CHC-NSC 2018
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Land and Sea Shaping the World
Terre et Mer Façonnant le Monde

The Evolution of an Autonomous Unmanned Surface Vessel and Software for Hydrographic Survey

Paul Donaldson

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- In 2017, Leidos, Inc. participated in both the Gulf of Mexico Unmanned Systems Operational Demonstration (GoMOD) and the Advanced Naval Technology Exercise 2017 (ANTX 2017)
- Survey data were collected using the R/V Pathfinder
- GoMOD was held at the Combat Readiness Training Center in Gulfport, MS on May 31 and June 1, 2017
    - Survey data were collected May 26 and May 27, 2017
- ANTX 2017 was held at the Naval Surface Warfare Center in Panama City, FL and Naval Undersea Warfare Center Newport, RI in August 2017
    - Survey data were collected August 12, 14-16, 2017

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Leidos started developing an autonomous surface vessel (Sea Hunter) in 2012 as part of a Defense Advanced Research Projects Agency (DARPA) contract

Autonomy engine is based on Point-to-Point Navigation which computes the best course and speed to the next WP based on the current vessel position

Capable of conducting transoceanic crossings with a > 70 day deployment duration and capable of achieving speeds in excess of 20kts

Integrates multiple systems in decision making process to maintain Convention on the International Regulations for Preventing Collisions at Sea (COLREGs) compliance

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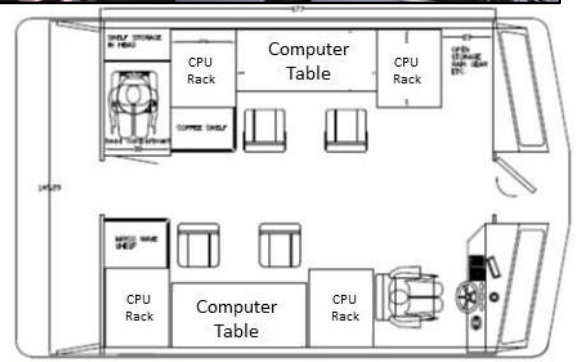
- RV Pathfinder: Is used as a test platform for Sea Hunter
- Architecturally consistent control systems as Sea Hunter



- 40 ft long and 12.5 ft wide
- 2 fixed equipment racks
- 2 optional equipment racks
- 4 work stations

Autonomous Survey Requirements

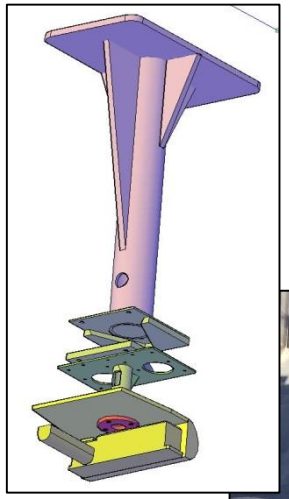
Vessel Control System and Survey Data Acquisition Control System

- **Vessel Control System**
  - **Maintain course over predefined survey line within +/- 5 meters**
  - **Maintain situational awareness such that it can remain COLREG compliant**
  - **Resume survey line after executing a COLREG engagement or avoidance maneuver**

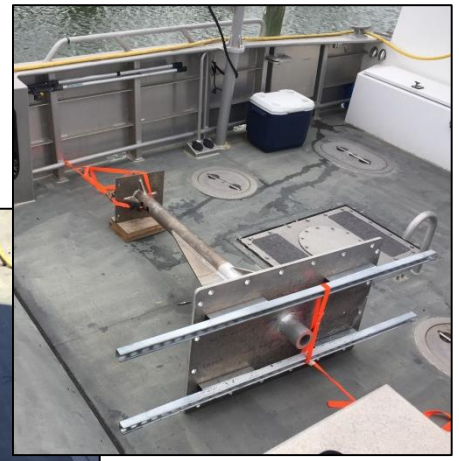
Vessel Control System and Survey Data Acquisition Control System

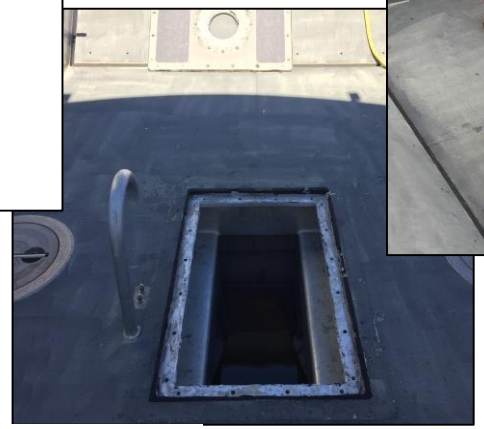
- **Survey Data Acquisition Control System**
  - **Confirm system readiness to commence survey operations**
  - **Automatically handle all aspects of sound speed profile (SSP) data**
  - **Continuously monitoring major systems and subsystems health**
    - **Report when non-compliant**
  - **Log key survey events and produce standardized time-stamped reports**

Outfitting the R/V Pathfinder for Survey

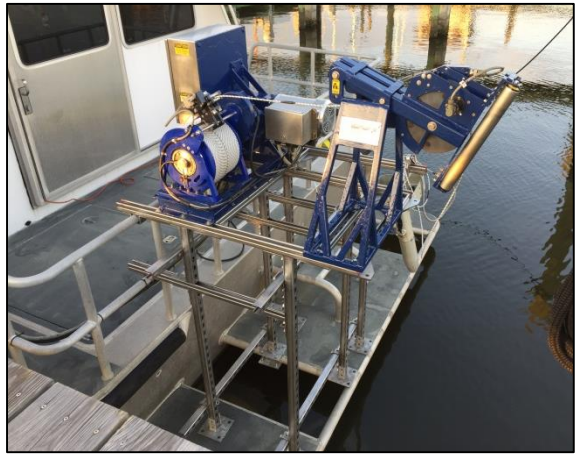


Multibeam Mount





Moving Vessel Profiler



Survey Suite

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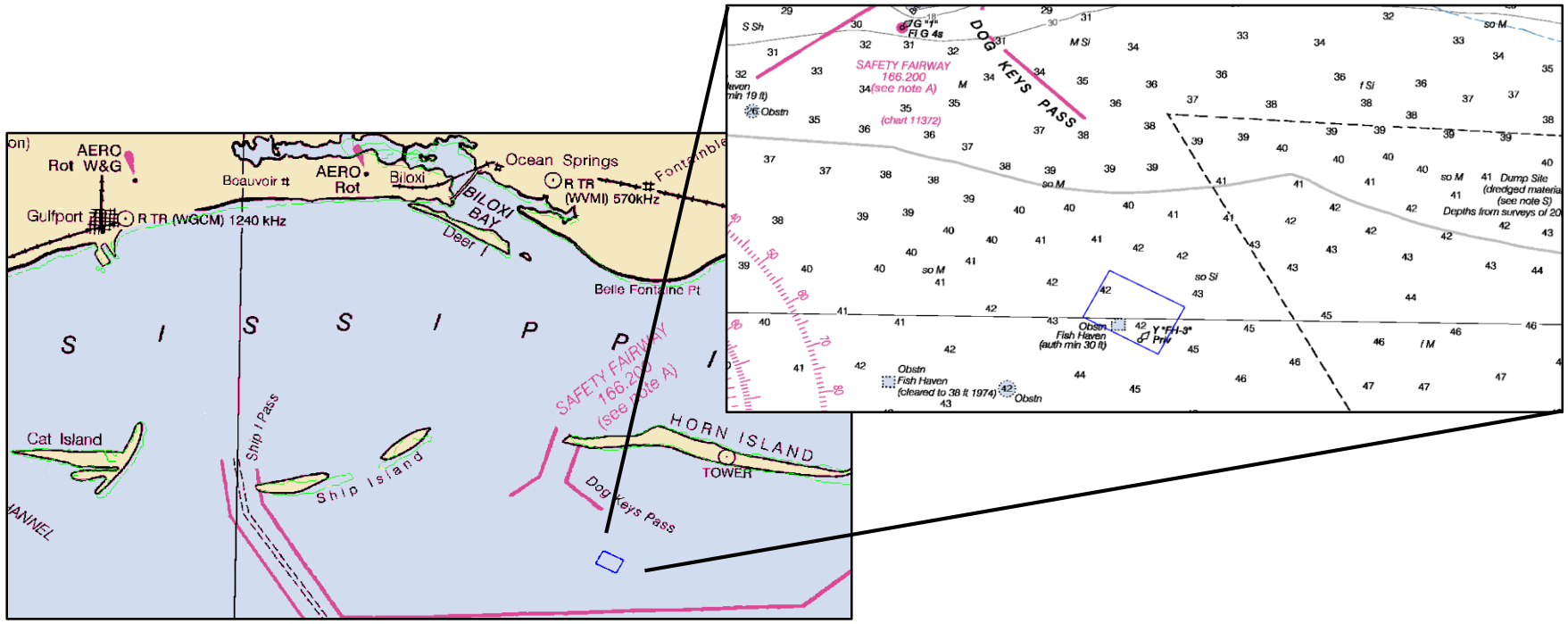
Preliminary Field Testing and GoMOD Survey



- **39.5 km Southeast of Gulfport, MS**
- **Within a Fish Haven Over a Known Wreck**

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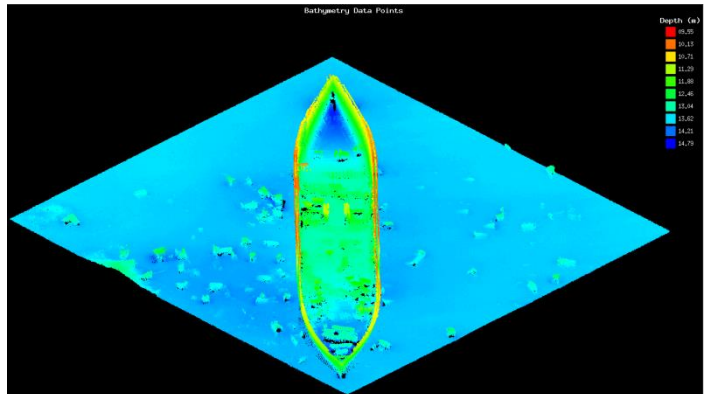
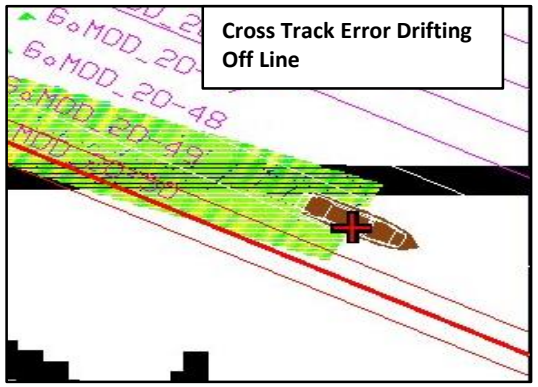
Preliminary Field Testing and GoMOD Survey

- **Initial field testing May 13-14, GoMOD survey May 25-26**
- **Standard Suite of survey equipment**
  - **Multibeam transducer not installed for initial field testing**
- **All enabled controls and software were operational and performed as expected**

Primary System	Description of use
Leidos Integrated Survey System (ISS-2000)	Integrates survey subsystems, logs all survey data, controls timing for all data, Survey Planning
Leidos iNavLog	Automatically captures key survey events
Leidos Autonomous Path Planner (ISS-2000A)	Controls vessel systems
Reson 7125 Multibeam Sonar	Collects multibeam bathymetry
AML Oceanographic Moving Vessel Profiler (MVP-30)	Collects sound speed profile data
Applanix POS/MV v5	Provides position, heading and motion corrections



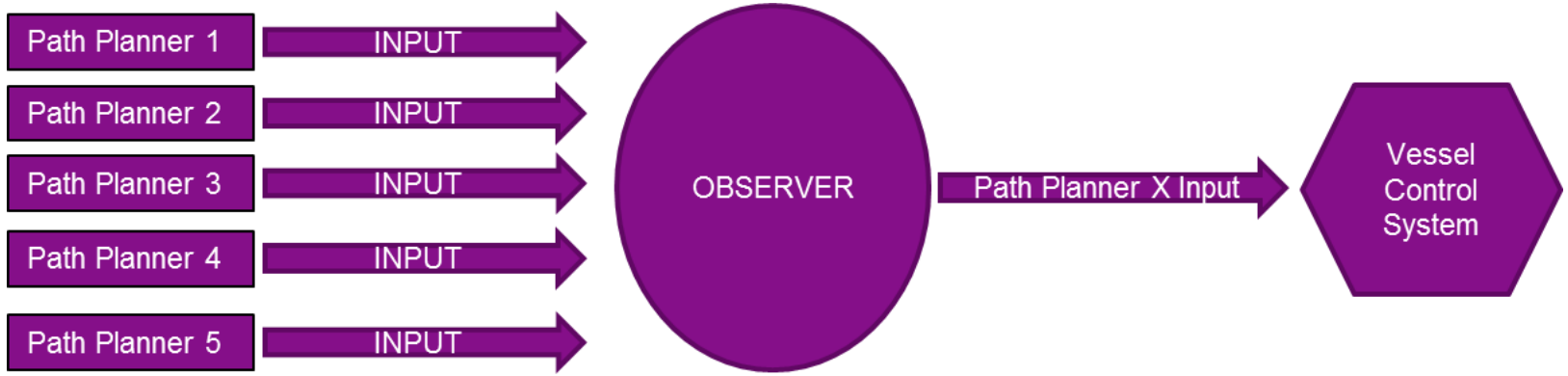
GoMOD survey data quality met International Hydrographic Organization (IHO) order 1a standards



Autonomy utilized the Sea Hunter waypoint to waypoint protocol for vessel controls

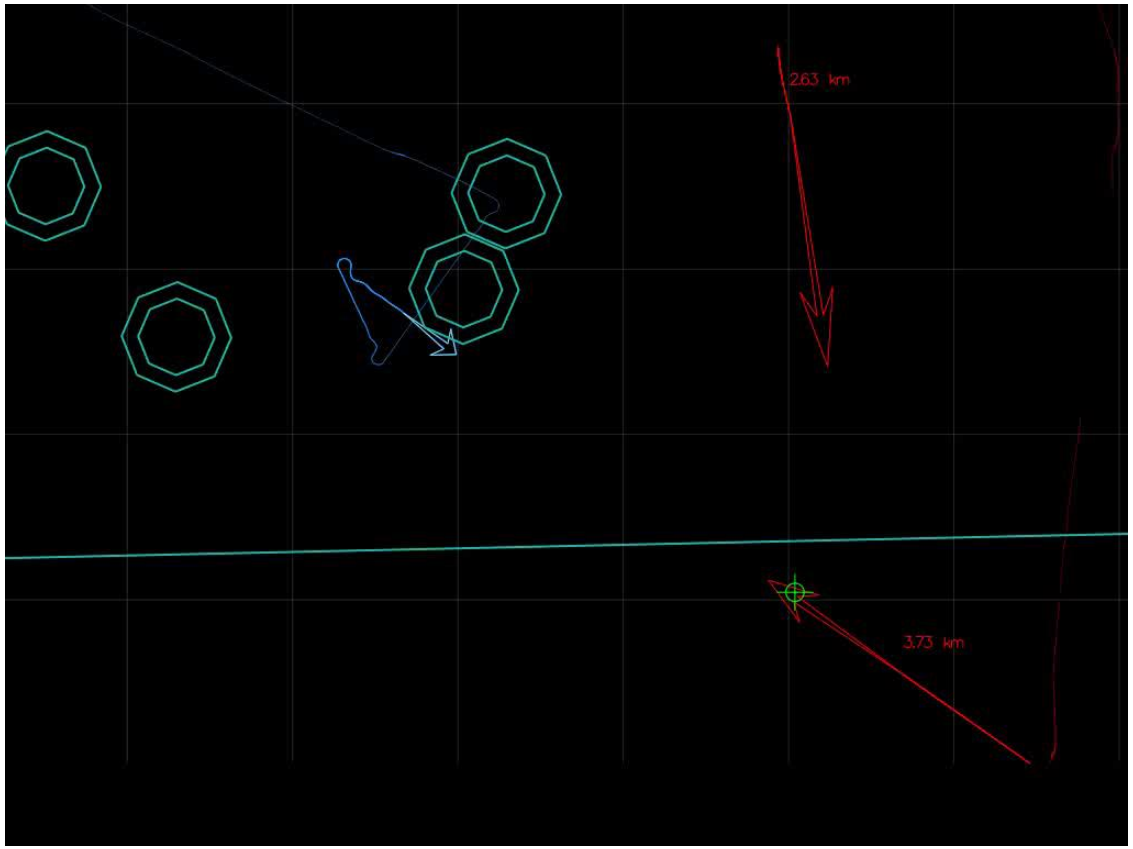
Enhancements Made to Vessel Control System Prior to ANTX

- **Vessel Control System**
  - **Added an additional path planner for line following**
  - **Layered the path planners so multiple planners could run at the same time**
  - **Incorporated an observer component which coordinates which path planners takes priority and therefore sends commands to the vessel control system**



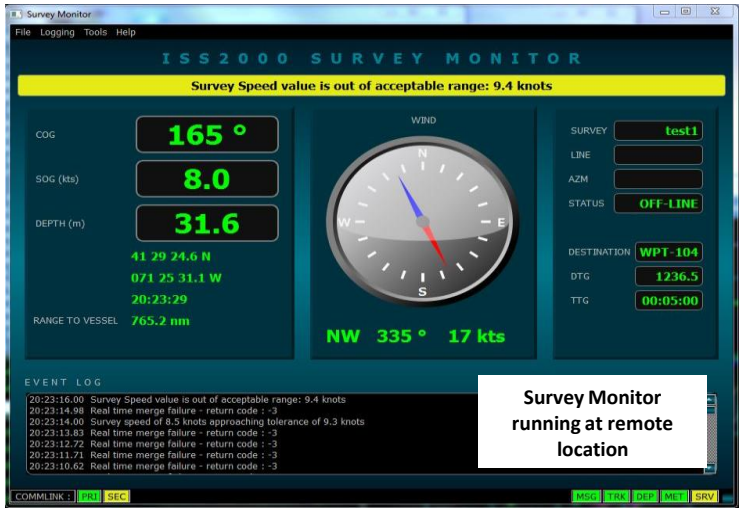
Autonomy Display with Interjected and Real-World Interferers Illustrating COLREG Maneuvers for

- Bow Meeting
- Starboard Crossing
- Overtaking
- Stationary Object



Enhancements Made to Survey Data Acquisition Control System Prior to ANTX

- **Two independent remote monitoring and control radios were incorporated**
  - **Allows data and displays to be sent to multiple remote locations**
  - **Bandwidth of 20 MHz with throughput up to 16 mbps and capable of transmission up to 50 km**
  - **Allows for remote monitoring and control of the survey systems from anywhere in the world**
  - **ANTX remoted desktops to Panama City, FL and Newport, RI simultaneously**
  - **Each site was capable of viewing and controlling all aspects of survey data collection and operation**
    - **Leidos software defined radio with integrated mobile adhoc network (MANET)**
    - **Kongsberg marine broadband radio (MBR) link**
- **Survey Monitoring program was incorporated to allow monitoring and reporting of system health**



Survey Monitor running at remote location

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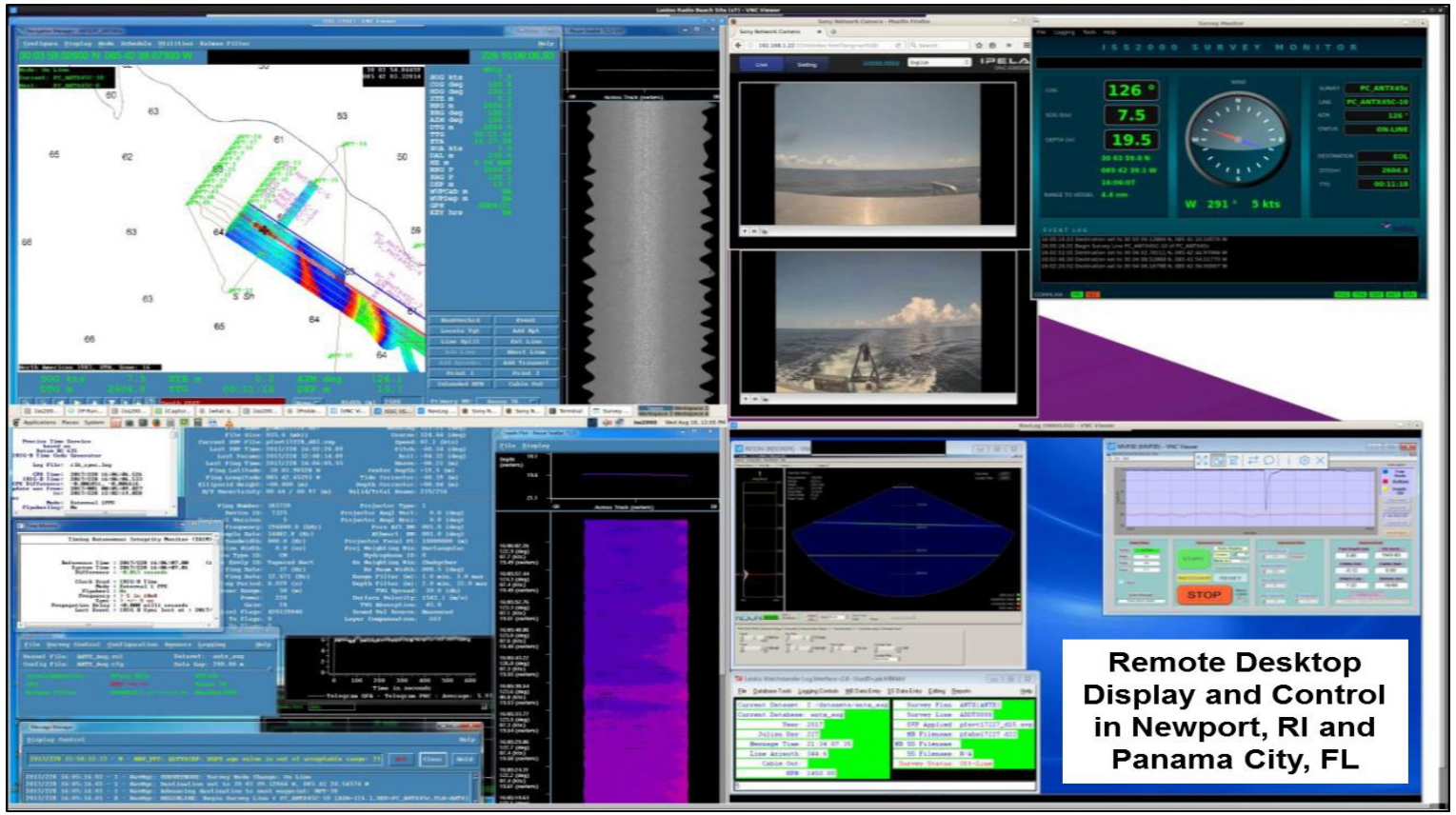

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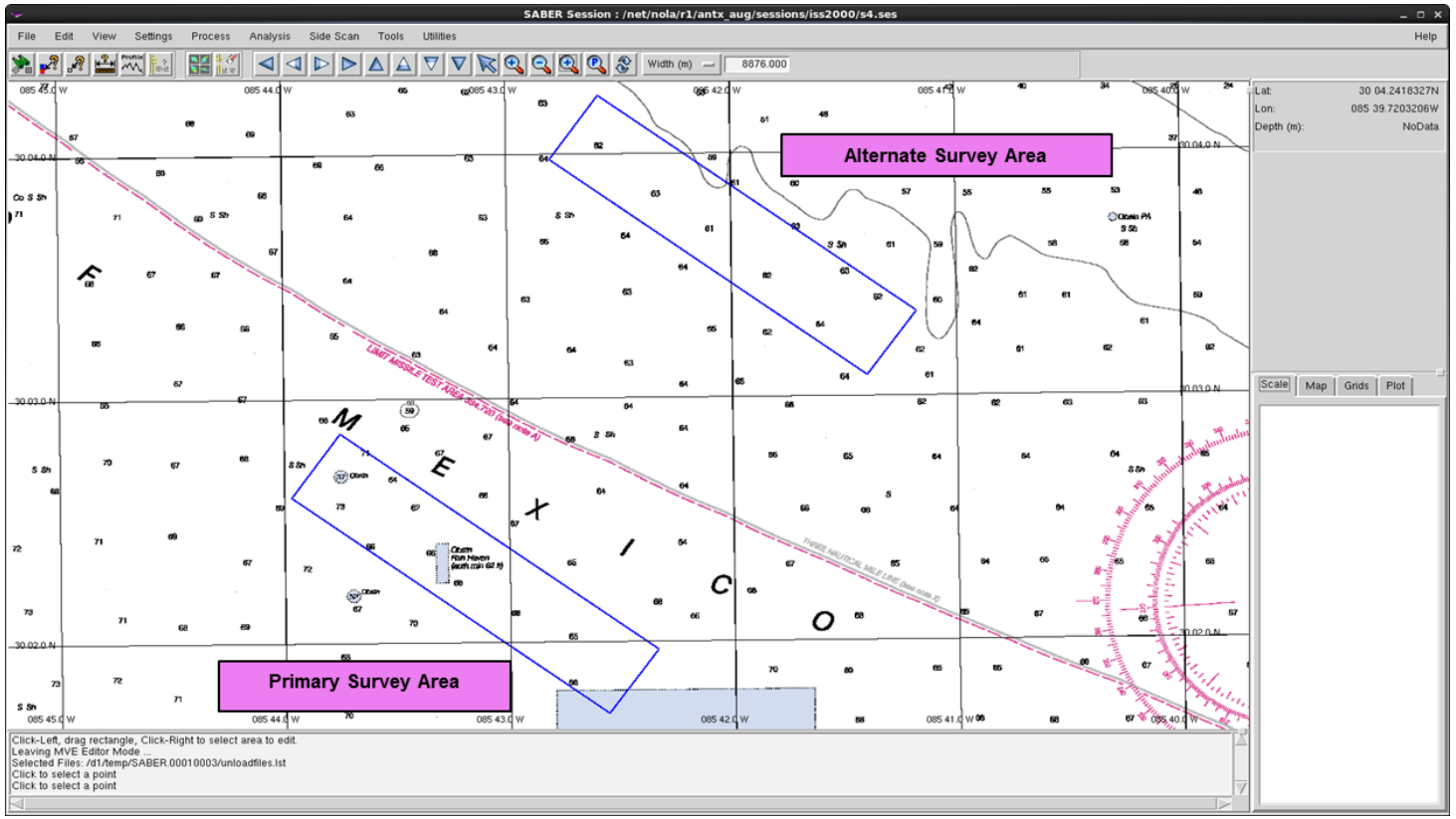
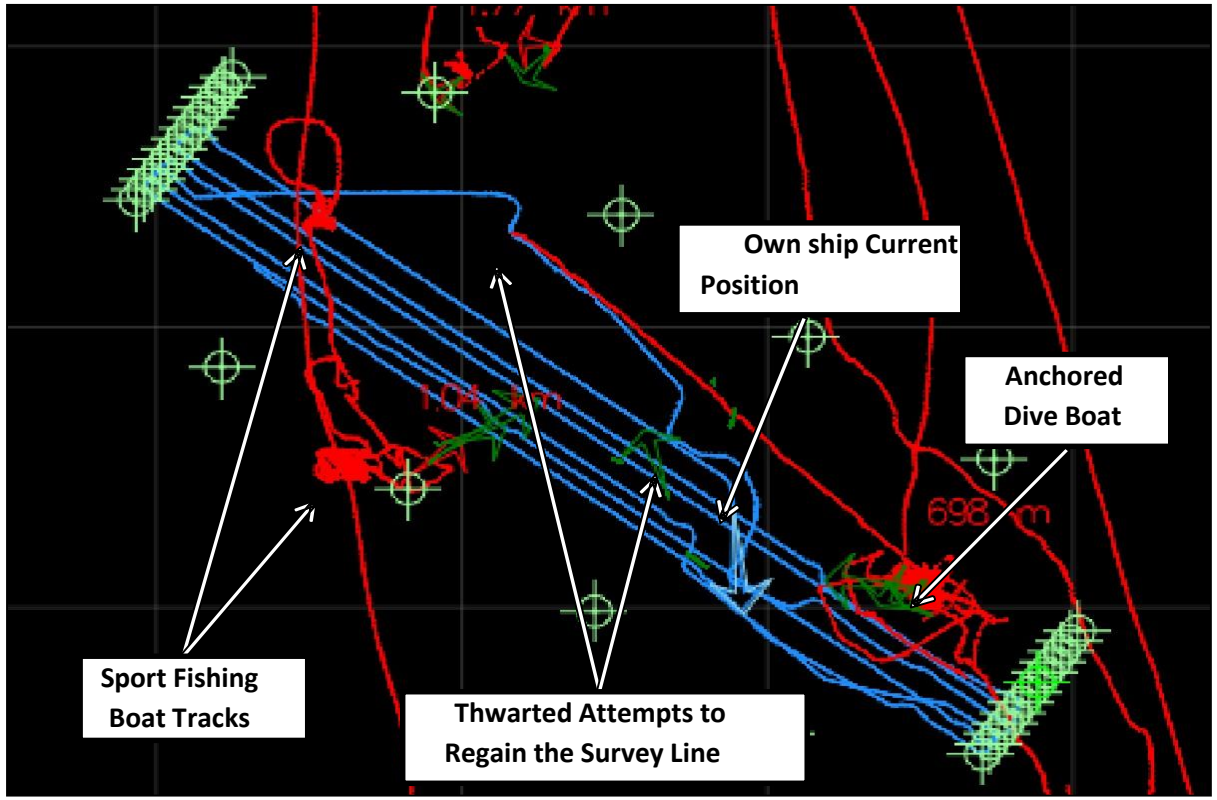
ANTX Survey

- 2 Survey areas 7.5 km south of Panama City, Florida
- Primary survey area over known objects such as bridge spans, wrecks, and debris
- Alternate survey area 2.5 km northeast of primary area without known features
- Piloted vessel from pier to sea buoy
- Deploy MVP tow body
- Set auto sound speed profiles to 20 minutes
- Engage vessel autonomy

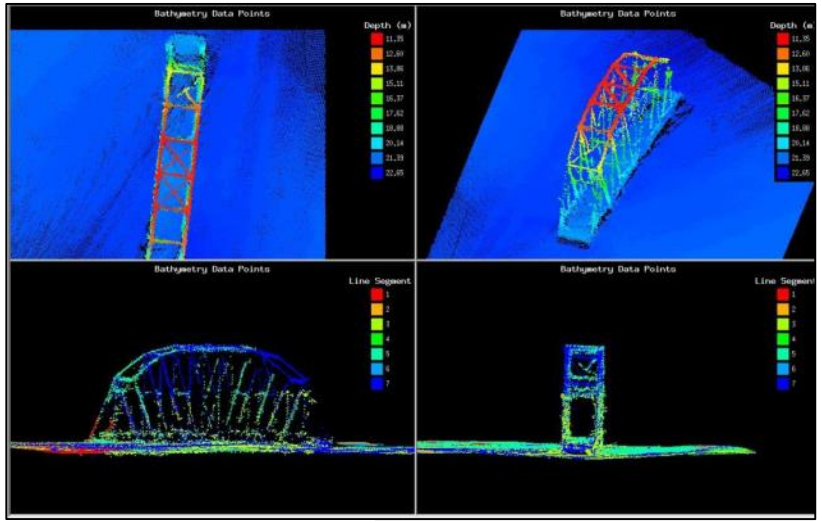


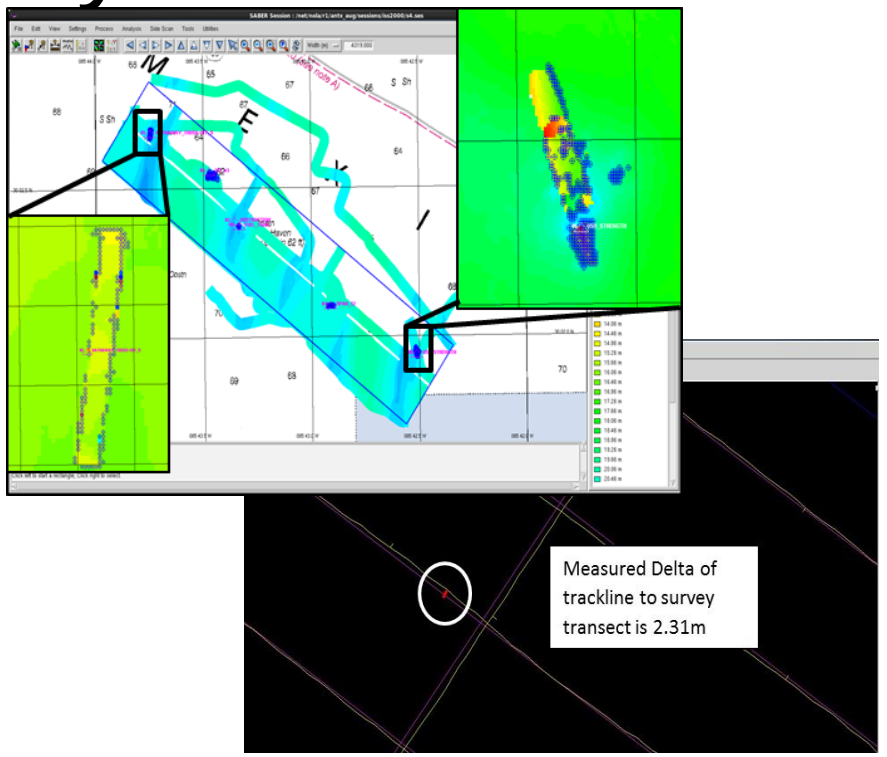
ANTX 2017					
Hours of Collection		Mileage (Linear Nautical Miles/Kilometers)		Sound Speed Profile Cast	COLREGs
Day	Hours	LNM	KM	#SSP Cast	Engagements
JD224	2	10.97	20.31	8	9
JD226	5	16.68	30.89	5	6
JD227	7	21.89	40.54	15	2
JD228	3	13.52	25.03	9	5
Totals	17	63.05	116.77	37	22



ANTX Survey Results – Primary Area

- **Data met IHO order 1a standards**
- **Any uncertainties exceeding the IHO order 1a uncertainties at the 95% confidence level were associated with features as would be expected**





- **Depth differences between the cross line data and mainscheme data were within 0.11 meters 96.46% of the time. Minimum and Maximum CUBE depths = 20.457 m and 22.693 m**
- **Comparisons of depth differences with historical bathymetry data (Registry # H12718) collected in 2015 and the northwestern half of the primary area were within 0.16 meters 95.92% of the time in water depths of 11.264 m to 22.941 m**

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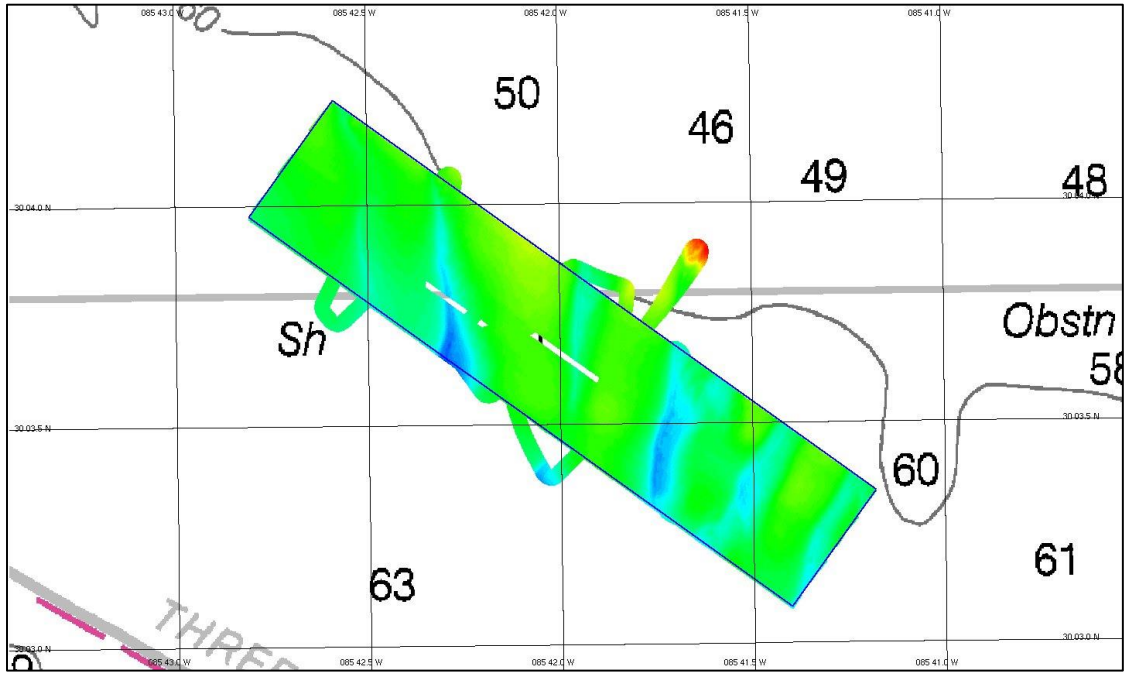
ANTX Survey Results Alternate Area

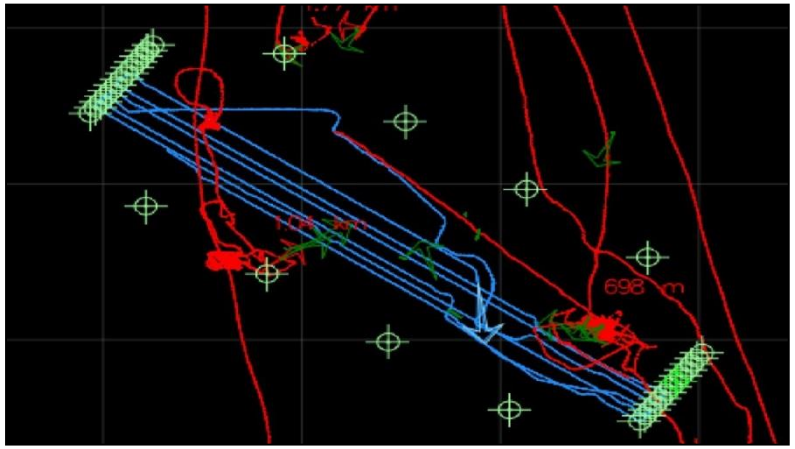
- **The final one-meter combined uncertainty and bathymetric estimator (CUBE) surface uncertainties ranged from 0.470 to 0.488 meters**
- **0 nodes in the CUBE surface exceeded the IHO order 1a uncertainties at the 95% confidence level**



- **Depth differences between the cross line data and mainscheme data were within 0.09 meters at 95.71% of the time. Minimum and Maximum CUBE depths = 18.635 m and 21.262 m**

Conclusions

- Demonstrated the ability to remain COLREGs compliant while collecting hydrographic survey data in a target rich environment
- Demonstrated the ability to collect fully corrected survey data in realtime in a fully autonomous mode
- Demonstrated the ability to remotely view and control data collection from remote sites with the use of two different types of radios
- The newly developed line following path planner was capable of maintaining a survey line within ±2.5 m with 15-20 kt wind and 2-3 ft seas on the beam and allowed the vessel to return to the survey line after an engagement limiting any gap in coverage to be consistent gaps created by crewed vessel operations



Questions?

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