Autonomous Surface Craft Provide Flexibility to Remote Adaptive Oceanographic Sampling and Modeling

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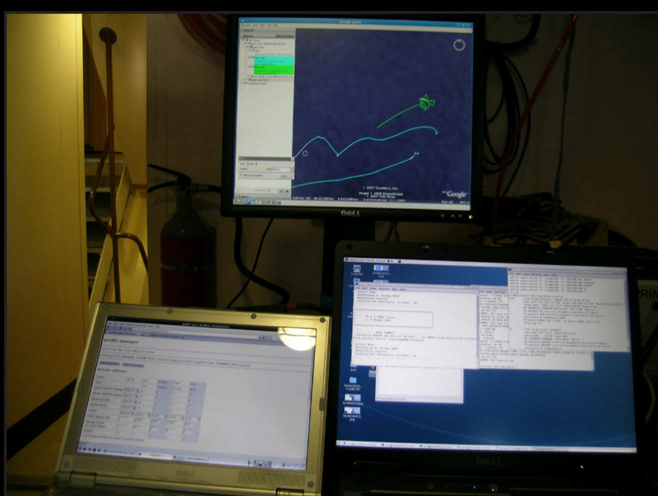

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The Oceanographers' Problem

The ocean is vast and even the microscale is interesting

- Ships are expensive
- Ship deployed instruments are often coarse sampling tools.

Proposed Solution: Autonomous Systems

- Low cost autonomous network (vehicles and shore computers) executes experiments making arbitrarily fine scale measurements

Focus for this talk is on physical oceanography; paradigm can be adapted to biology, chemistry, geology

Why Autonomous Vehicles?

Efficiency

- Automation of mundane tasks
- Reduced expense

Enables New Capability

- Robots can traverse hazardous environments
- Remote immediate sensing: instrument in contact with sample, but scientist removed (perhaps not at sea)
- Adaptive sampling: vehicle makes best use of resources based on new data

Why Autonomous Surface Craft (ASC)?

Low Cost

- Orders of magnitude less expensive than traditional AUVs

Testbed for algorithms

- Code can be tweaked while vehicles in water
- Faster time from simulation to real vehicles with less risk

Rapidly reconfigurable

- Payloads can be rapidly developed to meet changing needs

SCOUT Craft

Commercial off-the-shelf hardware

Basic plastic kayak

Computer
- Mini-ITX
- Debian GNU/Linux

Electric propulsion
- 3 knots full speed

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CTD / Winch Payload

SeaBird 49 CTD on 70 m cable

- 16 Hz serial stream
- Lightweight

Autonomously controlled winch

- Custom serial control board
- Capable of spooling up to 20 meters/minute

Communications

802.11 Wireless

- Allows above water ship to ASC communications
- Star network topology

EV-DO Internet

- Allows near shore vehicles contact to any internet connected machine (e.g. modeling computers)

WHOI Acoustic MicroModem

- Allows underwater communications at 80-5400 bps for several km

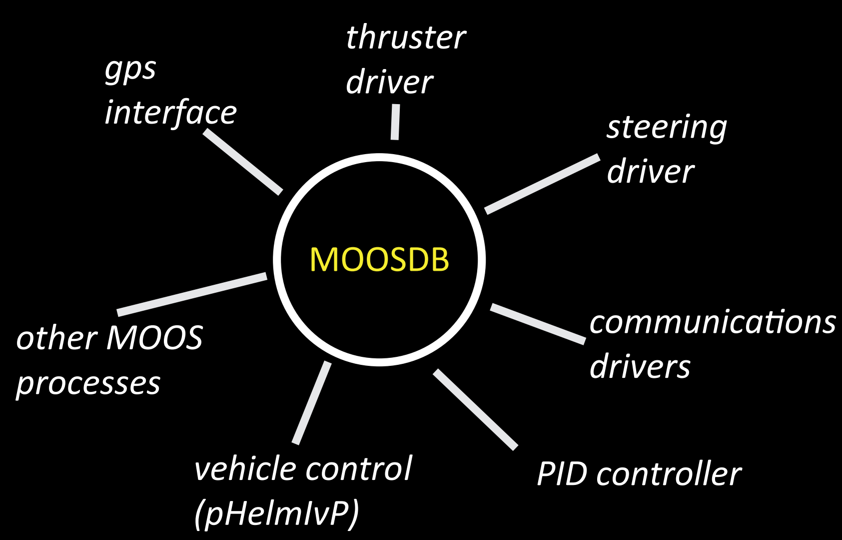
Autonomy System (MOOS-IvP)

Publish / subscribe architecture (MOOS)

- All processes only interact through central database
- Allows for rapid prototyping with multiple collaborators

Multiobjective behavior solver (IvP Helm)

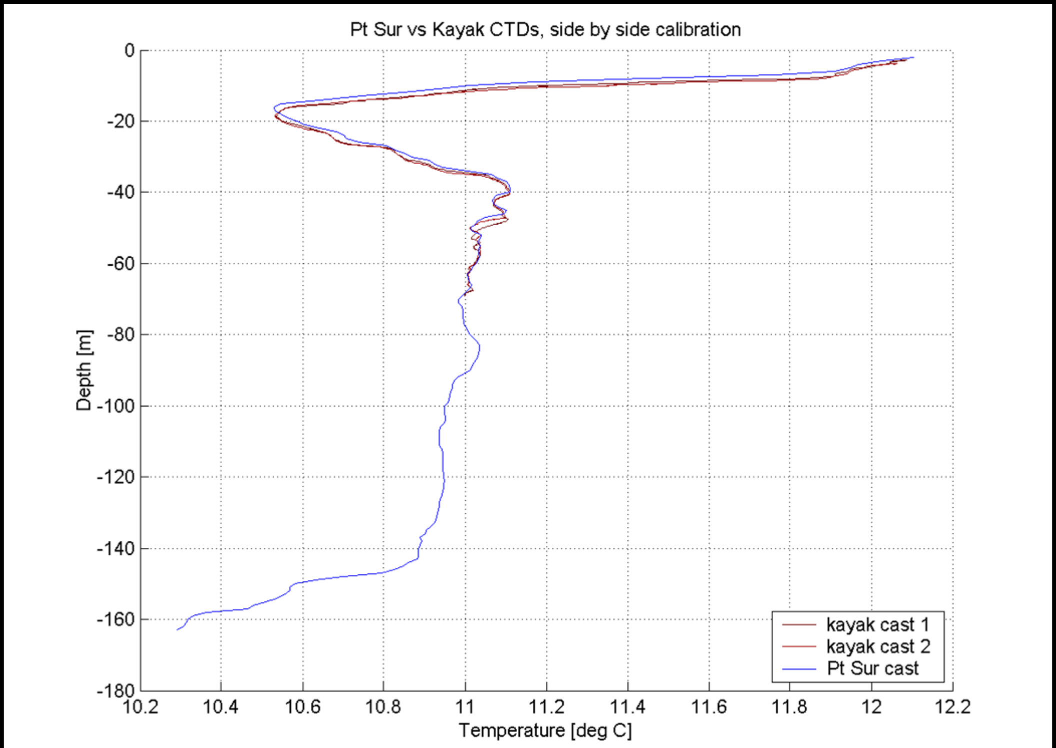
- Allows multiple behaviors to interact to determine vehicle's course and speed.
- Behaviors produce objective function rather than single objective value.



Initial Results | MB '06

Preliminary tests:

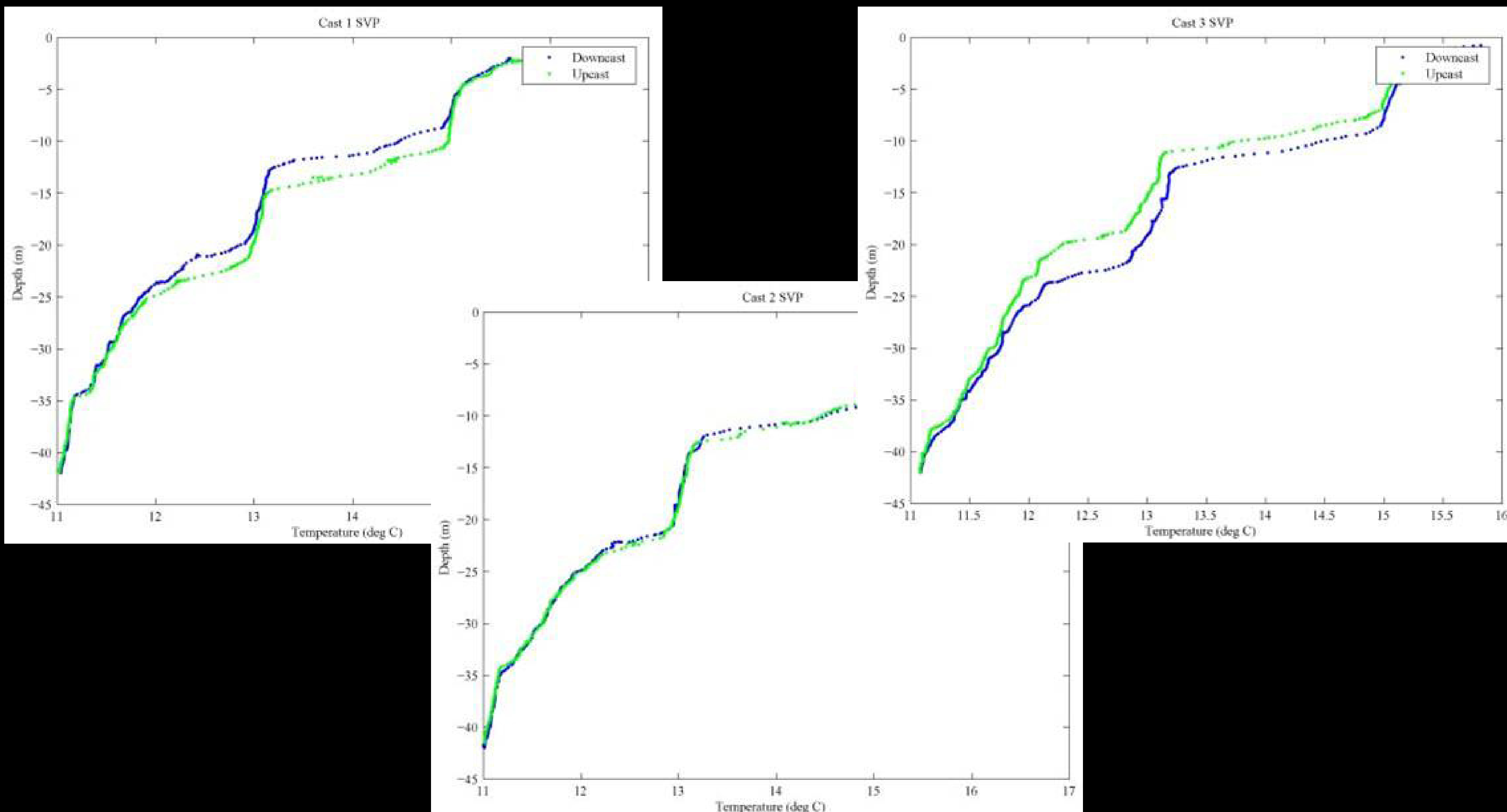
- CTD calibrated with ship instrument



- Autonomous (non adaptive) sampling track - ten casts spacially separated to form a rectangle

Initial Results | MB '06

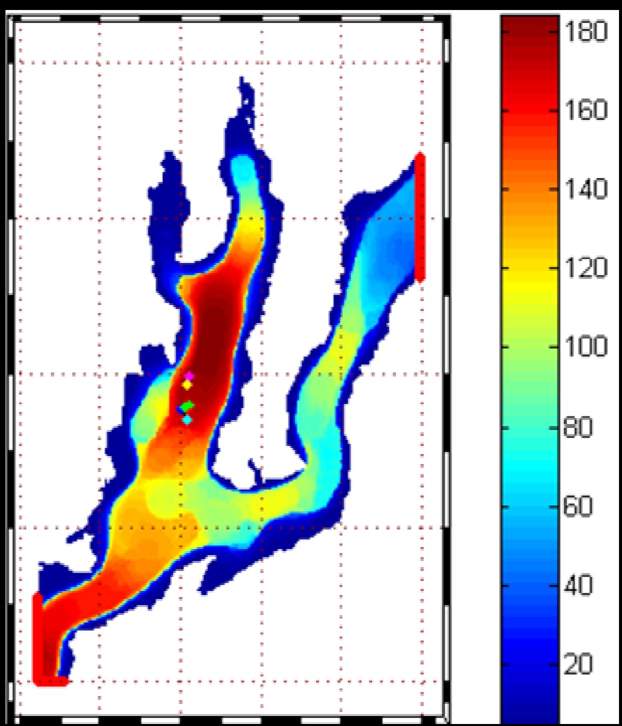
Subset of temperature profiles obtained from this run

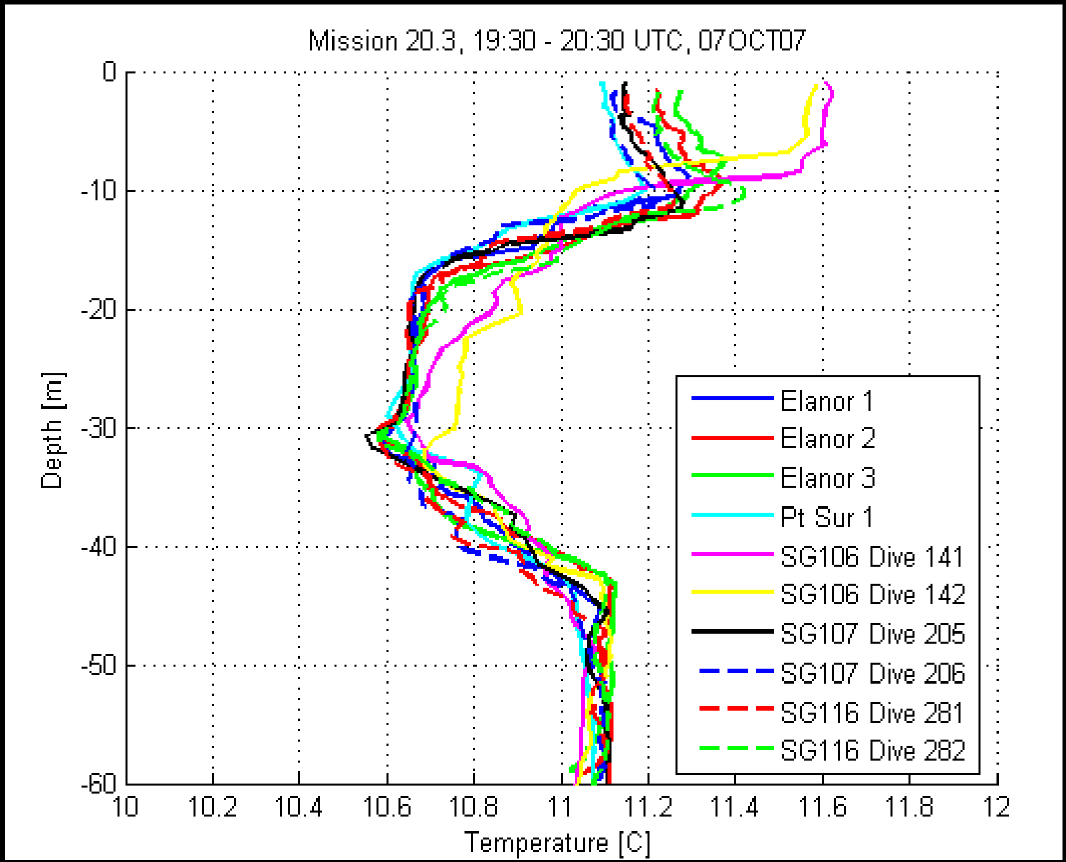


Initial Results | PN '07

EV-DO modem allowed:

- Remote command from MIT webserver
- ASC data available in real time at MIT from field





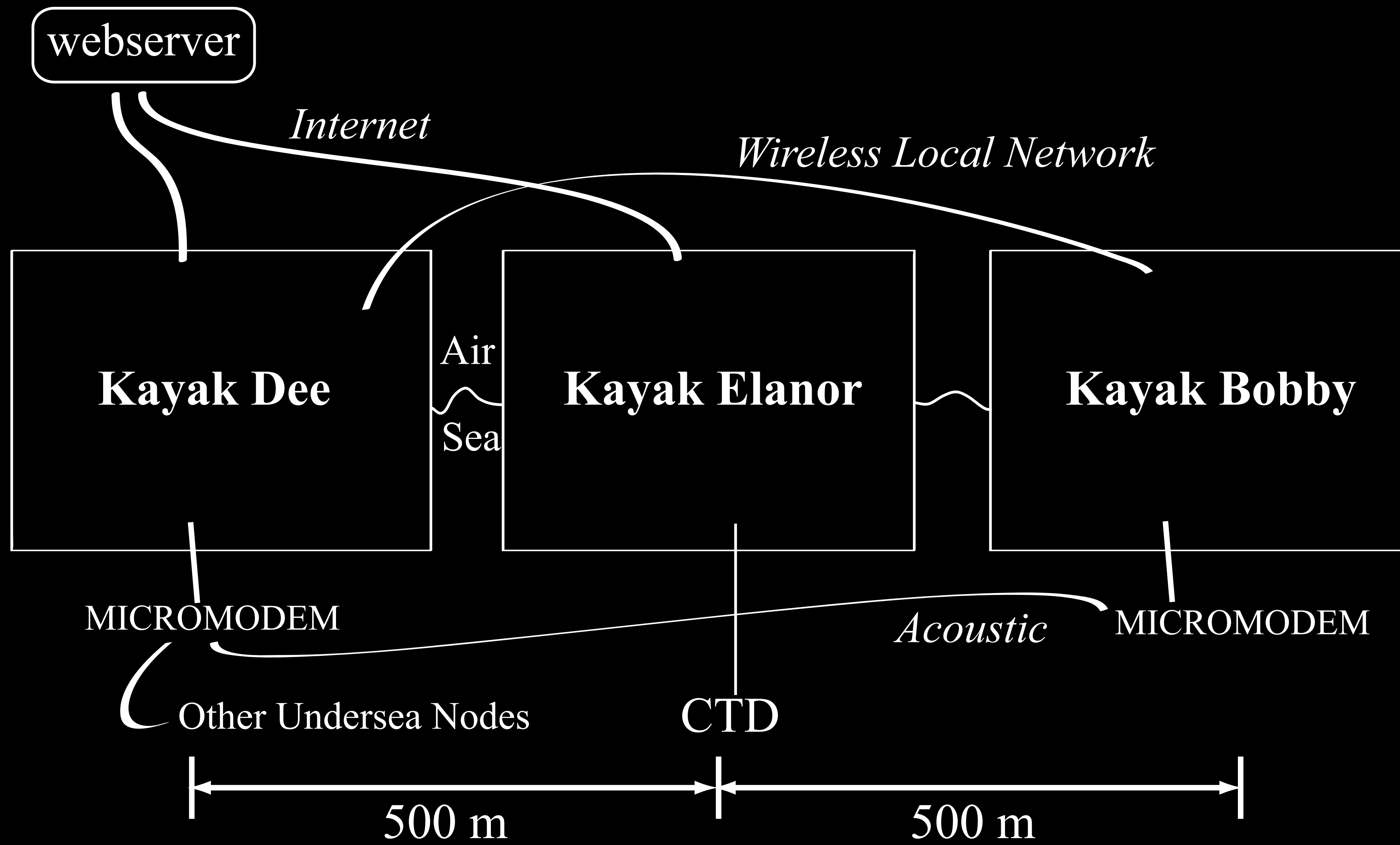
Collaborative Sound Speed Test | Setup

Goal: Extend CTD experiment to demonstrate autonomous multivehicle cooperation

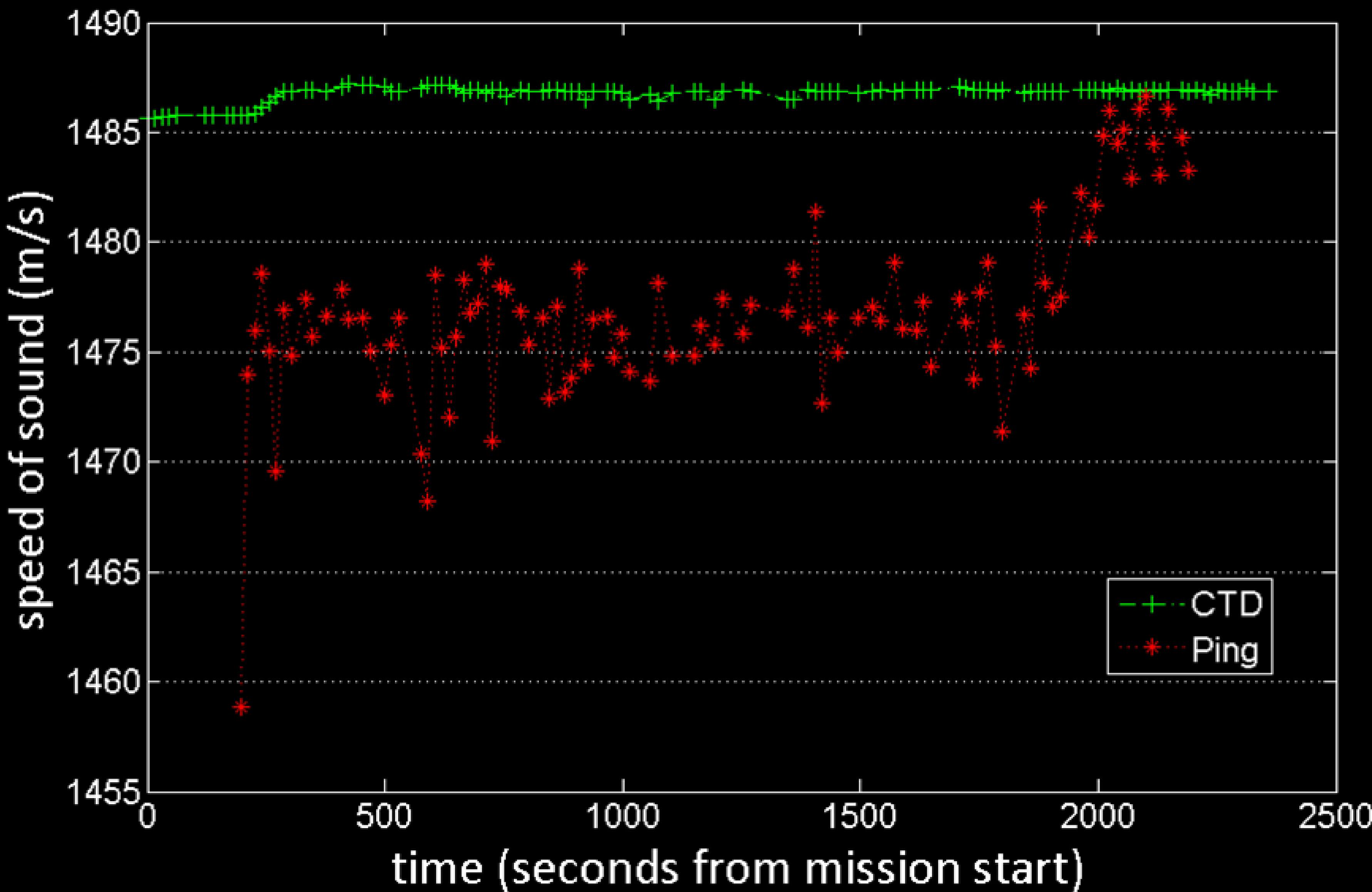
Implementation: Measure sound speed in two independent ways using three vehicles

- Elanor (CTD vehicle): take CTD cast and compute sound speed
- Dee, Bobby (modem vehicles): spread out 1 km (centered on elanor), ping modems and record transit time

Collaborative Sound Speed Test | Setup



Collaborative Sound Speed Test | Data



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The Future

Possibility Examples:

- Combine acoustic models with oceanographic data collected from surface craft and AUVs to automously generate 3D sound velocity profile.
- Integrate adaptive sampling on vehicle with off vehicle to give high resolution CTD sampling in areas of interest and low resolution in relatively homogenous regions

Bring remote adaptive system to other oceanographic disciplines

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