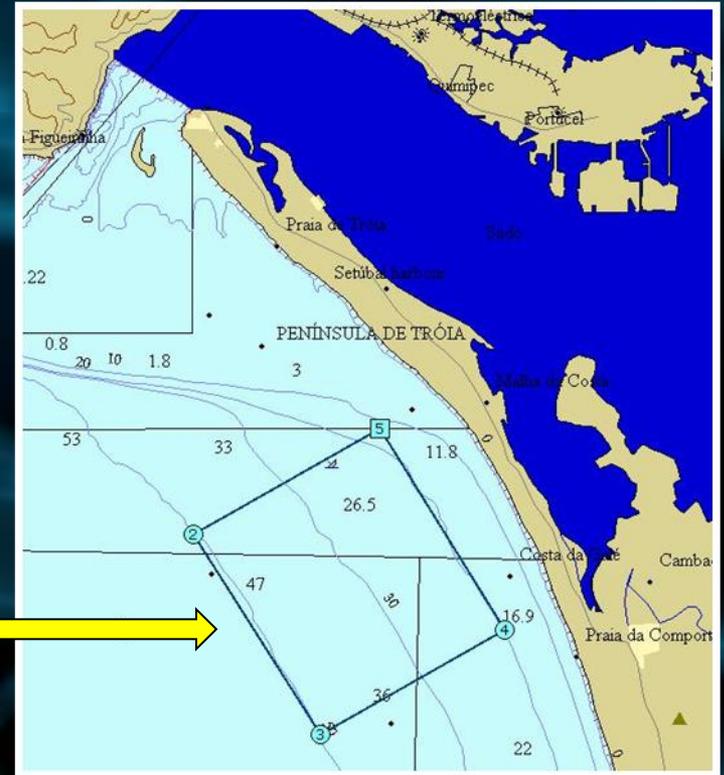


REP10A: Lightweight Autonomous Underwater Vehicles (AUVs) Performing Coastal Survey Operations



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18 OCT 2010

REP 10A OPAREA and Assets



- NURC, Portuguese Navy, U of Porto, NSWG-4/NUWC
- AUVs: Iver2, LAUV, Gavia (USV – Swordfish)
- NRP Bacamarte – Dive Team and RIBs
- UMASS, NURC, NRL

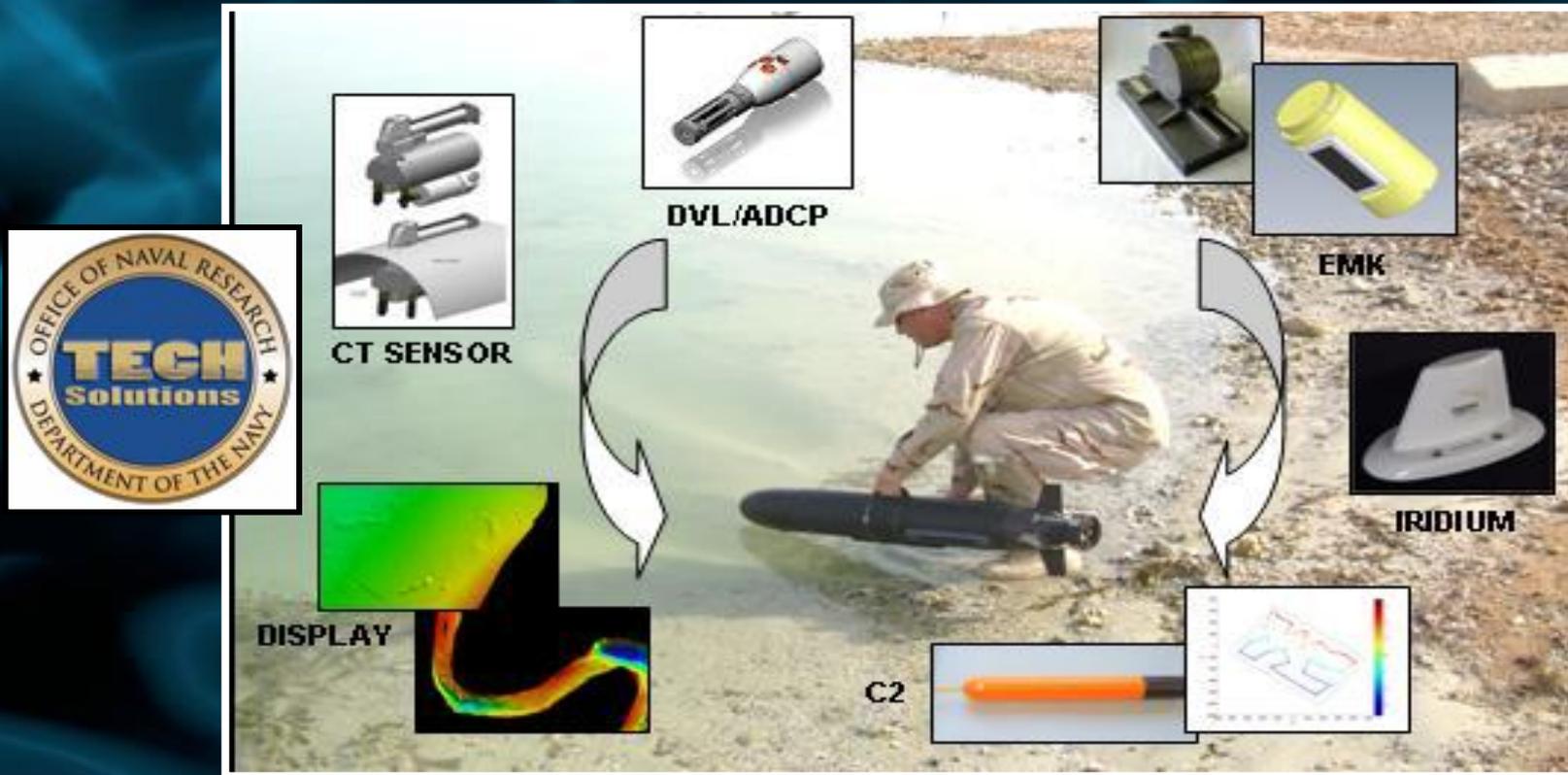
Lightweight NSW AUV

- **Supports a CONOPS for Intelligence Preparation of the Battlespace by forward deployed units – New operational paradigm**
 - **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**
- **Leverages industrial base through Iver2 AUV baseline and integration of commercial components**
- **Enhances Command and Control utilizing function libraries triggered by sensor data for autonomous, adaptive survey replanning**



Lightweight NSW AUV

Iver2 Commercial AUV & Components, CONOPS, and Capability Rqmts



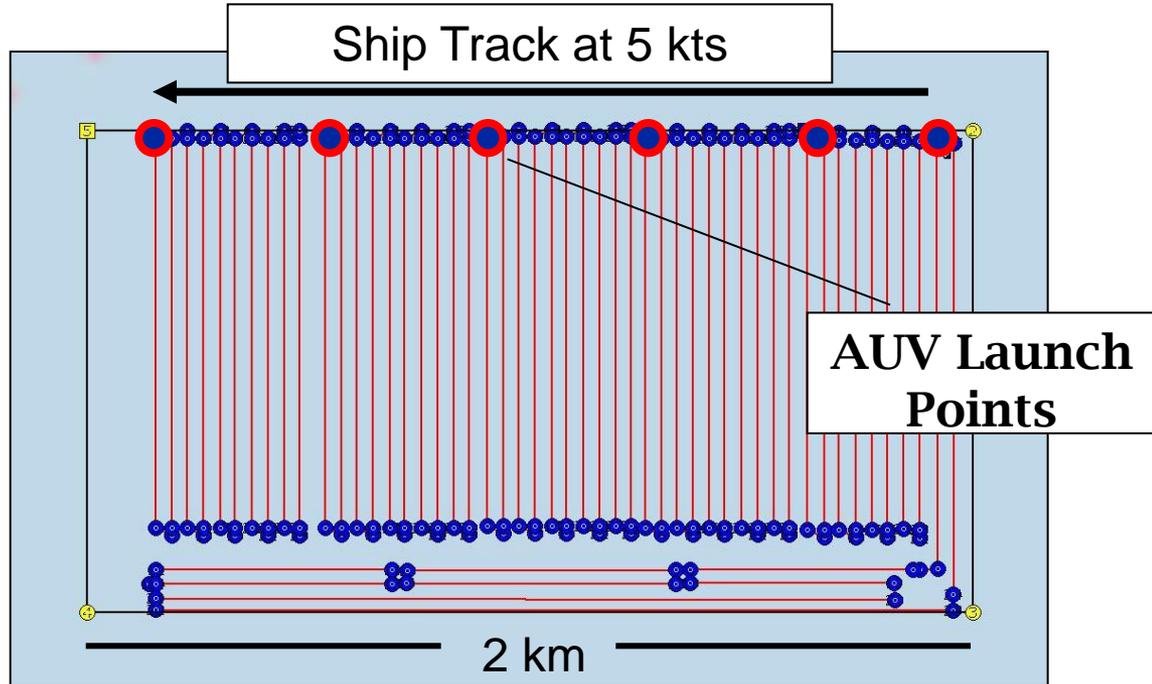
HW Integration

Baseline Iver 2 AUVs + Multi-Beam Sonar + DVL/ADCP + Environmental Sensors + Iridium Comms

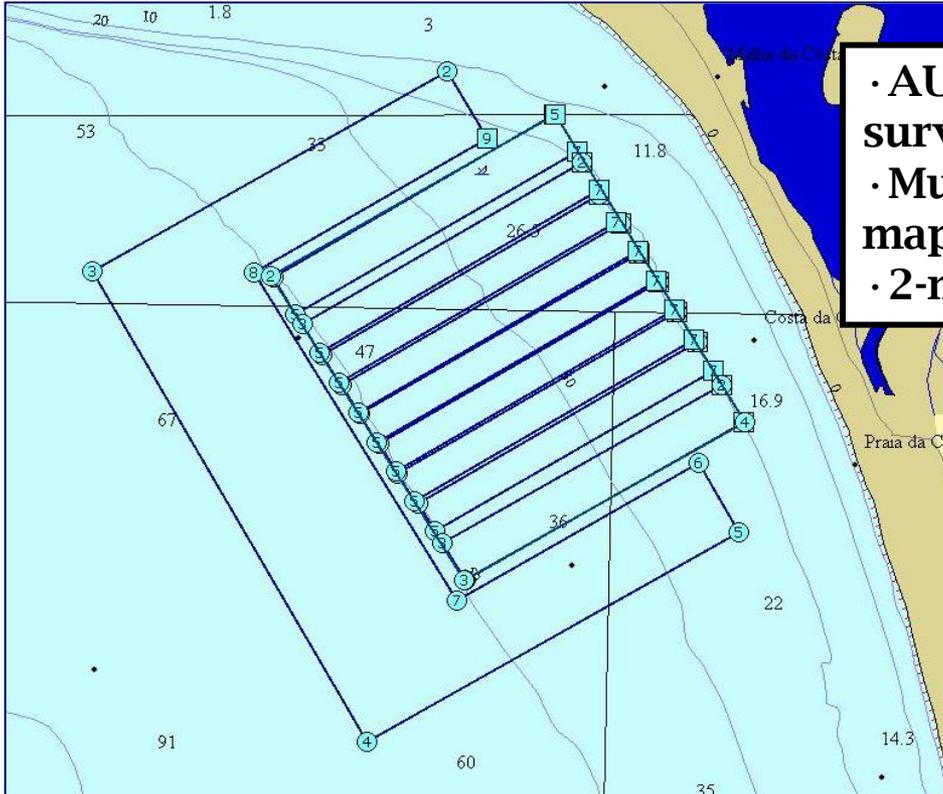
Command and Control SW Improvements/On-scene Products

- Local Processing/Display - TDAs- Vehicle Safety- Survey Optimization

REP10A: Ship Launch Missions



REP 10A: Shore Launch Missions

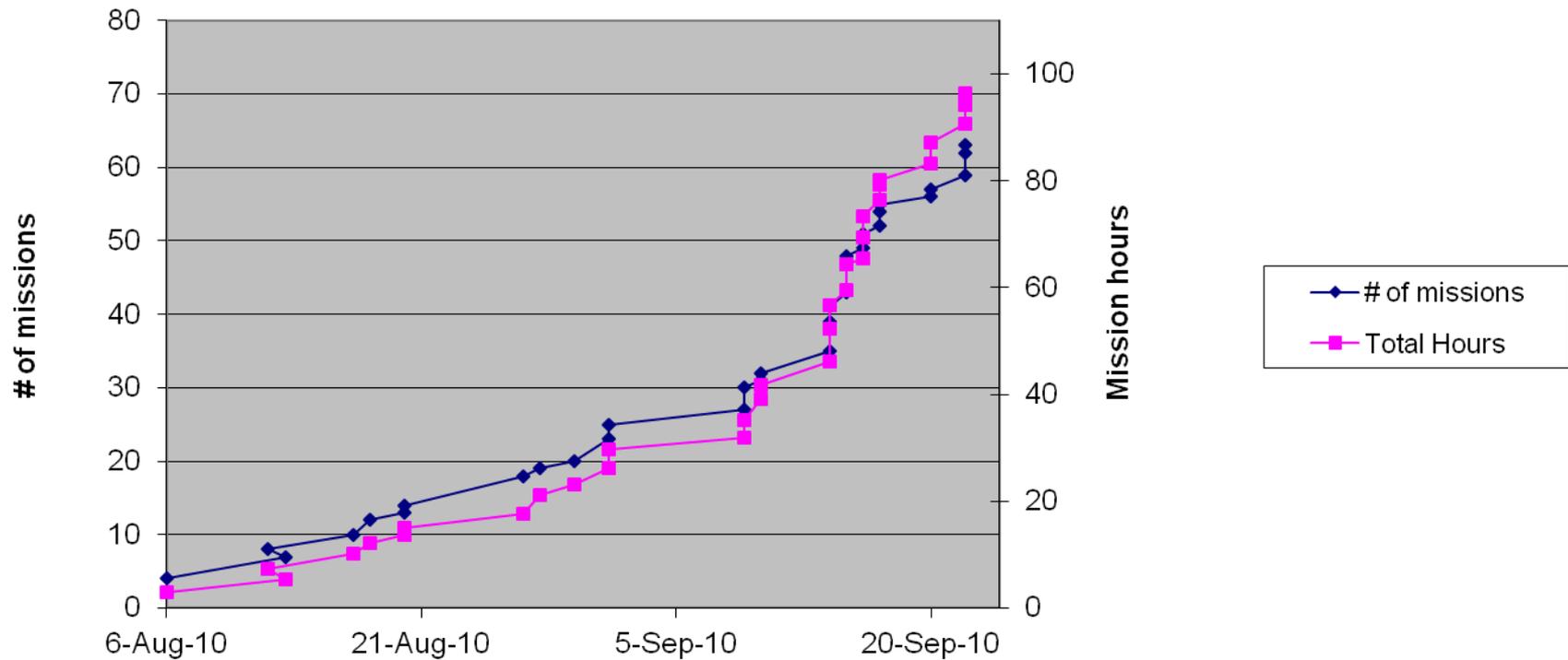


- AUVs shore-launched for concurrent survey missions
- Multi-Beam, Side Scan, and contour-mapping missions executed
- 2-minute launch sequence for 2 AUVs



Post-REP10A T&E

Cumulative AUV Run Statistics Aug. 2010 - Sep. 2010



On-Scene Products

CARIS, FalconView, and VectorMap

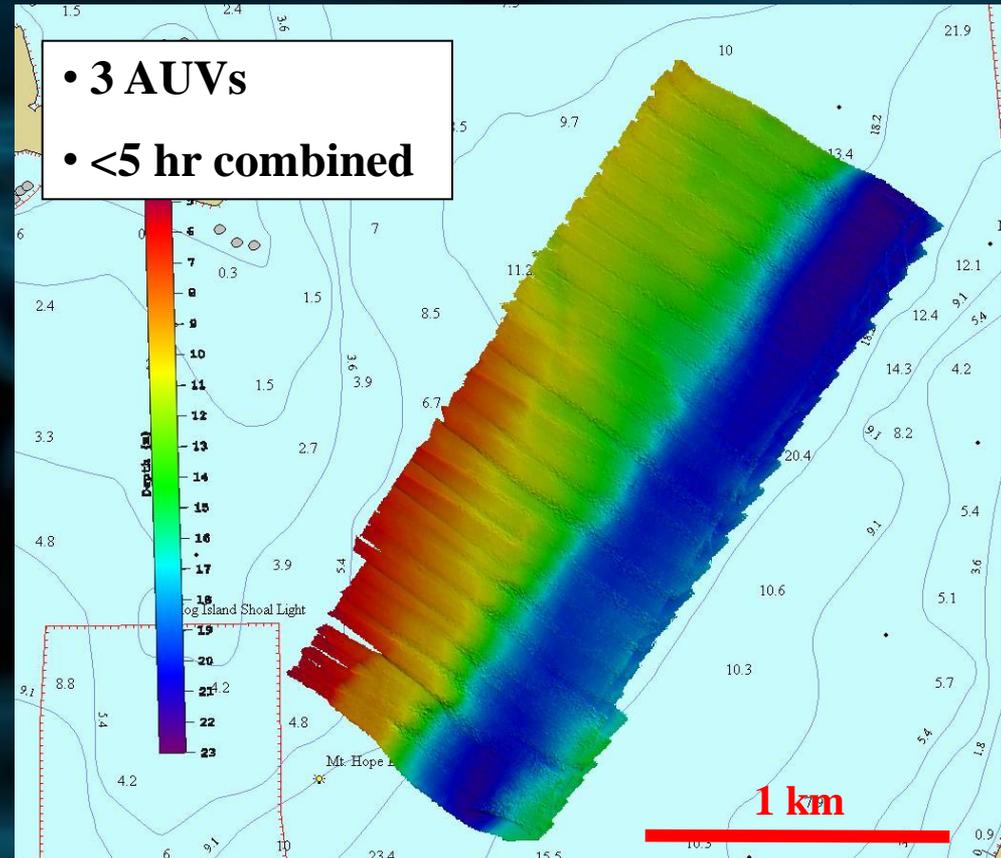
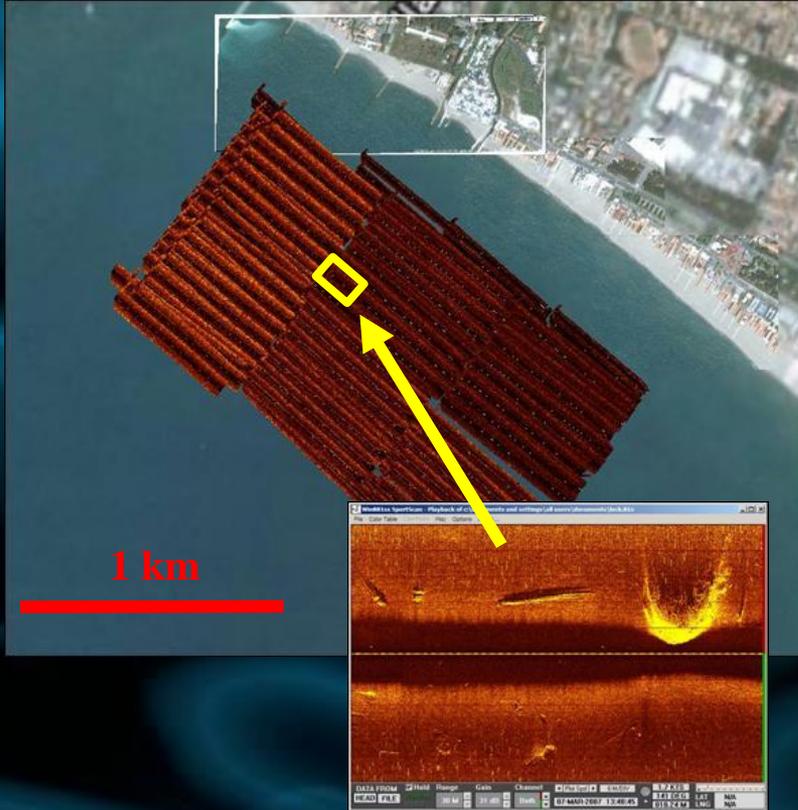
- **CARIS** - COTS SW for data processing & geo-display (SOF EMK)
- **FalconView** - SOF tactical decision aid
- **VectorMap** - OceanServer Technology, Inc. mission planning & review

Local data processing and production of graphics

GIS display (e.g., Google Earth)

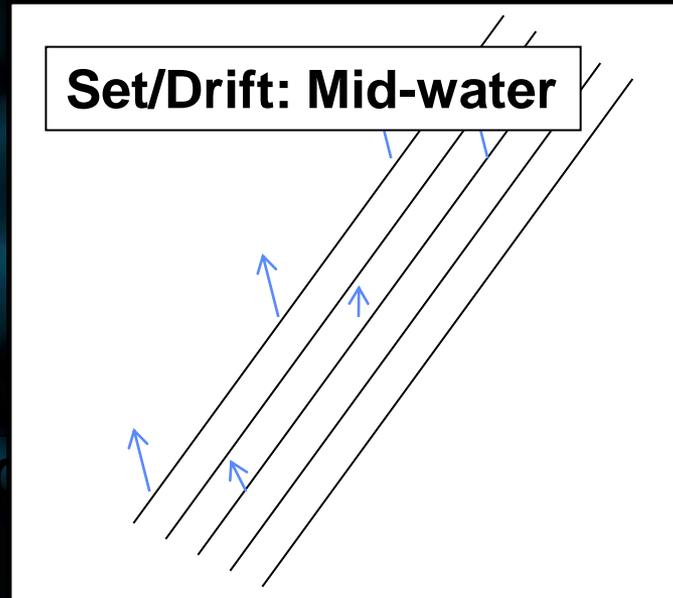
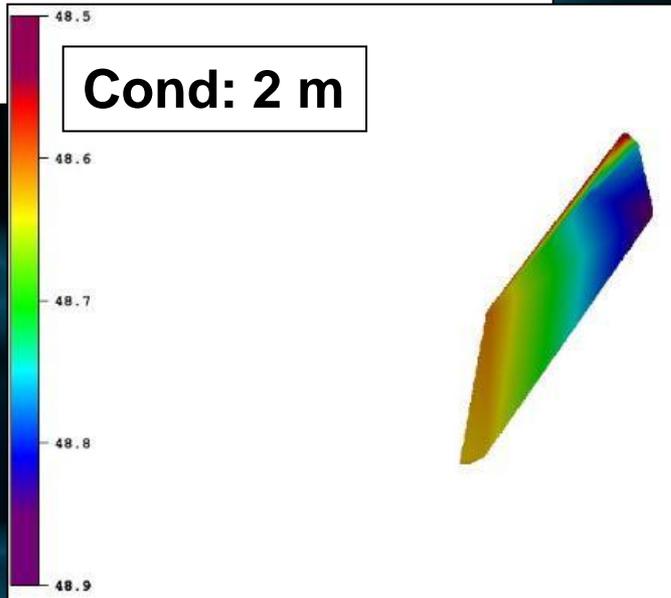
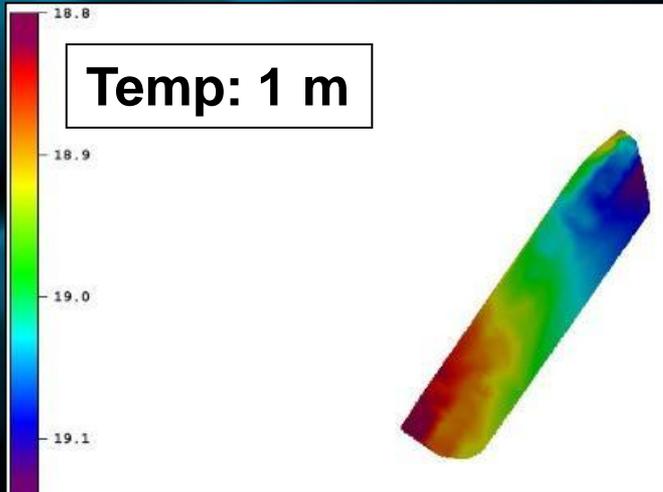
Export of data for Reach Back Cells baselining, integration, validation, and refinement: NURC, NRL

Iver2 SS and MB Bathymetry



- On-scene mosaicing
- CARIS – HIPS Processing
- On-scene Quick-Look, and NAVO RBC refinement < 8 hours
- Output formats include GeoTIFF for FalconView
- Automated workflow and plot templates

CARIS Products: Temperature, Conductivity, Currents

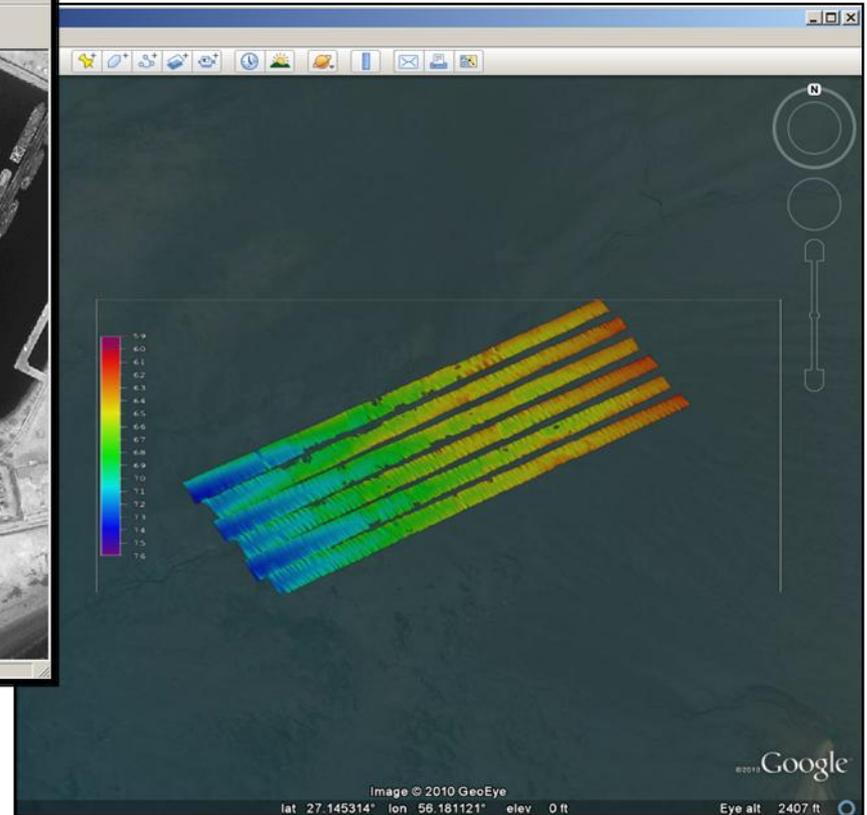


- Data is automatically filtered from full data logs for selected depth planes and interpolated.
- AUV tracklines on the graphic indicate the extent and density of contributing data.

FalconView Display

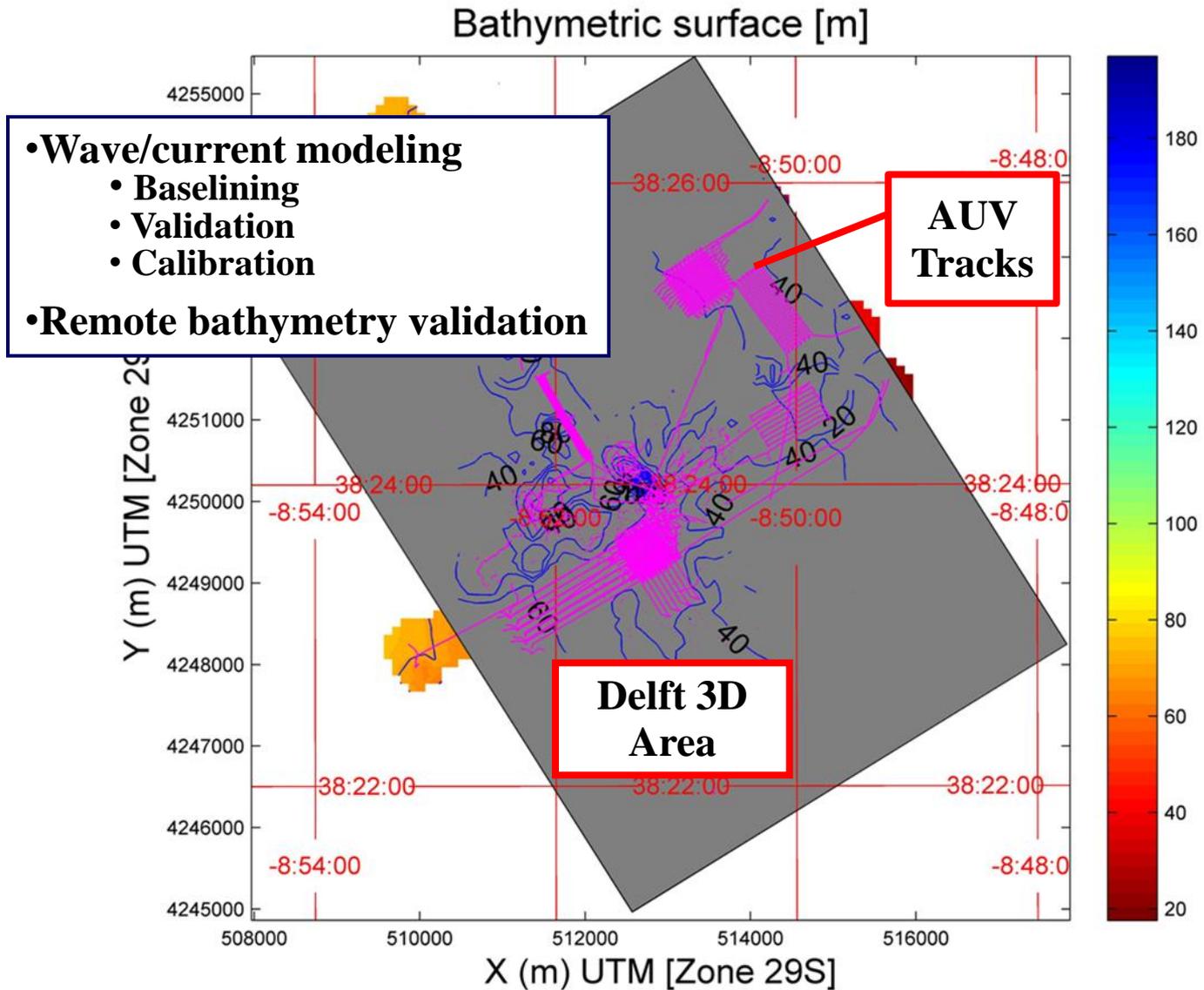


- **FalconView import and geo-registration of all CARIS and VectorMap products**
- **Mission plans and vehicle tracks plotted**
- **Import of background maps/images from VectorMap**



- **KMZ files produced for GIS display (e.g., Google Earth)**
- **Supports use in visualization and evaluation tools**

Model and Product Validation

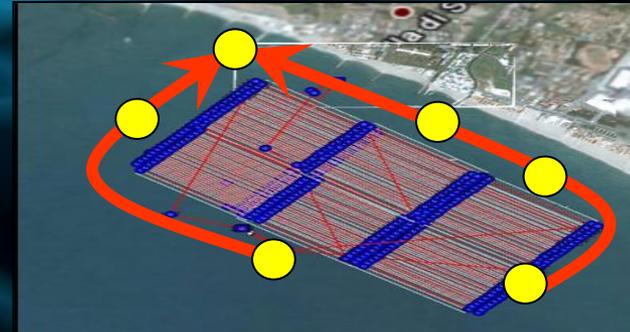


Command and Control (C2): Vehicle Safety

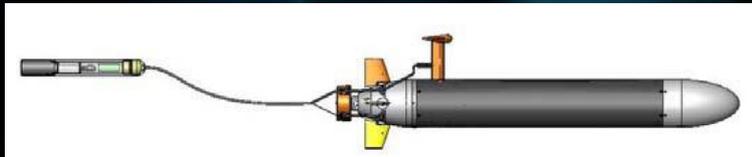
Internal Vehicle Safety Rules

SAFETY RULE	DEFAULT VALUE	MISSION 1 VALUE: SHALLOW WATER (≤50 ft)	MISSION 2 VALUE: DEEP WATER (≤80 ft)	MISSION 3 VALUE: ARRAY
Maximum pitch angle for climb/dive before Abort	±35°/10 sec	±25°/10 sec	±35°/10 sec	±35°/10 sec
Maximum time beyond calculated Mission Time to final WP (no Park time) before Abort	2 hrs	2 hrs	3 hrs	3 hrs
Maximum time for no Forward/Upward progress before Abort	60/40 sec	60/60 sec	60/60 sec	120/120 sec
Minimum altitude (distance to bottom) measured by altimeter and corrected for pitch	4 ft	10 ft	20 ft	50 ft
Maximum time allowed for achieving dive from the surface before Abort	10 sec	30 sec	30 sec	60 sec
Reverse sequence for vehicle making no forward progress	2X/3 sec	6X/3 sec	6X/3 sec	None

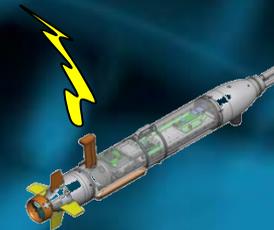
Safety Return Path



Emergency Towfloat



OTH Comms – Iridium SBD

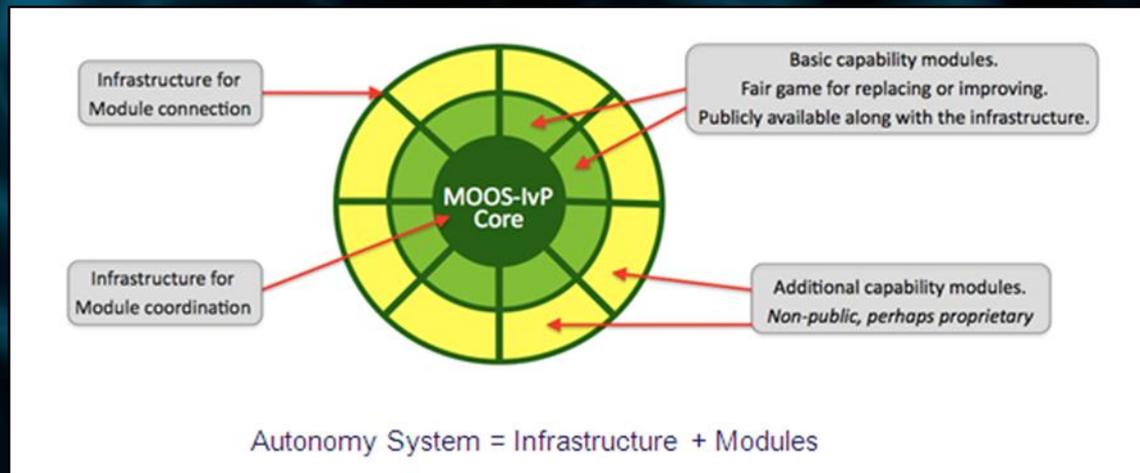


BSD Safety Rules

SAFETY RULE	DEFAULT VALUE	MISSION 1 VALUE: SHALLOW WATER (≤50 ft)	MISSION 2 VALUE: DEEP WATER (≤80 ft)	MISSION 3 VALUE: ARRAY
Maximum pitch angle for climb/dive before Abort	±35°/10 sec	±25°/10 sec	±35°/10 sec	±35°/10 sec
Maximum time beyond calculated Mission Time to final WP (no Park time) before Abort	2 hrs	2 hrs	3 hrs	3 hrs
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Command and Control (C2): Survey Optimization

- New C2 behaviors introduced independent of vendor
 - 2nd CPU and open, non-proprietary APIs
- Mission Oriented Operating Suite (MOOS) – IvP
 - function library and goal management

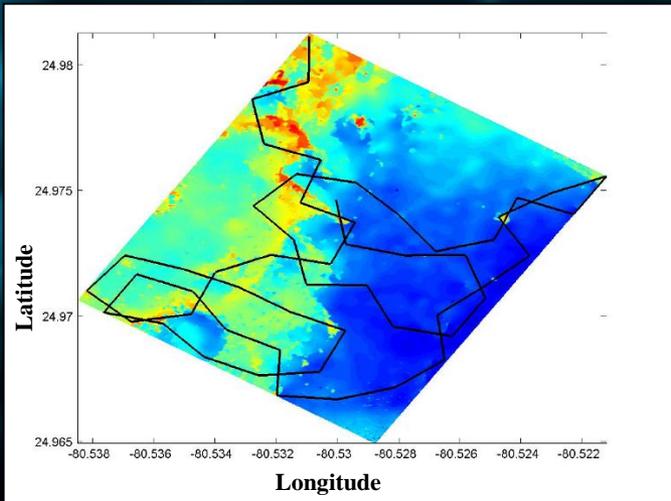


Command and Control (C2): Survey Optimization

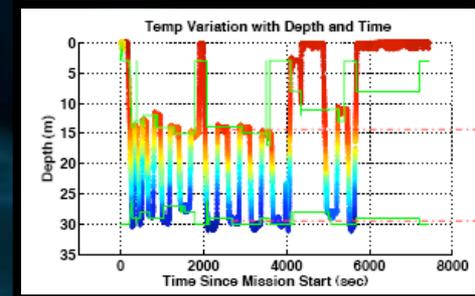
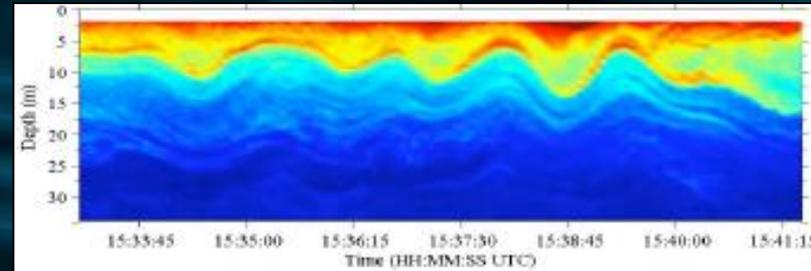
- **Four functions for Lightweight NSW AUV**
 - 2 leveraging existing algorithms and 2 developed at NUWC
- **Hybrid design for vehicle control**
 - Mission data provided by AUV mission planner
 - Functions residing in MOOS library triggered by through the sensor data
 - Control reverts to primary vehicle controller until next triggering event



C2 – Survey Optimization



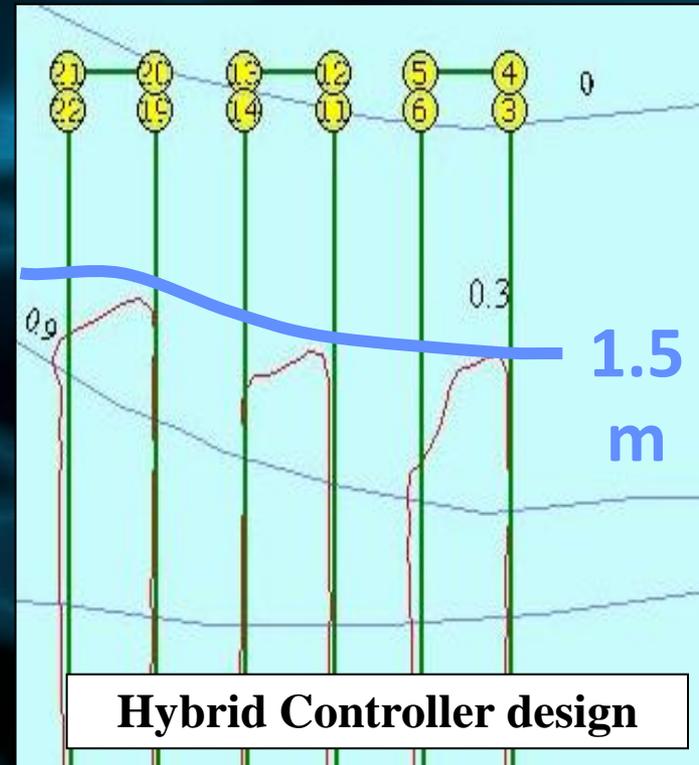
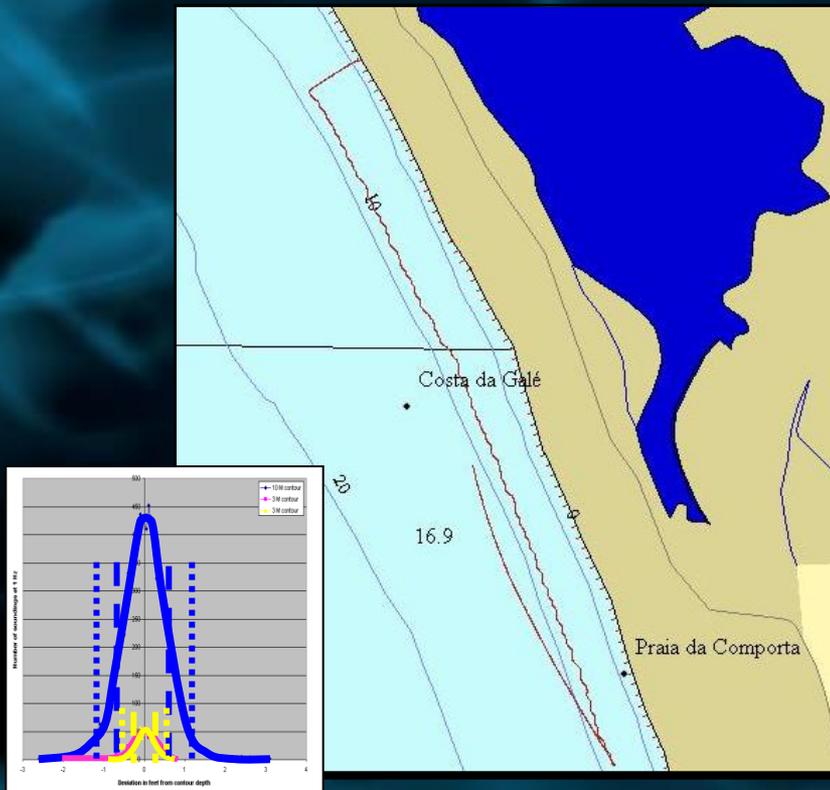
NATO Algorithm: Optimal Path Planning for Environmental Characterization (1 AUV, 3 kt, 2 hr)



MIT Algorithm: Thermocline Mapping with Reduced Survey Time

- **Streamline survey effort: equivalent product with reduced survey times**
- **Automated coordination of multiple vehicles**
- **Introduction required only 1 week for recoding, simulation, and test**

C2 – Survey Optimization and Safety



Hybrid Controller design

- Mapping of 10 m contour from shore launch
- Total Distance Run 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

Summary

- **REP10A provided an opportunity for operational evaluation of the Lightweight NSW AUV designed for IPB and search/survey missions by forward deployed units**
- **CONOPS were fully supported for a new paradigm in operational survey capability**
- **Commercial baseline and components were effective for broad leveraging of industrial base**
- **C2 architecture supports rapid and economical fielding of behaviors for vehicle safety and survey optimization**