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THE MAGAZINE OF THE NAVY'S CORPORATE LABORATORY

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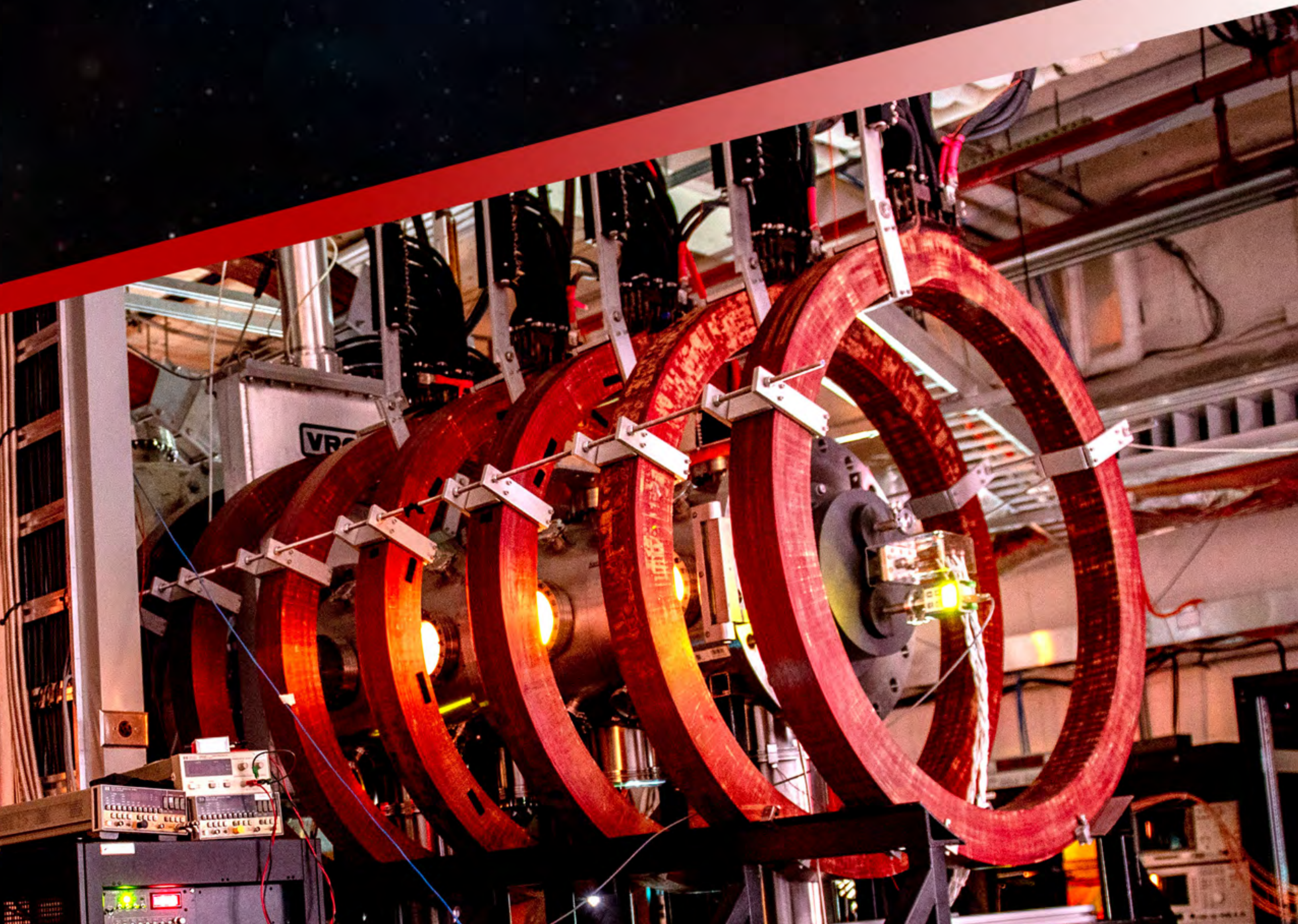
U.S. NAVAL RESEARCH LABORATORY



From the Associate Director

DR. PETER MATIC
Associate Director of Research for Materials Science and Component Technology

The Materials Science and Component Technology Directorate conducts multidisciplinary scientific research and technology development in materials, chemistry, biomolecular science, plasma and laser physics, and electronics for the Navy, Marine Corps, other services, the Department of Defense (DoD), and various government agencies.

The cross-cutting and interdisciplinary nature of our materials research is focused on achieving major breakthroughs in material design, processing, properties, and performance leading to revolutionary components, devices, and systems. The efforts span a wide range of materials and technologies. A few examples include:

- metals, ceramics, polymers, composites, and additive manufacturing;
- genomics, cellular processes, synthetic biology, and biomimetics;
- quantum science, 2d-materials, semiconductors, superconductors, magneto-electrics, and multiferroics;
- fuels, propellants, and explosives;
- corrosion science, paints, and coatings;
- neuroelectronics, advanced sensors, vacuum electronics;
- power electronics, pulsed power, and energy delivery;
- lasers, directed energy, and railguns;
- aerodynamics, hydrodynamics, reactive flows, jet engine noise reduction, and hypersonics.

To accomplish our mission, the directorate engages nationally and internationally with academia, industry, and partner governments to produce the science and engineering that is part of the future we are creating. At the same time, we collaborate with our military services, DoD agencies, and other government agencies to advance naval capabilities and solve problems of national interest.

The directorate's efforts impact a broad range of naval and DoD needs in the form of new military technologies, industry partners, and life cycle cost savings for our customers. Our work generates deep subject-matter expertise, new processes and practices, innovative prototypes and demonstrations, and significant transitions for the surface, undersea, land, air, and space communities.

These outcomes are the foundation of revolutionary changes in naval warfighting capabilities that ensure maritime superiority capable of maintaining freedom of the seas, deterring aggression, and winning wars.

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NRL's New Painter-friendly Topcoat Safer for the Environment

A Marine Corps AH-1Z Viper helicopter is painted with one-component (1K) camouflage gray polysiloxane topcoat on the exterior. Chemists at the U.S. Naval Research Laboratory developed the new topcoat for DoD aircraft, which is safer for the environment and easier to apply.

The U.S. Naval Research Laboratory's (NRL) Center for Corrosion Science and Engineering has developed a safer and more user-friendly topcoat for the exterior of Navy and Marine Corps aircraft.

The topcoat, which is a one-component (1K) polysiloxane based on organosilane polymers, is a new technology that is free of harmful isocyanates and other hazardous air polluting (HAP) chemicals. Isocyanates and HAPs are found in the two-component (2K) polyurethane topcoats currently used on Department of Defense (DoD) and commercial aircraft.

Erick Iezzi, Ph.D., senior research chemist at NRL, and engineers at Naval Air Warfare Center–Aircraft Division, applied the new topcoat to a U.S. Navy F/A-18 Hornet at Naval Air Station Patuxent River, Maryland. The 1K topcoat was also applied to Marine Corps UH-1Y Venom and AH-1Z Viper helicopters at Marine Corps Air Station New River in Jacksonville, North Carolina, and Marine Corps Base Camp Pendleton, California, respectively.

The 1K polysiloxane topcoat on these aircraft is scheduled for a one- to two-year evaluation period.

"We're very proud of this achievement," Iezzi said. "Polyurethane topcoats have existed for several decades, yet within a few years we've been able develop an environmentally, friendly alterative that provides similar laboratory performance and is easy for painters to use."

According to the Occupational Safety and Health Administration, (OSHA), exposure to isocyanates can result in irritation of the skin and mucous membranes, chest tightness, and difficulty breathing, and HAPs are classified as potential human carcinogens. Isocyanate exposure can also cause increased sensitivity upon subsequent exposures to even low levels, resulting in severe asthma attacks.

Replacing isocyanates with polysiloxane provides a safer coating for painters and anyone conducting maintenance in nearby areas. The new 1K topcoat also contains lower levels of volatile organic compounds, which negatively impact air quality when released during spray applications.

The 1K polysiloxane topcoat requires no metering or mixing of components because all chemicals are in a single container, thereby reducing time of preparation and providing a more homogeneous color on aircraft. The container is also resealable for future use, which reduces the generation of hazardous waste and disposal costs.

Iezzi and other NRL chemists previously developed coatings for surface ships, but the requirements for aircraft coatings are more demanding.

"Aircraft have aluminum skin, which means the coating must provide greater flexibility, especially at cold temperatures during high-altitude flight. An aircraft topcoat must also retain a camouflage appearance for longer periods of time," Iezzi explained.

As part of NRL's large patent portfolio, the polymers and polysiloxane coating technology are covered by U.S. Patents 9139753, 9701868, and 10190020. The first two patents are partially exclusively licensed by NCP Coatings, Inc. of Niles, Michigan, which produces the camouflage topcoat for demonstrations and field validation. NCP Coatings is also using this technology to develop semi- and high-gloss formulations for aircraft.

These topcoat applications were coordinated with the Naval Air Systems Command and sponsored by the Defense Department's Environmental Security Technology Certification Program with contributing funds from the Office of Naval Research.

By Victor Chen, NRL Strategic Communications Office

Pushing Nanoscience Boundaries to Lighten, Strengthen Warfighter Armor

A multi-disciplinary team of scientists at the U.S. Naval Research Laboratory (NRL) pushed grain size engineering to the limit and discovered previously unseen behaviors in nanocrystalline ceramics that could lead to the design of better-performing ceramic armor.

The discovery, a continuation of NRL research published in 2014, was made possible by a cutting-edge nanosintering technique, which is the process of essentially bonding nano-sized particles together.

"A few years ago, NRL was the first to show that if you decrease the grain size of ceramics to tens of nanometers, the hardness and strength increase," said Dr. James Wollmershauser, a materials research engineer in NRL's Materials Science and Technology Division. "Our current work takes this much further. We decreased the grain size of fully dense ceramics to record-breaking single digits, and analyzed the elasticity, hardness, energy dissipation, and fracture behavior in ceramics with a wide range of nanosize grains."

Dr. Heonjune Ryou, a postdoctoral fellow in NRL's Chemistry Division, characterized the mechanics of the nanocrystalline ceramics and found that they accommodate mechanical energy in a unique way. This aspect had never been seen before in bulk nanocrystalline ceramics, and may revolutionize the design of ceramic armor.

"NRL was the first to see the increase of energy dissipation in single digit nano-grain ceramics," said Dr. Boris Feygelson, a materials research engineer in NRL's Electronics Science and Technology Division, who led the team's efforts in nanosintering. "The better the material can accommodate mechanical energy, the better it can stop an incoming threat."

The key to unlocking these materials and their phenomenon is NRL's unique approach to forming large-scale nanostructured solids. The unparalleled nanosintering method is called Environmentally Controlled Pressure Assisted Sintering, or EC-PAS. It allowed NRL to break the world record for the smallest grain size in dense ceramics at 3.6 nanometers, which is about 30,000 times smaller than the width of a human hair.

"What we've done is develop a new way to make nanocrystalline materials and demonstrated that by varying the nano-grain size there is the capability to design a ceramic with specific combinations of properties," said Feygelson.

By pushing the boundaries of nanosintering science, NRL researchers showed that it may be possible to one day design a lightweight, nanocrystalline ceramic material that can better dissipate mechanical energy, such as from a sharp projectile, and absorb more damage while retaining its very high hardness. This discovery could pave the way for more efficient armor for Sailors and Marines.

"In general, the Navy wants to lighten the load of the warfighter," said Wollmershauser. "If you can make harder armor, or better performing armor, then you can put less armor on a person or vehicle, in turn increasing capacity for other things like munitions and electronics."

Behind the collaborative effort were individuals from three divisions across NRL, including Chemistry, Materials Science and Technology, and Electronics Science and Technology.

"We are fortunate to have a team from three different divisions . The diverse expertise of our team members allowed this work to happen." – Dr. Heonjune Ryou

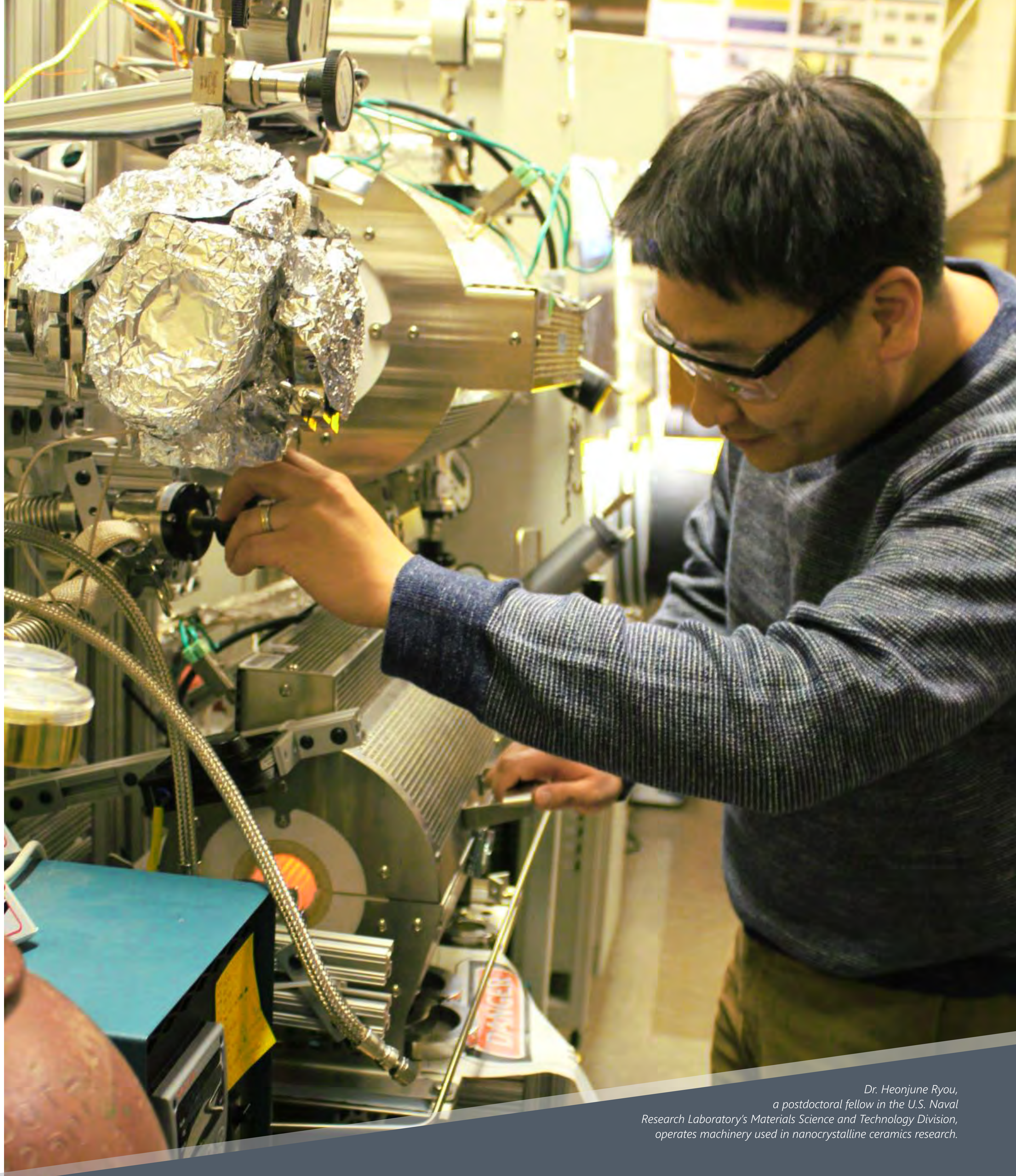
The team hopes to continue their work in bulk nanocrystalline ceramics, the development of the EC-PAS nanosintering technique being the key to future innovation.

"When we were doing this research we started to develop a vision for other applications. We realized that we could approach this research in nanocrystalline materials with a much broader perspective," said Feygelson. "EC-PAS opens the door to explore limits of many phenomena in nanostructured materials. Armor materials is just the beginning. So stay tuned."

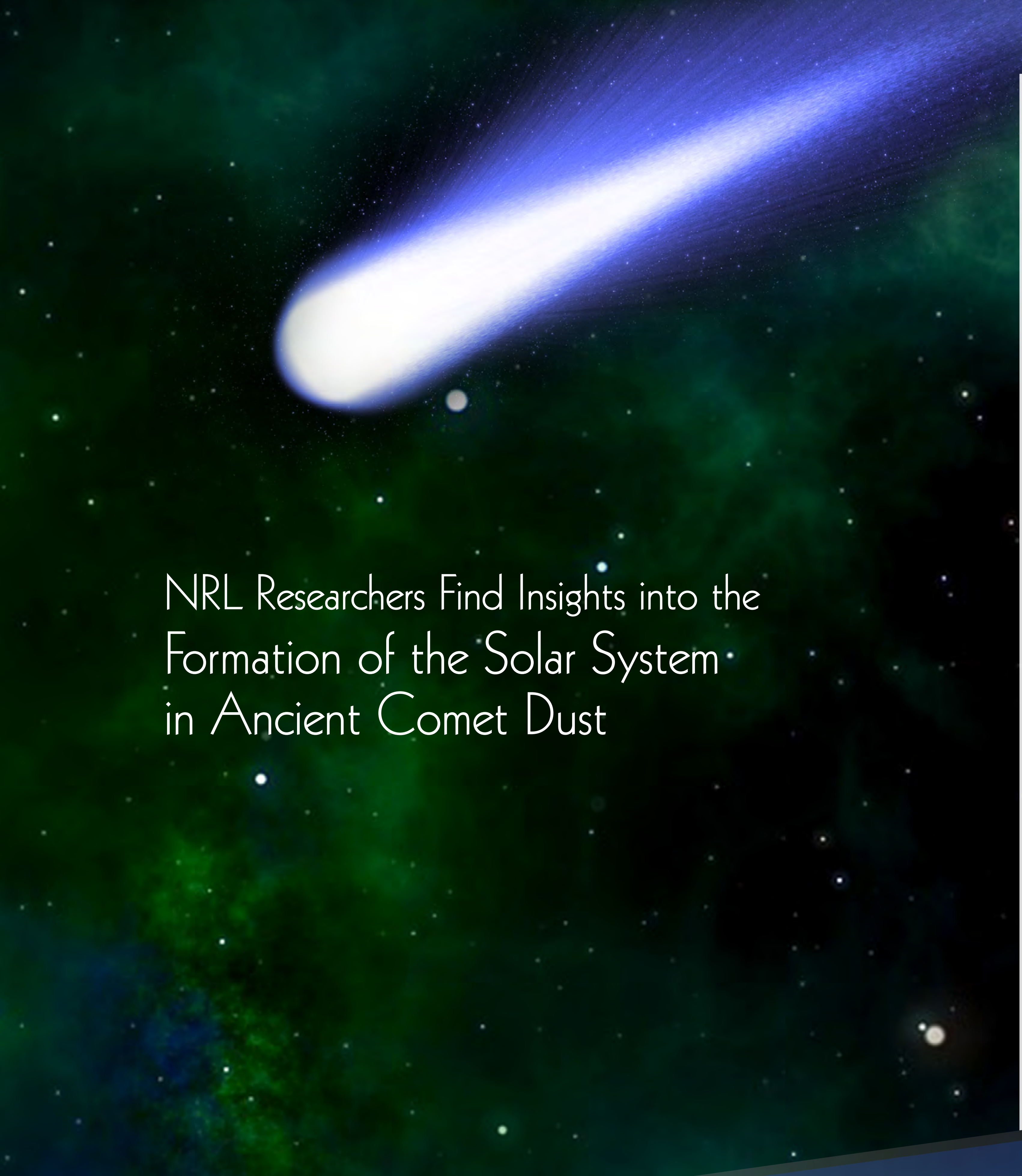
The team's research was recently published in American Chemical Society's *ACS Nano* and can be found on the web at: https://pubs.acs.org/doi/10.1021/acsnano.7b07380.

By Raeanna Morgan, Former NRL Strategic Communications Office

From left to right: Drs. Boris Feygelson, Heonjune Ryou, and James Wollmershauser, worked together to push the boundaries of nanocystalline ceramics in their work at the U.S. Naval Research Laboratory.



Dr. Heonjune Ryou, a postdoctoral fellow in the U.S. Naval Research Laboratory's Materials Science and Technology Division, operates machinery used in nanocrystalline ceramics research.



NRL Researchers Find Insights into the Formation of the Solar System in Ancient Comet Dust

Materials science researchers with the U.S. Naval Research Laboratory (NRL) have found ancient dust from the early stages of the solar system inside a primitive meteorite, named La Paz Icefield 02342 after the location of its discovery in Antarctica.

NRL scientists Rhonda Stroud and Bradley De Gregorio described the find in "A cometary building block in a primitive asteroidal meteorite," which was published in *Nature Astronomy* https://www.nature.com/articles/s41550-019-0737-8 Apr. 15.

To examine these tiny grains within the larger particle, the researchers relied on a unique capability of NRL's Nanoscience Institute, which has an aberration-corrected scanning transmission electron microscope that can shape its emitted electron beam to optimize image quality and resolution.

The microscope is one of only a few of its kind in the world. Along with other state-of-the art measurement and nanofabrication equipment located in the Institute, it enables NRL scientists and engineers to discover and develop new nanotechnology for the Navy and Marine Corps.

"Having this capability at the lab is ideal," De Gregorio said. "It helps us stay on the cutting edge of science, and contributes to amazing studies like this one."

De Gregorio, a researcher with NRL's Materials Science and Technology Division, called the confluence of cosmic events that led to the finding "amazing," and "an incredible journey" for an ancient dust particle.

> *"This particle formed at the beginning of our solar system"*
>
> – Bradley De Gregorio

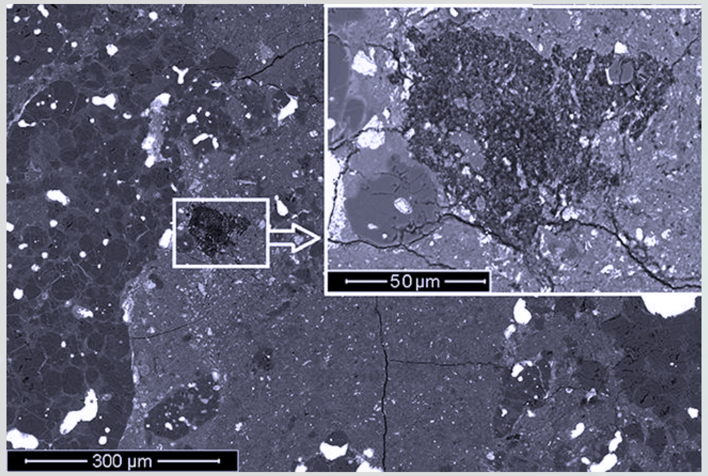
"[It] had to travel from the outer comet-forming regions, become embedded in asteroids forming in the interior of our system. [Then an asteroid had to] break apart in just the right way to form a meteoroid with the dust particle in it. Then the meteorite had to land on Antarctica in just the right spot to be collected by a field scientist."

The researchers validated the dust's heritage from its pre-solar grains, tiny particles of primarily carbon, which have a specific isotopic chemical signature not found in material originating within our solar system, and from the presence of glassy grains containing nanoscale iron metal and sulfides, which are commonly found in other studies of comet dust.

The meteorite was collected in Antarctica during the 2002 field season of NASA's Antarctic Search for Meteorites (ANSMET) program. This work was funded by NASA's Science Mission Directorate, through grants NNX10AI63G and NNH16AC42I, and by Spanish Ministry of Science grants AYA 2011-26522 and AYA 2015-67175-P.

The published research used resources of the Advanced Light Source, which is a U.S. Department of Energy Office of Science user facility under contract number DE-AC02-05CH11231.

By Victor Chen, NRL Strategic Communications Office



U.S. Naval Research Laboratory scientists Rhonda Stroud and Bradley De Gregorio, using an advanced scanning transmission electron microscope, found evidence of an ancient comet inside a meteorite collected in Antarctica. The finding provides insight into the formation of the solar system. The work was funded by NASA.

NRL Tests Sensor on the ISS to Protect Space-based Assets

The Space PlasmA Diagnostic suitE (SPADE) experiment, developed by the U.S. Naval Research Laboratory's Plasma Physics Division, in conjunction with the Spacecraft Engineering Department, launched from Kennedy Space Center in Florida to the International Space Station onboard the SpaceX Dragon resupply mission (CRS-17), May 4.

Integrated onto the Space Test Program-Houston 6 (STP-H6) pallet, SPADE is designed to monitor background space plasma conditions on-orbit the International Space Station and provide early warning of the onset of hazardous levels of spacecraft charging.

The space environment is filled with a collection of electrically-charged particles, plasma, and properties that depend on variable solar conditions. Satellite operations in space require continuous monitoring of plasma conditions and their effects on spacecraft.

Dr. Erik Tejero, a plasma physicist at NRL's Plasma Physics Division, compared the effects of spacecraft charging to the electrical charge build-up that occurs when walking across a carpet.

Photo Credit: NASA

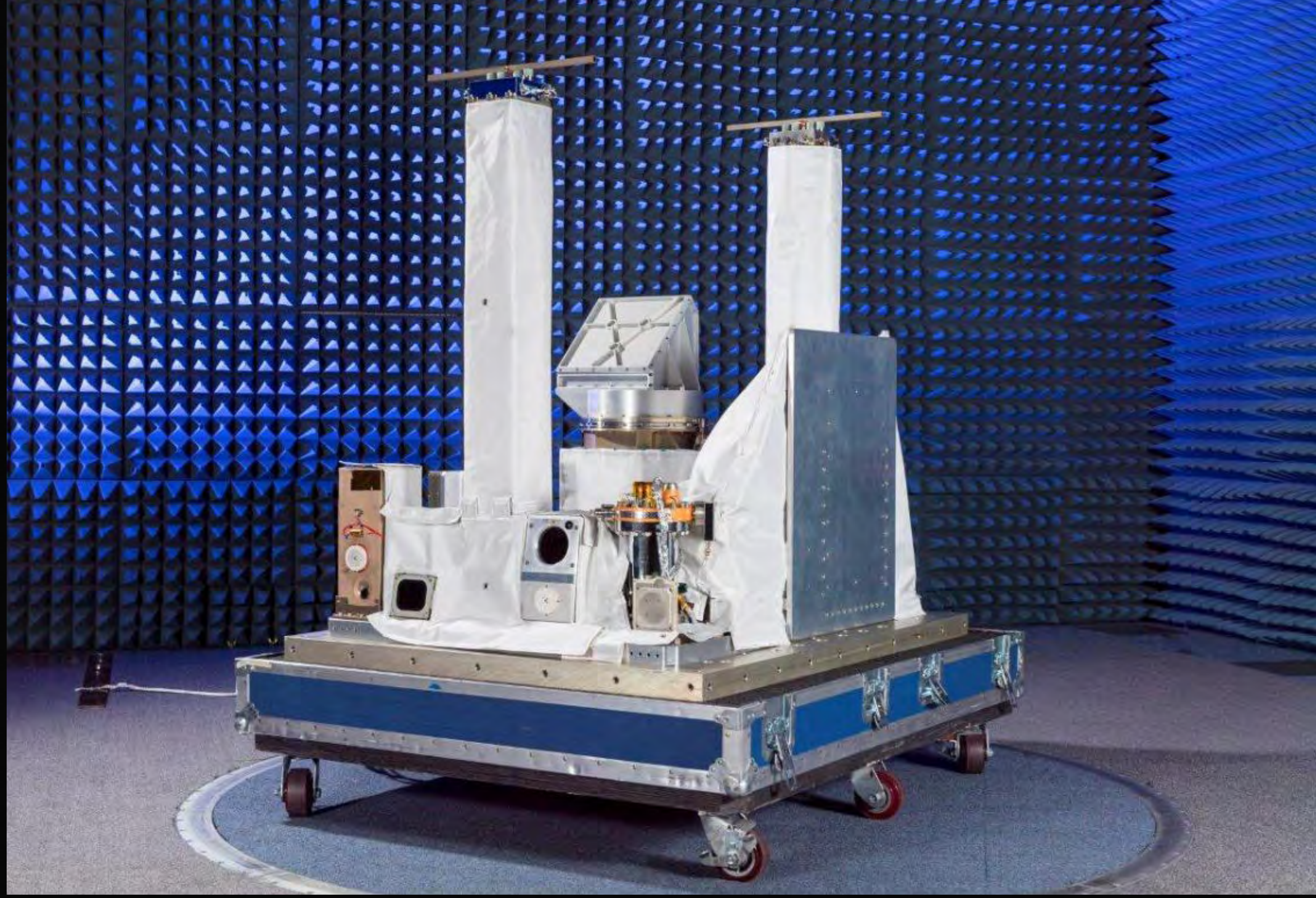
"While the shock you get from your carpet isn't dangerous, a sudden discharge in space can pose a serious threat or costly damage to sensitive satellite electronics," Tejero said.

At present, there are no simple, dedicated sensors to monitor spacecraft charging.

The SPADE experiment is designed to demonstrate the instrument's response to slight changes in the plasma sheath. This is often referred to as the Debye Sheath, which forms around a charged object and provides a unique NRL-developed method for early detection.

A component of the SPADE suite consists of an active antenna used to excite the local plasma and a passive antenna that observes that excitation.

The active probe is swept across a range of frequencies and DC voltage biases to determine the plasma impedance spectrum.



The Space PlasmA Diagnostic suitE (SPADE) experiment (tower-like structures in photo), is shown integrated onto the Space Test Program-Houston 6 (STP-H6) pallet. Developed by the U.S. Naval Research Laboratory Plasma Physics Division, in conjunction with the Spacecraft Engineering Department, SPADE is designed to monitor background space plasma conditions on-orbit the International Space Station (ISS) and provide early warning of hazardous levels of spacecraft charging. (NASA/Space Test Program-Houston 6)

The impedance measurement helps to determine the plasma's physical properties, such as density, plasma potential, and electron temperature. It provides data to indicate the charging level of the International Space Station relative to the local plasma.

"Laboratory investigations have illustrated that the NRL impedance probe can yield useful data in operational regimes where other techniques are less feasible," he said. "This opens many new possibilities for measurements in industrial processed plasmas and in atmospheric pressure discharge experiments."

The year-long mission will test SPADE's ability to detect hazardous station-charging events and provide long-term records of space weather conditions.

By Daniel Parry, NRL Strategic Communications Office

A New Manufacturing Process for Ultrathin Flexible Crystalline Silicon Solar Cells

In February, researchers at the U.S. Naval Research Laboratory (NRL) submitted a patent application for a new method of manufacturing ultrathin flexible silicon solar cells.

This new method alters commercial off-the-shelf crystalline silicon cells in a way that allows them to curve while still maintaining adequate performance at low cost. Many commercially available crystalline silicon solar cells are bulky and glass-like, rendering them unsuitable for many military applications because bending can damage them.

Solar cells created in this fashion could provide critical flexibility for power generation for both commercial and expeditionary applications, according to Dr. Woojun Yoon, NRL electrical engineer and principle researcher.

"Lightweight and portable solar power generation systems are critical to enhance operational capability, improve energy efficiency, and reduce reliance on supply lines for fuel," said Yoon.

The process mechanically thins interdigitated back contact (IBC) solar cells. These are commercial off-the-shelf crystalline silicon solar cells that have rear junctions and rear contacts that reduce shadow impacts and yield additional power. The off-the-shelf solar cells that researchers are altering in this process are already highly efficient, yet not as readily available as other solar cells.

"We developed low-cost cells to expand the range of applications that solar cells can be used for, including unmanned aerial vehicles, mobile solar markets, and other military applications," said co-inventor and electrical engineer David Scheiman. "Private industry could also integrate this technology into products such as homes and cars."

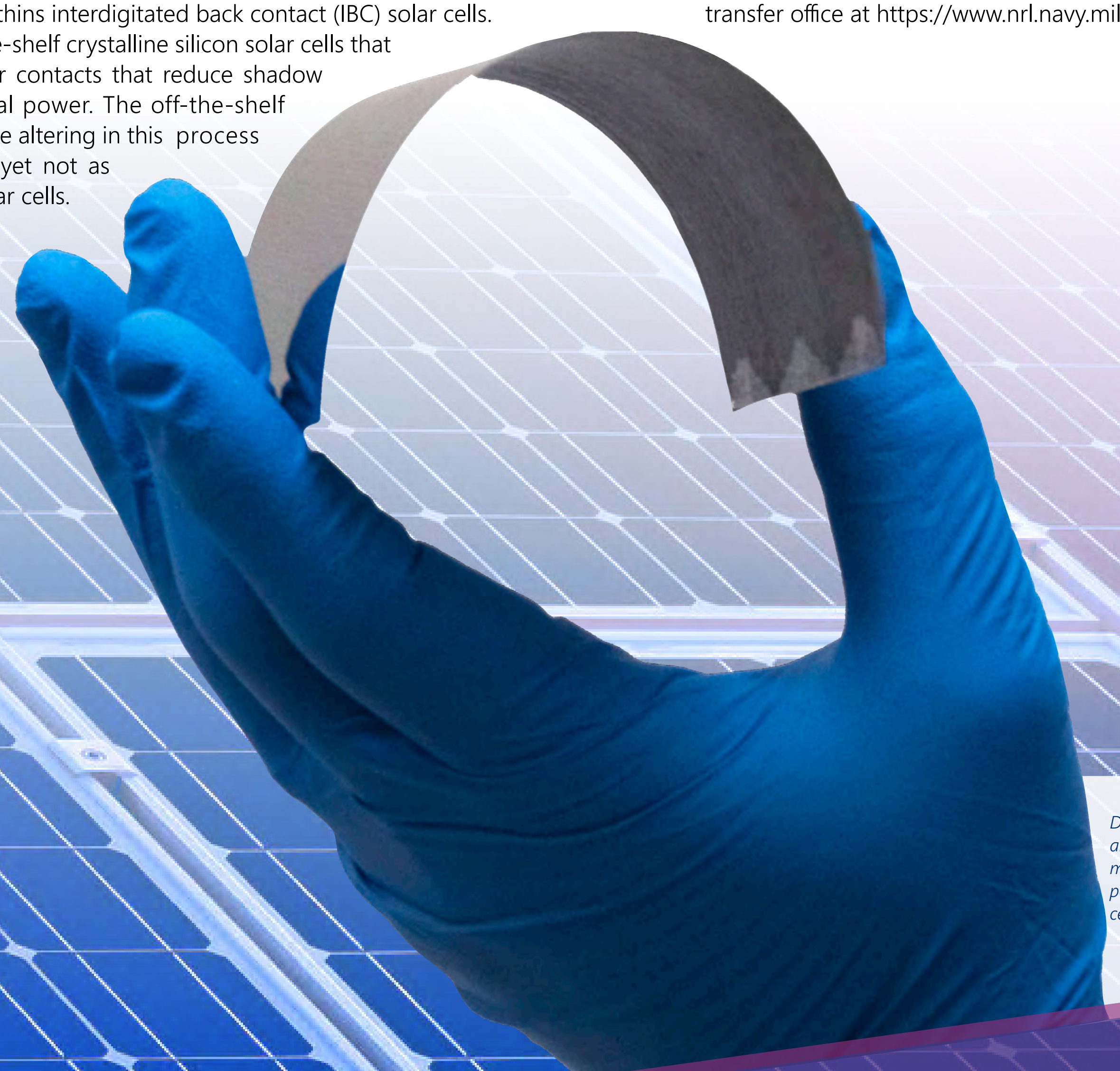
The new process is the second ultrathin solar cell manufacturing design by the researchers. In early December 2018, they submitted a patent application for a method of manufacturing ultrathin flexible mono- and multi-crystalline silicon solar cells. That method reduces the total thickness of a commercially available cell to approximately 30 microns and ensures its silicon surface won't crack when bent.

"By using commercially available crystalline solar cells we can convert those thick cells into thin flexible crystalline solar cells with minimum performance losses," Yoon explained. "The main application is for expeditionary solar power generation systems such as transportable solar blankets and unmanned vehicles."

NRL researchers developed these innovations as part of an ongoing effort to identify solar capability that will meet the cost constraints and capability demands to power equipment for the U.S. Navy, Marine Corps, and other Department of Defense organizations. The implementation of these solar cell technologies could help reduce reliance on fossil fuels and traditional batteries for powering and charging devices.

For more information about how to participate in a cooperative agreement with NRL to use this technology, contact the technology transfer office at https://www.nrl.navy.mil/techtransfer/contact.

By Cassandra Eichner, NRL Strategic Communications Office



Dr. Woojun Yoon, Electronics Science and Technology Division, displays an ultrathin flexible crystalline silicon solar cell that underwent a manufacturing process developed by NRL to thin the cell. The patent-pending method reduces the total thickness of a commercially available cell to approximately 30 microns and ensures its silicon surface won't crack when bent.

NRL Plasma Physics Division Seeking External Users for Space Chamber

The blackness of space is deceptive. It looks empty. It's not.

At the Earth's ionosphere, about 60 to 1,000 kilometers altitude, the sun's ultraviolet radiation ionizes the gasses of the Earth's atmosphere, knocking off electrons and leaving behind electrically charged positive and negative particles. That collection of particles is called a plasma, and the Earth is swathed in it. In fact, most of the visible universe is plasma, 99 percent of it, according to NASA.

Our sun is made of plasma. Stars are plasma. The tails of comets are plasma.

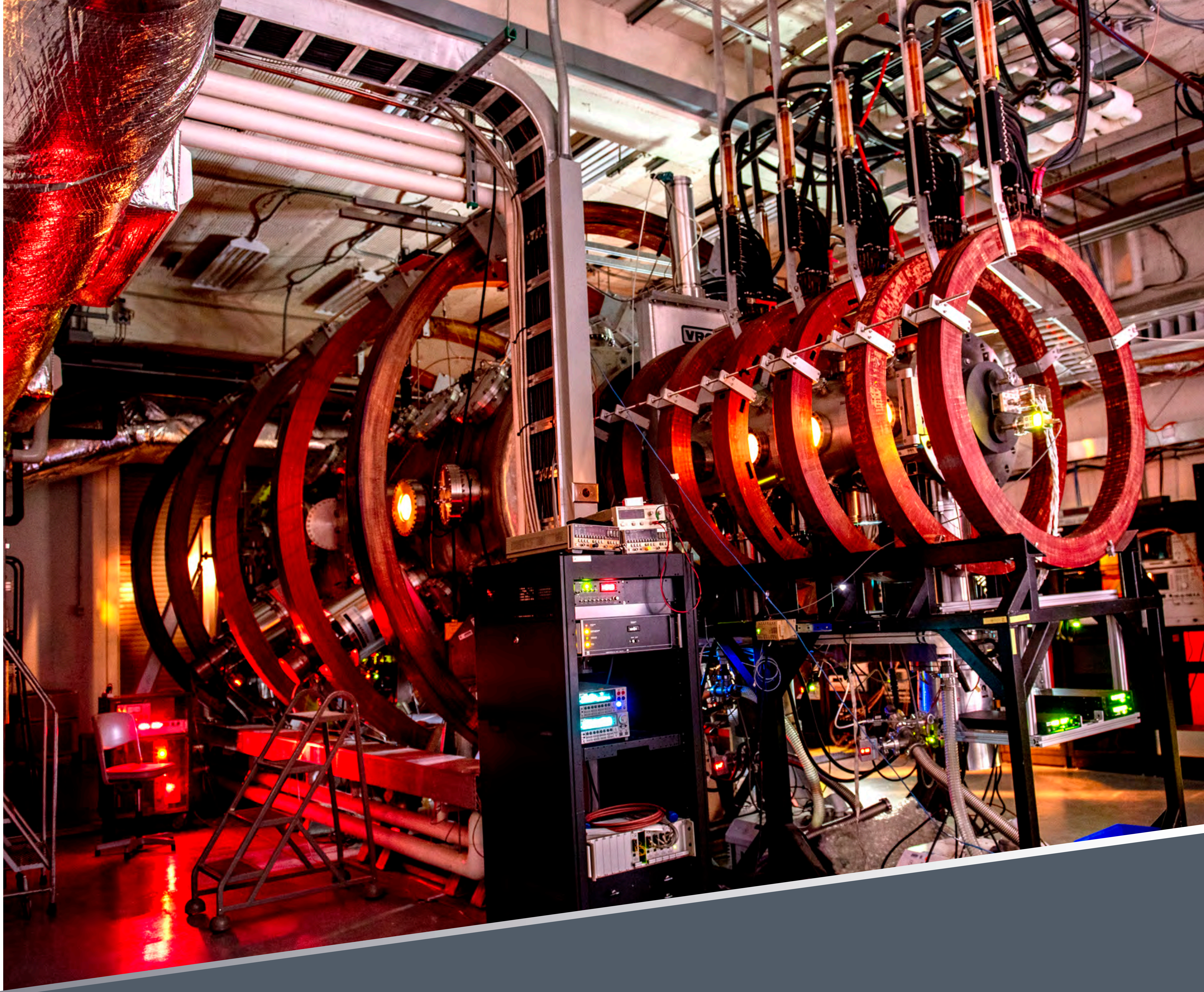
"It's a dynamic medium," explained Bill Amatucci, physicist and head of the U.S. Naval Research Laboratory's (NRL) Charged Particle Physics Branch. "[The concentration of plasma] decreases as you get away from planets, but most of the rest of the universe is in the plasma state. We just happen to live in a cold spot, relatively."

While naturally-occurring plasmas are rare on the Earth's surface, man-made plasmas can be found in such everyday things as neon signs and fluorescent lights. They can also be found at NRL's Plasma Physics Division, where Amatucci and his team of research physicists have been using a massive chamber to create and study them.

A large-scale vacuum vessel for the creation of space-like conditions, the Space Physics Simulation Chamber is one of only a handful of its kind in the United States and one of the biggest in the world. Now the researchers who operate it are looking for external partners who might want to use it to conduct space plasma experiments or test spacecraft hardware.

"There are a lot of people [within the Department of Defense] who build experiments to fly in space, and this is a place where you could test them in a realistic environment prior to flight," Amatucci said.

In the Charged Particle Physics Branch lab, Amatucci's team designs instruments to take their own measurements, and sometimes they design hardware that will fly in space as well. In May, their Space PlasmA Diagnostic suitE (SPADE) experiment launched on a SpaceX Falcon 9 resupply mission for the International Space Station.



The NRL Space Physics Simulation Chamber.

Research physicist David Blackwell performing a calibration of a plasma sensor inside the NRL Space Physics Simulation Chamber.

The experiment consists of a pair of "plasma impedance probes" designed to monitor the background plasma conditions for space weather measurements and also monitor for hazardous levels of spacecraft charging on the space station, which goes through day-to-night cycles of charging and discharging as it travels through different plasmas.

Now that SPADE is on the space station, everything is going according to plan, Amatucci said. Each day, his team downloads new data from the experiment.

"It's been fantastic," Amatucci said. "We're getting tons of data. More than we can swallow right now. So we're in the initial stages of doing our deep dives into the data."

As one of the biggest operators of satellites, the U.S. Navy has a keen interest in understanding the fundamental properties of space plasmas and the applied plasma physics problems that the lab is using the chamber to study.

Mimicking Space

NRL began construction on the chamber in 1990 and it was operational two years later. It is made up of two sections: the large, main chamber, which is 5 meters long and about 2 meters in diameter, and a smaller chamber that is 2 meters long and 0.5 meter in diameter.

The smaller section is called the source chamber; researchers use it to create and manipulate the plasmas before sending them into the main chamber.

During operation, researchers evacuate the chamber of air, fill it with noble gas (often argon, though they use a range of different gasses in their experiments), and then ionize the gas by stripping electrons from the gas atoms.

"Our chamber is unique in that we can make steady-state plasmas with properties that either match or scale to many different regions of near-Earth space plasmas," Amatucci said. "We have a steady feed of gas, which is steadily being ionized, creating this uniform condition in the chamber that we can scale to different regions of space."

To hold together the plasma inside the chamber, the researchers create a background magnetic field using electromagnet coils that encircle the vacuum chamber. During their experiments, they can fine-tune this magnetic field to mimic the different conditions in the ionosphere or different regions of the Earth's magnetosphere.

"Depending on where they occur in space, plasmas have a range of properties," Amatucci said. "There are places where the magnetic field is fairly uniform, so we can make a uniform magnetic field. There are places where it may be stronger in one area than another, and we can do that in the lab as well."

They're also using the chamber for diagnostic development and preflight testing of hardware that must withstand the rigors of spaceflight. Like the space station, a spacecraft passing through plasma will accumulate electrical charges, occasionally resulting in high voltages and electrical discharges that can damage electronics and even disable satellites.

"These charged particles can interact with each other over long distances," Amatucci said. "So there's a rich variety of disturbances and waves that can ripple through them. We want to understand the basic behavior of the medium so that we can have reliable and persistent operation of our satellites."

By mounting hardware, such as probes or miniature satellites, on a 3D-positioning system, the researchers can move the hardware within the full volume of the chamber through different areas of the plasma in precision fashion.

"It's great for diagnosing the entire plasma or moving your probe from one set of conditions to another set of conditions," Amatucci said. "That's a big selling point for external users."

By Emanuel Cavallaro, NRL Strategic Communications Office

Bill Amatucci, research physicist and head of the U.S. Naval Research Laboratory's Charged Particle Physics Branch, in front of the source chamber section of the Space NRL Physics Simulation Chamber.

Dr. Peter Matic, head of NRL's Materials Science and Component Technology Directorate.

On Jan. 20, the U.S. Naval Research Laboratory named Peter Matic to lead its Materials Science and Component Technology Directorate. Formerly the head of NRL's Materials Science and Technology Division, Matic holds a doctorate in applied mechanics from Lehigh University. He has worked at NRL for more than 25 years.

Recently, NRL Public Affairs sat down with Dr. Matic to discuss how he plans to tackle his new role leading a directorate that today boasts more than 550 science, engineering, administrative, and contract staff and an annual budget of approximately $300 million.

Q First off, congratulations on your appointment.

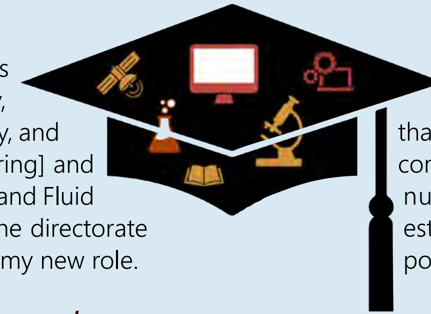
Thank you.

Q What will be your priorities leading the entire directorate?

First, it starts with our people. I want to continue supporting our engaged workforce that is continuously renewing itself with new skills and talents. Second, as leaders, we need to make sure our people have every opportunity to contribute to the scientific and technological missions of the Laboratory. We need to help the divisions continue to build interdisciplinary teams, which is one of NRL's great strengths. With many disciplines in one organization, we're able to solve important problems of Navy and national interest. Third, I want to make sure we help our people express the vision and context for their ideas which, in NRL's tradition, we develop from the bottom up.

Q As the former head of the Materials Science and Technology Division, you're coming from inside the directorate, so you have plenty of experience with the organization. How did that role prepare you for this one?

I was fortunate to lead that division because it has a variety of different disciplines and covers many areas. It has a great mix of physicists, materials scientists, and engineering disciplines. When I took on that role, I learned rather quickly how to work with people across different backgrounds engaging on a variety of projects.



The directorate as a whole has five divisions [Chemistry, Materials Science and Technology, Plasma Physics, Electronics Science and Technology, and the Center for Biomolecular Science and Engineering] and one group [Laboratory for Computational Physics and Fluid Dynamics]. I have had many interactions across the directorate over the years and look forward to many more in my new role.

Q A lot of the work of the directorate is basic research, as opposed to applied research or advanced technology development. How do you think you can demonstrate the value of basic research to today's Navy and Marine Corps?

We have to remember that even though basic research by definition has a long lead time to reach the Fleet, NRL and the directorate has a long history of delivering relevant technologies. Materials is unique in that there is a healthy mix of shorter and longer term payoffs generating new capabilities, cost savings and technical insights informing the acquisition processes for the Navy. Our researchers develop critical expertise in areas such as laser physics, corrosion and coatings, vacuum electronics, warfighter protection, chemical sensing and biomaterials. That's one of the rich traditions of the directorate: the ability to develop these relevant specialties through long-term relationships with external sponsors and deliver technologies as they mature. I am sure that we will continue to develop and deliver in new areas as well as those we currently have.

Q Workforce was the first priority you mentioned. Do you have any specific ideas you want to implement?

What I saw in the [Materials Science and Technology] division was that a third of our scientists and engineers were new to the division in the last five-and-a-half years. Part of that trend is demographics, since our employees hired in the 1980s are retirement-eligible, and the other part is driven by programs evolving into new areas. So we see people coming in with new skill sets and helping to establish those new areas of expertise.

Q That's interesting. What are some things you've done to accommodate these new skill sets?

Most of these new skills can immediately enhance our current efforts. Then, encourage them to develop new concepts for the base program or external sponsors that would be most relevant to the Navy.

In both cases, ensure that a long-term vision is there for the science along with a clear context for Navy and defense technology. Then, help our early career staff to develop into being top defense scientists and engineers with unique skills that complement our academic and industrial partners.

By the way, I use the terms "vision" and "context" a lot. I do think we always need to emphasize that. People start out with a good scientific idea, but communicating what it could mean is key. Put some numbers on it, even some back-of-the-envelope estimates. It's the combined vision of the science and its potential impact that will help to sell it.

Q There seems to be a lot of discussion about being more interdisciplinary, but also a lot of competition out there. How do you go about it?

Well, we just held our annual Research Advisory Council retreat where the new starts are discussed. There seemed to be general consensus that the interdisciplinary proposals that integrate multiple groups, often across two or more divisions, tend to be very impressive. This seems to give those teams a competitive edge with a more comprehensive approach to their objective. I also think in many cases we can do it better than academia and broader than industry.

Q Really? Can you elaborate?

Often in academia, I think faculty team together to propose some good ideas, but the nature of the pressures on individual faculty and their graduate students can lead them to perform somewhat separately.

At NRL, it's easy for ideas, teaming and funding to flow across divisions. Don't get me wrong, execution is not always easy. People have to take the time to learn about each other's specialty. But it is often the best way to solve complex problems in today's world.

Q So for all the potential recruits out there, how would you describe the profession of being a defense scientist?

The profession of being a defense scientist is an important one. It has its own unique features, not the least of which are broad portfolios of unique opportunities and national responsibilities. We're not academics because we don't have a course catalog to teach, and we're not industrial because we generally don't produce the end products for sale.

Of course there are some very smart people in those other two environments, but our environment requires the rigor of academia and the adroitness to do industry-relevant things. We have the ability to do basic research, applied research, prototyping, and beyond right here. We also can change directions quickly, and that's one of the things that makes NRL unique.

I must confess that a few years ago, after 25 years here, I asked myself why am I still here? I realized that, here at NRL, I was able to pursue three careers as well as the leadership opportunities. That kept me learning, engaged, and growing. I'm not sure you can do that in many other places. We have lots of options and many ways to pursue our careers here.

I tell potential new hire candidates who I have interviewed that you can come to NRL, do good science and develop good technologies, evolve into a scientific program leader, take on other leadership roles, and interact with other dedicated people in government, academia, and industry to solve problems of national importance. You indeed can have three careers within the same organization.

Q What kind of personal qualities help a person succeed in this environment?

I find that a really important factor is finding the people who don't want to see their work end in the lab. They understand that they can come here and take their ideas really far, and we want them to take their ideas far, because that's our mission.

Also, they are people who tend to like working horizontally and vertically. They like to work with a lot of other scientists and engineers. They are people who have special skills but also see the bigger picture. They want to be in an environment where they can move something forward beyond the laboratory stage.

Q Dr. Matic, thank you for your time.

Thank you. I'm really looking forward to understanding and helping the directorate use its immense talent and breadth in the best ways possible.

By Victor Chen, NRL Strategic Communications Office

NRL 'Connects the Dots' for Quantum Networks

Scientists in the Electronics Science and Technology Division at the U.S. Naval Research Laboratory (NRL) developed a new technique that could lead to future advancements in quantum technology.

The technique squeezes quantum dots, tiny particles consisting of thousands of atoms, to emit single photons (individual particles of light) with precisely the same color and with positions that can be less than a millionth of a meter apart.

"This breakthrough could accelerate the development of quantum information technologies and brain-inspired computing," said Allan Bracker, a chemist at NRL and one of the researchers on the project.

In order for quantum dots to "communicate" (interact), they have to emit light at the same wavelength. The size of a quantum dot determines this emission wavelength. However, just as no two snowflakes are alike, no two quantum dots have exactly the same size and shape—at least when they're initially created.

This natural variability makes it impossible for researchers to create quantum dots that emit light at precisely the same wavelength [color], said NRL physicist Joel Grim, the lead researcher on the project.

"Instead of making quantum dots perfectly identical to begin with, we change their wavelength afterward by shrink-wrapping them with laser-crystallized hafnium oxide," Grim said. "The shrink wrap squeezes the quantum dots, which shifts their wavelength in a very controllable way."

While other scientists have demonstrated "tuning" of quantum dot wavelengths in the past, this is the first time researchers have achieved it precisely in both wavelength and position.

"This means that we can do it not just for two or three, but for many quantum dots in an integrated circuit, which could be used for optical, rather than electrical computing," Bracker said.

The wide breadth of researcher expertise and science assets at NRL allowed the team to test various approaches to making this quantum dot breakthrough in a relatively short amount of time.

"NRL has in-house facilities for crystal growth, device fabrication, and quantum optical measurements," Grim said. "This means that we could immediately coordinate our efforts to focus on rapidly improving the material properties."

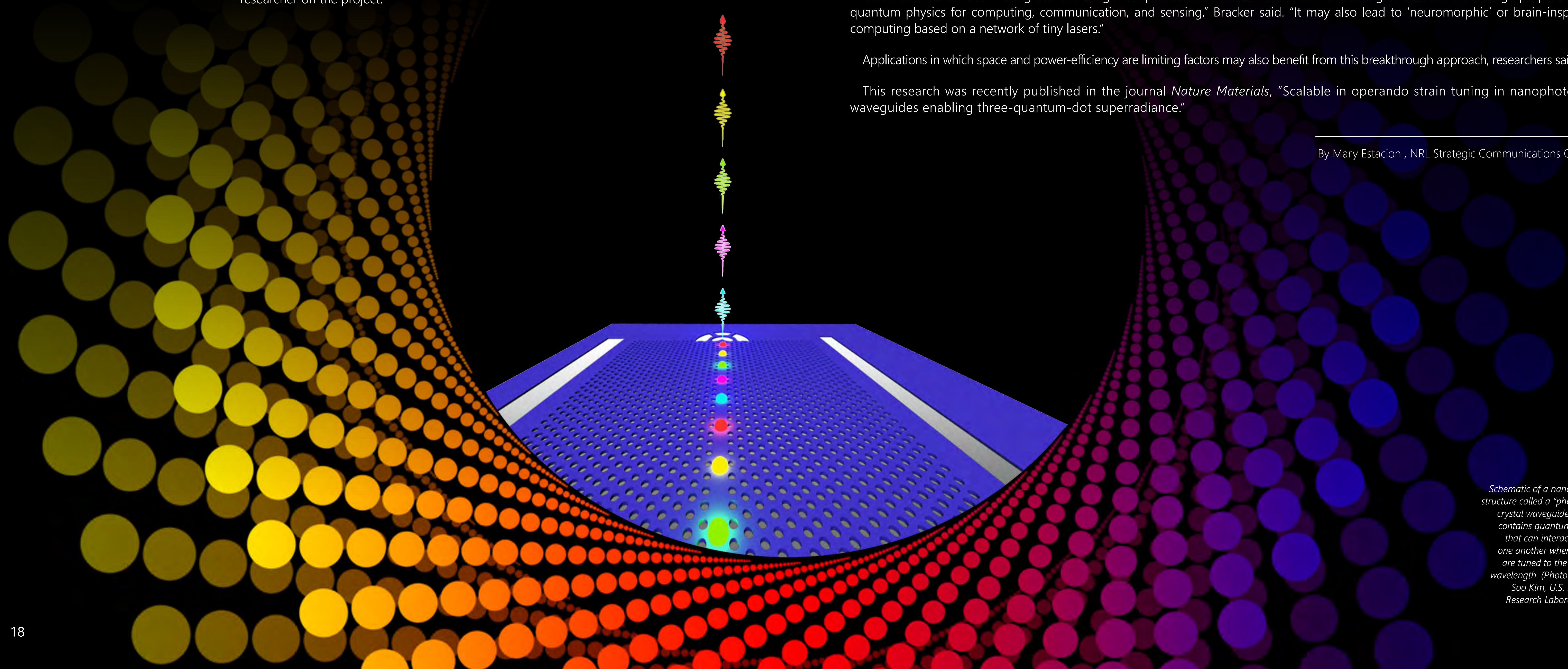
According to Grim and Bracker, this milestone in the manipulation of quantum dots could lay the groundwork for future strides in a number of areas.

"NRL's new method for tuning the wavelength of quantum dots could enable new technologies that use the strange properties of quantum physics for computing, communication, and sensing," Bracker said. "It may also lead to 'neuromorphic' or brain-inspired computing based on a network of tiny lasers."

Applications in which space and power-efficiency are limiting factors may also benefit from this breakthrough approach, researchers said.

This research was recently published in the journal *Nature Materials*, "Scalable in operando strain tuning in nanophotonic waveguides enabling three-quantum-dot superradiance."

By Mary Estacion , NRL Strategic Communications Office



Schematic of a nanoscale structure called a "photonic crystal waveguide" that contains quantum dots that can interact with one another when they are tuned to the same wavelength. (Photo: Chul Soo Kim, U.S. Naval Research Laboratory)

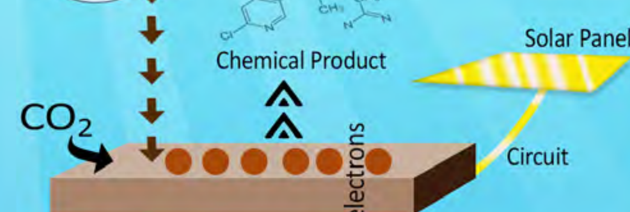
Sense & Respond

Wearable electronics interacting with skin bacteria to sense body chemicals.

Marine bacteria can sense chemicals which may be harmful to divers and report with electrical or fluorescent signals. Integrating dive gear or UUV's with modified living sensors can help divers detect chemicals.

Carbon Capture & Synthesis

Electron absorbing microbe *(Candidatus* Tenderia electrophaga*)* reduces carbon dioxide to grow. Such organisms are enriched from corroding metals and can be grown on electrodes.



CO_2 reduction coupled to electron transfer results in chemical product through a process called microbial electrosynthesis. Renewable energy, such as solar power, can provide electrons for carbon fixation in non-photosynthetic bacteria like *Candidatus* Tenderia electrophaga.

By driving more electrons into organisms, a natural reversible battery can be created. Reduced carbon can be stored for later energy production.

Solar Panel

CO_2

Chemical Product for storage

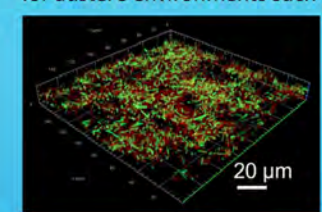
Electronics

Shewanella naturally pushes electrons into iron. *Shewanella* can reach out and make electrical connections through a protein electrical conduit. By inserting this protein conduit into another organism (e.g. *Marinobacter*) it does the same thing and can create an engineered bacterial circuit.

Shewanella *Marinobacter* *Marinobacter*

Marinobacter *Marinobacter*

Bacterial circuits are robust, self-healing electronics for austere environments such as the ocean.



The green cells in this image are harboring new DNA for electrical circuits.

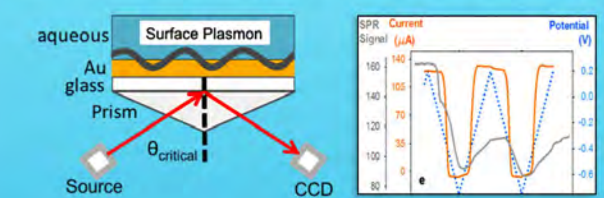
Exploiting the interaction of microbes with electronics, NRL has fused an electrode sensing protein with another characterized protein to create microbial electrical sensors. This allows bi-directional communication between cells and electronic devices.

Electrical Current

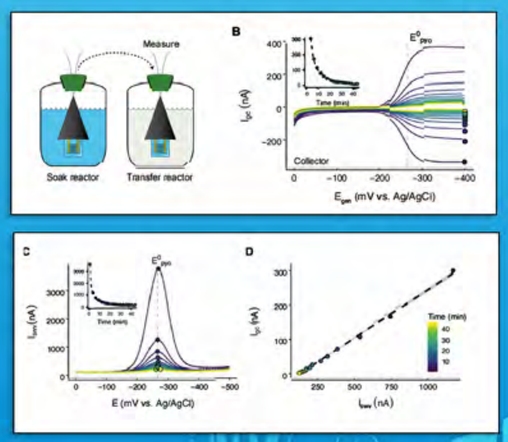
Measurements

NRL is a pioneer in development of methods to study how microbes move electrons in and out cells, to and from electrodes, and through thick biofilms.

NRL develops specialized measurement methods that advance fundamental understanding of electron flow through microbial electronic systems. These tools are used to track the movement of electrons through biofilms. The knowledge gained by these methods is used to develop microbial electronic technologies.



These same methods reveal how oxygen-limited *Pseudomonas* cells deep inside a biofilm-infected lung export their respired electrons in order to survive. Such information may one day form the basis of therapeutic methods to treat infections.



Study Uncovers a Strategy that Viruses use to Evade Immediate Immune Responses

Scientists in the Center for Bio/Molecular Science and Engineering at the U.S. Naval Research Laboratory (NRL) have identified a new algorithm that could help virologists better understand and treat infections caused by viruses such as Zika.

Patricia Legler, a research biologist at NRL, discovered the algorithm while developing Venezuelan Equine Encephalitis virus (VEEV) protease assays for drug discovery. One of the substrates she designed contained a human protein sequence that she thought could be cut by the viral protease.

After searching for similar cases, Legler found that most of the viral proteases that could cut host proteins were from positive sense single-stranded RNA viruses. She also noticed that the proteins being cut were involved in generating the innate, or immediate, immune responses to these viruses. Legler's findings showed that the viruses used what she called a "search and delete" algorithm to target and destroy host proteins.

"The virus's protease finds the key word—or protein sequence—[in a host cell] and then deletes the file containing the keyword; this is one mechanism that allows the virus to replicate," Legler said.

While studying how these viruses replicate, Legler realized that the procedures her team created to emulate a virus had uncovered an efficient way to describe how a virus edits a host's proteome. The process closely resembles that used by the CRISPR-Cas9 enzyme to destroy invading strands of phage DNA.

Also contributing to this study were Xin Hu and Juan Marugan of the National Center for Advancing Translational Sciences (NCATS/NIH), and Elaine Morazzani and Pamela Glass from the U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID).

Their findings were published in the April issue of Elsevier's *Antiviral Research* (DOI: https://doi.org/10.1016/j.antiviral.2019.02.001).

Finding the Targets of a Virus

Using established cultural cell lines, Legler's study identified human protein sequences that could be "cut" by the protease of the Zika virus. The "keywords" are what researchers call cleavage sites—in this case, the keywords were in proteins related to immunity. The viruses "delete" these proteins, allowing the virus to replicate and spread.

"That means that these aren't just any proteins being cut," Legler said. "This is a targeted strategy to antagonize your innate immune responses. That leads us to the idea that this cleavage site sequence actually corresponds to a host protein sequence."

Legler labeled these protein sequences Short Stretches of Homologous Host-pathogen Protein Sequences (SSHHPS) to acknowledge NRL. Some of the protein sequences that could be cut by the Zika protease were in proteins called FOXG1, NT5M, and SFRP1. These proteins are involved in brain and eye development. FOXG1 mutations have been associated with a syndrome characterized by microcephaly, an unusually small head size.

The algorithm the researchers uncovered identified new protein sequences that could aid biologists in understanding human antiviral defense systems and help determine which pathways the virus targets.

"We think we can actually use this to predict what the virus will do to the host," Legler said.

A New Way to Create Antivirals

Researchers can also use the algorithm to identify animal models by matching the proteins targeted by the virus in the human body with those in animals. Legler discovered species-specific differences in the cleavage sites while studying the Venezuelan Equine Encephalitis virus in tandem with Zika.

The Venezuelan Equine Encephalitis virus is aggressive in killing horses—with a 20-80 percent mortality rate. It is less successful in killing humans, who have only a 1 percent mortality rate. Using the algorithm to study the virus, Legler learned that horses lack part of an innate immune response protein that humans have that helps fight VEEV.

"That indicates that species with a cleavage site that matches to the virus have some kind of defense mechanism for these infections," she explained. "Whereas species that don't have the cleavage site may be the most susceptible to this disease."

The sequence differences may also make other species less likely to develop certain viral infections.

Legler's algorithm will allow researchers to compare the protein sequences attacked by a virus in the human body with databases of animal proteins to find matching sequences. The hope is that matching the protein sequences of animal models with those in humans could allow virologists to test antiviral medications and vaccines that are more effective at combating the effects of a virus.

Moving the Algorithm Forward

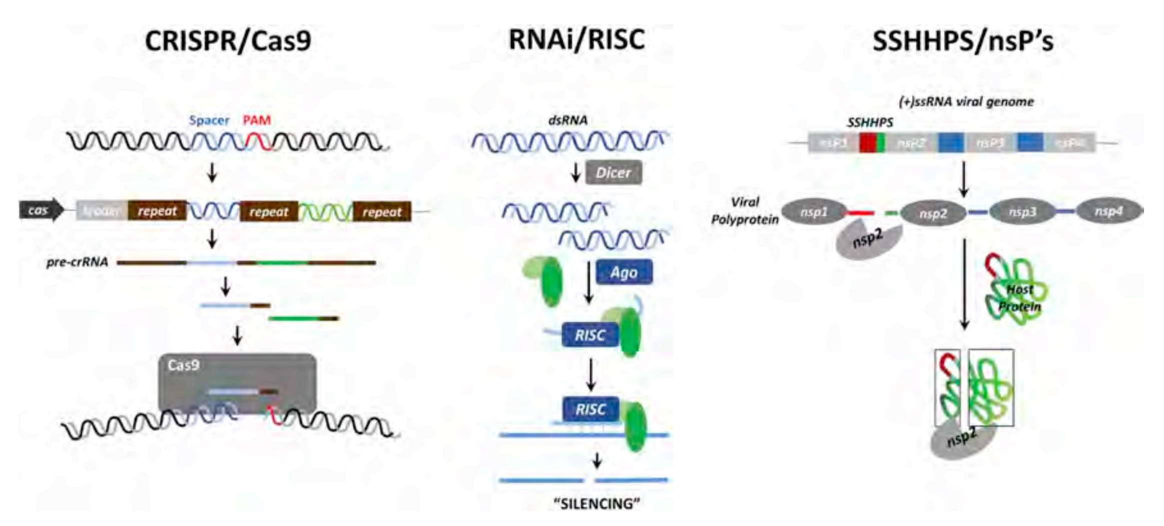
While the algorithm provided Legler with valuable information about the viruses she studied and a way to replicate their "search and delete" programs, she and her collaborators did much of their work by hand.

"When I was studying the Zika virus, I compiled a table of all of the host proteins that have been shown to be cut and drew them out," she said.

Legler and her collaborators hope to streamline this process by creating software to carry out the algorithm, removing the need to make the tables by hand.

"By creating software, we can find a way to provide other scientists with an easy interface to identify the host protein sequences in the viruses they're studying and parallel animal models," she explained. "[That will give] them a functional tool to use as they create antivirals."

By Gabrielle M. Gibert, Formerly, NRL Strategic Communications Office



DNA, RNA, Protein? Three mechanisms of silencing that are guided by a short sequence. In each case a short sequence is used to identify a larger target sequence; these mechanisms are analogous to "search and delete" programs that use a "keyword" that have been written in three different languages. Each system has an enzyme that recognizes the match between the short sequence and the target and then cuts ("deletes") the larger target sequence. The short sequence and target sequences belong to either the host or pathogen and the goal of these mechanisms is to antagonize or silence the effects of the molecule. These mechanisms are used to defend the host from viruses or to defend a virus from a host's immune system.

Rhonda Stroud researcher at the Nanoscale Materials Section of the Materials Science and Techonology Division.

NRL Researcher Discovers Noble Gas in Doped Nanodiamond

The U.S. Naval Research Laboratory's (NRL) own Rhonda Stroud made a scientific discovery that astounded her fellow researchers. She found argon trapped inside laboratory-grown nanodiamonds.

The finding, published in *Scientific Reports* earlier this year, has implications for advanced quantum computing technology.

"We discovered we could flexibly dope nanodiamonds with nearly any other atomic species we wanted without having to resort to ion irradiation," Stroud explained. "This allows us to better control optical and electronic properties of the diamond."

Doping nanodiamonds is essentially adding foreign materials into a diamond to tune the properties. While a dopant- and defect-free diamond is transparent, adding specific dopants can change the color and luminosity.

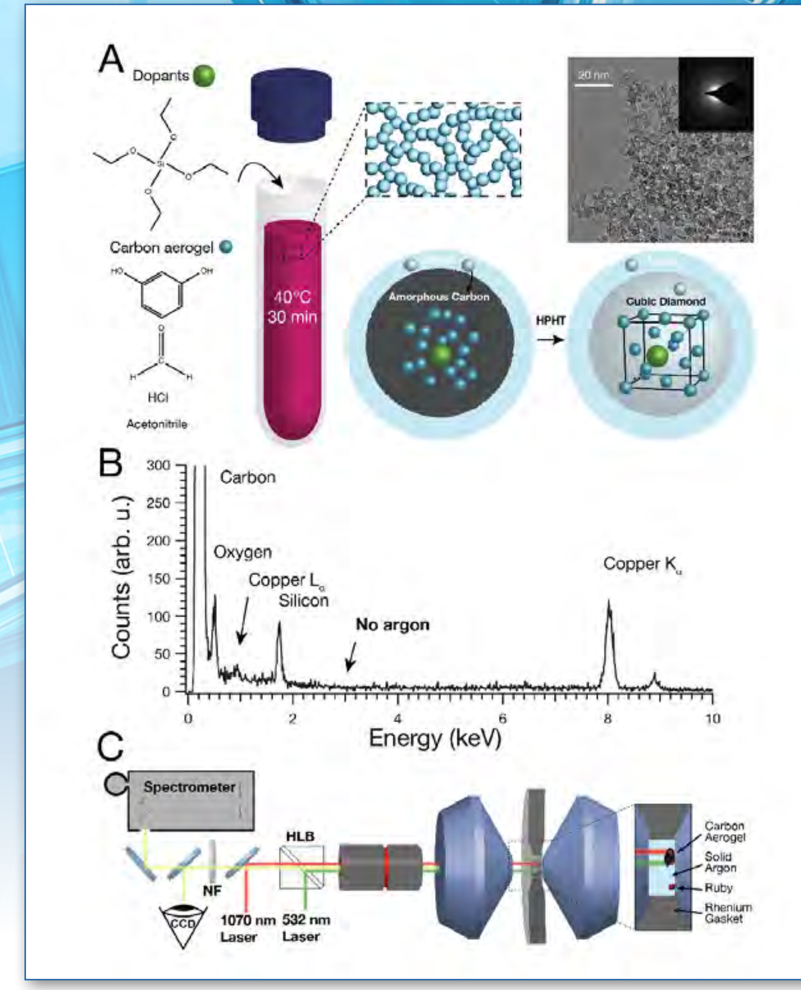
Researchers create synthetic nanodiamonds for practical use here on Earth. The unique photoluminescent glow of nanodiamonds renders them useful for a variety of applications, including quantum computing. Natural nanodiamonds also form in space environments, such as supernovae. In that case the incorporation of dopants, including noble gas atoms, is a clue to the cosmic origin, but understanding how the noble gases are incorporated into the cosmic nanodiamonds has been a mystery for more than 30 years.

Nanodiamond Genesis and Doping

To create nanodiamonds in the laboratory, Stroud's research partners squeezed amorphous carbon aerogel under extremely high pressure and temperature between two diamond anvils. They used argon to fill in the pore spaces within the aerogel particles to ensure the pressure of the anvils dispersed evenly. Argon is one of six noble gases in the periodic table of elements. They are very stable on their own, making it difficult for them to share electrons with other atoms.

Once the researchers had created the nanodiamond, they delivered it to Stroud so she could conduct single-atom-sensitivity measurements using one of the Department of Defense's most powerful electron microscopes.

Stroud's role in the research was to look at individual atoms within the nanodiamond to find silicon dopants that her research partners had identified through the nanodiamond's signature photoluminescent glow. When she peered through her NION Ultra STEM microscope, she discovered not just silicon dopants, but also argon incorporated into the nanodiamonds. Researchers did not anticipate finding any of argon in the diamond; the argon doping would have likely have gone unnoticed had Stroud not performed electron microscopy.



Carbon precursor doping mechanism and characterization. (A) Schematic representing the synthesis and doping of carbon aerogels, including BF-TEM image with SAED inset. Dopants are introduced alongside resorcinol and formaldehyde incorporate within the carbon aerogel grains. Upon conversion to diamond at high pressure and high temperature, dopants remain inside the diamond lattice as color centers. (B) EDS spectra of the carbon aerogel as synthesized show only the presence of carbon, silicon, and oxygen. Copper signal comes from the TEM grid. (C) Schematic showing a 1070 nm heating laser or polarized 532 nm Raman and photoluminescence laser focused into the pressurized diamond anvil cell, which is loaded with a carbon aerogel precursor, ruby for pressure measurements, and a solid argon pressure media, contained by a rhenium gasket.

> *"It demonstrated that the synthesis of the nanodiamond in the laser-heated diamond anvil allows us to essentially put anything from the periodic table that we want into diamond."*
> *– Rhonda Stroud*

Her expertise is in electron microscopy, not the synthesis. She continues to collaborate with researchers who seek to incorporate nitrogen complexes (clusters of four nitrogen atoms) or xenon into nanodiamonds. Among many potential uses, a nanodiamond doped with xenon is thought to make a good qubit.

Learn more about nanodiamond noble gases at https://arxiv.org/abs/1804.00350.

By Cassandra Eichner, NRL Strategic Communications Office

Renewed Collaboration to Detect, Respond to Airborne Hazards

The U.S. Naval Research Laboratory (NRL) extended its partnership agreement with the University Graduate Center in Kjeller, Norway, in January to continue work on a tool that provides emergency responders with predictions of where and how airborne chemical, biological, and radiological (CBR) hazards would disperse in the city of Oslo.

Dubbed CT-Analyst-Oslo, the project is an Oslo-specific, real-time modeling tool based on CT-Analyst, developed by NRL to provide accurate and instantaneous 3D-predictions of hazardous plumes in urban settings. The partnership's continued work will further customize and upgrade the Oslo version of CT-Analyst.

"We value our partnership with the University Graduate Center in Kjeller and look forward to equipping Oslo with an exclusive version of our high-quality, real time CBR-response tool, CTAnalyst," said Adam Moses, computer scientist in the NRL Laboratories for Computational Physics and Fluid Dynamics.

"CT-Analyst is an impressive tool," said Anders Helgeland, research manager, Flow and Materials, Comprehensive Defence Division, Norwegian Defence Research Establishment. "Ideally, we would like to combine implementation of CT-Analyst within fire departments in several Norwegian cities with continued development of the software in collaboration with NRL."

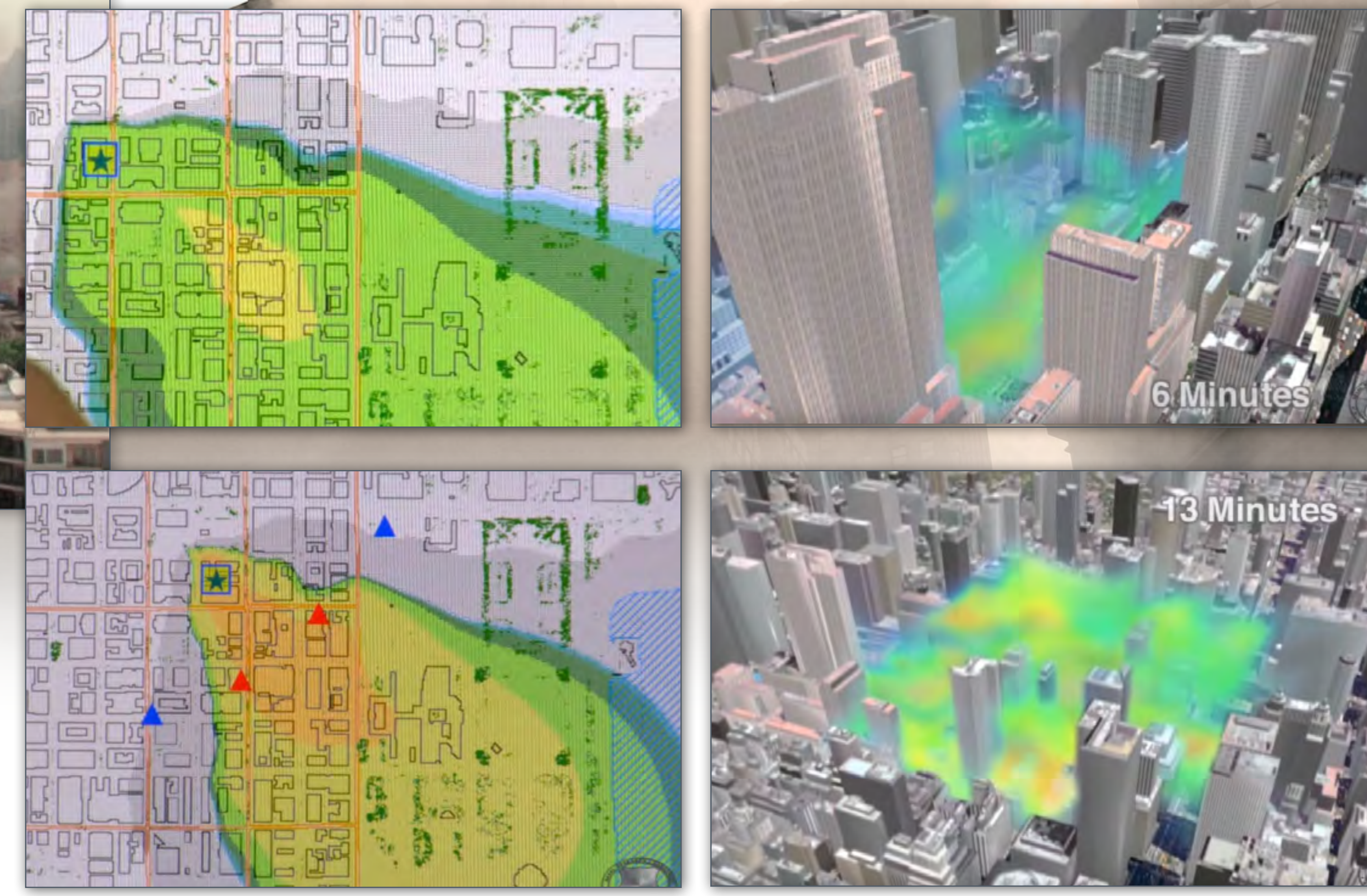
CT-Analyst algorithms integrate weather, structural, and geophysical data to predict the movement of airborne hazards throughout the city. The real-time information can be used by first responders to determine which areas will be most impacted by a CBR hazard and should be evacuated, and where to set up triage centers.

The technology can also use existing sensors throughout the city to determine protective measures if chemical, biological, radiological, nuclear, or enhanced explosive (CBRNE) hazards are present.

CT-Analyst has already been demonstrated in foreign and domestic markets. The tool has a user-friendly interface, and its predictions employ detailed, realistic topography. These attributes set it apart from other plume-modeling software and allow first responders to operate the program effectively even when they have received only minimal training.

Helgeland, whose division works on emergency preparedness and security measures for the armed forces and civil society, called CT-Analyst an excellent "next step" in his division's pursuit of more applied research within the field of CBRNE defense.

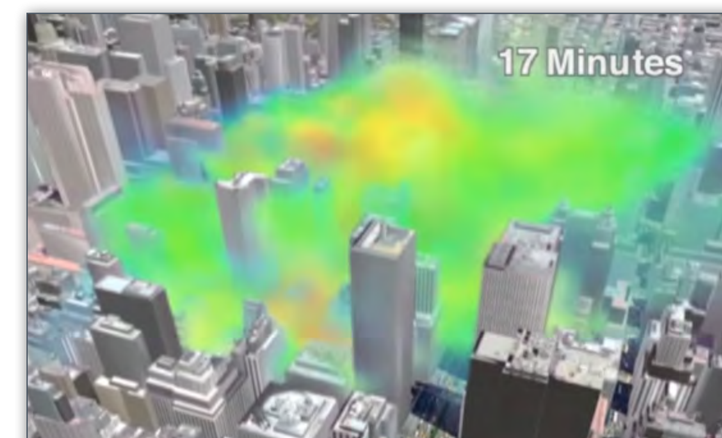
By Cassandra Eichner, NRL Strategic Communications Office



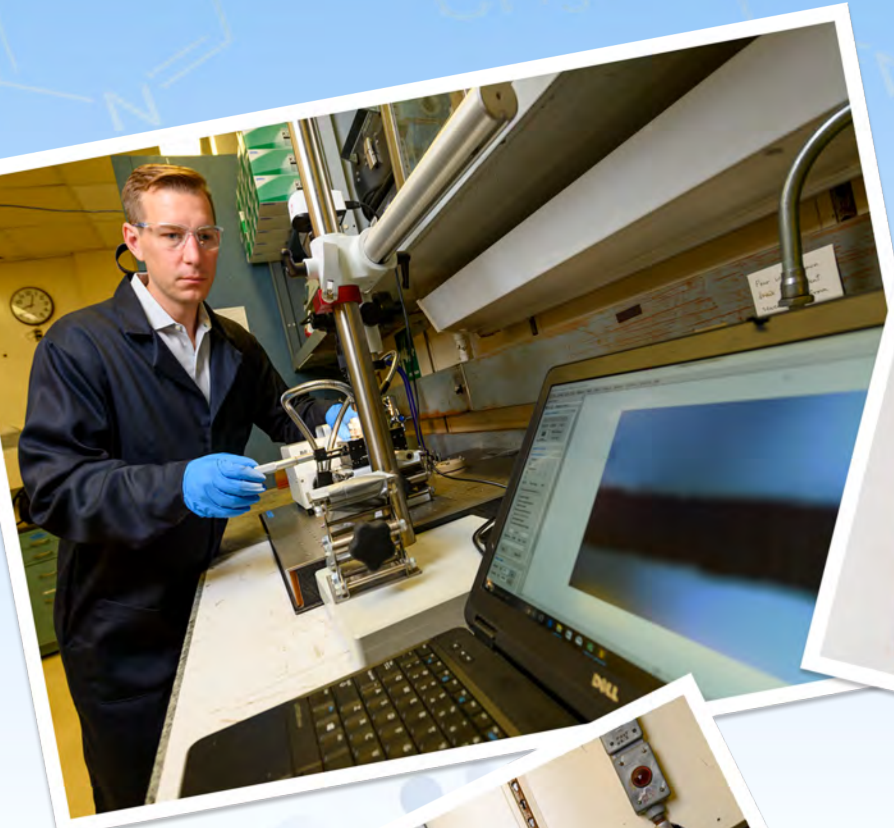
About CT-Analyst

- Works in real-time, providing results in just seconds.
- Utilized by governments around the world and cities across the United States
- Used in two presidential inaugurations.
- Designed for use by first responders.
- Customizable for individual customer needs.
- Incorporates natural and man-made structures

Available for license!
Contact NRL CT-Analyst experts at:
https://www.nrl.navy.mil/lcp/ct-analyst/contact

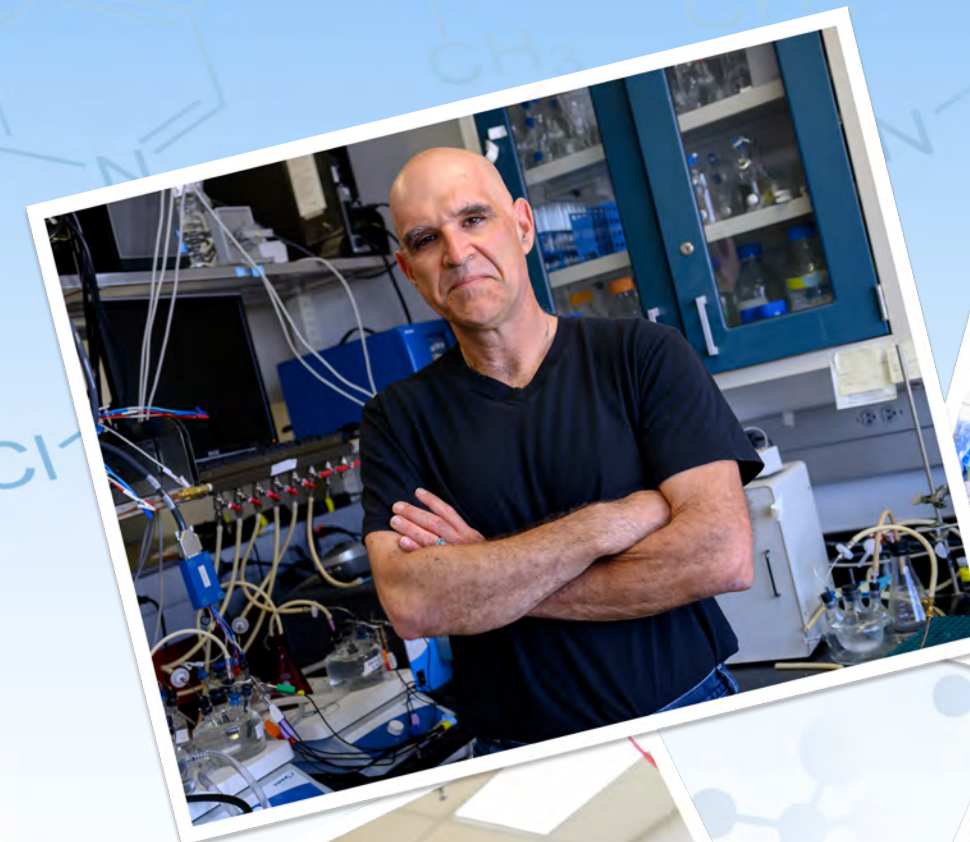


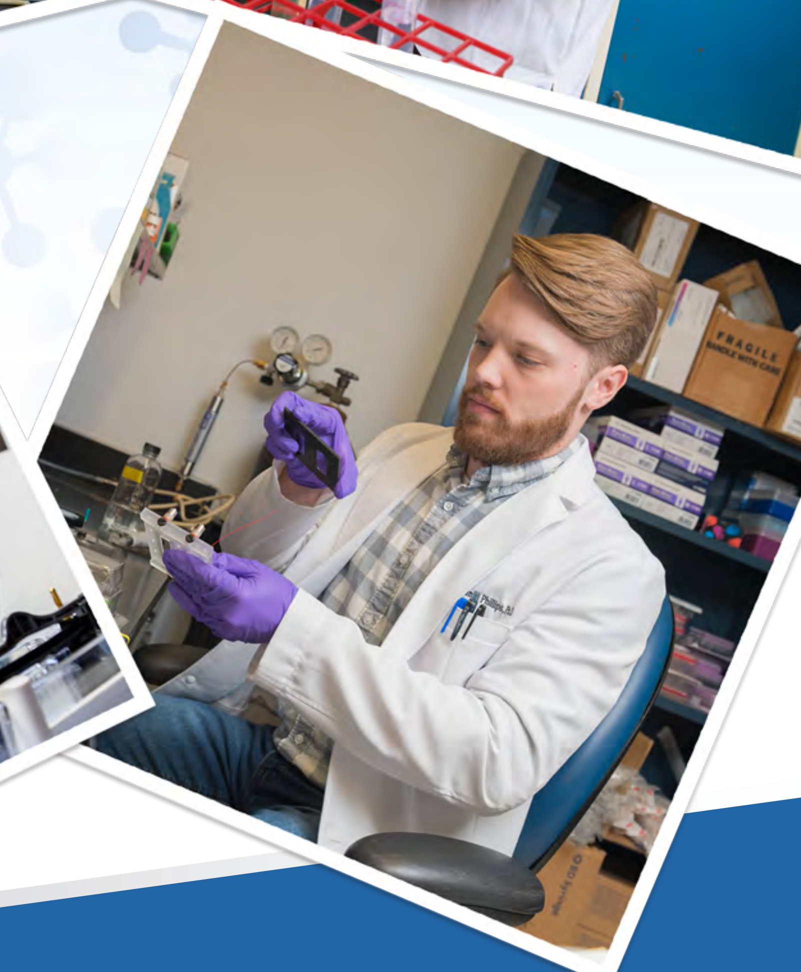
SNAPSHOT - Materials Research



Clockwise from top left: Corey Love, Ph.D., materials research engineer at NRL, aligns an optically transparent battery cell to visually observe its electrochemical behavio; lithium-ion battery cells before (left) and after (right) failure testing in the accelerating rate calorimeter; Corey Love and Emily Klein, undergraduate researcher, discuss calorimetry data after a battery failure test; Corey Love installs an instrumented canister containing a lithium-ion battery.

SNAPSHOT - Microbial Electrochemistry





Clockwise from top left: Lenny Tender, co-lead of NRL's Microbial Electronics Group studying how Pseudomonas aeruginosa, an opportunistic pathogen that infect lungs; Rebecca L. Mickol extracts DNA from marine bacteria, part of NRL's work in synthetic biology; Daniel Phillips assembles a microbial-electrochemical flow cell which enables real-time imaging of bacteria while electrically interacting with an electrode; Elizabeth Onderko extracts designer proteins from bacteria to test their ability to act as electrical circuits for future Navy technologies;.

AWARDS

Dr. Adam D. Dunkelberger Awarded Presidential Early Career Award for Scientists and Engineers

President Donald J. Trump awarded U.S. Naval Research Laboratory Research Chemist Dr. Adam Dunkelberger the Presidential Early Career Award for Scientists and Engineers (PECASE) at a ceremony held in Washington, D.C., July 25.

The PECASE award is the highest honor given by the U.S. government to scientists and engineers who are beginning their research careers. The award recognizes recipients' potential to advance the frontiers of scientific knowledge and their commitment to community service as demonstrated through professional leadership, education, or community outreach.

Dr. Adam D. Dunkelberger (l), NRL research chemist, received the Presidential Early Career Award for Scientists and Engineers from Kelvin Droegemeier, director of the Office of Science and Technology Policy, on July 25, 2019. (Photo Credit: U.S. Department of Energy)

Dunkelberger received the award for the discovery of tunable energy relaxation in vibration-cavity polaritons; for demonstrating ultrafast modulation of surface-phonon polariton resonances; and for mentoring and supporting postdoctoral associates and students.

"It's humbling and a huge honor to receive the PECASE," said Dunkelberger. "Above all, receiving this award makes me feel fortunate and incredibly thankful for the mentors and collaborators I've had along the way. Cutting-edge science is increasingly multidisciplinary, and everything I've been able to accomplish in the lab has depended on a large group of excellent coworkers."

Dunkelberger and a team of researchers were able to demonstrate surprising new phenomena that occur when infrared light is confined in optical devices so that it strongly interacts with nearby molecules. They can use this confined light to detect molecules with high sensitivity, change how they dissipate their energy, and, potentially, how they react chemically.

Established in 1996, the PECASE acknowledges the contributions scientists and engineers have made to the advancement of science, technology, engineering, and mathematics (STEM) education.

The White House Office of Science and Technology Policy coordinates the PECASE with participating departments and agencies.

By Daniel Parry, NRL Strategic Communications Office

Meet Adam Dunkelberger

Adam Dunkelberger is a chemist at NRL and a Presidential Early Career Award for Scientists and Engineers (PECASE). PECASE the highest honor bestowed by the United States government to outstanding scientists and engineers who are beginning their independent research careers and show exceptional promise for leadership in science and technology.

Q. Who is Adam Dunkelberger?

I just think of myself as a scientist. I've always really liked chemistry and always had fun doing experiments. It doesn't feel like I'm coming to work here since I get to do stuff I like for my whole day. I feel very lucky to be able to do that. I'm also a dad and a husband. I try to balance that a little bit.

Q. What do you study?

I study ultrafast processes. These are processes that happen in one-millionth of one-billionth of a second. Here at NRL, we're always on the lookout for ultrafast processes that could lead to new technology for the Navy. Anything that happens that quickly, we're interested in looking at, especially in the infrared.

Q. What's so unique about things that happen that quickly versus things that happen in normal speed?

It's the time scale that atoms move around and communicate to each other. So if you want to understand the most basic principles behind chemical reactions, you really have to get down to this time scale and see what the atoms are doing in real time. There's a lot of modeling that goes into trying to understand what our instruments tell us. It's not straightforward, but it's the only way to get at what's happening on these really fast time scales. We hope to use that basic knowledge to make advances in applications.

Q. What's your elevator pitch?

I tell people that we're trying to develop new ways to detect and get rid of chemical warfare agents and that I'm at the very basic end of the physics, looking for transformational developments with innovative methods. We think we're treading the right ground to make some real advances here.

Q. What's exciting about your field these days?

We've started looking at how molecules can interact with optical devices and how putting molecules in or near an optical device can drastically change how they react chemically. We've started to have some initial success with the ultrafast techniques; trying to tease apart the physics of what's happening there, how we might be able to use an optical device, flow a chemical through, and get to choose how it reacts. We're still a ways from that but we think there's real potential for it. Controlling chemistry with light is one of the holy grails of chemistry.

Q. How would you like your career to look like when you retire?

I hope in 30 years I can look back at a group of postdocs who I've helped the same way I have gotten help as a young scientist, and that I can say that I've had fun the whole 30 years doing science that's interesting to me. I hope to have been able to see some of our exciting results translate into useful technology for the Navy. So far so good.

By Mary Estacion, NRL Strategic Communications Office

AWARDS

Congratulations to all of this year's Dr. Delores M. Etter Top Scientists and Engineers Award recipients.

A special shout out to NRL's own:

Dr. Corey Love (Emergent Scientist Investigator Category).

Dr. Jason McKinney (Individual Scientist Category).

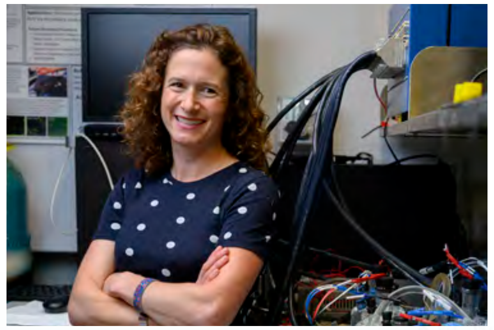
The Shipboard Engagement Activity Monitoring System (SEAMS) Development Team — Mr. Scott Sarama, Mr. James Waterman, Mr. Jason Edelberg, Dr. Michael Wilson, and Mr. Dale Linne von Berg (Team Category).

The Etter Award is presented annually in June to scientists and engineers whose work is technically outstanding and provides operational benefits to the Department of the Navy, Department of Defense, and national defense. The selection process is extremely competitive and each submission impressively demonstrated high levels of scientific and engineering achievement.

U.S. Naval Research Laboratory award recipients and officials at the Dr. Delores M. Etter Top Scientists and Engineers Annual Awards Ceremony at the Pentagon in Washington, D.C., June 28, 2019. The recipients were recognized for their scientific excellence and contributions to the Department of the Navy.

NRL OPPORTUNITIES

Advancing your career **further than you can imagine.®**



NRL job openings can be found at: **http://www.nrl.navy.mil/careers**

	Radar	Information Technology	Optical Sciences	Tactical Electronic Warfare	Chemistry	Materials Science and Technology	Computational Physics & Fluid Dynamics	Plasma Physics	Electronics Science and Technology	Biomolecular Science and Engineering	Acoustics	Remote Sensing	Oceanography	Marine Geosciences	Marine Meteorology	Space Science	Space Systems Development	Spacecraft Engineering
Aerospace Engineer				•			•									•	•	•
Astrophysicist												•				•		
Chemical Engineer				•	•	•	•		•	•								
Computational Research Linguist		•																
Computer Engineer	•	•	•	•										•			•	•
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Electrical Engineer		•	•	•	•	•		•	•		•	•					•	•
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Geologist														•				
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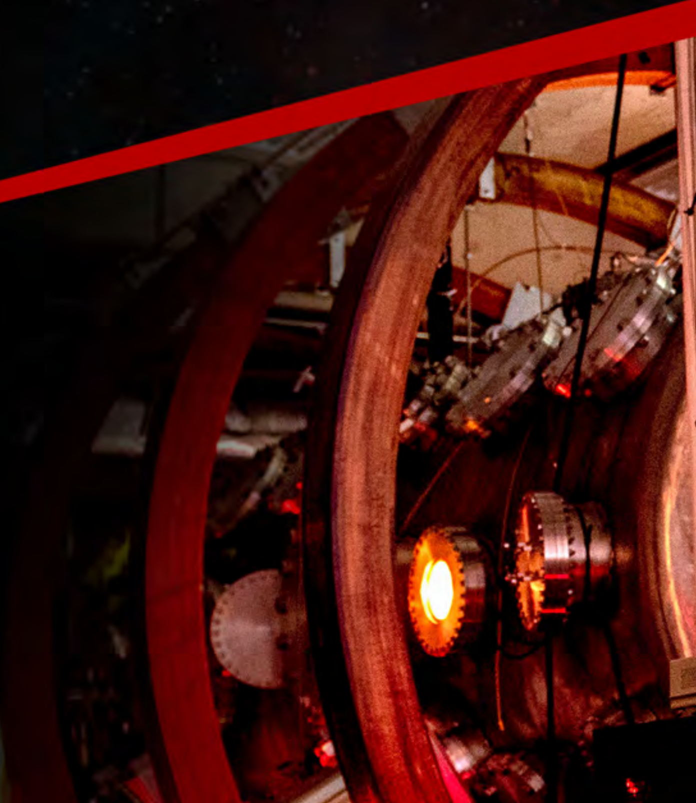
Research Biologist					•					•				•				
Research Chemist		•	•	•	•	•		•	•	•	•	•	•					
Social Scientist		•																

About the U.S. Naval Research Laboratory

The U.S. Naval Research Laboratory provides the advanced scientific capabilities required to bolster the nation's position of global naval leadership. NRL is headquartered in southwest Washington, D.C., with other major sites at the Stennis Space Center, Miss., and Monterey, Calif. About 2,500 scientists, engineers, and support staff serve at NRL, which has nearly 100 years of contributing to the warfighter. For more information, visit the NRL website or join the conversation on Twitter, Facebook, and YouTube.



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