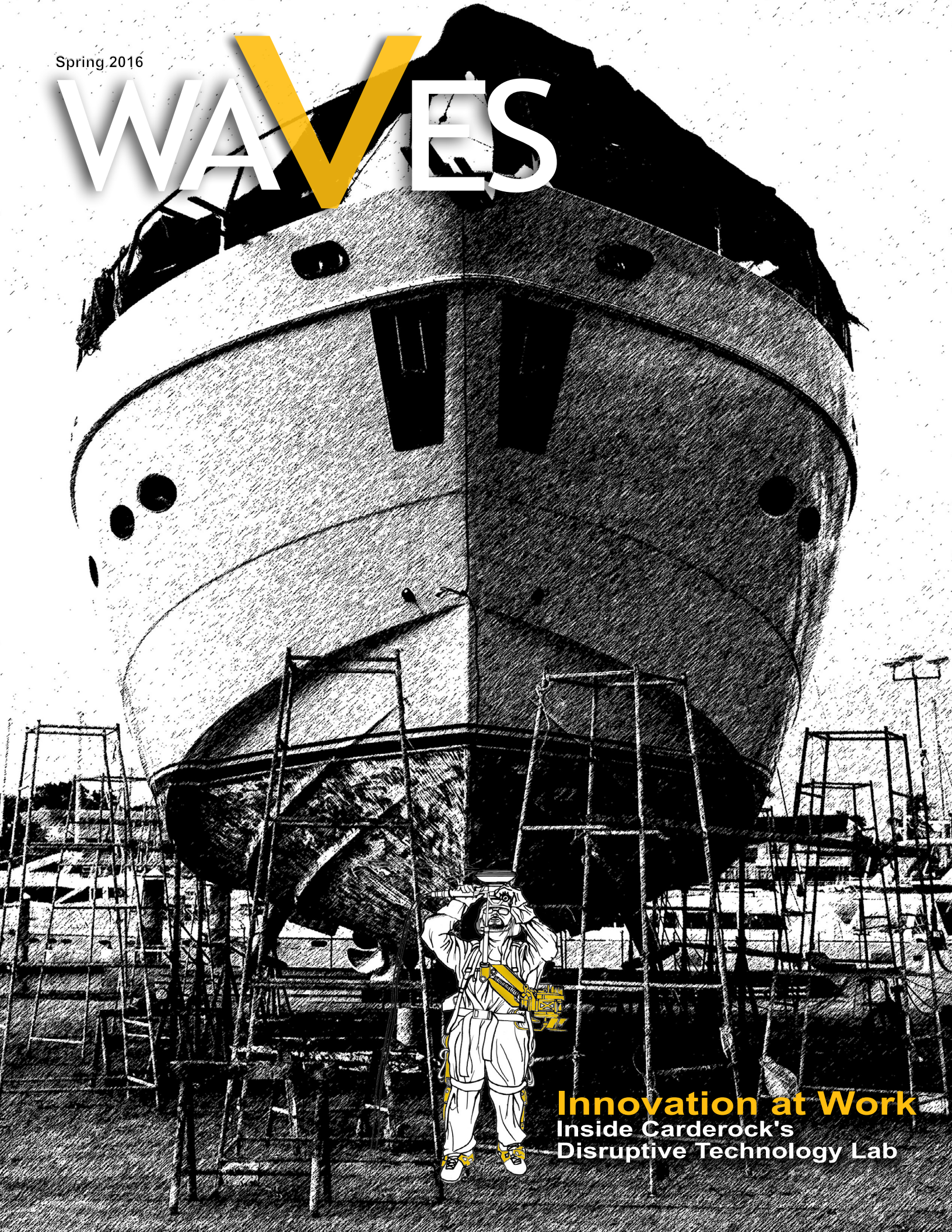


Spring 2016

# WAVES



**Innovation at Work**  
Inside Carderock's  
Disruptive Technology Lab





## IN THIS ISSUE

In this issue of WAVES you will find an article about our new MAKE (Manufacturing, Knowledge and Education) Lab located in Building 60 at our headquarters in West Bethesda, Maryland. The lab is a collaborative work space for everyone at Carderock and is a great addition to the existing production-grade printers in the model fabrication facilities. Training is available to for all Carderock employees on how to use the MAKE Lab 3-D printers as part of your work or help you with development of new ideas. Check it out!

Carderock figured prominently in this year's SECNAV Innovation Awards. The awards program recognizes the top individual and teams that have made remarkable innovative accomplishments to solve the Navy's most challenging problems. In March when Sen. Jack Reed toured Carderock with staff from the Senate Armed Services Committee, one of the things he wanted to know was how we support the fleet. The creative work done by our teams that won the SECNAV Innovation Awards provided a fine example of how we contribute to the greatest Navy in the world. Read the article to find out which projects developed here at Carderock took top honors.

In the coming year, Carderock will continue to focus on developing new technologies, further our gains made in energy storage and transfer, surface ship and submarine concept design and design tools, advanced signatures, cybersecurity, rapid prototyping and experimentation, additive manufacturing, unmanned systems, and continued support of programs focused on workforce retention and development. Many of the articles in this publication will expand on some of these focus areas.

As we look to the future, the Navy is transforming to achieve cross-domain synergy and provide Joint Force commanders a range of options in all domains to defeat anti-access/area denial strategies. This will require not only enabling technologies such as new energy systems for sustained operations and networks for information sharing with other domain nodes, but will also demand increased collaboration with other Warfare Centers and laboratories to build a system of systems to cover more area, more targets, more missions and the complete integration of manned/unmanned capabilities.

Whether you are a scientist, an engineer or a technician or in the contracts, comptroller or operations departments, we are all one team, one mission – supporting the current and future warfighter. Thank you for what you do!

**Dr. Tim Arcano**  
NSWCCD Technical Director

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## COVER

A concept sketch shows a non-powered industrial exoskeleton and how it could be used to increase worker performance in a shipyard setting. The exoskeleton allows the worker to displace the load usually associated with holding tools overhead, reducing fatigue and potentially increasing output while reducing strain injury. (U.S. Navy illustration by Michael White/Released)

## TEAM

Dr. Tim Arcano  
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# New prototype enhances ship-testing capability at Carderock

By Naval Surface Warfare Center, Carderock Division Public Affairs

A new 1,000-pound inertial actuator, the AMA1000, is giving engineers at Naval Surface Warfare Center, Carderock Division (NSWCCD) unprecedented capability in full-scale testing.

Dr. John Miesner, an engineer assigned to Carderock Division's Acoustic Signatures Technology Division, said the Navy has used actuators like the AMA1000 in a wet environment for many years, but the shakers, as they are called, were not capable of producing high forces at a broad range of frequencies until 2014. That is when the Carderock Division Shaker Lab developed a wet-capable shaker called the MA400 specifically for this purpose. The installed MA400s are performing well and produce about 400 pounds of force.

Dr. Miesner recognized that the MA400 design could be improved to produce 1,000 pounds within the same volume by replacing the rectangular magnetic laminations with axisymmetric components that better fill the cylindrical vessel. This also reduces the number of parts required and simplifies the manufacture and assembly of the shaker. "This shape naturally fills the cylindrical volume and allows all of the moving mass to be used for generating magnetic forces for higher acceleration of the inertial mass and increased output force" Miesner said.

Shakers are rooted in Isaac Newton's second law of motion ( $F = ma$ ) and researchers use them at Carderock Division to predict how a ship will respond to vibration sources including motors, pumps and other rotating equipment. The shaker does this by exciting the ship structure allowing the dynamic properties to be measured by an array of accelerometers.

The Navy submitted a patent application for the AMA1000 on May 6, 2015, and Miesner completed it July 7, 2015, with the assistance of Signature Measurement Technologies and Systems Division employee Matthew Willey, who did the detailed design drawings and oversaw the manufacture and assembly, and his fellow Acoustic Signatures Technology Division employee Richard Cohen, who did most of the machining.

"Dr. Miesner's patent application underscores the Acoustic Signatures Technology Division's reputation for technical excellence and innovation," said Marylou McNamara, division head, Acoustic Signatures Technology Division. "The development of the AMA1000

and the completion of the patent application process are incentives for my employees and for all potential Carderock inventors."

The prototype AMA1000 is currently being tested at the Carderock Division Shaker Lab at up to 1,200 pounds of force output and meets or exceeds design requirements.

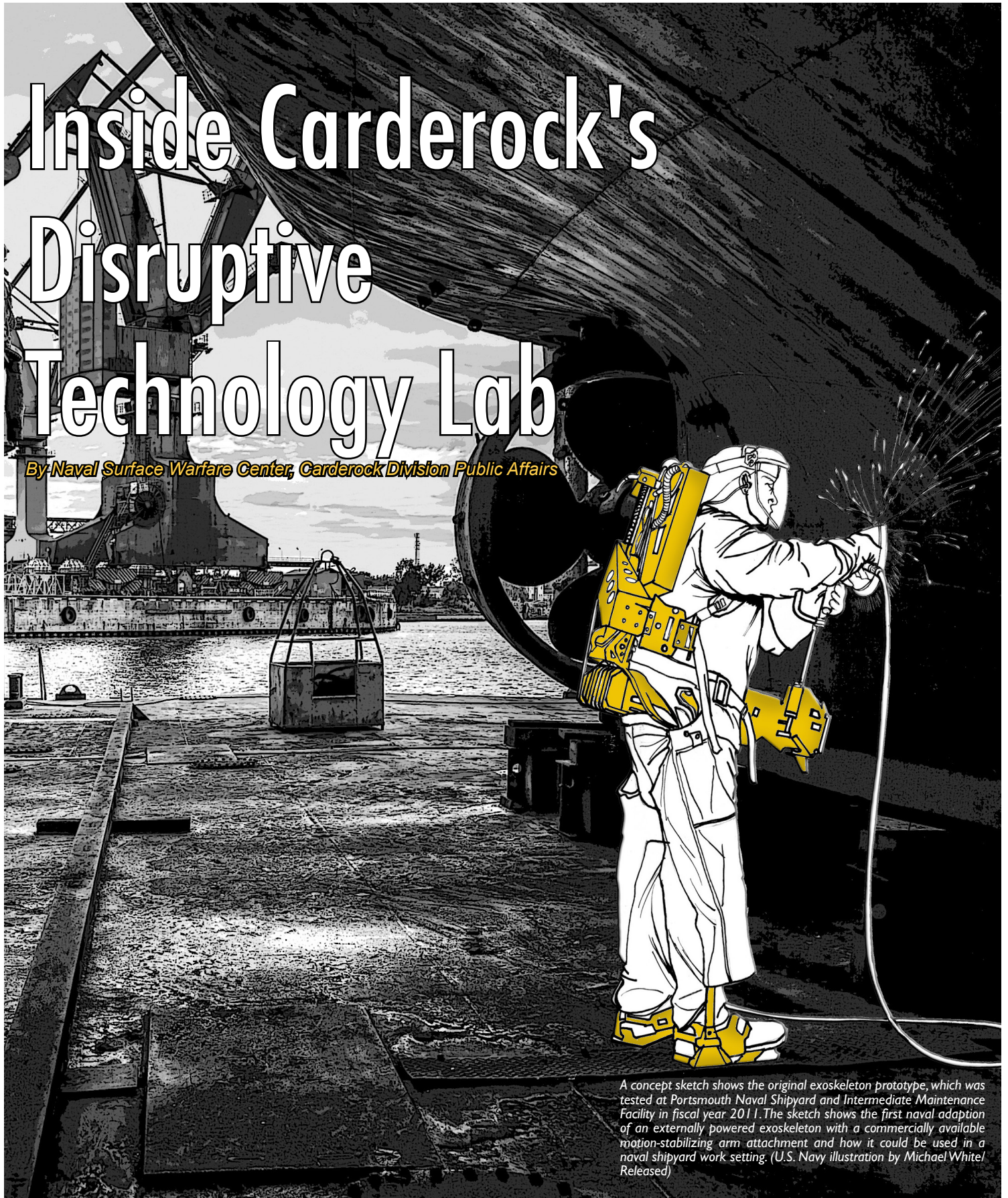
## How does a shaker work?

Dr. John Miesner explains, "It works by moving a mass back and forth. Newton's law says that the inertia of the mass produces an equal and opposite reaction force according to  $F = ma$  where 'm' is the moving mass and 'a' is amount of acceleration. Acceleration is typically measured in units of 'g' where 1 g is the acceleration due to gravity on the surface of the earth. If I have 100 pounds of mass and accelerate it at 1 g there will be a reaction produced of 100 pounds of force. The MA400 uses about 250 pounds of mass and accelerates it at 1.6 g to achieve the 400 pounds of force. The reaction force can be increased by using more mass or higher acceleration. It is challenging to increase the mass within the volume of the pressure vessel, but the AMA1000 uses about 275 pounds of mass. It accelerates this mass at 3.6 g to achieve the 1,000 pounds of force. The greater acceleration is due to larger coils and more powerful magnets allowed by the axisymmetric arrangement."



# Inside Carderock's Disruptive Technology Lab

*By Naval Surface Warfare Center, Carderock Division Public Affairs*



A concept sketch shows the original exoskeleton prototype, which was tested at Portsmouth Naval Shipyard and Intermediate Maintenance Facility in fiscal year 2011. The sketch shows the first naval adoption of an externally powered exoskeleton with a commercially available motion-stabilizing arm attachment and how it could be used in a naval shipyard work setting. (U.S. Navy illustration by Michael White/Released)



The U.S. Navy faces innumerable obstacles every day as it carries out its mission, and the scientists and engineers at Naval Surface Warfare Center, Carderock Division (NSWCCD) in West Bethesda, Maryland, are charged with helping to solve them so the fleet is ready with the latest capabilities and technologies when and where it needs to be.

To meet the challenge of combatting disruptive threats and realizing ever-changing operational demands, the Department of Defense (DoD) and Navy leadership are driving the Navy laboratory infrastructure to get new and innovative technologies into the hands of warfighters and maintainers quicker than ever. Carderock Division has taken a unique approach to this goal: to create a Disruptive Technology Laboratory (DTL) and charge it with generating ideas and solutions for the fleet and take them from concept to reality.

The DTL thrives on the premise that great ideas are not just random events – by putting together innovators in a nurturing environment, one that facilitates thought and is not hindered by historical paradigm, ideas can be predictably generated. Bringing those ideas to fruition and displacing the old solution with the new one in the marketplace is the bread and butter of the DTL. At Carderock, the DTL works to make innovative successes achievable, not onerous. The DTL premise is to move good ideas forward into the fleet.

“Innovation isn’t happenstance when you create the right environment. With persistent contact with new knowledge, it becomes predictable that you’ll have innovative events,” said Garry Shields, the lab’s director. “That’s what the Disruptive Technology Lab is doing – creating a sustainable innovation engine.” This innovation engine functions as an incubator for new ideas as part of fostering a culture of innovation.

The lab was formed several years ago when a group of Carderock employees was asked to look at the role of robotics in ship systems. Originally called the “Intelligent Mobile Machines Office,” this group came up with the idea to assess the exoskeleton technology, a human augmentation system designed to lighten the load of those who do manual work – for example, sanding or blasting a ship hull overhead or spray painting a wall. The commercially available “exoskeleton” has significant impacts on the Navy waterfront shipyard community as its applications are evaluated – there will likely never again be

humans having to perform such roles in an unaugmented manner in the future.

Following the success of the exoskeleton project, the group was next asked to study what kind of applications they would consider viable if given access to a submarine payload module. While there were many options to put in the payload module, they chose to explore the possibility of putting energy sources on board. A military effectiveness analysis showed that by providing these energy sources as a payload dispersed from the submarine module, that newly available energy would increase the endurance of unmanned vehicles operating in the area. Currently, unmanned systems are required to carry their energy organically in order have the persistence and endurance required for their missions. The energy needs force unmanned systems to scale up in size and complexity to meet mission requirements. The team’s concept is to make energy readily available where and when it is needed by placing energy reserves in strategic locations for vehicle use. This concept increases persistence and endurance while reducing the complexity and cost of unmanned systems. Without unmanned vehicles needing to carry all their own energy to meet mission requirements, this concept could change the nature of unmanned systems presence in the warfighting portfolio.

The DTL has worked on several other success stories that are transitioning to the warfighter and the marketplace. One such technology is a demonstration of an optical periscope detection and discrimination capability that complements radar techniques and results in high probability of overall detection with zero false alarms, providing a scalable, modularized and platform-independent surface ship periscope detection and discrimination capability.

Another example is the Unmanned Vehicles (UXV) Digital Manufacturing (DM) Massive Multiplayer Online War-game Leveraging the Internet (MMOWGLI). MMOWGLI is a collaboration environment that allows team participants to leverage crowd-sourcing approaches to highlight and discuss new and existing technologies for idea generation, and push them forward to obtain an optimal and achievable solution. This project will allow the Navy to respond to future UXV challenges; position the Navy to harness UXV DM technologies through a series of action plans; and develop new methods of pushing knowledge to Navy engineers. Further, it will build a roadmap toward Digital to Done where

design, simulation, testing and production are performed digitally thereby increasing efficiency, minimizing duplication of tasks and allowing for design flexibility that embraces digital manufacturing technologies. This supports the Secretary of the Navy Task Force Innovation initiative to move toward virtual design environments.

Over the last four years, the DTL has hosted weekly meetings. Speakers are invited to discuss topics ranging across the technology spectrum. The speakers may be local subject matter experts, or academic or industry experts inside and outside the Navy. Following these meetings, participants are challenged to form groups and examine the social, political, technical and entrepreneurial implications of each topic.

“Through roundtable discussions and weekly presentations the DTL exposes its members to new ideas, technologies, processes and methods of solving known and unknown technical problems,” said Harry Whittaker, a participant in the DTL collaboratory. “Carderock employees participating in the DTL are enabled to take back what they’ve learned to their technical codes.”

The team comprising the DTL is unique in its own right. It is not limited to senior experts and specialists, but rather people who think outside the traditional box are especially welcomed in the collaboratory. The group is non-traditional; it uses a “non-structured” environment. It functions as a web of people interconnected across the technical community with direct access to each other instead of a traditional top-down vertically aligned structure like much of the Navy. Recently the group has been using milSuite, a DoD suite of secure collaboration and networking tools that mirror social media platforms like Facebook and Wikipedia to foster collaboration and sharing.

Most recently, Shields and his staff have reached outside Carderock Division across the warfare centers and the Naval Research Enterprise to form a Disruptive Technology Lab “Enterprise” (DTLe). There are now regular meetings, teleconferences and brainstorming sessions that include participation from organizations including NSWC Panama City, Naval Undersea Warfare Center Newport Division, Puget Sound Naval Shipyard, NSWC Philadelphia, Naval Air Systems Command, Space and Naval Warfare Systems Command, the Office of Naval Research, the Defense Advanced Research Projects Agency and the naval shipyards.



# Carderock teams win 2015 SECNAV Innovation Awards

By Dustin Q. Diaz, Naval Surface Warfare Center, Carderock Division Public Affairs

Secretary of the Navy (SECNAV) Ray Mabus announced two Naval Surface Warfare Center, Carderock Division (NSWCCD) teams Feb. 9 as winners in the 2015 SECNAV Innovation Awards.

The awards program recognizes the top individual and team innovations that have made remarkable innovative accomplishments to solve the Navy's most challenging problems during this past year.

"We truly believe our team's commitment to excellence stems from a deep-seated dedication by all of you to our mission and to our Sailors," said Dr. Tim Arcano, NSWCCD technical director. "It is an honor for us today to draw out the work of several of our colleagues at NSWC Carderock Division who have been recognized by the SECNAV for their accomplishments."

NSWCCD's Underwater Wireless Energy Transfer (UnWET) system team was selected the winner of the Robotics/Autonomous Systems Category. This award recognizes contributions in robotics and autonomous systems within the Navy's science and technology community or within the operational forces.

The UnWET system team, comprising members from Carderock and Naval Surface Warfare Center, Philadelphia Division, earned the award for demonstrating the feasibility of transferring power to unmanned systems underwater during tests at Carderock in West Bethesda, Maryland, and Newport, Rhode Island, last year. They collaborated with personnel from the Naval Undersea Warfare Center, Division Newport, and Space and Naval Warfare Systems Center Pacific (SSC PAC).

The Navy currently uses its unmanned underwater vehicles (UUVs) to counter mine warfare threats, optimize remote sensing platforms and map the ocean floor. These UUVs launch from underway platforms and must return to recharge and offload data frequently.

"They have a very limited energy source, and that puts a lot of constraints and risks on our high-value assets, like our surface ships and submarines," said Alex Askari, NSWCCD UnWET technical lead. "Imagine if you could build an underwater 'gas station' for



The Naval Surface Warfare Center, Carderock Division Underwater Wireless Energy Transfer (UnWET) systems team were the winners of the 2015 Secretary of the Navy Innovation Award in the Robotics/Autonomous Systems Category. The team posed in front of a 6,000 gallon tank in the UnWET laboratory July 1, 2015, during the week-long demonstration held in West Bethesda, Md. From left: Dr. Burton Neuner, SSC-PAC optical communications lead; Dr. Robert Stark, NSWCCD UnWET physicist; Joseph Curran, NSWCCD- UnWET integration lead; Kevin Lin, NSWCCD UnWET electrical engineer; William Gottwald IV, NSWCCD NREIP intern; Alex Askari, NSWCCD UnWET technical lead; Mayer Nelson, NSWCCD demonstrator program manager; Crystal Lutkenhouse, NSWCCD mechanical engineer; Nick Frade, NUWC DIVNPT ANTIX test director; Kim Nguyen, SSC PAC MOCU integration lead; Dr. Michael Pfetsch, SSC PAC acoustic communications support; Dr. Tim Arcano, NSWCCD technical director; Dusan Radosevic, SSC PAC acoustic communications lead; Stuart Beazley, NUWC DIVNPT MARV software lead; Laureano Costa, NUWC DIVNPT docking lead; and James Wagner, SSC PAC acoustic communications support. (U.S. Navy by Devin Pisner/Released)

these unmanned systems. The UUVs can go there autonomously, recharge their batteries, offload their data and go to their mission again. Accomplishing this will significantly reduce burdens on the UUVs' host ships."

Askari said the team's work means that someday these vehicles could potentially operate indefinitely away from their ships, greatly expanding their operational capabilities.

During the first phase of development, all involved organizations developed their own system modules: West Bethesda headed the wireless power transfer effort, Philadelphia designed the battery state of charge indicator, NUWC Newport developed an open-architecture docking system for the Mid-Size Autonomous Reconfigurable Vehicle (MARV)

UUV, and SSC PAC provided acoustic and optical communication for data transfer.

In the second phase, the four organizations came together and integrated their modules into a complete system with the MARV UUV, and demonstrated the set up in a relevant environment (the Shallow Water Test Facility at Narragansett Bay in Newport, Rhode Island) during ANTIX 2015. The UnWET system recorded a nominal power transfer of 1.5kW to the MARV UUV, and an end-to-end efficiency of 89 percent in the seawater environment.

Throughout the development process, West Bethesda team members leveraged 3-D computer-aided design, parametric modeling and additive manufacturing technologies to accelerate the development of UnWET system



components. Kevin Lin, an electrical engineer and the lead designer behind the wireless power transfer coils, explains that “parametric modeling alongside 3-D printing allowed us to rapidly, inexpensively and iteratively test our coils, so that we could home in on the most optimal design for the MARV UUV.”

“If we want to remain the world leader, we need to look at innovative technologies and new concepts so we can compete with our adversaries,” Askari said. “Working on this has been a great experience. I personally believe if you want to accomplish something rapidly and effectively in the Navy, you have to collaborate across the different warfare centers. If you can bring your different capabilities and knowledge together, you can effectively develop and demonstrate your project—and that’s what we were able to do.”

The other members of the UnWET System Team recognized are Mayer Nelson, Joseph Curran, Dr. Michael Knauff, Willard Morris, Dr. Robert Stark, William Gottwald Jr., Crystal Lutkenhouse, Thomas Jiang, Dr. Steve Miller and Tristan Wolfe.

NSWCCD’S was Realtime Acoustic Imaging Team of Dr. Philip Gillett and Christian Sarofeen selected as the winner of the Data Analytics Category. This award seeks to identify members of the data-savvy workforce who implemented new approaches to using data analytics to improve performance, support decision making or provide meaningful insight to existing processes.

Gillett and Sarofeen’s goal when they began working together at Carderock was to find a way to display acoustic data so that it could be visually understood.

“Right now, you are sampling the sound field with your ears,” Gillett said. “When we do our tests in the water, we are sampling the sound field with thousands of sensors spaced throughout. You essentially have those two sensors. We can do different things to explore the physical phenomena that are creating sound in the environment and make the sensors more sensitive in a specific direction so we can determine what a specific object or location sounds like.”

Sarofeen said this data can be used to detect sources of noise to isolate and eliminate them.

The team determined they needed to enhance their available computing power to improve analysis of this data, moving from a one-dimensional analysis, which he compared to a single microphone that simply determines the presence of noise, or two-dimensional analysis,



Naval Surface Warfare Center, Carderock Division Acoustic Imaging Team members Dr. Philip Gillett (left) and Christian Sarofeen conduct a brief about biofouling during mid-year reviews in West Bethesda, Md., March 31, 2016. Gillett and Sarofeen were the winners of the 2015 Secretary of the Navy Innovation Award in the Data Analysis Category for their work in processing acoustic data. (U.S. Navy photo by Dustin Q. Diaz/Released)

which he compared to a still photograph, to a three-dimensional model.

“Going further, we can establish our physical model, sample these three-dimensional locations and actually look at it in a virtual world,” Sarofeen said. “We want to take these really large computers that we have access to, process things really quickly and process lots and lots of data and be able to get a real-time acoustic image in three dimensions of what’s going on, so that when we watch something go by, it can actually show us what’s happening in a very detailed manner.”

Sarofeen said that they worked toward this goal using the Department of Defense’s High Performance Computing Modernization Program to secure a computer he described as “pretty much 50 computers wired together, each one of those having 10 cores,” for a total of 500 cores, along with 50 NVIDIA brand advanced scientific graphic processing units. What the team did from here was to modify it so it was better suited for scientific computing and the specific algorithms they use. They improved their signal processing speed by using the graphic processing unit in addition to the central processing unit (CPU), as compared to conventional processing where only the CPU is utilized.

“We wrote the algorithm from the ground up specifically to take advantage of the architecture and hardware of this large computer to get every single little bit of performance we could out of it in order to get this algorithm so fast that it

could be used in real time to do lots and lots of processing,” Sarofeen said.

Gillett said they worked on this process for over a year and a half, also writing a research paper that was cited in their nomination for this award.

“We’d like to keep moving forward with this because there’s more work to be done,” he said. “This was a demonstration of how much some optimization can garner. We look forward to implementing that, but that’s not the end of where we’re going with this.”

Gillett said he and Sarofeen then entered Carderock’s Technical Director’s Innovation Challenge to pursue the next step in bringing this technology to the Fleet.

“We asked ourselves, ‘Now that I have some results and information, how do I present these results to the analyst, the commanding officer, or anyone else, in 2-D and 3-D, in a way they can sit down and look at it and immediately know what’s going on?’” Gillett said. “The visualization and presentation of the result is as critical and important as how the processing works.”

Gillett said that while he and Sarofeen received the SECNAV Innovation Award for their work on the processing side, they are eager to take their progress further and collaborate with others to deliver this enhanced data analysis capability to the warfighter.



# American Society of Naval Engineers recognizes Carderock senior scientists

*By Dustin Q. Diaz, Naval Surface Warfare Center, Carderock Division Public Affairs*

**D**r. Ted Farabee and Dr. E. Thomas Moyer earned recognition from the American Society of Naval Engineers (ASNE) during the ASNE annual awards banquet in Arlington, Virginia, March 3.

Farabee and Moyer, both senior scientists assigned to Naval Surface Warfare Center, Carderock Division (NSWCCD) in West Bethesda, Maryland, received the Gold Medal and Solberg awards from Rear Adm. Lorin Selby, commander, Naval Surface Warfare Center (NSWC), and Dr. Tim Arcano, NSWCCD technical director, respectively.

The Gold Medal Award (Engineering) is given to an individual who has made a significant naval engineering contribution in a particular area during the past five years. Farabee has served as NSWCCD's senior research technologist since 2009. Before that, he served at Carderock as a staff scientist providing technical oversight and scientific direction on ship silencing programs. Today, he works to identify enabling technologies and design initiatives for the Ohio Replacement design.

Farabee has been associate editor of the American Society of Mechanical Engineers' Journal of Vibrations and Acoustics since 2012 and has contributed to more than 50 manuscripts for that publication, along with authoring and coauthoring more than 90 journal articles, technical reports and presentations.

"To sum it up, he is someone who wakes up every morning and challenges himself by



*Dr. Ted Farabee, senior research technologist at Naval Surface Warfare Center (NSWC), Carderock Division, in West Bethesda, Md., receives the 2015 American Society of Naval Engineers (ASNE) Gold Medal Award from NSWC Commander Rear Adm. Lorin Selby at a ceremony during ASNE Day 2016 in Arlington, Va., March 3. The Gold Medal is the highest award ASNE presents. It is given to an individual who has made a significant naval engineering contribution in a particular area during the past five years. (Courtesy photo provided by Scott Gabriel/Released)*





asking, "What can I do for the fleet today?" said Selby, "and that is powerful."

While accepting the award, Farabee noted he felt the individual nature of the award was misleading about the collaborative nature of his accomplishments.

"Significant accomplishments result from the collective work of many, not an individual," Farabee said. "I am but the fortunate person who is being recognized for a group's achievements. For that I want to thank my colleagues with the Naval Sea Systems Command structure, at the various program offices, at the Carderock Division of NSWC, and most notably those in the Signatures Department at Carderock. It is their efforts for which I now stand here and receive this award."

The Solberg Award is given to an individual who has made a significant contribution to naval engineering through personal research. Moyer is the Navy's senior technologist for ship survivability modeling and simulation. He has more than 30 years of post-doctoral experience as a naval engineer and researcher improving the Navy's ability to achieve optimal survivability in its ships to maintain their warfighting superiority.

The award recognizes him for his work in developing advanced physics-based analytic design methods that Arcano said "will revolutionize the U.S. Navy's ability to predict weapons damage to warships, obviously of critical concern to the Navy in direct support of the warfighter."

"It's no small task to predict the response of surface ships to underwater explosions," Moyer said. "Ships are large, complex systems of systems, as well as complex structures necessitating large analysis models. I've had the benefit of support of various sponsors who have encouraged and facilitated my work."

Moyer thanked Robert Keane, an ASNE Life Member, for the nomination and Arcano for the introduction and his wife, Sue, for her "patience, love and support."

Arcano said that Moyer's work with the Office of the Secretary of Defense's Computational Research and Engineering Acquisition Tools and Environments - Navy Enhanced Sierra Mechanics ships program has the potential to streamline the entire ship design process and reduce costs.

"Through his teaching at MIT (Massachusetts

Institute of Technology), as an active member of the American Society of Mechanical Engineers, Moyer's past and continuing efforts help assure our Navy's capability to engineer America's maritime dominance," Arcano said. "It is a pleasure to recognize his leadership, experience and accomplishments with the 2015 Solberg Award."

Moyer has more than 50 publications in various professional journals and conference proceedings. In addition, he is the author or co-author of more than 100 technical reports provided to research sponsors and consulting customers including the U.S. Navy, U.S. Army, U.S. Air Force and National Aeronautics and Space Administration, as well as various commercial and foreign organizations.

Carderock engineers also won these awards last year, with Christopher Bassler receiving the Solberg Award and Adrian Mackenna receiving the Gold Medal Award.



# Carderock capabilities showcased at Washington Navy Yard

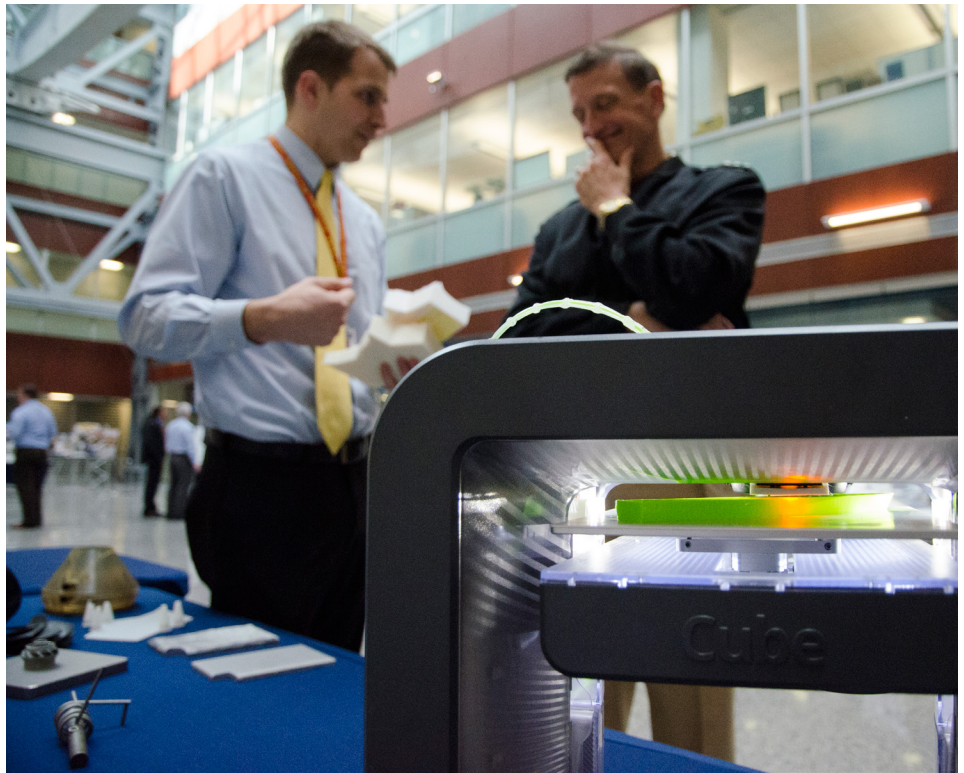
By Rebecca Grapsy,  
Naval Surface Warfare Center,  
Carderock Division Public Affairs

**N**aval Surface Warfare Center, Carderock Division was featured during a technical demonstration day at Naval Sea Systems Command (NAVSEA) in the Washington Navy Yard, March 23.

Dr. Tim Coats, who was representing Carderock's Little Creek Detachment, said the day was an opportunity to "Inform. Inform our counterparts here at NAVSEA. The exchange of knowledge and information is key to the success of our Navy. I'm seeing needs; they're seeing capability."

Subject matter experts (SMEs) represented nine of Carderock's areas of expertise through posters, videos and more interactive forms of display in the atrium of the Humphreys Building.

"I'm really glad we were able to bring a 3-D printer and show people what this technology looks like at work," said Ben Bouffard, an engineer representing additive manufacturing (AM) technology at Carderock. Bouffard was referring to the "cube" printer that had been set up to show attendees firsthand a consumer-grade 3-D printer creating a model ship out of plastic thread. "As people see how AM technology works and understand the applications we use it for, they understand all the benefits AM can bring to the Navy."



Ben Bouffard, an engineer representing additive manufacturing (AM) technology at Naval Surface Warfare Center, Carderock Division, talks to Vice Adm. William Hilarides, commander, Naval Sea Systems Command, during Carderock Day at the Washington Navy Yard, March 23, 2016. In the foreground a 3-D printer creates a model ship. (U.S. Navy photo by Monica McCoy/Released)

In addition to AM, the technologies represented at the demonstration day included submarine design, signatures and acoustics, surface ship design, power and energy, unmanned systems, innovation, STEM and reliability engineering.

Rear Adm. Moises DelToro, commander of Naval Undersea Warfare Center (NUWC), delivered the Naval Surface Warfare Center (NSWC) 101 brief. DelToro emphasized that within the NAVSEA structure, NSWC and NUWC are designed to be collaborative counterparts. This is reflected not just at the leadership level, where they share a senior executive, but across their capabilities.

Following DelToro's brief, Carderock Commanding Officer Capt. Rich Blank and Technical Director Dr. Tim Arcano presented an overview on Carderock Division and the warfare center's capabilities.

"The key is to make sure we are working together with our counterparts at other warfare centers," Arcano said. "It's not about the words on paper, it's about the conversations we are having and what we are doing. We are making

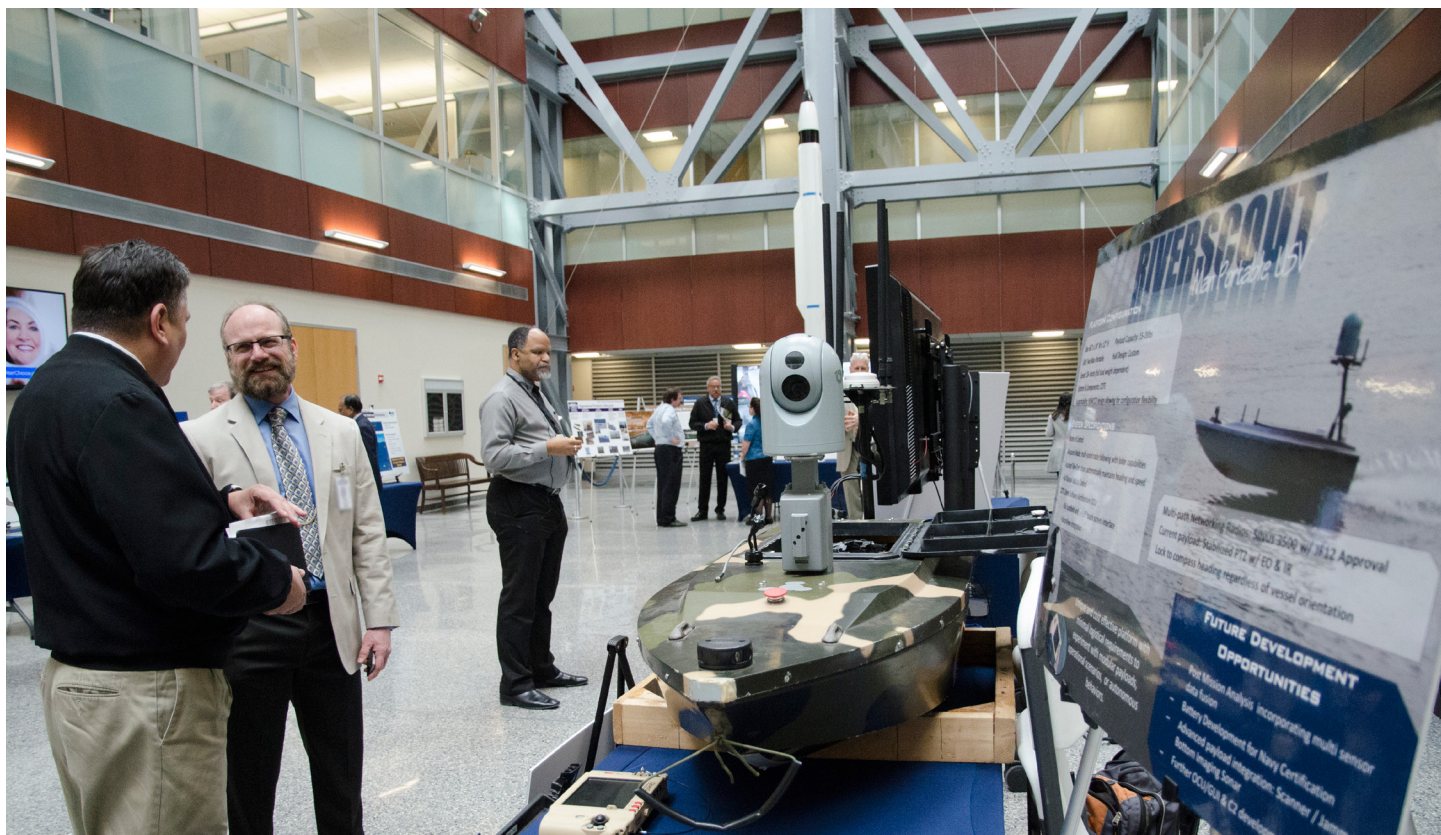
sure our customers are getting the team they need by combining the right competencies from the right people across the Naval Research and Development Establishment."

Harry Whittaker is a key member of the division's Disruptive Technology Lab and was representing innovation efforts. "Having direct access to both decision-makers and program offices, and hearing firsthand program managers' areas of interest, and where they need help, allows us to marry the technologies and solutions we have seen to specific problems," he said. "The program office can inform us on the issues they are facing, and we can apply solutions to them, as opposed to developing technologies and then looking for an application."

The educational presentations also included SMEs from each of Carderock's three technical departments briefing their areas of expertise. Brian Heidt covered submarine design, Dr. Paul Shang covered signatures and acoustics and Jeff Hough presented the brief on surface ship design.

Across the displays and discussions, there





Dr. Tim Coats (second from left) from the Naval Surface Warfare Center, Carderock Division, Combatant Craft Detachment in Little Creek, Va., talks about the Riverscout display during Carderock Day at the Washington Navy Yard, March 23, 2016. (U.S. Navy photo by Monica McCoy/Released)

was the theme of interest and investment in developing the upcoming naval engineer. In

their presentation, Blank and Arcano discussed the lifecycle of an engineer, noting that it can

take 20 to 25 years for an engineer to progress to full professional competence and development. A career for a Carderock engineer does not start at the entry level, they stressed, but with the outreach efforts that happen before they come to the base for their first internship or job.



“When students come for tours, we do activities like Sea Glide and SeaPerch, or build computer robots,” said Danielle Kolber, a naval architect at Carderock who became a full-time employee after interning at the division during school. Kolber was representing science, technology, engineering and mathematics (STEM) efforts, and said many of the people who came by her table were interested in volunteering with outreach efforts. “Being here today is an opportunity for leadership and NAVSEA employees to see how we are promoting STEM and investing in the future of the Navy at all levels.”

Reid McAllister (left) discusses unmanned systems with Capt. Rich Blank and Rear Adm. Moises DelToro during Carderock Day at the Washington Navy Yard, March 23, 2016. (U.S. Navy photo by Monica McCoy/Released)



# MAKE Lab opening brings new AM opportunities to Carderock Division

By Dustin Q. Diaz, Naval Surface Warfare Center, Carderock Division Public Affairs



Jonathan Hopkins, a mechanical engineer and Additive Manufacturing (AM) Tiger Team member, shows fellow employees at Naval Surface Warfare Center, Carderock Division objects created through AM during a tour of the new Manufacturing, Knowledge and Education (MAKE) Lab, which officially opened in Building 60 in West Bethesda, Md., March 24, 2016. The MAKE Lab will open training and production in AM, also known as 3-D printing, to all of Carderock's employees who desire to participate and exchange ideas. (U.S. Navy photo by Dustin Q. Diaz/Released)

Naval Surface Warfare Center, Carderock Division (NSWCCD) officially opened the Manufacturing, Knowledge and Education (MAKE) Lab, an open-access additive manufacturing (AM) space for all its employees, March 24.

The grand opening kicked off in the Maritime Technology Information Center auditorium with remarks by NSWCCD Commanding Officer Capt. Richard Blank; NSWCCD Technical Director Dr. Tim Arcano; Mike Brown, head of the Survivability, Structures, Materials and Environmental Department (Code 60); and AM Tiger Team members Caroline Scheck, deputy AM Tiger Team lead; Jonathan Hopkins; and Michael Britt-Crane.

"This is a collaborative space for everyone at Carderock to use to be innovative, develop new prototypes and work together to support the Navy mission," Brown said. "Rolling out this lab was done in a very thoughtful way by the AM Tiger Team. They've had to develop training for the machines, organize the laboratory and figure out how people would come on board and use the technology. I want to thank them for all the work and long hours they've put in to set this up."

Blank said the MAKE Lab is appropriately named, because Carderock Division will use it to further all the concepts in its title.

"It's going to be a learning tool for people. It's

also going to be a great manufacturing tool – it's the future. And it's going to be educating people on how to improve things and make them better," Blank said.

After the ribbon cutting in the Lab, the AM Tiger Team hosted tours to show their fellow employees the printers in the new space, how the printers function and how reserving time on them will work. The new MAKE Lab is opening with 12 consumer and prosumer-level AM printers. AM describes processes that create objects layer-by-layer.

"Additive manufacturing has been in use across Carderock for well over a decade," Scheck said. "This lab is designed for people to learn about





Sen. Jack Reed (D-RI) learns about the Manufacturing, Knowledge and Education Lab additive manufacturing (AM) facility during a tour of Naval Surface Warfare Center, Carderock Division (NSWCCD) in West Bethesda, Md., March 30, 2016. From left: Ben Bouffard, AM Tiger Team lead; Capt. Richard Blank, NSWCCD commanding officer; Liz King, minority staff director, Senate Armed Services Committee; Creighton Greene, professional staff member, Senate Armed Services Committee; Dr. Tim Arcano, NSWCCD technical director; Reed; and Jonathan Hopkins, AM Tiger Team member. (U.S. Navy photo by Devin Pisner/Released)

the technology and is a great addition to the existing production-grade printers in the Model Fabrication Facility. It gets people exposed to the basics so they can start to make informed decisions about the types of printers, materials and design aspects that might make the most sense for their application.”

In touring the space, Jim Higgins, head of the Environmental Quality Division (Code 63), said he was impressed by the technology, expected to take the training and participate himself, and saw applications for AM in his division’s work. “In my division we work on solid and liquid waste management,” Higgins said. “There could be situations where you have an immediate short-term need for a part for your plastic waste processor or your pulper used in liquid waste management – I can see where you could use this capability. It probably has applications to help enable lithium battery safety certification, which we are responsible for. The speed and accessibility of this is really what I see as the

greatest advantage. If you have a drawing and something you want made, this is the place to do it.”

AM Tiger Team member Jonathan Hopkins, who is leading the MAKE Lab effort, said this technology will also create new opportunities for the command’s science, technology, education and math STEM outreach programs. With the MAKE Lab, the AM Tiger Team can change the way students think and approach design and manufacturing, just as the team will do with their colleagues at Carderock. “Designing for AM takes a different approach,” Hopkins said. “The MAKE Lab will enable our workforce to explore methods of manufacturing while encouraging networking and sparking innovation.”

Arcano praised the members of the AM Tiger Team and former Carderock employee Dr. Jennifer Wolk, now at the Office of Naval Research, for their work in making this happen.

“This is a chance to unleash that innovative spirit in each of your technical areas,” he said. “And we have this unique community of experts across all the codes. You solve the Navy’s toughest problems. Hopefully, this tool – this MAKE Lab – will be a tool to set you on a trajectory to be able to solve these problems even better.”



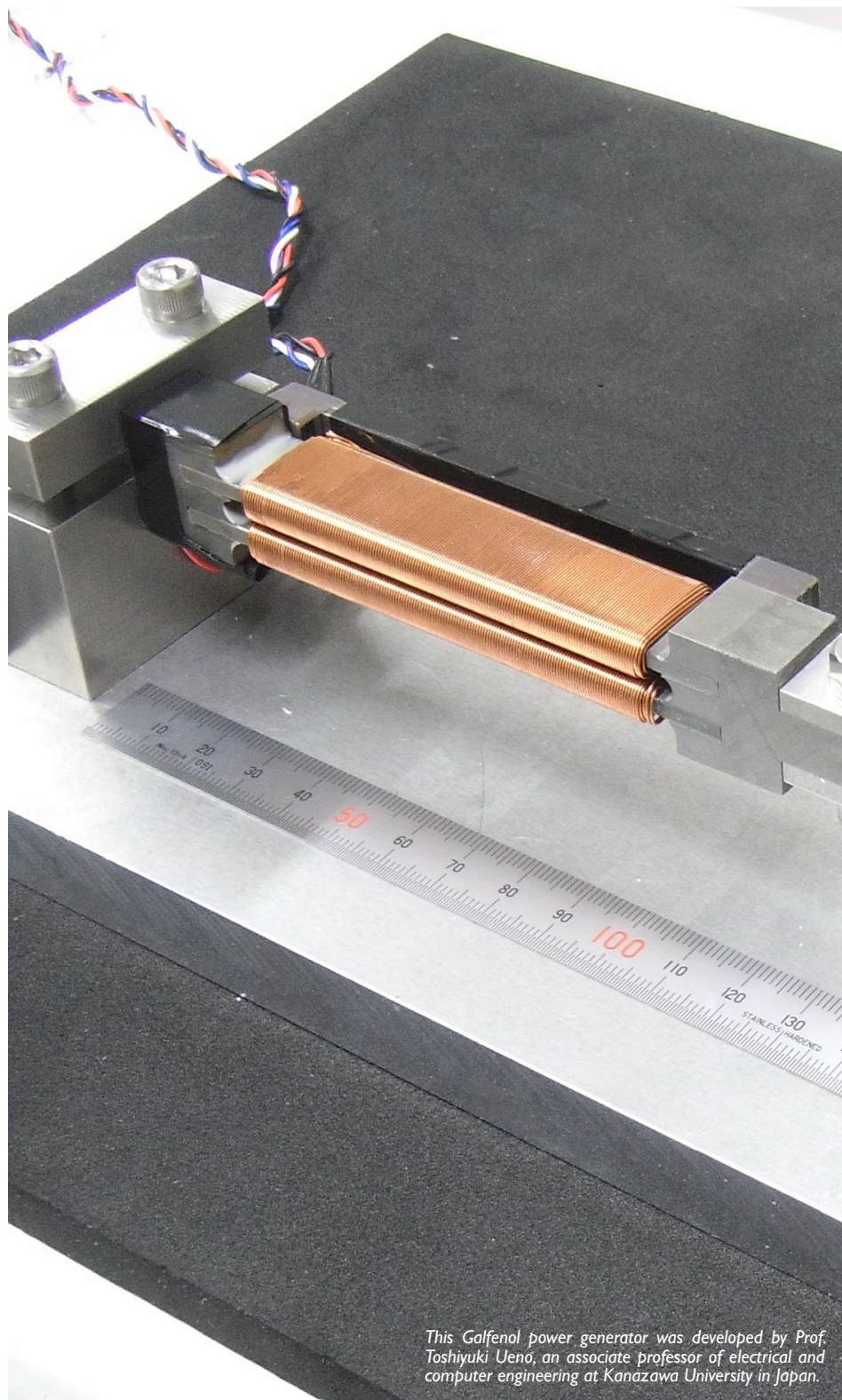
# Galfenol: A disruptive technology

By Marilyn Wun-Fogle and Dr. James B. Restorff, Future Force Fall Edition 2015

In late 1999, researchers at the Naval Surface Warfare Center, Carderock Division invented an exciting new smart material: Galfenol, an iron-gallium (Fe-Ga) alloy system. Smart materials are designed materials that have one or more properties that can be significantly changed in a controlled fashion by external stimuli, such as stress, temperature, moisture, pH, or electric or magnetic fields. Galfenol is a “magnetostrictive” material with a combination of properties unmatched by any existing smart material. Magnetostriction is a process whereby some materials alter their physical dimensions when a magnetic field is applied to them. It is important because it offers an avenue to convert electrical energy into mechanical energy, similar to the more familiar electric motor. These materials also can be used in the inverse manner and act as sensors.

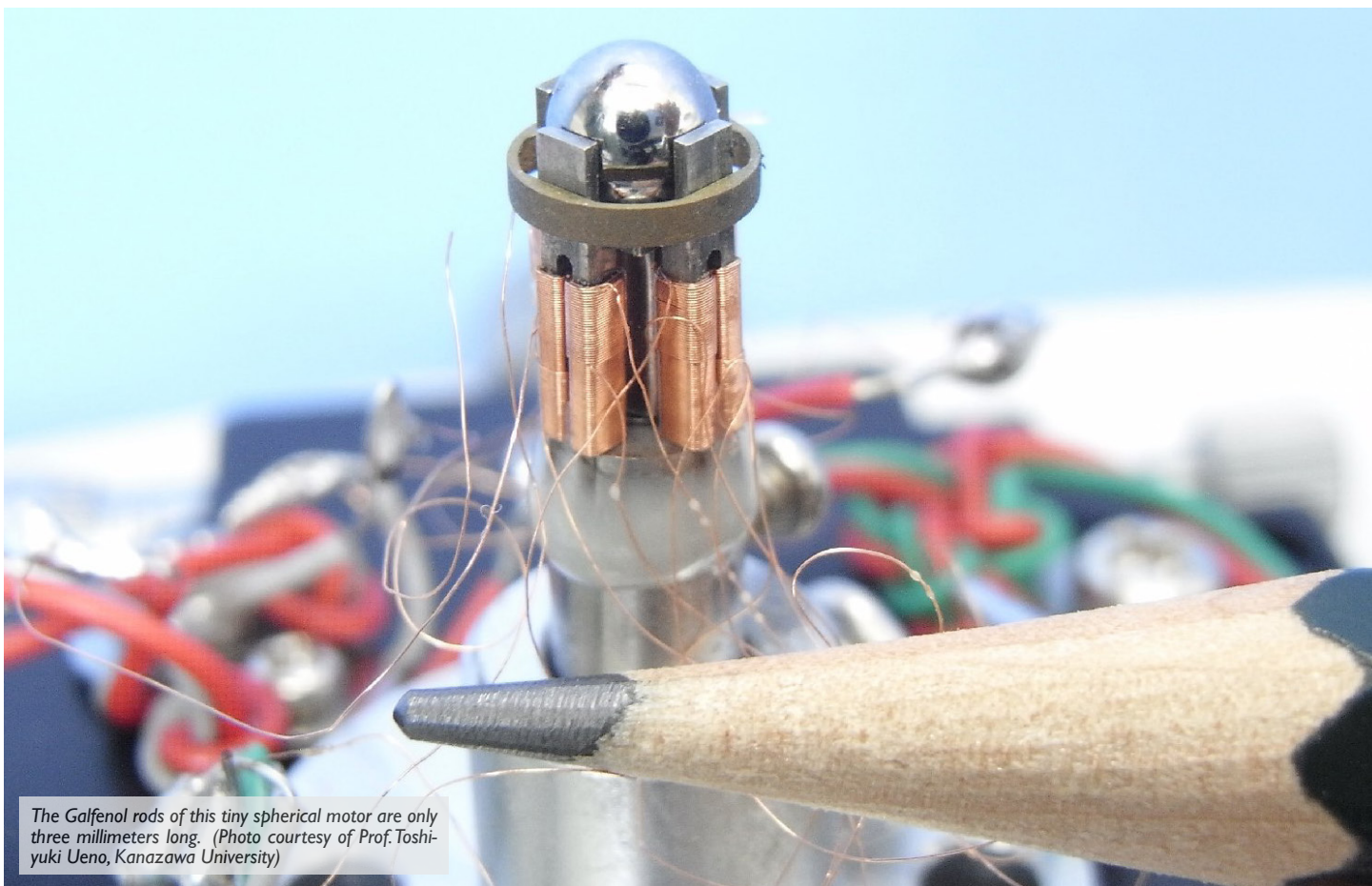
Magnetostriction is not new. It was discovered in 1847 when James Prescott Joule measured the change in length of an iron rod when it was placed in a magnetic field. In some applications such as magnetic recording or transformers, magnetostriction is considered to be highly undesirable because it leads to audible noise and energy loss. One person’s problem, however, is another person’s opportunity; materials with significant magnetostrictions have proven to be technologically valuable. In World War II, the United States and its allies used nickel in sonar transducers. Magnetostrictive materials were so crucial to the war effort that the Japanese, for whom nickel was unavailable, developed a new iron-aluminum (Fe-Al) magnetostrictive alloy to perform the same function.

Funded by the In-House Laboratory Independent Research program and the Office of Naval Research (ONR), the magnetic materials group at Carderock began a search for materials with room-temperature magnetostrictions larger than that provided by nickel and Fe-Al in the early 1970s. This culminated in 1979 with the discovery of the technologically useful giant magnetostrictive alloy Terfenol-D ( $\text{Tb}_{0.3}\text{Dy}_{0.7}\text{Fe}_{1.98}$ ), which has a useful strain of about 1,800 parts per million. Magnetostrictive materials can produce very high forces, but the range of motion is small. A 2.5-inch diameter rod of Terfenol-D that is 10 inches long, for example, can lift an 80,000-pound object (such as a fully loaded tractor trailer truck) 0.018 inches



This Galfenol power generator was developed by Prof. Toshiyuki Ueno, an associate professor of electrical and computer engineering at Kanazawa University in Japan.





The Galfenol rods of this tiny spherical motor are only three millimeters long. (Photo courtesy of Prof. Toshiyuki Ueno, Kanazawa University)

with the application of a modest magnetic field. These materials use low voltages and are generally rugged, impervious to adverse environmental conditions and highly reliable. Terfenol-D is now commercially available for transducer applications.

In 1998, Carderock began a search for another magnetostrictive material that was less expensive, had a high strain and could support substantial amounts of both compressive and tensile force. The search was prompted by the brittleness of Terfenol-D and its ceramic counterparts. These materials cannot be exposed to tensile stresses during either operation or handling. This search ended successfully with the discovery of Galfenol in collaboration with Ames Laboratory. Galfenol is the second room-temperature magnetostrictive material with large magnetostriction discovered by the Carderock group. A U.S. patent for Galfenol was issued in November 2012.

The Galfenol alloys fill a void in the spectrum of smart materials. They are mechanically tough and have saturation magnetostrictions as high as 400 parts per million in single crystal form and 300 parts per million in the more easily produced, highly textured

polycrystalline form. In addition, these alloys can sustain approximately 350 megapascals of tensile stress and are stable over a wide temperature range of minus 450 degrees Fahrenheit to above 300 degrees Fahrenheit. Galfenol alloys can be machined and welded with conventional metalworking technology. The full magnetostriction can be accomplished with an easily obtainable magnetic field. Galfenol alloys also can be stress-annealed by heating with a compressive force. This eliminates the need to apply an external compressive stress when the material is used in a device and it simplifies device design. Stress-annealed Galfenol is also magnetostrictively active under a tensile load that is not attainable with either Terfenol-D or piezoelectric ceramic materials.

"The magnetic materials group at Carderock has once again come up with an amazing new material," said Jan Lindberg, an ONR science officer. "Galfenol is a new active transduction material that both answers many current needs and challenges transducer designers to discover new mechanisms that, before the advent of the material, could not even be imagined. It is truly a disruptive technology because it is simple yet complex."

Galfenol is scientifically as well as technologically interesting. Unlike previous active materials, the physical mechanism that generates the magnetostriction is not well understood. In 2006, a five-year, multi-university research initiative led by the University of Maryland was awarded by ONR to investigate the entire class of alloys related to Galfenol, to advance strategies for processing of structural magnetostrictive alloys and to demonstrate heretofore unachievable actuation and sensing capabilities for these alloys in critical Navy applications. The research goals focused on understanding the fundamental mechanisms of magnetostriction in alloys such as Galfenol, learning how to optimize alloy fabrication and processing at the nano- and macroscale, and developing proof-of-concept devices and systems that demonstrate novel sensing and actuation capabilities. The systems investigated were compact, highly sensitive and shock-tolerant sonar sensors, load-bearing active elements for shock and vibration mitigation, energy harvesting devices and nanowire-based artificial cilia sensors for underwater acoustic sensors and communication systems.

The initiative's objective was to accelerate



the development of the next generation of structural iron-based magnetostrictive alloys through fundamental science and engineering studies that focused on three key research areas:

- The modeling needed to understand where the magnetostriction in Fe-Ga alloys comes from, how mechanical and/or magnetostrictive performance might be improved through the addition of ternary elements to these alloys and to use this understanding to identify alloys of different compositions that exhibit similar or even more desirable attributes;
- Investigations into the processes for making alloys with desired magnetomechanical performance at the nanoscale, microscale and macroscale; and
- The development and use of models for design, building and testing of prototype hardware to demonstrate and take advantage of the novel capabilities of these unique alloys in sensor, actuator and energy harvesting systems.

The initiative investigated a broad range of fundamental issues focused on the development of the next-generation, structural, iron-based magnetostrictive alloys. Eight partner institutions (University of Maryland, University of Minnesota, Ohio State University, Pennsylvania State University, Iowa State University, Virginia Polytechnic Institute and State University, University of California at Irvine and Rutgers University) participated. More than 125 journal publications, 16 doctoral degrees and eight master of science degrees resulted from this project.

Carderock also has been engaged in a cooperative research and development agreement with industry partner Etrema Products for further development and widespread use of Galfenol. For more than a decade, Carderock, Ames Laboratory and Etrema Products have collaborated to design the alloy, develop production processes and perfect methods of producing the material in large solid form, rolled sheets and wires in an effort to shorten the usual 20-year time frame between the discovery and commercial/military use of a new material. The diversity of forms allows Galfenol-based parts to be

**GALFENOL IS A NEW ACTIVE TRANSDUCTION MATERIAL THAT BOTH ANSWERS MANY CURRENT NEEDS AND CHALLENGES TRANSDUCER DESIGNERS TO DISCOVER NEW MECHANISMS THAT, BEFORE THE ADVENT OF THE MATERIAL, COULD NOT EVEN BE IMAGINED. IT IS TRULY A DISRUPTIVE TECHNOLOGY BECAUSE IT IS SIMPLE YET COMPLEX.**

used in a variety of new applications, both commercial and military.

ONR supported the magnetic materials

group's efforts in two initiatives: the Naval International Cooperative Opportunities Program (NICOP) and the Technical Cooperation Program (TTCP). Under NICOP, the Carderock group worked with Mechano Transformer Corporation in Japan and the University of Tokyo on Galfenol uses as a microactuator in a microspeaker, microinjector and other components. NICOP involvement was extended to the University of Kanazawa in Japan, where they are researching the use of Galfenol for energy harvesting applications. Under the TTCP, Carderock collaborated on an operating assignment with the defense laboratories in Canada, Australia and the United Kingdom, with an eye toward using these materials in defense applications. The success of this assignment resulted in a TTCP achievement award for significant advances in the development and exploitation of novel magnetostrictive and magnetic shape memory alloy technologies for defense applications—laying the groundwork for developing international acceptance standards and contributing to future substantial enhancement of military capabilities of the TTCP member nations.

Since the discovery of Galfenol in 1999, it has advanced from being a curiosity in a laboratory to a material being investigated worldwide by a variety of university and government laboratories. In the United States, efforts to commercialize the material are well under way and showing substantial progress. Continued development of magnetostrictive materials will result in their optimization for as-yet-untapped potential in structural applications: vibration sensors, vibration control actuators and energy-harvesting devices and systems. We believe this material has a bright future and will give designers a material with previously unavailable performance.





# Next-gen lithium-ion batteries

By Roxie Merritt, NSWCCD Public Affairs

**L**ithium-ion (Li-ion) batteries power most of the devices we use every day, and their usage as energy power storage is only expanding. From our cell phones, to our cars and the computers we work on, lithium is touching every aspect of our lives both at home and at work.

The push for clean power like wind and solar is a major factor in the growth of lithium-ion batteries. Clearly, lithium batteries are a major part of our energy sector today and are going to remain prevalent in energy storage in the future.

According to Eric Shields, a mechanical engineer with the Advanced Power and Energy Branch at Naval Surface Warfare Center, Carderock Division, lithium-ion batteries in the fleet have become more prevalent and the Navy faces the challenges and pressures of getting the best, safest product to the warfighter as quickly as possible.

Shields also helped to organize last summer's first Energy Storage Summit at Carderock in early June. Some of the areas discussed at the Energy Storage Summit include safety evaluation; acquisition, requirements and system standardization; cell sourcing and domestic suppliers, manufacturing and fuel cells.

NSWC Carderock is one of two Navy lithium battery test and evaluation labs capable of executing abusive safety tests. Carderock's technical experts subject lithium primary (non-rechargeable) and lithium secondary (rechargeable) batteries to abusive conditions

and Marines under all conditions. NSWC Crane Division executes a similar mission and also manages the in-service engineering of fleet-deployed batteries.

Carderock Division is now working with the second-generation lithium-ion battery prototypes. The growth in usage of lithium-ion batteries in applications such as phones/tablets, hover-boards, power tools and the automotive industry very much mirrors the growth the Navy has seen for military applications. Li-ion batteries now support Navy and Marine Corps missions on the ground, in the air, on the surface and under the sea. The advancements in capability of lithium batteries from the 1990s and early 2000s to today, have made them safer, more affordable and more capable of supporting a range of applications.

One area on the cusp of being fielded is that of the second-generation advanced lithium "NATO 6T" batteries. The "6T" is a standard format for a lead acid batteries used in pairs to power nearly every ground combat vehicle. This makes it one of the most commonly purchased batteries in the Department of Defense.

Li6T prototypes under evaluation today are beginning to show the performance and safety characteristics necessary for putting them in the hands of warfighters, and industry is working aggressively to make these systems affordable. The Army's Tank and Automotive Research and Development Engineering Command (TARDEC) has played a large role in investing in this battery system and helping industry make this progress.

other applications have the ability to double or triple the energy density of conventional storage systems and improve lifetime by greater than two to five times. This gives these systems a tremendous lifecycle cost advantage to any military force fielding them, while enhancing mission effectiveness in many different domains.

For the Li6T in particular, the majority of tactical military vehicles in all of the services will ultimately take advantage of the capabilities they have to offer. This will include previously fielded platforms like the Marine Corps' Medium Tactical Vehicle Replacement (MTVR) seven-ton truck, and future platforms like the Joint Light Tactical Vehicle (JLTV), which will be replacing the Humvee.

As in the public sector, energy storage is going to play an increasingly important role in enabling our future forces. Tactical vehicles will be hybridized with li-ion energy storage to enable silent watch capability while improving fuel economy. Unmanned air vehicles will use a combination of photovoltaic panels with lightweight lithium-ion batteries and soaring to enable persistent intelligence surveillance and reconnaissance, unmanned underwater vehicles will be capable of performing an array of missions with increased durations, and future shipboard weapons systems being developed by the Office of Naval Research (ONR) like the free electron laser and electromagnetic railgun will rely on li-ion as an enabling technology. These advancements will be incremental but consistent over the next 25 years, and NSWC Carderock Division will be there to ensure they are safe and effective.



A concept sketch of future shipboard weapons systems like the free electron laser and electromagnetic railgun that will rely on li-ion as an enabling technology.



# Carderock reaches out to local students through annual math contest

By Dustin Q. Diaz, Naval Surface Warfare Center, Carderock Division Public Affairs



Students compete in the Carderock Math Contest countdown round at Naval Surface Warfare Center, Carderock Division in West Bethesda, Md., March 18, 2016. Ben Kang (right) is the winner of this year's event. From left: Alex Chung from Longfellow Middle School in Falls Church, Va.; Daniel Yuan from Chesapeake Math Program in Columbia, Md.; Jason Hsu from Takoma Park Middle School in Silver Spring, Md.; and Kang from Longfellow Middle School. (U.S. Navy photo by James Contreras/ Released)

Nearly 200 students from 25 local middle schools competed at Naval Surface Warfare Center, Carderock Division (NSWCCD), in the seventh annual Carderock Math Contest (CMC) March 18.

The contest, featuring MathCOUNTS style tests and tours of Carderock, is part of Carderock Division's ongoing outreach efforts to encourage students to pursue careers in science, technology, engineering and math (STEM).

"This is a wonderful opportunity for these students to have a fun day of preparatory contests, while also learning about Carderock and the possibilities for jobs in science, math and engineering," said Dr. Nick Jones, a materials engineer and CMC planning committee member. "They also get to learn about possible extracurricular activities, internships and scholarships for college. The contest serves so many purposes and is fun for us, too."

The Carderock Math Contest, part of the National Defense Education Program, challenged the students both as individuals and teams. It began with the Sprint and Target Rounds, sets of math problems each student answered alone, then a Team Round that brought their efforts together under team names like Savage Honey Badger and the moniker that won Most Creative Team Name, E = MC Hammer.

"This is my first time here," said Oscar Lloyd, a sixth-grade student at St. Anselm's Abbey School in Washington. "I enjoy math, so I joined the club at my school. And I know people who have been here and done the contest before who said it was a lot of fun. I must admit I didn't do too well, but I still really enjoyed it."

These initial rounds of the contest were followed by tours of Carderock's facilities, including the welding laboratory, the Manufacturing, Knowledge and Education Lab and the Maneuvering and Seakeeping Basin.

"I really enjoyed going around the naval base and seeing all that," Lloyd said. "I liked going to see the big wave basins and the cranes. Just the scale of all that, it was really cool to see."

Dr. David Hess, a mechanical engineer and CMC tour guide, told students about Carderock's ship design work, how it saves the Navy money and how these models and the ships they mimic displace water and are buoyant. He also answered their questions about what kinds of STEM knowledge and degrees to pursue if they want to join Carderock when they are older.

"A lot of them are wowed when they see our facilities and ask a lot of good questions," Hess said. "These are more than your average students; they're STEM oriented anyway. I just hope that I can make them like STEM stuff enough that they want to keep doing it, so they can see an end result and realize this is a cool place they can work if they want to. And it would be nice if they did, but I'd be happy if



they did STEM stuff anywhere.”

The countdown round came after lunch and the tours, pitting the 16 highest-scoring students in the previous competitions against one another in a tournament to answer problems before their opponents.

“These are some really smart kids,” said Erica Scates, an aerospace engineer and CMC planning committee member who proctored the countdown round. “Often, they’re buzzing in to answer a question while the question is still being read. The competition gets pretty intense.” Scates said this year’s event took more coordination from Carderock’s volunteer team than usual since it was postponed from its traditional January date by that month’s historic blizzard, but that the end result went very smoothly.

Adam Roush, a sixth-grade mathematics teacher at St. Anselm’s Abbey School, said he was familiar with Carderock because his father was once a Carderock Division employee and that he was excited to bring his students here for the contest.

“I love the facility,” Roush said. “It’s a good way for students to see mathematics and science in action. They got into the team competition as well. They were very excited for that and it really brought them together.”

Ben Kang, a student at Longfellow Middle School in Falls Church, Virginia, won the overall

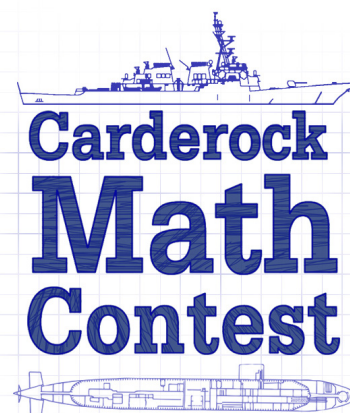


First-, second- and third-place winners of the seventh annual Carderock Math Contest Countdown Round pose after their win at Naval Surface Warfare Center, Carderock Division (NSWCCD) in West Bethesda, Md., March 18, 2016. From left: NSWCCD Commanding Officer Capt. Rick Blank; third-place winner Jason Hsu and first-place winner Ben Kang from Longfellow Middle School in Falls Church, Va.; second-place winner Alex Chung from Takoma Park Middle School in Silver Spring, Md.; and NSWCCD Deputy Technical Director Larry Tarasek. (U.S. Navy photo by James Contreras/Released)

competition and will be given an opportunity to shadow a Carderock employee for a day later this year.



Zachary Gayer (left) and Rohit Barrett from Maret School in Washington, participate in the Team Round during the Carderock Math Contest at Naval Surface Warfare Center, Carderock Division in West Bethesda, Md., March 18, 2016. (U.S. Navy photo by James Contreras/Released)







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