The Critical Link – Coordinating Undersea Activity & Gathering Subsea Sensor Data with Unmanned Surface Vehicles (USVs)

Deploying underwater assets and sensors is expensive. Getting data from these subsea assets often uses precious power and requires ships or buoys which limits deployment options, mission flexibility, and increases costs. Autonomous, unmanned systems with the ability to operate over long durations can open doors to both new applications and new and expanded real-time data sets. This session will provide real-life examples of how an unmanned surface vehicle can communicate with sensors at depths up to 3000 feet, establish the position of seafloor sensors to extreme accuracies, and exchange data with AUVs both below and above the surface. Because USVs can also carry compute capabilities, large amounts of data can be processed or analyzed in situ before being sent to shore via different communications channels such as satellite or radio. The presenter will discuss how multi-mission platforms in the form of USVs are enabling new applications such as subsea infrastructure monitoring, sensor placement, and coordinated robotic activity.

Introduction: Challenges and Opportunities Connecting Seafloor to Space

The past decade has seen significant progress in the development of unmanned surface vessels (USVs). Enabling technologies such as precision navigation and global telemetry have advanced the field. Innovative developments, notably the harnessing of wave energy for propulsion, have created a new category of persistent USV. The Wave Glider, pioneered by Liquid Robotics, has proven that long-endurance unmanned operations on the ocean surface are both feasible and productive. Early generations of the Wave Glider demonstrated the ability to survive extreme weather and cross oceans. As the technology matured numerous applications have been addressed through an increasing range of payload sensors and infrastructure. Towbodies have been developed to leverage the system's low acoustic signature and support active and passive sonar payloads. Today science, industry and defense customers are making active and routine use of Wave Gliders.

While USVs are becoming common tools, there remains a key limitation in undersea operations. The power of wireless technology, such as WiFi, LTE and GPS, has not yet been delivered to the deep. There are fundamental physics holding back the deployment of these terrestrial utilities underwater. Seawater limits the propagation of radio signals to roughly one wavelength. The practical outcome of this is that radio systems work through water at very short distances or demand huge antennas many kilometers long. Without easy access to the techniques driving smartphones ashore undersea operations depend upon acoustics, sound waves propagate well through seawater.

Using sound for undersea telemetry and positioning is well established. Decades of development have yielded capable and reliable technologies. Unfortunately, due to the relatively slow speed of sound waves in water the resolution and bandwidth of undersea acoustic systems are poor when compared to radio systems ashore. Also the functional range of acoustics is limited, typically to 5-8 kilometers at most. As a final obstacle, the ocean is not uniform and temperature and salinity variations can impair the performance of acoustic technologies. Typically, acoustic systems work best in the vertical, transmitting directly from the surface toward the seafloor. When performing at their best acoustic positioning and telemetry can enable significant operations such as undersea vehicles support and tsunami monitoring. Unfortunately, with an average depth of roughly 4 kilometers a given undersea system essentially needs an acoustic host directly above it.

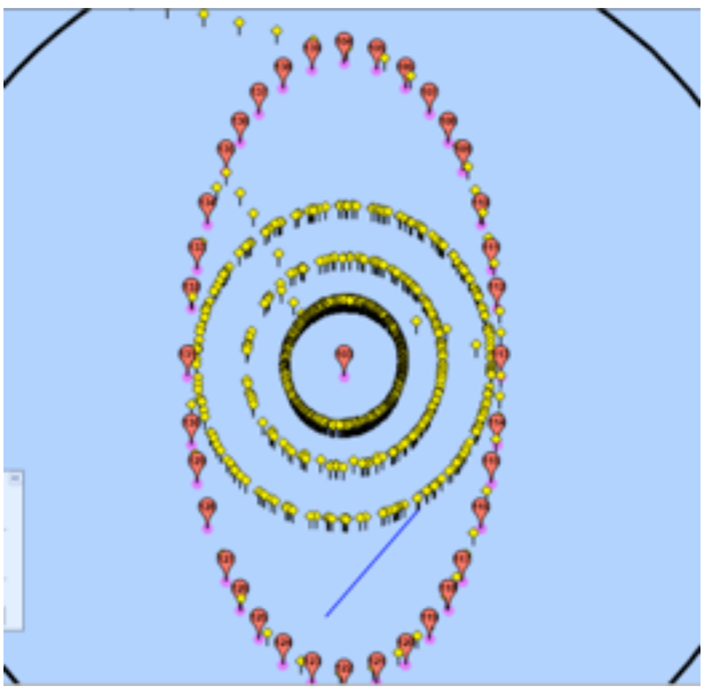

Figure 1 - The Wave Glider can hold station with a range of different patterns to meet mission needs

Unmanned surface vehicles have a natural role linking acoustic communications of the subsea with the radio communications of air and space. This creates a network that breaks economic and risk barriers to data collection, unlocks new opportunities, and connects silos of sensors and data and drives information, decision, and action.

Making the Connection: Wave Glider as Gateway

With its nearly unlimited endurance the Wave Glider makes a natural choice to support acoustic telemetry connections. It provides a “gateway” between undersea systems and the potent radio spectrum in the atmosphere, which provides positioning, and data access. Typically, such a configuration will use an acoustic system for telemetry to, and positioning of, undersea assets. While these payloads can be installed in the Wave Glider float, or sub, they are most often installed in a towbody. This provides further isolation from noise and a convenient way to streamline transducers. In some cases, the towbody carries supplemental batteries to ensure power for the payload when solar energy is limited.

In the course of development and deployment of Wave Gliders for gateway missions, a wide range of conditions have been experienced. Communications in depths of 4000 - 5500m with slant ranges of 5600m to 6300m (e.g., 750m – 3km watch circles) have been observed. Reliable acoustic telemetry can sometimes entail adjusting bandwidth expectations due difficult channel or sea state conditions. Wave Gliders as seafloor to space gateways have demonstrated telemetry bandwidth from 300 bps to 1200 bps.

There are many providers of acoustic systems and most of the leading choices have been successfully installed and demonstrated on Wave Gliders. Likewise, a large variety of applications have been evaluated. Collection of data from seafloor sensors in offshore oil fields and relay of tsunami warning buoy signals are two examples. Some of the most interesting recent use of gateway Wave Gliders come from the ocean research community. Scripps Institution of Oceanography (Scripps) and the Monterey Bay Aquarium Research Institute (MBARI) have employed Wave Gliders in support seafloor seismology and to support other unmanned maritime vehicles.

Figure 2 - Liquid Robotics towbody and motion isolating cable

Real-time seafloor seismic monitoring – Bringing back the data

Researchers at Scripps have developed a system to deploy seismological observatories in the deep ocean and relay data to shore in near real-time. They have created an innovative, unmanned observatory that provides real-time seismic telemetry from the seafloor through the water column to space and shore. With funding from the U.S. National Science Foundation and in collaboration with Liquid Robotics, they have developed the High Seas Telemetered Seismographic Observatory. This system was created to demonstrate the feasibility of placing permanent seafloor seismic observatories, paired with surface communications gateways, to directly measure seismic activity in locations far from continental sites or nearby islands.

To overcome the obstacle of communicating seafloor sensor data to the ocean's surface, Scripps scientists devised a two-part system comprised of the Ocean Bottom Package (OBP) sitting on the seafloor collecting and transmitting data to the Liquid Robotics' Wave Gliders which serve as a free-floating Ocean Surface Gateway (OSG).

In initial deployments, this team launched the Wave Glider, 30 km from Point Loma, CA, to travel west of San Diego approximately 300 km. In 4350 m of water, the Wave Glider held station, collected and transmitted telemetry data in near real-time from the bottom seismic sensors to the Iridium satellite to its destination ashore. Tests of the surface gateway demonstrated an acoustic efficiency of approximately 396 bits/J. The observatory has the ability to send 4 channels of compressed, 1 sample per second data from the ocean bottom to the surface gateway with an average power draw of approximately 0.15 W and a latency of less than 3 minutes. As long as the horizontal distance to the seafloor instrument was within an ocean depth, the data return rate was nearly 100%. During 68 days at sea, the system detected and recorded seismic earthquakes along with one small earthquake that did not appear in any earthquake catalog record on the nearest land station on San Clemente Island. This is the first near real-time observations of an earthquake from an autonomous offshore observatory. This data is invaluable to both national and international agencies to monitor and characterize earthquakes, tsunamis, and nuclear explosions.

Enhancing productivity & capabilities in maritime science – Robots talking to robots

MBARI a range of underwater vehicles and sensors that it has developed and used since its founding. However, both power and communications limited how some of these assets could be used. To address this gap, they created a Hot Spot payload for the Wave Glider, enabling both a disruption tolerant communications relay and the ability to find and track underwater robots and sensors.

The Wave Glider-based hotspot was created as part of MBARI's Controlled, Agile, and Novel Observing Network (CANON) project. This multi-year project seeks to understand marine microorganism life-cycles, including plankton bloom dynamics. This 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.

The MBARI Hot Spot consists of multiple radios and an acoustic modem on the Wave Glider and enables a store and forward network that transfers data between the Wave Glider and AUVs, benthic instrument packages, and systems on shore. It achieves a high-level of reliability in the tough ocean environment where communications are frequently disrupted or degraded.

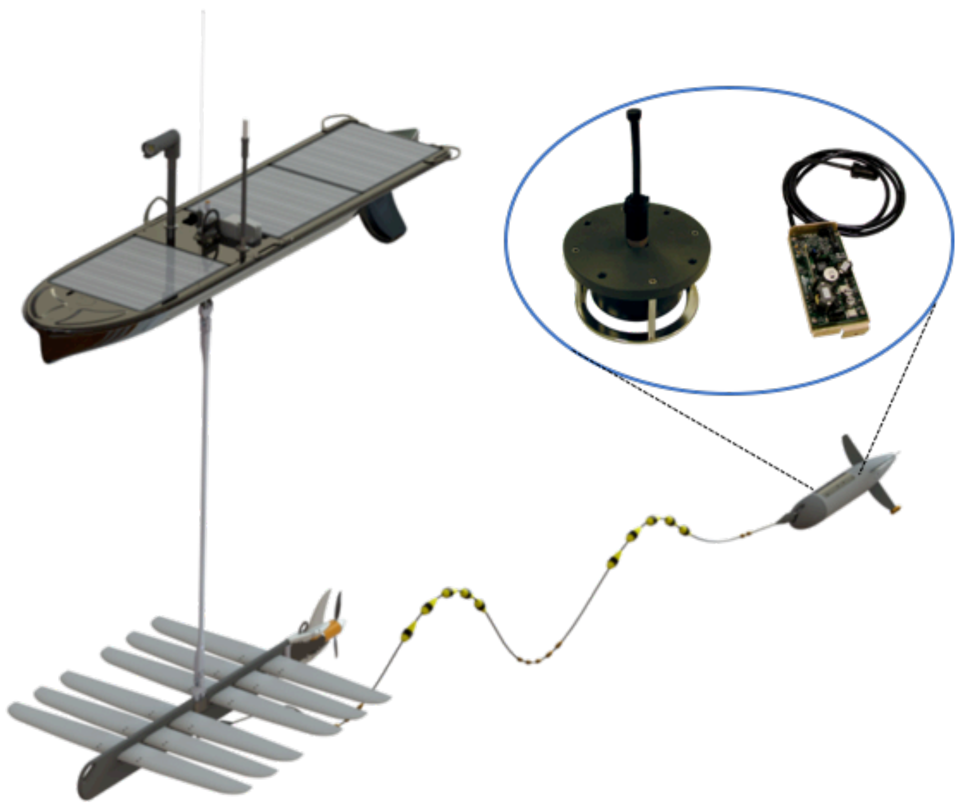

Figure 3 - Teledyne Benthos ATM900 series modem installed in a Liquid Robotics towbody

MBARI has successfully used and refined the Hot Spot over several years enabling applications that permit coordinated robot activity and helping scientists to get better data. Three primary applications for the Hot Spot include:

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

The utility of Wave Gliders as gateways to undersea systems has been well proven. But most such examples are at small scale, one Wave Glider and one undersea system at a time. There is not technical reason why these examples can't be expanded into larger networks.

The Future: Envisioning and Employing the Digital Ocean

Industry ashore has witnessed an exponential growth of wireless devices, mobile applications, robotics and sensors — all connected and available for instant communication and control. On land connected, smart thermostats such as the Google Nest can be controlled from any device (mobile phone or browser) and adapt based on our behavior. Behind the scenes, from manufacturing to online retail giants like Amazon, connected devices, robots, and sensors enable new efficiencies and opportunities. This digital transformation is rapidly unfolding on land, air, and in space, but not yet at sea. Such a transformation, to a "Digital Ocean" is now feasible.

The building blocks for a Digital Ocean are in play today and can accelerate the ocean economy. From new applications of maritime security that protect vital resources to new approaches to climate and maritime research, the ability to link together building blocks — satellites, ships, aerial craft, unmanned surface vessels, unmanned underwater vehicles, and sensors — into systems can enable new capabilities previously unavailable or cost prohibitive at both an organizational and national level.

As has been shown here, USVs, especially the Wave Glider, can create the necessary gateway from seafloor to space. This critical infrastructure provides the ability to communicate in real time across both the air-sea interface and the planet. With such capabilities, the world's nations can preserve and protect their natural and economic assets, practically, around the clock. This digital ocean will enable a world where ocean data can be accessed as instantaneously as you now launch a Google search.

Additional References

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