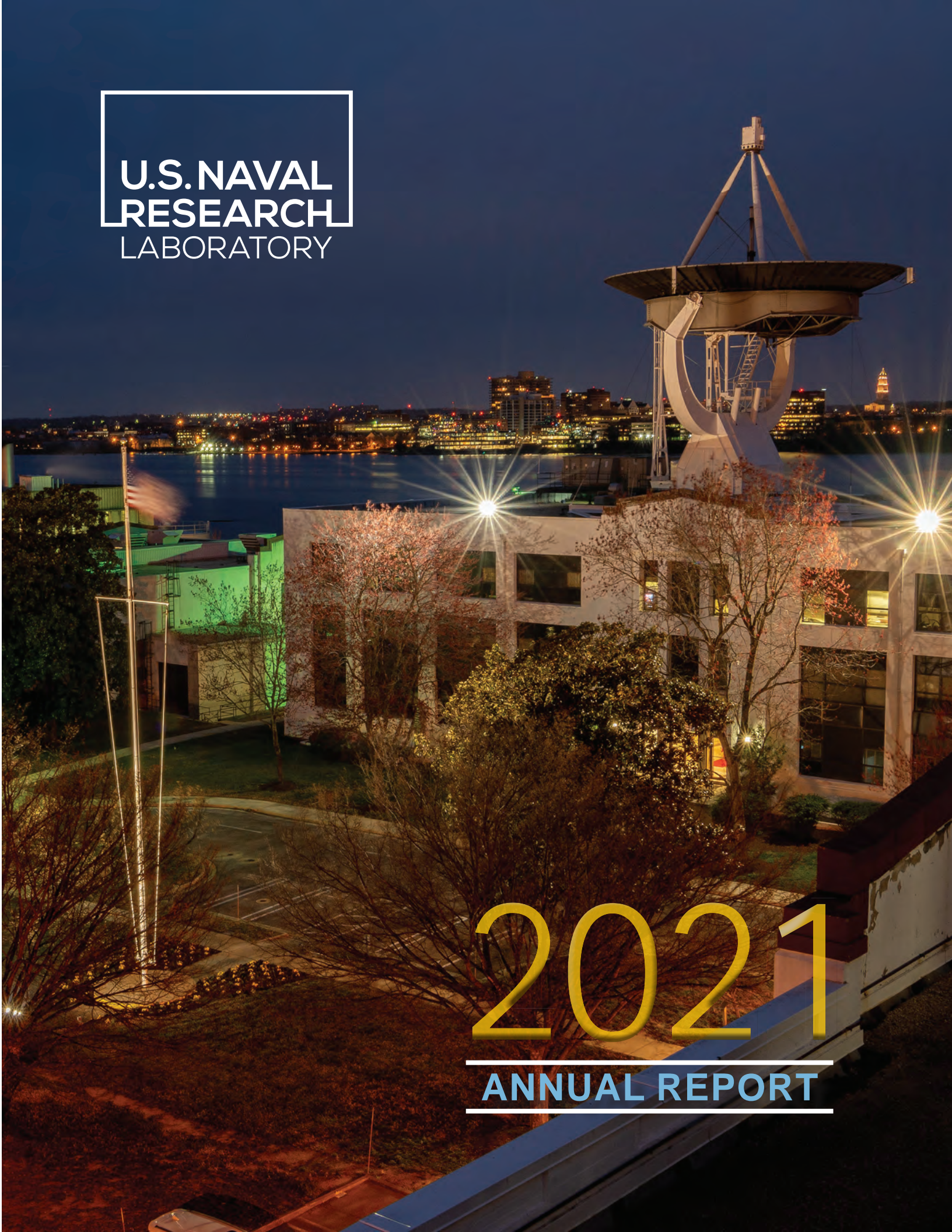


**U.S. NAVAL  
RESEARCH  
LABORATORY**



**2021**

**ANNUAL REPORT**

# ABOUT NRL

The U.S. Naval Research Laboratory (UIC N00173) has major facilities on the banks of the Potomac River in southeast Washington, D.C., at the Stennis Space Center, in Mississippi, in Key West, Florida, and in Monterey, California. NRL was dedicated on July 2, 1923, and is the Navy and the Marine Corps' 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 ITS 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 ONE (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



[www.nrl.navy.mil](http://www.nrl.navy.mil)

For more information, visit the NRL website or join the conversation on social media.



U.S. Naval Research Laboratory is dedicated to research that drives innovative advances for the U.S. Navy and Marine Corps from the seafloor to space and in the information domain.



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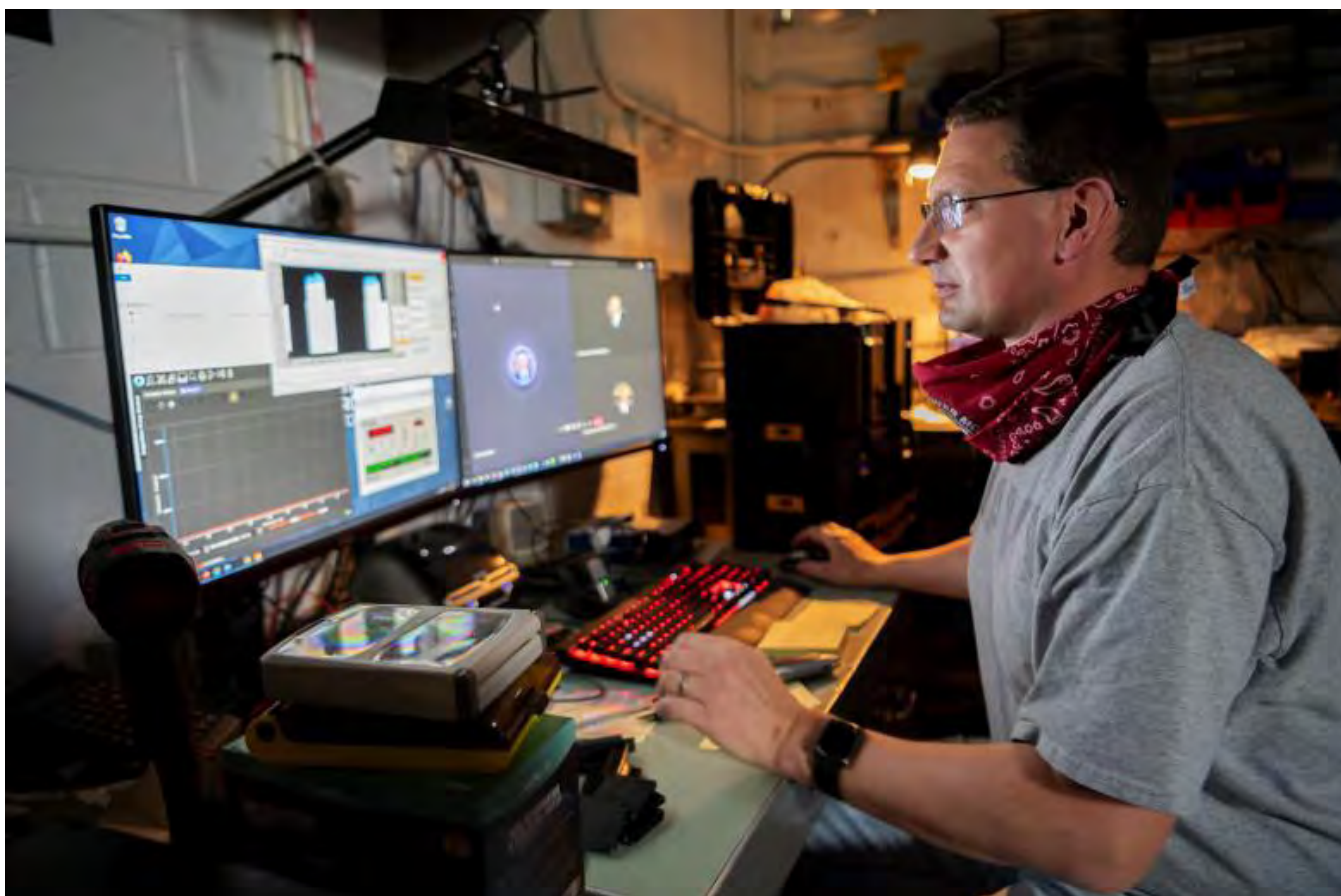


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NRL is a scientific and engineering command dedicated to research that drives innovative advances for the U.S. Navy and the Marine Corps from the seafloor to space and in the information domain. NRL is located in Washington, D.C. with major field sites in Stennis Space Center, Mississippi; Key West, Florida; and Monterey, California, and employs approximately 2,700 civilian scientists, engineers and support personnel. For more information, visit the NRL website or join the conversation on Twitter, Facebook, and YouTube.



Brett Huhman, a U.S. Naval Research Laboratory senior research engineer, communicates with other team members over video chat during testing of a pulsed Xenon gas lamp source in support of COVID-19 in Washington, D.C., on May 8, 2020. Huhman has been sending data to six other NRL researchers who have been teleworking to assess ultraviolet light sources for applications against COVID-19 for Navy and Marine environments. (U.S. Navy photo by Jonathan Steffen)

## NRL Researchers Evaluate Ultraviolet Sources, Combat COVID-19

U.S. Naval Research Laboratory researchers evaluated commercial ultraviolet (UV) sources for viral disinfection to combat COVID-19 on land and at sea, and established a dedicated UV characterization lab in five days to ensure safe introduction and effective operation of UV sources across the fleet.

The Navy is investigating UV-C band (UVC) light as a potential disinfection technique for niche applications against COVID-19 for materiel going onto a ship, for common-use areas on a ship, and for general room disinfection on ships or at shore facilities.

In a short period of time, Brett Huhman, in NRL's Plasma Physics Division, reconfigured a laboratory space, conferred with subject-matter experts across the NRL Materials Science and Component Technology directorate, and borrowed needed equipment to establish a UV characterization laboratory.

"Testing at NRL includes UV unit longevity and reliability, identifying easy-to-use dosimeters, reflections from shipboard surfaces, and secondary ozone

generation from these UV systems," Huhman said. "Scientists at other Navy labs are using NRL data to help them test efficacy against viral loads on Navy and Marine relevant surfaces, such as bare metal tools and painted metal surfaces, and cardboard boxes."

The Naval Sea Systems Command (NAVSEA) requested that NRL scientists study and characterize the energy density, UV spectrum, and reliability of commercially available units. Navy researchers continue to evaluate commercial units already being used in hospitals and for other applications for efficacy on Navy-relevant surfaces. The NRL UV team is receiving items on a bi-weekly basis for evaluation.

NRL's work will help identify situations in which use of UV provides sufficient viral disinfection at a particular energy level and also will help develop standard operating procedures to ensure safe UV operation for the fleet.

## NRL, NCATS Scientist Develop Method to Safely Study COVID-19, Other Contagious Diseases

Scientists and researchers at the U.S. Naval Research Laboratory and the National Center for Advancing Translational Sciences (NCATS), submitted their findings to *ACS Nano*, a monthly peer-reviewed scientific journal, on their collaboration to develop SARS-CoV-2 nanoparticle probes that are used to study fundamental interactions between SARS-CoV-2 spike proteins and human cells.

The manuscript is titled, “Quantum Dot-Conjugated SARS-CoV-2 Spike Pseudo-Virions Enable Tracking of Host Cell Surface Angiotensin Converting Enzyme 2 Binding and Endocytosis.” SARS-CoV-2 is known to use the external ‘spike’ proteins that cover its surface to attach to angiotensin-converting enzyme 2 (ACE2) receptors, which the virus uses to bind with and enter human cells.

Together with researchers at NCATS, part of the National Institutes of Health (NIH), they worked to develop non-infectious probes to study SARS-CoV-2, which is the causative virus of the current COVID-19 pandemic.

“Simply put, keeping the virus out of cells prevents it from replicating, propagating, and exacerbating infection,” said Mason Wolak, Ph.D., acting head of NRL’s Optical Nanomaterials Section. “The ultimate goals of the collaboration are to clarify the fundamental mechanisms by which SARS-CoV-2 causes infection and to screen and identify potential drugs to inhibit these mechanisms.”

One thing that fascinated the scientists was the potency of the quantum dot nanoparticles to induce translocation of ACE2 from the cell membrane to the interior of the cell through a process called endocytosis. Kirill Gorshkov, Ph.D., an NCATS research scientist, said experiments to block endocytosis prevented internalization of the quantum dot pseudovirus-and-ACE2-receptor complex.

“While we had some idea that this was possible, the extent to which this occurred with very low amounts of quantum dot pseudo virions suggested we had a powerful system to track viral attachment and effects on the cell in real time, since these quantum dots are fluorescent,” said Gorshkov.

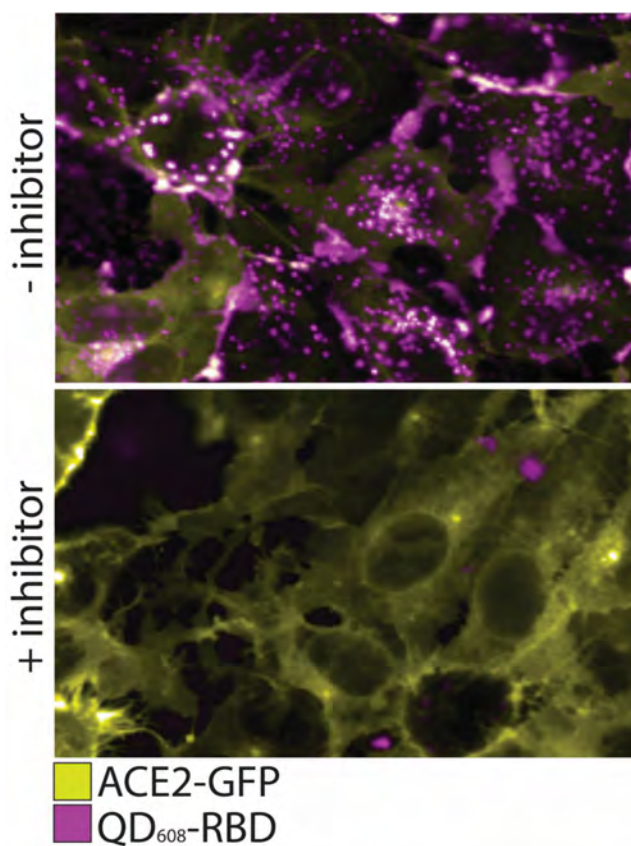
The nanoparticle probes developed at NRL comprise multiple spike protein subunits attached to the surface of a light-emitting quantum dot core.

NRL and NCATS are currently designing and testing the feasibility of high-throughput cellular imaging tests to screen entire libraries of therapeutic agents for inhibition of Spike/ACE2 binding and internalization.

These tests, carried out at NCATS, would allow for

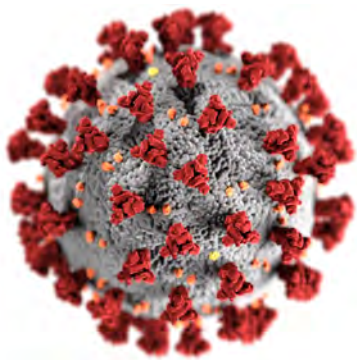
screening of up to 1,536 drug targets per experiment.

Further research is planned to investigate the mechanism that increases infectiousness of SARS-CoV-2 with mutated spike proteins. The NRL/NCATS team also plans to explore the possibility of using the pseudo-virions for site-specific intracellular drug delivery for purposes of disrupting SARS-CoV-2 replication mechanisms.



Here we see the QD608-RBD binds ACE2 and induces endocytosis. In this figure, the top panel shows ACE2-GFP-expressing (yellow) cells binding and internalizing QD608-RBD (magenta). In the bottom panel, an inhibitor is added to prevent binding of QD608-RBD to ACE2-GFP, and the presence of ACE2-GFP on the cell surface is strong with little to no QD608-RBD visible. Scientists at the U.S. Naval Research Laboratory and the National Center for Advancing Translational Sciences (NCATS), published their findings in *ACS Nano*, a monthly peer-reviewed scientific journal, on their collaboration to develop SARS-CoV-2 nanoparticle probes that are used to study fundamental interactions between SARS-CoV-2 spike proteins and human cells. (Photo by NCATS /RELEASED)

## NRL Chemists' Rapid Response Cleans Up



U.S. Naval Research Laboratory Chemistry Division researchers responded within four days to the Navy's request in early April for coronavirus (COVID-19) shipboard decontamination strategies.

The research team identified preferred chemistries and recommended products to disinfect large areas using commercially available products that were safe for sailors while minimizing the risk for causing shipboard corrosion.

Jim Wynne, a research chemist, led the efforts for the request. His expertise in surface decontamination directed the team to concentrate on the quaternary ammonium family of compounds. These compounds are known to exhibit broad-spectrum activity against a variety of pathogens at relatively low concentrations. They destroy microorganisms such as bacteria, fungi and viruses that cause harm to people.

These chemicals are commonly found in disinfectant wipes, sprays and other household cleaners designed to kill germs.

"Quaternary ammonium compounds were the most sensible solution for large-area shipboard use, because they can effectively deactivate the virus by destroying its protein membrane," Wynne said. "There are other chemicals that can be used to deactivate the virus, but they would be more corrosively aggressive to a ship's delicate ecosystem."

"It's always important to follow the manufacturer's product guidelines. From my experience, these kind of disinfectants should reside on the surface about 10 minutes to be considered sanitized."

The manner of application also was considered important for such large areas. The researchers recommended the product be applied as a fine mist directly to compatible surfaces to ensure surfaces were wetted adequately while also not disturbing contamination that may be residing on the surface. The NRL team's deep expertise of coating formulation, testing, and demonstration made the rapid response possible.

"Our extensive fundamental knowledge of chemical processes and the naval shipboard corrosion prevention risks and reduction led to the speedy recommendation," said Ted Lemieux, a chemical engineer and head of the Center for Corrosion Science and Engineering.

Corrosion is a key concern for shipboard applications since ships employ a wide range of metals and nonmetals that are not normally found in household applications. These concerns also include electrical equipment and electronics that are not designed for some modes of disinfection such as fogging or misting.



U.S. Navy Aviation Electrician's Mate 3rd Class Kyle Hernandez, from Denton, Texas, assigned to the Tomcatters of Strike Fighter Squadron (VFA) 31 (top), and U.S. Navy Aviation Ordnanceman Airman Brian Miller, from Mineral Wells, Texas, assigned to the Black Knights of Strike Fighter Squadron (VFA) 154 (bottom), disinfects a berthing aboard the aircraft carrier USS Theodore Roosevelt (CVN 71) with a multisurface sanitizer on April 12, 2020. Upon arriving in Guam on March 27, Theodore Roosevelt established an emergency command center, initiated a roving deep-cleaning team, and continually educated the crew on social distancing and proper protective procedures and behaviors to assist the crew in mitigating and controlling the spread of COVID. Theodore Roosevelt was in Guam for a scheduled port visit for resupply and crew rest during their scheduled deployment to the Indo-Pacific region. (U.S. Navy photos by Mass Communication Specialist Seaman Kaylianna Genier)

## NRL Conducts First Test of Solar Power Satellite Hardware in Orbit

U.S. Naval Research Laboratory engineers launched PRAM, the Photovoltaic Radio-frequency Antenna Module, aboard an Air Force X-37B Orbital Test Vehicle on May 17 as part of a comprehensive investigation into prospective terrestrial use of solar energy captured in space. "To our knowledge, this experiment is the first test in orbit of hardware designed specifically for solar power satellites, which could play a revolutionary role in our energy future," said Paul Jaffe, PRAM's principal investigator. The 12-inch-square tile module will test the ability to harvest power from its solar panel and to transform the energy to a radio frequency microwave.

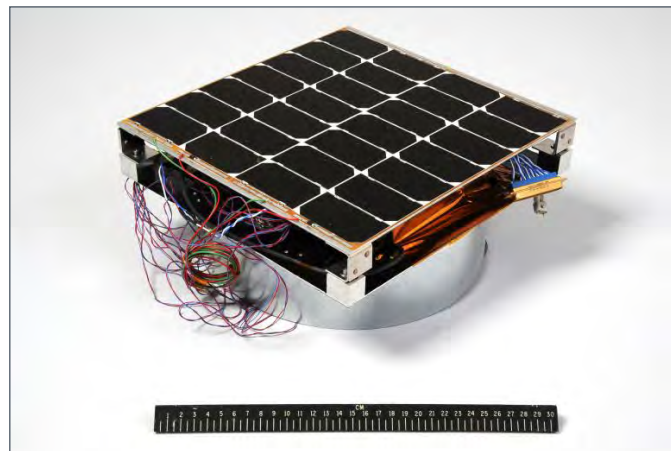
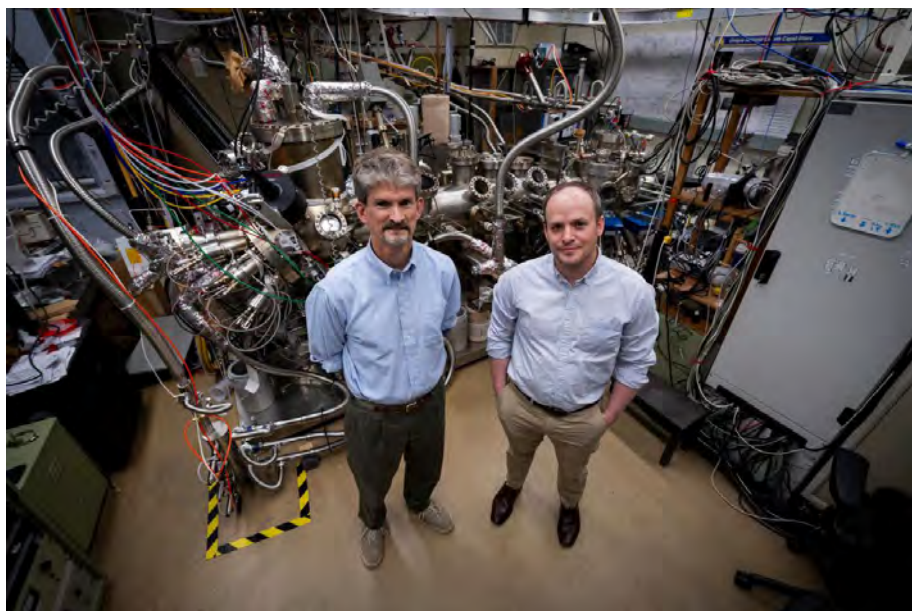


Image of the Photovoltaic Radio-frequency Antenna Module (PRAM) with a 12-inch ruler for scale. The hardware is the first orbital experiment designed to convert sunlight for microwave power transmission for solar power satellites. (Image Courtesy of the U.S. Naval Research Laboratory)

## NRL Researchers Create Electronic Diodes Beyond 5G Performance



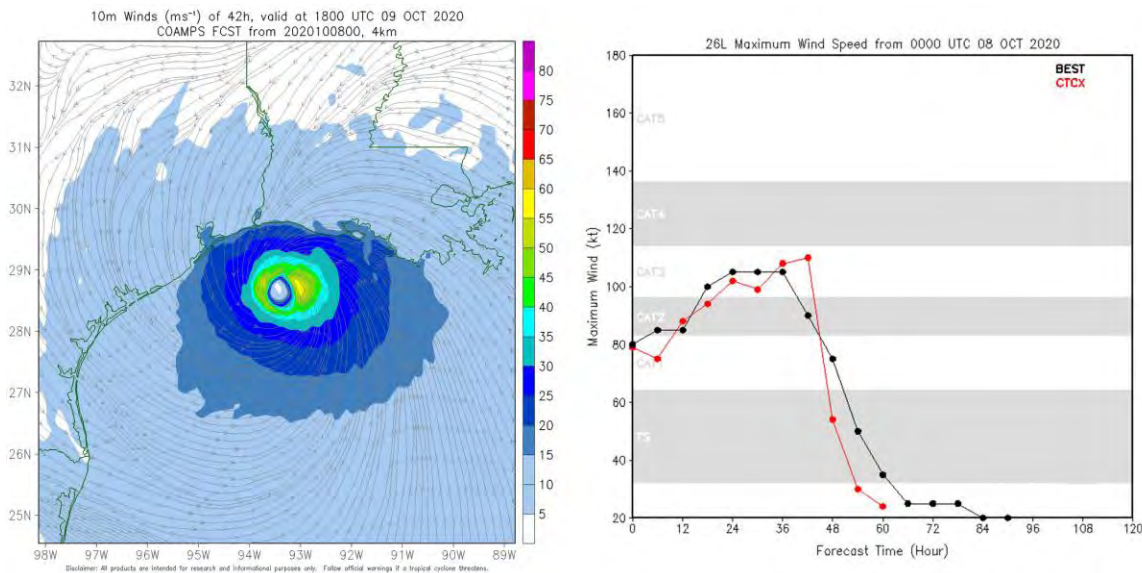
David Storm, a research physicist, and Tyler Growden, a National Research Council postdoctoral researcher, stand at the U.S. Naval Research Laboratory with their molecular beam epitaxy system that develops gallium nitride-based (GaN) semiconductors in Washington, D.C., on March 10, 2020. Storm and Growden published their research on GaN semiconductor materials, which showed high yield and performance well suited for high-frequency and high-power electronic devices in Applied Physics Letters. (U.S. Navy photo by Jonathan Steffen)

David Storm, a research physicist, and Tyler Growden, an electrical engineer, both with the U.S. Naval Research Laboratory, developed a new gallium nitride-based electrical component called a resonant tunneling diode (RTD) with performance beyond the anticipated speed of 5G. The fifth-generation network technology is now just starting to roll out across the United States. Storm and Growden's electronic component diode research findings were published March 19, 2020, in the academic journal Applied Physics Letters. "Our work showed that gallium nitride-based RTDs are not inherently slow, as others suggested," Growden said. "They compare well in both frequency and output power to RTDs of different materials." The diodes enable extremely fast transport of electrons to take advantage of a phenomenon called quantum tunneling. In this tunneling, electrons create current by moving through physical barriers, taking advantage of their ability to behave as both particles and waves.



## COAMPS-TC Recognized as Leading Tropical Cyclone Prediction Model

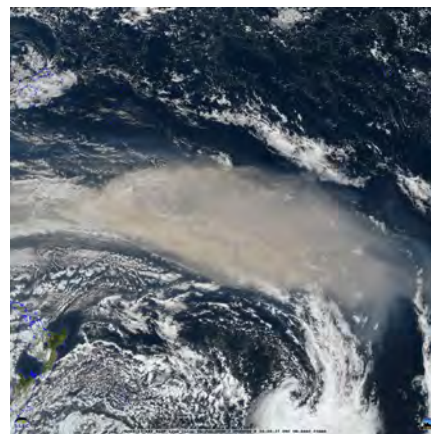
The U.S. Naval Research Laboratory’s Coupled Ocean/Atmosphere Mesoscale Prediction System for Tropical Cyclones (COAMPS-TC) model was named the world’s most accurate in predicting hurricane strengths during the 2019 Atlantic hurricane season by Jeff Masters, Ph.D., in Yale’s August 2020 *Climate Connections*. “The group of scientists we have work very hard and are committed to developing and improving the Navy’s tropical cyclone models to provide as accurate forecasts as possible,” said James Doyle, senior scientist at the NRL Marine Meteorology Division (MMD). “The COAMPS-TC model is used widely by civilian and DOD forecasters to provide guidance aimed at protecting life, property, and for the DOD to carry out its mission safely.” COAMPS-TC is operated by the Fleet Numerical Meteorology and Oceanography Center and its development has been supported by NRL and the Office of Naval Research. These three Navy organizations work closely on a new initiative aimed at closing the gaps in our understanding of hurricanes and tropical cyclones.



The left image shows a 42-hour COAMPS-TC forecast of wind speed with Hurricane Delta nearing landfall along the Louisiana coast valid on Oct. 9. The right graph shows a comparison of the COAMPS-TC maximum-wind-speed forecast (red) with the observed estimate (black). Recently, COAMPS-TC was recognized as the world’s most accurate hurricane intensity model during the 2019 Atlantic hurricane season (Jeff Masters, Ph.D., in Yale’s August 2020 *Climate Connections*). (U.S. Navy image)

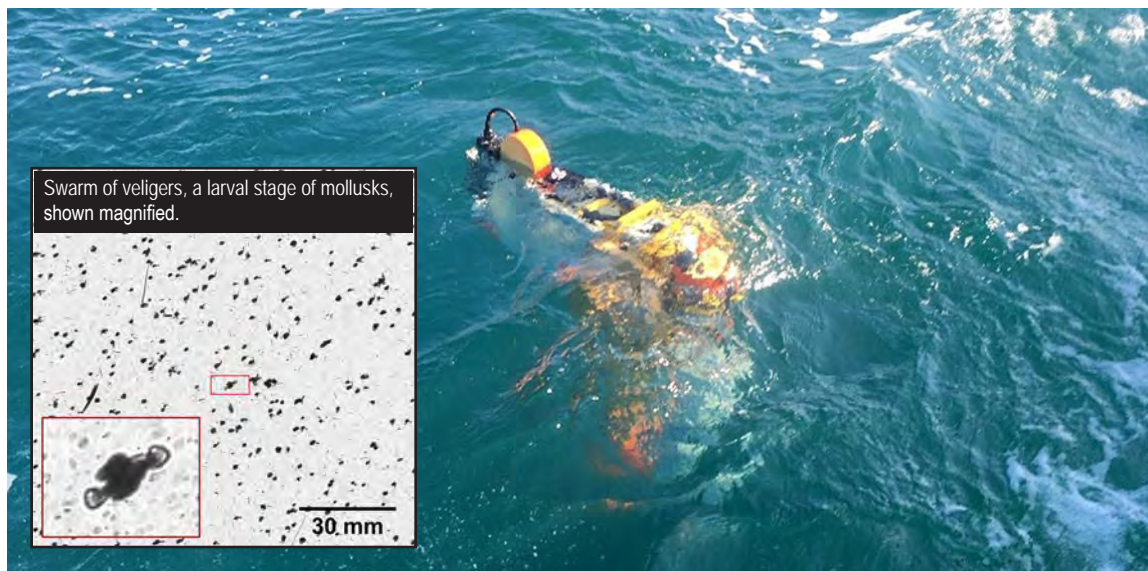
## Simultaneous Optical Beam Forming for Phase-Array Applications

Naval Research Laboratory Remote Sensing Division scientists continue to study the data pyrocumulonimbus (pyroCb) plumes generated during brush fires that ravaged southeastern Australia between Dec. 29, 2019, and Jan. 4, 2020. Researchers used the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite which provides insight into the role clouds and airborne particles play in regulating Earth’s weather, climate, and air quality. PyroCbs are fire-induced thunderclouds that inject massive amounts of smoke particles into the upper atmosphere. When these events are hot enough, wildfires can trigger convective updrafts, the heights of which extend well into the lower stratosphere. The lower boundary of the stratosphere can be as high as 13 miles.



This image from the Geostationary Operational Environmental Satellite-17 shows New Zealand in the lower left. The brownish-gray plume in the center is the large smoke aerosol mass that formed into the P1 plume that was generated during brush fires that ravaged southeastern Australia between Dec. 29, 2019, and Jan. 4, 2020. The white clouds below it are obscured due to the dense smoke. (Image by Cooperative Institute for Meteorological Satellite Studies/Space Science and Engineering Center)

## Navy Gains a Competitive Edge with Research into Biological Ocean Swarms



A Wirewalker, driven by waves and currents, sits at the ocean's surface during a field campaign led by oceanographers from the U.S. Naval Research Laboratory. The Wirewalker was equipped with a variety of instruments to measure light, conductivity, temperature, depth, light and acoustic backscattering, and dissolved oxygen throughout a water column. The NRL study was focused on characterizing biological ocean swarms. (U.S. Navy photo, Brad Penta)

Tiny and frightening-looking creatures lurking throughout our world's oceans can wreak havoc on Navy tactical decision-makers' ability to sense the environment or to plan and chart a navigation course. The simple presence of these animals, some the size of a pen tip, can affect Navy operations through attenuation of acoustic signals, bioluminescence, and ambient noise. To help increase our understanding of these intermediate trophic level (ITL) organisms such as tiny crustaceans and jellyfish, researchers conducted a 14-day field campaign last year off the coast of Delaware. The campaign, led by U.S. Naval Research Laboratory oceanographer Brad Penta, collected information about the dynamics of ITL ecosystems near ocean fronts — areas that tend to be biologically active.

## NRL's Remote Sensing Division Analyzes Ground Characteristics in Australia

U.S. Naval Research Laboratory physical scientists, engineers, and principal investigator Andrei Abelev visited Australia in May 2019 to validate their techniques for terrain characterization. Using multiple types of sensors to gain understanding of different soils, the team used the trip to see how their models performed with the soils Down Under, digging into the homes of some of the most dangerous animals in the world. "We are proud of being a one-stop shop at NRL for remote sensing of terrain and its characterization," Abelev said. "It's a capability that no other organization has, and we are unique in our multi-sensor, multi-modal approach." Understanding ground characteristics is part of the science and the art of geotechnical engineering, which can be useful in multiple areas, including project management and planning. Abelev said remote-sensing technologies can aid many applications in civil, environmental, and hydrological engineering, as well as in agriculture. For example, knowing specific soil properties can help in optimizing locations for new buildings and roads, can lead to better understanding of the dangers in possible landslides, or can devise estimates of surface water erosion during rain events.



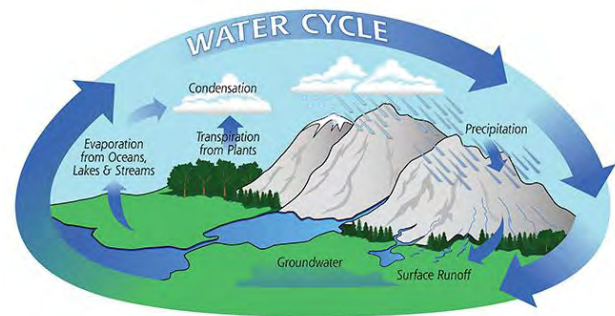
Physical scientists and engineers from the U.S. Naval Research Laboratory collect soil samples and conduct ground measurements with collaborators during a 2019 Australian field expedition to validate remote sensing techniques for terrain characterization. NRL's Remote Sensing Division uses multiple sensor modalities to understand geotechnical characteristics of the soil, such as soil type, composition, and strength. (U.S. Navy photo by Andrei Abelev)

## Researchers Shed Light on Perplexing Bay of Bengal Monsoon Oscillations

Oceanographers and meteorologists with the U.S. Naval Research Laboratory concluded an ambitious field research program in collaboration with the U.S. Office of Naval Research aimed at understanding the role of the Indian Ocean on monsoon intraseasonal oscillations (MISO) on June 26. The project seeks to understand this major weather phenomenon that impacts more than 1 billion people living in the Indian subcontinent and the Bay of Bengal rim nations. “Monsoons bring not only much-needed water resources, but also major disasters resulting from severe weather, flooding, and storm surges,” said Hemantha Wijesekera, Ph.D., who is a research oceanographer and the lead principal investigator. “The goal is to study and quantify oceanic processes that regulate the intensity and propagation of the MISO in the region.” Several times per year from May to October, a process called MISO occurs in the atmosphere over the Indian Ocean, the western tropical Pacific Ocean, and surrounding land areas. This weather event brings periods of extremely wet and extremely dry conditions to the area, significantly affecting the people and economies of those areas. Researchers do not currently know the extent to which the Indian Ocean affects the intensity of this process.



A radiosonde is deployed to record temperature, humidity, and pressure during the oceanographic cruise aboard R/V Sally Ride in the Bay of Bengal. (U.S. Navy Photo/Released)



## When a Speck Influences a Storm: Studying the Role of Aerosol Particles in the Hydrological Cycle

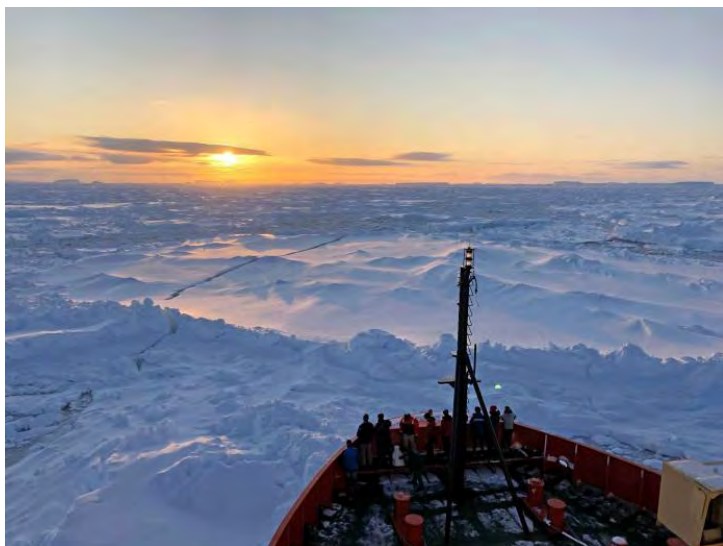
U.S. Naval Research Laboratory meteorologist Jeffrey Reid is at the forefront of research studying the role of aerosol particles, and the relationships between the particles with monsoon meteorology, clouds and the sun’s radiation. Aerosol particles floating through the environment harbor big mysteries to scientists globally. The particles range in size from bundles of molecules (10 nm) to a grain of sand, and are capable of surfing through the air for thousands of miles. Small and seemingly insignificant on their own, the particles travel as inanimate swarms, influencing the earth’s weather and climate in ways scientists do not yet fully understand.

Reid served as the mission scientist for the international field campaign, the Cloud, Aerosol and Monsoon Processes Philippines Experiment (CAMP2Ex), the largest airborne field campaign to date in maritime Southeast Asia. The NASA-initiated campaign studied tropical weather and aerosols in the Southeast Asian region last year from August to October. CAMP2Ex was a partnership with NASA, NRL, the Manila Observatory, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), and various academic organizations.

According to Reid, the information collected from the Philippines could be used to develop models to predict major weather events around the world, including those in the United States. This capability would prove valuable for the Navy, which maintains a constant forward-deployed presence.



## NRL-Developed Ocean Prediction System Steers Ice-bound Antarctic Vessel to Open Waters

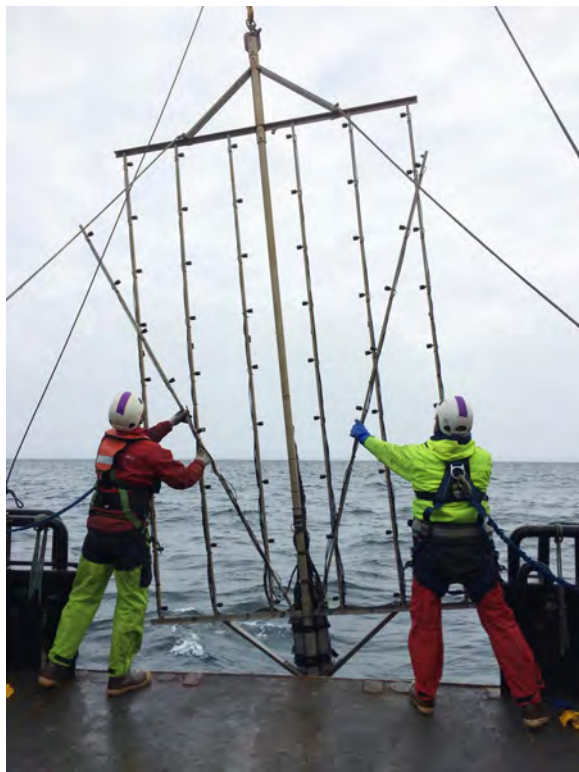


Personnel enjoy a Sunday morning sunrise aboard the research vessel Nathaniel B. Palmer on March 15 as the vessel moves into the Bellingshausen Sea. The crew participated in the International Thwaites Glacier Collaboration in the Amundsen Sea region. The U.S. Naval Research Laboratory’s Global Ocean Forecast System provided valuable environmental information that helped the ship navigate out of Antarctica’s ice-laden waters. (National Science Foundation photo by Cindy Dean)

The U.S. Naval Research Laboratory’s Global Ocean Forecast System (GOFS) provided valuable environmental information on March 18 that helped a research icebreaking ship navigate out of Antarctica’s ice-laden waters. The U.S. Antarctic Program’s ship Nathaniel B. Palmer, tasked with extended scientific missions in the Antarctic, could not maneuver around huge, stiff ice blocks while attempting to reach open waters traversing around Pine Island Bay in West Antarctica. The NRL-developed forecasting system assimilates ocean and ice observations from a number of sources and provides sea ice concentration, thickness and drift as well as areas of converging or diverging ice. Convergence happens when bodies of sea ice move toward each other and become more compact. Divergence happens when sea ice bodies move away from each other.

The ocean forecast system first released in 2013 evolved to incorporate a growing number of data inputs and a more refined understanding of ocean and ice physics. The Fleet Numerical Meteorology and Oceanography Center and the National Ice Center deploy GOFS and other tools to enable the Navy and coalition forces to navigate the ocean-and-ice environment safely.

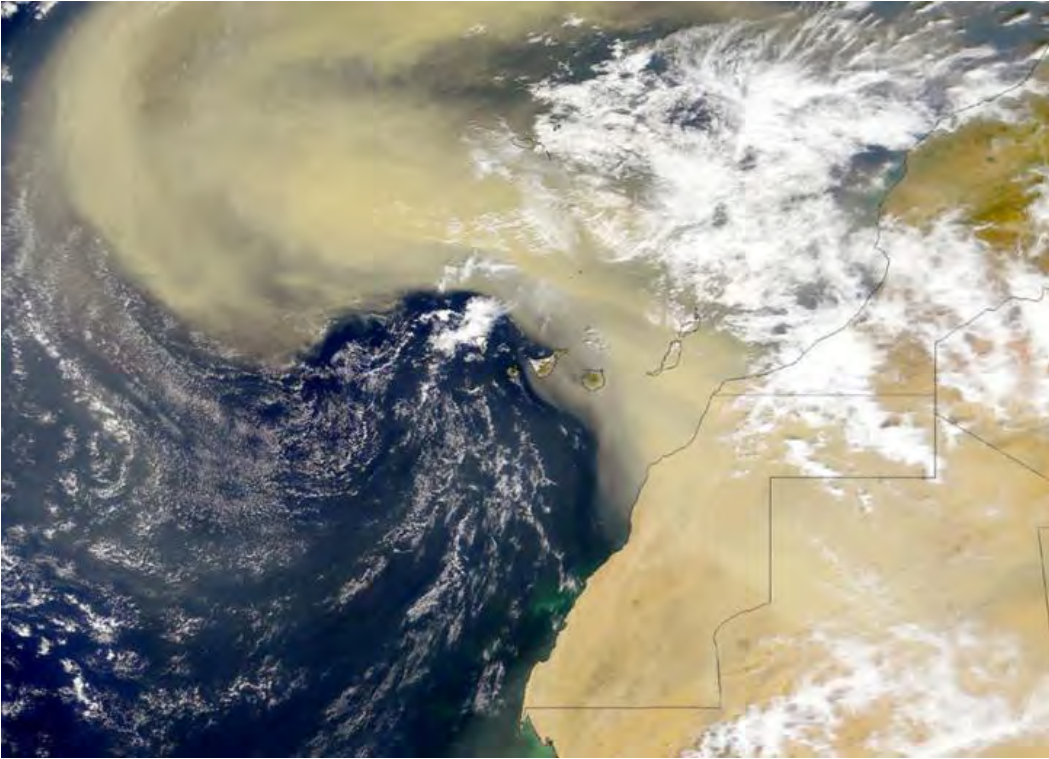
## NRL Researchers Monitor Changing Arctic Using Sound



U.S. Naval Research Laboratory scientists developed ice-tethered acoustic buoys to monitor the acoustic and oceanographic environment in the changing Arctic. The buoys provide critical oceanographic data to improve prediction capabilities of ocean and climate models. These buoys validated the Arctic researchers’ sound-propagation theories and will continue to guide and validate theoretical studies in the Beaufort Sea from March 2020 to March 2021. Ocean acoustic tomography is a technique that uses sound waves to image sections of ocean temperature and current. The buoys are a practical alternative to more traditional acoustic and oceanographic measurement techniques because they provide real-time monitoring and operational capability. Additionally, they enable under-ice acoustic communication and navigation capability for mobile platforms such as ocean gliders and underwater autonomous vehicles.

The U.S. Naval Research Laboratory-built Billboard Array is an acoustics instrument equipped with 64 receiver elements. It differentiates and amplifies sounds from different directions. The array provided remarkable acoustic data under both seasonal oceanographic and sea ice conditions during the multi-institutional Canadian Basin Acoustic Propagation Experiment (CANAPE) in the Beaufort and Chukchi seas. (U.S. Navy photo)

## NRL Meteorologist Tracks Transcontinental Dust Storms' Magnitude and Impact



A massive sandstorm blowing off the Northwest African desert has blanketed hundreds of thousands of square miles of the eastern Atlantic Ocean with a dense cloud of Saharan sand. The massive nature of this particular storm first was seen in this Sea-Viewing Wide Field-of-View satellite image acquired Feb. 26, 2000, when it reached over 1,000 miles into the Atlantic. (Courtesy image by Norman Kuring, NASA)

The amount of dust flying out of the Sahara Desert each year is seemingly unfathomable. Every year, 14 million metric tons of transcontinental dust travels across the Atlantic Ocean, said Arunas Kuciauskas, a U.S. Naval Research Laboratory meteorologist who tracks and quantifies the Saharan Air Layer (SAL). These dust storms envelop whole communities — blanketing homes, cars, and people. NASA research scientists estimate it would take 53,022 semi-trucks to move enough desert sand to equal the amount of dust transported from Northern Africa to the Greater Caribbean annually. How do these dust clouds affect community health? Can forecasters predict the large dust storms to help prepare affected communities? Health care professionals and meteorologists across the globe consider these questions every spring and summer when the northeasterly trade winds begin to pick up Saharan dust and to scatter it across thousands of miles. This meteorological phenomenon involves an extremely hot, dry air mass, carrying large concentrations of Saharan dust from Northern Africa across the Atlantic Ocean into the Greater Caribbean, South America, the Gulf of Mexico and southeastern United States. Kuciauskas collaborates with researchers at NASA, the National Oceanic and Atmospheric Administration (NOAA), and Caribbean organizations to model the Saharan dust storms and provide prediction tools to weather forecasters and health care professionals in the affected regions. One of the new forecasting resources he uses to track and quantify

SAL events is the NOAA Unique Combined Atmospheric Processing System, or NUCAPS, a software tool that processes radiance data from satellite measurements collected by NOAA's Joint Polar-orbiting Satellite System (JPSS) into thermodynamic parameters that describe the SAL.

The U.S. Navy also benefits from early SAL forecasts. Navy meteorologists monitor weather conditions over huge swaths of ocean and collect data from rawinsondes, which consist of airborne weather instruments used to measure temperature, moisture, and wind profiles from the surface to the top of the earth's atmosphere. This information is applied to study various weather-related properties of SAL.

Numerous global land-based sites routinely launch rawinsondes. Over the oceans or other bodies of water, rawinsondes are too sparsely located to provide a reasonable picture of SAL events, said Kuciauskas. By contrast, NUCAPS gathers information from satellites that provide continuous measurements over oceans, allowing forecasters to see clearly vertical profiles containing similar information to what is available over land.

## NRL Designated Navy's Quantum Information Research Center



Jonathan Kwolek, Ph.D., left, a U.S. Naval Research Laboratory research physicist, shows an atom interferometer to Chief of Naval Research Rear Adm. Lorin Selby on Sept. 14, 2020, at NRL facilities in Washington, D.C. Kwolek uses the instrument to measure motion for navigational purposes. (U.S. Navy photo by Jonathan Steffen)

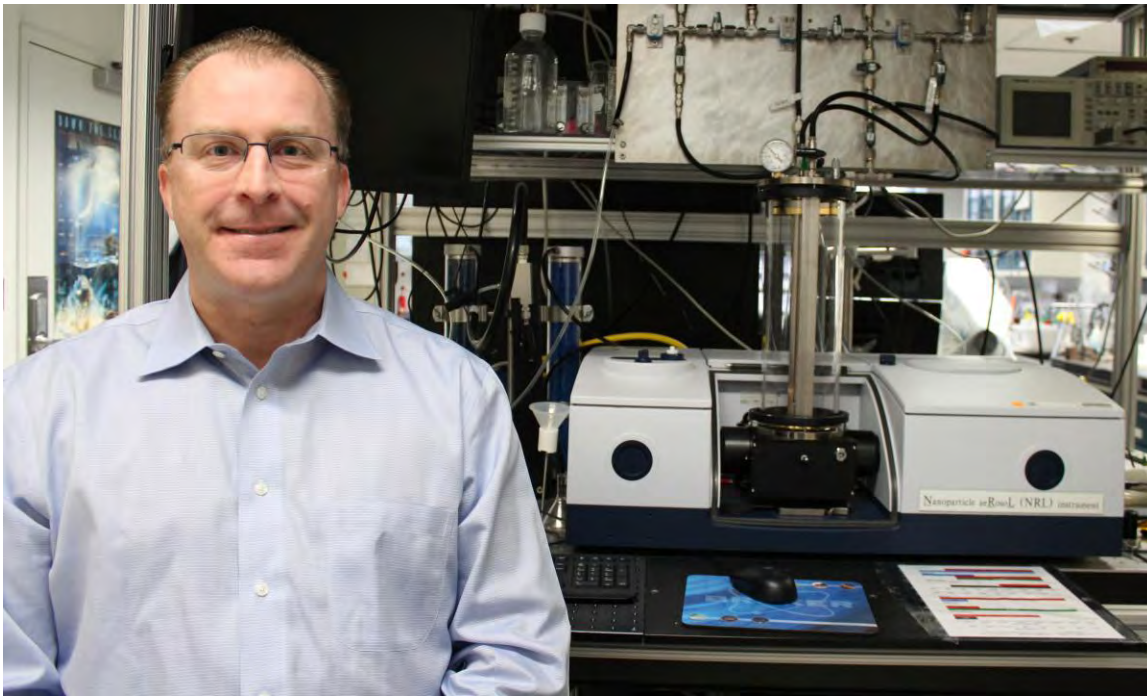
In March of 2020, the Department of the Navy designated the U.S. Naval Research Laboratory as the Navy's Quantum Information Research Center. The designation, mandated by the fiscal year 2020 National Defense Authorization Act, allows NRL to engage with public- and private-sector organizations to enhance and accelerate research, development, and deployment of quantum information sciences and QIS-enabled technologies and systems.

The quantum world is a realm so tiny its sizes are similar or smaller than those of atoms. In this realm, the general rules of physics become so unrecognizable that Albert Einstein described the quantum entanglement as, "spooky action at a distance." Much of modern physics and many current technologies in widespread use have their foundation in applications of quantum physics that have been in place since the 1930s. However, the application of some aspects of quantum physics, in particular quantum entanglement and quantum superposition, have not yet led to widespread uses, but hold promise for new applications. For nearly 30 years, NRL has been researching quantum systems and their applications.

NRL is also building bridges with industry and continuing a close collaboration on quantum memory with academia. In September 2020, NRL entered into an educational partnership agreement with the University of Maryland's Quantum Technology Center to identify and pursue opportunities related to quantum technologies research.

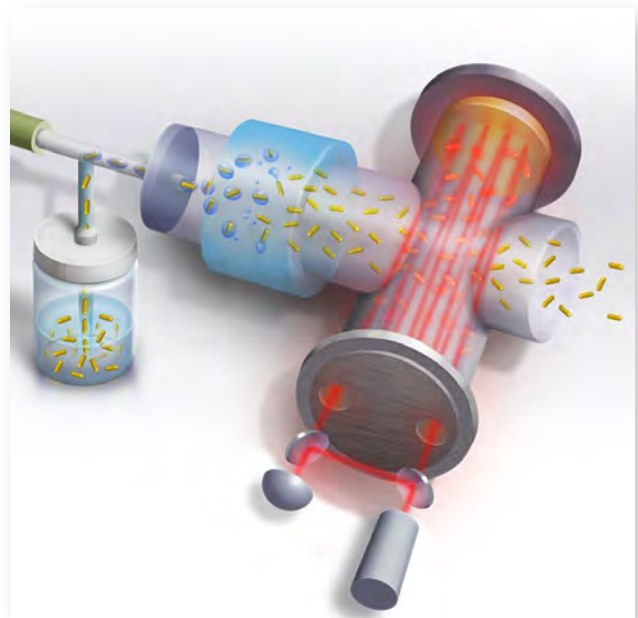
Quantum information science may offer vast technological improvements in computing, sensing, and communication. NRL scientists continue to look for dividends in these areas, such as solving computer problems in minutes that otherwise could take a lifetime, saving the lives of submariners with more precise location, or establishing more secure, virtually unhackable communications for sailors and Marines.

## NRL Researcher Optically Measures Aerosol Particles Smaller than a Wavelength of Light in Real Time



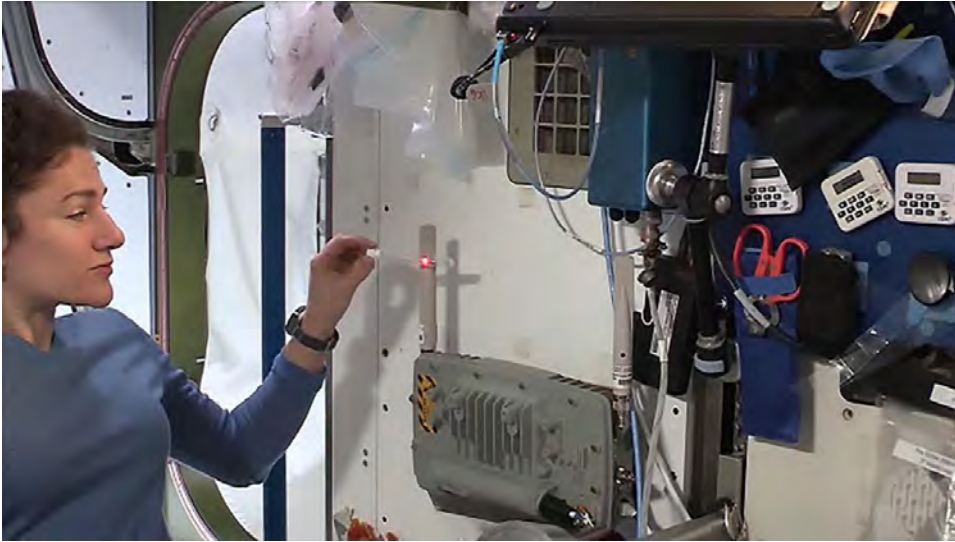
Research physicist Jake Fontana stands next to the Nanoparticle aeRosoL (NRL) instrument at the U.S. Naval Research Laboratory. The benchtop instrument measures the behavior of gases with particles of nanometer size in real time. The ability to see tiny aerosols can advance research in meteorology and other fields. (U.S. Navy photo)

A research physicist at the U.S. Naval Research Laboratory invented a new method to create and optically measure gases with particles smaller than a wavelength of light. Principal investigator Jake Fontana and his peers published the findings in February 2019 and have a patent pending on their technique. "We made an instrument which efficiently creates aerosols with nanometer-size particles. Because the particles are plasmonic, we can see them in real time," Fontana said. "This opens up a new world in being able to study nanoparticle gases at the benchtop." Plasmonic materials — such as gold, silver and platinum particles — contain oscillating electrons that couple efficiently to light. Artists have been using plasmonics for centuries without knowing the term. Early photographs, called daguerreotypes, used silver iodide in processing. The application of silver in daguerreotypes created visible images because the small clusters of silver deposited had plasmonic properties. "The tiny particles in aerosols have been very difficult to see in real time because they tend to couple poorly to light or are inhomogeneous in size and composition," Fontana said. "Now that we can see how they interact with their environment, we can look at how they influence cloud formation, convection and other remote-sensing applications."



The Nanoparticle aeRosoL (NRL) instrument invented by researchers from the U.S. Naval Research Laboratory measures the behavior of gases with particles of nanometer size in real time on the benchtop. The patent-pending technique combines the capability to aerosolize plasmonic materials efficiently with an atomizer and, simultaneously, to characterize them with a Herriott cell and an infrared detector. The ability to see tiny aerosols can advance research in meteorology and other fields. (U.S. Navy graphic by Jake Fontana)

## NRL Power-Beaming Demonstrated on International Space Station



NASA astronaut Jessica Meir demonstrates how the LECTenna™, a light-emitting rectifying antenna constructed by the U.S. Naval Research Laboratory, converts electromagnetic waves into electric current on the International Space Station. Similar technology could be used on the Earth's surface to convert electromagnetic waves beamed from space-based solar arrays. (Photo courtesy of NASA)

International Space Station astronaut Jessica Meir completed the first U.S. Naval Research Laboratory power-beaming demonstration in orbit on February 12, 2020, using relatively simple components suitable for STEM activities. Meir showed how NRL's LECTenna™, a light-emitting rectifying antenna, converted a wireless network signal, similar to home networks, into electric power. While the current generated and light emitted was a small amount, the setup proved the concept in space. Led by electronics engineer Paul Jaffe, researchers at NRL are investigating space solar and power beaming as a potential source of clean energy for a variety of military and civilian applications. Space solar is simply using solar panels in space to harvest the sun's energy, where the collection of rays would be unaffected by clouds or other interference. Power beaming would send the collected energy down to Earth, where it would be converted back — just like LECTenna™ did — to usable energy.

## Researchers Transmit Energy with Laser in 'Historic' Power-Beaming Demonstration



U.S. Naval Research Laboratory electronics engineer Paul Jaffe stands beside a monitor displaying a live feed from a highly specialized camera that captured an invisible laser beam and showed it as a purple light. (Photo by Leonard Pieton)

It was the second day of a three-day-long tech demonstration at the David Taylor Model Basin at the Naval Surface Warfare Center in Bethesda, Maryland, where attendees had gathered to stand around in the dark to look at something they mostly couldn't see. It was a long-range, free-space power-beaming system — the first of its kind. Attendees that day, May 23, could see the system itself — the two 13-foot-high towers, one a 2-kilowatt laser transmitter, the other a receiver of specially designed photovoltaics. But the important part, the laser that was beaming 400 watts of power across 325 meters, from the transmitter to the receiver, was invisible to the naked eye. On one end of the testing facility — one of the largest test facilities for model ships in the world — the receiver was converting the laser energy to DC power, which an inverter was turning into AC power to run lights, several laptops, and a coffeemaker that the organizers were using to make coffee, or "laser lattes," for the attendees.

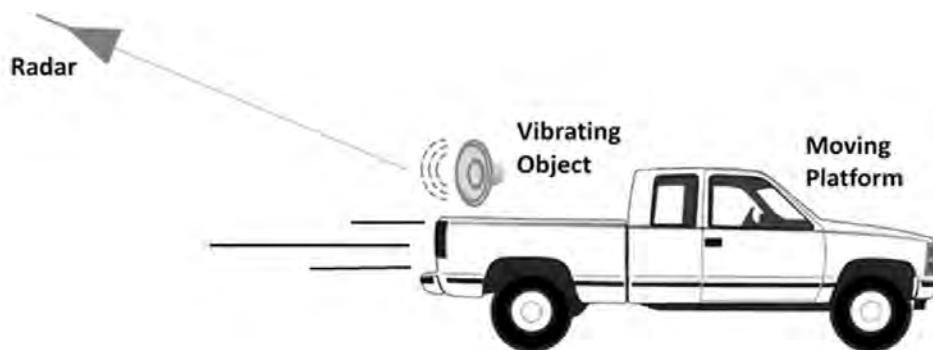


## NRL Researchers Use Advanced Radar to “Hear” Moving Targets



John Jakabosky, an electronics engineer from the U.S. Naval Research Laboratory's Radar Division, tests a millimeter-wave radar in Washington, D.C. The division developed a way to sense a target's subtle vibrations and to characterize the data in order to “hear” the target's activities. (U.S. Navy photo by Leonard Pieton)

Using an advanced radar, experts at the U.S. Naval Research Laboratory developed ways to detect subtle vibration changes in moving targets. Sensing vibrations with a millimeter-wave radar essentially gives radar operators the ability to “hear” what a target is doing. “We’ve taken vibration sensing and what we are effectively able to do now is use it as a remote-sensing technique for radar. You don’t have to be close and things don’t have to be still,” said Christopher Rodenbeck, electrical engineer in NRL’s Radar Division. “For example, many people, both military and civilian, use radar to take SAR (synthetic-aperture radar) images of the ground from space. Now we can add sound as another dimension and know what sound an object in the image is making.” Millimeter-wave radar uses electromagnetic waves between 1 and 10 millimeters with radio frequencies between 30 and 300 gigahertz, and has inherently high accuracy and resolution. The lower-power system Rodenbeck’s team used is capable of detecting a 1-square-meter target approximately 10 kilometers away.



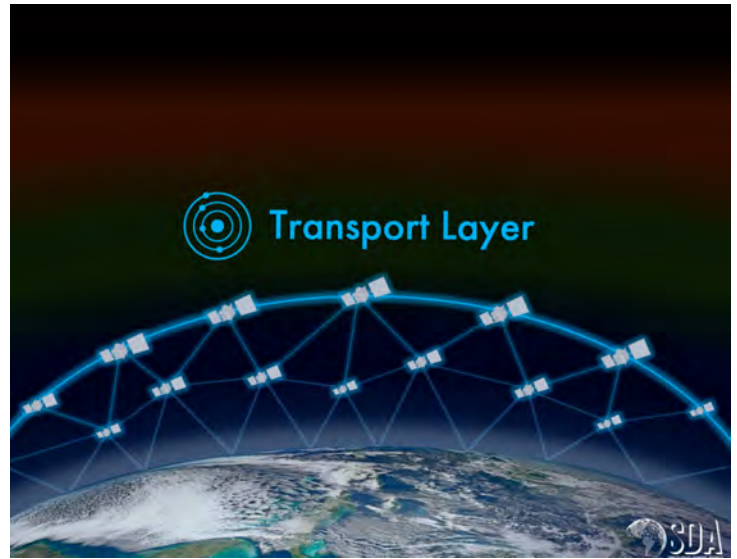
A millimeter-wave radar technique developed at NRL can measure vibration and reproduce sound, even for moving targets at standoff distances. (Graphic courtesy: Christopher Rodenbeck/U.S. Naval Research Laboratory)

## Mission Assurance: NRL Space Research Group to Validate SDA Satellite Interoperability

A U.S. Naval Research Laboratory research group will use its background in space system development to help ensure future satellites have the capability to work together. Announced Aug. 31, 2020, NRL's work supports the Space Development Agency's (SDA) two multimillion-dollar contract awards for the development of the first generation of the Transport Layer, representing the first major and highly visible step toward developing the National Defense Space Architecture's inaugural tranche, entitled Tranche Zero.

SDA is relying on NRL to build out a hardware-in-the-loop, software-in-the-loop (HIL/SIL) testbed that will be the gold standard for validating the interoperability of multiple satellites via Optical Intersatellite Links (OISL). SDA's satellites will be developed by two separate vendors and will be equipped with OISL technology to enable the sending and receiving of wideband data from one space vehicle to another and between space vehicles and ground stations.

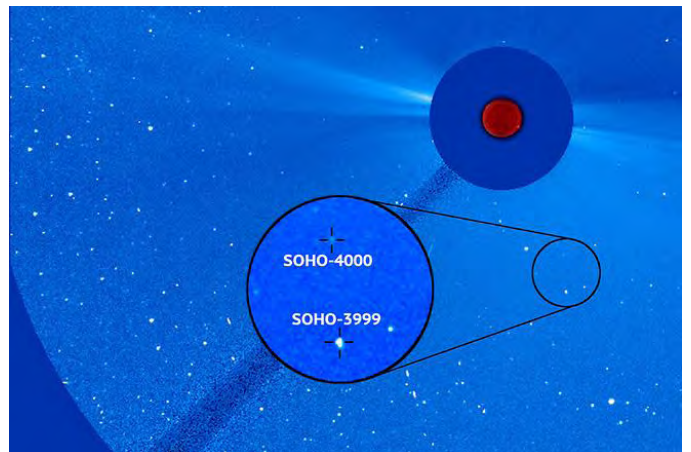
NRL's work helps SDA ensure joint warfighters have new, resilient methods of delivering time-critical information they need in diverse global environments.



The U.S. Naval Research Laboratory is working with the Space Development Agency to build a hardware and software testbed for optical communications to link interoperability between satellites. SDA seeks to build a space-based network equipped with Optical Intersatellite Links technology using these initial satellites. This network will enable the sending and receiving of wideband data from one space vehicle to another and between space vehicles and ground stations. (Graphic illustration provided by Space Development Agency)

## Mission Telescope Aboard ESA, NASA SOHO Discovers 4,000th Comet

The U.S. Naval Research Laboratory's Large Angle Spectrometric Coronagraph (LASCO) instrument identified the 4,000th comet discovered by the Solar and Heliospheric Observatory (SOHO), a joint mission between the European Space Agency and NASA, on June 15. LASCO, which is aboard SOHO, was developed in 1995 to see the extremely faint emission from the region around the Sun called the corona. Operating in space for nearly 25 years, the telescope has seen much more space action than researchers originally anticipated — discovering well over half of all known comets. "In less than 25 years, SOHO has added this huge volume to the archives of our comet knowledge, and it comes from a telescope not designed to see comets," said Karl Battams, NRL computational scientist. "This is exciting for many reasons, but perhaps mostly because LASCO is discovering comets that are otherwise completely unobservable from Earth due to their proximity to the Sun." The Navy has a unique interest in the Sun and the near-Sun environment. Much of the Navy's equipment, and equipment we use every day, such as GPS, is impacted by the Sun. Studying comets traveling near the Sun helps researchers gain a greater understanding of Earth's closest star, as they observe the comets reacting to its extreme environment.



The 4,000th comet discovered by ESA (European Space Agency) and NASA's SOHO observatory is depicted in an image from the spacecraft alongside SOHO's 3,999th comet discovery. The two comets are relatively close, at approximately 1 million miles apart, suggesting that they could have been connected as recently as a few years ago. (Credit ESA/NASA/SOHO/Karl Battams)

## NRL Scientist Discovers Monstrous Black Hole Explosion



NRL Radio Astronomer Simona Giacintucci discovered the black hole outburst using her expertise in special imaging tools to see images of low-frequency radio waves.

U.S. Naval Research Laboratory researchers led a team that discovered the most energetic outburst from a supermassive black hole. The scientists played a key role in discovering evidence for the most powerful black hole outburst in the universe, which, occurred about 400 light years away in the Ophiuchus galaxy cluster. The findings were published in February 2020 in *The Astrophysical Journal*. NRL Radio Astronomer Simona Giacintucci discovered the outburst using her expertise in special imaging tools to see images of low-frequency radio waves. The discovery combined and analyzed data and imagery from NASA's Chandra X-ray space observatory and XMM-Newton X-ray telescopes floating in space, the Murchison Widefield Array (MWA) low frequency radio telescope in Australia, and the Giant Metrewave Radio Telescope (GMRT) in India.

The black hole's outburst was hot and huge. In theory, such an event would heat up and shred everything surrounding it. But when researchers looked at the X-ray images, they saw an area with cool gas near the center of the cluster.

The finding challenged current theories on how gas around a black hole remains stable. As technology and telescopes advance, Giacintucci believes more of these mysteries will be uncovered.

## NRL-built Camera Provides View into Sun's Polar Regions

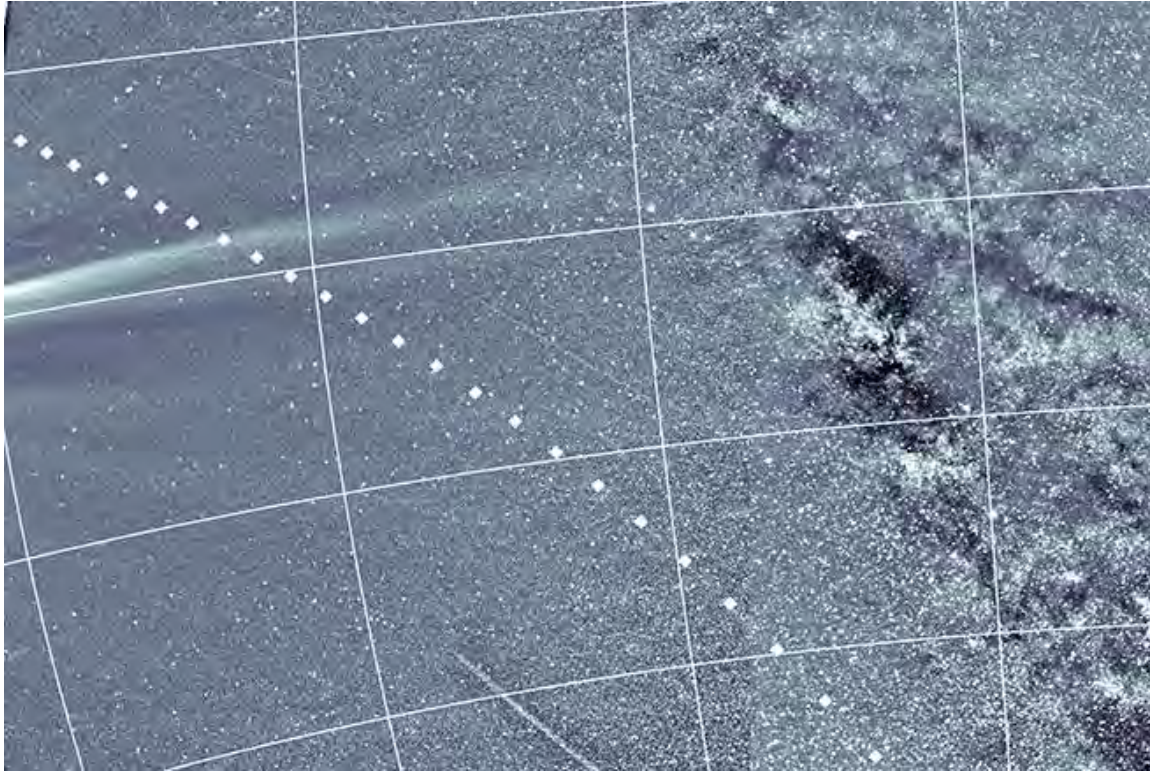


Artist's impression of ESA/NASA's Solar Orbiter spacecraft (Image Courtesy of ESA/ATG Medialab)

The Solar Orbiter mission will use a U.S. Naval Research Laboratory-designed and -built heliospheric camera, known as SoloHI, to provide unique perspectives and unprecedented views of the Sun's north and south poles. The spacecraft, a NASA and European Space Agency collaboration, launched aboard an Atlas V rocket at Cape Canaveral, Florida, on February 9, 2020. A number of other solar missions are currently studying

the Sun's impact on Earth. Those spacecraft, however, travel in the same plane that Earth orbits the Sun, while the Solar Orbiter circles at an angle off the ecliptic plane to provide views of each pole. "The magnetic field at the Sun's poles are controlling the overall magnetic structure of the interplanetary magnetic field. We're just embedded in the Sun's magnetic field," said NRL astrophysicist Robin Colaninno. "When solar storms occur, that's the Earth's magnetic field interacting with the Sun's magnetic field. That's what generates aurora borealis and similar events that have a great deal of effect here on Earth." An aurora is a light show caused by collisions between electrically charged particles released from the Sun that enter the Earth's atmosphere and collide with gases such as oxygen and nitrogen. The Northern and Southern Hemispheres light up around the magnetic poles. Researchers can use SoloHI and the other nine instruments on Solar Orbiter to examine phenomena on the Sun like never before.

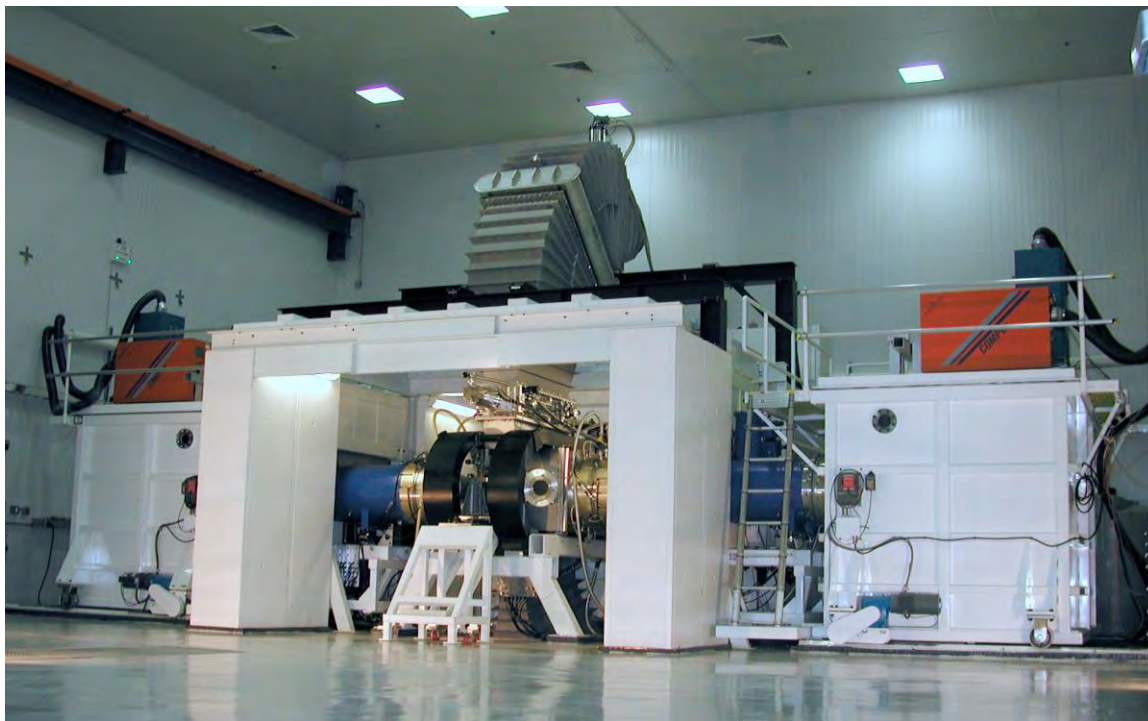
## NRL-Built Camera Aboard NASA Spacecraft Confirms Asteroid Phenomenon



An image from the Wide-Field Imager for Solar Probe (WISPR), a U.S. Naval Research Laboratory-built camera, displays the dust trail of asteroid 3200 Phaethon near the Sun on Nov. 5, 2018. The trail is visible for the first time in the region where the white dots are omitted. 3200 Phaethon's orbit intersects Earth's orbit every year, and results in the Geminid Meteor shower. (U.S. Navy photo by Brendan Gallagher and Guillermo Stenborg)

A U.S. Naval Research Laboratory-built camera mounted on the NASA Parker Solar Probe revealed an asteroid dust trail that has eluded astronomers for decades. Karl Battams, a computational scientist in NRL's Space Science Division, discussed the results from the camera called Wide-Field Imager for Solar Probe (WISPR) on Dec. 11, 2019, during a NASA press conference. WISPR enabled researchers to identify the dust cloud trailing the orbit of the asteroid 3200 Phaethon. "This is why NRL's heliospheric imagers are so ground-breaking," Battams said. "They allow you to see near-Sun outflows massively fainter than the Sun itself, which would otherwise blind our cameras. And in this case, you can also see solar system objects extremely close to the Sun, which most telescopes cannot do." He said the trail is best seen near the Sun, where 3200 Phaethon's dust is more densely packed, making WISPR a vital tool for scientists. The data captured by WISPR determined the asteroid dust trail weighs an estimated 1 billion tons, and measures more than 14 million miles long. The findings raise questions about the trail's origin.

## NRL-Built Argon Fluoride Laser Marks Breakthrough, Sets New Energy Record



The U.S. Naval Research Laboratory retrofitted one of its two gas laser facilities to use argon fluoride instead of krypton fluoride. Argon fluoride is a more efficient driver for laser fusion because of its short wavelength ( $\lambda = 193$  nm) and broad bandwidth. (U.S. Navy photo)

The U.S. Naval Research Laboratory research team set a new energy record on March 5 using an argon fluoride laser. This energy is twice the previous record. It delivered a laser beam capable of applying more energy to implode a laser fusion target — which provides the oomph needed for a nuclear fusion reaction — than any other laser. The research team tested this capability by computer simulations with a small pellet about the size of a pea made of deuterium and tritium. Deuterium and tritium are isotopes of hydrogen that have additional neutrons in the nucleus. The chemical components were frozen together and formed the inner skin of the hollow pellet. The NRL team wants to develop the science and technologies to a much higher energy scale — between 500,000 to 1 million joules — to drive a higher-performance fusion implosion. The production of a higher-energy laser will require a facility specifically designed for argon fluoride.

NRL researchers already leverage the laser fusion technologies they developed for krypton fluoride on their argon fluoride experiments. They hope a new laser facility specifically designed for argon fluoride will further prove the viability of this gas as a cost-effective alternative to current laser fusion approaches.

Steve Obenschain, a physicist and head of the NRL Laser Plasma Branch, said an argon fluoride laser is the shortest-wavelength laser with the theoretical capability to deliver the high energies needed to drive laser fusion implosions to produce much more energy than the inci-

dent laser beams.

Laser fusion involves using many laser beams at high power to uniformly illuminate a hollow, spherical target to cause an implosion with speeds more than 1,000 times that of a jet airliner. “If done with sufficient precision, the deuterium and tritium fuel within the target will ignite and, through a thermonuclear burn, produce much more energy than needed to implode the pellet,” Obenschain said.

If successful, laser fusion has applications as a test bed for defense tests and would be an attractive future power source. The short wavelength and other attributes make the argon fluoride laser the ideal laser to obtain high performance fusion implosions. However, because of its extremely short wavelength and other technical challenges, high-energy argon fluoride lasers were thought to be much too difficult to build.

“NRL was already the world leader in the similar, but longer-wavelength krypton-fluoride laser technology,” Obenschain said. “The team decided to explore the feasibility of employing argon fluoride laser as a fusion driver. In parallel, massive computer simulations investigated the advantages of utilizing the argon fluoride laser for fusion implosions. The results so far indicate argon fluoride laser could be a game-changing driver for high-performance laser fusion.”

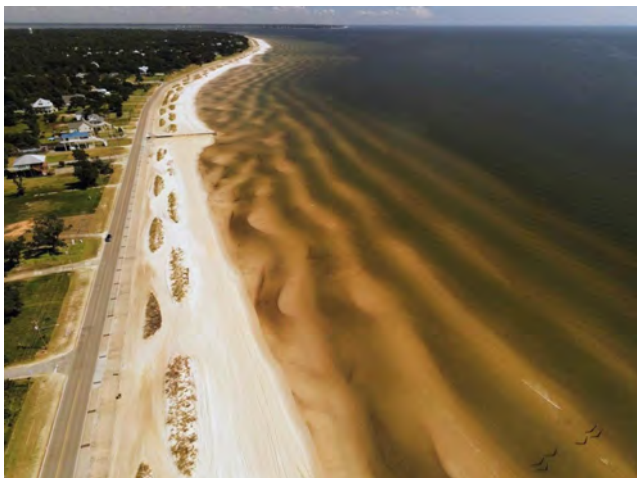
**The Drive to Create the Next Generation of Environmental Prediction Systems: The Earth System Prediction Capability**



Long-range mission planning is vital to naval operations and often is performed months in advance. Knowing the environment where ships, aircraft, sailors and Marines will be operating is crucial. Historically, planners have had to rely only on climatological conditions, but climatology only provides the average conditions of the environment and can be far different from reality. NRL is creating long-range environmental prediction systems, which are currently accurate only in the short term. In the environments the Navy and Marine Corps operate, sailors and Marines also have to navigate in the ocean, deal with waves, and, in the era of a great-power competition, grow their ability to work in and around sea ice. This need to know what to expect in the total environment is why researchers at the U.S. Naval Research Laboratory are working on extending the limits of environmental prediction by developing a globally coupled model called the Earth System Prediction Capability, or ESPC. “ESPC is probably the biggest project I’ve worked on,” said Carolyn Reynolds, Ph.D., a meteorologist at NRL’s Marine Meteorology Division in Monterey, California. “It’s the longest project. It could be the project with the most impact. I’m very excited.” Reynolds coordinates her division’s work on the atmospheric component of the ESPC.



## NRL's Ocean Sciences Division Connects Research with Industry and Academia



An aerial view of sandbar features near Bay St. Louis, Mississippi. Researchers at NRL's Ocean Sciences Division study coastal features to determine how they evolve and impact coastal infrastructure. The division is a partner in the new Gulf Coast Tech Bridge announced Dec. 9, 2020. (NRL photo by Shawn Harrison)

U.S. Naval Research Laboratory's (NRL) Ocean Sciences Division at Stennis Space Center, Mississippi, has joined a broader Navy effort to connect scientific discovery with civilian industry and universities across the nation and beyond. NRL joins the Naval Surface Warfare Center Panama City Division, and the Naval Meteorology and Oceanography Command, to form the new Gulf Coast Tech Bridge, which spans four states — Florida, Alabama, Mississippi, and Louisiana.

The Tech Bridge is future-focused, growing coastal science and unmanned vehicle development, assured maritime access, operational meteorology and oceanography, hosting industry events and expanding strategic partnerships.

NRL's Ocean Sciences Division conducts research in ocean physics, coastal remote sensing, coastal and seafloor sciences, and geospatial sciences. Researchers work to understand the complex interactions between the ocean and the atmosphere through a combination of sensing and simulation.

Since the establishment last year of Tech Bridges under a Navy program called NavalX, the initiative has harnessed collaboration and creativity to address naval concerns and capabilities.

NavalX serves as the Department of the Navy's research, development, and technology super connector focused on delivering and facilitating rapid implementation of proven technology with high impact and broad applicability. During the past year, NavalX has expanded the number of Tech Bridges to 15 across the United States and the United Kingdom.



Braedon Kimball, a U.S. Naval Research Laboratory Naval Research Enterprise Internship Program (NREIP) intern and a senior at Mississippi State University's Bagley College of Engineering, works on his neural network code to optimize performance on Nov. 12, 2020. (Photo provided by Braedon Kimball)

## Mississippi State Intern Makes Waves with AI at NRL

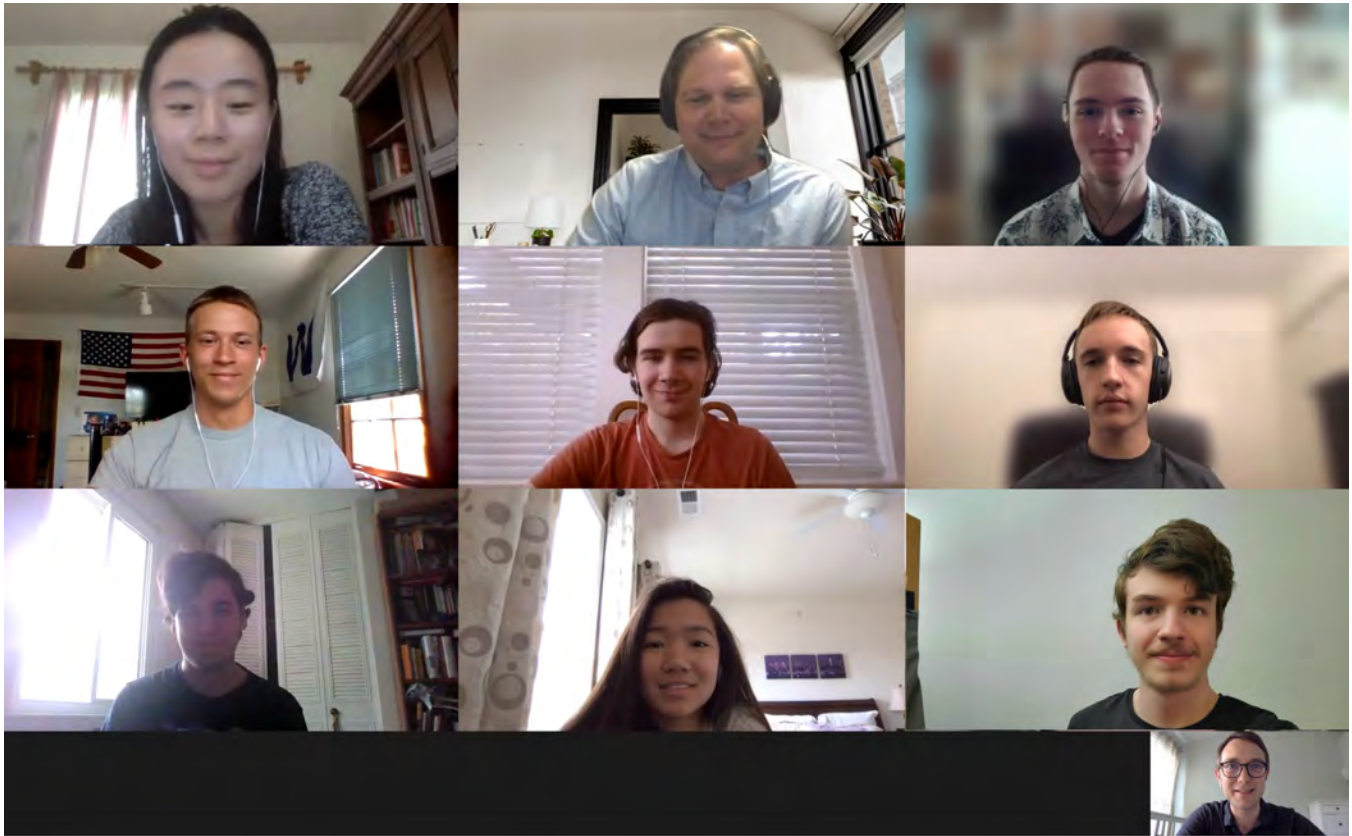
Braedon Kimball, a U.S. Naval Research Laboratory intern with the Naval Research Enterprise Internship Program (NREIP) who is a college senior majoring in software engineering at Mississippi State University's Bagley College of Engineering, learned about neural networks and data framing using Python software that helps programmers write clear, logical code for small- and large-scale projects at NRL's Ocean Sciences Division. This research potentially could increase the Navy's ability to provide more accurate wave forecasting as well as a foundation of machine learning that could be extensible to other forecasting tasks.

Kimball's NREIP mentor, James Dykes, a physical scientist with NRL's Ocean Sciences Division at Stennis Space Center, Mississippi, said neural networks show promise to improve weather and wave forecasting with numerical models.

NREIP typically provides an opportunity for about 800 college students to participate in ten weeks of hands-on research at 45 Navy laboratories during the summer, encouraging participants to pursue science and engineering careers. However, this year's NREIP program was done virtually. NRL mentors virtually hosted 67 college students and 11 high school students this summer and they hope students further their education via mentoring by laboratory personnel.

"I think we had a constructive experience and accomplished a lot," Dykes said. "The remote-connection environment provided a lot of flexibility; for instance, Braedon could work from home nearby, as well as from his school hundreds of miles away, at varying times without the need for an office building at a set 8-5 schedule."

## NRL Works Virtually with Summer Students



Physicists from the U.S. Naval Research Laboratory's Plasma Physics Division meet virtually with student interns on June 16, 2020. The division is adapting to coronavirus pandemic conditions and is maintaining engagement with the students with a software creation called turboPy. (U.S. Navy photo by Paul Adamson)

U.S. Naval Research Laboratory mentors found a new way to keep students engaged from afar while adapting to the COVID-19 global pandemic. NRL's Plasma Physics Division is using their own software creation, a Python code called turboPy, to provide their high school interns an opportunity to contribute to computational physics problems, such as creating a software model to predict how an intense beam of electrons turns air into plasma. "We're giving the students an opportunity to contribute to real physics code," said Paul Adamson, research physicist. "They'll form a team and become a real distributed-software-engineering group. At the same time, this is an opportunity for us to learn some new collaboration techniques." Adamson said computational physics problems often use common aspects to solve many different problems, such as a location grid, a clock, and rules for how things behave on the grid. TurboPy is a framework to incorporate common items that allows researchers to focus on developing the software code for their specific experiments, similar to allowing musicians to focus on creating music, rather than having to build their instruments from scratch for each song. "Having a framework that can deal with the basic aspects of a simulation provides great value for a lot of complex physics problems," said Steve Richardson, a research physicist who is the lead developer of turboPy.



### **NRL Researcher Receives American Ceramic Society Richard M. Fulrath Award**



The U.S. Naval Research Laboratory's Multifunctional Materials Branch head, Edward Gorzkowski, Ph.D., received the American Ceramic Society Richard M. Fulrath Award on Oct. 1 for excellence in research and development or ceramic sciences and materials. The Richard M. Fulrath promotes technical and personal friendships between professional American and Japanese ceramic engineers and scientists, while encouraging a greater understanding among the diverse cultures of the Pacific Rim. Gorzkowski's research areas include piezoelectric materials for sensor and actuator applications, unique processing methods to create bulk nano-structured ceramics including microwave, and high-pressure and aerosol-deposition processing for functional and structural applications such as hypersonics.

### **Two NRL Research Physicists Named 2020 Citation Laureates "of Nobel Class"**



Thomas L. Carroll



Louis M. Pecora

Thomas L. Carroll and Louis M. Pecora, two research physicists from the U.S. Naval Research Laboratory, were named Citation Laureates "Researchers of Nobel Class" by Clarivate on Sept. 23, 2020 for research in nonlinear dynamics including synchronization of chaotic systems. They were selected out of 24 world-class researchers from six countries identified as Citation Laureates. Science's highest honor, the Nobel Prize in Physics, was awarded by The Royal Swedish Academy of Sciences in Stockholm, Sweden, on Oct. 6, 2020. To date, 54 Citation Laureates listed in the Hall of Citation Laureates have gone on to receive Nobel Prizes.

### **NRL Physicist Awarded NDIA Undersea Warfare Bronze Medal for Achievement in Science**



Josette Fabre, Ph.D., the U.S. Naval Research Laboratory's Acoustics Stimulation Measurements and Tactics Branch head, received the National Defense Industrial Association (NDIA) Bronze Medal on Sept. 22, 2020, for technical achievement in undersea warfare during a virtual awards ceremony. The NDIA Bronze Medal recognizes outstanding individual achievement in science or engineering in the field of undersea warfare.

## NRL Chemist Receives Presidential Award



Paul Charles, a research chemist with the U.S. Naval Research Laboratory, was honored on Aug. 3 as a recipient of the Presidential Excellence Award in Science, Mathematics, and Engineering Mentoring (PAESMEM). The PAESMEM recognizes the critical role mentors play outside the traditional classroom setting in the academic and professional development of the future Science, Technology, Engineering, and Math (STEM) workforce. Colleagues, administrators, and students nominate individuals and organizations for exemplary mentoring sustained over a minimum of five years.

## 2020 Dr. Delores M. Etter Top Scientists and Engineers Award



Benjamin Gould



Brandon Redding



Michele Suite

Three U.S. Naval Research Laboratory scientists and engineers were awarded the prestigious Department of the Navy Dr. Delores M. Etter Top Scientists and Engineers of the Year Award on July 24, 2020, during an awards ceremony hosted by Naval Surface Warfare Center Carderock Division. The Etter Award is presented annually to scientists and engineers who have clearly demonstrated a superior accomplishment that is technically outstanding and highly beneficial operationally to the Department of the Navy and to national defense. The selection process is highly competitive and each submission impressively demonstrated high levels of professionalism and scientific and engineering achievement. Dr. Etter, a former ASN (RD&A), 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. 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 fields during the preceding calendar year. The NRL recipients honored as the 2019 Dr. Delores M. Etter Top Scientists and Engineers: Benjamin Gould, Individual Scientist; Brandon Redding, Emergent Scientist; and Michele Suite, Individual Engineer.



Cmdr. Ian Lilyquist assumes command of the U.S. Naval Research Laboratory's Scientific Development Squadron (VXS) 1 and delivers his welcoming remarks during a change-of-command ceremony at Naval Air Station Patuxent River in Patuxent River, Maryland, on Nov. 6, 2020. (U.S. Navy photo by Jonathan Steffen)

Cmdr. Ian Lilyquist relieved Cmdr. Jared Tharp as commander of the U.S. Naval Research Laboratory's Scientific Development Squadron (VXS) 1 on Nov. 6 during a change-of-command ceremony held at Naval Air Station Patuxent River, Maryland.

The U.S. Naval Research Laboratory's commanding officer, Capt. Ricardo Vigil, presented Tharp with the Meritorious Service Medal. Tharp served as the VXS-1 commanding officer from August 2019 to November 2020. Vigil said Tharp's distinguished leadership was instrumental to the squadron's continued record of superlative support to NRL's airborne mission.



Chief of Naval Research Rear Adm. Lorin Selby, the commander of the Office of Naval Research, presides over the U.S. Naval Research Laboratory's Scientific Development Squadron (VXS) 1 change-of-command ceremony at Naval Air Station Patuxent River in Patuxent River, Maryland, on Nov. 6, 2020. (U.S. Navy photo by Jonathan Steffen)

## Celebrating LASCO's Silver Anniversary of Revealing the Wonders of Our Sun



European Space Agency (ESA) engineers help build the Solar and Heliospheric Observatory (SOHO) spacecraft at Matra Marconi Space in Portsmouth, England, on Nov. 22, 1995. The SOHO spacecraft was prepared for launch at the SAEF-2 facility of the Kennedy Space Center in Cape Canaveral, Florida, before being fueled and encapsulated on top of the Atlas-Centaur AC-121 on pad 36B. The SOHO and LASCO consortium celebrated their 25th anniversary of international cooperation between the European Space Agency and NASA on Dec. 2, 2020. (Courtesy image from SOHO (ESA & NASA))

Since the early years of the space age, researchers in the Solar Physics Branch of the U.S. Naval Research Laboratory have been involved in observational and theoretical studies of the solar atmosphere. Experiments developed at NRL have flown on NASA missions such as the Skylab/Apollo Telescope Mount, the Orbiting Solar Observatory satellite series, NASA's third space shuttle mission STS-3, and the Spacelab-2 and Atlas missions — all feats of engineering that have helped humanity understand the wonders of the heavens. But, none has lasted as long as LASCO — the Large Angle and Spectrometric Coronagraph.

It was Dec. 2, 1995, when LASCO was launched into space as part of the European Space Agency (ESA)-NASA Solar and

Heliospheric Observatory (SOHO). Originally planned as a two-year mission, SOHO/LASCO is celebrating its silver anniversary — 25 years of scientific discovery of the sun, from its deep core to its outer corona and the solar winds.

"It is truly amazing," said Russell Howard, Ph.D., an NRL astrophysicist who has been with LASCO since its inception. "I believe it is the longest mission here at NRL that is still operating, at least. It is certainly cost effective to continue operating instruments as long as they are working well."

As with all missions, LASCO started as a concept to answer three questions related to the quiet sun: What are the structure and dynamics of the solar interior? Why does the solar corona exist and how is it heated to the extremely high temperature of about 1-million-degrees Celsius? And, where is the solar wind produced and how is it accelerated? Those questions started to define the LASCO instrument concept in the early 1980s.

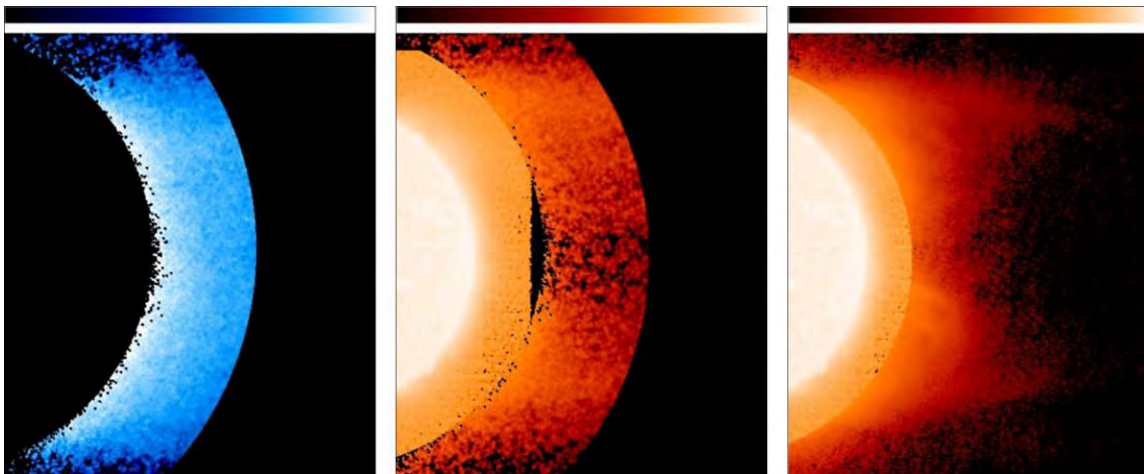
The NRL team also became co-investigators on a European Principal Investigator instrument called the Extreme-ultraviolet Imaging Telescope that flew on SOHO.

As with any mission, failures do happen with time and a catastrophic failure could occur at any time. Currently the region where SOHO is orbiting, about 1 million miles from Earth — about four times the distance as the moon is from Earth — is much safer than a low-Earth orbit.

Eventually, the SOHO/LASCO mission will come to an end. In 2016, LASCO observations were designated essential for space weather forecasting, spurring a request that NASA maintain observations until a replacement mission could be put into place.

The National Oceanic & Atmospheric Administration commissioned NRL to build two instruments, one to be launched about 2024-2025 in an Earth orbit and one to go to Lagrange point 1, where the SOHO spacecraft currently is bathed in sunlight all the time and can view the sun constantly — an advantage over an Earth orbit.

## Global Helium Abundance Measurements in Solar Corona



A composite image of the Sun showing the hydrogen (left) and helium (center and right) in the low corona. The helium at depletion near the equatorial regions is evident. (Courtesy of NASA)

Two U.S. Naval Research Laboratory Space Science Division (SSD) researchers joined an international cadre of scientists on July 27 in presenting the results of the first simultaneous global solar corona images of the helium and hydrogen emission that is helping scientists to better understand the space environment.

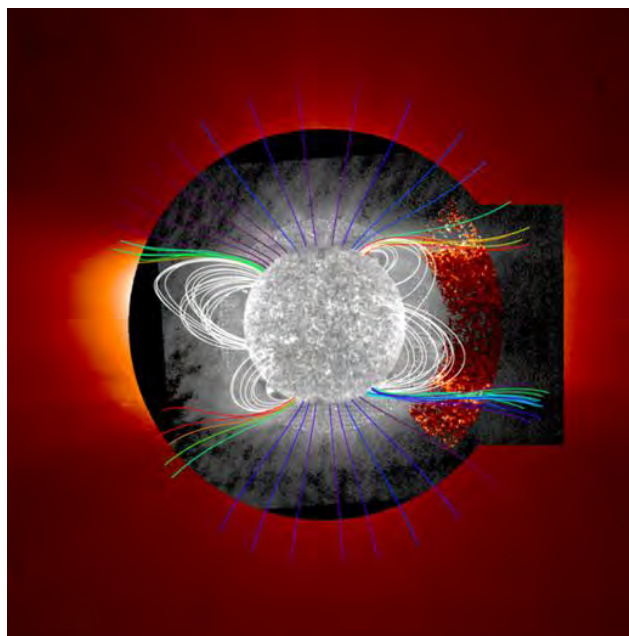
The paper, "Global Helium Abundance Measurements in the Solar Corona," was published online in *Nature Astronomy* and discusses the abundance of helium relative to hydrogen in the solar corona, the outer atmosphere of the sun, seen from Earth only during eclipses.

NRL Astrophysicist Dennis Wang, Ph.D., software lead for the Helium Resonance Scattering in the Corona and Heliosphere (HERSCHEL) rocket flight, was responsible for flight and ground software. His NRL colleague, Research Physicist Martin Laming, Ph.D., managed the new model of element abundance fractionation, to include helium.

The HERSCHEL sounding rocket, launched Sept. 14, 2009, provided a number of technological advances in space-based remote sensing. Using a concept developed at NRL for a coronagraph functioning in the extreme ultraviolet regime of the electromagnetic spectrum, the helium coronagraph obtained the first images of the solar atmosphere in the region of the solar wind source surface from light resonantly scattered from helium ions.

The leading model for solar wind variability used by the Department of Defense and National Oceanic and Atmospheric Administration space weather forecasters is an NRL SSD product, known as the Wang, Sheely, Arge Model, which is based on simple assumptions about the relation of the solar magnetic field structure and the solar wind, and is reasonably successful in predicting the overall variability of the solar wind as it reaches Earth.

Geomagnetic storms impact radio frequency transmission at frequencies refracted, or reflected, by the ionosphere. In various battlespace applications, the Navy uses magnetic sensors that could be disrupted during large geomagnetic storms and coronal mass ejections. These are major reasons why the Navy is interested in disruptions of the Earth's magnetic field structure in these measurements.



A composite image shows the Sun with open magnetic field lines (colored) overlapping with regions with enhanced helium abundance. (Courtesy of NASA)

## FY2020 PERSONNEL

Total FTP Personnel: 2536

Military on Board: 93

Scientists/Engineers: 1723

Social Science	1
Psychology	10
Program Management	1
General Natural Resources Management and Biological Sciences	32
Microbiology	3
General Engineering	14
Safety Engineering	1
Fire Protection Engineering	1
Materials Engineering	63
Architecture	1
Civil Engineering	8
Environmental Engineering	4
Mechanical Engineering	121
Electrical Engineering	64
Computer Engineering	56
Electronics Engineering	344
Aerospace Engineering	81
Chemical Engineering	17
General Physical Science	57
Health Physics	11
Physics	351
Geophysics	7
Chemistry	96
Metallurgy	5
Astronomy and Space Science	27
Meteorology	54
Geology	4
Oceanography	52
Operations Research	8
Mathematics	32
Computer Science	182

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Bachelor	638
Master	491
Doctorate	891



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Dasha Leary, U.S. Naval Research Laboratory research biologist, prepares a liquid chromatography-mass spectrometry (LC-MS) instrument for sample analysis in Washington, D.C., on Jan. 16, 2020. This equipment allows Leary to identify protein extracts from marine microbial organisms. (U.S. Navy photo by Sarah Peterson)

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