Advances in Unmanned Surface Craft

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Liquid Robotics

Mission	Change the economics of ocean data gathering and revolutionize how the world accesses our oceans
Business focus	Ocean data services provider and developer of the Wave Glider®
Market traction	Over 150 Wave Glider systems shipped globally
Target markets	DoD, Oil & Gas, Science & Oceanography
Oil & Gas	Joint venture with Schlumberger
Employees	110+
Investors	VantagePoint Capital Partners and Schlumberger
Incorporated	2007
Locations	California, Hawai'i, Washington DC

Awards

WORLD ECONOMIC FORUM
Technology Pioneer 2013

RBR 50

50 MOST INNOVATIVE COMPANIES

GoingGreen Global 200 -WINNER-

Wave Glider® Technology

Systems, Operations and Performance

The Wave Glider

Float

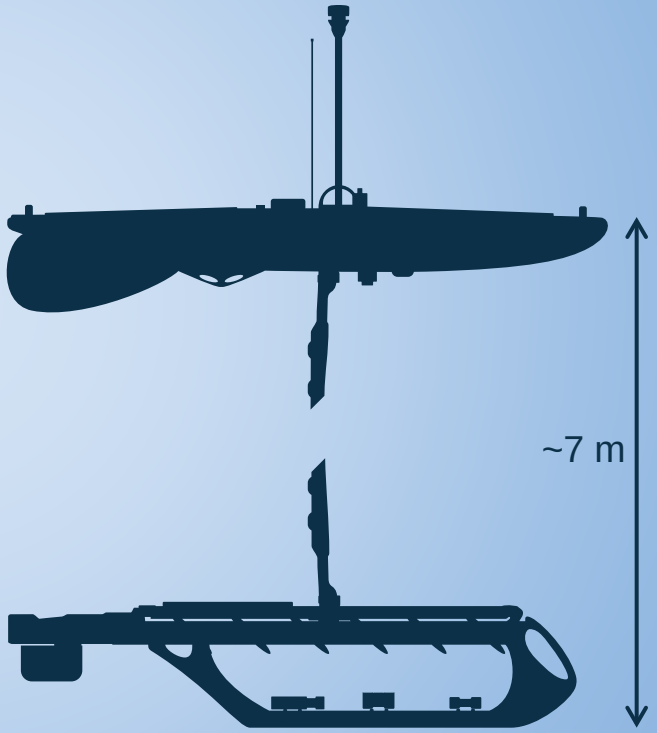
- Solar Panels
- Navigation
- Communications – Iridium or cellular
- Payloads

Sub

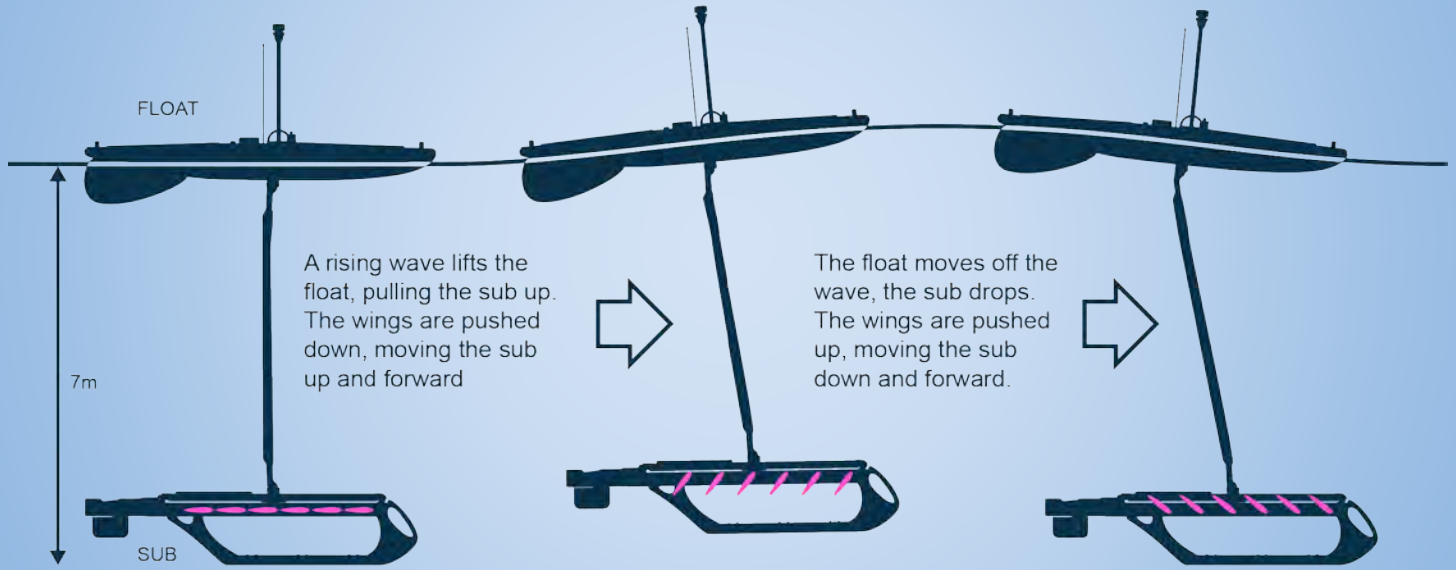
- Wave Powered
- Forward Thrust
- Rudder Control
- Payloads

Speed

- Averages 1 to 1.5 knots - STW

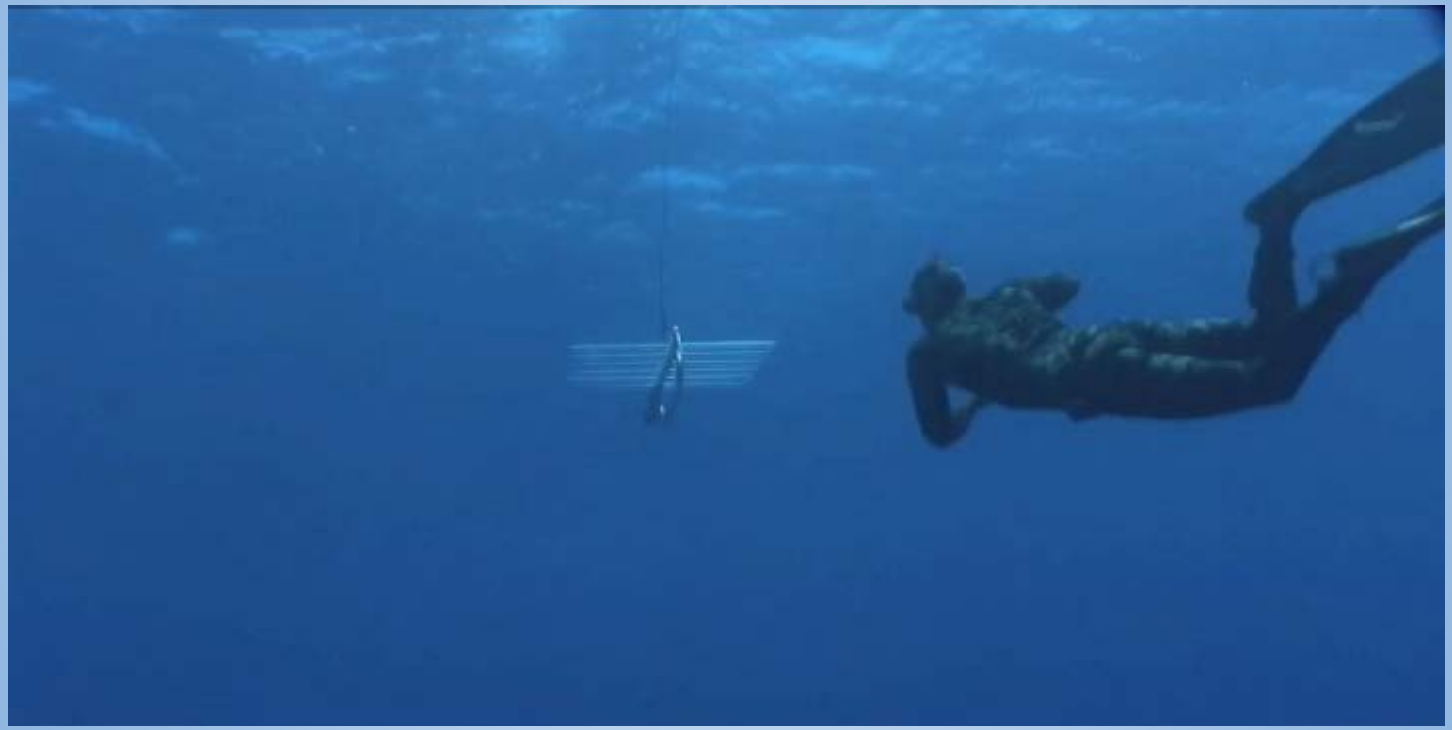


How It Works



3 U.S. and 9 foreign patents issued. 20 U.S. Provisional applications, 42 foreign applications.

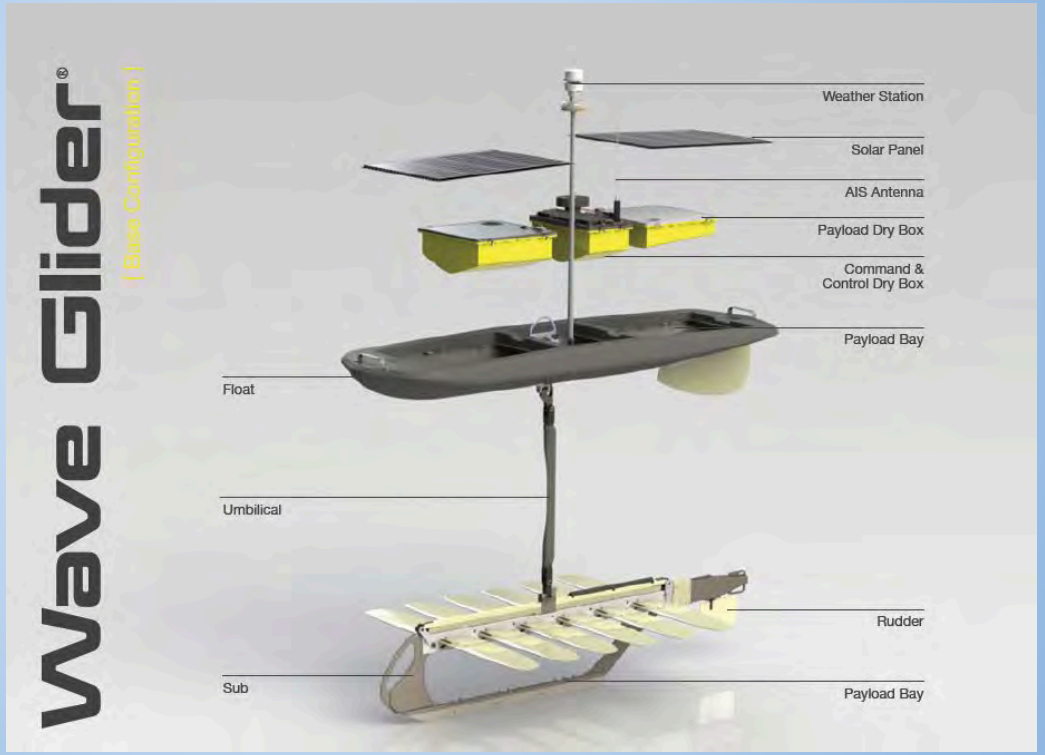
How It Works



System Architecture - Modular

Modular design

- Encourage sensor integrations
- Simple maintenance
- Custom algorithm development



Available Sensors

Surface Sensors

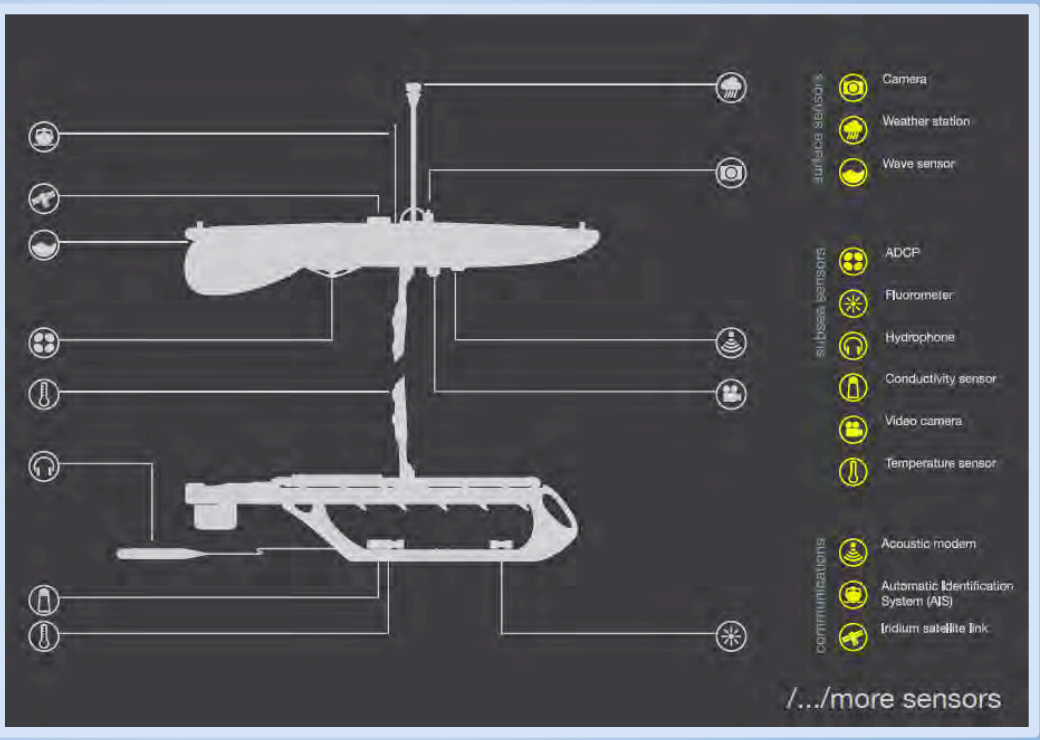
- Camera
- Weather Station
- Wave Sensor

Subsea Sensors

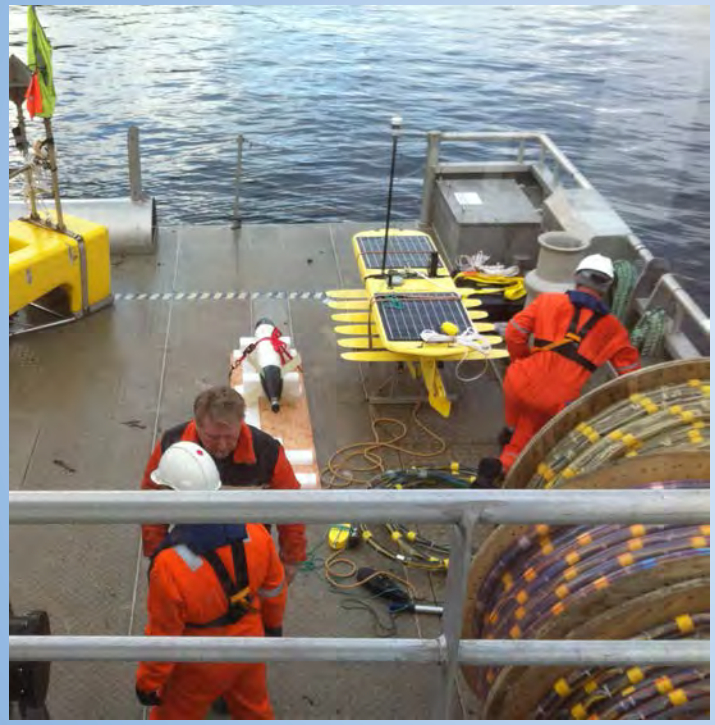
- ADCP
- Fluorometer
- Hydrophone
- CTD+DO
- Echosounder

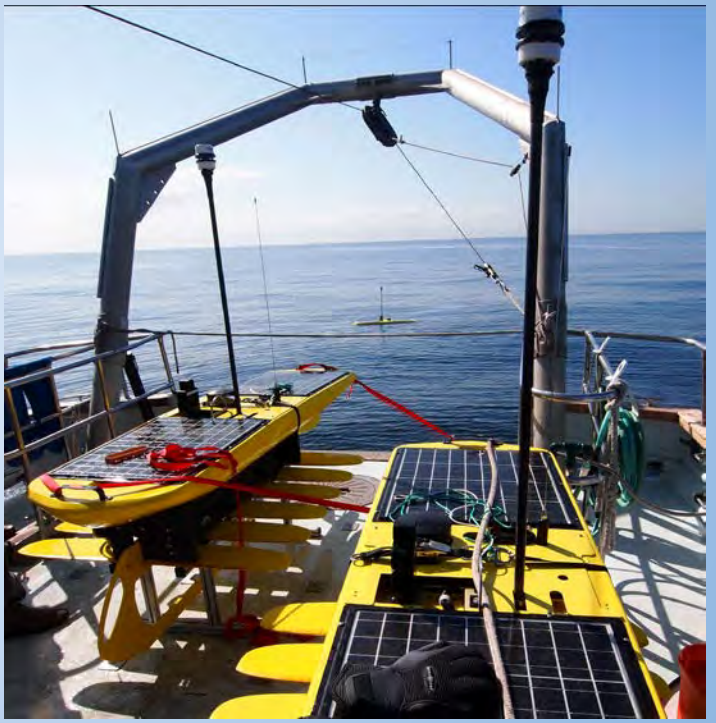
Communications

- Acoustic Modem
- Automatic Identification System (AIS)
- Iridium Satellite Link



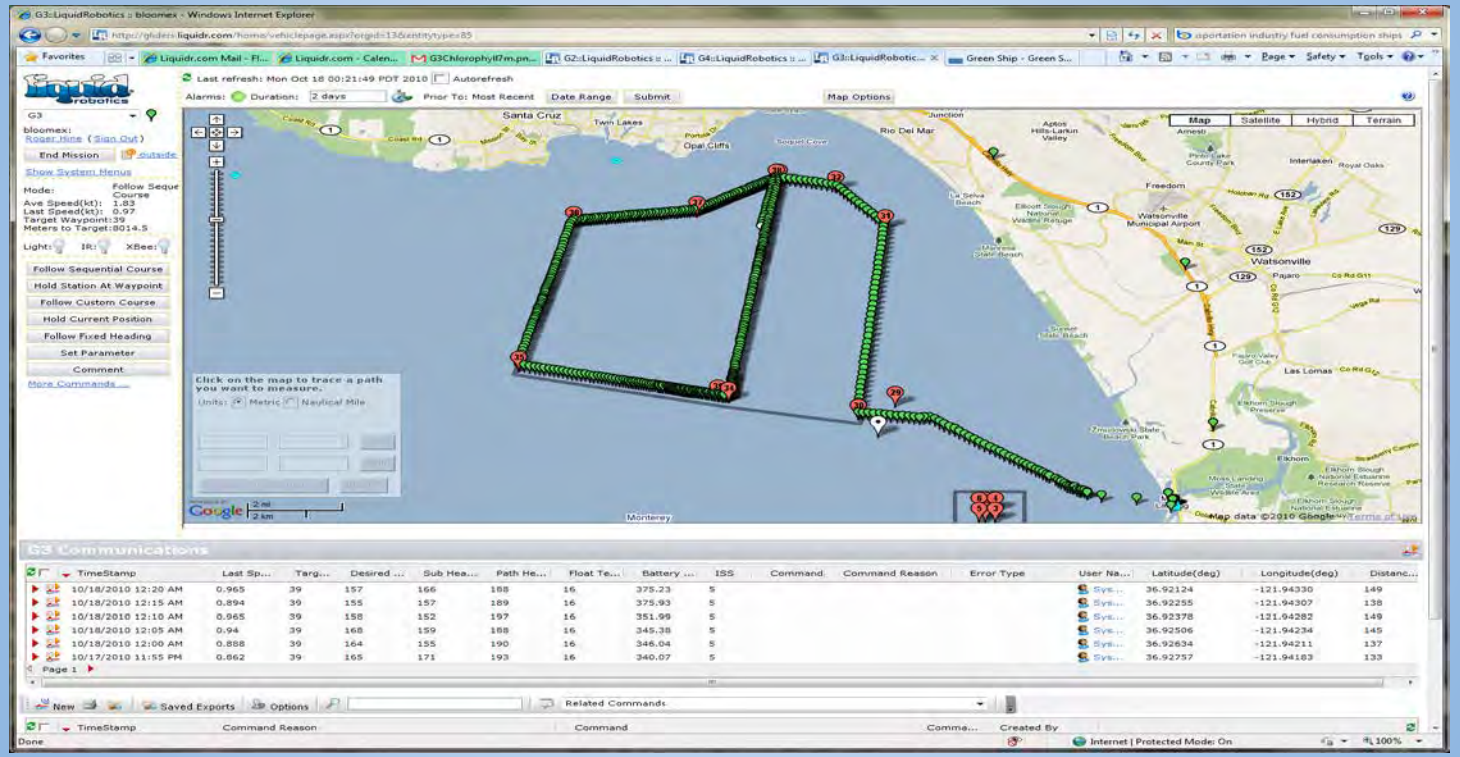
Marine Operations From Ships or Small Craft



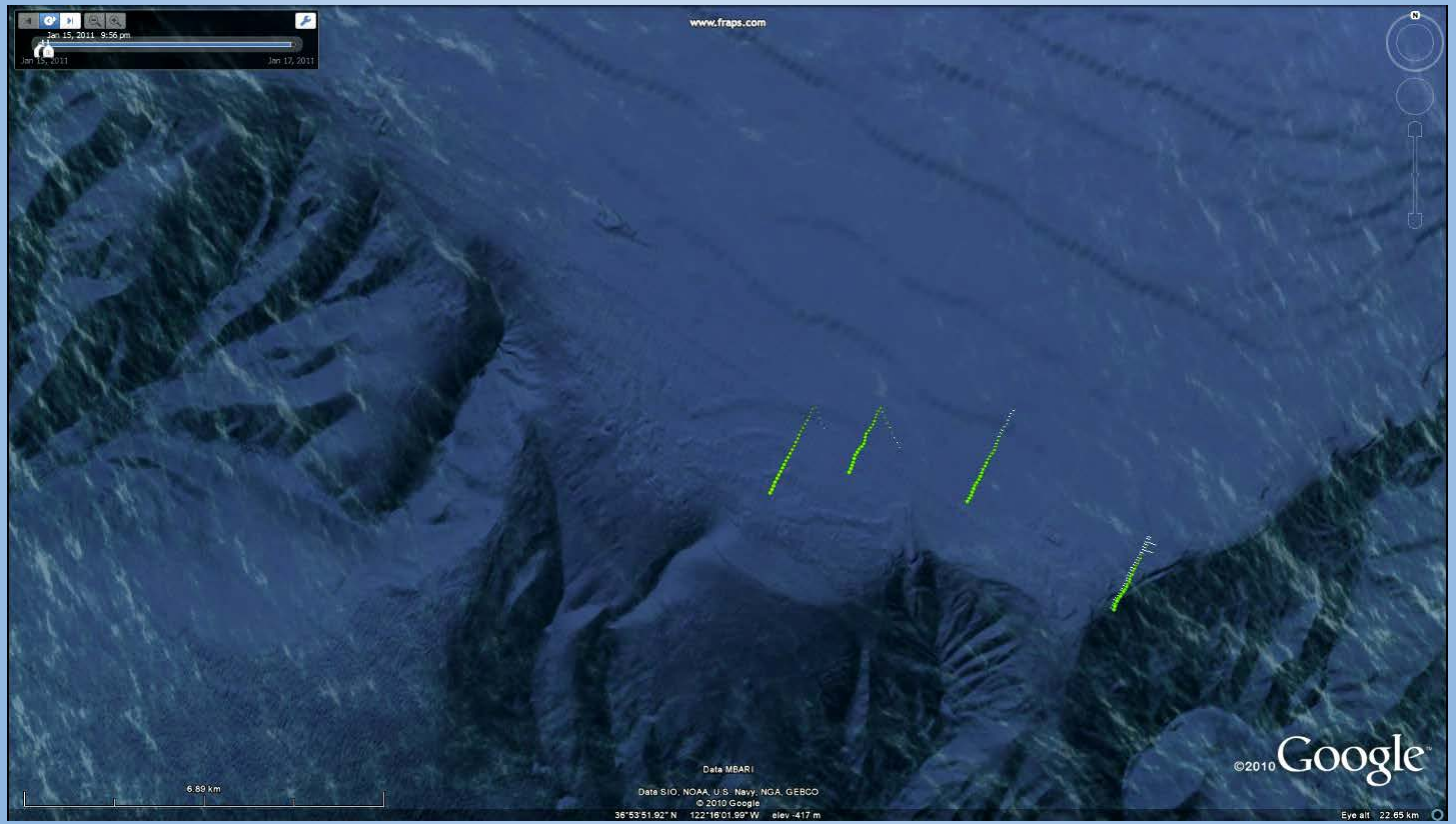


Launch and Recovery with Minimum Equipment

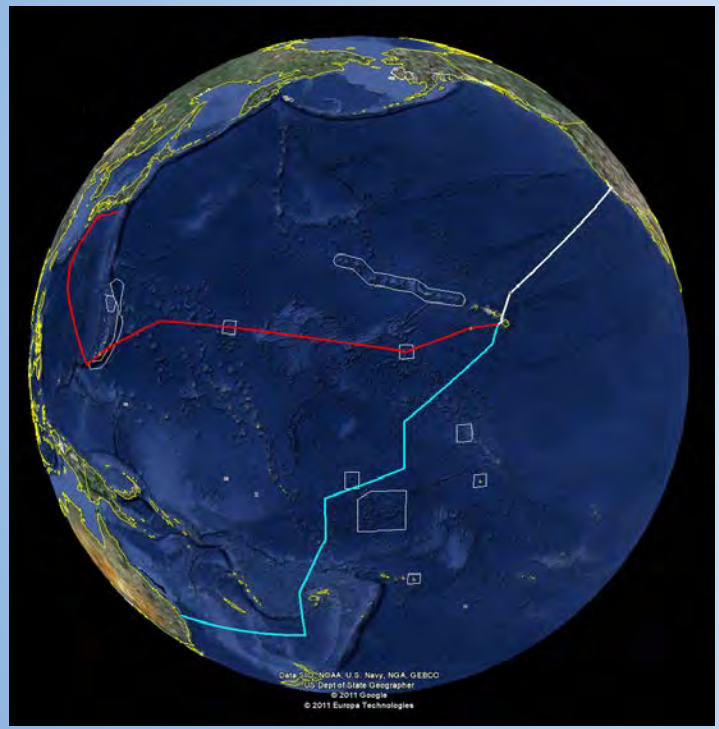
Wave Glider Management System (WGMS)



Line Following Array Demonstration



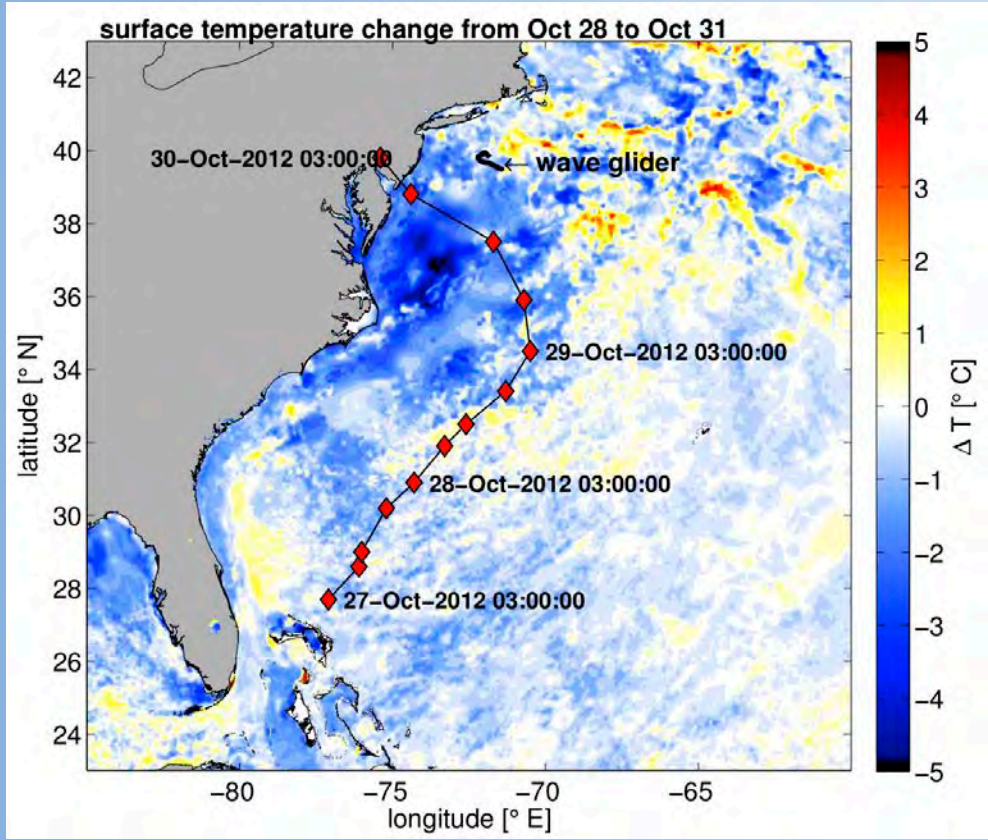
PacX Mission

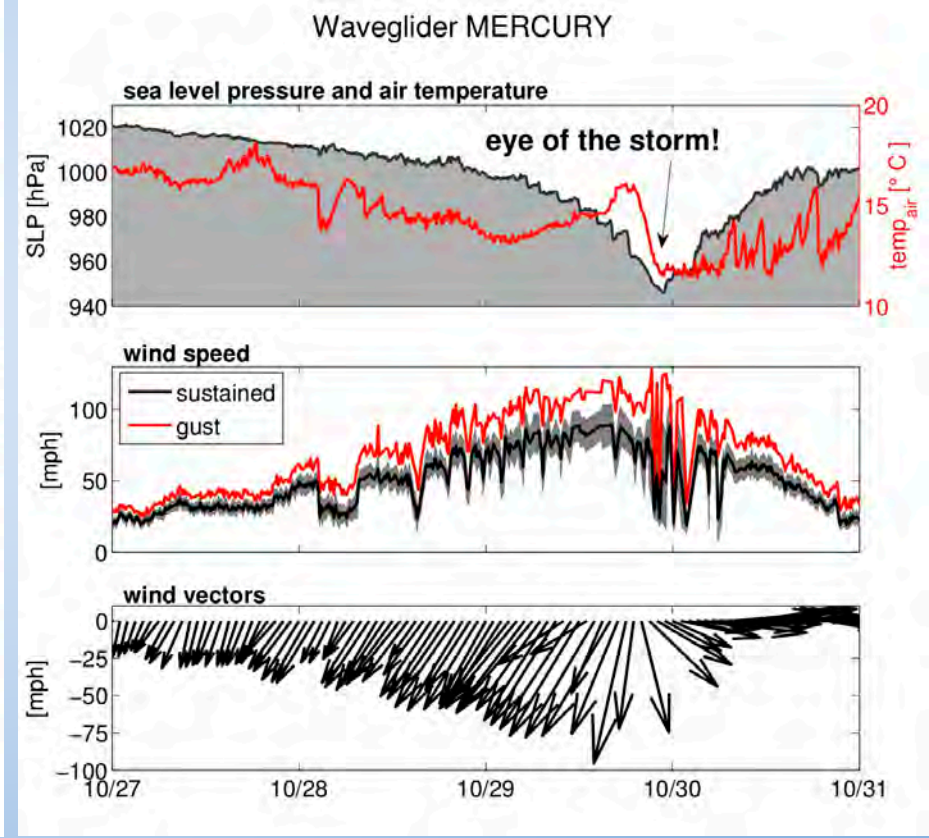


The Challenge

- 4 Wave Gliders
- 370 Days
- 2,250,000 Data Points
- 30,000+ Combined Nautical Miles
- All four seasons
- **All Data Available online for free**

Wave Glider Data - Hurricane Sandy

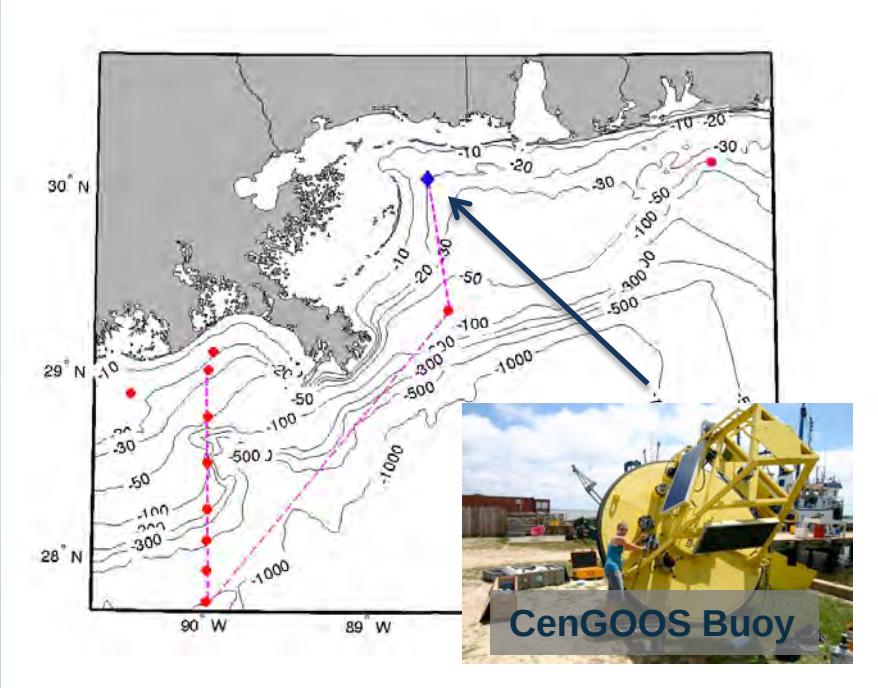




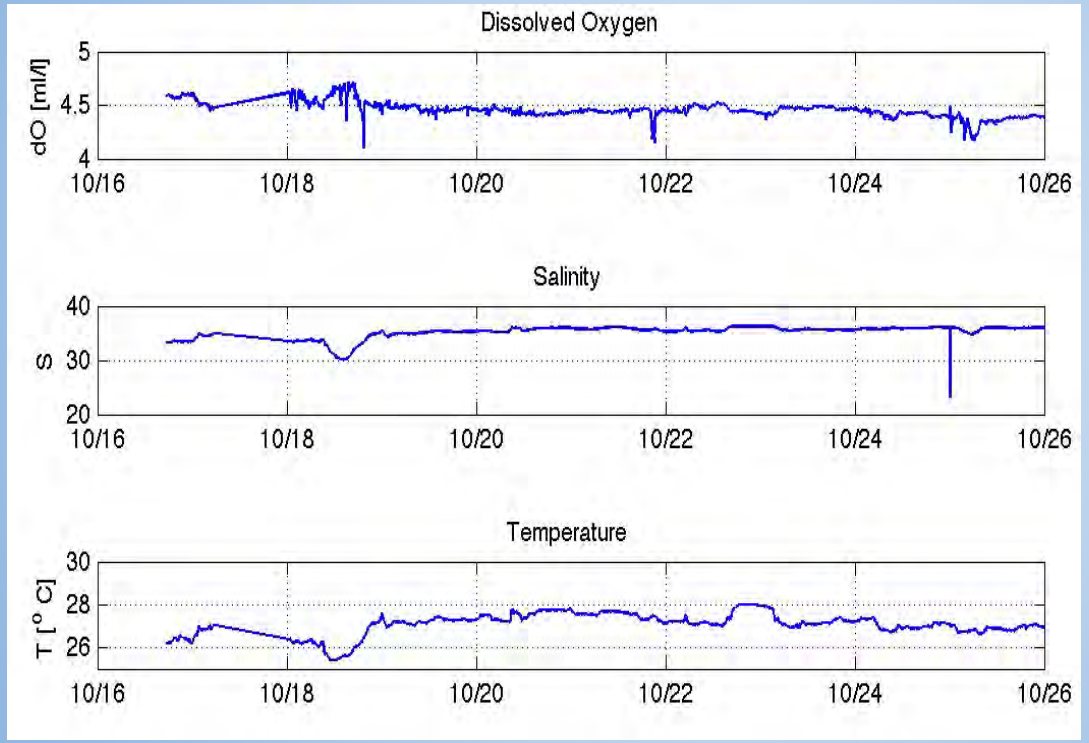
Wave Glider pCO2 Pilot Project – Northern GOM

Wave Glider Pilot Project

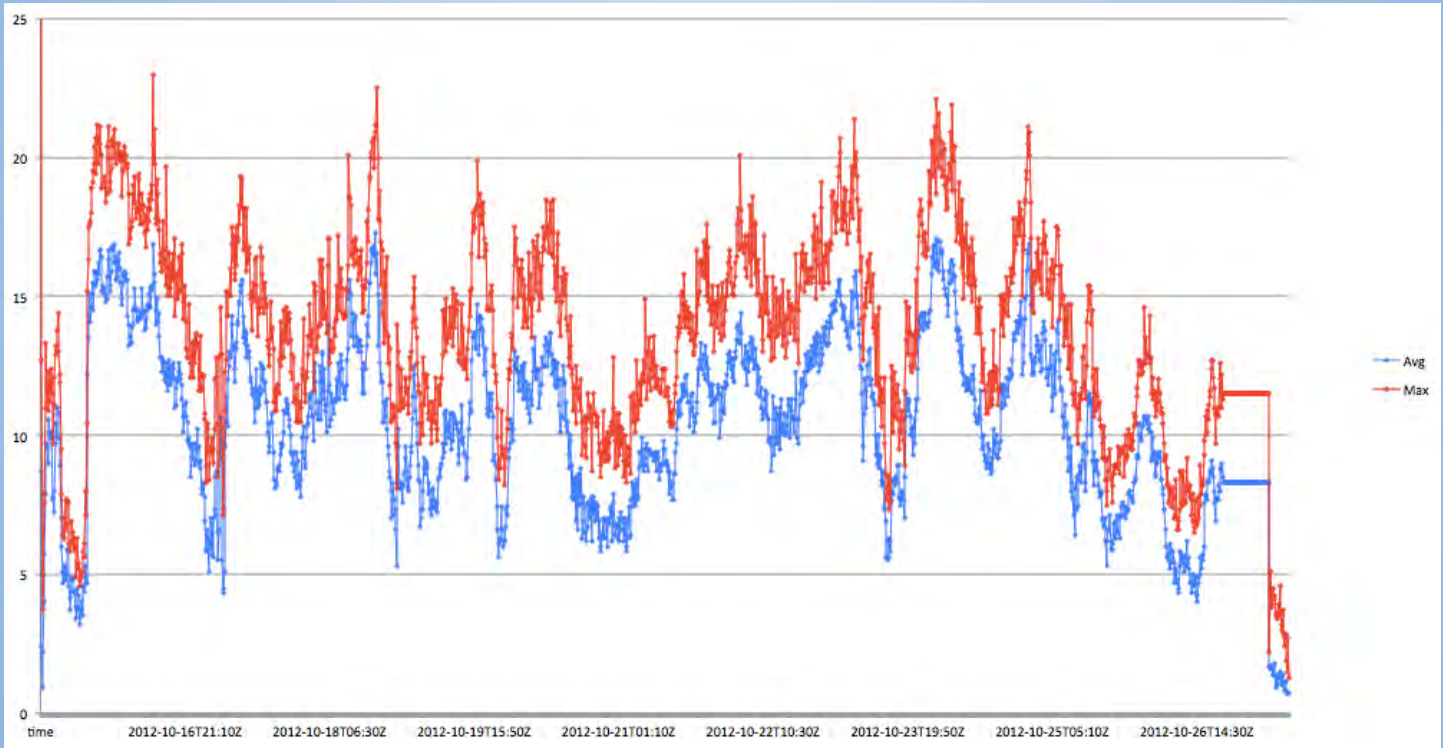
- Use a Wave Glider on a 36 day mission
  - MBARI pCO2 system
  - GPCTD + DO
  - Weather Station
  - Water speed sensor
- Follow 260nmi of GOMECC-III cruise
- Start at CenGOOS Buoy to correlate datasets
- Piloted from Sunnyvale



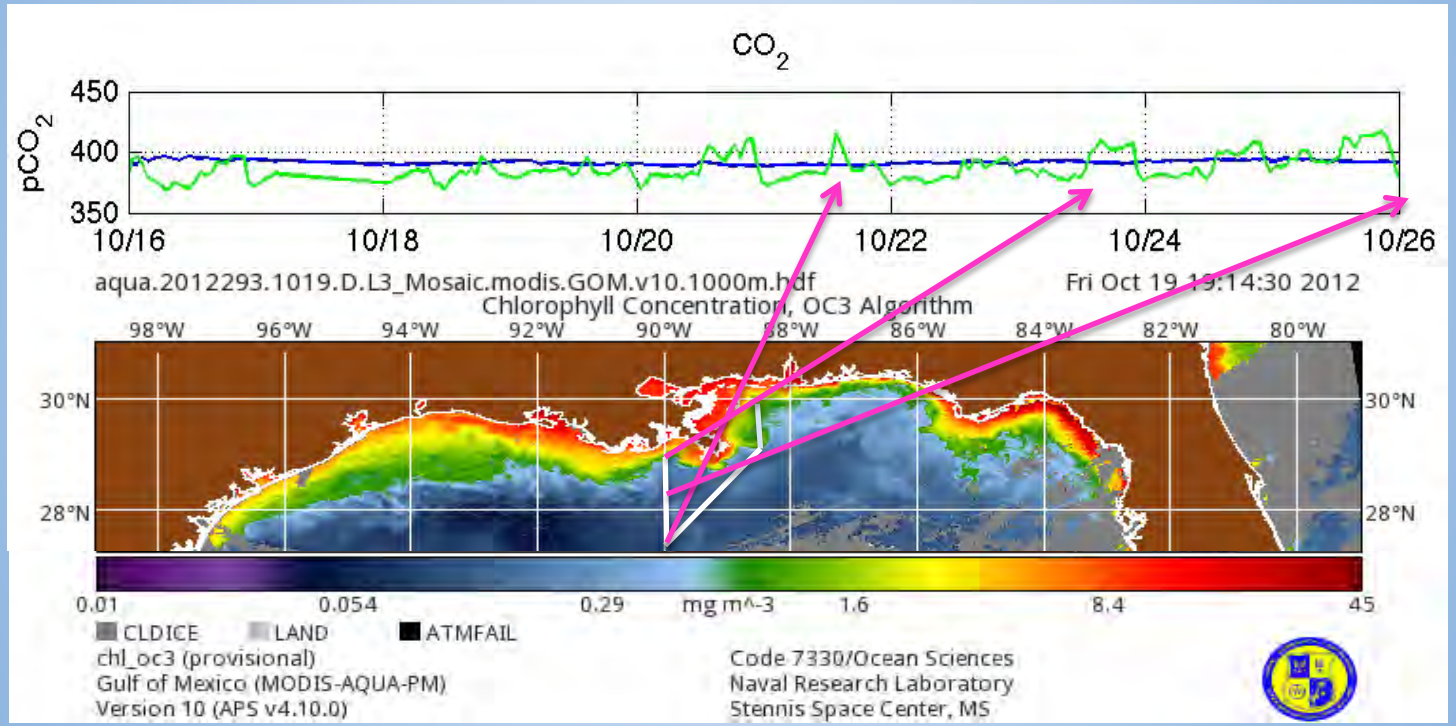
Real-Time, Preliminary GPCTD+DO Data



Real-time Preliminary Wind Speed Data



Real-Time, Preliminary MBARI pCO2 Data



Wave Glider SV3

Next Generation Platform

Introducing Wave Glider SV3

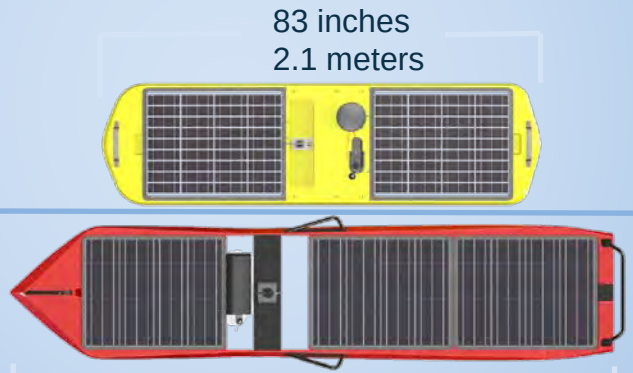
- Enhanced float and glider with new electric thruster
  - Propulsion in low wave states
  - Better collision avoidance
- Modular power system
  - 2x solar capacity
  - 10x battery capacity
  - Plug-in expansion
- Modular float design for fast reconfiguration and field service
- High performance onboard processing, plus new umbilical networking (100 Mbps)

Higher powered payloads, more frequent sampling

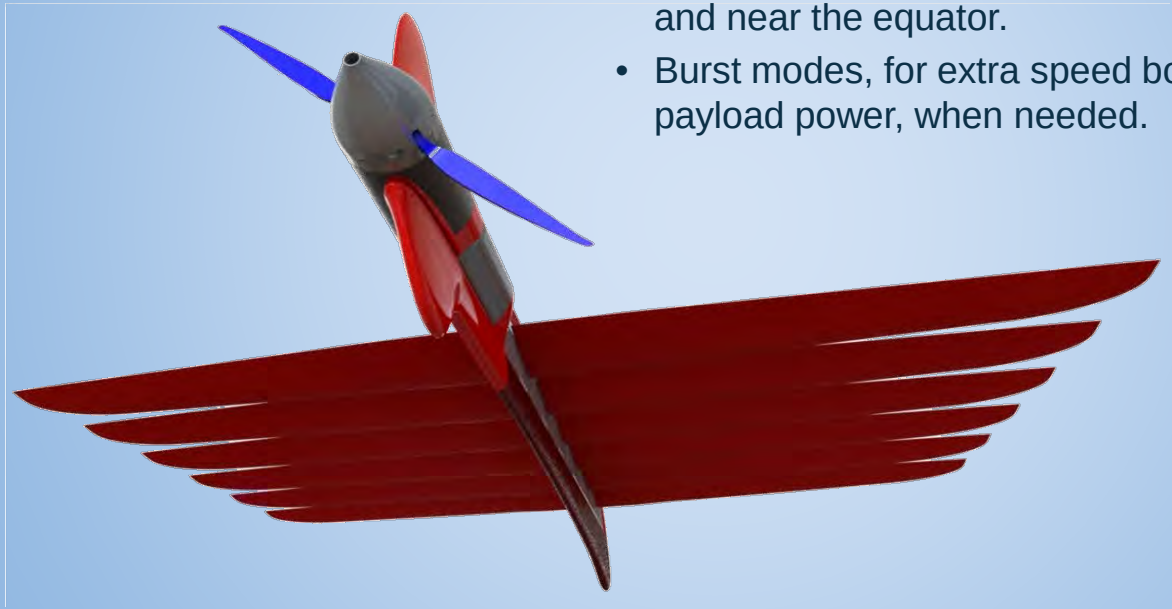
Power

Payload Size

	Peak to Payload	Solar Panel Peak	Volume	Weight
SV2	80W	86W	1.4 ft^3 48 L	40 lb 18 kg
SV3	400W	170W	3.3 ft^3 93 L	100 lb 45 kg



Auxiliary thruster for speed bursts



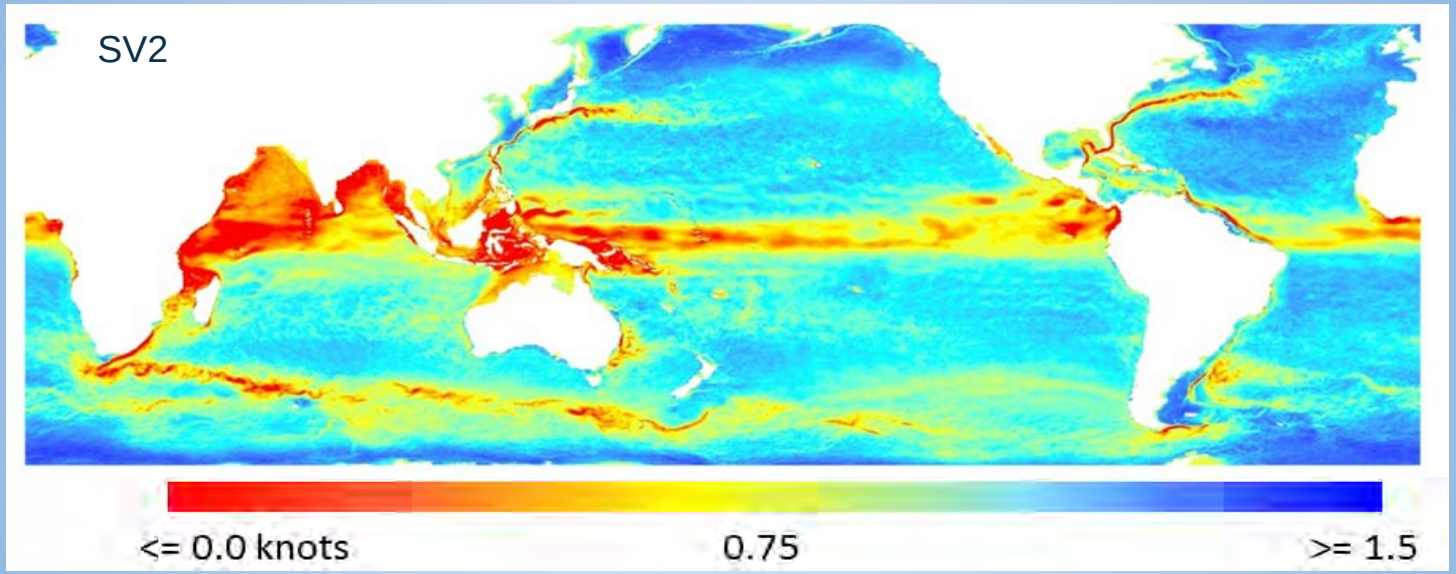
- Better station keeping performance in summer and near the equator.
- Burst modes, for extra speed boost or extra payload power, when needed.

Speedier = faster, shorter missions = lower costs

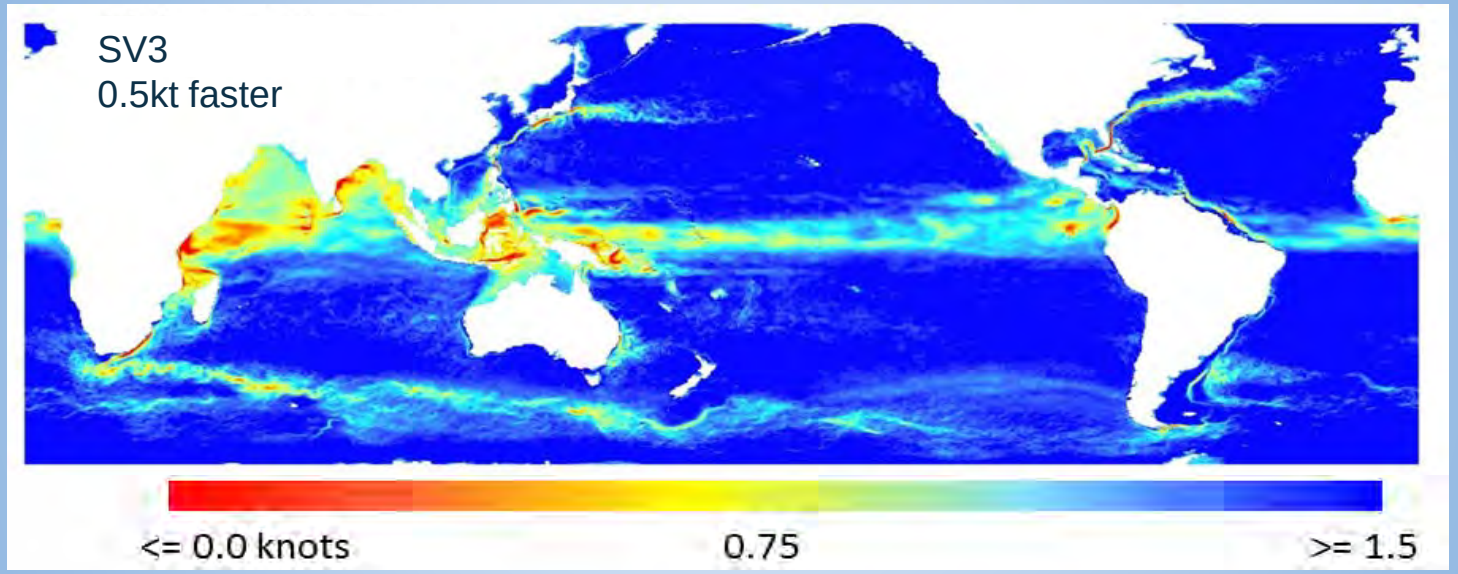
- Comparison testing in Hawaii:
  - Existing Wave Glider 1.4 knot
  - New SV3 1.9 knot
  - New SV3, Thruster @35W 2.4 knot

- Test conditions: 2-4 second, 0.5-1.0m waves

SV2 Global Speed Model



What Would Could Increased Speed Give You?



Hypoxia

Ideas for Hypoxia Monitoring

Wave Glider – Hypoxia Monitoring

- What is the maximum buoyancy change your glider can vertically transit?
- How shallow can your glider operate and what, if any, comprises that have to be made to achieve this (e.g., efficiency lowering mission duration, …)?
- How close to the seafloor can your glider's sensor package take measurements, including dO measurements and under what conditions is this possible?

Wave Glider – Hypoxia Monitoring

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As a surface vehicle, the Wave Glider is unaffected by changes in water density.

Wave Glider – Hypoxia Monitoring

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SV2

Two Umbilical options:

- **5.8m** (standard)
  - Min safe operation depth: 10m
- **4m** (option)
  - Min safe operation depth: 8m

SV3

One Umbilical option:

- **4m** (standard)
  - Min safe Operation depth: 8m

Wave Glider – Hypoxia Monitoring

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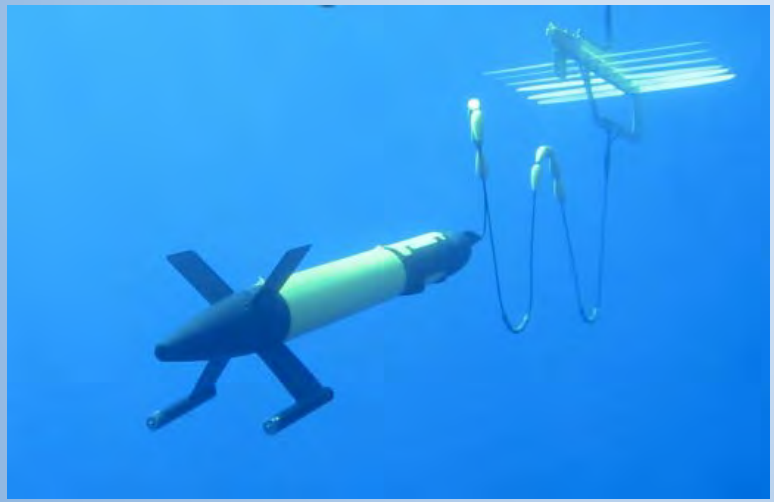
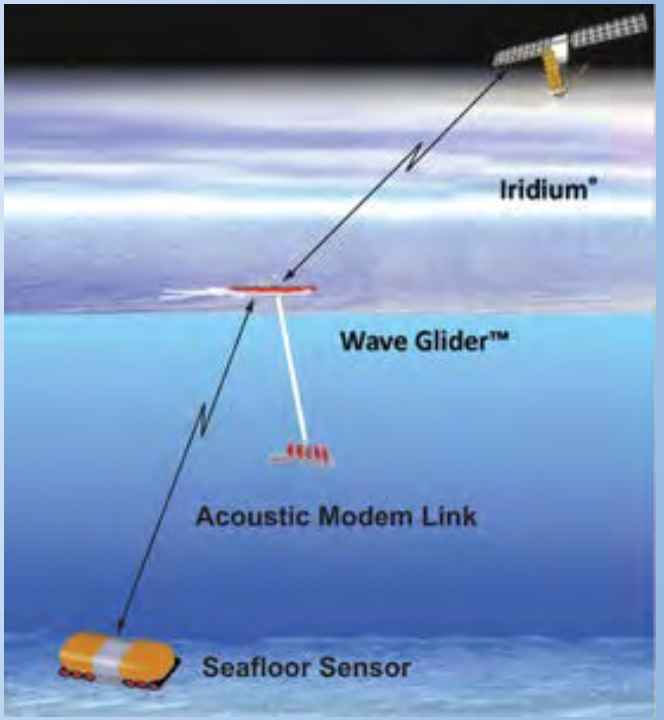
- How close to the seafloor can your glider's sensor package take measurements, including DO measurements and under what conditions is this possible?

While the Wave Glider is a surface vehicle with a maximum depth of 7m, there are several options for deploying sensors to greater depths to collect real-time data.

Wave Glider Hypoxia Monitoring

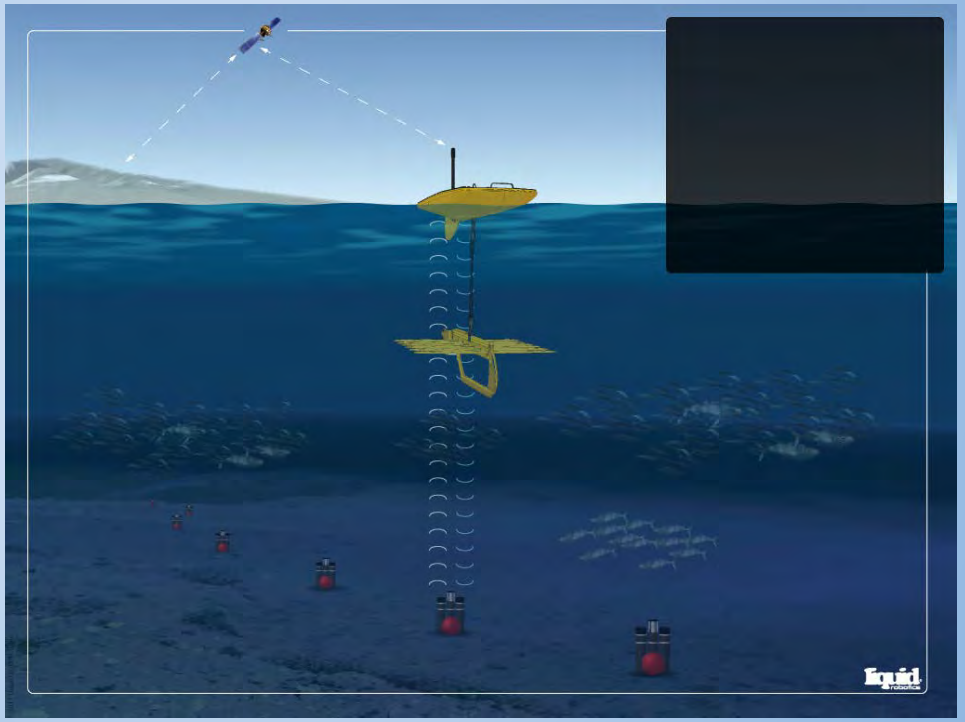
- Two main options
  - Bottom Sensor Packages
  - Towed/Winched Device





Wave Glider Acoustic Gateway

- Utilize the Wave Glider to query bottom sensor packages.
- Data sent ashore in real-time via Iridium.
- Wave Glider being utilized for this in multiple projects with seismic, pressure, or geodesy sensors.
- Support for Benthos & Sonardyne modems.

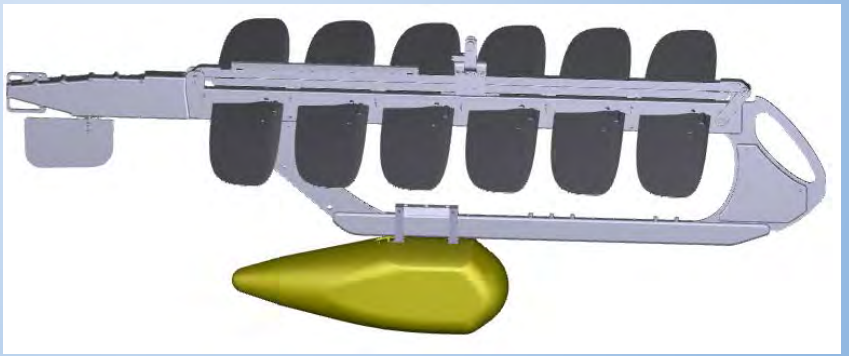


Wave Glider Towed/Winched Sensor

- Concept: Use a trailing cable to pull a DO sensor

- 3 levels of complexity:
  - Static length cable with DO sensor run along a single isobath
  - Sensor raised and lowered with a winch using an echosounder to control depth
  - Buoyancy controlled towbody

- Project currently underway at Scripps to integrate winch to raise and lower a CTD to 200m depth.



In Conclusion - Wave Glider

Persistent

- Year long missions without fuel or maintenance

Mobile

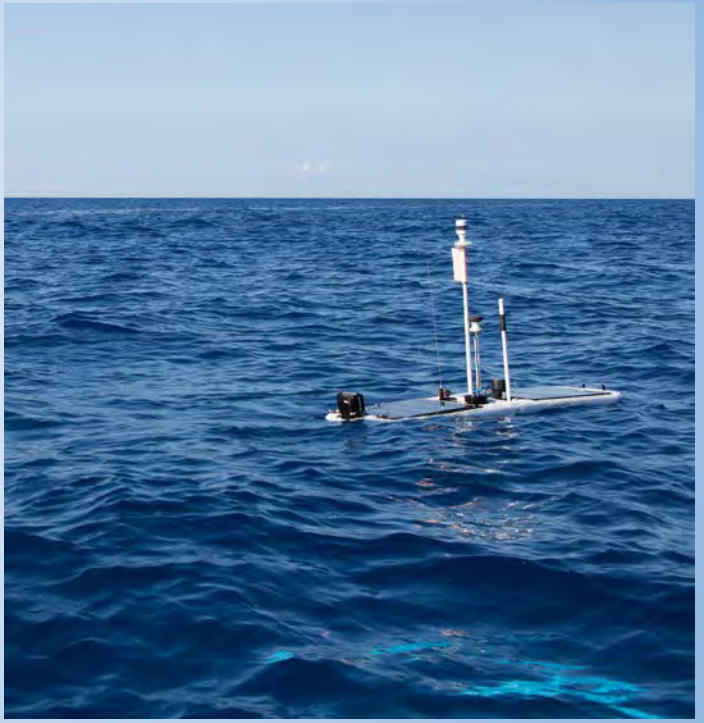
- Travel to op area, patrol, and return
- Capture spatial and temporal dynamics

Real-Time

- Data transmitted via satellite connection

Proven

- More than 150 systems shipped
- Over 300,000 operational miles



Questions?