How Unmanned Surface Vehicles Can Shine a Light on Dark Targets & Cue Assets for Inspection and Interdiction

Even in a world of increasing satellite coverage, 24/7 maritime monitoring is difficult and costly with traditional assets. Long duration, unmanned surface vehicles can form virtual walls or trip wire formations that employ passive acoustic sensors to detect dark targets. Alerts and acoustic data can provide actionable intelligence allowing organizations to cue other assets including sUAS, manned aircraft, patrol vessels and satellite imaging for inspection, tracking or interdiction.

Long duration, unmanned surface vehicles offer persistence and other capabilities that can be leveraged in concert with traditional manned assets to provide for a significant increase in operational efficiency and effectiveness. This paper will use results from Wave Glider missions to demonstrate how a fleet of mobile autonomous systems could be deployed to hot spot areas to increase the effectiveness of maritime domain awareness and lower the cost of monitoring and interdiction.

Introduction: Bringing Persistent Presence to the Vast Ocean

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 operationally and economically 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.

Long-endurance USVs, like the Wave Glider, offer a compelling new approach to ocean operations. With relatively low capital and operational costs compared to traditional surveillance and observational technologies these USVs can be a valuable complement to other ocean observation tools. Typical approaches to ocean monitoring include aircraft, vessels and buoys. All have different advantages and challenges and all are complemented by USVs. Wave Gliders, in particular, can provide a persistent presence in remote regions at favorable costs. While they may not deploy as much payload as vessels, or offer the field of view of aircraft, they offer persistent observing at a fraction of the cost of traditional assets. Even a small fleet can be employed for day rates significantly lower than aircraft or vessels making them increasingly affordable. Another advantage of Wave Gliders is their station keeping ability. This allows them to approximate the long-term presence of buoys without many of the technical complexities or risks, especially vandalism, entailed in remote mooring deployments. As a result, they can gather oceanographic data and act in a surveillance mode simultaneously. Persistent USVs turn the challenge of the ocean into an opportunity.

The deployment of unmanned systems requires substantially less capital and time than typical alternatives such as boats. In addition, they can operate in one area for longer periods than traditional patrol methods. These systems benefit from advances in autonomy and software which enables a small team of operators to support a significant number of distributed assets at sea. Basic decisions about target identification, vehicle course, and system health monitoring can all be made without human input. This allows operators to focus on meaningful decisions such as prioritization of dark targets and subsequent resource commitments for further investigation and ultimately prosecution. Many unmanned systems, such as tactical UAVs (unmanned aerial vehicles), have multiple human operators per asset.

Opportunity: Leverage the Challenges of the Vast Ocean

The ocean is a vast expanse with both distance and weather offering concealment to bad actors. But that isolation breeds complacency. The Wave Glider offers unparalleled performance in this environment, with a relatively low visual signature and virtually no radar signature, it can effectively operate near “dark” targets without risk of detection. With its undersea components, the Wave Glider is well suited for acoustic sensor towing and can provide a significant range extension in observation and detection of such targets. With long endurance and modest cost, coverage of large areas by multiple units or fleets is now an economically viable operational concept.

Use of USVs in coordination with traditional remote sensing can provide a powerful combination. Typically, vessel traffic can be monitored both visually and electronically. The automated identification system (AIS) usually indicates a legitimate vessel and when this signal is not seen the target is considered “dark.” Remote sensing, typically radar or optical imaging may still detect such vessels. Undersea acoustics can provide relatively long-range detection of dark targets (e.g., 8-35+ km / 4-20+ nautical mi as range varies based on engine size and ocean conditions). A network of unmanned systems can be connected via satellite or radio telemetry to build a persistent “underwater fence” that compliments aerial and patrol vessel sensing. The Wave Glider can act as a hub in this approach allowing for a more layered approach to security, one that use sea, sky and space to enhance maritime domain awareness (MDA).

A significant value in application of unmanned systems for MDA is optimization of tasking for manned assets. With unmanned systems providing surveillance other systems such as aircraft and manned vessels can focus on tasks that maximize their value. For example, aerial assets may not be able to provide the level of persistence required but can provide critical high-speed capabilities. Meanwhile the cost of manned vessels makes it hard to cover broad areas but their ability to interdict is fundamental to enforcing regulations. Effective MDA requires layers of detection and monitoring. These layers of defense are required to not only detect illegal activity, but document and support interdiction and eventual prosecution. Multiple sources of information are desired and often required to justify investment of resources for interdiction. Unmanned systems make such a layered approach possible.

Case Study: UK Foreign & Commonwealth Office — Pitcairn Islands MPA Maritime Surveillance

Despite massive spending each year on maritime security, defense and security forces are still under-resourced to effectively control territorial borders, reduce illegal trafficking, eliminate illegal fishing, and monitor marine protected areas (MPAs).

The UK Foreign & Commonwealth Office (FCO) sought to better understand and address these challenges, specifically the monitoring of a potential (and now official) MPA and the prevention of illegal fishing occurring in the MPA, using both satellite and unmanned systems. The challenge was how to protect 834,000 square kilometers of a distant MPA, the Pitcairn Islands, and how to detect and deter illegal, unregulated and unreported (IUU) fishing activities inside the area. It is worth noting that the Pitcairn islands are extremely remote, nearly 4,400 nautical miles south of Hawaii.

Participants in this successful proof-of-concept mission included Bertarelli Foundation, The Pew Charitable Trusts' Eyes on the Sea, satellite provider Catapult, and Liquid Robotics. The four-month mission demonstrated how a long endurance unmanned system could be used with other assets like satellites to provide valuable audio, visual, and environmental data. It was executed within a budget that was a fraction of the cost of operating a manned vessel (8-10x less than a vessel patrol). This could provide the FCO significant cost savings, along with valuable information on environmental and sea-surface conditions.

Multiple systems leveraged to achieve objectives

In this project, the direction of the Wave Glider drew upon multiple data sources. Satellite derived AIS data was complemented by satellite synthetic aperture radar (SAR) and local fishing forecasts. Active areas with potential dark targets were identified. Using this approach allowed a single Wave Glider to patrol a targeted area and seek to identify dark targets with both acoustics and visual confirmation, sea conditions permitting. This combination of data – AIS tracking, dark targets, acoustics, and visual data yields a comprehensive set of information about vessel activity and helps to define both enforcement and interdiction steps.

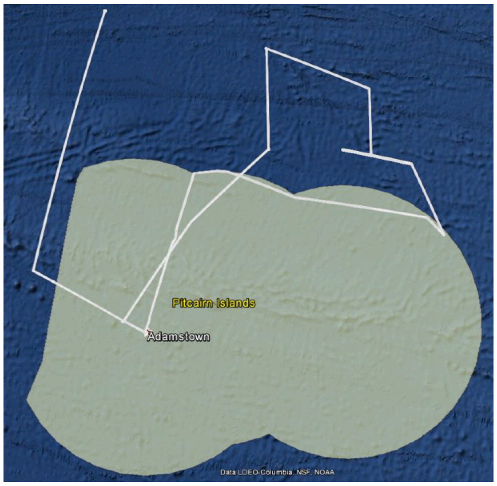

Figure 1 - Pitcairn EEZ boundary (appx.1923 nm) with Wave Glider repeated patrol path of 5,500 nm (white line)

Taking pictures of vessels from the surface of the ocean can be difficult due to unpredictable conditions. During the Pitcairn mission, the Wave Glider demonstrated how it could take pictures of a known vessel (this was not a dark target vessel). Though not shown here, a higher quality picture allows identification of the vessel.

Figure 2 - Known vessel in close proximity during Pitcairn mission

Demonstrated value and endurance

This project decisively demonstrated the value and capabilities of a long duration unmanned vehicle. This Wave Glider mission cost 8-10x less than the cost of operating a manned vessel in the same area ($5.8M/year). In this operation, the Wave Glider traveled a total of approximately 7,200 nautical miles with 4,400 of those on mission. The remaining 2,800 nautical miles were on return to the operations facility in Hawaii. Of note this ability to simply sail back to base reduced demobilization costs by a factor of ten compared to the expense of air shipment for mobilization. Overall the average speed of the Wave Glider in this mission was 1.73 knots and weather conditions peaked at five-meter waves and 40 knot winds.

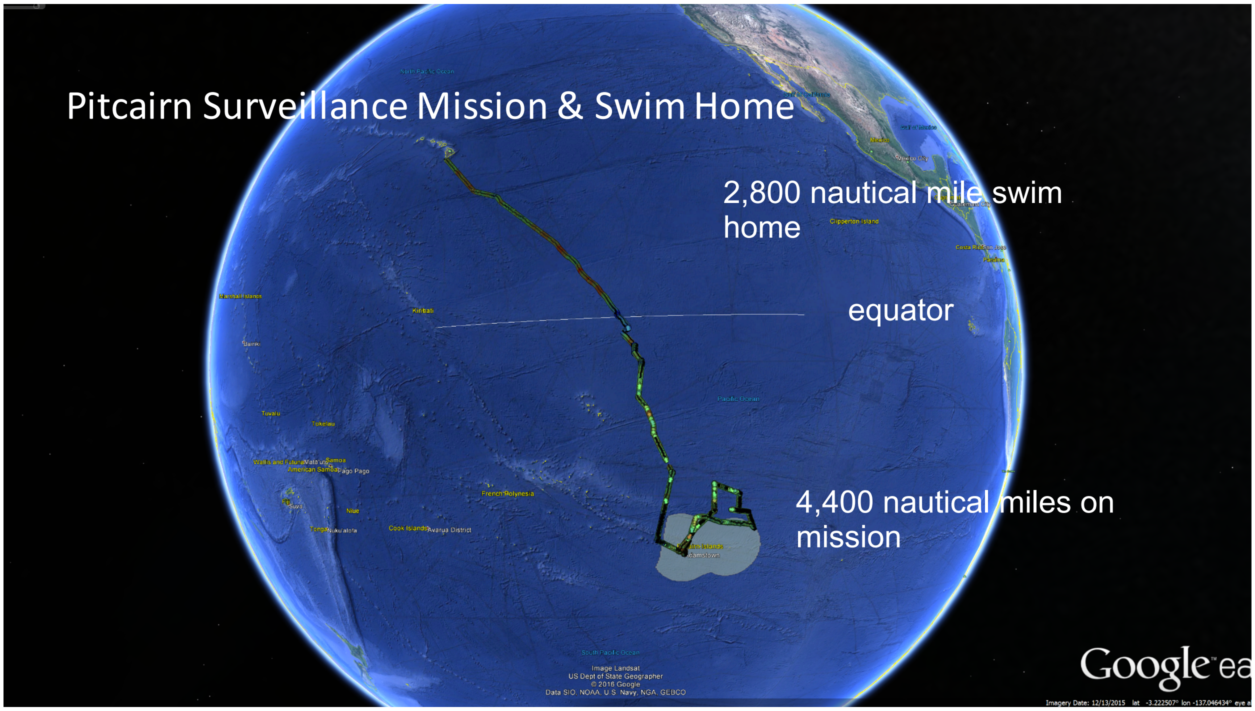

Figure 3 - Liquid Robotics Pitcairn Mission Map

While the Pitcairn demonstration made use of only one Wave Glider, the value of multiple unmanned vehicles can clearly be envisioned, especially when combined with other resources. First, these systems can perform both surveillance and gather valuable metocean data. Second, multiple systems provide a coverage network. And like all network-based systems, configuration of the nodes will be based on objectives such as probability of detection, the need to track targets, the geographic proximity of other assets such as drones or ships, and the need for visual confirmation of vessel activity. In addition, the capabilities of these acoustic detection nodes will be based on environmental and budget constraints.

Unmanned systems, and specifically Wave Gliders equipped for maritime surveillance, can be deployed in different formations. For example, an area coverage mode would offer the highest level of detection probability and the potential to track vessels. Yet, if little is known about illegal or dark target activity across a large area, a patrol formation might be more appropriate (see figure 4).

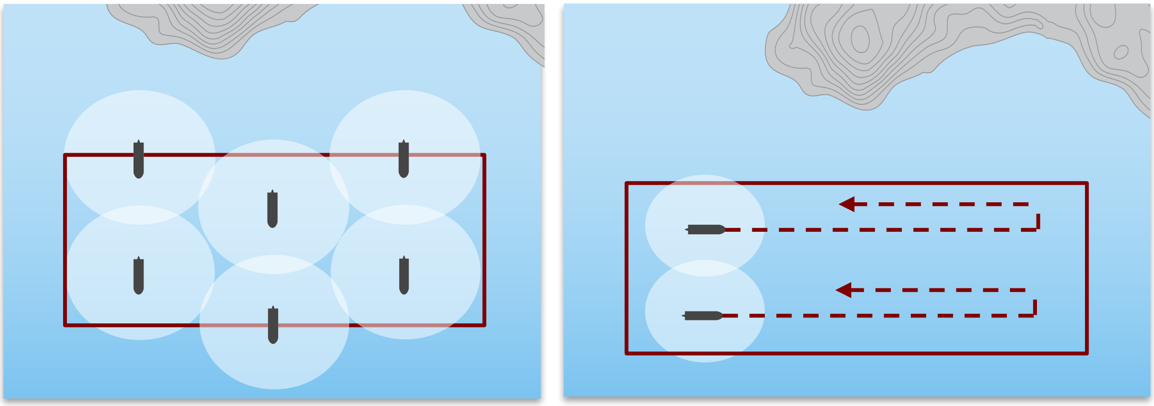

Figure 4 - Area coverage (left) and patrol formation (right) - these offer different probabilities of detection

In areas with known activity, a trip wire formation might be used to create a floating fence or even multiple floating fences in key hot spots to maximize intelligence gathering and possible interdiction.

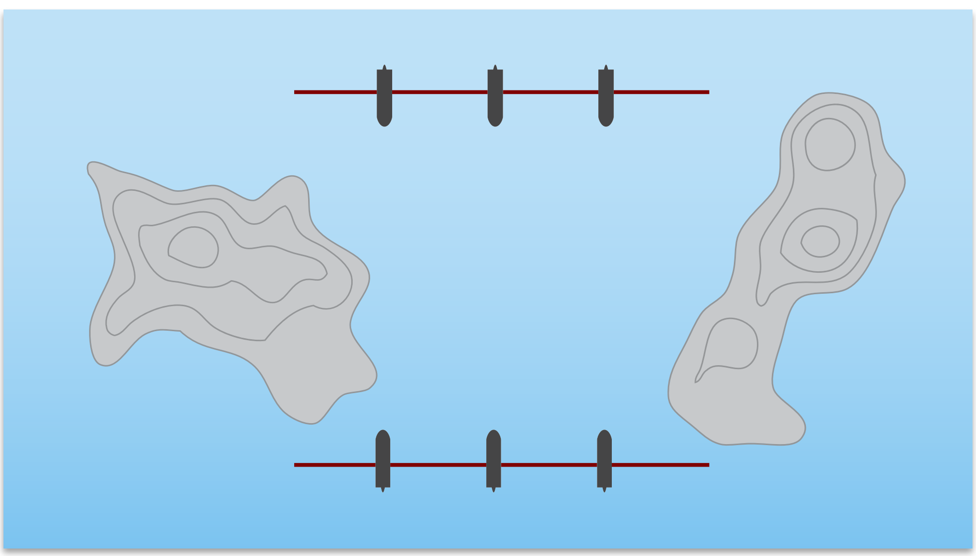

Figure 5 – Trip wire configuration in two locations

Affordable persistent monitoring enables significant data collection for analysis, leading to improved understanding of both legal and illegal activity trends in a region. Persistent, unmanned systems such as a network of Wave Gliders, can be integrated into broader operational systems to improve situational awareness and the use of high value assets such as drones and patrol vessels ultimately.

The Future: Employing the Digital Ocean for Maritime Security

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, 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.

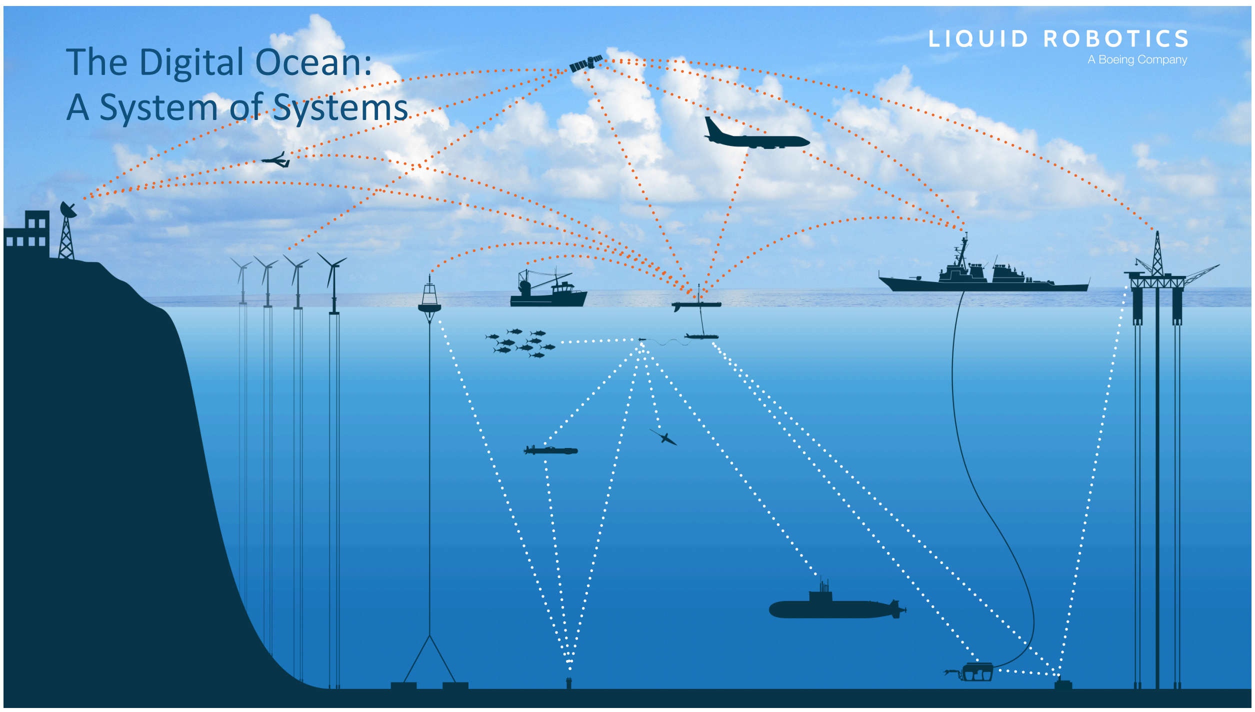

Figure 6 - Building a more Digital Ocean is a collaborative effort

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.

Governments, industry, and local communities will need to work together to monitor marine protected areas against threats such as illegal, unregulated, and unreported (IUU) fishing. People have needed to work together in new ways to change hearts and minds. In a similar light, traditional technologies such as boats and human surveillance must be augmented with unmanned systems. These systems help to extend the reach of data collection at lower costs, allowing stakeholders to prioritize resources and scale efforts. A digital ocean will provide a new infrastructure base for marine monitoring.