White Paper

The New Economics of Marine Environmental Monitoring

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LIQUID ROBOTICS
A Boeing Company

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> *"An important constraining factor on the development of the ocean economy could prove to be the further deterioration in the health of the ocean."*
>
> OECD 2016

Executive Overview

The idea of widespread, persistent environmental monitoring in the ocean is generally written off as being prohibitively expensive and too complex. And using traditional methods, it is. But the growing quality and proliferation of unmanned systems and sensors is rapidly changing the economics of marine environmental monitoring.

This is not the time for business as usual. Traditional maritime industries such as shipping, fishing, and offshore oil and gas continue to grow in response to rising incomes and population growth. Newer sectors such as offshore deep-water oil and gas, renewable energy, aquaculture and seabed mining have also begun to play a major role in the economy. It's clear today that the growth of a sustainable ocean economy will be constrained unless we develop responsible, well-informed approaches to economic development and environmental management.

This white paper explores how transformative technologies such as unmanned systems allow commercial organizations, scientists, and governments to design more cost-effective approaches to better assess both the health of ocean ecosystems and the impact of commercial activities. The future of the ocean economy which is expected to reach $3 trillion by 2030[1] depends on it. By unlocking perceived constraints on ocean ecosystem monitoring, we can accelerate sustainable economic development.

[1] "The Ocean Economy in 2030," Organisation for Economic Co-operation and Development (OECD), 2016.

The Growing Importance of Environmental Assessment Reports and Monitoring

You can't manage what you don't measure. Yet, all over the world humans are drilling offshore wells, constructing aquaculture farms, and starting seabed mining (SBM). There is a need to better understand the ongoing and cumulative impact of activities on our ocean as this is often greater than isolated and regional activities.[2]

We lack scientific data about the direct effect of commercial activities on our ocean. But it's not hard to see the impact. Today, there are more than 400 "dead zones" in the ocean, covering 95,000km2 of water where marine life cannot survive; 75% of the world's coral reefs are at risk from local and global stresses; 380-million gallons of oil enter the ocean every year; and 90% of global fish stocks are overfished or fully exploited.[3] The unfortunate truth is that while the ocean economy may be growing, the ecosystems that provide its foundation are in jeopardy.

Organizations like the OECD have warned that "an important constraint on the development of the ocean economy is the current deterioration of its health."[4] To effectively manage this resource, it's imperative that we better understand the impact of commercial activities throughout the lifecycle of projects.

Stages of the Environmental Monitoring Lifecycle

- Pre-installation surveys and baseline studies
- Impact monitoring during build or installation
- Environmental monitoring during operations
- Decommissioning and post-operational surveys

Lifecycle monitoring enables us to better understand the existing marine ecosystems and to effectively protect and track mankind's impact on the environment and marine life. It can also help industry identify natural resources, improve project siting, increase the safety and efficiency of operations, and avoid politically and financially damaging environmental impacts.

Highlights

The rapid expansion of the ocean economy challenges the health of the maritime environment. Environmental assessments and impact statements evaluate the impact of multiple factors and are critical tools for monitoring the impact of commercial activities throughout the lifecycle of a project.

[2] "It All Adds Up: Enhancing Ocean Health by Improving Cumulative Impacts Analyses in Environmental Review Documents," Stanford Environmental Law Journal, 2014.

[3] World Resources Institute, UN Food and Agriculture Organization, US National Resource Council, NOAA.

[4] "The Ocean Economy in 2030," Organisation for Economic Co-operation and Development (OECD), 2016.

Challenges of Traditional Approaches

The ocean is a large, complex, and harsh operating environment. Gathering data from it has been both difficult and expensive. And the farther from shore the operation, the greater the cost and risk. It can cost millions of dollars just to get scientists or buoys to offshore projects. Given the high operational and maintenance costs of traditional solutions, regulators and resource managers frequently lack cost effective tools to gather data before, during, and after a project's completion. This lack of data can result in delays, project cancellation, or ineffective regulations.

Traditional approaches for ocean monitoring involve the use of ships, buoys, or satellites, which suffer from numerous limitations:

Ships: The long-preferred choice of scientists and industry alike, equipped research vessels are highly mobile platforms with extensive capacity for scientists and their equipment. However, they're also extremely costly to operate. Food, fuel, and personnel costs can easily exceed $20,000 per day. These high operating costs limit the frequency and duration of missions. In the best of cases, manned missions can provide useful snapshots of data over relatively short periods of time. But they are not economically suitable for collecting continuous, real-time data over long durations. Operations located far offshore are even more costly to monitor from a vessel.

Buoys: Sensor-enabled buoys provide the benefit of continuous data collection from a fixed location, thus overcoming the temporal density limitations of manned missions. However, they are limited to measuring conditions within a relatively small area, and they can be expensive to deploy and maintain. The cost to purchase and deploy a stationary buoy network often starts in the millions of dollars and increases with the complexities (e.g., how far offshore), risk, and ambitions of the deployment. Additionally, it can take months to repair buoys, which can reduce the uptime of a buoy network.

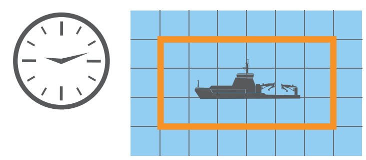
Satellites: Offering the advantage of extremely large coverage areas, satellites can be a useful platform for monitoring ocean surface conditions. But they can suffer from very low resolutions (on the order of 1km2), susceptibility to atmospheric conditions like cloud cover and sun angle, and the inability to measure conditions below the surface.

The high cost of these approaches severely limits their effectiveness for environmental monitoring, forcing undesirable tradeoffs between spatial and temporal density. Operators can either monitor a wide area for a short timespan or a small area for a longer duration. In many projects, these constraints make it practically and economically impossible to collect the data needed to accurately assess the environmental impact of a project throughout its lifecycle.

Highlights

The high cost of conventional monitoring platforms has left large information gaps and impeded the design of sustainable approaches to economic development in the ocean.

Traditional tradeoffs



Large area, short duration, point-in-time data

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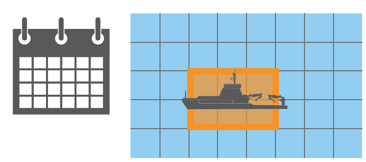
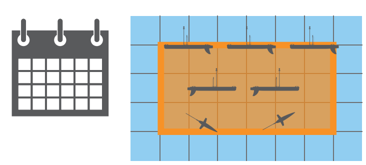


Small area, longer duration, local data

New economics



Large area, longer duration, comprehensive data

The Digital Ocean Will Change the Economics of Data Collection

The twenty-first century has seen an explosion in information across all areas of life. Today, we're surrounded by billions of sensors, in everything from mobile phones to the electricity grid; cheap, powerful microprocessors enable embedded intelligence and automation; and real-time connectivity gives us immediate access to information from anywhere. The connections enabled by these new technologies has fundamentally transformed the world around us on land, in the air, and in space, but not at sea.

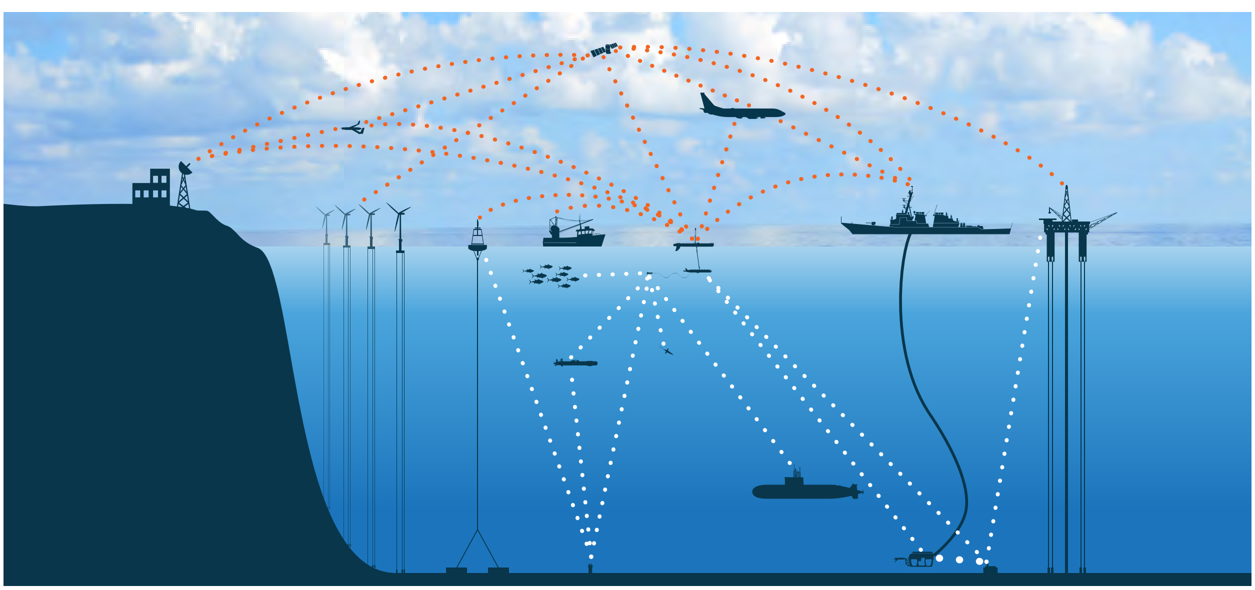
The unique operating requirements of the maritime environment have impeded the adoption of these technologies at sea. Maritime systems must be able to withstand everything from corrosion to hurricanes, while potentially operating thousands of miles from shore. Systems must be extremely robust and reliable, because it can be costly and time consuming to repair or replace them. Communication is also more challenging in the ocean, since signals cannot travel from far below the water to the air without the assistance of a gateway device.

Highlights

The Digital Ocean will be billions of sensors connecting the seafloor, surface, and space, making persistent, real-time access to ocean data a reality. New technologies are bringing down the costs of maritime data collection by automating a variety of tasks.

Yet, it's clear that we need these technologies—and the answers they can provide—more than ever. A lot of work has been done over the last two-decades to develop an entire ecosystem of autonomous maritime systems, from subsea sensors, to underwater vehicles, to smart buoys and unmanned surface vehicles on the surface. These systems have been deployed all over the world to help us better understand how the ocean environment is changing, to track and monitor marine life, and to automate tasks like seismic surveys, maritime surveillance, and meteorological and oceanographic (metocean) data collection.

A new vision is emerging. The Digital Ocean—powered by a vast network of unmanned systems and sensors—is transforming the economics of maritime data collection, giving us access to the same kind of information and control capabilities that we've come to expect on land.



Environmental Monitoring and Assessment in the Digital Ocean

Technologies like the Wave Glider are enabling the Digital Ocean and unlocking new models of environmental monitoring with lower costs and new capabilities. By breaking through traditional cost and risk barriers they enable missions that were previously too costly or dangerous. These and other new tools can now provide the data needed for new regulatory frameworks that will enable us to better assess the environmental impact of human activities in the ocean.

Mission Example: Persistent Hydrocarbon Monitoring

The ocean is rich in resources like oil. Yet, locating and safely extracting these resources can be a costly endeavor. Today, operators can use an unmanned surface vehicle like a Wave Glider to not only reduce the cost of seismic surveys but also cost-effectively monitor the environmental impact of oil fields. Wave Gliders can perform surveys prior to drilling to determine baseline hydrocarbon concentrations and assist with the setting of threshold values; they can continue to operate through the life of the field to detect leaks or spills; and they can monitor after decommissioning to ensure that there are not any adverse long-term impacts.

Highlights

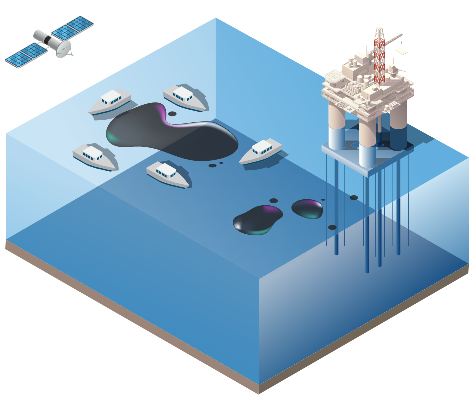
A Digital Ocean will make it possible to cost-effectively monitor and mitigate the environmental impact of commercial activities throughout their lifecycle.

These capabilities were demonstrated in the aftermath of the Deepwater Horizon disaster. BP deployed a fleet of four Wave Gliders to monitor water quality and detect any subsequent hydrocarbon events. As part of the deployment, Wave Gliders also logged data on marine mammal activity and measured currents, providing additional insight into the broader impact of the oil field on the environment and ecosystem.

It would have been expensive to implement this level of persistent environmental monitoring using manned assets. Crews get tired. Ships need to refuel. And the operating expense of running a vessel around the clock for months or years at a time would sink any budget. In contrast, with autonomous systems like Wave Gliders, operators can make a relatively small CapEx investment to avoid the high OpEx costs of persistent, lifecycle monitoring.

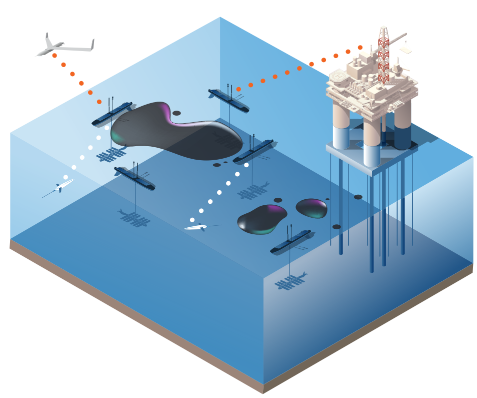
Traditional tradeoffs

- 24/7 monitoring is expensive
- Weather constrained operations



New economics

- Lower risk and cost of monitoring
- In situ monitoring, tracking, and validation



Environmental Monitoring and Assessment in the Digital Ocean (continued)

Mission Example: Fish Stock Assessment

Conducting acoustic fish surveys using ships is expensive (about $20,000 USD/day), which typically limits the duration and frequency of surveys. Yet, these surveys are critical to ensuring the responsible, sustainable management of fisheries, and for understanding the impact of other commercial activities on marine life.

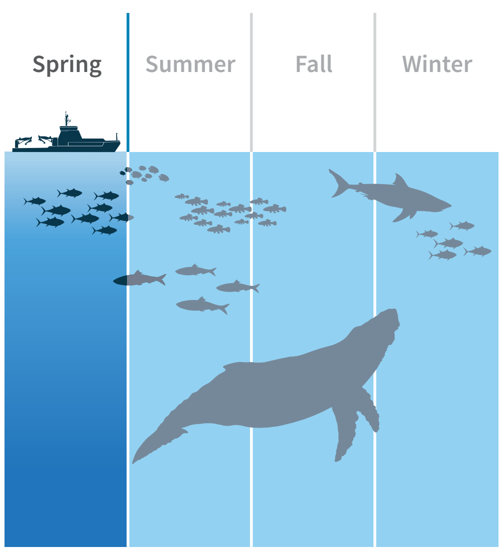
The Council for Scientific and Industrial Research (CSIR) has demonstrated how Wave Gliders can be used to augment traditional ship-based surveys to gather fish migration data more frequently and at a lower cost. Working with the Department of Agriculture Forestry and Fisheries (DAFF) in South Africa, CSIR deployed Wave Gliders to detect schools of fish over large bodies of water and perform biomass surveys in tandem with a research vessel. The data was 100% compatible.

The ability to gather fishery data more frequently and at a lower cost can help governments and scientists better understand and manage fisheries. It could also enable the fishing industry to improve the amount of fish it catches while ensuring the sustainability of their activities.

Conducting acoustic fish surveys using ships is expensive (about $20,000 USD/day), which typically limits the duration and frequency of surveys. Unmanned surface vehicles like a Wave Glider can perform surveys throughout the year for a fraction of the cost.

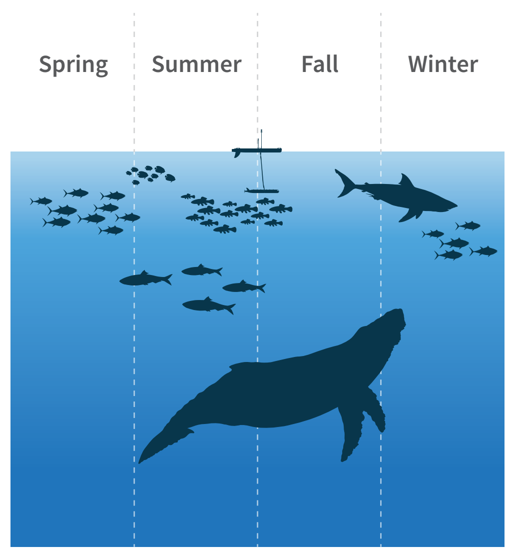
Traditional tradeoffs

- High cost limits frequency of survey
- Point-in-time assessments



New economics

- Persistent monitoring improves precision and accuracy
- Define lifecycle patterns of fishery



Environmental Monitoring and Assessment in the Digital Ocean (continued)

Mission Example: Coordinated and Mobile Ocean Monitoring

The Monterey Bay Aquarium Research Institute (MBARI) initiated a multi-year project called CANON (Controlled, Agile, and Novel Observing Network) to better understand marine microorganism lifecycles, including plankton bloom dynamics. This experiment required coordination and communication with multiple autonomous underwater vehicle (AUV) platforms, buoyancy gliders, drifters, and multiple ships including near-real time, coordinated observations made in the drifting Lagrangian frame.

To enable coordination and communication across multiple maritime systems in the ocean, researchers at MBARI created a Wave Glider-based hotspot, enabling a mobile and real-time monitoring system that could respond to changing conditions. MBARI has successfully used and refined the hotspot over several years enabling applications that permit coordinated robot activity and help scientists to get better data. Three primary applications for the Hot Spot include:

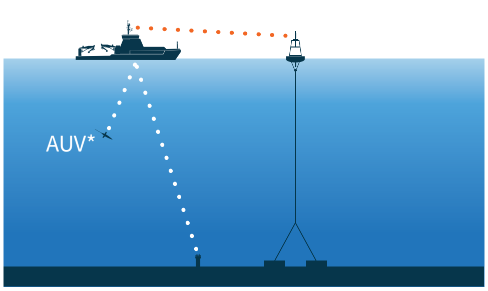
While the telemetry relay and acoustic tracking functions that the Wave Glider performs can be performed aboard a crewed ship, the cost of a ship is about 50x higher.

- **Gateway console** – Connect to Benthic moorings and instruments on the seafloor to locate, change roles, or adjust parameters
- **Track / Follow AUVs** – Track AUVs and or follow a patch of water over the horizon; recall a vehicle if a new mission is desired
- **Geolocate** – Locate undersea sensors and robots such as a profiling float at 650M or a Benthic rover as deep as 4000M

While the telemetry relay and acoustic tracking functions that the Wave Glider performs can be performed aboard a crewed ship, the cost of a ship is about 50x higher. The Wave Glider also allows MBARI to re-direct ships towards more valuable activities.

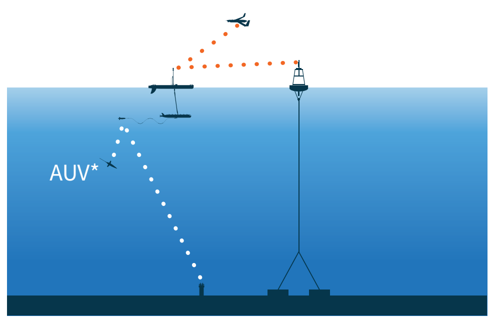
Traditional tradeoffs

- Crewed ship costs 50x higher
- Operations highly sensitive to sea state and weather



New economics

- Network effect of unmanned systems working together
- UAVs get back to work faster



* Autonomous Underwater Vehicle (i.e. buoyancy glider)

Environmental Monitoring and Assessment in the Digital Ocean (continued)

Additional Environmental Assessment Applications

- Establish baseline data to determine the impact of fishing (ocean and aquaculture), subsea mining operations, and transportation on ocean ecosystems
- Remote measurement and sampling of water quality during events to better model impacts and long-term trends
- Track marine life activities to understand how commercial activities influence migration patterns, breeding, and fish stocks
- Monitor currents, wave height, and meteorological conditions to improve operational efficiency and safety
- Detect early indicators of leaks, seeps, and other events before they turn into large-scale disasters

Of course, the availability of new technology tools, even as prices drop, doesn't mean that they will be adopted. For example, one problem with understanding worldwide fish stocks stems from the fact that most fishing organizations are comprised of small groups of individuals with relatively small revenues relative to other national industries. They don't have the resources or capability to monitor fish stocks. And they typically lack the influence required to convince governments to invest in new types of data collection programs. Ensuring more sustainable fishing requires more than new data, it requires new approaches to setting policies that promote more sustainable fishing.[5]

[5] "How to turn around the overfishing crisis," www.edf.org/oceans/how-turn-around-overfishing-crisis.

About the Wave Glider

Liquid Robotics is helping to close the ocean knowledge gap with the Wave Glider platform. Wave Gliders are long-duration ocean robots that help scientists, businesses, and governments gain new insights and improve decision making. Operating at the surface, they provide the essential link between sea, air, and space, transforming subsea sensors into real-time information sources, and bridging a data and access gap previously inaccessible.

The Wave Glider platform is at the forefront of the ocean transformation, helping to monitor and coordinate activity across platforms. It can autonomously operate in a range of ocean conditions, dynamically respond to changes, and provide real-time access to critical data—all at a fraction of the cost of traditional environmental monitoring solutions.

For the first time, commercial operators can cost-effectively collect data throughout the lifecycle of projects—from baseline assessments through to decommissioning surveys—to mitigate their environmental impact. This data can also be used to improve operational efficiency, performance, and safety, helping operators achieve key business objectives.

Wave Glider Benefits

- Increase the geographical range, frequency, and duration of monitoring with a multi-sensor platform that captures subsea, surface, and aerial data
- Collect data sets in environments and conditions where you can't safely or cost effectively send people
- Expand the duration and density of ocean observations with a 24x7x365 autonomous platform
- Real-time communications and on-board compute capabilities optimize the value of each mission
- Precision navigation system and built-in collision avoidance enable safe and effective autonomous operation

Highlights

The Wave Glider revolutionizes how we explore and understand the world's oceans by gathering data in ways or locations previously too costly or challenging to operate. Powered by wave and solar energy, the Wave Glider is an autonomous, unmanned surface vehicle (USV) that operates individually or in fleets delivering real-time data for up to a year with no fuel.

Summary

Now is the time for the Digital Ocean. As mankind seeks opportunity farther from shore and searches for answers deeper in the ocean, we need new technologies to ensure that the growth of the ocean economy doesn't come at the expense of the ocean itself. By bringing together manned and unmanned systems, we can create the Digital Ocean enabling instant access to the data we need to develop responsible, sustainable approaches to economic development—at a fraction of the cost of traditional approaches.

Unmanned systems will make it possible to overcome the spatial and temporal density limitations of traditional methods—enabling organizations to implement persistent environmental monitoring. A more complete understanding of the ocean will drive initiatives and projects that are both sustainable and profitable.

Highlights

Transformative technologies such as unmanned systems allow organizations, scientists, and governments to design cost-effective approaches to better assess the health of ocean ecosystems and the impact of commercial activities.

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