U.S. NAVAL RESEARCH LABORATORY

Annual Report

FY23

U.S. NAVAL RESEARCH LABORATORY
CENTENNIAL CELEBRATION 1923 - 2023

Advancing naval research further than you can imagine®

Cleared for Public Release

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America's Ears in Space: NRO Declassified NRL-Developed Electronic Intelligence Satellite Program

By Nicholas E. M. Pasquini

During a centennial exhibition held at the Pentagon on Sept. 28, 2023, to commemorate the U.S. Naval Research Laboratory's (NRL) 100 years of operations, the National Reconnaissance Office (NRO) declassified an NRL-developed electronic intelligence satellite program called Parcae.

"With 100 years of history, the Naval Research Lab has been advancing science in national security well before we could actually leverage space," said Dr. Troy Meink, principal deputy director of the NRO. "Today's centennial offers an opportunity to talk about how the Lab's many innovations have helped the National Reconnaissance Office use the vantage point of space to keep America safe and stronger."

Launched in 1976 and 1996 under mission numbers 7108 and 7120, respectively, Parcae and Improved Parcae were low-Earth-orbit electronic intelligence-collection systems that downlinked the collected data to ground processing facilities located around the world. Once received, the data was provided to the National Security Agency for processing and reporting to U.S. policymakers.

"What we are celebrating today is not simply the journey of the Navy's premiere research laboratory or its contributions to the naval service. Instead, we are celebrating a journey of American ingenuity and a legacy of our best scientists," said the presiding host, Under Secretary of the Navy Erik K. Raven. "Our ability to deal with national security and economic threats of today rests heavily on the work of the scientists, engineers and support staff at the Naval Research Laboratory."

For the first time, a model of Parcae was on display during the exhibition. The NRL workforce showcased their past, present, and future research and highlighted the enduring relationship with government partners and the need for continued investment in scientific research.

Secretary of the Navy Carlos Del Toro (left) presents a centennial commemoration plaque to the U.S. Naval Research Laboratory (NRL) during the NRL Centennial Exhibition at the Pentagon in Arlington, Va., on Sept. 28, 2023. NRL celebrated its 100-year anniversary as the Department of the Navy's corporate laboratory, providing advanced scientific capabilities required to bolster America's position of global naval leadership. Featured second from left: NRL Director of Research Dr. Bruce Danly, Under Secretary of the Navy Erik K. Raven, and NRL's commanding officer, Capt. Jesse Black. (U.S. Navy photo by Jonathan Steffen).

NRL's Blossom Point Tracking Facility Provides Command and Control for Space Development Agency Tranche 0 Mission Launch 2

By Nicholas E. M. Pasquini

The U.S. Naval Research Laboratory's (NRL) Blossom Point Tracking Facility (BPTF) provides command and control (C2) for the Space Development Agency (SDA) Tranche 0 (T0) mission Launch 2 on Aug. 31, 2023. (Jamie Hartman/U.S. Naval Research Laboratory)

The U.S. Naval Research Laboratory's (NRL) Blossom Point Tracking Facility (BPTF) provides command and control (C2) for the Space Development Agency (SDA) Tranche 0 (T0) mission Launch 2.

The 13 satellites launching aboard a SpaceX Falcon 9 rocket are provided to the mission from commercial companies SpaceX, York Space Systems, and Lockheed Martin, and will join the 10 satellites already deployed in Launch 1 as part of the inaugural Proliferated Warfighter Space Architecture (PWSA) to demonstrate the low-latency communication links to support the warfighter with a resilient network of integrated capabilities.

"NRL's Blossom Point facility is ideally suited to solve the incredibly challenging command and control of this constellation," said Dr. Steven Meier, director of the Naval Center for Space Technology at NRL. "Our small and agile team provides space system mission management for government and commercial customer classes in every orbit regime."

BPTF employs NRL's Neptune C2 software to automate ground resource monitoring and satellite tracking, telemetry, and command (TT&C). Neptune runs at more than 10 ground stations and operation facilities, providing command and control for a diverse set of missions at all classification levels, can be interfaced with any mission-planning system. and can provide data to any payload data-processing system.

"This program demonstrates a critical partnership between government and industry that empowers U.S. space interoperability and provides our nation the advanced capabilities to guarantee our free and unfettered access to space," said Meier.

NRL and NASA to Launch ComPair Instrument to Measure Gamma-Ray Emissions

By Mary Hamisevicz

During the thermal vacuum (TVAC) test campaign at NASA's Goddard Space Flight Center in Greenbelt, Md., in June 2023, Dr. Daniel Shy, a co-investigator on the ComPair Program, inspects the NRL-led CsI calorimeter box.

The U.S. Naval Research Laboratory (NRL) and NASA Goddard Space Flight Center (GSFC) launched ComPair aboard a high-altitude balloon from Fort. Sumner, N.M., on Aug. 10, 2023.

The ComPair mission instrument measures and detects gamma-ray emissions from astrophysical objects. The NRL instrument is one of the four subsystem instruments led by NASA GSFC. The mission name — ComPair — was inspired by the mechanisms by which gamma rays interact with matter.

"They do so via three dominant processes — photoelectric effect, Compton scattering, and pair production. These interaction mechanisms are dependent on energy, where photoelectric occurs at the lowest energies and pair production at the highest," said NRL Space Science Division research physicist Richard S. Woolf, Ph.D. "The design of the ComPair instrument employs technology to measure gamma rays from both the Compton and the pair production regimes, hence Compton-Pair, or ComPair."

"Gamma rays allow us to study the highest-energy processes in the universe, ranging from nucleosynthesis in supernovae, jets from supermassive black holes, and gamma-ray bursts from the merger of astrophysical objects with extreme densities, like neutron stars and black holes," Woolf said. "The atmosphere mostly blocks astrophysical sources of gamma rays from reaching the ground at sea level; to measure the rays, the instrument needs to reach above the majority of the atmosphere, up to 130,000 ft."

The goal in the development of this instrument is to increase the technical readiness level (TRL) of this gamma ray technology. One of the last steps in advancing the TRL for gamma-ray instruments is to fly on a high-altitude balloon.

NRL ISS Mission Seeks New Bioinspired Materials

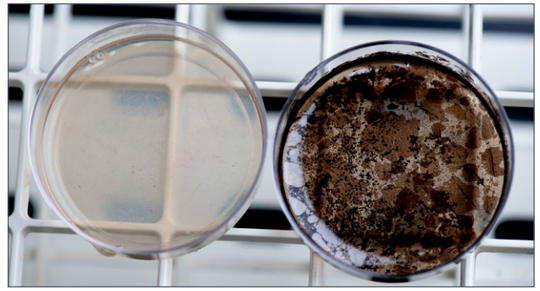
By Daniel Parry

The U.S. Naval Research Laboratory's Melanized Microbes for Multiple Uses in Space Project, or MELSP, will use the International Space Station (ISS) to search for production of melanin variants and other useful biomaterials that can have applications both on Earth and in space. The mission is scheduled to launch in early November 2023.

Melanin is described as a group of biopolymers responsible for various biological functions, including pigmentation of skin, hair, and the irises of the eyes, that helps protect body cells from solar radiation damage.

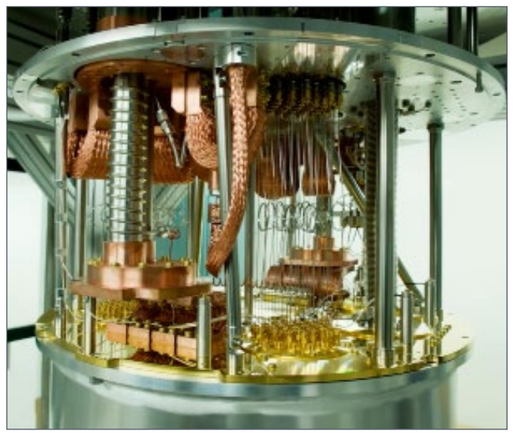
NRL scientists will analyze ISS-grown bacterial and fungal strains that lack the protective capacity of melanin to search for novel mechanisms of protection. The project will culture three microbial species aboard the ISS: the bacterium *Escherichia coli,* along with its engineered strain synthesizing eumelanin, and two melanized fungal strains: *Aspergillus niger* and *Exophiala lecanii-corni,* and their melanin-deficient mutants. Additionally, two defective DNA repair mutants of *A. niger* will be cultured to study the effects of space radiation on fungal DNA and melanin biosynthesis.

The MELSP project may lead to economic gain across multiple markets by providing invaluable insight into the discovery and development of novel biomaterials. It is anticipated that MELSP will generate information invaluable to the growth of this field, including key insights into melanin biosynthesis and its resulting structure-driven activity that can be harnessed for various applications on Earth.



(Left) Wild-type *Escherichia coli*, which does not produce melanin, and (right) a bioengineered *E. coli mutant* with the Tyr1 gene to produce melanin in liquid media, are displayed in Washington, D.C., on Oct. 10, 2023. (U.S. Navy photo by Jonathan Steffen)

These efforts will provide the first steps necessary to establish biomaterial production hosts for use during long-term space missions. The MELSP project will contribute to the growing body of data surrounding the influence of spaceflight on biological systems and will incorporate novel perspectives on the involvement of melanin in such processes.



New Quantum Capabilities for Naval Warfare Centers

The U.S. Naval Research Laboratory (NRL) and all 14 Naval Warfare Centers signed a memorandum of understanding on Dec. 2, 2022, with the Air Force Research Laboratory's (AFRL) Information Directorate to establish a conduit for exchange of technical expertise and the exploration of co-projects with a focus on creating useful quantum computing capabilities for the Department of Defense.

The agreement gives Navy scientists and engineers access to IBM's advanced quantum computing systems through the AFRL's hub in the IBM Quantum Network, providing the ability to explore Navy-relevant problem sets focused on operations research, quantum machine learning, quantum simulation, classical simulation, and cryptanalysis.

To manage access to the AFRL's IBM Quantum hub and to facilitate advancements in quantum computing, NRL stood up a Naval Quantum Computing Program Office (QCPO), with Naval Information Warfare Center (NIWC) Pacific serving as the co-lead and with other representation from Naval Warfare Center quantum subject-matter experts.

Collaboration among QCPO members will accelerate advancement in quantum research by creating a structure for the sharing of resources and information and the publication of joint findings.

NRL Launched First Time-Based Navigation Satellite in 1967

By Daniel Parry

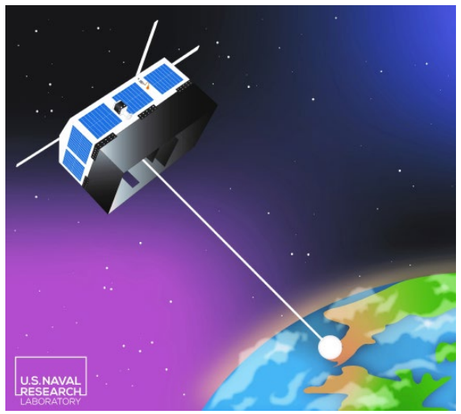
The launch of the TIMATION satellite on May 31, 1967, proved that a system using a passive ranging technique combined with highly accurate atomic clocks could provide the basis for a new, revolutionary navigation system, providing longitude, latitude, and altitude around the globe.

Before the era of artificial satellites, the accuracy of navigation had not improved much beyond that available from celestial techniques. With the introduction of satellite navigation systems, a new degree of accuracy became possible.

A vision of NRL research physicist Roger Easton, TIMATION, short for "time navigation," introduced continuous navigation fixes from satellites in low Earth orbit (LEO).

In the TIMATION system, a satellite contains a stable oscillator that controls its transmissions. A navigator receives these transmissions and compares them with outputs from their own ship-based oscillator. If both oscillators are suitably synchronized, the satellite's range and position can be determined and the navigator then can use celestial-navigation techniques to determine the position of their ship.

To authenticate the proof of concept, NRL-operated experimental space-surveillance stations in southern Texas were used to calibrate the satellite oscillator, and preliminary "looks" at the orbital data revealed that the satellite's position could be predicted well enough to provide navigation fixes that were accurate to within a few tenths of a mile.



Artist's conception of the TIMATION satellite in orbit. TIMATION is an experimental navigation satellite launched on May 31, 1967, by NRL under a program sponsored by the Naval Air Systems Command. It weighs 85 pounds and has a 6-watt solar cell power source. The standby power required by the oscillator telemetry and other circuits is 3 watts. The satellite is gravity-gradient stabilized. A passive ranging technique is used both for the navigation of fixed and moving vehicles and for the accurate transfer of time between separated points. The gravity-gradient stabilizer, tethered at bottom, ensures the satellite will always be facing Earth. (U.S. Naval Research Laboratory)

NRL Achieves 65-Year Milestone in Space Satellite Exploration

By Daniel Parry

The U.S. Naval Research Laboratory conducted the first American satellite program, named Project Vanguard, between 1955 and 1959, which became the prototype for much of what developed as the U.S. space program.

Sixty-five years ago, on March 17, 1958, the Vanguard I satellite was launched into Earth orbit. Vanguard I was the first solar-powered satellite, enabling it to continue transmitting for several years — other satellites of the time relied on batteries and only lasted weeks.

Vanguard I was the second artificial satellite successfully placed into Earth orbit by the United States and although communication with the satellite ceased in 1964, it remains the oldest man-made satellite in orbit today. With the success of the program, the Vanguard group, comprising approximately 200 scientists and engineers, became the core of NASA's spaceflight activities at its establishment in 1958. The group remained housed at NRL until the new facilities at the Goddard Space Flight Center in Beltsville, Md., became available in September 1960.

Post-Vanguard Years

The exodus created by the newly formed space agency did not signal an end to NRL satellite and space-based research. Through the advocacy of NRL engineer Martin Votaw, who believed the U.S. Navy had an important role to play in space, a small contingent of remaining NRL rocket scientists and technicians regrouped to form the Satellite Techniques Branch, headed by Votaw.

NRL engineers place Vanguard I atop the third stage of the launching vehicle. From left are Roger L. Easton, Sandy J. Smith, Robert C. Bauman, and Joseph B. Schwartz (Bauman and Schwartz transferred with the Vanguard Project to NASA). On March 17, 1958, Vanguard I started its historic journey into space. (US Navy Photo)

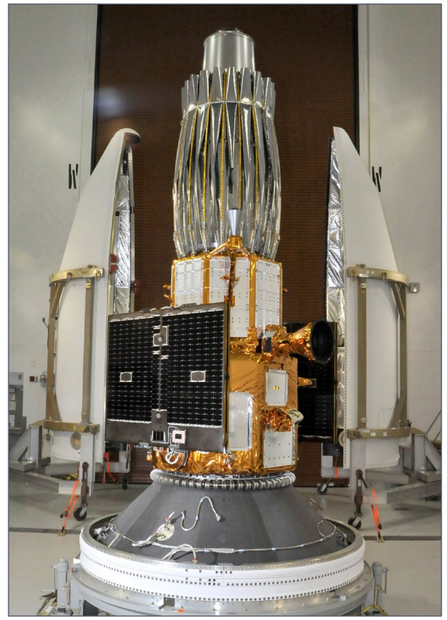
The Satellite Techniques Branch staff concentrated on the engineering hardware — referred to as the satellite bus — and was responsible for the structure, power supply, command, telemetry, and coordination of a satellite, along with its interface with the launch vehicle. Additionally, the team managed special circuitry needed to support satellite payloads.

The group's first post-Vanguard success was in June 1960 with the launch of the world's first orbiting astronomical observatory to study the sun's effects on the Earth. Piggybacked on Navy's Transit IIA satellite, the first satellite to study solar radiation, SOLRAD-I, was equipped with both X-ray and Lyman-alpha sensors. Determining that radio fade-outs were caused by solar X-ray emissions, SOLRAD-I had an immediate scientific impact — verifying a theory held by NRL research physicist Dr. Herbert Friedman of the direct relationship between solar X-ray variability and the strength of the Earth's ionosphere.

Shrouded in secrecy for nearly 40 years, SOLRAD-I also shared the first U.S. Navy electronic intelligence (ELINT) instrumentation for Cold War reconnaissance. The project originally was called Tattletale, but it was renamed the Galactic Radiation and Background satellite system, or GRAB, to conceal its purpose from the Soviets.

The GRAB receivers clandestinely catalogued the waveforms and pulse-repetition frequencies of Soviet air defense radars. The telemetered data was recorded on magnetic tape and was couriered back to NRL, where analysts evaluated and duplicated it and forwarded it to the National Security Agency (NSA) at Fort George G. Meade, Md., and the Strategic Air Command (SAC) at Offutt Air Force Base in Omaha, Neb., for analysis.

Between 1960 and 1973, successive SOLRAD satellites collected solar X-ray and ultraviolet data, with instrumentation and quality of data improving in each succeeding spacecraft in the SOLRAD series.



TacSat 4 was integrated with the Minotaur IV adaptor.

Building a Foundation for Space Exploration

Aside from measuring solar radiation and calibrating satellite tracking systems and a handful of classified deployments, NRL-made satellites have harvested massive amounts of basic data that became crucial for subsequent satellite design and for overall understanding of how the space environment can further the Navy's mission and capabilities.

One of the more notable of these capabilities came from the launch of the TIMATION satellite in 1967. A vision of NRL research physicist Roger Easton, TIMATION (short for "time navigation") proved that a system using a passive ranging technique combined with highly accurate (atomic) clocks could provide the basis for a new and revolutionary navigation system with three-dimensional coverage (longitude, latitude, and altitude) around the globe.

Through the development and launching of three additional experimental satellites — TIMATION II in 1969, the Navigation Technology Satellite (NTS-I) in 1974, and the first satellite to fly a cesium atomic frequency standard in a 12-hour orbit, NTS-2, in 1977 — Easton proved the practicality and unprecedented accuracy of satellite-based atomic clocks and laid the foundation for modern-day global positioning systems, better known as GPS.

Naval Center for Space Technology

By the mid-1980s, NRL was a key participant in the launching of nearly 80 satellites. In recognition of this sustained record of excellence, in 1986, the Navy formalized NRL's status as its lead laboratory in space technology by officially inaugurating the Naval Center for Space Technology (NCST) at NRL.

Leading the space program at NRL since 1964 and encompassing more than five decades of experience in the development, deployment, and operation of satellites critical to the nation's defense and intelligence-gathering capabilities, NCST was tasked to turn its attention toward deep-space exploration and NRL's first lunar satellite.

Formally named the Deep Space Program Science Experiment, NCST's first project — dubbed Clementine shortly thereafter due to its predestined, "one-way" mission — launched on January 25, 1994. Extensively mapping the moon between February 26 and April 22 of that year, Clementine captured nearly 2 million digital images of the lunar surface.

Aside from measuring solar radiation and calibrating satellite tracking systems and a handful of classified deployments, NRL-made satellites have harvested massive amounts of basic data that became crucial for subsequent satellite design and for overall understanding of how the space environment can further the Navy's mission and capabilities.

NRL Transfers NAUTILUS Instrument to University of Notre Dame, Strengthening Navy Research Academic Partnerships

By Nicholas E. M. Pasquini

Bruce Danly (left), Ph.D., the U.S. Naval Research Laboratory's (NRL) director of research, Capt. Jesse Black (second from right), NRL's commanding officer, and Jeff Rhoads (center), Ph.D., the University of Notre Dame's vice president for research, sign an Education Partnership Agreement transferring NRL's NAval Ultra-Trace Isotope Laboratory Universal Spectrometer (NAUTILUS) instrument to Notre Dame during an event in Washington, D.C., on Aug. 18, 2023. Looking on are Adm. Christopher W. Grady (right), vice chairman of the Joint Chiefs of Staff, and Rear Adm. Kurt Rothenhaus, the chief of naval research. (U.S. Navy photo by Sarah Peterson)

Vice Chairman of the Joint Chiefs of Staff U.S. Navy Adm. Christopher W. Grady served as the guest speaker at an event finalizing the agreement to transfer the U.S. Naval Research Laboratory's (NRL) NAval Ultra-Trace Isotope Laboratory Universal Spectrometer (NAUTILUS) instrument to the University of Notre Dame on Aug. 18, 2023, in Washington, D.C.

NRL researchers designed and built the NAUTILUS spectrometer instrument to provide new measurement capabilities unlike those available at other laboratories at the time. NAUTILUS was declared operationally capable of measuring nuclear, cosmo/geochemical, and electronic materials in 2015.

"The partnership between Notre Dame and the U.S. Navy is steeped in history, and I am incredibly proud to stand at the intersection of Navy and Notre Dame as we gather today to celebrate this future collaborative opportunity," said Grady. "The USNRL's long and fruitful relationship with industry, academia, and other government agencies is a testament to the power of partnership in pushing science forward as a force for good. To meet the challenges of providing the joint force with new capabilities, we must continue our work with industry, allies and partners, and academia to harness their collective energy, knowledge, and vision. Our collaboration is America's competitive advantage."

NAUTILUS's research goals encompassed the development of a novel suite of techniques for precision measurement of elemental composition across the entire periodic table for a wide range of sample types relevant to applications for the Department of the Navy, ranging from trace elemental analysis of nuclear fuels to materials analysis of new types of semiconductors, metal oxides, and two-dimensional materials.

NRL Scientists Present Latest Research Findings at American Geophysical Fall Meeting

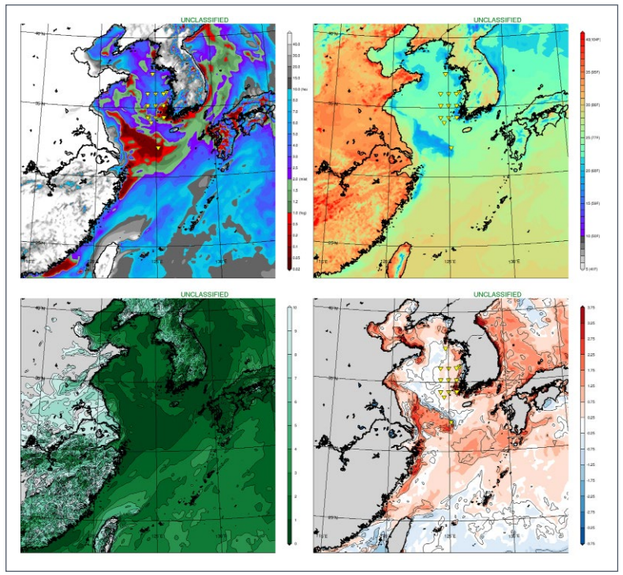
By Mary Hamisevicz

U.S. Naval Research Laboratory (NRL) scientist Sasa Gabersek, Ph.D., will present findings from the Air-Sea Interaction Affecting Fog Formation experiment over the Yellow Sea at this year's American Geophysical Union (AGU) annual meeting held Dec. 11–15 in San Francisco, Calif.

Marine fog affects land-, air-, and water-based transportation in coastal regions. The reduced visibility makes it challenging to navigate safely and increases risk of collision, traffic congestion, and accidents. Specifically, military operations related to visibility, such as visual observation and target acquisition, logistics and resupply, surveillance, and reconnaissance, are disrupted.

"This project explores fog and turbulence interaction in the atmospheric layer closest to the ocean," said Gabersek. "The goal is to enhance visibility forecasts for the Navy by identifying current shortcomings and implement improvements by using the measurements gathered during the field experiment."

More than 40 NRL scientists and engineers will showcase their research on a wide variety of topics, focusing on machine learning, geospace dynamics, and optical gas-sensing and ocean-prediction systems. The annual event is the most influential event in the world dedicated to the advancement of Earth and space science to better understand our planet and environment and our role in preserving their future. It is a results-oriented gathering rooted in celebrating and advancing positive individual and collective outcomes.



A COAMPS® 27-hour forecast on July 5, 2023, of the horizontal visibility (in kilometers) over the Yellow Sea at the surface (top left figure). Red colors are for fog (less than 1 km), green for mist (1–2 km), blue for haze (2–10 km). Some of the most important factors that affect the visibility are the surface temperature (top right figure), the dew point depression (bottom left figure), and the difference between air and water temperature (bottom right figure). Areas of low visibility coincide with cooler water temperature (patches of blue in top right), air that is closer to humidity saturation (patches of dark green in bottom left), and air that is warmer than the water (patches of red in bottom right). Yellow triangles represent waypoints of a research vessel during the ONR-sponsored FATIMA project field campaign over the Yellow Sea in June and July 2023, for which NRL Marine Meteorology Division provided COAMPS forecasts. (U.S. Naval Research Laboratory/Marine Meteorology Division)

Research Squadron VXS-1 Mobilizes Quickly to Track Hurricane Idalia

By Mary Hamisevicz

U.S. Naval Research Laboratory's Scientific Development Squadron (VXS) 1 mobilized a crew for an NP-3C Orion operation with less than 24 hours' notice to airdrop 18 SOFAR Spotter buoys into the Gulf of Mexico ahead of Hurricane Idalia on Aug. 28, 2023. The VXS-1 crew personally deployed the buoys from the aircraft on behalf of researchers working with the National Oceanographic Partnership Program (NOPP) Hurricane Coastal Impacts (NHCI) project.

VXS-1 airdropped the Spotters hours before Hurricane Idalia made landfall near Keaton Beach, Fla., at approximately 7:45 a.m. EDT. The squadron deployed the fleet of Spotters into the path of the hurricane from 1,000 feet aboard the P-3 traveling at 150 mph. The buoys observed Idalia's wave height, sea surface temperature, and barometric pressure in real time between the afternoons of Aug. 28 and Aug. 30. The precisely executed drop enabled the Spotters to make direct observations near the eye wall and dangerous right-front quadrant of Idalia.

The 10 Spotters continue to make real-time observations of wave conditions off the northwest coast of Florida. The data collected by the buoys will contribute to and improve existing forecast models, will enable better understanding of hurricane dynamics and prediction of hurricane impacts, and will be used to protect coastal communities. The NHCI project is focused on creating models for the U.S. Gulf Coast, the Florida coast, and the Eastern Seaboard.

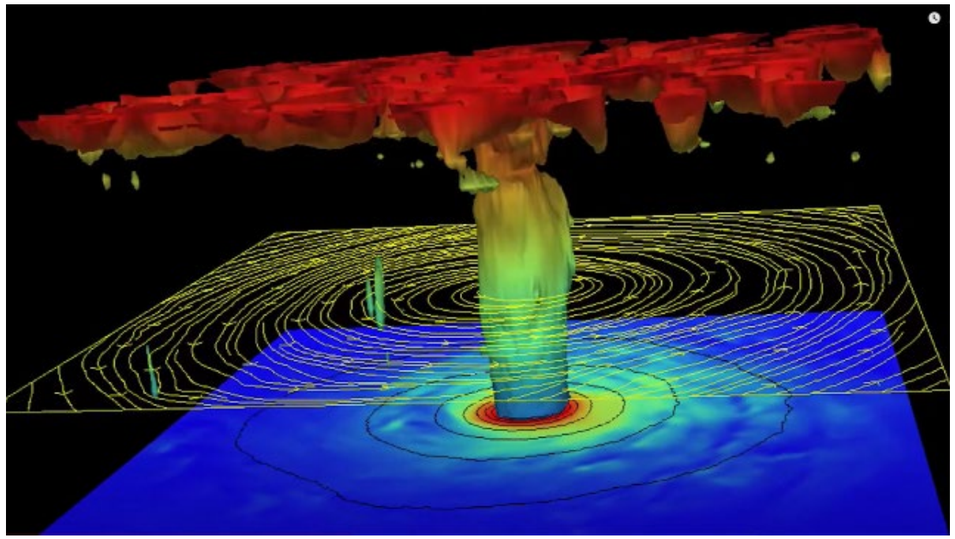
"Our unique mission and ability to operate around the world, enabling research for the Department of the Navy and its partners, is crucial to scientific and technological innovation," said VXS-1 Commanding Officer Cmdr. Aaron Roberts. "Airborne data-collection missions like the Idalia operation facilitate the next generation of scientific research and environmental prediction, keeping civilians and military members safe from extreme events."

The Marine Meteorology team uses NRL's proprietary Coupled Ocean-Atmosphere Mesoscale Prediction System for Tropical Cyclones (COAMPS-TC®) and 11-member prediction ensemble system to create accurate hindcasts that detail a hurricane's track, size, and intensity for retrospective analysis to contribute to atmospheric reforecasts and reanalyses. COAMPS-TC also provides real-time updates to other NHCI teams for timely prediction and operational readiness.

SOFAR Spotter buoys. Members of U.S. Naval Research Laboratory's Scientific Development Squadron VXS-1 dropped 18 SOFAR Spotter buoys into the Gulf Coast ahead of Hurricane Idalia in partnership with the National Oceanographic Partnership Program (NOPP) Hurricane Coastal Impacts (NHCI) on Aug. 28, 2023.
(U.S. Navy Photo / Released)

World-Class Technology Provides Navy Cyclone Forecasting

By Susan Guth



U.S. Naval Research Laboratory COAMPS-TC imaging of a tropical cyclone

June 1 marks the start of hurricane season. NRL has supported U.S. Navy military and humanitarian missions with global hurricane and typhoon information using the Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS®) since 1997. The latest version of the system, called COAMPS-TC®, provides high-resolution, five-day predictions of tropical cyclones anywhere in the world.

"COAMPS-TC is world-class in its ability to predict tropical cyclones, and we're continuing to make better forecasting for the Navy and DoD," said Dr. Jonathan Moskaitis, an NRL global modeling and marine meteorology scientist.

Using the COAMPS-TC Ensemble Prediction System, NRL scientists can evaluate high-resolution multiple images of cyclones anywhere in the world with enough detail to evaluate their sizes and intensities reliably. NRL's technology enables the Marine Meteorology Division, located at NRL's base in Monterey, Calif., to make 45-day forecasts of every cyclone around the world four times per day as routine storm-tracking research.

With decades of foundational research, NRL continues this effort to understand how hurricanes work. There are still many questions about the underlying processes of intensification and rapid intensification, said Dr. James Doyle, senior scientist at NRL's Marine Meteorology Division.

NRL shares data with partners to support DoD and organizations like the National Hurricane Center, , the National Oceanic and Atmospheric Administration, the European Centre for Medium-Range Weather Forecasts, the Joint Typhoon Warning Center (for Department of the Navy and United States Air Force operations), academic consortiums, and others.

NRL Centennial, 100 Years Strong!

The U.S. Naval Research Laboratory celebrated 100 years of service as the Navy's corporate laboratory, with a rich history of performing advanced scientific research and making significant contributions to U.S. military forces on, under, and above the seas.

Commissioned on July 2, 1923, as the Naval Experimental and Research Laboratory — later shortened to the Naval Research Laboratory (c.1926) — NRL has changed the way the U.S. military fights, improved its capabilities, prevented technological surprise, transferred vital technology to industry, and tilted the world's balance of power on at least three occasions: with the first U.S. radar, the world's first intelligence satellite, and the first operational satellite of the Global Positioning System (GPS).

"For nearly a century, NRL employees have been at the forefront of innovation and research, and we are excited to honor this centennial as we look to the next 100 years," said Peter Matic, Ph.D., NRL's Centennial Celebration coordinator. "Today, we are kicking off the celebration with an event at the Laboratory to share this momentous occasion."

A Vision Realized

In 1873, the U.S. federal government purchased 90 acres of Bellevue in southwestern Washington, D.C., and added that land to the adjacent Naval Gun Factory. The land was known as the Bellevue Annex to the Naval Gun Factory until 1923, when the federal government opened the U.S. Naval Research Laboratory on the site. The Laboratory remains on that tract of land to this day.

In a 1915 New York Times article, Thomas Edison suggested that the U.S. government should maintain a "great research laboratory." With this interview and with the progression of World War I, the idea of a central research facility for the Navy began to take shape.

Secretary of the Navy Josephus Daniels seized the opportunity created by Edison's public comments to enlist Edison's support. Edison agreed, serving 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 board postponed construction until 1920. On Dec. 6, 1920, Daniels broke ground for NRL's Building 1.

1923 and Beyond

After opening its doors, 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 the U.S.

Nearly a decade after Taylor and Young's breakthrough in detecting distant, moving objects via radio, a patent for "System for Detecting Objects by Radio" was approved November 27, 1934. Later referenced as radar — for "radio detection and ranging" — the technology contributed to major naval victories in battles at the Coral Sea, Midway, and Guadalcanal during World War II.

During the war, 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 uranium-235 isotope needed for one of the first atomic bombs.

During the years since World War II, the laboratory has conducted basic and applied research pertaining to the Navy's environments of land, sea, sky, space, and cyberspace. Investigations have ranged widely — from monitoring the sun's behavior, to analyzing marine atmospheric conditions, to measuring parameters of the deep oceans.

Laboratory researchers also performed basic research, for example, participating 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. Detection and communication capabilities have benefited from research that exploited new portions of the electromagnetic spectrum, extended ranges to outer space, and provided a means of transferring information reliably and securely to stare down massive jamming tactics.

Submarine habitability, lubricants, shipbuilding materials, firefighting, 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, biotechnology, and nanotechnology.

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) and development of the world's first intelligence satellite (GRAB-I), to inventing and developing the first satellite prototypes of the modern-day Global Positioning System (GPS).

The Naval Experimental and Research Laboratory's director, Capt. Edward L. Bennett, speaks at the Laboratory's commissioning ceremony on July 2, 1923, in Washington, D.C. Public release.

Office of Naval Research

Because of the major scientific accomplishments of the war years, the United States entered 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 scientific research, it also was encouraging NRL to broaden its scope. Placement of NRL within the Navy Secretariat allowed it to pursue long-range, high-risk projects and to serve the Navy in the broadest sense.

Commissioned on August 1, 1946, there was a transfer of NRL to the administrative oversight of ONR as well as 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 comprising all the division superintendents. This committee was impracticably large, so in 1949, a civilian director of research (DOR) was named and was given full authority over the program. Positions for associate directors, or ADORS, were added in 1954.

Leading Naval Research into the 21st Century

Today, NRL leads advances for the Navy in space systems development and support, as well as in fire research, tactical electronic warfare, microelectronic devices, and artificial intelligence (AI). The laboratory now focuses its research efforts on new Navy strategic interests in the 21st century, a period marked by global terrorism, shifting power balances, and irregular and asymmetric warfare.

NRL scientists and engineers strive to give the Navy the special knowledge, capabilities, and flexibility to succeed in this dynamic environment. While continuing its programs of basic research that help the Navy anticipate and meet future needs, including innovations in wireless transfer of solar energy, hypersonic technologies, and quantum information science, NRL also moves technology rapidly from concept to operational use when high-priority, short-term needs arise. Some past examples are pathogen detection, lightweight body armor, contaminant transport modeling, and communications interoperability.

The interdisciplinary and wide-ranging nature of NRL's work keeps this "great research laboratory" at the forefront of discovery and innovation, solving naval challenges and benefiting the nation as a whole.

Author's note: Don DeYoung, executive assistant to NRL's director of research, and Dr. Peter Matic, the associate director of Research, Materials Science and Component Technology Directorate, contributed to this article.

NRL to Launch First In-Space Laser Power Beaming Experiment

By Mary Hamisevicz

The U.S. Naval Research Laboratory is set to launch the Space Wireless Energy Laser Link (SWELL) to demonstrate laser power beaming in space as part of the scheduled U.S. Department of Defense Space Test Program (STP) H9 mission to the International Space Station (ISS) on March 15.

Power beaming is a means of delivering energy in the form of electromagnetic waves that does not require the transport of mass, so energy can be sent almost instantly. Its feasibility and safety have been proven on the ground, and now these efforts are expanding to space.

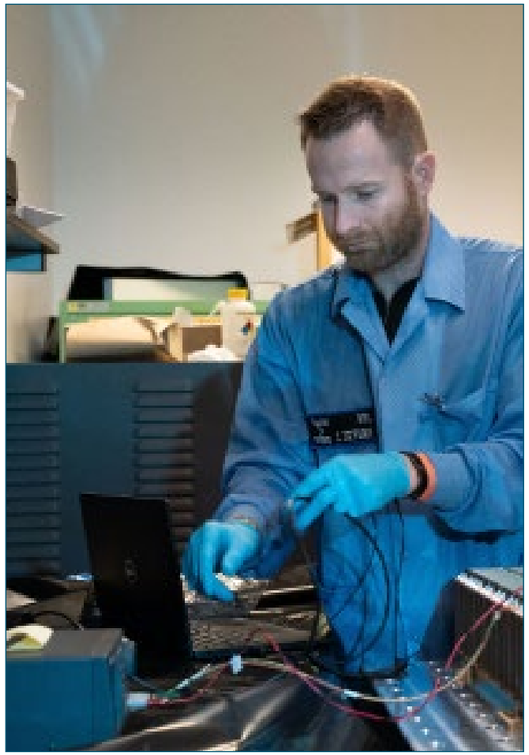
SWELL is one of several experiments that will launch aboard the SpaceX Dragon cargo vehicle to the ISS for the yearlong mission to collect data during a laser power-beaming link in space conditions. The experiment, which is sponsored by the Office of the Under Secretary of Defense for Acquisition and Sustainment and is supported by the Operational Energy Capability Improvement Fund , will explore challenges for power beaming's viability for space applications and also will highlight the possibilities for using power beaming to address energy challenges on Earth.

"With this modest experiment, we will identify key focus areas for developing links of greater power and longer distance for space," said Paul Jaffe, Ph.D., an electronics engineer who is the SWELL principal investigator. "By employing laser transmitters and photovoltaic receivers, power beaming links will be established that will pave the way for rapid, resilient, and flexible energy-delivery systems."

The yearlong SWELL experiment is expected to provide data that shows how the hardware functions in the space environment and shows which constraints are likely to affect the deployment of future operational systems.

By eliminating the need for moving fuel or batteries, or for stringing wires, SWELL could be a compelling option for the utilization of lunar resources and development on the Moon.

"Power beaming might also be used for distributing power for and around Earth, including from satellites that collect solar energy in space," Jaffe said. "SWELL is the next step into this new frontier."



Christopher Depuma, a U.S. Naval Research Laboratory electronics engineer, conducts a functional test of the laser power-beaming link on the Space Wireless Energy Laser Link (SWELL) in Washington, D.C., on April 3, 2022. SWELL will launch aboard the DoD Space Test Program-H9 payload (STP-H9) to the International Space Station in January 2023, where it then will be powered on and will operate for one to two years. SWELL will be the first on-orbit demonstration of laser power beaming. (U.S. Navy photo by Jonathan Sunderman)

NRL Recognized with FLC Innovation Award in Technology Transfer

By NRL Corporate Communications

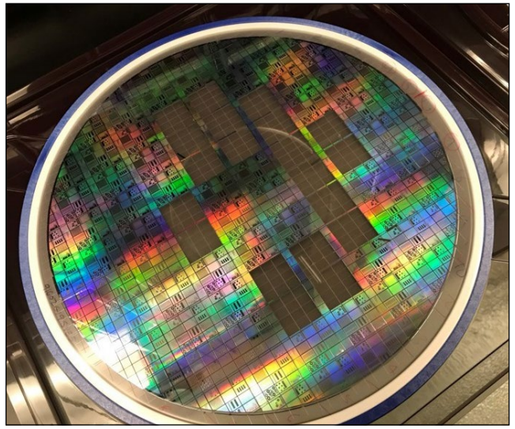
The U.S. Naval Research Laboratory was recognized with the Innovation in Technology Transfer Award at the 2023 Federal Laboratory Consortium (FLC) National Meeting on March 29, 2023.

NRL established a leading-edge program using trade secret law to protect and license government intellectual property, demonstrating the capacity for significant benefits, including cost avoidance, the speed of obtaining protection, increased security, and greater control.

"Federal agencies have always relied on the patent system to protect their inventions, but this can become expensive, slow, and requires public discloser of the invention," said Sean Walsh, NRL assistant counsel for intellectual property. "Using trade secret law to protect intellectual property is cheap, quick, and, by definition, requires the invention be kept secret."

After an extensive legal review, NRL concluded that 35 USC 207, traditionally used by federal laboratories to obtain patents for their inventions, also authorized federal laboratories to obtain trade secret protection for government inventions.

The Office of Naval Research adopted NRL's legal analysis in March 2021. With this new application, NRL discovered a powerful, new tool to support commercial licensing and to meet the intent of federal technology transfer. NRL then created a trade secret licensing program from the ground up and instituted mechanisms to ensure sustainability of the program.



A 300 mm photonic integrated circuit semiconductor wafer fabricated by AIM Photonics using a new low-optical-loss passive fabrication technique and components developed by the U.S. Naval Research Laboratory Optical Sciences Division is displayed in the National Cancer Institute Nanophotonics Characterization Laboratory in Washington, D.C., on June 2021. (Photo provided by U.S. Naval Research Laboratory Optical Sciences Division)

NRL also reworked the standard U.S. Navy license agreement template specifically to address trade secret considerations. NRL's first trade secret license was executed in December 2021 with the State University of New York Research Foundation (SUNY RF). This represented the Navy's first designation of a trade secret under 35 USC 207 and subsequent licensing.

Dr. Ruth H. Preller Receives Meritorious Executive Presidential Rank Award for High-Impact Achievements

By Nicholas E. M. Pasquini

Dr. Ruth Preller, former superintendent of the Ocean Sciences Division

Dr. Ruth H. Preller, a former U.S. Naval Research Laboratory (NRL) Ocean Sciences Division superintendent, received a 2022 Meritorious Executive Presidential Rank Award for leading innovative oceanographic research requiring interdisciplinary approaches and collaborations with the larger national and international ocean science community.

Preller has the distinction of being the first female senior executive at NRL. She demonstrated extraordinary leadership by maintaining the division's scientific quality and productivity and focusing the research on meeting customer needs.

Preller managed a focused research program providing warfighters with reliable predictions, known as nowcasts and forecasts, of ocean currents, temperature, salinity, optics, tides, waves, hurricane surge, and surf zone conditions.

Naval operations require precise knowledge of how the environment will impact operations in order to exploit that knowledge for tactical advantage against adversaries.

Ocean models must provide naval forces accurate predictions for open-ocean, shallow-water, near-shore, and riverine environments. Accurate ocean forecasts are essential to optimize mission planning, execution, and safety of naval and joint forces.

The Fleet Numerical Meteorology and Oceanography Center runs 10 to 12 operational ocean analysis and prediction systems daily to disseminate ocean-environment products to the fleet. Every one of these models is based on the research and technology developed by the Ocean Sciences Division.

Preller led the operational deployment of the Global Ocean Forecast System and, in collaboration with the Marine Meteorology Division, the transition and operational deployment of the Navy Earth System Prediction Capability (ESPC).

The Global Ocean Forecast System (GOFS) is the U.S. Navy's global ocean-prediction system that runs daily at Commander, Naval Meteorology and Oceanography Command (CNMOC) production centers. The GOFS provides the Navy with a first look of the three-dimensional ocean environment anywhere and at any time across the global ocean.

The Navy-ESPC ensemble system is the new global coupled atmosphere-ocean-sea ice prediction system for operational forecasting for time scales out to 45 days. Products include sea surface temperature and sea surface height forecasts, as well as parameters relevant for ocean acoustics, such as sonic layer depth and below-layer gradient. Sea ice products include ice concentration and ice thickness. For the ocean and sea ice components, this is the first time that measures of forecast uncertainty, as represented by ensemble spread, are provided. This is a first step toward long-range subseasonal climate predictions for Navy and civilian applications.

Preller led the division's development and transition of NRL's Global Predictive Seabed Model (GPSM), the first global, geologically consistent, physics-based, seafloor prediction capability. GPSM uses machine learning techniques to find correlations between observations, such as quantities whose values we want to predict everywhere, and predictors. Predictors are quantities that are different, but correlated to, those we observe whose values are either known or estimable everywhere we want to make a prediction. This novel system is being tested for operational deployment as input to acoustic models predicting acoustic bottom loss, an important performance parameter for anti-submarine warfare (ASW).

Preller also contributed impactful personal research to ocean analysis and forecasting and is the original developer of the Navy's sea ice forecasting system, the Polar Ice Prediction System (PIPS). PIPS forecasts ice thickness, ice drift, ice concentrations, and locations of ice edges. The Navy, the Coast Guard, commercial shipping, and civilian operations rely on the high-latitude ice conditions from PIPS. She was recognized in 1998 for developing PIPS by receiving one of the 75 prestigious NRL Awards for Innovation to celebrate the first 75 years of NRL.

NRL's Debra Rolison Elected 2023 National Academy of Inventors Fellow

By Mary Hamisevicz

Dr. Debra Rolison, Head, Advanced Electrochemical Materials Section

Debra Rolison, Ph.D., of the U.S. Naval Research Laboratory (NRL), has been named a Fellow of the National Academy of Inventors (NAI) for having demonstrated a highly prolific spirit of innovation in creating and facilitating outstanding inventions that have made a tangible impact on the quality of life, economic development, and welfare of society.

Rolison has been at the lab for more than 43 years and heads the Advanced Electrochemical Materials Section. The recognition by the NAI is attributed to the efforts made by her team's inventions related to a new form factor for zinc anodes in rechargeable alkaline batteries.

"Our team works with architected porous solids — composites of being and nothingness — that have sparked our imagination for a quarter of a century and spurred our in-lab innovations," said Rolison. "It is thanks to my co-inventors, who convert our scientific musings into fundamental results that link to applicable inventions, that I am being recognized by election to the National Academy of Inventors."

Rolison is a Fellow of the American Association for the Advancement of Science, the Association for Women in Science, the Materials Research Society, and the American Chemical Society. In addition to being the only woman to receive the E.O. Hulburt Award, she has received the William H. Nichols Medal, the Department of the Navy Dr. Dolores M. Etter Top Scientist and Engineer Team Award, the Charles N. Reilley Award of the Society for Electroanalytical Chemistry, the ACS Award in the Chemistry of Materials, and the Hillebrand Prize of the Chemical Society of Washington. She is the author of more than 275 articles and holds 47 U.S. patents.

Election as an Academy Fellow is the highest professional distinction awarded solely to inventors. The 2023 Class of Fellows comprises 162 distinguished academic inventors, who were slated to be honored and presented their medals by a senior official of the United States Patent and Trademark Office (USPTO) at the NAI's 13th Annual Meeting on June 18, 2024, in Raleigh, N.C.

NRL Researchers Receive Navy's Top Scientists and Engineers Award

By Nicholas E. M. Pasquini

U.S. Naval Research Laboratory scientists and engineers received the prestigious Assistant Secretary of the Navy, Research, Development and Acquisition (ASN RDA) Dr. Delores M. Etter Top Scientists and Engineers of the Year Award on June 15, 2023, during an awards ceremony hosted at the Pentagon.

"All awardees should be very proud of their accomplishments," said Frederick J. Stefany, acting assistant secretary of ASN RDA. "The technical excellence displayed by their achievements, their contributions, and the resulting payoff to the Department of the Navy is significant."

The Etter Award is presented annually to scientists and engineers who have demonstrated superior accomplishments that are technically outstanding and highly beneficial operationally to the Department of the Navy and national defense. Nearly 35,000 Navy scientists and engineers are eligible each year to receive the award. Selected honorees demonstrated exceptional scientific and engineering achievement in their field during the preceding calendar year.

Dr. Etter, a former ASN RDA, established the award in 2006 to recognize Navy civilian and military personnel for superior scientific and engineering achievements and to promote continued scientific and engineering excellence.

The NRL recipients honored as the 2023 Dr. Delores M. Etter Top Scientists and Engineers for achievement in Calendar Year 2022 are Brian Adamson, Dr. Kenan L. Cole, Dr. Sophie M. Colston, and the Flexible Distributed Array Radar (FlexDAR) team, including Mark A. Busse, Winjoy Cheung, J. B. Evins, Clifford W. Owen, and Gregory C. Tavik.

Brian Adamson,
Principal Engineer for
Advanced Communications
and Networking

Adamson delivered significant contributions in the development of advanced network and communications technology to support Navy and Department of Defense (DoD) tactical operations including providing technical oversight for the development and maturation of the Communications-as-a-Service (CaaS) software-based network routing and communications resource-management capability. Adamson's role was multifaceted, including software development for some portions of the technology, establishment of an agile, test-driven software development approach, and development of a rigorous, high-fidelity integration, testing, and evaluation framework for delivering a complex product with high assurance of operation in dynamic, tactical data communications environments.

Dr. Kenan L. Cole,
Mechanical Engineer

Cole successfully led the design, development, fabrication, and testing of advanced electronic attack systems for Navy and U.S. Army missions. Cole organized and successfully executed multiple electronic warfare (EW) field test campaigns involving industry partners and government organizations. Cole's work executing the high-profile test events required substantial interactions with multiple warfare centers, laboratories, industry, coalition partners, and the DoD.

Cole's work was instrumental in demonstrating advanced EW system performance during complex test events that involved multiple ships, ground vehicles, and aircraft. Cole's work advanced EW solutions addressing both Navy and Army needs. Cole's test events also resulted in key EW demonstrations marked as national firsts. Cole's work provided both risk reduction and acceleration of the Navy's Scaled Onboard Electronic Attack (EA) Program of Record.

Colston applied her background as a formally trained microbiologist and former officer in the U.S. Navy to develop a DNA sequencing package fieldable by a single person suitable for use by minimally trained operators.

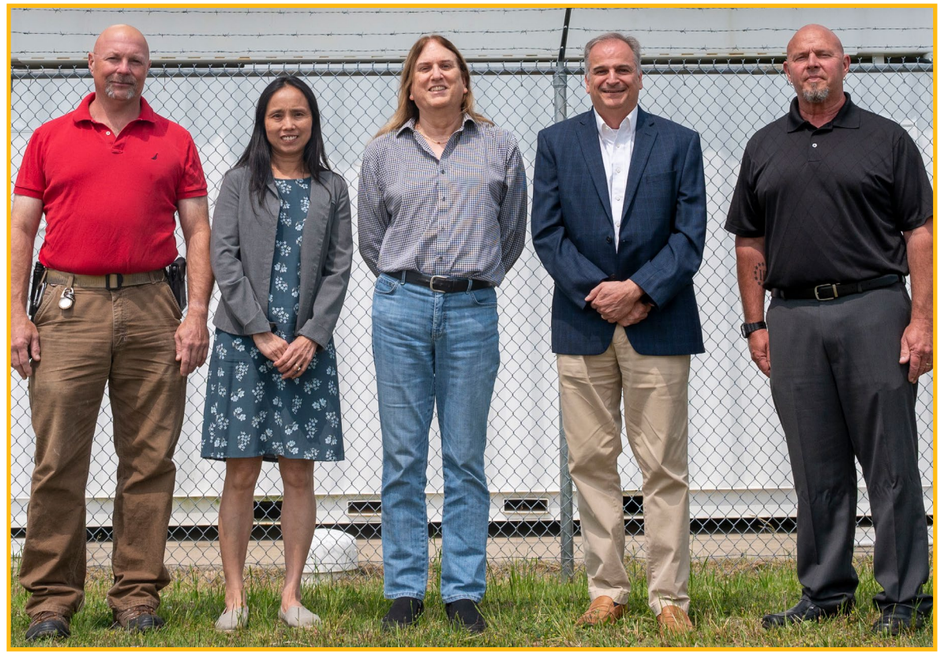
Dr. Sophie M. Colston,
Research Biologist

The core capability and training modules that Colston has developed provide the ability to "read" DNA in the field in near-real time and lend themselves to a number of different DON and non-DoD community uses. The technology has been demonstrated for DoN and DoD uses such as field identification of biological warfare pathogens, detection of SARS-CoV-2 from wastewater, determination of envenomation risks using environmental DNA sequencing at military diver training sites, and microbiome characterization in and on U.S. Navy surface vessels. The value of Colston's research to the DON and the DoD is timely and broadly applicable. Her focus on developing and validating the methods, software, and hardware necessary for robust DNA sequencing operations by minimally trained users in a variety of forward operational environments spans expeditionary to tactical use cases.

Since its invention in the 1930s at the U.S. Naval Research Laboratory, radar provides the U.S. Navy a tactical advantage and the ability to exploit the radio frequency (RF) spectrum for the detect, control, engage process. To date, radars serve as an organic component of the platform combat system. One highly visible example is the AN/SPY-1 radar integrated with the Aegis Combat System.

While these systems provide dominant capabilities to the warfighter, they are increasingly vulnerable to evolving threats. In response to this vulnerability, during the past decade, the NRL Flexible Distributed Array Radar (FlexDAR) team has made outstanding contributions to the development of advanced naval distributed radar technology. The ONR-sponsored program has been a collaboration between NRL and Raytheon Technologies.

The FlexDAR system represents the state of the art in distributed radar technology. The concept will guide the development of new radar systems that are widely expected to incorporate distributed operation, multiple beams, and dynamic reconfiguration.



Mark A. Busse, Winjoy Cheung, J. B. Evins, Clifford W. Owen, Gregory C. Tavik,
Flexible Distributed Array Radar (FlexDAR) team

FY2023 PERSONNEL

Total FTP Personnel: 2,698

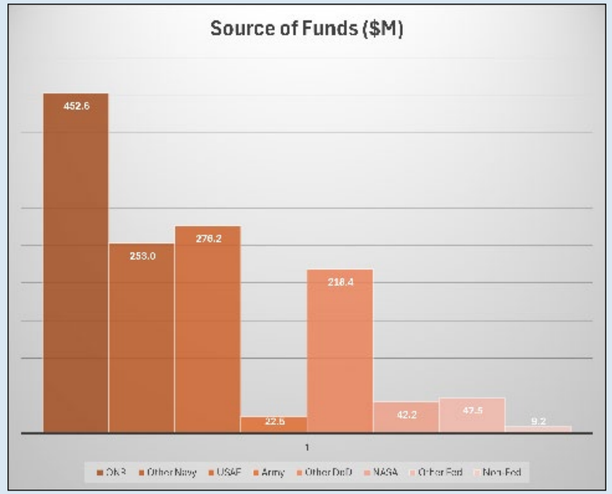
Social Science	1
Psychology	10
Program Management	1
General Natural Resources Management and Biological Sciences	32
Microbiology	2
General Engineering	15
Fire Protection Engineering	1
Materials Engineering	73
Architecture	1
Civil Engineering	7
Environmental Engineering	4
Mechanical Engineering	121
Nuclear Engineering	1
Electrical Engineering	78
Computer Engineering	61
Electronics Engineering	303
Aerospace Engineering	88
Chemical Engineering	15
General Physical Science	50
Health Physics	9
Physics	317
Geophysics	10
Chemistry	91
Metallurgy	4
Astronomy and Space Science	29
Meteorology	51
Geology	3
Oceanography	51
Operations Research	7
Mathematics	30
Computer Science	186
Data Science	1

Highest Degrees for All Full-Time Permanent Employees	FTP Civilians	ES	Total
Bachelors	660		660
Masters	480	3	483
PhDs	863	14	877

Members of the U.S. Naval Research Laboratory's Robotic Servicing of Geosynchronous Satellites (RSGS) team prepare the Robotic Arm System (RAS) for collision avoidance testing in the cryogenic thermal vacuum (TVAC) test room in Washington, D.C. June 16, 2022. The TVAC test room allows the team to collect data confirming the surroundings of the arm which provides its true position. (U.S. Navy photo by Sarah Peterson)

FINANCIALS

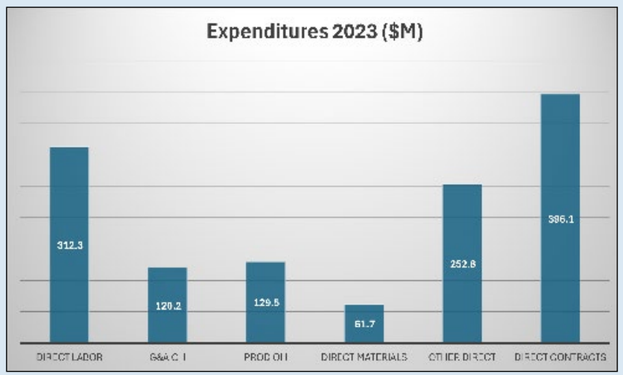
FY23 Source of New Funds



	Total ($M)
Office of Naval Research	$452.6
Other Navy	253.0
U.S. Air Force	276.2
U.S. Army	22.5
Other DoD agencies	218.4
NASA	42.5
Other Federal agencies	47.5
Non-Federal customers	9.2
Total Funds	$1,321.6

FY23 Distribution of Funds

	Total ($M)
Direct Labor	$312.3
General and Administrative Overhead	120.2
Production Overhead	129.5
Direct Materials	61.7
Other Direct Costs	252.8
Direct Contracts	396.1
Total Costs	$1,272.6



All data as of September 30, 2023

ABOUT NRL

The U.S. Naval Research Laboratory (UIC N00173) has major facilities on the banks of the Potomac River in southeastern Washington, D.C., at the Stennis Space Center in Mississippi, in Key West, Florida, and in Monterey, California. NRL employs approximately 2,700 civilian scientists, engineers, and support personnel. NRL was dedicated on July 2, 1923, and is the Navy and the Marine Corps's corporate laboratory charged with the mission of conducting basic and applied research in a broad, multidisciplinary program to advance science and technological development for the National Defense Strategy.

NRL AND FIELD SITES

Naval Research Laboratory
Washington, DC

Ocean Sciences Division
Stennis Space Center, MS

Marine Meteorology Division
Monterey, CA

Blossom Pt Tracking Facility
Welcome, MD

Chesapeake Bay Detachment
Chesapeake Beach, MD

Scientific Development Squadron (VXS) 1
NAS Patuxent River, MD

Midway Research Center
Quantico, VA

Free Space Antenna Range
Pomonkey, MD

Marine Corrosion Facility
Key West, FL

Multiple Research Site
Tilghman Island, MD

U.S. NAVAL RESEARCH LABORATORY

Reviewed and Approved
IR-1034-25-2-U
September 2025
CAPT Jesse Black, USN
Commanding Officer
4555 Overlook Ave. SW, Washington, DC 20375