Precision Acoustics for Subsea Communications

WHITE PAPER

Thanks to advances in GNSS-Acoustics, we are able to track seafloor motion at millimeter-scale accuracy through two miles of seawater.

Now, autonomous systems are changing the entire cost structure of subsea communications, making real-time data a cost-effective, viable option.

LIQUID ROBOTICS
A Boeing Company

+1 408 636 4200 www.liquid-robotics.com info@liquid-robotics.com

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Executive Overview

On land, we can measure Earth's movements with millimeter accuracy using a satellite-based GNSS technique. But the radio signals that GNSS relies on can't pass through water. Enter seafloor geodesy, an emerging scientific field that uses newly developed marine technology and GNSS-Acoustics to measure seafloor motion at millimeter-scale resolution.

One of the most exciting developments is the ability to precisely position a Sonardyne seafloor transponder from a Wave Glider in up to 5,000 meters of water depth. The ability to accurately locate infrastructure on the seafloor is not new; the ability to do it without requiring expensive surface vessels is.

Seafloor geodesy projects are underway across the globe, all in pursuit of scientific advances that will help us crack the code on earthquake and tsunami risk. In addition, the technology is being applied to offshore oil and gas operations to mitigate risk in oilfields. In each case, autonomous systems like the Wave Glider offer the ability to communicate with and collect data from seafloor sensors in real-time, which would be prohibitively expensive with boats.

In this white paper, you'll learn about:

- Four seafloor geodesy projects in progress around the Ring of Fire
- Commercial applications of GNSS-Acoustics in offshore oil and gas
- How the Wave Glider enables persistent subsea communications

This white paper was originally published in November 2017. Updated October 2019 with additional information.

GNSS-Acoustics and the Emergence of Seafloor Geodesy

How can you measure seafloor motion down to millimeter-scale accuracy through two miles of seawater? The satellite-based GNSS technique used on land doesn't work in the ocean, so we turn to GNSS-Acoustics.

When you combine GNSS and precision acoustics, made possible by advances in sensor technology, the result is incredibly accurate seafloor measurements—precise enough to track tectonic plate movement.

GNSS-Acoustics have been used successfully to monitor seafloor deformation from research vessels, but vessels are too expensive to be a practical long-term, real-time solution. Autonomous systems like the Wave Glider offer a cost-effective model for subsea communications.

Operating at the surface, the wave and solar powered Wave Glider can hold station above the seafloor sensors for many months at a time. The Wave Glider can precisely position a Sonardyne seafloor transponder in up to 5,000 meters of water depth and serve as a communications gateway to collect and transmit data in real time.

With these advances in technology, seafloor geodesy projects have sprung up around the world, in particular around the Ring of Fire where the most powerful earthquakes originate. What is the shared goal? To better understand earthquakes, tectonic processes and tsunami hazards, and ultimately to save lives.

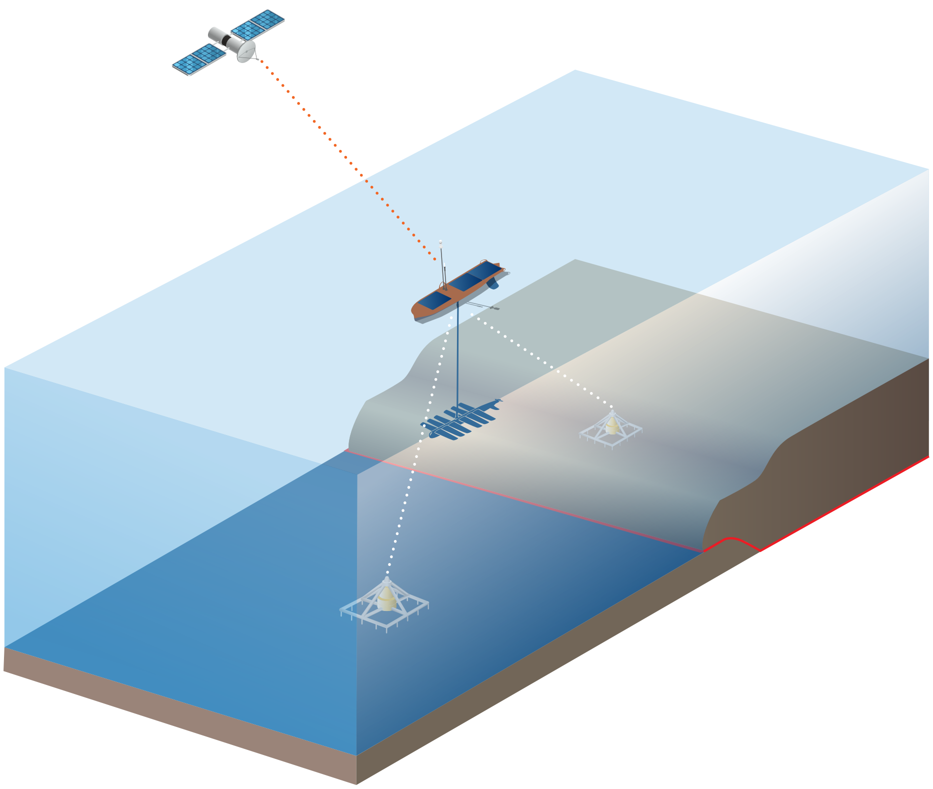


Figure 1. Wave Glider operating at the surface, communicating with stations monitoring seafloor motion.

Scientific Missions

Research in Progress Around the Ring of Fire

The Cascadia Subduction Zone

Scripps Institution of Oceanography and the United States Geological Survey

Dr. David Chadwell of Scripps Institution of Oceanography is working with the United States Geological Survey (USGS) to better understand the Cascadia Subduction Zone. In the Pacific Northwest, the fault line veers offshore; the offshore plate is pushing underneath the onshore plate, creating the Cascades mountain range up the coast.

The Cascadia Subduction Zone is particularly interesting because there has been no recent earthquake activity; scientists only learned of its existence fairly recently. Hundreds of years ago, the Pacific Northwest was only populated by Native Americans, and there was no written documentation of seismic activity. But there was evidence of an abrupt land subsidence, with a forest of trees suddenly killed by saltwater. Meanwhile, 5,000 miles across the Pacific, Japanese records showed a tsunami without an earthquake—what they called an orphan tsunami. Scientists were able to match that tsunami with its parent earthquake, ten hours apart in January of 1700.

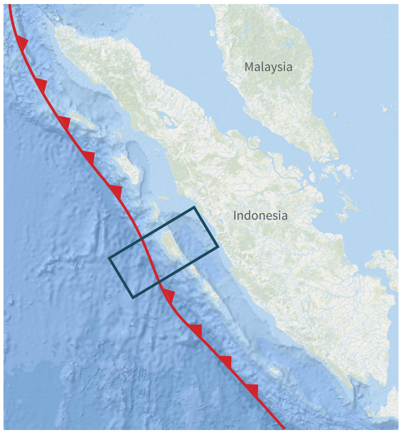
Since this discovery, scientists have calculated the earthquake recurrence interval to be 243 years. It has been 319 years since that last Cascadian earthquake, and millions of people now live in the impact zone; better data has the potential to save lives.

Dr. Chadwell's goal is to understand how these tectonic plates are interacting and moving, down to centimeter resolution. With better data, we can improve our understanding of when a major event is more likely to occur, rather than relying solely on historical intervals.

After selecting the Sonardyne acoustic modem, and validating its precision using a research vessel, Dr. Chadwell was looking for a more cost-effective way to collect the data going forward. His original plan was to use a diesel-powered buoy. However, after he realized the advantages that the Wave Glider's mobility and longevity could offer, he successfully petitioned the National Science Foundation (NSF) to use a Wave Glider instead. Since the initial installation of two arrays, Dr. Chadwell installed two additional arrays offshore Cascadia in June 2018.

In addition, Dr. Chadwell has received additional NSF funding to extend his seafloor geodesy research north to Alaska, and across the Pacific to New Zealand. In May 2018 three new arrays were installed offshore along the Alaskan peninsula bracketing the Shumagin Islands. In New Zealand, the work will focus on measuring deformation near the trench of the New Zealand Hikuangi subduction margin. In each area, the Wave Glider serves to enable more efficient and cost-effective GNSS-A measurements.

Scientific Missions (continued)



The Mentawai Seismic Gap

Earth Observatory of Singapore

At the Earth Observatory of Singapore, researchers are working to better understand earthquakes, tectonic processes and tsunami hazards in Indonesia.

The 2004 Mw 9.15 Sumatra earthquake and tsunami marked the beginning of a series earthquakes along the Sunda subduction zone. The Mentawai seismic gap is one of the remaining regions that did not experience a large earthquake in the last decade. At risk: one million people in Padang who are exposed to the seismic and tsunami hazard.

An extensive land-based network for geodetic measurements has been installed on islands along the fault line, but there are gaps offshore that prevent understanding tsunami generation dynamics. Seafloor geodesy can fill that observation gap.

The researchers — Dr. Sylvain Barbot (who has since moved to the University of Southern California), Dr. Emma Hill, and Dr. Sharadha Sathiakumar — equipped Wave Gliders with acoustic GNSS technology to monitor seafloor deformation off the shore of Sumatra. An autonomous platform is essential, as regular surveys using research vessels is too expensive to be practical.

The ultimate goal is to move towards persistent ocean laboratories [or towards extensive offshore geodetic networks] that can cover a large spatial footprint and build a multi-decade time-series of data on seafloor deformation. And the hope is that this can in turn lead to breakthroughs in earthquake and tsunami early warning.

Scientific Missions (continued)

The Nazca-South American Plate Boundary

GEOMAR Helmholtz Centre for Ocean Research Kiel

Off the coast of northern Chile, where some of the most powerful earthquakes on the planet originate, scientists from GEOMAR Helmholtz Centre for Ocean Research Kiel have installed a seafloor geodetic network called GeoSEA (Geodetic Earthquake Observatory on the SEAfloor) at depths ranging from 2,600 – 6,000 meters. Once installed, the next challenge is how to collect the seafloor data more frequently in a cost-effective way.

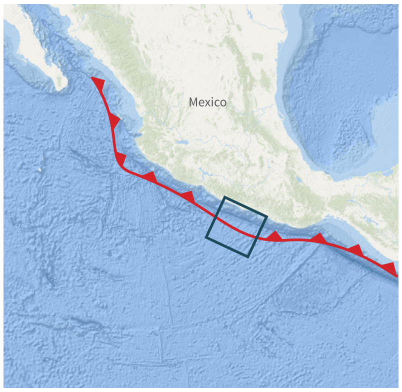
The GeoSEA network consists of autonomous monitoring transponders (AMTs) from Sonardyne installed on 4 meters high tripods. These seafloor stations were installed in three areas along the Nazca-South American plate boundary, an area identified to be in the latest stage of the seismic cycle. The other key component of the network is the Wave Glider. Operating autonomously at the surface, the vehicle holds position above the seafloor stations, monitors system health, uploads data from the seafloor node, and transfers it back to shore via satellite—allowing the research vessel to focus on other more valuable tasks.

The installation of the GeoSEA network with 23 seafloor stations was completed in December 2015, with some stations placed at seafloor depths up to 6,000 meters. Once the stations were installed, communication to all stations and within the network was confirmed. Data from all stations were successfully uploaded to the Wave Glider and/or a HPT modem lowered into the water from the research vessel.

Dr. Heidrun Kopp, Chief Scientist at GEOMAR, said retrieving data with a Wave Glider was an important first step to proving out the capability of the network. “In the future, as we think about other seafloor geodesy projects in remote places, these would not be possible without the Wave Glider.”

In the future, GEOMAR plans to use Wave Gliders to upload data in near real-time. With regular information from the sensors, scientists will be able to monitor changes in the deformation pattern, and, in the event of a major earthquake, rapidly acquire information on the processes that occurred.

Scientific Missions (continued)



The Guerrero Seismic Gap

A Collaboration Between Mexico and Japan

Along the Pacific coast of Mexico, between the towns of Papanoa and Acapulco, lies the Guerrero seismic gap, where there hasn't been a major earthquake in more than 100 years. There, a collaboration between Mexico and Japan is underway, as researchers seek to measure crustal deformation where the Cocos plate subducts beneath the North American plate.

The collaboration, led by Dr. Victor M. Cruz Atienza in Mexico and Dr. Yoshihiro Ito in Japan, has pulled together researchers from the National Center for Disaster Prevention (CENAPRED), National Autonomous University of Mexico (UNAM), Japan International Cooperation Agency (JICA), and the Japan Science and Technology Agency (JST).

To assess the risk of earthquakes and tsunamis, a network of more than 30 seismological stations and 45 geodetic stations was installed in November 2017, and the first data was collected in early 2018.

The seafloor stations, anchored to the seafloor at up to 5,000 meters deep, consist of a bottom pressure recorder, an ocean bottom seismometer, and an acoustic modem. As they measure the crustal deformation, a Wave Glider will hold station at the surface, sending and receiving acoustic signals from the seafloor stations.

The data this network collects will help advance their work on predictive models for earthquakes, and build on the seafloor geodesy work in progress around the globe.

Offshore Applications

Precision Acoustics for Tracking Seafloor Infrastructure

Next, we'll take a look at how precise seafloor measurements can be applied to offshore operations for oil and gas. Using GNSS-Acoustics, the Wave Glider can help position sensors and other devices on the seafloor with millimeter accuracy—while also serving as the data retrieval vehicle—so you can measure vortex-induced vibration (VIV), monitor pipeline buckling, or track escarpment movement close to a development.

Monitoring Seafloor Subsidence

As offshore energy operators seek to get more out of their existing reservoirs, it is important to closely monitor risks like seabed fractures, deformation, or subsidence. Understanding how much—and how quickly—the seafloor is subsiding over time enables the operators' geophysicists to make better decisions about their reservoir management plans, while ensuring safe continued operations.

Sonardyne's autonomous sensors offer the ability to record pressure data for monitoring seafloor subsidence precisely and reliably. The data stored within each sensor node is then available for on-demand harvesting by a vehicle at the surface. Previously, conventional survey vessels might have been sent to harvest the data, but the Wave Glider eliminates the need for such a costly vessel.

With the ability to remain at sea for months at a time in a wide variety of conditions, the Wave Glider is an ideal data harvesting vehicle. Equipped with Sonardyne's GNSS-A payload, the Wave Glider can swim to each bottom node's location and harvest logged data on demand.

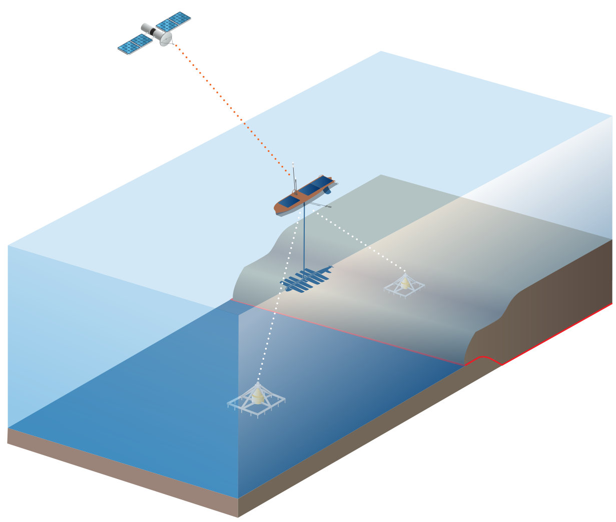


Figure 2. Wave Glider monitoring activity on the seafloor.

Offshore Applications (continued)

Monitoring Slope Stability

Slope stability is typically evaluated historically. Geohazard specialists find areas where mass movement has occurred and analyze shallow and deep seismic data, coupled with age dating to predict the chance of slope movement. Now operators can track seabed movement over formations in near real time, using inexpensive sensors and equipment, with Wave Gliders at the air/sea interface and Sonardyne sensors on the seafloor. This technology can also be coupled with existing motion tracking technology to accurately determine if a pipeline is moving subsea, so you can measure and predict vortex-induced vibration (VIV) or buckling—a risk mitigation technique that won't break the budget.

A lot of oil and gas finds are in the deep ocean, close to the continental slope. The seabed adjacent to or under some deep-water developments can be quite steep and often there is evidence of mass wasting in these areas. Until now, the way to identify and mitigate this hazard has been to take sediment samples, age date them to figure out the last time the slope moved. Then they work to figure out the likelihood of it moving again, ultimately determining the risk of placing infrastructure on or near the hazard based on historical data and geologic models.

Now, instead of an educated guess, people have the tools to track the actual movement of the seafloor. And because the Wave Glider is cost-effective to own and operate, it's no longer prohibitively expensive to get this data, as it would have been using boats.

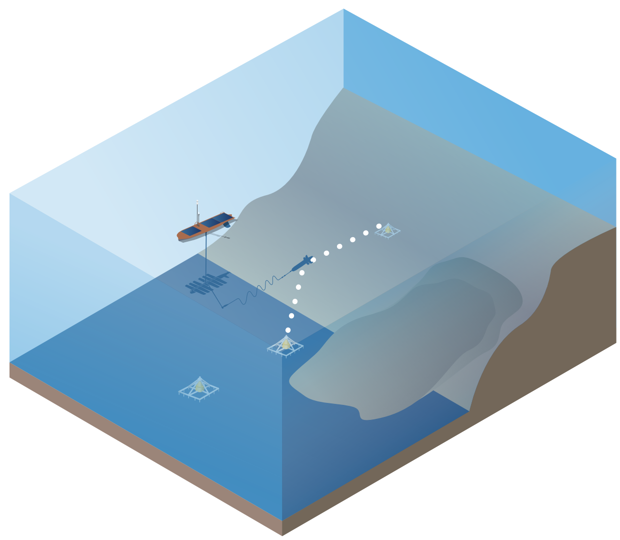


Figure 3. Wave Glider monitoring slope stability.

Offshore Applications (continued)

Monitoring Pipeline Movement

Another way to apply this capability is to measure the movement of infrastructure. With a pair of reference sensors on the seafloor, and a pair of sensors on the pipe, we can see how the pipe is actually moving. This is important in fields where pipeline movement, or "walk," is possible.

Increasingly, in deep-water developments, very hot oil is coming out of the ground at very high pressures, going through a pipeline in a really cold ocean. This axial stress caused by the metal expanding and contracting translates into horizontal movement called pipeline walking (or lateral buckling).

Your choices are limited when you want to figure out how the pipeline is moving. You can send a boat with a crew of 30 people out for $800,000 a day, then launch an ROV to visually observe and measure the walk. However, it's not cost-effective or practical to do this very often because it can cost you $1-$2 million just to get to location. You can monitor it with data loggers, but until you come back and download the data, you don't really know what's going on. With Wave Gliders, you can track the movement in real time.

Tracking the health of your subsea infrastructure doesn't have to be a quarterly effort. The Wave Glider, paired with Sonardyne technology, allows operators to determine the most efficient and desirable observation schedule of assets. This puts the power back in the hands of the professionals and makes the oilfield safer and more efficient.

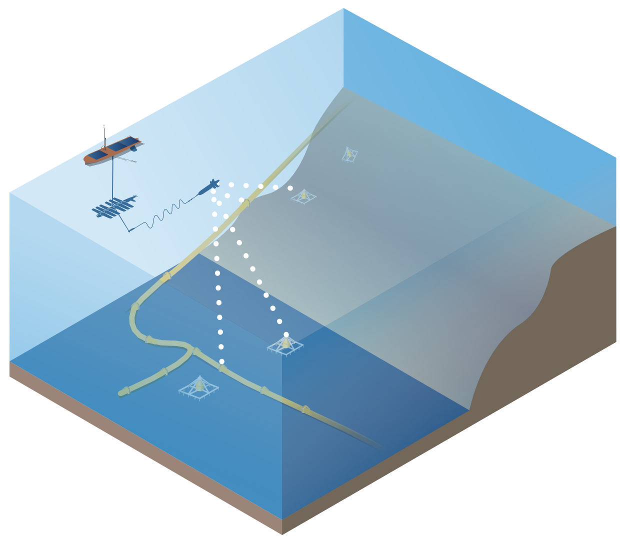


Figure 4. Wave Glider monitoring pipeline movement.

About the Wave Glider

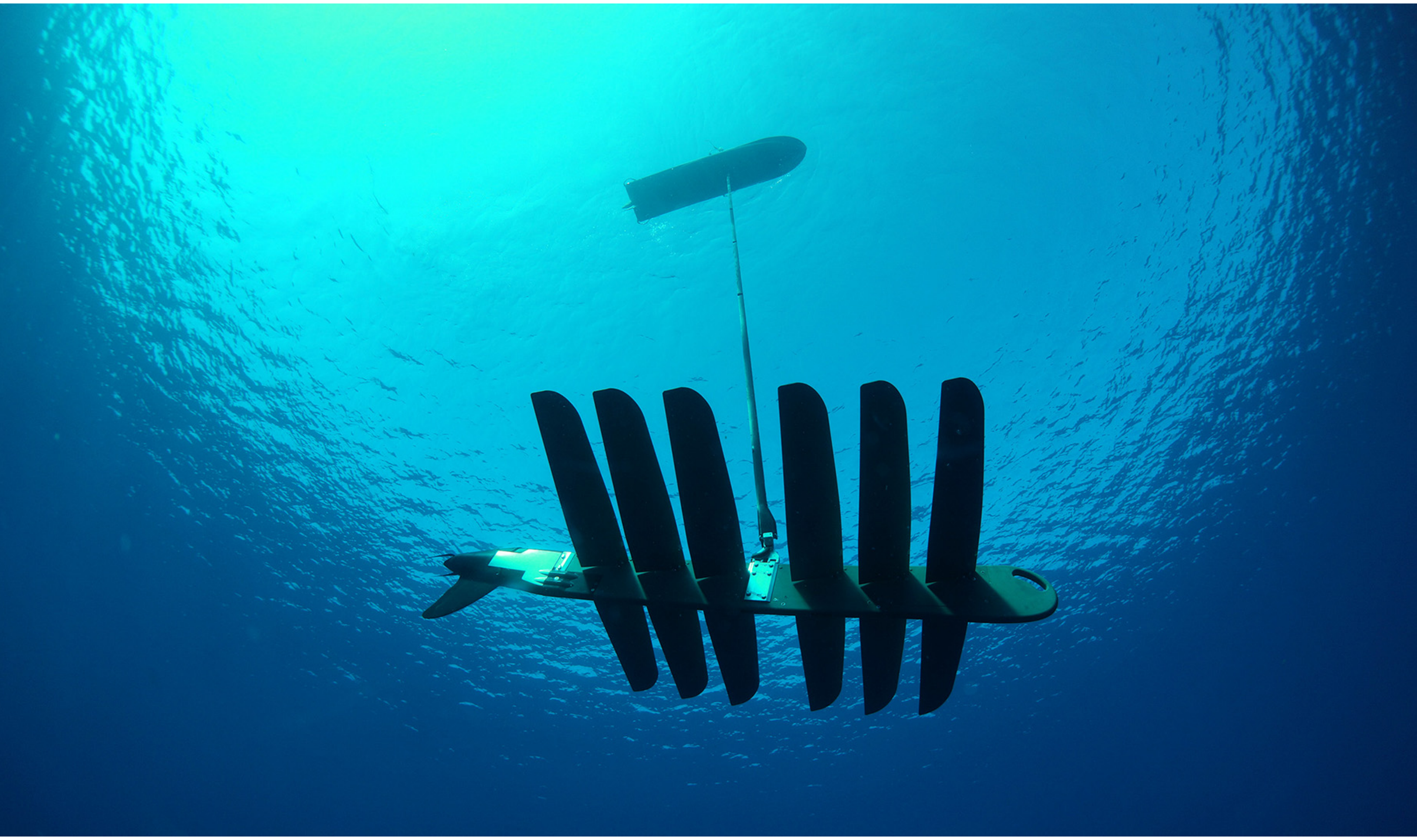
The Most Experienced Ocean Surface Robot on the Planet

Powered by wave and solar energy, the Wave Glider can operate 24x7 for up to a year,* in fleets or individually. The combination of wave-propulsion and stored solar energy enable persistence, continuous data collection, and real-time communications capabilities.

The Wave Glider platform also offers unrivaled flexibility for sensor and payload integration, accommodating multiple sensors per mission. An optimized motion and sound isolation system makes the Wave Glider well suited for towed acoustic applications and subsea communications.

Wave Gliders can operate independently with our Mission Management Software or have command-and-control integrated into broader Common Operating Picture (COP) systems. An open platform design, development tool kit, and component testing service allow sensor and payload customization to meet unique mission needs.

Our Mission Services are designed to ensure your success from start to finish. From planning and risk assessments, to vehicle launch and recovery, to piloting and maintenance services, we're with you every step of the way.



**Mission duration varies based on operating conditions and location; maintenance recommended every 4-6 months.*

Summary

Autonomous systems change the whole cost structure of subsea communications, helping us rethink how we get data from the ocean.

With GNSS-Acoustics, tracking seafloor motion at millimeter-scale accuracy became possible. And now real-time data, which would be prohibitively expensive with boats, becomes a viable option with autonomous systems like the Wave Glider.

This opens up a cost-effective way to mitigate risk in the oilfield, monitoring slope stability and pipeline movement. And for the emerging scientific field of seafloor geodesy, the economic and humanitarian impact goes far beyond simply providing a cost-effective alternative to vessels, as researchers pursue breakthroughs in earthquake and tsunami early warning that can ultimately save lives.

> *"In the long run, the next evolutionary step of seafloor geodesy would be to have a connection with the onshore geodetic network. This will require a benchmark at the sea surface, which is where the Wave Gliders come in. I'm very confident that within a few years we will be looking around the globe at a number of seafloor geodetic networks, and there will be a fleet of Wave Gliders acting as the surface node of that network."*
>
> - Dr. Heidrun Kopp, Chief Scientist at GEOMAR

Working on a seafloor geodesy or subsea communications project?
We'd love to hear about it.