The Naval Research Laboratory

NRL—Our Heritage

Today, when government and science seem inextricably linked, when virtually no one questions the dependence of national defense on the excellence of national technical capabilities, it is noteworthy that in-house defense research is relatively new in our Nation's history. The Naval Research Laboratory (NRL), the first modern research institution created within the United States Navy, began operations in 1923.

Thomas Edison's Vision: The first step came in May 1915, a time when Americans were deeply worried about the great European war. Thomas Edison, when asked by a *New York Times* correspondent to comment on the conflict, argued that the Nation should look to science. "The Government," he proposed in a published interview, "should maintain a great research laboratory....In this could be developed...all the technique of military and naval progression without any vast expense." Secretary of the Navy Josephus Daniels seized the opportunity created by Edison's public comments to enlist Edison's support. He agreed to serve as the head of a new body of civilian experts—the Naval Consulting Board—to advise the Navy on science and technology. The Board's most ambitious plan was the creation of a modern research facility for the Navy. Congress allocated $1.5 million for the institution in 1916, but wartime delays and disagreements within the Naval Consulting Board postponed construction until 1920.

The Laboratory's two original divisions—Radio and Sound—pioneered in the fields of high-frequency radio and underwater sound propagation. They produced communications equipment, direction-finding devices, sonar sets, and perhaps most significant of all, the first practical radar equipment built in this country. They also performed basic research, participating, for example, in the discovery and early exploration of the ionosphere. Moreover, the Laboratory was able to work gradually toward its goal of becoming a broadly based research facility. By the beginning of World War II, five new divisions had been added: Physical Optics, Chemistry, Metallurgy, Mechanics and Electricity, and Internal Communications.

The War Years and Growth: Total employment at the Laboratory jumped from 396 in 1941 to 4400 in 1946, expenditures from $1.7 million to $13.7 million, the number of buildings from 23 to 67, and the number of projects from 200 to about 900. During WWII, scientific activities necessarily were concentrated almost entirely on applied research. New electronics equipment—radio, radar, sonar—was developed. Countermeasures were devised. New lubricants were produced, as were antifouling paints, luminous identification tapes, and a sea marker to help save survivors of disasters at sea. A thermal diffusion process was conceived and used to supply some of the ^{235}U isotope needed for one of the first atomic bombs. Also, many new devices that developed from booming wartime industry were type tested and then certified as reliable for the Fleet.

NRL Reorganizes for Peace: Because of the major scientific accomplishments of the war years, the United States emerged into the postwar era determined to consolidate its wartime gains in science and technology and to preserve the working relationship between its armed forces and the scientific community. While the Navy was establishing its Office of Naval Research (ONR) as a liaison with and supporter of basic and applied scientific research, it was also encouraging NRL to broaden its scope and become, in effect, its corporate research laboratory. There was a transfer of NRL to the administrative oversight of ONR and a parallel shift of the Laboratory's research emphasis to one of long-range basic and applied investigation in a broad range of the physical sciences.

However, rapid expansion during the war had left NRL improperly structured to address long-term Navy requirements. One major task—neither easily nor rapidly accomplished—was that of reshaping and coordinating research. This was achieved by transforming a group of largely autonomous scientific divisions into a unified institution with a clear mission and a fully coordinated research program. The first attempt at reorganization vested power in an executive committee composed of all the division superintendents. This committee was impracticably large, so in 1949, a civilian director of research was named and given full authority over the program. Positions for associate directors were added in 1954.

The Breadth of NRL: During the years since the war, the areas of study at the Laboratory have included basic research concerning the Navy's environments of Earth, sea, sky, and space. Investigations have ranged widely—from monitoring the Sun's behavior to analyzing marine atmospheric conditions to measuring parameters of the deep oceans. Detection and communication capabilities have benefitted by research that has exploited new portions of the electromagnetic spectrum, extended ranges to outer space, and provided a means of transferring information reliably and securely, even through massive jamming. Submarine habitability, lubricants, shipbuilding materials, fire fighting, and the study of sound in the sea have remained steadfast concerns, to which have been added recent explorations within the fields of virtual reality, superconductivity, and biomolecular science and engineering.

The Laboratory has pioneered naval research into space from atmospheric probes with captured V-2 rockets through direction of the *Vanguard* project—America's first satellite program—to inventing and developing the first satellite prototypes of the Global Positioning System. Today NRL is the Navy's lead laboratory in space systems research, fire research, tactical electronic warfare, microelectronic devices, and artificial intelligence.

The consolidation in 1992 of NRL and the Naval Oceanographic and Atmospheric Research Laboratory, with centers at Bay St. Louis, Mississippi, and Monterey, California, added critical new strengths to the Laboratory. NRL now is additionally the lead Navy center for research in ocean and atmospheric sciences, with special strengths in physical oceanography, marine geosciences, ocean acoustics, marine meteorology, and remote oceanic and atmospheric sensing. The expanded Laboratory is focusing its research efforts on new Navy strategic interests and needs in the post-Cold War world. Although not abandoning its interests in blue-water operations and research, the Navy is also focusing on defending American interests in the world's littoral regions. NRL scientists and engineers are working to give the Navy the special knowledge and capabilities it needs to operate in these waters.

1999 in Review

In this last year of the century, NRL researchers continued to carry out innovative research across a broad swath of the physical sciences. In a further indication of the international state of post-Cold War science, researchers from the Laboratory's Marine Geosciences Division and the Materials Science and Technology Division participated in a research cruise to the Greenland-Norwegian Sea, with scientists from Russia, Germany, and Norway. The Russian oceanographic vessel *Akademik Mstislav Keldysh* served as home to the multinational team. The Americans investigated sites on the ocean floor where methane gas, hydrogen sulfide gas, and porewater are squeezed into the water column. Additionally, they looked for the presence of methane hydrates, whose presence in the sub-seafloor can affect acoustic propagation and which are also a future fuel source. The Greenland-Norwegian Sea has been a continuing site of research interest for NRL scientists.

In another area of historic research interest to NRL scientists, that of the ionosphere and near space, Laboratory researchers have developed a suite of ultraviolet and X-ray sensing instruments for use onboard the Air Force Space Test Program's Advanced Research and Global Observation Satellite (ARGOS). Observational data from the instruments, along with radio measurements of total electron content, will study the changing effects of solar radiation on the upper atmosphere and ionosphere. Scientists will thereby be able to create dynamic maps of the ionosphere, showing changes in chemistry, density, and temperature. ARGOS carries nine primary experiments with 31 different sensors and subexperiments. Five of the primary experiments were developed by NRL researchers and another two were developed with NRL collaboration. Laboratory scientists have been involved in scientific study of the ionosphere since the path-breaking research of E.O. Hulburt and A.H. Taylor on radio propagation in the upper atmosphere in the mid-1920s.

One of ARGOS's primary sensors was developed by NRL's Naval Center for Space Technology. This, the High Temperature Superconductivity Space Experiment (HTSSE), has as its mission demonstrating the feasibility of incorporating high-temperature superconductivity components into space-based sensors. Operating at about –200 °C, these components hold the promise of offering greatly increased capa-

After the Reading of Orders, CAPTs Rau and Buckley perform the Passing of Command.

bilities for microwave components and improved communications and signal processing onboard satellites. NRL initiated the HTSSE program in 1998.

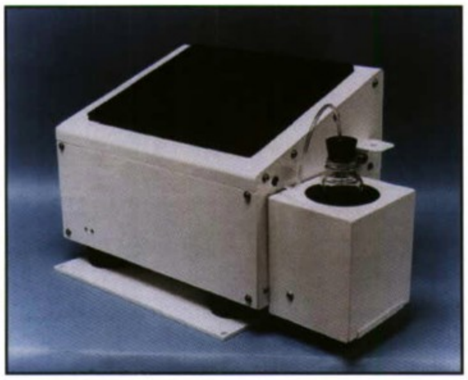
In yet another satellite-based experiment, NRL's Polar Ozone and Aerosol Measurement (POAM) III detector successfully monitored the evolving high-altitude plume from the eruption of the Shishaldin volcano in the Aleutian Islands. POAM measures vertical profiles of the atmosphere, and during the spring of 1999 it detected enhanced amounts of aerosols or particles in narrow layers. On April 23, POAM showed volcanic aerosols as high as 17 km, and from these observations NRL scientists have inferred that the plume was lofted as high as 19 km. The altitude and evolution of volcanic ash plumes are important because of the hazard they present to aviation. The POAM program has provided valuable insights into a variety of polar atmospheric processes, including the possible destruction of Arctic ozone and the development of ozone holes.

Scientists within NRL's Chemistry and Optical Sciences Divisions have developed composite aerogels for use as high-surface-area electrodes, catalysts, battery structures, and advanced thermoelectric materials, and as architectures around which to design chemical, physical, and optical sensors. Aerogels provide high surface areas and highly open spaces. This makes them well-suited to catalytic and sensing applications where rapid transport of reactants and large accessible surface areas are critical. The NRL researchers have developed design flexibility and expanded the range of aerogel properties by using colloidal silica sol, the gel's building block, as a nanoglue to trap suspended particles or colloids into the network of the wet gel. This technique has been successful in producing composite aerogels of silica with a range of physically and chemically diverse particulates. When the second phase of the composite is present above a certain threshold, its transport characteristics are imparted to the composite aerogel, even though it retains the low density and openness characteristic of pure silica aerogels.

Within the Laboratory's Optical Sciences Division, researchers have demonstrated a new diamond-pressure bonding (DPB) technique for heat-sinking semiconductor lasers, resulting in record-breaking performances. The new DPB technique greatly enhances the maximum continuous-wave operating temperature for optically pumped semiconductor lasers. It permits devices with their epitaxial sides adjacent to the heat sink to be illuminated from the top, and DPB is more convenient than conventional epitaxial-side-down heat-sinking procedures. When the technique is applied to the optical-pumping of mid-infrared type-II quantum well lasers emitting wavelengths between 3.0 and 7.0 microns, the method yields maximum continuous wave operating temperatures that significantly exceed any reported for semiconductor lasers in the same wavelength range.

Finally, in continuing efforts at NRL to produce environmentally safe materials, the Laboratory has negotiated a Project Arrangement between the U.S. and Canadian departments of defense. The objective of the project is to qualify high-velocity, oxygen-fuel (HVOF) thermal spray coatings as a viable replacement for hard chrome plating on military aircraft components. It is expected that by the conclusion of the project, HVOF thermal spray coatings will be in production within both the U.S. and Canada, resulting in both a cleaner environment and the savings of millions of dollars in maintenance costs. Chrome plating uses hexavalent chromium, which is a highly toxic carcinogen. Increasingly stringent environmental and worker-safety regulations are making chrome plating more expensive for manufacturers and the Department of Defense. HVOF thermal spraying is capable of depositing metal alloy, ceramic/metal composite, and polymer coatings rapidly and to thicknesses comparable to those of chrome plating without the environmental drawbacks. The HVOF development work was carried out within NRL's Chemistry Division.

Technology Transfer: During 1999, NRL's Technology Transfer Office continued to facilitate the implementation of NRL technology for commercial use and to benefit the civilian community. The two principal mechanisms for transfer of NRL technology and expertise are Cooperative Research and Development Agreements (CRADAs) and licenses to



Under license from NRL, Lockheed Martin markets the LaserNet Fines system for automated online analysis of wear particle debris in engine lubricants. The small size of the system makes it ideal for deployment on ships, at field sites, and on factory floors where it can be used to assess machine condition and assist in the implementation of a proactive machine maintenance program to prevent operational failures.

NRL's James Yesinowski and colleagues Robert Kleinberg from Schlumberger-Doll Research and Peter Brewer and George Molby from the Monterey Bay Aquarium Research Institute prepare a low field proton nuclear magnetic resonance instrument for future deployment on a remotely operated submersible vehicle to study the formation of solid gas hydrates in the deep ocean.

NRL patents. NRL signed CRADAs in 1999 on topics ranging from fundamental investigations with long-term prospects for commercialization to projects that involved the implementation of mature technology developed for defense use into commercial systems. NRL also used the CRADA mechanism to formalize its participation in a project aimed at educating schoolchildren about space science.

Under the scope of a CRADA with Utah State University, NRL worked with the NASA Space Grant Consortium on Project Starshine. NRL assisted in fabricating the Starshine satellite, which was covered with 878 reflective aluminum mirrors polished by schoolchildren around the world. After its launch by NASA in May 1999 on the Space Shuttle, students worldwide were able to make measurements, which were exchanged via the Internet, to calculate the satellite's orbit and various atmospheric parameters.

In a more commercial application of NRL technology, NRL is working with several companies to transition its Matrix Assisted Pulsed Laser Evaporation (MAPLE) and MAPLE Direct Write technologies for the deposition of thin film materials. For example, YSI, Inc., has entered into a CRADA to develop and evaluate chemical sensors using NRL's deposition technology and polymer chemistry expertise. NRL has also entered into a CRADA with Potomac Photonics to develop a commercial tool for fabricating electronic devices by MAPLE Direct Write. Both companies have expressed an interest in licensing NRL's patents on the technology.

An excellent example of commercial interest in NRL technology, originally developed for military purposes, is the application of software to the automated assembly of automobiles. This particular software determines the location and orientation of an object from range data. A CRADA has been signed by NRL and members of a joint venture that includes the Ford Motor Company, Perceptron, Inc., and Microdexterity Systems, Inc., with funds provided in part by an Advanced Technology Program funded by the National Institute of Standards and Technology. Under the agreement, NRL will assist in developing software for a vision system that will be part of a robotic tool for assembling automobiles.

Among NRL's CRADAs directed at fundamental research is an agreement whereby NRL, Schlumberger Technology Corporation, and the Monterey Bay Aquarium Research Institute (MBARI) will perform in situ experiments on the seafloor to study gas hydrate formation. The results will help understand these widespread, but hard to reach, materials and possibly lead to new energy sources for the future.

Lockheed Martin signed a license with the Navy in 1999 for NRL's LaserNet Fines Oil Debris Monitor, which was originally developed for Navy condition-based maintenance programs. The LaserNet Fines system uses laser imaging technology and wear particle analysis software to perform online measurements of wear debris in engine lubricants.

Also in 1999, NRL licensed its portfolio of patents on tip-based probes for measuring the nanomechanics of surfaces and single molecules to Graviton, Inc. Graviton will commercialize high-resolution chip devices for rapid identification of compounds of importance to the environmental, diagnostic, and drug discovery industries.

NRL Today

ORGANIZATION AND ADMINISTRATION

The Naval Research Laboratory is a field command under the Chief of Naval Research, who reports to the Secretary of the Navy via the Assistant Secretary of the Navy for Research, Development and Acquisition.

Heading the Laboratory with joint responsibilities are CAPT Douglas H. Rau, USN, Commanding Officer, and Dr. Timothy Coffey, Director of Research. Line authority passes from the Commanding Officer and the Director of Research to three Associate Directors of Research, a Director of the Naval Center for Space Technology, and an Associate Director for Business Operations. Research divisions are organized under the following functional directorates:

- Systems
- Materials Science and Component Technology
- Ocean and Atmospheric Science and Technology
- Naval Center for Space Technology.

NRL operates as a Navy Working Capital Fund (NWCF). All costs, including overhead, are charged to various research projects. Funding in FY 99 came from the Chief of Naval Research, the Naval Systems Commands, and other Navy sources; government agencies, such as the U.S. Air Force, the Defense Advanced Research Projects Agency, the Department of Energy, and the National Aeronautics and Space Administration; and several nongovernment activities.

PERSONNEL DEVELOPMENT

At the end of FY 99, NRL employed 3003 persons—50 officers, 127 enlisted, and 2826 civilians. In the research staff, there are 840 employees with doctorate degrees, 396 with masters degrees, and 570 with bachelors degrees. The support staff assists the research staff by providing administrative, computer-aided design, machining, fabrication, electronic construction, publication, personnel development, information retrieval, large mainframe computer support, and contracting and supply management services.

Opportunities for higher education and other professional training for NRL employees are available through several programs offered by the Employee Development Branch. These programs provide for graduate work leading to advanced degrees, advanced training, college course work, short courses, continuing education, and career counseling. Graduate students, in certain cases, may use their NRL research for thesis material.

NRL main site, located off Interstate 295 in S.W. Washington, D.C., as viewed from the Potomac River.

For non-NRL employees, several postdoctoral research programs exist. There are also agreements with several universities for student opportunities under the Student Career Experience Program (formerly known as Cooperative Education), as well as summer and part-time employment programs. Summer and interchange programs for college faculty members, professional consultants, and employees of other government agencies are also available.

NRL has active chapters of Women in Science and Engineering, Sigma Xi, Toastmasters International, Federally Employed Women, and the Federal Executive and Professional Association. Three computer clubs meet regularly—NRL Microcomputer User's Group, NeXT, and Sun NRL Users Group. An amateur radio club, a drama group (the Showboaters), and several sports clubs are also active. NRL has a Recreation Club that provides basketball and softball leagues and swim, sauna, whirlpool bath, gymnasium, and weight-room facilities. The Recreation Club also offers classes in martial arts, aerobics, swimming, and water walking.

The Community Outreach Program traditionally has used its extensive resources to foster programs that provide benefits to students and other community citizens. Volunteer employees assist with and judge science fairs, give lectures, and serve as tutors, mentors, coaches, and classroom resource teachers. The program also sponsors African American History Month art and essay contests for local schools, student tours of NRL, a student Toastmasters Youth Leadership Program, an annual holiday party for neighborhood children in December, a computer transfer program that provides surplus computers and peripherals to partnership schools, and a book donation program for both students and teachers. Through the Community Outreach Program, NRL has active partnerships with four District of Columbia, three Aberdeen, Maryland, and three Calvert County, Maryland, public schools.

NRL has an active, growing Credit Union. Since its creation in 1946, NRL Federal Credit Union (NRL FCU) has grown to over $200 million in assets and serves about 23,000 NRL employees, contractors, and their families. NRL FCU is a leader in providing innovative financial services such as a dynamic home page and Online Access (Internet home banking) with bill payer. Focusing on the credit union philosophy of *People Helping People*, NRL FCU offers a wide array of no-fee services plus financial education and assistance. NRL FCU is a full service financial institution providing various mortgage programs and creative lending services. For information about membership or any financial service, call (301) 839-8400 or click www.nrlfcu.org.

Public transportation to NRL is provided by Metrobus. Metrorail service is three miles away.

For more information, see the *NRL Review* chapter, "Programs for Professional Development."

SCIENTIFIC FACILITIES

In addition to its Washington, D.C., campus of about 130 acres and 102 main buildings, NRL maintains 14 other research sites, including a vessel for fire research and a Flight Support Detachment. The many diverse scientific and technological research and support facilities are described in the following paragraphs.

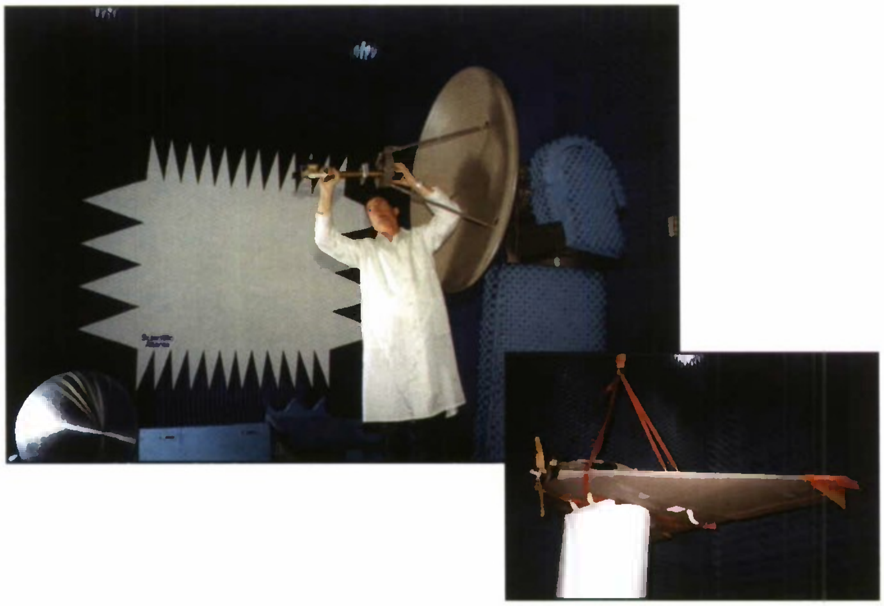
RESEARCH FACILITIES

Radar

NRL has gained worldwide renown as the "birthplace of radar" and, for a half-century, has maintained its reputation as a leading center for radar-related research and development. A number of facilities managed by NRL's Radar Division continue to contribute to this reputation.

A widely used major facility is the Compact Antenna Range (operated jointly with the Space Systems Development Department) for antenna design and development, as well as radar cross section measurements. The range is capable of simulating farfield conditions from 1 to 110 GHz with a quiet zone of approximately 7 ft in diameter and 8 ft in length. Instrumentation covers from 1 to 95 GHz. Another strong division capability is in the Computational Electromagnetics (CEM) Facility, which has capabilities for complex electromagnetic modeling, including radar target and antenna structures. The Radar Signature Calculation Facility within this group produces detailed computations of radar cross sections of various targets, primarily ships. The CEM facility includes multiple-cpu supercomputers that are also used to design phased array radar antennas. There is tremendous synergism between the CEM group and the Compact Range Facility. This provides the ability to design in the CEM environment, test in the compact, and have immediate feedback between the theoretical and experimental aspects to shorten the development cycle for new designs.

In connection with airborne radar, the division operates a supercomputer-based Radar Imaging Facility, and an inverse synthetic aperture radar (ISAR) deployed either in the air, on the ground, or aboard ship for radar-imaging data collection. A P-3 aircraft equipped with the AN/APS-145 radar and cooperative engagement capability is also available for mounting experiments.



A view of the interior of the compact range, with the primary reflector in the background. In the foreground, an antenna assembly is being readied for testing on the range positioner, while the inset photo shows a small unmanned aerial vehicle as it undergoes radar cross section measurements.

In connection with ship-based radar, the division operates a Radar Test Bed Facility at the Chesapeake Bay Detachment (CBD), Randle Cliffs, Maryland. Represented are radars for long-range air search, point defense, and surface search functions. The point defense radar, with its large (4 ft × 8 ft) X-band phased array antenna, and the ANSPQ-9B ADM systems are designed to be mobile so that testing is not limited to this specific environment.

Other installations operated by the division include an Electromagnetic Compatibility (EMC) Facility supported by a mode-stirred chamber, and a Computer-aided Engineering (CAE) Facility. The microwave microscope, a high-resolution (2-cm) capability for investigating backscatter from both surface and volumetric clutter is now operational, and a millimeter-wave radar system operating in the 94 GHz region is currently being developed. The division provides direct technical support and has direct access to data from the AN/TPS-71, the Navy's relocatable over-the-horizon radar. Concepts and engineering developments in connection with target identification are explored by using an experimental Cooperative Aircraft Identification system.

Information Technology

The Information Technology Division (ITD) is at the forefront of DoD research and development in artificial intelligence, telecommunications, computer networking, human-computer interaction, information security, parallel computation, and computer science.

The division maintains local area computer networks to support its research and hosts testbeds for advanced high-performance fiber-optic network research. These networks make available hundreds of high-performance computers to local and remote users. The ITD research networks connect to NRL's internal network via high-speed links ranging from DS-3 (45 Mbps) links on NASA Science Internet (NSI); to OC-03c on DREN/S-DREN; to OC-48c (2.4 Gbps) on ATDnet. The ATDnet is a metropolitan ATM network that supports advanced network research at OC-48c speeds and higher; other major partners include the National Aeronautics and Space Administration, the National Security Agency, the Defense Intelligence Agency, the Defense Advanced Research Projects Agency, and the Defense Intelligence Security Agency. Research on ATDnet includes introduction and testing of new networking protocols; wave division multiplexing to greatly increase network capacity; and the evolution to all-optical networks, with switching at the optical layer. Research on the high-end computational assets and networks result in close association with applications that demand these leading-edge capabilities and have allowed ITD to achieve significant results in a number of areas. These include current efforts in pushing the state of the art in motion imagery with progressive scan in high-definition TV (HDTV) where 1.5 Gbps data streams are needed to handle the raw output. The Defense Re-

The 128-processor Silicon Graphics Origin2000 system, currently with 128 Mbytes of RAM. The NRL Center for Computational Science, as a Distributed Center of the DoD High Performance Computing Modernization Program, provides such systems (at no cost) for anyone approved by the Program Office. The NRL CCS routinely upgrades high-end computing resources such as this.

search and Engineering Network (DREN) is a high-speed continental United States network that connects the four Major Shared Resource Centers (MSRCs) and fifteen Distributed Centers (DCs) of DDR&E's High Performance Computing Modernization Program (HPCMP) as well as a number of user organizations that use the HPCMP resources.

As a Distributed Center in the HPCMP, ITD's Center for Computational Science supports a range of shared resources including massively parallel computer systems and high-performance networks. Current systems include an SGI Origin2000 with 128 processors and 128 Gbytes of memory; an HP Exemplar SPP-2000 with 80 processors and 20 Gbytes of memory; and a Sun HPC Ultra with 148 distributed processors and 30 Gbytes of memory. The CCS also has more than 2.5 Tbytes of on-line shared rotating disk and robotic storage systems for fileserving and archiving that hold 300 Tbytes of multimedia data but are scalable to over a Petabyte. The Scientific Visualization Laboratory in CCS provides general support across NRL to assist scientists and engineers in producing visual renderings of their work. The Center manages the NRL local area network, NICEnet, which is transitioning from the older FDDI and shared Ethernet local area networks to a fully switched environment based on ATM backbones and both Fast Ethernet and ATM to the users's desktops. The evolutionary goal is to provide digital transparency of resources with security across the information infrastructure—from globally available archives, to the computational engines, to the networks that bring it all together at 10 Gbps directly to the desktops of the most demanding users in 2001. NICEnet provides external connections to other networks and to the Internet.

The division facilities also include an Information Security Engineering Laboratory, a Robotics Laboratory, a high-data-rate multimedia satellite transmission facility, and an experimental facility with special displays, eye and gesture trackers, and speech I/O devices for research in human/computer interaction. Laboratories for the development and testing of communication and network protocols both for Internet Protocols (IP) and ATM research are also included. These network testbeds are routinely interfaced to the DoD wide-area research networks for collaboration with other government laboratories. A wireless networking testbed is being used to develop Mobile Ad Hoc Networking (MANET) standards that can meet a wide range of military and commercial needs.

The Virtual Reality (VR) Laboratory provides the facilities and expertise to allow NRL scientists to use virtual reality in a variety of scientific investigations. Research areas include shipboard firefighting, simulation-based design, command, and control, and scientific visualization. A number of high-speed graphics workstations, including Onyx Reality Engine 2 and Infinite Reality computers, and a variety of VR peripherals comprise the VR Lab computer equipment inventory.

Current VR technologies available include desktop VR systems, head-mounted displays (HMDs), the Responsive Workbench, and the surround-screen Immersive Room. The Responsive Workbench is an interactive 3-D tabletop environment that displays computer-generated, stereographic images on the workbench surface for use in battlespace situation awareness, simulation-based design, and other applications. The surround-screen Immersive Room is a multiuser, high-resolution 3-D visual and audio environment that projects computer-generated images onto three walls and the floor to create an immersive, large-scale, shared virtual environment. It uses an SGI Onyx RE2 so scientists can interact and control their supercomputing calculations in real time.

The NEWAVE facility has been developed as a multiscreen distributed simulation laboratory and viewport. Powered by SGI and Pentium workstations and linked to the NRL parallel computing facilities with ATM/SONET networking, the facility is capable of handling high-performance computing, graphics, and distributed simulation.

Optical Sciences

The Optical Sciences Division has a broad program of basic and applied research in optics and electro-optics. Areas of concentration include fiber optics, integrated optical devices, signal processing, optical information processing, fiber-optic and infrared sensors, laser development, surveillance, and reconnaissance.

The division occupies some of the most modern optical facilities in the country. This includes an Ultralow-loss, Fiber-Optic Waveguide Facility using high-temperature infrared glass technology. There is also a Focal-Plane Evaluation Facility to measure the optical and electrical characteristics of infrared focal-plane arrays being developed for advanced Navy sensors. The IR Missile-Seeker Evaluation Facility performs open-loop measurements of the susceptibilities of IR tracking sensors to optical countermeasures. The Large-Optic, High-Precision Tracker system is used for atmospheric transmission and target signature measurements.

There are several fiber-optic sensor facilities with fiber splicers, an acoustic test cell, a three-axis magnetic sensor test cell, equipment for evaluating optical fiber coatings, and various computers for concept analysis. The Digital Processing Facility is used to collect, process, analyze, and manipulate infrared data and imagery from several sources. The Emittance Measurements Facility performs measurements of directional hemispherical reflectance. An extensive set of laboratories exist to develop and test new laser and nonlinear frequency conversion concepts and to evaluate nondestructive test and evaluation techniques.

The newest facility is the Infrared Test Chamber, or IR Range, which is an ultradry test chamber used to measure the IR signatures of new surface treatments, scale models, and components used for observables control on ships, aircraft, and missiles.

Electronic Warfare

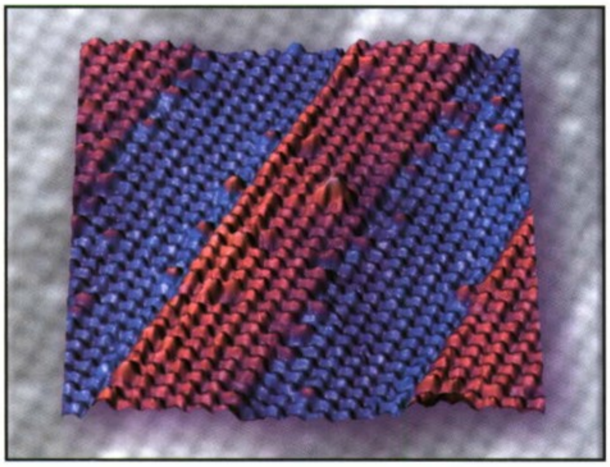
The scope of the Tactical Electronic Warfare (TEW) Division's program for electronic warfare (EW) research and development covers the entire electromagnetic spectrum. The program includes basic technology research and advanced developments and their applicability to producing EW products. The range of ongoing activities includes components, techniques, and subsystems development as well as system conceptualization, design, and effectiveness evaluation. The focus of the research activities extends across the entire breadth of the battlespace. These activities emphasize providing the methods and means to counter enemy hostile actions—from the beginning, when enemy forces are being mobilized for an attack, through to the final stages of the engagement. In conducting this program, the TEW Division has an extensive array of special research and development laboratories, anechoic chambers, and modern computer systems for modeling and simulation work. Dedicated field sites and an NP-3D EW flying laboratory allow for the conduct of field experiments and operational trials. This assembly of scientists, engineers, and specialized facilities also supports the innovative use of all fleet defensive and offensive EW resources now available to operational forces through the Naval Science Assistance Program.

Laboratory for Structure of Matter

This laboratory investigates the atomic arrangements in materials to improve them or facilitate the development of new substances. Various diffraction methodologies are used to make these investigations. Subjects of interest include the structural and functional aspects of energy conversion, ion transport, device materials, and physiologically active substances such as drugs, antibiotics, and antiviral agents. Theoretical chemistry calculations are used to complement the structural research. A real-time graphics system aids in modeling and molecular dynamics studies.

Chemistry

NRL has been a major center for chemical research in support of naval operational requirements since the late 1920s. The Chemistry Division continues this tradition with a broad spectrum of basic and applied research programs focusing on controlled energy release (fuels, fire, combustion, countermeasure decoys, explosives), surface chemistry (corrosion,



Color-enhanced scanning tunneling microscopy image of a cross-section showing the atomic-scale structure at the interfaces between GaSb and InAs superlattice layers. This work, incorporating sample preparation by scientists in the Electronics Sciences and Technology Division, STM measurement and interpretation by Chemistry Division staff, and modeling by theorists in the Materials Science and Technology Division, illustrates the multidisciplinary character of NRL research.

adhesion, tribology, adsorbents, film growth/etch), advanced materials (high-strength/low-weight structures, drag reduction, damping, polymers, thin films), and advanced detection techniques (environment, chemical/biological, surveillance). Facilities for research include:

Chemical analysis facilities, including a wide range of modern photon/electronic, magnetic- and ion-based spectroscopic/microscope techniques for bulk and surface analysis;

X-ray facility, with laboratory X-ray sources, monochromator, detectors, and related equipment for 0.7 to 25 KeV and dose rates up to 10^5 rads/s;

Synchrotron Radiation Facility, with intense, monochromatic X-ray photon beams tunable from 10 eV to 12 KeV available from two beam lines developed by NRL at the National Synchrotron Light Source at the Brookhaven National Laboratory. Environmental target chambers span a pressure range from 10^{-12} to 10^5 atm and temperatures from 10 to 1500 K;

Nanometer measurement facility, which includes fabrication and characterization capability based on scanning tunneling microscopy/spectroscopy, atomic force microscopy, and related techniques; materials synthesis/property measurement facilities with special emphasis on polymers and surface/film processing; and

Fire research facilities, ranging from laboratory combustion chemistry, to a 10^4 ft^3 fire-research chamber (Fire I) and the 475-ft ex-USS *Shadwell* (LSD-15) advanced fire research ship.

The new Environmental Quality Sciences Section has a mission that includes characterization of chemically polluted environments, remediation technologies and evaluations, pollution-prevention strategies for Fleet and shore-side operations, environmental security, and disposal of chemical-warfare agents. Facilities in support of this research are laboratories for molecular biology, microbiology, biodegradation assessment, environmental biosensors, and geochemistry. In addition, a mesocosm facility has been established to bridge between laboratory and field work, with controlled scale-up of environmental systems.

Materials Science and Technology

NRL has capabilities for X-ray and electron-diffraction analyses and for electron and Auger spectroscopy. Scanning, transmission, and combined scanning-transmission electron microscopes are used to study surface and/or internal microstructures. The division has a secondary ion mass spectrometer for surface analysis that significantly extends the diagnostic capability of the technique. A high-resolution, reverse-geometry mass spectrometer is used to probe reactions between ions and molecules. The Laboratory has a fully equipped fatigue and fracture laboratory, a modern vacuum arc-melting furnace for reactive metals, an ultrasonic gas-atomization system for making metal powders, and hot isostatic press facilities. The Laboratory's cryogenic facilities include dilution refrigerators and superconducting magnetic sensors for measuring ultrasmall magnetic fields. Also available are two molecular beam epitaxy devices for growing thin films. In addition, division facilities include:

High-Power Microwave (HPM) Facility: The large anechoic chamber (4.9 m × 4.9 m × 9.8 m) can be used at frequencies ranging from 0.5 to 94 GHz. Effects, susceptibility, and survivability of systems are the major research areas of interest.

Trace Element Accelerator Mass Spectrometry (TEAMS) – 3 MV Tandem Pelletron Accelerator Facility: Used for standard materials analysis such as Rutherford backscattering, for MeV-energy ion implantation, and for accelerator mass spectrometry (AMS). AMS measures trace elements in parallel with 3-D imaging at 10-μm lateral resolution (0.01 μm in depth) to 10-ppt sensitivity, and isotopes for sample dating and forensics.

Laser Facilities: Pulses of up to several joules are available from one system, while time resolutions down to 30 femtoseconds are produced by another. Synchronized Q-switched oscillators are configured for pump-probe experiments.

Thin-Film Preparation Facilities: The division has several major capabilities for preparation of thin films of advanced materials, such as high-temperature superconductors and active dielectrics. These include ion-assisted evaporation (which produces dense, adherent films), various dc plasma sources (which can etch as well as deposit films), and pulsed laser deposition (for production of chemically complex films).

Ion Implantation Facility: The facility consists of a 200-keV ion implanter with specialized ultrahigh vacuum chambers and associated in situ specimen analysis instrumentation.

Laboratory for Computational Physics and Fluid Dynamics

The Laboratory for Computational Physics and Fluid Dynamics is in round-the-clock production for computational studies in the fields of compressible and incompressible fluid dynamics, reactive flows, fluid-structure interaction (including submarine, ship, and aerospace applications), atmospheric and solar magnetoplasma dynamics, application of parallel processing to large-scale problems such as unstructured grid generation for complex flows, target tracking and correlations for battle management, and other disciplines of continuum and quantum computational physics. The facility is used to develop and maintain state-of-the-art analytical and computational capabilities in fluid dynamics and related fields of physics, to establish in-house expertise in parallel processing and on-line graphical rendering for large-scale scientific computing, to perform analyses and computational experiments on specific relevant problems, and to transfer this technology to new and ongoing projects through cooperative programs.

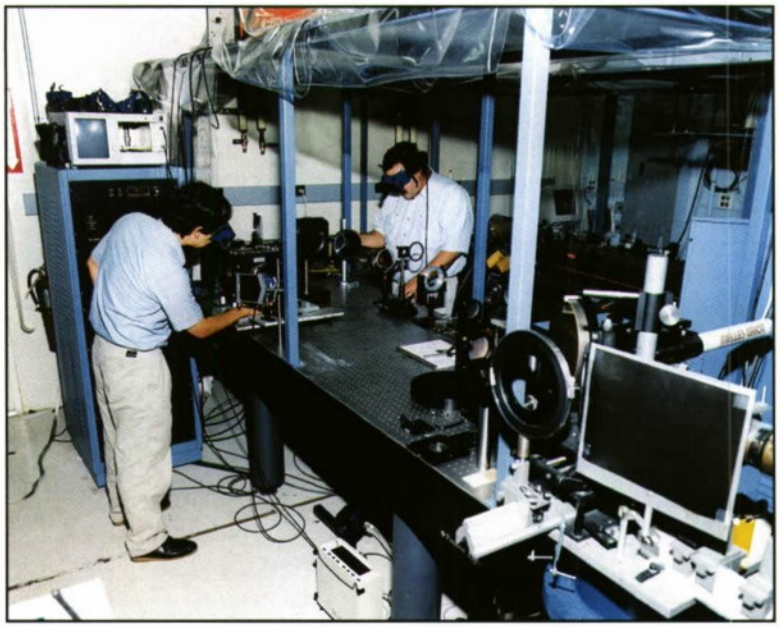
The Parallel High Performance Computer/Graphics Facility is a heterogeneous high-performance computer system composed of a number of autonomous computers with a composite peak speed equivalent to about 15 Cray 90 processors. The system is coupled directly to the advanced video recording center described below. The main computational engine comprises three Intel iPSC/860 Touchstone Gamma parallel supercomputers supported by the hardware and software environment necessary to develop, debug, and benchmark parallel simulations. With multi-Mflop processors as building blocks, the Intel iPSC/860 is a MIMD-distributed memory machine configured as a hypercube. These three machines comprise a block of 224 parallel nodes with a peak computational speed of 18 Gflops with a cross-connected disk farm file system and network connections.

The facility's disk farm also supports three IBM RS/6000 and three DEC AXP high-capacity compute-server computers, providing the facility with medium-to-large-scale memory and computational power enabling heterogeneous simulations with a significant scalar component, algorithm development, and diagnostic and postprocessing for large simulations. Special software allows simultaneous use of these computers on a single problem. Access to various other HPC capabilities around the United States is accomplished through this system by using the new DoD high-bandwidth communication networks. A six-processor, 5-Gbyte SGI Onyx provides the division with state-of-the-art high-performance visualization.

A high-quality video studio has been created around a Sony D2 digital recording system, with a coupled Lyon-Lamb animation controller and a large memory Silicon Graphics ONYX workstation. Through the network, other graphics stations, including the extensive resources of NRL's Visualization Laboratory, can create and record high-quality graphical images of simulation data for analysis and presentation by using digital recording techniques.

Plasma Physics

The Plasma Physics Division is the major center for in-house Navy and DoD plasma physics research. The division conducts a broad experimental and theoretical program in basic and applied research in plasma physics, which includes laboratory and space plasmas, pulsed-power sources, plasma discharges, intense electron and ion beams and photon sources, atomic physics, laser physics, advanced spectral diagnostics, plasma processing, nonlinear dynamics and chaos, and numerical simulations. The facilities in-



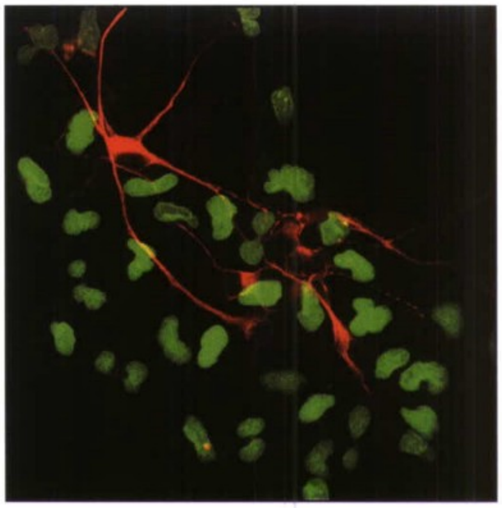
The NRL Table-Top-Terrawatt (T^3) Laser Facility. The T^3 laser currently operates at 0.4 ps, 2.5 TW, and 5×10^{18} W/cm^2 and provides a facility to conduct research in intense laser-plasma interactions, intense laser-electron beam interactions, and intense laser-matter interactions.

clude an extremely high-power laser—Pharos III—for the laboratory simulation of space plasmas and nuclear weapons effects studies and a short pulse, high-intensity Table-Top Terawatt (T^3) laser to study intense laser-plasma, laser-electron beam, and laser-matter interactions. The division also has an 11 m^3 space chamber capable of reproducing the near-Earth space plasma environment and a Large Area Plasma Processing System (LAPPS) facility to study material modification such as surface polymerization or ion implantation. The division has developed a variety of pulsed-power sources to generate intense electron and ion beams, powerful discharges, and various types of radiation. The largest of these pulsers—GAMBLE II—is used to study the production of megampere electron and ion beams and to produce very hot, high-density plasmas. Other generators are used to produce particle beams that are injected into magnetic fields and/or cavities to generate intense microwave pulses. A large array of high-frequency microwave sources (35 to 120 GHz) are available to conduct research on microwave processing of advanced ceramic materials. In particular, the division added a 15-kW, continuous wave, 83 GHz gyrotron to its facility for research on high-frequency microwave processing of materials. The Russian-made gyrotron produces a focused, high-intensity millimeter-wave beam (10^3-10^5 W/cm^2) that has unique capabilities for rapid, selective heating of a wide range of nonmetallic materials. The new gyrotron-based system will be used to investigate the application of such beams to important areas of material processing, including coating of materials, soldering and brazing, and treatment of ceramics, semiconductors, and polymers.

A major 3 kJ KrF laser facility (Nike) opened in June 1995. This facility is made up of 56 laser beams and is single pulsed (4 nanosecond pulse). This facility provides intense radiation for studying inertial confinement fusion (ICF) target heating at short wavelengths (0.25 microns) and high-pressure physics.

Electronics Science and Technology

In addition to specific equipment and facilities to support individual science and technology programs, NRL operates the Nanoelectronics Processing Facility (NPF), the Penthouse Processing Facility (PPF), the Laboratory for Advanced Material Synthesis (LAMS), the EPICENTER, the Laser Facilities (LF), and the Space Solar Cell Characterization Facility (SSCCF). The NPF's mission is to provide service to both NRL and external organizations requiring micro- and nanofabrication processing support. Lithography is a particular strength of the NPF, with definition of feature sizes down to 150 angstroms possible with an e-beam nanowriter. The NPF can supply items ranging from individual discrete structures and devices to circuits with very-large-scale integration complexity. The PPF is dedicated to processing III-V semiconductor devices and circuits in addition to serving the hands-on fabrication needs of individual NRL scientists. The PPF uses a single-pass air-ventilation system to minimize human risk from potentially hazardous III-V semiconductor processes and associated chemicals, thereby further meeting existing safety standards. The LAMS uses organometallic vapor phase epitaxy to synthesize a wide range of thin films such as InSb, InGaP, InP, and GaN. The EPICENTER (a joint activity of the Electronics Science and Technology, Materials Science and Technology, Optical Science, and Chemistry Divisions) is dedicated to the production of multilayer microstructures using in situ surface analytical techniques in one of several ultrahigh vacuum, molecular-beam-epitaxy growth and processing chambers—one for growth of conventional III-V semiconductors, one for vacuum processing, one for growth of III-V semiconductor ferromagnetic materials, one for growth of 6.1 angstrom II-V semiconductors and another for growth of magnetic materials and II-VI semiconductors. The Laser Facilities consist of an Ultrafast Laser Laboratory (ULL) that is optimized for the characterization of photophysical and photochemical processes in materials on a timescale of tens of femtoseconds and a Laser Single-Event Effects Facility (LSEF) that uses a synchronously pumped dye laser system for simulating the effects of charge deposited in semiconductors characteristic of space radiation. The SSCCF studies the effect of particle irradiation on new and emerging solar cell technologies for space applications.



Fluorescence photomicrograph of neural stem cells and stem cell-derived neurons. These cells supply cell elements for a cell-based sensor that can be used to detect toxins.

Bio/Molecular Science and Engineering

The Center for Bio/Molecular Science and Engineering conducts research and development using biotechnological approaches to solve problems for the Navy, DoD, and the nation at large. Problems currently being addressed include advanced material development (for electronic, biomedical, and structural applications), environmental quality (including pollution cleanup and control), and biological warfare defense. The approach to these problems involves long-term research focused on the study of complex materials systems, coupled with integrated exploratory and advanced development programs. The staff of the center is an interdisciplinary team that performs basic and applied research and development in areas that require expertise in bio- and surface chemistry, biophysics, genetic engineering, cell biology, advanced organic synthesis, solid-state and theoretical physics, and electronics and materials engineering. In addition, the center has many collaborations throughout the Laboratory, at universities, and in industry to ensure that a broad base of the required expertise and critical evaluations are part of the research and development programs. Highlights of the program include the manipulation of biologically derived structures on the nanometer scale, the development of ferroelectric liquid crystal systems with microsecond response times, discovery of an advanced resist system for high-speed, high-density integrated circuits, the patterning of neuronal cells to form neural networks, and the development of biosensors for environmental monitoring.

The center occupies recently renovated laboratories and offices in Building 30. These modern facilities, designed to be used well into this century, include general laboratories for research in chemistry, biochemistry, molecular biology, and physics. Specialized areas include a 600-ft^2 Class 1000 clean room; an advanced Electron Microscope facility; and a Scanning Probe Microscope laboratory. Instrument rooms provide access to a variety of spectrophotometers (IR, GC-MS, NMR, and UV-Vis) and other equipment used in biochemical or physical analyses of biomaterials. Additional laboratories accommodate an X-ray diffraction instrument, a liquid crystal fabrication facility, and equipment for advanced electronics and biosensor programs.

Acoustics

The Acoustics Division has three integrated acoustic pool facilities, including one with a sandy bottom, that support research in submarine target characteristics for antisubmarine warfare, submarine acoustic design and quieting, sensors for hull-mounted sonars,

NRL's Satellite-Linked Verticol Line Arroy (SVLA) buoy during o recent oceon deployment. Doto from on orroy of hydrophones ore collected ond stored within the buoy ond simultoneously tronsmitted to both ships in the vicinity ond distont shore stations using RF ond sotellite communicotions.

and structural acoustics for mine countermeasures and torpedo quieting. Scaled submarine targets, real mine structures, sensors mounted on hull simulators, underwater buried objects, and actual torpedoes can all be examined with advanced nearfield holographic and scanning 3-D laser vibrometer systems to measure and visualize the sound fields near a structure, the vibrations of the structure itself, the resulting farfield sound fields, and the physics of the sound-structure-fluid interactions.

The division operates several sound sources and receiving arrays for the generation and reception of sound in at-sea experiments. Sound sources include three XF-4 units that can be operated while being towed by a ship and two battery-operated organ-pipe sources that can project single tones from offboard moorings. In addition, the division has a battery-operated rubidium-clock-controlled, programmable sound source mooring that can transmit sounds having arbitrary waveforms. Receive systems include a moored 32-channel array that RF telemeters data to a recording site at a rate up to 50 kHz/channel, and a 64-channel seismic oil-filled array. The division also has unique, self-recording digital acquisition buoy systems (DABS) that are used to obtain multichannel (up to 128) acoustic data in the 10 Hz to 5 kHz regime. These systems provide up to 250 Gbytes of data on a single 15-inch reel of 1-inch tape. A Satellite Vertical Line Array (SVLA) Buoy System is designed for the collection of acoustic and oceanographic data unattended for up to one month; is capable of handling arrays of up to 64 hydrophones; and is capable of implementing signal processing algorithms onboard the buoy prior to transmission. The system supports two-way satellite communication—providing a high data-rate link (up to 1.5-Mbit/s) for data transfers from the buoy to shore, and a low-data-rate link in the opposite direction, permitting scientists to control buoy functions. A high-data-rate line-of-sight telemetry capability based on GPS-linked directional antennas is currently being installed.

The division conducts underwater acoustic communications research using digital, acoustic modems capable of receiving and processing signals from 8 channels at various carrier frequencies and with various bit rates. An Acoustic Communication Laboratory provides environment simulation, pre-experiment testing and preparation, and post-experiment data analysis.

The division operates high-frequency (up to 600 kHz) acoustic measurement systems to obtain scattering, target strength, and propagation data using bottom-moored instrumentation towers and a high-speed, remotely operated vehicle. These data are used to simulate the performance of weapons and mine countermeasure sonars.

The Tactical Oceanography Simulation Laboratory (TOSL) is a modeling and simulation architecture consisting of a set of tools for processing climatology and real-time environmental data and applying energy propagation models to those data. TOSL features a high-performance computational capability to provide real or near-real-time calculations in support of training, war games, operations rehearsal, and other distributed simulation functions. TOSL is coupled via Ethernet and SIPRNET with the Tactical Oceanography Wide Area Network (TOWAN) repository of environmental data, which allows full participation in a distributed simulation environment.

Remote Sensing

The Remote Sensing Division conducts a program of basic research, science, and applications to develop new concepts for sensors and imaging systems for objects and targets on Earth, in the near-Earth environment, and in deep space. The research, both theoretical and experimental, leads to discovering and understanding of the basic physical principles and mechanisms that give rise to background environmental emissions and targets of interest and to absorption and emission mechanisms of the intervening medium. Accomplishing this research requires the development of sensor systems' technology. The developmental effort includes active and passive sensor systems used for study and analysis of the physical characteristics of phenomena that evolve from naturally occurring background radiation, such as that caused by the Earth's atmosphere and oceans and man-made or induced phenomena, such as ship/submarine hydrodynamic effects. The research includes theory, laboratory, and field experiments leading to ground-based, airborne, or space systems for use in remote sensing, astrometry, astrophysics, surveillance, nonacoustic ASW, meteorological/oceanographic support systems for the operational Navy, and the environmental/global climate change initiatives. Special emphasis is given to developing space-based platforms and exploiting existing space systems.

The Remote Sensing Division conducts airborne hyperspectral data collections for characterization of the environment. Hyperspectral data are series of pictures, taken simultaneously, of a scene at many different wavelengths (colors). The sensors are built and calibrated in-house, although they rely heavily on commercial off-the-shelf elements. The most recent sensor was specifically designed for use over ocean areas. It covers the 400 to 1000 nanometer wavelength range with 128 different wavelengths (channels). The sensor consists of a standard video camera lens, a grating spectrograph, and a 1024×1024 pixel charge-coupled device (CCD). The spectrograph and CCD are specially designed to achieve high sensitivity in the blue end of the spectrum to optimize water-penetrating measurements. This makes possible measurements such as the determination of the ocean bottom type (coral, sea grass, sand, rock, etc.) to water depths of as much as 20 meters (in clear water), and the identification of material in the water column (phytoplankton, sediments, colored dissolved organic matter, etc.). The sensor is very compact and can be flown at heights of 8000 to 10,000 feet, simply "looking" out of a hole in the bottom of the airplane. At ground speeds of 90 knots, the data can still be collected digitally and stored on computer. It is then processed in a ground system operating on a standard personal computer.

Proper interpretation of the hyperspectral data requires calibration of the sensor. This means both radiometric calibration and spectral calibration. The latter plays a critical role in the successful correction of the data for atmospheric effects. The Remote Sensing Division operates an Optical Calibration Facility to perform these calibrations. NIST radiometric standards are transferred to a large integrating sphere. The integrating sphere has 10 precisely controlled quartz-halogen lamps to enable linearity measurements. A set of gas emission standards provides wavelength calibration. As a result, the complete process of data collection through data analysis can be handled in-house.

The Navy Prototype Optical Interferometer (NPOI), a major facility of the Remote Sensing Division, is actually two collocated instruments for making high-angular-resolution optical measurements of stars. Light from widely separated individual siderostats is combined simultaneously to synthesize the angular resolution of a telescope tens to hundreds of meters in diameter. Four siderostats are placed in an array with extremely accurate metrology to enable very-high-precision measurements of stellar positions (wide-angle astrometry). These measurements are used by the U.S. Naval Observatory to refine the celestial reference frame, determine Earth rotation parameters, and thus satisfy Navy requirements for precise time and navigation data. They also provide determinations of basic astrophysical parameters, such as stellar masses and diameters. Additional relocatable siderostats can be placed out to distances of 250 m from the array center and used to construct very-high-resolution images of stars. These images provide fundamental astrophysical information on stellar structure and activity. When complete, the NPOI will be the most advanced high-resolution imaging optical interferometer in the world.

To validate numerical and theoretical efforts ongoing within the Remote Sensing Division, extensive hierarchical-coupled experiments are carried out in the Free-Surface Hydrodynamics Laboratory. This laboratory is used to study free-surface turbulence interactions, wave-generation phenomena, jet-flow phenomena, vorticity dynamics, and free-surface/surfactant interactions. Emphasis is placed on those processes that determine the fluxes of heat, mass, and momentum across the air-sea interface. State-of-the-art diagnostic tools are available, such as Langmuir film balance to measure the properties of surface films, hot-wire and laser-Doppler anemometry, and the new quantitative flow techniques of laser speckle, particle tracking, and particle image velocimetry. The laboratory is also equipped with an IR camera with a 20×10^{-3} K resolution. These experimental diagnostic techniques use high-powered lasers, high-tolerance optical lenses, and extensive ultra-high-resolution video-imaging hardware and PC-based computerized systems. Further computational assets consist of powerful graphical computer work stations, the NRL Connection Machine, and other off-site Cray supercomputer systems.

Oceanography

The Oceanography Division is the major center for in-house Navy research and development in oceanography. It is known nationally and internationally for its unique combination of theoretical, numerical, experimental, and remote sensing approaches to oceanographic problems. The division numerically models the ocean and coastal areas of the world. This modeling is conducted on the Navy's and DoD's most powerful vector and parallel-processing machines. To study the results of this intense modeling effort, the division operates a number of highly sophisticated graphic systems to visualize ocean and coastal dynamic processes. The seagoing experimental programs of the division range worldwide. Unique measurement systems include towed sensor and advanced microstructure profiler systems for studying micro- and fine-scale ocean structures; a wave measurement system to acquire in situ spatial properties of water waves; a salinity mapper that acquires images of spatial and temporal sea surface salinity variabilities in littoral regions; an integrated absorption cavity, optical profiler system, and towed optical hyperspectral array for studying ocean optical characteristics; and self-contained bottom-mounted upward-looking acoustic Doppler current profilers for measuring ocean variability. In the laboratory, the division operates an environmental scanning electron microscope for detailed studies of biocorrosion in naval materials. The division's remote sensing capabilities include the ability to analyze and process multi/hyper-spectral, IR, SAR, and other satellite data sources. The division is a national leader in the development and analysis of Sea WiFS data for oceanographic processes and naval applications in littoral areas.

Marine Geosciences

The Marine Geosciences Division is the major Navy in-house center for research and development in marine geology, geophysics, geodesy, geoacoustics, geotechnology, and geospatial information and systems. The division has unique suites of instrumentation and facilities to support laboratory and field experimental programs.

The instrumentation used in the field experiments is deployable from ships, remotely operated and unmanned vehicles, and airborne platforms and by divers. Seafloor and subseafloor measurements use the Deep-Towed Acoustic Geophysical System (DTAGS—250 to 650 Hz); high-resolution sidescan sonars (100 and 500 kHz); the Acoustic Seafloor Classification System (ASCS-15, 30, and 50 kHz); ocean bottom seismometers and magnetometer; the In Situ Sediment Acoustic Measurement System (ISSAMS); underwater stereo photography; and nearshore video imaging systems. ISSAMS has specialized probes that measure acoustic compressional and shearwave velocities and attenuation, pore water pressure, and electrical conductivity in surficial marine sediments. Three unmanned, diesel-powered, radio-controlled, 8-m semisubmersibles are used to develop improved hydrographic survey techniques, sensor systems, and navigation capabilities. Two vehicles are modified 1985 Sea Lions called ORCAs, and one is a new vehicle called Remote Mine Hunting System Oceanographic (RMSO).

Laboratory facilities include sediment physical, geotechnical, and geoacoustic properties and sediment core laboratories. The Electron Microscopy Facility is the focal point for research in microscale biological, chemical, and geological processes. The key instrumentation includes 100 and 300 kVa transmission electron microscopes with environmental cells. The environmental cells allow hydrated and gaseous experiments. The Moving Map Composer Facility is used to design and write mission-specific map coverages for F/A-18 and AV-8B tactical aircraft onto militarized optical disks. The National Imagery and Mapping Agency also uses this state-of-the-art computer facility to update the compressed aeronautical chart library on CD for distribution. The Geospatial Information Data Base (GIDB) capability provides Internet access to the Digital Nautical Chart data, mapping data, imagery, and other data types such as video and pictures. This development tool can be used for planning, training, and operations. The division also operates the NRL Magnetic Observatory at Stennis Space Center, Mississippi. This magnetically clean area consists of an array of magnetometers that measure Earth's ambient magnetic field. The observatory is part of a worldwide observing system.

Marine Meteorology

The Marine Meteorology Division is located in Monterey, California. NRL-Monterey (NRL-MRY) is the only Navy facility with a mission to serve the Navy's needs for basic research in atmospheric sciences and its need for the development of meteorological analysis and prediction products to support global and tactical operations. The division is dedicated to advancing fundamental scientific understanding of the atmosphere, to applying scientific discoveries in the development of innovative objective weather prediction systems, and to developing ways to provide atmospheric data input to the tactical decision maker.

NRL-MRY is collocated with Fleet Numerical Meteorology and Oceanography Center (FNMOC), the Navy's operational center of expertise in numerical weather prediction. This provides NRL-MRY efficient access to a variety of classified and unclassified computer resources, databases, and numerical prediction systems. Large supercomputer mainframes and databases at FNMOC are used along with DoD High Performance Computing Modernization Program resources and local NRL-MRY resources to develop and transition operational analysis and prediction systems, and to provide on-site and remote access to the model output data for continued research purposes. In addition, interfaces to the Defense Research and Engineering Network have also been established.

Locally, to support research and development needs, NRL-MRY has established the Bergen Data Center. This Center includes a 24TB capacity data center with a hierarchical storage management capability to provide archival and easy retrieval of research data sets. The John B. Hovermale Visualization Laboratory provides state-of-the-art capability for data visualization, which aids the interpretation of both observational and modeled data and the development of weather briefing tools. High-performance graphics workstations, network file-servers, and tactical applications systems are used to conduct numerical weather prediction experiments, process and analyze satellite data, perform simulation studies, and provide demonstrations of tactical weather products. State-of-the-art satellite receiving and processing systems allow local collection of real-time geostationary data globally, from four different satellites, for applications research in support of the Navy and Joint Typhoon Warning Center operations. This capability has allowed NRL-MRY to take the lead in developing meteorological applications of satellite data for the NSDS-E (Navy Satellite Display System-Enhanced), which is currently being installed at the Navy's regional meteorological/oceanographic (METOC) centers.

Space Science

The Space Science Division conducts and supports a number of space experiments in the areas of upper atmospheric, solar, and astronomical research aboard NASA, DoD, and other government-agency space platforms. Division scientists are involved in major research thrusts that include remote sensing of the upper and middle atmospheres, studies of the solar atmosphere, and astronomical radiation ranging from the ultraviolet through cosmic rays. In support of this work, the division maintains facilities to design, construct, assemble, and calibrate space experiments. A network of computers, workstations, image-processing hardware, and special processors is used to analyze and interpret space data. The division's space science data acquisition and analysis efforts include: mission operations and data analyses of the Oriented Scintillation Spectrometer Experiment (OSSE) for NASA's Compton Observatory; observation of the Sun's interaction with the Earth's upper atmosphere through the Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) experiment in support of NASA's Upper Atmosphere Research Satellite (UARS); observation and analysis of solar flares using the Bragg Crystal Spectrometer (BCS) on the Japanese Yohkoh space mission; and observation and

In May, a group of 23 students involved in the Arizona State University satellite program visited NRL to learn more about the Navy's history and experience in the development and demonstration of space systems.

analysis of the evolution and structure of the solar corona from the disk to 0.14 AU. This latter effort involves acquiring and analyzing data from the Large-Angle Spectrometric Coronagraph (LASCO) and Extreme Ultraviolet Imaging Telescope (EIT) on the Solar Heliospheric Observatory satellite. In each of these missions, NRL maintains a complete database of spacecraft observations and control over acquisition of data from new observations. These data are available to qualified investigators at DoD and civilian agencies. In addition, the division has a sounding rocket program that affords the possibility of obtaining specific data of high interest and of testing new instrument concepts. These include the general area of high-resolution solar and stellar spectroscopy, extreme ultraviolet imagery of the Sun, and high-resolution, ultraviolet spectral-imaging of the Sun.

In addition, selected celestial and atmospheric targets in the ultraviolet and X-ray bands are observed by three Advanced Research and Global Observation Satellite (ARGOS) experiments—Global Imaging of the Ionosphere (GIMI), High-Resolution Airglow and Auroral Spectroscopy (HIRAAS), and Unconventional Stellar Aspect (USA). ARGOS was successfully launched on February 23, 1999. As part of this program, NRL is establishing collaborative programs to make use of ARGOS data to validate various upper atmosphere models and to study time phenomena in X-ray sources.

Optical calibration facilities, including clean rooms, are maintained to support these activities. These calibration facilities are routinely used by outside groups to support their own calibration requirements.

Space Technology

In its role as a center of excellence for space systems research, the Naval Center for Space Technology (NCST) designs, builds, analyzes, tests, and operates spacecraft as well as identifies and conducts promising research to improve spacecraft and their support systems. NCST facilities that support this work include large and small anechoic radio frequency chambers, clean rooms, shock and vibration facilities, an acoustic reverberation chamber, large and small thermal/vacuum test chambers, a control system interaction laboratory, satellite command and control ground stations, a fuels test facility, and modal analysis test facilities. Also, the Center maintains and operates a number of electrical and electronic development laboratories and fabrication facilities for radio frequency equipment, spacecraft power systems, telemetry, and command and control systems, and includes an electromagnetic interference-electromagnetic compatibility test chamber. NCST has a facility for long-term testing of satellite clock time/frequency standards under thermal/vacuum conditions linked to the Naval Observatory; a 5-m optical bench laser laboratory; and an electro-optical communication research laboratory to conduct research in support of the development of space systems.

RESEARCH SUPPORT FACILITIES

Technical Information Services

The Ruth H. Hooker Research Library carries out a comprehensive program of scientific information services to support the research of NRL-DC employees, on-site contractors, and ONR Headquarters staff. The Library maintains a 50,000-volume research collection of technical books and scholarly monographs; a scientific journal collection containing approximately 1,000 current subscriptions, with extensive back files maintained as bound volumes or on microfilm; and a research reports collection of more than one million items stored in paper, microform, and digital format. Services include the circulation of library materials, interlibrary loan, literature searches, and a full range of reference and information services covering both open-literature and classified information sources.

The Library is in the forefront in implementing digital services to enable researchers to meet their information needs 24 hours a day, 7 days a week, from work, at home, or while on travel. Through the InfoWeb Information System and Gateway [http://infoweb.nrl.navy.mil], NRL users in Washington, DC, Bay St. Louis, Mississippi, Monterey, California, and at ONR Headquarters in Arlington, Virginia, have a single point of entry to hundreds of locally stored and distributed databases and publications. Some important examples of InfoWeb resources are: the STILAS Web-based catalog with hyperlinks to thousands of reports the Library has digitized; OCLC First Search for searching 50 databases; the ISI "Web of Science" Science Citation Index Expanded, covering the years 1973 to present; the subscription module for the Contents-to-Go journal alerting service; and TORPEDO Ultra, for browsing and searching some 250 locally archived journals, thousands of research reports, and NRL publications including press releases, journal articles, and conference papers. InfoWeb also links users to another 300 journals available from publisher Web sites under license agreements implemented by the Library.

The Library has entered into a collaborative relationship with publishers and with other libraries to increase the range of digital resources it can make available. For example, it is currently assisting the American Institute of Physics in expanding the digital contents of its Web-based Online Journal Service under a Cooperative Research and Development Agreement (CRADA). In 1997, the Library formed the National Research Library Alliance with the libraries of the National Institute of Standards and Technology, NASA Goddard Space Flight Center, and the National Science Foundation. In 1998, it became an associate member of the New Mexico Library Alliance, strengthening its relationships with both Los Alamos National Laboratory and the Air Force (Phillips) Research Laboratory. In 1998, it also became part of the collaborative Digital Library Initiative at the University of Illinois at Urbana-Champaign. The NRL Library joins with other Navy libraries to license databases and electronic publications through the Consortium of Navy Libraries.

The new Technical Information Services Branch combines publications, graphics, and photographic services into an integrated organization.

Publication services include writing, editing, composition, publications consultation and production, and printing management. Quick turnaround black and white as well as color copying services are provided. The primary focus is on using computer-assisted publishing technology to produce scientific and technical information containing complex artwork, equations, and tabular material.

Graphic and photographic support includes technical and scientific illustrations, computer graphics, design services, photographic composites, display panels, sign making, and framing. Photographic services include still-camera coverage for data documentation both at NRL and in the field. Photographic images can also be captured with state-of-the-art digital cameras. Photofinishing services provide custom processing and printing of black and white and color films. Quick-service color prints are also available. Video services include producing video reports of scientific and technical programs. A video studio and editing facility with high-quality Beta Cam and digital video editing equipment are available to support video production. The NRL Exhibits Program develops and produces displays, audiovisual material, and multimedia programs for presentation at technical meetings, conferences, and symposia. The Multimedia Center has the capability of authoring/producing multimedia programs. The Center uses two complete multimedia systems with Macromedia Director and Adobe Photoshop and a digital video editing system, the AVID Media Composer 1000. The Imaging Center offers high-quality output from computer-generated files in EPS, Postscript, PICT, TIFF, Photoshop, and PowerPoint. Photographic-quality color prints and viewgraphs are available from Kodak dye-sublimation printers. High-resolution scanning to a Macintosh or PC disk is available. The NovaJet Pro 600c printer offers exceptional color print quality up to 600 dpi. It produces large-format posters and signs up to 60 inches wide.

The Administrative Services Branch is responsible for collecting and preserving the documents that comprise NRL's corporate memory. Archival documents include personal papers and correspondence, laboratory notebooks, and work project files—documents that are appraised for their historical or informational value and considered to be permanently valuable. The branch provides records management services, training, and support for the maintenance of active records, including electronic records and

The Visual Imaging Services Section of the Technical Information Division has a color, wide-format Novajet Pro 600E printer and laminator that produces prints up to 60 inches wide, unlimited length, and at resolutions up to 600 dpi.

e-mail, as an important information resource. The Administrative Services Branch is also responsible for NRL's postal mail services, NRL's Forms and Reports management programs (including electronic forms), coordination of NRL's parking facilities, and scheduling of NRL auditoriums. The Administrative Services Branch also compiles and publishes the NRL Code Directory and Organizational Index and provides NRL Locator service.

Center for Computational Science

The Center for Computational Science (CCS) conducts research and development to further the advancement of computing and communications systems to solve Navy problems. Promising technologies are transitioned to production systems. The CCS develops and maintains a leading-edge information infrastructure that provides support for NRL, Navy, and DoD research. The CCS participates as a Distributed Center in the DoD High Performance Computing Modernization Program with three massively parallel High Performance Computing (HPC) systems: a 128-processor SGI/Cray Origin2000 with 128 Gbyte of memory, an 80-processor HP/Convex Exemplar SPP-2000 with 20 Gbytes of memory, and a 148-processor Sun HPC Ultra with 30 Gbytes of memory. File services and archival storage are provided by robotic storage systems running the Multiresident Andrew File System (MRAFS) for both NRL and HPC applications.

The CCS pioneered and maintains the Washington area ATDnet experimental ATM network and is a partner in the MONET research effort. MONET is a leading-edge, all-optical, transparent network being deployed within ATDnet as a part of the DARPA/HPCC Next Generation Internet initiative.

The CCS collaborates with industry and DoD in the development of leading-edge progressive motion imagery for broadcast and network dissemination of all-digital HDTV signals at 720-p and 1080-p.

Additional CCS computational facilities are provided for general NRL use. These include the Scientific Visualization Laboratory (Viz Lab), which functions as an information center, a video production unit, and a training center for the latest tools in scientific visualization and visual supercomputing. Researchers have direct or networked access to computational and high-end graphics workstations. The Viz Lab staff also assists researchers in porting their scientific applications to the Virtual Reality Lab's GROTTO for 3-D, interactive, stereo viewing. In addition, the Viz Lab has recently installed a completely digital, broadcast-video editing suite. Alone or assisted, a researcher can quickly produce a professional-quality video, including titles and special effects, from a montage of computer-generated video, stills, graphs, overheads, or even raw data.

The CCS manages the NRL local area network, NICEnet, which provides access to NRL campus-wide and remote assets, including DoD unclassified and classified networks and the Internet. NICEnet has FDDI backbones and Ethernet, Fast Ethernet, ATM, and FDDI to the desktops. NICEnet provides dial-in services, including SLIP/PPP and ISDN, and has a laboratory-wide cable television network.

The CCS provides site license and support contracts for most workstations and desktop computers and manages acquisition contracts, on-line software distribution, consulting and e-mail support, and training services. The CCS staffs a help desk and facilitates software demonstrations to assist NRL researchers.

FIELD STATIONS

NRL has acquired or made arrangements over the years to use a number of major sites and facilities for research. The largest facility is located at the Stennis Space Center (NRL-SSC), in Bay St. Louis, Mississippi. Others include a facility at the Naval Postgraduate School in Monterey, California (NRL-MRY), and the Chesapeake Bay Detachment (CBD) in Maryland. Additional sites are located in Maryland, Virginia, Alabama, and Florida.

Flight Support Detachment (NRL FSD)

Located at the Naval Air Station Patuxent River, Lexington Park, Maryland, the Flight Support Detachment (NRL FSD) is manned by approximately 9 officers, 80 enlisted, four civilians, and 20 contract maintenance technicians. NRL FSD is currently responsible for the maintenance and security of six, uniquely configured, P-3 Orion turboprop research aircraft. The FSD conducts numerous single-aircraft deployments around the world in support of a wide range of scientific research projects.

In FY-99, NRL FSD provided flight support for diverse research programs including: Advanced Radar Periscope Detection and Discrimination (ARPDD), an advanced variant of the APS-137 ISAR radar used for detecting submarine periscopes; Cooperative Engagement Capability (CEC), an airborne suite to test USN Aegis Cruiser systems; Remote Ultra-low Light Imager (RULLI); Airborne Geographical Sensor Suite (AGSS), involving data and gravimeter testing to detect variations in the ocean floor; Real Ap-

NRL's Flight Support Detachment with one of the P-3 aircraft.

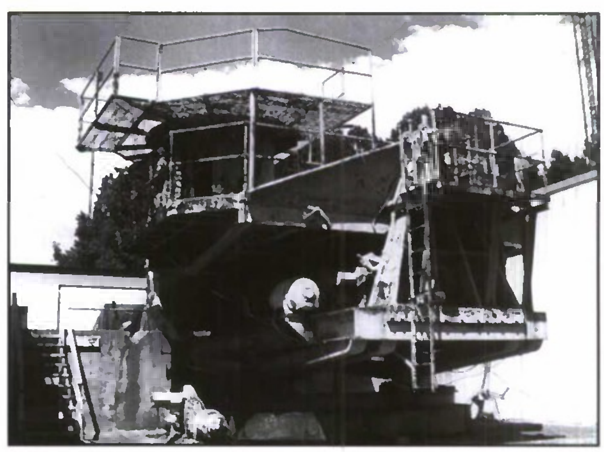
erture Radar (RAR); Integrated Electronic Warfare System (IEWS), a system that simulates radar of various surface and airborne platforms; Navy Tactical Aircraft Directional Infrared Countermeasures/Advance Technology Demonstration (TADIRCM), in-flight detection, threat determination and tracking technology testing; and NAVOCEANO Oceanographic Surveillance (OS).

The Flight Support Detachment continues to improve both capabilities and diversity among its aircraft platforms. Researcher 442 has completed its scheduled rework to install an E-2C "Hawkeye" rotodome antenna and is currently supporting the Navy's Theater Air Defense programs. The FSD also completed its 37th year of mishap-free flying, accumulating more than 57,000 flight hours.

Chesapeake Bay Detachment (CBD)

CBD occupies a 168-acre site near Chesapeake Beach, Maryland, and provides facilities and support services for research in radar, electronic warfare, optical devices, materials, communications, and fire research. A ship-motion simulator (SMS) is used to test and evaluate radar, satellite communications, and line-of-sight RF communications systems under dynamic conditions (various sea states). The SMS can handle up to 12,000 pounds of electronic systems. A roll motion of up to 30 degrees (15 degrees to port and 15 degrees to starboard) can be applied to this axis. The pitch axis has a fixed motion of 10 degrees (5 degrees to stern and 5 degrees to bow). Periods along both axes, pitch and roll, are variable—from a slow 32-s to a brisk 4-s rate. Variable azimuth motion can also be added to the pitch and roll action. Synchronized positioning information (×1 and ×36) is available for each of the three axes of the SMS.

Because of its location high above the western shore of the Chesapeake Bay, unique experiments can be performed in conjunction with the Tilghman Island site, 16 km across the bay from CBD. Some of these experiments include low clutter and generally low-background radar measurements. By using CBD's support vessels, experiments are performed that involve dispensing chaff over water and radar target characterizations of aircraft and ships. Basic research is also conducted in radar antenna properties, testing of radar remote-sensing concepts, use of radar to sense ocean waves, and laser propagation. CBD also hosts facilities of the Navy Technology Center for Safety and Survivability, which conducts fire research on simulated carrier, surface, and submarine platforms.



The ship-motion simulator, located on the shoreline of the Chesapeake Bay at NRL's Chesapeake Bay Detachment, allows radar, satellite communications, and line-of-sight RF communications systems to be tested before shipboard installation or in lieu of actual at-sea testing.

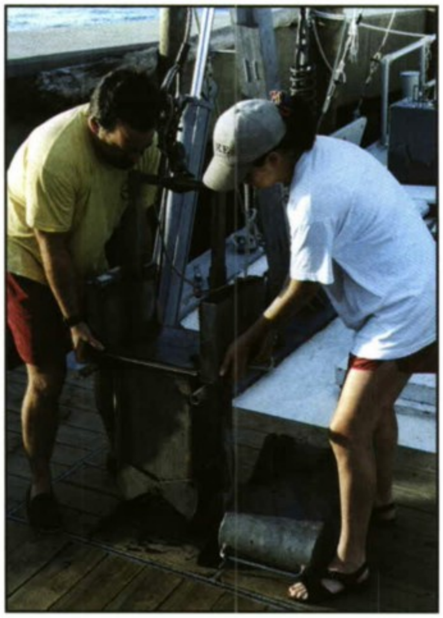
Marine Corrosion Test Facility

Located on Fleming Key at Key West, Florida, this facility offers an ocean-air environment and clear, unpolluted, flowing seawater for studies of environmental effects on materials. Equipment is available for experiments involving weathering, general corrosion, fouling, and electrochemical phenomena as well as coatings, cathodic protection devices, and other means to combat environmental degradation.

Stennis Space Center (NRL-SSC)

NRL-SSC, a tenant activity at NASA's John C. Stennis Space Center, is located in the southwest corner of Mississippi, about 50 miles northeast of New Orleans, Louisiana, and 20 miles from the Mississippi Gulf Coast. Other Navy tenants at SSC include the Commander, Naval Meteorology and Oceanography Command and the Naval Oceanographic Office, who are major operational users of the oceanographic and atmospheric research and development performed by NRL. The Naval Oceanographic Office provides access for NRL researchers to one of the Navy's largest supercomputers. This unique concentration of operational and research oceanographers makes SSC the center of naval oceanography and the largest such grouping in the Western world. Additional Navy tenants at SSC include Special Boat Unit 22, and the Human Resources Service Center, South East.

NRL-SSC provides administrative and business operations for entities of the Acoustics, Marine Geosciences, and Oceanography Divisions. NRL-SSC occupies more than 175,000 square feet of research, computation, laboratory, administrative, and warehouse space. Facilities include the new microscopy center, a visualization laboratory, numerous large antennas to receive available oceanographic and meteorological satellite data, the Magnetic Observatory—part of a worldwide observing system, the Pattern Analysis Laboratory, a Map Data Formatting Facility, and numerous laboratories for acoustic and oceanographic computation, instrumentation, analysis, and testing. Special areas are available for constructing, staging, refurbishing, and storing sea-going equipment.



Hands-on experience puts summer students in the middle of research and data collection at NRL-SSC.

Marine Meteorology Division (NRL-MRY)

NRL's Marine Meteorology Division (NRL-MRY) is located in Monterey, California, on the grounds of the Naval Postgraduate School (NPS) Annex, which is about a mile from the NPS main campus. As a tenant activity of the Naval Support Activity, Monterey Bay, the NRL facility is collocated with the Navy's operational Fleet Numerical Meteorology and Oceanography Center (FNMOC) and with a NOAA National Weather Service Forecast Office (NWSFO). The NPS Annex campus, which covers approximately five acres, comprises four primary buildings—one occupied exclusively by NOAA, one that houses the FNMOC supercomputer/operational facility, and two large buildings containing office space, computer laboratories, and conference facilities that are shared by FNMOC and NRL-MRY personnel. The site also provides warehouse space and recreational facilities. NRL-MRY occupies approximately 30,000 square feet in shared buildings. This includes not only office space, but also a small library, the John B. Hovermale Visualization Laboratory, the Bergen Data Center, the Geostationary Satellite Processing Facility, and space for the hardware supporting the Tactical Environmental Support System (TESS), the Tactical Atmospheric Modeling System/Real-Time (TAMS/RT), and the Master Environmental Laboratory.

NRL-MRY is dedicated to advancing fundamental scientific understanding of the atmosphere, including the air-sea interface, and to applying those scientific discoveries in the development of innovative objective weather prediction systems. FNMOC is the Navy's central site facility for the production and distribution of numerical weather prediction products in support of Navy operations around the globe, as well as to other defense-related activities. Fleet Numerical, and the Navy's regional METOC Centers, are the primary customer for the numerical weather prediction systems that are developed by NRL-MRY. This collocation of the scientific developer with the operational customer offers advantages for the successful implementation of new systems and system upgrades, and for the rapid infusion of new research results from the community at large. NRL-MRY has efficient access to FNMOC's large classified vector supercomputer and other systems. This allows advanced development to take place using the real-time on-site global atmospheric and oceanographic databases. Collocation also offers the opportunity for FNMOC scientists to team with NRL-MRY scientists during the transition and implementation process, and NRL-MRY scientists remain readily available for consultation on any future problems that arise.

NRL-MRY benefits from the opportunities provided by NPS for continuing education and for performing collaborative research with the Department of Meteorology and others. The NWSFO has also proven to be a valuable partner for both NRL-MRY and FNMOC. Data and products are exchanged, and valuable feedback is provided about the performance and utility of the numerical models and satellite-based products developed at NRL-MRY.

Midway Research Center

The Midway Research Center (MRC) is located on a 158-acre site in Stafford County, Virginia. Located adjacent to the Quantico Marine Corps' Combat Development Command, the MRC has 10,000 square feet of operations and administration area and three precision 18.5-m-diameter parabolic antennas housed in 100-ft radomes. The MRC, under the auspices of the Naval Center for Space Technology, provides NRL with state-of-the-art facilities dedicated solely to space-related applications in naval communications, navigation, and basic research.

Other Sites

Some field sites have been chosen primarily because they provide favorable conditions to operate specific antennas and electronic subsystems and are close to NRL's main site. Pomonkey, Maryland, a field site south of NRL, has a free-space antenna range to develop and test a variety of antennas. The antenna model measurement range in Brandywine, Maryland, has a 4.6-m diameter turntable in the center of a 305-m-diameter ground plane for conducting measurements on scale-model shipboard and other antenna designs. A site on the cliffs overlooking the Chesapeake Bay provides an over-the-water range of approximately 10 miles to Tilghman Island.

Research Platforms

Mobile research platforms contribute greatly to NRL's research. These include six P-3 Orion turboprop aircraft and one ship, the ex-USS *Shadwell* (LSD-15), berthed in Mobile Bay, Alabama. The ex-*Shadwell* is used for research on fire-suppression techniques on-board ship.

Looking Ahead

To provide preeminent research for tomorrow's Navy, NRL must maintain and upgrade its scientific and technological equipment to keep it at the forefront of modern research facilities. The physical plant to house this equipment must also be state of the art. NRL has embarked on a Corporate Facilities Plan to accomplish these goals. This plan and future facility plans are described below.

THE CORPORATE FACILITIES INVESTMENT PLAN (CFIP)

The CFIP is a financial spending plan to provide modern research facilities at NRL for the future. The plan calls for both Congressional and Laboratory investment and is updated and altered as changes occur in scientific emphasis and Congressional policy. During the past five years, Congressionally approved military construction (MILCON) funds were used to construct the new Electro-Optics Laboratory and a high-bay facility for the Naval Center for Space Technology. MILCON funds were approved in the FY 97 Congressional budget for the construction of an Ocean Acoustics Research Laboratory building at NRL-SSC. Future MILCON funds have also been requested for the construction of a Nano Science Research building at NRL-DC.

To complement these efforts, overhead funds have been used to renovate and upgrade laboratory and support areas in several existing buildings. Modern laboratory facilities have recently been provided for the Center for Bio/Molecular Science and Engineering, the Materials Science and Technology Division, the Remote Sensing Division, and the Acoustics Division. Work that is currently in progress will provide new facilities for the Information Technology Division and the Radar Division.

In parallel with efforts to upgrade laboratory buildings to the most modern standards, those buildings that were built during World War II and do not lend themselves to renovation are being demolished. This will provide space for the construction of future MILCON buildings, and it will also reduce the Laboratory's overhead costs.

Information Technology

The Information Technology Division's Center for Computational Science (CCS) operates three scalable, massively parallel Global Shared Memory (GSM) computer systems. A 128-processor SGI/Cray Origin2000 and 80-processor HP Exemplar SPP-2000 have cache-coherent Non-Uniform Memory Access (ccNUMA) architectures. A 148-processor Sun HPC Ultra distributed system has 96 processors that operate symmetrically in a Cache-Only Memory Access (COMA) architecture. These systems comprise the Distributed Center (DC) at NRL whose hardware is funded by the DoD High Performance Computing Modernization Program (HPCMP). The systems are used in the innovative exploration and evaluation of MPP technology for the solution of significant militarily relevant problems relating to computational and information science. The systems allow for leading-edge research in support of heterogeneous parallel processing applications by the Navy and DoD science and technology communities.

Chemistry

Nanostructured materials promise both challenges to current models of materials performance and opportunities for new technological solutions to Navy problems. A new laboratory building is planned to provide the carefully controlled environment (temperature, vibration, magnetic, electrical, humidity) necessary to work with atomic scale precision (0.1 nm).

Plasma Physics

The Plasma Physics Division has set up a Large Area Plasma Processing System (LAPPS) facility to investigate a new technique to produce plasmas for plasma processing. Applications include production of large-area flat-screen displays or elements for phased arrays or materials modification such as surface polymerization or ion implantation. The system is based on low-energy electron beam ionization of a background gas to produce the desired plasma. The system may have advantages over existing techniques for production of large-area (square meter) plasmas, efficiency of plasma production, and control of reactive species.

Electronics Science and Technology

Important division emphasis is focussed on the continual upgrading of the Nanoprocessing Facility (NPF) and the Penthouse Processing Facility (PPF) and expanding activities in the nanoelectronics, heterostructures, and vacuum electronics science and technology programs. The PPF has upgraded its capabilities in scanning electron microscopy. The NPF is replacing its Cambridge e-beam nanowriter with a second JEOL nanowriter to give this facility superior capability in defining nanoscale patterns and lines. The Laboratory for Advanced Material Synthesis facility will continue to upgrade its organometallic vapor-phase epitaxy equipment for thin-film semiconductors and provide safer and more environmentally benign processing and waste-disposal techniques. The EPICENTER (a joint activity of the Electronics Science and Technology, Materials Science and Technology, Optical Science, and Chemistry Divisions) will continue to expand into new materials areas to provide new insight into epitaxial semiconductor growth processes that will form the basis for use in the electronic devices of tomorrow. These facilities are enhanced by the new Joint Laboratory for Proximal Probe Nanofabrication that serves as a resource for characterization patterning and process definition necessary for advanced nanodevice fabrication.

Ocean Research Laboratory

NRL's Ocean Research Laboratory (MILCON Project P-006) is a 52,000 square-foot building that houses the Oceanography Division of the Ocean and Atmospheric Science and Technology Directorate. The building contains office space, oceanographic laboratories, staging areas, a small machine shop, electronic and secure laboratories, and computing facilities for research and development in ocean science and remote sensing.

Acoustics

NRL's Salt Water Tank Facility is designed to provide a controlled environment for studying complex bubble-related processes found in the ocean. It is an experimental pool facility for studies of underwater acoustics, fluid dynamics, and air-sea interface environmental topics under saline conditions. This facility is used to study the acoustics of bubbly media, including bubble entrainment and ambient noise generation, scattering from bubbly structures, and propagation through bubbly media. Related studies include the interaction of bubbles with turbulent flows, bubble coalescence and dissolution, effects of surfactants and contaminants, and bubble-related gas exchange across the air-sea interface.

For acoustic experiments at sea, the division is acquiring a new 128-channel, rubidium-precision-timed, internal recording system with vertical and horizontal arrays that can record up to 780 Gbytes (expandable to 1.8 Tbytes) of data on a schedule that can be either programmed prior to deployment or altered via acoustic modem after deployment.

Remote Sensing

The Remote Sensing Division has developed and installed 74 MHz receivers on the National Radio Astronomy Observatory's Very Large Array (VLA), thereby producing the world's highest angular resolution and most sensitive astronomical interferometric array operating below 150 MHz. In contrast to the VLA's maximum baseline of 35 km, all previous astronomical interferometers operating below 150 MHz had baselines less than 5 km because ionospheric structure had been thought to impose phase variations that would corrupt the interferometric imaging. Work in the Remote Sensing Division has shown that radio astronomical techniques can now remove the ionospheric phase variations and extend interferometer baselines to arbitrary lengths. In its first year of operation, the NRL/NRAO 74 MHz system has been used for a variety of innovative observations with encouraging initial results in solar system, Galactic, and extragalactic astrophysics. The success of the NRL/NRAO 74 MHz system indicates

NRL's Ocean Research Laboratory (MILCON Project P-006) at Stennis Space Center houses the Ocean and Atmospheric Science and Technology Directorate.

that it is possible to open a new high-resolution, high-sensitivity astronomical window by going to an even larger, more sensitive system. The Remote Sensing Division, in collaboration with the Netherlands Foundation for Research in Astronomy, is currently designing a follow-on instrument, the Low Frequency Array (LOFAR). LOFAR will be a fully electronic, broadband array operating in the 15 to 150 MHz range, with a collecting area of 1 square km at 15 MHz and a maximum baseline of 500 km resolution and sensitivity over the state of the art.

The Remote Sensing Division is also developing other new facilities-class sensors including the Navy Ultrawideband Synthetic Aperture Radar (NUSAR). NUSAR is a fully capable high-resolution (less than 1 meter impulse response) synthetic aperture radar system made to be operated from light aircraft. It is fully polarimetric and can operate as an along-track interferometer. Its frequency range will be expandable, and ultimately it will operate from VHF to X-band.

Marine Geosciences

The Marine Geosciences Division has greatly enhanced the capabilities and quality of seafloor sediment fabric analyses through completion of installation and staff training for its 300-kV transmission electron microscope (TEM) and accompanying environmental cell (EC). The TEM-EC is housed in a specially built facility imparting a null effect on the functioning of the TEM-EC electronics. The new facility will improve transition of developed capabilities and sediment fabric understanding to applied issues of acoustic and shock-wave propagation, mine burial, and mine countermeasures.

Vacuum Ultraviolet Space Instrument Test Facility

The Space Science Division facilities include an ultraclean solar instrument test facility in Building A-13 on the main NRL campus. The new facility is designed to satisfy the rigorous contamination requirements of state-of-the-art solar spaceflight instruments. The facility has a 400-ft^2 Class 10 clean room and a large Solar Coronagraph Optical Test Chamber (SCOTCH). This completely dry-pumped, 550-ft^3 vacuum chamber is maintained at synchrotron levels of cleanliness. Solar instrumentation up to 1 m in diameter and 5 m in length can be physically accommodated in the chamber. The instrument's optical performance is probed and calibrated with a variety of visible and XUV sources mounted on the chamber's 11-m beamline. The optical testing and characterization of the Large-Angle Spectrometric Coronagraph (LASCO) instrument for the European Space Agency's Solar Heliospheric Observatory satellite were conducted in this chamber. Coronagraph stray-light characterization was carried out by mounting a set of baffles in the main beamline, illuminating the instrument with a simulated solar beam, and measuring the residual radiation. A stray light background measurement of 10^{-12} was successfully measured in the LASCO C3 channel. Coronagraph calibration was carried out by installing back-illuminated calibrated opals in front of the instrument entrance aperture. Instrument polarization properties were analyzed by using a variety of polarizers installed in a wheel located between the opal and the instrument. The wheel was remotely controlled from outside the chamber. Instrument Mueller matrices were verified with a 12-in. diameter, two-plate partial polarizer. Calibration and focus of XUV solar instrumentation are accomplished by exposing the instrument to an XUV windowless collimator at the end of the tank. The facility also has a small thermal bake/vacuum test chamber used for vacuum conditioning and thermal testing of spaceflight components and subassemblies. Both the SCOTCH and the small test chamber are instrumented with temperature-controlled quartz-crystal monitors and residual gas analyzers for real-time, quantitative measurements of volatile contamination.

REHABILITATION OF SCIENTIFIC FACILITIES

Specialized facilities are being installed or upgraded in several of the research and support divisions.

Flight Support Detachment

NRL's Flight Support Detachment (FSD) has continued to improve both capabilities and diversity among its aircraft platforms. Aircraft 153442 continues to undergo extensive modifications with Lockheed Martin to install a "rotodome" antenna and full AEW radar system. These modifications will support the Navy's Theater Air Defense programs, while providing a testbed for advanced EW radar research. Additionally, all aircraft have completed extensive bomb-bay design improvements that will allow the aircraft to carry more diverse scientific payloads. Aircraft 158227's communications capabilities were significantly upgraded with a state-of-the-art satellite telephone; aircraft 154589 is next in line to receive this INMARSAT system. These upgrades and modifications will ensure that NRL will have the finest airborne research capabilities well into this century.

Information Technology

The Information Technology Division continues to transition stable technology from high-performance network testbed activities into the NRL local area network. This effort includes deployment of ATM technology at stream rates of 622 Mbps (OC12c) and 2.5 Gbps (OC48) across the enterprise. The current computing architectures, the SGI Origin2000, the HP Exemplar SPP-2000, and the Sun Ultra, are continuously undergoing upgrade and evaluation of both hardware and software. The NRL CCS works closely with the DoD HPC community and the HPC vendors to provide insight, balance, and value-added capabilities within the MPP testbed infrastructure.

Materials Science and Technology

Renovation is in progress for Building 3, which is composed of two of the original five buildings at NRL, to contain modern laboratories for studies of thin-film deposition and characterization, superconducting materials, magnetic materials, and other materials science projects. The new space will feature the most modern molecular beam epitaxy and other materials synthesis and processing equipment, an up-to-date fatigue and fracture laboratory, and state-of-the-art diagnostic equipment, including electron microscopes, spectrometers, and electron and X-ray diffraction equipment. The renovated building will also contain office and laboratory space for approximately 70 technical personnel.

Plasma Physics

A state-of-the-art short-pulse (0.4 ps), high-intensity Table-Top Terawatt (T^3) laser currently operates at 2.5 TW and 5×10^{18} W/cm^2 for a variety of physics studies. The T^3 laser will be upgraded to boost its power to 25 TW and intensities to $>10^{19}$ W/cm^2. This will provide a facility to do fundamental physics experiments in intense laser-plasma interactions, intense laser-electron beam interactions, and intense laser-matter interactions.

The division is building a repetitively pulsed (5 pps) krypton fluoride (KrF) laser called Electra. Electra will develop the technologies needed for inertial fusion energy (IFE). A laser for a power plant would have to fire five times per second, run for several years, and meet stringent cost and efficiency requirements. Electra will develop the technologies that can meet these requirements. It will have a laser output of around 400 to 700 Joules. The size of Electra was chosen to be large enough to be scalable to a power plant size, but small enough to be flexible.

Electronics Science and Technology

The Electronics Science and Technology Division continues to upgrade and expand its capability in nanofabrication science. Facilities will be enhanced with the addition of two new laboratories and an expanded EPICENTER that includes a new vacuum processing chamber and two new epitaxial growth chambers. The additional epitaxial growth chambers will allow new classes of ferromagnetic II-VI semiconductors to be grown. These semiconductors allow the realization of new device structures based on spin-polarized transport and the creation of lasers, detectors, and high-speed electronics important to DoD. The new laboratories are the Laboratory for Proximal Probe Nanofabrication (LPPN), which will explore the limits of nanolithography with proximal probes, and the Laboratory for Advanced Materials Processing (LAMP), which will explore the chemistry and physics of processes used routinely in the formation of modern devices and extend these processes into the nanoscale fabrication range.

The preceding pages dramatically illustrate the range of research capabilities that have been and are being developed to provide the Naval Research Laboratory with the world-class facilities for which we are known. However, these inanimate objects, however expensive and complex, are of no value without the highly motivated people who work here. It is these people who make the Laboratory the great institution that it is, who provide the ideas and sustained efforts to make these great research capabilities "come to life." In this section, we highlight some of these special people.

Our People Are Making a Difference

Mr. Don DeYoung is the Executive Assistant to the Director of Research. He was selected for the position in July 1997 to investigate general management issues, conduct special studies, and develop responses to Navy, DoD, and congressional policy. He came to NRL in 1980 after receiving a master's degree in Public Administration from Syracuse University. Since that time he has performed developmental assignments within the Office of the Secretary of Defense and the Office of Naval Research, earned a master's degree in National Security Studies from Georgetown University, and served as a Navy analyst on two DoD base closure projects. His efforts during BRAC-95 were recognized with a Special Act award presented by the Secretary of the Navy and with a Navy Meritorious Civilian Service award presented by NRL's Commanding Officer.

"I'm a strong believer in the role of the Government laboratory, in its value to our country, and in its continued relevance for the 21st century. I'm a believer largely because of NRL's extraordinary impact on science and national security. I consider NRL one of the Navy Department's crown jewels—along with the Carriers, the Marine Corps, and the "Silent Service." This elite group gives the U.S. Fleet its ability to project decisive combat power around the globe. Even though NRL isn't an operational force like the other three "jewels," it nonetheless gives the Fleet that kind of power. There was radar in World War II, lubricants for new gas turbine warplanes in Korea and for M-16s in Vietnam, the intelligence satellite in the Cold War, NAVSTAR GPS in the Gulf War, and electronic warfare decoys in The Balkans. These and many other NRL innovations have helped make the American Fleet the most formidable naval fighting force in the world. I'm proud of that."

Dr. Dylan Schmorrow is a Lieutenant Commander serving as an Aerospace Experimental Psychologist in the U.S. Navy's Medical Service Corps. He works in the Information Technology Division as the military scientist for modeling, virtual environment, and simulation science and technology. In this role, he coordinates the development and implementation of research and development programs that are focused on the rapid transition of NRL, ONR, and DARPA science and technology to the Fleet. "The need to capture knowledge from a sea of data and the demands of rapid decision making can only be dealt with through the advancement of modeling, virtual environments, and simulation science and technology. NRL provides the critical foundations for tomorrow's Navy through world-class, multidisciplinary research programs. I have learned first hand that this mission is, and will continue to be, accomplished through the focused team work I witness daily in the Information Technology Division and throughout NRL. It is an honor for me to have the opportunity to serve with the internationally renowned scientists and engineers at NRL and this, more than anything, continues to contribute to my development as a naval officer and scientist."

Ms. Jonna Atkinson is a Visual Information Specialist in the Publications Services Section of the Technical Information Division. She has worked in TID since she came to NRL in 1985. She designs and coordinates NRL's annual publication, the *NRL Review*. The numerous publications she has designed and produced have contributed immeasurably to the preservation of the "award-winning" reputation of the section. Ms. Atkinson is also responsible for maintaining the computers, hardware, and software for the entire section. Her continuity and efficiency in streamlining the work processes benefit the production of publications immensely. "I have enjoyed working at NRL from day one. I have learned an enormous amount about computer technology and the publishing process just by doing my job. I am grateful for the opportunities my supervisors have given me to expand my knowledge and creativity. I enjoy all aspects of my job. The *NRL Review* is such an enjoyable project for me and I look forward to its production each year. I truthfully believe I could not find a better place to work or a nicer group of people to work with. And for that I am grateful."

Dr. Jill Dahlburg is a research physicist in the field of plasma physics. She has been a member of the NRL Nike KrF Laser Program since its inception. She is head of the Theory Section in the Laser Plasma Branch of the Plasma Physics Division. She has developed and applied advanced numerical techniques in the fields of laser matter interactions, fundamental hydrodynamics, magnetohydrodynamics, and turbulence physics. "I think that NRL provides a paradigm for technical research for several reasons. One is that NRL has had a tremendously stable base of basic research funding. Another is the idea of the stable pyramid, which supports research that ranges from basic to highly applied and researchers who can interact on a daily basis over this range. Scientists here feel free to take risks because there is a safety net of reliable funding and intelligent oversight. This has created a lively, innovative, and daring research community that makes good use of the research investment. Finally, and probably the most important, reason why NRL is an ideal research environment is because of the people who work here. Together we have accomplished some amazing and wonderful things."

Dr. Curtiss Davis is head of the Optical Sensing Section of the Remote Sensing Division. The Section is pioneering the use of hyperspectral imaging for characterizing the coastal environment. Spectral information is used to estimate water depth, bottom type, and the properties of the water column. The section is unique in having the ability to build, calibrate, and characterize the sensors, and to make all of the necessary sea-truth measurements to develop and validate algorithms and products for the Navy. "In the five years that I have been at NRL, we have put together the team of scientists and the equipment and facilities needed to assume a world leadership role in this promising new area of research. I greatly appreciate the foresight and flexibility of NRL management that has made this rapid development possible. I am also the Project Scientist for the Naval EarthMap Observer (NEMO) spacecraft. The Optical Sensing Section is responsible for the algorithms that are used in that program. When NEMO is launched in 2001, it will provide a demonstration of the utility of hyperspectral imaging to meet Naval needs around the globe."

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