

## FINAL REPORT

### Wave Glider for Arctic Ocean Observations

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Award: N00014-15-I-2890

#### LONG-TERM GOALS

Study of the Arctic Ocean is challenging for many reasons, one of which is the difficulty of making observations on the surface in specific areas as the sea ice forms in the fall and melts in the spring. The cost of ships is high, and few are available. Those that are available are expensive and typically have many missions to perform. While surface moorings could collect weather and wave data, they are by necessity in fixed locations and, when located off the shelf, require a medium to large ocean-going vessel for deployment and recovery. The Wave Glider (Figure 1), in contrast, can be deployed from smaller coastal vessels, such as the R/V Ukpik used in July 2014 by Thomson and Freitag to deploy Seagliders and Wave Gliders

The Wave Glider was originally developed for acoustic monitoring of marine mammals. However, as the design matured its suitability for other surface-based oceanographic uses became apparent. Today more than 100 Wave Gliders have been produced, and many sensors have been integrated to accomplish different missions ([www.liquidr.com](http://www.liquidr.com)).

The goal of this project is to equip an SV-3 Wave Glider for Arctic operations in anticipation of future field campaigns such as the ONR DRI Stratified Ocean Dynamics of the Arctic (SODA).



Figure 1 Liquid Robotics SV-3 Wave Glider components. The umbilical is 4 m long.

**REPORT DOCUMENTATION PAGE**

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**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**  
This DURIP proposal seeks funding to purchase one Liquid Robotics Wave Glider to augment a previously purchased unit, and to outfit both them for use in sampling surface processes in the Arctic Ocean. The systems will be used in future Arctic Ocean experiments sponsored by the ONR, such as the Sea State and Boundary Layer Physics of the Emerging Arctic Ocean, a Departmental Research Initiative (often simply called the Waves DRI) with a field campaign in 2015. The Wave Gliders will be used to collect weather data and wave height, plus conductivity and temperature near the surface.

**15. SUBJECT TERMS**  
Arctic Ocean, Undersea Workstations & Vehicles, Signal Processing, Navigation, Underwater Acoustics

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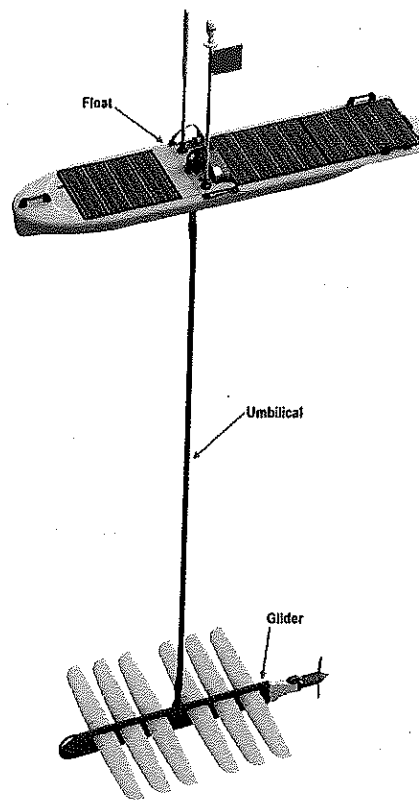


Figure 1 Liquid Robotics SV-3 Wave Glider components. The umbilical is 4 m long.

## OBJECTIVES

The in-situ measurements made with the Wave Gliders and other wave sensors will provide observations over the several-month temporal evolution of the MIZ, and as a function of location within the Beaufort Sea. The observations provide important information that helps define the impact of waves on the ice within the MIZ. Large swells can reduce solid ice to small floes within hours, and the decay of swell as it propagates into the MIZ (in different types of ice) is an example study parameter that the observations enabled by the Wave Glider will bring to the overall ONR MIZ DRI data collection effort.

The wave work to be undertaken by Thomson (APL-UW) using the data collected with the Wave Gliders (as well as the other proposed sensors) will target several specific areas of scientific inquiry that fall under the category of wave evolution, including wind forcing, breaking dissipation, and ice attenuation. For example:

1. Growth of local waves from forcing via wind stress.
2. Wave dissipation due to turbulence from breaking waves.
3. Wave damping due to ice interaction.
4. Fetch dependence in and near the MIZ.

Example wave data is shown in Figure 2, with the significant wave height from each of the two systems. The distance between the two Wave Gliders was between 20 and 50 km during this period, and the two measurements are highly correlated from 9/8 through mid-day on 9/9. At this point Wave Glider *Peary* encountered a small region of concentrated ice and became trapped within it, damping motion due to ocean waves. The data shown was sent back in real-time, and it was used by Jim Thomson in his study of waves, fetch and ice in the MIZ, and will again be in the next field campaign.

## APPROACH

*Adding Sensors.* The Wave Glider has room for multiple payload boxes in the float, in addition to the command and control dry box that contains the core computer, power system and Iridium terminal. User sensors may be added to the boxes, and externally in the area between the solar panels plus on the sub (Figure 3).

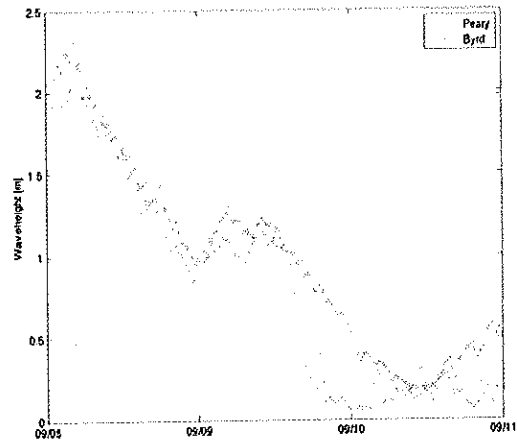
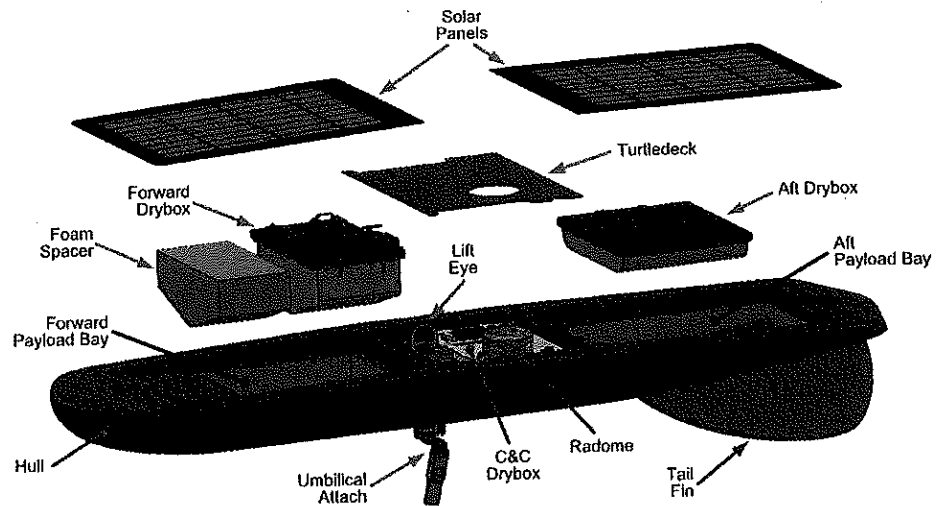


Figure 2 Wave height over time as measured and reported in real-time by the GPS-based wave software on the float. *Peary* was stuck in the ice starting on approximately Sept. 10 (courtesy Jim Thomson, APL-UW).

Figure 3  
Exploded  
view of the  
Wave Glider  
float showing  
the user  
payload areas  
(forward and  
aft dry boxes)  
Image: Liquid  
Robotics.



One of the concerns early in the deployment was whether there would be sufficient energy to supply the glider and payload with power through September when they were to be recovered. The concern about energy was quickly alleviated by monitoring the solar input and power draw, which showed that the solar cells were able to fully recharge the batteries on many days, depending on the cloud cover. The situation changed by mid-September, when a combination of less sunlight, a lower solar angle and increasing clouds greatly reduced the watt-hours per day that were available for battery recharging.

The lack of reserve energy meant that all of the non-essential subsystems had to be turned off in order to preserve energy to operate the core vehicle functions such as steering and telemetry. Thus the approach has always included power control over the sensors so that they can be selectively managed during the deployment.

## WORK COMPLETED

The sensors described below were procured from a number of sources and installed either at the factor by Liquid Robotics, at WHOI, or at APL/UW. There were three primary sensors that were added, meteorological, surface temperature, and wave motion.

**Meteorological Sensor.** The Airmar PB200 Weather Station (Figure 4) mounted on a 1 meter tapered fiberglass mast. The PB200 reports the following parameters once every 10 minutes:

- Air Temperature (degrees C)
- Wind Speed and Gust Speed(knots)
- Wind Direction (degrees true)



Figure 4 Airmar Weather Station

- Air Pressure (millibars)
- Time/Position

**RM Young ultrasonic anemometer.** While the Airmar sensor will be used to provide weather data, Jim Thomson of APL/UW requested that a more accurate anemometer be incorporated as well. The RM Young model 8100, which costs approximately \$3000, has a resolution of 0.01 m/sec and accuracy of 1%. In addition it can sample from 4 to 32 times per second, providing very high rate 3-axis measurements. In addition, it is low power, just over 1 W. The sensor is shown in Figure 5. It will be mounted on a secondary mast away from the main mast to reduce any likelihood of shadowing.

**CTD and Dissolved Oxygen.** Conductivity and temperature plus dissolved oxygen will be sampled with a sensor just under the float. The sensor was installed using an approach developed by Jim Thomson's engineering team at APL/UW.

**Xenics Infrared Camera.** In addition to the above sensors, an infrared (IR) camera was procured. The camera will provide an indication of ice, even if relatively far away and in poor visibility. The goal is to not discern small individual growlers, but lines of ice near or on the horizon. The image processing necessary to 'see' ice within an infrared image is simpler than with a standard camera, allowing for low-cost automation. The goal is to simply report whether there is an ice or no-ice state where the camera is pointing on a regular basis (half-hourly), and also to send back images where ice is detected on an occasional basis (several per day maximum).

## RESULTS

The Wave Glider was deployed during the September 2018 SODA cruise in the Beaufort Sea north of Alaska. It was operated from the *RV Sikuliaq* and piloted by Jim Thomson of APL/UW. Data was collected using the sensors described above (except the camera, which was not installed as part of the core science mission for this cruise). The data will be used as inputs to the surface and near-surface data analysis work that addresses the science questions described below in the Impact section.

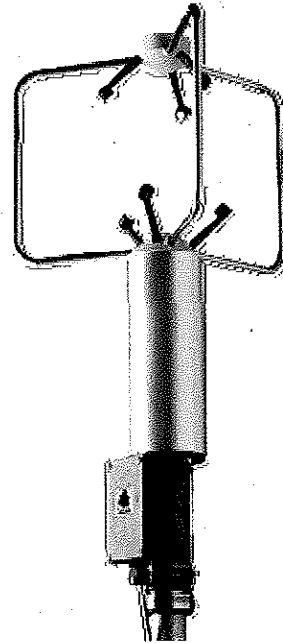


Figure 5 RM Young model 8100 ultrasonic wind sensor.

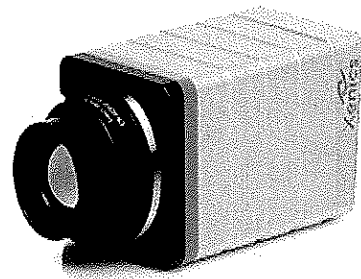


Figure 6 Xenics Infrared

## **IMPACT/APPLICATIONS**

Use of the wind, wave and near-surface conductivity and temperature data from this platform will help to answer these science questions:

1. What are the respective roles of surface-wave driven mechanical forcing, solar-radiation driven thermodynamic forcing and the delivery of heat through advection and diapycnal mixing (driven by direct wind-forcing, internal waves and small-scale, windstress curl-driven vertical exchange) in governing MIZ evolution? How do these processes couple?
2. How do surface waves evolve within the MIZ as a function of fetch and season? What is the input-dissipation balance of waves in a mixed fetch of open water and ice floes? How do surface waves attenuate/collimate across the MIZ?
3. What is the ice floe response to surface waves? What are the short-scale flexural variations across a floe?
4. How does the upper ocean response to wind forcing vary as a function of ice cover? How do wind-stress and ice-ocean stress vary across the MIZ, and how does this relate to mixed layer currents and internal wave intensity?

## **TRANSITIONS**

Potential transitions include any program related Arctic Domain Awareness and Maritime Domain Awareness in general. In addition, there are so few weather stations in the Arctic, and none on buoys in areas that are ice-covered in winter, so that the LRI Wave Glider, equipped with these sensors, may be an option to increase the reliability of local weather forecasts.

## **RELATED PROJECTS**

### **Current**

ONR: Stratified Ocean Dynamics of the Arctic (SODA).

### **Future**

ONR: Arctic Mobile Observing Systems (AMOS).

## OBJECTIVES

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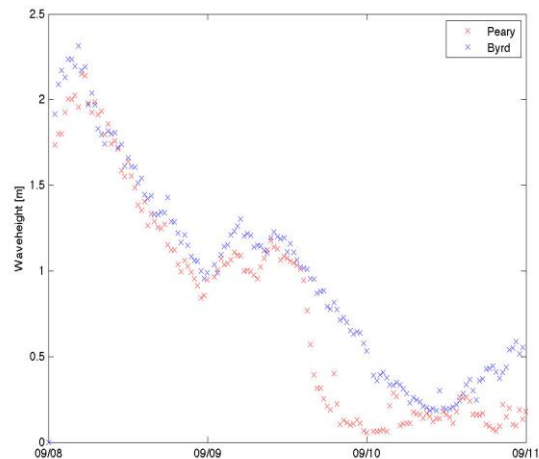
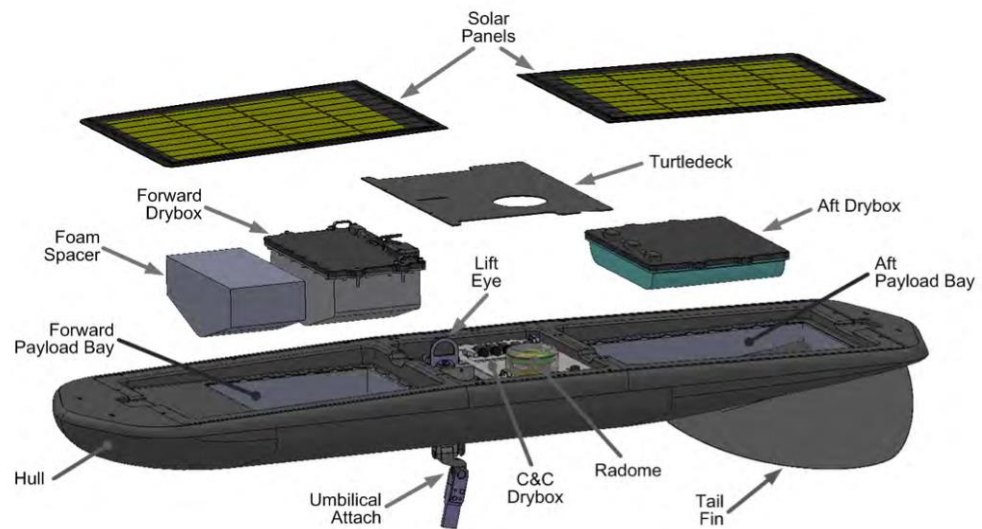


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