DEFENCE R&D DÉFENSE

The Application of AUVs in Support of the Canadian UNCLOS Submission

6th Biannual NRC-IOT Workshop on Underwater Vehicle Technology

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Project Cornerstone

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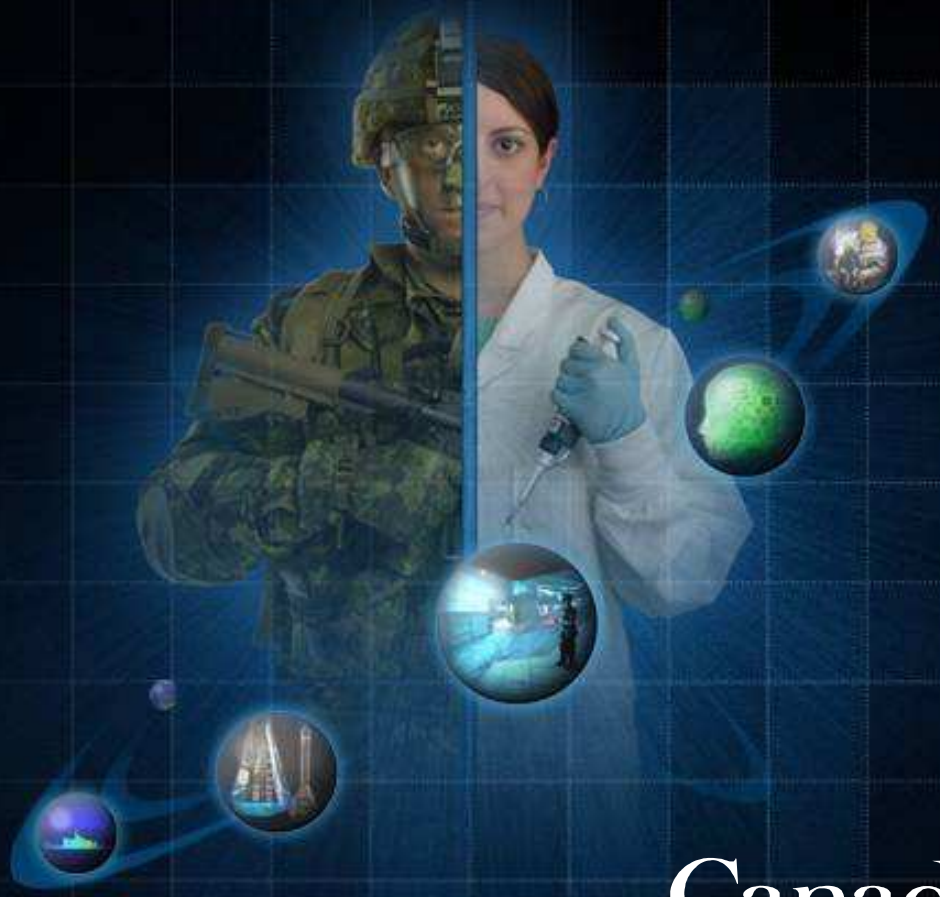

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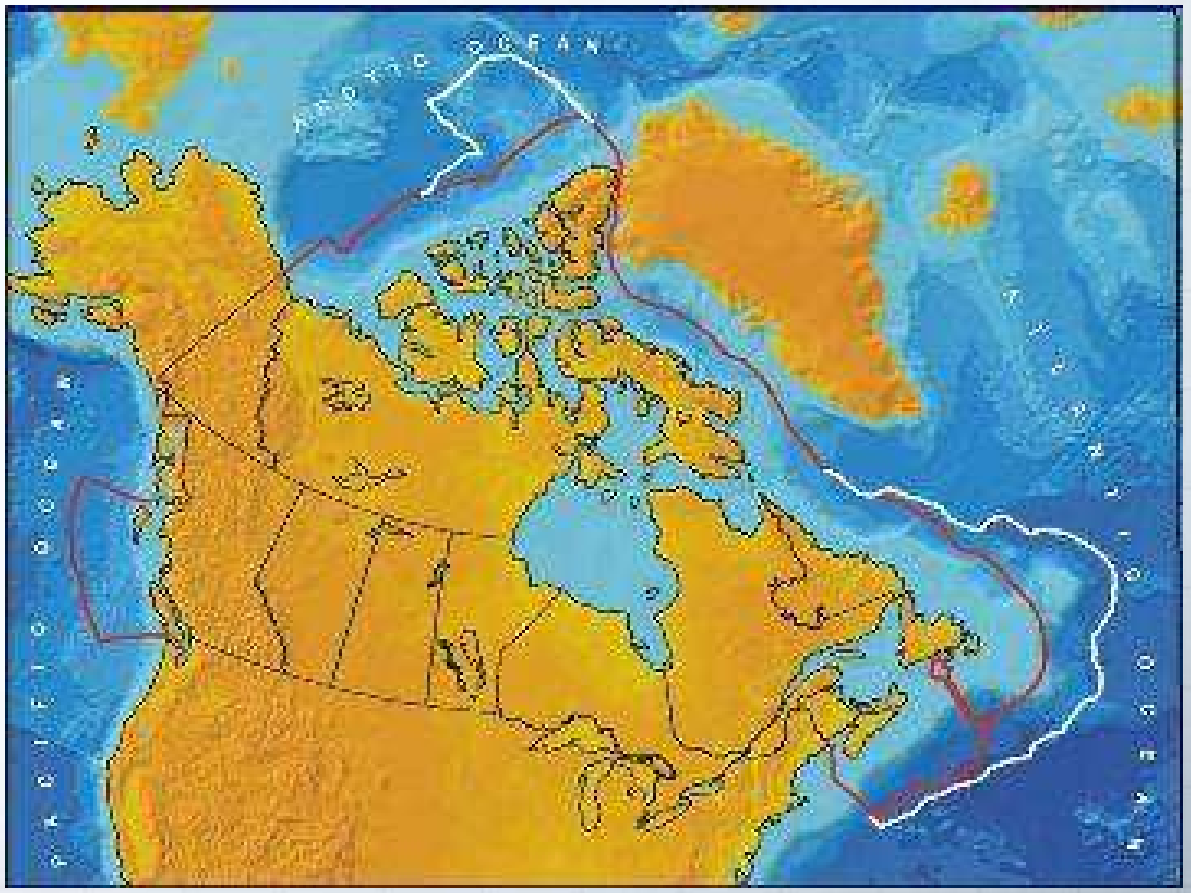
Canada

Presentation Overview

- Project Cornerstone Background
- Technical Challenges and Solutions
- Environmental Challenges and Solutions
- Arctic Field Operation 2010
- Results

UNCLOS

- The United Nations Convention on the Law Of the Sea
- Canada has until 2013 to submit a claim for the outer limit of the continental shelf where it extends beyond 200 nautical miles
- Represents a large area
- Scientific data is key
- NRCan, DFO, CHS collecting data



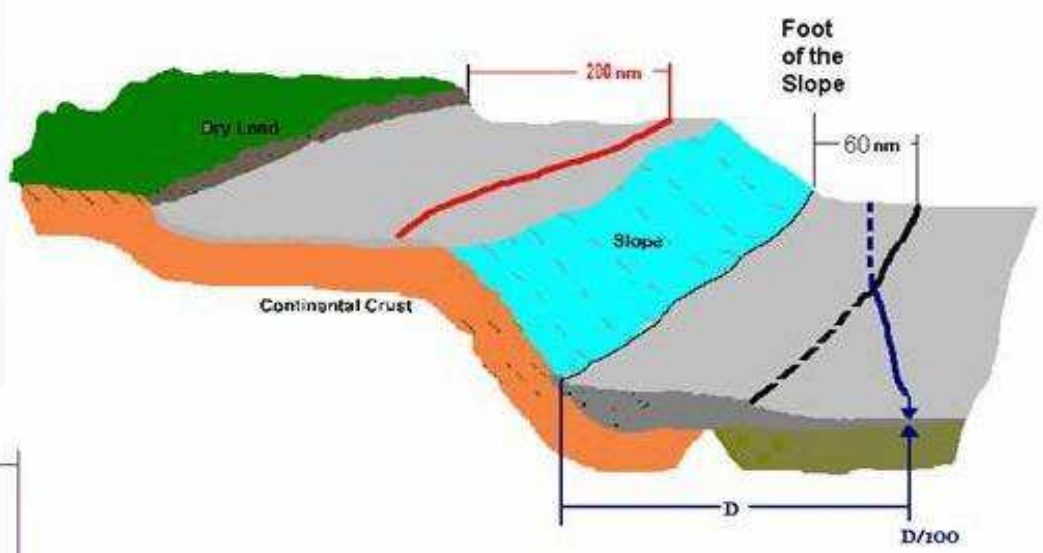
UNCLOS Claim Limits

Article 76 of UNCLOS requires the analysis and interpretation of the shape of the seabed, depth of seafloor and thickness of the underlying sedimentary layer.

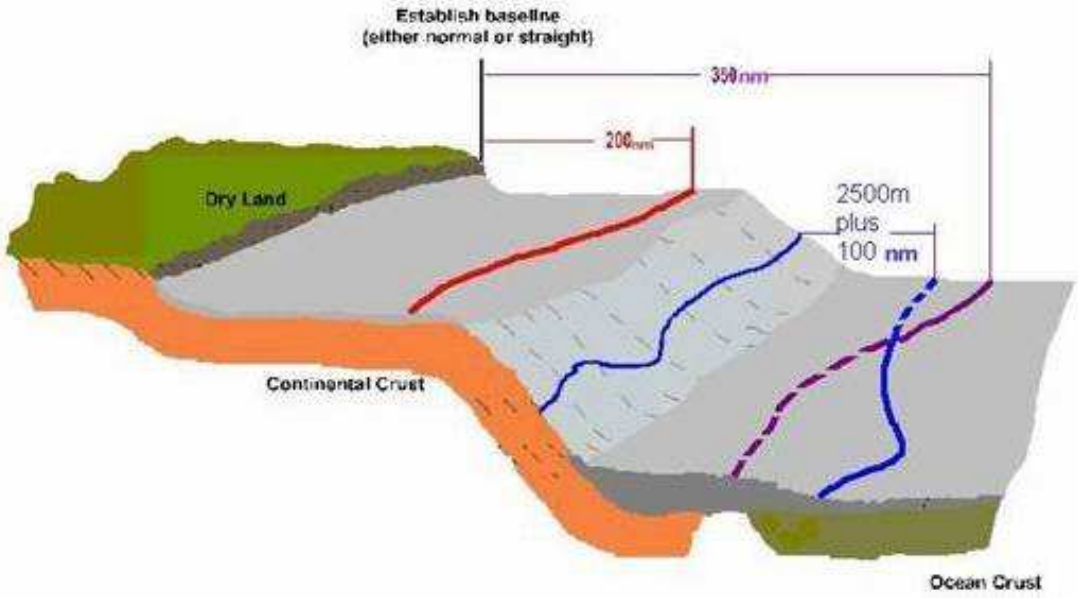
These measurements result in two limits:

1. the formula line, obtained by the application of distance formulas, and

2. the constraining line, defining the maximum extend of the outer limit.



Formula Line



Constraining Line

*** The formula line cannot extend beyond the constraining line, which is defined as the most seaward of a line 350 nm from the baselines of the coastal state, or a line 100 nm seaward of the 2500 m depth contour**

Project Cornerstone Overview

Objective

To use Autonomous underwater vehicles (AUVs) to collect high quality bathymetric data , in particular between the 2500 m contour line and the "foot of the slope", in ice covered waters in the Arctic

Benefits

- Provide risk mitigation against poor flying weather and poor ice conditions
- Providing data for an improved UNCLOS submission

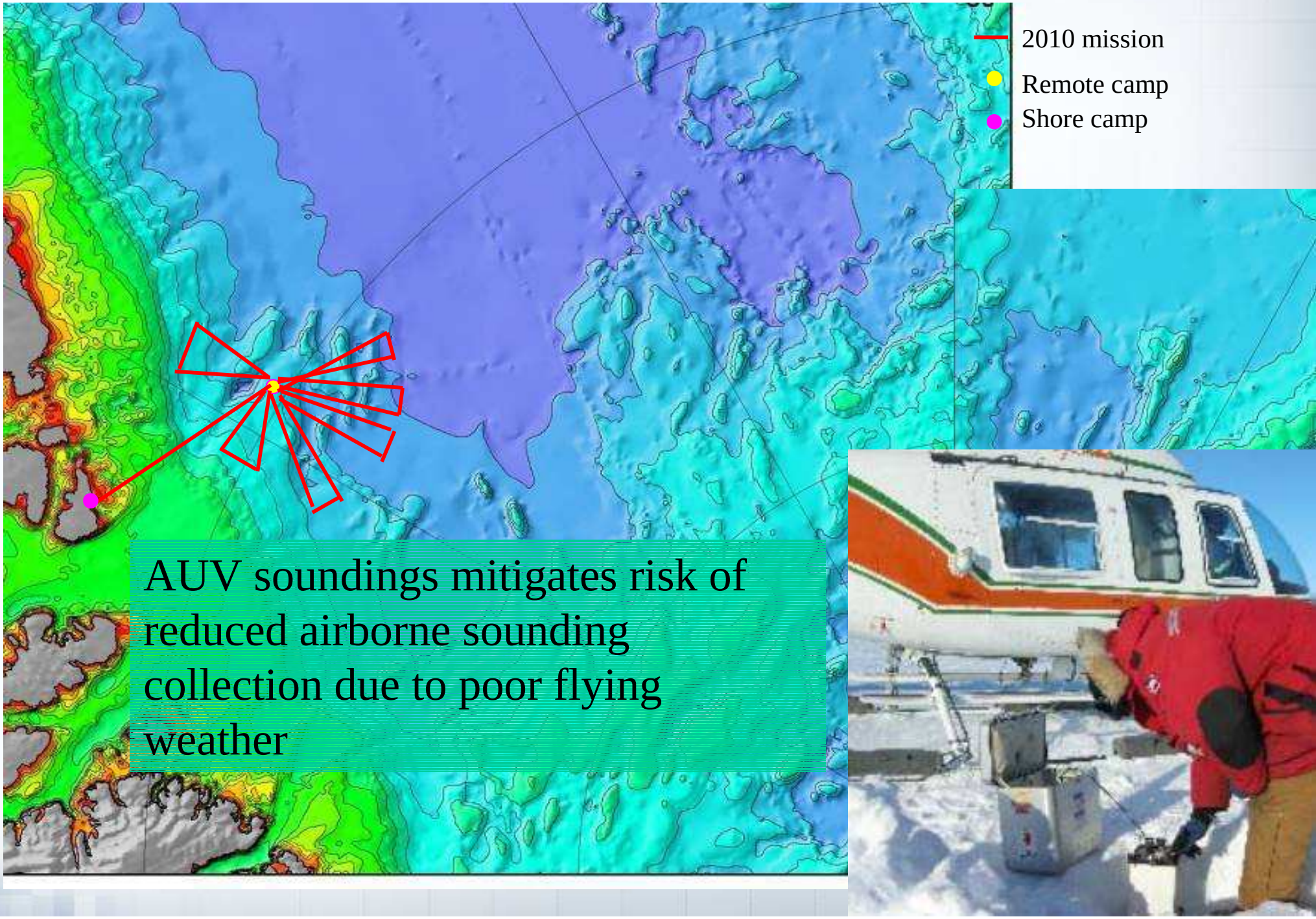
Project Execution

DRDC, Natural Resources Canada and Fisheries and Oceans Canada

Project Timeline

• ADM Steering Committee Approval	Jun 2008
• AUV Contract Award	Nov 2008
• IMOU Signed	Feb 2009
• Preliminary Arctic Trial	Mar / Apr 2009
• AUV Factory Acceptance Testing	Aug 2009
• AUV Sea Acceptance Testing	Sept / Oct 2009
• Engineering Trials	Nov 2009 – Feb 2010
• Arctic Survey 2010	Mar / Apr 2010
• Arctic Survey 2011	Aug/Sep 2011
• Option to extend for another season	(2012)

AUV Concept for Collecting Bathymetry

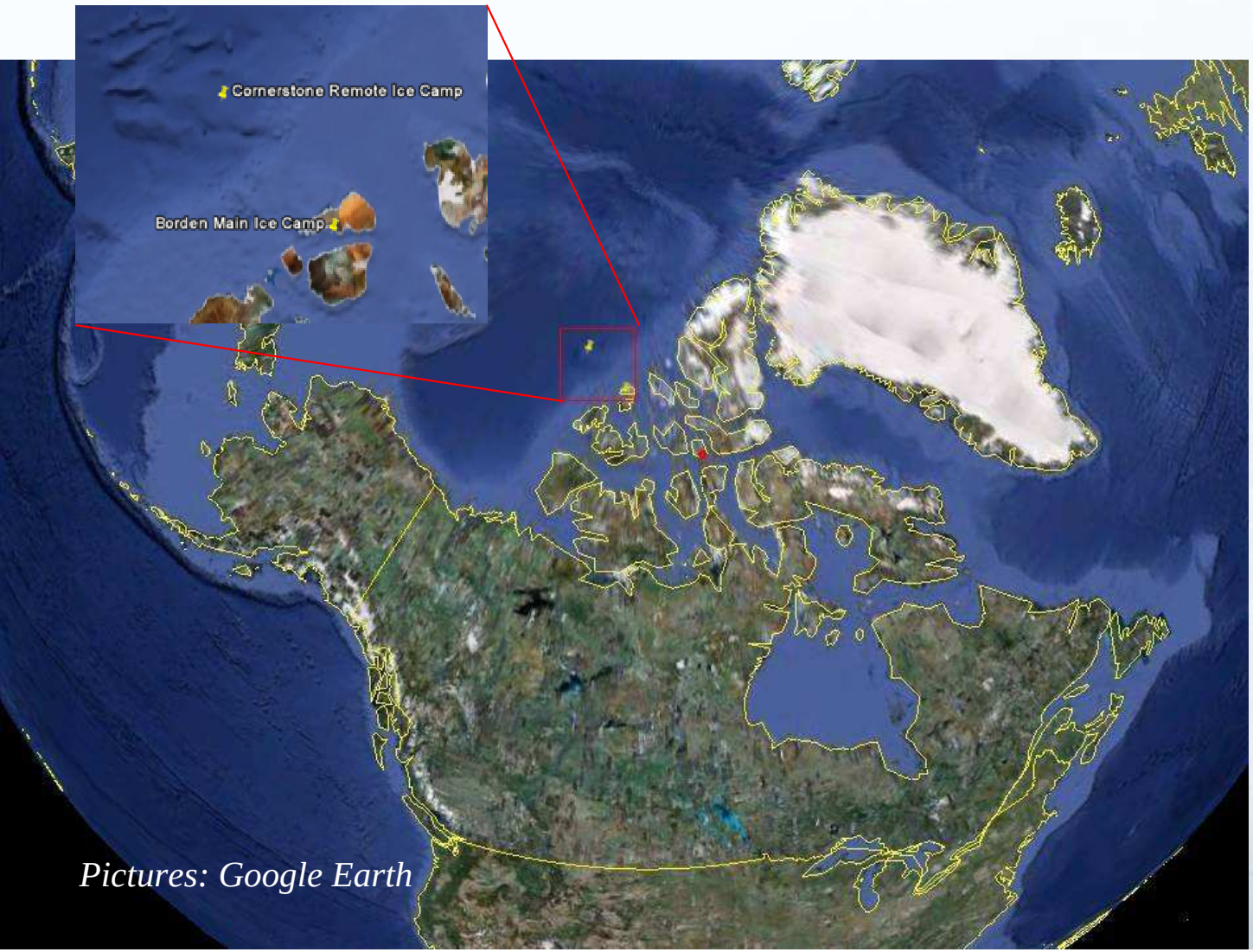


AUV soundings mitigates risk of reduced airborne sounding collection due to poor flying weather

Arctic Operation 2010 Locations

Location: Western High Arctic

- Support Base: Resolute Bay
- Two ice camps:
  - Borden Ice Camp: South of Borden Island
  - Cornerstone Remote Ice Camp: ~300km NW of main camp

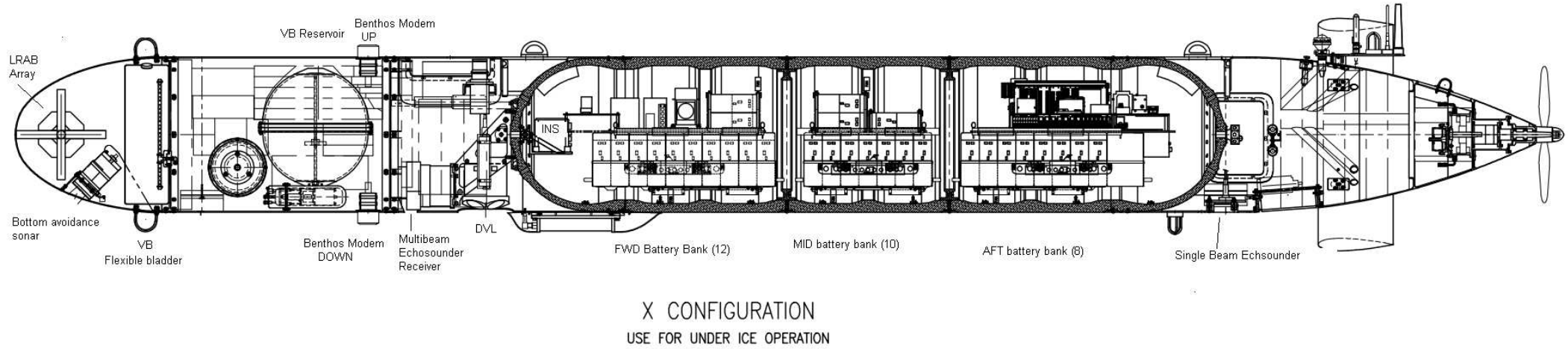


Pictures: Google Earth

Large distances involved

- 300km between camps
- 600km from Resolute
- 4000km from Toronto
- 4200km from Oslo

AUV “Arctic Explorer”



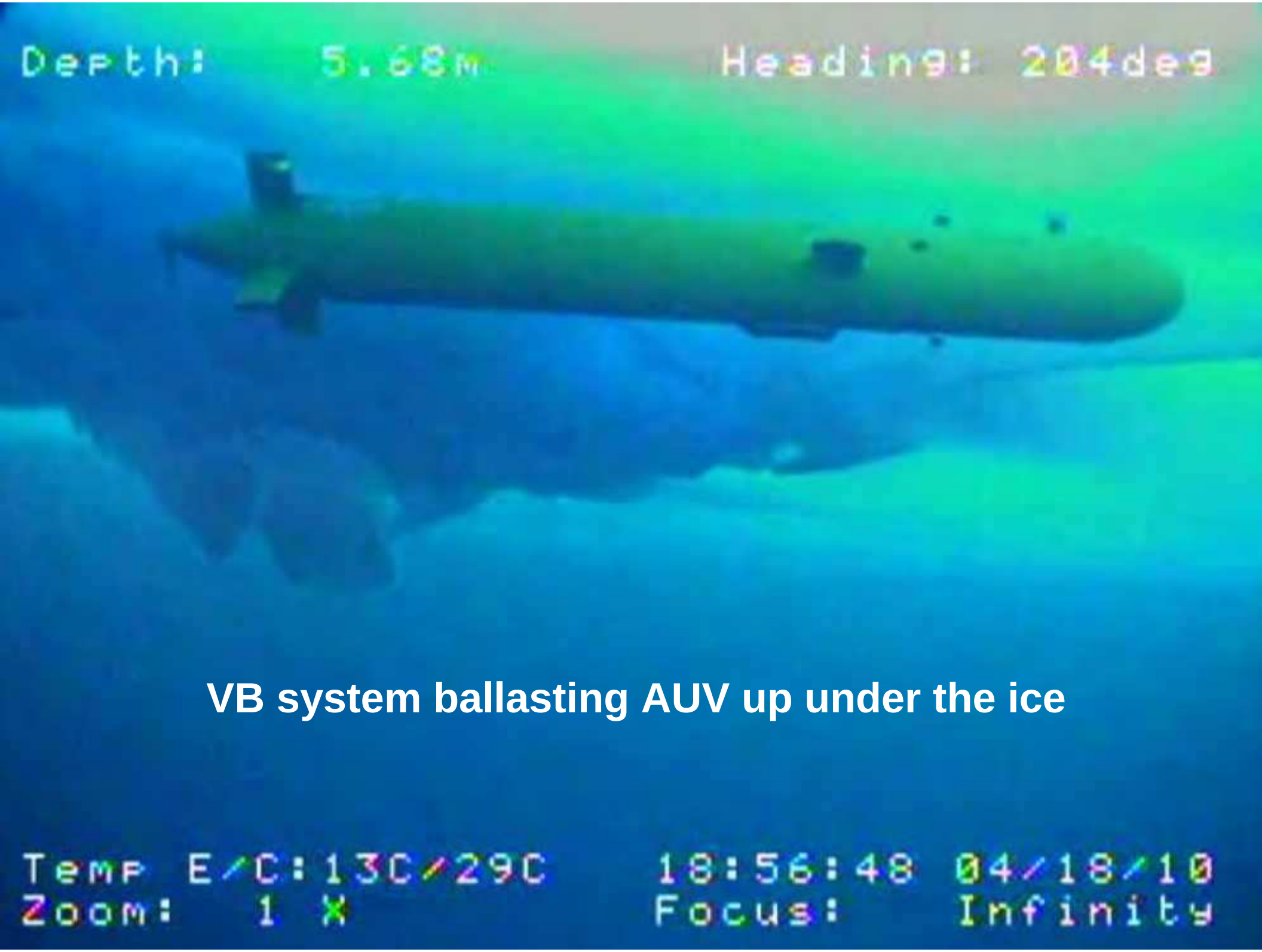
Length 7.3m, Weight 1800kg
Max Speed 5 knots (2.5m/s)
Endurance >350km @ 1.5m/s, 3 days
Deep diving to 5000m
Modular design

Bathymetric data collection
- **Knudsen single beam echosounder**
- **Kongsberg Simrad EM2000 multibeam echosounder**

Technical Challenges and Solutions

Variable Ballast System

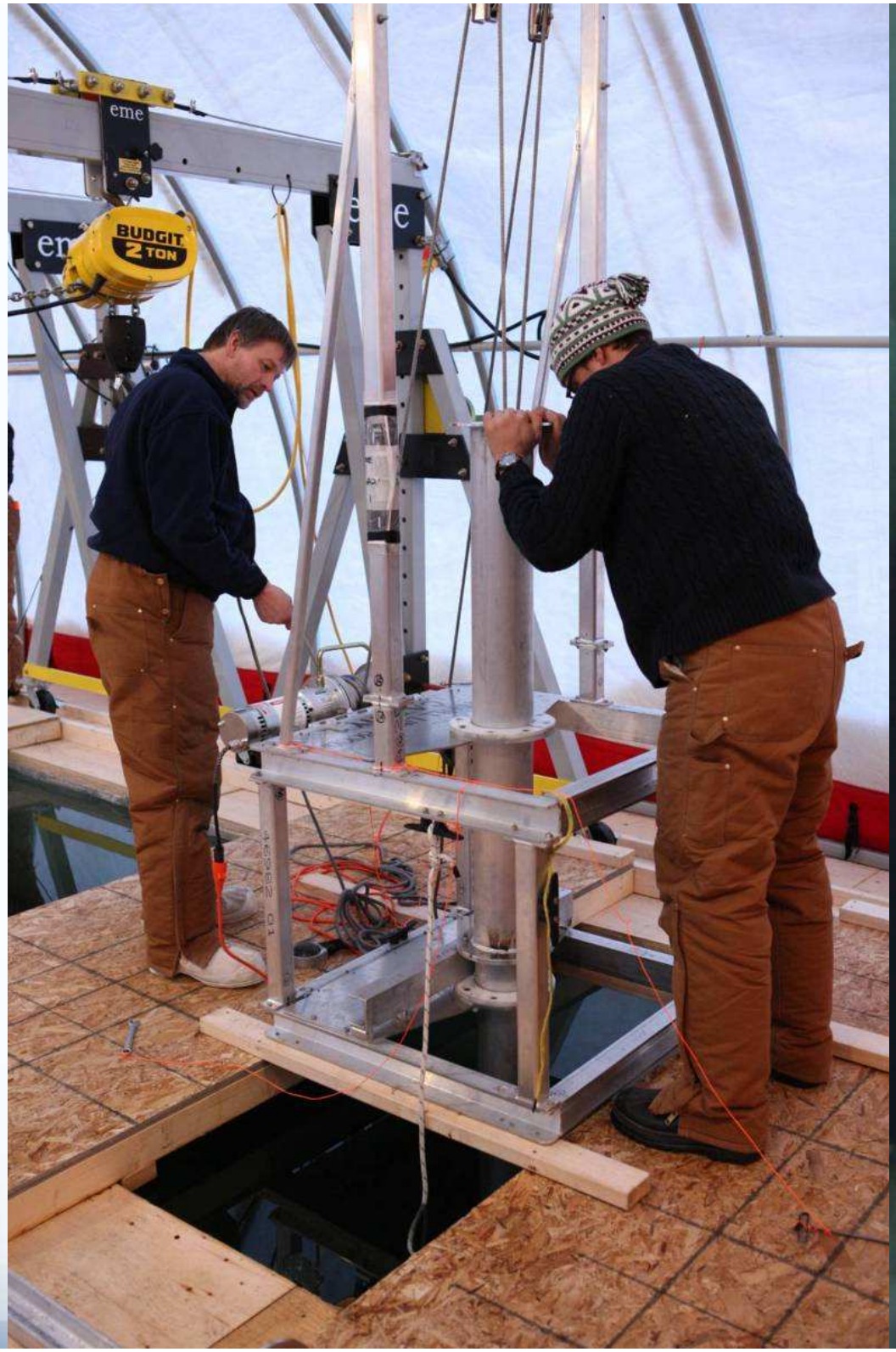
- The Concept of Operation required the AUV to park under the ice at the end of each mission
- Fault management also required ability to park on the sea bottom
- Developed a variable ballast system
  - Rating of 5000 m
  - Titanium sphere
  - Double pumps



VB system ballasting AUV up under the ice

In water Charging

- CONOPS required continuous operations from a remote camp with no facilities to recover the AUV
- Necessitated in-water recharging and data download after each mission using a special underwater mating connector
- Developed a novel pole assembly for positive AUV capture to facilitate attaching the charging cable
- Also allows for rotating the vehicle to align the INS if necessary
- An ROV was used to put a line on the AUV and the AUV was pulled over to the charging mechanism by hand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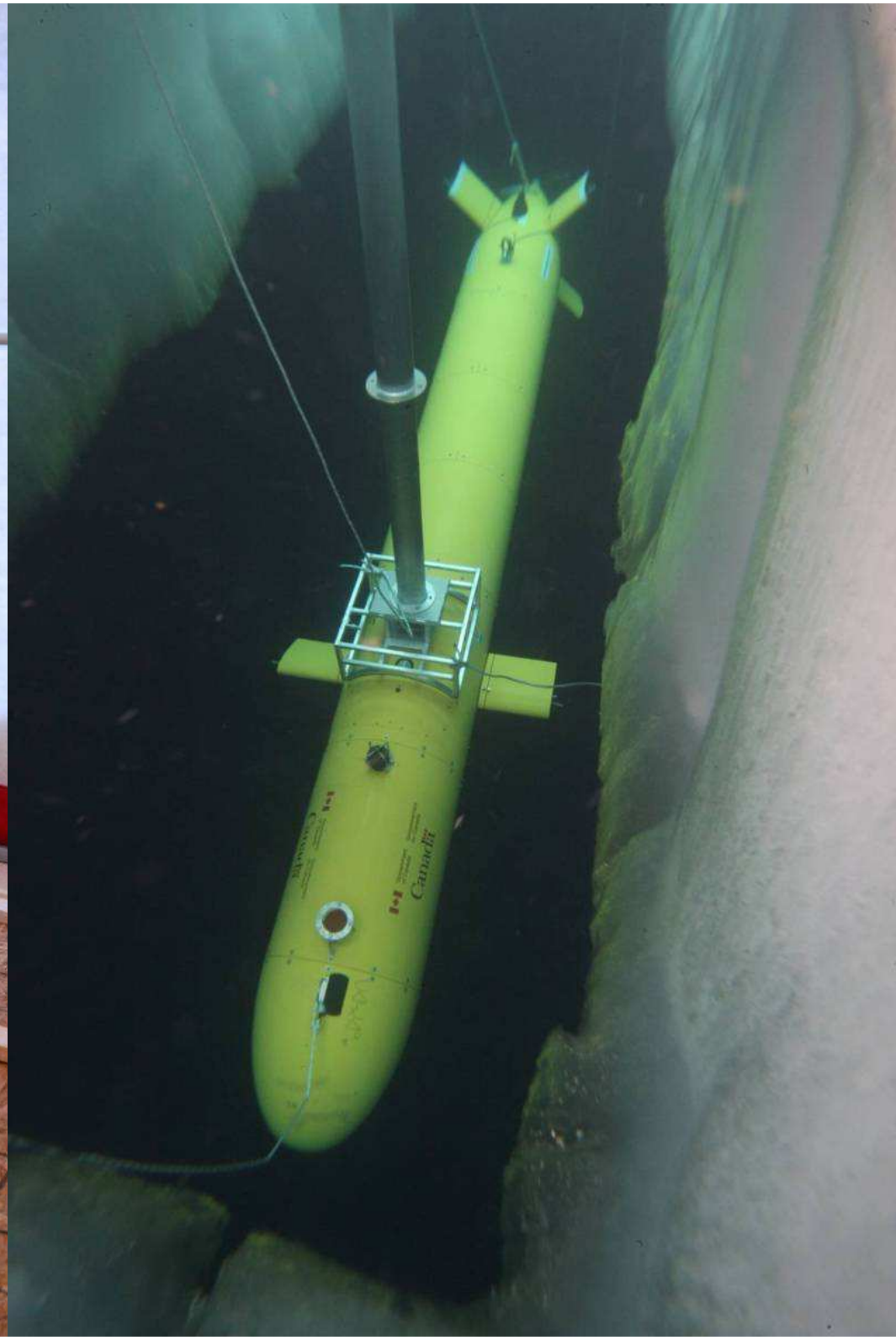


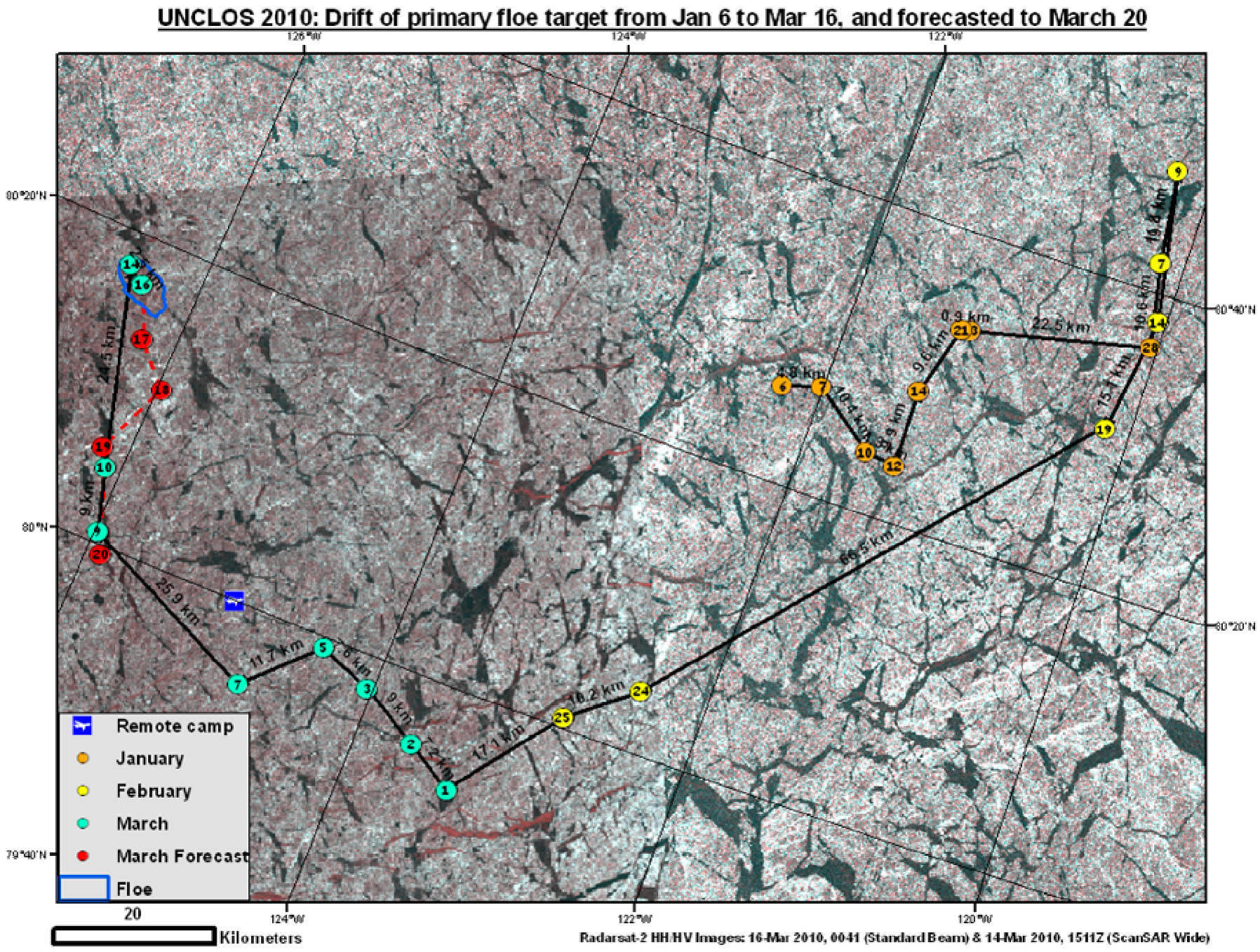
Navigation

- Other than standard navigational issues and high latitude problems with an Inertial Navigation System (INS) there are two additional difficulties:

1. On launch in deep water there is INS drift when the AUV is working its way down to where a bottom-lock is possible.
   - Utmost accuracy requires the INS to be reset on the bottom
2. On recovery the ice camp has drifted erratically for 3 days and may be as much as 50-60 km from the location where the vehicle was launched!
   - The vehicle has to find the ice camp by itself. We are not in control or in communication with the vehicle

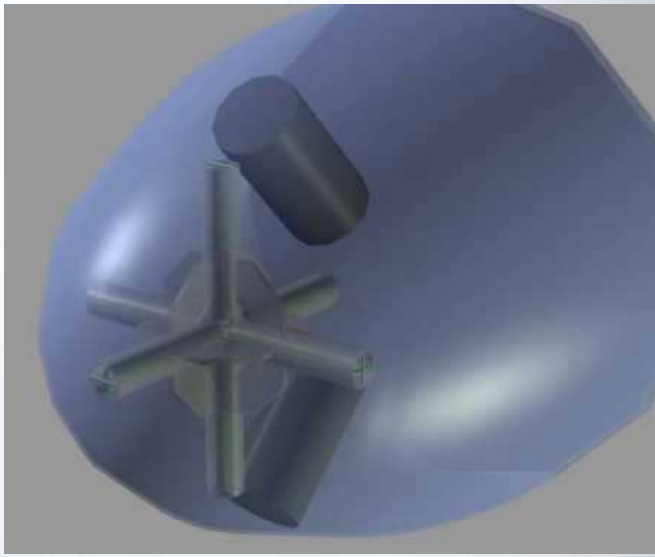
- DRDC Atlantic worked on solving these two issues

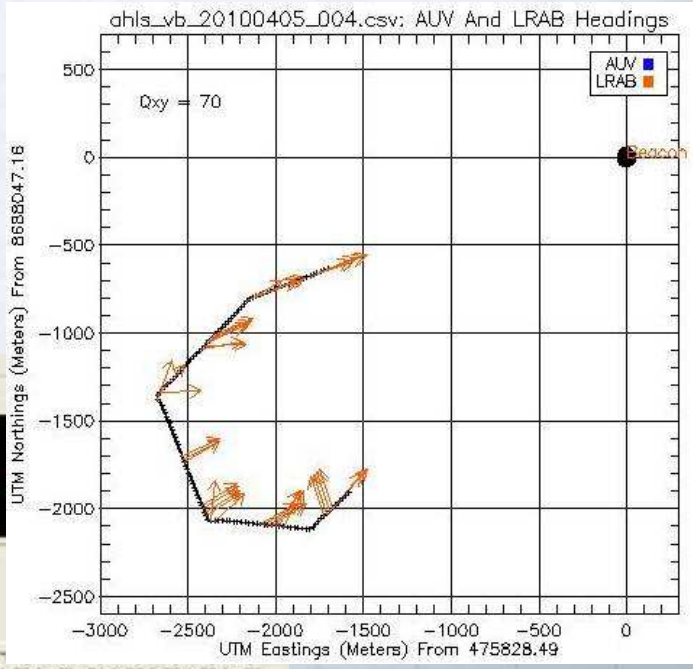
Ice Floe Drift – is a real problem

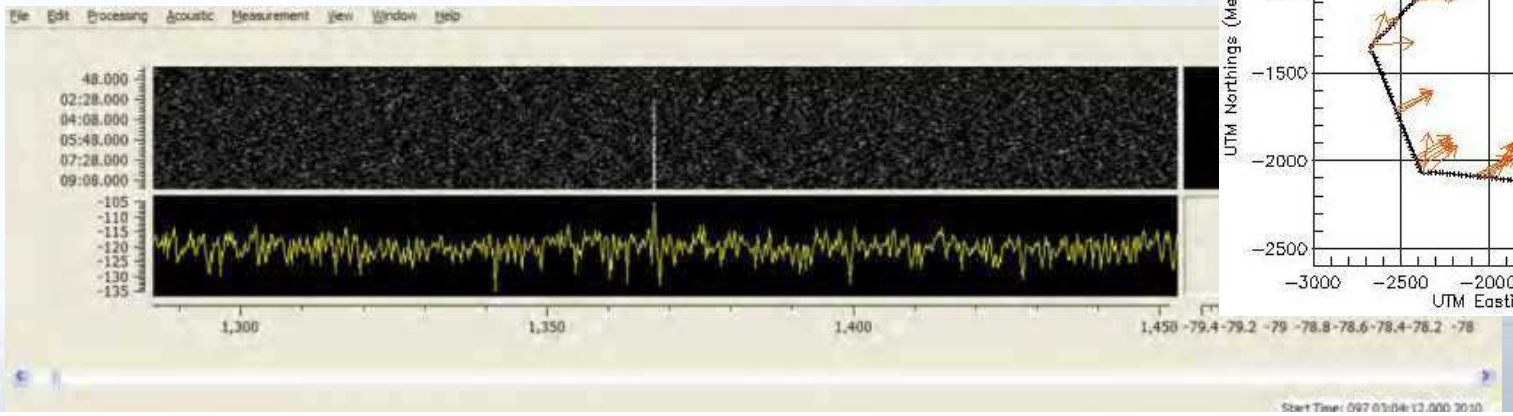


Homing

- AUV must return to a drifting ice camp that was erratically moving upward of 10 km/day!
  - For a 3 day mission, this is a total drift of 30 km
- Developed a custom 7 element hydrophone array that is mounted in the nose of the AUV
- Deploy a custom built 1300 hz, >190 db sound source at the ice hole
- Using specialized software on the AUV, the bearing angle from the AUV to the ice camp is calculated
- Homing at ranges greater than 50 km



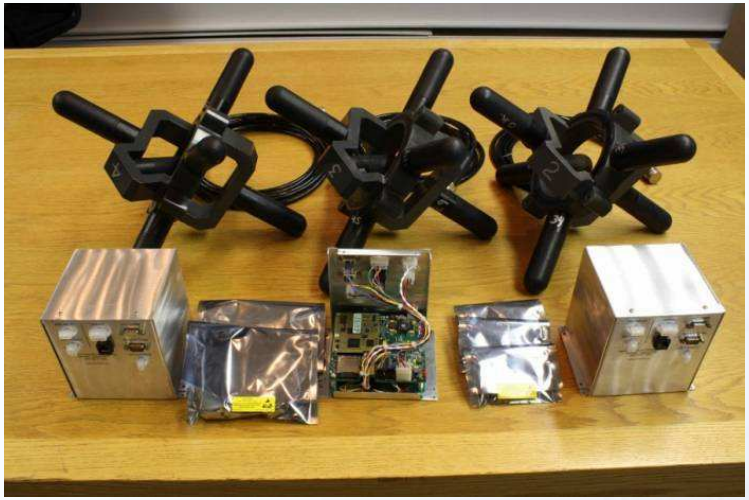




Homing & Positioning Systems Setup

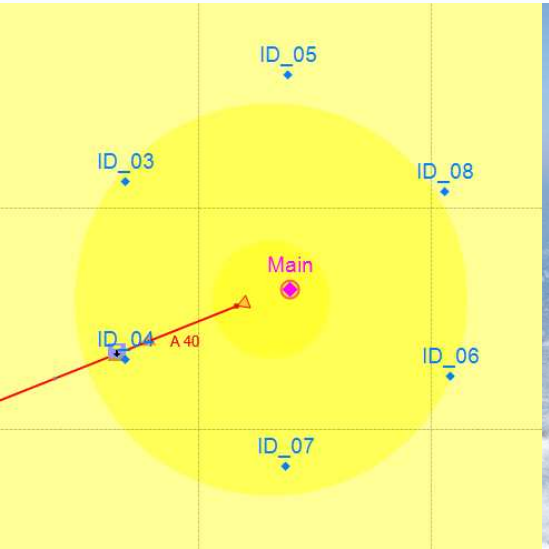
Long Range Acoustic Homing Beacon

- Guide AUV towards drifting ice hole from long distances (50-100km)



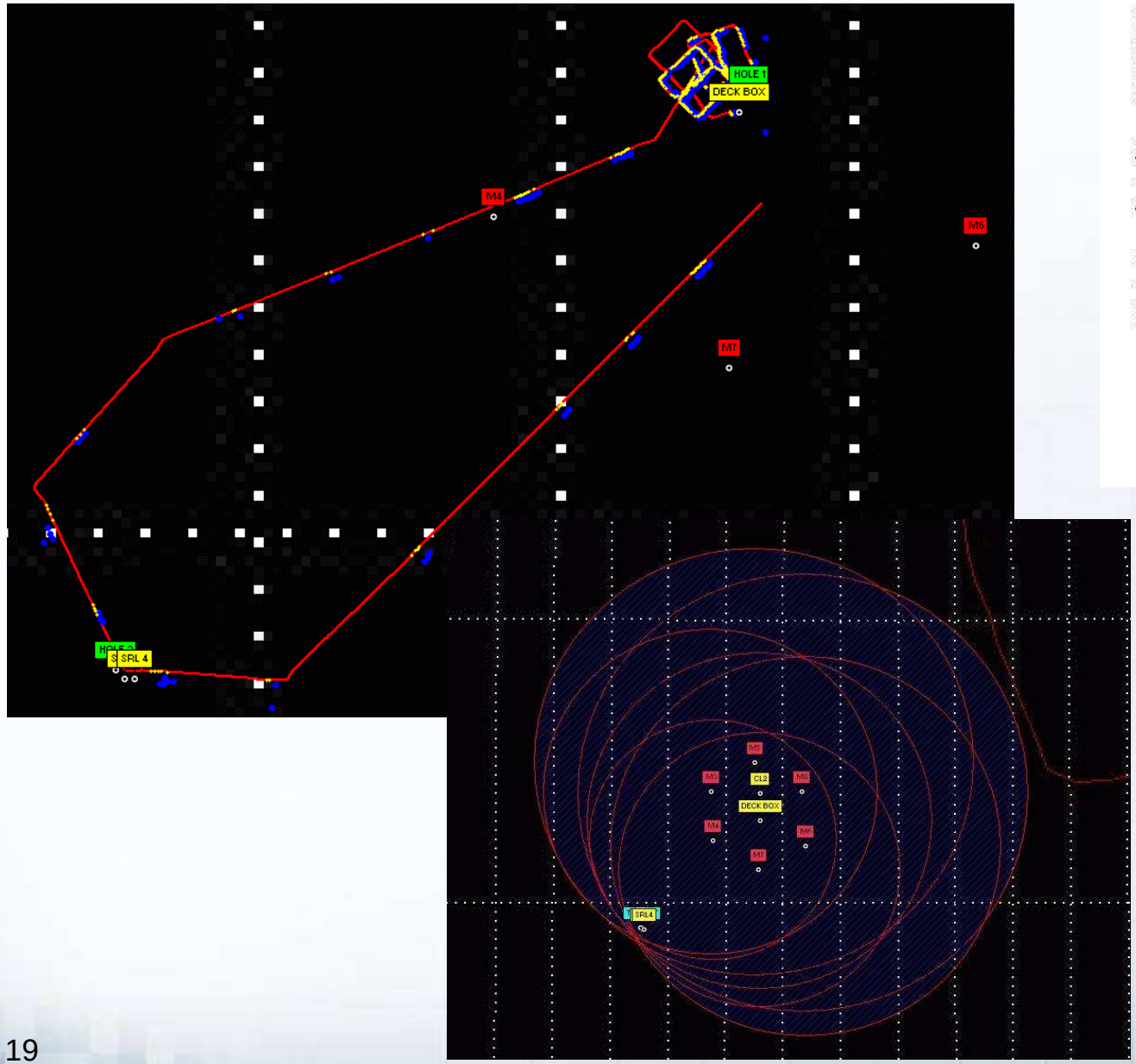
Short Range Localization System

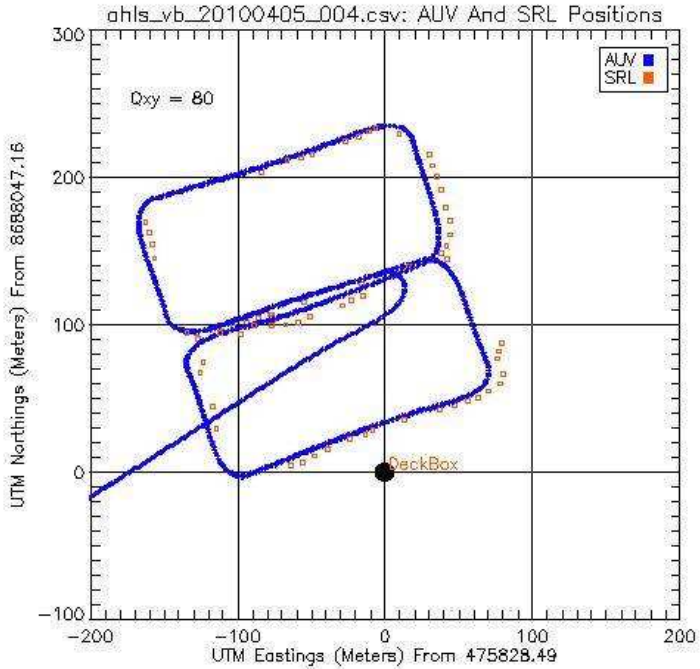
- Provide position updates to AUV at shorter distances (<4km from ice hole)



Short-Range Localization (SRL)

AUV (red) and positioning system (blue) results for test mission

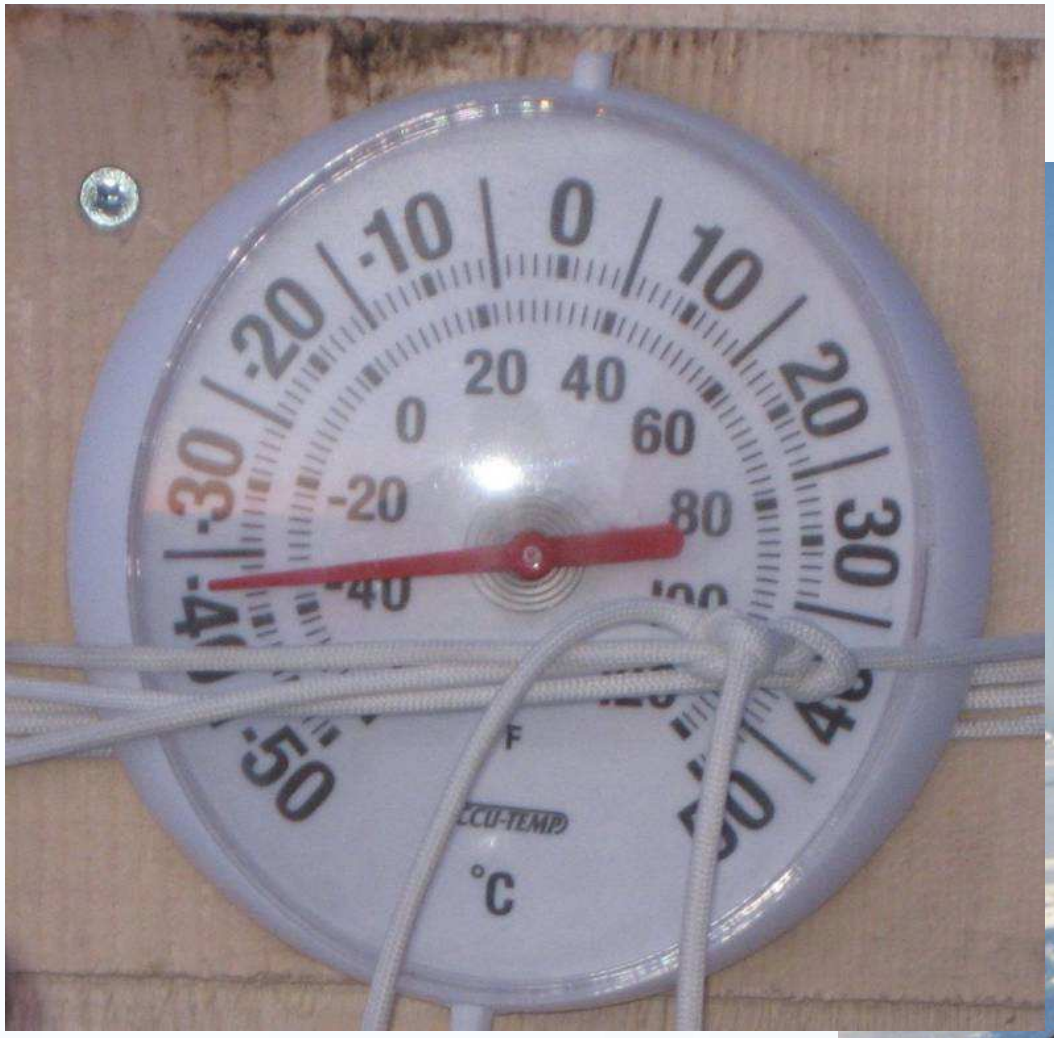


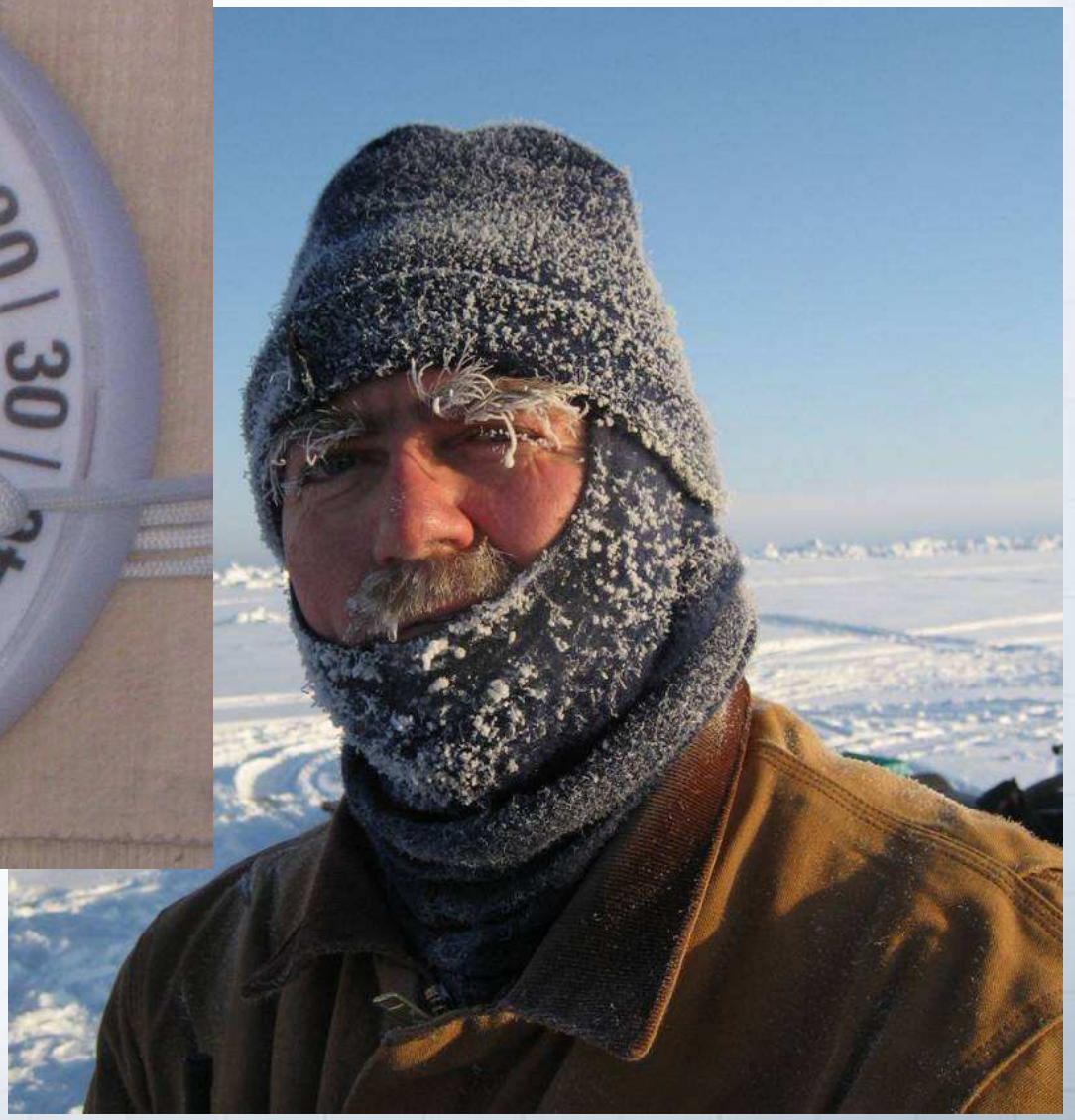


AUV (blue) and positioning system (red) results at start of test run

Environmental Challenges and Solutions

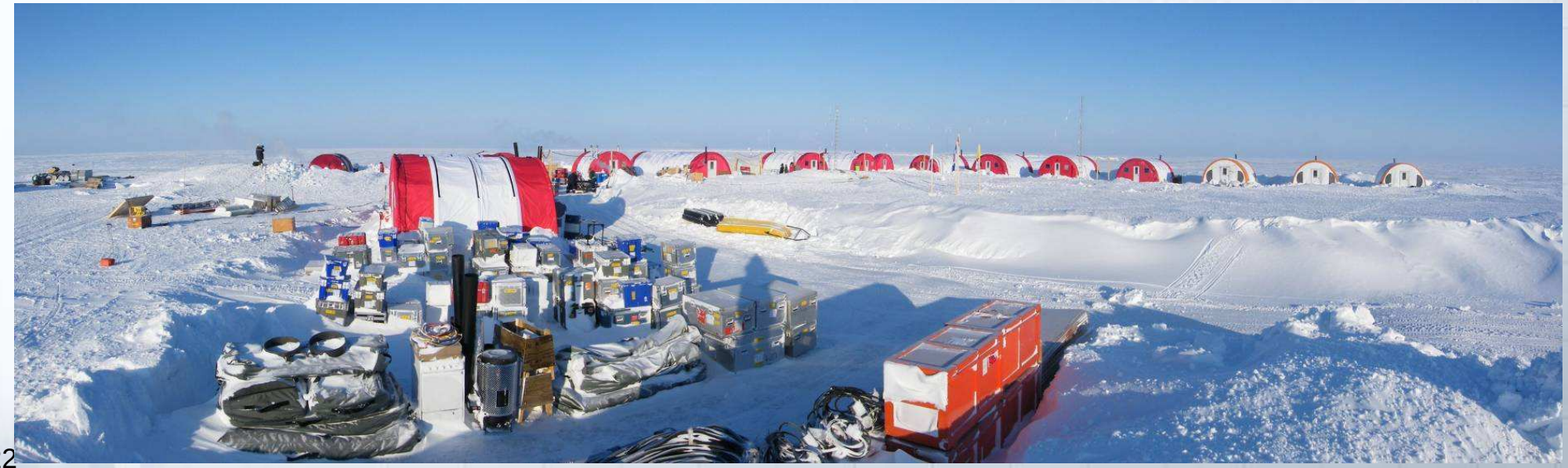
The Cold

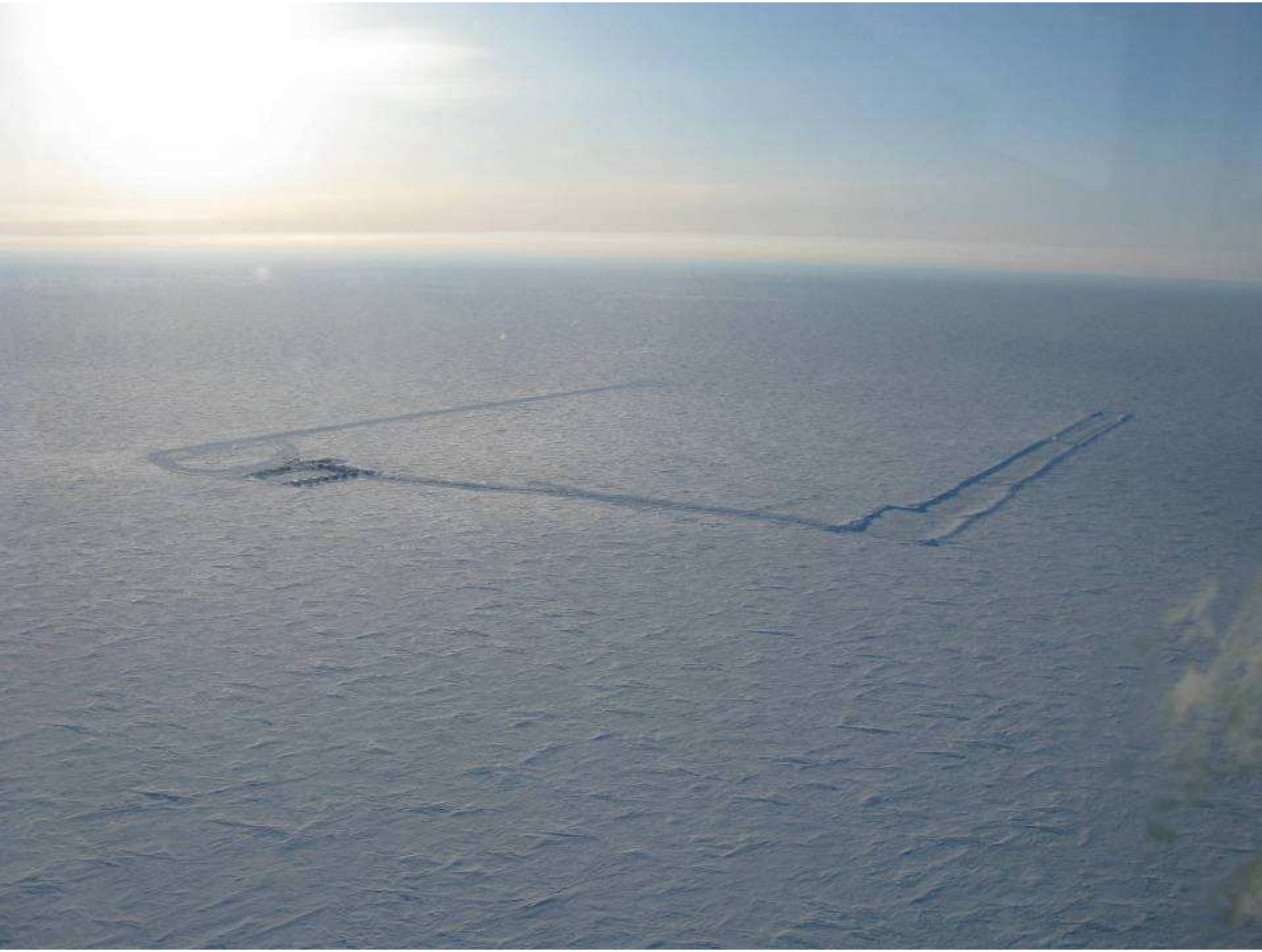




Main Ice Camp – Borden Island

- 78°15’N, 112°04’W
- Water Depth: 120m
- Ice Thickness: 7 – 10 ft.
- Heavy Snow, Temp -25 to -30C
- ~5km offshore Borden Island on 2nd year ice
- Very large camp; up to 40 people

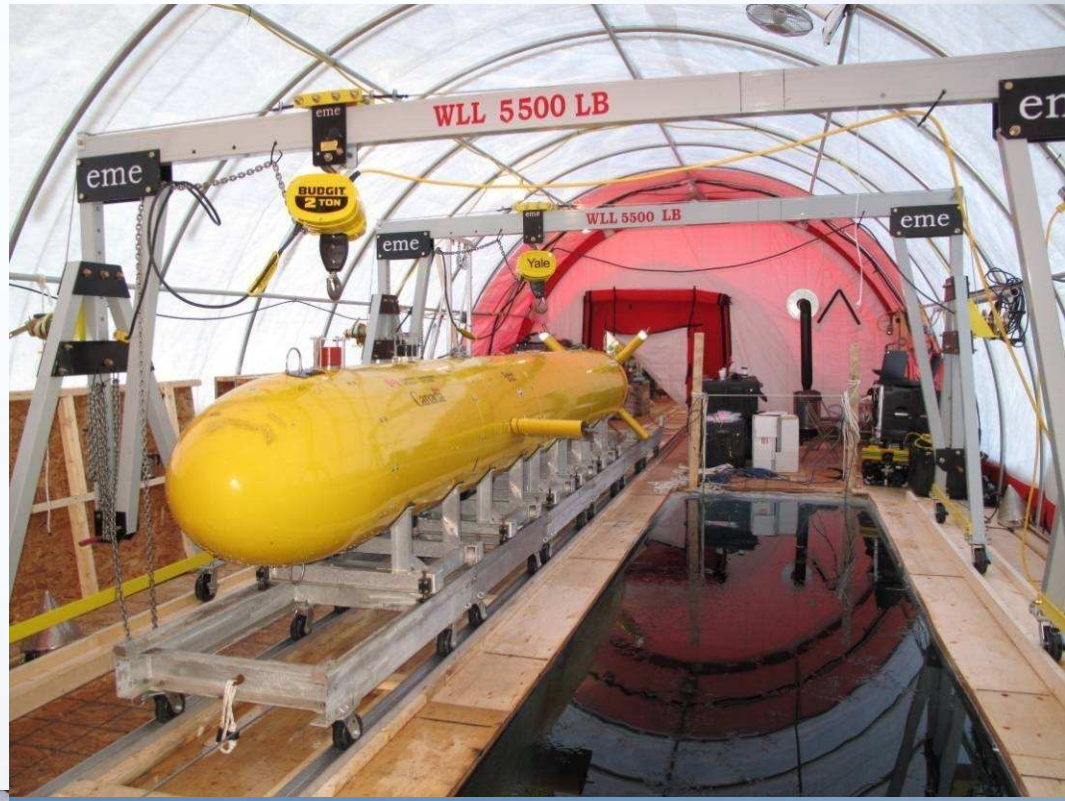




Camp Setup & Ice Hole Cutting

Main Camp

- Large ice hole (~8 x 2m)
- Two AUV tents (20’x48’, 14’x32’)
- Rail and Gantry System
- Supporting Equipment



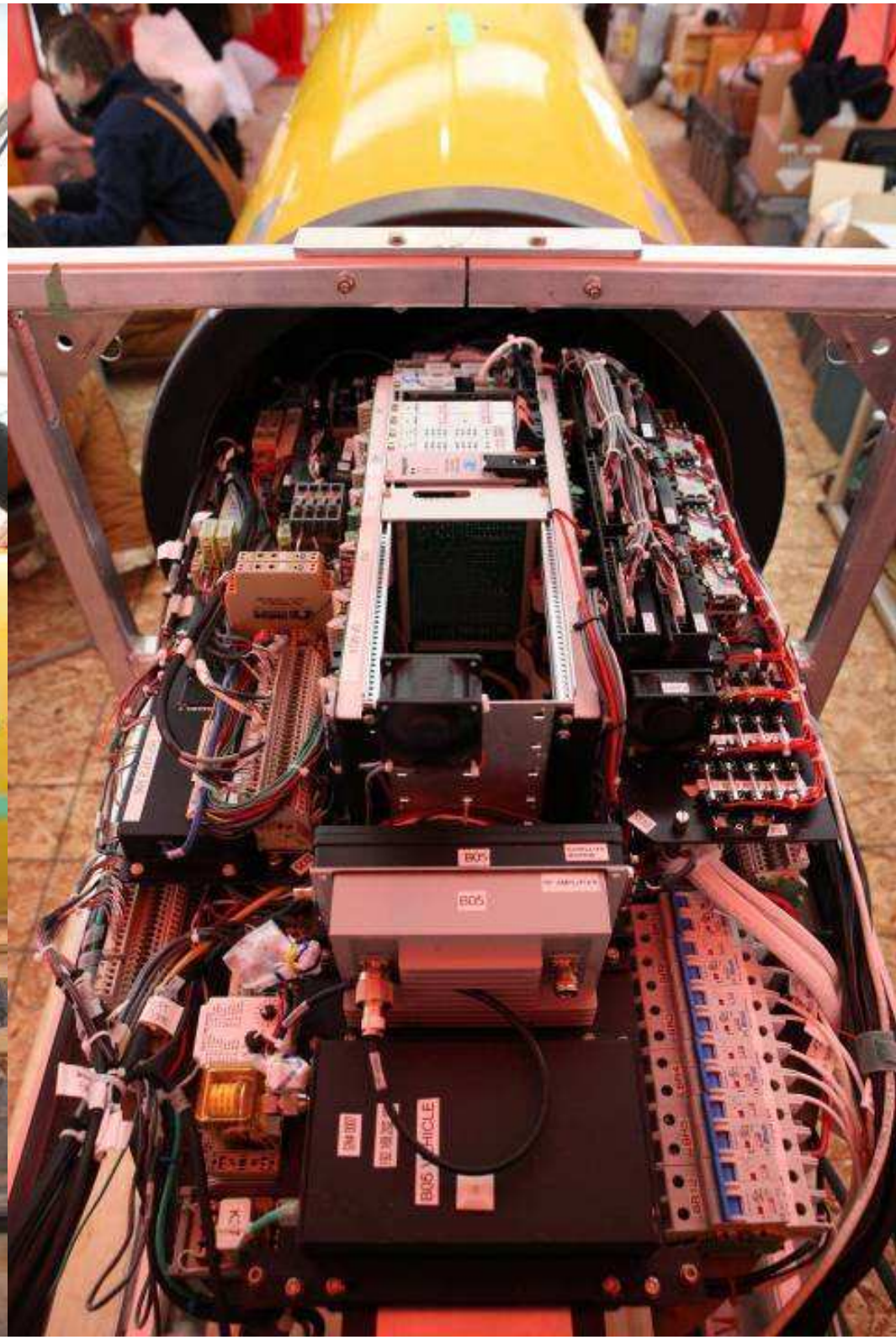
Transportation

- Loading the AUV at Resolute

Unloading at Borden Ice camp


Bobcat


B05
B05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Wildlife
Some of which are best avoided

Remote Ice Camp Cornerstone

79°N, 118-120°W (moving)

Water Depth: ~2200-2300m

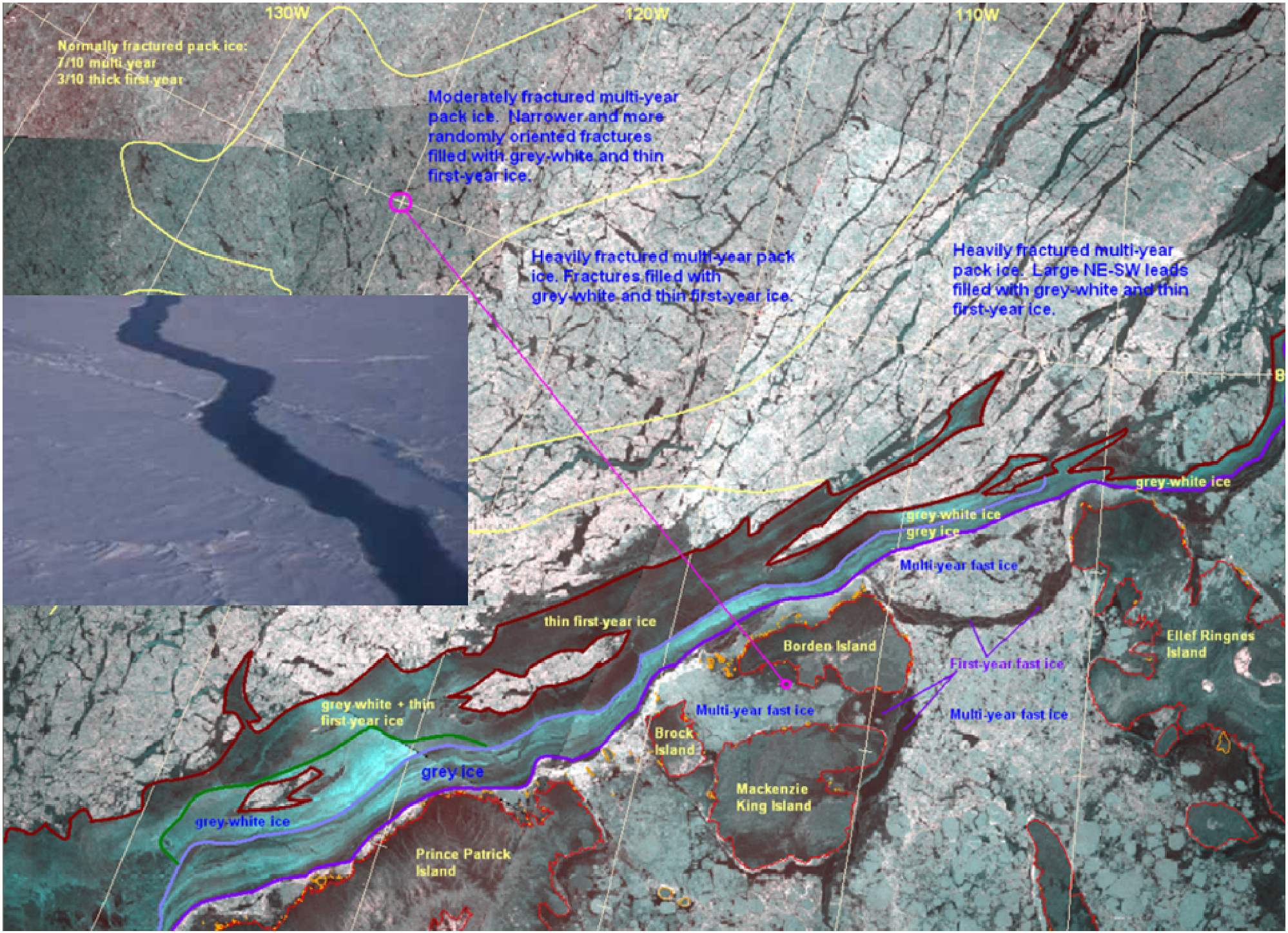
Ice Thickness: 7-10 ft.

Less Snow, Temp -25 to -30C

~300km offshore Borden Island on moving ice pan

Smaller camp; up to 11 people

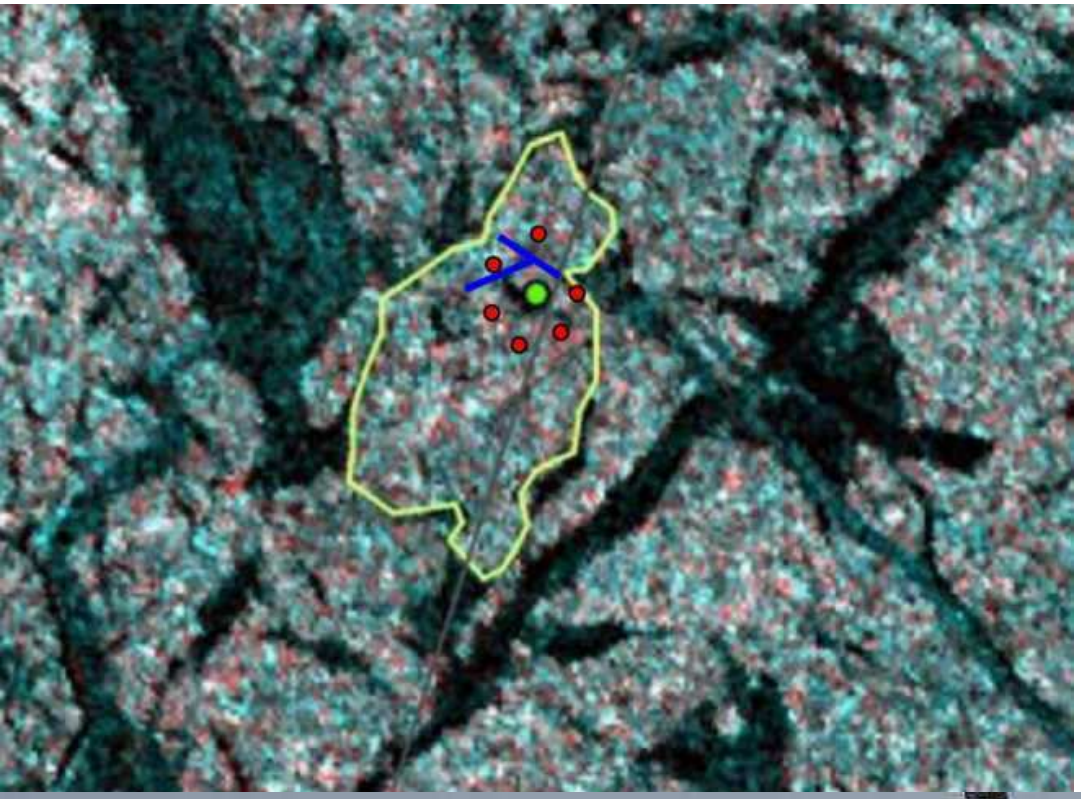
Poor Ice Conditions & Fog



Fog, snow and wind lead to many no fly days for helicopter spot soundings

Meanwhile the AUV survey mission carried on under the ice

Ice breakup at the Remote Camp



Green line – floe outline

Red dots – modems

Green dot – camp

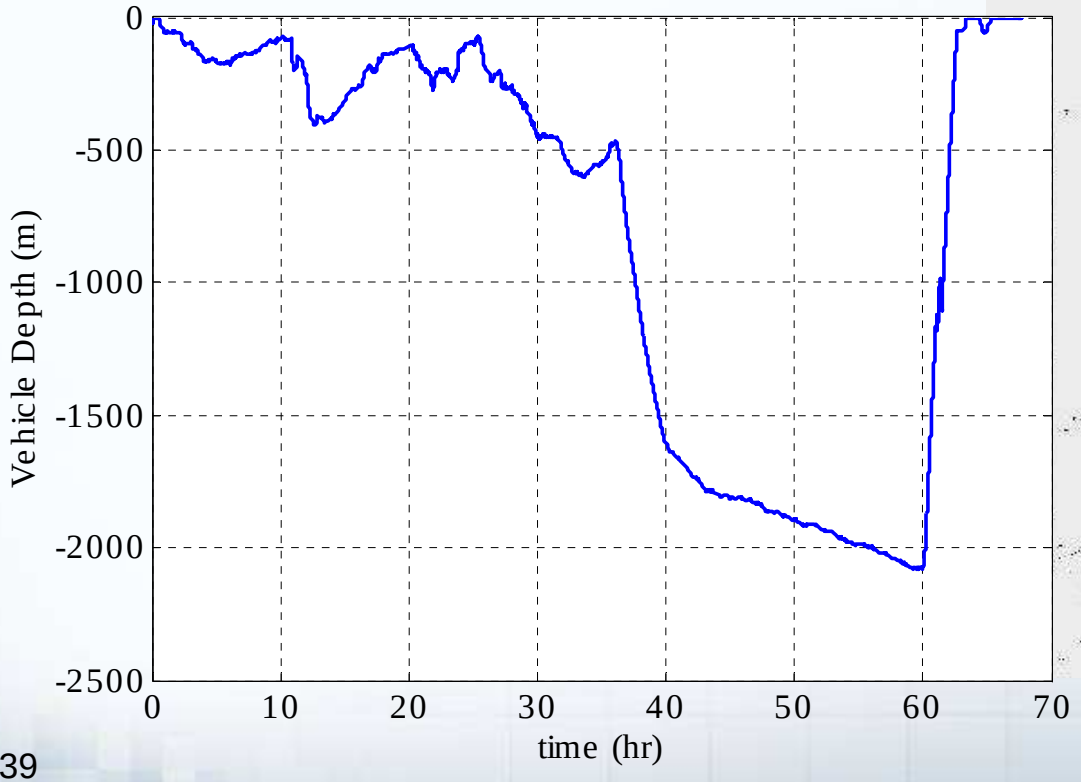
Blue lines – open leads

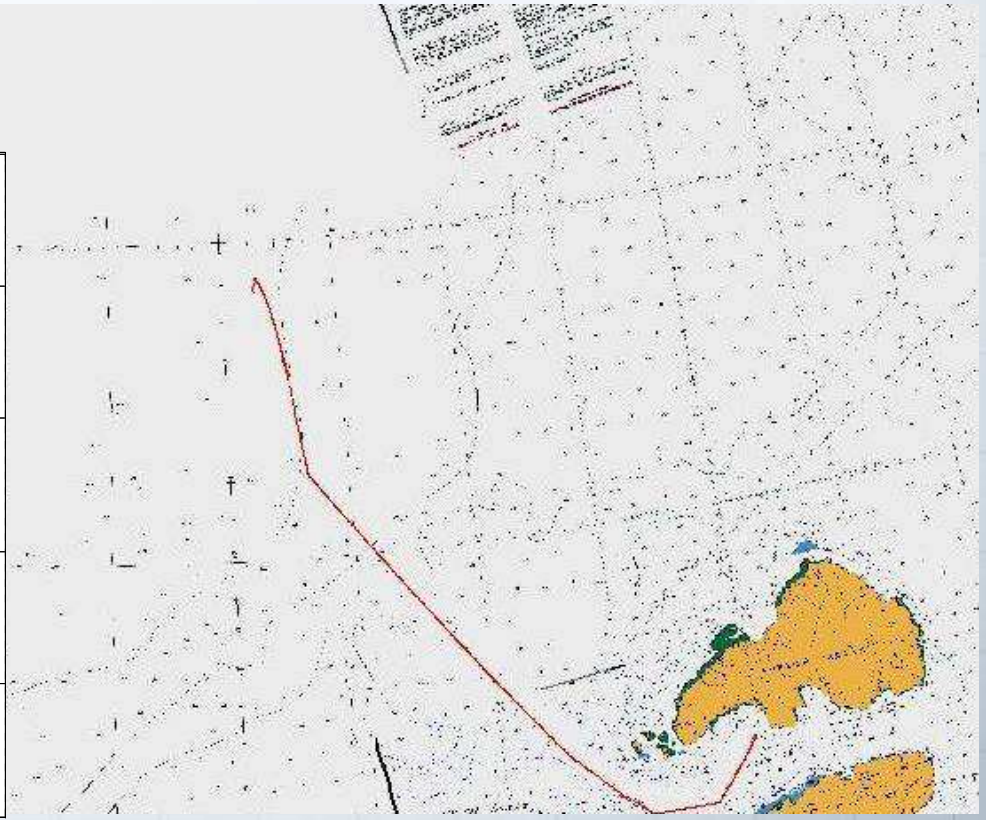
Dark areas – thin ice or open water

AUV Missions

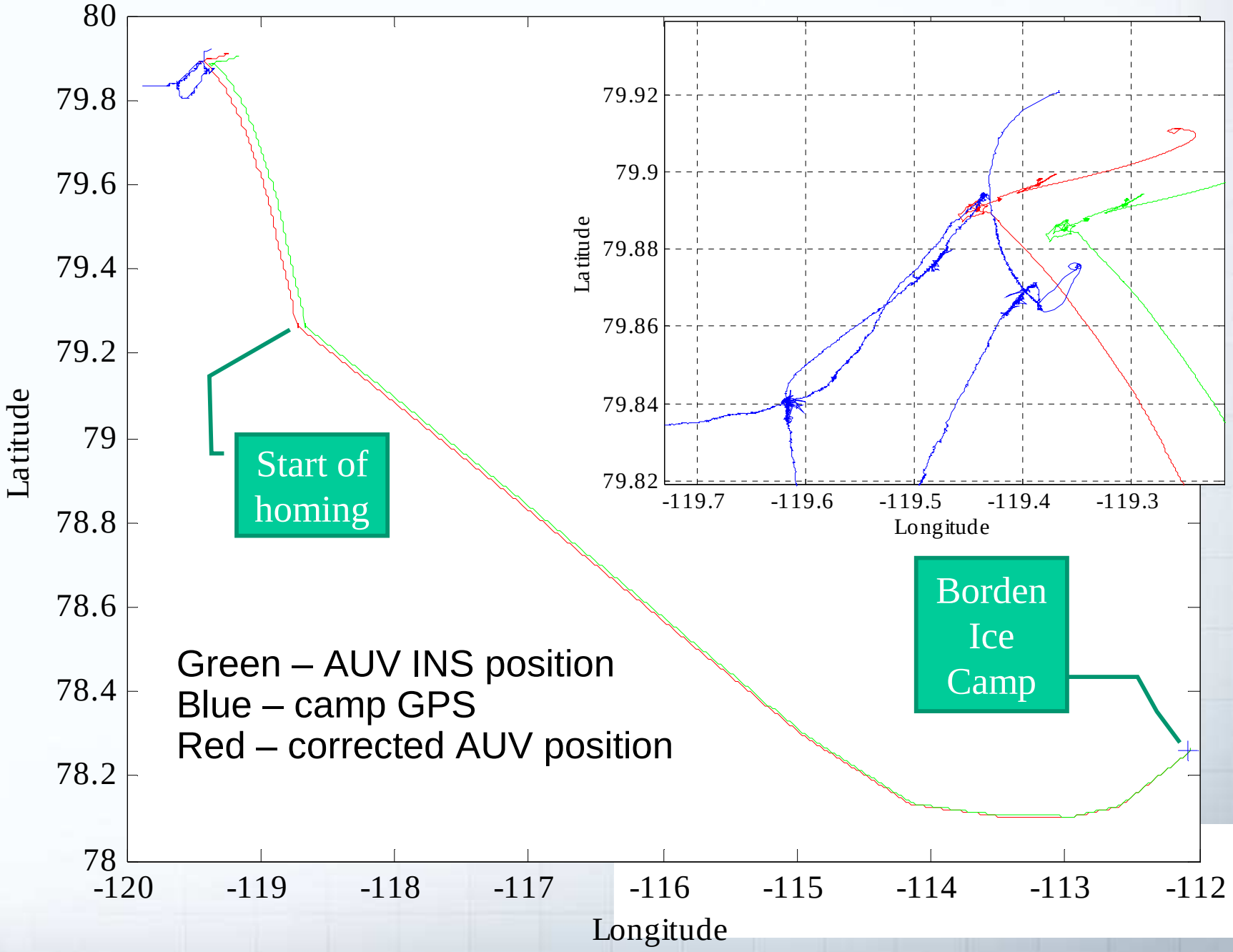
AUV Transit Missions

- Distance of ~300km
- AUV depths down to 2200m
- main camp out Wilkins Straight to remote camp
- collected single beam data



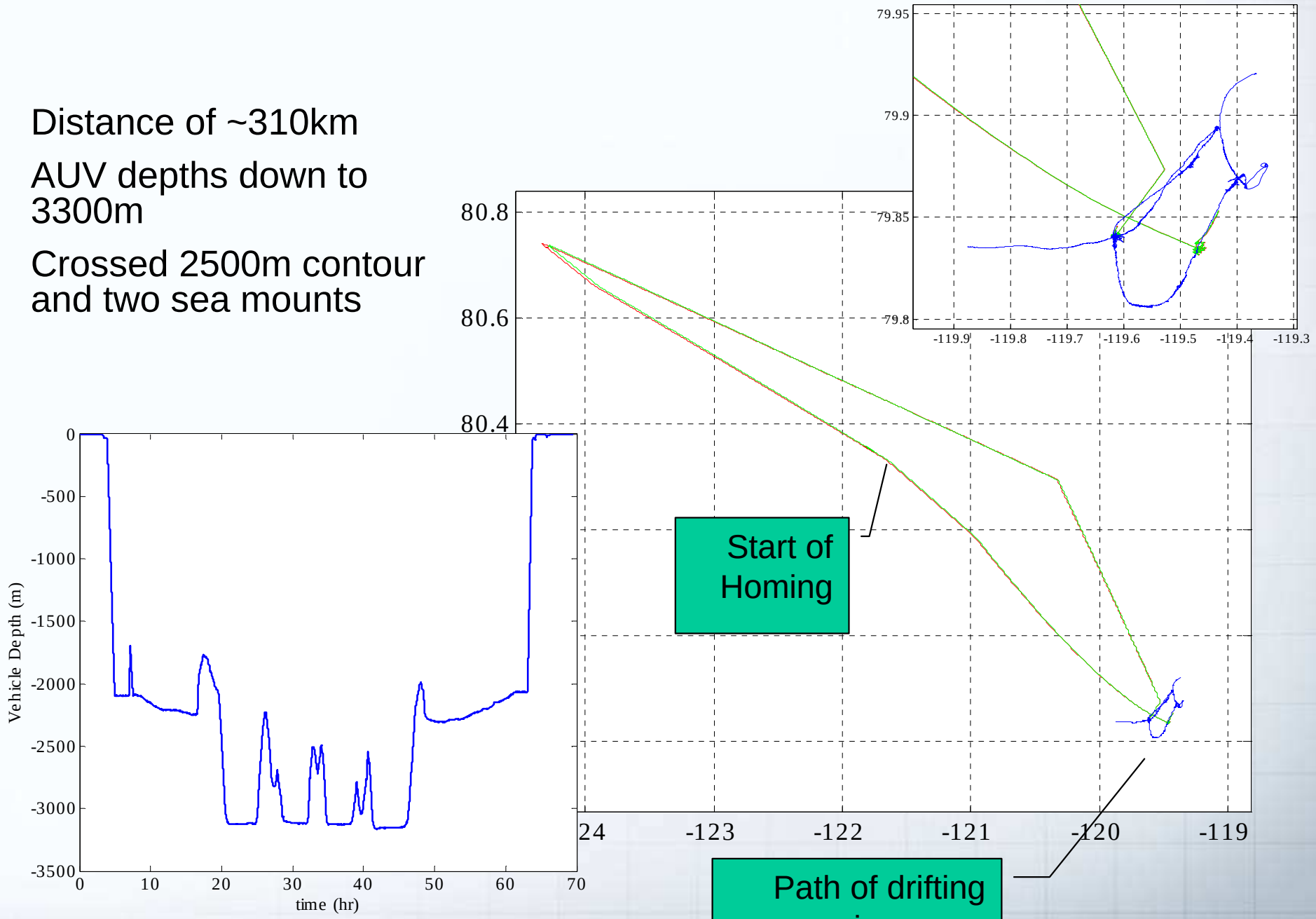


Transit to the Remote Camp



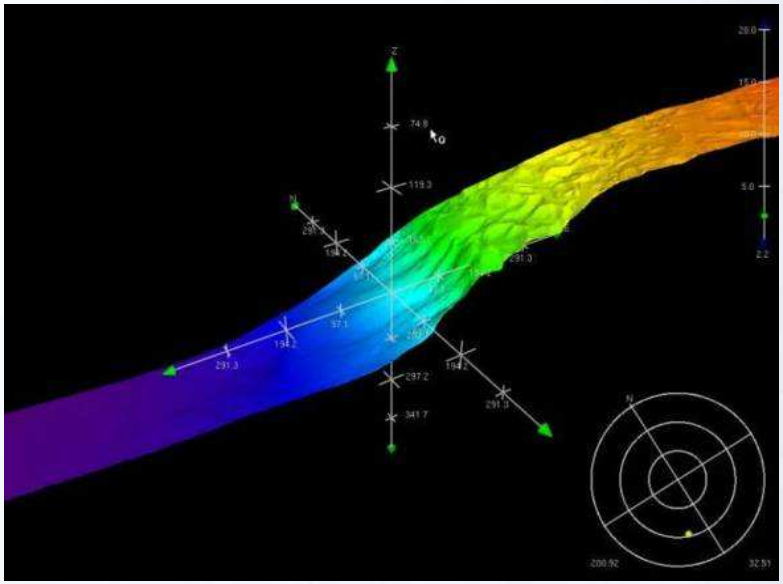
AUV Survey Mission

- Distance of ~310km
- AUV depths down to 3300m
- Crossed 2500m contour and two sea mounts

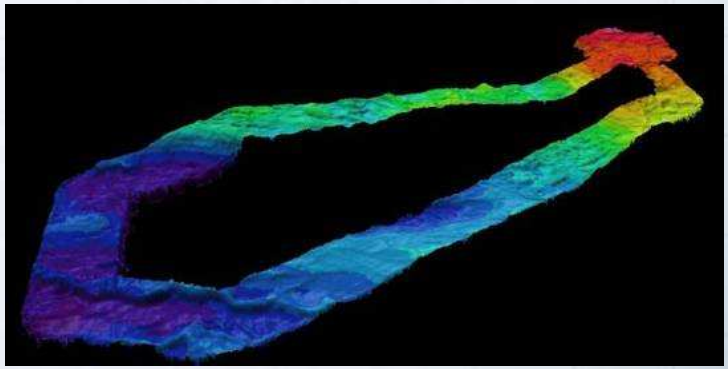


Survey Data Results

- Single-beam Sonar
  - Primary sensor, on for all missions
  - Data quality excellent
- Multi-beam Sonar
  - Secondary sensor
  - turned off for most transit missions to reduce power budget
  - Data quality good
- Positional Accuracy
  - Acceptable,
  - Correction factors for along track and cross track nav error have been estimated
    - Currently post processing survey data with these correction factors
    - positional accuracy can be significantly improved



Multi-beam Data From Portion of Transit Mission



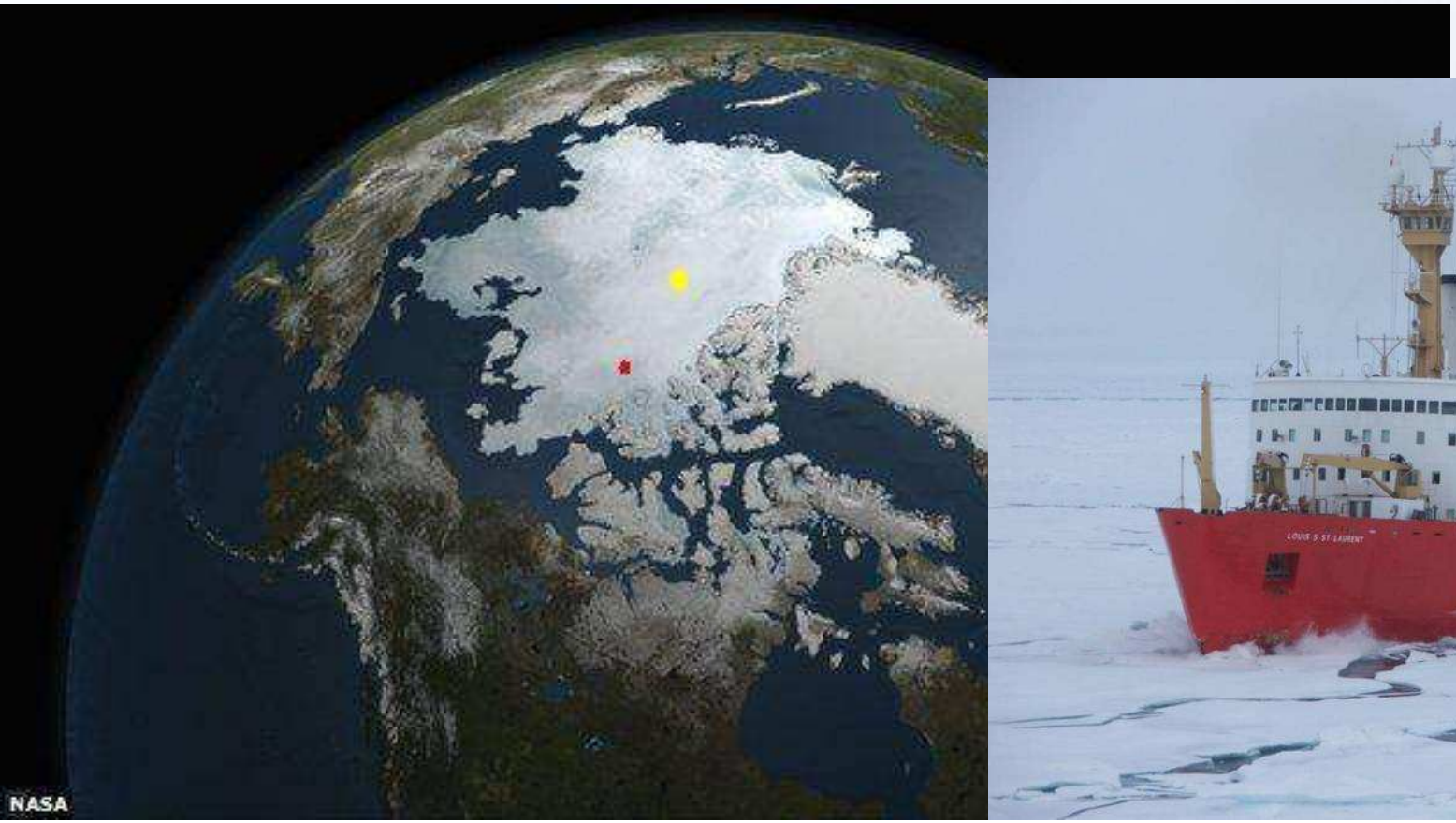
Multi-beam Data From Test Mission

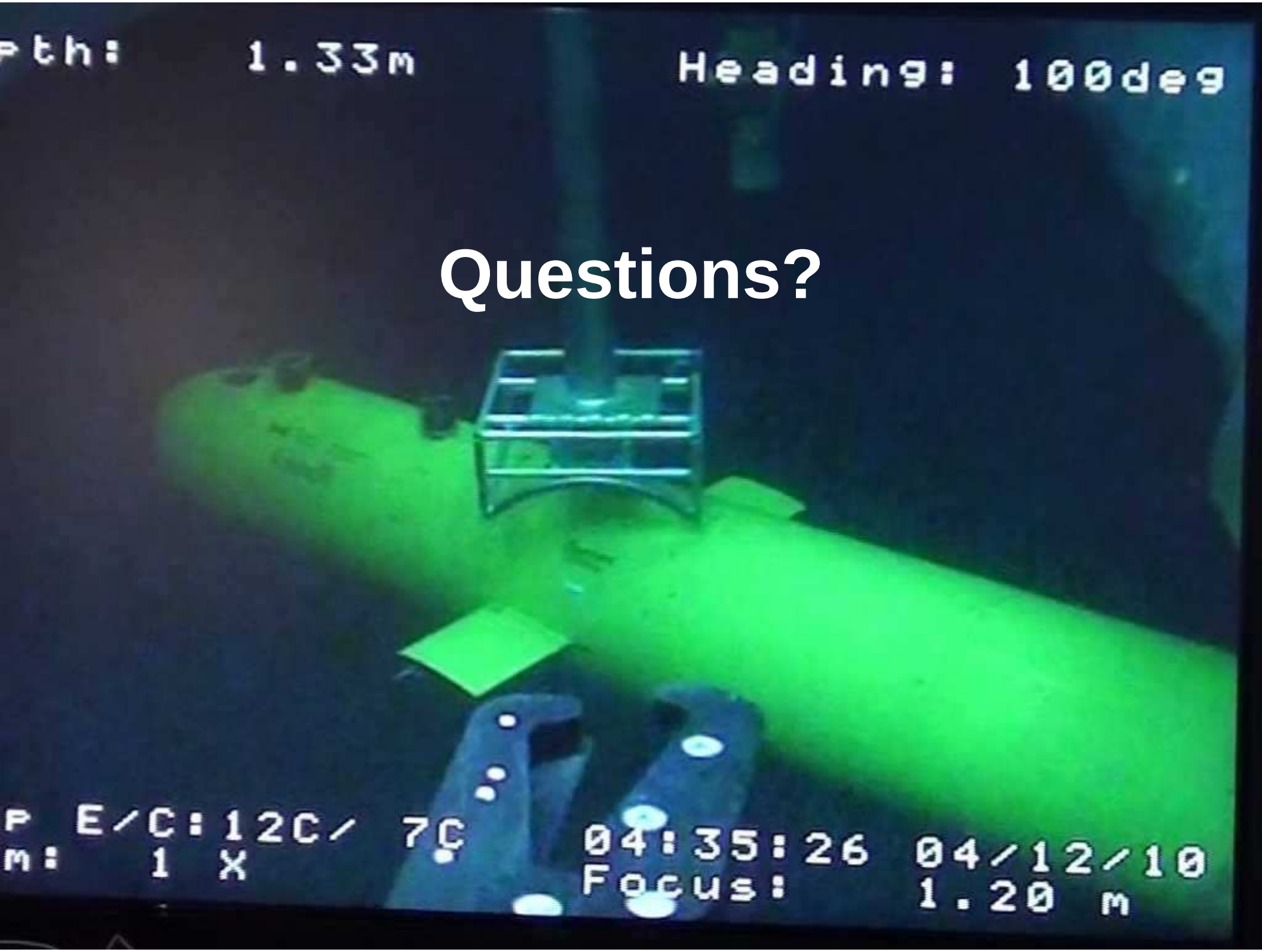
Results

- AUV conducted three surveys
- AUV reached depths under ice of 3300m
- AUV broke new ground in:
  - Endurance under ice (distances of ~300km/mission, over 1000km total)
  - Continuous in water operations (Apr 12 – 21; 10 days)
  - Repeated homing to moving ice camp
  - In water battery recharging
- Significant camp setup delays due to weather reduced the scope of the 2010 operation to one AUV
- Logistics for transportation, setup and operation of the AUV proven in the Arctic
- The successes and lessons learned from the 2010 season will provide an excellent basis for the 2011 season

2011 Arctic Survey Mission

- Area of interest very far North (yellow area)
  - *(red area survey area 2010)*
- Ice conditions too risky for an ice camp
- Long distant for aircraft
- Deploy AUVs from an ice breaker in Summer/Fall 2011

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The 2010 Arctic Survey Team

AUV under way on outbound Transit

Canada's Submission

- In 2004, the Federal budget allocated $69 million for Canada to carry out the mapping required to determine the outer limits of its continental shelf. This aimed to secure international recognition of the area where Canada has sovereign rights to explore and exploit natural resources of the seabed and subsoil of the continental shelf beyond our EEZ.
- In 2008, an additional $40 million over four years was provided by the Government of Canada for data collection and legal work to enable Canada to present an effective submission to the UN Commission on the Limits of the Continental Shelf.
- The mapping in which Canada is currently engaged is a legally-established, orderly process. When this process is finished, the Commission will review Canada’s submission and make recommendations regarding the outer limit.
- Canada will then establish the final and binding limits of its continental shelf on the basis of the Commission’s recommendations. It is important to note however that only the coastal state can establish the limits of its continental shelf.