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Transformation

Ocean Tech: Explorers

26 November 2024

Key takeaways

- The ocean covers 75% of the Earth's surface, yet there's so much we still don't know about it. In fact, we have only mapped around 26% of the global seafloor and are unaware of at least two-thirds of marine species. But analysis of ocean data can bring many benefits, including helping to better forecast the impact of a changing climate, predict undersea earthquakes and tsunamis, map marine life and establish subsea communications connections.
- Bank of America Institute's three-part 'Ocean Tech' series explores ocean technologies through three lenses: Transformers, Explorers, and Savers - all focused on entry points that interrelate with the ocean.
- In part two we discuss 'Explorers,' innovations that allow us to understand the ocean, including submersibles, AI, the 'ocean of things,' sensors, and sonar/LiDAR (light detecting and ranging) technologies.

Deep diving

As mentioned in the first part of our Ocean Tech series (see: Ocean Tech: Transformers), the ocean is critical to both our existence and our transforming world, but the opportunities it offers are often overlooked. To deep dive (pun intended) into what's possible when it comes to understanding the ocean and expanding the ways we interact with it, BofA Global Research identified three entry points. Today, we'll discuss the second.

- **Transformers** help us adapt the ocean and unlock ocean resources (e.g., subsea cables, underwater data centers, marine pharmacology, scarcity solutions, tidal energy, ocean real estate)
- **Explorers** allow us to understand the ocean (e.g., submersibles, marine security, AI, ocean of things, sensors, sonar/LiDAR (light detecting and ranging))
- **Savers** help restore ocean health (e.g., aquaculture, carbon removal, ocean waste clean-up)

Unchartered water

The ocean covers 75% of the Earth's surface, yet there's so much we still don't know about it. In fact, we know more about the surface of the Moon and Mars than we do about the deep sea. For instance, did you know that the deepest point of the ocean is ~6.8 miles down, 1.25 times deeper than the height of Mount Everest?

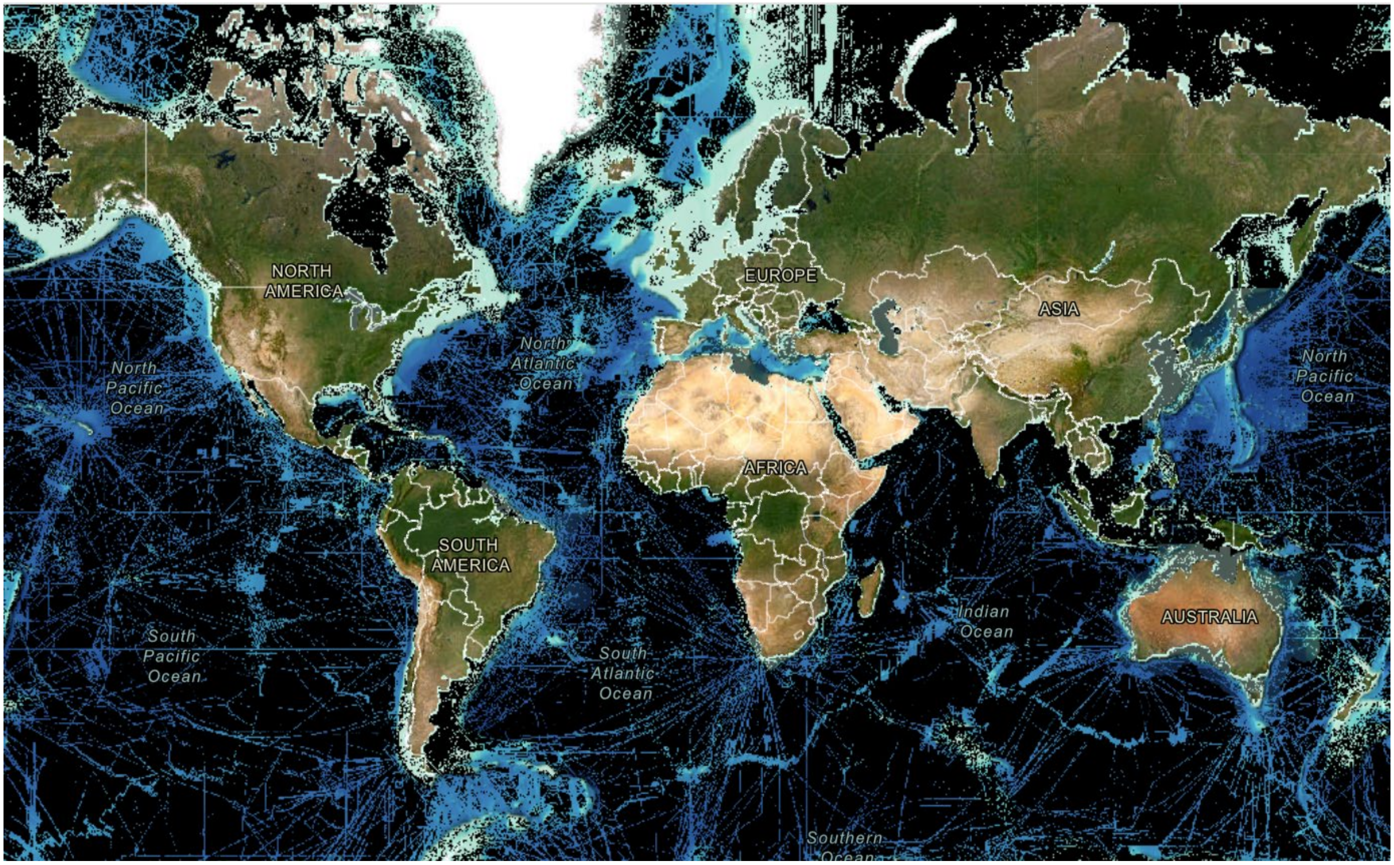
Yet, to date, we have only mapped about a quarter of the global seafloor with high-resolution technology. If you search for images of the seafloor on the internet, you get lots of pictures showing the variation in the ocean's depth (bathymetry). However, these are not maps but predictions of seafloor depth, estimated from changes in satellite measurements of gravity, and their resolution isn't good enough for real-world applications.

So, why haven't we mapped more? To map land, we rely on sending and recording wavelengths of light which can produce highly detailed images in a few days. However, light does not go through seawater beyond the first few hundred feet, which means we need alternative methods for mapping the seafloor. Additionally, the average ocean depth is approximately 2.3 miles – that's 4.5x the height of the Burj Khalifa, the world's tallest structure – so we need vessels that can withstand the pressure.

Today, bathymetric surveys help us understand the shape and composition (hard or soft texture) of the seafloor. This is important because both attributes affect the physical and biological processes in the ocean. The Nippon Foundation-GEBCO Seabed 2030 Project, typically referred to as Seabed 2030, is a global initiative to map the entire seafloor by 2030. It was set up in 2017, when only 6% of the ocean floor had been mapped to an adequate resolution. As of June 2024, about 26% has now been mapped (Exhibit 1).

Exhibit 1: As of June 2024, only ~26% of the ocean floor has been mapped to modern standards

Areas that are based on direct measurement (mapped) with color vs. areas based on indirect measurements (unmapped) in black.



Source: The GEBCO Grid, Earthstar Geographics, Esri, TomTom, FAO, NOAA, USGS, Seabed 2030. NOTE: Mapped: based on direct depth measurements - shows us characteristics of the ocean floor to the greatest detail and accuracy. Unmapped: never measured before or based on indirect depth measurements, e.g., interpolation or prediction - not to the greatest detail or accuracy hence are typically blurred out. Black is uncharted ocean. Colored is what has been mapped.
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At least two-thirds of marine species remain unknown to us

While knowledge of the seafloor can help us understand where potential habitats are located, it cannot identify marine species. We know more about the seafloor than the species that live in the ocean. How? Well, scientists estimate that there may be between 700,000 and one million marine species out there, of which at least two-thirds have yet to be discovered.[1] And identifying these could be key for marine-based pharmacology, next-gen beauty products or even ‘future fish.’

But wait, there’s more

Apart from mapping the seafloor and better understanding marine life, there are also other datapoints we can gather. These can be categorized as physical variables (temperature at the surface and at depth, salinity distribution, density of water/ice, sea-level rise), biochemistry (oxygen, nutrients, carbon, nitrogen oxide, carbon dioxide absorption), biology and ecosystems (species abundance, fish stock assessments, biodiversity, mangroves, or coral cover) and cross-disciplinary variables (ocean sound, ocean colour, underwater installations, positioning of cables, shipping routes, debris).[2]

At the global level, the main type of data archived by ocean data centers is physical data, followed by biological and then chemical data.[3] Less than half of ocean data centers provide data on pollutants or fisheries, and the top three ocean data/information products provided by ocean data centers are metadata, geographic information system (GIS) products and raw data access.[4]

[1] National Oceanic and Atmospheric Administration (NOAA)
[2] HubOcean
[3] United Nations Educational, Scientific and Cultural Organization (UNESCO)
[4] United Nations Educational, Scientific and Cultural Organization (UNESCO)

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Why do we need to explore the ocean?

- **To help forecast climate change:** The seafloor influences the behavior of ocean currents and vertical mixing of water. Because oceans play a critical role in moving heat around the planet, we can forecast future climate change with this information. In turn, we would also get a sense of how sea levels might rise in different parts of the world, which would improve prediction models related to weather and climate, tsunami impact zones and rises in sea levels. Additionally, countries would be able to prioritize conservation efforts to improve fish stocks and coral reefs.

  Bathymetry (or the study of the seabed, mentioned above) is crucial to understanding how ocean waters influence ice sheets and how they melt and raise sea levels. Without this, ice sheet models are limited. It is also key to understanding the cycling of heat and nutrients in the ocean.

- **To predict undersea earthquakes:** In places where tectonic plates collide (convergent boundaries), one plate will often slide under another. This process (called subduction) produces mountain ranges and volcanoes. Most undersea earthquakes and volcanoes are concentrated near faults in the seabed. High-resolution seabed mapping can help predict geologic events, including tsunamis, before they happen and minimize negative impacts on nearby communities by providing advanced warning.

- **To forecast tsunamis:** Buoys located in strategic spots throughout the ocean can gather data on the sea surface levels as a tsunami travels past them. After a tsunami is generated by an earthquake, a sensor located at the ocean floor communicates with the DART (deep-ocean assessment and reporting of tsunamis) buoy on the surface and can send information about the magnitude of the tsunami. On average, a tsunami can arrive at the closest coastline within around 20 minutes of an earthquake occurring, which can be critical advanced notice to minimize impact on nearby communities.

- **To map marine life:** Some undersea mountains (seamounts) are inert and often have high levels of biodiversity because their variable elevation creates different habitats. In turn, they are important for food production as many fisheries are located near these biodiversity hotspots. With high-resolution mapping, scientists can develop a clearer picture of life under the sea, manage fish resources and protect marine biodiversity. Scientists can use unmanned saildrones and pop-up buoys to collect information on temperature, salinity, chlorophyll and more.

  Additionally, scientists can process eDNA (environmental DNA, i.e., genetic material shed by organisms in the water column) to make new discoveries about marine life by collecting samples of mucus, feces, or tissue particles.[5] These samples can be compared to others in a DNA database and the organism can be identified down to its family, genus, or species.

- **To make communication connections:** There are over 800,000 miles of submarine data and communications cables across the seabed – enough to encircle Earth 32 times. While submarine cables are heavily reinforced, they are still liable to failure when placed on areas of the seabed that are near potential geologic agitation (e.g., volcanoes). With high-quality seafloor maps, cable-layers can avoid these areas.

- **For navigation:** At any given moment, thousands of ships are at sea. As the ocean grows busier, seabed maps are important to minimize environmental issues caused by damaged or disabled sea vessels and mitigate both logistical and infrastructure risks.

- **For energy:** Knowing more about the ocean can help us understand how oil pipelines, offshore drilling areas and wind turbines interact with other forms of marine activity.

The Explorers

The future analysis of ocean data has the potential to benefit many. As mentioned above, it could better forecast climate change, predict undersea earthquakes and tsunamis, map marine life and establish subsea communications connections. But to enhance our knowledge and understanding of the ocean, we need to collect and harness ocean data using technologies like submersibles, the ocean internet of things, sensors (e.g., sonar), satellites and AI, and here we discuss what's out there and what's next.

[5] National Oceanic and Atmospheric Administration (NOAA)

Submersibles

Submersibles are underwater robots deployed from ships into the sea where they can record and collect information about the ocean and its seafloor for scientific analysis. There are three main types of submersibles: 1) HOVs (human occupied vehicles), which are equipped with lights, cameras, sensors, manipulator arms and collection instruments, 2) ROVs (remotely operated vehicles), which are tethered underwater robots that allow control signals to be sent and received directly between topside operators and the subsea vehicle, as well as collect samples via a manipulator arm operated by a pilot, and 3) AUVs (autonomous vehicles), which are equipped with advanced sensors, enabling them to map the ocean floor, study marine life, and even detect pollutants, without real-time control by human operator.

Features of AUVs

AUV submersibles typically have relatively shallow working depths and range in size from lightweight to large diameter vehicles of over 32 feet in length. Smaller vehicles benefit from easier logistics (e.g., support vessel footprint, launch and recovery systems), while larger vehicles have advantages in terms of endurance and sensor payload capacity.

Additionally, AUVs do not require space for life support equipment or supplies (i.e., room for sleeping areas, food, water, air supply equipment, etc), which implies initial cost savings in manufacturing as well as savings in sustainment costs compared to manned vessels. This also means that AUVs can launch for longer periods without the need to return for resupply (i.e., they are energy source dependent), so for smaller AUVs, this can mean months at sea. Examples of AUV applications include:

- **Marine research and exploration:** Scientists use AUVs to study bodies of water including the ocean and the ocean floor. A variety of sensors can be put onto AUVs to measure the concentration of elements/compounds and the presence of microscopic life.

- **Environmental monitoring and conservation:** AUVs can help assess and monitor the health of coral reefs and other ecosystems. Specialized sensors can monitor water temperature, acidity levels and nutrient concentrations, giving insight into the health of these ecosystems.

- **Oil and gas:** The oil and gas industries use AUVs to make detailed maps of the seafloor before building subsea infrastructure so that pipelines and subsea completions can be installed in the most cost-effective way.

AUV challenges

- **Communication:** Radio waves do not travel far through water, but submersibles can use acoustic communication to determine where they are. While this sound travels long distances of up to ~3,200 feet, it is generally too slow to transmit video signals from the platform to a ship or shore because water refracts and delays signals, and as such, the ability to transmit and receive wirelessly becomes impaired. Some AUVs work in tandem with a host or "mother" ship that can act as a base for communications and energy resupply, but because of communication challenges, AUVs must be programmed ahead of time. Once a mission is complete, they are returned to the surface to offload their data.

- **Darkness:** There is very little natural light below 650 feet in the ocean and below 3,000 feet there is no sunlight at all. However, underwater vehicles need lots of light for their cameras to see, so need to position light sources far away to prevent reflection off 'marine snow' – tiny organic particles.

- **Navigation:** Global positioning systems (GPS) use signals from orbiting satellites to calculate position on land, in the air, and even at sea. These signals, however, cannot reach AUVs once they submerge below shallow depths as they are refracted and delayed by the water. Radio frequencies are similarly affected, which means without an undersea relay system, a AUV would have to surface to both communicate and receive location data.

  Therefore, AUVs and submarines may need different navigation systems. Quantum navigation could meet this requirement. Quantum communication may be needed to counter advances in quantum cryptanalysis to secure the future of communication.

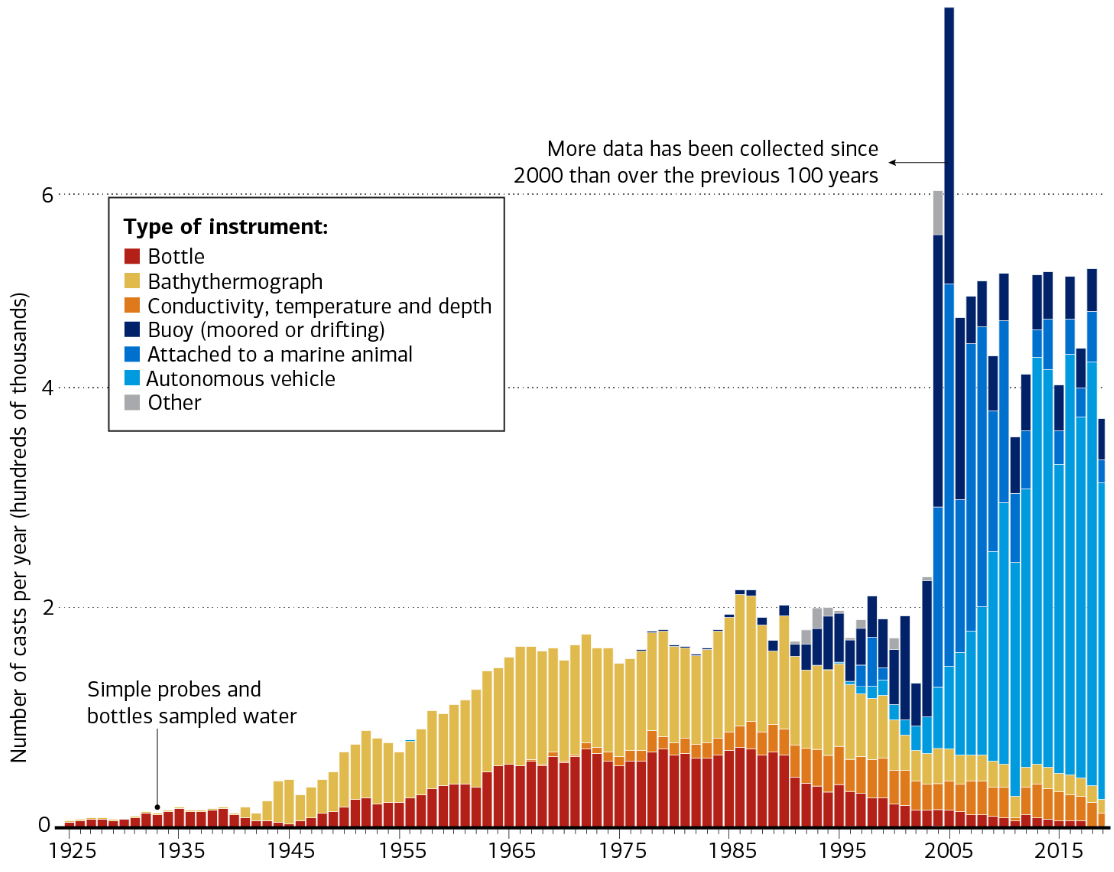
- **Corrosion:** Saltwater is an electrical conductor and accelerates the corrosion of metals immersed in it. Corrosion can cause failures in metal frames and pressure housings. Gold is very safe from corrosion but is not that strong and is expensive. Titanium is a good alternative, as it is lightweight, strong and affordable. Aluminium is strong but corrodes easily.

Artificial intelligence

The growing volume of data gathered by vessels will create demand for increasingly sophisticated analysis of that data e.g., leveraging AI. In fact, more ocean data has been collected since 2000 than over the previous 100 years and this will only grow. Additionally, AI enables 'continued learning' for vessels through machine learning techniques for autonomous navigation, obstacle recognition and avoidance of collisions.

Exhibit 2: More ocean data has been collected since 2000 than over the previous 100 years

Number of casts per year (hundreds of thousands) by instrument



Source: World Ocean Database; NOAA. Note: a cast is a set of measurements for a single variable, e.g., temperature or salinity at different depths. CTD stands for 'conductivity, temperature and depth', referring to a package of electronic instruments that measure these properties. A bathythermograph is an instrument designed to record water temperature as a function of depth.
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From the 'Internet of the Ocean' to the 'Ocean of Things' (OoT)

The ocean is changing rapidly, and it is the single biggest cog in Earth's climate engine, yet we have almost no observations of the subsurface ocean to understand how these changes are affecting the things we care about. One of the initiatives at Woods Hole Oceanographic Institution is to build the world's first internet for the ocean, called the Ocean Vital Signs Network. This large network of moorings and sensors will provide 4D eyes on the oceans – the fourth dimension being time – that are always on, and always connected to monitor carbon-cycling processes and ocean health.

Right now, there is only about one ocean sensor in the global Argo program (an international project that collects information from inside the ocean using a fleet of robotic instruments that drift with the ocean currents) for every patch of ocean the size of Texas. In the future, however, there could be a central hub in the middle of an ocean basin where a dense network of intelligent gliders and autonomous vehicles measures vital signs of ocean and planetary health. These vehicles can dock, repower and upload data they've collected and then go out to collect more, all while sharing information and making intelligent sampling decisions as they measure the chemistry, biology and eDNA for a volume of the ocean that's representative of how the ocean works.[6]

[6] The Conversation U.S.

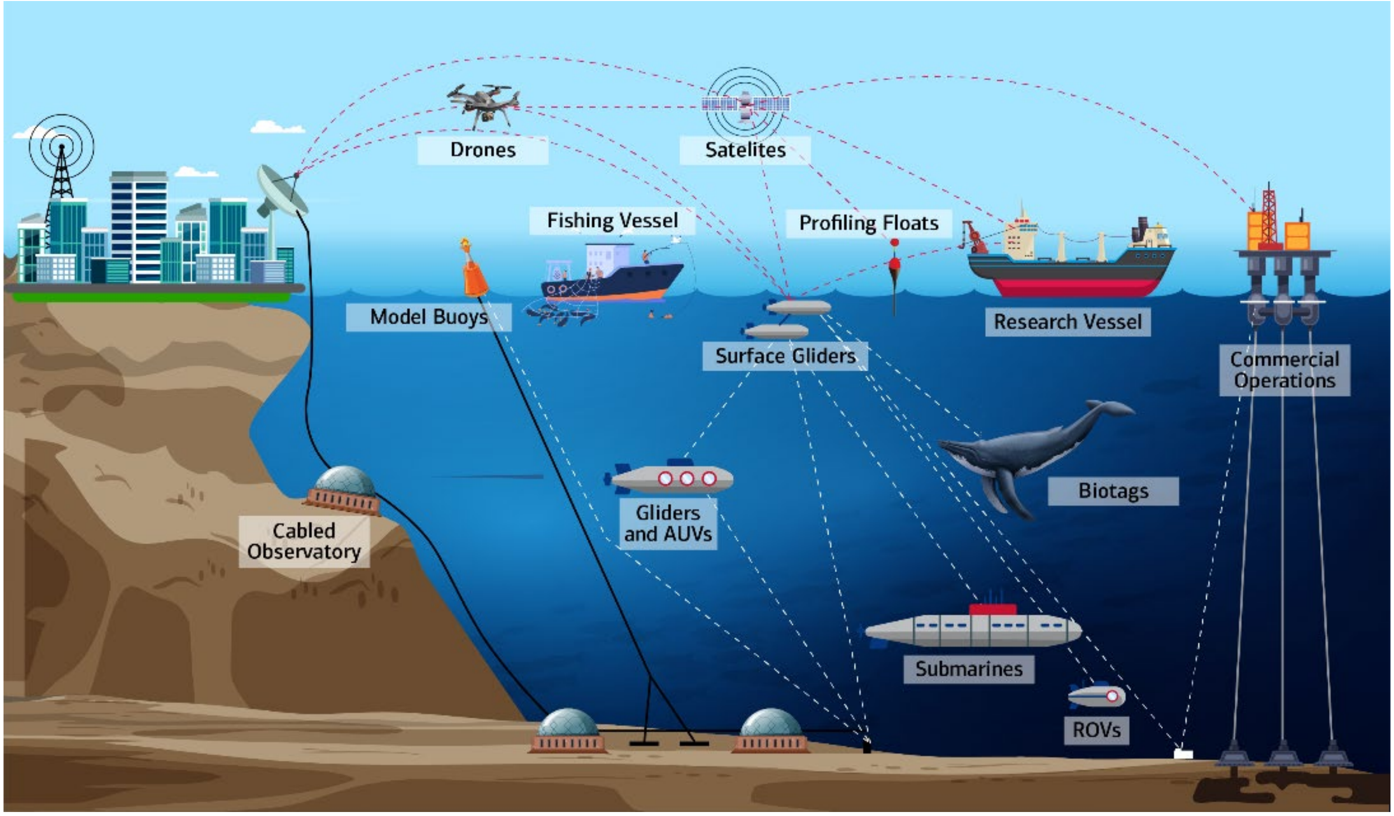
Satellites and Ocean combined to provide more data insights

While satellites can provide some information, DARPA (Defense Advanced Research Projects Agency) points out that there are gaps in their coverage – optical satellites cannot see through clouds, radar satellites only have limited coverage, and neither type can say much about what is going on underwater. Floating sensors, known as 'floats,' can gather far more detailed information, and remain at sea for months at a time. There is a network of almost 4,000 Argo science floats around the world, gathering data on ocean temperature and salinity.

A dense field of OoT sensors on or under the water will produce a mass of data of interest to oceanographers, meteorologists and biologists, with plans to share raw data online with researchers. The OoT may be able to monitor marine mammals like whales, watch hurricanes form from the inside, and track changes in ocean temperature.

Exhibit 3: Underwater IoT (internet of things) could look like floating sensors, swarms of crewless vehicles or a non-tethered, wireless robot

An infographic depicting the potential ocean internet of things (i.e., an OoT)



Source: Leape, J., M Abbott, H. Sakaguchi et al. 2020. Technology, Data and New Models for Sustainability Managing Ocean Resources. Washington, DC : World Resources Institute (WRI)
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Smarter ocean sensors are coming

New smart sensors, processes and techniques are generating significant improvements in sensitivity, accuracy, stability and resistance to harsh ocean conditions. Since the 1990s, there has been steady progress in automated sensing of key physical features such as current, salinity and temperature, and the past decade has seen advances in the form of novel in-situ sensors capable of monitoring some biochemical and biological features elements such as nitrates, methane and micro-nutrients. However, the road ahead is still long, specifically when it comes to biological and ecosystem-related sensors.

Single/split beam sonar

Sonar stands for 'sound navigation and ranging' and is a common way of mapping the seabed. There are two main types: active and passive. Active sonar systems emit a pulse of sound into the water, which then bounces off the seafloor, creating an "echo." Seafloor depth is calculable using the time difference between creating a sound and receiving its echo. Meanwhile passive sonar systems are quiet and detect environmental noise made by ships, submarines, and marine life.

The earliest sonar technology to be applied to seafloor exploration was 'single-beam sonar' consisting of piezoelectric crystals or ceramic transducers to generate and receive acoustic signals. The 1920s was considered to be the beginning of the echo-sounding era when single-beam sonar was used during the search for the Titanic wreck. Single-beam sonar is low-cost, small, and can be mounted on different observation platforms, even portable ones, depending on application scenarios. However, single-beam sonar is similar to a flashlight in that it can only illuminate a small area instead of a whole image of the environment.[7]

Multi-beam sonar

For large areas of geological survey, more efficient devices must be used, such as multi-beam sonar or side-scan sonar. Multi-beam can transmit a fan of beams simultaneously and receive echo signals to obtain signals over a swath of seafloor. It is more accurate and efficient than single-beam sonar. In fact, a state-of-the-art multi-beam sonar can have hundreds of beams and the swathe angle can achieve fuller coverage mapping. However, mapping the seafloor with multi-beam sonar is time-consuming. A ship must move slowly to ensure that there are no gaps in the mapping process.[8]

Side-scan sonar

Side-scan sonar is composed of two transducers equipped on tow fish (an underwater vehicle that is towed behind a ship to collect data or perform surveys), ships, or submersibles. Conventional side-scan sonar transmits sonar signals from both sides by transducers. Usually, a rugged, rough, and raised seafloor leads to a stronger echo while a soft, smooth, or depressed seafloor results in a weaker echo. The return sounds cast different shadows in the sonar image.[9]

(Bathymetric) LiDAR

Based on visible green light emission, bathymetric LiDAR (light detecting and ranging) enables the measurement of topography under water, which allows for crucial mapping of coastlines with continuity under water. Bathymetric LiDAR is one of the most effective and cost-efficient technologies to capture land and seafloor simultaneously in order to provide a detailed and continuous 3D elevation model along the coastline.

Bathymetric systems allow the capture of accurate data for coastline and shallow water mapping, acquiring base data for flood prevention, habitat mapping, measurement of aggradation zones, surveying for hydraulic engineering, hydro-archaeological surveying, generation of profiles of inland water bodies (rivers, lakes, channels), repeated survey of water reservoirs, canal surveying, landscaping, and surveys for planning and hydraulic engineering work.

LiDAR-sonar fusion

In the emerging innovation stage, LiDAR-sonar fusion, radar camera fusion, and georeferencing are disruptive technologies that are in the early stages of application and should be tracked closely. LiDAR solid state photodetectors, coherent LiDAR imaging, and GPS augmentation are some of the accelerating innovation areas where adoption has been increasing steadily.

Both LiDAR and Sonar collect and analyze data on the surrounding environment. LiDAR does this by collecting information through lasers whereas sonar does this through the emission of sound waves. LiDAR and sonar data can be fused to provide a more detailed picture on the surrounding environment.

Underwater communication

Due to the strong conductivity of seawater, radio frequency (RF) communications are severely attenuated in the ocean so cannot be used for underwater communication. Instead, underwater communication systems are composed of a transmitter, a communication channel, and a receiver. The transmitter can transmit information by modulating the information signal on the carrier signal. Widely used communication methods include fiber-optic, underwater acoustic and optical visible light communication.

However, the decades-long problem of communicating between underwater and the air remains unsolved. Underwater, submarines use acoustic signals (or sonar) to communicate and in the air, airplanes use radio signals like cellular or Wi-Fi – but neither of these signals can work across both water and air. In fact, submarines today still cannot communicate wirelessly with airplanes.

Currently, underwater acoustic communication is currently the most common method of communication underwater. The propagation loss of sound in seawater is much smaller than that of electromagnetic waves so this method of communication can span several kilometers by converting text, voice, image, and other information into electrical signals. After that, the encoder digitizes the information and then converts the electrical signal into an acoustic signal through a transducer. The acoustic signal will carry the information through the seawater medium to the receiving end. The other transducer will then convert the acoustic signal into an electrical signal and decode it to get the information.

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[7] National Center for Biotechnology Information (NCBI)
[8] National Center for Biotechnology Information (NCBI)
[9] National Center for Biotechnology Information (NCBI)

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Disclosures