the subject of a chapter in Volume 4 of this history series.

Similarly, the work of James A. Bowen and others to develop fuel-air explosives as an effective weapon was carried out from the early 1960s to the mid-1970s. This subject too is discussed in detail in Volume 4. Other notations in the text of this book regarding specific weapons systems will refer the reader to more complete accounts in the previous volume.

Photographs deserve a comment in this preface. Unfortunately, in the decades between the events recorded in this book and the present, much of the photographic record of China Lake has been lost. Storage space, in the days before digitization, was always at a premium. Periodic house cleanings were held; people edited their safes and files and threw out (or recycled, shredded, or burned) papers and photos that were not essential. This tendency to discard older material extended even to the base newspaper, the *Rocketeer*; virtually none of the original photos that were used by the paper were retained. Although the China Lake photo laboratory has holdings that date back to the base's origin, the bulk of these are technical photographs and test footage.

At least three repositories of photographs do exist; one is the China Lake alumni website (chinalakealumni.org), run by former China Laker Gary Verver. The site, which Gary has operated since 2002, is a unique asset for those interested in the history of the Navy at China Lake. A number of photos from the site are used in Volume 5, with permission.

A second source is the collection of photographs that Al Boyack took during the course of his 61-year career at China Lake. These are primarily informal snapshots of people in their work spaces.

A third source is a digitized collection of China Lake portraits: formal, official photographs, usually done at a point in an employee's career when he or she had reached middle to upper management. Many of these are used in this volume. With jackets and ties and dresses, these portraits present a more formal impression than is truly reflective of the times. China Lake was a place of casual dress, a "shirtsleeves" operation, and for most employees at every level, traditional business attire was reserved for special occasions, such as when one was escorting high-level visitors from off-Center.

Such informality, like the common use of first names between all levels on the civilian side of the house, was an important aspect of China Lake culture and was a plus in recruitment and retention. James L. Rieger—an electrical engineer at Columbia Broadcasting System when he met a China Lake recruiter—recalled, "The man said no one here wore neckties. I was sold."[5]

Although every effort was made to secure high-quality photos, Volume 5 does contain numerous depictions—many scanned from printed copies of the *Rocketeer*—that are of marginal quality. In those cases, I thought it better to include second- or third-generation copies rather than nothing at all.

This book would not have been possible without the support of many current and former China Lakers. Numerous people reviewed either individual sections of the book or the entire draft and provided corrections, additional information, and insights. I thank them all. Reviews notwithstanding, all errors, omissions, inconsistencies, and misinterpretations in this history are solely my responsibility.

Foremost among the people who assisted me with Volume 5 is Deanna Ripley-Lotee, a second-generation China Laker who was my principal contact at China Lake. She was assisted by Stephanie Baca, who did the bulk of the interview transcriptions; Vinnie Vargas, who is responsible for maintaining the historical archives; Bill Stephenson, illustrator and artist, who designed the cover for the paperback edition of this volume; and Mary Ray at China Lake's technical library, who could dig out old, arcane documents with the barest of bibliographic clues. While I worked from my office in Water Valley, Mississippi, Deanna and her team oversaw the immense task of guiding documents through the declassification process, acting as liaison between me and the various groups

[5] *Rocketeer*, 23 March 1979, 7.

at the Lake (the technical library, the photo laboratory, security, technical departments, etc.), and chasing down my myriad, often oddball, requests.

Volume 5 languished for several years after the original manuscript was completed. When it was revived in 2020, Michelle Campbell, an editor in the Technical Communications and Graphics Branch, took up the onerous task of editing the document, ably assisted by Amy Wyatt, who handled layout and formatting.

Leroy L. Doig III, China Lake's command historian and a second-generation China Laker, had probably forgotten more China Lake history than I know—and he still knew more than I. He was my go-to person for the most obscure questions of China Lake historical minutia, which, disconcertingly, he could usually answer off the top of his head. His passing in 2020 was a great loss to the China Lake community.

Liz Babcock, my mentor and friend, was always there to answer questions and provide advice during the book's sometimes halting path to publication.

Special thanks are due to former Naval Air Warfare Center Weapons Division Executive Director Scott O'Neil, who understands the importance of China Lake employees learning and drawing inspiration from their history. Without his support there would be no Volumes 4 and 5.

And finally, to my wife, Ramona Bernard, who has supported my efforts throughout the research and writing of both Volumes 4 and 5, I tender my deepest thanks. Your patience and understanding have made all the difference.

CLIFF LAWSON

Introduction

The book you hold in your hands continues the story of technical explorers who are national treasures. They worked in a secret city where invaluable capabilities emerged, new lessons were learned, and valued ones were reinforced. These pages record some of the many contributions made by members of this unique civilian-military team—a team of innovators investing in American freedom and security that endured in the face of continuous challenges.

The value of these lessons still shines bright enough to guide national defense leaders today and tomorrow. It illuminates the fundamentals and critical resources that America must preserve to enable her sailors, Marines, airmen, and soldiers to succeed in every mission and return home safely to their loved ones.

That's why the title of this volume, *Holding the Course*, is so relevant; our national security must endure through challenge and through change. Cliff Lawson has skillfully mined and shaped the message in Volume 5 of this series about a place called China Lake—a strong link in the chain of national defense that is anchored in the greater good of American security. I pray this chain will sustain its strength and its hold for many years to come. Its links are really the people—people who came to this desert and stayed to record their stories through test and technical reports, to illustrate them in design ideas, and to encourage each other with analyses of both their failures and their successes.

They told their stories to experienced military leaders, defense planners, and funding suppliers. As a community, they bonded over the experience of living and working in a remote place, sharing those stories in each other's garages after work and at family and social gatherings. They also shared what they valued—reasons why they worked at China Lake.

Their stories convinced others to join them, and a strong, effective, and visionary team became stronger. They shared the same vision with early shapers of America—a future of freedom, liberty, and security for family and loved ones. Let your mind's eye follow this chain of people all the way back to those who signed the Declaration of Independence and to explorers like Lewis and Clark who ventured into the unknown. From the people who came to China Lake in the 1940s and in the decades since to those who live and work here now—they all share a common unshakeable spirit.

The hard work of keeping ahead of adversaries and sustaining a dominant edge never put a damper on that spirit nor on the creative excellence and commitment of the people working here.

The dynamics of large organizations and their control has bedeviled defense technical workforces more than technology, science, cost estimating, and economic conditions in any given time period—the Department of Defense's overall perpetual restlessness with who owns what, who does what, and for how much keeps the ground beneath the workforce's feet less stable.

The lurches and turns of organizational alignment, increased acquisition-process complexity, and budget uncertainty are greater risks to the assured productivity of the people and delivery of capability than anything else.

Overall, it does not matter who in the department has organizational stewardship of the laboratory as long as that steward appropriately values the national security asset in the technical knowledge of the workforce.

Everyone who depends upon a weapons system developed at China Lake knows the importance of the knowledge in this team. Successive stewards, organizationally, have always praised the workers and defended their value.

It is understood that there is a necessary infrastructure, whether in the public or private domain, that people require to learn, grow, and remain current and relevant in their knowledge domain. It exists in effective education systems producing a supply of capable people, in laboratories for experimentation and testing, and in a body of relevant work for people to build necessary experience and grow from intern to master, experiencing both failures and successes.

Yet the assurance of team technical excellence, research productivity, profound systems knowledge, and the healthy development of succeeding generations can be difficult to maintain.

Why is stability and assured sustainment of such a knowledgeable government technical workforce so important? Because government is charged to preserve national security. Certainly industry people and leaders are equally patriotic and care the same way that government people care because they are all raising the next generation of volunteers to serve. But companies bloom and fade. They come and go. Sustainment of comprehensive insight that informs sufficient technical edge is uniquely a government imperative.

Industry must also possess this knowledge when engaged in developing and producing security systems, but their ability to sustain it ebbs and flows with the supply of government customer demand and investment.

The government project team must possess and maintain profound knowledge of a defense system technical baseline. Proprietary rights and industry competitive advantage are proper and must be preserved, but there is a need to see beyond these if the government is to sustain a system for multiple decades, analyze and fix failures in service long after development is complete, possess current threat intelligence that is applicable to required upgrades and improvements, and exercise the body of knowledge from other relevant systems and lessons learned.

The fundamental step of translating a stated military requirement into a sound technical baseline is just as important as—if not more important than—the resulting technology's design, test, and production. This translation requires a body of people with profound knowledge about numerous non-trivial items that include:

- System environment
- Human and system interaction
- System integration
- Existing capabilities and emerging possibilities in the sciences of materials, power sources, sensors, signals and circuits, computing power, chemistry, and energetics

Therefore, there is a core need for this knowledge to be sustained by the government. The items above are their own evidence as to why they are necessary for sustaining a technically knowledgeable workforce in the government.

The right body of knowledgeable people transforms the requirement into a sound technical baseline that can then be cost estimated, planned, budgeted, contracted with realism, measured in performance, and satisfactorily delivered.

Programs start better with a sound baseline that can be better estimated, better resourced, better executed, better measured, and better overseen. The better start produces a better contract because people know the fundamentals of what to incentivize. It generates a better technical baseline because people know the fundamentals of optimizing a stated system requirement, which can then be better resourced. It sets a better schedule because people know the fundamentals of testing, software development, schedule realism, supplier management, and production planning.

Complementing those fundamentals is the trust and transparency within a government and industry team whose members mutually respect each other while working together to develop a complex system. Such teamwork is priceless because high trust helps to illuminate the consequences of choices presented in the face of constrained resources.

We have always lived in a world of constrained resources. The coveted skill is the optimization of all constraints to achieve and continually pursue the best result possible at any point in time. This optimization is valued only if the task can be done and the desired capability can be delivered dependably, on time, and on cost.

"Completing the circuit" requires people and infrastructure to effectively deliver a defense system for national security. Dependably doing so on time and at cost is an optimization itself of who owns and manages both the people and the infrastructure; optimization and consequence management are kin.

I envy the opportunity that Cliff Lawson had to ponder the treasure trove of stories about the people here—their contributions and the challenges they faced—many more, I am sure, than he could reasonably include in these few pages.

Cliff's invitation to write this introduction was a special honor because it connected me to telling the story of China Lake. Dominant combat capability and the people who created it here touched my life long before I realized who or where they were. When I did realize it, the experience became more meaningful, because I got the opportunity to know the people here and to live and work at China Lake myself.

DAVID J. VENLET
Vice Admiral, U.S. Navy, Retired
Fighter Pilot
Test Pilot
Commander, Naval Air Warfare Center Weapons Division
Commander, Naval Air Systems Command

1

End of an Era

What is past is prologue.

—William Shakespeare[1]

On Saturday, 1 July 1967, at the stroke of midnight, the Naval Ordnance Test Station (NOTS) China Lake ceased to exist, and the Naval Weapons Center (NWC) China Lake came into existence. History does not record whether, at the moment of transition, any late night customers at the Officers' Club on base—the traditional watering hole for military officers and civilian scientists, engineers, and managers—raised a glass to the future of the base or in a salute to its past.

The NOTS to NWC name change was the result of the largest reorganization in the nearly 24-year history of the Navy's base at China Lake, part of the creation of 10 so-called Centers of Excellence that were designed to make the Navy laboratories more effective and efficient.

What one hand giveth, the other taketh away; at the same time that the reorganization added the Naval Ordnance Laboratory Corona (NOLC), with its 919 employees, to the China Lake organization chart, it stripped away China Lake's Pasadena Annex—866 billets and nearly all of the Station's undersea work. That, along with elements at San Diego and Hawaii, went to the newly created Naval Undersea Warfare Center (NUWC), Pasadena, California. Most disconcerting, from a morale perspective, was the loss of the widely admired and universally respected Dr. William B. McLean, who had been China Lake's Technical Director for 13 years (more than half the Station's existence), who opted to leave China Lake and assume leadership of NUWC.

McLean's decision did not come as a surprise to those who knew him well. In recent years, the man who had invented the Sidewinder missile concept had been devoting most of his attention and energy to fulfilling his vision of

---

[1] Shakespeare, *The Tempest, Act 2, Scene 1.*

Dr. William B. McLean.

an undersea Navy. The scope of that vision ranged from the tiny Moray submarine—often described as an undersea fighter plane, though McLean was careful to use the term "two-man torpedo," thus keeping the weapon within the base's assigned mission area—to vast undersea communities where people would carry out all the functions of a land base, a concept embodied in the Rock-Site feasibility demonstrations.[2]

The transition from Ordnance Test Station to Weapons Center did not pass entirely without ceremony. Later in the summer, an unofficial funeral was held to commemorate the demise of NOTS. The affair was small, attended by several long-time China Lakers, most of them current or former department heads, and a few onlookers. Presiding over the ceremony was local author, sage, and range guard Sewell "Pop" Lofinck. After a black coffin was lowered into the ground, the mourners bowed their heads before the crude grave marker. The epitaph read, "Here Lies NOTS, 8 Nov 1943–30 June 1967. Born in Adversity. Died in Bureaucracy."[3]

A Brief History

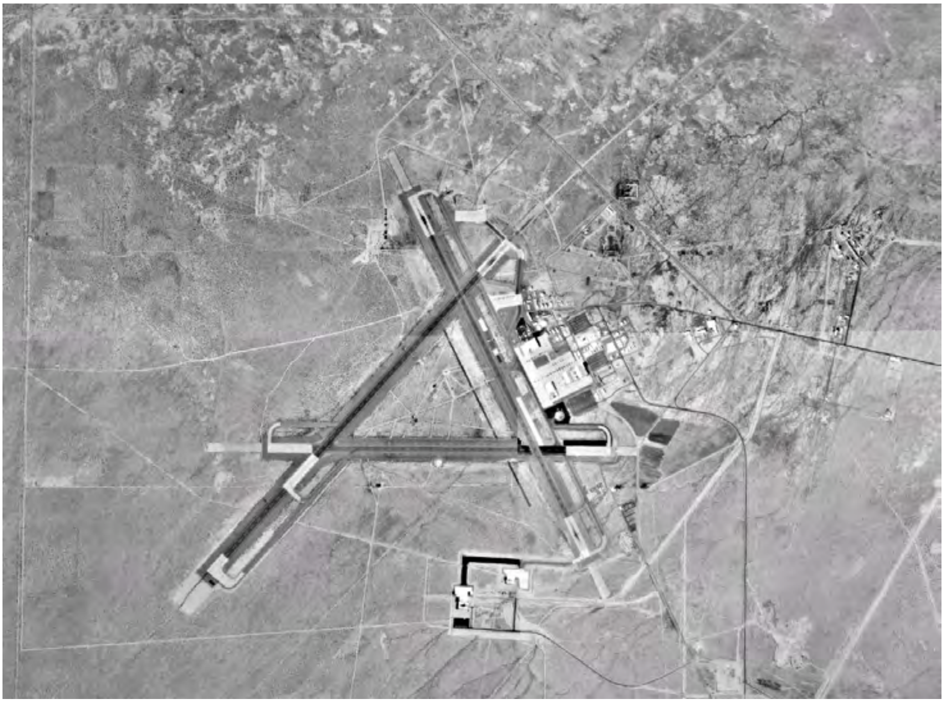
The adversity attending the birth of NOTS in November 1943 was the Second World War (WWII). That month, U.S. forces fought the Battle of Tarawa in the Gilbert Islands, an event that, in the span of 76 hours, cost the lives of nearly 1,700 U.S. Marines and sailors. In Europe in November 1943, more than 8,000 British and Italian troops surrendered to the Germans in the

[2]NAWC RM-24, "Presentation made by Wm. B. McLean," *Collected Speeches of Dr. William B. McLean,* 136. Moray and Rock-Site are discussed in detail in Volume 4 of this history series.

[3]Epitaph from photo record of the famous "NOTS Funeral," with list of pallbearers, China Lake Museum Foundation.

Battle of Leros; in the same month, Roosevelt, Stalin, and Churchill met in Tehran to discuss strategy for the war.

Three months prior to the establishment of NOTS, Commander (later Rear Admiral) Jack C. Renard and Dr. Charles C. Lauritsen, head of the Kellogg Radiation Laboratory at the California Institute of Technology (Caltech), were flying in a single-engine Beechcraft over the western Mojave Desert. The two were scouting for a location suitable for testing Navy air-launched rockets. They spotted Inyokern Airfield (an emergency landing field built under the Federal Air Commerce Act of 1926) and landed.



Aerial photo of base circa 1943.

This, they decided, was the site for their test range. There was access by road (U.S. Highway 6, now California Highway 14) and rail (Southern Pacific) and nearby water, electricity (the 88,000-volt lines of the California Electric Company), and telephone lines (Interstate Telegraph Company). And plenty of open space.

Inyokern Airfield lay on the western side of the Indian Wells Valley, which is bounded on the west by the Sierra Nevadas, on the north by the Coso Range, on the east by the Argus Range, and on the south by the Spangler and Rademacher Hills. Aside from the occasional small ranch, homesteader's spread, and miner's cabin, the area was flat and free of development and far from civilization.

A war was on; no time to waste. A 650-square-mile site was carved out of the desert and expanded by another 380 square miles the following year. Temporary headquarters was established at the village of Inyokern while work began on a new headquarters and building complex 7 miles east at the China Lake site, near a playa (dry lake bed) where, it was said, Chinese immigrants had mined borax in the 1800s.

Construction at NOTS was rapid under the direction of Captain Sherman E. Burroughs, NOTS' first Commanding Officer, and Captain Oscar A. Sandquist, Officer-in-Charge of construction, from the Bureau of Yards and Docks. Work proceeded according to a plan conceived in the space of a single week in mid-November under the general direction of Commander Kenneth M. McLaren of the Bureau of Ordnance.

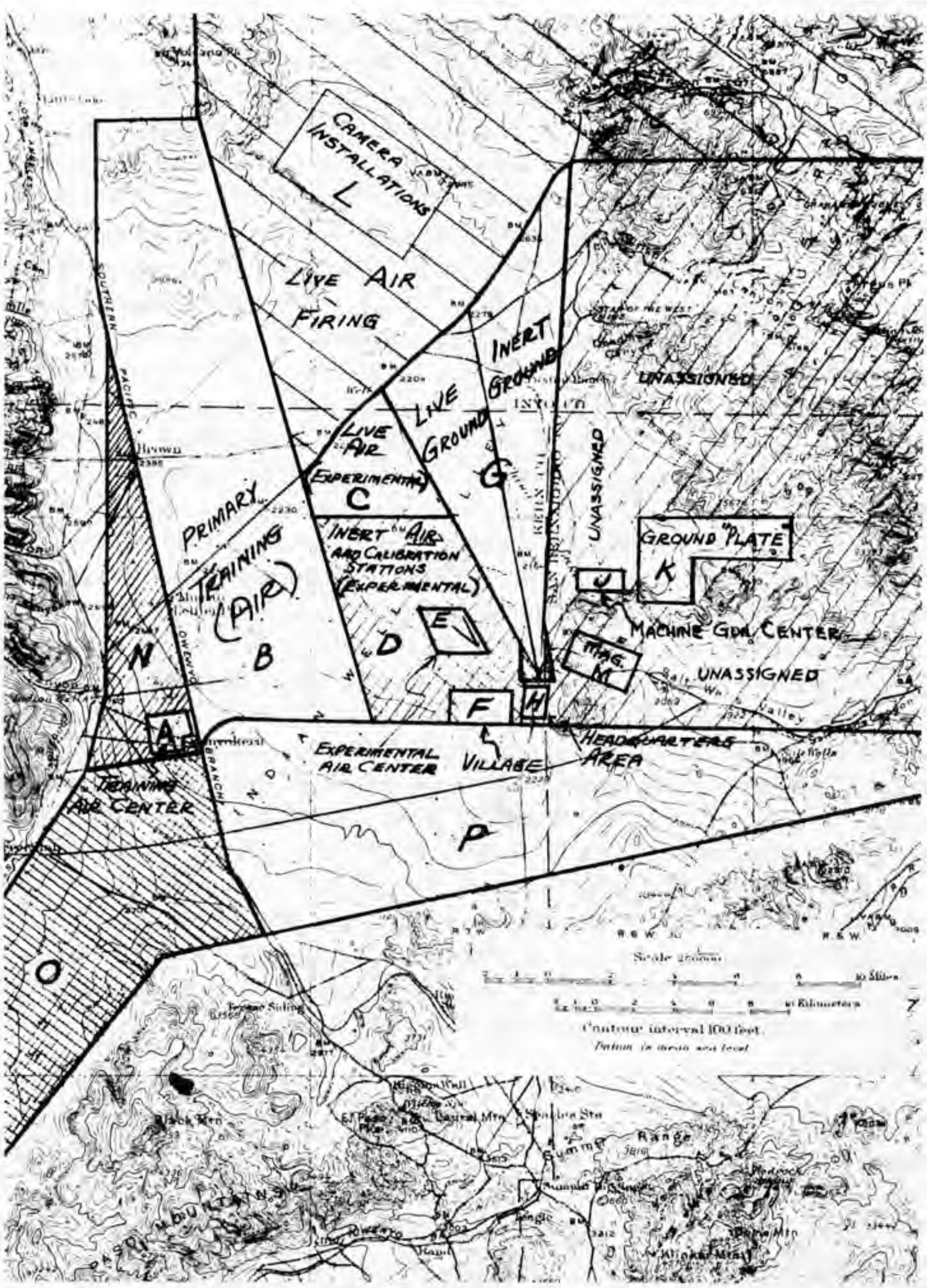
By early 1944, the Indian Wells Valley was booming, in the truest sense of the word. While carpenters swung hammers and surveyors squinted into theodolites, aircraft roared overhead and air-launched rockets exploded (or sometimes didn't—that's why it was called testing) on newly laid out ranges that spread out north toward the Argus Range. In little more than a year after the base's establishment, the population of the valley jumped from 28 to more than 14,000.[4]

Building a military base in the Mojave Desert during WWII was not for the faint of heart. This was the high desert: hot in the summer, cold in the winter, dry as a bone (except when the flash-flood-generating gully washers hit), and windy just about all year 'round. The site was remote even by the standards of the 1940s—a long day's drive from Los Angeles. Amenities were absent. Author Al Christman reported that the construction workforce numbered as high as 7,200 men at one time; to maintain such a large force, more than 24,000 men were hired in one 8-month period.[5]

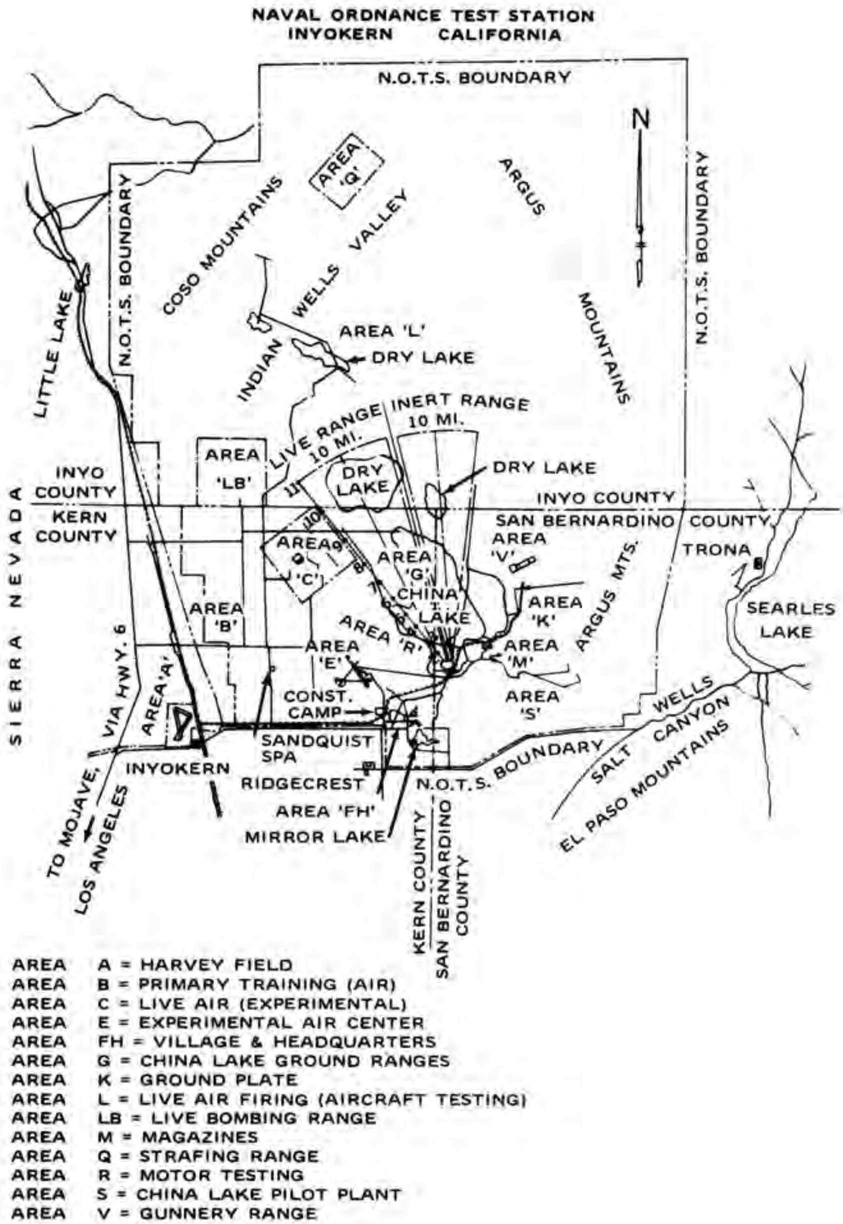
Living and working conditions were harsh, not only for the tradesmen and laborers who built the base but also for the scientists, engineers, and support personnel who worked there. Many came, took one look around, and left. But a surprisingly large number of the technical professionals came to the base,

[4]*Los Angeles Times*, 27 February 1945, A-1, A-6. The early rockets tested ranged from the small 3.5-inch-diameter aircraft rocket to the mighty 11.5-inch-diameter Tiny Tim.

[5]Christman, *Sailors, Scientists, and Rockets*, 226. When the aptly dubbed "termination winds" would blow, workers would quit in droves.



Proposed layout of facilities for NOTS, dated November 1943.



Map of NOTS, April 1944.

allowed as how they'd give it 6 months or maybe a year, and then never left, even after retirement following decades of government service.

The excitement of working hands-on with weapons of war was, and still is, part of the allure. A sense of this was captured in an early song that former China Lake Technical Director Dr. Walter B. LaBerge wrote; he called it the "theme song" of China Lake. The song's concluding verses were:

> When the bloom is on the desert
> and the skies are blue outside,
> 'tis the time for shooting missiles,
> which with targets do collide.
>
> And the glory of their crashing
> and the splendor of their burn
> is a sight you'll never see until
> you've come to Inyokern![6]

Within 2 years of its formal establishment, NOTS included a range complex for various types of weapons testing; the China Lake Pilot Plant (CLPP, pronounced "clip"), used for the development and production of urgently needed dry-extruded rocket-motor propellant grains; and the Salt Wells Pilot Plant for the production of the precision-shaped high-explosive "lens" that was used in the second nuclear bomb dropped on Japan in 1945. The China Lake portion of the Manhattan Project was known as Project Camel, and in 115 days, 80 buildings were constructed at Salt Wells, 52 of them permanent, at a cost of $13 million—the equivalent of more than $198 million in 2021 dollars.

An 11,000-plus-acre Naval Air Facility (NAF), a subcommand of NOTS, was completed in 1946 and sited at Armitage Field, named after Lieutenant John Armitage, who died while testing a Tiny Tim rocket in 1944. Armitage was one of five NOTS flyers to die in weapons testing accidents that year.

Housing was always a problem at NOTS. Initially, the government provided barracks and dormitories—often those ubiquitous, multipurpose Quonset huts, which were produced by the tens of thousands for the Navy in WWII. These were augmented by an assortment of small trailers, jerry-built shacks, and even tents around Inyokern and immediately adjacent to the new construction site in the tiny farming community called Ridgecrest (known prior to 1940 as Crumville). With the Salt Wells work for the Manhattan Project came $5 million that was earmarked for schools, housing, shopping, and other community construction projects.

---

[6]LaBerge, *From Research to Reality*, 25.

Officer's dance, 1944. Lieutenant Armitage, second from right.

Lieutenant Commander James A. Duncan, along with a committee of designers from the Bureau of Yards and Docks, designed a major laboratory as the center of the Station's technical operations. In August 1944, ground was cleared for the new laboratory complex that would be completed and dedicated in May 1948. With more than 10 acres of floor space, Michelson Laboratory—locally called Mich (pronounced Mike) Lab—remains at the core of the Center's technical work. The building is officially designated Building 5, being the fifth permanent building on which construction was begun at NOTS.[7]

Originally, China Lake was used principally for testing and evaluating rockets designed for the Navy by Caltech, and that role soon expanded to other types of aviation ordnance. The men who established the base, however, had a greater vision than mere rocket and bomb testing. The original mission statement, set out in November 1943, described the new base as "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." There was plenty of room for interpretation in that broad

[7]With Burroughs' help, Duncan became the NOTS Laboratory Officer. Duncan, a former student of Dr. Albert A. Michelson, suggested naming the laboratory after the great scientist.

Michelson Laboratory under construction, 1946.

statement, and through the years China Lake's leaders and some supporters in Washington would take full advantage of that breadth.[8]

China Lake's success has always been a team effort. Scientists and engineers are part of that China Lake team. So are the Fleet-seasoned aviators and military support personnel who bring real-world experience that shape and temper the civilians' weapons designs. From its inception, NOTS was a joint civilian-military operation. The intertwined military-civilian partnership was established by design, a philosophy of cooperation that was embodied in the Station's *Principles of Operation* (Appendix A).

Officially approved by the Bureau of Ordnance (BuOrd) and published in 1946, that brief (two-page) document embodied recommendations from the Station's civilian Research Board, under the leadership of Dr. Louis Ten Eyck Thompson, the Station's first Technical Director. In a nutshell, the principles placed the Commanding Officer (later Commander) in charge of the mission of the Station but delegated the control to carry out that mission to the civilian

[8]Secretary of the Navy Frank Knox to All Ships and Stations, memorandum, "Naval Ordnance Test Station," 8 November 1943.

Dr. L. T. E. Thompson.

Technical Director. At the time of its issuance, it was, according to a 1966 interview with Rear Admiral Malcolm F. Schoeffel, Chief of the Bureau of Ordnance, "something like the Declaration of Independence." As J. D. Gerrard-Gough and Christman wrote, "The Principles were written to meet the long-term needs for a management philosophy assuring technical direction by the technically qualified."[9]

This relationship was a delicate balance, swayed by the backgrounds and personalities of the individuals who held the two senior leadership positions. By and large, it worked out well. "We do wrestle constantly with the dichotomy between military authoritarianism and civilian permissiveness," said Dr. Richard (Dick) E. Kistler, "and I think we do it quite well to the benefit of both."[10]

Dr. Richard E. Kistler.

In 1945, the Pasadena facilities that had been part of Caltech's rocket- and torpedo-development program during the war became NOTS Pasadena Annex, adding underwater ordnance to the Station's portfolio of weapons development. Air-to-surface weapons development and testing was soon joined by air-to-air ordnance, and in 1950, the

[9]S-8, Schoeffel interview, 2, quoted in Gerrard-Gough and Christman, *The Grand Experiment at Inyokern*, 260.

[10]S-131, Kistler interview, 34. Kistler held numerous leadership positions at China Lake, including head of the Office of Finance and Management.

Sidewinder air-to-air missile began development. (It was released to the Fleet in 1956.)

New weapons flowed out of NOTS in a rapid succession, dwarfing the productivity of other government laboratories: the 2.75-inch Folding-Fin Aircraft Rocket (FFAR), the 5-inch Zuni, and the shaped-charge-tipped 6.5-inch Antitank Aircraft Rocket (ATAR, nicknamed Ram) that devastated enemy tanks in Korea; the spin-stabilized Bombardment Rocket (BOMROC); the Rocket-Assisted Projectile (RAP); and the 30.5-inch Bombardment Aircraft Rocket (BOAR) designed for a nuclear payload. Undersea weapons included the rocket-propelled depth bomb Weapon A, the Rocket-Assisted Torpedo (RAT), the Antisubmarine Rocket (ASROC), and a half dozen different torpedoes.

In the minds of the engineers and scientists at NOTS, there was nowhere to go but higher, deeper, further, and faster. NOTSNIK would fly to the edge of space (and perhaps into orbit), and the Station's Cable-Controlled Underwater Recovery Vehicle (CURV) would recover a lost hydrogen bomb in 2,850 feet of water off the coast of Spain.[11]

New facilities were continuously under construction to help build and test new concepts in weaponry. In 1953, the 4.1-mile-long Supersonic Naval Ordnance Research Track (SNORT), capable of speeds up to 6,000 feet per second, was completed. Skytop, a facility for testing Polaris rocket motors with a peak thrust of 10 million pounds, was completed in 1959. (The concept for Polaris itself was developed by China Lake's Weapons Planning Group and others at NOTS.)

Through the early 1960s, a China Lake-developed line of free-fall weapons known as the Eye series began to come on line—Bigeye, Briteye, Bugeye, Chaffeye, Deadeye, Deneye, Evileye, Fakeye, Fireye, Gladeye, Hawkeye, Marceye, Misteye, Padeye, Rockeye, Sadeye, Smokeye, Snakeye, and Weteye. Not all would become operational, but those that did, particularly Rockeye, Snakeye, and the television-guided Walleye, would be central to U.S. military efforts in the coming years of war. Under the auspices of the Advanced Research Projects Agency (ARPA), the base ventured into the world of special warfare, devising ingenious tools and weapons for the behind-the-lines missions of Navy Sea, Air, and Land teams (SEALs); Marine Force Reconnaissance; and other groups.

Entirely new concepts for weaponry were conceived and weaponized at the Station. Fuel-air explosives (FAEs) saw action in Southeast Asia and in

[11]Officially, NOTSNIK was called NOTS 1: a China Lake program to put a satellite in orbit with an air-launched rocket.

subsequent U.S. wars. Forward-looking infrared (FLIR) revolutionized nighttime ground-attack missions. Shrike, the first successful antiradiation missile, ended the dominance of radar-guided surface-to-air missiles (SAMs). Weather itself was molded into an instrument of war through Project Popeye.

NWC, like NOTS, was "born in adversity"—the Vietnam War. Nearly half a million U.S. combat troops were on the ground in Southeast Asia. With the draft sucking up nearly 40,000 young men per month, antiwar protests in the United States were growing in size and frequency. Unrest was widespread on the home front; 43 people died during racial rioting in Detroit in one of more than 100 civil disorders that ripped through America's cities in the summer of 1967.[12]

Little had changed between 1943 and 1968 in terms of China Lake's stated mission; it was now

> to conduct a program of warfare analysis, research, development, test, evaluation, systems integration, and Fleet engineering support in naval weapon systems, principally for air warfare, and to conduct investigations into related fields of science and technology.[13]

The "air warfare" qualifier had been interpreted liberally, and the base developed air-to-subsurface, air-to-surface, air-to-air, air-to-space, subsurface-to-subsurface, subsurface-to-air, surface-to-subsurface, surface-to-surface, and surface-to-air weapons—not to mention a variety of grenades, shoulder weapons, booby traps, and the like.

The year 1968 began calmly enough at China Lake. Just 6 months after the NOTS/NWC upheaval, the base was carrying on business as usual, people were getting used to the idea of the Coronans being part of NWC (although China Lakers were more comfortable with the situation than the Coronans themselves were), and the pace of weapons development was heavy.

One factor that had helped smooth the transition from Station to Center was the assignment of Haskell G. "Hack" Wilson as Acting Technical Director. He had been McLean's right-hand man for years, handling the greater part of the administrative aspects of base leadership, and he was not one to make waves in McLean's wake.

Vietnam was a palpable presence at China Lake and in the adjacent city of Ridgecrest as people began to move off the base and into town in greater

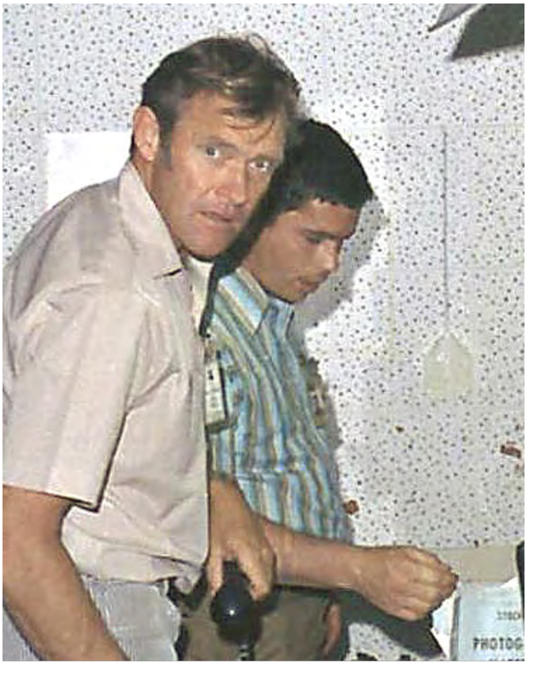
[12]NWC, like NOTS, would also die in bureaucracy. It became the Naval Air Warfare Center Weapons Division / Naval Air Weapons Station (NAWCWD/NAWS) in another massive Navy laboratory reorganization in 1992.

[13]TS 67-259, *Naval Weapons Center Silver Anniversary*, ii.

Hack Wilson.

numbers. The years 1967 and 1968 were two of the heaviest years of fighting in the Vietnam War, with a combined toll of over 27,000 U.S. military dead—nearly half of the total U.S. deaths during the war. Not just China Lake weapons but also China Lakers themselves were involved in the fray. This was to be expected of the military, of course. For many of the pilots, air crews, and enlisted support personnel at Armitage Field, a tour in Vietnam was either their previous duty assignment or their next one.

But China Lake civilians were finding their way to the war theater as well. Teams of engineers and technicians accompanied new weapons to the Fleet to train pilots and maintenance personnel and to resolve the inevitable technical problems that arose when a complex system was transitioned from the laboratory to the battlefield. The very first *Rocketeer* issue of 1968 reported on the Civilian Overseas Service Awards received by two Public Works Department employees, Jack Jeffers and Fred DeHam, who had recently returned from their service "at the war front." Larry V. Zabel, a Technical Information Department (TID) filmmaker and illustrator, went to Vietnam with the team introducing large-scale FAE weapons in July 1967. In a single month, the adventurous civilian flew nearly 50 flights, including



Larry Zabel (left) and Jim McKinney (right) of TID.

enough combat flights to qualify him for two Air Medals had he been in the military.[14]

A few China Lakers were also on the ground in-country with the Vietnam Laboratory Assistance Program (VLAP), providing a conduit between Navy and Marine combat units and the technical experts back in the stateside laboratories.

Times of Change

The old NOTS had been a product of its moment in history and its people. It was a different entity than NWC would become, just as NWC would be from its successor organizations, NAWCWD/NAWS.

In 1943, every person working at NOTS had lived through the Great Depression; for many of the NOTS plank owners (a Navy term for the original crew that takes a new ship to sea), it was economics—the promise of a steady paycheck—that brought them to this remote, harsh corner of the Mojave Desert.

By contrast, 1967's crop of newly hired Junior Professionals at China Lake (mostly entry-level scientists and engineers) had been born after the Depression. They had been raised in the booming years of America's post-WWII economic growth. During college in the 1960s, they had learned to question authority, and as a group they were beginning to question the classic paradigm of Dad slaving at a job so that Mom could stay home, make supper, and rear the kids. The newcomers believed, more so than their predecessors at China Lake, that there was more to life than work.[15]

Communal living, which in the 1960s was considered a characteristic of so-called "hippie" communities, had long been a way of life at China Lake. Civilians and military worked together, played together, and lived cheek-by-jowl in government-built housing. When Secretary of the Navy Paul R. Ignatius signed a statement of permanency for NWC in August 1968, he opened the door for mortgage availability to those who wished to build or buy in the surrounding communities. Over the next decade, the trickle of hardy souls who had accepted the challenge of living off-base became a flood.

---

[14]*Rocketeer*, 5 January 1968, 6; *Indian Wells Valley Independent and Times-Herald*, 27 July 1967, A-1.

[15]JPs, as participants in the Junior Professional program were called, spent their first year on base in 3- or 4-month tours with various departments. Through exposure to different facets of China Lake's activities, newcomers discovered the type of work they found most interesting and best suited to their talents.

Much of the communal aspect of life at NOTS was, for better or worse, lost to the newcomers.

The nature of the Center's work was itself changing. Reporting requirements were becoming ever more burdensome. The double-edged sword of high-speed computing and communications technology not only allowed young engineers to work faster and more productively but also put the sponsors in Washington virtually at desk side, in real time. The technology facilitated a degree of micromanagement at China Lake that would have been impossible back in the day when typed weekly reports were sent "Back East"—China Lake's colloquial term for Washington and the Department of Defense (DoD) bureaucracy there—by postal carrier and teletype.[16]

A principal role of a China Lake manager had always been to take care of the folks in his or her group and to shield them from the bureaucracy. But as the Washington bureaucrats bored their way deeper into the field organizations, that task became more difficult. Dr. Edwin B. Royce, head of the Research Department from 1976 to 1986, stated that his job as a manager was

Dr. Ed Royce.

> to protect my people from the kinds of direction that was coming out of Washington, the sense of micromanagement and requests for information and directives for the "what-you-should-do-and-how-you-should-do-it" and all the rest of that. You're going to drive a good engineer or a good scientist mad if he has to deal with that kind of thing. It almost drove me mad! The successful managers here at

[16]The laboratories were not the only ones chaffing under Washington micromanagement. Speaking of the conduct of the Vietnam War during this period, Vice Admiral Lawson P. Ramage, who had taken over as Deputy Chief of Staff, Pacific Fleet, in 1966, said:

> These people in Washington were dictating first the target that was to be struck, the number of planes that would go on that particular mission, the number of particular types of bombs that each plane in that formation would carry, and furthermore the actual profile that those planes would fly into and from the target. . . . They had absolutely taken every bit of initiative out of the business.

Ramage interview, 473–474. Ramage won the Congressional Medal of Honor and two Navy Crosses for his independent actions as a submarine commander in WWII.

> China Lake—and I'd like to think I was one of them—as best we could, we protected our people from that.[17]

Close direction of the laboratory's work from Back East affected the core of the China Lake culture. Traditionally, China Lake scientists and engineers, working closely with their customers in the Fleet, would identify a problem and then look for a solution. If a path to a solution was found—and among the fertile brains that worked at the Lake, there was a high likelihood that it would—then the workers would attack the problem with gusto. Approval through a lengthy chain of command and sitting around waiting for funding was not part of the China Lake problem-solving strategy.

Dr. Chalmers W. Sherwin conducted a study in the mid-1960s titled Project Hindsight, which examined the value of research to the DoD. He observed the behavior of so-called "innovators" or "idea producers:"

> They were usually in an organization which was directly in contact with a tough problem or which needed some end product. . . . Not only did they see what the problem was, they also invented the solution. . . . In the great majority of cases, in over 80 percent of the cases, by hook or crook they financed the initial demonstration of feasibility out of locally controlled funds. They didn't wait for approval up the line.[18]

Sherwin went on to comment:

> In my opinion, the idea producer is a disappearing person in the United States government, I am sorry to say. It is, I think, because of the tendency to produce central planning in too much detail and with too much rigidity and crystallization.[19]

The decade following NWC's establishment would see unremitting change affecting every aspect of China Lake's culture and operations. The reasons for that change were multiple and disparate. Many were internal to the Center: new Commanders and Technical Directors who wished to set their own courses for the Command and leave their own legacy; aging and obsolescent ranges and physical infrastructure, some of it a quarter century old and woefully out of date; a surge in homebuilding in the community that surrounded the base, coupled with skyrocketing rent on base and a reduction of the "perks" of inside-the-fence life; and a bewildering series of reorganizations, personnel reassignments, and departmental renamings.

---

[17]S-354, Royce interview, 58–59.

[18]Sherwin, "Major Weapon Systems Advances," 143. See also Sherwin and Isenson, "Project Hindsight."

[19]Ibid.

Another source of change was the proliferation of scientific and engineering breakthroughs in the late 1960s and 1970s: solid-state electronics, digital computers, microcircuitry, lasers, integrated avionics suites, stealth technologies, and others. The Center's technical focus was in constant readjustment in response to evolving Navy requirements stemming from the end of the Vietnam War, disastrous shipboard fires, the vulnerability of surface combatants to increasingly sophisticated threat missiles, the need for faster and more maneuverable targets, the increased importance of electronic warfare (EW), and the growing Soviet threat to the U.S. Navy's control of the sea.

National policy and politics also contributed to change—the new efforts to transfer and adapt military technology to civilian pursuits and the growing pressure to put traditional government functions into the hands of contractors. Other major contributors to change at China Lake were upheavals in the larger overall American culture: an awakening to the importance of equal opportunity for minorities and women, increased concern for the environment, reaction to surging inflation and a long-running energy crisis, and growing anti-war sentiment that led to an ignominious end to the Vietnam War.

Organization

A sense of the breadth and depth of operations at China Lake can be gleaned from the organizational structure as it stood at the beginning of 1968. At the top was the Commander (Code 00), Captain Melvin R. Etheridge, who had come to China Lake just 3 months earlier after a tour as skipper of USS *Wasp* (CVS-18).[20]

Captain Etheridge's civilian counterpart, the Technical Director (Code 01), was Hack Wilson, who since 1955 had served as Associate Technical Director to McLean. Wilson held the Technical Director position in a temporary (acting) capacity while higher authorities on the East Coast made the formal decision as to who should officially step into McLean's very-hard-to-fill shoes.

Answering to the Technical Director were the technical departments. Systems Development (Code 30), headed by Dr. Ivar E. Highberg, provided direction for the development of major air-launched tactical guided-missile systems. Aviation Ordnance (Code 35), headed by Dr. Newton E. "Newt" Ward, dealt with the development of aviation ordnance and operation of the air ranges. Weapons Development (Code 40), headed by Franklin H. Knemeyer, worked with airborne weapons delivery systems, guidance and navigation systems, and missile control systems. Missile Systems, Corona, (Code 42), headed by

[20]Captain Etheridge was the only China Lake Commander who wore "dolphins and wings," reflecting his status as both a submariner and an aviator.

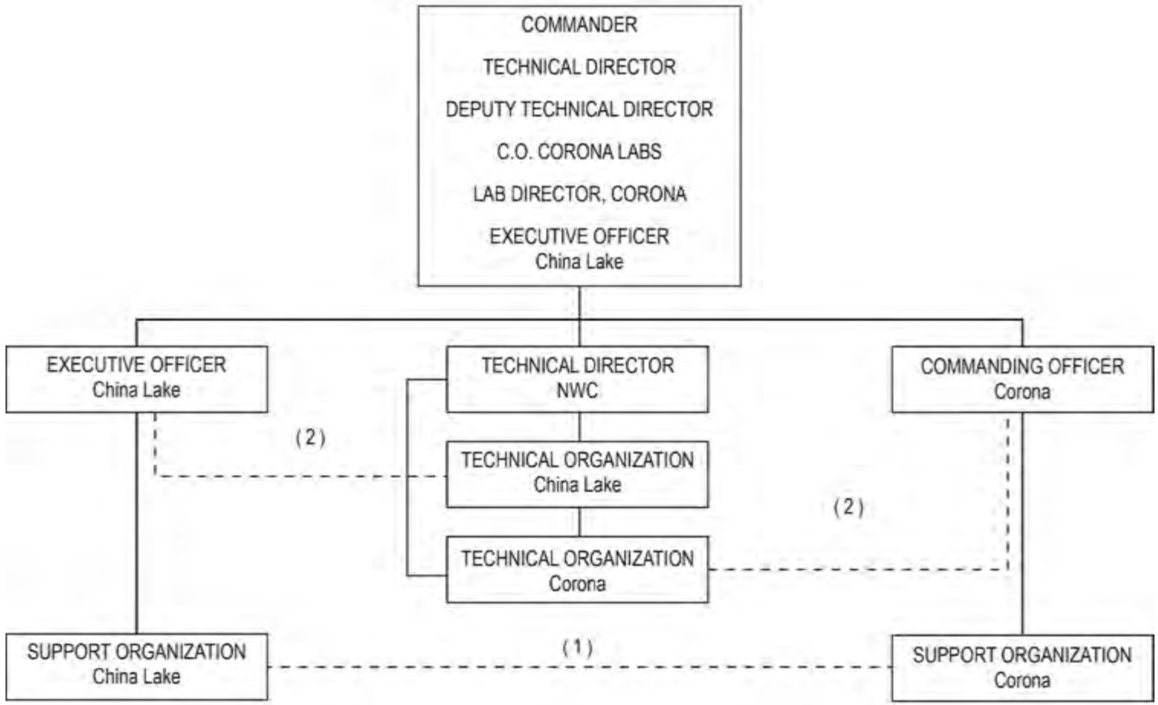
Frederick C. Alpers, developed missile guidance systems, instrumentation, and countermeasures. Propulsion Development (Code 45), headed by Dr. Guy W. "Bill" Leonard, developed propellants, explosives, pyrotechnics, warheads, and associated technologies. Fuze (Code 50), headed by Ben F. Huston, developed fuzing and safety-and-arming systems and technology. Engineering (Code 55), headed by Frederick A. Chenault, performed production engineering, production monitoring, and Fleet support. Research (Code 60), headed by Dr. Hugh W. Hunter, performed and supported basic and applied research.

At the same level as the technical departments were the Weapons Planning Group (Code 12), headed by Carl L. Schaniel, which provided a variety of operations research and systems analyses and studies, both for warfare areas (e.g., antisubmarine warfare [ASW] and surface-launched concepts) and individual weapon systems; the Technical Officer (Code 14), Captain Robert S. Moore, who with his staff was the principal advisor to the civilian technical side of the house on naval matters and the operational aspects of weapon systems' employment; and Central Staff (Code 17), led by Monroe B. "Mel" Sorge, which provided management, accounting, and disbursing services as well as internal reviews.

Support departments (or department-level entities) facilitated the work of the technical departments. The support departments reported to the Commander through the Executive Officer (Code 05), Captain Robert Williamson II. Personnel (Code 65), under Raymond A. Harrison, kept the employment and employee development functions operating smoothly and advised management on personnel policies. Public Works (Code 70), under Captain Kenneth C. Abplanalp, maintained the Center's infrastructure and utilities. Technical Information (Code 75), headed by Kenneth H. Robinson, served the technical communication and publications needs of the Center. Safety (Code 22), headed by Karsten S. "Kit" Skaar, developed programs to prevent accidents and personnel injuries in all aspects of the Center's operations, from automobile traffic to range operations. Supply (Code 25), under Captain Charles R. Lee, served the Center's supply needs and advised on supply policies and regulations. Security (Code 84), under Lieutenant Samuel R. McMullen, maintained physical, personnel, and information security. Command Administration (Code 85), under Commander William P. Baker, oversaw operations of the military messes, lodging, recreation, communication, mail service, and military records. The Medical Department (Code 88), under Captain Edward J. Jaruszewski, and the Dental Department (Code 87), under Captain Joseph A. Thimes, provided for the medical needs of active duty and retired military and their dependents.

NAVAL WEAPONS CENTER

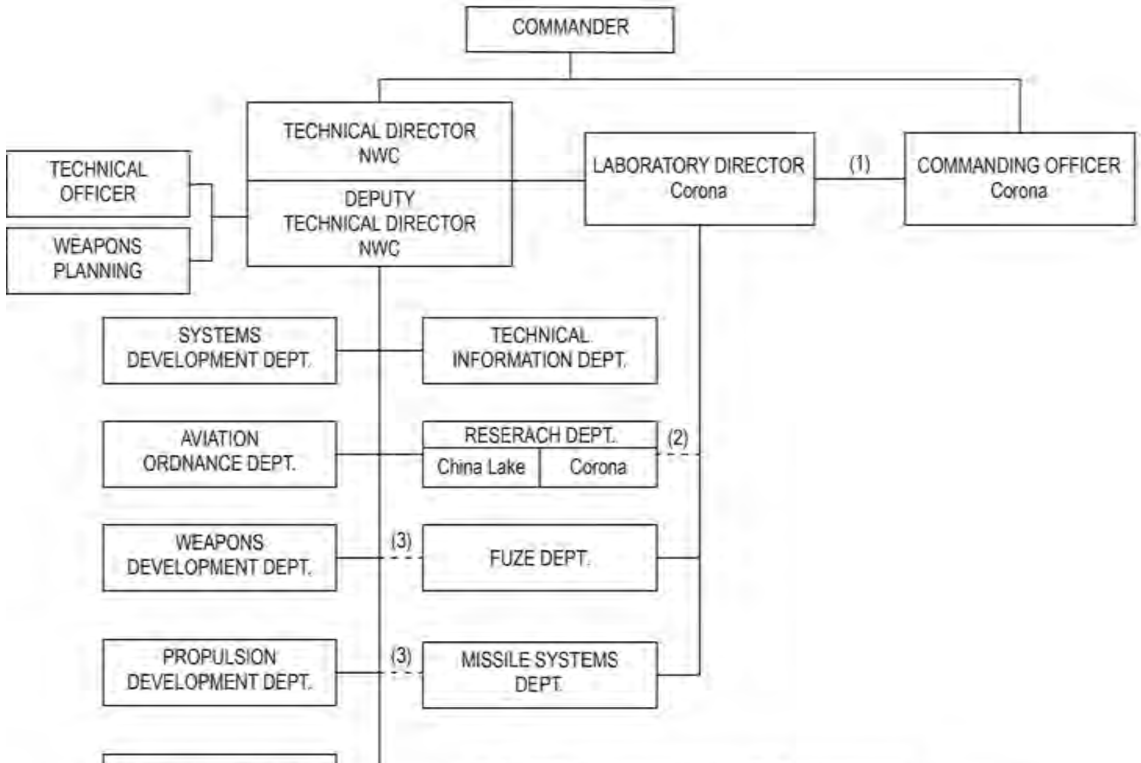
BASIC STRUCTURE



(1) Uniform policies and operating procedures.
(2) Integrate work of technical and support departments.

NAVAL WEAPONS CENTER

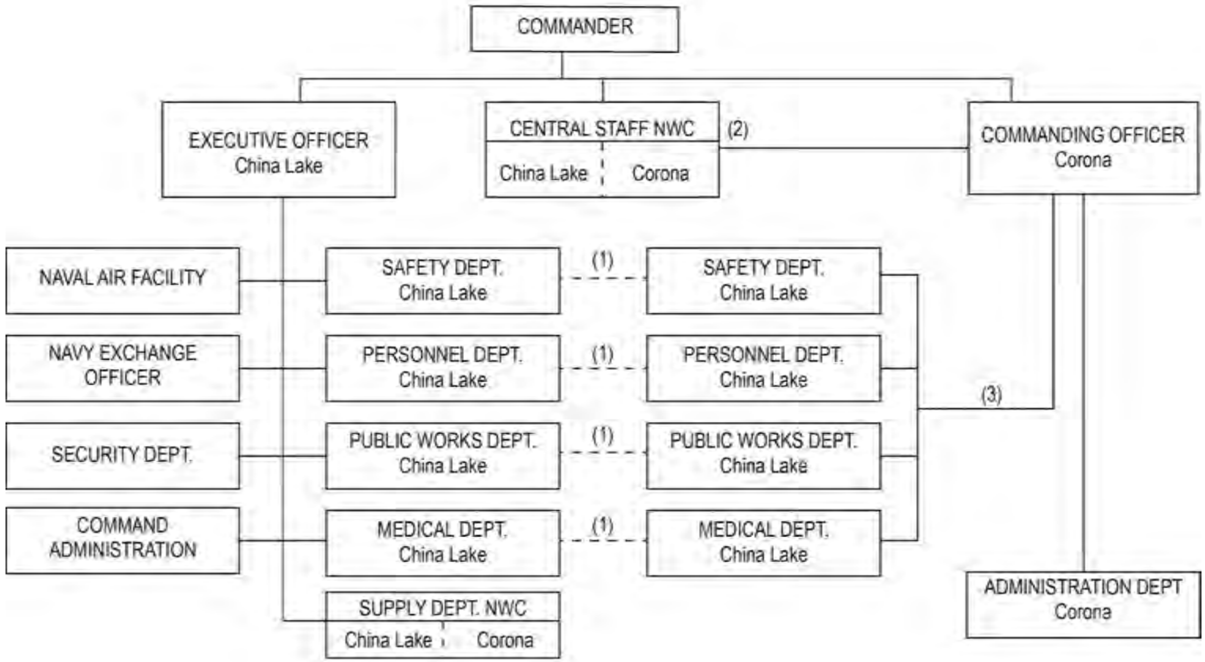
TECHNICAL ORGANIZATION



(1) Integration of Corona support activies with the technical program.
(2) Coordination of Corona Research division with other Corona technical departments.
(3) Day-to-day communication.

NAVAL WEAPONS CENTER

TECHNICAL ORGANIZATION



(1) Common policies and operating procedures.
(2) Integration of Central Staff will occur on 1 July 1968 upon institution of integrated financial management for NWC. Until that time, the corona component of Central Staff will continue to report to the Commanding Officer, Corona.
(3) CO Corona ensures responsiveness of Corona component to Corna requirements.

The Naval Air Facility (NAF, Code 18), commanded by Captain Rodney F. Schall, provided pilots, aircraft, and facilities to support the Center's system development programs.

Several of the support groups had mirror organizations at NWC Corona Laboratories to serve the local needs of that subcommand. Those reported through Corona's Commanding Officer (Code 02), Captain Robert L. Wessel, to Captain Etheridge.

Finally, there were attached activities—weather service, patent office, etc.—that were physically located at China Lake but not under Captain Etheridge's direct command. Chief among these was Air Development Squadron Five (VX-5), commanded by Captain W. Boyd Muncie. VX-5 wrote instructional books for new weapons, devised tactics for new and existing weapons, and performed independent operational test and evaluation (T&E) of new air weapon systems. Captain Muncie reported to the Commander, Operational T&E Force, Norfolk, Virginia.

Prospects

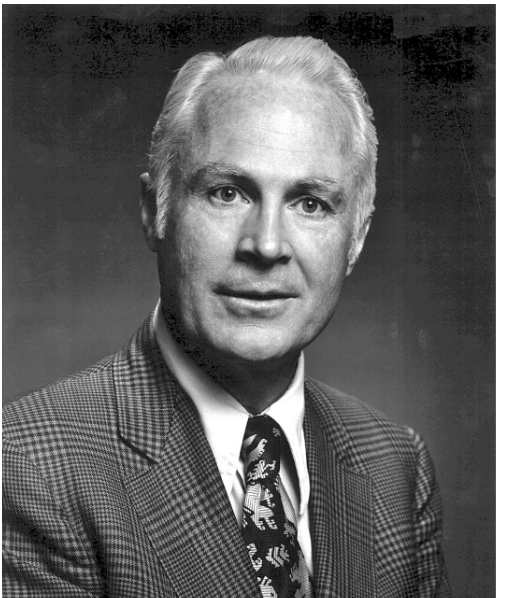
Hack Wilson's tenure as Acting Technical Director ended in January 1968 with the selection of Dr. Thomas Strong Amlie as Technical Director. Most China Lakers had thought that Wilson's acting position would be made permanent or that the position would go to either Frank Knemeyer or Leroy Riggs, both experienced managers and both of whom had applied for the position. The catapulting of a division head (one level below department head in the organizational hierarch) into the top slot was a surprise to most, including Amlie himself (see Chapter 5).

For the average China Laker, little time was available to ponder either the wisdom or the ramifications of Amlie's selection. As a common phrase from the mid-'60s put it, "When you're up to your butt in alligators, it's hard to remember that your initial objective was to drain the swamp." For China Lake in 1968, the alligators were a heavy workload, the hectic pace of development and testing, and increasing oversight and micromanagement from Back East. The swamp-draining part of the metaphor was providing the Marines and sailors in Southeast Asia with the best weapons possible.

The Center was at the peak of its productivity—with the war raging in Vietnam, defense spending was at its highest level since WWII. Weapon systems that had begun development in the late 1950s and early 1960s were coming on line. In the past quarter century, China Lake had ventured from the edge of space to the ocean depths and had spread its research and development (R&D)

Dr. Tom Amlie (left) with Captain Etheridge (right).

efforts across fields as diverse as weather modification, booby traps, nuclear weapons, optical and laser research, and—the mainstay of the operation—air-to-air and air-to-surface weapons. In 1968, the Center was still involved to some degree in all of those areas, save for the bulk of the undersea work.



Dr. Howie Wilcox.

The China Lake way of doing business did not fundamentally change between NOTS and NWC. Rather, it adapted—more politicking, marketing, and dialogue; more tendency to color within the lines; a bit less of, as former Associate Technical Director Dr. Howard A. Wilcox put it, "the Huns descending on Washington out of the West to run off with all the plums." Through it all, China Lake's workforce doggedly stayed the course, pursuing the Center's fundamental goal: to provide the Fleet with the tools needed to defeat its adversaries.[21]

The years between Tom Amlie's assignment as Technical Director in 1968 and Captain William B. Haff's assumption of the NWC Command in 1979 would be challenging and tempestuous for China Lake. But looking ahead from 1968, there was no way to see more than the barest outlines of the changes that would come—organizational, strategic, political, economic, and cultural. Instead, the Center's outlook was focused on the more immediate future. And for starters, there were some loose ends from the 1967 organization to be tidied up.

[21]S-196, Wilcox interview, 26.

2

Bringing it Together: The Corona Consolidation

We were building weapons, they were building the weapon fuzes; well, that's silly to have under two separate commands.

—Leroy Riggs, NWC Technical Director (Acting), 1973-1974[1]

Throughout 1968, as the war peaked in Vietnam and protest grew at home, China Lake employees and their families were quickly adjusting to the 1967 reorganization that had created NWC. One-hundred-fifty miles to the south, at a site far different from the high desert in climate and appearance, another community of Navy technical professionals and their families likewise considered the impact of the Washington-contrived restructuring and wondered what impact it would have on their future. The employees of the former Naval Ordnance Laboratory Corona (NOLC) would not have to wait long for the answer.

"A Most Unusual and Delightful Resort"

In 1929, the Hollywood elite were flocking to a new destination, some 50 miles southeast, among the lemon groves surrounding the small city of Corona. Millionaire developer Rex Clark, who founded Corona in 1920, had constructed a 62-acre lake and spent $4.5 million creating the Lake Norconian Club, extolled in Clark's newspaper advertisements as "a most unusual and delightful resort."[2]

Spread over nearly 700 acres, the complex included a world-class golf course, hot sulphur baths, a double Olympic-size swimming pool, stables and riding trails, an airstrip, chauffeurs' quarters, and, the crowning glory, a five-story, 250-guest-room, hotel-casino-spa complex just north of the lake.

---

[1]S-136, Riggs interview, 17.

[2]NWC AdPub 148, *The Navy in Corona; "News Bulletin, Lake Norconian Club," Los Angeles Times, 19 January 1929, 10; "Navy Buys Hotel Norconian for Hospital," Los Angeles Times, 16 December 1941, 14.*

Lake Norconian Club, Norco, California, 1929.

The new resort stressed its exclusivity: "Membership and Guest Cards issued only on approval of Membership Committee, in accordance with rules laid down by our leading Clubs," ran one advertisement. Another made the nature of the exclusivity plainer: "Discriminating ladies and gentlemen (of the Caucasian race) are invited to enjoy the matchless environment . . ." Jews, also, were unwelcome at the club.[3]

Success was short lived. With the stock market crash of '29 and the onset of the Great Depression, business faltered, then flagged, then faded. The grand Lake Norconian Club soon became the Rex Clark Hotel. (No more private membership: anyone's money was good.) However, with dwindling business and a growing delinquent-tax burden, Clark was forced to close the hotel and put it on the market in 1941.

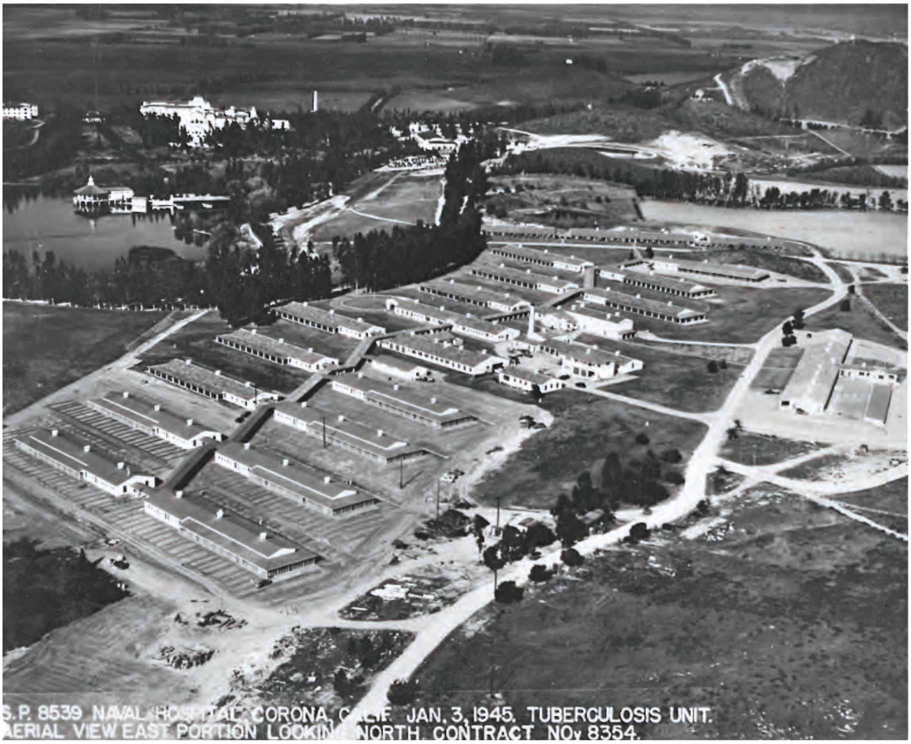
That year, the likelihood of war with the Japanese was apparent to senior officials in the U.S.

Navy. Anticipating a need for hospital space for the impending conflict, the Navy offered Clark half his asking price for the resort, and the property sold to the government for $1.6 million just days after the Japanese attack on Pearl Harbor.

In the huge building where once the wealthy of Hollywood had partied and gambled, hospital wards were constructed, and the casualties began to flow

[3]"New Bulletin, Lake Norconian Club," *Los Angeles Times, 19 January 1929, 10; display advertisement, Los Angeles Times, 23 July 1929, 8; Bash and Jouxtel, The Navy in Norco, 22.*

in from the Pacific. As the war continued, more wards were added. By 1943, the hospital was caring for 12,000 patients. Further expansion in 1944 added a rheumatic fever and malaria treatment center, precipitated by the large numbers of U.S. soldiers acquiring those diseases in the tropical Pacific.



Naval Hospital Corona, 1945.

Meanwhile, in Washington, DC, a little-known organization was outgrowing its facilities. Beginning before the war, the National Defense Research Committee had been established to harness science to the chariots of war. One of the committee's subgroups, Division Five, was located at the National Bureau of Standards (NBS) laboratory in Washington, where it worked on radio-controlled bombs and pilotless aircraft. The division, augmented with Navy and Army personnel, developed the ASM-N-2 Bat, a radar-guided glide bomb, which sank several Japanese ships toward the end of WWII.

After the war, Division Five was renamed the Missile Development Division. When NBS prepared to resume certain prewar programs that had given up their space to the missile group—notably, the hydraulics programs—

the missile group petitioned for its own laboratory. The request was approved by Congress, albeit with the condition that the new facility not be built within 50 miles of Washington, DC.[4]

By early 1950, the Corona Naval Hospital had been closed and the building and grounds declared surplus. An NBS delegation traveled to Corona and found the facilities there suitable for a missile laboratory. Arrangements were made, and part of the former resort and hospital was converted to a full-fledged missile laboratory. In the summer of 1951, the NBS move to Corona began; 77 intrepid employees left their Washington homes and moved west in a migration that presaged a similar mass transfer some two decades later.

The new laboratory soon expanded to employ 250 scientists, engineers, and technicians. In 1953, the NBS technical staff was transferred to the DoD, and thus began NOLC. In 1954, NOLC was assigned technical direction for all Navy missile fuzing R&D.

Dr. F. Stanley Atchison.

Relationships between NOLC and NOTS were cordial. Dr. F. Stanley Atchison, NOLC's Technical Director since 1955, and Dr. McLean, NOTS' Technical Director since 1954, were friends, and the work that their laboratories performed was often complementary.

By 1958, NOLC employees numbered 735, and in 1959, when the Bureau of Ordnance (BuOrd, NOLC's parent command) and the Bureau of Aeronautics were combined to create the Bureau of Naval Weapons, that number had grown to over 900. By 1961, NOLC boasted more than 1,000 employees and an annual budget of over $20 million.

In 1964, the Missile Evaluation Department (then one of four technical departments), which was chiefly focused on direct Fleet support rather than R&D, was split off to form the Fleet Missile Systems Analysis and Evaluation Group. In 1966, NOLC's responsibilities were expanded when it was designated lead laboratory for the Standard Antiradiation Missile (Standard ARM), the

[4]S-118, Frederick Alpers interview, 25. Alpers recalled that Senator Owen Brewster added the 50-mile rider to the bill, fearing that if Washington were bombed, too much of the nation's defense capability would be shut down.

development of which had been undertaken to overcome limitations of the smaller China Lake-developed Shrike antiradiation missile.

As one would expect of facilities that were so dissimilar in locale and physical plant (all of China Lake's buildings and infrastructure were "purpose built"), China Lake's and Corona's respective cultures were quite different, particularly in quality of life issues. NOLC nestled in a benign, verdant region, an easy drive from beaches and big-city life. Even decades after Rex Clark's dreamland had crashed on the reality of the Great Depression, the beauty and opulence of the Lake Norco setting remained. The Norconian Club, analogous to China Lake's Officers' Club as the hub of social activity, was housed in the original gambling casino perched on a peninsula jutting into Lake Norco. "I had been known to go out there during my lunch break, catch a fistful of bass that weighed up to 10 pounds," recalled engineer Clyde R. Lebsock in a 2010 interview.[5]

A difference in technical orientation between the two facilities was apparent to Robert M. Hillyer, who had come to Corona as a Navy ensign in 1957 and stayed on there after receiving his discharge in 1960. Hillyer would serve as China Lake's ninth Technical Director from 1977 to 1982.

"The Corona labs tended to be more academically oriented than China Lake," Hillyer observed. "They tended to put more emphasis on the research end of the business and the science end, as opposed to the development end that is prominent here at China Lake."[6]

Bob Hillyer.

But there were common characteristics as well, as Hillyer himself noted: "Although none of us admitted it at the time, there were more similarities between Corona and China Lake than there were differences." One similarity was the willingness to let young technical people take responsibility for tasks that were well beyond their

[5]S-309, Lebsock interview, 2. Lebsock moved from Corona to China Lake in 1970 and retired from the Fuze and Sensors Department in 1986. He still lives in Ridgecrest.

[6]S-134, Hillyer interview, 3.

pay grade and to be willing to let them make mistakes. Lebsock opined that there are three kinds of engineers:

> There's ones that have money so they can do stuff, and normally they're the ones that get along with people and get the money to do it. Then you got the ones that are not too smart, they're kind of dumb but they don't know what they can't do so they end up doing everything. And then you got the real smart ones that can tell you why you can't do something.[7]

He felt that the young Corona engineers—himself included—fell into the second group. They had created ingenious fuzing systems for a host of weapons and had devised a radically new antenna design for Shrike in record time; why, they could do anything! This managerial attribute of encouraging young engineers to take risks and responsibilities had also been key to the success of China Lake products as well as to the organization's extraordinary ability to retain employees.[8]

Organizational Consolidation

Through the mid-1960s, the Navy laboratories had been in disarray organizationally, as high-level study after study confirmed. Continuing a trend toward centralizing authority and responsibility, which had started under Defense Secretary McNamara, in April 1966 the Navy's 15 major laboratories were transferred from the Bureau of Weapons and Bureau of Ships to the Chief of Naval Material (CNM), Vice Admiral Ignatius J. Galantin. Four months later the bureaus themselves were disestablished and replaced with six Systems Commands (SYSCOMs).

Despite that major change, continuing top-level review—most notably a 1966 Defense Science Board study—indicated that more needed to be done. The board recommended that the laboratories themselves be reorganized, and Dr. John S. Foster Jr., the DoD's Director of Defense, Research and Engineering (DDR&E), concurred.

Late in 1966, Dr. Robert A. Frosch, the Assistant Secretary of the Navy for Research and Development (ASN R&D), floated the idea of reorganizing the laboratories into Centers of Excellence. Soon Foster was prodding the Navy

[7]S-309, Lebsock interview, 12.

[8]As a manager, Lebsock carried on the tradition of assigning responsibility to junior employees. On receiving the Technical Director Award for a new Phoenix target-detecting device (TDD) in 1979, he remarked that "the honor belonged to a group of young engineers who had been assembled to carry out the work under his direction. 'I just gave them the tools, and they took them and ran.'" *Rocketeer, 23 March 1979, 1.*

to implement the proposed reorganization scheme; Vice Admiral Galantin formally proposed the plan in 1967, and with Foster's blessing, it was approved.[9]

R&D activity at NOLC and NOTS had often been carried out collaboratively. Fuzes were essential to weapons, and many of the fuzing concepts that were created at Corona would subsequently be incorporated in the weapons developed at China Lake. This complementarity was the principal reason for the planned merger of Corona's fuzing group with China Lake in the impending reorganization.

Consolidation of NOLC and NWC was first publicly announced in April 1967. The 14 April *Rocketeer* noted that under the Navy's proposed Centers of Excellence, "the Naval Ordnance Laboratory, Corona, would be merged organizationally with NOTS as a component of this Center."[10]

At China Lake, the news was greeted with interest but not concern. There was greater dismay about China Lake's loss of the Pasadena Annex and all the associated ocean-oriented work (torpedoes, antisubmarine warfare, marine mammals, oceanographic research, undersea vehicles, and the like) to the new NUWC than there was much concern about the addition of a new organizational element half a day's drive to the south.

At Corona, however, the news was alarming. Wild rumors had been circulating to the effect that NOLC would be shut down. On 13 April, the Corona *Daily Independent* (not to be confused with the Ridgecrest *Daily Independent*) ran a front-page story with a headline that screamed "NOL Doom Rumors Scotched."[11]

In the article, NOLC's Commander, Captain Edward B. Jarman, tried to put speculation to rest. "This is not a geographical merger. It is an administrative and management thing," he explained. "No population change—no change in persons or programs—has been proposed." He told the paper (correctly) that the Fleet Missile Systems Analysis and Evaluation Group, numbering 400-plus employees, would not be affected by the change. The key error in the article came in the last paragraph, where both Captain Jarman and Atchison assured readers that this would be "a genuine merger, not a subordination."[12]

---

[9]It would take 7 years for the Navy's 15 laboratories to be entirely consolidated into nine centers.

[10]*Rocketeer, 14 April 1967, 3.*

[11]Reincke, "NOL Doom Rumors Scotched," 1.

[12]Ibid.

NWC Corona Laboratories, 1968.

NOLC's two senior managers probably believed that statement when they made it, but they were in for a rude awakening. Six days after the article appeared, Captain Jarman and Atchison joined representatives from China Lake and the Naval Electronics Laboratory Center (NELC) for a 3-day meeting at San Diego. On the final day of the meeting, Dr. Gerald W. Johnson, the Director of Navy Laboratories (DNL), spoke to the group. He made it clear that Corona was being integrated into a Center that was under China Lake's command. Johnson

> discussed his views of the merger, stating that Headquarters desires integration of the function, recognizes the geography and history, and acknowledges that this integration cannot be accomplished overnight. However, he is very anxious for the merger to be accomplished as soon as possible, hopefully by 1 July 1967.[13]

[13]Head, Central Staff, to Technical Board Members, memorandum, "NOTS Technical Board Meeting," Encl. 1, 20 September 1967, 1.

The merger was indeed accomplished on 1 July, and Corona became part of NWC as the Naval Weapons Center Corona Laboratories. Captain Jarman remained in command of the facility, though no longer as Commander but rather as Commanding Officer, a title that conveyed his subordination to the Commander of NWC.

Captain Jarman had announced his retirement at the April meeting in San Diego. When his tour ended in December 1967, he was relieved by Captain Robert L. Wessel. Atchison continued as Corona's Technical Director. But the 1967 establishment of NWC was not to be the end of the Corona / China Lake consolidation.

Hillyer remembers Captain Jarman calling the merger "a rabbit and elephant stew . . . one rabbit and one elephant." Hillyer added, "I don't need to say who the rabbit was."[14]

The Vise Tightens

To the surprise of many and the dismay of a few, Dr. Frosch selected Dr. Thomas S. Amlie as NWC's Technical Director in January 1968. Amlie had never been a department head; for the past 10 years he'd been running Development Division 4 in the Aviation Ordnance Department. Hack Wilson, who had been Acting Technical Director at China Lake since Dr. McLean left the organization in July 1967, had seemed a shoo-in for the Technical Director position. But Wilson didn't have a doctorate degree and Amlie did, and that was a deciding criterion in the DNL's decision.

Shortly after his selection as Technical Director, Amlie went to see Leroy Riggs, head of the Aeromechanics Division in China Lake's Weapons Development Department. Riggs was a hard-driving former Shrike program manager with a reputation for getting things done. He recalled:

> In February of '68, Tom [Amlie] came to me and he says, "You're going to Corona," and I said, "I don't want to go to Corona." He says, "You're going to Corona; there's a Missile [Systems] Department down there; they've got the Standard ARM. You did Shrike, you know all that stuff. They got people like Fred Alpers down there and so on, and we need two departments down there; one is going to be fuze and the other is going to be missiles."[15]

[14]S-134, Hillyer interview, 7. Rear Admiral Paul D. Stroop and Dr. William McLean had both used similar animal-stew metaphors when describing the consolidation of the (very large) Bureau of Aeronautics and the (comparatively small) Bureau of Ordnance into a single Bureau of Weapons in 1959.

[15]S-136, Riggs interview, 10.

Leroy Riggs.

Riggs finally accepted, and on 24 June, he replaced Fred Alpers, who had been acting head of the Missile Systems Department. Riggs' selection did not sit well with the Corona folks. "I was welcomed somewhat like a carpetbagger at the end of the Civil War," Riggs recalled. "They had just been merged into China Lake, as part of the same organization, and they were not given the opportunity to fill the empty slot of Missile [Systems] Department from their own people."[16]

Riggs was pretty sure that Corona was eventually going to be closed and its people moved to China Lake, although nothing in that vein had been said officially. Hack Wilson, now back in the Assistant Technical Director's slot, calmed Riggs' concern about leaving. "He told me, 'I think you'll be back up with your department, and that place will be closed in 3 years,' " Riggs later said. Actually, it happened more quickly than that.[17]

DNL Johnson and his board of consultants visited Corona in March 1968 to discuss problems facing the laboratories, and rumors began to fly. The dedication of a $1.5 million fuze modeling range at Corona in April 1968 allayed the concerns of some—surely the Navy wouldn't make such an investment in a base it planned to close—but those who understood how Navy construction funding worked knew that the commitment to construct the facility had been made long before the current reorganizational rumblings began.

A report in the Riverside *Press* on 18 September 1968 stated that "the Naval Weapons Center at Norco is under imminent threat of closure." The Corona *Daily Independent* picked up the story the next day, Thursday, contacting both the Corona base and the office of Democratic Congressman John V. Tunney.

[16]S-X41, Riggs interview, 16.
[17]S-136, Riggs interview, 11.

Tunney was the congressman from California's 38th Congressional District, which included the base.[18]

Corona's Technical Director Atchison called the reports "completely wrong" and stated "that he has 'absolutely no knowledge' of a supposed threat to close the center in 30 days should there be a news leak."[19]

Tunney told the paper that "there is a widespread feeling in Washington that the Naval Weapons Center Corona Laboratories may be closed," but he said "it would be the height of stupidity and irresponsibility to close the center."[20]

Tunney's Republican rival Robert O. Hunter (who had lost to Tunney in the 1966 congressional election and would do so again in 1968) asserted that "closing of the Norco Naval Laboratory is just part of the administration's program of diminishing our armed services." He warned that if the government continued to cut back weapons development and space exploration, "Russia will forge ahead of us."[21]

Tunney leapt into action, scheduling an appointment with Secretary of Defense Clark Clifford and preparing a five-page letter arguing for the laboratories' continued existence. Among other reasons, he stated that closing the base would cost $14 million more than keeping it open. Friday morning—the day after the *Daily Independent* report—he met with Under Secretary of Defense Paul Nitze and secured an agreement "to withdraw the Naval Weapons Center in Corona from a list of naval labs to be closed."[22]

The DoD was determined to cut costs, however, and the Navy laboratories were still on the chopping block. The following week, Tuesday, 24 September, the Navy formally announced that the 15 Naval Material Command (NAVMAT) laboratories would cut 2,400 civilians—10 percent of the workforce—in an economy move. This amounted to 416 people at China Lake and 98 at Corona. Still, it was better than a total base closure.[23]

No sooner was the imminent-closure crisis averted than there was another omen of impending trouble at the Corona facility. In October, less than a year after he'd assumed command of Corona from retiring Captain Jarman, Captain Wessel announced his early retirement, 2 years ahead of his planned

[18]NWC AdPub 148, *The Navy in Corona, 21; Reincke, "All-Out Effort,"* 1.

[19]Ibid.

[20]"Hunter Ired by Possible Lab Closure," [Corona] *Daily Independent*, 20 September 1968, 3.

[21]Ibid.

[22]Reincke, "Tunney Backs Claim that NWC Closure Costs Higher," 1; Reincke, "NWC Pulled From Navy's 'Cut List,' " 1.

[23]"Navy Will Cut 2,400 From Pay Roster," *Los Angeles Times*, 25 September 1968, 8.

Captain Robert L. Wessel.

retirement date. At the retirement ceremony on 25 October, during which Captain Wessel's former Executive Officer, Commander Roy E. Forbis, succeeded to command, Captain Wessel spoke with a frankness unusual for such a tradition-bound affair.

He reminded the audience that when he'd assumed command in December 1967, he'd promised to

> be dedicated to maintaining the high degree of technical competency and move further forward into new areas of research and development. . . . Today I stand before you with a feeling of humility and remorse. Those promises I made, I sincerely intended to fulfill. . . . Many events have taken place since those promises.[24]

He then said that "changes being made and proposed at [Corona] were impossible for me to reconcile in the light of command. Rather than abrogate those ingrained principles of loyalty up and loyalty down, on 27 May of this year I requested retirement."[25]

The Corona paper further reported on the remarks of Captain Etheridge, who had traveled from China Lake to his subordinate command for the occasion. The NWC Commander "recommended 'good integration' between the China Lake and Norco labs to 'further ensure' against any future closure actions."[26]

Integration of the two facilities was somewhat facilitated by the departure of Captain Wessel. According to Riggs:

> When [Wessel] departed, they just left the Exec [Commander Forbis], and it became obvious then that he was an Officer-in-Charge of that facility, and the Commander, NWC, was in fact the guy sitting up here. It was clear-cut. Whereas if Wessel had stayed, you'd have had a very senior captain down there, "black shoe," just about date of rank with our skipper up here.[27]

---

[24]Reincke, "Forbis Takes Over Command at NWC in Emotion-Charged Rites," 3.

[25]Ibid.

[26]Ibid.

[27]S-136, Riggs interview, 19. "Black shoe" refers to members of the surface Navy, as distinguished from "brown shoe," which denotes naval aviators. Naval aviators had worn brown shoes from 1913 until 1976, when the Chief of Naval Operations (CNO) ended the tradition. It was resurrected in 1985 by Secretary of the Navy John F. Lehman (a former naval

In December, 5 days after Christmas, the Corona *Daily Independent* ran a story titled "Atchison's Position Axed at Norco's NWC." The accompanying photograph of Atchison bore the subtitle "With the job goes the man."[28]

The reporter explained that "there will be one technical director—at China Lake's facility" and that "Dr. Atchison, contacted this forenoon, said he was offered a position of scientific associate to the technical director but that he has declined." In recapping Atchison's career, the article lamented the loss of local prestige, noting that

> a number of new programs have been added under his direction including the development of the Standard Anti-Radiation Missile, described by Rear Admiral R. L. Townsend [head of the Naval Air Systems Command (NAVAIR)] as "perhaps the most successful weapon systems development . . . that I have ever seen or been connected with."[29]

The "rabbit and elephant stew" Captain Jarman had described was beginning to look more like an elephant eating a rabbit.

Throughout 1968, the technical workforce at Corona determinedly forged ahead, designing and building fuzes, boosters, TDDs, safety-arming and arming-firing devices, destructors, electronic countermeasures (ECM) equipment, and similar systems and subsystems. Customers included such programs as Talos, Terrier, Tartar, and Standard Missile. In 1968, NWC's annual *Technical History* report, hereinafter referred to as *Tech History*, documented Corona's technical progress. It did note that

> in certain programs, such as the Standard Missile and the Advanced Surface Missile System (ASMS), the Laboratories' fuzing role on behalf of the Naval Ordnance Systems Command was to provide support, consultation, and advice, upon request, to prime systems contractors.[30]

The *Tech History* then commented editorially that "this role tends to weaken the government's in-house position because of lack of intimate association by fuze designers with respect to the specific application."[31]

---

aviator) after a campaign spearheaded by Captain John Jude Lahr, a naval aviator and a former NWC Commander. Captain Etheridge, despite his submarine service, was also a brown shoe, having been designated a naval aviator in 1947.

[28]Reincke, "Atchison's Position Axed at Norco's NWC," 1.

[29]In Standard ARM, Corona had let the contractor (Convair Division, Pomona) take the greater leadership role in pilot production, an approach that China Lake traditionally had eschewed but that Townsend endorsed.

[30]*NWC Tech History 1968, 6-3.*

[31]Ibid.

Overall, 1968 had been a tough year. In the 1968 *Command History*—an annual document required to be submitted by every Navy command to the CNO—the lead paragraph read:

> The major significant event of the year was the rumor of the closing of the laboratory. The story broke in the local newspapers on 18 September 1968. Developments continued to be reported during the balance of the year.[32]

As Atchison observed when the base dodged the imminent-closure bullet in September, the uncertainty was "de-moralizing and disturbing. . . . It causes many employees to start job hunting and the best people get the first jobs and, should neither the closure nor the cutback materialize, NWC still has lost good personnel."[33]

Physical Consolidation

The consummation of the China Lake / Corona merger was not far off. Most people felt it was simply a matter of time. But Captain Etheridge hung on to the idea that integration of the two facilities was still possible without closing one of them. In the January-February 1969 issue of *News and Views*, he wrote:

> I would like to see an intermixing of Corona and China Lake components. For those people in Corona who have a day-to-day need for the specialized facilities at China Lake, our ranges, etc., they should be physically located here and vice versa, either for a temporary tour or as a permanent move, depending on the need. There are, in fact, components at China Lake that can use to better advantage the facilities of Corona, and they should eventually be relocated there. Then if sometime in the future someone said we must close Corona, we could show that we are not talking about a separate Corona or a separate China Lake—we are talking about a Naval Weapons Center.[34]

All the hoping and strategizing to keep Corona open was for naught. On 24 April 1969, Secretary of Defense Melvin Laird announced that NWC's Corona facilities would be consolidated with China Lake by June 1971. The move would involve the elimination or transfer of 939 full-time civilian employees (634 to China Lake) and 3 military personnel. The 410 civilian employees of the Fleet Missile Systems Evaluation and Analysis Group would not be part of the consolidation. According to the DoD figures, the action would result in a savings of $4 million. The justification given was "to enhance

---

[32]OPNAV Report 5750-1, *Command History, Naval Weapons Center Corona Laboratories 1968, 1969, 1.*

[33]Reincke, "NWC Pulled From Navy's 'Cut List,'" 1.

[34]NWC, "Views of the NWC Commander," *News and Views, Points of View and Information on Management Matters*, January–February 1968, 4–5. *News and Views* was a bimonthly newsletter for managers published by China Lake's Central Staff from 1966 to 1974.

the technical efficiency and management effectiveness of both activities by providing the Corona mission with increased accessibility to the special facilities and test ranges that are unique to China Lake."[35]

The Corona community reacted with shock. Congressman Tunney's office commented:

> We think it unrealistic to cause 634 people to relocate into a desert area and yet "enhance technical efficiency" as has been reflected in the release by the Navy Department. To the contrary, mass movement of personnel in most cases produces the opposite effect.[36]

Glen I. Voran, Corona's public affairs officer, told the Corona *Daily Independent*, "I thought and hoped it [the closure possibility] had all blown over," and described the announcement as "a complete surprise."[37]

News of the consolidation was greeted with something less than enthusiasm at China Lake as well, starting with the Technical Director. Tom Amlie had always been outspoken to the point of being brash, a quality that endeared him to some but distanced him from others. Among the latter group were a number of high ranking civilians and military officers in Washington who expected to be treated with more deference than Amlie typically offered.

Amlie thought the transfer of the Coronans to China Lake and the closing of Corona was a mistake, as he told an interviewer in 1992.

> I fought it . . . I went to Washington and talked to [Congressman Tunney]. I said "I think it's a stupid idea." . . . I thought it was a silly idea because the people at Corona that I knew didn't want to come up here. . . . But the Navy said "You've got to do it," so we said "OK, we'll do it." . . . We did it as fairly and graciously as we could. Unfortunately, we lost about half the people. A lot of them went to Point Mugu. We lost some good people. . . . I didn't need a bigger empire. God knows, my empire was already too big for me. And I didn't need a bunch of unhappy people and unhappy wives being brought here against their will. It just sounded like a dumb idea.[38]

When asked by the interviewer what the winning rationale for the Corona / China Lake merger was, he responded, "Oh, streamlining management. The same old junk, you know, streamlining management."[39]

---

[35]"NWC Corona To Be Relocated To China Lake," *Rocketeer, 25 April 1969, 1.*
[36]Reincke, "NWC Closure Ordered," 1.
[37]Ibid.
[38]S-199, Amlie interview, 56–57.
[39]Ibid.

Beyond streamlining management, there were sound technical reasons for the physical consolidation (referred to in some official China Lake documents as the "amalgamation."). Much of the technology being developed at Corona required testing on the ranges and in the specialized facilities at China Lake, and personnel continuously traveled between the two sites by air and ground. Riggs recorded 200 trips between during his stint as head of the Missile Systems Department, mostly flying himself between the sites.[40]

The growing complexity and interdependence of weapons subsystems that had been a factor in establishing the centers was another argument for the Corona/NWC merger. "We were building weapons, they were building the weapon fuzes; well, that's silly to have under two separate commands," Riggs said. His reasoning was that the growing sophistication of weapons was leading to

> a much closer relationship between fuzing and guidance. We go back to just building a fuze, that its output is something to the explosive train, you could do that in a vacuum. But when you've gone to sophisticated guided missile fuzing, where you might well utilize guidance feedback as part of the fuzing function, you've got to do it all together. I think it was an obvious thing that had to happen.[41]

Finally, the issues of physical space and land values came into play. Corona was on property with no potential for expansion. Said Riggs:

> It was the old facility at the hospital down there, and we had all of this good space up here. It was logical to consider not only organizational consolidation, but I'm sure from the very beginning the plan was to move those people up here where we have all of this land for testing, and furthermore, we could marry the fuze and the warhead.[42]

In typical military hurry-up-and-wait fashion, China Lake was given less than a month to figure out how the physical consolidation would be effected. On 29 April 1969, 5 days after Laird's announcement, Captain Etheridge sent guidelines to his department heads for planning the relocation. The final plan had to be delivered to NAVMAT barely 2 weeks later on 15 May. It would cover facilities, personnel, housing supplies, and "fiscal matters." It would be time-phased in monthly increments over the 2-year period. As detailed in Etheridge's

---

[40]For amalgamation reference, see the following: Commander and Technical Director to Distribution, memorandum, "Realignment and Focusing Study for NWC," 11 September 1969, 2.

[41]S-136, Riggs interview, 17.

[42]Ibid.

guidelines, "the move should be planned for completion by 30 June 1971, or as soon thereafter as controlling milestones are met."[43]

One of the explicit objectives of the plan was "to have as many Corona personnel relocate to China Lake as possible. As a minimum, there will be 634 positions available at China Lake for personnel transferring from Corona." Captain Etheridge predicted that "the availability of office and laboratory facilities at China Lake and housing in the Indian Wells Valley will be the major constraining factors."[44]

Before the year was out, external influences began to whittle away on the target figure of 634 positions. In November, another reduction in force (RIF) was announced at Corona, affecting 23 people in the Research Department and Central Staff. Later that month, Corona's 28-person Infrared (IR) Division from the Research Department was transferred en masse to the NELC (formerly the inelegantly named Naval Command Control Communications Laboratory Center), San Diego. Along with the group went all its project funding and its $800,000 annual budget. In 1970, the Space Geophysics group, with 14 billets, was transferred to NELC, and the Countermeasures and Telemetry groups, with a total of 80 billets, went to Point Mugu.

But for most of those at Corona, moving to the desert was a fait accompli, and people at both locations turned to and did what they could to make the merger work. Corona employees and their wives were flown to China Lake and given tours of the base and town. Tom Amlie's wife, June, arranged for a busload of China Lake women to travel to Corona and talk with the families of potential transferees about life in the desert. Leroy Riggs' wife, Marilyn ("Ditty"), was on that trip. She recalled that in a question-and-answer session, a woman from Corona stood up. "She said, 'Do you have electricity and gas up there?' I wanted to stand up and say, 'No, we cook with buffalo chips.' Fortunately, I got ahold of myself."[45]

China Lake's excellent schools and the fact that the community was a great place to raise children were pluses. For the scientists and engineers themselves, the huge scientific and engineering resources of NWC were a strong draw, as was the base's reputation as a place where technical excellence and hard work paid off in promotions and increased responsibility.

---

[43]Commander, NWC, to Distribution, memorandum, "Guidelines for Developing Sub-Plans," 29 April 1969. The anticipated 634 billets were in addition to 120 billets received earlier in the year: 28 for Echo Range and 92 for Pierre Saint-Amand's atmospheric applications research (weather modification) project.

[44]Ibid.

[45]S-371, Ditty Riggs interview, 63.

Ditty Riggs with husband, Leroy.

In July 1969, Commander Charles D. Brown relieved Commander Forbis as the senior officer at Corona. The title had suffered yet another diminishment: from Commanding Officer to Officer-in-Charge. Brown would oversee the execution of the consolidation from the Corona side. In December, Brown received his copy of Office of the Chief of Naval Operations Notice (OPNAVNOTE) 5450 from the CNO to the CNM requesting that the Naval Weapons Center Corona be disestablished on 1 January 1970. What remained would, until the consolidation was complete, be known as the Naval Weapons Center Corona Annex (rather than Corona Laboratories).

By early 1970, it was clear that funding limitations for new construction at China Lake were going to delay the original Corona relocation plan. A new plan in February 1970 still called for full implementation by 30 June 1971 but "was predicated on utilizing existing facilities at China Lake through modification and renovation, rather than relying on the construction of new facilities through military construction appropriations."[46]

[46]*NWC Tech History 1970, 1-8.*

As Captain Etheridge had anticipated, the biggest problem in effecting the transition was finding or creating adequate office and laboratory space and housing. In 1970, 19 major projects (from $10,000 to over $400,000) and more than 50 miscellaneous projects (less than $10,000) were in progress at China Lake to meet the facility needs.

Even before the announced merger with Corona, housing had been a scarce resource at China Lake; now it was critical. Drastic measures were taken. A freeze on transfers between houses—for decades a complex juggling of waiting lists, new hiring, retirements, increases in family size, etc.—was put into effect. Personnel moving in at the GS-12 and -13 levels were offered housing normally given to those in the GS-9 level. A long-standing program to eliminate old, outmoded housing on base was put on hold.

At China Lake's request and with congressional approval, 117 acres were sold to Tanco Inc., which commenced building 24 single-family units (Cottonwood Estates) with plans for an additional 300 units plus shopping facilities. Speculation in land and new house construction in the city of Ridgecrest was rife.

Helping to compensate for the sad housing situation were the camaraderie with which the Coronans were welcomed and the newcomers' swift introduction to the ways of China Lake. When Bob Hillyer moved into his Capehart B house, he recalled:

> I stood out in front of that house the first day I came to China Lake and my old friend Frank Cattern, who was one of our advance guards from Corona, came around the corner and said, "What's the matter with you?" And I said, "Well, I really don't like that house." And he said, "Why not?" And I said, "For one thing, it's got that absolutely ugly room divider in there between the dining room and living room." And he said, "Well, we can fix that," so he went and got a sledgehammer and knocked the room divider out, and I liked that house ever since. . . . I then complained about the charcoal and pink decor, and Steve Little, who was one of my neighbors over there, came down the street and allowed as how I could paint that house any darn color I wanted and please don't ask Public Works because they would tell me I couldn't do it. So I did, and after that, that's the most comfortable home I ever lived in. Also, that first evening Jerry Zaharias came around the corner with a bottle of wine. I think those three things were indicative of the kind of reception we got.[47]

Shoehorning all the Coronans into the China Lake / Ridgecrest housing market had ramifications. In June 1971, *News and Views* ran an article that stated that "the present crunch can be truly described as a crisis," explaining that

---

[47]S-134, Hillyer interview, 4.

"for the first time recruiters are having to warn new and prospective employees that NWC cannot guarantee housing for their families."[48]

A Corona Annex Liaison Office was set up in Michelson Laboratory to assist "visitors from the Corona Annex who come to China Lake for business purposes, personal reasons, or perhaps in regard to the proposed move to NWC from Corona." The structure of the office was such that "as each division at Corona moves to China Lake, a representative of that office will join the staff of the Liaison Office, thereby ensuring a smooth, orderly method of communication between the two installations."[49]

Certainly many people did not want to relocate to China Lake. Or even if they were favorably disposed, they had spouses or children who were unwilling to accept a future of—as Tom Amlie summarized the Coronans' vision of life in the desert—"Desert. Sand. Snakes. Black widow spiders."[50]

Fred Alpers.

To a good number of the scientists, engineers, and other technical types, however, there were worse places than China Lake to continue their careers. The very gifted Fred Alpers was a plank owner at Corona and had been part of the NOLC team that, in 1951, developed contrast-tracking TV guidance, a technology that would later come to fruition in the Walleye weapons.

"I turned down a nice job in Washington, with a promotion, to [transfer to China Lake]," Alpers recalled. "I didn't want to work near Washington. Too much paperwork and fire drills and all the hassle of bureaucracy back there." Alpers received more than 60 patents

[48]NWC, "Housing Dilemma," *News and Views*, *Points of View and Information on Management Matters*, June 1971, 6.

[49]*Rocketeer, 1 May 1970, 3.*

[50]S-199, Amlie interview, 56.

during his career, and after he retired from NWC in 1981, he continued to live in Ridgecrest until his death in 2006. Among Alpers' many awards during his 37 years of government service were the Arthur S. Flemming Award for outstanding young men in government service and the L. T. E. Thompson Award, China Lake's highest honor.[51]

At some point, each prospective transferee from Corona had to commit, one way or the other. The Personnel Department distributed forms and encouraged the Coronans to take them home and discuss them with their spouses. According to Lebsock, when he was handed his form,

> I signed it and handed it back to him. He says, "Well, don't you want to discuss it with your wife?" I said, "Well, my wife and I kind of got an agreement. I make the money, she spends it. So where I make it, that's where we go."[52]

Eventually, China Lake received some 500 billets from the Corona transfer; about 385 employees and their families actually made the move. They brought with them the Navy's largest single repository of guided-missile fuzing expertise. The Fuze Department largely retained its mission and organization after the move. Corona's Research group merged with China Lake's Research Department, and the Missile Systems Department was integrated into several different departments, chiefly into the Electronic Systems (later Electronic Warfare) and Weapons Development departments.

On 02 July 1971, the *Rocketeer* reported:

> The stars and stripes that flew over the NWC Corona Annex fluttered down for the last time . . . The flag, sensing its role in the quiet mood, descended falteringly as if to resist its last trip down the halyards. And "retreat," the traditional bugler's "sundown" signal, seemed a mournful note as it was relayed second-hand through a tape recorder.[53]

Betty Reincke's article in the Corona *Daily Independent* was, as might be expected, more dramatic and tinged with bitterness.

> Rooms, once filled with the chatter of analog computers clicking and blinking out their responses to complex questions, echo only an emptiness. Columned outdoor corridors, once crowded with purposeful men bound on their missions, are occasionally crossed by rabbits that used to hide behind the shrubbery. . . . Scientists who stamped Corona on the Standard ARM have gone to NWC at China Lake in the desert or retired or sought work

[51]S-X15, Alpers interview, 53.
[52]S-309, Lebsock interview, 3.
[53]*Rocketeer, 2 July 1971, 1.*

> elsewhere because—once DOD inks obsolete on a facility, it dies. Slowly, like an angleworm that some unthinking child has cut in half.[54]

Benefits

NOLC had lost its autonomy. (The Fleet Missile Systems Analysis and Evaluation Group would be transferred organizationally to Naval Weapons Station, Seal Beach, in 1976.) The Corona Laboratories' corporate identity had been officially merged with that of China Lake. And although in some sense the elephant had eaten the rabbit, the rabbit had also effected a change in the elephant. For example, Corona brought to China Lake a valuable perspective on functional reliability. The fuze designers at Corona had routinely achieved a functional reliability of 0.9999 in their work for the simple reason that failure of a fuze can have more disastrous consequences than any other type of weapon failure. (Picture a weapon prematurely detonating on the wing of an aircraft or in the hold of a ship or in the tube of a mortar.) Conversely, at China Lake, the Corona-bred fuze personnel learned more about such skills as maintainability, documentation control, and systems integration.

Was the consolidation, overall, a plus or a minus? Bob Hillyer believed it was a good thing, although he had moved to China Lake reluctantly. "I fought like crazy against closing Corona," he shared. "I came here with some trepidation. You can still see the heel marks in Highway 395 where I was dug in."[55]

In 1982, looking back from the end of his 4-year tour as NWC Technical Director, Hillyer said:

> I think, therefore, that we're probably getting a better product today, or have for the past 10 years, than we would have if Corona had stayed open. The decision, again with 20-20 hindsight, was the right one. It's because of the drawdown in the numbers of people that we have in the R&D community, and it continues to happen today. China Lake is 20 percent smaller than it was in 1970 . . . The consolidated organizations minimize the support structure needed for them: finance, public works, supply, and the like. So, all in all I guess I have got to admit that it was a good decision. Although I sure had a lot of trouble with it at the time.[56]

---

[54]Reincke, "End of Era," 1.
[55]S-134, Hillyer interview, 4.
[56]Ibid., 10.

3

The War Slogs On

It was the middle Sixties . . . People were interested in things real fast; they wanted them right now.

—Milt Burford, China Lake weapons designer[1]

The Vietnam War was in high gear in 1968, despite almost daily pronouncements by U.S. and South Vietnamese officials that the end was in sight and the enemy couldn't hold out much longer. Money flowed into the war machine, and a larger share of this came to China Lake than to many other laboratories, because China Lake had positioned itself for a conventional, limited war back in the late 1950s, when most military strategists thought the next war would be nuclear.

A number of systems that NOTS visionaries had strenuously argued for developing at the turn of the decade were coming on line by 1968. Several of the new weapons coming out of China Lake were part of the famed Eye series. These were developed principally within Frank Knemeyer's Weapons Development Department under the cognizance of physicist Dr. Marguerite M. "Peggy" Rogers, who would later become the first woman department head in China Lake history.[2]

Eye-series weapons highlighted a weapons demonstration held at China Lake for President John F. Kennedy and a bevy of his top military and civilian advisors in 1963. While the Eye weapons constituted only 4 of the 30 firepower events—Snakeye, Rockeye, Walleye, and Gladeye—the president and his entourage came away impressed with China Lake's position at the cutting edge of conventional limited-warfare weapons development. China Lake's development strategy dovetailed perfectly with the "flexible response" position

---

[1]S-263, Burford interview, 9.

[2]The Eye series included Bigeye, Briteye, Bugeye, Chaffeye, Deadeye, Deneye, Evileye, Fakeye, Fireye, Gladeye, Hawkeye, Marceye, Misteye, Padeye, Rockeye, Sadeye, Smokeye, Snakeye, Walleye, and Weteye. Some never made it past the feasibility-study stage, and others remained in service use for years.

articulated by Kennedy's chief military advisor (and later Chairman of the Joint Chiefs of Staff), Army General Maxwell D. Taylor.

Dr. Peggy Rogers with model of Weteye.

Many of the weapon systems presented in this chapter were conceived prior to the period covered by this volume (1968 to 1979). Their development and use, as well as the people who played principal roles in the development process, are chronicled in greater detail in Volume 4 of the China Lake History series (1959 to 1967)—even when that entailed carrying the story well past 1967. Specifically, the programs described in Volume 4 are BOMROC, Chaff Dispensing Rocket (CHAFFROC), FAE, Helicopter Trap Weapon, RAP, Rockeye, Snakeye, VLAP, Walleye I, and unconventional weapons.

Khe Sanh: American Forces Under Siege

For the United States, 1968 was the costliest year of the Vietnam War: 16,899 service members were killed that year, nearly half again more than in the previous year or in the following year.[3]

January 1968 brought the Tet Offensive, catching American and South Vietnamese military units (and political leaders) unaware. Although the Vietcong campaign eventually resulted in far greater casualties for the Communist forces (both the Vietcong and the North Vietnamese Army), in America the bold, aggressive attack was a shock not only to the DoD but also to the American public. Night after night, the evening television news programs, which were the chief source of war information for most Americans, showed graphic footage of the defenders of the Marine base at Khe Sanh. Although the initial Tet attacks had occurred all over South Vietnam, the offensive soon focused on Khe Sanh, a remote firebase near the demilitarized zone in the northwest corner of South Vietnam.

President Johnson did not want Khe Sanh to become an American Điện Biên Phủ, the site of the 1954 battle in which the Communist Việt Minh, under Võ Nguyên Giáp, defeated the French Army, leading to France's withdrawal from French Indochina. Johnson ordered Khe Sanh held at all costs—and for both sides the costs were heavy. The siege was not broken for 4 months. Shortly thereafter, the Marines began evacuating the base, destroying everything they could not salvage. The last Marines left the base on 11 July 1968.

The amount of firepower expended in the battle for Khe Sanh was stupendous. According to the official Marine Corps history of the battle, more than 100,000 tons of bombs were dropped by American aircraft during the siege, and the defenders expended 150,000 artillery rounds.[4]

Most of the bombs (59,542 tons) were dropped from B-52s in a phase of the Khe Sanh defense that Army General William Westmoreland dubbed Operation Niagara. He later told an Air Force audience that he chose that name "because I visualized your bombs falling like water over the famous falls there in northern New York state."[5]

Many of the weapons used at Khe Sanh had China Lake in their lineage. The A-4 Skyhawks, for example, the nimble little single-seat jets that provided

[3]National Archives, "Statistical Information about Fatal Casualties of the Vietnam War," accessed 9 April 2013, http://www.archives.gov/research/military/vietnam-war/casualty-statistics.html#date.

[4]Shore II, *Battle for Khe Sanh*, 145.

[5]Nalty, *Fight for Khe Sanh*, 88.

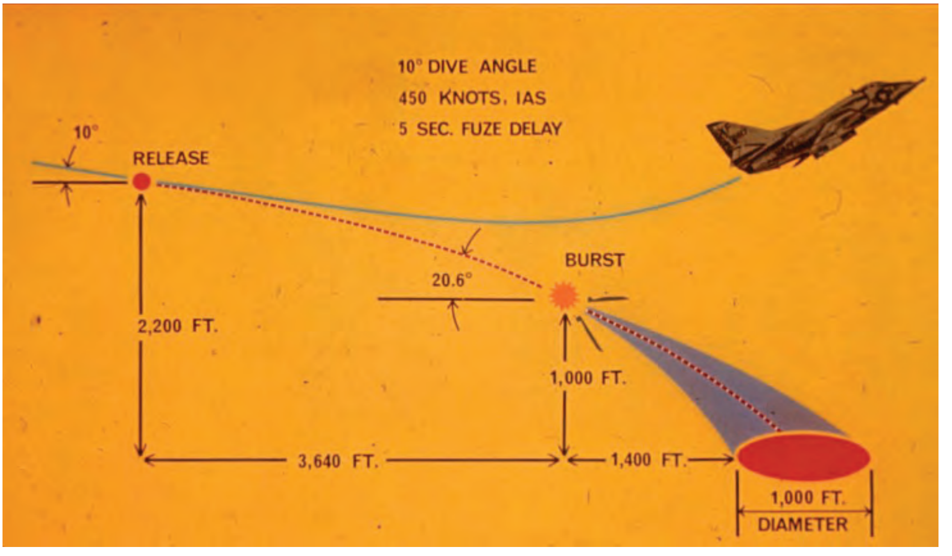
flak suppression to allow resupply helicopters into the Marine base, carried weapons straight out of NWC's laboratories and ranges.

Sadeye

Marine Major General Richard A. Gustafson, who was a VX-5 project pilot at China Lake from 1964 to 1967, went to Vietnam with (MAG)-12 just in time for the Tet Offensive. During his tour at China Lake, Gustafson (then a captain) had done developmental and operational testing of the Sadeye (CBU-75), an air-delivered weapon carrying bomblets in a clamshell-type container. The weapon's nose fuze opened the clamshell after a preset time delay and dispensed the submunitions. The bomblets' aerodynamic design induced a spin that armed them, and they detonated on target contact.[6]

Sadeye cluster weapon (CBU-75).

[6]The designation CBU-75 is the official name for Sadeye under the DoD's Joint Designation System, established in 1963. CBU is cluster bomb unit; AIM is air intercept missile, AGM is air-to-ground missile, etc.



Typical delivery mode of Sadeye.

"[Sadeye] was used by the Marines (myself included) during the 1968 siege of Khe Sanh," Gustafson recalled 40 years later.

> Marine infantry held the hills west of the Khe Sanh main base. They were surrounded by North Vietnamese Army regiments. These Marine units on the hills had to be supplied by Marine helicopters. To do so, enemy fire had to be suppressed around the Marine position so the helicopters could get to these positions, release the supplies, and get out safely.[7]

MAG-12 was assigned to carry out the suppression. Gustafson was flying the A-4E Skyhawk. "Release parameters and aim points were chosen so the bomblet pattern would cover the hillside up to the Marine positions just prior to the arrival of the helicopters," he explained. "Seemed to work OK. We also used Snakeyes and napalm for this suppression."[8]

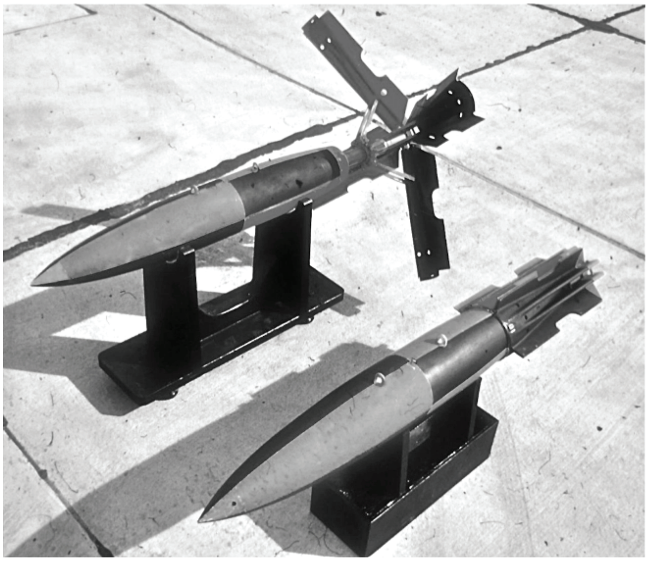
Snakeye

Snakeye, another China Lake product, and napalm ("snake and nape" or "shake and bake" in the vernacular of the troops on the ground who called in air strikes) were a potent combination for protecting U.S. and allied ground

[7] S-269, Gustafson interview, 5.

[8] Ibid. Sadeye was intended to be the cornerstone weapon of the so-called McNamara Line, a barrier across Vietnam from the South China Sea to Laos. Electronic sensors would warn of activity in the area—North Vietnamese attempting to infiltrate into South Vietnam—and 50 aircraft would be standing by to deliver the weapons. The project was never completed.

forces fighting in the jungle-covered terrain of South Vietnam. Snakeye solved a significant problem involved with accurate bombing in a close-air-support situation. Prior to the development of Snakeye, if an aircraft flew low enough to deliver a bomb accurately—sometimes less than 100 meters separated the good guys from the bad guys—the inertia of the aerodynamically shaped bomb tended to keep it flying in the same direction and with the same velocity as the launch aircraft after release. By the time the bomb hit the ground and exploded, the aircraft was often still close enough that it was within the bomb's blast-fragment pattern.



Snakeye in retarded (top) and unretarded (bottom) modes.

The solution was to add a set of air brakes to general-purpose bombs, such as the 250-pound Mk 81 and 500-pound Mk 82. The pilot could elect to drop the bombs either in the normal fashion, unretarded, or for close-in work, in the retarded mode; the spring-loaded air brakes deployed milliseconds after the bomb was released from the aircraft.

Snakeye was released for production in 1963 and soon thereafter was being used in Vietnam. After some difficulty with fins improperly opening, the fin shock absorber was redesigned in a product improvement program at China Lake. A complete bomb-conversion package, the Mk 15 Mod 3 Snakeye retarding tail assembly, was formally released to the Fleet in 1970.

Rockeye

By 1968, Rockeye had become a mainstay of air operations against the Communist forces, particularly in South Vietnam where its primary targets were men and material coming down the Hồ Chí Minh Trail from the north.

Originally called Hawkeye, the weapon was early on renamed Rockeye (later Rockeye I) because of the submunitions that constituted its payload—2.75-inch rocket warheads. (The 2.75-inch rocket had also been developed at China Lake, in the 1940s.)

Rockeye I was a relatively ineffective weapon—"a disaster," in the words of Marine Colonel (then Captain) Ray Powell, a VX-5 pilot who tested it at China Lake. Rockeye I contained 96 bomblets and used a Zuni motor to strip away the casing and scatter the payload. The weapon never completed development.[9]

In Rockeye II (CBU-100), which began development in 1963—a from-scratch development, unlike its pieced-together predecessor—the number of submunitions was increased to 247. These bomblets, specifically designed for the new weapon, were contained in a tubular dispenser originally fitted with canted fins that made Rockeye spin as it dropped. When an explosive cutting charge opened the dispenser, the bomblets were scattered over the target area. (It was later determined that spinning the dispenser was not required to achieve a suitable pattern, so straight fins replaced the canted fins.)

Rockeye II's Mk 18 bomblet, which was designed under the leadership of China Lake engineer Moyle L. Braithwaite, was intended primarily for tanks; it could penetrate 8 inches of hard armor. Although there were few enemy tanks in Vietnam, the bomblets played havoc with vehicular traffic on the Hồ Chí Minh Trail. A single Rockeye II weapon with its 247 bomblets has a dispersion pattern about the size of a football field. The *Tech History* reported:

> Within the impact pattern, hard targets are damaged or destroyed by the bomblet shaped charge, which is capable of penetrating 8 inches of hard armor. Soft targets are damaged or destroyed by either bomblet impacts or by fragments that saturate the impact area. POL [petroleum, oil, and lubricant] stores are ignited by the bomblet detonation or by the shaped-charge jet, which is capable of penetrating the roof of a storage building and igniting the POL stored below. [10]

Rockeye II pilot production began in 1967, and approval for service use and operational deployment to Southeast Asia came the following year. By 1970, Naval Ammunition Depot, Crane, Indiana, ratcheted up production to 1,700 weapons per month. In 1971, a second-source production contract was in place.

Vietnam was not the only conflict in which China Lake's Rockeye cluster weapon was employed by U.S. forces. In the early 1990s, nearly 28,000 Rockeyes (almost 7 million bomblets) were dropped by Marine, Navy, and Air Force aircraft during Operation Desert Storm.

[9]S-270, Powell interview, 41.
[10]*NWC Tech History 1970*, 2-52.

Antipersonnel/Antimaterial (APAM) Cluster Weapon

One variant of Rockeye was the APAM CBU-59. APAM uses a Rockeye dispenser but contains 717 bomblets (BLU-77) versus Rockeye's 247. At 750 pounds, APAM also weighs half again more than Rockeye.

The APAM development team was led by Milton K. Burford, who came to China Lake as a Junior Professional in 1962. He'd been in the Reserve Officer Training Corps (ROTC) at Missouri School of Mines and Metallurgy, so following his Junior Professional tour, he spent 2 years in the Army, where he wound up as Commanding Officer of a heavy maintenance company. (Motto: If we can't fix it, it ain't busted.)

While Burford was serving in the Army, engineer Michael A. Halling began work on the New Bomblet Feasibility Program, an outgrowth of work done by John Pearson. A China Laker for 32 years and an internationally recognized expert in the dynamics of warheads and explosives, Pearson had pioneered controlled-fragmentation technology, in which the inner surfaces of warhead cases were machined with grid patterns that optimized the shape and dispersal pattern of the warhead fragments. The New Bomblet Feasibility Program was supported by NAVAIR with Category 6.2 Exploratory Development funds. At this time, the bomblet work was conducted by Robert G. S. "Bud" Sewell's Warhead Branch in the Air-to-Surface Weapons Division.

Milt Burford.

When Burford returned to China Lake, the New Bomblet Feasibility Program had concluded, but he continued with the design of an advanced bomblet. The project transferred to the newly formed Warhead Development Branch, headed by Richard P. Birge, in the Propulsion Development Department, under Dr. Guy Leonard. Burford was assigned as manager and chief engineer for the bomblet project, which became the APAM Advanced Development project in 1967.

APAM was, in a sense, an experiment. It was assigned to China Lake at the request of the CNM

> as a test case to determine the capability of a field laboratory to carry a weapons system through design, development, and first volume production. . . . Complete technical, financial and management responsibilities—including funding of participating field activities—are vested in the NWC program office.[11]

Burford and his team used several technologies to design an entirely new bomblet that was the core of the APAM weapon, including a new flutter-oscillator arming mechanism under development by Peter D. Gratton at Naval Ordnance Laboratory (NOL) White Oak. Like the Rockeye II bomblet, the BLU-77 had two modes of operation: antipersonnel and antimaterial. However, the BLU-77 had a more sophisticated fuze and an added "pop-up" feature in the antipersonnel mode. The 1966 *Tech History* described the process:

> If the target-sensing nose element is subjected to very high deceleration, such as that associated with impact on armor, then the warhead will fire instantaneously, making optimum use of the shaped charge. If the nose element is subjected to lower deceleration, as would be experienced by impact on soft ground, then a pop-up propellant charge would be initiated, and a time delay would fire the warhead near its optimum burst height.[12]

Test-film analysis indicated that the bomblets generally exploded between 2 and 10 feet above the ground.[13]

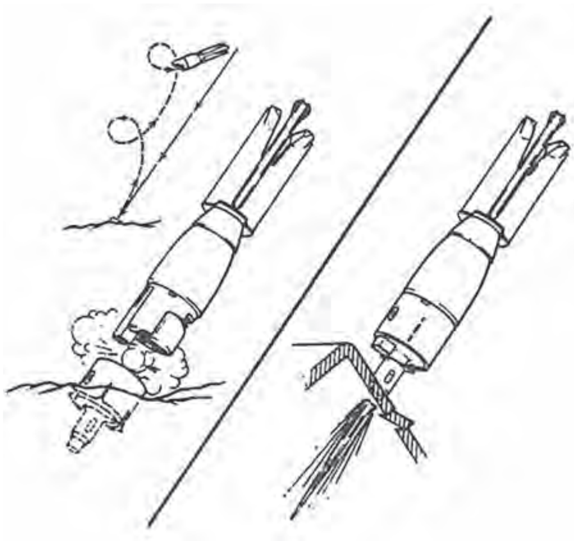
Through the late 1960s, the development program proceeded on schedule, going through five iterations of bomblet design. Burford and his team qualified the Mk 7 Rockeye II 500-pound-class dispenser as a 750-pound dispenser to accommodate APAM's larger bomblet load. They worked with NOL White Oak on the fuze mechanism and early in the development process brought in Honeywell Inc., Hopkins, Minnesota, which would eventually be the principal production contractor.

Like all China Lake weapons development projects, input from Fleet-experienced personnel was critical. Weapons must not only function properly on the ranges of NWC but must also be suited for every environment that the weapon might encounter from the day it leaves the production facility to the day of its demilitarization. In the case of APAM, a knowledge of the operational environment had a unique influence on the weapon's design. Burford explained:

> The Mark 7 dispenser comes apart into halves, and on the APAM weapon, we had painted a large black lightning bolt down either side of the weapon. And somebody might say, "Why are you doing that? To be fancy?" Well, when

[11]*Rocketeer*, 12 July 1974, 1.
[12]*NOTS Tech History 1966,* 4-57.
[13]*NWC Tech History 1971*, 3-4.

you're loading an aircraft carrier at night under red-light conditions, you can't read the writing on the sides of a lot of weapons. If you load a 500-pound weapon on an airplane, that's one thing. But if you load a 750-pound weapon on an airplane—physically, those two weapons look the same, but if you load it wrong on the airplane, the airplane's going to have trouble with a [catapult] shot, and he might have trouble flying. So when they specified a particular weapon, everybody knew the APAM weapon had the lightning bolt on it because it was quite obvious.[14]



Two firing modes of BLU-77.
Published in the 1973 *NWC Tech History*.

There was more to running an effective program than good engineering, as Burford soon discovered. Extensive coordination with Washington sponsors and potential sponsors was required. Because APAM was a triservice program, he had to brief military and civilian representatives, and often their bosses, in NAVAIR, the Naval Sea Systems Command (NAVSEA), the Office of the Chief of Naval Operations (OPNAV), the Marine Corps, and the Air Force. He told an interviewer:

> You take a look at a lot of those people, and you have to realize one thing. They can rotate in 12 months, and so you're back trying to bring somebody else up to speed. And you are encountering a constant rotation of personnel, both civilian and military, and you're getting different people from other Services interested or disinterested as the case may be, and so you're constantly briefing them.[15]

As with any lengthy development program, money was an ongoing issue. "It was the middle '60s, and there were interests in all kinds of things, and so funding was not stable," Burford said.

> People were interested in things real fast; they wanted them right now. . . . Sometimes you're fighting for funding, and sometimes it can be quite a fight. We did everything that we could to explain to people what our mission was

[14]S-263, Burford interview, 12.
[15]S-263, Burford interview, 11.

> and what the components were that we were working on, and I think, in general, we were pretty successful.[16]

At one point, he recalled, funding was halted for a time because of a decision in Washington "at a very high level" to take money marked for APAM and "spend it on a problem they were having with the A-7 jet engine."[17]

Other concerns threatened the program. In the early 1960s, Secretary of Defense Robert S. McNamara had demonized the idea of duplication of effort, and the Office of the Secretary of Defense was alert for any example of such supposed waste of resources. The similarity of Rockeye and APAM—two cluster weapons using the same dispenser—caught the attention of the NWC Advisory Board in May 1971.

A tradition that dated back to China Lake's earliest years, the advisory board was a select invited group of military, business, and academic leaders who visited the base twice each year to discuss and critique current programs and the base's overall performance. The board was established in 1949 and continued through the late 1970s. Each new board was a high-level group. Among the members in May 1971 were Vice Admiral John T. Hayward, USN (ret.), NOTS' first Experimental Officer; Vice Admiral Paul D. Stroop, USN (ret.), NOTS' fifth Commander; Professor Marcus E. Hobbs, University Distinguished Service Professor at Duke and one of the founders of the Research Triangle Institute (RTI); Dr. Zohrab A. Kaprielian, later dean and vice president of the University of Southern California (USC); and James W. Plummer, a Lockheed Corporation engineer who would later become the first director of the National Reconnaissance Office to come from private industry.

After praising APAM's "great promise," the board issued a caution in its summary report:

> The Rockeye and APAM, as two separate units for the future, deserve careful examination now so that the two-unit concept is defensible on strategic and tactical grounds, or the two units may be advisedly phased into a single unit in the near future if the examination shows the two-unit basis to be only marginally defensible.[18]

The board's concerns proved unfounded. No organized effort was mounted to combine the programs. There was competition for resources and some political infighting, involving parties both inside and outside China Lake, but despite the funding and bureaucratic pitfalls, APAM made it through the

---

[16]Ibid.

[17]Ibid.

[18]NWC, *Naval Weapons Center Advisory Board Report, Advisory Board Meeting, 13–14 May 1971*, May 1971, 7.

NWC Advisory Board, 1971. From left, standing: Vice Admiral John T. Hayward, USN (ret.); Prof. Marcus E. Hobbs; Dr. William B. McLean; NWC Technical Director Hack Wilson; Prof. W. Dale Compton; Rear Admiral Thomas B. Owen, USN (ret.); and Lockheed Corporation engineer James Plummer. From left, seated: Vice Admiral Paul D. Stroop, USN (ret.); Prof. Zohrab A. Kaprielian; Vice Admiral Ralph Weymouth, USN, Director of Navy Program Planning; Rear Admiral William J. Moran, NWC Commander; and Rear Admiral Thomas D. Davies, USN, Deputy CNM for Development. Published in the *Rocketeer*, 14 May 1971.

development process. In 1971, a 108-grain pyrophoric zirconium cap was added to the metal case to increase the weapon's incendiary capabilities. Navy technical evaluation (NTE) was completed in 1972, and in 1973, APAM passed operational evaluation (OPEVAL) and was released for unlimited production.

With development complete, program responsibilities were smoothly transferred from the Propulsion Development Department to the Engineering Department's Fleet Engineering Division, where Robert W. Zimmer took over the program. When the procurement contract was signed with Honeywell in 1974, it was "one of the largest weapon system contracts ever to be awarded by NWC through the Navy Regional Procurement Office in Long Beach." The contract was for 4,320 weapons at a cost of $22,538,000.[19]

Although APAM went to the Fleet at the tail end of the Vietnam War, it was in the arsenal, ready for future conflicts. In 1983, it saw action during the

[19]*Rocketeer*, 12 July 1974.

U.S. invasion of Grenada, and it was also employed in the U.S. actions against Libya in 1986.

Walleye

Another important NWC-developed weapon that figured prominently in the Vietnam War was Walleye, a TV-guided unpowered glide weapon that traced its roots to the 1930s and the early television work of Vladimir Zworykin. TV technology, however, was not mature enough to meet the design challenges for such a weapon until the 1960s.

In 1951, Fred Alpers at NOLC headed a team that developed the Automatic Video System of Edge Tracking (AVOSET), which, as the name implied, could identify and track edges on a video display. Six years later, China Lake engineers William H. Woodworth and Jack A. Crawford took the AVOSET technology to the next level and significantly expanded it by designing a tracking system that would guide an air-to-surface weapon. Originally called Snoopy and later Fetch, the concept was swept into the Eye series around 1959 and given the name Walleye. It would be a weapon used primarily against fixed or slow-moving, high-value targets such as ships, bridges, military production facilities, and coastal defense sites.

Walleye I (Mk 1 Mod 0 guided weapon), the initial operational version, was fielded in January 1967. It had been developed under the leadership of David N. Livingston, who headed the program for 12 years. Attack Squadron (VA)-212 flew it from USS *Bon Homme Richard* (CVA-31) in its combat operational evaluation flights against targets in Vietnam, and the weapon proved highly effective; it was used to shut down the Hanoi power plants in May 1967. (The development of Walleye I is detailed in Volume 4 of this history.)

Between 1966 and 1970 (when the Walleye I production contracts were completed), a total of 9,858 weapons had been produced by the Naval Avionics Facility, Indianapolis (NAFI), the pilot-production source; Martin Marietta Corp., the first production source; and Hughes Aircraft Co., the second source.

Dale E. Knutsen, who worked on Walleye I's aerodynamics from 1964 until its fielding, recalled that

> Walleye I carried a large, linear-shaped-charge warhead that was ideally suited for use against buildings and other above-ground structures. Once it was used in combat, the Fleet folks indicated that they'd like to have an even larger version for bigger targets. And so, "Fat Albert" or Walleye II was born, leading to a big-brother version with roughly twice the payload.[20]

[20]Knutsen, "Walleye Notes."

Work on Walleye II (Mk 5 modular guided glide weapon) began in January 1969; the goal was a greatly improved weapon in terms of range, lethality, accuracy, and ease of use. To the extent possible, it would be compatible with the interfaces (electrical, physical, etc.) of the existing Walleye. NWC Technical Director Dr. Tom Amlie listed the program as one of the "five most important items NWC is working on" in response to a query from Rear Admiral Goodfellow, the CNM.[21]

Max R. Smith, a mechanical engineer who was assigned as Walleye II's program manager in 1971, summarized the program:

> We had direction and authority out of CNO called RDC [Rapid Development Capability]. . . . We started from scratch. We did all the design work here on the wings, the fins, and the warhead. We modified the fuze, and modified the guidance section and the control section.[22]

War and politics affected the pace of the program. In November 1968, President Johnson, in response to domestic and international pressures, had ordered that U.S. bombing in North Vietnam cease. As the bombing lull stretched through the following year and into the next, while peace talks were underway in Paris, it began to look as if there might be a settlement to the war. The 1970 *Tech History* reported that "the urgency of the program waned during the year, which provided time to evaluate design improvements." Engineers and test personnel nevertheless continued to work feverishly on incorporating the improvements into the weapon.[23]

The original design for Walleye II called for a 2,400-pound warhead containing 1,160 pounds of explosive (compared with Walleye I's 850-pound warhead and 470 pounds of explosive). Later, the warhead weight was reduced to a still hefty 2,000 pounds with 1,070 pounds of explosive. "Normally," Smith said, "when you design a warhead, you want 50 percent metal parts and 50 percent HE [high explosive]."[24]

Modifications to the guidance section, including a rate gyro platform and an advanced integrated-circuit video camera, increased the standoff range at target lock-on and shortened the time required to achieve lock; both attributes increased aircraft survivability.

---

[21]Code 01 to Codes 00, 03, and 05, memorandum, "Response to Telecon from M. R. Hoagland," 2 January 1969. The other four items were an improved ordnance delivery system, an air-launched antiship missile, a low-cost air-launched cruise missile, and weather modification.

[22]S-89, Smith interview, 28, 30.

[23]*NWC Tech History 1970*, 2-8.

[24]S-89, Smith interview, 28, 30.

A-4F with Walleye II (Mk 5) at China Lake, 1969.

Many of the improvements intended for Walleye were part of an in-house program called the Walleye Improved Guidance System (WIGS), which included replacing the rear-mounted ram-air turbine (which accounted for about 25 percent of the weapon's aerodynamic drag) with an internal nose-mounted ram-air turbine. While these were not incorporated in Walleye, they were transitioned into the flagging Condor development program at North American Aviation.

In March 1970, development began of a Walleye with a greater range, enhancing the capability for ship attack. The weapon was named the Walleye II Extended Range (ER). Shortly thereafter, a command control feasibility experiment was conducted to assess the viability of adding a data link to Walleye II ER.

Walleye I and II had achieved what seemed to be the ultimate goal of attack pilots: an autonomous, launch-and-leave, standoff weapon that was highly accurate and unjammable. But the increased range of the Walleye II ER begged for greater operator control. As Smith explained:

> When you have an electro-optical system at 30 nautical miles, you can't define a window or a door in a building. You can define a town, a bend in a river, a coastline, a mountain top, or something of that nature. So we had to have some way to redefine the terminal impact point, and data link was the answer. . . . All you had to do was to point it in the right direction, lock it on a city

> or a lake, or something where the end target was in the vicinity. You let it fly locked onto that point for 10, 15, or 20 nautical miles until you could see the end impact target more clearly. Then you redefined [the target] by moving a control joystick in the cockpit, just like flying a toy airplane. Then you steer this thing directly into the window or the door. So that's the extended-range data link, and it proved out to be tremendously successful.[25]

The 1970 experiment, utilizing a bidirectional link between the aircraft and weapon that carried video from the weapon to the cockpit and commands from the cockpit to the weapon, was a success. As the *Tech History* states:

> Based on the test data and the pilots' comments, the Walleye data-link system is readily usable in a combat environment; it permits longer standoff ranges at launch, with the inherent decrease in pilot and aircraft risk, yet at the same time gives better lock-on refinement and consequently greater accuracy.[26]

Operator control after launch (command guidance) gave greater flexibility to Walleye. As the weapon drew closer to the target, the controller could change the aimpoint on which the Walleye tracked to pinpoint a particularly vulnerable point on a target. Or the controller could have a follow-up Walleye strike at the same point as the first to better disable a particularly hard target. Or the controller could switch targets entirely if a more suitable one appeared during the flight, which might last for several minutes and extend for more than 30 miles.

For the weapon controller—in a single-seat aircraft, such as the A-4, that person would also be the pilot—there was another advantage. The specific target selection could be made after the weapon had been launched and the pilot had turned to exit the (often "hot") launch area.

The Walleye II ER Data Link (ERDL) (Mk 13) program began in 1971. Larger wings, interchangeable with the standard Walleye wings, were designed to significantly expand the launch envelope; the wingspan was increased from 51 inches to 68, extending the range by 30 percent. (Walleye I's glide ratio was 3.5/1; Walleye II ERDL's, with the larger frame and wings, was 5/1.) Most importantly, the weapon could now be launched outside of the range of current threat SAMs.[27]

Two tests in 1971 and 1972 that combined the extended-range wings with the command data link were both failures. The problems were corrected and the third Walleye II ERDL test unit was launched. The ambitious test scenario called for the pilot to lock on and launch against a 10-trailer complex. After

---

[25]Ibid., 30.
[26]*NWC Tech History 1970*, 2-8, 2-6.
[27]*NWC Tech History 1971*, 1-26.

turning and heading in the opposite direction, he was to use his controller to shift the target lock-on point to a truck 8,000 yards down the road from the trailers.

Immediately, things went wrong. Before launch, the target locked on terrain to the left of the trailers. Ground control instructed the pilot to launch anyway. He did so, and the weapon remained locked on the terrain as the pilot made a 160-degree turn. He then took command of the weapon, 38 seconds after launch, and shifted the lock point to the trailers. About 12 seconds later he hand-tracked the trailers again, then relocked on them. At 82 seconds into the flight, he again hand-controlled the weapon and began a search for the truck. Clouds in the area made the process difficult, and he was instructed to relock on the 10 trailers. At 100 seconds into the flight, ground control told him to hand-track the upper right-hand trailer until impact. He did so. Impact occurred at the center of the trailer, 132 seconds after launch. The distance between aircraft and target at the moment of impact was 152,000 feet. Despite the difficulties encountered, the test was a success.[28]

In June 1972, Walleye II (Mk 5) was introduced to the Fleet. A six-man team from China Lake flew to the Gulf of Tonkin and worked for a month with two squadrons on USS *Kitty Hawk* (CVA-63), training the pilots and crews in the use of the weapon. By December 1972, 85 weapons had been launched in combat, most deep in North Vietnam in support of Operation Linebacker. The success rate—defined as the weapon guiding within 15 feet of the target, the fuze and warhead detonating, and damage being inflicted on the target—was 0.81 (81 percent). By comparison, for the 629 Walleye I weapons dropped between 1966 and the end of 1973, the success rate was a still-respectable 0.71.[29]

Also in 1972, a developmental data-link pod was sent to USS *Kitty Hawk* and tested in combat in July with three developmental Walleye II ERDLs. The *Tech History* documented this combat test:

> One was launched in adverse weather conditions that forced a steeper launch than planned; as a result the controller in a trailing aircraft did not recognize the target area and hence could not find the target before the weapon hit the ground. One weapon hit a vehicle bridge at the chosen impact point and demolished it. The third weapon was hand-guided into the mouth of a cave to destroy a coastal defense gun that could not be destroyed by conventional

[28] *NWC Tech History 1972*, 2-10, 2-11.

[29] *NWC Tech History 1973*, 2-10, 2-11. Operation Linebacker was a massive Air Force and Navy bombing campaign ordered by President Nixon in response to North Vietnam's Nguyen Hue Offensive. It lasted from May through October 1972.

bombing. This set off a secondary explosion that spewed from the cave into the Tonkin Gulf 10 seconds after impact.[30]

Attack Squadron 212 (VA-212) A-4 with Walleye over North Vietnam.

Even as it was being used in Vietnam, Walleye II ERDL (Mk 13) continued in development. In 1973, it had three notable testing successes; in one, under manual control, an inert-warhead Walleye struck a simulated tunnel entrance at China Lake after being launched from a range of 149,000 feet. In a second, an inert-warhead round under manual control passed through the hole made by the first Walleye in the simulated tunnel entrance. In a third, a live-warhead weapon tracked a YFU harbor utility craft underway at 8 knots near Point Mugu, striking the ship at the base of its superstructure and totally destroying the aft end. (The ship sank.)

[30]*NWC Tech History 1972*, 1-26.

"This marked the first time that a moving target was attacked and destroyed by a long-range standoff weapon," reported the *Tech History*. Operational evaluation was completed, and the Mk 13 was approved for service use. By year's end, both the Mk 5 and Mk 13 were released to full-scale production, and Walleye II ERDL went to the Fleet in 1974.[31]

Walleye II's command-video link added another aspect of flexibility to the Navy's attack arsenal. The weapon could be launched by one aircraft but controlled by another. After this was successfully demonstrated at China Lake, an NWC team went aboard USS *Midway* (CVA-41) in 1973 to help install data-link capabilities in two VA-115 A-6A Intruder aircraft. The A-6s were not set up to deliver the weapons, but they could control weapons that were released by A-7s from another squadron. This capability was advantageous when, for example, the delivery aircraft's pilot wanted to release two weapons in quick succession and then hand off control of one to a nearby aircraft. By 1979, all Fleet Walleyes (I and II) were in the process of being converted to the ERDL configuration.

Through the late 1970s and into the 1980s, periodic improvements from the Walleye engineers at China Lake were incorporated into the Fleet Walleyes. This was possible because of the modular nature of the Walleye electronics, something unique to Walleye at the time. "That really intrigued me when I first saw it as a JP—here's all these plug-in little modules," commented Marc L. Moulton. "Every function in the guidance section could be replaced, improved, updated as you need to by unplugging this module and plugging in another one."[32]

Among these improvements was a haze-penetrator capability. Fog, moisture, dust, smoke, all could reduce the range of Walleye. This limitation was addressed by installing carefully selected silicon vidicons (video camera tubes using a photoconductor target material scanned by an electron beam) that filtered "way down to the deep red—that gets rid of all the scattered light haze from the blue end of the spectrum, and that's where all of the haze from smoke is."[33]

A second improvement was the Phase II data link, which was a hardened (jam-resistant) version of the Phase I data link and compatible with the extensive Phase I inventory of Walleyes.

[31]*NWC Tech History 1973*, 2-11, 2-12, 2-15.

[32]S-245, Moulton interview, 46–47. Moulton was one of the designers of the second-generation Walleye seeker.

[33]Ibid., 44.

Marc Moulton with Walleye seeker.

Beginning in 1970, China Lake also worked on an Air Force program called Seek-Bang, which developed a nuclear warhead version of Walleye. Dale Knutsen recalled that

> the biggest problem we had in going nuclear was finding enough ballast weight because the low-yield nuclear package [created at Los Alamos Laboratories] was extremely lightweight. And so we had to balance the thing with metal parts to make sure that it handled the same as a regular Walleye. But there was quite a test series here of launching prototypes, obviously without nuclear components, from an F-4 at just under the speed of sound so they'd get a shot off and get away. Their biggest problem was getting out of the area as quickly as they could so that they would not be caught up in blast. We tried to convince them that it had more range than they thought, but the Air Force as usual had their own perspective on things and they were going to do heart-of-the-envelope shots.

Captive flight tests and launch tests at China Lake in 1971 and 1972 confirmed Walleye's capability as a vehicle for a nuclear warhead, and a number of nuclear Walleyes were produced.[34]

Rocket-Assisted Projectile (RAP) and Bombardment Rocket (BOMROC)

China Lake's RAP was first used in Vietnam in 1968. RAP was developed to extend the range of the Navy's 5-inch/38-caliber and 5-inch/54-caliber shipboard guns. The mighty battleships of WWII carried 16-inch guns that could hurl a 3,000-pound projectile more than 20 miles; however, the last of these was decommissioned after Korea. All that was left for ship-to-shore bombardment were the 5-inch guns of cruisers and destroyers, which could reach out only 9 miles with a relatively lightweight 55-pound round. RAP

[34]S-259, Knutsen interview, 8; *Major Accomplishments of the Naval Weapons Center*, 46.

consisted of a modified warhead and fuze as well as a rocket motor that fired a booster charge 23 seconds after launch and that burned for 2 seconds, boosting the projectile's velocity.[35]

Seek-Bang Walleye on Air Force F-4D Phantom at Armitage Field, December 1971. Photo courtesy of Gary Verver.

Development of RAP began in 1962. According to Duane Blue, the Genge Engineering technical writer assigned to document the program, RAP was the brainchild of engineer C. Walter "Walt" Abernathy. The plan, as Blue recalled, was, " 'let's stuff some propellant in the back of our 5-inch guns and see if we can't get/increase the range.' "

Blue further elaborated:

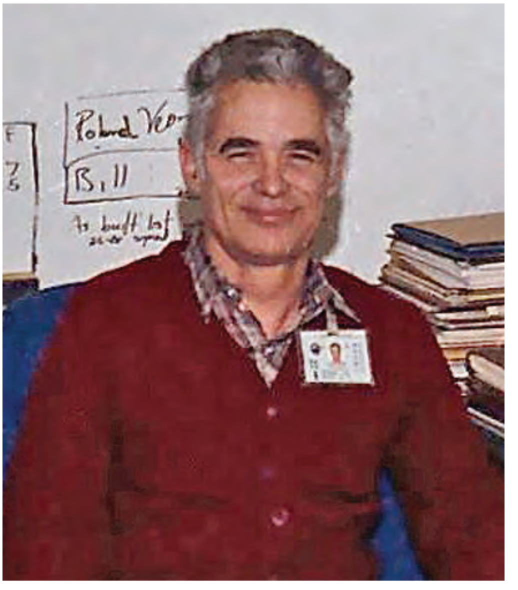
> So they went back and got funding to do a demo and that's exactly what they did. They stuffed a zirconium-based propellant in the back of the 5-inch RAP, fired them off, got a pretty nice increase in range, and they sold the program based on that. What they didn't tell the sponsors was that the zirconium-based propellant blew out the nozzles . . . They burned holes in the side of the 5-inch shells. So there was a lot of work that had to be done. And it did get done.[36]

The weapon presented NWC engineers and scientists with the unique challenge of developing a rocket-motor propellant that would survive both the

---

[35] *NWC Tech History 1968*, 5-42.
[36] S-372, Blue interview, 4.

shock of firing (about 18,000 *g*s) and the spin imparted by the 5-inch gun's rifled barrel (about 250 revolutions per second). "That does terrible things to propellant structures, wanting to tear the propellant apart," said Ray A. Miller, who at the time headed the Propulsion Development Department's Development Engineering Branch. "There are gas dynamic effects inside the rocket motor that took us a long time to come to grips with and understand and to counteract."[37]



Walt Abernathy.

To meet challenging requirements of range and test-item recoverability, an unusual test facility for firing RAP test rounds was set up on NWC's G-2 Range. The rounds were fired straight up. "Well, not quite vertical, a tiny bit off," explained Abernathy. To achieve the nearly vertical trajectory, the gun mount itself had to be tilted, since the maximum elevation of the barrel was 80 degrees. Test personnel remained at the site "under a nice protected roof" to observe where the rounds impacted. The fired rounds reached altitudes of 70,000 feet and consistently landed within 1,000 feet of the facility. Said Abernathy:

Ray Miller.

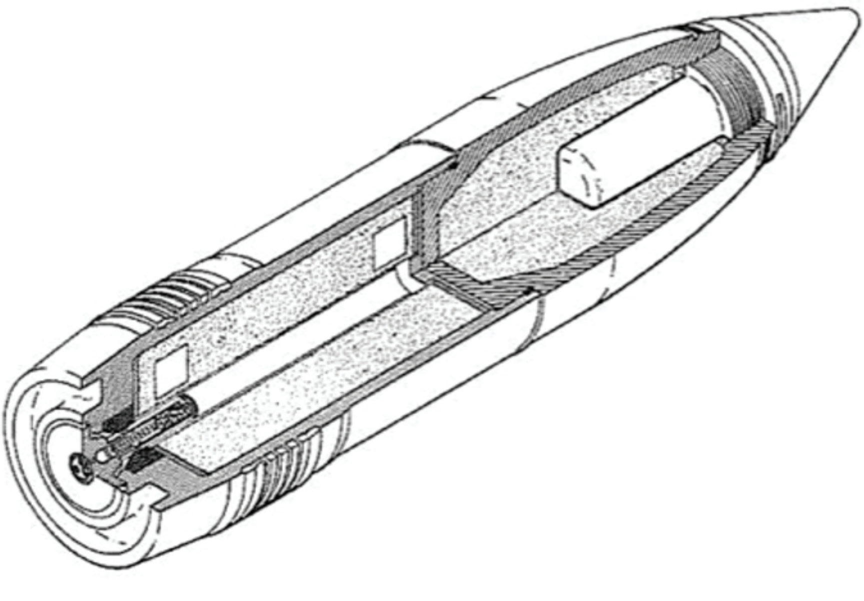
> We fired some standard rounds first to get a gauge of the wind . . . They would correct for it and then . . . because we didn't fire

[37]S-262, Miller interview, 33.

> real rapidly, as the day went on if it started to drift a little bit they would adjust for the next firing.[38]

The purpose of the vertical firings was to assess the effect of the firing shock on the rocket motor and projectile. "Damage is less when they come down butt first and hit the ground," explained Abernathy. "You get a much better idea of the effect of the firing . . . If you fire and recover from a nose-first hit, you're really less sure of what you're finding."[39]

Ironically, the first combat firing of RAP was from the 5-inch secondary batteries of the battleship USS *New Jersey* (BB-62), which had been recommissioned in April 1968 to support the war in Vietnam. The significantly increased range of the RAP projectiles allowed the Navy to extend its naval bombardments further inland, engaging additional enemy supply lines, SAM sites, and storage areas while maintaining a wary distance from enemy shore batteries. By 1992, it was estimated that some 100,000 RAP units had been sent to the Fleet.[40]



5-inch/38-caliber RAP. Published in the 1967 *NWC Tech History.*

[38]S-318, Abernathy interview, 33.
[39]Ibid., 34.
[40]NAWCWD, *China Lake Propulsion Laboratories*, 4.

The Spin-Stabilized Bombardment Rocket (SSBR) had been developed by Caltech and tested at NOTS during WWII. After the war, China Lake took over development of the weapon and by the early years of the Vietnam War, the weapon was being used by inshore fire-support ships along the coast of Vietnam at ranges up to 10,000 yards. A program begun in 1963 employed dual-thrust propulsion to a spin-stabilized rocket; the resulting weapon, called BOMROC, was fielded in 1968 and had a range of 18,000 yards.

Guided Projectiles (GPs)

A program closely related to RAP was the GP Program. The goal was a projectile that would be fired from a gun and would contain a warhead, rocket motor, and a semi-active-laser guidance and control system. Two versions of the projectile were developed: one 5 inches in diameter and another that was 8 inches in diameter.

Naval Weapons Laboratory (later Naval Surface Warfare Center), Dahlgren, Virginia, was assigned overall cognizance for the NAVSEA-sponsored program. In 1971, China Lake, based on its experience with RAP, was tasked with developing the 5-inch rocket motor and folding fins for the smaller of the two gun-launched projectiles.

Unlike the 5-inch RAP discussed above, the GP did not have to cope with the motor-burn difficulties created by a round spinning at extremely high rates. Instead, the GP motor employed a sabot-like obturator ring that fit around the projectile; the obturator decoupled the round from the gun's rifling while at the same time sealing the gun's chamber pressure (up to 40,000 pounds) behind the round, forcing it from the muzzle with an acceleration of 7,500 *g*s.

With an envisioned motor burn-time of more than 20 seconds, the projectile would also have a far greater range than RAP and, unlike RAP, it was designed not solely for shore bombardment but also for air threats (aircraft and antiship missiles) and ship threats.

Dwight L. Weathersbee, an aeronautical engineer in Ray Miller's Propulsion Systems Division, was assigned to head China Lake's 5-inch GP effort in 1972. He would remain at the helm until 1979, when the Center's motor development work was completed and responsibility for loading the government-furnished rocket motors was transferred to the Naval Ordnance Station (NOS), Indian Head. In 1978, Technical Director Bob Hillyer presented Weathersbee with the Technical Director Award for his work on the 5-inch rocket motor. In his acceptance, Weathersbee acknowledged the work of fellow engineers

Louis Renner, Russell Trovinger, Arthur Black, Edward Panella, Howard Gerrish, and Howard Payne and of technician Ernest Lanterman.

By 1976, the semi-active laser guidance version of the 5-inch projectile, designated EX 105 Mod 1, was in engineering development with Martin Marietta Aerospace as the prime contractor. Martin Marietta called the weapon Deadeye (not to be confused with an earlier China Lake-developed shape-charge weapon of the same name). An IR-guided version, the EX 106 Mod 0, was close behind. The Director of Defense, Research and Engineering (DDR&E), instructed the Army to consider the Navy's 5-inch GP for the 155 mm howitzer. Although funding for the program was reduced after the Vietnam War, NWC continued to provide rocket motors to Dahlgren and prepared a Block II drawing package for production.

Dwight Weathersbee.

The problem with the 5-inch GP, however, was not with the propulsion but with the guidance. In the 1980s, Secretary of the Navy John F. Lehman Jr. cancelled the 5-inch-GP program after being unable to extract a price reduction from the contractor. Under Secretary of Defense for Acquisition Richard P. Godwin reversed Lehman's decision in 1987, but he was overruled by Deputy Secretary of Defense William H. Taft IV. In 1993, the Navy tried again to develop a 5-inch GP, this time with Raytheon Co. as the prime contractor. The program was cancelled after 15 years. In 2015, the Navy was still pursuing a guided 5-inch round; Director of Surface Warfare Rear Admiral Peter Fanta said, "I'm at a point where I'm extraordinarily interested in [it] as soon as the cost comes down to something I can make a reasonable case for."[41]

The other GP, the 8-inch projectile, met a different fate. With the decommissioning of cruisers and battleships, the Navy had lost much of its large-gun capability. In 1970, a requirement was established for a new 8-inch gun, the 8-inch/55-caliber Mk 71, to supplement the 5-inch Navy guns. Among the proposed projectiles would be an 8-inch semi-active laser GP.

[41]Fox, *Defense Acquisition Reform,* 143; "Guided Rounds for Surface Ships," *U.S. Naval Institute News*, *Daily Update*, 9 April 2015.

Dwight Weathersbee (left) briefs Secretary of the Navy W. Graham Claytor Jr. (center) and Technical Director Bob Hillyer (right) on the 5-inch guided projectile in 1978. At rear are Captain Frederick Kinley, Vice Commander (left), and Rear Admiral William Harris, NWC Commander (right). Published in the *Rocketeer*, 20 October 1978.

Again, cognizance was assigned to Dahlgren, which tasked NWC to develop the propulsion afterbody, including the rocket motor, obturator, igniter, and fins.

Dependable gun-launched large-caliber rocket-assisted systems called for new technologies that were still in development. "A new technology is needed that pertains to the rocket motor for the 8-inch extended-range guided projectile," the *Tech History* reported in 1973. "Technology needed to resolve gun launch of this comparatively large motor is not yet available." Howard Payne and Dave Carpenter were the lead engineers on the project, assisted by, among others, a young engineer named Scott M. O'Neil.[42]

Four years later, significant progress had been made. The *Tech History* reported that

> during 1975, critical experiments were conducted that significantly reduced the technology risk for establishment of a demonstration baseline design in 1976-77. The propulsion system baseline and alternate configuration were established.[43]

By the end of 1977, China Lake had static fired a full-scale 40-inch-long rocket motor that developed a 24,000 pound-seconds impulse over a 24-second burn time; gun-launched an unfired 8-inch rocket motor that was recovered and successfully static fired; demonstrated folding fins and a latch system that would

[42] *NWC Tech History 1973*, 9-20.
[43] *NWC Tech History 1976–1977*, 9-18.

deploy when the round left the muzzle; demonstrated obturator seals that decoupled the round from the rifling but imparted a 15-revolution-per-second spin to deploy the stabilizing fins; and ballistically launched an 8-inch projectile to a range of 30 miles.

Howard Payne.

O'Neil remembered the testing.

> We would crank [the gun] up to 62 degrees, so it was pretty high in the air. The whole ideas was you shoot the bullet out of the gun and it would fly for about a second and a half and then its trajectory would sag to about 45 degrees and then we'd kick off the rocket motor. So we did this test—it was going to fly off the north end of the range. We were aiming east of Keeler, Darwin, up in the hills there. But we shot it and the projectile went up 62,000 feet on a ballistic trajectory and came down about 3 miles north of the north boundary of the range. We had a bunch of spotters out there trying to figure out where it came in at. Never found it. So it's out there somewhere still—an 8-inch, probably 7-foot-long projectile.[44]

Scott O'Neil.

The Center had also manufactured 27 of the rocket motors for testing and development purposes and developed for Dahlgren and Texas Instruments (the projectile prime contractor) a shock-resistant "gun-rugged" gas-generator system, based on technology developed by China Lake for Sidewinder, to be used for the projectile's steering and roll-control system.

[44]S-328A, O'Neil interview, 5.

Funding for further development of the GP ended when the Mk 71 gun itself failed operational evaluation in 1978. "So, therein lies another cancelled but successful program," said Miller.[45]

O'Neil said of the experience with the 8-inch projectile:

> It's like most programs. You work on things and they don't go anywhere and you get disillusioned and you find out that's just the way it is. But the technology is still good technology, and it really led the way for a lot of the propulsion that we know.[46]

Folding-Fin Aircraft Rockets (FFARs)

The two most heavily used, non-bullet ordnance items of the Vietnam War were China Lake products, although of earlier vintage than the ones already discussed. The 2.75-inch FFAR (also called Mighty Mouse but most often simply "the two point seven five") was conceived and developed at NOTS in the 1940s as an air-to-air salvo weapon. The 5.0-inch FFAR (Zuni) had been fielded in the late 1950s as both an air-to-air and air-to-surface weapon. Both the 2.75 and Zuni rockets were used in the air-to-ground mode in Vietnam, primarily from helicopters, and millions—literally—rained down on Vietnam during more than a decade of war.[47]

The 2.75 FFAR was carried by the Navy, Air Force, and Army on fixed-wing and rotary-wing aircraft. In 1965, China Lake analysts estimated that the 2.75 FFAR production rate at one Naval Ammunition Depot would reach 500,000 rounds per month. In 1966, Secretary of Defense Robert S. McNamara called for production of 800,000 2.75-inch FFAR rounds per month. That same year, the design of the weapon's rocket motor was simplified in a China Lake product improvement program, resulting in a procurement savings of $22 million.[48]

An incident involving the 2.75 FFAR illustrates the importance of proper manufacturing techniques—and of maintaining a laboratory with a comprehensive knowledge of a product's design and production requirements. China Lake received reports from the field that a number of 2.75-inch rocket

---

[45]S-262, Miller interview, 39.

[46]S-328A, O'Neil interview, 6.

[47]Although Zuni was used exclusively as an air-to-ground weapon in Vietnam, the only MiG shot down by an A-4 during the war was killed with a Zuni. In that May 1967 engagement, the A-4C, piloted by Lieutenant Commander Theodore "T. R." Swartz, flying from USS *Bon Homme Richard* (CVA-31), was jumped by two MiG 17s. Since he carried no air-to-air ordnance, Swartz salvoed his Zunis at the attackers, destroying one.

[48]*NOTS Tech History 1965*, 5-29; Judge and LaFond, "2.75-in. Rocket Effort," 16; *NOTS Tech History 1966*, 1-41.

Air Force F-86A Sabre firing 2.75-inch Mighty Mouse rockets, 1950.
Photo courtesy of Gary Verver.

motors were blowing up shortly after receiving the firing command. This prompted China Lake engineers to visit a manufacturing plant in Arkansas. According to Propulsion Development Department engineer James A. Bowen, the investigators found that although food was not permitted on the production line, employees were sneaking in candy and then sticking the wrappers into the rocket motors to hide them. But that was not the only problem. Tags were being inserted into the rocket motors to track the assembly status of the motors. Sometimes these tags were inserted too far and had to be fished out with scissors. The scissors scratched the motor interior, thereby causing a stress concentration when the motor fired that was sufficient to blow up the motor.[49]

Continuously throughout the Vietnam War, China Lake fielded improvements to the workhorse rockets in the areas of launchers, fuzing functions, warhead types and lethality, and weapon accuracy.

In the 21st century at the Naval Air Warfare Center Weapons Division (NAWCWD), China Lake, far more sophisticated versions of the 2.75-inch rocket are being developed and fielded. In 2010, the Low-Cost Guided Imaging Rocket (LOGIR) was demonstrated through a Future Naval Capability (FNC) program, and new modular missile technology is being developed and incorporated in the weapon. The Advanced Precision Kill Weapon System (APKWS) was fielded in 2012 with the Navy and Marine Corps. Both LOGIR and APKWS were tested on the same ranges as was their predecessor, Mighty Mouse, some 60 years earlier.

---

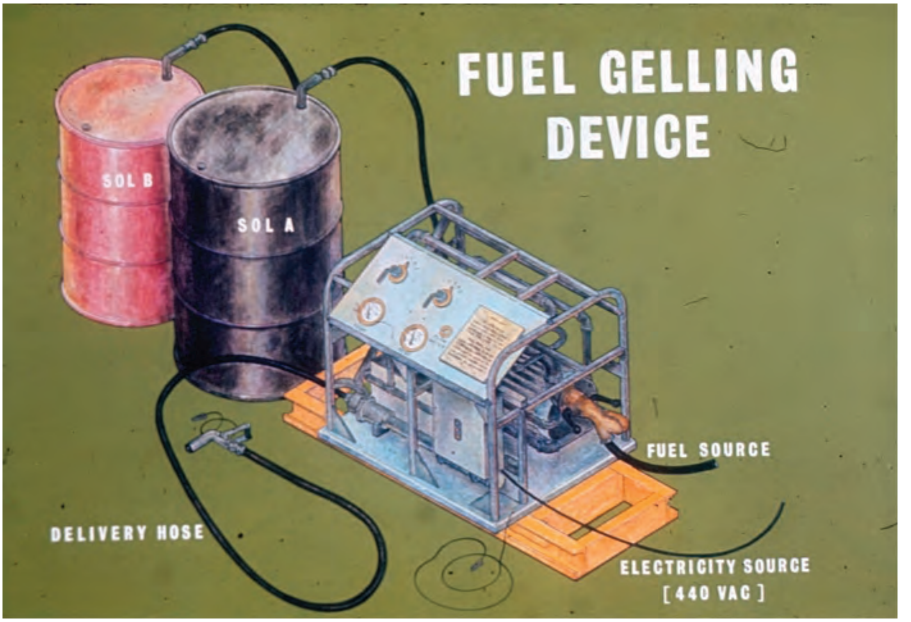
[49]S-304, Bowen interview, 6–7.

Fireye Fuel-Gelling Unit

Fireye was an incendiary weapon proposed as part of the Eye series. It was designed to improve upon the standard firebombs, being light, low-cost, in kit form, easily shipped due to a high stacking ratio when unfilled, and rapidly assembled with common tools. It would carry approximately 35 gallons of gelled aviation gasoline and have a filled weight of 250 pounds.

Early on, the program was troubled by failure of the low-density weapon to obtain safe separation from the delivery aircraft, and there were funding difficulties as well. Fireye itself did not proceed into production to replace the Mk 77 and Mk 79 firebombs.

The program, however, did produce one useful system that was fielded in 1968: the Mk 1 Mod 0 fuel-gelling unit. The unit used gelling agents and a mixing nozzle to form an instantaneous fire bomb gel using any aviation or vehicle fuel. Gel quality was not affected by contaminants, such as water, and so gelling could be accomplished under the most adverse operational conditions. Unlike napalm, which was invented at Harvard early in WWII and (as manufactured by Dow and DuPont and others) used extensively in Vietnam, the gel did not atomize or shear thin on ground impact and thus provided an intense fire of sustained duration. The gel had a more clearly defined edge effect and was thus better to use in close proximity to friendly troops. The *Tech*



Fuel-gelling unit.

History noted, "The users report that unit operation is safer and cleaner and requires 50 percent less personnel and 40 percent less fire bomb filling time than previous methods." The prototypes were sent to Vietnam in 1968, and the unit was released to production in 1969.[50]

Fuel-Air Explosives (FAEs)

Beginning in 1960, China Lake had established a relationship with the Advanced Research Projects Agency (ARPA) to develop weapons and tactics for conflicts that "lie below the threshold of that categorized by the term 'Limited' War." ARPA sponsored Project AGILE to support "military and paramilitary forces engaged in or threatened by conflict in remote areas of the world." One early AGILE-funded effort at China Lake was the development of FAEs.[51]

A fuel-air explosive weapon (originally shortened to FAX and later FAE) is a container that releases or generates an explosive aerosol cloud (liquid, gas, or even fine particles) and has a mechanism for igniting that cloud. FAE devices may be hand emplaced, air dropped, or launched by rocket. Their chief distinction from traditional bombs is that the primary damage mechanism is a long-duration blast overpressure, rather than fire and/or fragments. An enemy soldier in a foxhole or tunnel might survive a nearby bomb blast but might not avoid the blast pressure of an FAE detonation. Since FAE uses ambient air for an oxidizer, nearly all the weight of the weapon is fuel.

In Vietnam, FAEs were used for a variety of purposes, including an antipersonnel weapon, a method for clearing landing zones, and a means for detonating enemy mines. FAE grenades were experimented with, but the small devices proved ineffective.

Chemist William A. Gey did the original FAE development work, and Dr. Richard J. Zabelka began the initial weaponization process. James A. Bowen took over management of the FAE effort in 1966. At the time, the Vietcong were mining helicopter landing zones with a booby trap that, when hit by the downdraft from the helicopter, would arm a grenade and hurl it into the air. The fear of the devices was nearly as limiting to helicopter landing operations as the actual damage caused by the devices.

Working under an RDC priority, Bowen and Michael Aley (FAE chief engineer) and their team developed an FAE device capable of neutralizing the booby trap. This evolved into a 500-pound FAE weapon—the CBU-55 (for

[50] *NWC Tech History 1968*, 1-24.

[51] ARPA, *Project AGILE*, 1. ARPA became DARPA, Defense Advanced Research Projects Agency, in 1972; ARPA again in 1993; and DARPA again in 1996.

carriage on slow-speed aircraft such as helicopters) or the CBU-72 (for delivery from high-speed aircraft)—that was delivered to Vietnam in 1970. These were used successfully by Marine close-air-support units as well as Light Attack Squadron Four (VAL-4), the only Navy close-air-support squadron in Vietnam.

When used in the right situations, FAE was very effective. In the clinical language of the *Tech History*, FAE

> produces a homogeneous-effects region around the functioning point with a short, predictable cutoff range from a region of high lethality to a region of complete safety. This attribute is not only especially attractive for close air support, but is also important when the engaged targets are close to nontargets.[52]

"Nontargets," in many cases, referred to Marines or soldiers hunkered down and under fire within 100 yards of the enemy.[53]

Jim Bowen (left), Marine Lieutenant Colonel Bob Oliver from DDR&E (top right), and Mike Aley (bottom right) with FAE, Vietnam, 1970. U.S. Navy photo by Larry Zabel.

FAE weapons were devastatingly effective against enemy troops, and the weapons' mere presence in the battle zone was itself a psychological weapon. Soon the Air Force was also using the CBU-72 delivered from F-4 Phantoms.

[52]*NWC Tech History 1976-77*, 1-70.
[53]Ibid.

Starting in 1968, NWC-designed hand-emplaced 8-inch-diameter FAE units—designated Fuel-Air Weapon System One (FWS-1)—were used by Marines to clear pressure-sensitive mine fields. China Lake developed several variants on this mine-clearing technique for the Marines, including a rocket-launched version called Surface-Launched Unit FAE, a Catapult-Launched Unit FAE (which was actually rocket-launched from an amphibious assault vehicle), and a helicopter-delivered Mass-Air-Delivery FAE.

In the mid-1970s, development of an improved version of FAE, FAE-II, was undertaken as a joint-service program. The Navy was lead service, with the Air Force participating and the Army monitoring. A pair of weapons, the BLU-95/B (500-pound class) and BLU-96/B (2,000-pound class), resulted. Unlike the earlier FAE weapons, they could function unretarded at the maximum weapon delivery speeds of all the U.S. attack aircraft, which greatly increased weapon delivery accuracy.

May 1976 brought a tragic reminder that the weapons development business is, by its nature, dangerous. While testing an experimental Air Force FAE weapon on NWC's B-1 Range, three members of the China Lake workforce—scientist Joseph A. Holman, Chief Warrant Officer 4 Charles D. Alderman, and electrician's mate Petty Officer First Class Ralph E. Loux Jr.—were killed while performing a field examination of a booster component of the weapon, which had hit the ground as a dud. From 1968 through 1979, 10 military and 5 civilian employees lost their lives in various work-related accidents at China Lake.

As a means to actually clear vegetation from potential helicopter landing zones in wooded areas, a technique tried early in the war, FAE was not very effective. The explosion cleared the trees but left jagged stumps sticking up in the cleared area, which made it difficult for troops in full gear to debark from a hovering helicopter. On a pickup mission, when the soldiers or Marines might be carrying wounded and be under fire, reboarding the helicopters was nearly impossible. A more effective method for clearing landing zones was needed and, as usual, China Lake engineers had it.

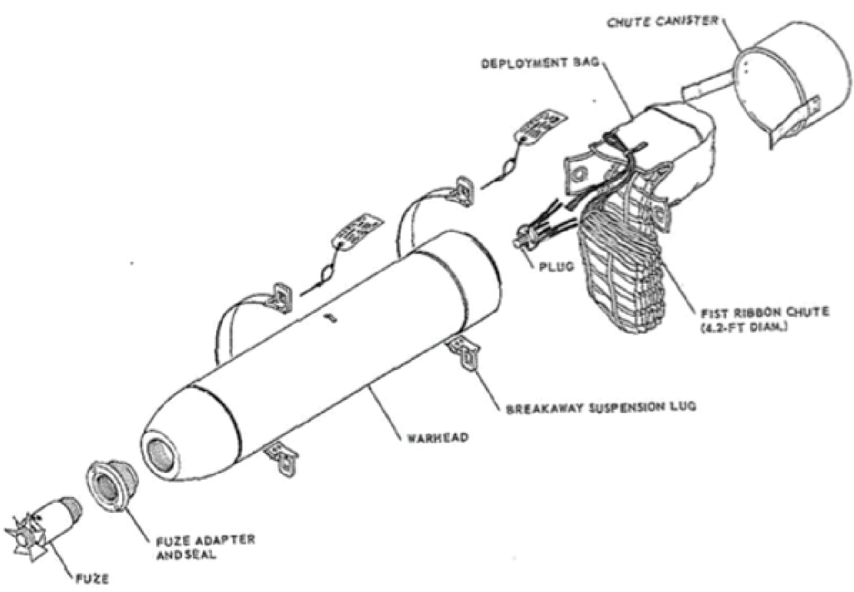
Helicopter Trap Weapon

A grenade launcher triggered by a helicopter downdraft wasn't the only ingenious technique used by the Vietcong to deny U.S. helicopters access to landing zones. An even simpler one, which started appearing early in the war, was to implant long bamboo poles vertically in open areas that might offer choppers a potential touchdown spot. The poles were nearly impossible to spot from above but were sufficiently stout to damage a helicopter's rotor.

An equally ingenious solution to this problem came from E. D. "Dall" Hughes' team in the Weapons Development Department. Their Helicopter Trap Weapon was built around a Zuni continuous-rod antiair warhead consisting of a bundle of 3/16-inch steel rods welded together at alternate ends in a cylindrical configuration around an explosive charge. When the warhead was detonated, the rods expanded (at 4,500 feet per second) into a ring designed to slice through the aluminum skin of an aircraft. Hughes' team attached the warhead to a parachute so that it fell in a vertical nose-down configuration, with a detonator at the tip of the warhead. Dropped on a potential landing zone from a slow-flying fixed-wing aircraft or helicopter, the weapon's steel ring, expanding close to and parallel with the ground, would clear a 50-foot circle of poles, brush, and small trees. Multiple units could be used for a larger landing zone. The first Helicopter Trap Weapons were sent to Vietnam in 1963 through the ARPA AGILE project.

Bulldog

In the 1950s, Martin Marietta had produced an air-to-surface weapon called Bullpup (AGM-12). Rocket powered, radio controlled, and carrying a 250-pound (later 1,000-pound) warhead, the weapon had a range of about 10 miles. In operation, the launch pilot controlled Bullpup through radio



Helicopter Trap Weapon.

signals, using a joystick and watching the weapon's tail-mounted flares as it flew toward the target.

Although Bullpup was launched in Vietnam by both the Navy and Air Force, it was not very effective against North Vietnamese bridges. Further, it required the pilot to follow behind the weapon in a straight line to the target as he steered Bullpup, lowering the odds of aircraft survivability. Worse yet, in 1960, the original solid-fuel rocket motor was replaced with a powerful liquid-fuel rocket motor (for greater range) that posed a hazard to the aircraft carriers.

In the late 1960s, Conrad Neal's Guidance Systems Branch in the Weapons Development Department adapted a laser-guidance scheme to Bullpup. They called the new weapon Blazer. When the Marine Corps, in 1969, established a requirement for a close-air-support weapon to be fired from behind friendly forces, the Center responded with the Blazer concept, now renamed Bulldog (the Pup grown up), later designated AGM-83.

China Lake opted to go with off-the-shelf hardware as much as possible to minimize time and cost. The result was a Bullpup airframe and warhead section controlled by modified Sidewinder 1A (AIM-9B) control fins and guided by a Sidewinder 1A seeker head modified for semi-active laser homing.

An advantage to the new weapon system was that it required no fire-control system on the aircraft. Bulldog guided on energy reflected from a laser designator operated by a ground-based or airborne forward controller. Neal's group was already working on the hand-held designator.

Marine technician checks Bulldog missile on A-4E Skyhawk, Armitage Field, 1972. Photo courtesy of Gary Verver.

Corona, meanwhile, was working on a strap-on laser-homing device for Mk 82 and Mk 83 bombs, so-called "convert-a-bombs," thus putting that laboratory in direct competition with China Lake's Bulldog. (Although Corona had been merged organizationally with China Lake in 1967, the physical consolidation of the two bases was still more than a year away.) Unlike China Lake—which had helped the Marine Corps write the close-air-support weapon operational requirement—Corona was unaware that the Marines wanted a powered weapon to assure that it did not fall short among friendly groups.

In a meeting at Corona with NAVAIR's Bob Fulmer (who reported to John Rexroth, then head of NAVAIR's Missile Development Office), the competing concepts were discussed. When the Marine Corp's desire for a powered weapon was pointed out, that was the end of the competition. Philip G. Arnold believed that the competition illustrated

> the difference between a laboratory fully engaged with all aspects of operational requirements, weapon development, and deployment [China Lake] and a technically competent laboratory working in a more conventional laboratory environment [Corona].[54]

Technical Director Tom Amlie decided that Bulldog program management should be handled by Corona. Donald R. Totten was selected to head the program. Raytheon, Texas Instruments, and Martin Marietta competed for a contract to build 35 guidance and control sections, and Texas Instruments won. The contract was awarded in March 1970.

Development went smoothly. Cost were low, largely because of the availability of stockpiled Bullpup airframes and warheads and Sidewinder 1A guidance and control systems. In fiscal year 1970, the Center received $3.6 million, and a similar amount was received the following year. NAVAIR released Bulldog to pilot production in

Phil Arnold.

[54]Phil Arnold review comments, 31 October 2014. In his 38-year career at China Lake, Arnold managed several major development programs and retired as head of the Weapons Planning Group.

1971. The projected production and conversion cost of Bulldog was estimated to be $14,000 per unit.

Claude Owen, an ex-Coronan and former naval aviator, was assigned as the flight test engineer for Bulldog. He recalls the first launch of the missile with a preprogrammed guidance system in 1970. Owen was in the back seat of the launch aircraft, a TA-4.

> After about three dry runs, we were cleared for our hot run (launch). We rolled in for that run, and at T-0 we punched her off. Then all hell broke loose; that rocket motor ignited, and it looked like a fiery telephone pole. The missile immediately pitched up directly in front of us, and if the pilot hadn't been on his toes and broke hard port, we would have hit the bird.
>
> The rest of the flight was as per plan, so after "impact" we went down for our low photo pass. We must have gotten too low to the "greasewood" because all of a sudden I felt a thud, and we started a violent turn left. Again the pilot was on his toes, and even though we had an excessive amount of port drag, he was able to bring it back to the Naval Air Facility and land.
>
> Following landing, we determined two things: 1) Our camera pad had struck something and had split wide open, and 2) the reason why that Bulldog pitched up in front of us was because the programmer had not fully reset.[55]

In 1971, concerns about the danger of Bulldog's liquid rocket motor aboard ships prompted a switch back to the original D5 Mod 2 double-base solid rocket propulsion motor. (A preliminary design for an IR seeker for Bulldog was also completed that year.) Out of 19 Bulldog firings from A-4 and A-6 aircraft that year against stationary and moving targets, 15 missiles guided to impact. For those 15 rounds, the average circular error probable (CEP) was 2.5 feet, well below the weapon's design goal of 10 feet and far better than the earlier Bullpup.[56]

Despite the progress, fiscal year 1972 funding for Bulldog was not forthcoming, and NWC submitted a new initiative to the CNO for development funds. A December 1972 *Rocketeer* article about Bulldog reported:

> Totten . . . announced recently that the development effort on this weapon is completed and that the first pilot production hardware rolled off the line in October. Preparation for Fleet introduction of the weapon is well under way.[57]

Although Bulldog was approved for service use in 1974, it never went to the Fleet. At the same time that Bulldog was being developed, the Air Force

---

[55]Owen, *Barnstorming to Spaceships*, 114-115.

[56]*NWC Tech History 1971*, 1-30. CEP is the radius of a circle, centered on the target, within which 50 percent of the rounds will hit.

[57]*Rocketeer*, 8 December 1972, 1.

was developing the laser-guided Maverick missile. The Office of Secretary of Defense decided that a common laser-guided attack weapon should be developed for the Air Force, Navy, and Marine Corps, and Maverick was selected. The Air Force was given the lead role in developing Laser Maverick, and Bulldog was cancelled.

Bulldog and Laser Maverick pointed out a fundamental difference in weapon system acquisition strategies between the Navy and the Air Force—in-house versus out-of-house development. Traditionally, a Navy laboratory, usually NWC, designed and developed a weapon, carrying it from exploratory research and concept formulation through validation, prototyping, and engineering development. The laboratory's end product was a detailed Level 3 drawing package telling the production contractor exactly what to build.[58]

For a variety of historical and technical reasons, the Air Force had not developed that in-house capability. Instead, they contracted out the design and development.[59]

Of the Navy approach to building missiles, senior systems engineer Dr. Bob Smith said, "It was a great way to lower cost in terms of competition. The contractor had to simply take those drawings and produce that particular product. They weren't involved in the engineering design per se." For necessary design changes to improve producibility or incorporate new technology, a mechanism known as the engineering change proposal (ECP) allowed the contractor, with the permission of the overseeing laboratory, to make specific changes to the Level 3 package.[60]

Of the Air Force approach, Smith commented:

> Their model was, "We simply tell [the contractors] what we want roughly and let them go do everything." We have seen that that doesn't work very well. In fact, the contractor would rather be told "I want you to do this, this, and this." They do it, they get paid, and they're happy. When you give them rather vague

---

[58]DoD had three levels of engineering drawings: Level 1, Conceptual and Developmental Design; Level 2, Production Prototype and Limited Production; and Level 3, Production.

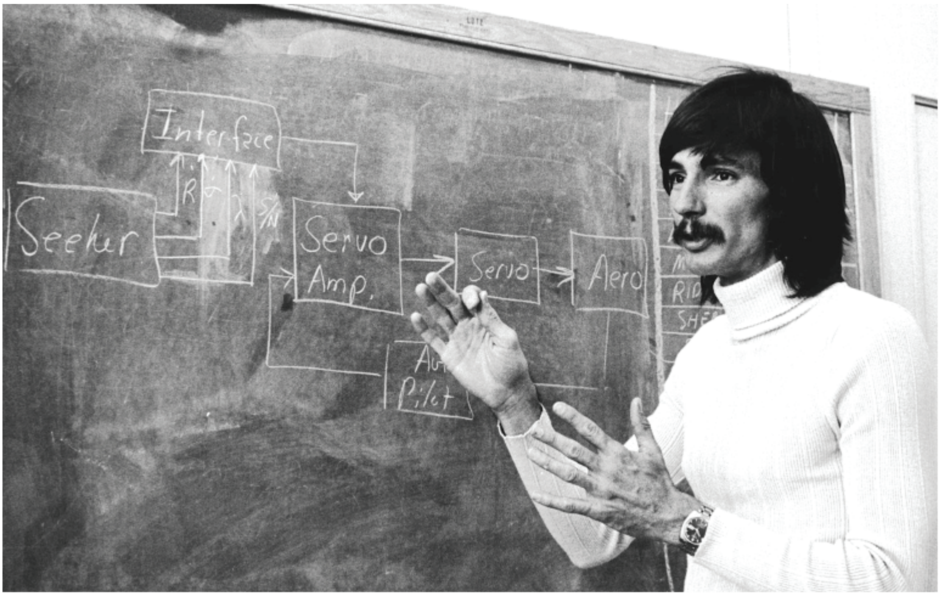
[59]Dr. William B. McLean, China Lake's longest-serving Technical Director (1954-1967) observed:

> Aircraft you fly and fix. Missiles you test and store. And the procurement procedures needed to have a product that you can put in storage, and be assured that it will remain viable and until it's taken out for its first and only flight, are quite different from the procurement technologies that you require in order to build aircraft that will be tested and flown every day and fixed when they break down.

B-1-75, McLean interview, 8.

[60]S-337B, Smith interview, 10. Smith is a 38-year China Lake veteran and a recipient of the Presidential Rank Award of Meritorious Senior Professional.

directions and ask them to develop certain things, I think you get in trouble because you don't really know exactly what they are going to develop.



Dr. Bob Smith.

For both the Navy and Air Force, the term "trouble" with contractors usually meant some combination of cost and schedule overruns, reliability problems, and performance shortcomings.[61]

Marc Moulton was less charitable in his assessment of the contractors' role in systems development.

> This place [China Lake] was originally set up so that engineers, technical folks, had the freedom to develop things without a profit motive so they could get them to work. Quick response, get them out into the Fleet.

As for the contractors,

> there's no way to be nice about it, they milk the projects, if the government's footing the bill, and the taxpayer gets ripped off almost every time. Sometimes it looks like you're getting ripped off, and you're not. More often, you are getting ripped off, just because there's a lot of money involved.[62]

When China Lake scientists and engineers had developed the systems that the contractors built, the Navy could recognize abuses. "We were in a strong

[61]Ibid.
[62]S-245, Moulton interview, 17.

technical position; we knew what we were talking about, because we were the guys who built this stuff. We drafted the technology; we understood it in every detail," Moulton said.

The Air Force, by contrast, was more vulnerable to contractor manipulation because the contractor themselves did the development work. "The Air Forces' approach was always, go to the contractor—monitor the contracts," observed Moulton. "We never could see a way for the person monitoring the contract to get smart enough to do that. The contractor could pull the wool over his eyes every time because, where's his experience?"

The real loser in the Laser Maverick acquisition was the Marine Corps. Before the weapon reached production, the Air Force rethought its position and cancelled the Air Force share of the proposed procurement. This action greatly increased the projected costs of the Marine Corps version. The Marines did not receive the Laser Maverick (AGM-65E) until 1985—and then at about $140,000 per copy.

Navy Pave Knife

Laser-guided bombs (LGBs) were first used in Vietnam by the Air Force beginning in 1968. The accuracy of these weapons far exceeded that of unguided bombs. Military historian Max Boot reported that

> 48 percent of Paveways [LGBs] dropped in 1972–73 around Hanoi and Haiphong achieved direct hits, compared with only 5.5 percent of unguided bombs dropped on the same area a few years earlier. The average Paveway landed within 23 feet of its target, as opposed to 447 feet for a "dumb" bomb.[63]

In July 1972, NAVAIR assigned China Lake an urgent program to develop and field: a self-contained system for "delivering laser-guided weapons in a hostile, clear-weather, daylight environment."[64]

Phil Arnold was assigned to manage the job. Arnold recalled:

> Rear Admiral Moe Wittman [Narvin O. Wittman, force material officer] in AIRPAC had called China Lake asking if we could recommend a quick-reaction solution to a requirement for airborne laser designators to be used with the LGBs now in the Navy inventory. Chuck Smith [Arnold's division head] and I looked about for possible systems, including a designator to be used with a FLIR sensor. We decided that Pave Knife, an Air Force-developed pod with a television sensor and laser designator, could be integrated with Navy

[63]Boot, "From Saigon to Desert Storm," 32. Many of the unguided bombs were dropped en masse from B-52 bombers in a style called saturation bombing.

[64]*NWC Tech History 1972*, 2-4.

> aircraft and be fielded in a time of months. We made the recommendation to Wittman and were given a QRC [Quick-Reaction Capability priority] project to get the job done.[65]

The Air Force was already using Pave Knife, developed by Philco-Ford (later Ford Aeronutronic) in Newport Beach, to deliver the Texas Instruments-developed Paveway LGB from the F-4 Phantom. It was an effective combination. Pave Knife, used with the GBU-11 LGB, facilitated the Air Force's May 1972 destruction of the Thanh Hóa Bridge—called Hàm Rồng or "Dragon's Jaw" by the Vietnamese—after hundreds of costly and unsuccessful raids by Air Force, primarily, and Navy aircraft.

Arnold's program was called Navy Pave Knife. China Lake acquired two of the Pave Knife pods that had been built and tested for the Air Force and, with the assistance of Ford and the Naval Air Rework Facility, Alameda, converted them for use on the A-6A.

As with most programs, there was some political opposition to Navy Pave Knife. Arnold philosophized:

> Project advocates see their programs as part of a zero-sum game. For every winner, they see a loser. In the case of Navy Pave Knife, the Precision Guided Missiles Program Coordinator, Captain Charlie [Charles W.] Fritz in OP-506 believed that procurement of a laser designator for the laser-guided bomb would put Data Link Walleye in jeopardy, so he was not favorably inclined to a Navy Pave Knife program. However, a requirement from the Fleet (AIRPAC is a Fleet command) is sacred in OPNAV, and a positive response to the requirement was forthcoming.[66]

Contained within the 1,200-pound low-drag Pave Knife pod—"a large, ungainly looking beast," Arnold described it—were a low-light-level television camera, laser designator, laser range receiver, stabilized sight, and a video tape recorder that replaced the kinescope in the original Air Force version.

Three A-6A aircraft were modified to accept the pods. In the cockpit, the Pave Knife instruments were split between the bombardier navigator in the right seat (hand controller for the laser designator and camera and a radar/TV display) and the pilot in the left seat (laser range display and sight-line indicators). In operation, the bombardier/navigator lined up the camera and designator on the target. The pilot used the sight-line indicators to maintain a heading that would not exceed the gimbal limits of the pod's optics.

By year's end, carrier suitability had been established and the necessary shipboard facilities had been defined, designed, and installed on USS *Ranger*

[65] S-275, Arnold interview, 36.
[66] Ibid., 37. Captain Fritz had been Commanding Officer of VX-5 from 1968 to 1970.

Navy Pave Knife on centerline station of A-6 aircraft.

(CVA-61). In Fleet-assisted operational evaluation, carried out by Attack Squadron (VA)-145, the system achieved a CEP of 18 feet in eight drops. The three aircraft were also modified to be compatible with the soon-to-be-fielded Walleye II data link.

In December 1972, 5 months after China Lake had been assigned the project, the A-6As equipped with Navy Pave Knives were flying combat missions in Vietnam; in nine Pave Knife attacks, seven bridges were damaged or destroyed. The following year, the *Tech History* reported that "the system enabled the squadron to destroy strategic enemy targets with pinpoint accuracy; in one mission, all 16 bridges to be attacked were destroyed in less than 3 hours." In all,

Bombardier/navigator Robert Champney (left) and pilot Pat Cornelius (right) aboard USS *Ranger* (CVA-61) during Pave Knife operational assessment.

the VA-145 flew 85 Pave Knife sorties before the *Ranger* returned to the United States in June 1973.[67]

By 1977, the Pave Knife system had been installed on Fleet A-6Es as well. It provided the only stabilized airborne laser-designation capability for delivering LGBs until the fielding of the A-6E target recognition and attack multisensor (TRAM) in 1979. Navy Pave Knife was a China Lake success story—a quick-reaction program completed within budget that provided a much-needed capability for the Navy's forces at war.

Laser Air Intercept Missile (LAIM)

In 1972, China Lake engineers modified an AIM-9B Sidewinder air-to-air missile to function as an air-to-surface weapon. Called LAIM, the seeker was modified "to guide on laser energy reflected from a surface target that a forward controller illuminates with a remote laser designator." With a launch range up to 14,000 feet, the weapon could be fired outside the range of 57 mm guns (one of the principal air-defense weapons of the North Vietnamese). In a test at China Lake, LAIM was launched at a slant range of 12,000 feet and guided to a direct hit on an M41 tank target, penetrating the hull with a non-explosive slug target. Another test using a Zuni warhead modified with a shaped-charge penetrated 11 inches of armor plate.[68]

LAIM intercepting tank target.

The *Tech History* that year reflected the enthusiasm of the developers:

> LAIM makes maximum use of proven systems and existing equipment. The Sidewinder servo and rocket motor are utilized unchanged. The Sidewinder seeker is only slightly modified to accept a new detector. The tracking electronics are changed to process laser pulses instead of low-frequency IR signals. For a fraction of the time and cost normally expended in providing such a capability, LAIM can be made operational.

However, there is no evidence that it ever was.[69]

[67] *NWC Tech History 1972*, 2-26; *NWC Tech History 1973*, 2-23, 2-4.
[68] *NWC Tech History 1972*, 2-15.
[69] Ibid., 2-16.

Laser Spot Tracker

In 1967, China Lake conducted an exploratory development program for a laser target-designator system. The study resulted in a Specific Operational Requirement (SOR) for the program, which began in 1968. As fielded in the A-4 aircraft in 1970, the system consisted of a ground-based or airborne laser designator that marked the target with a laser spot; a laser spot tracker mounted in the nose of the aircraft; a Farranti gunsight slaved to the spot tracker; a target position indicator that showed the pilot the target position relative to the aircraft's heading; and, of course, the laser-guided bomb. The reticle on the pilot's head-up gunsight was slaved to the search set, giving the pilot the option of either a manual attack or an automatic attack (in concert with the aircraft's weapon release computer).

By 1972, the laser target-designator system had become known simply as the Laser Spot Tracker. Eight A-4Fs from VA-164 were equipped with the system, and in January of that year, the squadron deployed to Southeast Asia where the systems "proved highly successful in combat."[70]

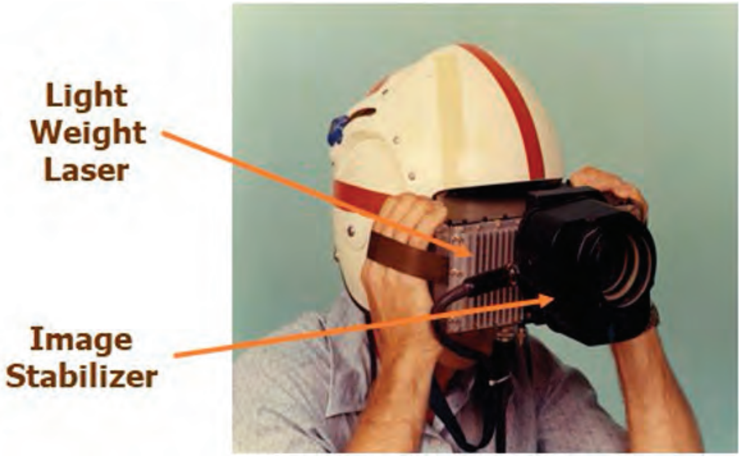
Lightweight Laser (LWL)

Beginning in 1971, China Lake designed, developed, and manufactured a lightweight (8-pound), 1.06 μm neodymium laser designator equipped with an image-stabilizer unit. The device was called the LWL. These hand-held

Engineer Gary Ozunas installing Laser Spot Tracker on A-4.

[70]*NWC Tech History 1972*, 1-31.

units were used in Vietnam from the back seat of TA-4s, OV-10s, and F-4Bs to designate targets for the GBU-10, -12, and -16 laser-guided bombs. The laser was fired through the aircrafts' plexiglass canopies. By November 1972, 300 laser-guided bombs had been dropped on targets that were designated with the LWL, with a 71 percent success rate. In 1973, the LWT, by then designated the AN/PAQ-2, was modified to increase its range to 6 kilometers. The device remained operational in the Fleet until 1978.[71]



LWL.

Mobile Universal Laser Equipment (MULE)

In 1976, the Army, which had been designated by the DoD as the lead service for all ground-based laser designators, turned to NWC for support of a program dubbed MULE. MULE was a man-portable laser-designator system that was designed primarily for use by artillery forward-observation teams. The system was designed with two purposes: location of targets by range, elevation, and azimuth with respect to true (grid) north and designation of targets for laser-guided weapons and for aircraft equipped with the laser spot tracker. It was to be used by both the Army and the Marine Corps.

MULE had three principal components: a laser designator/range finder, a north-finding module, and a tracking tripod on which the components were mounted. Hughes Aircraft was selected as the primary contractor, and China Lake's primary responsibilities were development of the north-finding module and assistance with developmental and operational testing. Dr. Truman "Ted"

[71]Ibid., 1-31; *NWC Tech History 1973*, 2-23; *NWC Tech History 1978*, 2-8.

Bergman, a physicist in the Laser Designator Branch, developed the original specifications for the module. Working with Sperry Gyroscope and Litton Industries, China Lake developed the modules, coordinating their efforts with the Army and Hughes.

As the north-finding module neared completion, additional military applications were found for what was essentially a man-portable gyrocompass. Increased interest was shown by several other Army activities, the Air Force, and foreign governments. The compass was approved for service use in 1983. George Baker, a production management specialist, was nominated for the Secretary of Defense Productivity Excellence Award for his work on the north-finding module. He was credited with saving the Marine Corps more than $16 million in production costs.[72]

In 1980, physicist Del Dobberpuhl, MULE's NWC test director, oversaw three weeks of extensive day-and-night testing of the system by a team of Camp Pendleton Marines at China Lake. Marines used the designator against a variety of targets and in various scenarios, ranging from the remote Junction Ranch Range in the Coso mountains to the roof of Lauritsen Laboratory.

Marines from Camp Pendleton testing MULE at China Lake. Published in the *Rocketeer*, 11 April 1980.

One story circulating at the time, perhaps apocryphal, was that engineers found that an electronic connector cable between two components of MULE kept breaking, despite being replaced with a sturdier cable and connectors. The cause was a mystery until one day someone noticed one of the Marines picking up the

[72]*Rocketeer*, 14 December 1995. Baker, who received his 40-year federal-service pin in 1995, joined China Lake as an electronic mechanic (WG-9) and retired as senior program manager (DP-4) for the Gator weapon program.

MULE by the cable, thinking it was a lifting handle. The cable was rerouted to avoid further confusion.

MULE was approved for service use in 1980 and given the designation AN/PAQ-3. Used by artillery forward observers, naval gunfire spotters, forward air controllers, and special operations teams, the equipment was eventually compatible with all laser-guided munitions in the U.S. and NATO inventories.

MULE.

Unconventional Weapons

Not all of the weapons China Lake provided for the Vietnam War were the Center's standard fare of bombs, rockets, and missiles. A subset of weaponry, often described as "unconventional," began development at China Lake early in the Southeast Asia conflict.[73]

In 1961, China Lake's Francis "Frank" M. Fulton, then head of the Propulsion Development Department, published a seminal work on limited-war weapons. Fulton envisioned systems ranging from FAEs and gasoline-fueled small arms to a one-man rocket-propelled flying platform (called Pogo) and drug warfare, including hallucinogens.[74]

Initially under Project AGILE (ARPA) funding, and later with direct funding from Navy Special Operations units (SEALs and underwater demolition teams [UDTs]) and other agencies and organizations, China Lake developed a small arsenal of weapons and gadgets designed for covert operations. The primary interface between China Lake and the special warfare groups was a small team

[73]When the adjective "conventional" modifies "warfare," it generally means non-nuclear—conventional war as opposed to nuclear war. The adjective "unconventional," however, is generally applied to weapons and tactics that are non-traditional and usually associated with guerrilla warfare or what are often called "special operations."

[74]Fulton, *Limited War Weapons*.

led by Robert H. Forster, an electrical engineer with a penchant for creating unusual, unconventional, and unique weaponry.

Some of the special operations items were based on China Lake concepts presented in Fulton's report. For example, the Navy SEALs operating in Vietnam wanted "exploding rocks"; that is, mines that were indistinguishable from rocks but that would explode if disturbed (or after a predetermined length of time). These were never fielded; problems with fuzing plagued the development program, which was finally halted.

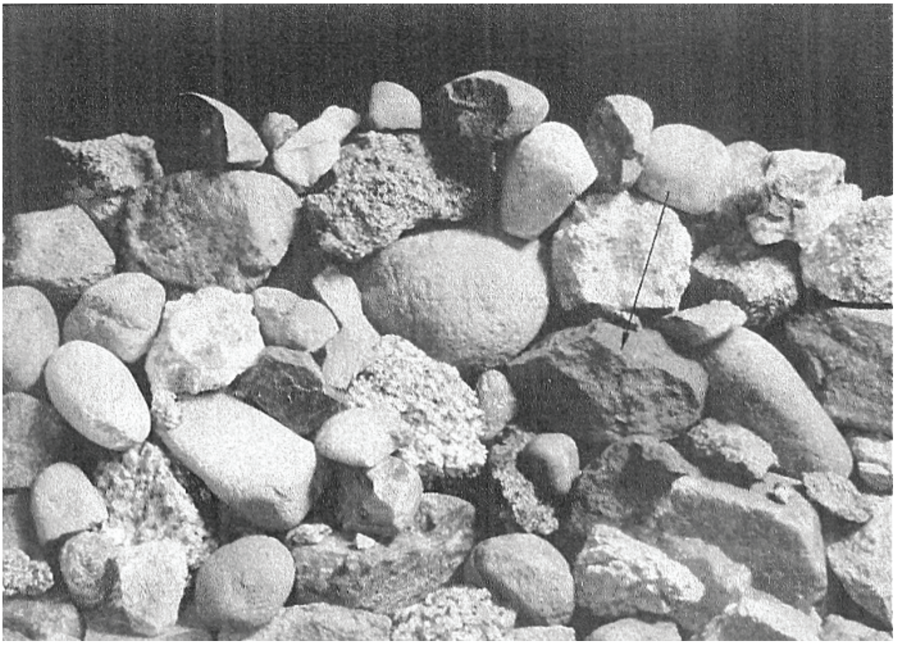
Other concepts were fully developed and shipped to the SEALs. These included booby traps disguised as cameras, binoculars, flashlights, M-16 magazines, .45-caliber pistols, and M-79 grenade launchers. Such items, left at the sites of an ambush, for example, would have a two-fold effect. They would kill or seriously wound an enemy. (The latter was preferred because it not only took the unfortunate victim from the fray but also imposed a burden on those who had to care for and carry him.) The booby-trapped items would also render an entire class of objects suspect in the eyes of the Vietcong, even if 99 percent of those were not booby trapped. One particularly terrifying type of booby trap was a hand grenade that had its 4-second delay fuze replaced with an instantaneous fuze so that the grenade would detonate as soon as the spoon was released.

Robert Forster.

Specialized small arms were designed by China Lake for Vietnam operations. Machinist Al Kermode, gun maker par excellence, built a .50-caliber sniper rifle that purportedly could fire a 6-inch group at 1,600 yards. A gun called the Five-Foot Rifle was a specially modified M-1 rifle designed for the smaller-statured South Vietnamese fighters. The weapon had moderate recoil and, with 90 rounds of ammo, weighed as much as a standard M-1 without ammunition.[75]

Other gun innovations included modified Ithaca shotguns that produced a 2-foot-high, 8-foot-wide pattern at 25 yards; a four-round pump-action 40 mm

[75]Kermode also fabricated, in his home workshop, a .45-caliber automatic pistol with no outside moving parts that fired a 300-grain bullet at 2,000 feet per second. *Rocketeer,* 11 March 1966, 3.



"Rock" (arrow, right center) of plastic-bonded explosive among actual rocks.

grenade launcher; and a selector switch for the M-16 that limited automatic fire to three-round bursts to conserve ammunition.

The Target Illumination and Recovery Aid (TIARA), which began as a Research Department project in 1961, was developed by NOTS into a host of chemical markers—chemiluminescent technology—that could be packaged as grenades, marker sticks, mortar shells, and, by 1967, air-delivered 100-pound bombs and modified Zuni rocket warheads. These eventually led to the invention of ChemLite™ by NWC chemists Herbert P. Richter and Ruth Tedrick and ultimately became a multimillion-dollar nonmilitary industry.

A 1966 survey of China Lake's SEAL and UDT customers revealed the need for a neutrally buoyant explosive haversack for use against underwater targets. The resulting 6.5-pound Mk 137 explosive haversack had an immersed weight of .25 pounds and could carry enough explosive to sink a ship. And because the SEAL teams did not have a detonating cord that worked reliably under water and could be tied in firm knots, China Lake developed a lightweight, high-strength, waterproof detonating cord for SEAL use. Extensive testing led to the selection of EX-6 explosive sheathed in two layers of Nomex®. The cord was released for Fleet use in 1971.

Other SEAL gear that China Lake produced was as simple as standard Silva fluid-filled compasses with an extra-long wrist strap to fit around a wet suit or

Several special weapons developed by China Lake during the Vietnam War.

plastic mud plugs for the M-16 that could be fired through without hurting the weapon or the shooter.

SEALs were frequent guests at China Lake, where they trained extensively on the new weaponry and tools under development at the Center. Training was carried out at a specialized range known as FLRIII (so named for its proximity to a remote flight-line-recorder station on the High-Altitude Bombing Range) and in the Underwater Test Facility at Salt Wells. SEALs also helped by providing feedback on such developmental programs as a hand-held acoustic locater and a single-swimmer propulsion unit.

Swimmer Delivery Vehicles (SDVs)

One of the most ambitious projects to be undertaken for the special operations forces during the Vietnam War was the SDV. In the late 1960s, the SEALs had contracted with industry for the design and development of an SDV, a vehicle capable of transporting SEALs from a submarine to an operational site—a ship, a beach, an off-shore observation post—and back. Two versions were contracted: a two-man "attack" model designated Mk IX and a six-man personnel/cargo version, Mk VIII.

The contract with the industrial developer was terminated in 1971, and NWC began to work the problem. In 1972, the Center was tasked by NAVSEA to update the existing Mk VII vehicle, develop the Mk IX, and determine if the contractor-developed Mk VIII could be approved for service use. The short answer to the latter part of the task was "no." NWC totally redesigned the Mk VIII, a task that was completed in 1975.

The Mk IX attack model was designed and developed, and that task, too, was completed in 1975. Both vehicles featured the latest in obstacle avoidance

Mk IX SDV circa 1972. Published in NWC TP 5296, *Final Report on SDV Instrumentation Package*, January 1972.

and Doppler navigation technologies as well as rendezvous and docking sonar. An SDV pilot/navigator course was developed to help the SEALs maximize the capabilities of the vehicles. The Mk VII vehicles were also updated with sonar systems.

Most of the work for the SDV was done in the Special Operations Branch of Bob Forster's Special Projects Division, which was part of the Electronic Systems Department until it was transferred to the Surface Missiles Department in 1973. The group later became the Mechanical Systems Branch of the Weapons Department; Bob Clapp was the branch head and principal mechanical engineer for the SDV projects. Bill Grady, an electronic technician, developed the sonar gear for the two craft, and Carl C. Halsey was in charge of testing and support facilities. Kenneth Specht was the original program manager, a job later held by engineer Jimmie Craig.

William B. Porter, who headed the Weapons Department through much of the development period, recalled:

> Every year there was a big battle because we were getting more money to work on the swimmer delivery vehicles and weapons and different devices

> for the swimmer delivery people, or the SEALs, than the lab that had the mission [the Naval Coastal Systems Laboratory, Panama City], and every year the sponsor would send the money and we'd go do the work for them and they were satisfied. And every year there would be more of a hue and cry about why were we doing that work that wasn't in our mission.[76]

Bill Porter.

In a Navy laboratory system that was increasingly compartmentalized into discreet missions and assigned responsibilities, the situation could not last.

> Each new [NWC Commander] would ask why were we doing it, and when we showed them what we were doing and so on, then they sort of looked the other way or they said, "Well, keep doing it as long as you can, but if push comes to shove, we may not be able to support you continuing to do it." Finally we reached the point where they transferred the swimmer delivery vehicle programs to Panama City [in 1977].[77]

Support to the special operations community demonstrated one of the strengths of the Navy laboratories: the ability to design and produce limited-production/limited-application items that are not cost effective for industry to develop. But it also pointed up one of the shortcomings of the laboratories: rice-bowl-ism, or the tendency of laboratories with an assigned mission to complain loudly when another laboratory appeared to infringe on that mission.

While China Lake's technical people were willing to take on any task they thought they could handle—as long as it came with funding, and occasionally, even if it didn't—the attitudes of the military commanders toward tasks that fell outside the assigned mission areas varied from full support (which could be career jeopardizing to a captain or rear admiral, particularly if the technical task did not go well) to firm opposition, the latter being the safer course and the one most appreciated by bureaucratic superiors.

---

[76]S-216, Porter interview, Part 2, 45.
[77]S-216, Porter interview, Part 2, 46.

During the glory years of the base, tension and friction between China Lake's civilian technical community and its military command had seldom been a problem. As the 1970s progressed, however, and a series of admirals took the helm at China Lake, it would become an issue of crisis proportions.

Vietnam Laboratory Assistance Program (VLAP)

A central element in China Lake's success as a weapons development laboratory was direct, unmediated contact between experienced Fleet military personnel and the scientists and engineers who devised the Navy's weapons. It was built into the structure of the base; from the Commander and Technical Director on down, military and civilians rubbed shoulders at work and at play, and the output of the Center reflected both technical sophistication and military practicality. Peggy Rogers was renowned for having a combat-tested military aviator sit in on briefs of new weapon concepts to provide a reality check for the enthusiastic technical types who might not have considered all the practical ramifications of their latest death ray design or intelligent bullet.[78]

The VLAP turned that idea on its head. Rather than bringing the military into the laboratory community, it put the laboratory community into the field. Established in 1966 by the DNL, VLAP sent civilian scientific and technical advisors to Navy and Marine combat units in Southeast Asia. Problems that seemed insurmountable to a military person were sometimes amenable to solution by the advisor. And if a solution wasn't immediately apparent, the advisor had the resources of the laboratories at his disposal.

NWC and NOL White Oak shared lead laboratory responsibilities for VLAP. China Lake was the West Coast coordinator, overseeing the VLAP activities of Naval Electronics Laboratory Center (NELC), 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.

There were little restrictions on the program; the general guideline was that no task should be undertaken that would cost more than $50,000 or take

[78]Dr. Ed Royce contrasted the attitudes of Office of Naval Research (ONR) and China Lake civilians to their respective military partners: "The ONR people would much rather have lunch in the Faculty Club than in the Officers' Club." S-354, Royce interview, 48.

The custom of sending technical people to the operating forces was not new to China Lake. Technical introduction teams had traveled to ships and stations with new weapons since Frank Wentink's and Bob Sizemore's trips in the mid-1950s (introducing the 2.75-inch FFAR and Sidewinder). The practice was formalized with the establishment of a Fleet service group within the Central Evaluation Group and later with the Engineering Department's In-Service Support Division, set up under Ted Lotee in 1957.

more than 90 days to complete, and no large-volume production should be undertaken.

China Lake engineers Frederick H. Davis and Bud Sewell and Corona engineer John J. Nastronero were the first three China Lake VLAP representatives to be sent to Vietnam. Another representative (who took five trips to Vietnam) was Gerry Schiefer, who in 1981 would become China Lake's Test and Evaluation (T&E) Director, in 1986 the Center's 11th Technical Director, and in 1989 the DNL. Dr. Newt Ward and Dr. Robert F. Rowntree, as program coordinators, maintained liaison between the field representatives in-country and the laboratory and range personnel at China Lake.

Fred Davis.

Given the fluid military situation in Vietnam during the late 1960s, VLAP assignments could be dangerous. Carl Halsey had been an explosive ordnance disposal (EOD) technician in the Korean War. Of his time working on some of Bud Sewell's projects in Vietnam, Halsey said, "I got more combat experience as a civilian than I ever did in the military."[79]

Gerry Schiefer.

VLAP projects ranged from the mundane to the esoteric. In 1968, China Lake developed a small ground beacon (radar transponder) used by friendly troops to identify themselves to A-6 Intruder aircraft at night or in bad weather. In 1969, VLAP projects included

> a moving-target-indicator radar, modification of an infrared camera

[79]S-287, Halsey interview, 5. Halsey would spend 54 years working at China Lake.

> and attachments, development of a map illuminator for reconnaissance patrols, and work on a luminous wristwatch dial for sea/air/land (SEAL) team night operations.[80]

A study by VLAP personnel that year found that the best way of countering Vietcong command-detonated mines was electromagnetic detection of the wires leading to the mines; the Center developed a prototype device for detecting the wires.[81]

A VLAP project in 1970, dubbed Tinderbox, was described with frustrating opacity in a then-classified item in the *Tech History*: "Tinderbox was a high-priority, quick-response project related to the use of fire." However, 12 years later the details were reported:

> Fifty-five-gallon fuel drums containing charcoal soaked in motor gasoline were adapted to hold M23 white-phosphorus igniters equipped with M173 aluminum fuzes. Drops from both a KC-130 cargo plane and a CH-46 helicopter indicated system feasibility for massive flame attacks against area targets. The system was not deployed because of changes in the tactical situation.[82]

Not all of the VLAP work involved the application of technical savvy to military problems. In a 2009 lecture on VLAP, Bud Sewell opined that "for many of the small problems, a Herter's [sporting goods] or a Sears catalog would solve them." He related the story of a Marine artillery unit at Con Thien that wanted spotting telescopes like hunters use when searching for big game at long ranges. That group talked with other artillery units; everyone wanted them. Sewell wound up with a request for 200 spotting scopes. The request was sent to Headquarters, Marine Corps, where it was denied because there were no MIL-SPEC scopes in the Marine Corps' supply system. Through Herter's, China Lake bought $60 zoom spotting scopes. Sewell recounted:

> The results were tremendous. They said it improved the accuracy of their gunfire tremendously to be able to see where the shells were hitting. The cost of each shell swamped the price of the spotting scopes bought from Herter's catalog. . . . You didn't have to worry about it being MIL-SPEC, those guys took care of that thing, it never saw a drop of rain![83]

In 1970, overall coordination of VLAP was assigned to NOL White Oak. As the phased withdrawal of Marines from Vietnam began, the VLAP program

---

[80] *NWC Tech History 1969*, 2-28.

[81] Ibid.

[82] *NWC Tech History 1970*, 1-17; *Major Accomplishments of the Naval Weapons Center*, 168.

[83] Sewell, "Vietnam Laboratory Assistance Program," video presentation. A MIL-SPEC, or military specification, is a detailed description of the physical and/or operational characteristics of an item authorized for use by the military.

itself wound down. "NWC participation in the VLAP program was essentially nonexistent during the last half of 1970," reported the *Tech History*. However, during that year, one of the most significant successes of the program—the interim lightweight 20 mm gun pod for the OV-10 Bronco—was delivered to VAL-4, the Navy OV-10 squadron. That system and a loading-lever assist for the .50-caliber machine gun were the only two VLAP projects to actually make it into the Navy inventory.[84]

Navy Science Assistance Program (NSAP)

As its VLAP involvement dwindled, China Lake became more involved in a similar program that had been established by the DNL, Dr. Joel S. Lawson, in 1969. While the functions of the VLAP advisors had been clearly delineated, those of the NSAP advisors "have been considerably more discretionary." Their primary role was consulting and advising with the head of the command to which they had been assigned, but ancillary duties included "advising the commanding staff of the host country's forces, acting as an unofficial communications link between the U.S. and host country's Navy Commands, and briefing visiting dignitaries."[85]

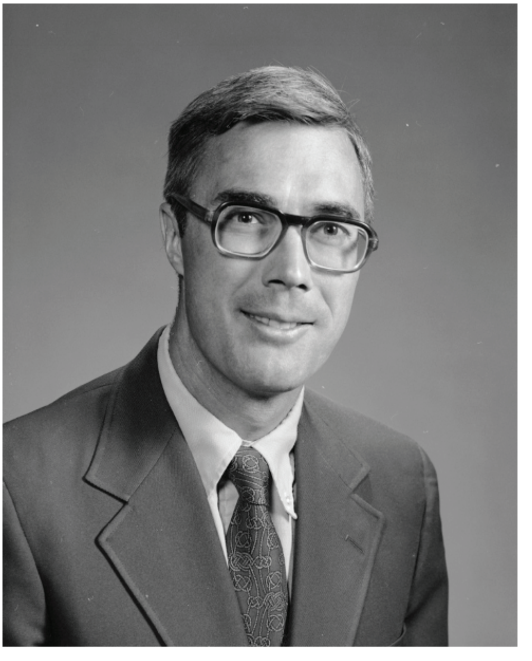
The intrepid Fred Davis, who had been China Lake's first VLAP volunteer, was also the first China Laker to take an NSAP assignment, as science advisor to Rear Admiral Victor A. Dybdal, Commander of U.S. Naval Forces, Korea. Davis began his assignment in May 1970, succeeding Barney Smith, former head of the China Lake Weapons Development Department (1958-1960), who served as Technical Director of the Naval Weapons Laboratory, Dahlgren, from 1964 to 1973. Davis brought ballistician Robert J. Stirton on board, as well as John Boyle, head of China Lake's Shallow Water Attack Boat (SWAB) program, who assisted the Republic of Korea Navy with their high-speed-attack-boat efforts.

By January 1971, the program had expanded to support three commands: Naval Forces, Korea; Naval Forces, Vietnam; and Antisubmarine Warfare Forces of the Sixth Fleet. Frank Buffum, of NWC's Weapons Planning Group, followed Davis to Korea; like Davis, he had his original 6-month tour extended an additional 4 months at the request of the host command. Duane H. Williams of the Propulsion Development Department was assigned as science advisor to the Commander of the Naval Amphibious Base, Coronado, in 1972. That same year, the Korean Command assigned several development and evaluation projects to the Special Projects Division of NWC's Electronic

[84] *NWC Tech History 1970*, 1-17.
[85] *NWC Tech History 1971*, 1-20.

Systems Department, including the replacement of an unstabilized quad 50-caliber weapon mount with a motion-stabilized platform (for ship or boat) carrying an M197 three-barreled 20 mm Gatling gun.[86]

As the years passed, the role of the NSAP expanded. By 1975, there were two categories of NSAP positions. The first was the NSAP science advisor, a senior scientist or engineer (GS-15 and above) who was specifically requested by a Navy or Marine Corps command. The advisor reported personally to the commanding flag or general officer on technical matters and was, to many senior military officers, the face of the Navy laboratory.



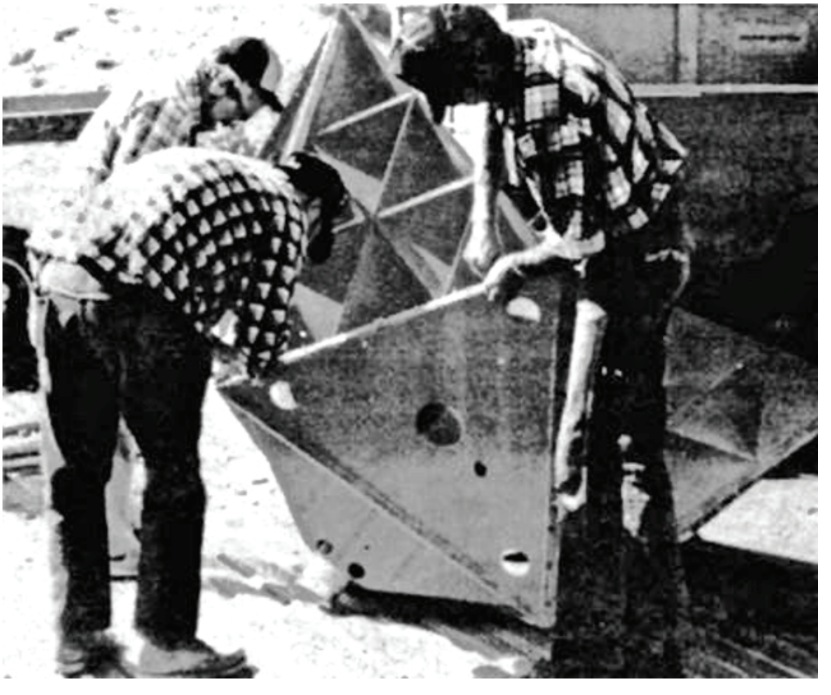
Frank Buffum.

Second was the NSAP laboratory representative, generally a GS-12 to GS-14 scientist or engineer. The representatives each had experience in operations or mission analysis, were particularly knowledgeable in a specialty area such as antisubmarine warfare (ASW), electronic warfare (EW), or antiair, and were experts in a particular weapon system or hardware type. The lab reps generally worked on a particular command's staff and did more hands-on work than the science advisor.

Numerous successes for the U.S. Navy and U.S. allies came from the NSAP program. Among them were the Floating at-Sea Target (FAST), an inexpensive radar-reflective floating target for bomb and gunnery practice at sea. Arguably more important than particular problems solved or assistance given was the top-level recognition by Fleet leaders that, when they had a technical issue beyond their immediate capability to resolve, there was a laboratory representative close by who was their direct conduit to the immense scientific and engineering capabilities of the Navy's laboratories.

[86]Buffum, who received the Navy Meritorious Civilian Service Award (the highest award that the head of a naval activity can bestow on a civilian) for his work in Korea, was appointed NSAP coordinator for China Lake in 1975.

NSAP also benefited the scientists and engineers who had the courage to step out of their routine and try something new and exciting. Bill Porter, NWC's Technical Director from 1989 to 1993 (the final Technical Director before China Lake became NAWCWD), spoke of NSAP as an example of "something which gets you out of your mold and gets you exposed to a bigger world." Ray Miller, who was the first NSAP advisor to the Commander in Chief, Atlantic Fleet, said:



From left: Randy Coleman, Jeff Mattick, and Bob Hoffman assemble a FAST. Published in the *Rocketeer*, 12 August 1983.

> I really didn't know what I was getting into, but it sounded exciting, and it sounded like a good learning experience. . . . I was shocked to learn that the Fleet's problems weren't primarily missiles. I thought the world revolved around missiles! But it turns out that they have many more problems that they struggle to deal with.[87]

In November 1979, Dr. James Probus, the DNL, recognized 19 current and former China Lakers with letters of commendation for their participation in the NSAP program. That the program continues today—under the name Office of Naval Research Global—more than four decades after its founding, is testimony to the symbiotic nature of the Fleet/laboratory relationship and

[87]S-216, Porter interview, Part 2, 73; S-262, Miller interview, 78–79.

to the foresight of the Station's founders in making that symbiosis an essential aspect of the Station's being.

Navy Laboratory Analysis Augmentation Group-Vietnam (NLAAG-V)

Vice Admiral Elmo R. Zumwalt Jr. visited China Lake in the summer of 1967, shortly before he took over his new position as Commander, Naval Forces, Vietnam. He met with Carl Schaniel, then head of the Weapons Planning Group, China Lake's in-house analytical think tank. Zumwalt sought Schaniel's assistance in setting up an expanded analytic capability on the staff of his new command. Zumwalt wanted analysts to spend 1-year tours in Vietnam, but Schaniel convinced him that this would drastically reduce the candidate pool because of family considerations. Four months was settled on as the tour length.[88]

Schaniel visited eight Navy research and development (R&D) centers and set up the program called NLAAG-V. Late in 1968, incoming DNL Dr. Joel Lawson formally assigned Schaniel to coordinate the program. Analysts, as well as engineers and scientists, served directly on the staff of the Commander in Saigon and contributed materially to the Navy's efforts in Vietnam and the surrounding waters. Tasks included asset distribution, resource requirement determination, intelligence analysis, mine countermeasures assistance, joint operations integration, in-country military construction priority assessment, cost-effectiveness analysis of various aircraft shelters, detection probability studies, and determination of mission suitability for watercraft versus aircraft.[89]

Carl Schaniel.

The NLAAG volunteers were particularly useful in support of Operation Market Time and Operation Game Warden. Market Time was a massive coastal surveillance and anti-infiltration effort that extended from the 17th parallel (the military

[88]Schaniel, *Carl's Career Chronology*, 84. PDF file provided by the Schaniel family.
[89]NWC, *Naval Operations in Vietnam*.

demarcation line between North and South Vietnam) to Thailand's Phú Quốc Island—essentially, the entire coast of South Vietnam. Game Warden sought to gain and maintain control of the major rivers, some of the minor rivers, and selected canals in South Vietnam's Mekong Delta—about 5,000 nautical miles of navigable waterways used by some 1,500,000 watercraft.

The first three China Lake participants (aside from Schaniel) were analysts John K. Well and Rodger A. Greenwall and physicist Fred H. Camphausen. All three received letters of commendation at the conclusion of their tours; Camphausen's noted:

> Your extensive analysis of methods to protect naval assets in the harbors and rivers of South Vietnam led to the development of a new anti-swimmer grenade and an original analytic model related to defense against the enemy swimmer/sapper threat.

The program began to wind down when Vice Admiral Zumwalt left Vietnam to become CNO in 1970 and ended by March 1971. Toward the end of the program, much of the analysts' efforts were devoted to studying the turnover of U.S. assets to the Vietnamese.[90]

As the '60s became the '70s, and the end of the Vietnam War became more and more a certainty, the interest in new weapons designed for Southeast Asian jungles slackened. Enough was enough; there were adequate bombs and rockets in the Fleet inventory and the production pipeline to last the fight. As the *Tech History* noted resignedly in early 1972:

> Near the end of each period of conflict in which free-fall weapons are the primary type of ordnance used, the emphasis on R&D shifts to the more technically challenging systems. This change in emphasis carries with it a reduction in R&D dollars available for development of free-fall ordnance. As a result, only selected free-fall programs remained in RDT&E during fiscal year 1971. The remaining effort was devoted primarily to product improvement and Fleet support.[91]

[90] *Rocketeer,* 4 April 1969, 5; *NWC Tech History 1970*, 7-8.
[91] *NWC Tech History 1971*, 3-3.

4

Electronic Warfare

HARM is a good systems-acquisition program to study because it had every possible mistake made at least once.

—Robert M. Hillyer, NWC Technical Director, 1977-1982[1]

From the perspective of a weapons development laboratory, the war in Vietnam was far different north of the 17th parallel than south of it. In the south, the enemy (Vietcong and North Vietnamese Army regulars) was an elusive force, hard to find and harder yet to destroy, taking advantage of the night, of the terrain, of the vegetation, and of the Americans' inability to distinguish friend from foe. With few exceptions, the United States and the South Vietnamese were not battling against entrenched enemies in fixed positions; they battled a highly mobile force that could attack, disappear, and after regrouping at a time and place of their own choosing, attack again. The air-delivered weapons of choice against these foes were generally free-fall ordnance and rockets, such as those discussed in the previous chapter.

In the north, it was quite different. American aircraft were attacking the North Vietnamese in their own cities, targeting, primarily, fixed installations. These included bridges, power plants, railroad yards, barracks, and other military and industrial targets. The weapons used against those targets included dumb bombs as well as radio-guided bombs, and later, LGBs (Paveways) and electro-optical (EO) / TV-guided weapons (Walleye). The big problem, however, was not so much destroying the targets but rather reaching them and returning to base or ship in one piece. The North Vietnamese defended themselves fiercely with radar-directed guns and missiles supplied by the Soviet Union and the People's Republic of China.[2]

---

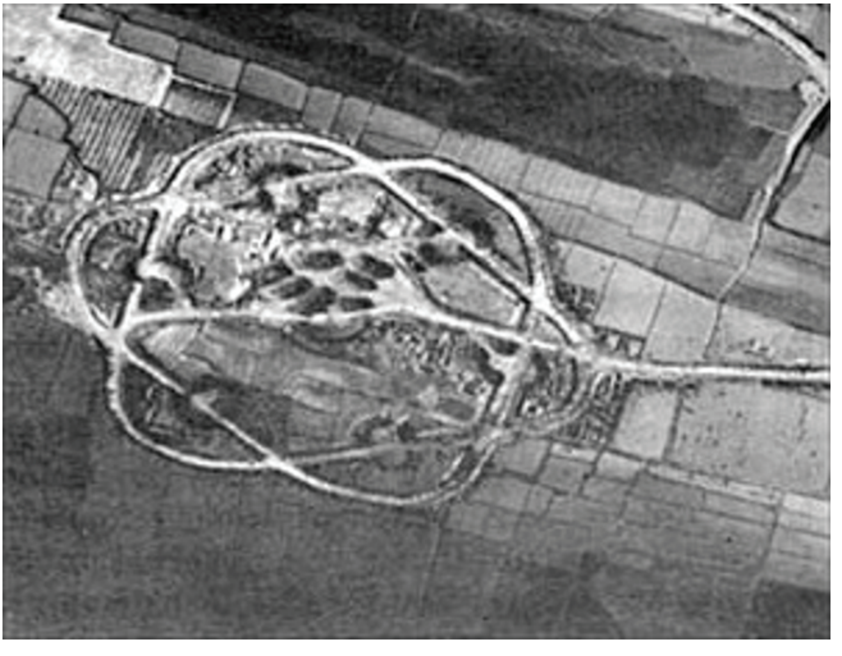
[1]S-134, Hillyer interview, 55.

[2]Beginning in 1965, the Soviets sent almost 17,000 SAM operators and technicians to North Vietnam, mainly to assist in the defense of Hanoi, the capital and industrial heart of the nation. Davies, *F-105 Wild Weasel*, 40.

There was no practical way to shoot down an SA-2 missile traveling at Mach 3. And even if there were, there'd be another one close behind it. The Achilles' heel of radar-guided weapons was the radar itself. EW had been around since the invention of radar in WWII, and the first countermeasures were developed in the same period. During the war, researchers at Harvard's Radio Research Laboratory invented chaff—small metallic or metalized strips or fibers that collectively create a false radar return—as did, independently, groups in England (where it was called window) and in Germany (where it was called *düppel*).

Shrike

China Lake had fielded the world's first operational antiradiation missile, Shrike (AGM-45), in 1965. (The weapon's development is detailed in Volume 4 of this series.) Shrike was an 8-inch-diameter air-launched missile fitted with a seeker that tracked the signals emanating from an enemy radar on the ground. The weapon arrived in Vietnam just in time, as U.S. aircraft were suffering heavy losses from the newly emplaced SAM batteries. In its tactical application, Shrike was carried by Navy attack aircraft—A-4 Skyhawks, A-3 Skywarriors, and A-6 Intruders—carrying out defense-suppression or Operation Iron Hand missions. The Air Force launched Shrike from their F-105 Thunderchiefs



North Vietnamese SAM site.

("Thuds") and later F-4G Phantoms in their own version of defense suppression called Wild Weasel.

Defense suppression did not require a hard kill on an enemy radar site (although that's what the shooters hoped for). It was enough that the enemy shut down his radar after a Shrike launch—the pilots' radio call was "Shotgun," which alerted his fellow airmen, as well as listening North Vietnamese and Soviet missileers, that a Shrike was in the air.[3]

In the absence of a radar signal to guide it, the SAM was incapable of tracking the bomb-laden attack aircraft that followed close behind the defense-suppression aircraft. The bombers were attacking the targets protected by the SAMs. The trick for the defense-suppression aircraft was to keep the enemy radars shut down while the bombers made their runs, released their ordnance, and left the target area.

SAM exploding over North Vietnam near VA-212 aircraft from USS *Bon Homme Richard*, 1966.

While Shrike saved countless aviators' lives, the weapon had room for improvement. The warhead was sufficiently powerful to destroy the radar antennas (which would keep the site off the air for a matter of hours until the

[3]The term "shotgun" came from the 22,000 tiny steel cubes that formed the kill mechanism of the Shrike warhead. Pilots were known to execute the signature Shrike-launch "dip" maneuver, fire an inexpensive Zuni rocket, and call "Shotgun!" in order to shut down a threat emitter.

antenna was repaired or replaced) but inflicted little damage on the radar vans themselves, which were located away from the antenna. Shrike's range required that the launch aircraft be inside the SAM's firing envelope, and its speed—time to target—was not great enough to shut down the radars before the SAMs reached their targets. The aircraft had to be headed almost directly at the target at launch for the missile to pick up the radar's signal, and if the radar shut down, the missile lost target lock. The launch aircraft did not carry a suite of avionics that could locate a single target in the signal-rich threat environment and accurately calculate a launch point. As Bill Porter put it:

> We had this simple, dumb missile hanging on the wing of an airplane with very little avionics to support it, and we ended up wanting the missile to behave like a Phi Beta Kappa, and it didn't have the built-in capability to do that.[4]

Shrike firing from A-4 aircraft.

[4]S-216, Porter interview, Part 2, 68. Porter managed the Shrike program at China Lake for 5 years and was the first High-Speed Antiradiation Missile (HARM) manager.

One of the biggest shortcomings of Shrike was that each new threat radar system required a new version of Shrike. This was a function partly of the technology available at the time and partly of the need to keep the missile small and inexpensive. During the lag time between detection of a new threat system and the fielding of a new missile to address it, U.S. aircraft were particularly vulnerable. Therefore, China Lake engineers tried to minimize the lag.

Richard Hughes.

Richard S. Hughes had designed the angle-gate circuitry for Shrike, which allowed it to lock on to one target signal and ignore others. He recalled:

> We got a very urgent input, I think it was from Jack Russell [then in Vietnam] . . . A Russian radar was causing havoc. . . . The pulse width of this guy was like four microseconds long. They needed to modify Shrike as soon as possible to go just after this radar. Well, the China Lake way, within a week I had the design done, and within a week and a half we had it configured, put it on a printed circuit board, and tested. Within three or four weeks it was in the Fleet.

Shrike became the most-fired guided missile of the Vietnam War, with more than 9,000 units expended in combat between 1965 and 1973.[5]

Standard Antiradiation Missile (ARM)

Naval Ordnance Laboratory Corona (NOLC)—at that time, 1966, still a separate command from China Lake—promoted the idea of a new antiradiation missile to address the shortcomings of Shrike. Bill Porter told an interviewer that

> Standard ARM was being pushed by Corona and we considered it a competitor to Shrike and not a very good competitor, something that would

[5]S-353, Hughes interview, 7; Knemeyer, "Shrike's Forgotten Lessons," 12. In 1973, seven different models of Shrike were in use, and three more were in the development pipeline; *NWC Tech History 1973*, Part 1, 5-4.

> cost ten times as much and not perform much better than Shrike. So we had lots of discussions, which at times were not too friendly, with our sister lab at Corona.[6]

Corona came out on top, and the Navy began to develop a second antiradiation missile: Standard ARM (AGM-78), also called STARM by some. The weapon was officially described as "an air-launched, solid-propellant, passive, radiation-homing missile designed to be effective against sources of electromagnetic radiation such as radar installations."[7]

Development work was conducted by General Dynamics, which was the prime contractor for the RIM-66 Standard Missile—a ship-launched (which the letter R designates) SAM that replaced the 1950s vintage Terrier, Talos, and Tarter series. Initially, the task was relatively straightforward: the first version of Standard ARM, AGM-78A, consisted of a Standard Missile mated to a Shrike antiradiation seeker. With a dual-thrust rocket motor and a new blast-fragmentation warhead, the missile had significantly greater range and a bigger bang than Shrike.

The program moved along briskly; much of the technology used in the missile was already developed, or "off the shelf." Fred Alpers recalled that

> people said you couldn't build a missile in less than 4 years, and that seemed to be about the going rate there through the '60s. But Standard ARM went from the first money applied to the thing to having a missile flying in Southeast Asia in, I think, 20 months.[8]

When Standard ARM began development, it was under the technical direction of NOLC. When Corona was put under NWC's authority in 1967, the missile became China Lake's responsibility, although for the time being the program offices remained at Corona.

In 1968, Leroy Riggs was sent to Corona by Technical Director Tom Amlie to run the Missile Systems Department. Riggs, one of the original developers of Shrike at China Lake and its first project manager, was somewhat skeptical of Standard ARM.

> It's not using what we really need in the way of advanced technology . . . It's just nothing but an overgrown Shrike. It's a little bitty step. We need to take a giant step. I wanted tail control, all kinds of things that I thought would make sense. I wanted a ramjet, maybe, you know, who knows, but I wanted it looked at, at least; I didn't want to be locked into—what was Shrike going to be expanded from—8 inches to 10 inches? You know, we are just going to

---

[6]TS 84-14-5, Porter interview, 2–3.

[7]General Dynamics, *Standard ARM Technical Progress Report*.

[8]S-118, Alpers interview, 79.

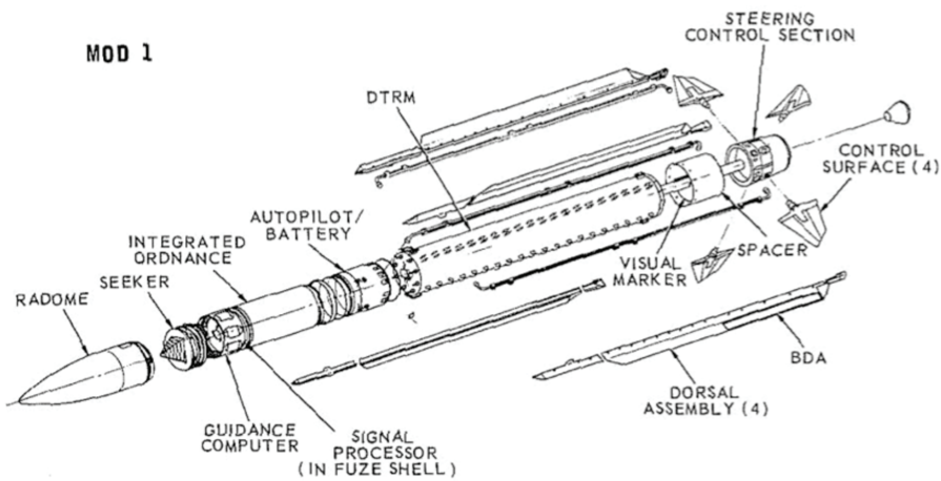
> blow this balloon up that much bigger and, yes, we're going to put in a fancier seeker because now we've got this longer capability, longer range capability, but by and large, I just didn't think it was being expanded enough.[9]

Charles B. May, an electronics engineer who had joined the Shrike program in 1961, moved to Corona in 1967 to work on Standard ARM. He remembered that the Standard ARM development

> started officially around December 1966. It had a very short IOC [initial operational capability] date. In fact, they were trying to get into the Fleet within about a year. That is what drove a lot of the off-the-shelf technology going into the system.

The first Fleet deliveries of the AGM-78A were made in February 1968.[10]

The AGM-78B soon followed the AGM-78A to the Fleet. Unlike the AGM-78A's strap-down (fixed) seeker, the AGM-78B used a gimbaled seeker that did not have to be pointed directly toward the target at launch. It also employed superheterodyne guidance, more sophisticated than Shrike's crystal video guidance, with broader frequency coverage. Another improvement in the AGM-78B was a pyrotechnic smoke generator that ignited at warhead detonation to identify the target so that other aircraft could prosecute a non-ARM attack on the radar site and ensure its destruction. (Some Shrikes carried a white phosphorous warhead for the same purpose.) All of the AGM-87s contained a bomb-damage-assessment subsystem that transmitted a signal to

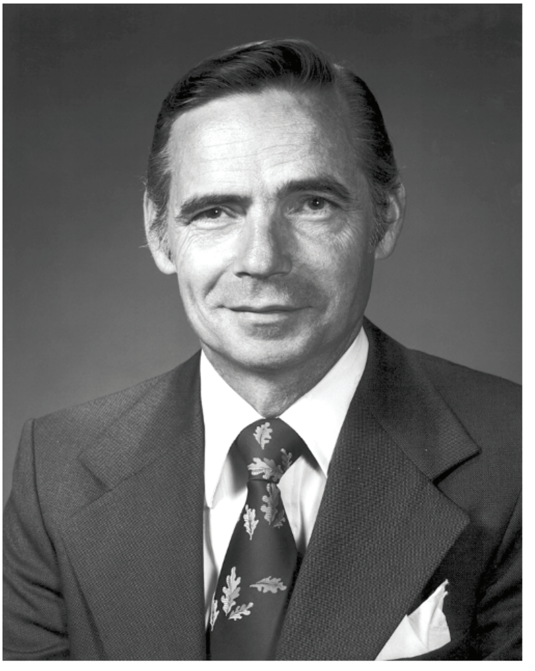


AGM-78 Standard ARM Mod 1. Published in the 1969 *Standard ARM Technical Progress Report*.

[9]S-136, Riggs interview, 66.
[10]TS 84-14-8, May interview, 15; *NWC Tech History 1968*, Part 1, 5-24, 5-31.

the launch aircraft (initially, the A-6B) indicating whether the missile acquired, missed, or lost the target.

AGM-78C, the third variant, incorporated further refinements, including wider-band guidance and greater flexibility of launch conditions. Both the B and the C variants went to the Fleet in 1969.



Charlie May.

May took over the Standard ARM program in 1970. He returned to China Lake in 1971 as head of the Standard ARM Program Office in the Electronic Systems Department (which would become the Electronic Warfare Department in early 1975). By 1971, R&D of the AGM-78D had been completed. This fourth-generation Standard ARM had refined the AGM-78C receiver to provide continuous coverage over a three-band frequency range. By 1973, 100 AGM-78A's had been converted to AGM-78Ds, and a contract had been finalized for a joint Navy / Air Force procurement of an additional 61 missiles starting in 1975.

All four versions of Standard ARM employed a particular bit of electronics that partially compensated for one of Shrike's shortcomings—loss of target lock when the threat-radar signal ceased. The Standard ARM seekers had memory circuitry built into the guidance system to retain the target's latest position; if the threat radar was shut down (as radar operators were wont to do when they knew an antiradiation-homing missile was in the air), the target-position data guided the missile during its terminal phase. The circuitry was inadequate to perform this task with sufficient accuracy to defeat the threat in most cases, but it was a step in the right direction.[11]

In the Navy's A-6B/E Intruder aircraft, Standard ARM operated in concert with the NWC-developed Target Identification and Acquisition System (TIAS) and the AN/APS-118 radar; in the Air Force's F-105F/G Wild Weasel,

[11] Some 25 years later, to address the target-shutdown problem, China Lake was investigating the use of imaging sensors with target-recognition capabilities for the final phase of the ARM flight. See the *Rocketeer,* 3 June 1993.

the missile operated with the AN/APR-35/36/37 radar warning and homing receiver. Modifications were required to accommodate the weapon, and each modification to the already crowded and complex aircraft systems added force to the argument that platforms, weapons, and sensors should not be considered as individual systems but rather as systems of systems. The more complicated and interdependent the various components and subsystems became, the greater the ability each had to either facilitate or constrain the capabilities of the other components and subsystems.

The Standard ARM development program was not without glitches. For example, in 1969 the contractor was unsuccessful in developing an active radio-frequency (RF) fuze that would fully meet the missile's requirements. "Efforts by the contractor to solve the problems were not successful, and after 6 months with little improvement in the production yield, the effort was terminated," the *Tech History* reported.[12]

Immediately, China Lake's Fuze Department (still physically located at Corona) began a crash in-house program. In 8 months, the group, led by Roy L. Nichols and Joe A. McKenzie, developed, tested, and fielded a new continuous-wave active-optical target-detecting device (TDD), the DSU-10/B, that met all the Standard ARM requirements. That incident pointed up one of the pitfalls of a program that was in a hurry; many of the developmental steps that would normally be done sequentially were done in parallel, adding to program risk.[13]

Standard ARM was not the ideal antiradiation missile. For one thing, it was heavy; 1,378 pounds versus Shrike's 390 pounds. At nearly 15 feet, it was also half again longer than Shrike.

"You couldn't carry as many of them as you could Shrikes," said Porter, and "you could not load as many on the [aircraft] carrier because they were a large missile taking up all the space in the magazines."[14]

At 215 pounds, Standard ARM's warhead weighed 76 pounds more than Shrike's; bigger, but not a game changer. Porter explained that

> with the Shrike warhead or the Standard ARM warhead you had to land within 50 feet or less to have any hope of damaging a target, especially since they could protect the targets and the only thing they had to leave exposed was the antenna. If you punch the antenna full of holes you didn't do much. If you destroyed the dipole on the antenna then they had to replace the antenna,

[12]*NWC Tech History 1969*, Part 1, 1-16.

[13]*Major Accomplishments of the Naval Weapons Center*, 185. A version of this revolutionary fuze was later used in the Sidewinder AIM-9L.

[14]TS 84-14-5, Porter interview, 20.

> but they could still revet [barricade], with earth or whatever, all the electronics and protect it pretty well.[15]

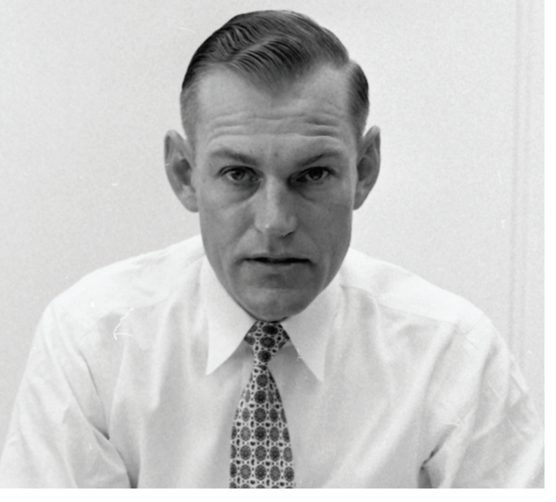
And there was a question of how effective the added range of Standard ARM actually was in combat. Porter said:

The targets did not come on the air [activate their fire-control radar transmitters] until we were essentially in envelope [within the range of the threat SAMs]. So there was really no way to take advantage of the 60, 70, 80 miles that Standard Missile would fly.[16]

Standard ARM also had reliability problems. Charlie May explained:

> The specification called for four-hours mean time between failures [MTBF, a measure of reliability] at 80 percent [confidence] level, which is a pretty lousy specification in the first place. But what really made it worse is that there was no demonstration requirement of that. There was a quality assurance environmental test required by contract on each lot of production, and out of eleven lots of production, nine failed. But the quality assurance environmental test was not a requirement for lot acceptance! So, the disciplines that the Center believed in, and had demonstrated through lessons learned, were not in that program.[17]

Frank Knemeyer, head of the Weapons Development Department during the years of Standard ARM development, attributed that weakness to the program's original assignment to NOLC before Corona merged with China Lake.



Frank Knemeyer.

> Corona really was the so-called program manager of it; however, Corona did not exert the type of technical control that China Lake exerted over the Shrike missile. In contrast, Corona had something like 80 people managing—that was not technical, just management. I never could figure out why they had so many people managing it and had so little control over it. It turned out that the project officer back in the Bureau [of

[15]Ibid., 19.
[16]Ibid.
[17]TS 84-14-8, May interview, 17.

> Naval Weapons] dealt pretty much with General Dynamics and didn't run his decisions through Corona.

Knemeyer felt that if the program had been conducted

> under the strict technical direction of an in-house laboratory . . . the documentation would have been different and would have been done in a more effective manner. In other words, industry would have been under close scrutiny.[18]

When May took over the program, he attacked the reliability issue, and the contracts were rewritten for the AGM-78D model. "We had a demonstration requirement in the contract of twenty hours MTBF," he said. "The actual demonstration was either 27 or 29 at 0.9 confidence. . . . To have reliability in a system, you have to demonstrate it."[19]

One of the biggest problems with Standard ARM was its cost. At $70,000 a copy, it was 10 times the cost of a Shrike. Consequently, Navy and Air Force units continued to fire far more Shrikes than Standard ARMs.

Finally, in terms of flexibility to accommodate new target types, Standard ARM was subject to the same limitations as Shrike. A new seeker or a variation on a previous seeker had to be developed, manufactured, and incorporated with the rest of the missile to meet new radar threats.

The Navy had been rushed into the antiradiation missile business. Shrike had been a hurry-up, stop-gap weapon, as had each of its subsequent frequency-specific versions, created to counter specific new threats. Standard ARM had also been rushed, cobbled together originally out of existing missile systems. This was not the way to do business, and the range and sophistication of electronic threats was growing. Eventually, May recalled, "They [weapons developers] started thinking about a more logical, thought-out, long-term approach to fulfilling the ARM requirements problem."[20]

Electromagnetic Radiating Source Elimination (ERASE)

In fact, China Lake had been taking such a long-term approach to ARM requirements—outside the framework of a weapons development program—since 1965. In that year, the Advanced Radiation Missile Guidance Program was established with the goal of developing a missile guidance system for an

---

[18]TS 84-14-3, Knemeyer interview, 20–21, 27. On his retirement in 1983, Knemeyer was presented with the Distinguished Civilian Service Award, the Navy's highest honorary award for a civilian employee.

[19]TS 84-14-8, May interview, 18.

[20]Ibid., 17.

advanced antiradar missile "designed to operate in the complex post-1970 electromagnetic threat environment." Duane J. "Jack" Russell, head of the Antiradiation Guidance Division, and his team—among them engineers Joseph A. Mosko, Robert Corzine, Robert E. Atkinson, and William P. Mayne—were looking at a wide range of issues. Their developmental objectives included:

> broad bandwidth, ability to operate in multiple-target environments, capability against all types of radar (such as frequency agile, continuous wave (CW), spread spectrum, and pulsed), capability of countermeasures for controlled radiation techniques or radar turnoff, and high sensitivity for increased detection range.[21]

Jack Russell.

By 1967, this program had evolved into an even broader ranging investigation called the ERASE program, with a mandate to provide "necessary guidance technology for the post-1972 antiradiation missile." Bob Corzine called it "a pure research and development program."[22]

He explained:

> You can see a solution to a problem…[but] you can see it's going to take a lot of mathematics, solving computer problems, conducting experiments to get to the end of this hypothetical item that you would like to have . . . If you have a missile-development program with an end date, you just know you're not going to have time to take that kind of an approach.

China Lake had long used research and technology programs operating outside the context of specific weapons- and systems-development programs to advance the state-of-the-art in explosives, propellants, warheads, guidance, and other areas applicable to weapons development.

Finding funding for such a high-risk, long-time-to-payoff program was tough, particularly during a war. However, it was just the sort of task a Navy

[21] *NOTS Tech History 1965*, Part 1, 5-43.
[22] *NWC Tech History 1967*, Part 1, 5-77; S-283, Corzine interview, 10.

laboratory could tackle, and Dr. Jess Miller in NAVAIR-03 provided funds to start the program. After that, Russell said, "We begged, borrowed, stole the funds in order to keep that work going because we recognized how critical that was." ERASE was originally located in Russell's division in the Weapons Development Department and later in Bob Corzine's RF Development Division in the Electronic Systems Department after Russell was selected to head that department in 1974.[23]

Under the ERASE program, many new technologies, analytical techniques, and actual components were developed, including a variety of broadband antennas, antenna feed circuits, and receivers. ERASE received criticism for creating actual components, i.e., hardware. "We had to fight very hard to allow some of that component work in the ERASE program," Russell recalled, "because there were a lot of people that felt that it was a waste of time to do that work and that we should be working on bigger and broader things." But when the ARM weapon development programs caught up to where Mosko and associates were, the hardware was waiting.[24]

In 1979, based on China Lake's experience in the ERASE program, the Center was selected by the Army to develop the passive sensor for an antiradiation projectile. The Army was looking for an artillery round that would locate and destroy a variety of battlefield emitters: battlefield surveillance radars, air-defense radars, counter mortar radars, counter battery radars, and command posts. The program was cancelled after 4 years, but the technology would later be incorporated in the advanced HARM seeker (AGM-88B and AGM-88C).

Just as a decade of long-range research by Nichols, McKenzie, Mosko, and others had set the stage for development of the DSU-10/B, so did ERASE provide a sound technology base for HARM. The willingness to focus resources on high-risk approaches to anticipated problems—problems that may or may not arise, and if so may be years or even decades in the offing—is seldom seen in industry. Shorter-term, lower-risk approaches are preferred because of the higher probability of near-term profits for corporate stockholders.

China Lake showed time and again that this phenomenon—investing exploratory-development and later advanced-development funds to solve anticipated rather than current problems—was money well spent. The Center designed systems incorporating in-process and projected technological advancements, which allowed the Navy to keep its designs well ahead of potential adversaries, as, for example, in the development of Polaris. This

[23]TS 84-14-4, Russell interview, 16. NAVAIR-03 was the code responsible for antiradiation weapons.

[24]Ibid.

approach would pay off again in the 21st century when China Lake's decade of development work on solid FAE would, when the need suddenly arose, allow the astonishingly rapid development of the Hellfire thermobaric warhead.

Shrike 73 / HARM

"Whatever happened to the '73 IOC for HARM? Why is that almost 10 years ago?" That uncomfortable question was put to NWC Technical Director Robert M. Hillyer in a 1982 interview, 18 months before HARM (AGM-88) entered the Fleet inventory. Hillyer responded, "HARM is a good systems-acquisition program to study because it had every possible mistake made at least once."[25]

From 1969 to 1972, as U.S. forces were doing the best they could with Shrike and Standard ARM (in conjunction with electronic jamming and the use of chaff decoys), China Lake participated in the Tactical Air Armament Study (TAAS), jointly funded by the CNO and NAVAIR. The program was initiated by former China Lake Experimental Officer Vice Admiral Thomas F. Connolly, then Deputy CNO (Air). Heading up the TAAS effort was Captain Boyd Muncie, a former VX-5 Commanding Officer; he was charged with examining current and planned tactical-air weapon systems to determine which would best serve the Navy in the 1970s. It was an important study, because on it would be based decisions of how and when to phase out obsolete and current air weapons and phase in new ones.

The analysts of China Lake's Weapons Planning Group played a principal role in the study. Leading China Lake's TAAS work were Alan H. Goettig, a mechanical engineer and operations analyst, and Dr. Bob Rowntree, a physicist and operations analyst who was the Program Director for Air Strike Warfare.

One portion of the TAAS concentrated on antiradiation weapons. Heading this segment was Captain Robert F. Doss. Recognized by military and civilian associates as a brilliant man, Doss was described by Porter as one of the most "outstanding persons I've ever had the opportunity to work with . . . People either loved him or hated him," while Riggs spoke of Doss as "stepping on every toe that he could, all the way along the line, captains and admirals meant nothing." Among the notable China Lakers who worked the ARM portion of the TAAS were Russell, Porter, and Gerry Schiefer as well as defense-suppression experts Philip G. Sprankle and Judson O. "Jud" Smith.[26]

---

[25]S-134, Hillyer interview, 55. When HARM began, the engineers had optimistically anticipated an IOC in 1973; the fact that there was a 10-year delay is what elicited Hillyer's response about "every possible mistake."

[26]TS 84-14-5, Porter interview, 20; TS 84-14-6, Riggs interview, 20. Doss continued to do

When the TAAS report was released, it opened the door for the next generation of ARM. As the *Tech History* summarized it, the report's major conclusions were

> (1) the potential threat requires action in the immediate future to assure effective air operations over enemy territory for the 1975-80 period; (2) Shrike and Standard ARM and their respective TIASs are neither adequate nor capable of direct modification for the need; and (3) a new aircraft/missile antiradiation weapon system is a feasible and highly acceptable option.[27]

The antiradiation group had come up with a concept for an ARM missile that was inexpensive, fast, and accurate. "It incorporates the more desirable characteristics of Shrike and Standard ARM and provides additional performance to correct the operational deficiencies of both," depicted the *Tech History.*[28]

Beginning in 1969 and working mostly on local funds—"For 2 years straight I put about $600,000 of my [Weapons Development Department] overhead in," said Frank Knemeyer—the team developed a weapon they called Shrike 73. The "73" part of the name reflected the optimistic belief that they could bring the project to initial operating capability in 4 years. In 1970, the weapon became formally known as HARM. The HARM Program Office first appears on the October 1970 NWC organization chart beside Gerry Schiefer's name on the staff of Russell's Electronic Systems Department. Schiefer would lead the program for the next 5 years. The Shrike 73 appellation would linger until 1973 passed, with the program still far from completion.[29]

Speed is central to the success of an antiradiation missile—the more the better. The ARM needed to be able to fly from the launch aircraft to the radiating target before the radiating target could direct its SAM to the launch aircraft. As Porter put it:

> The problem we had was the guy on the ground could build a really big missile and have a big booster and he didn't have to worry about hanging it on an airplane. So it was awfully hard to build a small missile which fits on an airplane and put enough propulsion on that missile so it could outshoot the guy on the ground.

Speed was also essential to reduce the time available for the enemy operators to shut down in anticipation of an attack.[30]

---

business with the Navy after his retirement as head of Farnsworth Cannon Company.

[27] *NWC Tech History 1969*, 7-27.

[28] *NWC Tech History 1970*, 2-24.

[29] S-200, Knemeyer interview, 125.

[30] TS 84-14-5, Porter interview, 21.

The new weapon was designed with a larger propulsion unit that produced significantly higher velocity than the original Shrike. With the cross-fertilization between programs that is one of the hallmarks of a full-spectrum laboratory, the design people from the ERASE program helped to put together a much more accurate guidance unit than the fixed-body Shrike system.

Shrike, meanwhile, continued development; work began on the AGM-45A-9, with broader frequency coverage, in 1972, the same year that Shrike production passed the 17,000-missiles mark. An AGM-45A-10 version would follow, and China Lake would continue to support Shrike until 1981, when that role was passed to Pacific Missile Test Center (PMTC), Point Mugu.

In 1973, a construction contract was awarded for a 7,558-square-foot addition to the existing ARM development complex. (The space in the existing complex was committed to Shrike and Standard ARM.) The project was classified as an urgent minor construction project. "The urgency in this case resulted from the assignment of a new weapon development program for the HARM to NWC with a short completion schedule," reported the *Command History*.[31]

By the end of 1973, China Lake had designed a weapon—164 inches long, 10 inches in diameter, and weighing 700 pounds—that was fast, accurate, and affordable. While it would cost twice as much as Shrike, it was still one-fifth the cost of Standard ARM. Its velocity would be Mach 4, twice that of Shrike and faster than an SA-2 SAM. Components and subsystems were being tested in laboratories and in live launches. "At the end of 1973," the *Tech History* reported,

> the HARM program was in the advanced development phase with release to engineering development and the selection of a prime contractor expected in 1974. Six test vehicles were fired to investigate airframe suitability, aerodynamic characteristics, and control section operation.[32]

At that point it looked like HARM, née Shrike 73, would be the state of the art in antiradiation weapons, and soon. Then, unfortunately, things got complicated.

While progress was being made on HARM, elsewhere in the Electronic Systems Department, work on the AN/APS-117 TIAS was more or less at a standstill. The job of the TIAS was to detect and classify threat radar emitters and to present the information to the aircraft pilot, who could then select from various attack options in terms of range, type of emitter, onboard weapons, etc. TIAS had been developed by China Lake and fielded in 1969, but by 1973, the

[31]OPNAV Report 5750-1, *NWC Command History* 1973, 9.
[32]*NWC Tech History 1973*, 1-33.

HARM on outboard stations of an A-7E aircraft.

China Lake TIAS office's principal task was managing a repair and maintenance contract for the six operational TIAS units. The 1973 *Tech History* entry for TIAS concluded with "subsequent plans for the TIAS are indefinite."

Rear Admiral Rowland G. Freeman III.

Rear Admiral Rowland G. Freeman III was the Navy's Deputy Chief of Naval Material (CNM) (Procurement and Production). He believed that HARM should not be built as a stand-alone weapon but rather as part of a system that included a TIAS or TIAS-like capability commensurate with the ever-increasing complexity of the electronic threat environment.

According to Burrell Hays:

> Admiral Freeman—who was NAVMAT-02 at the time—got involved and essentially said that "you can't build Shrike 73 or HARM alone. You've got to

> kind of build it as a system and that means that TIAS has got to be kind of a part of it." And he had personal knowledge that the TIAS or the aircraft avionics wasn't going all that well and China Lake wasn't doing all that great and it would probably be better not to let China Lake continue to struggle but to bring in industry under contract to do the whole design. And he had the control and power to do that.[33]

Burrell Hays.

Hays believed that this action by Freeman "had a greater impact on China Lake's ultimate ability to manage the scientific work at the Center than Freeman's effort to change the authority of the Technical Director." (See Chapter 5 for additional details.)[34]

Freeman's concept of "build it as a system" was even larger than Hays implied. Late in 1974 when Freeman, by then NWC's Commander, addressed a luncheon crowd at China Lake's commissioned officers' mess, he discussed the subject with typically acerbic directness:

> "Engineers and scientists doing research and development in new weapons systems must recognize that they are designing a 'part' of a system, no matter how all-inclusive their particular development may appear to be. For example, the HARM development going on here at NWC includes the missile, avionics, integrated logistic support, maintainability and reliability criteria, launchers, peculiar support equipment . . . just about everything, right?" he asked his audience. "Wrong," he answered. "HARM must fit into a larger system that already exists, which includes the carrier, selected delivery aircraft, replenishment ships, Naval ammunition depots which will handle the missile, training for pilots and ordnancemen at the squadron and air wing levels, and if it winds up like Shrike, being in service with the Air Force also, then it must be compatible with two distinct and different 'systems' which are not easily modified to accommodate special items of inventory."[35]

---

[33]S-221, Hays interview, 24–25.
[34]Burrell Hays review comments, 12 January 2015.
[35]*Rocketeer*, 27 September 1974, 4.

In 1974, the HARM program was put out for bids, and the winning bidder was Texas Instruments, which was the prime contractor for Shrike and had the contract for the TIAS maintenance and repair. Frank Knemeyer said:

> We did all of the initial advanced development on it, so we got the concept of how you went about it. That was the basis on which it went out for bid. TI [Texas Instruments] won it, and then immediately when they got the contract, they wanted to use an entirely different technical approach on it. And the Center objected to that vehemently.[36]

China Lake's antiradiation experts had envisioned a development program with significant technical involvement by the Center. They were acutely aware that Texas Instruments would have to be closely controlled to ensure a quality product. (The first Shrikes to go to Vietnam were produced not by Texas Instruments, the prime, but by the second-source contractor, Farragut, which had come on board late in the game but had, unlike Texas Instruments, built their missiles to the China Lake drawing package.)

Speaking of the HARM program, Leroy Riggs, Deputy Technical Director for the Electronic Systems Department, said:

> We had planned on about a 100-man technical effort at NWC, with people like [Bob] Corzine and [Joe] Mosko working the program. Just like we had done Sidewinder; just like we had done Shrike. We were going to come up with some drawings and then we were going to prove, as we had with those programs, that if you get two contractors you get a better product.[37]

Rear Admiral Freeman decided otherwise. Riggs said:

> Sitting in his [Freeman's] conference room one day with Frank [Knemeyer, Deputy Technical Director for Strike Systems] and me, he took this big ol' pen and took that proposed contract and he started lining through parts of that contract that were not going to exist. Well, when he got through there was no part for China Lake left.[38]

China Lake's responsibility for HARM design was phased out over a matter of months. The Center's new job was to serve as program monitor for the HARM program manager in Washington, as well as to oversee testing and to provide the government-furnished equipment required for the program. Knemeyer said:

> We had absolutely no authority in it, but then we were responsible for the testing and acceptance of the thing. . . . When the thing really got in trouble,

[36]S-200, Knemeyer interview, 125. And rightly so. Texas Instruments' technical approach resulted in production units that did not work.

[37]S-136, Riggs interview, 29.

[38]S-136, Riggs interview, 31.

> [the Office of the Assistant Secretary of the Navy for R&D] thought China Lake was responsible for this. It was a great surprise to them when they found out we weren't responsible.[39]

One novel approach that China Lake used in testing HARM, as well as Shrike, was called KNOZY (pronounced "nosey"). This consisted of a TA-4 (a two-seater A-4) with a custom radome in the front behind which the missile seeker was installed. The pilot would fly racetrack patterns against various emitters. Elvy R. Hopkins, an electrical engineer who oversaw the outfitting and wiring for the test aircraft, said, "They could upload different sets of algorithms for the seeker to see how those worked with the different target radars. So it essentially put a man in the missile and made a missile out of the airplane." The dual spellings for the system, which have confused generations of China Lakers, were Hopkins' design. "The Shrike Nosey was N-o-s-e-y and it was still flying, off and on. So there wouldn't be any confusion on the flight schedule, I'm the guy that chose K-N-O-Z-Y for the HARM KNOZY."[40]

The decade-plus development of HARM came during a time when the Navy and the Department of Defense were moving away from laboratory control of the weapons development process and toward contractor control. The stage had been set for this shift in emphasis back in 1966 with the issuance of the Office of Management and Budget (OMB) Circular A-76. That document mandated cost comparisons to determine which DoD activities should be performed by the government and which by the private sector: "Whenever possible, and to

HARM KNOZY. Photo courtesy of Gary Verver.

[39]S-200, Knemeyer interview, 126.
[40]S-314, Hopkins interview, 61.

achieve greater efficiency and productivity, the Federal government should conduct competitions between public agencies and the private sector to determine who should perform the work." (Following issuance of a much strengthened A-76 in 1979, privatization of support services would become a major issue for China Lake in the 1980s.)[41]

OMB Circular A-109, promulgated in 1976, focused on weapons system acquisition: it required that military services determine their weapon systems needs by a systematic analysis of their missions and that those needs be expressed in functional terms. Proposing development concepts to meet these needs would be a competitive process open to contractors and government laboratories. "The purpose," as one government task force put it, "is to benefit from the innovativeness of industry and eliminate the Services' tendency to focus prematurely on one technical approach."[42]

This trend to outsourcing was reflected in HARM's development. Charlie May, who took over the HARM office in 1975 after Gerry Schiefer moved up to associate head of the Electronic Warfare Department, stated:

> The acquisition strategy in DOD was changing to an A-109/A-76 kind of a strategy, which basically says that industry ought to be doing the predominant development of weapons. That is not to say that the laboratories could not compete in that process, but the mind-set was changing over to industry as supported by the laboratories and the universities. . . . HARM was one of the programs coming along as that new strategy was happening, and I do not think all the mechanisms were set in place to try to accommodate that strategy.[43]

May elaborated on China Lake's principal role in HARM:

> It was a NAVAIR contract to the contractor and our role was to monitor what was going on and advise NAVAIR. We really had no direct control . . . Most of our monitoring role consisted of reviewing what was going on and making comments and recommendations to the sponsor which he could either take or reject as he so chose.[44]

Technological development is a double-edged sword that benefits the foe as much as the friend. With the dizzying pace of new advances in electronics,

---

[41] *Circular A-76*, i; Kettl, *Sharing Power,* Chapter 3.

[42] Statement of Walton H. Sheley Jr., Deputy Director, Procurement and Systems Acquisition Division, before the Task Force on Government Efficiency, Committee on the Budget, House of Representatives. United States General Accounting Office, "The Effect of OMB Circular A-109 on Major Systems Acquisition and the Use of Competitive Procurement in the Department of Defense."

[43] TS 87-14-8, May interview, 22. In 1979, May received the Michelson Laboratory Award for "outstanding effort and professional excellence while serving as head of the Electronic Warfare Department's HARM / Standard ARM Program Office." *Rocketeer*, 12 January 1979.

[44] TS 87-14-8, May interview, 23.

miniaturization, and computers, there was never a good point to finalize the HARM system. As Knemeyer explained:

> Every time there would be a new threat that would come up, then the DSARCs [Defense Systems Acquisition Review Councils] would say, "Gee, we need to put that into HARM." So they'd just be about finished with the development, then they'd have to go back and change the design to put some other capability in. Then it got to the place where it just kept running along, and if they weren't careful, they'd never get it out, instead of getting the thing out and then putting things in as the program changes. And it was managed from back in Washington directly with the contractor.

Much of the technology that was used to implement the added capabilities came out of NWC's ERASE program.[45]

One problem with a system of systems approach is that when a major change is made to one of the systems, its effects ripple through the other systems. In 1969, the AN/ALR-45 radar-warning receiver (RWR) had been introduced as the next generation of radar warning systems for the Navy. The system used hybrid microcircuits with digital logic and clock drivers. It was incorporated into Navy aircraft during the first half of the 1970s.

During the same period, however, the electronic threats, primarily from the Soviets, were becoming more numerous and more sophisticated. Distinguishing one signal from another and prioritizing them became a major challenge, and an analog RWR was simply not up to the task. Warning systems had to not only provide information for passive antiradiation weapons but also to manage the radiating systems (jammers) on board the aircraft.

In 1975, NAVAIR decided to replace the AN/ALR-45 RWR with the new AN/ALR-67 countermeasures warning and control system in the A-7E aircraft. While this was a necessary advancement in EW technology, it caused problems for HARM. "This has resulted in significant CLC/CI [command launch computer / computer interface] redesign and new CLC/RWR gear interface requirements. These requirements are being addressed," reported the following year's *Tech History*.[46]

Again, delays ensued, and costs grew. Hays said:

> As a result of the long delays in HARM, the price of the system became very high. It wasn't all the contractor's fault. The Navy changed the requirements on HARM. Just about the time the contractor would get something to sort of work, they'd change the requirements: increase the bandwidth, change the number of…they'd change something. So, the contractor would have to start

[45]S-200, Knemeyer interview, 126.
[46]*NWC Tech History 1976–1977*, 5-13.

> over a bit. Unfortunately, he didn't always start completely over; he started band-aiding what he had.[47]

Richard Hughes said:

> TI did good work, without question they're great engineers. However, their design stagnated. The company was making money on the missiles. That's one thing that China Lake had going for it that nobody could match, we did it out of love, we did it out to save pilots' lives, we didn't have any economic involvement in it other than we got our paychecks. The contractors made missiles to make money. We made missiles because we loved the work.[48]

Finally, in 1982, the first production model of HARM was delivered. It was not what China Lake had expected of Shrike 73. It cost about a quarter-million dollars per missile. (Half of that cost was for the seeker.) The speed was Mach 2, about the same as Shrike. To change the missile's tactical software for different threats, the guidance section had to be sent back to the manufacturer. Still, HARM was nearly ready for action.

In November 1983, 14 years after China Lake had begun development of Shrike 73, HARM went to the Fleet with the A-7Es. IOC with the Air Force F-4G occurred in September 1984 and with the F/A-18 in February 1985.[49]

Uncertainty about the weapon's future continued. In 1983, Senator Ted Stevens of Alaska, chairman of the House Committee on Appropriations' Subcommittee on Defense, requested the GAO to look into the various procurement strategies proposed for HARM. Congress had authorized $83 million for a HARM second source.

The Navy wanted immediate establishment of the second source: low-rate production in the initial years "as the second source builds [its] production capacity" but then greater total production in subsequent years than under the single-source plan. The Navy also wanted incorporation of the HARM low-cost seeker, which had begun development at China Lake in 1983.[50]

The Air Force, fearful of a shortfall in HARM production, wanted second-source action but with greater production in the early years of the contract. Air Force officials did not want the low-cost seeker pursued. The DoD's Cost Analysis Improvement Group recommended that a cheaper version of HARM (with a low-cost seeker) be developed before any second sourcing took place.

---

[47]S-221, Hays interview, 26.

[48]S-306, Origins of ARM interview, Hughes, 33.

[49]Blake, ed., *Jane's Weapon Systems 1987-88*, 786.

[50]Frank C. Conahan, Director, National Security and International Affairs Division, GAO, to the Honorable Ted Stevens, letter, "Analysis of HARM Procurement Strategies," 12 September 1983, Appendix 1, 2.

HARM on F/A-18, circa 1984. Photo courtesy of Gary Verver.

GAO was skeptical of the low-cost seeker options:

> The Navy optimistically projects that the new seeker will be as much as 40 percent less expensive than the present HARM seeker which accounts for about 50 percent of the cost of a HARM missile. The documents that we examined suggest that realistically such a seeker will not be ready for production until about fiscal year 1990 when the currently planned procurement of HARM missiles will be nearly finished.[51]

In the end, the GAO sided with the Navy's plan for a second source to be brought on line, although warning, "In our opinion, there can be little assurance about the extent second-source investment costs will be recovered through the effect of price competition at the prime contractor level." Despite the report's conclusion and the congressional authorization, HARM continued as a single-source program.[52]

The program continued to suffer problems after Fleet introduction. For a brief period in 1986, the Navy stopped accepting missiles because of the large number of manufacturing flaws. HARM was first fired in combat against Libyan targets around the Gulf of Sidra in 1986. Over the next several years, it became

[51]Ibid., 4.
[52]Ibid., 1.

the principal defense-suppression weapon for U.S. forces, and by the end of 1990, more than 10,000 had been produced by Texas Instruments and later by Raytheon, after it acquired Texas Instruments' missile systems operations.

HARM did nothing to help the Center's reputation. Part of that was guilt by association, as the Center lacked control over the contractor's actions, but there was ample blame to go around. NWC might have taken a stronger advocacy role to push the weapon into the Fleet earlier and to reduce the number of changes that were demanded of the contractor. May said:

> I feel fairly strongly . . . that had people really examined the cost of doing the performance additions they probably would never had done them. . . . I personally would hate to lay all the blame on Texas Instruments or any other contractor. I think an awful lot of the blame for what has happened on HARM has to come right back to the Government. The battles between Congress, DOD, the Navy, or whoever, on what should happen on programs continues to go on.[53]

From 1976 until 1978, Captain Paul D. Stephenson was head of the Strike Warfare Section of the Tactical Air, Surface, and Electronic Warfare Development Division in OPNAV, where HARM was one of his programs. He subsequently served two tours at China Lake, one as Commanding Officer of VX-5 and one as NWC Chief Staff Officer. Shortly before his retirement in 1986, Stephenson summarized the problems with HARM from the perspective of a veteran Navy attack pilot.

Captain Paul Stephenson.

> If it's defense suppression, you suppress it. That doesn't mean you kill it. If you come in there and you fire one into the air, and they shut down long enough for you to do your job, you have succeeded. Now, that is all that we asked for. Once you get started . . . we always want to go one step further. "Well hey, not only would we like that [they] keep their heads down, and every now and then hit them, we'd like to just make sure that we'd kill them every time." That's a different requirement. So don't blame the developer for not killing the target each time with the weapon that was not designed to do that. If that's what you want, then reach in your hip pocket and stand by to pay a lot more money. . . It is not TI's problem that we drug this son of a bitch out for 14 years either.

[53]TS 87-14-8, May interview, 26, 28.

> You and I and the Pentagon and everybody else can take a little bit of credit for that.[54]

The HARM program significantly diminished China Lake's technical capability in the ARM area. Said May:

> When the decision was definitely made that the contractor would be the systems design agent, we essentially lost a whole branch, antenna and RF design people, because no one would pay their salary. The sponsor said that this is the direction that we are going to go and we do not need those people. We dispersed them throughout the Center.[55]

As Corzine remembers it, a few of the engineers stayed with the HARM program for a while but eventually drifted away.

> They were content for one year or two to look over TI's shoulder, if you will, . . . look at TI results, TI-gathered data. But some of our very best people left the HARM Program Office after a 1- or 2-year stint and went to other areas where they were afforded the opportunity to themselves do hands-on hardware work.

Fortunately, the ERASE program was able to maintain a core expertise in most of the ARM-related technologies.[56]

Richard Hughes recalled the period as one of uncertainty.

> Now what am I going to do? . . . I went to Jack Russell. I said, "Jack, should I be looking around the base for design jobs?" That's what I wanted to do. That's what I was good at. Jack said, "Hey Hughes, our job is to find you work. Your job is to do it." . . . The division broke up with Jack Russell heading down to Thompson Lab and Bob Corzine taking another RF division, staying there [the RF Guidance building, ¼-mile south of Thompson Laboratory]. And I went with Jack Russell. I just worked for him for a long time and I really respect him. So I went down there to Thompson Lab and worked on a project that nobody's ever heard of.[57]

Hillyer summed up his view of the shortcomings of the HARM development program.

> With the changing requirements it never settled down. No one individual, no single organization is to blame. If this Center had had system involvement, I think with those external changes the program still would have drug out. But every mistake possible was made in the system's acquisition process—

---

[54]S-160, Stephenson interview, 11–13.

[55]Ibid.; TS 84-14-8, May interview, 34.

[56]TS 84-14-9, Corzine and Sprankle interview, 23.

[57]S-353, Hughes interview, 7. The system Hughes worked on became the Selectable Seeker Simulator (Triple S), a generic antiship cruise missile simulator that became operational in 1975.

> under budgeting, diffuse responsibility, too many layers of control, too many decision makers, lack of the ability to freeze the design and get on with it, and lack of competition in the program.[58]

Schiefer noted a resentment that the laboratory had any role at all in HARM's design and development, or any other major weapon system.

> How many alphabet soup Sidewinders have we gone through when the bureaucracy says, "Okay, China Lake, you're not going to design the next one. It's going to be done in industry." And the industry lobbied for that. Even my friends at TI—and I call them my friends because we were a pretty darned good team—on HARM, didn't like it because we designed and fired the first four HARMs here at China Lake. And I said to my friend, "How piggish are you? Because here, for a few million dollars, we now have given you 20 billion dollars' worth of production and FMS sales, all of that." But industry would like to have the same role that we had on these various weapon systems, and I think that was the problem on Shrike '73.[59]

A behind-the-scenes leader in the Shrike / Standard ARM / HARM efforts was physicist and engineer Richard J. Mello, who'd come to China Lake from North American Aviation in 1960. Mello's work was low profile—scenario and threat analysis, system effectiveness, cost-effectiveness analysis, and related disciplines—but essential to the ARM programs. He became a national leader in the field of lethal defense suppression and ARM countermeasures.

Mello was selected in 1980 to head a new program called Sidearm, which developed a modification for the AIM-9C Sidewinder seeker. The AIM-9C was the semi-active radar-homing version of Sidewinder originally developed for use on the F-8 Crusader. When the Crusader was phased out of the Fleet in favor of the F-4 Phantom, nearly 1,000 AIM-9Cs were left without a launch platform and were put into storage at an ammunition plant in Hawthorne, Nevada.

The Sidearm seeker modification, coupled with the existing motor, warhead, and airframe, converted the Sidewinder to a short-range air-to-surface antiradar weapon, designated AGM-122, that could be launched from helicopters. During the 1980s, about 700 AIM-9Cs were remanufactured by Motorola as Sidearms, giving Marine Corps helicopters their first ARM capability.

In the late 1980s, China Lake would become more deeply involved in the technical developments of new versions of HARM (AGM-88B and AGM-88C), incorporating new features that were initiated in the antiradiation projectile program. China Lake also developed an alternative seeker (HARM

---

[58]S-134, Hillyer interview, 56.
[59]S-305, Schiefer interview, 14.

low-cost seeker). Beginning in the 1990s with a Small Business Innovation Research (SBIR) program, China Lake participated in the development of the AGM-88E Advanced Antiradiation Guided Missile (AARGM), the Navy's newest antiradiation weapon. Interestingly, whereas the function of the early antiradiation weapons was described as suppression of enemy air defenses, AARGM's official mission is destruction of enemy air defenses.[60]

Electronic Countermeasures (ECM) / Electronic Counter-Countermeasures (ECCM)

The Vietnam War caused a surge in the development of ECM (e.g., broadcasting a jamming signal to confuse a radar-guided missile) and ECCM (e.g., incorporating circuitry in the missile that can track the source of the jamming signal and direct the missile toward the jamming platform). It was a spy-versus-spy routine, where each new countermeasure deployed by one side set off a scramble by the other side to develop a counter-countermeasure response. The 1968 *Tech History* reported that

> the current activity in Vietnam and the increasing EW threat to the Fleet all over the world demonstrate the urgent need for ECM and ECCM development. It is particularly important that EW be considered during initial phases of weapon system design.

Throughout the war, scientists and engineers at China Lake worked not only to develop new means for blinding or confusing the enemy's electronics but also to incorporate counter-countermeasures in, primarily, aircraft-borne and missile-borne electronic systems. Extensive studies and simulations were conducted on U.S. systems to analyze their potential vulnerabilities. Engineers would then use the results to "harden" the circuitry of target-detecting devices (TDDs), radar warning receivers, communication gear, and similar electronic systems.

At the same time, different jamming techniques were tested against threat systems (some simulated, others captured from enemy forces or purchased from third parties) to exploit their frailties. Techniques varied from frequency hopping to frequency modulated / sine-plus-noise barrage jamming. Meanwhile, parallel efforts were underway at the Center for weapons and sensors that operated in the IR portion of the electromagnetic spectrum (e.g., Sidewinder) rather than the RF portion.

---

[60]During the 1980s, China Lake was also involved in the development and testing of Tacit Rainbow (AGM-136), a joint-service (Air Force-led) loitering antiradiation weapon built by Northrop Corp. The program was cancelled in 1991.

Echo Range

In the early days of attack aircraft operations, the basic targeting tool was the eyeball. A pilot flew around until he spotted a tank, a bridge, or a truck, then attacked it with a bomb, rocket, missile, or guns. The process was more complex than that—there was sun angle, dive angle, and bomb release computers, and later laser designators, either airborne or ground based—but the targeting process was fairly intuitive.

To locate, target, and attack an electronic threat was not so straightforward. An SA-2 radar-guided SAM, for example, was usually not visible until after it had launched and was closing fast on an aircraft. The radar that controlled that threat might be located remotely from the launch point, or the ground operators might transfer the tracking signal from, say, a long-range "Spoon Rest" radar to a closer-range "Fan Song" radar. The radars that were at the heart of the SAM system—long-range acquisition radars to locate the incoming aircraft and illuminator radars to "paint" the target for the missile's onboard guidance system—were often invisible to the attacking aircraft, but the radar signals themselves could be acquired, identified, and tracked by the aircraft's onboard systems. Cockpit sensors became the principal source of information about the nature, direction, and urgency of the threat. This shift in emphasis from the visible to the invisible required new sensors, new cockpit interfaces, and new tactics.

Less than a year after the first U.S. plane was downed by a SAM in Vietnam in July 1965—taken by the same type of missile that had shot down Francis Gary Powers' U-2 spy plane over the Soviet Union in 1960—the Navy asked the Applied Physics Laboratory at Johns Hopkins University (JHU/APL) to find a solution for the SAM problem. VX-5 sent two A-4s and flight crews from China Lake to assist, and there followed several weeks of testing in Nashua, New Hampshire, where the pilots flew against a Fan Song B radar (the SA-2B fire-control radar) simulation built by Sanders Corp. The home-built threat radar simulator was not a perfect duplicate of the Fan Song, but as JHU/APL historian Arthur Williamson wrote, "it was the only simulator available at the time."[61]

Out of the brief test series came the realization that a lot of questions could be answered, and problems solved, by testing U.S. aircraft in the presence of threat radars. "This realization," Williamson continued, "led to the proposition that a range equipped with instrumentation to test and evaluate countermeasures and tactics should be developed to provide a realistic threat environment." Thus was

[61] Williamson, "The EWTES (Echo Range) Story," 582.

conceived Echo Range—formally the Electronic Warfare Threat Environment Simulation (EWTES).[62]

A spot was chosen in the 800-square-mile Mojave B Complex of China Lake. Its remoteness (it's a 45-minute drive from Mainside) made it particularly attractive, free from prying eyes and sensors, and it was far from the many RF radiating sources near Mainside and Armitage Field in the North Range Complex.[63]

Echo Range was built from the ground up in the desert by China Lake's Range Operations Division under the leadership of Dr. James Colvard. The crews worked 14-hour days, 7 days a week, to meet an unrealistically tight schedule. When the range opened in November 1967, it consisted of simulators for the Fan Song B (SA-2 fire control radars) and Fan Song C (SA-2 tracking radars) as well as a captured Son-9 Fire Can radar, used to direct North Vietnamese antiaircraft guns. China Lake engineers built several more simulators from various U.S. radars and fire-control systems. Through buying, begging, borrowing, stealing, and reverse engineering, the range grew quickly, adding not only threat radars but also support equipment to track, monitor, and record the engagements that took place on the range.

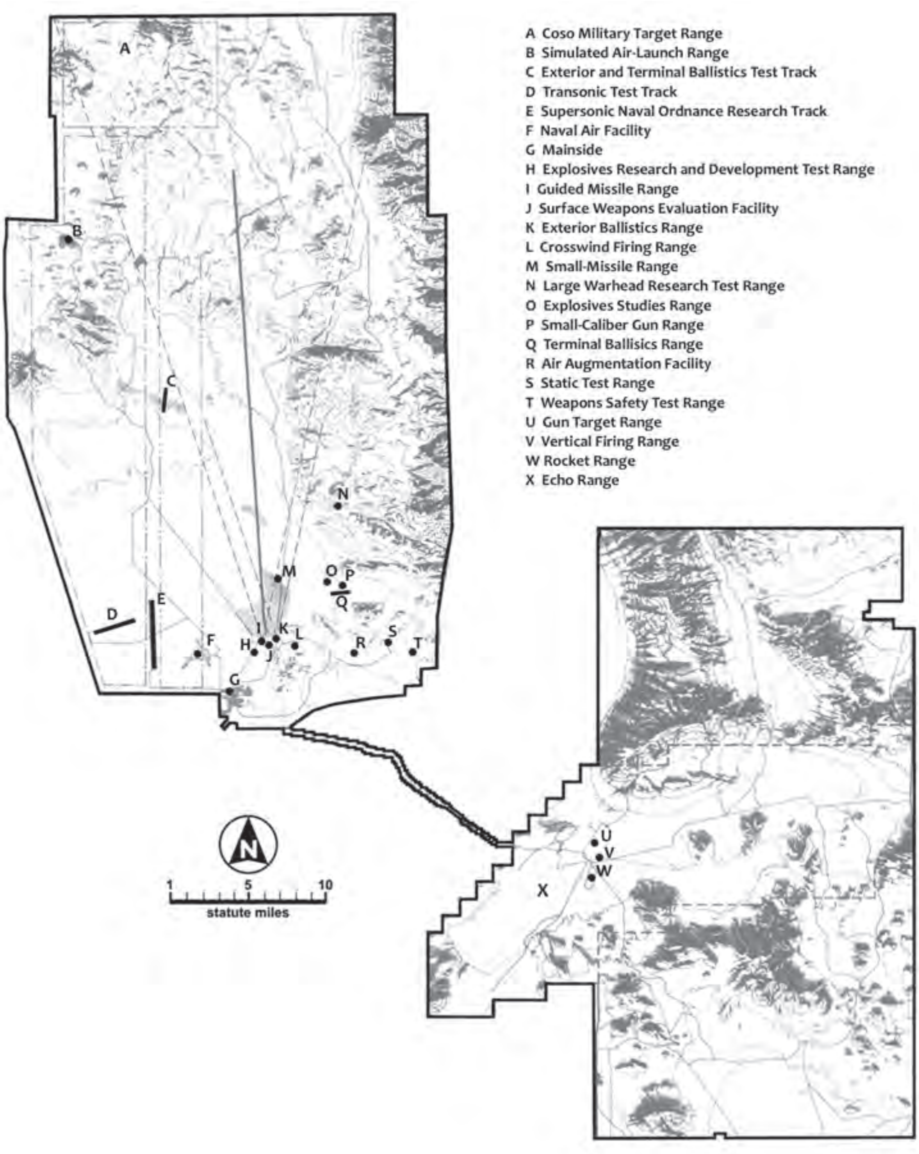
Echo Range had—and to this day has—several functions. One was to help develop tactics for approaching and eluding threat radars. For example, early flights against the range emitters led to a maneuver-based countermeasure that was highly effective against the Fan Song radar.

Additional purposes were to test new devices and countermeasures—jammers, chaff, radar-warning receivers, and other ECM-associated penetration aids—in a real-world scenario but without the bullets and missiles whizzing around as well as to test the effectiveness of threat counter-countermeasures. Yet another purpose was to train and test Navy aircrews in their ability to exercise EW gear and tactics against skilled operators.

---

[62]China Lake had done electronic-threat environment testing during the development of Shrike in the early '60s when Shrike seekers mounted in the nose of a TA-4 were flown against surplus WWII-vintage SCR-584 radars and Nike missile system radars. Seeker hardware was also carried aloft under hot-air balloons to aid in characterizing the interaction of the airborne seeker with the ground-based radar.

[63]Mainside is the unofficial name for the central portion of the base, where housing, administrative offices, and most laboratories are located, to distinguish it from the many ranges and facilities located across hundreds of square miles of Navy land to the north, east, and southeast.



Map of China Lake showing Echo Range.

Operations at Echo Range began late in 1967 and ramped up quickly. By the end of 1968, more than 185 flights had been completed, evaluating a variety of radar and countermeasure systems including the AN/ALQ-51A, AN/ALQ-100, AN/ALQ-81, AN/ALQ-89, AN/ALE-29, AN/APR-27, AN/APR-27 Mod 2, AN/ALT-27, and an expandable jammer called Channel I. The range also hosted carrier air wing (CAW/CVW) strikes "to allow the exercise of CAW defensive ECM equipment in a tactical radar environment."[64]

Aerial view of Land Site 1, Echo Range.

Initially, JHU/APL was responsible for Echo Range operations. Because of China Lake's growing expertise in EW, responsibility for the range's hardware and software was transferred to the Range Operations Division in 1971. That same year, optical augmentation of the range was begun with a laser rangefinder, closed-circuit television, azimuth and elevation encoders, and boresighted binoculars to simulate current and developing Soviet optical antiaircraft fire-control capabilities. Capabilities for nighttime target tracking with low-light-level television and IR imaging devices were also added.

[64]*NWC Tech History 1968*, 8-47.

In 1972, APL became a technical consultant, and full responsibility for the range became China Lake's. By then, Echo Range was becoming a standard venue for the developmental testing of new ECM systems; in 1972, 517 such tests were conducted for Navy, Air Force, and Army customers, and the numbers continued to increase as the years passed.

Addition to the arsenal of enemy simulations continued in the early 1970s with the acquisition of a "Low Blow" radar (the fire-control radar for the SA-3 Goa missile) and a "Peel Group" radar (the missile control radar for the SA-N-1, the naval version of the Goa missile). Addition of a sea site in 1974 provided a single site simulating various Soviet shipborne threats. Work also began on the formation of an integrated air-defense system simulation.

Aerial view of Sea Site, Echo Range.

By 1977, Echo Range was configured in five major sites: Land Sites 1 and 2, North Atlantic Treaty Organization (NATO) Site, Sea Site, and a target airfield that was protected by the collective EW suite. The range had the capabilities

> (1) to measure aircraft space position, (2) to compute threat radar tracking errors resulting from airborne countermeasures, (3) to simulate the launching of missiles against the tracked aircraft, and (4) to determine missile miss distances.

During 1976 and 1977, more than 1,000 flight tests were conducted on the range.[65]

In less than 10 years, Echo Range had gone from an empty expanse of wind-blown desert to one of the world's most sophisticated EW ranges serving the Navy, Marine Corps, Army, Air Force, NATO, and defense contractors. It would continue to evolve over subsequent decades, keeping pace with the nation's adversaries. Today, known as the China Lake Ranges EW Complex and spanning the entirety of the China Lake Ranges, it uses simulators, surrogates, and actual threat systems operating in the IR, RF, and EO regions to provide the most advanced threat-rich environment in the free world.

[65] *NWC Tech History 1976–1977*, 11-24.

5

Organizational Tumult

Operating in the twilight zone presents a challenge that is almost without precedent.

—Admiral I. J. Galantin, Chief of Naval Material (CNM),
on managing in a time of "half war, half peace"[1]

"The sickness started in [1967] when the Centers of Excellence were formed," Bob Hillyer told an interviewer in 1982. The sickness to which Hillyer referred was a lack of direction, poor morale, confusion, and organizational depression that affected China Lake in the 1970s. The malaise would peak under Rear Admiral Rowland G. Freeman III, China Lake's 19th Commander, and would subside under the leadership of Captain William B. Haff, who commanded the Center from 1979 to 1981.

If Hillyer was correct in his estimate of the onset date, the sickness was initially asymptomatic. In 1968 the war business was booming, and China Lake-developed weapons were being heavily used in the skies and jungles of Vietnam.

Among some of the Center's employees and their families, a sense of loss lingered after the previous year's departure of Dr. McLean, who had led China Lake's technical work for 13 years, and his wife LaV, who had been a mother figure to the community. McLean, by virtue of his reputation as the inventor of Sidewinder and the recipient of awards too numerous to mention, had clout in Washington; he had managed to shield his workforce from the worst of Washington politics and keep the base running smoothly.

McLean had an intuitive understanding of the *Principles of Operation* conceived by the Station's founders. Yes, China Lake was a military base, but in terms of its product—weapons and technology—it was run by civilians. "Simply stated," one author wrote,

[1]Galantin, *Defense Industry Bulletin*, inside back cover. "Material" in this context is pronounced as if it ended in "el" and with the stress on the final syllable.

> the Principles provided that the technical activities were the range of responsibility of a technical director. The provision of support for the technical activities was the responsibility of a military Commander. The Commander and the Technical Director shared equally the effective operation of the institution.[2]

McLean had developed harmonious relationships with eight different China Lake Commanders, maintaining the fragile balance between military control of the base and civilian control of the technical work. In the years ahead, this balance would be sorely tested, but in 1968, thanks largely to McLean, it was working well.

Through nearly all of McLean's tenure, he had been capably assisted in his job by Associate Technical Director Hack Wilson. Wilson did far more than simply lighten McLean's administrative burden. Carl Schaniel, long-time China Lake department head (Weapons Planning, Ordnance Systems, and Fuze and Sensors), recalled:

> Hack Wilson was the inside man in the China Lake top management team. Hack managed the plant, the people, the administration and the finances. Bill McLean was the outside man. I never saw such a perfectly matched team. Hack's ability to keep the home base going gave McLean the freedom to focus on new areas and new technologies.[3]

It had seemed only natural, then, that when McLean left to head the newly formed Naval Undersea Warfare Center (NUWC), Wilson would step into his shoes as Acting Technical Director of the fledgling NWC, which he did on 1 July 1967. Most people expected that the "acting" would soon be dropped from his title, as Wilson had the backing of the NWC Commander, Captain Etheridge. Dr. Newt Ward, head of the Aviation Ordnance Department (AOD) at the time, said:

Dr. Newt Ward.

[2]Babcock, *Magnificent Mavericks*, xxii.
[3]Schaniel, *Carl's Career Chronology*, 179.

> Mel Etheridge wanted Hack. He said so, out loud in front of lots of people—Bureau people and so forth . . . He told everybody that Hack was the only possible candidate. He told the selection committee that came out to interview candidates.[4]

The Amlie Directorship

The first of many organizational shocks to NWC came in March 1968 with the formal announcement that Dr. Thomas Strong Amlie had been selected as NWC's first Technical Director. (He had been appointed temporary Acting Technical Director on 17 January, pending Civil Service Commission approval of his permanent assignment to the top civilian slot.) Amlie had been leapfrogged from the position of division head over China Lake department heads. (Frank Knemeyer, Weapons Development Department, and Leroy Riggs, Electronic Systems Department, had both applied for the position.) "We all thought that Hack Wilson would have it," Knemeyer said, "but then all of a sudden Tom Amlie, who was a division head at the time, came from a division head up to Technical Director."[5]

Amlie was a larger-than-life character, technically brilliant and perceived in some quarters as eccentric. At China Lake he was renowned for his red shoes (which he wore in Washington as well); his prized 16-cylinder 1939 Cadillac convertible; and his pair of Irish Wolfhounds, which cavorted about the Center's housing area. Amlie's wife, June, was also a "Dr. Amlie"; she had a doctorate in analytical chemistry from Rutgers and held various positions in China Lake's technical departments.

Not only did Amlie have no experience managing a department, he had little administrative experience as a division head. "As a division head, I had absolutely no administrative duties of any sort," he told an interviewer in 1992. "PDs [position descriptions] were written for me by the personnel lady, who was a genius. Contracts were let by the contracts lady. The budget was kept by the budgets lady. I did nothing but technical work."[6]

According to Newt Ward:

> Frosch [Dr. Robert A. Frosch, ASN R&D] had said, "I want a guy with a PhD and young—under 40 preferably.". . . At China Lake there were two people as far as I know who met these criteria. One was Tom Amlie and the other was Pierre Saint-Amand.[7]

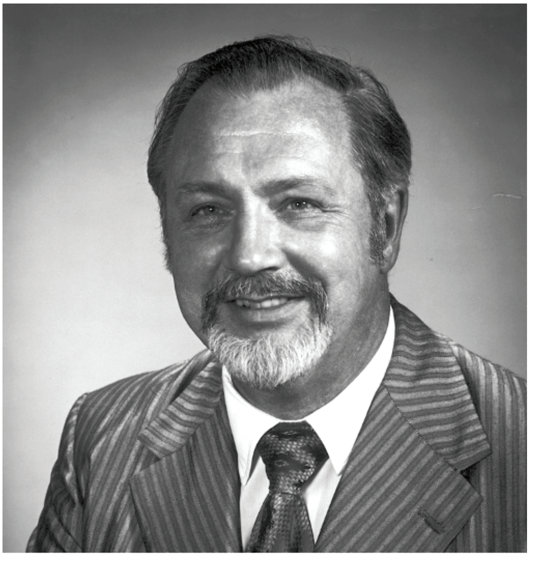
---

[4]S-94, Ward interview, 23.

[5]S-117, Knemeyer interview, 22.

[6]S-199, Amlie interview, 12.

[7]S-94, Ward interview, 23–24. There were actually several other people at China Lake who met the gender, education, and age parameters cited by Ward.



Dr. Pierre Saint-Amand.

At the time, Saint-Amand, who was as brilliant (and some would say as eccentric) as Amlie, was deeply involved in very highly classified efforts developing and implementing weather modification as a tool of war. And Amlie did have a good track record. Said Ward, "Tom had put a missile into the service practically single-handedly [the Sidewinder AIM-9C], which nobody else ever did—far more single-handedly than McLean ever did."[8]

Of Frosch's preference, Amlie commented laconically, "He wanted a PhD. I was and Hack wasn't."[9]

According to Leroy Riggs, a long-standing friend of Amlie's:

> Tom was embarrassed to be selected over Hack and he said so. In the very first department head meeting, Tom says, "This is the dumbest thing the Navy has done in a long time, and I'm telling you all right now, Hack—all you guys, all you 'robber barons' (as the department heads used to be called, you know), all you guys—Hack's still running this place, and I'll try and stay out of your hair."[10]

When interviewed by the *Rocketeer* about his promotion, Amlie spoke with humility.

> As you know I have been selected for the position of NWC Technical Director to replace Dr. McLean. I feel very much like Harry Truman did on April 12, 1945 [the day that Truman was sworn in as president, following the death of Franklin Delano Roosevelt]. All of a sudden I'm going to have very great responsibilities and I'm going to need all the help I can get to properly discharge these responsibilities. . . . The plan is not to rock the boat in any way. Any changes that I propose will, of course, be discussed with all the department heads and the Commander before they are implemented.[11]

[8]Ibid.
[9]S-150, Amlie interview, 16.
[10]S-136, Riggs interview, 77.
[11]*Rocketeer*, 8 March 1968, 1.

He added that his most important job would be "to act as 'chief salesman' to sell programs at the appropriate levels in Washington."[12]

Humility, however, was not Amlie's strong suit. In Ward's opinion:

> He was as diplomatic as the heel of a boot. He had a condescending attitude towards most officers . . . They were a bunch of dumbbells, and he had the same attitude towards most of the civilians in the Bureau of Weapons. He once got into an argument with John Rexroth, who was the senior civilian in the Bureau of Weapons missile business. They got into an argument about some radar or other and Tom said, "John, you wouldn't know a Mark X Radar if one fell on your head." So, he had less than a friend in John Rexroth.[13]

According to Rexroth, who was at the time of Amlie's tenure the Technical Director of NAVAIR's Missile Development Office:

> There was a very, very, distinct change with Amlie. He was very positive about things and didn't need any help from the Command. He knew what needed to be done. To him, the Headquarters function was to bale up the money and send it out to the Laboratory to be used in any way that he felt it should be spent. It was difficult to work with him and as a consequence a lot of good projects never got off the ground. . . . From the standpoint of the Command, we were almost ready to stop doing business with NWC entirely because it was so difficult to get him to allow the Laboratory to work on the things that we needed to have done.[14]

Ward and Rexroth were not alone in their assessment of Amlie's lack of finesse in the Washington arena. Dr. Hugh Hunter, head of the Research Department, said, "He went at the job without the diplomacy that has to be used to interface with Washington."[15]

Saint-Amand, head of the Earth and Planetary Sciences Division, said, "He had a personality that was somewhat abrasive, and he could not tolerate fools gladly, so he didn't stay in the job very long."[16]

Detonation physicist Bud Sewell, who had worked with Amlie in the early Sidewinder days, weighed in:

> Tom was a brilliant man, had the brilliance to be the greatest Technical Director. But he was not at all political. For instance, at one meeting, when a committee was here to evaluate the effectiveness of missiles, one of the men from Washington kept raising questions, and Tom finally said, "How many missiles have you personally gotten into the Fleet?" The man said, "Not any."

[12]Ibid.
[13]S-94, Ward interview, 25.
[14]NL-T33, Naval Laboratories Oral History Program Interview, Rexroth, 19–20.
[15]S-95, Hunter interview, 6.
[16]S-120, Saint-Amand interview, 31.

> Tom then said, "Well, I've put two in." In short, he was frequently right, but just not political.[17]

Dr. Joel Lawson, who assumed the position of Director of Navy Laboratories (DNL) in September 1968, didn't work well with Amlie. "China Lake's total budget was running 150 million dollars a year," Lawson told an interviewer in 1975. "About 3 million dollars a year of that money came from me and the laboratory was doing what it pleased with it."[18]

Ward recalled:

> Tom had disdain for Joel Lawson and didn't hesitate in expressing this one way or another . . . Tom knew he wouldn't do anything. He was kind of pompous and Tom observed that. Told Joel he couldn't fire him. Joel called him back one time and told him he was fired. Tom said, "You can't fire me, Bob Frosch appointed me."[19]

The 2 years following his appointment as Technical Director were rough for Amlie and, by extension, for the Center. On the home front, the Technical Director drew the ire of the Research Department when he insisted that they scramble for funding just as the engineering side of the house did. In 1983, Amlie told an interviewer:

> I said, "You want money, do like the rest of us, go to Washington and get it." . . . As far as we were concerned, aside from having premium housing, premium laboratory space, and higher grade levels, they didn't do a damn thing. I mean they worked. They were publishing the journals. Fine. That didn't make missiles work.[20]

Amlie also did not get along with his military counterpart, Captain Etheridge, who had enthusiastically supported Hack Wilson for the Technical Director slot. According to Wilson, who served as Amlie's Deputy Technical Director, "Somebody would call up Etheridge and say, 'What is your guy doing back here doing this?' and Etheridge would go back and say, 'Gosh, I don't know. I don't tell him what to do.' "[21]

When Amlie was asked in 1983 if his relationship with Command at China Lake was good, he replied simply, "No. Very bad."[22]

---

[17]S-106, Sewell interview, 8.
[18]BA-2-75, DNL Oral History Collection Interview, Lawson, 28.
[19]S-94, Ward interview, 27.
[20]S-150, Amlie interview, 13.
[21]S-96, Wilson interview, 47.
[22]S-150, Amlie interview, 13.

Business couldn't go on that way indefinitely. "Barney Smith [former China Lake department head and then Technical Director of the Naval Weapons Laboratory] came out to the Station," related Ward.

> And he said, "For goodness' sake, can't you do anything, Tom's in real deep trouble. He's got to quit sneering at these admirals around here, and particularly Etheridge." Well, I never mentioned this to Tom because I knew that Tom just wasn't about to change. . . . So finally Frosch was pushed into reassigning him.[23]

Just 2 years after Amlie's selection as NWC Technical Director, a brief note in the *Rocketeer* under Hack Wilson's photograph announced:

> ACTING TECHNICAL DIRECTOR—Capt. M. R. Etheridge, NWC Commander, announced the reassignment of Dr. T. S. Amlie, NWC Technical Director, to the position of Consultant to the Commander at a meeting held March 6. In the same announcement, Capt. Etheridge designated Deputy Technical Director H. G. Wilson as Acting Technical Director of NWC. This action was effective as of March 5, 1970.[24]

On 14 August 1970, Wilson was confirmed as Technical Director by the Office of Civilian Manpower Management.[25]

After 19 years at China Lake, Dr. Amlie and his wife and their three children left in August 1971 when Amlie took a management position in Washington with the Federal Aviation Administration (FAA).

Reorganization, 1970

China Lake was no stranger to reorganizations; one old joke at NOTS was that the acronym stood for Naval Organization Test Station. While not infrequent, such reorganizations were generally small-scale; a new branch created, two divisions combined, a juggling of middle managers within a department. The biggest reorganization had been that which ensued from the 1967 establishment of Centers of Excellence when Pasadena and the ocean work were stripped from China Lake and the functions at Corona were grafted on.

In 1970, a series of reorganizations began that reflected a Center groping for a unifying identity and trying to adapt to new technologies, new leaders, new directions, new threats, dwindling DoD budgets, and the end of a long war.

---

[23]S-94, Ward interview, 27–28.
[24]*Rocketeer*, 13 March 1970, 1.
[25]Ibid.

Rear Admiral William J. Moran took over from Captain Etheridge in October 1970. Moran had first been assigned to NOTS in 1950 for a 2-year tour as operations officer and returned in 1955 for a 3-year tour as Assistant Experimental Officer (air-to-air weapons). (It was Moran who persuaded China Lake engineers to begin work on the antiradar missile that would become Shrike.) He was familiar with the base and with the ins and outs of the weapons development process. He also appreciated the separation of duties between the military and civilian sides of the house as well as the dependency of each on the other.

Rear Admiral William J. Moran.

October 1970 also marked China Lake's first major reorganization since its 1967 inception. Dr. Dick Kistler, then an analyst in the Weapons Planning Group and later head of the Office of Finance and Management, recalled:

> The Center hadn't reorganized itself for 15 years, and all of the folks that Jim Colvard used to call the "robber barons" had been comfortably in place for more than a decade, same Technical Director much of the time—Dr. McLean was here a long time, Hack Wilson was the Deputy. So presently, Haskell shook up the Center, and after he became the Technical Director he made the big changes.[26]

One factor influencing the 1970 reorganization was the Center's high rate of general and administrative (G&A) overhead (the cost of Center operations that were not directly funded by the Center's customers). A table prepared by Central Staff in April 1970 compared G&A rates on a dollar-per-hour basis among eight Navy laboratories. China Lake was by far the highest at $6.15. Next highest was the Naval Research Laboratory ($4.42). Lowest was the Naval Air Development Center (NADC, $2.58).[27]

---

[26]S-131, Kistler interview, 26.

[27]Head, Central Staff, to Codes 00, 01, and 02 and Technical Department Heads, memorandum, "Overhead Rates Comparison," 6 April 1970, 1.

Many of China Lake's administrative and clerical positions were G&A funded, and the ranges ran on overhead when not charging to specific projects. However, there was room for improvement. As Kistler pointed out a little testily in a memorandum to his colleagues in the Weapons Planning Group and Central Staff, "Departments tend to operate as feudal baronies and thus perceive a need to maintain their own administrative (overhead) staffs to duplicate what Code 17 [Central Staff] does."[28]

Another factor affecting the reorganization was an internal realignment and focusing study conducted Center-wide in late 1969. The study was led, at Amlie's request, by Wilson. That study was prompted by Center management's realization that "the internal and external environment of NWC is changing or being subjected to change," that "pressure will be upon DOD to make do with a lesser [funding] growth rate than has been evident in the past," and that the Vietnam conflict "is expected to decline in terms of U.S. support."[29]

Since 1965, NWC had been operating under a Secretary of the Navy-mandated acquisition policy that required a contract definition phase wherein two or more contractors were brought on board early to work with the Navy development team—although this most often turned into a situation where the contractors were competing with the government, specifically, with the Navy laboratories, rather than cooperating. The policy was widely criticized by the laboratories.[30]

According to the record of the NWC Technical Board meeting in September 1969, at which Amlie announced the realignment and refocusing study, he also told the board that "Dr. Frosch and the higher levels in DOD are swinging away from Contract Definition and more towards the NWC philosophy." The meeting recorder then noted, "There was general agreement that the environment is changing and we'd rather develop weapons the Sidewinder and Shrike way than the Condor and Standard Arm [*sic*] way."[31]

---

[28]Kistler to Schaniel, McKenzie, Poppen, Goettig, and Swan, memorandum, "Notes on Meeting of 27 April," 28 April 1970, 2.

[29]Commander and Technical Director to Distribution, memorandum, "Realignment and Focusing Study for NWC," 11 September 1969, 2.

[30]The Contract Definition Phase was the reason that Chuck Bernard quit his job as head of the Propulsion Systems Division at China Lake. See S-189, Bernard interview, 92–93. Bernard later served as Technical Director for NOL Dahlgren, and Director of Land Warfare, USD(RDA).

[31]*NWC Technical Board Minutes*, 24–26 September 1969, San Diego, California, 2. The Technical Board was composed of the Commander, Technical Director, heads of the technical departments, and other invitees, depending on the topics under discussion.

Structurally, the 1970 organization was an attempt to put similar types of programs into the same departments—for example, radar-oriented systems in one department, EO systems in another. Prior to the reorganization, these activities had been scattered among three departments. Now, two departments were disbanded entirely: Newt Ward's AOD and Leroy Riggs' Missile Systems Department—Corona. The components of these departments were then allocated between two departments: Frank Knemeyer's existing Weapons Development Department (Code 40), and a new Electronic Systems Department (Code 35) to be headed by Riggs.

"We put it in a simple little formula on the blackboard," said Riggs.

> We're going to divide it at 100 megahertz. So all of the technology which is less than 100 megahertz frequency is in 35. Now that will mean all of the radar stuff and EW is there. We divided it at 100 because I was starting to do some work at 94 gigahertz in MICRAD [microwave radiometry]. . . . and Frank then took all the EO and IR stuff.[32]

Odd man out in the three-into-two department reorganization was Newt Ward, who was kicked upstairs to Hack Wilson's former post, Deputy Technical Director.[33]

The reorganization was more than just a movement of people and a changing of organizational lines of authority; lost in the shuffle was a piece of China Lake culture. AOD had been created in 1950. Its first head had been Dr. McLean, from whom Ward had taken over in 1954, and it was home to the original Sidewinder. An announcement of an AOD reunion in 1980 noted, "The department was known for its esprit de corps, its warmth, and individual cooperativeness. These were seen as an extension of the personality of Department Head Dr. Newton Ward."[34]

"There was a great deal of apprehension which was, of course, easy to hear about in the Ad [Administration] Building," said Kistler.

> "Isn't this going to have a devastating effect on morale? How will the guys feel when good ol' so-and-so isn't running the department anymore?" So we waited for the impact, and there wasn't any. Things went on about as usual.[35]

---

[32]S-136, Riggs interview, 22.
[33]Ibid.
[34]*Rocketeer*, 14 March 1980, 3.
[35]S-131, Kistler interview, 26.

LaBerge Directorship

In February 1971, Hack Wilson and Moran persuaded Dr. Walter B. LaBerge to return to China Lake as Deputy Technical Director. (Newt Ward became Associate Technical Director.) LaBerge, who held a doctorate in physics from Notre Dame, had been an early Sidewinder program manager. He had left China Lake in 1957 for Philco-Ford, where he'd held several top management positions, including head of the team that designed and installed the instrumentation at the National Aeronautics and Space Administration (NASA) Mission Control Center (later the Lyndon B. Johnson Space Center) in Houston.

Dr. Walt LaBerge.

> "Dr. LaBerge was recruited by Hack Wilson to come back to China Lake and take the position of Deputy Director and get in training to be Hack's successor as the Technical Director," Carl Schaniel wrote. "Hack was planning to retire in a year or two. This was Hack's way of leapfrogging the long time problem of succession to the Technical Director position."[36]

Wilson established the same relationship with LaBerge as he'd had with McLean, albeit the titles of the positions were reversed. "Walt came on board and operated as though he were the Technical Director with Hack's full support," Schaniel wrote. "Hack, who had the title of Technical Director, acted as the inside man, and LaBerge as the outside man. It was much the way McLean and Wilson had operated as a team in the NOTS days."[37]

Moran left China Lake in October 1972 and was replaced by Rear Admiral Henry M. Suerstedt Jr. For the previous 18 months, Suerstedt had served as Deputy Commander for Plans and Programs and Comptroller for NAVAIR. "He came with two strikes on him," Wilson said.[38]

---

[36] Schaniel, *Carl's Career Chronology*, 182.
[37] Ibid.
[38] S-96, Wilson interview, 56.

The first strike was that Suerstedt was the second choice for the China Lake Command. The first choice, made by the CNO, had been a rear admiral who had once worked for Secretary Frosch as a captain and whom Frosch had asked to be removed. While Frosch did not have a say in the selection of the China Lake Commander, he did have veto power, and he vetoed the first choice.[39]

Rear Admiral Henry M. Suerstedt Jr.

Strike two for Suerstedt was that when the selection board met that fall, they passed him over for promotion. "It is difficult for me to understand how sending him to China Lake was a responsible action if in fact he had been passed over," Hack Wilson would later say.[40]

Rear Admiral Paul E. Pugh.

In April 1973, 5 months after Suerstedt came aboard, Hack Wilson retired. As expected, LaBerge was appointed Acting Technical Director. Suerstedt had been having health problems since before his arrival at China Lake, and in early May 1973, after only 7 months as NWC Commander, his retirement was announced. On 30 May he was replaced by Rear Admiral Paul E. Pugh. The following month, LaBerge's appointment as Technical Director was confirmed. At that point, the prospect for a period of stability in China Lake leadership looked promising, but it was not to be.

[39]The first choice was Rear Admiral William L. Harris Jr., who would take command of NWC in 1977.

[40]S-96, Wilson interview, 56.

Reorganization, 1973

From the birth of the Station until 1952, the civilian side of China Lake had been divided into departments, each run by a department head. Within the departments were divisions, each subdivided into branches and sometimes further into sections. Department heads were guided by the Technical Director and two Associate Technical Directors, one for research and one for engineering. From 1952 to 1955, the research and engineering distinction was dropped; one Associate Technical Director was located at Pasadena and one at China Lake. From 1955 on, the Technical Director and a single Associate Technical Director oversaw the department heads. The title of Associate was changed to Deputy in 1968, but the position of Associate Technical Director was recreated as a place for Newt Ward when LaBerge came on board as deputy in 1971. Essentially, for the 18 years preceding LaBerge's ascendancy to the Technical Director's position in 1973, the civilian management structure had been one man at the top working with a right-hand man to manage all the department heads.[41]

No sooner had LaBerge been confirmed as Technical Director than he dropped an organizational bombshell. He created three "directorates" sited below his office in the civilian chain of command and above the departments. The directorates were headed by Deputy Technical Directors Leroy Riggs (Electronic Systems Directorate), Frank Knemeyer (Strike Systems Directorate), and Ivar Highberg (Air Combat Systems Directorate). The trio, which now collectively held the second tier of civilian authority at NWC, were sometimes referred to colloquially by China Lakers—and perhaps others—as The Triumvirate.

The Triumvirate: Riggs, Knemeyer, and Highberg.
Published in the *Rocketeer*, 29 June 1973.

[41]For many years each department head also had the title of Assistant Technical Director for (Engineering, Propulsion, Research, etc.) that reflected the person's advisory capacity in those fields.

To fill the empty slots thus created, three people moved in as acting department heads: Duane Jack Russell (Electronic Systems Department), Burrell Hays (Engineering Department), and Peggy Rogers (Weapons Development Department). A new department, the Surface Missiles Department, was created to recognize the Center's newly assigned responsibilities in antiship missile defense (ASMD); Bill Porter was selected as the department head.

The reorganization consolidated the range functions, which had been located in several departments, into a separate Test and Evaluation (T&E) Department headed by William R. Hattabaugh under Riggs' directorate. Excluded from the directorates and answering directly to the Technical Director were the Weapons Planning Group, the Research Department, the Technical Officer (Captain Tommy Wimberly), and the Technical Consultant (Dr. Howard A. "Howie" Wilcox).


Bill Hattabaugh.

It was the largest restructuring of China Lake top management since the base began in 1943. The *Rocketeer* article announcing the reorganization justified it obtusely:

> The intent is to delineate and evolve primary mission area assignments within each directorate, and to provide sufficient personnel assets and facilities to enable maximum flexibility and optimal resource allocation in meeting technical program requirements.[42]

Leroy Riggs opined that LaBerge did not see any single person who could be the second in command—as Wilson had been, functionally, for McLean and for LaBerge himself. So, Riggs believed, LaBerge divided up that second-in-command role among three top managers, each with a different set of skills, and he divided the technical departments between the three of them.

Hays thought that one of LaBerge's goals in the reorganization was "to provide a method of promoting younger managers to Department level," and "to reduce the influence of the old-guard managers." He notes that "Walt was under some pressure by DNL and ASN to move out the 'old blood,' and this was a first step in doing that."[43]

[42]*Rocketeer*, 29 June 1973, 1.
[43]Burrell Hays review comments, 12 January 2015.

When asked his reasons for the reorganization 16 years later, LaBerge was, perhaps intentionally, vague: "You reorganize the people to get the ones you want doing the things that you want to have them do." The challenge he saw in reorganizing was "how do we get—in a way that is honorable to people—things rearranged so that they get a set of people that ought to be doing things, doing things?"[44]

A memo from LaBerge to Dr. Lawson, the DNL, requesting permission for the reorganization, was more specific as to the new Technical Director's intent. The memo began by noting that the positions of Deputy Technical Director and Associate Technical Director were currently empty, through, respectively, LaBerge's promotion and Newt Ward's January 1973 retirement. LaBerge proposed that neither of these positions be filled.[45]

He went on to justify the establishment of three directorates: "The NWC Technical Director can reduce his present span of control to a traditional and more manageable span of control" and "delegate daily control to the separate Deputy Technical Directors."[46]

Further, he wrote:

> The proposed reorganization removes the inherent confusion of the "one-on-one" deputy. This one-on-one deputy arrangement is only workable in the very special cases of an ideal personality match (McLean/Wilson) or where the TD [Technical Director] has overtly picked his successor and decided to use the deputy position to quickly train him (Wilson/LaBerge). [Parentheses in original.][47]

"Lastly," LaBerge explained,

> this reorganization permits moving forward in responsibility the most capable of the presently coequal department heads (Mr. Riggs and Mr. Knemeyer) and through selection of Dr. Highberg, permits deferral for one year, until his retirement, the selection of the permanent third deputy not clearly selectable at this time. By raising these individuals, the direction, supervision, and training of the somewhat less capable department heads, will be increased. . . . This suggested reorganization is the result of extensive consideration, it is endorsed by the Commander, Naval Weapons Center, and considered essential by this writer.[48]

[44]S-178, LaBerge interview, 39.

[45]Technical Director, NWC, to DNL, memorandum, "Naval Weapons Center Organizational Changes," 8 June 1973.

[46]Ibid.

[47]Ibid.

[48]Ibid.

Rear Admiral Pugh's letter to Lawson supporting the reorganization had a somewhat different focus.

> The present organization of over a dozen technical departments and staffs does not have clearly defined objectives, does have significantly overlapping capabilities and programs, and individually no department has enough resources to undertake a major mission area. This reorganization will enable the senior management to concentrate its resources.[49]

Pugh also stressed the importance of working with the Systems Commands (SYSCOMs):

> It is the intent of this reorganization to select the first-line team of NWC leaders, to assemble the resources to work out with the Systems Commands major technical area responsibilities, and then to implement programs in these areas.[50]

Lawson approved the reorganization, subject only to minor name changes among the departments.[51]

In fact, the institution of directorates harkened back to the earliest organizational structure at China Lake. Prior to 1952, the Technical Director had been assisted in executing his management responsibilities by two Associate Directors: one for Research and one for Engineering.

Some people were unhappy with the second major reorganization in 3 years. Said the recently retired Ward:

> I was frankly a little appalled when Haskell had just run a reorganization not long before and now Walt comes in and starts churning the organization again. It wasn't clear to me personally that this was a very fruitful thing to do, but he was the boss.[52]

Looking back at it 8 years later, Frank Knemeyer said:

> Now you had three deputies where you had one before. This happened to be the way that LaBerge wanted to do it. I personally wasn't too hot for the idea. And in fact, I had the Strike Warfare [Directorate] and he wanted me to take two departments and make three out of them, and I successfully resisted him on that.[53]

49Commander, NWC, to DNL, memorandum, "Naval Weapons Center Organizational Changes," 18 June 1973.

50Ibid.

51Ibid.

52S-94, Ward interview, 35.

53S-117, Knemeyer interview, 20.

Dr. Hugh Hunter gave LaBerge the benefit of the doubt.

> It might have worked very well if Walt himself had stayed on. He did the things that he wanted to do in order to set up an organization that he could work with. And he may have had some Machiavellian ideas, I don't see how he could help having them, that was his nature, but he did have an organization that he was willing to work with—and then he proceeded to take another job.[54]

Riggs was fine with the change. "I think if Walt had stayed for the next 2 or 3 years it would have worked out beautifully," he said. Neither would be the case.[55]

A New Team Takes Over

In August 1973, less than 3 months after LaBerge had been confirmed as NWC Technical Director and with the dust barely settled from his reorganization, the *Rocketeer* carried a stunning announcement: "President Richard Nixon last Friday announced his intention to nominate Dr. Walter B. LaBerge, NWC Technical Director, for the high-level position of Assistant Secretary of the Air Force for Research and Development." Thus ended the brief directorship of LaBerge.[56]

Gerald O. Miller.

With three Deputy Directors, rather than one, there was no defined path of succession. Highberg was not a likely candidate; his retirement was fast approaching. Riggs was appointed as Acting Technical Director, with Bill Porter taking over as Acting Deputy Technical Director for Electronic Systems and Gerald O. Miller filling in behind Porter as head of the Surface Missiles Department. Both Riggs and Knemeyer applied for the Technical Director position.[57]

---

[54]S-95, Hunter interview, 7.

[55]S-136, Riggs interview, 74.

[56]*Rocketeer*, 24 August 1973, 1.

[57]In the mid-1960s, Gerald O. Miller had been the principal designer of the Shrike Improved Display System (SIDS), which Navy pilots called the "GOM Box."

As Riggs recalled:

> I said, "Hey, you know, it's no big deal for me. I'd be happy to go back, if we could, to the way it was all those good years at China Lake; make Frank [Knemeyer] Technical Director; he loves to travel to Washington all the time and he can go to Washington; and I'll be Hack Wilson; I'll be 03 [Deputy Technical Director]. It'll work great. Or you can make me Technical Director, I wouldn't mind being Technical Director; I think I am qualified. But don't bring in somebody from the outside because if there was anybody qualified outside, I would know them or Frank would know them or a few other people." I said, "We've put our heads together and there isn't anybody."[58]

A month after the announcement of

LaBerge's departure, Richard Nixon appointed David S. Potter Assistant Secretary of the Navy for Research and Development. Potter, a member of the National Academy of Engineering, had been a leading engineer at General Motors for many years.

At the time that Potter took charge of the Navy's R&D program, China Lake was responsible for the development of the Agile missile. The Agile program had suffered technical, management, and political problems, and costs had mounted dramatically (see Chapter 8). According to Burrell Hays—then head of the Engineering Department and, from 1982 to 1986, China Lake's Technical Director—Potter was astounded that China Lake had spent $70 million thus far and that the weapon was still only in advanced development.

In the fall of 1973, Hays was selected by the department heads to go back and talk with Potter and press for the selection of Knemeyer or Riggs as China Lake's Technical Director. Hays told an interviewer years later:

> Potter was extremely gracious to me, listened and what have you, and then said, "No, I think you've got incest out there. You guys have grown your own for so long that you've lost track of the real world, and I'm going to send you some guy that's had business experience."[59]

Potter summoned Leroy Riggs to Washington and offered him the Technical Director job at NADC, Johnsville, Pennsylvania. Potter's plan was that Riggs would take over Johnsville, and the current Technical Director there, Dr. Guilford Leroy Hollingsworth, would come to China Lake. Hollingsworth had the business experience that Potter was seeking, having been the director of technology for the Military Airplane Systems Division of Boeing Co., Seattle.[60]

---

[58]S-136, Riggs interview, 80.

[59]S-157, Hays interview, 35.

[60]Hollingsworth held a master's degree in electrical engineering from Oregon State University and an honorary doctor of science from Pacific Lutheran University.

Dr. Guil Hollingsworth.

Captain Richard D. Franke.

The idea of leaving China Lake for Johnsville was anathema to Riggs. "I said, 'I know those people back there, and they haven't done any work; they've just contracted it out.' And that didn't go over very well." Riggs turned Potter down. "Bang! He threw me out of the office," Riggs said. "A few days later, Paul [Rear Admiral Pugh] walked in and said, 'I know who my relief is going to be.' I said, 'Who's that?' And he said, 'Doc Freeman.' And I said, 'Well. I guess I might as well hang it up.' "[61]

Hollingsworth's selection as China Lake's next Technical Director was announced in May 1974. The same month, China Lake's well-respected Deputy Commander (the military second-in-command), Captain D. W. Alderton, retired. His replacement was to be Captain Richard D. Franke from the Naval Ordnance Systems Command. In June, the *Rocketeer* formally announced that Rear Admiral Rowland Godfrey Freeman III would be China Lake's next Commander.

In that early summer of 1974, for the first time since the base's creation, the top positions at China Lake would be filled simultaneously. (Franke arrived on 17 June, Freeman on 27 June, and Hollingsworth on 8 July.) Also for the first time, neither the Commander nor the Technical Director was a present or former China Laker.

Suddenly the handwriting was on the wall for a major shakeup. Rumors swirled. One theory was that Freeman and company were coming to destroy The Triumvirate of Riggs, Knemeyer, and Highberg. Phil Arnold, then head

[61]S-136, Riggs interview, 24, 35. Doc was the nickname China Lakers used when referring to Rear Admiral Freeman.

of the Agile Development Division, and later head of the Weapons Planning Group, wrote, "China Lakers saw this as an attempt by Secretary Potter to get China Lake 'under control.'" Others—Knemeyer and Jim Colvard—also saw the hand of Admiral Isaac C. Kidd Jr., CNM, in the attempt to shake up the Center. Kidd had assigned China Lake the lead laboratory role in antiship missile defense (ASMD) and was displeased with the Center's progress on the program.[62]

The Freeman Era

Few people figure larger in China Lake lore and legend than Rear Admiral Freeman. The period of his command is generally referred to by those who experienced it as "the Freeman Era." His impact on the Center was substantial.

Rear Admiral Rowland G. Freeman III.

Freeman had a remarkable career, and one that would continue its upward trajectory after he left NWC in May 1977. He arrived at China Lake with 32 years of exceptional naval service under his belt. Commissioned in 1943, he began his career as a night-fighter pilot flying from USS *Lexington* (CV-16). During the course of the war he earned two Distinguished Flying Crosses and five Air Medals. He once parachuted from his disabled aircraft, was picked up by a submarine near Okinawa, and spent a full war patrol aboard the vessel.

He'd served in a variety of positions, including a stint as a Navy test pilot, department head at Point Mugu, Bureau of Naval Weapons representative to McDonnell Aircraft Corp., Commanding Officer of USS *Procyon* (AF-61) (his driver at the time recalls him as "a fine officer" and "well-liked by the crew"), navigation officer and air officer on USS *Oriskany* (CVA-34) (earning the Vietnam Campaign Medal with two stars), and Deputy CNM (Procurement and Production).[63]

[62]S-275, Arnold interview, 40; S-117, Knemeyer interview, 21; James Colvard, telephone conversation, September 2012.

[63]Leonard J. Hascup, telephone conversation, 18 June 2013.

Freeman was smart. During his career he'd earned a master of business administration degree from Harvard. Burrell Hays said, "Freeman was a brilliant man, actually—very high IQ."[64]

Freeman did not hesitate to make decisions he felt were in the Navy's best interests, however unpopular they might turn out to be. "I well remember his opening words, the first time he ever met formally with his staff, namely the department heads," said Highberg. "He walked into the room, raised his right hand, and said, 'There can only be one boss and I am he.' "[65]

It is reasonable to assume that Freeman's initial perception of China Lake had been shaped by the views of those with and for whom he worked in Washington. In an August 1974 Board of Directors meeting, less than 2 months after he'd assumed command of the Center, Freeman shared those views with some two dozen of China Lake's senior military and civilian managers. The record of that session was prepared by Robert V. McKenzie, head of the Special Projects Division of Central Staff, who was for many years the secretary and recorder for top-management meetings.

> It was noted by RADM Freeman that NWC has garnered some unfavorable perceptions in the eyes of key Washington personnel. For example, we are sometimes perceived as being careless of adhering to dollar budgets and time schedules.[66]

That was the official version. In his "unadjusted notes," shared only with his boss, Central Staff head, Mel Sorge, and Dr. Dick Kistler, Sorge's associate for Resources Management, the picture was more graphic:

> With respect to perceptions from Washington about NWC . . . 1. Steal ideas from industry. 2. Pushy in attitudes:—we tend not to give alternatives (do it my way)—don't respect Washington types. 3. We do too many things—none well. 4. We are critical of industry. 5. We talk too long, too much. 6. We don't meet schedules or budget.[67]

Few details seemed below Freeman's notice, and anything was fair game for corrective action. Knemeyer recalled:

> When we used to go into [weekly Commander's meetings], if you got there last, then you got the poorest seat. But Freeman assigned a seat to everybody

[64]S-157, Hays interview, 36.

[65]S-121, Highberg interview, 21.

[66]McKenzie to Sorge, memorandum, in *Board of Directors Material—1970 to 1981*, 206.

[67]Ibid., 216. McKenzie commented in his memo that he and Bob Hillyer, head of the Fuze Department, had compared notes on that list.

> so he could just look up and see who was missing or if a substitute was there. He tried to get things organized and disciplined.[68]

When he wanted information, Freeman had no qualms about bypassing management channels.

> I like to go to the level of management that can normally provide the answer. I also hate to bother a supervisor when I can phone the source directly. . . . If the supervisor wants to change the information given me, then he should call me.[69]

Never one to shy from controversy, Freeman addressed matters head-on and didn't mince words. His speeches—they were, unlike those of his predecessors, generally printed verbatim in the *Rocketeer*—were filled with let-the-chips-fall-where-they-may lines. In September, for example, during a speech about his weapons-acquisition philosophy, Freeman managed to insult both the people who used China Lake's weapons and those who developed them: "The Naval service today is manned by young men and women whose education is not as sophisticated as that of the weapons' designers and builders," he said.

> We have weapon systems that were conceived and developed by brilliant engineers and scientists, but somewhere along the way the realistic appreciation of the capabilities and limitations of the service personnel who will operate and maintain them seems to have been factored out of the development process.[70]

Reorganization, 1974 (#1)

Vice Admiral Baldwin, Commander, Naval Air Force, U.S. Pacific Fleet, spoke at the change-of-command ceremony when Freeman replaced Pugh. Baldwin was prescient when he told the audience that Freeman "has a particularly active and imaginative mind that will certainly keep things moving at China Lake."[71]

On 6 September 1974, the *Rocketeer* had positive news for the Center. The three acting appointments to department head positions that had been made during the last reorganization were now permanent. The *Rocketeer* ran a photo spread of the newly minted department heads, stating that they were "captured by the camera in informal poses." Rogers—the first woman to achieve department head status at China Lake—is shown holding the reins of a Peruvian Paso, a breed she raised on her ranch in Ridgecrest. Russell, an

---

[68] S-200, Knemeyer interview, 159.

[69] NWC, "An Interview with the NWC Commander and Technical Director," *News and Views, Points of View and Information on Management Matters*, November 1974, 5.

[70] *Rocketeer*, 27 September 1974, 4.

[71] *Rocketeer*, 28 June 1974, 1.

avid motorcyclist, is leaning against his Yamaha dirt bike. Hays sits behind a cluttered desk, a smile on his face and a cup of coffee in his hand.[72]

New department heads: Dr. Peggy Rogers (left), Jack Russell (top right), and Burrell Hays (bottom right). Published in the *Rocketeer*, 6 September 1974.

Just a month later, on 4 October 1974, the hammer fell on The Triumvirate. In a new reorganization, Freeman announced the disestablishment of the directorate head positions. The September confirmation of the three new department heads had effectively closed the back door of reassigning the Center's three senior managers to their previous positions. Riggs was made Deputy Technical Director, Knemeyer was assigned as Organizational Study Director, and Highberg became Consultant to the Technical Director.

Interestingly, Freeman's rationale for eliminating the directorates was almost exactly the opposite of LaBerge's rational for creating them. He told *News and Views* in November 1974:

[72]*Rocketeer*, 6 September 1974.

> Dr. Hollingsworth and I felt it was important to look at a way which would get us in closer one-on-one contact with the department heads. Our span of control, working with the three deputy technical directors, just seemed too narrow.[73]

Already Freeman was beginning to sense the backlash from his actions, and he attempted to set the record straight.

> One thing we've heard that should be put to rest is that this had not been discussed with anyone beforehand. This simply is not so. . . . It was discussed in great detail by Dr. Hollingsworth and me with the three deputies involved before we took any action.[74]

Freeman by no means thought the organizational restructuring was complete; Knemeyer's group was charged with "conducting a review of programs, activities, and organizational structure of the Center, including staff and support operations as well as technical activities." The goal was "to develop an optimum organizational structure to accomplish the mission of the Center as set forth in the NWC Operating Principles of Aug. 14, 1974."[75]

In November, Freeman emphasized that his reorganization effort

> is expected not only to redistribute assets, but reduce manpower as well, including comparable reductions in overhead. This will require a hardnosed management attitude to preserve the "need to have" and eliminate the "nice to have."[76]

Principles of Operation

Freeman believed that he was the man in charge at China Lake. Technically, he was correct. He was the Commander and had final say-so over every aspect of his command, which—aside from a few attached activities, notably VX-5—included everything and everyone on the base. With the confidence born of many years of military command, he did not hesitate to make decisions based on his own judgment, however unpopular those decisions might turn out to be.

China Lake, however, had always had a unique balance of military and civilian leadership. That balance was considered so important by the base's earliest managers that it was enshrined in the *Principles of Operation*, authored with the guidance of China Lake's first Technical Director, Dr. L. T. E. Thompson, in 1946 and approved by the Chief of the Bureau of Ordnance.

---

[73]NWC, "An Interview with the NWC Commander and Technical Director," *News and Views*, *Points of View and Information on Management Matters*, November 1974, 1.

[74]Ibid., 2.

[75]*Rocketeer*, 4 October 1974, 1.

[76]*Rocketeer*, 1 November 1974, 4.

In the introduction to Volume 3 of this history, Vice Admiral Ashworth (China Lake's Commander from 1955 to 1957) summarized: "In their simplest definition, the Principles provided that these laboratories would effectively be civilian operations supported by the military."[77]

Dr. McLean had spelled out his views on the military-civilian relationship in an official memorandum in 1961: "The basis for the organization of this Station is the concept of the military providing an attractive working climate for a scientific community under the direction of a permanent civilian Technical Director."[78]

That worked well, as long as someone with the strength, reputation, and track record of McLean was working with senior officers who understood the principles and appreciated that China Lake was unique among naval commands. Walt LaBerge once remarked that after Rear Admiral Moran ("an old China Laker"), the base under the leadership of Pugh and Suerstedt ("Systems Command people") changed from "sort of 60-40 civilian-run, which was the Moran era, with Bill's [McLean's] conscious intent to make it that way, to sort of 50-50, to then 30-70 when Doc came."[79]

In the principles that had guided China Lake's operations prior to Freeman's arrival, the relevant sections read as follows:

> 5. The Commander, a senior naval officer, is responsible to the Chief of Naval Material for all phases of operation of the Center. He delegates line authority to the Technical Director for the technical program.
>
> 6. The Commander and the Technical Director are jointly responsible to the Director of Navy Laboratories for policy matters affecting the Center and interlaboratory relations, and for the effective and economical internal functioning of the Center in accomplishing the mission.
>
> 7. The Technical Director, a recognized civilian scientist or engineer, is responsible to the Director of Laboratory Programs for implementing technical guidance affecting the Center.[80]

[77]Babcock, *Magnificent Mavericks*, xxii.

[78]McLean to Golden, letter, in AdPub 107, Encl. 1, 18 Aug 1961, 21.

[79]S-178, LaBerge interview, 36–37. Burrell Hays, China Lake's 10th Technical Director (1982–1986), contested LaBerge's numbers. "I would say it was 80-20 under McLean and then 20-80 under Hollingsworth, and that was not because of the rewrite of the Principles but because no one at China Lake's senior management level resisted it." Hays' review comments, 12 January 2015. Senior management analyst John Bodenburg put the ratio of who "ran the show" (Commander or Technical Director) under Freeman as 85 Freeman to 15 Hollingsworth. By contrast, he put the Haff/Hillyer ratio as 10/90: "Haff looks at his job as more of a military representative and public relations job, and he's willing to let the TD run the show." S-115, Bodenburg interview, 15–16.

[80]NAVWPNSCEN 5450-1, *Organizational Manual*, September 1971, 6.

Assigning the military to such a support role did not sit well with Freeman and, as per his nature, he did something about it. Freeman rewrote the principles to make his vision of military primacy unequivocally explicit. His rewritten version was made official in August 1974 and contained the following:

> The Technical Director is delegated the authority by the Commander to ensure the continued technical excellence . . . Ultimate responsibility for technical, administrative and military excellence of the programs at the Naval Weapons Center rests with the Commander and is not delegable.[81]

To an outsider, perhaps, the word changes were subtle. But to the old timers, the tampering bordered on sacrilege. Riggs remembered, "The day Freeman tore up the *Principles of Operation* of NWC, I thought Hugh Hunter would come unglued in the meeting. . . . Guil Hollingsworth just said 'Well, that sounds just fine to me. I'll sign it.' "[82]

At a two-day Board of Directors meeting in California City shortly after the new principles were released, dissatisfaction among the department heads was evident. In one evening session, Bob McKenzie took informal notes.

> [Highberg to Freeman] Is not there an inconsistency of delegation with respect to the letter of principles (just issued)? [Freeman] I am operating a military center. Cannot legally delegate responsibility. I wanted to lay that out in my principles letter.[83]

The Public Works Officer, Captain W. H. Sturman, voiced a question.

> [Sturman to Freeman] How does 01 [Hollingsworth] "ensure technical excellence"? [Freeman] Not sure how 01 is going to operate. [Sturman to Hollingsworth] Code 01, how are you going to ensure for technical excellence? [Hollingsworth] Have to focus on people. How can we arrange to get leverage out of people. . . . Do a good job of picking people. Be selective in people picking. Broaden people. Develop and train people . . . Will work on some small number of fractional projects . . . Will work in a line authority.[84]

The combination of a strong-willed Freeman and a compliant Hollingsworth shifted the weight of leadership—support and technical—in favor of the rear admiral. Hunter said that Hollingsworth was seen "as a man who is not going to direct the organization. And that's hard for the old timers

---

[81]OPNAV Report 5750-1, *NWC Command History* 1974, 2. The 1971 version of the *Principles* carried under the word "Approved" the signatures of the CNM, the DNL, the NWC Commander, and the NWC Technical Director. The 1974 version, by contrast, carried the signatures of Hollingsworth and Franke above the approval line; the only approval signature was that of Freeman himself.

[82]S-136, Riggs interview, 27.

[83]McKenzie to Sorge, memorandum, in *Board of Directors Material—1970 to 1981*, 216.

[84]Ibid.

to accept. They think the Technical Director ought to technically direct." Dr. Ed Royce, who succeeded Hunter as head of the Research Department, was terse: "Hollingsworth had very little influence on anything."[85]

Hollingsworth's feelings for the principles were made clear to China Lake's military and civilian leaders. At another meeting in California City in December, recorder McKenzie set down the following comments by Hollingsworth: "Don't worry about the Operating Principles. They are not terribly important. Change as necessary. They are just statements on a piece of paper. I don't mind contravening the Principles or fixing them up if they need it."[86]

Freeman was aware of the sensitivity and, in the *News and Views* interview quoted earlier in this chapter, he addressed it, somewhat disingenuously.

> Another concern that has arisen is that of military dominance. We should get this out on the table where people can see it. As Center Commander, there's no way I can shed my responsibility for the total operation of the Center. This has historically been recognized in the NWC Operating Principles.

The interviewer did not ask why, if that responsibility had "historically been recognized," it needed to be so forcefully restated in the newest version.[87]

Reorganization, 1974 (#2)

The October reorganization was followed by another in December. This time, two new offices were created, along with two new applicable head positions: Resources and Technology Office (Riggs acting head) and Systems Acquisition Office (Knemeyer acting head). A Technical Planning Board, consisting of the heads of the technical departments, was set up to advise the Executive Committee (as Freeman, Hollingsworth, and Franke were styled). Highberg remained as Consultant to the Technical Director.

---

[85]S-95, Hunter interview, 7; S-354, Royce interview, 22. By contrast, Tom Amlie once said of his own directorship, "The job is neither technical nor are you directing anything." S-109, Amlie interview, 16.

[86]McKenzie to Sorge, memorandum, "Attached Informal Notes to Board of Directors [Meeting], 16 December 1974,"Att. 1, 2.

[87]NWC, "An Interview with the NWC Commander and Technical Director," *News and Views*, *Points of View and Information on Management Matters*, November 1974, 2. Burrell Hays commented that "Hillyer was the first TD after Hollingsworth and he led the Center as if the original Principles were still in effect. . . Although unannounced, Hillyer managed to the old Principles and when I moved up to the Technical Director position in 1982, I continued to lead as though the originals Principles were in effect." Hays review comments, 12 January 2015.

"The intent of this realignment," wrote Freeman,

> is to bring together functions that offer promise of greater effectiveness or efficiency, if consolidated, to make the technical planning and systems acquisition process more effective; to enhance organizational visibility; and to prepare for predicted changes in the nature of the Center's workload, all with a minimum of disruption.[88]

Peggy Rogers' Weapons Development Department was renamed the Aircraft Systems Department. A dozen divisions and branches were shuffled among seven departments. The Mathematics Division of the Research Department, which had been in existence since the 1940s, was phased out over a 6-month period; its personnel were "reassigned to the projects which they support."[89]

Just days before the reorganization, Freeman had attended an all-hands (GS-12 and above) in which he had remarked, "Continuity is one of the most overworked words we have in the Navy shore establishment."[90]

Riggs had known from the start that he would have trouble with Freeman. "If I was TD, one or the other of us would have fought a bloody battle. When I thought I could stay here and really help, I really tried." Riggs had originally planned to remain at China Lake and retire in 1982 at age 55. "That was my basic plan, career-wise. And I left in '75, so I left 7 years early." Highberg and Riggs both retired in June 1975.[91]

With The Triumvirate dismantled, there was no organized resistance from the civilian side of the house to the changes that followed. Two more major reorganizations would be carried out under Freeman's watch.

Reduction in Force (RIF), 1975

In the same December meeting at which Freeman made his remark about "continuity," Hollingsworth reported that the Center needed to reduce its personnel count by 100. He explained, "There is some possibility of a small RIF . . . it's nothing to be greatly worried about at this time."[92]

---

[88] *Rocketeer*, 13 December 1974, 1.

[89] NAVWPNCEN Note 5450, "Organizational Realignment."

[90] *Rocketeer*, 6 December 1974, 4.

[91] S-136, Riggs interview, 36. Knemeyer outlasted his contemporaries. He continued to make important contributions to the Center until his 1982 retirement as head of the Weapons Planning Group and even after his retirement, as a congressional gadfly. Among the awards he received during his distinguished 34-year career at China Lake were the L. T. E. Thompson Award, China Lake's highest honor, and the Navy Distinguished Civilian Service Award, the Navy's highest award for a civilian. Knemeyer died in 2014 at the age of 92.

[92] *Rocketeer*, 6 December 1974, 5.

In February 1975, however, a brief announcement in the *Rocketeer* stated that "a reduction-in-force of 38 positions has been directed by the Commander, Naval Weapons Center, so that departments can achieve their assigned ceilings by the target date of April 30, 1975."[93]

At another all-hands (GS-12 and below) meeting on 16 April, an employee questioned why, if the actual personnel ceiling limit wasn't due until 30 June, the people being RIFed would be let go 2 months early. Freeman responded that some people were doing work that wasn't required. "This RIF should have started last July—not April 30 or June 30," he said.[94]

The exact number of people who actually went "out the gate" on that RIF cannot be determined; it was probably less than 10. Eva Bien, who as head of the Personnel Department oversaw several RIFs, commented:

> Every RIF we ran, very few people, if any, went out the door. All that is accomplished in a RIF is to create a lot of bad feelings and games for supervisors to play who are afraid to fire people for performance, have good young people leaving, and shift the deadwood around at "saved pay."[95]

Bob Hillyer summed it up: "RIFs are always done very, very badly."[96]

Eva Bien.

Reorganization, 1975

By 1975, it was clear to everyone that relationships between Command and the civilian populace at China Lake were not going well. Even the *Rocketeer*, the official house organ of the base, could not avoid alluding to it. The paper reported on the 16 April meeting:

> Another member of the audience contributed this question: "What is the cause of dissension? The Command seems to feel unliked and the employees appear to be unhappy with the Command." "This starts with an assumption

[93] *Rocketeer*, 21 February 1975, 1.
[94] *Rocketeer*, 25 April 1975, 4.
[95] Eva Bien, email, 23 February 2015.
[96] S-134, Hillyer interview, 37.

> of dissatisfaction," the Technical Director said. He recognized that changes in the organization have upset some, but expressed the hope that such persons would get over it.[97]

Chuck Smith.

In September 1975, the Air Weapons Department, home both of Agile and the AIM-9L, was abolished. This was the department headed by Charles "Chuck" P. Smith, who had a reputation as one of the hardest working managers in China Lake's history (see Volumes 3 and 4 of this series). Freeman and Hollingsworth stated that "this step is to be taken in order to deal with an imbalance between the Center's workload and its manpower resources." According to Arnold, "Freeman was unhappy with Chuck's leadership and decided to relieve him."[98]

The department's functions were parceled out to Bill Porter's Surface Missiles Department, which was renamed the Weapons Department; Peggy Rogers' Aircraft Systems Department, which was renamed the Systems and Simulation Department (and quickly re-renamed the Systems Development Department), and Burrell Hays' Engineering Department.

"Chuck Smith was left with no suitable job," explained Arnold. Like Highberg before him, Smith was assigned to Hollingsworth's staff. "Chuck had no problem getting a job in industry," Arnold said. "Raytheon snapped him up and he moved to Bedford, Massachusetts, to happily do the kind of work where he was peerless." At his retirement party, Smith spoke with perhaps a touch of bitterness. "I figured," Smith said, "when the work ceased to be interesting, then it would be time to move along. The work hasn't ceased to be interesting to me, and I hate to disillusion you, but I'm leaving because the pay is better."[99]

[97] *Rocketeer*, 25 April 1975, 4.
[98] *Rocketeer*, 19 September 1975, 1; S-275, Arnold interview, 49.
[99] *Rocketeer*, 2 July 1976, 4.

Reorganization, 1976

Freeman's final major reorganization of the Center took place in August 1976. At the time, it was believed that the NAVAIR Program Management Offices would be moved to China Lake. To prepare for this, Freeman established a Program Management Office reporting directly to him. It would be led by a senior military officer, although not one from the Center's current officer complement, with Frank Knemeyer as deputy. That was just the start.

Although not 2 years earlier Freeman had eliminated the three directorates set up by LaBerge—explaining at the time that the span of control, with three Deputy Technical Directors, was too narrow—he now established three new directorates: a Laboratory Directorate under Bob Hillyer (with Technical Officer Captain Will Haff as deputy); a T&E Directorate under Bill Hattabaugh (with former Naval Air Facility [NAF] Commander Captain Conrad B. Olson as deputy); and a Support Directorate under Captain Franke (whose title was now changed to Vice Commander).

The sense of disorder brought about by the reorganizations at China Lake was amplified by the rapid pace of change in leadership. Consider that in the 2 years between August 1972 and August 1974, China Lakers answered to four Commanders, four Technical Directors, and four Secretaries of Defense, each with different goals and different ideas of how business should be conducted. Dr. Hugh Hunter said of the first half decade of the 1970s, "We've had 5 years that I think of as being about as bad as could possibly have been engineered if we had been trying to engineer it badly."[100]

Morale Plummets

It would be unfair to blame Freeman, Hollingsworth, and Franke for all the troubles that beset China Lake from 1974 to 1977. Being outsiders with no China Lake experience, they, particularly Freeman, were easy scapegoats. Many of the actions that incensed China Lake civilians during the era were driven by nationwide and Navy-wide trends and problems that were well beyond the control of the Executive Committee.

The 1970s was a decade of anger and cynicism. Throughout the nation, faith in government and authority was shaken by the Kent State and Jackson State killings, the resignation of a disgraced Vice President Agnew, the Watergate scandal, and the impeachment and resignation of President Nixon. Energy prices were out of control, primarily as a result of the 1973 oil embargo by the Organization of Arab Petroleum Exporting Countries and a decrease in

[100] S-95, Hunter interview, 6.

U.S. oil production. Inflation was running rampant through the U.S. economy, reaching 11 percent in 1974 and a record 13.5 percent in 1980 (the highest yearly rate between 1947 and the present).

The decade epitomized that twilight zone to which Admiral Galantin had referred; half war, half peace. With the fall of Saigon in 1975, America had formally lost the Vietnam War. Bitterness lingered on the home front, and the war's end reduced demand for the products that were NWC's specialty. Contractors were pushing for a bigger piece of the military R&D pie and, through the efforts of their lobbyists in Washington, were getting it. Against this backdrop, and in part driven by it, Freeman and his Executive Committee made announcement after announcement that whittled away at China Lake traditions.

In the fall of 1974, Freeman banned the serving of liquor during lunch at the commissioned officers' mess (the Officers' Club, or O' Club). "We have thousands of lost man-hours in the country due to the alcohol problem," he said,

> and I don't think we ought to contribute to it. This is why hard liquor no longer is served during lunch at Center messes. The three-martini lunch is not all that unusual. Considering our kind of work, an unclear head can cost one's life, millions of dollars in misdesign, cause divorces, accidents, etc. My bias tells me that whatever good may come out of imbibing at lunch is way overbalanced by the bad.[101]

Banning the tradition of having a drink with lunch (or at least the option of one), which dated back to the Center's founding, seemed to communicate that Freeman did not trust Center employees to carry out their work properly. To insult the China Lake work ethic was to strike at the very core of the Center's success. Even Dr. McLean was taken aback by Freeman's action, as reflected in a 1975 interview. McLean: "[China Lake is] a very tight organization but it's also one where you can upset it by going in and [pause] I understand Admiral Freeman has abolished liquor at the club at lunch." Interviewer: "Really?" [End of interview][102]

Other, smaller actions also increased the general dissatisfaction of the workforce. Most China Lake professionals who held a doctorate had earned their degrees in physics, mathematics, chemistry, etc. These were "hard" scientists, but seldom was the honorific "doctor" used by them or their coworkers in

[101]NWC, "An Interview with the NWC Commander and Technical Director," *News and Views, Points of View and Information on Management Matters*, November 1974, 5.

[102]BA-1-75, DNL Oral History Collection Interview, McLean. One wonders if the transcriptionist considered using an exclamation point rather than a question mark as end punctuation.

conversation. The tight-knit manner in which folks worked and socialized at China Lake put nearly everyone, at least among the civilian workforce, on a first-name basis. In contrast, Hollingsworth, who had been awarded an honorary doctorate from Pacific Lutheran College, requested that he be called Dr. Hollingsworth. This was a small point but emblematic of the sense of distance between Center top management and the employees.

In January 1975, Rear Admiral Freeman foresaw a general "belt tightening" in China Lake operations. "In addition to the normal checks and balances of on-going programs," he announced,

> there also will be periodic reviews on the basis of a program's success or lack of success in terms of a rather new yardstick. If our projects are not in conformance with established design-to-cost criteria, then the possibility of seeing their development curtailed, or even terminated, will go up markedly.[103]

The employees at China Lake, those "Magnificent Mavericks," were not accustomed, nor receptive, to threats.[104]

The division of work between contractors and civil servants was also undergoing a sea change during the Freeman years. Early in 1976, Freeman spoke to the Kern County Business Outlook Conference. He stated:

> Not too many years ago, the Naval Weapons Center spent about 80 per cent of its budget in-house and only contracted out 20 per cent. Last year, we spent 44 per cent in-house and went out with about 56 per cent. In the year ahead, we will be contracting out about 60 per cent of our new work and retaining only 40 per cent.[105]

He described this shift as "a conscious policy of the Department of Defense. I agree with it." His eventual goal was two-thirds contract, one-third in-house.[106]

Increasing the contractors' piece of the pie was, in part, a response to two factors: shrinking manpower levels and increased RDT&E funding. A Naval Material Command (NAVMAT) report traced the Navy's RDT&E funding and total authorized manpower levels at CNM-commanded RDT&E activities from 1966 to 1974. It found that

> during a period when funding support grew by about 28 percent, the total authorized manning was reduced by 4 percent. Though some of this differential can be accounted for by reduction in buying power of the dollar, only about one half of the difference can be assigned to that factor. The remainder illustrates

[103]*Rocketeer*, 24 January 1975, 5.
[104]Ibid.
[105]*Rocketeer*, 30 January 1976, 4; 21 January 1977, 5.
[106]*Rocketeer*, 30 January 1976, 4.

> the increasing pressure for in-house laboratory output and the increasing pressure to contract out portions of the laboratory assigned effort.[107]

During his command at China Lake, Freeman oversaw an exodus of civilians from base housing. It had started before him, driven in part by the arrival of hundreds of Corona employees and their families in 1970 and 1971, and would continue into the 1980s. As described in Volume 4 of this history, the movement off base was a "push-pull" process. The push was a steady series of rental hikes for on-base housing as well as a reduction in the services (commissary, gas station, and the like) available to civilians on-Station. The pull was the increasing quality and quantity of housing available in Ridgecrest, coupled with an array of new financing mechanisms and regulations that made it easier to purchase a home in town.

In another break with the past, Freeman announced in late 1974 that all non-military and non-civil-service employees would be given 1 year to find residences off base. (There were, at the time, some 60 school district personnel living on base.) The tradition of allowing doctors, teachers, and other professionals to reside on base had originated in the early days, when the base was the only suitable place to live in the Indian Wells Valley. Decent, reasonably priced housing was essential to recruiting qualified professionals to the desert. When Freeman was asked in an all-supervisors' meeting at the Center Theater why he was making that decision, when there were currently 500 vacancies in China Lake homes, Freeman described the move "as a means of reducing both home maintenance and to conserve energy usage at China Lake."[108]

Since 1950, every China Lake resident had been a member of the China Lake Community Council (CLCC), a successor to the Employees Welfare Association that had been established in 1945. The role of the CLCC was to be the civilian community's representative in the base decision making process. The *Rocketeer* described the group's function as

> representing community sentiment to command levels, furnishing information on new problems before problems become critical, commenting on proposed policy or administrative regulation which affects the community, and finally, proposing courses of action.[109]

CLCC meetings were held on everything from proposed rent hikes to regulations on dogs running loose, and the meetings often became quite contentious. In 1974, the *Rocketeer* gave Freeman's view of the council:

---

[107] MAT 03514, *Addendum to the Realignments*, 32a.
[108] *Rocketeer*, 6 December 1974, 5.
[109] *Rocketeer*, 10 November 1967, 7.

> RAdm. Freeman stated that he was a strong supporter of the Naval Weapons Center's China Lake Community Council and expressed the hope that where there are issues involving the community, Center employees and residents would provide input to the local civic group to whom he could then turn for information and advice before making decisions on matters affecting the community.[110]

Two years later, citing the reduced civilian population living on the base (more than 1,000 families moved off base between 1972 and 1977) and low voter turnout in the most recent CLCC election of officers, Freeman terminated the council's relationship with the base. He advised the council that "the services formerly provided by members of the CLCC will be accomplished through the regular administrative organization of the Command."[111]

Admiral Thomas H. Moorer.

Nor was the military side of the house immune to Freeman's decisive actions. The NAF at Armitage Field had been a subcommand of NOTS/NWC since the 1940s. Among the thousands of naval aviators who had flown from there in support of the China Lake mission were Admiral Thomas H. Moorer, who would eventually attain chairmanship of the Joint Chiefs of Staff; Vice Admirals Paul D. Stroop, Thomas F. Connolly, Paul McCarthy, and Thomas J. Walker III; and astronaut Wally Schirra.

In December 1976, NAF was disestablished as a separate command and became the Center's Aircraft Department. Freeman explained that the change was made

> in order that we continue to realize the most efficiency and greatest utilization of our resources at China Lake. This reorganization represents a conscious decision derived from a series of studies on how to improve NWC's overall management of its cost of operation.[112]

[110]*Rocketeer*, 6 December 1974, 5.

[111]*Rocketeer*, 21 January 1977, 1; 3 December 1976, 3. The Community Council would be re-established in February 1982 during Captain Lahr's tour as NWC Commander.

[112]*Rocketeer*, 3 December 1976, 3.

If organizational stability needed another jolt, it came in February 1977 with the institution by Freeman of a policy of "mobility of senior managers." Initially, Burrell Hays (Engineering Department) and Dr. Guy Leonard (Propulsion Department) were instructed to swap departments. Freeman stated that

> the way it will happen, from time to time selected employees will be afforded an opportunity to broaden their "base" by moving a bit, or when we feel there is a need to have a fresh look by new faces at some problem. This is the way it will be done, quite consciously and with consultation.[113]

The policy extended to branch heads and division heads as well.

Of his policy, Freeman commented, "Stability says that it's nice to work in the same shop forever. If I stay here long enough, I'll be department head. That doesn't happen very often." Ironically, Hays had started as a Junior Professional in the Engineering Department and, save for a year at the Massachusetts Institute of Technology (MIT) as a Sloan Fellow, had spent his entire career in the same department, becoming department head in 1973. But Hays welcomed the transfer to a development department and had in fact requested it as a career-enhancing step in talks with Hillyer (then Laboratory Director) and Hollingsworth.[114]

One touchy issue that would come back to trouble Freeman after he left the Center involved a road closure. In December 1975, Center Command announced, in the *Rocketeer*,

> the conversion of Enterprise Rd., between Essex Circle and Lexington Ave., to a cul-de-sac. Closure of this block of Enterprise Rd. will provide for enlargement of the park area on the west side of the street for recreational activities and greater safety for Center residents who use the area for drill team practice and casual walks.[115]

The road that was being closed was the road that ran in front of Freeman's and Franke's quarters; cost of the project was $23,885.

In his testimony before the U.S. Senate Committee on Governmental Affairs in June 1979, after he had been nominated to head the General Services Administration (GSA), Freeman elaborated:

> I demanded that the Center be accountable for the manner in which we spent Government funds. Regrettably, the changes, coupled with the changing

[113]*Rocketeer*, 11 February 1977, 4.

[114]*Rocketeer*, 11 February 1977, 1. Laboratory Director is an office under the Commander and Technical Director, established under Freeman's previously discussed reorganization.

[115]*Rocketeer*, 19 December 1975, 5.

> national mood that existed, introduced substantial vandalism in the vicinity not only of my quarters, on Government land, but to surrounding housing and other base facilities. Such instances were stripping wires in my cars, small explosives of a general destructive nature, beer bottles, parties, speeding in front of my house, which had a park in front of it which was used by children.[116]

A reporter for the *Washington Star* had alleged that Freeman contacted a low-level employee at China Lake and asked the person to cover up or sanitize documents relating to the cul-de-sac that could be embarrassing. When Senator Percy questioned him about the charges, Freeman responded that "the allegations are fraudulent and a lie." Freeman was ultimately confirmed, and he served as Director of the GSA from July 1979 to January 1981.[117]

During his tenure as head of the GSA, Freeman continued to make decisions that baffled and angered many who worked for him and that he defended with supreme self-confidence. He decided to ship archival records from Washington to regional offices throughout the country, a step he claimed would save taxpayer dollars. Many scholars who used the records on a routine basis protested loudly. Speaking to a group of irate historians about his decision, Freeman said, among other things, "I have a tremendous sense of history. I have helped make it. . . . I'm an expert in almost every area you work. . . . I am the head of the General Services Administration. . . . The buck stops with me."[118]

Agenda

Was Freeman sent to China Lake with an agenda from Potter and/or Kidd to get China Lake "under control"? Most of the people who served under him at NWC as middle and senior managers believed so.

Freeman had given fuel to that belief less than a week after assuming command of NWC in 1974. Speaking to a joint meeting of the Rotary and Kiwanis Clubs in Ridgecrest, he said:

> I don't think it would be quite appropriate for me to comment on a number of areas, for I haven't had the opportunity to take a really broad view, but having just come from Washington, I do know what the direction should be.[119]

---

[116]United States Senate Committee on Governmental Affairs, *Nomination of Rowland G. Freeman III,* 15.

[117]Ibid., 23.

[118]Grubisich, "History Lesson," A5.

[119]*Rocketeer*, 5 July 1974, 1.

He was more explicit when speaking extemporaneously in an all-hands meeting at the Center Theater in 1975:

> Over a period of years any organization needs to be shaken up a bit. The Center exists to serve the Fleet, not China Lake, and I can't subordinate the desires of China Lakers to the needs of the Fleet [*sic*]. NWC has a need for some reorientation, and this is what we are aiming for.[120]

He was most forthright in his testimony to the Senate Committee on Governmental Affairs. Freeman told the senators:

> I was sent out [to China Lake] because of an unstable management situation which had existed at China Lake for a period of over 3 to 4 years. Several new technical directors, at least three new commanders in a 3-year period. While there I effected a number of changes at China Lake. There were concerns from the scientific community that I was changing what had been there, which was true. I had a responsibility for not only the range which was about 1,700 square miles but also the laboratory, with some $200 million in research projects; *it was imperative that we bring this kind of thing under control*. [Emphasis added.][121]

Part of the difficulties between Rear Admiral Freeman and the civilians at China Lake stemmed from the fact that Freeman had been such a strong and effective leader in numerous military units. At China Lake, instead of running an operation comprised of military men and women with similar training and discipline, Freeman was faced with the likes of Tony San Miguel, a national expert in solid propellant technologies, holder of a dozen patents, and author of 70 technical reports and open-literature papers.

"I float in specialties, because it's the nature of the research and development business," San Miguel said. "I look around and try to create my own work by identifying problems and talking someone into funding work on them. When a problem is solved, or I find that it has no immediate solution, I drop it and go on to the next project."[122]

And then there was the Engineering Department's Bob Lauer: "I shun regimentation. Most of my work within the Civil Service and private industry has been related to research and development, an activity which is basically unregimented. Otherwise, R&D would come to a halt." To Rear Admiral Freeman, trying to control civilians like these must have been exasperating.[123]

---

[120]*Rocketeer*, 25 April 1975, 4.

[121]United States Senate Committee on Governmental Affairs, *Nomination of Rowland G. Freeman III*, 15.

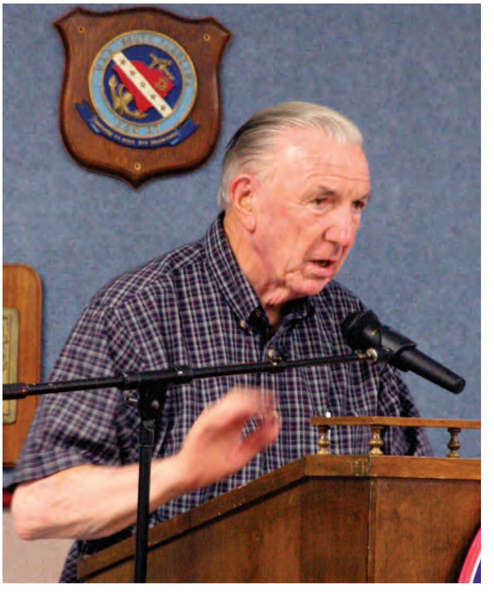
[122]*Rocketeer*, 26 November 1976, 7.

[123]Ibid.; 14 January 1977, 7.

There is little question that Freeman changed that base, or that the base changed during Freeman's reign. In 2001, Walt LaBerge stated:

> If you look at the China Lake glory days, they have clearly defined beginnings and ends. They started in 1943, ended in 1974, and a whole different China Lake exists now. . . . Ike Kidd sent Doc Freeman out to get the place under control. There was a clearly defined shift in roles from being the provisioner to the Navy of its air armament to being a helper to the Systems Commands in the provisioning of armament to the Navy.[124]

While there were, and among some of the old China Lakers still are, hard feelings about the Freeman Era, not everyone at China Lake felt animus toward the rear admiral. John Di Pol was associate head of the T&E Department during Freeman's tenure and later head of the Range Department. He said:



John Di Pol.

> Although I disagreed with many of [Freeman's actions], I've always felt that the actions that he took were motivated by a sincere desire of what he believed was right. In spite of all that, he was a real supporter of us out here in the test area, on the ranges, and a person that we could talk to on a one-on-one basis. And personally, I liked him.[125]

Freeman was a strong supporter of the ranges. He pushed hard for Project 21, a carefully prepared master plan for range upgrades and modernization. The plan led to some $70 million in range investment and, by 1983, completion of a state-of-the-art Range Control Center (RCC). In his remarks upon concluding his 3-year tour as China Lake's Commander, Freeman said, "The greatest—and most irreplaceable—asset of the Center is its instrumented test ranges."[126]

Bob Hillyer moved up from his position of Laboratory Directorate Head to become Acting Technical Director when Hollingsworth hastily left after a scandal in May 1977, shortly before Freeman's tour ended. In December,

[124]LaBerge, *From Research to Reality*, 25.
[125]S-119, Di Pol interview, 17.
[126]*Rocketeer*, 27 May 1977, 1.

Hillyer's position was confirmed. He would hold the directorship for nearly 5 years, adding much needed stability to top management.

Of Freeman, Hillyer said:

> He wasn't sensitive to the personality of the organization. If we ever could have gotten that sensitivity into him, he would have been a world beater. I should say he was the easiest guy to work directly for that you can imagine. I was under his wing and was one of the fortunate ones. When you worked directly for Admiral Freeman (unless you ever made the mistake of taking him on in public) you could do anything, convince him of anything, argue with him, even win arguments; he'd be completely rational. It was with people several layers removed that Admiral Freeman had his problem.[127]

Dr. Hugh Hunter spoke to a reporter in 1979 regarding Freeman's tour at China Lake: "He was a vigorous, intelligent individual who failed completely to further the organization's strengths."[128]

According to China Lake's command historian, Leroy Doig III, Rear Admiral Freeman was asked numerous times for an interview, particularly around the time of China Lake's 50th anniversary in 1993. He declined, through various intermediaries. This author sent Freeman two letters requesting an interview in 2010. Neither was answered.

Rear Admiral Rowland G. Freeman III left China Lake on 26 May 1977 for a new assignment as commandant of the Defense Systems Management College at Fort Belvoir, Virginia. He was replaced by Captain Frederick H. M. Kinley, who had replaced Franke as Vice Commander in December 1976.

Captain Frederick H. M. Kinley.

Even before Kinley assumed command of the Center, he was echoing the sentiments of Freeman. He spoke of realignments, reorganizations, and RIFs as means to manage the Center's budget and workload. "Too much emphasis is placed on 'status quo,' when there is just about no such thing in defense

[127]S-134, Hillyer interview, 22.
[128]Kessler, "Tough Approach to GSA Problems," A5.

research and development," he told the local chapter of the National Association of Supervisors. "Budgetary imbalances, unmanageable overhead costs and personnel reductions should be recognized as the imperatives that they are." He noted that the Public Works Department was running a $1.5 million deficit and that the same level of scrutiny being given to that department would be exercised Center-wide.[129]

Kinley spoke of an impending RIF (initiated by Freeman)—the Center had requested a reduction of 153 positions of full-time permanent personnel. He also informed the audience that five areas had been identified for contracting out studies pursuant to the Office of Management and Budget (OMB) Circular A-76—warehousing, packing, and crating; aircraft maintenance; vehicle operation and maintenance; housing maintenance and management; and machine shops.

At the Freeman/Kinley change-of-command ceremony, Vice Admiral Vincent A. Lascara, Vice CNM, presented the outgoing Commander with the Legion of Merit. In his remarks, Lascara commented, "There have been painful changes here—yet I am confident that this Center is now in a strong position to face the future."[130]

Freeman, characteristically, spent much of his remarks lecturing the Centerites on how they should conduct business. "NWC can, and should, be intimately involved in the validation of the need for a new system," he said, adding that the Center's exploration of alternatives should include "detailed explorations of all alternatives—not just one or two of the most promising in terms of future work at the Center."[131]

Kinley's tenure was brief. In July 1977, Rear Admiral William L. Harris Jr. was selected to take command of NWC in September. Kinley would step back to Vice Commander.

Rear Admiral William L. Harris Jr.

[129] *Rocketeer*, 8 April 1977, 1.
[130] *Rocketeer*, 27 May 1977, 1.
[131] *Rocketeer*, 27 May 1977, 4.

This was Harris' second time to be selected for the top position at China Lake. In July 1972, he had been announced as Rear Admiral Moran's replacement. The following month, the Chief of Naval Personnel announced that instead, Harris would be assigned as deputy to the president of the Naval War College.

Harris was a naval aviator with a distinguished career. Among other assignments, he had flown 53 combat missions in the A-1 Skyraider during the Korean War, commanded USS *Midway* (CV-41), and commanded Carrier Group Seven during the final evacuation from South Vietnam. He came to China Lake from a tour as NAVAIR's Assistant Commander for T&E.

A change-of-command ceremony was traditionally the top front-page story in the *Rocketeer*. However, Harris' assumption of command was overshadowed by a larger story. The top headline on the 16 September 1977 *Rocketeer* was "RIF notices delivered; 123 positions at NWC abolished."[132]

In his remarks at the change-of-command ceremony, Harris "pledged himself to efforts dedicated to strengthening the military and civilian team relationship on the Center and to a continued bolstering of the relationship between the Center and its neighbors in the Indian Wells Valley."[133]

Harris had a short temper. One nickname for him was Mr. Bang. Bob Hillyer recalled that Harris

> was the opposite of Admiral Freeman. He was the hardest man to work for I ever met in my life. But if you were two levels away from him [which Hillyer, as Technical Director, was not], he was relatively easy to get along with. So, those guys were just mirror images of one another. Admiral Harris had a temper that made him very difficult to work directly with.[134]

Other senior managers shared that assessment. Di Pol commented that "Bob [Hillyer] tried to help Admiral Harris in overcoming some difficulties he had in dealing with the civilian organization." Milt Burford recalled Harris as "a very feisty individual." Burrell Hays, who was at that time running the Ordnance Systems Department, said, "I was very pleased that Bob [Hillyer] was there and not myself . . . Bob made a very good buffer."[135]

Harris carried on the range-improvement work begun under Freeman and, like Freeman, he concentrated on cutting costs and tightening budgets. At the

[132]*Rocketeer*, 16 September 1977, 1. Through normal attrition (retirement), changes of individuals to a lower grade, and job reassignments, the actual number of people going out the gate was eventually reduced to two.

[133]*Rocketeer*, 16 September 1977, 1.

[134]S-134, Hillyer interview, 23.

[135]S-253, Di Pol interview, 67; S-263, Burford interview, 30; S-157, Hays interview, 40.

same time, however, he insisted on major infrastructure improvements for the Center, including boiler-plant modifications and energy-saving systems for major buildings. Dr. Dick Kistler said:

> The Admiral insisted upon a dramatic change in our financing of the Center to essentially double the amount of money spent on maintaining and repairing the plant facility. And that's had a permanent effect, because in spite of the angry protestations that accompanied some fairly arbitrary actions on his part, I think the folks have come to realize since that, that was a vitally important action, long overdue.[136]

During his tour at China Lake, Harris was very aware of the importance of good relations between the base and the city of Ridgecrest—home to an ever-growing segment of the China Lake workforce—as well as Kern County. He was proactive in establishing cooperative agreements in such areas as search and rescue and emergency services. In March 1979, he received the Los Angeles Executive Boards' Federal Employee Distinguished Service Award. The citation noted not only his support for equal employment opportunity (EEO) programs and environmental protection but also his policy of "open cooperation and sharing of NWC's resources with Federal, state, county, and local agencies and community groups."[137]

Captain William B. Haff.

Harris' command of China Lake ended with his retirement in July 1979. Selected as his replacement, to the overwhelming satisfaction of the civilian workforce, was Captain William B. Haff, a naval aviator who had first served at China Lake from 1970 to 1972 as Assistant Technical Officer (Air). From 1972 to 1975, Haff served as NAVAIR's Sidewinder program officer, then returned to the Center again as Technical Officer and Deputy Laboratory Director until his selection for command. He had twice won the Distinguished Flying Cross, held a Bronze Star with Combat "V," and had earned 21 Air Medals. In

[136]S-131, Kistler interview, 24.
[137]*Rocketeer*, 9 March 1979, 1.

1977, he had been awarded the L. T. E. Thompson Award, the Center's highest recognition for outstanding individual achievement.

Haff's connection with China Lake, and his understanding of the unique manner in which it operated, was deeper than any of his predecessors since Rear Admiral Moran (who had served as operations officer at China Lake in 1950 and spent three additional years there as Assistant Experimental Officer in the mid-1950s). Haff understood how the program was supposed to work, as did Hillyer. Once again, two China Lakers were at the helm. Haff told the crowd assembled at his assumption of command:

> When I ask for more than you have already given, when I urge you to try again, be assured that it is only because I appreciate the real potential of this Center. So reach for the outer limit and accept nothing less. This is your Center, your Navy, your country, and if it is to be, your free world.[138]

Haff's philosophy of management was very much in line with that embodied in the old *Principles of Operation*. He said:

> You have a technical director whose prime responsibility is to look after the technical side, and he will apprise you, if you let him run the technical side. I think it is healthy both for the Commander and for the technical community.[139]

For his part, Hillyer heaved a sigh of relief. In a 1982 interview, he shared:

> The Center had had, rightfully or wrongfully, a traumatic set of experiences with both Admiral Freeman and Admiral Harris for different reasons, and it needed a period of quiet and settling down. Will Haff was the guy. . . . He had a unique ability to understand what was important and what needed his attention and what didn't need his attention. He was willing to let decisions that should be made at lower level be made at lower level. He was willing not to shoot people when they made bad decisions, but to help them get out of the situation they'd gotten themselves into and to coach them on how to make better decisions in the long term. Will was just a joy to work for and with.[140]

The team of Haff and Hillyer would continue to guide the Center for the next 2 years. During that time, a positive attitude, one not seen at China Lake since the 1960s, re-emerged. As one decade ended and a new one began, the time of tumult was drawing to a close. China Lake was back on track.

---

[138] *Rocketeer*, 6 July 1979, 1.
[139] S-125, Haff interview, 16.
[140] S-134, Hillyer interview, 24–25.

6

War of Another Sort

"Better" is the enemy of "good enough."

—Motto reputed to have hung in the office of Sergei Gorshkov,
Admiral of the Fleet of the Soviet Union and
Commander in Chief of the Soviet Navy

As the Vietnam War began to draw down, attention turned to the next big threat. Not surprisingly, it was again the Russian bear, the Soviet military presence in the world that had driven Washington and Pentagon policymaking through the 1950s. While the Vietnam experience had distracted the United States at every level of society, the Union of Soviet Socialist Republics (USSR, in Russian, CCCP), and particularly the Soviet Navy, had been quietly forging ahead.

Time magazine, in a 1968 cover story, alerted the American people to the magnitude of the threat. The cover picture was an unsmiling Sergei Gorshkov against a background of a Soviet submarine running at periscope depth.

Gorshkov was 57 and had been running the Soviet Navy for a dozen years. As a combat veteran of WWII—he had welded T-34 tank turrets on motorboats to create a riverine force that attacked Germans along the Danube River—he had, at age 31, become the youngest admiral in Soviet history. His tenure as head of the Soviet Navy would eventually reach 29 years, during which period, by contrast, the U.S. Navy had run through nine CNOs.

One advantage Gorshkov had over his Western naval counterparts was that he was not as heavily burdened with history. John Boyle, China Lake's small-attack-boat expert, observed, "The U.S. Navy, after WWII, had a severe disadvantage in that it had a glorious naval tradition to uphold. On the other hand, in the Russian navy, most of the Russian sailors were taken off their ships and used as infantry in WWII. So Gorshkov, when he took over in the '50s, built a navy."[1]

---

[1]S-180, Boyle interview, 30.

Admiral Sergei Gorshkov.

As the epigraph of this chapter implies, Gorshkov was not a great fan of "bells and whistles." What his navy lacked in sophistication—and it lacked a lot—it made up for in numbers. Particularly troublesome to the West were the submarines and torpedo/missile boats. By 1968, the Soviets had approximately 360 submarines versus the United States' 155 (although the United States' nuclear submarines outnumbered the Soviets' 75 to 55). The *Soviet Yankee*-class nuclear submarines, first launched in 1968, eventually numbered 34; each carried 16 SS-N-6 Serb ballistic missiles with a range of 1,500 miles. (The U.S. Polaris A-3 ballistic missile in service at the time had a range of about 2,500 miles.)

Because Gorshkov was not a believer in the efficacy of naval guns, he built a fleet of 560 torpedo/missile boats capable of carrying the 25-mile-range SS-N-2 Styx antiship missiles. Larger Soviet combatants carried SS-N-1 Scrubber (100-mile range) and SS-N-3 Shaddock (200-mile range) antiship missiles.

Gorshkov remade Russian's military image; as one observer wrote, "[Gorshkov] successfully challenged the conventional dogma that classified Russia as only a land power and supplemented this with his sea power doctrine."[2]

Sea power, as envisioned by Gorshkov, went well beyond naval power. In the foreword to the English translation of his most widely read book, he wrote:

> The author gives a Soviet explanation for the sea power of the state, emphasizing its economic importance—as well as its military aspects—in the circumstances of today. Convinced that this economic factor will remain firm and constant, the author believes that the seas and oceans must above all serve to raise standards of living and to consolidate amicable relations between nations. The military aspect of sea power is of but transitory importance, which will continue to decrease as world peace becomes more secure.[3]

To this end, in 1968 the Soviets had the world's largest fishing fleet and the world's largest oceanographic fleet—although those too had a military component as they also functioned as intelligence-gathering platforms.

During the 1960s, Soviet military spending had surged while the American military focused its resources on a politics-plagued and unwinnable (as fought) war in Vietnam. Suddenly, the Soviets' once shore-hugging coastal-defense force was a worldwide presence. At the same time, the U.S. Fleet was aging, and shipbuilding was lagging. In 1969, CNO and former China Laker Admiral Tom Moorer testified to Congress that

> the Soviet Navy is building and deploying sophisticated warships that have been carefully designed to serve Soviet interests. The large number of their warships with surface-to-surface missiles is clearly intended to offset the capabilities of our carrier striking forces.[4]

He also noted that "58 percent of our ships are at least 20 years old . . . less than one percent of the Soviet Navy's surface combat ships and submarines are 20 years old or older."[5]

Although it would be another 6 years before hostilities formally ceased in Vietnam, the handwriting was on the wall. Defense spending peaked in 1969 and began a precipitous decline that was not reversed for another decade. With

---

[2]Chapman, "Admiral Gorshkov and the Soviet Navy."
[3]Gorshkov, *Sea Power of the State*, vii, viii.
[4]*Rocketeer*, 7 March 1969, 3.
[5]Ibid.

a newly recognized Soviet naval threat and diminished resources with which to meet it, Pentagon planners needed to formulate a strategy, and they did.

Speaking to the Commonwealth Club in San Francisco in 1971, Secretary of the Navy John H. Chafee said:

> We have made the decision to retire many of our older ships now and put the money saved into research and development and the construction of new, much more capable ships and planes for the final decades of this century. Thus we have put procurement of new ships, weapons, and systems ahead of the maintenance of large forces at sea right now. We have invested in research and development in order to have more ways to counter the developing Soviet threat.[6]

Admiral Elmo R. Zumwalt Jr., CNO at the time, wrote in his memoir:

> The only way I could see for the Navy to free funds for developing up-to-date ships and weapon systems that could cope with the new Russian armaments was to retire immediately large numbers of old ships and aircraft. That meant that the price the nation would have to pay for sufficient and appropriate naval capability in the 1980s would be seriously reduced naval capability during at least the early seventies, while the new systems were being designed, built, and deployed.[7]

Soviet Ship Vulnerability Program (SSVP)

Effectively countering the Soviet threat, however, required a thorough understanding of it. Not only how big it was and what its capabilities were (these questions were generally the purview of the intelligence community) but also its weaknesses.

Some shortcomings were fairly obvious. Sustainability, the ability to replenish ships operating far from their home bases and maintain combat operations at sea, had been developed by the U.S. Navy over the course of multiple wars. The Soviet fleet did not have that capability, which has been offered as one factor in the Soviets backing down in the Cuban missile crisis of 1962. Also, Soviet naval air power was extremely limited; the navy had few carriers, and those primarily for rotary-wing aircraft. This equated to essentially no sea-based tactical air support capability. By contrast, in 1968 the United States had 15 attack carriers.

What was missing from the understanding of the Soviet naval threat was its vulnerabilities, its weaknesses, the points at which force, properly applied, could render a combatant vessel incapable of achieving its mission.

[6] *Rocketeer*, 19 February 1971, 1.
[7] Zumwalt Jr., *On Watch: A Memoir*, 59.

The Tactical Air Armament Study (TAAS, see Chapter 4), begun in 1969, had the overall goal of examining the U.S. Navy's existing and planned tactical-air weapons to determine which would best meet the Navy's responsibilities through the decade of the 1970s. It was clear to everyone that the USSR would be the major naval threat; therefore, it was essential to understand the Soviet fleet's vulnerabilities. In 1971, the TAAS generated vulnerability and weapon effectiveness estimates for two Soviet ships—a start, but a lot more was needed.

Admiral Zumwalt, CNO from 1970 to 1974, had, in the mid-1960s, been the first director of OPNAV's newly formed Division of Systems Analysis. According to Carl Schaniel, before Zumwalt left to command the Navy's forces in Vietnam in 1968, he pointed out to OPNAV that there was "an immediate need for targeting and vulnerability data on the Soviet Navy."[8]

Zumwalt, on returning from Vietnam to succeed Moorer as CNO in 1970, found that essentially nothing had been done about the targeting requirement. China Lake was the logical focus for an effort to gather these data, given the base's experience in operations analysis and weapons-effectiveness studies. Schaniel, head of the Weapons Planning Group, was called to Washington by one of Zumwalt's staff, Captain (later Admiral) Charles F. Rauch Jr., to discuss Soviet-ship-vulnerability issues.

In July of the following year, the CNM directed the Chief of Naval Development to establish the SSVP, "a multi-year program to generate detailed descriptions of major Soviet ships, create deactivation diagrams for each ship type, and do weapons effectiveness calculations."[9]

Schaniel organized a program that involved NWC; the David W. Taylor Naval Ship Research and Development Center, Carderock; NOL White Oak; and the Naval Intelligence Support Center, Suitland. An SSVP Advisory Group, made up of representatives from the member organizations, advised the NAVMAT SSVP manager, and China Lake's SSVP office acted as staff to the manager and coordinated the program.

---

[8]Schaniel, *Carl's Career Chronology*, 93. PDF file provided by the Schaniel family. Schaniel headed the Weapons Planning Group from 1965 to 1976.

[9]Ibid., 94. The deactivation diagrams show the functional relationships between subsystems and components that are necessary for a threat system—in this case, a Soviet ship—to carry out its mission and that, if disrupted, will preclude mission completion.

To manage the program, Schaniel selected Jack Latimer, a Weapons Planning Group mathematician, who reported directly to the NAVMAT sponsor. During his 41-year career at China Lake, Latimer would also serve as the Center's Program Director for Intelligence.[10]

Jack Latimer.

The importance of the SSVP was recognized at top levels of the Navy. At one point, Schaniel traveled to Washington to brief the SSVP's sponsor, Rear Admiral Thomas D. Davies, CNM for Development. Among the attendees was Dr. Joel Lawson. Schaniel recalled:

> During the pitch, one of the things I pointed out was that we didn't have any naval architects working on Soviet ships, and we couldn't get off dead center until we solved that problem. And during the speech, why, Dr. Lawson, the Director of Navy Labs, had disappeared, and I thought, "Oh well, I'd really bombed." But by the time I'd finished he came back smiling and interrupted me to say, "We solved one of your problems; we now have two new naval architects assigned to your program."[11]

An Intelligence Working Group was formed to facilitate the SSVP's work. Consisting of experts in "shipboard weapon systems, weapon effects, electronic systems, engineering systems, damage control, hull forms and ship structures, fire control, seaworthiness and stability," and related fields, the working group focused on improving the quality of intelligence on Soviet ships.[12]

By 1972, the SSVP also included the Naval Weapons Laboratory, Dahlgren, and the Naval Coastal Systems Laboratory, Panama City, as well as personnel from NAVAIR, Naval Ordnance Systems Command, and Naval Ships Systems Command. Vulnerability studies on specific Soviet ship classes,

[10]In November 1972, Latimer was made an NWC Fellow in Ordnance Science "for his outstanding leadership and professional and managerial excellence in directing the Soviet Ship Vulnerability Program, and other programs." *Rocketeer*, 10 November 1972, 5. Latimer retired as senior staff analyst for the NAWCWD Executive Director in 2004 after 40 years of China Lake service.

[11]S-323, Schaniel interview, 27.

[12]*NWC Tech History 1971*, 6-13.

such as *Kashin* destroyers, were underway, and extensive experimental work, weapons effectiveness testing, and kill-probability studies for various systems were conducted by the participating laboratories. About one-third of the work was done at China Lake because of the availability of local expertise in weapons, energetics, warheads, and other pertinent disciplines.

"We learned a considerable amount about how to attack a Soviet ship; how to sink it, how to put it out of action, how to get a mobility kill, how to kill the electronics," said Latimer.

> Do you want to drop a bomb on the ship or do you want the bomb to go off up above the ship, in the antennas and the riggings? If you want to put a missile into the ship, do you want it to explode when it hits the side of the ship or do you want it to go through the side of the ship and explode inside? We knew that if you exploded weapons underneath the keel of a ship, it would cause a wave action that would actually break the back of the ship, break it in half. So we blew up ships, we set off explosives under ships, we set off things up in the rigging and learned a considerable amount. . . . It allowed us to design things like Harpoon. Did it make sense for Harpoon to explode as soon it hit the side of the ship or did you want it to penetrate the ship and go off inside? If so, how far inside? Where would you get the most damage? . . . A lot of information that was generated from [the SSVP] had a very significant impact on our ability to attack Soviet ships.[13]

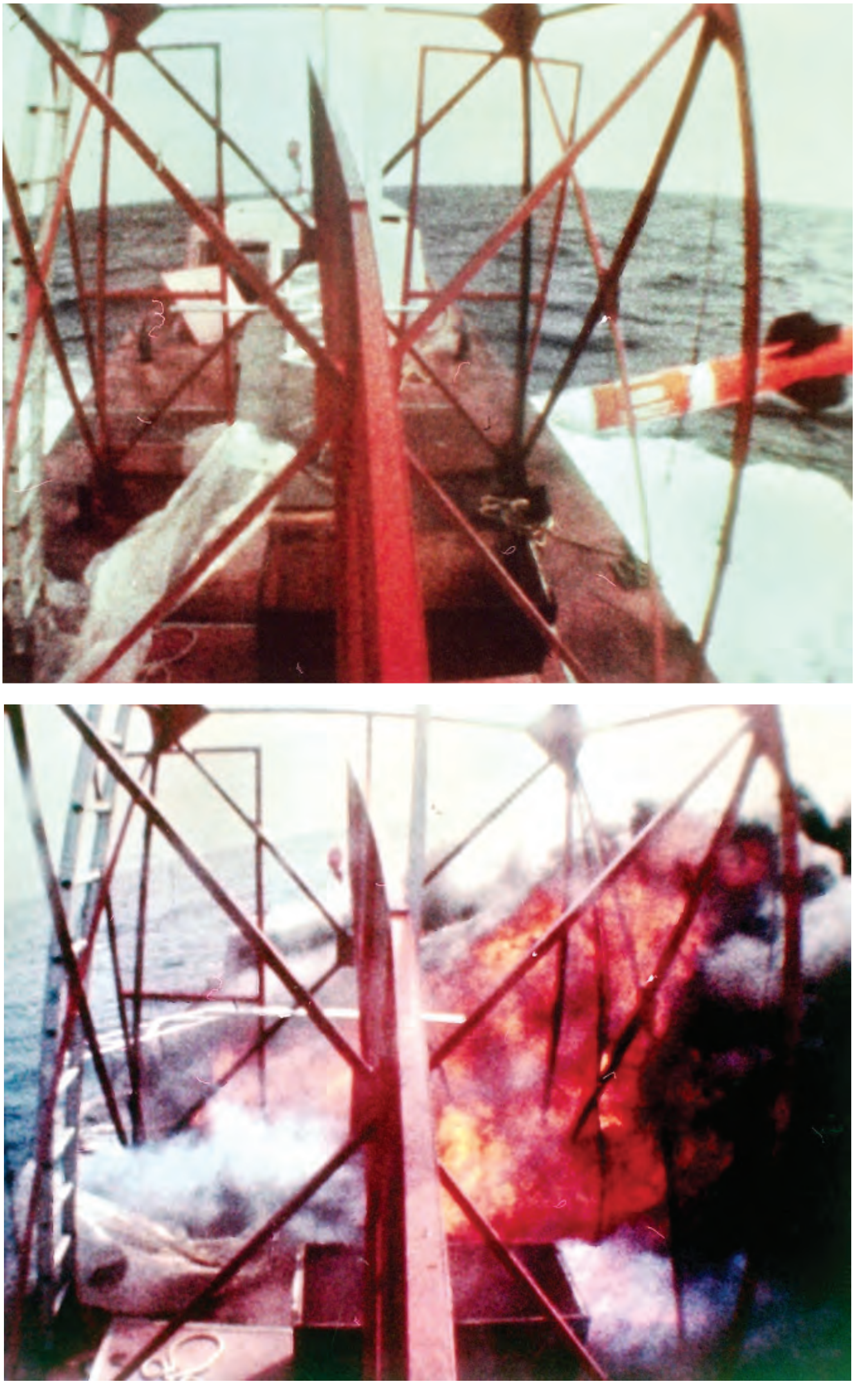
In 1973, the SSVP focused its efforts more narrowly. Specifically, it looked at Soviet surface ships equipped with surface-to-surface and/or SAMs and their vulnerability to air-trajectory weapons, and it began development of a library of computer vulnerability models of Soviet ships. The latter would be used to optimize U.S. antiship weapons during their development phase and to evaluate the effectiveness of existing U.S. weapon systems.

As the decade progressed, the program expanded. By 1976, the SSVP had prepared a ship weaponeering handbook—basically a how-to-kill-it guide for a particular ship class—and additional Soviet ship types, such as the *Krivak*-class frigate, were being analyzed. The program also provided effectiveness estimates for multiple launches of Harpoons, Condors, and Walleyes against nine Soviet ship types. In 1976, the DoD-wide Joint Technical Coordinating Group for Munitions Effectiveness, which had been formally established in 1966, appointed an SSVP representative to the Methodology and Evaluation Working Group.[14]

---

[13] S-356, Latimer interview, 8–9, 22.

[14] The successor to the *Krivak*-class frigates were the *Admiral Gorshkov* class; the lead ship, *Admiral of the Fleet of the Soviet Union Gorshkov*, was launched in 2010.



Harpoon impacting (above) and detonating (below) inside QST-35 Seaborne Powered Target (SEPTAR).

The year 1978 saw the SSVP's publication of physical and functional descriptions for the *Kiev* aircraft carrier, *Kashin* destroyer, and *Nanuchka* small missile ship as well as the development of component vulnerability data. The following year, the *Kara* antisubmarine warfare (ASW) cruiser was added. Damage calculations were performed for bombs, cluster bombs, electro-optical (EO) guided weapons, and antiradiation weapons. At NWC's Encounter Simulation Laboratory in Corona, fuze-target interactions were characterized using a 1/20-scale NWC-built model of the *Nanuchka* and a Mk 73 fuze.

Latimer said:

> For each ship we put out a document, which says here's what the ship is, here's what its mission is, here's what's on it, and here's how to kill it. So if you're going to go attack one of these ships, put these kinds of weapons on your airplane, that sort of thing, and we did that for the major ships of the Soviet Union.[15]

Weapons and Tactics Analysis Center (WEPTAC)

China Lake's growing presence in the intelligence world opened new opportunities for exploiting intelligence to benefit the warfighter. One such opportunity was WEPTAC, which began development in 1978 and commenced operation in 1979. WEPTAC was a war-gaming facility, combining China Lake's ever-growing databases on weapons and tactics (both U.S. and foreign) with the Center's rapidly expanding ability to find new applications for computer technology.

War gaming was not new to the military. In the U.S. Navy, it dates back to the mid-1880s, when Captain Alfred Mahan, president of the Naval War College, encouraged the use of German-developed games known as *Kriegsspiel* (German for war game). In the modern military, it ranged in scale from abstract paper studies for predicting the outcomes of hypothetical military conflicts to full-scale joint-service military exercises with "Red" and "Blue" Forces meeting in large, real-time simulated conflicts.[16]

Prior to WEPTAC, a common method used at China Lake to evaluate weapons and concepts of operations was called "the map study." These studies involved "geographic area maps upon which enemy and U.S. forces are

---

[15] S-356, Latimer interview, 9.

[16] Operation Strikeback, a 10-day NATO war-game exercise in 1957, involved more than 200 warships, 650 aircraft, and 75,000 personnel from the United States, Britain, Canada, France, Norway, and the Netherlands.

interacted [*sic*] in a 'table-top' battle. Results of these interactions are compared on the basis of specific measures of effectiveness for each battle scenario."[17]

What WEPTAC brought to the war-gaming table was the use of computerized interactive graphics in real time. The facility initially used a Hewlett-Packard 1000 computer with multiple stations or "command centers." Each command center had a terminal for data and command inputs, a 19-inch tactical display screen, and a printer that maintained a log of all the war-gaming actions and events. The software was designed to allow either one-sided interactive analysis (using preplanned decision logic to select the enemy response) or full two-sided gaming between individual command centers.

WEPTAC was created by the Weapons Planning Group (Code 12), under Frank Knemeyer. The Center was set up as part of the Advanced Systems Concepts Program, headed by John W. Lamb. Operations research analysts Terry Haven, Paul Severson, and James Baird assembled the program; Haven would head up the Center until Linda K. Andrews took it over in 1986.

Carl Schaniel, who had preceded Knemeyer as head of the Weapons Planning Group, credited the original idea for WEPTAC to Walt LaBerge. "At Philco Ford [where LaBerge had held several senior positions in the 1960s], Walt had been impressed with the payoff the company got from computer simulation of operations," Schaniel recounted.

> He asked me to get a team together and see what kind of simulations made sense. After brainstorming, we reported to Walt that the problem in naval operations was that the Navy was combating a devious opponent who kept changing his strategy as the game went on. We felt the real need was in the area of two-sided war games. With his encouragement, we began experimenting with real-time two-sided war gaming. This eventually turned into WEPTAC.[18]

The flexibility of WEPTAC's software allowed a variety of applications. A China Lake engineering development team could focus on a single weapon system, varying parameters and seeing how they played out in operational scenarios. Military personnel could evaluate new tactics against an existing threat weapon or platform—whose technical parameters came to WEPTAC straight from the intelligence community—or against a hypothetical system that might simulate something in the threat developmental pipeline. WEPTAC was well suited to "what if" scenarios. What if, for example, a threat air-to-air missile was fielded with an improved rocket motor that increased the weapon's

---

[17] *NWC Tech History 1976–1977*, 2-40.

[18] Schaniel, "Carl's Career Chronology," 182–183. LaBerge left his position as NWC Technical Director in 1973 to become Assistant Secretary of the Air Force for R&D.

range by 15 percent? What would be the import for a Navy pilot's engagement tactics or weapons loadout or use of countermeasures?

Not only did the Fleet operators benefit from trying out new tactics in the benign environment of a computer console before taking them to the air, weapon designers and engineers also benefitted from the military perspective on proposed new weapons or weapon improvements. This give-and-take between the operational and developmental community has been a cornerstone of China Lake's success since the base's inception.

Strike weapons specialist Dale Knutsen observed:

> There were a number of occasions where we would try things out on them [pilots from the Fleet]. "If you had this kind of a widget, would it do you any good?" And many times the answer was, "No, so don't bother us with that." But you get really constructive feedback and it was genuine feedback. It wasn't contrived, it wasn't politically correct, it was right off the top.[19]

Knutsen also spoke to the limitations of WEPTAC:

> There are some of the analytical community who believe it's not very analytically "pure." And in fact, it's not. It's an operational simulation. It's not a technical simulation. It does bring technical fidelity but not the sort of thing you get with a computer printout. It's more of a "we did this and we lost so many airplanes," and it's not a matter of running out Pk [probability of kill] numbers or that sort of thing. But it does have a ring of authenticity when you bring in actual Fleet operators to make the decisions on what the airplanes and weapons are going to do.[20]

Phil Arnold, who took over the Weapons Planning Group from Knemeyer in 1982, agreed:

> The traditional analysts didn't see war gaming as a proper analysis function . . . WEPTAC and the more conventional operational systems-analysis functionaries were always at odds, and little could be done to calm it. Any analysis or war-gaming function is only as good as the assumptions behind the project, but each function has its value. System analysis in Code 12 is done at the battle force level to give quantitative information, again depending on the validity of assumptions. War gaming is not able to offer credible quantitative information, but it can bring to bear the human element into the problem by exploring tactical and counter-tactical options. Each has its place.[21]

As a facility for developing and testing tactics, WEPTAC was particularly useful to Fleet aviators. Pilots exercised tactics not only in a one-on-one basis against a fellow aviator in an adjoining command center but also in the context

---

[19] S-259, Knutsen interview, 43.
[20] Ibid.
[21] S-275, Arnold interview, 67.

of the "big picture," including the carrier battle group (CVBG). For example, if the CVBG was being attacked, the success or failure of the ships' surface-to-air missile (SAM) engagements would have a direct impact on the conduct of air operations, including tactics, weapon selection, fuel management, etc. WEPTAC could model conflicts up to a force-level campaign with 200 units (platforms) that each had up to 30 different weapons and platforms. The exercises were recorded and could be replayed from any point, introducing new weapons and tactics.

A final report was compiled at the end of each exercise, with inputs from the players, operators, analysts, and the "umpire"—the single participant with a complete knowledge of all maneuvers and the disposition of all forces during the game. The report contained both quantitative data (number of kills, etc.) and qualitative data (comments from the players and analysis of the decisions made by the participants). Pilots, after returning to their squadrons, reported back on the success of the tactics outside the WEPTAC environment. "The pilots provide us with a reality check when they go back to the Fleet and try the tactics in the complexity of a real-world cockpit environment," said Linda Andrews. "What may seem like a simple task in the war-gaming environment might just be too much for a pilot in a combat setting."[22]

WEPTAC was also used by Navy decision makers to validate (or invalidate) claims about the operational effectiveness of new weapons, particularly when it came time for making tough funding decisions. Contractors or even in-house development personnel might tend to oversell the capabilities of a new weapon or aircraft, but exercising it in a variety of WEPTAC war-game scenarios could point up vulnerabilities or deficiencies before too much money was invested in hardware development. An aircraft billed as "invisible," for example, might prove to be susceptible to losses when confronted with specific enemy weapons and tactics under certain conditions.

One notable example of WEPTAC's capability as a high-level decision-making assistant came in the Navy's 1989 Carrier Air Wing Study (CAWS 2010), a 9-month WEPTAC study conducted in association with Fleet and VX-5 personnel "to support critical decisions determining the future air wing course of the U.S. Navy" and "to assess the Navy's capabilities and recommend which airplanes and air-launched weapons would best keep the Navy in the forefront of technology." Andrews was awarded the Navy Superior Civilian Service Medal by the Assistant CNO (Air Warfare) for leading WEPTAC's study. According to the letter of nomination, "WEPTAC results and insights, provided to the

[22] *Rocketeer*, 14 February 1991, 1–8.

Major Aircraft Review for the Secretary of Defense, were considered a critical and essential component of the resulting strong Navy position."[23]

Other Intelligence Exploitation Programs

The SSVP and WEPTAC were two aspects of a broad expansion of intelligence activities at NWC during the 1970s. Another was the Scientific and Technical Intelligence Liaison Office (STILO), established at China Lake at the direction of Dr. Joel Lawson, Director of Navy Laboratories (DNL), in response to a recommendation by the Rear Admiral Frederick J. Harlfinger II, Assistant CNO for Intelligence.

Setting up the STILO at China Lake was the job of Earl Towson, an aerospace engineer who wound up spending most of his 33-year career in the Weapons Planning Group as an analyst and later head of the NWC Corporate Plan Program. Towson's task was formidable, calling for

> a more specific and formal emphasis on intelligence coordination, foreign material acquisition programs, review of document threat statements, the tasking of the intelligence community for specific intelligence information, the use by the Center of available intelligence information, briefing of employees involved in intelligence programs, and providing an identified NWC intelligence representative for outside conferences.[24]

Earl Towson.

The program Towson structured was used as a model for STILOs at the other Navy laboratories as well, and in 1971 Towson won the R. W. Bjorklund Management Innovation Award for his efforts. In the course of networking China Lake engineers with the intelligence community and vice versa, the STILO office amassed a huge library of intelligence data that, Latimer commented in 2014, "probably still is the best on the West Coast as far as the Navy labs are concerned."[25]

---

[23]*Rocketeer*, 26 October 1990, 1, 7.

[24]*NWC Tech History 1969*, 7-19.

[25]S-356, Latimer interview, 6. Towson also instituted the bimonthly Olympus briefings that presented senior Center management with a digest of relevant documents and an insider's view of Washington developments, as well as the annual View from Mount Olympus package,

One avenue for gathering intelligence data of particular interest to engineers and systems designers was foreign material exploitation (FME), which involves hands-on analysis of actual threat and potential threat systems and materials. Latimer explained:

> You get your hands on some foreign equipment and you have your engineers tear it apart and look at it and see how it's made, see how well it works, is there anything we can do to countermeasure this thing or make sure that it doesn't work if they use it against us. . . . Soviets had a lot of allies around the world that they sold stuff to, and some of them were our friends, too, and sometimes we got our hands on things and we could tear them apart and look at them. Bring them out here, we could take them to the lab, we could test them, we could put them on the rate tables, we could fire them and see how they worked. Sometimes these were big pieces of equipment and sometimes they were a piece of equipment, something that somebody found in a garbage dump.[26]

Coordination between the intelligence gathering community and Navy scientists and engineers was beneficial to both groups, and China Lake made a greater effort in that direction than its sister laboratories. Management analyst John Bodenburg commented in 1980 that

> we are more closely affiliated with the intelligence community than any other DNL laboratory. Code 12 does a marvelous job in that area, so we get apprised of what the enemy has and what he's doing, what technology he's developing, what new weapons systems have come out or are about to come out, and so forth. And we do our darndest within the constraints allowed us to argue for product improvements or new weapon systems . . . [the need for which] might not otherwise be recognized.[27]

Of the intelligence collectors, Latimer commented:

> They're not technical experts. They're people who look at photographs, who look at signals, who look at charts and try to learn what they can. But they don't understand infrared or they don't understand electro-optics or they don't understand the physics of propulsion or warheads. . . . A lot of times we could help them, and then of course that helped them get more money to do more exploitations . . . It was tit for tat.[28]

Supporting the Center's FME work were the elite in-country exploitation (ICE) teams. "This was a group of experts on the base," said Latimer.

---

which summarized his view of where the Navy was headed in the context of international events, Washington politics, the budgetary outlook, and the nation's business climate.

[26]Ibid., 17.

[27]S-115, Bodenburg interview, 46.

[28]S-356, Latimer interview, 19.

> We might have an infrared expert. We might have an electro-optic expert, an aerodynamics expert, a propulsion expert. We had a team of four, five, six guys. They had suitcases full of equipment. They had all the shots they needed. They had valid passports. If something happened where we could get access to something, they could be on the road within 24 hours with all their equipment. . . . We had a lot of engineers here that were designing systems that just loved that kind of information because they could tweak their systems to counter whatever the Soviets were doing.

The exploitation efforts were not carried out exclusively at China Lake. Army, Navy, and Air Force organizations shared their expertise and visited each other's facilities to examine foreign equipment. Latimer recalled:

> I have a little bottle of sand at home, which is sand from the Sinai Desert that I took off the treads of a device in Alabama [Missile and Space Intelligence Center, Huntsville] that I had a chance to look at. . . . It was pretty exciting work.[29]

Condor

Analyzing the Soviet Navy's vulnerabilities was one issue; exploiting them with air-launched weapons was another task, one for which China Lake was superbly suited.

Neutralizing Soviet ships called for weapons with a damage mechanism that would disable the ship (warhead design was, and had been since WWII, a major area of effort at the Center), a fuzing system to initiate the warhead at the proper moment (which sometimes meant the fuze must survive penetration of many inches of steel armor), the speed and range to reach the ship before the ship could kill the launch aircraft, and appropriate countermeasures to ensure that the weapon penetrated the target's tiered defense system.

Walleye, discussed in Chapter 3, matured into an effective antiship weapon. Starting as a relatively short-range fire-and-forget weapon for use against enemy industrial targets, it was developed into Walleye II, with greater range and lethality than the original, and finally into the Walleye II Extended Range Data Link (ERDL), which went to the Fleet in 1974.

Coincident with the original Walleye program, the Navy began a series of studies to define a standoff, EO-guided, liquid-fuel-propelled, air-to-surface missile—essentially, a powered Walleye. Condor was planned as an attack weapon for use against high-value targets such as bridges, power stations, dams, and—most relevant to the Soviet threat—ships. By 1964, the concept

[29]Ibid., 11.

was sufficiently refined to go out for bids under what was then known as the project definition phase (PDP) of development.

Under the PDP approach—originally called the concept definition phase when it was promulgated under Secretary McNamara in 1961—the two contractors offering proposals that were judged most likely to meet the Navy's requirements competed against each other to see which would be awarded the engineering development phase contract. The theory was that, since the contractor itself proposed the cost and performance specifications that were in turn incorporated into the engineering development contract, the winning contractor could not complain (as would frequently happen) that the government had imposed impossible or unreasonable specifications.

North American Aviation Inc. and Northrop Corp. offered the best proposals among the seven bidders and began the head-to-head competition. Of the design proposals and specifications presented by the two companies at the end of the PDP, North American's was judged superior; in June 1966, North American was awarded an $118.5 million (maximum) contract for engineering development. NAVAIR (PMA-245) was assigned project management responsibility, and China Lake was delegated responsibility for technical management and direction of Navy field-activity support.

Nadim Totah with one contractor's Condor PDP final report, excluding fiscal volumes. Published in the 1966 *NOTS Tech History*.

Under the philosophy of the PDP, the contractor had full responsibility for meeting specifications. The government's role was to monitor progress and to "hold the contractor's feet to the fire"; no technical direction was allowed, because it might relieve the contractor of responsibility for its performance.[30]

[30]Crawford, "Condor Program Brief History," 2.

Tom Amlie commented:

> Navy headquarters had written a contract with a very strong "hands in the pocket" clause for us. That is, we couldn't tell the contractor what to do. In fact, the Navy privately encouraged the contractor not to even give us the drawings on what he was doing or any information.[31]

It was not an efficient way to conduct business. "We had assigned to the Condor some of the very top technical people on the Station," Amlie continued. "Jack Crawford, a tremendous guy. He was thoroughly frustrated, because he saw the contractor do all kinds of things wrong. He would tell them about it and they would go and cry to Washington that China Lake was picking on them."[32]

Crawford, who headed both the Walleye and Condor programs, wrote:

> We learned that the contractor has asbestos boots so when you hold his feet to the fire all you get is burnt wrists. Apparently the legal argument was that the Government, by reviewing and approving contractor generated specifications, was in effect certifying that they were achievable, hence, any failure on the part of the contractor to be able to comply with these specifications was the Government's fault. The practical result of the process was that we weren't allowed to direct the contractor and couldn't hold him responsible either.[33]

North American selected Hughes Aircraft Corp. as the weapon/aircraft data-link subcontractor and Thiokol Corp. as the rocket-motor subcontractor. The warhead was a China Lake design, developed under the guidance of project engineer Mel McCubbin.

Work went smoothly on the data link, but from the start there were difficulties with the propulsion unit—a dual-thrust prepackaged liquid restartable system that burnt chlorine trifluoride (CTF) and a mixed hydrazine fuel, with a total impulse of 150,000 pound-seconds. This motor type was selected because its exhaust had very low attenuation of the radio frequency (RF) data-link signal that would be transmitted and received from the aft end of the missile.[34]

The seagoing Navy was leery of liquid fuels aboard ship, and CTF was particularly difficult to work with. Lee N. Gilbert, who started with Condor as a propulsion engineer and eventually became head of the Condor airframe, propulsion, and warhead effort, said, "We tried and tried to make fuel bladders

---

[31]S-109, Amlie interview, 9–10.

[32]Ibid.

[33]Crawford, "Condor Program Brief History," 2.

[34]*NOTS Tech History 1965*, 5-23. The data link consisted of a video link from the missile to the controlling aircraft and a command link from the aircraft to the missile.

that would contain it and were unsuccessful. Almost every live Condor firing we ever made blew up on the stand because of the volatility of CTF."[35]

In 1967, North American Aviation (now North American Rockwell) switched propulsion subcontractors, taking the work from Thiokol and giving it to Rockwell's own Rocketdyne Division. But Rocketdyne could not deliver a liquid-fuel engine either. Finally, Rockwell proposed that they change their specifications and use a solid-propellant rocket motor. Not only was the program delayed 2 ½ years, but Rockwell also filed a $28.9 million claim for added costs, a claim that was eventually paid by the government.

Of his time with the Condor program, Gilbert recalled:

> The first half of it I was working as an engineer, and the second half I was working as a technical advisor to the Navy lawyers on the lawsuit that followed . . . when North American was suing the Navy because they said the technology wasn't there to do the job the Navy wanted. . . . That was an interesting year and a half, but very boring working with lawyers.[36]

The propulsion crisis was over, but now problems began with the seeker/autopilot and the data-link controls. The Hughes-developed jam-resistant data link was particularly expensive, and Condor's unit cost was increasing dramatically beyond original estimates.

Not all the problems were big ones, but they all had to be solved. For example, Ray Blackwell, who was the systems engineer for Condor, recalled an issue with the pilot's clothing: "If he has sun reflecting off his orange flight suit, all he's seeing when he looks at that small 5-inch Sony display is orange. So it makes it harder for him to pick up a target to lock on." Work began on a high-voltage projection tube display.[37]

Lengthy delays and setbacks in the development pointed out a distinction between the China Lake approach to weapons development and the contractor approach. Amlie explained:

> Around here with McLean in charge [prior to the institution of the PDP] the corporate pride was minimized . . . It was possible for us to recognize and terminate losers early, where, to be fair, the commercial guy can't do it. His board of directors, his profit picture. He is going bankrupt if he does that.[38]

In part because of this difference in approaches, China Lake had an unparalleled track record of success in its weapons development programs. "So the Navy wanted to be able to say to the Congress and to the CNO that we

[35]S-300, Gilbert interview, 3.
[36]Ibid., 2.
[37]S-329, Blackwell interview, 10.
[38]S-109, Amlie interview, 9.

were in charge of the [Condor] program, except they didn't want us in the program," said Amlie.[39]

Condor's first successful powered flight test was made in 1970. When the weapon struck the target, the launch aircraft was 56 miles away. In 1971, a Condor with a live warhead flew 33 miles to a target ship, the ex-USS *Vammen* (DE-644), resulting in "a complete mobility kill, with over 10 hours estimated to restore even minimal ship functions." At the time of impact, the A-6 launch aircraft, with the bombardier-navigator aboard controlling the missile, was 45 miles away from the target.[40]

The same year, with costs still rising and critics in Washington calling for the program's termination, a design-simplification program was begun to try to bring down system costs. This time, China Lake was given technical direction of the contractor, and each of the 50-odd work assignments were individually managed. "This method of contracting for development effort is far superior to the fixed-price method, which was used for engineering development," the *Tech History* explained. "It gives the Navy a better look at the status of the program and permits Navy technical and management direction as the program proceeds." Nadim Totah, in Jack Crawford's Electro-Optical Division, was assigned to run the program. Rockwell was given the design-simplification data developed by China Lake under the Walleye WIGS project and incorporated these improvements in the company's design.[41]

As well as using a China Lake-designed seeker and gyro-control system, the improved Condor also used a powered clutch actuator (that China Lake designed for Walleye) to replace the unreliable spring clutch Rockwell had developed. One Walleye engineer, Marc Moulton, received patents on four inventions for Condor.

Bill Woodworth, a guidance and control expert with both Walleye and Condor, spoke of the reaction of the Rockwell engineers when China Lake was brought in:

> The toes that were stepped on! The engineers at Columbus [Rockwell headquarters], of course, had a proprietary interest in this seeker that they had. And here comes this thing shipped to them, and they were directed, "You evaluate this!" Oh, God! In order to do that, some of them had to come

[39]Ibid.

[40]Van Fleet and Armstrong, *United States Naval Aviation*, 281; *NWC Tech History 1971*, 2-6.

[41]*NWC Tech History 1971*, 2-8. Totah received the Technical Director Award from Tom Amlie in 1972 and a Michelson Laboratories Award in 1974 for the successful completion of the design-simplification program. Over time, the Michelson Laboratories Award came to be known as the Michelson Laboratory Award, singular.

> out here and be lectured to on this damn seeker. I can remember them being up on the fourth floor, and the rictus was probably uncontrollable. . . . How happy would you feel? They had a corporate pressure, so they had to listen to what we said. Otherwise, they'd be out the door, too.[42]

Grumbling about Condor continued in Washington. The chief critics were from the "black shoe" side of the Navy, which favored Harpoon as the Navy's principal antiship weapon. They argued that the ship-launched Harpoon was needed because on some occasions there would not be Condor-carrying aircraft around. However, the "brown shoe" Navy, the aviators, saw Condor as a more effective weapon because of its ability for aimpoint-selection during flight. Condor also had a greater range than Harpoon, which significantly increased launch-aircraft survivability chances. A *Washington Post* article in 1973 quoted an unnamed Pentagon official as saying, "The Navy is falling in love with Harpoon prematurely."[43]

Navy technical evaluation (NTE) of Condor was completed successfully in 1973, and the Condor prime contractor, now Rockwell International, was awarded a pilot-production contract.[44]

A 1974 incident involving Condor showed that even in an efficiently run organization like China Lake, things sometimes go amiss. In the case of Condor, it was a test missile that was lost after a firing over the north ranges. No one knew where it had gone.

Captain Tommy C. Wimberly was the NWC Technical Officer at the time. (He had been christened Thomas, but as a "crazy teenager" he insisted his parents have his name officially changed to Tommy.) The Technical Officer was, in the language of NWC's Organizational Manual, the "Senior Naval Advisor and Principal Military Consultant to the Technical Director and Deputy Technical Director on naval matters including requirements and operational aspects of weapon systems development."[45]

Wimberly conducted the investigation into the lost missile. Based on the last radar plots, he and Hal Ritchie (head of the Air Operations Division) and Commander Howie Alexander (Wimberly's assistant for Air Operations) drove

---

[42]S-215, Woodworth interview, 66. Woodworth won the first of his two William B. McLean Awards for work on the Walleye and Condor guidance systems.

[43]Getler, "Dispute Rages in Navy," A21.

[44]North American Rockwell merged with Rockwell Manufacturing in 1973.

[45]NAVWPNCEN 5450-1, *Organizational Manual,* September 1971, 17. The position of Technical Officer (originally Experimental Officer) was established in 1946 as the principal interface between Fleet operations and the Center's civilian scientific community. Several men who held this position progressed to the rank of vice admiral, and one, Admiral Thomas H. Moorer, wore four stars and served as Chairman of the Joint Chiefs of Staff in the early 1970s.

AGM-53A Condor missile on A-6 aircraft. Photo courtesy of Gary Verver.

a pickup truck north on Highway 395, then headed east into the Coso Hot Springs area. They located the missile, and it was recovered by range personnel.

The incident had occurred during the Christmas holidays. "From the operational schedule's point of view, the testing needed to be considered. From the personnel point of view, people wanted some leave at Christmas time," Wimberly said. "I concluded that if the regular full-time crew had been in charge of that test, we wouldn't have lost that missile. And so I came up with some nasty recommendations." Wimberly turned in the results of his investigation to Rear Admiral Freeman. "He didn't do what I recommended but it certainly got everybody's attention."[46]

Other variants of Condor were also developed and tested: a glide Condor; a surface-launched Condor; an active radar seeker Condor developed by the Naval Avionics Facility, Indianapolis (NAFI); a dual-mode (radar and TV) Condor; and an NWC-built "turbojet-propelled version of Condor, [which achieved] a direct hit on a moving Seaborne Powered Target (SEPTAR) boat from a launch range of over 100 nmi."[47]

A production contract for 205 Condors began in April 1976. Per the *Tech History*, in the June Defense System Acquisition Review Council (DSARC) IIB,

[46]S-290, Wimberly interview, 19–20.
[47]Crawford, "Condor Program Brief History," 2.

"full-scale production was authorized upon completion of the follow-on test and evaluation, first-article acceptance tests, and reliability demonstration."[48]

But it was too late for Condor. The long-stretched schedule and ballooning costs of the weapon—the original cost estimate of $70,000 per copy had increased to more than $415,000 per missile in 1976 dollars—plus the existence of other weapons that could do a similar job (i.e., Harpoon and Walleye II ERDL) had taken a toll. In the 1976 Congressional Reviews, the Office of Management and Budget (OMB) recommended cancellation of the program. As in every large-dollar government project, politics played a role in Condor, and nowhere more so than in its demise.

A 1976 Senate report by the Joint Committee on Defense Production stated that "it is difficult to overestimate the importance of this program to the prime contractor." Noting that Rockwell's revenues from its defense work had slipped from $1 billion per year in the early 1960s to less than $500 million in 1971, the report characterized Condor as "a 'foot in the door' for Rockwell International." The report further stated that

> given the "modular" concept for the Condor stressed by the Navy and the contractor, the company would have been in a position to propose add-ons, improvements, and design changes to extend Condor's range or provide all-weather capability [e.g., the turbojet and dual-mode variants mentioned earlier]. The basic production, plus the design changes, would have assured [Rockwell] a constant stream of orders for Condor-related work.[49]

As soon as the OMB recommended the program be axed, Deputy Secretary of Defense William P. Clements wrote to President Nixon seeking its reinstatement. Secretary of the Navy J. William Middendorf and Director of Defense, Research and Engineering (DDR&E), Dr. Malcolm Currie sent letters to Secretary of Defense Rumsfeld in support of such reinstatement, letters "completely supporting and protecting the Condor program."[50]

Unfortunately, Currie's intervention hurt the program more than it helped it. As the committee report stated:

> In March 1976, Secretary of Defense Donald Rumsfeld reprimanded Dr. Malcolm Currie, Director of Defense Research and Engineering, for violation of the Department of Defense Directive 5500.7 relating to standards of conduct as a result of a visit Dr. Currie made to a residence owned by a defense contractor, Rockwell International, at Bimini in the Bahamas, over Labor Day weekend in 1975.[51]

[48] *NWC Tech History 1976–1977*, 2-4.
[49] *Condor Missile Program*, 104.
[50] Ibid., 129.
[51] Ibid., 1.

Significantly, the committee's investigation of the Condor situation was requested by Senator Thomas Eagleton of Missouri—home of McDonnell Douglas, prime contractor for the Harpoon missile.

Harpoon

In January 1968, Dr. Newt Ward was requested to do a brief (2-month) study on an air-launched missile to attack enemy ships, ranging from surfaced submarines to guided missile frigates. This effort was one piece in a crowded field of studies and proposals regarding what was generally called the Air-Launched Ship Attack Missile (ALSAM). The rash of studies was precipitated by the sinking, 4 months earlier, of the Israeli destroyer INS *Eilat* by Styx missiles launched from Egyptian *Komar*-class missile boats.

Dr. Amlie, freshly appointed as the temporary Acting Technical Director (his selection would be made permanent in March), took the lead on the study. He informed the NWC Technical Board that McDonnell Douglas had already come to NAVAIR (sponsor of most of the programs carried out at China Lake) with a proposal and had been assigned to do a long-term study. China Lake's study was characterized as short-term. "It was the feeling that the McDonnell study will be a design study and that it should be, in fact, an operational analysis," the board secretary noted.[52]

The board's deliberations gave an insight into the complexity of the issue—technical challenges aside. "It appears that the ALSAM effort is badly out of perspective because of pressures, political hassling, technical difficulties, etc., at the Headquarters level," the secretary reported. The technical end point appeared clear:

> Ultimately, we will require a radar missile . . . Code 01 [the Technical Director, Amlie] indicated that we must solve this problem—it is probably the Navy's number two problem—the number one problem being finding the submerged submarine, and secondly of protecting against a ship-launched cruise missile. Otherwise, the intelligence of having an aircraft carrier makes no sense at all.[53]

The board agreed that "the Center should propose to take the management role for an interim system."[54]

During 1968, ALSAM was formally named Harpoon. Initially Captain C. P. "Bud" Ekas Jr. was selected to lead the Headquarters team for the ALSAM effort, but soon thereafter he was made Assistant Chief of Staff for

[52]*NWC Technical Board Minutes*, 17–19 January 1968, 4.
[53]Ibid.
[54]Ibid.

Commander, Carrier Division FIVE. (As rear admiral, Ekas would later be the Navy's Chief of Naval Development [MAT-03].)

In a June 1969 letter to Ekas, Amlie summarized the progress made over the previous 16 months in his typically direct and somewhat hyperbolic manner:

> You will be astonished to know that the Harpoon is no further along than when you were on it. Bob Fulmer [NAVAIR, Material Acquisition] succeeded in selling the McDonnell Douglas study missile up the line to the OP 07s [Deputy CNO, Development] and we sold the OP 05s [Deputy CNO, Material] that you don't really need to develop a new missile, the Condor with the NAFI [active radar seeking] head will do the job. There are all sorts of politics and intrigue, every peddler in the U.S. of A. is stalking the halls of Disneyland East, and Admirals Connolly [Deputy CNO, Air] and Ruckner [Deputy CNO, Research and Development] are arguing with each other. Fulmer in the meanwhile has changed his mind, realizes the enormity of what he's done and is sorry. John Rexroth [technical assistant, NAVAIR Aircraft and Weapon Systems Division] is as hard-headed as ever and just wants to let a fixed-price "prime contractor" type development contract. In short, we aren't getting anywhere.[55]

Amlie's cynicism notwithstanding, progress was made during that year. The Navy bought NWC's ALSAM concept—a cruise missile with a turbojet engine. Dr. Newt Ward reported to the NWC Technical Board in August that Gerald O. Miller of the Shrike Program had been assigned as the NWC project manager (Bill Porter held the position briefly in early 1969) and that

NAVAIR had tentatively selected NWC as "Technical Director" for the Harpoon systems-integration contract.[56]

NWC's Harpoon efforts in 1969 were directed toward characterizing a weapon that would fit the Navy's Specific Operational Requirement (SOR) 11-74-R1: "an air- and surface-launched missile for attack of surface vessels, including submarines." The work was in four areas. Seeker tests included flight testing with the Swedish DX-290 seeker, among others. Warhead studies and tests included 58 detonations (both internal and external) against 14 target ships. (Existing Bullpup, Sparrow, Shrike, Standard ARM, Condor, and Talos warheads were tested as well as specially built warheads.) Environmental tests on the P-3 aircraft included in-flight thermal measurements of the aircraft, made with the assistance of Patrol Squadron 10, Fleet Air Atlantic, and development of thermal requirements and specifications. Management support to NAVAIR included numerous studies evaluating seekers, warheads, fuzing techniques,

[55] Amlie to Ekas, letter, 3 June 1969.
[56] *NWC Technical Board Minutes*, August 1969, 10.

safety and arming considerations, propulsion design, terminal effectiveness, and other areas.[57]

Studies continued in 1970. The original McDonnell Douglas approach had been for a limited-range rocket-propelled system. However, NWC studies found that while a solid-propellant rocket system would be appropriate for ranges up to about 35 nautical miles, "beyond this range, and especially for the low-altitude cruise mode, the turbine engine was the logical choice." China Lake collaborated with NASA's Lewis Research Center on the design of a turbojet engine for the weapon. The design was firmed up. A 150-inch-long turbojet-powered cruise vehicle version would be aircraft launched, and a 180-inch-long rocket-boosted (drop-away) version would be ship launched. The missile's body diameter was 13.5 inches, and the folding-fin span (unfolded) was 36 inches. Thus, Harpoon would be compatible with the launch systems on virtually all the Navy's Antisubmarine Rocket (ASROC) and Standard Missile-equipped surface combatants. Moreover, it could be launched from submarine torpedo tubes using a buoyant capsule. The range of the weapon was in excess of 60 nautical miles.[58]

Warhead tests continued. According to the *Tech History*:

> It was determined that a penetrating warhead in the 500-pound class, designed for detonation within the target vessel, would be the most appropriate choice. . . . It is expected that this Center will be tasked to develop the Harpoon warhead, starting in 1971.[59]

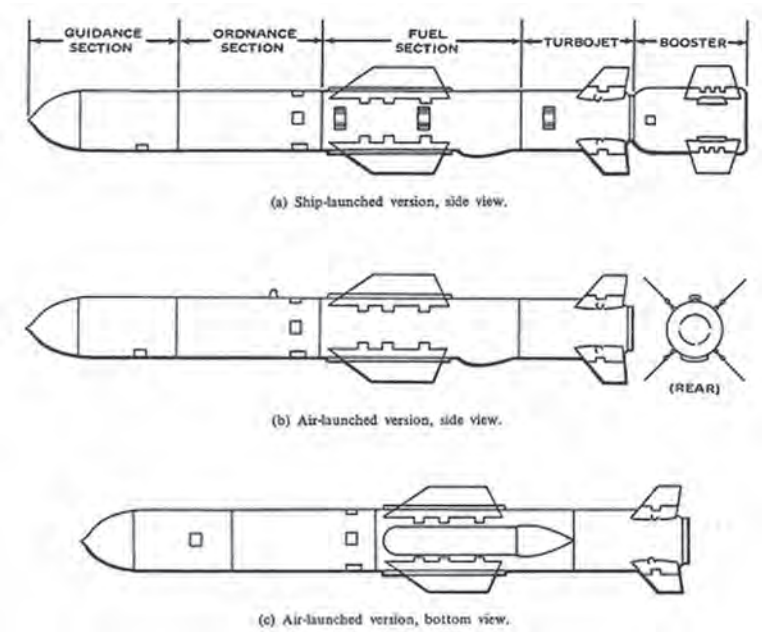
China Lake also recommended, for use against very-low-profile surfaced submarine targets, a side-looking active optical fuze. NWC's fuzing experts constructed a breadboard of such a fuze to demonstrate its feasibility.

The year 1971 was pivotal for China Lake's technical programs. As the *Tech History* reported:

> Considerable shift in program emphasis at the Naval Weapons Center took place during 1971 as a result of the nation's continuing disengagement from hostilities in Southeast Asia and the greater recognition of the vital need to counter a new Soviet challenge to our control of the seas.

Harpoon was not the only standoff ship-attack weapon in the works. Condor development was moving ahead; in February, the weapon successfully killed the ex-USS *Vammen*. In March, development of the Walleye II ERDL began, with Fleet introduction anticipated in mid-1974. The Center initiated

[57] *NWC Tech History 1969*, 2-36–2-39.
[58] *NWC Tech History 1970*, 2-31.
[59] *NWC Tech History 1970*, 2-31.



Harpoon ship-launched and air-launched variants.
Published in the 1971 *NWC Tech History*.

the BQM surface-to-surface missile (SSM) program: the rapid development of an interim long-range antiship missile consisting of a BQM-34A target drone fitted with a warhead. In a September demonstration at the San Clemente Island Range, two BQM/SSM test vehicles successfully intercepted ship targets.[60]

In June 1971, McDonnell Douglas Astronautics Co. (MDAC) was selected as the integration contractor for the Harpoon missile, now designated AGM-84A (RGM-84A for the ship-launched variant). As expected, China Lake was tasked with the development of the warhead—or, formally, the integrated ordnance section (IOS) consisting of a blunt-nosed, blast-fragmentation type warhead; safety-arming device; contact and proximity fuzes; tactical telemetry system; and command-destruct flight-termination system. Dale Knutsen, who managed the IOS development, would become China Lake's Harpoon program manager in 1972 when Gerald Miller became head of the Advanced Systems Program Office (and soon thereafter, associate department head of the Surface Missiles Department).

The IOS was to be the only piece of government-furnished equipment in the system; a variety of subcontractors were tasked with development of

[60] *NWC Tech History 1971*, 2-3, 2-25–2-26.

the other components. "McDonnell Douglas didn't build anything in the Harpoon," explained Amlie. "They built the fuel tank, the jet fuel tank. It leaked. That was the only thing they built. Everything else they bought. The seeker and the altimeter and the engine and stuff."[61]

Said Burrell Hays, tongue in cheek, "The only thing [McDonnell Douglas] made was the gas tank. And they made as much money on the gas tank as all the rest of the components put together."[62]

China Lake engineers designed and built a clever little gadget called Bugeye for use during Harpoon development. This miniature EO device provided a real-time video display of the seeker's antenna motion during captive flight to assist in evaluating aimpoint wander. The Center also brought its aircraft-interface experience to bear in evaluating and monitoring the efforts of Lockheed California Co., the P-3 aircraft interface subcontractor.

Harpoon development continued apace through 1972 and 1973. MDAC worked closely with the SSVP in a terminal-effectiveness study of the developing missile, and the Center conducted the first phase of a nuclear Harpoon warhead study. The Center also began investigating the compatibility between Harpoon and the A-7 aircraft. At Point Mugu in April 1974, the P-3 Orion fired its first Harpoon, scoring a direct hit on a remote-controlled SEPTAR boat.[63]

The year 1975 saw the establishment of the Condor-Harpoon Imaging Infrared Program (CHIRP). When Condor was cancelled in 1976, the program continued as HIRP. Ford Aerospace designed the IR imager, and China Lake provided the gimbal and servo electronics and designed and developed an automatic search-and-acquisition system. MDAC oversaw system integration at its St. Louis plant.

Problems began to surface in the Harpoon development program. A 1975 front-page article in *The Washington Post* excerpted a leaked "for official use only" memo by Assistant Secretary of Defense for Program Analysis Leonard Sullivan Jr. Sullivan said that the Pentagon's attempts to design weapons to cost

---

[61]S-199, Amlie interview, 22.

[62]S-221, Hay interview, 13. The decades have tempered a competitive and often adversarial posture that once characterized the relationship of China Lakers and defense contractors. From the 1960s into the 1980s, an "us-versus-them" attitude prevailed. This was developed in part through China Lake's responsibilities in the "smart buyer" role, in which the Center exercised stewardship of the taxpayers' dollars through close monitoring of contractor activities. The Center's aggressive oversight was often perceived—by government sponsors and contractors alike—as arrogance. In the 21st century, the roles of China Lakers and contractors are more closely intertwined; they are collocated in work spaces, share resources, and have a greater sense of being equal members of a single Navy team supporting the warfighter.

[63]Van Fleet and Armstrong, *United States Naval Aviation*, 306.

less had "failed to take hold," and he cited Harpoon as one of eight weapons that had exceeded their cost goals by 16 to 28 percent.[64]

When Harpoon transitioned from the full-scale development phase to the production and deployment phase, local management responsibility for the Harpoon work at China Lake was transferred from the Weapons Department to the Engineering Department. As the already-expensive missiles rolled out of MDAC and into operational evaluation (OPEVAL, the independently conducted assessment of the weapon's suitability for Fleet use), the missile's weaknesses became obvious.

Harpoon failed OPEVAL. Not once, but twice. Component failures were rife. "The Harpoons were failing drastically in reliability," recalled Burrell Hays.

> They would ship them from Dallas—because that was where the last part was put in, the seeker—they would ship them from Dallas to Mugu. They'd ship them back, and people used to say, you know, they were wonderful as long as they homed on Dallas. They had a 100 percent success rate of homing on Dallas.[65]

As China Lake saw it, the problem with Harpoon was a lack of proper oversight authority. Under the acquisition philosophy that prevailed in Washington at that time, contractors were treated as technically capable and responsible. It was believed, perhaps naively, that by giving them control of the program early in the development process, they would put the needs of the Navy first and produce weapons of the same quality and cost effectiveness that had been coming out of the Navy's laboratories for decades. That was not how it worked.

Bill Porter, who managed many programs, including Harpoon, during his 40-year career at China Lake, said:

> There's a whole string of programs, starting with Sparrow, where the Center maybe had a minor support role or was, quote, a technical monitor, and then the program got in some sort of difficulty in production or in OPEVAL, and then we were asked to become more heavily involved. . . . We were not really in the driver's seat . . . The way we eventually came back into those programs and had a strong role was because the program got in trouble, usually in OPEVAL or in production.[66]

China Lake, with the encouragement and support of Rear Admiral Ekas, was brought in to identify and, if possible, fix Harpoon's problems. The Center had gained a reputation for being able to correct contractor reliability issues

[64]Wilson, "U.S. Arms Choices," A1.
[65]S-221, Hays interview, 12–13.
[66]S-216, Porter interview, Part 2, 50, 56.

(with the AIM-9B in the 1950s, AIM-9D in the 1960s, and Shrike during the mid-1960s, when China Lake qualified a second production source for Shrike based on careful documentation and quality control). China Lake had reinforced that reputation in the early 1970s, when a team led by Burrell Hays had turned the Sparrow AIM-7 program around by imposing strict quality assurance and documentation controls in the AIM-7F second-source program (see Chapter 13). The same meticulous, attention-to-detail approach was taken with Harpoon.

Ekas did not believe Harpoon needed a second source—another contractor assembling the weapons—although China Lake had repeatedly shown that such an approach cut costs through competition. According to Hays, Ekas said:

> I don't want to have two MDACs putting together Harpoons. But I want MDAC to have two suppliers of every major component, and I want MDAC to have to buy those parts from those suppliers with the same disciplines that you guys have, with the same solder specs, the same quality, etc.[67]

China Lake sent a "Tiger Team" to the McDonnell Douglas plant to begin evaluating the dimensions of the problems. Amlie remembered:

> Burrell was leading this team, so instead of going to the Executive Dining Room for lunch, he went to the naval officer in charge of contracts there and had him pull all the contracts and found that McDonnell Douglas was lying by a factor of three on all the assemblies. They came back from lunch, and Burrell said, "Well, you know, do you want to talk to me or do you want to talk to the FBI?" And they said, "Let's talk." They cut the price in half in a day. They were lying by a factor of three.[68]

Roland Baker returned to China Lake from supporting the Annual Service Practice (ASP), a Chaparral (MIM-72) firing exercise in Hawaii in mid-1976, only to find that his Chaparral Office in the Weapons Department had been abolished. Support for the Army missile (developed by China Lake) had shifted to an "as requested" basis. Hays invited him over to the Engineering Department for a talk, knowing, as Baker put it, "that I was 'in the wind,' so to speak." Baker recalled that Hays

> was sitting back with his feet up on his desk, chewing on a cigar, and he thought he had me. He wanted me to be Harpoon Production Manager. . . .

---

[67]S-221, Hays interview, 12. Hays received the L. T. E. Thompson Award, the Center's highest, in 1974. The citation noted "his outstanding contributions to the field of weapons design and development, and especially his skills in the process of transition from development to production." *Rocketeer,* 19 April 1974, 1.

[68]S-199, Amlie interview, 22–23. Hays clarified, "They were charging the government at least three times the amount they were paying their subcontractors on fixed priced contracts for the sub-assemblies." Hays, email, 20 January 2014.

> I told him I didn't want it because Harpoon had just failed OPEVAL for the second time. I said, "You want me to take over at the punish-the-innocent phase." . . . So he was telling me how important it was and said, "The Fleet really needs this missile." And finally he said the magic words; he said, "Rollie, if you take this job, I'll get you your GS-15." I said, "Burrell, you got me."[69]

Many years later, Baker shared that he was

> very disappointed to find out that the previous production manager had put a one-sentence line-item in the Harpoon Program Support Plan and asked for one million dollars. I assessed that was far too little for the problems that existed and the effort needed.[70]

Lack of effective coordination between the prime contractor and subcontractors was a big contributor to the reliability problems encountered with Harpoon. When retired Rear Admiral Mark W. Woods performed an independent review of the Harpoon program in 1976-77, one of the subcontractors interviewed noted that, for a particular component, "there was no specified MTBF [mean-time-between-failures] requirement," which prompted Woods to comment:

> That statement is a very small monument to what appears to have been one hell of a big lack of communication between prime contractor and subcontractor. Other subcontractors with lesser total subsystem failure rates seem not to have been overly disturbed by all this.[71]

Wood's report was, in places, caustic:

> Texas Instruments has substantial background in building complex electronic devices in quantity and would seem to be a good source for the seeker. However, the Review Group noted two disturbing factors at TI. First, important members of the initial design team appear to have been reassigned to other things. Secondly, the quality standards applied to Harpoon are less rigorous than those in other government programs in the same plant. The seeker is the most complex part of the missile and is most likely to experience environmental-stress failure. TI knows how to build it better, but they are not required to do so by their contract.[72]

Reliability and quality problems were more difficult than cost cutting. First, China Lake had to take control of the data package, which, with Ekas' support, it did. "The prime contractor has delivered virtually all master documentation of the missile subsystem production data package," reported the *Tech History*.

---

[69]S-326, Baker interview, 21.
[70]Baker, email review comment, 10 October 2014.
[71]Woods, *Harpoon Weapons System Program*, *Volume II*, A-34.
[72]Ibid., *Volume I*, II-4.

> NWC reviewed all the submitted documentation (except for the seeker assembly) for conformance to requirements. Comments describing errors, inaccuracies, inadequacies, and omissions were prepared and forwarded to the contractor for action.[73]

The Center pressed on, establishing

> criteria and specific details for mission profiles, a parts and materials program, design-limit determination tests, qualification testing, acceptance testing, test matrix, product assurance requirements, production data package, physical audit, system simulation, and a laboratory and test facility.[74]

In 1977, Baker became China Lake's Harpoon program manager. "The atmosphere between China Lake and St. Louis was horrid," he said.

> I went around Mich Lab and there were these cartoons on bulletin boards that showed McDonnell Douglas Astronautics Company with golden arches in front of it, and caricatures of Harpoon missiles with the fuel tanks leaking and the seekers homing on Dallas. I tore them down and threw them away and I got all my people together before the next quarterly review and I said, "If I hear anybody bad mouthing Harpoon or McDonnell Douglas, or anything that is counterproductive, you will not be working on Harpoon when we get back to China Lake. We are going to work with these people. We're going to get this Harpoon to the Fleet."[75]

At the quarterly review, as Baker recalls, he met privately with Cliff Marks, McDonnell Douglas' vice president and the company's Harpoon program manager, and the two agreed that their teams would work closely and cooperatively. "Once we started working together, the problems started getting solved, and soon the problems with Harpoon seemed to become very small ones, like a screw being too short."[76]

Baker had a motto that "the interrogative is mightier than the imperative." "When dealing with the contractor," he said, "it is always better to ask questions rather than make statements. Statements can be interpreted by the contractor as new contract requirements, and that can get you into a heap of hurt. By asking questions, you are in control."[77]

According to Woods' review, Harpoon's seeker (built by Texas Instruments) comprised "some 6,000 identifiable separate components." These critical components did not escape China Lake's scrutiny:

---

[73]*NWC Tech History 1976–1977*, 6-14.
[74]Ibid.
[75]S-326, Baker interview, 22; Baker, email review comments, 10 October 2014.
[76]Baker, email review comments, 10 October 2014.
[77]Ibid.

> Historically, the magnetron used in the Harpoon seeker has been a commercial item with a high failure rate. Because of its poor reliability and high cost, an effort was undertaken in 1977 to better define the requirements for this device by preparing a military specification for its acquisition.[78]

The new magnetron specification also required that the supplier produce qualification articles for evaluation. "The magnetron manufacturer didn't think that he should be required to use the soldering specification because the magnetron had only five solder joints," Baker said. "They brought one into the meeting and it had four of the classic soldering problems—one joint had too much solder, one had too little solder, one was a 'birdcage,' and the fourth was a cold solder joint." By 1978, qualification testing was underway for three new suppliers.[79]

"Harpoon, I think, became a success story," said Hays. "All the major components became second sourced. Reliability became quite high. First test yields came up."[80]

Porter attributed the turn-around to

> getting the documentation under control, making sure they had good configuration management, good solid quality-assurance programs. Having done that and having satisfied the customer or the sponsor, then as they talked about improving the weapon, we got in on the ground floor on the improvements.[81]

Dr. Dick Kistler and Bob Glenn made a similar observation years later, when China Lake was developing the Standoff Land-Attack Missile (SLAM):

> China Lake played a principal role on a team that went into the [Harpoon] prime contractor's plant (as well as to subcontractors), carried out fact-finding activities, put together a get-well program, and worked with the contractor to implement the program. Harpoon has had remarkable success since that program was implemented. China Lake is now the lead R&D Center for the SLAM development, which can be thought of as a modification and improvement of Harpoon.[82]

Harpoon integration on Navy attack aircraft proved to be a challenging task. Originally, the only Harpoon-capable aircraft was the P-3, a lumbering four-engine (propeller) patrol aircraft. The P-3 carried 300 pounds of Harpoon-specific avionics as well as a dedicated operator for the weapon system. In

---

[78]Woods, *Harpoon Weapons System Program*, *Volume II*, A-32; *NWC Tech History 1976–1977*, 6-14.

[79]Baker, email review comments, 10 October 2014.

[80]S-221, Hays interview, 13.

[81]S-216, Porter interview, Part 2, 51.

[82]Kistler and Glenn, *Notable Achievements*, 24–25.

1974, NAVAIR tasked China Lake to "integrate and demonstrate" Harpoon operation with a single-seater.

Working with Ling-Temco-Vought (LTV), the A-7E manufacturer, China Lake—primarily the Center's rapidly developing A-7E Weapon System Support Activity (WSSA)—managed to duplicate the capabilities of the P-3's 300 pounds of avionics in the A-7E's TC-A2 airborne computer. According to one NWC history, the first flight of a Harpoon from an A-7E in December 1975 was not only a by-the-book success, it was also Harpoon's longest-range and fastest-airspeed launch up to that time and the weapon's first off-axis launch.[83]

Harpoon went to the Fleet in 1977. The weapon was steadily improved as the years passed, with many of these improvements originating at China Lake and validated in the Harpoon Missile Guidance Simulation and Engineering Test Laboratory at China Lake. This facility was proposed in 1977 as "part of the plan to fulfill the need of a corporate memory for Navy production support." Groundbreaking took place in 1980, and the military construction (MILCON)-funded facility opened in 1983.[84]

In March 1986, surface- and air-launched Harpoons saw combat use in the Gulf of Sidra, off the coast of Libya, sinking at least one Libyan ship. Harpoon was again used in combat in 1988, sinking the Iranian frigate *Sahand*. Norman Friedman wrote in 1989 that "Harpoon is probably the most widely-deployed of all modern Western antiship missiles; it is used by 19 navies (including 9 NATO navies)."[85]

Gator

A Soviet invasion of Europe was a persistent concern of U.S. and NATO forces during the Cold War. Many military analysts believed that, if the Soviet attack came, it would be spearheaded by tanks rolling through the Fulda Gap, an area of lowlands between East and West Germany (the same avenue along which Napoleon's Grand Army had retreated after losing the Battle of Leipzig in 1813).

To stem the invasion, U.S. and allied forces would have little choice but to rely on tactical nuclear weapons; these included artillery-launched nuclear warheads yielding 10 tons to 40 kilotons (TNT equivalent) as well as hand-emplaced nuclear mines yielding up to 1 kiloton.

---

[83]NWC AdPub 391, *What Have You Done for the Fleet Today?*, 26.

[84]*NWC Tech History 1976–1977*, 6-14. MILCON funds are congressional funds earmarked specifically for construction on military installations.

[85]Friedman, *World Naval Weapon Systems*, 93.

American and NATO military planners, however, concluded that a more graduated and flexible response capability would better serve the interests of the United States and its European partners. They turned to land mines. Through most of military history, land mines had been used primarily as defensive weapons, deployed along borders or emplaced by retreating forces. Now they would become an offensive weapon. The U.S. Army was already working on artillery-delivered mines, and in the mid-1970s, the DoD set out to develop Gator, a system to deploy mines from high-speed aircraft. These air-delivered minefields could be used for terrain denial and to interdict and destroy enemy forces and their supply lines.

One Army analyst commented that

> Gator mines are designed to be effective for interdiction of second-echelon forces in assembly areas and columns. . . . The purpose of these minefields is to disrupt and disorganize enemy forces and to deny the use of key areas.[86]

The Soviets were quick to appreciate the threat. In a 1979 article in *International Defense Review*, based entirely on Soviet sources, Soviet affairs specialist C. N. Donnelly wrote:

> Most dangerous of all, say Soviet tacticians, is the enemy's ability to deliver mines remotely, right into the depths of the attacking forces. . . . remotely scattered mines are considered to pose a serious problem if they take the advancing troops by surprise.[87]

Yet, Donnelly wrote, "the problem of dealing effectively with remotely delivered minefields has yet to receive adequate coverage in the Soviet press."[88]

A true joint-service effort, Gator—formally described as an "aircraft-delivered target-actuated munition system"—used an Army-developed mine delivered from both Air Force (SUU-66/B) and Navy (Mk 7 Rockeye II) dispensers. China Lake was tasked to put the package together; specifically, to develop the mine-to-dispenser kit modification unit (KMU). "The Air Force was lead service because they were the ones who were going to buy the most," said Moyle Braithwaite, Gator program manager and head of the Terrain Denial Weapons Branch in Milt Burford's Conventional Weapons Division. "The Army said, 'We'll build the mine.' So our job was to then take the Army's mine and package it in the Navy and Air Force dispensers."[89]

---

[86]Chase, "Scatterable Mines," 7. Chase was chief of the Concepts, Plans, and Analysis Division of the Development Project Office for Selected Ammunition, U.S. Army Armament Research and Development Command.

[87]Donnelly, "Overcoming NATO Antitank Defenses, Part 1," 23, 25.

[88]Ibid.

[89]*NWC Tech History 1976–1977*, 3-10; S-317B, Braithwaite interview, 20.

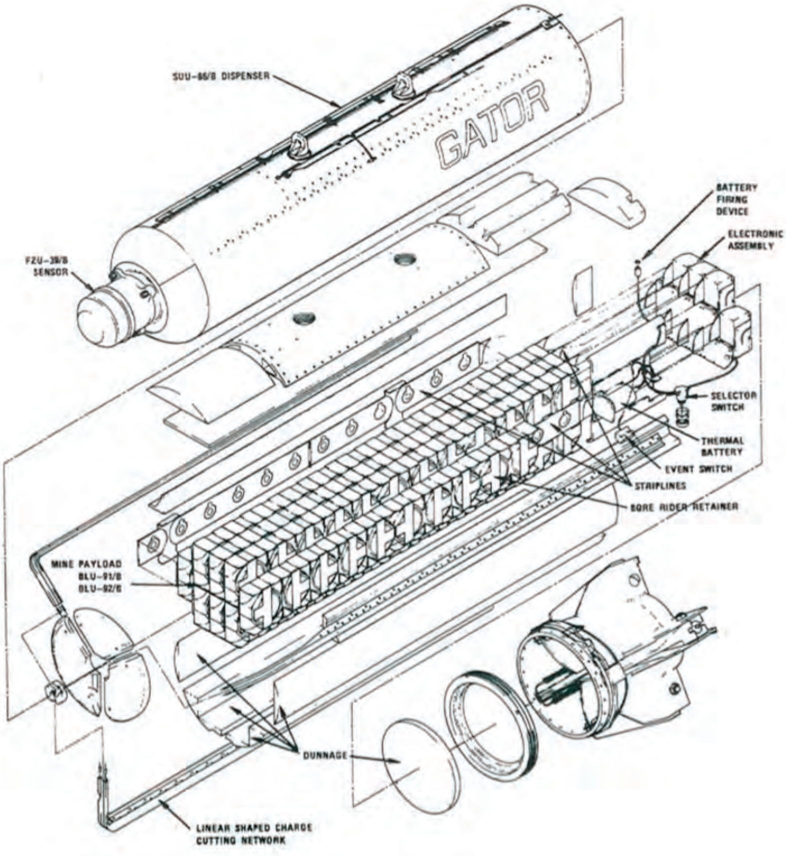
China Lake was assigned the task principally because of its experience with the Deneye and Rockeye cluster weapons. Deneye began development in 1962 as part of China Lake's Eye series of conventional weapons, and its program objective was "to develop and provide an aerially delivered antipersonnel/antimaterial mine that could be set to self-destruct at a predetermined time by a battlefield commander." Development continued at a low level, with a hiatus in 1965 and 1966 "because of DOD deferral of all service use of land mines."[90]

Funding for Deneye was sporadic after 1966; development of the mine submunitions focused more on the antipersonnel version than the antitank mine because of the Vietnam War requirements. The mine under development, upon reaching the ground, deployed 25-foot trip wires in three directions. Testing included "exploratory investigations into basic responses of personnel in Deneye-type minefields." By 1972 (when the program became inactive "because of low Navy and Marine Corps priority"), the design baseline was sufficiently mature "to allow manufacture and test of the first quantity of evaluation hardware."[91]

Rockeye had begun as Hawkeye in 1960. Rockeye 1 used a backward firing Zuni rocket to open the dispenser casing and scatter the submunitions. The system was inefficient, and it was soon replaced by Rockeye II, which used a linear shaped charge to open the container and scatter 247 Mk 118 bomblets with target-discriminating (hard or soft) fuzes. Rockeye II went into production in 1967 and was widely used in Vietnam and subsequent U.S. conflicts. During more than a decade of designing, building, and testing cluster weapons, China Lake had developed expertise in various methods for storing, releasing, scattering, and arming air-delivered submunitions.

Around 1970, the Army Armament Research and Development Command at Picatinny Arsenal began to develop a series of mines called the Family of Scatterable Mines (FASCAM). Two FASCAM mines were selected for Gator, both originally developed for the Army's Ground Emplaced Mine Scattering System. One was an antiarmor mine, the BLU-91/B, activated by magnetic influence, and the other an antipersonnel mine, the BLU-92/B, activated by tripwires. In operation, both types would be dispersed together (at a ratio of about three antiarmor to one antipersonnel) to deter minefield-clearing operations by ground support troops.

[90] *Major Accomplishments of the Naval Weapons Center*, 23; *NOTS Tech History 1965*, 7-16.
[91] *NWC Tech History 1969*, 1-26; *NWC Tech History 1972*, 3-4.



CBU-89/B Gator munition, Air Force variant.
Published in the 1979 *NWC Tech History*.

A particularly desirable characteristic of the Gator mine system, one that had been a goal of the Deneye system developers, was that the mines had a self-destruct capability. Immediately before a mission, a switch on the dispenser set the time after which the mines would become disabled or self-destruct, a period ranging from a few hours to weeks, depending on the requirements of the specific tactical situation.

Work began on Gator at China Lake in 1975. Over the next 2 years, progress was made in manufacturing and flight testing aerodynamic mine shape and in completing the preliminary design of the KMU. As with any development program, there was the occasional unexpected setback. In July 1977, for example, it was found that some of the mine components provided by the Army were not the correct parts. According to the *Tech History*:

> This resulted in (1) the loss of the data bank from previous tests, (2) the need to revise the mine and KMU design, and (3) the rework of a large quantity of test mines for the Navy and Air Force. The schedule slipped 3 months as a result of these problems.[92]

By 1979, China Lake had completed design and testing of the KMU and had manufactured and tested new mine self-destruct kits with three time-delay options. The Navy Gator was now designated CBU-78/B and the Air Force version CBU-89/B; components for the two systems were approximately 80 percent interchangeable. Tests on the China Lake ranges and at Eglin validated the dispersal pattern of the mines; the size of the pattern was dependent on the altitude at which the dispenser opened.

Gator successfully completed OPEVAL in 1982, and as was the practice at China Lake, responsibility for the program shifted from the Ordnance Systems Department to the Engineering Department, where James H. Irvine was assigned as Gator production manager. Continuing to work with the system to facilitate its transition to production were engineers William R. Bryant, William R. Nevins, Jerry L. Gentry, and Roy Ito, assisted by documentation specialist Walter J. Hannon, technicians Edward Gaunt and Roger McEntee, and administrator/budgeteer Ron Keck.

Gator's transition from prototype to production was difficult. The weapon system was complicated and contained many close-tolerance parts provided by a variety of contractors and government agencies. At one point early in the production run, the Gators coming off the line began to fail. This was one of what Irvine called "half-a-percent problems" that didn't show up in developmental testing but began to show when production volume ramped up. The culprit proved to be a small tab on a Mylar® strip that was shorting a battery—in the original design, the tab had been cut off, but the detail had not made it to the production drawings.[93]

"The tight dimensions gave us fits," said Irvine. "They were just super annoying and we could have done without them." One specification called for an aluminum end plate to be machined to a tolerance of 0.005 inches. As the system moved from low-rate production into full-rate production, the design team continued with product improvement efforts. In 1986, Irvine, Hannon, and mechanical engineer Neal M. Lundwall received a commendation from Secretary of Defense Casper Weinberger for designing a cast-iron plate to replace the aluminum end plate, reducing the cost per plate from \$300 to \$60.[94]

---

[92] *NWC Tech History 1976–1977*, 3-10.

[93] S-335A, Irvine interview, 20.

[94] Ibid., 17.

Secretary Weinberg's letter said in part:

> This remarkable achievement represents a substantial contribution to more efficient government operations. Improved productivity is vital to the defense and economic well-being of our nation. Contributions such as yours support my conviction that every civilian employee and military member can play a major role in improved government service.[95]

Gator was used extensively during Operation Desert Storm; the Air Force delivered 1,105 CBU-89/Bs, and the Navy and the Marine Corps delivered, respectively, 148 and 61 CBU-78Bs. In a 1992 paper on China Lake contributions to that effort, Matt Anderson, head of the Engineering Department, wrote that Gator "performed very well in limiting the mobility of the Iraqi Army and it played a key role in Desert Storm."[96]

Supersonic Tactical Missile (STM)

In the 1970s, China Lake formally began advanced development of the technologies required for a supersonic air-launched cruise missile capable of defeating enemy land- and sea-based air defenses. The weapon, the STM, was to be ready for deployment in the mid-1980s. The design, which would incorporate a ramjet and a new guidance system, was premised on the belief that the weapon's supersonic velocity would make it less susceptible than a subsonic cruise missile to the enemy's surface-to-air missile (SAM) defenses.

Soviet SAMs, which had wreaked havoc on U.S. aircraft during the Vietnam War, had not flagged in their development. Foreign systems, such as the Soviet S-300 SAM, fielded in 1978, were a lethal threat. The military requirement for the STM was stated bluntly in the program's master plan:

> Increasing sophistication of the potential enemy's defense systems (both land and sea) are posing an increasing threat against our aircraft's ability to penetrate those defenses. Current projections indicate that by the mid-1980s, aircraft approaching or attempting to penetrate the potential enemy's territory will have an unacceptably high attrition rate due to these improved defense capabilities. Therefore it is imperative that the development of a missile system with the capability of being launched at a distance, operating under day/night and adverse-weather conditions, and operating at supersonic speeds be developed in order to minimize interception, thereby increasing the odds of penetration and decreasing the potential loss of our aircraft and personnel.[97]

---

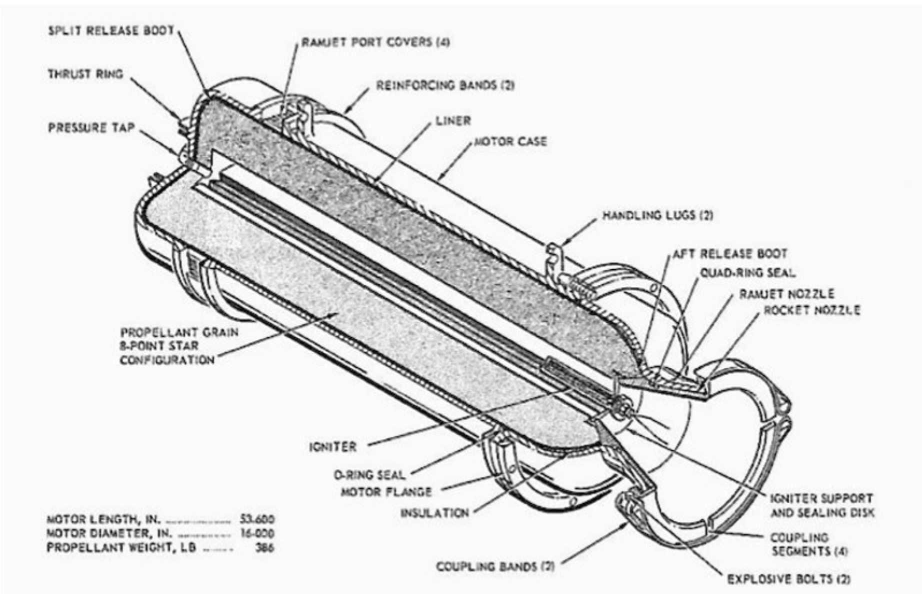
[95] *Rocketeer*, 17 October 1986, 7.

[96] DS79.724.U6G85, *Gulf War Air Power*, 103, Table 3; *Rocketeer*, 23 January 1992, 8. By comparison, the three services dropped 27,987 Mk 20 Rockeye weapons during the operation, more than half by the Marine Corps.

[97] NWC 39042-46, *Supersonic Tactical Missile*, 1-1.

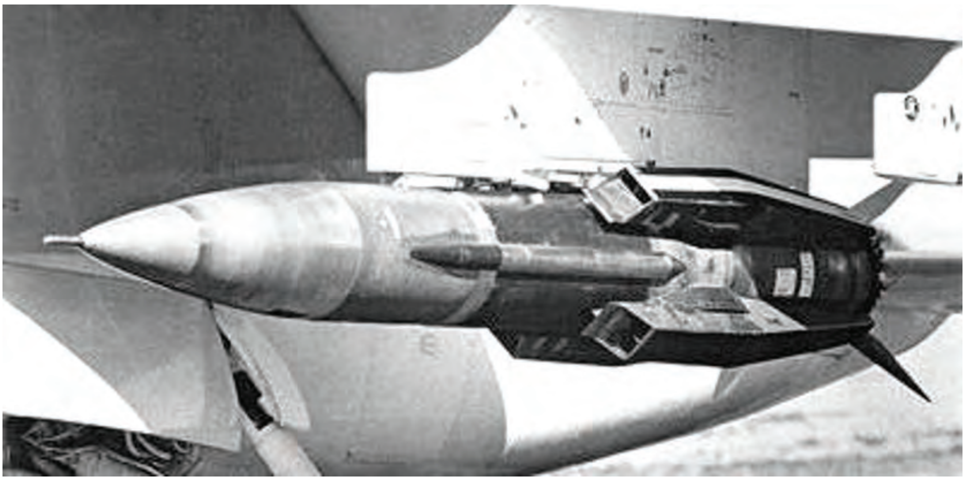
The basis for the STM project was the CNO's issuance in September 1968 of Advanced Development Objective 11-56X, which called for an "Advanced Tactical Standoff Missile." In 1969, NWC was assigned the role of systems integrator for the missile and was charged with preparing and updating Technical Development Plan (TDP) W11-56X, *Advanced Tactical Standoff Air-to-Surface Missile Systems*. In 1972, the CNM approved the Center's TDP as well as an advanced procurement plan (APP) to integrate the Air-Launched Low-Volume Ramjet (ALVRJ) with a missile guidance system.

Even before the CNO's 1968 call for the weapon, China Lake had been pursuing the technologies that would go into STM. Beginning in 1965, engineers had been at work developing a low-volume ramjet that utilized a common combustion chamber. The rocket portion would boost the missile system to from Mach 0.7 at launch to Mach 2.5; at booster burnout, the ramjet port covers in the forward end of the motor would open inward and trigger explosive pistons that would separate the rocket nozzle from the motor and initiate the ramjet sustainer.



Rocket motor and combustion chamber for low-volume ramjet, circa 1966. Published in the 1966 *NOTS Tech History*.

By 1968, successful static test firings had been performed at China Lake, and the Center began working with LTV to develop an advanced version of the low-volume ramjet that would be small and light enough to power an air-launched missile. Testing and modification continued into the 1970s, using fuels developed at China Lake as well as rocket motors cast at the Center. The resulting propulsion system, which began flight testing in 1974, employed a 15-inch-diameter booster with 410 pounds of carboxyl-terminated polybutadiene propellant in an eight-point-star configuration. Between 1974 and 1976, the system flew five tests at the Pacific Missile Test Center (PMTC), Point Mugu, achieving speeds of over Mach 2 and ranges in excess of 100 nautical miles as well as demonstrating the ability to maneuver and to fly both on the deck and at high altitudes.



ALVRJ on A-7. Photo by LTV.

In a development effort running parallel to the integrated rocket/ramjet program, China Lake engineers had been investigating a tactical inertial guidance system (TIGS) since 1964. TIGS was a strapped-down (fixed to the body of the missile, rather than gimbaled) system that provided position, velocity, and acceleration data for use by the missile's guidance system. In October 1967, NWC initiated the Advanced TIGS (ATIGS) program, "a 5-year effort to define a tactical strapped-down guidance system configuration for release to engineering development." The program investigated two types of inertial measurement units (IMUs), which were described in the 1967 *Tech History*: "IMU 1 employs conventional inertial sensors, whereas IMU 2 uses unconventional sensors (that is, a ring laser gyro)." Nick Schneider, an associate division head in the Weapons Development Department, was assigned as ATIGS program manager.[98]

The ring laser gyro was a three-axis gyroscope developed by Honeywell Inc. and delivered to China Lake in 1966. The original intent of China Lake's

[98]*NWC Tech History 1967*, 7-35.

investigation of this technology was broad: to determine the potential applicability of a ring laser gyro for Navy use on ships and aircraft, including navigational devices and a shipboard weapons-stabilization system. The Honeywell unit was more of an experimental device than an operational weapon system or navigation component. China Lake's project engineer for the ring laser gyro, Eugene E. Curry, said that the gyro was "somewhere between the research and development stages."[99]

Nick Schneider.

A *Rocketeer* article explained the operation of the gyro thusly:

> Three gas lasers, coherent light beams are projected in opposite directions from the triangular lasing tube. At each corner of the triangle, a mirror reflects the light through the next leg of the triangle. One of the mirrors is lower in efficiency than the other two, and allows some of the light to pass through, where it is recorded.[100]

The system accurately detected motion in three axes (roll, pitch, and yaw) and reduced many of the problems inherent with traditional analog IMU systems: unlike mechanical or gimbaled gyros, it had no moving parts that could break down or wear out. It could withstand high *g* forces and seldom required recalibration (about every 5,000 hours as compared with 10 to 100 hours for a mechanical gyro).[101]

John Hoyem became head of NWC's ATIGS program in 1967. Over the next several years, China Lake integrated the ring laser gyro into a navigational system, and Navy and Honeywell engineers worked together to develop new applications for the technology. A significant breakthrough came in 1972 with the development of improved mirrors and better material for the block (the gyro body).

In 1974, the first flight tests of an ATIGS took place at NWC, with the system carried in a pod on an A-7. William F. Ball, then ATIGS program

[99]*Rocketeer*, 16 September 1966, 3.
[100]Ibid.
[101]Ibid.

manager, said, "Flight tests have shown that we have exceeded the performance requirement for the air-to-surface missile application, and have demonstrated a performance potential for strike aircraft navigation." He gave much of the credit for the success of the flight-test program to Ray Francis, ATIGS project engineer. A *Rocketeer* article reported that Honeywell's Aerospace Division, which had been given the specifications for the ATIGS air-to-surface missile application, had in some cases "bettered these specifications by a factor of 10."[102]

Another guidance system being developed at China Lake for the STM was microwave radiometry (MICRAD). This technology, reported the *Tech History* in 1967,

> holds promise of providing passive, 24-hour, all-weather operational capability for navigation, surveillance, and guidance systems. Essentially, MICRAD is a passive detection system that can sense the difference in radiometric temperature between objects and their backgrounds. Areas or objects having high radiometric temperatures are contrasted with those having low radiometric temperatures, such as a river and its surrounding terrain.[103]

By 1970, a large (36-inch-diameter pod) MICRAD system was being tested on OV-10s and an A-6A. In 1971, China Lake engineers, using recent developments in parametric amplifiers, mixers, and intermediate-frequency amplifiers, began to develop a MICRAD system for midcourse and terminal guidance of an air-to-surface missile. This was a dual-mode system using area-correlation position fixing for midcourse guidance (the MICRAD system would make midcourse location determinations that would be used to update the inertial guidance system) and salient-feature terminal guidance that would lock on to the radiometric contrast of the target and provide data to the inertial guidance system for the homing phase of the attack. The system was being tested using a CH-46 helicopter.

At the same time, a MICRAD digital adaptive area correlator was under development using Independent Exploratory Development (IED) funding. The system used MICRAD maps developed from aerial photographs that were correlated with the view seen by the MICRAD sensor on board the test aircraft, an OV-10A.

MICRAD development work began to pay off in 1973. That year, the *Tech History* reported that

> an experimental fixer [position-update system] was successfully flight-tested, yielding accuracies sufficient to guide a missile into the acquisition basket of the MICRAD seeker even when dealing with targets located in a dense urban

[102] *Rocketeer,* 2 August 1974, 3, 1.
[103] *NWC Tech History 1967*, 1-29.

> industrial environment. An experimental seeker was also successfully flight-tested, demonstrating acquisition ranges and accuracies sufficient for terminal guidance of supersonic air-to-surface missiles.[104]

The test employed a pod-mounted MICRAD unit on a CH-46 helicopter. In July 1976, a flight test of an integrated ATIGS-MICRAD subsonic system demonstrated both midcourse and terminal-guidance capability.

The Supersonic Tactical Missile NAVAIR Technology Demonstration Program, dubbed the STM Project, was formally established in 1977, with China Lake as program manager. Justin W. Malloy, head of NAVAIR's Advanced Weapons Systems Division and a long-time supporter of China Lake, was the program director. Max R. Smith, a former Walleye program manager, was designated China Lake project manager, and fellow Weapons Department engineer Karl Kuehn was assigned as chief project engineer.

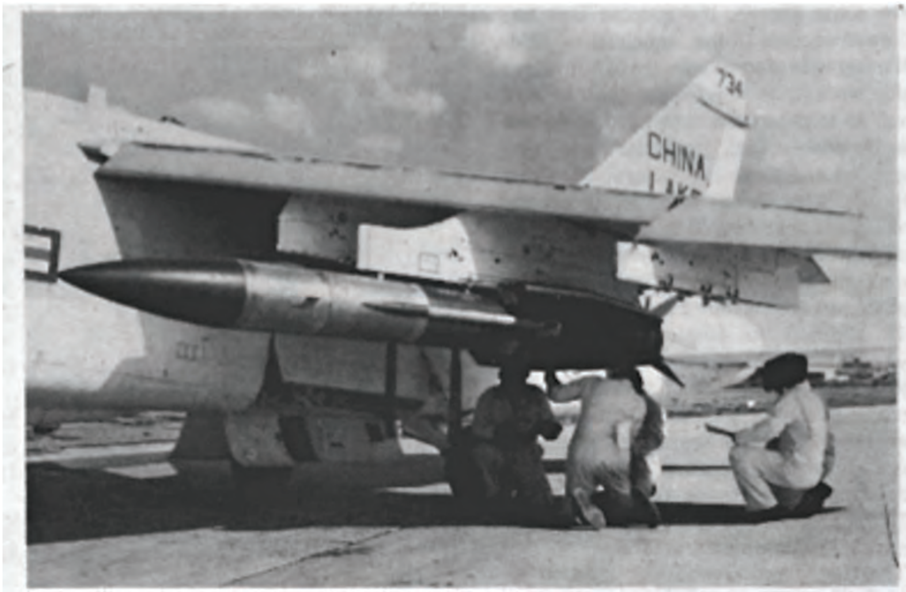
Vought Corp. was awarded an $8.4 million contract in January 1978 to produce four flight demonstration missiles: one to demonstrate propulsion (designated STM-P), one to demonstrate guidance (STM-G), and two designated as advanced tactical vehicles to demonstrate the engineering feasibility of the integrated guidance and propulsion systems. Honeywell was to develop and test the STM ATIGS for the demonstration missiles and, in 1978, was given a contract to develop a MICRAD seeker for terminal-phase guidance. The entire advanced technology development program was expected to take 30 months.

United Technologies' Chemical Systems Division, under contract to Vought, modified the China Lake-developed ALVRJ for the STM flight-test program. The resulting propulsion unit employed a hardened stainless steel combustor that was 52 inches long, 15 ½ inches in diameter, and loaded with an NWC-developed booster grain. After motor burnout (about 5 seconds after launch), jet fuel entered the combustor from the side, 3 inches aft of the motor's forward dome, and was mixed with air from four air inlets arranged symmetrically around the case. This "side dump" combustor had been found to achieve the most uniform fuel combustion.

On 21 April 1979, the STM-P was launched from an A-7 at 35,000 feet above the Sea Range. During the flight, the missile successfully transitioned to ramjet operation, flew for over 2 minutes at 2,000 miles per hour, and performed a preprogrammed dive from 35,000 feet to sea level in the terminal stage of the demonstration, some 82 miles from the launch point. Of the flight,

[104] *NWC Tech History 1973*, 2-17.

Navy historians wrote, “It is described as a major step toward development of a new generation of high performance, air-to-surface tactical standoff missiles.”[105]



STM-P being prepped for flight test. Published in the *Rocketeer*, 22 June 1979.

That rosy prediction was not to be. The Joint Cruise Missile Project Office had been established in January 1977 at the initiation of the Carter administration, and both the Navy and Air Force were directed to develop their cruise missiles using a common technology base. The subsonic cruise missile, equipped with turbofan propulsion and terrain contour matching guidance, became the primary strike weapon for the Navy. In 1980, the STM program was restructured “from a guided-weapon demonstration to an advanced adverse-weather guidance technology development,” a joint Navy-Air Force effort.[106]

Dale Knutsen, who was overseeing several strike weapons in the late 1970s, including STM, said that the STM

> was a case of something probably being ahead of its time. . . . The airframe propulsion combination worked beautifully. At that point in time we didn’t really know how to guide it that well, because it was moving so fast that most guidance techniques that we had then were not really very suitable to hit an aim point that was basically a pinpoint. Today we would use GPS, but at that

[105]Van Fleet and Armstrong, *United States Naval Aviation*, 319. Max Smith received the Technical Director Award for his execution of the STM-P test program.

[106]*NWC Tech History 1980*, 11.

> time that was not even on the horizon. So you had a solution waiting for a question.[107]

The silver lining to cancelled programs is that when the funding dries up, the technology developed for the program doesn't go away. It may crop up again months, years, or even decades later in a similar or totally unrelated program—if the people assigned to the new program are aware of the earlier work. China Lake's corporate memory was a shared entity; people worked across organizational and program lines, and often a scientist or engineer would recall an earlier effort that had applicability to a current program.

A more dependable mechanism for accessing the lessons or earlier programs was through an annual publication known as the *Annual Report of Technical Progress* or, informally, the *Tech History*. Begun in 1950 as the *Technical Progress Report*, the *Tech History* contained a detailed report on all but the most highly classified programs. It was published at the confidential level, and each submission (required from every program) was reviewed through the branch, division, and department levels. Running about 250 pages per issue, the *Tech History* was well indexed and contained not only summaries of current work but bibliographic data on all NWC-generated technical reports and open-literature articles. Until its demise due to funding cuts in the 1980s, the *Tech History* was the repository of each year's successes and failures, an essential reference tool for anyone embarking on a new technical program.[108]

After the STM program was cancelled in favor of Tomahawk, the ALVRJ was shelved, awaiting a missile program committed to ramjet propulsion. The ramjet technology was subsequently used in the Advanced Common Intercept Missile Development program, the ramjet version of the Advanced Air-to-Air Missile, and the Supersonic Low-Altitude Target, all in the 1980s. MICRAD technology developed during the STM program was incorporated in the Center-developed vertical-seeking seat (VSS).

Secure Telemetry

Both sides in the Cold War went to great lengths to steal each other's military secrets. The payoff for successful espionage was considerable; when one side knew that the other was developing a new system or tactic, it was easier to get a jump on developing a defense or counter tactic. The task of intercepting

[107]S-259, Knutsen interview, 38.

[108]The *Tech History's* formal names vary from *Technical Program Review* (1958) to *Technical History* (1959 to 1975) to *Command and Technical History* (the combined 1976–1977 issue and the following 2 years) to *Annual Report of Technical Progress* (1980) and thereafter until the series was eliminated in the mid-1990s.

signals from operational systems often was carried out by spy ships, thinly disguised ocean-going electronic-surveillance vessels. The Soviet's spy ships—called auxiliary general intelligence (AGI) ships by the United States—were often disguised as trawlers (fishing boats). The United States claimed its spy ships were "research vessels." One of the most famous of these ocean-going intelligence-collection platforms was USS *Pueblo* (AGER-2), which was seized by North Korea in 1968.[109]

Opportunities for electronic intelligence collection existed ashore as well. Here the rewards for success could be even greater; acquiring intimate technical knowledge of a foe's developmental systems not only provided a gauge of future capabilities (and an early jump on developing countermeasures) but also let the intelligence collector steal technological advances that may have cost the target nation years of effort and millions of dollars in R&D to develop.

On the DoD's test ranges, two principal mechanisms communicated test-item performance to the engineers and technicians: time-space-position information (TSPI, provided by cameras, theodolites, and radar) and telemetry. TSPI told the observers what was going on outside the aircraft or missile under test and precisely where it was in space from moment to moment, while telemetry told the technical story of what was going on inside the test item: how a missile tracked its target, when fuzing occurred, temperatures and pressures at critical junctures, vibration, power levels, and so forth. One limitation on the amount of information that could be obtained was the size of the test item—a lot more capability could be crammed into a 10-inch-diameter High-Speed Antiradiation Missile (HARM) than a 5-inch-diameter Sidewinder.

In a single test lasting only a matter of seconds, hundreds of parameters might be monitored and transmitted by radio signals to receiving stations (surface or airborne). After collection, the data would be converted into usable form—a process called data reduction—for engineers and scientists to pour over, seeking to understand what went right and, often as not, what went wrong with the test.

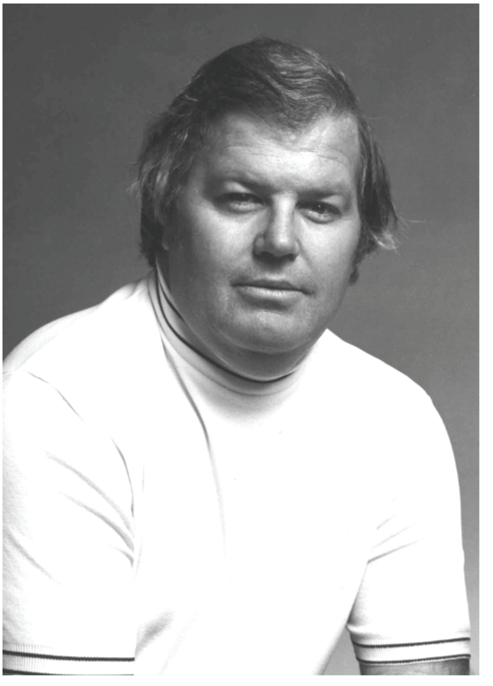
Telemetry was vulnerable to interception. In the hundreds of square miles of land immediately adjacent to the China Lake test ranges (most of it public-use land under the management of the Department of Interior [DOI]), it was possible that sophisticated electronic devices recorded the telemetry signals for use by a potential adversary. While ground testing at the Center could be conducted discretely—at remote sites, out of public view—there was no

[109]The *Pueblo* is still a commissioned U.S. Navy vessel, listed as an "environmental research ship," even though, more than half a century after its seizure, the *Pueblo* is still held captive in Pyongyang.

way to hide what went on in the sky. Engineer George Teate recalled, "There's all kinds of stories that they've been sitting up here on [Highway] 395 and those [antennae] bristling out of their vans, but they're not on the Center property, and there's not a whole lot you can do about it."[110]

James L. Rieger, an engineer particularly gifted in telemetry development, wrote:

> The best opportunity for someone to receive the telemetry data is when it is first transmitted from air to ground, such signals travel a long way—certainly beyond the fences of the range involved, but also across borders and into international waters.[111]



George Teate.

Jim Rieger.

The first telemetry station at China Lake was established during WWII to assist in the Caltech rocket development and testing program. A rough facility, it consisted of a concrete pad on which were parked two trucks packed with telemetry receiving and recording equipment. The site, dubbed T-Pad, was upgraded with permanent structures during the 1950s. The term T-Pad is still used today to refer to the Center's Telemetering Receiving Center complex.

During missile development testing, the warhead was often replaced with a telemetry unit. Missile-development teams—as well

[110]S-337C, Teate interview, 25.
[111]Rieger, "Telemetry Scrambling," 187.

as the naval aviator "shooter"—gloated when their missile knocked down a drone target even without a live warhead. But the most important results of the test were not the intercept; they were the detailed record of every onboard function of the missile and its subcomponents—guidance and control unit, rocket motor, aerodynamic control surfaces, hydraulics, fuzing, and more—that were transmitted to the receiving stations from before launch until flight termination.

Through the 1950s and '60s, the technology of telemetry advanced in step with the semiconductor revolution and new microminiaturization techniques, squeezing smaller and more complex telemetry transmitters into increasingly complex test items. About the only thing that did not change about telemetry was its vulnerability to interception. Telemetry signals were sent as so-called "plain text." Anybody with an antenna properly aimed could intercept the signals.

In 1960, the government's military and civilian test ranges were given a 10-year use permit for telemetry in the 200 megahertz (MHz) band—part of the very-high frequency (VHF) band that extends from 30 to 300 MHz. By 1 January 1970, the ranges would need to begin operating in the ultra-high frequency (UHF) band, which encompasses frequencies between 300 MHz and 3 gigahertz (GHz). Specifically, the units would be operating in the following bands: 1435 to 1540 MHz, 2200 to 2300 MHz, and 1710-1740 MHz (the latter for video in such systems as Condor). China Lake set a target date of 1 July 1969 to achieve the conversion, which entailed complete redesign of ground and air telemetry components.

NWC's Corona Laboratory, which had become part of the Center in 1967, was the Navy's lead activity for developing standardized telemetry hardware in the UHF frequencies. Under the direction of T. B Jackson, who headed the Instrumentation Division, the Coronans developed a new UHF decommutation system. (A commutator on board the test item changed the measured parameters into electronic pulses that modulated a transmitter; after the transmitted signal was received on the ground, the decommutator translated the signals back into measurements.) The decommutator worked on the principal of pulse-amplitude modulation (PAM) of a frequency-modulated (FM) carrier signal: PAM/FM. Earlier systems were FM/FM or pulse-duration modulation / FM.

The first live firing of a missile with UHF telemetry on China Lake's ranges took place in November 1967 with a UHF-telemetry-equipped Shrike missile. Robert Merriam in the Systems Development Department led the effort; George Hudson was the project engineer for the Shrike switchover. Although plain text was still the standard of transmission, Center engineers at China Lake and Corona were making advances in telemetry design, aided in large measure by the explosive growth of smaller and more rugged solid-state circuitry. UHF was capable of carrying far more information than VHF, and it also opened the door to conformal (wraparound) transmitting antennas flush with the missile body, a difficult task in the VHF band.

Still, the telemetry signals were an open book to anyone with the right gear to receive them. Although there was discussion among laboratory personnel of the plain-text vulnerability issue in the 1960s, no formal mandate to rectify the problem was made until 1969, when the CNO issued instructions on encrypting classified data from weapons under test. Despite the top-level direction, little progress was made during the 1970s, and still the use of telemetry at the Center continued to expand as systems became more complex. A proliferation of telemetry efforts in various organizations around the Center led NWC management in the mid-1970s to consolidate all the telemetry work into the Airborne Instrumentation Division under Gary Davis. The division was renamed the Telemetry Division in 1976.[112]

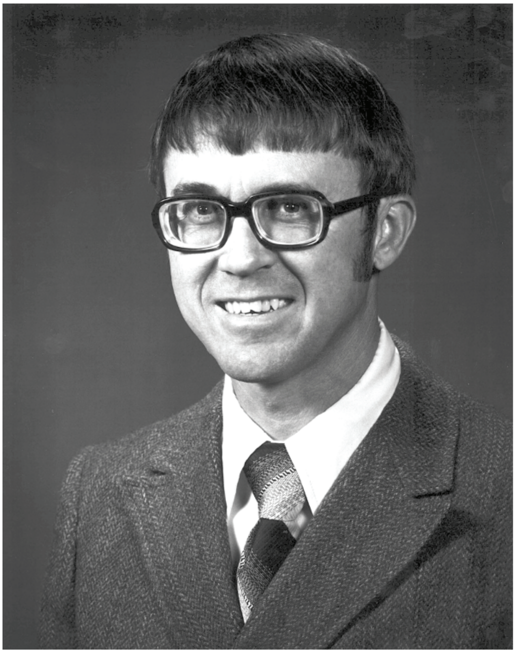
Gary Davis.

In 1978, serious steps were taken to address the telemetry encryption issue through the establishment of a triservice secure-telemetry program. Working under a memorandum of agreement, the Air Force, Army, and Navy formed the Joint Service Secure Telemetry Steering Committee (JSSTSC), with the Navy as the lead service. NAVAIR selected NWC as the lead laboratory. The specific task of the JSSTSC was to conduct a Secure Telemetry Certification Program, demonstrating that tactical missiles and aircraft could indeed transmit telemetry to ground stations in such a way that the data could only be understood by the intended recipient.

Chairing the committee was Jerry L. Reed, associate head of the NWC Range Department, with Gary Davis as the executive secretary. In addition

[112]Gary Davis retired as the Range Department's special projects manager in 1992 after 35 years of service.

to the Navy, Air Force, and Army, the National Security Agency (NSA) was represented on the JSSTSC in an advisory capacity; by having the NSA on board, the JSSTSC had access to the agency's encryption skills and devices. To handle China Lake's work for the committee, the Secure Telemetry Program Management Office was established in the Telemetry Division in March 1979. John Shearer was appointed head of the program, with Jack Brown (head of the Telemetry Technology Branch) as secure telemetry project engineer.[113]



Jerry Reed.

Through the NSA, China Lake obtained a KG-66 encryptor and an SO-66 decryptor. Brown's team built an airborne pod to encrypt telemetry signals using pulse-code modulation. This technique was used because the pulses are already digitized, unlike PAM or FM. As a *Rocketeer* article explained, "A pulse is a 1, and the non-pulse is a 0. An encryptor randomizes existing pulses, and the decryptor de-randomizes the received pulse-coded data." The pod could be flown at any research, development, test, and evaluation (RDT&E) range and was used to assess a range's capability for receiving secure telemetry signals. The pod was successfully flown over the China Lake ranges in March 1979.[114]

The second task for Brown and his group was to package a secure telemetry system in an actual missile. Successful reception and decommutation of the signal during an air-launched test firing would verify the practicality of encrypting test telemetry. Selected for the test was a Sidewinder AIM-9L production-verification missile. Sidewinder was chosen because it was the most difficult challenge for packaging: the missile's diameter was only 5 inches, as compared with a Shrike (8 inches) or Phoenix (15 inches).

"The AIM-9L was fired in July after several captive flights," the *Tech History* reported. "Launch-to-target-intercept was approximately 5 seconds, with the

[113]Jack Brown started his career at China Lake as an electronic mechanics apprentice. After completing the apprenticeship, he took 3 years leave without pay and earned a bachelor of science in engineering at Cal State, Fresno, before returning to the Center.

[114]*Rocketeer*, 11 January 1980, 1.

total flight exceeding 8 seconds. The encrypted telemetry system provided 100 percent coverage with zero bit droppage." That year the Secure Telemetry Program Management Office also prepared a draft Secure Telemetry Application Handbook, which was reviewed and approved by the JSSTSC.[115]

AIM-9L intercepts target drone over the China Lake ranges. Published in the 1979 *NWC Tech History*.

Secure telemetry had been achieved. "The greatest problem encountered in implementation seems to be providing access to the [encryption] key loading socket when the missile is put together," Rieger observed.[116]

Jack Brown was presented the Technical Director Award for his leadership in the AIM-9L secure telemetry demonstration. When Technical Director Bob Hillyer presented the award, he underscored the importance of the work: "A lot is learned by the U.S. about Soviet Russia's weapons systems by intercepting telemetry signals and, in similar fashion, the Russians learn about this nation's weapons from telemetry signals."[117]

Converting the Navy's ranges required more than simply finding a technical solution for the secure telemetry problem, however. As Rieger pointed out, ancillary costs included such mundane matters as

> additional physical security . . . including door locks and barricades to assure that only people cleared to view the now-classified data can be in rooms

115 *NWC Tech History 1979*, 11-7.
116 Rieger, "Telemetry Scrambling," 187.
117 *Rocketeer*, 4 January 1980, 1.

> where the data is displayed, and containers to store the classified data received as well as the classified hardware and punched tapes containing the crypto key variables.

He estimated the costs for adding the necessary items at ground stations to be up to $200,000 for some sites.[118]

Other challenges revolved around restructuring a system that had been unclassified to one governed by the Navy's rigorous and comprehensive security procedures. "Perhaps the largest problem encountered with the introduction of telemetry security equipment involves the personnel using the equipment," Rieger wrote. "While dealing with classified documents is nothing new to most people in the missile-testing business, creating secret paperwork and issuing it by the foot is still somewhat disconcerting to most people." He noted the difficulty of applying classification procedures designed for communications to the telemetry business and concluded, "Since the hardware itself is considered classified material even after its codes have been erased, we even have to account for the pieces if the test item is destroyed or lost at sea, which it often is."[119]

China Lake continued as the Navy's lead laboratory for secure telemetry through the 1980s. One of the most significant technical accomplishments during that decade was the development, in 1989, of a method to protect imaging video through encryption. At the time, the AIM-9R Sidewinder was under development at China Lake. The AIM-9R employed a revolutionary focal-plane array seeker using charge-coupled detector technology. The imaging video from flight testing was precisely the type of information that would have been of extraordinary benefit to an adversary—but traditional secure telemetry techniques and technology were incapable of handling the signal securely.

Rieger and Sherri Gattis, another engineer from the Aerosystems Department (where the Telemetry Division had found a new home in 1982), developed the first digitized compressed video system (a compander) that worked with the NSA's airborne encryptors. Department head Milt Burford, in a letter nominating the two for the Technical Director Award, noted that "the digitization of full motion picture video was orders of magnitude greater than current bit-rate technology."[120]

---

[118]Rieger, "Telemetry Scrambling," 188.

[119]Ibid.

[120]*Rocketeer*, 6 January 1989, 1. Jim Rieger, who worked as an engineer for CBS before coming to NWC, once told a reporter, "The recruiter told me that China Lake was a great place to work and that they wouldn't hassle a person if he did a job in an unconventional manner. Besides that, the man said no one here wore neckties. I was sold." *Rocketeer*, 23 March 1979, 7. An acknowledged "character," Rieger carried business cards on which his name was followed by

At China Lake today, all telemetry is secure. Aeronautical telemetry is encrypted aboard the aircraft or test item (at levels from confidential to top secret and higher), and the data stream is received at ground collection sites. From there the data is transmitted over secure range-communication channels to either the Range Control Center (RCC), Echo Range Central Site, or secure destinations outside the Center. On arrival, the streams are decrypted and transported to test bays for recording and real-time display.

The Continuing Struggle

By the end of the 1970s, the Soviet Navy had grown dramatically. It had about twice the number of ships as the U.S. Navy, outnumbering the United States in surface combatants and submarines (both attack and ballistic missile). It was fully a match for the U.S. Navy. At China Lake and at other weapons development centers throughout the DoD, scientists, engineers, and analysts continued the constant game of one-upmanship: improving the range of America's weapons, their lethality, their accuracy, their countermeasure and counter-countermeasure capabilities, and their survivability—while at the same time trying to keep costs within resource limits and to fight the political and administrative battles necessary to keep programs alive and on track.

But the Soviets were doing the same thing. By 1985, Admiral James D. Watkins, CNO, would note with alarm that

> in the last 10 years, 13 classes of Soviet submarines have made their appearance, capable *Kirov* class battle-cruisers have put to sea, and a nuclear-powered, conventional takeoff-and-landing, mid-sized aircraft carrier is being built. The Soviet Navy is large, capable, and growing. In fact, their Pacific fleet, their largest of four fleets, is larger than our entire Navy.[121]

The great struggle for maritime supremacy between the two superpowers would continue without resolution until the collapse of the Soviet Union in 1991. Admiral Gorshkov's "good enough" had been bettered, not by superior technology but by a tectonic shift in the world's balance of political, economic, and military power.

"Pb, Tk, TFs, Pk, HRIc"—which he readily explained was "pusher of buttons, turner of knobs, teller of funny stories, and head Russian in charge."

[121]Office of the Chief of Naval Operations, *Understanding Soviet Naval Developments*, fifth edition, 1985, i.

7

Point Defense

When you get within about a mile of the target, there's nothing you can do that's going to alter where that thing is going to hit. You've got a couple of thousand pounds moving at 800 feet per second, you are not going to change its mind that close to the target. . . . Put all the rounds you want in it, it's still coming right at you, because you didn't knock it out of the sky.

—NWC engineer Marc Moulton[1]

Throughout the second half of the 20th century, the U.S. Navy's worldwide strategy for both peacekeeping and war making was built around two principal elements: the ballistic missile submarine and the aircraft carrier. Tom Amlie was speaking plainly when he told the NWC Technical Board in early 1968 that, without protection against ship-launched missiles, "having an aircraft carrier makes no sense at all."[2]

An aircraft carrier is hard to conceal (although in the early 1960s Dr. McLean had proposed doing just that, with underwater aircraft carriers). The *Nimitz* (CVAN-68), for example, whose keel was laid in 1968, was more than 1,000 feet long at the waterline and towered more than 20 stories. The ship displaced over 100,000 tons and was pushed through the water by four 25-foot-diameter propellers at a top speed of 30 knots. This was about a third slower than a Soviet *Osa*-class guided-missile patrol boat and one-fiftieth the speed of a Styx missile. An aircraft carrier couldn't hide, and it couldn't run.

Antiship Missile Defense (ASMD)

Through the 1960s, the United States had been putting its money primarily into nuclear submarines, aircraft carriers, and the ships that comprise a carrier division (later called a carrier battle group [CVBG]). The Navy's chief sea-going adversary, the Soviet Union, had not only been developing its own submarine

[1] S-245, Moulton interview, 37.
[2] *NWC Technical Board Minutes*, 23 February 1968, 4.

fleet but had been designing and building ships that relied heavily on antiship missiles. And as McLean had correctly predicted in 1963, "The effectiveness of antiship missiles can be expected to improve more rapidly than the capabilities for missile defense."[3]

As the war in Vietnam wound down at the end of the 1960s, the blinders came off U.S. Navy planners. The wake-up call was Egypt's 1967 sinking of the Israeli destroyer INS *Eilat* by Styx antiship missiles. A scramble to play catch-up in the ASMD arena began.

Exacerbating the problem of the threat's antiship missiles was a Soviet tactic called "tattletale." A Soviet ship would follow a U.S. CVBG and report the details of its location and operations. Many sailors believed that if hostilities broke out between the United States and the USSR that the tattletale would immediately launch its antiship missiles at the group. This tailing tactic so irritated Vice Admiral Isaac C. Kidd Jr. when he was Commander of the Sixth Fleet in the early 1970s that he suggested a cordon sanitaire be imposed around CVBGs. This cordon sanitaire was described as

> an area relative to U.S. Naval Forces, defined by either geographic boundaries or a circle centered on the formation in which the presence of units of a potential enemy would be considered a hostile act, making such units subject to military action.[4]

The results of a 1973 China Lake evaluation of three U.S. weapons—Chaparral, Sparrow, and Shrike-on-Board—in the "tattletale role" is still classified.[5]

Osprey

China Lake was a logical place for the Navy to look for expertise in defending against antiship missiles; the Center already had experience with the development of short-range air defense systems. This was not coincidence; it was calculation. The Center's top management had been trying for some time to establish credibility in point defense (the defense of a point target, ashore or at sea, from a threat, usually airborne and at short range), using in-house discretionary funding to develop relevant systems and technologies. Howie Wilcox, Consultant to the Technical Director and formerly McLean's principal assistant on Sidewinder, told an interviewer in 1973 that

---

[3]NAWC RM-24, "Opinions and Predictions of Weapon Requirements," *Collected Speeches of Dr. William B. McLean*, 166.

[4]Gilchrist, "Cordon Sanitaire," 132.

[5]Ibid.

> in the past we have not had a recognized position in the field in the antiship missile defense area, ASMD. So we used IED [Independent Exploratory Development (in-house discretionary funds)] money to try to develop such a position. For instance, we used substantial funds to adapt the Chaparral missile for shipboard use, and in other areas of ASMD.[6]

One of those other areas was Osprey, the brainchild of Frank Cartwright, who held a doctorate in physics from Berkeley and had been project manager for the Sidewinder 1C program (AIM-9C and -9D). In 1960, Cartwright was thinking of leaving China Lake but was persuaded to stick around and develop a ground-launched version of Sidewinder for point defense. The program was originally called Hamburger (the "ground round").

Frank Cartwright.

Cartwright's team tested Sidewinder IR-guided and semi-active radar seekers, AIM-9D and AIM-9C, respectively, with an 8-inch dual-thrust motor (to make up for the absence of air-launch velocity). The launcher was a modified 5-inch/38-caliber naval gun mount, and fire control was provided

[6]NWC, "The Independent Programs," *News and Views, Points of View and Information on Management Matters*, May 1973, 3.

by the Mk 37 gun director. “Estimated slant ranges of 12,000 yards against incoming targets provide small ships with a defense against Mach 0.9 (and lower speed) aircraft delivering conventional bombs and rockets,” reported the *Tech History*. Despite promising results in the demonstration phase, the system was never transitioned into development.[7]

Osprey during testing at China Lake.

Sea Chaparral

Chaparral was developed during the same period as Osprey. Again, as with Osprey, the idea was a ground-launched, Sidewinder-based missile, but this time with the same 5-inch motor as Sidewinder. Chaparral had its genesis in the failure of the Army’s Mauler surface-to-air missile (SAM) development program. That program was cancelled, but the Army’s requirement for a short-range air-defense weapon for use in Europe did not go away, so the Army turned to its sister service, and China Lake was assigned the task of developing the missile. The first units, designated MIM-72, went to the Army in 1967, and the first Army Chaparral battalion was created in 1969.

[7] *NOTS Tech History 1961*, 134.

While Chaparral was successful, it was not, as fielded, suitable for the defense of a high-value ship target from a high-speed threat. "An operator, stationed in the mount, acquires and tracks the target aircraft with the aid of binoculars," explained an early *Tech History*. In the age of sea-skimming missiles and Soviet Backfire bombers that could fly at 1,200 miles per hour, a more dependable automated system was needed.

Another strike against Chaparral was that it employed an early IR seeker better suited to tail-on or side pursuits, in which the target's heat signature was most available to the seeker. The head-on IR signature of a threat missile would be difficult to detect at longer ranges. For a high-speed, head-on threat, a better tracking source, at least for acquisition and mid-course tracking, was a radar signal. That signal could be either a radar signature reflected from the threat to the point-defense missile seeker or the signal actually broadcast from the threat's active radar seeker, which would then be used as a tracking source for the point-defense missile seeker.[8]

Shortcomings notwithstanding, a version of the Chaparral designed for ship defense and named Sea Chaparral (RIM-72D) was developed in a crash project at China Lake in 1972. The project was carried out under Hip Pocket, a Navy-wide program that supported early evaluation of experimental systems on ships. Beginning in August 1972, a China Lake group under the leadership of Roland Baker developed a weapon system called CHIMP II (from Chaparral Improved) and installed and tested it on USS *Lawrence* (DDG-4) against low-flying targets. The work was completed in 6 months. The system deployed to Vietnam with the *Lawrence*, this time equipped with low-light-level television to aid acquisition. The *Tech History* reported:

> Though no antiship cruise missile or aircraft attack was encountered, the threat did exist throughout the operations in the combat zone. This was particularly true when a *Komar*/Styx capability was reported in the Haiphong area.[9]

In 1973, responding to a quick-reaction request, "an austere Sea Chaparral system" was installed on nine Navy destroyers operating on the gun line off the coast of Vietnam. Meanwhile, Baker's group installed a more sophisticated point-defense system incorporating Redeye and Hornet missiles with the Chaparral aboard USS *Hoel* (DDG-13). The *Tech History* disclosed that during tests of that system in 1973, two CHIMP II Sea Chaparral missiles were fired "at incoming BQM-34 drones equipped with Hayes plume augmenters. Both

[8]*NOTS Tech History 1962*, 116.
[9]*NWC Tech History 1973*, 6-11.

missiles scored instantaneous kills." For his work with Sea Chaparral, Baker received the first NWC Technical Director Award.[10]

Sea Chaparral aboard destroyer.

A study on "estimates of the terminal lethality of Sea Chaparral in encounters with the Styx antiship surface-to-surface cruise missile" was conducted at the Center in 1973. The results of that study are still classified, but it is notable that in the long run the Navy did not opt to buy the Sea Chaparral system, although it was exported to Taiwan.[11]

In addition, 1973 was the year that the Phalanx Close-In Weapon System underwent initial Navy evaluation on USS *King* (DLG-10). General Dynamics had developed the weapon to provide close-in defense against an antiship missile in its terminal phase. The stand-alone system consisted of a Ku-band radar-controlled 20 mm autocannon firing armor-piercing tungsten penetrator rounds at a rate of 75 rounds per second.

The system did poorly in its initial evaluation. However, through the 1970s, numerous improvements were made, and in 1980 the first complete system became operational on USS *Coral Sea* (CVA-43). Phalanx is still the last line of defense for naval ships against antiship missiles.

[10]Ibid., 6-11, 6-12; *Rocketeer*, 25 May 1973, 1.
[11]*NWC Tech History* 1973, 6-12.

ASMD and Politics

Until mid-1973, China Lake's work in ASMD was located in the Systems Development Department headed by Captain Frederick A. Chenault, USN (ret.). Responsibility for coordinating the Center's ASMD effort was given to Bill Porter, Chenault's associate department head for ASMD programs. Numerous point-defense technologies and systems were under development, including new IR and RF seekers and an improved target-acquisition system.

Chenault had served as China Lake's popular and respected Executive Officer from 1955 to 1958. A Naval Academy graduate, he was a former surface warfare officer and in his post-service career at China Lake was still well connected in Naval Sea Systems Command (NAVSEA). Chenault tasked Porter to pull together a team and, as Porter described it, "establish a presence in the surface world and work with NAVSEA. . . . This was really tough because NAVSEA didn't particularly want our help."[12]

Kidd, who had become CNM in December 1971, was fully aware of the importance of point defense to the Navy's future, and he was aware of China Lake's work in the field. In July 1972, he assigned NWC the lead laboratory role for ASMD. In December, then-Deputy Technical Director Walt LaBerge wrote to Kidd, "Responding to your request to be kept informed on my activities in ASMD." Among other information, he noted that the Naval Ordnance Systems Command (NAVORD) had asked NWC to review four proposed ASMD programs, and he assured Kidd that the Center was "careful to work with" the Naval Air Development Center (NADC) and with the NOL, the Navy laboratories responsible for two of the programs. China Lake had a not-undeserved reputation for muscling in on areas of development that were properly the purview of other laboratories.[13]

NWC's ASMD lead charter, signed out by Rear Admiral Thomas, Deputy CNM for Operations, on 20 February 1973, was quite broad. As Chenault told the NWC Board of Directors, it covered "planning, direction, control, and integration of effort within [NAVMAT] for definition, development, T&E, acquisition, and installation of ASMD systems: SAMs, SSMs, guns, tactical data systems, etc." Further, China Lake was to "direct and integrate the joint efforts of SYSCOMs [Systems Commands] and NAVMAT component activities." Finally, the Center was responsible for the planning, direction, and control of the programs and all funding, and it answered directly to Vice Admiral Kidd.

[12]S-216, Porter interview, Part 2, 63.
[13]LaBerge to Kidd, letter, 03/WBL:lo, L-94, 21 December 1972, 1, 2.

At the time, approximately 70 people were working on ASMD-related projects under Porter's lead.[14]

In June 1973, China Lake's new Technical Director, Walt LaBerge, shook up the Center's organizational structure with a major overhaul, creating three directorates headed by what was known as The Triumvirate: Knemeyer, Highberg, and Riggs. (The trio had formerly been the most powerful department heads on Center.) In the hoopla surrounding the changes and the elevation of key people to fill the vacated department head slots, the creation of a new department went almost unnoticed. It was the Surface Missiles Department, headed by Bill Porter. "It was the smallest technical department at China Lake," said Porter.[15]

NWC's primary sponsor was NAVAIR, the Systems Command from which most of the Center's work issued. However, pursuant to Kidd's charge of Navy-wide leadership in the ASMD work, Porter went about forging connections with the other SYSCOMs—in April, Rear Admiral R. E. Spreen, head of NAVORD, visited China Lake for briefings on the ASMD program. Porter also worked to establish productive connections with NAVSEA, although he recalled, "It was sort of a shotgun wedding."

When Rear Admiral Freeman took command of the Center in June 1974, priorities changed. Freeman was concerned, particularly in an era of shrinking budgets, lest the Center's efforts be fragmented between the very different requirements and distinct political/organizational contexts of the air Navy and the surface Navy.

In a Board of Directors meeting held early in December 1974 at California City, the rear admiral made his views clear (although he stated at the outset to the recorder, Bob McKenzie, that he did not want formal notes made). According to McKenzie, Freeman said, "There is not a surface weapon system mission for NWC. Probably is zilch. Don't see any surface mission work coming to the Center." Freeman elaborated and reiterated:

> [NAV]AIR work is going up, and we can increase our participation. But if we fragment (to surface) we will lose out in AIR . . . [I] want to spend my energies with AIR, not NAVSEA . . . As the Navy shrinks, our primary focus must be on AIR. . . . Support Bill [Porter] but don't get hung-up on ASMD.[16]

In the third NWC reorganization of his tenure, in September 1975, Freeman eliminated the Air Weapons Department. He parceled out its

[14]Historical file notes in *Board of Directors Material—1970 to 1981*, 186, 187.
[15]S-216, Porter interview, Part 2, 63.
[16]Historical file notes in *Board of Directors Material—1970 to 1981*, 246, 247.

functions to other departments, including Porter's. He also changed the name of Porter's organization from the Surface Missiles Department to the more generic Weapons Department.

SeaSparrow

One of the ASMD programs under Porter's cognizance was SeaSparrow. The Sparrow (AIM-7) was a medium-range air-to-air missile that, in various versions, had been in service since 1956. Sparrow was a semi-active-radar missile that homed on a reflected radar signal from the target.[17]

There were problems in adapting Sparrow to shipboard use. The missile was designed for high-speed launch, not acceleration from zero. Its center-mounted wings were optimized for maneuvering at high speed in thin higher-altitude air, not at (initially) low speed near sea level. The fact that the wings were non-folding made the footprint of the launch cells on a ship's deck larger than it needed to be.

Adaptive shortcomings notwithstanding, the Basic Point-Defense Surface Missile System (BPDSMS), based on the Sparrow AIM-7E, was introduced into the Fleet in 1970. SeaSparrow, as it was called, was 12 feet long, weighed about 600 pounds, and had a range of 8 to 12 nautical miles. It employed the Mk 15 illuminator radar and the Mk 25 trainable launcher.

SeaSparrow firing.

[17]The system's name is spelled variously SeaSparrow, Seasparrow, and Sea Sparrow in the literature.

Vertical-Launch SeaSparrow and Chaparral

One immediate problem with SeaSparrow was the launcher. Multiple launchers were required on a ship in order to eliminate "blind spots," or directions in which the missile could not be fired because of the ship's superstructure. A solution proposed for this problem—one equally applicable to Chaparral in the point-defense role—was a vertical-launching system. The missile would be launched straight up and then, at a minimal height above the ship, it would pitch over in the direction of the incoming target.

NAVSEA's prototyping people were already working with General Dynamics on a vertical launcher. Robert B. Dillinger, who headed the Systems Technology Branch in Ray Miller's Propulsion Systems Division, said, "We could see vertical launch on the horizon coming on down there, coming on slowly." Sparrow would just be the beginning.[18]

Bob Dillinger.

Because missile velocity was so low at launch, the missiles' control surfaces could not perform the pitch-over movement. What was needed was propulsion steering: using rocket-motor force to change the direction of the missile. Loyd C. Moore, head of the Improved Missile Branch in John Lamb's Surface Weapons Division, was assigned the task of demonstrating the feasibility of vertically launching SeaSparrow. Moore, a former Coronan who'd come to China Lake in 1970, was assisted by William R. Long, the project engineer.

Modifications to the missile itself for vertical launch were contracted to Raytheon, the Sparrow prime contractor. Joe Reese, Bill Bailey, William R. Morrow, and Les Mayer of the Systems Development Department designed the fire-control system. Mike Jacobson, in Ray Miller's division, designed the jet vane control (JVC) unit, which attached to the tail of the missile airframe and

[18] S-327, Dillinger interview, 36.

gave it the vertical-launch capability. The JVC unit used vanes that extended into the rocket exhaust to deflect the exhaust and thus change the direction of thrust.

"We could just use it for the first part of flight where the missile was going in the wrong direction [up]," said Dillinger. "There was a quick disconnect system with an explosive band. We actually powered those jet vanes with power out of the missile's power supply, the hydraulic system that drove the wings at the same time." Immediately after the pitch-over maneuver, the unit was jettisoned.[19]

During testing in June and July 1973, the SeaSparrow vertical-launch program met all its goals. The *Tech History* enumerated:

> 1. Safe separation of a vane-controlled missile from a vertical launcher. 2. Slew of the missile to an altitude commanded by a fire-control system prior to launch. 3. Successful target acquisition. 4. Successful JVC jettison. 5. Successful target intercept.[20]

Additionally, a *Rocketeer* article noted:

> A unique feature of the fire control system's design was that all launch commands, radar controls, and remote site surveillance was accomplished by advanced digital communication techniques which involved the use of a computer and a single digital data link.

Loyd Moore received the Technical Director Award from Dr. LaBerge for his capable leadership of the program.[21]

A similar program was carried out to assess feasibility of vertically launching Chaparral. The principal difference was that instead of JVC, the Chaparral vertical launch employed jet reaction control. This was obtained from a foot-long unit that was installed near the front of the missile between the guidance control group and the warhead. Four orthogonally mounted thrusters could generate 450 pounds of side force for about 1.5 seconds. The direction in which the missile needed to pitch over, and the degree of pitch, determined which of the thrusters fired and for how long. The feasibility of this approach was demonstrated in three live firings in 1972, but further development was not pursued.

---

[19]Ibid., 37.
[20]*NWC Tech History 1973*, 6-5.
[21]*Rocketeer*, 15 June 1973, 3, 1.

NATO SeaSparrow

Development of an Improved Point-Defense (IPD) system was begun in parallel with the BPDSMS program to incorporate emerging technologies into SeaSparrow. Moore was assigned as the IPD project manager.

In a parallel effort, four members of NATO—Denmark, Italy, Norway, and the United States—formed a consortium in 1968 to develop a common point-defense system. In 1969, the consortium awarded a contract to Raytheon Co. to develop the Mk 57 NATO SeaSparrow Surface Missile System (NSSMS). Production began in 1972, and the system became operational in 1975 as the RIM-7H.

Improved SeaSparrow

After the Sparrow AIM-7E production line was shut down in 1973, NWC was tasked with investigating modifications to the AIM-7F that would make it suitable for the point-defense mission. The work was carried out in conjunction with the Naval Ship Weapons System Engineering Station, Port Hueneme. Dr. Roger E. Fisher, head of the Fuze Projects Branch III, received the Technical Director Award that year for his work in evaluating SeaSparrow's semi-active fuzing system.

By 1976, China Lake had completed the prime item-development specification for what was now designated the RIM-7F SeaSparrow. Numerous problems that had come to light with the RIM-7F were addressed in an NWC test program, and modifications were made to various missile subsystems, particularly the fuze and fuze-antenna systems. By 1977, NWC was working on improvements to the fuzing systems for three SeaSparrow variants: BPDSMS, IPD, and NSSMS.

In 1978, NWC developed a motor arming-firing device for SeaSparrow that was also adaptable to a number of other weapons and rocket-powered targets. The Center also conducted studies on the effects of atmospheric refraction on SeaSparrow performance and the blast effects—"thermal, pressure, acoustic, erosive, and corrosive"—of the missile's rocket motor on the launch ship.[22]

The following year, the Center optimized the time delays for the SeaSparrow fuzes for maximum kill probability (P_k) across the spectrum of target types. Center engineers also investigated rapid automatic kill-assessment techniques that used the Doppler-radar returns from the missile/target encounter to determine the nature of the kill. "The resulting rapid kill assessment allows use

[22]*NWC Tech History 1978*, 10-43.

of a missile-conserving firing doctrine that can increase the effectiveness of each missile by as much as 40 percent, depending on the scenario," explained the *Tech History*.[23]

The improved SeaSparrow went to the Fleet in 1983. China Lake's involvement with SeaSparrow and its successor, the Evolved SeaSparrow Missile (ESSM), continues to this day. In the first decade of the 21st century, China Lake (now the Naval Air Warfare Center Weapons Division [NAWCWD]) codeveloped, with Raytheon, software improvements to the ESSM that added a surface-to-surface capability, allowing the missile to be used against fast, maneuvering small boats. In 2013, the Center was the technical direction agent for the ESSM.

Sea Phoenix

Phoenix (AIM-54) had begun development in 1960 as a long-range air-to-air missile for use with the F-111B, the planned naval variant of the F-111 fighter-bomber, formerly the TFX. The F-111B was never ordered into production; however, the missile continued development for the Grumman F-14 Tomcat, which would serve as the Fleet's principal fighter for some 30 years. Phoenix was a semi-active/active radar missile supported by the F-14's Hughes-built AN/AWG-9 radar system. The F-14/AIM-54A combination was successfully tested at China Lake and Point Mugu in 1973 and entered the Fleet 1974.

The same year, China Lake was tasked to investigate the feasibility of adapting the AIM-54 to ships, specifically to protect aircraft carriers from cruise missiles. The effort to convert the system from air-launched to surface-launched continued through 1975. In 1976, according to military historian Bill Gunston, "a virtually unmodified Phoenix was successfully fired at NWC China Lake, traveling more than 13 1/2 miles (22 km) downrange in 90 sec, more than twice the limit for SeaSparrow." Furthermore, he stated, "The existing F-14A Tomcat radar, AWG-9, could be transferred almost bodily to a ship, 27 of the 29 [electronics] boxes being compatible."[24]

The air-launched version of Phoenix was clearly capable of downing antiship missiles; Friedman reports that "in a 1983 test, Phoenix shot down eleven of eleven Harpoons." And with a maximum speed in excess of Mach 4 and an 80-nautical-mile range, the Phoenix had the ability to engage enemy antiship missiles at a safe distance from the targeted ship.[25]

[23]*NWC Tech History 1979*, 10-21.
[24]Gunston, *World's Rockets and Missiles*, 204–205.
[25]Friedman, *World Naval Weapon Systems*, 253.

A 1976 paper by Commander Peter T. Tarpgaard, who was the project officer for the Sea Phoenix study, concluded that "such a system was found not only to be feasible but to offer the possibility of providing even small combatants with an AAW [antiair warfare]/ASMD capability far beyond that available with any other system today." But because of maintenance and reliability issues and high cost, the Sea Phoenix program was not pursued further and did not transition into development.[26]

Vertical-Launch Antisubmarine Rocket (VLA or VL ASROC) and Harpoon

Vertical launch showed great promise for point defense, antiaircraft defense, and surface-to-surface (sea or land target) applications. The idea was simple: a fixed vertical launcher that could accommodate a variety of ship-borne missiles. The launcher would be inexpensive as it would not need to be trainable in azimuth or elevation; it would launch straight up.

Converting to vertical launch, however, required a conceptual shift analogous to Dr. McLean taking the fire-control system out of the aircraft and installing it in the Sidewinder missile. The vertical-launch missile designers would take initial trajectory control out of the launcher and instead install it in or on the missile, using propulsion control to pitch the direction of the missile from the vertical into the azimuth and inclination called for by the mission. Depending on the weapon, the propulsion steering unit (thrust vector control [TVC], gimbaled nozzle, etc.) would either remain with the weapon or, as with Vertical Launch SeaSparrow, be jettisoned after the pitch-over maneuver.

An initial step in demonstrating vertical-launch feasibility for Fleet-wide use was to see if a representative airframe could, practically and economically, be launched vertically and then pitched over to a prescribed heading. That goal was achieved in the Low-Cost Controllable Booster (LCCB) program, begun in 1974 and demonstrated at China Lake's Top Hat test site in May 1976. An ASROC airframe was launched, pitched over to 60 degrees from vertical, then pitched back to 45 degrees from the vertical and stabilized.

"The resulting 45-degree flight path angle corresponds to the normal attitude of an ASROC fired from its standard launcher. The flight accomplished all of the major goals of the demonstration program," the *Tech History* reported, although separation of the payload from the booster module was not attempted. The LCCB demonstration led China Lake to set up a program that would

[26]Tarpgaard, "The Sea Phoenix," 31.

"develop, integrate, and demonstrate a propulsion control module keyed to the vertical launch task."[27]

NAVSEA tasked China Lake with two vertical-launch efforts. One was to integrate a booster motor, TVC unit, and autopilot into a controllable booster module that could be used with various missiles. The second was to investigate the feasibility of vertically launching two existing ship-borne weapons from a vertical launcher that was already under development by Martin Marietta Corp. The weapons were ASROC, which had been in the Fleet since 1961, and the antiship missile Harpoon, which was nearing the end of development. (It would be fielded in 1977.)[28]

The two weapons posed different challenges for vertical launch. ASROC was a ballistic missile: it was pointed along the azimuth from the launcher to the target and its range was controlled by an onboard thrust-cutoff system that also released the weapon's torpedo payload.

Harpoon employed a turbojet engine; for ship launch or subsurface launch, it was brought to flight velocity by a solid-propellant rocket booster and then maneuvered according to its guidance commands. (The air-launch version required no booster.)

Bob Dillinger was China Lake's program manager for the vertical-launch effort. Scott O'Neil was the vertical-launch system engineer, and Mike Ripley-Lotee was the project engineer. Philip Bowen and George Teate of the Weapons Department's Electronics Systems Branch were responsible for the modular booster's autopilot and control electronics.

Scott O'Neil (left) and Mike Ripley-Lotee (right) with VLA motor.

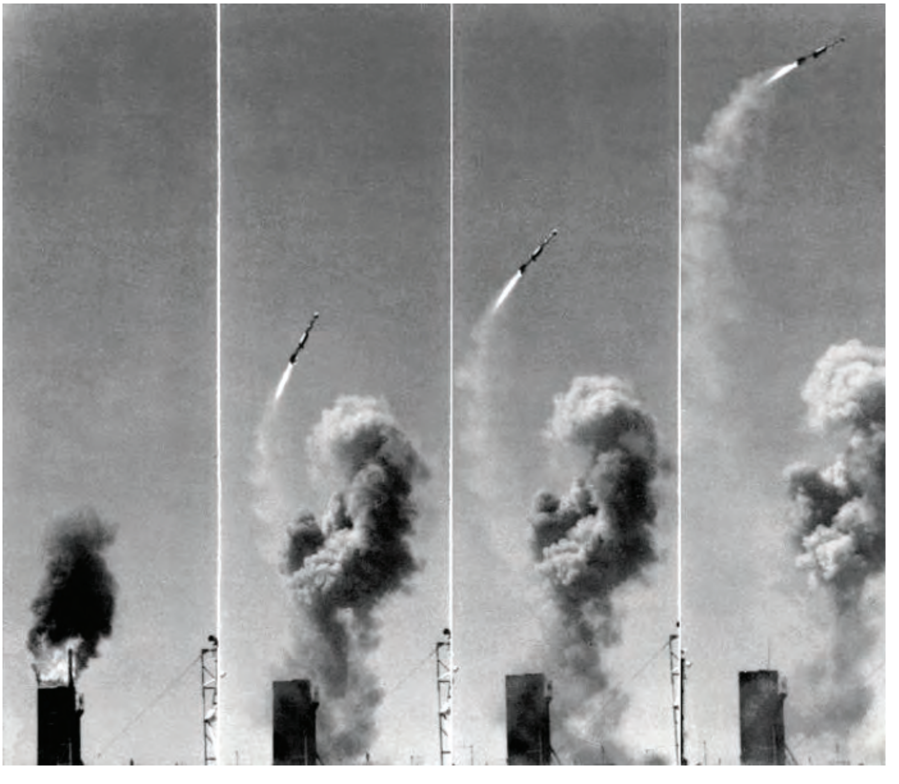
In April 1978, a Harpoon and an ASROC were vertically launched at China Lake from an engineering development model (EDM-1) of Martin Marietta's vertical-launch system. The Harpoon was a ballistic

[27] *NWC Tech History 1976–1977*, 9-20.

[28] Thrust-vector control is the process of redirecting the course of a rocket-powered body by changing the direction of the rocket's thrust.

test vehicle (BTV); it left the launcher at 85 degrees from horizontal and flew ballistically to impact.

The ASROC, a controlled test vehicle (CTV) fitted with the NWC-designed propulsion and steering system using jet-vane TVC, left the launcher at 90 degrees from vertical. (The CTV's dummy torpedo payload contained thermal batteries, telemetry, an analog autopilot, and the cold-gas power supply to drive the jet-vane actuators.) At approximately 50 feet above the launcher, the CTV performed a pitch-over maneuver to 60 degrees from vertical and then a second maneuver to return to a 45-degree trajectory. Airframe separation and torpedo deployment occurred on the autopilot's command at 39.892 seconds into the flight.[29]



VLA CTV in 1978 feasibility demonstration.

[29]NWC TP 6092, *Vertical Launch ASROC*, 5.

The feasibility demonstration was a success. "By combining the two concepts of vertical launch and TVC," the *Rocketeer* reported,

> Center weapons system specialists envision a future scenario in which a Navy surface vessel fires three missile types within seconds of each other and from a common launcher. The missiles would be targeted in different directions and to air, surface, and subsurface targets.[30]

O'Neil thought that a vertical-launch Harpoon system could be designed that would use Harpoon's missile-guidance unit to control a TVC propulsion system as the ASROC CTV's autopilot had. However, compatibility studies with McDonnell Douglas, the Harpoon prime contractor, did not bear fruit. "I thought Harpoon would be the one that would be the first one to go vertical but it turned out to be ASROC," said O'Neil.[31]

In October 1978, Bob Hillyer presented O'Neil, Ripley-Lotee, and Bowen with a Technical Director Award "in recognition of their part in the successful implementation of the Vertical-Launch ASROC flight demonstration program."[32]

By 1982, development of the VLA (RUM-139) was formally underway, with the Naval Ocean Systems Center (NOSC), San Diego, as the lead laboratory. China Lake was responsible for the missile propulsion and control system, which included the digital auto controller and TVC unit, the missile staging ordnance, the onboard telemetry instrumentation system, and the command-destruct system. O'Neil headed the Vertical Launch ASROC Program Office at NWC until he left for the Tomahawk Program in 1985.

John Robbins worked as O'Neil's deputy on the VLA program and succeeded him as program manager when O'Neil left. Robbins said of the early years of ASROC:

> It was a tremendous opportunity to do a hands-on design and development project in-house. We did the rocket motor, we did the TVC, we did the autopilot. We got to put our hardware together and take it out on the range and fly it, and that was an exciting 3 years.[33]

There were still serious technical challenges to be faced. For example, the TVC used in the ASROC CTV demonstration was designed to last 2 seconds. "So we needed to get the life of the jet vanes up from 1½, 2 seconds to, we thought, probably 5½ seconds," O'Neil explained.

---

[30]*Rocketeer*, 5 May 1978, 7.
[31]S-328A, O'Neil interview, 22.
[32]*Rocketeer*, 13 October 1978, 1.
[33]S-293, Robbins interview, 2.

> When we finally got the vertical launch ASROC as a program, we didn't really need 5½ seconds. We needed 15 seconds. So there was some serious work being done trying to extend the life of the jet vanes in the rocket motor [an environment of about Mach 4.5 and nearly 6,000°F].[34]

John Robbins.

Engineer W. Richard Thompson, an aeronautical engineer who came to China Lake in 1962, played a central role in developing copper-impregnated tungsten vanes that met the VLA time requirements. Frank Markarian, former head of the NAWCWD Research and Engineering Department, described Thompson as "the expert in the analysis of aerodynamic heating," and credited Thompson with getting China Lake "into the computer age of solutions for heat-transfer equations." Thompson was selected as an NWC Fellow in 1990.[35]

VLA entered the Fleet in 1993, a China Lake program from start to finish. Nearly three decades later, it is the principal antisubmarine weapon for *Aegis*-equipped cruisers and destroyers.[36]

Ripley-Lotee would retire from China Lake in 2012 as senior advisor to the Executive Director after 38 years of service. O'Neil—"the fuzzy-cheeked engineer with the long hair," as Miller referred to him affectionately—would become China Lake's 15th civilian leader (the title changed from Technical Director to Executive Director in 1998), guiding NAWCWD from 2005 to 2016—a tenure exceeded only by that of Dr. McLean.[37]

---

[34] S-328A, O'Neil interview, 9.
[35] S-291, Markarian interview, 6.
[36] Ibid.
[37] S-262, Miller interview, 38.

Rolling Airframe Missile (RAM)

In the early 1970s, Vice Admiral Merrill H. Sappington commanded NAVORD. As captain, he had headed NAVORD's Surface Missiles Project Office. He was convinced that ship defense against cruise missiles could be handled by a RAM in the size range of the Redeye and Stinger missiles—about 2½ inches in diameter with a correspondingly small warhead. (Redeye and Stinger were designed as man-portable systems.)[38]

John Lamb.

As indicated in the epigraph of this chapter, China Lake engineers believed that eliminating a high-speed threat missile would require a substantial punch—more than could be carried in a 2½-inch weapon. Engineers John Lamb and Ken Powers and mathematician Amy Griffin put together a study using data from 20 test firings "where you shot real targets with real missiles and you followed the trajectory of where [the target] went after it was intercepted," said Lamb. "It did not deviate from its course by very much." They presented the data to Sappington's staff, and the original 2½-inch RAM program was killed.

The rolling-airframe concept, however, was still alive, and an operational requirement was issued in May 1975. In 1976, the United States, Germany, and Denmark agreed to jointly build an ASMD weapon called, simply, the Rolling Airframe Missile, or RAM. General Dynamics/Pomona Division (which later became part of Hughes Aircraft, which still later was acquired by Raytheon) was selected as the RAM development contractor.

RAM (RIM-116) was a dual-mode (IR and RF) 5-inch-diameter missile based on the Sidewinder AIM-9L. It consisted of the new rolling airframe (the roll imparted by fins at the rear of the missile); a Sidewinder fuze, warhead, and rocket motor; an IR seeker from the Stinger missile; and a new RF seeker. The weapon system was economical in terms of space; five RAMs could be fitted

[38] In a RAM, stability is achieved by the airframe rolling on its longitudinal axis, much like a rifle bullet.

into a single missile cell on a SeaSparrow launcher. The standard RAM launch system would be a 24-round modified Phalanx automatic gun system.

Shipboard firing of RAM.

According to Bob Corzine, "The engineers at China Lake were not particularly enamored with the Rolling Airframe Missile." One reason was that the airframe had only two canards with which to maneuver rather than the four employed by a non-rotating missile. Because of this, the time necessary to change missile direction was slightly greater. (The canard commands could not be given until the missile had rolled into the correct position relative to the target.) In a Mach 4 encounter, even the smallest delay could reduce the odds of intercept.[39]

In 1978, NAVSEA designated NWC as the "missile round acquisition engineering agent," supplying the government-furnished material for the program. As reported in that year's *Tech History*, the Center was also tasked to develop specific hardware items: "the contact fuze, a modified active-optical target detector [the -9L's DSU-15/B], a mid-IR fuze, and a remote rocket-motor arming-firing device."[40]

[39]S-283, Corzine interview, 36.
[40]*NWC Tech History 1978*, 6-5.

Dual-mode guidance gave RAM flexibility in a variety of weather conditions and engagement scenarios. The missile received both IR and RF from the target. "It continually sampled the two signals until the thermal one got high enough, then it transferred over [to IR] because the thermal seeker has the accuracy, but not the range. The radar has the range but not the accuracy," explained NWC engineer Jerry Saholt, who worked on RAM. China Lake also developed a hardware-in-the-loop test capability for RAM, the first ever built for a dual-mode seeker.[41]

In terms of program control, China Lake's role was limited. As with other programs—Sparrow and Harpoon, for example—the expectation of politicians and high-ranking DoD officials was that the contractor would take the lead in designing an effective and reasonably priced weapon. "We were in a hands-off position on the RAM program until the program got into serious trouble," said Bill Porter, "and then we were asked to come in, and we worked our way back into a very key role."[42]

With repeated problems—particularly frequent developmental test failures—placing the international program in jeopardy, the Assistant Secretary of the Navy tasked China Lake to become more involved. Bob Campbell, who had recently returned from a 1-year Sloan Fellowship program at Massachusetts Institute of Technology, was assigned to the program. Campbell and his team, consisting of Paul Amundson, Jack Crawford, and Dr. Gunther Winkler, worked with NAVSEA and General Dynamics to identify and correct various issues and established program credibility with the international community.

Crawford, one of China Lake's foremost engineers and managers, oversaw the repackaging of the RAM guidance and control section to improve its producibility and reliability. He said:

> When I first looked through the design of the thing, my thought was, "This has got to be the dumbest way to make a missile I have ever seen." After I understood how it actually worked, I realized it was an extremely clever design. We spent a lot of work with General Dynamics in redesigning the electronics to come up with a simpler and more reliable design.[43]

Members of the Intercept Weapons and Engineering Departments produced a Level 3 technical data package that allowed the government to manage a competitive procurement, maintain design integrity in production, and support competitive procurements. For this the participants received an

[41]S-257, Saholt interview, 61.
[42]S-216, Porter interview, Part 2, 50.
[43]S-241, Crawford interview, 25–26.

NWC Team Award in 1991, and the following year the first RAM Block 0 system entered service on board USS *Peleliu* (LHA-5).

In the late 1990s, Winkler facilitated the successful transition of RAM into both the U.S. and German fleets. A more advanced model, the Block 1, completed operational evaluation in 1999. By 2013, the Center had initiated the RAM Block 2 upgrade and seen the program into production. RAM today is a key element in the Navy's point-defense architecture and is also in use by several allied nations.

Standard Missile

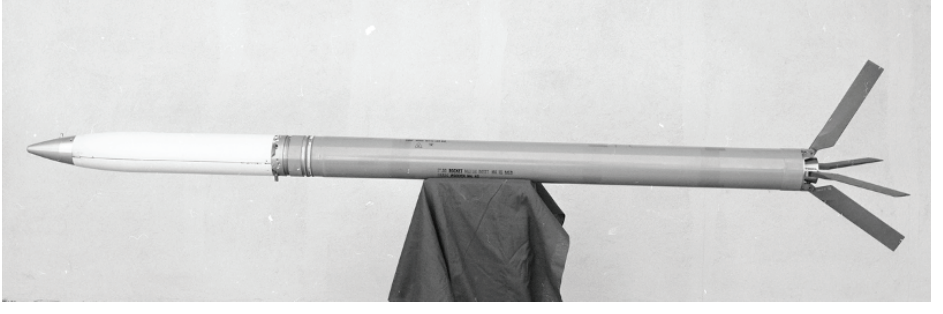
First fielded in 1968, the Standard Missile (SM-1) replaced the Navy's 1950s vintage Terrier and Tartar 1 air-defense missiles. NWC developed the revolutionary Mk 45 target-detecting device (TDD), which began production in 1972, and subsequent iterations of that TDD. Other China Lake contributions to the Standard Missile included studies for an advanced ordnance system, development of a drone-mounted electronic countermeasures (ECM) set for fuze testing, antenna testing, fixes for the arming-firing device used in the missile destructor system, warhead and fuze analyses, propellant studies, combustion instability research, consultation on the Mk 56 booster, development of specialized test facilities, program coordination and prototype demonstrations for the Vertical-Launch Standard Missile program, and Fleet support. NWC also developed the fuzing system and flight-termination system for the Standard Missile Type 2, Nuclear (SM-2[N]). SM-2 today is the Navy's principal surface-to-air air-defense missile.

SM-2 fired from U.S. Navy guided-missile destroyer.

Chaff Dispensing Rocket (CHAFFROC)

Pursuant to a requirement issued by the CNO to NAVORD in 1966, China Lake was tasked to develop a shipboard chaff decoy rocket to divert incoming antiship missiles. Fourteen months later, the Center had completed development of CHAFFROC, a 5-inch Zuni rocket with a chaff warhead. Fired to a predetermined dispersion point, the warhead released a cloud of aluminum dipoles (chaff) that created a false ship target for a threat radar-homing missile. The CHAFFROC system included the fuze, chaff warhead, launcher, fire-control system, and ready-service lockers.

Each 34-inch-long CHAFFROC warhead weighed between 28 and 34 pounds and contained approximately 126 million silicon-coated aluminum dipoles. By 1968, the system was operational on eight ships, procurement of 4,800 chaff warheads was underway, and China Lake was producing a more advanced version of the decoy system. In 1969, 20 of the new systems were installed on Navy destroyers. Pre-deployment reviews were also underway for installation of CHAFFROC on carriers. China Lake supported CHAFFROC training schools at San Diego and Dam Neck, Virginia, as well as a mobile training unit at Yokosuka, Japan.[44]



CHAFFROC.

Further modifications to the CHAFFROC system were made in 1970, including the incorporation of a larger Naval Research Laboratory-developed 36-pound warhead and a launcher developed by the Naval Ordnance Station (NOS), Louisville. Development of a smaller CHAFFROC system with a greater number of available rounds was also begun, and studies of an air-launched version of CHAFFROC were underway. In 1971, operational evaluation of CHAFFROC revealed performance and safety deficiencies that led to the suspension of Fleet use.

[44]*NWC Tech History 1969*, 8-55, 1-13, 2-71.

In 1972, development of a third-generation version of CHAFFROC, dubbed the Decoy Launching System (DLS), was undertaken. DLS carried a larger loadout of smaller rockets. (The Zuni rocket motor's 3-mile range far exceeded that necessary for a decoy). Unlike the earlier CHAFFROC systems, DLS was more highly automated and fully integrated into the ship's defensive system. Upon detection of a threat, a computer would automatically select the correct launcher and would train, elevate, and fire the rocket (although regulations required a man-in-the-loop decision for each rocket firing). The launcher was stabilized with signals from the ship's master gyro.

NAVORD appointed China Lake as the technical direction agent for the DLS, which by that time involved NOS, Louisville (launcher and controls); NOS, Indian Head (rocket motor); Naval Ship Missile Systems Engineering Station, Port Hueneme (integrated logistics and reliability); Naval Ship Engineering Center, Hyattsvil1e (ready-service lockers); Naval Weapons Laboratory, Dahlgren (chaff head); Naval Ordnance Systems Support Atlantic, Philadelphia (training); Naval Research Laboratory, Washington (effectiveness analysis); and numerous contractors.

A more complex system meant greater logistics requirements, and considerable effort was expended in training personnel in the operation, repair, and maintenance of the prototype systems. In 1973, according to the *Tech History*, NAVORD "decided to wait further evolution of decoy requirements before committing more funds to this system" and suspended work on the system. That was the end of the CHAFFROC line, although some CHAFFROC systems remained in the Fleet.[45]

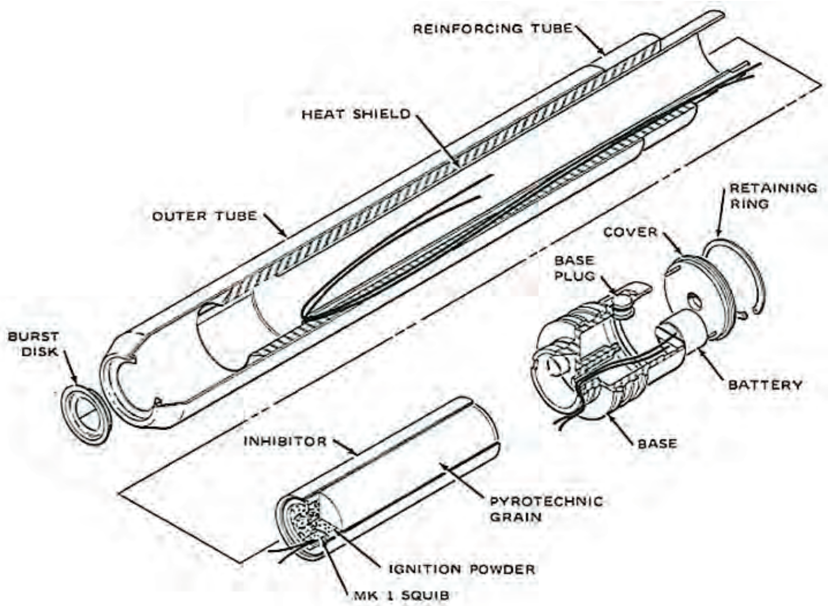
CHAFFROC had originally been fielded as a rapid response to a Vietnam-era need and was never used in combat. It was eventually replaced by a system designed specifically for the ship-launched decoy role: the BAE-developed mortar-launched Mk 36 Super Rapid Bloom Offboard Countermeasures system.

Ship's Ordnance Infrared Decoy (SOID)

China Lake scientists and engineers began developing a decoy for IR-guided antiship missiles in 1969. Called SOID EX (later Mk) 48, the system deployed a modified Mk 25 pyrotechnic floating marker flare. When the flare landed in the water, a salt-water-actuated battery fired the initiating squib. The Mk 25 had an output of 1 kilowatt per steradian (kW/sr) in the 3- to 5-micron region for approximately 75 seconds. For the first design iteration, the flare

[45] *NWC Tech History 1973*, 6-11. The CHAFFROC system on USS *John F. Kennedy* (CV-67) was not replaced until 1983.

was deployed manually. Initial tests were promising, and pre-pilot production began late in 1969.[46]



SOID cutaway view.

The following year, the preproduction rounds were used in an operational evaluation of the launch system and flares. The *Tech History* reported that "the Operational Evaluation was considered successful, but insufficient units were available for the complete test." NAVORD ordered 150 more rounds, but that lot failed acceptance testing and was rejected. The problem was identified and resolved. The *Tech History* optimistically stated that "it is expected that 3,000 units will be fabricated during fiscal year 1971," and indeed, in that fiscal year, the Naval Ammunition Depot, Crane, produced 3,700 units for the Fleet.[47]

Point defense continues to be a priority for the Navy, and today's Navy point-defense systems are designed, engineered, and produced with the same attention to detail, fiscal responsibility, commitment to quality, and comprehensive testing that are the hallmarks of China Lake's development process.

---

[46]*NWC Tech History 1969*, 3-34.

EX stands for experimental. It was often used in the designation of a weapon under development until such time as a Mark number (Mk) was assigned.

[47]*NWC Tech History 1970*, 3-25; RDTR No. 203, *Project SOID*, iv.

8

Ill-Fated Agile

> *Agile: adjective. Marked by ready ability to move with quick easy grace.*
>
> —Merriam-Webster definition[1]

Never was a missile more aptly named. Agile did indeed "move with quick easy grace," turning on a dime and tracking targets at ridiculously large off-boresight angles (away from the centerline of the missile). Agile was like no missile before; it would have rewritten the book on aerial combat. The Agile *program*, however, was the antithesis of quick, easy grace; it offers a cautionary tale of how a revolutionary weapon system can be mismanaged into oblivion.

Project Quickturn

The story of Agile (AIM-95) starts with Project Quickturn, which began at the Center in 1968. Propulsion engineers had long known that propulsion steering—TVC—was useful in two scenarios. One was to steer a rocket at slow speeds, when the airflow against the control surfaces was not strong enough to quickly change the rocket's direction of movement. This low-speed steering was the purpose of using a TVC booster in Vertical-Launch SeaSparrow, which had to make a large pitch-over maneuver immediately after launch from the deck of a ship.

A second application for TVC was for steering a rocket in space, where aerodynamic systems—wings, control fins, and canards—were useless because of the absence of air.

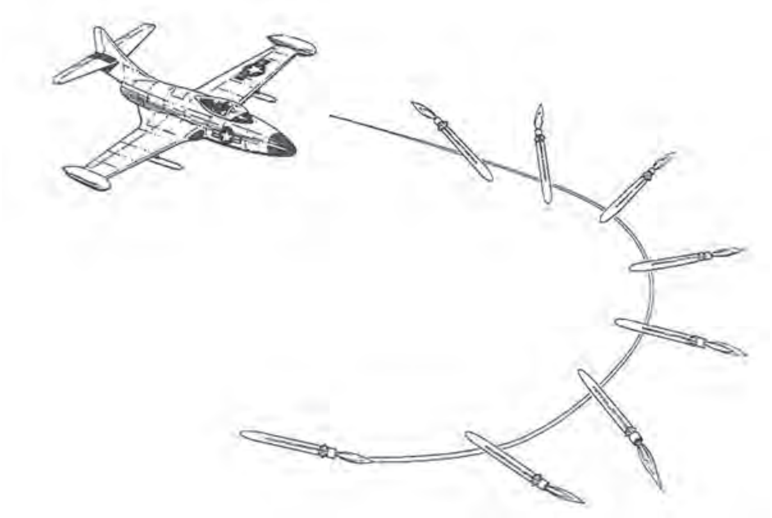
Both these scenarios were the subject of China Lake technology development in the late 1950s and early 1960s. In 1961, TVC was investigated for incorporation with the Guided Flight Vehicle, a China Lake-developed prototype antisatellite weapon. A Naval Ordnance Test Station (NOTS)-500

[1]Merriam-Webster's Collegiate Dictionary, 10th ed., 2001, 23.

rocket motor was fitted with a liquid-Freon injector system and coupled to an aerodynamically unstable airframe and an autopilot. The *Tech History* reported that "the successful firing demonstrated that thrust-vector control by liquid-Freon injections is feasible, and that vectoring forces over 10 percent of axial thrust can be achieved without degrading the axial thrust."[2]

The same year, China Lake designed, developed, and successfully tested a fluid-injection TVC system for the Polaris A-3 second-stage motor. "It was demonstrated that the system was capable of producing the required maximum side force of 1,800 pounds," stated the *Tech History*.[3]

The third application of TVC was investigated with Project Quickturn. Air-to-air missiles are launched at relatively high speeds, and turning the missile quickly after launch offers a huge tactical advantage to the shooter. However, aerodynamic control surfaces do not provide the desired maneuverability when the launched missile's speed is only slightly above the speed of the launching aircraft. TVC has the ability to change the heading of a missile 180 degrees in seconds, which dramatically improves the ability of the missile to intercept targets at high off-boresight angles. This application was still a high-risk technology, because the missile would be nearly always in an aerodynamically unstable state.[4]



Concept of Quickturn maneuver. Published in the 1961 *NOTS Tech History*.

[2]*NOTS Tech History 1961*, 105, 106.

[3]Ibid., 107.

[4]Phil Arnold recollected that Lucien (Luc) Biberman, a former China Laker and Institute for Defense Analysis analyst, after watching films of an Agile flight test, exclaimed, "You've accomplished a technological tour de force; you made a telephone pole fly!" S-275, Arnold interview, 42.

Leroy Krzycki.

Leroy J. Krzycki, head of the Propulsion Development Department's Engineering Applications Branch, set up the Quickturn program. "He got a lot of quick support directly out of NAVAIR for the innovative and creative things he was talking about doing," said Bob Dillinger, head of the Propulsion Components Branch (later renamed the Systems Technology Branch). "He was the kind of guy that would give you a job to do and if you didn't have it done in 3 days, he'd do it himself."[5]

In 1969, NWC tested two Thiokol Chemical Corp. gimbaled nozzles and two Lockheed Propulsion Co. flex-seal nozzles. Jim Andrews, an engineer in Dillinger's group, explored the various nozzle concepts. Tests that year "proved that small, lightweight movable TVC nozzles are capable of vector angles to 20 degrees, with very fast response times of 20 to 30 milliseconds (that is, a nozzle slewing rate of 600 to 900 deg/sec)." Work began on ballistic and flight test vehicles.[6]

Jim Andrews.

Dave Carpenter in Ray Feist's Engineering Projects Branch was the chief engineer for developing the rocket motor: an 8-inch-diameter solid-propellant motor with an average thrust of 3,500 pounds for 7 seconds and better than 24,000 pound-seconds total impulse. This burn-versus-time profile (a function of

[5]S-327, Dillinger interview, 30.
[6]*NOTS Tech History 1969*, 2-88.

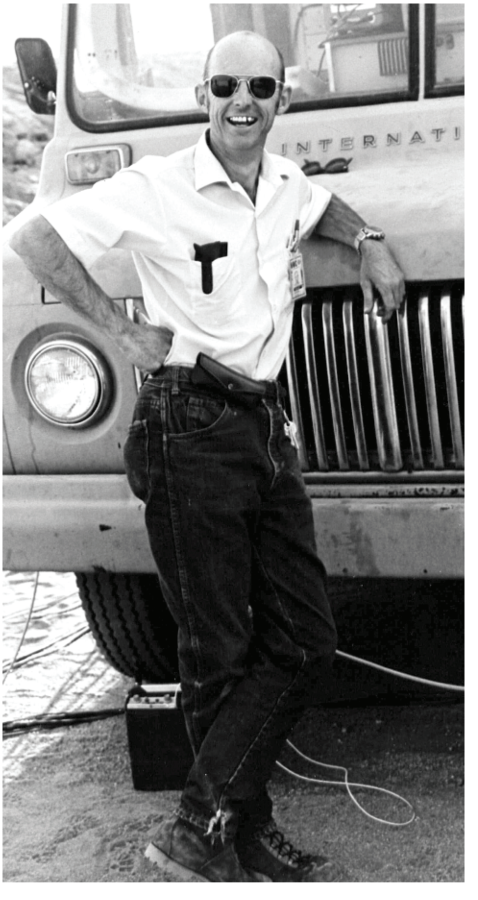
the internal geometry of the motor) permitted the missile to make the turn toward the target in minimal distance before increasing thrust to obtain high velocity until impact.

The motor design later evolved to a 32,000 pound-seconds thrust boost/sustain rocket motor. Speed and endurance were paramount. "It was all reaction steering," said Scott O'Neil, "so when the rocket motor burned out, you better have hit the target, the fuze better have gone off, or else you just wasted a bullet."[7]

Flight tests soon followed, using a Thiokol omniaxis gimbal-ring TVC nozzle and a Sparrow hydraulic power supply system. Several flight tests were conducted. In the most impressive one, "a Quickturn flight vehicle demonstrated a 55-g 118-degree angle-of-attack maneuvering capability under a high-dynamic-pressure environment."[8]

Meanwhile, NWC management was itching to get the new technology incorporated in a weapon system—and not just the TVC technology. "The general Agile concept evolved from numerous discussions with fighter pilots on their desires and insights concerning an air-to-air dogfight weapon system," stated one report. "The basic desire was for an if-I-can-see-him-I-can-hit-him weapon system."[9]

China Lake had proposed a new version of the Sidewinder called the AIM-9K. The concept, developed by Dr. E. E. "Mickie" Benton, had very similar performance to that envisioned for Agile but was aerodynamically, not thrust-vector, controlled. However, opposition from the Air Force killed further efforts on the program.



Dr. Mickie Benton.

[7]O'Neil, "Thrust Vector Control," video presentation. O'Neil worked on a team attempting to reduce the number of plastic and metal parts in the TVC nozzle.

[8]*Major Accomplishments of the Naval Weapons Center*, 129.

[9]NWC TM 2506, *Agile-AVC Hardware Descriptions*, iii.

In 1969, Justin W. Malloy, director of NAVAIR's Advanced Weapons Systems Division, proposed a new missile system for the Navy, called Agile, that would use China Lake's Quickturn technology as well as seekers with large gimbal angles being developed by Hughes Aircraft Company and Philco-Ford. The weapon would be given the formal designation AIM (Air Intercept Missile)-95.

Agile gave China Lake an opportunity to propose the incorporation of other new technologies, all at various stages of maturation. In 1970, NWC described the candidate next-generation air-to-air weapons system:

> The principal features of the current Agile base-line design are (1) a head-coupled visual target-acquisition system; (2) passive all-target-aspect guidance, with a large gimbal angle capability; (3) a relatively clean body airframe incorporating thrust vector control; and (4) an all-aspect ordnance package with an active optical fuze and an annular blast fragmentation warhead.[10]

Denny Kline served during the Agile years as technical presentations coordinator and later as the Center's public affairs officer. He recalled:

> Here was this extraordinary capability, it skipped a generation, it went from a forward-hemisphere Sidewinder to something that looked, locked, and launched, where you could look over your shoulder and actually do something, which was an incredible Star Wars jump in those days.[11]

The Agile team wasn't the only group looking to build the next great dogfight missile. The Air Force had its own concept, the AIM-82, which was intended for use with the then-in-development F-15 fighter. The AIM-82, like Agile, was planned as an "all-aspect" missile—that is, it could track the target from any angle, unlike the Sidewinder of the day that had to be aimed from behind the target aircraft to lock on the hot engine exhaust.

The Navy wanted a more generalized missile with both interceptor and self-protection applications, one that could be used on ordnance-toting attack aircraft, such as the A-7, which were generally less maneuverable than the F-15 or the current threat fighters. Captain Tommy Wimberly, Technical Officer at China Lake during Agile development, said:

> We briefed and said, "Put this Agile on an attack airplane, and if somebody attacks him, he'll shoot them down." The fighter pilots didn't like that idea. The Air Force guys claimed they didn't want any 8-inch diameter missile. It was too big, give them something that was smaller and let them fly the airplane to get on the guy's tail, that's what they wanted to do.[12]

[10]*NWC Tech History 1970*, 2-33.
[11]S-289, Kline interview, 53.
[12]S-290, Wimberly interview, 7.

That issue—whether to rely on the maneuverability of the aircraft or of the missile—was decided in favor of the Navy, and Agile was given the go-ahead. According to Technical Director Walt LaBerge:

> The basis for the decision was in part a belief by DDR&E [Dr. John S. Foster] that the Navy had a better solution and in part a Connolly/Glasser agreement [Deputy CNO (Air) Vice Admiral Thomas F. Connolly and USAF Deputy Chief of Staff R&D Lieutenant General Otto J. Glasser] that if the Air Force did not contest an Agile assignment to the Navy, the Navy would not contest the Air Force assignment of high energy laser application to air-to-air warfare.[13]

Interservice politics aside, the Agile program faced many technical obstacles. Perfecting a TVC nozzle that could operate precisely and at extremely high slew rates through the full range of the Agile envelope posed both engineering and materials challenges. Agile also required the design and development of a new lightweight 8-inch-diameter annular-blast warhead that would yield aircraft structural kills at the anticipated miss distances. The missile would need a very sophisticated autopilot because, as Phil Arnold (who would later manage the program) pointed out, "Agile routinely flew through low to zero to negative airspeed regimes while rapidly turning with high angles of attack and with a continually shifting center of gravity."[14]

Agile's revolutionary airframe, unlike any seen before in a Navy missile, had no wings at all and only six (later eight) small aft-mounted fins for initial flight stability. As the missile left the launcher, the fins precluded yaw that could lead to impact with the launch aircraft. The TVC was locked down as well so that the missile wouldn't come back on the shooter's wingman—which it well could do; the fins kept the missile stable and straight until it was away from the vicinity of the aircraft. Once TVC guidance commenced, the fins had no purpose.[15]

Because of Agile's extraordinary speed and maneuverability, Center designers wanted to replace the traditional hemispherical seeker dome with a much-lower-drag pyramidal window made of triangular flat segments cemented together—a goal that had eluded engineers since the 1950s.

---

[13]Technical Director, NWC, to Commander, NWC, memorandum, "Agile Background," 4 June 1973, 1.

[14]S-275, Arnold interview, 45. The missile's center of gravity, and thus its center of pressure, would change as the rocket-motor fuel burned from back to front. The autopilot accounted for the constantly changing turn moment and maintained stable flight, even through zero airstream velocity (as when the missile turned toward a target aft of the launch aircraft).

[15]Initially, the fins were mounted on a rotating collar; after a 1973 test showed the rotational capability to be unnecessary, the fins were fixed to the body of the missile.

Agile needed an all-aspect seeker that could track the target tail-on, side-on, or head-on. It had to be capable of locking on the target when the pilot pointed his head in the direction of the target (rather than, as with Sidewinder, pointing his aircraft at the target). This required a gimbal that could slew the seeker to high off-boresight angles at slew rates of 200 degrees per second. The look-and-lock capability also required a means of slaving the seeker to the pilot's helmet. That feat was accomplished by computing the helmet's position using light sensors in the cockpit and light-emitting diodes in the helmet. The concept was called the Visual Target Acquisition System (VTAS).

Initially, four seekers were Agile candidates—three of them IR, one electro-optical (EO). One was a Philco-Ford product using an NWC-built seeker head platform. Another was a Hughes Aircraft Company-built seeker, which underwent major redesign in 1971. A third was a Sidewinder AIM-9D seeker mounted in two extra sets of gimbals to provide the wider gimbal angle required for the Agile envelope. Finally, NWC was developing an EO TV-type seeker—in early testing with a Honeywell Inc. helmet-mounted sight, the EO system demonstrated pointing accuracy of less than 1 degree of error out to 90 degrees off-boresight.

In addition to the four candidate seekers, a two-color sandwich-type IR detector was being developed at China Lake under an Independent Exploratory Development (IED) program that began in early 1971. Operating in two bands would minimize the effects of clutter and decoys and would optimize terminal homing by biasing the missile trajectory away from the target's engine plume and onto the aircraft itself. China Lake was also developing a sophisticated fuzing system for Agile involving an aft-mounted active optical target-detecting device.

Supporting equipment for the Agile system was in the pipeline as well. For example, Center engineers and human-factors experts were investigating the incorporation of a voice advisory system in which audio displays by a simulated human voice would alert the aircrew to onboard aircraft problems. The goal was to minimize the time the crewmember spent scanning cockpit displays and maximize the eyes-out-of-the-cockpit time.

The technical challenges presented by Agile were significant but not, China Lake felt, insurmountable. Political, personality, and management issues, however, affected the program from the outset.

Late in 1968, Dr. Frosch, Assistant Secretary of the Navy for Research and Development (ASN R&D), asked Dr. Joel S. Lawson, Director of Navy

Laboratories (DNL), "whether or not we could assign a major project to the laboratories, and if so, which laboratories would be assigned the projects?"[16]

Lawson told Frosch, "You could assign a major project to China Lake anytime you wanted, but on the other laboratories I didn't think so." He went on to explain:

> My personal motivation was two-fold. The leading one was that I thought it would do the laboratories good. It would make them a little bit more tolerant of headquarters if they had to go through this rat race. The other one was the fact that in most of our development programs, the real problems are technical and I felt, and so did Dr. Frosch, that we ought to put some of the more technical programs into the hands of the technical people. We could afford a few goofs in the bookkeeping ends of the game.[17]

Dr. Frosch assigned control of the Agile program directly to China Lake, bypassing NAVAIR. Phil Arnold said:

> Agile was part of an experiment by the Assistant Secretary for RDT&E by assigning management authority directly to China Lake . . . I happened to be attending a meeting in NAVAIR on the A-7 FLIR when the announcement was made and saw first-hand the reaction in NAVAIR. As you might expect, the reaction wasn't positive.[18]

LaBerge later stated:

> To my knowledge, no effort to obtain for NWC this anomalous reporting assignment had been undertaken by Rear Admiral Moran [NWC Commander] or Mr. Wilson [Technical Director]. Notwithstanding, the arrangement, when announced, engendered apprehension and resentment on the part of our major customer, NAVAIR.[19]

"Dr. Frosch is the one who tried to force the issue of project management by laboratories," said John Rexroth, who was, at the time, NAVAIR's technical assistant for the Aircraft and Weapons Systems Division.

> It was he who decreed that the Agile missile would be under the management control of the Naval Weapons Center and I thought that was a loser. I worked with Hack Wilson to arrive at a working arrangement between HQ and the Center that I think would have seen the project through.[20]

---

[16]BA-2-75, DNL Oral History Collection Interview, Lawson, 32.

[17]Ibid., 33–34.

[18]S-275, Arnold interview, 43.

[19]Technical Director, NWC, to Commander, NWC, memorandum, "Agile Background," 4 June 1973, 1.

[20]NL-T33, Naval Laboratories Oral History Program Interview, Rexroth, 33.

According to Arnold, "They prepared a memorandum of agreement that acknowledged China Lake's assignment as manager, but gave NAVAIR responsibility for 'handling the Washington scene.'" Justin Malloy, who had been the principle Navy salesman for the Agile concept, was designated the Agile project coordinator in NAVAIR-03.[21]

It was at that point, early 1971, that LaBerge reported to China Lake as Deputy Technical Director, being groomed by Wilson for the Technical Director's position. Wilson's first instruction was "figure out how to get Agile done."[22]

LaBerge lamented the early elimination of the AIM-9K from the competition:

> It was estimated to be considerably cheaper in development and probably 15 percent less expensive than the TVC Agile in production. However, [Agile] had been sold to DDR&E on the basis of the riskier, less well performing, probably more costly TVC design. . . . NWC had viewed the problem of rationalizing a more expensive, less performing Agile as NAVAIR's problem, not its own. When we got the Dr. Frosch letter [assigning China Lake management responsibility], the problem became ours.[23]

Neither NAVAIR nor NWC was familiar with this type of a working arrangement, and there was a lack of communication and trust between the two organizations. At one point, for example, NAVAIR and Hughes Aircraft supported the use of a rate-stabilized platform seeker in Agile. China Lake engineers believed that such an approach would cause friction coupling that could jeopardize airframe stability, so they opted instead for a momentum-stabilized rotating-mass optical system similar to Sidewinder's. LaBerge cited this example in a 1973 background memo on Agile to the newly arrived NWC Commander, Rear Admiral Paul Pugh. LaBerge called it a "question of arithmetic" and stated, "If we cannot agree on items of fact, we can never agree on questions where the facts are less clear."[24]

Bob Hillyer, who headed the Fuze Department and would later become NWC Technical Director, blamed the conflicts on Secretary Frosch's decision to assign program management to the Center.

> He forgot to change the rest of the system when he did that. The result was resentment in the Naval Air Systems Command and some other places in the development chain, and authoritarianism on the part of China Lake. That

[21]S-275, Arnold interview, 43.

[22]Technical Director, NWC, to Commander, NWC, memorandum, "Agile Background," 4 June 1973, 1.

[23]Ibid., 3.

[24]Ibid., 4.

> resulted in poor communications between us and the Systems Command, and we didn't change the fundamental way we did business.[25]

LaBerge had his marching orders from Wilson and quickly took action. At the time, the Agile program was being managed at China Lake by D. P. "Phil" Ankeney, assisted by Clarence "Zip" Mettenberg in Dr. Highberg's Systems Development Department. In mid-1971, acting with the concurrence of Wilson and Moran, LaBerge switched department heads, putting Highberg in charge of the Engineering Department and moving Chenault to head the Systems Development Department where the Agile program resided. LaBerge felt that while Highberg was "bright and well intentioned," he "characteristically did not involve himself with detail and was very slow to action." Leroy Riggs saw the replacement of Highberg as a personality- and management-style issue.

> Walt was trying to do Agile as Bill McLean did Sidewinder. . . . that relationship just didn't work like it did way back in the '50s with a McLean [Technical Director] to a Newt Ward as the department head . . . . So he pulled Highberg . . . Highberg and Walt didn't hit it off, so Highberg wasn't the man.[26]

Next LaBerge hired Frank Cartwright, who was working at Philco-Ford, to return to the Center and manage the Agile Division in Chenault's department. Cartwright was a renowned engineer and missile designer who had worked on the original Sidewinder and had won the L. T. E. Thompson Award for his management of the Sidewinder 1C program (which developed the AIM-9C and the AIM-9D). He had left the Center in 1961 to go to Philco-Ford, where he worked on the Sidewinder AIM-9E. After his return to China Lake and assignment to Agile, there were some mumblings of cronyism; Cartwright and LaBerge had long worked together at China Lake, and both had worked for Philco-Ford.

LaBerge's next step was to start development of a backup version of Agile that did not use TVC but instead maneuvered with traditional aerodynamic control surfaces—forward-mounted cruciform canards and a cruciform tail. Called the aerodynamically controlled vehicle (ACV), it was a 5-inch diameter missile. An NWC report stated that

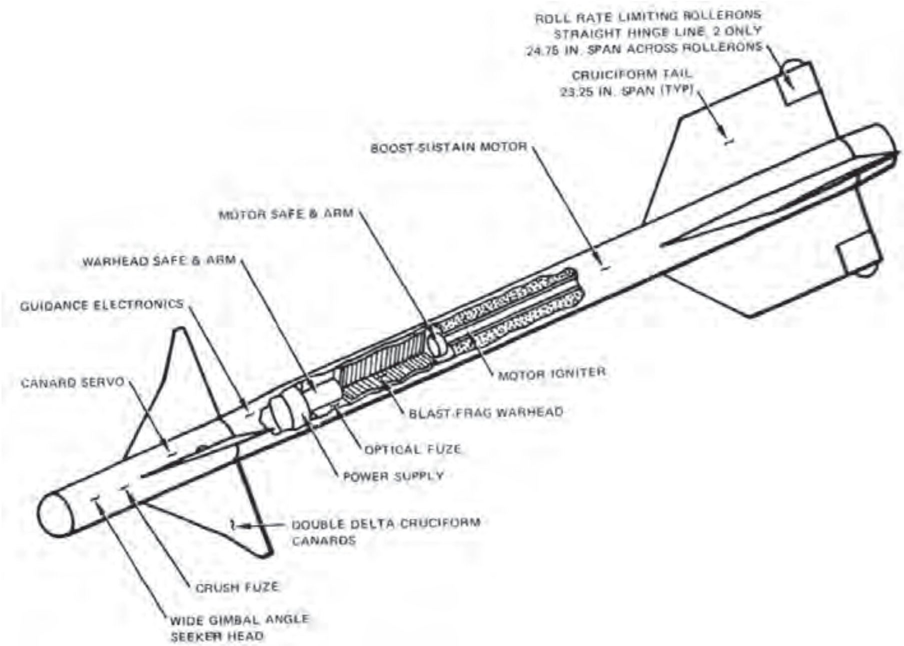
> in comparison with the TVC, the ACV missiles were allowed to have less performance while having the imposed design constraints of low risk and cost. However, the ACV missiles were designed to be much superior in performance to existing air-to-air missiles.[27]

---

[25]S-134, Hillyer interview, 30.

[26]Technical Director, NWC, to Commander, NWC, memorandum, "Agile Background," 4 June 1973, 3; S-136, Riggs interview, 73–74.

[27]NWC TM 2506, *Agile-ACV Hardware Descriptions*, ii.



Agile ACV concept. Published in *Agile-ACV Hardware Description*.

Despite the ACV program's low level of effort (LaBerge estimated it would be about 5 percent of the overall Agile program), it drew on some of China Lake's top talent: Ralph Carter, Art Gross, John Skoog, Steve Benson, Don Quist, Harry Loyal, Doug Turner, Mel McCubbin, and William Holzer. James R. Bowen, who would later head Project 2000, was the development manager.

In mid-1972, a setback occurred for the Agile program when Captain William Mohlenhoff was selected as the point of contact between NWC and NAVAIR. "He had spent a tour at Point Mugu and considered himself competent to make technical decisions," opined Arnold.

> The captain had a different idea of how he should exercise his responsibility for the "Washington scene" than did China Lake managers. There was constant friction between Mohlenhoff and the China Lake Agile project management.[28]

"There was nobody in town [Washington] to be the spokesman for the Agile program," Hillyer said. "There was so much contention between the organizations that instead of its proponent he [Mohlenhoff] became its critic."[29]

[28]S-275, Arnold interview, 43.
[29]S-134, Hillyer interview, 30.

Again, personalities were at play. Arnold said that Cartwright "had little to no tolerance for the disputatious maneuvers of Mohlenhoff who was determined to gain control of the project." Even LaBerge, who had selected and recruited Cartwright, described him as a "very brittle" person who "does not do well with people he considers dishonest or absolutely incompetent."[30]

Hillyer, admitting that he was exercising "20-20 hindsight," contended that the Center should have hired two program managers.

> One should be a civilian technical manager to run the program; the other should have been a Navy captain that you bought a credit card for, to use on the airlines, so he could go to Washington three times a month and defend the program. Because Washington requires that you do that. So the management scheme was poorly thought out.[31]

At that time, there were numerous versions of Agile in the works, with different combinations of TVC systems, seekers, airframes, and launching systems. The Agile ACV alone came in three different versions—the ACV, the All-Boost ACV, and the Austere ACV.[32]

LaBerge justified this profusion of models:

> DDR&E wanted NWC to design a cost effective missile usable by both services. It wanted demonstration of alternatives by DSARC review, and Dr. Foster said that he was relying on the technical integrity of NWC to do what was right to develop the alternatives for cost/performance selection. DDR&E, or at least Dr. Foster, was in no way constrained to the baseline Navy proposal.[33]

But from the outside—and even to some on the inside—there seemed to be too much indecision in the program. "All of these things were going in parallel," Hillyer said. "Nobody bothered to make their mind up. Nobody bothered to say, 'Hey, let's settle this down.' "[34]

Despite the apparent confusion, real advances were being made. A then-secret 1972 technical film describes the progress on the various components and technologies. One sequence shows a June 1972 test of a preprogrammed Agile flight-test vehicle. Launched from the ground, it accelerated to 1,525 feet

---

[30]S-275, Arnold interview, 43; Technical Director, NWC, to Commander, NWC, memorandum, "Agile Background," 4 June 1973, 3.

[31]S-134, Hillyer interview, 30–31.

[32]The low-risk Austere ACV version used many AIM-9L components, including the rocket motor.

[33]Technical Director, NWC, to Commander, NWC, memorandum, "Agile Background," 4 June 1973, 2.

[34]S-134, Hillyer interview, 31–32.

per second, turned to an angle of attack of 110 degrees, and then turned back to its original heading. The film recounts that

> despite angular accelerations of up to 4,000 degrees per second squared, roll rate and yaw remained under good control. Evaluations not only showed no unfavorable flight characteristics, but proved the Agile airframe to be more stable than predicted.[35]

In January 1972, China Lake physicist Floyd Kinder received a patent for a head-coupled aiming device that he developed for Agile. In 1973, George S. Burdick, head of the Avionics Branch, received the Technical Director Award for a successful demonstration of the Agile seeker, avionics, and visual acquisition system. Burdick's team had taken a Honeywell-produced VTAS, modified it to meet Agile operational requirements, and installed it in the front and rear cockpits of an F-4J carrying an Agile. Reported the *Rocketeer*:

> The Agile infrared seeker was slaved to the pilot's or radar observer's VTAS, positioned on target, and put into the automatic tracking mode. Successful acquisition, lock-on, and tracking operations were achieved by both crew men during operational maneuvers throughout the Agile missile launch envelope.[36]

In January 1973, David S. Potter succeeded Dr. Frosch as ASN R&D. Unlike Frosch, Potter had no stake in the Agile laboratory program management experiment. Six months later, on 30 May, Rear Admiral Pugh assumed command of the Center, and a week later, LaBerge was formally selected as Technical Director. (His previous 23 months of trying to "figure out how to get Agile done," per Wilson's instruction, had been as deputy Technical Director). On the same day he took over his new post, LaBerge briefed Pugh for an up-and-coming Agile conference. Among his recommendations were that both Mohlenhoff and Cartwright be moved.

No time was wasted. On 29 June 1973, the *Rocketeer* reported that Cartwright "had been selected by Dr. Walter B. LaBerge to serve as a senior technical consultant with Dr. H. A. Wilcox [Howie Wilcox, Technical Consultant to the Technical Director]." Phil Arnold was chosen to replace Cartwright.[37]

---

[35]TMP 291, "Agile, Closing the Gap," video presentation.

[36]*Rocketeer*, 13 July 1973, 3. Flying the TA-4 target aircraft was Lieutenant Mel Etheridge, son of Captain Mel Etheridge, who had been China Lake's Commander when the Agile program began.

[37]*Rocketeer*, 29 June 1973, 3.

"The China Lake Agile office functioned as a division with the program manager as division head," Arnold said.

> This arrangement was similar to that of Sidewinder where it functioned well. My preference would have been a matrix arrangement with a small program office supported by the line organization so that I could be relieved of much of the supervisory responsibility. But Agile was underway and I accepted the job as it was organized.[38]

Captain Mohlenhoff was removed by the NAVAIR Commander and replaced with Mohlenhoff's assistant, Captain James Quinn. Arnold and Quinn "immediately developed a partnership based on mutual respect," said Arnold. "The management ambiguities were removed, the program had a competent representative in Washington, and I was relieved of a major inhibitor to focus on other issues."[39]

Arnold's leadership team consisted of Lee Gaynor (administration), George Burdick (avionics, including helmet-mounted sight), Irv Witcosky (missile engineering), Jim Oestrich (system synthesis and simulation), and Don Quist—and later Fay Hoban—(seeker development). As well as a large in-house team, the program had contracts with Hughes for guidance and system integration and Thiokol for propulsion and TVC. "Probably half the base worked on Agile," Scott O'Neil remembered 40 years later. "It was a huge program."[40]

Technical progress continued under Arnold's leadership. One advantage Agile had over earlier missile development programs was a sophisticated simulation capability for use as a design tool and to augment flight testing. "The Agile simulation was a technological marvel that was absolutely necessary to design a vehicle operating in the missile's flight regime," said Arnold.

> As an example, the team had recorded radar tracks of aircraft flying mock combat—the location and velocity vectors of aircraft engaged in simulated dogfights. These tracks were then flown in simulation to test the ability of the propulsion-autopilot of the TVC airframe to handle launches anywhere in the engagement. The most stressful launch conditions, called the "hard shots," were used in defining the missile design specifications.

By 1973, the program was using data from 400 actual one-on-one aerial engagements plus 350 "dog fights" conducted in the Ling-Temco-Vought (LTV) manned combat simulator. Monte Carlo simulations, conducted by Arnold

---

[38]S-275, Arnold interview, 44.
[39]Ibid., 45–46.
[40]O'Neil, "Thrust Vector Control," video presentation.

Moline, were used to determine the effects of various missile modifications on the missile's overall capabilities.[41]

A troubled Navy budget in fiscal year 1973 caused heavy cutbacks, delaying the Agile flight-test program. Major changes were still being made in various subsystems. By the end of the year, the *Tech History* commented that "the current project tactical Agile was changed significantly from previous designs." The pyramidal seeker window was one casualty of the funding cutbacks.[42]

Baseline Agile, 1973. Published in the 1973 *NWC Tech History*.

When Secretary Potter reviewed the Agile program, Hillyer, as head of the Fuze Department, participated in the review. "He said to the Naval Weapons Center, 'Folks, what did you do with $70 million?' " recalled Hillyer.

> And so we spent a day telling him how we spent $70 million, and at the end of the day he said, "Folks, what did you do with $70 million?" So we regrouped, spent all night working, and tried again the next day, and he went back to Washington and hired Doc Freeman to change that damn place. That's not much of an exaggeration. [Freeman arrived at China Lake in June 1974.] We didn't answer his question well. The fact is we didn't spend $70 million on Agile. We spent about $20 million on Agile, and we spent about $50 million on technologies which may have had application to Agile. We should have settled the program down faster.[43]

Burrell Hays also viewed the Potter meeting as the harbinger of Agile's end:

> When Agile was killed, they were still working on five different Agiles. They had three different seeker gimbal limits, and they had two airframes. They had the tail thrust vector control and they had the canard. And, they were working on all five of them simultaneously, and they just didn't want to stand up to tell Potter that. They hadn't wasted any money in the sense that they were buying furniture or something, but they were working on five systems instead of one.[44]

LaBerge, who had been trying to fix the Agile program since he arrived in 1971, left the Center suddenly in September 1973, when he accepted the

[41]S-275, Arnold interview, 44–45.
[42]*NWC Tech History 1973*, 4-11, 4-6.
[43]S-134, Hillyer interview, 32.
[44]S-157, Hays interview, 37.

position of Assistant Secretary of the Air Force for Research and Development. Leroy Riggs stepped into the Technical Director's position behind him in an acting capacity. In his wake, LaBerge left organizational confusion; during his short tenure as Technical Director, he had instituted the directorate system, essentially adding another layer of management between the Technical Director and the department heads and elevating his three most senior department heads to lead the new directorates.

How well the new organizational structure would work was moot. "It was never given an opportunity to work," said Riggs. "Walt left a few months later. I moved over to the Ad Building [as Acting Technical Director]. I wasn't about to upset the applecart at that stage of the game."[45]

As the '70s progressed, funding became an increasing problem. Arnold said:

> The need for funding deficiencies in other programs receiving high priority in OPNAV proved stronger than support for Agile. Each October at the start of the fiscal year, the program received an injection of cash and we ramped up the team. Around December or January, funds were reprogrammed from Agile, our budget was halved, and we had to ramp back down.[46]

"I remember poor Phil Arnold just getting beat to death," Kline said. "Three months into [the fiscal year] they reclaimed half of their money . . . and then halfway through they came for more and just absolutely sucked the program dry. They cut its head off and let it die."[47]

Meanwhile, the Air Force was criticizing Agile as too costly and complicated and offered its own candidate—Dillinger referred to it as a "paper missile"—that was called, pointedly, Concept for a Low-Cost Air-to-Air Missile (CLAW). In their briefings, the Air Force officers argued that the maneuverability issue, which Agile was designed to address, would be resolved with their anticipated new high-performance fighters.[48]

Toward the end of Agile, Arnold cut back on the program, realizing that ACV with the pyramidal dome "wasn't going to be ready on the Agile schedule, if ever." So he cancelled the ACV effort. In an interview, Arnold stated that his action

> made me pretty unpopular with many smart and competent people at China Lake who had no love for the TVC. I make no apologies for canceling

[45] S-136, Riggs interview, 74.
[46] S-275, Arnold interview, 46.
[47] S-289, Kline interview, 53.
[48] S-327, Dillinger interview, 32.

> [the ACV] under the circumstances when we were fighting for the life of the program.[49]

Agile did well in its 1974 Defense System Acquisition Review Council (DSARC) review. However, Tony Battista, staff director for the R&D Subcommittee of the House Armed Services Committee, applied the program's coup de grace. As an engineer, Battista had worked at Dahlgren for Chuck Bernard, a former China Laker. On many weapons systems and weapon development issues, Battista was a strong supporter of China Lake's positions. According to Ray Miller, Battista had a

> very influential position, short of having been elected to serve on the committee. He could influence programs very readily because he had the smarts and the access to the people who made the votes and signed the legislation.[50]

Arnold claimed that former Technical Director Tom Amlie convinced Battista

> that Agile was terribly expensive, wouldn't work, and wasn't needed. Tony killed Agile. I talked to Tony during the period leading up to the Committee markup, and he was friendly enough, he just thought proceeding with the Agile program was a mistake.[51]

Although Battista may have been the immediate agent of Agile's demise, the cause was a combination of factors. Lack of effective communication and cooperation between China Lake and NAVAIR in the early years of the program was one factor, which may be blamed, in part, on Frosch's assignment of the program to China Lake management without clearly articulating the relationships and apportionment of functions between the laboratory and its principal customer.

An attempt to make one missile that would be "all things to all people" was another weakness. A reaction-controlled missile of that size could not be an effective mid-range or long-range weapon, which gave rise to the ACV variant (which could continue maneuvering after motor burnout). "When you develop a missile to do a specific job, you shouldn't knock it because it won't do something else. You want it to do what it's designed for, and do it well," said Highberg.

The absence of a single overarching vision of what Agile should be and how it should be developed was a significant problem. LaBerge might have had a vision, but once he left for the Air Force, the program began to drift. Because

---

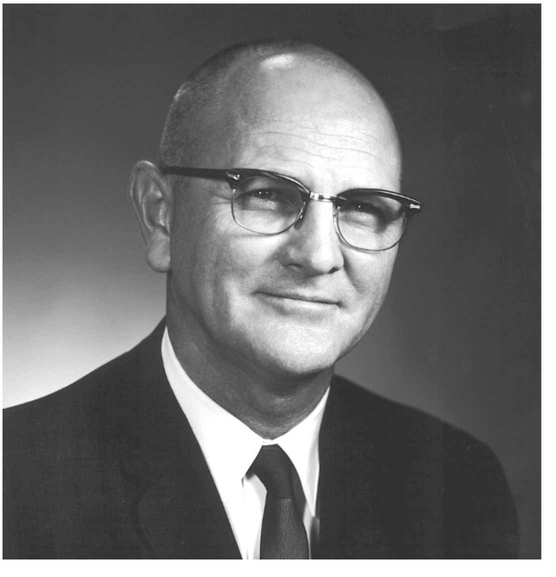
[49]S-275, Arnold interview, 48.
[50]S-262, Miller interview, 46.
[51]S-275, Arnold interview, 47–48.

the direction and goals were ambiguous to NWC, it was impossible for the Center to convince powerful people in the upper reaches of the Navy and DoD that Agile was doable and necessary.

Dr. Dick Kistler, noted warfare analyst and long-time head of the Office of Finance and Management, blamed the program's failure on NWC's inability to sell the program.

> I can remember something that Admiral Freeman said which I'll remember for a long time: that China Lake did a very good job in NAVAIR, but never got to the "E" Ring [the Admirals' offices] of the Pentagon. . . . the cancellation of the Agile program seemed incomprehensible here but the admiral's point was nobody ever sold it to the flag levels. They didn't even know what it was. It was an aggregation of NAVAIR technology programs which people thought could be put together into something pretty spectacular, but when the money started drying up it disappeared quickly, and the senior military in the Navy just couldn't care less.[52]

Ernest G. Cozzens, who worked with many major weapon systems, including a stint as project manager for Shrike, argued that the problem with Agile was one of conflicting priorities. When China Lake originally proposed Agile, it was as a long-term program:



Ernie Cozzens.

> The conceptual phase, a year or 2 years, then an advanced-development phase of 3 or 4 years, and then a full-scale development of 2 or 3 more years, and at a cost of something like a hundred and some million dollars. Well, the Navy needed the weapon, needed it badly. . . [China Lake] kept massaging three or four different versions, and the people in NAVAIR, the sponsors in 03, said, "Freeze on one and let's get into engineering development on it." And our people said, "No, we're not through," and they just kept saying that. And they just kept spending money. And when they got to $82 million and they had not yet even gotten to engineering development, the sponsor says, "They aren't going to get there. Kill it."[53]

[52]S-131, Kistler interview, 10.

[53]S-126, Cozzens interview, 8–9.

Cozzens added, "I firmly believe that it was one of the most utterly and completely mismanaged programs the Center ever undertook."

For the people who had worked on Agile, battered morale was part of the collateral damage from the program's termination. Phil Bowen explained:

> You spend a number of years of your career working on something that doesn't go anywhere. . . . A lot of blood, sweat, and tears and a lot of long hours and it's kind of frustrating . . . I think people do it, like myself, because it's a challenge and we want to do it, we want to prove we can do it. But it would be nice to have it go somewhere.[54]

The morale effects of program termination were part and parcel of the RDT&E world, where far many more programs were started than would ever wind up in the Fleet. Richard Hughes commented on the phenomenon:

> A number of people said "Everything I've done, everything I've designed is laying in a corner, never to be used." . . . Bright guys and girls left the Station because they wanted to be useful and they couldn't be useful. . . . In general, nothing they did followed on to anything, and I think this should be expected in any organization. You're given a job and, oh, this contract runs out, or we didn't get the money for this, or we proved it wouldn't work, or whatever. That's to be expected. What bothered me was that we lost a lot of really, really good engineers that tried to work themselves into a position where they could be meaningful and they couldn't do it. This was not a management problem, this is just part of the system, part of being engineers and scientists.[55]

The millions spent on Agile were not a total loss, because technologies developed for the missile resurfaced in programs as disparate as Sidewinder seekers, helmet-mounted targeting devices, the vertical-seeking ejection seat, and Navy vertical-launch systems.

One example is the trapped-ball nozzle. Agile was originally designed with the same hot-gas trapped-ball (ball-and-socket) nozzle that had been used in Quickturn. That nozzle had been designed by Thiokol, under contract to the Navy. The first Agile had a 24,000 pound-force second impulse motor, and engineers expressed concern that the Thiokol nozzle, which had 10 critical components, might exhibit overheating in sensitive areas of the nozzle.

When the Agile motor specification was increased to 30K impulse, combustion pressure rose by nearly 20 percent. In anticipation of the potential inadequacy of the 10-component nozzle, China Lake engineer Bill Thielbahr led a design team consisting of Richard Purcell, Richard Thompson, and John Patton, with assistance from Milt Wolfson, to design an entirely new

[54]S-336, Bowen interview, 22.
[55]S-353, Hughes interview, 10–11.

cold trapped-ball nozzle. The team used their experience in materials, heat transfer, and thermostructural analysis to create a nozzle with only three major components and a 70 percent reduction in parts over the Thiokol design. The team also introduced a new nozzle graphitic material, ATJS (used in atmosphere-reentry nose cones), to the nozzle-design community. The nozzle performance was demonstrated in a series of nine rocket motor/nozzle tests. The team's work resulted in a state-of-the-art TVC nozzle that employed a pneumatic actuator system.

After Agile ended, China Lake retained the documentation for the nozzle. When the Tomahawk Mk 111 TVC booster was being developed, the contractor was having difficulty with gas leaks in a hot trapped-ball nozzle. China Lake transferred the Navy-owned documentation and drawings of the cold trapped-ball nozzle to the contractor, which introduced it successfully into the booster. Subsequently, the same contractor used the China Lake-developed nozzle technology in the Mk 72 booster for the Standard Missile.[56]

Agile, in concept and technology, was well ahead of its time. Even the enemy knew it. Several years after Agile's cancellation, according to Dillinger,

> one of the first questions asked by a defecting MiG pilot was "what's the status of Agile?" They were convinced it had "gone into the black world" of hidden, more highly classified programs, but were obviously still concerned about it.[57]

Ironically, the Soviets' belief that Agile was being developed in the black caused them to ramp up efforts on their own high-tech dogfight missile—the Vympel R-73 Archer, with TVC, helmet-mounted sight, and high off-boresight capability—that began development in 1973 and was fielded in 1982.[58]

Today, U.S. Navy and Air Force pilots rely on the Sidewinder AIM-9X as the principal weapon for short-range air-to-air combat. This $600,000-per-round missile employs TVC (jet vane, rather than movable nozzle), a helmet-mounted cueing system, and the ability to lock on targets up to 90 degrees off-boresight. The -9X's technology and materials are far more advanced than its predecessor missiles, but its technological and conceptual roots go back 40 years, to the AIM-95, the ill-fated Agile.

---

[56]The nozzle was revisited by China Lake engineers in 1978-79, resulting in a greatly simplified design and the fabrication of a flight-weight nozzle and blast shroud weighing only 11.3 pounds. *NWC Tech History 1979*, 4-11.

[57]Dillinger, "TVC Beginnings," 2.

[58]Ibid.

9

A Moral Awakening

There is no Black Navy, no white Navy—just one Navy—the United States Navy.

—Vice Admiral Elmo R. Zumwalt Jr. on racism[1]

Black Americans

When President Harry S. Truman signed Executive Order 9981 on 26 July 1948, it met with immediate resistance from the military services. The order stated plainly, "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 majesty of that statement was weakened somewhat by the sentence that followed: "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."[2]

Segregation in the military—in barracks, mess halls, job assignments—was deeply entrenched, and the fight for full integration would be a long uphill battle. Integration received a boost in 1950 when several all-white Army units were badly mauled during fighting in Korea and drew their replacements from all-Black support units operating in the rear. Not surprisingly, in hindsight, the integrated units performed as well as the segregated ones. Although controversy surrounded the performance of the all-Black 24th Infantry Regiment in Korea, two of its members were posthumously awarded the Medal of Honor, the nation's highest award for valor. Stereotypes began to be challenged.

---

[1]Z-Gram Z-66, "Equal Opportunity in the Navy," 17 December 1970, accessed 14 January 2013, http://www.history.navy.mil/faqs/faq93-66.htm.

[2]Executive Order 9981, "Establishing the President's Committee on Equality of Treatment and Opportunity in the Armed Services," 26 July 1948, quoted in *Freedom to Serve, Equality of Treatment and Opportunity in the Armed Services, A Report by the President's Committee* (Washington: United States Government Printing Office, 1950), xi.

Soon Blacks were signing up to join the Army in such large numbers that they could no longer be accommodated in the all-Black segregated units, and by the end of the war, Blacks were being integrated into formally all-white units without the catastrophic results that had been predicted by the foes of an integrated military.

By the mid-1950s, nearly all branches of the military services had been integrated, at least nominally. There was still a long way to go before the proportions of Blacks and whites in the military reflected those in the general population. For example, in 1962—when the percentage of Blacks in the U.S. population was 11 percent—the percentage of Black enlisted personnel in the Navy was only 5.1 percent, and the percentage of Black officers in the Navy was a mere 0.2 percent.[3]

Integration did not mean equality. Blacks, particularly in the Navy, were concentrated in the lower levels of the officer and enlisted ranks, and on both the military and civilian sides of the Navy, Blacks were usually assigned the most menial positions: stewards, truck drivers, laundry workers, grounds keepers, and the like. The key to moving minorities into positions on a par with white employees was equal employment opportunity (EEO).

EEO became an issue for China Lake—and indeed for the entire U.S. Armed Services—in March 1961, when President John F. Kennedy signed Executive Order 10925 establishing a Committee on Equal Employment Opportunity. The committee, chaired by Vice President Johnson, included the Secretary of Defense and each of the service secretaries, among other senior officials. The committee's goal was "to realize more fully the national policy of nondiscrimination within the executive branch of the Government." The order extended the obligation of EEO to all government contractors and subcontractors as well.[4]

In June 1962, President Kennedy's nondiscrimination policy was implemented in the Navy via Navy Civilian Personnel Instruction 713. Captain Quensé (NOTS Executive Officer) was initially designated the Center's Deputy Employment Policy Officer, responsible for administering the Navy's equal employment policies at the Station. Later that year, the responsibility was assigned to Captain Blenman, the Station Commander.

[3]Gesell, *Equality of Treatment and Opportunity,* 6.

[4]The American Presidency Project, John F. Kennedy, "Establishing the President's Committee on Equal Employment Opportunity," Executive Order 10925, 6 March 1961, accessed 22 June 2021, https://www.presidency.ucsb.edu/documents/executive-order-10925-establishing-the-presidents-committee-equal-employment-opportunity.

Captain Blenman appointed a five-member EEO Advisory Committee in 1963. It was chaired by John L. Cox, an NWC mechanical engineer. (Cox, who was white, fully appreciated the value of employment opportunity; after graduating from Caltech with an engineering degree in 1932, during the Great Depression, the only work he could find was at a service station, changing tires for 10 cents an hour.)[5]

Initially, EEO activity at China Lake was reactive, not proactive. EEO procedures were triggered only when someone complained of discrimination or preferential treatment based on race. As the article in the *Rocketeer* introducing Cox's EEO committee put it, the committee would try to "resolve incipient complaints of discrimination expeditiously and informally." The announcement also noted, however, that "the work of the advisory committee does not deprive the individual of his right to file a formal complaint under this program." Attesting to the effectiveness of this process, China Lake's first formal EEO complaint was not filed until 1971, and in that case, "all of management's actions were sustained."[6]

A framework for EEO dispute resolution had been established, but it did little to change the status quo. The President's Committee on Equal Employment in the Armed Services reported in 1963 that

> many of the Negroes in the Navy and Marine Corps are still grouped in assignments which perpetuate the image of the Negro as a menial or servant in respect to the total activities of these Services, and it will take some time before the more recent assignment trends rectify this discrepancy.[7]

Harold Metcalf, a chemical engineer and associate head of the Weapons Development Department, relieved Cox as chair of the EEO Advisory Committee in February 1964. Years later Metcalf recalled that the problem was not one of prejudice in hiring at China Lake but rather the lack of an upward path for minority employees once they were hired:

> I don't think people are saying, "This person is a minority so we ought to keep him down." It probably was he didn't have the training he needed to be the best-qualified person or to be equally qualified, and so it involved looking into possibilities of apprentice opportunities that would place a person in a position for upward mobility.[8]

A 2-month review of China Lake's EEO program conducted by the Personnel Department in 1964 found some areas "where additional effort is

---

[5]*Rocketeer*, 22 October 1971, 7.
[6]*NWC Tech History 1971*, 1-15.
[7]Gesell, *Equality of Treatment and Opportunity,* 18.
[8]S-236, Metcalf interview, 29.

needed to improve the program" but noted that the committee "has provided an opportunity for employees to discuss the problems of discrimination in an informal manner and has resolved these issues in a sound fashion." Captain Blenman found the results "generally favorable" but added that he and Dr. McLean "do not feel that they offer opportunity to relax vigilance against discrimination."[9]

EEO at the Station seemed to be moving forward slowly, if without great urgency. All that changed in the summer of 1965.

On the evening of 11 August 1965, what began as a routine traffic stop of a young Black man by a California Highway Patrol officer quickly escalated into a confrontation as a crowd gathered. The officer called for backup, but the situation rapidly spun out of control. Within hours, arson, looting, and destruction began to spread, eventually encompassing an area of more than 40 square miles. The rioting—called the Watts Riots or, by some, the Watts Rebellion, after the Watts neighborhood in which the violence started—lasted 6 days, claimed more than 30 lives, and resulted in $40 million in property damage.

Watts was a wake-up call to the nation. Black Americans' anger in America's large cities had reached the boiling point. The problems that fed that anger—discrimination, segregation, overcrowding, police brutality, lack of economic opportunity, substandard schooling—could no longer be ignored. Less than a year later, the Division Street Riots erupted in Chicago. Then in July 1967, 26 people died when rioting struck Newark, New Jersey. A week after Newark, a riot began in Detroit that would ultimately leave more than 40 people dead, hundreds injured, and thousands of buildings destroyed.

While the Detroit rioting was still underway, President Johnson established the National Advisory Commission on Civil Disorders under the leadership of Illinois governor Otto Kerner. The Kerner Commission was directed to find out what had shattered the civil peace, why it had happened, and what could be done to prevent it from happening again. In remarks made when he signed the order establishing the commission, President Johnson told the members, "We are asking for advice on short-term measures that can prevent riots, better measures to contain riots once they begin, and long-term measures that will make them only a sordid page in our history."[10]

---

[9] *Rocketeer*, 27 March 1964, 5.

[10] The American Presidency Project, Lyndon B. Johnson, "Remarks Upon Signing Order Establishing the National Advisory Commission on Civil Disorders," accessed 27 December 2012, http://www.presidency.ucsb.edu/ws/?pid=28369.

Seven months later, on 29 February 1968, the commission issued its report—a scathing indictment of white racism and failed racial policies. It recommended major government programs that would have cost billions of dollars. President Johnson, whose administration had already passed the Civil Rights Act of 1964 and the Voting Rights Act of 1965, rejected the commission's findings. Less than 5 weeks after the report was released, Dr. Martin Luther King Jr. was assassinated, an event that precipitated rioting in scores of cities throughout the nation.

The Indian Wells Valley was never seriously in danger of seeing such riots—the community lacked the aggravating elements of overcrowded minority housing, high unemployment, and hostile relations between police and residents that characterized most of the rioting cities. However, antiwar protests were turning violent across the country as well. Despite its dependence on the Department of Defense, the community did have its share of antiwar sentiment.

On 9 August 1968, the *Rocketeer* carried a "reminder to civilian personnel regarding the provisions of Public Law [90-351], Section 7313 on riots and civil disorders." Public Law 90-351 was the Omnibus Crime Control and Safe Streets Act, which had been passed into law less than 2 months previously. The law declared that "Congress finds that the high incidence of crime in the United States threatens the peace, security, and general welfare of the Nation and its citizens" and created the Law Enforcement Assistance Administration, banned interstate trade in handguns, established warrant procedures for wiretaps, and increased the Federal Bureau of Investigation (FBI) budget by 10 percent.[11]

The section of the Omnibus Act that was cited in the *Rocketeer* article amended Title V of the U.S. Code (which governs civil service employees) to require that any person convicted of "inciting, . . . organizing, promoting, encouraging, or participating in a riot or civil disorder" or of "aiding and abetting any person" so doing would be ineligible to hold any position in the U.S. Government.[12]

Rioting continued in the summer of 1968, and overt manifestations of Black Americans' discontent were not confined to the nation's inner cities. The military services also experienced violent episodes attributable to Black Americans' anger over unfair treatment. Initially, the most serious incidents

[11] *Rocketeer*, 9 August 1968, 2; Omnibus Crime Control and Safe Streets, Public Law 90-351, 82 Stat. 197 (19 June 1968), accessed 12 March 2013, http://transition.fcc.gov/Bureaus/OSEC/library/legislative_histories/1615.pdf.

[12] Omnibus Crime Control and Safe Streets, Public Law 90-351, 82 Stat. 197 (19 June 1968), accessed 12 March 2013, http://transition.fcc.gov/Bureaus/OSEC/library/legislative_histories/1615.pdf.

were in the Army and the Marine Corps. On 29 August 1968, at the Army's stockade near Long Bìhn, Vietnam (the Long Bìhn Jail, or LBJ as it was called), Black prisoners took over the prison, beating white prisoners and guards. That same month, prisoners (mostly Black) at the Third Marine Amphibious Force brig took over the brig for 24 hours. Black Marines at Camp Lejeune rioted in early 1969, killing one white Marine. In Vietnam on the night of 5 February 1970, a Black Marine threw a grenade into a crowd of white Marines watching an Australian girl band at an enlisted club near Da Nang. One marine was killed and more than 60 wounded.

The war was putting a strain on U.S. military manpower. Even though compulsory military conscription—the draft—was in effect, the Army and Marine Corps had lowered their enlistment standards to bring in educationally disadvantaged youths. This step was necessary to meet high enlistment quotas caused by the buildup of ground troops in Southeast Asia. The Navy, meanwhile, partly owing to the more sophisticated technologies associated with its weapon systems and platforms, became a haven for smart young men who wanted to avoid ground service in Vietnam. The phenomenon was called "draft-induced volunteerism." Better, the reasoning went, to enlist in the Navy or Air Force than to be drafted and end up carrying a rifle in the jungles of Southeast Asia. Thus, by 1968, according to one researcher, when Blacks represented about 11 percent of the U.S. population, "blacks made up 13 percent of the Army, 10 percent of the Air Force, 8 percent of the Marines, and 5.6 percent of the Navy."[13]

Richard M. Nixon, in his campaign for the presidency in 1967, had endorsed the all-volunteer military concept. When he was elected in 1968, he ordered the draft to be phased out by 1973. Melvin Laird, Nixon's Secretary of Defense, realized that with the end of the draft, the supply of bright youngsters who had joined the Navy to avoid ground combat would soon dry up. The Navy would have to cast its net further to fulfill its manpower obligations. As one historian explained:

> Without conscription, these individuals [the draft-induced volunteers] would avoid service altogether, compelling the Navy to recruit lower test category personnel, including large numbers of Blacks, just as the Army and Marine Corps had been doing throughout the war. Laird believed that the racial unrest suffered by its sister service might soon spread to the Navy.[14]

At China Lake, the various Commanders had complied with the then-in-force requirements of equal opportunity. The base had the required committees

[13]Flynn, *The Draft*, 206.
[14]Sherwood, *Black Sailor, White Navy*, 30.

established and programs in place. In 1966, a team from the base, including the Executive Officer, Captain Leon Grabowsky, addressed a meeting of the local National Association for the Advancement of Colored People (NAACP). Captain Grabowsky outlined the program and advised the audience to familiarize themselves with the Navy Manual on Equal Opportunity. “It is about a 15-page manual and is the Bible in this area,” he told them. Harold Metcalf, head of the Center’s EEO Committee, told the group, “We are not policemen. We try to advise on complaints in informal discussions. However complaints may always be filed through formal channels.” He added that of the four discrimination complaints handled by the committee to that date, discrimination had not been found in a single one.[15]

Roy Wilkins, Executive Director of the NAACP, was a member of the Kerner Commission. In March 1968, Wilkins and several NAACP officials visited China Lake and Ridgecrest at the invitation of the local NAACP chapter. On base, they discussed the Center’s EEO efforts with, among others, Technical Director Tom Amlie, Executive Officer Captain Robert Williamson II (Captain Etheridge was away from the Center), and Metcalf.

At the time, the multipurpose room at Burroughs High School was the largest off-Center venue in the valley, and it was chosen as the site for Wilkin’s talk. The meeting was open to the public and many local dignitaries were present. Ridgecrest Mayor Ken Smith (who was also a member of the local NAACP chapter) presented Wilkins with the seal of the city.

Wilkins spoke on the subject of civil rights, and at the conclusion of his presentation, the floor opened for questions. In the audience was Rod McClung, who had come to the base in 1946. McClung knew from personal experience that the community had come a long way in terms of race relations; he told an interviewer that in his early days at the base, “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.” Wilkins affirmed McClung’s feelings:

> I remember Mr. Wilkins said, “Look, there’s no place that’s perfect, but take my word for it. What you’ve got here is far better than most of the rest of the country.” And at that point we began to feel better about ourselves. We felt we had achieved some progress. We had gotten some Black supervisors and some Black professionals.[16]

[15]*Rocketeer*, 18 February 1966, 3.
[16]S-188, McClung interview, 70–71.

A civil-rights discussion at NWC among (from left) Dr. H. Claude Hudson, Roy Wilkins, Jesse Scott, and James Jefferson, all of the NAACP, and Captain Robert Williamson II, NWC Executive Officer. Published in the *Rocketeer*, 29 March 1968.

In 1969, the Center's EEO Committee, still under Metcalf's leadership, took a new tack: instead of merely trying to resolve EEO complaints and disputes, it began to take steps to increase the representation of minorities in non-traditional—for them—roles. More than 60 people attended a January public meeting of the committee and the local branch of the NAACP. For the first time there was mention of "affirmative action." The *Rocketeer* announced that information about the Center's affirmative action plan would be forthcoming in future issues. Affirmative action had been mandated for government contractors since September 1965 through President Johnson's Executive Order 11246, but it was not made applicable to the civil service until August 1969 through President Nixon's Executive Order 11478.[17]

In April, the EEO Committee announced that the Center's affirmative action plan was initiated "to go one step beyond the minimal requirements" of President Kennedy's original 1961 EEO mandate. The new plan would ensure "equal opportunity not only in employment but also in employee development,

[17] *Rocketeer,* 24 January 1969, 9.

on-the-job training, educational opportunities and promotional opportunities." Affirmative action was a significant shift from mere equal opportunity. The program would "seek out those who, through lack of retraining or education, have gone as far as they can go, but who have the potential to become more valuable employees to the Center." Training classes for supervisors had begun in February.[18]

An all-hands message from Secretary of Defense Laird in June stressed the importance of affirmative action, stating:

> The social implications of this program, and elementary fairness, require that a great deal be accomplished in a short time. . . . Proper administration of our program must necessarily include actions to remedy employment problems created in the past.[19]

In December 1969, Robert E. Hampton, chairman of the Civil Service Commission, reiterated President Nixon's mandate for affirmative action. He further stated that statistical information for minority group employment would be maintained "on ADP [automatic data processing] equipment" and that an agency evaluation plan would "furnish comprehensive data for the periodic information and personal attention of the President."[20]

Nicholas Oganovic, Executive Director of the Civil Service Commission, was blunt about the issue, telling federal managers that anyone who failed to pursue an active EEO program would be looking for a new job. Among his recommendations, which he said should be considered "mandates," was that "every manager must embrace equal employment opportunity in a new perspective. It must be a part of every consideration." Regarding the EEO program he said, "We have been playing a game of catch-up and now must move ahead."[21]

Affirmative action came none too soon, because by 1970, the Navy was experiencing severe personnel problems. The reenlistment rate for first-time enlistees was about 10 percent, a third of what it had been a few years before. The draft was winding down as the pace of the war in Vietnam slowed. (The last three men to be drafted into the Navy were inducted in November 1971.) Secretary of the Navy John Chaffee realized that the Navy had to make major changes to meet its personnel requirements in terms of numbers and skill

---

[18]*Rocketeer,* 18 April 1969, 5.

[19]*Rocketeer*, 20 June 1969, 7.

[20]*Rocketeer*, 12 December 1969, 3.

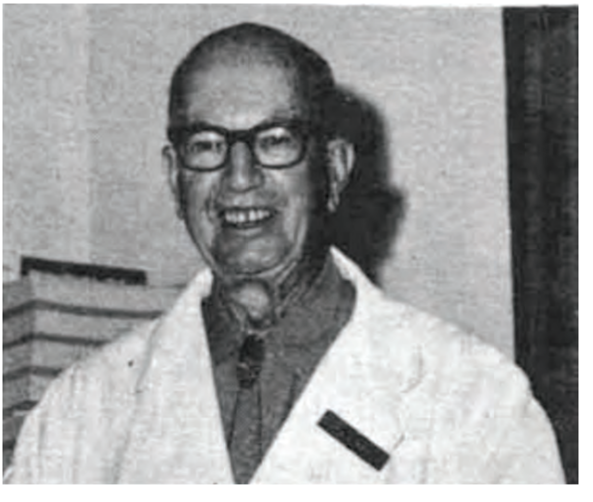
[21]NWC, "Agencies Warned on Minority Employment" (excerpted from *Federal Times*, November 1969), *News and Views, Point of View and Information on Management Matters*, September–October–November 1969, 3.

levels. At the same time, the Navy needed to raise the percentage of Blacks in the service.

Admiral Thomas H. Moorer, a former China Lake Experimental Officer, served as the Navy's CNO from 1967 to 1970. From that post he was selected to be Chairman of the Joint Chiefs of Staff—the nation's highest ranking military officer. To replace Moorer as CNO, Secretary Chaffee wanted someone who would take bold steps to improve the Navy's personnel structure.

At the time, Vice Admiral Elmo R. Zumwalt Jr., a 49-year-old Naval Academy graduate, was serving as Commander, Naval Forces Vietnam. Zumwalt had graduated from the Academy with distinction in 1942. He was a protégé of Paul Nitze, who served as Secretary of the Navy from 1963 until 1967. As well as having impeccable command credentials, Zumwalt was well versed in personnel matters, having served a tour in the Office of Naval Personnel as a detailer (the individual who matches available naval personnel with billets that need filling). A 2-year stint as Secretary Nitze's executive assistant and senior aide (1963 to 1965) had familiarized him with the workings of Washington politics.

Coincidentally, Vice Admiral Zumwalt's father, Dr. Elmo R. Zumwalt Sr., served as China Lake's industrial medical officer from 1964 to 1972. (He died in 1973 at age 81.) When Vice Admiral Zumwalt was serving as Commander of Naval Forces, Vietnam, he would have occasion to fly into China Lake to meet with representatives of the Vietnam Laboratory Assistance Program (VLAP) and the Navy Laboratory Analysis Augmentation Group–Vietnam (NLAAG-V) and to visit with his parents.


Dr. Elmo Zumwalt Sr.

Secretary Chaffee interviewed Zumwalt and liked the cut of his jib. He recommended Zumwalt for CNO (passing over 33 more senior naval officers), and in April 1970 President Nixon formally nominated Zumwalt for the position. In July Zumwalt was promoted to full (four-star) admiral and took office as CNO, becoming the youngest man ever to hold that position. The slow progress toward minority equality in the Navy was not good enough for the new CNO. From its founding up through the 1960s, the Navy had been, in Admiral Zumwalt's word, "lily white." He was determined to revitalize the service and to change the rhetoric of EEO into a reality.

Mention Admiral Zumwalt to any sailor who served in the 1970s and they will talk about "Z-Grams." The Office of the Chief of Naval Operations (OPNAV) routinely issues Naval Operations messages (NAVOPS) for distribution to all hands in the Navy. Admiral Zumwalt's NAVOPS carried a "Z-" designation before the NAVOPS number to make it clear to one and all that the messages issued directly from him and were on matters in which he had a personal interest.

Z-Grams were the new CNO's tool of choice for implementing what he called Programs for People, the purpose of which were to make the Navy an attractive option for young people when compared with the other services or the civilian economy. He grouped his Z-Grams (he issued 120 between July 1970 and April 1974) into four categories: personal behavior, operational schedules, increased responsibility and opportunity for advancement, and, he wrote, "the fourth and most important was to throw overboard once and for all the Navy's silent but real and persistent discrimination against minorities."

In the first category came NAVOPS Z-57, "Demeaning and Abrasive Regulations, Elimination of." (Zumwalt originally wanted to call it "Mickey Mouse Regulations, Elimination of," but his Vice CNO, Admiral Ralph Cousins, dissuaded him.) Z-57, issued in November 1970, liberalized Navy regulations regarding hair length, beards, sideburns, civilian clothing, uniforms, conditions of leave, operation of motorcycles, and many other "quality of life" issues. The *Rocketeer,* announcing the Z-Gram in a front-page article, quoted the admiral: "The worth and personal dignity of the individual must be forcefully reaffirmed." The portion of the instruction relating to hair grooming caused such a ruckus that the CNO issued a clarifying Z-Gram 2 months later. It was again discussed in a front-page *Rocketeer* article under the headline "Admiral Zumwalt Contends: 'Beards Do Not Detract From Navy's Mission.' "[22, 23]

Generally, Zumwalt's Z-Grams were well received by junior Navy personnel. When radioman first class Jerry Lee Pixler was selected as China Lake's Bluejacket of the Month in May 1971, he was asked by a *Rocketeer* reporter if he was a career man. Pixler replied, "Certainly. The Navy is really a nice life, especially now with Admiral Zumwalt and the Z-Grams." He added,

---

[22]*Rocketeer*, 20 November 1970, 1.
[23]*Rocketeer*, 29 January 1971, 1.

Radioman first class
Jerry Lee Pixler.

with un-sailor-like eloquence, "He is rapidly making the Navy palatable to young men."[24]

It was Z-66, issued in December 1970, that directly confronted racism in the service. In his typically candid and direct style, Zumwalt wrote:

> Last month, Secretary Chafee and I, along with other senior officials of the Navy department, met on one occasion with representative Black navy officers and their wives and later with a representative group of Black enlisted men and their wives. Prior to these meetings, I was convinced that, compared with the civilian community, we had relatively few racial problems in the Navy. However, after exploring the matter in some depth with these two groups, I have discovered that I was wrong—we do have problems, and it is my intention and that of Secretary Chafee to take prompt steps toward their solution.[25]

What followed was a barrage of action items. All Commanders and Commanding Officers would appoint a minority officer or senior petty officer as the special assistant for minority affairs who would "be consulted on all matters involving minority personnel." Shore-based commands would ensure that a minority group wife was included in the Navy Wife Ombudsman Program (established by Z-24). Ship stores would stock Black grooming aids, and commissaries would stock Black cosmetics. Barbershops would have "at least one qualified Black barber/beautician." The message specified that Black books, magazines, and records would be available in libraries, wardrooms, and clubs. It promised that Zumwalt's special assistant for minority affairs, Lieutenant Commander William Norman, would meet with minority personnel and their dependents and that Zumwalt and Secretary Chaffee would continue to look into the matter and issue further reports.[26]

Z-66 concluded with the now famous line: "There is no Black Navy, no white Navy—just one Navy—the United States Navy."[27]

---

[24]*Rocketeer*, 28 May 1971, 8.

[25]Z-66, "Equal Opportunity in the Navy," 17 December 1970, accessed 14 January 2013, http://www.history.navy.mil/faqs/faq93-66.htm.

[26]Ibid.

[27]Ibid.

Zumwalt's initiatives did not go down smoothly in the Navy. Major racial incidents occurred aboard several Navy vessels in the fall of 1972: a racial riot in which at least 47 people were injured aboard USS *Kitty Hawk* (CVA-63), a smaller riot that left five injured aboard USS *Hassayampa* (AO-145), and a Black sit-down strike and near mutiny aboard USS *Constellation* (CVA-64). The incidents were exacerbated by extended duty off of Vietnam, long (18- to 20-hour) working days, little shore leave, and drug use. Minor racially based incidents were documented on scores of naval vessels over the next 2 years.

Part of the blame for these incidents was white backlash against the rapid pace of Zumwalt's progressive policies and part was Black sailors trying to accelerate that pace. *Time* magazine characterized the situation as "rising civil-rights expectations rubbing against static reality" and ascribed the core of the problem to "stubborn residual racism among the Navy's 'middle management.' "[28]

Zumwalt's response to the three major shipboard incidents was immediate. He held a meeting for Washington flag officers (admirals) on 10 November 1972 that he opened to the press. He made it crystal clear that he felt racial discrimination was a failing of leadership:

> I am now directing, via this speech and in a communication to all Flag Officers, Commanders, Commanding Officers, and Officers in Charge that every effort be made to . . . make equal opportunity a reality and discrimination, for any reason, an unacceptable practice."[29]

He also directed them to "place equal opportunity and race relations training at the same priority level in their training programs for officer and enlisted personnel as professional performance in the operational billet tasks assigned." He concluded his stem-winder by telling them what he believed was the key to addressing the racial difficulties. "It is not a push to the far edge of the untried I am suggesting, gentlemen. It is a return to our oldest and most proven tradition. Command by leadership."[30]

That same day, 14 November 1972, he issued Z-Gram 117, "Good Order and Discipline." It was printed in full in the *Rocketeer* 3 days later, pursuant to Zumwalt's request that it be given the widest possible dissemination. "The prejudice against good order and discipline is as bad as the prejudice of race," Zumwalt stated. Just as he had lectured the admirals on leadership, he lectured the sailors, in particular "those of our more junior personnel who have entered the Navy in this period of transition," on the importance of discipline, "the

[28]"Armed Services: Keelhauling the United States Navy," *Time*, 11.
[29]Zumwalt Jr., *On Watch*, 237–238.
[30]Ibid., 237–238.

intelligent obedience of each for the effectiveness of all," and in particular of their responsibility for self-discipline. "This self-discipline and subordination of self for the good of all is absolutely mandatory for any organization, civilian or military, to function properly. It cannot be any other way."[31]

As might be expected, traditional conservatives—inside and outside the military—were appalled at the changes Zumwalt was bringing to the Navy and had been railing against what they derisively called Zumwalt's "three B's—beer, beards, and broads." Many of the CNO's critics coupled the racial incidents aboard Navy ships with the "permissive" nature of Admiral Zumwalt's Programs for People, and by 1972, dissatisfaction with Zumwalt's program resulted in an investigation by the House Armed Services Committee. The committee was chaired by Felix Edward Hébert, Democratic representative from Louisiana's First Congressional District and a staunch conservative who had opposed school desegregation and the 1964 Civil Rights Act. Hébert selected Floyd V. Hicks, a Democratic congressman from Washington, to lead the investigation to

> inquire into the apparent breakdown of discipline in the United States Navy and, in particular, into the alleged racial and disciplinary problems which occurred recently on the aircraft carriers USS *Kitty Hawk* and USS *Constellation*.[32]

In its final report, the Hicks committee pilloried Zumwalt's racial programs—concluding that it was a breakdown in discipline, rather than racism, that led to the shipboard incidents. The negative findings, however, did little to slow the implementation of Zumwalt's equal opportunity goals, which still had the strong backing of the Secretary of Defense and the new Secretary of the Navy (John Warner, who had replaced John Chaffee in May 1972).

At China Lake, affirmative action became the order of the day. In 1971—the same year that Samuel Lee Gravely Jr. became the Navy's first Black to attain the rank of rear admiral—the *Rocketeer* ran a three-part series titled "The Black Man in the Navy." The articles described the historical participation of Blacks in the U.S. Navy and chronicled their many contributions to the service (though the text waffled between use of the term "black" and "negro"). Features such as this were designed not only to instill pride and a sense of naval heritage in Black sailors but also to educate their white shipmates to a side of naval history that had long been ignored.[33]

Similarly, Negro History Week, which had begun in 1926, was celebrated at the Center for the first time in 1971, although a cautious or confused *Rocketeer* editor chose to label it "Black (Negro or African-American) History Week." The

---

[31] *Rocketeer*, 17 November 1972, 1.

[32] 92nd Congress, 2nd session, H.A.S.C. 92-81, "Racial Incidents."

[33] *Rocketeer*, 5 February 1971, 3; 12 February 1971, 2; 19 February 1971, 5.

following year it was called "Afro-American History Week," as Black Americans struggled to replace "negro" with a term that conveyed a new identity and a rejection of decades of second-class citizenship. "Afro-American History" remained the term used until 1983, when "Black" became the preferred usage.[34]

Nomenclature, however, was not the issue. Dr. Clyde Aveilhe, Associate Director of the Educational Testing Service, speaking to an audience of 180 people at China Lake's Black History Week Banquet in 1979, said, "It doesn't matter what Blacks are called. We need cooperation and support to achieve equality."[35]

Dr. Clyde Aveilhe.

Recruitment became an important element of providing equal opportunity for all races. In 1973, a subcommittee was established on the Center Recruiting Panel "to assist in recruiting minorities and women." "Members of the committee," stated the current EEO brochure, "will recruit at such institutions as Tuskegee Institute, Tennessee State, and New Mexico State, and will also recruit at high schools and junior colleges in Southern California, appealing especially to minority graduates."[36]

Racial awareness classes began at China Lake in 1974. This training was part of the Navy's Understanding Personal Worth and Racial Dignity (UPWARD) program. UPWARD, a DoD-wide program that had begun in 1969, was at heart a mechanism to enhance the image of the Armed Services and to attract and keep highly qualified people in both the military and civil service.

When Admiral Zumwalt took over as CNO, he chose to make universal racial awareness training the centerpiece of the first phase of the Navy's

[34] *Rocketeer*, 26 February 1971, 5; 11 February 1972, 2.

[35] *Rocketeer*, 16 February 1979, 1. Black author Keith Boykin has written, "I don't care if you call yourself Negro, colored, African American or black (in lower case or upper case). . . . The true diversity of our people cannot be fully represented by any one term."

[36] TS 74/86, "Unequal Opportunity is a No-No at NWC." The first two schools cited are "historically black colleges and universities": schools established before 1964 to serve the Black community. New Mexico State is a self-described "minority-serving institution."

UPWARD program. He felt that this would show that there was indeed racism in the Navy and help develop ways to combat it.

At the forefront of the training were racial awareness facilitators (RAFs), who were sailors, usually working in teams, one Black and one white, who were specially trained in techniques that were very similar to the Erhard Seminars Training, which was a popular 1970s self-realization technique. Typically, a 3-day RAF training session involved face-to-face discussions of difficult subjects in which attendees came to grips with their own beliefs, attitudes, presumptions, and stereotypes. During the final 4 hours of the course, each participant was asked to take some positive action toward alleviating racial injustice.

By August 1975, three UPWARD seminars a month were being held at China Lake for both military and civilian personnel. The events were so popular that two Air Development Squadron Five (VX-5) RAFs, chief data processing technician Chester C. Tussey and third class aviation jet mechanic Bennie R. McCargo Jr., were invited to share their program with children at the China Lake elementary schools. Rear Admiral Rowland G. Freeman III, NWC Commander, speaking of the 3 full days the course required, said, "I view this as a very small price to pay in the interest of doing something positive to reduce

Third class aviation jet mechanic Bennie McCargo (far left) and chief Chester Tussey (second from right) conducting a VX-5 UPWARD seminar. Published in the *Rocketeer*, 22 February 1974.

both personal and institutional prejudice and bigotry." By 1975, the Navy's first time reenlistment rate had increased from its 1972 low of 10 percent to nearly 40 percent.[37]

The process of ending racism in the Navy and improving the lot of Black sailors and civilians did not happen overnight—it was not until 1978 that the Navy's Black enlistment rate matched the percentage of Blacks in the general population. And the struggle for equality continued. It was not until 1996 that J. Paul Reason, who has since retired, became the first and only Black four-star admiral. But because of the courageous actions of Presidents Kennedy, Johnson, and Nixon and of naval officers like Admiral Zumwalt, discrimination against Blacks in the Navy was dramatically reduced, replaced by successful affirmative-action programs that eventually brought Blacks into positions of leadership in both the civilian and military sides of the service.

Women

To say that sexism—a term coined about 1963 as a conflation of "sex" and "racism"—was rampant at China Lake in the 1960s would be accurate but unfair. Sexism was rampant throughout the country, and both men and women were caught up in what Anna Quindlen called "the mystique of waxed floors and perfectly applied lipstick." With a few notable exceptions, China Lake's laboratories and, heaven forbid, the ranges, were no place for the "delicate sex."[38]

Manifestations of sexism could be amusing. For example, a 1971 *Rocketeer* photograph of local artist Ruth Meyer standing beside one of her paintings bears a cutline that begins "ONE MAN SHOW—The painting of Ruth Meyer. . . ." Other examples were demeaning. Leroy Jackson remembered when, during the mid-1950s, community manager Richard C. O'Reilly established a skirt-length requirement at the Station Theater. "For the theater, young girls would have to come in and get down on their knees, and they would measure from the floor to the tip of the skirt, and the skirt had to be within so many inches from the floor."[39]

---

[37] *Rocketeer*, 1 August 1975, 1; data from NAVSO P-3523, "Budget and Forces Summary," cited in Zumwalt Jr., *On Watch*, 533.

[38] Anna Quindlen, in the introduction to Friedan, *The Feminine Mystique*, 13.

[39] *Rocketeer*, 1 October 1971; S-186, Jackson interview, 9.

This cartoon from the 15 April 1960 *Rocketeer* captured the prevailing attitude toward the roles of men and women.

It was generally accepted that the job of a married woman at China Lake was to tend the home fires and support her husband's job. To do otherwise could have serious consequences, particularly among the military. Tony Tambini, a Navy Commander who served as a project pilot at China Lake from 1961 to 1965, wrote that

> officers who had the misfortune of being married to wives who were outspoken were told that if they couldn't control their wives, then they damn sure couldn't control their troops. Fitness reports of these unfortunate officers suffered . . . For them, China Lake was a miserable place to be.[40]

Men and women were different, the popular reasoning went, and certain activities, professions, types of behavior, etc., were appropriate for women, while others were not. Although the same reasoning applied for both genders, the range of options available for men was far greater than that for women.

Not only men but many women as well believed in distinct and appropriate gender roles when it came to employment. Some were housewives, or those

[40]Tambini and Tambini, "The Flying Tambinis," 9.

planning to become housewives, who felt that "a woman's place is in the home." Others were female employees in traditionally female jobs: telephone operators, secretaries, typists, waitresses, etc. There seemed to be a general amnesia of the fact that during WWII, a mere two decades prior, women had built ships, driven trucks and tractors, ferried aircraft, and done all manner of "unfeminine" work.

Even some professional women who had succeeded in mostly male and mostly white professions shared the entrenched beliefs. When Mary Moore, the Navy's only female patent advisor, visited the base in 1958 to set up procedures for the Patent Division, she told the *Rocketeer* that she considered patent law "a good field for women because much of the work is quite detailed and women tend to excel in professions requiring particularity."[41]

America has always had a small and vocal group of women (and a few men) who rebelled against gender-assigned roles. They had fought for women's right to vote in the early years of the 20th century and were fighting for legal rights and employment equality during the second half of the century. By the 1960s, the concepts of feminism and women's equality were spreading quickly, particularly on college campuses and among young people. And, as with the fight against racism, strong leaders stepped up to lead the fight. Friedan, Bella Abzug, Shirley Chisholm, and others would become household names as they pressed for gender equity.

In 1961, President John F. Kennedy established the Commission on the Status of Women, chaired by Eleanor Roosevelt, widow of President Franklin D. Roosevelt. Two years later the Federal Women's Program was established to help implement the commission's recommendations (essentially, eliminating employment discrimination and unequal pay for men and women), and the same year the Equal Pay Act of 1963 prohibited discrimination in pay based on gender.[42]

President Lyndon B. Johnson's 1965 Executive Order 11246 prohibited discrimination in employment because of "race, color, religion, or national origin." In October 1967, he amended this mandate through Executive Order 11375, which added the word "sex" after "religion." At a time when newspapers still routinely carried classified sections advertising for "Help Wanted, Men" and "Help Wanted, Women," that move was a bold one, yet it reflected a growing sentiment in the nation that if a woman could do a job, she should be given the opportunity.

---

[41] *Rocketeer,* 21 February 1958, 1. The same issue carried a photograph of the T&E Department's newest crop of Junior Professionals: 22 men and 1 woman.

[42] Several former members of the President's Commission were among the founders of the National Organization for Women (NOW) in October 1966.

The Office of Personnel Management (OPM) integrated the Federal Women's Program into the Equal Opportunity Program in 1969. Subsequent OPM regulations required that federal agencies designate a Federal Women's Program manager to advise on matters affecting women's employment and advancement.

At China Lake in the early 1960s, there were a few women in positions of leadership, but they were overwhelmingly outnumbered by their white male counterparts. That would not soon change. As the decade progressed, however, indications appeared that women were moving into traditionally "men only" areas. For example, Don Herigstad, who spent a 40-year career designing weapons at the base, was vice president of the Sierra Gun Club in 1968 when he helped organize a firearms orientation program for women. In addition to classroom instruction, the women spent 2 weeks on the NWC Pistol Range learning to operate handguns. A premise of the program (which was sponsored by, among others, the Indian Wells Valley (IWV) Civil Defense Council and the China Lake and Ridgecrest chiefs of police) was that when such training was offered in other communities, "the criminal realizes that women are no longer as defenseless as they used to be."[43]

In an attempt to raise the visibility of women's roles in NWC's technical programs, the *Rocketeer* ran a photo spread titled "Women Play Prime Role in Center Technical Mission" in March 1970. Featured in their work settings were several of China Lake's top professional women: architect Catherine "Katie" Bell; cartographer Carmen Burkhalter; chemists Dr. Marion Hill, Dr. June Amlie, Carol Panlaqui, and Mary Pakulak; engineers Nancy Carter and Bertha Ryan; mathematicians Jane Bachinski, Amy Griffin, Janice Zenor, and Margaret Zulkoski; physicists Dr. Jean Bennett and Dr. Marguerite (Peggy) Rogers; and engineer Diane Thompson.[44]

It was a dazzling display of talent, but among the group was only one division head (Rogers) and one branch head (Griffin). Upper management at China Lake was still an overwhelmingly male domain and would remain so for many years.

In October 1970, Margaret A. "Nancy" Raphael was appointed the first federal women's coordinator at China Lake. Raphael was a mathematician in the IR Systems Division of Frank Knemeyer's Weapons Development Department. Raphael was outspoken in her criticism of inequality for women. In a 1971 Employee in the Spotlight article, she asserted:

[43]*Rocketeer*, 12 July 1968, 3.
[44]*Rocketeer*, 20 March 1970, 1.

> The prevailing attitude in the education of women, from the first grade up, is to be housewives, secretaries, school teachers, and nurses. In order for a woman to be educated in the professions—mathematics, engineering, medicine, law, science—the woman must be a loner. She will suffer from all sorts of attitudes ranging from cynicism to snobbery and humiliation. For a woman to succeed in any type of job she must have a BA degree to do the same kind of work that a man can do with an eighth grade education.[45]

By this time, there was a backlash to the increasing activism of women. The woman's liberation movement, as it was often called, was targeted for criticism, and women who fought for equal rights were often ridiculed as "women's libbers." (West Virginia Senator Jennings Randolph characterized the women's liberation movement as "a small band of bra-less bubbleheads.") Despite Nancy Raphael's harsh critique of the male-dominated status quo, the unknown *Rocketeer* writer who interviewed her commented that "Nancy is no women's-libber."[46]

Nancy Raphael.

As awareness of the gender inequities grew, people began to see evidence of sexism that had been long overlooked. In 1971, the *Rocketeer* published a defensively toned article titled "Females Can Cause Big Trouble Especially If They're Hurricanes." The writer noted that the practice of naming hurricanes after women—begun in 1953, replacing the Army/Navy phonetic alphabet system (Able, Baker, etc.)—"has been criticized recently by crusaders for women's rights, some of whom consider it derogatory." George P. Cressman, Director of the National Weather Service, was quoted as saying:

> We intend no slur on women. In fact quite the opposite. Hurricanes are among the most awesome forces in nature. No other storms equal them in combined strength, length of life, and power. Forecasters regard them with great respect.[47]

[45] *Rocketeer*, 28 May 1971, 7.
[46] "Women Demand Equal Rights," *Los Angeles Times*, 30 August 1970, F5.
[47] *Rocketeer*, 30 July 1971, 3.

Those who perpetuated sexist behavior were on the defensive, and the momentum for women's rights was building. The National Organization for Women (NOW) had picketed the U.S. Senate in February 1970 and followed up with the Women' Strike for Equality in August. The Equal Rights Amendment (ERA)—"Equality of rights under the law shall not be denied or abridged by the United States or by any state on account of sex"—originally written in 1923, was finally introduced in Congress and was passed on 24 March 1972.[48]

More significant to China Lake than the ERA was the release on 7 August 1972 of Admiral Zumwalt's Z-Gram 116: "Equal Rights and Opportunities for Women in the Navy."

The previous December, Zumwalt had sent a newsletter to his flag officers that dealt with the issue of retaining Navy women. He wrote in part:

> Nothing is so demoralizing and disheartening to the young RM2 [radioman second class] WAVE [Navy women] who graduates at the top of her "B" school class and is then assigned at her new command to such stimulating duties as running the ditto machine and keeping the coffee mess going. There may be a number of attitudes at work here—e.g., the professional jealousy of the male supervisor who cannot admit that the woman can do the job as professionally as her male counterpart, or the complete bewilderment of the division officer who has never had a professional woman working for him before and doesn't quite know what to do with her! In the former the misuse is deliberate, in the latter it's thoughtless—but in both it adds up to a real waste of talent.[49]

Z-116 opened up a host of opportunities for women—including, for the first time, the assignment of women to sea duty. In his memoir, Zumwalt admitted that in Z-116 he anticipated passage of the ERA, "which would make most restrictions on female service in the armed forces of doubtful constitutionality."[50]

The effect of Z-116 at China Lake was almost instantaneous. Three days following its release, radioman seaman Elizabeth Vass reported for duty at China Lake as a teletype operator in the Message Center. "The Naval Weapons Center's first regular duty enlisted woman in recent years," proclaimed the *Rocketeer*. By December of 1972, seven Navy women were serving at China Lake, including one officer (Lieutenant Rosemary Waller) and one 28-year veteran, Master Chief Avionics Technician Italia Birkinsha, who had enlisted during WWII because "I thought I could help."[51]

---

[48]The ERA failed to gain the requisite 38-state ratification that would have made it law, despite President Jimmy Carter's 39-month extension of the original 7-year deadline.

[49]Zumwalt Jr., *On Watch*, 262.

[50]Ibid., 283.

[51]*Rocketeer*, 18 August 1972, 8.

Radioman seaman Elizabeth Vass is welcomed aboard NWC by Captain D. W. Alderton, NWC Deputy Commander.

Elizabeth B. Beggs, special adviser to the Assistant Secretary of the Navy on the Federal Women's Program and Federal Women's Program coordinator for the Navy, spoke at China Lake in November 1972. Beggs was an aerospace electronics engineer and had previously been NAVAIR's project engineer for the Sidewinder guidance and control unit as well as NAVAIR's administrator of guidance and control technology. Still, the *Rocketeer* writer could not resist describing her as "the recently promoted (to GS-16) Alexandria, Va., housewife."[52]

Beggs used numbers to illustrate the depth of the women's equality problem in the Navy and specifically at China Lake. Across the Navy, about 92 percent of women were employed in grades GS-8 or lower. Only 0.6 percent were GS-15 or above. China Lake was not much better, with 83 percent of women in the GS-8 or lower grades. In NWC's workforce of more than 4,500, only 13 women—about 0.3 percent—were in the GS-13 to GS-15 range. Beggs told the audience frankly that she would have expected NWC to have a more

[52]*Rocketeer*, 24 November 1972, 3.

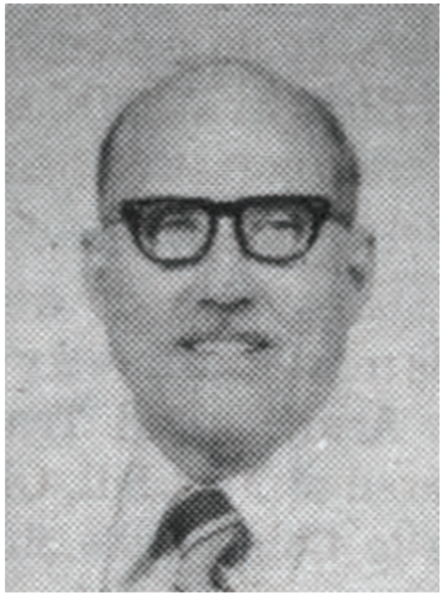
impressive record. "NWC is better than the Navy-wide situation," she said, "but not good enough."[53]

Lieutenant Rosemary Waller confers with personnelman Senior Chief Petty Officer Clarence Hicks in the Naval Air Facility (NAF) Personnel Office.

As corporations and government agencies scrambled to make things right, the competition to hire qualified women science-and-engineering graduates increased dramatically. China Lake recruiters were handicapped: they could not meet the starting salaries of their industrial competitors. They could, however, offer something that—to the rare person—was even more attractive: the opportunity to serve one's country while doing exciting, hands-on work.

[53]Ibid.

James R. Wills was a mathematician in the Fuze (later Fuze and Sensors) Department who had come to China Lake with the Corona Laboratories physical consolidation in 1971. Along with his fuzing work (among other accomplishments, he led the development of the Sidewinder AIM-9L target-detecting device), Wills also took a leadership role in China Lake's Junior Professional program and was an active recruiter for the Center. On a 1972 trip to the University of Idaho (UI), Moscow, he was one of several recruiters who spoke at a seminar for prospective employees.



James Wills.

One of the students in attendance recalled:

> He had this tiny little box, a little cube, in his hand. He stood in front of the room and he said, "I love my job. This is a fuze and the fuze goes into a weapon. [China Lake] is the only place I know where you can take your ideas, put them on paper, have them built, put them on a weapon or some other technical/mechanical thing and then they're useful for the world and you can defend your country." Wow, I thought.[54]

For this particular student, though, Wills had competition. This was a woman with a bachelor of science in mathematics, near to earning her master's in electrical engineering. "Ross Perot's company [Electronic Data Systems] down in Texas wanted to hire me very badly for a lot of money," she recalled. "But they didn't want to hire me, they wanted to hire my gender." Bell Labs also wanted to hire her, for the same reason.

> The fellow from the Navy, Wills was his name, he didn't say anything like that . . . He said you can come and you can use your brain and you can use your skills and you can do something worthwhile and I said, "Where do I sign up?"[55]

The next year, Karen Higgins was designing and developing software and digital hardware at China Lake. Two and a half decades and another degree later, after a career that included stints as the Sidewinder technical project manager and head of the Weapons/Targets Department, Dr. Higgins was selected as

[54]S-334, Higgins interview, 4.
[55]Ibid.

Executive Director of the Naval Air Warfare Weapons Division: the highest civilian position at China Lake.

Dr. Karen Higgins.

Pressure for equality was not confined to employment. Fall of 1973 saw a blossoming of women's sports at China Lake with the inaugural game of the Woman's Flag Football League. In August, Carol Benton, sports publicist for the Special Services Division, began the Femme Line column on the paper's sports page to "disseminate the woman's point of view in the world of sports." Of China Lake's female gridiron athletes, Benton wrote:

> Such enthusiasm could never be matched in a men's game. And these are sexy women on the field—not libbers and tough girls. The girls are eager to play and just as eager to play properly. They take instruction and suggestions well from their coaches and managers, who, for the most part, are men. Can you imagine men taking direction from women? Wow! And the girls on the bench are ladies, too. There is no foul language nor abusive gestures.

Later that month, kegler Pat Brightwell took home Athlete of the Month honors, the first time a woman had done so since the inception of the award in 1968.[56]

The year 1973 brought another first for women in the Navy, and at China Lake. Jo Anne Hellman was a 23-year-old Fuze Department Junior Professional with a degree in mechanical engineering. In January 1973, she was notified that she'd been selected as one of eight women nationwide to participate in the Navy's first flight training program for women.[57]

Of course, women in the Indian Wells Valley were not all abandoning their traditional roles to become pilots, pistol shooters, and football players. However, they did take an increased leadership role in community and civic

[56]*Rocketeer*, 10 August 1973, 6, 10; 26 October 1973, 6.

[57]Ms. Hellman dropped out of the program in June 1973 after marrying Lieutenant James Wilsey, USN. *Gettysburg* [Pennsylvania] *Times*, 12 June 1973, 7.


Jo Anne Hellman.

affairs and used a growing sense of empowerment to tackle new initiatives. In 1974, Rose Varga and several other women in the China Lake / Ridgecrest community formed a group called We Care. Its aim was simple: "To take over where the other organizations leave off." The group offered transportation to those who needed it, "whether it's to the beauty parlor, or the doctor." "The whole idea," Varga said, "is to be a good neighbor, a real friend." We Care later evolved into the Rose Varga Discretionary Fund and has continued to carry out its original mission of helping those who need it. In 2010, the City of Ridgecrest named a park for Rose Varga; it lies at the intersection of Ridgecrest and China Lake Boulevards, the site of Ridgecrest's first stoplight in the early 1980s and traditionally the center of town.[58]

Attaining women's equality at China Lake was an evolutionary, rather than revolutionary, process. It might have progressed more quickly—this was, after all, an educated, progressive community—but there were other factors at work.

The most obvious constraint was supply and demand. China Lake could not hire more females for senior positions than there were qualified women available, and that number in turn was limited by the rate at which women graduated from university technical programs. Mathematician Lillian Regelson, who came to China Lake in 1951, had her own branch by 1954, and moved on to the Environmental Protection Agency in 1969, saw the problem first hand:

> I tried hard to hire women scientists without much success. There were very few women studying math and science; when I was at UCLA there were no

[58] *Rocketee*r, 2 August 1974, 5.

> female math majors, either undergraduate or graduate. It took a long time for that to change."[59]

UI was one of the chief sources of engineers at China Lake. (In the 1973 Center reorganization, three of the new department heads were from the university, as was then-division head Bob Hillyer. Engineer Marc Moulton commented that "we got called the Idaho Mafia, because there were so many of us around at one time.") A look at the gender composition of the university's graduates is instructive. In 1960, women represented only 8 percent of those receiving bachelor of science degrees from UI. By 1970, that had increased to 25 percent. In 2010, it had reached a more equitable 45 percent.[60]

Another barrier to women's advancement was the entrenched belief that certain types of work simply weren't appropriate for women. Those perceptions began to crack in 1975 with the institution of the Center's Upward Mobility Program. Envisioned as a means to move people from lower-graded positions of limited promotional potential into fields with advancement potential, the 2-year training program provided an avenue for women to move out of the secretarial pools and into both blue collar and white collar fields.

The program's popularity exceeded its capacity: 136 applicants filed a total of 221 applications for the first three positions. Two of the first three trainees selected were women. By August 1975, nine employees had been placed in the program, seven of them women. They were being trained in fields that traditionally had been male domains, including electronics and mechanical engineering technicians, budget analysts, and procurement specialists.

In the Public Works Department, women began to train in the trade positions, which had long been almost exclusively male. Andrae "Andy" Holloman left her job as a Telmart (telephone ordering system) operator in the Supply Department to hire on as a trainee sign painter helper, and was surprised by the attention that this move attracted from the *Rocketeer*. " 'I don't see what all the fuss is about,' she said, demurely. 'My college training is in graphics and design, and sign painting should be right up my alley.' "[61]

The first selection of a female as Bluejacket of the Month, the honor accorded to an outstanding China Lake petty officer, came in 1975. The *Rocketeer* article describing yeoman third class Martha Zielke's accomplishment concluded with "one interesting note, AMH1 Zielke [Dan, Martha's husband]

---

[59]Lillian Regelson to the author, email, 2 September 2008.

[60]University of Idaho, *Sixty-Fifth Commencement*, 5 June 1960; University of Idaho, *Commencement Program*, June 1975; University of Idaho, *Degrees Conferred*, 2010–2011, June 2011.

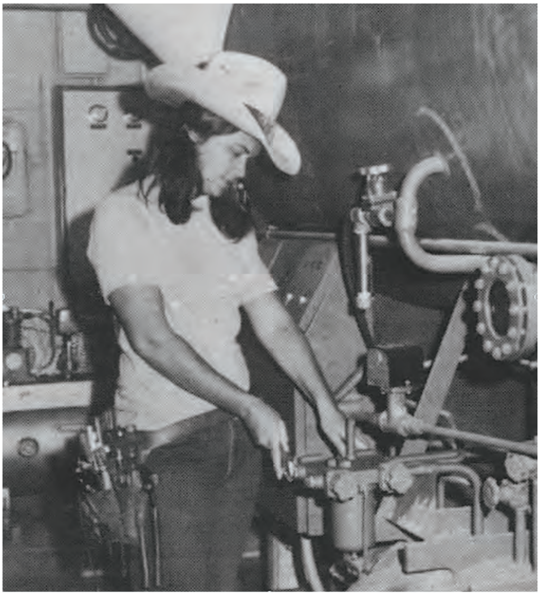
[61]*Rocketeer*, 13 September 1974, 4.

Yeoman third class Martha Zielke.

does all the cooking. 'I hate to cook,' the first female Bluejacket of the Month noted."[62]

In NWC's officer ranks, 1977 saw the arrival of Lieutenant Rosemary Conatser, the Navy's first female A-7 pilot. Lieutenant Conatser mentored many female aviators, who called themselves "Rosemary's babies." One local China Lake woman who was inspired to fly by Conatser was Frank Knemeyer's daughter Elizabeth, who became an Air Force pilot and later flew for United Airlines.

In 1979, Ann Stark, a former secretary, became the first woman in the history of China Lake's Public Works Department to earn her journeyman status. The air conditioning and refrigeration mechanic had trained for 4 years for the position. Other trade positions for which women were training included electricians and high-voltage linemen.



Ann Stark.

Gradually, through the 1970s, women's access to senior management positions increased. In September 1974, Marguerite "Peggy" Rogers became the first woman technical department head at China Lake as well as the first woman at China Lake to achieve "supergrade" status (GS-16, the forerunner of the Senior Executive Service pay scale that would be enacted in 1978). Progress was not rapid—it would be 19 more years before another woman, Linda Andrews,

[62] *Rocketeer*, 10 January 1975, 4.

took a technical-department-level position (the Weapons Planning Group, in 1993).

Dr. Jean Bennett, probably the most honored woman scientist in the history of China Lake, spoke to an interviewer for the Optics Society of America shortly before assuming the presidency of that group in 1986.

> I believe that discrimination for women is decreasing, and some of that remaining is in the eyes of the women who want to blame their lack of achievement on something other than their lack of effort. So I think it behooves all of us to work hard and try to do our very best.[63]

And work hard China Lake women did. Whatever "glass ceiling" still existed at the base was shattered in July 1998 when Dr. Higgins assumed China Lake's senior civilian position.

Advancement in leadership roles was not so rapid for women on the military side of the Navy. The first Navy woman to make rear admiral lower half (one star, the lowest of the four active flag ranks) was Alene Duerk, Director of the Nurse Corps, in 1972. The first to earn the fourth star of full admiral was Michelle J. Howard in July 2014. (Admiral Howard is also Black.) It is notable that no Navy woman officer, nor any Black or Hispanic officer, has ever commanded China Lake, the Navy's premier RDT&E laboratory. Not yet, anyway.

[63]"New President Shares Her Views," *Optics News*, January 1986, 30.

10

Conflagration

The ability of Navy combatants to operate effectively has been degraded by catastrophic explosions from unintentional initiation of munitions.

—Operational Requirement: Insensitive High Explosives[1]

For as long as there have been ships, fire at sea has been one of the mariner's greatest fears. Naval ships were especially vulnerable to the dangers of fire because they carried ordnance. Aircraft carriers were in greatest danger because of the huge quantities of aircraft fuel on board as well as thousands of items of aircraft weaponry—bombs, rockets, gun ammunition, and flares.

Fires aboard U.S. Navy ships weren't a new phenomenon nor, in the 20th century, a rare one. Most troubling, their occurrence persisted despite inquiries, review boards, recommendations, and adoption of new firefighting tools and practices. In 1953, USS *Leyte* (CVS-32) was undergoing refurbishment in Boston when an explosion and ensuing fire claimed the lives of 37 men. In 1961, seven sailors died in a fire on USS *Saratoga* (CV-60) while at sea. Fires aboard USS *Ranger* (CVA-61) in 1959 and 1965 took three lives. USS *Oriskany* (CVA-34) suffered a fire in 1966 that killed 44 and put the ship out of action for months. These fires did not only cause death, they also caused countless millions in damages and reduced Fleet readiness.

The incident that shocked the nation and spurred the Navy to unprecedented efforts in controlling and preventing fires was the disaster on USS *Forrestal* (CV-59) on 29 July 1967. An accidental Zuni rocket firing on the ship's deck during combat operations resulted in a fire and explosions that ultimately killed 134 sailors, injured 161, caused over $72 million in damage to the ship, destroyed 21 aircraft valued at more than $44 million, and damaged another 40 aircraft. Repairs took about 2 years.[2]

---

[1]OR No. S-0363-SL, "Operational Requirement (OR) Insensitive High Explosives (IHE)," quoted in Beauregard, *History of Insensitive Munitions*.

[2]Chief of Naval Operations to Judge Advocate General, memorandum, "Investigation of *Forrestal* Fire," Encl. 1, 21 August 1969; NWSY TR 85-5, *Explosive Accidents Involving Naval*

Crew members fight fire aboard the *Forrestal*, 29 July 1967.

Raging fire, sustained by some 40,000 gallons of fuel from damaged aircraft, was the principal destructive agent in the *Forrestal* incident. Equally significant, however, was the destruction caused by ordnance exposed to fire. About 90 seconds after the fire started, bombs began to go off. (The first one to explode killed 26 men.) Nine major explosions (one 500-pound bomb, one 750-pound bomb, and seven 1,000-pound bombs) occurred during the fire, and rockets and missiles also cooked off, causing further fatalities and spreading the fire. Bombs blew holes in the decks and allowed the burning fuel to spread to the interior compartments.

The Navy lexicon classifies such incidents as mishaps:

> unplanned events or a series of events, which interfere with or interrupt a process or procedure and may result in a fatality, injury, or occupational illness to personnel or damage to property. They occur as a result of failing to identify and reduce or eliminate hazards.[3]

Munitions, 13. See also Stewart, *Impact of the USS Forrestal's 1967 Fire*. A vivid description of the *Forrestal* fire is presented in JOC John D. Burlage, "Brave Men of the USS *Forrestal*," *Naval Aviation News*, October 1967, 6, and a riveting account of the *Oriskany* incident and the courageous onboard firefighting response is contained in Moser, "A Carrier's Agony."

[3]OPNAVINST 5102:1D, MCO P5102.1B, *Mishap and Safety Investigation*, 2-1.

The Russell Report

The Navy immediately ordered an inquiry into the *Forrestal* fire. Two panels investigated the disaster. The first panel, which is required in such incidents, sought to find the cause of the accident and affix responsibility. This group, headed by Rear Admiral Forsyth Massey, began work on 3 August 1967; its final report was submitted on 29 August and released on 19 September. The findings of the Massey panel focused on shortcomings in firefighting and damage-control procedures and equipment. The report cited a multitude of causes, including poor procedures, inadequate training, and insufficient equipment. As to the responsibility, although it noted several shortcomings and errors on the part of various personnel from the ship's Commanding Officer on down, it concluded that "the deaths and injuries resulting from the fire aboard *Forrestal* on 29 July 1967 were not caused by the intent, fault, negligence, or inefficiency of any person or persons embarked in *Forrestal*."[4]

A second panel was established by Admiral Thomas Moorer, CNO, on 21 August. This was the Aircraft Carrier Safety Review Panel, under the leadership of retired Admiral James S. Russell, a former naval aviator who had served as Vice CNO. The panel's report was submitted on 16 October 1967.[5]

Though spurred by the *Forrestal* fire, Russell's group looked at broader issues of aircraft carrier safety. It received 76 separate briefings from organizations across the Navy—Frank Knemeyer, head of NWC's Weapons Development Department, briefed the panel on the safety features designed into the weapons developed at China Lake.

Russell's recommendations were wide in scope, ranging from extending the tour of attack carrier Commanding Officers to 18 months ("to achieve greater command stability and continuity") to improving training and usage manuals (citing such problems as "red printing on manuals to be used in darkened spaces at night").[6]

In the aftermath of the report, NAVAIR set up the Aircraft and Ordnance Safety Program to develop tests for measuring cookoff times and to investigate

---

[4]Chief of Naval Operations to Judge Advocate General, memorandum, "Investigation of *Forrestal* Fire," Encl. 1, 21 August 1969, 120.

[5]In 1957, as Chief of the Bureau of Aeronautics, Russell had offered Dr. McLean the position of chief scientist at Point Mugu; Dr. McLean had declined, commenting, "I consider my position as Technical Director of the Naval Ordnance Test Station the most challenging and interesting civilian scientific position in the Navy. . . . My interest in being able to see a job through to completion and in having the tools available to do it will probably keep me working here as long as these conditions exist." McLean to Russell, letter, Code 01/WBM:nft, NOTS, 29 May 1957.

[6]Russell, *Safety in Carrier Operations*, A-91, A-83.

insulation and thermal-protection materials to protect warheads from heat-induced detonation.[7]

Hazards of Electromagnetic Radiation to Ordnance (HERO)

Several of the recommendations in the Russell Report were directly pertinent to work that was being done, or could be done, at China Lake. Recommendation No. 1-17 called for a HERO survey to be conducted for every aircraft carrier after each inter-deployment maintenance period in a Navy shipyard "or major modification to electronic equipment." Complementing this recommendation was No. 4-6, which urged that

> present efforts to design and deliver HERO-safe new production munitions continue at high priority and that stocks of non-HERO-safe ammunition be restricted from carriers and limited to use only on shore-based aircraft.[8]

The latter restriction was presumably given because an electromagnetic-radiation-induced incident would be less disastrous on a shore base than on a ship.[9]

Electromagnetic radiation, fire, and shock—at levels sufficient to detonate an explosive—are, in the jargon of munitions developers, "unplanned stimuli." NOTS had been working to overcome the challenges that electromagnetic radiation posed to ordnance since the late 1950s.

China Lake engineer Frank Wentink, speaking of the 1950s vintage Sidewinder AIM-9B, noted:

> We did have a few little problems, as I recall, with the electrical connections. They weren't HERO-safe, and they were suspected of perhaps having caused a few problems with inadvertent firings. . . . Even though we don't know an awful lot about it now [1971], we do know more than we did then.[10]

"Problems with inadvertent firings" were dangerous enough on the test range, but on an aircraft carrier they could be—and had been—catastrophic. One difficulty with HERO compliance was that it was a moving target—new emitters (for communications gear, jammers, radar, etc.) created new potential hazards for existing weapon systems; what might be HERO-safe one day might not be the next. HERO plans developed for weapons sometimes required that when a certain type of ordnance was on the carrier deck, a specific emitter

---

[7]In the early 1980s, the program became the Insensitive Munitions Technology Transition Program (IMTTP).

[8]Russell, *Safety in Carrier Operations*, A-49, A-70. Both NWC and NWL, Dahlgren, made presentations on HERO to the Russell group.

[9]Ibid.

[10]S-198A, Wentink, et al. interview, A13.

system had to be shut down. When complied with, this could impact the ship's communications or situational awareness. If not complied with, the consequences could be fatal. These problems needed to be coordinated between designers of both ordnance and emitter systems, who were often working in entirely different organizations.

In 1958, the Station organized the Electromagnetic Compatibility (EMC) Group with a charter "to investigate the causes for accidents due to exposure of weapons to electromagnetic fields and to develop safety measures to prevent future accidents." In its HERO efforts, China Lake worked closely with Naval Weapons Laboratory, Dahlgren, which was charged with performing final weapon testing to demonstrate an ordnance item's resistance to electromagnetic radiation.[11]

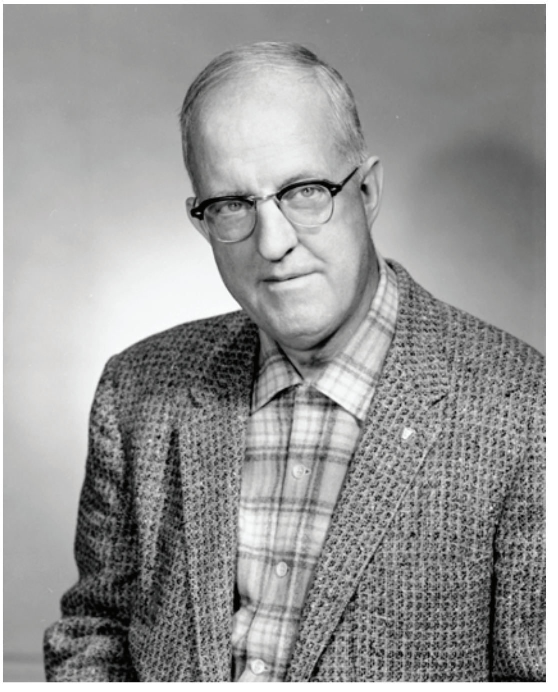
In 1959, NOTS had developed a modification for the 2.75-inch Folding-Fin Aircraft Rocket (FFAR) Aero 7D launcher that "eliminates the danger of accidental firing of rockets by exposure to ambient electromagnetic fields existing on the flight deck of an aircraft carrier." The Station had developed "dummy round" instruments to measure the amount of energy delivered to firing devices; the instrumentation packages were sufficiently compact and sensitive to be used even with small explosive devices, such as launcher ejection cartridges.[12]

Ted Lotee.

China Lake hosted a 2-day HERO seminar in 1966 with participants from around the Navy; Ted Lotee of the Engineering Department delivered the keynote address. China Lake's efforts in HERO from 1958 to 1969 were directed by Russell N. Skeeters, who, according to the *Rocketeer*, was "known from ship-to-shore

[11]NWC TM 2426, *Environmental Impact of Naval Weapons Center Activities*, 153.
[12]*NOTS Tech History 1959*, 200–201.

for the past 10 years as NWC's 'Mr. HERO.' "[13]



Russ Skeeters.

By the mid-1970s, the EMC Group had broadened its role to take a more holistic approach to the electromagnetic environment. Its subdisciplines included not only HERO but also

> radiation hazards to personnel; electromagnetic vulnerability (EMV) of the weapon system to external radiating sources; electromagnetic interference (EMI) experienced or caused by the weapon and its interface with its platform and nearby equipment; the effects of electromagnetic pulse (EMP) caused as a result of a nuclear detonation; and special electromagnetic interference (SEMI) created to deceive or cause malfunctions in electro-optical, infrared, and laser weapons.[14]

Carrier Aircraft Support Study (CASS)

In July 1968, the CNO directed the Chief of Naval Material (CNM) to provide quarterly updates on progress in meeting the recommendations of the Russell Report, and in November NAVAIR established a CASS group. Although the CASS final report would not be released until 1971—a mammoth 14-volume study, with the safety volume alone running to over 500 pages—and implementing instructions and milestones would not be released until 1974, the CASS team was active in carrier-safety efforts from its inception.[15]

Admiral Moorer, in early 1968, had assigned Captain Frank W. Ault to do an end-to-end review of the Navy's air-to-air missile systems. This action was prompted by the poor showing the U.S. missiles were making against enemy aircraft in the skies over Vietnam. Among other things, Ault's wide-ranging

[13] *Rocketeer*, 29 April 1966, 7; 7 February 1969, 7.

[14] *NWC Tech History 1976–1977*, 11-20.

[15] Systems Associates, *Carrier Aircraft Support Study (CASS)*; CNM, *Milestone Schedule and Status Report*.

report, commonly known as the *Ault Report*, considered the safety aspects of air-to-air weaponry.[16]

Ault observed that "although considerable progress has been made since issuance of the 'Russell Report' in October 1967, there remain numerous 'loose ends' in the safety areas associated with air-to-air missiles." He also stated that "safety requirements are frequently in conflict with operational requirements, if not contradictory and confusing per se."[17]

On 15 January 1969, less than 2 weeks after the *Ault Report* was issued, disaster struck the Navy again. This time it was USS *Enterprise* (CVAN-65), the Navy's first nuclear-powered aircraft carrier, which was operating about 70 miles southwest of Pearl Harbor. An operational readiness inspection was underway.

It started with the loud boom of a rocket warhead going off. The official report of the investigation stated that

> at about 0815 an MD-3A jet aircraft starter unit was positioned on the starboard side of an F-4J, aircraft side number 105, such that its exhaust outlet was in line with and within twenty-four inches of a loaded LAU-10 Zuni rocket launcher mounted on the starboard wing of the aircraft.[18]

The exhaust temperature of the starter unit, 2 feet from the exhaust port, was approximately 590°F. (A temperature of 358°F was sufficient to detonate a Zuni warhead, which contained 15 pounds of Composition B HE.) At 0819, the warhead exploded.[19]

Aircraft No. 105 and the MDA-3 were at the aft end of the flight deck in a group of 15 aircraft that carried a total of 34,000 gallons of JP-5 fuel. The aircraft were also loaded with Mk 82 bombs, Zuni rockets, and 2.75-inch rockets. The resulting fire, and the explosions resulting from ordnance cookoff, killed 27 men and injured 344. Damages ran to $50 million, and 15 aircraft were lost.

---

[16]A dozen years earlier, then-Commander Ault and Leroy Riggs had constituted the entirety of the Navy's Astronautics Office in Washington, which had been hastily established in response to the Russian's launch of Sputnik.

[17]Ault, *Capability Review* (*Ault Report*), 46, 20.

[18]*Investigation into the Enterprise Fire*, vii.

[19]Ibid.

Battling the *Enterprise* fire.

Problems with starter-unit exhaust overheating ordnance had been documented in several incidents in the Fleet, though there had been no actual explosions. Despite the awareness, the safety procedures used by the crew did not incorporate specific guidance regarding this danger. The investigating board found that the primary cause of the accident was the design of the starting unit.[20]

Number one on the list of recommendations by the investigators was

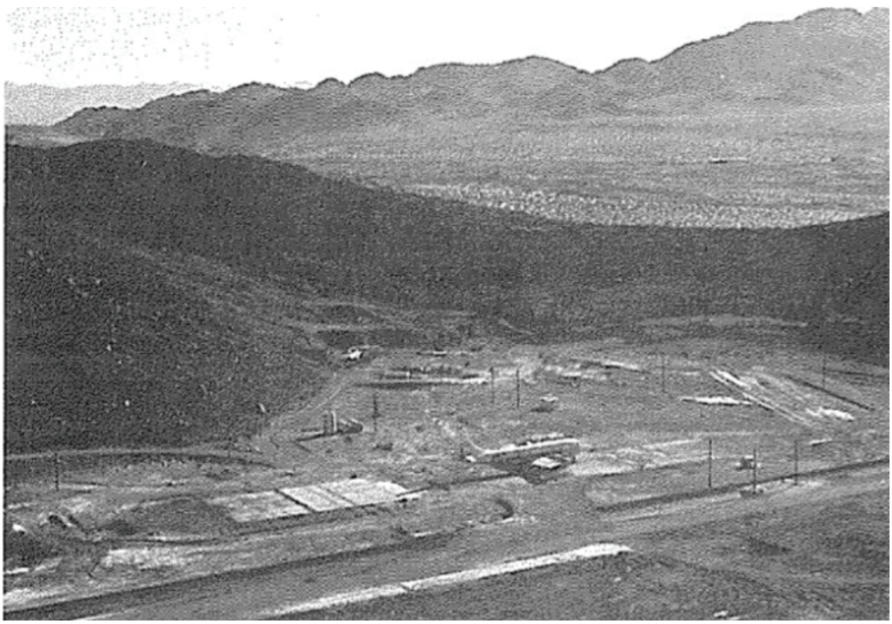
> that as a matter of the highest priority, a new system be developed to control flight deck fires, whether enemy- or self-inflicted, involving fuel, aircraft and weapons. This system must include massive cooling as well as rapid extinguishment. It must provide flexibility, selectivity, and redundancy.[21]

[20]Ibid., xv.
[21]Ibid., xli.

Minideck

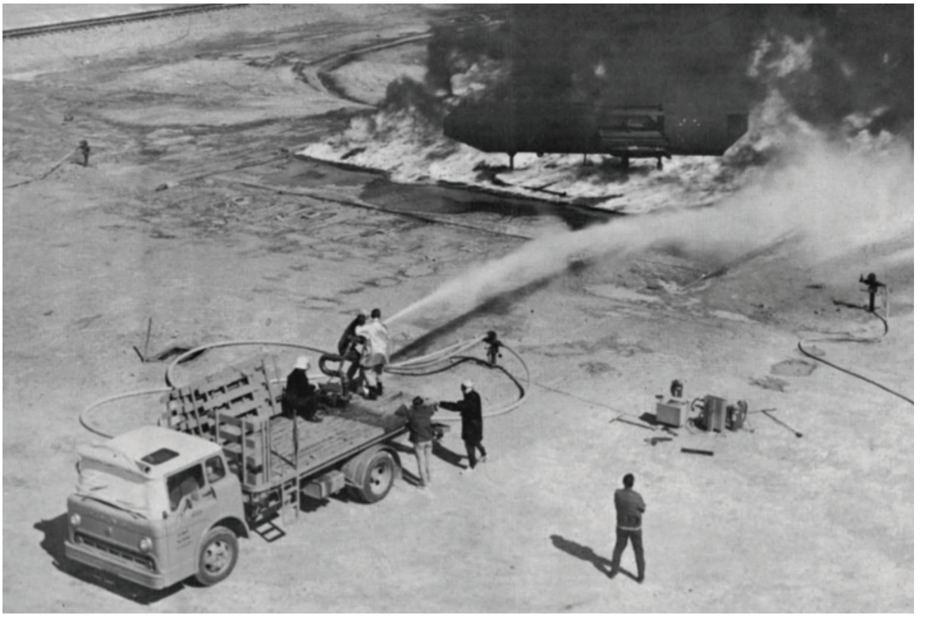
Shortly after the *Enterprise* fire, construction started on a new facility at China Lake. Located on the K-3 range, about 2 miles northeast of Mainside, the site was assigned the descriptive but unwieldy name Aircraft Carrier Conflagration Control Test Facility, which was soon vernacularized to Minideck. The CASS group was assigned to evaluate various firefighting agents and methods of delivering them to the carrier deck; Minideck was built to facilitate the evaluation process.

At the heart of Minideck was a 36- by 64-foot simulated flight deck surfaced with ¼-inch steel plate, which was soon replaced by an 83- by 125-foot simulated flight deck constructed of heat-resistant concrete. Support infrastructure included a 23,000-gallon tank for water and firefighting agents, a 3,500-gallon jet-fuel storage tank, and distribution lines for water and fuel. From a nearby fire-control building, test personnel monitored tests and controlled cameras, water, and fuel flow.



Minideck, looking southeast. Published in TP 5564, *Major Test Facilities of NWC,* 1975.

A major variable in an actual carrier-deck fire is airflow across the deck, which is a function of ambient wind and the ship's speed and direction. To create cross-deck airflow, a C-97 aircraft was located beside the Minideck. The propellers generated wind flows up to 40 knots across the deck.



Testing at Minideck, 1970. Published in the *Rocketeer*, 29 May 1970.

A mock-up of a damaged aircraft, rigged to leak fuel, simulated a realistic obstruction a firefighting team would encounter in a real on-deck fire. By the end of its first year of operation, Minideck had been used to test several methods of delivering firefighting agents, including flush-deck nozzles, deck-edge nozzles, monitors (aimable, high-capacity water jets), and vehicles with articulated booms.

As with most major projects on the base, the creation and operation of Minideck cut across organizational boundaries and relied on the broad range of expertise available at the Center. Bill Burke designed the Minideck's deck, and Lou Sidney coordinated the construction; both men were in the Public Works Department. The project was overseen by Don Grasing and Frank Pitman of the Systems Development Department's Range Operations Division. Warren Smith (Weapons Development Department) and Carroll

Wilson (Systems Development Department) provided field temperature measurements, and Jack M. Pakulak Jr. (Propulsion Development Department) instrumented inert weapons and then analyzed their responses to the deck-fire environment. Firefighting expertise was supplied by Fire Chief Jack Brust and members of the NWC Fire Division.

Through the 1970s, Minideck was used for testing new firefighting materials, equipment, protocols, and vehicles, and it quickly became a national asset. In 1972, a three-fire test series at Minideck evaluated the effectiveness of several firefighting vehicles, ranging from an Air Force Snorkel Squirt unit to a leased Cat-Klein 627, a monster with a 7,200-gallon-capacity tank used at some civil airports. The test series was sponsored by the Tri-Service System Program Office for Aircraft Ground Fire Suppression and Rescue.

Various firefighting agents, such as “light water” (synthetic perfluorinated surface active foaming agent), which forms a blanket on the fuel surface, and aqueous film-forming foam (AFFF), were tested at Minideck. The ability to control the extent and duration of the fire, to attempt different techniques of fighting fires in various scenarios, and to measure heat intensity and duration both within and near the fire gave government and industry researchers invaluable information for refining responses to deck fires.

When the Navy rolled out a vastly improved P-4A aircraft firefighting and rescue truck (for airfields) in 1976, the $132,000 vehicle was sent to Minideck. The P-4A featured 50 percent greater tank capacity than existing trucks, a unique ability to dispense firefighting agent in a large adjustable fog pattern, and the capability of hooking up to fire hydrants to help fight structure fires—such as a hangar—which no other Navy crash trucks could do. Using a mock-up of a C-5 aircraft, China Lake Fire Division personnel, under the leadership of Fire Chief William R. Knight, conducted step-by-step operations to evaluate the vehicle’s performance and establish its capabilities. In late August 1976, more than 90 representatives from Navy and Marine Corps air facilities throughout the country came to China Lake for a week of orientation and hands-on training with the P-4A at Minideck.[22]

Gradually, under the leadership of the CASS, the Navy developed an integrated fire-protection system for aircraft flight decks that included converting the former nuclear-biological-chemical wash-down system into a fire-protection system that used light water; a new hose system that required fewer personnel to operate; and a new tool, the P-16 aircraft carrier firefighting vehicle, to replace the heavy MB-4 and TAU-2 firefighting vehicles in use on carriers. The new vehicle would be constantly running throughout flight operations and could reach any spot on the carrier deck within 10 seconds.

In 1977, the P-16 was tested at Minideck. One critical test it passed was the complete extinguishing of a fuel fire on an aircraft in less than 90 seconds. “The 90-second requirement was established as the amount of time necessary in order to have prevented the catastrophic fire on the aircraft carrier USS *Forrestal* a decade ago,” reported the *Rocketeer*, alluding to the time between the fire’s start and the first bomb explosion.[23]

---

[22]*Rocketeer*, 13 August 1976, 1, 3; 27 August 1976, 1.
[23]*Rocketeer*, 4 November 1977, 1.

From left: William R. Davis, head of the Safety and Security Department; William R. Knight, fire chief; Rear Admiral Rowland G. Freeman III, NWC Commander; and Captain Conrad B. Olson, Commanding Officer, NAF, with preproduction model of the P-4A.

Testing the P-16 at Minideck. Published in the *Rocketeer*, 4 November 1977.

The *Rocketeer* noted that the price of the vehicle was estimated at $75,000 per unit. By the time the first production models of the P-16 were put through their paces at Minideck, 2 years later, the price was $85,000 per unit. Given the annual inflation rate of about 8 percent during that period, that was effectively a price reduction, not an increase. Not only was the P-16 more effective than the systems it replaced, its use reduced the topside weight of the carrier "by some 20,000 pounds, which would leave room for another combat airplane."[24]

[24]*Rocketeer*, 16 March 1979, 1.

Despite all the effort expended since 1967 to eliminate or control carrier fires, the problem had not been solved. A fire and subsequent ordnance explosions aboard USS *Nimitz* (CVN-68) in May 1981 took the lives of 14 sailors and injured 27. Three aircraft were destroyed and total losses were nearly $60 million. The following year, at the recommendation of Rear Admiral James H. Webber, Vice Commander of Naval Sea Systems Command (NAVSEA) and head of the CV Firefighting Flag Level Steering Committee, a follow-up program was begun at Minideck.

The *Nimitz* accident scenario was recreated in more than 50 fires at Minideck. Dennis Sorges and Al Wearner of the Weapons Survivability Laboratory operated the C-97 aircraft wind generator, providing 30-knot winds across the deck. Firefighting teams from the China Lake Fire Department, led by Assistant Fire Chief Richard Rivers and Captain Larry Rizzardini, fought the fires. The *Rocketeer* reported that

> no new equipment or chemical fire suppressants were tried during this current test series. Aim of the tests was to determine what the best use of equipment already in the Fleet would have been in fighting the fire on USS *Nimitz*.[25]

Jack Pakulak, by then supervisory chemist in the Ordnance Systems Department's Thermal Research Section, installed instruments in inert Shrike and Sidewinder motors that were strategically placed in the fire scenarios. The resulting data helped evaluate the effectiveness of firefighting equipment and techniques as they related to the cookoff times of the ordnance items.

Throughout the 1980s and 1990s and to the present day, Minideck has continued to serve the DoD and U.S. allies as a state-of-the-art research, test, and training facility. It is a national resource in the continuing quest to prevent and minimize fires at sea.

Ship Structures

In John O'Malley's Structures Branch in the Ordnance Systems Department, engineers were approaching ship fire prevention from a structural perspective. The premise of their work was that "a ship's structure and its insulating materials must be examined as a system in order to determine the craft's chances of surviving a fire."[26]

O'Malley's group set up a 77-cubic-meter Compartment Fire Test Facility at Salt Wells, where they tested materials and configurations for the NAVSEA-sponsored Ship Fire Protection Program.

[25] *Rocketeer*, 5 November 1982, 5.
[26] *Rocketeer*, 29 April 1977, 1.

Since WWII, Navy ship superstructures—the part of the ship above the main deck—had been partially constructed of aluminum to save topside weight. Aluminum, however, is less resistant to fire than steel. The aluminum was protected with insulating materials (usually a heavy asbestos-based material), but tests of these materials had not been conducted within actual ship compartments or in the context of the overall design of the craft. Much of the impetus for the efforts of the Structures Branch was the *Belknap* incident.

In November 1975, the guided missile cruiser USS *Belknap* (CG-26) was seriously damaged in a collision with USS *John F. Kennedy* (CV-67). A fire broke out when JP-5 fuel from the *Kennedy* poured down onto the *Belknap* and was ignited by sparks from an electrical switch box damaged in the collision. In the words of the official investigation:

> The fire was exceedingly hot and caused CHAFFROC, pyrotechnics, and 3"/50 ammunition to explode in many directions, creating further damage. The heat of the fire melted the aluminum superstructure. Molten aluminum in turn poured through overheads, creating further fires on the next deck below. It eventually pooled to cool and harden throughout the 01 level.[27]

USS *Belknap* after fire.

[27]Chief of Naval Operations to Judge Advocate General, memorandum, "Collision Between USS *John F. Kennedy* (CV 67) and USS *Belknap* (CG-26)," 7 September 1976, 757.

The cause of the accident was poor training, poor seamanship, and inadequate navigational lighting on the larger ship. Eight sailors died and 48 were injured. Repairs took 4 years and cost $200 million.

The Coast Guard was particularly interested in the *Belknap* incident because it was planning to purchase 24 new 270-foot ships to patrol the nation's recently expanded 200-mile coastal fishing-control zone. To minimize fuel consumption, lightweight construction materials had been selected for the new craft. Although the candidate insulation materials had passed the Coast Guard tests when tested alone, China Lake found "thermostructural incompatibilities" when the materials were evaluated in the Compartment Fire Test Facility.[28]

The Center also acquired the *Gulf Streak*, a former commercial vehicle that was sister ship to USS *Flagstaff* (PGH-1), a 73-foot-long Navy hydrofoil gunboat on loan to the Coast Guard. The *Gulf Streak* was brought to China Lake, where it was used in thermostructural testing to optimize compartment layout and insulating materials for Navy and Coast Guard ships. The Structures Branch made extensive use of predictive computer modeling in its work, validating the models with thermostructural tests on the *Gulf Streak* and various ship-structure models.[29]

In 1987, the Navy decided to go back to steel superstructures on new Fleet ships, a decision based more on steel's greater strength and resistance to cracking than on its fire resistance.

Cookoff Reduction

Controlling fire on a ship, particularly fire fueled by thousands of gallons of highly flammable jet fuel, was a huge problem. Exploding ordnance—bullets, bombs, rockets, warheads, and pyrotechnics—compounded the problem and complicated the search for solutions. The problem had to be approached from two directions: one was the development of better firefighting tools, tactics, techniques, and training. The other was reducing, if not eliminating, the violent reaction of weapons to the heat of fire and the shock of exploding ordnance.

The *Enterprise* fire, coming so close on the heels of the *Forrestal* fire, renewed emphasis on the development of elastomeric explosive systems (incorporating elastic polymers) that were more resistant to cookoff and reacted less violently—i.e., burned rather than detonated—in a cookoff situation.

Starting about 1957, China Lake researchers and others had been investigating "insensitive high-temperature explosives." The justification

[28]*Rocketeer*, 29 April 1977, 3.
[29]Ibid., 1, 3.

for the early work was "widespread concern over premature detonation of nuclear weapons subjected to fires as well as a need for explosives for external carriage of missiles at high Mach numbers." Fires in magazines—ordnance-storage structures—was also a concern.[30]

Dr. Harold Gryting.

Castable warhead formulations that were in wide use had a low heat tolerance. The target solution was to develop explosives resistant to temperatures of 500°F or higher for at least 1 hour and to improve flame resistance of new and existing explosives so that they could better withstand shipboard fires and, if they did react, would burn rather than detonate.

Norm Rumpp.

The year 1965 saw the approval for service use of three new plastic-bonded explosives (PBXs) by the Navy: PBXN-5, a booster in the Mk 51 warhead for the Tartar missile; PBXN-101, for the Shrike missile's Mk 52 warhead; and PBXN-102, for the Sidewinder's Mk 54 warhead. All three were China Lake products, having been developed by Dr. Harold J. Gryting, Norm Rumpp, Barbara Anne Stott,

[30] *NOTS Tech History 1958*, 45.

Barbara Anne Stott.

and Dr. Martin H. Kaufman. Contributing the ballistics measurements, loading research, and warhead design were Dr. C. D. Lind, Chuck Falterman, Jack Sherman, Bill Osmundsen, Paul Cordle, Dick Dirge, and Mel McCubbin.[31]

According to Dr. Taylor B. Joyner, who wrote a two-volume history of the NWC explosives program, most of the credit for the Navy's earliest PBX work goes to Barbara Stott, a chemist with a master's degree from Occidental College. In 1965, Stott and Dino Sbrocca shared a patent for a method for processing PBX compositions, and in 1969, Stott was named a China Lake Fellow in ordnance science. She was the principal developer of PBXN-107, used in the WDU-36 warhead for the Tomahawk missile.[32]

Dr. Marty Kaufman.

Shock resistance of Navy ordnance was also a safety problem. Aside from the obvious dangers of ordnance struck by bullets in combat, there were instances where high-order detonations had occurred after falls from aircraft or during shipboard loading. By 1970, NWC had been apprised that

> premature explosions have occurred in 5"/38 and 5"/54 rocket-assisted projectile (RAP) warheads and 5"/54 projectiles containing

[31]PBXN-101 was later replaced by PBXN-106.
[32]NWC RM-22, *NWC Explosives Program*; S-156, Joyner interview, 9, 33.

> Composition A-3 explosive in cases where severe setback forces [acceleration from firing, about 12,000 *g*s] were encountered.[33]

A problem facing China Lake chemists and engineers studying shock resistance of ordnance was that the test results from measuring sensitivity to various initiating forces (e.g., heat or impact) in small samples, such as those produced in initial research, did not correlate well with production-scale sample test results. Improved means to correlate the two needed to be developed.

Throughout the 1960s and 1970s, China Lake scientists and engineers continued efforts to better characterize new and existing explosives and to create formulations that would be safe—as safe as a bomb or rocket can be—on the wing of an aircraft or the deck of a carrier. NWC created new formulations; new binders; new additives; new oxidizers; new particle shapes and sizes; new mixing, pressing, casting, curing, and testing procedures; new bomb and motor casings and venting mechanisms; and new initiators. To the existing empirical avenues of research were added more theoretical approaches, focusing on measurement of the advancing wave front of an explosion. These avenues of research entailed the design and calibration of complex measurement equipment and instrumentation.

Still, by 1976, there was not a thorough understanding of what made a particular explosive more or less sensitive to heat and shock under various conditions. The *Tech History*, discussing the progress made by adding elastomers as the polymeric binder in explosive compositions, noted:

> The physical properties of the elastomeric binder appeared to be largely responsible for the differences in sensitivity behavior; however, the specific properties necessary for such changes are not clearly defined. Other factors may make important contributions to desensitization to cook-off and impact.[34]

Despite the intensive efforts of NWC and other Navy laboratories throughout the 1970s, there were no easy fixes for the fire-at-sea problem, and particularly flight-deck fires. Raymond L. Beauregard writes that

> from October 1966 [the *Oriskany*] to November 1988 [a second *Nimitz* fire with fatalities], there were four flight deck accidents on U.S. aircraft carriers that involved fires and munition explosions. Two hundred and twenty sailors and naval aviators were killed, and seven hundred injured. Ninety-six planes . . . were either destroyed or severely damaged. The ships were forced to leave the operational areas and undergo extensive repairs in shipyards. The material damage alone cost the Navy over 1.3 billion dollars.[35]

[33]*NWC Tech History 1970*, 4-39.
[34]*NWC Tech History 1976–1977*, 9-68.
[35]Beauregard, *History of Insensitive Munitions*.

In 2011, 10 sailors were injured in a flight-deck fire aboard USS *John C. Stennis* (CVN-74). The struggle to reduce the incidence and degree of damage from fires aboard ship is a continuing one.

Roseville-Benson

When laboratory people talk about a weapons system's life cycle and the laboratory's "womb to tomb" responsibilities, they are referring not only to the span of a weapon system's life, from inception through demilitarization, but also to every step along the way: every environment that weapon will or even might encounter during its existence. People involved in the weapon development business have a duty to design a system that will be safe from every known danger as well as "other unplanned stimuli," which is DoD code for "just because it's not mentioned doesn't mean you're off the hook if it happens." Much like the traditional Navy ship Commander who is culpable if the ship hits a reef—even if it isn't shown on the charts—weapon designers are supposed to make their weapons and ancillary equipment (container, test equipment, loading and handling equipment, etc.) disaster-proof from anything that might be encountered from "cradle to grave."

"Ordnance safety and reliability are directly related to the behavior of the explosive system under a variety of kinetic regimes," the 1973 *Tech History* stated. "These can include very slow reactions at storage temperatures, measurable decompositions occurring prior to cook-off, and very fast, localized events responsible for impact, shock, or spark initiation."[36]

Such "kinematic regimes" also include those encountered by nuclear bombs when the aircraft carrying them crash or are involved in mid-air collisions, as happened near Thule Air Force Base, Greenland (1968), and Palomares, Spain (1966).

Another example of unplanned stimuli occurred aboard SS *Badger State*, a States Marine Lines transport carrying 5,976 tons of bombs to Vietnam in December 1969. A storm buffeted the ship, and the metal bands and wood pallets securing the weapons proved inadequate to the task. Heavy seas continued, and the crew made "strenuous efforts" to secure the bombs rolling about below decks. Eventually, one bomb exploded, blowing a hole in the ship's side. The captain ordered his vessel abandoned, but the wind blew away the two ship's life rafts. When 35 men climbed aboard the single life boat, a 2,000-pound bomb rolled out of the ship and landed on the boat. Despite the

[36] *NWC Tech History 1973*, 9-40.

quick arrival of a Greek cargo ship, only 14 of the 40-man crew were rescued. Days later, the ship sunk.[37]

Unplanned stimuli also include the case of conventional bombs riding in a railroad car when a fire breaks out. The scenario lead to three incidents in which NWC investigators became deeply involved.

In 29 June 1969, a Western Pacific Railroad train was passing a siding near Tobar, Nevada, when an explosion occurred. The train was hauling 71 cars, including 22 carrying Air Force M-117 bombs loaded with Minol-2 (trinitrotoluene [TNT] / aluminum / ammonium nitrate) from the Cornhusker Army Ammunition Plant in Nebraska. The explosion caused fires on several cars and more bombs exploded. Ultimately three boxcars were destroyed and one moderately damaged. Four people (two crew members and two transients riding the train) were injured, one seriously, and the tracks were extensively damaged.

On 28 April 1973, a fire was observed in a boxcar on a siding in Roseville, California. The car was carrying Air Force Mk 81 bombs filled with a Navy-developed explosive called Tritonal. The fire department was called but before it could respond, an explosion destroyed the railroad car. The fire spread. Over the next day and a half, 18 boxcars exploded. No one was killed, but 48 people were injured and the railroad yard was destroyed, with 600 rail cars destroyed

Roseville train fire.

[37]Marine Board of Investigation, casualty report, *SS Badger State*.

or damaged. The explosions and hot shrapnel also caused fires in Roseville that destroyed eight buildings.

Less than a month after the Roseville fire, a train pulling 12 boxcars loaded with Navy Mk 82 Tritonal-filled bombs was approaching Benson, Arizona, when an explosion occurred in one of the cars. The resulting fire and additional explosions caused no injuries, but the 12 cars, plus 460 feet of railroad bed, were destroyed. It was ultimately concluded that all three incidents were caused by fire or possibly, in the Tobar case, by a bomb falling through the boxcar floor and rubbing against the rotating axle or wheel.

Lawsuits started flying immediately after the Roseville incident. Western Pacific, which was nearing the deadline for filing in the Tobar incident, sued Pantex Corporation (which ran the Cornhusker Army Ammunition Plant) and the U.S. Government. Southern Pacific filed against the government for $40 million in the Roseville incident. All in all, more than $100 million in lawsuits were filed against the U.S. Government, including suits by civilians who had suffered various types of damages in the accidents.

More than money was at stake. Public confidence in the safety of military munitions—which were routinely hauled through populated areas—was shaken. The Department of Transportation placed an embargo on munitions shipments in the U.S., but that was soon rescinded.

The plaintiffs in the lawsuits against the government contended that the incidents were caused by some chemical instability in the bombs that led to spontaneous ignition. China Lake, on the other hand, believed that the cause was heat, caused by a fire from a stuck brake or insufficiently lubricated journal bearing.

Given the strong antiwar sentiment in the country at the time, particularly in California, there was even talk of sabotage in the Roseville case. Regarding that possibility, one of the China Lake investigators commented:

> If it was sabotage, it was not by a detonating device; it was by an incendiary device. ATF [Bureau of Alcohol, Tobacco, Firearms, and Explosives] had a good team on it, but they couldn't develop evidence, and you can't prove a negative. After 18 cars of bombs explode, you're damn well not going to find many pieces of an initiating device if there was one in there.[38]

The government quickly zeroed in on China Lake as the repository of technical expertise that would be needed to defend against the charges that the bombs or the filler were defective. In August, Captain Mark Lechleiter, Inspector General of the Naval Ordnance Systems Command; Dr. Ludwig Benner, head

[38]S-156, Joyner interview, 15.

of the National Transportation Safety Board's Surface Transportation Safety Division; and Harvey Hardin, chief claims adjuster for the Southern Pacific Transportation Co. (the operators of the Roseville train) met at China Lake with representatives of NWC's Propulsion Systems Department and the Research Department.[39]

Dr. Bill McEwan.

A core group of technical experts was assembled to be the government's technical resource throughout the years of investigation and litigation that would follow. (Large lawsuits are often long lawsuits, and final settlement in the Roseville incident did not come until 1980.) At China Lake, the project was referred to simply as Roseville-Benson, the Tobar suit having been dismissed shortly after the China Lake experts began to assemble evidence.[40]

Dr. Taylor Joyner.

Each of the China Lake core team members brought a different perspective to bear on the problems associated with the investigation. Along with Dr. William "Bill" S. McEwan, head of the Research Department's Chemistry Division, was research chemist Dr. Taylor B. Joyner, physical chemist Jack Pakulak,

[39] *Rocketeer*, 31 August 1973, 3.

[40] Of Tobar, the accident report states, "One can surmise that the original explosion was caused by a bomb in the 61st car having been subjected to excessive heat from a source arising from some condition of the car or its lading" and mentions the possibility of "a floor-stringer failure, permitting a bomb pallet to drop in such manner that a bomb rested against a rotating axle and/or wheel, and subsequently exploded as a result of being subjected to friction heating in excess of 350°F." Federal Railroad Administration, Railroad Accident Investigation Report No. 4153, *Accident at Tobar, Nevada*, accessed 29 June 2021, http://www.wplives.com/about-wp/accident-reports/1969_tobar_nv.php.

and mechanical engineer Howard C. Schafer.

Jack Pakulak.

There was a bit of a learning curve for the China Lakers. "Everybody's train wreck, just about, is their first one," Joyner said years later. "You don't take classes in studying train wrecks, which in a way is fortunate. By the time we worked on our third one, we knew what we should have been looking for on the first one."[41]

Of the four men, only McEwan had experience in such work. In WWII he had become a bomb-damage expert, beginning by collecting German munitions manuals from abandoned tanks and translating them as he moved across Europe. By war's end, he had served as the chief of the United States Army Air Forces (USAAF) Bomb Evaluation Division, instructed in the USAAF Ordnance School, and done photographic surveys of bomb damage to railroads and industries in Italy.

Howard Schafer.

The railroads had their experts as well, including chemist Melvin A. Cook, author of *The Science of High Explosives*, originator of slurry explosives, and an investigator in the disastrous 1947 fertilizer explosion in Texas City, Texas, which killed nearly 600 people and led to the first class-action lawsuit against the government. Another of the plaintiffs' expert witnesses was Dr. Julius Roth, one of the principal contributors to the Picatinny Arsenal-produced *Encyclopedia of Explosives and Related Items*.

[41]S-156, Joyner interview, 13.

The odds were against the government. As Joyner pointed out:

> The thing about explosives trials . . . They are such emotional issues. [The explosions] do so much damage. They hurt so many people that your defense comes in under a handicap from the start. There's just a natural tendency to blame the damn explosive. There's no doubt that the explosive did the damage, but what gets lost is what caused the explosives to do the damage.[42]

Schafer was the first point of contact for the Roseville work, organizing a rapid response effort and coordinating the efforts of the other investigators. Using his expertise in the effects of temperature, vibration, friction, and shock on explosives, he examined the environmental factors involved in the incident and characterized the train and cargo environments. McEwan examined the physical and photographic evidence from the accident sites, bringing to bear his expertise in chemistry and explosives as well as his understanding of railroad yard destruction based on his WWII experience.

Joyner served as an expert witness in the Roseville trial. As the *Rocketeer* reported, he

> described for the court and jury the mechanisms that caused the first boxcar of munitions to explode. This is believed to be the most important point since it convinced the judge and jury that an external fire started in the brake shoe of a railroad boxcar was the cause of the fire which then led to the explosions.[43]

Pakulak was the workhorse of the team. The *Rocketeer* noted:

> Pakulak has analyzed debris and photographs, walked railroad yards, interviewed witnesses, planned and conducted scores of small and large cook-off studies (ranging up to boxcar size), and supervised careful laboratory analytical studies.[44]

He also

> conducted field investigations at explosion sites, served as a consultant to the Department of Justice, and appeared as an expert witness. On top of all this, he shouldered the principal administrative burden connected with the entire investigation.[45]

Working at the accident sites as well as in China Lake's laboratories and on its ranges, the defense team built the proverbial iron-clad case for the government. Three of the actual cars that had survived the Roseville explosions

[42] Ibid., 19.
[43] *Rocketeer*, 2 November 1979, 4.
[44] Ibid., 1.
[45] Ibid., 1.

were brought to China Lake for testing with fire and live explosives. Cookoff tests replicated the conditions under which the accidents happened.

More than 400 NWC employees contributed in various ways to the accident investigations. There was a tremendous amount of detail work involved. For example, Madge Bryant conducted thermal characterization studies of brake-shoe material, grease, debris accumulated on boxcar wheels, and other artifacts.

Dr. Albert Lepie supervised an effort in which explosive-sensitivity data was obtained from more than 360 Tritonal samples recovered at the Roseville site. When two samples from a sectioned bomb showed trace alkalinity (loading documents specify that Tritonal shall show no alkalinity), Lepie had more-sensitive tests run. The tests showed that the alkalinity was probably introduced into the sample during the cutting process.

Dr. Albert Lepie.

In the end, the NWC researchers, and ultimately the government, prevailed. They proved what caused the accidents—heat—and what did not cause them—faulty explosives. Joyner said:

> We were able to refute every one of the contentions, literally, every single one of the contentions of Southern Pacific's experts regarding ordnance. We did not have to put our case on. We won on their time. We called our first expert witness, Ray Beauregard from Washington. He would have made an outstanding witness, except Southern Pacific called the case off after he got on the stand for about 2 hours.[46]

NAVSEA funded the majority of the analytical work, although the Army contributed as well. The costs were not inconsequential. In 1979 alone, the Roseville-Benson investigation was funded for $288,000. Still, the expenditures were a small percentage of the estimated $50 to $90 million saved in damage settlements. And much of the work had ancillary benefit to the Center, the

[46]S-156, Joyner interview, 17.

Navy, and munitions safety in general, extending the knowledge of ordnance behavior under slow and fast cookoff conditions.

In 1973, Joyner, Pakulak, Schafer, and McEwan received the first group Technical Director Award for their work on the Roseville-Benson project. In 1975, the four were further honored with Navy Superior Civilian Service Awards. More than 40 of the Roseville-Benson investigation participants received an Award of Merit for Group Achievement in 1979, shortly after a federal judge ruled against Southern Pacific's allegations that the bombs had caused the Roseville fire.

McEwan recalled that when the Roseville case was finally concluded, the U.S. attorney in Sacramento invited the NWC investigators and their wives to a final-decision party.

> It was well catered and it was a terrific party. Everybody was buddy-buddy with these guys that had been suing the daylights out of each other. And the thing to me was that out of the whole thing there was something like 90 lawyers and 4 scientists.[47]

Safe Transport of Munitions (STROM) Program

Arising directly from the Tobar, Roseville, and Benson accidents was the STROM program. NWC was the Navy's participant in this triservice program, which was comprised of the Army, Navy, and Air Force, and Pakulak was in charge of the effort. China Lake's principal task in STROM was to develop a fire-detection and -suppression system for boxcars. Small- and large-scale fire tests were conducted to understand how boxcar fires are initiated, how fire spreads within the car, and how burn-through occurs on the floor of the car—which might be saturated with spilled oil from years of use. And, because it was China Lake, where one could do it, the effectiveness of candidate detection and suppression systems was measured by testing them in a railroad boxcar filled with munitions.

One system developed under this program, by Pakulak, research chemist Dr. Carl Anderson, and senior engineering specialist Bob Reid, used entirely off-the-shelf components. Designed for either boxcars or truck-trailers, the system utilized water released at 500 psi through tiny nozzles to produce a fog of 2-to-3-micron droplets. In its initial test, "a deliberately-set fire on a 4-foot square section of boxcar floor was allowed to burn for about 2 hours. It was quenched completely in 10 seconds using approximately a quart of water."[48]

---

[47]S-249, McEwan interview, 63.

[48]*Rocketeer*, 4 June 1979, 1. In 1979, the STROM program funding at China Lake was $434,000.

In 1990, Pakulak, then in his 38th year at China Lake (and with more than 100 publications on thermal behavior to his record), commented on the benefit of doing hands-on explosives work at China Lake. "The universities deal strictly with theoretical studies, and there are limited laboratories that can research in this manner," he said. "Once us old guys disappear, it's going to be very difficult to solve these problems."[49]

Explosives Detection

In the late 1970s, NWC entered a new field of research when the Center began investigations into methods for determining the presence of live energetic materials. The goal of the NAVSEA-sponsored "explosives detection program" was "improved safety in developing, testing, and using ordnance; retrieval of ordnance from ranges; and preparation of ordnance for recovery or resale." The state-of-the-art instruments for explosives detection belonged to the same agencies that, in the 21st century, are often associated with explosives detection—Customs Service, ATF, FAA, and the Energy Research and Development Administration (ERDA, the nuclear laboratories at Lawrence Livermore and Los Alamos). Center researchers began their investigations using equipment borrowed from these agencies. China Lake carried out investigations into detecting and tagging explosive materials, refining techniques for thermionic detection, and characterizing explosives through electron capture with gas chromatography. In the 1990s, this work would grow in scope and significance with the increase in terrorism and the use of improvised explosive devices as weapons of war.[50]

Explosive Safety Knowledge Improvement Operation (ESKIMO)

Closely related to the problem of ordnance cookoff is that of shock initiation: bullet impacts, falls, or fragments from explosions of adjacent ordnance. The threat is particularly great in shipboard magazines, since they cannot be located in remote areas (as is often the case with on-shore bases), where the threat to personnel is slight. Also, a magazine explosion on a shore base will not sink the base.

In 1944, the Navy conducted full-scale explosive tests of standard Army and Navy 27- by 80-foot igloo-type magazines (so named for the dome-shaped buildings' resemblance to an Eskimo igloo) at the Naval Proving Ground

[49] *Rocketeer*, 7 September 1990, 17. Pakulak won the Technical Director Award for his direction of the STROM program in 1982.

[50] *NWC Tech History 1976–1977*, 9-60–9-70; *NWC Tech History 1978*, 9-41. ERDA merged with the Federal Energy Administration in 1977 to form the Department of Energy (DOE).

near Arco, Idaho. The purpose of the testing was "to investigate the safety and feasibility of spacing igloo magazines at half the normal standard distance in order nearly to double the capacity of ammunition storage depots."[51]

The following year, the Underwater Explosives Research Laboratory, Woods Hole, Massachusetts, conducted similar tests on one-tenth scale models of igloo magazines. These tests were conducted at Camp Edwards on Cape Cod. The Navy did follow-on testing of the scale-model igloo magazines at the Naval Proving Ground, Arco, and concluded that standard igloos "do not reduce blast effects sufficiently to warrant dividing the [American Table of Distances] safety distances by two."[52]

Beginning in 1960, China Lake participated in the Dividing Wall program, an effort to assess the usefulness of erecting concrete walls between magazines to reduce the likelihood of explosions propagating from one bay to the next. The program was a joint effort of the Army, Navy, Air Force, Defense Atomic Support Agency, and the Armed Services Explosives Safety Board. By 1961, test results "showed conclusively that many present special-weapon [nuclear] storage and handling facilities are inadequate."[53]

In 1963, four steel-arch magazines under dirt fill were tested at China Lake as part of the same program. This portion of the test series was to compare the intermagazine protection of the more economical steel-arch design with that of the reinforced-concrete arch-type magazine. One of the four magazines contained a donor charge of 100,000 pounds of Composition B and C explosives, and the three acceptor magazines each contained eight 100-pound spheres of cyclotol. Side-to-side separation distances were in feet equal to 1.25 and 1.5 W1/3 and back-to-back distances of 1.5 W1/3, where W equals the explosive weight in pounds. These distances were judged to be adequate, and the Department of Defense Explosives Safety Board (DDESB) approved the siting specifications for earth-covered steel-arch magazines.[54]

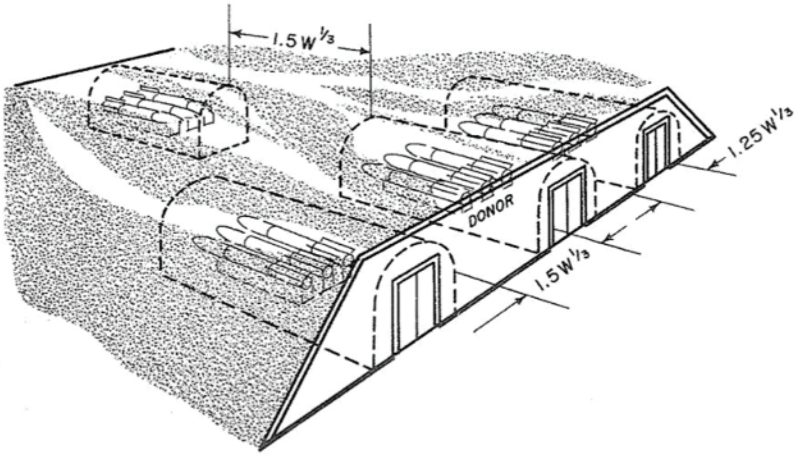
The Dividing Wall program continued to test a variety of types of magazine construction and spacing as well as various technologies and materials to reduce the likelihood of sympathetic detonation (the unintended detonation of one piece of ordnance initiated by the detonation of another). A China Lake-

[51]Technical Paper No. 4, *Explosion Tests,* 1.

[52]Ibid., 110.

[53]*NOTS Tech History 1961*, 218. The Armed Forces Explosives Safety Board (also known as the Armed Services Explosives Safety Board) was founded in 1928 following a 1926 explosion at the Naval Ammunition Depot, Lake Denmark, New Jersey, that killed 21, injured 53, and destroyed the depot. The board's name was later changed to the Department of Defense Explosives Safety Board.

[54]*NOTS Tech History 1963*, 7-39; DDESB, *Approved Protective Construction*, 21.



Setup for steel-arch magazine tests. Published in the 1963 *NOTS Tech History*.

developed "fragment mortar," which fired 70-pound loads of concrete rubble at repeatable velocities, was used to establish baseline sensitivity of munitions and rocket motors to fragment impact as well as to test the protection afforded by different types of shielding materials and devices. Meanwhile, in the Station's laboratories, engineers and scientists were studying the mechanisms of explosives initiation and propagation.

In 1971, the Explosive Safety Knowledge Improvement Operation series began. ESKIMO, the *Rocketeer* took pains to point out, was "an acronym devised by the sponsor," the DDESB. The purpose of the program was to determine safe separation distances and proper construction of explosives magazines. Working closely with China Lake through the series were DDESB staff members Russell G. Perkins and Dr. Thomas A. Zaker.

There are few places in the country where the military can safely detonate, simultaneously, 200,000 pounds of HE. Fewer still where more than a third of a million pounds of HE can be touched off at one time. China Lake is one of those fewer-still places.

ESKIMO 1, conducted at Randsburg Wash Test Range on 8 December 1971, consisted of the simultaneous detonation, in an existing magazine, of 13,696 155 mm projectiles containing 200,000 pounds of TNT. Surrounding the donor magazine were the acceptor structures—"four newly constructed earth-covered, arch-type magazines [and] two concrete block magazine structures," containing explosive warheads and rocket motors. Blast gauges, transducers, cameras, and other instrumentation maximized the data yield from the tests.[55]

Experts from across the Center contributed to ESKIMO 1. Participating departments included Security, Public Works, Supply, Research, and Engineering as well as the Explosive Ordnance Disposal (EOD) Detachment and the Naval Air Facility (NAF). Fred Weals, Ray Schreiber, and A. R. Sound coordinated the test; Roy Pullen, Frank Pitman, Robert Rasmussen, Joe Winter, and Mel Miller handled safety, instrumentation, and range operations; and L. E. Sidney and E. J. Seybold oversaw site preparation and magazine construction. Even the Air Force weighed in, with a two-plane flyover to gather data on fragment dispersion using IR scanning.

Contributing in another way—generating business—was the Technical Information Department (TID). As Fred Weals recalled:

> John Dunker [TID film maker and later head of the Center's Video Group] did a lot of movies for us. John also did movies for the fire tests, and I might say that was a real asset to getting work here. They could come up with a visual report, what the test was like, and they could distribute this widely.[56]

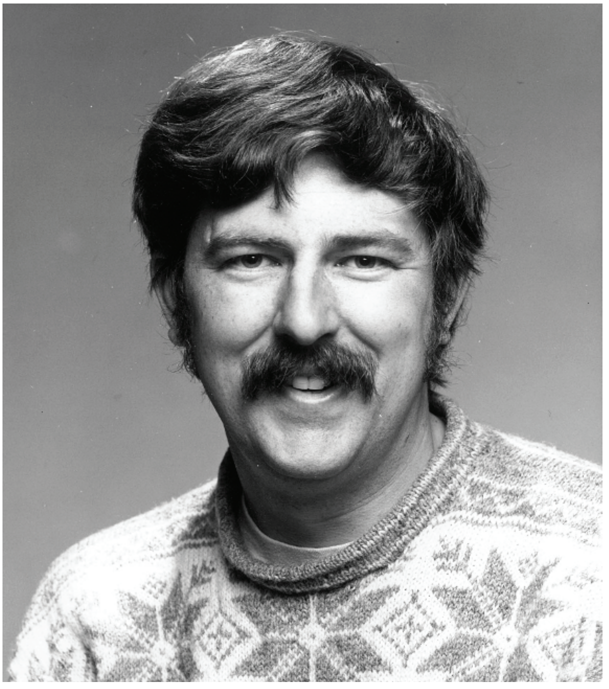
As with the Navy tests at Arco, Idaho, a quarter century earlier, the participants hoped that the test data

> could lead to approximately 50 percent reduction of the spacing distance between the lines or rows of magazines, thus providing considerable opportunity for savings in real estate for new magazine construction sites or for greatly

Fred Weals.

[55]Ibid.; *Rocketeer*, 17 December 1971, 3. Using ordnance rather than bulk explosive also provided data on fragment damage and dispersion. Sympathetic detonation testing uses the term "donor" for the item being intentionally detonated and "acceptor" for the item that may or may not be initiated as a result of the donor explosion.

[56]S-261, Weals interview, 8. At his retirement in 1980, Weals was presented the Navy Meritorious Civilian Service Award for, among other things, his management, planning, and coordination of "unusual test programs of extreme diversity and complexity." *Rocketeer,* 1 February 1980, 1.



John Dunker.

augmenting the numbers of magazines that can be located at existing sites now fixed in the area.[57]

Not surprisingly, given the magnitude of the explosion and the anticipated spectacular show, high-level visitors from as far away as Norway found reason to be on hand for the occasion.[58]

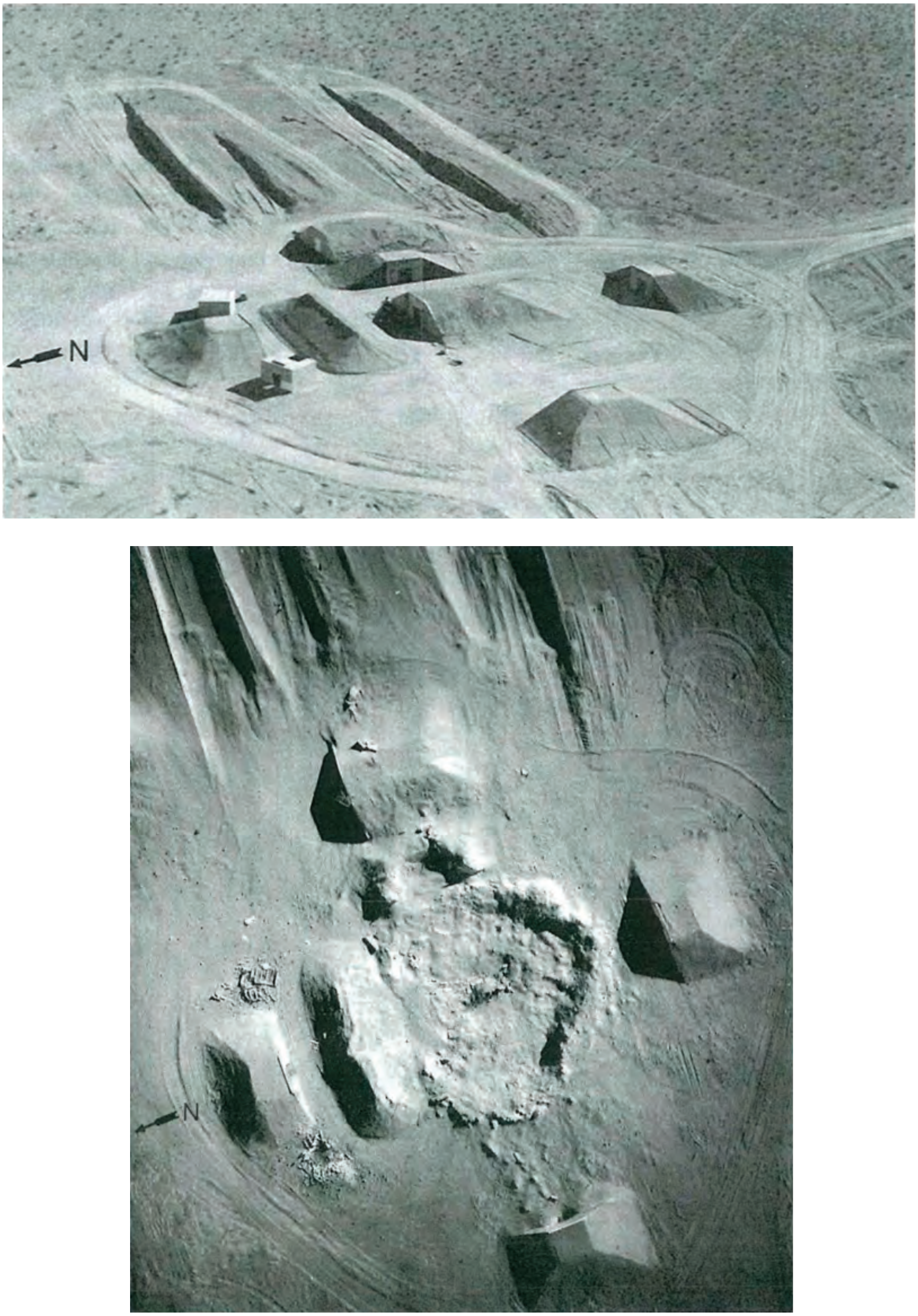
As a result of the explosion, two rocket motors in the northeast concrete-block building burned, and four of the eight charges in the northwest concrete-block building burned. There were no explosions in the acceptor magazines or buildings.

ESKIMO II was held in July 1973. This time, new headwalls (the main front wall of a magazine) and doors were tested. In addition, window frames and window glass commonly used in commercial buildings were tested. Ten vehicles, "foreign and domestic," were arrayed at various distances from the blast based on U.S. and NATO safety standards for distance to highways and inhabited buildings.[59]

[57]*Rocketeer*, 17 December 1971, 3.

[58]Ibid. Colonel William Cameron III, DDESB chairman, helped EOD set up the final firing line hookup and closed the firing switch to set off the blast.

[59]*NWC Tech History 1973*, 11-12.



ESKIMO II test setup, before and after. Published in the 1971 *NWC Tech History*.

For this exercise, representatives from Germany, the United Kingdom, and France joined the high-level U.S. visitors. "All of the NATO countries had essentially the same problem," said Weals. "They were trying to save real estate by limiting the [magazine] spacing to what was the minimum necessary."[60]

Vice Admiral Eli T. Reich, Deputy Assistant Secretary of Defense for Production, Engineering, and Material Acquisition, was accorded the honor of initiating the explosion, which consisted of 72 Mk 117 bombs containing 27,800 pounds of Tritonal (24,000 pounds TNT equivalency). As the *Tech History* reported:

> Test data indicated that overpressures and impulses recorded at the igloo headwalls were somewhat higher than planned. Damage to doors and headwalls varied considerably with the type of igloo construction.[61]

ESKIMO III was conducted in June 1974 to expose a new earth-covered, oval, steel-arch magazine to the explosion of an adjacent magazine "at the minimum side-to-side spacing between magazines now permitted by standards." Another steel-arch magazine of different construction was also included as a target, and vehicles and wood-frame window test cubes were placed at the test site. An old, unflyable B-29 aircraft was placed 1,200 feet from the donor magazine. The source of the blast was 908 Mk 117 bombs with a total explosive weight of about 350,000 pounds.[62]

Henry Paquin from the Supply Department's Ordnance Division oversaw the transportation of the bombs to the Center from sites in California and Colorado. According to Paquin, "the bombs were all unserviceable and their use in this test work resulted in a cost savings to the government." Woodrow Bertrine's crew handled the bomb unloading at the test site. The bombs were primed for simultaneous detonation by an EOD team under Lieutenant John Sedlak.[63]

---

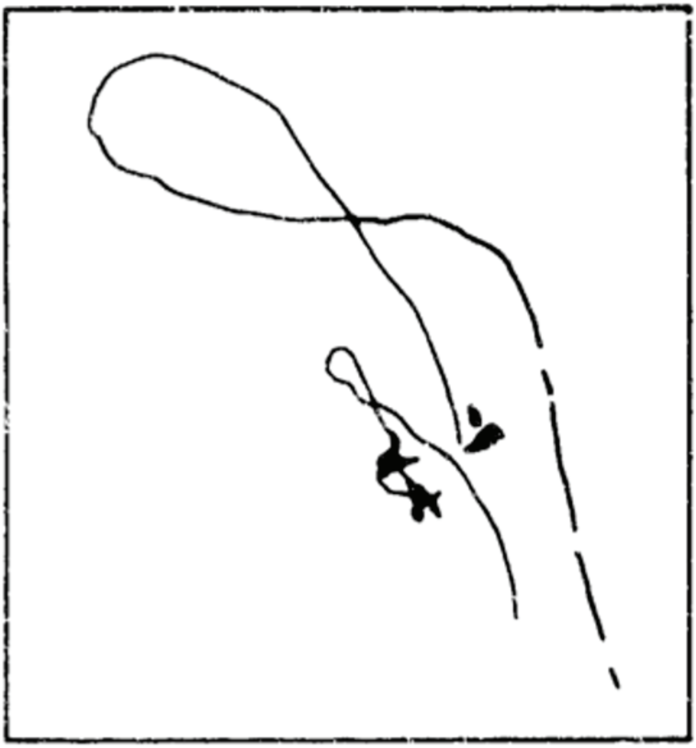
[60]S-261, Weals interview, 7.
[61]*NWC Tech History 1973*, 11-12.
[62]*Rocketeer*, 5 July 1974, 1; NWC TP 5771, *Eskimo III*, 4, 7.
[63]*Rocketeer*, 5 July 1974, 3.

Lieutenant John Sedlak with Rear Admiral William J. Moran, circa 1972.

Weals, assisted by Carroll Wilson, coordinated the overall event; Roy Pullen directed camera installation, range operations, and safety, with help from Mel Miller, Bob Rasmussen, and Bill Lamb. For construction of the test site, George Hartzell oversaw the carpenters, structural ironworkers, welders, glaziers, machinists, equipment operators, riggers, laborers, and electricians with assistance from foremen Elmer Davis and "Tiger" Lyons.

Instrumentation was extensive; its installation was handled by Joe Winter, Bob Rockwell, and Virgil Christensen. In addition to the instrumentation used in previous ESKIMO tests, the explosion was monitored by California Institute of Technology (Caltech) seismic stations across Southern California and by U.S. Geological Survey seismic teams.

One unique type of instrumentation involved the vehicles that were subjected to blast pressures. Down-pointing spring-loaded styli attached to the vehicles provided a signature of the vehicle's motion on an aluminum sheet fixed to the ground. An approximate actual-size signature is shown below.



Signature from the Buick station wagon located 2,115 feet from the donor magazine. Published in NWC TP 5771, ESKIMO III Magazine Separation Test, February 1977.

ESKIMO III's large contingent of observers included more than a dozen representatives of industry and other non-governmental activities who had an interest in ammunition and explosives storage.

The test was a success:

> The oval steel-arch igloo withstood the donor explosion effects very well. It is considered that all components of this structure would have provided ample protection to explosive contents in the orientation tested.

The other magazine structure fared less well, but adequately.[64]

[64]NWC TP 5771, *Eskimo III*, 45.

Regarding the vehicles and window test cubes, "in general, the test supported the U.S. inhabited-building distance standards and the U.S. public highway separation distance." As to the B-29, the damage was heavy: "an aircraft at this distance would have been damaged beyond economical repair."[65]

China Lake's ESKIMO tests continued into the 1980s with ESKIMO IV (September 1975, 350,000 pounds), V (August 1977, 75,000 pounds), VI (July 1980, 44,000 pounds), and VII (September 1985, 13,616 pounds). The series led to the design of safer munitions storage structures and generated a wealth of data on the nature of blast propagation and the effects of shock, overpressure, and fragment damage to not only the explosives-storage facilities themselves but also potential civilian infrastructure elements that might be near a blast.

In a related project, Carl Halsey developed a process for using pumice as a shock-absorbing material in explosives-storage containers. Halsey, Dr. Carl Austin, and others were conducting explosive testing around old pumice mines in the remote Upper Cactus Flat area of the Coso Mountains. "We did magazines, underground tunnels; build everything for 6 months and microseconds later it was gone," said Halsey. Much of the work was highly classified and, according to John Di Pol, head of the Range Department, the group "had their own private warhead test range" and operated with some autonomy. "Carl Halsey was a very competent guy," Di Pol said. "If it was something unusual they were going to do, big bang or otherwise, he would keep us informed."[66]

Carl Halsey.

[65]Ibid., 49, 26.

[66]S-287, Halsey interview, 8; S-253, Di Pol interview, 49.

In the course of the work, Halsey serendipitously observed the shock-absorbing characteristics of pumice.

> We had to fire a projectile into something and recover the fragments, and I had a pumice bank close by so I fired into that. Normally it's hours before you can actually pick up fragments from an exploding projectile or bomb and I noticed these were kind of cool. Fifteen minutes later I could pick them up without a glove on. So in my spare time I just started doing different things with pumice then I found out it would absorb pressures and fragments, and the EOD folks needed a magazine for quick reaction.[67]

For the rest of his career, Halsey continued to develop explosive-containment and hazard-reduction applications for pumice.

> I was able to develop containers that would hold different explosives and if one thing went off nothing else detonated in the magazine—like setting off a stick of C-4 [plastic explosive] 3 inches away from another one and there was no detonation.[68]

Today the pumice technology developed by Halsey's group is used in military and industrial applications related to explosive safety.

Insensitive Munitions (IM) and Explosives Advanced Development (EAD)

Driven by the Roseville, Benson, Tobar, *Forrestal*, *Enterprise*, *Badger*, and other munition accidents, efforts to eliminate the unintended detonation of explosive ordnance continued apace at China Lake and other Navy laboratories through the 1970s and into the 1980s.

In August 1979, Vice CNO (later CNO) Admiral James D. Watkins issued Navy Operational Requirement (OR #S-0363-SL) for Insensitive High Explosives. It spelled out the problem plainly:

> The ability of Navy combatants to operate effectively has been degraded by catastrophic explosions from unintentional initiation of munitions due to explosives sensitivity to fire, fragment impact, mechanical shock, and as a result of chemical degradation.[69]

---

[67] S-287, Halsey interview, 9.

[68] Ibid.

[69] OR No. S-0363-SL, "Operational Requirement (OR) Insensitive High Explosives (IHE)," quoted in Beauregard, *History of Insensitive Munitions*.

Three months later, Watkins established the EAD Program. "The EAD Program was brought into existence by Ray Beauregard of NAVSEA," wrote Joyner in his comprehensive history of explosives work at NWC.[70]

EAD brought together the several threads of explosives development, including maximizing energy while minimizing resistance to heat and shock. Previously, the process by which explosives moved from the exploratory stage to production had been handled "in a not particularly systematic fashion" by the individual weapons development programs. Joyner elaborated:

> When adopting a new explosive, those programs paid for process development, advanced testing, and specification packages. The system worked. However, it seemed there should be a better way to do it. . . . To impose order on the development process, [EAD] established a rigid system of head-to-head competition between explosives, mandatory milestones, and strict limits on the roles of the laboratories, pilot plants, and other participants.[71]

Acceptance of the new program was not universal—Joyner notes that he himself "felt the rigidity excessive and some rules ill-advised"—but as time passed, "a welcome measure of flexibility developed."

In its first year, EAD funding was $800,000, of which NWC's allotment was $85,000. By 1983, NWC's share had climbed to $938,000 out of the total program funding of $4,331,000.[72]

In 1984, the EAD Program became the Insensitive Munitions Advanced Development (IMAD) Program. IMAD was refocused to include not only the high-explosive components of a weapon but rather the entire munition. It was not until 1984 that the formal definition of IM was coined by a small group of experts that included China Lake's Dr. Lloyd Smith.

> Insensitive Munitions are those that reliably fulfill their performance, readiness, and operational requirements on demand, but are designed to minimize the violence of a reaction and subsequent collateral damage when subjected to unplanned heat, shock, fragment or bullet impact, electromagnetic pulse (EMP), or other unplanned stimuli.[73]

Over next the two decades, more than 20 PBX formulations were developed under the IMAD Program, many at China Lake, that retained high performance while minimizing sensitivity to unplanned stimuli.

---

[70]NWC RM-22, *NWC Explosives Program*, 169. Beauregard was an IM expert who worked in NAVSEA.

[71]Ibid., 169–170.

[72]Ibid., 171.

[73]Beauregard, *History of Insensitive Munitions*.

Dr. Lloyd Smith.

Other IM efforts have included the design of weapons and rocket-motor cases that are more resistant to external stimuli but that, should an unplanned reaction of the motor or filler occur, will minimize the overall reaction (for example, by venting the reaction through specially designed ports in the casing). At the same time, the technical requirements for IM testing—bullet, fragment, spall, and shaped-charge-jet impact; fast and slow cookoff; and sympathetic detonation—have been refined and standardized.

So important is the role that IM plays in the nation's military preparedness that an IM mandate is enshrined in the U.S. Code: "The Secretary of Defense shall ensure, to the extent practicable, that insensitive munitions under development or procurement are safe throughout development and fielding when subject to unplanned stimuli."[74]

[74]Ensuring Safety Regarding Insensitive Munitions, 10 USC § 2389.

In the second decade of the 21st century, China Lake is more active than ever in the field of IM, with positions of technical leadership in the Joint IM Technology Program, the IMAD Program, and the Insensitive Munitions Technology Transition Program. In addition, the Center provides the nation's finest ranges and facilities for IM T&E, welcoming customers from throughout the DoD and the free world.

11

The Avionics Revolution

If you see something that needs to be done, and the guy that is responsible for it isn't doing it, and it's something that you see is going to be beneficial to the Navy, go do it.

—Frank Knemeyer, Head, Weapons Development Department
and Weapons Planning Group[1]

On 17 December 1903, at a windblown beach on North Carolina's Outer Banks, two brothers from Ohio hooked up a set of dry-cell batteries to a crude four-cylinder motor and fired it up. The batteries were disconnected, and a Miller-Knoblock 10-volt magneto took over the task of providing the ignition spark. Moments later, the Wright Flyer was airborne for its historic 12-second flight. From that day to this, electricity has been essential to heavier-than-air flight.

With the introduction of aircraft-borne radio sets in WWI, the aircraft industry made its first foray into electronics—using electricity not merely to supply spark, power, heat, and light but also to manipulate information by exploiting the properties of electrons through the use of vacuum tubes. Thus the field of avionics (aviation electronics) extends back more than 100 years.

Until WWII, managing aircraft electrical and electronic systems was relatively straightforward. Each function—ignition, aircraft lighting, cockpit displays, communication sets—had its own point-to-point wired system. But during the course of the war, the number and complexity of the electronic elements on board significantly increased. In addition to communication and navigation devices, aircraft now carried radar sets, autopilots, jammers, and bomb-sighting systems. All consumed power and space and added weight to the aircraft. Over the next 20 years, managing the proliferation of electronic gadgets and their associated wiring became a major challenge for the aircraft industry. Cary Spitzer writes:

[1]S-200, Knemeyer interview, 133.

> By the late 1960s and early 1970s, it was necessary to share information between various systems to reduce the number of black boxes required by each system. A single sensor providing heading and rate information could provide those data to the navigation system, the weapons system, the flight-control system, and the pilot's display system.[2]

In addition, trading several black boxes for one black box meant weight and volume savings that could translate into larger fuel or weapons loads.[3]

For the Navy, the initial focus for avionics was the Naval Ordnance Plant, Indianapolis. This had been the production location for the famous Norden bombsight used by the Army Air Corps during WWII. After the war, the facility continued avionics development for the Navy, and in 1956 its name was changed to the Naval Avionics Facility, Indianapolis (NAFI).[4]

Avionics was a natural for China Lake. The remote desert base was home to people who were trained in the relevant engineering and scientific disciplines. It had its own airfield and aircraft, ranges for testing, and experience with integrating individual systems into larger systems of systems. China Lake's avionics development in the 1940s and 1950s included bomb director (Mk 3 Mods 4 and 5, Mk 6 Mod 3, and the EX 1), bomb-director sets (AN/ASB-7 and -8), and aircraft fire-control systems (Mk 8, Mk 16, and the EX-16).

At a period when state-of-the-art meant bulky vacuum tubes and printed circuit boards whose area was measured in square feet, the attempt to automate fire control—precision gun aiming as well as bomb and rocket release—was an ambitious undertaking. Yet each new system improved dramatically on its predecessor, and soon vacuum tubes gave way to transistors and mechanical computers were replaced by the NOTS-invented Mk 101 computer. A 1955 Naval Ordnance Systems Command (NAVORD) report detailed the computer's capabilities:

> It accepts data on the attack conditions, makes the computations for firing guns and rockets, and causes the sight unit to generate the lead angle for a hit . . . accomplished in a package that weighs only 20 pounds and has a volume of only 0.321 cubic feet.[5]

In the mid-1950s, China Lake developed the Mk 9 Mod 0 bomb director, which was used to compute the release point for the NOTS-developed Bombardment Aircraft Rocket (BOAR, a nuclear weapon with a maximum

[2]Spitzer, ed., *Avionics*, 1–2.

[3]Ibid.

[4]In 1992, NAFI was renamed the Naval Air Warfare Center Aircraft Division, Indianapolis; the organization was eliminated under the Base Realignment and Closure (BRAC) Commission of 1995.

[5]NAVORD Report 3470, *Rocket Quarterly*, 19–20.

range of less than 10 miles). In 1963, during Project Emergency Shrike Effort (ESE)—a crash program to build Shrikes for use against Soviet SA-2 missile sites in Cuba—China Lake engineers modified the Mk 9 Mod 0 and redesignated it the CP-741/A weapons-release computer. Delivered to the Fleet in 1966 for use with the A-4 Skyhawk, the CP-741/A used the aircraft's radar range-to-target and barometric altitude data to calculate weapon release points for free-fall bombs and terminally guided missiles (e.g., Shrike) in stick, toss, loft, and over-the-shoulder delivery modes.[6]

Captain Gary Palmer, who served three combat tours in the Western Pacific (WESTPAC), said of the CP-741/A, "I had that system in my airplanes when I was a squadron commander on [USS] *Kitty Hawk* and I made sure the damn thing worked because it was better than my young pilots. So we did pretty good."[7]

One problem with the CP-741/A and earlier fire-control systems was that they predicated the weapon-release point on a specific speed and trajectory for the attacking aircraft. In dive bombing, the *Tech History* explained,

> the aircraft enters the dive from a certain altitude above target at a prescribed airspeed, power setting, and trim condition. Normally, because entry conditions are not fulfilled exactly, the aircraft will have neither the correct airspeed nor the correct dive angle when the desired release altitude is reached.

These errors could be corrected for by adjusting the release height or by aiming offset, but such calculation "requires considerable pilot training and is especially difficult against unfamiliar targets where few visual cues are available." Not to mention that the targets might be shooting back.[8]

To solve the weapon-release-point problem, NOTS was assigned a program in 1963 called Improved Conventional Ordnance Delivery for A-4C/E Aircraft. The following year, program engineers fabricated an experimental differential-correction computer dubbed Conventional Ordnance Release Computer (later designated the Computer, Ordnance Release, CP-841/A) for the A-4. The new system would assist the pilot "by changing the release slant range to correct for any variations in dive angle, airspeed, and angle-of-attack." The philosophy of taking a difficult task away from the pilot and handing it off to a computer underlies much of avionics development.[9]

When the CP-841/A became operational in Fleet A-4C aircraft in 1969, "results of its first operational trials were both good and bad," reported the *Tech*

[6]ESE was also known as Early Shrike Effort.
[7]S-280, Palmer interview, 22.
[8]*NOTS Tech History 1964*, 7-31.
[9]Ibid.

History. The good was “excellent accuracy” and minimal training requirements. However, “system in-flight reliability of 81 percent was poor; this was influenced by the 87 percent radar reliability.” China Lake suggested a modification that would replace the radar range input with barometric altitude as the primary computer input.[10]

The following year, VX-5 conducted operational evaluation with the modified CP-841/A and “recommended that the modified CP-841/A be investigated for procurement and installation, as well as additional testing, in the F-4B, -4G, and -4J aircraft.” However, there is no evidence that this recommendation was ever acted on.[11]

Avionics increased in complexity as Navy air-delivered ordnance expanded from bombs to guided missiles, such as Shrike. In 1967, William P. Mayne’s Special Project Branch (part of Jack Russell’s Antiradiation Division) completed development of the Shrike Improved Display System (SIDS) for the A-4E aircraft. Before SIDS, pilots had difficulty distinguishing one threat radar target from another on the Shrike display, particularly in a target-rich environment. SIDS displayed the radiating targets as light spots on the APG-53 radarscope. The Shrike, when fired, would track the target centered on the scope.

SIDS was a quick fix for the problems Shrike shooters were encountering in Vietnam; contemporaneously with SIDS development, Mayne’s branch was developing the Shrike Target Identification and Acquisition System (TIAS), which was fielded in 1969 as the AN/APS-117. TIAS had the same capabilities as SIDS, only with greater sensitivity and lower false-alarm rates; it could also be used with Standard Antiradiation Missile (ARM), and it incorporated damage-assessment capability. In its first full year of service with the Fleet, TIAS had a mean time between failures (MTBF) of 190 hours and an availability rate greater than 98 percent.[12]

Angular Rate Bombing System (ARBS)

The ARBS (often written as angle rate bombing system) was invented by Roy Dale Cole, a research physicist. Dr. Peggy Rogers, Cole’s department head, once said, “Mr. Cole has a mind of great mathematical originality and a real flare for the practical aspects of mathematical physics.”[13]

[10] *NWC Tech History 1969*, 3-11.
[11] *NWC Tech History 1970*, 3-8.
[12] *NWC Tech History 1970*, 2-18.
[13] *Rocketeer*, 4 May 1973, 3. In 1973, Cole received the William B. McLean Award for his ARBS contributions.

Cole's patent abstract succinctly expressed the system's function:

> an angular rate bombing system which utilizes angular rate and angle measurements from an automatic target tracker, pitch and roll information from a standard vertical gyro, true airspeed data, and angle of attack information to compute an azimuth lead angle to release ordnance at the correct elevation lead angle.

Roy Cole.

ARBS was designed as an onboard system to give Navy attack aircraft an accurate, first-pass day-or-night automatic bombing capability.[14]

Prior to ARBS, the principal parameter for deriving a targeting solution was radar-derived slant range to the target. ARBS computed a solution based on the nose-mounted seeker's line-of-sight angle to the target and the rate of change of that angle.

Dick Boyd.

ARBS began in Newt Ward's Aviation Ordnance Department (AOD) in 1962. The program moved along slowly until a major reorganization at China Lake in November 1970, when, with the dissolution of AOD, the program was moved to Richard "Dick" V. Boyd's Guidance and Control Systems Division in Frank Knemeyer's Weapons

[14]Roy D. Cole, angular rate bombing system, U.S. Patent 3,699,310, filed 6 November 1970, issued 17 October 1972.

Development Department. Soon thereafter, Boyd's division was renamed the Avionics Division.

"The program had been canceled just before it came into the division," Boyd said. "Within about a week, I had to go back and try to get that program started again, and was successful in getting that done." Knemeyer recalled the transfer of the

> nearly terminated Angular Rate Bombing System exploratory- and advanced-development effort. With the transfer of the ARBS program to the department, a different approach was taken which resulted in new sponsor support and funding.[15]

The "different approach" was Boyd's remedying what he saw as too much innovation and too little management.

> You'd define an idea and by the time you had it two-thirds implemented, you had another idea. So you went in all these different directions, and one of the largest problems I had was just the configuration management for the program. . . . I finally wrote a memo and said, "This is the block diagram. This is what we're going to do. And nobody has the authority to change that without my permission. If you absolutely feel you have to do that, come talk to me. But you've got to convince me before you can do it."[16]

The November 1970 "realignment and refocusing" that moved ARBS to Boyd's division also recognized the importance and the complexity of integrating the expanding family of new avionics systems. In a joint interview published in *News and Views*, Walt LaBerge (Technical Director) and Hack Wilson (Deputy Technical Director) spelled out their views:

> We have modified the primary mission of the Weapons Development Department (Code 40) to include *integrated design of aircraft avionics and weapons* for strike aircraft. This includes the current guided weapons activity by the Weapons Development Department but places added emphasis on establishment of simulation and test facilities to better understand the requirements for new aircraft weapon systems." [Emphasis added.]

Of the Engineering Department (Code 55), LaBerge and Wilson said, "We expect to take on in the missile and avionics areas much more responsibility for the Navy, and much of this will be handled by Code 55." Alluding to that department's role in the AIM-7F second-source production, they added, "We hope similarly to establish a long-term position in the avionics business for

---

[15]S-220, Boyd interview, 78; Knemeyer, "Franklin H. Knemeyer (Frank)," official NWC biography, 6.

[16]S-220, Boyd interview, 79.

NAVAIRSYSCOM [Naval Air Systems Command]—a role that Code 55 would then assume."[17]

By 1972, the ARBS team had put together a workable unit using a modified Walleye TV tracker mounted in gimbals, an analog computer, cockpit controls, and a head-up display (HUD). The HUD allowed the pilot to view the ARBS target data projected on a transparent screen without having to look down at the instrument panel during a ground-attack run.

ARBS on TA-4F Skyhawk. Photo courtesy of Gary Verver.

At the time, HUDs were not in very wide use. Boyd recalled that in the mid-1970s, he was giving a presentation on ARBS to Rear Admiral Freeman, the base Commander.

> He climbed up the ladder and was sitting in the cockpit and we turned the thing on, and I was talking over his shoulder telling him what it was. He looked up—we had a head-up display, you know—and he said, "I don't like head-up displays." And I said, "Oh?" I said, "Well, how much experience have you had with them?" "Well, I really haven't had any experience with them." "Well, why don't you give us a chance to prove you're wrong?" . . . And he said, "OK!"[18]

[17]NWC, "Center Realignment and Refocusing," *News and Views, Points of View and Information on Management Matters*, June 1971, 2.

[18]S-220, Boyd interview, 96–97.

Boyd further recalled that Freeman later wrote letters, "personals, to very high levels back in NAVAIR and back in OPNAV, being very supportive of the system."[19]

ARBS was successfully demonstrated in flight tests in 1971 and 1972. An ARBS with an NWC-developed computer was tested against an analog computer developed for the Air Force by Norden Division of United Aircraft Products. A total of 680 bombs were dropped on China Lake's ranges, and the NWC computer achieved the smaller circular error probable (CEP).[20]

Contributing to the development and flight-test effort were Cole, Bob Berry, Harry Loyal, Carl Burkey (system engineer), Larry Raper, John Isenhower, Oscar Davis, Madilyn Adams, Fred Ikenoyama, Richard "Dick" Seeley, Gene Thomas, and Doug Turner. As a result of the tests, Marine Corps Headquarters began to promote ARBS for the A-4 and AV-8B aircraft. The Corps merged its support for the laser spot tracker and the ARBS into a single program, the A-4M/AV-8B Improved Weapon Delivery System (IWDS) Program. Heading IWDS was Dr. William H. Smith, a China Lake engineer with a doctorate in systems engineering.[21]

After a brief system-definition study, ARBS entered advanced development in 1973. Two hardware approaches were selected. One, by Hughes Aircraft Company, was a direct follow-on to NWC's work: a dual-mode (TV and laser) tracker (DMT) coupled with an International Business Machines (IBM) Corp. SP-1 digital computer. The second, by Martin Marietta, used a dual-mode seeker, a Sperry Flight Systems Division digital computer, and an Elliot Brothers (England) HUD.

In 1973, the CNO issued Specific Operational Requirement (SOR) 11-71: Angle Rate Bombing System, which spelled out the system's operational requirements and clarified flight-test objectives. Naval Air Test Center (NATC) Patuxent River was assigned responsibility for the flight-test evaluation program.

In 1974, the systems were installed in separate TA-4 aircraft and tested for 2 months at China Lake by personnel from VX-5 and NATC. As with every large development program, the ARBS testing brought together personnel from a number of organizations. Dr. Smith, the IWDS manager, noted particularly the contributions of John Halligan and Paul Alexander of the T&E Department as well as of Gary Davis' telemetry crew. Coordination with Hughes-IBM and

[19]Ibid.

[20]*NWC Tech History 1972*, 3-26.

[21]ARBS was also considered for the joint Navy-Air Force A-X aircraft program, which was later cancelled. The laser spot tracker began development at China Lake in 1967 as the Laser Target Designator System.

Martin-Sperry was handled by, respectively, Claude Owen and Carl Burkey. Pilots flying the tests were Marine Majors Cap Pinney and Dan Baker, Marine Corps Captain Stan Wright, Navy Commander Howie Alexander, and Navy Lieutenant Tom Scheber.[22]

Full-scale development of ARBS under Marine Corps sponsorship began in 1975. In March 1976, the Avionics Division began construction of the ARBS Real Time Data/Display Facility. (The Avionics Division at that point was located in Peggy Rogers' Systems Development Department; Nick Schneider had taken over the division when Boyd moved up to be associate department head.) The facility, completed in January 1977, received ARBS telemetry data in real time—the HUD, cockpit control settings, and the DMT display could be observed while a flight test was in progress and simultaneously be recorded for post-flight processing. "Problems have been solved and alternate plans or corrections made while a test was in progress," the *Rocketeer* reported. "Both the number of flights required and the overall cost of the test program have been reduced dramatically." For their work in establishing the new facility, Gene Thomas, Ken Trieu, Thomas O'Neill, and Louis Shantler shared a $1,000 Achievement Award.[23]


Carl Burkey.

Numerous technical challenges still faced the ARBS team: switching from analog to digital computing, for example, and incorporating new state-of-the-art seeker electronics as they came on line. The engineering, integration, and evaluation efforts were led by Burkey, who in 1979 received the Technical Director Award for his accomplishments with ARBS.

Through the end of the 1970s, a host of not-so-visible but equally critical tasks were underway for the ARBS. These included developing and testing ground-support equipment; ensuring that environmental and EMI standards

[22]Retired Navy Captain Archie B. Treadwell was the ARBS Project Manager for Martin-Sperry; the Martin crew referred to ARBS as "Archie's Random Bombing System." Owen, *Barnstorming to Spaceships*, 122.

[23]*Rocketeer*, 17 June 1977, 4.

were met; and designing, programming, testing, and integrating the operational flight programs (OFPs, the computer software embedded in the aircraft avionics). China Lakers were also working with Hughes Aircraft to modify ARBS for the AV-8B.

Technical evaluation of ARBS began in November 1977, followed by operational evaluation in 1978. The *Rocketeer* reported in August 1979 that "the system has successfully completed technical evaluation and operational evaluation, during which all requirements were met or exceeded. Bombing accuracy was approximately 1½ times better than the goal."[24]

ARBS full-scale development was completed in 1979, and production began the same year. The ARBS Real Time Data/Display Facility was expanded and converted from a developmental tool to a support facility. In 1983, ARBS was fielded as the AN/ASB-19 on the A-4M—the final model of the A-4 aircraft series. The system went to Marine Corps Harrier squadrons in 1986.

Night Attack

Beginning in the 1950s, researchers at China Lake were attempting to develop a night-vision capability for aircraft utilizing the IR portion of the electromagnetic spectrum. With IR, it was radiated heat, not reflected visible light, that revealed the potential target, be it a person, an idling tank motor, or a building (or portion thereof, such as a door or window) that radiated heat differently than its surroundings.

A program called the Advanced Development Attack Missile (ADAM) was started with Independent Exploratory Development (IED) funding in 1962. ADAM was to be an IR-guided air-to-surface weapon. The missile portion was soon set aside, but the ADAM search set, an external pod-mounted forward-looking infrared (FLIR) system for attack aircraft, continued in development. According to the *Tech History*, "The set is intended for use on strike missions and will provide target detection, target classification, and target acquisition."[25]

In 1967, the technology developed by China Lake for ADAM was the basis for a new FLIR sensor named, appropriately, EVE. Operating in the 8- to 14-micron region, the scanner could be slewed in azimuth and elevation, permitting an in-cockpit view 27 degrees in azimuth and +5 to -90 degrees in elevation. The EVE FLIR was a joint China Lake and Hughes development, formalized in a memorandum of agreement. China Lakers Eddie Allen and

---

[24] *Rocketeer*, 17 August 1979, 1.

[25] *NOTS Tech History 1964*, 5-47. Earlier aircraft-borne IR sensors used for aerial mapping were downward-looking (DLIR).

Larry Jeffris, working at Hughes' Culver City facility, did the mechanical design; Hughes handled the electronics and overall system design.

During this period, U.S. and South Vietnamese military planners were concerned by a supply line that carried material and personnel south from North Vietnam, along the so-called Hồ Chí Minh Trail through the Laotian panhandle, into South Vietnam. The need to disrupt this flow was driving development of better ways to detect and identify targets—difficult enough in daytime, nearly impossible at night or under poor visibility conditions.

One effort to address this problem began in 1966 with the Navy's Trails and Roads Interdiction Multisensor (TRIM) program. TRIM investigated various low-light-level television approaches, illuminators (visual and IR), radars, FLIR, emplaced sensors, and other detection systems and technologies. TRIM's goals were to "add night search and attack capability to all strike/ASW aircraft as state-of-the-art of sensor design points" and to "develop special strike capability utilizing such aircraft as the A-6, A-7, VSX, and VFAX [two proposed aircraft] with specially designed sensors, integrated systems, and coordinated tactics."[26]

TRIM utilized P-2 and EA-6A aircraft for system and technology test beds. By 1968, the China Lake / Hughes EVE FLIR was operating in Vietnam, "installed in two AP-2H aircraft operated by VAH-21 [Heavy Attack Squadron 21] for search and detection of enemy supply vehicles and boats at night."[27]

Closely connected with TRIM was China Lake's Night Attack System (sometimes called Night Attack Weapons System or Night Attack Program), begun in 1967. The system consisted of an aircraft-mounted FLIR and an IR seeker that was "compatible with almost any missile airframe 5 inches or more in diameter," such as Bullpup (or Maverick, after the missile's introduction with the Air Force in 1972).[28]

Working with the TRIM program, the Night Attack System continued development through the early 1970s. In 1976, three successful Night Attack System tests at China Lake and the Pacific Missile Test Center (PMTC) were conducted from an A-6. One was against a stationary target, the second against a moving M-48 tank target, and the third against a Seaborne Powered Target (SEPTAR) boat traveling at high speed. The first two were long-range shots,

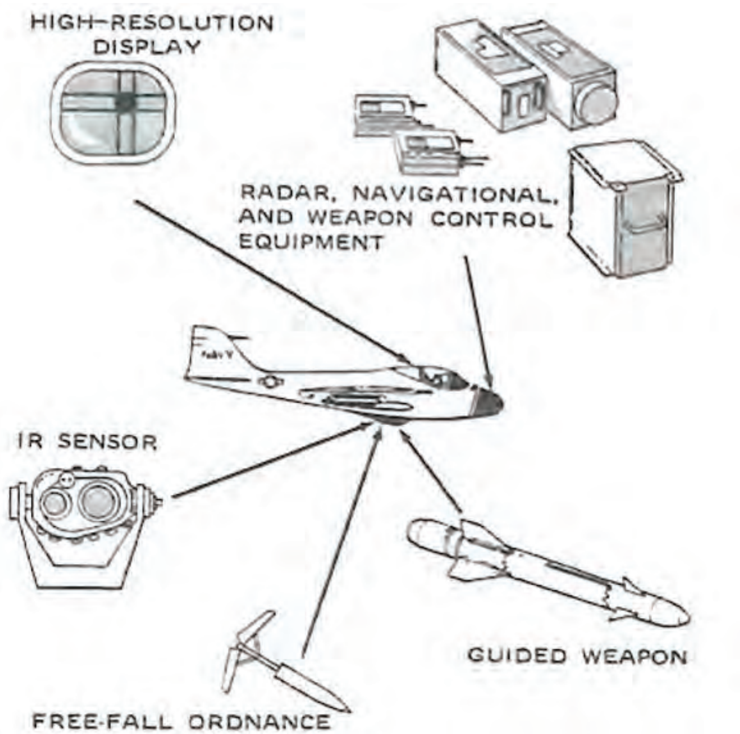
---

[26] *NOTS Tech History 1966*, 3-7.

[27] *NWC Tech History 1968*, 7-32. The AP-2H was a P-2 Neptune modified for night ground attack with FLIR and low-light-level TV, carrying fuselage-mounted grenade launchers, downward-firing miniguns, napalm, and bombs.

[28] *NWC Tech History 1967*, 1-22.

and all three scored direct hits. The missiles used were Mavericks with modified IR seeker heads.



Night Attack System.

One of the major challenges of the Night Attack System was boresight correlation: aligning the IR seeker in the missile with the FLIR turret on the aircraft so that when the FLIR was pointed at the target, the missile seeker was as well. In 1976, China Lake engineers created a boresight-correlation computer (BSC) that used digital cross-correlation techniques to align the sensor and the missile seeker. Under contract with Raytheon, an improved BSC was constructed in 1977.

In 1979, the Night Attack System was combined with several other in-house efforts to become the IR Attack Weapon program, which the following year completed formulation studies for what would become the Navy IR Maverick (AGM-65F). The Center prepared the draft IR Maverick system and missile specification. The Navy IR Maverick has a penetrating 300-pound warhead, more than double the weight of the Air Force version, and is optimized for tracking ships; it went to the Fleet in the late 1980s and is still operational with Navy aircraft.

A program to provide all-weather day and night attack capability for the A-6E aircraft began in 1972. Known as the Target Recognition and Attack Multisensor (TRAM) program, it started with the development of thermal imaging (FLIR) and laser range-finding systems for electro-optical (EO) detection and ranging. NAVAIR managed the program, and the principal development work was carried out by various contractors: Grumman Aerospace (aircraft), Hughes Aircraft (EO systems), United Technologies Norden Division (multipurpose attack radar), and IBM (computers). Doug Cowan was the original program manager at NWC; the Center's role in the early years of the program was primarily technical support, monitoring contractor developments and performing the occasional in-house study.

TRAM on A-6A Intruder, 1973. Photo courtesy of Gary Verver.

By 1977, when A-6E software support was transferred from Naval Surface Weapons Center, Dahlgren, to China Lake, NWC engineers were monitoring developmental tests of the first TRAM-configured A-6E at NATC Patuxent River. The following year, the Center's A-6E TRAM team continued to support the system with "program monitoring, test monitoring and evaluation, safety program monitoring, design reviews, and data reviews and approvals."[29]

[29] *NWC Tech History 1978*, 2-26.

China Lake was selected to integrate a Navy-developed Global Positioning System (GPS) called NAVSTAR into the A-6E TRAM in 1979. The incorporation of a detection and range set (DRS) with integrated EO and laser suites further enhanced the TRAM's mission capabilities. The Center also developed an A-6 mission simulator with which it was possible to test nearly all of the operational flight software for the A-6E TRAM. Operational evaluation (OPEVAL) of TRAM began late in the year.

When the A-6E TRAM went to the Fleet in October 1979, it gave the Navy an unmatched target discrimination and attack capability. In 1981, the TRAM team received the prestigious Daedalian Weapon System Award, which was presented to NAVAIR, NWC, and the contractors.

From left: Chuck Newmeyer, B. J. Gorrono, George Ramirez, Dick Walters, Captain John Jude Lahr, Ike Fujiwara, Roy Hasting, Don Iwamura, and Bob Campbell with Daedalian Award.

Night Observation Gunship System (NOGS) / Night Observation System (NOS)

In 1970, China Lake was approached by the Marine Corps to adapt FLIR to the OV-10A Bronco aircraft and create NOGS.

The concept that became the OV-10 was originally conceived at China Lake by Major (later Colonel) Knowlton P. "K. P." Rice, who was assigned to VX-5 in 1960. Rice and fellow Marine Major W. H. Beckett, stationed at Marine Corps Air Station El Toro, Irvine, California, designed a close-air-support aircraft for integrated operations with ground troops. With twin turboprop engines, a 20-foot wingspan, and a landing-gear width of 6.5 feet, the craft was designed to be able to operate from roads and small fields and to take off and land in 500 feet, clearing a 50-foot obstacle. Ordnance would be mounted on the centerline for accuracy and there would be a small bomb bay for "tactical flexibility," wrote Beckett.

> We gave up a lot of what was standard because it wasn't absolutely required for the mission. This included things like ejection seats; aviation type navigation and communication equipment; and especially the single-engine performance, fuel, and equipment requirements associated with airways instrument flight.[30]

That aircraft eventually became the OV-10, though not before the military bureaucracy and joint-service politics had severely compromised the original design. In Beckett's view:

> The original concept of a small, simple aircraft that could operate close to the supported troops had been almost completely eviscerated by the "system." The ability to operate from roads (20-foot wingspan and 6.5-foot tread) had been ignored, and performance compromised by the short 30-foot [wing] span [later lengthened to 40 feet!], the extra 1,000 pounds for the rough field landing gear, and another 1,000 pounds of electronics. The "light, simple" airplane also had a full complement of instruments, ejection seats and seven external store stations.[31]

As the triservice OV-10 program was working its way through development—the first flight was in 1965 and first operational deployment was in 1969—China Lake was developing a sophisticated FLIR research, development, test, and evaluation (RDT&E) capability.

---

[30]W. H. Beckett, K. P. Rice, and M. E. King, *The OV-10 Story: Innovation vs. The "System,"* accessed 12 November 2013, http://www.volanteaircraft.com/ov-10.htm, 3.

[31]Ibid., 16.

NOGS. Published in the 1970 *NWC Tech History*.

Phil Arnold was a program manager in Chuck Smith's Infrared Systems Division (home of the Center's FLIR work), part of Knemeyer's Weapons Development Department. In 1970, as Arnold recalled,

> We got a call from Luc Biberman [a former China Laker who worked for the Institute for Defense Analyses, a group that advised the Secretary of Defense on science and technology issues]. The Marines wanted to put FLIR on the OV-10. They didn't like the existing FLIR. We proposed a different FLIR—NOGS.[32]

Specifically, what NWC proposed was an OV-10A (redesignated YOV-10D) with a chin-mounted FLIR sensor, a three-gun belly-mounted 20 mm gun turret slaved to the sensor, and associated displays, controls, and avionics.[33]

At NAVAIR, NOGS was assigned to Captain Gene Shine, the TRIM project manager. Shine gave management control to China Lake and had Arnold brief the project to interested parties in NAVAIR. Following a question and answer session at the end of the presentation, Arnold said that Shine told the group that any questions or complaints later would be considered "bureaucratic bellyaching."[34]

Progress was phenomenally fast; this was a Quick-Reaction Capability (QRC) program, and many of the niceties of traditional programs were

[32]Babcock, Arnold interview, *The News Review*.
[33]Ibid. The "Y" prefix designated prototype.
[34]Arnold review comments, 31 October 2014.

dispensed with. "In effect, China Lake had a fixed-price contract with the Navy to deliver a product with a schedule and within a fixed total cost," wrote Arnold.

> The vendors were selected without competitive bidding, and we sat down after work had been in progress for some time to hammer out a cost plus fee contract with each. We were on the hook to manage the program and get the job done at the cost we proposed.

The three contractors were North American Rockwell (aircraft modifications), Hughes Aircraft (FLIR), and General Electric (armament / fire control).[35]

The *Tech History* captures the tempo of the work:

> Two YOV-10D aircraft were delivered to NWC in November. During December the armament subsystems and FLIR sensor systems were installed; the first test flight with a full all-up system was flown on 16 December. Gun-firing tests were successfully completed in early December after the XM-197 20-mm armament system was installed.[36]

As with any development program, there were glitches. For example, the vertical depression of the gun was designed not to exceed -62 degrees from horizontal. This was ensured by a friction clutch and, should the clutch fail, by a metal block below the gun. However, as Arnold recounts:

> During the firing test, the clutch burned out, the arresting block didn't hold, and the gun ended up hanging straight down. The barrels are pretty long, far longer than the landing gear could accommodate, and the pilot had a problem. The chief test pilot from Columbus was there for the test and took over from the company ground controller to talk the pilot in. The plane landed with the shallowest feasible glide slope and ground the barrels down on the runway surface with an imposing show of fire and sparks. The landing was safely made, and except for a groove in the strip and short gun barrels, no damage was done.[37]

Navy technical evaluation (NTE) was conducted in February 1971. The system was judged to be "excellent for the mission concept"; however, with NOGS installed, the OV-10s were overweight and underpowered.[38]

> Headquarters, U.S. Marine Corps, and NAVAIRSYSCOM carefully considered these conclusions and decided that the benefits that could result

[35] Arnold to the author, email, 12 May 2009.

[36] *NWC Tech History 1967*, 1-30. The night-firing capabilities were exercised against a WWII Liberty ship anchored in Chesapeake Bay.

[37] S-275, Arnold interview, 29.

[38] *NWC Tech History 1971*, 2-49.

> from a combat evaluation overshadowed the risk of deploying the YOV-10D in the overweight, underpowered condition.[39]

The two NOGS aircraft—one of them equipped with a 1.06-micron laser designator and a mission recorder—were deployed for combat evaluation the following month. They were accompanied by Arnold and the Marine Corps aircrews and maintenance technicians, who had been trained in the system's operation at China Lake and Camp Pendleton. The aircraft operated from the Navy's base at Bình Thủy in Vietnam's Mekong Delta as part of Light Attack Squadron Four (VAL-4), the Black Ponies. "The flat delta region was ideal for the underpowered YOV-10D aircraft," said Arnold.[40]

The system worked as intended. The *Tech History* reported that

> during the 64 flying nights, 207 combat evaluation flights were made, for an average of 3.24 flights per night. The 207 flights by the YOV-10D aircraft constituted only about 13 percent of the total squadron flights, but these flights accounted for well over 50 percent of the battle damage inflicted on enemy troops, waterborne supply vehicles, and structures."[41]

The *Tech History* also noted that "in this operation, NOGS destroyed or damaged 103 sampans and 43 structures, and caused 50 secondary fires or explosions."[42]

Arnold recalled one vivid example of the system's effectiveness:

> We got back film of one mission flown on a moonless night that was a graphic example of the brutal nature of war in general and Vietnam in particular. A Vietcong patrol had infiltrated a bunker filled with sleeping Army of Vietnam soldiers and killed all of them. The NOGS appeared as they were filing out, and NOGS in turn killed every one of the VC. The whole operation was recorded on the film, and the remarkable resolution of the FLIR clearly showed the slaughter. Rear Admiral Bill Moran, China Lake Commander at the time, ordered that if we ever showed that film that we mute the sound of the Marine air crew voices on the radio as they attacked, and that we be careful about who saw the video.[43]

During their tour in Vietnam, the NOGS aircraft were always supported by on-site members of the China Lake team, including Bill Irby, Oren Gilbertson, and Ron Jones. Other NOGS contributors were Doug Cowan, Bill Maddox, Bob Sizemore, and Mike Sanitate. Speaking for the NOGS team, Arnold said,

---

[39]Ibid.
[40]S-275, Arnold interview, 32.
[41]*NWC Tech History 1971*, 2-50.
[42]Ibid., 1-29.
[43]S-275, Arnold interview, 32.

"We did that program in less than a year. We were very proud of that. . . . That's what you can do with a lab like China Lake."[44]

China Lake continued to provide support to NOGS through the mid-1970s. Doug Cowan took over the program in 1975 and refocused it on a reconnaissance, observation, and forward-air-control mission. The gun was removed and the system was redesignated NOS, using principally the FLIR and the laser-designation systems as well as two larger engines and new propellers. George Goetz was China Lake's systems engineer for the program, which proved highly effective for observation, surveillance, and forward air control during its combat evaluation in 1971. Eventually, beginning in 1978, the Marine Corps modified 18 OV-10As to OV-10D NOS aircraft.

A-7 Weapon System Support Activity (WSSA)

By the mid-1970s, aircraft and weapon systems were becoming so interdependent that the distinction between platform and weapon was getting murky. The increase in interconnectivity between subsystems, both in the aircraft and in the weapon system, had gone beyond hard-wiring part A to part B. Part A might now be required to communicate different parameters and commands to parts B, C, and D at different times and receive data from parts E, F, and X.

As computers became smaller and their computing capacity greater, software was the intermediary for intersystem communication among and between systems and subsystems. A weapon could be built with a capacity for growth—broader frequency range in the seeker of an antiradiation missile, for example. That growth would not be implemented by physically replacing the seeker with a different one but rather by reprogramming the software contained in the existing seeker. Avionics software was becoming a communication network that encompassed the entire aircraft-weapon entity, where the antiradar missile would need to communicate with the aircraft navigation system, its stores-management and display systems, and its threat-warning system.

One example of such intersystem networking was cited by Commander Bob "Ramjet" Ramsey, a former Navy A-7E combat pilot, speaking of the integration of the High-Speed Antiradiation Missile (HARM) with the A-7E in the early 1980s:

> It would be silly for the pilot not to be able to take advantage of that very, very sophisticated [HARM] seeker out there, to let you know what's going on in

[44]Babcock, Arnold interview, *The News Review*.

> the RF threat environment, because it's more sensitive, more capable than the on-board radar homing and warning equipment that we've got.[45]

In 1962, the Navy announced acquisition of a new attack aircraft, its airframe based on the Ling-Temco-Vought (LTV) F-8 Crusader. A development contract was awarded in 1964, and the first flight of the new aircraft, designated the A-7 Corsair II, took place late in 1965, and the aircraft went to the Fleet in 1967. The A-7—specifically the A-7E—made the leap from previous hardware-intensive aircraft that were independent of their weapon systems to a new software-intensive aircraft in which the platform and weapons were parts of an integrated system.[46]

One aspect of China Lake's involvement with the A-4 Skyhawk, which the A-7 would replace, was installation and maintenance of the CP-741 weapons-release computer. This analog computer was designed by China Lake and built by NAFI. As new systems were added to the A-4, problems began to surface with system interfaces and incompatibilities. As Fleet introduction of the A-7A approached, it was clear to the A-7 team that the new aircraft, which had been fielded at an accelerated pace, would have similar problems to those encountered with the A-4.

A-7A aircraft at China Lake Hot Line. Photo courtesy of Gary Verver.

[45]TS 84-14-14, Commander Bob Ramsey interview, 7.

[46]The suffix "II" was in deference to the venerable Chance-Vought F4U Corsair of WWII / Korean War vintage.

In 1967, the 18 A-7A aircraft of Attack Squadron 147 (VA-147, the Argonauts) had just undergone major modifications by Vought, including changes to the weapon systems and to the active and passive electronic countermeasures (ECM) equipment. The squadron was scheduled to deploy to WESTPAC (the area in the Western Pacific from whence Navy air operations were conducted in North and South Vietnam).

China Lake's Robert "Bob" J. Freedman, who had worked with the CP-741 system since its inception, suggested that the new A-7s should have their computer problems addressed *before* deployment. To implement Freedman's suggestion, a program called Operation Brushup was conducted in 1967.

Bob Freedman.

According to a history of China Lake's A-7 program:

> Brushup was the first attempt at troubleshooting an integrated "weapon system"—aircraft, navigation system, weapons-delivery computer, weapons interfaces and controls, electronic warfare equipment, and on-board displays.[47]

At the time, there was no standard procedure for checking avionics. The experts on the team—from China Lake, Point Mugu, Patuxent River, and several contractors—"drew upon their collective experience with aircraft and weapon systems to come up with an efficient test procedure and measures of effectiveness."[48]

The aircraft were a mess. Nearly every plane required repairs and modifications. At one point, there was not a single flyable plane in the squadron. Vought sent more than a dozen trouble shooters to assist. Parts were flown in from Dallas on a daily basis. Team members worked days and nights to identify and resolve the problems. Although not called for in the original Brushup plans, the Argonauts validated the Brushup fixes with live attack runs, dropping bombs and firing Shrike and Bullpup air-to-surface missiles on China Lake's ranges.

"Brushup was considered successful, having met two of its three objectives," reported the *Tech History*.

[47]NWC AdPub 391, *What Have You Done for the Fleet Today?*, 7.
[48]Ibid.

> Ground check-out of the aircraft, including correction of deficiencies, was accomplished on all 18 aircraft. Bombing and ECM flights were accomplished for all aircraft, and ECM training was provided for each pilot. Maintenance training, the third objective, was not accomplished because of the many deficiencies that had to be corrected and the limited amount of time available before squadron deployment. As a result of Brushup, VA-147 deployed on schedule in a combat-ready condition.[49]

During 1968, Brushup II (at Naval Air Station [NAS] Cecil Field) and Brushup III (at NAS Lemoore) were held for other A-7 squadrons deploying to WESTPAC. In these exercises, there was a heavy emphasis on training maintenance personnel in teams comprising the four enlisted ratings associated with the aircraft electronics and weapon systems: aviation fire control technician, aviation electronics technician, aviation electronics mate, and aviation ordnanceman. After Brushup III, no further Brushup operations were required, "since the ensuing A-7A/B squadrons have adopted the [Brushup] idea and are conducting similar operations during their normal training cycle."[50]

During Brushup, China Lake and Vought built a strong working relationship. The goal of the program had not been to fix blame for the inadequacies of the A-7s as delivered but rather to make the aircraft ready for combat.

The A-7E was the first model to replace the CP-741 analog computer with the IBM-built ASN-91 (TC-2) digital computer. The A-7 was the Navy's first digital airplane, and the Navy wanted in-house expertise in case major problems arose. In September 1968, Captain Thomas "Black Tom" Gallagher, NAVAIR's A-7 project manager, told Freedman that he wanted NWC to become part of the A-7 project.

A February 1969 AIRTASK from NAVAIR formally incorporated NWC into the A-7E program, and Bob Freedman—Big Daddy, as he was called—was selected as the NWC A-7 program manager. China Lake assembled a team of 30 engineers, physicists, and mathematicians and sent them to Vought for a 3-day indoctrination course. When Vought trotted out its corporate-training personnel, Dick Seeley, who was a supervisory physicist at China Lake, insisted that the NWC team meet instead with the aircraft and subsystem design engineers. Following the Vought visit, the team traveled to IBM to get a fuller understanding of the A-7E's onboard computers and their mathematical framework.[51]

---

[49] *NWC Tech History 1967*, 1-10.

[50] *NWC Tech History 1967*, 1-16.

[51] AIRTASK is a tasking document for programs conducted under the sponsorship and direction of NAVAIR.

Dick Seeley.

For each of the eight major components of the navigation and weapon system—the so-called "Big Eight"—a single team member was assigned to develop technical expertise, traveling throughout the country to learn from the people who had designed and built the component. The Center was also monitoring the A-7E flight work being conducted at NATC Patuxent River; Eglin Air Force Base; and NAS Lemoore.[52]

In 1969, NWC started development of an A-7 simulation and support facility, beginning with three laboratories: simulation, navigation-systems integration, and weapons integration. The China Lake team was gaining more hands-on experience in the avionics software business. The *Tech History* that year noted that "progress was made toward developing the capability of changing the mathematics flow to incorporate future changes to the tactical computer software program" and that "software changes were developed and programmed to increase the Walleye envelope to one that is more realistic."[53]

A Scientific Data Systems Sigma 5 computer, delivered to China Lake in 1970, was at the heart of the A-7 Simulation Laboratory. Here, hardware and software were thoroughly wrung out before flight testing. The simulation laboratory was first located in Michelson Laboratory and was later moved to Armitage Field. By 1971, all three laboratories were operational. The A-7 Weapon System Integration Laboratory was housed in Hangar 3 at Armitage Field, and the A-7 Navigation System Integration Laboratory was located in

---

[52]The Big Eight were the ASN-91 digital computer, ASN-90 inertial measurement set, AVQ-7 head-up display, ASN-99 projected-map-display set, APQ-126 forward-looking radar, CP-953 air-data computer, APN-190 Doppler radar, and armament station control unit. NWC AdPub 391, *What Have You Done for the Fleet Today?*, 11.

[53]*NWC Tech History 1969*, 1-18.

a converted housing dormitory at Mainside. An A-7E was assigned to China Lake in 1970, followed by a second in 1971.

The A-7 team began developing capabilities for the contractor to incorporate in the OFP. NAVAIR announced that China Lake would be the official "Software Program Manager for the Tactical Operational Flight Program." All contractor changes to the OFPs were sent to China Lake for validation before being released to the Fleet in preparation for NWC taking over engineering support from the contractor.[54]

Software was the medium that allowed aircraft and weapon subsystems to exchange data and commands. In 1973, A-7 project engineers at China Lake recognized the need for a portable device that could be brought to an aircraft to quickly upload an OFP or to download the aircraft's existing computer memory for reloading after maintenance was performed. The previous method for performing software changes on the AN/ASN-91 airborne computer was slow and cumbersome.

Working under NAVAIR tasking, engineers in W. D. "Woodie" Chartier's A-7 Facilities Branch designed and built a new system called the memory loader verifier (MLV) and demonstrated it for Fleet A-7 squadrons. The device not only uploaded and downloaded flight programs and test plans for the airborne computer but also verified the correctness of the load. The MLV dramatically decreased the size, weight, and cost of previous memory loaders. Procurement began in 1977, and the first production units, from Texas Instruments, were delivered to the Fleet in 1978. The MLV (AN/ASM-607) was subsequently adapted for use with the AYK-14 airborne computer on the A-4M, EA-6B, F/A-18, AV-8B, and EP-3E.

China Lake's aggressive attitude in tackling the problems associated with software in aircraft did not go unrecognized in higher naval echelons. Captain (later Vice Admiral) Ernest R. Seymour was the Navy's A-7 program manager (and later, Commander, NAVAIR). According to China Lake's official history of the A-7 WSSA, Seymour characterized China Lake's responsiveness to the sponsor's needs as

> superb. . . . Had they not been, it was early enough in the game that we would have said, 'to heck with you' . . . One of the reasons I didn't have subs [split up the support tasks] is that China Lake was responsive.[55]

In 1973, former China Laker (VX-5) Captain Carl "Tex" Birdwell, as NAVAIR A-7 class desk officer, announced that China Lake would be the official

[54]NWC AdPub 391, *What Have You Done for the Fleet Today?*, 12.
[55]Ibid., 14.

Software Support Activity (SSA) for the A-7. This caused some consternation at the Naval Air Rework Facility, which had responsibility for the A-7's "black boxes." NAVAIR settled the issue by breaking out the Big Eight from the rest of the aircraft's avionics.

It was not unusual for other Navy activities to feel that China Lake was infringing on their turf. But the attitude of China Lake's management (with some exceptions, such as Rear Admiral Freeman and Dr. Hollingsworth) was, essentially, if we can do it better, let's do it, mission and organizational barriers be damned. Frank Knemeyer summed it up:

> If you see something that needs to be done, and the guy that is responsible for it isn't doing it, and it's something that you see is going to be beneficial to the Navy, go do it. At least it's going to get things stirred up to where something's getting done. Either you're going to do it or it's going to get the other guy off the dime and make him do it.[56]

Cultural and organizational biases were an impediment to effective weapon/platform integration. As in the story about the blind men describing an elephant, weapons developers and aircraft developers saw the overall weapon/platform system from different perspectives, based on each group's unique experience. Thus, when the allocation of space, weight, accessibility, power, and other limited resources was at issue, parochial attitudes came into play. These attitudes had their roots in the Navy's organizational history, in the Bureau of Aeronautics and the Bureau of Ordnance. The former—the platform side of the house—traditionally relied on industry for research and development (R&D), while the latter—the weapon developers—looked to the in-house laboratories for design, engineering, and preparation for manufacture. (The two bureaus had been combined into a single Bureau of Naval Weapons in 1959.)

Integration issues were generally well managed within the individual communities. At China Lake, for example, warhead developers, guidance engineers, rocket-motor designers, and aerodynamicists all worked relatively harmoniously to integrate their individual subsystems into an effective weapon. Compromise was essential: if you make a larger warhead, I have less room for my rocket motor. What is the proper balance between range and speed and terminal destructiveness?

Effective integration of the larger weapon and platform communities was slower coming. John Lamb described the problems encountered in integrating the Standoff Land-Attack Missile (SLAM) with the F/A-18 in the 1990s. "The SLAM missile really needed to talk to the airplane back and forth," said Lamb. Signals regarding missile readiness and seeker functions as well as target

[56]S-200, Knemeyer interview, 133.

tracking needed to be shared by the weapon and aircraft before weapon launch. Lamb elaborated:

> We tried and tried and tried to tell the F-18 people that you really need to look at this and you really need to be a part of this. The response from the F-18 people was, "We were told that we could have SLAM on the airplane but . . . we can't make a change in the airplane, period."

That particular situation persisted for about a year and a half before NAVAIR stepped in to ensure a greater degree of cooperation.[57]

As China Lake developed new OFPs for the A-7E, they were designated NWC-1, NWC-2, etc. Occasionally there were Alpha or Bravo versions. Before one OFP was fully integrated into Fleet aircraft, NWC software engineers would be integrating fixes, refinements, and new capabilities into the next version. The A-7E team recognized that the new high-tech facilities and simulations had their limitations:

> The ultimate laboratory of the A-7E WSSA, of course, was the aircraft itself. Laboratory simulation and testing was never considered to be a substitute for thorough flight testing. Every integration, every software update, was exhaustively flight tested by the Center before it ever left China Lake—and by VX-5 before it went to the Fleet.[58]

Not only were there an airfield, aircraft, and highly instrumented ranges under restricted airspace close at hand, the software developers and integrators at China Lake also had the benefit of specialized facilities available nowhere else in the country. During the integration of the A-7E with HARM, for example—the first integration of a software-intensive aircraft with a software-intensive missile—the A-7/HARM team had the benefits of testing its work at China Lake's Electronic Warfare Threat Environment Simulation (Echo Range), with its unique assortment of threat radiators.

Freedman and Chartier (the last NWC A-7 program manager) recognized that the A-7 model was not just a China Lake success.

> It was the Vought people, the weapon-system manager and NAVAIR people, the weapons and electronics vendors' people, and the Fleet people, too. All working together. . . Personal relationships played an extremely important role; we accomplished a lot just because we would get together for dinner, or go and talk over a beer. As in any marriage, there were some "rocky" times, but those personal relationships that got the program started kept it going.[59]

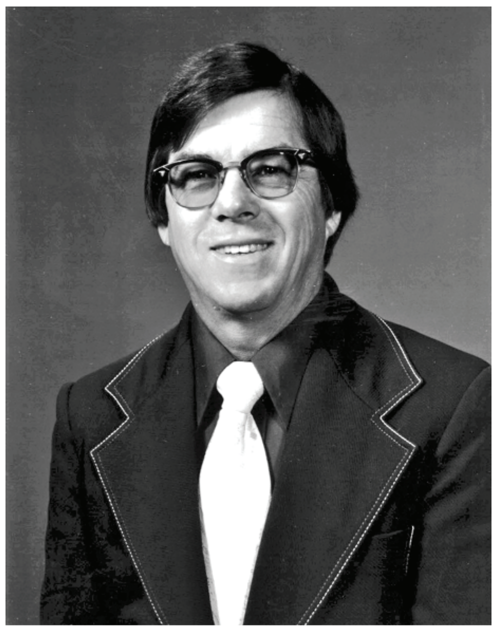
[57]S-313, Lamb interview, 61.
[58]NWC AdPub 391, *What Have You Done for the Fleet Today?*, 20.
[59]Ibid., 4.

Since the A-7E was the first of the digitally enabled aircraft, NWC had the jump on other Navy laboratories and facilities as avionics became a driver of new aircraft design. In 1977, the Center was designated the SSA for the A-6 (the function was transferred to China Lake from the Naval Surface Warfare Center, Dahlgren) and the WSSA, a broader designation that recognized the "total systems aspects of the required support," for the A-7E, F/A-18, and AV-8B. In 1979, NWC was designated WSSA for the A-4M and, in 1984, for the AH-1. All of this work traced its lineage to the aircraft fire-control systems that China Lake had begun developing in the mid-1940s.[60]

Dick Boyd, who'd spent 5 years as the head of the Avionics Division, commented on the importance of having in-house Navy expertise to integrate weapons and platforms:

> What we need to have out there are Navy airplanes, because each one of these [aircraft] manufacturers had its own set of rules, its own set of experiences. . . . The only kind of a mechanism that existed for transfusing the lessons-learned across all those contractors was through an operation like this.[61]

In 1980, most of NWC's avionics and integration efforts were consolidated in one department, the Aircraft Weapons Integration Department, under the leadership of Leroy D. Marquardt. Bill Ball ran the Avionics Facilities Division, which contained the aircraft-specific facilities; Nick Schneider headed the Avionics Division, which oversaw development of technologies for navigation systems, armament systems, and the like; and Werner Hueber headed the Targeting Division, which explored targeting technologies and approaches (CO_2 laser, IR, target recognition, etc.).



Leroy Marquardt.

[60]*NWC Tech History 1976–1977,* 1-68; *NWC Tech History 1978*, 1-7; *NWC Tech History 1979*, 3-9.

[61]S-220, Boyd interview, 38–39. Boyd, who retired in 1994 as head of the Range Department, worked at China Lake for 42 years. Among the many honors he earned was the L. T. E. Thompson Award, NWC's highest.

Rounding out the department was Dick Seeley's Tactical Software Engineering Division.

Ground breaking for a $5.1 million Weapon System Support Facility took place in September 1981. Located adjacent to Hangar 3 at Armitage Field, it would eventually house all the Center's SSA and WSSAs. When the large, dark-blue building—soon known as the Blue Whale—was dedicated in June 1983, NWC's Commander, Captain John Jude Lahr, told those gathered for the ceremony that it was no longer possible to think separately of an aircraft and its weapons. "The machine can only be as good as the minds that combine the two," he said.[62]

China Lake's A-7 facilities continued to serve the A-7 community through the aircraft's service life and its capstone combat role in Desert Storm in 1991. The A-6, F/A-18, AV-8B, A-4M, and AH-1 avionics and systems support organizations followed the successful model established by Freedman and his A-7 team. In the 21st century, integrating weapons and avionics for the Navy's tactical aircraft is still a major role in China Lake's service to the DoD.

[62] *Rocketeer*, 24 June 1983, 5.

12

Leveraging the Taxpayer's Dollar

You write your report and you give [the customer] the 25 copies that your contract calls for and then he puts them in his desk drawer and that's the end of that. It becomes quite disillusioning if you really are trying to do something for the taxpayer.

—Dr. Hugh H. Hunter, Head, NOTS/NWC Research Department,
on the frustration of trying to maximize the utility of
federal research dollars[1]

Smart Buyer

"Trying to do something for the taxpayer" takes many forms. At China Lake, the most obvious manifestation was the Center's role in seeing that contractors—that consume by far the lion's share of the systems-acquisition and -support budget—gave a dollar's worth of value for each dollar spent by the government. Ideally, that watchdog, or "smart buyer," process began early in the systems-acquisition process. "We go in when a contract is being let and allow the government to be a very smart buyer when it brings a contractor on-board," said Captain William B. Haff, China Lake's 22nd Commander. "We shake out the proposals to see which one really looks good. And from our experience, we know the company's capabilities, we know which ones are liable to give us the best product for the dollar."[2]

Dr. Dick Kistler, who took over as head of the Office of Finance and Management in 1975, felt that the smart-buyer role extended well beyond contract oversight and evaluation. He articulated a widely held belief among China Lakers that the Center should

[1]S-95, Hunter interview, 26. Hunter was speaking not of his China Lake experience but of his 5½-year stint at the not-for-profit Research Triangle Institute.

[2]S-125, Haff interview, 12.

> keep enough people involved in testing and evaluating the weapons in order to help the Navy know what it is getting and make sure it works, and have enough people around who have kind of lived with the weapon all the way through from inception to deployment so that they know what will probably go wrong with it and how to fix it, and when the Navy is using it at sea they'll be available to fix it.[3]

For Dr. Robert A. Frosch, who served as the Assistant Secretary of the Navy, Research and Development (ASN R&D), from 1966 to 1973, the smart-buyer function was one rationale for a strong basic research program in the Navy laboratories. During an interview, Frosch stated:

> If you have knowledge of your own, you can't be gulled, whether purposely or accidentally. Somebody can't sell you a lead brick painted gold if you have an expert around who just looks at it and says, "That's a lead brick painted gold." It's not a defense against fraud. It's more a defense against confusion and buying the wrong thing in the wrong way, because you specify it wrong.[4]

Being a good steward of the taxpayer's dollars was, to Bob Hillyer,

> the raison d'etre of a Center such as this. Everything else we do is in support of doing that role well—of being the conscience and the technical watchdog of the Navy as it acquires its systems. It has been our fundamental role and will be so in the future. Sometimes we'll have that role from the point of view of being designer and controller, as we have been on every variant so far of Sidewinder. Sometimes it'll be as an advisor—Tomahawk or Harpoon are examples—and sometimes in between those two extremes. But that will be the fundamental role, and we've got to remain flexible enough to do that role regardless of which method of operation is chosen by the sponsor Systems Command.[5]

Hillyer also felt that maintaining the technical skills necessary to keep one step ahead of the contractors—being the "conscience and technical watchdog of the Navy"—required that "a certain percentage of the work in an organization such as this must be hands-on design work. If it's not, the place will atrophy and 20 years from now we'll look like a Systems Command."[6]

Second Sourcing

Another means by which NWC saved the taxpayer money (very large amounts of money) was by establishing multiple competitive production sources for every possible system and component, a process called second sourcing. This practice, generally disliked by the initial contractor but welcomed

[3]S-132, Kistler interview, 21. Kistler retired in 1996 after 33 years at China Lake.
[4]DeVorkin, "Interview of Dr. Robert Frosch."
[5]S-134, Hillyer interview, 70.
[6]Ibid., 71.

by its competitors, introduces an additional element of competition into the procurement business. And competition, as has been demonstrated time and again, has numerous benefits in terms of both cost and quality. "We proved in the Shrike and Sidewinder programs that competition is good, not only in terms of reliability of product but in terms of keeping weapons cost down," summarized Bill Hattabaugh.[7]

One of history's best examples of the benefits of second sourcing is Sidewinder. In 1956, Philco Corp. (later Philco-Ford) was the sole producer of the Sidewinder 1A (AIM-9B) guidance and control unit. The Bureau of Naval Weapons put out a call for second-source contractors. Eight companies were finalists in the second-source competition, and General Electric Corp.'s Light Military Electronics Department was the winner. According to *Aviation Week and Space Technology*, the Navy's tactic was simple: "Both companies were asked to submit prices on a variety of different quantities. BuWeps then computed the most advantageous split of its previous year's production, based on each company's pricing schedule." By 1962, the price for the guidance and control unit had been cut by 70 percent. This was made possible because China Lake created and controlled the documentation package and maintained control of production changes.[8]

Saving money was not the only reason for second sourcing. Another benefit was that it made the supply of a weapon system less subject to destabilization if the original source had business setbacks, such as a long-term strike or a natural disaster affecting a manufacturing plant. A third benefit was that a second source helped to ensure reliability. A strong incentive for quality was introduced when two contractors, each supplying a percentage of the government's requirement, were aware that a new contract would be periodically negotiated and that the percentage of allocation would be increased for the company that performed best over the term of the initial contract.

Second sourcing is only as good as a weapon's documentation package, and that is only as good as the technical expertise and experience of those who review and approve (or disapprove) proposed changes once the system is in production. This lesson was driven home profoundly in the production history of the Shrike antiradiation missile. The production contractor was Texas Instruments. The Bureau of Weapons had determined that China Lake, which had developed the weapon, did not need to be involved in oversight after the missile had transitioned into production.

---

[7]S-127, Hattabaugh interview, 30. Hattabaugh was China Lake's T&E Director when, in 1981, after 20 years at the Center, he moved to PMTC, Point Mugu. In 1985, he became PMTC's Technical Director.

[8]Klass, "Sidewinder 1-A Price," 89.

When the first Shrikes were delivered by Texas Instruments, they simply didn't work. The company had made hundreds of changes to the missile design that resulted in a weapon that could not perform properly. The contractor's engineering change proposals (ECPs) had been approved by Defense Contract Administrative Services personnel who did not understand the production processes or the technology of the missile and thus the consequences of the changes they approved.[9]

Shrike on A-4 aircraft at NAF China Lake.

In the meantime, China Lake had been negotiating with Sperry-Farragut to become a second source for Shrike. Sperry had no experience with the missile but agreed to build it to the Center's original documentation package. Leroy Riggs, head of the Aeromechanics Division at the time, recalled that a Sperry engineer told him:

> "Look, we're going to build to print. If you've made a mistake on [the drawings] and it says drill a 3/4-inch hole and then it comes along and says run a 3/8-bolt through it, to me, obviously, it's going to rattle . . . we're going to build to print, and you're going to get it that way." And we said "Fine. Don't change anything." And it turned out that was a fabulous set of documentation. . . . Few people know that the first missiles that we took in 1966 to Vietnam did not come from TI, which was the principal contractor. They came from

[9]Roland Baker, who managed several major programs for China Lake during his 32-year career, once said of ECPs, "I think what they do is they take the dumbest [people] and send them to evaluate ECPs, when you really should have your best people go evaluate ECPs. 'If it ain't broke, don't fix it' is still good advice." S-326, Baker interview, 62.

> Sperry-Farragut, who was the second-source contractor, who came in late, was handed a set of drawings, and built to print.[10]

Comprehensive production engineering, thoroughly documented, was the foundation of effective second-source production. China Lake engineers brought to bear an understanding of materials availability, commercial standards and tolerances, and general manufacturing and processing methods to ensure that the product designed in a laboratory environment was suitable for mass production in industrial settings.

Captain Ken Dickerson (China Lake's 24th Commander) told an interviewer in 1984:

> When you take out the government laboratories, or the Weapon Center in particular, from the contractor and turn [the weapon] strictly over to the contractor, the price of the product goes out of sight. The beauty of the way things are developed here at China Lake is bringing in competition, and to bring in the competition you must have design knowledge of the weapon systems. Basically, having a good set of design drawings and being able to go out to industry and compete those with more than one producer. When you put any weapon system in the hands of a single producer, his motives are profit.[11]

Energy Independence

When considering the costs of running a Navy laboratory, energy was not traditionally one of the first items to come to mind. Items such as new buildings, land acquisition, infrastructure maintenance, employee salaries, chemicals for the chemists, and metals for the metallurgists were the obvious cost drivers. Energy, through the post-war years and well into the 1960s, was a relatively steady background expense. In fact, from 1950 to 1970, the inflation-adjusted price of gasoline actually fell by about 20 percent.

The equation changed after a series of summer brownouts swept major East Coast cities in the late 1960s. A sense of unease was abroad in the country. People began to talk about an "energy crisis," referring initially to the shortage of electricity. In November 1970, President Nixon's Director for Energy Policy, S. David Freeman, spoke of rising costs, fuel shortages, and what he saw in America as "almost a runaway market for energy." Promoting a plan to increase energy efficiency through rate restructuring, he asked rhetorically, "What better

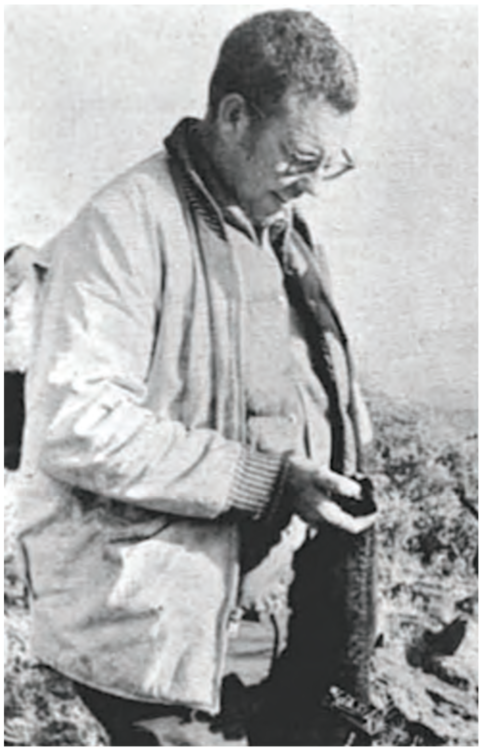
[10]S-136, Riggs interview, 29–30. Riggs, two-time winner of the Navy Meritorious Civilian Service Award, retired in 1975 as head of the Center's Resources and Technology Office.

[11]TS 84-14-11, Dickerson interview, 5. Dickerson and Captain John Jude Lahr (China Lake's 23rd Commander) flew Shrike defense-suppression missions together over North Vietnam in the mid-1960s when they were lieutenant commanders.

way is there to give people an incentive to conserve energy than to make them pay more for wasting it?"[12]

U.S. oil production peaked in 1970 and then began to fall. Meanwhile, demand for oil continued to grow. In March 1973, President Nixon imposed controls on oil prices (including gasoline and home heating oil) for the country's 23 largest oil companies.

In May 1973, the *Rocketeer* announced that Dr. Carl Austin, a geologist and head of the Research Department's Petrodynamics Branch, was one of 30 energy experts in California who had been invited to Sacramento to discuss the energy problem. The article quoted from Lieutenant Governor Ed Reinecke's invitation: "The energy crisis is becoming more real to us daily in California."[13]



Dr. Carl Austin.

Austin was, and had been since the early 1960s, an acknowledged expert in the field of geothermal power. In January 1971, he had addressed the China Lake Chapter of the American Society for Public Administration on the subject. The announcement of his talk in the newspaper observed that "throughout California and the west, an increasing concern over energy, coupled with critical power shortages, has resulted in public attention being focused on geothermal energy as a source of pollutant-free power." In 1972, Austin spoke on the same subject to the Institute of Electrical and Electronic Engineers (IEEE), discussing "the fundamentals of geothermal technology for the primary purpose of electric power generation and how it might affect the national ecological program."[14]

With his brother, Ward H. Austin Jr., and head of the Propulsion Development Department, Dr. Guy W. Leonard, Dr. Carl Austin had authored

[12]Ripley, "Rate Rises," 1.
[13]*Rocketeer*, 18 May 1973, 1.
[14]*Rocketeer*, 11 December 1970, 7; 17 March 1972, 5.

a series of papers titled *Geothermal Science and Technology*. "His work on geothermal activity and its possible application for the purpose of generating electrical power has involved an extensive analysis of the Coso Hot Springs thermal area on the Naval Weapons Center," the *Rocketeer* reported. Carl Austin had published his first report on Coso's geothermal potential in 1964, and by 1966, he had established a small field laboratory at Coso Hot Springs. That year's *Tech History* reported that "development of a geothermal steam well is in progress to provide the facility for land-based research and development."[15]

Dr. Guy Leonard.

China Lake was uniquely fortunate in having geothermal resources readily available while also having the technical and managerial expertise on board to exploit those resources. Yet even as the initial steps of geothermal development began, numerous other efforts were underway to cut energy use across the Center. Some were simple—a sticker by the door to remind a person leaving the room to switch off the lights—while others were more creative, relying on such developing technologies as photoelectric power and computerized energy-management systems.

As fiscal year 1973 drew to a close in September of that year (the federal fiscal year runs from 1 October to 30 September), the Chief of Naval Material (CNM) called for the Navy to reduce its energy use by 15 percent in fiscal year 1974. The point man for this task at China Lake was Ensign L. S. Murphy, a contract and project officer in the Public Works Department. The young officer was assigned the title of Naval Weapons Center Utilities Conservation Officer. His marching orders were "to institute programs and seek voluntary compliance with proposals that will be aimed at reducing the Center's utility consumption rate by 7 per cent by the end of December [1973]."[16]

Five days after that announcement of Ensign Murphey's new task, the Organization of Arab Petroleum Exporting Countries imposed an embargo

[15]*Rocketeer*, 18 May 1973, 1, 4; *NOTS Tech History 1966*, 2-35.
[16]*Rocketeer*, 12 October 1973, 1.

on the sale of oil to the United States in response to America's support of Israel in the Yom Kippur War. The embargo, the nation's increasing dependence on foreign oil, declining U.S. oil production, and the lack of a coherent national energy policy led to the so-called 1973 oil crisis. By the time the embargo was lifted in March 1974, oil's price per barrel had quadrupled.

On 7 November, 3 weeks after the embargo began and against a background of long lines at gas stations (the images had replaced Vietnam firefights as the signature visual on the TV evening news shows), President Nixon addressed the nation on the subject of energy shortages. His tone was alarmist: "We are heading toward the most acute shortages of energy since WWII. Our supply of petroleum this winter will be at least 10 percent short of our anticipated demands, and it could fall short by as much as 17 percent."[17]

Among his prescriptions to fix the problem were "reductions of approximately 15 percent in the supply of heating oil for homes and offices and other establishments," adding, "Incidentally, my doctor tells me that in a temperature of 66 to 68 degrees, you are really more healthy than when it is 75 to 78, if that is any comfort."[18]

Nixon accepted no blame for the crisis but rather pointed the finger at his audience.

> Part of our current problem also stems from war—the war in the Middle East. But our deeper energy problems come not from war, but from peace and from abundance. We are running out of energy today because our economy has grown enormously and because in prosperity what were once considered luxuries are now considered necessities.[19]

The week after the President's address, China Lake's Commander, Rear Admiral Pugh, outlined steps by which the Center would reduce its energy use, including a speed limit of 50 miles per hour for all NWC vehicles (on and off Center). "All exterior holiday season decorative lighting in industrial, administrative, and housing areas will be eliminated," ordered the Skipper. "The only exception will allow lighting of the Chapel area."[20]

"Energy crisis," "energy crunch," and "energy conservation" were fodder for intense radio, television, and the press coverage. The *Rocketeer* was no exception. Liz Babcock (author of Volume 3 of this history series) penned a

[17]The American Presidency Project, Richard M. Nixon, "Address to the Nation About Policies to Deal with the Energy Shortages," 7 November 1973, retrieved 25 November 2013, http://www.presidency.ucsb.edu/ws/?pid=4034.

[18]Ibid.

[19]Ibid. Nixon cited home air conditioning as such a necessity.

[20]*Rocketeer*, 16 November 1973, 5.

front-page story for the 30 November 1973 issue titled "Study of Total Energy Community to Demonstrate Wise Energy Use." The Total Energy Community (TEC) program was "a plan to supply ultimately, through local resources, all the energy needs of a community." China Lake planned to meet the TEC goal through the use of solid waste, geothermal, and solar energy. In the same issue of the paper, it was announced that shuttle bus service on base would be cut back "as a result of the current energy crisis," that the Public Works Department would reduce hall and corridor lighting in public buildings by 50 percent, and that thermostats should be set to 68°F during daylight hours.[21]

Liz Babcock.

On the last issue before Christmas, 1973, the paper solemnly announced that the traditional and very popular "fabulous light display" at the home of Ernie Loscar (long-time Public Works employee) and his family on Upjohn Avenue in Ridgecrest would be darkened "due to the energy crisis."[22]

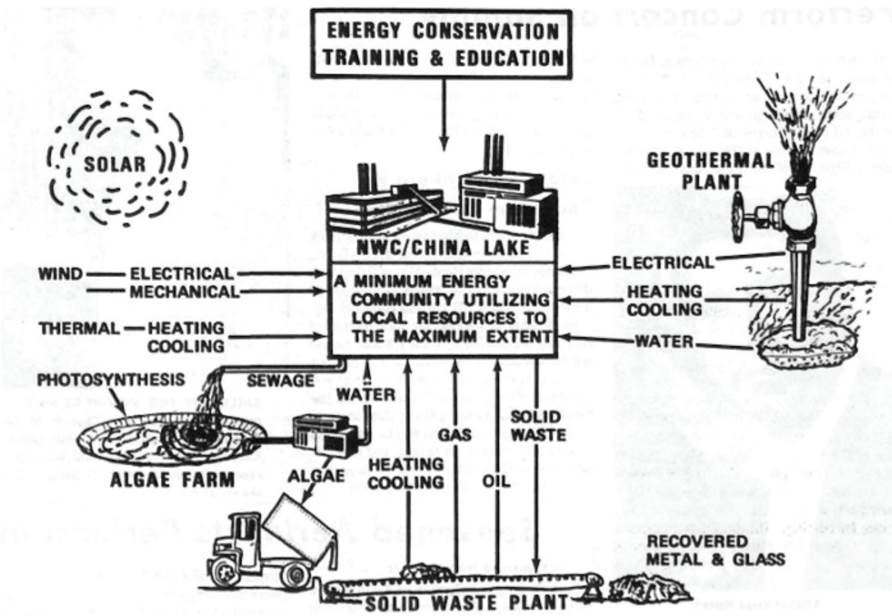
Early in 1974, Dr. Leonard spoke to another IEEE meeting—an "overflow crowd"—and outlined the TEC plan in more detail. This was a period when environmental awareness and environmental activism were beginning to achieve prominence, and Leonard tried to strike a balance between energy generation and good stewardship of environmental resources. He noted

> a tendency to project a frightful picture for the year 2000 when the air will be so polluted that all will have to wear gas masks, and the water will kill the wildfowl trying to use it. . . . I think we can have a wonderful life without having to go back to living in a cave.[23]

[21]*Rocketeer*, 30 November 1973, 4.
[22]*Rocketeer*, 21 December 1973, 4.
[23]*Rocketeer*, 1 February 1974, 3.

Leonard laid out a range of energy-saving options that he hoped the Center would investigate. It was a litany that, though new to his audience, has become familiar over the ensuing decades: alternatives to gasoline (ethanol and hydrogen), wind and solar energy (including residential rooftop collectors), geothermal energy, and reduced water usage (redesigned toilets). The goal was to make China Lake "a minimum energy community utilizing local resources to the maximum extent."[24]

The Energy Coordinating Office was established in the Propulsion Development Department in November 1977 under Richard "Dick" Fulmer. The same year, China Lake, working with the national Energy Research and Development Administration (ERDA), set up a photovoltaic station to run a remote radar installation on the North Range Complex.



The TEC plan. Published in the *Rocketeer*, 1 February 1974.

At Randsburg Wash, six tracking mounts were set up to track the sun and focus the sun's rays on target plates as part of an ERDA study of heliostats (solar collectors) for use in central-tower solar/thermal electric generators. China Lake researchers also installed a circumsolar telescope (to measure the amount of direct solar radiation) and pyranometers (to measure solar irradiance). Three

[24]Ibid.

Dick Fulmer.

vertical-axis wind machines were set up to assess their use for residential heating, and NWC chemists were studying "the technology needed to produce petroleum-like products (principally high octane gasoline) from the organic fraction of trash, and to quantify the gasoline yield and energy efficiency." By 1977, China Lake had succeeded in cutting energy consumption by 20 percent from the 1973 baseline level—while at the same time experiencing a growth rate of 10 percent.[25]

Another innovative approach to saving energy was the Low Energy Structures Program, begun in 1977. The concept was a structure containing a central atrium with a skylight through which sun provided heat and light to the interior. (A concept demonstration structure was built in the CLPP area.) Insulated 4- by 8-foot Mylar®-backed louvers rotated to cover the skylight at night. The windowless structure was surrounded by an earthen berm for insulation, and a rock temperature-storage system beneath the floor was coupled with an evaporative cooler and heat-pump system to modulate the temperature of the structure.

Dave Wirtz, an engineer who worked on the project, recalled that the employees had bamboo growing in the atrium. At one point, someone from the China Lake Police Department peaked in. "[He] thought that we were growing marijuana. And so we got called on the carpet until we went in and showed them no, no this is not marijuana, this is bamboo."[26]

In a project funded by the Department of Energy's (DOE's) quaintly named Office of Fossil Energy, Center scientists and engineers studied heat-exchanger technology. One spin-off was a low-cost method of fabricating fluted tubes (using aluminum, Type 409 steel, and titanium), for low-temperature waste-heat recovery.[27]

The Center's accomplishments in energy conservation did not go unrecognized. In 1980, Secretary of the Navy Edward Hidalgo announced that

[25]NWC Fact Sheet, *Conversion of Solid Waste to Gasoline* (China Lake: 1977).
[26]S-414, Wirtz interview, 53. Wirtz retired in 2016 after 55 years of service at China Lake.
[27]*NWC Tech History 1978*, 1-45.

NWC was the winner of the Navy Energy Conservation Award for large shore facilities for fiscal year 1979. The Secretary stated:

> In these times of uncertain supplies and soaring fuel prices, energy conservation must be more than a slogan. The example set by the winners of this competition must be followed throughout the Navy and Marine Corps if we are to meet the energy challenges of the near future.[28]

In July 1980, NWC won the Naval Material Command (NAVMAT) Energy Conservation Incentive Award. Winners shared the savings in energy costs—$1 million—resulting from their energy conservation programs. The Center's share was $200,000, which could be spent "for any legal purpose." However, the CNM "strongly recommended that the money be spent for personnel support facility projects."[29]

Coso Geothermal Field

Of all the proposed avenues to China Lake's energy independence, the most promising appeared to be geothermal. By sheer luck, when the Navy had carved NOTS out of the western Mojave Desert, the land withdrawn from public access included an area known as Coso Hot Springs. At that time (1943), there was little activity there. Beginning about 1914, a small piece of private property known as the Coso Hot Springs Resort had attracted folks to the area for the supposed medical benefits of the springs—"the greatest natural radio hot springs in America," boasted an early entrepreneur—but business had dwindled during the Great Depression.[30]

The Coso area, characterized by fumaroles, or volcanic vents that release steam hotter than 200°F, holds an important place in the folklore and mythology of the Paiute-Shoshone Native Americans. Representatives of Native American groups still hold ceremonies and perform rituals there through a memorandum of agreement entered into in 1979.[31]

Austin had suspected the geothermal potential of the area since the early 1960s, and by the mid-1970s, others began to take a serious look at harnessing the power of the geothermal field. In 1975, NWC Commander Rear Admiral Rowland G. Freeman III and the head of the Public Works Department,

---

[28] *Rocketeer*, 6 June 1980, 1.

[29] *Rocketeer*, 25 July 1980, 1.

[30] *Rocketeer*, 6 July 1973, 5. The Navy purchased the Coso Hot Springs Resort property from the owners soon after the base was established in 1943. In 1978, Coso Hot Springs was listed on the National Register of Historic Places for its historic buildings and its importance to Native Americans.

[31] Access is controlled on a case-by-case basis, based on safety and security considerations.

Fumaroles in the Coso area.

Captain W. F. Daniels, joined Austin and Leonard for a trip to the Big Geyser geothermal field near Cloverdale, California. The *Rocketeer* detailed their visit:

> They were taken on a tour of the facilities, looking at various steam wells and drill rigs to gain a first-hand knowledge of the magnitude of the equipment involved in such an operation and the associated environmental problems.[32]

Pacific Gas and Electric then hosted the group's tour through one of their operating geothermal power plants in the area.[33]

In 1974, the Federal Energy Administration was created to address the energy crisis at the national level. The Energy Research and Development Administration was activated in 1975 to manage energy R&D as well as the nation's nuclear weapons and naval reactors. The two agencies, as well as the Federal Power Commission (later renamed the Federal Energy Regulatory Commission) were combined to form the DOE in 1977.

Dr. Peter Waterman, Special Assistant for Energy Research and Development from the Office of the Secretary of the Navy (R&D), visited China Lake in

[32]*Rocketeer*, 24 October 1975, 5.
[33]Ibid.

November 1976 to inspect the first test hole that was being drilled in the Coso area. He was briefed on various aspects of the geothermal work, including the overall Navy geothermal program (by Dick Fulmer), siting (by Dr. Steve Lee, head of the Applied Analysis Branch), corrosion studies of geothermal fluids (by Dr. Carl Austin), legal considerations of geothermal development (by Lieutenant Commander Marv Commander, assistant staff judge advocate), and environmental impact (by Tilly Barling, head of the Natural Resources Office).[34]

Tilly Barling with Captain William B. Haff.
Published in the *Rocketeer*, 25 January 1980.

Dr. James A. Whelan, head of the University of Utah's Geology and Geophysics Department, visited the Center in January 1977 to urge development of geothermal resources on military bases. He emphasized the lower initial costs of geothermal energy ($4 to $7 million to establish a 55 megawatt geothermal plant versus $25 million for a conventional steam plant), lower operating costs (generating electricity at "half or a third the normal cost"), and the "necessity for the U.S. to be free of dependence on other nations for oil and natural gas."[35]

[34]Commander was Marv's last name in addition to his rank.
[35]*Rocketeer*, 7 January 1977, 3.

Serious drilling started in 1977 when Battelle Memorial Institute's Pacific Northwest Laboratories, under a contract to the DOE, drilled 17 heat-flow holes and a 1,350-foot-deep test hole. The DOE then completed a 4,845-foot-deep test well that proved commercially viable flow rates and temperatures were present. A new Geothermal Utilization Division, headed by Austin, was established in the Public Works Department.[36]

The Department of Interior (DOI) let a $667,661 contract to Rockwell International in 1978 to prepare an environmental impact statement for geothermal leasing and development in the Coso Known Geothermal Resource Area (KGRA), as it was now called. The Coso KGRA included about 80,000 acres. About 50,000 were on Navy land and the rest on public lands administered by the Bureau of Land Management (BLM), part of the DOI. Under a cooperative agreement between the DOI and the Navy, the BLM would handle the sale of geothermal leases, and subsequent development would be supervised by the DOI's U.S. Geological Survey (USGS).

Some people were unhappy with the development of the Coso geothermal area. Native American groups feared that it might impact the hot spring sites that were part of their mythology and spiritual practices. These concerns were taken into consideration in the environmental studies and in the location and guidelines for the plant development, and today test wells are continuously monitored to ensure that plant operations are not adversely affecting the hot springs.

In 2008, Richard Stewart, a member of the Big Pine Band of Owens Valley Paiute, spoke to a group at China Lake about the Coso Hot Springs area. He acknowledged that there were still such concerns among tribal members,

> but when you get out there you can see that for all the work that's going on and the massive size of the geothermal project, that if there was a direct effect or a direct link to what was going on down here [at the ceremonial site], this thing would have disappeared a long time ago.

He noted that "the power plants are a good kilometer and a half, two kilometers south of the site. . . They're creating steam from hot rocks, they're not taking steam out of the ground . . . It's cutting-edge type technology."[37]

---

[36]NWC TS 92-20, *Coso Geothermal Development*, 3. When Austin retired as head of the Geothermal Program Office in 1991, after 30 years of service at China Lake, he was awarded the Navy Superior Civilian Service Award.

[37]Stewart, "Paiute Legends of Coso Hot Springs," video presentation, 20:08, 36:23. Stewart, a "tradition bearer" and historical researcher, is the grandson of Jack Stewart, who was an informant for the famous anthropologist Julian H. Steward.

On the base itself there were people who felt that geothermal development might interfere with China Lake's ability to carry out its mission, particularly the ability to test on the north ranges. The Center's *Tech History* for 1977 explicitly stated that "NWC will continue to support the Coso geothermal development with the provision that this development does not jeopardize the Center's primary mission."[38]

Bill Hattabaugh, who left the base in 1981 as T&E Director when he transferred to Point Mugu, told an interviewer:

> We're going to have one of the largest geothermal installations in the country located on our north range. We've taken steps to mitigate the impact of that, but we are going to have problems and it's going to lessen our capability to do some work, especially on the north ranges, when that occurs.[39]

The business model selected for Coso geothermal development by the Geothermal Program Office is called "farming in," a time-tested process in the energy industry.

The approach is based on the premise that when front-end, high-risk exploration is done by a company [the Navy] at their own expense, they may decide for one reason or another that the prospect does not meet their economic criteria. So, they seek a partner who is willing to make the investment, and they take an overriding interest in the play. Agreements between the parties are fully negotiated, taking into consideration how much was put into the delineation phase, current market conditions, and current/projected operating expenses. In short, if the economics of a project do not "pencil out" favorably, no deal will be struck.[40]

In 1979, California Energy Company Inc. of Santa Rosa won a 30-year contract to produce geothermal energy at Coso and provide the Navy with low-cost energy. Two years later the company began drilling its first well, and in 1986, groundbreaking ceremonies were held for the initial power plant. A 28-mile power transmission line was built by American Line Builders to get the anticipated power out to the grid. Finally, on 15 July 1987, at 1521 Pacific Daylight Time, Navy Geothermal Plant One (Navy One), Unit One, delivered its first power to the public utility grid. The plant was rated at 25-megawatt capacity, at a time when the Center's peak power demand was 20 megawatts.

---

[38]*NWC Tech History 1976–1977*, 1-56.
[39]S-127, Hattabaugh interview, 9.
[40]Monastero, "Model for Success," 193.

Navy Geothermal Plant One.

Unit One was later joined by Units Two and Three, and in 1989, Navy Geothermal Plant Two (Navy Two) went on line, with a capacity of 80 megawatts. By 1992, total electricity production from the complex was 240 megawatts—enough power to serve one million people.

The Navy did not permit China Lake to keep all the proceeds that flowed from the project; rather, the money went into the Navy-wide Energy Cost Avoidance Program managed by the Naval Facilities Engineering Command. In 1992 alone, $3.2 million was made available to worthwhile energy conservation projects, and one quarter of that went to China Lake projects.[41]

Although difficult to quantify in dollars, the reduction in hydrocarbons afforded significant benefit to the environment and to air quality while moving the nation closer to energy independence. "Generating one megawatt of electricity from geothermal for one year," the Coso geothermal developers noted, "is equivalent to saving 2,400,000 barrels of oil or 8,000,000 pounds of coal."[42]

[41] *Rocketeer*, 8 October 1992, 1.
[42] NWC TS 92-20, *Coso Geothermal Development*, 5.

The Coso geothermal project is a classic example of military-industry cooperation in the development of energy resources, and it has been a spectacular success in saving taxpayer dollars. None of the Navy's money was spent for plant construction or operation, and from 1987 to 1991 the Center received $15.3 million in direct reductions of its electricity bill. The entire project was done under Navy control with minimal interference to the Center's mission or encroachment on the ranges.[43]

Steam plume from Coso Navy power plant. Published in NW CTS 92 20, *Coso Geothermal Development*, 1992, cover.

[43]Ibid.

Technology Transfer

WWII had not been over for half a dozen years when NOTS began a program, sponsored by the Bureau of Ordnance, to apply explosives to purposes other than destructive. The work culminated 9 years later in the development of an explosive press, a method of harnessing the force of energetic materials to deform metal in ways not possible with traditional commercial presses.

The new technology, developed by John Pearson and Edward LaRocca, was unveiled at a press conference in Los Angeles in September 1958. By the end of that year, 31 companies had contacted Pearson for additional information about the process. These included "major research and aircraft firms, as well as a number of diversified companies producing various items for public consumption." The developers stated that the process could decrease costs of military production—tax dollars—by $30 million ($284 million in 2021 dollars) annually.[44]

Although not called "technology transfer" at the time, the idea behind sharing the explosive-press concept was the same: disseminate taxpayer-funded technology developments into the larger commercial sphere and make the greatest economic use of federal resources. According to the Federal Laboratory Consortium, "Technology transfer is the process by which existing knowledge, facilities, or capabilities developed under Federal R&D funding are utilized to fulfill public and private needs." Most of China Lake's technology-transfer efforts benefitted civil institutions, including state and municipal governments, other branches of the military, numerous federal agencies, and even other nations.[45]

Technology transfer got its start as a formal DoD program at the height of the Vietnam War. In a September 1968 speech, Secretary of Defense Clark M. Clifford discussed a concept he called "total national security." He said:

> The most modern of weapons will be inadequate to ensure our survival in today's world, unless our society is keyed to the steady improvement of our political institutions and concerned that all our people participate and share in the benefits of that society.[46]

[44]*Rocketeer*, 19 September 1958, 1; 9 January 1959, 1.

[45]The Federal Laboratory Consortium, accessed 12 December 2013, http://www.Federallabs.org/flc/home/faqs/.

[46]Clifford, "Address by the Honorable Clark M. Clifford," quoted in U.S. Congress, *Congressional Record—Senate*, S. 28814.

Speaking of the DoD, he said:

> A department which consumes nine percent of the gross national product of our nation, a department which employs four and one-half million Americans, has a deep obligation to contribute far more than it has ever contributed before to the social needs of our country.[47]

In October, Dr. John Foster, Director of Defense, Research and Engineering (DDR&E), challenged the laboratories to come up with specific ideas for those contributions to which Clifford alluded. He asked NWC for a list that would include "a brief discussion of each idea; RDT&E costs, if any, associated with each program; and likely long-term costs, benefits, and cost savings." Fred Nathan, editor of China Lake's *News and Views* management newsletter, dutifully printed the request.[48]

In the following month's issue of the newsletter, Nathan wrote:

> If your response to DOD's request for ideas to help solve the nation's important domestic problems is any indication, NWC could support a significant effort in nonmilitary R&D for many years. There was much enthusiasm in evidence both among rank and filers and key managers for NWC to get part of this action.

He noted that the ideas submitted were primarily in the R&D area and involved medical instrumentation, air and water pollution, weather modification, education and training, aircraft collision warning, crime control, urban transportation, and automobile safety.[49]

When Melvin Laird took the reins of the Defense Department in January 1969, he continued to support the program, now known as the Domestic Action Program. It was expanded to include efforts to help low-income communities. Later that year, China Lake established the Medical, Engineering, and Scientific Working Group (MESWG) to work with doctors at the China Lake Dispensary and San Diego's naval hospital. Fred Nathan was appointed business manager. During the next 2 years, under the auspices of MESWG, China Lake would develop an air-operated bone mill for tissue banks (designed and fabricated by Leroy Stayton with assistance from Ted Herling) and chemical-biological techniques for the study of valley fever (coccidioidomycosis); at that time there were about 200 cases reported annually in Kern County. Dr. Pierre Saint-Amand and Dr. Richard Clark led the valley fever investigations.

---

[47]Ibid.

[48]NWC, "DOD Challenges Labs for Ideas to Help Solve Domestic Problems," *News and Views, Points of View and Information on Management Matters*, October 1968, 1.

[49]NWC, "Ideas to Solve Domestic Problems Abound," *News and Views*, November 1968, 7.

Leroy Stayton.

Saint-Amand and his colleagues in the Earth and Planetary Sciences Division had been engaged in technology transfer since the mid-1960s, applying their rain-inducing and fog-reducing technologies to assist agriculture and civil aviation throughout the United States and abroad. They also trained local authorities in rainfall-augmentation techniques. (The principal military focus of the group's efforts in the late 1960s through the mid-1970s was on rain-making along the Hồ Chí Minh Trail; see Volume 4 of this history.)

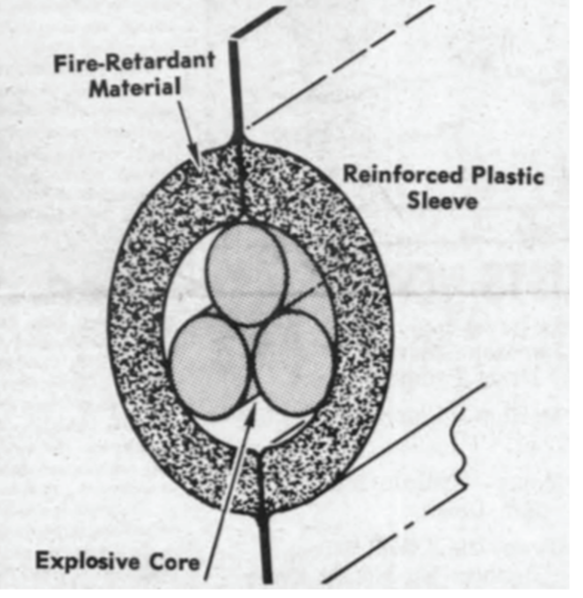
The pace of technology transfer picked up in the early 1970s. "Forest Service comes along and says they've got a problem on how to create a fire line barrier," Dr. Hugh Hunter related. "Is there some explosive way that would assist them? Carl Austin says, 'Yes, I think maybe there is, let's cobble up something,' and he takes something and shows that it works and they go off happy."[50]

Dr. Hunter was referring to China Lake's development of a method for cutting fire lines through heavy brush and timber, a process that is traditionally done with dozers or by crews using hand tools. Jim Lott, a U.S. Forest Service employee, had a Marine friend who told him about some of China Lake's explosives capabilities that he had seen demonstrated in Vietnam under the Vietnam Laboratory Assistance Program (VLAP). In 1970, Lott met with Bud Sewell and Austin, and the three quickly came up with a solution: a flexible plastic tube about 2 inches in diameter with an explosive primacord core surrounded by a fire-retardant material. The tube could be cut to any length. When detonated by means of a standard time fuze, the cord cleared a path about 4 feet wide without initiating any fire.

In 1971 and 1972, the system was tested on fires, under the close supervision of NWC explosive experts, and by 1974, the system was being used effectively by five-man smokejumper crews battling fires in the Idaho

[50]S-95, Hunter interview, 16.

Panhandle National Forest. Hands-on development and testing was done by Austin, Samuel W. Kendall, and Carl Halsey, who would receive a patent for their work in 1977.



Cutaway view of fire-line-clearing device. Published in the *Rocketeer*, 4 September 1970.

NASA, with all the developments spinning off from the space effort in the 1960s, had been an early pioneer in technology transfer. It approached the subject systematically; NASA Technology Application Teams and Biomedical Application Teams were in place at various nonprofit research institutes across the country. The teams investigated problem areas—water pollution, transportation, biomedicine issues, etc.—and talked with working-level people in these areas. The teams then prepared three- to four-page Active Problem Statements summarizing the background, constraints, possible approaches to solving the problems, and relevant technologies. In 1970, NASA agreed to have their teams work with NWC and provided a variety of Active Problem Statements on matters as diverse as criminalistics ("a nonreflective thin coating is needed to ascertain the ordering of writing at crossovers on questioned documents"), biomedicine ("determination of precise orientation of the spine"), and mine safety ("an explosion-detection device which is automatic and foolproof is needed").[51]

Interest in China Lake's program for technology transfer was growing. In February 1971, Congressman Barry M. Goldwater Jr. (son of Arizona Senator Barry Goldwater) visited NWC for a briefing on the Center's technology-transfer efforts.

A chance meeting on an airplane between a technology-transfer advocate and Zip Mettenburg, then an engineer in Marquardt's Instrument Development Division, led to the idea of a technology utilization assessment study at China Lake. It was conducted over a period of 3 months by Perrin Associates, a Los

[51]NWC, "NWC to Look for Technology Applications to Domestic Problems," *News and Views*, special bulletin, 22 December 1970, 2–4.

Angeles consulting firm that specialized in technology transfer. An NWC internal document reported that "only a small part of NWC's developed technology was studied and applied to the current problems of the civil agencies." It was enough, though, to convince Center management that there was much at NWC that could benefit other government agencies. Perrin Associates was engaged as a transfer agent and became the link between the Technology Development Division and potential users.[52]

A new phrase, "adaptive engineering," began to be heard around the Center. The term was suggested by Edward M. Glass, in the Office of the DDR&E, to distinguish the DoD technology-transfer efforts from those of NASA. Whereas the NASA-NWC relationship was primarily a data-exchange program, the NWC-Perrin program was one of active engagement. J. Richard Perrin, of Perrin Associates, understood the distinction. In a January 1971 letter to the Congressional Research Service, he wrote:

> Knowledge of available technologies is not obtained through reading quarterly progress reports that report "I'm doing fine and have no problems," because they never provide viable contributions or approaches to solving a given problem. Technology is transferred only when boundaries of the problem and the limitations of the proposed solution are known to both parties through an active or personal communication approach.[53]

Glass suggested in January 1971 that a pilot study be made of technology transfer involving several DoD laboratories, with NWC as the lead laboratory. His suggestion was supported by Georgia Congressman John W. Davis (chairman of the Science, Research, and Development Subcommittee of the House Science and Astronautics Committee) and Foster (DDR&E). Foster assigned China Lake the lead-laboratory role in coordinating a DoD multi-laboratory program to transfer technology to civilian agencies. Leroy Marquardt and Curt Bryan, at Hack Wilson's direction, took the lead in setting up the Center's Technology Transfer Pilot Program. "The program is based upon the need to motivate 'technology users' to seriously consider the application of NWC-developed technology to the solution of civil problems," reported the *Tech History*.[54]

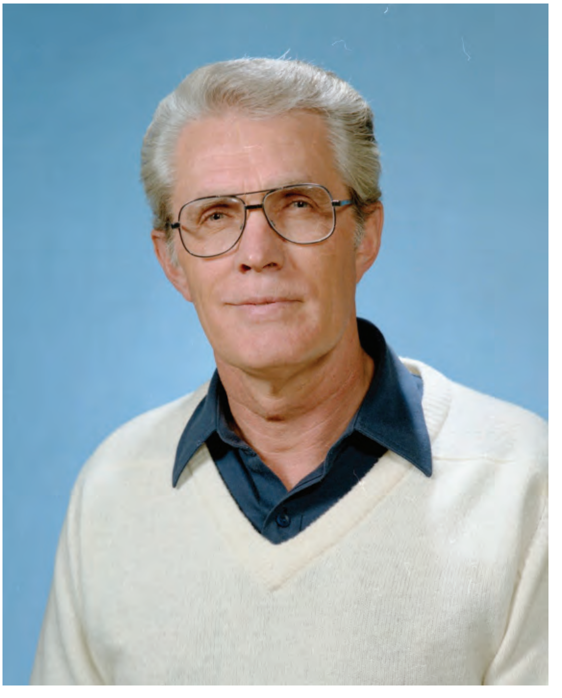
---

[52]Marquardt and Bryan, "NWC Pioneering DOD Lab Efforts," 5. Marquardt's Division was renamed the Technology Development Division in 1971.

[53]Doig, *FLC History*, 12. Perrin's comment notwithstanding, Frank Markarian, former head of the NAWCWD Research and Engineering Department, stated that he, Tom Loftus, Wayne Tanaka, Stacy Howard, and others "prided ourselves on the technical excellence of the ONR Air Weaponry Technology Program quarterly progress reports." Markarian review comment, December 2014.

[54]*NWC Tech History 1971*, 1-22.

To handle the increased workload, the Technology Utilization Office (TUO), headed by George Linsteadt, was established in March 1971. It was located on Marquardt's staff in Dr. Highberg's Systems Development Department. As head of the TUO, Linsteadt was assisted in his technology-transfer outreach efforts by Dr. Harold Gryting (solid waste), Fred Nathan (for MESWG), Dr. Rick Roberts (air pollution), Paul Erickson (environmental engineering), and Tilly Barling (natural resource conservation).



George Linsteadt.

Beginning in May, Linsteadt and Richard Perrin (whose company had been retained to broker the consortium effort) visited several Navy, Air Force, and Army laboratories to drum up support for the technology-transfer pilot program. As a result, representatives from 11 DoD laboratories met at NWC on 1 July 1971 to discuss technology transfer. Glass chaired the conference. The upshot was a consortium, an informal group financed principally by NWC discretionary funds "directed toward demonstrating the efficacy of a multiservice-laboratory-centered program of active technology transfer."[55]

In less than a year, the number of laboratories in the consortium—initially called the DoD Technology Transfer Laboratory Consortium and later renamed the Federal Laboratory Consortium for Technology Transfer, or FLC—had grown to 15. By the end of 1972, the number of participating laboratories had increased to 21, and by the end of 1973, to 30. Linsteadt was the first chair of the FLC; when he handed over the reins of leadership to Loren Schmidt of the DOE in 1983, more than 350 federal laboratories and centers were members.[56]

[55]Doig, *FLC History,* 19.

[56]The FLC was formally chartered through the Federal Technology Transfer Act of 1986 (PL99-502).

A national conference of the American Society for Public Administration held in Denver in April 1971 brought together people from around the country who were engaged in technology transfer. NWC's Deputy Technical Director, Walt LaBerge, keynoted the Science, Technology, and Public Policy segment of the conference; he discussed the benefits of technology transfer, although he did note that it was difficult to implement.

At the conference, China Lake representatives held discussions with members of the National Science Foundation (NSF), which had set up a program called Research Applied to National Needs in 1970. The Center and the foundation agreed that China Lake would provide an engineer who would work under the NSF auspices "to couple the technologies of a consortium of DOD laboratories to the needs of potential users."[57]

Chemical engineer Harold Metcalf, former associate head of the Weapons Development Department, volunteered for the new post. "They needed somebody as a switchboard, a central communications switchboard in Washington, D. C. . . . They asked me if I'd be willing to take that assignment, and I said, 'Boy, would I!' " Metcalf's 1-year assignment stretched to 3 years.[58]

After the first flush of enthusiasm, China Lakers had learned that a difficult part of the technology-transfer process lay in connecting the people who developed a specific technology with an outside entity that might have other uses for it. That relationship was not always intuitive. Metcalf recalled an incident that occurred while he served at the NSF. The foundation wanted to provide a $50,000 grant to the New York City Police Department to adapt military technology to apprehend criminals; Metcalf went to New York and was brought in to see the city's chief of police. "He said, 'What do I need with a grant to apprehend more criminals?' " Metcalf recalled. "He said, 'Thirty-nine of every 42 felons that we arrest are turned back on the street. We don't have any place to put them. We don't need a grant to apprehend criminals." Metcalf commented to the interviewer, "You don't transfer the technology you *think* somebody needs. You transfer the technology that *somebody needs*."[59]

Metcalf and his associates regrouped and focused their assistance on helping the police department with its inventory and plant-accounting system, which "quickly resulted in high dollar savings for the City of New York."[60]

Interest in implementing technology transfer spread through government agencies. An August 1971 visitor to the Center was Dr. Edwin Golding,

---

[57] *Rocketeer*, 16 June 1972, 3.
[58] S-236, Metcalf interview, 44–45.
[59] Ibid., 49–50.
[60] Doig, *FLC History,* 28.

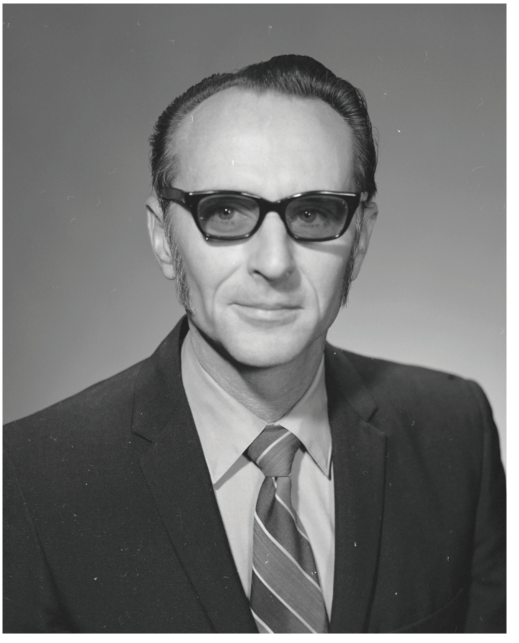
chief of the Center for Criminal Justice, Operations, and Management, Law Enforcement Assistance Agency. His purpose was "to gain an understanding of how the Center might play a continuing role in support of research and development in his organization."[61]

Dr. Edwin I. Golding (left) of the Center for Criminal Justice is greeted by George Linsteadt (center) and Leroy Marquardt (right). Published in the *Rocketeer*, 20 August 1971.

As the 1970s progressed, technology transfer became an integral part of the Center's business. In 1972, MESWG made numerous technological contributions to the naval hospital at San Diego. These included a cataract detector, invented and patented by Jack Lyons; a laser for medical research, designed by Dellmar Dobberpuhl; a study of the ocular pulse, conducted by Horace Joseph; a pilot study on using IR thermography to detect hearing in newborns, conducted by Dr. E. Ronald "Ron" Atkinson; and a mathematical model of the human circulatory system, developed by Dr. Robert L. Rockwell for use in diagnosing cardiovascular diseases.

[61]*Rocketeer*, 20 August 1971, 4.

Del Dobberpuhl.



Ron Atkinson.

Dr. Bob Rockwell.

The same year saw China Lake carry out a firefighting design study for a short takeoff and landing airport; weather-modification work for the FAA; ChemLite™ adaptations for the National Highway Traffic Safety Administration; applications of FLIR for the Treasury Department; and three-dimensional air-pollution studies for the State of California.

By 1973, the standard DoD form for reporting planned R&D work (DD Form 1498) was modified to include potential civil applications for the proposed work. The *Tech History* that year noted that "NWC has three major areas of expertise and competence where accomplishments can be seen that are of interest to other governmental agencies. The areas are (1) fire and safety, (2) environment, and (3) energy." Under area number 1, China Lake hosted a visit by members of the Less Lethal Weapon Task Force, organized by the district attorney for Los Angeles County. The group met with Linsteadt and China Lake Police Chief Stephen L. Kaupp to discuss such tools as "rubber bullets, water balls, and an electric shock device."[62]

China Lake Police Chief Steve Kaupp.

In 1973, Linsteadt's TUO was moved from Marquardt's division (which had been transferred to the new Surface Missiles Department earlier that year) to the staff of Dr. Guy Leonard's Propulsion Development Department. The stated purpose was "to provide technology transfer capability and to focus interest in what this Center can offer in the way of technical contributions in the public, domestic realm."[63]

The following year, Linsteadt helped establish the Technology Transfer Society (T2S), a not-for-profit professional organization composed primarily of government laboratory representatives. T2S has evolved into an academic organization that publishes the highly respected *Journal of Technology Transfer*.

[62]*NWC Tech History 1973*, 1-24; *Rocketeer*, 20 July 1973, 3.
[63]*NWC Tech History 1973*, 1-7.

The mission of T2S, however, remains unchanged: the identification and dissemination of best practices in technology transfer.[64]

In 1980, Congress passed, and President Carter signed, the Stevenson-Wydler Technology Innovation Act (PL-96-480). The law required all federal laboratories to specifically budget funds for technology transfer and required any laboratory with over 200 employees to have at least one full-time person operating an Office of Research and Technology Applications (ORTA). At China Lake, to the surprise of no one, the person selected for the ORTA was George Linsteadt.

Through the 1970s and 1980s, technology transfer at China Lake generated hundreds of contributions to city, county, state, and federal agencies as well as academic institutions and industrial organizations throughout the country. These contributions are far too numerous to list, but a 1993 retrospective on the subject by Barry McDonald, a China Lake newspaper editor and writer, noted some of the highlights of China Lake's transferred technology:

> Perhaps the most successful China Lake-developed patent is for Chemlites [Herb Richter and Ruth Tedrick, 1970]—the small tubes that, when bent and shaken to cause the contents to mix, emit a bright light. Shuttered video cameras developed by China Lakers [George Silberberg, Pat Keller, and Richard White, 1978] to allow stop-action viewing of tapes of high-speed test operations, have found broad commercial application in sports telecasts, sports medicine and training, spectral analysis, biokinetics and other fields. Calcification-prevention tablets [Geoffrey Lindsay, Michael Hasting, Michael Gustavson, 1990] originally developed to reduce build-up in ships' sewer systems, are now being produced and sold for use in pleasure craft and commercial ships and buildings. Thermally-resistant, antireflection and antioxidation coatings will soon be finding their way on to vehicle windshields, camera lenses and eye glasses as the result of another China Lake patent license.[65]

Also notable is the transfer work of one of China Lake's most prolific engineers, Richard Hughes, a world authority on logarithmic amplifiers. Hughes is the holder of more than 20 patents, and he designed the amplifiers used in the first ultrasound and ultrasonic C-scan equipment used by the Mayo Clinic and the Albert Einstein College of Medicine.

---

[64]Professor Donald Siegel, dean of the University of Albany School of Business and president of the Technology Transfer Society, telephone conversation, 11 December 2013.

[65]Barry McDonald, "T2 Comes of Age," *Rocketeer*, 4 November 1993, 13.

Bob Hillyer (left) presents the William B. McLean Award to George Silberberg (right), 1977.

In 2004, the DoD established an award to recognize "the DOD technology transfer professional who has performed extraordinary efforts and has produced outstanding results in transferring technology from DOD laboratories to their partners in the public and private sectors." The award is named the George F. Linsteadt Technology Transfer Achievement Award in honor of Linsteadt who, the DoD Office of Technology Transition states, "is widely recognized as a pioneer in Federal Technology Transfer and a founding father of the FLC."[66]

Stretching the dollar continues at China Lake today, as Center-developed technology is disseminated through such mechanisms as Cooperative Research and Development Agreements, patent licensing, partnerships with industry, Small Business Innovation Research (SBIR) projects, and direct technical assistance to government agencies.

Collectively, the Center's technology-transfer activity through the years has saved an incalculable amount of taxpayer money and industrial-development dollars that would otherwise have been spent on "reinventing the wheel."

[66]OSD DUSD, *Report to Congress*, C-2.

Discretionary Funding

Discretionary funding—money that could be spent pretty much as the Technical Director saw fit—seems an unlikely mechanism for saving taxpayer dollars. But from 1949 on, approximately 5 to 10 percent of direct project funds were diverted every year by the Technical Director (and with the blessing, or at least the legal approval of, China Lake's sponsors) to fund local projects that showed promise. The program was originally called Exploratory and Foundational funding and later Bid and Proposal (B&P) funding.

Originally, dispensing of the money was at the fiat of the Technical Director, but in the early 1970s, the funding decisions were made more systematic. Bill Porter recalled, "We formalized the B&P process and made it a corporate process where anybody could come in with their ideas and present them, and we had a process for screening out what were the ideas that had the most potential."[67]

B&P funding saved tax dollars in two ways. First, it attracted bright, motivated people to seek Center employment, even though the pay rate was lower than in industry. Prospective employees knew that if they had an idea, however wild it might seem, and could make a convincing case for it, they would receive a modest amount of funding—perhaps half a man-year, perhaps less—to pursue the idea and, hopefully, prove its feasibility.

Dr. L. T. E. Thompson, China Lake's first Technical Director (1945 to 1951) said, "In my opinion, this provision [establishing discretionary funding] meant as much as anything ever done in the effort to attract and hold good R&D people."[68]

The second way that discretionary funding leveraged the taxpayers' dollars was by providing a relatively inexpensive method for separating the wheat from the chaff, separating the concepts that showed true promise from those that, which though they sounded good initially, had the potential to turn into hugely expensive programs that never lived up to their initial billing. For the programs that did demonstrate feasibility under B&P funding, off-Center sponsorship was sought to continue funding the program through development.

While the structure of the discretionary funding programs varied under different senior Center managers, it was always competitive. The proposing engineer had to convince other, senior, seasoned engineers that there was merit in the proposal. As Porter put it, "You have more good ideas for B&P dollars than you have dollars." Unlike industry, proposals were assessed for the potential

[67]S-216, Porter interview, Part 1, 11.
[68]S-5, Vice Admiral George F. Hussey and Thompson interview, 106.

benefit they would have for the national defense rather than how much money they might eventually add to a contractor's bottom line.[69]

Discretionary funding was responsible for some of China Lake's signature programs, including Sidewinder, Walleye, Moray, and Rock-Site. It financed either the initial feasibility demonstration for these programs or carried them through critical periods when no other funding was available.

Other programs funded by discretionary monies did not have the same name recognition but were nonetheless important. Leroy Riggs, who was Acting Technical Director in 1973 and 1974, said:

> I funded Burrell [Hays] B&P money so he could work on a solder spec [specification], because soldering was the biggest bugaboo in all the electronic industry. . . . I funded that with internal funds, overhead if you will. That specification has become nationally known and utilized. If you go to any major electronic industry in this country they'll know of that solder spec, and if you do things to that solder spec, your equipment will work.[70]

Another successful B&P project was Smokey Sam, developed to assist Navy and Air Force pilots in combatting what had been one of the enemy's deadliest weapons in the Vietnam War: the surface-to-air missile, or SAM.[71]

During the war, thousands of SAMs were launched against U.S. aircraft, primarily during U.S. bombing raids over North Vietnam. The SAM most frequently used by the North Vietnamese was the Soviet-designed V750 Dvina, commonly known to Americans as the SA-2 Guideline, a combination of its DoD and NATO designations. The weapon was effective—205 U.S. aircraft, ranging from tiny O-1 Bird Dog observation aircraft to B-52 Stratofortress bombers, were destroyed by SAMs during the war, all but 10 of them by SA-2s.[72]

Often, the first inkling a pilot had that he was the target of a SAM was when he saw the smoke trail of the missile immediately after launch. SAMs were either radar or optically guided; in the latter case, there would be no warning from the aircraft's onboard sensors that it was being painted by a tracking radar. Once the SAM was in the air, accelerating to its top speed of Mach 3.5 (approximately 2,600 miles per hour), the pilot's best option for survival was to get out of its way. Fortunately, most U.S. aircraft could outmaneuver the SAM if they had adequate time to respond.

---

[69]S-216, Porter interview, Part 1, 19.

[70]TS 84-14-6, Riggs interview, 18.

[71]Some sources spell the name "Smoky Sam"; during the design and development program at China Lake, it was spelled Smokey SAM.

[72]Hobson, *Vietnam Air Losses*, 271. The remaining 10 were downed by man-portable 9K32 Strela-2 (SA-7 Grail) missiles.

Smokey Sam began as a request from Nellis Air Force Base, home of the Red Flag aerial combat training exercise. China Lake's Ordnance Systems Department was asked to find or develop a replacement for the Estes™ model rockets that were being used to simulate ground-launched antiair missiles. A system was needed that would be range-qualified and would meet performance standards that the commercial rockets could not achieve. Underlying the request was a formal Air Force requirement for "realistic conditions, including visual cues," at its tactical-air-combat ranges—specifically, a training device that would help a pilot learn how to deal with a SAM headed for his aircraft. Realism was essential.[73]

"Typically during pilot training, when they were flying against simulated enemy radars, the pilot would fly through the zone with his head down," explained Ray Miller, head of the Propulsion Systems Division during Smokey Sam's development.

> He was watching his cockpit instruments. In the meantime, in a real combat environment, he may have been fired at by a Strela or other ground-to-air missile, and he wasn't aware of it unless he saw the plume of the rocket motor.[74]

Sandee Schwarzbach, a second-generation China Laker, was assigned to lead the project. She requested and was given $50,000 of B&P funding in 1979 to start a project that would satisfy the Air Force request. She assembled a team of engineers, including Frank Pickett (propellant development), Lou Renner and Ernie Lanterman (missile design), and Claude Brown (electronics).

Schwarzbach was involved from the start in negotiating with the Air Force and reconciling the several constraints driving the Smokey Sam design: as well as realism, low cost was essential, because the devices would be used in large numbers during training exercises at bases around the nation (and later, throughout the world). "We had to pass the same safety and environmental requirements as an all-up-round weapon, be biodegradable, and not cause an irretrievable flameout of a jet engine if ingested. It was a lot to ask of a little program," she recalled.[75]

---

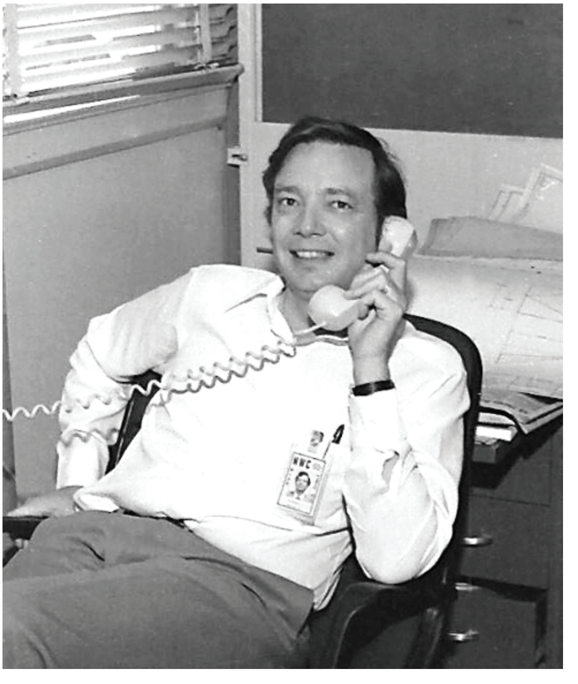
[73]ROC 305-76, *Improvements*, quoted in PSAD 78-83, *Air Force Requirements*, 7–8. Smokey Sam was formally called the SAM / MANPADS Multiservice Visual Signal Simulator Training Round.

[74]S-262, Miller interview, 67.

[75]Schwarzbach, email, 6 January 2015. Smokey Sam's digestibility was tested. "They fired a live burning rocket motor into the intake of a jet engine," said Pickett. "Sure there was some damage, but it kept running at military power." Lanterman said, "The engine coughed and sputtered but it kept running." S-338, Pickett interview, 18; S-332, Lanterman interview, 11.

For Pickett, the task was ironic; he'd spent a good part of his career developing reduced- and minimum-smoke propellants for air-to-air missiles. "Every air-launch system went to minimum-smoke propellants because none of them wanted that big smoke trail behind them," he said. "Everybody in the area knew right where you were." But Pickett loved the Smokey Sam program.

> Smokey Sam was just like being a kid playing with toy rockets again. . . . I made zinc and sulfur propellants as a kid and lots of white smoke, just lots of smoke. So I decided the ingredient to put in the propellant for this is zinc. . . It had 40 percent zinc in it. As this thing went streaking up into the sky, it put out an enormous ball of fire because all of that zinc was being spewed out, but it was immediately burning in the atmosphere, an enormous ball of fire and huge smoke trail. So it looked exactly like the launch of a Russian missile.[76]



Frank Pickett.

After experimenting with various shapes and sizes, a final design was selected. It was, Miller related,

> basically a paper-towel tube—stronger, of course, than a paper-towel tube, but about that size and shape—filled with a zinc-containing propellant that Frank Pickett came up with which yielded huge quantities of smoke; a polyurethane foam nose cap; and an airfoil ballistic stabilizer, a tail fin, that fit around the tube of propellant and stabilized the missile in flight. And this could be launched from any simple ground launcher, and it would fly to approximately 1,000 feet altitude, leaving this huge white smoke cloud.[77]

[76]S-338, Pickett interview, 7, 17.
[77]S-262, Miller interview, 68.

Smokey Sam launch.

Renner recalled:

> We used phenolic [paper] tubes, no metal, a foam nose cone, and a foam tail cone and fins—you were only going to use these once, and they were going to be gone—and a very, very smokey propellant, so that even though it was only a small diameter it looked like a big missile coming up at you.[78]

China Lake was known for handing people all the responsibility they could handle, which is one of the reasons it was so successful in attracting bright young scientists and engineers—even when the government pay wasn't up to industry standards. Schwarzbach's case was typical. "I was GS-9," she recalled some 35 years later,

[78]S-331, Renner interview, 8.

> and I was put in charge of a program that eventually involved funding and support from all three services as well as foreign sales. I was leading a team of professionals who had been in the business far longer than I. In Washington I had to stand up and defend my program to four-star generals. At my DRC [Design Review Committee, consisting of senior Center managers and subject-matter experts: the final step at which the system design is approved by the Center], Frank Knemeyer brought the committee into the parking lot and had me throw the Smokey Sam system, including the shipping container, off the back of a pickup truck, twice, to see how it held up, because Frank knew how Marines handled equipment in the field. Where else but China Lake would a junior engineer receive that kind of experience?[79]

Operational assessment of Smokey Sam was satisfactorily concluded in 1980. The Navy fired 60 live rockets and the Air Force expended 500 under actual operating conditions during the Red Flag 80-4 Exercise. The final product—a Level 3 production documentation package—was completed within approximately 18 months of the original proposal.

Smokey Sam was a success. It had begun as a $50,000 B&P program in which Schwarzbach and the Smokey Sam team demonstrated the value of the concept, which led to triservice interest and subsequent funding for the development program. According to Miller, "[Schwarzbach] was able to sell that program to the Air Force and to Navy sponsors and get the funding to actually produce several hundred, to demonstrate and prove the viability of the system."[80]

The China Lake effort produced an approved Level 3 drawing package and a patent award. Production was transferred to Naval Ordnance Station (NOS), Indian Head, where several thousand Smokey Sams were produced. In the 1990s, a production contract was let to Israel Military Industries, and tens of thousands of the training rounds were produced. Today, Smokey Sam, official designation GTR-18, as modified by the Air Force, is still in use by U.S. and allied forces.[81]

Discretionary funding levels in recent decades have not reached the original 5 to 10 percent of direct project funds. (In recent years they have been well below 5 percent.) Still, it provides seed money for many important projects and also supports valuable hands-on training for young engineers.

---

[79]Schwarzbach, telephone conversation, 2 September 2014.

[80]S-262, Miller interview, 68.

[81]Smokey Sam was also featured in a Jack Ryan novel, where it was used by the *mujahideen* to decoy a Russian helicopter into Stinger range. Tom Clancy, *The Cardinal of the Kremlin* (Penguin Putnam Inc., 1989), 126–7.

Trident

Routine technical discoveries sometimes lead in a roundabout way to significant cost savings. One example was the Trident pot-life (propellant curing time) extension catalyst.

China Lake had supported Trident since the program began in 1971 as a replacement for the Polaris and Poseidon submarine-launched ballistic missiles. The new missile was designed with a range in excess of 4,000 miles (versus 2,500 miles for Poseidon), which would greatly expand the areas in which the U.S. submarine fleet could launch an attack as well as the depths from which missiles could be launched, increasing launch-platform survivability.

Trident was not only the development of a new missile program but also included a new fleet of submarines: the Ohio class, the U.S. Navy's largest submarine before or since, on which the missiles would be carried. The Trident system was conceived in STRAT-X, a study of U.S. nuclear deterrent capabilities conducted in the late 1960s under the direction of General Maxwell D. Taylor, then president of the Institute for Defense Analyses.[82]

Initially, China Lake tested and evaluated candidate Trident propellants to aid in contractor selection and studied combustion instability issues associated with the Trident cross-linked double-base-propellant motors. Then in May 1974, a Trident motor blew up at the Hercules Inc. facility at Bacchus, Utah, destroying the test facility and bringing full-scale motor testing to a standstill. A nationwide survey by the Strategic Systems Project Office (SSPO) was undertaken to identify a facility capable of continuing the urgent work. NWC was selected "based on the availability of experienced personnel, existing test facilities, control rooms and instrumentation, as well as the capability for X-raying large rocket motors."[83]

The first full-scale motor test was conducted at NWC's Skytop facility just 28 days after NWC's selection. Under the direction of Roy Johanboeke, head of the Range Department's Ballistics Test Branch, additional facilities were built to accommodate the special needs of the Trident program. These included two new test bays at Skytop for testing large (up to 500,000-pound-thrust) ballistic motors; one of the bays was designed for high-hazard detonation investigations.[84]

---

[82]The name STRAT-X is a combination of "strategy" and "x" for experimental or the unknown.

[83]*Rocketeer*, 28 March 1980, 1. China Lake had been intimately involved in the concept development and testing of the Polaris missile and its successor, Poseidon.

[84]At least two Trident explosions occurred during NWC testing: in June 1975 and May 1976. There were no injuries. "While the risk of a detonation was not considered to be high,

Trident second-stage motor firing at Skytop.

Between June 1974 and January 1978, 64 Trident motors were tested at the Center under the supervision of Edmund Reagan, a supervisory aerospace engineer. Prior to firing, the motors were X-rayed by personnel in Royce Monk's Test Engineering and Nondestructive Evaluation Section. William Francis, head of the Instrumentation Branch, was responsible for instrumentation, and Warren Oshel was the data-acquisition engineer. Crill Maples, Trident program manager at NWC, oversaw the design and fabrication of a vertical test stand, which allowed more accurate characterization of motor performance in simulated in-flight attitudes. Leroy Stayton served as the NWC Trident program coordinator with the SSPO in Washington.[85]

China Lake also conducted alternative-propellant studies and high-energy-propellant safety investigations as well as a system definition and feasibility study for the Trident Accuracy Improvement Program. Between 1974 and

the possibility was well recognized. For this reason, the test was conducted in a remote area." *Rocketeer*, 14 May 1976, 3; Shapley, "Trident in Trouble," 51.

[85]The test stand, built around a surplus launcher from the cancelled Air Force Navaho ICBM program, required more than a ton of welding rod for construction.

1980, $14 million was expended on Trident and Polaris test-and-evaluation work at China Lake.

At one point in the Trident motor development, contractor engineers were stymied by a problem caused by the large size of the first-stage motor. The issue was "pot life," which the *DoD Composite Materials Handbook* defines as "the period of time during which a reacting thermosetting composition remains suitable for its intended processing after mixing with a reaction initiating agent."[86]

Frank Pickett, who at the time headed the Propellants Branch in the Propulsion Development Department, explained:

> Now when you mix your propellants, with Trident's huge mixers, like 600-gallon mixers, you have to initiate the cure reaction by adding a catalyst. You add the catalyst last because you're mixing the propellant hot, and if you add the catalyst at the beginning, it starts to cure right away. . . . You put the catalyst in last and then you need to have enough time to take this very large mixer of propellant and cast it into whatever you're going to cast it into. In this case it was going to be Trident. Well, they ran into a pot-life problem. When they added the catalyst and it started to cure, it cured much too rapidly and they didn't have time to get it out of the big mixer into the Trident. It just got too thick and it wasn't castable.[87]

Pickett's group had recently been experimenting with various catalysts and had discovered one that had a curious property. The new catalyst didn't start curing immediately. "It wouldn't start to cure for two or three hours, it just, kind of, sat there and all of a sudden it started curing," Pickett shared. "We, at that time, didn't think too much about it, but about then is when the Trident ran into their pot-life problem."[88]

Trident was the first missile to use the new catalyst. "They started out with one-gallon mixes, then five-gallon mixes, then twenty-five-gallon mixes, and sure enough it sailed all the way up to the huge mixers and gave Trident plenty of pot life so they could make their motors," said Pickett.[89]

There was, moreover, another advantage to the catalyst. Pickett explained:

> It's not just big motors that are made in big pots. If you can make a large batch of propellant and cast a whole bunch of smaller motors, let's say Sidewinders, that's a great advantage because every batch of propellant must be tested before it goes into the field by firing rocket motors . . . You've got to fire one hot and one cold out of every batch, so the bigger the batch, the less motors you waste

[86]MIL-HDBK-17-3F, *Polymer Matrix Composites*, 1-28.
[87]S-338, Pickett interview, 11.
[88]Ibid.
[89]Ibid., 12.

during testing to accept that batch of propellant. So having a very long pot life really became an extreme advantage when you were going to make a whole bunch of little motors out of one great big pot of propellant because you need several hours to do that. That very quickly became the standard of the industry and, of course, has been ever since.[90]

Versatile Training System (VTS)

In 1967, a new Navy subsonic light-attack aircraft was introduced as an eventual replacement for the A-4 Skyhawk. The A-7 Corsair II built by Ling-Temco-Vought (LTV) was a state-of-the-art aircraft jam-packed with the latest in military avionics. By year's end the Corsair was in the thick of the fray in Vietnam.

Maintenance of the Corsair II was carried out by Navy enlisted personnel. In 1972, Vought, as part of its support of the A-7E squadrons, had developed a rudimentary computer-based program to facilitate A-7 maintenance training for enlisted personnel at NAS Lemoore. NAVAIR saw the potential for efficiencies extending beyond that scope and assigned NWC the task of developing and expanding the program.

At China Lake, the job was assigned to a team led by computer specialist Harry E. Hamerdinger in the Avionics Division and included engineers Ted Holtermans and Alan Craig. They developed a comprehensive system called the VTS that analyzed training needs and matched individual qualifications, experience, and training records with a squadron's maintenance personnel needs. Previously, this tedious, time-consuming work had been done by hand and often resulted in the loss of key records.

Harry Hamerdinger.

Hamerdinger's team analyzed training needs, investigated computer hardware, developed software, and integrated their efforts into workable systems, tailored to the needs of each of their

[90]Ibid.

customers. These were modified in the field as users requested improvements and additional capabilities.

The VTS group—formally, the Instructional Systems Branch in the Systems Development Department—expanded the scope of the VTS to encompass other aspects of training, including real-time projection of student load, which minimized the scheduling time and administrative burdens required for training operations. Whereas data for required reports had once been compiled at the cost of many man hours, with VTS it was available within minutes. As one commentator wrote:

> The focus of the VTS effort has always been on the user's needs. This development was a demonstration that a project working from the bottom up rather than from the top down can provide quicker response and more value per dollar to the user.[91]

VTS was further expanded to include training for both officers and enlisted personnel and was applied to all aircraft in the Navy inventory, including helicopters and fighter, attack, and patrol aircraft. In 1975, Admiral James L. Holloway III, Chief of Naval Operations (CNO), designated VTS as the standard training support system for all Navy readiness squadrons, and by 1981, the system was operational at 9 major jet aircraft training units, 4 submarine training activities, and 10 reserve training sites across the Navy and Marine Corps.

As news of the success of the system spread, more and more activities requested it. The new system performed far better than the manual procedures that it replaced as well as provided numerous capabilities that were previously unavailable, including inventory and control of maintenance testing units, simulators, and lesson-ware. One measure of VTS's success is that much of the funding for individual systems came from the field activities that requested the systems—by 1980, that included "nine Naval Air stations in various parts of the United States, at four submarine schools or training facilities, and on two surface ships." Plans called for additional VTS installations at numerous Navy Reserve training sites.[92]

Leroy Marquardt, in nominating Hamerdinger for a Technical Director Award for VTS in 1980, commented, "Training in the Navy has entered the computer age through VTS." The *Rocketeer* reporting the award stated:

> Based on an independent cost-benefit analysis sponsored by NAVAIR, it was concluded that VTS can achieve significant cost savings in training personnel

[91] *Major Accomplishments of the Naval Weapons Center*, 182.
[92] *Rocketeer*, 23 May 1980, 5.

> to handle administrative functions, and its use has the potential for freeing significant numbers of personnel from administrative tasks, thus providing additional manpower for maintenance work that will lead to improved squadron operational readiness.[93]

Captain James E. Doolittle, who headed the Aircraft Department from 1979 to 1982, noted that the VTS

> really wasn't in the Center's mission. . . It's just that the talent happened to be here and the individuals' interest was triggered and they moved out and put together a simple program in no time that competed with other programs that were horrendously expensive.[94]

Other Economic Activities

Other activities by the Center that saved taxpayers a considerable amount of money don't fit into any of the categories described above. In the Roseville-Benson incidents, for example (discussed in Chapter 10), the Navy was sued for damages consequent to fires and explosions on munitions-carrying railroad trains. China Lake experts were called in to help, and their testimony, backed up by months of careful testing and documentation of the incidents, was central to proving lack of culpability on the part of the Navy and in saving the government an estimated $50 to $90 million in damage settlements.

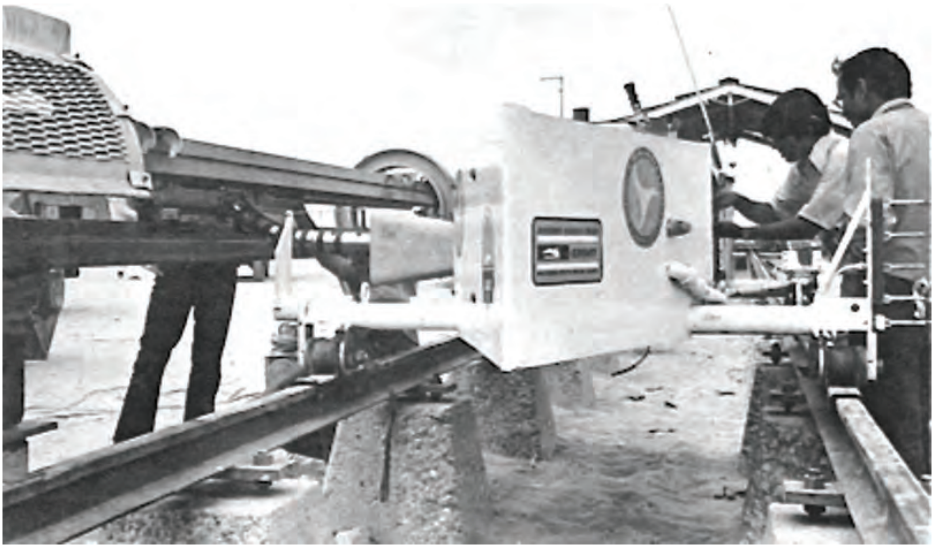
In 1973, Hughes Aircraft sued the United States, claiming that the company had invented much of the technology underlying the multibillion-dollar communications satellite business. The ultimate decision, 20 years later, was for Hughes (then a unit of General Motors Corp.), resulting in a $114 million patent infringement judgment against the government.

Researchers at China Lake, however—some of whom had been directly involved in the original China Lake satellite-launch work, from whence the disputed technology was developed—worked with a small group of Department of Justice lawyers that was outpowered and outgunned by Hughes's massive legal team. Nevertheless, the evidence presented by the Department of Justice saved the government from being taken for a great deal more money; Hughes was seeking $3.3 billion in royalties and back interest.[95]

Sharing Center resources is another method of maximizing tax-dollar investments, and China Lake frequently makes its facilities available to other government agencies and industrial partners. In 1972, for example, the Baker-4

[93]Ibid., 1, 4.
[94]S-130, Doolittle interview, 12.
[95]Andrews, "Patent Case," Section 1, 35, 36.

track (one of three major supersonic test tracks at the Center) was used by AiResearch Manufacturing Co. and the Federal Railroad Administration to test components of a high-speed ground transportation system. A 1,500-foot section of the nearly 3-mile long test track was modified by installing 122 concrete posts along its length to support three electric rails. As the Tracked Air Cushion Research Vehicle (TACRV) moved down the track, its extendable collector arm transferred current from the electric rails to the vehicle.



Setting up the TACRV for testing at Baker-4 track.

Through smart buying, second sourcing, energy generation, technology transfer, resource sharing, and other activities, China Lake has consistently demonstrated good stewardship of the taxpayer dollars—while at the same time meeting the challenges periodically imposed by volatile economic conditions at the national level. The bottom line for the Center has always been to provide the warfighters with the best weapon systems possible in the most efficient and economic manner.

13

Air-to-Air Mastery

There is an example of what a laboratory can do, in harmony with contractors, to build just a first-cabin missile.

—Jerry L. Reed, Technical Director, Joint Cruise Missile Project Office, speaking of the Sidewinder AIM-9L[1]

For the U.S. air-to-air missile community, the Vietnam War was an eye opener—some would say a slap in the face. Overall, the kill rate for Navy and Air Force AIM-9 Sidewinders during the war was 18 percent, the miss rate was 35 percent, and the failure rate was an alarming 47 percent. Comparable figures for the AIM-7 Sparrow were 9 percent, 25 percent, and 66 percent. The kill rate for the Air Force's AIM-4D Falcon was 9 percent (five kills in 54 firings).[2]

AIM-7 Sparrow launched from an F-4 aircraft.

[1]S-151, Reed interview, 6.

[2]Michel, *Clashes*, 156. No comparable figures are available for the AA-2 Atoll, a Soviet-built, reverse-engineered Sidewinder AIM-9B used by North Vietnamese forces.

AIM-9 Sidewinder on an F-4 aircraft.

AIM-4D Falcon with Air Force personnel.

Excuses abounded: poor maintenance, pilots shooting outside the firing envelope, the use of aerial-combat tactics that had been developed for the gun-carrying aircraft of WWII. But the fact remained that the primary air-to-air weapons for U.S. forces were not pulling their weight.

A report on the Navy's air-to-air capabilities was ordered in 1968 by CNO Admiral Thomas H. Moorer and was prepared by a team under Captain Frank W. Ault, former Commander of USS *Coral Sea* (CVA-43). *The Report of the Air-to-Air Missile System Capability Review* (or the *Ault Report*, as it is commonly known), did not pull punches. Its abstract began:

> Almost 600 air-to-air missiles have been fired by Navy and Air Force pilots in about 560 hostile engagements in Southeast Asia [in the 39 months preceding the *Review*]. Performance in combat indicates a probability of achieving about one kill for every ten firing attempts in any engagement where air-to-air missiles are employed in an environment similar to that in Southeast Asia.[3]

Maintenance and handling were factors in the poor performance. The environment, both in-country and on the aircraft carriers, was not conducive to optimal functioning for high-tech electronics. Marshall Michel contrasted combat conditions for air-to-air missiles with "the almost antiseptic conditions of the test programs." He wrote:

> Once the missiles got to the combat area, they were no longer hand massaged, but treated as another round of ammunition. They were roughly handled, hung on aircraft for long periods of time with only the most cursory checks, and exposed daily to drastic changes in temperature and humidity—from the Southeast Asia ground climate heat to the extreme cold of high altitude—and often their seeker heads were damaged by rain and hail or by debris kicked up on takeoff by the aircraft in front of them. Conditions were worse on Navy carriers, where missiles were exposed to the salt air and more cramped conditions.[4]

Tired ordies (aviation ordnancemen) on 12-hour shifts did not exercise the same care in loading and unloading ordnance as would, say, a crew working with weapons developers at Armitage Field. Still, testing and maintenance on Sidewinder were substantially less complicated than Sparrow.

The *Ault Report* noted:

> Sidewinder is tested on board ship with a relatively uncomplicated portable tester every 100 hours of activated time, or approximately every 50 captive flights. Once loaded on the aircraft, a preflight check is made by illuminating the seeker with a flashlight and verifying the presence of an audible signal. . . .

[3]*Ault Report*, 1.
[4]Michel, *Clashes*, 157.

> Sidewinder's performance is superior to Sparrow's because of a less complex design, better inherent design reliability, and lesser impact of subsystems (e.g., missile control system) interfaces.[5]

One of the problems inherent to Sidewinder and a significant contributor to the low kill rate was the missile's small firing envelope—the physical relationship of the shooter and target and the range of conditions (speed, altitude, *g*s, etc.) in which the missile could be fired with a reasonable chance of making a kill. In the early 1950s, Sidewinder had been envisioned as a defense primarily against Soviet bombers. Investigative journalists Jack Anderson and Fred Blumenthal described the weapon in a 1957 article as

> the Navy's snub-nosed, supersonic, bomber-hunting missile known as the Sidewinder. . . . The Sidewinder is a missile with a revolutionary principle: it is warm-blooded. Built to detect heat and track it to its source, the air-to-air missile will snuggle right up to the jet furnaces that power invading bombers.[6]

But a multiengine bomber was a different animal than the fast-maneuvering MiG a U.S. pilot faced in the skies over Vietnam. The Sidewinder 1A (AIM-9B), which was the first Sidewinder model used in Vietnam, had a very small engagement envelope against the enemy fighters. The missile had to be fired pretty much from directly behind the target, and the shooter could not be exceeding a 2 *g* maneuver when the missile was launched.

Distance to the target was a critical envelope parameter. When the pursuing aircraft was within what would have been gun range in WWII, it was too close to the target to employ Sidewinder, which had a minimum range of about 3,000 feet. Michel reports that the out-of-envelope firing rate for the AIM-9B in Vietnam was 28 percent.[7]

The IR-guided AIM-9D Sidewinder, which was the workhorse air-to-air missile in the later years of the Vietnam War, had a better but still narrow shooting envelope. Approaching an enemy aircraft from the rear, the shooting envelope was about 30 degrees to either side of the target's tail. But as soon as even moderate maneuvering began—which was highly likely if the enemy realized that there was a U.S. fighter on his tail—the envelope shrank rapidly. If the aircraft were turning at a high *g*-rate, the envelope disappeared entirely.

---

[5] *Ault Report*, 32.

[6] Anderson and Blumenthal, "Offense vs. Defense," 4.

[7] Michel, *Clashes*, 155. Part of the problem of out-of-envelope firings was inadequate training, an issue which the *Ault Report* also addressed and which resulted in the creation of the Navy Fighter Weapons School (TOPGUN) at NAS Miramar.

AIM-9G

At the beginning of the AIM-9D's development in the late 1950s, the Sidewinder 1C (which included both the IR-guided AIM-9D and the RF-guided AIM-9C) was a candidate for a new technological development called the Sidewinder Acquisition and Track (SWAT) system. Heretofore, the pilot of the Sidewinder-equipped aircraft had to maneuver his plane so that the target was within the small (2.5-degree) field of view of the missile before detection and lock could be achieved. Success was indicated by a tone in the pilot's headphones. SWAT, which was proposed by Sidewinder engineer Frank Cartwright, would perform a spiral search pattern and ease the pilot's burden by effectively widening the missile's field of view.

SWAT was developed by Magnavox for the Sidewinder 1C/F8U-2N aircraft combination. When the F8U-2N went out of production in 1962, the SWAT system was shelved—temporarily. The acquisition problem didn't go away. In 1965, the *Tech History* observed that

> pilots of aircraft armed with AIM-9D missiles experienced target-acquisition problems caused by the limited field of view of the seeker. To satisfy missile firing conditions, the target must be maintained within the seeker's field of view. In beam or head-on attacks or attacks against maneuvering targets, it becomes extremely difficult to maintain this condition.[8]

SWAT was revived, this time under the name Sidewinder Expanded Acquisition Mode (SEAM), with Magnavox again the prime contractor for development. SEAM had greater capabilities than the earlier system, and its development was coordinated with a rework program on the F-8D and F-8E aircraft.

Using SEAM, the missile seeker could be either slewed in a search pattern or slaved about the axis of the aircraft's radar antenna. The seeker would lock on any target that came within the field of view and met the signal-strength criterion. SEAM essentially expanded the Sidewinder seeker's field of regard (the total area that the sensor can perceive) from 2.5 to 7.5 degrees, allowing the pilot both to "lead" his target and not have to pull the aircraft into a pursuit path and put excessive *g*s on the missile at the launch point.

In 1966, work began to integrate SEAM with the new F-4 aircraft, and in 1968, at Naval Air Test Center (NATC) Patuxent River, SEAM was evaluated with the F-4. The *Tech History* reported that "this evaluation culminated in successful firings under high look-angle conditions." The system completed operational evaluation and was released to the Fleet in 1969. NWC also assisted

[8] *NOTS Tech History 1965*, 5-5.

in the design of a SEAM installation for the F-14 and F-5 aircraft. The AIM-9D with the SEAM upgrade was designated the AIM-9G. By 1972, Raytheon had built over 2,000 units.[9]

AIM-9H

Several approaches to improving Sidewinder's air-combat performance in Vietnam were consolidated into the Sidewinder Improvement Program, which began in 1968.

To decrease the minimum range of the missile, NWC engineers explored larger canards (the cruciform forward steering fins). Theoretically, these would increase the airframe maneuverability and thus allow successful encounters at shorter ranges against maneuvering targets. Nine instrumented missiles were constructed and fired to verify the effectiveness of the modification.

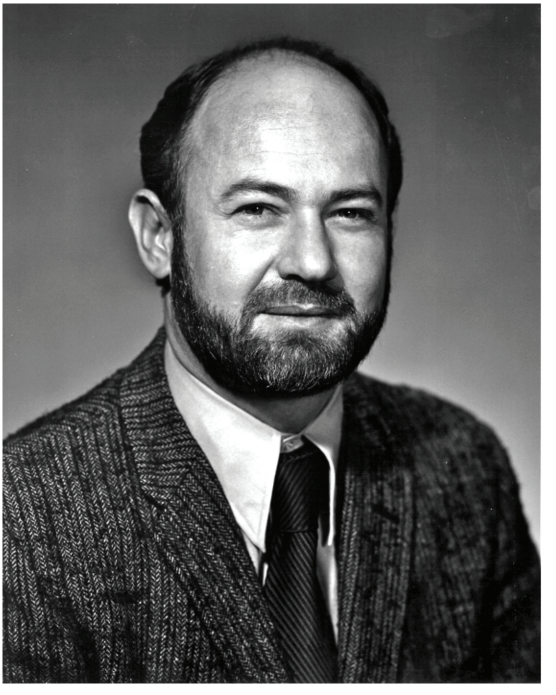
Deficiencies in the Mk 15 target-detecting device (TDD) against highly maneuvering targets led to development of a skewed-approach amplifier (SKAMP). Ten ground firings were conducted with SKAMP. Ten air firings were also scheduled, but only six were carried out. "Because of the successful performance of the SKAMP modification, it was concluded that further expenditure of missiles and drones was unwarranted at that time," recorded the *Tech History*.[10]

In the mid-1960s, China Lake had begun to investigate a solid-state Sidewinder—the technology had matured sufficiently, and Center experts believed that the benefits in terms of reliability and space/weight savings would be coupled with a chance to make major improvements to the overall missile. The idea got a boost in Captain Ault's widely read report: "The proposed next generation, solid state Sidewinder is needed in the Fleet inventory, primarily on the basis of increased reliability," he wrote.[11]

Unlike the Air Force AIM-9s, Navy Sidewinders had to be able to withstand the high shock forces of carrier catapult-assisted takeoffs and the even greater impact of carrier-deck landings. With an aircraft sink rate of 12 feet per second, the process of putting a plane on the deck of the ship—sometimes called a "controlled crash"—played hell with vacuum-tube electronics as well as mechanical components. As a consequence, system reliability for Navy Sidewinders was not as high as might be desired and diminished with repeated takeoffs and landings.

---

[9] *NWC Tech History 1968*, 5-34.
[10] Ibid.
[11] *Ault Report*, 29.

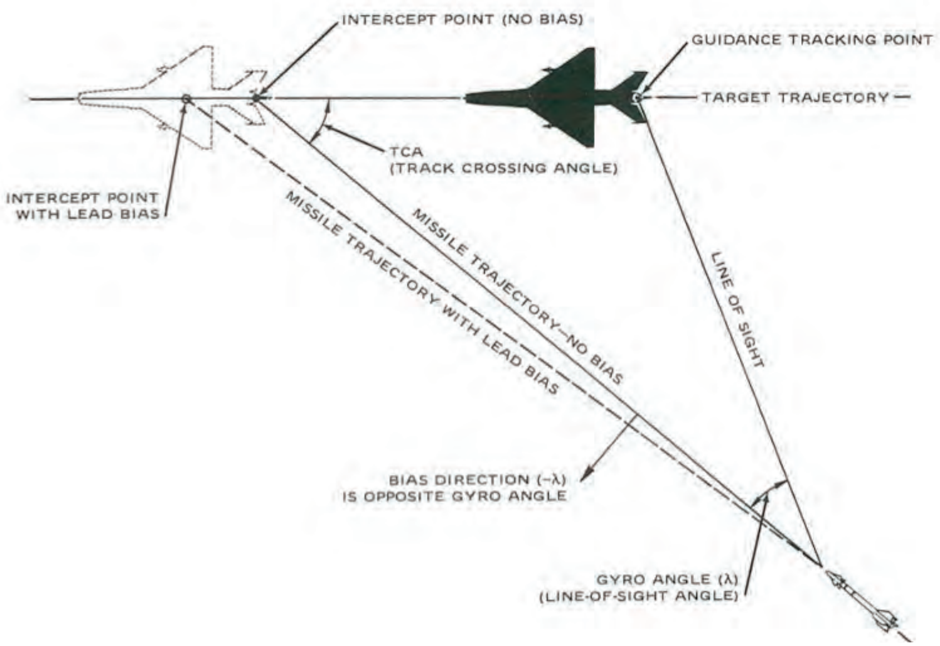


Walt Freitag.

Walter Freitag, head of the Guidance and Control Division, was China Lake's chief proponent for a total remake of the Sidewinder guidance and control group in a solid-state design, as opposed to an incremental switchover from vacuum tube to solid-state technology, as had been proposed by the AIM-9D development contractor, Philco-Ford. Freitag's group worked with General Dynamics, which delivered nine solid-state guidance and control group units to NWC in 1968. The solid-state guidance and control group was coupled to the seeker, which was built around a nitrogen-cooled lead-sulfide (PbS) detector. After thorough testing (high-speed track, environmental, and captive carry), the first solid-state Sidewinder, designated AIM-9H, was successfully flight-tested in a firing on 6 December 1968. NAVAIR budgeted for 200 of the solid-state production units in 1969.

AIM-9H also incorporated faster tracking than its predecessors (20 degrees per second) and more powerful control-surface actuators. NWC developed the lead-bias circuitry for the AIM-9H, which modified the terminal-guidance maneuvering so as to bring the intercept point forward of the target-aircraft exhaust and thus improve kill probability. "Of six missiles flight-tested in the final [lead-bias] configuration, all six were successes; four were contact hits," stated the *Tech History*.[12]

[12]*NWC Tech History 1972*, 4-22. The modification involved changing the method used to process the range information output from the seeker's lead-sulfide detector.



AIM-9H guidance tracking geometry with lead bias.
Published in the 1973 *NWC Tech History*.

In 1971, at the request of the Naval Weapons Laboratory, Dahlgren, NWC launched a comprehensive electromagnetic-vulnerability test program on both the AIM-9G and -9H guidance and control groups. Conducted on an urgent basis over a 23-week period, the program required design and fabrication of unique test hardware and was successful in resolving concerns about the guidance and control group's performance in both friendly and threat high-density radio frequency (RF) environments. George F. Barker, Donald B. Clark, and Vernon Gallaher of the Engineering Department's Systems Electronics Branch were presented Superior Achievement Awards for their work on the program.

The AIM-9H began production in 1972 and went to the Fleet in 1973; more than 8,500 units were built by Raytheon and Ford-Philco. Although introduced too late to make a difference either in the outcome of the Vietnam War or the overall Sidewinder success rate, the AIM-9H was the most effective air-to-air missile employed by U.S. forces during the war.

AIM-9E, AIM-9J, and AIM-9N

The AIM-9D—which, along with its radar-guided sister missile the AIM-9C, went to the Fleet in 1964—employed a nitrogen-cooled detector as the heart of the seeker. The AIM-9D was carried on a LAU-7 launcher, designed by China Lakers Dick Meeker and Mike Kamimoto, that incorporated a nitrogen bottle to cool the detector prior to the actual launch. Air Force Sidewinder launchers did not incorporate this cooling bottle and thus were not compatible with the AIM-9D.

Instead, the Air Force took a separate Sidewinder development route. In 1967, the service fielded the AIM-9E. This was a converted AIM-9B (the missile that shot down MiG fighters over the Straits of Taiwan in 1958). The AIM-9E incorporated a Philco-Ford-designed seeker that used Peltier thermoelectric cooling. It also had hybrid electronics (solid-state and vacuum tube), a larger acquisition envelope than the AIM-9B, faster tracking speed, and a reduced-drag ogive nose. The motor, fuze, and warhead (blast/fragment, as compared to the continuous-rod warhead of the Navy AIM-9 C and -9D) were standard AIM-9B, although a reduced-smoke-motor version designated AIM-E2 was also fielded. Some 5,000 AIM-9E/-E2s were produced.

Several reasons have been proposed for the Air Force decision to split off from the Navy's Sidewinder family. First, the Air Force was already heavily invested in the AIM-4 Falcon, although in combat this turned out to be a far less effective air-to-air missile than the Sidewinder. Second, while the Navy's F-4B, -J, and -N Phantoms flown in Vietnam were not equipped with guns, the Air Force F-4C and -D usually carried a gun pod, and the F-4Es were equipped with an internally mounted M67 Vulcan cannon, giving the Air Force Phantoms an extra weapon for the dogfight. Third, the AIM-9Bs that were used to build the AIM-9Es were cheap. Tens of thousands had been produced since the mid-1950s.

AIM-9J began development in 1968 and entered service with the Air Force in the summer of 1972. It converted AIM-9Bs/-9Es to mostly solid-state electronics. The model was distinctive for its larger double-delta or "cranked" canards. Further improvements were made in an AIM-9N upgrade, among them a longer-burning gas electric-power generator, which increased the missile's range. The AIM-9J/N had poor low-altitude performance but had a larger envelope than its -9E predecessor, particularly during high-*g* maneuvering encounters. More than 20,000 AIM-9Js and AIM-9Ns were built for the Air Force.

AIM-9L

In 1970, the *Tech History* reported:

> An intensive study was conducted in September and October to define an improved Sidewinder missile that would satisfy the aerial intercept missile needs of the Army, Navy, and Air Force. The missile design, known as the AIM-9L, would be basically an updated AlM-9H.[13]

AIM-9L was an ambitious undertaking. It would exploit the newest technologies available to air-to-air weapon designers and a triservice program. The Army's interest in AIM-9L was as part of a product improvement program for the Chaparral ground-based air-defense weapon system, which employed a modified AIM-9D. Among other constraints, that meant the AIM-9L would have to possess "an all-aspect engagement capability to extend the forward reach of the [Chaparral] weapon system to the extent necessary to obtain a substantial increase in target aircraft kills and provide point- and self-defense capability." In this context, "all-aspect" referred to a missile that could be fired at a target from any angle, including nearly head-on, rather than, as with the existing IR detector-based Sidewinders of the day, from abeam or abaft of the target. AIM-9L would be the missile that, Michel writes, "finally fulfilled the heat seeker's promise."[14]

The Navy already had an all-aspect Sidewinder—the radar-guided AIM-9C, which Tom Amlie's Development Division 4 in the Aviation Ordnance Department developed contemporaneously with the IR-tracking AIM-9D in the Weapons Department. The problem with the AIM-9C was, first, that it was more complicated than the fire-and-forget AIM-9D, requiring the target to be continuously "painted" by the airborne radar. Second, the only aircraft that carried the AIM-9C was the F-8D/E Crusader, which flew from the small SCB-27C WWII-era aircraft carriers that could not accommodate the newer F-4 Phantoms. As the carriers and the F-8s were phased out in the late 1970s, so too would the AIM-9C pass into history.

All-aspect capability was important to the Air Force as well to the Army. The performance of Air Force versions of Sidewinder in Vietnam (the AIM-9E, -9J, and -9N) had been poor relative to the Navy's, although much of that deficiency was attributable to Air Force training. The Air Force sorely needed a reliable next-generation high-performance air-to-air missile. Walt LaBerge was Deputy Technical Director at China Lake when the AIM-9L program began and was directly involved in the initial technical development. In 1973,

[13] *NWC Tech History 1970*, 1-26.

[14] Ibid., 2-27; Michel, *Clashes*, 287. The development of Chaparral is discussed in detail in Volume 4 of this series.

LaBerge, then NWC's Technical Director, left the Navy for the Air Force. He told an interviewer:

> I got to be the Assistant Secretary of the Air Force for R&D on the basis of an interview with General Brown [George S. Brown, Chief of Staff of the Air Force and later Chairman of the Joint Chiefs of Staff], who had only one real question, which was, "Will the AIM-9L work?" He knew I came from China Lake. The Air Force really needed to have a head-on capability.[15]

Engineering development of the AIM-9L began in 1971, and NWC was assigned technical management and design cognizance. Glen Hollar, head of the AIM-9L Project Management Branch, and James R. Bowen, head of the AIM-9L Technical Project Branch, both in the Systems Development Department, headed up the early effort. In December, four officers and one civilian from the Air Force joined Bowen's branch; they represented Lieutenant Colonel R. P. Gould, the Air Force AIM-9L program manager in Washington. In 1972, Bowen moved into the Agile program, and Martin Landau took over his branch, now renamed the AIM-9L Technical Development Branch.

Glen Hollar.

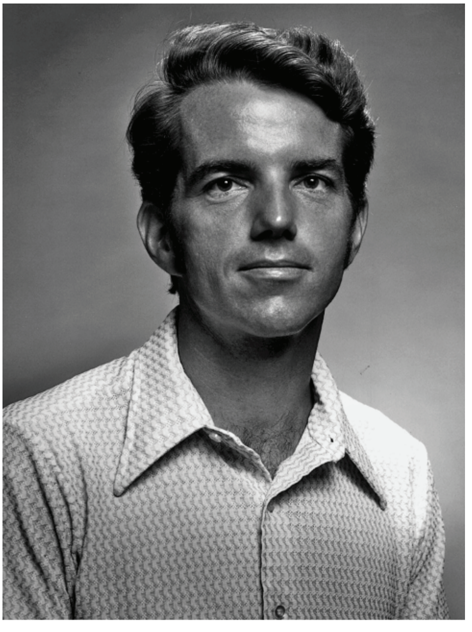
James R. Bowen.

Early AIM-9L development was shaky. Funding for Sidewinder at China Lake had peaked at about $15 million in 1960, at the height of AIM-9C and -9D development, then from 1963 to 1970 had hovered between $5 and $7 million per year. With the advent of the AIM-9L, it rocketed

[15]S-207, LaBerge interview, 12.

from $6 million in 1971 to $18 million in 1974. There were cost overruns, and Congress (for fiscal year 1973) decided to delay funding for AIM-9L production.[16]

Technical difficulties were numerous while adapting new technologies to the emerging weapon, but the China Lake engineers and their Raytheon (prime contractor) associates persevered. Lead-bias, such as that incorporated in the AIM-9H, caused problems. After two missiles fired in 1972 both failed to hit the target because of the lead-bias circuitry, NAVAIR, on China Lake's recommendation, ordered that the circuitry be eliminated from the AIM-9L and that its development be carried on in parallel to the program. AIM-9L's original design had replaced two of the rolleron wings on the aft end of the missile with flat-plate wings to decrease drag. However, after roll instability was seen in 1973 testing, the designers went back to four rolleron wings.


Dr. Allen Gates.

Hollar and Landau received Superior Achievement Awards from Rear Admiral Pugh, NWC Commander, in August 1973 for keeping the troubled program on schedule through the conclusion of engineering development. Early the following year, the two AIM-9L branches were consolidated into the AIM-9L Program Office, part of the Systems Development Department (later the Air Weapons Department), with Hollar in charge. In mid-1974, the office was taken over by Dr. Allen B. Gates. In November 1975, the office was renamed the Sidewinder Program Office and moved to the Engineering Department staff. Gates headed the office until March 1976, when he was selected for a Sloan Scholarship to the Massachusetts Institute of Technology (MIT).[17]

[16]NWC, "Sidewinder Program Information," Attachment 3, "Sidewinder Programs Funding Chart," 5. Fifteen million dollars in 1960 dollars equaled about $27 million in 1974 dollars.

[17]Gates, with the assistance of an NWC Fellowship, had received his PhD in engineering from Case Western Reserve in 1971. Gates once commented about a Center visitor's concern that carrying a missile capable of high-off-axis target lock might lead to a pilot shooting down

The key to having an all-aspect capability in an IR-guided missile was the seeker design. For the AIM-9L, Mickie Benton's Optical Design Branch replaced the existing lead-sulfide detector with an indium antimonide detector. This newer detector extended the wavelength of the seeker's operation. Changing to a longer wavelength allowed the seeker to track the enemy aircraft's skin and exhaust pipe as well as the exhaust plume. The new seeker developed by Benton's team also offered better background discrimination than previous seekers by increasing the contrast between the target and the background radiation.[18]

For years, Benton and his associates had been looking to implement the new seeker concept, and AIM-9L provided the opportunity—as well as joint-service funding. "We gave presentations to the Air Force, the Navy, and Army on how the AIM-9L would perform," Benton said. "We had quite a team putting those pitches together. Chuck Smith was one of the instigators of helping us pull this together and get the Air Force convinced that our approach was a sound, low-technical-risk approach."[19]

A design study of the steering fins (canards) produced a new double-delta configuration, similar to the Air Force AIM-9J. In wind-tunnel tests conducted in 1971 at Naval Ordnance Laboratory (NOL) White Oak, the new design, designated DD-4, proved suitable for the AIM-9L's intended envelope and gave the -9L increased maneuverability.

The AIM-9L's warhead, WDU-17/B, was designed for a greater catastrophic-kill probability against high-performance targets than that of the Mk 48 continuous-rod warhead used in the AIM-9C, -D, -G, and -H. The WDU-17/B was an annular blast fragmentation warhead, which spread fragments from rods in an annular (circular) pattern around the warhead. The dual-end initiated titanium prefragmented rod warhead weighed about 20 pounds, of which about 7.5 pounds was PBXN-3 explosive. As described in the *Tech History*, the new design

> maximizes the initial available energy, utilizes the gas products cloud to increase and support fragment velocity, concentrates the fragment and blast

---

his own wingman: "That would be like worrying about giving a saber to a cavalry man for fear he might cut himself." S-275, Arnold interview, 45.

[18]Enhancing target signature by detecting aerodynamic heating of the aircraft skin is dependent on such factors as aspect angle, speed, altitude, and background. Benton had earlier developed an advanced prototype Sidewinder (designated AIM-9K) as one of several alternatives to the Agile missile, but the Air Force had blocked further development.

[19]S-193, Benton interview, 48. Chuck Smith was head of the Infrared Systems Division in Knemeyer's Weapons Development Division, and he later headed the Systems Development and Air Weapons Departments before his retirement in 1975. Since taking over the original Sidewinder flight-test program in 1953, Smith had been involved with every Navy version of the AIM-9.

energies into a disk-shaped pattern, and then efficiently dissipates the warhead energies within an intercepted target structure.[20]

Tests showed greater effectiveness due principally to higher-velocity fragments and improved energy transfer to the target. An additional benefit of the higher-velocity kill mechanism was that it reduced the "fuzing equation delay compromise" necessary for all-aspect encounters.[21]

The AIM-9L warhead design benefitted from an increased emphasis on terminal-encounter simulation studies. Prior to 1971, such studies had been conducted mostly to analyze warhead interactions with surface targets, but now the Center began to build an air-encounter simulation capability as well. The expanded capability kept pace with new warhead and fuze technology developments and used the latest intelligence and damage data to refine target-vulnerability models.

Modeling fuze/aircraft encounter in NWC's Encounter Simulation Laboratory at Corona. Published in D503 *Encounter Simulation Laboratory*, 1976.

[20] *NWC Tech History 1972*, 4-16, 4-17. Target/missile intercept speeds can vary from, theoretically, close to 0 feet per second to over 5,000 feet per second.

[21] Ibid.

Another important advancement incorporated into the AIM-9L was its active optical target detector (AOTD), which gave more precise target detection and resulted in better burst control. Designated the DSU-15/B, the fuze, developed under the direction of James R. Wills and produced by Santa Barbara Research Center, employed gallium-arsenide solid-state lasers and was more resistant to countermeasures than previous Sidewinder fuzes.

Other AIM-9L improvements over earlier Sidewinders were a more powerful Mk 36 rocket motor and a reengineered Mk 13 Mod 2 safety-arming device capable of arming under high lateral-acceleration loads.

Simulation played a greater role in the AIM-9L development program than with any previous Sidewinder. A six-degree-of-freedom (6-DOF) analog Sidewinder simulator—roll, pitch, and yaw—had been around since its development by W. G. "Gene" Younkin, part of the original Sidewinder team in the 1950s. For the AIM-9L, new breakthroughs in electronics were utilized to construct a far more efficient (and faster) digital 6-DOF simulation. Bill Porter, who would go on to be China Lake's 12th Technical Director, said (caveating that his numbers were approximate):

Gene Younkin, with pointer.

> We fired 120 missiles on the AIM-9H to get through the development. When we went to the AIM-9L, we fired 60-some. And when we went to the -9M, we fired about 30, and I think you'll always have to fire at least 30-some to get through a development . . . The simulation had progressed and was so much better by the time we got to the AIM-9M that we knew as much by firing 30 missiles as we had known by firing 100-plus on the earlier versions.[22]

Joint Navy-Air Force initial operational test and evaluation (IOT&E) began in January 1975. Over the next 2 months, more than 40 missiles were fired. Performance was good, although deficiencies were noted in the areas of

[22]S-216, Porter interview, Part 1, 7.

IR counter-countermeasures and background rejection. In January 1976, a review by the Defense Systems Acquisition Review Council (DSARC III) gave Ford Aerospace (the Air Force's prime Sidewinder contractor) and Raytheon the green light for production, and soon the AIM-9L was being delivered to the operational forces.

China Lake had demonstrated the utility of second-source contracting during the 1960s. By 1978, the *Tech History* could report that

> full-rate production of the Sidewinder AIM-9L was achieved on all major components with at least two contractors for each. . . . NWC provided technical support to the production contractors for the Sidewinder guidance and control section, WDU-17/B Warhead, Mk 36 Rocket Motor, Mk 1 Mod 0 Wings, BSU-32/B Fins, DSU-15/B Target Detector, and the Mk 13 Mod 2 Safety-Arming Device.[23]

Surprisingly, the pacing item for all-up-round production that year was not the technically advanced seeker nor the guidance and control section but rather the fins (canards). "Three industrial sources are under contract for these fins," explained the *Tech History*.

> Precision Metal Products Inc. delivered approximately 1,500 fins with 6,000 more to be delivered. Deliveries from Precision Metal Products are currently 12 months behind schedule because of tooling problems with the forging contractor. The Genii Research Company, N. Amityville, N.Y., submitted and failed first-article testing on its fin contract. The first-article units are scheduled to be resubmitted in February 1979. Welbilt Electronic Die Corp., Bronx, N.Y., the third production source for fins, is scheduled to submit first-article units in April 1979 with production deliveries to begin in August 1979.

Wayne Doucette.

Resolving such problems, as well as hundreds of other equally urgent Sidewinder challenges, was the job of Wayne Doucette, who had taken over the Sidewinder

[23]*NWC Tech History 1978*, 4-3.

Program Office from Gates just about the time the first AIM-9Ls were going to the Fleet. In September 1978, on the occasion of his receiving the Technical Director Award, the *Rocketeer* reported:

> Under Doucette's cognizance for the past 2½ years, a full-time complement of 200 Center employees, which has at times nearly doubled, has been heavily involved in guiding the initial production of the AIM-9L, overseeing the integrated logistics support, and providing training for initial Fleet introduction of the weapon.[24]

In 1983, former China Laker Jerry Reed, then Technical Director of the Joint Cruise Missile Project Office, described the AIM-9L as

> the premier short range air-to-air missile in the world. And it has proven itself in a variety of combat situations, in Lebanon, in the Falklands, and in the isolated geopolitical incident near Libya. There is an example of what a laboratory can do in harmony with contractors to build just a first-cabin missile.[25]

Air Intercept Missile Evaluation–Air Combat Evaluation (AIMVAL-ACEVAL)

In the mid-1970s, the DoD's various air-intercept-missile programs were in disarray, and the lack of coordination between services and apparent duplication of effort caught the attention of Congress. At the time, the Air Force AIM-82 had been cancelled in favor of Agile—which was still limping along, though close to termination. In 1974, Air Force representatives went before a congressional committee and tried to get more money for production of the Air Force-specific AIM-9J Sidewinder, complaining that "because of slips in the program, where the AIM-9L [being developed for both services by the Navy] is quite late, we find a serious shortfall exists and continues to exist on through the years to 1980."[26]

Meanwhile, the Army argued to the same committee that there was 95 percent commonality between the Army's improved Chaparral (using

---

[24]*Rocketeer*, 29 September 1978, 1.

[25]S-151, Reed interview, 6. The "isolated geopolitical incident" was the shoot-down, in 1981, of two Libyan Su-22 "Fitter" fighters after they attacked two Navy F-14 Tomcats. The radar intercept officer on one of the Tomcats was Lieutenant David J. Venlet, who as rear admiral commanded NAWCWD from 2003 to 2004 and subsequently, as vice admiral, commanded NAVAIR and served as Program Executive Officer for the Joint Strike Fighter F-35.

[26]Statement of Lieutenant Colonel Robert G. Dilger, Air Force Requirements Office, *Departments of the Navy and Air Force, Air-to-Air Missiles* (meeting, U.S. Senate, Subcommittee on Tactical Air Power of the Committee on Armed Services, Washington, DC, 27 March 1974, Senator Sam Nunn presiding), 4,689.

the AN/DAW-1 guidance section) and the Navy's AIM-9L. (The committee had, the previous year, instructed the services to look into the possibility of a common air-intercept missile.) The Navy countered that "the Navy's position is 90-plus percent commonality . . . however, the other 10 percent or perhaps 5 percent, are such that the two missiles would require 2 years of R&D to make them fill one role."[27]

The Air Force representative stated that his service had four separate dogfight missiles currently in the inventory (AIM-9E, AIM-9J, and two versions of the AIM-9P) and proposed an entirely new missile concept called Concept for Low-Cost Air-to-Air Weapon (CLAW). The Air Force did, however, admit that "the CLAW missile does not meet the Navy's requirements for a high performance air-to-air missile in the future."[28]

In addition, the air-combat/air-intercept-missile mix included the mid-range Sparrow AIM-7E and AIM-7F and long-range Phoenix missiles as well as various Navy and Air Force launch platforms: F-4, F-14, F-15, etc.

To help clarify just what was needed in an air-intercept missile, and by which service, the DDR&E, at the request of Congress, directed that the Navy and Air Force conduct a joint-service program: AIMVAL-ACEVAL. The purpose of the testing was "to aid in the determination of an operational requirement for the Advanced Short-Range Air-to-Air Missile (ASRAAM)." The back-to-back exercises, consisting of hundreds of mock combat air-to-air engagements, were held between 1975 and 1977 at Nellis Air Force Base, Nevada.[29]

ACEVAL examined the tactics of high-performance U.S. aircraft (F-14 Tomcats and F-15 Eagles), designated the Blue Force. They flew against F-5E Tiger IIs, similar to the MiG-21, that simulated threat aircraft and that used enemy tactics. The F-5Es were designated the Red Force. ACEVAL was premised on the belief that the Soviet Union had, or would soon have, all-aspect missiles such as the AIM-9L, and therefore the Red Force was equipped with the same seekers as the Blue Force. AIMVAL looked at several air-to-air missile concepts that might be replacement candidates for the Sidewinder AIM-9L.

---

[27]Statement of Captain William B. Haff, Navy Sidewinder project manager, *Departments of the Navy and Air Force, Air-to-Air Missiles* (meeting, U.S. Senate, Subcommittee on Tactical Air Power of the Committee on Armed Services, Washington, DC, 27 March 1974, Senator Sam Nunn presiding), 4,687.

[28]Air Force-submitted response to a prepared question from Senator Strom Thurmond, *Departments of the Navy and Air Force, Air-to-Air Missiles* (meeting, U.S. Senate, Subcommittee on Tactical Air Power of the Committee on Armed Services, Washington, DC, 27 March 1974, Senator Sam Nunn presiding), 4,724.

[29]*NWC Tech History 1978*, 4-4.

Rear Admiral Julian S. Lake was the first Joint Test Director for AIMVAL-ACEVAL, a position subsequently held by Rear Admiral Ernest E. Tissot and later by Rear Admiral Robert P. McKenzie. Commanding the Navy portion of the Blue Force was Rear Admiral Jimmie W. Taylor, Officer-in-Charge of the VX-4 detachment at Nellis. China Lake's Lieutenant Commander Theodore H. Faller was the staff engineer and engineering director for the exercises, a task for which he received the Joint Service Commendation Medal in June 1978.[30]

Phil Arnold was the Center's principal contact with AIMVAL-ACEVAL. Initially, Arnold was head of the Agile Division, until that division was eliminated in the September 1975 reorganization, at which time he became head of the Electro-Optical Division.

A tubular airspace 30 nautical miles in diameter on the Air Force's Air Combat Maneuvering Instrumentation (ACMI) Range north of Nellis formed the AIMVAL-ACEVAL arena. There were no altitude limitations and very few restrictions on the participants. Blue Force and Red Force aircraft would enter from opposite sides and engage. The engagements were all dogfights; beyond-visual-range missiles, such as the Navy's long-range Phoenix, were not permitted. A shooter had to make positive visual identification of his foe.

While the Blue Force had better radars and were able to locate the Red Force fighters more quickly, the Red Force F-5s were smaller and harder to identify. Tactics developed quickly. "One contingent would go out to a fight and be surprised by something the other contingent did, come back, and spend hours devising something to counter, then use it the next day," wrote one commentator.[31]

Both sides were aided by the mapping and analysis capabilities at Nellis. "The [ACMI] tracked all the fighter aircraft in real time—computers were just getting good enough to process all this info—and ran simulated missile fly-outs once the pilot pulled the trigger," explained Mike Mumford, who was in the Air Force, stationed at Nellis at the time, and worked on the project.[32]

The Navy and Air Force pilots selected for the exercise were among the service's best, and there were lots of "bragging rights" at stake as the pilots of the three aircraft types competed in as near to real aerial combat as one could get. "Everyone wanted to look good. Personal reputations and service honor were at stake. Nobody wanted to lose," said Wilcox.[33]

[30]Faller would perish in the crash of an F-86F in Ridgecrest in 1979.

[31]Wilcox, *Wings of Fury*, 48.

[32]Mike Mumford, email, 11 November 2014. Mumford had a distinguished 34-year career at China Lake, retiring as head of the High-Speed Strike Office in 2006.

[33]Wilcox, *Wings of Fury*, 48.

Among China Lake's responsibilities in AIMVAL-ACEVAL was providing the AIM-9L captive flight-test missiles or captive test units (CTUs) that were used on the three aircraft types. "There were 7,200 sorties flown with the AIM-9L CTUs during AIMVAL-ACEVAL," reported the *Tech History*. "The reliability of the CTU was considered good. Two [units] were flown in over 3,500 sorties and 26 were flown in over 200 sorties. At the conclusion of the program 30 CTUs out of 30 were operational."[34]

China Lake also supplied a new seeker, the Navy surrogate seeker (SS)-2, "a high-performance 3-axis wide-gimbal-angle IR seeker mounted to a captive flight pod." These seekers were fabricated by Hughes Aircraft Co. in a joint China Lake / Hughes "high schedule/risk program" with first item delivery scheduled for less than 12 months after program commencement. The 1977 *Tech History* reported that "all hardware was delivered either ahead of schedule or ahead of need dates. The program has been a success in terms of meeting hardware schedules and performance of delivered hardware." Ten SS-2 CTUs were successfully integrated with Blue Force F-14s and F-15s for evaluation in combat against the Red Force.[35]

China Lake also conducted analyses and studies of a Navy-concept missile known as Delta, which relied on a seeker slaved to a Visual Target Acquisition System (VTAS). A Monte Carlo study was run to develop an employment rule-of-thumb for the missile. As recorded in the *Tech History*,

> the study results showed a greater than 80 percent success when using the rule of thumb, "If the target can be seen and the seeker has target signal, the missile can be fired." Restricting the launch range to 3 nmi (5,600 meters) increased the successful launches to greater than 90 percent.[36]

The flight test portion of AIMVAL-ACEVAL concluded in 1977. Near its completion, a technical working group (TWG) was formed at Nellis to write a Joint-Service Operational Requirement (JSOR) for the ASRAAM. The group included representatives from the operational commands as well as pilots who had participated in AIMVAL-ACEVAL.

NWC and the Armament Development and Test Center, Eglin Air Force Base, participated cooperatively to provide technical consultation to the TWG. This work included "quick-reaction studies of seeker, guidance and control, aerodynamics, warhead, fuzing, and propulsion" and "digital computer trajectory simulations." According to the NWC *Tech History*, "The resulting

---

[34]*NWC Tech History 1976–1977*, 4-7.
[35]*NWC Tech History 1976–1977*, 4-4, 4-6.
[36]Ibid., 4-5.

draft JSOR is, in a sense, the final outcome of AIMVAL-ACEVAL in that it reflects what the TWG perceived as the real-world implications of the exercise."

Ken Banks, an analyst with China Lake's newly formed ASRAAM Program Office under Bill Holzer, was assigned to the TWG support role. He recalled years later that the China Lake team "dissented in significant ways" from the conclusions of the Air Force analyst group from Eglin.[37] Banks said in an interview:

> The basic problem with the exercise is it became a stylized sort of test where the somewhat artificial constraints of the exercise sometimes had a bigger impact on the outcome than you would hope for. . . The exercise started out with the intent of determining what was the best approach to an air-to-air missile for the Navy's next or the country's next air-to-air missile. And I think in the end it did not answer the questions that were asked, and I tried to say that in that report.[38]

In 1978, NWC participated in additional activities related to AIMVAL-ACEVAL and ASRAAM, including a test series dubbed Pave Prism, which was held on China Lake's ranges. This program involved side-by-side fly-by testing of 11 different seekers, including not only the joint Navy-Air Force AIM-9L and AIM-9M seekers but also candidates from Ford Aerospace and Communications (two seekers), Hughes Aircraft Co. (two seekers), Raytheon (two seekers), McDonnell Douglas Astronautics Co. (one seeker), Xerox Corp. (one seeker), and NWC (a charge-coupled device). Ultimately, none of the candidate seekers were able to meet all of the ASRAAM JSOR requirements.

At the time, Pave Prism was the largest side-by-side testing of seekers ever done. The program earned Technical Director Awards for Don Cooper (cochair of the Pave Prism Steering Committee), Albert Koch (project engineer), Gary Ozunas (instrumentation design), and Lieutenant Commander Bill West (test planning and test pilot). Pave Prism would lead, in the 1980s, to the Long Jump series of side-by-side fly-by seeker testing conducted by NWC at Barcroft Station, high in the White Mountains northwest of China Lake.

High-Altitude Project (HAP)

AIM-9L found its way into another China Lake development effort of the early 1970s known as HAP. The project was undertaken in response to the Soviet Union's remarkable MiG-25 Foxbat aircraft. The MiG-25 could fly higher—far higher—than any fighter aircraft in the U.S. inventory. In fact, the

---

[37]Ken Banks, email, 11 November 2014.

[38]S-401, Banks interview, 8.

MiG-25 still holds the Federation Aeronautique Internationale (FAI) absolute world altitude record for a ground-launched manned aircraft.[39]

The U.S. and its allies were concerned about MiG-25s that were flying reconnaissance missions over Israel in the run-up to the Arab-Israeli War of 1973, and the proposal was made for an air-to-air missile that would be capable of reaching the MiG at altitude.

Mike Ripley-Lotee, who worked on HAP, recalled:

> Some guys at China Lake had come up with a concept of taking the brand new Sparrow rocket motor that hadn't even entered service yet for the AIM-7F and matching it with a Sidewinder front end with the new -9L canards, the big canards, and then some guidance algorithms to allow it to take advantage of the new, improved sensitivity of the seeker for Sidewinder. . . . The whole concept was that an F-4 would have one of these things on a rack and zoom up to about 55,000 feet where it was just flaming out and be in front of the MiG-25, which would be going at Mach 3 or 4, nice and hot, a good signature, get tone from the Sidewinder front end, and fire this thing, and it would have the oomph to engage the MiG-25 up at 70 or 80,000 feet.[40]

HAP missile model on display at China Lake Museum of Armament and Technology. Note 8-inch-diameter Sparrow motor and 5-inch-diameter Sidewinder front end.

The HAP missile also contained components from the ACV, the aerodynamic version of Agile, a program soon to be cancelled. A 1973 technical note on HAP by China Lake engineer Jim Irvine noted that eight missiles were built; six were tested with telemetry warheads, and the remaining two "were built up in a tactical configuration with live warheads." In an interview four

[39]The FAI record altitude is 37,650 meters (123,523 feet), achieved by pilot Alexander Fedotov on 31 August 1977.

[40]S-330, Ripley-Lotee interview, 11.

decades later, Irvine recalled of the two tactical-configuration missiles that "we put them in the magazines and we left them there," until, in the late 1970s, "I finally had the missiles torn down."[41]

AIM-9M

Progress in the air-to-air missile business is not just a matter of keeping up with the enemy; it's also a matter of keeping up with oneself. At some point, every missile-development team needs to "freeze" the design, even though new technologies and new materials continue to be developed and the missile is obsolescent by the time it reaches the Fleet. That is why when the Chinese Nationalists shot down four MiG 17s over the Formosa Strait in 1958, using China Lake-designed (and, in that case, China Lake-assembled) AIM-9Bs, the base was already 2 years into development of what would become the AIM-9C and -9D Sidewinder variants.

Similarly, after the AIM-9L's IOT&E in 1975 revealed deficiencies in IR counter-countermeasures and background rejection, the Center formally began what was titled the AIM-9L PIP in 1976. As well as correcting the identified deficiencies, the -9L PIP would incorporate several other improvements: repackaging the guidance and control section and AOTD (the DSU-24/B, subsequently redesignated the DSU-15A/B) "to reflect the latest manufacturing technology and to reduce cost," a closed-cycle cryogenic system in place of the -9L's nitrogen cooling system, and (scheduled to start in 1978) a reduced-smoke rocket motor. The AOTD would employ "value engineering principles" to cut the per-unit production cost to $4,000, as opposed to the $7,700 price tag of the DSU-15/B.[42]

China Lake engineers did the initial design work for the AIM-9L PIP. NWC was also responsible for motor, missile, and aircraft integration of both the reduced-smoke rocket motor (developed by Thiokol Corp. with Air Force funding) and the cryogenic cooler (developed by Hughes Aircraft Co. for the Maverick missile with Air Force funding). In September 1977, Raytheon was awarded a contract to fabricate and package the engineering and pilot-production models. The PIP was scheduled for completion in 1981.[43]

Budgets were tight in the aftermath of the Vietnam War, and the long-term threat picture was uncertain. The Navy's strategy was "a decrease in new tactical air weapons and an increased emphasis on product improvement." The service's priority was "to obtain an increased operational readiness coupled with

[41] NWC TN-556-73-6, *HAP Missile,* 1; S-335, Irvine interview, 11.
[42] *NWC Tech History 1976–1977*, 4-13.
[43] Ibid., 1-71.

cost savings and improved maintainability whenever operational requirements could be met by product improvement."[44]

The AIM-9L PIP was redesignated the AIM-9M in March 1978. Bob Rowntree, NWC's Technology Base Coordinator during the period, commented that

> the AIM-9M was conceived as a way of developing and applying new ideas in technology and satisfying new requirements that came up during the development of the -9L. Rather than stopping the -L or inserting this new stuff, both the SYSCOM sponsors and the congressional staff, even while the -9L was still receiving R&D funding, said, "We'll start this new program. You put all these new ideas and satisfy the requirements in that and get on with the -9L and get it done."[45]

While the AIM-9L PIP had been targeted for completion in 1981, the schedule for completing the AIM-9M was pushed back to December 1980. The development, test, and evaluation (DT&E) phase began in May 1978, and in November, Engineer Mark F. Stenger took over the AIM-9M Technical Management Office. One of his first tasks was to explain the program to the CNO, Admiral Thomas B. Hayward, who visited China Lake that month. The year saw several successful AIM-9M test firings with the new guidance and control section and AOTD.

Mark Stenger.

In May 1979, the AIM-9M completed DT&E. That phase included numerous flight tests from F-4s, F-14s, and F-15s. (F-16 and F/A-18 integration would come in 1980.) The following month, Deputy Technical Director Burrell Hays passed out Group Special Act of Service Awards to more than 80 China Lakers. While the program had been managed out of the Weapons Department, the recipients also hailed from the Ordnance Systems, Fuze and Sensors, Engineering, Aircraft, and Range Departments as well as

[44] *NWC Tech History 1978*, 1-6.
[45] S-176, Rowntree interview, 80.

the Office of Finance and Management and the T&E Directorate. Like every China Lake success, the AIM-9M DT&E phase was a group effort.[46]

As joint technical evaluation began in the spring of 1979, there were still glitches ahead. Military test programs are often accused of being too lax on the weapon under test and not adequately simulating the difficult conditions to which a weapon would be subjected in real combat. The Navy and Air Force participants were determined that this would not be the case with the AIM-9M. As the *Rocketeer* reported,

> during the Joint Test and Evaluation phase, every effort was extended to insure that realistic scenarios were followed, while it was the aim of the operational test and evaluation effort to push the AIM-9M guidance system to the extremes of its capabilities.[47]

Push it they did, and during Navy operational testing in October 1979, a serious design flaw was found. Repeated hardware failures with the AIM-9M's closed-cycle cooler led to its replacement with an open-cycle cooler.

When Stenger became head of NWC's Sparrow Program Office in January 1980, Jimmie McCalester took over the AIM-9M program. McCalester, who had been with the program since its inception as the AIM-9L PIP in 1976, oversaw the cooler replacement, repackaging, and integration. The fix was validated in an April 1980 firing, allowing operational testing to continue without slipping the program schedule. The same year, the missile was successfully integrated with the F-14, F-15, and F-16. Operational testing was completed in March 1981, and in April the AIM-9M was released to production.[48]

Norm Woodall was now leader of NWC's overall Sidewinder team. (Doucette had left in November 1980 to take over the Weapons Development Division.) Woodall was assisted by technical manager Joe DiPasquale, RDT&E technical manager Dr. Bernard Wasserman, reliability engineer Randall Langham, and configuration manager David Rugg.

---

[46]A listing of the awardees and their contributions may be found in the *Rocketeer*, 22 June 1979.

[47]*Rocketeer*, 15 May 1981, 3.

[48]McCalester was awarded the Technical Director Award in July 1981 for his AIM-9M leadership.

Norm Woodall.

Dr. Bernie Wasserman.

Randy Langham.

Dave Rugg.

In 1983, the AIM-9M was delivered to the operational forces. China Lake continued to support the missile, primarily through the product-assurance efforts of the Engineering Department—the Navy had learned its lessons about production quality with the Vietnam-era Sidewinders. After several years of production of the AIM-9M, Burrell Hays recalled in an interview:

> We got really into alternate sourcing, signing every ECP [engineering change proposal], having teams of people go to the factory and watch what's going on. . . . The Engineering Department was charged with doing that. They did it very well. They probably did it with more fervor than a lot of people would have liked. . . . As far as I'm concerned, it's no mistake that the AIM-9M is being bought in 1986 dollars for the same amount of money we bought the less-complicated -9L for in 1981 dollars. And the reliability is as high. Those contributions wouldn't have happened if it wasn't for the Engineering Department's strong product assurance.[49]

The AIM-9M was used successfully by the United States during the Gulf War and has been widely adopted by U.S. allies. In various iterations (often denoted by two numbers for the Navy and Air Force versions, e.g., AIM-9M-6/7), it remained the nation's principal short-range dogfight missile until the advent of the AIM-9X in 2003.

AIM-9X, with an imaging IR focal-plane array seeker and the Joint Helmet Mounted Cueing System, has taken the air-to-air missile a quantum leap beyond its earlier AIM-9 brethren. But after Sidewinder's 60 years of continuous improvement, it seems unlikely that the -9X will be the last AIM-9 bearing the fingerprints of China Lake.

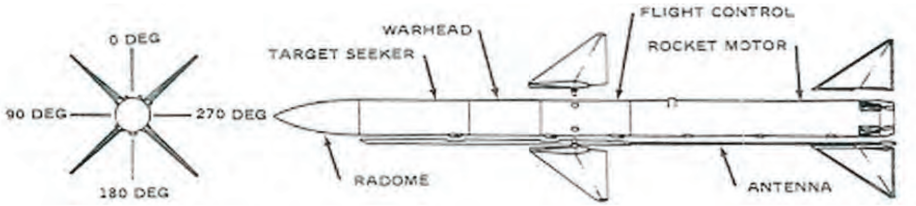
Sparrow AIM-7F

As the *Ault Report* had noted in January 1969, the semi-active RF-guided Sparrow air-to-air missile did very poorly in Vietnam. Efforts to correct this over the following 2 years had not improved matters. Raytheon and the Navy had tried various fixes to the AIM-7E (successor to the AIM-7D used earlier in the Vietnam War), but despite value-engineering attempts and a PIP, the upgraded AIM-7E—designated AIM-7E2—was faring no better than its predecessors.

To make matters worse, a new version of the Sparrow begun in 1966, designated AIM-7F, had failed developmental testing. The AIM-7F featured solid-state guidance and control, a Doppler-radar fuzing system, an NWC-designed warhead, and a new dual-thrust (boost-sustain) motor. The Navy was stretching out the program to give the contractor, Raytheon, time to redesign the weapon; however, the future of Sparrow looked shaky. By 1971, there was

[49] S-15, Hays interview, 10.

growing sentiment in Congress to abandon Sparrow entirely and start with something else.



AIM-7F Sparrow missile. Published in the 1971 *NWC Tech History*.

Twice, NAVAIR approached China Lake with the idea of having the Center qualify a second source for the AIM-7F, and twice, Technical Director Hack Wilson turned the SYSCOM down, pleading a lack of manpower to handle what would surely be a massive job. Wilson did not add that, aside from the Sidewinder AIM-9C, China Lake had little experience with semi-active radar-guided weapons. (The person most familiar with AIM 9C, Tom Amlie, had only recently been removed as Technical Director and would be gone from China Lake by mid-1971.)

John Rexroth, NAVAIR's chief engineer, was behind the push for China Lake involvement. He was familiar with the technical expertise demonstrated by the Center in successfully qualifying a second-source for the Shrike AGM-45 antiradiation missile, straightening out Raytheon's second-source production efforts on the AIM-9D, and, more recently, in managing the AIM-9L PIP improvements.

The third time NAVAIR broached the AIM-7F second-source plan, early in 1971, one important change had taken place at China Lake. Walt LaBerge had been brought on board as Deputy Technical Director, a role designed to groom him to take over as Technical Director when Wilson left. According to Burrell Hays, LaBerge saw the Sparrow AIM-7F second-source project as an opportunity for the Center to get more fully into the Navy's air-to-air program. "He had a grand scheme to get China Lake involved in all the air-to-air work . . . and this of course, fit right in."[50]

LaBerge had no illusions that qualifying a second-source would be easy. In March 1971, he and Fred Chenault, head of the Engineering Department, laid it out for the Board of Directors.

[50]Ibid., 18.

> This is a high-risk project to the Center. The basic aim is to develop a second-source contractor. This will require a data package, and *will, by necessity, require that the design and documentation package be brought under control.* Fundamentally, the premise for accepting the job was that there is a salvageable design. . . . The Center accepted the assignment because (1) it was a necessary and useful thing to do for the Navy, (2) we can help in the design of useful changes, and (3) it will naturally allow for participation in the associated radar and electronic equipment within the aircraft. . . . This is a $3 or 4 million project per year which will last several years . . . Some of the best people from all the Center codes will be needed on this project. [Emphasis added.][51]

Before the Center could even think about the second source, it would have to understand what was wrong with the first source, why the missiles were consistently failing. Was it inadequate design or problems with the manufacturing process itself? It would turn out to be both.

China Lake was assigned the technical-direction responsibility, and Burrell Hays was put in charge of the program. Hays promptly selected Allen Beggs as the program manager. "Allen worked 66 hours a week and just did a herculean job," commented Hays. Dave Simmons, one of the few China Lakers with semi-active-radar experience, was assigned as the radar engineer. Simmons "did exceptionally well," said Hays, "opposing contractor proposals for the radar system that were not necessarily in the best interests of the Navy and the taxpayers."[52]

The first step was for Hays to take a review team to Raytheon's AIM-7F production facility and conduct a review.

> After the review the team reported that it was not possible to determine if the design was satisfactory because it appeared no two 7Fs up to that time had been built to the same configuration, and also because product assurance was so bad it could not be determined if failures were because of the design or complete lack of quality control.[53]

There was a five-step plan for accomplishing the second-source qualification, which was coordinated with Captain Bill Brandel, Sparrow program manager in NAVAIR. First, compare the AIM-7F documentation package (which had been delivered by Raytheon and accepted by the government) with a delivered -7F guidance and control unit. Second, fund the contractor to train NWC engineers in the -7F system and subsystem design as well as in the test-facilities

[51]*Notes, Board of Directors Meeting, 17, 18, 19 March 1971*, Reg. 1703-100-71, Encl. 2, 2.

[52]S-157, Hays interview, 19; Hays to the author, email, 26 March 2014. Hays was selected to head the Engineering Department in 1973. Dr. Dick Kistler once said of Hays, who would later become China Lake's 10th Technical Director, "He pretty much revolutionized the Engineering Department." S-131, Kistler interview, 23.

[53]Hays to the author, email, 26 March 2014.

design and operation. Third, fund the contractor to establish, at China Lake, a full production-test capability. Fourth, award a limited-production contract to Raytheon to build units using China Lake's product-assurance requirements and under the oversight of NWC. Finally, competitively select five potential second-source contractors. They would each be given the -7F documentation and a -7F guidance and control unit to study so they could bid knowledgeably on a production contract.

From the beginning, the project was fraught with difficulty. For example, the documentation that the contractor had delivered to NWC did not match the guidance and control unit they had delivered. The Engineering Department's Jim Barry led a China Lake team that worked with Raytheon to change the documentation through formal ECPs so that the documentation package would match the contractor's baseline design. Part of the deal with Raytheon was that Raytheon, and not the Navy, would submit the ECPs. Thus, the contractor could not claim that China Lake was forcing changes on them.

The problems went deeper. According to Hays:

> More than 100 additional subsystem specifications had to be added to allow proper production test and control. The application of the product-assurance requirements to the new production contract forced the contractor to essentially refurbish his entire facility and retrain the production employees before he could achieve compliance.[54]

It was a difficult process for both the Center and the contractor, but it paid off. AIM-7F guidance and control unit production numbers increased dramatically. Mean time between failures increased over 3,000 percent. First-time acceptance testing, which had been about 20 percent, climbed to over 93 percent. And with the second-source competition, fixed-price unit costs dropped by 45 percent.[55]

The AIM-7F went into production in 1975—the same year the Vietnam War ended with the fall of Saigon to the North Vietnamese—and became operational with the Fleet in 1976. General Dynamics, Pomona, was the winner of the second-source competition. It delivered its first preproduction units in early 1976. The *Tech History* reported that

> Government testing of the hardware, including a free-flight record of five successes out of six, resulted in granting qualification approval to General Dynamics for the manufacture of the Sparrow AIM-7F guidance sets. A follow-on quantity of 70 units was delivered in late 1977.[56]

---

[54]Hays, "Sparrow," 8.
[55]Ibid., 9.
[56]*NWC Tech History 1976–1977*, 4-17.

During the second-source effort, a number of inherent design problems had surfaced. Solutions for these problems were subsequently incorporated in the AIM-7F through a PIP, adding "a number of ECPs that significantly improved the design."[57]

An added benefit of the second-source turnaround of AIM-7F is that it allayed the congressional concerns about the effectiveness of Sparrow and paved the way for the higher capability AIM-7M. That version incorporated active fuzing, a high-performance inverse monopulse seeker, and an autopilot, and was the first Navy air-to-air missile that used an onboard digital computer to control the seeker's functional modes. The Sparrow AIM-7M went to the Fleet in 1983 and was subsequently adopted by U.S. allies throughout the world.

[57]S-157, Hays interview, 20.

14

NOLO: No Onboard Live Operator

The greatest value of my invention will result from its effect upon warfare and armaments, for by reason of its certain and unlimited destructiveness, it will tend to bring about and maintain permanent peace among nations.

—Nikola Tesla, Inventor[1]

Nikola Tesla, the Austrian-born engineer, inventor, and archetypal mad scientist, envisioned his patented method for remotely controlling vehicles not only as the mechanism for achieving world peace but also as a boon to other aspects of civilization—"killing or capturing whales or other animals of the sea, and for many other scientific, engineering, or commercial purposes." His prediction of the diversity of uses was not far off the mark. While the remotely controlled vehicles of the 21st century do not employ the same technology that Tesla patented in the 19th, their military, law enforcement, commercial, and recreational applications continue to grow, with no end in sight.[2]

In the Navy, the terminology for remotely controlled vehicles that fly—as distinct from Seaborne Powered Targets (SEPTARs), remotely operated underwater vehicles, and mobile land targets—is a continuously expanding maze of acronyms. A remotely controlled aircraft, broadly known as a drone, may also be called a remotely piloted vehicle (RPV), remotely piloted aircraft, full-scale aerial target (FSAT), unmanned aircraft system, unmanned aerial vehicle (UAV), rotary-wing (as opposed to fixed-wing) unmanned aerial vehicle, vertical takeoff and landing tactical unmanned aerial vehicle, unmanned combat air vehicle, micro air vehicle, and the list goes on.

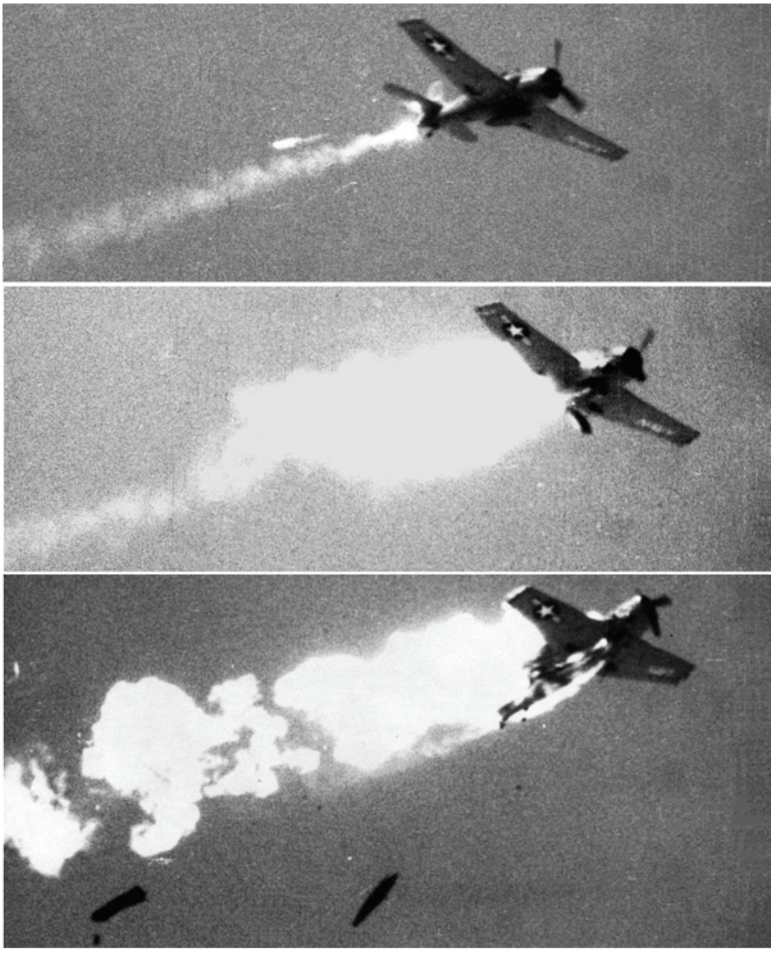
Drones have been employed at China Lake since the early 1950s. In those early days, West Coast drones were the purview of the Naval Air Missile Test Center (NAMTC, later NMC), Point Mugu. Drones were essential to

---

[1]Nikola Tesla, method of and apparatus for controlling mechanisms of moving vessels or vehicles, U.S. Patent 68,809, filed 1 July 1898, issued 8 November 1898.

[2]Ibid.

the realistic testing of air-to-air and surface-to-air weapons; thus, many of them were needed at NOTS. As Liz Babcock describes, "Point Mugu officials subjected their drones reluctantly to the ever-more-accurate weaponry of China Lake." NAMTC had an agreement with China Lake to provide drones one day each week on a weather-permitting basis.[3]



AIM-9B Sidewinder hits F6F-5K Hellcat drone at China Lake, 1957.

A 1952 *Rocketeer* described the drone-control process:

> At Armitage Field, drones are manipulated during the takeoff period by a control man seated at an operating panel at one side of the runway. Such operations are known as "NOLO flights" (no [onboard] live operator), and the control man is always an experienced pilot.

[3]Babcock, *Magnificent Mavericks*, 414.

> After the drone is airborne, the mother plane circling the field begins to take over control of it. Transferring control of the pilotless craft is done gradually . . . All mother ships have their guns fully loaded and ready to fire in the event that the drone should get out of control. In such an emergency the mother plane could shoot down the drone to make certain that it didn't crash land of its own accord in some populated area.[4]

China Lake's dependence on the grudging cooperation of Point Mugu to obtain drones ceased in 1954. In May of that year, in response to the increased pace of testing of the surface-launched beam-riding antiaircraft missile Terrier, a drone unit was established at the Naval Air Facility (NAF, at Armitage Field). The first drones used by the Target Drone Branch were WWII-vintage F6F-5 Hellcats that had been converted to radio control during the Korean War. (Fitted with 2,000-pound bombs and controlled by AD Skyraiders, they had been flown against North Korean bridge targets.)

While numerous different types of drones were used at China Lake, they fell into two major categories. First were the drones that were manufactured and acquired as drones, including BQMs (target drones capable of launch from multiple environments), AQMs (air-launched target drones), and KD2R-3s (Radioplane target drones), manufactured by Teledyne-Ryan, Beechcraft, and others.

Then there were the "repurposed" targets: aircraft (and missiles, such as Regulus) that were modified to the target function. Their designations were the aircraft designations preceded by a Q, indicating target—QB-17, QF6F-5, QF-9, QF-86, etc. Aircraft that had been modified to be drone controllers were designated with a D prefix, e.g., DT-28A (a modified T-28 Trojan trainer). Drones were usually painted red, as were the tails or vertical stabilizers of the controller aircraft.

There were pros and cons to both types of drone targets. Generally, the converted aircraft were less expensive than the manufactured targets, simply because the cost of an obsolete fighter was often just the expense of ferrying it to a conversion facility and adding a fairly simple radio-control system. But converted aircraft depended on the vagaries of supply. (Such a vagary would spell the end of the QT-38 program in the 1970s.)

Converted aircraft, the Q aircraft, had the advantage of being more realistic. Their radar and IR signatures were more realistic than manufactured targets, and their damage susceptibility was similar to actual threat aircraft, since they were originally designed as combat aircraft.

---

[4] *Rocketeer*, 24 September 1952, 8.

QF-9G drone at Armitage Field, 1965. Photo by Dave Woolsey and courtesy of Gary Verver.

Drone technology was rudimentary in the early days of China Lake operations. When the ground station lost control of the drone, the aircraft would automatically go into a circular pattern until contact was reestablished or the drone ran out of fuel and crashed. Operations, however, did not always go as planned. Harry L. Myers, who joined China Lake's drone program at its inception and by the mid-1970s was head of the Aerial Targets Instrumentation Division, recalled one incident. He told a *Rocketeer* reporter, "Once we had one that got away from us and ran out of fuel near Spokane, Wash. It landed virtually intact in a field, where the farmer was heard to wonder where the pilot was."[5]

Harry Myers. Published in the *Rocketeer*, 14 June 1974.

Maurice Hamm, who began his 30-year China Lake career in 1955, recalled that the errant drone was spotted over Elko, Nevada, heading north, and then over Idaho. "The Idaho

[5]*Rocketeer*, 14 June 1974, 7. With fellow workers Lloyd Holt and Gordon Zurn Jr., Myers held several drone-related patents, including destruct system for target aircraft, U.S. Patent 3,311,324, filed 25 June 1965, issued 28 March 1967.

Maurice Hamm.

National Guard had located it up there, and this guy was flying wing on it and he saw that it was painted red, so he knew it was a drone, and he got in real close and could see there wasn't anybody in there. He was out on some gunnery practice. He was trying to get permission to shoot the damn thing down, and by the time he got permission the thing ran out of gas, about 15 miles south of Spokane."[6]

Drone flying could also be dangerous. Policy required that before each drone flight, a pilot take the craft up for a safety check. In 1958, a drone on such a flight at Point Mugu flipped over on landing, killing the pilot, Lieutenant (Junior Grade) Paul J. Bezilla. "It was not clear whether the pilot had control of the obsolete F6F Hellcat craft or if the craft was still being handled by a ground-control crew," reported the *L.A. Times*. "It is possible for pilots to take over the controls of the drone craft without notifying ground direction crews."[7]

Air-to-air missiles under development at China Lake were becoming increasingly more difficult for drone controllers to elude during live firing tests, and drones—either bought or built—were not cheap. The drone group took to fitting IR decoys to the aircraft wingtips so that the missile, which was most often fitted with an inert warhead or with a telemetry package in place of the warhead, would be less likely to strike the fuselage of a prop plane or to fly up the tailpipe of a jet. Still, there were hits. It was not uncommon for the airborne drone controller to transfer control of a marginally flyable drone, with part of a wing missing or a hole through its tail, to the ground controller, who would attempt to land the target at Armitage Field.

By the end of 1960, the *Command History* would report that "an average of four pilotless drone aircraft were launched each week of the year." The following year, the NAF's inventory of drones consisted of 10 converted F9F-6K Cougar jets, 4 converted propeller-driven F6F Hellcats, 7 Ryan turbojet KDA-4 Firebees (redesignated AQM-34C in 1963), and 5 Beechcraft propeller-driven KDBs.[8]

---

[6]S-166, Don Hart, Hamm, and Schafer interview, 29–30.

[7]*Los Angeles Times*, "Drone Plane Crash," 2.

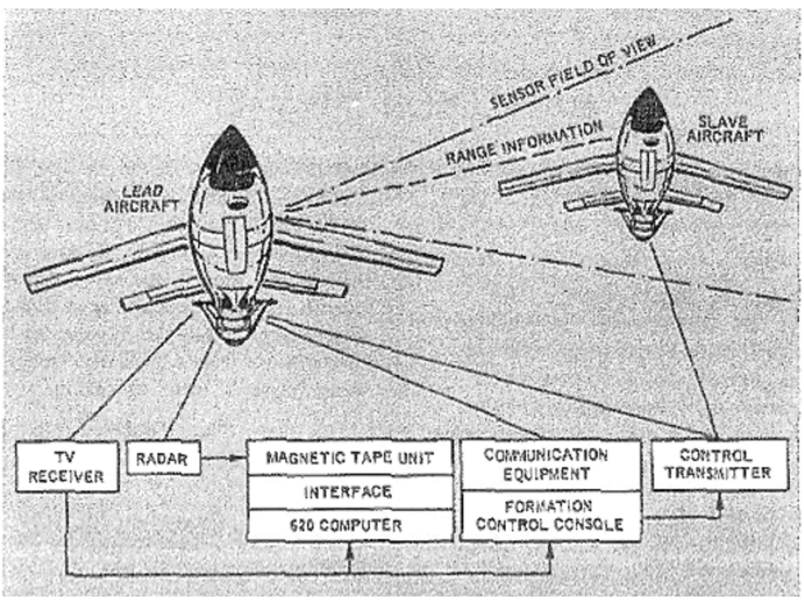
[8]OPNAV Report 5750-5, *NAF Command History* 1960, 1; *Rocketeer*, 17 March 1961, 1. The first jet drones at China Lake were converted T-33 Shooting Stars (or T-Birds). Because the

Formation Flying

In 1964, weapons like Tartar (RIM-24) were employing multiple-target-discrimination circuitry. In response, China Lake began work on a system for flying two drone targets in formation "to permit evaluation of a missile's ability to discriminate or to home on one target, and to demonstrate how a salvo of two or more missiles homes on several targets."[9]

Initially, the system was complicated. The lead drone, flown by an airborne drone controller, carried a TV camera aimed at the slave drone. Video imagery, as well as range from the lead drone to the slave drone, was transmitted via a data link to a ground-control station. Based on that information—and, one would assume, on real-time audio communication between the two controllers—the ground controller kept the second drone in formation.[10]

Development of an automatic formation drone control (AFDC) program began in 1967 and was supported by NAVAIR PMA-247. That year's *Tech History* described the program's capabilities:



Dual-drone formation control system. Published in the 1967 *NWC Tech History.*

conversions didn't have automatic braking systems, the former Air Force jets were fitted with tailhooks and landed with arresting gear.

[9]*NOTS Tech History 1964*, 8-16.

[10]Ibid.

> It will enable aerial targets to operate from 50 feet above the terrain to approximately 50,000 feet altitude in an all-weather environment, and it will be capable of maintaining a target separation of 200 to 2,000 feet with a position error of ±50 feet and a relative velocity not to exceed 15 ft/sec.[11]

By 1968, drone operations had not changed very much since the early 1950s and were still cumbersome in their execution. The *Rocketeer* reported:

> A bright reddish orange F-9 [QF-9] jet drone known as a “Redbird” begins thundering down the runway. A perfectly normal take off is initiated except that the pilot is in another airplane, a T-28 [DT-28B] prop-driven aircraft. The T-28 races just a few feet above the runway, following the Redbird through lift off and climb out, all of which is being controlled by the pilot in the T-28. As the jet drone begins to outrun the T-28, two F-8 [DF-8] Crusaders sweep in and take control of the drone. The drone is then used for target practice with some of the new missiles being developed at NWC.[12]

DF-8 Crusader Drone Controller at Armitage Field, circa 1965. Photo by Dave Woolsey and courtesy of Gary Verver.

The AFDC system employed a digital-proportional control system, pulse-code modulation telemetry, and a tracking-error detector. The AFDC control van, located at NAF, housed a DMI 620 digital computer and display and

[11]*NWC Tech History 1967*, 1-33.

[12]*Rocketeer*, 9 August 1968, 4. Actually, the initial takeoff roll would be controlled by the drone control van. The airborne controller in the DT-28B would take over when the drone was about two-thirds down the runway. The drone control pilot would fly the drone using toggle switches mounted on top of his glare shield, above the aircraft’s instrument panel; he would fly his own plane with his left hand.

control equipment. An AN/MSQ-51 target-control radar was integrated with the system for tracking, command-control, and television reception.

An engineering-development contract to produce the AFDC system was awarded to the Technical Research Group / Control Data Corp., Melville, New York. The contract called for a prototype system to be delivered by July 1970, followed 8 months later by delivery of a preproduction system to Point Mugu.

The digital proportional control system produced a lifelike stick-and-throttle response to the controller's commands. The *Rocketeer* explained:

> In operation, command signals that are sent by the controller are translated into serial digital messages which are modulated on a carrier. Messages are sent (each is a complete flight update) at the rate of 5.5 per second, assuring smooth control of the drone. . . . In this manner, commands are sent to the drone for pitch, roll, throttle, rudder / nose wheel functions, as well as high priority on-off commands such as carrier recovery, drag chute jettison, flaps, landing gear, trim, speed brakes, arresting hook, etc.[13]

In August 1968, the first AFDC flight of two QF-9J aircraft was made at China Lake. The effort was expanded to include automatic formation control of the BQM-34A, and in April 1969, an AFDC flight of a QF-9J and a BQM-34A (the latter equipped with China Lake-designed speed brakes) was successfully carried out.

At the same time, China Lake was exploring ways to make the drone-control operator's task simpler through a program called Visual Control (VISCON). The goal was to make the flying experience as realistic as possible for the drone operator. A television camera was installed in the nose of a QF-9J and the aircraft was operated by a ground controller using the TV display. Flight testing of VISCON began with touch-and-go landings, and soon controllers were demonstrating the "all-maneuvering capability of this control system, including split 'S' and low-altitude terrain-avoidance maneuvers."[14]

The combination of a digital-proportional flight-control system and nose-mounted television was a hit. "The VISCON and AFDC programs have complemented each other in creating a drone aircraft which affords an aerobatic potential and includes a precise, stable, aircraft platform," the *Command History* reported in 1969. The programs were used in the final nine F-9 NOLO flights that year, and "results obtained have revised drone flight efforts in order to

[13]*Rocketeer*, 5 December 1969, 7.

[14]*NWC Tech History 1969*, 8-19. One technique that was investigated used ultrawide-angle (180-degree) movies coupled with a rear-projecting hemispheric viewing system.

utilize this easier, simpler, and more reliable system on all F-9 drone operations at this facility."[15]

AFDC work was carried out in the Systems Development Department with Leroy Marquardt as the AFDC manager, assisted by Curt Bryan. Floyd Kinder managed the VISCON development. All told, 26 civilian and 18 military personnel were involved in the combined effort. Engineering support was provided by Robert Stedman, Don Sherman, Terry Hern, Bill Lalor, Tommy Nickell, Tom Hamilton, Rod Beran, Tom Demay, Larry Edmonson, Jack Basden, Ron Stoutmeyer, Tom Stogsdill, and Stan Powell. Installation was handled by Lloyd Holt, George Mullett, and Warrant Officer Harry Miller. Flying the drones were two NAF pilots, Lieutenants Virgil Kempenaar and Hugh Lankford. China Lake completed its work on the programs in 1970.[16]

Lieutenant Virg Kempenaar flies a drone from the AFDC control van. Published in the *Rocketeer*, 5 December 1969.

[15]OPNAV Report 5750-1, *NWC Command History* 1969, 1–2.
[16]*Rocketeer*, 13 June 1969, 3.

The industrial contractor's AFDC program did not fare as well. By the end of 1970, the contractor still had not satisfactorily demonstrated performance of two of the critical subsystems of the AFDC. In September 1971, NAVAIR cancelled the program. The *Tech History* reported:

> Primary reasons for termination were insufficient funding and the lack of any stated requirement of any missile system to test against formation targets. [Tartar had been replaced in the Fleet by the RIM-66 Standard Missile.] The many project delays due to contractor technical problems constituted a contributing factor to the termination.[17]

The same month that AFDC was cancelled, China Lake established the Remotely Piloted Vehicle Project Office. It was organizationally situated in Leroy Marquardt's Technology Development Division in the Surface Missiles Department (later the Weapons Department). The mission of the RPV Office, later renamed the Systems Branch, was "to provide a control point for coordination of the Center's RPV-related projects." Curt Bryan was selected to head the office, a position he would hold until he took over the Weapons Development Division in 1977.[18]

With the experience gained in AFDC and VISCON, China Lake was now positioned to become the principal drone conversion facility for the Navy. The Center's drones could approximate an adversary aircraft in dog-fight maneuvering (though there were still attitude and *g*-force limits), jamming, and countermeasures deployment. Air weapons developers were testing their developmental systems against targets that were increasingly threat-like.

As well as developing the technical expertise and building the technology for aircraft drone conversions and control, the Center had established a philosophy for using drones. Instead of having an airborne controller flying a drone by flipping toggle switches with one hand while he flew his own aircraft with the other, the controller pilot should be on the ground, flying the drone as if he were in it, using the same controls and with the same visual feedback as if he were airborne, seated in the drone's cockpit.

QF-86H

Establishment of the Remotely Piloted Vehicle Office in 1971 reflected the growing importance of aerial target work at China Lake; it marked the beginning of the FSAT Program, which would continue at the Center for more

[17] *NWC Tech History 1971*, 8-90.

[18] Ibid., 8-91. Bryan would subsequently head the Aerosystems Department and later the Office of Comptroller. Marquardt would retire in 1982 as head of the Aircraft Weapons Integration Department.

than 20 years. The 1972 *Tech History* heightened the visibility of this work by adding a new section to the Supporting Technology chapter titled "Remotely Piloted Vehicles."

The introduction to the section stated that "present inventories of air-to-air weapon systems have not been adequately tested in the air combat maneuvering (ACM) environment prior to actual combat use." It noted the need for a target system with a "single-plane, high-*g* maneuvering capability" and observed that "to date, however, there is not a real-size, all-attitude, highly maneuverable RPV available that can adequately test these air-to-air weapon systems in a realistic ACM environment."[19]

An interim solution—while "more representative, all-attitude target systems are being evolved"—was the QF-86H, an aircraft chosen "because of the current availability of both aircraft and logistics, and also because of performance capabilities that closely simulate subsonic threats that may be encountered in the near future."[20]

Designed in the 1940s, the F-86 Sabre went into service in 1949. It was the principal U.S. fighter of the Korean War, acquitting itself well against the Soviet-built MiG-15. The H model was the fighter-bomber version. During 1972, a pair of F-86Hs were converted to the QF status, and the prototypes were checked out for operational suitability.

Complementing the new RPV was a new ground control facility, the next evolution in controller technology. The facility was an actual cockpit from an F-86H trainer "with all the instruments, controls, and switches identical to and located in the same positions as those in the real aircraft, thereby providing a more realistic interface for the remote pilot." Rounding out the ground displays was a map showing a real-time X/Y plot of the drone's position. The drone pilot could sit in the cockpit and fly the drone as if he were actually on board the aircraft. For the controller pilot, this was the next best thing to being there.[21]

"We actually took an F-86 and cut the cockpit up and made it so that the controller was sitting in a cockpit environment," said Donald E. Hart Jr., the project's production control specialist at NAF. "When he pushed the stick forward, that's what happened to the airplane. The instruments on the panel were what was happening in the airplane."[22]

Vance Hansen was assigned to head the QF-86H conversion program. Assisting him were Lieutenant Commander Larry Blose, program test pilot;

---

[19]*NWC Tech History 1972*, 9-91.
[20]Ibid.
[21]Ibid., 9-92.
[22]S-166, Hart, Hamm, and Schafer interview, 34.

Harlan Reep, ground controller; and Hart. Jay Bornfleth and John Owens, engineers in Curt Bryan's RPV office, designed the command and telemetry functions for both the RPVs and the ground station, assisted by technician Hal Schmeer. Like so many projects at China Lake, there was indispensable help from the officers and sailors at NAF, including members of the Intermediate Maintenance Division; Line Servicing Division; and the Airframes, Power Plants, and Avionics Sections of the Organizational Maintenance Department.

Air Force operational units had progressed to the F-100 Super Sabre and the F-4 Phantom by the early 1970s, but there were still F-86Hs available from Air National Guard units around the country. Don Hart went after them. "Little by little, the Air National Guard from Syracuse and Baltimore flew all of these F-86s out here to China Lake and handed us the pink slips on the darn things," he said. "Didn't cost the Navy anything."[23]

On 30 March 1973, the first successful NOLO flight of a QF-86H was conducted from Armitage Field. The successful flight elicited a message from Admiral Elmo R. Zumwalt Jr., CNO, which read in part:

> Accomplishment of [the] development program with meager funding and in minimum time reflects the ingenuity and technical competence which have made the Naval Weapons Center, China Lake, such an important contributor to the nation.[24]

First QF-86H target drone NOLO flight (left) with manned F-86G chase plane (right). Photo courtesy of Gary Verver.

[23]Ibid., 32.

[24]*Rocketeer*, 20 April 1973, 1.

In October, the first actual presentation of one of the two prototype targets was made for a Sparrow AIM-7F missile test. The target made four high-speed, high-*g,* all-attitude presentations. One Sparrow was fired and hit the drone. Although the QF-86H could still fly, the structural damage made it unsafe to land at NAF, and it was crash landed in the desert.[25]

Hansen, Owens, Bornfleth, Schmeer, and Bryan shared a $1,500 Superior Achievement Award in 1973 for their work with the new FSAT. The following year, Bornfleth took over the QF-86H program. He had worked with drones since coming to China Lake as a Junior Professional in 1970. He once told a reporter:

> I look upon my job as an effort to keep the (air-to-air) missile people honest. Our people work hard on the drones, and, in a way, almost hope the missiles will miss them. But on the other hand, the national defense requires that our weapons destroy their targets. This system works well, for when each team is doing its best to outmaneuver the other, the nation gleans its best weapons.[26]

Jay Bornfleth.

After the two prototypes, China Lake converted another 29 F-86Hs into RPVs between 1973 and 1976, working with the conversion contractor, Aacom Division of Systron-Donner Corporation. Support was also provided by Ling-Temco-Vought (LTV) and Sperry Flight Systems.

The first step in converting the aircraft to an RPV was to put it back into fully flyable condition and flight-test it. The certified aircraft was then moved into Hangar 2 at NAF, where LTV workers partially disassembled it, removing the tail, engine, and various panels. Aacom employees then installed the drone equipment. The aircraft was reassembled, the systems were tested using a remote-control ground station, and then the aircraft was flight-tested

[25] *NWC Tech History 1973*, 1-41.

[26] *Rocketeer*, 9 April 1976, 7.

with a pilot on board. Cost per conversion, including engineering work and documentation, was $130,000 per drone.

Once the conversion was complete, the QF-86H was assigned to the Targets Department at NAF, where it was either put into service, transferred to another Navy facility, or stored for later use. (NWC was NAVAIR's official drone storage facility.) Three of the early conversions were transferred to the Naval Missile Center, Point Mugu, which built a ground-control station based on documentation supplied by China Lake.

The QF-86H target was a remarkable advancement over its predecessors. Prior to the -86H's development, a drone was limited to a maximum of 4 *g*s in a turn. By civilian standards, that would be a tight turn, but in a tactical situation, a pilot trying to evade an air-to-air missile would be expected to turn harder than that. The QF-86H could make 7 *g* turns, as well as do rolls and loops, and could present at a blistering Mach 0.96—just a hair under the speed of sound. This was the first "all attitude" full-size drone, capable of being operated remotely with no limitations on the maneuvers it could perform. As a realistic target, it was without equal in its day.

QT-38A

In 1972, even as the two prototype QF-86Hs were being converted, a requirement was established for a new target that would be inexpensive, supersonic, and afterburning. The task of developing the target was assigned to China Lake under the sponsorship of NAVAIR (PMA-247).

QT-38 target drone at Armitage Field. Photo courtesy of Gary Verver.

Afterburning is the process of injecting fuel into the exhaust of a jet engine, downstream of the turbine, thereby dramatically increasing the engine's thrust. It is a common feature in supersonic aircraft. Because afterburning, or operating "wet," consumes much more fuel than operating dry and greatly increases the aircraft's IR signature, it is a pilot-selectable feature. In Navy aircraft, it is used principally for carrier takeoffs and during aerial combat.

The T-38 Talon, the world's first supersonic trainer, was selected for the conversion. Introduced in 1961, more than 1,100 were built for the Air Force by Northrop Corp., and the aircraft is still used as a trainer today. In 2003, when over 400 remained in the Air Force inventory, it was estimated that the service life would extend "well beyond 2020."[27]

"The T-38A," reported the *Tech History*, "because of its afterburner and supersonic speed, provides a good simulation of the MiG-21." Chris Hobson credits the MiG-21 (NATO name Fishbed) with downing 56 U.S. aircraft during the air war in Vietnam. Although the MiG-21 was a single engine fighter and the T-38A had two engines, the performance envelopes of the two aircraft were similar (although the MiG-21 was significantly faster).[28]

A 3-month study of converting the T-38A to the QT-38A was conducted in 1973. The next step was getting them from the Air Force, and Don Hart located some just down the road at Edwards Air Force Base. "They had about 12 T-38A aircraft that had already been programmed for these various generals to put nicely out on pedestals on their stations, and I went in there and said, 'Can you bring them to China Lake?' " The answer was affirmative; however, the aircraft required assembly. "They were all scattered out in pieces at the hangars at Edwards Air Force Base," said Hart. By the end of 1973, 10 of the aircraft had been transferred to China Lake.[29]

John Keen was appointed the QT-38A project manager. Assisting him were John Owens (project engineer), Walter Beebe (documentation), Darwin Rice (ground control station), and Dennis Bishop (mechanical design). Helping with various aspects of the conversion were Hansen (who had moved to the staff of Captain Haff, Technical Officer), Bornfleth, Schmeer, and electronics technician William Stuart. The conversion plan called for building and demonstrating two prototypes before converting the other eight aircraft. Like the QF-86H, the QT-38A would include a destruct package as a safety backup.

[27]Young, "Gallery of USAF Weapons," 175.
[28]*NWC Tech History 1973*, 10-25; Hobson, *Vietnam Air Losses*, 271.
[29]S-166, Hart, Hamm, and Schafer interview, 36.

The first of the QT-38A RPVs made its maiden NOLO flight on 24 November 1975 from Armitage Field, with Harlan Reep operating the aircraft from the ground-control station. The QT-38A checked out beautifully. Reep made three supersonic runs over G range, incorporating turns greater than 6 *g*s, before bringing the aircraft in for a smooth landing at NAF.

Reep had been a fighter pilot in the Navy for 24 years, including two tours during the Korean War, flying F9F Panthers off USS *Oriskany* (CVA-34) and USS *Boxer* (CVA-21). He'd been assigned to China Lake as targets officer in 1970 and had stayed on as a civilian, flying drones, after his military retirement in 1972.

By 1977, China Lake employees and support contractors had converted eight former Air Force T-38As to QT-38As. The high-speed, high-performance QT-38A contributed to the T&E of various air-to-air missiles, principally the AIM-9L, which was fielded in 1978. Additional conversions were planned for and funded but there was a problem; no more T-38A airframes were available from the Air Force.

In the summer of 1977, Curt Bryan took over the Weapons Development Division and Bornfleth moved into Bryan's former position as head of the Systems Branch, which in June of the following year was renamed the RPV Technology Branch. At this point, as the FSAT supply dwindled through attrition, the primary target in use at China Lake and Point Mugu was the Teledyne Ryan BQM-34 Firebee subscale target.

QF-86F

The absence of a supply of T-38 airframes for conversion to QT-38s emphasized the need for a new FSAT, one that could be obtained in sufficient numbers to meet the needs of Navy weapons developers. It would be an interim FSAT to fill the gap until a triservice FSAT was selected. The Navy chose the F-86F (Block 40) Sabre jet, and the QF-86F program began in February 1977. NAVAIR approved reprogramming the remaining QT-38 funds to start the program.

North American Aviation's F-86F Sabrejet was an old aircraft; it had entered service with the Air Force in 1949. It was the Sabre, in fact, that, flown by Nationalist Chinese pilots, had shot down four MiG-17s over the Formosa Strait in 1958—the first combat use of China Lake's Sidewinder missile. Taiwan, Japan, Italy, and other allies had received hundreds of F-86Fs through the Mutual Defense Assistance Program after the Korean War.

QF-86F target drone at Armitage Field.

Now it was time to get some of these assets back for drone conversion. The CNO (Admiral James L. Holloway III, who had replaced Admiral Zumwalt in June 1974), approved the reacquisition, and Jay Bornfleth was assigned to lead the project. Again, Hart stepped in to help. As the *Rocketeer* reported,

> Don Hart, the logistic support specialist for the NWC Aircraft Department, was able (through his contacts abroad) to set the wheels in motion for obtaining four of what is expected will be a total of around 50 F-86s.

The program also managed to secure some 600 tons of spare parts from Spain.[30]

Prior to the F-86F, the trend in FSATs had been toward targets that matched the evolving capabilities of potential adversaries. In that sense, the F-86F was a step backward. It did not have the performance of the QF-86H or the QT-38; it did, however, have the quantities available that would tide the Navy over until the triservice FSAT was fielded. And the QF-86F was tough; as a target it could be flown, damaged, recovered, repaired, and flown again.

The first four F-86Fs were received, disassembled, from Japan. They were rebuilt, and the first was flown in June 1977 by Harlan Reep, by then head of the Target Operations Branch in the Aircraft Department's Targets Division. That aircraft, and the second one, would be used for pilot proficiency training. The other two became prototype QF-86F target drones.

[30]*Rocketeer*, 22 July 1977, 1.

Because of the number of conversions involved, China Lake engineers designed a conversion kit, which was proven on the two prototype targets. The kits were installed by Kentron International at Air Force Plant 42 in Palmdale, California. Each kit consisted of

> the flight control system, surface actuators, command-control system [including telemetry and sensors], smoke [generation] and destruct systems, forward-looking television, and (depending on the aircraft) possibly a gyro system.[31]

John Owens was the system design engineer, assisted by engineers Larry Smith and Dave Kurdeka and technician Hal Schmeer. China Lake engineers also designed an aircraft interface unit (AIU) that was produced under contract by Pacific Aero Systems, San Diego.[32]

Price was another plus for the new FSAT. "The QF-86F cost less to convert, including all the engineering, logistics, and support, than the BQM-34 subscale target then in use," according to Bornfleth. The QF-86F was also designed for compatibility with the integrated target control system (ITCS) under development by Motorola and scheduled for production in 1979. ITCS would combine command-and-control and tracking in a single system.[33]

Surplus F-86F aircraft were obtained primarily from Japan but also from Taiwan, Spain, and Korea. China Lake looked at F-86Fs all over the world, from South America to Thailand to Pakistan. However, most of the Block 40 models were too close to the end of their service lives to make repair feasible.

Conversion was a complicated process, and the post-conversion checkout and flight acceptance testing took 4 to 6 weeks. ATCS John Bosony ran the quality assurance staff, electronic technician Ron Wilson was responsible for acceptance of the aircraft from the contractor, and electronic technician Dean Miller was responsible for acceptance of the AIU. The first production QF-86F was transferred from NWC to Point Mugu in the summer of 1980. By 1990, 136 F-86Fs had been converted to QF-86F targets. [34]

Ever-Present Danger

Lieutenant Commander Theodore H. Faller was a project pilot at China Lake. Like all the military members of the community, Faller's life was more than his flying job. He had a family: his wife Betty and two young children,

[31] *Rocketeer*, 22 July 1977, 5.
[32] Ibid.
[33] *Rocketeer*, 13 December 1990, 12.
[34] *Rocketeer*, 29 August 1980, 1, 5; 13 December 1990, 1, 12.

Tommy and Christine. In 1979, he served as cochair of the Navy Relief Society fund drive. He played catcher that year for the NWC team in the NWC versus Air Development Squadron Five (VX-5) officer's baseball game at Schoeffel Field.

Lieutenant Commander Theodore H. Faller.

On 13 August 1979, Faller took off from Armitage Field on a familiarization flight in an F-86F that was scheduled for conversion to an FSAT. His plane developed mechanical problems. He chose to stay with the stricken plane and maneuvered it to a controlled crash landing in a clearing within a residential area, narrowly missing the Ridgecrest Heights Elementary School. Faller survived the crash and was extricated from the aircraft by China Lake firemen. An NWC helicopter flew him to Ridgecrest Community Hospital, where he was pronounced dead on arrival.

The following month, the school that Faller had expertly avoided hitting was renamed the Theodore H. Faller Elementary School, and a memorial to the pilot was built at the school by local Seabee reservists. Faller was posthumously awarded the Distinguished Flying Cross, which was presented to his wife and children.

Lieutenant Commander Faller's death underscored, lest anyone had forgotten it, the danger inherent in the Center's work. In the same year, four other military personnel—Chief Warrant Officer Donald Monk, Chief Warrant Officer Michael Mooring, Lieutenant Commander Peter Luem, and Ensign Steven Herning—died in aircraft accidents while supporting China Lake's mission.

QF-4

A study in 1978 concluded that the F-4 Phantom II would be the best aircraft for a triservice FSAT. The twin-engine McDonnell Douglas-built fighter-bomber had first became operational in 1960. A powerful, supersonic, afterburning high-performance aircraft that some called "a triumph of thrust over aerodynamics," the Phantom II was also readily available. More than 5,000 had been built (about five times as many as the T-38). Although comparable in performance to many potential adversary aircraft, the Phantom was obsolescent; by the late 1970s, the Navy and Air Force were switching to, respectively, the F-14 Tomcat (introduced in 1974) and the F-15 Eagle (introduced in 1976).

QF-4 target drone in flight.

An earlier version of a QF-4 had been built by Naval Air Development Center (NADC), Johnsville, in the mid-1970s; however, this conversion "provided the pilotless aircraft with limited capability to maneuver and a radio control link which has now become obsolete." Few were built.[35]

In the summer of 1979, nine F-4Bs were transferred from the Air Force's aircraft bone yard at Davis-Monthan Air Force Base in Tucson, Arizona. One had already been restored and was flown into Armitage Field. The others were airlifted in by Army CH-54 Skycrane helicopters from the Army's 273rd Transportation Company out of Fort Sill, Oklahoma.

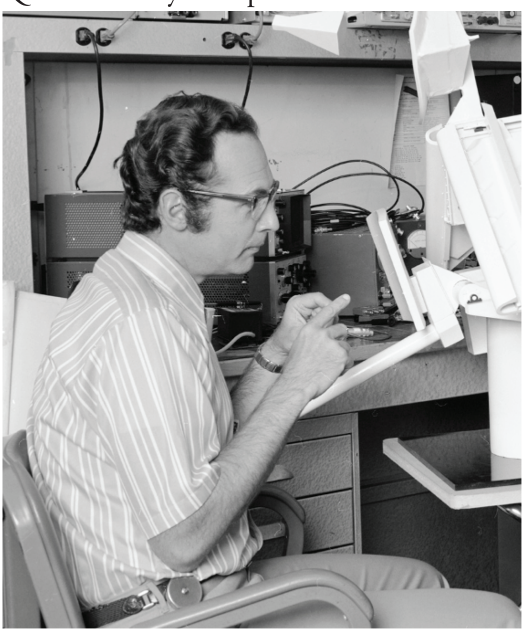
While Targets Division personnel and specialists from McDonnell Douglas and Vought restored the eight F-4s to flyable status, Bornfleth's RPV

[35] *Rocketeer*, 13 July 1979, 5.

Technology Branch began the process of developing the drone conversion package. Paul Dietrich was FSAT program manager (later Leo Budd took over the job), and John Owens was the QF-4 project engineer. Other RPV Technology Branch personnel assisting in the conversion process were Larry Smith, documentation specialist Beebe, and technicians Wilson and Miller. From the Aircraft Department, instrument mechanic Joe Chesney and metalsmiths Gene Boyts, Don Kennicott, and Bob Whisman rounded out the China Lake side of the civil service/contractor team.

An F-4B Phantom, slung under the belly of an Army CH-54 Skycrane, approaches Armitage Field. Published in the *Rocketeer*, 13 July 1979.

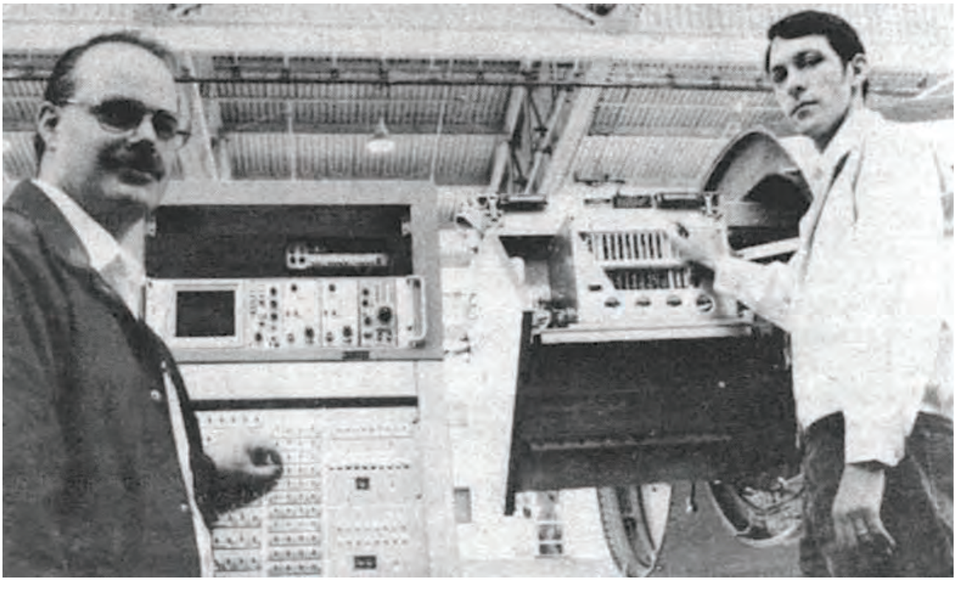
The core of the QF-4 conversion would be a digitally controlled autopilot that would both increase the capabilities of the QF-4 far beyond previous FSATs and minimize the weight and size of the onboard package. The QF-4 would be controlled by a universal control console (UCC, a modified Link trainer) operating through the ITCS. In an early example of haptic technology, the stick forces in the UCC were produced artificially, simulating those the pilot would feel if he were manually controlling the control stick in the aircraft's cockpit. Don Harris joined the program to handle the task of programming the microprocessors.



Paul Dietrich.

At the end of 1979, development of the conversion package was well underway, and by the end of 1980, design of the engineering prototype change kit had been completed and the first aircraft was being converted. On the completion of engineering development in 1982, Owens and Harris were awarded the Technical Director Award for their contributions. The first prototype drone was completed in 1983 and, following technical evaluation at Point Mugu, was sent to Roosevelt Roads, Puerto Rico, for use as a target at the Atlantic Fleet Weapons Training Facility.

The QF-4 was the most difficult drone conversation program undertaken by the Center. The sheer complexity of the aircraft and the transition from analog to digital control created myriad problems through the early 1980s, but



Don Harris (left) and John Owens (right). Published in the *Rocketeer*, 29 January 1982.

the program pressed on. James A. Bowen, who took over the FSAT program in 1983, said, "The QF-4 first prototype almost crashed. The result of the investigation was that the test pilot could have killed himself. It wasn't his fault. The fault was [some] wires were crisscrossed."[36]

The bottom line of the success of each drone conversion was the acceptance testing. The aircraft was flown remotely, with a pilot on board in case something went wrong. For that pilot, it was a tough, dangerous job. Bowen described the process:

[36]S-175, Bowen interview, 50.

> Each target that we make, we put a pilot in there and take it off. He's sitting there. He's not supposed to do anything except in an emergency. And we make it dive, go straight down, and we cut the drone control off, the ground station off, pretend we've lost complete control. And there's an automatic system in the airplane that, even if he's upside down in a dive, it will automatically right the aircraft and then go to a certain attitude and altitude and go into a circle in a certain direction, provide time to repair the ground station. And the poor pilot has to sit through that while we demonstrate it.[37]

Jim Bowen.

Commander Billy C. Boatright received the Technical Director Award in 1983 for his role as project pilot during the engineering development of the QF-4B. His nomination by Dillard G. Bullard, head of the Weapons Department, read in part, "Test flights required skill, courage, and perseverance in order to continue after problems were encountered, solutions implemented, and critical flight parameters retested."[38]

Commander Bill C. Boatright.

Eventually, the QF-4 became the target of choice for antiair weapons designers. Fitted with electronic

[37]Ibid., 51.

[38]*Rocketeer*, 29 April 1983, 1.

countermeasures (ECM), chaff, IR decoys, and other specialized equipment, and with its all-attitude capability and powerful J-79 engines, the QF-4 in the hands of a skilled controller was the closest thing to an enemy aircraft against which to test developmental weapons. It served both the Navy and the Air Force well into the 21st century.

Dillard Bullard.

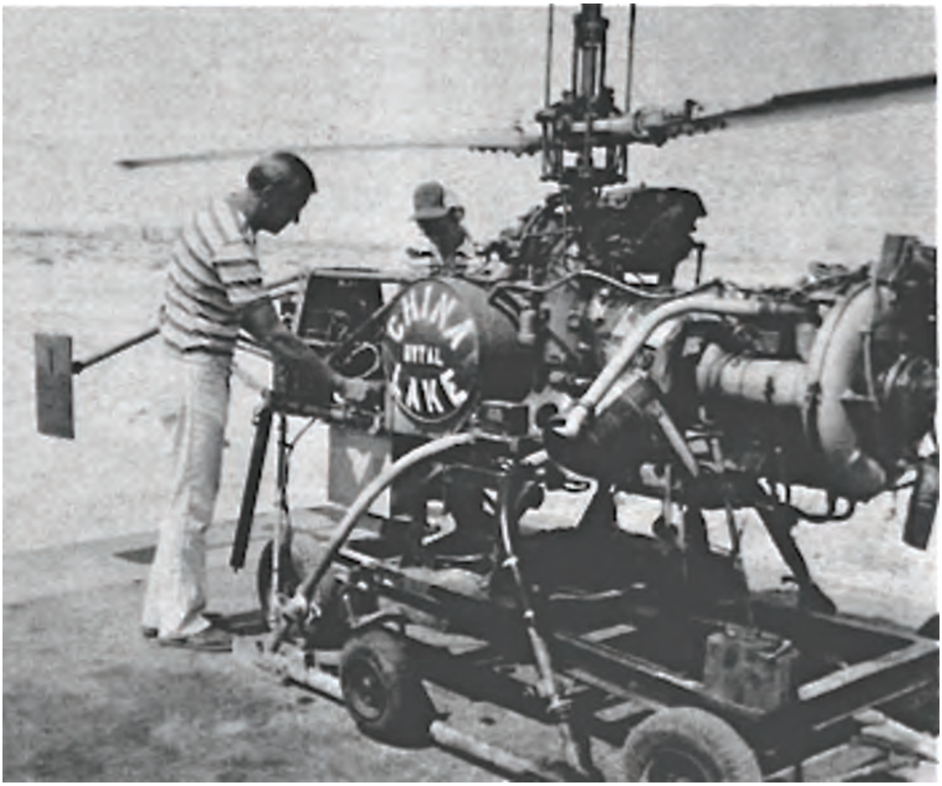
Hybrid Terminal Assist Landing (HYTAL)

In the late 1950s, Gyrodyne Company of America developed the QH-50 Drone Antisubmarine Helicopter (DASH) and sold it to the Navy. It was designed as a long-range antisubmarine weapon for ships too small to accommodate full-sized helicopters. Unmanned, and cheap enough to be expendable, the twin-rotor (counter-rotating) QH-50 could carry a torpedo or nuclear depth charge. The drone could cruise at 60 miles per hour and carry a payload of approximately 1,000 pounds, and it had a range of about 80 miles. Although the program was cancelled in 1969, the Navy still retained a large inventory.

In 1974, China Lake began a program called the HYTAL system, "a low-cost, lightweight automatic recovery guidance system for RPVs, helicopters, and V/STOL [vertical/short takeoff and landing] aircraft in both day and night operations aboard aviation-capable ships and remote land sites." The system also had to have a small footprint on the host ship and minimal equipment installed on the RPV. The QH-50 was chosen for the test vehicle, the goal being to eventually develop an automated over-the-horizon targeting capability for antiship cruise missiles.[39]

HYTAL combined an RF approach-control system with an optical system for precision landing. At long ranges, a microprocessor in the portion of the RF system aboard the ship (the aircraft carried only fixed antennas and a

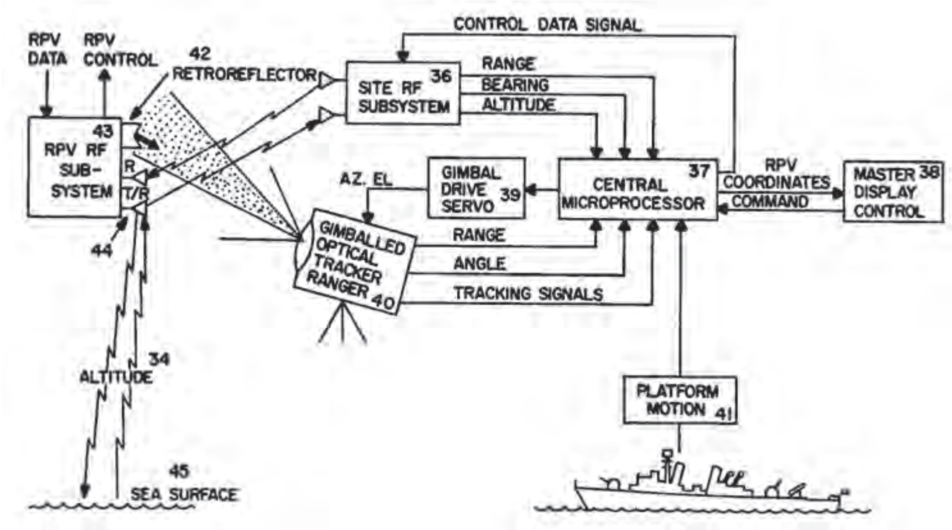
[39] *NWC Tech History 1976–1977*, 10-63.



Electronics technician Al Sorenson checks out HYTAL-equipped QH-50 helicopter. Published in the *Rocketeer*, 16 June 1978.

transponder) continuously measured the altitude, azimuth, and range of the helicopter in relation to the ship. When the helicopter was directed to return to the ship, the microprocessor kept it on the prescribed glide slope. As the drone approached the ship, the RF system handed off control to the more precise optical system, which tracked the helicopter's retroflector to guide it in for the landing, all automatically.

HYTAL development was a cooperative effort of the Systems Study Branch (Fuze and Sensors Department), the RPV Technology Branch and the Dynamics and Control Branch (Weapons Department), and the Targets Division (Aircraft Department). Joe McKenzie was the principal design engineer; Dan Goss, Harold Jaeger, Mits Hata, and Dan Morris designed and fabricated the RF approach-control system; and Larry Stephens, Pete Leet, Jim Mott, and Tom Loftus developed the optical tracker hardware. Jay Bornfleth designed the modifications to the QH-50 to interface with HYTAL, and Al Sorenson was responsible for the system modification, test, and checkout. Bruce Hardy



HYTAL functional block diagram from U.S. Patent 4,157,544.

handled the analog simulation work. Roy Nichols was the HYTAL program manager and was awarded a U.S. patent for the system in 1979.[40]

The HYTAL QH-50's first flight took place at China Lake in June 1978. The aircraft demonstrated takeoff, flight, precise close-in automatic positioning, and a soft landing on a 5-foot diameter target circle. (Standing by for manual backup drone control was Harlan Reep.) Additional flight tests in 1979 verified the HYTAL's long-range RF tracking performance. HYTAL continued development into the 1980s.

Tactical Applications for RPVs

China Lakers frequently referred to the converted aircraft as FSATs, but targets were only one function of RPVs. For example, they could also be used as a safe launch-platform for initial shots of experimental missiles (which on occasion have been known to blow up under the wing or fly erratically into the launch-aircraft's fuselage).

Since WWII, drones had been used tactically to deliver ordnance and for reconnaissance work. Reconnaissance drones came into their own in the Vietnam War. According to one writer:

> Between 1964 and 1972 . . . 3,435 RPV combat sorties were flown by Strategic Air Command's 100th Strategic Reconnaissance Wing [formerly

[40]Roy L. Nichols, hybrid terminal assist landing, U.S. Patent 4,157,544, filed 21 October 1977, issued 5 June 1979.

> the 4080th Strategic Reconnaissance Wing] over North Vietnam, China, Laos, and elsewhere. [They] suffered an attrition rate of less than 10 percent while performing missions of photographic intelligence, damage assessments, electronic intelligence, chaff dispersal, and propaganda-leaflet distribution.[41]

In 1971, Earl Towson in the Weapons Planning Group wrote a point paper on the use of drones in the attack role, and by 1973, China Lake was investigating tactical uses for drone aircraft. In 1977, Center engineers designed a "10,000-pound-class fixed wing, turbojet powered CTOL [conventional takeoff and landing] vehicle that had high sea-base compatibility and multimission effectiveness," reported the *Tech History*. "Payload capability was established at 2,400 pounds, including weapons and equipment pods installed for each mission on four available wing rack stations." The following year, investigations were begun into several critical technology areas. This work continued into the 1980s.[42]

Fred Camphausen, Albert S. Gould Jr., and others conducted tactical RPV studies, which were sponsored by NAVAIR. Applications that were investigated included reconnaissance, surveillance, remote sensing, decoys, air-to-ground strike, air-to-air combat, antisubmarine warfare, propaganda leaflet distribution, battle-damage assessment, and the like. These seminal studies, some of which are still classified, helped lay the groundwork for today's broad military use of unmanned aircraft.

Al Gould.

The Last QF-86F

By 1993, China Lake was down to one last QF-86F target. The other 135 had gone the way of all FSATs, blown to hell and gone in the skies over China Lake, over the ocean off Point Mugu, and on the ranges of the Atlantic Fleet Weapons Training Facility, or ignominiously relegated to a ground target or the scrap heap. The average life of an aircraft was 15 hours before it was either shot down or could no longer be cost effectively repaired. On

[41]Major G. D. Thrash, USMC, "Remotely Piloted Vehicles—The Unexploited Force Multiplier," accessed 16 July 2021, http://www.globalsecurity.org/intell/library/reports/1989/TGD.htm

[42]Doc. No. 12-833, "Remote Controlled Attack Drones"; *NWC Tech History 1978*, 7-24.

23 September, the last China Lake QF-86 taxied down a runway at Armitage Field and took to the air, the target for an Advanced Medium-Range Air-to-Air Missile (AMRAAM) test.

In a good-news bad-news scenario, the AMRAAM missed the drone. However, it had an inert warhead and passed within lethal kill range. For the missile, the test was a success.

At the controls of the QF-86F that day was Harlan Reep, in flight suit, helmet, and a white silk scarf. He had flown the first QF-86F in 1977 and, by golly, he would fly the last. Before the final flight, a reporter asked him if the mission would be nostalgic for him. "You bet," he responded. "I hope I don't cry."[43]

The mission called for a plan B; if the AMRAAM didn't down the target, two F/A-18s from Point Mugu's VX-4 would use it for gunnery practice with their 20 mm cannons. However, after several attempts, exhausting the Hornets' ammunition, the drone was still flying. Damaged, but controllable. Reep brought it in for a landing. After 209 flight hours as a target, it was destined for preservation, and now is displayed at the Naval Museum of Armament and Technology in Ridgecrest, California.

[43] *Rocketeer*, 21 October 1993, 1.

Harlan Reep, ready for his final mission. Published in the *Rocketeer*, 21 October 1993.

That September test marked the end of the Center's QF-86F program. Two months later, Harlan Reep would retire after spending 24 years dodging multiple generations of air-to-air missiles high over the Mojave Desert, thus ending yet another chapter in the history of China Lake.

15

Research and the Technology Base

When you want to do something to assist research people, give them what they need and get out of the way.

—Dr. Hugh W. Hunter, Head, Research Department[1]

By 1968, China Lake's research program had come a long way from 1945, when 20 scientists worked out of two Quonset huts at China Lake and an office in Pasadena. Over the years, the original four research fields—ballistics, chemistry, mathematics, and physics—had expanded to include lasers, semiconductors, combustion instability, geophysics, and more.[2]

Research at China Lake was primarily, though not exclusively, the purview of the Research Department—Code 60, until Rear Admiral Freeman's final Center reorganization in August 1976, when it became Code 38. Most of the "pure" or "basic" or "fundamental" research—that which seeks to solve nature's mysteries for the sake of science—was conducted in that department. Other, more targeted research—often called "applied" or "directed" research—was underway throughout the Center by chemists, physicists, mathematicians, biologists, psychologists, and others who sought specific solutions to problems encountered during the weapon development process.

China Lake's research, development, test, and evaluation (RDT&E) funding from the Systems Commands (SYSCOMs), primarily from NAVAIR, was designated with DoD numbered categories that approximately tracked the stages of development from gleam-in-the-eye to fielded system. These categories were 6.1 Research, 6.2 Exploratory Development, 6.3 Advanced Development, 6.4 Engineering Development, 6.5 Management Support, and 6.6 Operational Systems Development.

Furthermore, funding category 6.3 was divided into two subcategories. In 6.3A, Advanced Technology Development or Advanced Technology

[1]*Rocketeer*, 11 June 1976, 4.
[2]TS 67-259, *Naval Weapons Center Silver Anniversary*, 13.

Demonstration, hardware was developed to test the operational feasibility of the concepts that had been developed in the two preceding stages. In 6.3B, Advanced Development, hardware was developed for the actual systems under development. (This confusing and sometimes overlapping distinction was eliminated in 1997.) Additionally, category 6.6 was not an official designation but rather was used to describe funds for systems already approved for production and service use (as in product improvement programs).

The apportionment of funds among these categories fluctuated, depending on where various NWC programs were in the acquisition process. For example, in fiscal year 1968, 6.1 and 6.2 funding—Research and Exploratory Development—accounted for 22.1 percent of the Center's RDT&E funds received from the SYSCOMs. In 1973, that number had dropped to 19 percent. In fiscal year 1979, it was 16 percent. By contrast, for those same years, the amount spent on 6.4 Engineering Development was 20.2 percent, 19 percent, and 28 percent.[3]

A concept might pass very rapidly from category 6.1 into category 6.2—or might not proceed at all. Category 6.2 could entail virtually the same research work as 6.1, but it had to be directed toward a specific military problem area.

Dr. Hugh Hunter.

Dr. Hugh Hunter headed the Research Department from 1965 until 1976. He had worked at China Lake since 1948 (he'd been recruited by L. T. E. Thompson, NOTS' first Technical Director), except for a 6-year stint as vice-president for research at Research Triangle Institute. Hunter held a bachelor of arts in chemistry and a doctorate in physics. Since his arrival at China Lake, he'd headed three different departments and was a respected scientist and manager. As the executive secretary of the Research Board (comprised of the Technical Director, Experimental Officer, and technical-department heads), Hunter understood not only the importance of China Lake's research efforts but also the politics and philosophizing that surrounded the issue of

[3]*NWC Tech History 1968*, 1-7; *NWC Tech History 1973*, 1-5; *NWC Tech History 1979*, 1-7.

spending taxpayer dollars for research that might not pay off for decades—if ever.

During the 1960s, the DoD spent about 4.6 percent of its RDT&E budget on basic research. In the 1970s, this figure dropped to 3.6 percent, and by 1988 had reached 2.1 percent. This may reflect not so much a waning interest in research as a rapidly escalating cost in the development and procurement of higher-tech weapon systems.

Outside competition compounded the funding diminishment; a proportionately larger piece of that dwindling research pie was going to academia at the expense of the laboratories. After a period during the Vietnam War, when higher educational institutions largely eschewed DoD dollars because of the unpopularity of the conflict, universities began to reestablish connections to DoD research funding. Entities such as the National Science Foundation (NSF) and the National Institutes of Health simply did not have the deep pockets of research dollars that the DoD had.

Bob Rowntree attributed the expansion of DoD-funded work at the universities to "the growing sophistication of the university community as a political force." Acting through their congressional representatives, the universities argued—accurately and effectively—that the numbers of graduate students in engineering and physical science were decreasing and that it was in the interests of national defense to reverse the trend by injecting money into the universities.[4]

One potentially crushing blow to the DoD laboratories' research freedom came in 1969. Senator Mike Mansfield (D-WA) introduced an amendment to the Military Authorization Act that forbade DoD funds being used for "any research project or study unless such project or study has a direct and apparent relationship to a specific military function or operation."[5]

The effect was immediate and chilling. The introduction to the Exploratory and Foundational Research chapter in the 1969 *Tech History* began with the following sentence: "Although exploratory and foundational research efforts were reduced during 1969, a number of significant accomplishments were made." The following year, the introduction noted "a reduction in total effort followed the pattern set in 1969."[6]

---

[4]S-176, Rowntree interview, 69.

[5]Public Law 91-121 (19 November 1969), 83, accessed 4 February 2014, https://www.govtrack.us/congress/bills/91/s2546/text.

[6]*NWC Tech History 1969*, 6-3; *NWC Tech History 1970*, 6-3.

Years later, Dr. William P. Raney, former Chief Scientist of the Office of Naval Research (ONR) and Scientific Advisor to the President, stated:

> The Mansfield Amendment was a great club. Even though it was withdrawn as a piece of legislative requirement after only a year . . . I don't think the defense research community has ever recovered from that. In point of fact, the ability of the defense basic research community to attract the sort of competence in staff it needs has been seriously damaged.[7]

Raney, and other senior scientists in the Defense Department, realized a principal and valid reason for category 6.1 basic research in the DoD laboratories—one that is just as valid today as it was in the 20th century. It helps in recruiting bright young scientists and engineers with vision and imagination who want to pursue exotic research far ahead of the cutting edge.[8]

The Research Department muddled through the Mansfield phase; Hack Wilson, the Technical Director from 1970 to 1973, shared Dr. McLean's philosophy of letting good men and women do what they do best, and he did not interfere with Hunter's basic research programs. And to Hunter's credit, he did try to steer additional effort into helping the engineering side of the house. In 1971, the introduction to the *Tech History's* Exploratory and Foundational Research chapter stated:

> To an extent surpassing that of previous years, substantial assistance was rendered engineers in the applications of science to weapon development programs at the Naval Weapons Center, as well as to the Fleet and elsewhere.[9]

Walt LaBerge's brief Technical Directorship in 1973 was a tough period for the Research Department. LaBerge was a physicist by training (PhD, Notre Dame) who had commanded a minesweeper in the Pacific during WWII. At China Lake he had cut his teeth in the Sidewinder project, eventually heading that program. He left for private industry in 1957, becoming a vice president for Philco-Ford before returning to the Center as Deputy Technical Director in 1971. He assumed the Technical Director position in June 1973.

---

[7]NL-T31, Raney interview, 36. The Mansfield Amendment was neutered by Congress in October 1970 when it modified the Military Authorization Act by adding, "It is the sense of Congress that . . . an increase in Government support of basic scientific research is necessary to preserve and strengthen the sound technological base essential both to protection of the national security and the solution of unmet domestic needs." Public Law 91–441, Title II, §205, 84 Stat. 908 (7 October 1970), accessed 20 July 2021, https://www.govinfo.gov/content/pkg/STATUTE-84/pdf/STATUTE-84-Pg905.pdf#page=8.

[8]On the other hand, 6.1 funding was referred to by some cynics as "talk-in-the-hall" money.

[9]*NWC Tech History 1971*, 7-3.

LaBerge's attitude toward research was common in the DoD and the anathema of many DoD scientists. "Walt made it very clear that he'd like to have research people, but he didn't really want them doing research," Hunter said.

> He wanted them doing the things he felt were useful instead. . . . He likes the research mind and the research capability and the products of research tremendously well, and he felt that somehow the only thing he had to do with the Research Department was to just get them into something useful.[10]

Sherwin had shown in Project Hindsight that the "something useful" LaBerge wanted out of China Lake's researchers might not prove its utility for 20 years or more. And this was the rub to managers conscious of budgets and deadlines: Charles E. Wilson, President Eisenhower's Secretary of Defense, is said to have explained the term "pure research" thusly: "if successful, it could not be of any possible use to the people who put up the money for it—that made it pure."[11]

Despite decades of debate, LaBerge's attitude—a belief in the need for an immediate, or at least a short-term, payoff from research dollars—continues to contend with the belief that basic research is essential to the DoD's technological leadership in the world. In 2009, a JASON summer study funded by the Director of Defense, Research and Engineering (DDR&E), examined the issues of basic research in the DoD and pointed out two widely held fallacies regarding the subject.

> The first fallacy can be summarized as "Why invest when the net present value (NPV) of basic research funding is so low?" The response here is that NPV may provide a useful metric in comparing the outcomes of alternative investment choices. But national security is not fungible with other goals or rewards. Further, *even if* the average NPV of research investments were low, the country needs insurance against worst-case technical surprise.
>
> The second fallacy is simply stated as "Let someone else pay for basic research and we'll just reap the rewards." While perhaps appealing, it fails in practice, since the global technology market is not "efficient." Further, first-mover advantages in taking basic research to application are real and many—the people involved have experience that is not easily purchased, physical proximity of the basic and applied work aids the application ("tech transfer is a contact sport"), and a culture of discovery broadly begets further innovation.

---

[10]S-95, Hunter interview, 18. Tom Amlie, whose 26-month stint as Technical Director ended 3 years before LaBerge took over, felt similarly about the Research Department. He once told an interviewer, "We were busting our butts to make Sidewinder, Walleyes, and Shrikes, and bomb director systems, and whatever, and these guys [Research Department personnel] were living high off the hog on our efforts." S-150, Amlie interview, 12–13.

[11]Buderi, *Naval Innovation for the 21st Century*, 39.

> Indeed, US industry has not always been successful at a "just reap the rewards" strategy, and there is no reason to suppose DOD would do better.[12]

Burrell Hays ascribed part of the Center's research problems in the 1970s to the pressure from Washington for ever-increasing productivity, the same sentiment embodied in Office of Management and Budget (OMB) Circular A-76. "They even wanted to have productivity improvements in research and in development," Hays said.

> It took a lot of effort, surprisingly, to convince them that you really couldn't make measurements of creativity that way. I remember we used to make the argument that if you could really do that, then find the two or three scientists that are going to cure cancer and fund them and knock all the rest of it off. Because we're doing the same kind of thing, only we're not looking for that kind for research.[13]

After LaBerge left China Lake for the Air Force in September 1973 (and eventually from there to industry), Leroy Riggs was Acting Technical Director for 9 months, a period that Hunter described as "a neutral situation." With the arrival of Gil Hollingsworth in July 1974, the Research Department fared better. "Hollingsworth, since his arrival, has made it very clear that he wants a Research Department not very different than what the people in the department want," said Hunter.[14]

A look at the formal mission of the Research Department confirms Hunter's assessment of the two conflicting views of the role of research. In 1971, the mission was to conduct "basic and applied research *in subject areas most likely to influence the development programs* of the Center." [Emphasis added.] In 1976, under Technical Director Hollingsworth, the department's mission was couched as a more ambiguous mandate: to conduct "basic and applied research which strengthens the Center's capabilities to utilize science and technology effectively."[15]

Dr. Edwin B. Royce took over the Research Department in 1976. Dr. Hunter had retired the previous year but had agreed to remain in his position until the post was filled. Although Royce had spent the first years of his life just down the road from China Lake in Trona, he was not a China Laker. He came to the base mid-career, following a 5-year tour as head of the Environmental Protection Agency's Office of R&D in Washington. An unabashed environmentalist—

[12]JSR-08-146, *S&T for National Security*, 12. Emphasis in the original. JASON is not an acronym; it is an advisory group, named after Jason of Greek mythology.

[13]S-221, Hays interview, 36.

[14]S-95, Hunter interview, 18.

[15]NAVWPNCEN 5450-1, *Organization Manual*, September 1971, 68; NAVWPNCEN 5450-1, *Organization Manual*, March 1976, 99.

he had served as California's regional vice president of the Sierra Club—he brought strong credentials to his new job: a bachelor's degree in physics from Caltech, a doctorate in applied physics from Harvard, and 8 years of research at Lawrence Livermore Laboratory, resulting in some 50 scientific papers and presentations.

The Research Department had something of a reputation as a good old boys' (and girls') club. As an "outsider," Royce's task was challenging. Leroy Riggs said of him, "I'm sure he has 15 guys that have been here 30 years that are going to keep him on the straight and narrow."[16]

Royce was aware of the tension existing in the DoD and on the base between advocates of "pure" science and "applied" science. On assuming the leadership of the Research Department, he astutely told a reporter:

> Two things I'll emphasize will be maintaining the already established high quality of research work by the department [pure], and assuring that the department is fully integrated and supportive of the overall mission of the Center [applied].[17]

When Gil Hollingsworth, at Rear Admiral Freeman's behest, left the Center in 1977, Bob Hillyer was selected as Technical Director. Although he'd been at China Lake since 1970, he was, like Royce, somewhat of an outsider—he'd come over in the transfer of the Fuze Department from Corona, where he'd spent the previous 14 years.

Because of his background at Corona, Hillyer appreciated the value of research. The emphasis there had traditionally been more on research than development. "That was probably due mostly to the character of the leader, Dr. Stan Atchison, who was by nature himself a scientist more than an engineer, and the place sort of imaged Stan's personality," he said.[18]

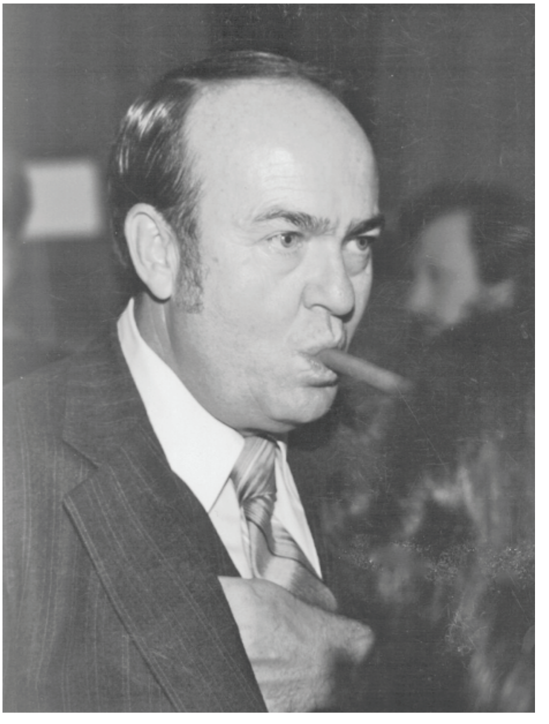
Hillyer added, however, that

> if there was an exception to that, it was the Fuze Department [in which Hillyer worked at the time of the Corona transfer and which he later headed], which did more developmental work and less basic and applied research.[19]

According to Burrell Hays, who succeeded Hillyer as Technical Director:

> When Hillyer took over as TD he made it clear that one of his goals was to focus the Research Department's efforts to better align with the overall mission and active weapons developments of the Center. Over the years the Research

[16]S-136, Riggs interview, 106.
[17]*Rocketeer*, 28 May 1976, 1.
[18]Ibid, 3.
[19]Ibid.



Burrell Hays.

> Department had done some very valuable research and applied research that was incorporated in the Center's overall mission and programs (such as explosives, optics, and propulsion). However, there were also some efforts that were quite valuable and well done but were of little or no value to the Center's mission or development efforts.[20]

Hillyer assigned the task to Hays (then Laboratory Director), and the two established a plan:

> 1) Manage the Independent Research, Bid and Proposal, and discretionary funding received by the Research Department to be only for research that would (could) directly support the Center's overall mission.
>
> 2) Hire researchers into the Department that only had interest in research that would directly support the Center's mission.
>
> 3) Slowly realign the Research Department to more closely match the Center's mission, developments and goals.
>
> 4) Make the Research Department more user friendly to the development codes and encourage collaboration on development efforts.
>
> 5) Undertake and execute the plan without a lot of discussion and confrontation in order to avoid needless disruption in the Department.[21]

Hillyer wanted a multiyear effort: "heavy handed changes were not required or desired." Royce was to be the point man for the department's reorientation.[22]

Royce realized that the Center was lucky to even have a Research Department. Prior to 1969, the department had been funded out of overhead,

[20]Hays to the author, email, 17 February 2014.

[21]Laboratory Director was a position under the Commander and Technical Director, established under Rear Admiral Freeman's 1976 reorganization.

[22]Ibid.

but with the switch to Navy Industrial Fund (NIF) accounting in 1969, competition for funds increased. "The NIF puts us in the marketplace," said the Office of Finance and Management's John Bodenburg, a highly respected management analyst with a broad background in government and industry.

> We go to a prospective customer and say, "From our knowledge of the technology and of the warfare area, the mission of the Navy, and our mission, and the bucks available, this is what has to be done. Here's how we intend to do it." So we make it sort of easy for the guy to say, "Yeah, I'll sign on the dotted line, I'll see that you get the money." And it gets done. But you have this interface. We then have to meet the needs of the customer, we have to perform in accordance with the contract we've written.[23]

As Hays viewed the NIF concept:

> If in fact the organization had a quality product to deliver and somebody wanted to buy it, then the organization ought to be there. And, if you didn't have something somebody wanted to buy, then the organization hadn't ought to be there. So, if you think in terms of institutional money, which the Air Force and the Army have for their laboratories, those people really don't have to prove anything; whereas a China Lake or a NOSC [Naval Ocean Systems Center] or whoever has to go back and sit down and essentially prove to the sponsor that he ought to fund you because you are going to give him some value added.[24]

In this competitive arena, it was harder to find sponsors for the pure or long-term research that was foundational to the China Lake Research Department—and had been since the department's inception. Although so-called 6.1 money for research came directly to China Lake from ONR, half that money, under the rules of NIF, went into Center overhead.

Said Royce:

> Now, all the other RDT&E centers saw the same thing and their answer was to do away with the separate department. They had some research here and there scattered around the landscape, if those guys could bring in some money to support themselves . . . but it wasn't in a separate department.[25]

The decision to maintain the Research Department as an independent entity at China Lake was made under Rear Admiral Freeman, but according to Royce, credit for maintaining it went to Hillyer. "Hillyer was an outspoken

---

[23]S-115, Bodenburg interview, 24. Among other positions Bodenburg held prior to coming to China Lake were program manager for simulations on the Apollo Command Module and Technical Director of the Naval Training Devices Center.

[24]S-157, Hays interview, 47.

[25]S-354, Royce interview, 31–32.

defender of that decision," said Royce. "I think he was probably the one that made it happen."[26]

As with any major organizational decision, there were pros and cons to having a department dedicated to research. Royce explained:

> If you scatter those [researchers] then those folks get rather effectively coupled with the engineers who are doing project engineering, development programs, and so any good results coming out of the research . . . can move on into, and support, engineering development. The bad feature of that system is that after a while you may have started out with some good research scientists, you turn them into just another engineer and you no longer have research being done. . . . On the other hand, if you take your research people and you put them in a group, now you can protect those people from being in a certain sense sucked into the development process. But now you've got to work very hard, because the natural tendency of that group will simply be to stay isolated and have fun doing whatever they're doing and not really make a contribution to what the rest of the Center is doing.[27]

This was the philosophical tension that led to the Hillyer-Hays plan that Royce helped carry out.

Royce tackled the issue of the department's isolation—"it really was kind of an ivory tower"—head-on.

> I said to each of my division heads, "In your performance plan, your job is to foster technical collaboration between members of your division and some other part of the Naval Weapons Center. I don't care the nature of the interaction. I don't care if it has money involved with it or not. I want our people talking to some other people on NWC and document those interactions and that's in your performance plan." And it was in my performance plan. And the people went at it and it turned out that they were pretty good at interacting once they were told that's what they were supposed to be doing.[28]

Royce was also successful in accomplishing the first two items of the Hillyer-Hays plan: turning the course of research to more closely align with the Center's mission. In hiring, he and his division heads would select the best people they could find, based on publications and dissertations. Prospective employees were brought to the Center to present seminars demonstrating their knowledge and skills. Then the research options and limitations available to the newcomer were presented diplomatically, but clearly.

"Rather than say, 'You're going to come to China Lake and work on a booster for the Trident' or something like that," Royce explained,

---

[26]Ibid., 32.
[27]Ibid.
[28]Ibid., 33.

> I would say, "The Naval Weapons Center has an interest in energetic materials for a wide variety of applications. We are looking for a chemist to come and work on energetic materials doing basic research on these materials. If you come, we'll expect that that's what you'll be doing." . . . We picked topics where it was pretty obvious that if you made some interesting breakthroughs there would be people on this Center who would be very happy to pick that up and go do something with it . . . We'd pick a broad topic of that nature and say, "We're not hiring you to do a specific project; you're going to have some freedom to do whatever you want, but it's going to be in this general area. Now, do you want to come to us or not, because we're not offering you universally total freedom to pick your project and do anything you want, but we are offering you more freedom than you would probably find if you went into any industrial organization."[29]

Hays acknowledged Royce's leadership in carrying out the plan that he and Hillyer had devised for the Research Department. It

> took the full cooperation, support, and execution by Dr. Royce and it was well understood he would take some heat for it. From my standpoint Dr. Royce performed this task extremely well and fully supported upper management's goals. He fully accepted the burden of making the changes without complaint or backlash to management. Job well done.[30]

Hillyer, at the conclusion of his tour as Technical Director in 1982, observed:

> Our research program has had some marvelous invention in it over the years, has had high payoff, and we don't get quite the recognition that we deserve. . . . The Center has contributed more broadly than just weapons and parts of weapons.[31]

Computing

Computing at China Lake, as in the rest of the world, has undergone remarkable changes. An engineer who started his career with a mechanical analog computer in his pocket (a slide rule) during the 1950s would retire three decades later with a small digital computer on his desktop. Computers were used not only for solving problems, such as calculating ballistic tables, but also for processing quantities of data.

---

[29]Ibid., 44–45.

[30]Burrell Hays to author, email, 17 February 2014. In 1983, Dr. Royce received the L. T. E. Thompson Award, the Center's top award for individual achievement, for his role in modernizing the Center's computer usage and for "his strong leadership aimed at making the Research Department more of an integral part of NWC's weapons development research and technology base." *Rocketeer*, 10 June 1983, 4.

[31]S-134, Hillyer interview, 55.

Data processing—that is, extracting meaningful information from large amounts of raw data, as for example the data produced by multiple tracking radars during the test of an air-launched weapon—was an essential function from the first days of NOTS' existence. Converting the raw data into numbers for classifying, sorting, and analyzing was a labor-intensive, tedious, and seemingly endless task.

When Lee E. Lakin Jr. came to China Lake in 1946 (he would eventually head China Lake's Computer Sciences Division from 1960 to 1981), film reading of Doppler radar outputs was a principal job. "We had to count each pulse or each little measurement we made and write it down by hand," he said. The work was done looking through a microscope, and there were many complaints of vision problems.

Lee Lakin.

> There is a famous fellow who didn't think our people were reading film energetically enough through microscopes. He decided to show us how to do it. After a few months, all of sudden his eye wouldn't focus; I think he still has trouble with his eyes.[32]

Electromechanical calculators, such as those made by Friden and Marchant, were sometimes used to assist in the work. Lakin remembered:

> We thought it was great when you could add, subtract, multiply, and divide on these mechanical calculators, which at that time cost about as much as our annual salary. If you had one of those you were really one of the elite.[33]

Despite mechanical calculators and the efforts of eye-weary technicians, the need for data processing exceeded the Station's capability, so the engineers turned to contractors. "The Test Department people had three separate 1-year contracts with companies down in Los Angeles and Woodland Hills,"

[32]S-122, Lakin interview, 3.
[33]Ibid., 3.

explained Bruce Wertenberger, a physicist who headed the Test Department's Data Reduction Branch in those years.

> One of them did one type of film data, another did another type of film data, and the third one yet another . . . and each of the supervisors in the Data Reduction Branch had their own types of data to handle, and, originally, their own contractor . . . The fortunes of these small companies varied according to the range activity up here and how well they serviced the people up here.[34]

Interestingly, this need led to the beginning of a support-contractor presence in Ridgecrest that has, over 60 years, been an important element of the Center's workforce. Lakin said:

> We had to figure out what work could be done down in Los Angeles to help us to enlarge. That meant that we had to pack our work, film, and data, and take it down to Los Angeles. . . . The next step was to say, "That's great, except we really need that ability up here for timely work." We used to fly the raw data down to L.A. in the airplane and back, and that was terrible, because you'd lose a day both ways, and time losses for corrections. So we said the contractors had to move up here so we could get finished data in an hour.[35]

Analog devices were widely used to reduce data and solve computationally intensive problems. Often home-built by the scientists and engineers from scrounged parts, these gadgets used gearboxes, servomechanisms, hydraulics, and fluctuating voltages to represent changing values. The process of setting the devices up and feeding problems into them was cumbersome, but they did reduce the time necessary for solving straightforward mathematical problems that required crunching large amounts of individual pieces of data.

In 1946, with a great fanfare, the world's first digital computer, the Electronic Numerical Integrator and Calculator, began operation. Invented at the University of Pennsylvania with half a million dollars in Army R&D funding, the monster computer filled a 30- by 50-foot room, contained more than 17,000 vacuum tubes, and sported 6,000 manual switches. Such a device was far out of the reach of China Lake. The base continued in the analog tradition with the purchase of a state-of-the-art Reeves Electronic Analog Computer, the core of the Station's first Central Computing Facility, in 1951.

Technology rapidly improved, and digital computers became more accessible. Harley E. Tillitt, who headed the Computing Branch in the Research Department, led China Lake's effort to acquire a digital computer in the early 1950s. At the time, the Naval Weapons Laboratory, Dahlgren,

---

[34]S-172, Wertenberger interview, 12.
[35]S-122, Lakin interview, 18.

which produced the ballistics tables for the Navy, had the Navy's only digital computer. Lakin said:

> It was Harley's job to convince the Navy that they needed more than one computer, because Dahlgren had the charter for digital computers. And most of the people in Washington, in the old BuOrd group, said, "Gee, how can we possibly have use for more than one computer?" [36]

In 1953, China Lake acquired its first digital computer, the IBM 701 Defense Calculator, one of only 18 built. Among the other customers for IBM's first large-scale commercial electronic computer were the National Security Agency, the U.S. Weather Bureau, the University of California at Los Alamos National Laboratory, and various defense contractors.

Digital computers of the day were not turnkey systems; they required a lot of tweaking to make them handle the types of data inputs that China Lake scientists and engineers used, and they demanded a certain amount of programming skill on the part of the user. Tillitt, Lakin, and Wertenberger were in the forefront of keeping the center abreast of developments in computer technology.

"The technology here was moving so fast . . . You just barely got one [computer] working right, and all of a sudden, immediately you had to start on the new one. You didn't have any lack of problems to solve," said Lakin.[37]

"There weren't very many standards in the early days, and there was a lot of learning going on," Wertenberger remarked. "Each of the early IBM computers, each new one, was largely incompatible with what had gone on before, so every change of computer meant redoing the software again."[38]

Meanwhile, computer designers were cranking out model after model, taking advantage of an explosion of new technologies and materials. Wertenberger recalled, "The 701 was followed by the 704, and the 709, and the 7090, and the 7094, and that was the end of the string of IBMs. Then we started in on the UNIVACs [Universal Automatic Computers]."[39]

Parallel to the growth of computing was an expansion of the time-space-position information (TSPI) and telemetry equipment used on the ranges. Miniaturization allowed more (and more complex) components to be carried in a test item, and the functioning of these components were telemetered

---

[36]S-195, Di Pol, Lakin, William Ward, and Wertenberger interview, 22.
[37]Ibid.
[38]S-172, Wertenberger interview, 18.
[39]Ibid., 3.

to ground stations in real time during a test. The amount of data requiring computerized reduction grew exponentially.

With the growing capabilities of computers, China Lakers found more ways to exploit those capabilities. Until 1960, range personnel were still photographing Doppler radar records, and technicians would measure the pulses by hand. The Naval Ordnance Data Automation Center, developed at the Center in the late 1950s and sited next to the IBM 709, eliminated that tedious process. It converted the analog electrical signals from the radar to digital format and fed them directly into the computer at a rate of 33,000 conversions per second.

Not surprisingly, bureaucracy stepped in, in the form of the Brooks Bill (U.S. Public Law 89-306), enacted in 1965. The purpose of the bill was "to provide for the economic and efficient purchase, lease, maintenance, operation, and utilization of automatic data processing (ADP) equipment by Federal departments and agencies." The bill was a response to the willy-nilly proliferation of computers throughout the government, the attendant expense, and concerns for the security of data stored in the computers. Wertenberger grudgingly admitted that the law was well intended.

> It was probably a good idea. It was in part done in response to perceived dominance of the computer market by IBM. It was to foster competitiveness in the market place. But, in the way of all good administrative laws, it became a horrendous bureaucracy.[40]

As one commentator put it, "While the Brooks bill and its corresponding procedures have saved a great deal of money, they have also interjected additional layers of bureaucracy which impeded procurement."[41]

A *Rocketeer* article in 1978, a dozen years after the bill's passage, noted:

> While at first only the management data-processing equipment was covered by Brooks Bill provisions, now all computers on the Center are. This creates a mammoth problem since there are an estimated 300 computers of varying sizes scattered throughout NWC, in addition to the giant UNIVAC 1110.[42]

The UNIVAC 1110 had been acquired in July 1977 to replace the overworked UNIVAC 1108/1105 system—which had replaced the IBM 7094 in 1967—and to help with the burgeoning need for computational power, but

---

[40]Brooks Automatic Data Processing Act, Public Law 89-306, H.R. 4845, 89th Congress (30 October 1965), accessed 19 July 2021, http://www.gpo.gov/fdsys/pkg/STATUTE-79/pdf/STATUTE-79-Pg1127.pdf; S-172, Wertenberger interview, 8.

[41]Bjorklund, *Command and Control*, 34.

[42]*Rocketeer*, 14 July 1978, 5.

soon it too was hard pressed to keep up with the demand. The *Tech History* reported:

> During 1976–77 the Central Computing Facility expanded its operation of the UNIVAC 1110 automatic data-processing system from two shifts per day to three shifts per day, 5 days per week, to effectively meet the Center's increased automatic data processing requirements. System use at the end of 1977 was approximately 30 percent higher than that at the end of 1975. Weekends were also heavily used for software development, preventive maintenance, and work load backlogs.

Similar overload had been reported with the UNIVAC 1108 in 1973, when the *Tech History* reported 24/7 usage and noted that "remote demand jobs increased 73 percent over the previous year."[43]

The high-capacity digital computers used at China Lake in the 1950s and '60s were expensive, large, and required special power and air-conditioning infrastructure; as a consequence, they were centrally located in the Research Department and the Test Department, the primary users. As the need for computer time expanded dramatically in the 1970s, the centralized computing architecture couldn't keep pace with the new demands of the Center's R&D programs, so smaller, remotely located computers were proliferating.[44]

By the early 1970s, "minicomputers" were making inroads. In 1968, Hewlett-Packard came out with the HP-9100A calculator, which the company sales literature described as a "computing calculator . . . like having a computer sitting on the corner of your desk!" The HP-9100A retailed for $4,900. Digital Equipment Corporation (DEC) released the PDP-11 minicomputer in 1970, costing from $5,000 to $40,000 and up. DEC (unlike IBM) used a data bus that made it quick and easy to get many different types of data into and out of the computer. In 1972, HP came out with a shirt-pocket-sized version of its -9100A, the HP-35A, listing at $395, which soon became ubiquitous on the base. Engineer and inventor Richard Hughes, speaking of the advent of HP's small computers, said, "Slide rules were dead overnight."[45]

[43]*NWC Tech History 1976–1977*, 11-21; *NWC Tech History 1973*, 11-22, 11-23. The entry also noted that "total disc storage is now 1.056 billion characters."

[44]An exception to this trend was Echo Range, which was served by a UNIVAC 1230 from its inception in 1968 until 1992, when the heavily overworked system was replaced by Encore 97/80s.

[45]*HP 9100A Calculator*, sales brochure, 1968, accessed 19 July 2021, http://archive.computerhistory.org/resources/text/HP/HP.9100A.1968.102646164.pdf; S-353, Hughes interview, 19.

When Royce arrived at China Lake to take over the Research Department in 1976, it quickly became clear to him that the overall architecture of the computer system at China Lake was amiss.

> The problem that I found was we had a UNIVAC, which was inadequate for the job. It was overloaded. This was in the days of a central site where if you wanted to get computing done, you took your little project, which was a stack of punch cards in those days, and you brought it down to the central stack and you put it in this window and sometime later your output came out this window . . . maybe the same day or whatever.[46]

Because of the bureaucracy spawned by the Brooks Bill, attempts to get another large digital computer wound up with the Center purchasing a second UNIVAC, albeit a more advanced model. Meanwhile, frustrated users around the Center were making end runs around the regulations by going directly to their funding sources.

Royce explained:

> Projects could go to the sponsor and say, "We need to buy a VAX [VAX-11/780, DEC's 32-bit version of the PDP-11] to do your project." And the sponsor would say, "Oh, that's great, fine; here are umpteen bucks and go buy yourself a VAX." So by the time the new UNIVAC got here we had probably three or four dozen VAXs around this place in all of the projects and everybody was using them to do all of their work, and all of a sudden this new UNIVAC didn't have much work being done on it.[47]

The VAXs became the nodes for the Center's first ad hoc communications and computing network.

The Research Department tried briefly to bring customers from the technical departments back to the UNIVAC, which by then was being used chiefly by the Office of Finance and Management (Code 08). "So I said, 'Well, see if you can bring anybody back by making it free,' " recalled Royce.

> And so we made it free and we still didn't get the business. The only reason 08 was on there was because they didn't have any money to buy their own computer. See, all the technical projects had their computers, whereas Supply and Central Staff, old Code 08, and so on didn't have money to buy computers and so they were on the UNIVAC. So we just gave it to 08 and said, "It's all yours."[48]

By the end of the 1970s, top Center management had formally recognized the need for an overall Center strategy to guide the integration and effective

---

[46]S-354, Royce interview, 23.

[47]Ibid., 24. VAX was an acronym for virtual address extension.

[48]Ibid., 28.

use of computers. Spearheading the effort was Royce, who was double-hatted as head of the Research Department and Director of Computer Applications. Working with him was Wertenberger, who since 1978 had been ADP coordinator on the staff of Laboratory Director Burrell Hays, and Dr. William G. Lane, a consultant who had established the graduate program in computer science at Chico State.

"The three of us were kind of the people planning the computing future of China Lake," Royce said.

> And we made in that planning effort the fundamental decision that the central piece of our computing organization is going to be not a central computer but the communications network itself. That was unique in Navy laboratories. . . . We put China Lake on the path of what was I think a very constructive future, recognizing we got to have computers everywhere—they're going to be on everybody's desk.[49]

Starting with programs like the Automated Technical Information Processing System in 1980, China Lake moved forward with that strategy. Progress was not without fits and starts; customer needs, new technology, funding issues, Navy and DoD policy, cultural and economic issues ("Mac vs. PC"), and other factors occasionally collided. The shape and direction of China Lake's computing infrastructure and culture were strongly impacted by development of the Advanced Research Projects Agency Network (ARPANET), which went operational in 1975; the Military Network, which became independent of ARPANET in 1983; and the internet, which exploded in the mid-1980s. Today, perhaps no other technology is more central to the Center's operations than computers in their myriad forms and functions.

Advances in Science

The period from 1968 to 1979 saw numerous accomplishments in research from the innovators at China Lake. The areas of research were as varied as one might expect to see at any large university, and the depth of research was indicated by the numbers of patents and publications that flowed from the Center's laboratories. In that span of a dozen years, NWC scientists and engineers contributed 859 open-literature publications (papers, articles, and books cleared for public release), processed 711 patents (classified and unclassified), and published more than a thousand NWC Technical Publications (TPs, primarily classified or unclassified / not publicly released). In addition, hundreds of internal technical publications (Technical Notes [TNs] and

[49]Ibid., 25.

Technical Memos [TMs]) and Technical Motion Pictures (TMPs) were used to share information within the NWC technical community.[50]

Detailed recounting of the scope of China Lake's research accomplishments during that decade-plus is beyond the scope of this volume. These were not the sort of discoveries that made headlines in the popular press—the payoff, in terms of fielded systems or new technologies for the consumer, would come years later, if at all. A sampling of the significant achievements from the Exploratory and Foundational Research chapter of the Center's annual *Tech History* reports for the period indicates the arcane nature of the work.

1968: Applied Mathematics.

> Existence and stability theorems for exterior ballistics were provided. These extend or supplement previously published results and include (1) analysis of observed cases of steady conical yaw and steady mixed oscillations, both in the presence of appreciable yaw of repose, and (2) stability results for the mixed mode case which are, so far as is known, the first to be published for a general class of problems that include the ones at hand.[51]

This research by Dr. William R. "Duke" Haseltine was published in the *Journal of the Society for Industrial and Applied Mathematics*.[52]

Dr. Duke Haseltine.

In applied research that year, a fisheye design for an aimable warhead was demonstrated experimentally, producing a jet in the aimed direction that was about 10 times more effective than the blast from an isotropic charge weighing the same amount.

1969: Physical Optics.

> The optical constants of artificially tarnished Ag_2S films were determined by a Kramers-

[50]Mary Ray, technical information specialist, NAWCWD Scientific and Technical Library, email, 4 November 2014.

[51]*NWC Tech History 1968*, 2-4.

[52]W. R. Haseltine, "Existence and Stability Theorems for Exterior Ballistics," *Journal of the Society for Industrial and Applied Mathematics*, J Ser. A, CONTR, Vol. 6, No. 3 (August 1968): 386–400.

> Kronig analysis of normal-incidence transmittance measurements, using the computer program of Dr. P. O. Nilsson of Chalmers University of Technology, Gothenburg, Sweden.[53]

This research by Dr. Jean M. Bennett, Dr. James L. Stanford, and Edmond J. Ashley was published in the *Journal of the Optical Society of America*.[54]

1970: Crystal Physics. In the field of epitaxial crystal growth by vacuum deposition,

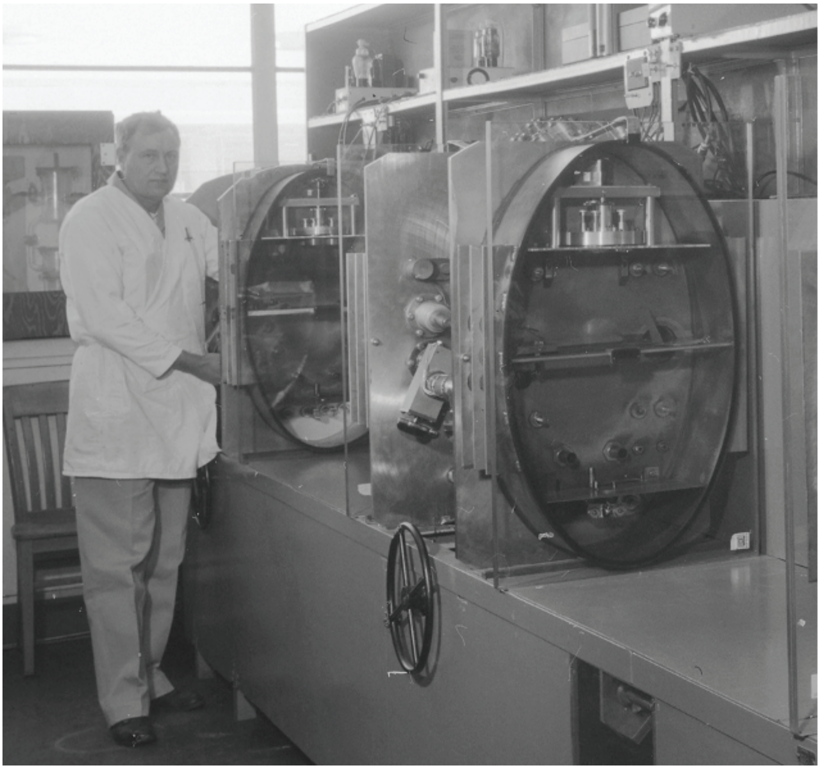
> major effort was made in extending the range of tractable substrates to include the lead chalcogenides. Lead sulfide is available in natural single crystal form (galena), and a preliminary study was made using galena for a substrate. Both Au and Ag films on PbS were studied.[55]

Dr. Jean Bennett.

[53] *NWC Tech History 1969*, 6-8.

[54] J. M. Bennett, J. L. Stanford, and E. J. Ashley, "Optical Constants of Silver Sulfide Tarnish Films," *Journal of the Optical Society of America*, Vol. 60, Issue 2 (1970): 224–231.

[55] *NWC Tech History 1970*, 6-10.



Ed Ashley.

The results of this work by Arold K. Green, John Dancy, and Dr. Ernst Bauer were reported in the *Journal of Vacuum Science and Technology*.[56]

1971: Semiconductor Physics (Amorphous Semiconductors).

> In a gratifying cooperative effort with other laboratories, the observation and theoretical explanation of an anomalous peak in the UV absorption were correlated to the influence of substrate temperature on film density.[57]

This research by the Research Department's Dr. Terence M. Donovan and Dr. Klaus Heinemann of NASA's Ames Research Center was reported in the *Physical Review Letters*.[58]

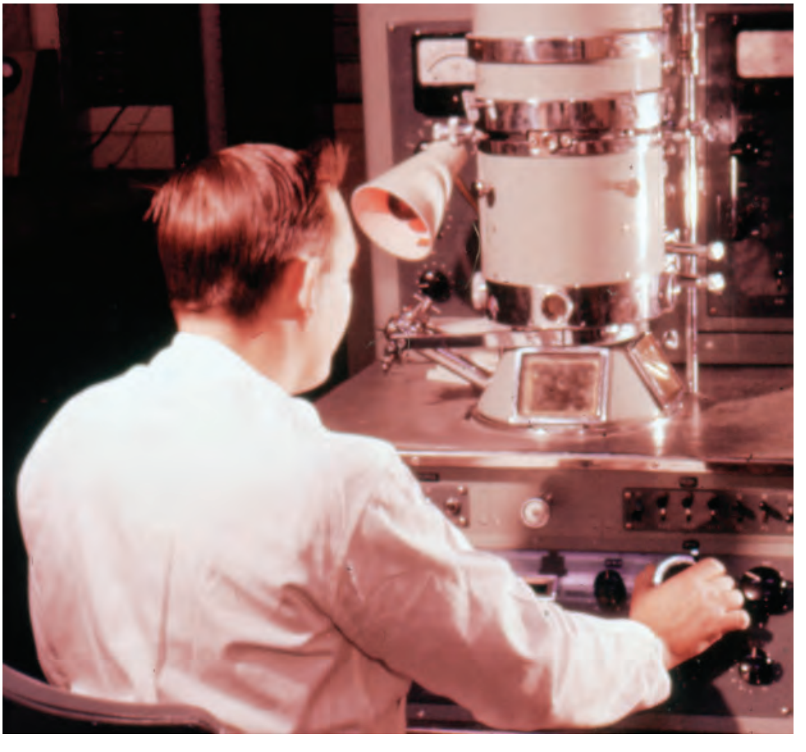
---

[56]A. K. Green, J. Dancy, and E. Bauer, "Growth of FCC Metals on Lead Sulfide," *Journal of Vacuum Science and Technology*, Vol. 8, Issue 1 (1971): 165–170.

[57]*NWC Tech History 1971*, 7-14, 7-15.

[58]T. M. Donovan and K. Heinemann, "High Resolution Electron Microscope Observation of Voids in Amorphous Ge," *Physical Review Letters*, Vol. 27, No. 26 (December 1971): 1794–96.

John Dancy.



Dr. Ernst Bauer.

1972: Metal Combustion.

> A new series of systematic quantitative experiments was performed on the combustion of single laser-ignited aluminum droplets burning in various gases, including CO_2 and mixtures of oxygen/nitrogen and oxygen/argon (both wet and dry). . . . The droplet-burning model in use for aluminum and other metals has been shown to be inadequate.[59]

Jack Prentice's research was reported in *Combustion Science and Technology*.[60]

1973: Applied Mathematics.

> The reduction of composite systems stability and control properties to the like properties for the subsystems was studied. A relation between stability and controllability was exploited, as was matrix structure theory, to obtain sufficient conditions for the desired reduction.[61]

Gary A. Hewer's and Dr. Roy Leipnik's results were presented in *Proceedings of the American Mathematical Society* and *Transactions of the First NWC Symposium on the Application of Control Theory to Modern Weapons Systems*.[62]

1974: Physical Optics. A polarization-modulated ellipsometer was employed to better understand the residual gas effects on prepared mirror surfaces such as silver. Among the findings were:

> The deleterious effects of O_2 and H_2O vapor on the reflectance of silver films, when present during deposition to pressures in the 10^{-6}-torr range, were shown to correlate with surface roughness. However, the effects are typically three times larger than can be accounted for by the roughness (as derived from scattered light) alone.[63]

The work by Steve Jasperson (NWC consultant) and the Research Department's Dennis Burge and Robert O'Handley was reported in *Surface Science*.[64]

---

[59] *NWC Tech History 1972*, 8-46.

[60] Jack L. Prentice, "Experimental Burning Rates of Single Laser-Ignited Beryllium Droplets," *Combustion Science and Technology*, Vol. 3, No. 6 (August 1971): 287–94; "Reaction of Nitrogen With Burning Beryllium Droplets," *Combustion Science and Technology*, Vol. 5, No. 6 (August 1972): 273–85.

[61] *NWC Tech History 1973*, 8-43.

[62] G. A. Hewer, "A Generalization of an Inequality of Coppel" in *Proceedings of the American Mathematical Society* 44 (1974), 151–156; also in *Transactions of the First NWC Symposium on the Application of Control Theory to Modern Weapons Systems* (China Lake, California: NWC, June 1973). G. A. Hewer and R. B. Leipnik, "Behavior of Composite Systems," in *Transactions of the First NWC Symposium*.

[63] *NWC Tech History 1974*, 8-9, 8-10.

[64] S. N. Jasperson, D. K. Burge, and R. C. O'Handley, "A Modulated Ellipsometer for Studying Thin Film Optical Properties and Surface Dynamics," *Surface Science*, Vol. 37 (June 1973): 48–58.

1975: Propellant Combustion.

> A scheme was developed for maximizing acoustic energy losses due to condensed-phase products (particle damping) from aluminized solid propellants. The approach involves scientific tailoring of the size distribution of condensed-phase products to achieve optimum particle damping.[65]

The work by Dr. Ronald Derr was reported in *Proceedings of the Twelfth JANNAF Combustion Meeting*.[66]

1976: Atmospheric Modeling.

> A computational method using Monte Carlo techniques was applied to a variety of chemical reaction models. Results indicate this numerical simulation method gives better solutions than other methods, and is applicable to the field of chemical reaction kinetics, especially those cases of nonlinear, spatially uniform systems driven far from chemical equilibrium.[67]

Dr. Daniel T. Gillespie's work was reported in the *Journal of Computational Physics*.[68]

1977: Quantum Surface Dynamics.

> Important advances have been reported in [determining] 10.6-micrometer damage and optical characteristics of highly reflecting metal surfaces generated by a variety of preparation and finishing techniques.[69]

The work by Dr. James O. Porteus, Dr. Donald Decker, James Jernigan, and William Faith was presented in a variety of publications and journals, including the *Journal of Quantum Electronics*.[70]

1978: Geophysics.

> Extensive fault mapping was completed that further delineated the structural nature of the Coso Range. The investigator's interpretation of this structure does not support the present theory of circumscribed ring fractures that are

---

[65] *NWC Tech History 1975*, 8-40.

[66] R. L. Derr, et al., "Combustion Instability Studies Using Metallized Solid Propellants: Part I, Experimental Verification of Particle Damping Theory," in *Proceedings of the Twelfth JANNAF Combustion Meeting* (Newport, Rhode Island, 11–15 August 1975), Vol. II, Chemical Propulsion Information Agency Publication No. 273 (December 1975), 155–166. Derr would succeed Royce as head of the NWC Research Department in May 1986.

[67] *NWC Tech History 1976–1977*, 8-36.

[68] D. T. Gillespie, "A General Method for Numerically Simulating the Stochastic Time Evolution of Coupled Chemical Reactions," *Journal of Computational Physics*, Vol. 22 (December 1976): 138–140.

[69] *NWC Tech History 1976–1977*, 8-21.

[70] J. O. Porteus, et al., "Evaluation of Metal Mirrors for High Power Applications by Multithreshold Damage Analysis," *IEEE Journal of Quantum Electronics*, Vol. 14, Issue 10 (August 1978): 776–780.

From left: Dr. Dan Gillespie, Candy Kunz, and Dr. Roy Leipnik.

> volcanically influenced, or a single dominant caldera. East-west extension and associated crustal thinning, typical of the basin and range physiographic province, is supported by this work and by seismic evidence collected by the United States Geological Survey.[71]

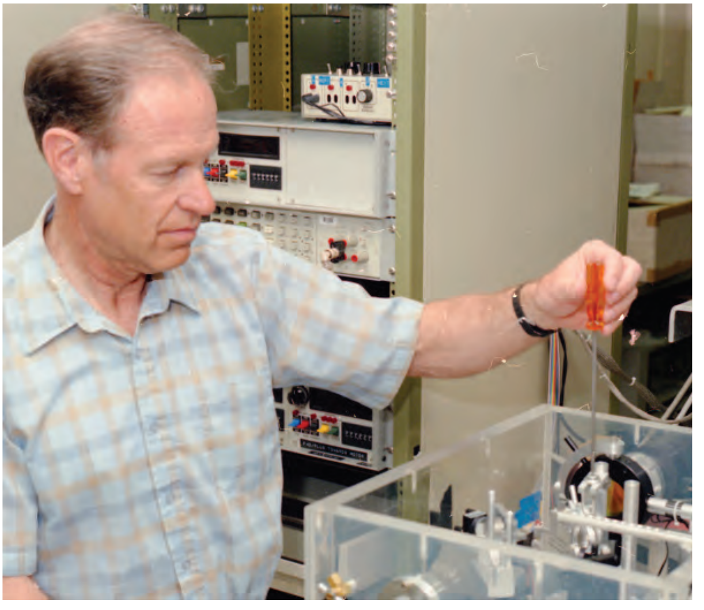
Dr. Glenn R. Roquemore's research and findings were reported in *Geological Society of America, Abstracts*, and *Seismological Society of America, Abstracts*.[72]

The same year, Drs. William P. Norris, Ronald L. Atkins, and Arnold T. Neilson of the Research Department were honored for their work with hexanitrobenzene (HNB). China Lake was the first organization in the free world to synthesize HNB, also known as CL-20, which was then the most powerful organic explosive known.

---

[71] *NWC Tech History 1978*, 8-54.

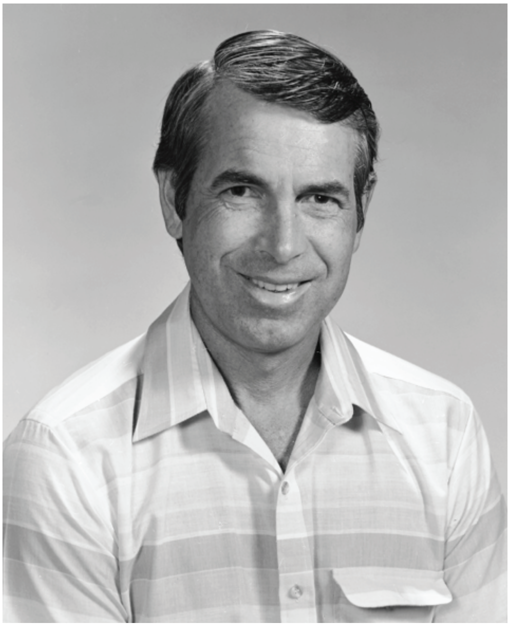
[72] Glenn R. Roquemore, "Evidence for Basin and Range/Sierra Nevada Transitional Zone Structures in the Coso Mountains, California," *Geological Society of America, Abstracts*, Vol. 10, No. 3 (1977): 144; "Active Faults and Related Seismicity of the Coso Mountains, lnyo County, California," *Seismological Society of America, Abstracts*, Vol. 49, No. 1 (1978): 24.



Dr. Jim Porteus.

1979: Material Science.

> The damage energy criterion developed at NWC is being used for measuring and characterizing the extent of propellant damage. The energy concept was applied to study the effect of damage on various basic propellant properties, and a test series was conducted to determine whether the fracture initiation of a damaged propellant differs from that of an undamaged propellant.[73]



Dr. Don Decker.

The results of the study by Dr. Albert Lepie and Dr. Arnold Adicoff were presented in the *Journal of Advanced Polymer Science*.[74]

It is notable that in the late 1960s and early 1970s, when

[73] *NWC Tech History 1979*, 7-45.

[74] A. H. Lepie and A. Adicoff, "Energy Balances and Uniaxial Failure of Solid Propellants," *Journal of Advanced Polymer Science*, Vol. 23, Issue 7 (1979): 2169–78.

sentiment against the Vietnam War was running high in the nation, the authors' affiliations were sometimes listed in technical journals as "Michelson Laboratory [or Michelson Laboratories], China Lake, California," rather than "Naval Weapons Center."

Specialized Facilities

While China Lake researchers still used traditional test tubes, Bunsen burners, and balance scales, a variety of far more complex and technically sophisticated tools and facilities were necessary to keep Center researchers at the forefronts of their fields. These instruments and laboratories existed all over the Center and included facilities for research into specialized areas such as aerothermochemistry, detonation phenomena, earth and planetary sciences, electro-optics, high-energy materials, human factors, materials science, physics, propulsion, simulation, solid-state phenomena, and warhead dynamics.

Exemplifying the diversity of specialized tools and instruments developed to facilitate the Center's research programs were those used for optical research. The Diamond Turning Facility, for example, which began development in 1977, was jointly designed by NWC and Pnuemo Precision Inc. of Keene, New Hampshire. The heart of the facility was a super-precision, two-axis, air-static-bearing, optical-component diamond-turning machine. This device took a traditional machine-shop practice—single-point turning, with a tool impinging on a rotating surface—and transformed it into an optical-surface-finishing process capable of greater precision than had theretofore been achieved.

The single-point cutters in this case were gem-quality diamonds, about 1/10 carat, the by-product of jewelry making. Diamond turning could be used on certain metals—silver, copper, gold, and various alloys—and on such nonmetallic materials as silicon, germanium, magnesium fluoride, calcium fluoride, and sodium chloride. (It did not work on glass and some metals, such as ferrous metals, because of a chemical reaction between the material and the diamond cutter.)

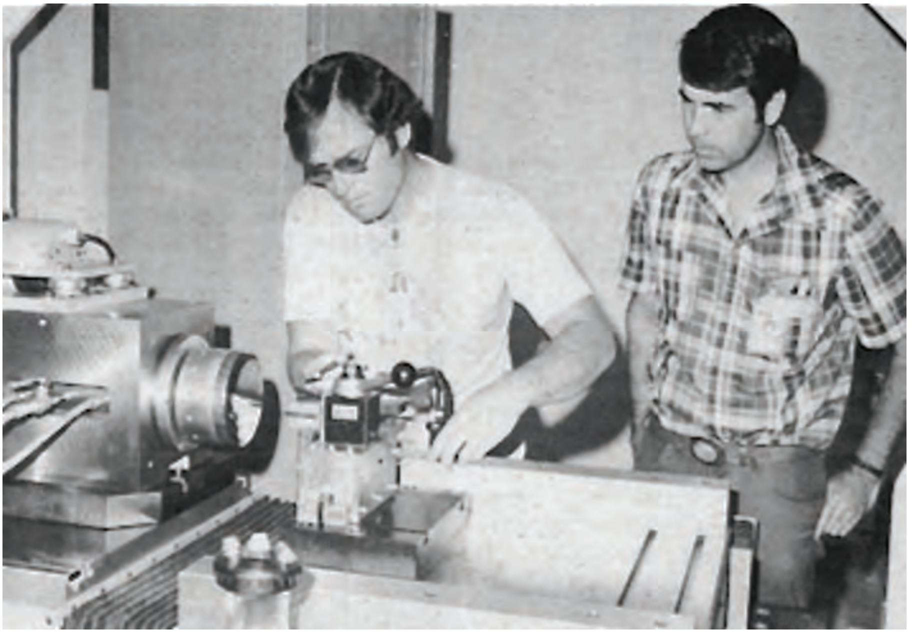
A distinct advantage of the new process, as opposed to those employed by a traditional optics shop (of which China Lake had one of the DoD's finest), is the fact that the cutter was numerically controlled. Opticians can readily create spherical shapes, but other contours, such as a parabola, require specially shaped laps (tools) and polishing strokes. Numerical control allows the precise reproduction of any surface that can be mathematically described.

Development of the facility at China Lake was carried out by Dr. Donald Decker, a research physicist and head of the Advanced Optics Technology

Branch, and Darrell Grandjean, an electronics technician. For researchers such as Dr. Jean Bennett, who was interested in the interplay of surface roughness and scattering phenomenon, the new facility presented the opportunity to obtain samples specifically tailored to her research interests.

In operation, the feed rate of the tool carriage, which moved the cutter across the part being finished, was about 300 millionths of an inch for each revolution of the spindle that held the part. At a spindle speed of 1,000 RPM, a 6-inch-diameter part could be completed in 10 minutes. The finished surfaces had root-mean-square roughness of less than 10 angstroms, as measured by total integrated scattering. During the following year, two papers were presented describing the characteristics of parts created with the facility.[75]

The Diamond Turning Facility illustrated the interplay of research, engineering, and application. The same tool that could finish surfaces for advanced research could also perform the task for very high quality lenses, domes, and mirrors used in forward-looking infrared (FLIR) systems, IR seekers, and laser applications. Even as NWC was using the machine to generate



Darrell Grandjean (left) and Dr. Don Decker (right) adjust the diamond-turning machine.

[75]Decker and Grandjean, "Diamond-Turning," 122–130; Decker, Grandjean, and Bennett, "Diamond-Machined Infrared Windows," 293–303; *Rocketeer*, 2 June 1978, 7.

materials for optical-surfaces research, an identical machine was delivered to the Honeywell Inc. Electro-Optics Center in Lexington, Massachusetts, which used it to produce far-IR optics for military applications. That technology-transfer program was jointly funded by the Navy Independent Research and Independent Exploratory Development (IR/IED) program, the Air Force Weapons Laboratory, and the Army Redstone Arsenal.[76]

The Diamond Turning Facility was part of a larger complex of capabilities known as the Optics Laboratory, run by Dr. Hal Bennett, head of the Research Department's Physical Optics Branch. The laboratory included the Optical Evaluation Facility, funded by the Defense Advanced Research Projects Agency (DARPA) and designed by Hal Bennett. Most of the parts were built in the shops of Michelson Laboratory and were assembled by Phil Archibald and other members of the branch.

As described in an article by Jean Bennett, the Optical Evaluation Facility, which became operational in 1973,

> uses a large hemispherical mirror, called a Coblentz sphere, to collect all the light scattered from the sample, which can be either a plane or concave mirror up to 16 inches in diameter. The scattered light very close to the specular direction can also be measured, a feature which is not found in most other instruments that measure scattering.[77]

In 1977, an absorption-measurements capability was added to the facility.[78]

As with many of the department's facilities, there was as much utility for systems designers as for research scientists; the facility could measure scattering and absorption in operational mirrors at 18 different laser wavelengths. "The existence of this and other unique measurement facilities at NWC," the *Tech History* reported, "was instrumental in bringing a significant amount of project support money to the Center."[79]

A third optical research facility developed in the 1970s was the Laser Damage Facility, developed by Dr. James O. Porteus with colleagues James Jernigan and William Faith. The facility was used to monitor up to eight laser-damage-related phenomena on a sample. The results were used "not only to gain a better understanding of damage mechanisms, but also to develop optical components that are more damage resistant."[80]

---

[76]*NWC Tech History 1979*, 31–32.
[77]*Rocketeer*, 27 April 1973, 5.
[78]Ibid.
[79]*NWC Tech History 1973*, 8-3.
[80]*Rocketeer*, 13 January 1978, 1, 3.

With the development of new laser capabilities came the need to test developing systems at larger-than-laboratory distances. The Joshua Ridge Electro-Optical Test Range was established for that purpose in 1970 at a site some 20 miles north of Michelson Laboratory at an elevation of 4,880 feet in the Coso Range. Few places in the country could provide what China Lake offered:

> Primary and secondary test sites located in the Coso Mountain area have been selected so as to provide optimum operational and environmental test conditions. A variety of inter-site optical paths are available with lengths to 35 miles offering security from hostile observation and in most cases natural terrain backstop for absorption of high-energy laser radiation, if required.[81]

The initial installation, funded by NAVAIR with $400,000, featured instrumentation shelters, access roads, utilities, and three targets sites. Instrumentation included

> wide-band seven-track tape recorders, oscilloscopes, oscillograph, function generators, electronic counters, visibility measuring apparatus, spectroradiometers, secondary reference sources, optical power meters, and several types of lasers: helium-neon, tunable-dye, carbon dioxide, and neodymium-doped yttrium aluminum garnet (YAG).[82]

Jack T. Leininger, an engineer in Leroy Riggs' Electronic Systems Department, oversaw operations at the new range. In its first year of operation, the facility was used to evaluate in-house and contractor radiometers for use in a laser-intercept receiver, and new techniques were developed for the collection of baseline data. In the following years, Joshua Ridge rapidly grew in size, capabilities, and importance, and by 1980 the term "Test Range" was replaced by "Field Laboratory." Joshua Ridge has played an important role in testing a variety of Navy and DoD laser systems, such as the man-portable Modular Universal Laser Equipment, fielded with the Marines in the early 1980s and used in the Gulf War to designate targets for laser-guided munitions.

NWC was building its reputation as the place to go for optics. In 1977, 21 companies, 4 universities, and 6 government agencies all contracted with the Center for specialized optical-component measurements. Outgrowing its space in Michelson Laboratory, the Laser Damage Facility was moved to a larger area in Lauritsen Laboratory in 1977. By 1978, the facility had become "the most extensive component evaluation and pulsed laser damage facility in the Department of Defense." Improvements and expansion continued through

[81]Executive Secretary Robert McKenzie, memorandum, "Additional Advanced Written Material for the Center Board of Directors Meeting," 2.

[82]*NWC Tech History 1971*, 1-24.

the end of the 1970s, as lasers, and laser-damage, became less a theoretical study and more a genuine issue for developers of both offensive weapons and defensive/protective measures.[83]

During the 1970s, lasers and optics were areas in which the usually lengthy gap between pure research and technological payoff was dramatically reduced. As quickly as researchers published new results, engineers were implementing the breakthroughs in hardware. The old paradigm of researchers creating solutions for problems that didn't yet exist was no longer applicable. There was an urgency about the effort; an arms race was underway in the field of laser weapons and other military applications (range finding, target designation, chip manufacturing, and micromachining).[84]

The development of specialized optic and laser facilities and capabilities at China Lake led to DARPA announcing, in 1978, a major 3-year program to be managed by the Center. The goal was to develop a U.S. industry capability for producing optical components for use in pulsed excimer lasers.

Technology Base

Prior to the 1970s, there was little use of the term "technology base," other than as a catchall for the sum of the technologies that made up a given area, such as the fuze technology base or the propellants technology base. With the rampant inflation in the economy during the 1970s, however, and the drawdowns in the DoD budget, mid- and long-range planning became more important to the DoD. The missile of 5 years from now would be built with technologies that were presently in the developmental stage, some in the conceptual phase. The road from thinking to tinkering to actually testing and proving an item—a radar transmitter, an explosive initiator, a high-*g*-resistant fuze—was long and expensive. Planners and design engineers needed to know what was and what was not possible in a given time frame, which in turn required that they understand the current and anticipated state-of-the-art. The next logical step was to identify gaps or high-risk areas in the technology toward which resources could be directed.

Nationally, there was a growing awareness of the importance of technology as distinct from the products of technology. In 1972, Congress established the Office of Technology Assessment "to help legislative policymakers anticipate and

[83]*Rocketeer*, 13 January 1978, 3.

[84]In 1978, at the Air Force Weapons Laboratory, Kirtland, New Mexico, China Lake fired two air-intercept missiles (modified by the Air Force to simulate laser damage in flight) against target drones. Results were used to verify Air Force vulnerability analyses of the missile as part of the High Energy Laser Program. *NWC Tech History 1978*, 11-13.

plan for the consequences of technological changes and to examine the many ways, expected and unexpected, in which technology affects people's lives."[85]

Technology base, as an entity to itself, was a collection of building blocks available for future system developments or improvements and had been addressed at China Lake for years. However, the approach was shotgun and had no direction or coordination. Those who had the foresight to see technology needs in the out years scrabbled together the funding to try and lay the groundwork for those technologies, usually through 6.2 and 6.3 programs—getting beyond "possible" to "doable." But funding was erratic; some was in-house discretionary and some was from individual sponsors with interests in particular technologies.

Talk of "block funding" began in 1970. The concept represented a new approach to the tug of war for control of 6.2 Exploratory Development funds. Block funding would be chunks of money given to the laboratories to pursue exploratory development in specific areas—blocks—such as propulsion or fuzing or air weaponry. The question was, should the decision of what laboratory programs were worthy of exploratory development rest with Washington, which presumably had the big picture of the Navy's overall future needs? Or should it more properly be made by the individual Laboratory Director (Technical Director), who understood which of the research programs under his control were the most promising and worthy of additional development?

Not everyone at the laboratories liked the idea of block funding. Tom Amlie was among those who argued against it. In 1976, he told an interviewer, "If you just give a laboratory a huge wad of money and say, 'Go thou and do good,' they are not in competition with anybody anymore and they are going to fritter it away. . . . I think block funding is a disaster."

Amlie recognized that there was a problem in deciding how funds for research and exploratory development should be spent, and not all the answers were back on the East Coast. "The bureaucrats, the ones back in Washington, have quite literally never seen a guided missile," he said. "But they are in charge of spending hundreds of millions of dollars a year."[86]

Dr. Joel S. Lawson Jr., Director of Navy Laboratories (DNL), believed in keeping the control of research funding local.

> Personally, I'm dead set against block funding. . . . I have support from Dr. Frosch [ASN R&D], Admiral Davies [Deputy Chief of Naval Material

[85]OTA-ISC-374, *The Defense Technology Base*, unnumbered end paper.

[86]S-109, Amlie interview, 11–12. Amlie's solution: relocate the bureaucrats to the laboratories. "The people, once moved, will all buy Honda 50s for their kids and a camper for themselves. They would be a hell of a lot better off. Living in Washington is a drag." Ibid., 12.

> for Development], and Dr. Foster [DDR&E] to increase the Independent Exploratory Development [IED, locally directed applied-research funds] program. Thus the laboratory directors will have more funds under their direct control to do those things they think are important but perhaps cannot convince the bureaucracy should be done.[87]

Lawson did, however, concede that

> with the laboratories' greater involvement in systems development, they have a more immediate application of the technology development in 6.2. This also means there's a real danger of peddling their particular pet technology rather than the one that would be best for the system.[88]

Despite the opposition of Lawson, Amlie, and others, for better or worse, block funding was initiated. In May 1972, the CNM announced that "significant blocks" of 6.2 Exploratory Development funds would be sent directly to the Navy laboratories to fund broad technology programs "within functional areas selected in conformance with laboratory mission / function statements." The funds should lead to "direct contributions to advanced development within a three year period."[89]

While there was controversy about block funding, there was little dispute about the importance of a strong technical base. The technical base was not defined by the "color" of the money; rather, it was the aggregate product of all the 6.1, 6.2, and 6.3 developments. It was the crucial technical pieces of future systems, and the better it was documented, coordinated, and planned, the less likelihood there was for surprises at critical moments in a system's development.

Discretionary (undirected from outside the Center) technology-base funding at China Lake was known as Direct Laboratory Funding (DLF). Bob Rowntree remembered that

> at China Lake, they didn't have any particular ideas at that time, so what they did instead was take a bunch of existing and proposed programs and throw them in the hopper for DLF. [Associate Technical Director] LaBerge quickly became concerned at the hodgepodge of things that hadn't any organization to them, and so he asked that I become the manager.[90]

Under the DLF program, NWC submitted two task area plans (TAPs) for block funding to the CNM. These DLF TAPs, as they were called, were

[87]NWC, "Views of Dr. Lawson, an Interview With Dr. Joel S. Lawson, Jr., Director of Navy Laboratories/Laboratory Programs, Naval Material Command," *News and Views, Points of View and Information on Management Matters*, December 1971, 4.

[88]Ibid.

[89]NWC, *Action Items Deriving From The 9-10 November 1972 Advisory Board Meeting*, Encl. 1, 6.

[90]S-176, Rowntree interview, 5–6.

in the areas of advanced weapons technology and advanced weapons control technology. Both were accepted and funded.

In the past, farsighted work in developing new technologies for propulsion and warheads had been conducted with 6.3 funding. However, as Rowntree pointed out,

> the extent to which there was any formalized planning and coordination of that was pretty much nonexistent. People worked in the various technology areas, pursued what was fashionable, and—if the sponsors Back East agreed—had the tech-base-colored money to do it. If sponsors Back East didn't agree, well, one looked around for some discretionary overhead or procurement funds.[91]

Complicating the funding picture were two other sources of discretionary funding: Independent Research funds, which were largely delegated to the Research Department, and IED funds, which were administered by the Technical Director. In 1973, Howie Wilcox set up (at LaBerge's request) a funding review committee to jointly review the three programs once a year.

Rowntree attempted to bring order to a system that, previously, had seen the Technical Director and department heads as the chief arbiters of how the advanced development funds were spent. "The department heads' efforts tended to be short-term," he said,

> principally focused on day-to-day problems, and not much effort was spent thinking about where one wanted to be 5, 7, or 10 years hence, and what the totality of technologies would be that one would want at hand.[92]

The concept of block funding by technology-base area caught on. In a visit to the Center in November 1974, H. Taylor Marcy, the new Assistant Secretary of the Navy, Research and Development (ASN R&D), identified one of his preliminary goals for 1975: to "provide better consolidated or block funding of 6.2 (Exploratory Development Funding) dollars, rather than fragmented small support."[93]

A Center-wide reorganization in December 1974 established a new group called the Resources and Technology Office (Code 06, which reported directly to the Commander), under Leroy Riggs. Within the office, Bob Rowntree headed the Requirements Group, Richard M. Johnson the Resources Group, and Dr. Frank Cartwright the Technology Group. Riggs' responsibilities included "evaluation of long-range Navy requirements and assisting in the establishment

---

[91]S-176, Rowntree interview, 65.
[92]Ibid., 64–65.
[93]*Rocketeer*, 22 November 1974, 1.

of long-range goals and plans for the Center to meet these requirements." This office brought together the expertise to assess mid- and long-term technology goals in the context of the Navy's and DoD's ever more complicated Planning, Programming, and Budgeting System.[94]

When Riggs retired in 1975, Hillyer took over the Resources and Technology Office. Hillyer was promoted to Laboratory Director in November 1976, and the Requirements, Resources, and Technology Groups (now joined by Dr. Roger Fisher's Fleet Support Office) continued to report to him. In June 1977, Rowntree's title was changed to Head of Plans and Programs, and Conrad Neal took over the Technology Group. The following year, Rowntree's title was again changed, to Technology Base Coordinator (Code 031).

Richard M. Johnson.

Rear Admiral Freeman, who had taken over as Commander in the summer of 1974, just a month before Hollingsworth assumed the Technical Director's position, was an ardent supporter of technology-base work. In an all-hands meeting in 1977, he spelled out 17 areas that he believed were important for NWC planning efforts. The very first of these was a strong technology base. "A visible, dynamic, and innovative technology base is a direct source of our future military strength," he told the Center's military and civilian personnel. "By our management of block funding and our participation in the formulation of technical strategies, we can ensure more effective transition from exploratory development to operational hardware for the Fleet."[95]

At the outset, developing a workable block program was unchartered territory both for the bureaucrats Back East and for the laboratories, and because of the breadth of the programs involved, it was a complicated and time-consuming task. Frederick C. Alpers, an engineering legend at the Center

[94] *Rocketeer*, 13 December 1974, 3.
[95] *Rocketeer*, 13 May 1978, 1.

Dr. Roger Fisher.

who had come over from Corona in 1971, was drawn into the program. Alpers told an interviewer:

> Before Riggs left NWC, he assigned me as guidance technology manager in the Air Weaponry Block Program. I was the first guidance technology manager and I had to set up procedures, go back to Washington and try to get the different groups back there that were involved in that to talk to each other, and try to work it out here at NWC, too. Everybody had different ideas, and the Block Program coordinator and various technology managers had to try to get a coherent program out of it—to decide which project to push and which not. The Block had to support Washington in planning future weapons, and I would have to support the Block in what I thought guidance needs would be.[96]

Dr. Charles Thelen was one of the early block funding coordinators. On the staff of the Propulsion Development Department (later the Ordnance Systems Department), he would plan the missile-propulsion technology programs and assign projects and funds, both on- and off-Center. When he received a Sustained Superior Performance Award from Burrell Hays, his department head, in 1976, it was noted that the program he'd set up "was used as a model in establishing the NAVAIR Strike Warfare Block Program and the NAVMAT Smokeless Propulsion Block Program."[97]

Another innovator in the technology-base field was Clint Spindler. In 1973, as head of the Concept Analysis Branch in the Propulsion Systems Department, he began to develop weapon technology requirements and evaluate new weapon concepts for NAVAIR, including the first air weaponry "needs and concepts" document. Later he worked with Rowntree to find new technology-base work. As Rowntree recalled, "Clint Spindler and I did the leg work for Hillyer on a number of technology strategies."[98]

---

[96]S-118, Alpers interview, 87–88. Among Alpers' many awards during his 37 years of government service were the Arthur S. Flemming Award for outstanding young men in government service and the L. T. E. Thompson Award, China Lake's highest honor.

[97]*Rocketeer*, 1 January 1978, 5.

[98]S-176, Rowntree interview, 18. Upon his retirement in 1992, Spindler received the Meritorious Civilian Service Award.

Some things didn't fit neatly in boxes. Rowntree explained that

> there was a lot of China Lake tech base activity beyond the air weaponry block, and it didn't have a focus as the block program office did, so I tried to provide a place, a collection of information for people who wanted direction and advice about those things, and this gradually became the tech base coordinator's function.[99]

Dr. Charles Thelen.

Over time, block funding struck a balance between the needs of those in Washington and the laboratories. With specialists such as Rowntree, Alpers, and others to look at the big picture from a local level, the funds could be applied to areas that would best serve the Navy's technology-base needs and at the same time make the most effective use of the Center's expertise and experience.

Clint Spindler.

An understanding of the technology base—what was and what wasn't feasible within a given time frame in a specified area of technology—was beginning to have an impact on program direction. In 1977, the *Tech History* reported on development of an aimable warhead for the lightweight torpedoes used in shallow water. The developers discussed initial test results and then stated:

[99]Ibid.

> The test difficulties indicated that the technology base was insufficient to allow further evaluation of this warhead concept during the technology assessment phase. . . . Further exploratory development efforts are needed to provide the technology base and at least establish that potential performance improvements are possible.[100]

Further, they recommended that

> exploratory development support be provided by the NAVSEA undersea weaponry block program to establish the necessary technical base by investigating the effects of individual parameters on total warhead performance.[101]

Technology-base funding, like basic research funding, was sometimes a target when weapon developers were looking for money to spend on more "practical" aspects of the acquisition system. A 1988 report from the Congressional Office of Technology Assessment observed that

> funding for technology base programs is particularly vulnerable during times of tight budgets. . . . The lack of obvious, tangible outputs from R&D projects makes the value of individual programs difficult to define. Technology base programs are particularly vulnerable to "raiding" to support programs in procurement or the later stages of development.[102]

China Lake saw that vulnerability first hand. In a report for Bob Hillyer, prepared for a 1980 Commanding Officers / Technical Directors meeting in Washington, John Bodenburg wrote:

> The aforementioned period [fiscal years 1975 through 1980] has seen a decrease of 17.5 percent in constant 1980 dollars in NWC Independent Research (6.1) discretionary funding, and a decrease of 64.5 percent in constant dollars in Independent Exploratory Development (IED, 6.2) discretionary funding. During the same period the NWC block-funded advanced development (6.2) programs experienced a diminished support averaging 15 percent in constant fiscal year 80 dollars. The technology-oriented Advanced Development programs have suffered funding losses during the last several years, averaging 18 percent per year in constant dollars.[103]

In 1985, in his last full year as head of the Research Department, Royce was also double-hatted as Technology Base Director, Code 01T. (Rowntree remained as Technology Base Coordinator, Code 01T1.) Royce's new high-level

---

[100] *NWC Tech History 1976–1977*, 9-85.

[101] Ibid.

[102] OTA-ISC-374, *Defense Technology Base*, 5. That report was prepared with the assistance of the Defense Technology Base Advisory Panel—chaired by Walter B. LaBerge, Vice President of Corporate Development, Lockheed Corp.

[103] "Center Issues 1980," appended to S-115, Bodenburg interview.

office was similar in function to the earlier Resources and Technology Office and was established to pull together the varied technology-base programs under a single umbrella for more efficient and responsive use of the Center's resources. At the time, more than 600 Center personnel were involved in technology-base efforts at China Lake.

Announcing the formation of the new organization, Technical Director Burrell Hays said, "Much technology base work in our mission area hasn't been explored. With the new organization we should be able to achieve maximum success in meeting Navy needs."[104]

Center involvement in technology base development has steadily grown. In the 21st century, China Lake continues to maintain a strong technology base program through basic and applied research in the physical sciences. Now, as in the past, a successful research program requires a simple combination: the right tools, the right people, and adequate funding. As Dr. Hunter said at his retirement ceremony, "When you want to do something to assist research people, give them what they need and get out of the way."[105]

[104]*Rocketeer*, 22 March 1985, 3.

[105]*Rocketeer*, 11 June 1976, 4. At his retirement ceremony, Dr. Hunter was presented with the Navy Meritorious Civilian Service Award.

16

Looking to the Future

Aside from our people, the greatest asset this Center has is its ranges. Over the past decade they have suffered from "benign neglect," and modernization is long overdue.

—Rear Admiral Rowland G. Freeman III,
NWC Commander, 1974–1977[1]

China Lake was feeling pretty smug back in 1968. The base was celebrating a quarter century of Fleet service, more than half of which took place during war time. Secretary of Defense McNamara, as quoted in the 1968 *Tech History*, stated that "80 percent of the air-launched weapons used in the free world" had been developed by the Center. The *History* also reported that "NWC designs have been responsible for some 40 billion dollars in production orders to industry." China Lakers were on ships at sea and on the ground in Southeast Asia. Admiral Tom Moorer, a former China Laker, was CNO, the Navy's senior flag officer.[2]

Yet over the following decade, signs of decline appeared. The Vietnam War ended, and with the defeat came a reduced need for such Center-developed weapons as Snakeye, Rockeye, and Shrike—the most-fired guided missile in history. Nationally, the economy slipped into a post-war decline marked by double-digit inflation and ballooning debt. The cost of energy skyrocketed. In Washington, there was growing support to transfer many of the laboratories' activities from civil service to contractor performance, pursuant to OMB Circular A-76. At China Lake, a series of reorganizations and reassignments rattled the workforce, and, as pressures mounted for civilians to move off the base, the traditional culture of civilians and military working and socializing together began to erode.

[1] *Rocketeer*, 25 March 1977, 4, speaking of Project 21.
[2] *NWC Tech History 1968*, 1-3.

A significant indicator of deterioration, one suffered by any organism, biological or institutional, was that things began to wear out. Technology that had been state-of-the-art when the base's infrastructure was first built was obsolescent, and in some cases, already obsolete. On the research side of the house there had been some bright spots—notably the 56,000-square-foot $3.46 million Lauritsen Laboratory for laser research, which was dedicated in 1976—but there was little renewal on the China Lake range complex, that assemblage of instrumented facilities that constituted the "T&E" in RDT&E. Wood structures were decaying, metal was rusting, equipment was burning out, facilities were approaching (and most exceeding) their expected useful life. Operations and maintenance (O&M) costs were increasing.[3]

Lauritsen Laboratory.

The term "range" was used broadly at China Lake. It could be the sprawling Airport Lake Range, 38 square miles of desert playa where nearly anything could be blown up without threat to life, limb, or structures. Or it could refer to highly specialized facilities such as the Accidental Release Track, a 220-foot track where engineers simulated ordnance items breaking free from aircraft during arrested landing on a carrier deck.

[3]A 1977 study carried out by Bob McKenzie's Management Analysis Branch concluded that more than 75 percent of the range equipment had exceeded its life expectancy.

Many of the Center's ranges, such as the 121-square-mile Baker Range, had been in continuous use since the base's establishment in WWII and had seen little upgrading since their creation. Ranges designed for WWII-era aircraft and weapons were now being called on to host tests of systems that were faster and more complex. Range customers demanded copious amounts of data about the systems and subsystems under test, and they wanted it now. Range instrumentation was, to put it charitably, dated, and in some cases was unable to deliver the necessary resolution or to even measure the parameters that weapons developers needed for newer, faster, more precise weapon systems.

Aircraft Survivability

There had been some progress through the years. In 1970, for example, a new facility was established at China Lake's K-Range, 6 miles east of Armitage Field. It was officially referred to as the Aircraft Survivability Range (or sometimes Aircraft Survivability Complex) but generally referred to simply as Aircraft Survivability. The new capability was created in response to the shocking number of U.S. aircraft that had been lost during the Vietnam War—more than 7,610.[4]

No aircraft could withstand a direct hit by a SAM or an accurate burst from a radar-guided ZU-23 antiaircraft cannon firing 23 mm projectiles at a rate of 1,000 rounds per minute from each of its twin barrels. In Vietnam, however, aircraft (particularly helicopters) were even being brought down by rifle fire from ground troops. While technological innovators in weapons laboratories had been concentrating on refining the weapons of war (the swords), the technology to withstand the enemies' weapons (the shields) had been neglected. To increase the survivability of U.S. aircraft, their vulnerabilities had to first be understood.

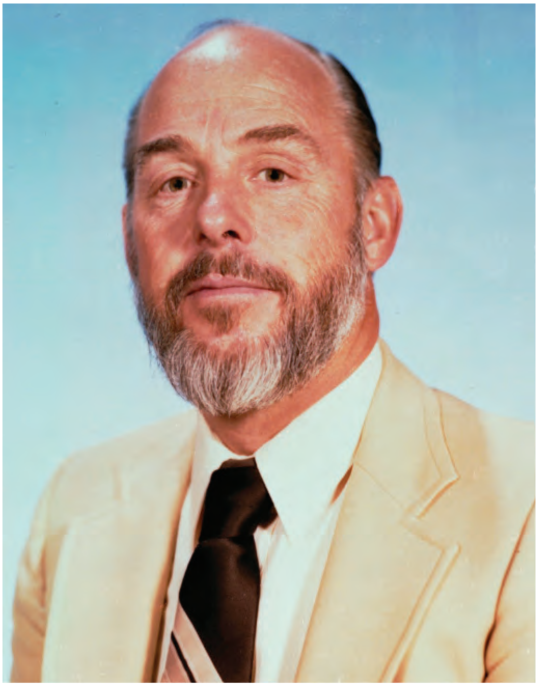
Jay Kovar, who would later head NWC's Weapons Survivability Laboratory, described survivability as the third link in a kill chain. The challenge is, first, to escape detection; failing that, to avoid the threat weapon itself; and failing that, to survive the engagement. Put simply, "Can you see me? Can you hit me? Can you kill me?"[5]

NAVAIR funded the construction of the facility, designating China Lake the lead laboratory for a long-range R&D program "on the vulnerability and survivability of combat Navy aircraft." The focus of the work was ballistic impact survivability: "the ability of an aircraft to continue to function after

[4]Clodfelter, *Warfare and Armed Conflicts*, *Volume 2*, 1,290.
[5]S-385, Kovar interview, 2.

being hit by small-caliber projectiles, fragments, or blast from air-to-air and ground-to-air guns and missiles." Jerry Reed was named program manager.[6]

Hugh Drake, who ran the Warhead Analysis Branch in Paul Cordle's Warhead Division, was one of the experts brought in to assist in survivability studies. In his previous work, he'd focused on the "sword" side of the equation: "We did the warhead testing, gathered the information, characterized the warhead, and analytically assessed the ability of that warhead to kill the targets it was supposed to kill." The flip side of that work was target vulnerability, and there was a synergy between the two fields.


Hugh Drake.

> We did a lot of redesign on aircraft, to aid the aircraft in survival, the crew as well as the aircraft itself. We continued our vulnerability work against targets so we could not only support aircraft survivability but also our warhead weapons-analysis work.[7]

Much of Drake's warhead work had been done in conjunction with the triservice Joint Technical Coordinating Group for Munitions Effectiveness, which was established in 1964. In 1971, again in response to high U.S. aircraft loss rate in Vietnam, the Joint Technical Coordinating Group for Aircraft Survivability was established. It served as a vehicle for sharing many of the advances that grew out of the testing done at China Lake's dedicated survivability facility.

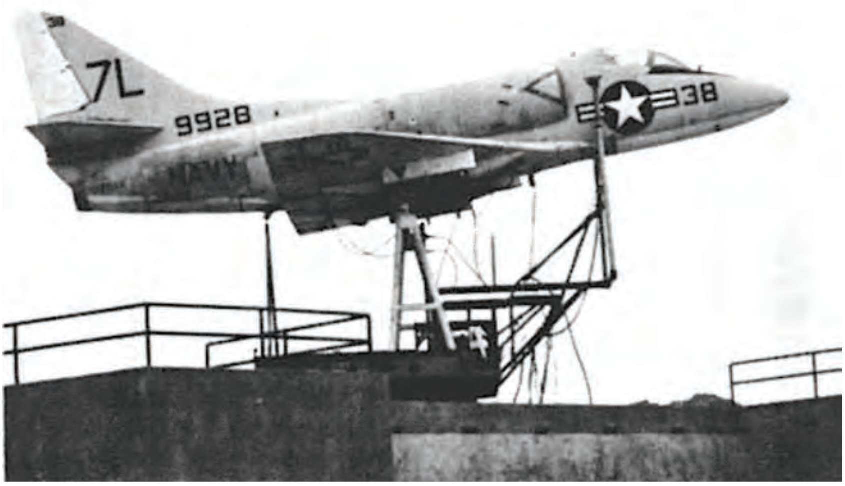
Unique to the Aircraft Survivability Range was the ability to fire a variety of projectiles into a full-scale aircraft (up to 100,000 pounds) running at up to 50,000 pounds thrust under controlled conditions. The aircraft was mounted on a turntable, rotatable 360 degrees in azimuth and plus or minus 15 degrees in elevation. The size, speed, angle, and trajectory of the projectile

[6] *Rocketeer*, 23 January 1970, 1.

[7] S-333, Drake interview, 4. In 1975, the functions were joined organizationally with the formation of the Survivability and Lethality Division, which Drake was selected to head.

could be controlled, as could the precise point at which it impacted the aircraft. Instrumentation included still, motion, and TV cameras as well as 50 channels for telemetered data. An airflow generator simulated various flight conditions. Control of aircraft engine speed, gun firing, camera and instrumentation, and firefighting equipment was performed by test engineers in a fire-control building.

Testing at Aircraft Survivability began immediately after its completion in the summer of 1970. By 1972, some three dozen A-4s and F-4s (stricken from the active aircraft list) were awaiting testing in the 6-acres storage area at Aircraft Survivability. Tests that year also included lightning-strike damage assessment. In 1973, NAVAIR invested more than $1 million in the program, and the high-velocity airflow system was added in 1974.



Dynamic testing of A-4 Skyhawk fuel-system vulnerability to 12.7 mm Soviet projectiles, Aircraft Survivability Range, October 1971. Published in the *Rocketeer*, 19 November 1971

Initially, the facility's work consisted of research, experimentation, and analysis of aircraft systems (e.g., fuel systems) and components to determine where redesign efforts were needed. As the results of the testing flowed back into the aircraft design community, the facility was also used to validate the survivability value of improvements to new designs.

But the Aircraft Survivability Range was an exception to the overall obsolescence of the China Lake ranges. Across the Center, range managers, maintenance personnel, test engineers, technicians, and planners were struggling to keep pace with a decaying infrastructure, heavier test load, faster weapons with larger footprints, and increasing demands from test customers for more sophisticated data products, delivered in as close to real time as possible.

John Di Pol had come to China Lake as a mechanical engineer in 1950, and by 1975, he was associate head of the T&E Department. He said:

> We had range improvements at times, you know, even from the early years, but on a sustaining basis they have been at a very low level, way less even than was required to replace equipment that was simply wearing out and breaking down, much less replace equipment that can do better things and do it cheaper and more effectively.[8]

When new range development did happen, it came in spurts and was usually driven by a specific customer's needs. "Most of those [improvements] tended to be related to a particular project or particular function," Di Pol commented. "For instance, the original Polaris program caused a large number of facilities in the propulsion test area to be built. Polaris put up the bulk, if not all, of the money, and they were the driving force."[9]

Declining range conditions had been accompanied by a decrease in range business and a corresponding reduction in the number of range personnel. "I think they went from about 500 people in 1960 down to about 230 or 40 when I went out on the range in '73," said Bill Hattabaugh, who was selected as head of the T&E Department in June 1973.[10]

For a major Navy laboratory that prided itself on providing comprehensive T&E services throughout the weapon development process, the situation was neither healthy nor sustainable.

In the early 1970s, DoD studies recognized the fact that certain T&E facilities were not only service-specific assets but were unique national assets that required DoD-level attention. In 1975, the DoD established the Major Range and Test Facility Base (MRTFB), which included 25 facilities nationally, 7 of them Navy. China Lake's T&E facilities were included as one element of the MRTFB. The purpose of the new organization was to apply uniform DoD policies (including funding policies) to their operation, to facilitate interservice use of the facilities, and to minimize duplication of effort.

---

[8]S-119, Di Pol interview, 4.

[9]Ibid.

[10]S-127, Hattabaugh interview, 6.

Project 21

It was against this backdrop that the Center, in December 1975, received a new instruction from the CNM. Naval Material Command Instruction (NAVMATINST) 5450.27A set out a detailed description of the missions and functions of the nine field activities commanded by Admiral Frederick H. Michaelis, Chief of Navy Material. These activities were NWC, the Naval Air Development Center (NADC), Naval Coastal Systems Laboratory (NCSL), Naval Electronics Laboratory Center (NELC), Navy Personnel Research and Development Center, David W. Taylor Naval Ship Research and Development Center, Naval Surface Weapons Center, Naval Undersea Center, and Naval Underwater Systems Center. In total, the CNM field activities employed 21,000 people and had an annual budget of about $1,300,000,000.

Since the laboratory reorganization in 1967 that created the "Centers of Excellence," there had been confusion and competition regarding which of these nine organizations was supposed to do what, and for whom. The background section of 5450.27A noted that when the CNM had taken over the field activities in 1966, "these activities had been operating under broad mission statements and often overlapping functional assignments which resulted in competition for resources and some nonessential duplication of effort." The original NAVMATINST 5450.27, issued in 1972, had sought to reduce that overlap. The current instruction was "intended to further that effort, and to foster and stimulate closer cooperation among these activities."[11]

The text of the new instruction spelled out the formal mission of each organization as well as the product lines, and it mapped the product lines to CNM product areas. At China Lake, for example, under the CNM product area Free-Fall Systems were three of the Center's product lines: bombs, dispenser munitions, and fuel-air explosive (FAE) systems.

Also included for each organization was a section called Specialty Products. These were defined as "categories of work that either fall outside the [product areas] or outside their nominal mission and functional assignments. This results from their particular competence, special facilities, and other special circumstances."[12]

At China Lake, these specialty products included 19 different product lines, ranging from "communications systems/equipment (electro-optical air-to-surface and surface-to-air)" to "explosives (safety studies, materials, arming and fuzing, explosive devices, performance, and testing)." The specialty

[11]NAVMATINST 5450.27A, *CNM-Commanded Laboratories and Centers*, 2.
[12]Ibid., 4.

products included such items as swimmer vehicles and weapons, for which the principal laboratory was NCSL, and airborne subsystems (propulsion, sensors, data links, recovery guidance, and ground stations), for which the principal laboratory was NADC.[13]

It was clear that there was a lot of overlap in the work that the laboratories were doing. Pentagon leaders still clung to former Secretary of Defense McNamara's precept that duplication meant waste—although there was widespread belief in the laboratories that duplication actually meant competition and resulted in better products for the Fleet.[14]

One mechanism by which NAVMATINST 5450.27A attempted to enhance efficiency and reduce duplicative efforts among the field activities was by ordering each to prepare a 5-year program plan that would be reviewed and approved by the CNM. The plans would set forth "the work assignments that can be anticipated based on the latest approved Five-Year Defense Plan (FYDP)" and would also include an annex that

> extends this plan out to ten years for purposes of determining resource needs which involve longer lead times, such as personnel needs and goals, special facilities to be built with military construction (MILCON) funds, and major new computer acquisitions.[15]

China Lake management decided to take on an even more daunting task than a 5-year plan with a 5-year annex. The *Tech History* reported:

> It was clear that one of NWC's principal assets was the unique combination of remote desert real estate, dedicated military airspaces, and instrumented facilities that constitutes the Center's range complex. It was also clear that in fiscal year 1977 technical requirements for range facilities would begin to exceed current capabilities.
>
> In order to identify the required major capital improvements to its T&E base, the Center began in January 1976 to outline a 25-year modernization plan for its ranges.[16]

The effort was assigned the name Project 21, since it was designed to prepare China Lake for 21st century T&E requirements.

---

[13]Ibid., Enclosure 9.

[14]The CNM Five-Year Plan, issued in 1977, asserted that NAVMATINST 5450.27A had been "developed to redress the imbalance between competition and cooperation" at the Navy's laboratories and centers. DNL, *Corporate Plan for Laboratories Commanded by the Chief of Naval Material*, January 1977, 1-1.

[15]NAVMATINST 5450.27A, *CNM-Commanded Laboratories and Centers*, 6.

[16]*NWC Tech History 1976–1977*, 1-4.

Bill Hattabaugh was assigned the task and selected Jerry Reed, head of his Project Engineering Department, to lead the project. "I was on the old Test and Evaluation Resources Board that John Di Pol chaired," Reed recounted in 1983, after he had moved on from China Lake to become Technical Director of the Joint Cruise Missile Project Office in Washington,

> and we used to go over and carve up the funds that were set by NAVAIR. And there was so little there that we all said we ought to do something about this. We ought to convince people that there's a greater need, there are cost benefits to throwing out the old and bringing in the new. There are technical benefits. And we did.[17]

Reed built a team, drawing experts from across the Center, and within a month of the receipt of 5450.27A, the group was hard at work. In less than 6 months they completed the study. In June 1976, the results were presented to the Assistant Secretary of the Navy for R&D. "We got the help of some very bright, capable guys like Hank Snell, and Bruce Bonbright [both from the Office of Finance and Management]," Reed said,

> and an army of technical people, Bill Lamb [head of the Test Support Division in the T&E Department] and his whole gang, and the Electronic Warfare people and others, and really built the underpinnings of an extremely solid plan, technically, with time lines connected to cost-benefit analysis.[18]


Bill Lamb.

Also taking lead roles in the project were Bruce Wertenberger, in the T&E Long-Range Planning Office; Cecil Daley, for the northern range complex; Ron Morey, for environmental, warhead, and propulsion test facilities; Jerry Macy, financial management; and Ed Pyle for the Electronic Warfare Threat Environment Simulation (EWTES, or Echo) Range. Not to be overlooked was NWC's Commander, an enthusiastic supporter of China Lake's

[17]S-151, Reed interview, 19.
[18]Ibid.

T&E mission. "Admiral Freeman . . . was a very, very solid supporter of our ranges and our test facilities," said Di Pol. "He recognized the value that they were to the Center as a whole, and he gave us a lot of support, both material and management support."[19]

Ron Morey.

Rear Admiral Freeman said of Project 21:

> Aside from our people, the greatest asset this Center has is its ranges. Over the past decade they have suffered from "benign neglect" and modernization is long overdue. Project 21 is an ambitious plan, but its payoff in terms of more capability and economical testing is readily apparent. I view the execution of this plan as one with a very high priority in the Center's future efforts.[20]

Carefully constructed, using anticipated U.S. and threat capability predictions that were generated in conjunction with the Weapons Planning Group's intelligence library, the Project 21 study was a masterpiece of cooperative effort. Experts from sponsors' offices in Washington were consulted, and Reed's team worked closely with representatives from NAVAIR's Assistant Commander for T&E (AIR-06), the Office of the CNM (MAT-03), and the Office of the Chief of Naval Operations (OP-983).

Two types of modernization were recommended by the study team.

> The first category includes improvements that will result in higher operational efficiency and reduced cost of operation [e. g., replacing aged equipment]. . . . The second category includes new capabilities required to meet technical requirements [such as developments and improvements at Echo Range].

[19]S-119, Di Pol interview, 5.
[20]*Rocketeer*, 25 March 1977, 4.

The plan looked for investments in centralization, automation (in anticipation of decreased billet allocations), and modernization that would increase productivity of the Center's T&E ranges and facilities and enhance their usefulness for weapons developers and other range customers.[21]

Range requirements in three time frames were considered: near-term (fiscal years 1977–1981), mid-term (fiscal years 1980–1990), and long-range (fiscal years 1991–2000). Richard Murphy, special assistant to the head of the Weapons Department, assisted by people from several departments, oversaw the requirements studies. Most accurate were the near-term needs based on project plans and interviews with sponsors. Mid-term data were extracted from observed technology trends and existing plans, such as the *Naval Aviation Plan*. For the far-term, the planners looked to the CNO's then-in-progress *Sea Plan 2000: Naval Force Planning Study* and similar documents.

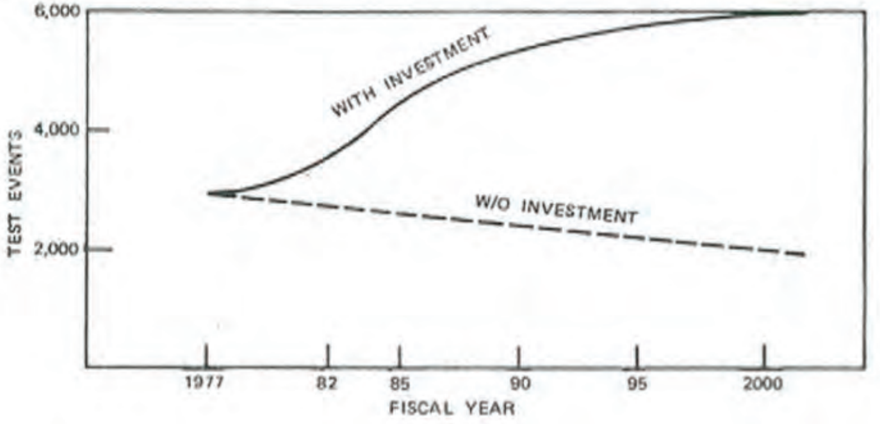
A key element of the NWC range-modernization plan, and a big factor in the Center's subsequent receipt of modernization funds, was the meticulous financial data presented in a series of life-cycle costing analyses. The analyses showed that the Navy, by making significant investments in the T&E infrastructure, could in the out-years save amounts far exceeding the initial investment costs. Cost-avoidance mechanisms would include not only reduced O&M costs but also money saved by customers who received rapidly produced high-reliability data packages. The detailed analyses were backed up by figures that graphically portrayed the potential savings.

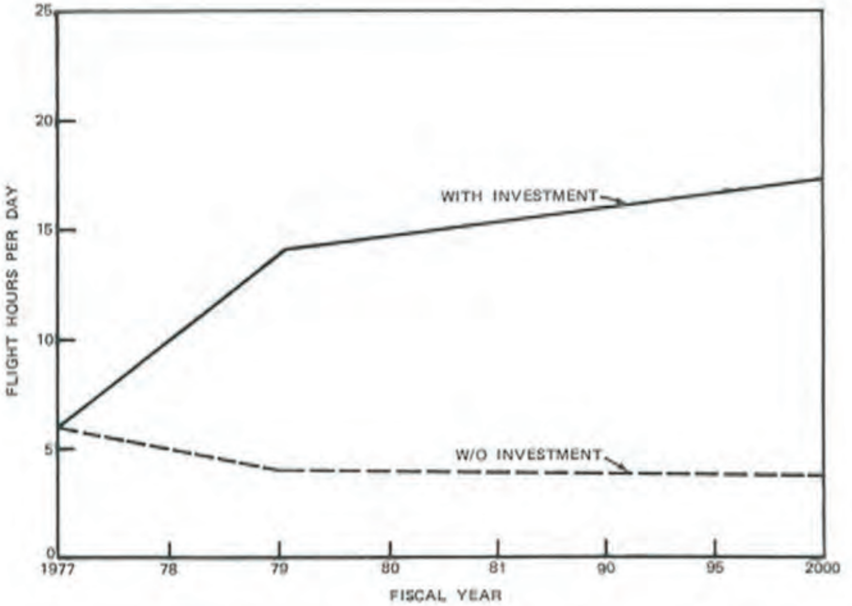
In October 1976, at the request of NAVAIR's Assistant Commander for T&E, Rear Admiral William L. Harris Jr., a 3-day long-range T&E planning seminar was held at NWC. Reed, who had become head of the Long-Range Planning Office, coordinated the event. Attending were representatives from the Navy's MRTFB institutions, the core members of the DoD's T&E infrastructure, as well as from the Air Force and Army.

Rear Admiral Harris was impressed with China Lake's study to the point that he directed all of the Navy members of the MRTFB to submit, by February 1977, a 25-year plan for range and test facility modernization based on China Lake's Project 21 model. In addition, Reed was selected to head a study team developing a 5-year plan for all the Navy's T&E facilities. The group recommended a $165 million Navy-wide modernization program, which began in fiscal year 1979.[22]

[21]NWC AdPub 170, *Project 21*, 1-1.

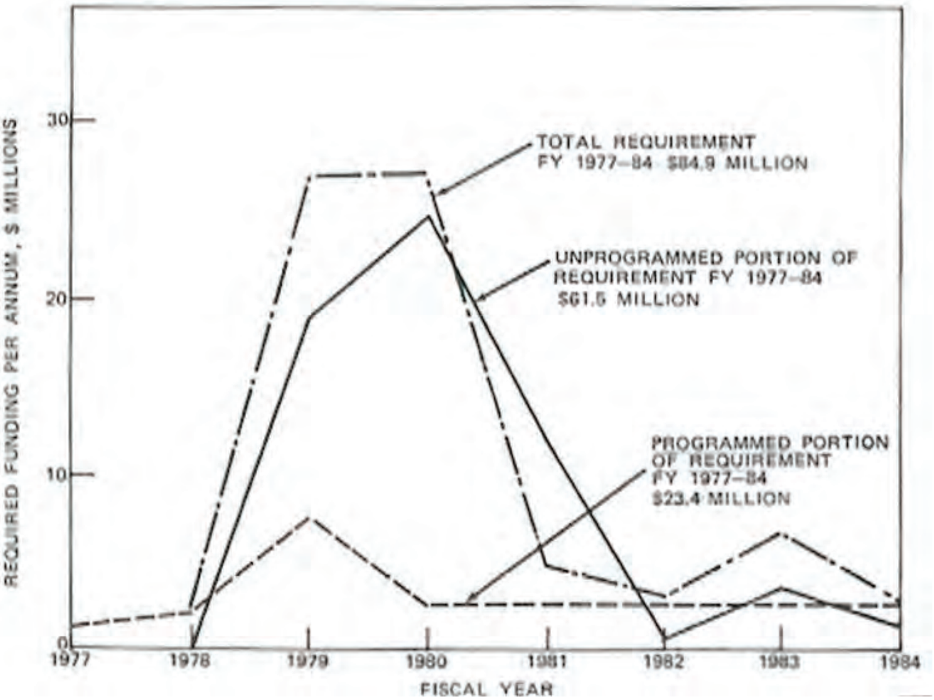
[22]In September 1977, Rear Admiral Harris would report for duty as NWC's Commander.





Typical graphs from Project 21 study. Top: warhead, propulsion, and air/ground ranges productivity. Bottom: Echo Range productivity. Published in D558 AdPub 170, *Project 21*, February 1977.

China Lake was not seeking a blank check for modernization. The base spoke in specific dollar amounts and identified the individual projects on which the funds would be expended. First on the list was a Range Control Center (RCC) that would centralize range operations and planning activities.



NWC T&E funding requirements, fiscal years 1977 to 1984. Published in D558 AdPub 170, *Project 21*, February 1977.

Project 21, A Long-Range Modernization Plan for the NWC Ranges was published in February 1977. It consisted of three volumes: an unclassified summary, a more-detailed classified data volume, and a classified volume dealing exclusively with the unique needs of Echo Range. It was followed in September by a second report, unclassified, that summarized the Project 21 planning data and listed specific costs for individual projects.

As a result of Project 21, China Lake received "substantially increased institutional support." A $70 million master plan for T&E modernization was approved, with the first focus on the north ranges (the primary air and ground ranges) and later encompassing propulsion, warhead, electronic warfare (EW), and tracks. Project 21 served as a roadmap for range modernization throughout the 1980s and also provided the impetus for Navy-wide long-range T&E planning and investment.[23]

Jerry Reed said:

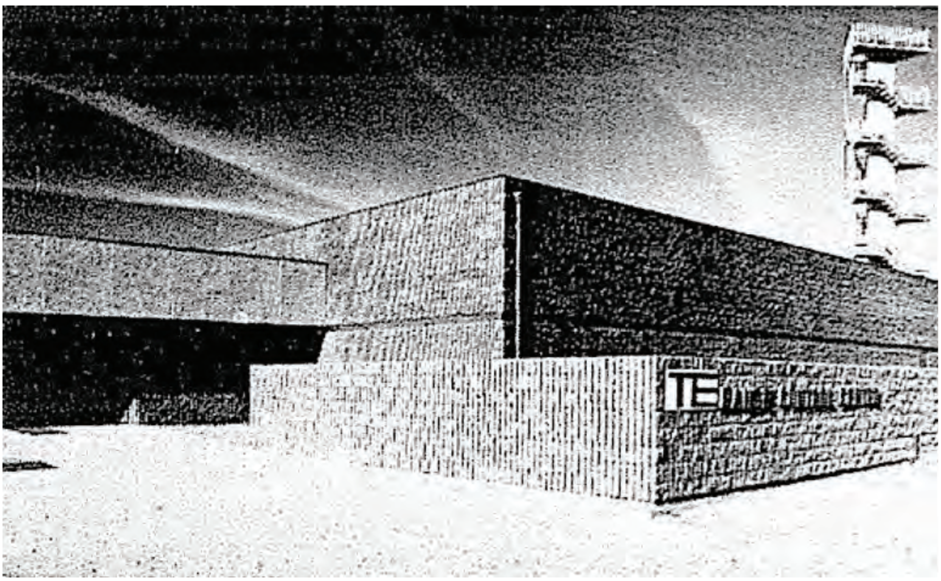
> We teed everybody in the world off. We came back to NAVAIR and sold [Project 21] and then, of course, NADC and PMTC [Pacific Missile Test

[23]*Major Accomplishments of the Naval Weapons Center*, 190.

> Center] said, 'Wait, a minute you guys, you're too far out in front.' So we had to wait until they caught up. That's facts. Now I think it was wise to wait till they caught up, because I feel good when I go down to PMTC or to NADC and see the benefits down there as well.[24]

RCC

Most urgent of the needs for the China Lake ranges, according to the Project 21 study, was a centralized control and monitoring facility that would consolidate air and ground test control, telemetry, range communications, and drone operations. This MILCON project was approved in 1977; it was called the RCC and was scheduled for construction during fiscal year 1979.



Range Control Center, circa 1981. Published in NWC TP 6413, *Major Accomplishments of the Naval Weapons Center*, 1982.

The $3.5 million project ($11.5 million in 2021 dollars) would include construction of a 34,000-square-foot building to serve as the hub of China Lake's range test activity. Located just east of Armitage Field at the intersection of Water Road and Charlie Range Access Road, the RCC would

> centralize existing air-range test-control centers; control and scheduling of the ground and airspace of all NWC ground, air, and track ranges; surveillance

[24]S-151, Reed interview, 19. Reed left China Lake for NAVAIR in June 1980 to become Technical Director of the T&E Group (AIR-06B).

> radar monitoring systems; drone target control facilities; real-time data processing and test data display and control facilities; and all associated support facilities.

Equipment for the RCC was requested separately from the MILCON through a project analysis memorandum approved by the CNO. [25]

Bids were solicited for the building in 1978, but when they were received and opened in December, all of them exceeded the $3.5 million available for the project. Redesign was done, and the square footage was reduced to 32,000 square feet. Bids were once again taken, and in July 1979 a contract was awarded by Western Division Naval Facilities Engineering Command to the J. R. Youngdale Construction Company of San Diego (the same firm that had built Lauritsen Laboratory). The bid amount was $3,229,500.

Telemetry expert Fran LaPierre was the RCC program manager. Overseeing construction of the RCC building itself was only part of his challenge; the functional core of the facility was to be the Range Control Center Integration and Processing System (RIPS)—a computer center, a range-status center, a range-coordination center, and three test-control centers.

Between the new technologies involved, the large number of instruments and facilities to be interconnected, and the sheer physical distance between range elements, just getting a handle on the overall RIPS architecture was a major task. Among the existing or envisioned functions that would need to be integrated into a single system were range scheduling; restricted-airspace surveillance; range communications; data collection and reduction; meteorological soundings; standard and metric video collection; a yet-to-be-installed on-axis data system; bomb scoring; telemetry; range timing; safety and flight termination; and monitoring and control of all test aircraft, including drones.

In October 1979, a conference was held at China Lake as a preliminary step to seeking bids for the RIPS. The invitation to potential RIPS contractors and manufacturers asked them to be

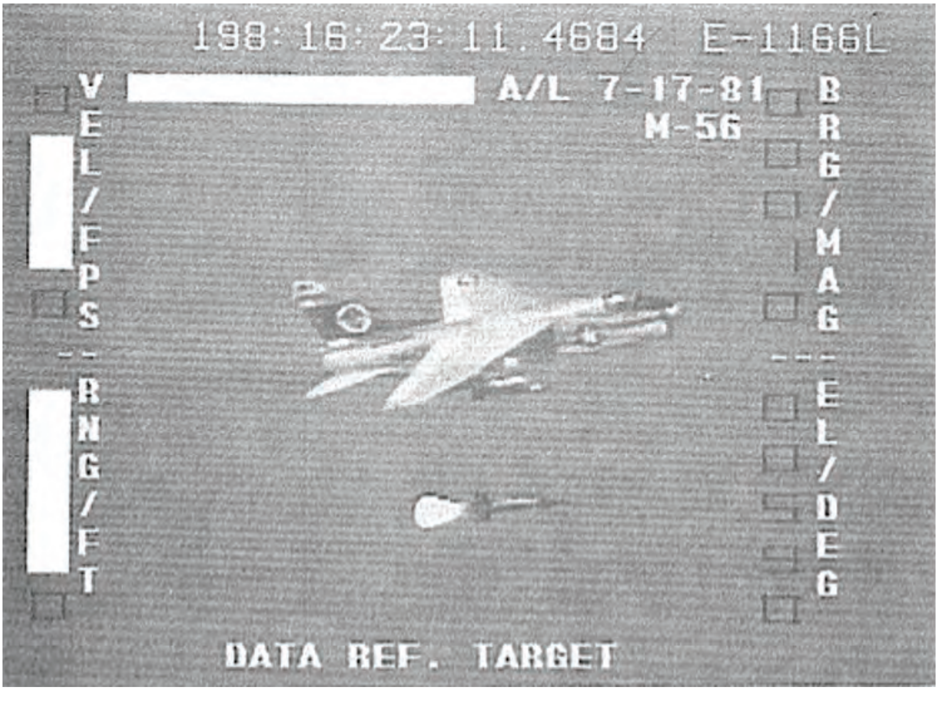
> prepared to comment on such matters as complexity of the RIPS requirements relative to the state-of-the-art; possible revisions that would allow a more cost-effective approach or solution; changes that would provide maximum increases in capability with a minimum cost impact; and revisions that could provide maximum utilization of off-the-shelf hardware or software instead of having to develop such equipment for use in the Range Control Center.[26]

---

[25] *NWC Tech History 1976–1977*, 11-27.
[26] *Rocketeer*, 26 October 1979, 5.

Representatives from 17 contractors and manufacturers attended the 1½-day event chaired by LaPierre. After presentations by NWC personnel on the various systems that would interface with the RIPS, a "lively interchange," as the *Rocketeer* put it, ensued between the industry visitors and LaPierre and his RCC systems engineering team, headed by Robert A Harriman. That team included six representatives from Computer Sciences Corp., the RCC's systems engineering and technical-assistance contractor.

The following year, the RIPS was put out for bid. Installation and system integration, at a cost of $11 million, was not completed until 1984, but the RCC became operational (with 120 employees) in 1981. That year, the metric-video system was integrated with the RCC. Replacing the old camera-and-film system that had been used on the ranges for decades, metric video (invented by China Lake engineer George G. Silberberg) was faster and cheaper—it could stop action at effective exposure times from 1/500 to 1/10,000 of a second. As video came in from range tests, computers imprinted it with timing and bookkeeping data in near-real time.



Metric-video image with pertinent test data displayed in the RCC. Published in *CTE*, 4 June 1982, in S255, Silberberg material.

As well as consolidating test activities for the north ranges—Baker, Charlie, George, Airport Lake, and Coso Military Target—the RCC also controlled selected activities at Randsburg Wash and the Mojave B Complex. To minimize microwave bandwidth and frequency allocation issues, the various range instrumentation systems, where possible, were connected to the RCC by underground TV and wideband data transmission lines.

Customers from both on and off Center scheduled additional time on the ranges. Bill Hattabaugh reported in 1981:

> We now only do 50 percent of our work on the range for the laboratory. The other 50 percent is for all other customers outside, and that part of our business is growing. The laboratory business stays about steady, but I see a larger share of our business on the ranges and the aircraft facility utilization being from outside customers in the future.[27]

Project 21 led to a technological renaissance on the China Lake ranges in the late 1970s and early 1980s. In addition to the RCC—which in 2021 was still the keystone of range operations at the Center—China Lake installed in 1979 the on-axis data system, a star-field calibrated tracking radar with slaved optical systems that greatly enhanced the quality of time-space-position information (TSPI) collected during range operations. In 1979, the Center was also funded $3 million to procure the integrated target control system (ITCS) for remote control, tracking, and telemetry linking with airborne targets. In 1 week during February 1984, ground-breaking ceremonies were held for the $4.5 million Range Operations / Instrumentation Laboratory adjacent to the RCC and the $6.6 million Trident II Rocket Motor Vertical Firing Facility located at Skytop. More projects would follow as the Center followed the roadmap set out by Project 21.[28]

As important as Project 21 was for the Center, it was perhaps more significant to the Navy. It set a model for systematized cost-effective modernization of ranges and facilities based on an in-depth "big picture" of current and anticipated Navy needs, careful analysis of present capabilities versus realistically expected requirements, and rigorous cost-benefit analysis of alternatives.

Project 2000

Witnessing the success of Project 21, managers and planners around the base began to think of similar projects that might justify additional investments in their own infrastructure. Clarence Renne, who headed the Engineering Division in Burrell Hays' Ordnance Systems Department, recalled, "We decided

[27] S-127, Hattabaugh interview, 6.

[28] *Major Accomplishments of the Naval Weapons Center*, 147. In 1982, it was estimated that the total investment in NWC's ranges over the decades—land, buildings, and equipment—was nearly $500 million.

that [Project 21] worked out so well for the Test Department, the capabilities in our department were degenerating. . . . let's do a study up here."[29]

Rich Printy, who would take over the Engineering Division when Renne retired, took on the task. After they had been working the study for a while, Renne recalled:

> We went down along with Burrell and made presentations to the Technical Director [Bob Hillyer] and the Commander [Rear Admiral Harris] . . . Then they decided, "Okay, that's very good, except why are we doing it just for one department? Let's do it for the whole Center."[30]

Clarence Renne.

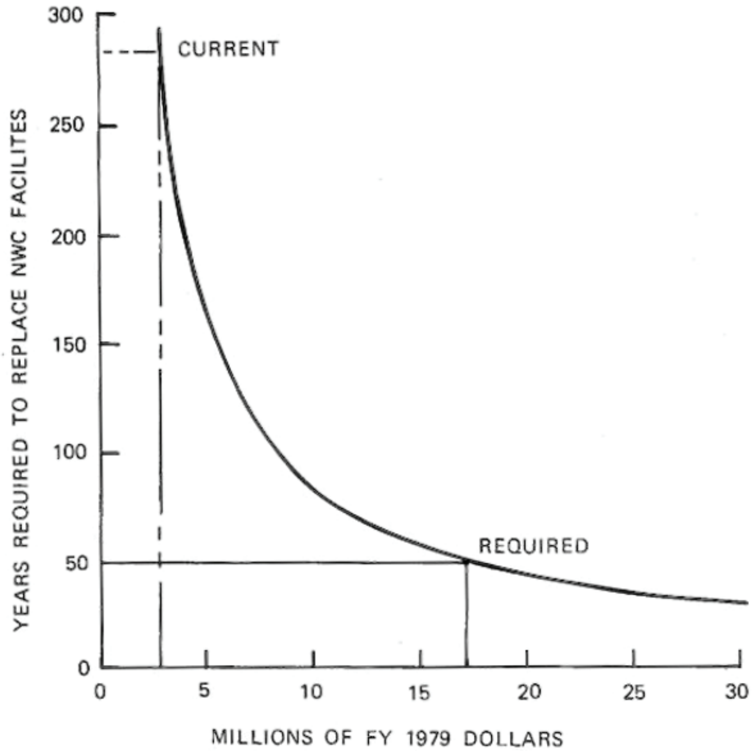
Rich Printy.

Eva Bien, who was Civilian Personnel Officer and head of the Personnel Department at the time, recalled it differently.

> Everybody thinks that the civilians came up with that, but it was Harris who pushed for that. . . . He's the one that I heard lecturing, "You guys have to replace your facilities, and you have to maintain them, or you're going to be obsolete!"

[29]S-114, Renne interview, 22.
[30]Ibid., 23.

The economic analysis bore Harris out.[31]



Annual NWC MILCON investment versus time needed to replace facilities. Published in AdPub 267, *Project 2000 Summary Report*, February 1983.

James R. Bowen was assigned to head the Project 2000 Office (on the staff of Technical Director Bob Hillyer) in June 1978. Bowen had come to China Lake as a Junior Professional in 1958 after earning his bachelor of science in electrical engineering at Arizona State. He started out in the Engineering Department but soon moved to the Systems Development Department, where he served as development manager for Agile and technical manager for the AIM-9L. In the reorganization of July 1973, he moved back into the Engineering Department as associate head of the Product Design Division. He later headed both that division and the Engineering Design Division.

Project 2000 was Project 21 writ large. Rather than looking just at NWC's T&E requirements, Project 2000 encompassed the entire base and all aspects of the services it provided to the Navy and DoD; the intent was to develop a long-range corporate investment plan that would address total resource requirements

[31]S-251, Bien interview, 32.

for the next 25 years. The goal was to identify, and ultimately acquire, the major resources to ensure that the Center could effectively perform its mission out to the year 2000. Another aim of the project was to create a more logical and efficient geographical arrangement of RDT&E, support, and community facilities. These generally had been sited with little thought to future needs, flexibility of use, traffic patterns, or contiguity to related functions. Finally, the project presented the opportunity to replace old, substandard, inefficient structures (often trailers and Quonset huts that had originally been considered "temporary") with newer buildings.

Bowen assembled a four-person team. To get department level buy-in for the project, the team made a presentation to each NWC department in July 1980. The *Tech History* reported:

> Departments were requested at that time to submit information on the status of existing facilities and major research and support equipment under their cognizance and to consider formulating questions they would like top management to address.[32]

That exercise generated a list of 127 questions that were presented to the Center's top managers. The questions addressed

> both current and future concerns and interest in such areas as mission and roles, product areas and line of opportunity, facilities, research and support equipment, personnel constraints, centralization and consolidation, encroachment, safety, and environmental impacts.[33]

Management's answer to these questions were transmitted to the departments for guidance in planning their long-range resource requirements.

Anticipating future product areas was the most critical element necessary for extending Project 2000's view beyond the traditional 5-year window. "When these requirements are defined," Bowen said,

> we can conduct an analysis of the resources necessary to support those expected requirements. Also, we must carefully examine the product areas and lines so that the resource requirements can be properly prioritized in order to make maximum use of available dollars.[34]

If money was to be forthcoming to implement the investment plan, customer focus was essential to success. "NWC's resource requirements must be focused on the needs of our customer," Bowen said. "Marketing, unlike selling,

---

[32]*NWC Tech History 1978*, 1-49.
[33]*Rocketeer*, 17 November 1980, 1.
[34]Ibid., 5.

which is based on the needs of the seller, is based on the idea of satisfying the needs of the customer by means of a superior product or service."[35]

Working with the Weapons Planning Group, which by virtue of its intelligence and analysis activities had the best long-term picture of the threat scenarios and projected Navy capabilities, the Project 2000 team embarked on a market research program. The projections were looped back through the departments for validation and amplification.

Reflecting the continuing evolution of threat capabilities and U.S. naval strategies, several technical areas were identified in which increased capabilities were needed. Among them were tactical target detection (classification and identification), air and surface; long-range standoff missiles for strike and antiship warfare; antiair intercept missiles (point defense), both air- and surface-launched; penetration of EW defenses; and the increasingly complex field of aircraft weapon-system integration.

In January 1979, Project 2000 released to all departments a guidance document based on the completed market research. It looked ahead to the year 2000, examining market trends and predicting market opportunities in the Center's major product areas. The departments reviewed the guidance document and came up with 139 candidate projects "which they perceived as necessary to meet their anticipated resource needs to the year 2000."[36]

At the same time, the Project 2000 team closely scrutinized the Center's maintenance and repair requirements, which were rising alarmingly. The Public Works Department let contracts to four architectural and engineering firms to inspect the Center's facilities for structural, mechanical, and electrical deficiencies. One finding of this effort was that nearly 80 percent of the Center's buildings had already exceeded their expected useful life as defined by the Naval Facilities Engineering Command.

Combining the department inputs and the results of the facilities study, a list of 62 MILCON projects was assembled and prioritized by the fiscal year in which they were required and their importance to China Lake's mission. The Project 2000 team reached out to the technical workforce to help develop new computerized programs for economic and facilities analysis, and an economic analysis was completed for each planned project. The 62 projects provided the core of the Center's long-term investment plan.

---

[35]Ibid.

[36]NWC TM 3732, *Long-Range Planning Guidance*, cited in NWC AdPub 267, *Project 2000 Summary Report*, 3.

A Center-wide computerized equipment-management program was also developed. The Project 2000 team contacted industrial organizations that performed work similar to the Center's and found that these companies replaced their equipment on a 3- to 8-year cycle, whereas the Center had been following a 13- to 16-year cycle. "Fully 70 percent of NWC's equipment was found to have passed beyond its expected useful life," stated the *Project 2000 Summary Report*. The program centralized all of NWC's plant-accounted equipment-management and -investment activities. A walk-through inspection program was established, and a computerized equipment-planning database was developed to help in long-range equipment planning.[37]

The economic analyses conducted for Project 2000 indicated that the improvements made through the Center's corporate investment plan were "largely self-amortizing. Reduced maintenance costs, heightened operational efficiency, and reasonable customer charge rates will combine to offset the capital investment that must be made in facilities and equipment."[38]

The purse strings in Washington began to loosen up. In 1980, Congress approved two special-emphasis projects. One was focused on energy conservation; the other, titled Safeguarding Investments, was a MILCON project that allowed NWC to buy up land that lay under the two low-level, high-speed aircraft approach corridors leading into the test ranges. In September 1981, ground was broken for the $5.1 million Weapon System Support Facility that would consolidate the Center's burgeoning work in weapons system support, software support, and tactical aircraft avionics.

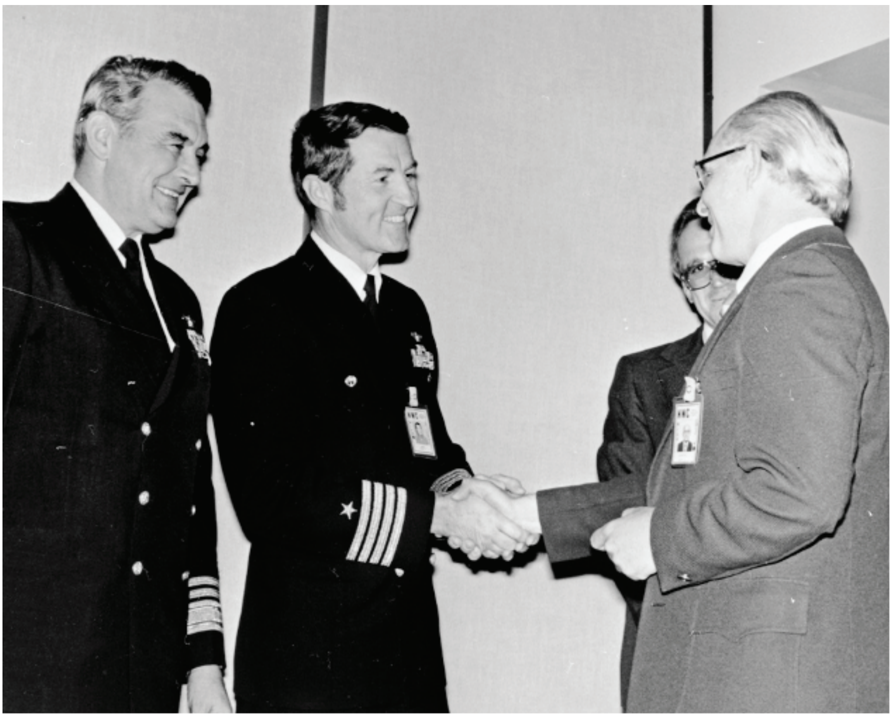
Captain John Patterson.

The same year, Bowen was selected for the newly created position of Deputy Support Director, where he assisted Captain John W. Patterson, head of the Support Directorate. Replacing Bowen as head of Project 2000 was Gary Shawler, who had come over from

[37]NWC AdPub 267, *Project 2000 Summary Report*, 3.
[38]Ibid.

Corona in 1970 as a supervising mathematician. The Project 2000 Office was moved from the Technical Director's staff to Bowen's.[39]

Project 2000 was formally ended in 1982, but its functions were institutionalized in Shawler's NWC Planning Manager's Office on the Deputy Support Director's staff. During Shawler's tenure there, which ended with his retirement in 1988, the Center had 17 MILCON projects approved for a total of $37 million.[40]



From left: Vice Admiral Ernest R. Seymour, NAVAIR Commander, Captain John Jude Lahr, NWC Commander, and Robert Hillyer, NWC Technical Director (in background), present the NAVMAT Productivity Excellence Award to Gary Shawler.

[39]In June 1986 Patterson would assume command of NWC. Bowen would eventually retire as head of the Morale, Welfare, and Recreation Division. He received the Commander's Award in 1982 for negotiating a delicate deal to demolish excess housing adjacent to Ridgecrest while retaining the land for the Navy's use.

[40]Shawler was largely responsible for the Navy-wide adoption of the Asset Capitalization Program in 1983. On his retirement in 1988, he received the Navy Meritorious Civilian Service Award.

The Demo Project

Half a century of range deterioration had led to the conditions that inspired Project 21 and Project 2000. A similar situation existed on the personnel side of China Lake; despite a multitude of reorganizations and numerous changes in command, the Center still operated under a rigid and stultifying civil service system that no Commander or Technical Director had the power to alter. The system, in place with only minor modifications since the late 1800s, controlled the distribution of power and responsibility between managers and employees and had created a ponderous compensation and advancement process that was based, primarily, on seniority. Negative stereotypes of civil servants asleep at their desks, waiting for retirement, had become a staple of comedians and reform politicians.

Although China Lakers had prided themselves since the base's inception on hard work, long hours, shared responsibility, and bending the rules as needed to accomplish the mission, the civil-service system was inflexible; time-in-grade requirements and measured, incremental advancements dictated the compensation of even the most outstanding employees and provided little incentive for extra effort. On the other side, those few poor performers could inch forward to higher pay levels by virtue of the passage of time. The system also made recruiting difficult in a competitive job environment; while China Lake was known for giving new employees as much responsibility as they could handle, industry offered more material benefits to its new employees, could fast-track those who performed best, and could fire those who didn't measure up to expectations. At the end of the 1970s, however, the system for advancement and compensation was about to change for the better at China Lake.

On 13 October 1978, President Jimmy Carter signed the Civil Service Reform Act (CSRA, Public Law 95-54) into law. This was the first major civil service reform act in 95 years, coming at a time when the American public was deeply disenchanted with the way the federal government operated. Causes for the soured attitude toward government included a widely accepted belief that the decade-long Vietnam War had been a mistake, broad condemnation of the "dirty politics" that had led to the Watergate scandal and President Nixon's resignation, and dissatisfaction with the U.S. response to the 1973 Organization of Arab Petroleum Exporting Countries oil embargo and the ensuing energy crisis. The faith of the American people in their most fundamental institution was shaken, and the CSRA was an attempt to restore that faith.

Carter, in his State of the Union speech in January 1978, said:

> I consider civil service reform to be absolutely vital. Worked out with the civil servants themselves, this reorganization plan will restore the merit principle to a system which has grown into a bureaucratic maze. It will provide greater management flexibility and better rewards for better performance without compromising job security.[41]

To reach the first stated goal of the CSRA—"to provide the people of the United States with a competent, honest, and productive Federal workforce reflective of the Nation's diversity, and to improve the quality of public service"—the act endorsed "merit system principles." One of the policy statements in the act's Statement of Purpose reads, "In appropriate instances, pay increases should be based on quality of performance rather than length of service." For its day, that was a major step forward; the idea of seniority-based advancement was deeply embedded in federal employment practice and policy.[42]

Structurally, the act disestablished the nearly century-old U.S. Civil Service Commission and in its place set up the Office of Personnel Management (OPM), the Merit Systems Protection Board, and the Federal Labor Relations Authority. The 55,000 word act laid out in painstaking details a new set of merit-based rules, procedures, and protections for federal civilian employees.

The comprehensive act also contained a particular authorization that would have a major and long-lasting impact on China Lake. This was Title VII, Research, Demonstration, and Other Programs. As spelled out in the act's Findings and Statement of Purpose,

> Research programs and demonstration projects should be authorized to permit Federal agencies to experiment, subject to congressional oversight, with new and different personnel management concepts in controlled situations to achieve more efficient management of the Government's human resources and greater productivity in the delivery of service to the public.

The projects were limited to 10 nationwide, each limited to 5 years in duration, and each to have a maximum of 5,000 affected employees.[43]

Technical Director Bob Hillyer saw in this provision the opportunity to give line managers and supervisors greater authority, responsibility, and accountability for their personnel resources. He recalled going to San Francisco

[41] Carter, "State of the Union," 95.

[42] Civil Service Reform Act of 1978, Public Law 95-454 (S 2640) (13 October 1978), Findings and Statement of Purpose, Section 3, 1, 7, accessed 9 June 2015, http://archive.opm.gov/biographyofanideal/PU_CSreform.htm.

[43] Ibid., 8.

for a required 2-day class on the CSRA, then coming back to China Lake and reviewing how the Navy planned to implement the act.

> I said to myself, "Self, what are the five biggest problems you've had in personnel management in your 20-several years in this R&D business?" And so I listed them in my head and on a piece of paper. And I asked myself, "Self, is the Civil Service Reform Act going to address these problems?" And it didn't address any of them. So I said, "Well, gee, that seems like a good reason to take advantage of this clause that says, 'Let's have a separate program, or a separate demonstration project.' "[44]

To develop the China Lake Demonstration Project, Hillyer established a task team headed by Dr. Ed Alden of NWC's Office of Finance and Management and including Jerry Reed (then associate head of the Range Department) and Steve Sanders (acting head of the Personnel Department). Ross Clayton, a management analyst who would later become dean of the School of Public Administration at USC, was one of the intellectual architects of the project.

Meanwhile, the Naval Ocean Systems Center (NOSC) leadership had also noticed the opportunities in Title VII and had begun to develop its own project under the leadership of Randy Riley. Top management at both centers agreed to merge their projects, and Riley, Eva Bien, and Sanders handled that task. In April 1979, the two commands forwarded a demonstration project proposal to Navy authorities.

Implementing the Demonstration Project—or as it was generally called, the Demo Project, or simply the Demo—was a collaborative effort involving all segments of the Center workforce. Beginning in July, the *Rocketeer* ran articles examining every aspect of the project, including a 4-week series of lengthy Q&A articles. In November, after tentative approval of the Project by OPM, NWC set up five task teams comprising 50 people to actually create the nuts-and-bolts structure by which the project would be carried out. The task teams were Pay (chaired by Hugh Drake), Classification Standards (Marcel Marineau), Performance Appraisal (Thom Boggs), Training (Clara Erickson), and Communication (Dave Livingston).

The Demonstration Project formally began on 13 July 1980. The project was rolled out in consecutive increments, the first being all scientists and engineers and all other personnel in General Schedule (GS) pay grades GS-13 and above. Dr. Dick Kistler, head of NWC's Office of Finance and Management during the development of the Demo Project, described the basic elements of the project as "entry-level salary flexibility, very wide pay bands instead of

[44]S-134, Hillyer interview, 36.

15 steps and 10 gradations within each step, and a very much increased line-management involvement in deciding who gets promoted and when."[45]

A dual-career-ladder concept was built into the Demonstration Project. Prior to the project, the principal way an individual progressed to the higher pay levels was by moving into management. Consequently, good scientists and engineers sometimes became mediocre branch or division heads in an effort to advance their careers. The Demonstration Project allowed people to be promoted and compensated while continuing to do hands-on work within their specialized fields. When Senator Ted Stevens of Alaska visited the Center in 1986 to assess the idea of expanding the Demo Project throughout the federal government, he interviewed 21 employees. Among them was Dave Andes, who described himself as "a living example of the dual-ladder concept." Andes was a nonsupervisor who was promoted to DP-4 (a Demonstration Project grade equivalent to a GS-15).[46]

Line-management involvement was one of the biggest changes of the Demo Project, taking control out of the hands of anonymous personnel specialists who, though experts in the labyrinthine system by which people were graded and categorized, had little knowledge of an individual's performance within his or her work group. As Dr. James Colvard observed:

> You need to have more discretion in the hands of the line manager. I'm responsible for the work outcome, but the decision about the status level and pay of my employees is done by personnel who are not responsible. That division of accountability and authority is not effective.[47]

Under the Demo Project, managers and their employees negotiated, monitored, and evaluated measurable performance goals for the employee. The success with which the employee met, exceeded, or failed to meet the goals would determine the size of the employee's payout. [48]

---

[45]S-131, Kistler interview, 14.

[46]*Rocketeer*, 18 July 1986, 7. Andes, who created the Navy's Artificial Neural Network Program, retired in 2001. In 2014, he received the George R. Stibitz Computer and Communications Pioneer Award for leading the team of scientists and engineers that built the world's first neural computer and for designing the electronically trainable analog neural network chip.

[47]S-285, Colvard interview, 39.

[48]Ibid.

Dr. George F. J. Lehner, a former professor and consultant at University of California, Los Angeles (UCLA) (and director of the UCLA Psychological Clinic) provided management consultant services to China Lake for more than 30 years. In a 1984 interview, he reported

> an increased appreciation of the importance of looking at people as important, as well as the importance of getting the job done. And I see a kind of almost uniform appreciation among managers here at China Lake for the welfare of the participants and the team members.[49]

Speaking specifically of the managers, he said:

> They've attended more seminars that have stressed the importance of considering people, and they are now honoring a little more of the old phrase that people are a most precious resource and we've got to treat them well. I think the Demonstration Project has also helped in the better and more crisper contracting between the manager/supervisor and subordinate on what's expected of each other.[50]

Reduction-in-force (RIF) procedures were also changed by the Demo Project. Previously, veteran's preference, tenure standing, and service computation dates had been the prime factors in determining RIF standing. Under the Demo Project, those factors remained but became secondary determinants behind individual performance.

Integration of the project into the Center's operations and culture went smoothly, though not flawlessly. One of the principal problems the Demo Project had been designed to correct was, according to Hillyer, "our inability to couple pay to performance, although that isn't the way I thought of it—inability to properly reward the best contributors, is the way I thought of it. It came out with the buzz words 'pay to performance.' " But in trying to correct that problem, Hillyer admitted:

> We made a fundamental mistake in implementation . . . We said we were going to have a system which coupled pay to performance, and instead we designed a system which coupled pay *increase* to performance and that's different. That is, you couldn't tell a person, "Charlie, you're doing a great job. By the way, you're making enough money for the job you're doing."[51]

That problem was corrected in one of the many modifications to the original project structure.

In recognition of the joint accomplishment of NWC and NOSC in implementing the Demonstration Project, OPM presented the Ribicoff/

[49]S-153, Lehner interview, 12–13.
[50]Ibid.
[51]S-134, Hillyer interview, 37.

Percy Award for Excellence in Civil Service Reform Implementation to the Department of the Navy in 1981.

In 1985, Congress passed, and President Reagan signed, a bill sponsored by California Representative Pat Schroeder to extend the NWC/NOSC Demonstration Project until 30 September 1990. The success of the project was by then recognized widely; in 1981, the Defense Science Board Summer Study had recommended the project be implemented DoD-wide, and other government organizations outside the DoD were developing similar models. The project was again extended, this time until 1995, under President George H. W. Bush in January 1989.

An OPM study in 1987, after 8 years of the NWC/NOSC Demonstration Project, illuminated the attitudes of those actually participating in the project. It compared responses to the same survey questions given before the Demo Project began, in 1979, and again in 1987 by respondents at the two Demo labs and two non-Demo control laboratories.

> Before implementation of the demo and government-wide merit pay systems for supervisors in grades GM-13 to GM-15 (senior managers), less than 50 percent of the employees at the Demo and control labs saw a pay-performance link. By 1987, two-thirds of the employees at the Demo labs reported a link between performance and rewards, but the change at the control labs was not significant.[52]

The results also showed a greater sense of "fairness" at the Demo laboratories. In 1979, only 44 percent of employees at both Demo and control laboratories perceived their performance ratings as fair, and "perceptions were significantly more negative at the two Demo labs"; by 1987, however, perceptions of the fairness of performance ratings had increased 20 percent at the Demo laboratories and only 10 percent at the control laboratories.[53]

Pay satisfaction also favored the Demo laboratories. Whereas only 44 percent of respondents at all four laboratories were satisfied with their pay in 1979, by 1987, that figure for those satisfied had increased to 55 percent at the Demo laboratories and decreased to 39 percent at the control laboratories. (In 1987, 54 percent of supervisors at the Demo laboratories agreed that they could determine their employees' pay, compared with 17 percent at the control laboratories).

Similarly positive trends for the Demo laboratories were seen in authority to remove poor performers, authority to promote employees, turnover of high performers, and supervisors' influence over classification decisions.

[52] *Rocketeer*, 5 May 1989, 10.
[53] Ibid.

In another bright note for the Demo Project, the Merit Systems Protection Board reported that, government wide, job satisfaction was highest at the Navy laboratories, and the highest levels of job satisfaction were at NOSC and NWC.

Finally, the *Rocketeer* reported that

> support for the Demonstration Project has increased at Demo labs from less than a third in 1979 to 70 percent of all survey respondents in 1987. Further analysis of variables shows that pay alone does not explain the increasing positive attitudes at the Demo labs.[54]

National Parachute Test Range (NPTR)

The year 1979 saw the largest structural change at NWC since the severing of the Pasadena Annex and the addition of the Corona Laboratories a dozen years earlier. It began with a mid-1970s DoD review of test facilities to determine if economies could be achieved through consolidation. One area examined was the Navy's base at El Centro in California's Imperial Valley. Commissioned as a Naval Air Station (NAS) in 1946, and later designated Naval Air Facility (NAF) El Centro, the base hosted an organization—the Joint Parachute Facility—whose principal work was to design, test, and evaluate aeronautical escape systems (primarily parachutes) for the Navy and Air Force. That portion of the El Centro operation was designated the U.S. Naval Aerospace Recovery Facility (NARF) in 1964, and in 1973, NARF and NAF El Centro were merged to form the NPTR.

Bernie Connolly.

In August 1976, Frank A. Shrontz, Assistant Secretary of Defense (Installations and Logistics), set up an ad hoc interservice working group (Navy, Army, and Air Force), chaired by the Navy. The group's task was to develop a plan that would move NPTR's mission and function to other facilities. Representing China Lake in the group was John Di Pol, head of the Range Department. Bernard Connolly,

[54] *Rocketeer*, 5 May 1989, 11.

NWC's Deputy Comptroller, was tasked with planning, organizing, developing, and executing the study that would form the basis for the group's plan.

The working group published its recommendations and detailed plans in April 1977. Six months later, based on those findings, the DoD ordered that NPTR be disestablished and its missions and functions be transferred to NWC. Naval Air Forces, Pacific, would continue to operate the El Centro airfield, which was redesignated NAF El Centro.[55]

Deadline for the switchover was 1 April 1979. The one-time cost of the move was estimated at $2.7 million; however, the consolidation was expected to "reduce total annual costs and manpower requirements by approximately $3 million."[56]

Why was NWC selected? One reason was the same reason that the Navy's base at China Lake had been established there in the first place: the large, open, relatively uninhabited land area with 360 days of clear weather each year. Beyond that, China Lake had a support infrastructure that would enhance NPTR's operations. Textiles engineering, for example, one of the core skills of the parachute group, was enhanced by access to the Center's staff of materials engineers and chemists. High-speed tracks, such as the Supersonic Naval Ordnance Research Track (SNORT), could be used for preliminary parachute testing at velocities as fast as any aircraft.

China Lake and the Navy's parachute organizations at El Centro were no strangers; they had worked together through the years on a variety of aircraft escape systems, such as the mid-1970s Helicopter Escape and Personnel Survival (HEPS) system. HEPS, though never fielded, was designed to bring a disabled CH-46 helicopter and crew to earth using a combination of parachutes and retro-rockets.[57]

It was one thing to assign a function from one base to another; quite another to move the people and equipment involved, find suitable facilities, and arrange for housing. An equally challenging task was to incorporate the activities of the NPTR into China Lake's already crowded and tightly scheduled airspace. The parachute group's work included many types of aircraft and tests of experimental equipment—including test vehicles weighing up to 20,000 pounds—at altitudes from 50 to 50,000 feet, night and day, in every

[55]Tri-Service Working Group, *Plan for Relocating*. Connolly, who would eventually head the Technical Information Department (TID) before retiring in 1982, received the Michelson Laboratories Award in 1978 for his work on the NPTR transfer study.

[56]*Rocketeer*, 11 November 1977, 1.

[57]*NWC Tech History 1976–1977*, 9-23, 9-24. When the CH-46 was retired in 2004, after 40 years of Navy service, it still had no crew escape system.

sort of weather. (Water drops, another important part of the group's activity, were conducted at Lake Isabella, a 35-mile flight to the west.)

John Crossley of NWC's T&E Directorate was assigned the job of relocation manager. Crossley had handled that task from the other side when, as a GS-14 supervisory engineer in Corona in 1969, he had been assigned to head the liaison group at China Lake for the Fuze Department transfer. Donald B. Goodrich, a division head at NPTR, served as relocation coordinator.

NWC had been down this road before when it moved the Fuze Department from Corona to China Lake. Management was aware of the importance of reaching out to not only the civil service and military personnel who would be transferred but also their families. Members of the Desert Empire Board of Realtors and of several City of Ridgecrest departments took part in meetings at El Centro to discuss housing, schools, recreation, and shopping facilities.

Rear Admiral William L. Harris, NWC Commander, addressing the Kern County Business Outlook Conference in Bakersfield on 18 January 1979, spoke of the 110 civilian and 71 military personnel (6 officers and 65 enlisted) who would be added to the NWC workforce through the NPTR transfer and commented, "This will mean about 600 more residents in Ridgecrest and China Lake."[58]

Throughout early 1979, there was action on several fronts. Stevens Co. of Lancaster, California, under a nearly quarter-million-dollar contract signed in December 1978, was enlarging two camera pads and enclosures to accommodate the larger state-of-the-art equipment—Contraves cinetheodolite cameras and Photo-Sonics cinesextants—that would be brought to China Lake from El Centro. The company was also constructing earth mounds topped by concrete slabs on isolated footings that would afford camera and other instrumentation a vibration-free view of the drop zone. The drop zone itself was located on G Range about 10 miles north of Mainside and consisted of a circular primary impact area 1 mile in diameter and an adjacent rectangular secondary impact area measuring 2 miles by 1 mile.

Environmental test chambers and tensile-testing equipment from El Centro was being installed in Michelson Laboratory where it would be used by the Parachute Systems Department's textiles experts as well as personnel from the Engineering Department's Materials Engineering and Environmental Engineering Branches.

At Armitage Field, a 50- by 220-foot metal parachute-fabrication and -assembly building was under construction. The Stran Steel building, just

[58]*Rocketeer*, 26 January 1979, 1.

northeast of Hangar 3, would also house the Navy parachute test jumpers. Over on 73 Bard Street at Mainside, a 5-minute walk from the Center's Administration Building, Public Works was remodeling an old dormitory that would serve as the engineering and administrative offices of the Parachute Systems Department. Meanwhile, the staff was housed in the Old Dispensary complex.

Material from El Centro continued to flow into the base. At Salt Wells, the textiles-engineering equipment that required explosive components was set up. Parachute packing tables, rigging equipment, high-tech sewing machines, and other arcane items unique to the parachute business came in a steady stream of trucks. To expedite the move, extra trucks were borrowed and commercial drivers were hired.

Also part of the move were three NPTR aircraft: an A-3 Skywarrior, a C-117 Skytrain, and a modified YF-4 Phantom. The planes were transferred to the Aircraft Department's inventory. The *Rocketeer* noted:

> The C-117 will be used to deliver live jumpers and dummy payloads and small test vehicles at lower airspeeds; the YF-4 can fire test ejection seats and externally stored payloads at speeds up to Mach 1; and the A-3 delivers live jumpers, dummy payloads, and bomb bay-carried vehicles at higher speeds (over 300 knots) and at altitudes up to 45,000 ft.

The parachute group would also rely on several China Lake aircraft (jet, propeller, and rotary-wing) to launch jumpers and test items.[59]

Every few months, China Lake issued a new organization chart (informally called the "org chart") listing all the Center's directorates, departments, divisions, branches, special offices, and attached activities as well as office locations and telephone numbers. It was an essential tool for communication between individuals and organizations at a base whose work spanned nearly every aspect of military system RDT&E.

The first entry for the NPTR organization was on 1 April 1979. It listed the Parachute Systems Department, with Howard Fish as department head. (Fish moved to China Lake in April but maintained an office at El Centro until the transfer was completed in July.)[60]

---

[59] *Rocketeer*, 8 June 1979.

[60] Fish was an engineer with degrees from the University of Rochester, Stanford, and the Naval Postgraduate School. He retired in 1984 after 32 years of service to the Navy.

Anthropomorphic dummies used in parachute tests. Published in *Range Users Guide*, 1988.

At that point, the department consisted of a single division, the Parachute Engineering Division (Fish as acting head, soon to be replaced by Gene R. Drew), which contained three branches: Engineering Investigations (Don Goodrich), Product Support (K. Luskin), and Textiles Engineering (Goodrich, acting). Cathy de Wolfe, who had joined China Lake as an undergraduate summer hire in 1968, was appointed department head of staff. By July, the Test Engineering Division, under Wally Fung, was added to the department roster.

Acquiring the NPTR function also resulted in a change to the Center's mission statement:

> The mission of the Naval Weapons Center is to be the principal Navy RDT&E center for air warfare systems (except antisubmarine warfare systems) and missile weapon systems; and the National range/facility for parachute test and evaluation.[61]

On 20 April 1979, the first parachute test was conducted on China Lake's north ranges. The purposes of the test were to obtain baseline physiological data on two parachutists as their canopies opened to ensure that the NPTR biomedical packs were compatible with the G Range telemetry ground stations

[61]*NWC Tech History 1979*, v.

and to give range operations personnel experience in taking motion-picture footage and still-camera photos of the parachutists' descent and landing. The jumpers exited the C-117D aircraft at 7,200 feet above ground level (AGL) and, after a 30-second delay, opened their parachutes and glided to a landing near the target and about 100 feet from each other. The test was a success in all respects.

Lieutenant Robert Moynihan (parachutist, left) and Department Head Howard Fish (right) attach telemetry electrodes to Robert Hudson (parachute rigger, chief petty officer, center). Published in the *Rocketeer*, 28 April 1979.

On 1 July 1979, NPTR El Centro was officially disestablished. Between 1947 and 1979, 42,617 jumps had been made at NPTR. By November, jumpers from the Parachute Systems Department had logged 100 test jumps at China Lake.

A major milestone was achieved by the department in 1980 when aircrew survival equipmentman (PR) second class Anne Mooney, aircrew survival equipment airman (PRAN) Lisa Arsenault, and PRAN Nancy Schrankel became the first women to qualify as Navy test parachutists. The acceptance of woman into military flying assignments, including piloting combat aircraft, required reevaluation of the equipment, training, and procedures—all originally

Test parachutist PRAN Lisa M. Arsenault with telemetry pack and NB-7 parachute. Published in NWC TP 6283, February 1982.

designed for men—associated with emergency escape from a disabled aircraft.

Curt Bryan took over the department in June 1982 when Fish became special projects manager for the Aircraft Department. One of his first official acts as department head was to congratulate PR first class William Leuallen, who logged the 45,000th premeditated live jump by a Navy test parachutist.

Two months later, the department was renamed the Aerosystems Department, reflecting a broader scope of activities: RDT&E was being conducted into newer non-parachute recovery and deceleration systems for aircraft, weapons, and people. Bryan would guide the Aerosystems Department work for the next 3 years, until he moved to Central Staff and Milt Burford took over.

Today, the Human Systems Competency (formerly the Aerosystems Department) continues to advance the techniques and technologies of parachutes and related systems for the Navy, NASA, sister services, and U.S. allies. Modern parachute testing is normally accomplished with complex electronic sensors rather than live human testing; however, the early test parachutists at both El Centro and China Lake were key to the development of parachutes that are still in use by the U.S. military in the 21st century.

Vertical-Seeking Seat (VSS)

Flying jets for the Navy is risky business. Even riskier is an in-flight ejection. In the mid-1970s, the Navy's fatality rate for ejections was a little over 20 percent. The majority of these deaths occurred when the ejection took place "out of seat envelope." The envelope was defined by a combination of aircraft speed, altitude, attitude, and sink rate (how fast the aircraft was approaching the ground).

In 1974, according to a *Rocketeer* article, more than a third of Navy pilot ejections that were initiated at less than 500 feet AGL resulted in fatalities—and half of all Navy pilot ejections were initiated at less than 100 feet AGL. In 1976, 60 percent of all ejection fatalities were caused by out-of-seat-envelope ejections.[62]

Many aircrew members who survived an in-flight ejection still paid a price. Severe neck and back injuries were commonplace, caused by the tremendous acceleration of the ejection seat as it left the cockpit, followed by the rapid parachute deployment after ejection. The theory behind the fast out-and-open approach was that in a rapid sink-rate scenario, with the aircraft close to the ground (as was frequently the case when the ejection was initiated), the pilot needed to be hanging under an open canopy as quickly as possible. This approach had, in the words of the *Tech History*, "been pursued to a point of diminishing returns."[63]

The VSS project was classically China Lake. First, the idea was crazy. If you had told folks a decade earlier that, one day, an escape system would allow a pilot to safely eject from an aircraft when it was only 50 feet above the deck and flying upside down, you'd have been laughed out of the ready room. (Just as you would if you had told a fighter pilot in 1949 that you were going to put a fire-control system inside a rocket.)

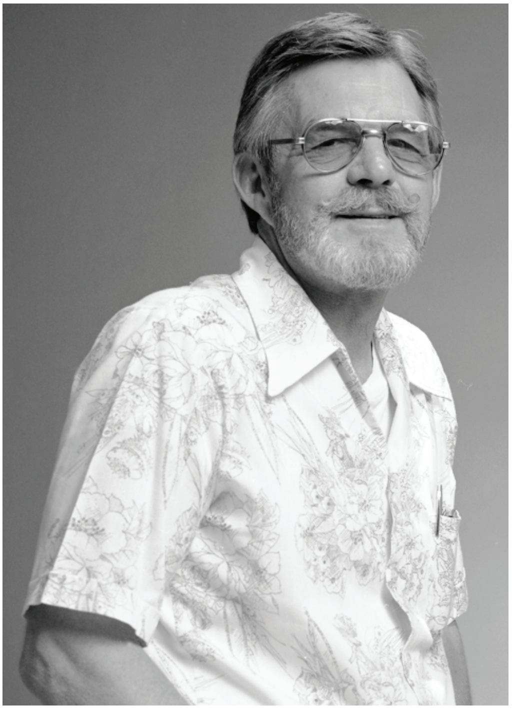
Second, the VSS required a suite of skills rarely found within a single organization: electronic, mechanical, and propulsion engineers; chemists; parachute designers; human factors engineers; and many more experts, ranging from mathematicians who calculated complex trajectories to technicians who assembled the wiring harnesses to welders and riggers and laborers who constructed the elaborate test stands.

W. J. "Bill" Stone was an aerospace engineer in the Propulsion Development Department. Stone was described by fellow engineer (later NAWCWD Executive Director) Scott O'Neil as "a very ingenious engineer" and by his branch head, Bob Dillinger, as "a hard charging guy."[64]

In the late 1950s, Stone had worked on the Rocket Assisted Personnel Ejection Catapult (RAPEC), a China Lake-developed ejection seat system. RAPEC could be used at extremely low altitude (on the runway during takeoff,

[62]*Rocketeer*, 2 December 1977, 3; *NWC Tech History 1978*, 1-61.
[63]*NWC Tech History 1976–1977*, 9-21.
[64]O'Neil, "Thrust Vector Control," video presentation; S-327, Dillinger interview, 44.

for example) and propelled the pilot high enough for the parachute to open safely. The system employed a two-stage ejection rocket that avoided the spine-crushing (and blackout inducing) vertical acceleration shock of contemporary ejection cartridges. RAPEC saved the lives of many A-4 pilots through the years of the Vietnam War.


Bill Stone.

RAPEC engendered in Stone an interest in ejection systems that he pursued for years. In 1975, he proposed an IED program to develop an ejection seat that would be self-propelling, self-steering, and would automatically seek a vertical orientation after initiation. Stone, according to Dillinger,

> started equating the [thrust vector control] work on Agile with what might happen on an ejection seat, and he came to the obvious conclusion that [the seat] was a device you couldn't steer aerodynamically but with thrust vector control you maybe could.[65]

At the same time, NADC, Johnsville (the Navy's lead laboratory for life-support systems), started development of a completely new ejection system for Navy aircraft. The effort, headed by NADC's John J. Tyburski, was titled the Maximum Performance Ejection Seat (MPES, also referred to as the Maximum Performance Escape System) program. The system would be state-of-the-art, using such innovations as a seat structure fabricated from an aluminum honeycomb sandwich and composite materials.

China Lake was funded to develop Stone's vertical-seeking subsystem for the MPES. (The second S in VSS is variously defined as seat and subsystem.) The seat's vertical-seeking component consisted of an 8-inch, spherical, thrust-vector-controlled rocket motor mounted in two gimbal rings beneath the seat, a three-axis electromechanical rate gyro, and a microprocessor-controlled autopilot that would tell the motor which direction to turn to put the seat in a vertical trajectory.

[65]S-327, Dillinger interview, 44.

Ron Stoutmeyer.

Stone was assigned as the VSS project manager. Ron Stoutmeyer, a physicist in the Weapons Department, tackled the autopilot development; after Stoutmeyer left the Center in 1980, Ray Morrow took over the task. Gene Drew, head of the Parachute Systems Department's Engineering Investigations Division (which moved to China Lake during VSS development), designed the MPES stabilization and recovery system (parachute) and the pilot-restraint system.

In the VSS's first design iteration, the autopilot took its reference attitude from the aircraft's onboard systems and the autopilot calculated the shortest course to steer the seat to vertical. There was one flaw in that thinking. As Ray Miller tells it:

> Bob Hillyer [NWC Technical Director], during a review we were giving him on the program, said, "Where does this seat get its intelligence so it knows which way is up?" And we said, "Well, the aircraft has all these systems in it, that the seat would be updated from the sensors on the aircraft." And he said, "You dummies! That's probably the reason he's going to crash! Find a way to do it passively!"[66]

Various options for ascertaining the orientation of the seat at ejection, independent of the aircraft, were considered, including systems based on the polarization of the earth's electrostatic field and IR sensors that could distinguish the heat of the earth from the sky. The VSS team finally selected microwave radiometry (MICRAD), and development was begun on a MICRAD Attitude Reference System (MARS) to be installed on the top of the seat. This passive, instant-on system detected natural microwave radiation from the earth and sky and, when coupled with the autopilot, computed the shortest course to vertical. Bruce Heydlauff, an electronics engineer from the Millimeter Wave Systems

[66]S-262, Miller interview, 19.

Branch of the Electronic Warfare Department, was lead engineer for the MARS development. Assisting in the design was his branch head John Hooper.

The first test of the VSS took place in November 1977 at the SNORT facility. The seat was mounted in an A-6 cockpit for a zero-altitude, zero-velocity demonstration to determine the pitch and roll stability using preprogrammed gimbal movements. "Stabilization was excellent," reported the *Tech History*, despite the seat's greater than anticipated deviation from the vertical. The problem was traced to the seat's 67-hertz natural frequency, so the frequency was increased to 154 hertz.[67]

In a second test in March 1978, the seat was ejected from an A-6 cockpit that had been elevated 100 feet above the ground between two towers at SNORT. For this, the second of three planned tests, the seat was oriented parallel to the ground, as in an aircraft rolled 90 degrees from horizontal. The seat dropped a mere 2½ feet before turning to vertical and climbing to an altitude of 428 feet before initiating parachute deployment.

This test showed another important advantage of the VSS. The time required for the seat to rise to the opening altitude and the relatively long period of stabilized flight would, in an actual in-flight ejection, have allowed wind resistance to slow the forward velocity of the seat before parachute deployment, thus reducing the opening shock of the parachute and lessening the likelihood of neck and spine injuries.

In July 1978, the third and final test of the VSS exploratory development phase was conducted. This time the A-6 cockpit hoisted to 100 feet AGL and rolled 175 degrees—essentially, upside down, pointed at the ground. When the ejection sequence was initiated, the seat dropped 45 feet as the rocket motor turned the seat top toward the sky, reversing direction. The lowest point in its trajectory was 53 feet AGL. It climbed to 137 feet AGL, the parachute deployed, and the anthropomorphic dummy parachuted safely to the ground.

More than 150 people witnessed the test, including representatives from other government agencies and private companies. "We put a lot of pressure on ourselves by inviting so many off-Center personnel," Stone told the *Rocketeer*, "but the test was such a major milestone in personnel recovery systems that interest was extremely high."[68]

Successful execution of the three-test series marked the end of the exploratory development portion of the VSS program. In 1979, it moved into advanced development.

---

[67] *NWC Tech History 1976–1977*, 9-21.
[68] *Rocketeer*, 14 July 1978, 5.

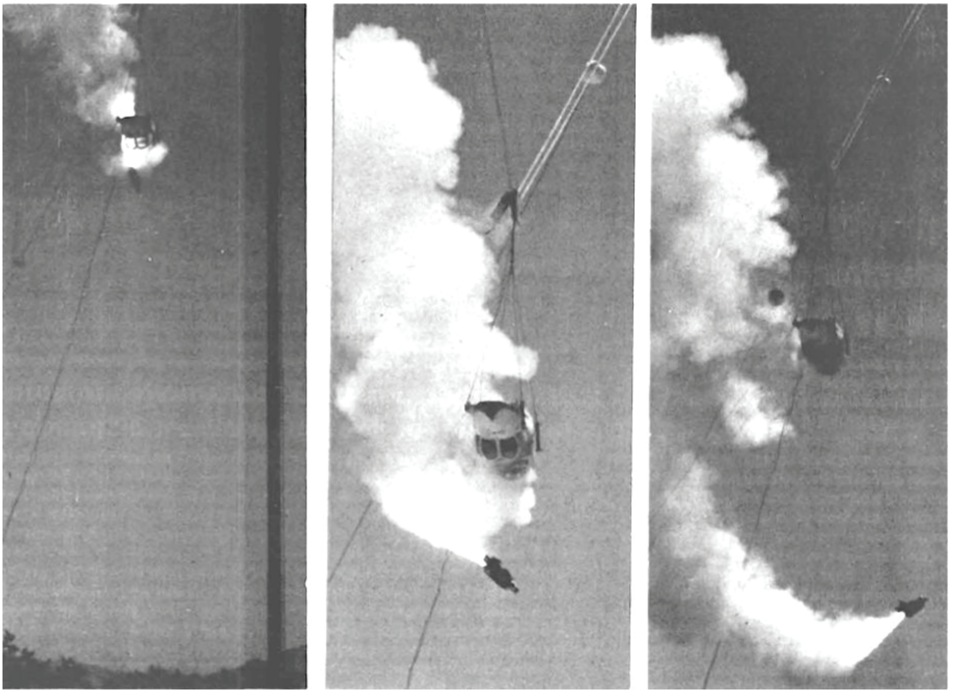


Photo sequence showing July 1978 test of VSS at SNORT. Published in the *Rocketeer*, 14 July 1978.

The demonstration tests in the exploratory development phase had used a pre-programmed autopilot to provide the seat's steering commands; MICRAD hardware had been incorporated to provide data for MARS development. By 1979 a MARS system had been designed, fabricated, and tested. Developmental testing took place at a specially built facility consisting of a tower atop which was mounted a two-axis rate table. This setup simulated the operational environment for the MARS hardware-in-the-loop tests.

MARS and the VSS were successfully integrated in 1980 and demonstrated with a seat-launch and MICRAD-controlled flight from an A-6 cockpit rolled 30 degrees from vertical. The *Tech History* stated:

> This was the first test in which seat altitude [*sic*: attitude] was determined independent of aircraft systems. The MARS correctly sensed the vertical, appropriate steering commands were computed by the autopilot, and the commands were carried out by the propulsion/steering system.[69]

That test in November 1980 was followed by another successful MARS-equipped VSS test in February 1981.[70]

---

[69]*NWC Tech History 1980*, 11.
[70]Ibid.

The original VSS had used a single spherical motor that provided thrust-vector control in the pitch and roll axes. Subsequent 6-degree-of-freedom computer simulations established a requirement for third axis (yaw) control as well. The propulsion system was redesigned to accommodate two 7-inch-diameter spherical motors positioned by hydraulic actuators and servo valves.

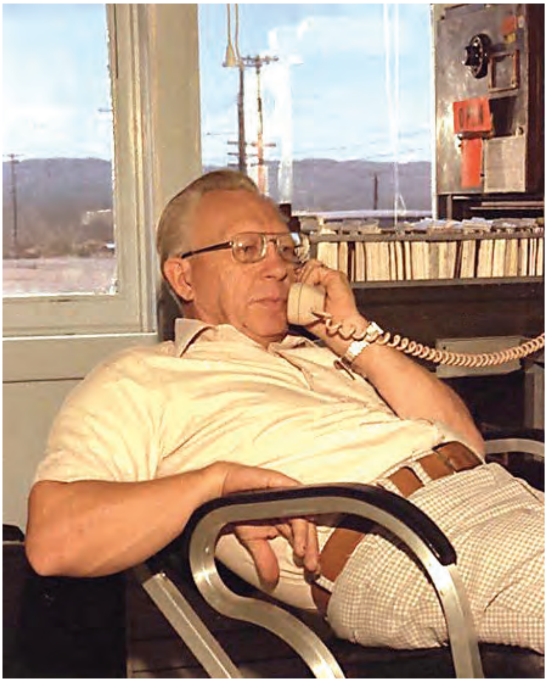
Several China Lakers were formally recognized for their work on VSS. In 1978, Bill Stone and Ron Stoutmeyer received the Technical Director Award. In the nomination letter, Carl Schaniel, head of the Ordnance Systems Department, wrote, "A pioneering spirit and enthusiasm existed on this program which is reminiscent of NWC's heritage and is rare in these times of decreasing laboratory hardware involvement."[71]

Stone, Stoutmeyer, and Gene Drew were honored by the Survival and Flight Equipment Association at a banquet in December 1979. In October 1981, Dennis Sorges (who took over the program that year), Drew, Heydlauff, and Morrow received the Technical Director Award for developing the MARS. Among others at the Center who played an important part in the VSS development were aerospace engineer Vern Burklund, chemical engineer George Sieg, SNORT test engineer Bob Bush, mechanical engineer Dennis Bishop, and electronics technician Vern Monckton.

From left: Gene Drew, Bruce Heydlauff, and Dennis Sorges after receiving the Technical Director Award.

Flight tests of the MPES were scheduled for 1983, but that didn't happen. MPES was cancelled, and the VSS never made it to the Fleet. The reasons for the cancellation are vague. Ray Miller recalled that the research and development manager, an admiral, "couldn't find any way to

[71] *Rocketeer*, 9 November 1978, 3.



Vern Burklund.

George Sieg.

meet his requirement other than to cancel that program." Miller called it

> a so-called "Midnight Massacre" in the Pentagon. The Navy decided to put that program away. So it never got into an aircraft. And even if it were done today, it would still save aircrews' lives, if the Navy would step up and put it in some of their airplanes. [72]

Mike Ripley-Lotee, based on meetings he attended as a member of the project, believes the reason for the cancellation was economic. "They thought the number of lives that might be saved just wasn't worth the cost of the system."[73]

In the 1980s, China Lake would participate in the Navy Aircrew Common Ejection Seat (NACES) Program, a common ejection system developed by Martin-Baker for the F/A-18, EA-18G, and T-45. The system was deployed in 1991, and more than 2,000 seats were fielded to both the Navy and U.S. allies. To date, the seat has saved more than 100 lives and "has a 100 percent successful rate for ejections within the ejection envelope."[74]

[72]S-306, Origins of ARM interview, Miller, 109; S-262, Miller interview, 18.

[73]Mike Ripley-Lotee, telephone conversation, 18 April 2014.

[74]"Naval Air Systems Command Fact Sheet, Navy Aircrew Common Ejection Seat (NACES)," accessed 27 July 2021, https://www.navair.navy.mil/product/Navy-Aircrew-Common-Ejection-Seat-NACES.

However, the adverse attitude problem has yet to be solved. The official lecturer's guide for NACES classroom training states, under the heading Envelope for Optimum Ejection: "Attitude—straight and level (the NACES is NOT a vertical seeking seat)." [Emphasis in original.][75]

Peace Time Hero

For the Navy, 1979 was in an interlude between hostilities. The Vietnam War had formally concluded in 1975, and the F-14 shoot-down of two Libyan fighters over the Gulf of Sidra would not occur until 1981. Combat, however, is not the only venue in which the military demonstrate their bravery.

On 15 May 1979, Air Force F-105G No. 63-8350, piloted by Captain Will H. Carroll Jr. and flying out of George Air Force Base, was involved in a mock dogfight with two other F-105s about 45 miles north of China Lake. Carroll's aircraft lost control, and he and his electronic warfare officer, Captain Michael R. Carlson, ejected. Carroll was fatally injured on impact. Carlson suffered major injuries and was stranded on a rocky slope.

Lieutenant Commander L. E. Crume piloted the China Lake SAR helicopter to the scene, on the west side of Panamint Valley. "The terrain was steep, with loose shale and rock, and the only thing keeping the victim from falling down a 75- to 80-degree slope another 100 to 150 yards, was his parachute, which had snagged in a few rocks," Crume told a *Rocketeer* reporter. "Talking to the victim on his survival radio, I learned he was slowly slipping, and that both his legs and one arm were immobile."[76]

Even the helicopter rotor's downwash caused rocks to slide. Crume feared that if the helicopter's downwash blew the parachute free, Carlson would tumble down the steep mountain slope.

Among those aboard the UH-1N chopper was aviation structural mechanic Petty Officer Third Class (AMS3) Frederick R. Schloesser, a native of Brooklyn, New York. Schloesser had joined the Navy in 1976 and had come to China Lake straight from aviation metalsmith "A" School in Memphis in 1977. In December 1977, he graduated from the SAR aircrew school in San Diego, and in February 1978 he was chosen as NWC's Sailor of the Month.

Schloesser volunteered to be lowered by hoist to a point about 50 yards below the downed pilot and to climb upslope to secure him for a rescue attempt.

"While ascending the treacherous terrain, AMS3 Schloesser was constantly being bombarded by falling rocks which knocked off his helmet and inflicted

[75]CNATRA P-1286 (Rev. 9-99) PAT, *Lecture Guide*, 1-12.

[76]*Rocketeer*, 7 September 1979, 1.

a severe laceration on his head, impeding the vision of one eye," reported the *Rocketeer*. Still, he kept on. "After reaching the injured airman, he directed the helicopter overhead and with considerable difficulty and personal risk, secured the victim in the rescue sling."[77]

Crume was unaware that his crewman had been injured until Schloesser was brought back aboard the helicopter. "Considering the terrain and distance AMS3 Schloesser had to cover after the loss of his head protection, it was unbelievable that he was not knocked unconscious or killed by the falling shale and rock," Crume said. "He displayed true heroism during his efforts to assist the downed pilot." Carson and Schloesser were flown back to China Lake for medical treatment.[78]

Captain William B. Haff presents AMS3 Fred Schloesser with the Navy and Marine Corps Medal for heroism.

[77]Ibid., quoting the Navy and Marine Corps Medal citation.
[78]Ibid.

Crume later told the *Rocketeer* that "after being injured [Schloesser] disregarded his condition because he was the person doing the rescue and not the one being rescued."[79]

For his actions, Schloesser received the Navy and Marine Corps Medal for heroism. The medal was presented on behalf of the President of the United States by NWC Commander Captain William B. Haff. The honor put the young sailor in a select group of individuals who had performed courageous deeds at the risk of their own lives—it was the same medal presented to John F. Kennedy for his rescue work after the sinking of PT-109 in 1943. Their actions, as the citations attest, "were in keeping with the highest traditions of the United States Naval Service."

End of an Era

As the final year of a tumultuous decade, 1979 saw a change in China Lake. Part of the change was the addition of the NPTR, the first major expansion of the Center's mission in a dozen years. And part was a new perspective that had sprung from Project 21 and Project 2000. The focus was now on the future, uncertain though it was. The Center had shown that, with careful, far-sighted planning, China Lake could prepare for those uncertainties and equip itself with the tools to address unknown challenges. If the Navy didn't know exactly what the enemy had up his sleeve, well, neither did the enemy know what China Lake was preparing in its state-of-the-art laboratories, specialized facilities, and finely equipped and instrumented ranges. Buffeted by a series of technical, economic, and organizational challenges during the 1970s, China Lake had held the course, and a feeling was taking hold in the workforce that the Center could cope with whatever the future might hold.

With the arrival of Captain Will Haff, an era ended at China Lake: the so-called "reign of the admirals." One might assume that, to China Lakers, the assignment of a mere captain to be base Commander would be a cause for dismay. Save for the 4-month tenure of Captain Kinley, the Center had been under the command of rear admirals for nearly 9 years. In the Navy, the step between captain and admiral—joining what is called "flag rank"—is the largest, and by far the toughest, single step in the ten-level officer ranks.[80]

---

[79] *Rocketeer*, 7 September 1979, 7.

[80] Navy officer ranks are ensign, lieutenant junior grade, lieutenant, lieutenant commander, commander, captain, rear admiral (lower half), rear admiral (upper half), vice admiral, and admiral. The percentage of eligible commanders being selected for captain is about 50 percent; that of captains attaining the rank of rear admiral is 2 to 3 percent.

But the reign of the admirals had not been good for China Lake. The critical balance of control between Technical Director and Commander, which had been maintained for 13 years under Dr. McLean and eight different Commanders, all captains, had been lost. Between McLean's departure in 1967 and Bob Hillyer's assumption of the Technical Director position a decade later, five different Technical Directors had been matched (or mismatched) with seven different Commanders, with varying degrees of overlap in their tours. The balance required to give stability and direction to the workforce had never been found.

The tendency of the admirals—perhaps in part because they were admirals and had reached the pinnacle of leadership in an organization that requires the prompt unquestioned obedience to orders—was to try and impose on the base a more military sensibility. Look to Washington and the sponsors for instructions, then carry them out promptly. The so-called "maverick" civilians who made China Lake thrive were the antithesis of that military model of excellence: they were disorderly, unimpressed by titles, and generally followed their own instincts rather than the orders of others. This set of traits did not sit well with some admirals.

"There has always been a point of view of 'get the civilians the hell out of that place and put military in all the department head positions and run it as a naval station,'" said Hack Wilson. "There have always been proponents for that. You have to be aware that there can be rising support for this kind of thing, and you have got to have support elsewhere to offset that when it happens."[81]

The idea that a captain could be better for the Center than an admiral was counterintuitive. Ernie Cozzens, head of the Engineering Department's Weapon Systems Office when Captain Haff took over as Commander, explained.

> I was not alone in my perception that, during the periods of time that we had captains as Commanders of the base, we were somehow being shortchanged; that what we really needed was a flag rank Commander, one who could interface on a one-for-one basis with the admirals in headquarters and talk on the same level.[82]

Conceptually that made sense, but experience indicated otherwise. Cozzens continued:

> It has been my observation since we did start having rear admirals as Commanders of this Center that our relationship with headquarters rapidly deteriorated. I am not in a position to understand precisely why; however, I feel that, starting with Admiral Moran, followed by Admirals Suerstedt, Pugh,

[81]S-96, Wilson interview, 59.
[82]S-126, Cozzens interview, 5.

> Freeman, and finally, Admiral Harris, the Center's external relationships with its sponsors did, in fact, deteriorate. Therefore I note with some sense of relief that we now are back to a senior captain. Although it's only one year into this new leadership, there is a much greater sense of strong bondage between the civilian and military leadership of the Center.[83]

Haff himself dismissed the rank difference.

> There's a bit more status with an admiral, and perhaps he can pull a few more strings for you occasionally in Washington. But I think either one of them can operate, and we've had both of them here. I think the thing that really makes the fit is the individual himself, not so much whether he's an admiral or a captain.[84]

Five more captains would follow Haff as Commander at China Lake before the Naval Weapons Center was disestablished on 31 December 1992.

The biggest difference between Haff and his one-star predecessors was not rank—it was rather that Haff was a China Laker and the others (with the exception of the first, Moran) were not. Suerstedt, Pugh, Freeman, and Harris had their first exposure to the China Lake culture when they assumed command of the Center. Haff had been immersed in that culture for 5 ½ years.

Haff had first served at China Lake from 1970 to 1972 as Assistant Technical Officer (Plans and Operations). He had arrived as a Commander with an academy ring; a master's in aeronautics and astronautics from the Massachusetts Institute of Technology (MIT); and a pair of Distinguished Flying Crosses, a Bronze Star with "V," 18 Air Medals, and 3 Navy Commendation Medals. His second tour at China Lake (following 2 years in Washington as NAVAIR Sidewinder program manager), as Technical Officer, began in June 1975. In August 1976, he was assigned the position of Deputy Laboratory Director, which he held until his elevation to Commander, NWC, in June 1979.

Haff understood the *Principles of Operation*. He said:

> You have a Technical Director whose prime responsibility is to look after the technical side, and he will apprise you if you let him run the technical side. I think it is healthy both for the Commander and for the technical community. . . . You can't possibly keep on top of all this. When they have a problem and they need your assistance, the door should be open, and the technical community should have access to it. But outside of that, you'd better rely on them to bring you the problems instead of saying, "I'm going to be intimately involved and up to speed on every program," because you can't possibly cut it.[85]

---

[83]Ibid.

[84]S-125, Haff interview, 15.

[85]Ibid., 16.

Hillyer too, unlike his predecessor Gil Hollingsworth, was a China Laker. Perhaps a better term was a naturalized China Laker; he'd come to the desert when the Naval Weapons Center Corona Laboratories closed in 1970. He'd been part of the organization long enough to understand the unique nature of the creative people at NWC and the necessity of, if not coddling, at least putting up with them.[86]

Under Will Haff and Bob Hillyer, balance was restored to the Center. The two men appreciated that managing China Lake required a degree of finesse beyond that for a traditional military base. "It is very, very important for the senior managers of this Center to recognize its fragility," Hillyer said in 1982, echoing a sentiment former Technical Director Hack Wilson had made nearly a decade earlier.

> It is a very, very fragile organization. If it is hurt—emotionally hurt—it'll withdraw into itself. It'll go on, exist, and appear to be productive and do what it wants or do what's asked of it, what's wanted of it, but it won't be the creative, outgoing place that has a significant impact on the Fleet. There's got to be a tolerance of that maverick scientist and engineer, and I focus on them because that's the focus of the Center. There must be a tolerance of those people.[87]

Together, Haff and Hillyer set the tone for NWC as it entered the 1980s, a decade that would prove to be one of the most exciting and productive in the history of the Navy at China Lake.

[86]Hillyer had spent 3 years as a Navy officer at Corona before transferring into the civilian workforce there in 1960. "My first job included acting as the messenger between the Fuze Department in Corona and the contentious bunch of people at China Lake that we dealt with," he said. He served as Director of Navy Laboratories (DNL) in 1982 and as Technical Director of NOSC from 1983 until his retirement in 1990. He died in 2013. S-134, Hillyer interview, 1.

[87]Ibid., 75. In the same vein, Wilson had said at his retirement party, "What's been built here at China Lake is dynamic and active, but it's also fragile and will need the dedication, concern and involvement of just as many people in the future as it has in the past." *Rocketeer*, 11 May 1973, 5.

Appendixes

A. *Principles of Operation*, 12 May 1971

Reproduced in facsimile.

1. The Naval Weapons Center is a primary research, development, and test activity of the Naval Material Command. The Commander, Naval Weapons Center is responsible to the Chief of Naval Material for administering assigned funds, conducting operations, and accomplishing the mission of the Center.

2. The mission of the Naval Weapons Center is to originate and analyze new ideas in weapons systems and related fields of science and technology; to advance them through research, development, experimental production, test, and evaluation; and to assist in introducing the resultant weapons systems and technology into production and service use.

3. The technical program of the Center is planned jointly by the Chief of Naval Material and the Commander, Naval Weapons Center and is integrated and positively directed toward accomplishing the mission.

4. To accomplish the mission, superior military and civilian personnel are essential, each with proper authority and responsibility, each complementing the other, and each supported by adequate facilities and funds.

5. The Commander, a senior naval officer, is responsible to the Chief of Naval Material for all phases of operation of the Center. He delegates line authority to the Technical Director for the technical program.

6. The Commander and the Technical Director are jointly responsible to the Director of Navy Laboratories for policy matters affecting the Center and interlaboratory relations, and for the effective and economical internal functioning of the Center in accomplishing the mission.

7. The Technical Director, a recognized civilian scientist or engineer, is responsible to the Director of Laboratory Programs for implementing technical guidance affecting the Center.

8. The Deputy Technical Director and the Deputy Commander are jointly responsible to the Commander and Technical Director for directing and integrating the work of all departments in accomplishing the mission.

9. The Heads of Departments are responsible to the Deputy Technical Director and the Deputy Commander for providing leadership in their respective programs in supporting and accomplishing the mission.

10. The primary function of all groups of the Center is to further the technical program. All departments participate according to their responsibilities in accomplishing the mission of the Center.

11. The responsibility of the professional staff is to produce superior technical accomplishments in research, development, design, experimental production, test, and evaluation of weapons systems.

12. The primary responsibility of the technical officers of the armed services attached to the Center is to assist and advise the civilian technical staff on matters relating to the development of naval material designed to meet service requirements and operating conditions.

13. The Naval Weapons Center is an integral part of the Naval Establishment. Its personnel, military and civilian, are equally a part of that establishment. Every effort is made to provide opportunities for professional advancement and recognition, to the end that all will be proud that they are a part of the Navy.

Approved 12 May 1971:

[Signed]

J. D. Arnold, Chief of Naval Material

Joel S. Lawson Jr., Director of Navy Laboratories /
Director of Laboratory Programs

W. J. Moran, Commander, NWC

H. G. Wilson, Technical Director, NWC

B. Selected China Lake Systems Delivered to the Warfighter, 1968 to 1979

Year	System Name	Description
1968	Chaff dispensing rocket (CHAFFROC)	Shipboard chaff-rocket decoy system
1968	Scuttling and destruct system	Ship scuttling and equipment destruction
1968	Fireye fuel-gelling unit Mk 1 Mod 0	Advanced flame-weapon fuel production unit
1968	Helicopter Trap Weapon Mk 115 Mod 0	Munition for clearing booby traps from helicopter landing zones
1968	Radio firing device Mk 100 Mod 0	Secure radio-link firing device
1968	Rocket-Assisted Projectile (RAP) Mk 57	5-inch/38-caliber RAP
1968	Rockeye II	Antipersonnel/antimaterial (APAM) cluster bomb (Mk 20)
1968	AGM-45A-3, -3B, and -4 Shrike	Antiradiation missile
1968	AIM-9G Sidewinder	Air-to-air missile with Sidewinder Expanded Acquisition Mode (SEAM)
1968	AGM-78A and -78B Standard Antiradiation Missile (ARM)	Air-to-ground antiradiation missile
1969	MIM72A Chaparral	Surface-to-air missile (Army)
1969	DSU-10/B	Target-detecting device (TDD) for Standard ARM
1969	CP-841/A	Weapons-release computer
1969	AGM-87A-1 Focus, limited	Night-attack air-to-ground version of AIM-9 Sidewinder
1969	Lightweight gun pod Mk 12, interim	20 mm
1969	SEAM	SEAM seeker head

Year	System Name	Description
1969	AGM-45A-7 Shrike	Antiradiation missile, expanded frequency coverage
1969	AN/APS-117 Target Identification and Acquisition System (TIAS)	Detection and classification of radar emitters
1969	Zuni warhead Mk 63 Mod 0	5-inch directed-fragmentation rocket warhead
1970	CBU-55/A fuel-air explosive (FAE)	Slow-speed-delivery FAE
1970	Hand-emplaced FAE	FAE canisters for mine clearance
1970	Quick Bloom Mk 84	CHAFFROC chaff package
1970	RAP Mk 58	5-inch/54-caliber RAP
1970	AGM-45A/B-6 Shrike	Antiradiation missile, expanded frequency coverage
1970	Snakeye tail assembly Mk 15 Mod 3	Retarding-tail-assembly conversion package for Mk 82/83 bombs
1970	RIM-7E SeaSparrow	Basic point-defense ship missile system
1970	Target-designator system / laser spot tracker	Designates targets for air attack
1970	AGM-78C Standard ARM	Antiradiation missile, expanded frequency coverage
1971	Ship's Ordnance Infrared (IR) Decoy	Ship-launched IR flare
1971	IR decoy flare Mk 46	Used with AN/ALE-29A chaff dispenser
1971	Night Observation Gunship System (NOGS), limited	M-197 20 mm gun slaved to forward-looking infrared (FLIR) on a non-dedicated OV-10 platform
1972	IR decoy flare Mk 50 Mod 0	Used for low-speed, low-altitude aircraft
1972	NOGS YOV-10D	Fully integrated gun system and platform

Year	System Name	Description
1972	Shrike On Board (S.O.B.)	Shipboard Shrike, quick-reaction installation
1972	Walleye II Guided Weapon Mk 5	TV-guided air-to-surface glide weapon, greater accuracy, larger warhead, data link
1972	AN/AVQ-10/A Navy Pave Knife	Stabilized airborne laser target designator
1972	Navy-Marine Corps ordnance requirements (NAVMOR)	Computer program using least-cost-per-kill as the basis for ordnance selection
1972	TDD Mk 45	Dual-beam TDD for Standard Missile
1973	CBU-72/B FAE	High-speed-delivery FAE
1973	QF-86H	Full-scale aerial target/drone
1973	RIM-72C Sea Chaparral	Seaborne version of MIM 72A Chaparral
1973	AIM-9H Sidewinder	Air-to-air missile, first solid-state Sidewinder
1973	AGM-78D Standard ARM	Antiradiation missile, expanded frequency coverage
1974	Actuation mine simulator	Used for mine-sweeper training
1974	SUU-53 cartridge dispenser	Catalyst-generator dispenser for weather modification
1974	AGM-45A/B-9 Shrike	Antiradiation missile, broader bandwidth
1974	AGM-78D-2 Standard ARM	Antiradiation missile, active optical fuze, larger warhead
1974	CBU-59 APAM	Successor to Rockeye, cluster bomb
1974	BQM / surface-to-surface missile (SSM) BQM-34A Firebee, limited	Drone modified for long-range antiship surface-launched-missile use
1974	Walleye II Extended-Range Data Link (ERDL) guided weapon Mk 13	ERDL TV-guided air-to-ground glide weapon

Year	System Name	Description
1975	Expendable seeker simulator	Drone-carried, imitates antiship cruise missile (ASCM) emissions
1975	Selectable seeker simulator (Triple S)	Airborne generic ASCM simulator
1975	Swimmer delivery vehicle (SDV) Mk IX	Two-man SDV
1975	QT-38	Supersonic aerial target/drone
1976	AIM-7F Sparrow	Air-to-air missile, with China Lake fix of production problems
1976	OFP-NWC-1	Operational flight program for the A-7E
1977	OFP NWC-2	Operational flight program for the A-7E; fixed problems, added new capabilities
1977	RGM/AGM/UGM-84 Harpoon	Air-to-surface missile
1977	QF-86F	Full-scale aerial target/drone
1978	AIM-9L Sidewinder	Air-to-air missile, first “all-aspect” Sidewinder
1978	OFP-NWC-2C	Operational flight program for the A7E trainer
1978	OV-10D Night Observation System	FLIR / laser designators on OV10 platform
1978	AN/ASM-607 memory loader verifier	Used for loading aircraft software
1978	A-7E FLIR	FLIR light-attack-aircraft avionics system
1979	OFP-NWC-3	Operational flight program for the A7E with FLIR and improved tactical computers
1979	QLT1C mobile land target	Remotely controlled target vehicle
1979	A-6E target recognition and attack multisensor	All-weather day-night attack system

C. Biographies of Naval Weapons Center (NWC) Commanders, 1968 to 1979

Captain Melvin R. Etheridge

Commander, Naval Weapons Center

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 3-year class at the academy. He graduated and was commissioned in 1942. He served on submarines during World War II (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 Sea Control Squadron 22 (VS-22) and Attack Squadron 42 (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, Naval Weapons Center (NWC), 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 NWC 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 weapons 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 United States 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.

Rear Admiral William J. Moran [Vice Admiral]

Commander, Naval Weapons Center

22 October 1970 to 18 October 1972

William J. Moran was born 20 July 1919 in San Mateo, California. He entered the Navy in February 1941 from Reno, Nevada, and was designated a naval aviator in December 1941. His first squadron was Fighter Squadron THREE (VF-3). He subsequently served with VF-72 on USS *Hornet* (CV-8). After the *Hornet* was sunk in October 1942, he flew from the escort carrier USS *Nassau* (CVE-16) and from the island of Guadalcanal.

From 1943 until August 1944, Vice Admiral Moran was an instructor in advanced fighter training. After that he served with VF-10 aboard the carrier USS *Intrepid* (CV-11) until the end of the war.

Vice Admiral Moran's first postwar assignment was on the staff of the Commander, Carrier Air Division 17. A tour of duty with the Commander, Fleet Air, Alameda, followed. Upon graduation from the Navy General Line School, Monterey, in 1949, he reported to the U.S. Naval Ordnance Test Station, Inyokern, California. In 1952, he joined the Pacific Fleet Night Interceptor Squadron (VC-3). A year later he assumed command of VF-23 deployed in USS *Essex* (CV-9).

In July 1954, Vice Admiral Moran was ordered to the Naval War College, Newport, Rhode Island, and in 1955 again reported to the U.S. Naval Ordnance Test Station, where he participated in airborne weapon systems development. He subsequently served on the staff of the Commander, Naval Air Force, Atlantic Fleet, and as Executive Officer of the *Essex*. After a tour as naval aide to the Assistant Secretary of the Navy for Research and Development from 1961 to 1964, Vice Admiral Moran attended the National War College.

He assumed command of USS *Rainier* (AE-5) in August 1965 and of USS *Randolph* (CVS-15) in October 1966. He was Commander of Antisubmarine Warfare Group Three from August 1967 until November 1968. Following an assignment in Washington as Director of the Navy Space Program Division for the Chief of Naval Operations, Vice Admiral Moran reported as Commander, NWC. He completed his tour in 1972, was promoted to vice admiral, and was assigned as Director for Research, Development, Test, and Evaluation in the Office of the Chief of Naval Operations. He retired in May 1975 with 34 years of service.

During his tour at China Lake, Vice Admiral Moran strengthened ties between the Center and the Washington Systems Commands and was a strong defender of the embattled Agile program.

His decorations include the Legion of Merit with one gold star, the Distinguished Flying Cross with two gold stars, and the Air Medal with three gold stars.

Vice Admiral Moran was married to the former Ruth E. Nelson of Saint Croix Falls, Wisconsin. They were the parents of three daughters: Margaret, Chris, and Mary. Vice Admiral Moran died in Boulder, Colorado, on 9 May 2009.

Rear Admiral Henry M. Suerstedt Jr.

Commander, Naval Weapons Center

18 October 1972 to 30 May 1973

Henry M. Suerstedt Jr. was born 14 October, 1920. He entered the Navy in May 1941. He served as a squadron operations officer and later Executive Officer of Composite Squadron 21 (VS-21) in WWII, flying Avenger torpedo bombers from the escort carriers USS *Marcus Island* (CVE-77) and USS *Commencement Bay* (CVE-105). During the Korean War, he was the Skyraider project officer in the Bureau of Aeronautics Attack Design Branch and later served as Commander, Fighter Squadron 54 (VF-54), flying Skyraiders in combat operations from USS *Valley Forge* (LPH-8).

After graduation from the Armed Forces Staff College in 1955, Rear Admiral Suerstedt was assigned as technical assistant to the systems director in charge of aviation ordnance research and development at the Bureau of Ordnance. He subsequently held the post of military assistance training officer for Asian navies and the Marine Corps on the Joint Staff, Commander in Chief, Pacific. In 1961, he became the Director of Strike Warfare Programs in the Bureau of Naval Weapons.

Early in the Vietnam War, he was assigned command of the helicopter assault aircraft carrier USS *Tripoli* (LPH-10), directing five amphibious assault operations. After tours as the Naval Air Systems Command's (NAVAIR's) Executive Director for Logistics and Fleet Support as well as Assistant Commander for Logistics and Fleet Support, he returned to Vietnam in 1970 as Commander, U.S. Naval Forces, Vietnam.

Following his second tour in Vietnam, Rear Admiral Suerstedt held the post of Commander of Joint Task Force Eight, based at the Defense Atomic

Support Agency, Sandia Base, Albuquerque, New Mexico. He directed a high-altitude nuclear-related test shot in the Pacific and was responsible for the military planning of Operation Cannikin in the Aleutian Islands, the largest underground nuclear test ever conducted by the United States.

Rear Admiral Suerstedt subsequently served 18 months as Deputy Commander for Plans and Programs and Comptroller, NAVAIR, before assuming command of NWC in 1972. Upon the conclusion of his tour in 1973, he retired with more than 32 years of naval service.

Secretary of the Navy John Warner, in a letter read at Rear Admiral Suerstedt's retirement, stated:

> You have demonstrated most ably your ability to perform duties demanding great professional competence, superior judgment, and strong leadership. . . . You have met the demands, complexities, and challenges of each assignment, ranging from combat aviation to duties in two wars to your present assignment as Commander of the Naval Weapons Center with determination, resourcefulness and ingenuity.[1189]

Among the rear admiral's decorations were the Silver Star, Legion of Merit with four gold stars (two with Combat V), Distinguished Flying Cross with two gold stars, Bronze Star Medal (Army) with Combat V, Air Medal with one silver star and four gold stars, and Navy Commendation Medal with Combat V. Following his retirement, Rear Admiral Suerstedt held various positions in private industry, including that of Director, Western Region, PRD Electronics Inc.

Rear Admiral Suerstedt was married to the former Mary Josephine Bass; they had two daughters, Candice Cecillia and Cynthia Marie. Rear Admiral Suerstedt died in Coronado, California, on 12 April 1990.

[1189]*Rocketeer*, 1 June 1973, 3.

Rear Admiral Paul E. Pugh

Commander, Naval Weapons Center

30 May 1973 to 27 June 1974

Paul Edward Pugh was born in Sulphur, Oklahoma, on 11 August 1918. He received his bachelor of science degree from the University of California, Berkeley, in 1940; entered naval service on 15 March 1941; and was designated a naval aviator in January 1942. Following tours as a flight instructor and gunnery officer, he joined Fighter Squadron TWO (VF-2) in 1945, flying Hellcats from USS *Shangri-La* (CV-38).

Following WWII, Rear Admiral Pugh served as fire control project officer at the Naval Air Test Center, Patuxent River, Maryland, for 4 years. He was in the first class of the Test Pilot School. A stint as the F2H Banshee project officer with Experimental Squadron THREE in 1959 was followed by a tour with the Air Force's 4th Fighter Intercept Group in Korea, flying F-86s against the enemy. He is credited with two MiG-15 kills.

Rear Admiral Pugh attended General Line School in Monterey and the Naval War College, Newport, Rhode Island; headed the Bureau of Inspection and Surveys as well as the Fighter Squadron (VF) Project Branch at Naval Air Test Center (NATC); and was then assigned to command Fighter Squadron 211 (VF-211). He next served as Commander, Carrier Air Group 21 (CVG-21), and later was on the staff of Commander, Carrier Division Four. From 1960 until 1962, he served in the Office of the Chief of Naval Operations, followed by a 1-year tour as a student at the Industrial College of the Armed Forces. Next were successive assignments as Commanding Officer, USS *Eldorado* (AGC-11); Commanding Officer, USS *Kitty Hawk* (CVA-65); and Commander, Attack Carrier Strike Group 77.5.

In August 1967, Rear Admiral Pugh became deputy for current operations, Commander in Chief, U.S. Pacific. He next reported as Commander, United States Naval Forces, Marianas, with additional duty as Commander in Chief Pacific representative, Guam / Trust Territory of the Pacific Islands. In 1972, he was detached for duty as senior Navy member, Military Studies and Liaison Division, Weapons Systems Evaluation Group, Director of Defense Research and Engineering (DDR&E), Office of the Secretary of Defense, a post he held until taking command of NWC. Following his tour at China Lake, Rear Admiral Pugh retired with 33 years of active naval service. Following his retirement, he worked for 3 years with Hughes Aircraft Co.

During his tour at China Lake, Rear Admiral Pugh was a strong supporter of the Agile program and also worked to keep the Center competitive by keeping the cost of operations down.

Among Rear Admiral Pugh's many decorations are the Legion of Merit with one gold star; the Distinguished Flying Cross with oak leaf cluster (Air Force); the Bronze Star; the Air Medal with five gold stars and oak leaf cluster; and the Navy Unit Commendation Ribbon for the *Kitty Hawk*, awarded under his command.

Rear Admiral Pugh was married to the former Clarine Coppock of Whittier, California. They had three children: Paul E. Jr. (Eddie), Mark, and Nancy. Rear Admiral Pugh died at Coronado, California, on 6 December 2006.

Rear Admiral Rowland G. Freeman III

Commander, Naval Weapons Center

27 June 1974 to 26 May 1977

Rear Admiral Rowland Godfrey Freeman III was born in New York City on 11 February 1922. He attended the University of Massachusetts before enlisting in the Naval Reserve in June 1942. Upon completion of flight training in May 1943, he participated in most of the major engagements in the Pacific during WWII as a night fighter pilot aboard USS *Lexington* (CV-16) and USS *Wasp* (CV-18).

In November 1945, Rear Admiral Freeman transferred from the Naval Reserve to the U.S. Navy. He flew with Bombing Squadron 150 and Attack Squadron 14-A (VA-14A) until 1947, then served as overhaul and repair inspection officer at the Naval Air Station (NAS), Jacksonville, Florida. In 1950, after attending General Line School, Newport, Rhode Island, he reported as assembly division officer (overhaul and repair) at NAS, Norfolk, Virginia. In 1953, he earned a master's degree in business administration from Harvard and was assigned to the Bureau of Aeronautics as a contracting officer in the Contracts Division; he subsequently served as assistant head of the Components Purchase Section and then head of the Workload and Statistics Section.

In 1957, Rear Admiral Freeman reported as head of the Air-to-Air Missile Department, Naval Air Missile Test Center (NAMTC), Point Mugu, California, where he also served as head of the Missile Test Department and the Astronautics Department. In 1960, he was prospective Commanding Officer of Attack Squadrons 125 and 126 (VA-125 and VA-126) and then assumed command of Attack Squadron 144 (VA-144). In 1961, he was navigator on USS *Oriskany* (CV-34), and in 1962, he became the ship's air officer. He was the Bureau of Naval Weapons representative at the McDonnell Aircraft Corporation, St. Louis, in 1963 and 1964 and served as Phantom II production test pilot. He assumed command of USS *Procyon* (AF-61) in December 1964, and in 1966 served in the Aero Systems Division, Air Force Systems Command, Dayton, Ohio, as manager for the Navy F-111B program.

Rear Admiral Freeman became Deputy Chief of Naval Material (Procurement and Production) in 1968. He came to China Lake from his assignment as Study Director of the Navy Enlisted Occupational Classification System, Bureau of Naval Personnel, Department of the Navy, Washington, DC, a position he had held since July 1973.

Following his tour as NWC Commander, Rear Admiral Freeman served as commandant of the Defense Systems Management College, Fort Belvoir, Virginia. After retiring as a rear admiral in 1979 with more than 36 years of service, he served as the administrator of the General Services Administration until January 1981. Following his federal service, he worked with McDonnell Douglas Corp. as vice president for strategic planning and energy systems ventures.

During Rear Admiral Freeman's tour as NWC Commander, he oversaw many changes that, while not always well received by China Lake's civilians, helped to position the Center for the challenges of expanded range testing, shrinking budgets, and a more contractor-centered mode of weapon system development and acquisition.

Rear Admiral Freeman's decorations include the Navy Distinguished Service Medal, two Legion of Merit awards, two Distinguished Flying Crosses, eight Air Medals, and numerous theater and unit awards. He was married to the former Dorothy Gates Gleason of Lawrence, Kansas; they had four children, Christopher, Geoffrey, Rowland, and Diana. Rear Admiral Freeman died on 29 November 2014 in Williamsburg, Virginia.

Captain Frederick H. M. Kinley

Commander, Naval Weapons Center

26 May 1977 to 12 September 1977

Captain Frederick Henry Michael Kinley was born on 31 March 1932 in Calcutta, India, where his father was an engineer for Ingersol-Rand. The family returned to York, Pennsylvania, where he spent his youth. Following high school graduation he was certified for the U.S. Naval Academy, Annapolis, Maryland, where he graduated as a surface warfare officer in 1954 and was assigned to USS *McGowan* (DD-678). Several sea duty tours followed, including service as a weapons officer on USS *Barney* (DDG-6), Executive Officer of USS *Charles F. Adams* (DDG-2), and Commanding Officer of USS *Warsaw* (AN-91).

In 1962, Captain Kinley received a master of science degree in physics from the Naval Postgraduate School, Monterey, California. He later returned there and earned a master of science degree in systems acquisition management in 1972. He also attended the Command and Staff course at the Naval War College, Newport, Rhode Island.

Overseas tours included participation in the Dominican Republic Operation in 1963, a North Atlantic Treaty Organization exercise in the Norwegian Sea and Arctic Circle in 1964, and offshore operations in Southeast Asia in 1971 as Commanding Officer of USS *Lang* (FF-1060).

Subsequently, Captain Kinley was assigned to the Strategic Plans Division in the Office of the Chief of Naval Operations. Before coming to China Lake as Vice Commander in 1976, he also served with the Naval Sea Systems Command (NAVSEA) as Director, Gun Fire Control Division, and Head, Plans and Program Office (Surveillance Radar Division).

For nearly 4 months in 1977, Captain Kinley served as NWC Commander. After the assignment of Rear Admiral William L. Harris as Commander, Captain Kinley returned to his post as Vice Commander. In 1979, he was assigned as Commanding Officer of the Fleet Combat Training Center Atlantic, Dam Neck, Virginia.

Following his retirement in 1981, after 27 years of naval service, Captain Kinley worked with HBH Co., training Commanding Officers and crews for the Royal Saudi Naval Forces, and was subsequently employed by American Management Systems.

Although Captain Kinley's tour as NWC Commander was brief, he maintained the continuity of his predecessor's programs, and he kept lines of communication open to the employees during the run-up to a significant reduction-in-force (RIF) action. He was active in strengthening ties between the China Lake community and the city of Ridgecrest.

Captain Kinley's decorations include the Bronze Star and Navy Commendation Medal. He was married to the former Priscilla Mohr of Jackson, Mississippi, and they were the parents of two sons, Guy and Paul, and a daughter, Kara. Captain Kinley died on 7 July 1999 in Virginia Beach, Virginia.

Rear Admiral William L. Harris Jr.

Commander, Naval Weapons Center

12 September 1977 to 29 June 1979

Rear Admiral William L. Harris Jr. was born in Kansas City, Missouri, on 10 January 1924. He enlisted in the Naval Reserve in 1942 and in 1943 entered the U.S. Naval Academy, graduating in 1946. After duty aboard USS *Princeton* (CV-37), he reported to Pensacola, Florida, for flight training. Following designation as a naval aviator in 1949, Rear Admiral Harris served in Fleet squadrons, flying various Navy attack aircraft; he flew 53 combat missions over Korea.

Following his Korean War duty, Rear Admiral Harris attended the Naval Postgraduate School, Monterey, California, for nearly 3 years, earning a bachelor of science degree in aeronautical engineering and a master of science degree in electrical engineering. After a tour as a maintenance and operations officer for Attack Squadron 34 (VA-34), he was assigned to the Naval War College, Newport, Rhode Island, where he attended the Command and Staff course.

In 1963, following a tour as Executive Officer of Attack Squadron 76 (VA-76) operating from USS *Enterprise* (CVA(N)-65), Rear Admiral Harris formed and commanded Attack Squadron 75 (VA-75), the first operational Fleet squadron of A-6 aircraft, a post he held until May 1964 when he was sent to nuclear power training. In 1965, he was designated a nuclear power plant operator and assigned as operations officer on USS *Enterprise*. Beginning in 1966, he served as executive assistant and naval aide to the Assistant Secretary of the Navy for Research and Development.

He next served as Commanding Officer of the amphibious assault ship USS *Alamo* (LSD-33), which received the Battle "E" under his command during amphibious combat operations in Vietnam. A 1-year tour as force readiness officer for the Commander, Naval Air Pacific, was followed by Rear Admiral Harris' assignment as Commanding Officer of USS *Midway* (CV-41) during 1971 and 1972 cruises off Vietnam. While under his command, USS *Midway* received both the Meritorious Unit Commendation and the Presidential Unit Citation.

Promoted to flag rank in 1972, Rear Admiral Harris served as Deputy to the President, Naval War College; Director, Tactical Air, Surface, and Electronic Development Division, Office of the Chief of Naval Operations (OP-982); Commander, Carrier Group Seven (where he directed the cyclone disaster relief operations on the Indian Ocean island of Mauritius and participated in the final evacuation of South Vietnam); Commander, Attack Carrier Strike Force, Seventh Fleet; and Commander, Carrier Group Five. Prior to assuming command of NWC, Rear Admiral Harris served as Assistant Commander for Test and Evaluation, Naval Air Systems Command. At the conclusion of his tour as NWC Commander, Rear Admiral Harris retired with more than 33 years of naval service.

During his command tour at China Lake, Rear Admiral Harris was a strong supporter of and advocate for numerous naval air weapons and technologies, including Harpoon, the Sidewinder AIM-9L, the Supersonic Tactical Missile, Advanced Air-to-Air Missile, and the low-cost integral rocket ramjet.

Rear Admiral Harris' personal decorations include the Legion of Merit with one gold star, Bronze Star, Meritorious Service Medal, Air Medal, and Navy Commendation Medal. He was married to the former Jean Odence of Great Neck, New York. They had five children: Elizabeth, William, Maureen, Ken, and Mary. He died on 3 April 2014 in Palo Alto, California.

Captain William B. Haff

Commander, Naval Weapons Center

29 June 1979 to 30 June 1981

Captain William Burton Haff was born in Lorain, Ohio, on 21 August 1928. He graduated from the Naval Academy in 1951 and reported for flight training at Pensacola, Florida; he was designated a naval aviator in November 1952. He had tours of duty flying the F-9, F-8, and F-4 aircraft in both the Korean and the Vietnam conflicts.

Captain Haff's first operational assignment was with VF-191. He served with the Air Force at Nellis Air Force Base, Las Vegas, Nevada, and later became an instructor at the Jet Transitional Training Unit, Olathe, Kansas. He then entered a postgraduate program at the Naval Postgraduate School and the Massachusetts Institute of Technology; he holds a bachelor of science degree in aeronautical engineering from the Naval Postgraduate School and a master of science degree in aeronautics and astronautics from the Massachusetts Institute of Technology.

Next, Captain Haff served with Fighter Squadron 124 (VF-124) and Fighter Squadron 111 (VF-111), after which he became the aircraft handling officer aboard USS *Midway* (CV-41). Another tour with the Air Force followed, at Norton Air Force Base, San Bernardino, California. Captain Haff returned to the Pacific Fleet in 1966, serving with Fighter Squadron 121 (VF-121) and Fighter Squadron 154 (VF-154), and in 1968, he was assigned to Commander, Seventh Fleet, as Fleet readiness officer.

Captain Haff was ordered to NWC in September 1970 as the Assistant Technical Officer, Air. In the early spring of 1972, he began a tour at the Naval Air Systems Command (NAVAIR), Washington, DC, as the Sidewinder program manager. He returned to NWC in July 1975 as Technical Officer and later was appointed Deputy Laboratory Director, a position he held until his selection as Commander, NWC. Following his tour as Commander, Captain Haff retired with more than 30 years of naval service.

During his command tour, Captain Haff kept NWC on a steady course and worked successfully to restore the balance of civilian oversight of the Center's technical programs. His previous tours at China Lake and his experience as a NAVAIR program manager contributed to strengthening relationships between the Center and its primary sponsor.

Decorations awarded to Captain Haff include the Legion of Merit, Distinguished Flying Cross with one gold star, Bronze Star with Combat V, 6 individual Air Medals, 21 Strike Flight Air Medals, and 5 Navy Commendation Medals with Combat V. Captain Haff resides in Nine Mile Falls, Washington; he has one son, Robert.

Bibliography

Many sources are in the archives of, or accessible through, the Naval Air Warfare Center Weapons Division's Corporate Customer Support Department.

Compilations

Biographical information, NWC Commanders.

Board of Directors meeting minutes and observations, compiled by Executive Secretary Robert V. McKenzie, 1970–1981.

Change-of-Command brochures, 1961–1989 (incomplete).

News and Views, collection of newsletters published by NWC Central Staff, 1968–1974.

NWC Advisory Board meeting minutes and recommendations, 1968–1976.

NWC Technical Board meeting minutes, partial collection, 1968–1970.

Public Papers of the Presidents of the United States, Jimmy Carter, 1978, Book 1—January 1 to June 30, 1978. Washington, DC: Office of the Federal Register, National Archives and Records Service, GSA. 1979.

Rocketeer, files of China Lake's in-house weekly newspaper.

Manuscripts

CNO. "Investigation of *Forrestal* Fire; Return of, Encl. (1) Copy of Findings, Recommendation and Opinions of Investigations into Fire On Board USS *Forrestal* (CVA 59) and First, Second, and Third Endorsements Thereon." Memorandum from Chief of Naval Operations to Judge Advocate General, Op-0982.ipl, Ser 09P098, 21 August 1969.

CNO. "Investigation to Inquire Into the Circumstances Surrounding the Collision Between USS *John F. Kennedy* (CV 67) and USS *Belknap* (CG 26) Which Occurred on 22 November 1975." Memorandum from Chief of Naval Operations to Judge Advocate General, Ser 00/500878, 7 September 1976.

Colvard, James. "Navy Technical Structure in Disarray." Unpublished manuscript by Dr. James Colvard, provided by Colvard, 8 December 2008.

Crawford, Jack A. "Condor Program Brief History (A Personal View)." Unpublished manuscript, circa 1982.

Dillinger, Robert B. "TVC Beginnings." Unpublished manuscript, August 2013.

Harrison, Raymond H. "Development of Technical Executives." Report prepared for the Board of Directors, April 1968.

Kistler, Dick. "Notes on Meeting of 27 April [1970, with Captain Etheridge and Hack Wilson]." Memorandum from Dick Kistler to Carl Schaniel, Bob McKenzie, Gale Poppen, Al Goettig, and Ed Swan, 28 April 1970.

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

Knutson, Dale. "Walleye Notes: A Few Rambling Remembrances from Dale Knutson." Prepared for the China Lake Museum Foundation, July 2007.

LaBerge, Walt. "From Research to Reality, A Retrospective on the Development and Acquisition of Naval Capabilities During the Cold War Era." Draft report of a seminar held at the Naval Postgraduate School, 12 and 13 June 2001.

McKenzie, Bob. "Attached Informal Notes to Board of Directors [Meeting]." Memorandum from Bob McKenzie to Mel Sorge, 16 December 1974.

McKenzie, Robert. "Additional Advanced Written Material for the Center Board of Directors Meeting—12, 13 November [1971]." Memorandum from Executive Secretary Robert McKenzie, memo 1703.RVM:gs, Reg. 1703-036-71.

McKenzie, Robert V. "Highlights from Board of Directors Meeting, 15–16 August 1974 at California City." Memorandum from Robert V. McKenzie to Mel Sorge [Head, Central Staff], 10/RMcK:1f 3/4, Reg. 17-215-75. Encl: *Board of Directors Material—1970 to 1981*, by R. McKenzie, Code 08B, April 1984.

———. "Unadjusted Notes from the Board of Directors Meeting, California City, 15, 16 August 1974." Memorandum from Robert V. McKenzie to Mel Sorge, Head, Central Staff, 10/RMcK:1f 3/4, Reg. 17-215-75. Encl 3: In *Board of Directors Material—1970 to 1981*, by R. McKenzie, Code 08B, April 1984.

McLean, William B. "Basic Information on U.S. Naval Ordnance Test Station China Lake, California. In Reply to Secretary McNamara's Task No. 97." Letter from William B. McLean to John Golden, 18 Aug 1961, in AdPub 107, Encl. 1.

NAVWPNCEN Note 5450, 00/RGF:ifp. "Organizational Realignment of the Naval Weapons Center." Naval Weapons Center, 9 December 1974.

NAWC Retrievable Manuscript RM-24. *Collected Speeches of Dr. William B. McLean*. Technical Information Department, Naval Air Warfare Center Weapons Division, September 1993.

NAWS AdPub 012. "Draft Comprehensive Land Use Management Plan (CLUMP) for Naval Air Weapons Station China Lake, California." Naval Air Weapons Station and Bureau of Land Management, September 2001.

NOTS. "NOTS Technical Board Meeting." Memorandum from Head, Central Staff, to Technical Board Members, 17/MGD:blc, 20 September 1967. Encl. 1: Minutes of Technical Board Meeting of 19–21 April 1967.

NWC Retrievable Manuscript RM-8. *History of Pyrotechnics at NWC/NOTS*, by B. A. Breslow, partial copy, Naval Weapons Center, April 1982.

NWC Retrievable Manuscript RM-17, Vol. 1. *NOTS-NWC Code Directories, 1949–1965*. Technical Information Department, Naval Weapons Center, January 1982.

NWC Retrievable Manuscript RM-17, Vol. 3. *NOTS-NWC Code Directories, 5-Year Supplement, 1981–1985*. Technical Information Department, Naval Weapons Center, October 1985.

NWC Retrievable Manuscript RM-17, Vol. 4. *NOTS-NWC Code Directories, 5-Year Supplement, 1986–1990*. Technical Information Department, Naval Weapons Center, June 1991.

NWC Retrievable Manuscript RM-17, Vol. 2. *NOTS-NWC Code Directories, 1965–1980*. Technical Information Department, Naval Weapons Center, August 1982.

NWC Retrievable Manuscript RM-22. *The NWC Explosives Program History and Analysis. Volume I: The History*, by Taylor B. Joyner, Engineering Sciences Division, Naval Weapons Center, March 1986.

NWC TS 85-38. *Draft History of the Experimental/Plans and Operations/Technical Officers/Deputy Laboratory Directors at the Naval Ordnance Test Station/Naval Weapons Center (NOTS/NWC)*, by Frances Matthews, Technical Information Department, and Mary McIntire, Office of Finance and Management, Naval Weapons Center, October 1981.

NWC. "Agile Background." Memorandum from Technical Director, NWC, to Commander, NWC, 01/WBL:lo, 4 June 1973.

———. "Biography, NWC Technical Directors, March 1968–March 1970, Thomas Strong Amlie." Compiled by Michelle Ballinger, Special Writing Projects, Naval Weapons Center, Summer 1976.

———. "Center Issues." Annotated draft by John Bodenburg, Special Projects Group, Office of Finance and Management. 1980.

———. "Equipment Management Study." Conducted by Ivar Highberg at the request of Technical Director Hollingsworth, May 1975.

———. "Final Report of the Organization and Program Realignment and Refocusing Study," by Frank Knemeyer and others. June 1975.

———. "Franklin H. Knemeyer (Frank)." Official NWC biography, expanded and annotated by Frank Knemeyer, July 1978.

———. "Guidelines for Developing Sub-Plans for Relocating Corona Programs, Functions, Personnel, Equipment and Facilities." NWC internal guidance document by M.R. Etheridge, Commander, NWC, April 1969.

———. "Information Concerning Present Problems and Future Plans for Housing and Community Development at China Lake." Memorandum from Commander, Naval Weapons Center to Commander, Naval Air Systems Command, 7 March 1968.

———. "Naval Weapons Center Organizational Changes; Request for Approval." Memorandum from TD, NWC, to DNL, 01/WBL:mms, Ser 3127, 8 June 1973.

———. "NWC Pioneering DOD Lab Efforts in Technology Transfer, or, Another DOD Lead Lab Role for NWC." NWC internal report by L. D. Marquardt and C. V. Bryan, February 1971.

———. "NWC Program Priorities." Advisory Board briefing by Haskell G. Wilson, 9 November 1972.

———. "Overhead Rates Comparison." Memorandum from Head, Central Staff, to Codes 00, 01, 02, and Technical Department Heads, 17/MBS/ral, 6 April 1970.

———. "Realignment and Focusing Study for NWC; Establishment of." Memorandum from Commander and Technical Director to Distribution, 1712/RVM/dc, 11 September 1969.

———. "Recollections of Vertical-Launch ASROC," by Philip W. Bowen. Prepared for the Technical Communication Office, January 2014.

———. "Response to Telecon from M. R. Hoagland (MAT-0331) of 31 December 1968." Memorandum from Code 01 to Code 00, 03, 05, 01/TSA:drq, 2 January 1969.

———. "Sidewinder History." Unpublished manuscript prepared from the files of the Sidewinder Program Office, 1971–74, by David Rugg, 1982.

———. "Sidewinder Program Information." Unpublished manuscript, November 1964. Attachment 3, "Sidewinder Programs Funding Chart."

———. "Technical Planning Board Charter," by RADM R. G. Freeman III USN, and G. L. Hollingsworth, 24 February 1975.

———. "The In-House Laboratories—What Should We Be Doing Now to Shape Their Future Role?" Point paper by R. M. Hillyer, February 1977.

———. "Walleye/Condor History after 1967." Unpublished manuscript by Marc Moulton, circa 1991.

OR #S-0363-SL. "Operational Requirement (OR) Insensitive High Explosives (IHE)." Enclosure to CNO Memorandum Ser 987/239915, 22 August 1979. Quoted in Beauregard, Raymond L. *The History of Insensitive Munitions*. Accessed 10 October 2013. http://www.insensitivemunitions.org/history/navy-issues-an-operational-requirement-or-for-insensitive-high-explosives/.

Schaniel, Carl. "Carl's Career Chronology." Unpublished autobiographical manuscript, August 2007. Provided by the Schaniel family.

Sorge, Mel B. *Comparative Review of Average (Mean) Salaries of Scientists and Engineers Representing the Private Sector With Center Scientists and Engineers*. Memorandum for the Technical Director, Naval Weapons Center, June 1972.

Tambini, Tony, and Angie Tambini. *The Flying Tambinis*. Unpublished autobiographical manuscript, circa 1988. Excerpts provided to the author by Tony Tambini.

Tri-Service Working Group. "A Plan for Relocating the RDT&E Mission and Functions of the National Parachute Test Range." 7 November 1977.

NOTS/NWC Technical Histories

NOTS TP 2127. *Naval Ordnance Test Station Technical Program Review 1958.* China Lake: Naval Ordnance Test Station, 1 January 1959.

NOTS TP 2374. *Naval Ordnance Test Station Technical History 1959.* China Lake: Naval Ordnance Test Station, 1 January 1960.

NOTS TP 2906. *Naval Ordnance Test Station Technical History 1961.* China Lake: Naval Ordnance Test Station, 1 January 1962.

NOTS TP 3119. *Naval Ordnance Test Station Technical History 1962.* China Lake: Naval Ordnance Test Station, 1 January 1963.

NOTS TP 3428. *Naval Ordnance Test Station Technical History 1963.* China Lake: Naval Ordnance Test Station, 1 June 1964.

NOTS TP 3726. *Naval Ordnance Test Station Technical History 1964.* China Lake: Naval Ordnance Test Station, 1 April 1965.

NOTS TP 4001. *Naval Ordnance Test Station Technical History 1965.* China Lake: Naval Ordnance Test Station, April 1966.

NOTS TP 4237. *Naval Ordnance Test Station Technical History 1966.* China Lake: Naval Ordnance Test Station, April 1967.

NWC TP 4456, Part 1. *Naval Weapons Center Technical History 1967*. China Lake: Naval Weapons Center, April 1968.

NWC TP 4680. *Naval Weapons Center Technical History 1968*. China Lake: Naval Weapons Center, April 1969.

NWC TP 4832. *Naval Weapons Center Technical History 1969*. China Lake: Naval Weapons Center, April 1970.

NWC TP 5042. *Naval Weapons Center Technical History 1970*. China Lake: Naval Weapons Center, April 1971.

NWC TP 5266. *Naval Weapons Center Technical History 1971*. China Lake: Naval Weapons Center, April 1972.

NWC TP 5442. *Naval Weapons Center Technical History 1972*. China Lake: Naval Weapons Center, April 1973.

NWC TP 5600. *Naval Weapons Center Technical History 1973*. China Lake: Naval Weapons Center, April 1974.

NWC TP 5723. *Naval Weapons Center Technical History 1974*. China Lake: Naval Weapons Center, April 1975.

NWC TP 5830. *Naval Weapons Center Technical History 1975*. China Lake: Naval Weapons Center, April 1976.

NWC TP 6000. *Naval Weapons Center Command and Technical History 1976–1977*. China Lake: Naval Weapons Center, April 1978.

NWC TP 6070. *Naval Weapons Center Command and Technical History 1978*. China Lake: Naval Weapons Center, April 1979.

NWC TP 6170. *Naval Weapons Center Command and Technical History 1979*. China Lake: Naval Weapons Center, April 1980.

NWC TP 6265. *Naval Weapons Center Annual Report of Technical Progress 1980*. China Lake: Naval Weapons Center, June 1981.

Oral Histories: China Lake

S-1. Dr. L. T. E. Thompson. Interview by Albert B. Christman, 6 and 7 November 1965.

S-5. Vice Adm. George F. Hussey and Dr. L. T. E. Thompson. Interview by Albert B. Christman, April 1966.

S-8. Admiral Schoeffel. Interview by Albert B. Christman, 21 April 1966. Quoted in Gerrard-Gough, J. D., 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*. Washington, DC: Naval History Division, 1978. Washington, DC: Naval History Division, 1971.

S-15. Dr. L. T. E. Thompson. Interview by Albert B. Christman, May 1966.

S-34. Capt. John I. Hardy, USN. Interview by Albert B. Christman, 13 February 1967.

S-56. Early Timer's Meeting Speeches, 1 May 1968.

S-57. Vice Admiral Thomas Connolly, 25th Anniversary Speech, 8 November 1968.

S-58. China Lake 25th Anniversary Dinner Speeches, 9 November 1968.

S-60. Duane W. Mack. Interview by Albert B. Christman, January 1969.

S-61. Vice Adm. F. L. Ashworth, USN (Ret.). Interview by Albert B. Christman, 9 and 10 April 1969.

S-62. Dr. J. E. Henderson and Vice Adm. F. L. Ashworth, USN (Ret.). Interview by Albert B. Christman, April 1969.

S-87. Dr. William B. McLean. Interview by Albert B. Christman, 16 November 1973.

S-89. Max R. Smith. Interview by J. D. Gerrard-Gough and R. G. Douglas, 30 October 1973.

S-91. Newton Ward. Interview by J. D. Gerrard-Gough and Max R. Smith, 24 May 1974.

S-93. Haskell G. Smith. Interview by Albert B. Christman, 11 September 1970.

S-94. Dr. Newton E. Ward. Interview by Albert B. Christman, 23 October 1974.

S-95. Dr. Hugh Hunter. Interview by Elizabeth Babcock, 30 May 1975.

S-96. Haskell G. Wilson. Interview by Albert B. Christman, 9 July 1975.

S-97. Dr. William B. McLean. Interview by Albert B. Christman, July 1975.

S-99. James H. Jennison. Interview by J. D. Gerrard-Gough, 23 October 1975.

S-100. George Pollak. Interview by J. D. Gerrard-Gough, 24 October 1975.

S-103. Douglas Wilcox. Interview by J. D. Gerrard-Gough, 23 October 1975.

S-105. Robert G. S. Sewell. Interview by Minchen Strang, 14 October 1975.

S-106. Robert G. S. Sewell. Interview by Minchen Strang, 26 August 1975.

S-107. Dr. Howard Wilcox. Interview by Minchen Strang, 23 May 1976.

S-108. Dr. Gilbert Plain. Interview by Elizabeth Babcock, 9 December 1975.

S-109. Dr. Thomas S. Amlie. Interview by Michelle Ballenger, 24 August 1976.

S-110. Calvin J. Fallgatter. Interview by Carolyn Ogilvie, 6 December 1976.

S-112. Aviation Ordnance Department, Group Interview: Dr. Thomas S. Amlie, Dr. W. Frank Cartwright, Jack A. Crawford, Earl J. Donaldson, J. Raymond Schreiber, Charles P. Smith, Dr. Newton E. Ward, Dr. Howard A. Wilcox, Haskell G. Wilson. Interview by William F. Wright, 14 March 1980.

S-113. Edith LaVerne McLean. Interview by William F. Wright, 18 March 1980.

S-114. Clarence Renne. Interview by Michelle Kilikauskas and Susan Priest, 18 December 1980.

S-115. John Bodenburg. Interview by Elizabeth Babcock, 30 December 1980.

S-117. Franklin H. Knemeyer. Interview by Andrew Kilikauskas, 20 February 1981.

S-118. Frederick C. Alpers (with Robert C. Fletcher). Interview by Leroy L. Doig III, 27 and 28 January 1981.
S-119. C. John Di Pol. Interview by Leroy L. Doig III, 9 February 1981.
S-120. Dr. Pierre Saint-Amand. Interview by Leroy L. Doig III, 27 March 1981.
S-121. Dr. Ivar E. Highberg. Interview by Leroy L. Doig III, 1 April 1981.
S-122. Lee E. Lakin. Interview by Andrew Kilikauskas, 17 February 1981.
S-123. Ken Powers. Interview by Elizabeth Babcock, 18 May 1981.
S-124. Franklin H. Knemeyer. Interview by Leroy L. Doig III, 3 June 1981.
S-125. Capt. William B. Haff, USN. Interview by Leroy L. Doig III, 24 June 1981.
S-126. Ernest G. Cozzens. Interview by Leroy L. Doig III, 25 June 1981.
S-127. William R. Hattabaugh. Interview by Leroy L. Doig III with Joseph M. Burge, 9 July 1981.
S-128. Tilly Barling. Interview by M. P. Barnes, 9 February 1982.
S-129. Robert F. Barling. Interview by M. P. Barnes, 16 January 1982.
S-130. Capt. James Doolittle. Interview by Leroy L. Doig III, 10 January 1982.
S-131. Dr. Richard E. Kistler. Interview by Leroy L. Doig III, 23 February 1982.
S-132. Dr. Richard E. Kistler. Interview by Leroy L. Doig III, 24 February 1982.
S-134. Robert M. Hillyer. Interview by Leroy L. Doig III, 14 and 27 May 1982.
S-135. Ann "Nancy" Carter. Interview by Elizabeth Anderson, 1 May 1975.
S-136. Leroy Riggs. Interview by Leroy L. Doig III, 18 and 19 June 1982.
S-137. Walter M. Schirra. Interview by Leroy L. Doig III, 26 June 1982.
S-138. Haskell G. Wilson. Interview by Leroy L. Doig III, 10 August 1982.
S-141. Frederick C. Alpers. Interview by Leroy L. Doig III, 16 November 1982.
S-142. Thomas J. and Nancy Word. Interview by Leroy L. Doig III, 27 November 1982.
S-143. Thomas J. Word. Interview by Leroy L. Doig III, 28 and 29 November 1982.
S-146. Capt. John Jude Lahr, USN. Interview by Leroy L. Doig III, 10 and 14 June 1983.
S-150. Dr. Thomas S. Amlie. Interview by Leroy L. Doig III, 30 June 1983.
S-151. Jerry Reed. Interview by Leroy L. Doig III, 13 July 1983.
S-152. Capt. Melvin R. Etheridge, USN (Ret.). Interview by Leroy L. Doig III, 23 September 1983.
S-153. Dr. George Lehner. Interview by Leroy L. Doig III, 7 December 1984.
S-156. Dr. Taylor Joyner. Interview by Leroy L. Doig III, 18 March 1986.
S-157. Burrell W. Hays. Interview by Leroy L. Doig III, 21 April and 4 December 1986.
S-160. Paul Stephenson. Interview by Leroy L. Doig III, 10 June 1986.
S-163. Robert H. Forster. Taped self-interview, circa 1980.
S-166, Part 1. Don Hart, Maurice Hamm, and Howard Schafer. Interview by Linda Lou Crosby, December 1985.
S-168. Leonard T. "Lee" Jagiello. Interview by Leroy L. Doig III, 15 January 1988.
S-169. Charlie May. Interview by Elizabeth Babcock, 27 and 28 April 1988.
S-170. Minchen "Mickey" Strang. Interview by Elizabeth Babcock, 24 May 1988.
S-171. Jack A. Crawford. Interview by Elizabeth Babcock, 20 September 1988.
S-172. Bruce Wertenberger. Interview by Elizabeth Babcock, 6 December 1988.
S-174. Jim Campbell. Interview by Elizabeth Babcock, 25 January 1989.
S-175. James A. Bowen. Interview by Elizabeth Babcock, 14 April 1989.
S-176. Dr. Robert and Esther Rowntree. Interview by Leroy L. Doig III, 7 and 21 June 1989.

S-177. Vice Adm. Levering and Mrs. Beulah "Boots" Smith. Interview by Elizabeth Babcock and Leroy L. Doig III, 15 June 1989.

S-178. Dr. Walter B. LaBerge. Interview by Elizabeth Babcock, 1 September 1989.

S-180. John M. Boyle. Interview by Elizabeth Babcock, 31 August 1989.

S-181. Ted and Eleanor Lotee. Interview by William R. Blanc, 13 March 1990.

S-183. Gene Younkin. Interview by Elizabeth Babcock, 12 July 1990.

S-184. Dr. Jean M. Bennett. Interview by Elizabeth Babcock and Earl LaFon, 19 July 1990.

S-185. Donald K. Moore. Interview by Elizabeth Babcock, 11 October 1990.

S-186. LeRoy Jackson. Interview by Elizabeth Babcock, 16 November 1990.

S-187. Vice Adm. William J. Moran, USN (Ret.). Interview by Leroy L. Doig III, 5 December 1990.

S-188. Rod McClung. Interview by Elizabeth Babcock, 22 March 1991.

S-189. Charles W. Bernard. Interview by Elizabeth Babcock, 3 May 1991.

S-190. John L. Cox and Frederick M. Nathan. Interview by Elizabeth Babcock, 24 and 29 March 1991.

S-191. Vice Adm. Paul D. Stroop, USN (Ret.). Interview by Elizabeth Babcock and Leroy L. Doig III, 11 June 1991.

S-192. Frederick M. Nathan. Interview by William R. Blanc, 17 July 1991.

S-193. Edward E. "Mickie" Benton Jr. Interview by Dr. Ron Westrum and Elizabeth Babcock, 26 August 1991.

S-194. Dr. W. F. "Frank" Cartwright. Interview by Elizabeth Babcock and Dr. Ron Westrum, 28 August 1991.

S-195. John Di Pol, Lee Lakin, William Ward, and Bruce Wertenberger. Interview by Frank St. George, 5 September 1991.

S-196. Dr. Howard A. Wilcox. Interview by Elizabeth Babcock, 22 November 1991.

S-197. Haskell G. and Jane Wilson. Interview by Elizabeth Babcock, 23 October 1991.

S-198A. Francis C. Wentink, et al. Interview by David Rugg, November 1970–January 1971.

S-199. Dr. Thomas S. Amlie. Interview by Elizabeth Babcock, William R. Blanc, and Mark Pahuta, 1 June 1992.

S-200. Franklin H. Knemeyer. Interview by Elizabeth Babcock, Leroy L. Doig III, and Mark Pahuta, 20 November and 13 December 1991.

S-204. Cecilia A. "Tina" Knemeyer. Interview by Elizabeth Babcock and Mark Pahuta, 20 February 1992.

S-207. Dr. Walter B. LaBerge. Interview by Elizabeth Babcock and Mark Pahuta, 27 April 1992.

S-208. Thomas M. Moorer. Interview by Elizabeth Babcock and Mark Pahuta, 4 May 1992.

S-209. Carl F. Bernard. Interview by Elizabeth Babcock and Mark Pahuta, 13 and 14 July 1992.

S-210. NOTS South Interviews: Lois Allan, John M. Boyle, Cdr. Wade Cone, Russell O. Huse, LaV McLean, Harold H. "Pat" Patton. Interviews by Elizabeth Babcock and Leroy L. Doig III, 10 June 1992.

S-211. Dr. Newton E. and Maryon Ward. Interview by Elizabeth Babcock, Leroy L. Doig III, and Mark Pahuta, 11 June 1992.

S-214. Don R. Yockey, Interview by Elizabeth Babcock, William R. Blanc, and Mark Pahuta, 11 August 1992.

S-215. William H. Woodworth. Interview by Elizabeth Babcock, William R. Blanc, and Mark Pahuta, 20 August 1992.

S-216, Parts 1 and 2. William B. Porter. Interview by Elizabeth Babcock, William R. Blanc, Leroy L. Doig III, and Mark Pahuta, 3 December 1992 and 30 March 1993.

S-218. Ron Dettling. Interview by Leroy L. Doig III, William R. Blanc, and Mark Pahuta, 12 November 1992.

S-220. Richard Boyd. Interview by Elizabeth Babcock, Mark Pahuta, and Leroy L. Doig III, 19 November and 9 December 1992.

S-221. Burrell W. Hays. Interview by Leroy L. Doig III, William R. Blanc, and Mark Pahuta, 6 January 1993.

S-225. Peter and Polly Nicol. Interview by Elizabeth Babcock, William R. Blanc, Leroy L. Doig III, and Mark Pahuta, 31 March 1993.

S-226. Vice Adm. Frederick L. Ashworth. Interview by Elizabeth Babcock, William R. Blanc, Leroy L. Doig III, and Mark Pahuta, 16 and 17 April 1993.

S-227. Ken Smith. Interview by Elizabeth Babcock, William R. Blanc, and Mark Pahuta, 16 March 1993.

S-228, Part 2. Duane Mack. Interview by Leroy L. Doig III and Mark Pahuta, undated, circa 1993.

S-235. Robert A. "Al" and Darlene Boyack. Interview by Eileen Beach and Mark Pahuta, 6July 1994.

S-236. Harold Metcalf. Interview by Leroy L. Doig III, 1994.

S-238. Capt. John I. Hardy, USN (Ret.). Interview by Elizabeth Babcock, Leroy L. Doig III, and Mark Pahuta, 13 June 1995.

S-241. Jack Crawford. Interview by Leroy L. Doig III and Mark Pahuta, 4 March 2005.

S-243. Cdr. Mike Cater, USN (Ret.). Interview by Leroy L. Doig III and Mark Pahuta, 12 October 2007.

S-245. Marc Moulton. Interview by Leroy L. Doig III and Mark Pahuta, 14 June 2007.

S-247. Robert G. S. Sewell. Interview by Leroy L. Doig III and Mark Pahuta, 10 March 2007.

S-248. Richard J. "Dick" DeMarco. Interview by Elizabeth Babcock and Mark Pahuta, 22 and 28 May 2008.

S-249. Dr. William S. McEwan. Interview by Elizabeth Babcock and Mark Pahuta, 12 May 2008.

S-251. Eva Bien. Interview by Elizabeth Babcock, Duane Blue, and Mark Pahuta, 15 May 2008.

S-252. Bill Davis. Interview by Elizabeth Babcock and Mark Pahuta, 21 August 2008.

S-253. C. John Di Pol. Interview by Elizabeth Babcock and Mark Pahuta, 27 April 1992.

S-254. Dr. Robert Rockwell. Interview by Elizabeth Babcock and Mark Pahuta, 30 April and 7 May 2008.

S-255. George Silberberg. Interview by Elizabeth Babcock and Mark Pahuta, 17 July 2008.

S-256. Bob McKenzie. Interview by Leroy L. Doig III, 30 July 2008.

S-257. Jerry Saholt. Interview by Leroy L. Doig III and Mark Pahuta, 29 July 2008.

S-258. Melvin J. McCubbin. Interview by Elizabeth Babcock and Mark Pahuta, 1 October 2008.

S-259. Dale Knutsen. Interview by Elizabeth Babcock and Mark Pahuta, 17 September 2008.

S-260. Gerry Wisdom. Interview by Elizabeth Babcock and Mark Pahuta, 16 April 2008.

S-261. Fred Weals. Interview by Elizabeth Babcock, 24 April 1992.

S-262. Ray Miller. Interview by Elizabeth Babcock, Duane Blue, and Mark Pahuta, 4 September and 10 September 2008.

S-263. Milton K. Burford. Interview by Elizabeth Babcock and Mark Pahuta, 26 June 2008.

S-267. Dr. James Colvard. Transcript of speech given at China Lake's Legends dinner, 11 March 2009.

S-269. Maj. Gen. Richard A. Gustafson, USMC (Ret.). Self-interview, 13 September 2008.

S-270. Col. Ray Powell, USMC (Ret.). Interview by Cliff Lawson, 13 September 2008.

S-271. Vernon D. Burklund. Interview by Elizabeth Babcock, Duane Blue, and Mark Pahuta, 15 October 2008.

S-272. Dr. James Colvard. Interview by Cliff Lawson, 11 December 2008.

S-273. Howard Auld. Interview by Elizabeth Babcock and Mark Pahuta, 4 and 5 June 2008.

S-275. Phil G. Arnold. Self-interview, 28 April 2009.

S-277. Allyn R. Berryman. Interview by Leroy L. Doig III, BJ Holden, and Mark Pahuta, 11 May 2009.

S-278. Phil E. DePoy. Interview by Cliff Lawson, 24 November 2008.

S-279. Pat Burke. Interview by Cliff Lawson, 7 October 2008.

S-280. Capt. Gary H. Palmer, USN (Ret.). Interview by Cliff Lawson, 18 November 2008.

S-282. Jack Lyons. Interview by Elizabeth Babcock and Mark Pahuta, 22 October 2008.

S-283. Robert Corzine. Interview by Elizabeth Babcock and Mark Pahuta, 9 October 2008.

S-285. Dr. James Colvard. Interview by Elizabeth Babcock, Mark Pahuta, and Deanna Ripley-Lotee, 11 March 2009.

S-286. Dr. Mickie Benton. Interview by Elizabeth Babcock and Mark Pahuta, 8 April 2008.

S-287. Carl Halsey. Interview by Mike Ripley-Lotee and Mark Pahuta, 17 June 2009.

S-288. Richard J. Mello. Interview by Mike Ripley-Lotee and Mark Pahuta, 8 January 2009.

S-289. Denny Kline. Interview by Mike Ripley-Lotee and Mark Pahuta, 28 July 2009.

S-290. Tom Wimberly. Interview by Leroy L. Doig III and Deanna Ripley-Lotee, 23 July 2009.

S-291. Frank Markarian. Interview by Mike Ripley-Lotee and Mark Pahuta, 22 July 2009.

S-292. Wayne Tanaka. Interview by Mike Ripley-Lotee and Mark Pahuta, 17 June 2009.

S-293. John Robbins. Interview by Mike Ripley-Lotee and Mark Pahuta, 13 May 2009.

S-296. Carolyn Shepherd. Interview by Leroy L. Doig III and Mark Pahuta, 27 August 2008.

S-297. Robert G. S. Sewell, Franklin H. Knemeyer, Larry L. Lincicum, and Leroy L. Doig III. Interview by Cliff Lawson, 28 October 2009.

S-298. Lt. Cdr. Joel Premselaar, USN (Ret.). Interview by Cliff Lawson, 13 November 2009.

S-300. Lee Gilbert. Interview by Mike Ripley-Lotee and Mark Pahuta, 18 December 2009.

S-301. Dr. Pierre Saint-Amand. Interview by Leroy L. Doig III and Mark Pahuta, 27 January 2010.

S-302. Maurice Hamm. Interview by Leroy L. Doig III and Mark Pahuta, 23 March 2010.

S-304. James A. Bowen. Interview by Leroy L. Doig III and Mark Pahuta, 23 February and 2 March 2010.

S-305. Gerald R. Schiefer. Interview by Leroy L. Doig III and Mark Pahuta, 9 March 2010.

S-306. Bud Biery, Paul Cordle, Harold Cummins, Dick Hughes, Bob Huntley and Ralph Stearman, Dave Janiec, Charlie May, Ray Miller, Al Mousseau, Richard Hughes, and Craig Rae (Origins of ARM). Interview by Leroy L. Doig III and Mark Pahuta; June, August, September 2004.

S-307. Larry Zabel. Interview by Leroy L. Doig III and Mark Pahuta, 29 May 2010.

S-308. Don McLean. Interview by Leroy L. Doig III and Mark Pahuta, 29 May 2010.

S-309. Clyde Lebsoc. Interview by Leroy L. Doig III and Mark Pahuta, 18 June 2010.

S-310. Jon Rogerson. Interview by Leroy L. Doig III and Mark Pahuta, 22 June 2010.

S-313. John Lamb. Interview by Leroy L. Doig III and Mark Pahuta, 20–22 July 2010.
S-314. Elvy Hopkins. Interview by Leroy L. Doig III and Mark Pahuta, 14 July 2010.
S-317. Moyle Braithwaite. Transcript of China Lake Museum Tour given by Braithwaite to Dr. Robert Smith, 2009.
S-317B. Moyle Braithwaite. Interview by Deanna Ripley-Lotee, 2013.
S-318. Walt Abernathy. Interview by Leroy L. Doig III and Mark Pahuta, 22 November 2010.
S-320. Norm Estabrook. Interview by Leroy L. Doig III and Mark Pahuta, 9 August 2011.
S-321. Tom Lang. Interview by Leroy L. Doig III and Mark Pahuta, 9 August 2011.
S-322. Steve Little. Interview by Leroy L. Doig III and Mark Pahuta, 9 September 2011.
S-323. Carl Schaniel. Interview by Deanna Ripley-Lotee with Mary Schaniel Bechtal, 27 May 2012.
S-324. Crill Maples. Interview by Cliff Lawson, 10 October 2009.
S-326. Roland Baker. Interview by Deanna Ripley-Lotee and Tim Tyson, 25 June 2013.
S-327. Robert Dillinger. Interview by Deanna Ripley-Lotee and Tim Tyson, 28 August 2013.
S-328A. Scott O'Neil. Interview by Deanna Ripley-Lotee and Tim Tyson, 12 September 2013.
S-328B. Scott O'Neil. Interview by Deanna Ripley-Lotee and Mark Pahuta, 14 November 2014.
S-329. Ray Blackwell. Interview by Deanna Ripley-Lotee and Tim Tyson, 24 September 2013.
S-330. Mike Ripley-Lotee. Interview by Deanna Ripley-Lotee and Tim Tyson, 31 October 2013.
S-331. Lou Renner. Interview by Deanna Ripley-Lotee and Tim Tyson, 19 November 2013.
S-332. Ernie Lanterman. Interview by Deanna Ripley-Lotee and Tim Tyson, 20 November 2013.
S-333. Hugh Drake. Interview by Deanna Ripley-Lotee and Tim Tyson, 21 November 2013.
S-334. Dr. Karen Higgins. Interview by Deanna Ripley-Lotee and Tim Tyson, 21 January 2014.
S-335A and B. Jim Irvine. Interview by Deanna Ripley-Lotee and Tim Tyson, 5 and 12 February 2014.
S-336. Phil Bowen. Interview by Deanna Ripley-Lotee and Tim Tyson, 4 February 2014.
S-337B. Dr. Bob Smith. Interview by Jay McConnell, 16 May 2013.
S-337C. George Teate. Interview by Jay McConnell, 11 June 2013.
S-338. Frank Pickett. Interview by Deanna Ripley-Lotee and Tim Tyson, 25 February 2014.
S-348. Dr. George Handler. Interview by Deanna Ripley-Lotee, Tim Tyson, and Phillis Thrower, 4 June 2014.
S-353. Richard Hughes. Interview by Deanna Ripley-Lotee and Mark Pahuta, 18 June 2014.
S-354. Dr. Ed Royce. Interview by Deanna Ripley-Lotee, Leroy Doig III, and Mark Pahuta, 13 June 2014.
S-356. Jack Latimer. Interview by Deanna Ripley-Lotee, Mark Pahuta, and Jay McConnell, 26 June 2014.
S-357. Robert Campbell. Interview by Leroy Doig III and Mark Pahuta, 29 January 2001.
S-358. Monte Frisbee. Interview by Deanna Ripley-Lotee and Tim Tyson, 1 July 2014.
S-360. Paul McQuaide. Interview by Deanna Ripley-Lotee, Tim Tyson, and Phyllis Thrower, 22 July 2014.
S-365. Ed Simmons. Interview by Deanna Ripley-Lotee and Tim Tyson, 11 August 2014.
S-371. Ditty Riggs. Interview by Deanna Ripley-Lotee, 11 and 12 December 2014.
S-372. Duane Blue. Interview by Deanna Ripley-Lotee and Scott Clarke, 10 February 2015.

S-373. Jim Annos. Interview by Deanna Ripley-Lotee and Scott Clarke, 12 February 2015.

S-374. Tony Damiano. Interview by Deanna Ripley-Lotee and Mark Pahuta, 29 October 2014.

S-375. Leah Little. Interview by Deanna Ripley-Lotee and Scott Clarke, 18 February 2015.

S-379. Sandee Schwarzbach. Interview by Deanna Ripley-Lotee and Scott Clarke, 10 March 2015.

S-385. Jay Kovar. Interview by Deanna Ripley-Lotee and Mark Pahuta, 24 July 2015.

S-401. Ken Banks. Interview by Jay McConnell, 31 May 2013.

S-414. Dave Wirtz. Interview by Deanna Ripley-Lotee, 21 September 2016.

S-X15. Frederick Alpers. Interview by Dr. Ron Westrum, 24 February 1993.

S-X41. Leroy Riggs. Interview by Dr. Ron Westrum, 23 February 1993.

TS 84-14-1. Frederick C. Alpers. Interview by Leroy L. Doig III, circa 1984. ARM History Project.

TS 84-14-2. Gerald O. Miller. Interview by Leroy L. Doig III, circa 1984. ARM History Project.

TS 84-14-3. Franklin H. Knemeyer. Interview by Leroy L. Doig III, circa 1984. ARM History Project.

TS 84-14-4. Duane J. "Jack" Russell. Interview by Leroy L. Doig III, circa 1984. ARM History Project.

TS 84-14-5. William B. Porter. Interview by Leroy L. Doig III, circa 1984. ARM History Project.

TS 84-14-6. Leroy Riggs. Interview by Leroy L. Doig III, circa 1984. ARM History Project.

TS 84-14-7. Gerald Schiefer. Interview by Leroy L. Doig III, 24 January 1984. ARM History Project.

TS 84-14-8. Charles May. Interview by Leroy L. Doig III, circa 1984. ARM History Project.

TS 84-14-9. Robert Corzine and Phillip Sprankle. Interview by Leroy L. Doig III, circa 1984. ARM History Project.

TS 84-14-10. Joseph Mosko. Interview by Leroy L. Doig III, circa 1984. ARM History Project.

TS 84-14-11. Capt. Kenneth A. Dickerson, USN. Interview by Leroy L. Doig III, circa 1984. ARM History Project.

TS 84-14-12. Capt. Roger P. Flower, USN. Interview by Leroy L. Doig III, circa 1984. ARM History Project.

TS 84-14-13. Jack Eyre. Interview by Leroy L. Doig III, circa 1984. ARM History Project.

TS 84-14-14. Cdr. Bob Ramsey, USN. Interview by Leroy L. Doig III, circa 1984. ARM History Project.

TS 84-14-15. Lt. Col. Charles H. Dubac, USMC (Ret.), and Charles Bowling. Interview by Leroy L. Doig III, circa 1984. ARM History Project.

TS 84-14-16. Dr. Dean C. Allard and Dr. David K. Allison. Interview by Leroy L. Doig III, circa 1984. ARM History Project.

Oral Histories: Other

B-1-75. Dr. William B. McLean. Interview by Dr. Sam Rothman and Mrs. Susan Frutkin, circa 1975.

BA-1-75. William McLean. DNL Oral History Collection Interview, 1975.

BA-2-75. Dr. Joel Lawson. DNL Oral History Collection Interview, 1975.

"Interview of Dr. Robert Frosch by David DeVorkin at the National Air & Space Museum, September 15, 1981," Session IV, accessed 5 February 2014. http://www.aip.org/history/ohilist/28066_4.html.

NL-T31. Dr. William P. Raney interview, 29 November 1980.

NL-T33. John Rexroth. Naval Laboratories Oral History Program Interview, 1980.

Vice Admiral Lawson P. Ramage, USN (Ret.), interview by John T. Mason Jr., U.S. Naval Institute, Annapolis, MD, June 1975.

Plays

Shakespeare, William. *The Tempest*, Act 2, Scene 1.

Published Articles and Papers

Albert, Joseph R. "Electronic Combat Range." *National Defense Industrial Association, Targets, UAVs, and Range Operations Symposium* (26 October 2011): 1–16.

Anderson, Jack, and Fred Blumenthal. "Offense vs. Defense: Who's Winning the Race of the Missiles?" *Parade*, 3 February 1957, 4.

Andrews, Edmund L. "Patent Case May Cost U.S. Billions." *New York Times*, 22 April 1989.

Asian Defence Journal. "The Radar Warning Story." January 1982, 71.

Aviation Week & Space Technology. "Industry Observer [Phoenix]." 8 September 1975, 13.

Aviation Week & Space Technology. "Industry Observer [Sea Phoenix]." 23 September 1974, 13.

Boot, Max. "From Saigon to Desert Storm." *American Heritage* (November/December 2006): 32.

Bulletin, Chemical Propulsion Information Agency. "STM Pacific Flight Successful." June 1979, 1–2.

Chapman, Donald. "Admiral Gorshkov and the Soviet Navy." *Air University Review* (July–August 1982). Accessed 8 July 2013. http://www.airpower.maxwell.af.mil/airchronicles/aureview/1982/jul-aug/chipman.html.

Chase, Martin B. "A Unique New Capability: Scatterable Mines." *Army Research, Development, and Acquisition* (March–April 1980): cover, 6–9.

Clifford, Clark M. "Address by the Honorable Clark M. Clifford, Secretary of Defense, at the National Security Industrial Association, Washington, D.C., September 26, 1968." Quoted in U.S. Congress. *Congressional Record—Senate: Extensions of Remarks*. 1968. Accessed 24 August 2021. https://www.govinfo.gov/content/pkg/GPO-CRECB-1968-pt22/pdf/GPO-CRECB-1968-pt22-3-3.pdf.

Decker, D. L., and D. J. Grandjean. "Physical and Optical Properties of Surfaces Generated by Diamond-Turning on an Advanced Machine." *Laser Induced Damage in Optical Materials: Tenth ASTM Symposium* (Boulder, Colorado, September 1978).

Decker, D. L., D. J. Grandjean, and J. M. Bennett. "Optical and Surface Physical Characteristics of Diamond-Machined Infrared Windows." *The Science of Ceramic Machining and Surface Finishing II* (Gaithersburg, Maryland, November 1978).

Doc. No. 12-833. "Intelligence Point Paper on Remote Controlled Attack Drones," by Earl Towson. China Lake, 1970.

Donnelly, C. N. "Soviet Tactics for Overcoming NATO Antitank Defenses, Part 1." *International Defense Review* (July 1979).

Donnelly, C. N. "Soviet Tactics for Overcoming NATO Antitank Defenses, Parts 1 and 2." *Infantry* (September–October 1978, November–December 1978): 22–26, 18–23.

Freeman, Rear Admiral Rowland G., III, USN (Ret.). "Letter to the Editor." *Acquisition Review Quarterly—Summer 1999* (17 May 1999): 321–325.

Galantin, I. J. "The Naval Material Command—A System of Systems." *Defense Industry Bulletin* (April 1969): 1–7, inside back cover.

Gilbert, Kelly. "Fire in Hangar Bay One!" *All Hands* (February 1967): 12–15.

Gilchrist, Stanley F. "The Cordon Sanitaire—Is it Useful? Is it Practical?" *International Law Studies—Volume 68, Readings on International Law From the Naval War College Review, 1978–1994* (1995): 131–145.

Grubisich, Thomas. "GSA Chief Gives Archivists a Geography Lesson." *The Washington Post*, 22 December 1979, A5.

Hays, Burrell. "Sparrow AIM-7F Comes to China Lake." *The China Laker* (Spring 2003): 1, 8–9.

Hayward, John T. " 'High-Low,' Comment and Discussion." *U.S. Naval Institute Proceedings* (August 1976): 69–72.

Hillinger, Charles. "Sea More Hostile Than Space, Carpenter Says." *Los Angeles Times*, 29 September 1965, 3, 25.

Indian Wells Valley Independent and Times-Herald, 27 July 1967, A-1.

Judge, John F. "Navy Meeting Need for 2.75-In. Rocket." *Jane's Missiles and Rockets* (22 November 1965), 16–17.

Judge, John. F., and Charles D. LaFond. "Shortages Slow 2.75-in. Rocket Effort." *Jane's Missiles and Rockets* (18 April 1966): 22-23.

Kessler, Ronald. "Freeman Plans Prayers, Tough Approach to GSA Problems." *The Washington Post*, 5 April 1979, A5.

Klass, Philip J. "Competition Slashes Sidewinder 1-A Price." *Aviation Week and Space Technology*, 9 April 1962, 89.

Knemeyer, Frank. "Shrike's Forgotten Lessons." *The China Laker*, newsletter of the China Lake Museum Foundation, Fall 2004, 12.

Getler, Michael. "Dispute Rages in Navy on Missile System." *The Washington Post*, 25 March 1973, A21.

Lerner, Preston. "Sidewinder, the Missile That Has Rattled Enemy Pilots Since 1958." *Air & Space Magazine*, 1 November 2010.

Linsteadt, George F., and Leroy L. Doig III. "Maintaining the High-Tech Edge: Government-Industry Technology Transfer and the Federal Laboratory System in California." *J Technol Transfer* (September 1987): 19–26.

Los Angeles Times. 27 February 1945, A-1, A-6.

Los Angeles Times. "Case for a Nuclear Navy." 27 February 1968, A4.

Los Angeles Times. "Drone Plane Crash Fatal to Navy Pilot." 28 August 1958, 2.

Los Angeles Times. "Navy Buys Hotel Norconian for Hospital." 16 December 1941, 14.

Los Angeles Times. "Navy Will Cut 2,400 From Pay Roster." 25 September 1968, 8.

Los Angeles Times. "News Bulletin, Lake Norconian Club." 19 January 1929, 10.

Los Angeles Times. "Russ Unveil Apparently New Type Submarine, Mysterious 'Mighty Underseas Boat' Displayed Briefly at Navy Ceremony." 29 July 1968, 5.

Los Angeles Times. "Women Demand Equal Rights." 30 August 1970, F5.

Martin, Wallace. "Secret Weapons of the Secret City." *The China Laker* (Winter 2013): 1, 2–4.

Monastero, Francis C. "Model for Success, an Overview of Industry-Military Cooperation in the Development of Power Operations at the Coso Geothermal Field in Southern California." *Geothermal Resources Council Bulletin* (September/October 2002): 188–194.

Moser, Don. “A Carrier’s Agony—Hell Afloat, the On-Board Drama of the Fire that Racked ‘Oriskany.’ ” *LIFE,* 25 November 1966, 104–119.

NWC. *Naval Operations in Vietnam and NLAAG-V 1968-1969*. China Lake briefing package, circa January 1969.

Optics News. “OSA Past, Present, Future: New President Shares Her Views.” January 1986, 28–30.

Pickering, W. H. “William B. McLean, 1914–1976.” *National Academy of Sciences Biographical Memoirs* (September 1985): 399–408.

Reincke, Betty. “All-Out Effort On Today To Keep Naval Weapons Center.” *The* [Corona] *Daily Independent*, 19 September 1968.

Reincke, Betty. “Atchison’s Position Axed at Norco’s NWC.” *The* [Corona] *Daily Independent*, 30 December 1968.

Reincke, Betty. “End of Era Marked Today at Norco Weapons Center.” *The* [Corona] *Daily Independent*, 30 June 1971, 1.

Reincke, Betty. “Forbis Takes Over Command at NWC in Emotion-Charged Rites.” *The* [Corona] *Daily Independent*, 25 October 1968.

Reincke, Betty. “NOL Doom Rumors Scotched.” *The* [Corona] *Daily Independent*, 13 April 1967.

Reincke, Betty. “NWC Closure Ordered for Mid-1971.” *The* [Corona] *Daily Independent*, 22 April 1969, 1.

Reincke, Betty. “NWC Pulled From Navy’s ‘Cut List.’ ” *The* [Corona] *Daily Independent*, 23 September 1968.

Reincke, Betty. “Tunney Backs Claim that NWC Closure Costs Higher.” *The* [Corona] *Daily Independent*, 23 September 1968.

Rieger, James L. “Impact of the Introduction of Telemetry Scrambling at Navy RDT&E Ranges.” *Proceedings, International Telemetering Conference, 1980, San Diego, CA* (1980): 187–188.

Riley, John. “The Navy’s Top Handyman.” *LIFE,* 6 January 1967, 16.

Ripley, Anthony. “Rate Rises Urged in Saving Power.” *The New York Times*, 20 November 1970, 1.

Schreadley, R. L. “The Naval War in Vietnam, 1950–1970.” *U. S. Naval Institute Proceedings, Naval Review 1971* (1971): 182–209.

Shapley, Deborah. “Trident in Trouble: New Missile May Resemble Poseidon, After All.” *Science* (9 January 1976): 51–52.

Sheley, Walton H., Jr. “The Effect of OMB Circular A-109 on Major Systems Acquisition and the Use of Competitive Procurement in the Department of Defense.” Press release, United States General Accounting Office, 9 November 1979.

Sherwin, Chalmers. “Major Weapon Systems Advances Through Multiple Innovations,” in *Climate for Creativity*, Calvin W. Taylor, ed., Pergamon Press (1972): 143. See also Sherwin, Chalmers W., and Raymond S. Isenson, “Project Hindsight. A Defense Department Study of the Utility of Research,” *Science*, Vol. 156 (23 June 1967).

Tarpgaard, Peter T. “The Sea Phoenix—A Warship Design Study.” *Naval Engineers Journal* (April 1976): 31–44.

The [Corona] *Daily Independent*. “Hunter Ired by Possible Lab Closure.” 20 September 1968, 3.

The News Review, Philip Arnold interview with Liz Babcock, circa April 1999.

Time. “Armed Services: Keelhauling the United States Navy.” 27 November 1972, 11.

Time. “Russia, Power Play on the Ocean.” 23 February 1968, cover, 23.

U.S. Naval Institute News, *Daily Update*. "Navy Interested in Guided Rounds for Surface Ships Pending Price Reductions." 9 April 2015.

Williamson, Arthur C. "The EWTES (Echo Range) Story." *Johns Hopkins APL Technical Digest* (2000): 582.

Wilson, George C. "Cost Expert Scores U.S. Arms Choices." *The Washington Post*, 23 August 1975, A1.

Wilson, H. G. "R&D Facilities (If Any), the Name of the Game." *RDT&E CNM Laboratory Facility Planning Conference* (21–23 September 1971): 1–9.

Young, Susan H. H. "Gallery of USAF Weapons, 2003 USAF Almanac." *Air Force Magazine*, May 2003, 175.

Published Books, Reports, and Brochures

9WRWP 105-7. *Seeding Supercooled Cumulus Clouds*. McClellan AFB: Headquarters, 9 MRW (MAC), 15 October 1974.

ARPA. *Project AGILE, Advanced Research Projects Agency, Semiannual Report, 1 July–31 December 1963*. Columbus, Ohio: Remote Area Conflict Information Center, Battelle Memorial Institute, 1 February 1964.

Babcock, Elizabeth. *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*. Washington, DC: Naval History Division, 2009.

Bash, Kevin, and Brigitte Jouxtel. *The Navy in Norco*. Charleston: Arcadia Publishing, 2011.

Beauregard, Raymond L. *The History of Insensitive Munitions*. Accessed 10 October 2013. http://www.insensitivemunitions.org/history/navy-issues-an-operational-requirement-or-for-insensitive-high-explosives/.

Berger, Carl, ed. *The United States Air Force in Southeast Asia, 1961–1973*. Washington, DC: Office of Air Force History, 1977.

Bjorklund, Raymond C. *The Dollars and Sense of Command and Control*. Washington, DC: National Defense University Press, 1995.

Blake, Berhard H. L., ed. *Jane's Weapon System, 1987–88*. London, Great Britain: Jane's Publishing Company Limited, 1987.

Buderi, Robert. *Naval Innovation for the 21st Century, the Office of Naval Research Since the End of the Cold War*. Annapolis: Naval Institute Press, 2013.

Christman, Albert B. *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*. Washington, DC: Naval History Division, 1971.

CIM 204.90. *A Comparison of Long-Range Bombers and Naval Forces*, by David A. Perin. Alexandria: Center for Naval Analyses, 1991.

Clayton, Tyrus Ross. *Leading Collaborative Organizations, Insights into Guiding Horizontal Organizations*. Bloomington: iUniverse LLC, 2013.

Clodfelter, Michael. *Warfare and Armed Conflicts, a Statistical Reference to Casualty and Other Figures, 1618–1991, Volume 2*. Jefferson, North Carolina: McFarland & Company, 1992.

CMH Pub 51-3-1. *Defense Acquisition Reform, 1960–2009, an Elusive Goal*, by J. Ronald Fox. Washington, DC: United States Center of Military History, 2011.

CNATRA P-1286 (Rev. 9-99) PAT. *Naval Aircrew Common Ejection Seat (NACES)*. Corpus Christi: Naval Air Training Command, 1999.

CNM. *Milestone Schedule and Status Report for Implementing the Recommendations of the Russell Panel Report and the Carrier Aircraft Support Study (CASS)*. Washington, DC: CNM, 20 March 1974.

CNM (MAT 03514). *Addendum to the Realignments of the CNM RDT&E Activities, 1966 to 1970, for the Period 1970 to 1975*, by R. G. Iverson. Washington, DC: Naval Material Command. 2 December 1974.

Code Ident 99584 CR 6-340-294-004. *Standard ARM Technical Progress Report*. Pomona: Pomona Division of General Dynamics, November 1966.

Committee on Armed Service, United States Senate. *Fiscal Year 1975 Authorization for Military Procurement, Research and Development, and Active Duty, Selected Reserve and Civilian Personnel Strengths. Hearing on S 3000, Part 9, Tactical Air Power*. Washington, DC: 93rd Congress, 2nd Session, March 22, 27, 28, and 29 and May 2, 1974.

COMOPTEVFOR DDC Control No. 31056. *Final Report on Project C/S88 —Conduct a Concurrent Evaluation of the Mk 31 Mod 0 Flare Launching System*. Norfolk: Operational Test and Evaluation Force, 17 May 1973.

CRS 7-5700, R40854. *Circular A-76 and the Moratorium on DOD Competitions: Background and Issues for Congress*, by Valerie Bailey Grasso. Washington, DC: Library of Congress Congressional Research Service, 2011.

Davies, Peter. *F-105 Wild Weasel vs SA-2 "Guideline" SAM*, Vietnam, 1965–73. Oxford: Osprey Publishing, 2011.

DDESB. *Approved Protective Construction (Version 2.0)*. Alexandria, Virginia: DDESB, June 2004.

Director of Naval Intelligence and Chief of Information. *Understanding Soviet Naval Developments*. Washington, DC: Office of the Chief of Naval Operations, April 1975, January 1981 (4th ed.), and April 1985 (5th ed.).

Dockery, Kevin. *Special Warfare Special Weapons, the Arms & Equipment of the UDT and SEALs from 1943 to the Present*. Chicago: Emperor's Press, March 2001.

Doig, Leroy L., III. *FLC History, Establishing a National Presence*. Federal Laboratory Consortium Special Reports Series No. 4. Washington, DC: Government Printing Office, September 1994.

DOOO29701. *Manhattan District History, Project Camel, Book VIII, Volume 2, Chapter 2* [declassified 5-21-13]. Washington, DC: Army Corps of Engineers, 1946.

DS79.724.U6G85. *Gulf War Air Power Survey Summary Report*, by Thomas A. Keaney and Eliot A. Cohen. Washington, DC: Air Force Historical Studies Division, 1993.

Flynn, George Q. *The Draft, 1940–1973*. Lawrence: University Press of Kansas, 1993.

Friedan, Betty. *The Feminine Mystique*. London: W. W. Norton & Company, 2001.

Friedman, Norman. *The Naval Institute Guide to World Naval Weapon Systems*. Annapolis: U.S. Naval Institute, 1989.

GAO/NSIAD-83-59. *Analysis of HARM Procurement Strategies*. Washington, DC: United States General Accounting Office, September 1983.

Gerrard-Gough, J. D., 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*. Washington, DC: Naval History Division, 1978. Washington, DC: Naval History Division, 1971.

Gesell, Gerhard A. *Equality of Treatment and Opportunity for Negro Military Personnel Stationed Within the United States, Initial Report*. Washington, DC: The President's Committee on Equal Opportunity in the Armed Forces, 13 June 1963.

Glass, E. M. *Report of the Task Group on Defense In-House Laboratories, Executive Summary*. Washington, DC: Office of the Director of Defense Research and Engineering, 1 July 1971.

Gorshkov, S. G. *The Sea Power of the State*. Annapolis: Naval Institute Press, 1976.

Gunston, Bill. *The Illustrated Encyclopedia of Rockets and Missiles*. New York: Crescent Books, 1979.

Hobson, Chris. *Vietnam Air Losses, United States Air Force, Navy, and Marine Corps Fixed-Wing Aircraft Losses in Southeast Asia 1961–1973*. Hinckley: Midland Publishing, 2001.

JSR-08-146. *S&T for National Security*. McLean, Virginia: MITRE Corporation, May 2009.

Kettl, Donald F. *Sharing Power, Public Governance and Private Markets*. Washington, DC: Brookings Institution, 1993.

Kistler, R. E., and R. M. Glenn. *Notable Achievements of the Naval Weapons Center*. China Lake, California: Naval Weapons Center, 1990.

Kohn, Richard H., and Joseph P. Harahan, eds. *Air Interdiction in World War II, Korea, and Vietnam: An Interview with Gen. Earle E. Partridge; Gen. Jacob E. Smart; and Gen. John W. Vogt, Jr*. Washington DC: Office of Air Force History, 1986.

Lambeth, Benjamin S. *The Transformation of American Air Power*. Ithaca: Cornell University Press, 2000.

Lepre, George. *Fragging*. Lubbock: Texas Tech University Press, 2011.

LS81-14. *Thrust Vector Control for Tactical Missiles, a Bibliography*. Laurel: Chemical Propulsion Information Agency, April 1981.

Marine Board of Investigation. *SS Badger State, Explosion Aboard and Eventual Sinking in the North Pacific Ocean, December 26, 1969*. Washington, DC: Department of Transportation, 7 December 1971.

Michell, Marshall L., III. *Clashes, Air Combat Over North Vietnam, 1965–1972*. Annapolis: Naval Institute Press, 1996.

MIL-HDBK-17-3F. *Department of Defense Handbook, Composite Materials Handbook, Volume 3. Polymer Matrix Composites Materials Usage, Design, and Analysis*. Washington, DC: Department of Defense, June 2002.

Miller, David, ed. *The Illustrated Directory of Modern American Weapons*. St. Paul: Zenith Press, 2002.

Milstein, Jeffrey S. *Dynamics of the Vietnam War, A Quantitative Analysis and Predictive Computer Simulation*. Columbus: Ohio State University Press, 1974.

Nalty, Bernard C. *Air Power and the Fight for Khe Sanh*. Washington, DC: Office of Air Force History, 1973.

National Guard Bureau. *Final Environmental Impact Statement, Relocation of the 146th Tactical Airlift Wing of the California Air National Guard, Volume 1, EIS Text*. Washington, DC: Air Directorate, National Guard Bureau, 1985.

NAVAIR. *Report of the Air-to-Air Missile System Capability Review, July–November 1968* (the *Ault Report*). Patuxent River: NAVAIR, 1 January 1969.

Naval Explosives Development Engineering Department. *Explosive Incident Summaries*. Yorktown: Naval Weapons Station, June 1984.

NAVMATINST 5450.27A. *CNM-Commanded Laboratories and Centers; Missions and Functions of*, by Chief of Naval Material Admiral F. A. Michaelis. Washington, DC: Naval Material Command, December 1975.

NAVORD Report 3470, NOTS 1074, Vol. 3, No. 2. *Rocket Quarterly, Bulletin of Activities in the Rocket Program*. China Lake: Naval Ordnance Test Station, March 1955.

NAVWPNSCEN 5450-1. *Organization Manual 1 Sept. 1971*. China Lake: Naval Weapons Center, September 1971.

NAVWPNSCEN 5450-1. *Organization Manual 1 March 1976*. China Lake: Naval Weapons Center, March 1976.

NAWCWD. *The China Lake Propulsion Laboratories* (brochure), by J. M. Robbins and R. W. Feist. China Lake: Naval Air Warfare Center Weapons Division, July 1992.

NAWCWPNS AdPub 019. *History of the Naval Weapons Evaluation Facility, Albuquerque, New Mexico, 1948–1993*. China Lake: Naval Air Warfare Center Weapons Division, March 1993.

NOTS TM 1113. *First Aid for Pet Projects Injured in the Lab or on the Range, or What To Do Until the Statistician Comes*, by R. M. McClung, Aviation Ordnance Departments. China Lake: Naval Ordnance Test Station, March 1952.

NWC. *Albert A. Michelson and the Michelson Museum* (brochure), by the Publishing Division, Technical Information Division. China Lake: Naval Weapons Center, 6 July 1973.

———. *NWC* (brochure), by the Publishing Division, Technical Information Division. China Lake: Naval Weapons Center, 13 September 1972.

NWC 125. *Michelson Laboratory 25th Anniversary*, by the Technical Information Department. China Lake: Naval Weapons Center, April 1973.

NWC 39042-46. *Preliminary Project Master Plan Review and Approval for Supersonic Tactical Missile Advanced Development Technology Phase*, by Max Smith, STM Project Office (System Coordination), Code 39042. China Lake: Naval Weapons Center, 30 September 1977.

NWC 391. *Michelson Laboratories, Handbook of Professional Training Assignments, 1973–1974*, by the Technical Information Department. China Lake: Naval Weapons Center, September 1974.

NWC 760. *Naval Weapons Center, China Lake, California: An Inside Look at Exciting Career Opportunities at NWC*, by the Technical Information Department, China Lake: Naval Weapons Center, December 1974.

NWC AdPub 143. *A Manual of Search and Rescue*, by Carl F. Austin, Research Department. China Lake: Naval Weapons Center, May 1968.

NWC AdPub 148. *The Navy in Corona*, by Glenn I. Voran. China Lake: Naval Weapons Center, September 1971.

NWC AdPub 163. *Dedication of the Lauritsen Laboratory*, by the Technical Information Department. China Lake: Naval Weapons Center, June 1976.

NWC AdPub 170. *Project 21, A Long Range Modernization Plan for the NWC Ranges (Volume 1, Unclassified Matter)*. China Lake: Naval Weapons Center, January 1977.

NWC AdPub 267. *Project 2000 Summary Report*. China Lake: Naval Weapons Center, December 1982.

NWC AdPub 311. *Ground Range Testing at the Naval Weapons Center*, by the Test and Evaluation Directorate. China Lake: Naval Weapons Center, 11 September 1984.

NWC AdPub 323 (Revision of NWC TP 5120). *NWC Supersonic Research Tracks: Transonic, Supersonic, Hypersonic*, by the Test and Evaluation Directorate. China Lake: Naval Weapons Center, 13 September 1984.

NWC AdPub 332. *Range Users' Guide*, by the Range Department. China Lake: Naval Weapons Center, July 1988.

NWC AdPub 357. *Naval Weapons Center Long-Range Plan (FY 1987–1991 and Beyond)*. China Lake: Naval Weapons Center, 30 January 1987.

NWC AdPub 391. *What Have You Done for the Fleet Today? A Brief History of the A-7E Weapon System Support Activity*, by the Technical Information Department. China Lake: Naval Weapons Center, April 1989.

NWC IDP 3576. *Chemistry Division Research*, by Dr. Adolph B. Amster, Chemistry Division. China Lake: Naval Weapons Center, November 1979.

NWC PSD 0175U, TS 82-56. *R-2508 Visibility-Protection Program*, by the Environmental Branch, Engineering Division, Public Works Department. China Lake: Naval Weapons Center, September 1982.

NWC TM 2426. *Survey and Evaluation of the Environmental Impact of Naval Weapons Center Activitie*s, by James R. Ouimette, Public Works Department. China Lake: Naval Weapons Center, June 1974.

NWC TM 2506. *Agile-ACV Hardware Descriptions*, by the Agile Development Division, Air Weapons Department. China Lake: Naval Weapons Center, February 1975.

NWC TM 2558. *HAVE ROBE Basic Infrared Measurements Test Plan*, by Don Kummer, IR Optics and Measurements Division, Air Weapons Department. China Lake: Naval Weapons Center, September 1975.

NWC TM 2890. *Environmental Impact Assessment, Mojave "B" Test Ranges*, by Tilly C. Barling, Engineering Division, Public Works Department. China Lake: Naval Weapons Center, August 1976.

NWC TM 3321. *Project 21, A Long Range Modernization Plan for the NWC Ranges (Summary of Planning Data)*, by the Long-Range Planning Office, T&E Directorate. China Lake: Naval Weapons Center, September 1977.

NWC TM 3732. *Long-Range Planning Guidance (U), Volumes 1 and 2,* by the Project 2000 Office. China Lake: Naval Weapons Center, January 1979. Cited in NWC AdPub 267. *Project 2000 Summary Report.* China Lake: Naval Weapons Center, February 1983.

NWC TN 556-73-6. *HAP Missile Mechanical Design, Fabrication, and Assembly*, by James H. Irvine, Engineering Department. China Lake: Naval Weapons Center, November 1973.

NWC TP 5296. *Final Report on SDV Instrumentation Package*, by Gaylon L. West, Electronic Systems Department. China Lake: Naval Weapons Center, January 1972.

NWC TP 5415. *Solution Burner for Weather Modification, Advanced Development of an Airborne Jet Seeder*, by J. W. Carroz, Research Department, and M. F. Durham, Electronic Systems Department. China Lake: Naval Weapons Center, 14 December 1972.

NWC TP 5578. *Agile Gimbal Nozzle Mechanics Investigation*, by M. R. Wolfson and R. D. Ulrich, Propulsion Development Department. China Lake: Naval Weapons Center, January 1975.

NWC TP 5665. *Thermal and Structural Design Analysis of the Agile Gimbal Nozzle*, by R. G. Purcell, W. H. Thielbahr, and W. R. Thompson, Weapons Development Department. China Lake: Naval Weapons Center, May 1975.

NWC TP 5771. *ESKIMO III Magazine Separation Test*, by Frederick H. Weals. China Lake: Naval Weapons Center, February 1977.

NWC TP 6092. *Vertical Launch ASROC Prototype Demonstration*, by S. M. O'Neil, M. J. Ripley-Lotee, Ordnance Systems Department, and P. W. Bowen, Weapons Department. China Lake: Naval Weapons Center, June 1979.

NWC TP 6380. *Future Telemetry Requirements*, by J. L. Rieger, Aerosystems Department. China Lake: Naval Weapons Center, December 1982.

NWC TP 6413, Part 1. *Major Accomplishments of the Naval Weapons Center and its Predecessor Organizations*. China Lake: Naval Weapons Center, 1982.

NWC TS 25A/B/C/D. *Professional Development for Aeronautical Engineers/Electronic Engineers/Mechanical Engineers/Physicists* (Junior Professional brochures). China Lake: Naval Weapons Center, 14 October 1971.

NWC TS 61-134. *Limited War Weapons for Indigenous Forces and Covert Operations*, by Frank Fulton. China Lake: Naval Ordnance Test Station, May 1961.

NWC TS 67-259. *Naval Weapons Center Silver Anniversary*, by the Technical Information Department, Publishing Division. China Lake: Naval Weapons Center, October 1968.

NWC TS 74/86. *Unequal Opportunity is a No-No at NWC*. China Lake: Naval Weapons Center, December 1973.

NWC TS 92-20. *Coso Geothermal Development*. China Lake: Geothermal Program Office, 1992.

NWSY TR 85-5. *Explosive Accidents Involving Naval Munitions*, by Howard R. Nelson Jr., Naval Explosives Development Engineering Department. Yorktown: Naval Weapons Station, July 1985.

OPNAV Report 5750-1. *Command History of the Naval Weapons Center, China Lake, California*, for the years 1968–1974. China Lake: Central Staff, Naval Weapons Center.

———. *Command History, Naval Weapons Center Corona Laboratories,* 1968. Corona: Naval Weapons Center, April 1969.[1190]

OPNAV Report 5750-5. *Command History of U.S. Naval Air Facility, China Lake, California*. China Lake: Naval Air Facility, 1960.

OPNAVINST 5102:1D, MCO P5102.1B. *Navy & Marine Corps Mishap and Safety Investigation, Reporting, and Record Keeping Manual*. Washington, DC: Office of the Chief of Naval Operations, 7 January 2005.

OSD DUSD, AS&C. *Report to Congress on the Activities of the DOD Office of Technology Transition*. Washington, DC: Office of Technology Transition, 2006.

OTA-ISC-374. *The Defense Technology Base: Introduction and Overview—A Special Report on OTA's Assessment on Maintaining the Defense Technology Base*. Washington, DC: U.S. Congress, Office of Technology Assessment, March 1988.

Owen, Claude E. *Barnstorming to Spaceships*. Onyx, CA: Owen Consulting Specialists, 1981.

Peck, Gauillard R., Jr. *America's Secret MiG Squadron, the Red Eagles of Project Constant Peg*. Oxford: Osprey Publishing, 2012.

Polmar, Norman. *The Naval Institute Guide to the Ships and Aircraft of the U.S. Fleet*. 18th ed. Annapolis: U.S. Naval Institute, 2005.

Probus, James H. *Director of Navy Laboratories Corporate Long-Range Plan for CNM Commanded Laboratories for FY 77–FY 81*. Washington, DC: Headquarters, Naval Material Command, January 1977.

"Racial Incidents Onboard USS Kitty Hawk (CVA-63) and USS Constellation (CVA-64) in 1972," in *Report by the Special Subcommittee on Disciplinary Problems in the US Navy*, 92nd Congress, 2nd session, H.A.S.C. 92-81, Washington, DC: Government Printing Office, 1973.

Rasimus, Ed. *Palace Cobra, A Fighter Pilot in the Vietnam Air War*. New York: St. Martin's Press, 2006.

RDTR No. 203. *Project SOID*, Research and Development Department. Crane: Naval Ammunition Depot, 30 September 1971.

Report of the Investigation into the Enterprise Fire. 1969. Accessed 18 September 2013. http://www.jag.navy.mil/library/investigations/BASIC%20FIRE%20ON%20USS%20ENTERPRISE%2014%20JAN%201969.pdf.

Robinson, Anthony, ed. *Weapons of the Vietnam War*. Greenwich: Bison Books Corp., 1983.

ROC 305-76. *Improvements to Tactical Air Force Ranges*. Rev. ed. 6 December 1976. Quoted in PSAD 78-83. *Air Force Requirements for Electronic Warfare Operational Test and Training Equipment*, by the Comptroller General of the United States. Washington, DC: USGAO, 1 March 1978.

Russell, James S. *Final Report of the Panel to Review Safety in Carrier Operations, Annex A, Rationale for Recommendations*. Washington, DC: Office of the Chief of Naval Operations, 16 October 1967.

Sherwood, John Darrell. *Black Sailor, White Navy, Racial Unrest in the Fleet During the Vietnam Era*. New York: New York University Press, 2007.

Shore, Moyers S., II. *The Battle for Khe Sanh*. Washington, DC: History and Museum Division, Headquarters, USMC, 1969.

Smith, John T. *The Linebacker Raids, the Bombing of North Vietnam, 1972*. London: Casell & Co., 1998.

Spitzer, Cary R., ed. *Avionics: Elements, Software and Functions (The Avionics Handbook*, 2nd ed.). Boca Raton, Florida: CRC Press, 2013.

[1190]*Command History of the Naval Weapons Center, China Lake, California*, for the years 1968–1974, and *Command History, Naval Weapons Center Corona Laboratories*, 1968, have the same report identification number.

Stewart, Henry P. *The Impact of the USS Forrestal's 1967 Fire on United States Navy Shipboard Damage Control*. Fort Leavenworth: U.S. Army Command and General Staff College, 2004.

Subcommittee on Investigations of the Joint Committee on Defense Production, Congress of the United States. *Conflict of Interest and the Condor Missile Program*. Washington, DC: Joint Committee Print, 94th Congress, 2nd Session, September 1976.

Sweetman, Jack. *American Naval History, an Illustrated Chronology of the U.S. Navy and Marine Corps, 1775–Present*. 3rd ed. Annapolis: Naval Institute Press, 2002.

Systems Associates. *Final Report: Carrier Aircraft Support Study (CASS)*. Long Beach, California: Systems Associates, December 1971.

Taylor, Calvin W. *Climate for Creativity*. Elmsford: Pergamon Press Inc., 1972.

Technical Paper No. 4. *Scale Model Igloo Magazine Explosion Tests, Naval Proving Ground, Arco, Idaho*. Washington, DC: Army-Navy Explosives Safety Board, August 1946.

Thompson, James Clay. *Rolling Thunder, Understanding Policy and Program Failure*. Chapel Hill: University of North Carolina Press, 1980.

United States Senate Committee on Governmental Affairs. *Nomination of Rowland G. Freeman III, to be Administrator, General Services Administration*. Ann Arbor: University of Michigan Library, 2012.

Van Fleet, Clark, and Armstrong Wm. J. *United States Naval Aviation, 1910–1980*. Washington, DC: Deputy Chief of Naval Operations (Air Warfare) and Commander, Naval Air Systems Command, 1981.

Westrum, Ron. *Sidewinder: Creative Missile Development at China Lake*. Annapolis: Naval Institute Press, 1999.

Wilcox, Robert K. *Wings of Fury, from Vietnam to the Gulf War—the Astonishing True Stories of America's Elite Fighter Pilots*. New York: Pocket Books (Simon & Schuster Inc.), 1996.

Winchester, Jim, general ed. *Military Aircraft of the Cold War*. Rochester, Kent: Grange Books, 2006.

Wise, Nancy Baker, and Christy Wise. *A Mouthful of Rivets, Women at Work in World War II*. San Francisco: Jossey-Bass Inc., 1994.

Woods, M. W. *Independent Review of the Harpoon Weapons System Program, Volumes I and II*. Laurel, Maryland: Johns Hopkins University Applied Physics Laboratory, 1981.

Zumwalt, Elmo R., Jr. *On Watch: A Memoir*. New York: Quadrangle / The New York Times Book Company, 1976.

Zumwalt, Elmo Jr., and Elmo Zumwalt III. *My Father, My Son*. New York: MacMillan Publishing Company, 1986.

Video Productions

"Agile, Closing the Gap." Technical Information Department (TID), TMP 291, DA-LHL 72-14, 1972, 20 minutes.

"A Workshop Like No Other." China Lake Video Projects, DVD 1687, 2010, 32 minutes.

"ASROC, An Anti-Submarine Weapon." NOTS Documentary Film Section, China Lake and Pasadena. TMP 93, 1960.

"China Lake Technical Library: Have I Got a Story for You! 100 Wild Weasels Missions in Vietnam, Presented by Bob Huntley." China Lake Video Projects, 2004, 58 minutes.

"China Lake Technical Library: Have I Got a Story for You! Briteye, Presented by Vern Burklund." China Lake Video Projects, VP 09-059, 2009, 26 minutes.

"China Lake Technical Library: Have I Got a Story for You! Doing Something About the Weather, Presented by Pierre Saint-Amand." China Lake Video Projects, VP 06-054, 2006, 55 minutes.

"China Lake Technical Library: Have I Got a Story for You! Evolution to a Revolution, Origins of Thrust Vector Control, Presented by Scott O'Neil." China Lake Video Projects, VP 08- 022, 2007, 58 minutes.

"China Lake Technical Library: Have I Got a Story for You! Paiute Legends of Coso Hot Springs, Presented by Richard Stewart." China Lake Video Projects, VP 06-052, 2005, 45 minutes.

"China Lake Technical Library: Have I Got a Story for You! Safe-Arm Devices to Cable Cutters, a Career in Product Development, Presented by Walt Smith." China Lake Video Projects, VP 07-120, 2007, 91 minutes.

"China Lake Technical Library: Have I Got a Story for You! Solving the Mystery of the Roseville Bomb Train, Presented by Jack Pakulak." China Lake Video Projects, VP 006-051, 2005, 51 minutes.

"China Lake Technical Library: Have I Got a Story for You! Technology Transition at China Lake, Standard ARM Missile, Presented by Tom Loftus." China Lake Video Projects, VP 08-013, 2004, 56 minutes.

"China Lake Technical Library: Have I Got a Story for You! Vietnam Laboratory Assistance Program, Presented by Robert G. S. 'Bud' Sewell." China Lake Video Projects, VP 07-032, 2007, 67 minutes.

"China Lake Technical Library: Have I Got a Story for You! Women in Science and Engineering, Presented by Jean Bennett, Lois Reed, Bettye Moody, Kim Berard, and Samantha Hawkins." China Lake Video Projects, VP 06-094, 2006, 64 minutes.

"Pictures of Us II, Episode 5, Television on Target." China Lake Video Projects, 2008, 63 minutes.

"Pictures of Us II, Episode 6, From Submarines to Satellites: Part 1, Science and Cetaceans." China Lake Video Projects, 2008, 49 minutes.

"Pictures of Us II, Episode 7, From Submarines to Satellites: Part 2, Around the World in No Moving Parts." China Lake Video Projects, 2008, 49 minutes.

"Pictures of Us II, Episode 8, Way Off Boresight." China Lake Video Projects, 2009, 61 minutes.

"Pictures of Us II, Episode Openers." China Lake Video Projects, 2009, 55 minutes.

"Secret City. A History of the Navy at China Lake." China Lake Video Projects Branch (distributed by China Lake Museum Foundation), November 1993, 194 minutes.

"The Origins of ARM. Defense Suppression and the Shrike Antiradar Missile." China Lake Video Projects, VP 04-154, DVD 1195, 2004, 77 minutes.

"The Pursuit of Precision. Walleye, the TV-Guided Glide Bomb." China Lake Video Projects, VP 07-082, DVD 1628, 2007, 108 minutes.

Glossary of Acronyms and Abbreviations

6-DOF	six degrees of freedom
A	attack (aircraft)
AARGM	Advanced Antiradiation Guided Missile
ACEVAL	Air Combat Evaluation
ACM	air combat maneuvering
ACMI	Air Combat Maneuvering Instrumentation (range, Air Force)
ACV	aerodynamically controlled vehicle
ADAM	Advanced Development Attack Missile
ADP	automatic data processing
AdPub	administrative publication (NOTS/NWC, publication designator)
AFDC	automatic formation drone control
AFFF	aqueous film-forming foam
AGER	experimental research ship
AGI	auxiliary general intelligence (ship)
AGL	above ground level
AGM	air-launched surface-attack missile
AH	attack helicopter
AIM	air-launched aerial-intercept missile
AIMVAL	Air Intercept Missile Evaluation
AIR	NAVAIR office designation (e.g., AIR-06)
AIRPAC	(Naval) Air Force, Pacific
AIU	aircraft interface unit
ALSAM	Air-Launched Ship Attack Missile
ALVRJ	Air-Launched Low-Volume Ramjet
AMH1	aviation structural mechanic (hydraulics) first class
AMRAAM	Advanced Medium-Range Air-to-Air Missile
AMS3	aviation structural mechanic petty officer third class
AN/ASB	bombing, navigation system
AOD	Aviation Ordnance Department
AOTD	active optical target detector
AP	patrol with electronic- and signal-intelligence modifications (aircraft)
APAM	antipersonnel/antimaterial
APG	fire-control radar
APKWS	Advance Precision Kill Weapon System
APP	advanced procurement plan
APQ	radar
AQM	air-launched target drone
ARBS	angular (angle) rate bombing system
ARM	Antiradiation Missile
ARPA	Advanced Research Projects Agency
ARPANET	Advanced Research Projects Agency Network
ASMD	antiship missile defense

ASN	Assistant Secretary of the Navy
ASP	Annual Service Practice
ASRAAM	Advanced Short-Range Air-to-Air Missile
ASROC	Antisubmarine Rocket
ASW	antisubmarine warfare
ATAR	Antitank Aircraft Rocket
ATCS	aviation electronics technician senior chief petty officer
ATF	Bureau of Alcohol, Tobacco, and Firearms
ATIGS	advanced tactical inertial guidance system
AV	attack, vertical takeoff and landing (aircraft)
AVOSET	Automatic Video System of Edge Tracking
AYK	data-processing computer
AZ	azimuth
B	bomber (aircraft)
B&P	Bid and Proposal (funding)
BA	bachelor of arts
BAE	British Aerospace Engineering
BLM	Bureau of Land Management
BLU	bomb, live unit
BOAR	Bombardment Aircraft Rocket
BOMROC	Bombardment Rocket
BPDSMS	Basic Point-Defense Surface Missile System
BQM	target drone capable of launch from multiple environments
BSC	boresight-correlation computer
BSU	fin
BTV	ballistic test vehicle
BuOrd	Bureau of Ordnance
BuShips	Bureau of Ships
BuWeps	Bureau of Weapons
C	transport, cargo (aircraft)
Caltech	California Institute of Technology
CASS	Carrier Aircraft Support Study
CAW	carrier air wing
CAWS	Carrier Air Wing Study
CBU	cluster bomb unit
CEP	circular error probable
CG	guided missile cruiser
CH	cargo helicopter
CHAFFROC	chaff dispensing rocket
CHIMP II	improved Chaparral (weapon system for shipboard use)
CHIRP	Condor-Harpoon Imaging Infrared Program
CI	computer interface
CLAW	Concept for a Low-Cost Air-to-Air Missile
CLC	command launch computer
CLCC	China Lake Community Council

CLPP	China Lake Pilot Plant
CNM	Chief of Naval Material
CNO	Chief of Naval Operations
CO_2	carbon dioxide
CSRA	Civil Service Reform Act
CTF	chlorine trifluoride
CTOL	conventional takeoff and landing (aircraft)
CTU	captive test unit
CTV	controlled test vehicle
CURV	Cable-Controlled Underwater Recovery Vehicle
CV	aircraft carrier
CVA	aircraft carrier, attack
CVAN	aircraft carrier, attack, nuclear
CVBG	carrier battle group
CVN	aircraft carrier, nuclear
CVS	seaplane carrier
CVW	carrier air wing
D	drone controller
DARPA	Defense Advanced Research Projects Agency
DAW	IR seeker (U.S. Army)
DDESB	Department of Defense Explosives Safety Board
DDG	destroyer, guided missile
DDR&E	Director of Defense Research and Engineering (Department of Defense)
DEC	Digital Equipment Corporation
Demo	demonstration project
DLF	Direct Laboratory Funding
DLG	destroyer, guided missile, leader
DLS	Decoy Launching System
DMT	dual-mode (TV and laser) tracker
DNL	Director of Navy Laboratories
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DRC	Design Review Committee
DSARC	Defense Systems Acquisition Review Council
DSU	target-detecting device
DT&E	development, test, and evaluation
EAD	Explosives Advanced Development (program)
ECCM	electronic counter-countermeasures
ECM	electronic countermeasures
ECP	engineering change proposal
ECR	Electronic Combat Range
EDM	engineering development model
EEO	equal employment opportunity

EMC	electromagnetic compatibility
EMI	electromagnetic interference
EMP	electromagnetic pulse
EMV	electromagnetic vulnerability
EO	electro-optical
EOD	explosive ordnance disposal
EP	patrol, signal reconnaissance (aircraft)
ERA	Equal Rights Amendment
ERDA	Energy Research and Development Administration
ERDL	extended range data link (Walleye)
ESE	Early/Emergency Shrike Effort
ESKIMO	Explosive Safety Knowledge Improvement Operation
ESSM	Evolved SeaSparrow Missile
EW	electronic warfare
EWTES	Electronic Warfare Threat Environment Simulation
EX	experimental
F	fighter (aircraft)
F/A	fighter/attack (aircraft)
FAA	Federal Aviation Administration
FAE	fuel-air explosive
FAI	Federation Aeronautique Internationale
FASCAM	Family of Scatterable Mines
FAST	Floating at-Sea Target
FAX	fuel-air explosive
FBI	Federal Bureau of Investigation
FFAR	Folding-Fin Aircraft Rocket
FLC	Federal Laboratory Consortium for Technical Transfer
FLIR	forward-looking infrared
FM	frequency modulation
FME	foreign material exploitation
FSAT	full-scale aerial target
FWS-1	Fuel-Air Weapons System One
FY	fiscal year
FYDP	Five-Year Defense Plan
g	acceleration equal to the force of gravity at sea level
G&A	general and administrative (funding or costs)
GAO	General Accounting Office
GP	guided projectile
GPS	Global Positioning System
GS	General Schedule (civil service classification and pay system)
GSA	General Services Administration
GTR	ground-launched training round
H	helicopter (aircraft)
HAP	High-Altitude Project

HARM	High-Speed Antiradiation Missile
HE	high explosive
HEPS	Helicopter Escape and Personnel Survival (system)
HERO	hazards of electromagnetic radiation to ordnance
HIRP	Harpoon Imaging Infrared Program
HNB	hexanitrobenzene
HP	Hewlett-Packard
HUD	head-up display
HYTAL	hybrid terminal assist landing (system)
IBM	International Business Machine
ICBM	intercontinental ballistic missile
ICE	in-country exploitation
IDP	internal distribution publication (NOTS/NWC, publication designator)
IED	Independent Exploratory Development (funding)
IEEE	Institute of Electrical and Electronic Engineers
IM	insensitive munitions
IMAD	Insensitive Munitions Advanced Development
IMI	Israel Military Industries
IMU	inertial measurement unit
IOC	initial operational capability
IOS	integrated ordnance section (Harpoon)
IOT&E	initial operational test and evaluation
IPD	Improved Point Defense (system)
IR	infrared
ITCS	integrated target control system
IWDS	Improved Weapon Delivery System
IWV	Indian Wells Valley
JANNAF	Joint Army Navy NASA Air Force
JASON	Not an acronym; an advisory group, from Jason of Greek mythology
JHU/APL	Johns Hopkins University Applied Physics Laboratory
JP	Junior Professional
JSOR	Joint-Service Operational Requirement
JSSTSC	Joint Service Secure Telemetry Steering Committee
JVC	jet vane control
K	drone conversion (aircraft, before 1962), tanker (aircraft)
KGRA	Known Geothermal Resource Area
KMU	kit modification unit
KNOZY	Not an acronym; a TA-4 with a custom front radome that permitted missile seekers to be flown in the aircraft's nose
kW/sr	kilowatt per steradian

L.A.	Los Angeles
LAIM	Laser Air Intercept Missile
LAU	launcher
LCCB	low-cost controllable booster
LGB	laser-guided bomb
LHA	amphibious assault ship, multipurpose
LHL	designation prefix for China Lake Photographic Archives
LOGIR	Low-Cost Guided Imaging Rocket
LTV	Ling-Temco-Vought
LWL	Lightweight Laser
Mac	Macintosh (computer)
MANPADS	man-portable air-defense system
MARS	Microwave Radiometry Attitude Reference System
MAT	Chief of Naval Material office designation (e.g., MAT-03)
MBA	master of business administration
MDAC	McDonnell Douglas Astronautics Co.
MESWG	Medical, Engineering, and Scientific Working Group
Mich	Michelson Laboratory (pronounced Mike)
MICRAD	microwave radiometry
MiG	type of Russian fighter aircraft (after aircraft designers A. I. Mikoyan and M. L. Gurevich)
MILCON	military construction
MIL-SPEC	military specification, a detailed description of the physical and/or operational characteristics of an item authorized for use by the military
MIM	guided missile, ground-launched, mobile
MIT	Massachusetts Institute of Technology
Mk	mark; sequential equipment variant- or configuration-designator for, generally, weapons systems and components (e.g., Mk 1, Mk 2)
MLV	memory loader verifier
mm	millimeter
Mod	model; equipment configuration designator, following mark, as in "Mk 13 Mod 2 safety-arming device"
MPES	Maximum Performance Ejection Seat
MRTFB	Major Range and Test Facility Base
MTBF	mean time between failures
MULE	Mobile Universal Laser Equipment
NACES	Navy Aircrew Common Ejection Seat
NADC	Naval Air Development Center
NAF	Naval Air Facility
NAFI	Naval Avionics Facility, Indianapolis
NAMTC	Naval Air Missile Test Center (Point Mugu)
NARF	Naval Aerospace Recovery Facility
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration

NATC	Naval Air Test Center (Patuxent River, Maryland)
NATO	North Atlantic Treaty Organization
NAVAIR	Naval Air Systems Command
NAVAIRSYSCOM	Naval Air Systems Command
NAVMAT	Naval Material Command
NAVMATINST	Naval Material Command Instruction
NAVOPS	Naval Operations message
NAVORD	Naval Ordnance Systems Command
NAVSEA	Naval Sea Systems Command
NAVSTAR	Not an acronym; the Navy-developed Global Positioning System
NAVWPNSCEN	Naval Weapons Center
NAWCWD	Naval Air Warfare Center Weapons Division
NBS	National Bureau of Standards
NCSL	Naval Coastal Systems Laboratory
NIF	Navy Industrial Fund
NLAAG-V	Navy Laboratory Analysis Augmentation Group—Vietnam
NMC	Naval Missile Center (Point Mugu)
nmi	nautical miles
NOGS	Night Observation Gunship System
NOL	Naval Ordnance Laboratory
NOLC	Naval Ordnance Laboratory Corona
NOLO	no onboard live operator
NOS	Night Observation System
NOS	Naval Ordnance Station
NOSC	Naval Ocean Systems Center
NOTS	Naval Ordnance Test Station
NOTSNIK	Officially, NOTS 1: a China Lake program to put a satellite in orbit with an air-launched rocket
NOW	National Organization for Women
NPTR	National Parachute Test Range
NPV	net present value
NSA	National Security Agency
NSAP	Navy Science Assistance Program
NSF	National Science Foundation
NSSMS	NATO SeaSparrow Surface Missile System
NTE	Navy technical evaluation
NUWC	Naval Undersea Warfare Center
NWC	Naval Weapons Center
NWC-	designator for operational flight programs developed by the Naval Weapons Center (e.g., NWC-2)
O&M	operations and maintenance
OFP	operational flight program
OMB	Office of Management and Budget
ONR	Office of Naval Research
OP	Chief of Naval Operations' office designation (e.g., OP-983)
OPEVAL	operational evaluation

OPM	Office of Personnel Management
OPNAV	Office of the Chief of Naval Operations
OPNAVNOTE	Office of the Chief of Naval Operations Notice
ORTA	Office of Research and Technology Applications
OSD	Office of the Secretary of Defense
OV	observation, short takeoff and landing (aircraft)
P	patrol (aircraft)
PAM	pulse-amplitude modulation
PBX	plastic-bonded explosive
PBXN	plastic-bonded explosive, Navy
PC	personal computer
PD	position description
PDP	project definition phase, programmed data processor
PGH	patrol gunboat, hydrofoil
PhD	doctor of philosophy; also, a person who has been awarded a PhD
Pk	probability of kill
PMA	Program Manager, Air
PMTC	Pacific Missile Test Center
POL	petroleum, oil, lubricants
PRAN	aircrew survival equipment airman
Q	target
QF	fighter aircraft converted to a drone
QH	helicopter converted to a drone
QRC	Quick-Reaction Capability
QT	trainer converted to a drone
R&D	research and development
RADM	rear admiral
RAF	racial awareness facilitator
RAM	Rolling Airframe Missile
RAP	Rocket-Assisted Projectile
RAPEC	Rocket Assisted Personnel Ejection Catapult
RAT	Rocket-Assisted Torpedo
RCC	Range Control Center
RDA	research, development, and acquisition
RDC	Rapid Development Capability
RDT&E	research, development, test, and evaluation
Ret.	retired
RF	radio frequency
RGM	ship-launched surface-attack missile
RIF	reduction in force; often used as a transitive verb (“two people were RIFed”)
RIM	ship-launched surface-to-air missile
RIPS	Range Control Center Integration and Processing System
RM2	radioman second class

ROTC	Reserve Officer Training Corps
RPM	revolutions per minute
RPV	remotely piloted vehicle
RTI	Research Triangle Institute
RUM	ship-launched antisubmarine missile
RWR	radar-warning receiver
SA	surface-to-air
SAM	surface-to-air missile
SBIR	Small Business Innovation Research
SCB	ship characteristics board
SDV	swimmer delivery vehicle
SEAL	Sea, Air, and Land (team), a SEAL-team member.
SEAM	Sidewinder Expanded Acquisition Mode
SEMI	special electromagnetic interference
SEPTAR	Seaborne Powered Target
SIDS	Shrike Improved Display System
SKAMP	skewed-approach amplifier
SLAM	Standoff (or Surface) Land-Attack Missile
SM	Standard Missile
SNORT	Supersonic Naval Ordnance Research Track
SOID	Ship's Ordnance Infrared Decoy
SOR	Specific Operational Requirement
SS	Surrogate Seeker, screw steamer
SSA	Software Support Activity
SSBR	Spin-Stabilized Bombardment Rocket
SSM	surface-to-surface missile (BQM/SSM Program)
SSPO	Strategic Systems Project Office
SSVP	Soviet Ship Vulnerability Program
STARM	Standard ARM
Stat.	statute
STILO	Scientific and Technical Intelligence Liaison Office
STM	Supersonic Tactical Missile
STROM	Safe Transport of Munitions (program)
SUU	stores release and suspension unit
SWAB	Shallow Water Attack Boat (program)
SWAT	Sidewinder Acquisition and Track
SYSCOM	Systems Command
T	telemetry, trainer (aircraft)
T2S	Technology Transfer Society
T&E	test and evaluation
TAAS	Tactical Air Armament Study
TACRV	Tracked Air Cushion Research Vehicle
TAP	task area plan
TD	Technical Director
TDD	target-detecting device

TDP	Technical Development Plan
TEC	Total Energy Community
Tech	technical
TFX	tactical fighter, experimental
TI	Texas Instruments
TIARA	Target Illumination and Recovery Aid
TIAS	Target Identification and Acquisition System
TID	Technical Information Department
TIGS	tactical inertial guidance system
TM	Technical Memorandum (NOTS/NWC publication designator)
TMP	Technical Motion Pictures (NOTS/NWC publication designator)
TN	Technical Note (NOTS/NWC publication designator)
TNT	trinitrotoluene
TP	Technical Publication (NOTS/NWC publication designator)
TRAM	target recognition and attack multisensor
TRIM	trails and roads interdiction multisensor
TS	Technical Services (NOTS/NWC publication designator)
TSPI	time-space-position information
TUO	Technology Utilization Office
TV	television
TVC	thrust vector control
TWG	technical working group
U.S.	United States
UCC	universal control console
UCLA	University of California, Los Angeles
UDT	underwater demolition team
UH	utility helicopter
UHF	ultra-high frequency
UI	University of Idaho
UNIVAC	Universal Automatic Computer
UPWARD	Understanding Personal Worth and Racial Dignity
USAAF	United States Army Air Forces
USAF	United States Air Force
USC	United States Code, University of Southern California
USD	Under Secretary of Defense
USGS	U.S. Geological Survey
USN	United States Navy
USS	United States Ship
USSR	Union of Soviet Socialist Republics
V	device on a military ribbon denoting that the recipient was exposed to personal hazard during direct participation in combat operations
VA	Attack Squadron
VAH	Heavy Attack Squadron
VAL	Light Attack Squadron
VAX	virtual address extension (computer)

VC	Vietcong
VF	Fighter Squadron
VFAX	fighter attack, experimental (aircraft)
VHF	very-high frequency
VISCON	Visual Control (program)
VLA	Vertical-Launch ASROC
VLAP	Vietnam Laboratory Assistance Program
VSS	vertical-seeking seat, vertical-seeking subsystem
V/STOL	vertical/short takeoff and landing (aircraft)
VSX	antisubmarine, experimental (aircraft)
VTAS	Visual Target Acquisition System
VTS	Versatile Training System
VX	Air test and evaluation squadron
VX-5	Air Development Squadron FIVE
W	explosive weight in pounds
WAVE	member of the Women Accepted for Volunteer Emergency Service
WAVES	Women Accepted for Volunteer Emergency Service, formally U.S. Naval Reserve (Women's Reserve)
WDU	warhead
WEPTAC	Weapons and Tactics Analysis Center
WESTPAC	Western Pacific
WIGS	Walleye Improved Guidance System
WSSA	Weapon System Support Activity
WW	World War (I and II)
Y	prototype (aircraft, e.g., YF-4)
YAG	yttrium aluminum garnet
YOV	prototype observation, short takeoff and landing (aircraft)
Z-Gram	Naval Operations message issued by Admiral Elmo R. Zumwalt Jr.; e.g. "NAVOPS Z-57, Demeaning or Abrasive Regulations, Elimination of"

Index

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

B

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

C

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

D

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

E

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

F

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

I

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

N

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

O

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

P

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

S

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.

Numbers in **bold** designate footnotes, photographs, maps, and other illustrations.