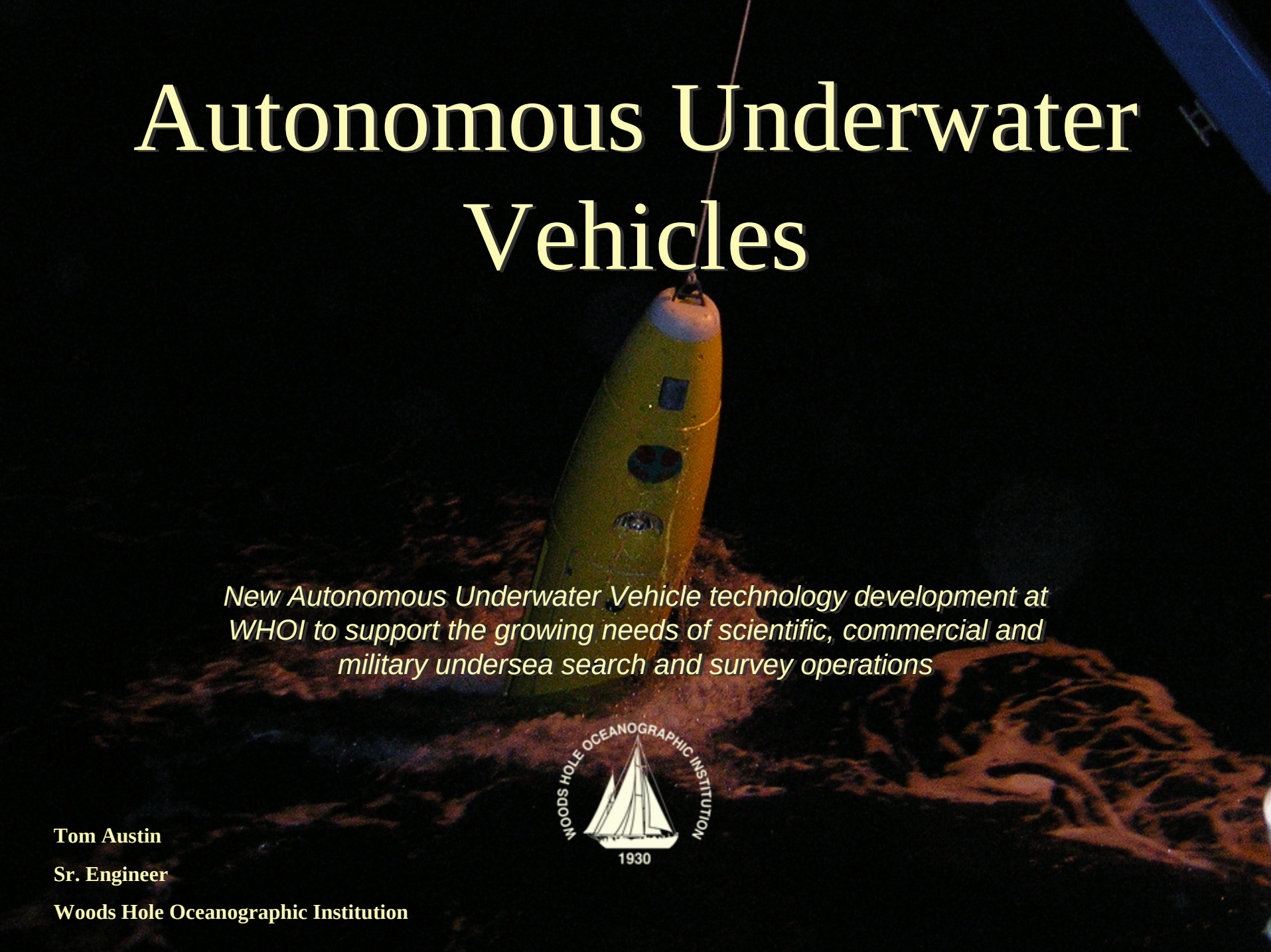
Autonomous Underwater Vehicles



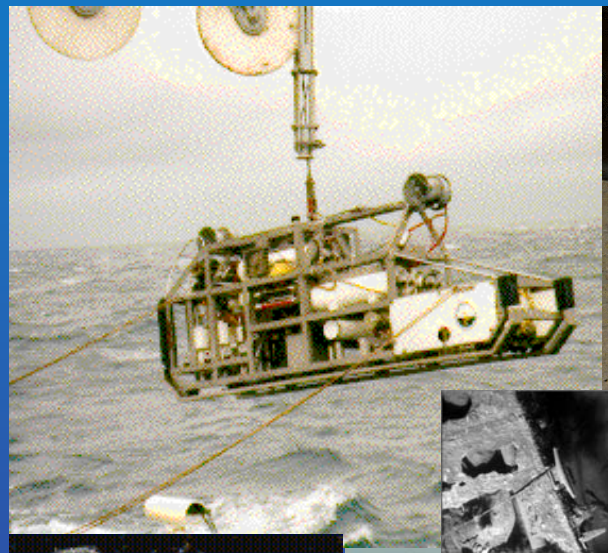
New Autonomous Underwater Vehicle technology development at WHOI to support the growing needs of scientific, commercial and military undersea search and survey operations

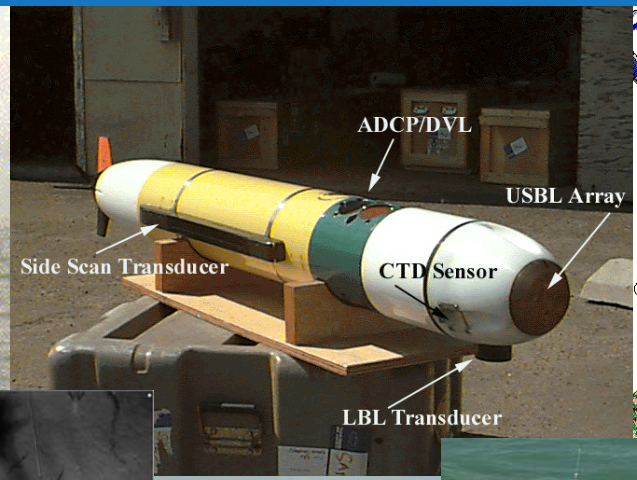
Tom Austin

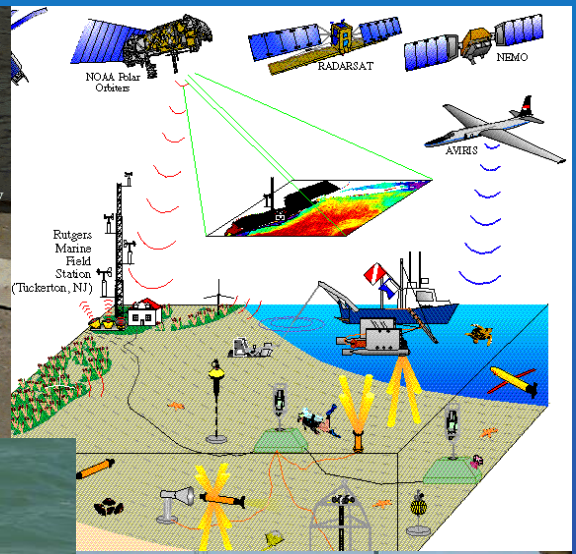
Sr. Engineer

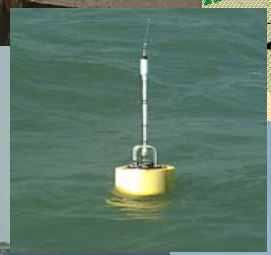
Woods Hole Oceanographic Institution

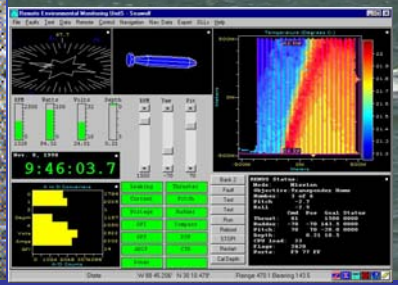
Oceanographic Systems Laboratory









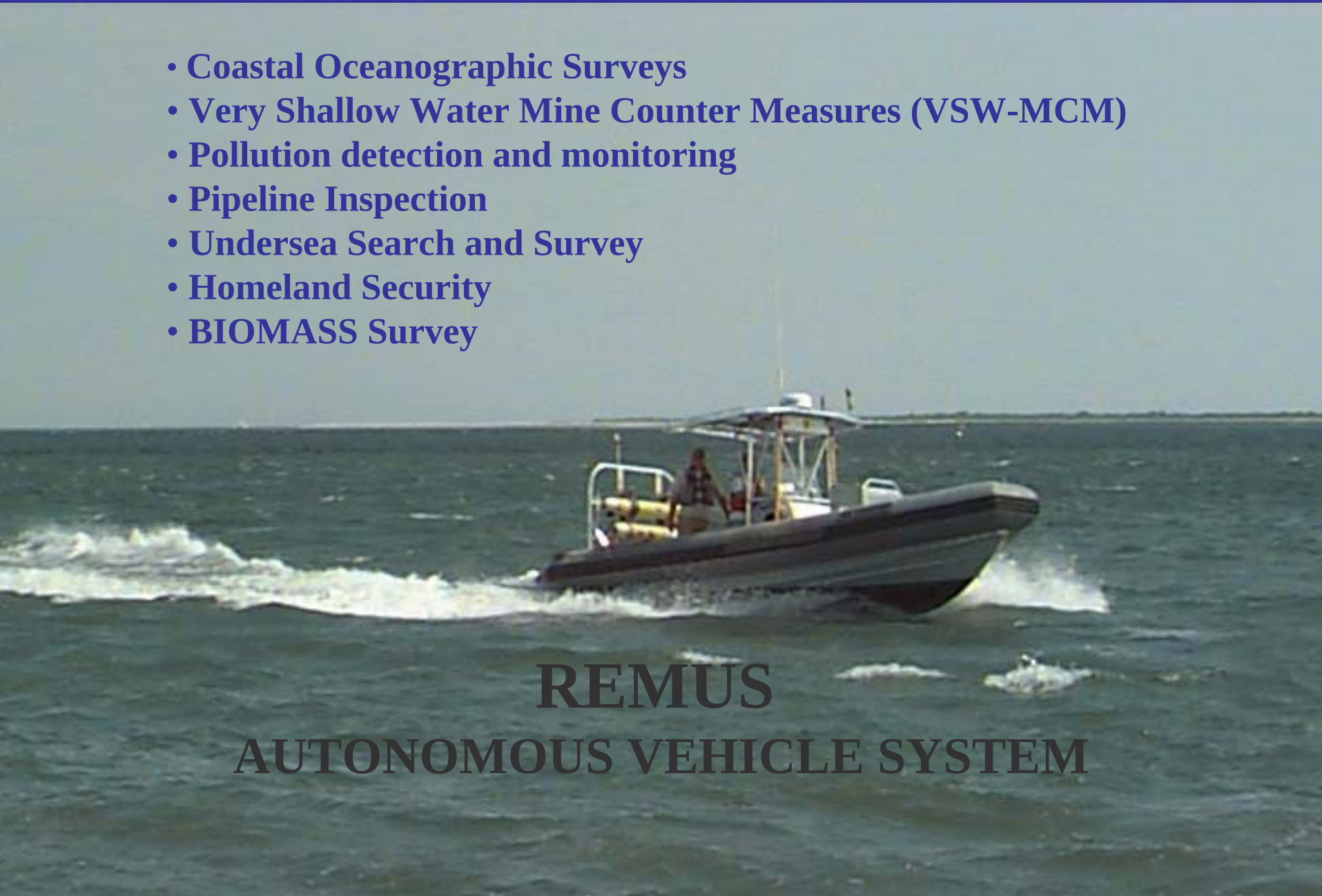


REMUS-100

- **Small, portable, low cost AUV capable of performing extended missions accurately and efficiently.**
- **>100 km maximum range with re-chargable batteries**
- **Self-navigating**
- **Numerous Sensors:**

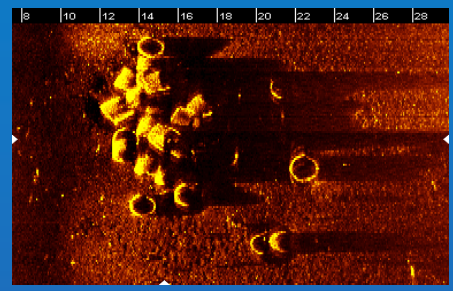
  Side Scan Sonar, conductivity, temperature, bathymetry, optics, water currents, bioluminescence, plankton camera, flourometer, radiometer, electronic still camera, video camera……

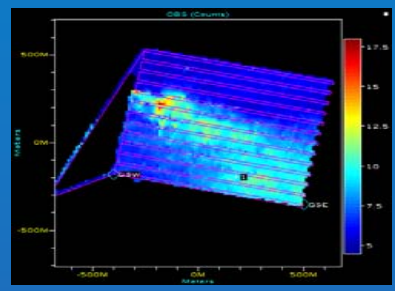
- Coastal Oceanographic Surveys
- Very Shallow Water Mine Counter Measures (VSW-MCM)
- Pollution detection and monitoring
- Pipeline Inspection
- Undersea Search and Survey
- Homeland Security
- BIOMASS Survey

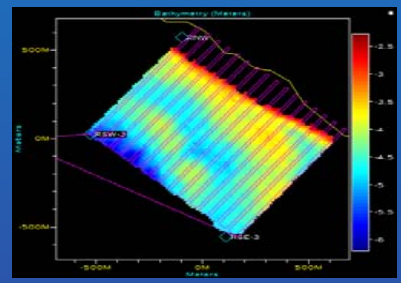


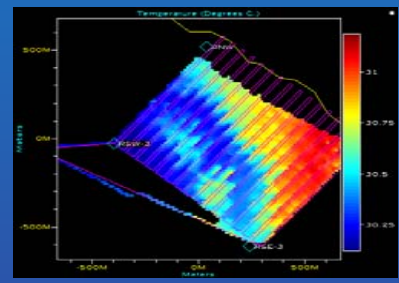
REMUS
AUTONOMOUS VEHICLE SYSTEM

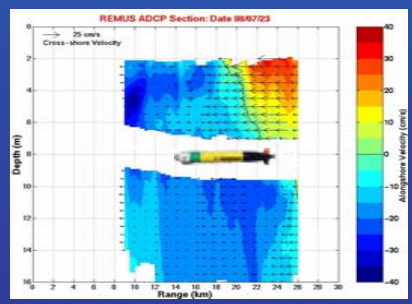
- Sensor Data is available immediately upon recovery of the vehicle.
- Combining the sensor data with the navigation data provides instant two and three dimensional visualization of the environmental parameters measured by the vehicle.

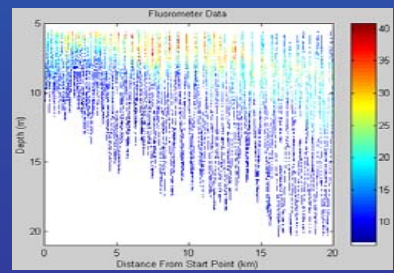












REMUS-100 Total Turn-key Package

- REMUS
- Transponders
- Floats & Anchors
- REMUS Ranger
- GPS receiver
- Ruggedized laptop computer
- CD-ROM writer, blank CDs
- Power/Data Interface
- Cables
- Spares/Maintenance Kit
- Vehicle Stand

REMUS-100 Baseline Configuration

80 pound vehicle with18 hour mission duration at 3 knots
Shipped via commercial overnight carrier

- **Survey capabilities**
  - Both Search Classify and Map and Reacquire and Identify capabilities
  - Adaptive (proactive) path planning – following a plume to its source
  - Multiple Vehicle Operations: Up to four vehicles simultaneously in an area
- **Navigation**
  - Acoustic LBL and USBL navigation
  - Optional ring-laser-gyro / Doppler DVL inertial navigation
  - WAAS GPS
- **Acoustic / Satellite Communication**
  - Mission redirection during deployment
  - Survey data upload – environmental data, sonar snippets (future)
  - Upload of vehicle status to hand held unit in boat
- **Payload Modules**
  - Docking, video imaging, forward look sonar, side scan sonar, profiling sonar, CTD, Bioluminescence, flourometer, radiometers, video plankton recorder, micro-structure turbulence ….

REMUS Navigation

Summary of Capabilities

- **Long Baseline Transponder Navigation**

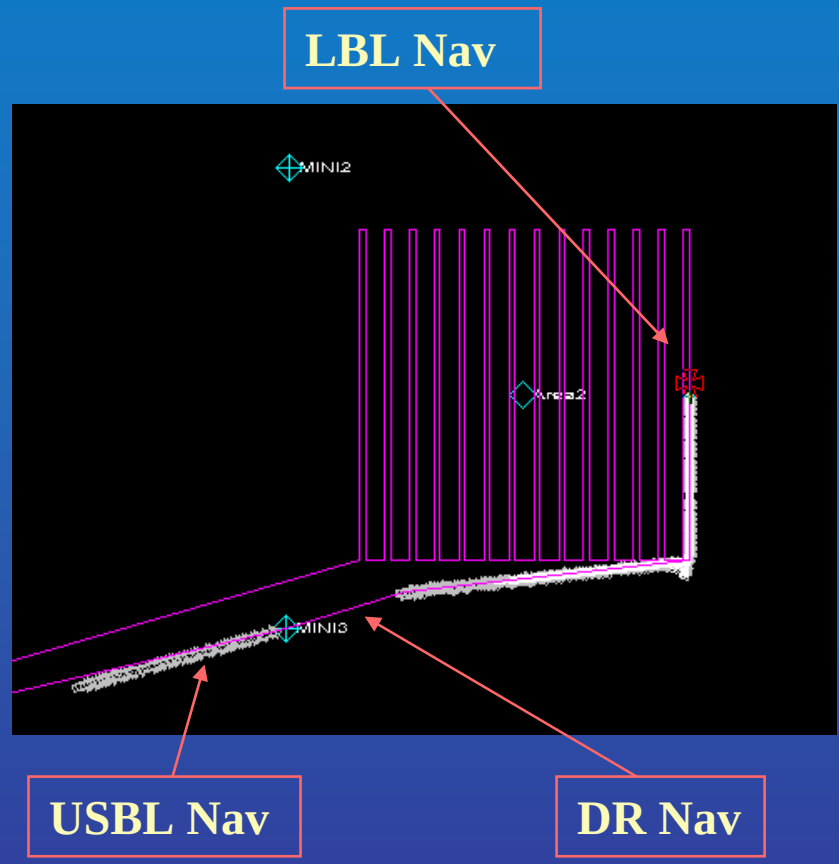
  Used most often for survey work. Needs at least two transponders.

- **Ultra-Short Baseline Transponder Nav.**

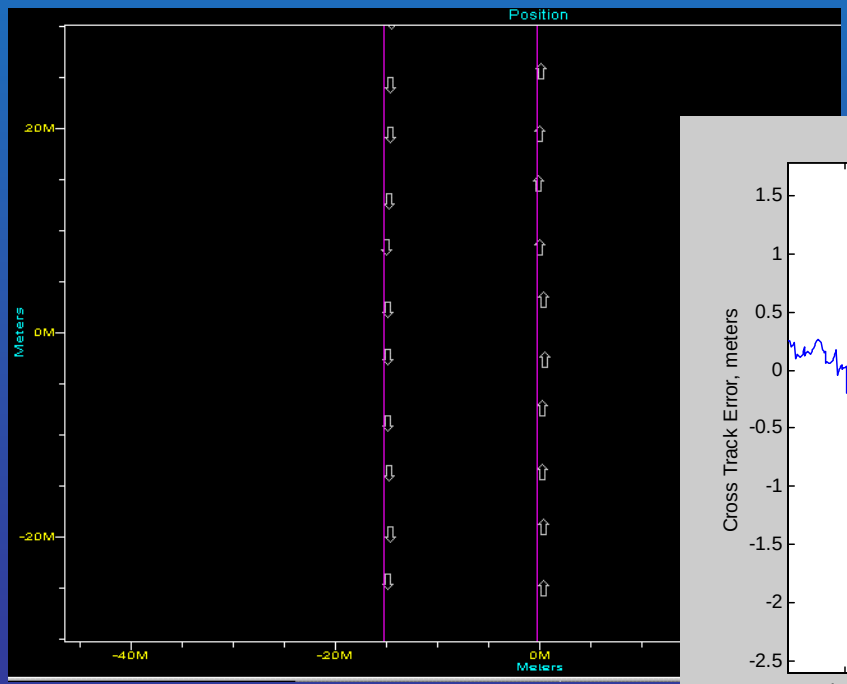
  Used for homing, docking, and recovery. Only one transponder is required. Fix is based on range, bearing, and heading.

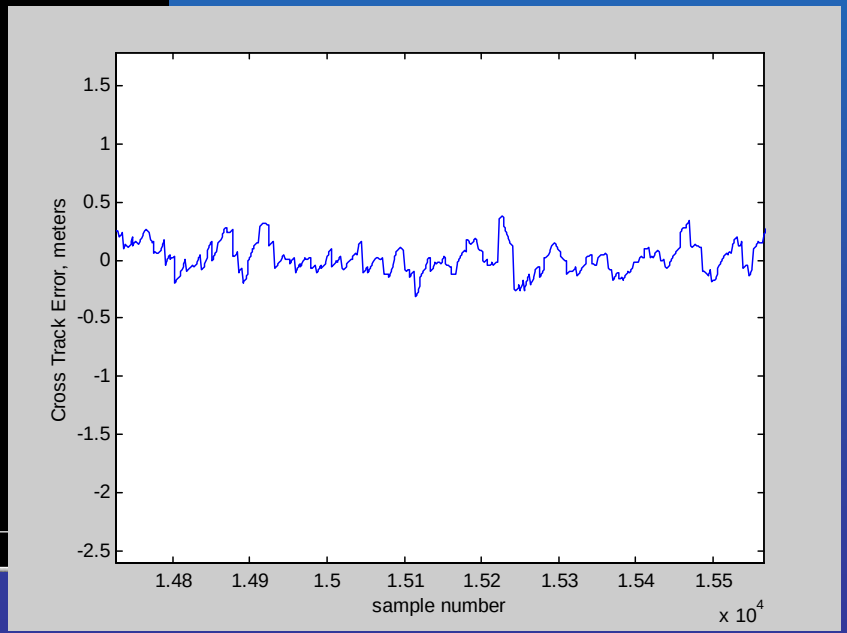
- **Dead Reckoned Navigation**

  Used to estimate position between acoustic fixes, or when transponders are not available. Based on lateral and axial velocities from ADCP, combined with heading from compass/rate gyro. Inertial navigator extends dead reckoned accuracy to approximately 5 meters per hour of error.



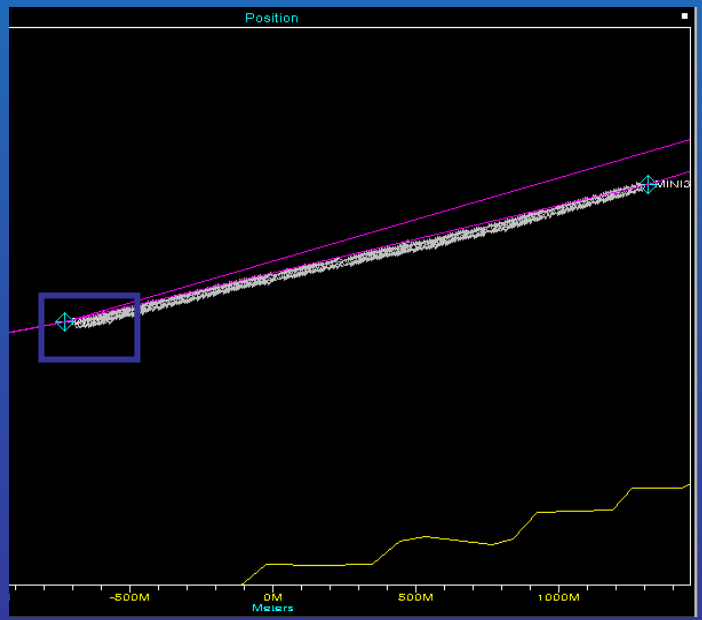
- Track-line following to well within 1 meter,
- Reliable Ranging to 2000 meters or more.



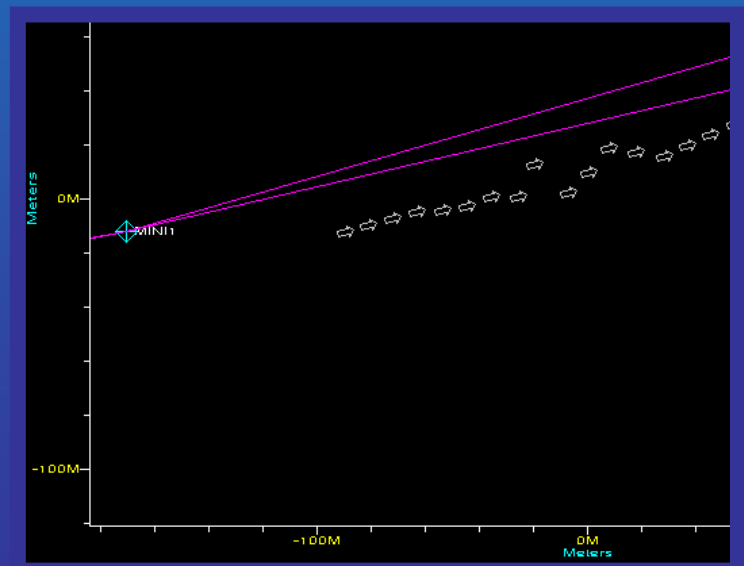


Unfiltered Position Data

- Angular Resolution better than +/- .5 degrees including heading errors,
- Accuracy limited by compass error, typically 1 -3 degrees.
- Reliable acquisition and tracking to 2000 meters.

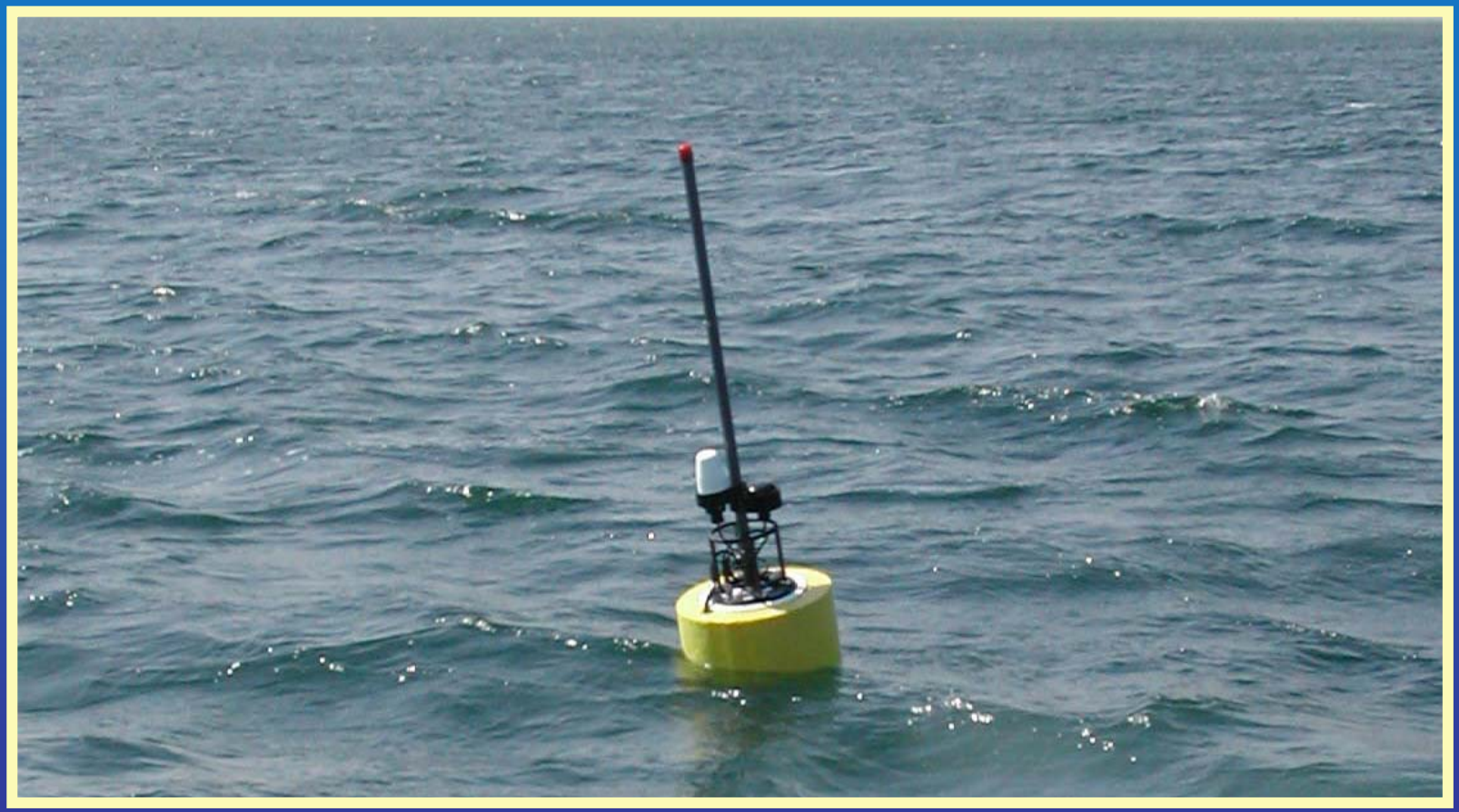


Worst case error at longest range



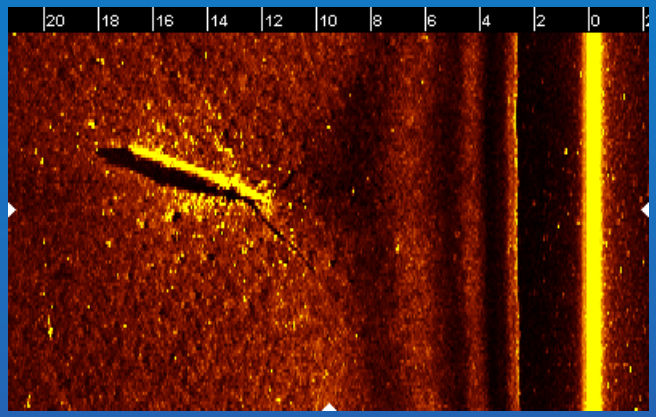
Gateway Buoy

Allows for remote monitoring, tracking and control.

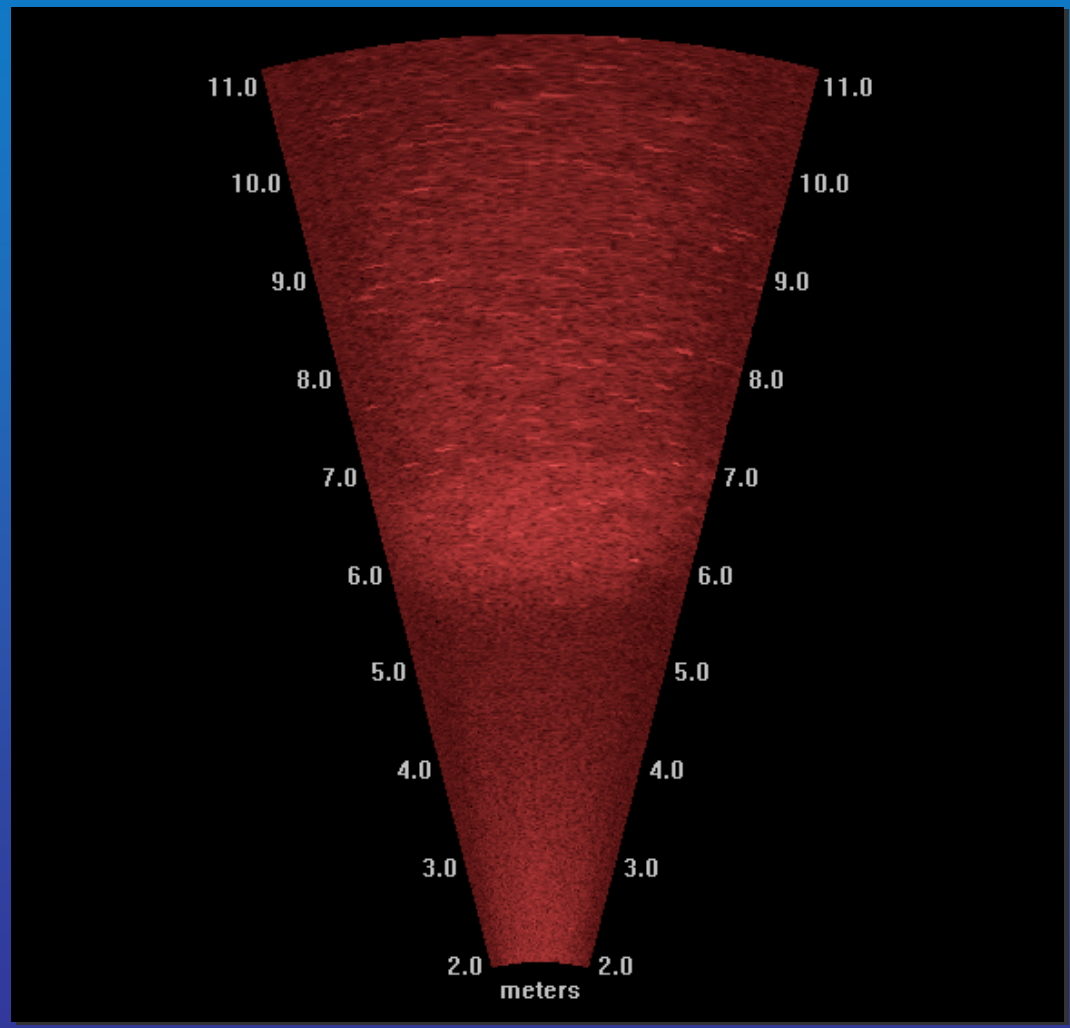


Courtesy Hydroid, Inc.

AUV Fest 2003 found old test torpedo



- Unknown torpedo detected with sidescan
- Reacquired and imaged with DIDSON vehicle



New Antennas
GPS, GPS/Iridium and Wi-Fi

- Rugged, compliant design
- Allows for over-the-horizon deployments
- Eliminates the need for transponders in some missions.
- Wi-fi greatly improves operational convenience

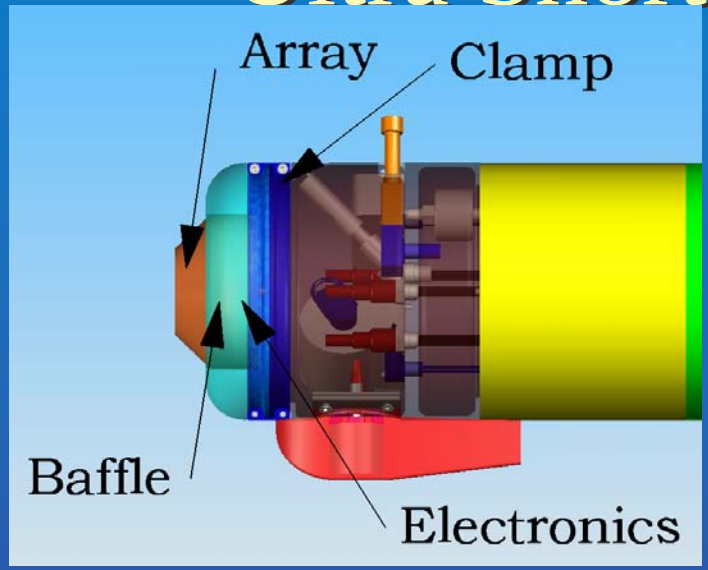
New: Inertial Navigation and phased array ADCP

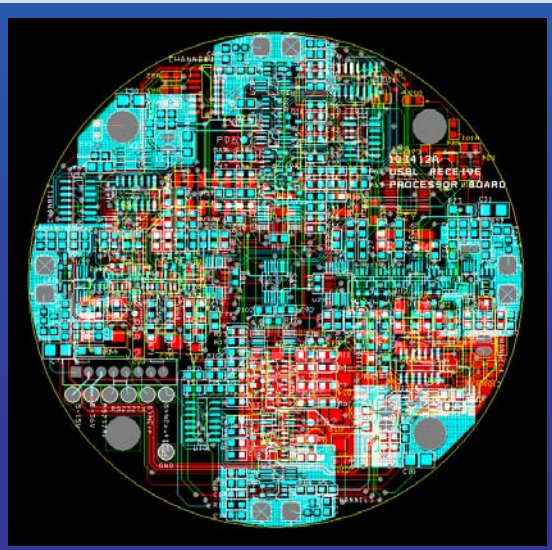
- Kearfott RLG, Integrated with RDI ADCP
- Typically provides errors less than 4 m/hr.
- Allows for extended periods of navigation without acoustic or GPS fix.
- Phased Array ADCP reduces length and adds 600 kHz for higher altitude bottom lock.

New: Video Camera

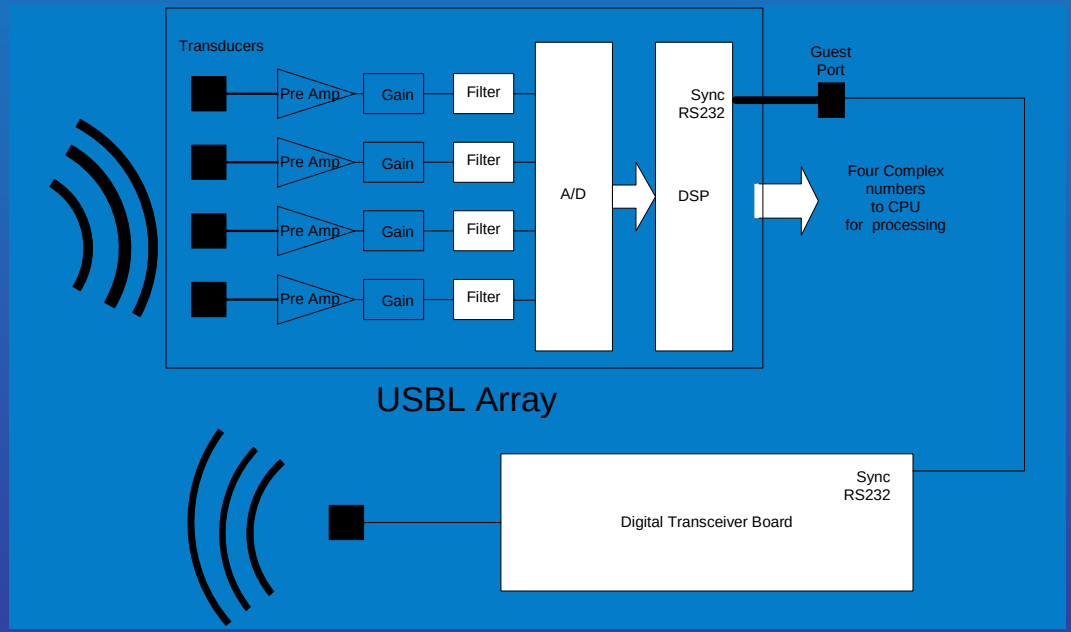
Courtesy: Rich Arietta, SPAWAR

Ultra Short Base Line Docking Module



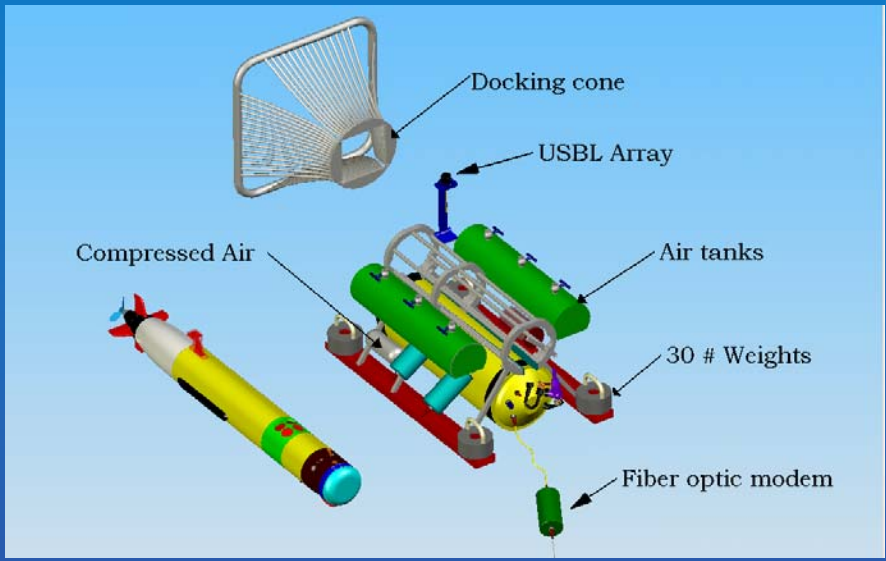


Array Electronics



Array block diagram

Autonomous Reconnaissance, Surveillance, and Docking Demonstrations with Enhanced REMUS/SAHRV Technology



Objectives

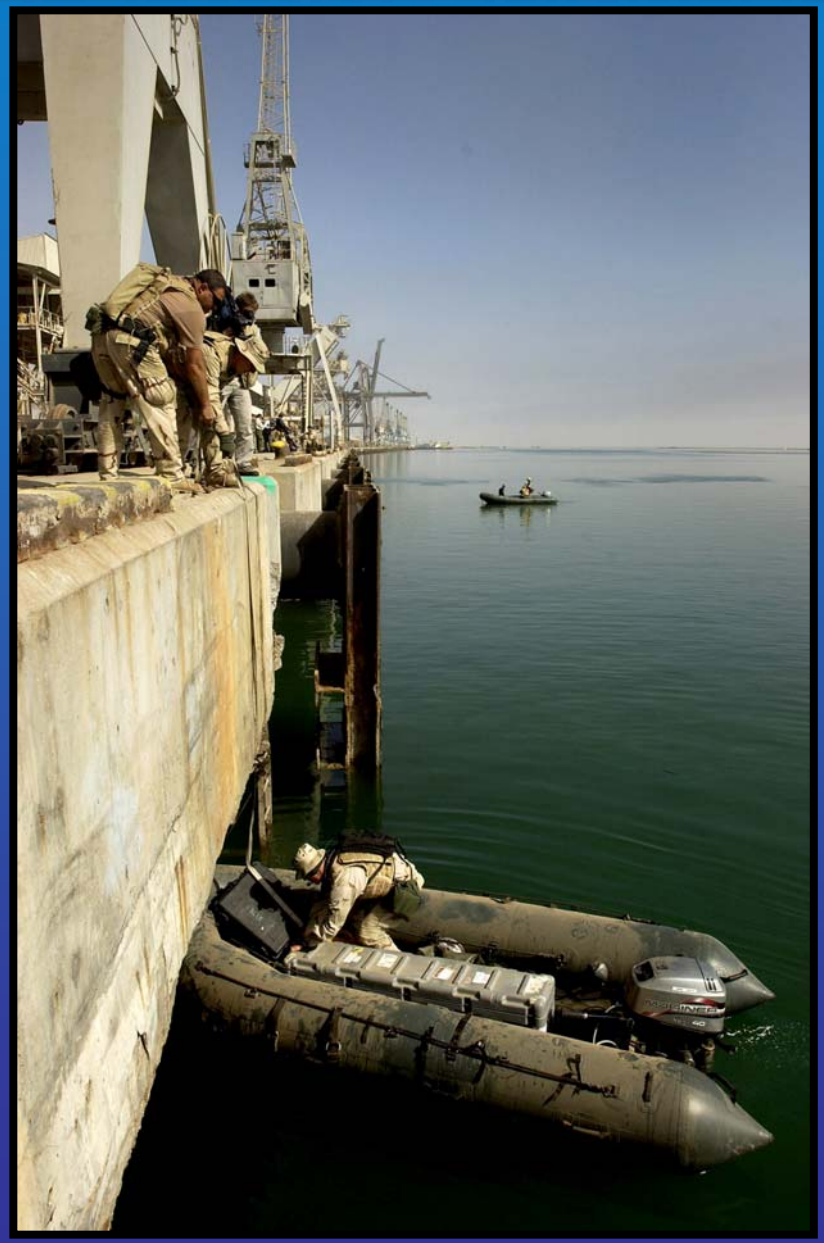
- To transition a field deployable self-powered autonomous docking systems for the REMUS/SAHRV vehicle that will support long term reconnaissance operations in littoral waters
- To develop a periscope camera that will support harbor penetration missions

Principal Investigators

Christopher von Alt
Thomas Austin
Roger Stokey
Woods Hole Oceanographic Institution

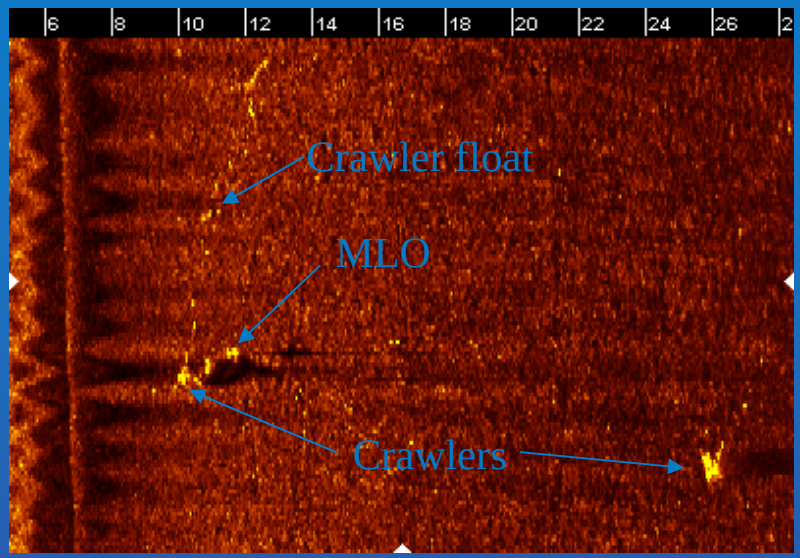
Approach

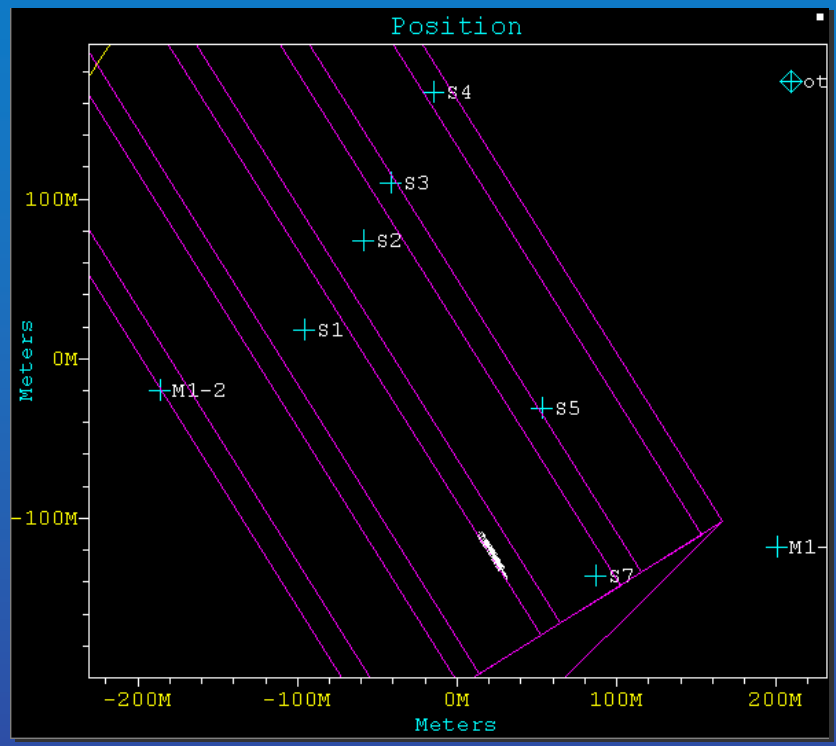
- Develop system so that it may be deployed from an SDV, ASDS, RHIB, CRRC
- Develop the capability to perform harbor penetrations with periscope camera
- Developed the capability to perform 6-8 missions per fueling – approximately 7 days of operation
- Develop field exchangeable battery packs that support refueling from SDV, CRRC, & AUV



REMUS was used to search the Port of Um Qsar in preparation for the arrival of the Sir Galahad, a ship carrying humanitarian relief supplies.

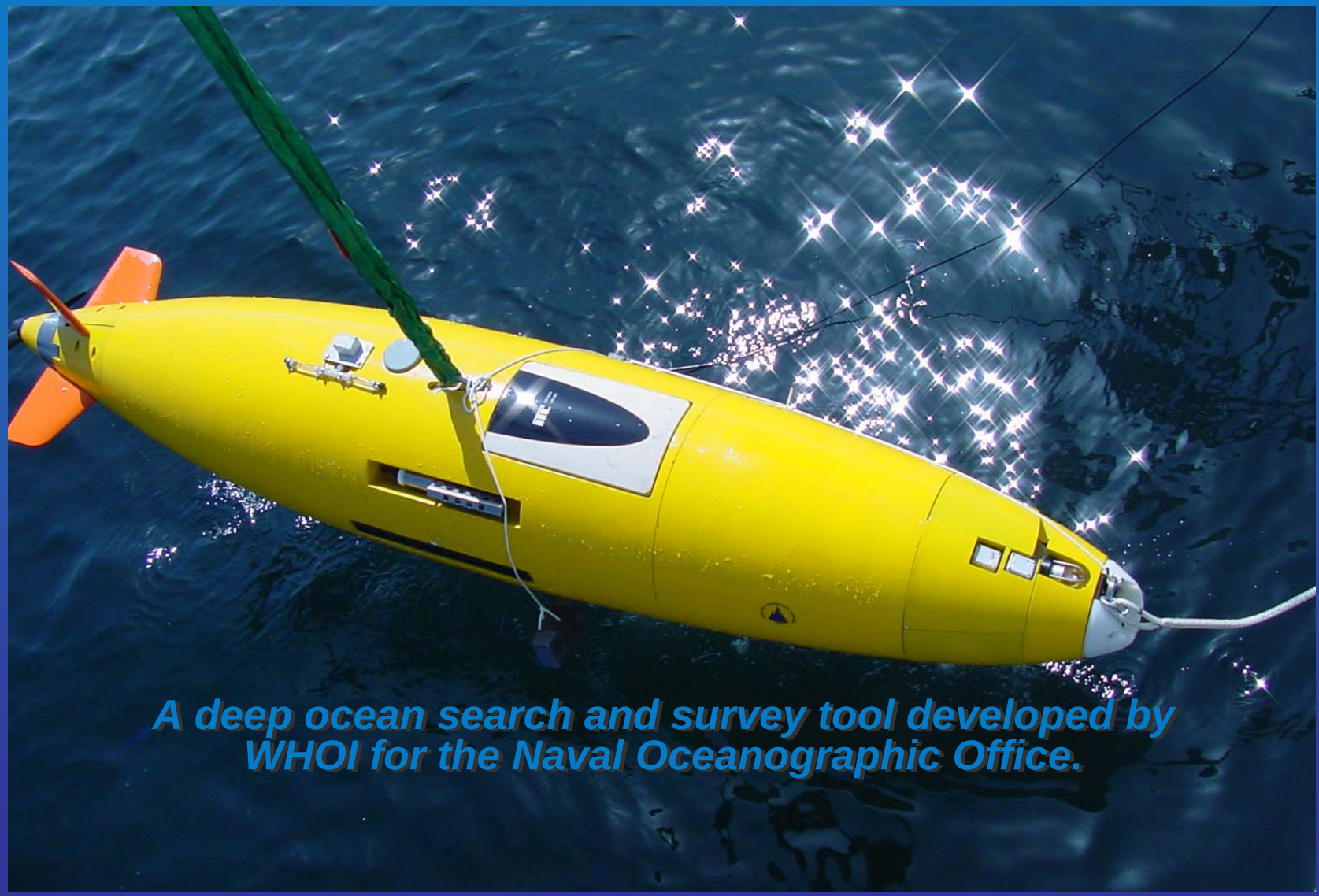
AUV 2003 Multiple Vehicle Operations





- Crawlers and multiple REMUS vehicles communicated without operator intervention
- One REMUS transmitted MLO locations; other assets acted on the information
- REMUS ESC vehicle self redirected over MLOs.

REMUS-6000

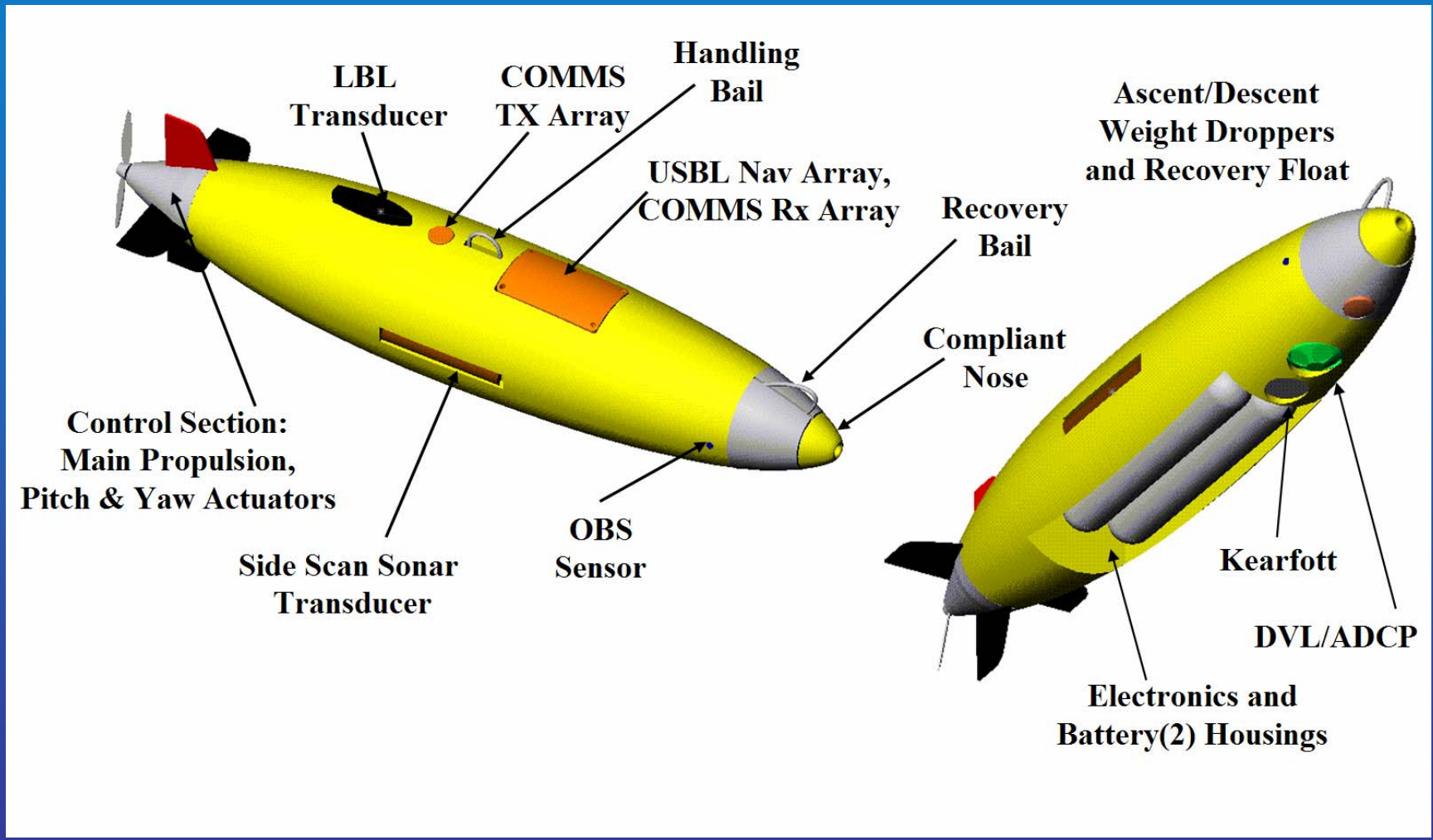


A deep ocean search and survey tool developed by WHOI for the Naval Oceanographic Office.

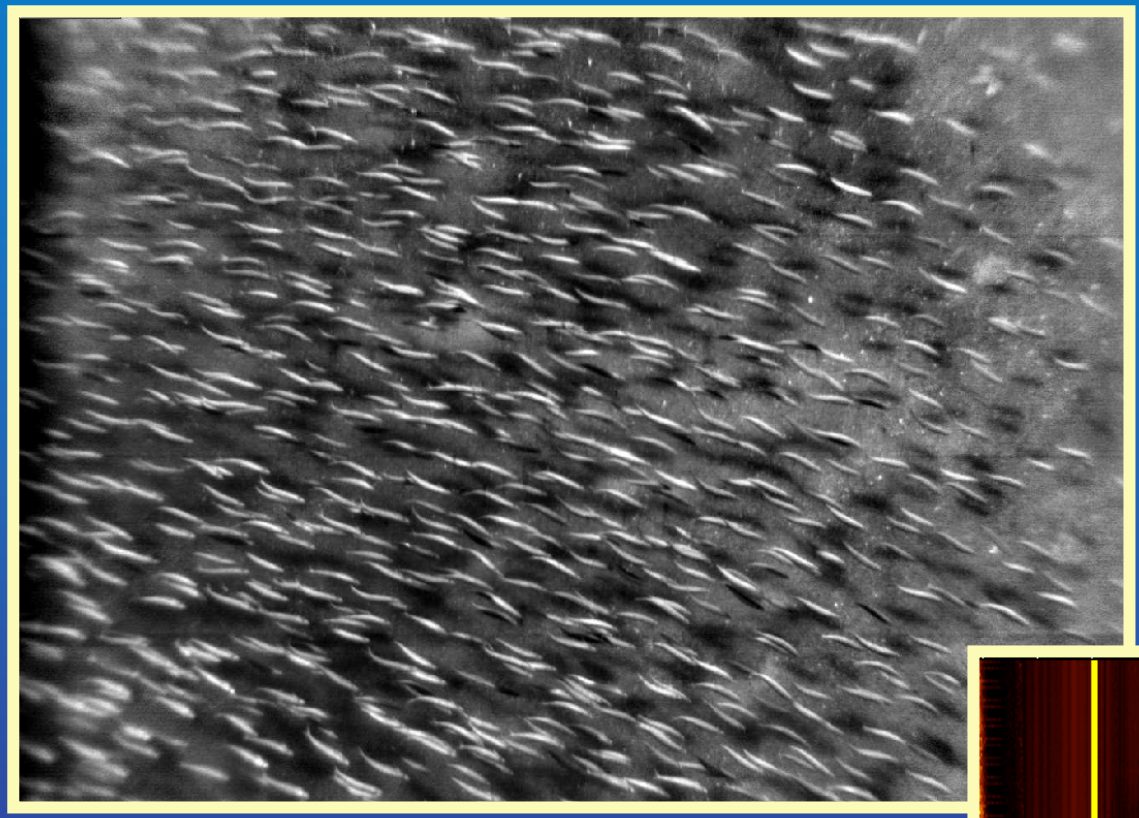
REMUS-6000

- Stand-alone self contained 6 km rated system
- Includes vehicle, operations van, launch and recovery and ship support systems
- Developed in cooperation with NAVOCEANO and ONR
- Productive 6-10 times current survey rates with towed vehicles
- Affordable -
- Multiple vehicle operations (Two vehicles simultaneously)

REMUS-6000 Configuration

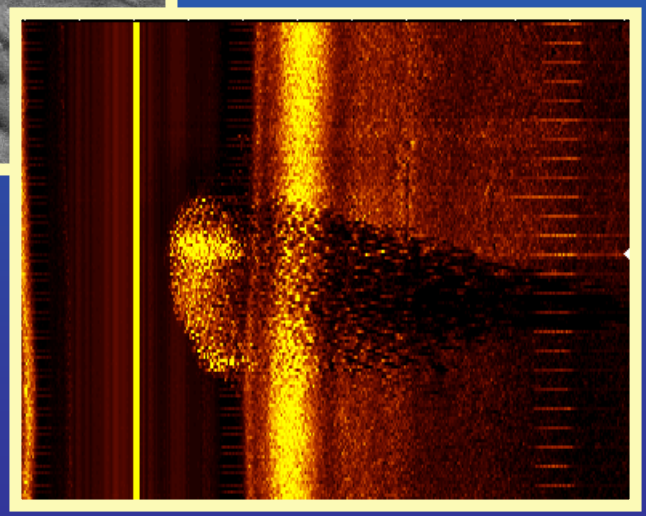


Low Altitude Imaging (4 meters)



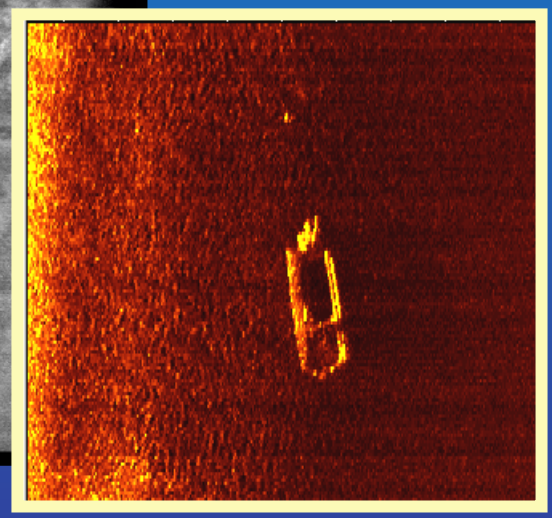
Electronic Still Image, with 200 W-S strobe illumination

900 kHz Side Scan



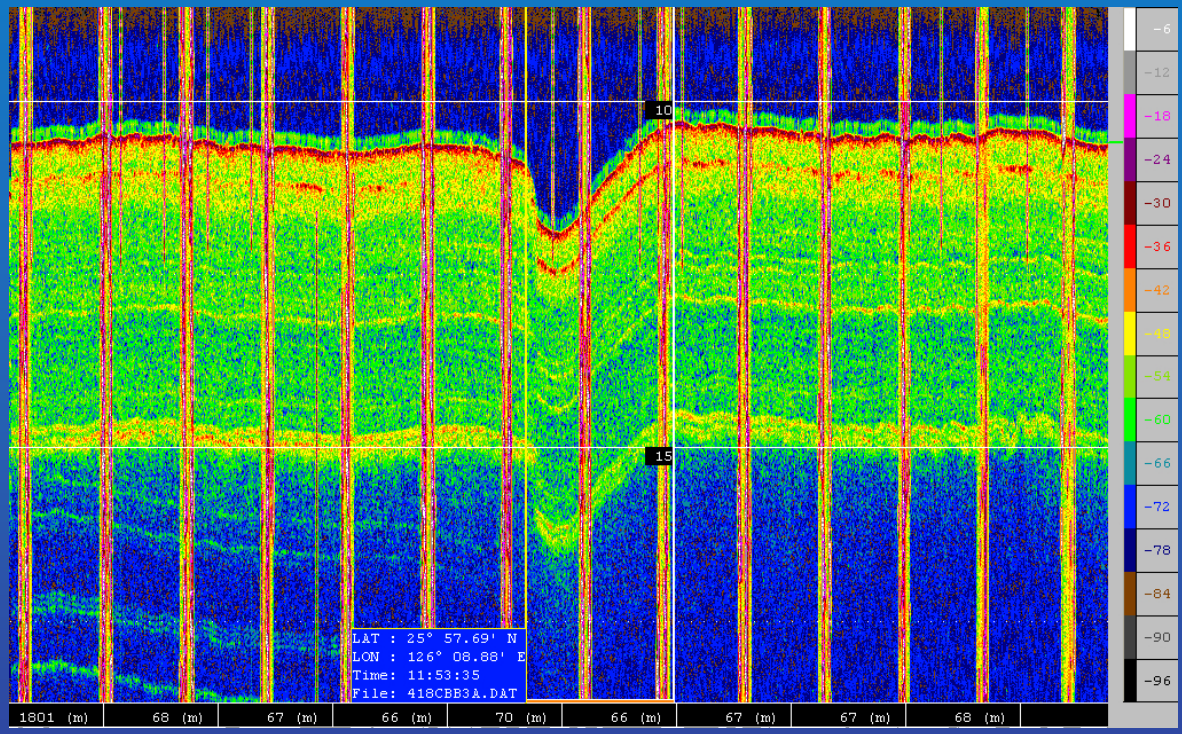
Sunken boat discovered at 3,500 meters depth

5 meter altitude electronic still image, with 200 W-S strobe illumination.



900 kHz, 30 meter range scale sonar image

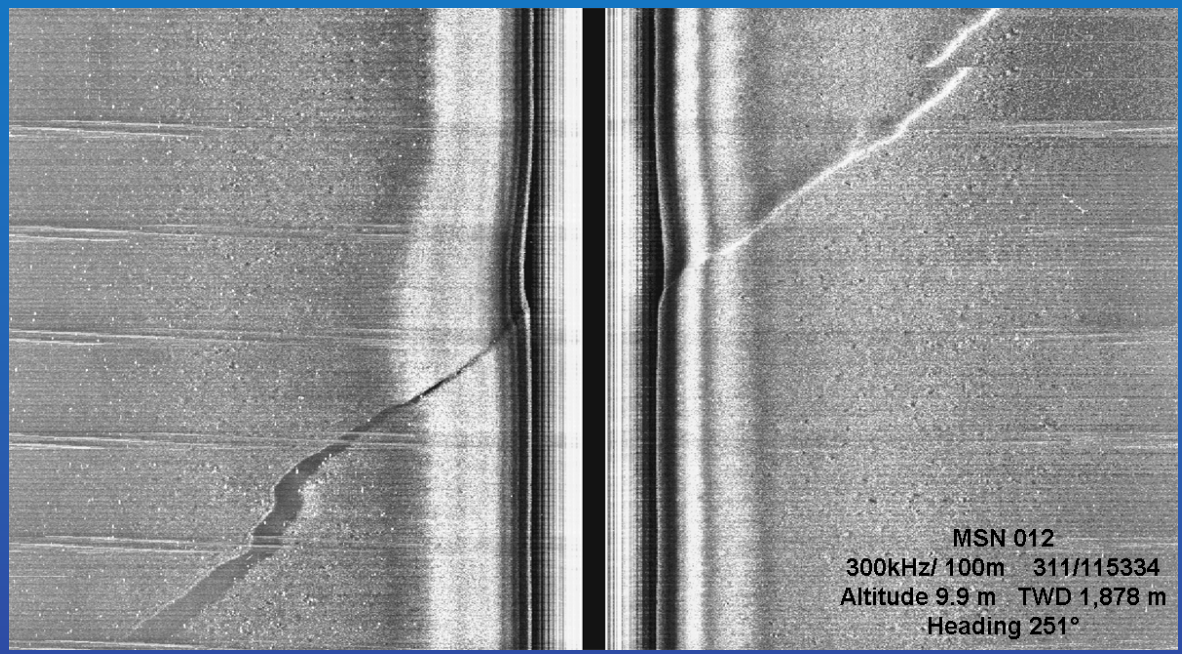
Sub-bottom profiler



PFRS subbottom profile display crossing same fault feature. Vertical (altitude) and horizontal (distance along track) scales are shown in center and bottom of Image, respectively. The vertical red bars are the result of acoustic interference generated by the SAMS II acoustic modem.

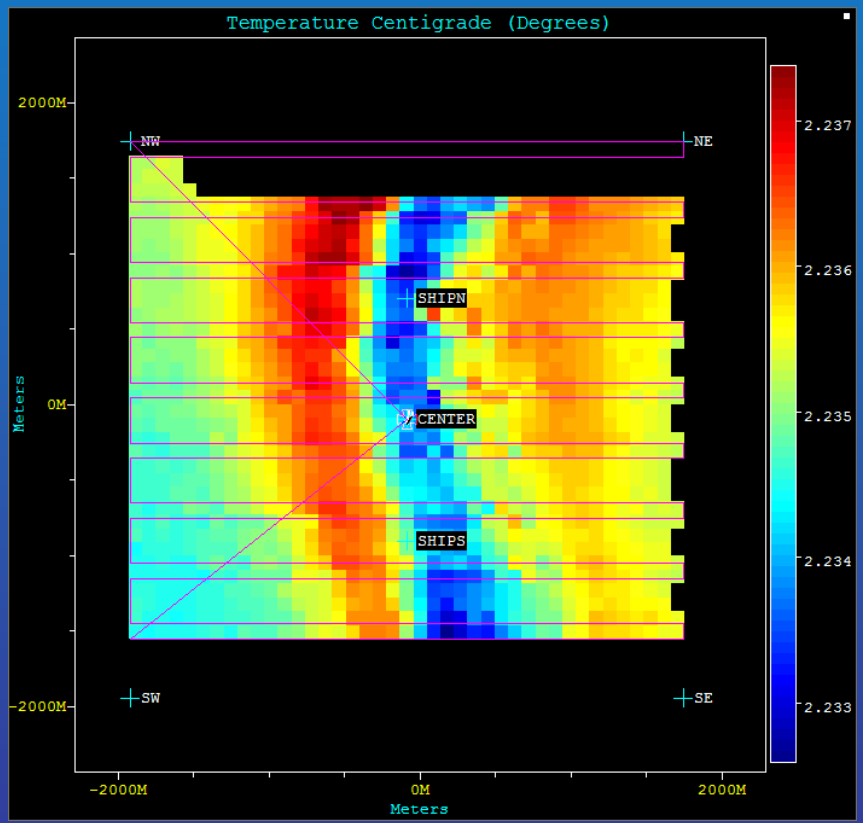
Parametric sonar developed by OMNI Technologies

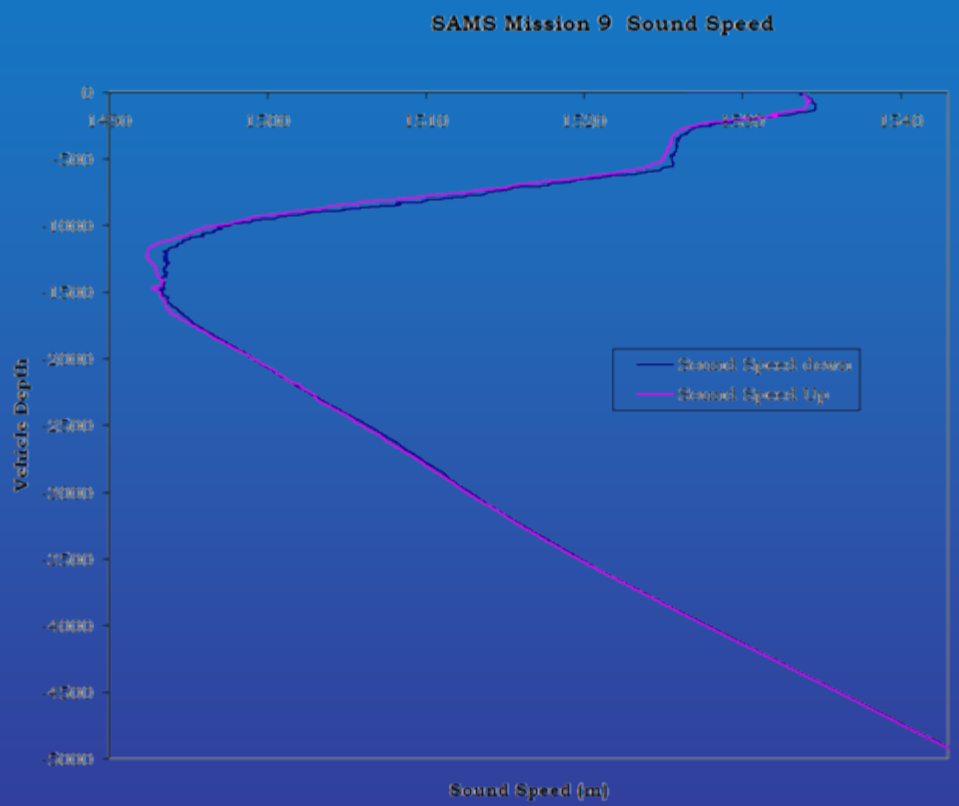
Fault line detected



SAMS II, MSN012, 300kHz Side Scan Image showing transit across fault.

Temperature and Sound Speed Data





REMUS-6000

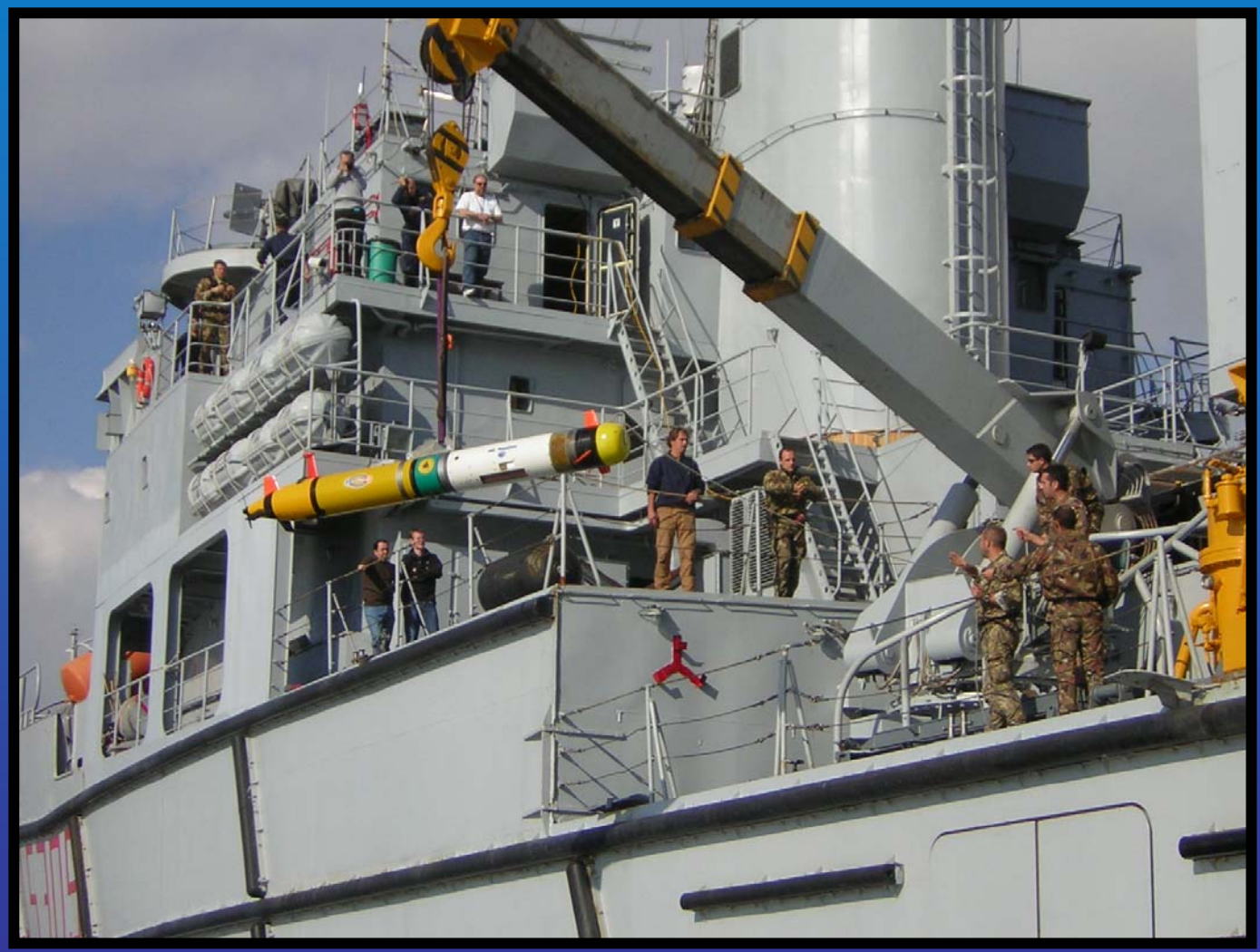
Launch and Recovery System

REMUS-600 exists

RF Systems

GPS, Iridium, Wi-Fi

Italy 06



REMUS Development Team