



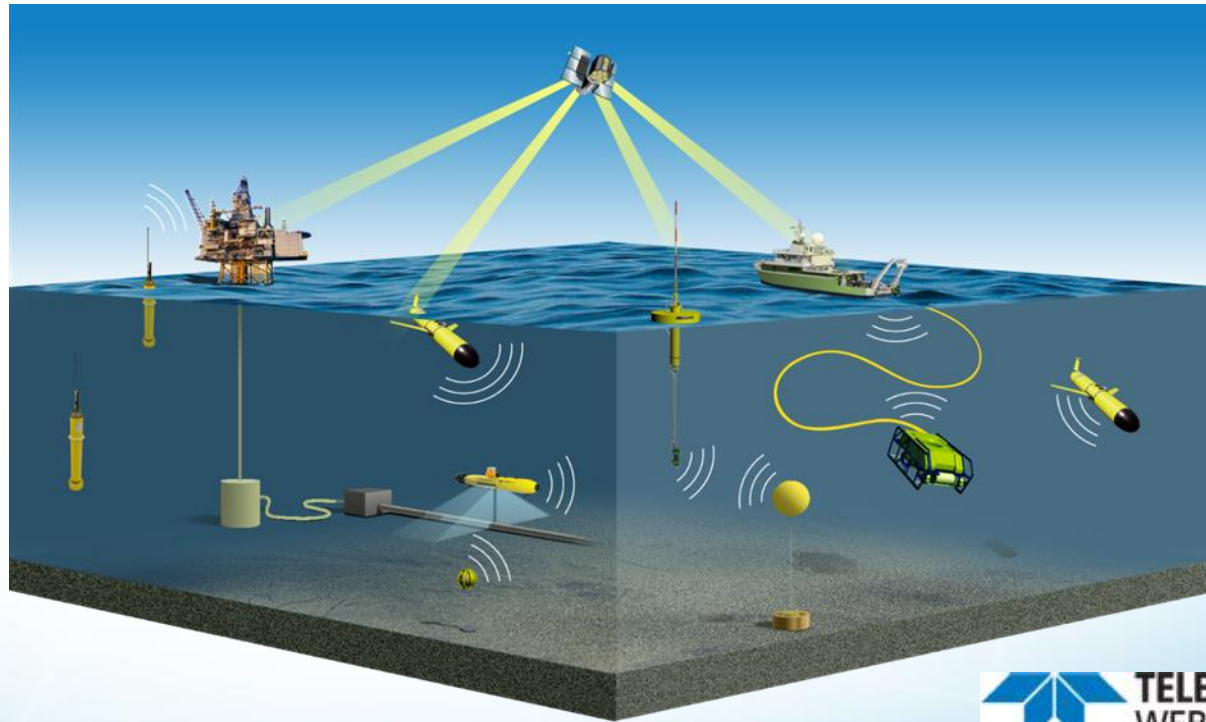
College of Earth, Ocean,
& Environment

Anatomy of a Slocum Electric Glider AUV



Presented by Douglas White
at INMARTECH 2014

Many thanks to Clayton Jones from Teledyne Webb Research



College of Earth, Ocean,
& Environment

Many thanks to the ORB Lab

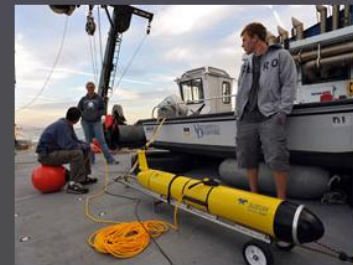
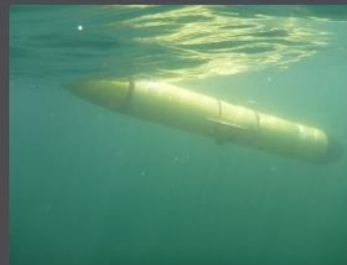


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OCEAN EXPLORATION, REMOTE SENSING, BIOGEOGRAPHY LAB



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THE CHALLENGER GLIDER MISSION



Celebrating 22 Years

The RUCOOL Team celebrates 22 years of Ocean Observation at Rutgers University



[slideshow archive >>](#)

Welcome to the RUCOOL!

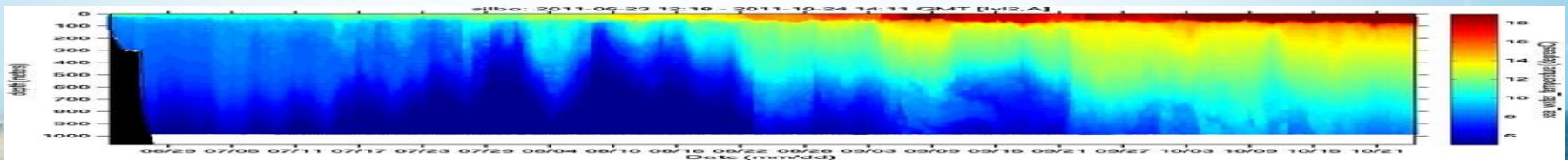
Welcome to the Rutgers University **Coastal Ocean Observation Lab!** RU COOL! Our research focuses on the bio-physical processes of the coastal ocean. Our lab is constantly involved in research projects where operational observatories are used to collect real-time data for adaptive sampling. We study the coastal waters off New Jersey and around the World. We continue to collaborate with other research groups and commercial companies, developing new technologies for ocean sampling.

I'm Not An Expert!

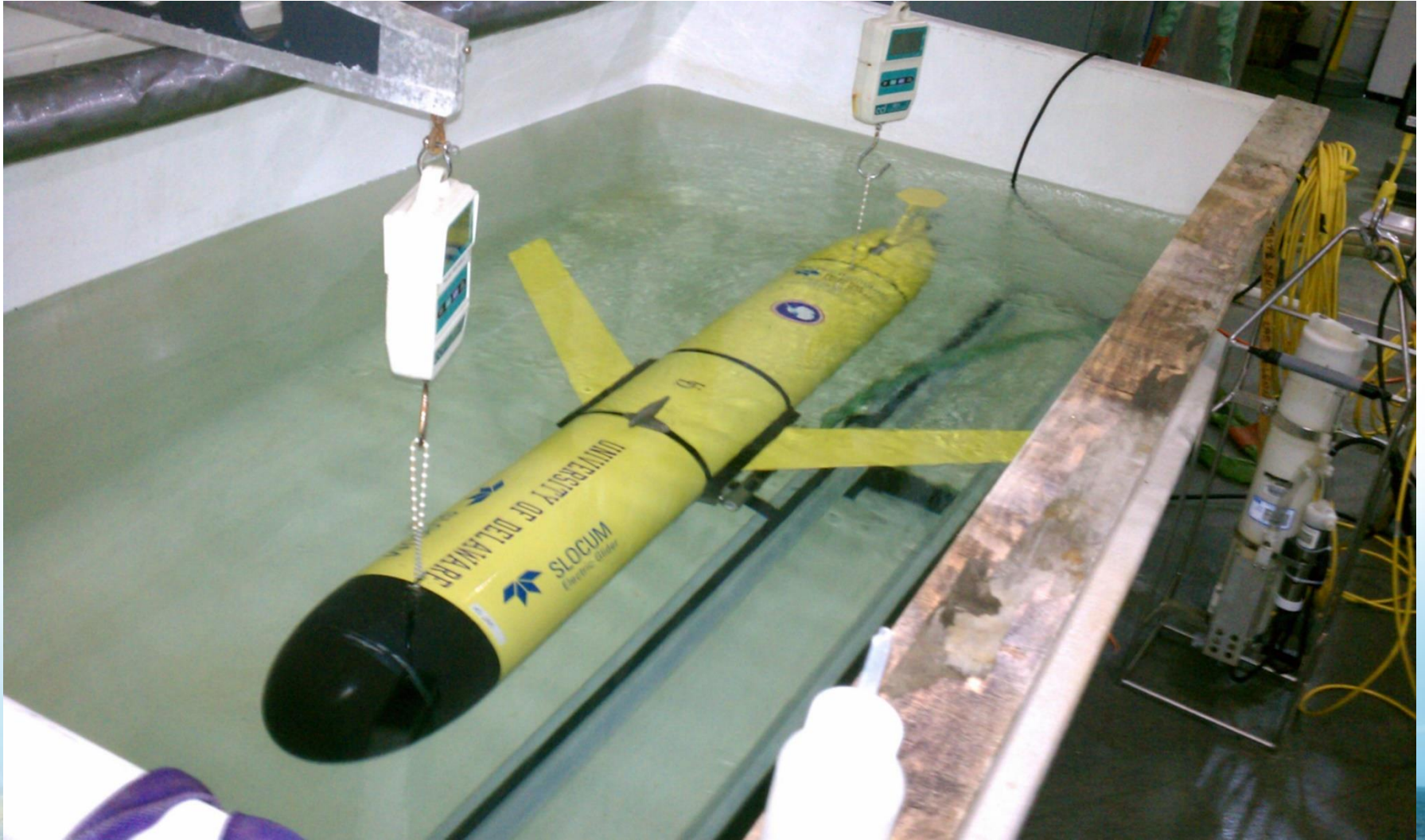


...but I do play one on TV

Ocean Crossings



Ballasting



General Safety Warnings

- Electrical Shock
 - Backup battery
- Heavy Objects
 - Heavier in front (2 person job to lift)
 - Slippery When Wet! (anti-biofouling coatings)
- Heavy Parts
- Pinch Points

Shipping Specs

- Glider Shipping Crate (large grey plastic case)
 - 95" x 29" x 34" @ 429 lbs
 - If returning the glider with lithium batteries installed, follow IATA shipping, labeling, and documentation requirements.
- Alkaline Battery Crate
 - 34" x 12" x 12" @ 70 lbs
- Lithium Battery Crate
 - UN certified cardboard box 34" x 27" x 15" @ 80 lbs
 - If returning lithium batteries, follow IATA shipping, labeling, & documentation requirements.

Ejection Weight

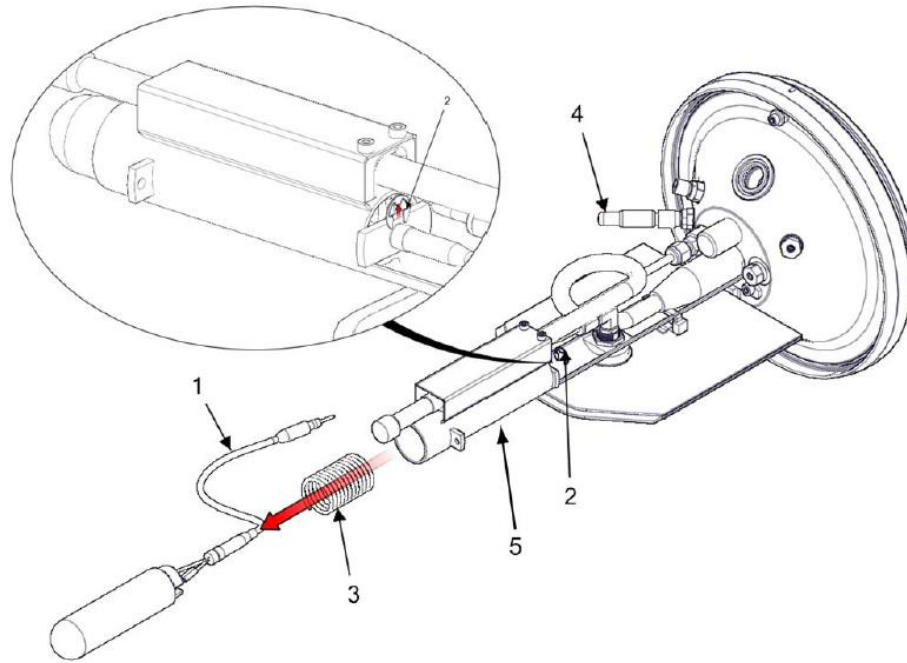


Figure 2-37 Weight release assembly.

- Burn process lasts for a few seconds in salt water and approximately four hours in fresh water
- Held in place by a 20 AWG Inconel burn wire

Hazardous Material Warnings & Safety Precautions

- AquaShield (aka Aqua Lube?)
- Dielectric Grease
- Drakeol 9 Light Mineral Oil
- Loctite 2440, 262, 567 Pipe Sealant
- NatraSorb S
- Parker O-Lube & Super-O-Lube
- Royal Purple Motor Oil
- Sea-Bird Anti-Foulant Device (AF24173)

O-Ring Lube

- Parker Fibrous O-Lube 884-4 (Petroleum Naphthenic Oil and Barium Soap) is recommended. Others used based on tech suggestions.
- Wear the appropriate PPE—eye protection and chemical resistant gloves—while using these products.

http://www.parker.com/literature/ORD%205700%20Parker_O-Ring_Handbook.pdf

Hazardous Material Warnings & Safety Precautions

- Alkaline Batteries
 - “Small but finite possibility” they will release a combustible gas mixture, especially if the batteries are exposed to water or sea water and/or shorted.
 - When the batteries are confined in a sealed instrument, the gases can accumulate and an explosion is possible.
 - A catalyst has been added inside the glider to recombine hydrogen & oxygen into water, and the glider hull will relieve excessive pressure buildup by having the hull sections separate under internal pressure.

Hazardous Material Warnings & Safety Precautions

- CSC Lithium Batteries
 - Sulfuric acid can form if lithium batteries come in contact with water.
 - Appropriate fire extinguishers should be readily available when working with batteries (Class D?)
 - Lithium cells and batteries are classified as a hazardous materials in the United States unless the specific cell or battery meets an exemption in the 49 CFR.
 - Info on handling & working safely with lithium batteries on Electrochem's site for lithium sulfuryl chloride cell batteries:
 - <http://www.electrochemsolutions.com/pdf/high-rate/csc93/3B0030Datasheet.pdf>
 - [http://www.electrochemsolutions.com/pdf/Safety and Handling Guide.pdf](http://www.electrochemsolutions.com/pdf/Safety_and_Handling_Guide.pdf)

Hazardous Material Warnings & Safety Precautions

- CSC Lithium Batteries cont.
 - In general, the conditions that cause damage to cells and batteries and jeopardize the safety of personnel are summarized on the label of each cell. These conditions include:
 - Short circuit
 - Charging
 - Forced over discharge
 - Excessive heating or incineration
 - Crush, puncture, or disassembly
 - Rough handling or excessive shock and vibration

Battery Capacities

Alkaline battery packs, which are nominally at 15 volts, consist of 10 diode-protected Duracell C-cells in series. As indicated below, the number of packs can be adjusted, depending on reserve buoyancy after payload considerations. Given 26 packs (260 C-cells), the total battery weight is ~18.2 kg with 7,800 kjoules of available energy.

Battery Type	Number of Battery Packs	Open Circuit Voltage (OCV)	Total Amp Hours (with a factor of safety of 10%)
Alkaline			
Pitch pack	12	N/A	73.44 Ahr
Aft pack	11	N/A	67.32 Ahr
Emergency pack	1 (located in aft pack)	N/A	6.12 Ahr
Lithium			
Pitch pack	12	11.79 V	324 Ahr with a constant load of 6 A
Aft pack	14	11.79 V	378 AHR with a constant load of 7 A
Emergency pack	1	11.79 V	6.3 AHR

For power management, typically all of the packs, except one of the aft battery packs, are tied into the main battery. In the event of a power loss, the emergency pack runs the main controller boards and performs the following functions:

- Abort timer
- Burn wire
- Argos
- Pinger (if available)

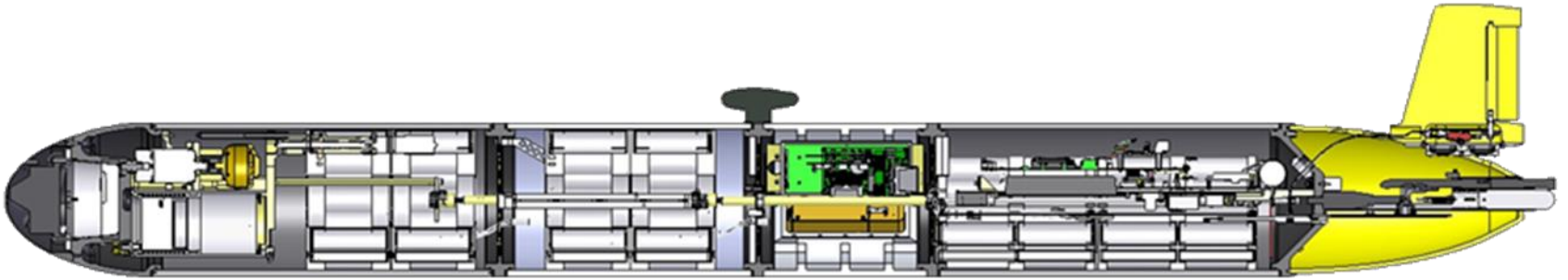
Internal Pressure Sensor

- Vacuum drawn on the glider prior to operation
 - Target is 6" Hg (7 for 1000 m)
 - Varies with temperature
- Micron 2000 PSIA strain gage transducer
- Less vacuum indicates a leak
- Positive pressure may indicate dangerous gas accumulation

Never

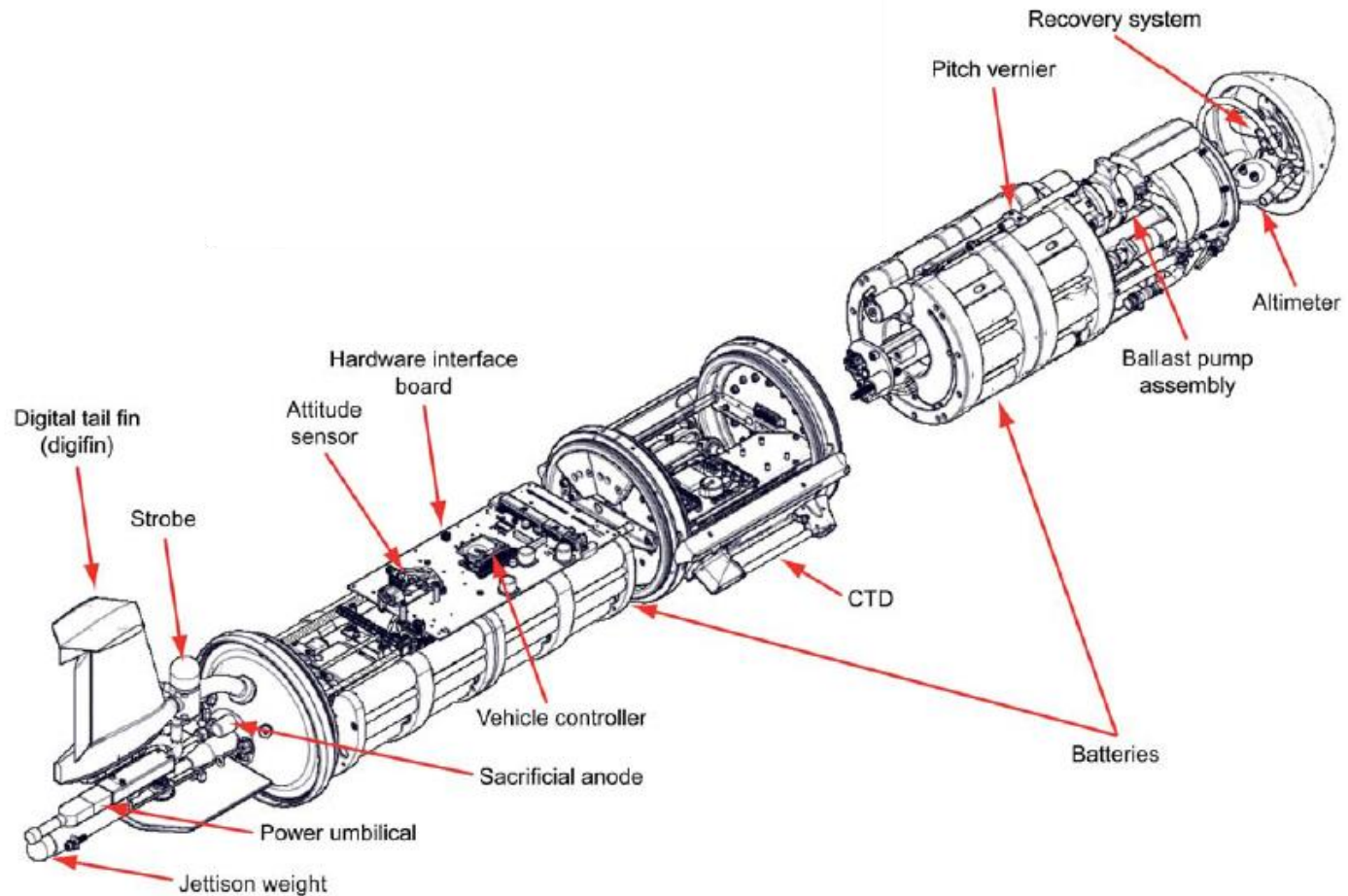
- Never power a glider without a vacuum.
- Never run a simulation on a glider other than *on_bench*.
- Never deploy a glider in simulation.
- Never deploy a glider in *boot pico*.
- Never exit to pico during a deployment.
- Never deploy a glider in *lab_mode*.
- Never perform the top of a yo below 30 meters (with 100- or 200-meter pumps).
- Never secure the glider to the glider cart while the cart is not secure or over the railing or in the water.
- Do secure the glider properly in crate with all three straps for shipping.
- The ejection weight can come out with moderate force (do not stand behind and activate)

G2 Glider Cross-Section

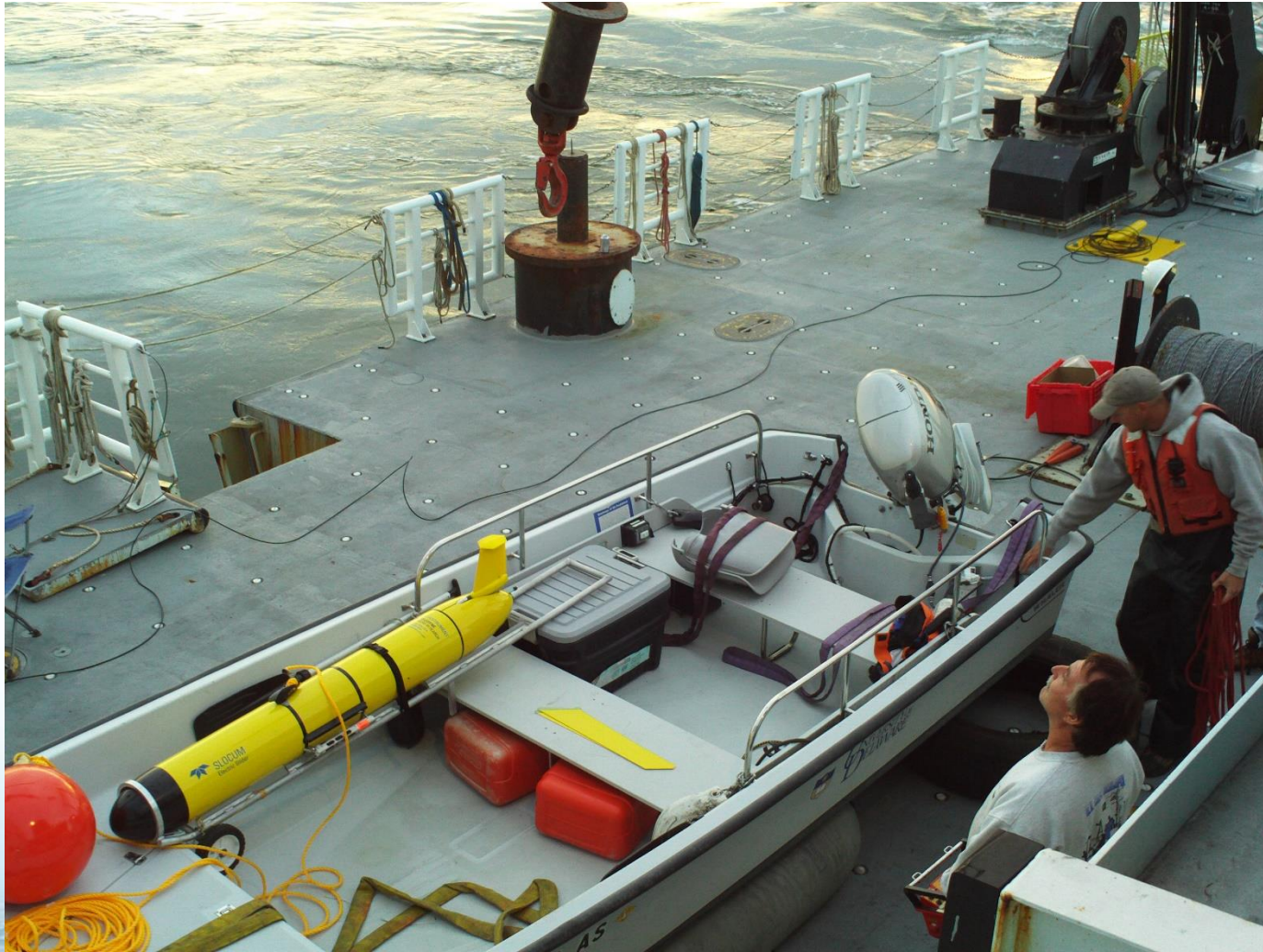


- 54 – 62 Kg (depending on configuration)
 - ~ 120 – 140 lbs *
- Nominally 1.8 m long
 - ~ 6 ft *
- 21 cm diameter
 - ~ 8.3 in *
- Composite material or 6061 T6 aluminum

G2 Glider Cross-Section



Glider Deployment



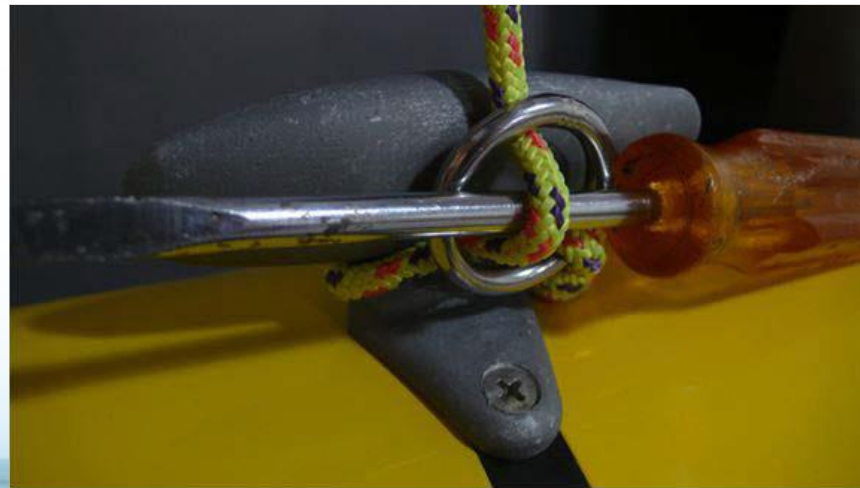
Glider Deployment



Glider Deployment



Quick Release (from manual)



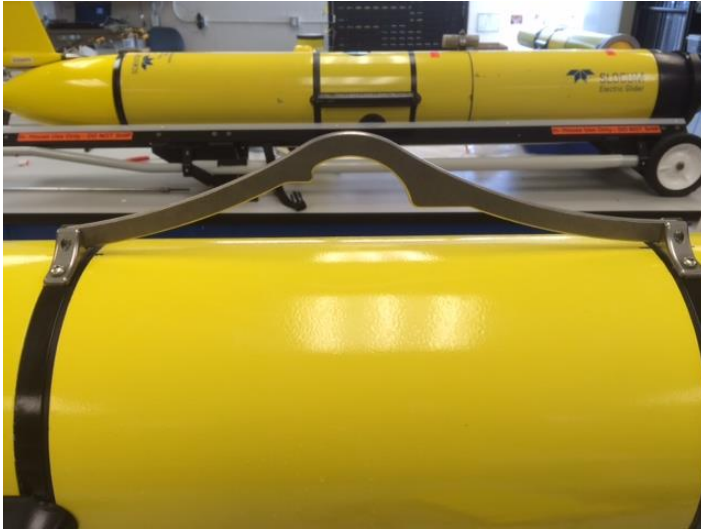
Glider Recovery

- Virtual Mooring Mode or Hold Mission
- Recovery via small workboat & glider cart
- Optional strobe light on tail section
- Recovery via optional nose release system (~ 10 m of line)
- Optional pick points & lifting bails

Glider Recovery



Pick Points

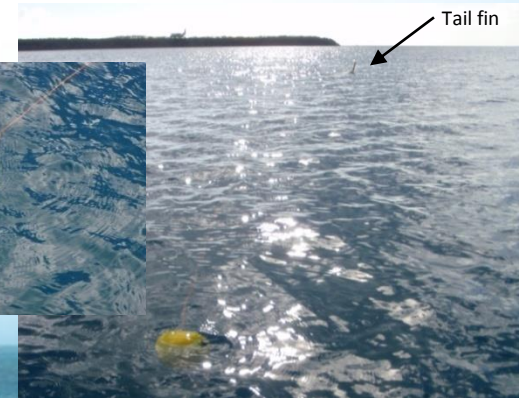
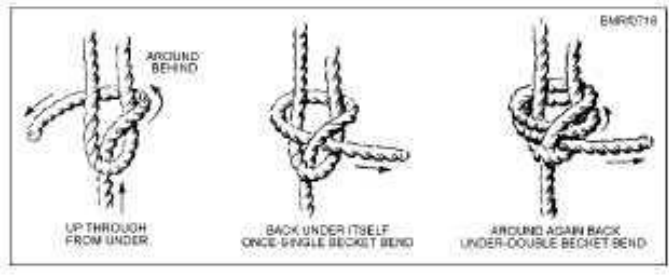
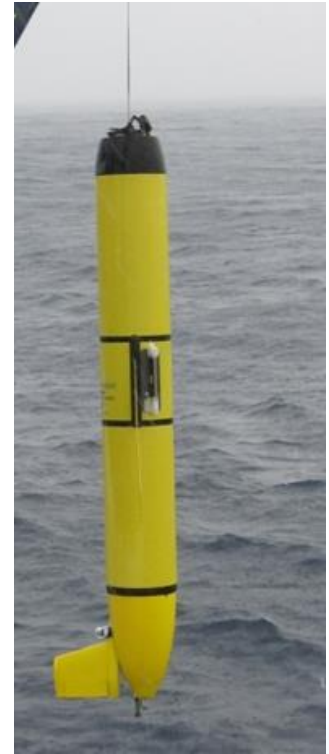


- Optional pick points:
- Hydrodynamic pick point
- Lifting bail



Nose Release

- Commanded by glider pilot for recovery
- Yellow floating nose cone, 10m floating line
- Grapple line and bring nose cone on board
- Disconnect nose cone
- Attach to line with a double becket bend
- Hoist glider up vertically A-frame or davit
- Control sway with U shaped fittings on poles



Glider Recovery (rinse w/ fresh water)



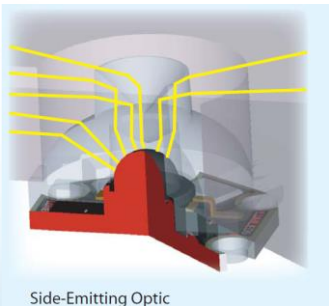
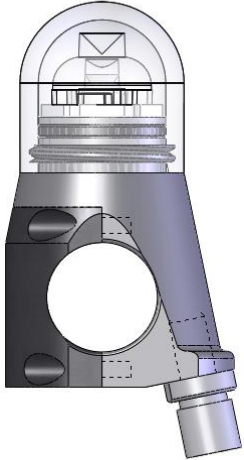
Beware of Bottom Mounted Sensors



Don't Open Until Christmas



Strobe (optional)



Side-Emitting Optic

Range of visibility (luminous range) of light in nautical miles D	Luminous intensity of light in candelas for K = 0.8 miles
1	0.9
2	4.3
3	12
4	27
5	52
6	94

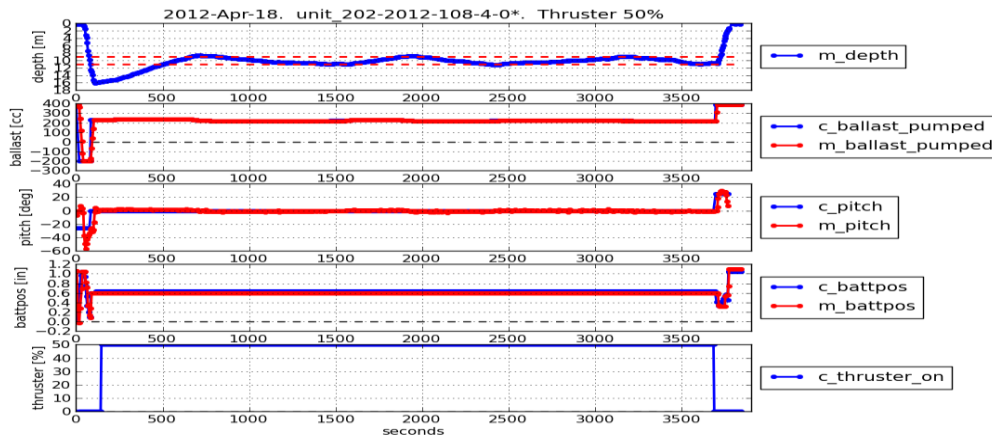
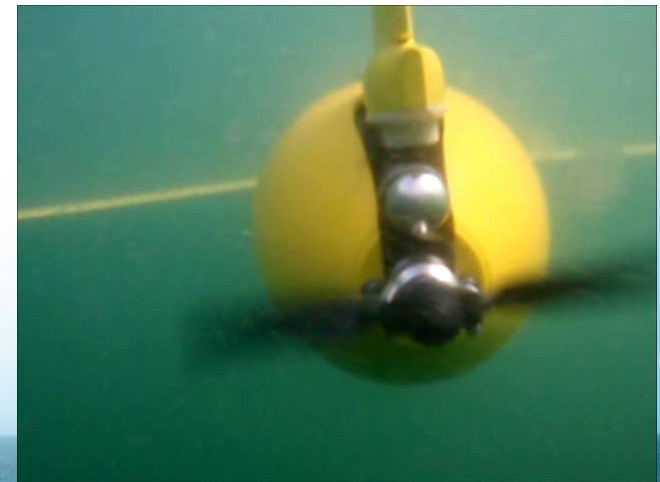
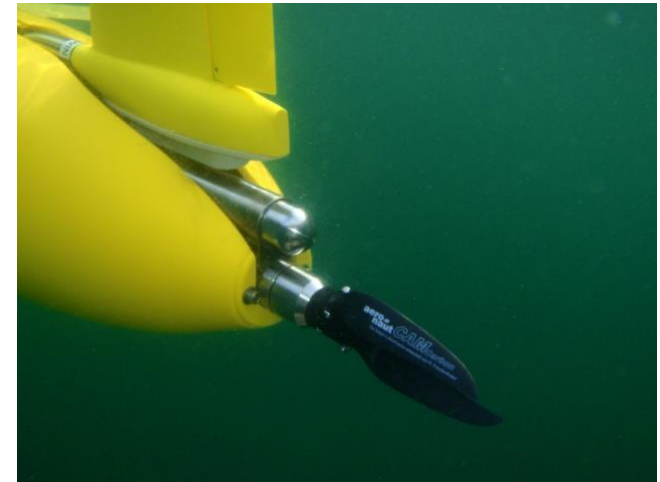
High power, amber, side emit strobe light blinks once every three seconds when turned on by glider pilot.

Strobe



Slocum G2 Hybrid Glider

- Greater speed – up to 1.8 knots
- Increased vehicle capability using the standard mission construct
- Freshwater lens penetration for surfacing events



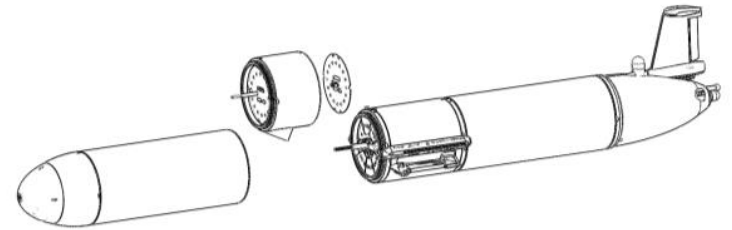
HYBRID CAPABLE



Slocum G2 Hybrid Glider



Sensor Suites



- Modular 6 L Payload Bay
- Nominally 3 – 6 kg air weight
- Customized for a variety of acoustic, optic and chemical sensors
- Science Bays can be stacked or stretched.

Acoustic Modem

ADCP/DVL

Altimeter

Bathyphotometer (bioluminescence)

Beam Attenuation Meter

Conductivity, Temperature, Depth

Echo Sounder

Nitrate

Optical Backscatter

Optical Attenuation

Oxygen

Fish Tracking

Fluorometer

Hydrocarbon

Hydrophones

PAR sensor

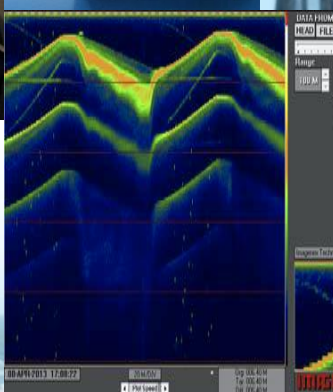
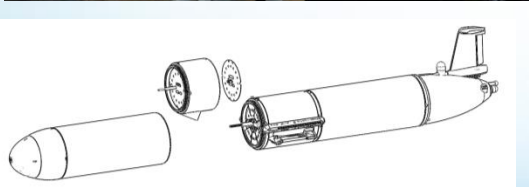
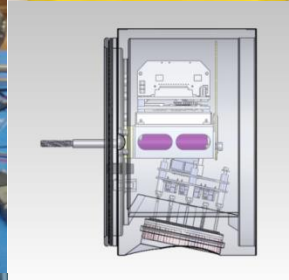
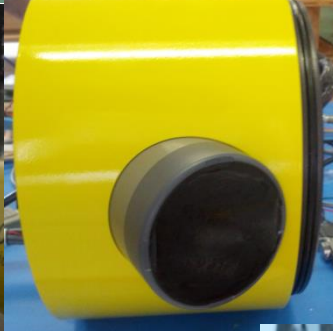
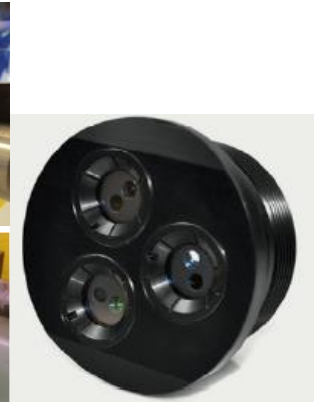
Radiometer

Scattering Attenuation Meter

Spectrophotometer (red tide detection)

Turbulence

Sensor Suites cont.



Not A Handle



Flow through CTD



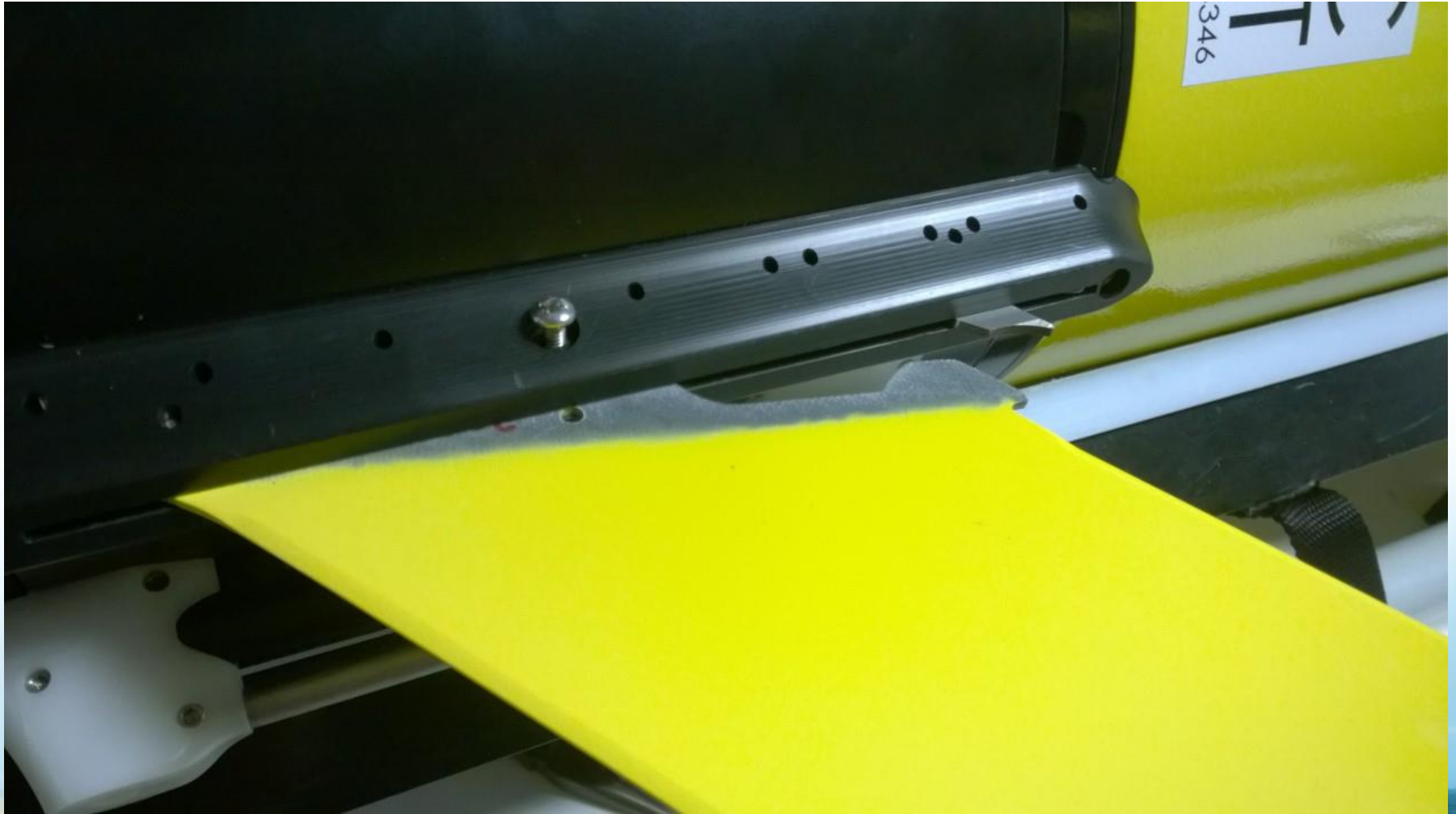
Snap Off Wings (not buoyant)



Thumb Release



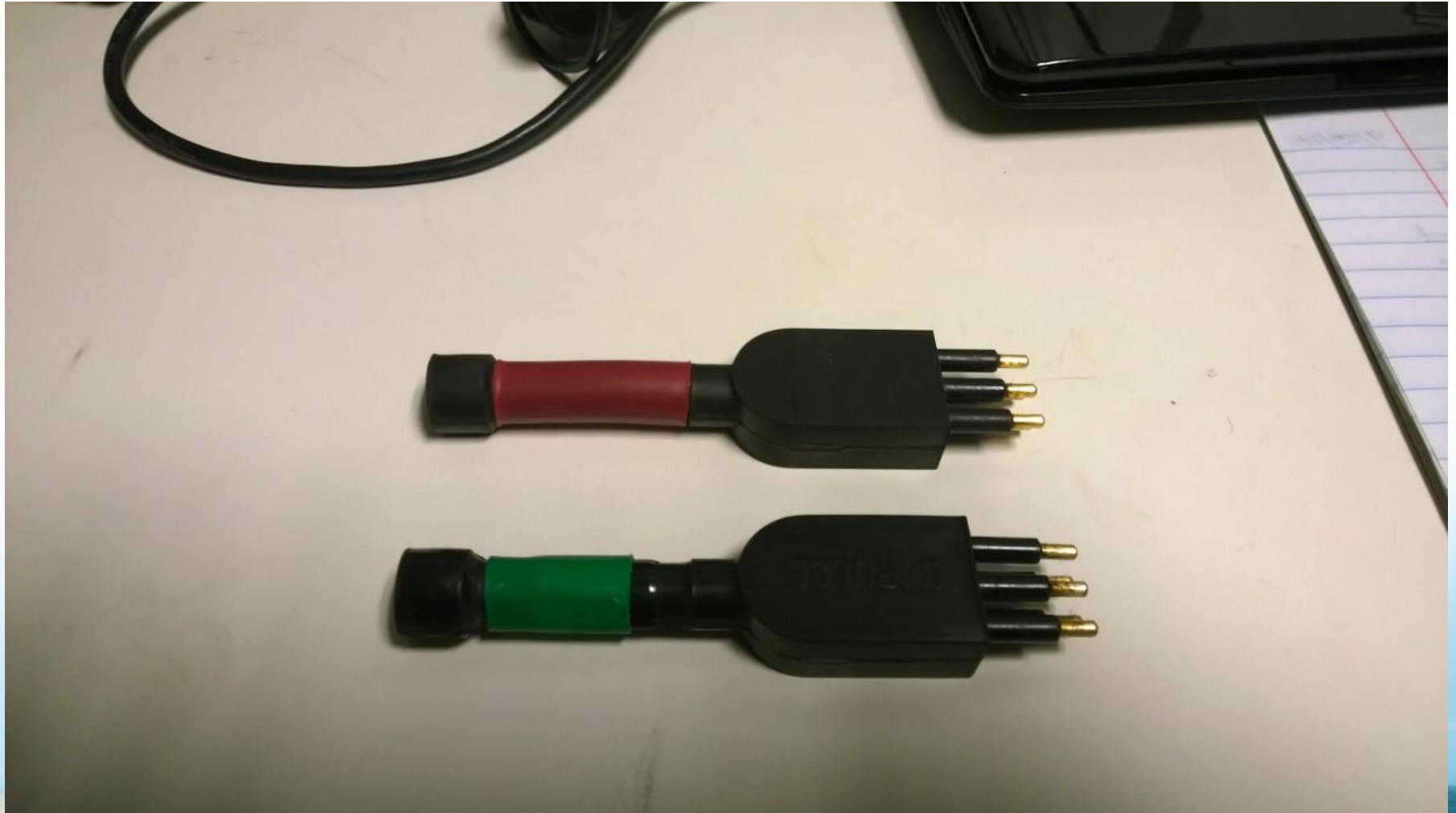
Thumb Release



Wing Rail Weights



Power Plugs



Emergency Weight



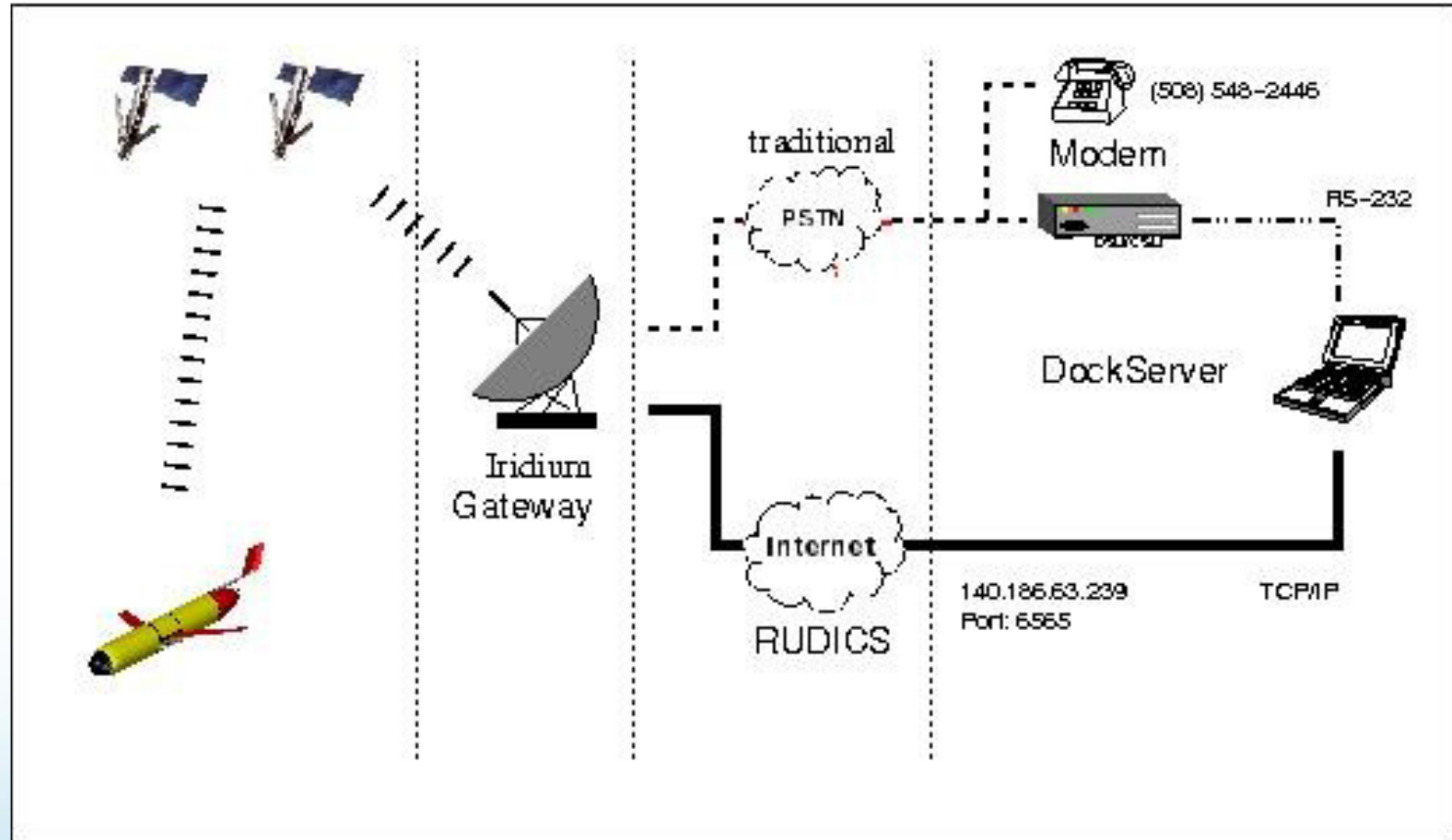
Secure Glider in the Lab



Glider Communications

- Iridium 9522b bidirectional satellite modem
 - ~1600 MHz and power of ~1.1 watt
 - Used in the absence of Freewave
- FreeWave 900 MHz radio modem
 - Used for local high-speed communications with the glider (19200,N,8,1)
 - 1 watt nominally, but it can be configured to transmit at 0.05 watts
- Argos
 - ~401 MHz and power of ~1 watt

Glider Communications



Thank You

Douglas White

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