The Changing Picture of UUV Development in the U.S. Navy

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ABSTRACT

Five years ago Howard Talkington briefed the 18th meeting of the United States/Japan Cooperative Program in Natural Resources (UJNR), Marine Facilities Panel, on the many changes taking place within the organization of the U.S. Navy Laboratories, many of which have been visited by the UJNR committee during study tours in the United States. Since that time, the changes have continued; more facilities have been reorganized, some totally eliminated, and the missions of many others have changed. The Navy has transitioned from a Cold War period where the development of deep ocean unmanned undersea vehicles (UUVs) was emphasized, to a period where their major applications are in the shallower littoral environment, mine warfare, and missions concerning conflicts in third world countries. Deep ocean developments such as the Advanced Unmanned Search System (AUSS) have given way to the new Long-term Mine Reconnaissance System (LMRS) - a submarine launched autonomous vehicle. This paper will discuss the many changes that have occurred within the Navy system during the last several years, identify today's key organizations in the area of unmanned undersea vehicle technology, and define their missions and plans for the future.

INTRODUCTION

When Howard Talkington gave his paper in 1992 at the 18th Meeting of the UJNR Panel, the U.S. Navy had just completed a significant reorganization. The Navy's research, development, test and evaluation activities were consolidated into a streamlined corporate laboratory and four warfare centers. In addition, mission purifications were completed, where projects and personnel were transferred to centers which were more aligned with applicable platforms, i.e. air, surface, undersea. Accordingly, the Naval Air Warfare Center (NAWC), the Naval Surface Warfare Center (NSWC), and the Naval Undersea Warfare Center (NUWC) were established. The forth warfare center, the Naval Command, Control and Ocean Surveillance Center (NCCOSC), was added to address technologies that overarch all of the previous centers. What was previously the Naval Ocean Systems Center (NOSC) is now NRaD; NCCOSC's Research, Development, Test and Evaluation Division. Additional consolidations have been completed since that time, and more continue today as the Navy works to preserve its core mission capability in the face of significant budget and personnel reductions.

The remainder of this paper will discuss the missions of the primary organizations in the area of Navy unmanned undersea vehicle (UUV) research and development (R&D) programs today, what UUV R&D is ongoing today, NRaD's role, and what the future may hold.

NAVY R&D ORGANIZATIONS

The following section will discuss the organization, missions and present roles of key activities in the U.S. Navy involved with UUV R&D, including the university laboratories that work closely with them.

Naval Command, Control and Ocean Surveillance Center (NCCOSC)

NCCOSC reports to the Space and Naval Warfare Systems Command, Figure 1, which is in the process of relocating from Washington D.C. to San Diego, California. NRaD continues as the research and development arm of NCCOSC with the following mission:

To be the Navy's research, development, test and evaluation, engineering and fleet support center for command, control and communication systems and ocean surveillance and the integration of those systems which overarch multiplatforms.

Among the eight leadership areas that support the above mission is Ocean Engineering, which continues NRaD's long standing role as a leader in the area of UUVs - a position highlighted by decades of excellence in the development of UUVs and related technology.

Naval Surface Warfare Center (NSWC)

The NSWC reports to the Naval Sea Systems Command (NAVSEA), Figure 1, and has been assigned the following mission:

To be the Navy's full spectrum research, development, test and evaluation, engineering, and fleet support center for ship hull, mechanical, and electrical systems, surface ship combat systems, coastal warfare systems, and other offensive and defensive systems associated with surface warfare.

Among the fourteen leadership areas are:

- Surface and Undersea Vehicle Hull, Machinery, Propulsors and Equipment
- Mines, Mine Countermeasures and Mine Clearance Systems.

Under the present NSWC command is their Carderock Division, Bethesda, Maryland, which includes the David Taylor Model Basin Facility, a complex of model basins, towing carriages, a circulating water channel, and cavitation water tunnels. The UJNR study tour visited the facility in 1995. The Carderock Division's detachment in Annapolis, Maryland is the site of their Deep Ocean Pressure Simulation Facility.

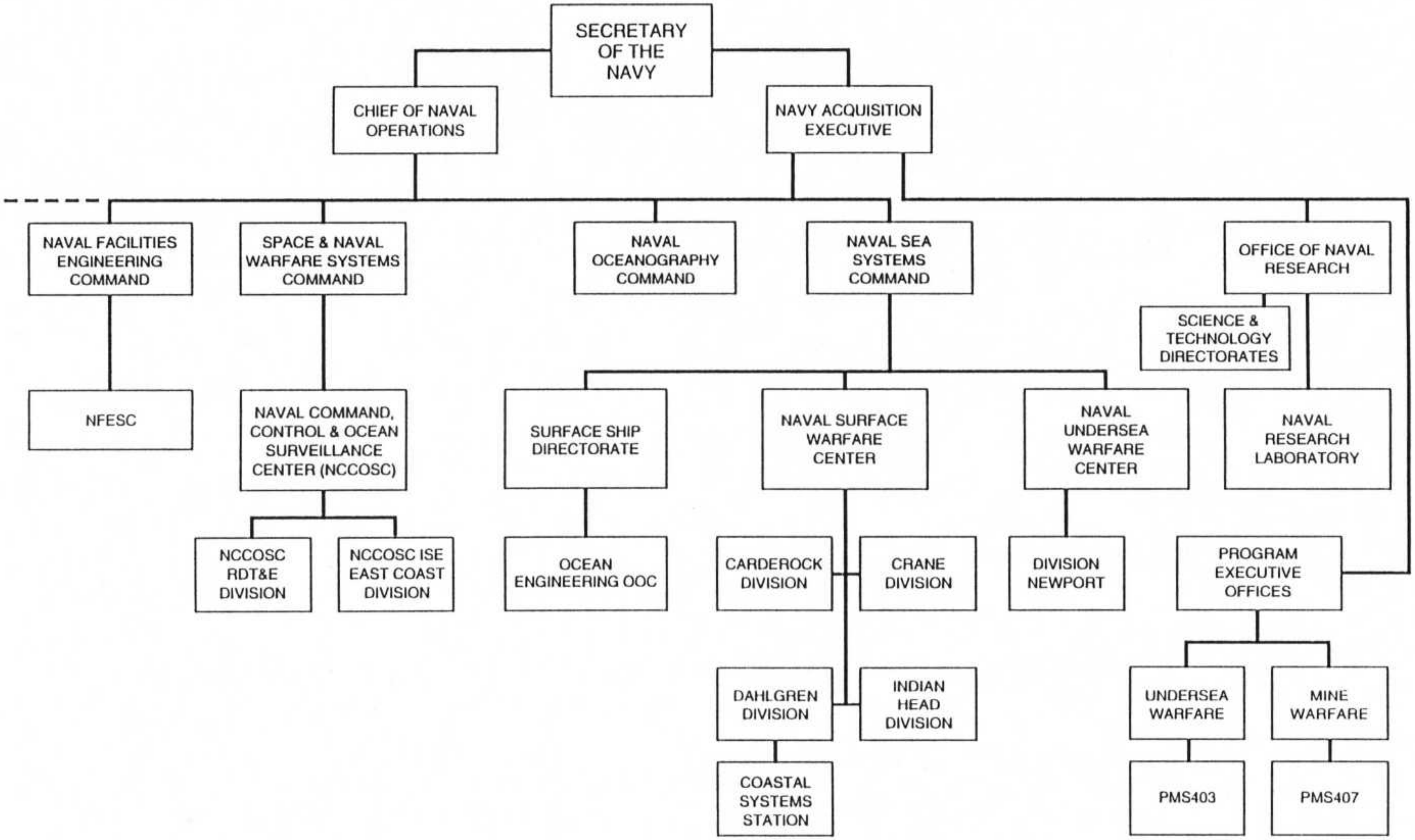


Figure 1. Navy Organizational Relationships

In addition, NSWC, Dahlgren Division, Dahlgren, Virginia, is the parent command for the **Coastal Systems Station (CSS)** - formerly the Naval Coastal Systems Center in Panama City, Florida - which is a key organization in the area of UUVs and mine warfare. Through programs funded by ONR, they are highly involved in the development of the following systems for application to 21 inch diameter UUVs:

- Toroidal Volume Search Sonar (TVSS)
- Side Look Sonar (SLS)
- Low Frequency Synthetic Aperture Sonar (LFSAS)
- High Frequency Synthetic Aperture Sonar (HFSAS)
- Superconducting magnetic gradiometer
- Laser Visual Identification System (LVIS)

Naval Undersea Warfare Center (NUWC)

NUWC also reports to NAVSEA, Figure 1, and has been assigned the following mission:

> *Operate the Navy's full-spectrum research, development, test and evaluation, engineering and fleet support center for submarines, autonomous underwater systems, and offensive and defensive weapons systems associated with undersea warfare.*

Among NUWC's eleven leadership areas is undersea vehicle active and passive signatures. NUWC has several ongoing UUV programs that are based on their background in torpedo technology.

Director of Ocean Engineering, Supervisor of Salvage and Diving

The Office of the Director of Ocean Engineering, Supervisor of Salvage and Diving (SUPSALV or OOC) reports to the Surface Ship Directorate of the Naval Sea Systems Command, Figure 1. SUPSALV is responsible for all aspects of ocean engineering, including salvage, ship repair, contracting, towing, diving safety, and equipment maintenance and procurement. Although not actually an R&D organization, they are the primary component of the Navy involved in the emergency reaction to at-sea disasters, where their fleet of Navy owned, and/or commercial vehicles under contract, are deployed to perform all aspects of undersea operations from body recovery to the location of black boxes from airplane disasters. Presently, Oceaneering Technologies Incorporated provides UUV contract support to OOC using vehicles such as Deep Drone, CURV III, the Orion search system, and others.

Naval Facilities Engineering Command (NAVFAC)

The Naval Facilities Engineering Command (NAVFAC), Figure 1, is the parent command for the Naval Facilities Engineering Service Center (NFESC), located in Port Hueneme, California. The mission of NFESC follows:

Deliver quality, specialized technical products and services in the areas of shore and ocean facilities engineering, environmental services ashore, energy and utilities services, and amphibious and expeditionary engineering through RDT&E, consulting, and field engineering.

Formerly the Naval Civil Engineering Laboratory, the Center has a long standing reputation for coastal engineering to include UUV applications, cable burial, and diver and underwater tools, including seawater operated versions.

Office of Naval Research

The Naval Research Laboratory (NRL) reports to the Chief of Naval Research, Office of Naval Research (ONR), Figure 1. An important component of ONR, the Navy's corporate laboratory - NRL - has the following mission:

To conduct a broadly based multidisciplinary program of scientific research and advanced technological development directed toward maritime applications of new and improved materials, techniques, equipment, systems, and ocean, atmospheric, and space sciences and related technologies.

NRL has additional divisions located at the Stennis Space Center, near Bay St. Louis, Mississippi; part of the NRL Ocean and Atmospheric Science and Technology Directorate (OAST).

Naval Oceanographic Office

The Naval Oceanographic Office (NAVOCEANO), Figure 1, is the largest field component of the Naval Meteorology and Oceanography Command (NAVMETOCCOM), and is located at the John C. Stennis Space Center. NAVOCEANO provides oceanographic support to the Department of Defense (DoD) through a wide range of oceanographic modeling, prediction, and data collection techniques. NAVOCEANO's mission is:

To provide specialized and unique oceanographic products and services to joint warfighters in a manner and timeframe that allows them to meet their objectives.

Program Executive Officers (PEO)

Program Executive Officers (PEO) report to the Assistant Secretary for Research, Development and Acquisition, Figure 1. The following, in particular, play a significant role in the acquisition of UUVs for the U.S. Navy.

Unmanned Undersea Vehicles Program Office (PMS-403)

PMS-403 reports to the Undersea Warfare Program Executive Officer (PEO-USW) and is in charge of the Near-Term Mine Reconnaissance System (NMRS) and the Long-Term Mine Reconnaissance System (LMRS) systems, which are discussed later in this paper.

Mine Warfare Systems Program Office (PMS-407)

PMS-407 reports to the Mine Warfare Program Executive Officer (PEO-MIW) and is in charge of ship deployed mine countermeasure (MCM) systems, including the Navy's Mine Neutralization System (MNS).

University Laboratories

For the last half century, five university laboratories have worked to solve problems of interest to the Navy, Figure 2. They are structured to address selected research, development, test, and evaluation (RDT&E) problems in a timely, cost effective, and innovative fashion. The Marine Physical Laboratory (MPL) is managed by the Office of Naval Research, while SPAWAR has cognizance for the remaining four laboratories, Figure 2. The laboratories are discussed in the following paragraphs.

The Applied Physics Laboratory at the Johns Hopkins University (JHU/APL)

JHU/APL is involved in the development and application of science and technology for the enhancement of the security of the United States and the solution of problems of national and global significance. With this broad mission, their expertise spans most aspects of Naval warfare and strategic systems.

As part of the Navy UUV Program, JHU/APL led an integrated product team of Navy and university laboratories tasked with establishing conceptual designs for the LMRS, in addition to supporting PMS403 in the conduct of the LMRS Cost and Operational Effectiveness Analysis (COEA). They're also involved in advanced propulsor technology and advanced sensors.

The Applied Physics Laboratory at the University of Washington (APL/UW)

APL/UW contributes to the nation's technology base through a program of fundamental research and technological advancement in ocean science, ocean acoustics, and ocean engineering. Their involvement in UUV includes research conducted using their Self-Propelled Underwater Research Vehicles (SPURV). The SPURVs, first developed in 1967, are untethered vehicles controlled through internal programs and an acoustic link.

The Applied Research Laboratory at The Pennsylvania State University (ARL/PSU)

ARL/PSU advances the Navy's technology base through R&D in a broad base of technical competence areas which include acoustics and vibration control, hydrodynamics and hydroacoustics, guidance and control, propulsors, signal processing, close-cycle thermal power plants, systems analysis, materials science and manufacturing technology. In particular, ARL's Engineering Science and Vehicle Technology division is involved in the following ONR funded programs:

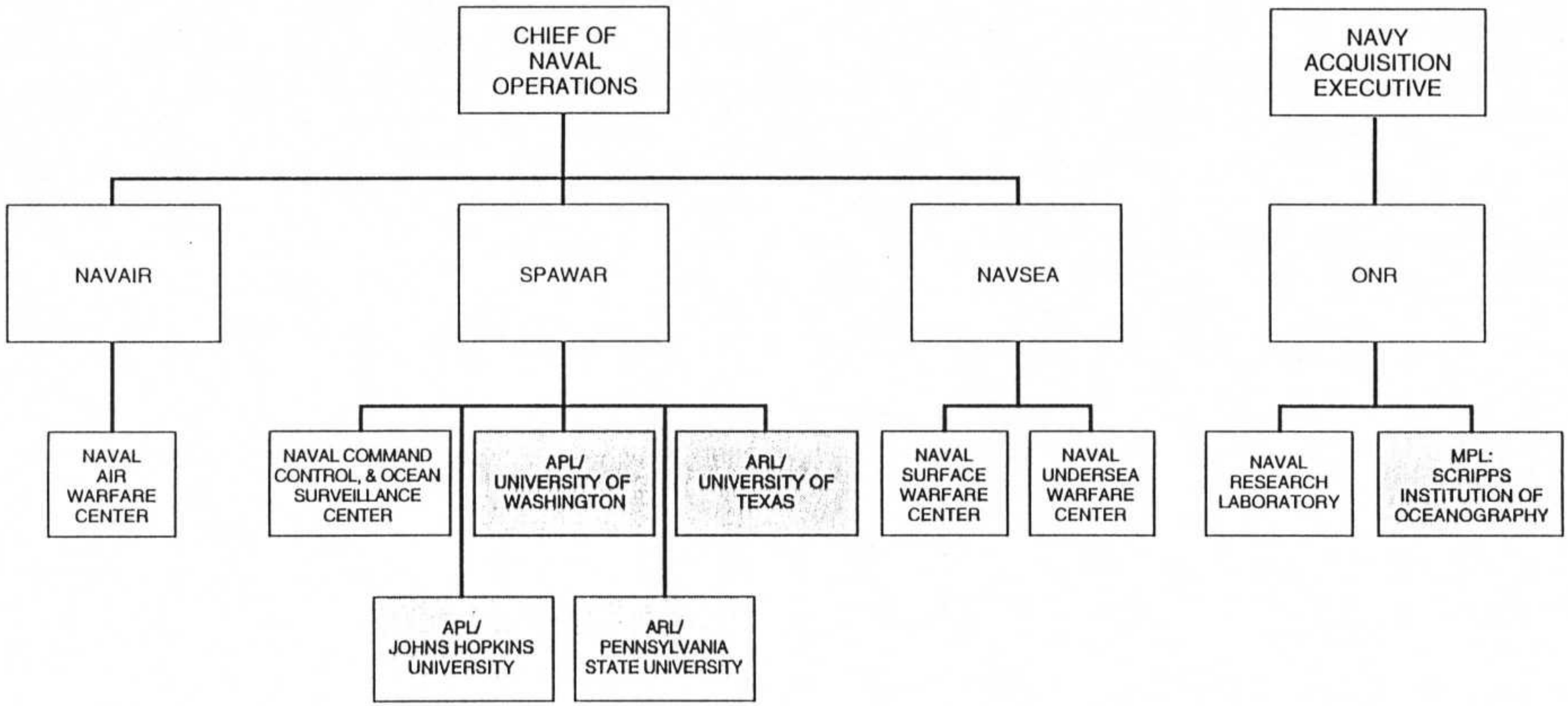


Figure 2. Relationships Between University Laboratories and Key Navy Organizations

- High energy density power sources for UUVs (the LMRS in particular) under the ONR exploratory development science and technology program for underwater weapons. The highest energy density systems are based on liquid metal combustion energy sources. Less energetic closed-cycle systems based on hydrocarbon (JP-5) wakeless combustion energy sources are also being developed.
- Propulsor research for UUVs.
- Intelligent vehicle control architectures for multiple UUVs.

The Applied Research Laboratory at The University of Texas (ARL:UT), Austin, Texas

ARL:UT's mission revolves around their contributions to fundamental scientific advancements in the areas of acoustics; satellite, geophysics and electromagnetics; and information technology. Their Advanced Sonar Group has been involved in developing state-of-the-art sonar architecture for the Navy such as the deep submergence/obstacle avoidance sonars installed on the USS DOLPHIN and NR-1 submarines, the new obstacle avoidance sonar for the 688 class of U.S. Navy submarines, and the modular sonar installed on the UUVs developed for the Defense Advanced Research Projects Agency (DARPA) by Draper Labs, discussed later in this paper.

The Marine Physical Laboratory at The University of California at San Diego, Scripps Institution of Oceanography (MPL)

The Marine Physical Laboratory (MPL) is an R&D organization with a strong multidisciplinary program of scientific research in marine physics/geophysics, ocean environmental acoustics, signal processing and ocean technology. They are part of the University of California and are associated with the Scripps Institution of Oceanography. They are responsible for the Deep Tow vehicles, which are towed instrumentation platforms capable of reaching depths to 7,000 meters.

THE CHANGING ROLE OF THE UUV

In recent years there has been a redirection in development philosophy of future military UUV systems. This has been caused by two significant events; the first is the end of the cold war, and the second is the potential of hostilities with smaller countries that could wreak havoc through terrorism or unconventional warfare techniques. Driven by those changes, the U.S. Navy began to rethink its at sea strategy and a new focus on littoral warfare began to dominate. Areas of application for UUVs include surveillance, intelligence collection, tactical oceanography, special warfare, counter-narcotics and counter terrorism. However, the area of MCM was identified as critical.

The damage of two U.S. warships in the recent Gulf War by World War II mines that were placed in the area by small craft has forced navies around the world to rethink their approach to the threat of mine warfare. The adages that "every ship is a mine sweeper once" and "a single mine can ruin your whole day" lost their humor after those incidents - at least in the U.S. Navy. Because of such instances, the U.S. Navy is planning to spend upwards of $300M U.S. on advanced mine countermeasure (MCM) systems, operated from helicopters, surface ships and submarines from 1996 through 2001.

It became very clear to Navy planners that if future battles are to be fought along the world's coastlines, with mobility a key factor, then safe operating areas will need to be found or established. With such a scenario in mind, the U.S. Navy is now developing submarine launched UUVs for mine countermeasures and reconnaissance. This was recently established in the Navy's UUV Program Plan where clandestine MCM was given top priority. To meet that goal, several systems are planned for development by the Unmanned Undersea Vehicle Program Office - **PMS403**. The first two priorities are the development of the Near-Term Mine Reconnaissance System (NMRS) and the Long-Term Mine Reconnaissance System (LMRS). Together, they are scheduled to nearly reach a $140M U.S. combined budget for 1996-2001.

Near Term Mine Reconnaissance System (NMRS)

The NMRS contract was awarded to Northrop Grumman Corporation (formerly Westinghouse Corporation's Oceanic Division, Annapolis, MD). The system is carried onboard a submarine with the vehicles, operator consoles, tether, winches and other system components housed like torpedoes on the standard storage racks. The vehicle is launched and recovered through the torpedo tube using a drogue that provides a docking point to haul the vehicle back in. The vehicle is battery operated, using silver-oxide batteries and communicates with the mother ship via a fiber optic cable. The system will have the ability to return to the submarine for autonomous recovery should the communication link be broken.

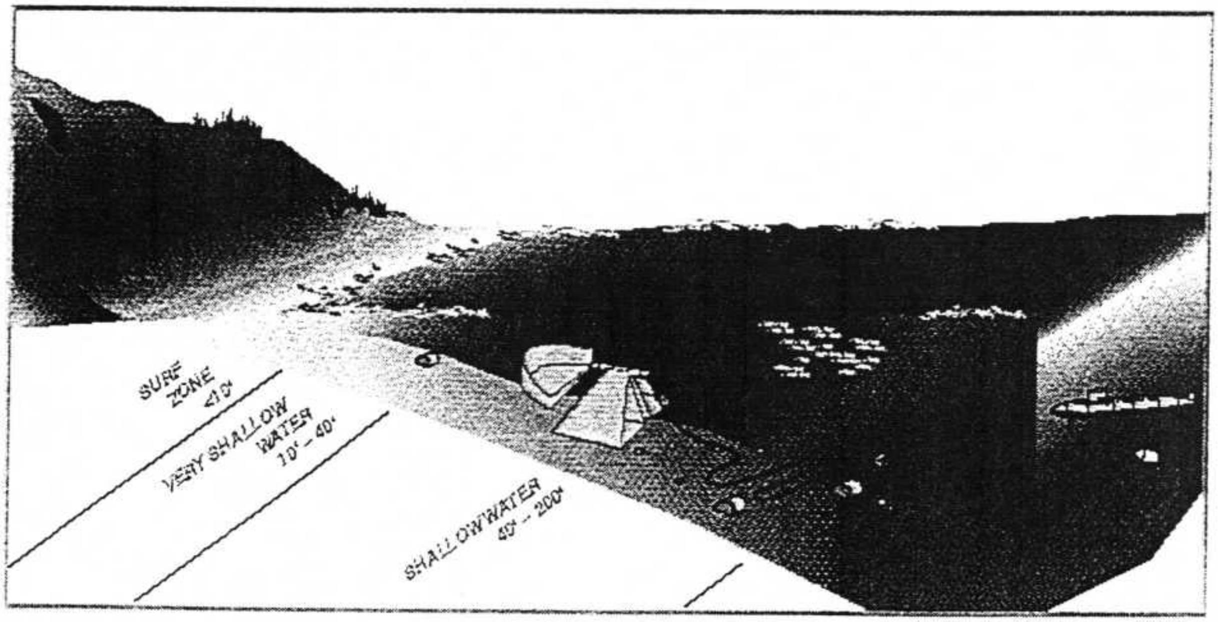


Figure 3. Near-Term Mine Reconnaissance System

The NMRS vehicle is 21 inches in diameter and 206 inches long. Onboard the 2,250 pound vehicle will be a sensor suite made up of a forward-looking sonar for detection and classification of mine like objects in the water column and a side-looking sonar to handle the bottom targets. A concept of the system is provided in Figure 3. The initial operational capability (IOC) of the NMRS is planned for 1998-99.

Long-Term Mine Reconnaissance System (LMRS)

The LMRS, with an expected contract value worth nearly $400M U.S. over the next 20 years, will replace the interim NMRS. The NMRS will fill the need until the production of 6-12 LMRS systems meet a planned IOC of 2003. Unlike the NMRS, the LMRS, Figure 4, will be fully autonomous, with either short range underwater communication with the mother submarine or long range RF communication on the surface. The vehicle concept will remain similar to the NMRS, with a full sensor suite to locate and classify mine like objects, but the requirements will be more stringent. The goal of the system is to achieve the following:

• Vehicle Sortie Reach (nm)	120
• Total System Area Coverage (nm2)	650
• Area Coverage Rate (nm2/day)	50
• Minimum Mine Reconnaissance Water Depth (ft)	40
• Maximum Vehicle Operating Depth (ft)	1500
• Nominal Single Vehicle Endurance (hr)	62

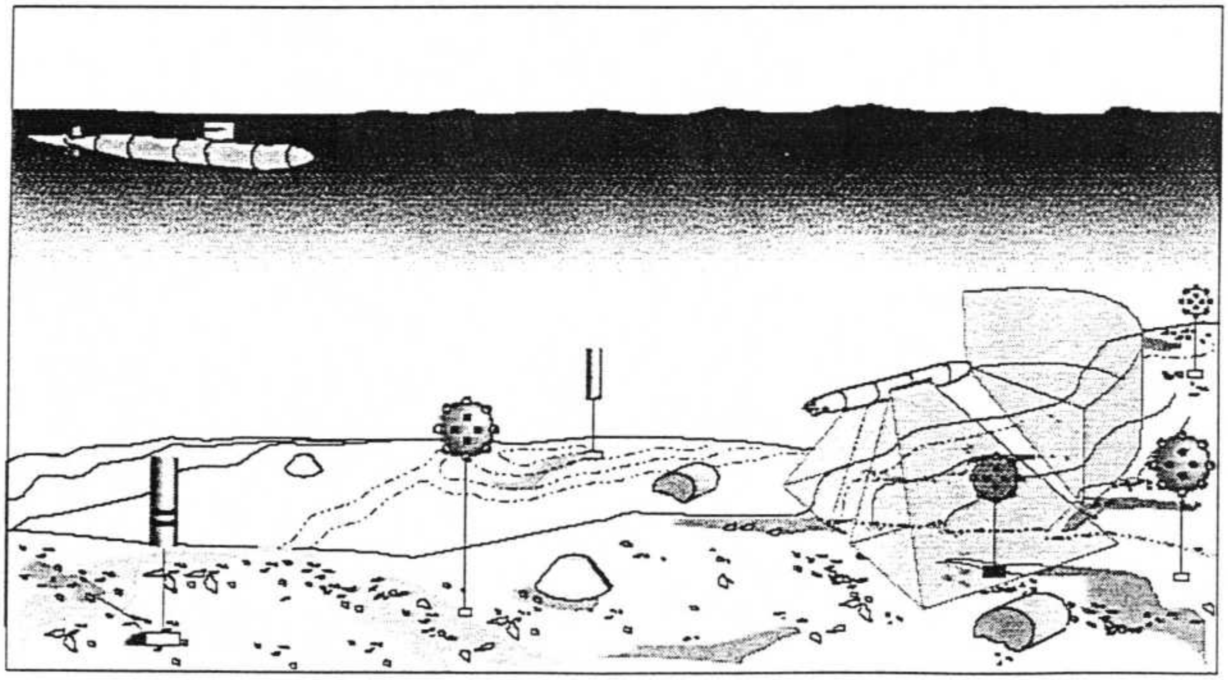


Figure 4. Long-Term Mine Reconnaissance System

Adding to the complexity of the ambitious LMRS are the high reliability criteria, plus the required reduction in magnetic and acoustic signatures. The development of the LMRS will be a real challenge for the winning contractor. The U.S. Navy awarded a one year preliminary design competition contract to three contractors: Northrop Grumman Corp., Lockheed Martin Corp. Government Electronic Systems Division, and the Autonetics and Missile Systems Division of Rockwell International Corporation (Rockwell was acquired by Boeing Co. last year). The Navy will select two contractors for the final design competition and then award the final development contract to the single best contractor.

Remote Minehunting Operational Prototype (RMOP)

Complimenting the development of PMS403's clandestine MCM capability from submarines will be a new surface ship system based on the semi-submerged vehicle technology developed by International Submarine Engineering in Canada with their Dolphin vehicle. The U.S. Navy has been investigating the use of such vehicles for MCM in programs such as the Remote Minehunting Operational Prototype (RMOP) and has now focused on the Remote Minehunting System (RMS) with an IOC of 2005. The basic concept is to provide over-the-horizon mine reconnaissance using the semi-submerged, diesel powered, ROVs to tow sensors below the surface on a retractable tow cable. This technique underscores the new doctrine of placing the search sensors in front of the ships to locate the mines, instead of driving the ships over the mines while looking for or neutralizing them - not a wise approach considering the capability of modern mines.

Mine Neutralization System (MNS)

Not to be excluded is the largest U.S. Navy MCM program existing today - at least when considering the number of operational vehicles - the AN/SLQ-48(V) Mine Neutralization System (MNS) - the original prototype was developed by NRaD. The vehicles, Figure 5, are now manufactured by Alliant Techsystems Inc. under the direction of **PMS407**. Using a conventional electromechanical cable, the vehicle can reach a speed of 6 knots, and operate to a depth of 1,000 meters, while carrying two cable cutters (MP-1) and a bomblet (MP-2). It has a high resolution sonar, low light TV and meets stringent military specifications. It is presently operated by only the U.S. Navy, with 57 vehicles built that operate from the fleet of 14 full ocean MCM (Mine Counter Measure) ships and 12 coastal MHC (Mine Hunter Coastal) ships.

Defense Advanced Research Projects Agency (DARPA) Programs

In addition to the NMRS and LMRS programs, one of the most ambitious programs in support of U.S. Navy missions was DARPA's Unmanned Undersea Vehicle program. DARPA contracted to Charles Stark Draper Laboratory, Inc., in 1988 to develop two "rapid prototype" UUVs for an initial award

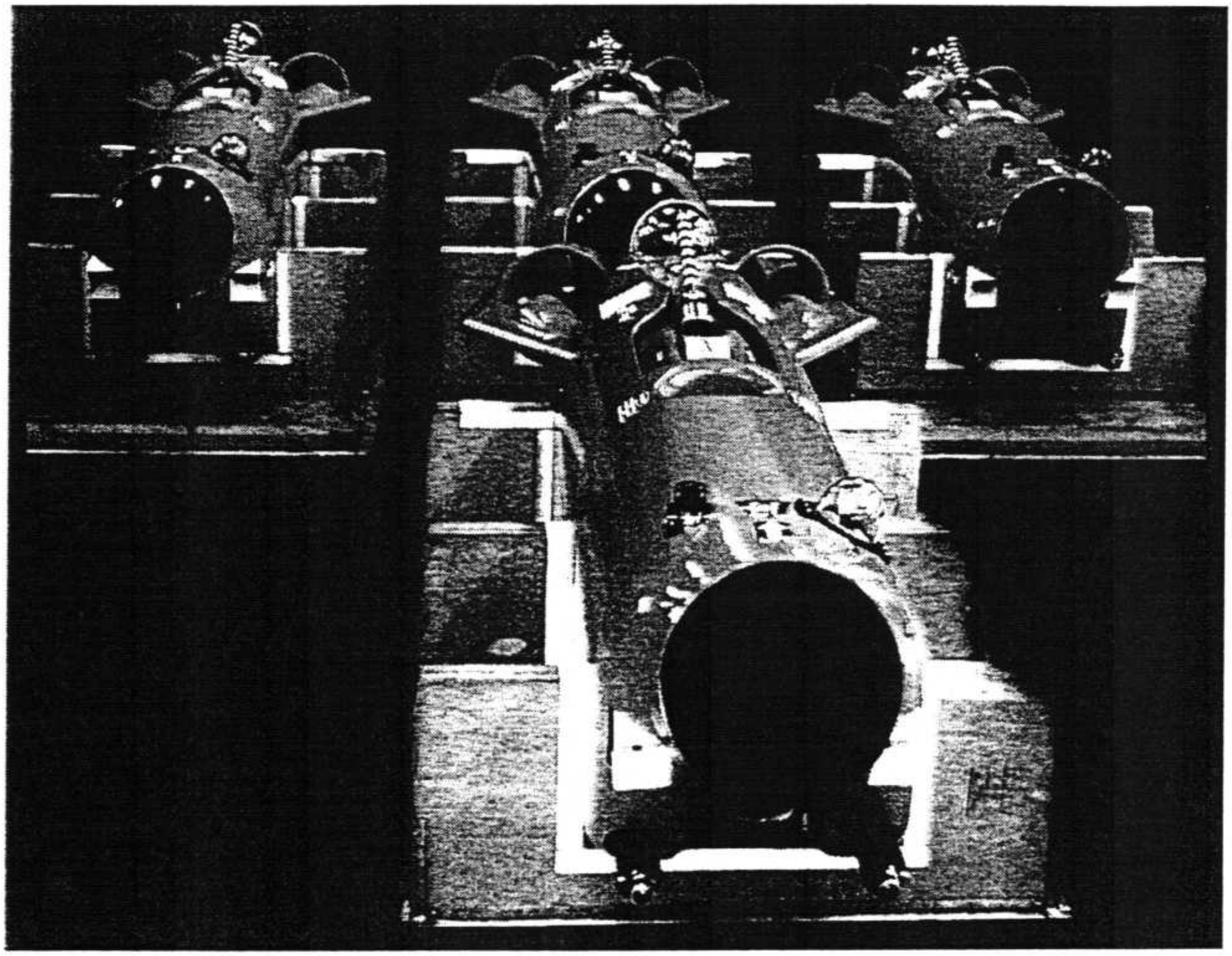
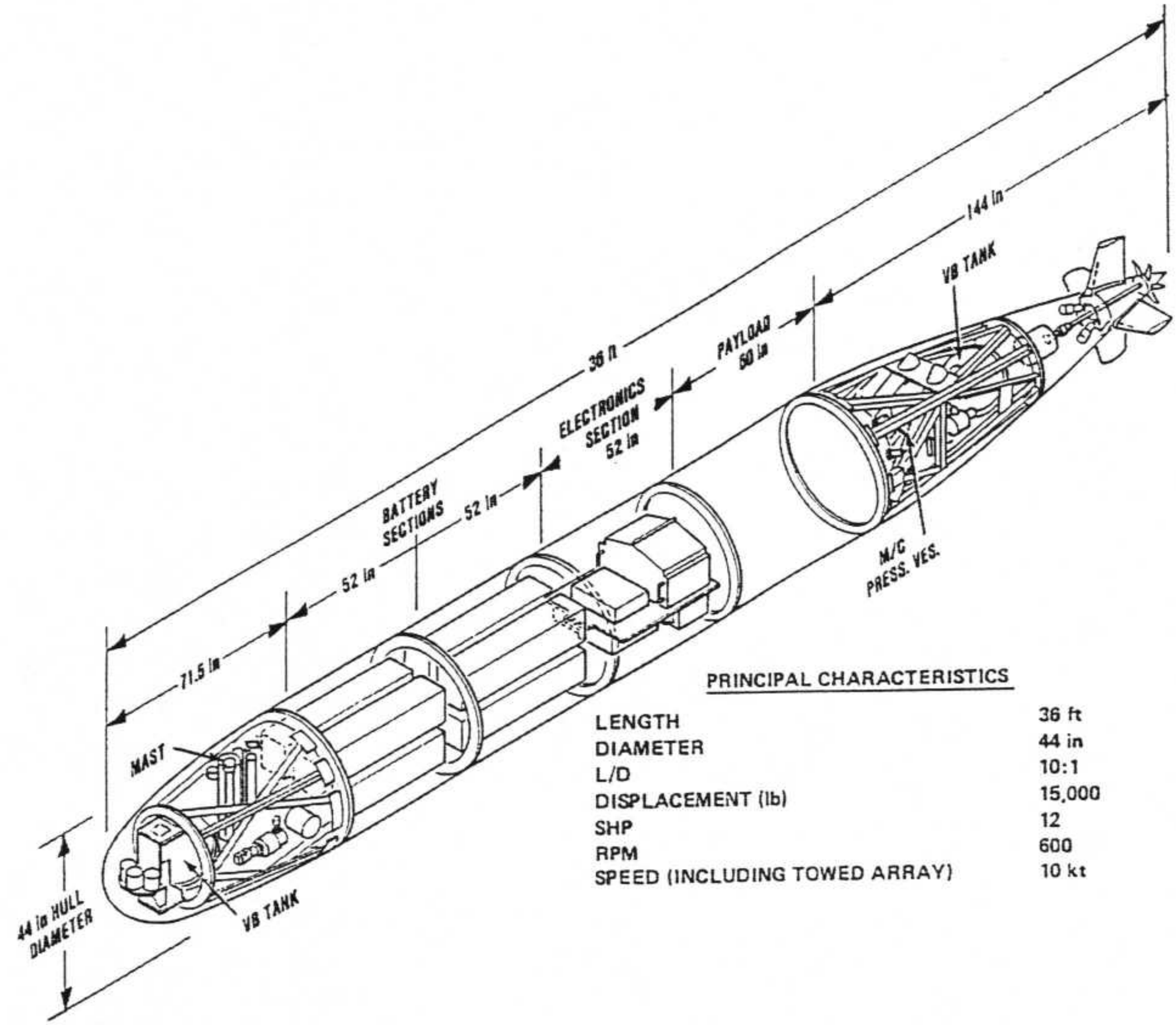


Figure 5. Mine Neutralization System

of nearly $24M U.S. The vehicle, Figure 6, weighs 15,000 pounds in air, can be operated to a depth of 1,500 feet and has an endurance of 24 hours at 10 knots. It has the capability to communicate via radio frequency, underwater acoustics or optical fiber cables.

Navigation is provided by a correlation velocity log and a doppler sonar. It uses silver zinc batteries with a rated capacity of 325 kWh. The structure uses a high cost rib-stiffened titanium pressure hull, in multiple sections, with a fiberglass fairing. The hull was designed to provide a 60 inch long payload volume for demonstration of various mission packages

The first of two primary missions that the vehicles have investigated was the TAS (Tactical Acoustic System), with the payload provided by Martin Marietta Aero and Naval Systems, which was a classified mission. The second demonstration was the Mine Search System (MSS) with the payload developed by Lockheed Missiles and Space Corporation, which included a mission controller, fiber optic tether and tether management



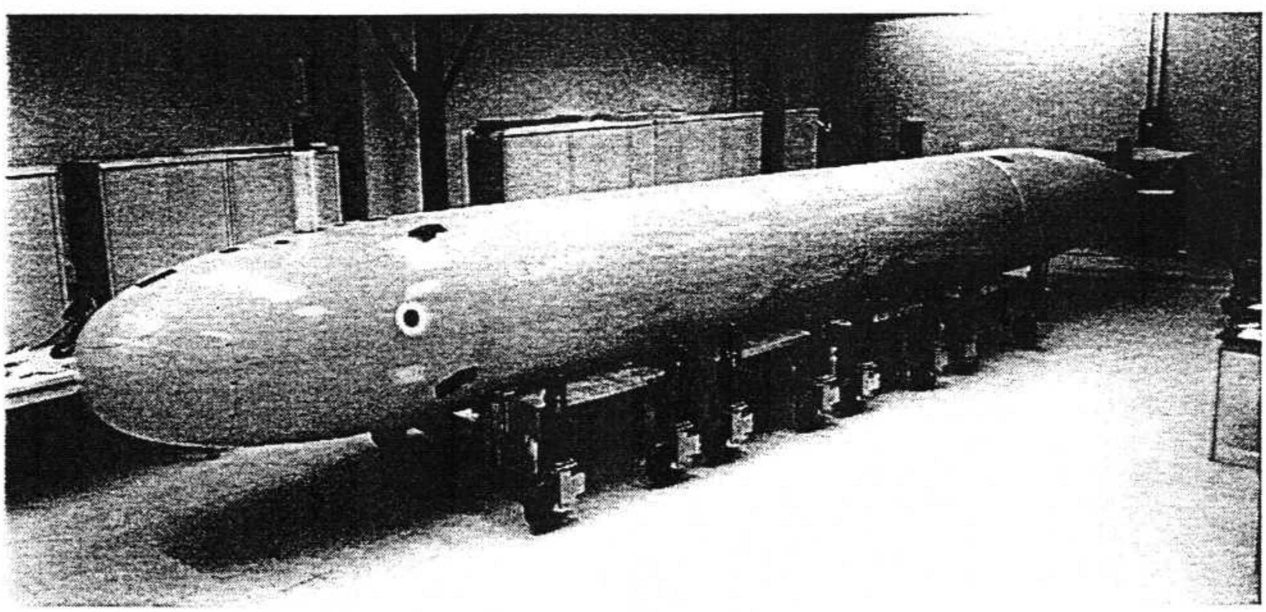


Figure 6. DARPA UUV

system. The mission also included a government supplied forward looking and side looking sonar system developed by ARL:UT. The goal was accurate reconnaissance and penetration of a suspected minefield and/or safe guidance of a submarine through a minefield while under semi-autonomous control. Other areas addressed include the Autonomous Minehunting and Mapping Technologies (AMMT) mission and evaluation of technologies including fuel cells and magnetic communications.

One of the communication technologies demonstrated by the vehicle included a laser communication system. This was demonstrated between the UUV and NRaD's USS DOLPHIN submarine off San Clemente Island, California, in 16 meter attenuation length water. A maximum data transmission rate of 100 Mbps was achieved at a range of 250 feet while transiting at 2.5 knots.

Naval Undersea Warfare Center Programs

NUWC is using/developing two UUV test beds for testing of UUV payloads and advanced technologies, many of which will be directly applicable to programs such as the LMRS. The two vehicles are the Large Diameter Unmanned Underwater Vehicle (LDUUV), Figure 7, and a 21 inch diameter torpedo size vehicle (21UUV), Figure 8.

The LDUUV is an electrically powered, torpedo shaped vehicle, 26.5 inches in diameter, and 300 inches long. It is fully autonomous, operates at speeds in the 4-12 knot range from depths ranging from 10 to 600 feet with an endurance of 30 nautical miles at 6 knots. Operational since 1993, the test bed is very quiet and thus capable of stealthy operation which allows testing of sonar systems, acoustic communication links and other systems requiring quiet operating conditions.

The 21UUV testbed is currently under development. It is a tactical sized UUV and will be used to integrate and test systems such as advanced mine countermeasure sensors and payloads, advanced energy storage and propulsion systems, signature reduction systems, and non-traditional navigation systems. Active research programs at NUWC include:

- The Thrust-Vectored Pump Jet (TVJP) with ARL/PSU.
- Acoustic Communication System.
- Intelligent Mission Controller with Texas A&M University.
- Low Speed Controller and Hydro-Dynamic Simulation.
- Variable Ballast System.
- UUV Motor System

Office of Naval Research Program

Among the many research programs of ONR is the Unmanned Undersea Vehicle Technology Program, located in the Engineering, Materials, and Physical Science & Technology Department. The program is targeting the following specific areas:

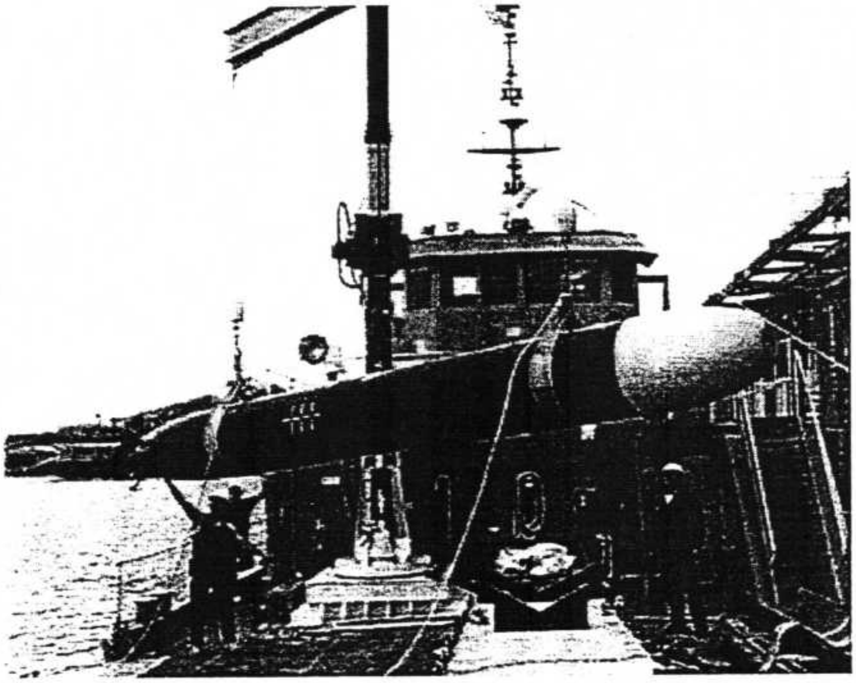


Figure 7. Large Diameter UUV

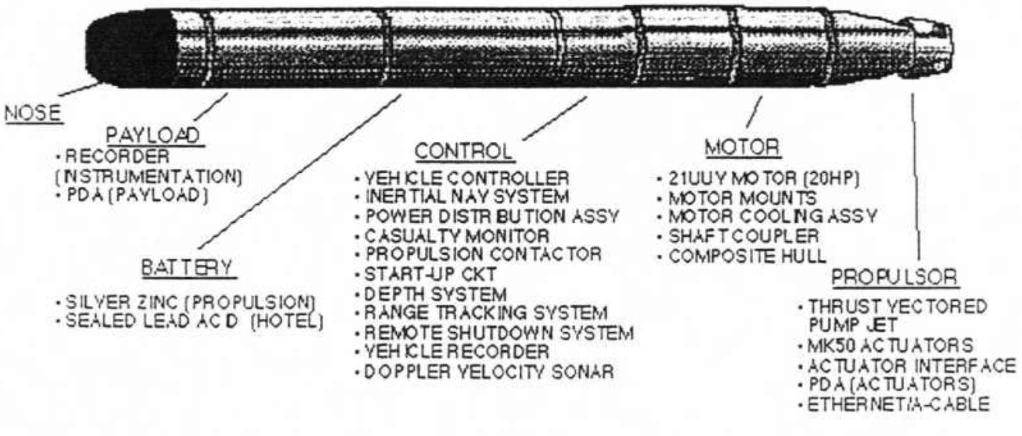


Figure 8. 21-Inch Diameter UUV

- Long Endurance Propulsion/Energy
- Sensors/Signal Processing
- Communications
- Mission Management Control
- Navigation
- Vehicle Design

The previous ONR technology programs appear throughout this paper. They will be tested on the NUWC LDUUV and 21UUV vehicles with the ultimate application the LMRS vehicles. The technology is also being developed at ARL/PSU, APL/UW, the Coastal Systems Station and the Woods Hole Oceanographic Institution (WHOI).

NRAD'S ROLE

Past

Although considerable reorganization has been performed within the Navy community, NRaD still retains its role as the lead Navy lab in ocean engineering. Past developments in ocean engineering have been highlighted by advances in the areas of fiber optic and acoustic communication links, non-metallic materials for deep pressure hulls and viewports, manipulator and work system development, command and control systems, and, in general, the in-house development of twenty-seven manned and unmanned undersea vehicles as shown in Table 1. The four vehicles developed in-house by the other Navy labs (other than towed or maneuverable grappling systems) were UFSS, RUMIC, CSTV, and LSV.

Present

It has been said that if one is too successful in research and development, he may eliminate his own job. Well, that is close to the case in the U.S. Navy, especially in the area of tethered ROVs - a mainstay of early NRaD R&D. In-house successes, and the subsequent transfer of technology to commercial firms - not to mention the additional advancements in industry - has established a mature technology base from which the Navy can procure needed ROV systems. However, that base does not exist in the autonomous underwater vehicle (AUV) arena. Thus, the Navy continues to develop technology and systems for AUVs. This work also continues at NRaD where the mainstays of command and control systems, fiber-optic and acoustic communication links, non-metallic materials, and general vehicle development continue. In addition, NRaD still maintains two AUV testbeds: FreeSwimmer II (FSII) and the Advanced Unmanned Search System (AUSS).

The FSII, Figure 9, is a torpedo sized AUV which can be used for autonomous vehicle research, or it can be controlled through a fiber optic microcable.

Remotely Operated Vehicles (ROV)	Year Completed
CURV I	1963
CURV IIA	1966
CURV IIB	1967
CURV IIIA	1969
CURV IIIB	1970
CURV IIIC	1971
SNOOPY	1973
ELECTRIC SNOOPY	1974
NAVFAC SNOOPY	1975
SCAT I	1973
SCAT II	1984
MNV	1977
RUWS	1975
FOCUS	1980
ATV	1992
NOZZLE PLUG	1979

Manned Vehicles	Year Completed
MORAY	1964
DEEPJEEP	1965
HIKINO	1966
DEEPVIEW	1972
MAKAKAI	1972
BTV	1970

Autonomous Underwater Vehicles (AUV)	Year Completed
AUSS I	1983
AUSS II	1990
FS I	1978
FS II	1983
MNV (AUSD)	1989

Table 1. NRaD Vehicle Development History

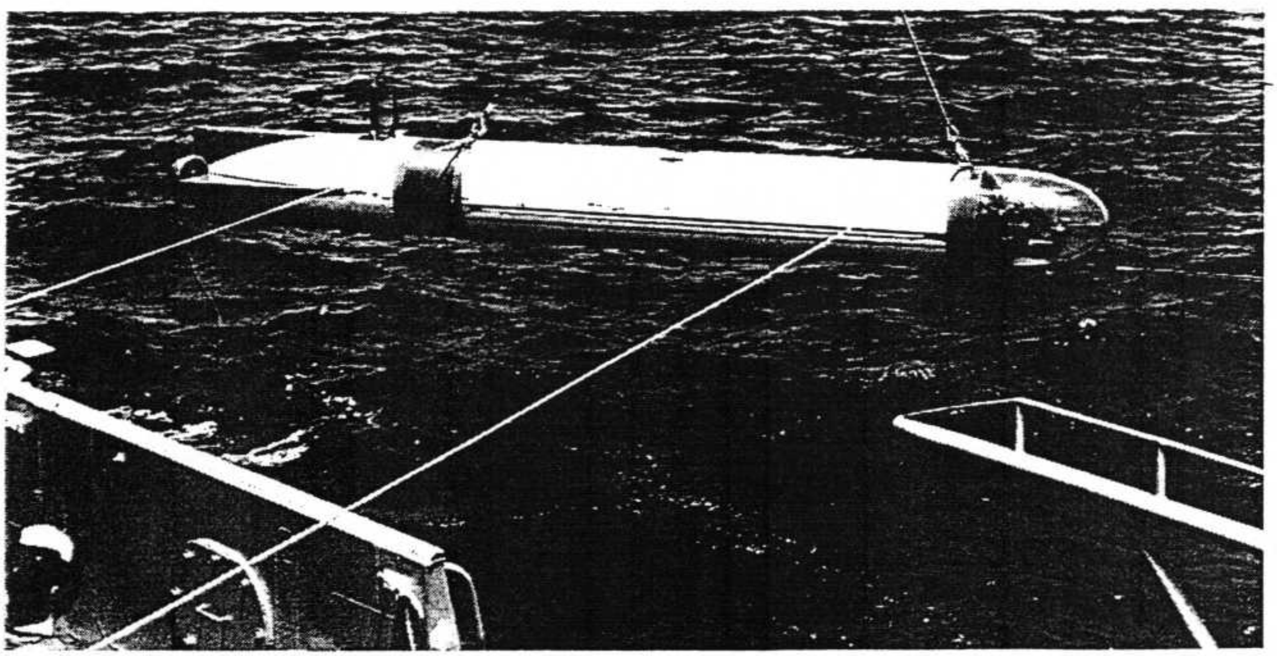


Figure 9. FreeSwimmer II

The AUSS, Figure 10, is by far the most advanced full ocean depth search system in the world today. With its acoustic communication link, it has the ability to transmit real time sidescan sonar data, or CCD television pictures, to the surface from depths of up to 20,000 feet. Due to its tetherless design, it can reduce the search time by an order of magnitude over conventional towed search systems. To date, AUSS (including its prototype version) has logged 134 dives, and is presently on standby for future R&D or operational tasks.

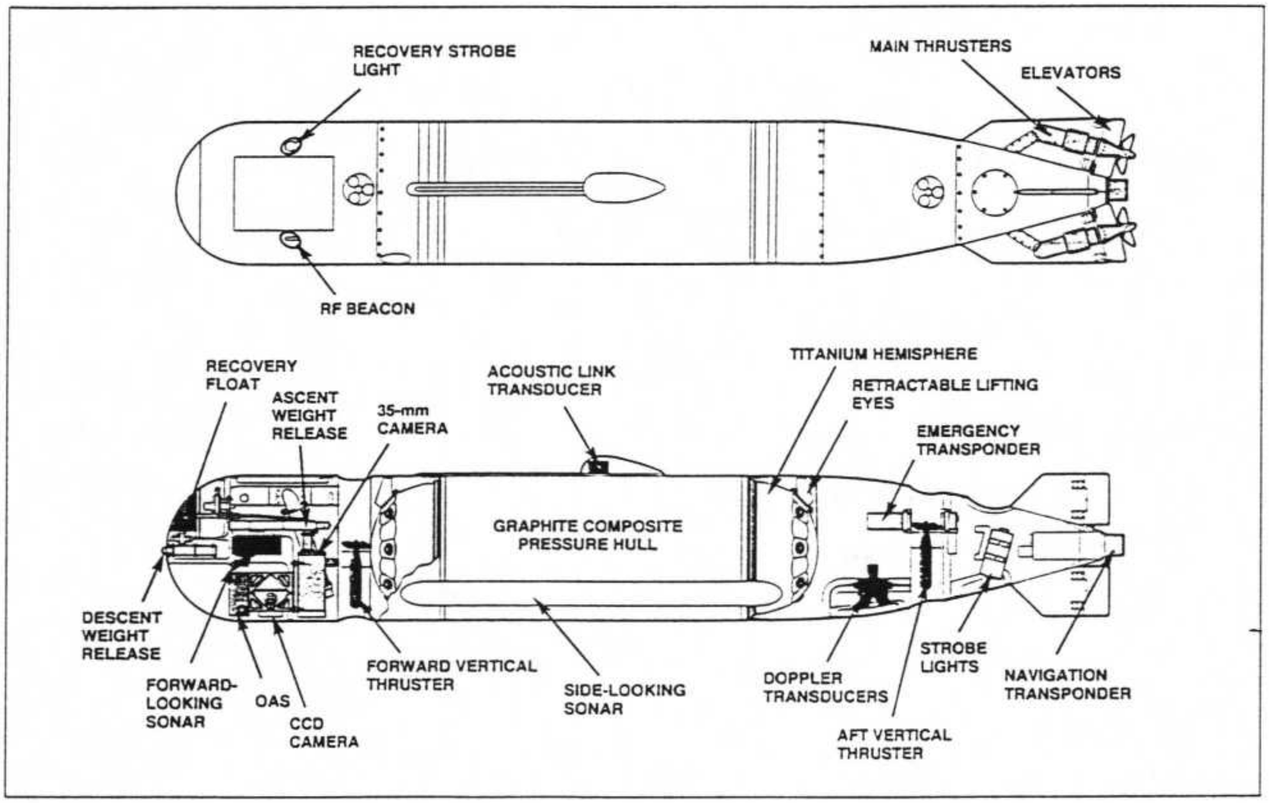
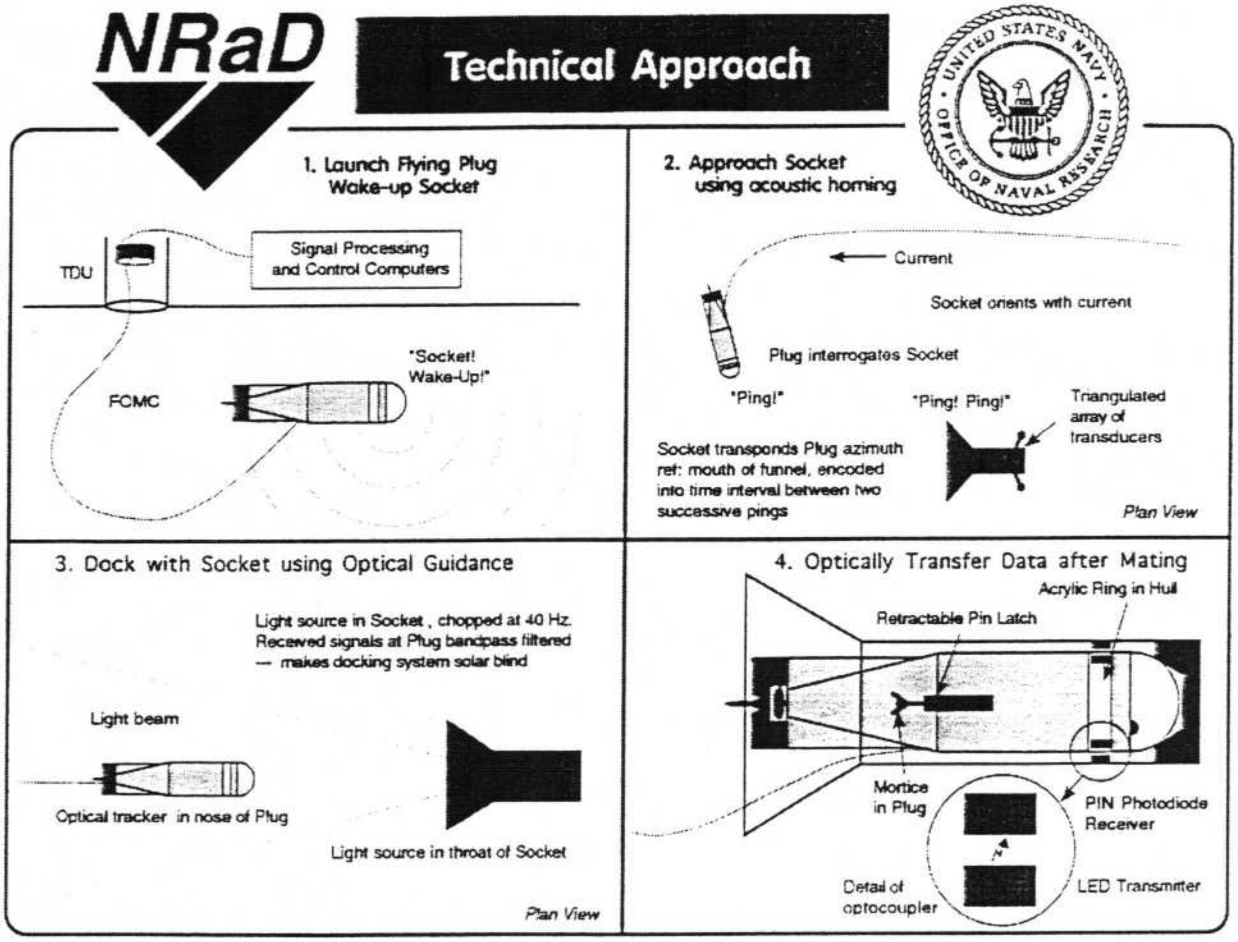


Figure 10. The Advanced Unmanned Search System

One other ongoing program at NRaD worth mentioning is the "Flying Plug" system which has been funded by ONR. The Flying Plug, Figure 11, is a small vehicle which, after being launched from an air, surface, or subsurface platform, deploys a fiber-optic micro-cable communication link. The vehicle then docks with an underwater "socket," completing the communication link between the platform and the underwater system, i.e. an underwater sensor network or surveillance system, from which the



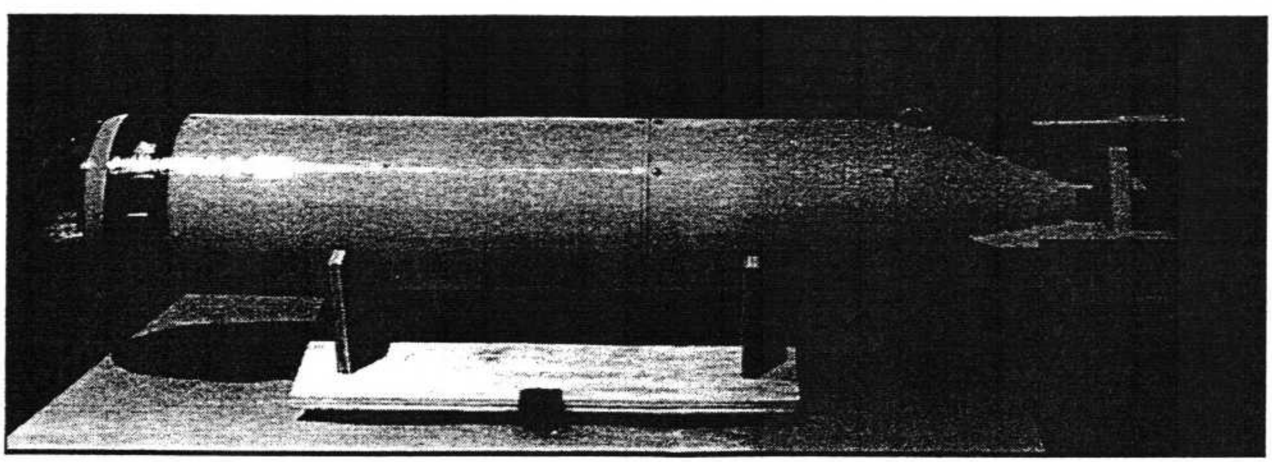


Figure 11. Flying Plug

platform will be able to transfer information at a very high data rate. The docking is accomplished through a combination of acoustic and optical homing sensors.

THE FUTURE

The world military outlook has moved from the deep ocean to the near shore environment because of the end of the cold war and the concern of conflicts along the shorelines of smaller nations. This new doctrine will be driven by quick response; with that comes the age of information warfare - ISR (intelligence, surveillance, and reconnaissance). Whether it is reconnaissance to help with the egress of submarines from their home ports or to watch others, the goal is to perform it covertly, and that provides the opening for unmanned vehicles. Just as space satellites perform this task from above the ocean, unmanned vehicles will play the role of ocean satellites and perform it silently from below in the future - as innerspace satellites.

The need for UUVs have been addressed within the Navy, the missions of the laboratories have been "purified" to eliminate duplication of effort, and funding is beginning to appear to support the future integration of unmanned technology into the Navy's arsenal. As with tethered ROVs, UUV technology - especially that for autonomous systems - will mature within the Navy R&D system, and eventually work its way into commercial applications. Transitioning this technology from adolescence to maturity will revolve around the availability of adequate funding, because the infrastructure within the Navy is in place and ready to respond to the needs of the future.