



Using the Gavia AUV system to locate and document Munitions Dumped at Sea.

Presenter: Mr. Chris Roper
Roper Resources Ltd.



 **GAVIA**
THE GREAT NORTHERN DIVER

Gavia?



Gavia immer
(common loon; great northern diver)

October 2007

Autonomous Underwater Vehicle (AUV)

Compact size

200, 500, 1000 & 2000 meter depth rated

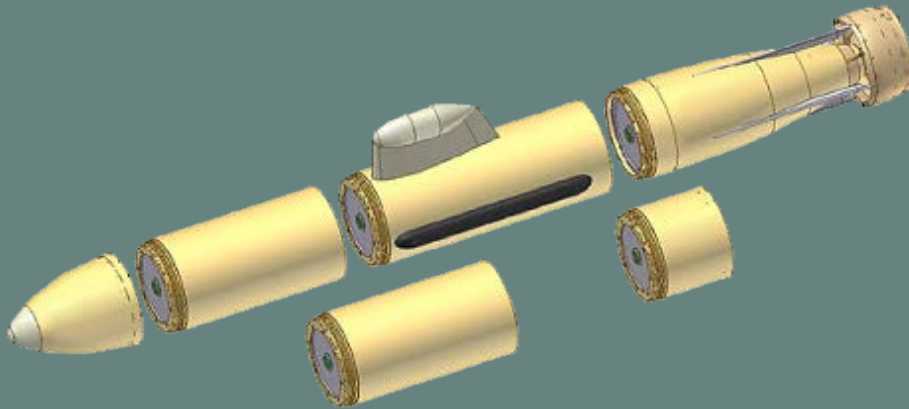


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HAFMYND Ehf

Reykjavík



- Gavia is a modular AUV system, new sensors and devices can be integrated in the shortest possible time.
- Headquartered in Reykjavik, Iceland
- 19 full time employees with international representative network
- Majority ownership Mallard Investments, Icelandic New Technology Venture fund, University of Iceland, and employees

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AUV Operations



- Completely Autonomous – no umbilical
- Map based used interface
- Missions are planned using waypoints
- All aspects of the mission programmed through the interface
- Data is recovered at the end of the mission

Gavia Artificial Intelligence A.I. Crew

- Gavia is operated like a ship and all A.I. crew members have individual tasks and responsibilities.
- The Captain has overall vessel responsibility, he can and will over ride any AI crew members command if his vessel is put in harms way.
- The AI crew consists of: Mission Commander, Navigator, Engineer, Instrument Operator, Data Analysts and Pilots. Pilots can be easily added for a particular task, one knows how to track the seafloor, another knows how to avoid obstacles etc.
- The client can add his own AI Crew Member "Mission Specialist" The Mission Specialist is used to operate the client proprietary sensor which can be installed in the Payload module and I don't have to know what the Mission Specialists task is.

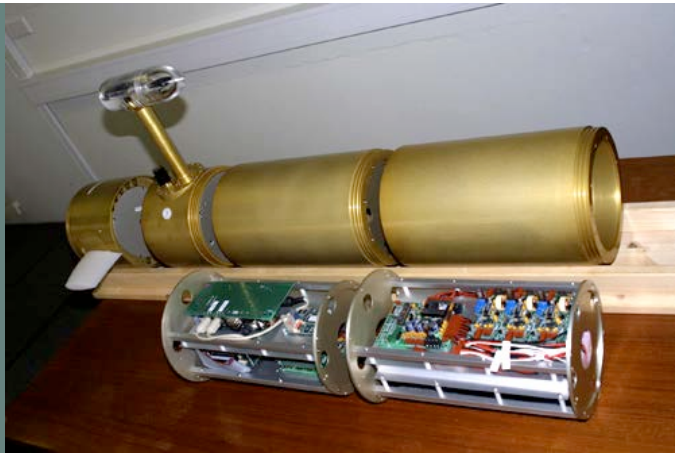


GAVIA

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- 1996 Development of the Gavia begins
- 1997 First Gavia prototype's maiden voyage
- 1999 Hafmynd commercialized
- 2000 First sales in Iceland
- 2003 2cnd Generation Gavia introduced
- 2004 First export sales of the Gavia
- 2005 First deliveries of 2cnd generation Gavia to the export market

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PRODUCTION & TESTING

- Fully modular Gavia AUV production on-going
 - First customer deliveries early 2005
- Out-sourced standard component fabrication
 - Mechanical parts in Iceland, Denmark, UK
 - Commercial Off the Shelf technology (COTS) used for all sensors
- In-house assembly and testing
 - Pressure testing to full operating depth
 - Extreme temperature operation
- Quality assurance
 - QA program ISO 9001 underway

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Hafmynd Current Customers

- US Navy's SPAWAR division
- University of British Columbia
- Canadian National Research Council
- University of Iceland
- Reykjavik Energy
- Royal Danish Navy
- Australian DSTO



National Research Council Canada
Conseil national de recherches Canada



Orkuveita Reykjavíkur
Bæjarhálsi 1 - 110 Reykjavík
Sími 516 6000

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DIVERSE APPLICATIONS

- Marine Science
- Environmental Monitoring
- Limnology and oceanography
- MCM and harbour surveillance
- ASW Training Target
- Pipeline Inspection
- Search and Recovery
- Hydrographic surveys



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ENGINEERING TESTBED

National Research Council, Canada



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LIMNOLOGY RESEARCH

University of British Columbia, Vancouver



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DUAL-ROLE MCM / HARBOR PROTECTION

SPAWAR, US Navy, San Diego



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Harbour search & recovery

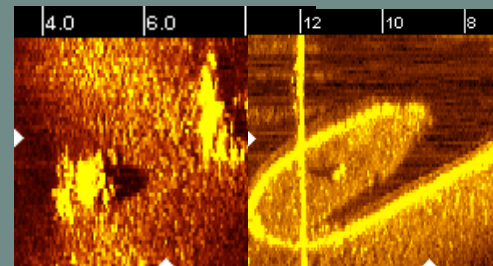


"The divers dropped down the shot lines placed using Differential GPS on the coordinates from the Gavia side scan sonar images, and found themselves **within a hands reach of the targets**."

The Gavia AUV was **the most accurate and effective search tool** used in this operation, which also employed divers, towed side-scan sonars, and ROVs."

-Mikael R Olafsson
ICE-SAR search coordinator

Gavia participation in Search and Recovery operation with Icelandic Search and Rescue teams.



- ◆ Power boat crashed into rock outside harbour mouth
- ◆ One passenger missing after attempting to rescue trapped fellow passenger
- ◆ Very low visibility - 150 m² initially searched by divers

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175.000 m² searched in 90 minutes

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User Interface - Planning Mode

Gavia Control Center - SG_Day_1 - [MapWindow]

File Connect View Mode Planning Analysis Operation Window Help

103 58.920E 103 58.980E 103 59.040E 103 59.100E 103 59.160E 103 59.2

1°N 23' 700" 1°N 23' 640" 1°N 23' 580"

50m

Line6

crosstrack1

crosstrack2

run_home lawnmower

Mission Planning

SG_Day_1

- Line
 - Run1
 - crosstrack1
 - sidescansonar
 - geoswath
 - crosstrack2
 - run_home
 - Line5
 - Line6
 - Line7
 - LawnmowerPattern
 - lawnmower
 - sidescansonar

name	crosstrack2
speed	700rpm
constdepth	4.0m
bottomtrack	Not Set
mindepth	Not Set
location1	1 23.625N 103 59.113E
location2	1 23.709N 103 59.102E
trackoffset	0.0m
postdelay	0s
triggerDown	Not Set
triggerUp	Not Set
Length	157.2m
TTG	1min
Active	

heading lat
roll lon
pitch depth
surge altitude
heave position-quality
sway timestamp
authority time since la no data

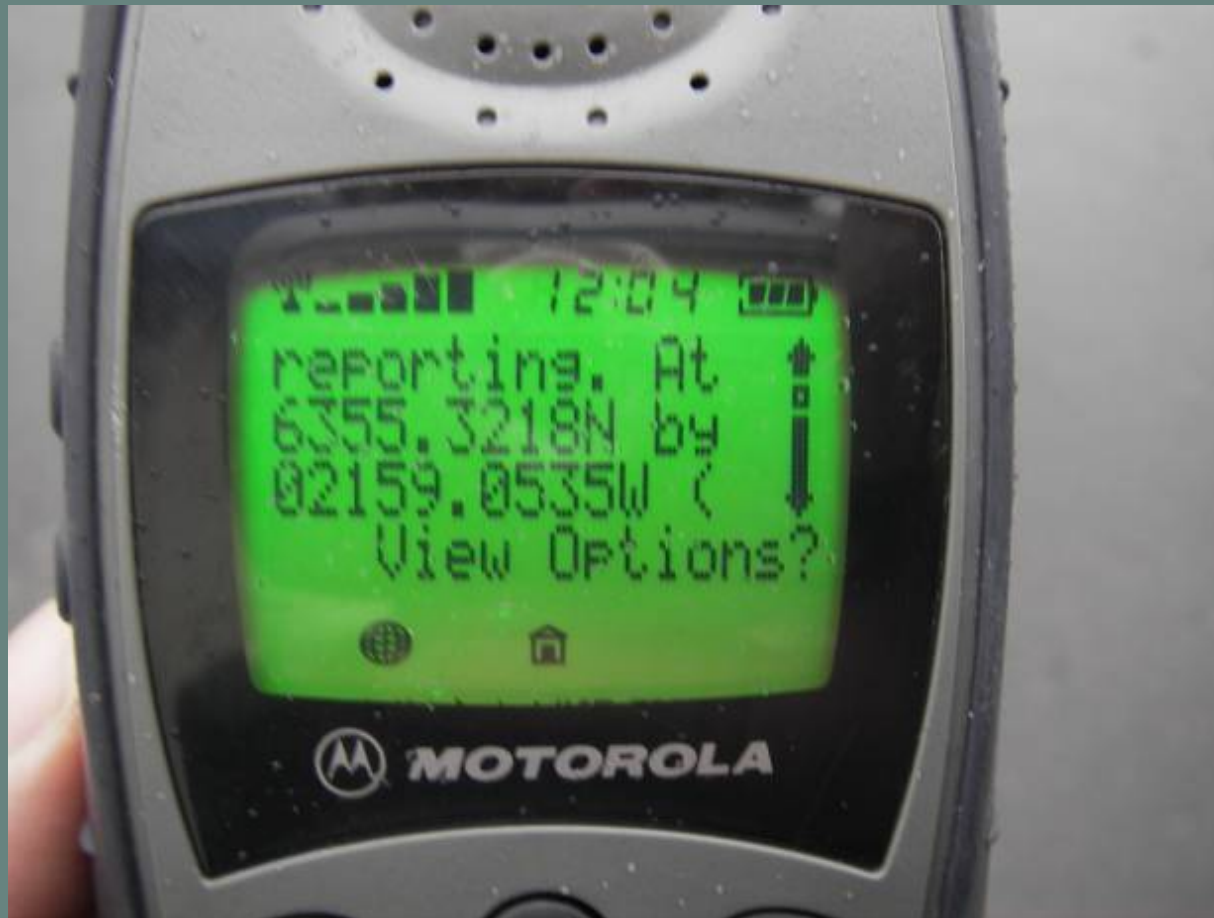
1 23.707N 103 58.885E

start Gavia Control Center ... Skype™ - arnarsteing... Elizabeth Unger (Onli... large shot of area.JP... EN Search Desktop 12:23

Surface and subsurface communications

Over-the-horizon satellite comms

Underwater acoustic comms



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Available Expansion Modules: Various



- **Collision Avoidance** (Imagenex Single Beam) 15° beam angle 30m range.



- **Camera and Strobe** (Var.) Low light variable frame rate and various resolutions available

- **Acoustic Modem**

- **Upgrade** (LinkQuest) **Acoustic Modem Upgrade w/ USBL/LBL upgrade** (PinPoint 1500)



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Available Expansion Modules: Environmental Sensors



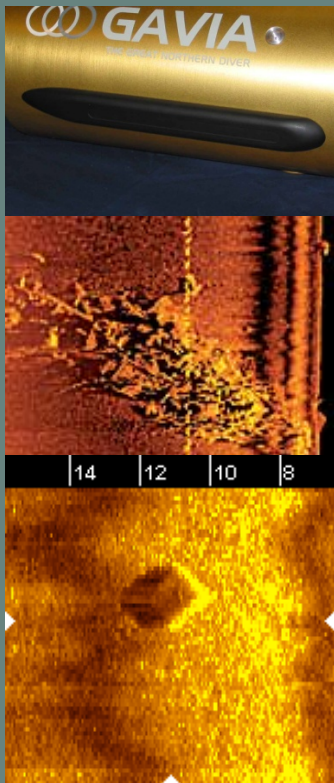
- **ECHO SOUNDER:** A 120 kHz Echo sounder is available for Gavia.
- **BACKSCATTER METER:** The Wetlabs ECO BB3 Puck Backscatter Sensor is used to determine water clarity
- **SOUND VELOCITY METER:** measures sound velocity is used for correcting acoustic data for variations in the speed of sound through water.
- **CTD:** Seabird SBE 49

Precision navigation

Inertial or Acoustic nav
GPS on surface

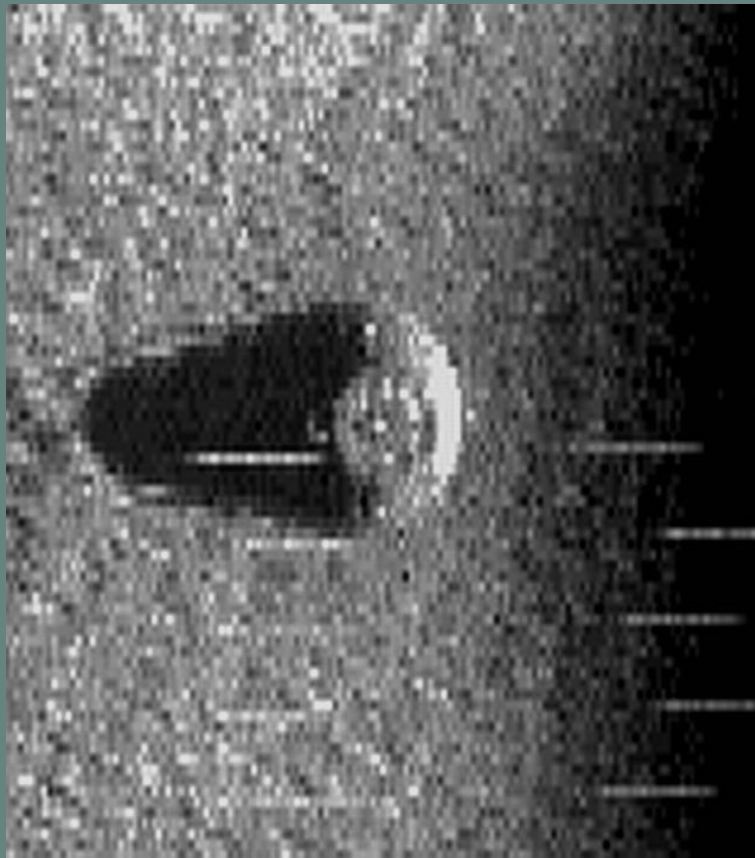


Available Expansion Modules: Side Scan Sonar



- **Side Scan Sonar:** Marine Sonic Mounted in Command and Communication module
- Available in a number of frequencies
- Data stored on dedicated solid state memory that can be expanded for larger capacity if desired

Side Scan Image of a Manta Mine



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MCM Roles

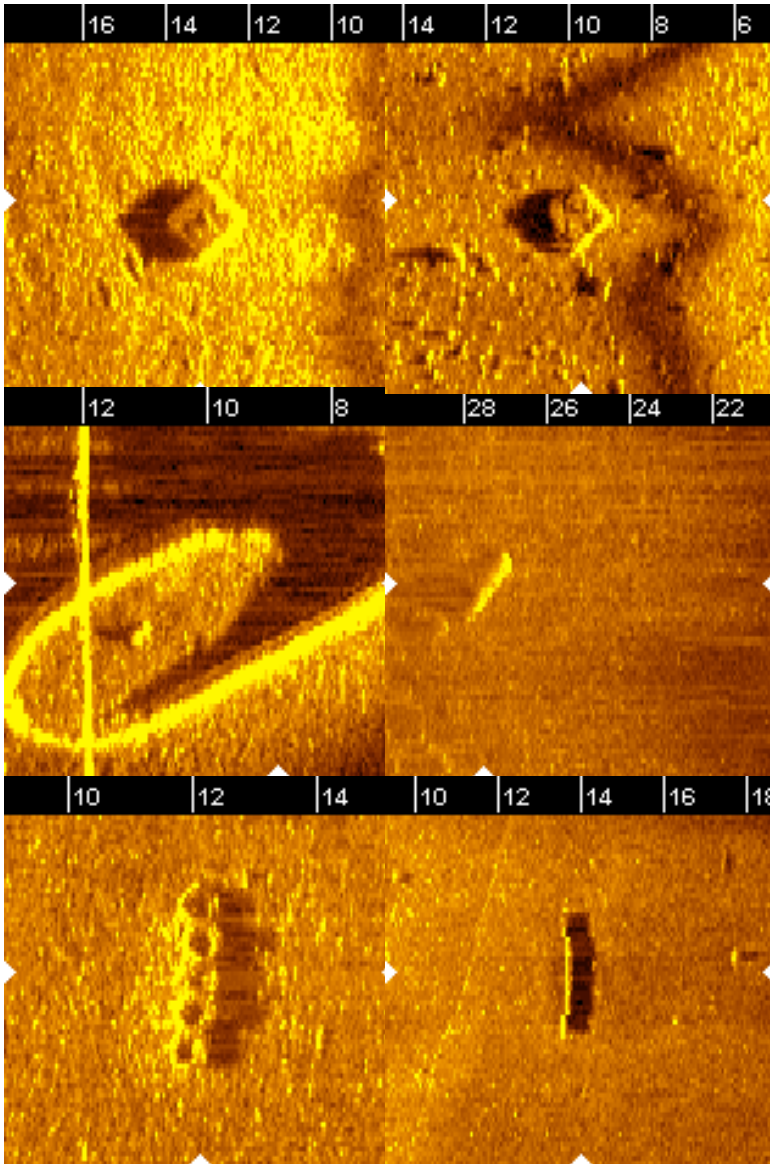
SEARCH – CLASSIFY – MAP

Initial survey conducted using low frequency Side Scan Sonar.

Classify using high frequency Side Scan Sonar.

CAD - Computer Assisted Detection

CAC – Computer Assisted Classification



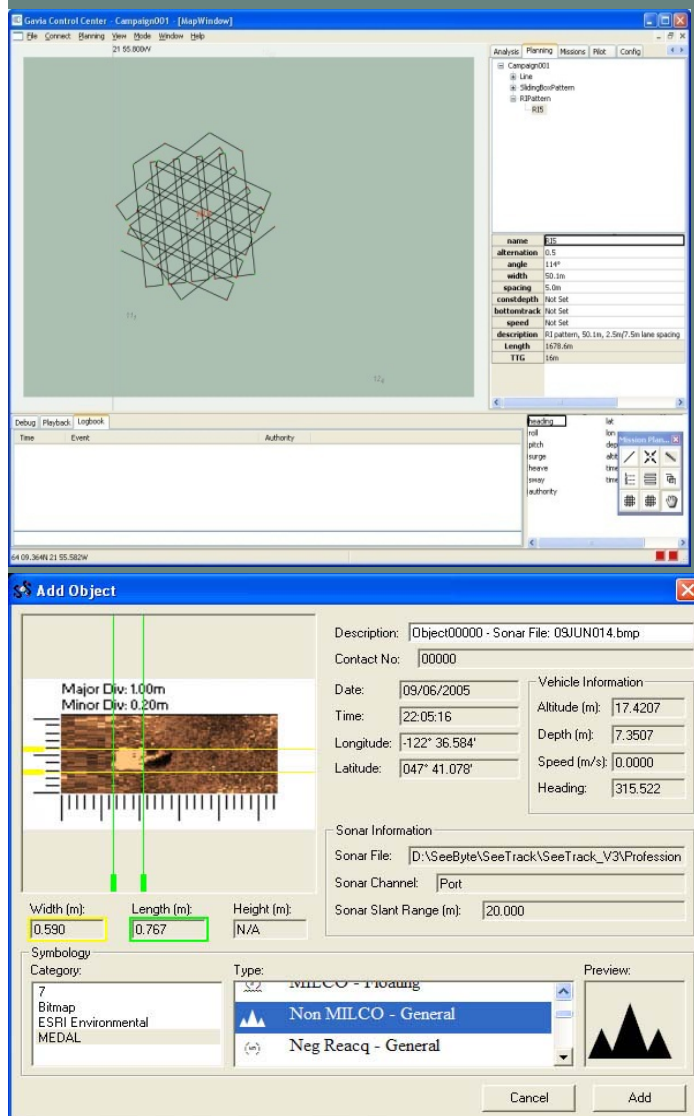
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MCM Roles

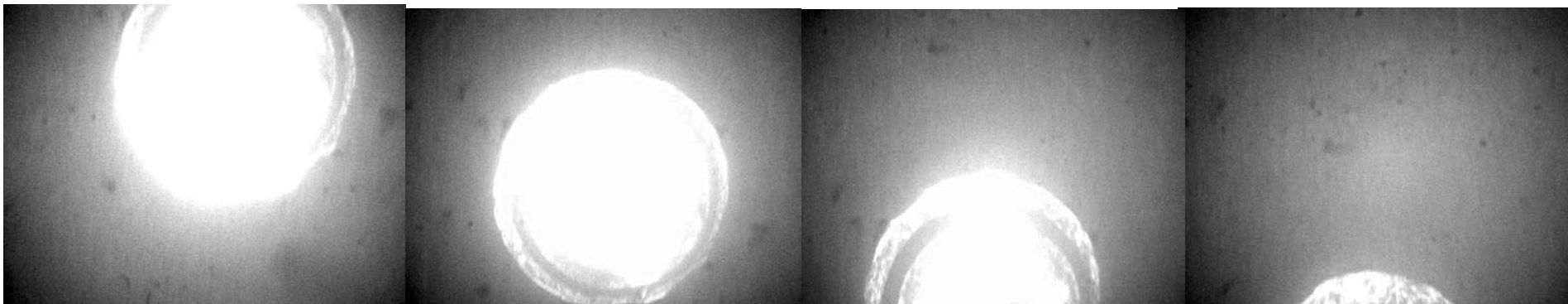
REACQUIRE-IDENTIFY

Side Scan Sonar

- High-resolution SSS around MLO
 - 1800kHz
- Third party post-processing
 - SeeTrack post-mission visualization
 - MEDAL format messages



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MCM Roles

REACQUIRE - IDENTIFY

Optical imaging

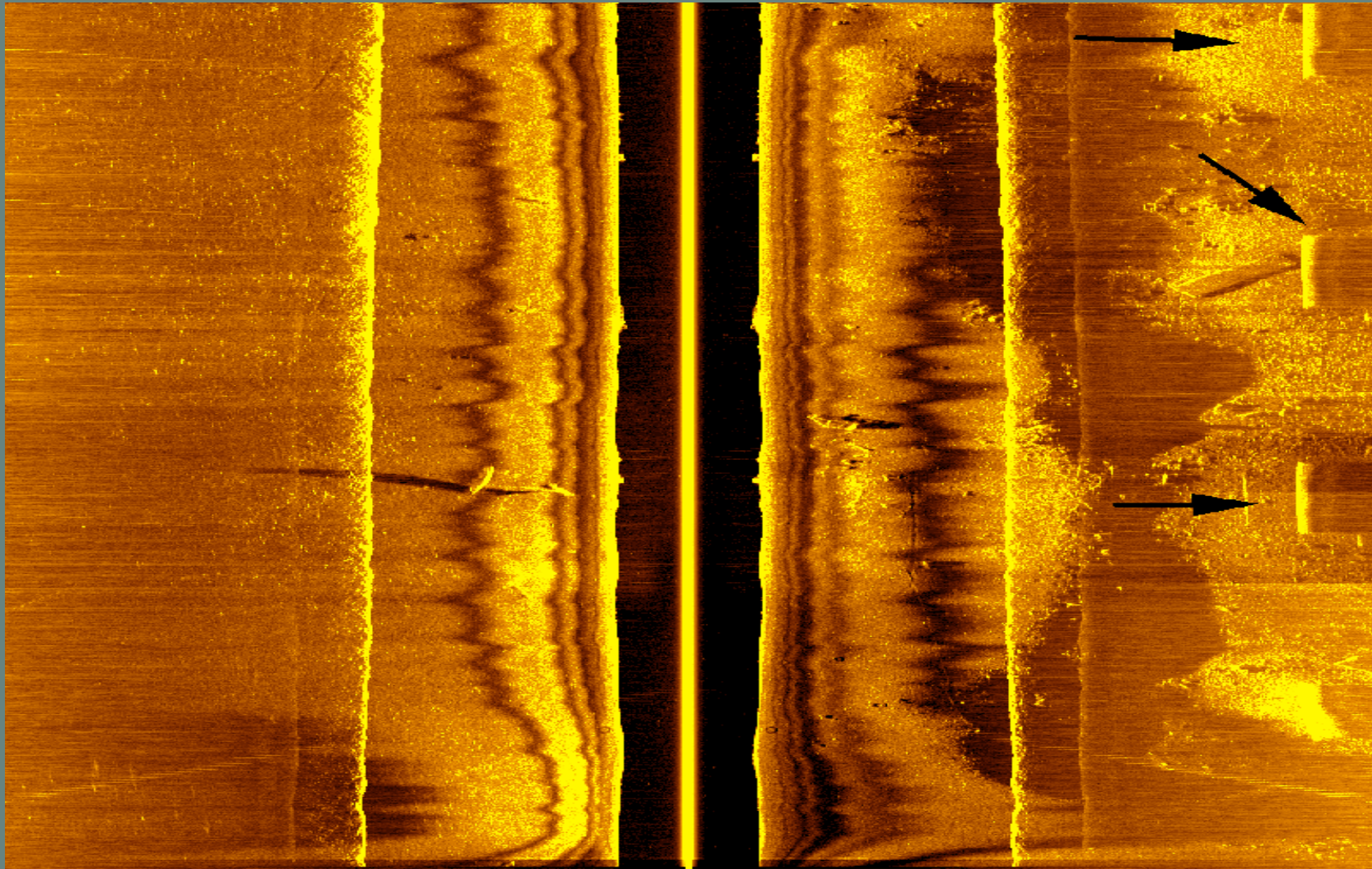
- Digital still images around MLO
 - Variable frame rate for coverage
 - Sensitive b/w or colour
 - Optional LED Strobe



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2 D Side Scan

- Pier Pylon





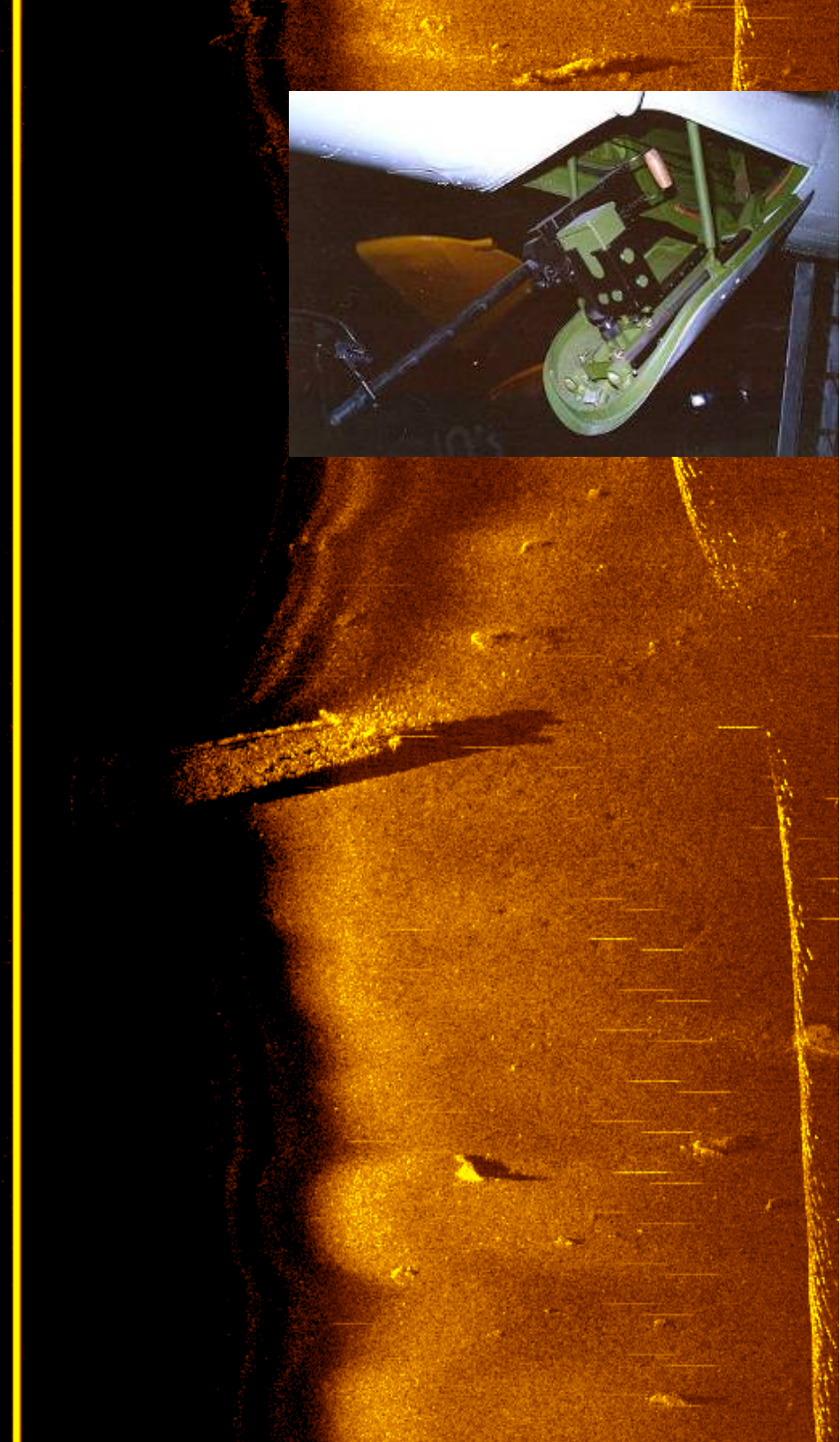
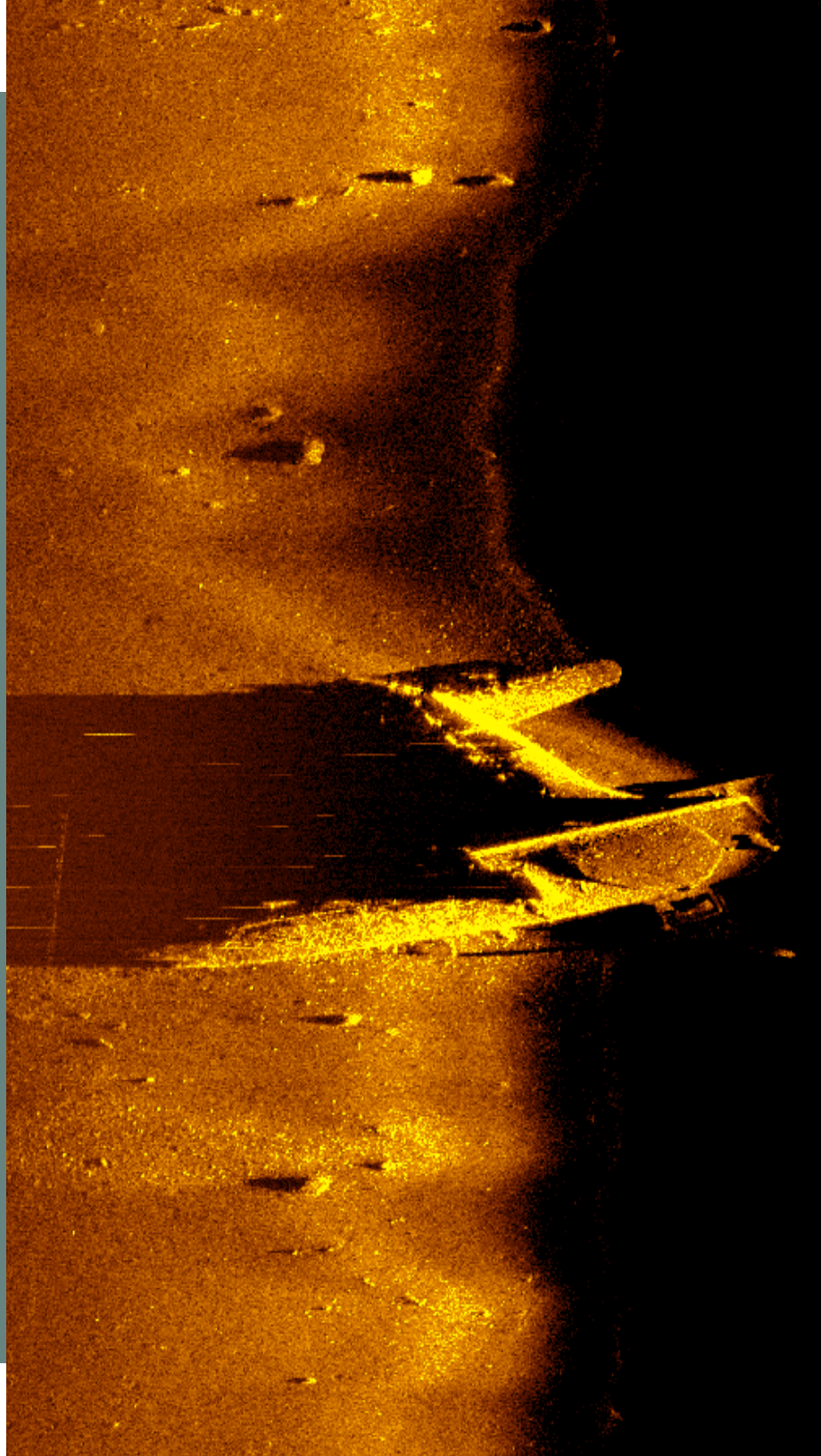
GeoSwath Plus Sonar on Gavia AUV

A Commercial Deployment



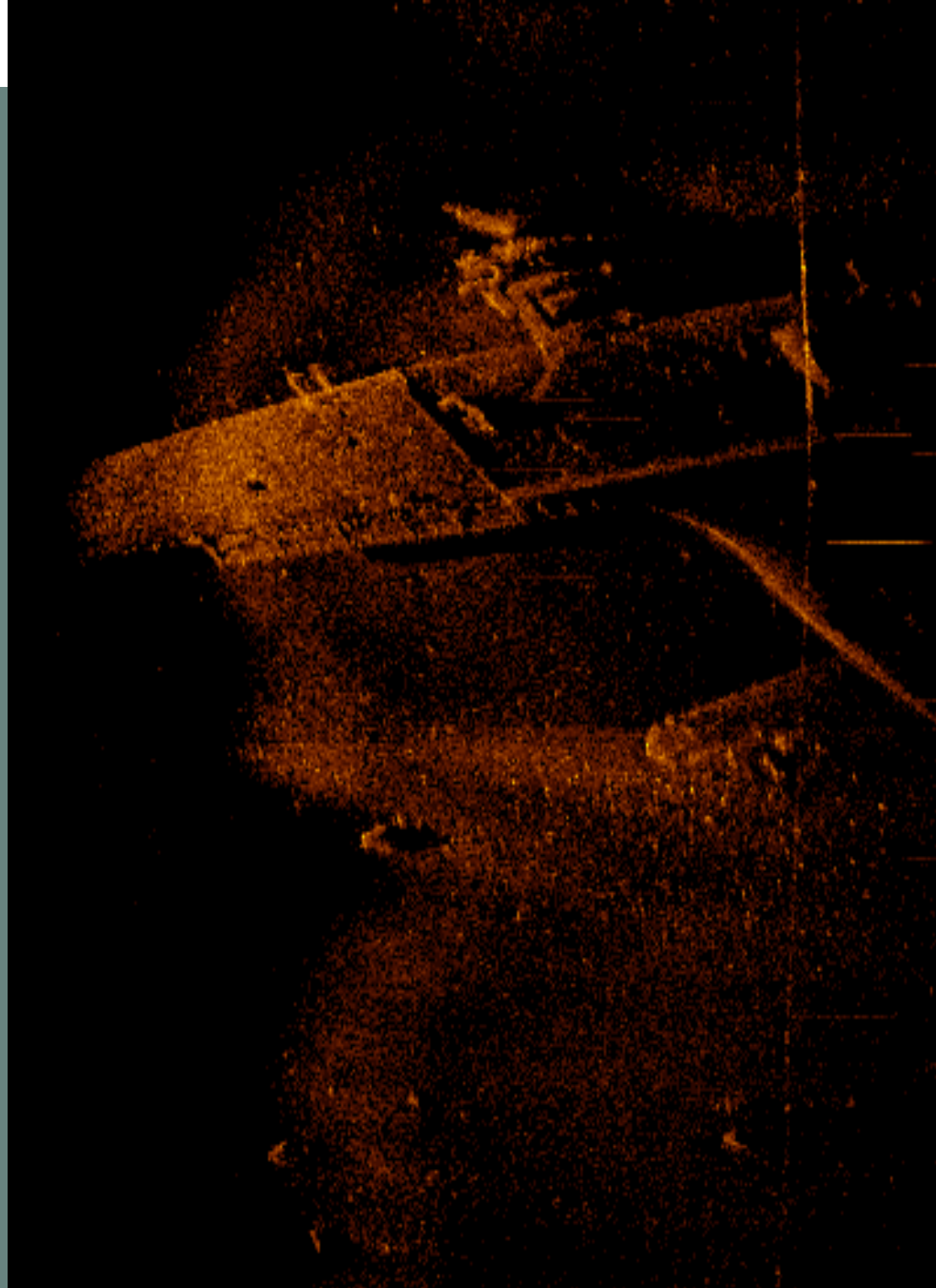
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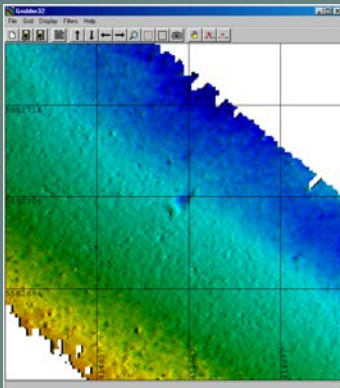
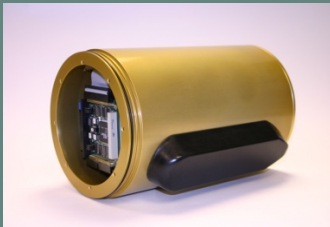


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VIA
NORTHERN DIVER

Available Expansion Module: GeoSwath IHO Standard Bathymetric Sonar



- **Geoswath Plus 500 kHz Bathymetric Sonar**
- **GeoSwath Plus** is a PC based, swath bathymetry system supplied by GeoAcoustics Ltd., UK, which meets IHO standards for hydrographic survey. The GeoSwath swath bathymetry system offers swath coverage of up to 12 times water depth.
- The GeoSwath system can also give a third dimension to side scan images, enhancing the ability to detect objects on the sea bed, and place these in the context of the sea bed terrain.

DVL aided INS System



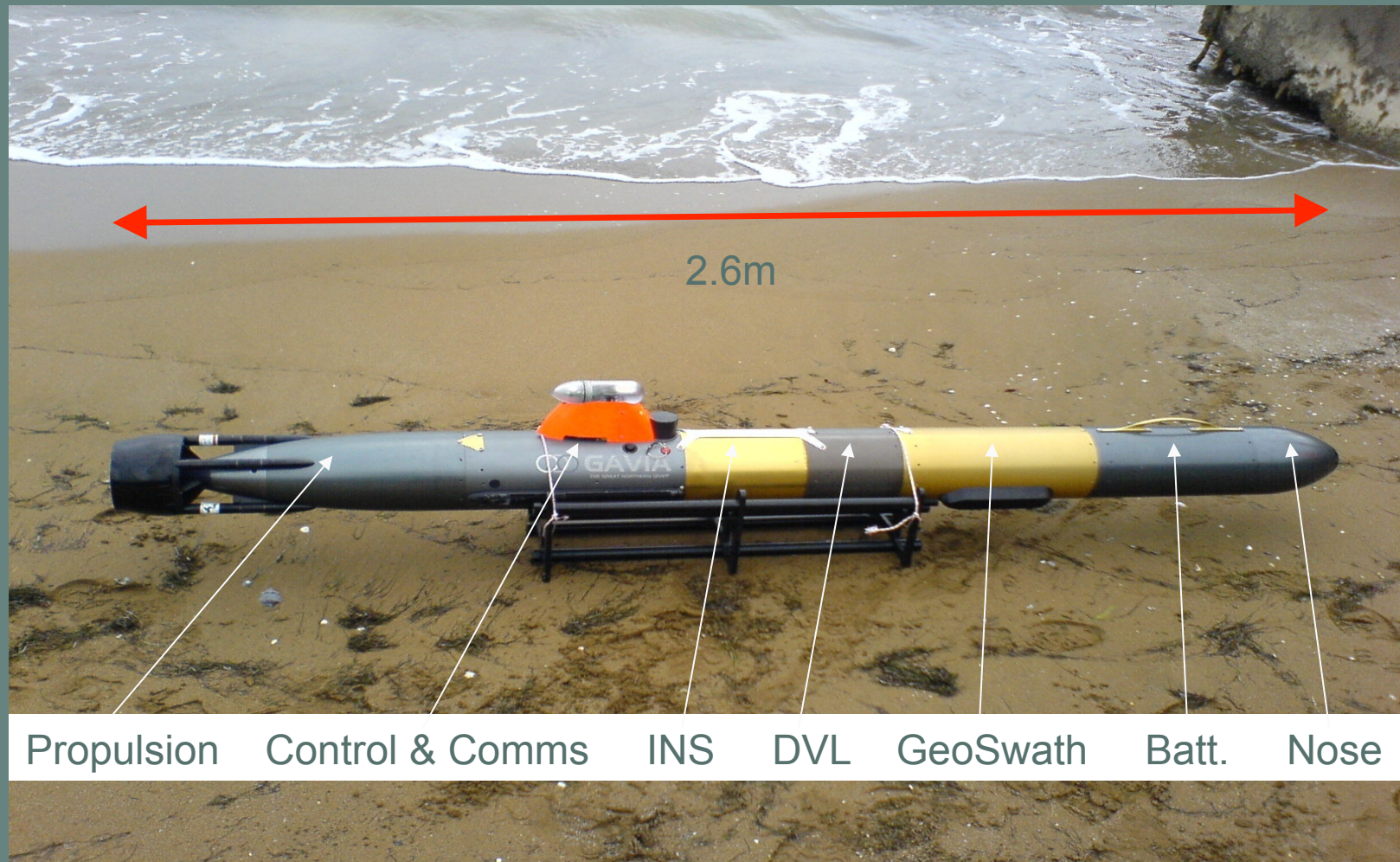
- **DVL –AIDED INS SYSTEM**
- The DVL – aided INS system consists of two modules:
- The RD Instruments 1200 kHz DVL Gavia module, 30° beam angle, 30m bottom lock.
- The Gavia INS module containing either the Kearfott T-16 or the higher accuracy T-24 INS system or the Ixsea PHINS derivative
- DVL INS provides Gavia with highly accurate buoy free navigation (3m hour drift for the T-24 and 10m for the T-16)

Payload Modules



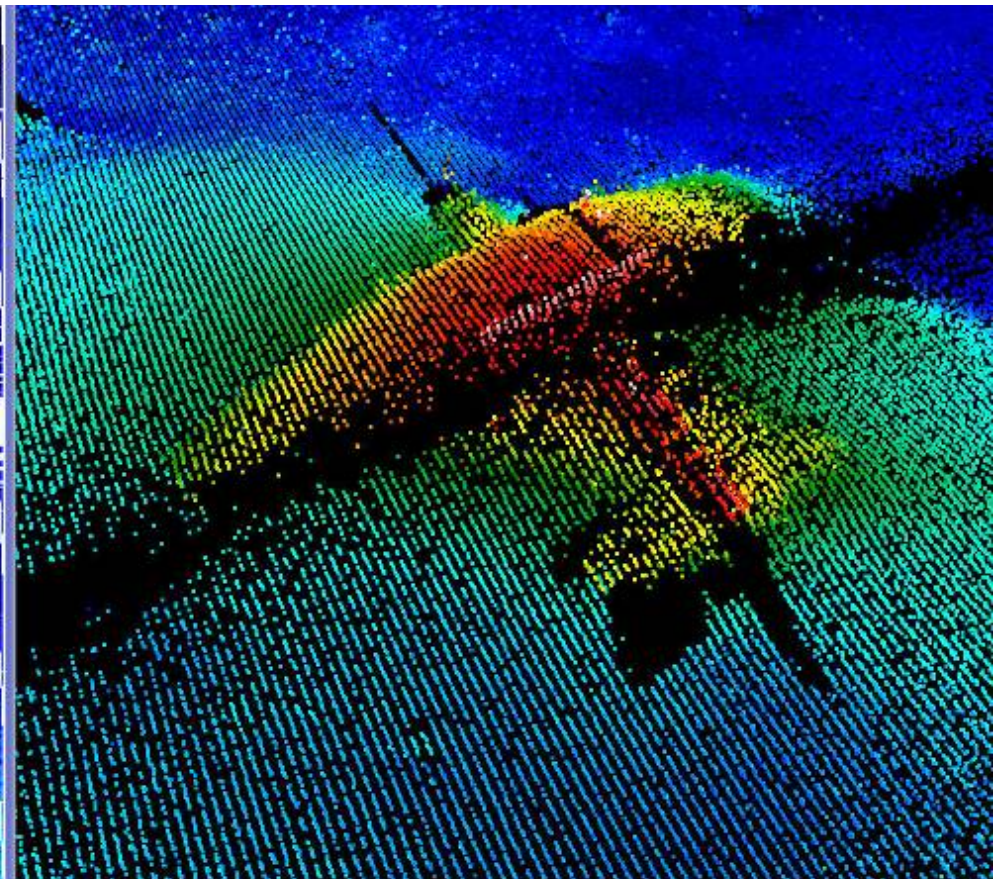
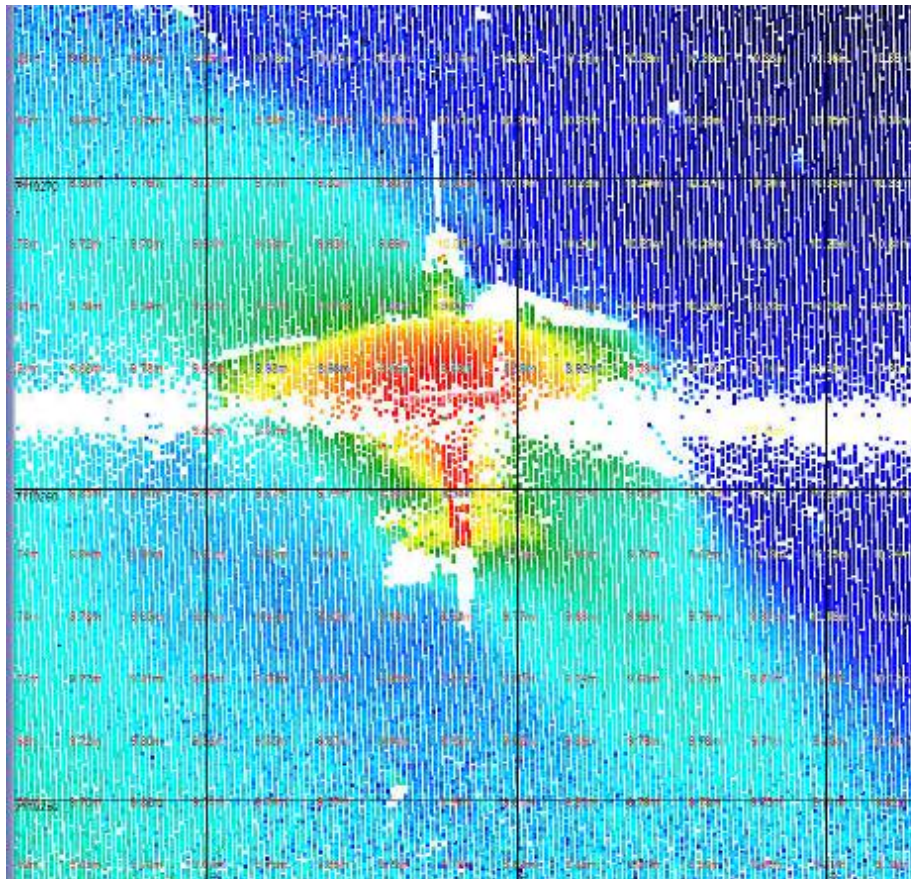
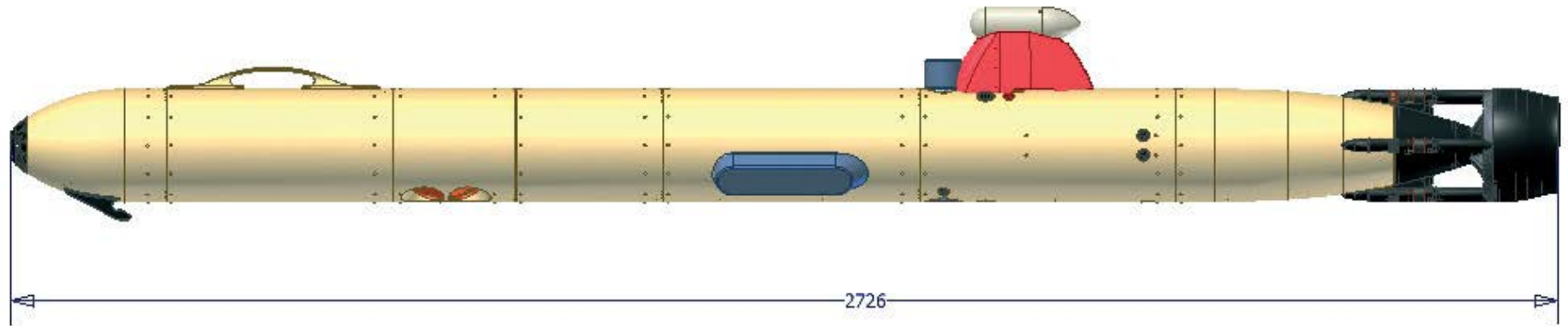
- The PAYLOAD MODULE is available for custom sensors and equipment.
- The Gavia payload module includes Gavia electronic stack that interfaces the module to the rest of the vehicle.
- A software development kit (SDK) is available for the Payload module.

Gavia Outfitted to do Real Bathymetric survey

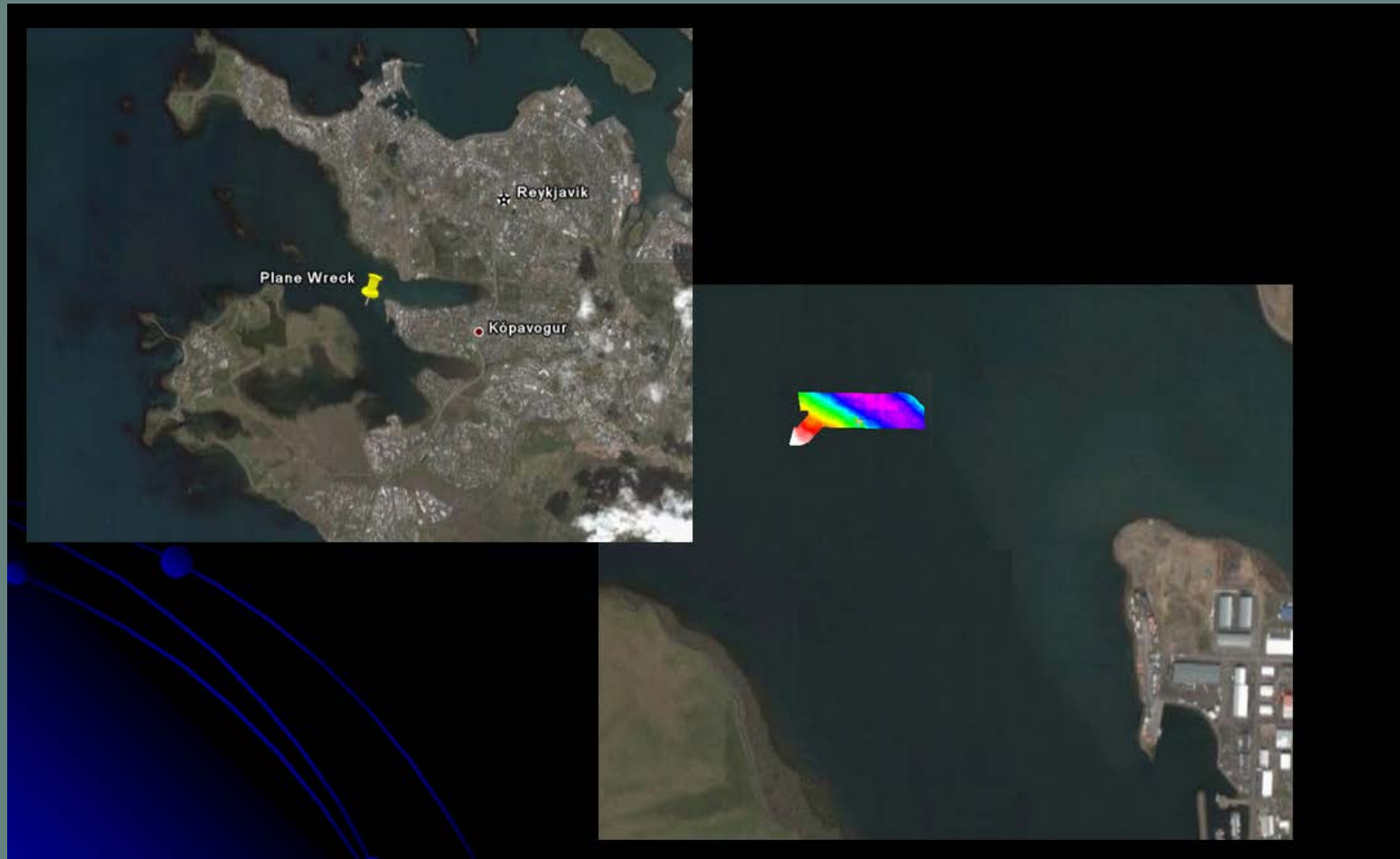


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Gavia Bathymetric Survey Configuration with 500 kHz GeoSwath Plus AUV Mount

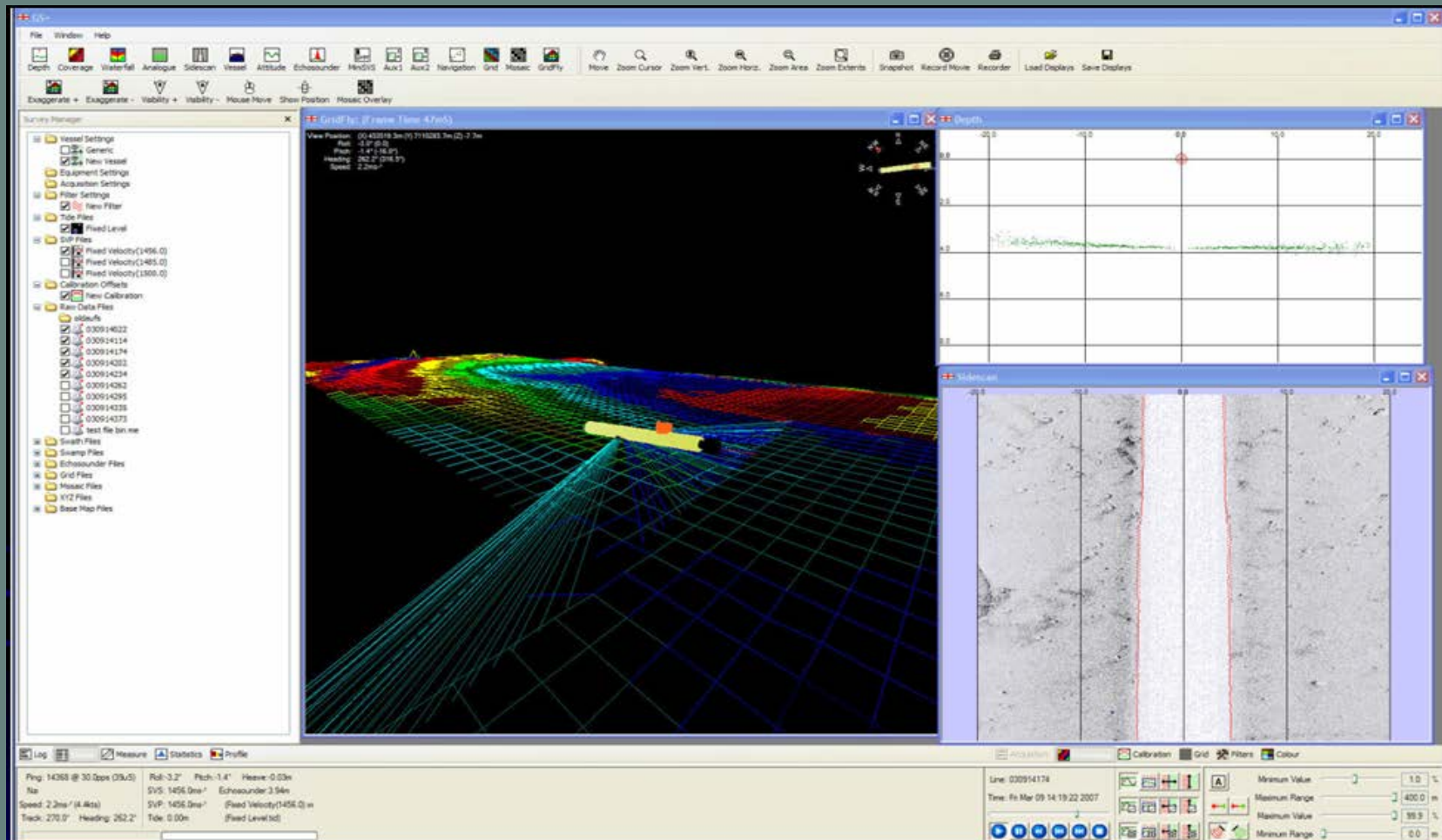


Survey Examples: GeoSwath Plus on the Gavia AUV



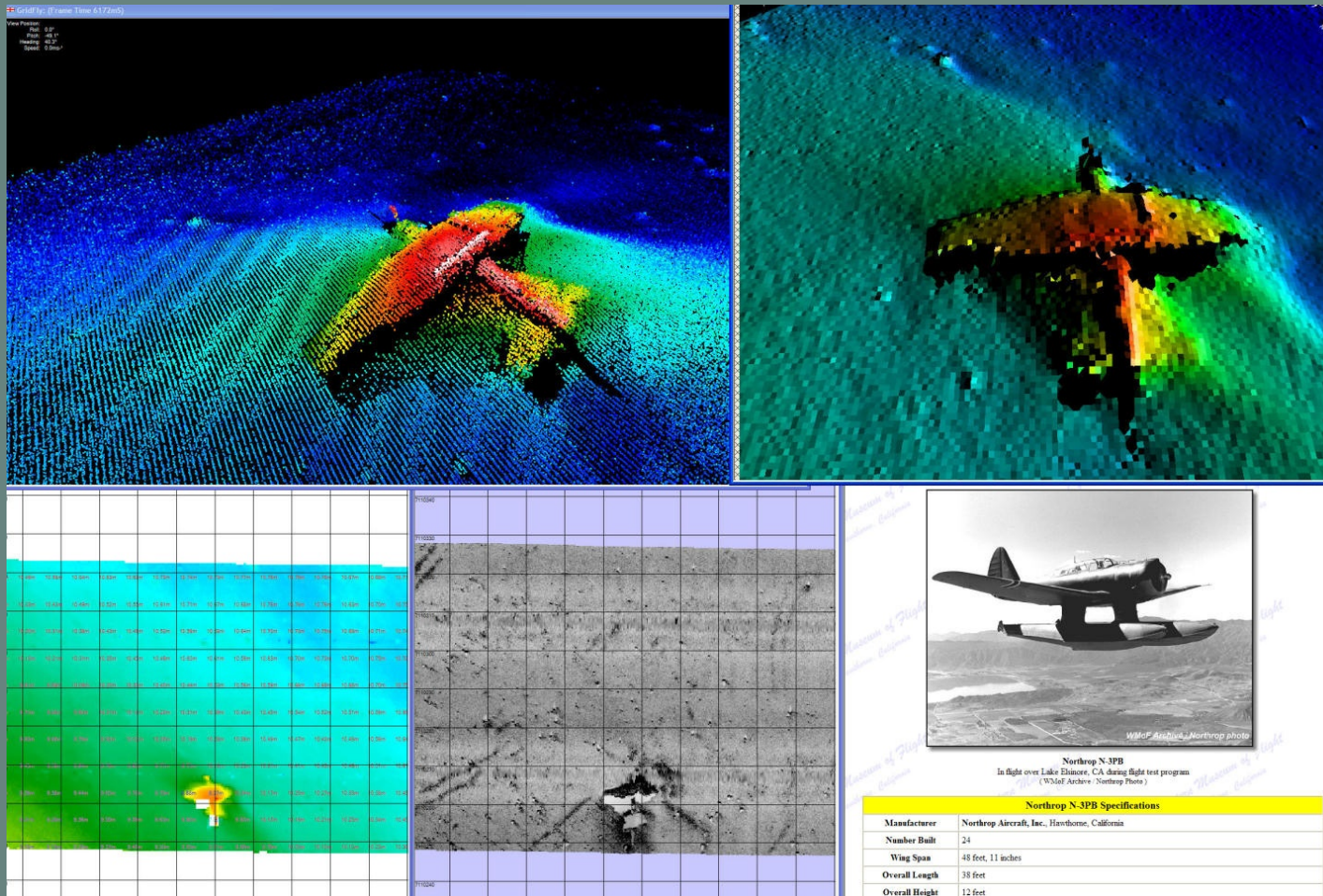
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GeoSwath Plus on the Gavia AUV

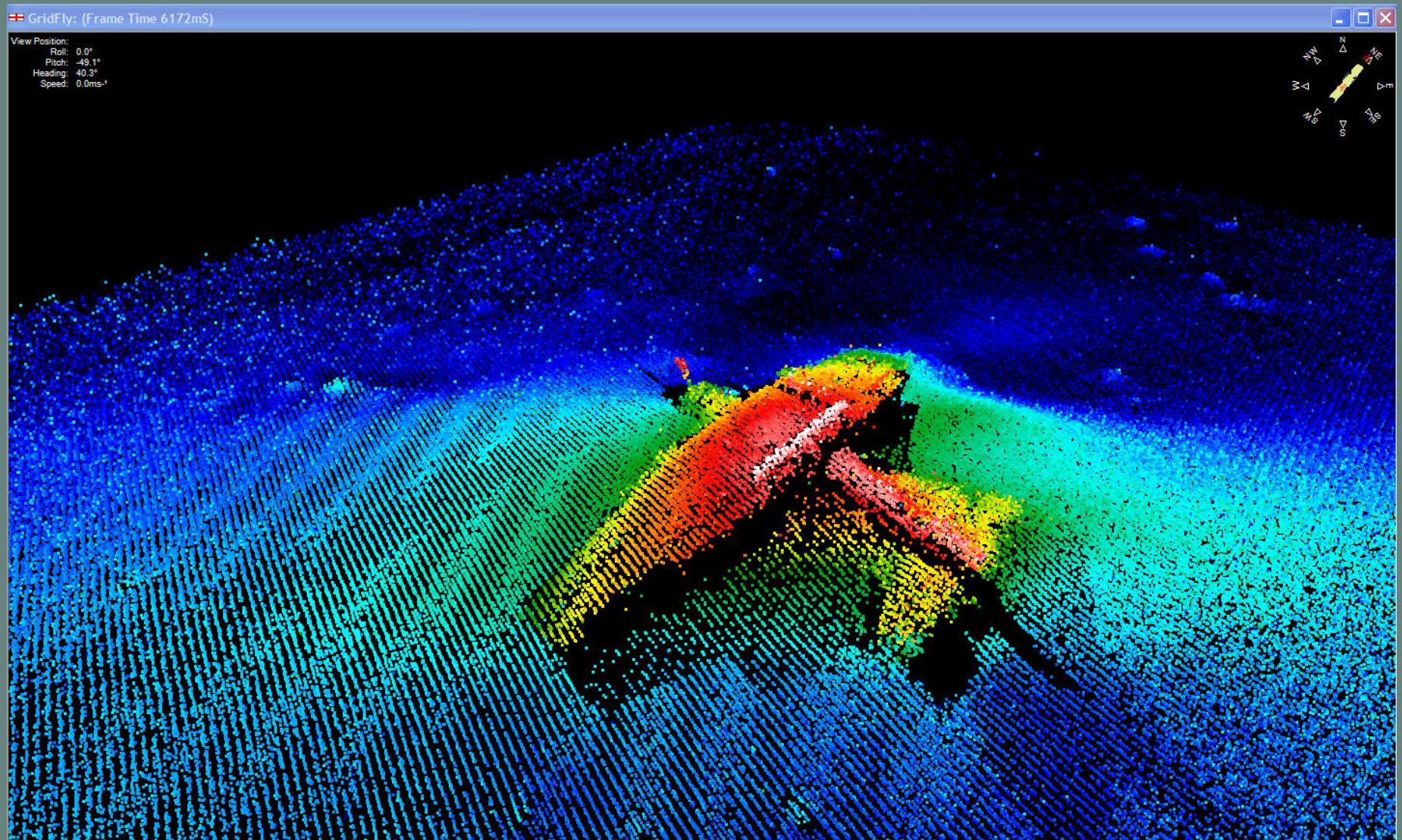


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500KHz data from GS+ on Gavia

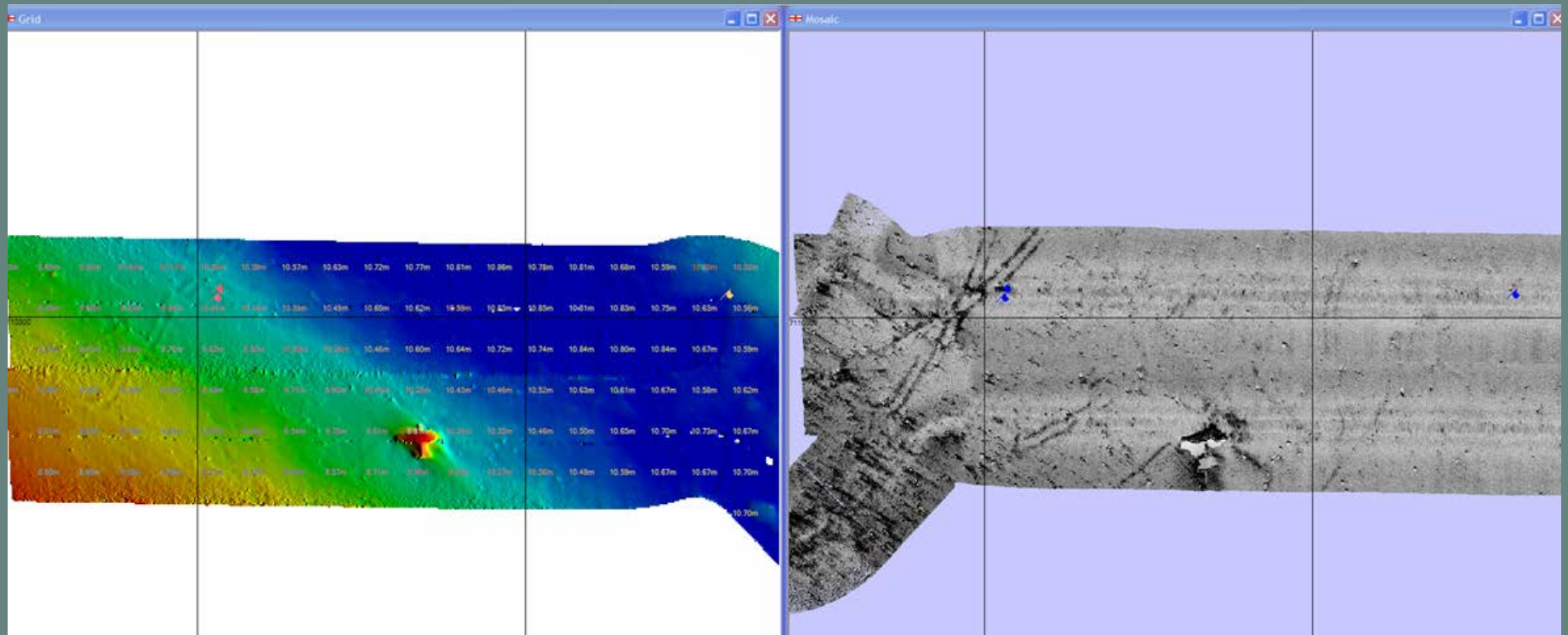


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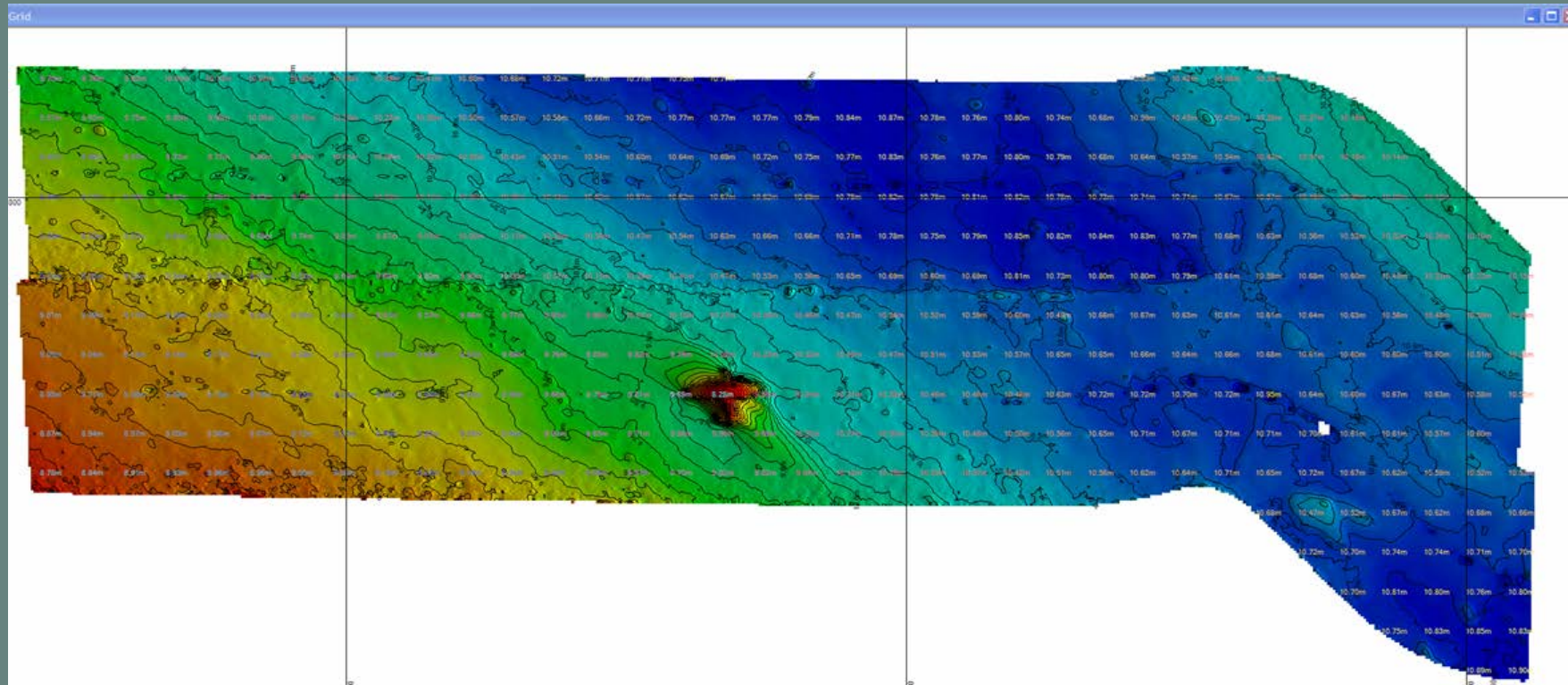
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Iceland Gavia data



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GeoSwath Plus on the Gavia AUV



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View Position: (X) 454504.6m (Y) 7115130.5m (Z) 0.0m

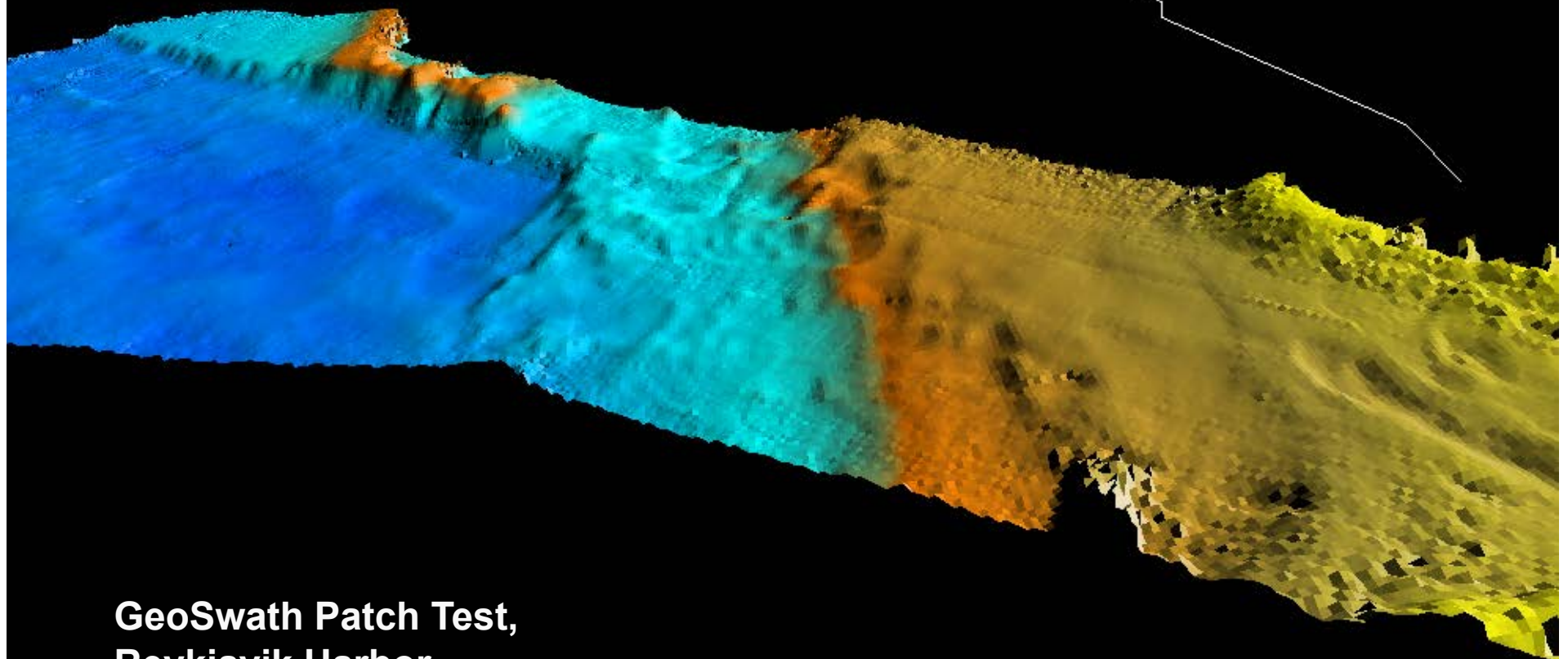
Roll: -8.6° (0.0)

Pitch: -0.9° (-29.3°)

Heading: 122.0° (184.6°)

Speed: 0.0ms⁻¹

Vertical X: 2

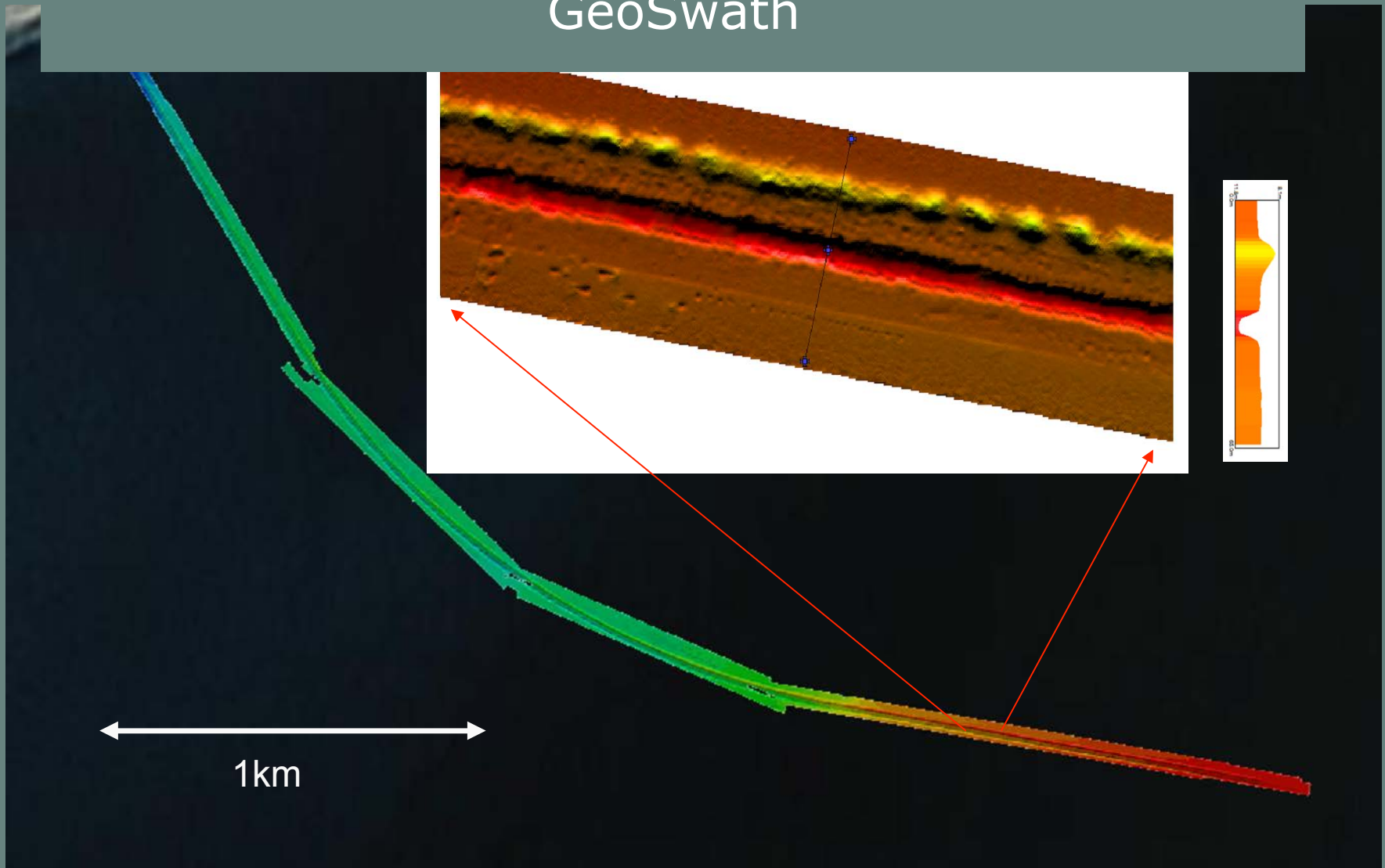


GeoSwath Patch Test, Reykjavik Harbor

GAVIA AUV MOUNTED
0701

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Pre-lay pipe trench survey using AUV mounted GeoSwath

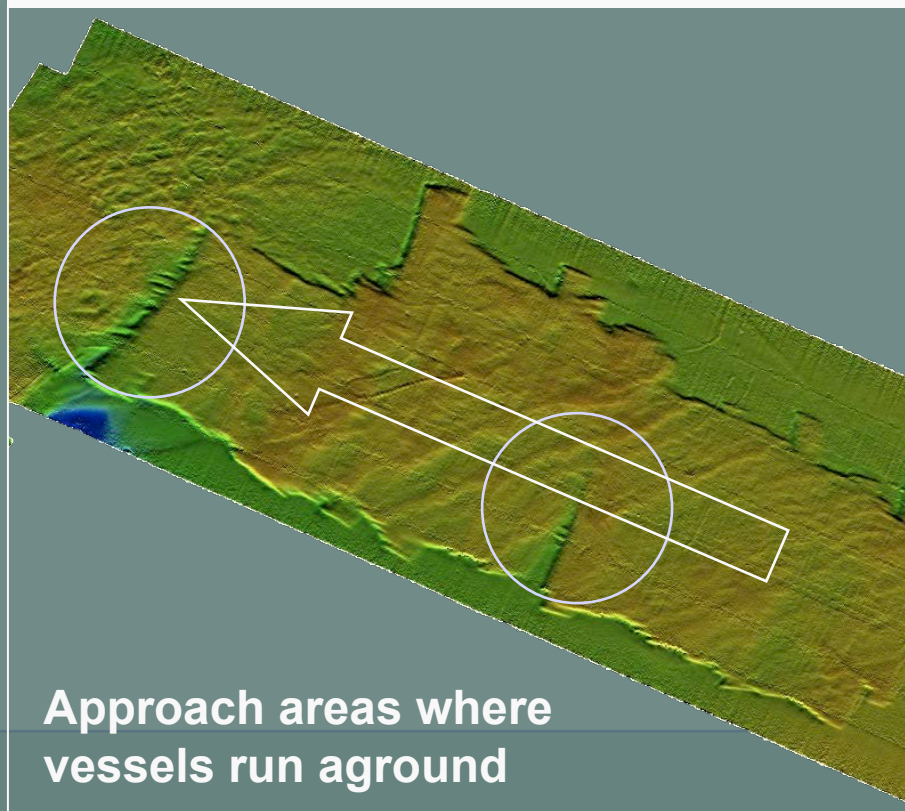


Unique 3-D mapping of littoral areas

Flown in from the UK to meet urgent survey demand, the GAVIA AUV is the only self contained man-portable IHO compliant survey solution.



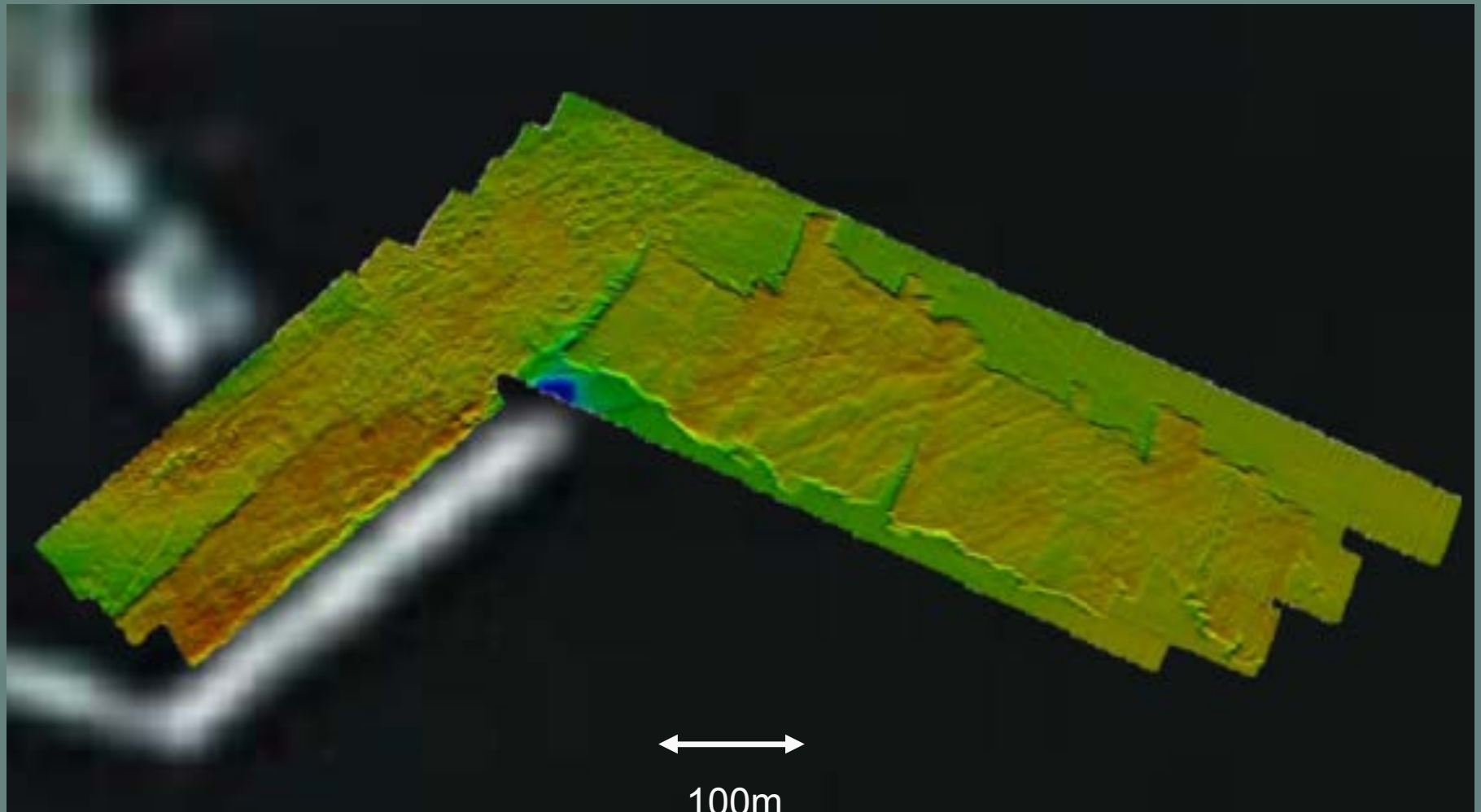
Harbour approach lane Caspian Sea



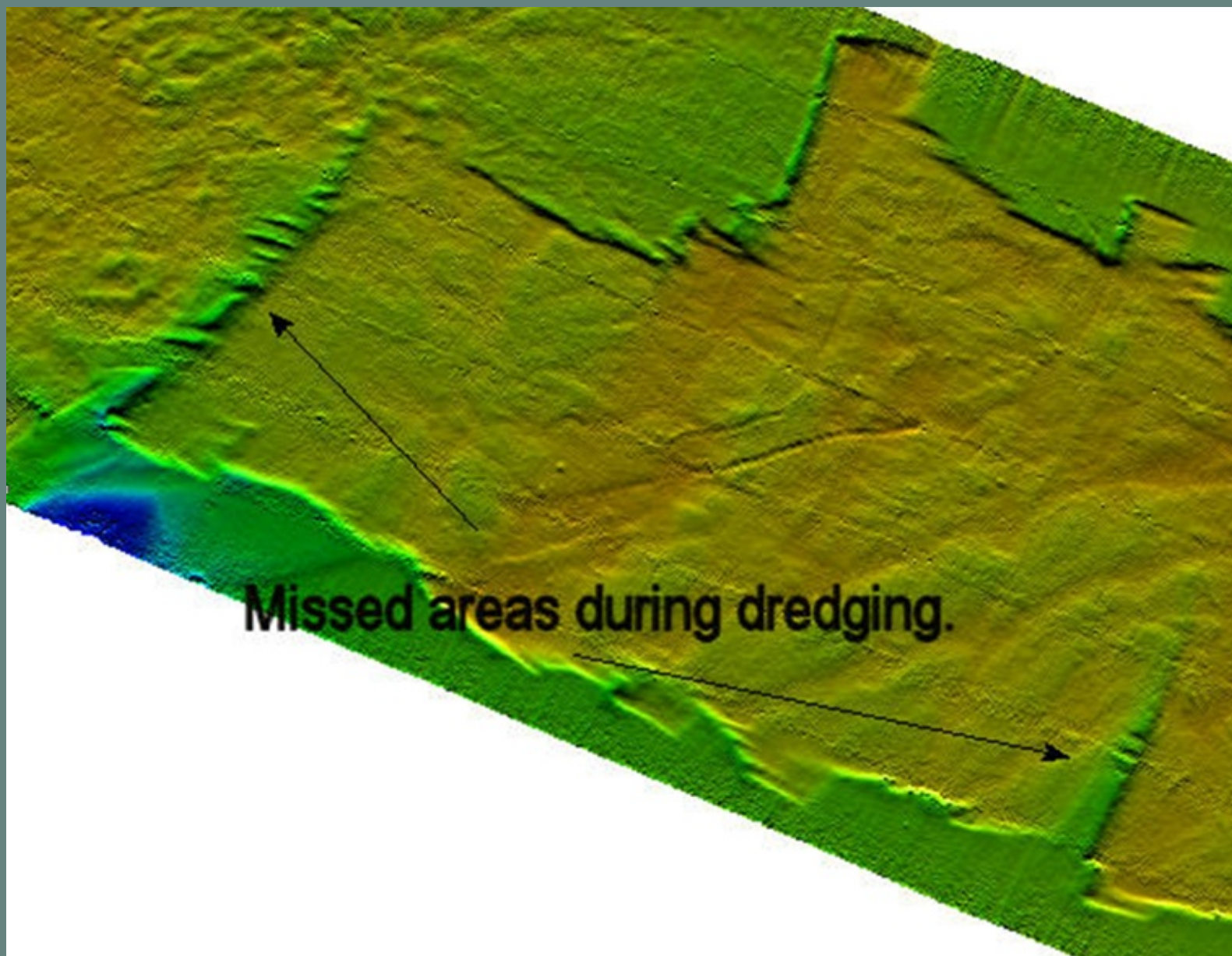
Approach areas where
vessels run aground

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Harbour post-dredge survey using AUV mounted GeoSwath sonar.



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Brest, France Harbor Protection Demonstration, Nov 2005



LUNDI 28 NOVEMBRE:
APRES MIDI

Évaluation de la précision de navigation et de localisation lors d'une recherche en zone portuaire (mise à l'eau et récupération par embarcation légère)

Espace entre rails 15 m
Distance parcourue : 4900 m
Durée de travail : 1 heure
Vitesse de chasse : 2,5

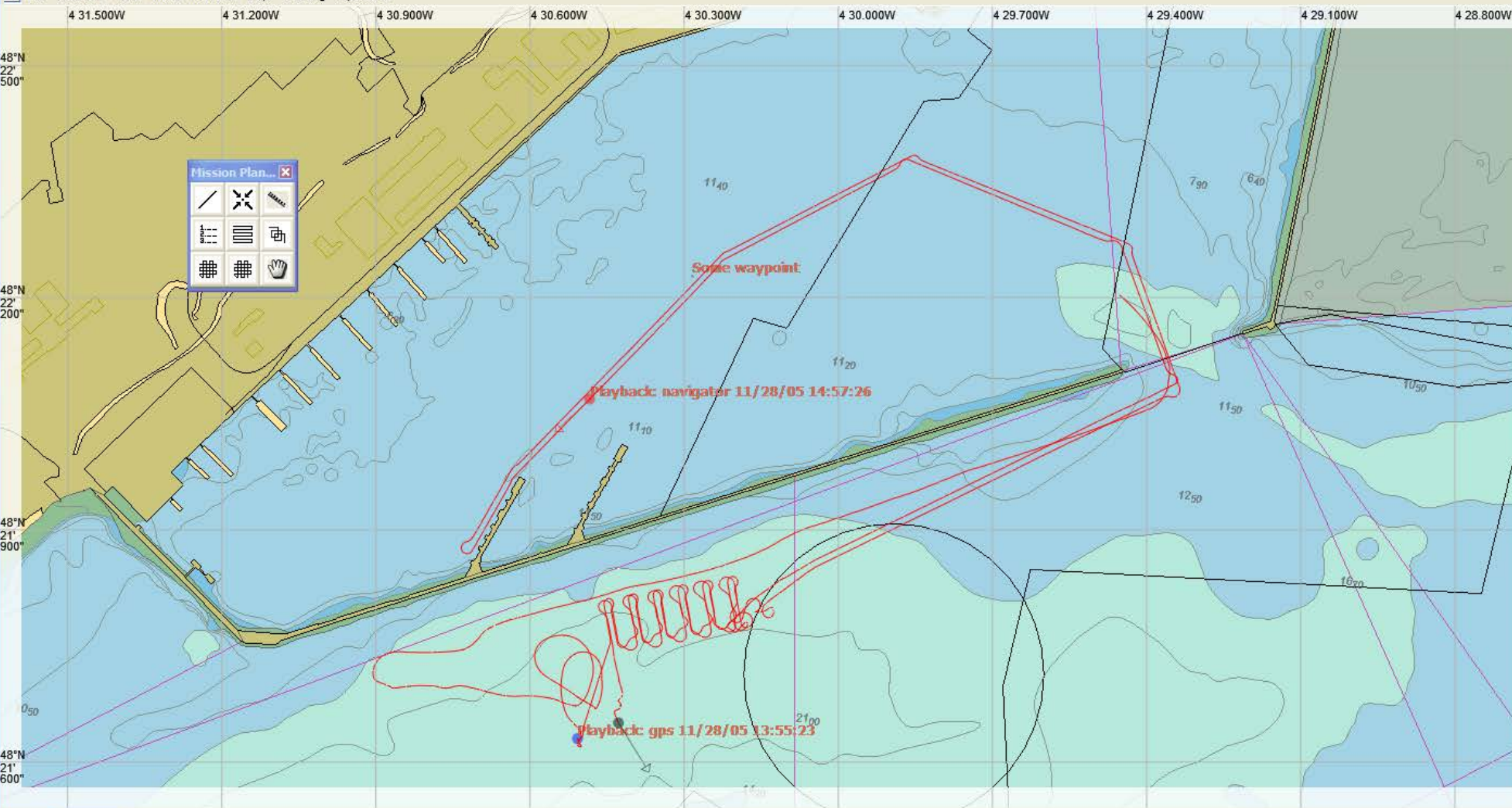
Mines d'exercice : Manta, Rockan, Tronçon
Base de données KLEIN, MULTI FAISCEAUX et CMT

Pattern réalisé au départ et à la fin de la mission: Écartement croissant des rails

Recalage GPS

Recalage GPS

TECHNICAL SUPPORT

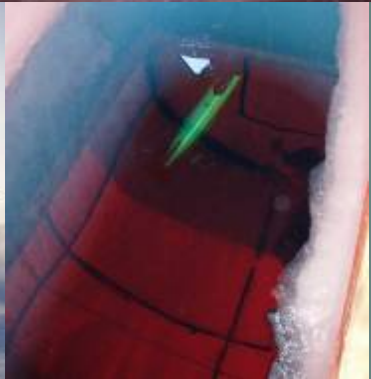
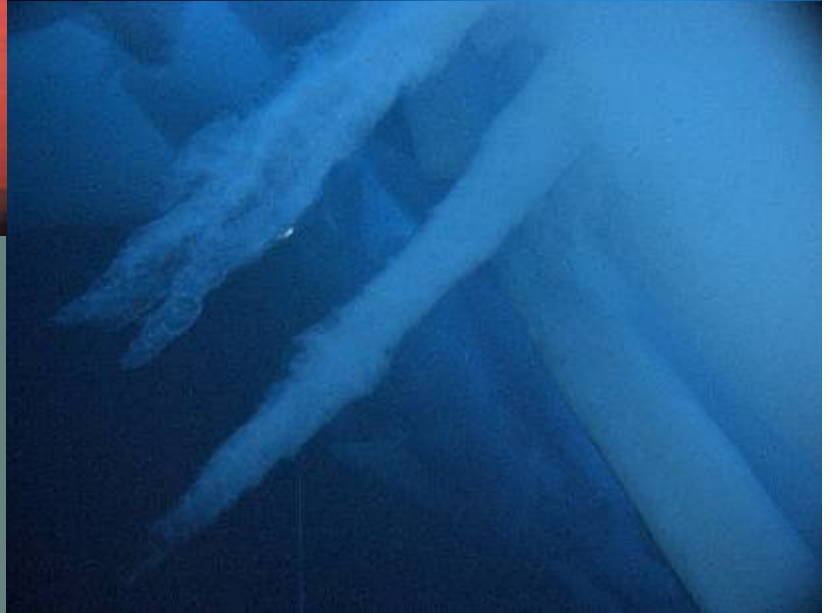
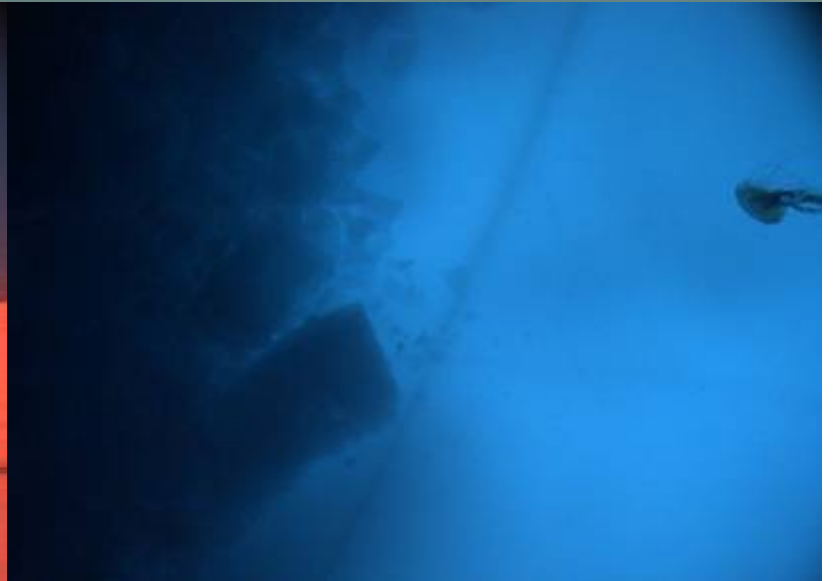


Time	Event	Authority
11/28/05 16...	Stop station keeping	captain
11/28/05 16...	Start station keeping	captain
11/28/05 16...	Mission end	captain
11/28/05 15...	Stop station keeping	captain
11/28/05 15...	Start station keeping	captain
11/28/05 15...	Mission end	captain
11/28/05 14...	Stop station keeping	captain
11/28/05 14...	Start station keeping	captain
11/28/05 14...	Mission end	captain

Brest Mission Statistics

- Distance travelled during initial lawnmower pattern and transit in and out of harbour: 8.3 km
- Mission duration of portions 1 and 2; 1hr 45 minutes
- Speed was 1.8m/s or 3,49 knots
- Navigation precision approximately 4m, based on difference in GPS positioning and INS positioning after the completion of the initial lawnmower pattern route and berthing when vehicle surfaced.
- Preparation: approx 1 hour
- Data download: 6 min via WLAN without recovering vehicle
- 280.000 m2 surveyed

Under Ice Experiments April 2007



The Survey Area



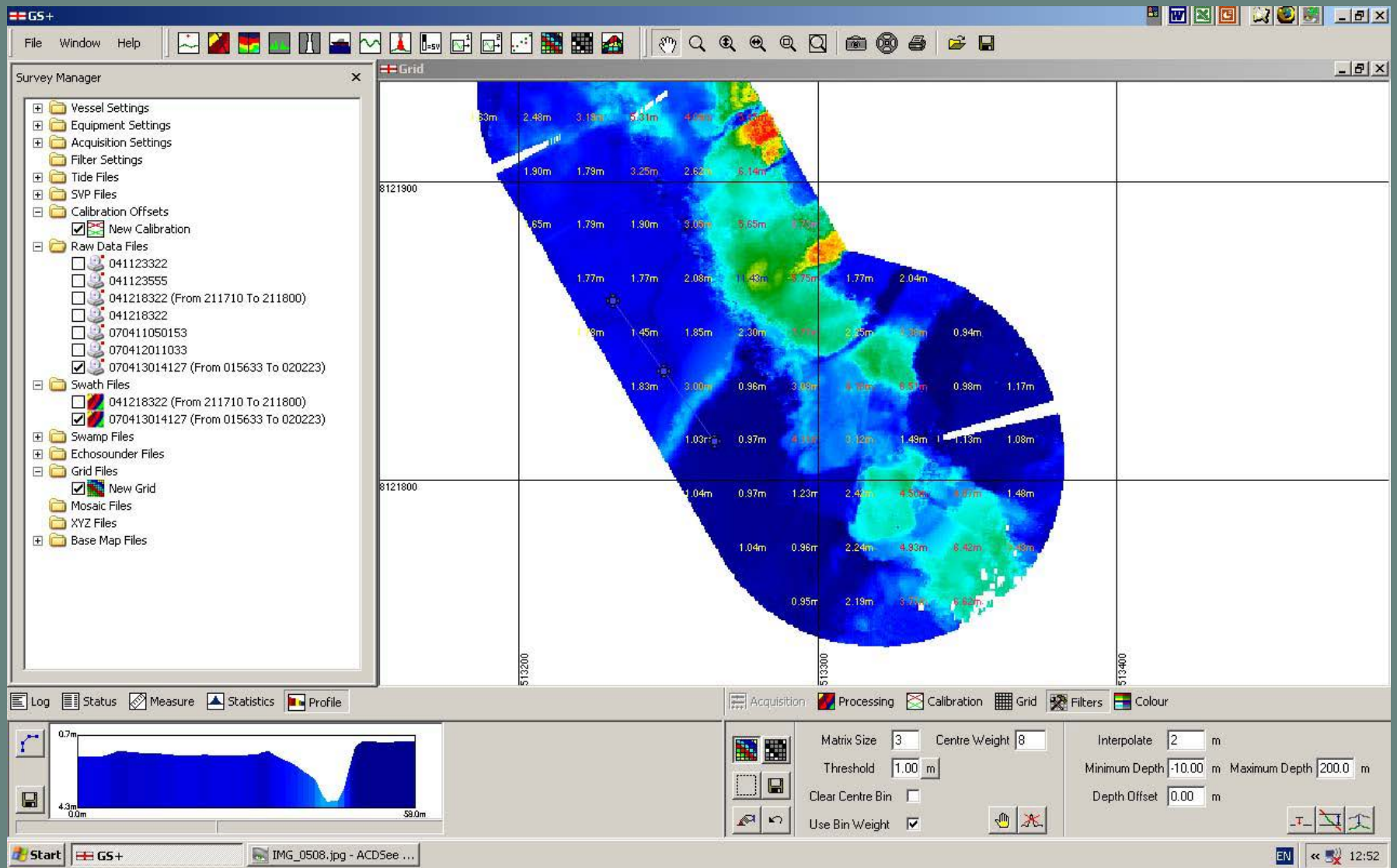
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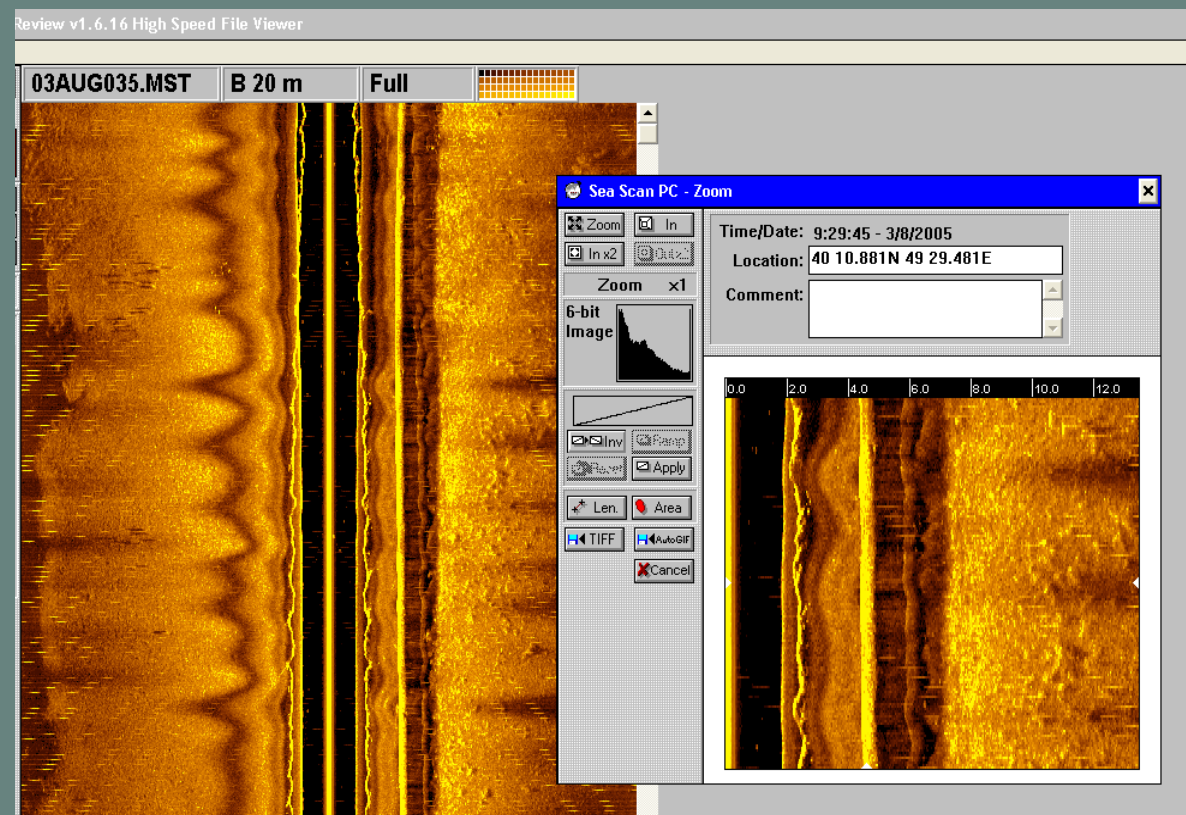
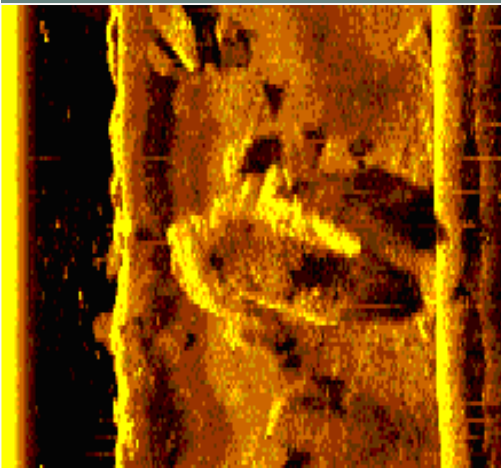
Mission Data



August 2007

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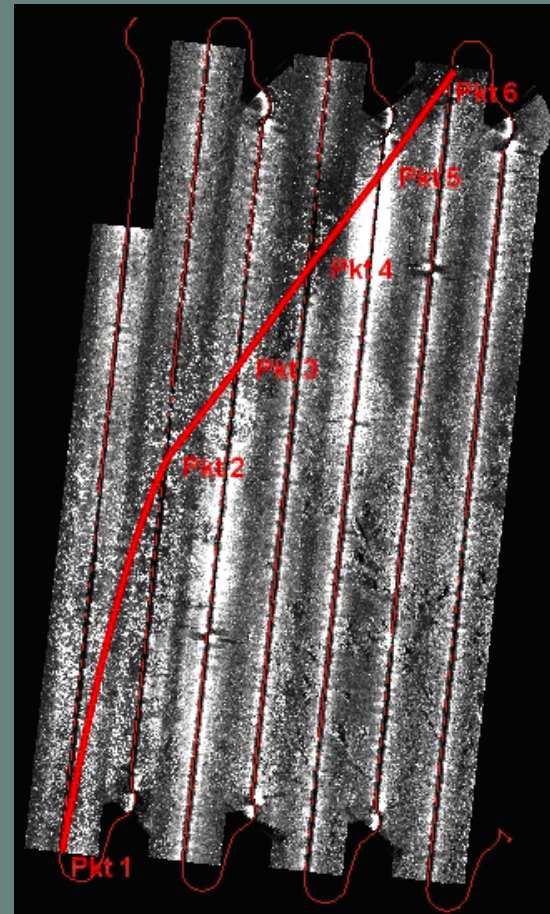
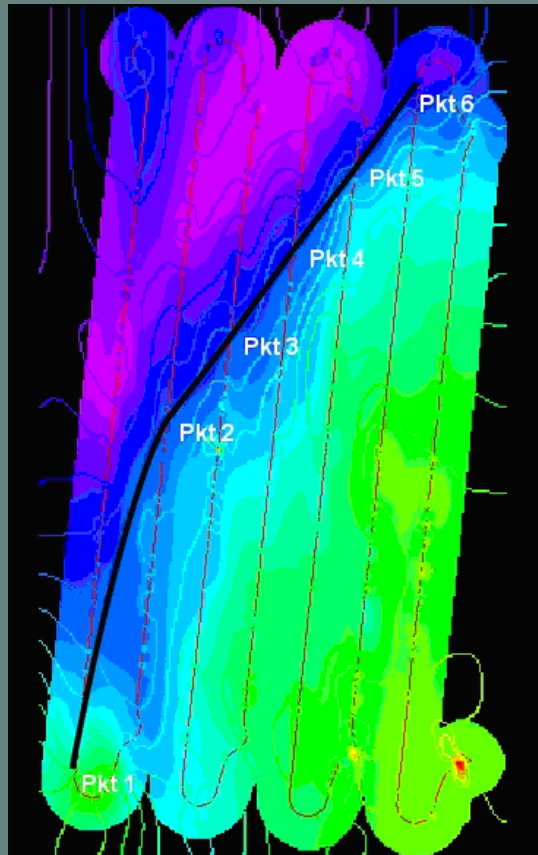
DEVELOPMENT OF AUTOMATIC PIPELINE TRACKING SOFTWARE



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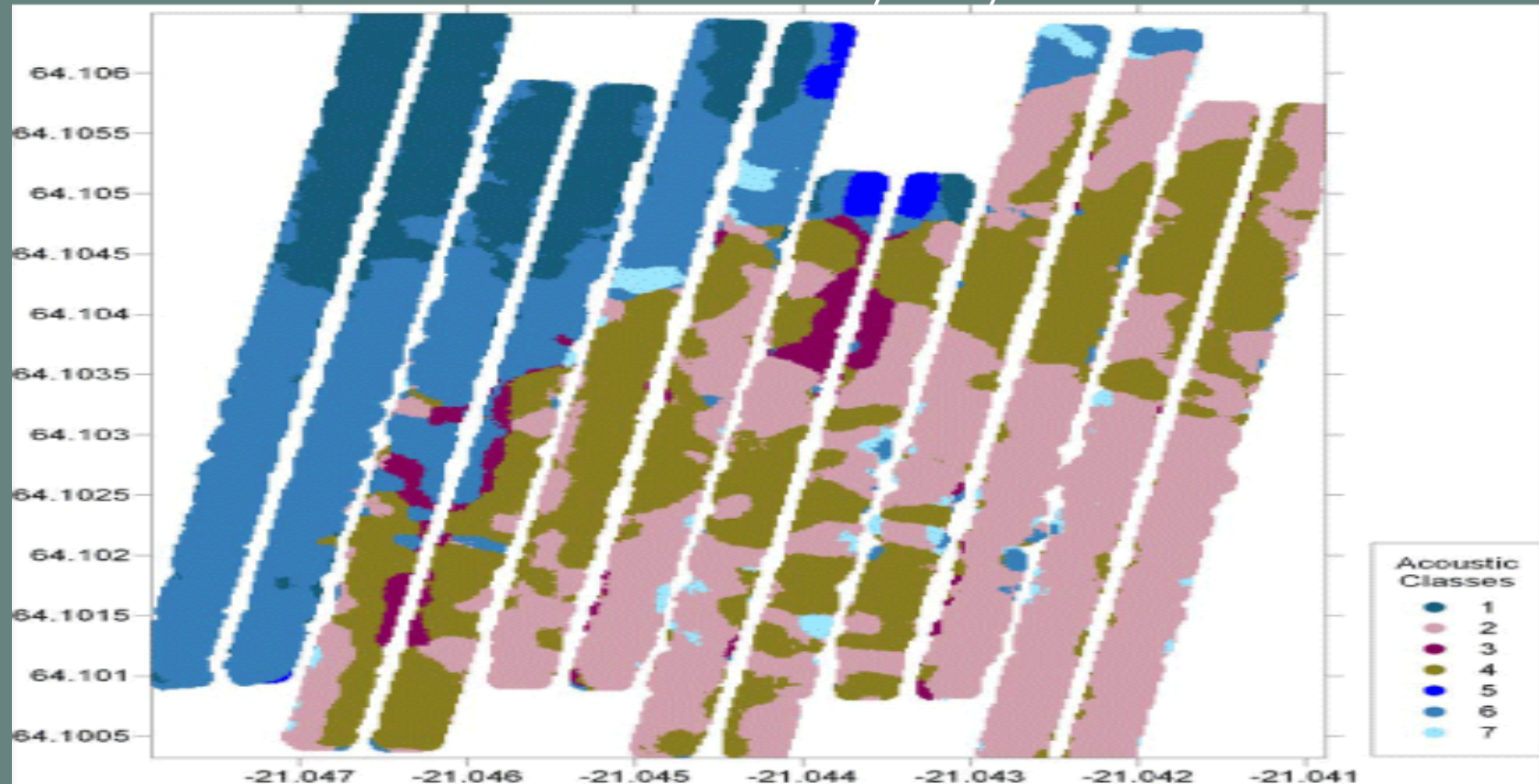
PIPELINE ROUTE SELECTION

based on bathymetry and environmental data



PIPELINE ROUTE SELECTION

based on bathymetry and environmental data



Courtesy of Quester Tangent

DEVELOPMENT OF AUTOMATIC PIPELINE TRACKING SOFTWARE

Using the GeoAcoustic SWATH + sonar system the Gavia will be used to track an oil pipeline in real time. The GAVIA AI sonar operator and the GAVIA AI Navigator will cooperate and together they will keep the Gavia AUV 2 meters above the pipeline and traveling on the exact as laid course of the pipeline. The Gavia will travel at 3 knots and it will perform a full pipeline inspection autonomously. Data will be collected using the following sensors: SWATH 3D Bathymetry, Continuous Digital Video & Still Photos, CTD and Turbidity.

DEVELOPMENT OF AUTOMATIC PIPELINE TRACKING SOFTWARE

Using the GeoAcoustic SWATH + sonar system the Gavia will be used to track an oil pipeline in real time. The GAVIA AI sonar operator and the GAVIA AI Navigator will cooperate and together they will keep the Gavia AUV 2 meters above the pipeline and traveling on the exact as laid course of the pipeline. The Gavia will travel at 3 knots and it will perform a full pipeline inspection autonomously. Data will be collected using the following sensors: SWATH 3D Bathymetry, Continuous Digital Video & Still Photos, CTD and Turbidity.

DEVELOPMENT OF AUTOMATIC TNT PLUME TRACKING SOFTWARE

In the past 3 years there have been a number of Ocean institutes that have been working on actively tracking TNT plumes with AUV System. The funding has come from ONR, Office of Naval Research. The newly developed sensor has been designed to detect several kinds of commercial and military explosives while riding on a remotely controlled surface vehicle that wirelessly transmits data to a hand-held computer. The sensor uses electrochemical means to detect explosive residues. In developing the sensor, researchers took into account the fact that TNT in sea water undergoes biodegradation in a number of different ways. The new sensor and its platform were designed at the Center for Ocean Technology of South Florida University and funded by the U.S. navy.

DEVELOPMENT OF AUTOMATIC TNT PLUME TRACKING SOFTWARE

Institutes working on the effort include:

Woods Hole Oceanographic Institute (WHOI)

Battelle PNW Laboratories (BPNWL)

Mass. Institute of Technology (MIT)

Commercial groups working on this effort include:

Hafmynd – Gavia AUV

Hydroid – Remus

Battelle _ Bluefin Robotics

DEVELOPMENT OF AUTOMATIC TNT PLUME TRACKING SOFTWARE

- The WHOI AUV system Remus has successfully lock onto and tracked a TNT plume using the ICX Nomadics "SeaPup". Currently WHOI has the lead in tracking plumes and their main interest is not in tracking TNT plumes but in tracking plumes that are associated with black smokers. Black smokers are active seafloor volcanoes that belch a number of organic gases including H₂S and methane. The WHOI AUV has successfully located black smoker plumbs at various water depths and has actively tracked these plumbs back to source.

THE TRUTH ABOUT DEVELOPING AN AUTOMATIC TNT PLUME TRACKING SOFTWARE SYSTEM THAT WILL WORK WITH AUV SYSTEM

The Truth

- 1) It is not easy to track a plumb underwater but the nice thing about the TNT molecular chain is it stay together.
- 2) It is not easy to track a plumb underwater but all submerged munitions have one thing in common, they will all eventually leak.
- 3) It is not easy to do what we are proposing to do, but if we don't do it "WHO WILL"?

Bottom Line is:
WE STILL HAVE A LOT TO LEARN
AND WE HAVE SOME GREAT TEACHERS
QUESTIONS ?



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