MBARI's AUV Technology

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Outline

- Brief history of AUVs
- Introduction to MBARI's AUV program
- Dorado AUV concept
- ALTEX mission and vehicle
- AUV-CTD mission and vehicle
- Mapping mission and vehicle
- AUV Docking
- Conclusions

What is an AUV?

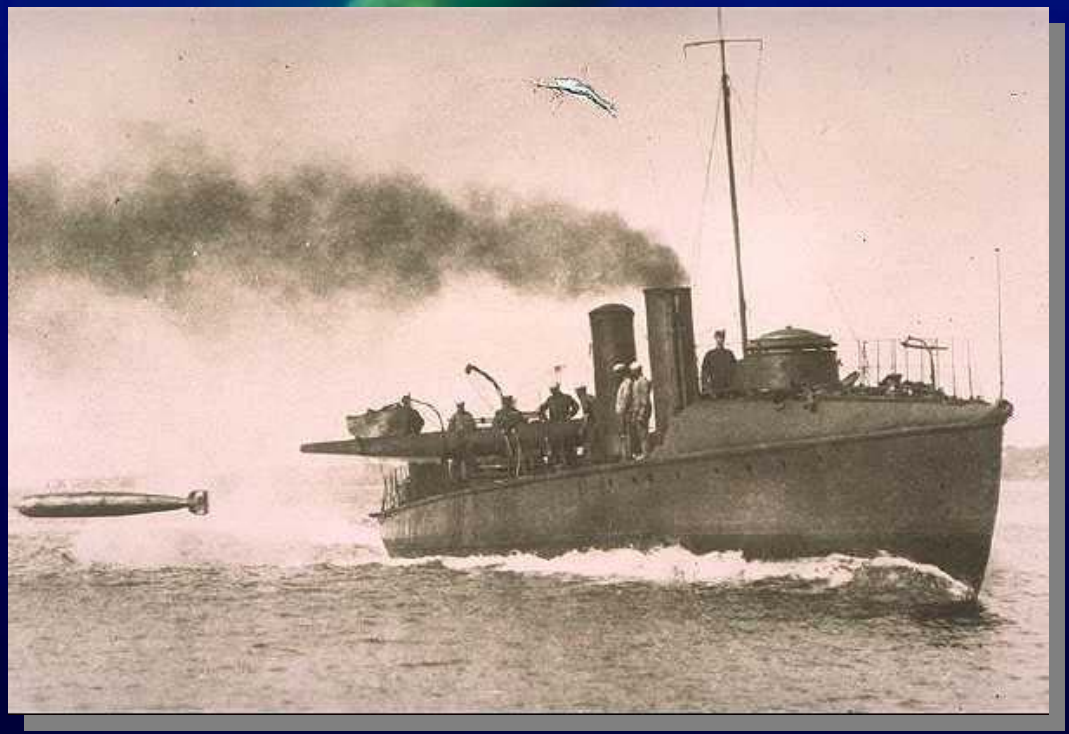
- Autonomous underwater vehicle
- No tether to ship
- No acoustic communications for command and control
- Onboard energy, navigation, and control
- Energy storage - largest limiting technology
- Scientific, military, commercial applications

AUV History

- Early torpedo technology in the 1890s
  - Compressed Air/Kerosene, electric, and peroxide/kerosene propulsion
  - Gyro/pressure depth guidance
- First AUV's in the 1970s
  - SPURV (self propelled underwater research vehicle) & SeaSpook (US)
  - MT-88 (USSR)
- Early systems severely limited by energy (50 Whr/kg) & computing (0.1-0.2 mips/W)

Early Whitehead Torpedo

- Actually called "Whitehead Automobile Torpedo"
- Compressed Air Propulsion (1 NM range)
- Gyro guidance
- Powder charge ignition



SPURV

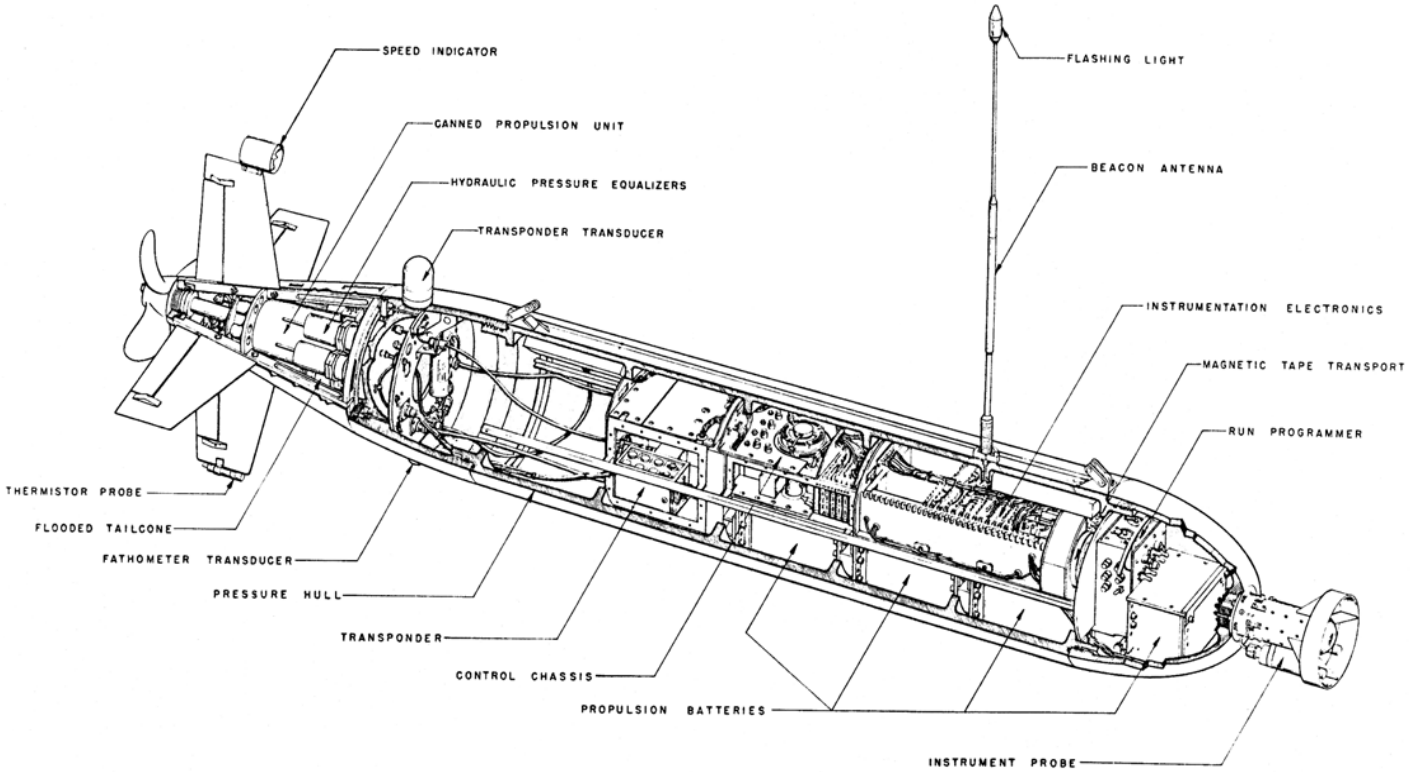
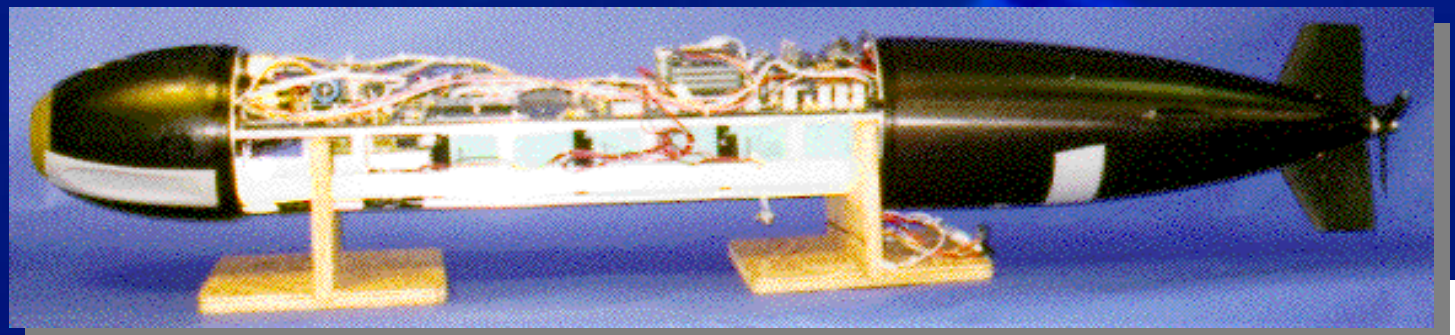


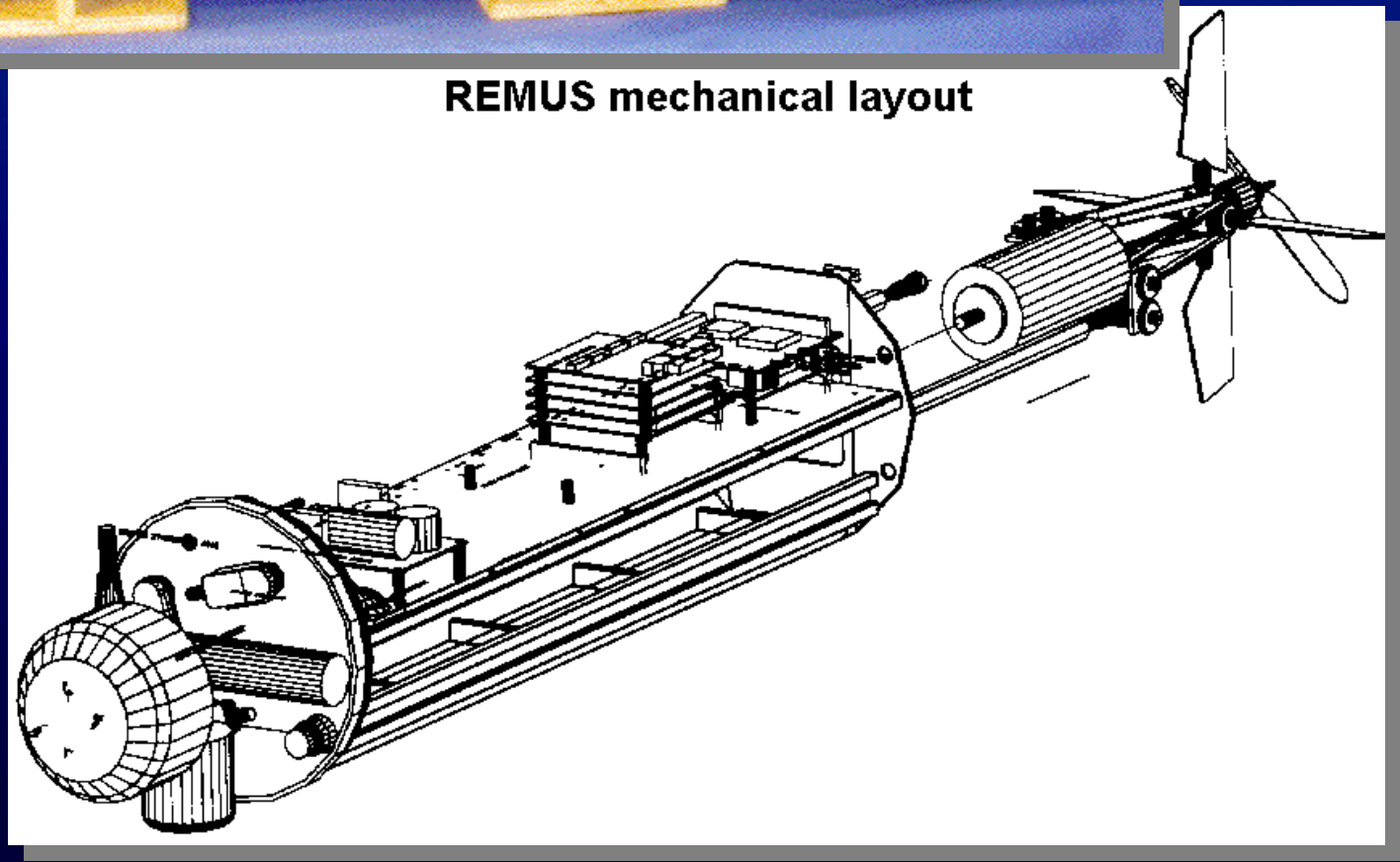
Figure 1. Self-propelled underwater research vehicle--cutaway drawing.

MT-88 AUV (USSR)

- Large class
- Differential thrusters
- Free-flooding
- Side-scan sonar, sub-bottom profiler
- Titanium pressure housings

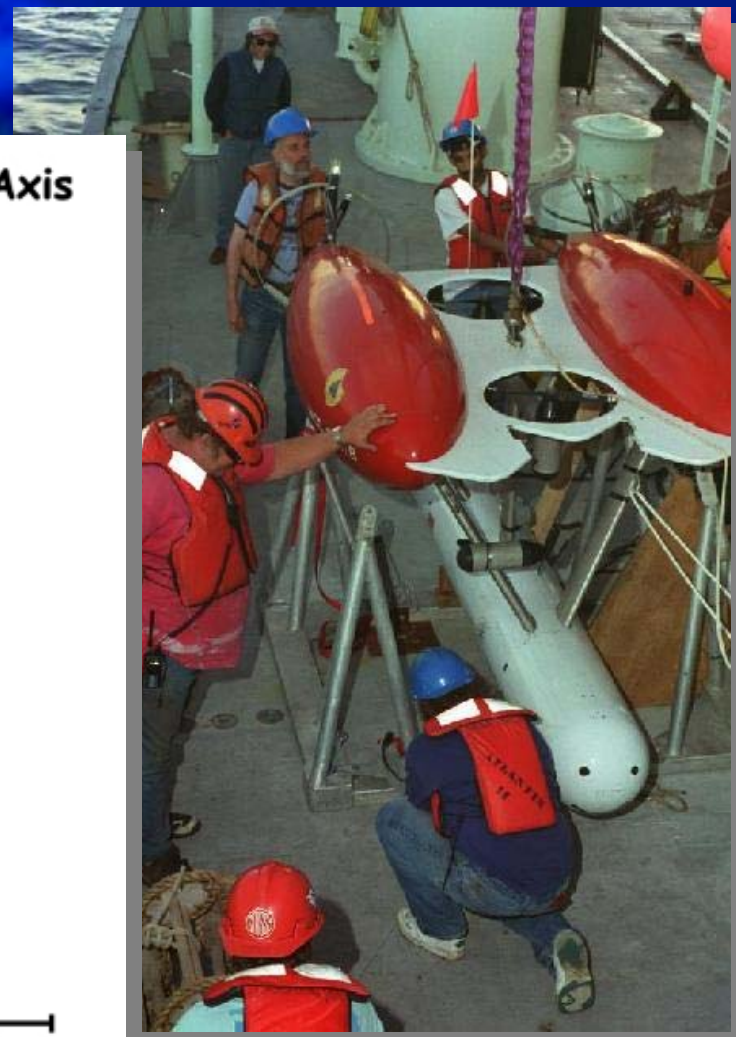
AUVs Today - Remus





AUVs Today - ABE

Autonomous Benthic Explorer



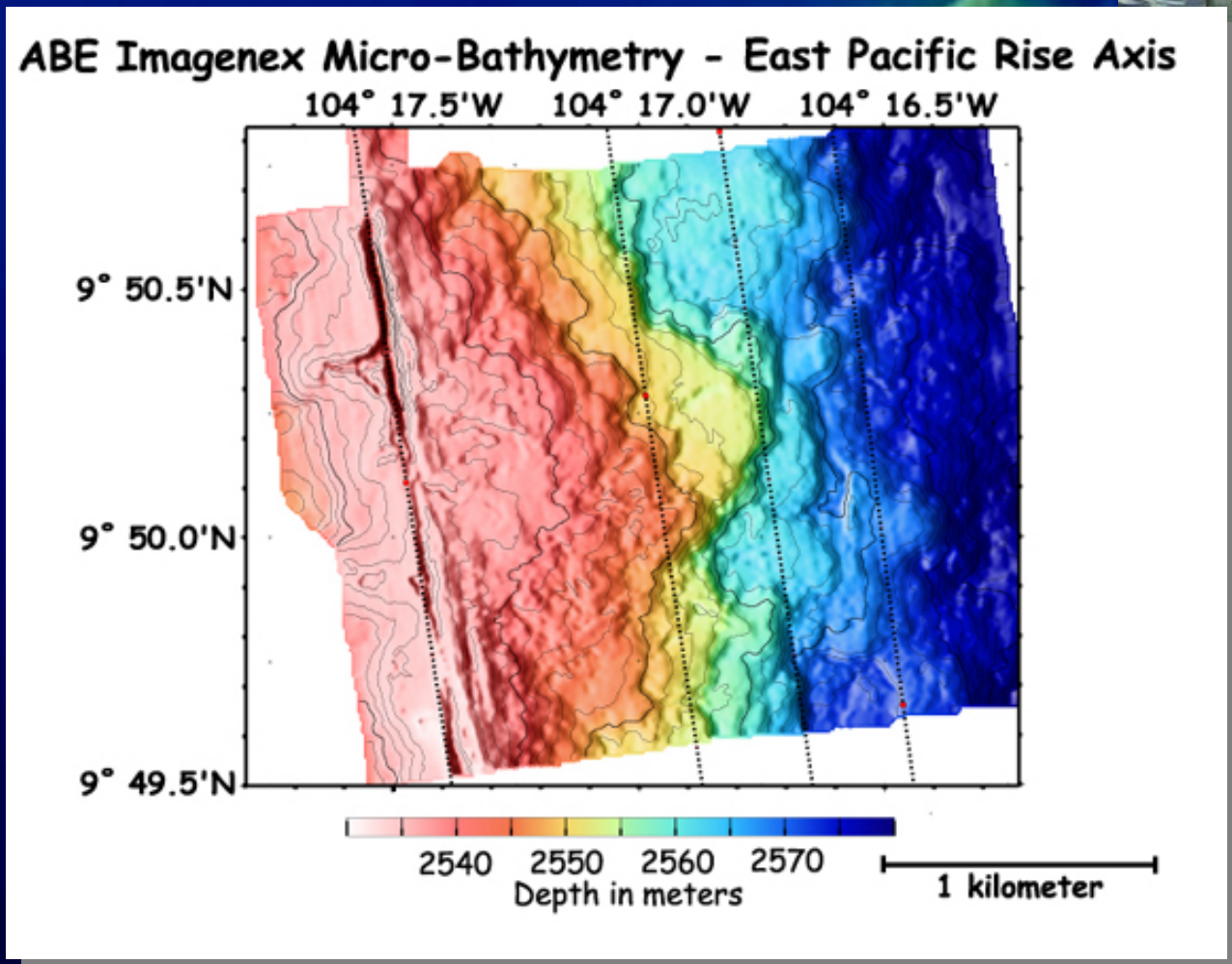
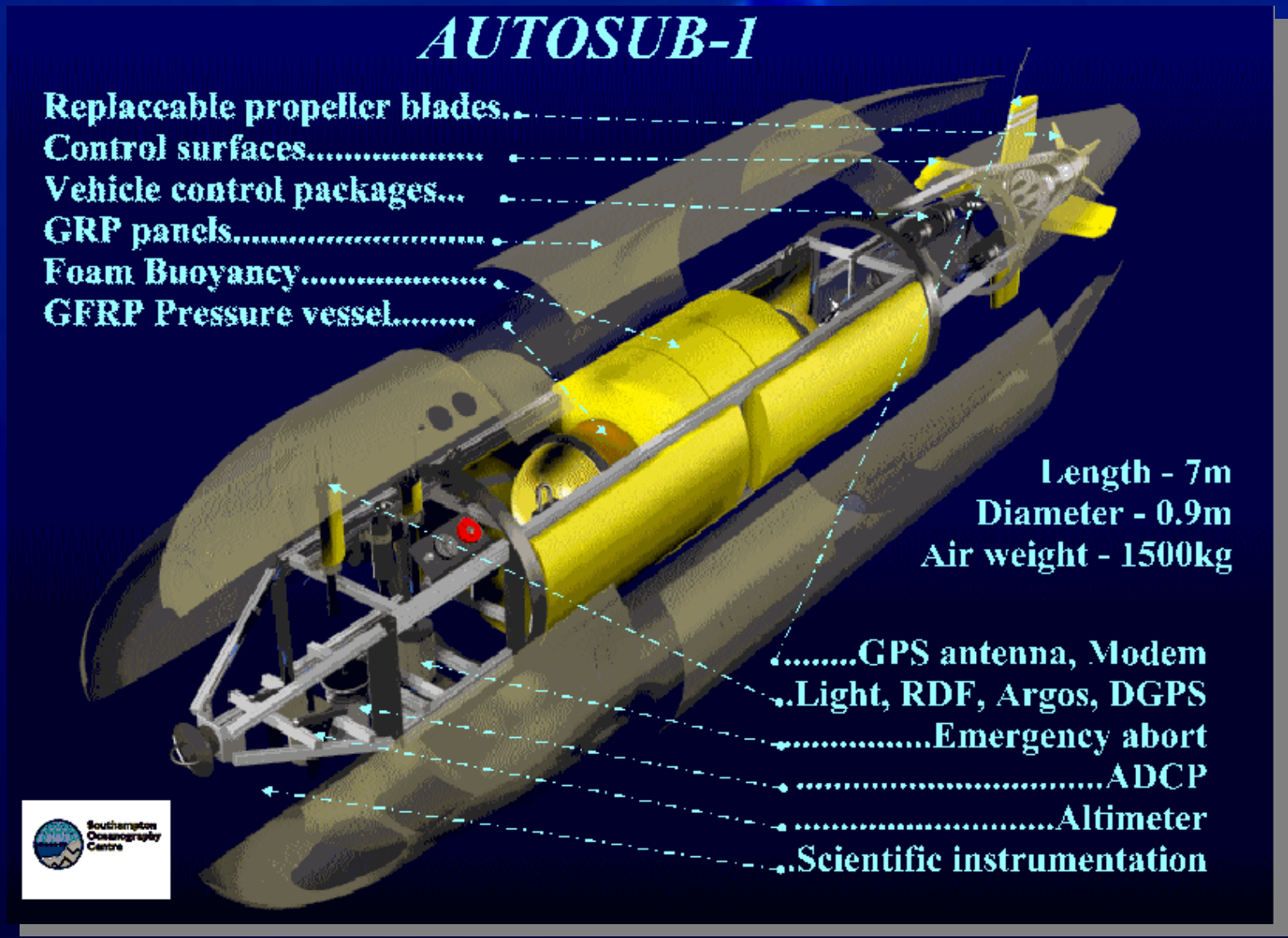
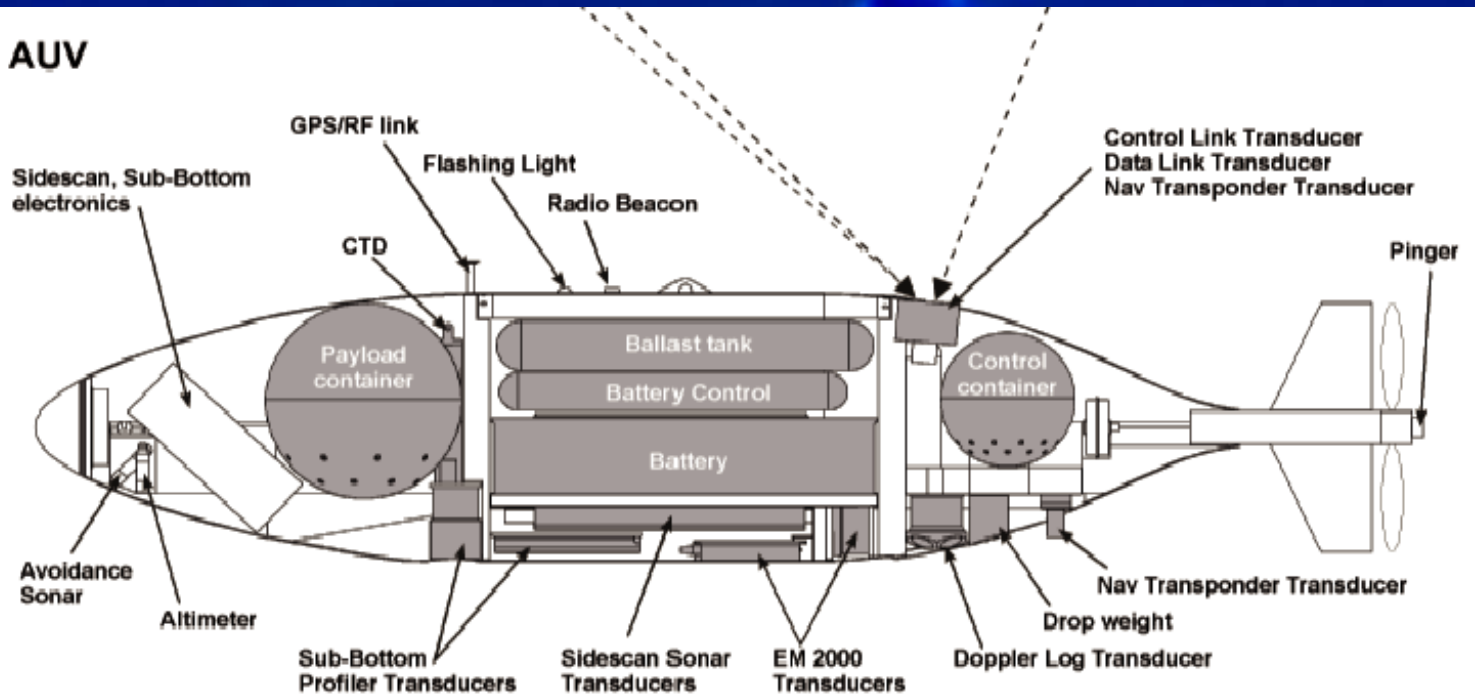


Image by Paul Johnson of HMRG

AUVs Today - Autosub



AUVs Today - HUGIN 3000



KONGSBERG
SIMRAD

AUVs Today - Maridan 600

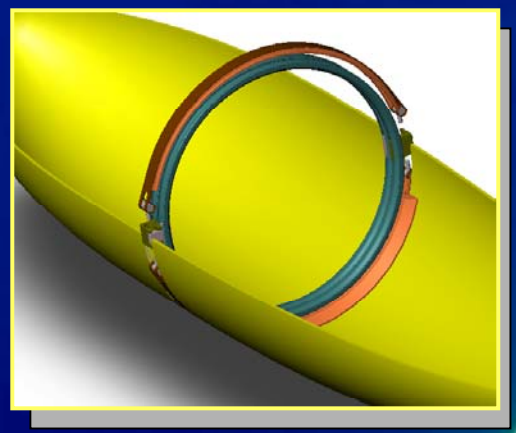
MBARI's AUV Program

- Uses
  - Physical, biological, and chemical oceanography
  - Ice draft measurements
  - Seafloor mapping
  - Docking technology
- Research began with Odyssey IIb
- ALTEX program created a new class
- Modularity is the goal

Dorado History

- Odyssey IIb from MIT
  - VME Cage, 68k CPU, single threaded
  - Fins + prop
- Dorado
  - Upgraded computing and software
  - Modularity was a design goal
  - Comms and power busses
  - Ducted tailcone - patent pending

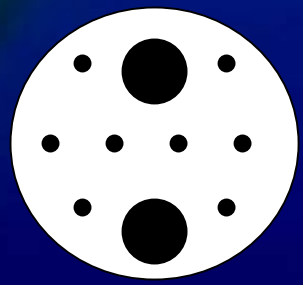
Dorado Concept
Mechanical Modularity



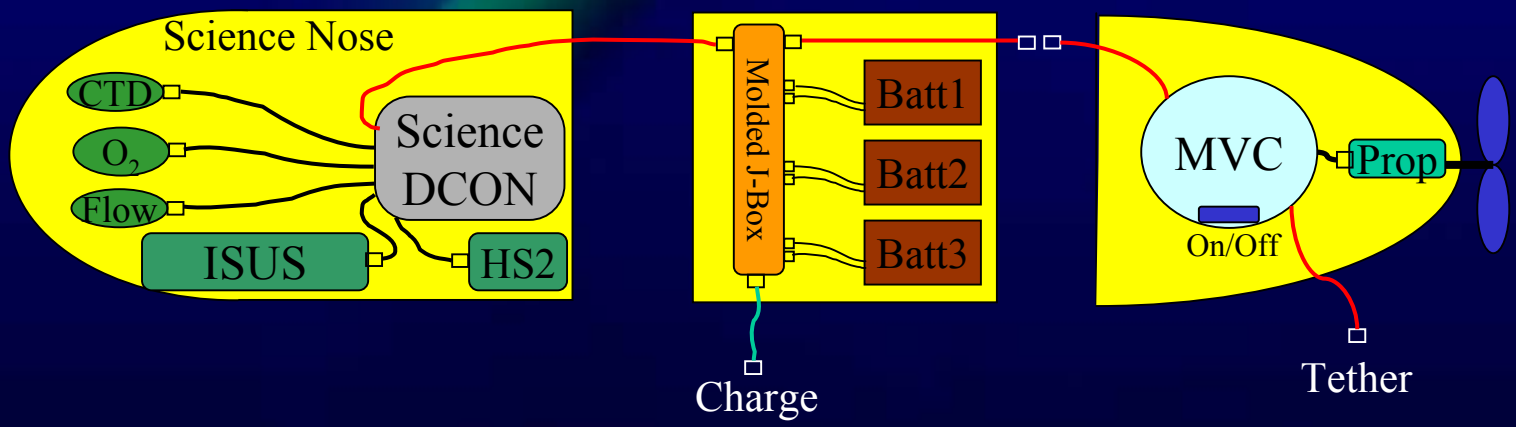
- Joining rings
- Positive buoyancy
- Tailcone, energy, payload, nose sections

Dorado Concept
Electrical Modularity

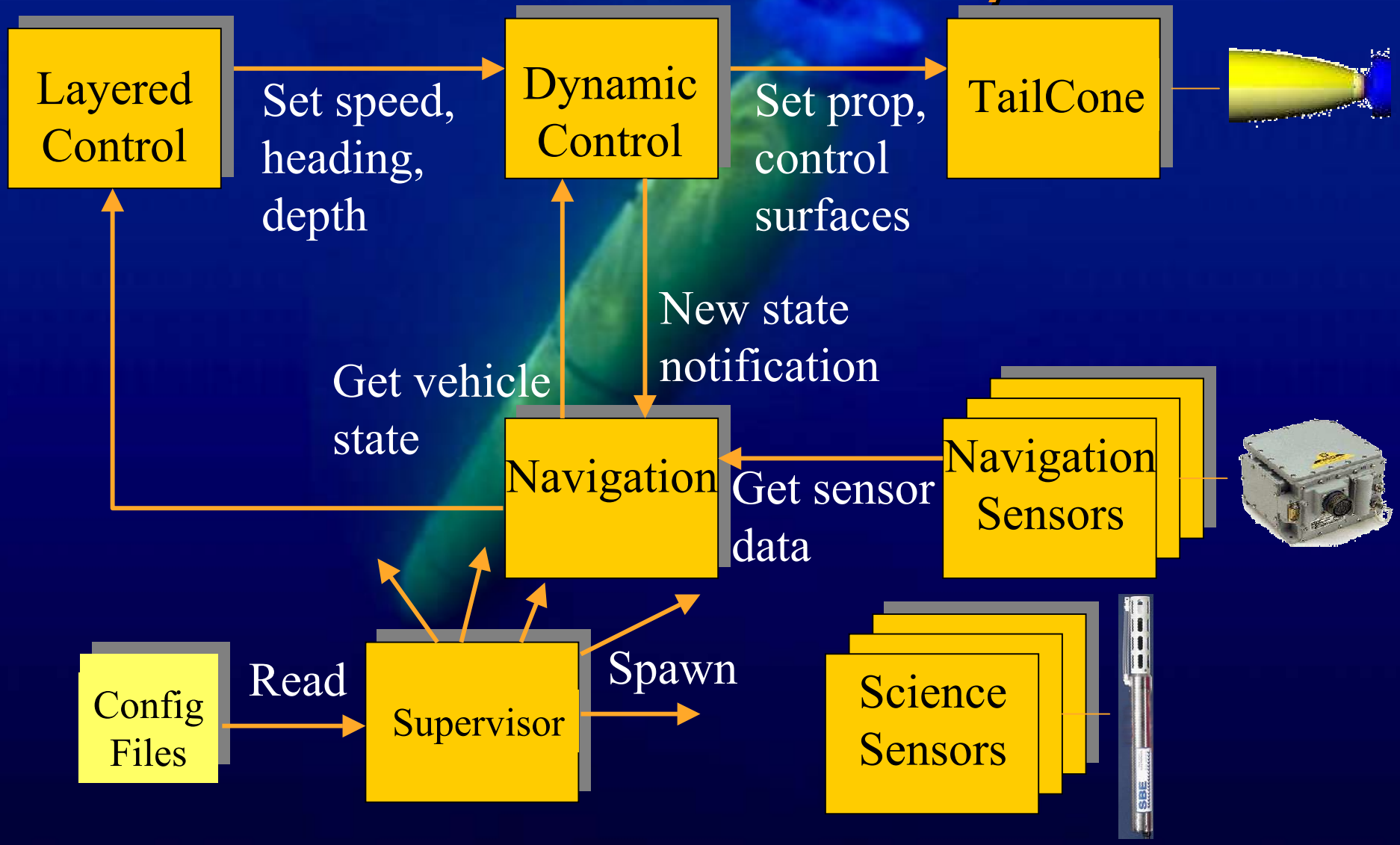
- One cable provides power and comms
- Standard circular connector for bus
- Comms are CANbus and Ethernet
- Galvanic isolation



- 2 pins power
- 4 pins ethernet
- 2 pins CANbus
- 1 pin shields
- 1 pin enable

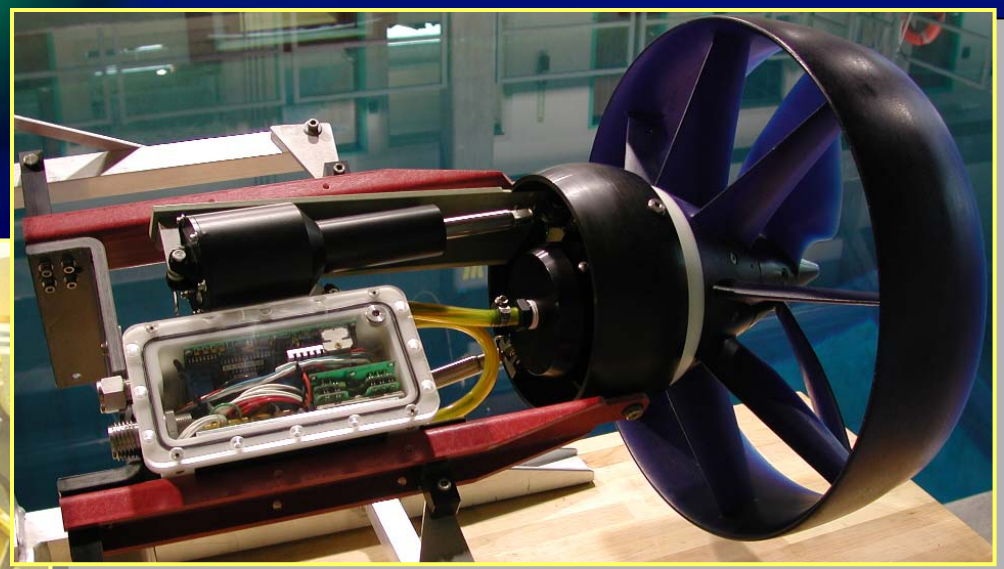


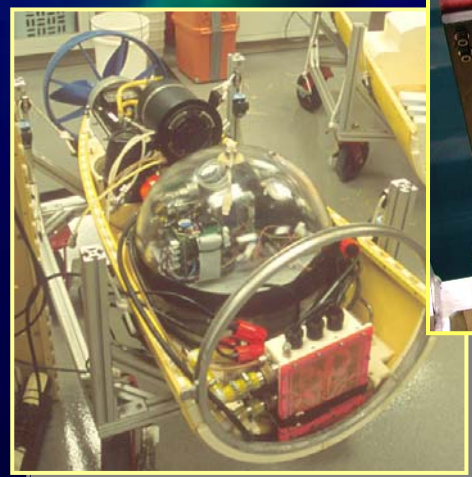
Dorado Concept
Software Modularity



Tailcone

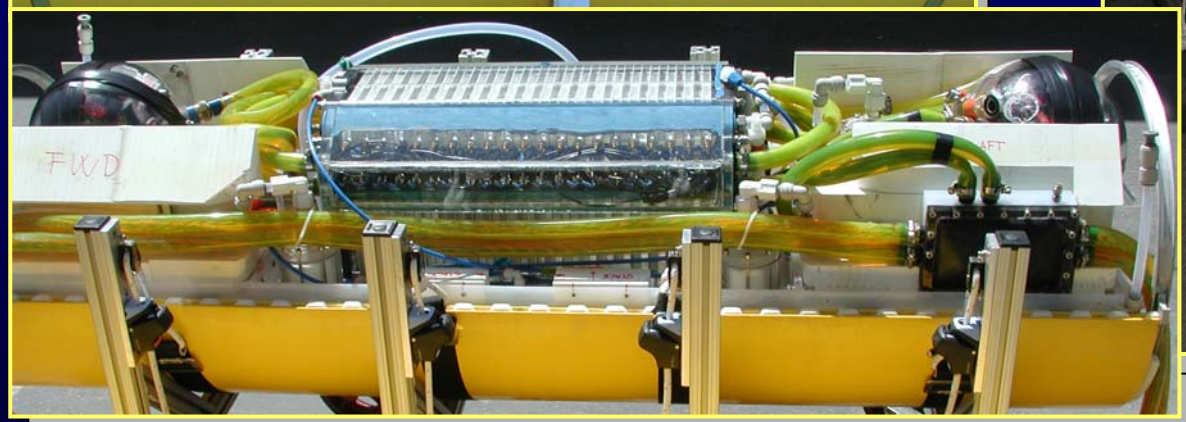
- Ring-wing produces 5x greater lift
- Duct provides a robust housing for prop
- Stepper motors and brushless DC servo
- Oil compensated
- Embedded motion control

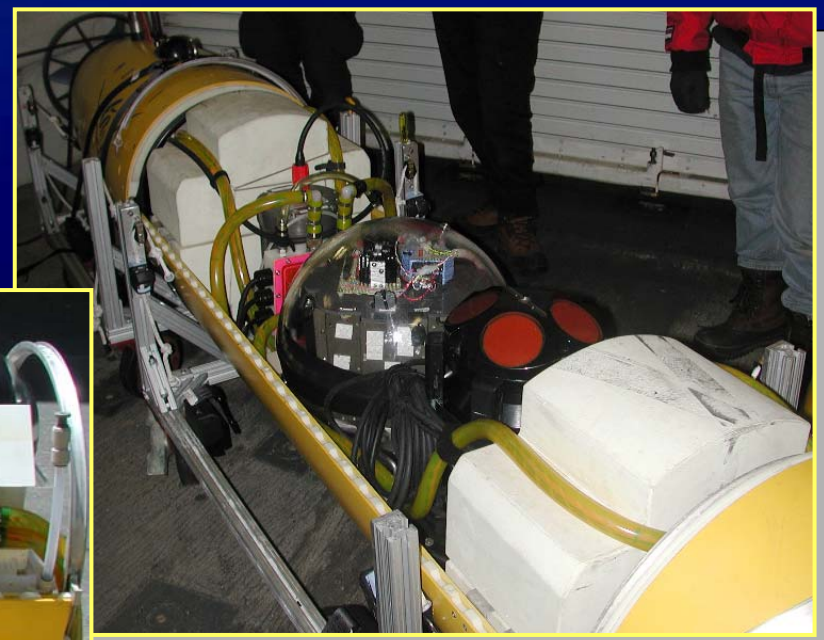




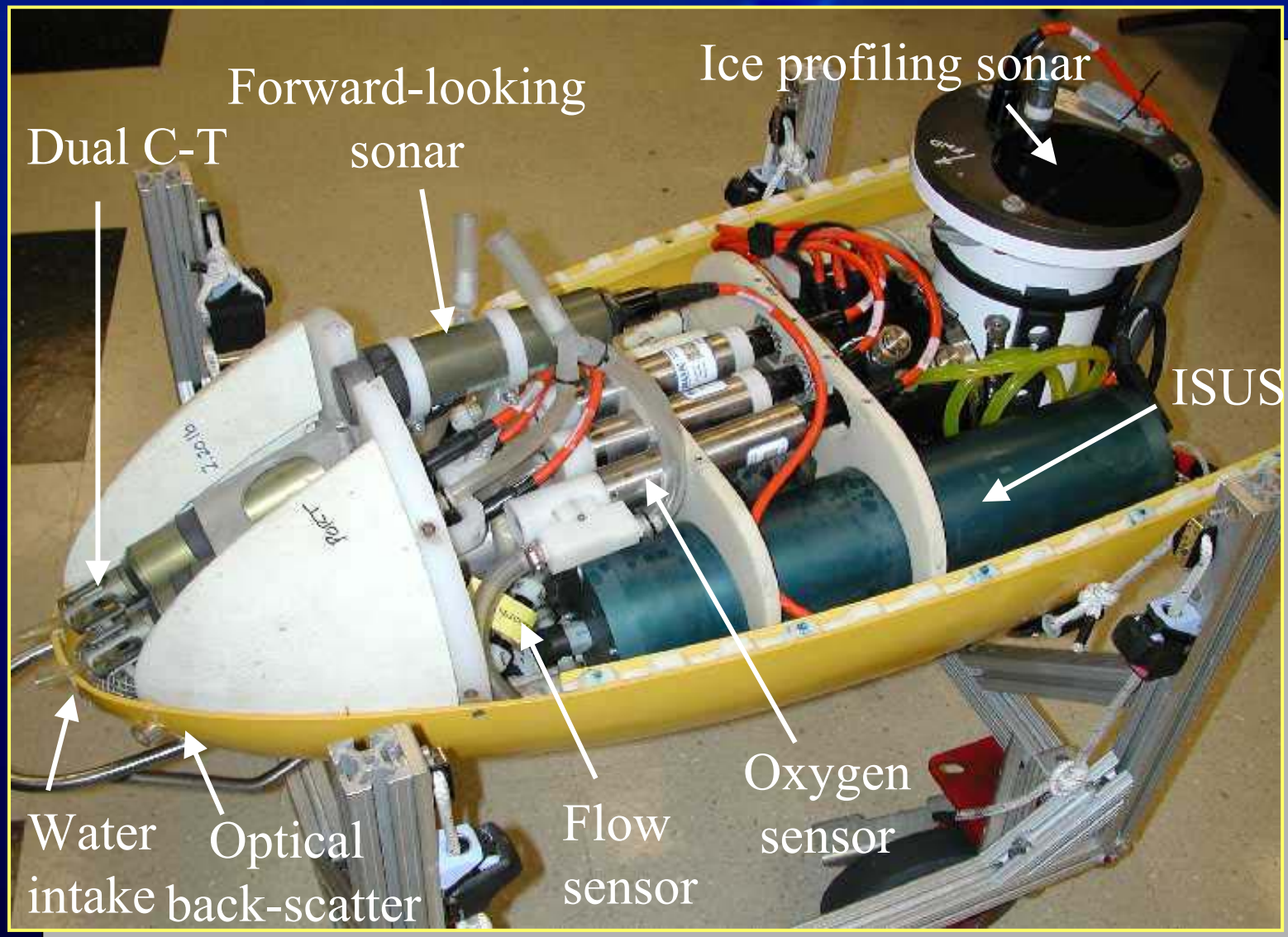
Battery Mid-Body

- Payload space for navigation
- Payload space for science sensors
- Silver-zinc, Li-polymer, semi-fuel cell

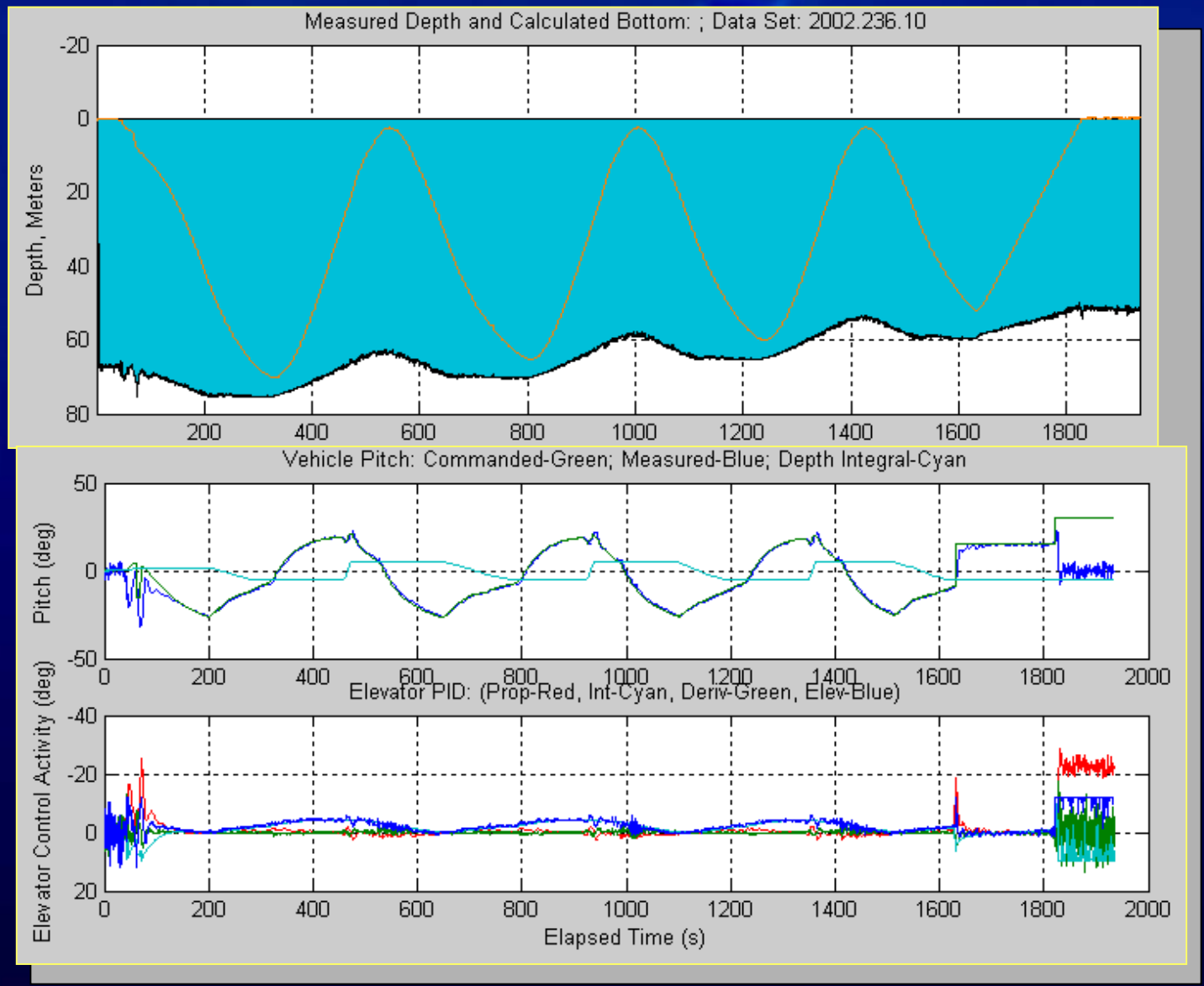




Science Nose

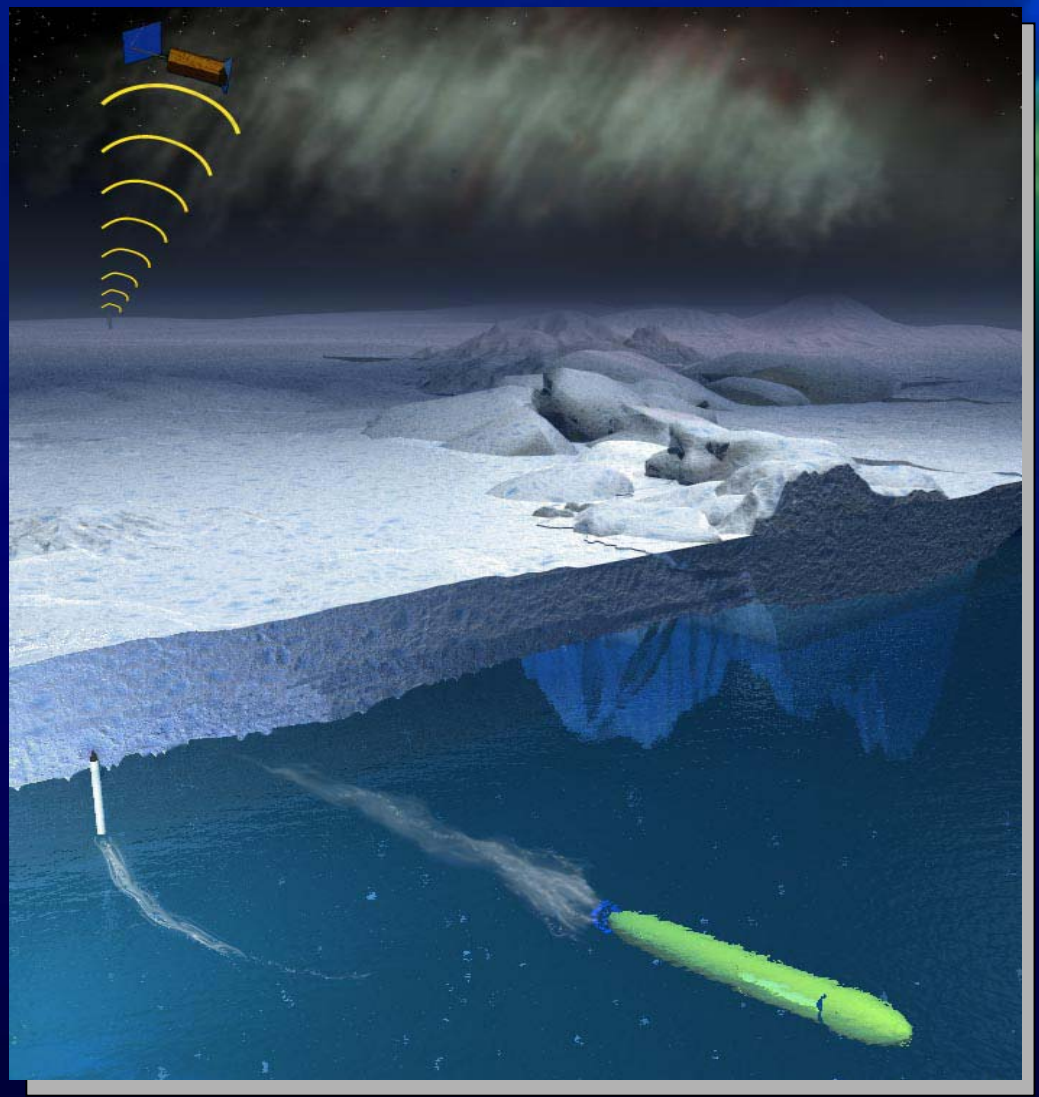


Vehicle Telemetry Data



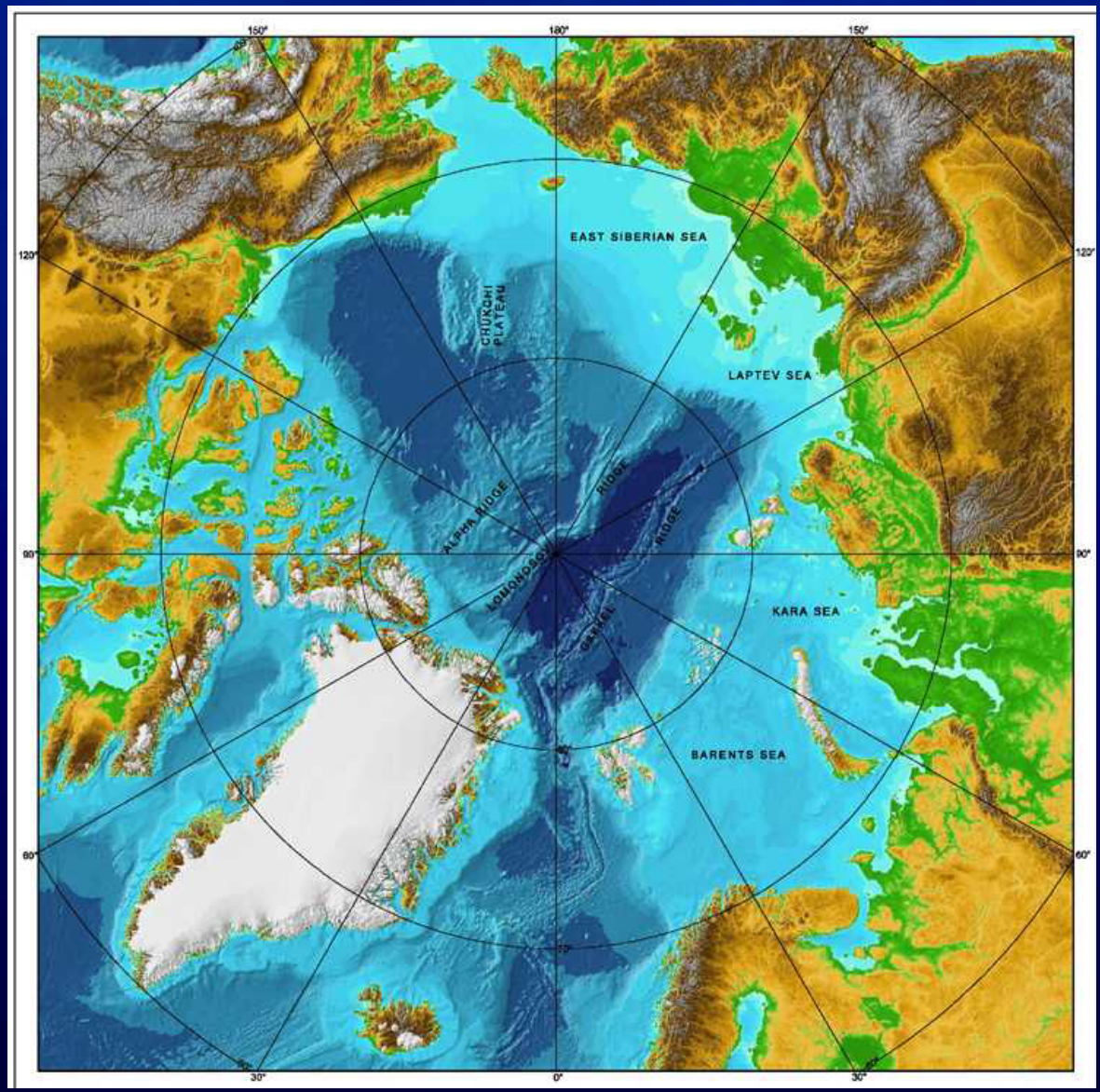
ALTEX

Atlantic Layer Tracking EXperiment



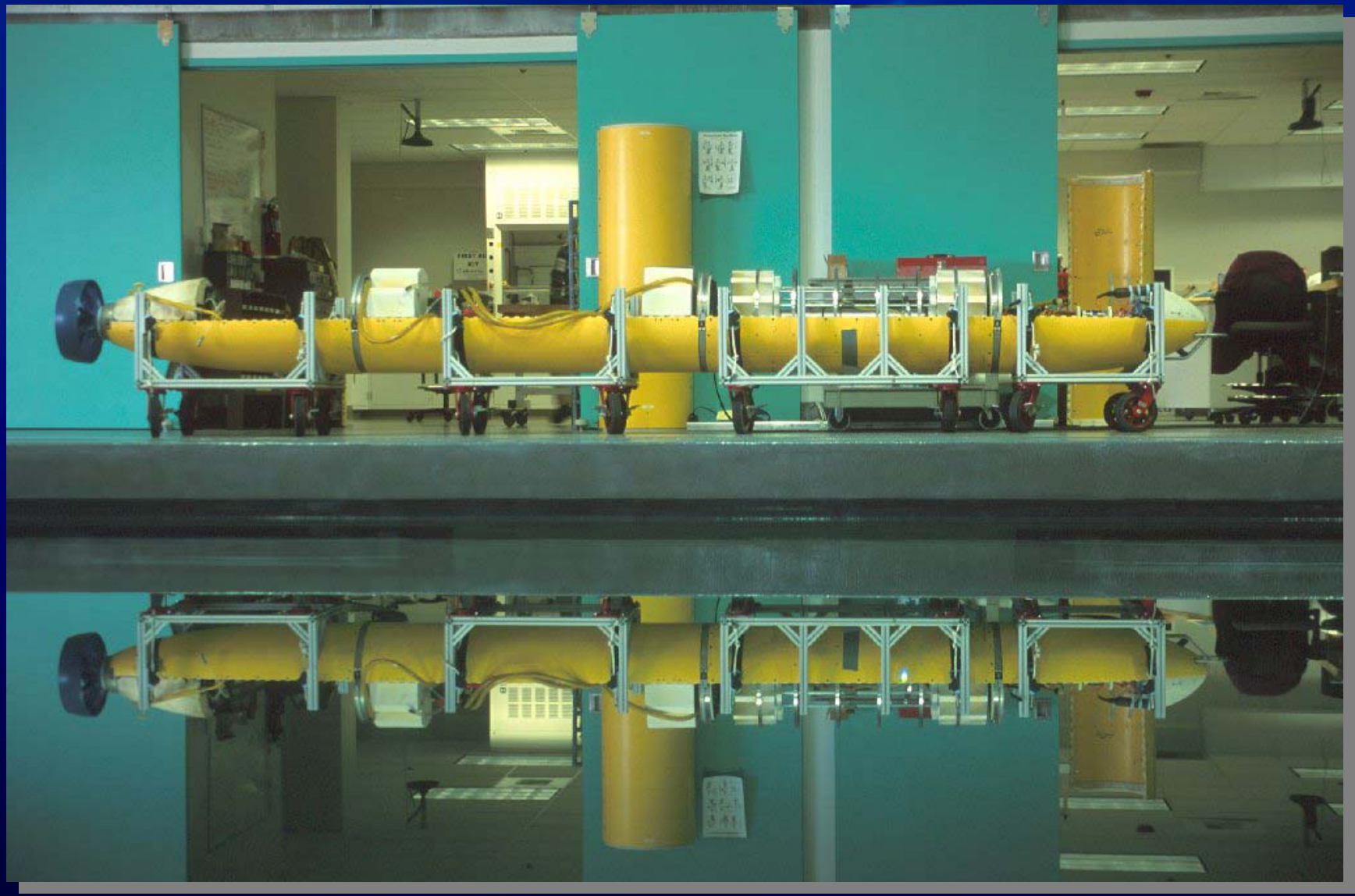
- Autonomy - 2 weeks
- Range - 1500 km
- Depth rating
  - 4500 m
- Satellite reporting
- Modular/reconfigurable
- Ice draft calculations
- Physical oceanography
- Dorado class AUV

ALTEX Cruise

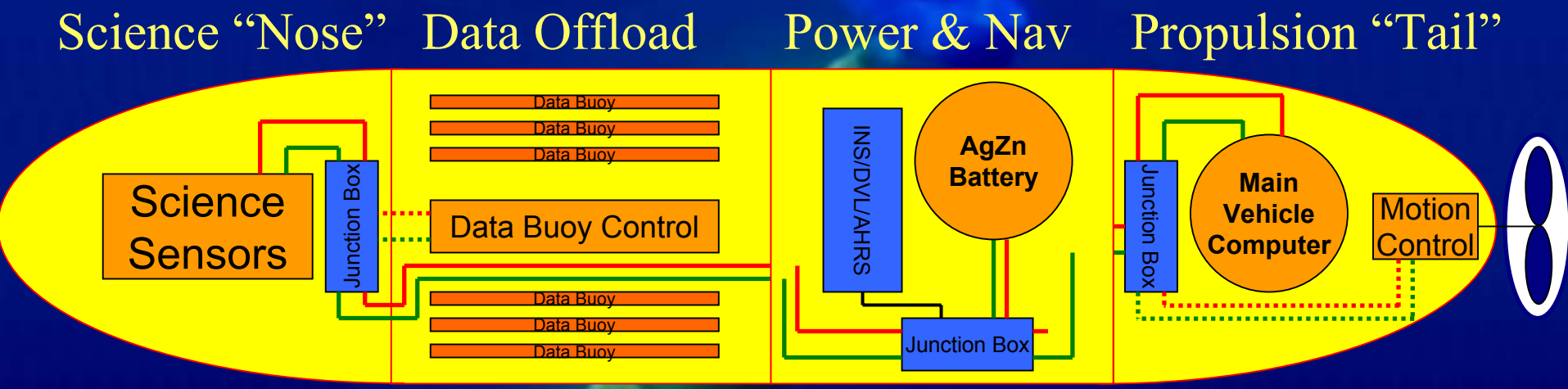


Map credit: http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/provisionalmap.html

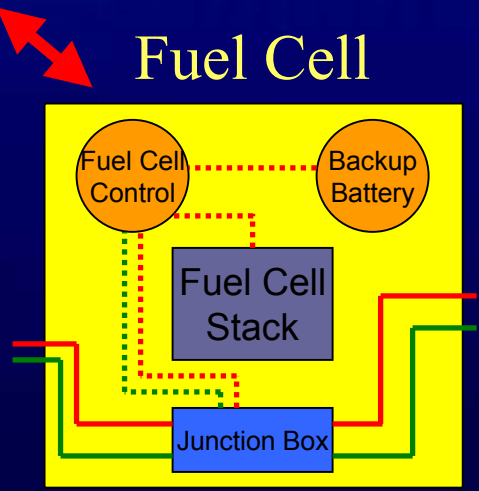
Full Length ALTEX Configuration



ALTEX Dorado Configuration

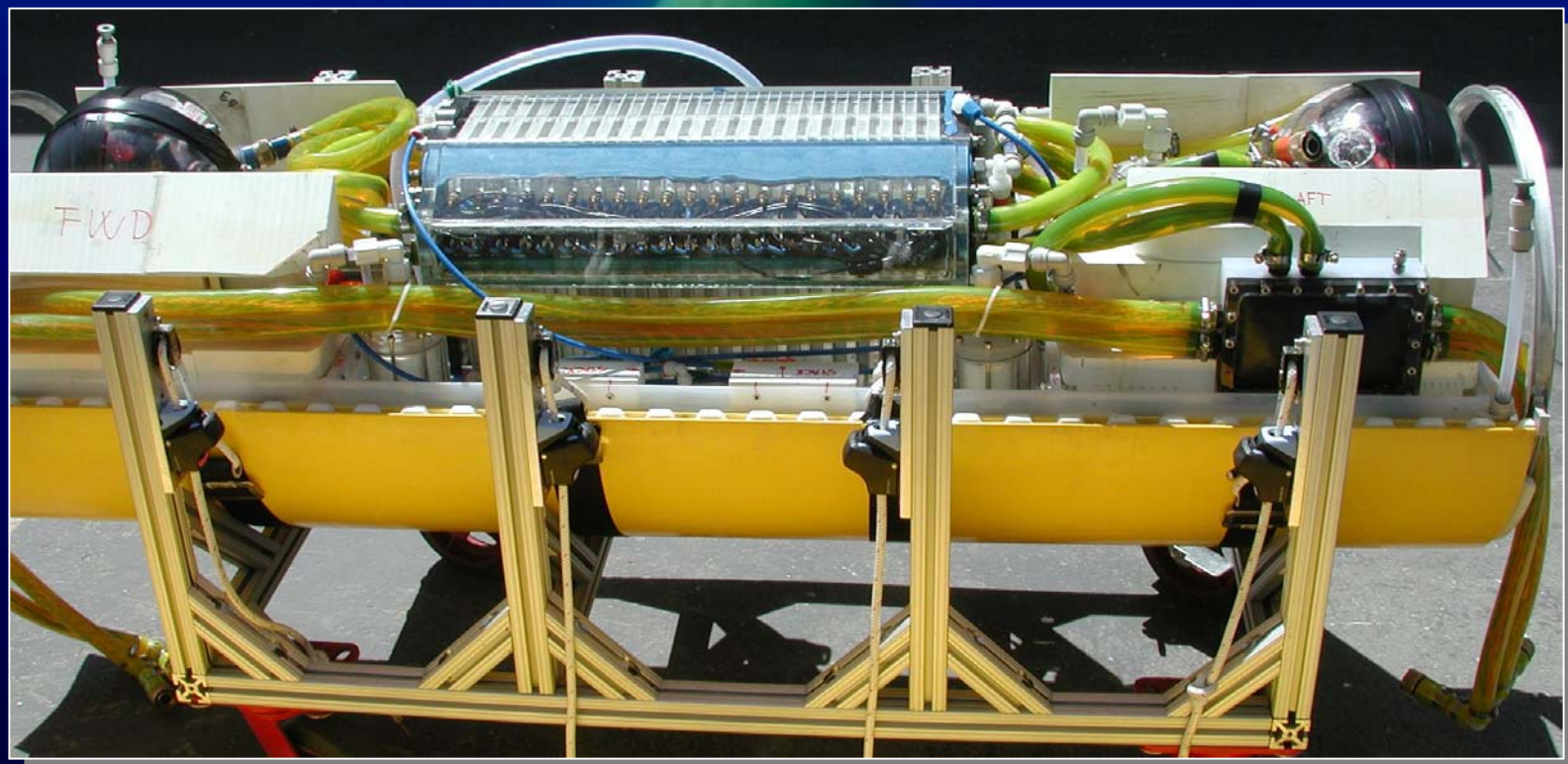


- AgZn or Al Semi-Fuel Cell (80 kW-hr for full mission)
- INS/DVL or gyrocompass navigation (.03% to .1% accuracy)
- Physical oceanography science suite (CTD, OBS, DO, Nitrate)
- Ice-melting data buoys for ARGOS data relay (50-60 KB/day)

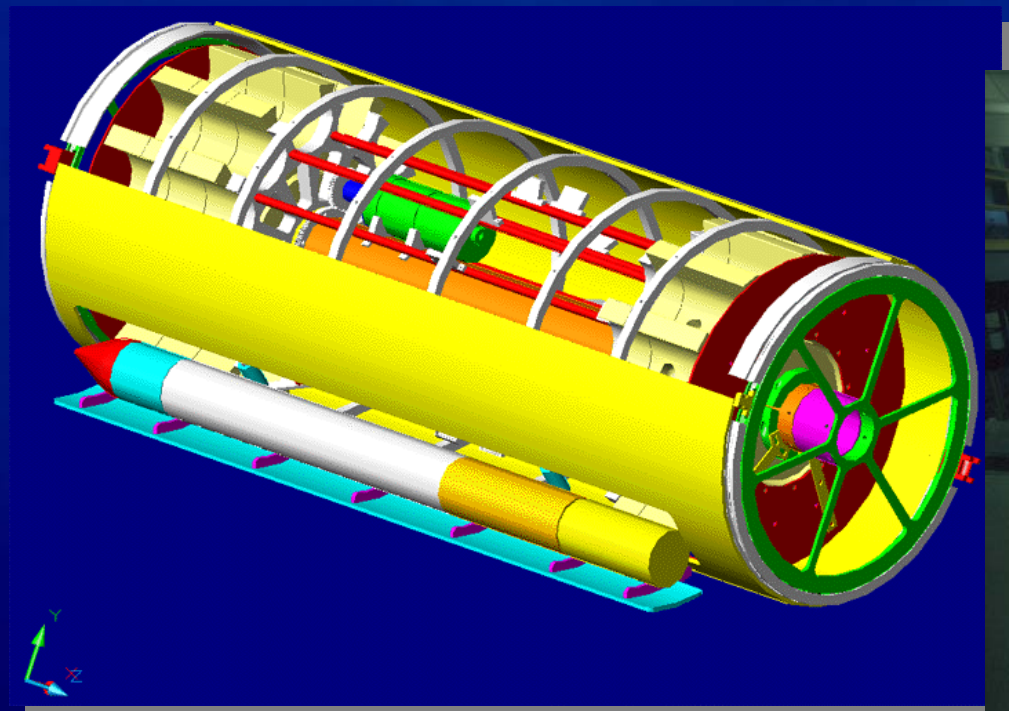


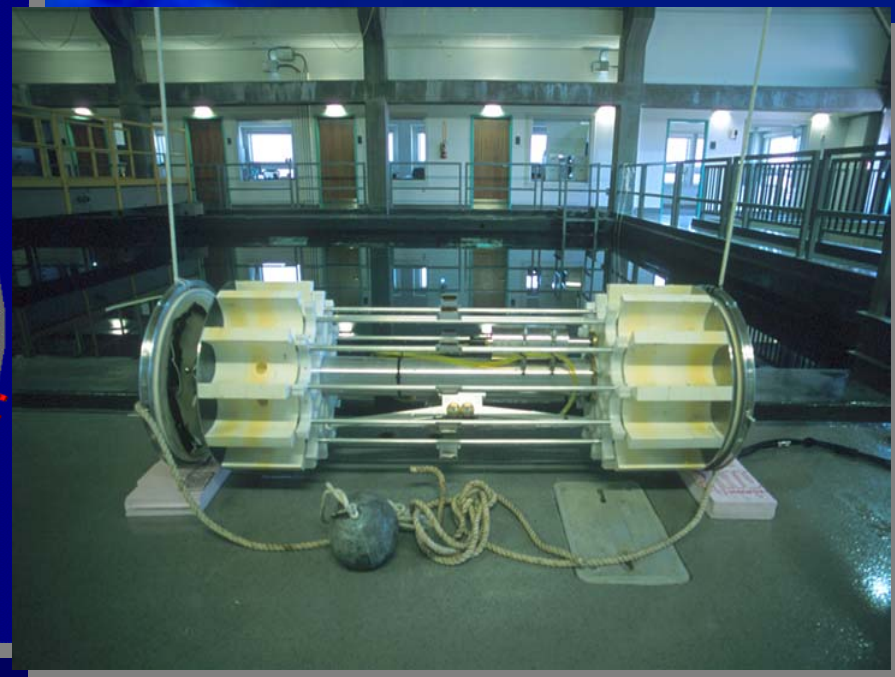
ALTEX Fuel Cell

- 80 KW-hr energy
- Pressure tolerant to 4500m
- Tested at sea



ALTEX Data Buoy Section



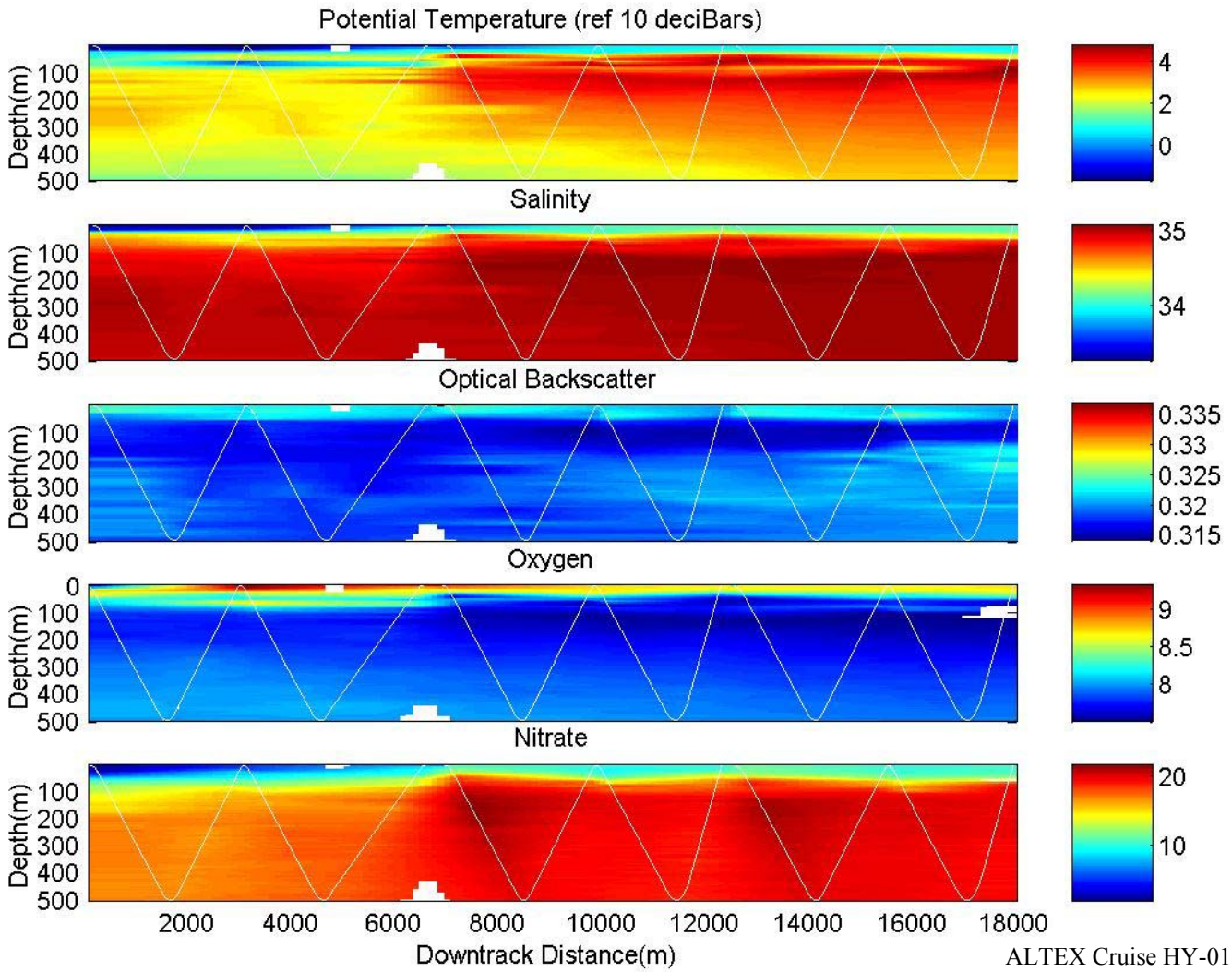


- Designed and manufactured by SSI, Inc.
- Launcher carousel holds 12 buoys
- Buoys have 1 meter ice penetrating capability
- Buoys transmit data to ARGOS for up to 7 days
- Section connects to vehicle via one connector

ALTEX Data Buoy

ALTEX Deployment

ALTEX Science Data



ALTEX Cruise HY-01-03
MBARI J. G. Bellingham

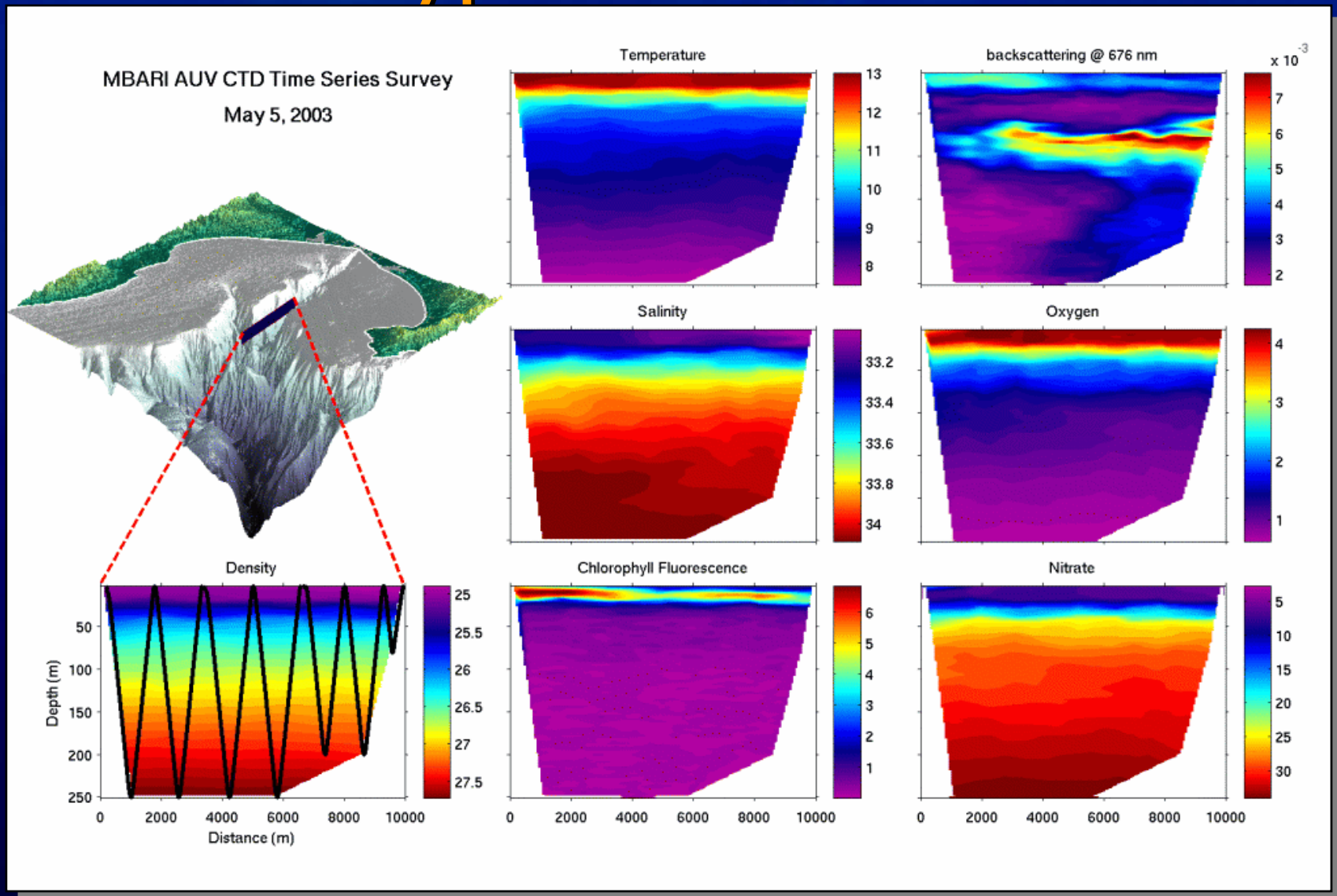
AUV-CTD Vehicle

- Built for upper-water physical, chemical, and biological oceanography missions
- Replaces costly CTD casts from ships
- Standard payload includes dual CTD, dissolved O_2, optical backscatter, fluorometer, ISUS
- Extended payload includes bathyphotometer and particle size distribution instruments
- Standard guidance, control, navigation, and control tail section

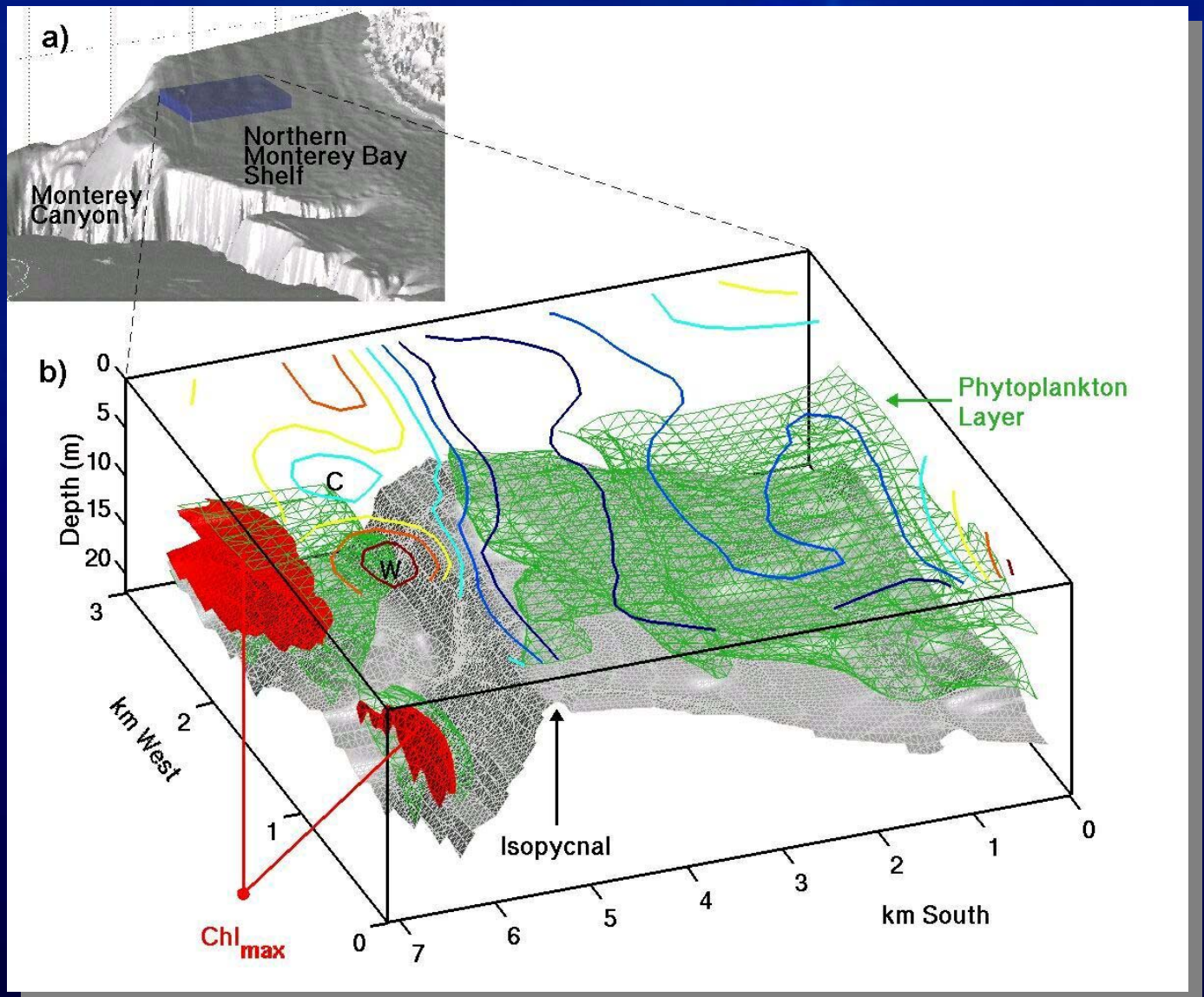
Dorado Specifications
Upper-Water Science

- 1-2 m/s (1.5 m/s nominal)
- 20 hour mission (110 km)
- 6 KW-hr Lithium Polymer energy
- CTD & ADCP instruments
- Payload in nose and/or parallel midbody
- 4500m depth rating
- 0.533m (21”) diameter
- 4.26m length typical

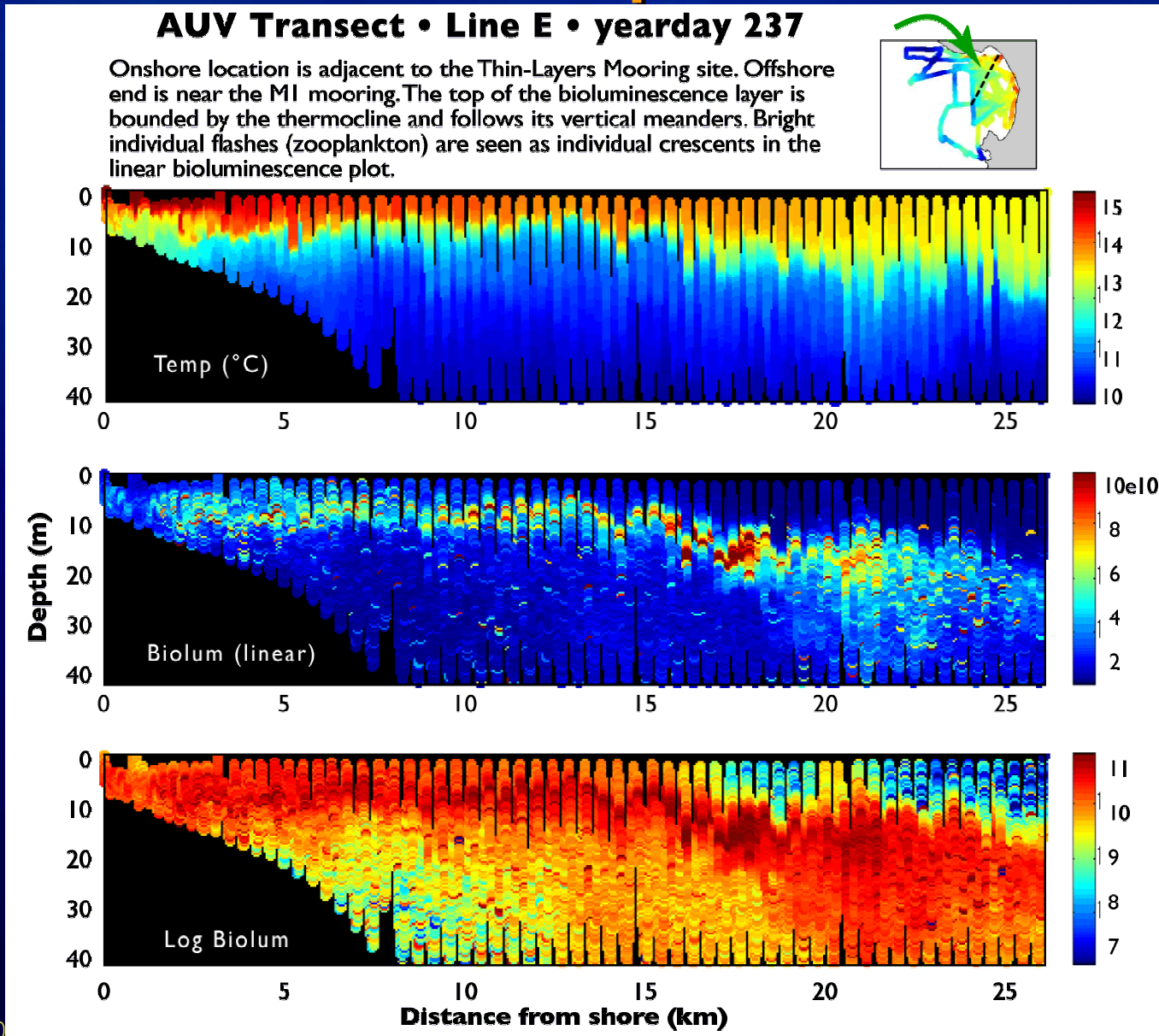
Typical Dataset



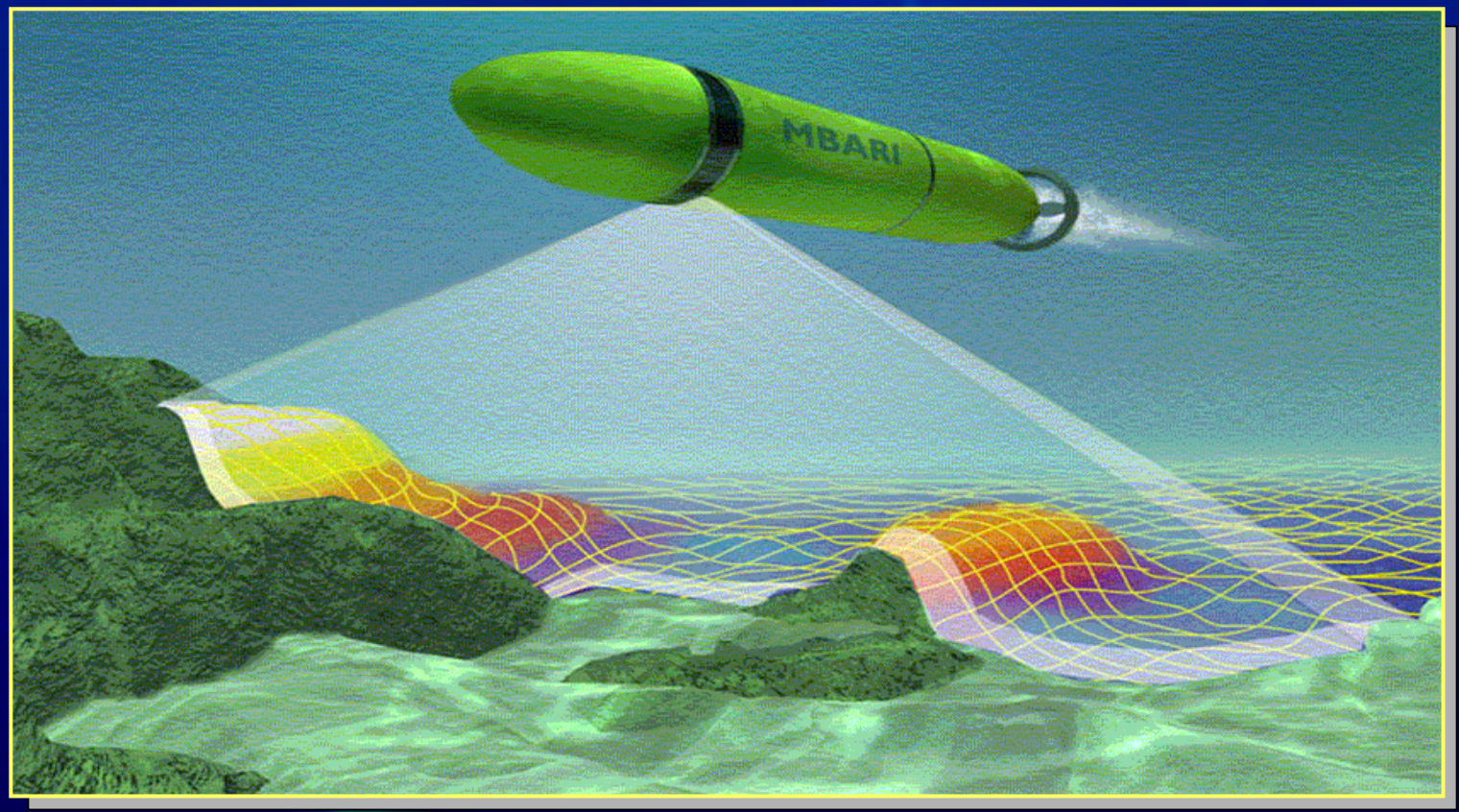
Frontal Processes (MUSE)



Bioluminescence Spokes Cruise

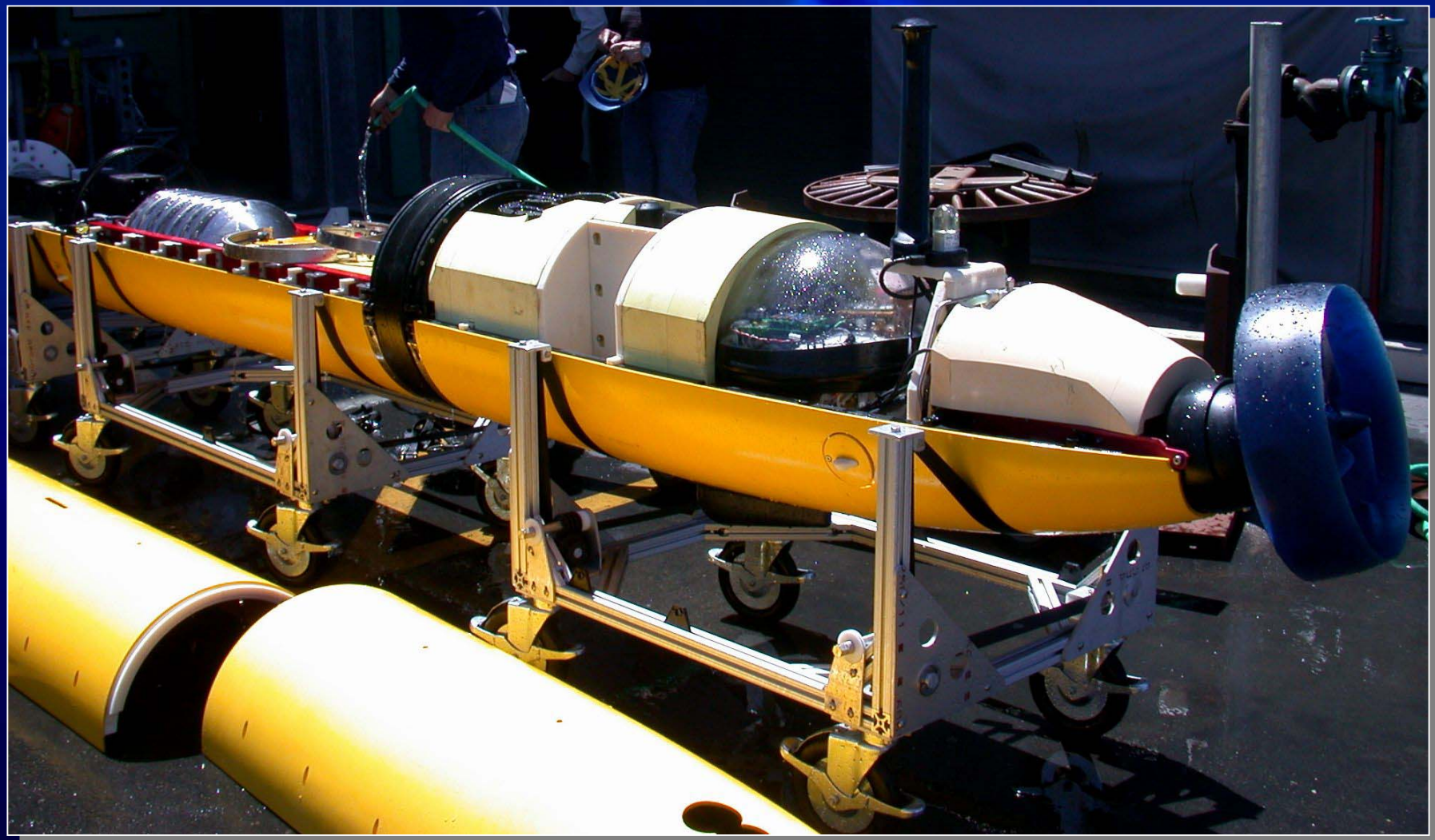


Seafloor Mapping



- 6000m depth rating
- Reson multibeam sonar
- Edgetech SSS, SBP
- Kearfott SeaDeViL INS
- Acoustic comms
- Satellite comms

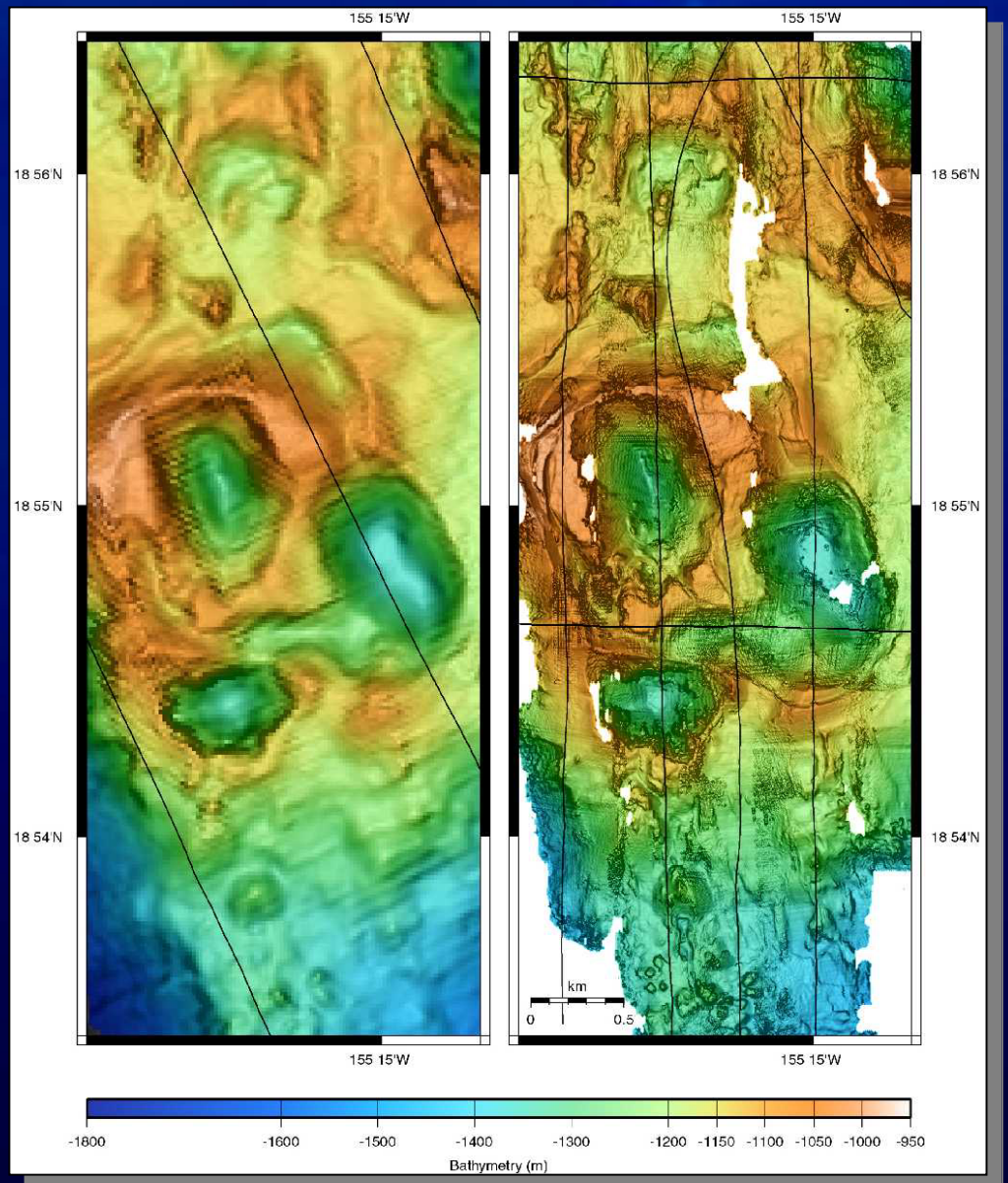
Seafloor Mapping AUV

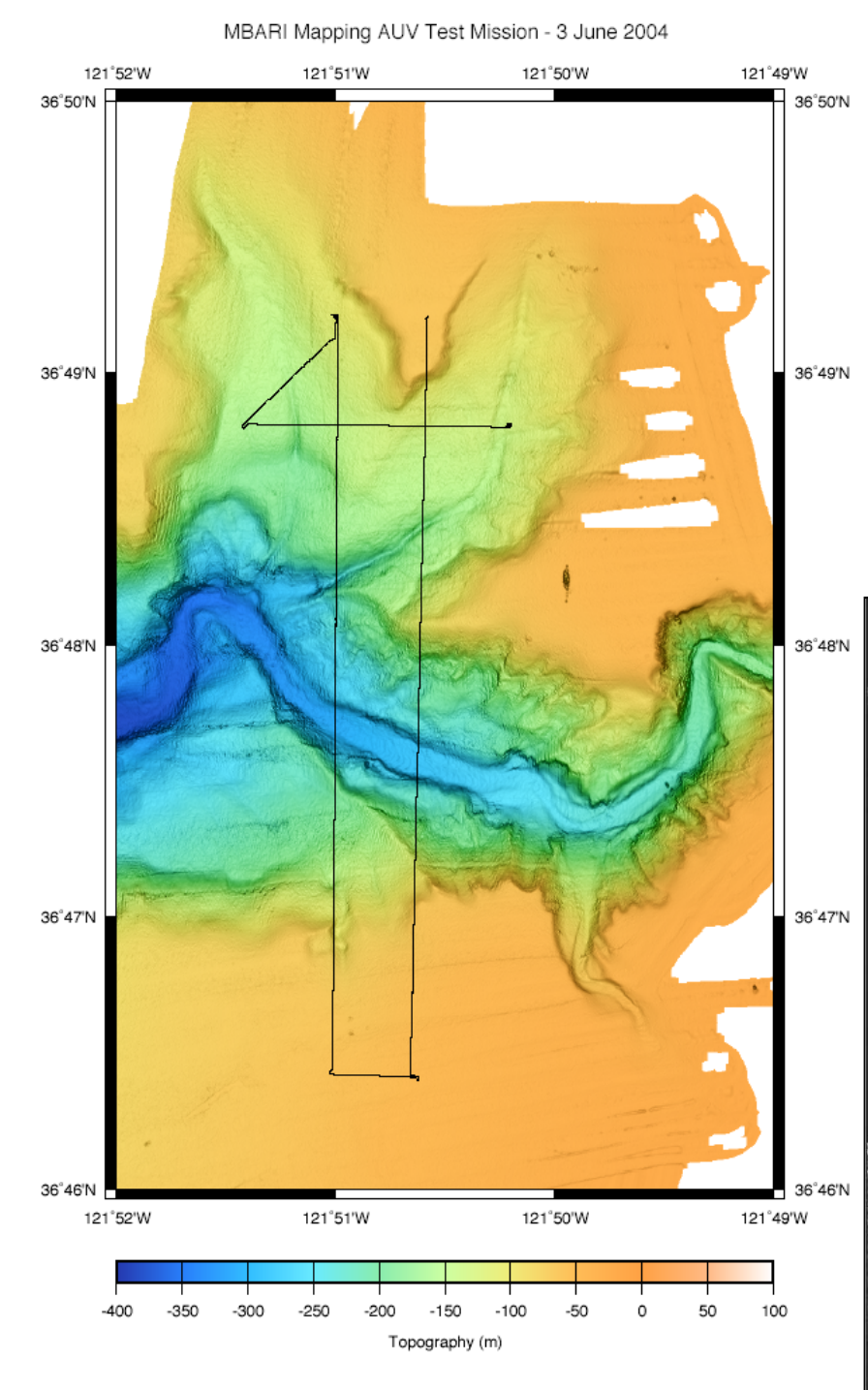


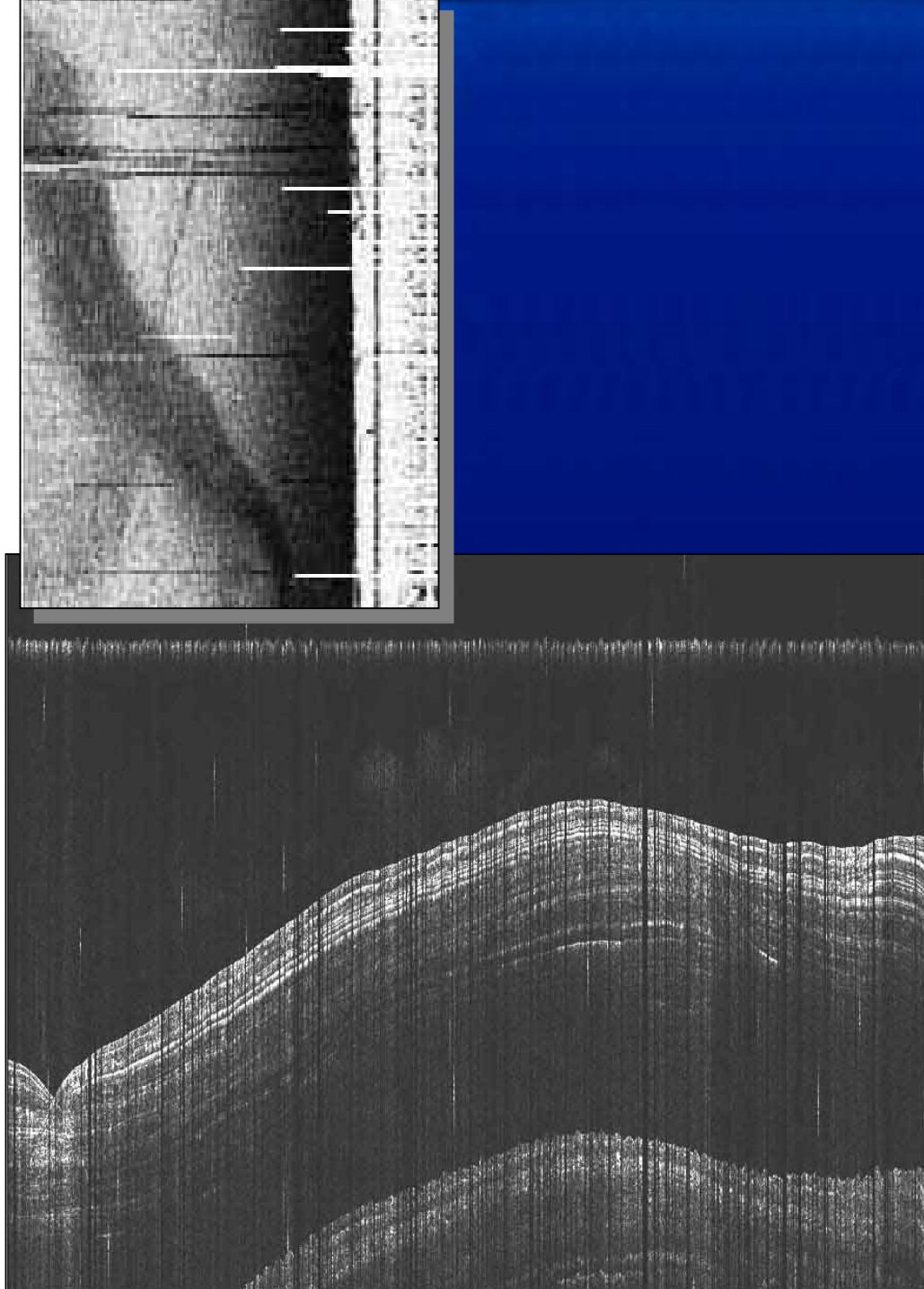
Dorado Specifications
Deep Water Mapping Surveys

- 1-2 m/s (1.5 m/s nominal)
- 10 hour mission (55 km)
- 6 KW-hr Lithium Polymer energy
- CTD, multibeam, SBP, side-scan sonars
- Payload in parallel midbody
- 6000m depth rating
- 0.533m (21”) diameter
- 5.68m length typical

Previous Multibeam Work




MBARI Mapping AUV Test Mission - 3 June 2004
121°52'W
121°51'W
121°50'W
121°49'W
36°50'N
36°49'N
36°48'N
36°47'N
36°46'N
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
Topography (m)



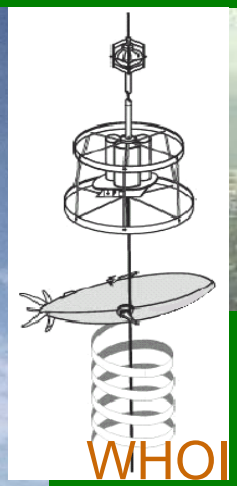
Docking Technology

- Recharge batteries
- Download collected data
- Upload new missions
- Acoustic homing
- Multiple missions per ship deployment
- Maintenance once every 12 months

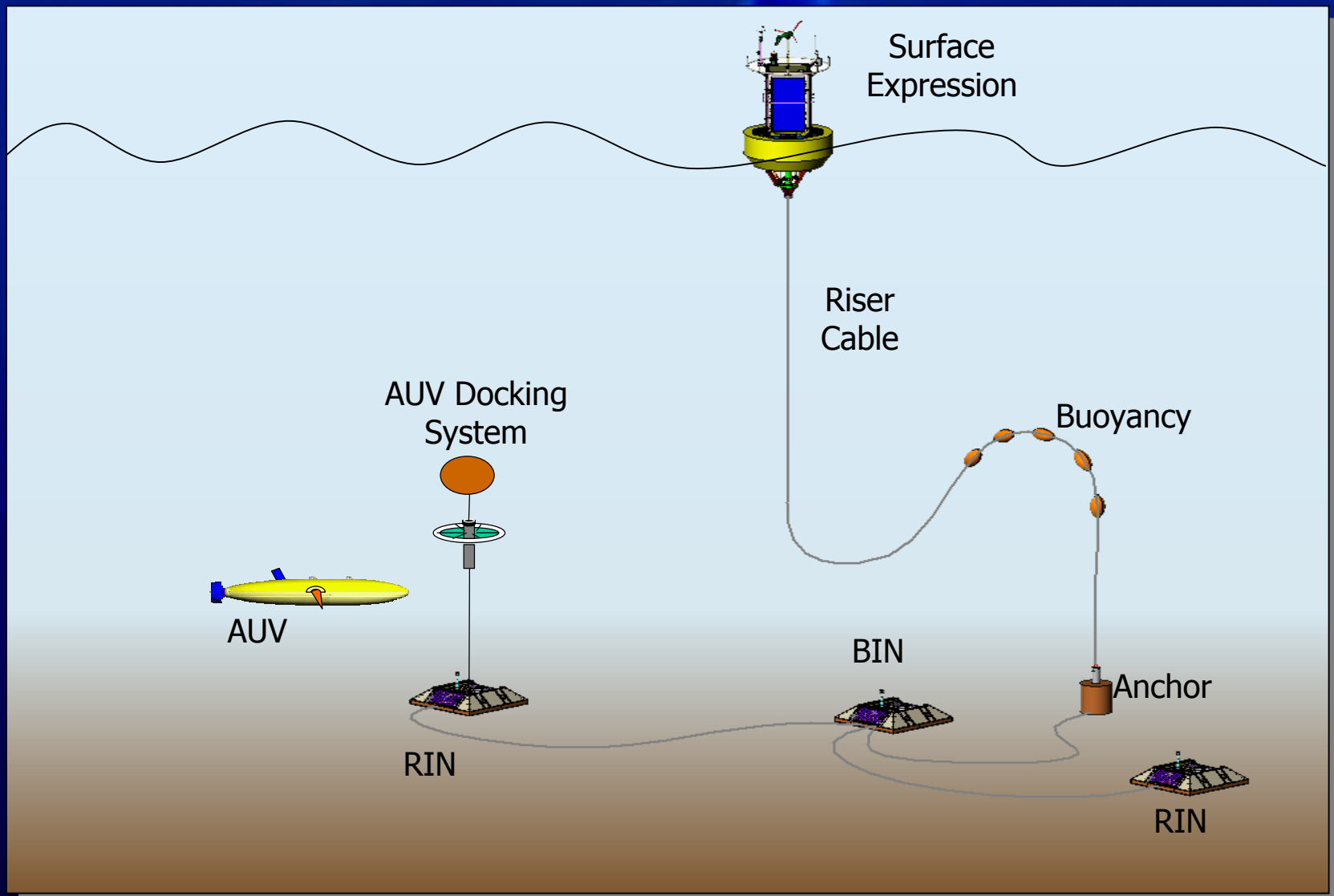
Extended Presence

- Extend spatial coverage of observatory nodes
  - Ability to deploy beyond observatory footprint
- Acquire high resolution 4-D data sets
  - Characterize spatial variability
  - Provide context for point measurements
- On-demand operations (no ship scheduling required)
- Event detection through routine, scheduled surveys
- Autonomously respond to episodic events
  - Weather driven processes
  - Seafloor events (eruptions, slides…)
  - Detection of biological processes

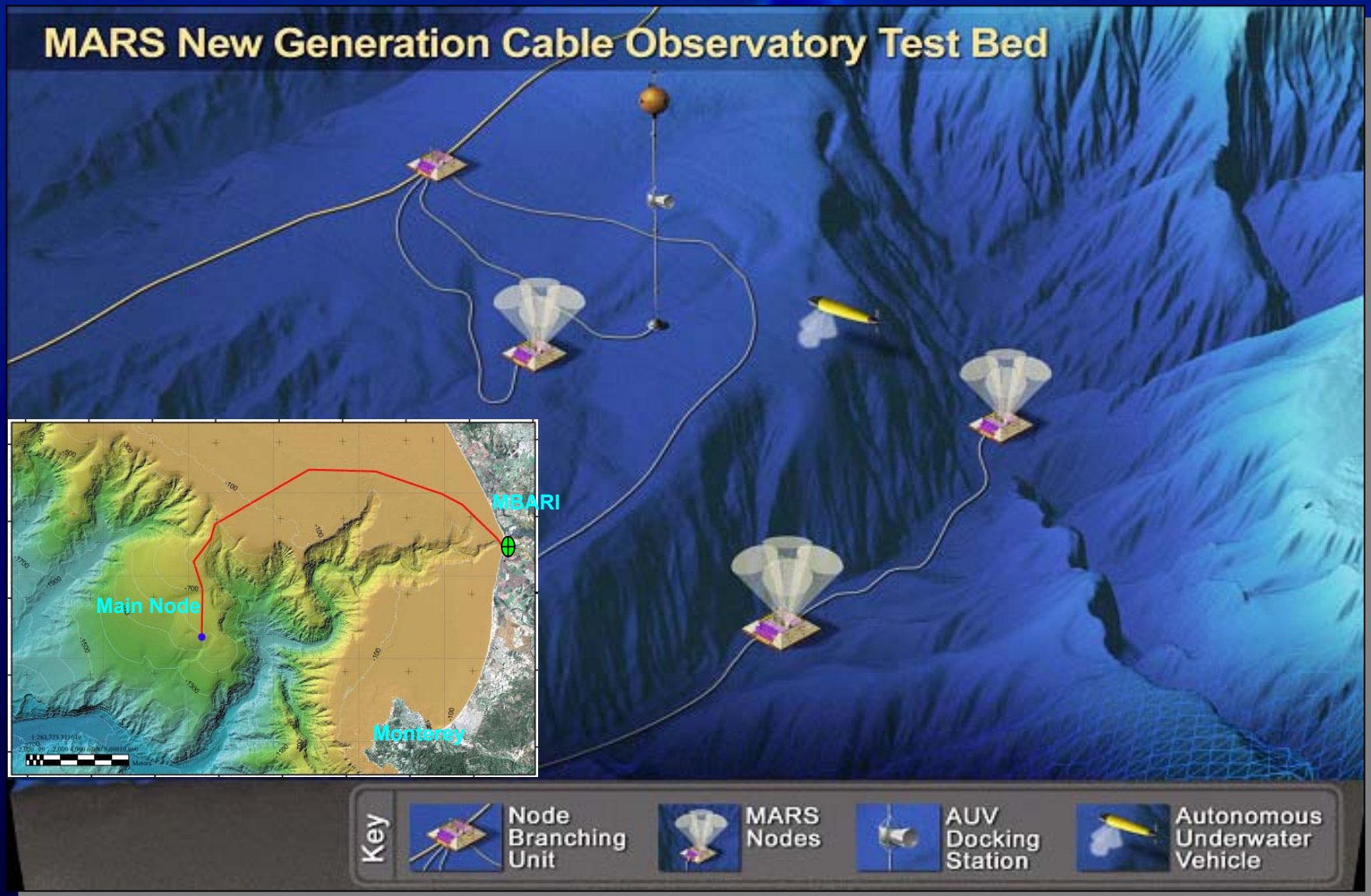
Previous Docking Implementations



Docking Concept for MOOS



Docking Concept for MARS



Conclusions

- Dorado AUV - operational asset
- One vehicle - multiple payloads
- Modules - easily replaced
- Modules - easily upgraded
- Odometer > 1000km

Operations At Sea

- Y2000 - Doradossey MUSE cruise
- Y2001 - Dorado prototype sea trials
  - 25 days
  - 12 different configurations
- Y2001 - ALTEX cruise
  - 10 days
  - Under ice, out of tracking range
  - Higher than 82° latitude operation
- Y2002 - Spokes cruise
- Y2003 - "Delivery" of AUV for full-time science use
- Y2003-Present - Regular CTD transects
- Y2004-Present - Seafloor mapping sea trials

Acknowledgments

National Ocean Partnership Program (NOPP) - managed by the Office of Naval Research
Technology Development - Early Testing
(N00013-98-1-0814)

National Science Foundation
Arctic Operations - Proof of Concept
(OPP-9910290)

David and Lucille Packard Foundation
Monterey Bay Aquarium Research Institute - Dorado AUV activities
(600024)

MBARI Colleagues

Bill Kirkwood
Rob McEwen
Paul McGill
Jim Bellingham
Tom O'Reilly
Dave Caress
Ed Mellinger
Farley Shane
Tarun Podder
Rich Henthorn
Hans Thomas
Duane Thompson