A Review of Automatic Depth Contour Following with MOOS-IvP

Scott R. Sideleau
NUWC Newport
Code 2534
scott.sideleau@navy.mil

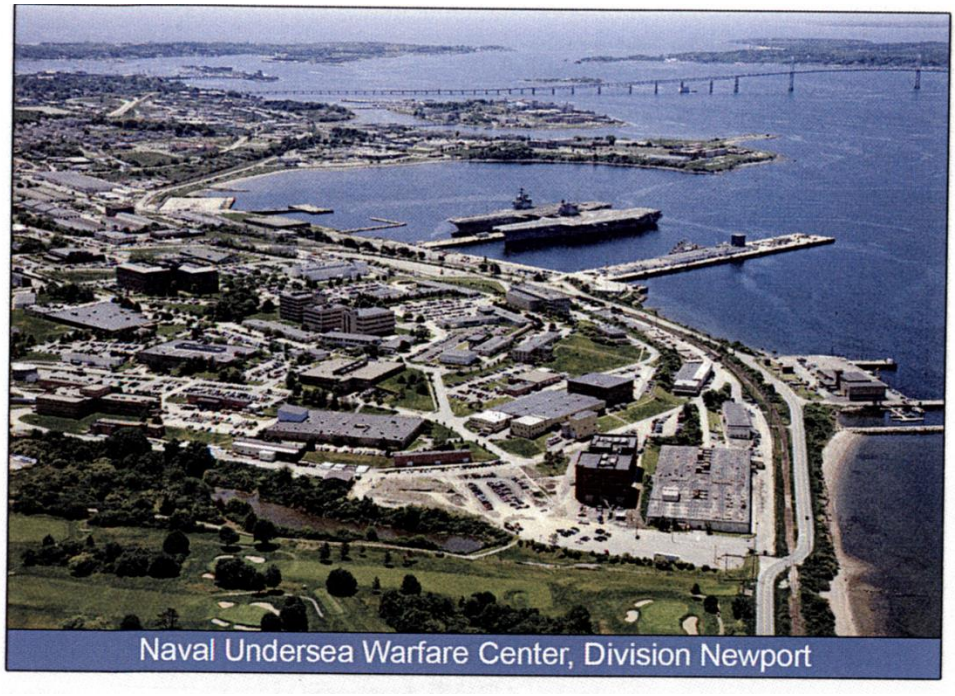
Michael L. Incze, PhD
NUWC Newport
Code 2534
michael.l.incze@navy.mil

Overview

- About us
  - NUWC Newport
  - Command & Control Asset Pool (C2AP)
  - Iver2 UUV by OceanServer
- What is automatic depth contour following?
  - Concept of Operations (CONOPS)
  - Behavior / algorithm evolution
  - Supporting MOOS Apps
- Future work

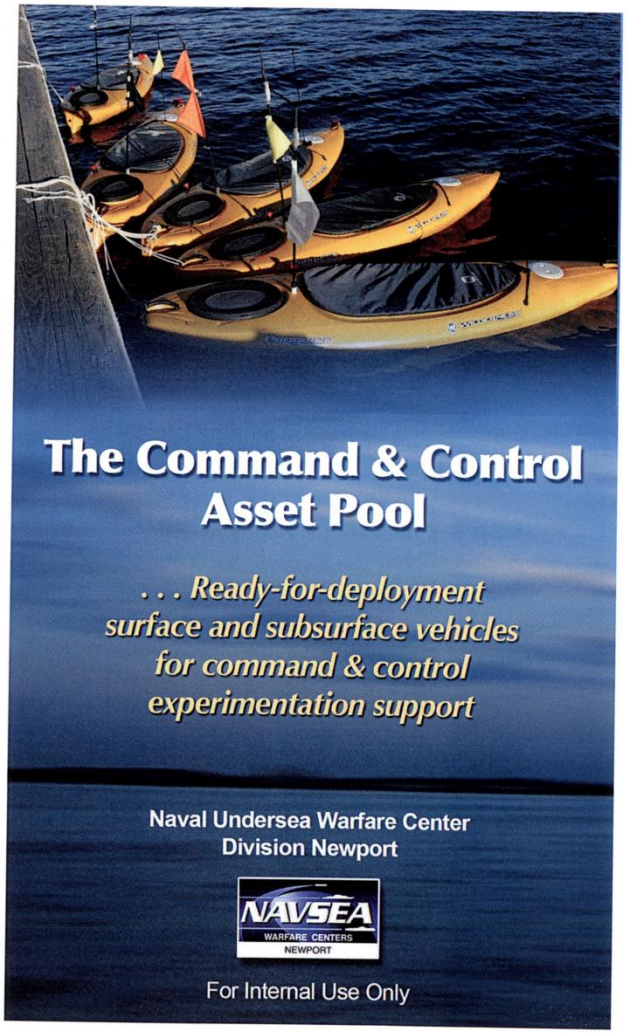
NUWC Newport

- RDT&E engineering and Fleet support facility for the US Navy
- Employing ~4k scientists and engineers (government and contractor support)
- Focus on all aspects of undersea warfare
  - Submarines
  - Offensive and Defensive Weapons Systems
  - Maritime UxVs

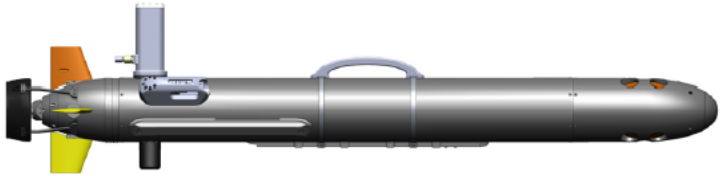

Naval Undersea Warfare Center, Division Newport

Command & Control Asset Pool

- Cross-departmental team with:
  - MOOS-IvP behavior development expertise
  - MOOS App development expertise
  - Modeling & Simulation expertise
  - Operational expertise from participation in several US Navy and NATO exercises around the globe
- Maritime robotics platforms:
  - 3x “classic” Iver2 UUVs
  - 1x Lightweight NSW Iver2 UUV
  - 1x Iver3 UUV
  - 3x Scout ASCs



Iver2 UUV by OceanServer

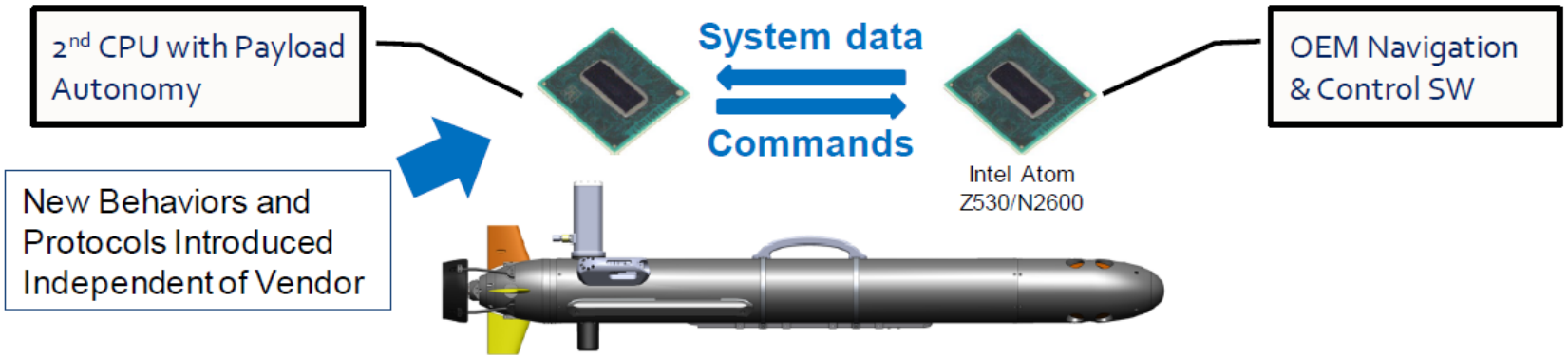


- ✓ **Commercial Product with Transition to Fleet**
  - Developed with private industry internal R&D funds
  - Vehicle components and payload predominantly COTS
  - Continuing upgrades and component integration driven and funded by market (non-Navy) demand
  - Special functions and payloads via Navy development
- ✓ **Low-Cost**
  - Economical procurement and operation
  - Multiple platforms operated at reduced risk
  - Surrogate for high-cost or unavailable platforms
  - $53K-$63K base; $110K-$250K SOF loadout
- ✓ **High Operability and Robustness**
  - Rapid training cycle
  - Flexible launch/recovery
  - On-scene maintenance and repair

RESULT = HIGH OPTEMPO

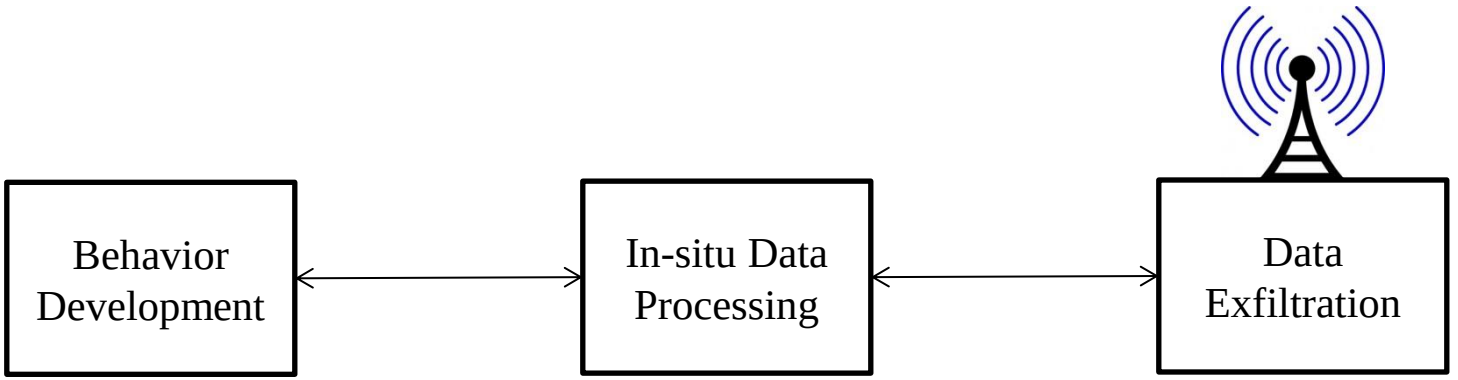
Enabling C2 Development

- **Payload autonomy on secondary CPU to streamline process independent of vendor and reduce development risk**
- **Fully exposed and documented APIs for all sensors and vehicle control/status parameters**
- **2-way exchange of data and commands**



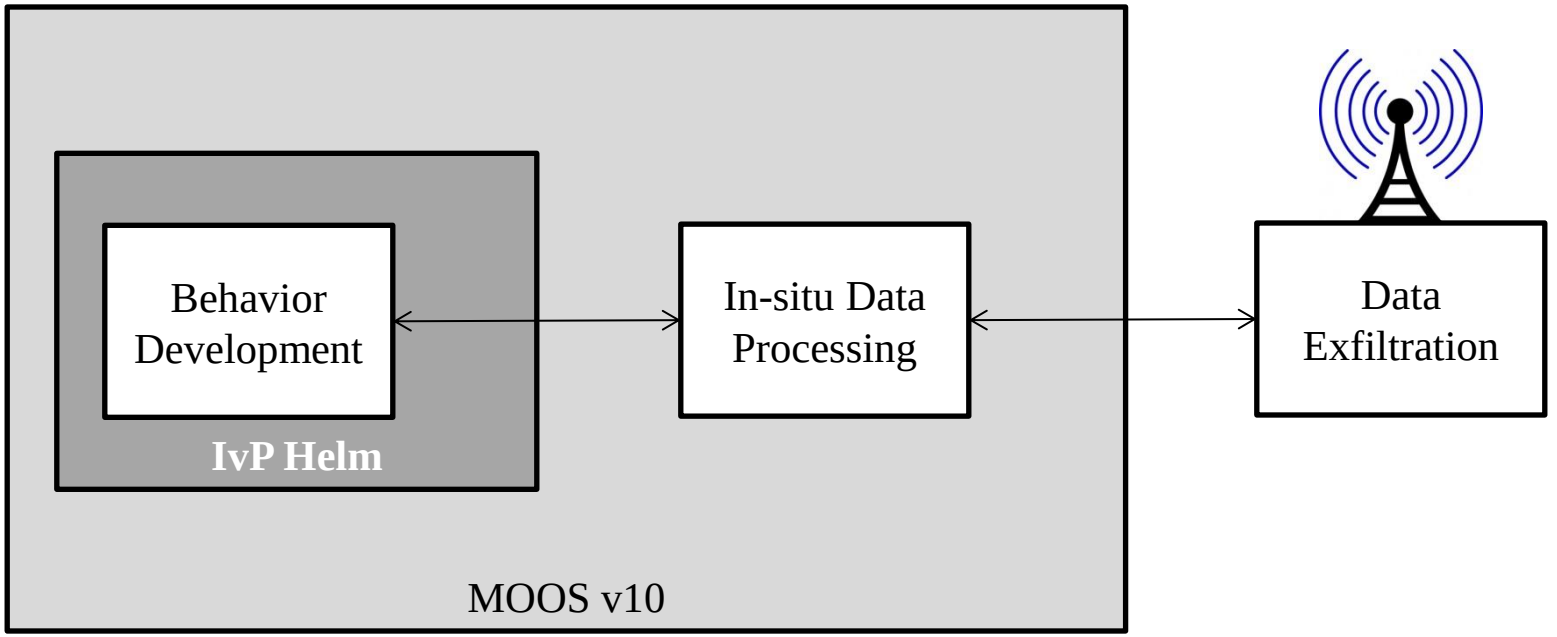
Rapid, low-cost development and introduction of new functions independent of vendor

CONOPS: Three Pillars



Not just behavior development…

MOOS-IvP + CONOPS



Full operational concept development demonstrated on surrogate platforms.

Desire for Adaptive Contour

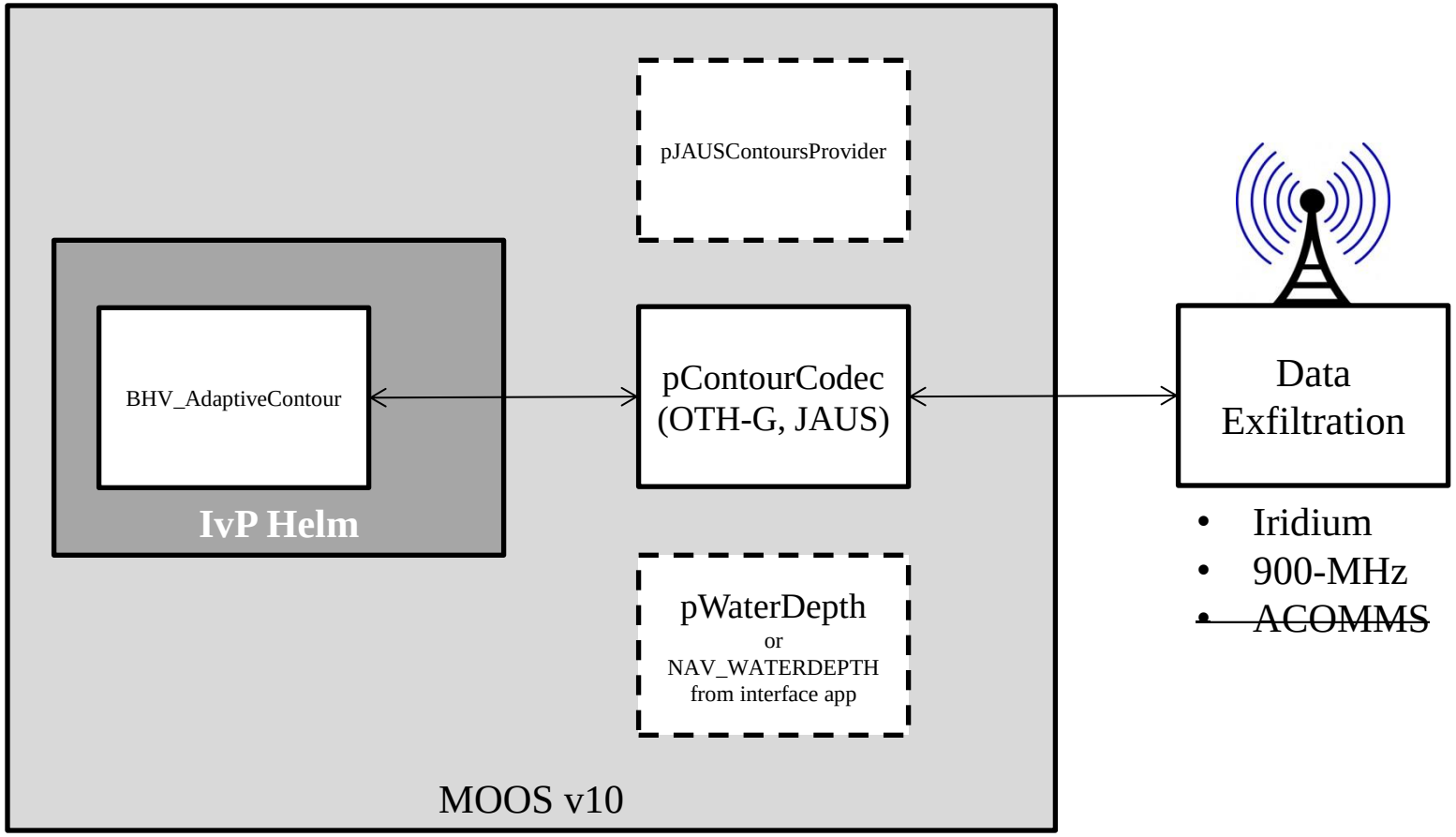
- Warfighters increasingly in operational areas where low resolution data exists close to shore
- Warfighter need to map depth contours of interest for:
  - Ingress / Egress
  - Other types of route planning (mission specific)
  - Safety
- In the past, warfighter might have mapped contours manually or waited for third-party data
- Can we enable robots to increase the optempo?

*Rapidly **provide** an 80% solution to the warfighter.*

Adaptive Contour CONOPS

Inputs

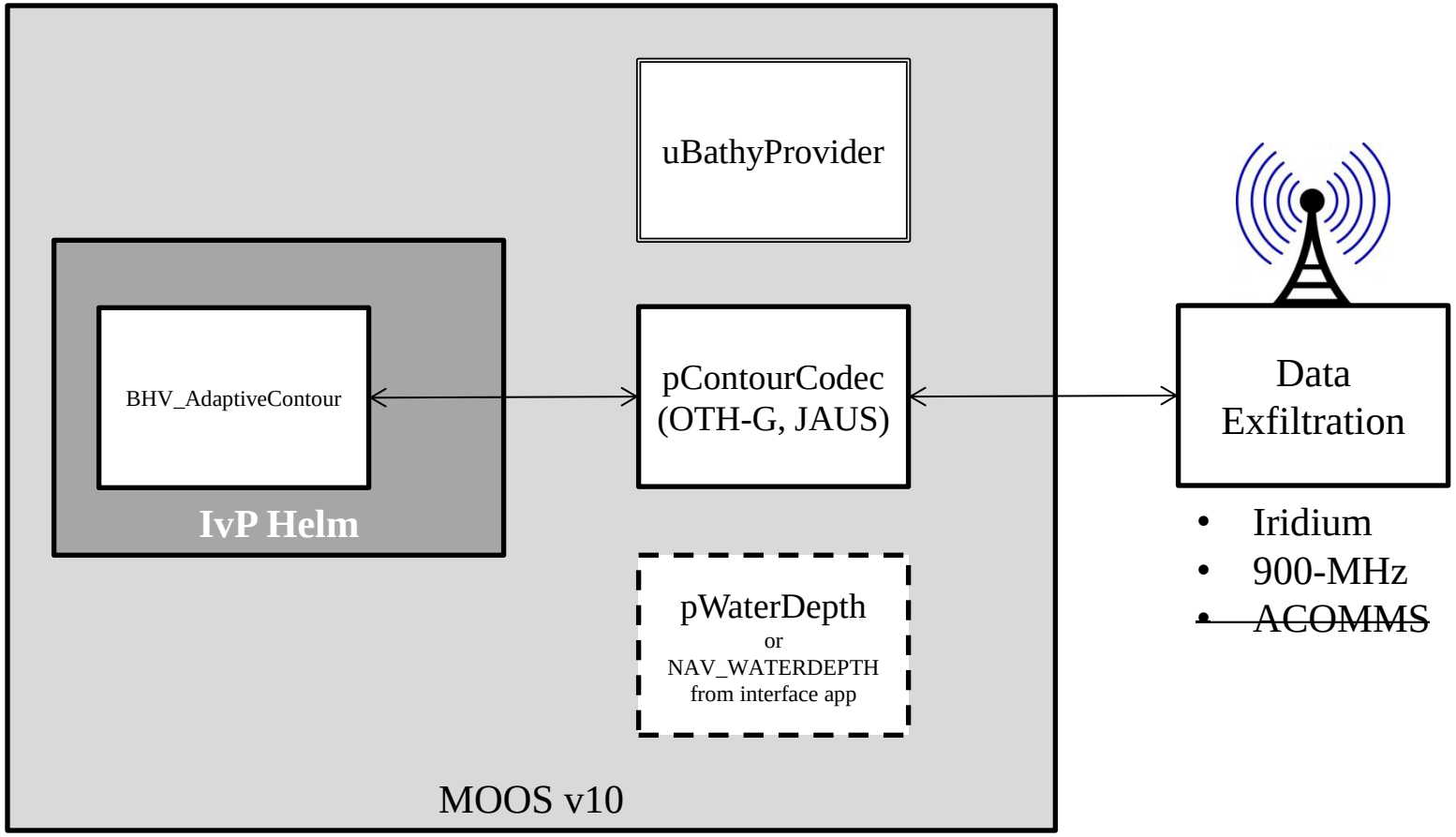
- Contour (list)
- Distance (m)
- Initial Heading (degrees)
- Deadband (m)
- Max Distance (m)
- Max Distance to New (m)
- First Turn Direction (L or R)



Sim/Stim for Adaptive Contour

Inputs

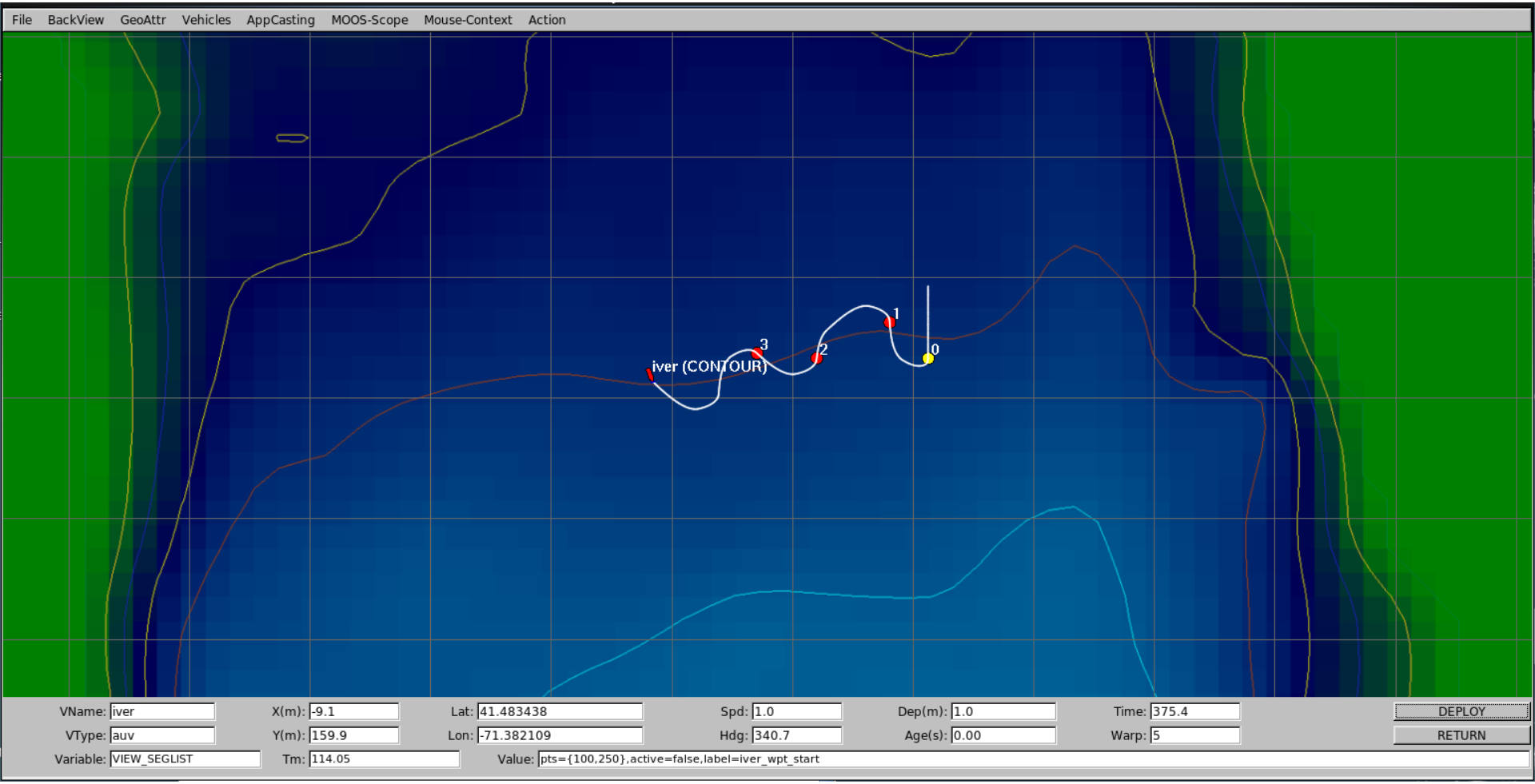
- Contour (list)
- Distance (m)
- Initial Heading (degrees)
- Deadband (m)
- Max Distance (m)
- Max Distance to New (m)
- First Turn Direction (L or R)



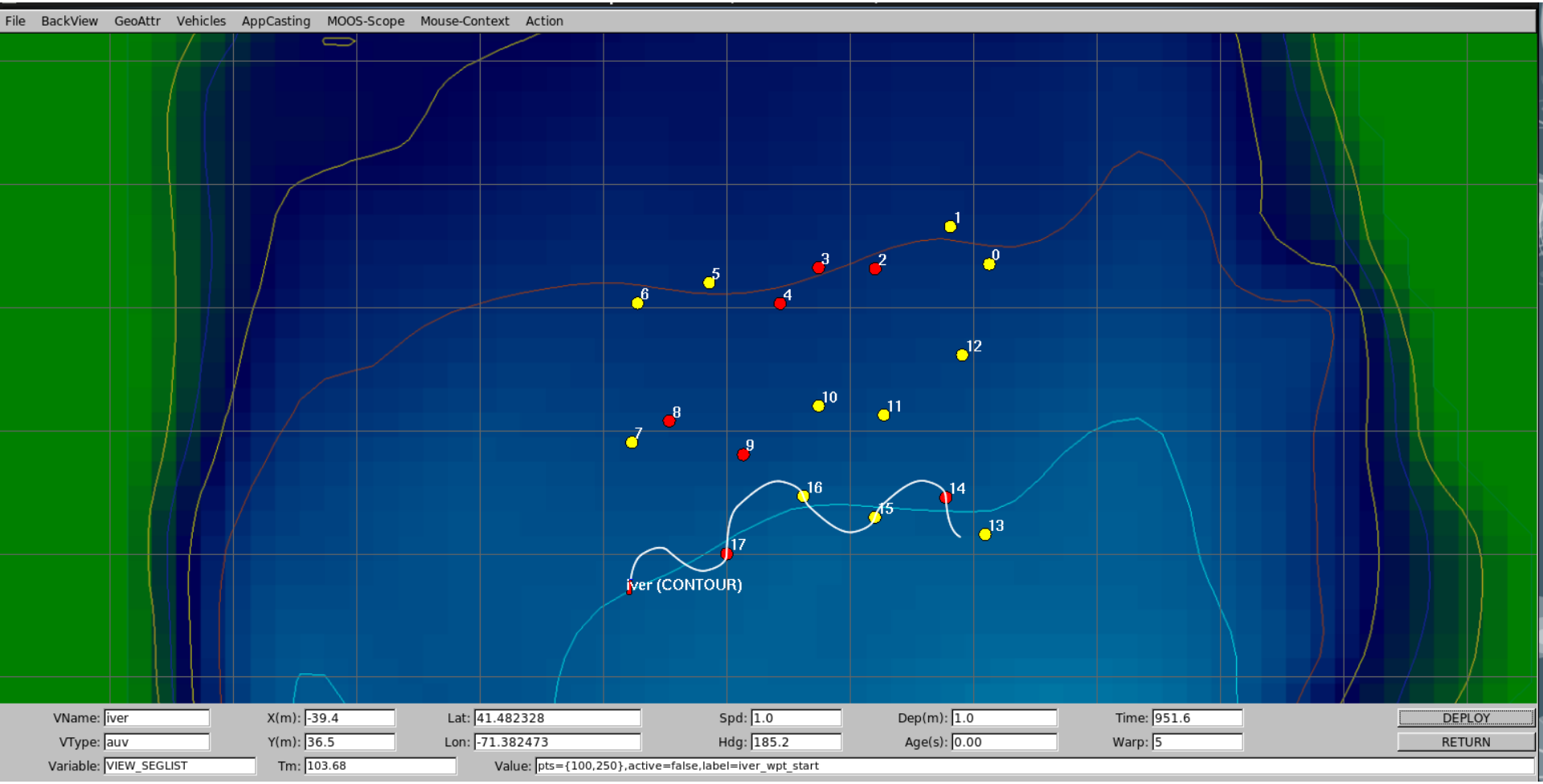
BHV_AdaptiveContour Details

- On startup, determine if starting *shallow* or *deep*
- Travel on *initial_heading* until contour crossed
  - If *max_distance* reached and not found, abort the behavior.
- If we cross the contour of interest…
  - Mark the location (X, Y)
  - First crossing:
    - Increment/decrement heading by 135-degrees and resume search
      - To avoid traveling parallel to the contour if crossing was perpendicular
  - Subsequent crossings:
    - Increment/decrement heading by 45-degrees and resume search
- If we don't cross the contour of interest again…
  - Spiral outward and continue the search
  - If *max_distance* (this time, tracked while creating the spiral) reached and not found, abort the behavior.

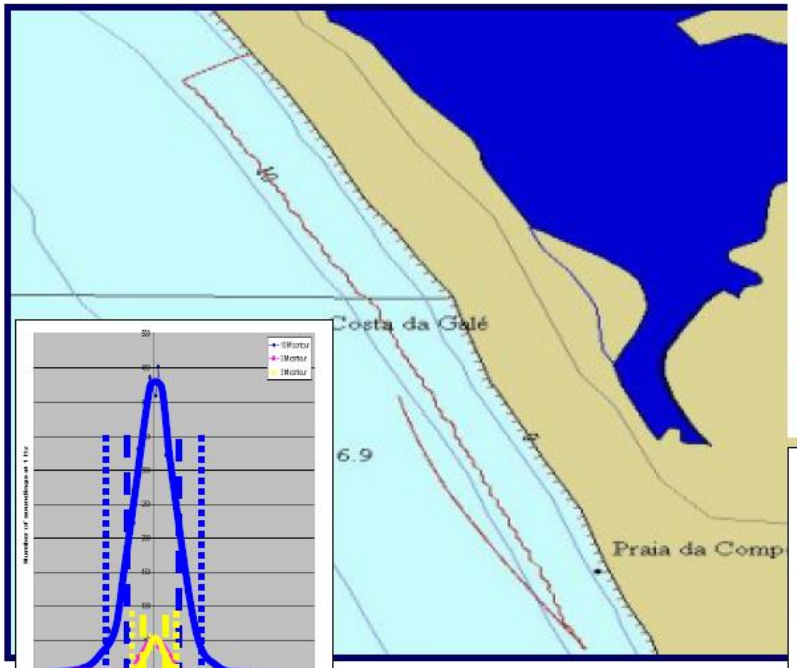
Single Contour Tracking

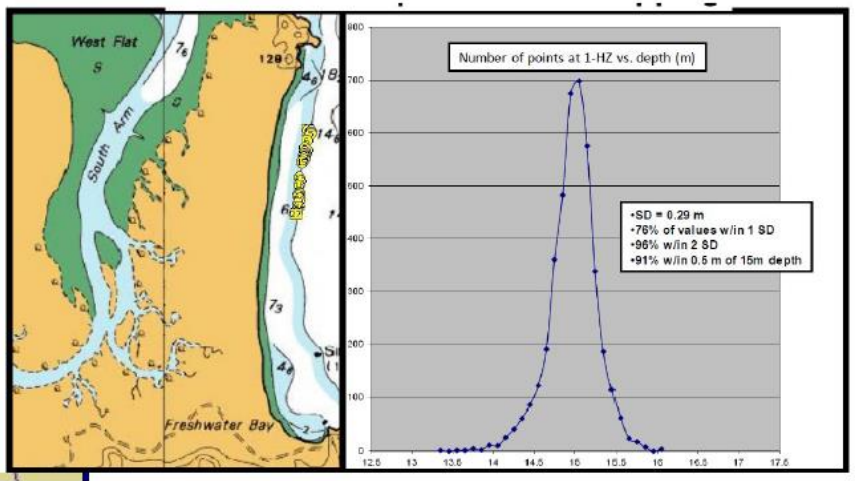


Multiple Contour Tracking



Exercises REP-10A and TS-11



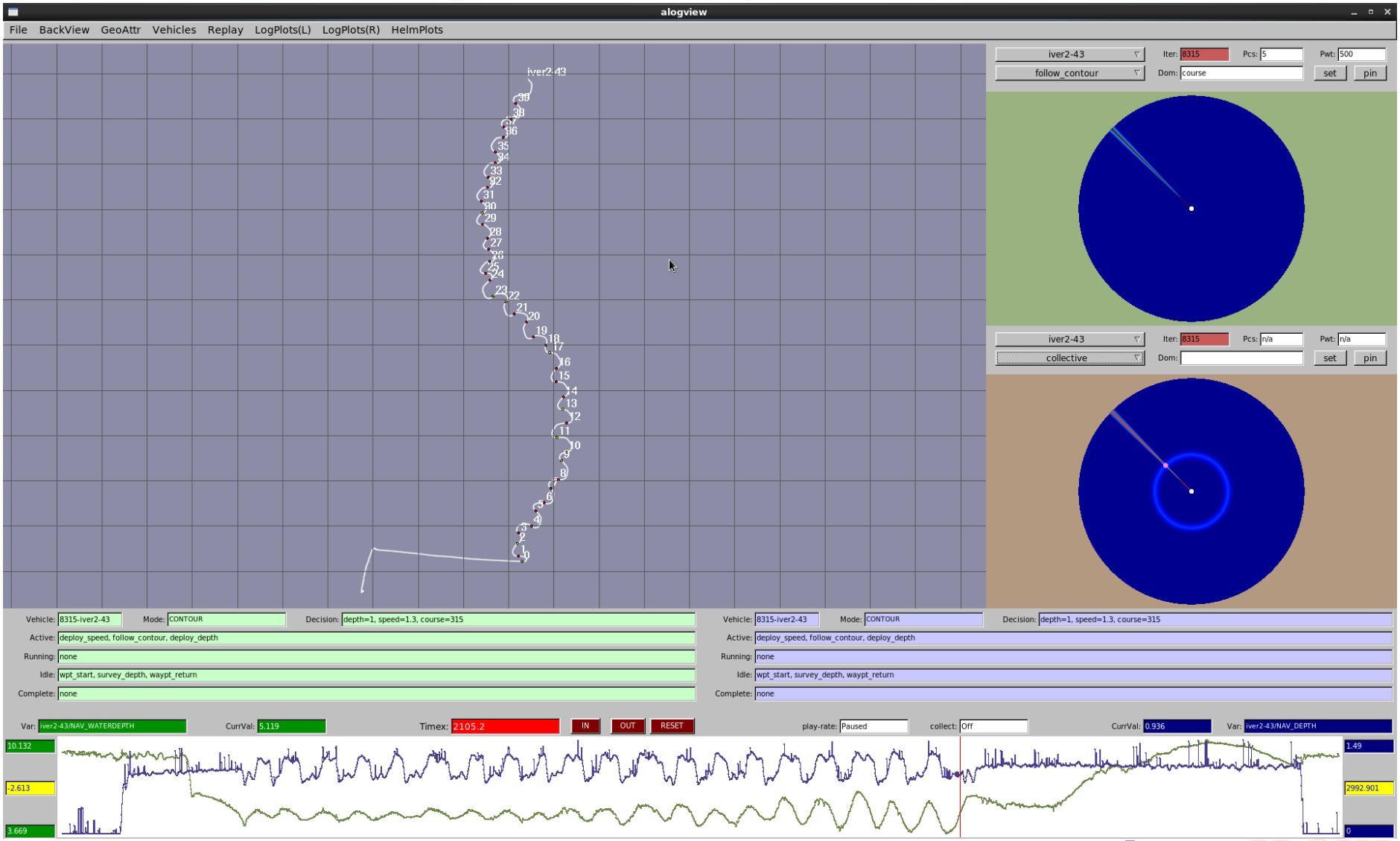


- Mapped 15m depth contour from boat launch
- 2250 m mapped in < 70 min. 3900 m total track
- 1.5 m head seas
- Bottom gradient ≈ 1/200 in this area
- SD = 0.95 ft; 96% msmts in 2 SD; 76% in 1 SD
- 91% w/in 0.5 m of 15m depth

- Mapped 10 m contour from shore launch
- Total Distance Run 8% › Contour Length
- SD = 0.6 ft; 95% msmts in 2 SD; 71% in 1 SD

On-Board Processing and EXFIL as OVLY3

Narragansett Bay (Nov 2014)



Recent Results

- 40-crossings of 5-m contour on NUWC's north test range
- 15-m cross-track error filter applied in-situ on platform
- Results in 12-crossings of interest to be exfiltrated
  - Using ~30% of data reduces bandwidth requirements while conveying the 80% picture desired in a C2 overlay

time=1414784192.97620893,contours={depth=5.0,points={41.53901126,-71.31087703:41.53937174,-71.31099475:41.54101861,-71.30982732:41.54118963,-71.30968617:41.54118963,-71.30968617:41.54147927,-71.30994994:41.54203605,-71.30979270:41.54316613,-71.31013392:41.54417160,-71.31130216:41.54428732,-71.31164447:41.54594558,-71.31193089:41.54862290,-71.31074467}}

- Demonstrated overlay appearing in 3x different C2 GUIs
  - pMarineViewer
  - FalconView
  - a NASA World Wind product, currently only available to DoD
- Can support multi-contour following, if desired

Future Work

- Enable pContourCodec support of multiple depth contours
  - Data Exfiltration approach currently limited to one contour
  - Infrastructure to support multiple contours already in place
    - Including in custom SAE-JAUS service
- Construct and map plane using DVL/ADCP data
  - By mapping plane, should be able to reduce total distance traveled
  - Desire to maintain a stream of points of contour of interest
    - Current approach only affords individual soundings on crossings
- Collaborative multi-contour mapping
- Any interest in expanding the operational envelope?
  - Always open to collaboration