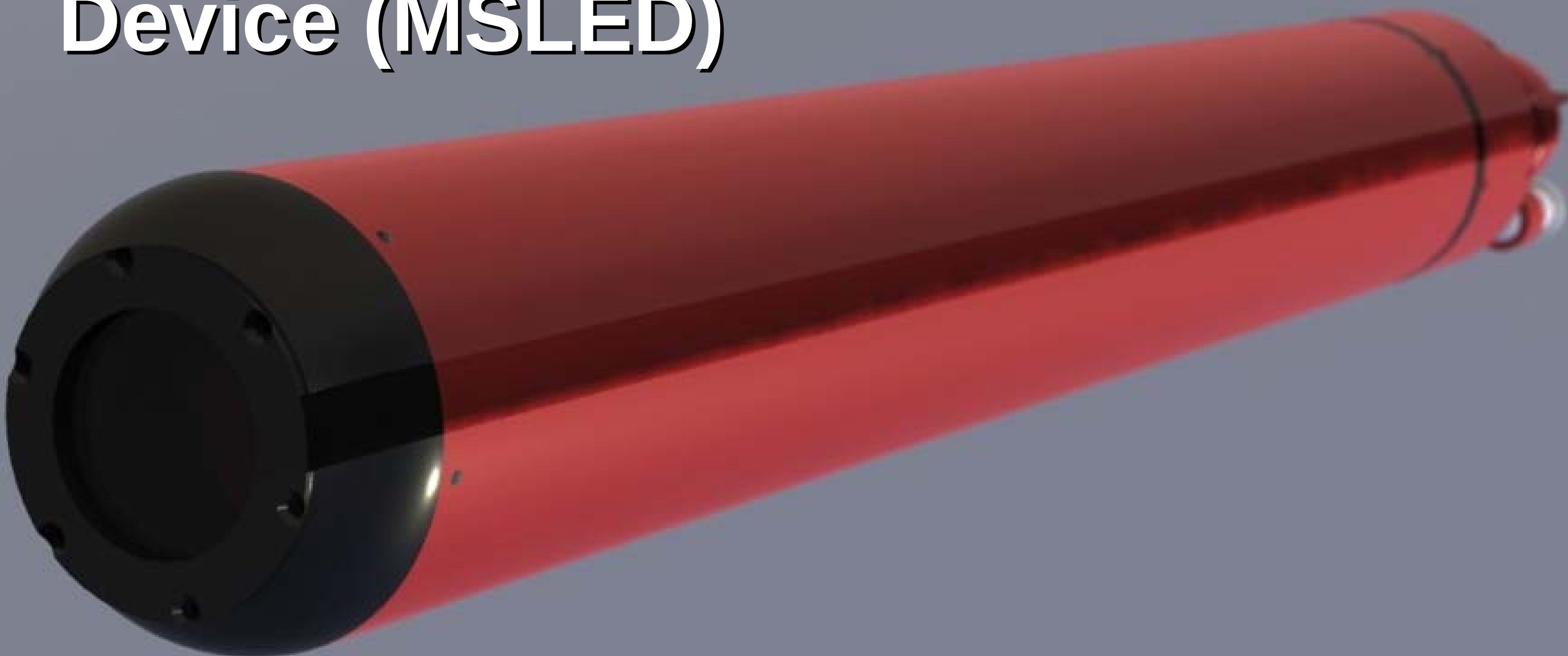
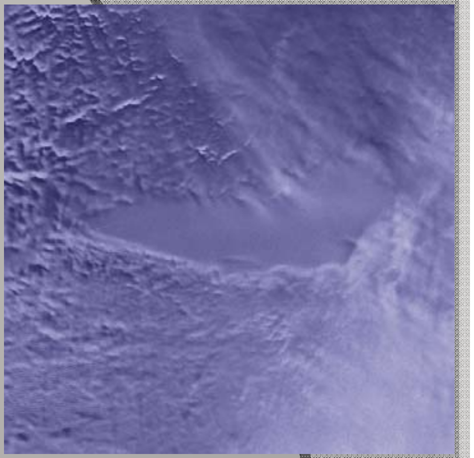
Micro-Subglacial Lake Exploration Device (MSLED)

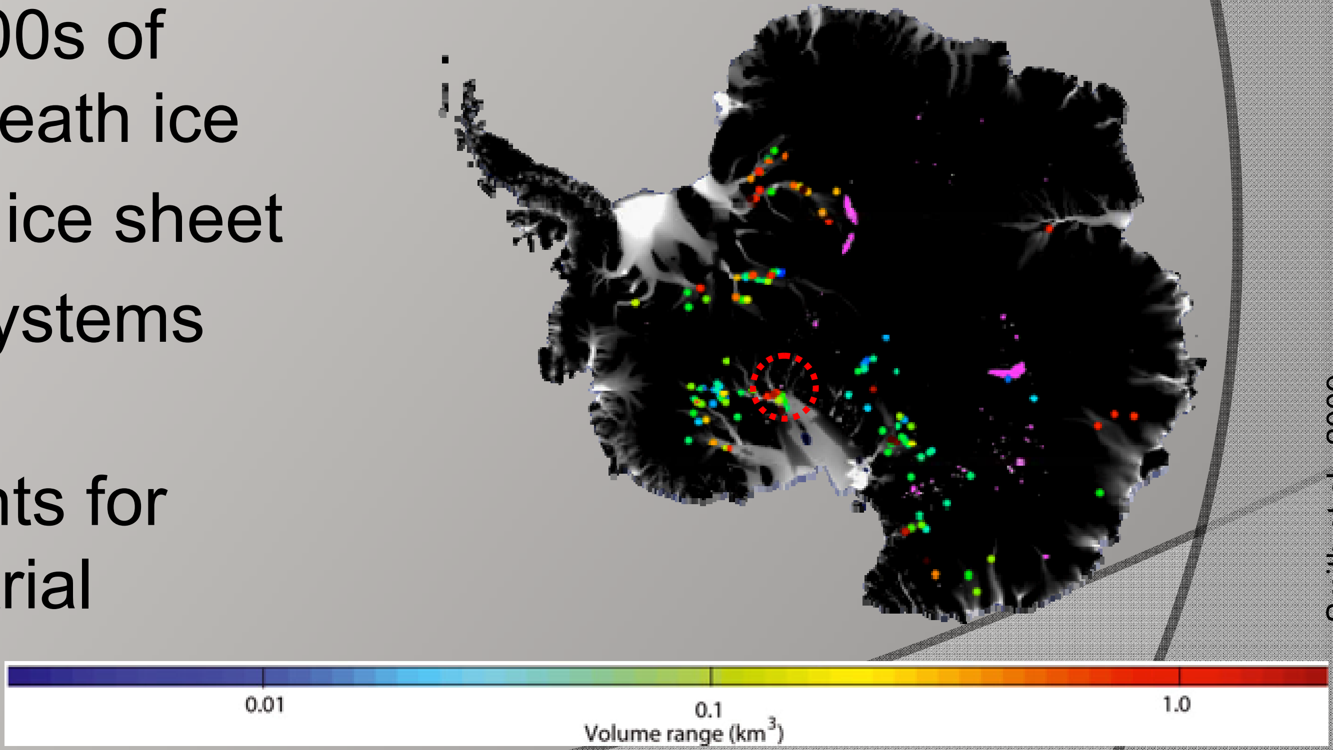


Dr. Alberto Behar

Antarctic Subglacial Lakes



- 145+ Antarctic subglacial lakes
- 100s to 1000s of meters beneath ice
- Influencing ice sheet
- Biotic ecosystems
- Analog environments for extraterrestrial bodies



Smith et al., 2009

Why Subglacial Lakes?

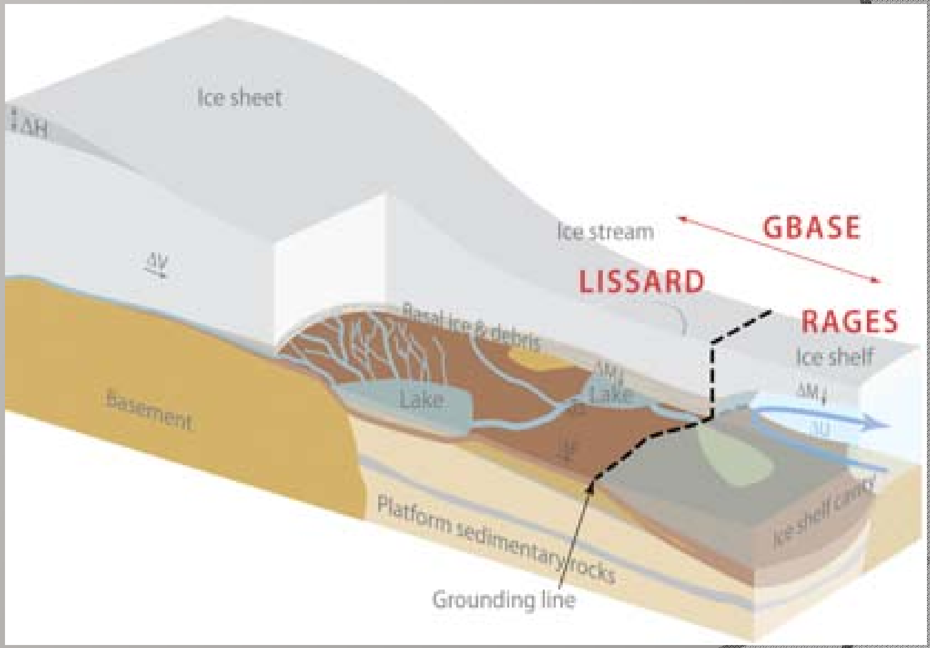
- Subglacial lakes originally thought to exist as isolated, water trapped in deep depressions carved in bedrock by moving ice.
- However, more recent discoveries determined these lakes are pumping water in and out on time scales of months to years, demonstrating these lakes are part of an interconnected system of water drainage.

Source: http://www.wissard.org

WISSARD Expedition

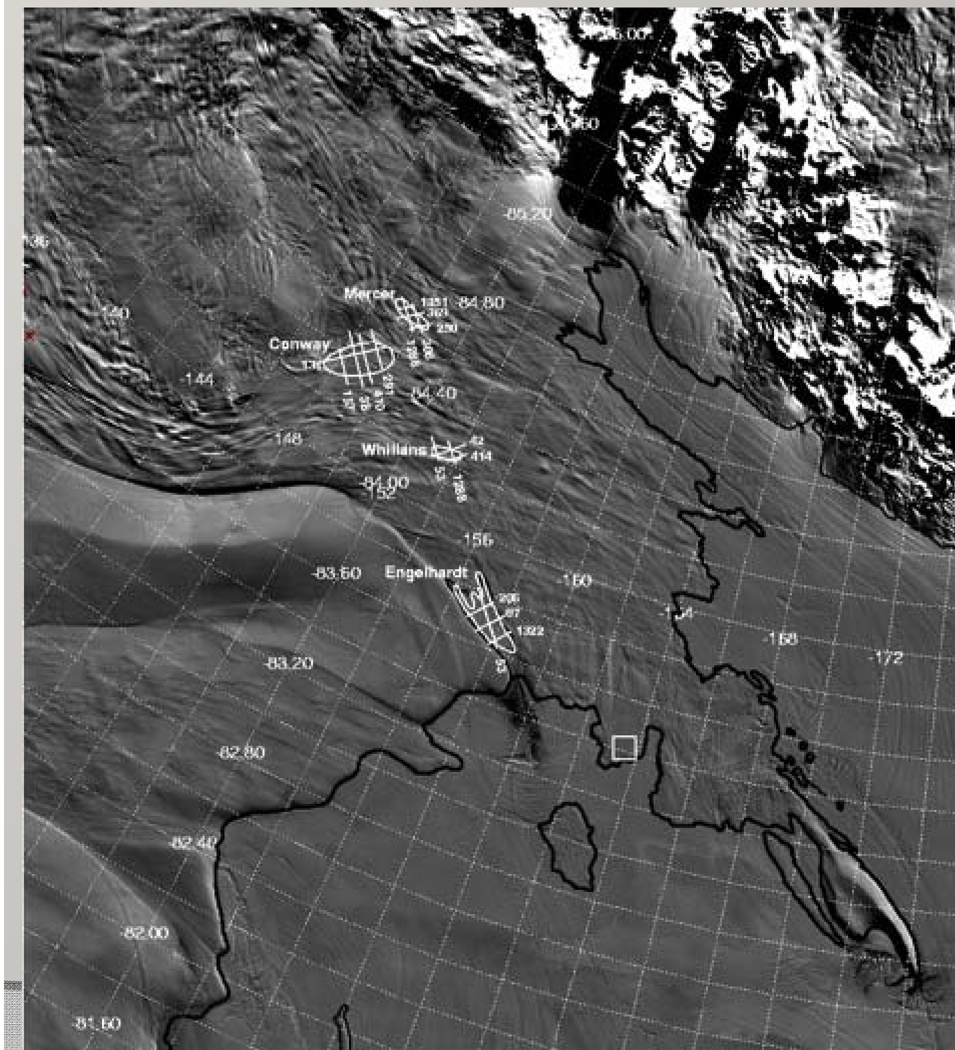
Whillans Ice Stream Subglacial Access Research Drilling

- **GeomicroBiology** of Antarctic Subglacial Environments (GBASE)
- Robotics Access to **Grounding-zones** for Exploration and Science (RAGES)
- Lake and Ice Stream **Subglacial** Access Research Drilling (LISSARD):
→ 8” borehole for MSLED

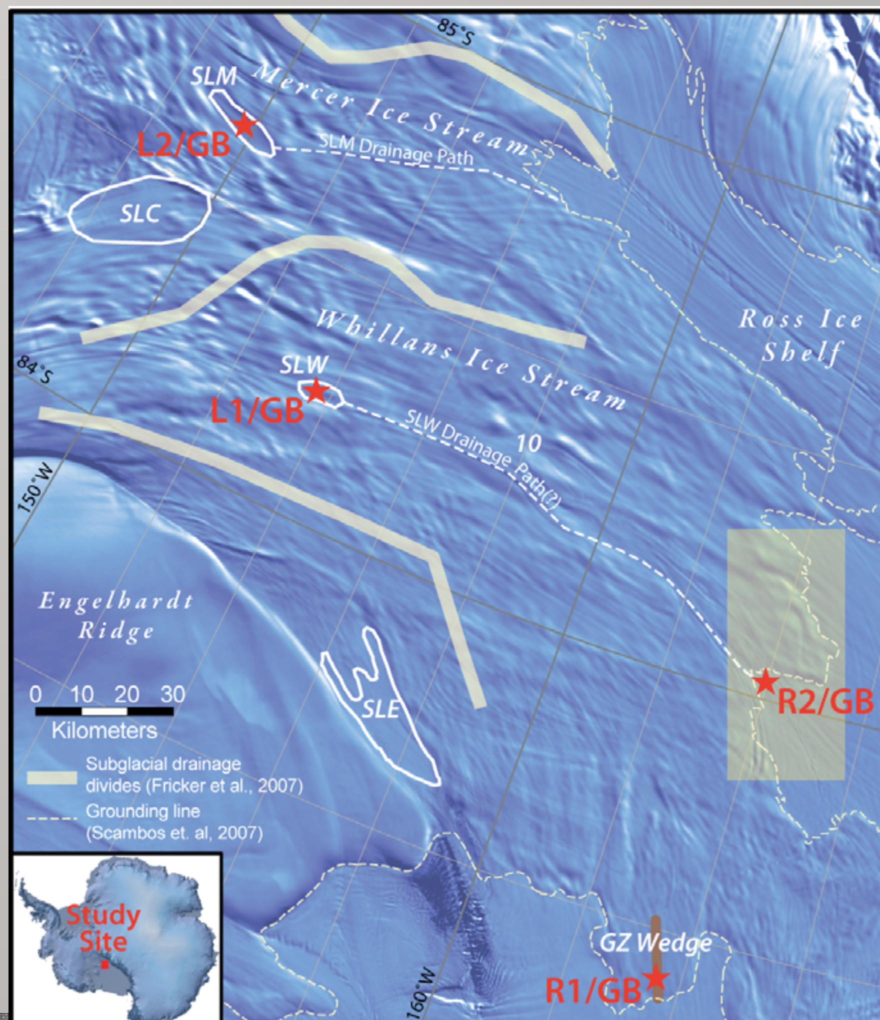


Whillans Ice Stream

- Sub ice-shelf cavity
- Grounding zone wedge
- Subglacial Lake Whillans



Why Subglacial Lakes?



Lissard Objective

- Focusing on subglacial lakes to determine how fast the West Antarctic ice sheet loses mass to the global ocean and influences global sea level changes

Source: http://www.wissard.org

MSLED Objectives

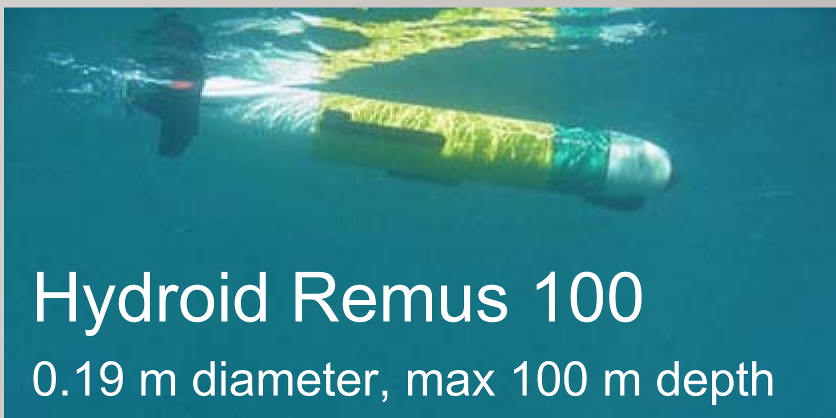
- Investigate water-ice interface
- Determine vertical and horizontal structure of water column
  - Physical: pressure and temperature
  - Chemical: salinity and pH
  - Visual inspection
- Visually investigate lake floor for geologic and sedimentary processes
- Look for biological features

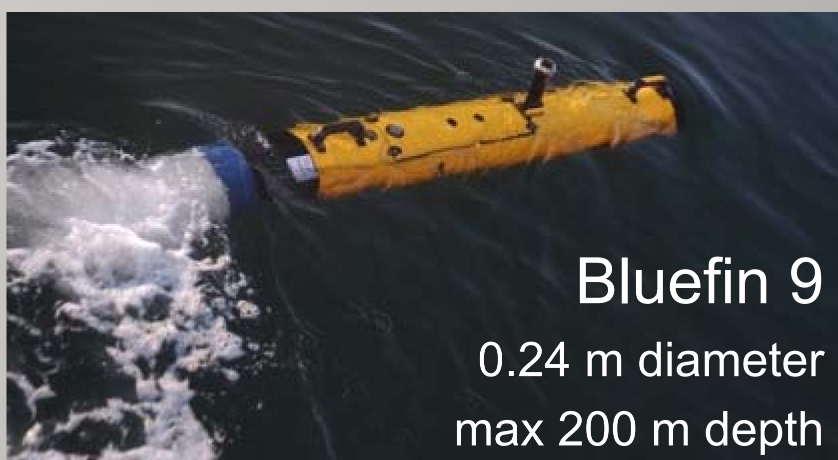
System Requirements

- Sensors: high resolution **video**, **temperature**, **salinity** and **pressure**
- Operational range of **1 km**
- Operating at **depth up to 1.5 km**
- Maximum **8 cm diameter** and 70 cm length
- **Remotely operated** from surface
- Localization of measurements
- Operate for minimum **2 h**
- **Two-way communication** with surface in real-time
- Return to the borehole for **retrieval**
- Operate in **temperatures** from **-10°C to 50°C**
- Utilization of **commercial-off-the-shelf** components
- Withstand decontamination for clean access
- Utilization of **existing infrastructure** (Ice Borehole Probe)

Comparable Vehicles

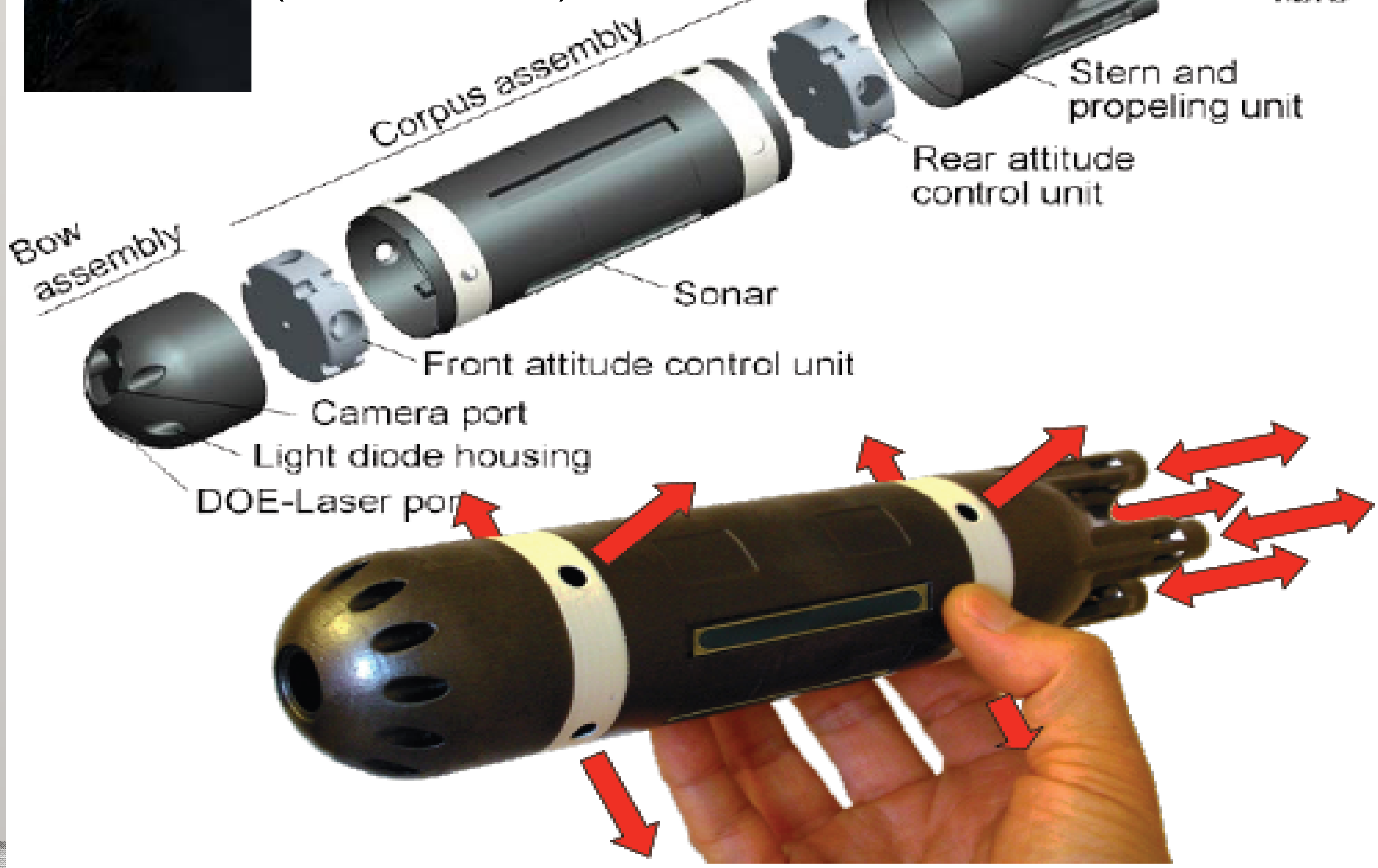
Required:
1500 m depth
max 0.08 m diameter





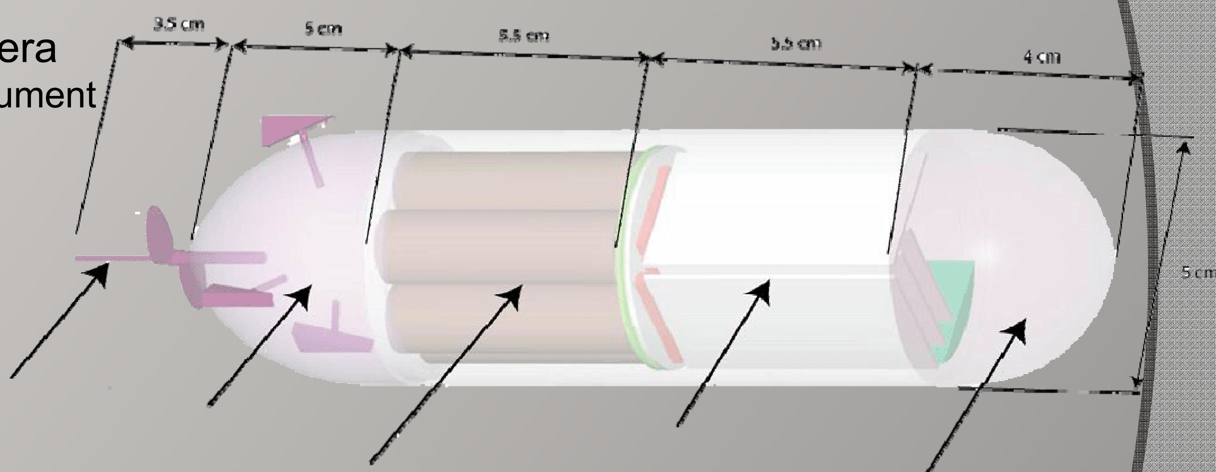
Sources: Hydroid, Inc., Bluefin Robotics, Inc., International Submarine Engineering Ltd.

Angstrom Space Technology Center, Uppsala, Sweden
Focus on MEM instruments (former student)

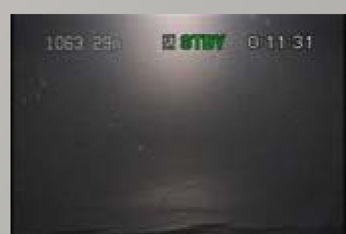


Early Concept: Mini-Sub Explorer ‘01

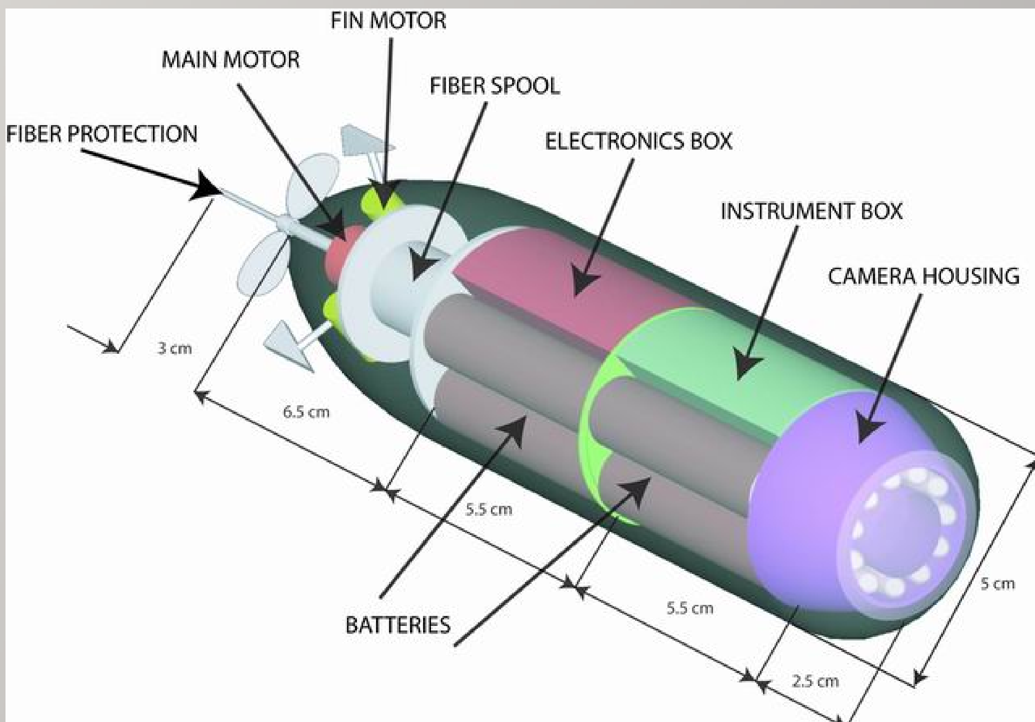
- Size: 5 cm x 20 cm
- Range: >5 km
- Instruments: CTD, Camera
  + 1 mission specific instrument

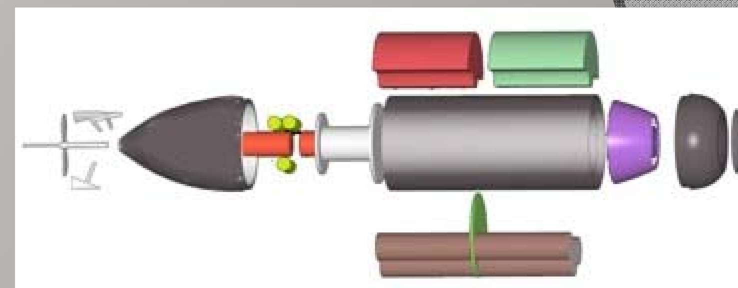


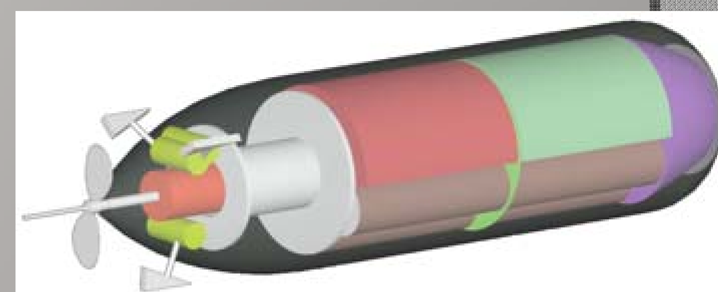
- Applications
  - Europa
  - Ice Shelves
  - Acidic Lakes
  - Alkaline Lakes
  - Sub-Glacial Lakes
  - Hydrothermal Vents
  - Submerged Volcanoes

Micro-Sub Vehicle Concept





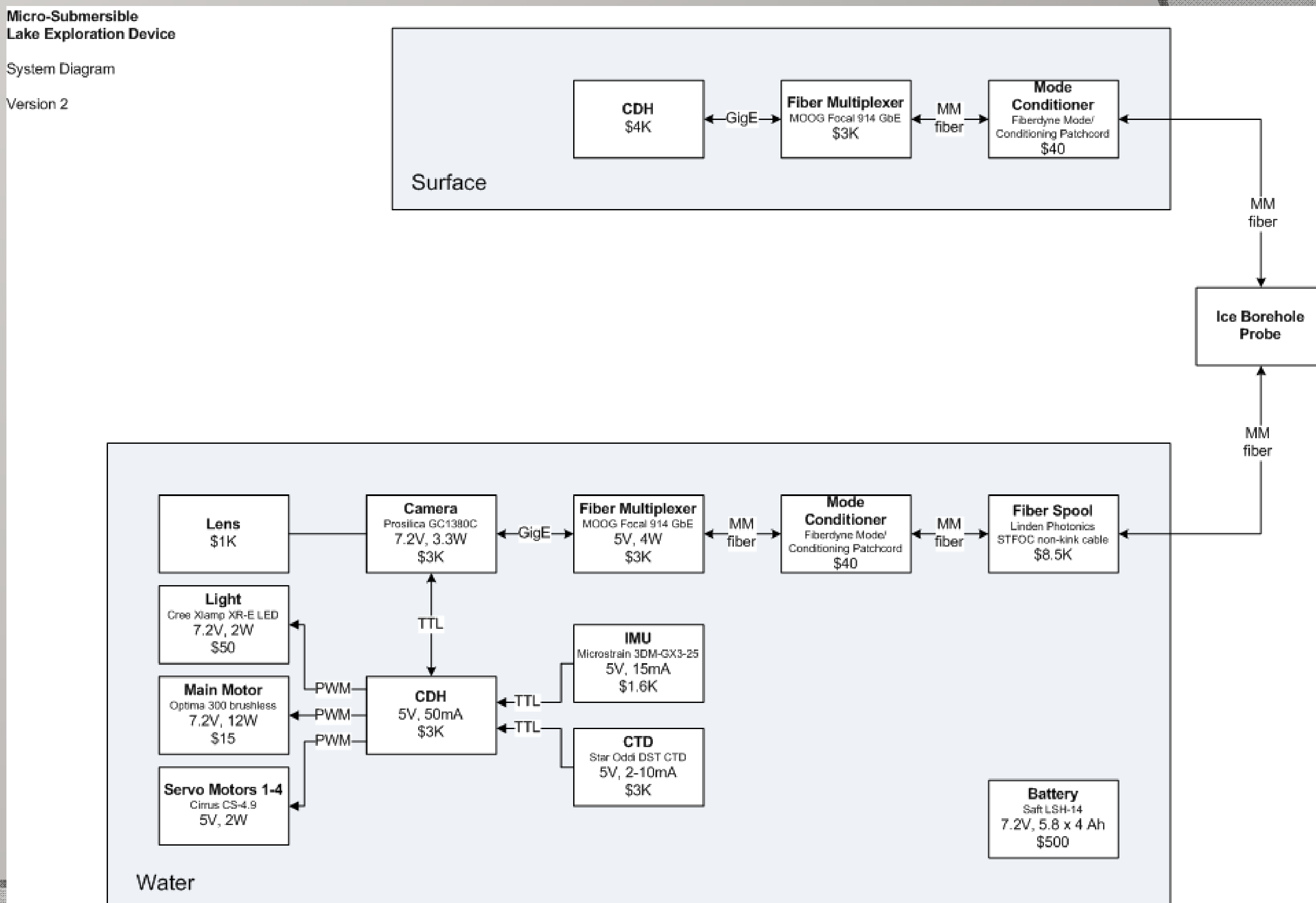


MSLED Concept Development

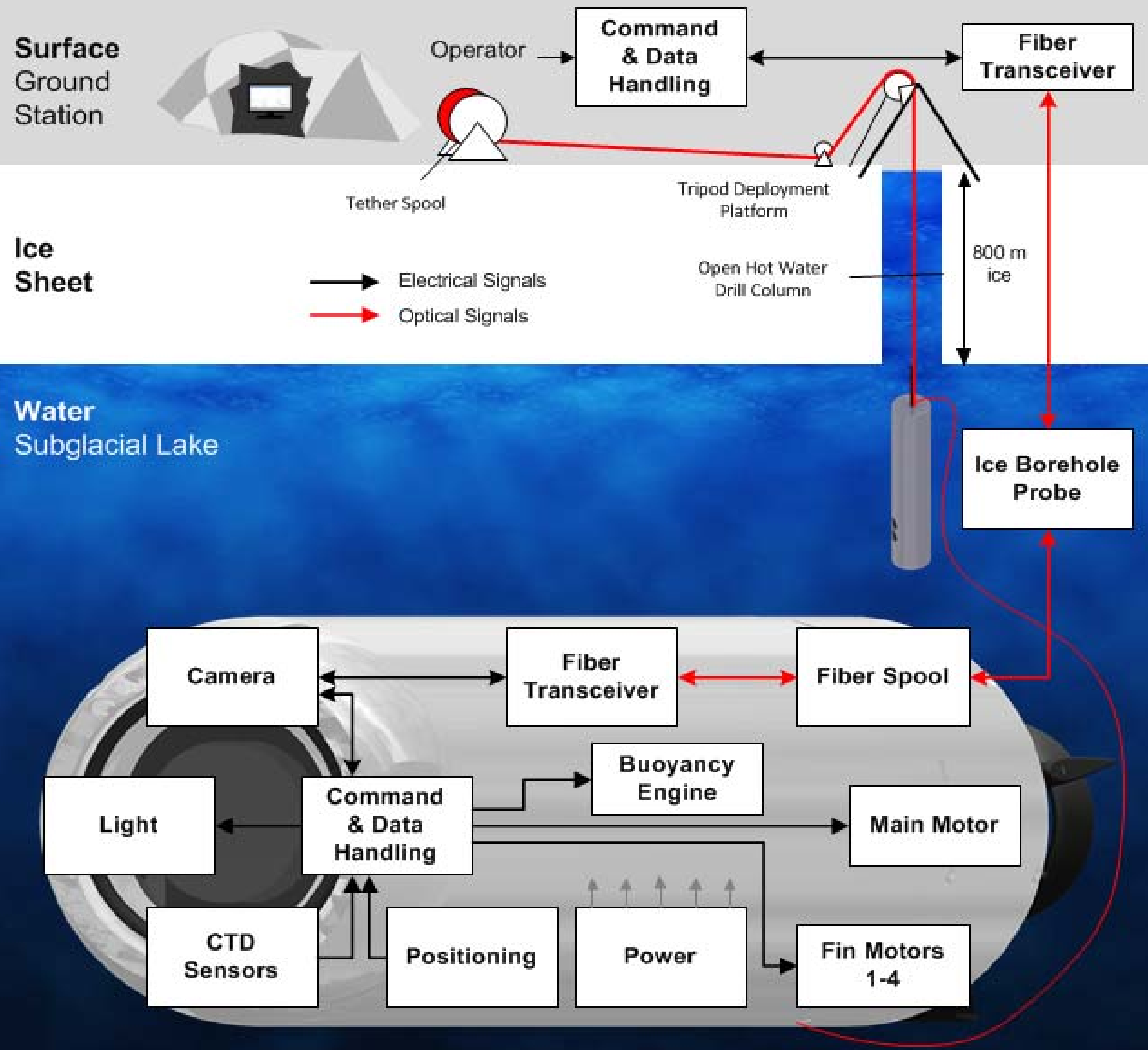
Original conceptual detail design work was done at JPL (June-August 2010)

Team members:

- Christian Walter
- Andrew Elliot
- Anna Camery
- Tom Nordheim
- Evan Olson
- Colin Ho



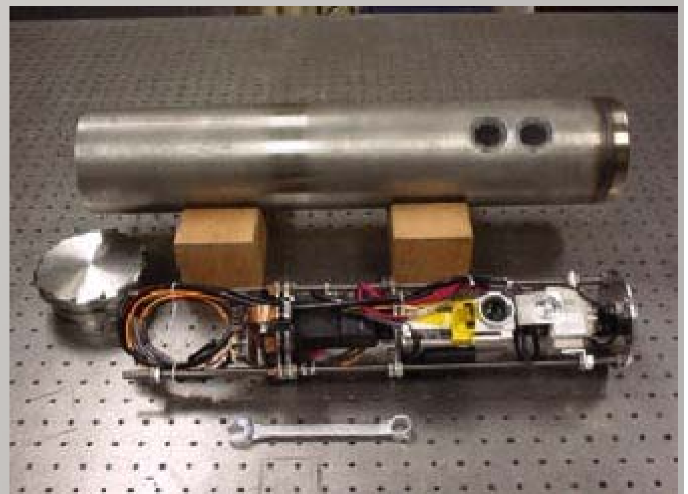
System Prototype

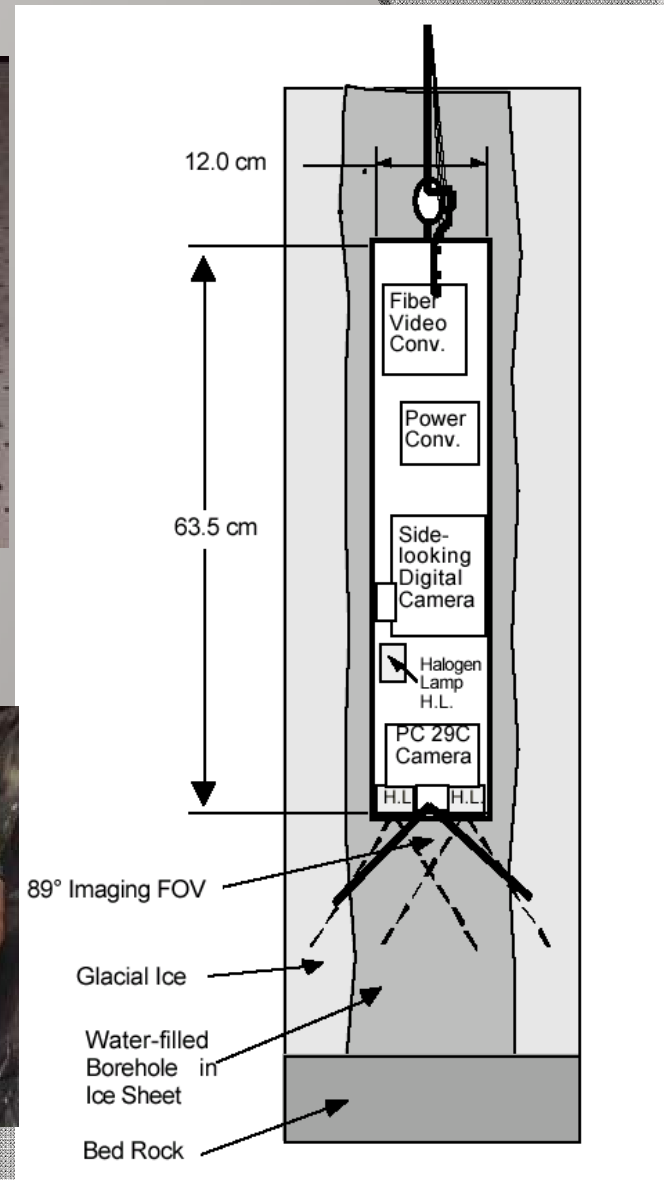


Background image: Flickr, WoaH

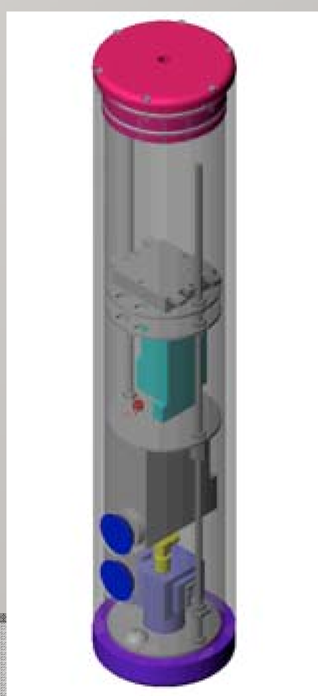
Ice Borehole Probe

- Stainless Steel Pressure Housing
- 12 cm dia
- 63.5 cm long
- 2 Quartz windows on side for one camera & one halogen lamp
- 1 Quartz window on bottom for one camera and two lamps
- 4 Fiber optic lines (2 for video signals, 1 for IR control, 1 spare)

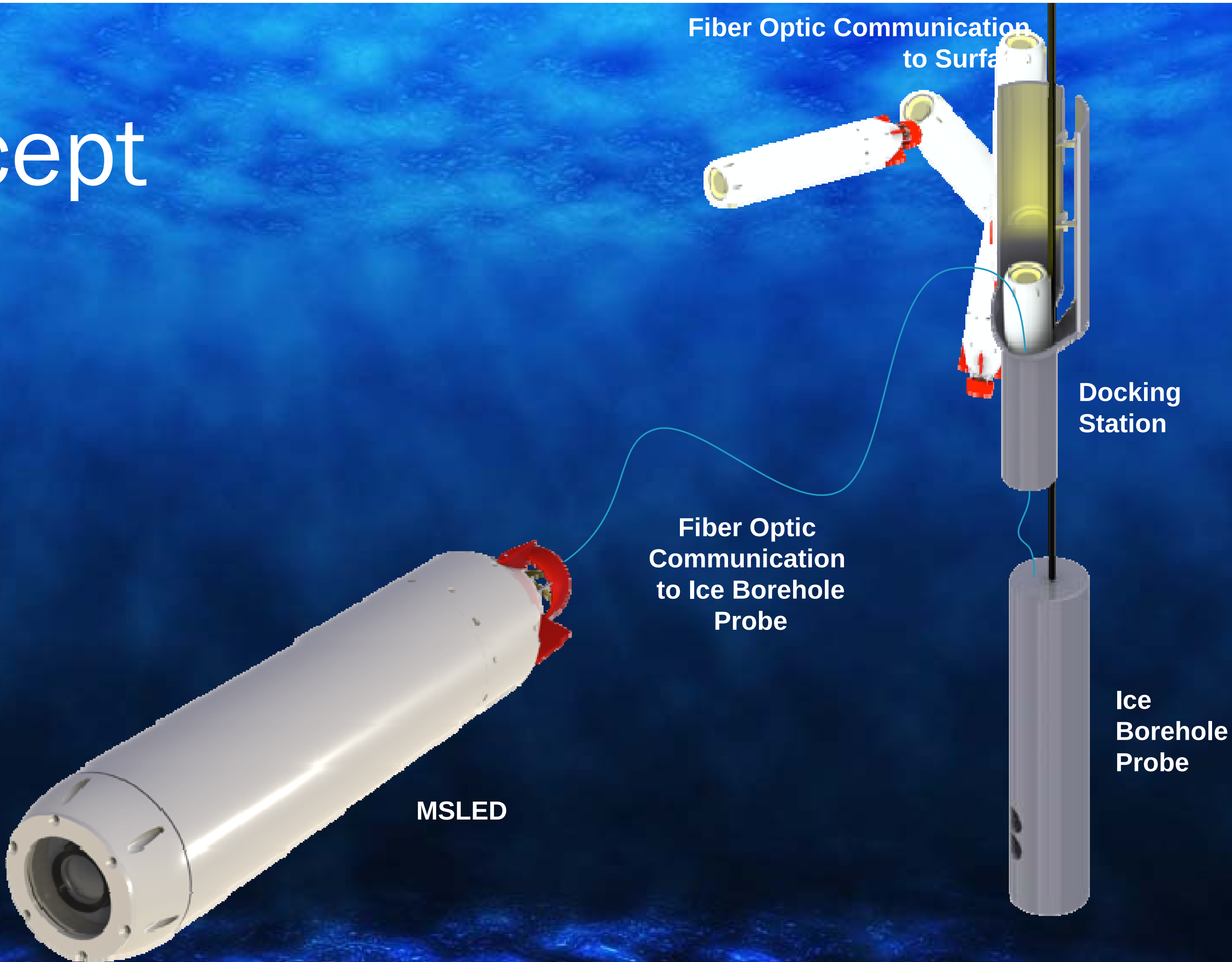




Ice Probe Currently in Use at
Pine Island Glacier Project
PI: Bob Bindschadler



Concept



Background image: Flickr, WoaH

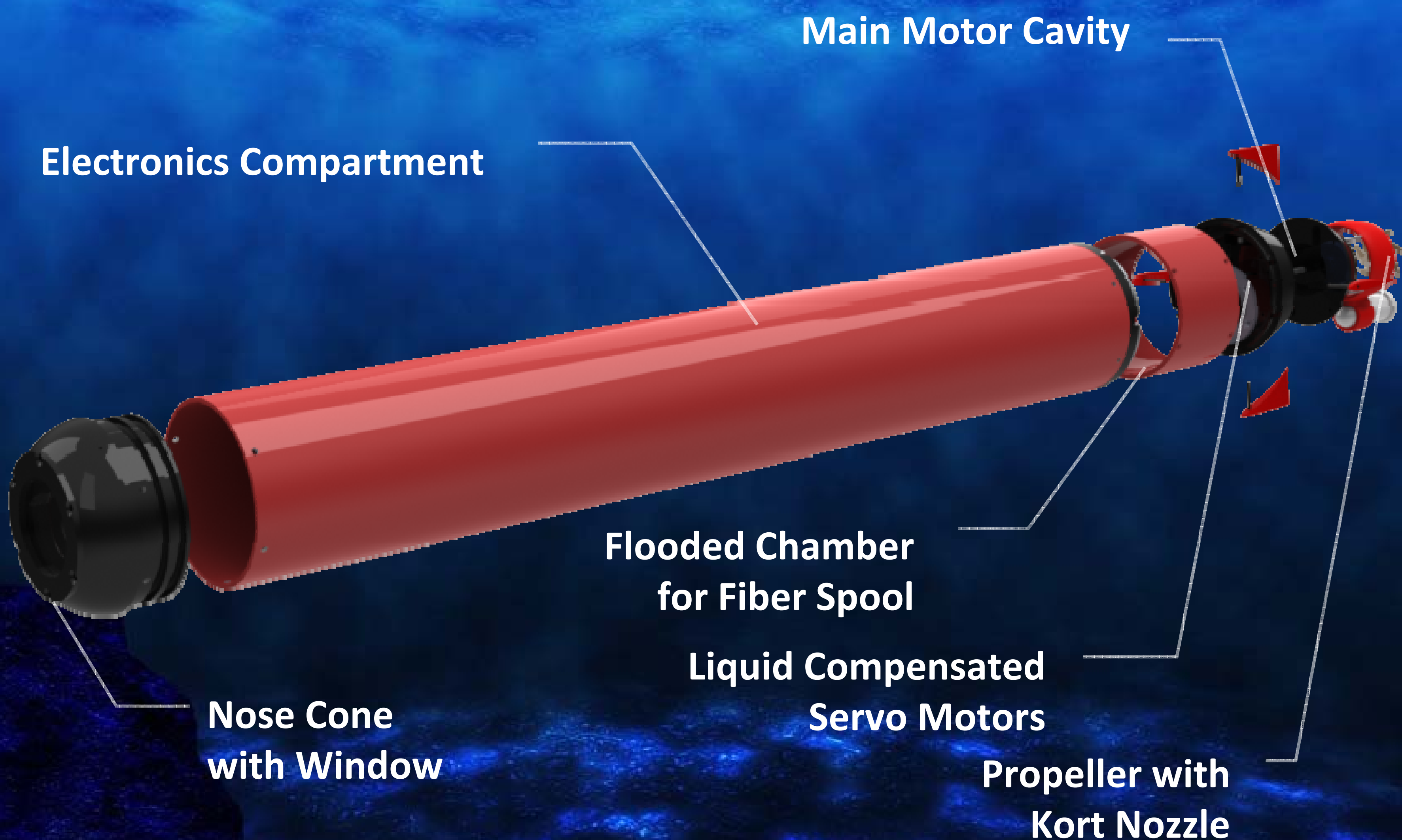
System: Main Challenges

- Form factor constraints (borehole, mission)
- High pressures (environment)
- Low temperature (environment)
- High bandwidth communication with surface (payload)
- Interface constraints (Ice Borehole Probe)

Subsystems

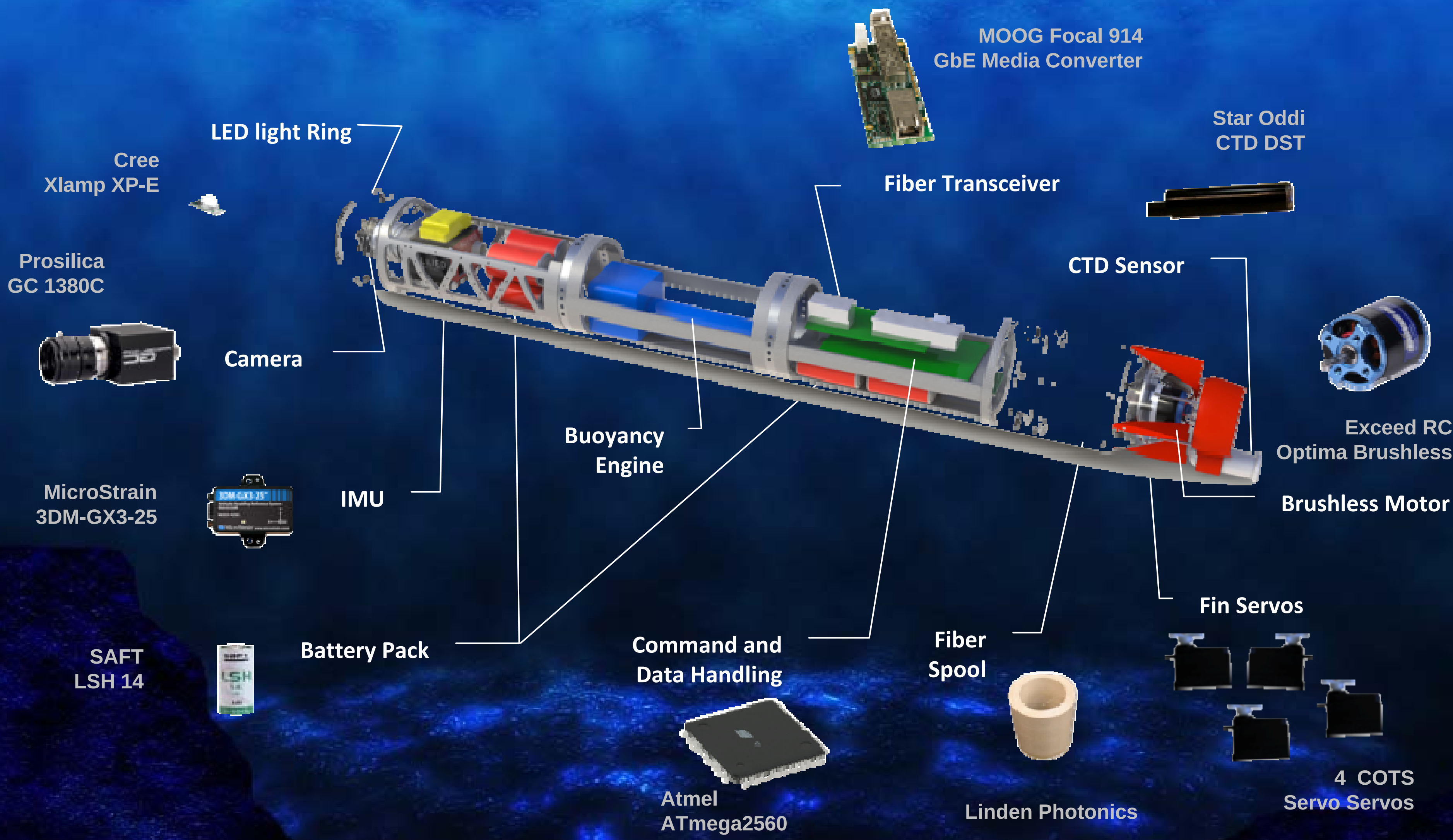
- Structure
- Communication
- Command and Data Handling
- Instrumentation Payload
- Positioning
- Steering and Propulsion
- Power

Structure



Background image: Flickr, WoaH

Internal Components

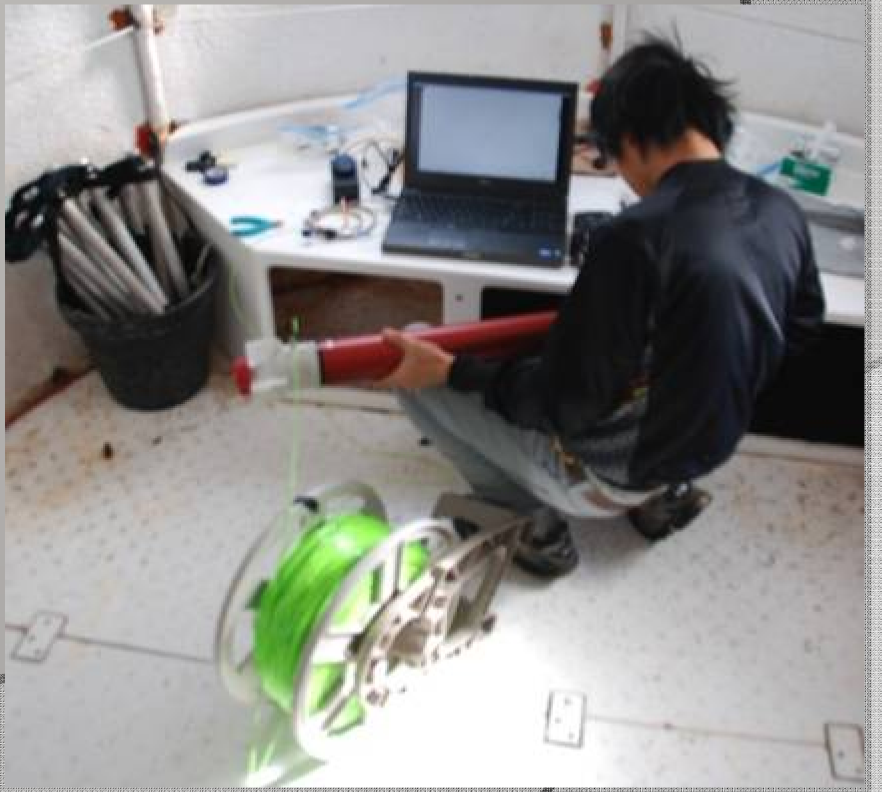


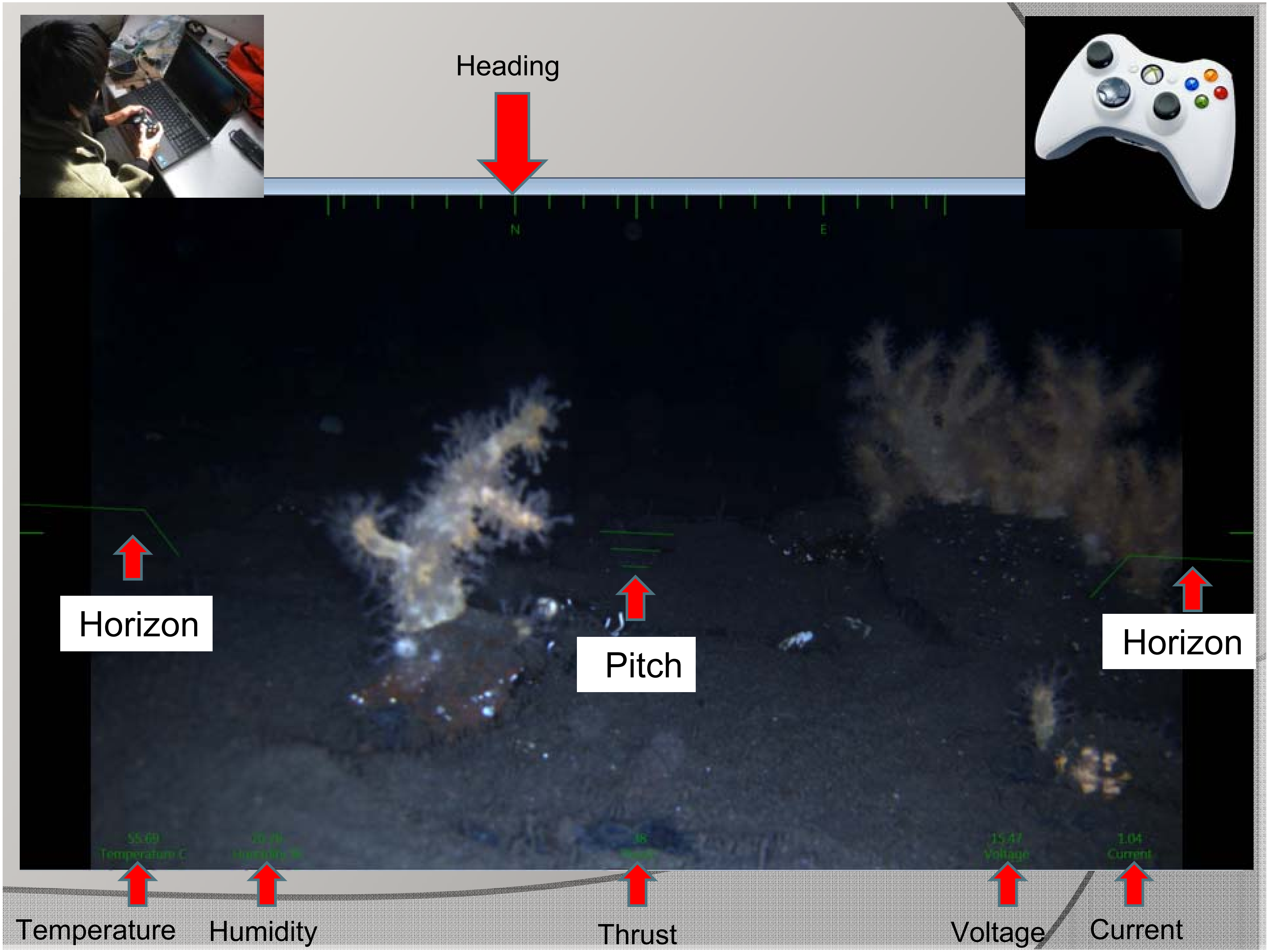
Background image: Flickr, WoaH

Operations Concept

- MSLED is controlled through the fiber optic connection from the Operator Control Station

- Graphical User Interface (GUI) for the computer program communicating with the micro-sub vehicle, scientists can:
  - command
  - receive vehicle status
  - collect scientific data in real time




Heading
N
E
Horizon
Pitch
Horizon
55.69
Temperature C
15.47
Voltage
1.04
Current
Temperature
Humidity
Thrust
Voltage
Current

Recent Pressure Testing – MSLED 2nd Copy

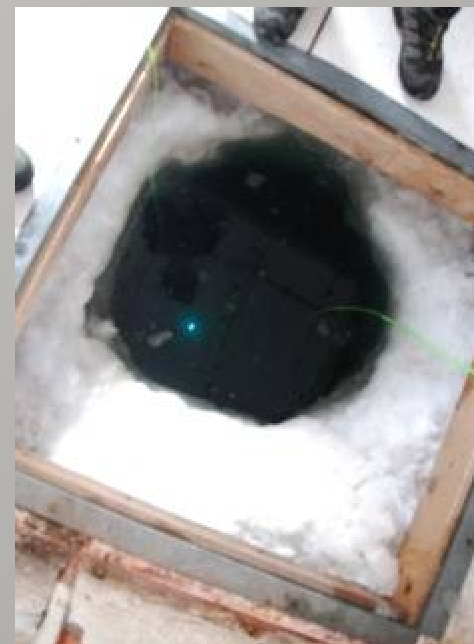
Test Facility: Deep Sea Power and Light (San Diego, CA)
Test limit: 1.2km (1700psi)
Failed at 1200 psi
Tolerances not as precise as 1st copy

Current Status

- Initial prototypes developed and fabricated
- Structural testing and verification finished
- Testing end-to-end system (here in Sea Ice)
- Preliminary Change Logs are created
- Development focus shift now to:
  - Making field system more robust
  - Integration with Antarctic Ice Probe
  - Release and capture concept
  - Fiber Tether system Solution
  - Possible automatic bouyancy compensator
  - Active roll stabilization

- Planning now for test in Tahoe/Crater Lake in April 2012

Deployment of MSLED (now)



Chase Vehicle

Video

Field Seasons

- 2011 – Field Test Deployment
  - McMurdo Station (November-December)
- 2012 – Possible re-test
  - McMurdo Station with Full up system
- 2013/2014 –Field Deployment
  - WISSARD
    - Whillans Ice Stream Antarctica
- Analogue Testing Ongoing:
  - Lake Tahoe
  - Crater Lake
  - Arizona lakes
  - Pool Testing

Future Directions

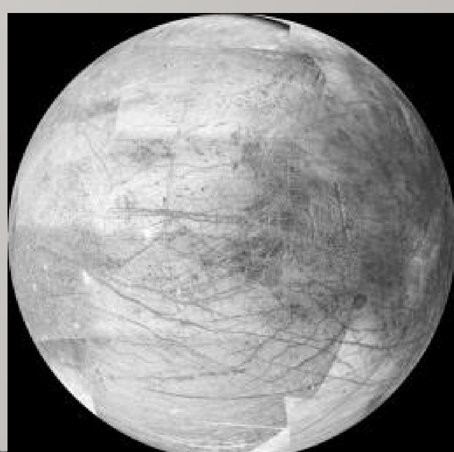
- Semi-autonomy
- Full autonomy, autonomous underwater vehicle (AUV)
- Integration of new Science Instruments
- More local manuevarabiltiy

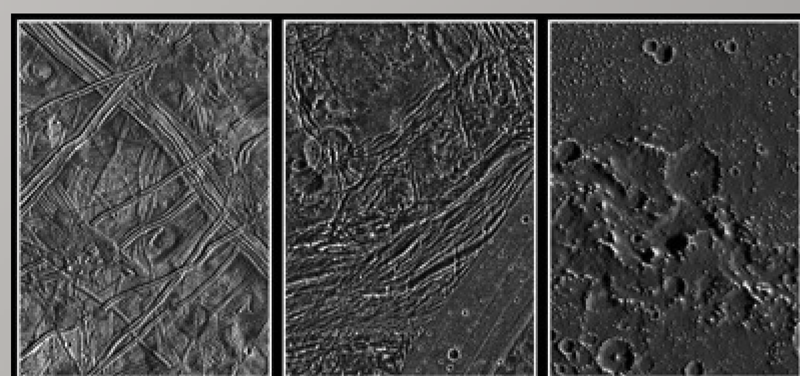
Acknowledgements

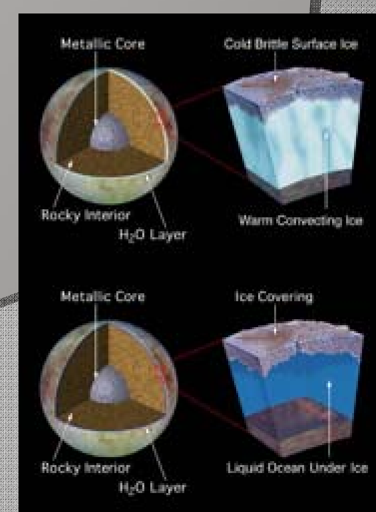
- NSF AISS and Cryosphere Program
- NASA Cryosphere Program
- Slawek Tulaczyk, University of California Santa Cruz
- Helen Fricker, University of California San Diego
- Hans Thomas, Monterey Bay Aquarium Research Institute
- Chris German, Woods Hole Oceanographic Institute

Europa Cryobot

- Proposed ice-penetrating Cryobot and Hydrobot to explore the ice-covered ocean on Jupiter's large satellite, Europa
- Cryobot would melt through the ice cover and deploy a hydrobot, a self-propelled underwater vehicle to analyze the chemical composition of the ice/water in a search for signs of life







Bibliography

- Bamber J.L., Riva R.E.M., Vermeersen B.L.A. and LeBrocq A.M. (2009) Reassessment of the Potential Sea-Level Rise from a Collapse of the West Antarctic Ice Sheet. *Science*, 324(5929), p.901.
- Carsey F., Behar A., Lane A.L., Realmuto V. and Engelhardt H. (2002) A borehole camera system for imaging the deep interior of ice sheets. *Journal of Glaciology*, 48(163), pp.622-28.
- Christoffersen P., Tulaczyk S., Carsey F.D. and Behar A.E.. (2006) A quantitative framework for interpretation of basal ice facies formed by ice accretion over subglacial sediment. *Journal of Geophysical Research*, 111, p.F01017.
- Christoffersen P., Tulaczyk S., Carsey F.D. and Behar A.E. (2007) Reply to comment by A. W. Rempel et al. on "A quantitative framework for interpretation of basal ice facies formed by ice accretion over subglacial sediment". *Journal of Geophysical Research*, 111, p.F02037.
- Fricker H.A., Scambos T., Bindschadler R. and Padman L. (2007) An Active Subglacial Water System in West Antarctica mapped from Space. *Science*, 315, pp.1544-48.
- Gray L., Joughin I., Tulaczyk S., Spikes V.B., Bindschadler R. and Jezek K. (2005) Evidence for subglactial Water Transport in the West Antarctic Ice Sheet through three-dimensional Satellite Radar Interferometry. *Geophysical Research Letters*, 32, p.L03501.
- Mercer J.H. (1978) West Antarctic Ice Sheet and CO2 Greenhous Effect: A Threat of Disaster. *Nature*, 271, pp.321-25.
- IPCC (2007) *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.
- Smith B.E., Fricker H.A., Joughin I.R., Tulaczyk S. (2009) An inventory of active subglacial lakes in Antarctica detected by ICESat (2003–2008). Journal of Glaciology 55(192), pp. 573-95.