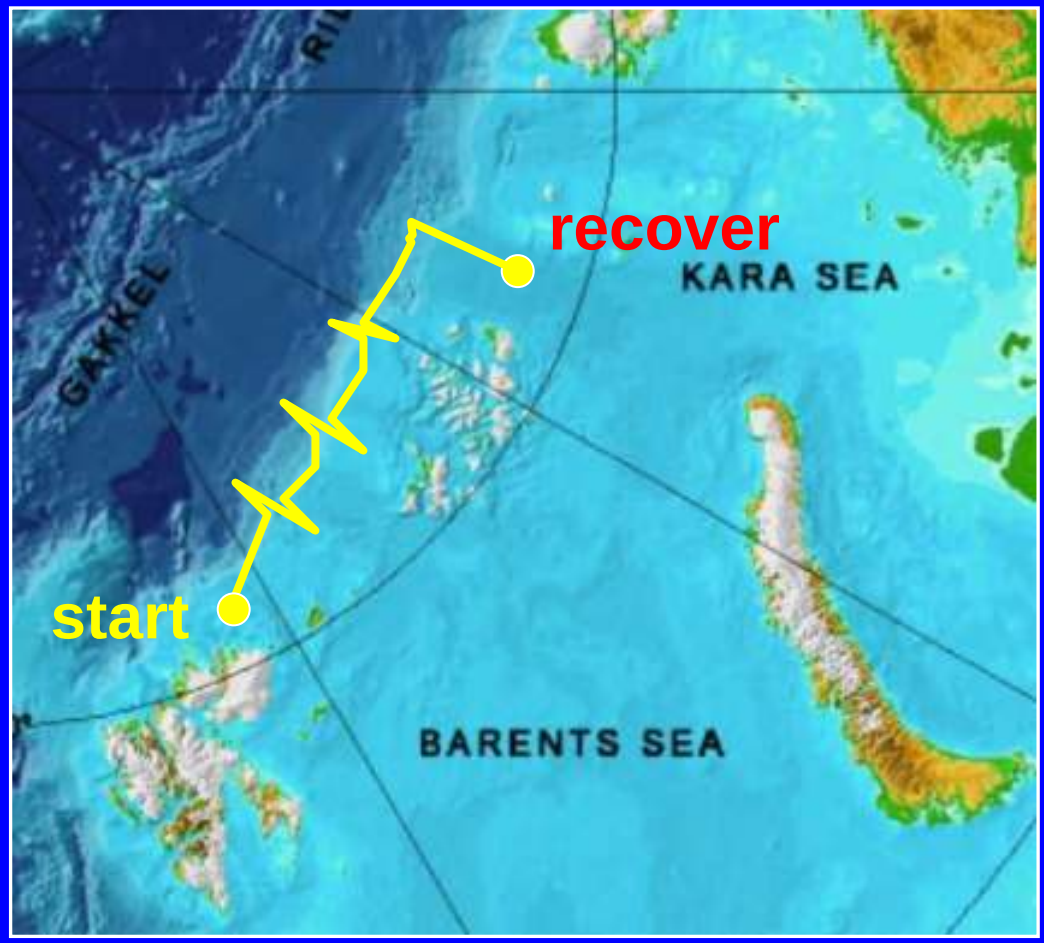
MBARI AUV Experiences

Hans Thomas
MBARI

NOC/AUV Masterclass
3/29/2006

Basic Mission Concept

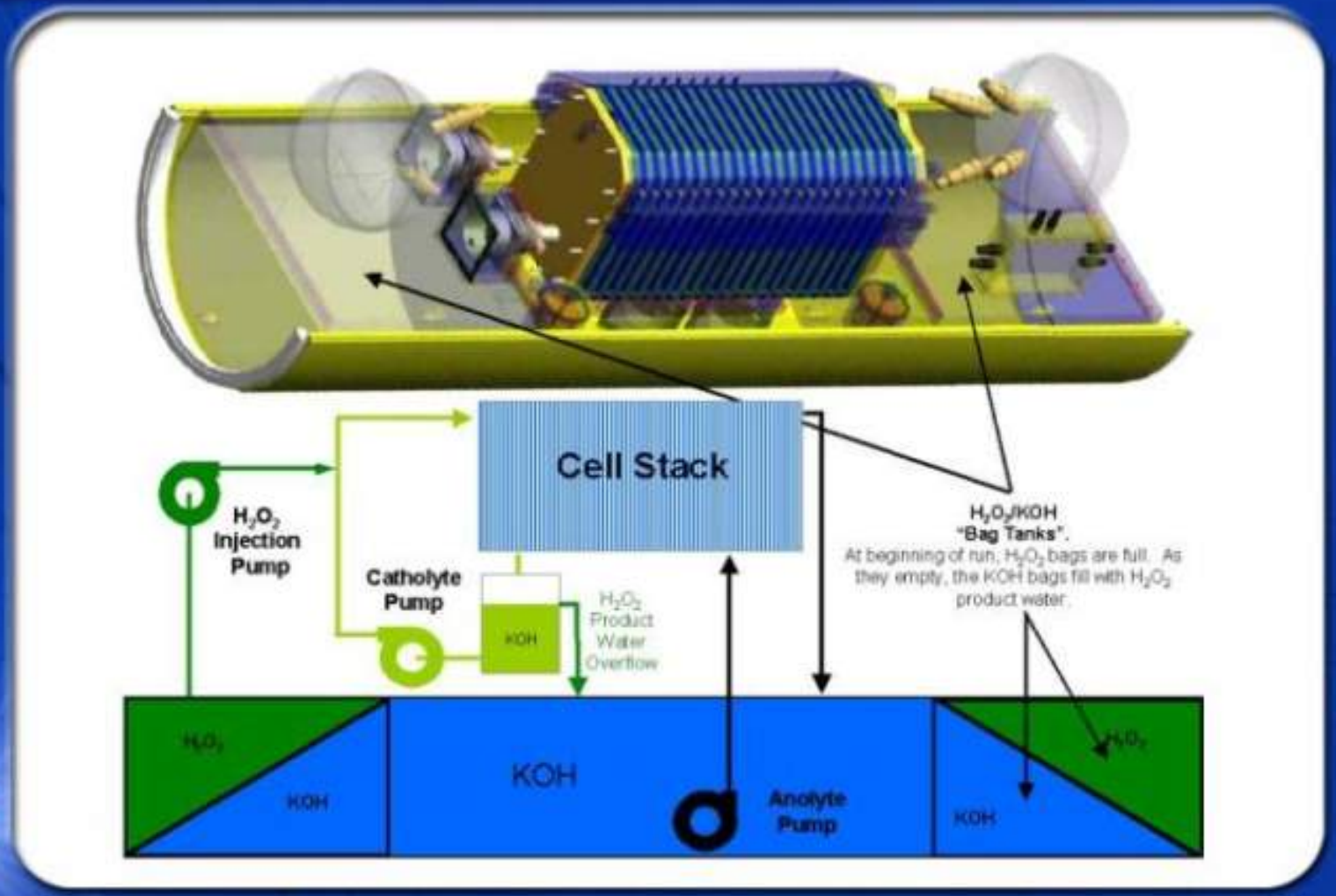


- Atlantic Layer Tracking Experiment
- Follow 1500m isobath from Svalbard east for 10 days (1000km)
- Yo-yo between 200 and 600 meters
- North-south excursions every third day
- Descend to 1100 meters once per day
- Ascend to 50 meters, launch data buoy once per day
- Engineering Mission Fall 2001

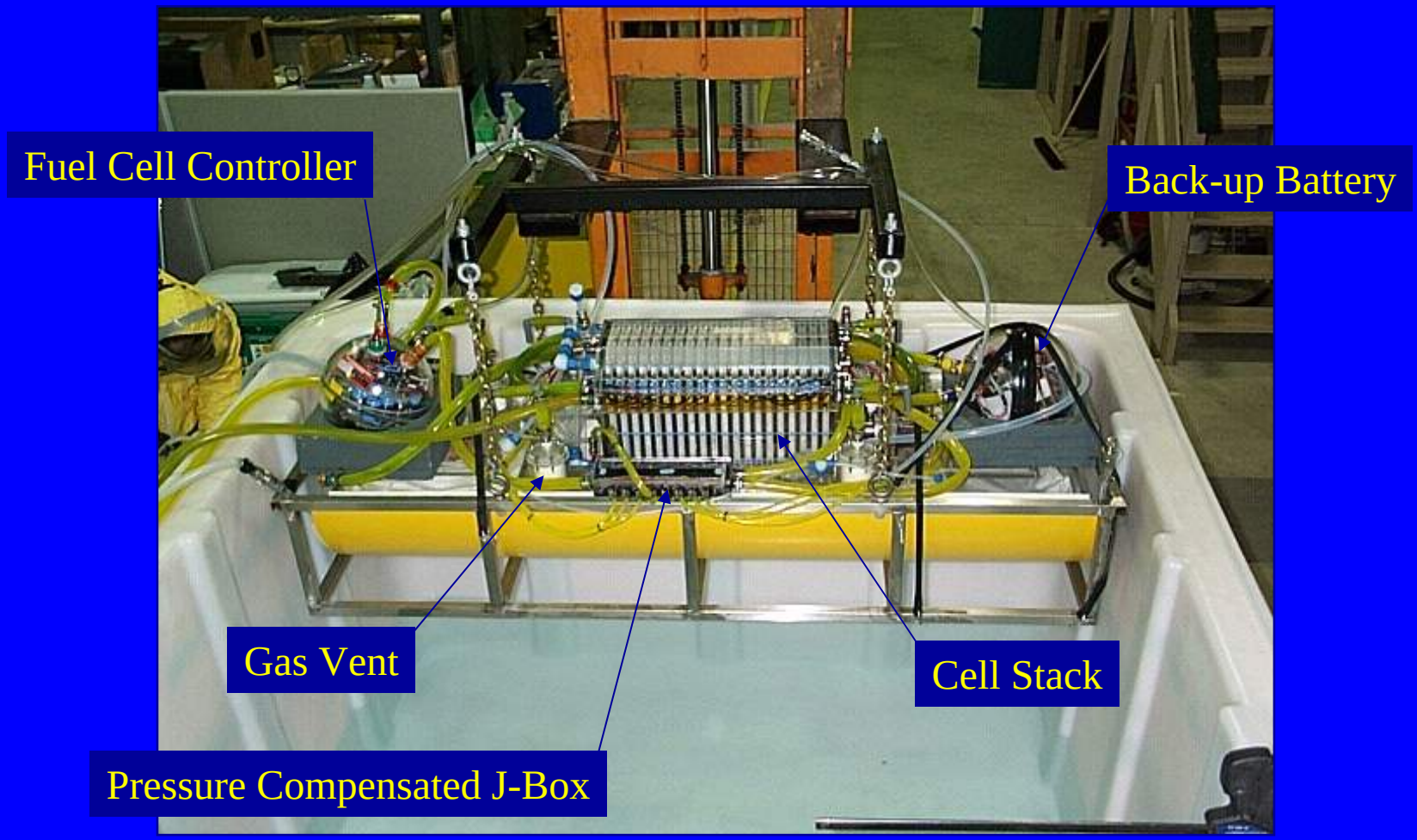
Map credit:
http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/provisionalmap.html

ALTEX Vehicle Configuration

ALTEX - Energy System Overview



Pressure Tolerant Semi-Fuel cell in pool tests




FUEL CELL
TECHNOLOGIES LTD.

FCT Developments 2001 thru 2002

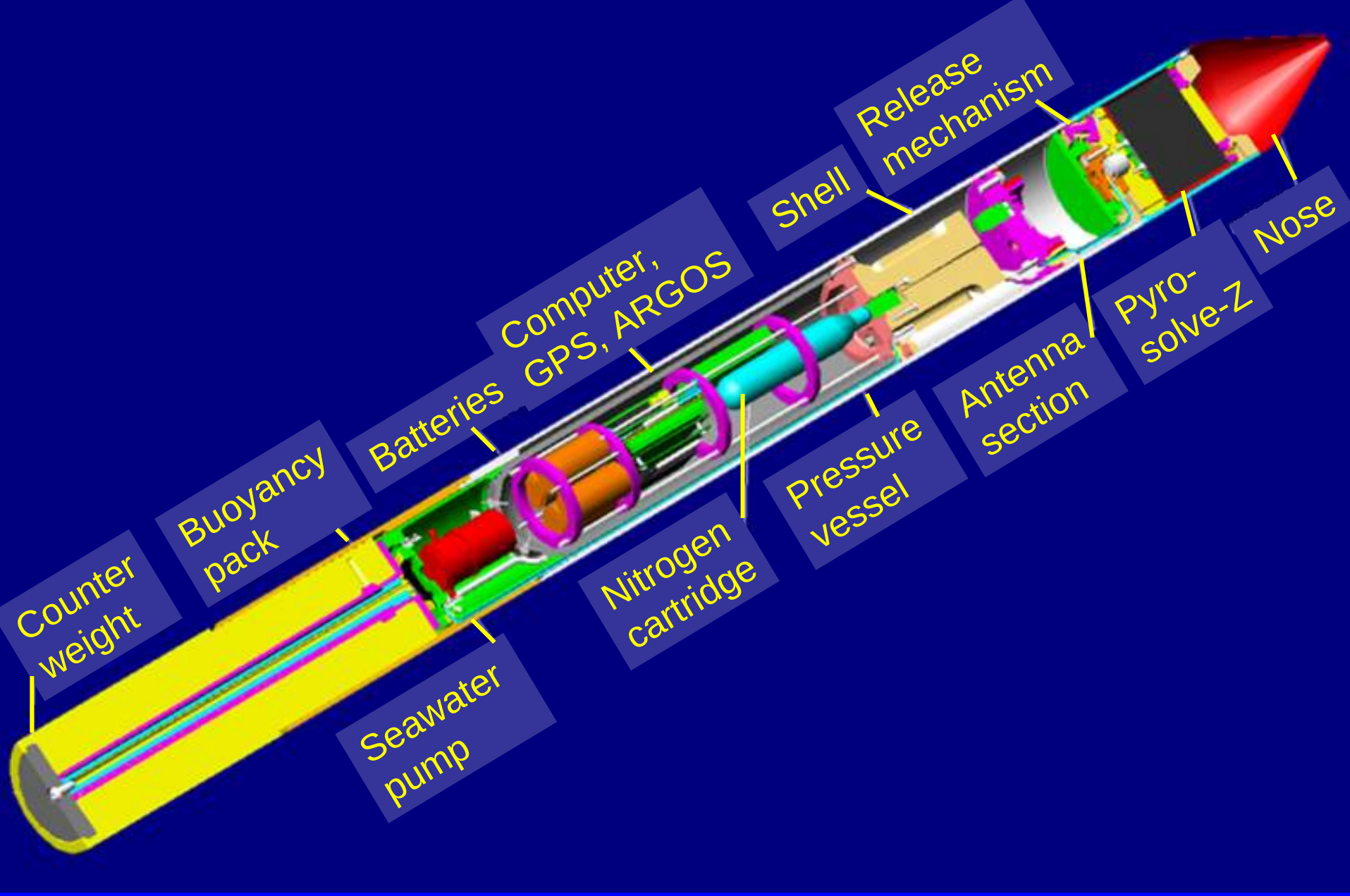
DIR Stack

Re-Worked ALTEX Stack

363W on 4 Cells

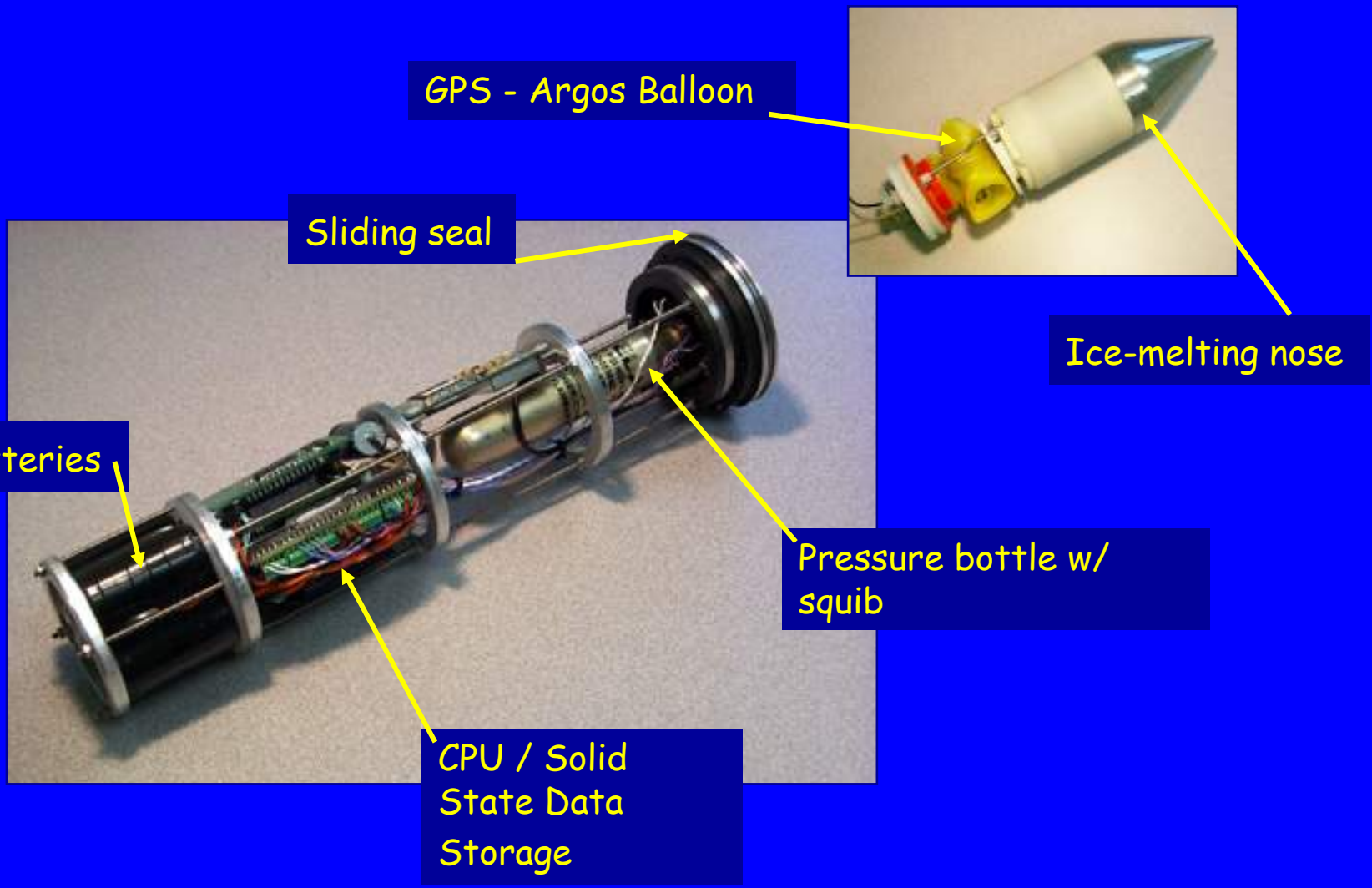
Anode Utilization

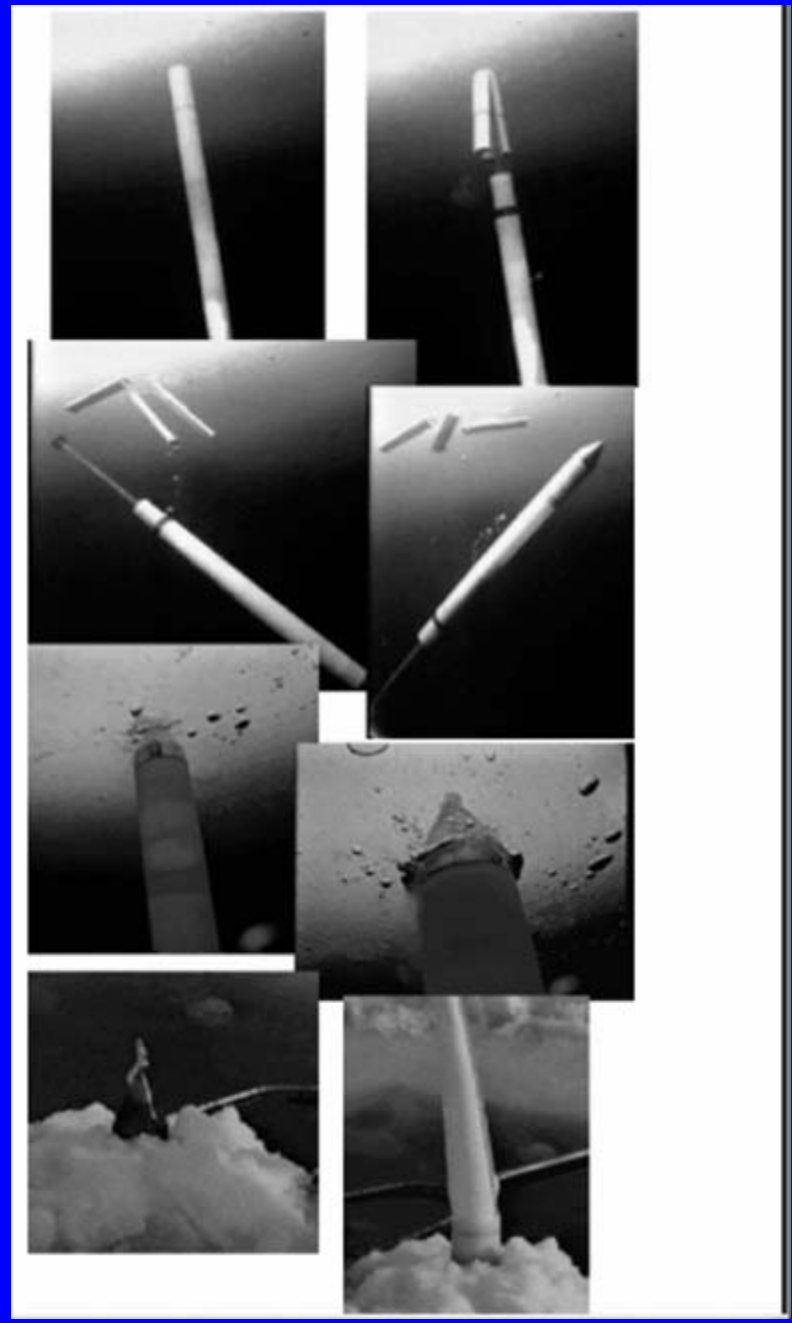
- Subsequent redesign efforts supported by Canadian Defence Dept and internal funding
- Cell frame redesign to reduce costs, increase performance & reliability, and eliminate stack leakage
- Increase Volumetric Energy Density from 1200 to 1600 Whr/liter(33%)
- Increase Gravimetric Energy Density from 1000 to 1400 Whr/kg (40%)
- Increase of maximum current density by 84%
- Anode Efficiencies up to 92%
- H_2O_2 Efficiencies up to 79%



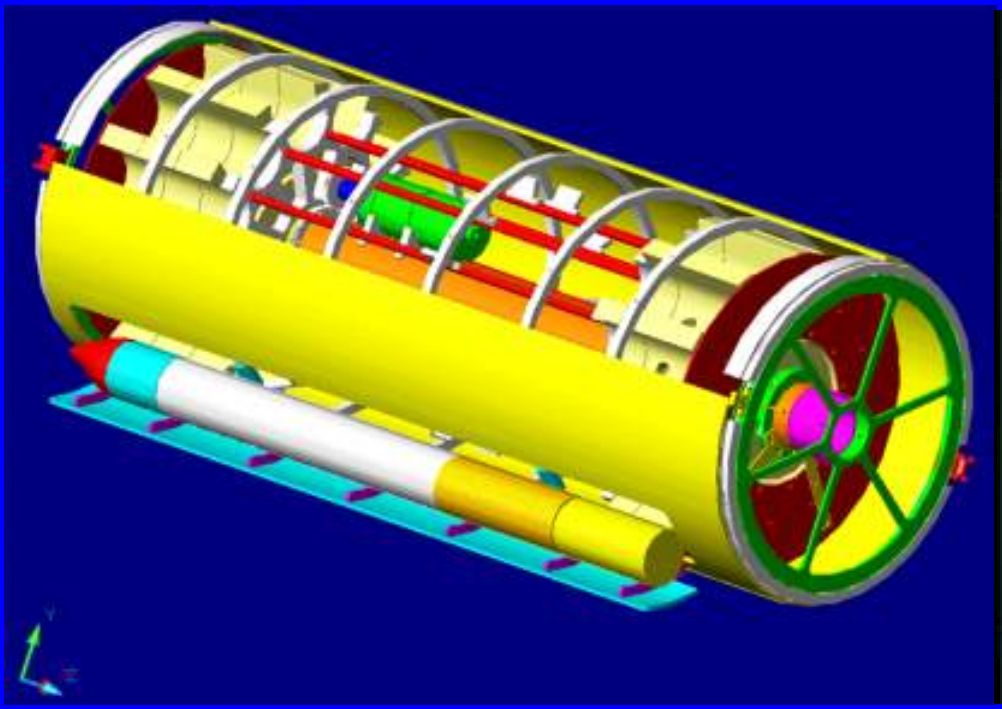
Ice Penetrating Data Buoy

Ice Penetrating Data Buoy





Buoy Launcher

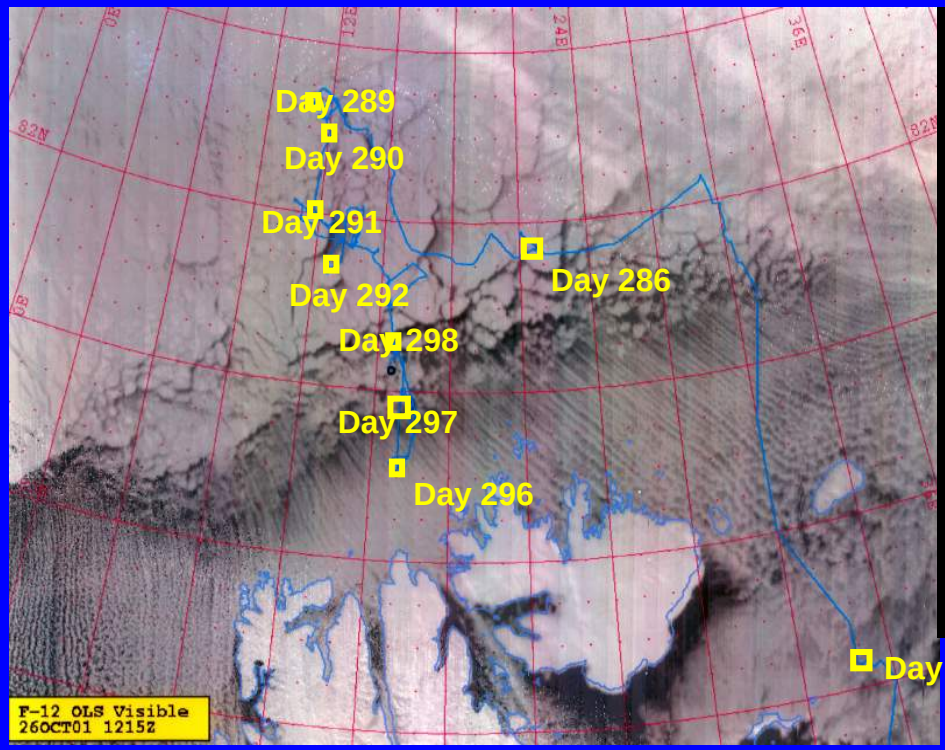


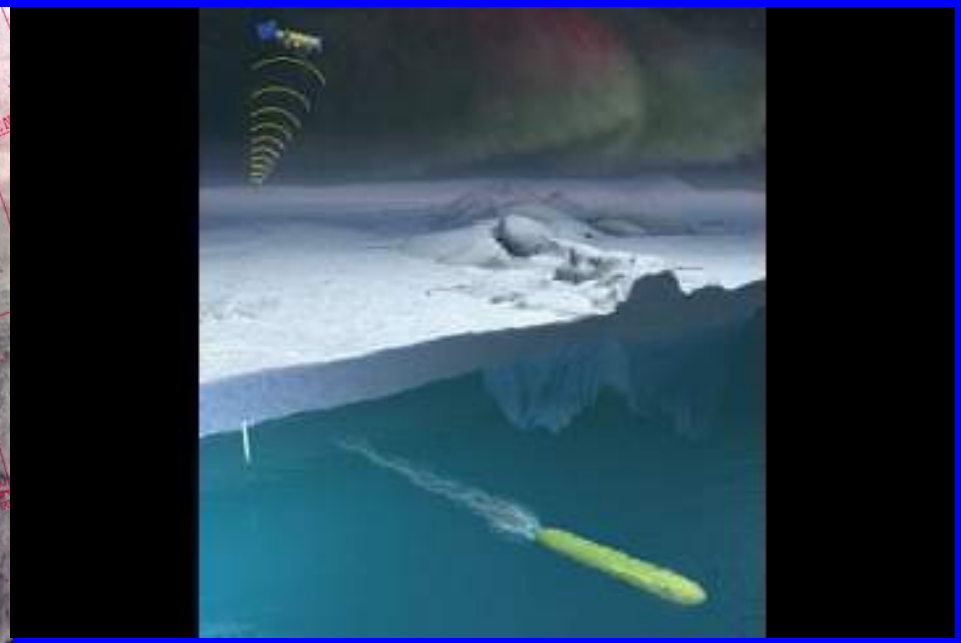
- Hold up to 12 buoys
- Transformer Coupled link for data transfer
- Magnetic switches to confirm ejection and encode rotation

High Latitude Navigation

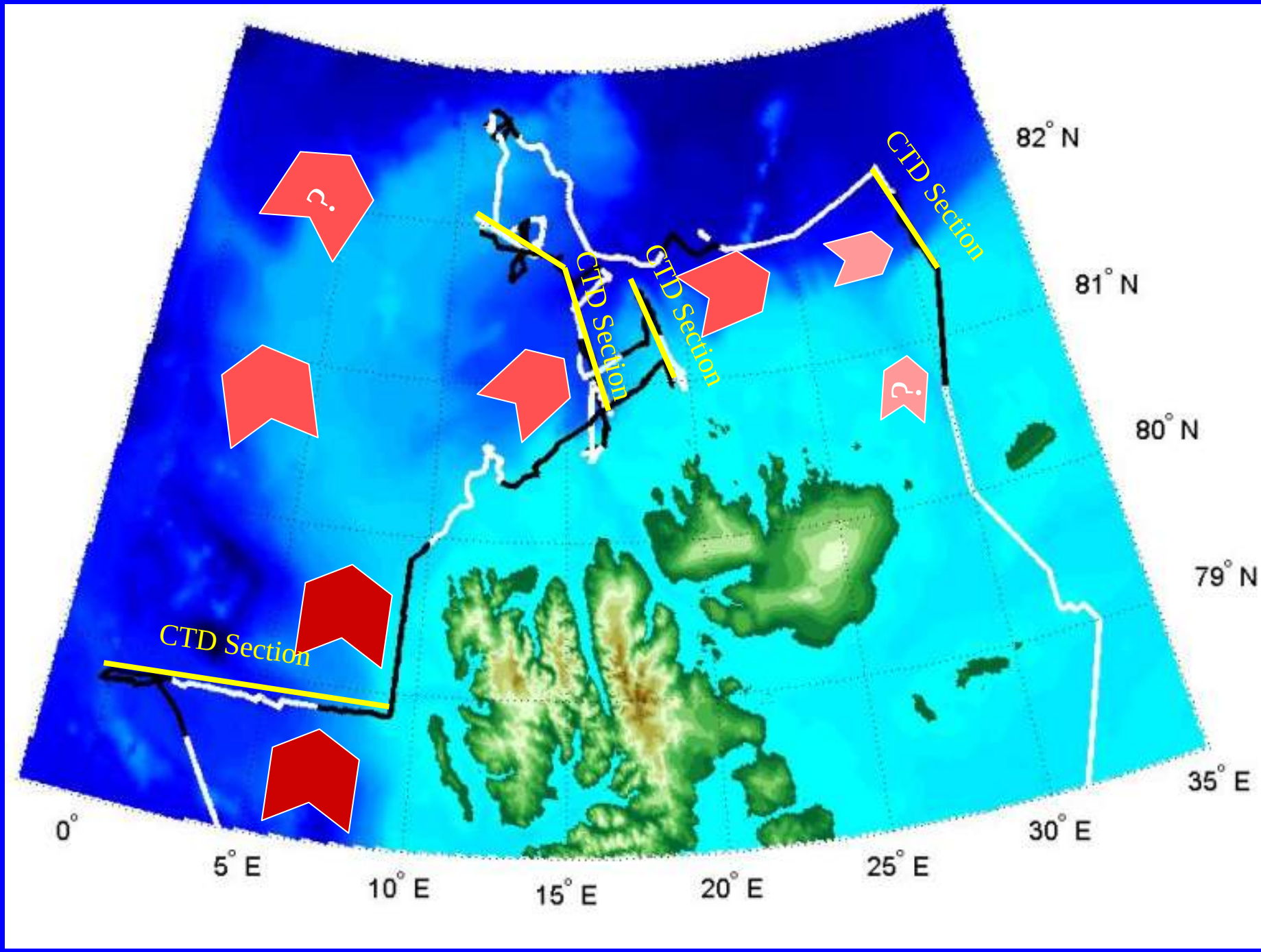
- Multiple systems tested
  - Kearfott RLG
  - IXSEA Octans FOG
  - Litton LN250 IFOG
- Kearfott INS/DVL/GPS SeaDevil
  - Ring Laser Gyro INS
  - 300 kHz Doppler Velocity Log
    - Altitude and velocity over bottom
  - GPS at surface
  - Kalman filter combines INS, DVL, and GPS
    - Estimates biases and drifts for each instrument
  - Accuracy (Real-Time):
    - .05% Distance Traveled CEPR w/ DVL bottom track
    - .5 to 1 km/hr free inertial drift (observed)

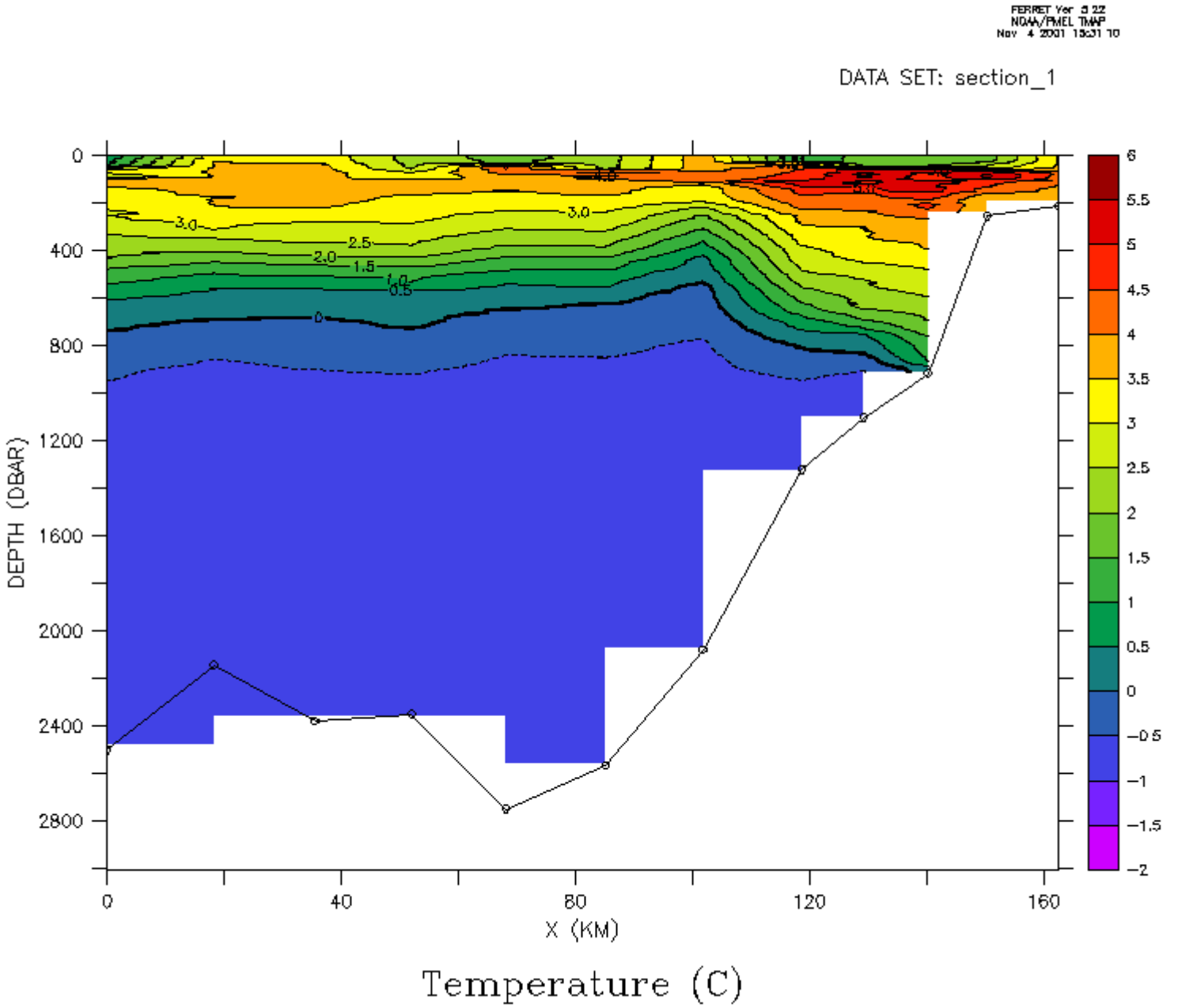
ALTEX AUV Operational Areas

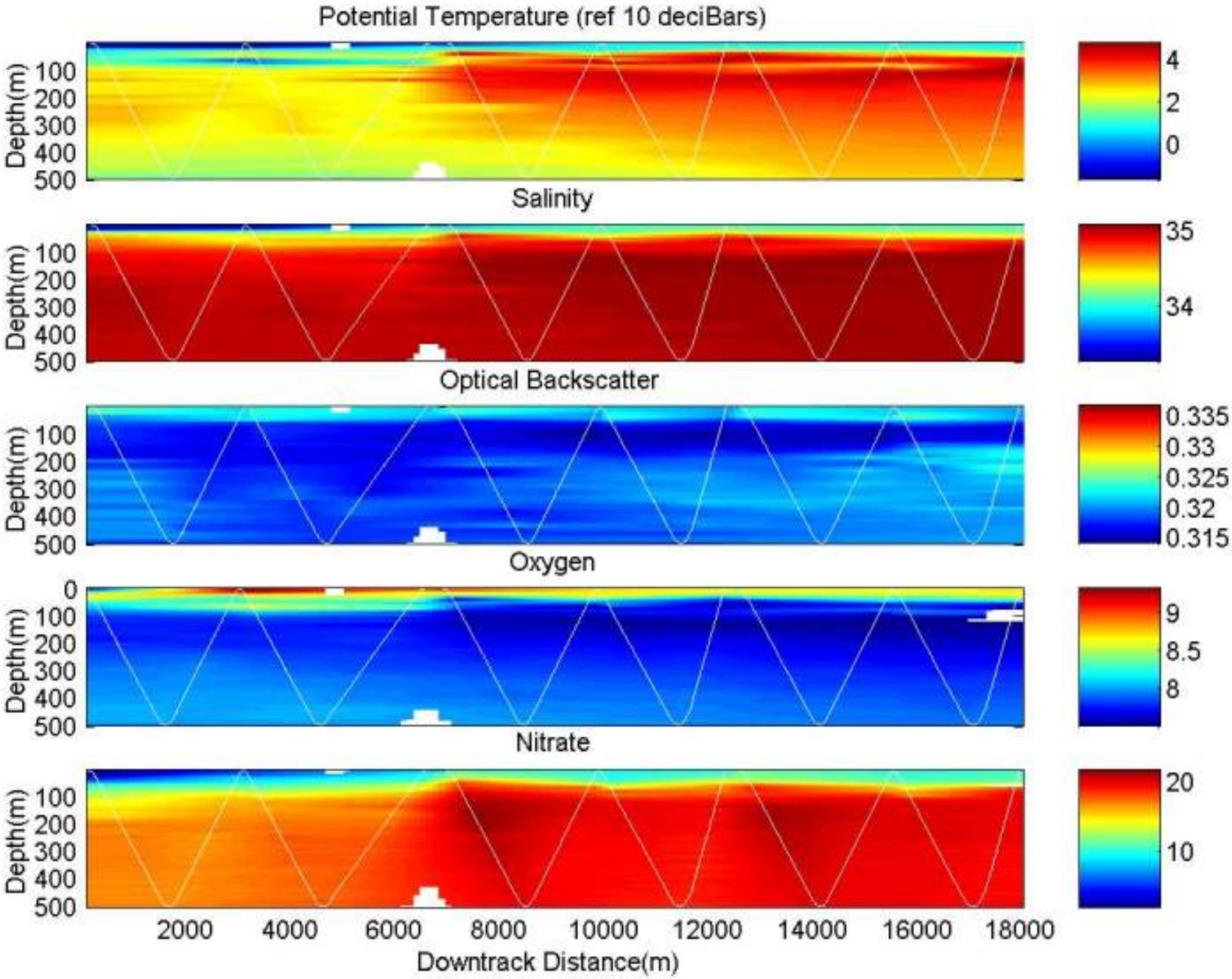




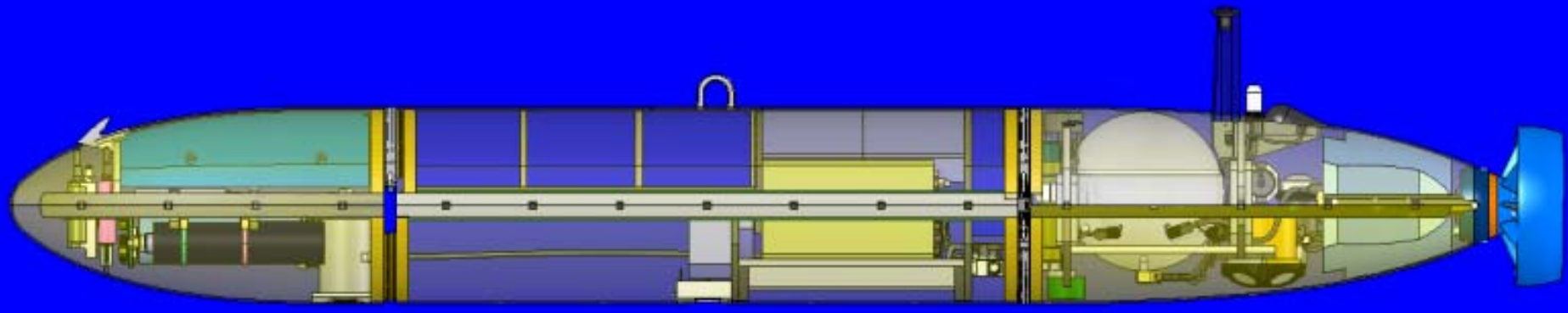
- 30 Day Cruise onboard USCG Healy
- Joint cruise with science team from National Ice Center/NRL/JPL (Son Nghiem, JPL PI)


CTD Section
CTD Section
CTD Section
CTD Section
CTD Section
82° N
81° N
80° N
79° N
35° E
30° E
25° E
20° E
15° E
10° E
5° E
0°

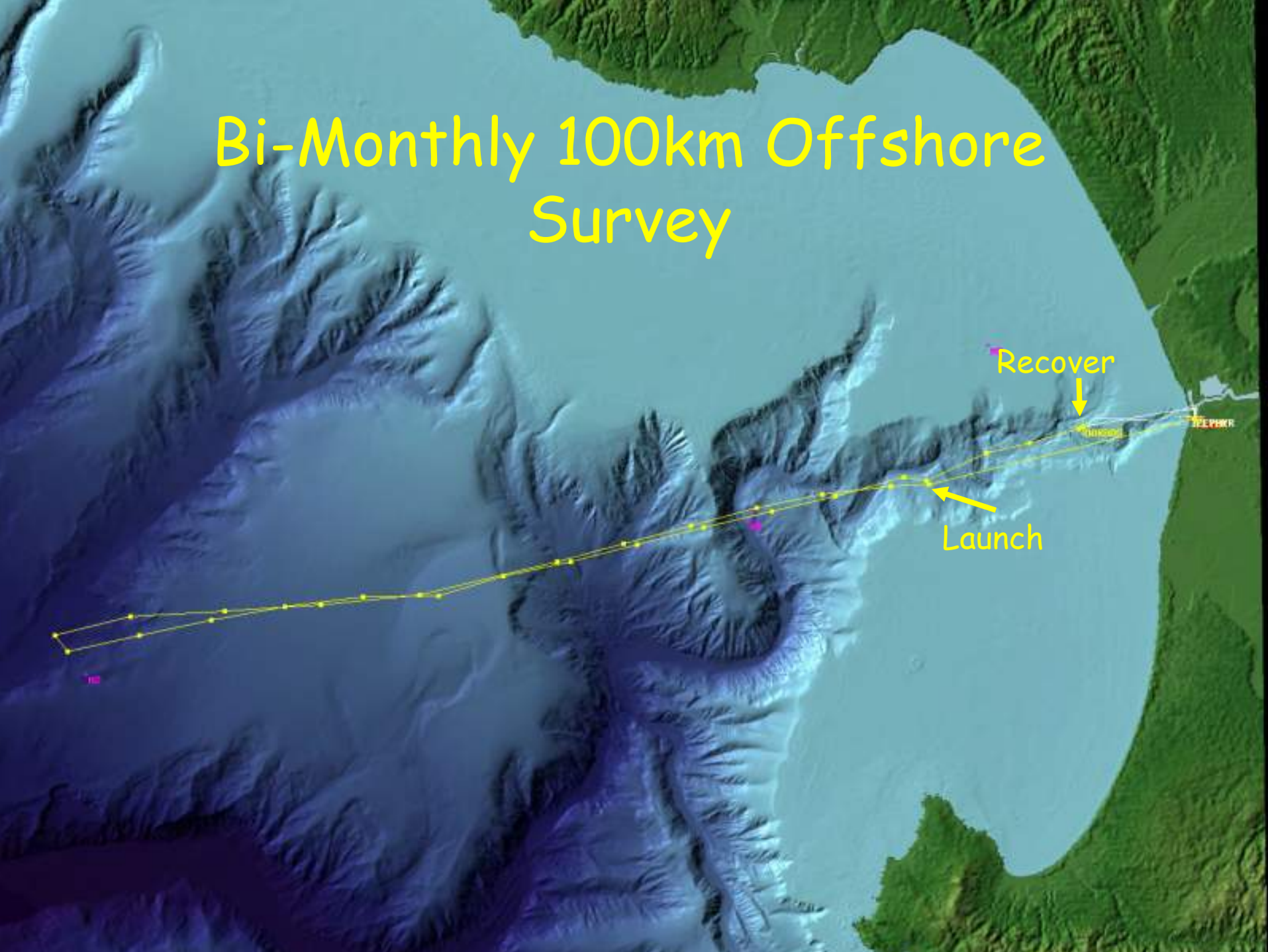

FERRET Ver. 6.22
NOAA/PMEL TMAP
Nov 4 2001 15:31:10
DATA SET: section_1
DEPTH (DBAR)
0
400
800
1200
1600
2000
2400
2800
X (KM)
0
40
80
120
160
3.0
2.5
2.0
1.5
1.0
0.5
0
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
Temperature (C)

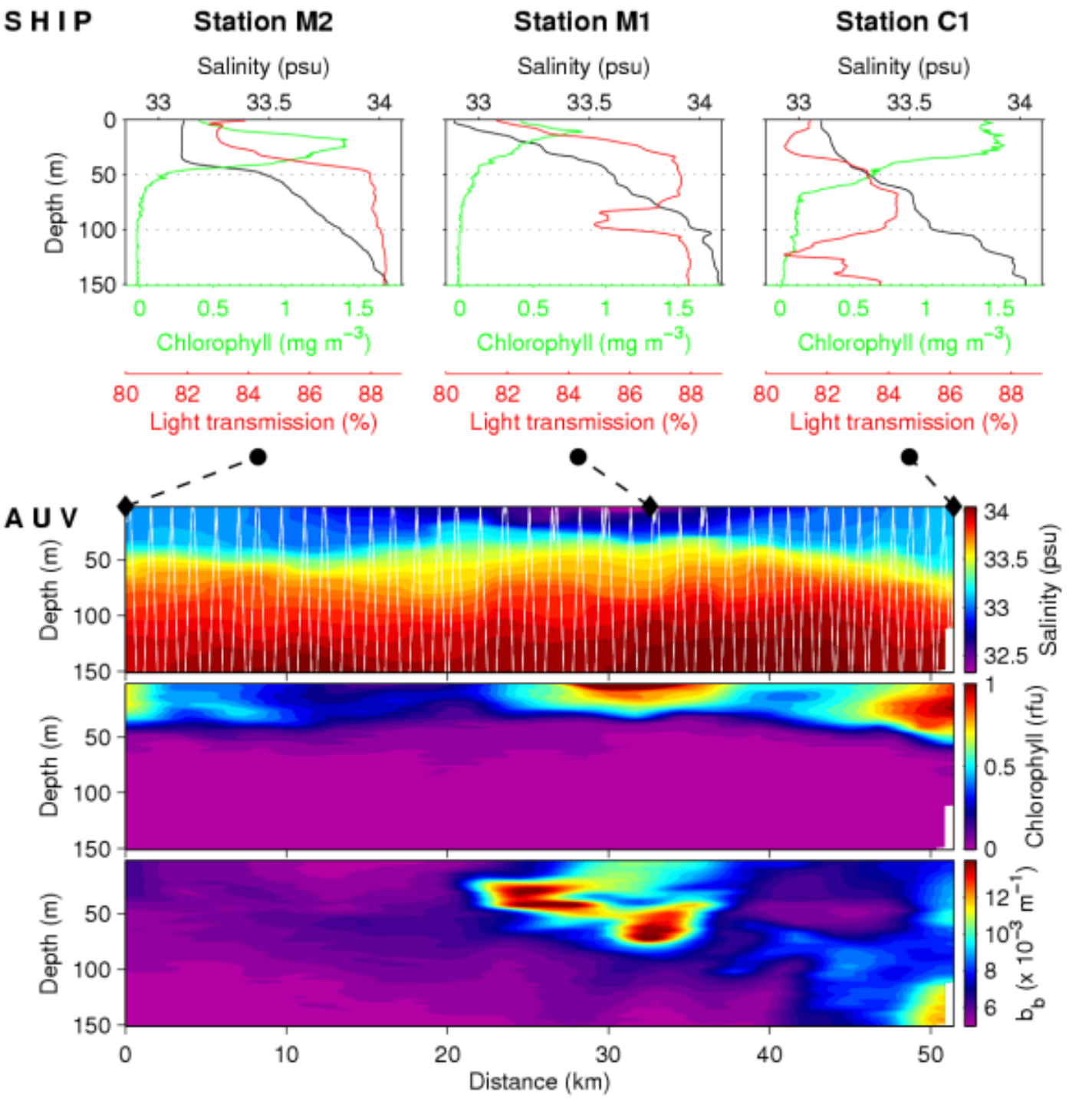

Potential Temperature (ref 10 deciBars)
Depth(m)
100
200
300
400
500
4
2
0
Salinity
35
34
Optical Backscatter
0.335
0.33
0.325
0.32
0.315
Oxygen
0
9
8.5
8
Nitrate
20
10
2000
4000
6000
8000
10000
12000
14000
16000
18000
Downtrack Distance(m)

AUVCTD Vehicle

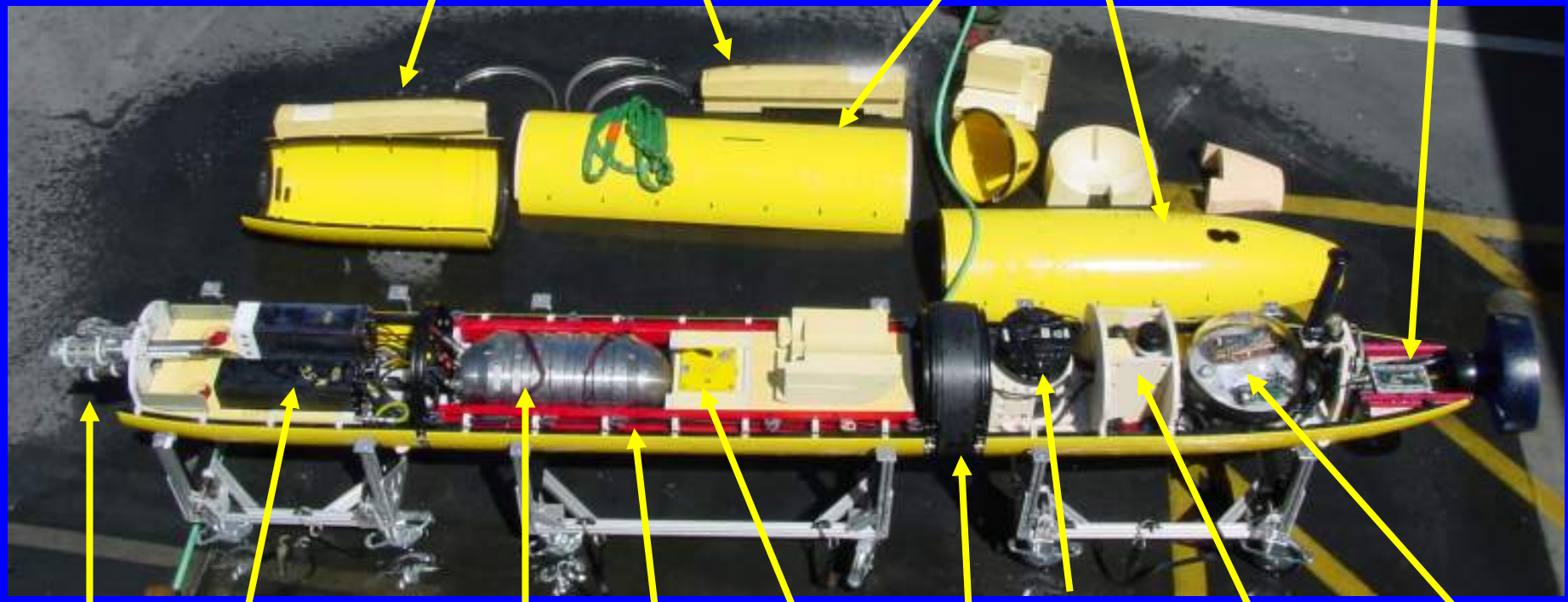


- 4500m Operational Depth (deepest dive 900m)
- 6 kW-Hr/20 Hour Endurance w/ 5 hr recharge
- Core Instruments (Nose)
  - 2 x SBE3/SBE4/SBE5 Pumped CT
  - 1 x SBE43 DO, 1x MBARI ISUS
  - Hobilabs HS2 Fluorescence/Backscatter
  - Networking & Data Acquisition Electronics
- Midbody
  - Large reserve volume/buoyancy for additional instruments
  - Current Payload
    - UCSB Bathyphotometer, Sequoia Scientific LISST-100


Bi-Monthly 100km Offshore Survey
Recover
Launch

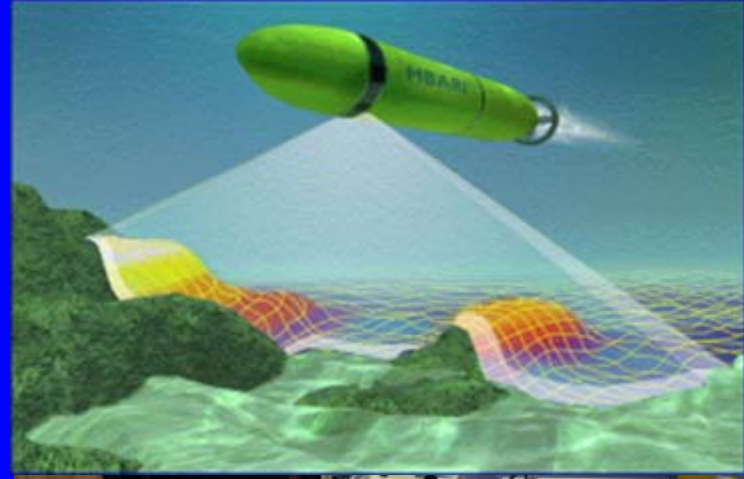

SHIP
Station M2
Station M1
Station C1
Salinity (psu)
33
33.5
34
Depth (m)
0
50
100
150
0
0.5
1
1.5
Chlorophyll (mg m^{-3})
80
82
84
86
88
Light transmission (%)
AUV
Depth (m)
Salinity (psu)
32.5
Chlorophyll (rfu)
b_b (x 10^{-3} m^{-1})
6
8
12
0
10
20
30
40
50
Distance (km)

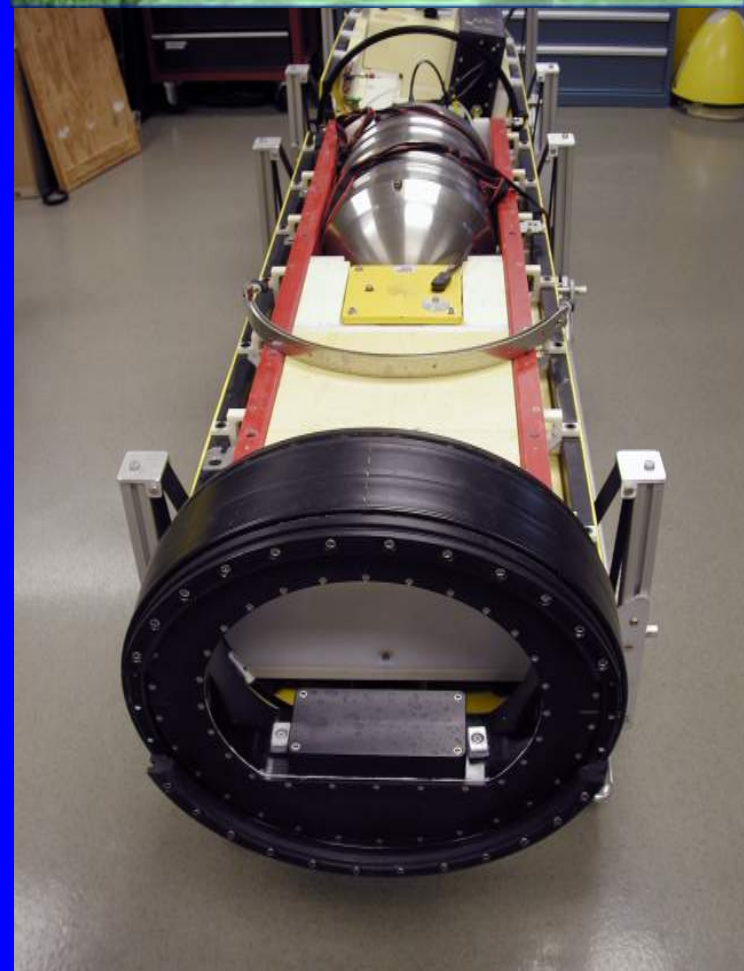
Interior of the Mapping AUV

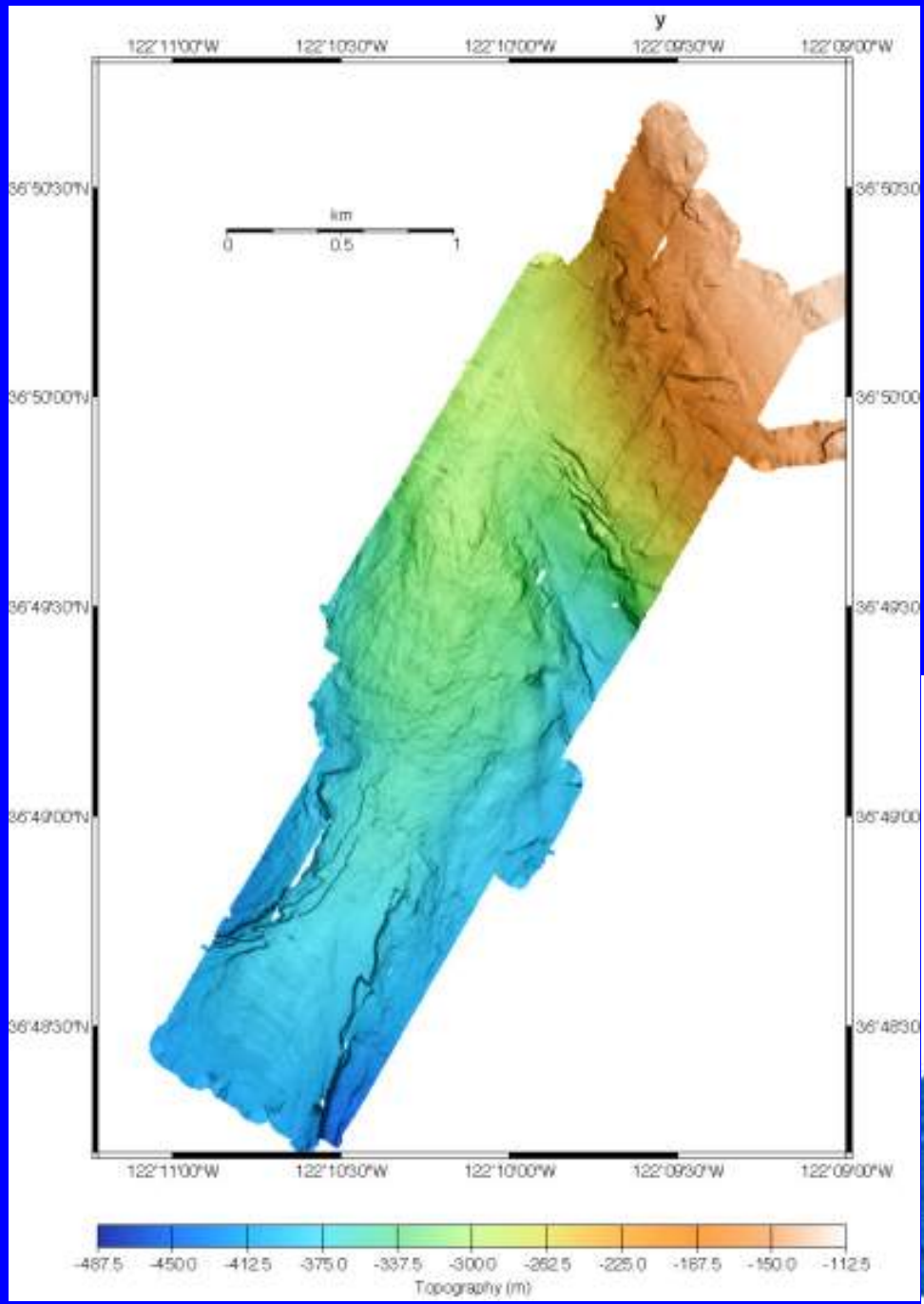


Sonar Payload

- Reson 7100 Multibeam Sonar
  - High resolution bathymetry data
  - 200 kHz
  - Circular receive array
    - Currently using 7125 model with flat receive array
  - 0.94 degree X 0.94 degree beams
  - 30 cm footprint at 20 m altitude
  - 1.5 m footprint at 100 m altitude
- Edgetech 110/410 khz chirp Sidescan Sonars
  - Images seafloor character & fine-scale features (~10 cm resolution)
- Edgetech 2-15 kHz chirp Subbottom Profiler
  - Images subsurface sediment structure

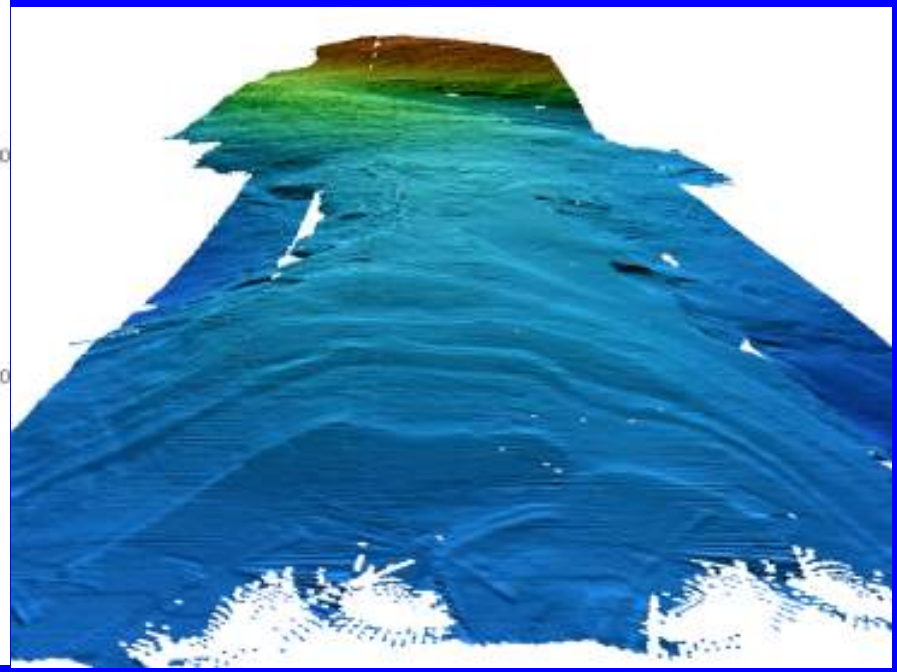






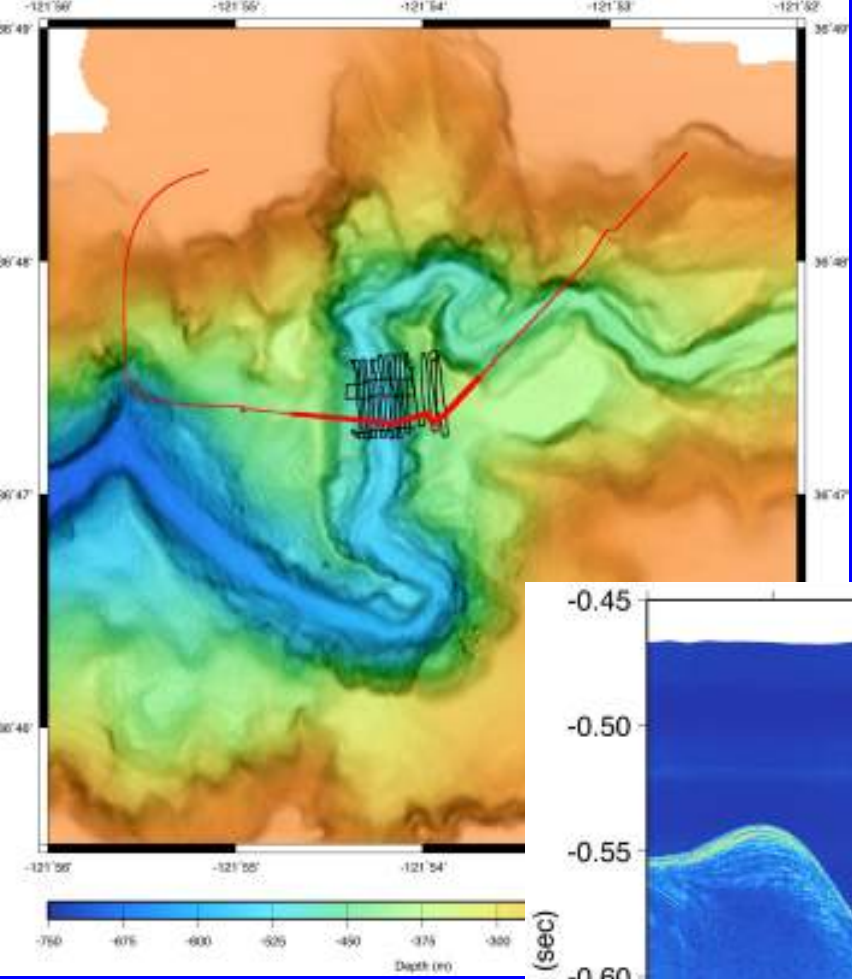
Smooth Ridge Neck Survey 11/19/2005

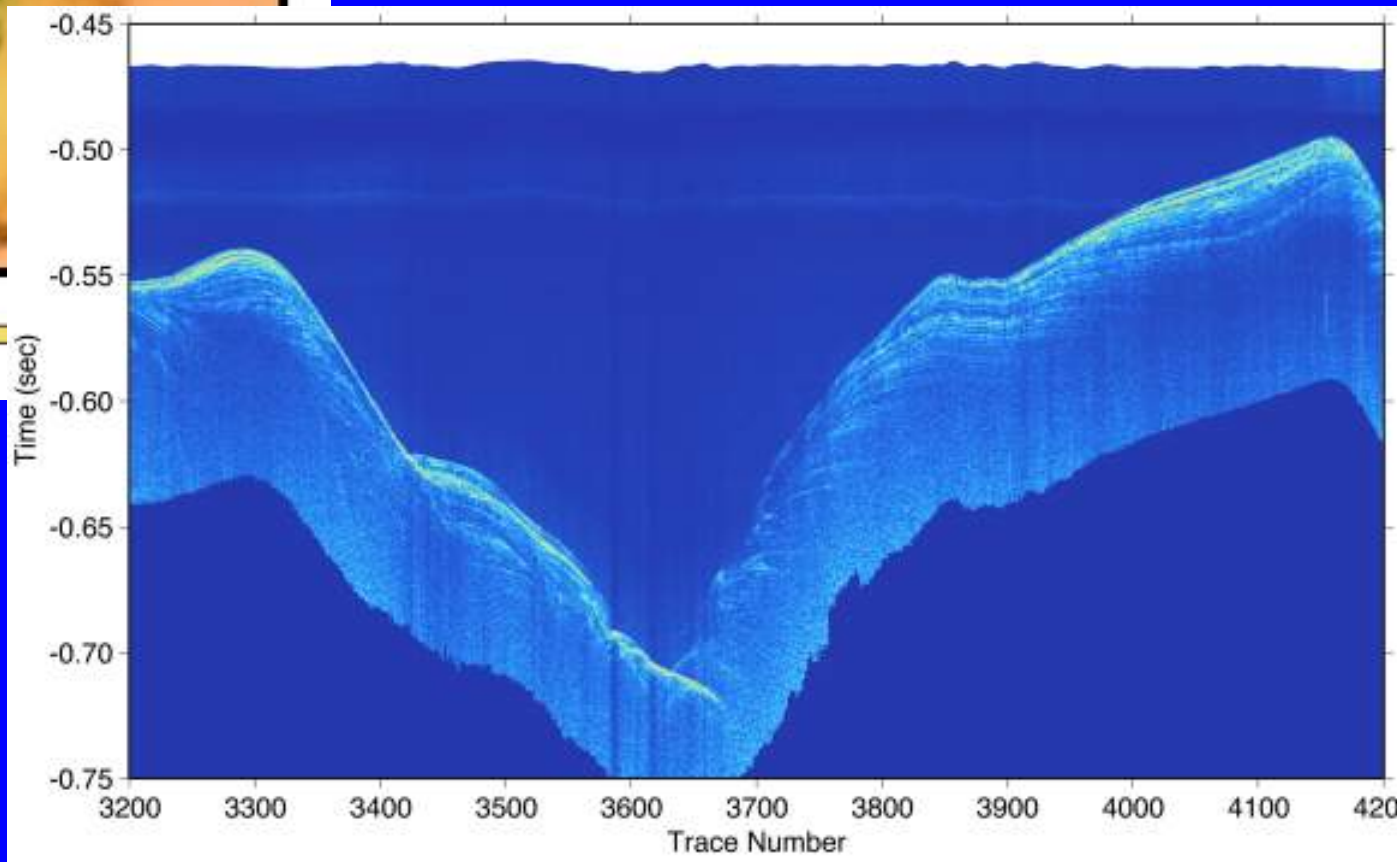
- 7.5 hour survey to 500m depth
- Imaged intruding canyon, slumping, and scarps along MARS cable route



Autonomous Survey Test

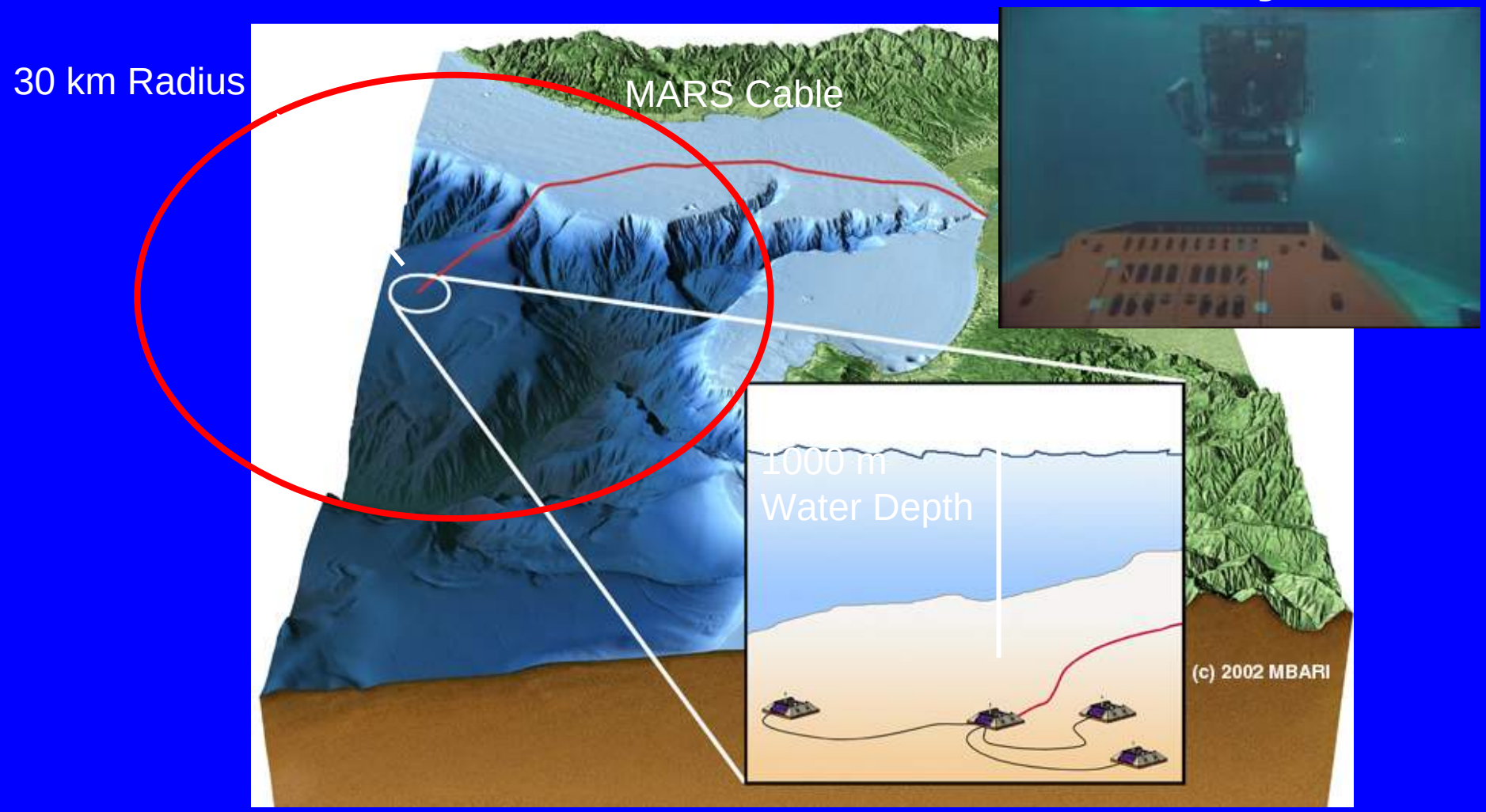
Line across the 520 m Repeat Mapping Site

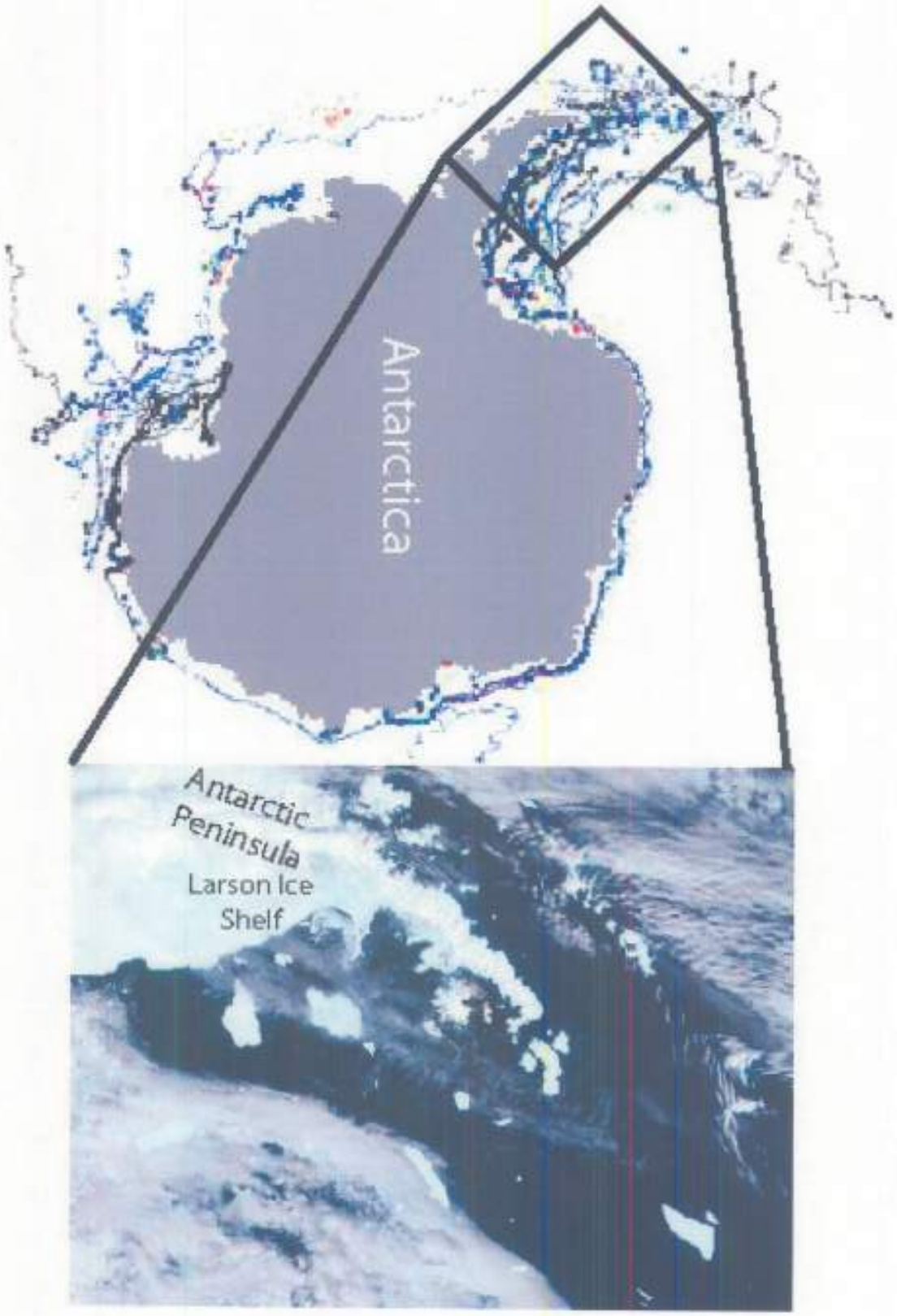


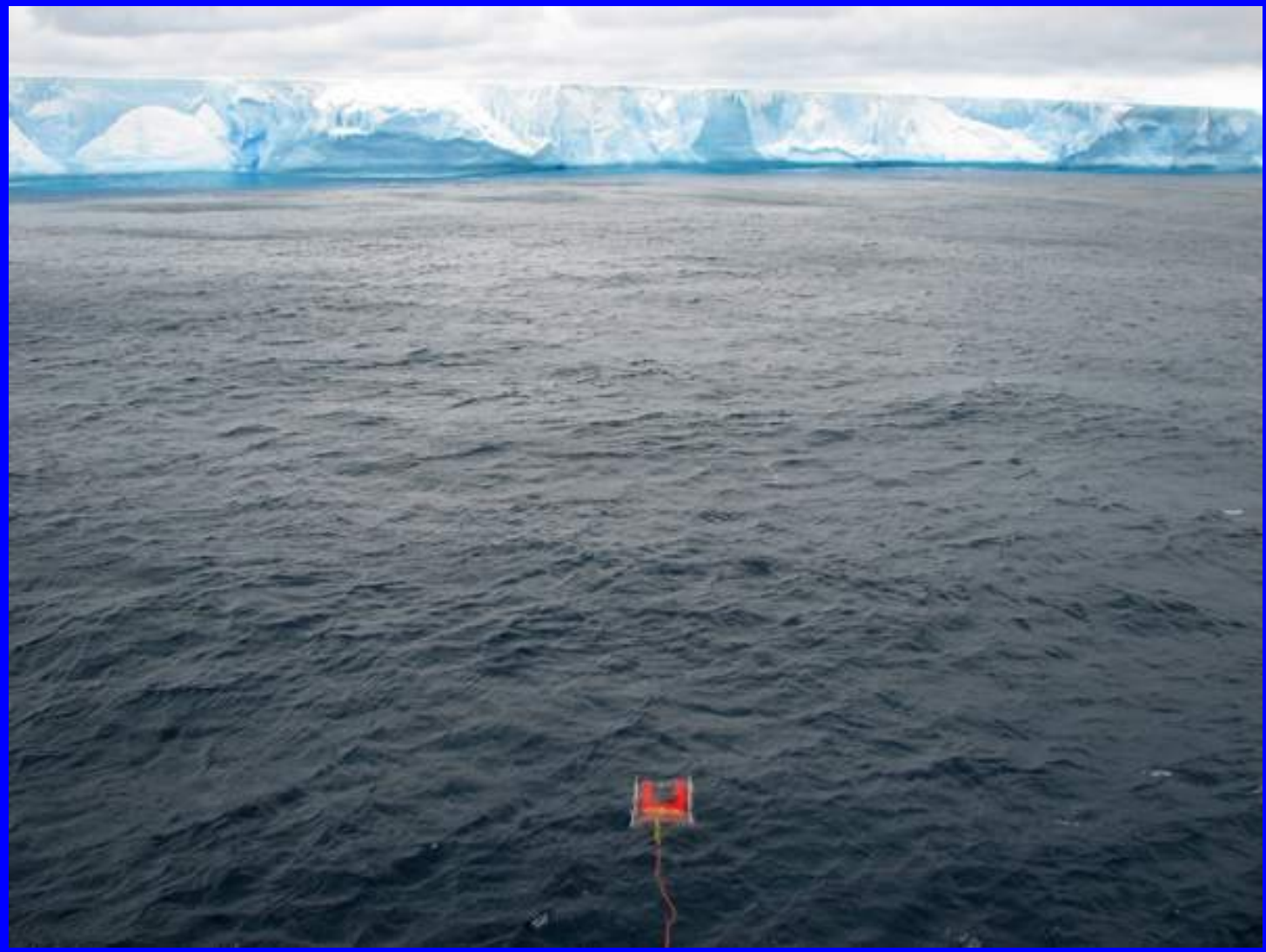


AUV Docking – ’07 Operations

MBARI’s MARS Cabled Observatory




Antarctica
Antarctic Peninsula
Larson Ice Shelf



Heading for A-52

Thick cover on a shoulder

ALTEX Team

- Scientific Solutions International (buoys)
- Fuel Cell Technologies LLC (fuel cell)
- MBARI (vehicle integration, navigation)
- NOAA Pacific Marine Env. Lab (science)
- United States Coast Guard

Conclusions

- AUVs becoming routine, commonplace and *preferred* tools for ocean science
  - High quality systems, subsystems, and instruments now commercially available
  - Long-term deployments in remote high latitude environments e.g. Labrador Sea, arctic, antarctic)
  - Gathering high-quality physical/biological/chemical datasets is a complex integration effort
- Major limitations
  - Energy – need higher performance low-rate systems, or better energy scavenging technology
  - Autonomy
    - current AUVs are limited in ability to react to evolving ocean processes (no deliberative planning/execution capacity in most systems)
    - Multi-vehicle survey is more energetically efficient, but requires high-level coordination & good ocean modeling to exploit