CONTINUING R&D FOR DEFENSE: THE NINTEEN EIGHTIES

Introduction

The 1980s can be characterized as a period of transition in international security affairs. A major portion of the decade was marked by the Soviet Union's massive military buildup—consuming as much as 15 to 17 percent of its annual Gross National Product (GNP). This large, unmatched investment provided the Soviets with a position of strategic nuclear parity, quantitative conventional force superiority around the Eurasian rimland, and a modern, globally deployed navy.

During this period, there was also a revolution in military technology. Additionally, many Third World countries experienced a combination of economic growth and technological maturation.

The first objective of the Reagan administration's National Security Strategy was to restore United States military strength after a period of decline. Along with this military buildup came a bipartisan awareness of the necessity for maintaining technological superiority through coherent military research and development programs.

The consolidation of NELC and NUC came at an appropriate time. The consolidation provided increased flexibility and larger blocks of funding for broader and more comprehensive investigations. More than any other benefit, consolidation of the two Centers produced a broad-spectrum system capability in intelligence, surveillance, sensors, C^3, undersea weapons, and countermeasures in support of the Navy's mission of controlling the seas.

Throughout the 1980s, NOSC continued to serve the U.S. Navy through state-of-the-art efforts in research and development. Important new systems developed in NOSC's major product lines included the Advanced Combat Direction System (ACDS) and the Tactical Flag Command Center (TFCC); submarine broadcast, ship-to-shore, and satellite communications systems; over-the-horizon radars and the Integrated Undersea Surveillance System (IUSS); and the Mk 50 torpedo and the Mk 116 ASW Control System. Additionally, NOSC planned and coordinated submarine ice exercises in the Arctic and developed an ice-avoidance sonar.

This past decade was also a period during which NOSC experienced change and innovation administratively. Some administrative programs such as the Personnel Demonstration Project gave NOSC special visibility throughout the Federal workforce. Other administrative changes explained in this section were more specific to DoD or NOSC.

Center Reorganization

Effective 1 July 1984, NOSC implemented a reorganization plan aimed at enhancing efficiency by reducing layers of management. Since its beginning, NOSC had six directorates: five in technical areas and one overseeing support activities. These directorates, under the cognizance of Technical Director Dr. H. L. Blood, had helped to smooth the merger over the first 7 years. In the new organizational structure, the directorates were abolished, and the technical departments were given increased authority. R. M. Hillyer, now Technical Director of NOSC replacing Dr. Blood, advocated the plan as a means to push decision-making responsibility down to appropriate levels, thus allowing project personnel to concentrate more effectively on their technical work.

The year 1984 also brought a restructuring of the Arctic Submarine Laboratory due to an increased emphasis on arctic research and expansion of fleet support activities. A career submariner, Captain E. J. "Jack" Sabol, was appointed Director, reporting directly to the NOSC Commander and Technical Director. (The Arctic Submarine Laboratory Director would also serve as a member of the staffs of the Commanders of both the Pacific and Atlantic Submarine Forces.) Dr. Waldo Lyon was appointed Chief Engineer and Senior Scientist of the Arctic Submarine Laboratory.

Personnel Demonstration Project

Since 1980, both NOSC and the Naval Weapons Center (NWC) at China Lake have participated in a Personnel Demonstration Project. The project is an innovative revision of basic personnel management systems and is intended to simplify those systems, make them more responsive to Center needs, and enhance recruitment and retention. The Personnel Demonstration Project as implemented at NOSC provides simplified position classification and performance appraisal, links performance with pay, and emphasizes performance-based retention. At the heart of the system are broad paybands arranged in five career paths with progression closely related to work performance.

NOSC uses the Personnel Demonstration Project in the normal conduct of business, participates in its evaluation as a potential government-wide personnel system, and provides information to other government agencies about the system. The Department of the Navy received the Ribicoff/ Percy Award for excellence in Civil Service Reform Implementation for the NOSC/NWC-sponsored Personnel Demonstration Project.

Public Law 100-566, signed 11 November 1988, extended the Personnel Demonstration Project until 30 September 1995.

Reorganization of Navy Laboratories

Reassignment from NAVMAT to CNR

In April 1985, the Secretary of the Navy (SECNAV) disestablished the Naval Material Command to which the Center and seven other Navy laboratories (apart from NRL and the Naval Ocean Research and Development Activity [NORDA]) had reported since 1964. Under the resulting new organization, the NAVMAT laboratories were reassigned to the Chief of Naval Research (CNR).

As part of this reorganization, SECNAV directed a major change in management for the Navy exploratory development (6.2) program. CNR was directed to establish a block programming management structure with the Navy laboratories and centers, instead of the systems commands, as program claimants. The systems commands would no longer be involved in directing 6.2 work, but the Office of Naval Technology (ONT), under CNR, would continue to provide top-level management for the approximately $500 million in Navy 6.2 programs. The laboratories and centers were themselves to perform the detailed planning and execution of the programs.

Reassignment from CNR to SPAWAR

In February 1986, SECNAV transferred the management of the Navy R&D centers from CNR to the Commander, Space and Naval Warfare Systems Command (SPAWAR). Effective 24 February 1986, SPAWAR assumed management responsibilities for NOSC, seven other Navy R&D centers, four affiliated university laboratories, and the office of the Director of Navy Laboratories (DNL). The objective of the transfer was to align the laboratories more appropriately with SPAWAR's material and technical support organization, to streamline administration, and to bring the centers more effectively under the Navy's top-level engineering managers.

NOSC Strategic Plan

Based on decisions made during a strategic corporate planning retreat held on 19 and 20 July 1988, NOSC management prepared the NOSC Strategic Plan. The plan established long-range strategic thrusts based on NOSC's corporate values and vision of the future.

The NOSC Strategic Plan addressed eight business thrusts: (1) command and control, (2) communications, (3) surveillance, (4) integrated ASW, (5) arctic warfare, (6) ocean science and engineering, (7) intelligence, and (8) warfare systems architecture and engineering (WSA&E).

The plan also addressed the Center's technology base thrusts since the technology base is an essential part of all future systems.

Finally, the plan addressed management thrusts that supported NOSC's technical thrusts. NOSC pledged to continue to foster a corporate team spirit, to encourage excellence, and to create a work environment conducive to creative and productive efforts.

Issued in July 1989, the NOSC Strategic Plan defined areas of primary focus in the future:

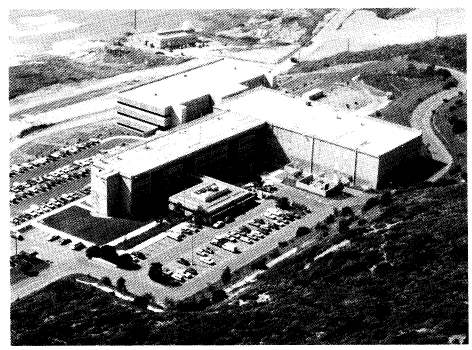
> *We intend to make NOSC the lead laboratory for C^3 and be recognized as a world-class center for information warfare. We also intend to continue our leading role in ocean surveillance. We will strengthen this role by expanding the aerospace aspects of surveillance. We have always seen the need to provide the Navy with follow-on generations of superior air- and surface-launched undersea weapons systems; now we see an even more important need to develop integrated ASW systems. To complement and support these efforts, we will continue to provide leadership in arctic submarine warfare and ocean science and engineering. Because of our broad expertise, mission, and support areas, we will support the collection, processing, and dissemination of intelligence. Finally, we will support these efforts by building and coordinating an even stronger technology base. These efforts define our areas of primary future focus and form the basis for our strategic business thrusts.*

New NOSC Facilities

Ocean Surveillance Laboratory, Building 605, Seaside

Opened in 1982, Building 605, the Ocean Surveillance Laboratory, provides for the development, physical integration, and testing of surveillance systems on a total platform and multiplatform basis. The facility provides for near real-time message processing, realtime signal processing and information processing, and the merging of hardware and software design. Adjacent to the NOSC C^3 SITE, Building 605 provides an electromagnetically shielded, realistic operational environment with line-of-sight access to fleet operating areas.

In 1983, the Acoustic Research Center (ARC) was relocated to Building 605 from Moffett Field, where it had operated as a Defense Advanced Research Projects Agency (DARPA) facility. The ARC greatly enhanced the scope and capability of NOSC's on-site data links and reduced the need for remote installations and linkages. The ARC was later expanded to include all source surveillance data, and the facility is now known as the Surveillance Test and Integration Center (STIC).



Ocean Surveillance Laboratory, Building 605, Seaside. Shown adjacent to the C^3 SITE.

Ocean Sciences Laboratory, Building 111, Bayside

Completed in 1986, Building 111, the Ocean Sciences Laboratory, provides unique facilities for RDT&E in marine biology, environmental sciences, and radiation physics. The laboratory has filtered salt water and includes special facilities for work with marine organisms; laboratories for oceanographic research, chemistry, and biochemistry; laboratories for nonmedical biotechnology studies; and laboratories with analytical instrumentation facilities for environmental research and monitoring. NOSC is the only Navy laboratory involved in marine environment studies. Building 111 houses state-of-the-art chemical and biological laboratories for such studies. Also, radio frequency interference (RFI)-shielded spaces within the facility provide for R&D in lasers and microelectronic systems.

Ocean Sciences Laboratory, Building 111, Bayside.

New Systems and Research

Advanced Combat Direction System (ACDS)

NOSC has continued the work of NEL and NELC in conducting research on tactical data systems. A key element in the continuing improvement of the Navy Tactical Data System (NTDS) is the Advanced Combat Direction System (ACDS) Block 1 upgrade. This upgrade has significantly enhanced NTDS in the areas of sensor management, tactical data exchange, warfare area coordination, and system coordination. NOSC began development of ACDS Block 1 in October 1981. Once ACDS Block 1 is introduced to the Fleet, subsequent improvements will be deployed in roughly 3-year increments. Such enhancements will enable all units of the Fleet to have similar tactical command programs to support command needs.

NOSC work in tactical data systems also includes the Flag Data Display System (FDDS), which is a subsystem of the Tactical Flag Command Center (TFCC) developed in the mid-1970s. The FDDS provides access to force information held by Navy command and control (C^2) systems ashore. Fleet installation of this upgraded system has begun.

ACDS. A replacement for NTDS, ACDS provides force-level command decision systems and combat direction systems to non-Aegis ships.

Enhanced Verdin System (EVS)

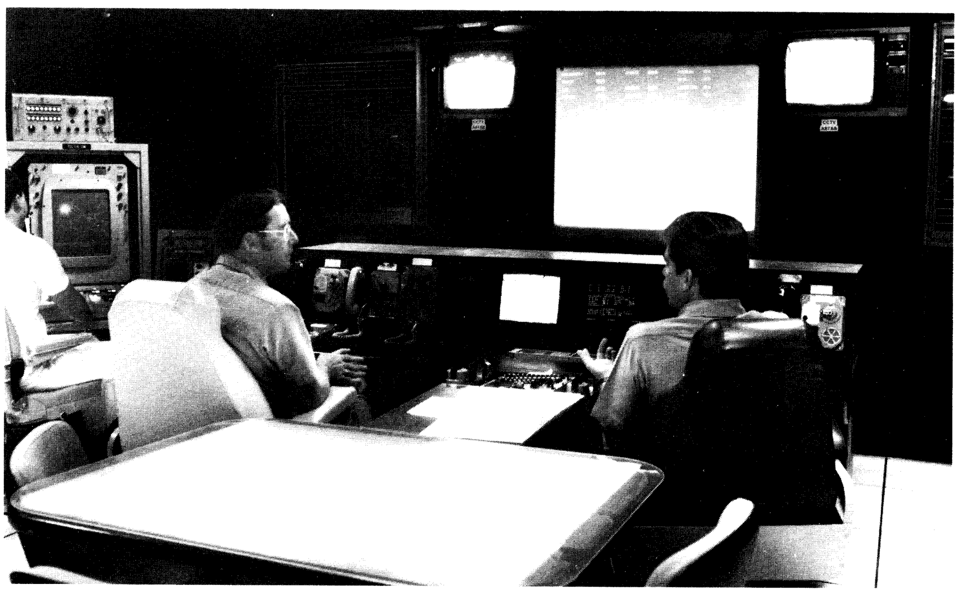
Throughout the 1980s, NOSC personnel have played a major role in the development of the Enhanced Verdin System (EVS), designed to update the submarine communications system developed in the 1960s.

EVS is more powerful and has a much higher capacity to process digital communications that improve connectivity, reliability, accuracy, and speed of delivery of VLF/LF traffic to naval strategic forces deployed around the world. This EVS replacement system provides vastly improved strategic command and control communications from the Joint Chiefs of Staff and the National Command Authority to submarines and aircraft.

Before fleet installation, EVS was subjected to rigorous technical testing in the Atlantic Ocean to demonstrate the system's reliability in transmitting and receiving emergency action messages.

EVS has now been installed on all *Trident* submarines and Atlantic Fleet ballistic missile submarines (nuclear propulsion) (SSBNs).

Mock-up, located at NOSC, of the TFCC aboard USS America *(CV 66). TFCC is the primary battle station for the embarked battle group commander and his staff.*



Secure Conferencing Project (SCP)

The Secure Conferencing Project (SCP) supports unified commanders worldwide with better data and information flow. Other conferencing systems in use must route all secure voice communications through a central bridge. For example, users dial into a central location where connections are made manually. However, with the advent of the Secure Conferencing Project, operation is totally automatic; a person picks up the phone and dials, as with a conventional phone. To achieve this level of automation, SCP uses satellites and electronic conference directors as the conferencing bridges and switches via a distributed architecture.

In addition, SCP features a dial tone, a busy signal, and a distant ring. The graphics mode allows teletype data to be transmitted as easily as facsimile copy, with the same degree of security.

NOSC shipped the first complete suite of SCP equipment in September 1985. SCP represents a significant achievement for several reasons. The system was composed of new equipment, and SCP was the first secure communications system to use a Defense Satellite Communications System SHF link. SCP was also the first system to employ jam-resistant, secure communications, spread-spectrum satellite modems to provide nuclear-survivable connectivity.

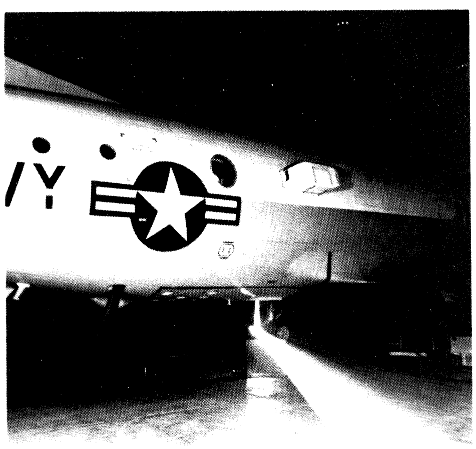
NOSC is now spearheading enhancements to SCP, and the system is being installed in over 40 command centers worldwide.

Satellite Laser Communications (SLC)

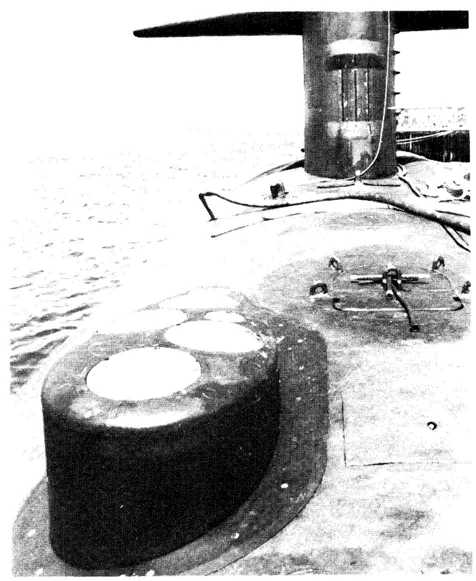
In today's Navy, communications to a nuclear attack submarine must be conducted at or near the surface of the ocean due to the poor propagation of radio frequency (RF) energy through seawater. Because of this requirement, all present communication connectivity is in some manner submarine initiated. The Satellite Laser Communication (SLC) program was originated to develop one-way unscheduled communications to submarines at depth and speed.

Communications to submarines at depth is possible due to a window in the transmission characteristics of seawater. This window occurs in a narrow band in the blue-to-green visible light region of the electromagnetic spectrum. Proper choices of laser transmitters and matching optical receivers allow communications to operational depths.

NOSC, with over a decade of experience in submarine laser communications research, demonstrated in 1988 that blue laser and receiver communication technology was suitable for transition to a space-based SLC system.



Laser transmitter installed on Lockheed P-3C aircraft. In 1988, NOSC demonstrated blue laser and receiver communications technology suitable for transition to a space-based, SLC system.



Optical receiver installed on USS Pintado *(SSN 672) for the 1988 blue laser and receiver communications technology demonstration.*

The difficult question remaining for submarine laser communications is that of affordability. The costs of a satellite system are high. In 1989, NOSC's Research, Evaluation, and Systems Analysis (RESA) facility was used to provide interactive wargaming and analysis of the impact of SLC on operations. It is anticipated that continuing wargaming under varying scenarios and capabilities will assist in setting submarine laser communication requirements.

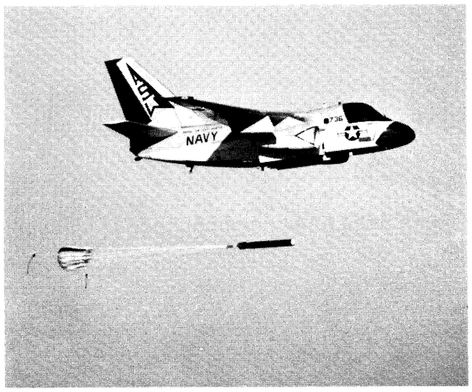
RESA. A flexible and capable battle force simulation system, the RESA facility supports interactive wargaming as well as technology assessments, interoperability testing, and warfare system architecture assessments.

Surface- and Air-Launched Undersea Weapon Systems

The Torpedo Mk 46 remains the Navy's payload in all surface- and air-platform ASW systems, and it continues to be the standard in lightweight antisubmarine torpedo warfare throughout the free world. Introduced in 1966, the Mk 46 has undergone a series of improvements that will prolong its life into the next century. The Near-Term Improvement Program (NEARTIP) upgraded the Mk 46 Mod 1 and Mod 2 torpedoes to the Mk 46 Mod 5 torpedo. Later upgrades to the NEARTIP program were implemented into the Fleet in the mid- and late-1980s and included the shallow-target upgrade and the shallow-water upgrade. NOSC, as the technical direction agent and design agent for the Mk 46, provides engineering support that encompasses a wide range of efforts, including overall production engineering, product assurance, acceptance test and evaluation, and product improvement. Approximately 750 U.S. Navy aircraft and 250 ships employ the Mk 46 in antisubmarine warfare.

NOSC is the lead laboratory for the Torpedo Mk 50, which will eventually replace the Mk 46. The Center monitors developments in U.S. torpedo systems and tactics as well as in enemy threats to assess their impact on the Mk 50. NOSC also directs contractor performance and coordinates with other laboratories and government agencies to integrate the Mk 50 with other weapon systems. NOSC engineers have developed the engineering change proposals to modify the attack and fire control consoles of ships to enable them to launch the Mk 50 when it becomes operational.

The antisubmarine rocket (ASROC) missile system has been deployed in the Fleet for over 30 years and is expected to continue to be a viable stand-off weapon until 2025 when the last ASROC-equipped surface ship is scheduled for retirement. Since 1980, NOSC has been lead laboratory for the Vertical Launch ASROC (VLA). The VLA is one aspect of the modular Vertical Launching System (VLS) that permits up to 61 missiles per magazine (VLA, standard missile, or Tomahawk) to be fired from individual cells. Like the other missiles, the VLA is designed for a 360-degree engagement zone and for the high rate of fire made possible



Torpedo Mk 50 launched from ASW fixed-wing platform during full-scale development testing.

VLA. The VLA is shown here on a test shot from a vertical launcher on USS Hewitt *(DD 966) off San Clemente Island.*

by the VLS on ships on which it will be installed: DD 963, CG 47, and DDG 51 classes. Just as the other missiles multiply the offensive power of these ships, the VLA vastly increases their defensive power and load-out flexibility.

The ASROC is launched from a deck-mounted launcher (Mk 165 or Mk 26) at a fixed ballistic angle, which limits the direction at which ASROC can be fired without turning the ship. The new launcher/missile design increases the original ASROC's limited engagement coverage and comparatively short range, and decreases its multiwarfare engagement limitations (such as reaction time).

Antisubmarine Warfare Control System (ASWCS)

To support the increased need for a coordinated ASW effort, NOSC began development in 1980 of the Antisubmarine Warfare Control System (ASWCS). ASWCS is the integrating element of the AN/SQQ-89 Surface Ship ASW Combat System. The AN/SQQ-89 provides an advanced ASW capability by bringing together the AN/SQQ-28 Light Airborne Multipurpose System (LAMPS), the AN/SQS-53B/C Hull-Mounted Sonar, and the AN/SQR-19 Towed Array Sonar. ASWCS uses data from these sensors to mutually aid in the detection, localization, classification, tracking, and prosecution of underwater targets in greater numbers and at greater ranges than existing systems.

NOSC is the technical direction agent for the ASWCS Mk 116 Mod 7 portion of the AN/SQQ-89 system and is the design agent and lifecycle management agent for all remaining Mk 116 mods. Currently NOSC supports 13 different baseline programs for shipboard use in this effort. During 1989, 11 new software program deliveries were made to fleet units to provide additional capabilities such as VLA and improved signal processing.

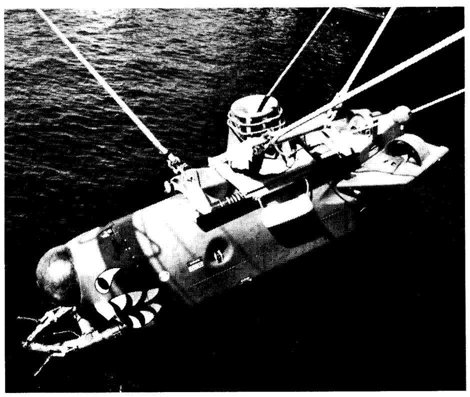
ASWCS Mk 116. The Mk 116 consists of tactical software implemented in a Navy standard AN/UYK-7 or AN/UYK-43B computer interfaced with Navy standard peripherals and display consoles.

Mine Neutralization System (MNS)

The NOSC-developed Mine Neutralization System (MNS) evolved from extensive ROV work done at NOTS Pasadena and NUC San Diego. The MNS vehicle was envisaged from the start as deployable from a fleet ocean minesweeper and able to locate and classify mines. It would then be able to drop a charge near a bottom mine or attach a cable cutter to a moored line.

Such capabilities would give the Fleet the long overdue ability to neutralize the modern mine threat. Technical evaluation and operational testing of the MNS were completed in 1982. A production contract for 12 systems and 27 submersible vehicles was awarded to

Honeywell Corporation in July 1984. The MNS went into production in 1985, and late in 1986, the first units were delivered to shipyards. In 1987, the first MNS (the AN/SLQ-48) was installed aboard the mine countermeasures ship, USS *Avenger* (MCM 1), and other units continue to be delivered to the Fleet.



MNS. The first MNS was installed aboard USS Avenger *(MCM 1) in 1987 to provide the ability to neutralize modern mine threats.*

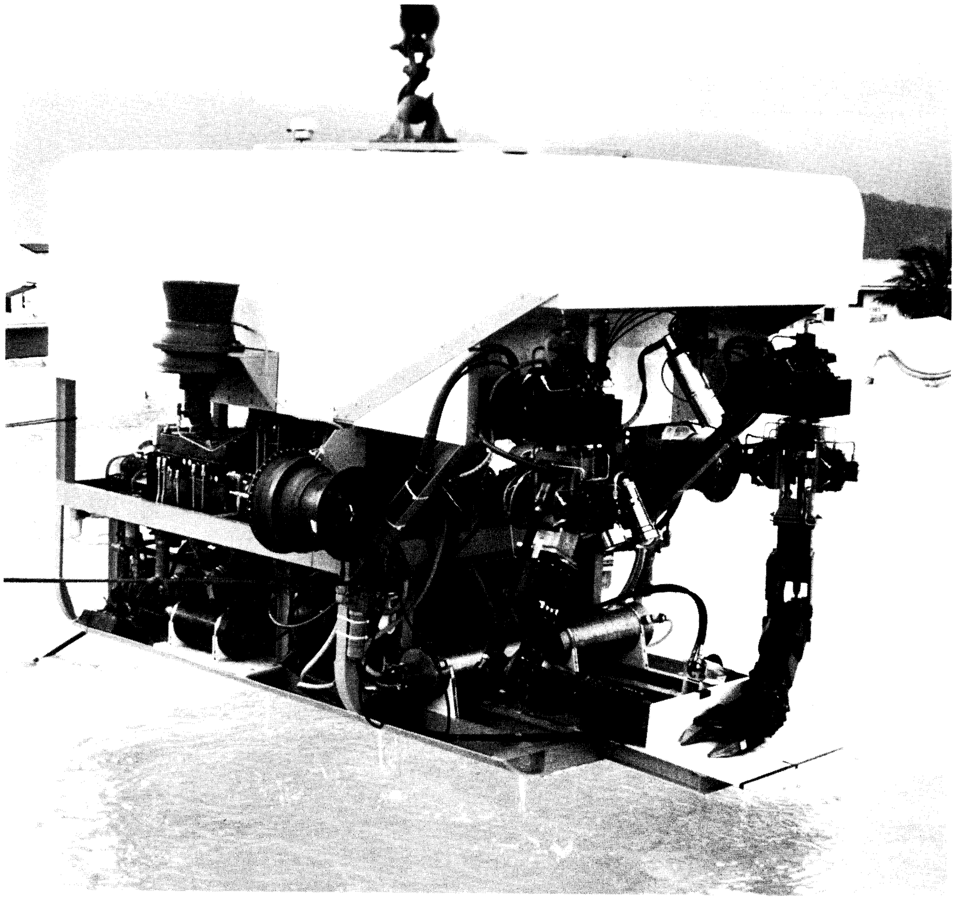
Unmanned, Undersea Vehicles (UUVs)

Two unmanned, undersea vehicles (UUVs) have been developed by NOSC in-house as one-of-a-kind units for operation by the Submarine Development Group One in San Diego.

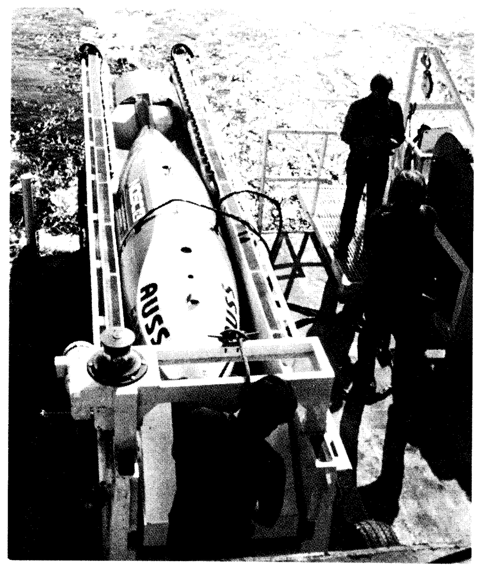
The first, the Advanced Tethered Vehicle (ATV), began as a design study in 1980. The ATV provides a deep-ocean work capability for the Navy: primarily, the recovery of objects and equipment. The ATV is a remotely operated, submersible work system consisting of a neutrally buoyant vehicle, a tether cable, a surface control station, launch/recovery and cable handling equipment, power generators, and maintenance shelters. The ATV is designed to be easily transportable and operable from ships that meet specific requirements for deck space and stationkeeping. The ATV carries manipulators, tools, and sensors, including TV cameras and sonar. During 1985, operational tests of a prototype system were completed, and the vehicle made a record dive of 12,100 feet. Based on data developed during these tests, NOSC began design of the fleet system in 1986.

The production ATV represents the culmination of vehicle system experience at NOSC. Both formal and informal reviews were established to take advantage of the background of NOSC operators and designers. The system design has been a careful balance of the tradeoffs between technology, operability, and performance. The principal technical advancement is the tether cable, its optical fibers, and the associated digital telemetry link. The ATV is capable of performing fleet missions to depths of 20,000 feet.

The complementary system to the ATV is its companion Advanced Undersea Search System (AUSS). The AUSS is an acoustically controlled, free-swimming ROV. The primary innovations of the AUSS include its acoustic telemetry system, its graphite composite hull, and its state-of-the-art microelectronic processing circuitry. Acoustic telemetry frees the vehicle from the constraints of a tether and enables the AUSS to transmit digitized data from operating depths. The AUSS can be used to locate an object to depths of 20,000 feet, and the cable-powered and controlled ATV can be used to work on the object once it is found.



ATV. The ATV is a remotely operated, submersible work system that provides a deep-ocean work capability for the Navy.



AUSS. An acoustically controlled, free-swimming ROV, AUSS can be used to locate objects to depths of 20,000 feet.

Submarine Arctic Warfare

The Chief of Naval Operations (CNO) officially added submarine arctic warfare to the NOSC mission statement in April 1980. By the early 1980s, submarines of the Soviet Navy were discovered in the Arctic, and the work by Dr. Waldo Lyon and the staff of the Arctic Submarine Laboratory (ASL) suddenly demonstrated its full significance.

Throughout the decade, the ASL continued to support the CNO's Arctic Warfare Initiative by serving as lead laboratory for highly successful arctic submarine ice exercises (SUBICEXS). During this time, the ASL also conducted laboratory and field research to provide submarines with maximum capability to operate and exploit all ice-covered seas during all seasons.

A major NOSC program completed in the 1980s to support the Navy's Fleet operations in the Arctic was the improvement to the AN/BQS-14 sonar for *Sturgeon*-class submarines. The AN/BQS-14 sonar is a now-obsolete design (but the best available when that class of submarines was designed in the mid-1960s). The Arctic Pulsed Experimental (APEX) sonars are "add-on" units to the AN/BQS-14 sonars.

The APEX sonars upgrade the AN/BQS-14s and solve several operational problems. The "add-on" approach of the APEX produced an up-to-date sonar in less time and at much lower cost than would have been possible with development and production of a completely new ice-piloting sonar. Only 18 months passed from the time the submarine force asked for help to the first APEX test in the Arctic. The ASL completed delivery of the APEX IIA sonars to the Fleet in 1988. The APEX unit completely solved the operational problems of the AN/BQS-14 and was met with enthusiastic acceptance by the submarine community. Every *Sturgeon*-class submarine deploying to the Arctic has been so equipped.

NOSC is now developing an APEX-like "add-on" sonar for the AN/BQS-15 sonars onboard *Los Angeles*-class submarines. This program is called SPECTRA (Special Transmissions). The prototype SPECTRA sonar was "shop tested" in 1988 and completed its first sea trial in 1989.

USS Queenfish *(SSN 651) during arctic deployment.*

The Future

The Naval Ocean Systems Center has a clear tradition of excellence, and the present situation in the world will demand that we strengthen that tradition. We can all take some measure of hope in what we see happening in the world today, as the Cold War ends and the bankrupt ideology that supported that war begins to collapse on itself. We now live in a world with a greatly reduced threat of nuclear holocaust, a world that promises some of the blessings we already enjoy to millions of others who have never known these blessings.

We, who work at DoD laboratories like NOSC and who develop much of the technology that makes our own nation great, can take pride in what we have accomplished. The Soviet Union, after decades of spending too much of its energies, its resources, and its people on massive military development, has recognized that it cannot compete with us in both the military and economic arenas. The military systems we develop are the products of a culture combining free enterprise and democracy, and that combination is without equal. Our military systems have provided us the security necessary to allow our economic and political systems to mature and shine. As we look back on the history that led to NOSC's 50-year milestone, we see impressive contributions to the military strength of our nation, contributions that helped bring about the very changes we see in the world today.

The technology development that has been our reason for existence, not only supported the nation's military might, but its economic and industrial strength as well. Science and technology know no boundary between military and civilian enterprise, and we at NOSC have contributed our share, as evidenced clearly by the more than 400 patent applications we have filed in the past 10 years.

Our first 50 years began with the challenge of World War II and have ended with the end of the Cold War; we can truly say we helped the Navy and the nation meet that challenge. Our second 50 years begin with a challenge of equal magnitude: the despair and virtual slavery in Eastern Europe have been replaced by hope and promise of freedom, but the relative stability of a bi-polar world dominated by two superpowers has been replaced with a good deal of uncertainty and instability.

We live in a world in which superpower influence has diminished, a world in which a number of countries that previously looked to either the U.S. or the U.S.S.R.

for leadership now boast strong military, political, and economic systems of their own. And, in many of the smaller countries, the destabilizing influence of the end of the Cold War has increased the possibility of violent regional conflict, based as much on economic and religious factors as political ones.

In this new world, the role of research and development will be greater than ever. It is the basis for our military strength, and the most fundamental element of our economic strength. If that challenge were not great enough by itself, we face it at a time when the public and the Congress are clamoring for a peace dividend and seeking it through a substantial decrease in the defense budget. The result will be a draw-down in the size of the defense industry and a shift away from the tech base and systems development within the private section so essential to our country's military strength.

From an economic and military standpoint, the efforts of the DoD research laboratories, particularly in the high technology area, thus become significantly more important. As the potential returns to the defense industry from basic research and development appear to be dwindling, fewer and fewer contractors will be risking capital investment on military programs, and there will be increasing requirements for laboratories like NOSC to make up the shortfall.

To support a modern Navy and an island nation in an uncertain world, the need for science and technology, the need for scientists and engineers, will be greater than ever.

Throughout our five decades of service to the Navy, this laboratory has pursued excellence in a variety of technical fields. We must not only continue that pursuit; we must intensify it. While we can expect to see changes in the way we do business, as the world forces us to change, our role will remain strong. We face a future every bit as exciting and challenging as our past. As the employees of this laboratory met the challenges of World War II, Korea, Vietnam, and the Cold War, we must look ahead to meet the challenges of the new century so rapidly approaching. The work that we do here in our major mission areas is of essential importance to the United States Navy, and we must pursue it with the same enthusiasm and dedication we've shown for the past 50 years.

Captain J.D. Fontana
Commander
Naval Ocean Systems Center

Bibliography

Books

Anderson, W. R. 1959. *Nautilus 90 North*. World Pub. Co., Cleveland, OH.

Baxter, J. P. 1968. *Scientists Against Time*. M.I.T. Press, Cambridge, MA.

Boyce, J. C., ed. 1947. *New Weapons for Air Warfare: Fire-Control Equipment, Proximity Fuzes, and Guided Missiles*. Little, Brown, and Co., Boston, MA.

Burchard, J. E., ed. 1948. *Rockets, Guns and Targets: Rockets, Target Information, Erosion Information, and Hypervelocity Guns Developed During World War II by the Office of Scientific Research and Development*. Little, Brown, and Co., Boston, MA.

Bush, V. 1970. *Pieces of the Action*. Morrow, New York, NY.

-----------. 1949. *Modern Arms and Free Men: A Discussion of the Role of Science in Preserving Democracy*. Simon and Schuster, New York, NY.

Christman, A. B. 1971. *History of the Naval Weapons Center, China Lake, California. Vol. 1, Sailors, Scientists, and Rockets*. Naval History Division. Government Printing Office, Washington, D.C.

Corse, C. D., Jr. 1975. *Introduction to Shipboard Weapons*. Naval Institute Press, Annapolis, MD.

DiCerto, J. J. 1967. *Missile Base Beneath the Sea: The Story of Polaris*. St. Martin's Press, New York, NY.

Gerrard-Gough, J. D. and A. B. Christman. 1978. *History of the Naval Weapons Center, China Lake, California, Vol. 2, The Grand Experiment at Inyokern*. Naval History Division. Government Printing Office, Washington, D.C.

Hooper, E. B., D. C. Allard, and O. P. Fitzgerald. 1976. *The United States Navy and the Vietnam Conflict. Vol. 1, The Setting of the Stage to 1959*. Naval History Division. Department of the Navy. Washington, D.C.

Lockwood, C. A. 1951. *Sink 'em All: Submarine Warfare in the Pacific*. Dutton, New York, NY.

Lord, W. 1967. *Incredible Victory*. Harper & Row, Publishers. New York, NY.

Ridgway, S. H. 1987. *The Dolphin Doctor.* Yankee Publishing Incorporated, Dublin, NH.

Sapolski, H. M. 1972. *The Polaris System Development: Bureaucratic and Programmatic Success in Government.* Harvard University Press, Cambridge, MA.

Stewart, I. 1948. *Organizing Scientific Research for War: The Administrative History of the Office of Scientific Research and Development.* Little, Brown, and Co., Boston, MA.

Thiesmeyer, L. R. and J. E. Burchard. 1947. *Combat Scientists.* Little, Brown, and Co., Boston, MA.

Administrative and Technical Reports

Booz, Allen and Hamilton, Inc. 1976. "Review of Navy R&D Management: 1946–1973." Department of the Navy, Washington, D.C.

Flower, D. and L. Roth. 1982. "Cultural Resource Inventory: Archaeological, Historical, Architectural. Navy and Coast Guard Lands on Point Loma." CR 81-C-5747. San Diego, CA.

Jolie, E. W. 1978. "A Brief History of U.S. Navy Torpedo Development." NUSC TD 5436 (Sep). Naval Underwater Systems Center, Newport Laboratory, Newport, RI.

LaFond, E. C. 1965. "Oceanographic Research Tower: Its Development and Utilization." NEL Report 1342 (Dec). Navy Electronics Laboratory, San Diego, CA.

Naval Electronics Laboratory Center. 1969. "NELC Command History for Calendar Year 1970." Naval Electronics Laboratory Center, San Diego, CA.

___________. 1970. "NELC Annual Report." NELC TD 100. Naval Electronics Laboratory Center, San Diego, CA.

___________. (1970) "NEL/NELC Highlights: A Summary of Technical Achievement 1945–1970." NELC TD 104. Naval Electronics Laboratory Center, San Diego, CA.

___________. 1971. "NELC Annual Report." NELC TD 150. Naval Electronics Laboratory Center, San Diego, CA.

___________. 1972. "NELC Annual Report. Vol. 1, Administrative and Management Highlights." NELC TD 200. Naval Electronics Laboratory Center, San Diego, CA.

___________. 1973. "NELC Annual Report. Vol. 1, Management and Technical Highlights." Naval Electronics Laboratory Center, San Diego, CA.

___________. 1974. "NELC Accomplishments in Electronic Warfare." Naval Electronics Laboratory Center, San Diego, CA.

___________. 1974. "NELC Annual Report." NELC TD 350. Naval Electronics Center, San Diego, CA.

___________. 1975. "NELC Accomplishments in Antennas." Naval Electronics Laboratory Center, San Diego, CA.

___________. 1975. "NELC Today." Naval Electronics Laboratory Center, San Diego, CA.

Naval Ocean Systems Center. 1977–1989 (Annual). "Naval Ocean Systems Center Brief." Naval Ocean Systems Center, San Diego, CA.

___________. 1978. "Ocean Technology: A Digest." NOSC TD 149 (Mar). Naval Ocean Systems Center, San Diego, CA.

___________. 1979. "Command, Control, and Communication Systems Integration Test and Evaluation Site (C^3 SITE)." NOSC TD 271 (Oct). Naval Ocean Systems Center, San Diego, CA.

___________. 1981. "Ocean Technology: A Digest." NOSC TD 149 Rev. 1 (Feb). Naval Ocean Systems Center, San Diego, CA.

___________. 1983. "NOSC Command History: Calendar Year 1982." NOSC TD 594 (Mar). Naval Ocean Systems Center, San Diego, CA.

___________. 1987. "Command History: Calendar Years 1985 and 1986." NOSC TD 844 (Jan). Naval Ocean Systems Center, San Diego, CA.

___________. 1988. "Command History: Calendar Year 1987." NOSC TD 1256 (Jan). Naval Ocean Systems Center, San Diego, CA.

___________. 1989. "Command History: Calendar Year 1988." NOSC TD 1542 (Jun). Naval Ocean Systems Center, San Diego, CA.

___________. 1989. "NOSC Strategic Plan." NOSC TD 1475 (Jul). Naval Ocean Systems Center, San Diego, CA.

Naval Undersea Center. 1972–1974 (Annual). "NUC Brief." Naval Undersea Center, San Diego, CA.

Naval Undersea Center. 1975. "Ocean Engineering." NUC TP 278 Rev. 1 (Jan). Naval Undersea Center, San Diego, CA.

Naval Undersea Research and Development Center. 1969–1971 (Annual). "NUC Brief." Naval Undersea Research and Development Center, San Diego, CA.

Naval Undersea Warfare Center. n.d. "Command History: July 1967–December 1968." Naval Undersea Warfare Center, San Diego, CA.

Naval Weapons Center. 1968. "Naval Weapons Center Silver Anniversary: NOTS 1943-1968 NWC." (Oct). Naval Weapons Center, China Lake, CA.

Navy Deep Submergence Systems Project and Northrop Nortronics. 1968. "Sealab III Experiment Press Handbook." Northrop Nortronics, Palos Verdes, CA.

Navy Electronics Laboratory. n.d. "Command History: 1 June 1940–31 December 1958." Navy Electronics Laboratory, San Diego, CA.

___________. 1961–1965 (Annual). "Command History." Navy Electronics Laboratory, San Diego, CA.

___________. 1965. "Oceanographic Activities: September 1964–September 1965." Navy Electronics Laboratory, San Diego, CA.

Office of Scientific Research and Development, National Defense Research Committee. 1946. "Summary Technical Report of Division 3, NDRC. Vol. 1, Rocket and Underwater Ordnance." Washington, D.C.

Office of Scientific Research and Development, National Defense Research Committee. 1946. "Summary Technical Report of Division 6, NDRC. Vol. 1, Survey of Subsurface Warfare in World War II." Washington, D.C.

___________. "Vol. 4, Methods and Devices Developed for the Selection and Training of Sonar Personnel." Washington, D.C.

___________. "Vol. 6A, The Application of Oceanography to Subsurface Warfare." Washington, D.C.

___________. "Vol. 7, Principles and Applications of Underwater Sound." Washington, D.C.

___________. "Vol. 12, Design and Construction of Crystal Transducers." Washington, D.C.

___________. "Vol. 17, Underwater Sound Equipment IV. Frequency-Modulated Sonar Systems." Washington, D.C.

Pickwell, G. V. and W. E. Evans, eds. 1972. "Handbook of Dangerous Animals for Field Personnel." NUC TP 324 (Dec). Naval Undersea Center, San Diego, CA.

Smith, H. D. 1965. "Description of the NOTS Hydroballistics Laboratory." IDP 2241 (Aug). Naval Ordnance Test Station, Pasadena, CA.

———. 1966. "The Hydroballistics Laboratory at NOTS." NAVWEPS Report 9035, NOTS TP 4032 (Apr). Naval Ordnance Test Station, China Lake, CA.

University of California Division of War Research. "Completion Report." (Made to Chief of the Bureau of Ships, Navy Department Covering Operations of the University of California Division of War Research at the Navy Electronics Laboratory, San Diego, CA, under Contract NObs-2074 [formerly OEMsr-30] from 26 April 1941 to 30 June 1946.)

Oral History Interviews

Bishop, C. Interviewed by M. Jacobsen. October 1987. Naval Ocean Systems Center, San Diego, CA.

Blood, H. Interviewed by A. B. Christman. 10 March 1978. "Navy Laboratory Management Philosophy and Problems." Naval Weapons Center, China Lake, CA.

Cooper, E. P. Interviewed by G. Scott. 5 May 1988. "His Career at NOTS Pasadena, NRDL, NUC, and NOSC." Naval Ocean Systems Center, San Diego, CA.

Heselton, L. Interviewed by M. Jacobsen. September 1987. "The Blue Ribbon (Fitzhugh) Report on DoD Organization, 1970." Naval Ocean Systems Center, San Diego, CA.

Myers, R. Interviewed by M. Jacobsen. 22 May 1986. "His Career, NEMO, Deep Ocean Engineering, Sealab, USS *Elk River*." Naval Ocean Systems Center, San Diego, CA.

Oberndorf, P. Interviewed by M. Jacobsen. 15 June 1988. "Ada Development." Naval Ocean Systems Center, San Diego, CA.

Rosenburg, S. Interviewed by M. Jacobsen. 17 December 1987. "Circuit Mayflower." Naval Ocean Systems Center, San Diego, CA.

Talkington, H. R. Interviewed by M. Jacobsen. November 1987. "The Role of NOTS Pasadena in the Polaris Underwater Launch System." Naval Ocean Systems Center, San Diego, CA.

Washburn, D. Interviewed by M. Jacobsen. November 1987. Naval Ocean Systems Center, San Diego, CA.

Wilcox, D. Interviewed by A. B. Christman. 13 March 1978. Naval Weapons Center, China Lake, CA.

Wilcox, H. A. Interviewed by A. B. Christman. 15 March 1978. "Trends, Leaders, History of Navy Laboratories." Naval Weapons Center, China Lake, CA.

Wilson, C. Interviewed by M. Jacobsen. December 1987. Naval Ocean Systems Center, San Diego, CA.

Wirth, J. Interviewed by M. Jacobsen. 7 December 1987. Naval Ocean Systems Center, San Diego, CA.

Periodicals

Keach, D. L. LT CDR, USN. 1964 (Jun). "Down to *Thresher* by Bathyscape." *National Geographic*, vol. 125, pp. 764-777.

Naval Electronics Laboratory Center. 1967–Feb 1977 (Biweekly). *NELC Calendar*. Naval Electronics Laboratory Center, San Diego, CA.

Naval Ocean Systems Center. Mar 1977–1989 (Biweekly). *Outlook*. Naval Ocean Systems Center, San Diego, CA.

Naval Undersea Center. Mar 1968–Feb 1977 (Biweekly). *Seascope*. Naval Undersea Center, San Diego, CA.

Navy Electronics Laboratory. 1947–1967 (Biweekly). *NEL Calendar*. Navy Electronics Laboratory, San Diego, CA.

Piccard, J. "Man's Deepest Dive." 1960 (Aug). *National Geographic*, vol. 118, pp. 225-239.

Talkington, H. R. Jun 1960. "NOTS, San Clemente Island." *Naval Institute Proceedings*. (pp. 92-101).