SEA HUNTER and Maritime Autonomous Behaviors

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Maritime Business Development

Sponsored by:

Office of Naval Research Medium Displacement Unmanned Vehicle Program
DARPA ACTUV Program

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Leidos Maritime Capabilities and Enabling Technologies

Sensors

- Below water sensor modalities
- Above water sensor modalities
- Command and control

Autonomy

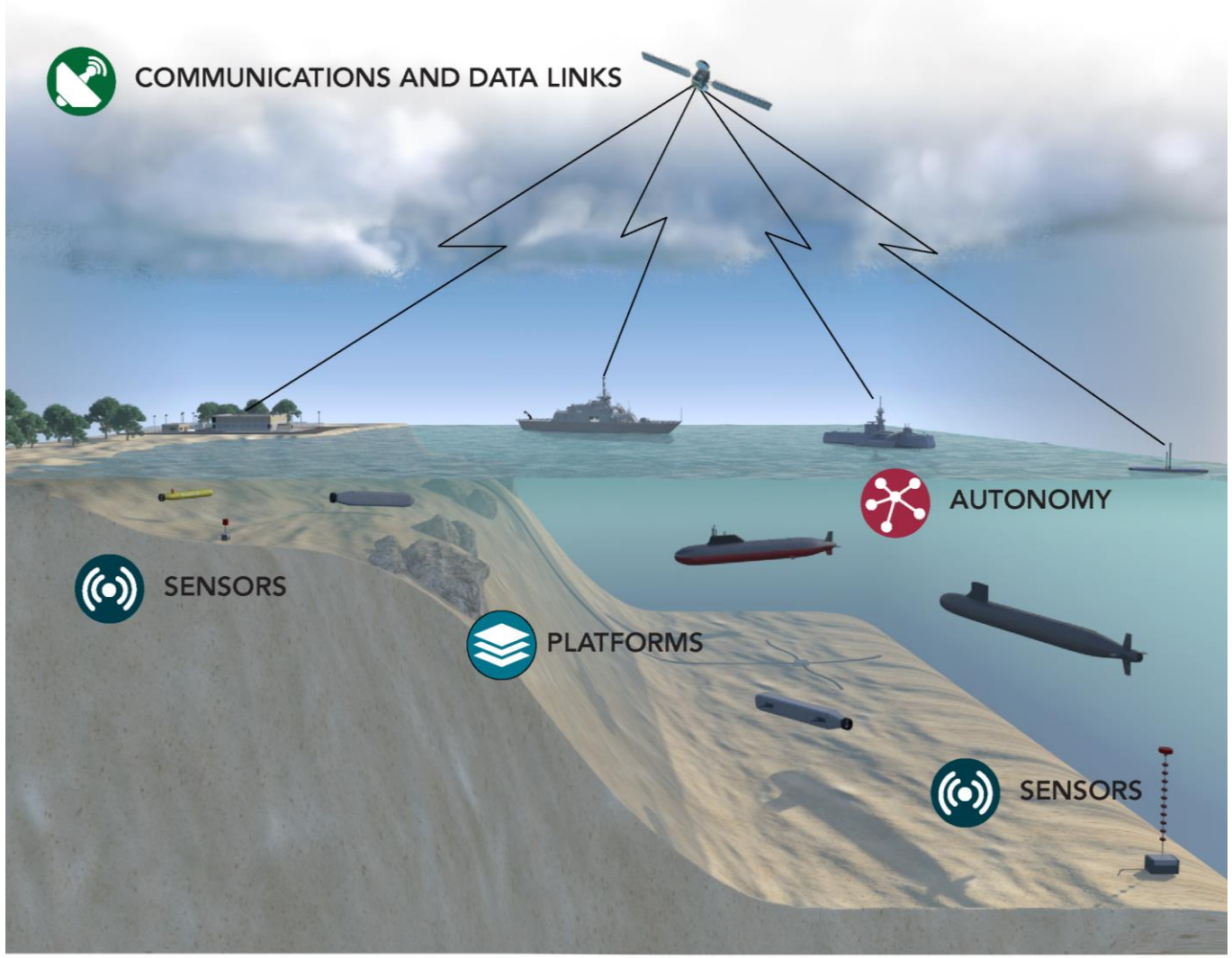
- Single platform and collaborative team autonomy
- Distributed hierarchical autonomy
- Open systems architecture
- COLREGS behaviors
- Mission behaviors

Processing

- Detection, classification, localization, and tracking
- Fusion
- Communications
- Automation

Physics and Phenomenology

- Propagation modalities
- Interference and noise
- Targets



Communications and Data Links

- Modalities: radio frequency, acoustic, and optical
- Features
  - Waveforms
  - Terminals
  - Antennas
- Data exfiltration
- Command and control
- Mobile ad hoc networks
- Software defined radios
- Data reduction and compression
- Information assurance and anti-tamper
- Reliable protocols
- Disconnected, intermittent, and limited capability

Platforms

- Unmanned vessels
- Command and control
- Navigation
- Signature control

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Maritime Autonomy and Unmanned Surface Vessels (USVs)

- **Autonomy development in three areas:**
  - Unmanned vessel autonomy
  - Optionally manned vessel autonomy
  - Autonomy for situational awareness

- **Increasing mission capability and capacity at lower cost and risk**
- **Enable new missions**

Get prototypes into the Fleet to demonstrate feasibility and value early – and to solicit feedback

Autonomous Vessels

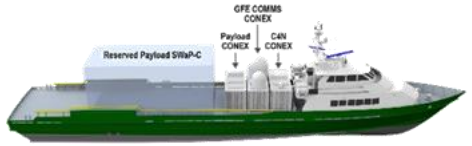
Office of Naval Research (ONR) / Defense Advanced Research Projects Agency (DARPA) SEA HUNTER I

"Autonomized" Manned Vessels

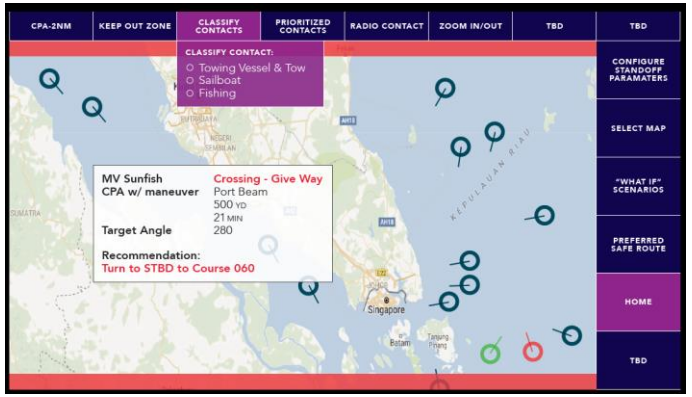
Leidos Research Vessel (R/V) PATHFINDER

Marine Corps Warfighting Lab (MCWL) Landing Craft Mechanized-8 (LCM-8)

Large Displacement Autonomous Commercial Ship



Bridge Decision Aids



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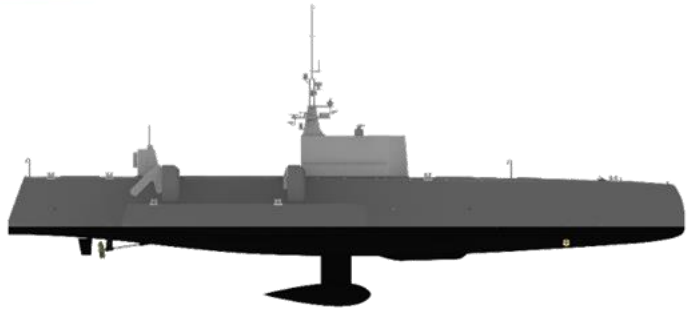
ONR MDUSV SEA HUNTER I Overview



- **The DARPA ACTUV Program has transitioned to US Navy ONR as the MDUSV Program – January 2018**
  - SEA HUNTER I
- **Under contract with ONR to build second hull SEA HUNTER II**

MDUSV Program Goals:

- **Demonstrate a MDUSV capable of deployed blue-water operations, enabling a new class of naval system**
- **Demonstrate long-range and endurance autonomous operations of an MDUSV under sparse remote human supervisory control**
- **Establish operator trust in safe, reliable operation**

ONR is Developing MDUSVs for the Navy:

- **"SEA HUNTER" is a 132 foot medium displacement unmanned surface vehicle (MDUSV) prototype**
- **Cost was $23M for the first SEA HUNTER prototype**
- **A 2nd SEA HUNTER platform will be constructed - design cycle to incorporate lessons learned from Sea Hunter I**
- **Supports additional at-sea testing and provides for further development and maturation of autonomy**
- **Advanced autonomy for highly reliable surface collision avoidance - advanced electro-optical / infrared (EO/IR) capability**

Organization	Role
SPAWAR Systems Center Pacific	Provides program test oversight, safety, environmental, and integration with Fleet operations
DARPA	Funded concept design, autonomy development, vessel fabrication, and initial testing
ONR	Funding at sea testing, enhancements, payload(s) integration, additional vessel build
Leidos, Inc.	Prime contractor for vessel design, autonomy development, and payload(s) integration
Johns Hopkins University – Applied Physics Laboratory	Technical support organization for autonomy, sensors, and COLREGS

Considerations:

- **COLREGS in the context of a goal**
- **Tolerable level of risk to execute goals**
- **Payload integration**

COLREGS = International Regulations for Preventing Collisions at Sea

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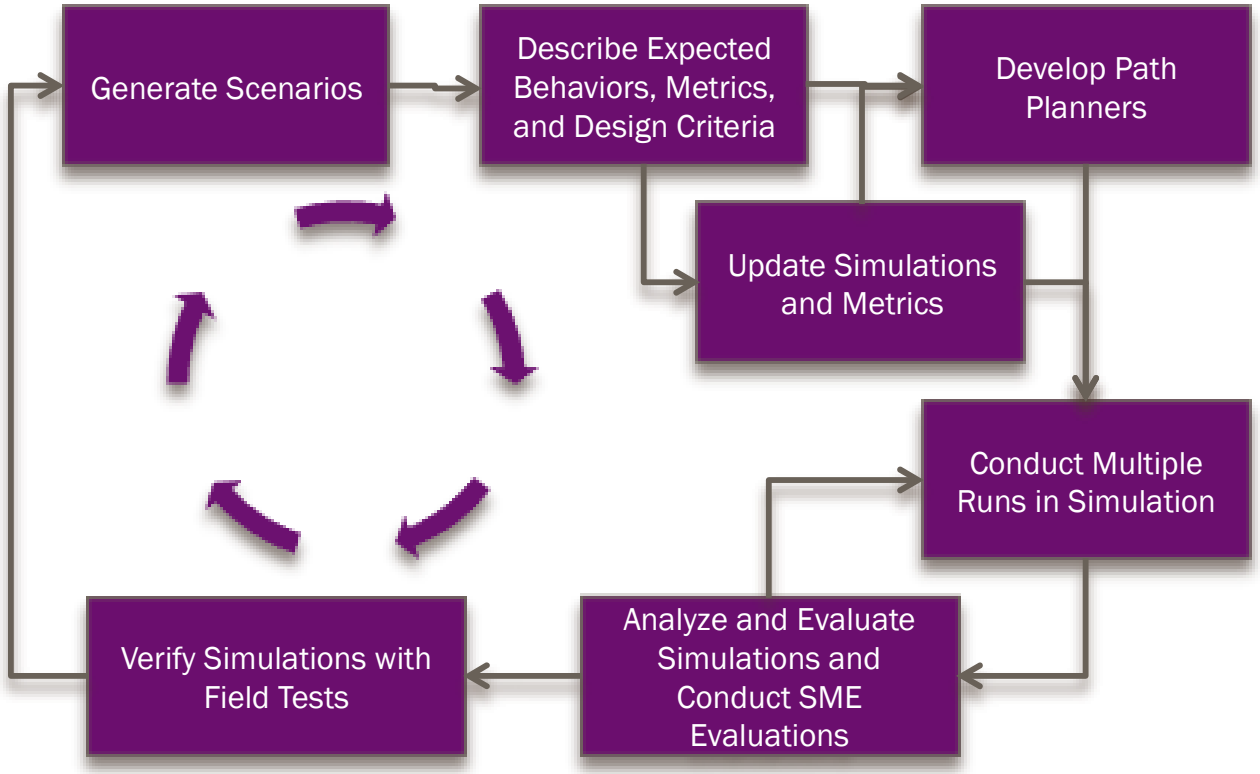
Leidos Maritime Autonomy

- **Transferable, modular, open systems architecture**
  - Standardized key interfaces
  - Supports timely, cost effective, and low risk transferability, capability upgrades, and integration
- **Distributed and hierarchical**
  - Supports fault tolerance
  - Supports safety critical functionality
  - Supports IP management for Government and Industry
  - Simplifies autonomy testing, verification, and validation
- **Proven testing approach**

Autonomy Testing Approach



SEA HUNTER I

USV Surrogate:
Research Vessel (R/V) PATHFINDER

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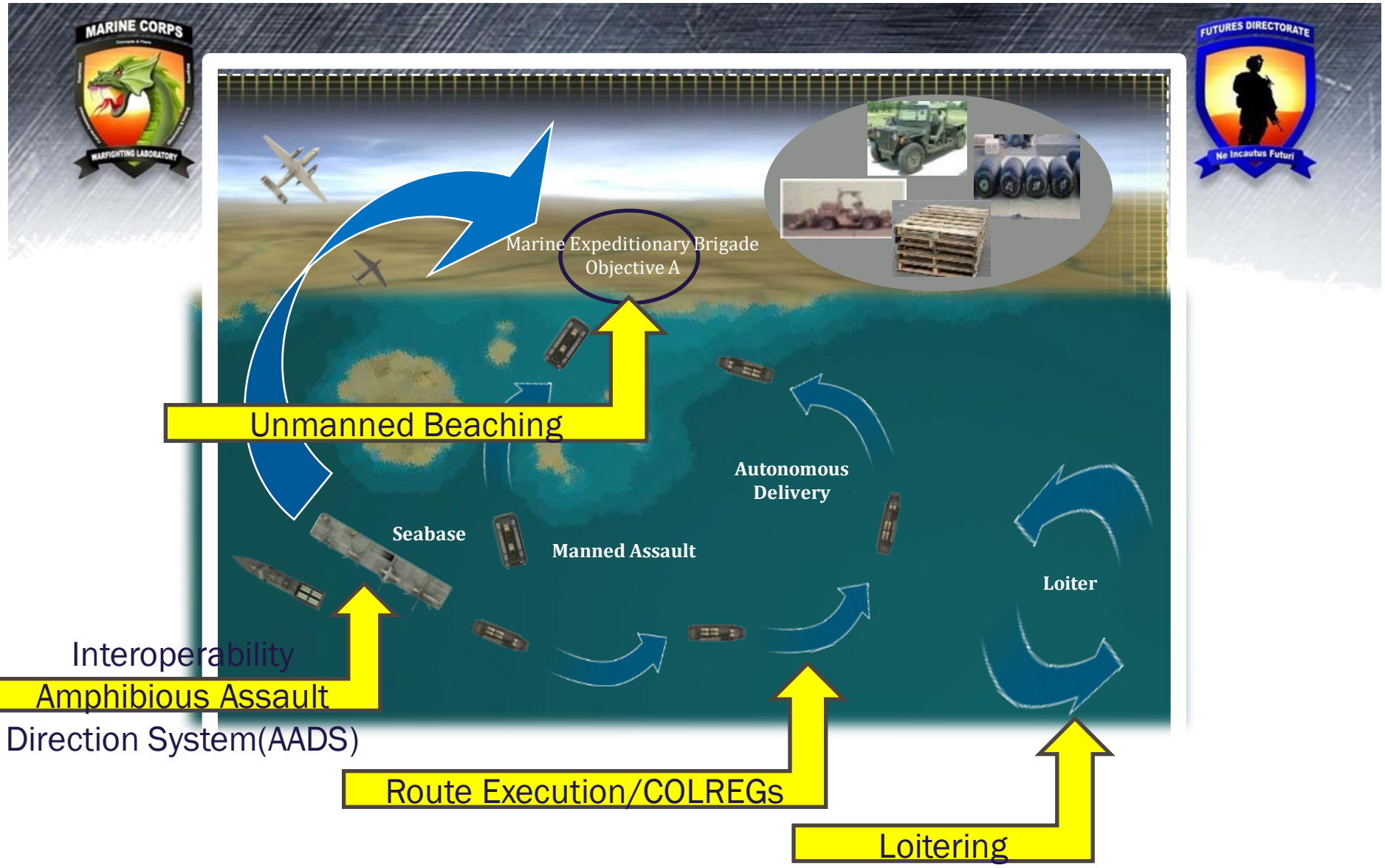
Marine Corps Autonomous Littoral Connector
High-Level Operational View (OV-1)



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Autonomous Logistics: Autonomizing the Marine Corp Warfighting Lab (MCWL) LCM-8: Autonomous Shore Re-Supply

- **Provides capability to execute autonomous shore resupply logistics**
  - Unmanned ship-to-objective maneuver (STOM) connector
- **Integrated capability provides:**
  - Local tele-operation control from shore / sea base to loiter point
  - Autonomous transit to next loiter position – including obstacle avoidance and COLREGS autonomy behaviors
  - Remote supervisory control over autonomous operations
  - Local tele operation control to / from shore

- **Establishes autonomous logistics feasibility**
  - Reduces cost and risk
  - Solicits warfighter feedback and input

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Autonomous Logistics: Autonomizing the MCWL LCM-8

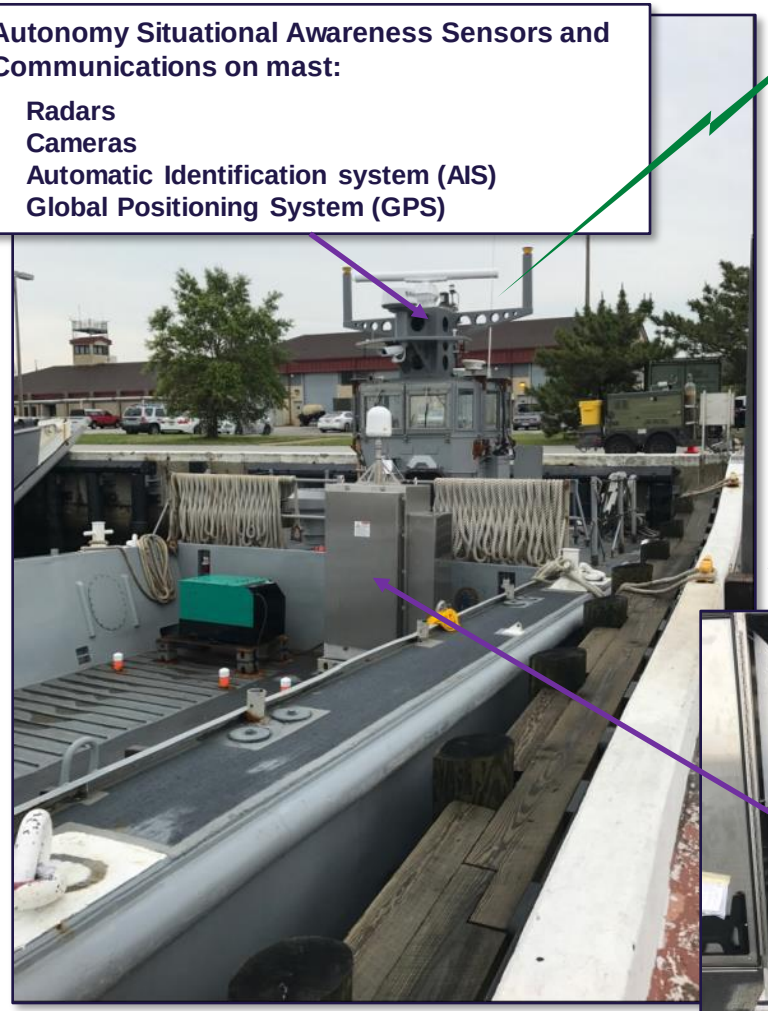
Integrated Capability

Over-the-Horizon Communications

MCWL LCM-8: ACU2-13

Autonomy Situational Awareness Sensors and Communications on mast:

- Radars
- Cameras
- Automatic Identification system (AIS)
- Global Positioning System (GPS)



Autonomy Processor and Air Conditioning

Remote Supervisory Control Station (RSCS)

Remote Operator Control Van

Handheld Local Tele-Operations Control Station (LTCS): Line-of-Sight Communications

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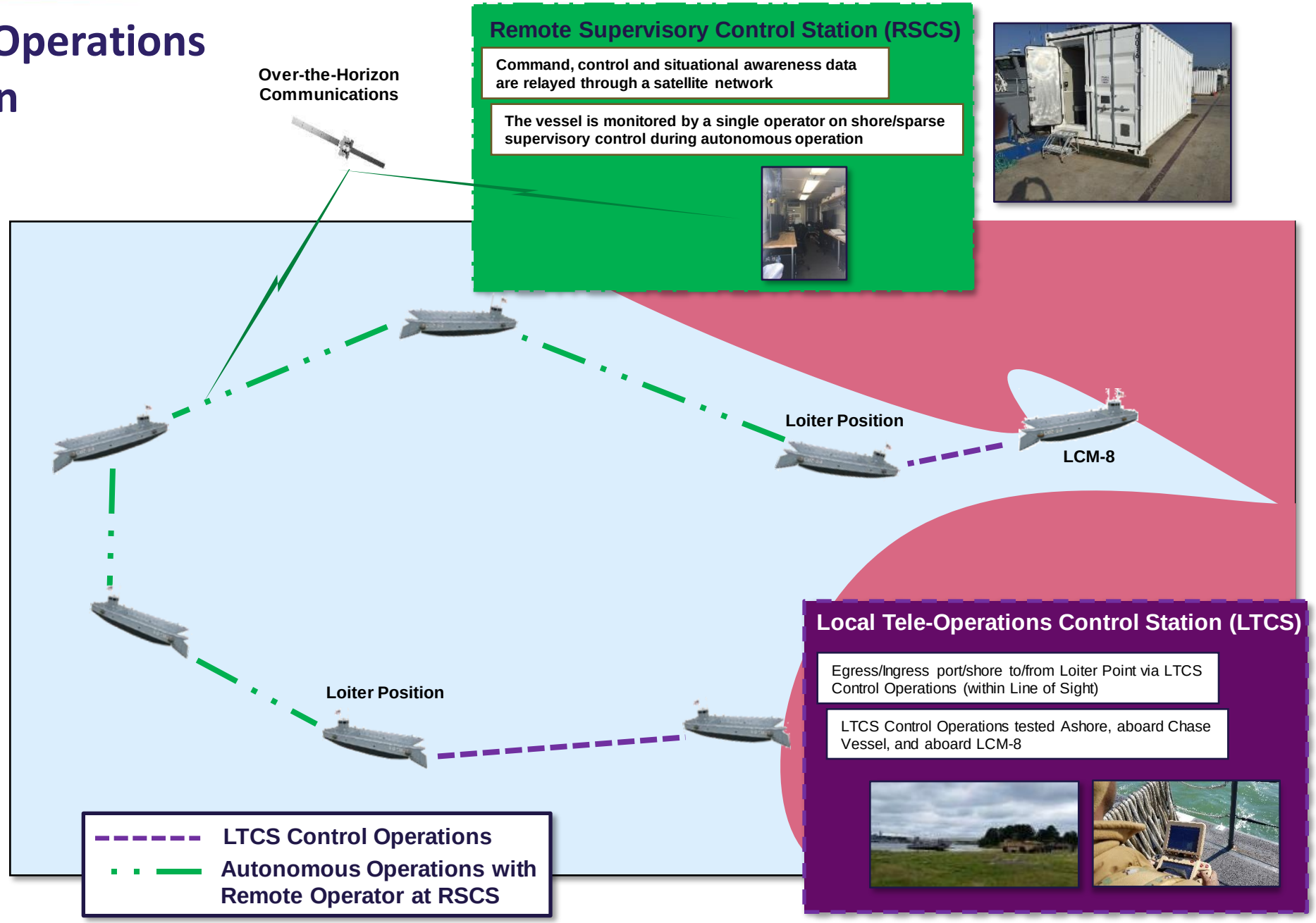
STOM Concept of Operations and Demonstration

- **Conducted several successful demonstrations – ongoing**
- **Potential next steps:**
  - Autonomous beaching behaviors
  - Formation behaviors
  - Command, control, and communications improvements



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Summary

- **Autonomy development in many areas:**
  - Unmanned vessel autonomy
  - Optionally manned vessel autonomy
  - Autonomy for situational awareness
  - Product lines: Autonomous vessels, “autonomized” manned vessels, and bridge decision aids
  - Increase current mission capability and capacity at lower cost and risk, and enable new missions

- **The ACTUV Program and SEA HUNTER I vessel have successfully transitioned from DARPA to ONR as the MDUSV Program**
  - SEA HUNTER I currently undergoing testing
  - Variety of missions being considered
  - Under contract for a second hull SEA HUNTER II

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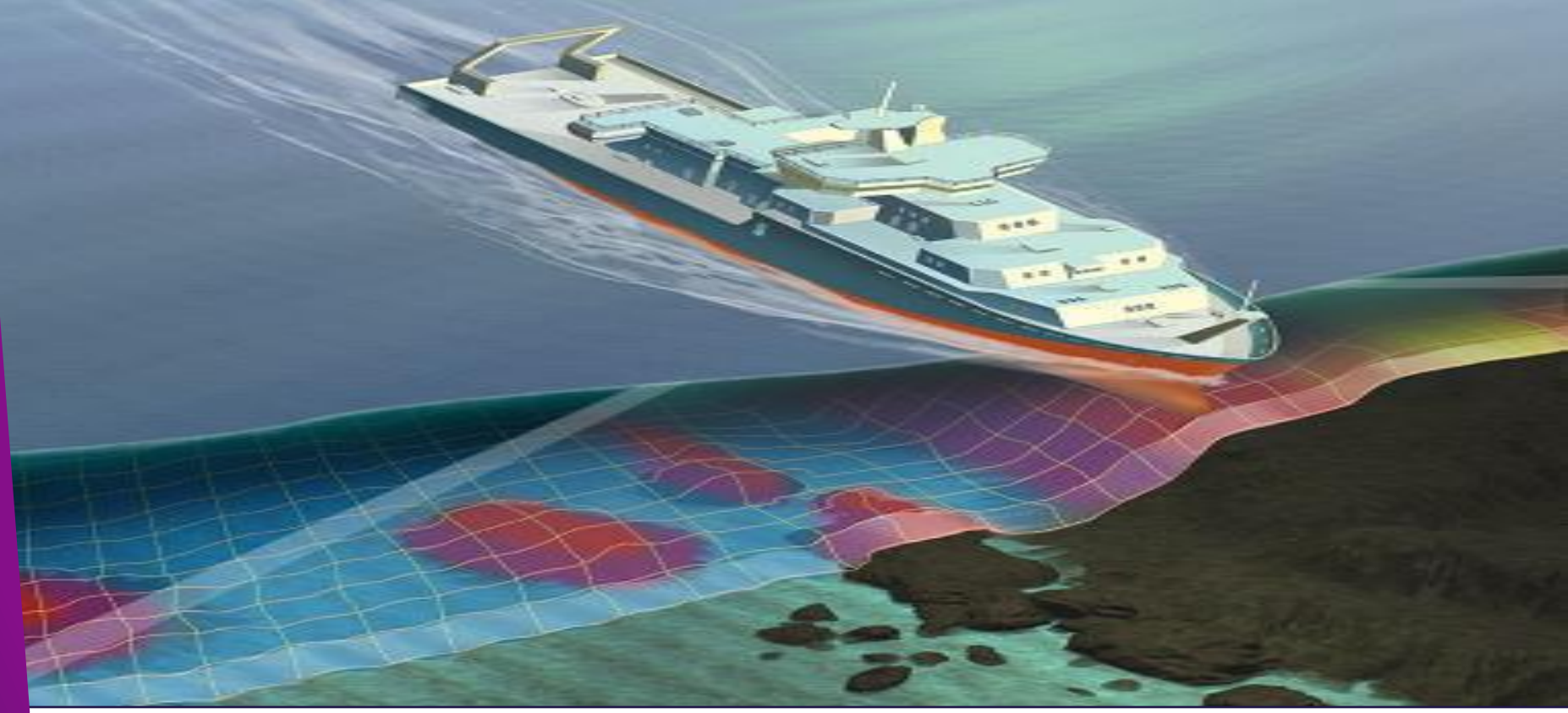

Autonomous Survey Mission: Internal Research and Development (IRAD)

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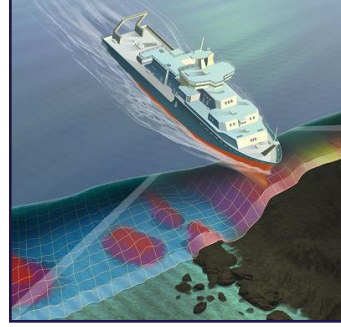
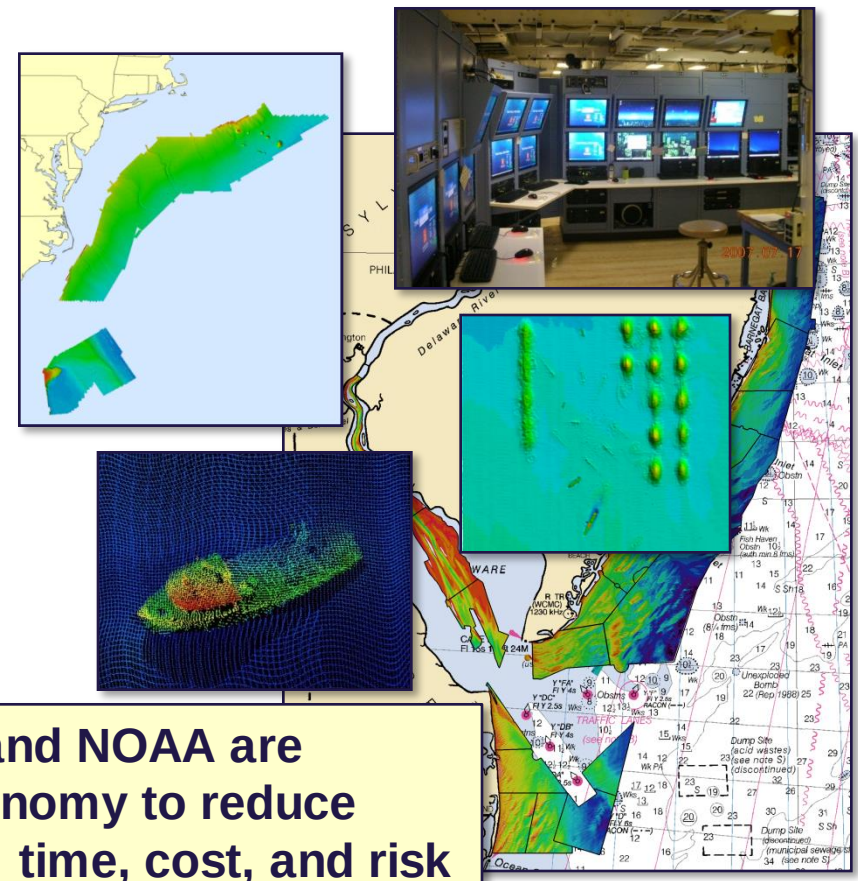
Leidos Hydrographic Survey Operations, Bathymetry Processing, and Production



- **Primary Customers:**
  - United States (U.S.) Navy Naval Oceanographic Office (NAVOCEANO)
    - Bathymetric Data Production
  - U.S. Department of Commerce National Oceanic and Atmospheric Administration (NOAA)
    - Survey Operations and Processing: Over 95 high-resolution, shallow water bathymetric surveys spanning over 4700 square nautical miles (nm^2)
- **Core survey capabilities:**
  - Hydrographic, cable route, search and locate and bathymetric surveys
  - Prototype to production software development
  - Hardware / software system integration
- **Major survey technologies:**
  - Integrated Survey System (ISS) – system used to conduct surveys to International Hydrographic Organization standards
    - NAVOCEANO ISS-60 development
    - Leidos commercial ISS-2000 development and maintenance
  - Survey Analysis and Area-Based Editor (SABER) survey data processing software
  - Combined Uncertainty Bathymetric Estimator (CUBE)
  - Bathymetric Attributed Grid (BAG)
  - Automated Contact Detection (ACD)
- **International Organization for Standardization (ISO) 9001:2015 certified**



NAVOCEANO and NOAA are looking to autonomy to reduce survey mission time, cost, and risk

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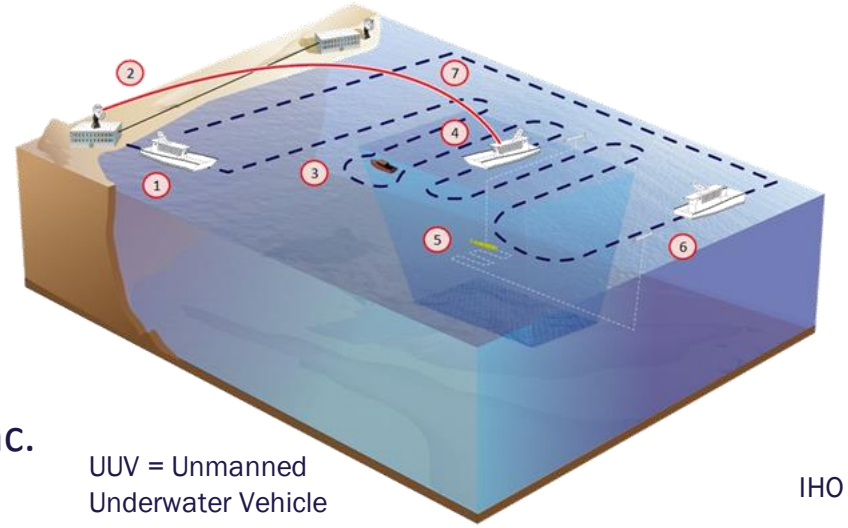
Autonomous Bathymetric Survey Demonstration: 2017

- **Integrated Bathymetric Survey Payload on Leidos Research Vessel (R/V) PATHFINDER**
  - Multi-beam sonar
  - Moving Vessel Profiler (MVP)
  - Position and Orientation System for Maritime Vessels (POS MV)
  - ISS-2000 – Leidos, Inc.
  - UUV and towed launch and recovery dock – Leidos, Inc.
  - High Data Rate Software Defined Radio – Leidos, Inc.

Autonomous Survey Mission Profile



UUV = Unmanned Underwater Vehicle

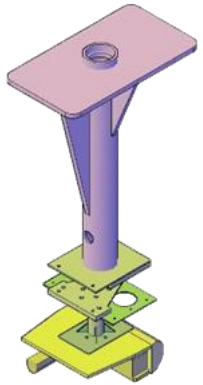
1. PATHFINDER self-deploys to survey region
2. High bandwidth line of site communications established
3. PATHFINDER executes COLREGS maneuver around surface contact and resumes survey plan
4. PATHFINDER collects IHO Order One bathymetry and provides snippets and survey summary to a remote operator
5. Autonomous UUV deployment in response to high interest target identified in survey data
6. UUV retrieved and data exfiled to shore site
7. Pathfinder returns to base

IHO = International Hydrographic Organization

Leidos R/V PATHFINDER

Payload Integration

Multi-Beam Sonar and Mount



Leidos UUV and Towed Launch and Recovery Dock

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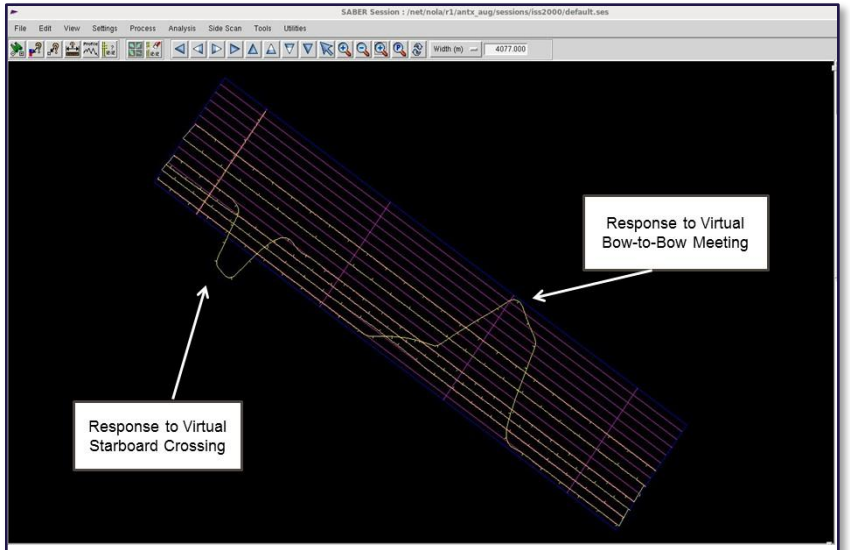
Autonomous Bathymetric Survey Demonstration: 2017

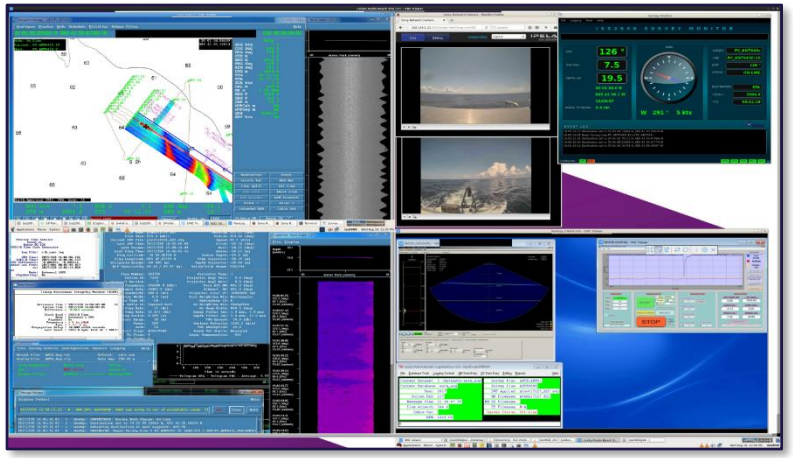
- **Successful autonomous bathymetric survey**
  - 63 nautical miles (nm) at approximately 7.5 knots (kts)
  - No operator intervention – over 3 days
- **25 COLREGs maneuvers**
  - 16 real interfering contacts
  - 9 virtual contacts
- **4 / 4 successful UUV autonomous launches and recoveries from USV**
  - 1 initial recovery miss – successful autonomous retry
- **Successful real time data exfiltration**

Planned and Actual Survey Lines – Gulf of Mexico

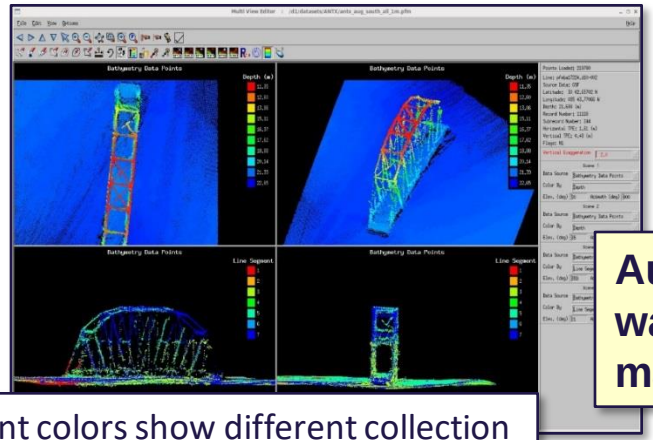


Maneuvering off of survey plan consistent with COLREGS. Note behavior to move back to line prior to next waypoint

Remote Operator Control Display – Rhode Island



Example Survey Object of Interest – Bridge Truss



Different colors show different collection lines over the same bridge truss

Next steps:

- **Autonomous "holiday" behaviors**
- **Object of interest investigation**
- **Autonomize Hydroghraphic Survey Launch (HSL)**
- **Additional demonstrations**

Autonomous line following performance was consistent and commensurate with manned survey missions

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