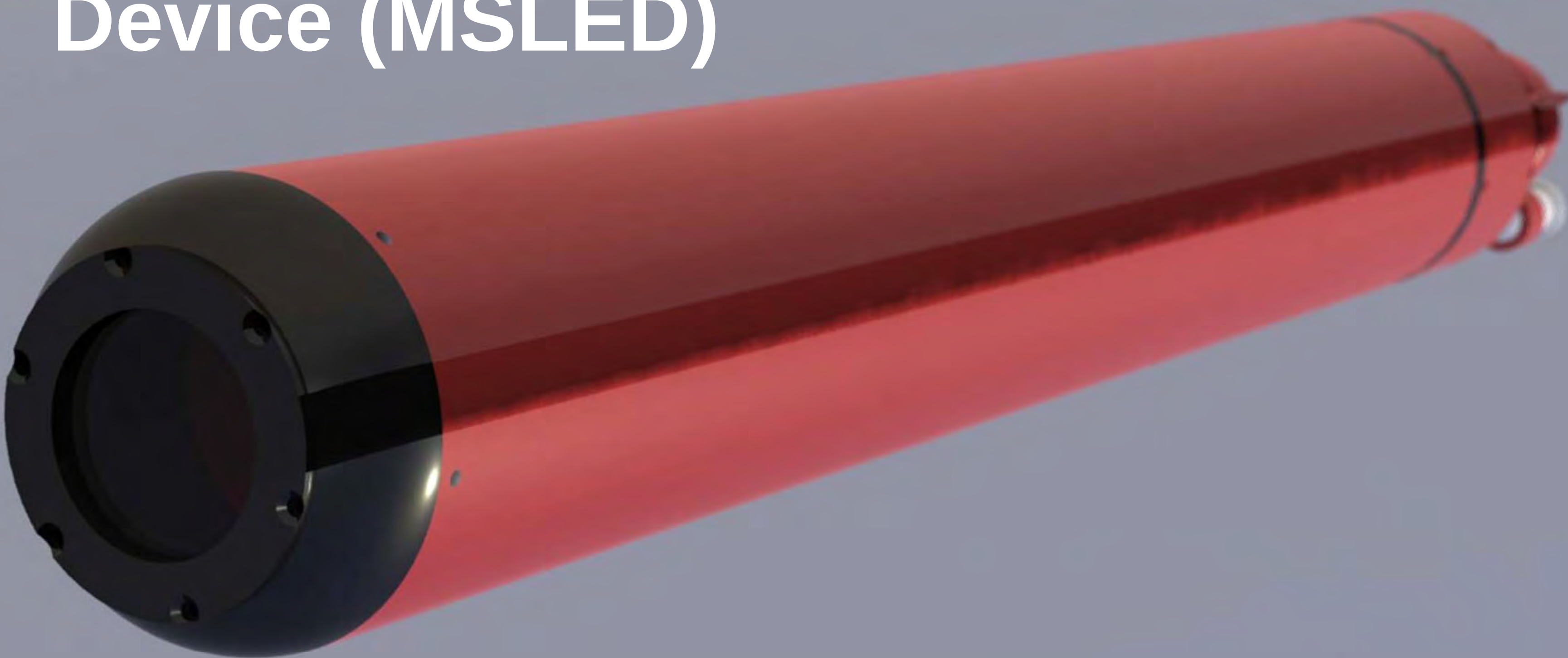
# Micro-Subglacial Lake Exploration Device (MSLED)



**Dr. Alberto Behar**
Associate Professor
Arizona State University

# Outline

- **Introduction**
  - Motivation
  - Mission Objectives
  - Comparable Vehicles
- **Micro-Subglacial Lake Exploration Device**
  - System Requirements
  - Concept & Subsystems
  - System Design
  - Implementation and Testing
- **Conclusions**
  - Current Status
  - Ways Forward
  - Field Seasons
  - Future Perspectives

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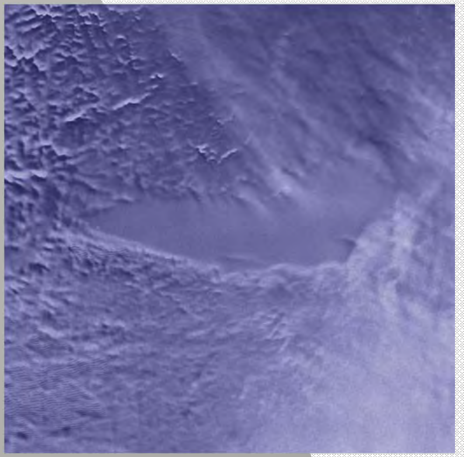
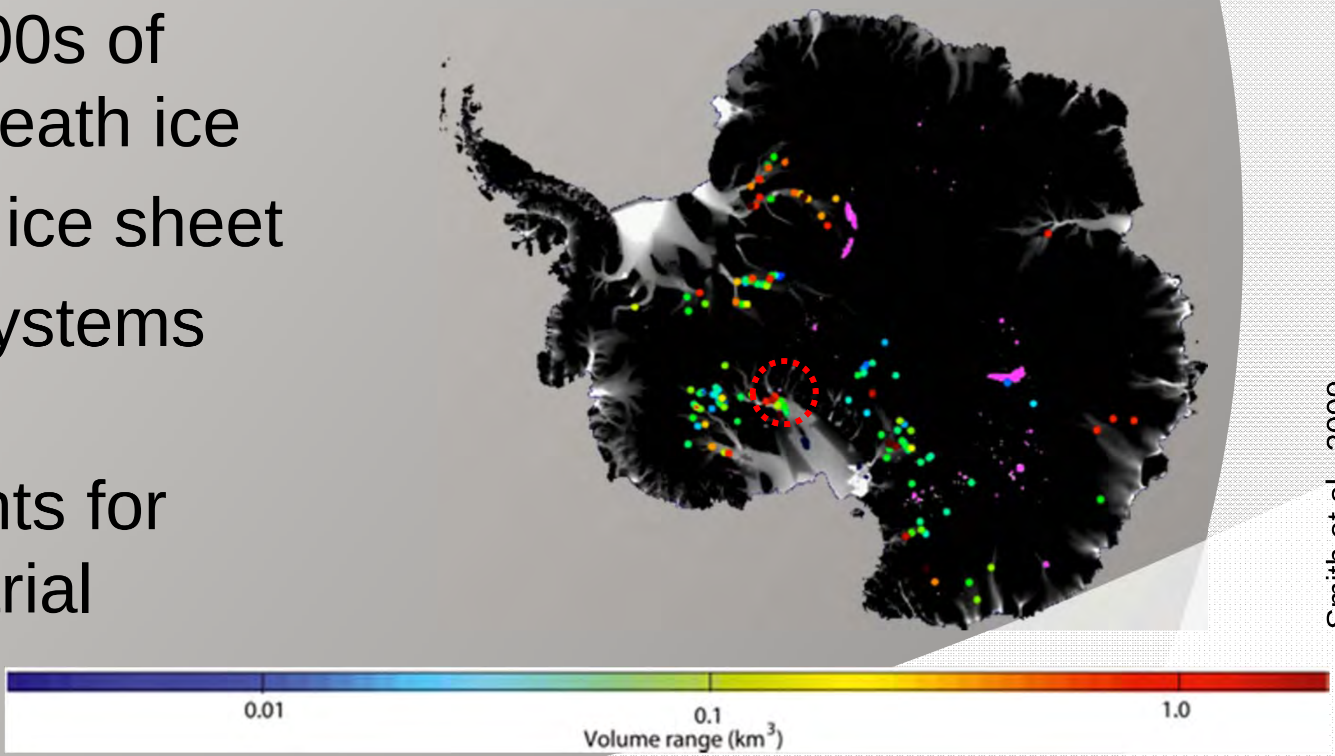
# Motivation: Polar Cryosphere

- **Polar ice:** 75 % of world‘s freshwater (IPCC, 2007)
- **Melting of West Antarctic Ice Sheet:** +5 m sea level (Mercer, 1978; Bamber, 2009)
- **Melting of polar ice:** decreased surface albedo, positive feedback

# Motivation: Antarctic Subglacial Lakes

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

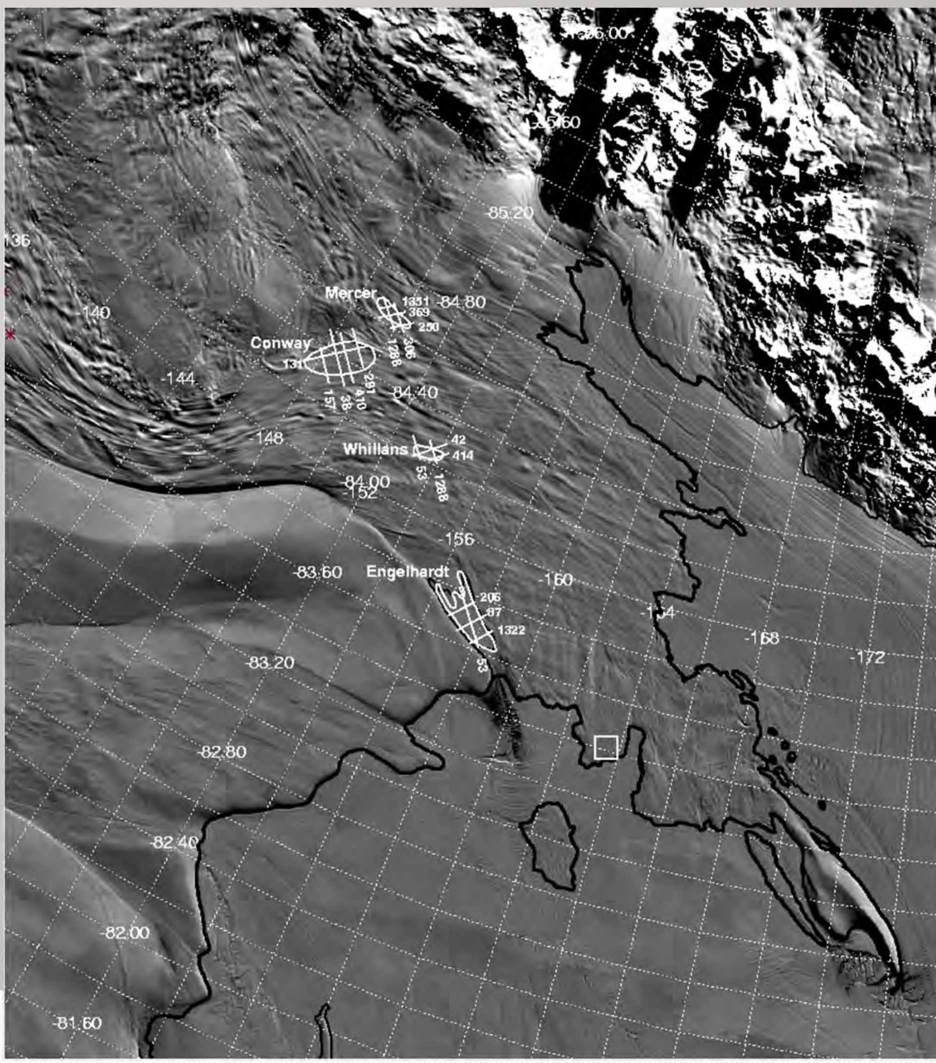


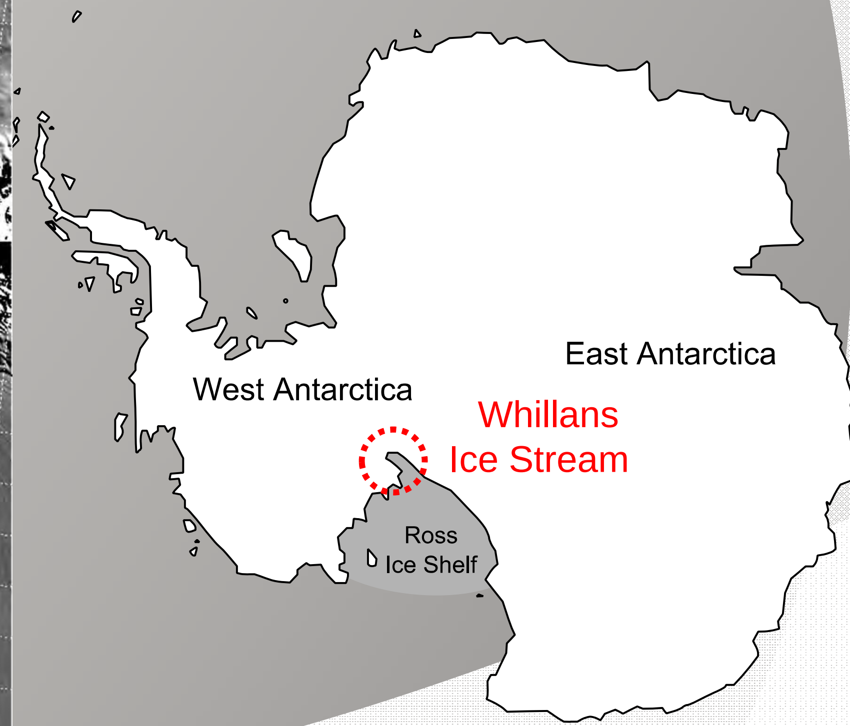



Smith et al., 2009

# Motivation: Whillans Ice Stream

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

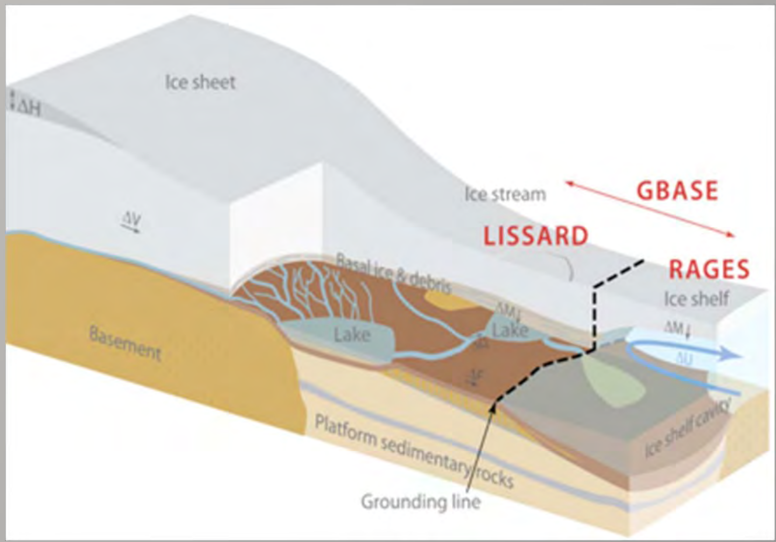


# Motivation: WISSARD Expedition

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**

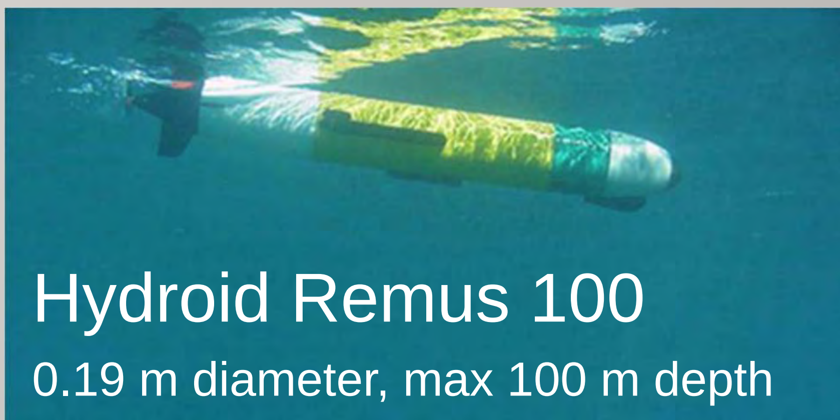


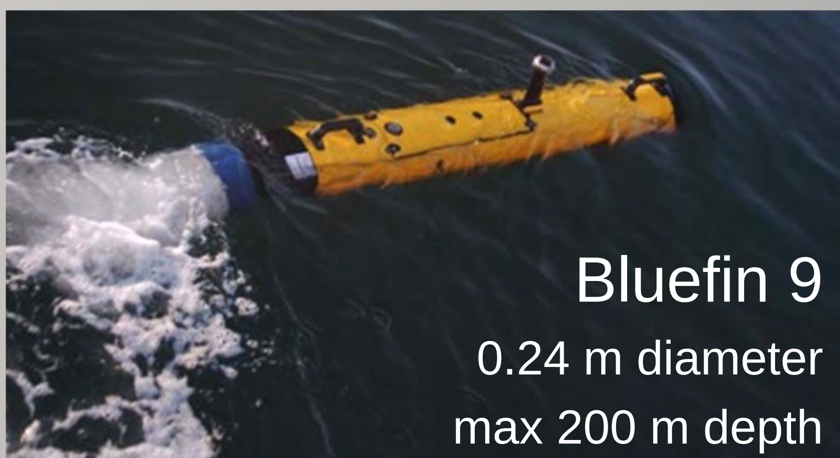
# Mission Objectives

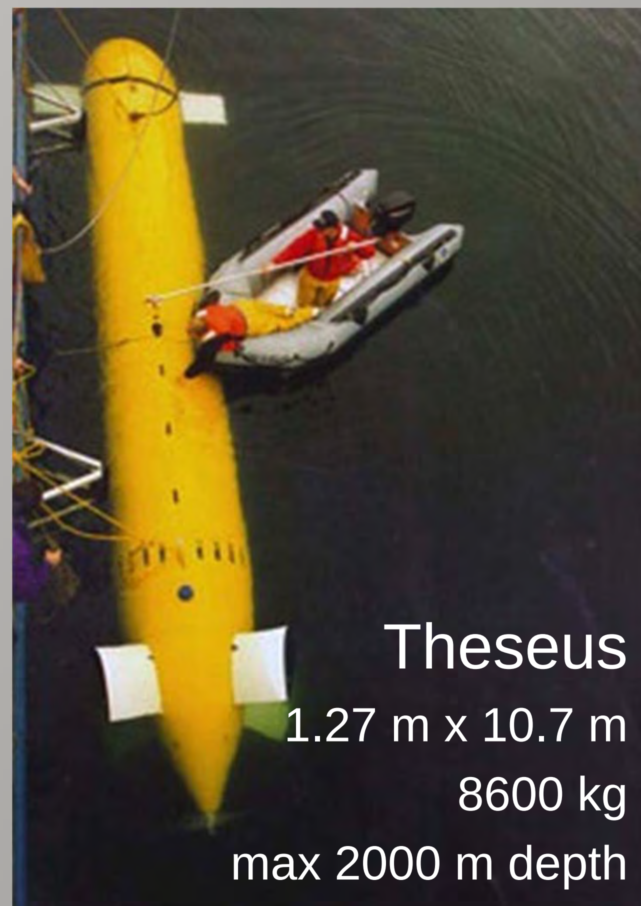
- Investigate water-ice interface
- Determine vertical and horizontal structure of water column
  - Physical: pressure and temperature
  - Chemical: salinity and pH
  - Visual inspection
- Visually investigate lake floor for geologic and sedimentary processes
- Look for biological features

# Comparable Vehicles

**Required**:
1500 m depth
max 0.08 m diameter

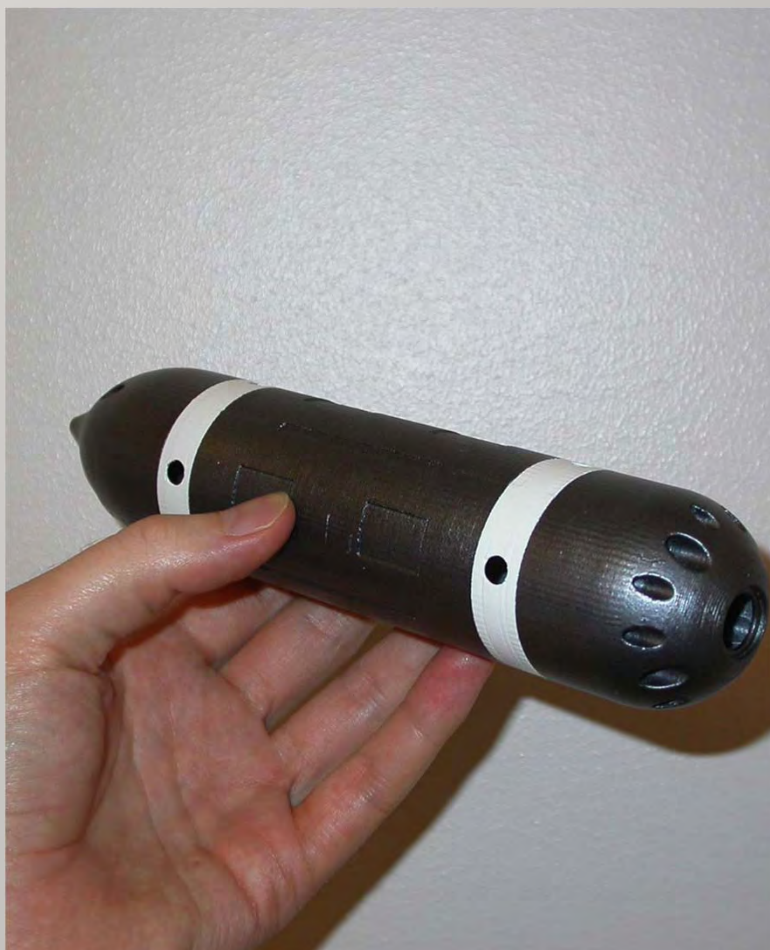


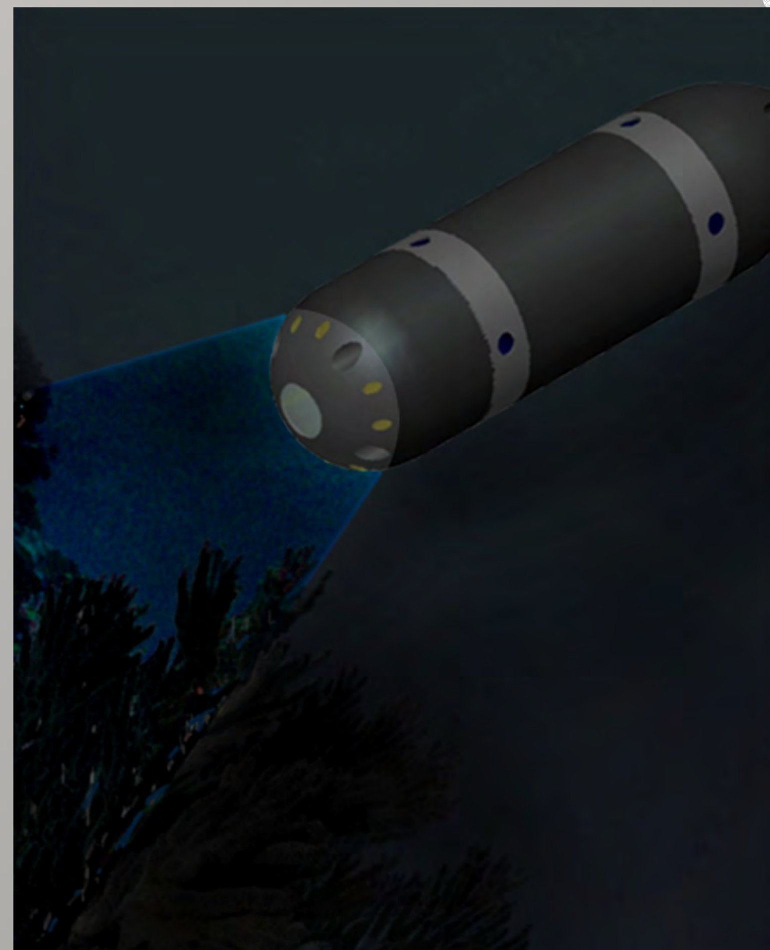




Sources: Hydroid, Inc., Bluefin Robotics, Inc., International Submarine Engineering Ltd.

# Smaller Scale – Uppsala (former student)





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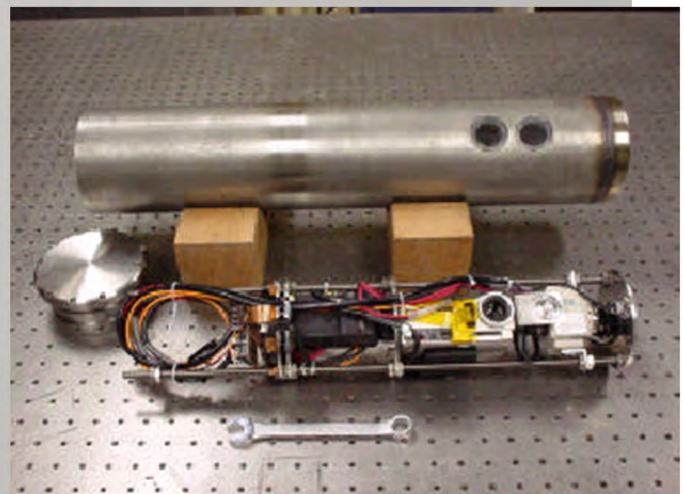
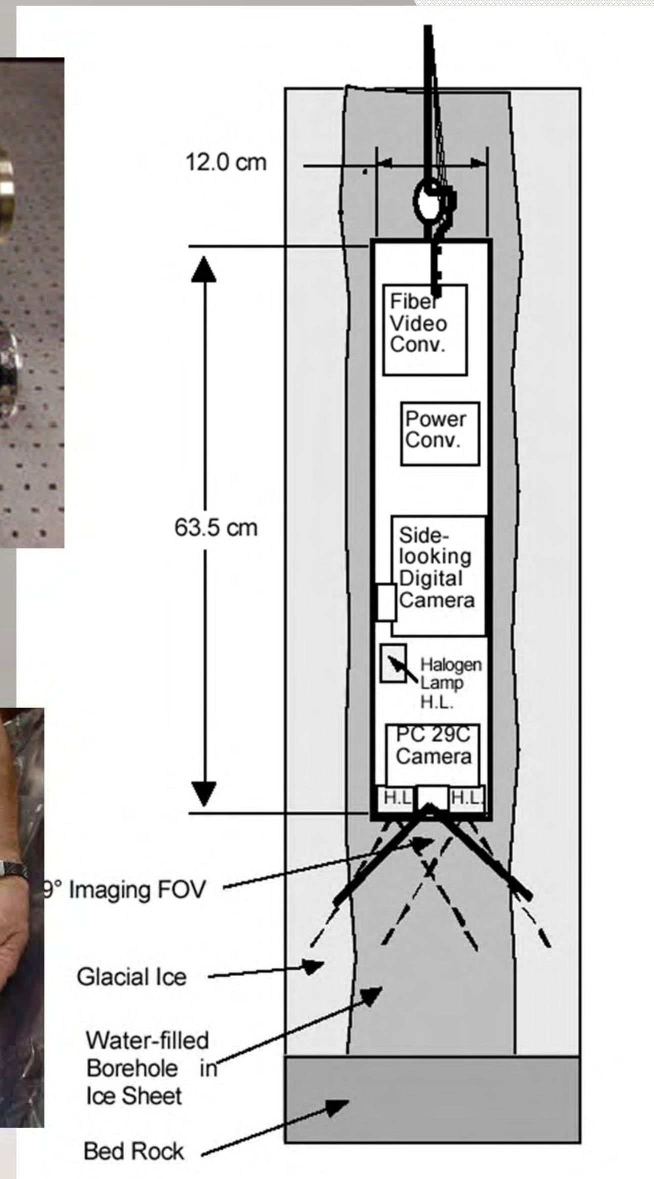
# System Requirements

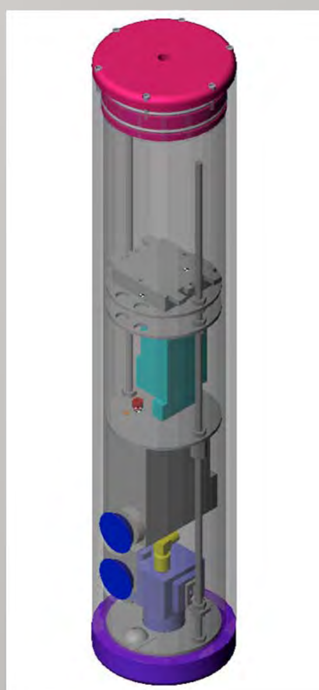
- Sensors: high resolution **video**, **temperature**, **salinity** and **pressure**
- Operational range of **1 km**
- Operating at **depth up to 1.5 km**
- Maximum **8 cm diameter** and 70 cm length
- **Remotely operated** from surface
- Localization of measurements
- Operate for minimum **2 h**
- **Two-way 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)

# 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)





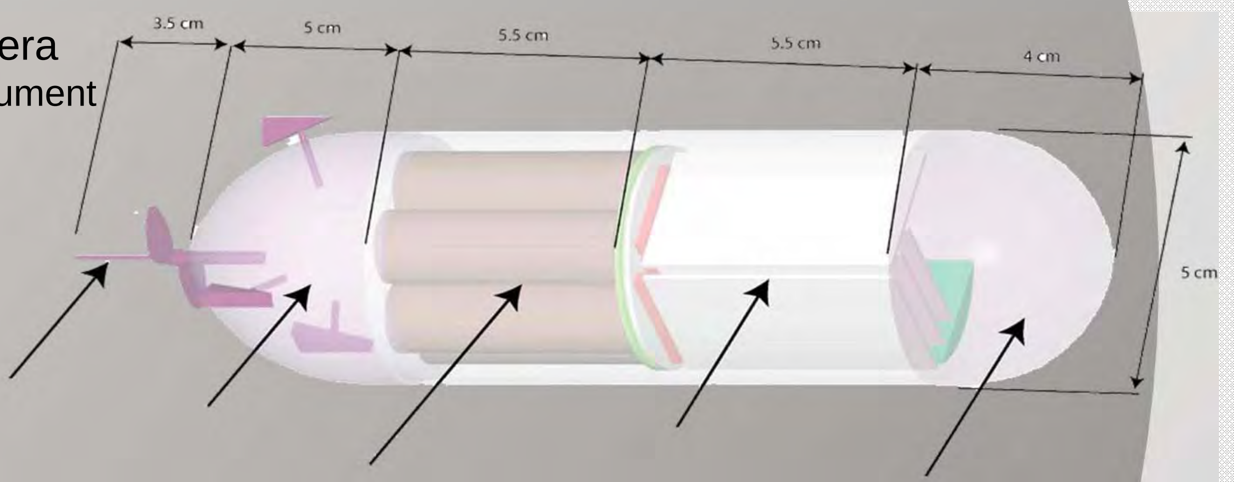



1058.23m


1057.26m
SP
REC
0:25:01

# Early Concept: Mini-Sub Explorer ‘01

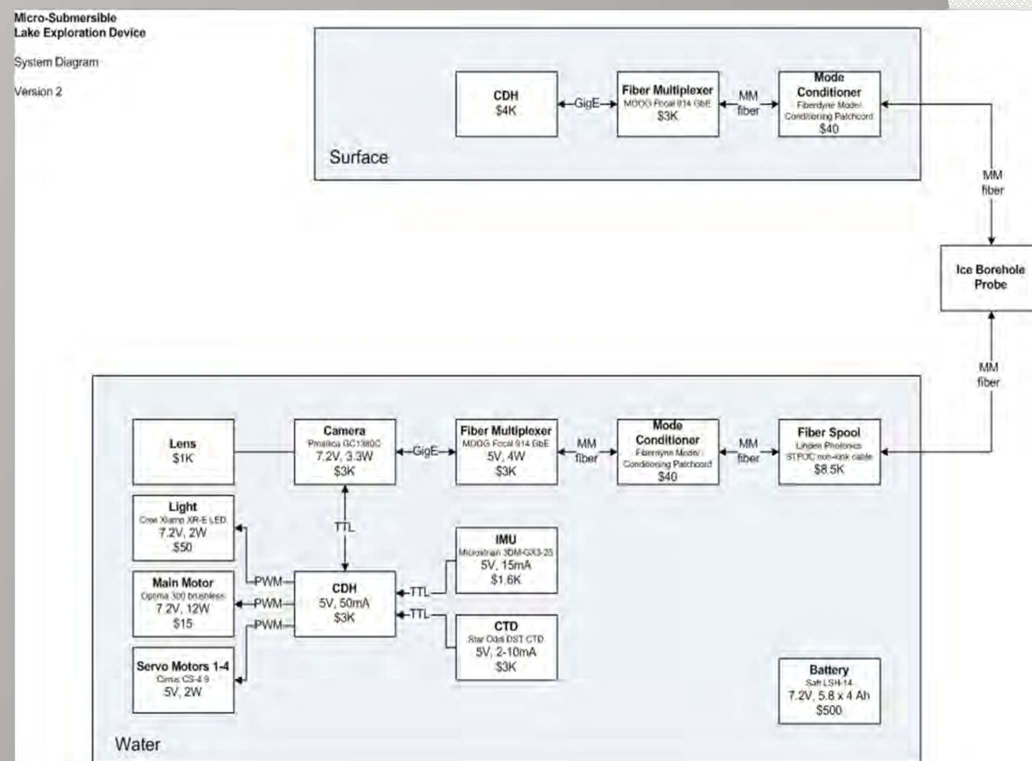
- Size: 5 cm x 20 cm
- Range: >5 km
- Instruments: CTD, Camera
  + 1 mission specific instrument



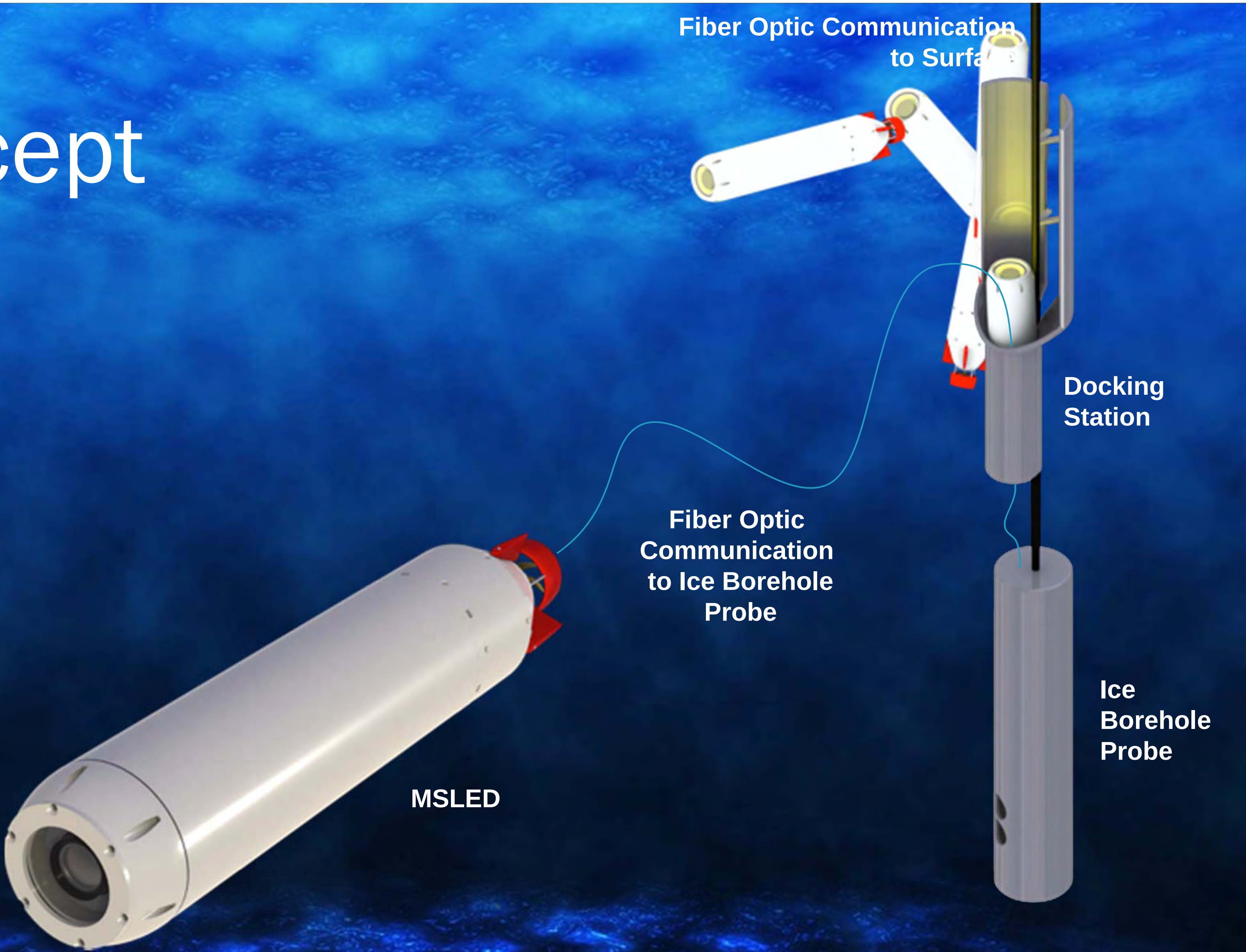

- Applications
  - Europa
  - Ice Shelves
  - Acidic Lakes
  - Alkaline Lakes
  - Sub-Glacial Lakes
  - Hydrothermal Vents
  - Submerged Volcanoes


# Concept

- 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



# Concept




Background image: Flickr, WoaH

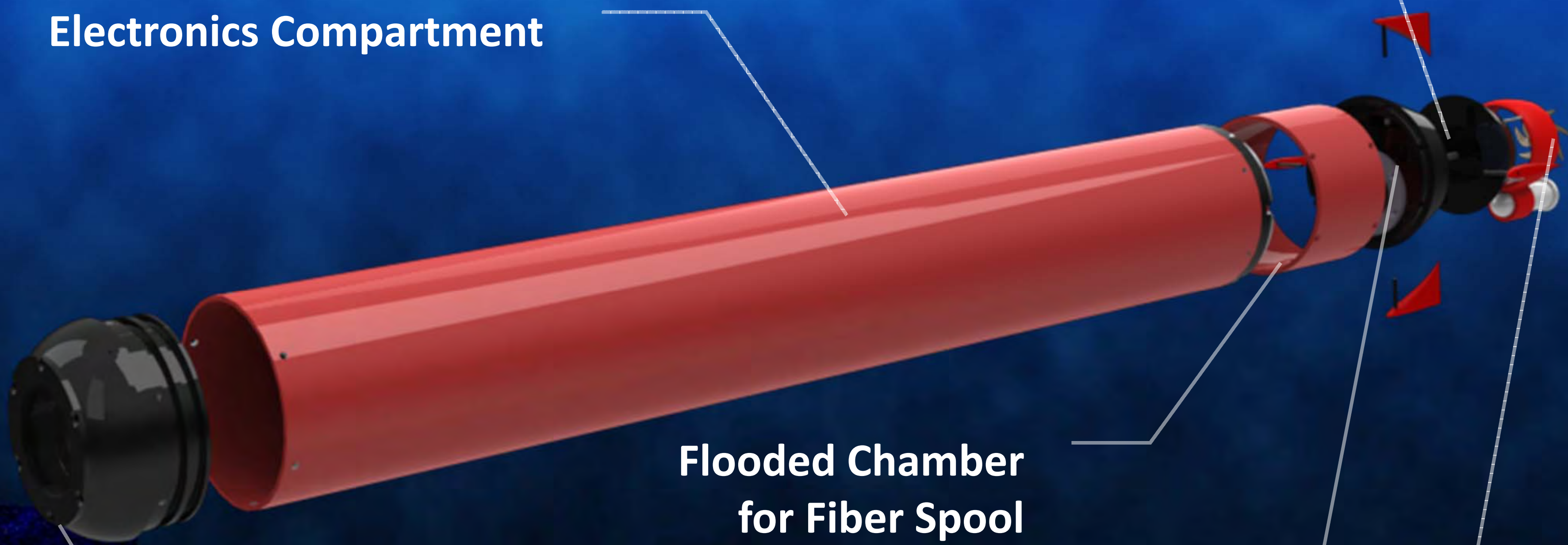
# System: Main Challenges

- 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

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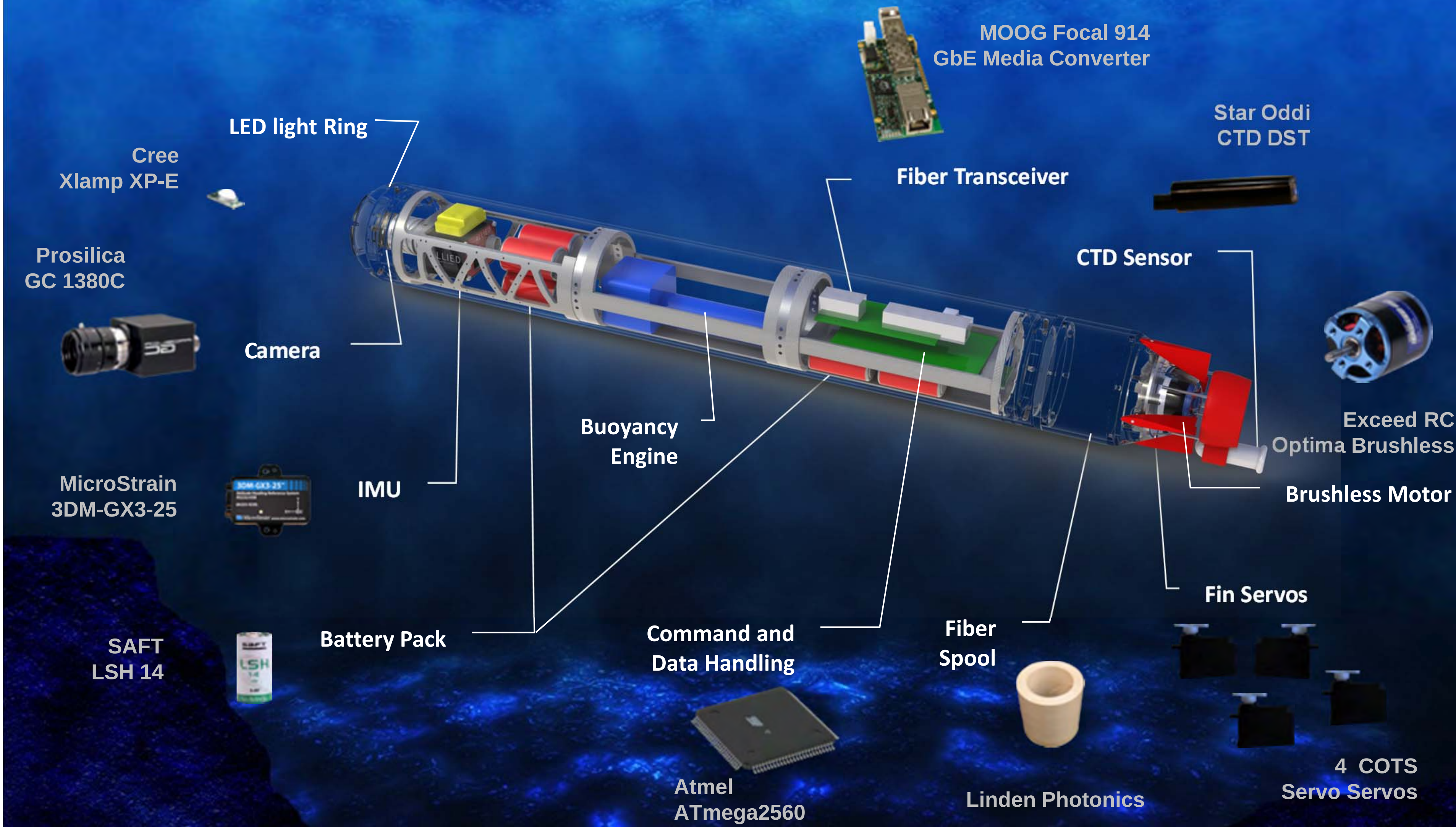
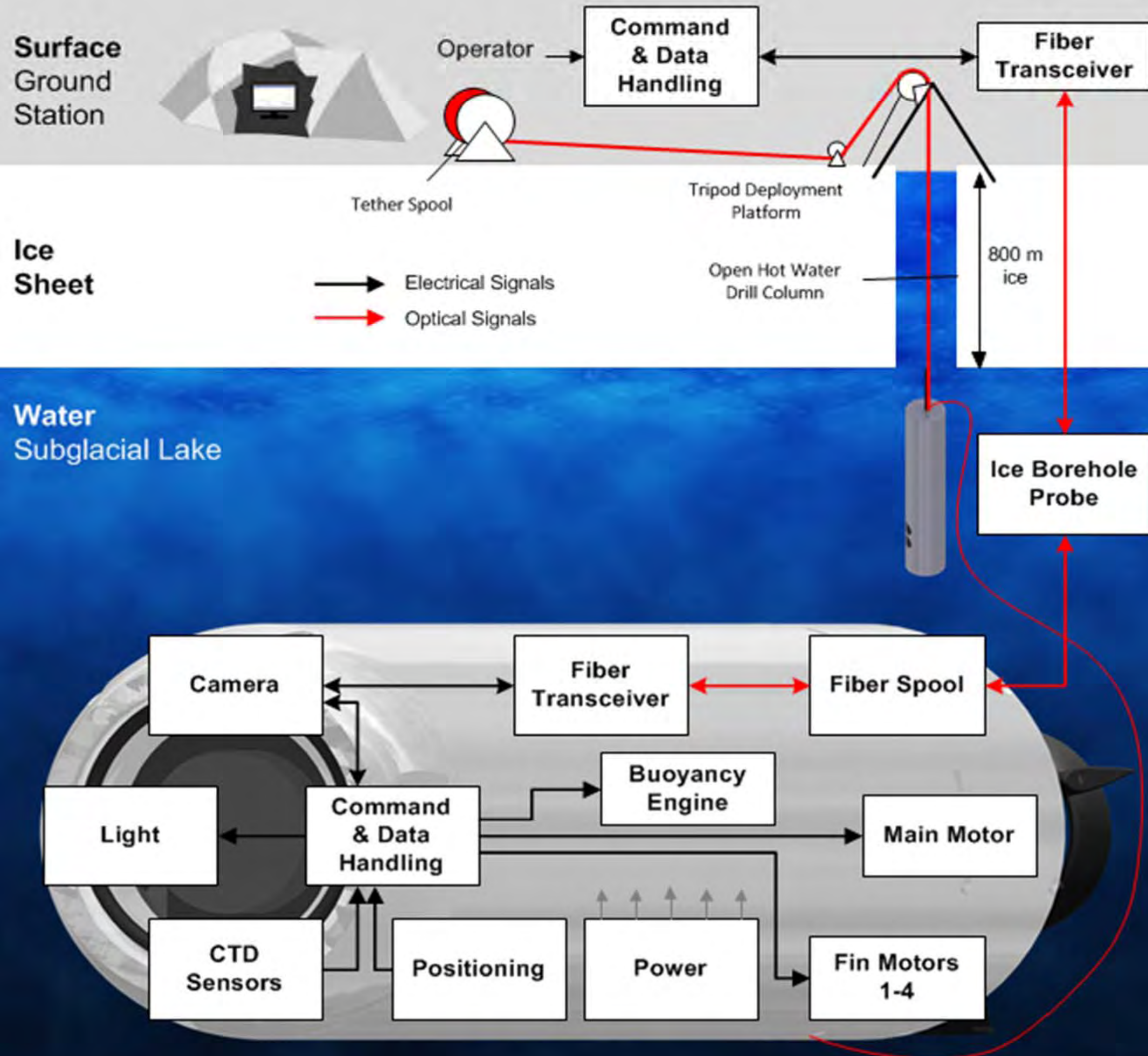
# Internal Components




Background image: Flickr, WoaH

# System Design: Communication




Background image: Flickr, WoaH

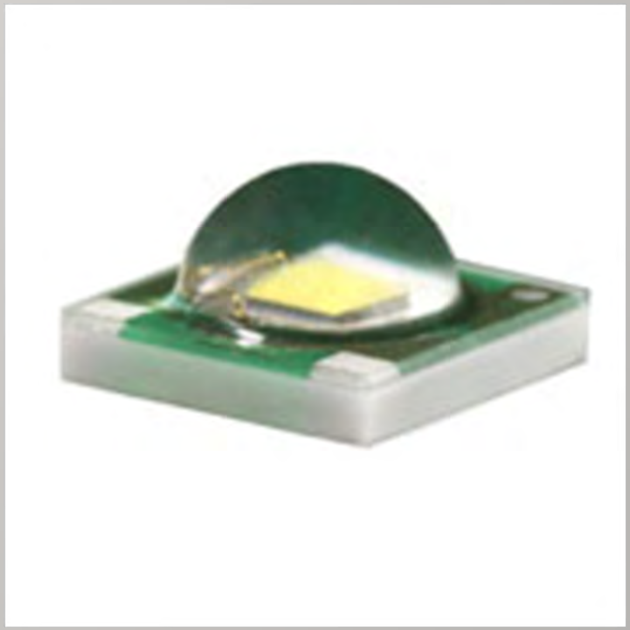
# Instrument: Camera


Allied Vision Technologies

Prosilica GC1380C:

- Large sensitive 2/3“ CCD
- 1.4 Megapixels
- Large sensor element area (6.45 µm)²
- Compact
- Lightweight (102 g)
- Gigabit Ethernet interface

# Lighting



- Front ring replaced with aluminum-backed printed circuit board.
- 6 CREE XP-E LEDs running at 500mA
- Maximum output of nearly 900 lumens
- Cool white color for water penetration

# Instrument: Salinity, Temperature, Depth

University of Aberdeen

Star Oddi DST CTD:

- Small (max. 17 x 75 mm)
- Robust (calibrated depth at least 2000 m)
- Lightweight (21 g)


# Command and Data Handling

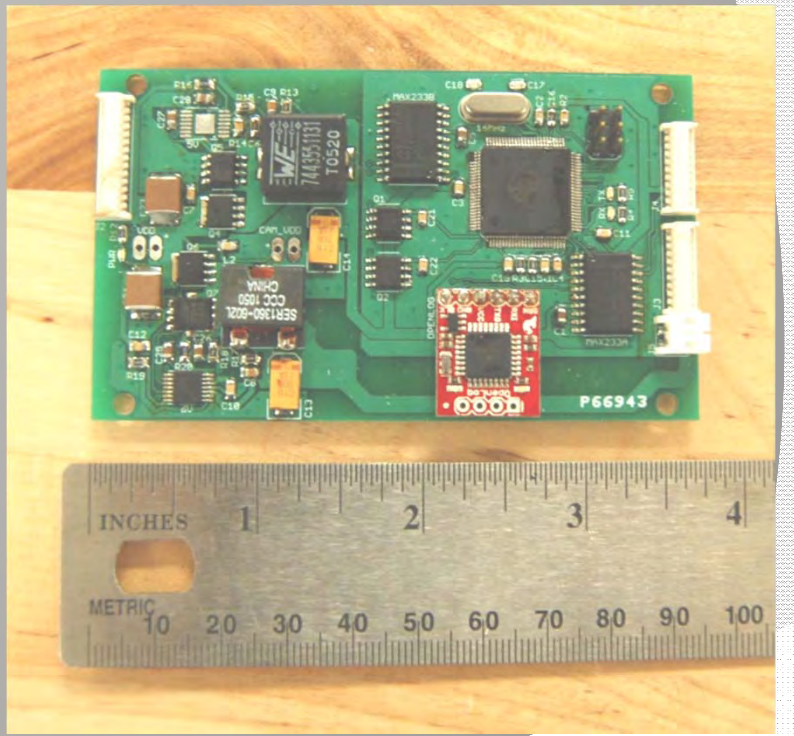

Atmel ATmega2560

- Low power (1,8 V, 0.5 mA at 1 MIPS, 0.1 µA idle)
- Up to 16 MIPS
- Inputs:
- Sensor data (CTD, IMU, power etc.)
- Ground station commands
- Outputs:
- Data for ground station
- Actuator control (lighting, steering and propulsion

Atmel, Inc.

# Implementation: Power Distribution and CDH

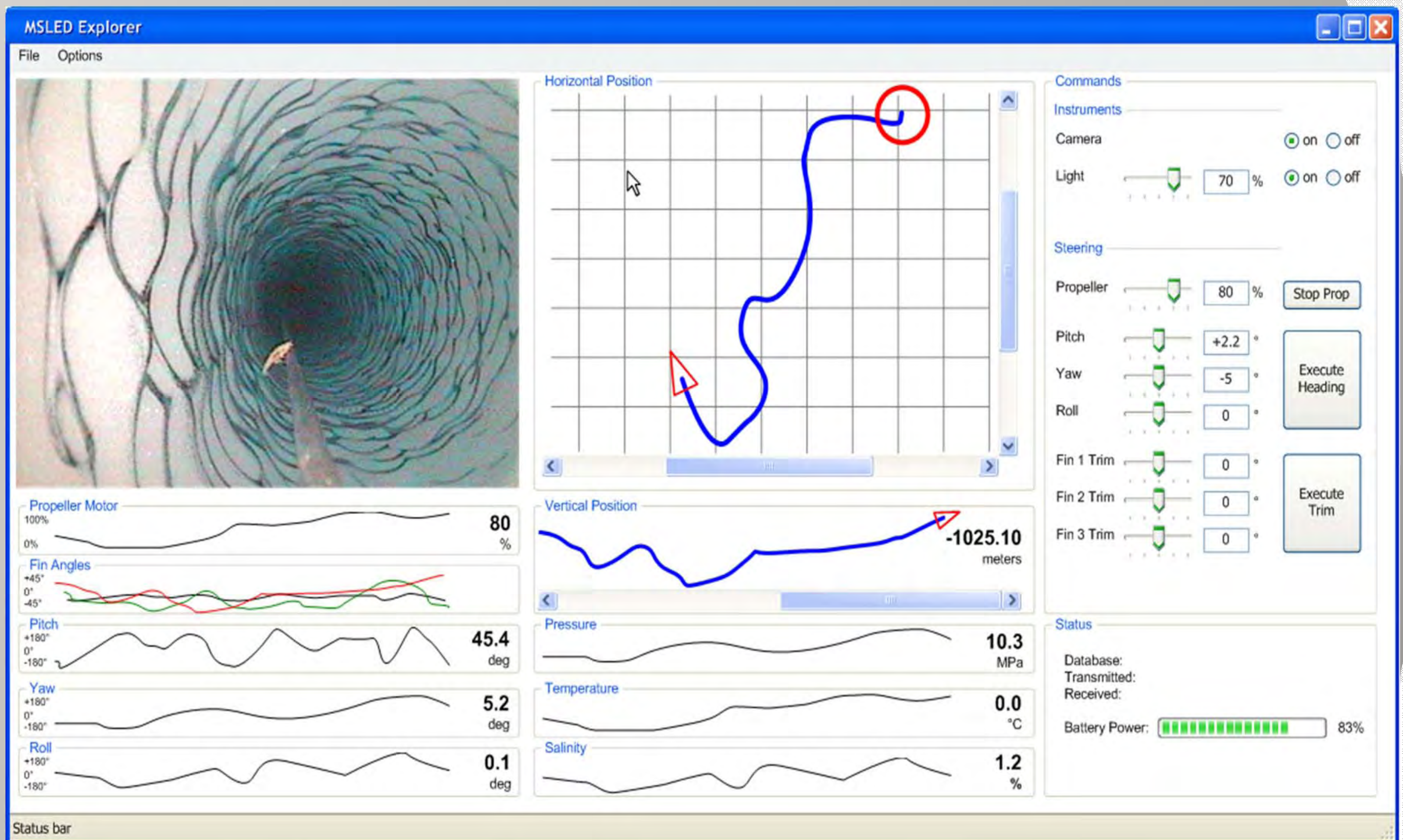
- LDO Regulators provide 5V, 6V, and 12V
- Up to 4 RS232 Transceivers
- Multiple power configurations
- On board data logging



# System Design: Localization & Positioning


- Inertial Navigation System (MicroStrain 3DM-GX3-25)
  - AHRS (pitch, yaw, roll)
- Acoustic Position System
  - Custom hydrophone array
  - provides absolute positioning and heading
- Visual Odometry

# Ground Station and Control (TBD)

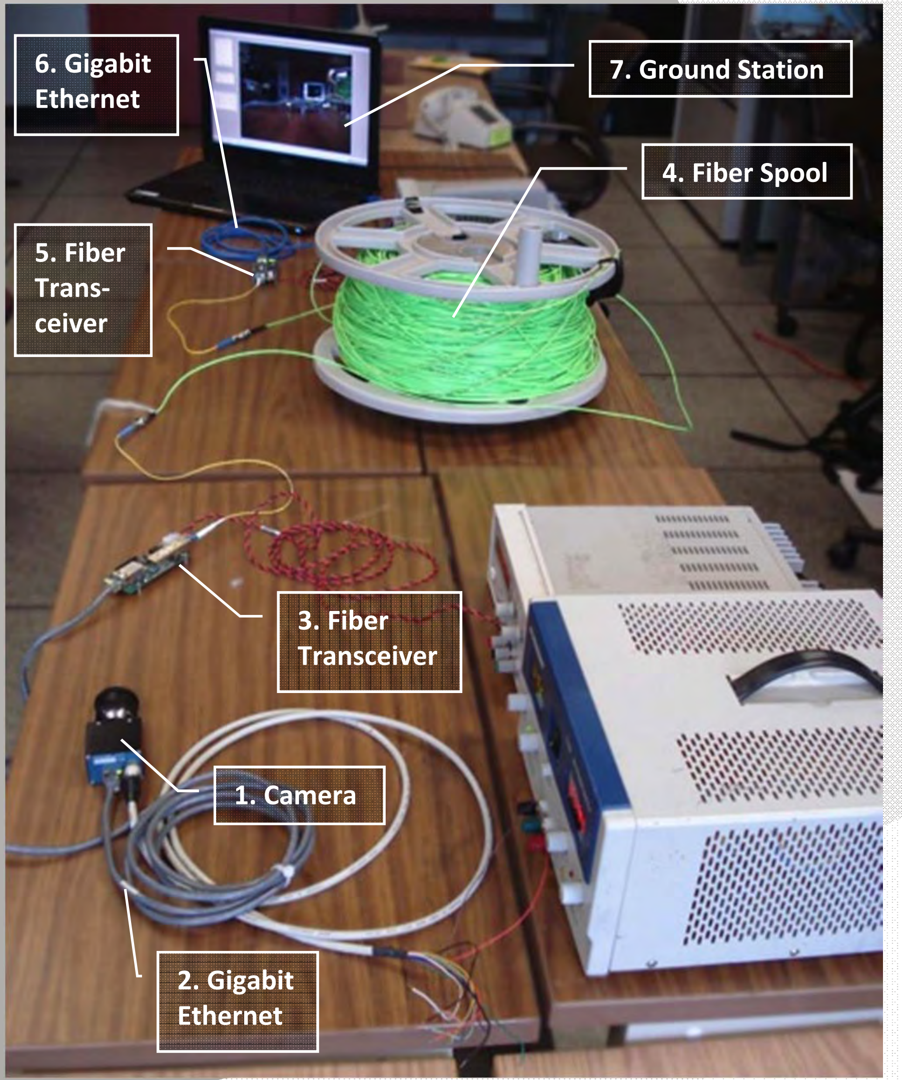


# Implementation: Pressure Hull

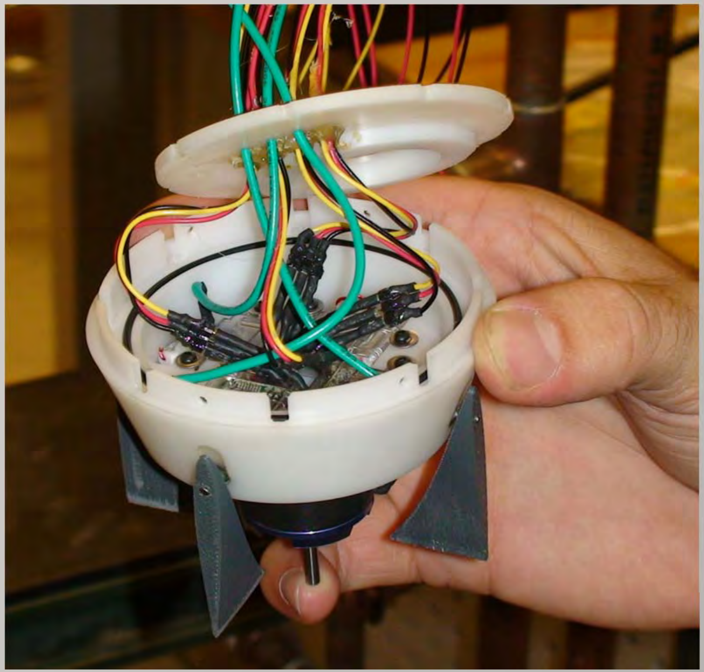
- 7075 Aluminum
- Hard anodized for chemical resistance
- 3mm wall, internal support rings
- Optimized for strength/weight

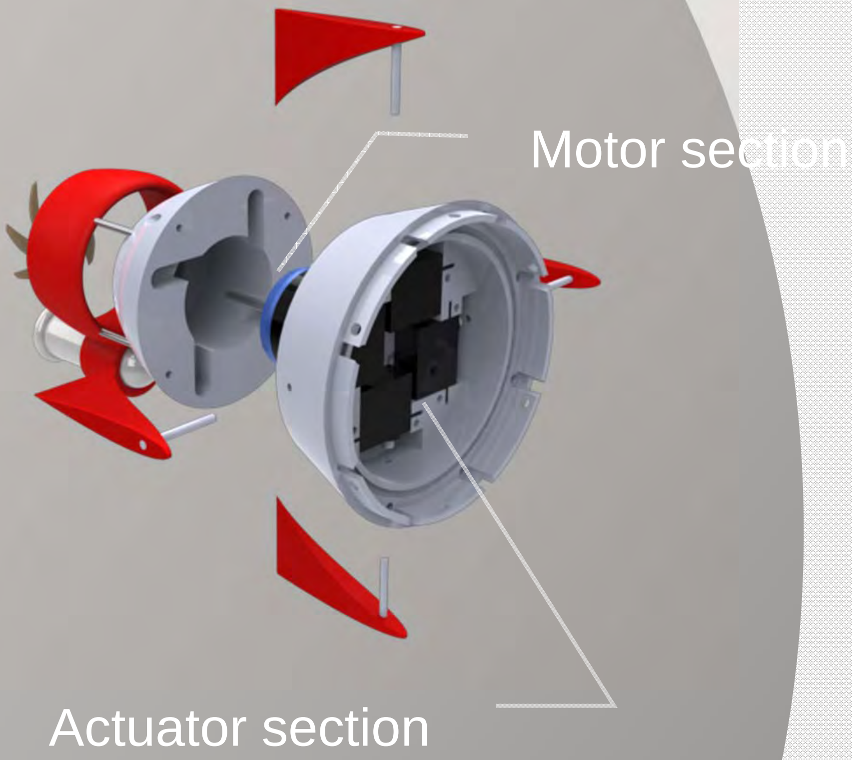
# Implementation: Media Conversion

- Camera
- Communication
  - Fiber Transceiver
  - Fiber Spool
- Command and Data Handling (CDH)



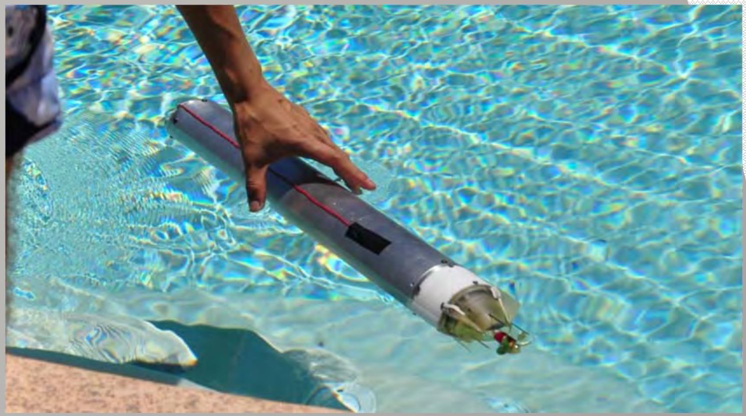
# Implementation: Propulsion and Steering






- Integrated Propulsion and steering unit
- Liquid compensation

# Pool Testing



- Initial pool test
  - Tail section leakage
  - top speed ~1 m/s
- Second pool test
  - New tail section – no leakage
  - control over fiber optic
  - Leak in rear test bulkhead
- Lesson: Sealing is difficult

# Pool Test Video

# Pressure Testing

- MBARI Pressure Tests
- 1km – tested well for 5 minutes
- 1.2 km
  - Sapphire window total failure after 1 hr (3mm thick)
- New Sapphire window (6mm thick) – passed!

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# Current Status

- Initial prototypes developed and fabricated
- Structural testing and verification
- Developing end-to-end system

# Ways Forward

- Iterative testing
  - Battery life
  - Temperature
- Optimization
  - Computational Fluid Dynamics
  - Finite Element Analysis
- Extensive in-water testing at analogue sites
- Field season in West Antarctica

# Field Seasons

- 2011 – Field Test Deployment
  - McMurdo Station (November-December)
- 2012 – RAGES/Pine Island Glacier
- 2013/2014 –Field Deployment
  - WISSARD/LISSARD – Whillans Ice Stream Antarctica

# Future Perspectives

- Semi-autonomy
- Full autonomy, autonomous underwater vehicle (AUV)

# Acknowledgements


- Slawek Tulaczyk, University of California Santa Cruz
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- Chris German, Woods Hole Oceanographic Institute
- Hans Thomas, Monterey Bay Aquarium Research Institute

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# 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