SMART GLIDERS
Multiplying Operational Impact

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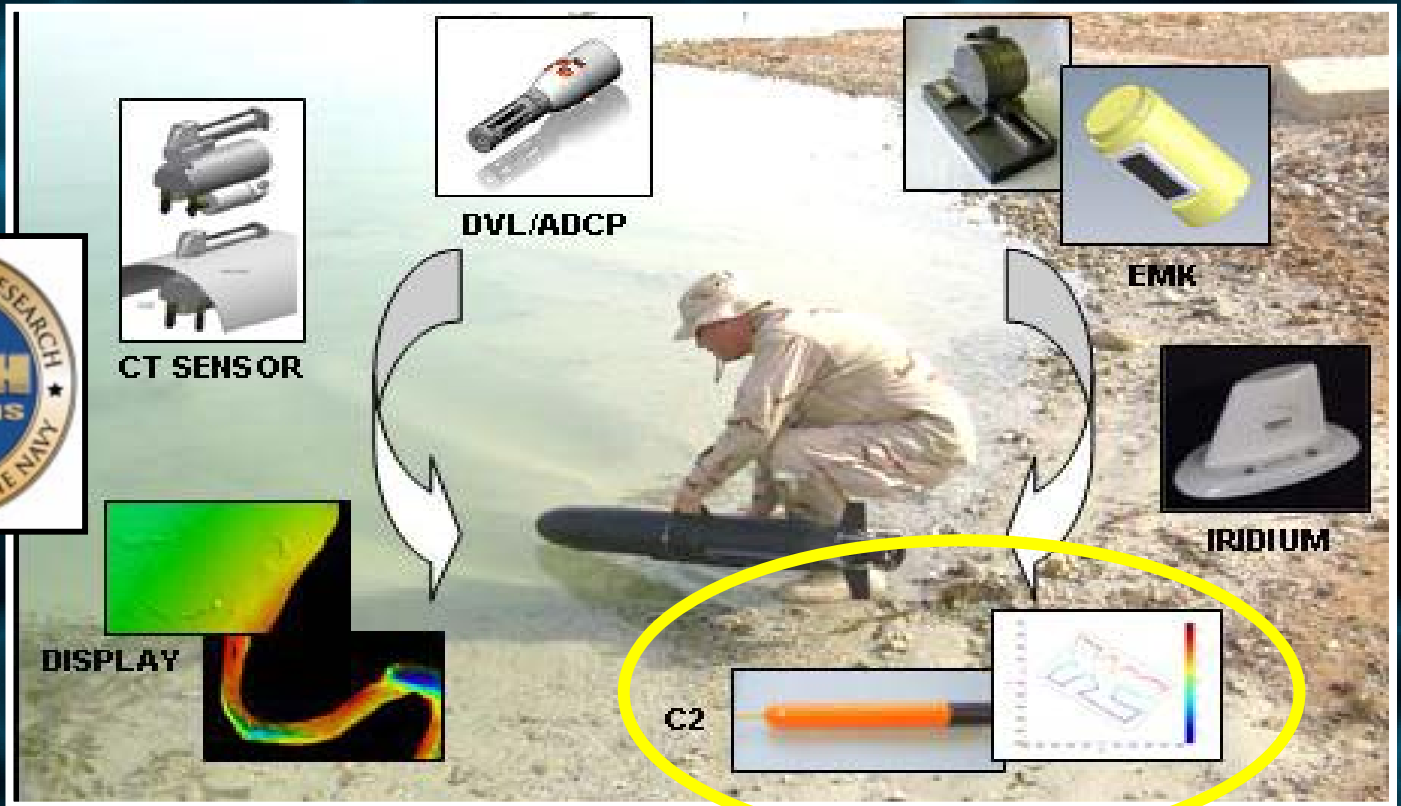
C2 Groundwork Established with Lightweight NSW AUV Project in 2010



HW Integration

Baseline Iver 2 AUVs + Multi-Beam Sonar + DVL/ADCP + Environmental Sensors + Iridium Communications (2-way SBD)

Command and Control SW Improvements/On-scene Products

- Local Data Products -Vehicle Safety -Survey Optimization

Lightweight NSW AUV Achievements

- Supports CONOPS for Intelligence Preparation of the Battlespace by forward deployed units
  - Meets operational requirements
  - Man-portable
  - High operability: ship and shore launch
  - Economical: multi-vehicle OPS, risk mitigation
  - "1-to-many" operations
  - Field maintenance and repair
  - Local data products
- Integration of commercial components with Iver2 AUV baseline to leverage industrial base
- Enhanced Command and Control functions triggered by through-the-sensor data for autonomous, adaptive survey replanning supporting mission optimization and safety

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Command and Control (C2) Implementation Approach

- 2nd CPU for C2 behaviors independent of vendor
- Mission Oriented Operating Suite (MOOS) – IvP
  - Function (behavior) library
  - Goal management for multi-objective scenarios
- Hybrid design for vehicle control
  - Mission data provided by AUV mission planner as simple waypoint file, not tied to vendor.
  - Functions residing in MOOS library triggered by through the sensor data or event. Control reverts to primary vehicle controller after function completed, awaits next triggering event.

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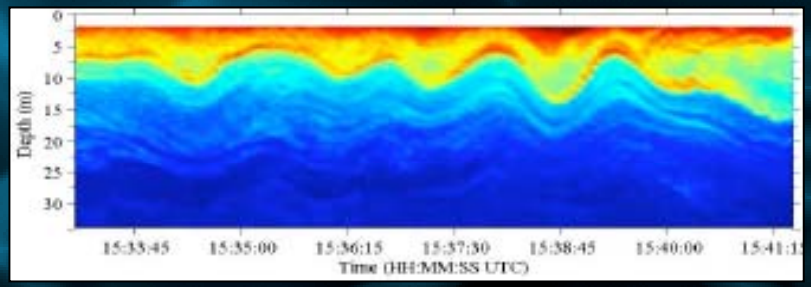
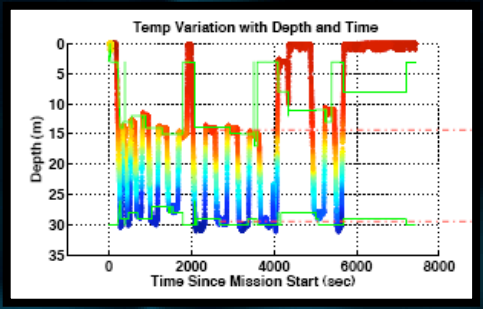
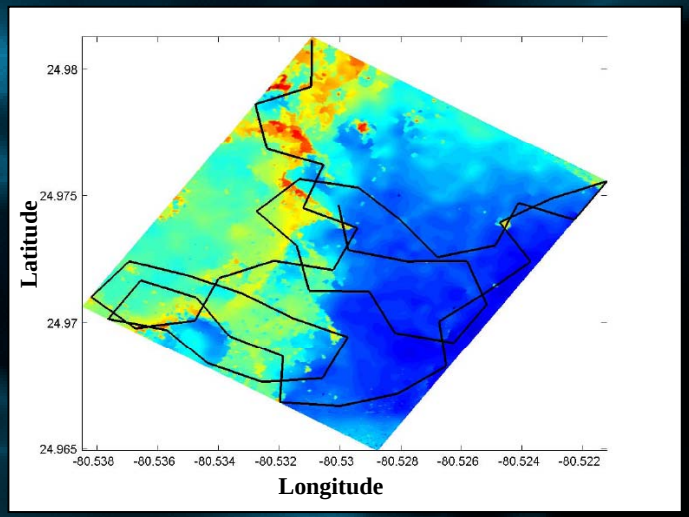
NSW AUV C2 Functions
Survey Optimization





MIT Algorithm: Thermocline Mapping with Reduced Survey Time



NATO Algorithm: Optimal Path Planning for Environmental Characterization (1 AUV, 3 kt, 2 hr)

- Streamline survey effort: equivalent product with reduced survey times
- Automated coordination of multiple vehicles

****Introduction required only 1 week for recoding, simulation, and test****

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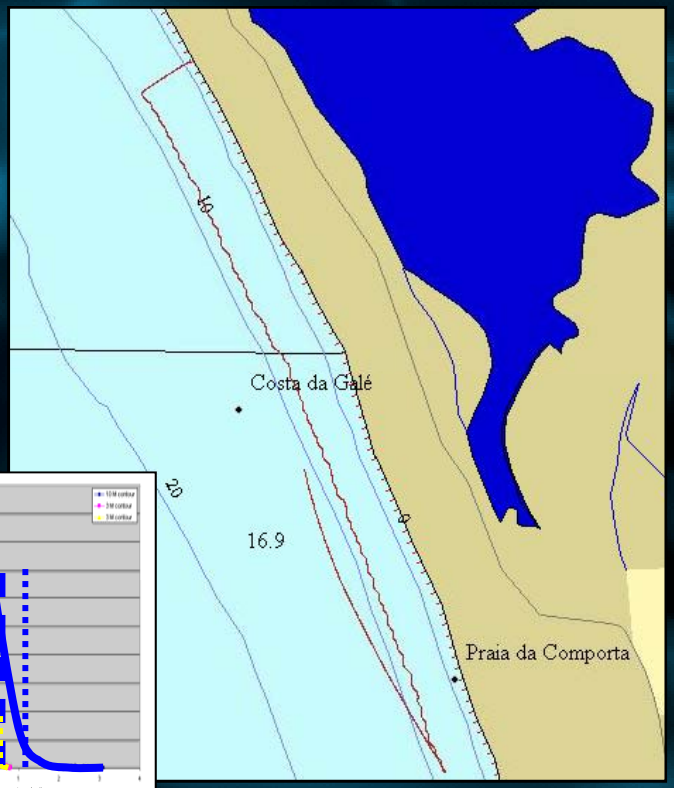
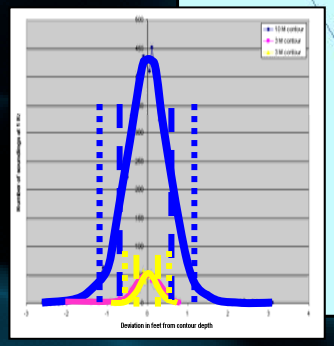
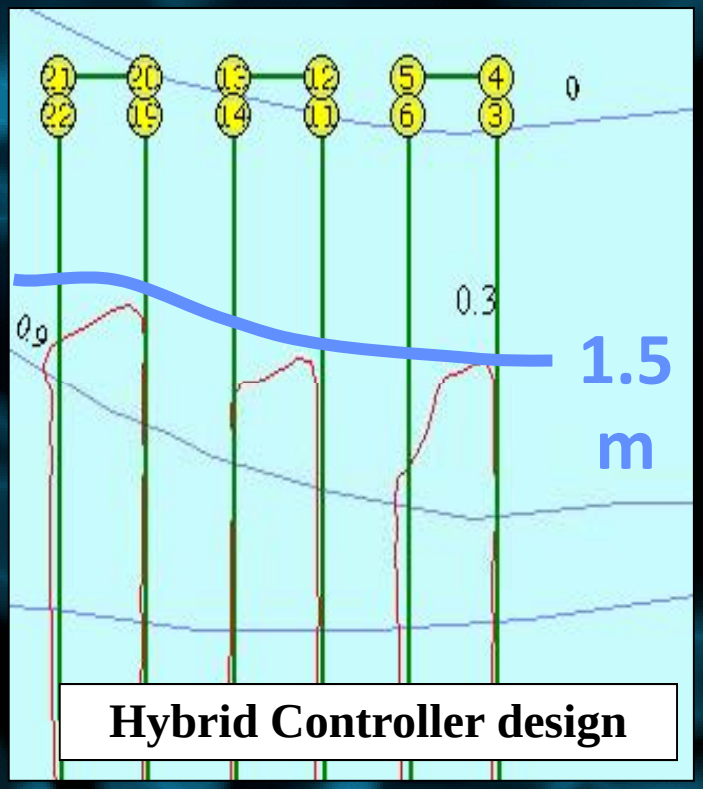
NSW AUV C2 Functions
Survey Optimization and Vehicle Safety







- Mapping of 10 m contour from shore launch
- Total Distance Run Only 8% Greater Than Contour Length; SD 0.6 ft
- 95% msmts in 2 SD; 71% in 1 SD

- Follow mission plan until depth threshold triggered
- MOOS function provides rate-driven response behavior
- Control reverts after depth cleared

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Benefits of C2 Implementation

Advantages to Implementation Approach

- Economy of updates
- Rapid update cycles
- Leveraging broad development efforts
- Cross-decking to platforms

Operational Benefits

- Survey effort reduction (time, resources)
- Reduces risk to survey assets
- Promotes one-to-many operations
- Product fidelity increase
- Reduces modeling anomalies

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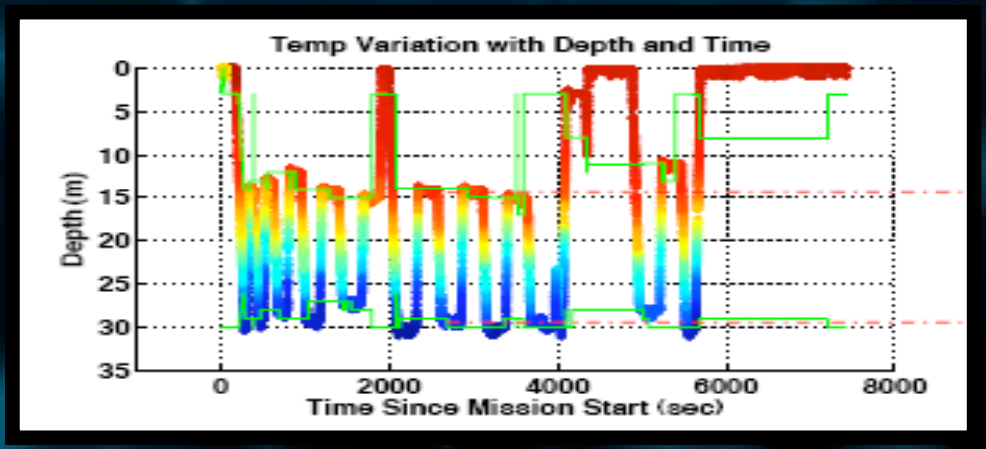
Example: Rapid Algorithm Update



Thermocline-Following Algorithm Updates

- MIT: set floor and ceiling with full depth excursion and maintain for subsequent yo's
- INESC Porto: establish floor and ceiling with full depth excursion and re-assess with every yo
- MBARI: assess gradient on each depth excursion and dive/climb when gradient achieved

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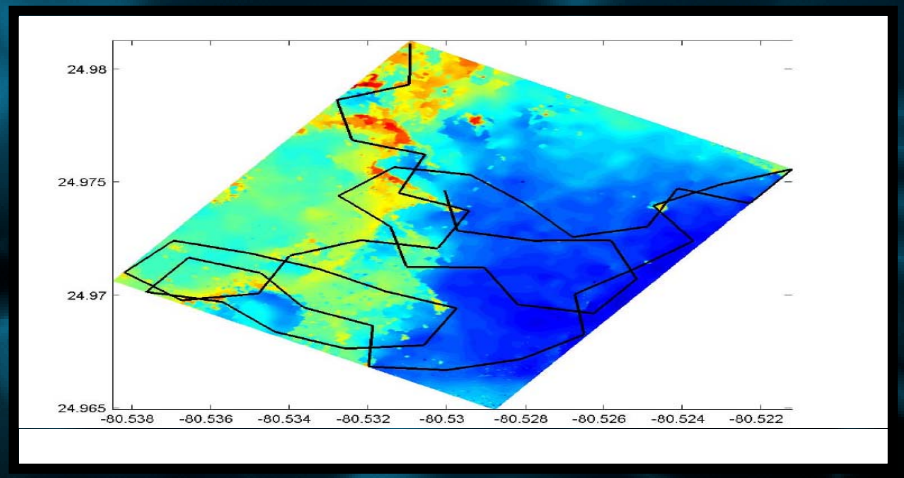
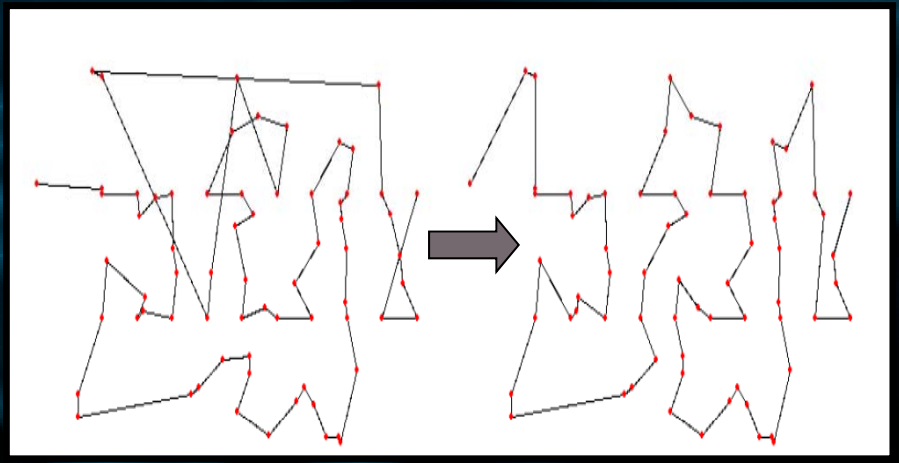
Example: Leveraging Multi-Agency Research





Optimal Path Calculation Approaches

- IPB: NATO algorithm based on area, time, resources, and speed
- IPB/MIW: U of Idaho genetic algorithms for route planning of selected points using ocean current effects
  - Implemented in MOOS
  - Rapid run time (4 s) for on-board re-planning

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The Key to Survey Optimization: Adaptive Search

Hybrid Implementation w/ Back-Seat Driver for mapping of patchy phenomenon/boundaries

- **Performs adaptive search on-site without post-mission review and re-vectoring of assets**
  - reduces time and risk
  - captures dynamic processes
  - maintains original mission geometries
- **Increases data product fidelity**
  - rapid feature identification
  - full characterization of feature
  - data “bulls eyes” and anomaly filtering avoided

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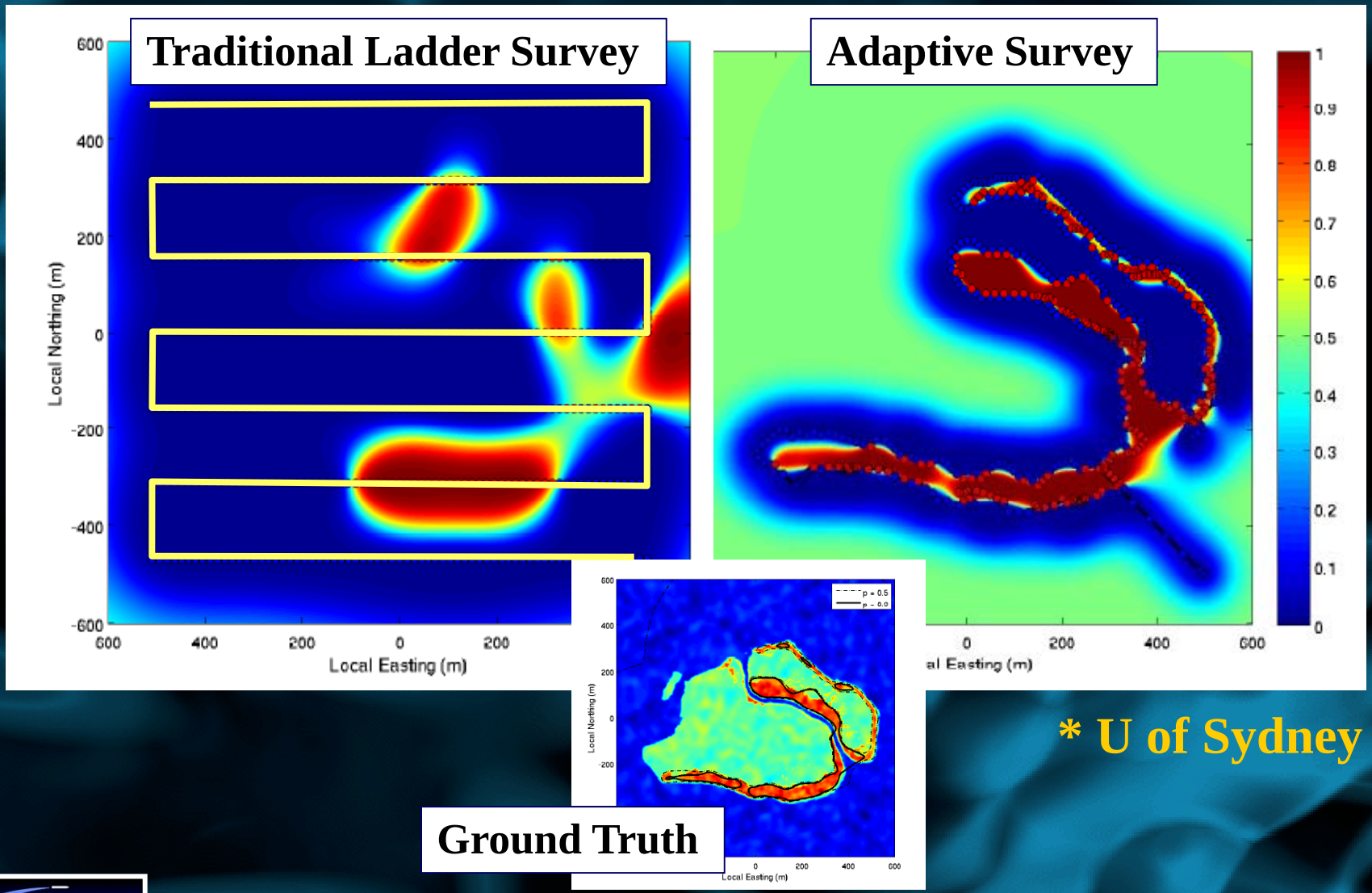
Example of Adaptive Search



* U of Sydney

Product value increase with 50% of survey commitment

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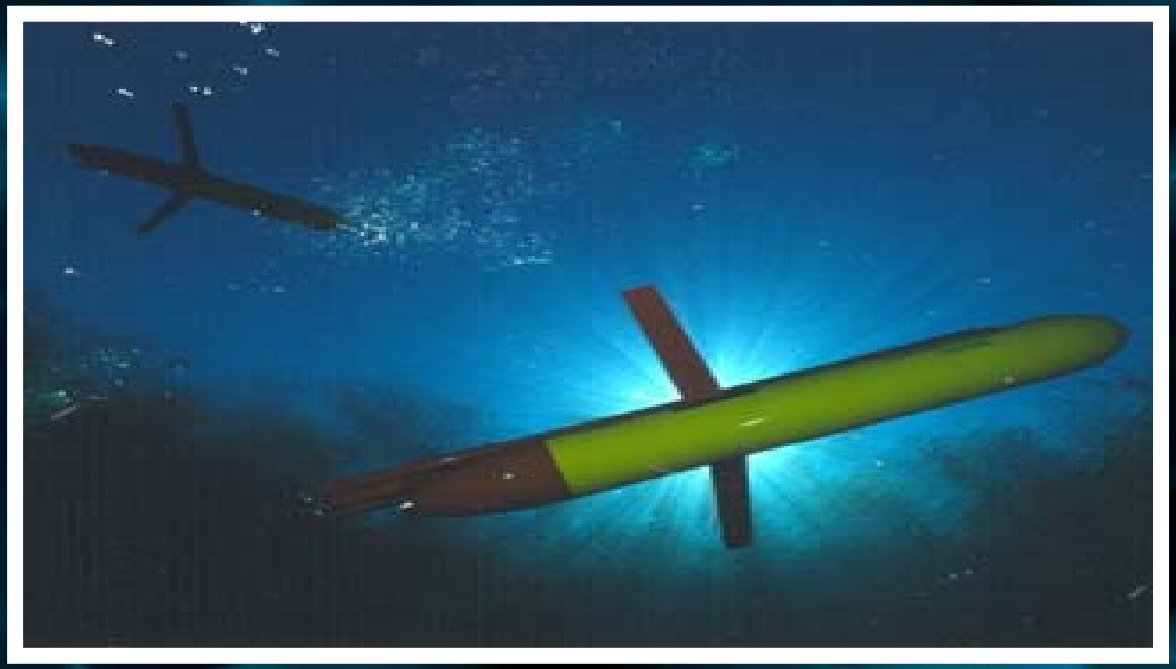
PROPOSAL: ADAPTIVE OCEANOGRAPHY HYBRID AUV FLEETS



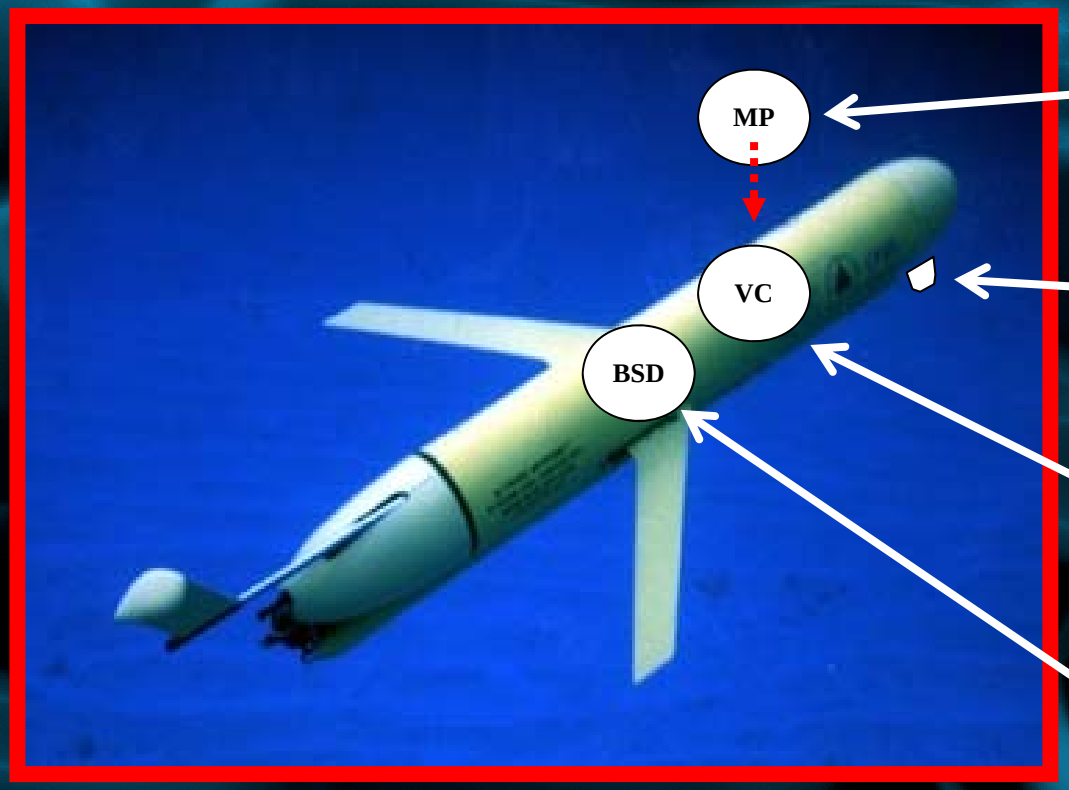
Phase 1 (2011)

1. Migrate Hybrid Controller design to 2nd CPU with MOOS-IvP on the ANT/SLOCUM gliders
2. Demonstrate adaptive single-platform survey behaviors

Phase 2 (2012)

1. Demonstrate AUV communications and networking for fleet response
2. Demonstrate layered autonomy and Command and Control in a sampling network

HW and Firmware in AUVs



Off-Board Mission Planner

WHOI Acoustic Micromodem *

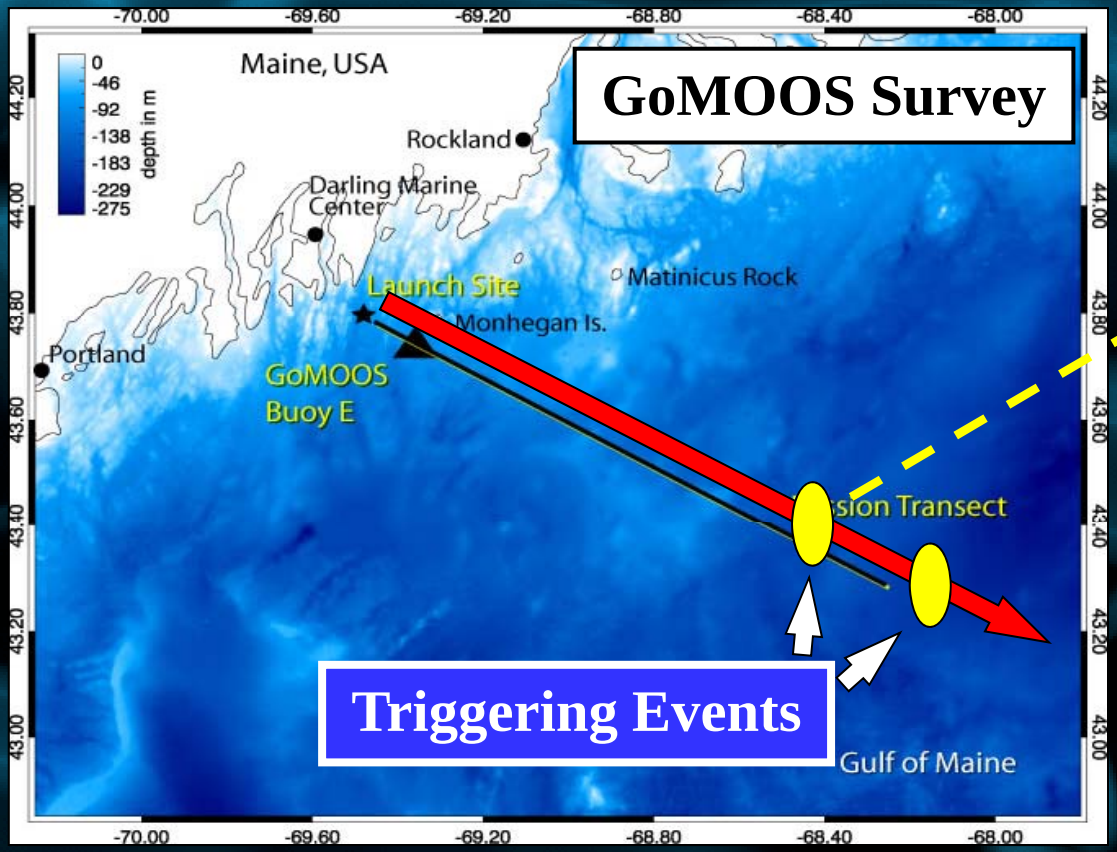
Primary Vehicle Controller from Vendor

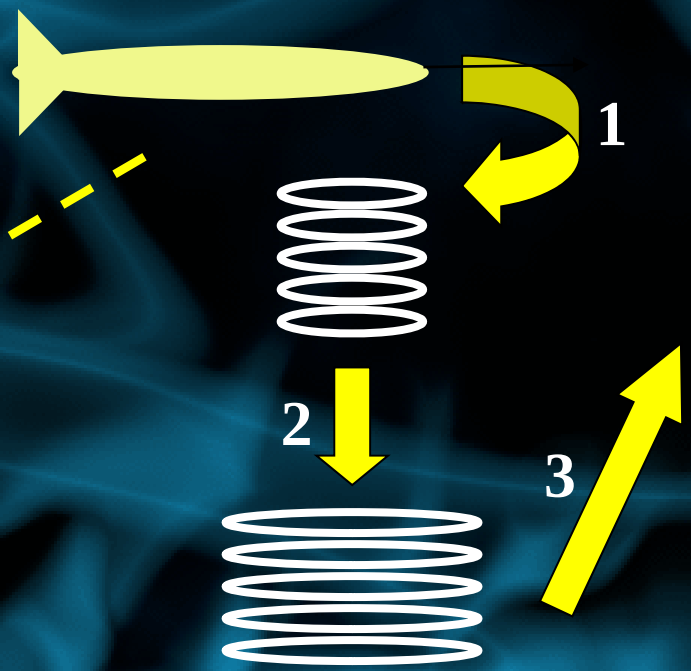
2nd CPU (BSD) w/ MOOS IvP for C2 Initiatives *

*** Integration Item**

Energy budget and ballasting accommodate integration for coastal missions

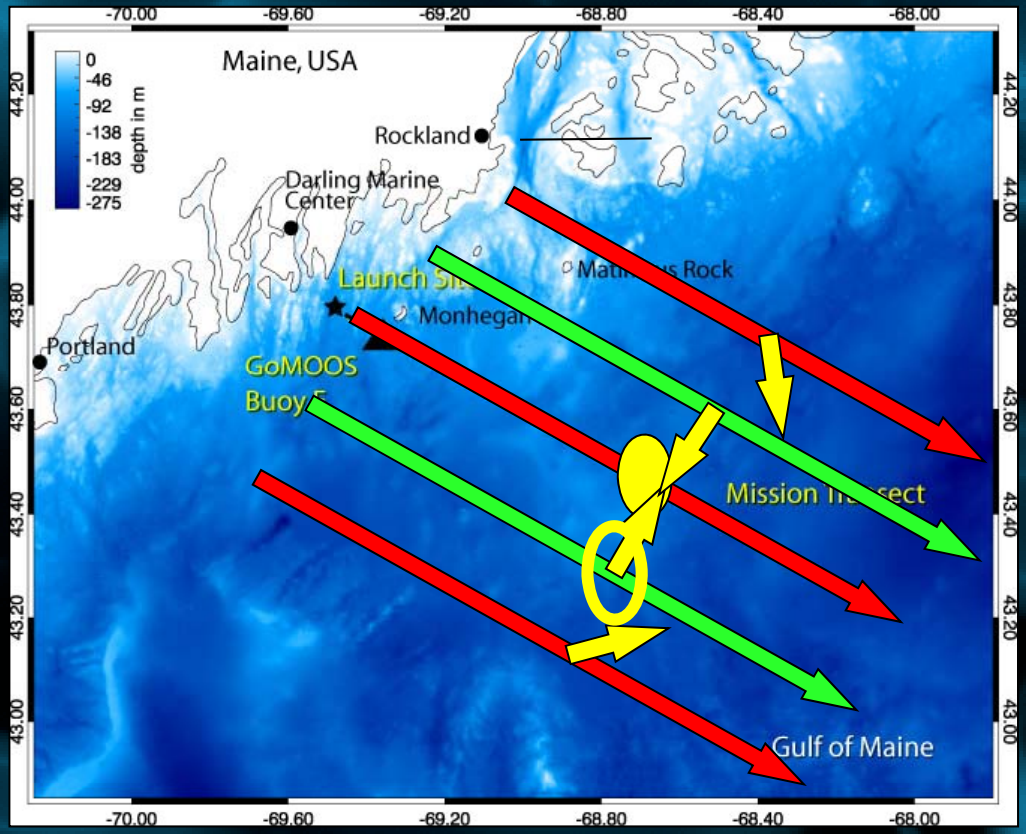
Adaptive Search Triggered by Through-the-Sensor Data





1. Spiral search when detect parameter threshold (e.g., transmissivity)
2. Adapt search to sensed data in real time to map feature boundaries
3. Resume original baseline mission plan (e.g., transect)

Autonomous Fleet Response



Trigger Event

Comms Event

Re-vector

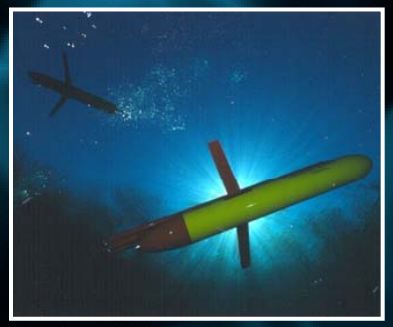
Glider

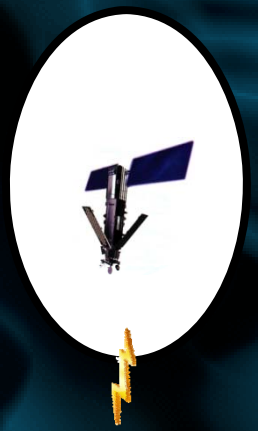
Powered AUV

- Adaptive functions triggered by through-the-sensor data
- Communication to fleet and remote C2 node of event
- Individual asset track plans in fleet updated autonomously

Layered C2 & Communications for Networked Surveys with Hybrid AUV Fleets

ANT and Slocum Gliders





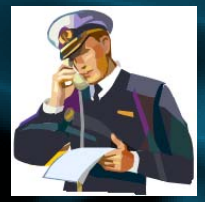
GoMOOS Buoys

Fleet Collaboration

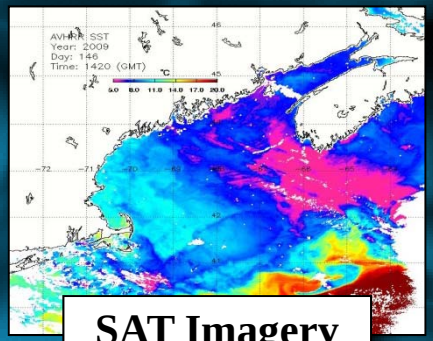
C2

GATEWAY,

IRIDIUM



C2



SAT Imagery

Low-Powered AUVs

Summary

- The Back-Seat Driver design supports rapid and economical fielding of behaviors for survey optimization and vehicle safety, and represents a near-term Navy solution for AUV C2
- The hybrid implementation provides true adaptive oceanographic survey capability to AUVs allowing response to sensed data
- Glider operations can immediately benefit from implementation of adaptive survey behaviors in terms of operational performance, reduced risk, support of 1-to-many operations, and improved data products
- Layered Command and Control allows for optimal use of hybrid AUV fleets and other resources in survey applications

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