



# “Crossing the Chasm”

Today's Gliders versus  
the alternatives

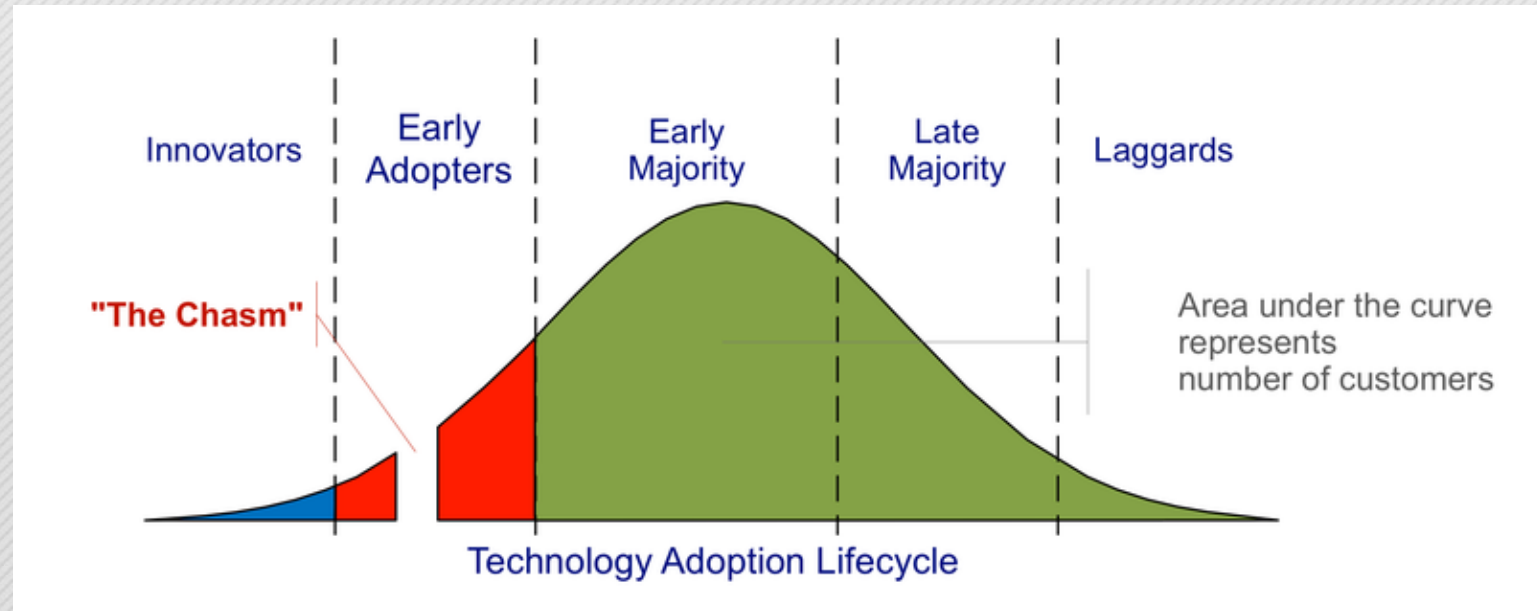
Edison Hudson  
Director  
iRobot Maritime Systems





# Crossing the Chasm : Rate of Technology Adoption

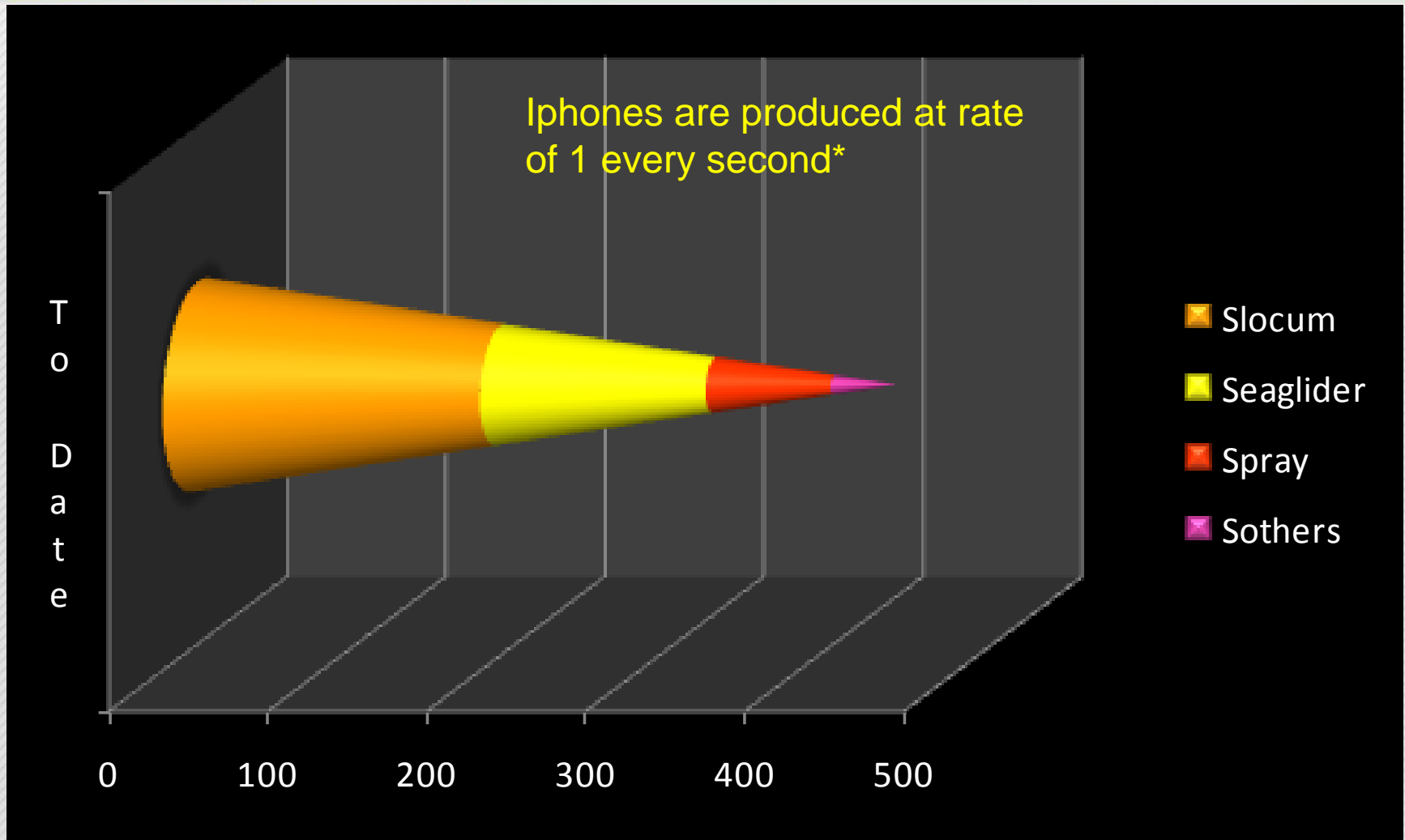
**iRobot**  
Seaglider



**With every new technology, there exists an opportunity to lose momentum and to miss transition to the next stage.**

“Crossing The Chasm” by Geoffrey Moore, Harper Business Essentials, 2002

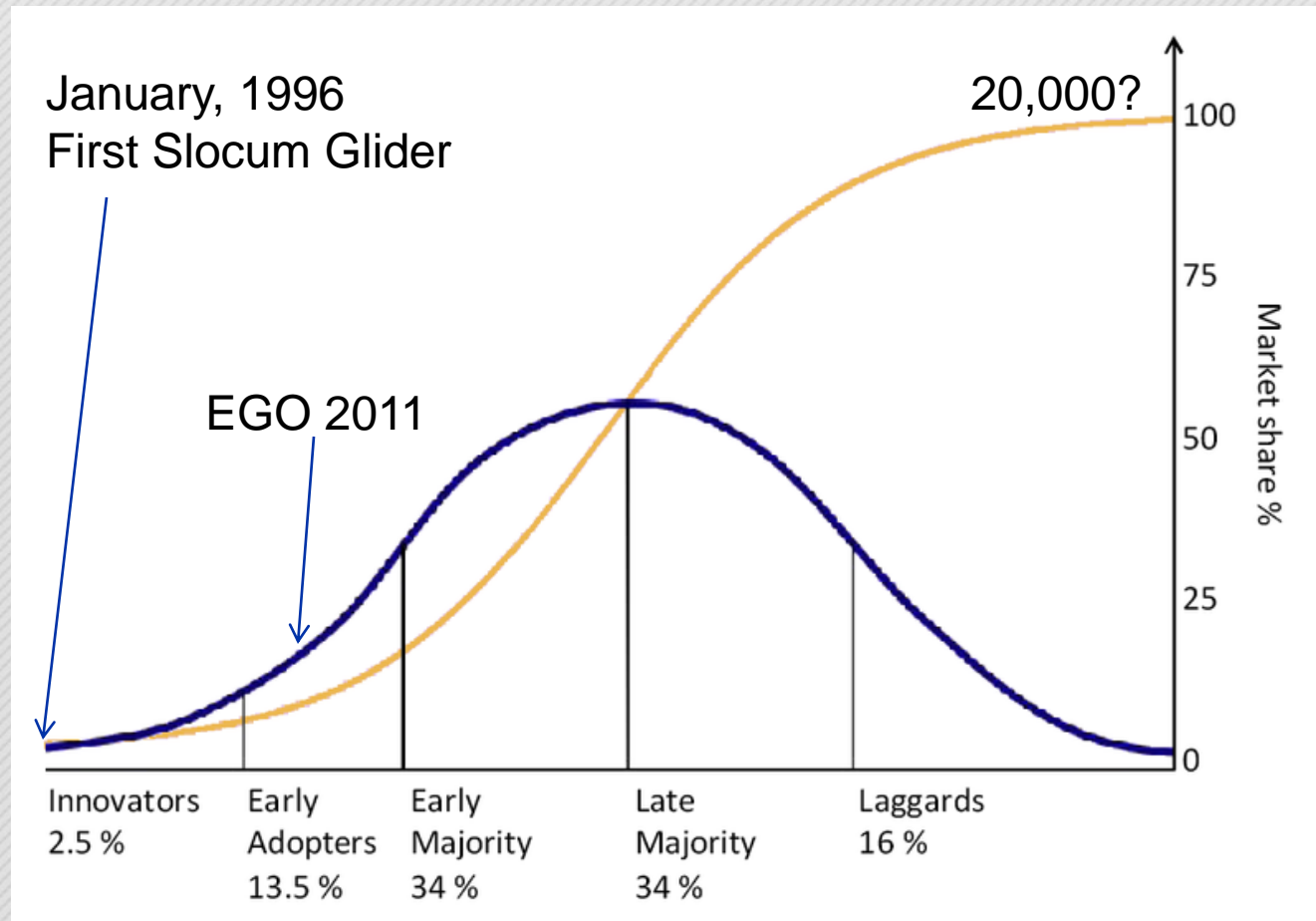
# Glider Production noses forward



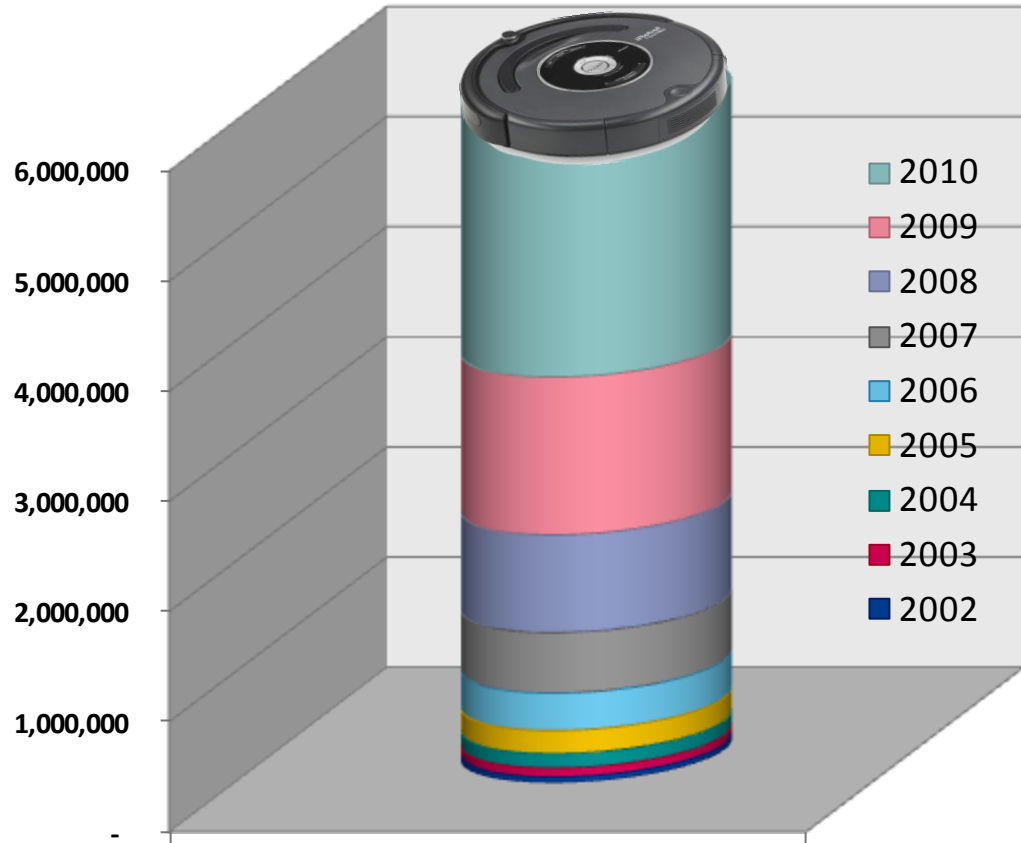
iPhones produced: 31.5 m in 2010, 25.1 m units sold in 2009, 13.7 m in 2008, 2.3 m in last quarter 2007



## The Product Life Cycle : From Innovation to Market Saturation



## Robots that Crossed the Chasm



Roombas



# World Record Distance- TransAtlantic Crossing



Over 7000 km covered in 7.3  
mos by Rutgers University  
modified Slocum RU27

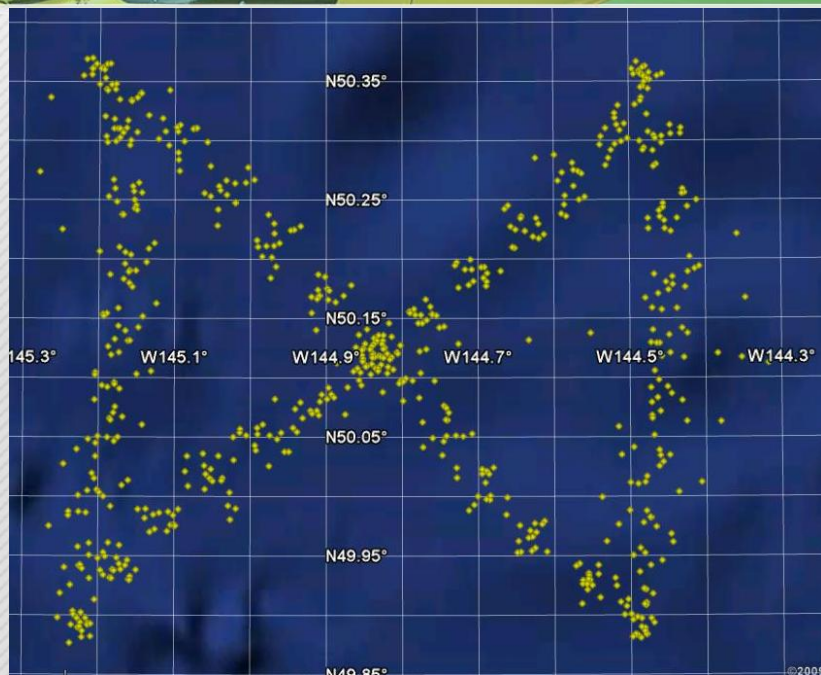
Equivalent to 21,700-mpg!



# World Record Endurance – SG144 achieves 9.6 months

(April 2, 2010)

**iRobot**  
Seaglider



## SG144 – Ocean Station Papa Mission\*

6/14/2009 – 4/2/2010

Dives: 878

Duration at Sea: 9.6 months

Vertical Distance through Water: 1734 km

Horizontal Distance over Ground: 5076 km

Horizontal Distance through Water: 6798m

Velocities through Water:

Max Horizontal: 39.9 cm/s

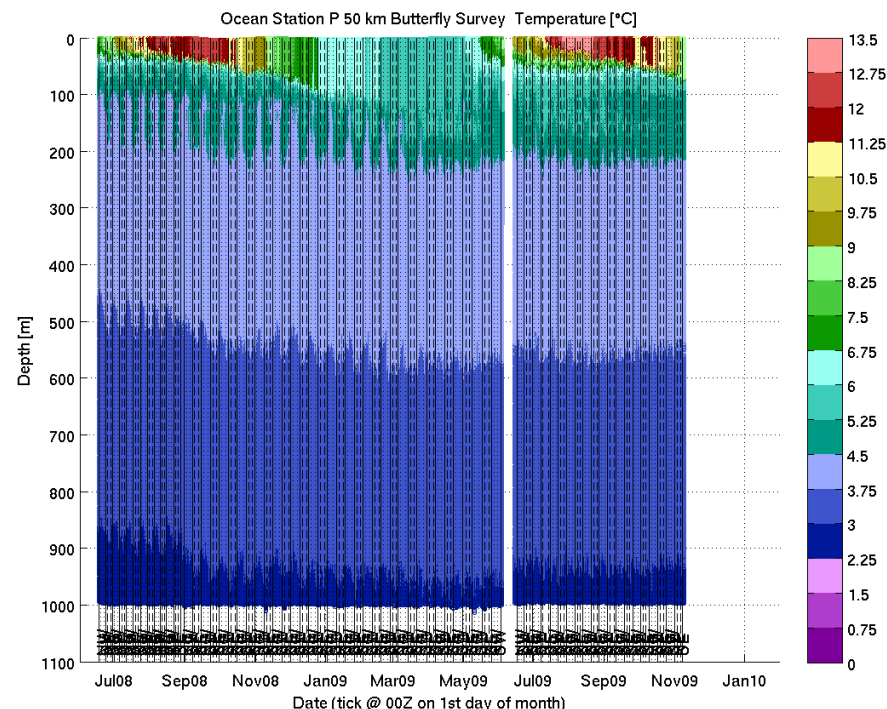
Average Horizontal: 21.6 cm/s

Max Vertical: 9.3 cm/s

Average Vertical: 6.25 cm/s

Total Battery Remaining after Mission: 13%

**Back to back glider missions for 18 Months  
sampling at a single location unveils  
mesoscale structure**



## Sensor Payload :

Seabird CTD, 2 x O2 (Aanderaa + Seabird),

Wet Labs ECO Triplet

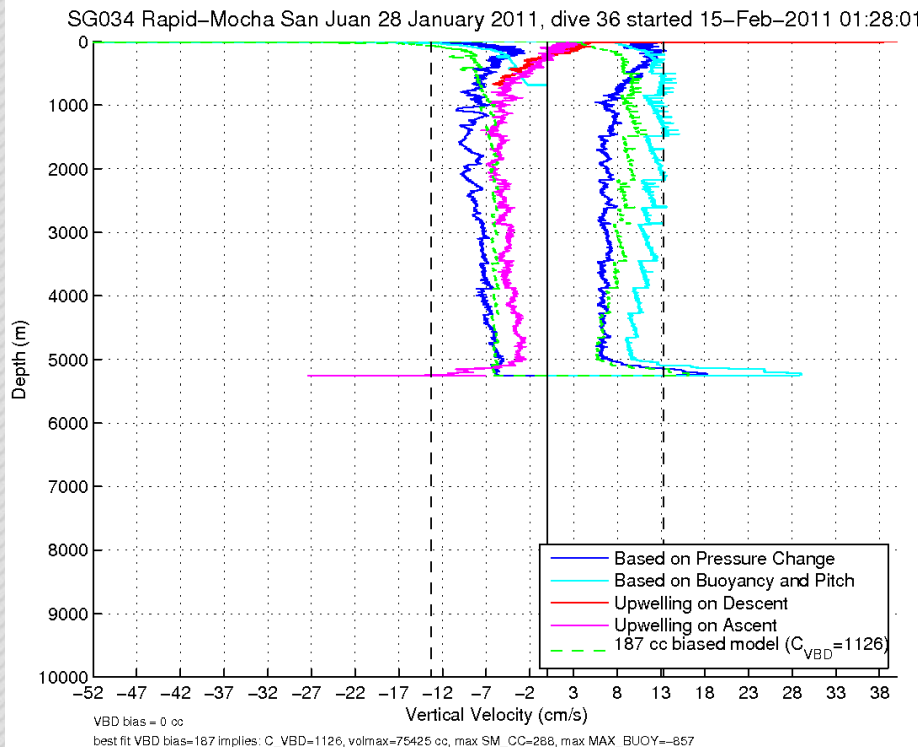
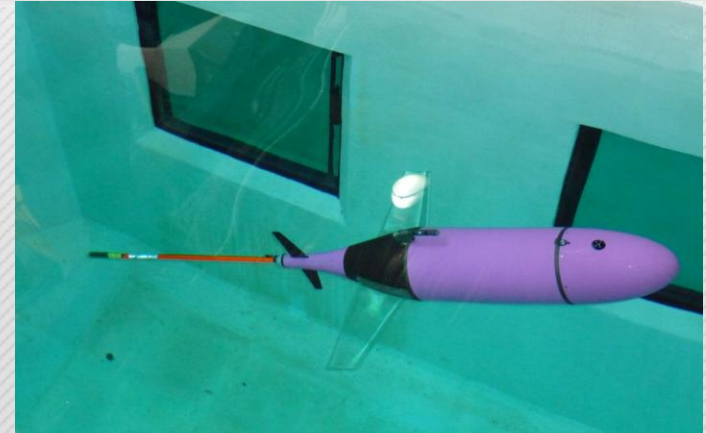
1 M resolution sampling over ascent / descent to 1000 m

**Robot**

# Record Glider Depth – 6,000 meters!

August 6, 2010, the “Deepglider” version of Seaglider developed by Professor Charlie Eriksen and team at UW has achieved 6000 m dives off coast of Puerto Rico.

*This depth milestone means that gliders can now cover 98% of Earth’s Oceans*





# Under the Antarctic Ice – Ross Sea (December 2010)



Dr Vernon Asper of University of Southern Mississippi's (U.S.M.) Department of Marine Science at the NASA Stennis Space Center and a diverse team of colleagues from U.S.M., the University of Washington in Seattle, Old Dominion University in Norfolk, Va., the Virginia Institute of Marine Sciences, and the U.K.'s University of East Anglia

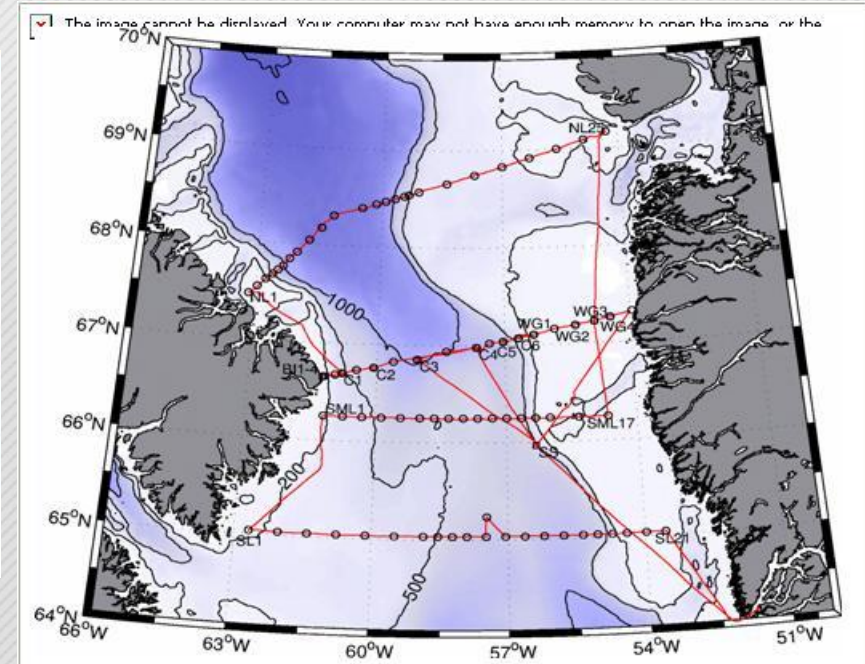
<http://www.scientificamerican.com/article.cfm?id=antarctica-seaglider-phytoplankton-study>



# And in the Arctic for many years already



Professor Craig Lee of APL -  
University of Washington has  
used Seagliders extensively in  
the arctic – see:



Davis Straits  
Under ice runs using RAFOS

[http://www.youtube.com/watch?v=ajbQhb-LITE&feature=player\\_profilepage](http://www.youtube.com/watch?v=ajbQhb-LITE&feature=player_profilepage) - t=208



# Gliders in the Gulf: Responding to the Deep Water Horizon accident

Surfacings of SG-515 in  
Gulf of Mexico

Deep Water Horizon





# What other good can Gliders do?

Anyone know of a good underwater scintillation counter ( radiation)?





**Oil companies, Navies are concerned about regulations on impacts to mammals**



iRobot and Duke University Marine Lab are integrating acoustic mammal tracking on Seagliders

**How does the  
glider market  
continue organic  
growth and cross  
the chasm?**





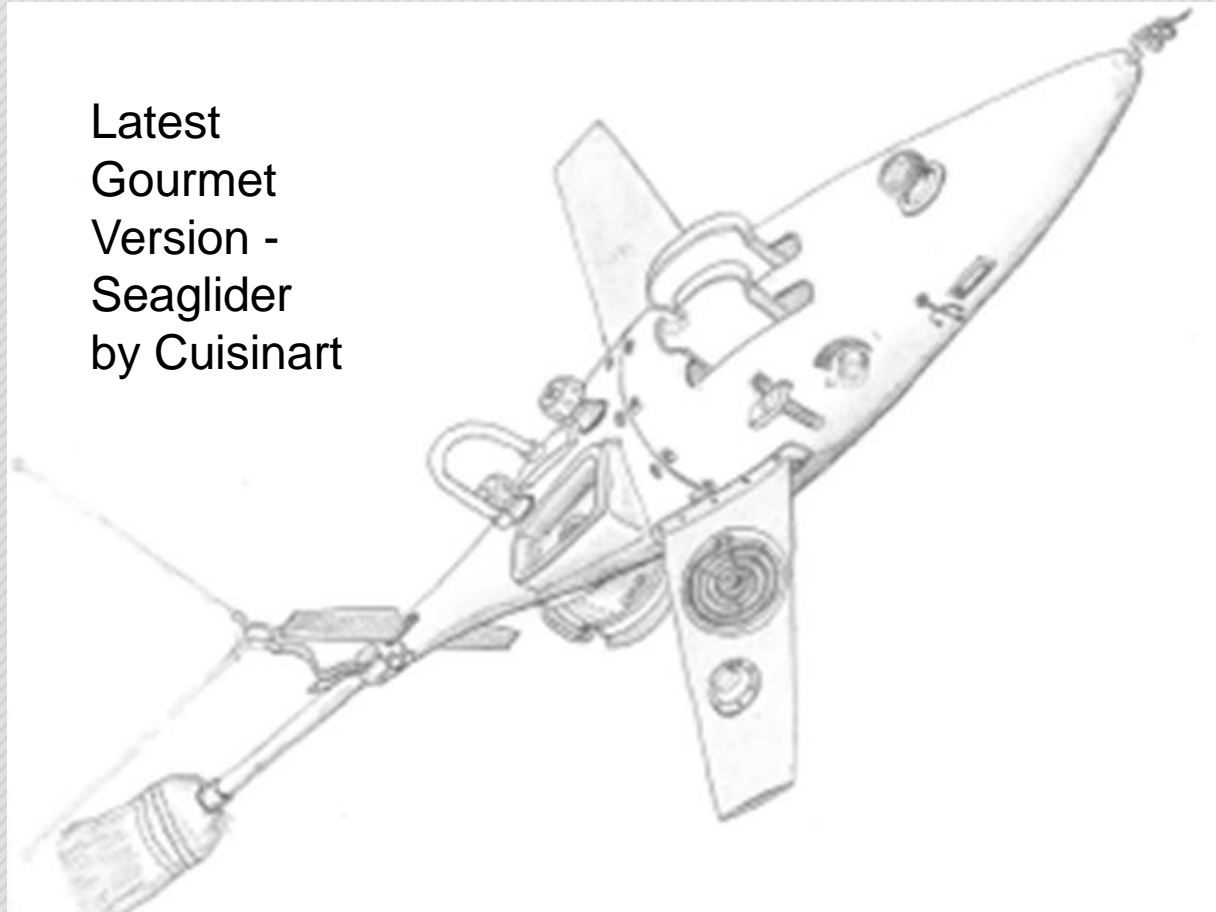
# Everything Glider?

• **Empathic design** is a user-centered design approach that pays attention to the user's feelings toward a product (McDonagh and Lebbon, 2000; Fulton-Suri, 2003; Crossley 2003).

The foundation of empathic design is observation, the goal is to identify latent customer needs.

• Latent needs are product requirements that customers don't even know they desire, or in some cases are solutions that customers have difficulty envisioning due to lack of exposure to new technologies or being locked in the mindset of working with existing products and services.

Latest  
Gourmet  
Version -  
Seaglider  
by Cuisinart



# Seaglider Horizons Roadmap

Broad Markets

**iRobot**  
Seaglider

"Crossing The Chasm" by G. Moore, Harper Business Essentials

Early Adopters

- Existing Research Seaglider users

**Horizon 1**  
0 to 12 months

Market Growth

- Shallow to deep
- Integrated ADCP
- In situ chemistry sensors
- "Data mule" function
- Larger buoyancy range
- Higher horizontal speed

**Horizon 2**  
12 to 36 months

**Horizon 3**  
36 to 72 months

- Networked Gliders
- Hybrid Glider
- Deep Glider 6K
- Advanced Navigation
- Imaging glider
- Advanced SAT-NLOS – OTH RF comms

Research Directions

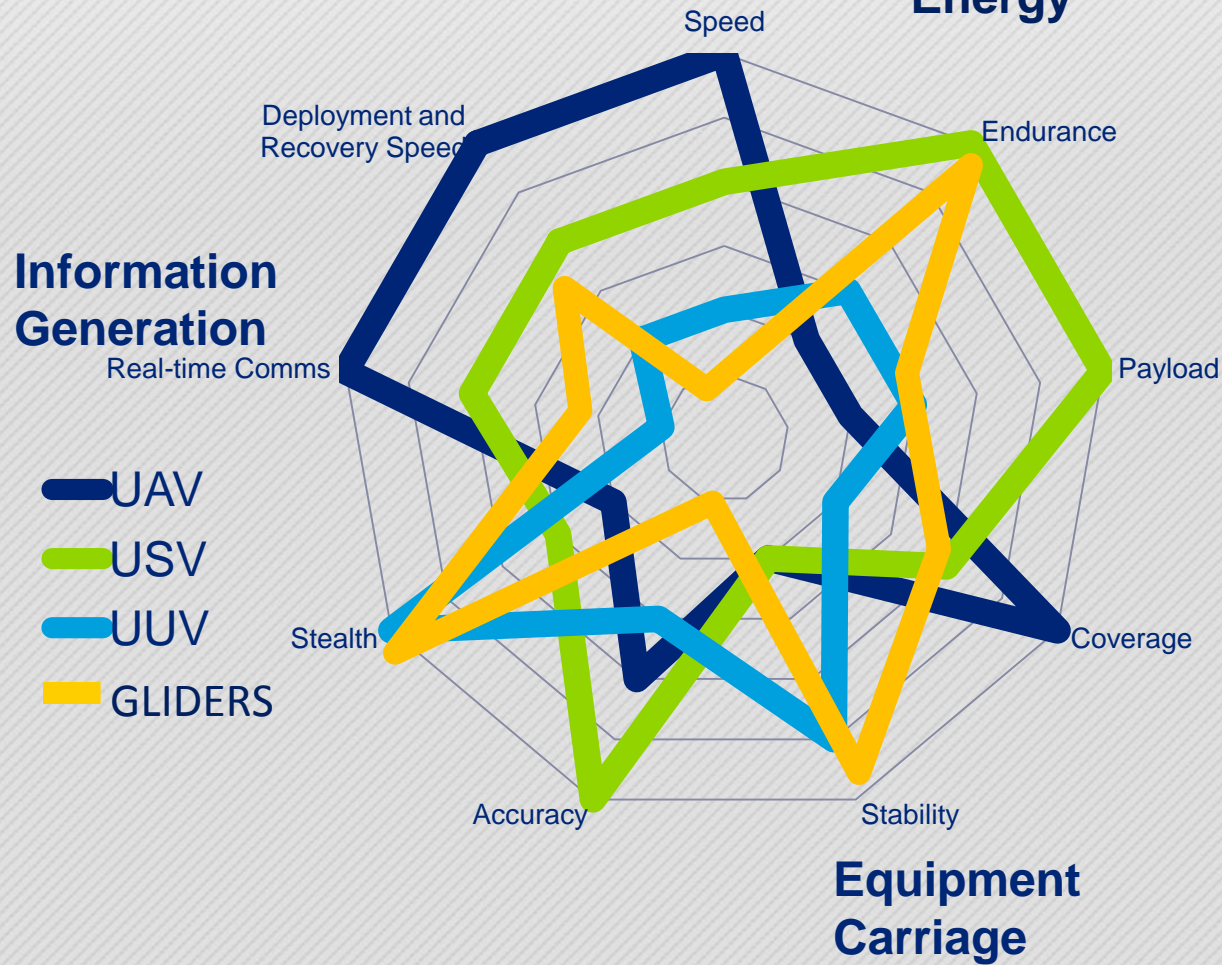
- Hybrid propulsion
- Software modernization
- Energy Capture concepts
- Underwater localization
- Advanced Navigation
- Low power imagers / SONARS / Blue-Green Flash LADAR

Jan 2009 Jan 2010 Jan 2011 Jan 2012 Jan 2013 Jan 2014 Jan 2015 Jan 2016

**iRobot**



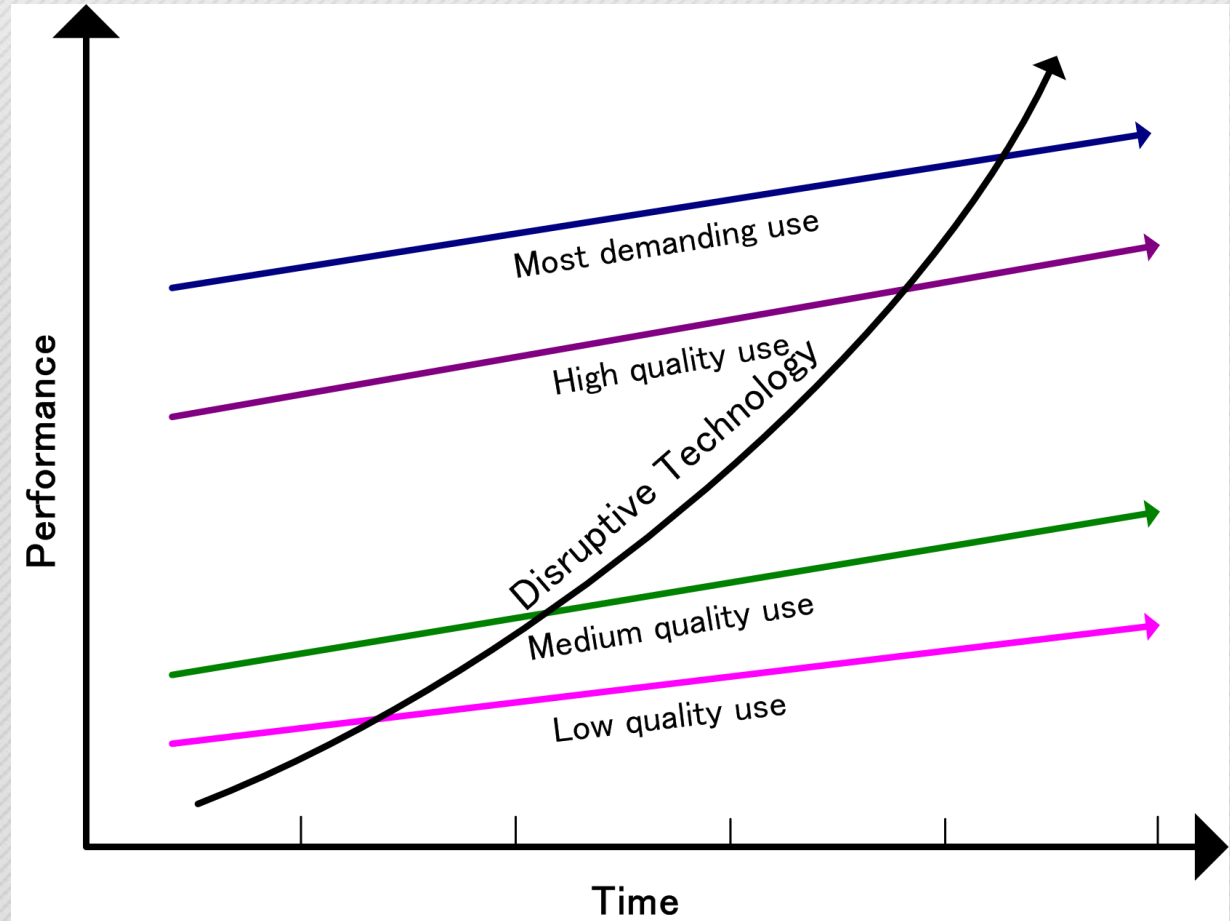
## Gliders have plenty of Unmanned competition



Source: After ACTUV Brief, Rob McHenry, AUVSI Program Review 2010, data based on an analysis of published UxS characteristics

## Disruptive Glider Technologies?

- Advanced batteries
- Energy Capture
- Hybrid propulsion
- Miniature Sensors
- Increased Depth?
- Low cost expendable gliders
- All of the above?





# - Quasi Gliders – are they disruptive?



## **NOC – UK Long Range AutoSub**

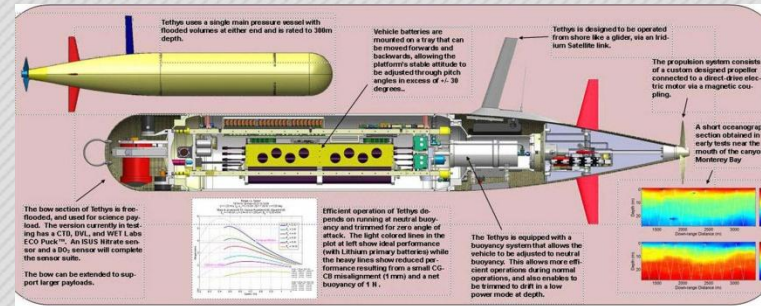
-By travelling rather slowly (0.4 metres per second), and keeping a tight rein on the power available to its sensors, it will be capable of missions of up to six months duration and ranges of 6,000 kilometres.

- It can dive to a depth of 6,000 m



## **Liquid Robotics – Wave Glider**

- Wave Glider concept brings Year long endurance by capturing Wave power and station keeping with GPS
- Limited to measurements near surface



## **MBARI Tethys LRAUV Goals**

- Travel over 1,000 kilometers at approximately one meter per second with sensors drawing eight watts
- Cover more than 3,000 kilometers with minimal sensors and slow speeds (0.5 meters per second).

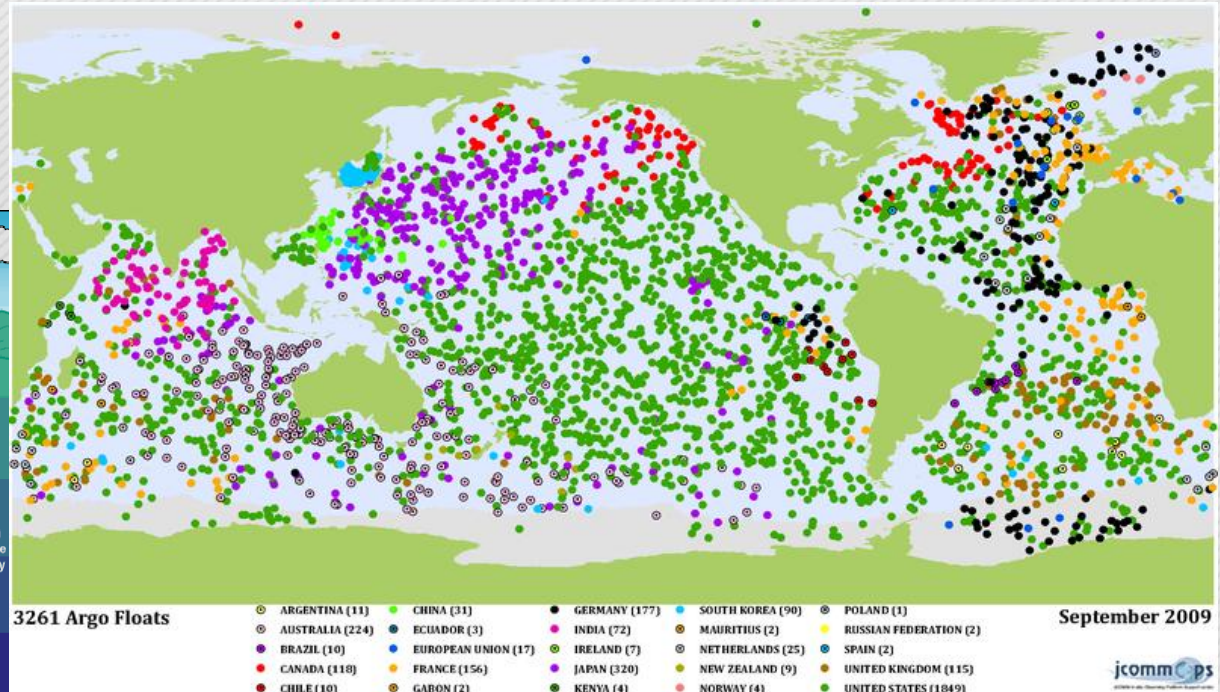
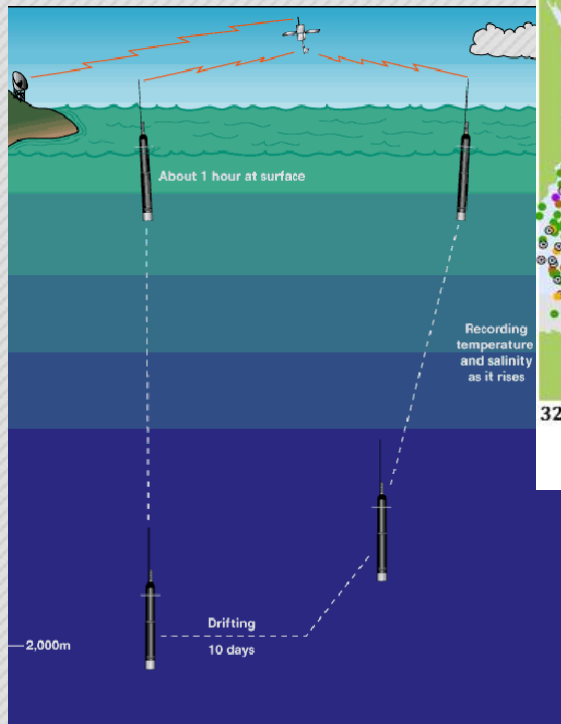
## So Many 'APPS' –but also many alternatives

Platform	Mode of Operation	Typical Deployment Duration	Spatial Scales	Sensor Payload
Surface Drifter	Floats on surface, sometimes drogued at depth	Weeks to years	Regional to global	Moderate, power-limited
Float	Neutrally buoyant, sometimes profiling	Weeks to years	Regional to global	Moderate, power-limited
Glider	Profiles, controls horizontal position by gliding	Weeks to months	Regional	Light, power and size-limited
Autonomous Underwater Vehicle (AUV)	Powered horizontally through water, e.g., by propeller	Hours to days	Local	Heavy

Rudnick, D.L. and M.J. Perry, eds., 2003, ALPS: Autonomous and Lagrangian Platforms and Sensors, Workshop Report,



## ARGO Floats– More than 5000 deployments



Next generation floats may be able to operate for years in some parts of the mid latitudes oceans



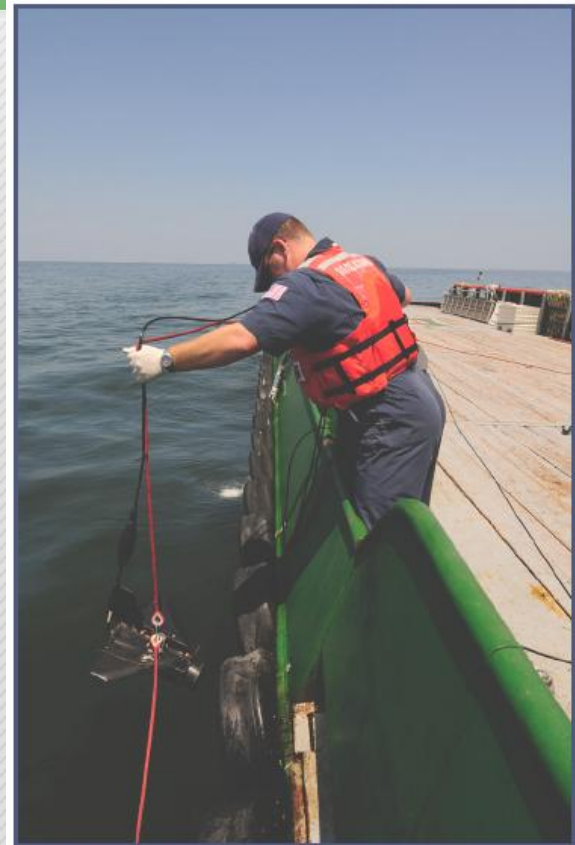
**Whole product** is a generic product augmented by everything that is needed for the customer to have a compelling reason to buy. The core product is the tangible product that the customer experiences. The whole product typically augments the core product with additional elements required for the product to have compelling value to a customer. For example, if a personal computer is the core product, then whole product would include software applications, training classes, peripheral devices (mouse, keyboard, printer, etc), and internet service. Without these additional product components, the core product would not be very useful.

**\*The Whole Product will also be of higher economic value relative other alternatives**



## Enabling economic comprehensive underwater assessment –

- Seagliders sample 7/24, for months without manual intervention
- GUMBO Seaglider fleet operating costs projected operating costs including satellite link, piloting services and vehicle depreciation amounts to less than \$400 / day
- NOAA reports that the costs to deploy a research ship is more than \$44,000 / day, while fleet of 20 Seagliders as in GUMBO – about \$4,200 day

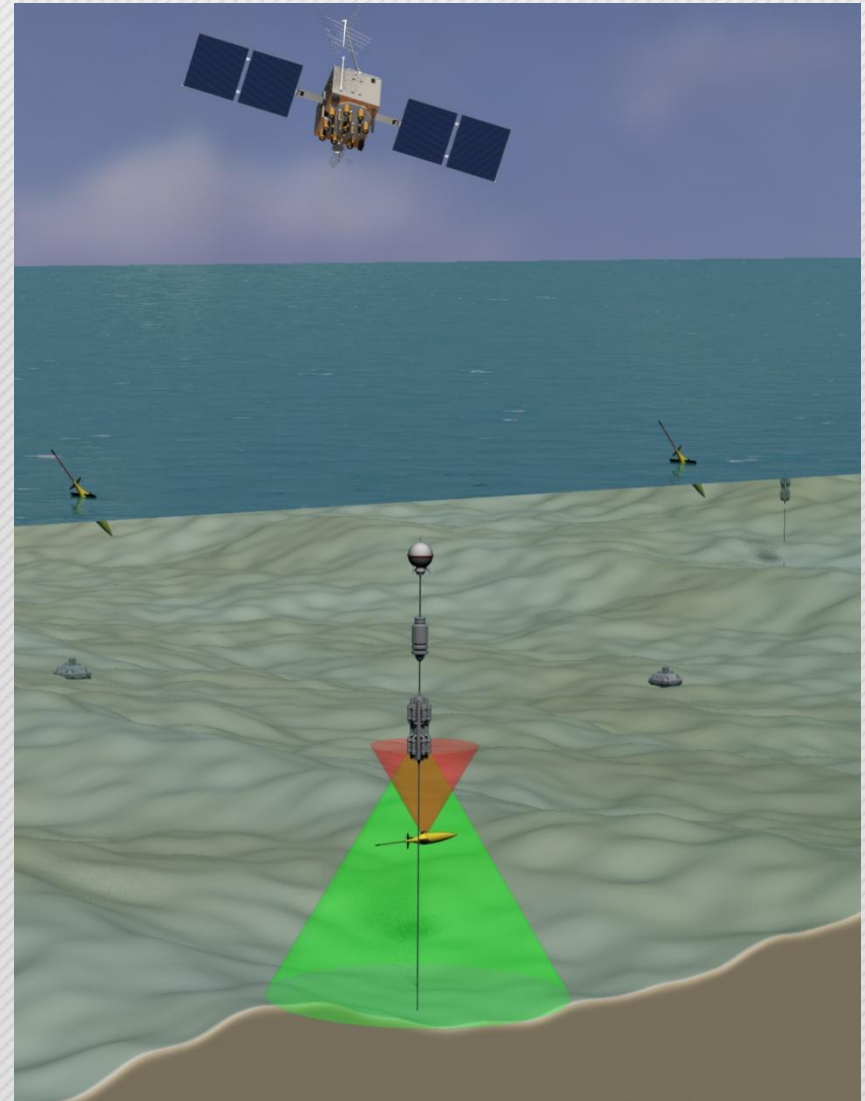


U.S. Coast Guard Petty Officer 2nd Class Dave Martin, a specialist in hazardous material and oil spill response, lowers a fluorometer into the Gulf of Mexico May 27. The device collects water samples and field data, which help environmental scientists determine the effectiveness of dispersants used to break down oil. U.S. Coast Guard photo by Petty Officer 2nd Class Luke Pinneo

# Glide Mailman for Moorings without surface expressions



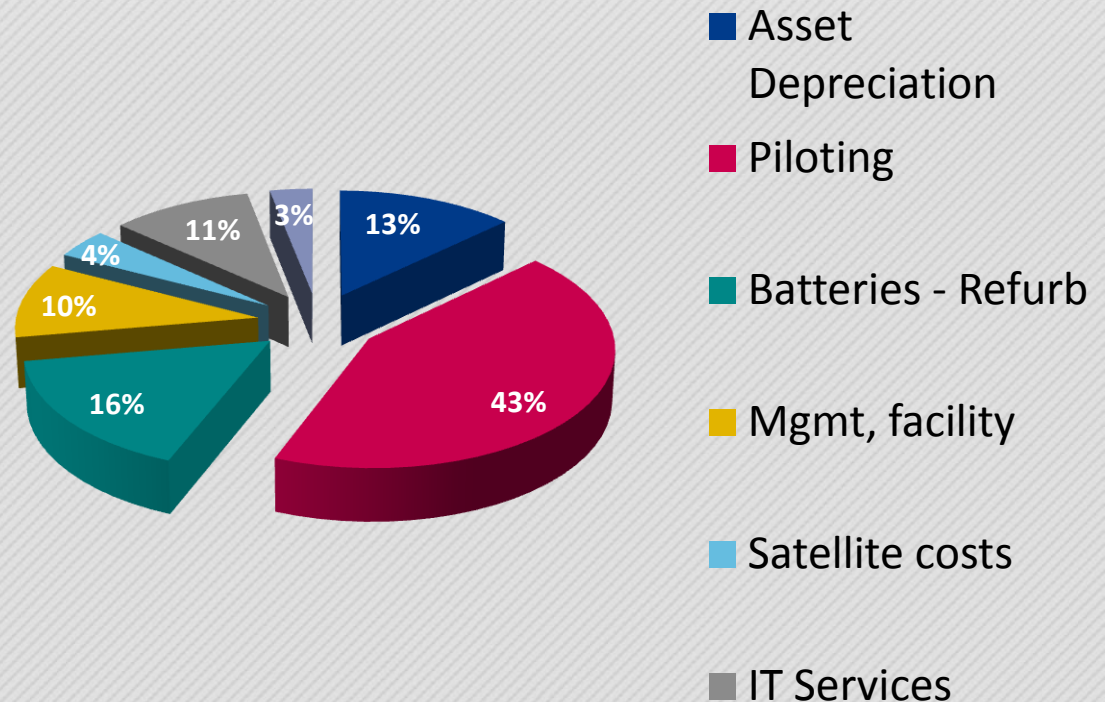
Vulnerable to vandalism, fishing,  
Storms, and collisions, moorings have  
High costs of ownership





**The Whole Product will  
address the true Cost of  
Owning and operating  
gliders**

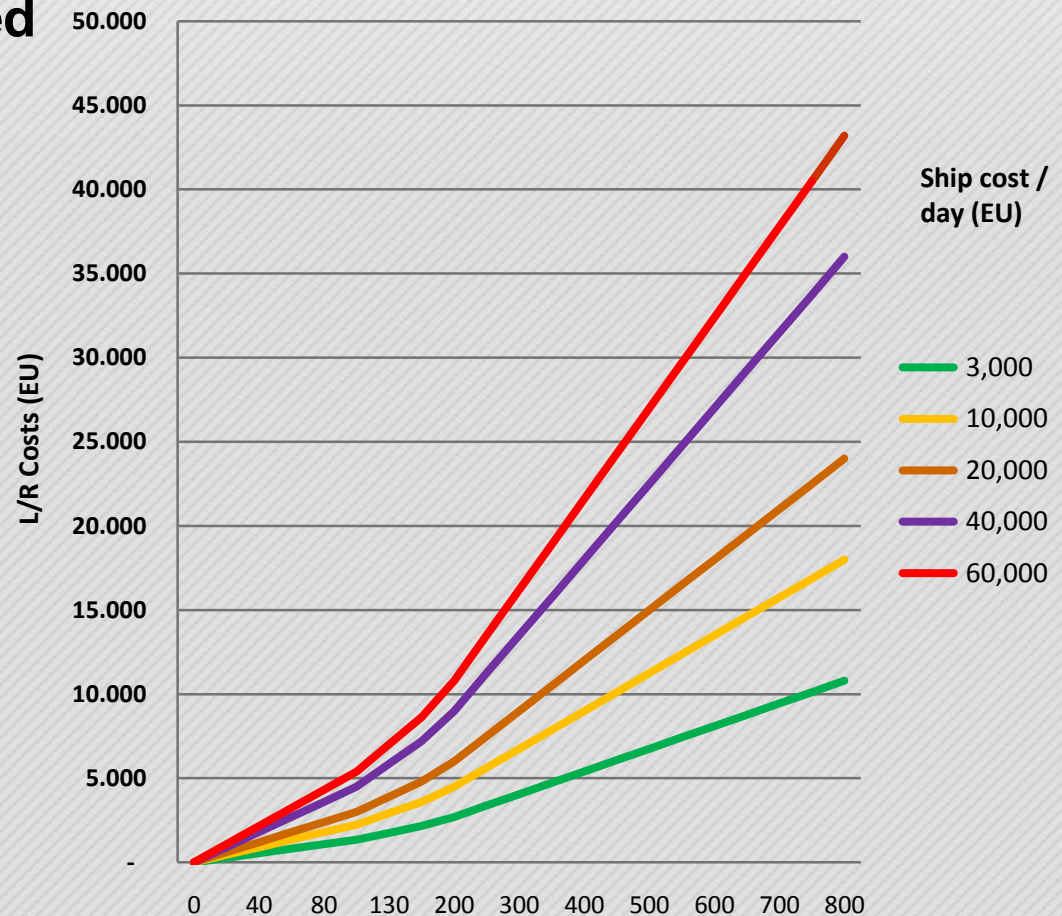
**Glider Operating Cost / Week**  
(not including Launch / recovery / ship cost)



**Launch / Recovery costs are driven by distance to target location / ship size & speed**



**Launch / Recovery by distance / ship Cost**

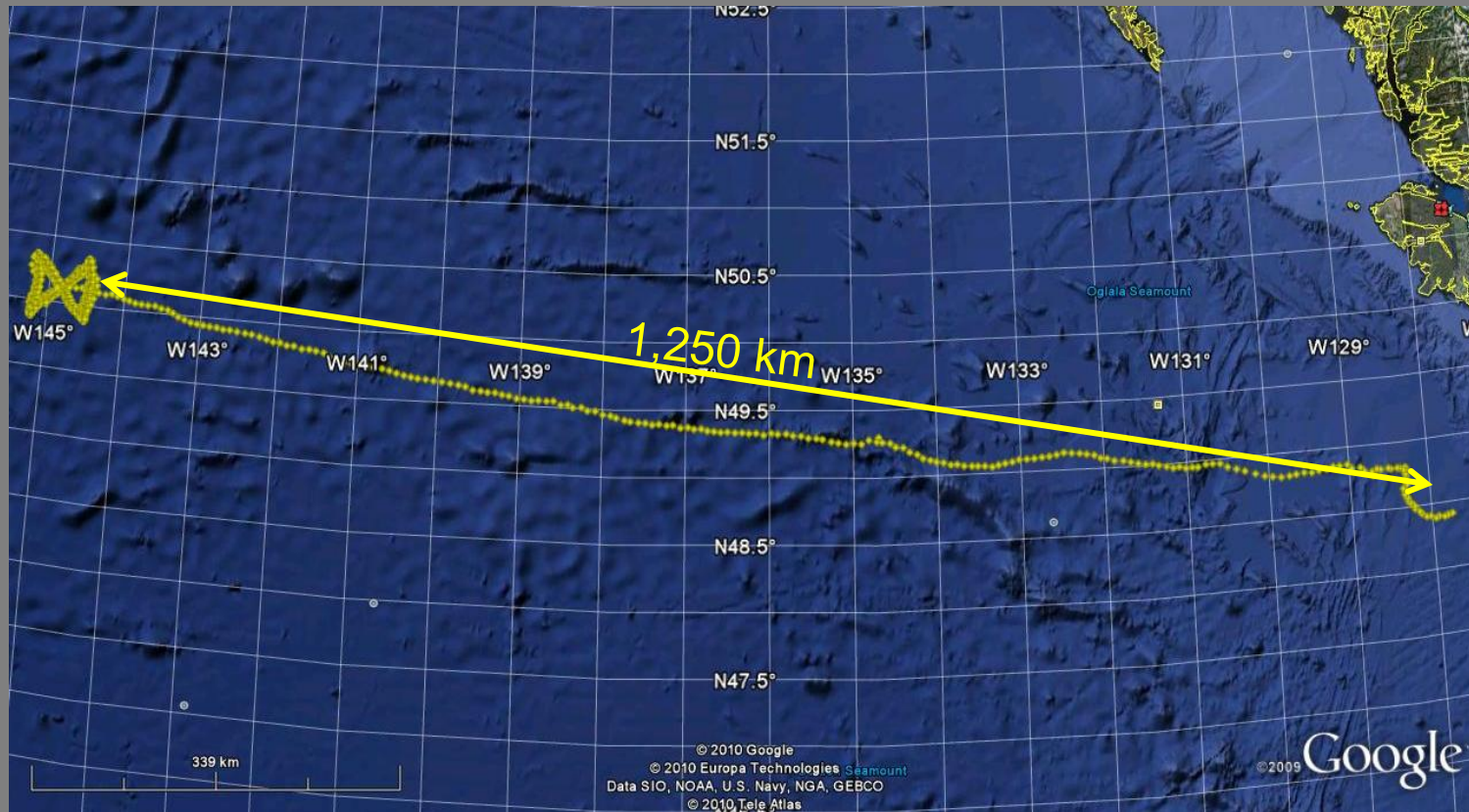




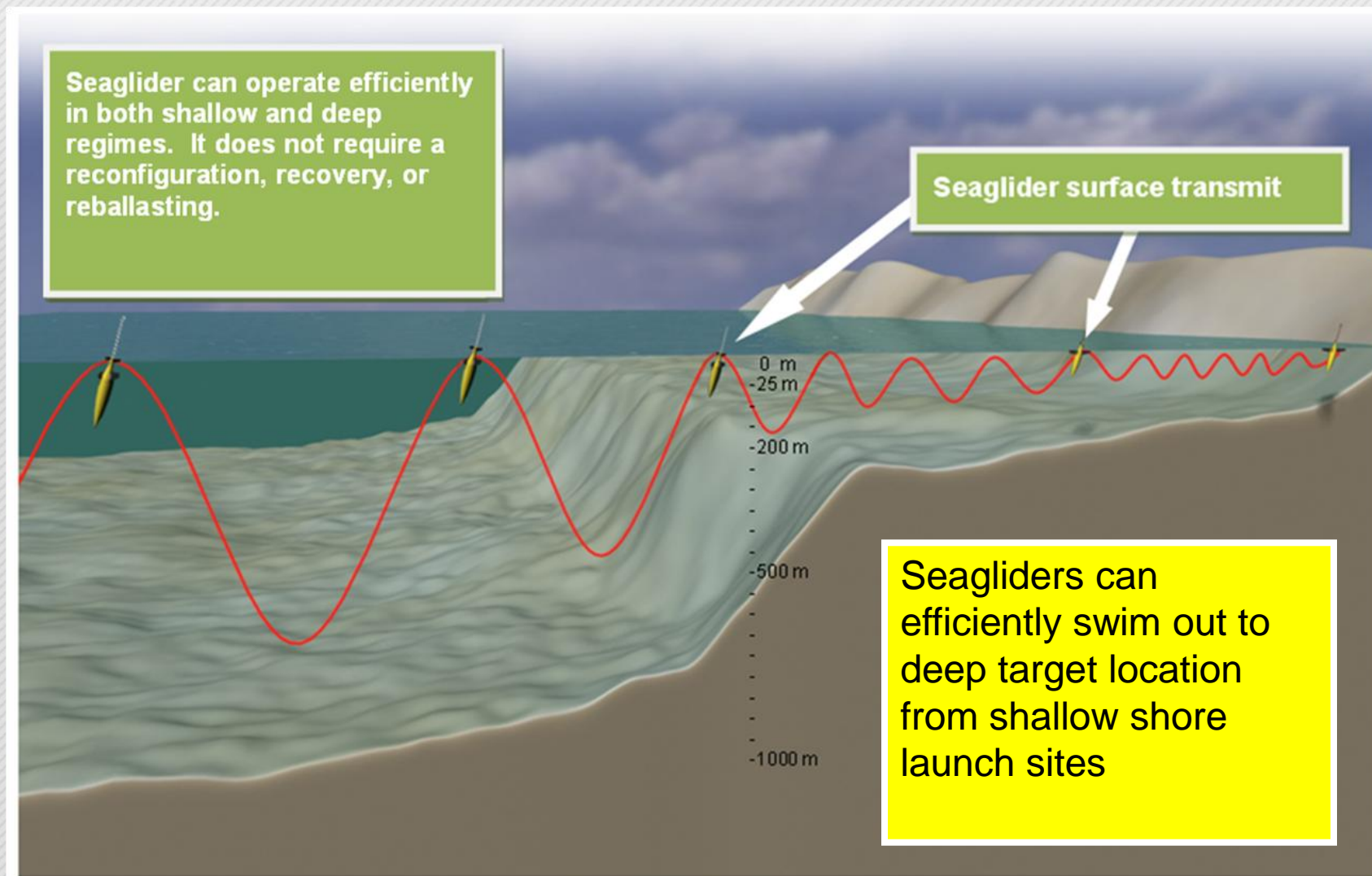


Seaglider can swim to location

## SG144 – Entire Ocean Station Papa Mission



# Seagliders now efficiently perform “shallow to deep” in a single mission





For glider technology to flourish – making piloting easier is vital

GLMPC

USERNAME admin	ROLE ADMIN	MISSION Hawaii_2008	GLIDER SG137	DATE & TIME 2009-09-01 23:43 UTC	KML
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Tracks

Dives

Profiles

Diagnostics

Commands

Science

Routes

Help

No New Messages.

Show All (4)

Glider Status

Glider	Menu	Dive	Due	Health
SG128		241	0717Z	
SG136		148	2144Z	
SG137		140	0519Z	
SG138		159	2002Z	
RU05		2100004	UNK Z	
RU16		2580004	UNK Z	
SL113		1700002	UNK Z	
SL114		1400018	UNK Z	

Track Filter

☒ Growing: From dive 1

☐ Sliding: Last 139 dives

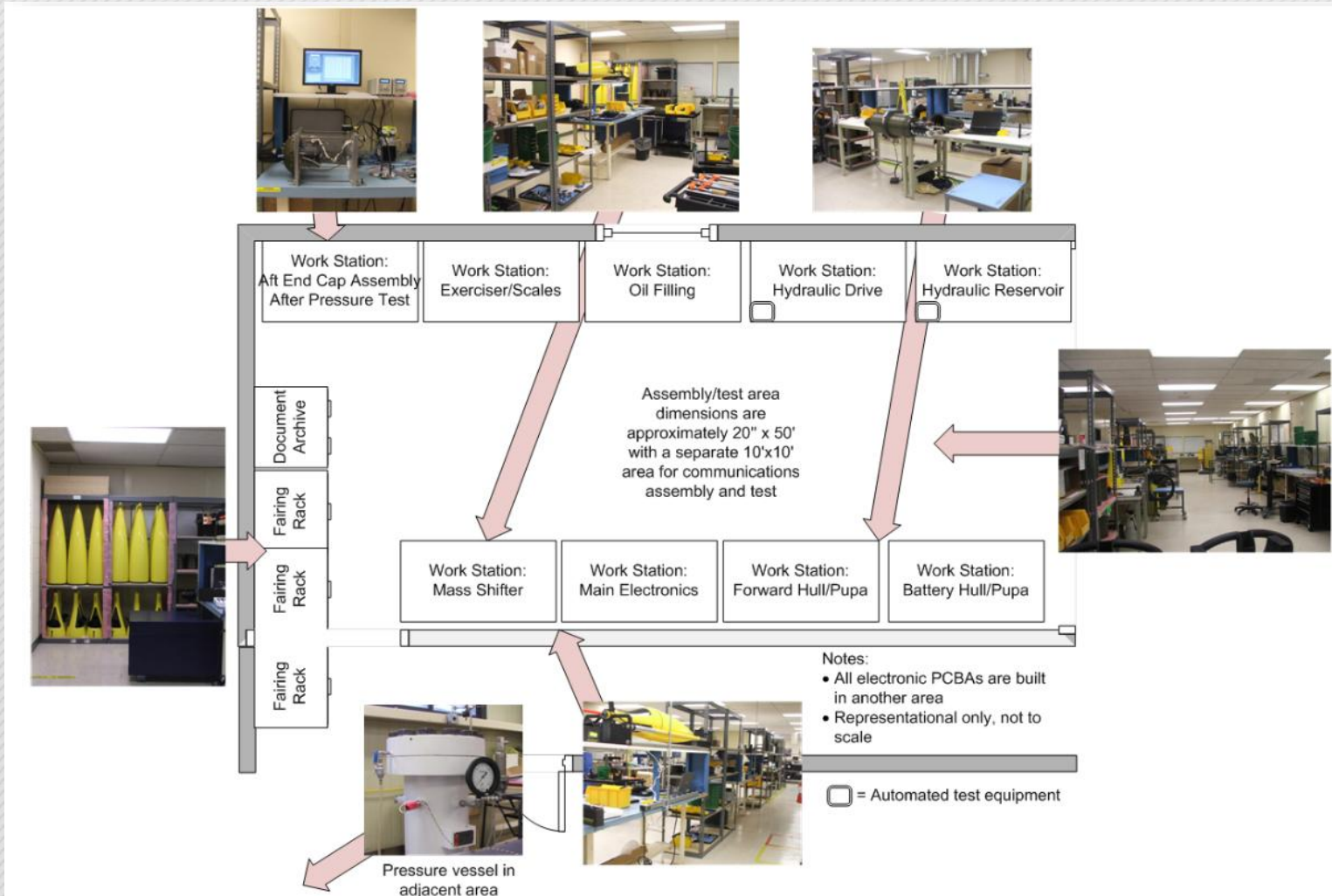
☐ Fixed: From dive 1 to 140

Update Track

Display Options

Item	Visibility
Graticules	
Grid	<input checked="" type="checkbox"/>
Labels	<input checked="" type="checkbox"/>
SG128	
DAC	<input type="checkbox"/>
Route	<input type="checkbox"/>
Track	<input checked="" type="checkbox"/>
SG136	
DAC	<input type="checkbox"/>
Route	<input type="checkbox"/>
Track	<input checked="" type="checkbox"/>
SG137	
DAC	<input type="checkbox"/>
Route	<input type="checkbox"/>
Track	<input checked="" type="checkbox"/>
SG138	
DAC	<input type="checkbox"/>
Route	<input type="checkbox"/>

# Quality Production Systems are an integral part of the Whole Product at iRobot





# The 'Product' is the support and engagement by the whole team

## SEAGLIDER

### SEAGLIDER FUNDAMENTALS | Seaglider Components

Roll over the system components below for more information.

- Fiberglass Fairings
- Wings & Rudder
- Antenna Mast
- Aluminum Pressure Hull
- Acoustic Transducer
- Main Electronics Assembly
- Mass Shifter
- Pressure Sensor
- Hydraulic System
- Conductivity-Temperature (CT) Sensor
- Optional Sensors

The Seaglider's ability to pitch and roll comes from moving the mass shifter, containing the 24V lithium primary battery, forward and backward and rotating it to starboard and port.

Lesson Menu

## SEAGLIDER

### FIELD TEAM OPERATIONS | Carrying the Seaglider

The Launch and Recovery Cradle can be used to carry the Seaglider. The Seaglider weighs 115 lbs. (52 kg) when dry and should be carried by two people. Each person should hold one of the cradle ends. To prevent back injury, remember to lift with your legs instead of your back.

Lesson Menu

## SEAGLIDER

### PILOT TEAM OPERATIONS | Analyzing Dive Plots - Roll Turn Rate

This chart shows the roll control vs. the turn rate and helps with dive and climb to see how fast the glider is turning, in degrees per second.

This chart can be used to verify what changes should be made to any or all of the parameters from the Roll Control chart.

Lesson Menu

## SEAGLIDER

### FIELD TEAM OPERATIONS | Seaglider Disassembly - Rudder

After returning to shore, disassemble the Seaglider. The rudder disassembly procedure is shown below. Select the hyperlink in each step to toggle the graphic on the left.

To remove the rudder:

- Prop up the Launch and Recovery cradle or slide the Seaglider backwards until the rectangular slot on the aft end facing is clear of the cradle end. [\[Graphic\]](#)
- Loosen and remove the rudder screws. [\[Graphic\]](#)
- Remove the rudder from the rectangular slot, being careful not to pinch the cables. [\[Graphic\]](#)
- Set aside the rudder for packing and put the two rudder screws back in the plastic bag that is included in the plastic spares kit. [\[Graphic\]](#)

Lesson Menu

## SEAGLIDER

### PILOT TEAM OPERATIONS | Control File Parameters

Dive Profile	Buoyancy Limits	Flight Behavior and Improvement	Navigation
Setting the depth and time of the dive: \$D_TGT \$T_DIVE \$T_MISSION	Setting the minimum and maximum buoyancy boundaries: \$NAK_BUOY \$NAK_CC	Setting the flight through the water and adjusting the flight path: \$C_VID \$PITCH_GAIN \$C_ROLL_DIVE \$C_ROLL_CLIMB \$D_SURF \$GLIDE_SLOPE \$D_FLARE \$C_PITCH	Setting the position, course, and distance of the dive: \$NAV_MODE \$KALMAN_USE \$HEADING \$TGT_DEFAULT_LAT \$TGT_DEFAULT_LON

There are a large number of parameters available to pilots. However, there are some that are used most often. These parameters can be broken into categories:

- [Dive profile](#)
- [Buoyancy limits](#) - use to save energy
- [Flight behavior and improvement](#)
- [Navigation](#)

Select the hyperlinks above to learn more about each category.

Lesson Menu

## SEAGLIDER

### PILOT TEAM OPERATIONS | Check on Learning 4

What parameters are used to program the Seaglider's dive profile?

- ☒ \$T\_DIVE
- ☒ \$HEADING
- ☐ \$T\_MISSION
- ☒ \$GLIDE\_SLOPE
- ☐ \$KALMAN\_USE
- ☒ \$D\_TGT

Correct

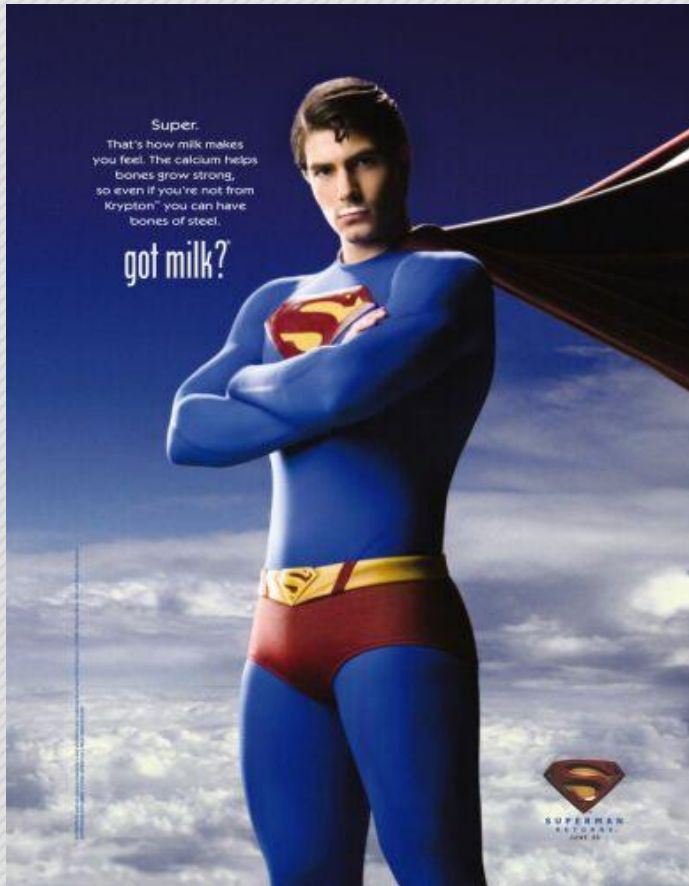
The correct answers are: \$T\_DIVE, \$HEADING, \$GLIDE\_SLOPE, \$D\_TGT

Review

Lesson Menu



## Got Glider?



Gotta give those gliders some love...





Edison Hudson  
iRobot Corporation  
Maritime Systems  
4625 Industry Lane  
Durham, NC 27713 USA  
[ehudson@irobot.com](mailto:ehudson@irobot.com)

BUILD COOL STUFF  
DELIVER GREAT PRODUCTS  
**MAKE MONEY**  
**HAVE FUN**  
**CHANGE THE WORLD**

## Early Adopters:

**Visionaries that match technology to strategic opportunity**

- **Looking for a fundamental breakthrough for a business goal: order-of-magnitude return**
- **Least price sensitive segment-a source of capital on early projects**
- **Easy to sell, hard to please (dream vs. reality)**
  - Need to carefully manage expectations
- **Project oriented, structure each phase so:**
  - It can actually be accomplished quickly
  - Results in a marketable product
  - Provides a concrete return on investment to be celebrated
- **They find you through innovator referrals**