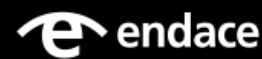


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Sailors aboard the aircraft carrier USS Theodore Roosevelt watch as the guided missile destroyer USS Kidd sails behind the littoral combat ship USS Gabrielle Giffords in the Pacific Ocean in July. Prior to launching naval operations in remote parts of the world, Navy officials could learn from DARPA's Ocean of Things sensors whether Global Positioning System signals are available. Navy Petty Officer 3rd Class Erick A. Parsons.

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By George Seffers

The smart sensors effort may spur widespread ocean digitization.

The U.S. Defense Department could one day place thousands of low-cost, floating sensors into the ocean to collect environmental data, such as water temperature, as well as activity data about commercial vessels, aircraft and even fish or maritime mammals moving through the area. But others also are dropping similar sensors in the world's oceans, and defense researchers suggest many of those systems could be integrated into an even more comprehensive ocean-based Internet of Things.

The growing Internet of Things is mostly a land-based phenomenon, frequently in large cities with loads of sensors. But researchers at the Defense Advanced Research Projects Agency (DARPA) foresee a wide range of military and civil benefits from extending the Internet of Things out to sea.

The agency announced its **Ocean of Things** program in 2017. John Waterston, a program manager within DARPA's Strategic Technology Office, says the sensors will float along the surface for at least one year, transmitting short messages via the Iridium satellite constellation back to a central location for analysis. "It's a 280-byte in and 340-byte out message, so it's a little bit more than a tweet. I like to say these things tweet about their environment," he says.

The goal is to increase maritime awareness in a cost-effective way. Using existing systems to continuously monitor vast regions of the ocean would be cost prohibitive, DARPA notes on the program website. By coupling powerful analytical tools with commercial sensor technology, the agency intends to create floating sensor networks that significantly expand maritime awareness at a fraction of the cost of current approaches.

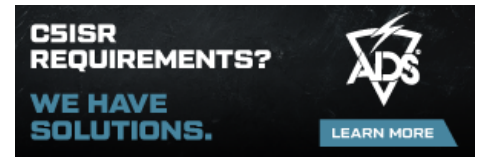
Waterston says one of the most interesting missions for the sensor might be to simply determine whether GPS signals are available in an area of interest for military operations. "It doesn't risk a plane or risk whatever platform you were going to use to go over there and say, 'Oh, GPS is good. Go ahead and do whatever mission you were going to do.'"

The program also could help improve ocean modeling, which is important for forecasting weather, finding people who have fallen overboard or locating debris from a crashed aircraft. "Interestingly enough, we've learned the ocean models are horrible. This is one of the first things we're going to fix."

The agency has yet to determine how many sensors it might eventually deploy, but they could number in the tens of thousands. To put that into perspective, DARPA officials compare the final density to placing a penny on the national mall, which Wikipedia says covers about 309 acres between the Ulysses S. Grant Memorial and the Lincoln Memorial.

"In phase one of this program, we're building 4,500 sensors and we're deploying them in 15,000 square kilometers right off of Southern California, inside the Catalina Islands. We're going to try to do about one sensor per 3 square kilometers. The next phase, we're going to expand the area to 150,000 kilometers and put in 15,000. That gives us 1 per 10 [square kilometers]. I think the final system is going to be about 50,000 floats for 1 million, so that's 1 per 20 square kilometers," Waterston reports. "Initially, we're going to deploy overly dense to figure out what the right density is going to be."

DARPA officials indicate they are unaware of any other organization planning to deploy ocean sensors in such large numbers, but many indicate interest. For example, DARPA is partnering with the National Oceanic and Atmospheric Administration, the National Weather Service, the University of Southern Mississippi, the University of Miami, multiple private companies and other entities. Waterston notes that he has brochures from Chinese and Spanish companies working on similar systems.



Oceanographers, military operators and civil and commercial organizations all want devices to gather data from the ocean for their own purposes, and they mostly operate independently. Waterston notes that the National Academy of Sciences wants to study the Gulf Stream. He also says he is familiar with one individual with an ocean sensor system aimed specifically at the surfing community.

In addition, Argo, an international program, uses several thousand battery-powered, robotic floating devices to measure temperature, salinity and current for climate and oceanographic research. The floats mostly drift 10 days at a time below the ocean surface. After rising and transmitting their data to satellites, they return to depth to drift for another 10 days. The floats go as deep as 2,000 meters, according to the [Argo website](#).

Furthermore, the idea for the Ocean of Things was inspired by young researchers in Norway, who were combining [Raspberry Pis](#), which are low-cost, credit card-sized computers, with [Arduinos](#), another low-cost, open-sourced platform. "Really what spawned this idea was some kids in Norway were taking some Raspberry Pis and Arduinos and putting them in a container and throwing them off a boat into the fjords," he reported. "If they can do that, we can."

He also met a Navy science advisor who placed an Arduino in a waterproof Pelican case and dropped it off the coast of Hawaii. "I think you can go look at it today. It's out there with a solar panel," Waterston adds.

The sheer level of interest and activity told Waterston that something had fundamentally changed. "I think it is that we have ubiquitous communications globally. Period. Anyone can make a call anywhere on the Earth any time they want," he says, allowing that connectivity is not as fast or easy in some locations as others. "The next thing that has changed is low-cost, low-power processing." He points out that three-year-old cellphones have more computing power than much larger computers of the past.

Asked whether DARPA's sensors could ultimately be integrated with sensors developed and deployed by friendly nations or other civil or commercial organizations, Waterston acknowledges the possibility. "I think we could. It would be great to integrate like that."

He adds that he would like to see involvement from military, commercial and scientific communities. "I would love for this to move past the DOD. I think we can move the fastest, and we have the funds to show the feasibility, but I would like all those groups to just start diving in."

It is possible an ocean-based Internet could provide data on demand to a variety of customers inside and outside the Defense Department. If, for example, a government agency needs the water temperature in a given area reported every six hours, or a combatant command needs to know what's happening in the Mediterranean, or NATO officials want information between Gibraltar and Sicily, or commercial fishermen need data on where the shrimp or tuna are, they could simply request it. "It's about serving the end users. If you can use that data, we can generate it for you," he offers. "It's a little bit like floats-as-a-service or data-as-a-service."

Another option is that other organizations could purchase and deploy the DARPA-developed sensors. "I hope people want to come up with their own sensors or want to buy these. I imagine a marketplace where you get many commercial people buying these. Everyone could buy 500 and then take advantage of the service provided by the thousands that are out there. I could imagine this as that foundational community," Waterston suggests.

The program focuses on two primary technical areas: float development and data analytics. Under float development, proposers must design an intelligent float to house a passive sensor suite that can survive in harsh maritime environments. The floats will be required to be made of environmentally safe materials, pose no danger to vessels and comply with all federal laws, regulations and executive orders related to protection of marine life. Each float would report information from its surroundings for at least one year before safely scuttling itself in the deep ocean.

The floats can be scuttled on demand when necessary. They also can sink themselves if batteries are too low, or if they lose communications or the GPS connection.

The data analytics portion of the program requires proposers to develop cloud-based software and analytic techniques to process the floats' reported data. This effort includes dynamic display of float locations, health and mission performance; processing of environmental data for oceanographic and meteorological models; developing algorithms to automatically detect, track and identify nearby vessels; and identification of new indicators of maritime activity. "We're actually trying to process at the edge, and that's a real hard challenge that we're just now getting to," Waterston notes. "We're doing a DevOps [software development operations] environment in the Amazon Web Services GovCloud."

DARPA currently is working with three teams led by the Palo Alto Research Center, better known as PARC, Areté Associates and Numurus LLC to develop the floats. DARPA will select two suppliers to go head-to-head on the last phase of the competition. Leidos, Draper Laboratory, SoarTech and Geometric Data Analytics are providing software for data visualization, performance prediction, float command and control and detection. The program will begin phase two in the 2020 fiscal year and phase three the next year. It will end in 2022.

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