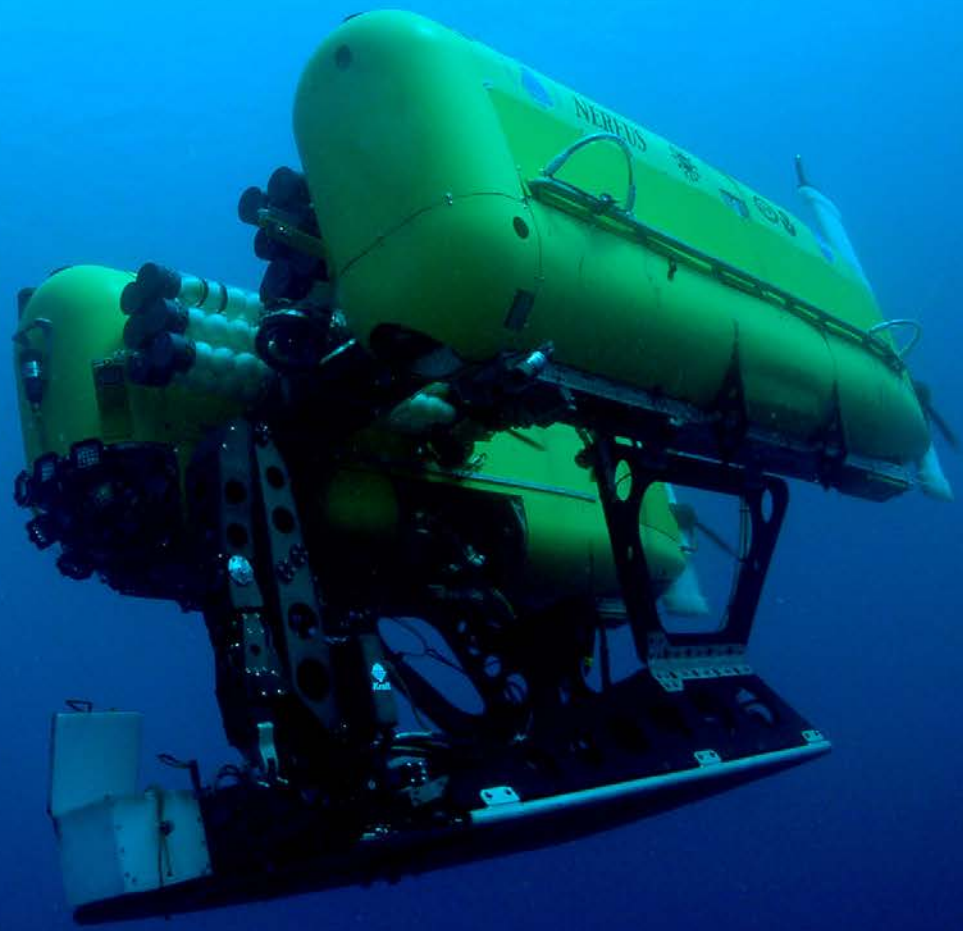
Nereus

Several Cruises either funded or Proposed:

- Shank
- German
- Wheat
- Fryer

Testing real-time control via Optical Modem this Fall



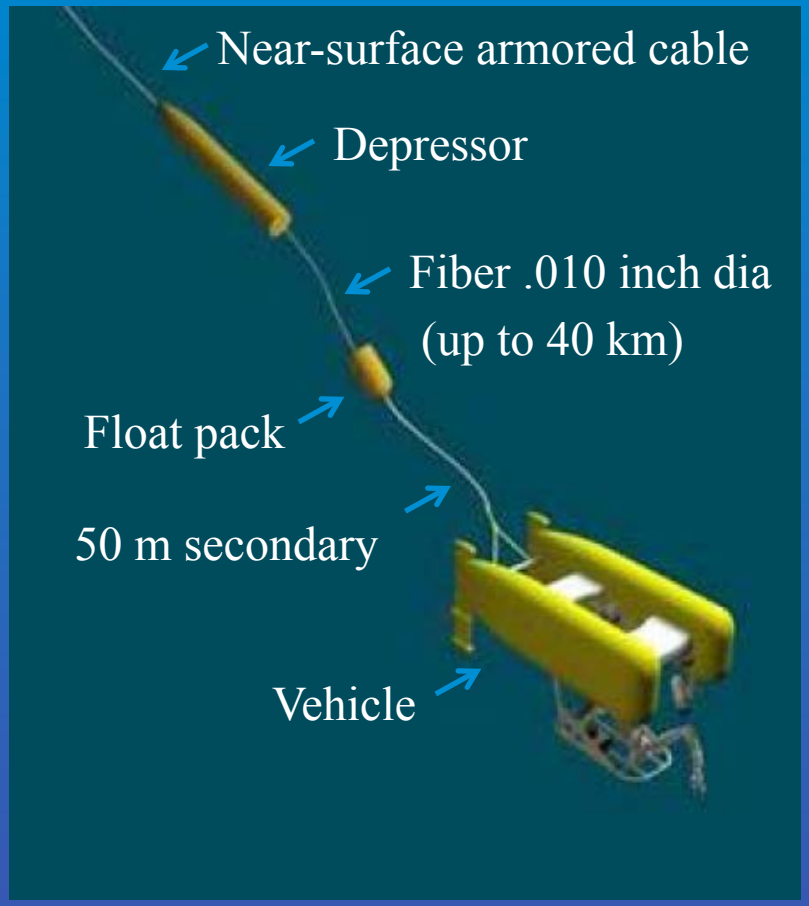
Nereid UI:
Under Ice Light-Tethered ROV

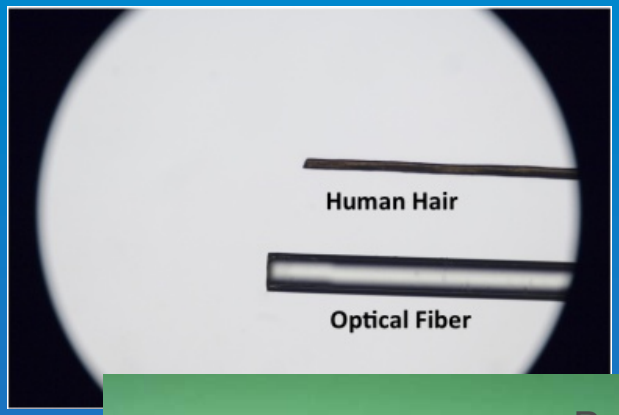
Andrew Bowen[1], Dana R. Yoerger[1], Christopher German[2], James C. Kinsey[1], Louis L. Whitcomb[1, 3], Larry Mayer[1,4]

[1]Department of Applied Ocean Physics and Engineering
[2]Department of Geology and Geophysics
Woods Hole Oceanographic Institution
[3]Laboratory for Computational Sensing and Robotics
Johns Hopkins University
[4]Center for Coastal and Ocean Mapping
University of New Hampshire

Photo courtesy S. McPhail, NOC

Antecedent Tech: Nereus 11 km HROV





Micro-Fiber Tether System

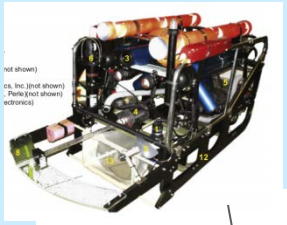
WOODS HOLE OCEANOGRAPHIC INSTITUTION
1930

The Under-Ice Scientific Imperative

- Near-Ice Inspection and Mapping
- Boundary Layer Investigations
- Grounding Line Inspection
- Sediment Sampling
- Ice Shelf Cavity Physical Oceanographic Mapping
- Instrument Emplacement*

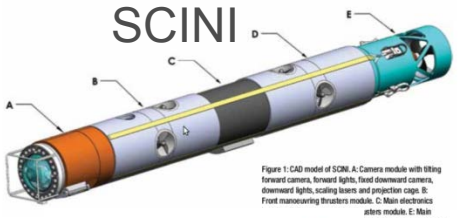
WOODS HOLE OCEANOGRAPHIC INSTITUTION
1930

Conventional ROVs



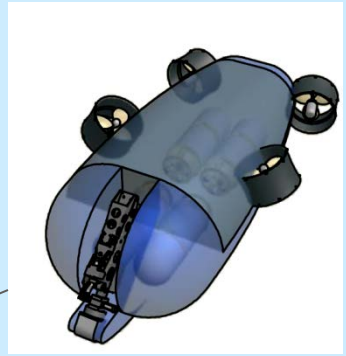
SIR*

SCINI



MSLED*

Nereid UI*

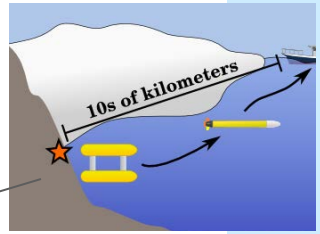


Capability

Manipulation

Inspection

Mapping/Survey



Multi-Node AUV Systems*

Autosub

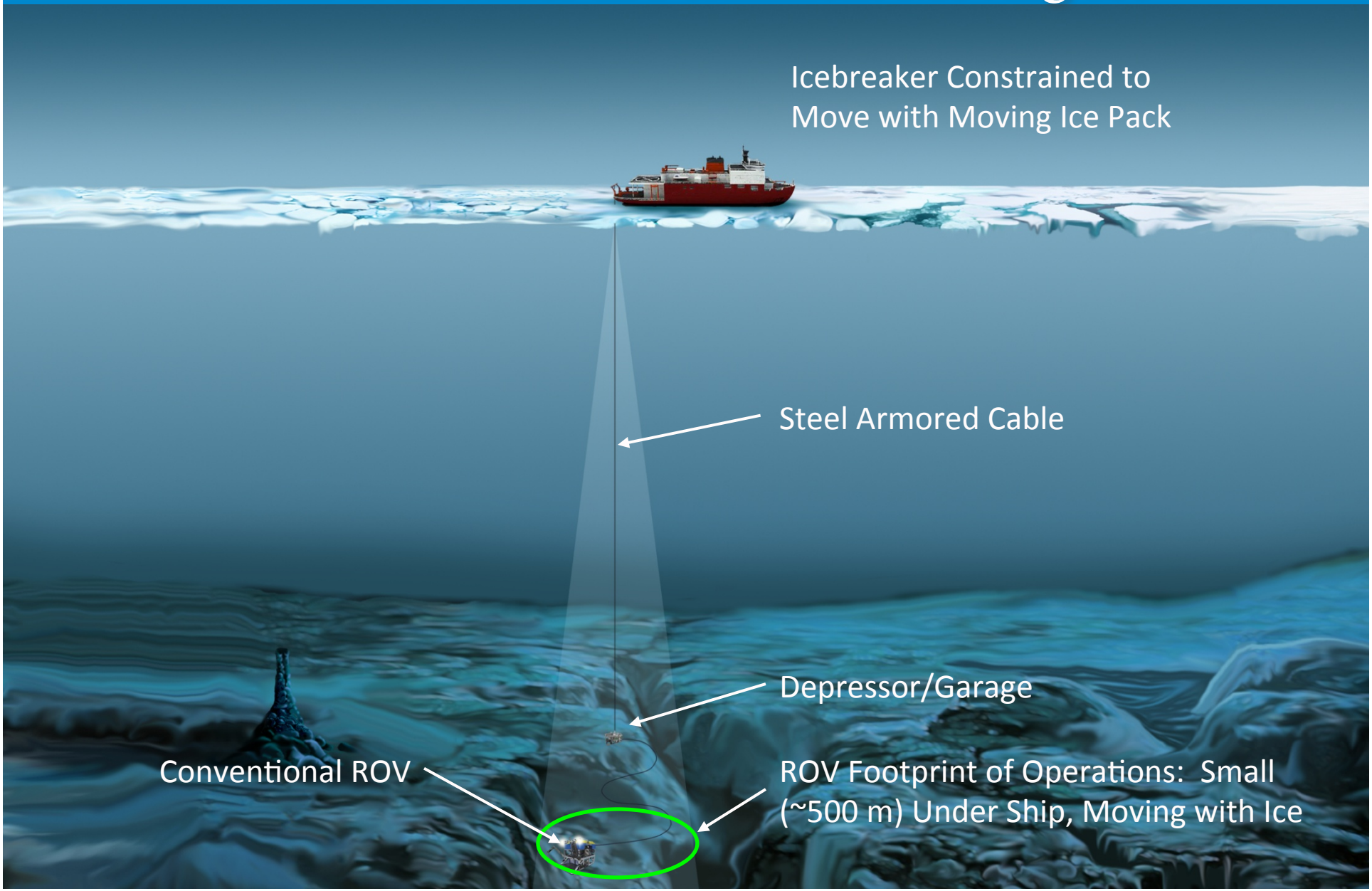
Gliders

100 m 1 km 10 km 100 km

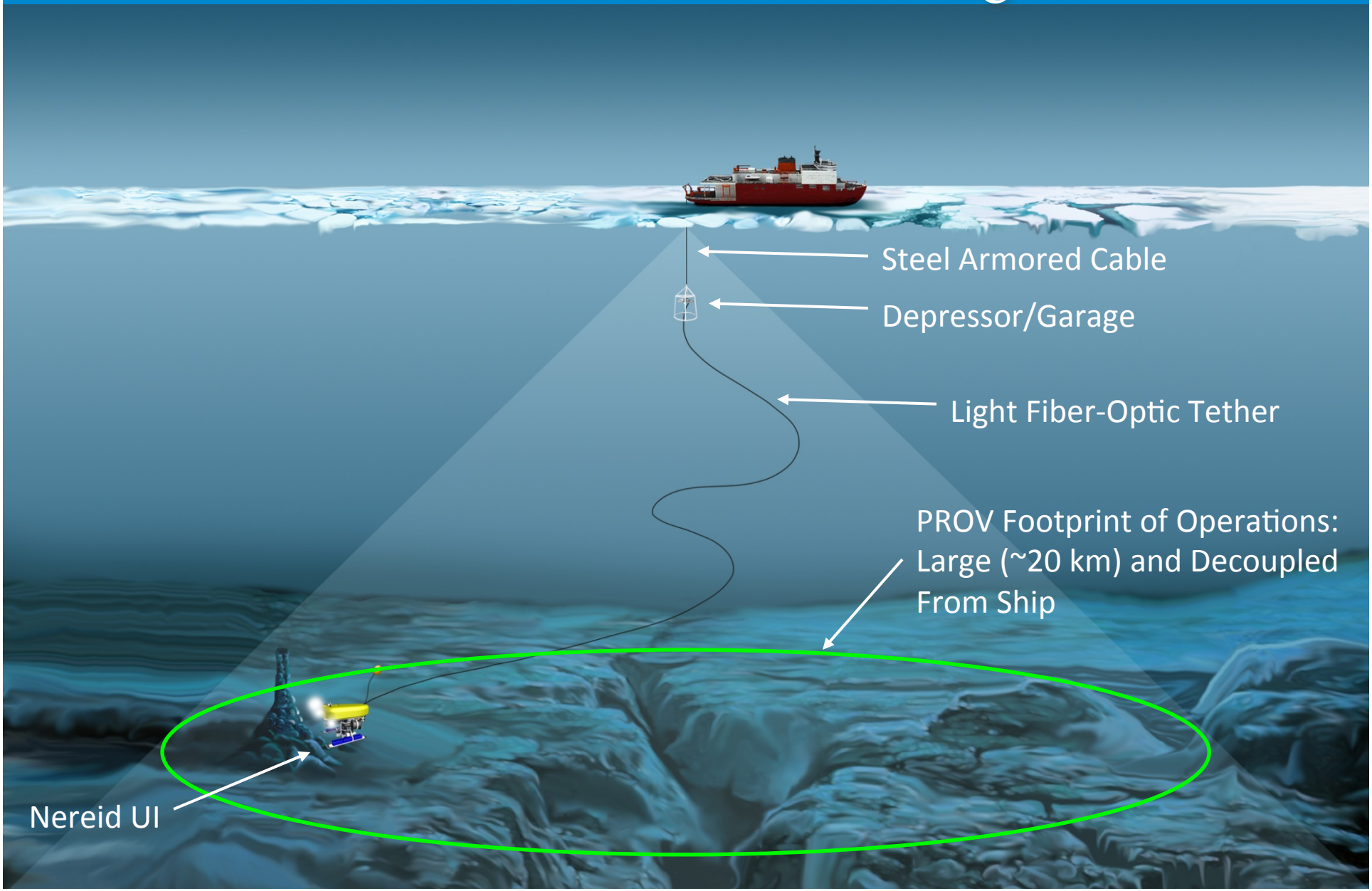
Range

*Under development

Problem: Conventionally Tethered ROV Operations from Icebreaker in Permanent Moving Ice



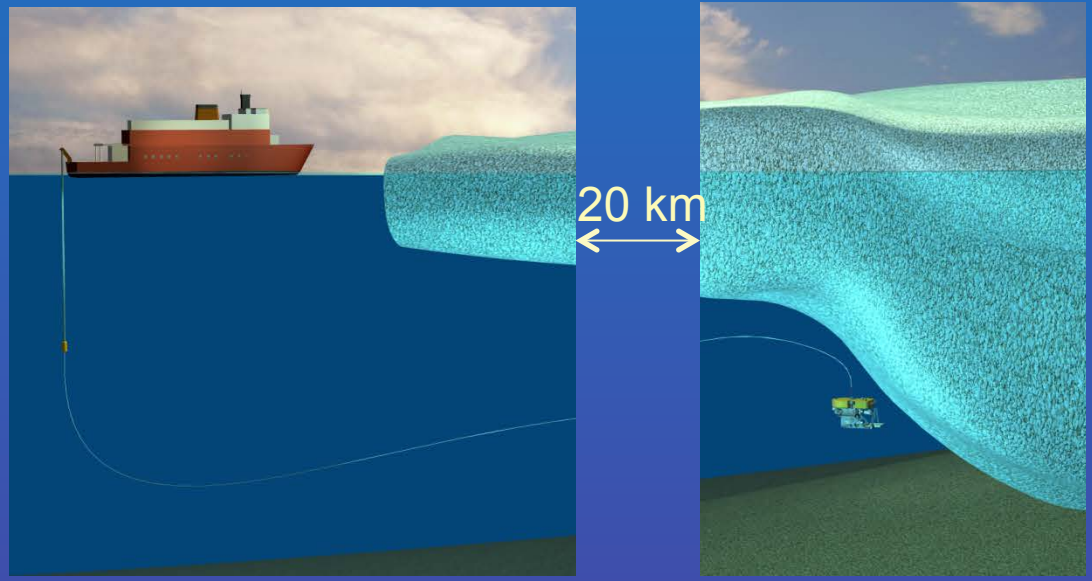
Solution: Light-Tethered Nereid Operations from Icebreaker In Permanent Moving Ice



PROV Concept of Operations

Mission:

- Penetrate under **fixed ice** up to 20 km as a tethered vehicle while supporting sensing and sampling in close proximity to the under-ice surface
- Return safely to the ship



Notional Concept of Operations:

- Install acoustic Nav/Comms as required near ice-edge
- Deploy from vessel at ice edge as tethered system
- Transit to ice-edge and begin survey activities under-ice to the maximum range of the tether.
- Complete mission and return to the vessel as an AUV and recover onboard in open water

WOODS HOLE OCEANOGRAPHIC INSTITUTION 1930

Nereid UI Capabilities

- Exploration
  - Real time visualization
  - Immediate Re-tasking
  - 20 km standoff
- Maneuverability
  - Close inspection
  - Precision access to under-ice boundary layer
- Future manipulation and sample retrieval capability

Design Parameters

- Bathymetry -> Depth rating
- Ice Draft -> Maneuverability/Sensing
- Water column structure -> Need for, and capacity of VBS
- Circulation and Tides -> Minimum speed
- Sea-Ice and Sea State -> LaRS complexity
- Phenomena -> Special design considerations
- State of Knowledge -> Conservatism in design
- Logistics -> Special design considerations, field-planning

- Regions Studied:
  Antarctic Ice Shelves
  Greenland Glaciers
- Assumptions:
  Ship-based, open-water launch/recovery, sub-type for through-ice deployment

Design Constraints: Antarctica

- Bathymetry -> Depth rating: 2000 m
- Ice Draft -> Maneuverability/Sensing: mission-driven/??
- Water column structure -> Need for, and capacity of VBS: mission-driven, potential for creative solutions
- Circulation and Tides -> Minimum speed: 0.5 m/s
- Sea-Ice and Sea State -> LaRS complexity: simple, AUV-like
- Phenomena -> Special design considerations: minimize entrained volume, thermally couple as much as possible, detect ?, pre-launch washdown
- State of Knowledge -> Conservatism in design: reliability-driven
- Logistics -> Special design considerations: What can be learned from small, proxy vehicles?

Supercooled Water and Frazil Ice

- Formed in supercooled water, 0.01-0.03 C below freezing: polynyas, water-layer interfaces, glacial interfaces, brinicles

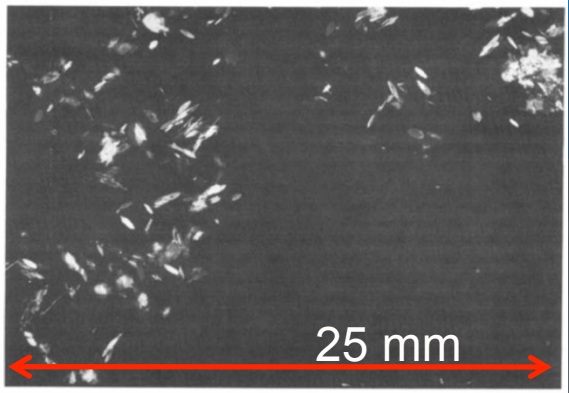
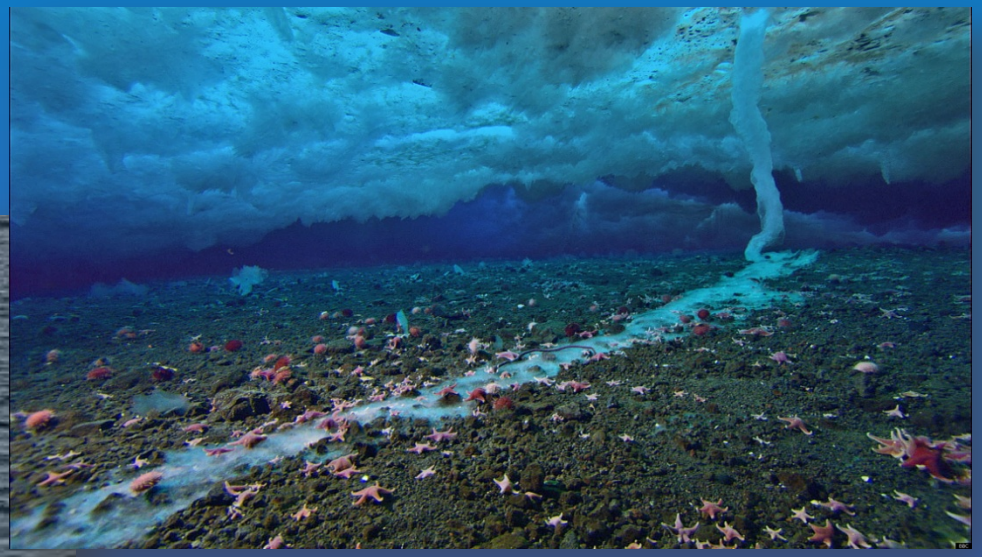
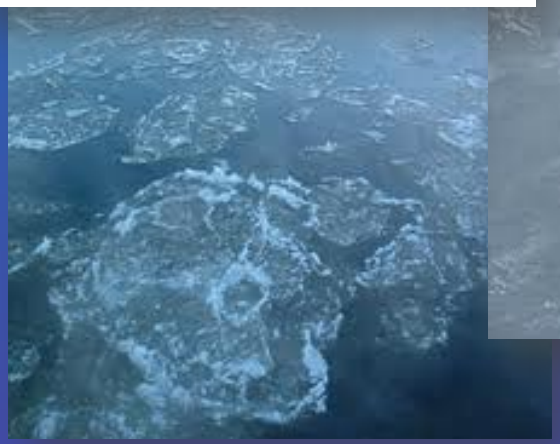


Figure 1 Photograph through crossed polaroids of a suspended solution of frazil-ice crystals; the photograph covers 25 mm in the vertical (from Martin & Kauffman 1981).

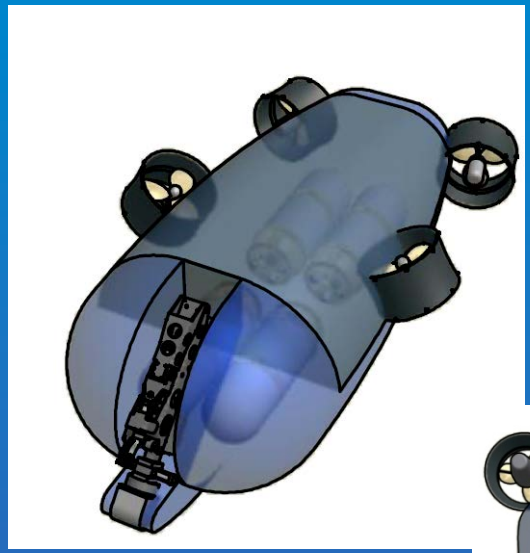




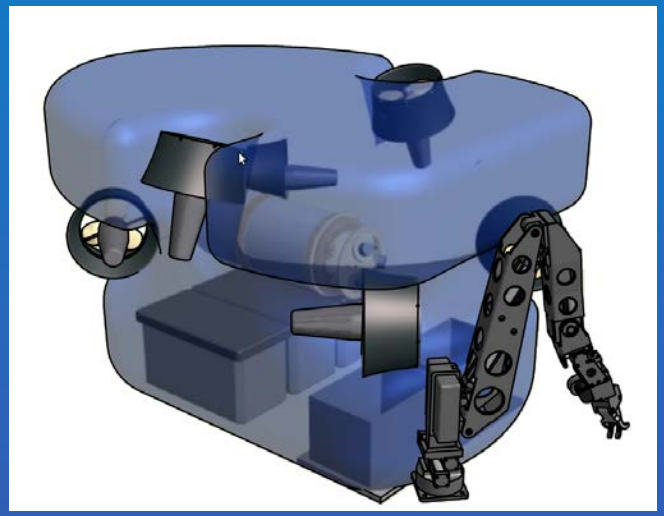
http://www.bbc.co.uk/nature/15835017

WOODS HOLE OCEANOGRAPHIC INSTITUTION
1930

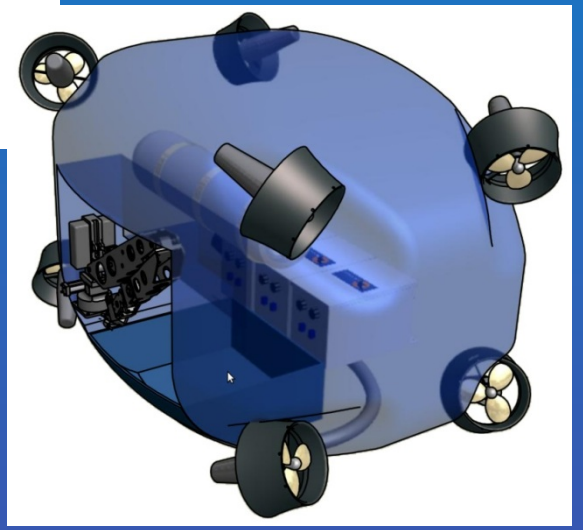
Concepts



Flatfish



Conventional



Crab

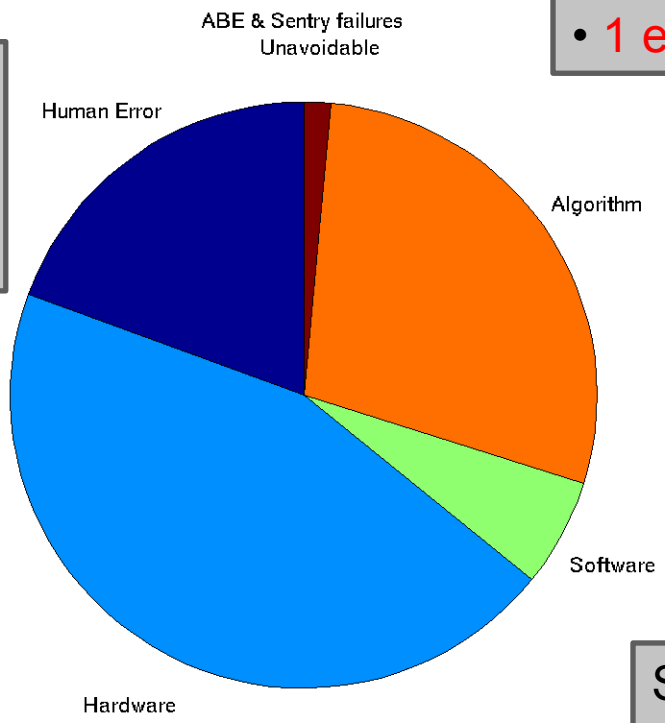
WOODS HOLE OCEANOGRAPHIC INSTITUTION
1930

Specifications	Range	20 km horizontal excursion
	Air Weight	1800 kg
	Depth Rating	1000 m
	Battery	16 kWhr lithium-ion
Navigation	Inertial	Phins INS
	Acoustic	LF 1000 m range up/down altimetry; up/down ADCP/DVL; LF (3.5 kHz) homing; imaging sonar for obstacle avoidance
Communication	Tether	Fiber-optic Gb Ethernet, 20 km
	Acoustic	LF (3 kHz) 20-300 bps for ship to vehicle; HF (10-30 kHz) 300 bps for vehicle to sensor; vehicle to vehicle
Imaging	Acoustic	Reson 725 multibeam or Mesotech 675 profiling (upward-looking)
	Optical	Real-time color HD video; high resolution digital camera; LED lighting
Chemical/Physical Sensors		Seabird CTD; pH; micro-structure probes on deployable sonde
Biological Sensors		Optical backscatter; Photosynthetically Active Radiation (PAR); Chlorophyll; Turbidity; Dissolved Oxygen
Auxiliary payload allowance		20 kg; 500 Wh

Design for Reliability/ Fault-Tolerant Control/Design

Photo courtesy S. McPhail, NOC

ABE and Sentry failures in 350 dives



Unavoidable
- 1 entanglement

Human error
- 3 setup
- 7 mission programming
- 2 incorrect ballast

Algorithm
- 5 bottom-following
- 9 abort process
- 5 lbl

Software
- 2 inadequately tested change
- 2 programming blunder

Hardware
- 4 lbl elec/acoustics
- 2 connector failure
- 2 faulty battery
- 7 release failure
- 13 (4) Thruster elec/mechanical
- 1 computer failure

23 FATAL UNDER ICE

Come-Home Capability

- Act upon loss of tether
- Timeout before Bailout
- Standown
- Home Acoustically
- Breadcrumbs
- Deadman Initiation
- Constant Depth
- Top-Follow
- Bottom-Follow
- Visualize Bailout
- Recall Election

Conclusions

- More detailed exploration under permanent fixed ice will be enhanced by the Nereid Under Ice vehicle and lead to important new knowledge difficult to gather with autonomous systems having limited bandwidth communications
- Both operational and scientific techniques developed during this project should be of interest to those contemplating missions on other planets
- Teaming of human explorers to robotic tools over high bandwidth links promises most efficient of resources