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A REPORT BY

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ASSISTANT SECRETARY OF THE NAVY
(RESEARCH, ENGINEERING AND SYSTEMS)

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ON THE
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FOR THE
NAVY RESEARCH, DEVELOPMENT, TEST AND EVALUATION PROGRAM

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THOMAS F. FAUGHT, JR.

BIOGRAPHY

Thomas F. Faught, Jr., is the Assistant Secretary of the Navy for Research, Engineering and Systems. In this capacity he is responsible for an annual budget of nine billion dollars for planning and directing research, development, engineering, testing and evaluation for the Navy and Marine Corps.

Prior to his Presidential appointment as Assistant Secretary, Mr. Faught was President and Chief Executive Officer of Dravo Corporation, a one billion dollar, NYSE company. Dravo is engaged in project management, engineering, factory automation, construction, national resource development and materials handling systems manufacturing. Before becoming Dravo's CEO in 1983, he served the company as President and Chief Operating Officer, Chief Administrative Officer and Chief Financial Officer as well as being a member of the Board of Directors.

Prior to joining Dravo in 1974, Mr. Faught's industrial career included the F & M Schaefer Corporation, as Executive Vice President, Gould, Inc., Booz, Allen & Hamilton, an international management consulting firm for which he worked and lived abroad for ten years, and the Ford Motor Company, where he was an engineer and manufacturing manager.

In 1986 Financial World named Faught as the nation's outstanding engineering and construction industry Chief Executive Officer. He also received the same recognition with the Wall Street Transcript's Silver Award that year.

Mr. Faught's background includes project management and finance, technology transfer, factory automation systems development, program planning and control development, manufacturing facility evaluation, research and development organization planning and the planning and oversight of counter-trade transactions.

He was born in Salem, Oregon, and is a graduate of Oregon State University where he received a BS degree in Technology & Business, concentrating in industrial management, personnel and industrial analysis. He also holds an MBA degree from Harvard University and additional graduate work at The Massachusetts Institute of Technology concerning the industrial applications of nuclear energy.

Mr. Faught has served on the Board of Trustees of the Presbyterian University Hospital, WQED (Public Broadcasting and Television) and Carnegie Mellon University (CMU), all of Pittsburgh. He also was vice chairman of CMU's Board's Research Committee. In 1984 Mr. Faught was appointed by the President to the Advisory Committee of the Export-Import Bank of the United States, becoming Chairman of that committee in 1985. He earlier served on a Presidential Task Force to encourage the development of private enterprise abroad.

Mr. Faught served in the U.S. Marine Corps both as an enlisted man and as an officer. He is married to the former Lynda Clancy and they have two sons, ages three and one. He also has four children, two sons and two daughters, by a previous marriage.

INTRODUCTION

The purpose of this report is to inform the Congress of the status and future direction of the Navy's research and development (R&D) activities. It is the eleventh annual report provided for this purpose.

To better understand the position and plans of the research, development, testing and evaluation (RDT&E) effort within the Department of the Navy, it first is essential to gain a clear understanding of the environment and how it is changing.

The Environment

The environment which influences Navy's RDT&E development is changing more than at any time in the recent past. This dynamic situation arises from factors within and outside the control or influence of the federal government.

Among the principal environmental considerations is the nation's need to reduce its deficit. The President, the Administration and the Congress have worked diligently on this challenge. The Department of Defense and the Department of the Navy, recognizing the strategic importance of a financial and economic strong United States, are participating in the solution of the deficit issue. All realize the importance of immediate and significant action. Consequently, funds planned for the Navy's RDT&E efforts have been curtailed. Because the deficit challenge must be met in an orderly fashion, it is possible that the growth of Navy RDT&E over the foreseeable future also will be limited. This is a change in the general environment from that of the recent past; a change well recognized by RDT&E management, and one which impacts plans for FY 1989 and influences our future strategy.

It indeed is fortunate, however, that the Congress foresaw the strategic necessity for expansion of the naval forces during the past decade. As a result of this wisdom, and the Administration's support, today the United States Navy is the most modern, well equipped and best trained naval fighting force in the world. Our predecessors in RDT&E contributed significantly to this strength. It is our responsibility to assure that this stewardship is enhanced. Our job is to be certain that the fleet's position is maintained and that every war fighting and support asset which the Navy possesses achieves its maximum technological potential. This is especially important as the Navy continues to be the service of choice regarding response to contingencies or crises throughout the world.

In essence, the Navy's and our Nation's Maritime Strategy, one structured both for deterrence and for war fighting, is the keystone of this RDT&E plan.

Other major factors which influence our position and plans include:

- The increasing importance of submarine and anti-submarine warfare capability, the need for greater stealth and the overall importance of space to the Navy's mission.
- The potential impact of the INF Treaty and possible START agreement on our weapons plans.
- The political difficulty of sustaining foreign military bases.
- The requirement to increase the Marines' mobility and speed.
- The heightened need to meet effectively the challenges of regional conflicts as well as global war.

- The financial technological and marketing benefits of expanding international cooperative systems development efforts, particularly as Foreign Military Sales experience declines.
- The Soviet military policy transition from one of "Supremacy" to "Parity" to "Sufficiency," assuming this is a credible direction.
- The prudent trend to Interoperability, Inter-Service RDT&E cooperation, and OSD oversight and coordination.
- The eroding technology base, both in the government and U.S. industry.
- The fact of rapidly and persistently advancing Soviet military technology, one which now has achieved leadership in important areas.
- The growth and diversity of the worldwide military weapons trade, requiring countermeasures against allied and other nations' systems as well as those of the Soviets and our own.
- The future importance of technological areas in which Navy possesses significant leadership such as submersibles detection, radar capability, guidance-navigation-communications systems, computer capability, electro-optics, signature reduction, robotics, fiber optics and acoustics.

The Navy's RDT&E plan, one which is designed to sustain our technological strength now and in the future involves in-depth consideration of the above environmental factors. It is a comprehensive strategy which can meet the innovative and technological requirements of our naval forces and defend the nation. It also is somewhat flexible, recognizing that funding constraints may necessitate that we accomplish our plan with no greater annual funding than we have at present, even though, as will be seen in this report, real funding for the Navy's RDT&E effort has grown very little in past years!

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BACKGROUND

Historically, the applications of technology have impacted U.S. naval warfare and national defense significantly. The results of our RDT&E efforts - through the universities, industry and our own Navy laboratories and research and test centers - have materially strengthened every major platform, weapons system and command, control and communications structure.

In general, all of the basic weapons and platforms in today's naval inventory were employed in World War II, many in earlier conflicts. However, today's systems are a far cry from those used in the past. All - from space systems to M-16A2 rifles - have seen significant revolutionary improvements resulting from the application of technology; much of which was not available as recently as twenty or thirty years ago. Technologies required in the year 2000 and beyond must be moving from basic research to exploratory development today! Without such attention we might not be able to match the skills and fortitude of our fighting men in readiness to deter potential aggressors.

A good example of modern day technology is the F-14 carrier-based fighter aircraft. The advanced, proven innovations of the TOMCAT are illustrated in Figure 1.

F-14 TOMCAT TECHNICAL IMPROVEMENTS

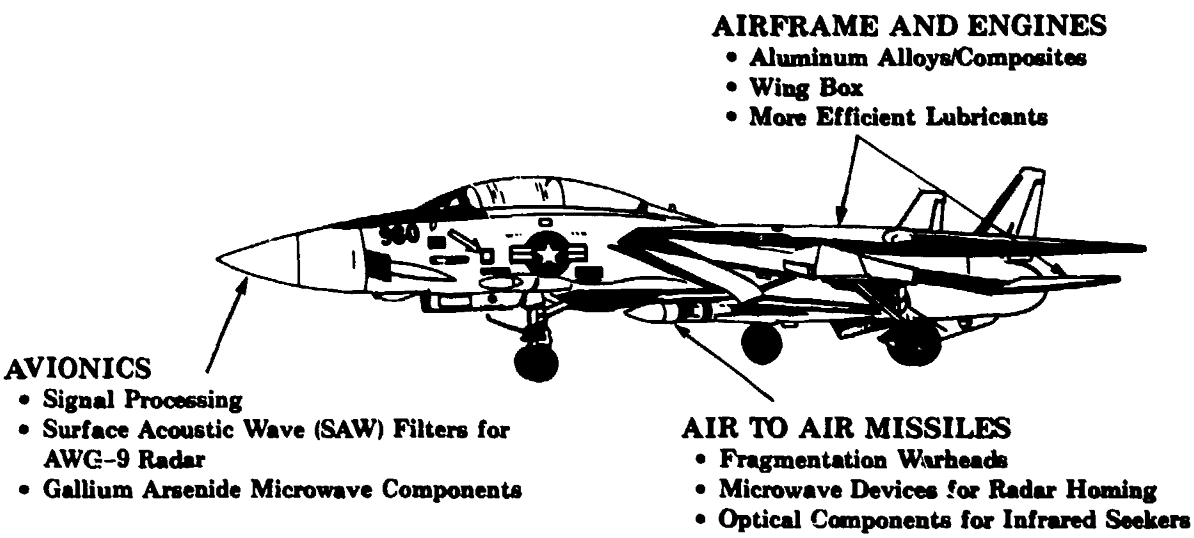


Figure 1

The F-14 entered active service in 1974, and since that time has been the Navy's mainline air defense weapon for our Carrier Battle Groups. Its unique design and use of innovative technology permits it to perform several diverse roles in fleet defense. As one example, its advanced variable geometry wing enables the TOMCAT to sprint to defense vectors at Mach speeds and, if necessary, remain on station for relatively long periods of time.

Coupled with the F-14's unique flight characteristics, the fire control system, radars and weapons are flexibly tailored to the air defense mission. The AWG-9 radar allows it to search, track and direct several long-range PHOENIX intercept missiles to various targets near simultaneously. Also, the TOMCAT carries shorter range missiles such as the SPARROW (AIM-7) and SIDEWINDER (AIM-9) for relatively close-in engagements.

I have used the F-14 as an example for the following reasons: First, as a replacement for the Navy's venerable F-4, much of the technology the TOMCAT possesses today represents numerous updates of R&D efforts in the 1960's. Thus, we have used a reliable basic platform, one which had flexibility designed into it initially, to meet future needs.

Second, the F-14 initially was conceived in 1966. We spent eight years moving this system from concept to operational status! In 1966 it was estimated to cost $16 million per aircraft. By the time production was achieved, the cost had increased to $28 million. A significant amount of this, 80%, resulted from the time taken to achieve Initial Operating Capability (IOC), and this was one of our most rapid transitions! Needless to state, shortening the development time from Tentative Operational Requirement (TOR) to IOC is among our key RDT&E objectives!

The F-14 remains today our primary air-to-air fighter aircraft, and improvement on this fine platform continues. However, it derived from innovations funded by the Congress many years ago. The same is true regarding the AEGIS cruiser, the TRIDENT Program, numerous sonar achievements, the AEGIS weapons system and the ongoing SSN-21 Program.

RESOURCES

The Navy's RDT&E activities involve more than 44,000 people operating at many locations in the United States and abroad. The RDT&E annual budget in recent years has varied between $9.5 billion and $10.0 billion.

Responsibilities are quite decentralized, throughout the Navy and Marine Corps departments and commands. These centers include: Research, Development, Requirements, Test and Evaluation - Navy (OP-098), Marine Corps Research, Development & Acquisition Command (MCRDAC), the Office of Naval Research (ONR) and the Office of Naval Technology (ONT), Space and Naval Warfare Systems (SPAWAR), Operational Test and Evaluation Force (OPTEVFOR), and the various Office of the Chief of Naval Operations organizations (OPNAVs).

People

We are proud of our people. They are the real drivers behind RDT&E developments and major resources for the Navy. Most of our people are scientists or engineers with many years of dedicated work and fine contributions. We have supported the research efforts of 29 Nobel laureates over the past four decades, including Dr. Jerome Karle, a long time employee of the Naval Research Laboratory. Dr. Karle shared the Nobel Prize for Chemistry in 1985. The work of our scientists and engineers is recognized worldwide through numerous advances in their respective science and technology fields.

In addition to the innovative talent in science and technology, we have strong technology management talent throughout our RDT&E system. This includes our civilian leaders and our military professionals who bring real fleet operational experience to the RDT&E community.

These people are Navy corporate as well as national assets that must be sustained. If the past is any measure of the future, then with adequate funding, these people are well able to provide innovative developments that are essential for the future fleet.

Funding

RDT&E expenditures within the Navy, as would be expected, are highly program-oriented. For example, in FY 1988, Acquisition Category I through IV programs, including compartmented projects, represented 72% of the total $9.5 billion budget. Technology Base costs - constituting basic research and exploratory development - in 1988 approximated 7.8% of the budget. A significant portion of the "Tech Base" budget is placed with universities.

As the Congress is aware, the scope of the Navy's RDT&E activities extend from the inception of a system's concept (TOR) to initial operational capability (IOC), or full scale production. Funding for Navy RDT&E (see Figure 2) comprises about 9.5% of the total Navy budget.

Last year, we advised you that the Navy R&D effort would require $10.490 billion in FY 1988 and $10.045 billion in FY 1989. Since that time the Congress completed work on FY 1988 with the result that Navy RDT&E is nearly $1.0 billion lower, at $9.513 billion. Additionally, Congress and the President agreed on lower levels for Defense for FY 1989. As such, the Navy's RDT&E budget request for FY 1989 is $829 million lower than requested last year, at $9.216 billion. We all realize the need which our nation faces in getting our fiscal house in better order, and, therefore, the requirement to reduce expenditures wherever possible.

Figure 2 indicates the distribution of the Navy's RDT&E budget by major program categories for both of the plans for FY 1989, i.e., a year ago and the President's current amended budget as submitted to Congress. Figure 3 shows this same information for the recent past.

NAVY RDT&E BUDGET

FY 1989 PRESIDENT'S BUDGET
(FYDP DOLLARS, MILLIONS)

MAJOR PROGRAM CATEGORIES	ORIGINAL FY 88/89	AMENDED FY 88/89	DIFFERENCE FY 88/89
ACAT I	$ 4,698	$ 4,164	$ -534
ACAT II	1,324	1,678	+354
ACAT III	740	607	-133
ACAT IV	422	335	- 87
CMC	228	209	- 19
NON-ACAT	1,103	866	-237
SUPPORT	636	584	- 52
TECH BASE	894	773	-121
TOTAL	$ 10,045	$ 9,216	$ -829

Figure 2

It will be noted from these data that significant acquisition programs (ACAT I and ACAT II) represent approximately 60% of the Navy's FY 1989 RDT&E budget. Consequently, because of their importance, we tend to concentrate on these in controlling our costs. However, I should emphasize that there are several other programs which, because of their technical sophistication, significance as sub-sets of ACAT I and II programs or for other reasons, we also monitor and control closely. Accommodating the future needs of our Navy's forces while living with such budget constraints isn't easy!

NAVY RDT&E PROGRAM DISTRIBUTION
(CONSTANT FY 1988 DOLLARS)

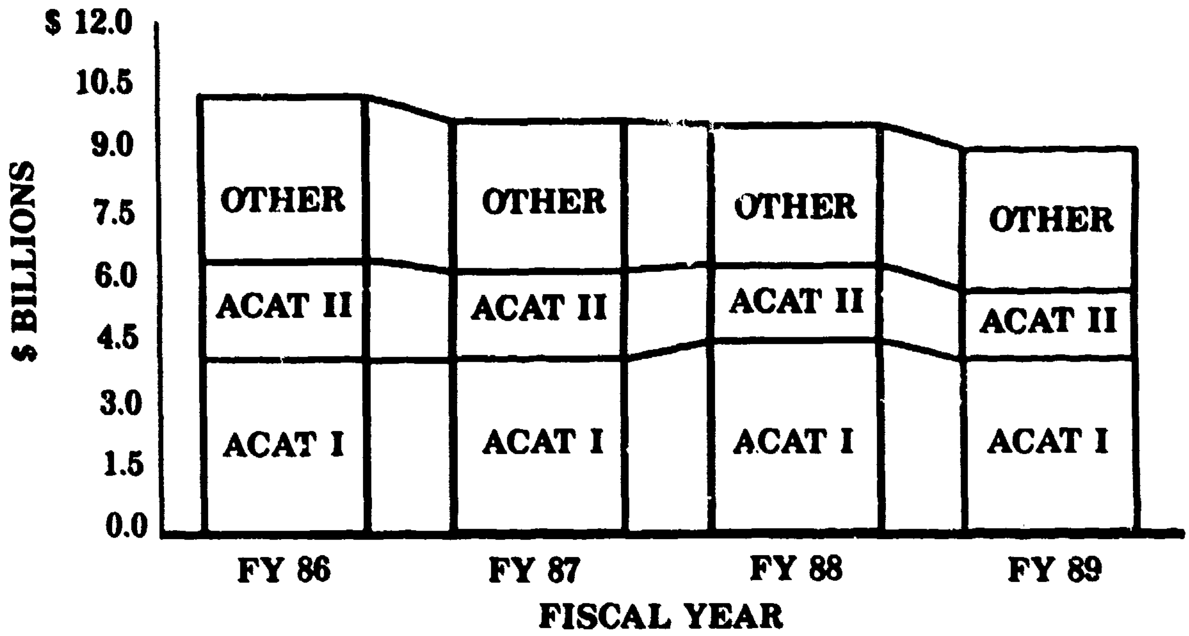


Figure 3

Clearly, there must be a balance between requirements, resources and programs. The concept of being able to "turn on" and "turn off" technology to meet a new threat must be considered carefully. Funding stability is vital. Avoiding the ragged ups and downs of program funding prevents false starts, delays, terminations and inefficient stretch-outs.

However, in the environment of constrained resources which began in FY 1988, and continues for FY 1989, we have had to "cut the pattern to fit the cloth." Programs which we have cancelled, or deferred include the following:

- Airship - intended to provide over-the-horizon early warning radar protection for our major battle groups - status: cancelled.
- NROSS - a remote, ocean sensing system to provide environmental data for submarine and anti-submarine warfare - status: cancelled.
- SV-22A - a vertical take off and landing, anti-submarine warfare aircraft - status: deferred.
- HFAJ - a high frequency, C^3 anti-jamming system for combat communications - status: design study continues, remainder cancelled.

Programs which have required significant restructuring include:

- A-6F - a restructured program is being defined to reduce the cost of the changes made to the A-6 and to remanufacture existing aircraft rather than procure new aircraft to meet fleet inventory requirements.

- EW Programs - funding reductions require stretch-out of efforts. These include:
  - ASPJ P3I (Airborne Self Protection Jammer Upgrade)
  - Advanced Airborne Expendable Decoy (one version)
  - EA-6B Transmitter Update
  - EA-6B C^3CM Improvement
  - Offboard Deception Devices (some cancelled)
- SEALANCE - funding reduction will delay the flight test program.
- Advanced Air-to-Air Missile - restructured to accomodate the FY 1988 Congressional funding reduction and the FY 1989 budget pressures within the Department of Defense.
- Submarine Laser Communications Satellite - restructured due to budget constraints.

It is only through consistent and adequate funding that technology can continue to fill the Navy's modernization needs. We seek your support in pursuing an aggressive R&D program in order to preclude a future Soviet edge in naval weapons systems quality or a military challenge that we would find very difficult and costly to counter.

As shown in Figure 4, money is spent for five major budget activities. The Tech Base (Basic Research and Exploratory Development) is about 8.2 percent of the overall R&D program. It

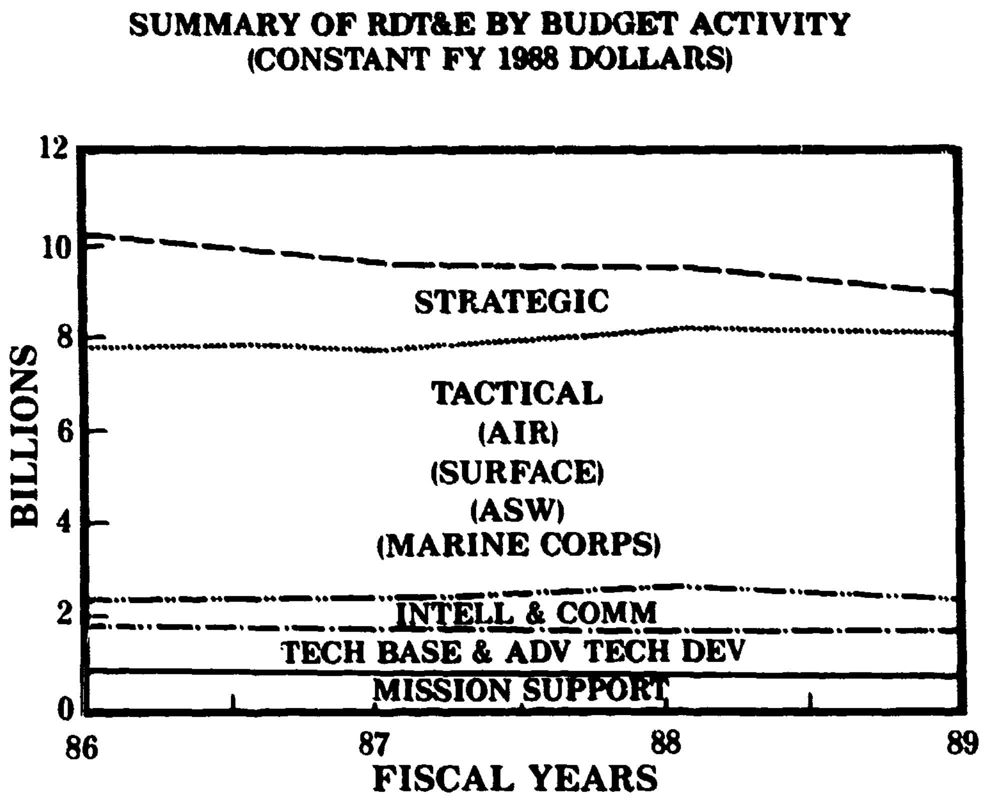


Figure 4

provides fundamental knowledge and new technologies that find a wide range of applications and generate concepts for new systems. Seven percent is used for mission support which funds management support in the operation and maintenance of RDT&E ships and aircraft, test ranges, laboratories, facilities, and other areas necessary to support our RDT&E programs. The largest share of resources, approximately 85 percent, is devoted to the development of tactical and strategic platforms and weapon systems and their associated intelligence and communications systems. The allocation of funds over these budget categories for FY 1988 is roughly proportionate to that of FY 1987, but the actual dollars allocated to each activity have been reduced. The FY 1989 distribution across these areas will be similar to FY 1988, but again reduced in dollar amount (see Appendices A and B).

The Navy's commitment to support only those programs which possess the greatest potential again is demonstrated by the decline in the total number of Navy RDT&E programs over the last six years (see Figure 5). In FY 1983 there were 532 ongoing programs. In FY 1989 there are

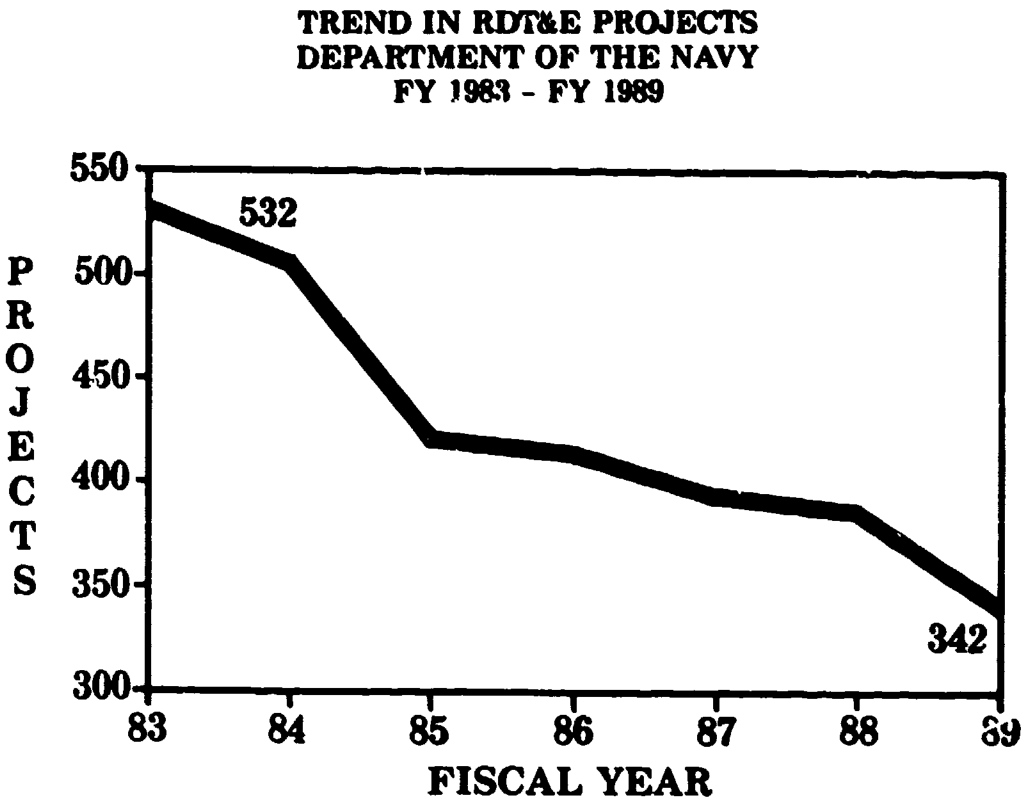


Figure 5

342 planned. The Navy has accomplished this reduction by identifying and supporting only those programs which provide our fleet with the most flexible and effective tools to perform their world-wide mission.

TECHNOLOGY BASE

The key role of the Navy RDT&E program is to gain and maintain technology leadership that is essential to counter our adversaries.

Essential to this strategy is the Navy Technology Base - Tech Base - program comprised of Basic Research (6.1) and Exploratory Development (6.2). Through a spectrum of research and development in areas of engineering, life, physical, mathematical and environmental sciences, including oceanography, we focus on Navy and Marine Corps operational needs in high priority areas, such as anti-air warfare, antisubmarine warfare and command, control and communication support. The major portion of our Basic Research, about 53 percent, is conducted with universities, 36 percent with Navy laboratories, and 11 percent with industry and other sources. Our division of Exploratory Development funds goes 59 percent to Navy laboratories, 31 percent to contractors, seven percent to universities and three percent to other sources, such as non-Navy laboratories.

In managing our activities we seek the finest talent available to make informed recommendations. Leaders, whose sophistication extends outside the domains of science and who have an awareness of global changes and of the forces bringing them about, are sought to serve on the Naval Research Advisory Committee (NRAC). The Committee has been instrumental in providing direction to the Navy's RDT&E community by conducting comprehensive studies on laser eye protection, forward area ASW, affordability and availability of new technology, the Navy's role in the Air Defense Initiative, and plans to initiate a study of the Navy's investment in superconductivity.

The Center for Naval Analysis (CNA) also provides special research, studies, and investigations needed for our Navy management decisions. Their work addresses the development and application of naval capabilities, improvements in operating force effectiveness and the development of operational data for use in force planning and evaluation studies. With approximately 240 highly qualified analysts, CNA maintains a continuing schedule of studies and places analysts in field assignments with various key shore and sea commands.

We have several initiatives designed to strengthen the abilities of universities to conduct research and educate scientists and engineers in major technologies important to national defense. We support scholars pursuing careers in science and engineering, doctoral and postdoctoral educations, and we support academic appointments to Navy laboratories and minority and small business opportunities. A Young Investigator Program supports young scientists and engineers who show exceptional promise for doing creative research. The Office of Naval Research Graduate Fellowship Program is a means of increasing the number of U.S. nationals trained in disciplines of science and engineering critical to the Navy.

The Navy RDT&E program includes all the essential elements from basic research through improving current fleet systems. Important aspects of technology "push" and requirements "pull" are built into the system. Recognizing the importance of technology transition and cost control at every phase of development is a priority of the Navy program.

The entire range of RDT&E functions now are within the direct management of the Navy Secretariat. This streamlined organization is able to provide more consistent direction to the RDT&E process and ensure that Navy RDT&E initiatives are responsive to operational needs. It also assures better control of funding as a function of military requirements and improved execution of acquisition policy to the best benefit of the Navy and Marine Corps.

ORGANIZATION FOR TECHNOLOGY TRANSITION

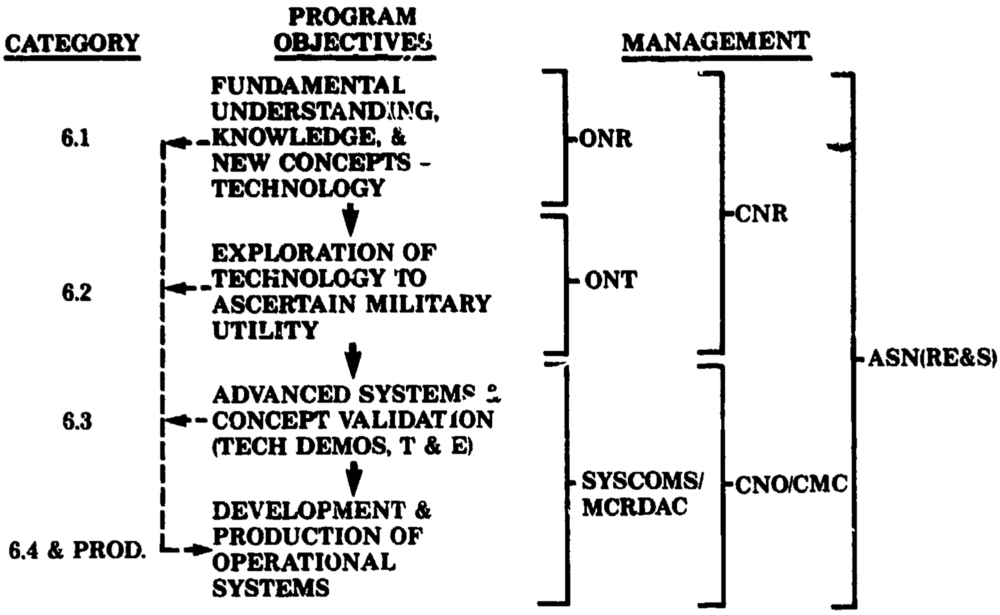


Figure 6

Figure 6 depicts the specific program management objectives of Navy RDT&E funding categories. The Assistant Secretary of the Navy (Research, Engineering and Systems), Chief of Naval Operations (CNO), and Commandant of the Marine Corps (CMC) join to provide policy guidance, operational needs, define major research, development and acquisition thrusts to the Chief of Naval Research (CNR), the Systems Commands (SYSCOM's), and the Marine Corps Research, Development and Acquisition Command (MCRDAC). Basic Research and Exploratory Development programs are closely coupled under the direction of the CNR. The Office of Naval Research (ONR) and the Office of Naval Technology (ONT) provide Tech Base program oversight, translate policy and operational needs into technical objectives, allocate funding, assess the Tech Base program and facilitate technology transition. Navy Research and Development Centers/ Laboratories, industry, and universities all participate in Tech Base program execution. ONT's organizational and management structure, together with its co-location with ONR under one command, has paved the way for accelerating the process that begins with a research idea and ultimately results in a new or improved system for the fleet.

Transition of technology occurs via many routes as illustrated by the dashed line in Figure 6. The classic transition route is evolution from research through exploratory, advanced, and engineering development into production. However, because of the interactions and close team work among the pictured organizations it is often possible to transition technology into production or fleet use at earlier stages. For example, the Persian Gulf crisis has again demonstrated what a key defense resource our Tech Base program is - Tech Base anti-ship missile modeling and simulation tools transitioned within weeks to meet a serious threat to the survival of our ships and those of our allies.

Recognizing the importance of expeditious technology transition, the Navy established a program of Advanced Technology Demonstration (ATDs), with emphasis on the rapid but orderly transition of most promising new technologies and force multipliers into Advanced (6.3) and Engineering (6.4) Development. This program uncovers potential problems prior to large investments, and is the Navy's primary means of transitioning high-risk/high-payoff concepts into weapons systems. You will see growth in this area due to its importance to the Navy.

R&D ACCOMPLISHMENTS

Accomplishments from Tech Base investments that have had numerous positive impacts on the fleet are summarized in Figure 7. Among the more significant is the computer, a technology

NAVY'S BASIC RESEARCH AND EXPLORATORY DEVELOPMENT ACCOMPLISHMENTS

SCIENCE/TECHNOLOGY	CAPABILITY/APPLICABILITY	SIGNIFICANCE
COMPUTER ARCHITECTURE	STRUCTURED COMPUTER-AIDED LOGIC DESIGN (SCALD)	ONE OF THE MOST SUCCESSFUL TRANSFERS OF TECHNOLOGY TO INDUSTRY; REDUCED COMPUTER DESIGN TIME BY NEARLY 50%
MICROWAVE AMPLIFICATION (MASER) RESEARCH	EVOLVED INTO THE LASER	RESULTED IN MYRIAD SCIENTIFIC, MEDICAL AND INDUSTRIAL APPLICATIONS FOR LASER
ALLOY MATERIALS	STRESS CORROSION RESISTANT ALUMINUM ALLOYS IN ALL PRODUCTION AIRCRAFT	DURABLE, LIGHTER AIRFRAMES; INCREASED SAFETY; REDUCED MAINTENANCE COSTS
METAL MATRIX COMPOSITE MATERIALS	TRIDENT-MISSILE GUIDANCE COMPONENTS	ELIMINATED DEPENDENCE ON HARD-TO-OBTAIN STRATEGIC MATERIAL (BERYLLIUM)
INFRARED SENSORS AND PROPULSION	SIDEWINDER AND OTHER MISSILES HAVE GREATER TARGET ACQUISITION RANGE, DECOY EVASION AND LETHALITY	STRENGTHENED U.S. AIR SUPERIORITY; ABLE TO DETECT AND DESTROY HOSTILE BOMBERS BEFORE THEY CAN LAUNCH THEIR WEAPONS
ROBOTICS AND ARTIFICIAL INTELLIGENCE	REMOTE COMBAT AND FIRE CONTROL SYSTEMS FOR MARINE CORPS LAND/AIR TELE-OPERATED VEHICLES	REDUCED SIGNIFICANTLY POTENTIAL BATTLEFIELD CASUALTIES
ANTI-SUBMARINE TECHNOLOGIES	ADVANCED EXPLOSIVES, TORPEDOES, ACOUSTIC SENSORS, SIGNAL PROCESSING; IMPROVED PENETRATION OF ADVERSARY'S NEW SUBMARINE HULLS	ADVANCED U.S. ASW POSITION; AND PROTECTED THE MOST SURVIVABLE LEG OF NUCLEAR TRIAD (TRIDENT)
UNIVERSAL BLOOD AND SYNTHETIC RED CELLS	ENZYMES TO CONVERT ALL BLOOD TO UNIVERSAL O TYPE STORABLE FOR MONTHS AT ROOM TEMPERATURES	INCREASED LIFE OF PLASMA AND REDUCED INVENTORIES FOR TREATING BATTLE CASUALTIES AND CIVILIAN ACCIDENT VICTIMS

Figure 7

in which the Navy played a major role in the 1950's through project "Whirlwind," at the Massachusetts Institute of Technology. This science, spearheaded by Navy R&D, has dominated industry for 30 years, making feasible the widespread use of computers. Today we are playing a major role in laying the foundation for the next generation of computers, even beyond supercomputers, which will have increased speed and capacity through the use of superconducting materials and parallel or distributed systems. Until recently, technological restrictions precluded realistic naval application of superconductivity. Since the 1986 discovery of superconductivity in copper-containing ceramic oxides and the subsequent derivation of an entirely new class of superconducting materials, we have been engaged in matching tomorrow's technology requirements with today's scientific opportunities in this vital area. The prospects for future growth and improvement in advanced superconductivity are good and must be exploited to the fullest.

Nearly every technological advancement Navy R&D has achieved during the past four decades can be improved upon through potential superconductivity application. Figure 8 displays potential shipboard applications of superconductivity. Aircraft, submarines and many weapon systems also will benefit from this technology.

SUPERCONDUCTIVITY'S POTENTIAL SHIPBOARD APPLICATIONS

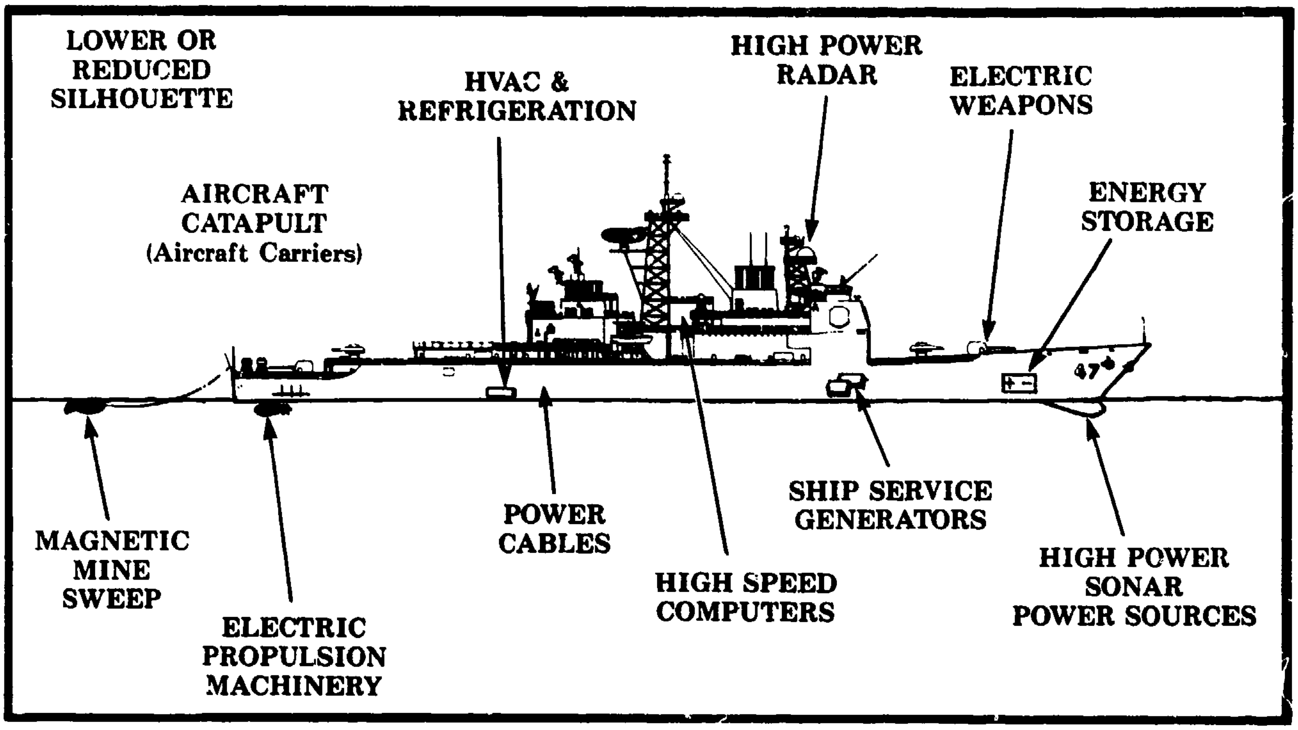


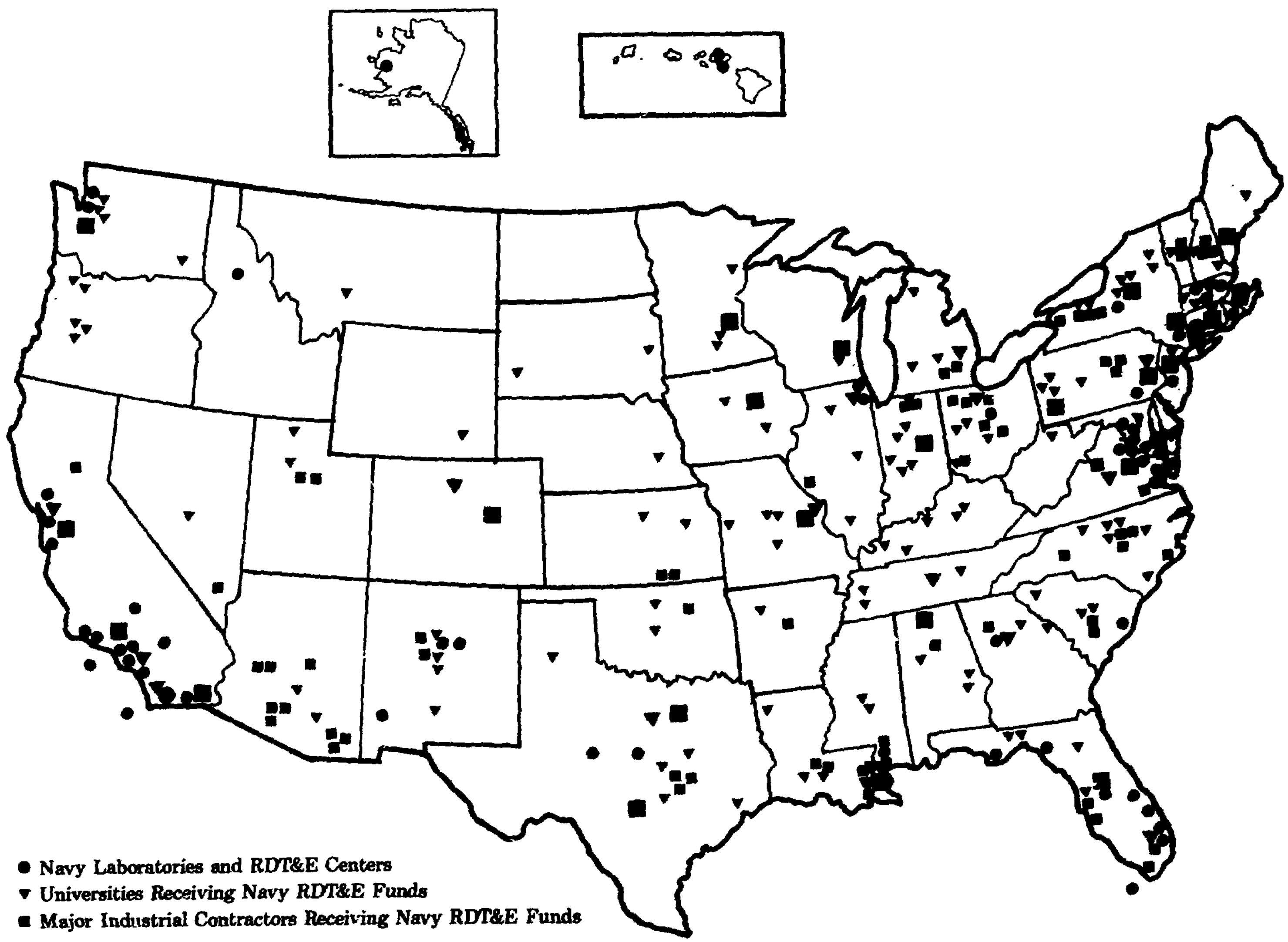
Figure 8

Many other recent platform, weapon system, and weapon development accomplishments are noted in the later program section of this report.

I wish to emphasize that our laboratory system is a key resource in evolving and developing new technologies, testing them, and transitioning them to the fleet. As the Tech Base of U.S. industry declines, it is absolutely mandatory for the security of our nation that this key Navy asset be sustained and strengthened.

The Navy is proud of its laboratory system. Utilizing over 40,000 personnel located at many sites, this network of people and facilities performs the full range of support to our total Navy RDT&E process. In addition, the nation's university system and major industrial contractors also play a key role in the RDT&E process (see Figure 9).

LOCATION OF NAVY LABORATORIES AND CENTERS, UNIVERSITIES, AND MAJOR INDUSTRIAL CONTRACTORS RECEIVING NAVY RDT&E FUNDS



Note: 1. Larger symbols denote 3 or more sites.
2. See Appendices C, D and E for Labs/Centers, Universities, and Industrial Contractors, respectively.

Figure 9

The combination of these laboratories, universities and industrial contractors allows the Navy to integrate research into the full range of product lines, from new ship hull designs to advanced electronic countermeasures.

Significant contributions by each R&D center and laboratory were made during 1987 to improve combat effectiveness. Major support to Persian Gulf operations included rapid evaluation of hostile water-borne mines and the development of tactics and mine-sweeping countermeasures, development of night vision equipment and missile countermeasures. Fleet support by laboratories covers all major operating units worldwide employing on-site scientists and engineers assigned to the Navy Science Assistance Program. Through this program, seasoned scientists and engineers are selected from the labortory system to go into the field and serve as R&D liaison staff to Flag level shore and sea commands, and at certain high activity sites like the Persian Gulf. They are in an ideal position to identify needs that can be met rapidly and at low cost by rapid technology transition or application of off-the-shelf technology.

The pace, sophistication and complexity of weapons systems requirements are increasing constantly. These factors place constant pressures on two principal elements of our laboratories - people and facilities. This environment necessitates that we recruit, train and retain a skilled, experienced complement of scientists and engineers within our laboratory system. This task is difficult because of lack of compensation comparability with industry and because of complex bureaucratic procedures and regulations which complicates and slows personnel actions. One method to improve this situation for our key people is the Personnel Demonstration Project. This Project, currently in place at two of our major West Coast R&D locations, has operated successfully for nine years under careful scrutiny. This demonstration, originally intended as a 2-year program, has proven that it is feasible to provide R&D managers simplified staffing procedures affording the flexibility needed to achieve adequate compensation for outstanding performance; and to do so in a timely manner! <u>One of our principal goals this year is to seek Congressional assistance required to enable us to broaden this proven program to cover all RDT&E scientific and engineering personnel</u>. This objective is strongly supported by the Defense Science Board Summer Study recommendations to the Secretary of Defense. The Packard Commission Report to the President "A Quest for Excellence" has also pointed out this Navy Demonstration Program and noted its excellent results (Appendix J, page 157). This would be a major, long needed first step to strengthen the overall personnel compensation and development process.

Funding support also is needed for improvements in the Navy's RDT&E facilities, many of which pre-date World War II. Thanks to strong Congressional support during the past two years selected key projects such as the Navy Large Cavitation Channel structure and other projects are underway. However, the backlog of R&D military construction projects now are approximately twice the value of those being funded. We are taking steps to consolidate more of our research and development facilities, and plan to increase these efforts in FY 1989. However, even with these streamlining actions, we are not keeping pace, particularly in vital areas such as electronic warfare, special counter-measures, energetic materials and computer facilities.

Maintaining our technology base and restoring excellence in critical, non-industrial R&D areas dictate that we strengthen our support to personnel and facilities, beginning in fiscal year 1989.

COOPERATIVE DIRECTION

The Navy plays an active role in international armaments cooperation. Meaningful collaboration with our allies in developing systems that meet common requirements is becoming increasingly important as weapon needs expand, costs increase and funding shrinks.

In addition, there is the fact that the U.S. no longer has a monopoly in all technology areas. There are other advantages for cooperation in the development and acquisition of systems and equipment. These include elimination of duplicative R&D, enhanced interoperability and standardization, economies of scale and accelerated availability dates.

The Navy is aggressively pursuing cooperative programs with our allies. Some of our avenues are:

- Senior National Representative (SNR) meetings between the Director of Research, Development, Test and Evaluation and his allied counterparts provide the forum to focus international multi-lateral and bi-lateral collaborative programs; there are currently six SNR relationships with four more pending. SNR meetings are useful to:
  - Obtain information on allied technologies, systems and equipment potential for USN/USMC use.
  - Explore cooperative RDT&E initiatives.
  - Identify opportunities to enhance allied interoperability and standardization.
  - Resolve problems and expedite progress of collaborative initiatives.
  - Inform allies of USN/USMC programs of interest.
- Data exchange agreements with 17 foreign governments provide for the sharing of data and technical information. Through this program, the Navy gains insight into the technological capabilities of our allies, develops leads for cooperative armament projects and obtains information useful in national programs.
- The NATO Cooperative R&D Program was established by Section 1103 of the FY 1986 DOD Authorization Act. The focus of this activity for policy, management, and fiscal control is through my office. The program encourages cooperative projects between the U.S. and one or more allies to:
  - Develop new conventional defense equipment and munitions; and
  - Modify existing military equipment to meet U.S. and allied requirements.

In 1986, when this program started, the U.S. Navy initiated five cooperative projects with our allies. The Navy RDT&E requirements for these projects total $3.8 million with the allies contributing $1.4 million. In FY 1988, 14 projects were approved (see Figure 10). The DOD Appropriations Bill of 1988 notes that the program would be more beneficial if expanded and "... pursued among the U.S. and its major, non-NATO allies, all of whom share the NATO objective of deterring aggression and promoting stability in their respective areas of the world." Figure 10 notes two non-NATO programs with Israel and Australia. Programs will start when Memoranda Of Understanding are signed.

NAVY'S CURRENT NATO AND NON-NATO COOPERATIVE RESEARCH AND DEVELOPMENT PROJECTS

PROJECT \ COUNTRY	CANADA	UNITED KINGDOM	FRANCE	GERMANY	NETHERLANDS	DENMARK	SPAIN	ITALY	ISRAEL	AUSTRALIA
• SURFACE SHIP TORPEDO DEFENSE		X								
• NIGHT ATTACK AVIONICS		X			X			X	X	
• REMOTELY PILOTED VEHICLE (MOSP)										X
• PHOTONIC MAST		X								
• BURIED MINE HUNTING		X		X	X					
• LOW FREQUENCY ACTIVE SONAR		X								
• E2C DISPLAY SOFTWARE		X								
• HULL DEGAUSSING SYSTEM		X	X	X						
• TOWED TWIN ARRAY		X			X					
• MASS MEMORY MODULE	X									
• AUTOMATIC SHIP CLASSIFICATION		X		X		X				
• ELECTRO-OPTIC INFRARED DET		X								
• RADAR UPGRADE FOR FIGHTER AIRCRAFT	X									X
• NATO ANTI-AIR WARFARE SYSTEM	X	X		X	X		X			

Figure 10

- Foreign Weapons Evaluation (FWE) and NATO Comparative Test programs assess foreign weapons, systems and technologies to determine their potential for U.S. service use. Forty funded projects are in the FY 1988 program. If the Navy were to develop similar systems unilaterally, it is estimated that it would cost over $1.6 billion in FY 1988 dollars.

We plan to increase Navy and Marine Corps involvement in international cooperative programs. International cooperation will assure access to and sharing of allied technological developments to build the most operationally capable and cost effective weapons systems needed by the U.S. and our allies. U.S. industry will be assured of allies' market places and the military capabilities of the free world and will be able to build on the best technology available.

RDT&E ACQUISITION PRACTICES AND PROCEDURES

We are taking a fresh look at acquisition practices and procedures. In so doing, we are emphasizing flexibility rather than rigid doctrinaire policies. Our approach is to analyze each program on its merits and determine the best business approach. We consider timing, technical, cost and schedule performance and the risk remaining in the program. However, in order to achieve the optimum results in such endeavors, there must be a synergistic approach by not only Navy, but by the Congress and industry as well.

There are eight initiatives needed to improve our acquisition practices and policies.*

First, we need constant and stable funding for each program to the maximum extent possible. Such stability provides a consistent labor force, a continuation of project teams (Navy and industry), continuity of ideas and talent, and a balanced, well thought out risk reduction process.

Second, we need to consider the best contract approach; that is, fixed price versus cost reimbursable. Each of these contract categories bring to the table advantages that must carefully be considered. To make the best possible choice, risk must carefully be considered, organizations must be optimal on the part of the buyer and seller, requirements and work content must be precise and both parties must be highly disciplined.

Third, we must reduce the staggering amount of regulations, policies, legislation and "players" in the acquisition process. If we all succeeed in this effort, the reduction of non-value added activities will reduce costs and time to field a system or piece of hardware.

Fourth, we must continue to emphasize a career path to flag rank for program managers. Presently, the materiel professional program in the Navy and Marine Corps is in the fourth year and is working well. We are rigorously selecting managers who have the best education, experience and proven performance. What is needed now is to permit these managers to exercise their judgment and if their performance is found lacking, replace them.

Fifth, we must pursue initiatives to encourage strengthening the industrial Tech Base. At the present time, the Navy Secretariat is coordinating a study with the Undersea Warfare Executive Committee of the American Defense Preparedness Association. Its purpose is to explore those acquisition policies that will allow us to run equitable competition at reduced cost and less impact on the Tech Base. In addition, we are carefully coordinating the activities of the Chief of Naval Research, the Systems Commands and the OPNAV sponsors regarding Tech Base program interface with the Navy laboratories, universities and industry.

Sixth, we must emphasize the incorporation of manufacturing technologies at the earliest possible time in the systems that we develop. We must ensure that we produce and manufacture products by the most innovative and cost-effective means that will yield consistent high quality.

Seventh, it is worthwhile to consider concurrency and prototyping in development of new systems depending on proven technologies and risk. The use of either of these development schemes, when applicable, would save money and time.

*A closer scrutiny will show that these initiatives encompass many of the Carlucci Initiatives on Improving the Acquisition Process of April 1981.

Eighth and finally, we must continue the technique of naval industrial funding (NIF) at our laboratories and engineering centers, since these activities are required to be totally self sufficient in conducting their own base operations and maintenance in service engineering and research. The NIF program covers the overhead expenses, common to any business, and generates asset capitalization funds, a form of profit, which is used to modernize and improve its productivity.

Much progress has been achieved in the past year toward implementing Packard Commission recommendations concerning acquisition organization and procedures. In accordance with their proposals,* the Secretary of the Navy appointed a Service Acquisition Executive for the Navy last fall. Also, as recommended, he is a top-level civilian Presidential appointee, of rank equivalent to a Service Under Secretary. In fact, in the Navy, the Service Acquisition Executive is the Under Secretary.

As the Navy Acquisition Executive (NAE), the Service Acquisition Executive makes decisions regarding continuation of major programs (ACAT I and some ACAT II) at each milestone in the acquisition cycle, provides acquisition policy guidance and direction and provides recommendations directly to the Defense Acquisition Executive. The role of the Assistant Secretary of the Navy for Research, Engineering and Systems, ASN(RE&S), has been refined further to support the NAE. The reorganization of the office of the ASN(RE&S) currently is in its final phase; the re-structuring being based on the Goldwater-Nichols Reorganization Act of 1986.** The ASN(RE&S) provides advice and assistance to the NAE regarding all programs, from design and development through transition to Limited Rate Production.

The Navy Director for Research, Development, Requirements, Test and Evaluation (Dir, RDT&E) and the Commanding General, Marine Corps Research, Development and Acquisition (CG, MCRDA) decide on the continuation of the next level of programs, categorized as ACAT III. These two military organizations report to the ASN(RE&S) in matters of research and development and R&D acquisition. Concurrently, they have specific responsibilities for and report to the Chief of Naval Operations and to the Commandant of the Marine Corps, respectively.

Again, referring to the Packard Commission recommendations, the Navy now has adopted a streamlined, limited-layer organization between the Program Manager and the Navy Acquisition Executive. There is a direct reporting relationship between the Program Executive Officers in the SYSCOMS to the NAE on acquisition matters.

Test and Evaluation (T&E) bridges the gap between R&D and the introduction of weapons systems to the fleet. In the acquisition process, T&E verifies the operational effectiveness and suitability of the systems, serving as another means of reducing risk prior to major buys for the fleet.

The Navy is in compliance with the FY 1987 National Defense Authorization Act, conducting extensive survivability testing during development, where appropriate. Specifically, individual

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*Recommendations set forth in Chapter Three, Section V, A, 2 and 3, pages 54-55, "A Quest for Excellence," Final Report to the President's Blue Ribbon Commission on Defense Management, June 1986

**Goldwater-Nichols Department of Defense Reorganization Act of 1986, §5011, 5013, 5014, and 5016.

components undergo destructive and non-destructive testing, individual shock tests or live-fire tests to determine suitability.

We plan to continue to provide for adequate T&E of major defense acquisition programs. However, meeting the stringent operational security (OPSEC) requirements during the T&E process has resulted in additional costs at our test ranges. To continue meeting the future T&E milestones it is important to insure that major range test facilities base (MRTFB) funding is approved at the requested amounts.

Three Enterprise Programs have been selected in accordance with the FY 1987 National Defense Authorization Act. They are the SSN-21 attack submarine, the T-45 training system (T45TS), and the TRIDENT II (D-5) missile. The T45TS and the TRIDENT missile have been selected for Milestone Authorization of funds. One of the tenets of the Enterprise Program initiative, streamlined chain of command, was implemented in the Navy for these programs, as well as for all major systems, well in advance of the requirement by statute. We are currently conducting an in-depth study to determine the most effective way to streamline documentation and reporting requirements for not only these programs, but for all ACAT I, II and III programs. In conjunction with this initiative, the content of existing program documentation is being analyzed to determine the most informative, yet non-redundant, approach to become the program baseline.

Unlike the acquisition of production "off-the-shelf" items, procurement of R&D frequently involves unique aspects requiring new and innovative ideas. To encourage the greatest number of submittals incorporating the best innovative thinking, the Navy now emphasizes the use of Broad Agency Announcements. Based on the quality of these submissions, a shortened form of research contract then is awarded. The competitive range of potential research vendors also is being narrowed in the early stage of the procurement process by negotiating only with those firms which evidence quality and depth to have a reasonable chance for practical success.

Analyses currently are underway at Navy laboratories to evaluate the uniqueness and practicability of submitted ideas, with the goal to reduce procurement administrative lead time through such early screening. Encouraging results are being experienced, including some reduction in the procurement processing time, while continuing to operate within existing regulations.

In the relatively esoteric area of high-tech software development the Navy has designed new guidelines to encourage the use of software prototyping in the development of Command, Control and Communications systems. Also, to provide better advance notice to industry concerning prospective research and development work, a Market Research Guide is being developed.

The Department of the Navy aggressively continues to pursue opportunities to improve program quality while reducing time and cost. In the concluding section of this report, several RDT&E goals have been set forth. The success in accomplishing some of these objectives will require the understanding and assistance of the Congress; particularly goals relating to program stability, multi-year funding and the reduction and streamlining of procedures.

NATURE AND STATUS OF KEY RDT&E PROGRAMS

The previous sections of this report discussed the general character of the Navy's RDT&E activities. Highlighted were descriptions and trends of RDT&E funding, organization, development, the progress being achieved vis-a-vis Packard Commission recommendations and Goldwater-Nichols legislation and a summary of environmental considerations and assumptions used as the basis for developing the Navy's RDT&E plan.

The ensuing section describes the characteristics and status of key RDT&E programs. These are presented in terms of warfare or battle management areas.

Please note the increasing significance given to inter-Service cooperation, international cooperative development efforts, DARPA and OSD coordination, more focused laboratory and university research, modifications planned because of possible impact of the INF Treaty and R&D actions being taken to fulfill Navy's interest and obligation toward reducing the nation's deficit.

ANTISUBMARINE WARFARE

Anti-Submarine Warfare (ASW) continues to be the Navy's top priority warfare area. It is the keystone to any maritime strategy and returns a significant warfighting payoff for the investment.

The Navy recently has initiated several developments of advanced combat systems for our major ASW platforms. The first AN/BSY-(1) submarine combat system was delivered to the SSN-751 attack submarine on schedule and within cost. The leader/follower Full Scale Engineering Development (FSED) contract for the AN/BSY-(2) combat system for the SSN-21 attack submarine has been awarded, and a second source for the leader/follower competition in FSED for the AN/SQQ-89 Improvement surface ship ASW combat system has been selected. In addition, the FSED contract award for the P-3 Update IV advanced air ASW combat system has been awarded. This suite, along with the ASW Operations Center (ASWOC), will provide the key to our future air ASW capabilities in P-3 and Long Range Air ASW Capable Aircraft (LRAACA). Our ship and carrier based ASW aircraft of the future, using the shipborne Carrier ASW Module (CVASWM), will adopt a subset of the Update IV system for improved on-board ASW effectiveness. These improvements will greatly enhance the effectiveness of our platforms against the increasingly difficult Soviet submarine threat.

Regarding undersea weapons, some of our major weapons development programs now are nearing completion. The MK-48 Advanced Capability (ADCAP) torpedo is nearing completion of Navy operational testing, and will soon be introduced to the fleet. This marks the introduction of the most advanced and sophisticated undersea weapon in the world. Notwithstanding initial management problems, the MK-50 lightweight torpedo is achieving notable technical success in development and it will enter the final phase of development testing early next year. Our newest mine, the Advanced Sea Mine (ASM) has entered system design definition in a collaborative effort with the United Kingdom (U.K.).

The uniqueness of ASW as a battle management area lies in its universal application across platform types (see Figure 11). ASW is conducted from submarines, surface ships (both combatants and non-combatants), fixed wing and rotary wing aircraft and from shore-based facilities. Each of these platforms face severe challenges if the Navy is to maintain an advantage over ever-improving Soviet submersible systems in detection, classification, tracking and our ability to attrite the enemy in the event of hostilities. These challenges must be met effectively if the U.S. is to maintain its qualitative leadership in ASW. and it will not occur without its price. Improvements must begin in the "wet end" of our Navy's undersea systems. In this regard, funds will be necessary to improve both active and passive sensors and sensor systems for all platforms. New sensors for surveillance are being developed within the Fixed Distributed System (FDS), our "front line" advanced system to meet the anticipated challenge. In the Navy's air ASW systems, both advanced passive and active sensors are under development. Sensor development for surface ships and for submarines reside within the R&D programs of these two platform groups. Sensor detection equipment requires considerable improvement to keep pace with advanced Soviet technology, and represents a high priority funding need.

In addition to the critical value of advanced sensors, there are other new initiatives which result also in significant increases in ASW effectiveness, especially if detection ranges become smaller and engagements are "close aboard." Warfare engagement analyses indicate that submarine protection as well as off-board aids combine to make ASW platforms sufficiently effective to attrite significant numbers of high quality targets even when U.S. submersibles are highly outnumbered. As a result, RDT&E investments in torpedo defense systems and in off-board vehicles are being made both to aid in the detection of enemy platforms and to facilitate safe

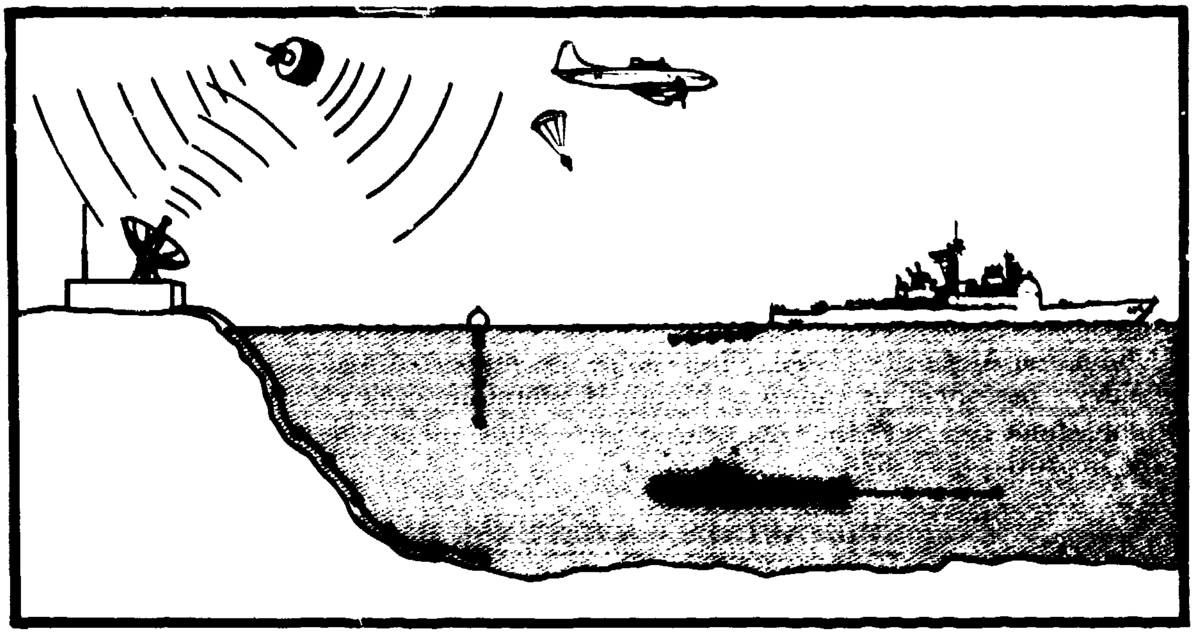

Figure 11

penetration into contested waters. Continuing Congressional support is required to assure that these systems soon are placed in the hands of fleet commands. Peacetime ASW preparation requires that our naval forces be proficient and held in a reasonably high state of readiness. To accomplish these goals, improvements in our trainers and development of more realistic ASW targets is required. Mine warfare also must be improved to assure that we are not handicapped by future, unorthodox beliefs of third world adversaries. The Navy is attempting to meet these requirements through its Exploratory Development (6.2) efforts, and the development of an advanced sea mine along with CAPTOR encapsulated torpedo upgrades.

Economics as well as possible additions to the Navy's own technologies indicate that we look to our allies for assistance and cooperation in developing advanced systems. We already are involved in a collaborative development proposal of an advanced sea mine with the U.K., and also are planning to sign a Memorandum of Understanding with the British leading to a collaborative effort in the development of a surface ship torpedo defense system. In addition, discussions are underway with France and the U.K. regarding cooperative development in the active acoustics. An Anti-Submarine Warfare Strategy, contained in our Maritime Strategy, is essential to the future security of the Nation, but both because of funding limitations and technological hurdles, significant challenges must be overcome in the next few years. Security breaches in the recent past have afforded the Soviets information which forces us to accelerate our own counter- and counter-counter-measures. We have combined Navy-wide programs into our anti-submarine warfare master plan which has been delivered to the Congress. We solicit your counsel and questions regarding our master plan, and look forward to maintaining a continuing dialogue with you concerning future trends and direction in this fundamental battle management area.

SUBMARINE WARFARE

Previous investments in submarine warfare have had high payoff results. We must continue to make the most of the significant defense bargain that our submarine force provides.

Navy submarine RDT&E programs center on inherent submarine characteristics: stealth and survivability - the ability to engage the enemy in any area, including forward northern regions - and decisive firepower with little force devoted to self-defense. Continued full funding of these programs should restore previous margins of superiority against emerging Soviet improvements, and will provide the striking power and unseen presence necessary for continued deterrence.

Submarine programs are highly cost-effective. Our nuclear submarine force size has increased to comprise 38% of the Navy's combatants while total costs remain constant at 20% of Navy Total Obligation Authority (TOA). These ships are supported and maintained with only 10% of the Navy's personnel, as shown in Figure 12. Total life cycle costs of SEAWOLF SSN-21 will be only about 10% more than improved SSN-688 but will provide three times more capability than the improved SSN-688.

SUBMARINES - A DEFENSE BARGAIN

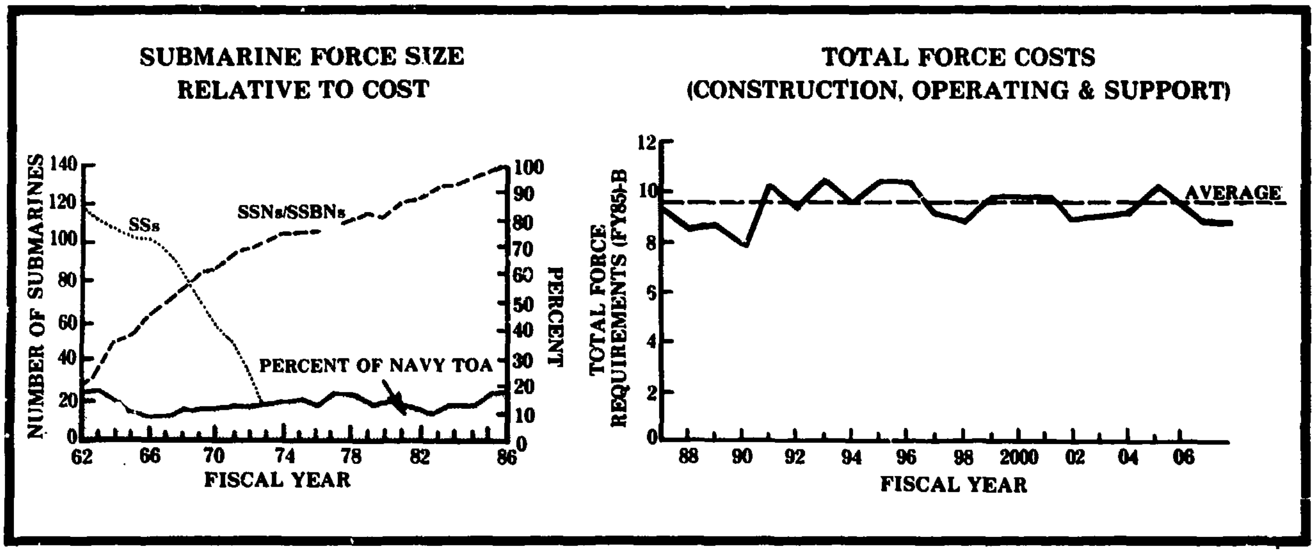

Figure 12

Submarine RDT&E programs have continued to be successful. The detailed design of the SEAWOLF SSN-21 is on track as it enters the seventh year of a 12-year design and development process (see Figure 13). Through the use of extensive prototyping, and computer aided design, and the cooperative efforts of both submarine yards during all design phases, the SEAWOLF program continues to meet all requirements while remaining within budget. The AN/BSY-2 submarine combat system for SSN-21 has entered Full-Scale Engineering Development under a fixed price contract which provides for all warfighting requirements within the "design-to-cost" price. This system, along with SSN-21, should restore our long-term margin of submarine superiority. The on-schedule, on-cost delivery of the AN/BSY-1 submarine combat system to the USS SAN JUAN (SSN-751) will provide our 688 class submarines vital acoustical and weapons launch improvements, system reliability and full arctic capability. The submarine launched MK-48 ADCAP torpedo met all requirements and expectations during its initial phase

SSN 21 R&D ON TRACK

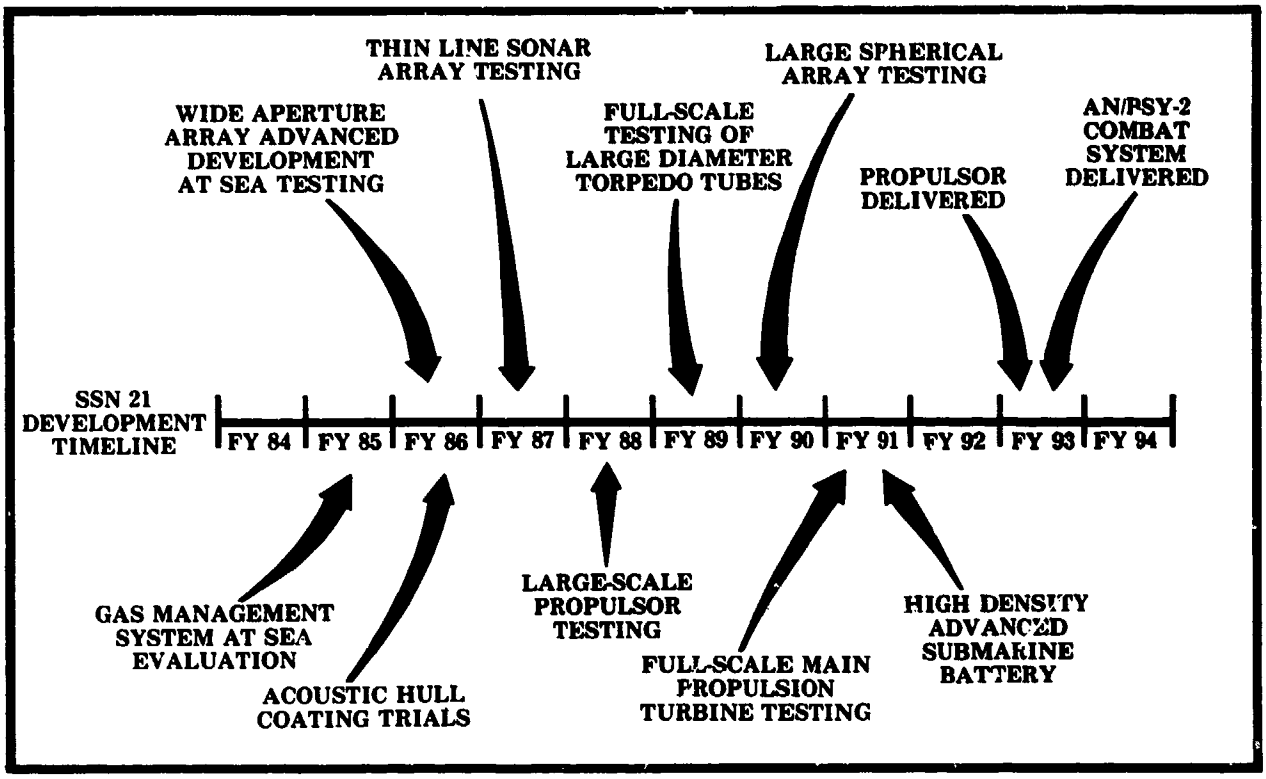

Figure 13

of operational testing, and subsequent approval for limited production. This capable weapon will give the Navy a quantum improvement in torpedo speed, depth, acoustic performance and homing against current and projected adversary systems.

In the coming year we will: (1) continue SSN-21 detailed design work, and award the contract for the lead ship; (2) continue the full-scale development of the AN/BSY-2 submarine combat system; (3) provide needed Combat System Improvements to our 637/688 class submarines, upgrade and modernize hardware and software to allow for the deployment of the MK-48 ADCAP torpedo and TOMAHAWK missile; (4) deliver the MK-48 ADCAP torpedo to the fleet and develop vital block upgrades; and (5) continue development efforts on the SEALANCE ASW standoff weapon through initial missile test; and (6) continue vertical launched TOMAHAWK development.

In addition, the Navy is reviewing long-term submarine R&D requirements. We are, within fiscal constraints, investigating opportunities of integrating and stimulating our efforts in advanced submarine technology throughout the entire R&D community. Congressional initiatives in FY 1988 have been implemented, with DARPA managing a program which takes a broad look at long-term submarine technology. These efforts could support the concept of revolutionary prototype submarines which incorporate new designs and configurations, new systems and new materials. In addition, many of these technologies have significant retrofit potential to current and planned submarines. We specifically are focusing these efforts, with the consideration of at sea testing and prototyping for the mid-1990's. Figure 14 diagrams RDT&E relationships.

ADVANCED SUBMARINE R&D

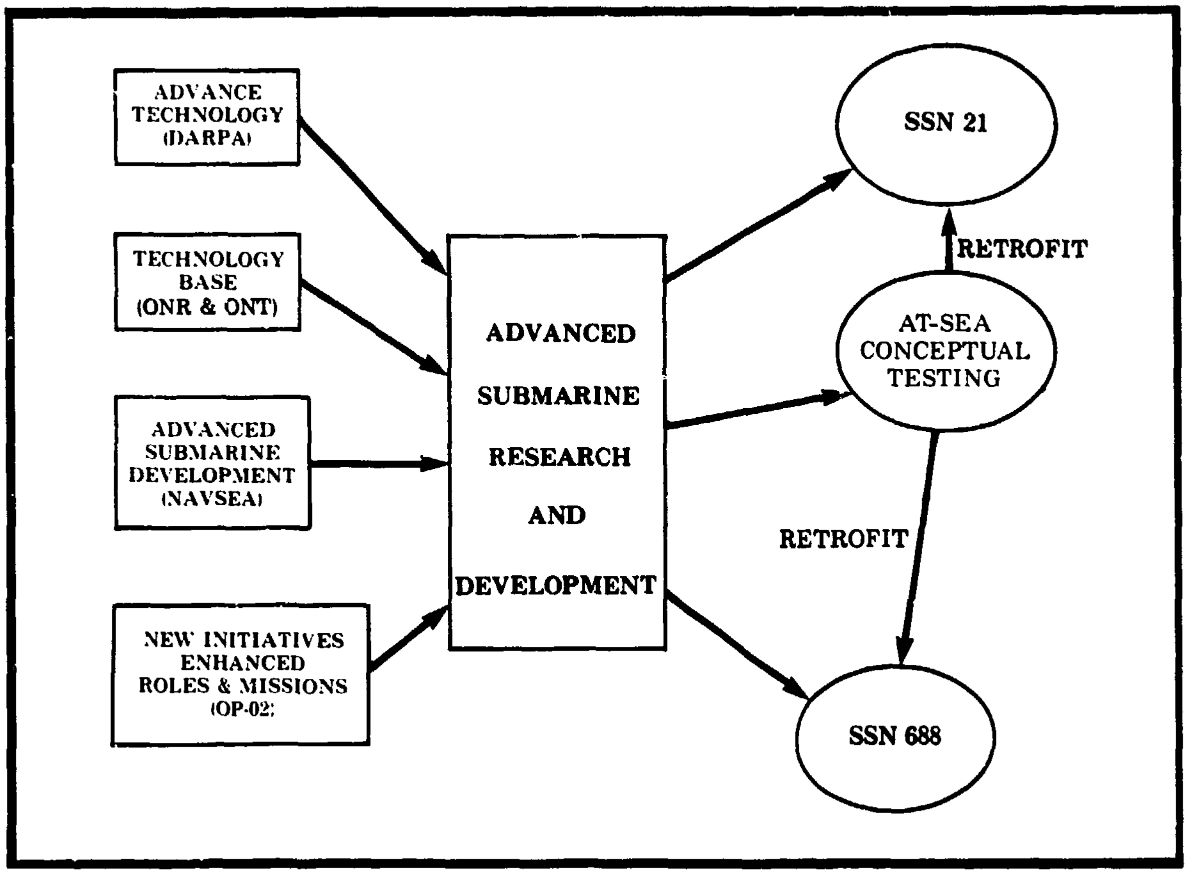

Figure 14

To counter expected advances in Soviet submersible technologies and to provide additional warfighting and deterrence capability, new approaches are being examined to take further advantage of our submarines inherent stealth and attractive financial leverage. In addition to identifying and pursuing revolutionary changes in the anti-submarine warfare the Navy's future RDT&E effort will focus on our superiority to develop new and broader roles in surveillance, anti-air warfare, special warfare, communications, mine warfare, strike and anti-surface warfare. Emerging technologies such as fiber optics will be further developed for use in new concepts like advanced off-board vehicles and submarine launched anti-air missiles.

AIR WARFARE

Two major changes have been made in the Navy's FY 1989 Air Warfare RDT&E program due to affordability considerations. The Naval Airship program has been terminated and the A-6F program has been restructured. The Airship offered promise in providing continuous airborne surveillance for Navy battle groups. The concept has considerable merit but a Naval Airship program is not affordable at this time. Likewise, the A-6F as previously defined could not be supported within the constraints of the Navy procurement budget. A restructured program is being defined to reduce the cost of the changes made to the A-6 and to permit the remanufacturing of existing aircraft to meet fleet inventory requirements.

The Advanced Tactical Aircraft (A-12) is the Navy's highest aviation priority. We urgently require its substantial increase in aircraft survivability in the 1990's to permit the Navy to effectively combat very sophisticated Soviet technologies. The Secretary of Defense continues to encourage an accelerated IOC because of its major technological advances and warfighting potential. The A-12 will be a replacement for the A-6 aircraft, and as such will be produced in sufficient numbers to provide and maintain a fully carrier capable medium-attack force. The A-12 will exceed the A-6 in performance and survivability. The Air Force has agreed that a variant of the A-12 can meet Air Force requirements for the F-111 follow-on. The Navy recently selected the team of General Dynamics and McDonnell Douglas to develop the A-12, and has awarded a contract for Full Scale Engineering Development. This advanced two-seat aircraft will incorporate a derivative of the F-404 engine from the F/A-18.

The Secretary of the Navy and Secretary of the Air Force signed a MOU in 1986 on the cross-service utilization of the A-12 and the Advanced Tactical Fighter (ATF) based on the realization that neither service could afford the development of two separate tactical aircraft in the 1990's. The Navy is committed to proceed with a Navy variant of the ATF (NATF). The ATF contractors have completed a study of a number of NATF designs. No significant problems are seen at this time in the development of an NATF to fully meet Navy requirements. To further enhance interservice commonality, the Navy, Air Force and Army are working on compatible advanced avionics through a Joint Integrated Avionics Working Group for ATA, ATF and possibly an LHX.

Commensurate with the priority accorded ASW within the Navy, airborne ASW programs have strong support within Naval Aviation. The P-3 Update IV Avionics program entered Full Scale Engineering Development during the past year. Boeing was awarded a contract last July. The Update IV avionics will provide capability to counter Soviet submarine quieting technology. This avionics system will be retrofitted into existing P-3C's and will be the system for the new Long Range Air ASW Capability Aircraft (LRAACA). A contract will be awarded this summer to develop the LRAACA; an aircraft which will provide substantially increased range, time-on-station and payload. Competing approaches include derivatives of commercial aircraft and a modified P-3. Potential cooperative development and production programs are being discussed with West Germany for both the Update IV avionics and the LRAACA. These cooperative programs not only will conserve RDT&E resources, but also will enhance NATO airborne ASW interoperability and total allied capability against adversaries.

In response to Secretary of Defense direction, the Navy is exploring potential F/A-18 upgrade configurations to ensure F/A-18 effectiveness through the year 2000. Our objective is to define a program that meets the new aircraft requirements of some of our allies as well as the needs of the U.S. Navy and Marine Corps. Initial discussions have been held with several allied nations to determine their interests and requirements. Their requirements will be used in final configuration definition. The Navy is exploring cooperative development program possibilities starting with Nunn Amendment funding as early as this fall.

Development of the V-22 aircraft continues with first flight scheduled for the second half of 1988. The V-22 Tiltrotor technology will have a significant impact on the air transportation system of the future and opens a new market for commercial application. The civil tiltrotor program will require other R&D efforts and studies from agencies such as the National Aviation and Space Administration (NASA) and the Federal Aviation Agency (FAA). The Navy has taken the initiative by starting a joint program with NASA to look at technology past the V-22 to the next generation of tiltrotor concepts. This joint effort will pay great dividends not only to DOD, but will benefit civil aviation as well.

The Navy is on schedule with its develoment of the T-45TS, a replacement undergraduate jet pilot training aircraft/system. The projected T-2/TA-4 aircraft shortages due to attrition and service life expiration, as well as increasing operating and support costs, required the T-45TS development as a cost effective replacement. The first T-45 aircraft will rollout on 16 March 1988 and is scheduled for first flight later that month. The first pilot production aircraft will be delivered in fourth quarter FY 1989.

The need for an Advanced Air-to-Air Missile (AAAM) is driven fundamentally by the threat in the outer air battle environment by the mid-to-late 1990's. The threat will grow in the following key areas:

- Increased numbers of long-range aircraft with their anti-ship missiles (ASM's),
- Increased numbers of jammer aircraft,
- The presence of fighter escorts armed with longer range air-to-air missiles, and
- Use of low observable technology.

AAAM will meet this threat by providing at least twice the effective range of the PHOENIX missile, allowing greater down-range and cross-range engagement capability. AAAM will be multi-aircraft compatible (F-14, F/A-18, A-12 and NATF with potential for the F-15 and ATF) and, due to its smaller size, will increase the loadout over PHOENIX. AAAM represents a significant advancement in the use of multimode, multispectrum guidance and advanced propulsion technology, to defeat reduced observable and maneuvering elements of the threat environment.

The AAAM demonstration and validation program will be a modest investment to field a critically needed weapon. The economic gains resulting from multi-aircraft compatibility, its joint service potential (for F-15 and ATF compatibility) and its increased operational effectiveness make AAAM a very sound and effective program.

The continued operational involvement of the Navy throughout the world and the fleet's ever increasing role in direct and potential air warfare engagements in areas such as the Persian Gulf mandate continued improvements to our Strike Warfare capabilities. The Navy, because of its continued presence "in harms way," has aggressively moved forward with innovative and comprehensive acquisition strategies to rapidly field affordable weapons while developing integrated plans for future growth. Our Service has been the leader in instituting coordinated "roadmaps" and "neckdown" plans which develop required warfighting capabilities, and plans for the orderly phase-out of existing weapons and systems to meet budget realities. The Navy's Conventional Strike Warfare (CSW)/Anti-Surface Warfare (ASUW) Master Plan has been the benchmark and fundamental framework around which we have developed a detailed acquisition plan. The plan has been strongly endorsed by all levels of leadership in the Navy and Marine Corps. Because of the Navy's already existing and well developed acquisition approach in these areas, it has led the way with proposals to DOD to fulfill Congressionally mandated requirements for master plan "joint" concepts concerning RPV's and standoff weapons.

Our most immediate needs are in the Standoff Weapons (SOW) and reconnaissance areas. Three weapons programs in the Master Plan are highlighted in the following paragraphs. These are the High Speed Anti-Radiation Missile (HARM), the Standoff Land Attack Missile (SLAM) version of HARPOON, and the new Advanced Interdiction Weapon System (AIWS). Additionally, the Navy has made significant progress in meeting critical Remotely Piloted Vehicle (RPV) requirements by "roadmapping" service requirements into a well planned acquisition strategy.

The HARM Improvement Plan, approved by DOD and sent to Congress in August 1987, will complete development of the Low Cost Seeker (LCS). The decision has been made to proceed into FSED and low rate production with LCS. LCS is intended to counter the advanced air defense weapons rapidly being fielded by the Warsaw Pact. Additionally, LCS, which will be competed against a modification of the present HARM seeker (Block IV), will provide a fully qualified second source for an improved HARM and ensure competitive prices. This program also should expand the industrial base available for anti-radiation missiles.

The Standoff Land Attack version of HARPOON, called SLAM, will provide a fully qualified near term long-range precision standoff weapon against high value targets in port or on land. This system is strongly supported by the fleet, and was implemented in accordance with previous Congressional initiatives to take advantage of off-the-shelf, proven hardware and provide early operational capabilities, at significantly reduced development costs. The SLAM development program has met every scheduled milestone, including several series of system integration flight tests. Development risks are low and the SLAM Weapon System is on schedule for early operational capability.

If selected as the Joint Standoff Weapon, the low cost of the Advanced Interdiction Weapon System (AIWS) would enable DoD to buy weapons in sufficient quantities to neutralize or destroy the Soviet's dense Surface-to-Air Missile (SAM) and air defense systems, and other threats which could be encountered during low intensity conflicts. A firm $50,000 per unit cost cap has been established on the AIWS program, based on proven technology in low cost strapdown inertial guidance, Global Positioning System (GPS), kinematically efficient air vehicles, composite construction and cluster munitions. Based on these components, we can develop a baseline launch-and-forget AIWS for delivery at low altitude with sufficient standoff range to increase significantly the survivability of our attack aircraft. If low cost solutions to imaging seekers and data links are possible, we will add range and "man-in-the-loop" accuracy to AIWS, but only if we remain inside an affordable cost cap. There is a solid need for such a weapon, but we will not permit AIWS to become another high cost "golden bullet". The principal technologies involved in AIWS are shown in Figure 15.

In July 1985, the CNO and CMC directed that Unmanned Air Vehicle (UAV) Systems -- Short- and Medium Range Remotely Piloted Vehicle (RPV) Systems, AMBER air vehicles and Tactical Air-Launched Decoys (TALDs) -- be acquired as quickly as possible to correct reconnaissance and over-the-horizon targeting operational deficiencies. Less than a year later, the first PIONEER Short-Range RPV System was delivered to the Navy.

During 1987 and the first quarter of FY 1988, the PIONEER RPV System established itself as a viable operational support element for both the Navy and Marine Corps. Nearly 1000 flight hours have been logged both ashore and afloat on the battleship USS IOWA (BB-61), using the five PIONEER Systems delivered to date. Fleet Navy and Marine personnel have supported training and operations with missions that included Naval Gunfire Support, Bomb Damage Assessment, Beach Surveillance and Reconnaissance. PIONEER has been flown extensively at night using a Forward Looking Infrared (FLIR) system. The IOWA has accumulated nearly 150 hours on its PIONEER System as of this February during its recent deployment to the

ADVANCED INTERDICTION WEAPON SYSTEM PROGRAM

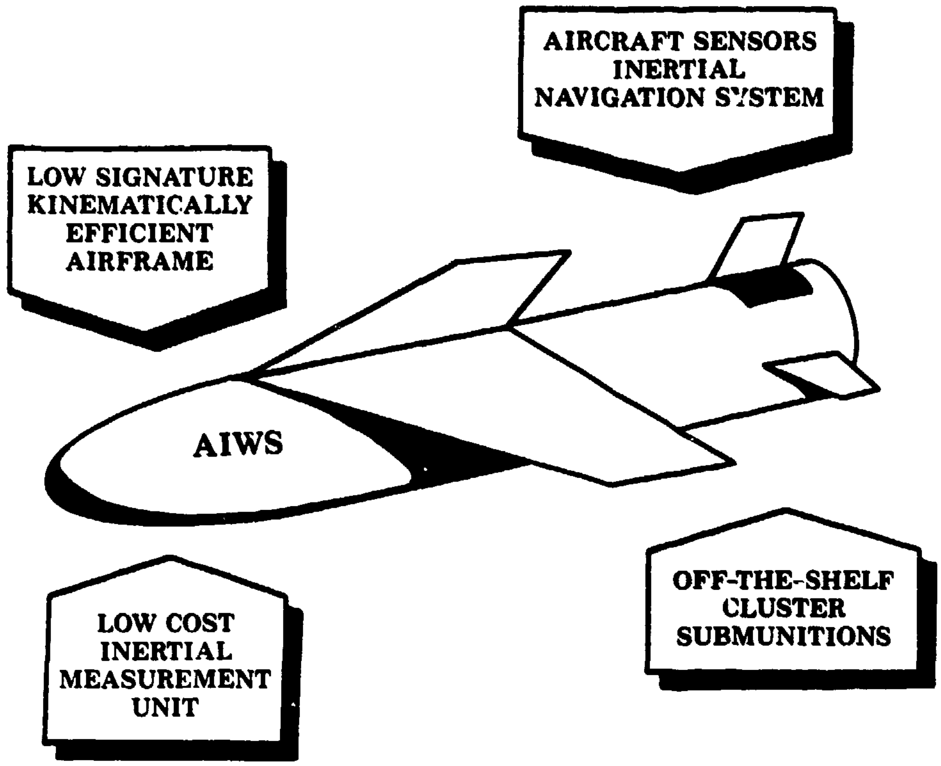

Figure 15

Mediterranean and Persian Gulf. The USS IOWA's PIONEER detachment continues to amass impressive operational statistics during its current operations in the Persian Gulf and has been utilized during numerous reconnaissance missions. In conjunction with fleet activity, the Navy and Marine Corps have conducted operational assessments of the PIONEER System and identified changes to better meet the requirements. These changes will be introduced in FY 1988 and evaluated during operational testing in FY 1989.

The TALD Program moved along rapidly last year. Based on the SAMSON decoy, the TALD is an extremely low cost glide vehicle that confuses enemy surface-to-air defensive systems. The first TALDs completed first article testing and were delivered to the fleet last year, less than two years after contract award.

The Navy is the demonstrated DOD leader in acquiring and fielding operationally effective UAV Systems quickly and at low cost. In less than two years from contract award, two new major UAV systems have been introduced successfully to the fleet. In addition, the PIONEER and TALD procurements both incorporated innovative, competitive approaches which led to firm fixed-priced and tailored initiatives to preclude "gold plating".

SURFACE WARFARE

The Navy's advances in R&D are providing new and increasingly effective platforms that afford required flexibility in the use of sea power. Our surface combatants continue to be the key vehicles in displaying a strong U.S. presence around the world. The investments made in R&D in the past and the guided course now being taken in this era of reduced spending will continue to provide a surface naval force suitable to ever changing needs of global politics.

Our rapid and successful response of U.S. globally deployed surface ships to the unplanned requirement in the Persian Gulf and their performance to date exemplifies the level of readiness of our surface force. The systematic and immediate retaliatory destruction of the Iranian oil assets utilizing on-scene surface systems further demonstrates the readiness of our surface fleet.

Stressing cost effective acquisiton while continuing to upgrade the Fleet, we are pursuing programs which will lead to significant advances in the future. Several systems described here illustrate the direction of our RDT&E thrusts vis-a-vis the surface Navy.

- The surface-to-air Standard Missile-2/Block IV program has been successfully competed although the program itself was capped 60 percent below the initial estimates for design and procurement. Engineering development of the Block IV version commenced this year. When the SM-2 Block IV achieves IOC, we will have reduced surface ship vulnerability against targets under highly stringent engagement conditions, such as high altitude and high crossing flight profiles. Our near-term efforts have produced a significant unit cost reduction through second sourcing for the Block II production line. Additionally, the first tests of the Standard Missile-2/Block III, which will be incorporated into the Block IV varient, have been successfully conducted.
- Further exemplifying cost effectiveness, the Navy's multi-source procurement strategy of the state-of-the-art AEGIS Weapons System is reaching its final stages with the selection of the second source team now completed. It is anticipated that contracts will be awarded in the next few months.
- The NATO Anti-Air Warfare (AAW) program has entered a concept exploration phase under a six nation MOU among the U.S., Canada, Germany, The Netherlands, United Kingdom, and Spain. This program will enhance the fleet's short range AAW capability in the mid-to-late 1990's and will provide for the development of a short range system to counter very low flyer, low radar cross-section, high speed weapons operating in a dense electronic countermeasures, high clutter environment. The program will result in an integrated detection-to-engagement system to effectively counter future threats.
- We have completed the first year of a comprehensive effort to improve ship hull, mechanical, electrical, and combat system designs through the introduction of a wide variety of technology and engineering developments. These advancements will become an integral part of a family of new, more capable warships entering the fleet in the 21st century. Our "Revolution at Sea" program is pursuing high-leverage technologies that hold promise for improved hull propulsion plant and combat system effectiveness. Superconducting electric motors, composite materials and hull coatings, high-energy weapons, and advanced electronics and photonics are examples of the technologies being pursued for application in these new surface warships. More efficient use of shipboard manpower will be achieved through automation and artificial intelligence, and by improvements in shipboard work methods. The principal objective of this program is to develop a totally integrated new warship that is capable of greater efficiency and effectiveness in delivering more ordnance using fewer people.

- Improvement of the surface fleet's self defense systems also is well underway. An example is developments and improvements of our Close-In Weapon System (CIWS). The CIWS Block I upgrade is undergoing testing against representative targets. This upgrade will result in higher search angles, larger magazines, higher firing rates and improved signal processing. Further efforts in this area include study of the near-term testing, comparative evaluation and possible procurement of other existing close-in-defense systems and the design and development of shipboard compatible directed energy weapons.
- Significant progress has been made in our 5" Rolling Airframe Missile (RAM) Program. We successfully demonstrated required flight reliability in February 1987 for this Anti-ship Missile Defense System. This past fall a Joint Production Memorandum of Understanding was signed with Germany which will greatly lower proccurement costs.

These programs represent a well planned, effective approach to modernize our fleet, and to achieve ever increasing utilization of present assets.

STRATEGIC AND CRUISE MISSILE PROGRAMS

The TRIDENT II (D-5) missile is achieving all performance objectives, and is on schedule to provide the first sea-based deterrent covering the full spectrum of the adversary's strategic targets.

Through the first year of testing, the TRIDENT D-5 has recorded eight successful development flight tests. The ninth flight, conducted in January 1988, encountered problems during the final portion of its powered flight and was auto-destructed. The problem is still under investigation, but we should achieve IOC on schedule. All areas of the flight environment have been probed and all missile systems evaluated. Missile accuracy has exceeded established requirements. Development of other portions of the TRIDENT II, including the fire control system, submarine navigator and launch system, also are on schedule. Installation in the TENNESSEE is nearing completion and that ship will conduct its sea trials this year. Development flight tests should be completed this year, and test launches, evaluating the entire TRIDENT II System, will begin shortly thereafter. Beginning next year, all missiles tested will be manufactured using production tooling and test equipment.

The Navy's sea-based strategic capability is the backbone of the nation's strategic deterrence, and with treaty considerations, its importance will continue to grow in the future. It is cost effective with some 50 percent of the nation's warheads provided using less than 25 percent of the strategic budget. Our ballistic missile nuclear submarine (SSBN) force provides survivability, flexibility, and responsiveness equal to or better than the other two legs of the Triad. The Navy is involved actively in a joint effort with the Air Force to improve our ability to penetrate existing or potential upgraded Soviet ballistic missile defenses. We are also accessing how to use the D-5 to attack strategic relocatable targets and deeply buried Soviet command, control infrastructure and war industry facilities. The ability of our SSBN force to reliably conduct strikes at the enemy from any quadrant vastly complicates their strategic war planning. This alone will make the TRIDENT D-5 even more important in the years ahead. Congress has provided strong support for the TRIDENT D-5. However, Congressional reductions imposed in FY 1988 have brought the program to the point where any additional funding reductions could result in a slip of the planned IOC date. Not only could this adversely impact our ability to deploy fully equipped TRIDENT SSBNs, but it could significantly weaken our capability to bargain from a position of strength in upcoming START arms control negotiations.

Strategic communication system improvements continue to enhance SSBN connectivity, reliability and survivability.

Development of the E-6A HERMES aircraft is proceeding on schedule with flight tests beginning last spring. The joint Navy/Air Force development of a solid state high power VLF amplifier and dual trailing wire VHF antenna was also started in early 1987 and is proceeding on schedule. The overall E-6/TACAMO acquisition has been highly streamlined to minimize cost and to introduce the improved capability as early as possible. However, the status of the selection and funding both of the transitional and permanent basing sites for the aircraft jeopardizes the program. We solicit Congressional support in this funding issue to avoid losing the savings achieved in our acquisition of this valued system.

Navy's contribution to SDI is in various laboratory, research, and test efforts — directed energy being a salient example.

Recent studies have indicated that a diversely capable and forward-deployed Navy, especially convert submarines, can make substantial operational contributions to SDI. The elimination of an SSBN prior to launching would reduce the number of warheads which our Strategic Defense System would have to counter in flight. Thus, the Navy's present ability to apply constant pressure against the Soviet SSBN force already contributes significantly to our strategic defense. In addition, Navy's long-time involvement in worldwide command-and-control and its 30-year experience in computer-based tactical data systems may make it uniquely qualified to participate in development of the SDI Battle Management Command, Control, and Communications (BMC^3) system. Overall, therefore, Navy's valued contributions to strategic defense are likely to grow substantially in the next several years.

TOMAHAWK cruise missiles now are deployed on ships and submarines around the world, including our naval forces in the Persian Gulf.

Today, approximately 20 surface ships, including battleships, and 31 attack submarines have TOMAHAWKs on board. In the future, almost every surface combatant and attack submarine will carry TOMAHAWKs. This will compound significantly the Soviet's warfighting challenge, necessitating that their defensive naval power be disbursed across a large base.

The fourth of the planned TOMAHAWK variants, the TLAM-D, successfully resumed flight tests last August. Recent, fully successful TLAM-D flights, including live-warhead tests, have demonstrated the missile's mission ability to accurately dispense submunition clusters on multi-targets.

Several TOMAHAWK improvements currently are underway. These include: (1) incorporation of Global Position Satellite (GPS) navigation, (2) a more capable booster rocket, (3) a higher thrust turbofan engine, and (4) time-of-arrival control. In parallel, a major improvement in TOMAHAWK Theater Mission Planning Centers (TMPC) is under development. This upgrade will reduce significantly the time required to plan land attack missions. It also will permit more flexible route planning for the TLAM-N nuclear variant. The TMPC upgrade will contribute to installing TOMAHAWK mission planning capability aboard ship, providing the local commander the ability to employ TOMAHAWK more flexibly and more responsively. A major effort currently is being made to improve Over-the-Horizon Targeting (OTH-T) and performance to permit the full anti-ship TOMAHAWK capability to be used.

TOMAHAWK dual-sourcing continues to be among the Navy's most successful competitive acquisitions. While all of cruise missile hardware, including the surface ship weapon control system, the Theater Mission Planning System, and depot support operations, are competitively procured, the "all-up-round" rightfully receives the most attention. Since submission of the President's FY 1986 budget, TOMAHAWK all-up-round procurement costs have been cut over 15 percent as a direct result of competition. In FY 1988 alone, the savings from the President's budget approximate $100 million.

The Navy is involved actively in developing a framework to implement the Intermediate Nuclear Forces (INF) treaty. Among other things, we are working with the DOD arms control organization and with the Air Force to accommodate Soviet inspection provisions for this treaty. Congressional recision of FY 1987 GLCM and TOMAHAWK procurement funds has complicated the GLCM issue. We need the support of the Congress to insure that maximum flexibility is retained in making use of these important assets.

ELECTRONIC WARFARE

In response to FY 1988 Congressional actions concerning the services Electronic Warfare (EW) programs, the Navy has taken steps which accommodate to funding reduction while, at the same time, meeting the needs of the naval forces. These steps have involved (1) developing EW programs to counter multiple threats from the third world as well as from the Soviets, (2) seek a greater commonality and interoperability among the services to achieve both EW objectives as well as those of the Navy, (3) combining advanced technology with less sophisticated systems approaches and (4) restructuring some ongoing developments to accomplish most requirements at lower cost.

The overall EW goal of the naval forces is to deceive, deny, disrupt, and exploit weaknesses in the enemy's electronic emissions. The dangers the Navy faces today have proliferated across the electromagnetic spectrum. These range from low frequency surveillance radars to radio frequency guided missiles, from longer wave infrared detection devices and missile seekers to optical- and laser-directed challenges. These challenges by our adversaries are integrated through an external and extensive command and control network. Moreover, today's threat is three-dimensional, and simultaneously can present itself from any bearing and at longer ranges. Literally, the Navy's engagement envelope extends from the depths of the oceans to the boundaries of space.

In every engagement a fairly predictable sequence of events occurs; commencing with target detection, progressing rapidly to weapons launch and culminating in terminal action. To counter this sequence, the Navy's EW development strategy addresses every phase of engagement, and provides a balanced offensive and defensive capability to the fleet across the engagement timeline in support of all our warfare areas. The engagement phases and timeline are graphically portrayed in Figure 16, which follows:

ENGAGEMENT TIMELINE

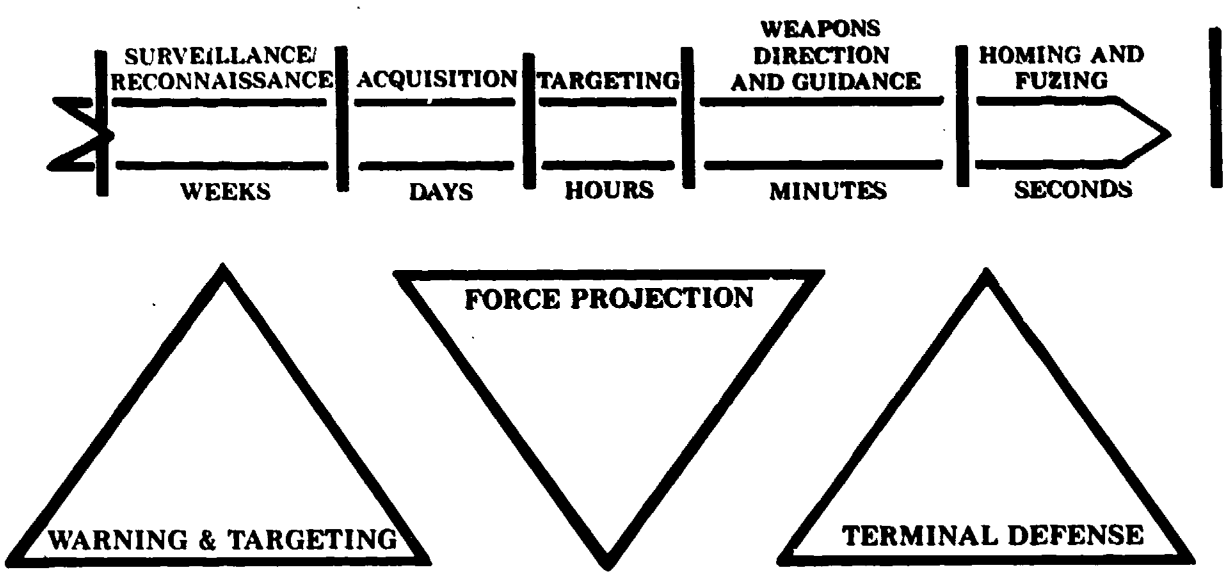

Figure 16

During an engagement's warning and targeting phase, long range passive sensors are used to detect, locate, identify and target the enemy before he can detect our forces. Systems under development for this warning and targeting phase will provide extended warning of hostile actions and also information permitting our Navy's forces to engage in a time and at a place of our choosing. Systems currently under R&D activity include the ES-3/Battle Group Passive Horizon Extension System (BGPHES), EP-3 Conversion in Lieu of Procurement (CILOP) and Combat DF System.

In the force projection phase, offensive actions are taken to counter enemy electronics and command and control systems using electronic countermeasures such as jammers, expendables and decoys as well as through deception. These actions delay, disrupt or deny the enemy's ability to successfully locate and engage our forces. Examples of systems being developed for the force projection phase are such as the ADVCAP EA-6B, the improved SLQ-32 and onboard and offboard decoys; the latter to deceive and provide screening.

In the terminal phase, the objective is to reduce the enemy's probability of kill and to enhance our survivability. To achieve these objectives, the Navy developed platform EW packages, not as independent systems but as parts of an integrated unit consisting of warning receivers, active onboard jammers and onboard and offboard decoys. This approach precludes after-the-fact trade-offs, and maximizes simultaneous complementary of supplementary operations. Developments for this phase, for example, are the ALR-67 Advanced Special Receiver, ALQ-165 (ASPJ), improved SLQ-32 and the Navy's expanding family of airborne launched decoys. These platform packages are complemented or supplemented by dedicated EW support systems such as the previously mentioned ADVCAP EA-6B and BGPHES.

Overall, the Navy now is developing its Electronic Warfare capability with a strong emphasis on complementing Air Force and Army efforts. We continually review all of our EW R&D activities and naval force requirements for areas of commonality and interoperability. This is done through analysis and frequent conferences with the other service R&D organizations. The common goal among the services is to design and develop a total EW program which is non-duplicative, affordable and compatible. The recently established Joint Airborne Expendable Decoy Office is a constructive step toward identifying areas of possible commonality and coordinating development of such systems. Current joint service programs include ASPJ, Advanced Airborne Expendable Decoy (AAED) and the ALE-47 chaff dispenser.

In addition to Navy's joint efforts within the Department of Defense we have cooperative electronic warfare R&D efforts with principal allies. As examples, we have a joint R&D decoy development effort with Australia, several EW comparative test programs with NATO and have procured an inflatable radar decoy (SLQ-49) developed by the U.K. The Navy also is the sponsor for an infrastructure project for Phase IIA of NATO's Multi-Services Electronic Warfare Support Group (MEWSG). This project will provide NATO a dedicated, airborne EW training capability consisting of three EW aircraft equipped with ECM and threat simulation equipment. To ensure commonality within the Navy, we recently agreed to install improved SLQ-32 systems on aircraft carriers instead of procuring the SLQ-17. This should ensure that we eventually have one EW system on all of our surface combatants. In the air warfare area, we have reduced the types of radar warning receivers to one for all aircraft, i.e., the ALR-67(V).

To strengthen the training of operators and line personnel, we have developed computer models, EW ranges and simulators to give our people a realistic, mixed force battle scenario. This permits our EW operators to train and test in a real world-oriented threat environment which contains representative jamming of his own sensors. Such training is required for operators to develop and practice hardkill and softkill tactics optimizing our offensive capability and increasing the defensive advantage we possess with coordinated EW systems. High technology in EW computer monitoring and threat simulation have made impressive contributions to developing, testing and deploying a wide variety of new electronic warfare equipment and tactics to the Persian Gulf.

To ensure that we develop and acquire economically-sound systems, we "Red Team" our development efforts. This process evaluates the available or possible counter-countermeasures against our new EW systems from an adversary perspective. The Red Team identifies simple or inexpensive actions with which the Soviets could negate our relatively costly systems investments. They also identify tactics in developments which we possibly can employ to monitor if adversary counter-countermeasures are being developed or fielded. These actions, in turn, may give us direction to develop a new or diverse set of countermeasures, and vividly illustrates a historic thrust and counter-thrust nature of electronic warfare systems R&D.

Electronic warfare programs which have been delayed, restructured or cancelled because of budgetary constraints include:

- ASPJ P3I (Airborne Self Protection Jammer Upgrade)
- Advanced Airborne Expendable Decoy (AAED) (one version)
- EA-6B Transmitter Update
- EA-6B C^3CM Improvement
- Offboard Deception Devices (some cancelled).

DEVELOPING COMMAND, CONTROL, COMMUNICATIONS, AND INTELLIGENCE SYSTEMS

Gathering, fusing, interpreting and protecting strategic and tactical sensor data is among the Navy's highest priorities. Command, Control, Communications, and Intelligence (C^3I) Systems represent the vital "glue" that enables naval forces to achieve effective strategic planning, tactical surprise and the optimum use of warfighting assets.

Throughout the history of naval warfare rapid gathering and the exploitation of intelligence information has provided the "force multiplier" which enables a commander to seize the warfare initiative. With over three-fourths of the earth's surface the domain of naval forces, the importance of fast, accurate communications to naval force engagements and to our nation's defense is readily apparent. Against a numerically superior enemy possessing long-range, over-the-horizon (OTH) weapons, operating in highly sensitive "edge-of-war" scenarios, the outcome of a modern naval engagement -- warfighting or deterrent -- is greatly dependent on who has won the Information Challenge during the preceding hours or days.

As we proceed into the 21st century, enhancements in sensor technology, weapon speed, stealth and accuracy dictate that we push the perimeter of battle farther away from the defended force. Early detection and identification of enemy forces leading to the development of the tactical "picture" far in excess of local sensor capabilities will be essential in all areas of modern naval warfare. Success against the Soviet's larger force will depend largely on off-board sensors to narrow search areas and provide locating data that can be reliably communicated to the Fleet (see Figure 17).

U.S. NAVY DATA FUSION

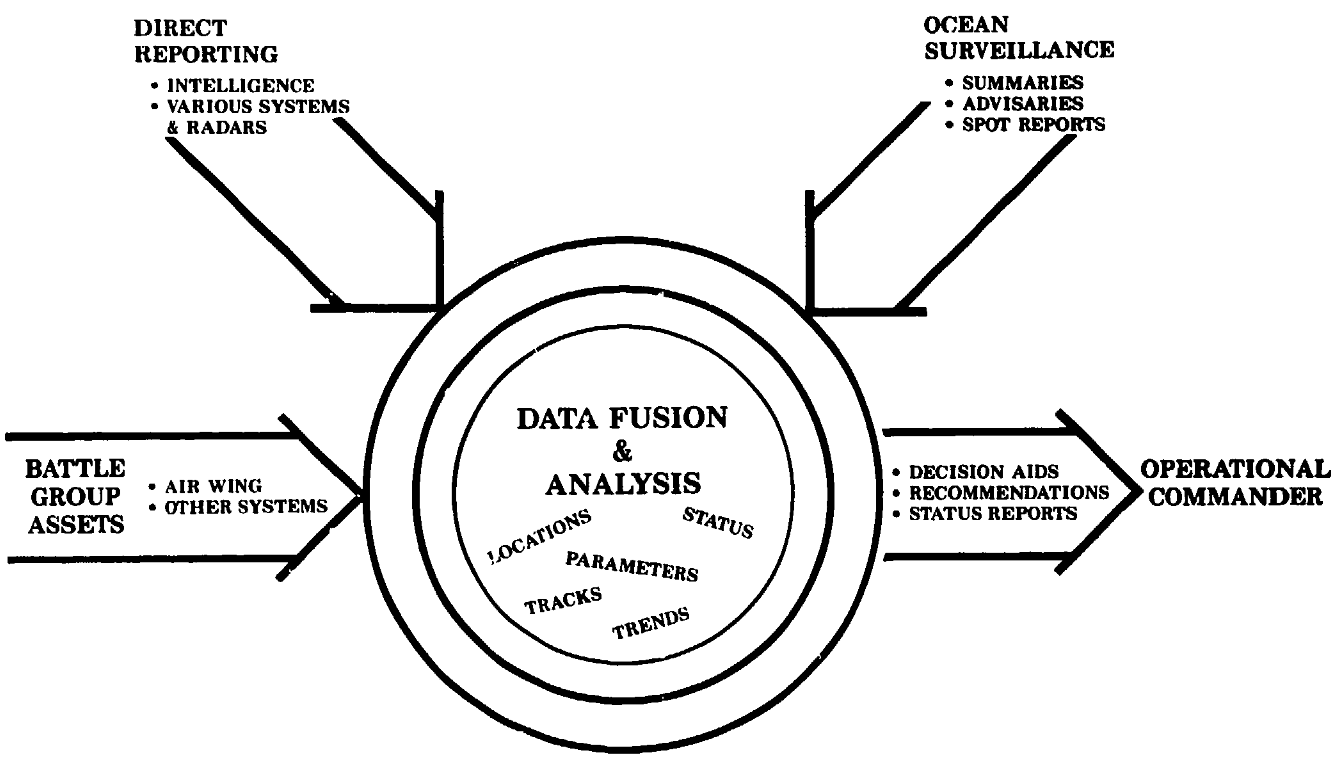

Figure 17

The C^3I system receives information from various sources, processes it into a useful coordination, timing, resource allocation and weapons control product and disseminates it to Operational Commanders. The C^3I system is comprised of nodes ashore and afloat and the related connectivity. There are over 40 C^3I nodes worldwide, and they are, in essence, a globally distributed information system. The existing ashore C^3I nodes are the result of independent developments. System interface problems, manual operations and fragmented data bases have resulted in restrictive interfaces, limited correlation capability and lengthy throughput times. Also, correlation ashore is manpower intensive and, in crises, can be easily saturated. Ongoing efforts to upgrade the ashore Navy Command and Control System (NCCS) will result in a more compatible, fully integrated system.

On the afloat side, the Composite Warfare Commander (CWC) doctrine provides for optional delegation of warfare tasks. This doctrine presents connectivity problems, but greatly increases robustness. Another afloat problem is correlation of non-organic information with organic (battle force) data, primarily a manual process now. As increased organic and non-organic surveillance information becomes available, an automated capability afloat is required to integrate this information. This automated capability must include the ability to integrate selected information directly from remote sensors in the event of the loss of the ashore capability. Track management, another major battle force concern, requires accurate gridlock, precise navigation, and timely inputs. Communciations connectivity ashore and battle force links afloat must therefore be assured.

Although we have looked at each warfare area separately in previous sections of this report the simultaneous execution of warfare tasks actively requires considerable interaction among warfare commanders. Their respective C^3I systems make decisive interaction possible. Five common warfare C^3I requirements can be identified.

- First, as we endeavor to gain battle space through improved surveillance, the need increases for better management of the surveillance product. The rapid correlation and fusion of data is especially critical. Manual correlation methods simply cannot keep pace with increased information flow. This information processing problem will be exacerbated as direct reporting of high data rate remote sensors becomes more common.
- Second, as the combat horizon expands and the range of weapons increases, accurate navigation and geographic based gridlock become essential for all units in the battle force.
- Third, all warfare commanders and coordinators require a method for displaying critical information in a tactically useful fashion.
- Fourth, sophisticated decision aids are needed that exploit, to the maximum extent possible, the expensively derived, fused data base to plan and execute missions. These decision aids will become more critical as our force levels decline relative to the Soviets and as the speed and lethality of modern weapons dramatically increase the cost of an unsuccessful course of action.
- Fifth, all warfare commanders and coordinators need secure, interoperable, jam-resistant communications to carry out their missions.

C^3I systems are extremely dependent upon our continuing successful technology based efforts in computer system development. We are conducting a major Warfare System Architecture and Engineering analysis based upon Top Level Warfare Requirements (TLWR's) to determine where we should focus our C^3I efforts, now and in the future. To answer requirements for surveillance and targeting, we are pushing ahead with deployment of Relocatable (OTH) Radar (ROTHR) as the best cost-effective near term, active, wide-area surveillance system with a quasi-global reach. To provide secure, jam resistant communications paths for the exchange of tactical information and the issuance of force orders, we are committed to the Joint Tactical Distribution System (JTIDS), LINK-II Improvement, and the Ultra High-Frequency (UHF) Satellite Communications Follow-On (UFO) system. In support of information processing and, fusion and analysis afloat, we are developing the Tactical Flag Command Center (TFCC), Advanced Combat Direction System (ACDS), Command and Control Processor (C^2P), and the Afloat Correlation System (ACS)/Electronic Warfare Command Module (EWCM) systems. The new Global Positioning System (GPS) will provide accurate navigation, and the MK XV Identification Friend/Foe (IFF) system is being developed to minimize blue-on-blue engagements during battle.

Ashore, we are improving intelligence forecasting and analysis by developing the OSIS Baseline Upgrade (OBU) Intelligence Support Group (ISG) program. For ashore command and control and operational support, the operations support system (OSS) will provide C^2 data fusion, display, and decision aids to assist fleet theater situation assessment, force allocation and dynamic war planning through the 1990's.

Progress being achieved concerning inter-service interoperability shows in several areas. The establishment of the Joint Tactical C^3 Agency (JTC^3A) is a significant step. The joint secure SATCOM voice problem that surfaced is being reduced with VINSON modifications, and will be eliminated with the introduction of the Advanced Narrow Band Digital Voice Terminal (ANDVT). Joint tactical interoperability is improving through multi-service programs such as:

- JTIDS,
- EHF SATCOM,
- GPS,
- MK XV IFF,
- HAVE QUICK,
- SINCGARS, and
- ROTHR.

In the future, efforts must be focused on the major technical challenges facing the Navy in C^3I. We must work toward standardizing system interfaces and protocols, distributed computing processes, data base management structures, fault tolerant hardware and software systems, communication bus architecture, terminal display technology, man-machine interfaces and artificial intelligence. The results of these efforts will enable better understanding of the command decision making process. Also, it must be the accepted norm that all future C^3I equipment must be jam resistant, secure, higher capacity and interoperable.

WARFARE INFORMATION

Recent changes in Navy R&D development policy for software intensive warfare information systems to provide for increased user involvement, earlier delivery of operational systems and increased re-use of existing software.

Navy Command and Control (C^2) information systems are complex, software intensive projects that require a lengthy period between requirements validation and IOC. During this period, interaction between user and developer has been inadequate. Because of system complexity and lack of user interaction, system delivery time has been excessive and actually has resulted in systems' obsolescence. For these reasons, users have sought solutions to operational problems through sources outside the normal acquisition process. While this approach can alleviate some operational difficulties in the short term, it leads to the creation of software that lacks logistics support and compatibility, and has not been subjected to thorough operational testing and evaluation.

Establishing the requirements is the most difficult and crucial part of the software building process; one requiring interaction between the designers and users. To ensure effective interaction between the ultimate user and the provider and to encourage early delivery of C^2 Information Systems, new development plans replace traditional software approaches which require almost complete system development prior to useable product delivery.

The Navy's new development process specifies early user involvement and begins the process with a visit by the developer to the user's site. Prototyping, the cornerstone to the Navy's new C^2 software development policy, provides the user with an early product and requires field experimentation in the initial steps of the process. The prototype software once validated is left with the user while the designer completes that portion of the project and documentation phases.

Another element of our new development policy is to encourage common software and software reuse. In an effort to reduce redundant development of functional algorithms like message passing, storing, updating, retiming and displaying, and to develop common software, the Navy has begun a software library. Our goal is to preserve effective products of past software development, avoid introduction of errors or incompatibilities in new software and to eliminate overlapping software costs caused by redevelopment of existing algorithms.

The Navy also is continuing its implementation of the DOD's common high order language, Ada. This effort started in 1985 and is expected to reach Milestone III (i.e., production) in early FY 1990. The goals of Ada are to improve maintainability, transportability and reuse of software code and to reduce the life cycle costs associated with our weapon systems.

Among the first programs to use the new software development policies are the Navy's Anti-Submarine Warfare Coordination Center (ASWOC) and the Operational Support System (OSS) portion of the Ocean Surveillance Information System (OSIS). In the case of ASWOC over 70% of existing algorithms have been used in providing the new software. Conversely, OSS takes advantage of early user involvement and rapid prototyping through the use of a fleet established testbed which provides functionalities that are directly translatable into usable software applied to solving fleet problems.

EXPEDITIONARY FORCE WARFARE (MARINE CORPS PROGRAMS)

R&D is essential to the Marine Corps. Upgrading power projection requires enhanced speed, mobility and firepower of assault forces to assure that Marines are ready to fight and win intense battles on their own far from our continental support bases.

R&D efforts over the past seven years have significantly enhanced the warfighting capability of the Corps. Today's Marine is ready and better equipped for operations ashore than at any time in the Corps' history. The Marine Air-Ground Task Forces have been dramatically modernized with improved aircraft, weapons, equipment, vehicles, and support systems. Combat sustainability never has been better. The Navy-Marine Corps Team has capitalized on technology to replace aging systems or introduce vital new capabilities as exemplified in the Landing Craft Air Cushion (LCAC) and V-22 OSPREY tilt rotor aircraft.

This progress must be protected and sustained by continued RDT&E efforts to overcome the serious current deficiencies, and to meet the anticipated Soviet capabilities of the 21st century. A most pressing need is to provide greater tactical mobility and fire support required for successful amphibious assault. The 50 nautical mile over-the-horizon (OTH) launch requires advanced ship-to-shore capabilities. Improved and more capable amphibious ships, landing craft, naval gun fire support and reconnaissance are vital to the OTH concept. Amphibious forces must be supported by the V-22 OSPREY coupled with an adequate number of LCAC providing needed speed, range and survivability. Naval Surface Fire Support directed by the remotely piloted vehicles (RPVs) and integrated with the improved AV-8B Harrier close air support aircraft are essential to a successful amphibious assault. Anything less than this seriously jeopardizes our ability to succeed!

As an expeditionary force in readiness, the Marine Corps must be prepared for the "full spectrum of conflict." There are serious deficiencies in vital mission areas that demand immediate attention. These "Battle Stoppers" are receiving a significant portion of the relatively small Marine Corps R&D budget of 182 million for the current fiscal year.

BATTLE STOPPERS

- **MINE DETECTION & DESTRUCTION**
- **ANTI-ARMOR SYSTEMS FOR INFANTRY**
- **AIR-DEFENSE**
- **DIRECTED ENERGY**
- **NUCLEAR, BIOLOGICAL & CHEMICAL DEFENSE**

These requirements will receive a high priority in FY 1989, but not at the expense of a balanced utilization of assets, applied equitably among warfighting areas, as shown in Figure 18.

The Marine Corps is involved in over 150 development projects and must be extremely prudent with its limited resources. To achieve maximum financial leverage we use other service laboratories and programs, and have increased utilization of foreign weapon evaluations. Prime attention is given to meeting our requirements with non-developmental items, product improvements, or limited development efforts. This "lean and mean" strategy is further enhanced with

APPLICATION OF FUNDS TO USMC WARFIGHTING AREAS

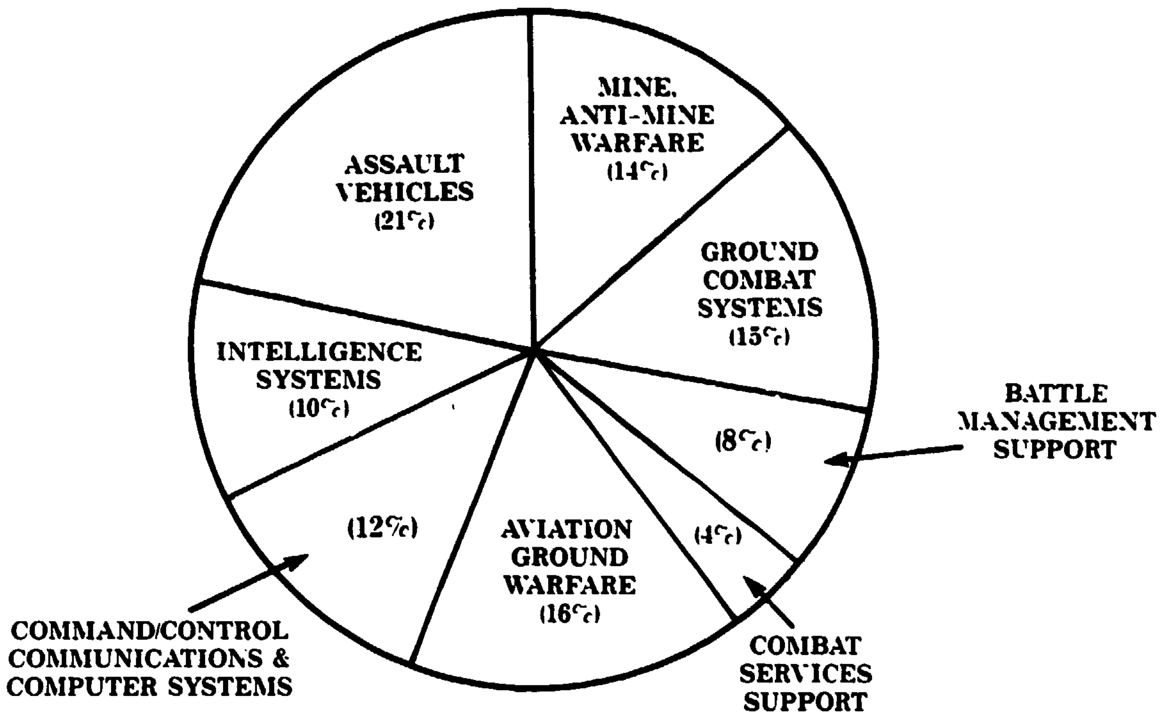

Figure 18

the recent establishment of a new centralized Marine Corps Research, Development and Acquisition (RDA) Command (MCRDAC). This reorganization will:

- Streamline the RDA process;
- Focus authority, responsibility and accountability;
- More quickly exploit emerging technology;
- Increase responsiveness to field commanders.

This "do more with less" philosophy can have severe repercussions when budgets are cut. In short, stable funding support is particularly important to the Marine Corps.

As the Navy–Marine Corps team approaches the 21st century, renewed emphasis will be given the expeditionary capability of the Marine Air-Ground Task Force to fight in all "climates and places." We must increase the combat punch of the Corps without a significant increase in the amphibious lift requirement. To quote the Commandant of the Marine Corps ". . . amphibious forces must be light enough to go where they must, yet heavy enough to win once committed."

The Marine Corps will continue to exploit advanced technology for practical warfighting requirements and to meet the challenges of the next decade, recognizing always that every Marine is first a rifleman!

CONCLUSION

Much has been accomplished in the Navy's RDT&E program. However, because of the dynamics of RDT&E the changing environment, much yet remains to be done. This section summarizes and emphasizes the conclusions developed in this FY 1989 report. These are as follows:

- Technology is the Navy's future. The "Tech Base" is a fragile asset which requires understanding, nurturing, support and protection. This long term view applies to U.S. industry as much as to the Navy, perhaps more!
- Interservice and international cooperative efforts are major elements in the future Navy RDT&E program. We must rapidly and objectively explore those interoperability and cooperative opportunities that make sense for the Navy. The Marine Corps "get more for less" philosophy provides an excellent example of what is possible through cooperative interservice action.
- Strong relationships between the Congress and the Navy's R&D management is needed. Direct communications will enhance understanding of each other's activities, concerns and solutions. The Navy's R&D management attitude vis-a-vis the Congress will be "the door is always open."
- Greater *applications*-focus will make Navy Tech Base efforts more productive. Clearly, a portion of the Tech Base budget should be reserved for long term scientific research and innovative Exploratory Development efforts. However, military concepts and needs identified by naval force strategists should be the controlling "bottom line" for Tech Base planning and budgeting.
- More coordination is needed among the various Navy RDT&E organizations. Recognized by the Goldwater-Nichols legislation, this will improve planning, organization, control, use and accountability of resources. It will also reduce duplication and resultant cost.
- The Navy's senior, top level, policy and planning management should be "Battle Management" or "Warfare" organized; middle management on the other hand, should be "Platform" oriented. This action will strengthen mission focus which should assure that RDT&E efforts provide improved, more balanced results.
- More streamlining and flexibility are required in the Navy RDT&E process in order to reduce the time it takes for a weapons concept to reach IOC. The Carlucci Initiatives and Packard Commission each emphasized the excessive time and cost resulting from the nature and number of service, DoD and Congressional procedures, controls, regulations and legislation. Although some of these are valuable and necessary, evidence suggests that the absence of such are among the reasons why industry can "market" a product quicker and cheaper than the services. Each of us must understand that some degree of risk is attendent to any worthwhile enterprise. While we must be prudent to attempt to control for the worst case scenario, in most programs too much red tape is counter-productive. We must analyze the "whys" of the best program cases and devise and apply only appropriate measures.
- Future Navy RDT&E strategy (plans) must take into account (1) the "first to fight" global and regional responsibilities of our naval forces, (2) the nation's critical need to achieve significantly more effective weapons systems, and (3) our quantitative manpower limit vis-a-vis several of our potential adversaries. Thus, our RDT&E activities will focus on survivability, sustainability, maintainability, commonality, life-cycle extension and operational economy. This focus will apply to concepts including stealth/counter stealth;

manual vs automated technology trade offs; counter-countermeasures; comprehensive, faster and secure communications; simpler, effective and flexible strike assets; and long range, zero CEP conventional weapons for INF initiatives.

- Insure that the future does not find us with too many programs and too few dollars. In a time of declining resources we must have the courage to say no to many "good" ideas and the wisdom to focus on the "best" ideas that will address the needs of our future naval forces.

FUTURE GOALS

Given the challenge of constrained resources, we have taken deliberate steps to develop a strategic plan for the future. This plan exists within a framework that considers the real world environment and the way it impacts the future fleet. To summarize our plan, let me provide you an insight into my four principal goals and the associated action areas for each.

GOALS	ACTION AREAS
1. Strengthen Basic Research and Exploratory Development	- Improve on the way we capitalize on opportunities presented by our Tech Base - Eliminate duplication - Strengthen participation by the operational Navy and Systems Commands - Strengthen retention and recruitment of technical personnel
2. Refine Our Contracting Relations and Approaches, and Reduce Time to IOC	- Modify instructions to increase flexibility - Streamline process, reduce oversight - Review Navy involvement in special tooling, and contractual aspects to strengthen the industrial base - Incorporate proven technology - Enforce technology and engineering "freezes" in development cycle - Computerize contractors' manuals and data for more rapid and accurate updating - Assure prime and subcontractors incorporating and maintain CPM scheduling technology; MANTECH approaches to automation - Provide budget stability - Improve concurrency balance - Increase interoperability
3. Strengthen Our R&D Organization and Structure	- Consider functional rather than "Appropriation" Plan - Complete implementation of SECNAV 5430 (Assignment of Responsibilities to ASNs for RE&S and S&L) - Strengthen continuity through Material Professional Program
4. Expand International Cooperative R&D Agreements	- Institutionalize procedure - Create organization; obtain funding - Review feasibility of 10% target, 25% projection - Assure technology transfer security

Appendix A

APPLICATION OF ANNUAL RDT&E BUDGET

DEPARTMENT OF THE NAVY

(Fiscal Years in Millions of Constant 1988 Dollars)

		1985	1986	1987	1988	1989
6.1	Basic Research	$ 375.5	$ 367.8	$ 367.3	$ 342.0	$ 345.5
6.2	Exploratory Development	498.0	476.8	449.3	408.0	402.8
6.3	Advanced Development	2,179.8	2,530.2	1,947.8	2,664.7	1,865.5
	a. Advanced Technology Demonstration	124.0	96.6	149.3	233.4	197.6
	b. All Other Advanced Development	2,058.8	2,433.6	1,756.1	2,431.3	1,667.9
6.4	Engineering Development	4,694.9	4,477.1	4,779.3	4,360.4	4,428.9
6.5	Management & Support (Equipment & Maint., etc.)	669.3	648.6	612.4	581.2	565.4
6.6	Operational Systems Development	1,594.6	1,732.0	1,509.0	1,156.7	1,316.9
	TOTAL:	$10,012.1	$10,232.5	$9,665.1	$9,513.0	$8,925.0

Appendix B

NAVY RDT&E AS A PERCENT OF NAVY TOA

In Constant FY 1988 Dollars
(Dollars in Millions)

	RDT&EN	DON TOA	% RDT&EN
1979	6,892	64,370	10.7%
1980	6,402	65,858	9.7%
1981	6,486	73,177	8.9%
1982	7,137	83,502	8.6%
1983	7,204	94,702	7.6%
1984	8,679	92,282	9.4%
1985	10,012	103,423	9.7%
1986	10,233	100,853	10.2%
1987	9,665	98,608	9.8%
1988	9,513	102,598	9.3%
1989	8,925	93,224	9.5%

NAVY LABORATORIES AND RDT&E CENTERS

Navy Clothing and Textile Research Facility	Natick, MA
Naval Underwater Systems Center	Newport, RI
	New London, CT
	Seneca Lake, NY
	Bermuda
	Charleston, S.C.
	West Palm Beach, FL. (Autec)-Bahamas
	Fort Lauderdale, FL
	San Diego, CA
	Keyport, WA
Naval Submarine Medical Lab	Grotton, CT
Naval Dental Research Institute	Great Lakes, IL
Naval Air Propulsion Center	Trenton, NJ
Naval Air Development Center	Warminster, PA
	Key West, FL
David Taylor Research Center	Carderock, MD
	Bremerton, WA
	Bayview, ID
	Portsmouth, VA
	Cape Canaveral, FL
	Annapolis, MD
Naval Medical Research Institute	Betheeda, MD
Naval Surface Warfare Center	Dahlgren, VA
	White Oak, MD
	Wallops Island, VA
	Fort Lauderdale, FL
Naval Air Test Center	Patuxent River, MD
Naval Research Laboratory	Washington, D.C.
	Chesapeake, MD
	Patuxent NAS, MD
	Orlando, FL
Naval Explosive Ordnance Technology Center	Indian Head, MD
Naval Coastal Systems Center	Panama City, FL
Naval Aerospace and Medical Research Lab	Pensacola, FL
Naval Ocean Research and Development Activity	Bay St. Louis, MS
Naval Biodynamics Lab	New Orleans, LA
Naval Ordnance Missile Test Station	White Sands, NM
Naval Weapons Evaluation Facility	Albuquerque, NM
Naval Health Research Center	San Diego, CA
Navy Personnel Research and Development Center	San Diego, CA
Naval Ocean Systems Center	San Diego, CA
	Hawaii (Oahu)
	San Clemente Island, CA
	Cape Prince of Wales, AK
Navy Space Systems Activity	Los Angeles, CA
Pacific Missile Test Center	Point Mugu, CA
	Hawaii & Oahu, Hawaiian Islands
	Ventura County, CA
	San Nicholas Island, CA
Naval Civil Engineering Laboratory	Port Hueneme, CA
Naval Weapons Center	China Lake, CA
	Corona, CA
	El Centro, CA
Naval Environmental Prediction Research Facility	Monterey, CA

NAVY LABORATORIES AND RDT&E CENTERS

Office of Naval Research	Arlington, VA
Operational Test and Evaluation Force	Norfolk, VA
ONR Detachment Boston	Boston, MA
ONR Detachment Pasadena	Pasadena, CA
ONR Detachment Bay St. Louis NSTL Station	Bay St. Louis, MS
Institute for Naval Oceanography	NSTL Station, MS

OFFICE OF NAVAL RESEARCH RESIDENT REPRESENTATIVES

Georgia Institute of Technology	Atlanta, GA
University of Illinois	Chicago, IL
Ohio State University Research Center	Columbus, OH
Charles S. Draper Laboratory, Inc.	Cambridge, MA
Harvard University	Cambridge, MA
Massachusetts Institute of Technology	Cambridge, MA
National Academy of Science	Washington, DC
New York University	New York, NY
University of Washington	Seattle, WA
Stanford University	Stanford, CA
University of California, Berkeley	Richmond, CA
California Institute of Technology	Pasadena, CA
University of California San Diego	La Jolla, CA
University of New Mexico	Albuquerque, NM
University of Texas, Austin	Austin, TX
Engineering Support Offices	Richardson, TX
	Cambridge, MA
	Chicago, IL
	Pasadena, CA
	Los Angeles, CA

Appendix D

UNIVERSITIES RECEIVING NAVY RDT&E FUNDS

Alabama A&M University
American Association of Physics Teachers
American University
Amherst College
Arizona State University
Atlanta University
Auburn University
Baylor College of Medicine
Biophysical Society
Boston College
Boston University
Boston University School of Medicine
Bowling Green State University
Brandeis University
Brigham Young University
Brown University
California Institute of Technology
California State University - Long Beach
California State University - Sacremento
Carnegie-Mellon University
Case Western Reserve University
Catholic University of America
Chicago Medical School University
Claremont Mens College
Clarkson College of Technology
Clemson University
College of William and Mary
Colorado School of Mines
Colorado State University Research Foundation
Colorado State University
Columbia University
Community College Allegheny County
Cornell University
Dartmouth College
Drexel University
Duke University
Duke University Medical Center
East Carolina University
Eckerd College
Emory University
Fisk University
Florida Atlantic University
Florida A&M University
Florida Institute of Technology
Florida International University
Florida State University
George Mason University
George Washington University
Georgetown University
Georgia Institute of Technology
Georgia State University
Georgia Tech Research Institute
Hahnemann Medical College and Hospital
Hampton Institute
Harvard University
Hollins College
Howard University
Hunter College
Illinois Institute of Technology
Indiana University
Indiana University Foundation
Institute for Amorphous Studies
Iowa State University
Jackson State University
John B. Pierce Foundation of CT
John Carroll University
Johns Hopkins University
Johns Hopkins University Office of SP
Kansas State University
Kent State University
Kentucky WNE College
Lehigh University
Lincoln University/Chester
Lincoln University/Jefferson City
Lincoln University/San Francisco
Loma Linda University
Long Island University Southhampton
Louisiana State University - School of Medicine
Louisiana State University/Baton Rouge
Loyola College/Baltimore
Loyola College/Chicago
Loyola University/New Orleans
Manhattan College
Massachusetts Institute of Technology
Medical College of Georgia, Augusta
Medical College of Pennsylvania
Medical College of Wisconsin
Medical University of South Carolina
Meharry Medical College
Miami University/Oxford
Michigan State University
Michigan Technological University
Midwest Research Institution
Montana State University
Mt. Sinai School of Medicine
National Technical University
New Mexico Institute of Mining Technology
New Mexico State University
New Mexico Technical Institute
New York Blood Center
New York State College of Ceramics
New York University Medical Center
New York University/Washington Square
Norfolk State University
North Carolina A&T State University
North Carolina State University
North Texas State University
Northeastern Ohio

UNIVERSITIES RECEIVING NAVY RDT&E FUNDS (Continued)

Northeastern University
Northern Illinois University
Northwestern University
Nova University
Oakland University
Oberlin College
Ohio State University Research Foundation
Oklahoma State University
Old Dominion University Research Foundation
Old Dominion University
Ollins College
Oregon Graduate Center
Oregon Health Sciences
Oregon State University Administration Office
Oregon State University
Pennsylvania State University
Philadelphia College of Textiles
Polytechnical Institute of New York
Portland State University
Potomac Institute for Economic Research
Princeton University
Public Health Research Institute
Purdue Research Foundation
Purdue University
Radcliffe College
Regents of University of California Berkeley
Regents of University of California Lajolla
Rensselaer Polytechnic Institute
Research Foundation Suny/BC
Research Foundation Suny/NYC
Research Foundation Suny/Albany
Research Foundation Suny/Buffalo
Research Foundation/Mental Hygiene
Rice University
Rochester Institute of Technology
Rockefeller University
Rose-Huiman Institute of Technology
Research Foundation of California State University/Hayword
Research Institute of Scripps Clinic
Rutgers State University
San Diego State University Foundation
San Diego State University
San Francisco State University
San Jose State University Foundation
Seattle University
South Dakota School of Mines and Technology
South Dakota State University
Southeastern Massachusetts Technology
Southern Illinois University Carbondale
Southern Methodist University
St. Josephs
St. Louis University
Stanford University
Standford University SPO
State University of New York
Stevens Institute of Technology
Syracuse University
Temple University
Tennessee State University
Tennessee Technology University
Texas A&M Research Foundation
Texas Christian University
Texas Tech University
The Trustees of Tufts College
Tufts College
Tulane University Medical Center
Tuskegee Institute
United States Naval Academy
University of California - San Diego/Lajolla
University of California - San Diego/Marine Physics Laboratory
University of California - San Diego/Scripps Clinic
University of California/Berkeley
University of California/Davis
University of California/Irvine
University of California/Los Angeles
University of California/Riverside
University of California/San Francisco
University of California/Santa Barbara
University of California/Santa Cruz
University of California/Scripps Institute of Oceanography
University of Colorado Medical Center
University of Colorado/Boulder
University of Connecticut Health Center
University of Denver - Colorado Seminary
University of District of Columbia
University of Maryland/Baltimore
University of Maryland/College Park
University of Minnesota Minneapolis
University of Minnesota St. Paul
University of Nevada - Desert Research
University of North Carolina/Chapel Hill
University of North Carolina/Wilmington
University of South Mississippi
University of Southern California
University of Southern California - Contract/Grants
University of Southern California - LA
University of Southwestern Louisiana
University of Wisconsin Milwaukee
University of Akron
University of Alabama
University of Alaska
University of Arizona
University of Arkansas
University of Central Florida, Orlando
University of Chicago
University of Cincinnati
University of Connecticut
University of Dayton

UNIVERSITIES RECEIVING NAVY RDT&E FUNDS (Continued)

University of Deleware
University of Detroit
University of Florida
University of Florida, Gainesville
University of Georgia
University of Hawaii
University of Houston
University of Illinois
University of Illinois/Chicago
University of Illinois/Urbana
University of Iowa
University of Kansas
University of Kentucky
University of Kentucky Research Foundation
University of Louisville
University of Lowell
University of Maine
University of Maryland/Cambridge
University of Maryland/MPL
University of Massachusetts
University of Miami
University of Michigan
University of Minnesota Delute
University of Mississippi
University of Missouri/Arl
University of Missouri/Columbia
University of Missouri/Kansas City
University of Missouri/Rolla
University of Nebraska Lincoln
University of New Hampshire
University of New Haven
University of New Mexico
University of New Orleans
University of Notre Dame Du-Lac
University of Oklahoma
University of Oregon
University of Pennsylvania
University of Pittsburgh
University of Rhode Island
University of Richmond
University of Rochester
University of South Carolina
University of South Florida
University of Tennessee
University of Texas
University of Texas at Arlington
University of Texas at Austin
University of Texas at Dallas
University of Texas Medical Branch
University of Texas Research Center
University of Texas - APL
University of Tulsa
University of Utah
University of Vermont
University of Virginia
University of Washington
University of Washington - APL
University of Wisconsin
University of Wyoming
Utah State University
Vanderbilt University
Vanderbilt University - School of Medicine
Virginia Commonwealth University
Virginia Mit Brooklin PO
Virginia Poly Institute and State University
Virginia Tech
Washington School of Psychiatry
Washington State University
Washington University
Wayne State University
West Chester State College
West Virginia University
West Washington University
Western Kentucky University
Western Michigan University
Williams College
Wm. M. Rice University
Worcester Polytechnic Institute
Wright State University
Xavier University of Louisiana
Yale University
Yeshiva University-Belfer Grad

Appendix E

MAJOR INDUSTRIAL CONTRACTORS RECEIVING NAVY RDT&E FUNDS

A-Z Maintenance Corp
AAI Corporation
Abam Engineering
Academy for Inter-Science Methodology
ADS
Advanced Digital Systems
Aero Corporation
Aerojet Corporation
Aeroneutronic-Ford
Aerospace Corporation
Aguidneck Data Corporation
Air A Plane Corporation
Air Logistics Corporation
Air Research Manufacturing Company
Allegheny Ludlum
Allied Bendix Corporation
Applied Corporation (Bendix Oceanics)
Allison Gas Turbine Operation
Aluminum Company of America
American Airlines
American Cyanamid Company
American Defense System, Inc.
American Management Systems
American Optical
Ametek Straza
Amex
Anacada Science, Inc.
Analysis & Technology, Inc.
Analytics, Inc.
Andrulis, Inc.
Applied Technology
Aqua Chemical
Arctec
Arete Associates
Argo Systems, Inc.
ARL
Aro Corp
Astronautics, Company
AT&T Bell Lab
Atac, Inc.
Atlantic Research Corporation
Automation Industries, Vitro Laboratory Division
Avondale Shipyards, Inc.
AVW
Babcock and Wilcox
Barnes Engineering Company
Baron Information System
Bath Iron Works
Battelle Memorial Institute
BB&N Laboratories
Beech Aircraft
Bell Aerospace Textron
Bell:Boeing
Bell Telephone Laboratories
Bendex Corporation
Betac Corporation
BGS Systems, Waltham
BK Dynamics, Inc.
Boeing Aircraft
Bolt, Beranek and Newman, Inc
Booze-Allen & Hamilton, Inc.
BPM Corporation
Brunswick Corporation
Bunker Ramo
Burroughs (Unisys)
C&M, Inc.
Caci
Calcolon Corporation
Canyon Research Group, Inc.
Casde Corporation
Catalyst Research Corporation
CBI Na-Con
Center for Naval Analysis
Charles Stark Draper Laboratory
Chemical Systems Division, United Technology
Chicago Pneumatics
Cincinnati Electric Company
Coastal Marine Research
Colt Industries
Combustion Engineering, Inc.
Comptek Research, Inc.
Computer Sciences Corporation
Consultants & Designers
Control Data Corporation
Corning Glass
CRT Corporation
Cubic Corporation
Culric Corporation
D. H. Wagnel Associates
Dalmo Victor
Data General Corporation
DCS Corporation
DDL-Omni Engineering
Delta Electronics
Designers and Planners
Detroit Diesel Allison
Dielectric Communications
Digital Equipment Corporation
Dilex Systems, Inc.
Diving Unlimited, Inc.
Douglas Aircraft Company
Draper Laboratory
Duedalean Association, Inc.
Dynalectron Corporation
Dynamics Systems, Inc.
Dynamics Technology, Inc
Dynatee Corporation
Dynatrend

MAJOR INDUSTRIAL CONTRACTORS RECEIVING NAVY RDT&E FUNDS (Continued)

E Systems, ECI Division
E-Systems Melpan
Eaton Corporation
ECI
ECO, Inc.
EDO Corporation
EG&G Corporation
Electrodynamics Corporation
Electronic Warfare Association
Electronics Communications
EMT
Epoch Engineering
ESL, Inc.
Essex Corporation
Ethyl Corporation
Evaluation Research Corporation
Evaporated Coating
Fairbanks Morse
Fairchild Space and Electronics Company
Fenn
Fiber Materials, Inc.
Flight Systems, Inc.
FMC Corporation
Ford Aerospace & Communications Corporation
Foster Wheeler Development Corporation
Foster-Miller Associates, Inc.
Frequency Electronics
Frequency Engineering Laboratory
G. G. Sharp, Inc.
G&H Technology
Garrett Airesearch
General Dynamics
General Electric
General Motors Corporation
General Physics Corporation
General Telephone & Electronics Corporation
Gentex Corporation
Geo-Centers, Inc.
George C. Sharp
Giannotti & Associates
Gibbs and Cox, Inc.
Goodyear Aerospace Corporation
Gould, Inc.
Grumman Aerospace Corporation
GTE
Hamilton Standard Corporation
Hanlon Industries, Inc.
Harns Corporation
Harris Corporation
Hayes International Corporation
Hazeltine, Corporation
Helionetics
Hercules Corporation
Hewlett-Packard
Hi-Shear Corporation
Honeywell Corporation
Horrigan Analytics
Hudson Institute
Hughes Aircraft
Hughes Associates, Inc.
Hughes Optical Products, Inc.
Hydroacoustics, Inc.
IBM
IDC Corporation
IIT Research Institute
Illinois Tool Works
Indiana Gearworks
Instructional Science and Development
Integrated Systems Analysts, Inc.
Interferometrics, Inc.
Intermetrics, Inc.
International Nickle Company
International Signal & Control
International Telephone & Telegraph
Interstate Electronics Corporation
ISA
ISC Defense System
ITE, Inc.
J. J. McMullen
Jaxcor, Inc.
Jet Propulsion Laboratory
John Deer Tech, Inc.
Kados, Inc.
Kaman Aerospace
Kaman Science Corporation
Kentron
Kern Company
KLD Associates
Lanxide Corporation
Lawrence Livermore National Laboratories
Lincoln Laboratories, MIT
Litton Industries
Lockheed Aircraft Corporation
Lockley Manufacturing
Locus, Inc.
Logicon
Loral Electro-Optical Systems
Lucas
Lundy Electronics, Inc.
M. Rosenblatt & Sons
M. C. Avano, Inc.
Magnavox Corporation
Mansville Corporation
Marine Corps Operations Analyses
Marine Environments, Inc.
Marine Technical Division
Mark IV FCD Corporation
Markon, Inc.
Marquardt Corporation
Martin-Marietta Corporation
Matutech, Inc.
Maxwell Laboratories, Inc.

MAJOR INDUSTRIAL CONTRACTORS RECEIVING NAVY RDT&E FUNDS (Continued)

MBS Systems
McDonnell-Douglas Aerospace Corporation
Meco Corporation
Milcom
Mission Research Corporation
Mitre Corporation
Moog-Carlton
Morton Thiokol, Inc.
Motorola, Inc.
MTS Systems Corporation
National Academy of Sciences
National Astronautics & Space Administration
New York Blood Center
Newport News Shipbuilding
Norden Systems
North America/Rockwell
Northern Ordnance Corporation
Northern Research Corporation
Northrop Corporation
Northwestern Motor Corporation
Numerix Corporation
OAS
ODSI Defense Systems, Inc.
Olin Corporation
OMNI Analysis, Inc.
ORI, Inc.
Orlin Brass
Oshkosh Truck Corporation
Ozone
P. R. Mallory
Pacer Systems, Inc.
Pacific Sierra Research Corporation
Perceptronics
Perkin Elmer Corporation
Philadelphia Gear Corporation
Planning Systems, Inc.
Polar Research Laboratory
Potomac Systems & Engineering, Inc.
Pratt & Whitney Aircraft Corporation
PRC
Precision/Echo
Presearch, Inc.
Presser Industries, Worthington Division
PSI
Public Services Gas and Electric Company
Purvis Systems
Quest Research Corporation
R. M. Vredenburg & Company
R&B Enterprises
Radio Corporation of America (RCA)
Ramtek Corporation
Raven, Inc.
Raytheon Corporation
Rehab Group, Inc.
Republic Electronics
Resclel
Research & Development Laboratories
Resource Consultants, Inc.
Rexnord, Inc.
RMI, Inc.
RMS Technologies
Robotic Vision Systems, Inc.
Rochester, Inc.
Rocketdyne
Rockwell International
Rockwell/Collins
Ryan Computer Systems
S Tron
Sachs-Freeman
Sanders, Inc.
Santa Barbara Research
Sargent-Fletcher Company
Sci Technology, Inc.
Science Applications International Corporation
Science Applications, Inc.
Scientific Atlantic
Scope, Inc.
Scott Aviation
Scripps Institution of Oceanography
Sedco
Seicor, Inc.
Ship Analytics
Sierra Research Corporation
Sigma Research
Sikorsky
Singer Corporation
Sippican Corporation
Sixdb, Inc.
SKF Industries, Inc.
Softech
Solar Turbines International
Solid Photography
Sonalysts, Inc.
South Carolina Research Authority
Southern Maryland Electric
Southwest Aerospace Corporation
Southwest Research Institute
Sparton Corporation
SPC
Spears Associates
Spectra Research Sysstems
Spectran, Inc.
Spectrum Research Systems
Sperry Corporation
SPS, Inc.
SRI International
Sterimatics Company
Sterling Systems, Inc.
Submarine Signal Division
Sundstrand
SWL, Inc.
Synergy

MAJOR INDUSTRIAL CONTRACTORS RECEIVING NAVY RDT&E FUNDS (Continued)

Systems Development Corporation
Systems Engineering Analysis Company
Systems Exploration, Inc.
Systems Planning and Analysis
TAI
TCOM
Techmatics
Technology Services Corporation
Techplan Corporation
Teledyne Systems Company
Tetra-Tech, Inc.
Texas Instruments
The Assessment Group
The Energystics Corporation
The Maxima Corporation
Titan, Inc.
Tracor, Inc.
Tractor, Inc.
Triad, Inc.
Triburon Systems
Triga
Trillium Corporation
TRW
Turbo Mach, IRC
Undersea Medical Society
Unidynamics
Unisys
United Information Systems
United Technology Norden Systems
United Technologies
Univac
Universal Fuel
Value Systems Engineering
Varian Associates
Vector Cable Corporation
Vega
Vineta, Inc.
Vitro Corporation
Vought Corporation
Wakefield Data, Inc.
Washington Consulting Group
Weiman Gordon
Western Gear Corporation
Westinghouse
Williams International
Woods Hole Oceanographic Institution
Xetron, Inc.
York Engineering
York International