Naval Research Laboratory Takes Science from the Lab to the Fleet

Senior Chief Mineman Abraham Garcia, left, and Aerographer's Mate 1st Class Joshua Gaskill, members of the Knifefish unmanned underwater vehicle test team, work tending lines during crane operations as part of an operational assessment conducted by members from Operational Test and Evaluation Force. U.S. Navy / Mass Communication Specialist 1st Class Brian M. Brooks

As the U.S. Navy's corporate laboratory, the purpose of the Naval Research Lab in Washington, D.C., is to be cognizant of – and have world-class expertise in – the very basic sciences that are fundamental to all the technologies that we have in our society, and to create new technology through continued investment in science at the very basic level.

NRL comes under the Chief of Naval Research as head of the Office of Naval Research (ONR). ONR directs much of the work of the Naval Research Enterprise (NRE), of which NRL is a part, along with Navy warfare centers, academic institutions and federally funded research and development centers.

"We are a working laboratory at NRL, and we execute science and technology development and transition it to the fleet," said NRL's Acoustics Division Superintendent Dr. Brian Houston.

"Our work is basic and exploratory, all the way up to applied research and transitions. Unlike many of the organizations in the NRE, we do very basic science work – so-called 6.1 level work, where you have people on the lab, for example, that are developing new mathematical theories, and making new materials using surface science techniques, or developing new optics and

lasers at the very fundamental level. Like much of NRL, in the acoustics division we intertwine that very basic science with exploratory research [6.2 research] where it's more applied, taking what we've learned from the basic science and identify what can evolve into technology that might eventually benefit our warfighters," Houston said.

According to Houston, NRL must be aware of the work being conducted by colleagues in the other organizations in the NRE. But, he said, while the other organizations tend to engage in engineering refinement, NRL explores new basic science and develops technologies from it.

"When you see some NRL research that's resulted in a breakthrough technology or capability, you're just seeing the tip of the iceberg. That's because there is so much basic science behind it. Our technology development teams that are bringing new capabilities and systems to our ships, aircraft and submarines have scientists who understand the very basic physics integrated with those technology teams."

Houston came to NRL as a student, but says, "It just became a home very quickly because of the people, the facilities here and the really great problems we have to solve. I've been here 35 years and have never worked anywhere else.

"The acoustics piece of undersea warfare represents a lot of what we do – and it's a very challenging area," Houston said. "That includes finding things in the water, like submarines and things on the seabed, like mines. A major area encompassed by undersea warfare is mine warfare and not just offensive mines, but how to detect and localize adversary mines and how to deal with them. A mine is a very inexpensive weapon, and it's relatively easy to make effective. It costs very little compared to the targets it goes after, like a billion-dollar warship, for example. They're very difficult to detect and classify. We worry about mines today as much as we ever did.

“With regards to detection, there is a lot of stuff in the water column and even more stuff on the bottom. Mines are typically used in close proximity to the bottom, so you have to sort out the mines and detect and classify them in the context of all of this clutter and the topology of the bottom itself.”

Transcending Platforms

Houston said his work transcends platforms, sensors and processing, to include the systematic employment of all of that together. NRL has developed both a sensor approach as well as methods to analyze the data to carry out missions. From the sensor perspective, that whole technology area is what NRL calls low-frequency broad- band (LFBB), an active sonar that employs synthetic aperture processing, with processing that employs artificial intelligence for detection and classification.

“LFBB exploits the structural acoustics involved with underwater sonar. When you transmit sound, the acoustic return is very different depending on the physical object reflecting that acoustic energy. It might be a naturally occurring thing like a rock on the bottom or something that’s man-made, like a mine. In the water column, it might be a submarine versus a whale. What’s in the acoustic return is very different for each of those targets. Sonar has traditionally helped us know where something is, how far a way it is and sometime provides an image. But in addition to bearing and range, we can now determine what it is,” Houston said. “That return has specific physics in it that we can exploit, and we can know something about the physical object and based on how it responds.”

Houston said structural acoustics focuses on the inter- action of the sound with structures in a fluid – in this case, water.

“If I ping on an object underwater, the sound will propagate across the water volume and interact with the structure. The

acoustic energy will cause the casing of a mine, or the hull of a submarine, to vibrate. So, the interaction of sound with a structure, and then the re-radiation of sound, is the realm of structural acoustics. Some years ago, we put together our one-of-a- kind Laboratory for Structural Acoustics here at NRL to focus on precision measurements."

Houston's team frequently uses unmanned systems in their research, and not just as platforms to hang sensors on or as scientific measurement tools.

"We're also trying to figure out how to use them in under- sea warfare," Houston said. "We're engaging in the development of the artificial intelligence that's needed to make those platforms work for the Navy. We're figuring out how to best use them in terms of sensor platforms, in an applied way, the way the Navy might apply them in terms of an offensive capability. There's a lot going on here."

The NRL team has used their autonomous underwater vehicles Reliant and Black Pearl to develop LFBB for mine countermeasures, ASW and counter-UUV applications. Many mine-hunting UUVs employ change detection – knowing what's on the bottom and coming back later to see if anything has changed.

"You can do change detection with almost any sonar system, including our systems, but we do not rely on change detection. Our system operates at a very high-performance level to go into an area and you can rely on the results from just a single pass," said Houston. "That's the objective."

The Reliant and Black Pearl vehicles are unique compared with other platforms.

"The major difference is the sonar itself," Houston said. "One of the reasons why we like the General Dynamics Bluefin Robotics 21-inch vehicle – both Reliant and Black Pearl are Bluefin vehicles – is they are 'open ocean capable.' They have a lot of energy on them, fairly high- end navigation systems,

plus we have other things on them to make them very useable and capable in the open ocean. We also can go into shallow water areas and even very shallow water areas. So, we like that aspect of it. We want to have some ‘legs’ on the vehicle and navigate accurately. The sensors themselves aren’t consistent with a small vehicle, particularly because the low frequencies require larger sources and sensor apertures. We are doing a lot of onboard processing, so we can take the data and process it on board the vehicle to enable autonomous decision making enabled by the sensors, so it has access to the real-time processing of the sensor data, and it makes decisions based on that.”

Cuts Like a Knifefish

NRL has worked closely with the acquisition community. The LFBB sonar is now operational aboard the Knifefish Surface Mine Countermeasure Unmanned Undersea Vehicle Program, used to find buried, bottom and volume targets in highly cluttered environment. The system consists of two unmanned undersea vehicles along with support systems and equipment and is a critical element of the Littoral Combat Ship (LCS) Mine Countermeasure Mission Package. Knifefish received Milestone C approval last year, and the system entered low-rate initial production.

Knifefish is being built in blocks to incorporate new technology as it matures, to increase performance in each block. In addition to the LCS mine countermeasures mission package, the system can also be employed from other vessels of opportunity. Like NRL’s Reliant and Black Pearl reserve vehicles, Knifefish employs a General Dynamics Mission System Bluefin-21 vehicle.

“Knifefish’s common open systems architecture design and modularity provides the ability to quickly reconfigure the mission package to respond to evolving and dynamic mission requirements, and can be readily upgraded as new technologies

or payloads are developed," said Dr. Andrew Rogers, vice president, Undersea Defense Systems at General Dynamics Mission Systems.

For Houston and the NRL team, the scientists, engineers, and the people who know how to bend metal and make it function, are all working together in an integrated fashion to accelerate the transition of scientific discoveries to applications.

"If you don't have that connectivity, you just can't make the arguments that will bring a new piece of science to an application that the fleet needs," Houston said.

The result is a program of record that will help the fleet safely find mines. "We demonstrated at-sea performance and were successful in transitioning the technology into a program of record," Houston said. "It was basic research – the science – that started it all."