


# Ocean Science and Technology

*This is the second in a series of essays, exclusive to The Journal of Ocean Technology, that focus on the role of ocean technology in society today. This essay explores the relationship between science and technology in the ocean realm. We welcome your comments on this important topic.*



 INSTITUTE FOR EXPLORATION

Clams and tube worms.



 BRAD DE YOUNG MEMORIAL UNIVERSITY OF NEWFOUNDLAND

Underwater glider.

**T**he ancient Greeks and Romans regarded both science and technology as sources of knowledge. In 1987, Paul Curran, a renowned geographer specializing in remote sensing, summarized a symbiotic relationship between technology and science as follows: “(i) very few technological events lead directly from an idea in science; (ii) typically, a major technical innovation is based on many ideas, some of which will come from science; (iii) typically, development in technology is not ‘pushed’ from behind by a scientific idea but is ‘pulled’ forward by human need; and (iv) the relationship between science and technology is not unidirectional, for while science can play a part in some technical developments, science developments are often made possible by technology.” This essay explores the relationship between science and technology in the ocean realm.

“The future is in applying technology to the ocean,” says Glenn Blackwood, Executive Director of the Fisheries and Marine Institute of Memorial University in St. John’s, Newfoundland. “I believe we are on the verge of doing something very significant in the oceans sector. We’re using advanced satellite communications and positioning technologies, and combining them with advanced acoustic remote sensing and ocean instrumentation to ‘lift the lid off big blue.’”

Uncovering the mysteries of the deep ocean is what marine geologist and oceanographer Robert Ballard has been doing for the past 30+ years. Currently the Director for the Centre for Ocean Exploration at the Graduate School of Oceanography at the University of Rhode Island, in 1977 Ballard and a team of scientists used sophisticated deep sea submersible technology to look for open fissures in the newly created volcanic terrain along the spreading axis of the Galapagos Rift in the Eastern Pacific Ocean. “We were expecting to just see hot water coming out of a crack,” he recalls. “We had no idea that this harsh environment would support a large community of new organisms based upon chemosynthetic

processes” – a discovery that disproved the longstanding belief that photosynthesis is needed to support life. Ballard and his team also discovered “black smokers” – valuable polymetallic sulphide mineral deposits around the hottest hydrothermal vents. “Both discoveries were by accident,” he recalls. “Using technology to look for something, we bumped into something more important.”

Eight years later, Ballard led a team of scientists to search for debris from the *Titanic*, by towing television cameras on a sled-like device 4 km beneath the ocean surface. Instead, the famous ship itself appeared, and the search for lost history in the deep sea was born.

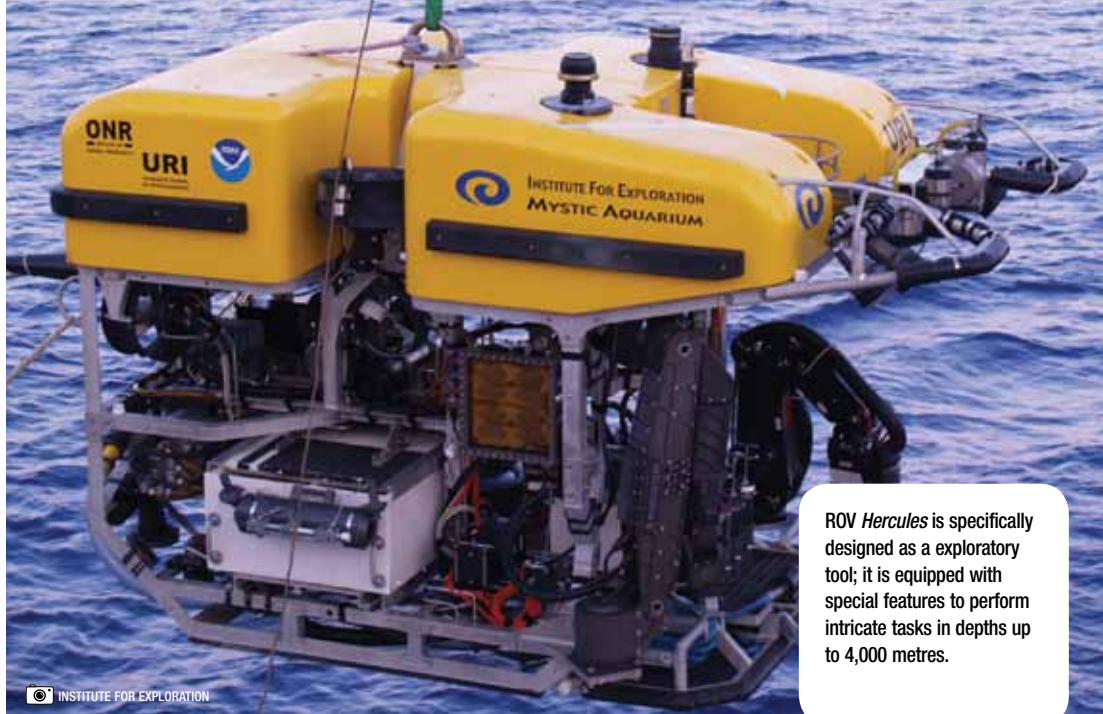
Today, Ballard is leading a global exploratory program to further unlock secrets that lie in the deep ocean, while bringing science to life for young people by including them in the discovery process. Outfitted with a full crew, a scientific director and a teacher, the Ocean Exploration Trust’s E/V *Nautilus*, itself a sophisticated system of technologies, roams the oceans, using ROV and remote sensing technologies to observe and record exotic marine life. The images recorded by high definition CCTV cameras are shared in real time with specialist scientists from around the world who help guide the exploration, while students in schools and youth-at-risk in the Boys and Girls Clubs watch and ask questions in real time. Harnessing a host of integrated information and communication technologies is what makes this form of “electronic travel,” which Ballard calls “telepresence,” possible.

“We couldn’t have done any of this without technology,” Ballard notes, “starting with a ship that has been outfitted with dynamic positioning technology; multi-beam sonar for imaging the seabed; deep ocean ROVs fitted with force-feedback manipulators, high-definition cameras and tremendous lighting systems, high bandwidth fibre optic cable to carry the data back to the surface; satellite technology to beam the data off the moving ship without losing the connection with a



Hawksbill Turtle swimming  
over coral reef.





platform in geosynchronous orbit; Internet 2 to get the data out to the scientists, and the Web to reach the students.”

One way of viewing the relationship between a scientist’s vision and the practical means of achieving it through technology, suggests Ron O’Dor, Senior Scientist, Census of Marine Life (Census), and Biology professor at Dalhousie University, is to see the two as partners in a marriage. He notes that “science tends to raise the big questions and then people go out and develop the technologies to allow the scientist to answer the questions.” In medical science, the need to cure disease leads people to develop scientific approaches which, in turn, generate the need for new technologies. O’Dor said this approach has been less common in his field, and cites as an example the inability of biologists to articulate a technology for understanding evolution. However, he added that genetics is taking a step in that direction by providing a tool to understand the relationships between organisms.

As the Census of Marine Life’s exploration of the oceans got underway, the rate at which new samples were coming in far exceeded taxonomists’ ability to classify them. It

would have taken 500 years to describe them using traditional methods, reports O’Dor. To dramatically shorten that gap, project scientists applied a technology from genetics that looks at 700 base pairs of DNA in a particular location in the organism’s DNA sequence. This method of identification provides enough information to distinguish the species, which is then assigned a unique barcode. “Even if the barcode didn’t get us to a description of a species, it was at least a placeholder,” explains O’Dor, as it could then be looked at by a specialist. Census partners put the picture of the animal and its DNA sequence online, and taxonomists looked at it to determine if it might be a new species – a far more efficient first step than travelling around the world and looking at specimens in museums. “Process technology solved the problem for science,” says O’Dor, “but it was, in fact, also a new kind of science.”

He cites acoustic tagging as another instance where technology is enabling science. The classic problem is: you know a certain fish species is in your bay, and you want to know more about it: its precise whereabouts, where it has come from, and where it goes when it ‘disappears.’ By implanting an acoustic transceiver in the fish and installing acoustic



listening devices on the ocean floor, the movements of fish can now be tracked, along with (opportunistically) the salinity and temperature of the water – important physical measures of the environment in which the fish are living. O’Dor explains that scientists have been concerned about the disappearance of sturgeons in California’s river systems. Thanks to acoustic tagging as part of the Pacific Ocean Shelf Tracking Project, they learned that sturgeon, an endangered species in California, spend about six months of their lives off the northern end of Vancouver Island, and some go as far north as Alaska. “The technology was a new driver for making a scientific discovery,” notes O’Dor. The problem was that some of the sturgeon were ending up as bycatch in fishing trawls outside of the area they were believed to live. “Now we have protection for the species up and down the coast,” he reports.

O’Dor heads up the Ocean Tracking Network at Dalhousie University in Halifax, which facilitates the global sharing of information about marine animals – from fish to birds to polar bears – enabled through implanted tags, acoustics, telemetry, and satellite communications. The metocean data is used to build a record of climate change.

The global reach of projects like the Ocean Tracking Network would have been unthinkable

in the days before modern information and communication technologies for collection, storage, analysis and transmission of massive amounts of data and information. The same is true for the work of Daniel Pauly, a professor at the University of British Columbia Fisheries Centre and Zoology Department and Principal Investigator of the Sea Around Us Project. His investigation of how the fisheries affect marine ecosystems led him to view “fisheries as part of an integrated system that acts globally as one.” Using geographic information systems and databases, Pauly has concluded that between 1950 and 1980, the lateral area covered by fisheries activities grew by about one million square kilometres per year. With the intensification of open-ocean fisheries in the 1980s, this expansion grew to three to four million square miles annually. He also notes that expansion into the ocean’s depth is also increasing, by several tens of metres per year, and that fisheries effort has been shifting to the south by about 0.8 degrees of latitude annually since 1950. “This expansion both in depth and to the south characterizes the fisheries as essentially never sustainable,” he says. “If you have to expand to maintain the catch, it means you are in trouble.”

Geographic information systems integrate diverse geographic datasets in ways that allow Pauly and his colleagues “to see relationships



Memorial University of Newfoundland's *Explorer* AUV is designed with a 3,000 metre depth capability and can carry 200 kg of scientific equipment.



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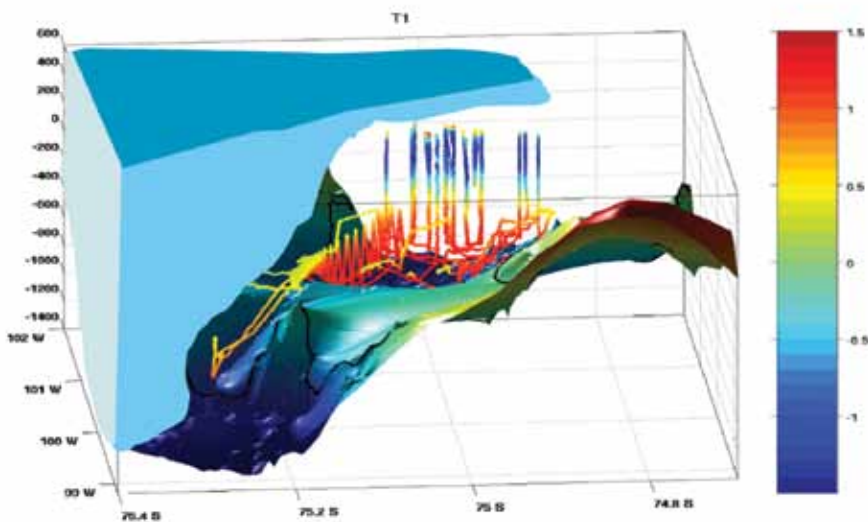
Algae and tube worms on coral reef.

between things that would have previously been seen separately.” For example, he talks about global forces that dictate why sardines caught in Senegal are reduced to fishmeal and sold to Europe to feed pigs and salmon, rather than being dried and shipped to the country’s interior where the protein will last without refrigeration. The database of fish catches he uses to do this analysis includes about one billion cells. “Technology allows us to see these linkages,” he observes, “and it enables science to occur on a level that was not possible without it.”

Using FishBase (a database that is also used within the Census Ocean Biogeographic Information System and the Ocean Tracking Network), scientists can reference vast amounts of information about a particular species to a point on a map. A rapid Internet connection enables them to infer ecosystem elements which helps them to make further discoveries. For example, if a school of orange roughly is sighted on a seamount, and since it is known that seamounts do not support primary producers, the scientist can infer that food has been brought into the area by currents.

He cites another instance of technology enabling science: the use of ROVs to document sites that support biodiversity, which can in turn help to protect them from trawlers. On the flip side of the coin, Pauly adds that in Chile, ROVs are used to photograph the seafloor underneath aquaculture cages to document the loss of biodiversity resulting from aquaculture operations.

Just as ROVs can aid science by venturing into areas beyond human reach, autonomous underwater vehicles (AUVs) are serving scientists in cold regions. “We now have technologies we can use to take systematic measurements under floating parts of the Antarctic ice sheet,” observes Gwyn Griffiths, Head of the Ocean Technology and Engineering Group at the National Oceanography Centre in Southampton, UK. Until recently, scientists had no way of knowing in detail the shape of the ocean floor underneath an ice sheet, where melting is occurring. The roughness of its underside affects the rate of melting, as does the shape of the ocean floor underneath. He explains that drilling holes through the several-hundred-metre-thick ice sheet and dropping instruments



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3D view under a section of Pine Island Glacier. The coloured lines show Autosub3 tracks, with the colour indicating the fraction of glacial meltwater, on the scale to the right.

through to take measurements does not give a complete picture of the cross-section underneath. “AUV technology allows us to get a comprehensive view beneath the ice sheet,” Griffiths says. “It’s no longer a black box. Technology has really opened that up.”

AUVs are also helping to estimate the abundance of krill which form the basis of the food chain in Antarctica. Griffiths explains that “by going stealthily under the sea ice” AUVs collect measurements that are more reliable than those captured by ice breakers which, when breaking ice, make noise that scatters the animals. Using these measurements, scientists discovered that the krill population peaked between one and ten kilometres inside the edge of the sea ice. “Knowing the distribution of krill under sea ice was a first for science, and AUV technology,” he exclaims.

The Antarctic Circumpolar Current transports about 150 million cubic metres of water per second through Drake Passage, between Antarctica and South America. The ability to take year-round measurements in this area, compared to the annual measurements currently collected by research ships, would improve oceanographers’ understanding of

the global ocean circulation system. Griffiths explains that what is needed is an AUV that is capable of a round-trip from the Falkland Islands to Antarctica, taking measurements from the surface to a depth of over 4,000 metres. “We feel we’re on the threshold,” he says. “We talk about these as aspirations and drive towards them.” Engineering trials for an AUV that could tackle such a mission were carried out successfully in January 2011.

Funded by the National Science Foundation, United States Antarctica Program marine scientists are also using gliders (a special type of AUV) to locate a certain type of water mass known as the Modified Circumpolar Deep Water (MCDW). Supported by Raytheon Polar Services (RPS) marine technicians, the gliders are pre-programmed to look for parameters associated with the MCDW. They are sent out, and when those features are located, the gliders surface and relay the information via satellite which is then downloaded at the home base. Dan Herlihy, RPS Manager of Marine Science Operations, points out the advantage of being able to do this kind of reconnaissance before setting out on a cruise. “Before this,” he says, “we would have used the best prediction models and it would have been hit or miss.





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In Seychelles during October whale sharks gather to head south; there they are tagged to monitor their population over the years.

Using the gliders can save having to steam around for several days at a time, at a cost of \$50,000 to \$60,000 a day for ship time.” The gliders are engineered at the Rutgers University Institute of Marine and Coastal Sciences Coastal Ocean Observation Lab.

Another technological innovation that Herlihy’s team has recently adopted is a new type of oceanographic winch cable used to deploy instruments over the side of a ship. In the past, oceanographers used electromagnetic cables to control sub-sea instruments. With new hybrid electromagnetic-fibre optic cables, they can now control multiple instruments simultaneously. Whereas the old cable

“struggled to carry even a low-resolution signal,” the new cables carry four independent high-definition video signals, a gigabyte of data, Ethernet, and hundreds of serial communication channels.

“Previously we would, for example, send a coring device down blindly hoping that it would hit the type of sediment that we wanted to sample,” says Herlihy. “Now we can put a camera system above the coring device and wait until we actually see the type of sediment we want to sample before tripping the device. This guarantees a nearly 100% return on our time investment. Before, if we had a 50% return, that would have been considered high. This cable opens up to the scientific community a whole different avenue for the types of sampling that can be done.”

Technology has also been a key enabler in the field of ocean observation, notes Tom Gross, Program Specialist, Global Ocean Observing System, with UNESCO in Paris. He cites developing communications between instruments and storing the data as an example, and adds that “the data communications field has totally transformed our ability to do ocean observation.”

He points to the Argo float which the World Ocean Circulation Experiment introduced 20 years ago. This autonomous instrument sinks to 2,000 metres, then changes buoyancy and rises toward the surface taking temperature, salinity, and depth measurements along the way. Once on the surface it transmits the data using satellite communication. “The Argo float has been fundamental to knowing how ocean water circulates,” Gross says, “and to establishing the pressure gradients that drive ocean circulation. For the past four or five years, we’ve had 3,000 or more of these instruments bobbing up and down and giving us 3D ocean data the likes of which we had never seen before. This single piece of technology is transforming science for numerical modellers and statisticians, and opening up an entirely new way to do physical oceanography.”



Cod caught using baited pots – a sustainable method to harvesting – enable harvesters to achieve a higher price for their product as the cod pots help to maintain the quality of the fish. The pots also enable scientists to improve their stock assessment process: fish can be captured for tagging and lower mortalities are noted when compared to other methods.



Gross says the Argo float system would not be possible without satellite communications, indicating the synergistic way that one technology often enables another. “And when a new technology does develop,” he adds, “most likely some great new science will come out of that.”

Sometimes, when science benefits from technology development, it is an unintended consequence. When the Centre for Sustainable Aquatic Resources at the Fisheries and Marine Institute of Memorial University in St. John’s developed cod pots for catching Northern cod their goal was to provide fishermen with a sustainable way to catch this revered Newfoundland resource. Little did they know it would also help scientists improve their stock assessment process by providing an improved method of capturing live cod for tagging. Cod swim into the baited cod pots sitting on the ocean floor and cannot exit. If the fisherman has to leave the pots longer than expected due to rough weather, the cod remain alive, and none of the fish have to be discarded when the pot is hauled in.

More than 95% of cod-pot cod survive the tagging process, reports John Bratney, a research scientist with Fisheries and Oceans Canada. “The cod pot provides the best method for capturing fish for tagging, and results in lower mortalities compared to other methods such as otter trawls.”

“We’ve tagged cod-pot cod over a large geographic area and have more confidence about the number of these tagged fish available for subsequent recapture,” says Bratney. “This should give us better estimates for fishing mortality. Since there are more tagged fish available to the fishery, this should improve scientific estimates of the fraction of the stock removed by fishing.”

There is no question that the relationship between science and technology is more symbiotic than hierarchical. In some cases the technology has been developed in response to

a particular scientific objective. This was the case, for example, with Argo floats. In some cases, technology has been developed without a specific application in mind (for example, the Autonomous Benthic Explorer developed at Woods Hole), but was then found to be particularly useful for scientific investigation in the deep ocean. In some cases, technology developed for other purposes (for example, ROVs) are being applied to science. And in many other cases, technology from other fields such as geomatics, information and communications technologies, etc. are being adapted for use in the ocean realm. Whatever the lineage, there is no question that technology is enabling scientists to study and understand the oceans in new and exciting ways.