Simulated Flys Ear, Aim-able Undersea Sound Beams Aid Hunt for Red Octobers

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by Barbara Honegger Senior Military Affairs Journalist

Two Naval Postgraduate School Undersea Warfare students got the message loud and clear: If the key to real estate is location, location, location, the key to stealthy submarine communications and sub detection is direction, direction, direction.

Lt. Tim Shivok, a submarine officer, received the Naval Undersea Warfare Center Newport Award for Excellence in Undersea Warfare Technology for his research on tiny microphones that can detect the direction of a sound source based on how flies hear, and Lt. Noble Hetherington III, a surface warfare officer, won the Chief of Naval Operations Undersea Warfare Award for his work with special speakers that radiate sound so loud it changes frequency and becomes confined to a tight beam, like a sonar spotlight. The two technologies may soon provide for improved underwater communications and submarine detection.

"A major problem with current underwater sound technology is that we can hear things but don't know which direction they're coming from," Shivok explained. "If you're towing a linear array, for example, you can only tell the bearing of a sound event – say 40 degrees from the center line -- but not the direction, left or right, so the ship needs to reposition to eliminate the uncertainty. It's very important not to have to turn the sub to resolve the bearing, because doing so puts flow noises into the ocean, which makes us more detectable and compromises stealth.

"Having directional microphones will make a huge difference in helping our subs run more silent while detecting potentially unfriendly subs," Shivok stressed. "In fact, it was 'The Hunt for Red October' – the movie about the challenge and excitement of tracking enemy submarines -- that got me into the Navy.

"Directional microphones will also be an important addition to unmanned aerial and unmanned underwater vehicles," Shivok added, "because they need to be able to autonomously turn towards a sound event or explosion, and to do that they need to be able to determine the direction it's coming from."

Shivok's microphones aren't just directional, they're also extremely small. "They're literally micro microphones," he said. "We're talking 1 millimeter by 2 millimeters – so light and micro they can be used on even the smallest UAV or UUV, as well as on submarines and in surface ship towed arrays. After all, the micro-electro-mechanical technology they're based on is modeled on the hearing mechanism of the tiny Ormia ochracea fly that uses coupled bars hinged at the center to achieve directional sound sensing by monitoring the difference in vibration amplitude between them."

Shivok's master's thesis research simulated the physics and operations of the device using a computer program, developed its specifications and tested a physical prototype.

If the key to Shivok's research is to be able to tell which direction an incoming underwater sound is coming from, the heart of Hetherington's is to be able to tightly control the direction in which underwater sound is sent and also narrow the direction from which it can be heard.

"My thesis research is about how the physics of loud -- or high intensity -- sound waves interact with the air or water medium they're in to create new frequencies that are not directly produced by the speaker, and which form an aim-able beam of sound on which voice signals can be transmitted or information encoded," Hetherington explained. "These piggybacked signals channeled inside the aim-able beam can

then be exploited for underwater communications and, potentially, for indirect detection of a target submarine's position.

"This nonlinear acoustic effect is important, because it lets you use a much smaller array than traditional arrays or hydrophones to create a low-frequency sound beam which radiates out and is heard only along the direction it's aimed -- like an underwater audio spotlight," Hetherington stressed. "The new low frequencies that are generated in this way can travel farther and much stealthier in the water, and the signal at the receiving end experiences less degradation due to reverberation because of the narrowness of the beam. Traditional hydrophones and arrays can't be directed nearly as well at low frequencies because their sound radiates out in all directions, which makes your own ship, the source, far more detectable."

Both award-winning USW students highly value the time they invested in the Naval Postgraduate School.

"Nowhere else can you earn a technical master's degree along with officers from other branches of the Department of Defense and foreign militaries in an environment totally committed to improving DoD capabilities," Hetherington said.

Shivok strongly agreed. "The NPS undersea warfare program is an incredible experience that's both tactically relevant and academically challenging," he stressed. "The big take away from NPS is advanced problem solving, regardless of your specialty. In my field, I learned a great deal about undersea warfare and the tactics for exploiting the natural characteristics of the oceans to hide and to find other subs. I will highly recommend it to every junior officer on my ship."

Shivok received a Master of Science in applied physics and Hetherington a Master of Science in engineering acoustics from the Naval Postgraduate School in September. Shivok's thesis is titled "Micro-Electrical Mechanical System (MEMS) Polymumps-based Miniature Microphone for Directional Sound Sensing," and Hetherington's is "Investigations of Nonlinear Acoustics Using a Parametric Array."

Though the goal is to detect and control the direction of signals underwater, both students conducted their experiments in air.

"I used air as the medium because it's easier to do the experiments and understand the physics, which was the goal," Hetherington explained."The same principles also apply to water, and taking the research underwater is the next step."

Shivok received his Bachelor of Science degree in nuclear engineering technology from Thomas Edison State College in 2000. He entered the Naval Service as an enlisted nuclear electrician's mate in 1991, served on the USS Spadefish (SSN-668) and taught at Nuclear Field "A" School. After obtaining his degree, he entered the officer corps via Office Candidate School in Pensacola, Fla. After again completing the Nuclear pipeline, he served as a junior officer onboard the Los Angeles class submarine USS Annapolis (SSN-760). Shivok attended NPS after completing his junior officer sea tour where he also completed the Naval War College Joint Professional Military Education, Phase I. He will next attend Submarine Officer Advanced Course in Groton, Conn.

Hetherington received his Bachelor of Science degree in applied physics from Rensselaer Polytechnic Institute and entered the Naval Service in May 2000 through the Naval Reserve Officer Training Corps there. Following training at the Surface Warfare Officer School in Newport, he reported to USS Hawes (FFG-53) in Norfolk, Va., as a first lieutenant, where he qualified as Surface Warfare Officer. Hetherington then studied naval nuclear power in Charleston as well as in the Modifications and Additions Reactor Facility in West Milton, N.Y. He reported in June 2003 to USS George Washington (CVN-73) for duties as propulsion plant watch officer and reactor laboratories division officer. He qualified as a naval nuclear engineering officer in April 2005. While at NPS, Hetherington also completed the Naval War College Joint Professional Military Education, Phase I. He is slated to serve as operations officer onboard the USS Russell (DDG-59).

(Left) Lt. Noble Hetherington III with then Chief of Naval Operations Adm. Mike Mullen following Summer 2007 graduation ceremonies. Hetherington won the Chief of Naval Operations Undersea Warfare Award.