SEA HUNTER and Maritime Autonomous Behaviors

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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
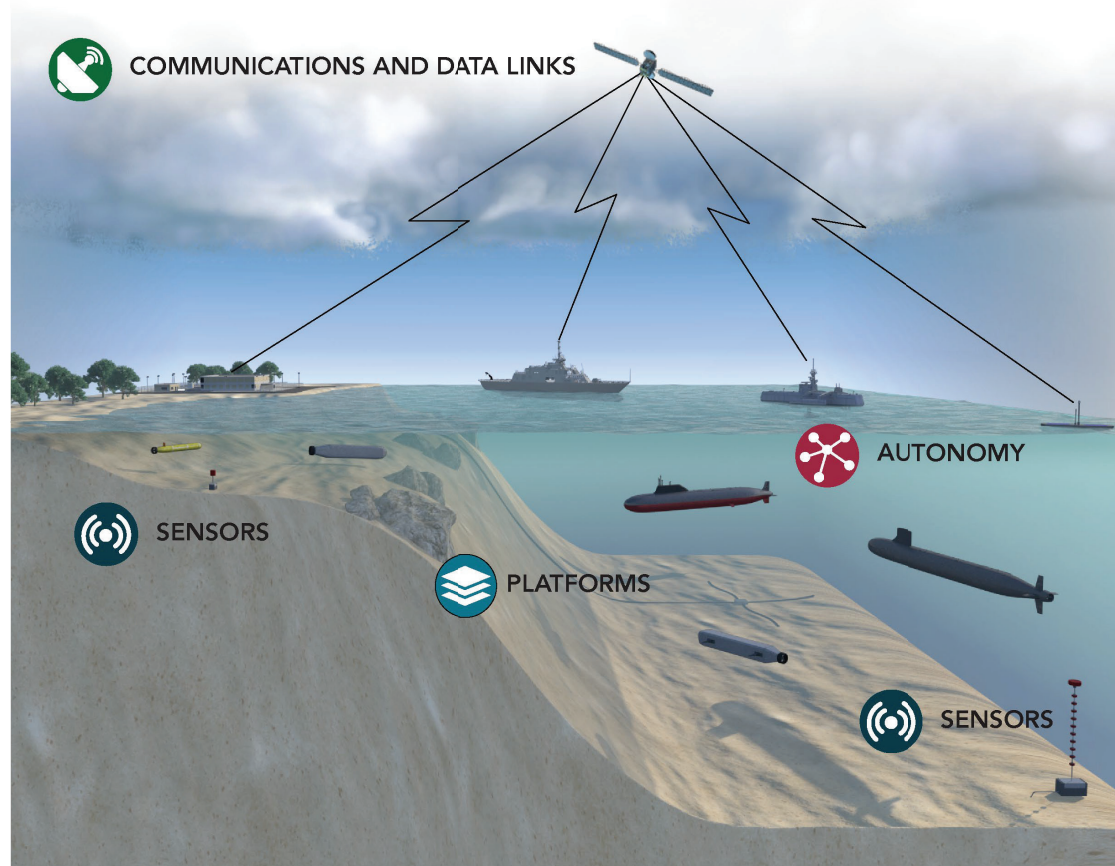- Fusion
- Communications
- Automation

Physics and Phenomenology
- Propagation modalities
- Interference and noise
- Targets

COMMUNICATIONS AND DATA LINKS

SENSORS

AUTONOMY

PLATFORMS

SENSORS

PROCESSING

PHYSICS AND PHENOMENOLOGY

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	"Autonomized" Manned Vessels	Bridge Decision Aids

Office of Naval Research (ONR) / Defense Advanced Research Projects Agency (DARPA) SEA HUNTER I
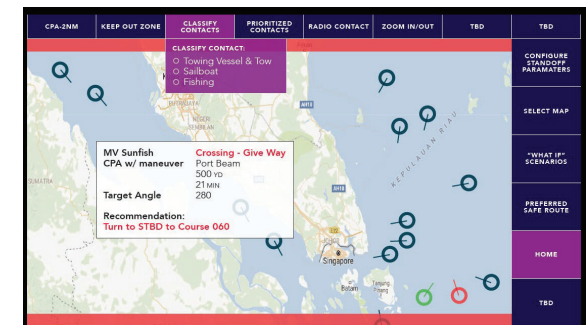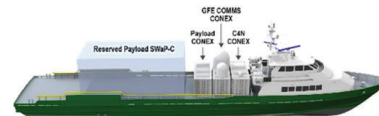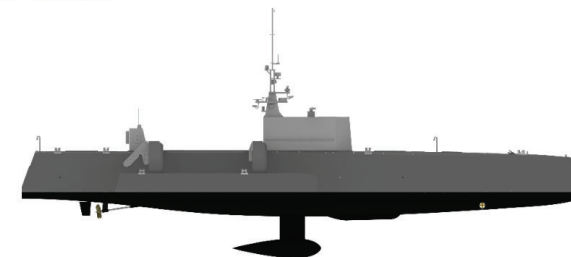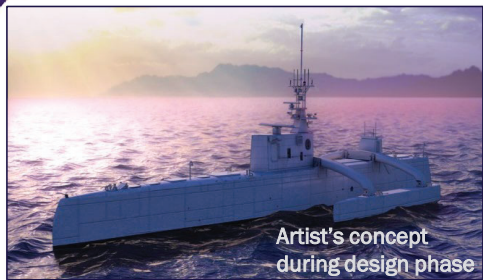
Leidos Research Vessel (R/V) PATHFINDER

Large Displacement Autonomous Commercial Ship

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

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ONR MDUSV SEA HUNTER I Overview

Artist's concept during design phase

MDUSV Program Goals:	ONR is Developing MDUSVs for the Navy:
· 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	· "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

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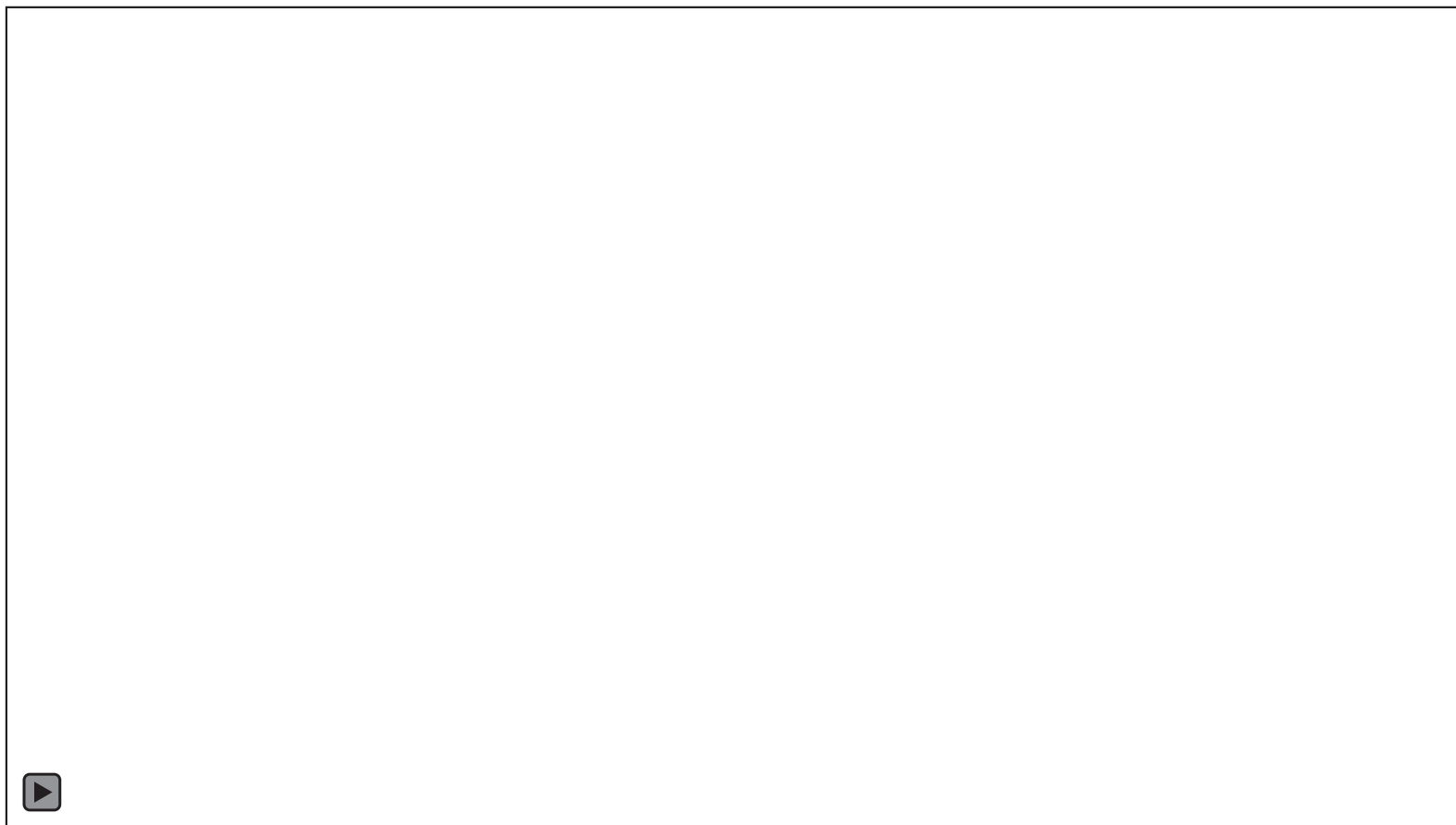- Under contract with ONR to build second hull SEA HUNTER II

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

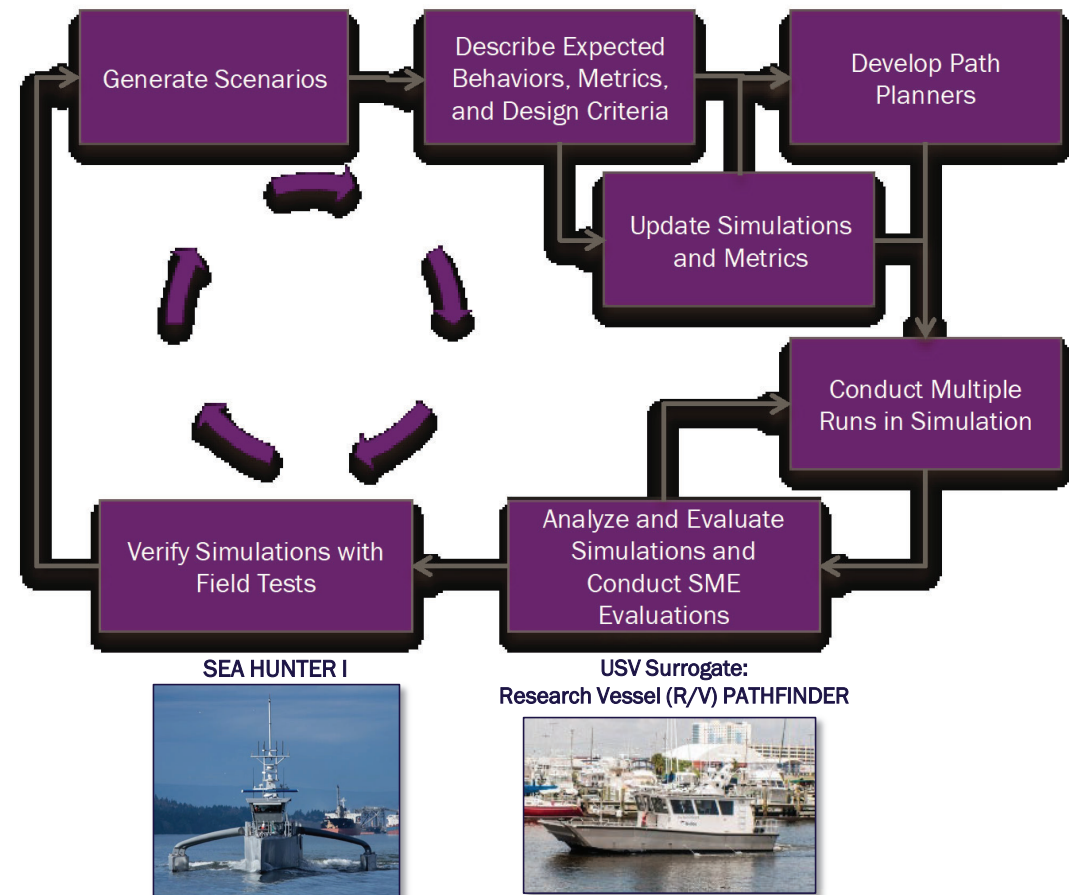| Organization	Role
SPAWAR Systems Center Pacific	Provides program test oversight, safety, environmental, and integration with Fleet operations
DARPA	Funded concept design, autonomy development, vessel fabrication, and initial testing
ONR	Funding at sea testing, enhancements, payload(s) integration, 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

COLREGS = International Regulations for Preventing Collisions at Sea

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Sea Hunter at Sea

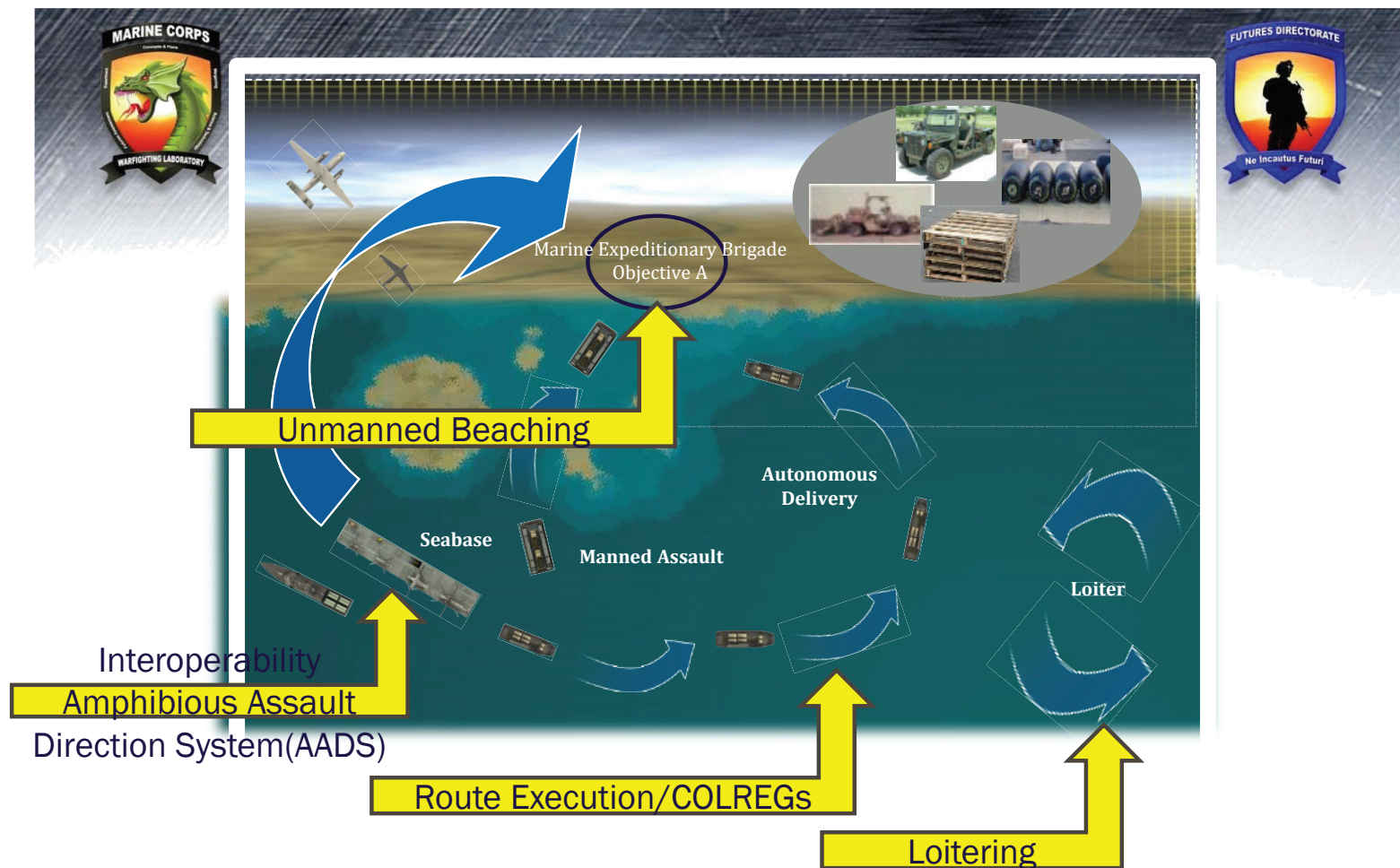**Distribution A – Approved for Public Release**

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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

Generate Scenarios → Describe Expected Behaviors, Metrics, and Design Criteria → Develop Path Planners → Update Simulations and Metrics → Conduct Multiple Runs in Simulation → Analyze and Evaluate Simulations and Conduct SME Evaluations → Verify Simulations with Field Tests

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)

Marine Expeditionary Brigade Objective A

Unmanned Beaching

Autonomous Delivery

Seabase

Manned Assault

Loiter

Interoperability
Amphibious Assault
Direction System(AADS)

Route Execution/COLREGs

Loitering

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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

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

Over-the-Horizon Communications

MCWL LCM-8: ACU2-13

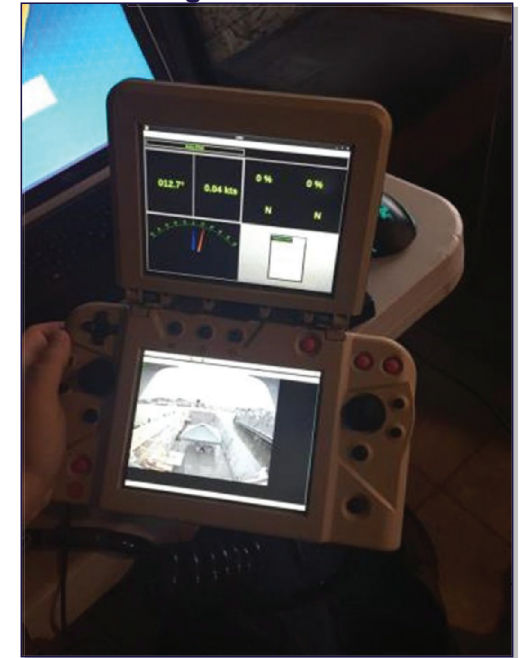**Autonomy Situational Awareness Sensors and Communications on mast:**
- **Radars**
- **Cameras**
- **Automatic Identification system (AIS)**
- **Global Positioning System (GPS)**

Autonomy Processor and Air Conditioning
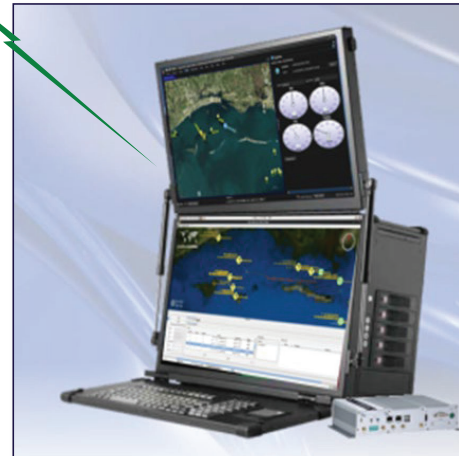
Remote Supervisory Control Station (RSCS)

Remote Operator Control Van

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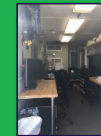
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STOM Concept of Operations and Demonstration

Over-the-Horizon Communications

Remote Supervisory Control Station (RSCS)

Command, control and situational awareness data are relayed through a satellite network

The vessel is monitored by a single operator on shore/sparse supervisory control during autonomous operation

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

Loiter Position

LCM-8

Loiter Position

Local Tele-Operations Control Station (LTCS)

Egress/Ingress port/shore to/from Loiter Point via LTCS Control Operations (within Line of Sight)

LTCS Control Operations tested Ashore, aboard Chase Vessel, and aboard LCM-8

- - - - - - **LTCS Control Operations**

–·–·– **Autonomous Operations with Remote Operator at RSCS**
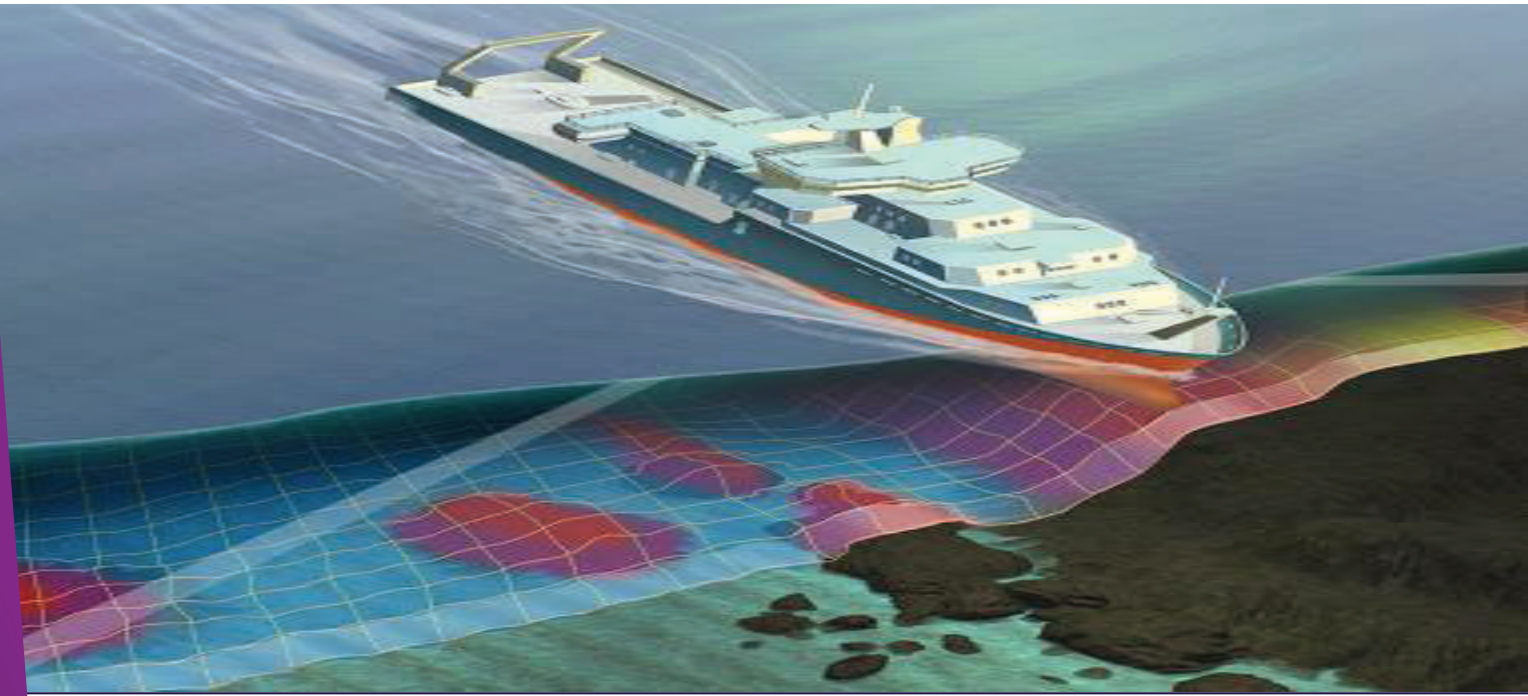
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Summary

- **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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Maritime Business Development

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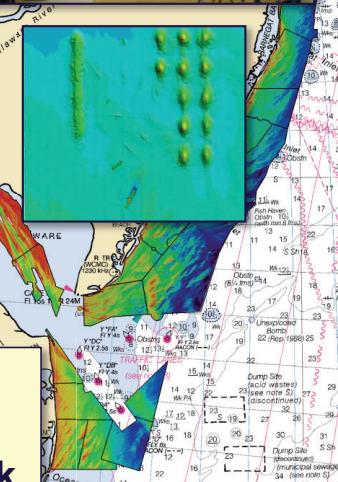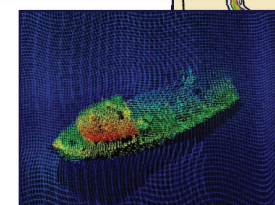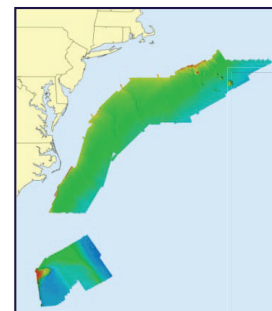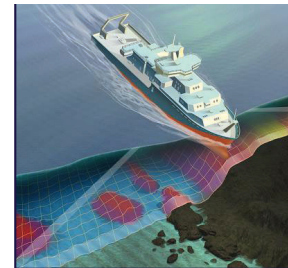
NAVOCEANO and NOAA are looking to autonomy to reduce survey mission time, cost, and risk

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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**
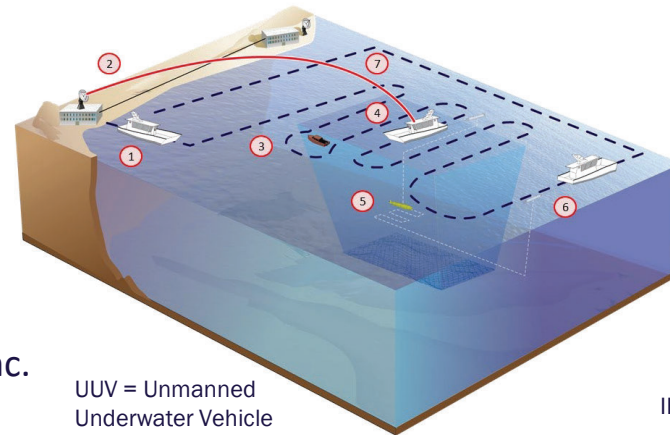

UUV = Unmanned Underwater Vehicle

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

MVP
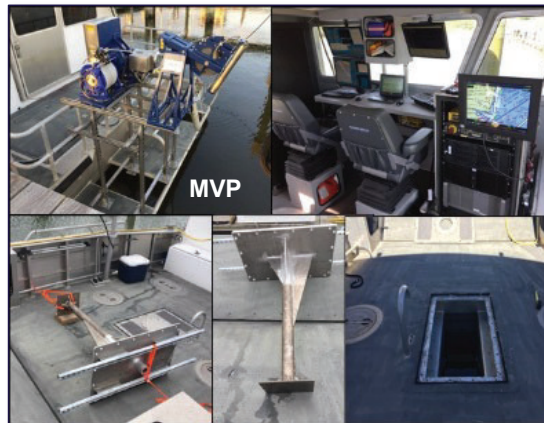
Multi-Beam Sonar and Mount
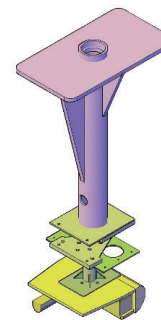
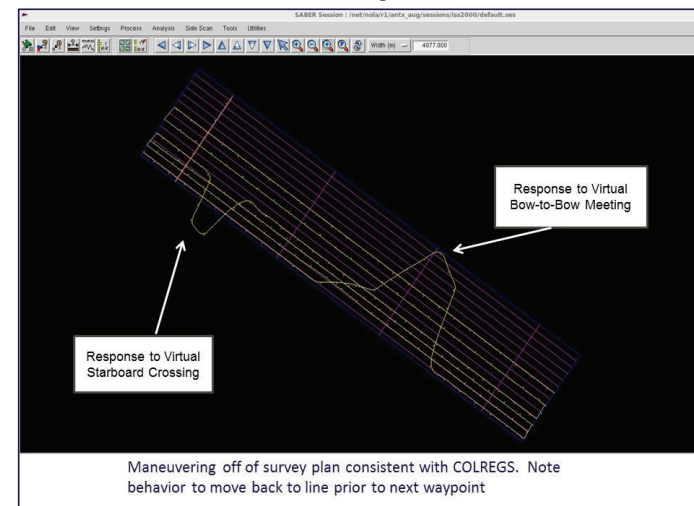**Leidos UUV and Towed Launch and Recovery Dock**

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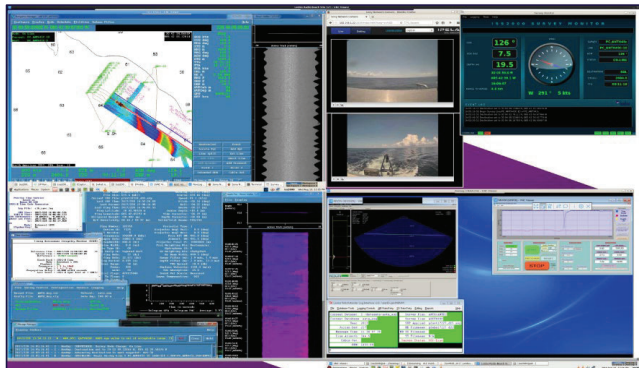Leidos LP-LG-4 Approval: 18-LEIDOS-0402-2067

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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
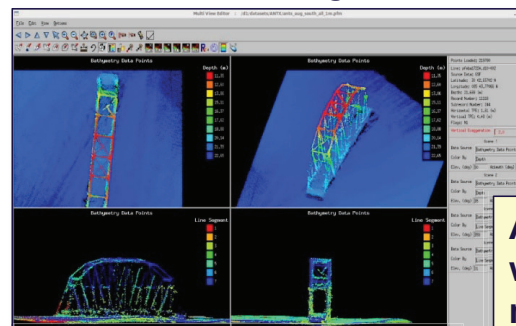- **Successful real time data exfiltration**

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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