
# NOC MARINE AUTONOMY & TECHNOLOGY SHOWCASE

National
Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

noc.ac.uk/matshowcase

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

**Mr Roland Rogers**

Advisor Marine Law and Policy NOC

# Session Chair Bathymetric Survey Workshop

# Marine Autonomous Systems Bathymetric Survey Workshop

IHO STANDARDS FOR HYDROGRAPHIC SURVEYS (S-44)
5th Edition February 2008

**TABLE 1**
Minimum Standards for Hydrographic Surveys
*(To be read in conjunction with the full text set out in this document.)*

| Order | Special | 1a | 1b | 2 |
|---|---|---|---|---|
| **Description of areas.** | Areas where under-keel clearance is critical | Areas shallower than 100 metres where under-keel clearance is less critical but *features* of concern to surface shipping may exist. | Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area. | Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate. |
| **Maximum allowable THU 95% *Confidence level*** | 2 metres | 5 metres + 5% of depth | 5 metres + 5% of depth | 20 metres + 10% of depth |
| **Maximum allowable TVU 95% *Confidence level*** | a = 0.25 metre<br>b = 0.0075 | a = 0.5 metre<br>b = 0.013 | a = 0.5 metre<br>b = 0.013 | a = 1.0 metre<br>b = 0.023 |
| ***Full Sea floor Search*** | Required | Required | Not required | Not required |
| ***Feature Detection*** | Cubic *features* > 1 metre | Cubic *features* > 2 metres, in depths up to 40 metres; 10% of depth beyond 40 metres | Not Applicable | Not Applicable |
| **Recommended maximum Line Spacing** | Not defined as *full sea floor search* is required | Not defined as *full sea floor search* is required | 3 x average depth or 25 metres, whichever is greater For bathymetric lidar a spot spacing of 5 x 5 metres | 4 x average depth |
| **Positioning of fixed aids to navigation and topography significant to navigation. (95% *Confidence level*)** | 2 metres | 2 metres | 2 metres | 5 metres |
| **Positioning of the Coastline and topography less significant to navigation (95% *Confidence level*)** | 10 metres | 20 metres | 20 metres | 20 metres |
| **Mean position of floating aids to navigation (95% *Confidence level*)** | 10 metres | 10 metres | 10 metres | 20 metres |

**rxr@noc.ac.uk**

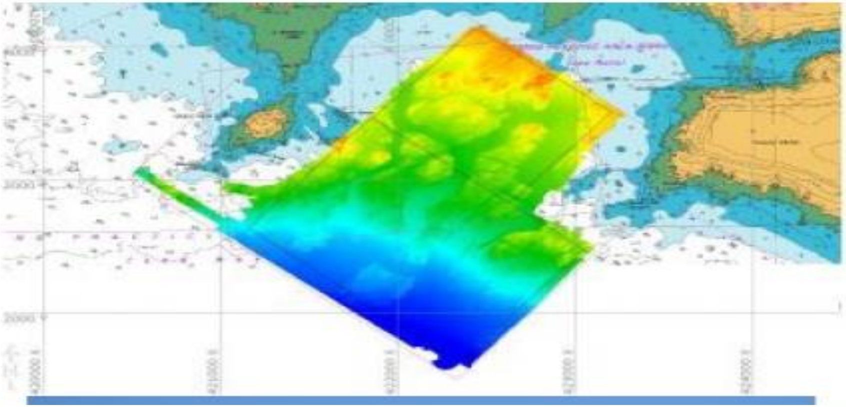
# Marine Autonomous Systems Bathymetric Survey Workshop

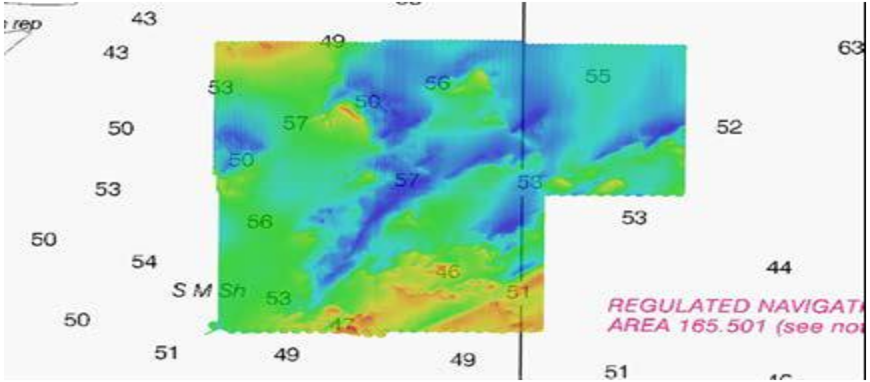
This workshop will cover the rapid growth in the application of MAS in the area of Hydrographic Surveying and the current maturity of MAS to deliver survey data to the exacting applicable IHO standards.

It will look at the utility of both autonomous underwater vehicles (AUVs) as well as autonomous surface vehicles (ASVs) in meeting the necessary Class 1 A Standard.

The workshop will also cover advances in survey planning, positioning accuracy, quality control and deployment mechanisms.

# Marine Autonomous Systems Bathymetric Survey Workshop



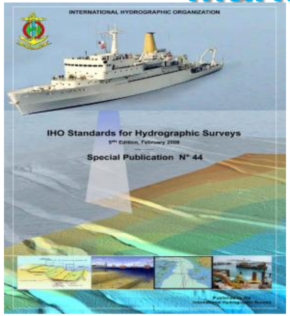


*"However, until the* ***<u>technology has matured,</u>*** *we have no plans to employ MAS under the programme.*

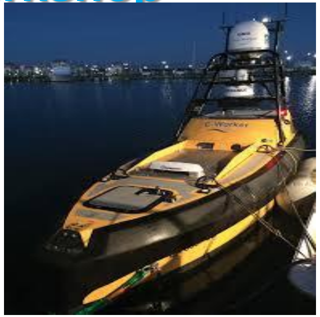
*As you might imagine, we are watching this area closely and are aware of a number of trials that have recently taken place.*

*We await the results with interest."*

# Marine Autonomous Systems Bathymetric Survey Workshop







## Programme

- **Introduction and Setting the Scene** — Roland “Rolly” Rogers [NOC]
- **Hydrographic Data Collection from an AUV** — Richard “Bungy” Williams [Hydroid Inc], Craig Wallace [Hydroid Inc]
- **Hydrographic Data Collection from an USV** — Dan Hook [ASV Ltd]
- **Positioning and Communications** — Geraint West [Sonardyne Ltd]
- **Questions to Panel**
- **Discussion and way ahead**

# Marine Autonomous Systems Bathymetric Survey Workshop


rxr@noc.ac.uk

*"However, until the technology has matured, we have no plans to employ MAS under the programme.*

*As you might imagine, we are watching this area closely and are aware of a number of trials that have recently taken place.*
***We await the results with interest**."*

*What is the way ahead?*

*[1] Use SMI's Maritime Autonomous Systems (MAS) Council to lobby for acceptance that the technology is mature enough.*

*[2] Open a dialogue with IHO to see if the existing codes/standards need to be modified to include a MAS delivery capability*

*[3] MAS Community produces its own code/standard*

# Marine Autonomous Systems Bathymetric Survey Workshop


rxr@noc.ac.uk

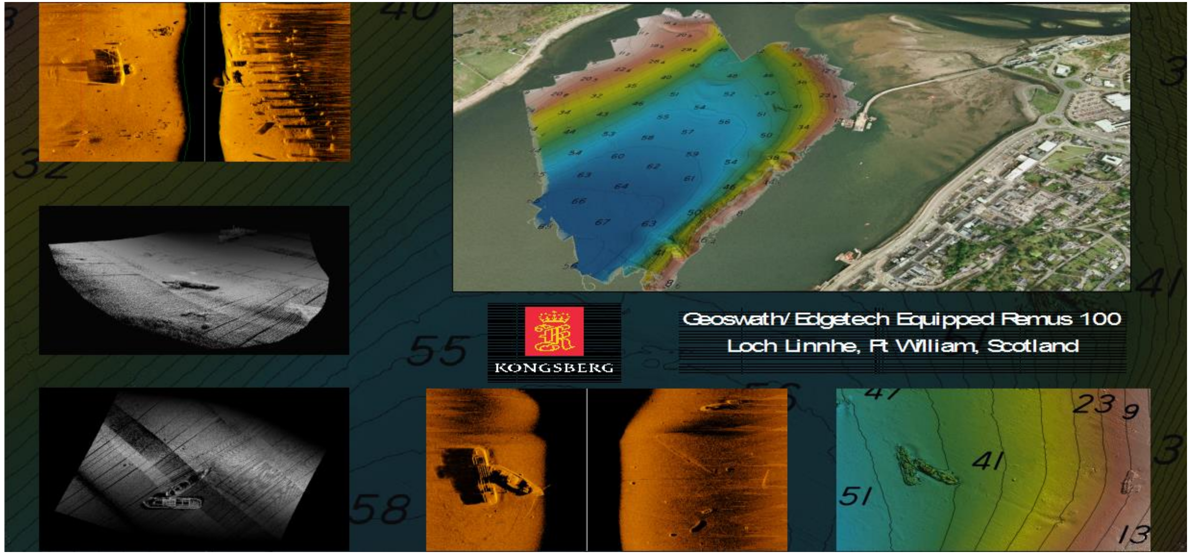
**Richard “Bungy” Williams**

Hydroid

# Hydrographic Data Collection from an AUV

Hydrographic Data Collection from AUVs






Bungy Williams: Regional Manager Europe Hydroid Inc
and
Craig Wallace: Kongsberg Maritime Ltd

# Kongsberg Organization

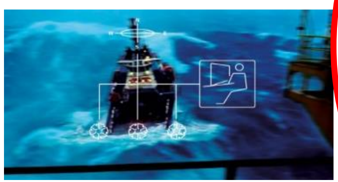


# KONGSBERG Maritime Division



## Kongsberg Maritime

- Merchant
- Marketing & Sales
- Business Dev
- Offshore
- Subsea



4763 Employees
59 Offices worldwide in 20 Countries

(June 2015)

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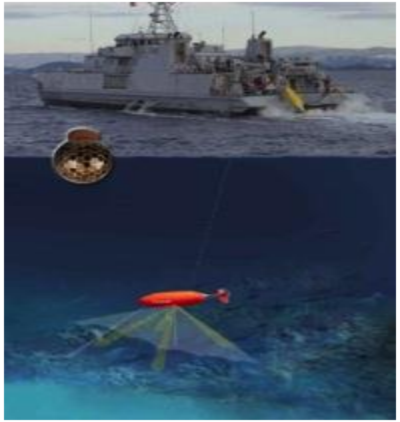
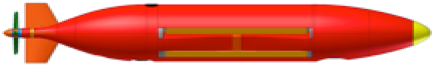
# Kongsberg Maritime - Subsea

KONGSBERG



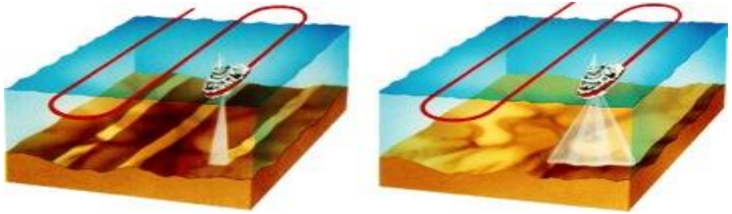
Underwater positioning

Naval sonar systems

AUVs

Seabed mapping



Underwater surveillance

# Kongsberg & Hydroid AUV Group



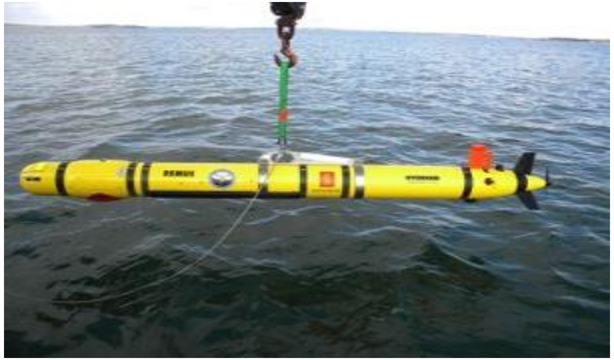

US Office

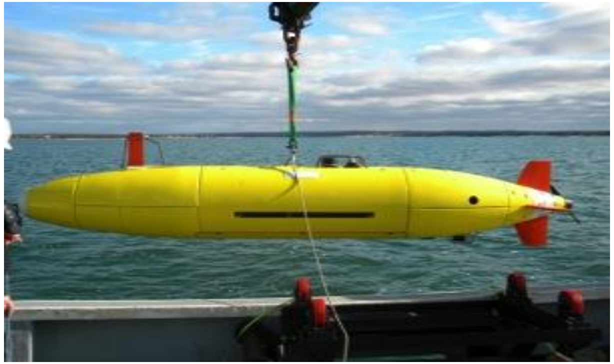
Norway Office

UK Office

# Kongsberg and Hydroid Autonomous Underwater Vehicles





# Is an IHO Order Survey Achievable with an AUV ?



In short – YES

Is it easy – NO

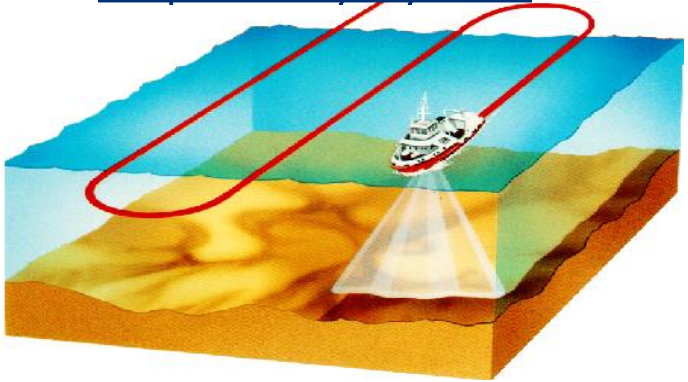
Will an AUV ever completely replace a surface platform – UNLIKELY

Can an AUV compliment IHO Order surveys – DEFINITELY

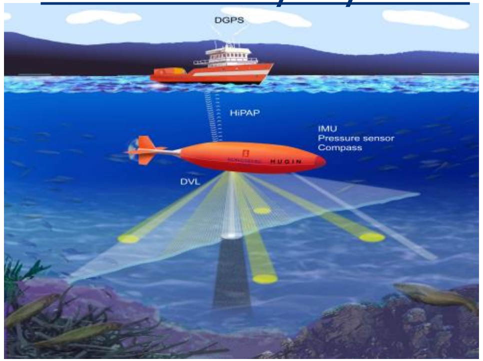
# Hydrographic Surveying with AUVs



## Ship Survey System



## AUV Survey System




Real-time data collection and storage on ship

Real-time data collection and storage in AUV system

↓

Survey company data processing system

↓

Client

# Hydrographic Surveying with AUVs



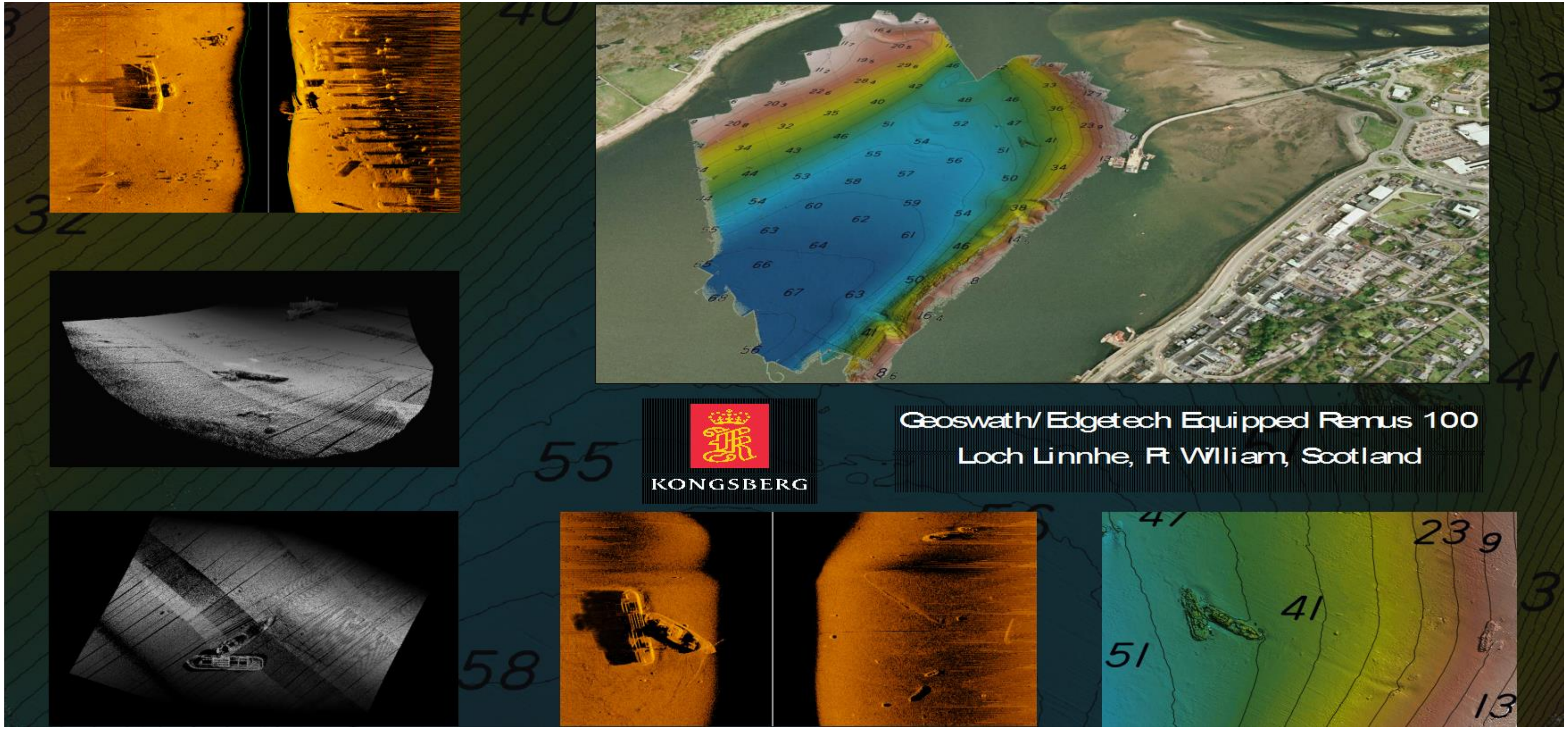
- Increased data quality
  - Stable platform
  - Low platform noise. Acoustic synchronization of sensors
  - High-performance navigation and positioning solutions
  - Possibility to operate below difficult water layers
- Increased mapping resolution
  - Advanced sensors are brought in optimal position for detailed seabed mapping
- Increased mapping efficiency (speed) compared to tow-fish and ROV

- Simultaneous recording of full geophysical sensor suite and oceanographic data
- Only solution for demanding applications
  - Deep water detailed surveys
  - Under ice survey
  - Naval
- Some missions can (must) be carried out autonomously

# Hydroid REMUS 100 & GeoSwath Plus

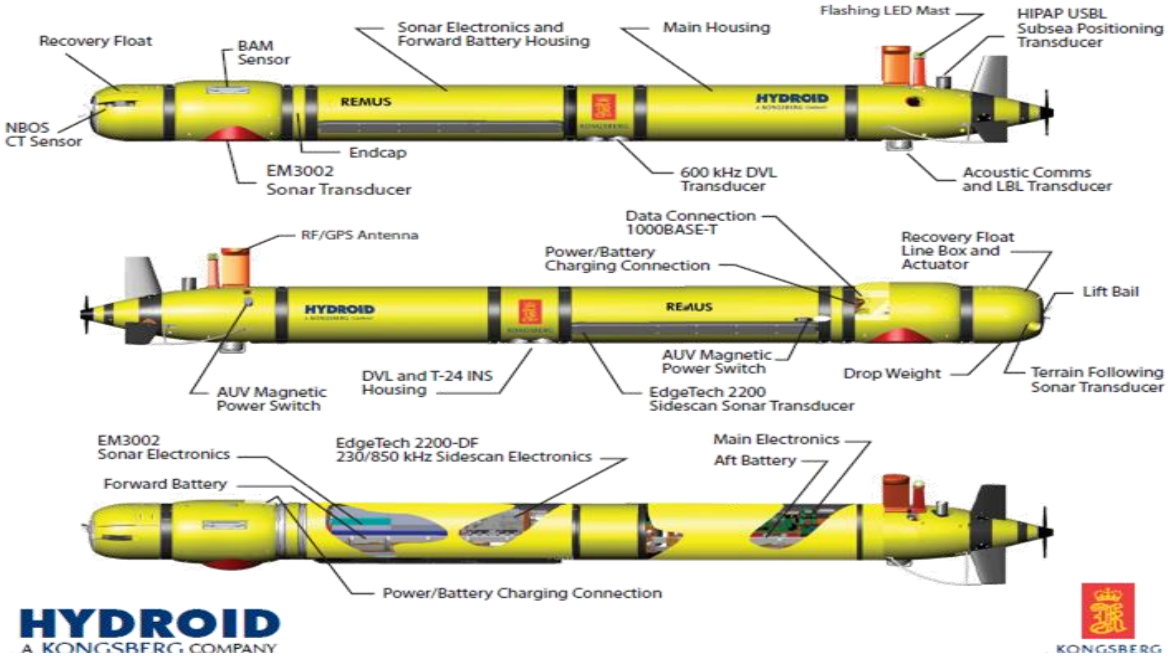


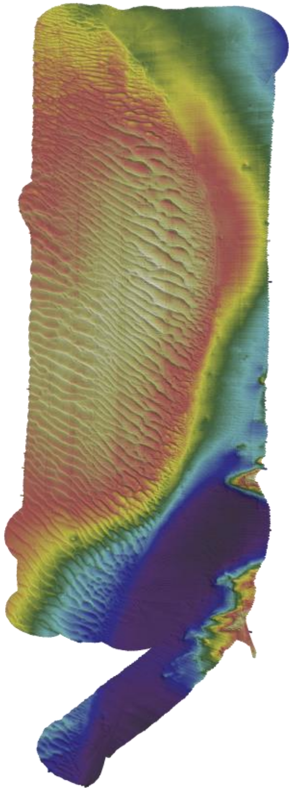
| | GeoSwath Plus REMUS 100 - 500 kHz |
|---|---|
| Power Requirements | 24 VDC, 40 W (at max ping rate), 20 W (standby). |
| Max Depth Rating | GeoSwath Plus module: 1000 m, REMUS 100: 100 m |
| Electronic Module Size | 20 cm OD x 36.6 cm long. |
| Electronic Module Weight | 12 kg (in air), 3 kg (in water). |
| Data Storage/Retrieval | min. 120 GB hard drive, 1 GbE Ethernet link |
| Mission Endurance | 12 hour data collection |
| Interface to Remus AUV | Ethernet (2 x 1 Gbit Ethernet ports available), RS232 for ancillaries |


Geoswath/ Edgetech Equipped Remus 100
Loch Linnhe, Ft William, Scotland
KONGSBERG

# Hydroid REMUS 600 & EM3002

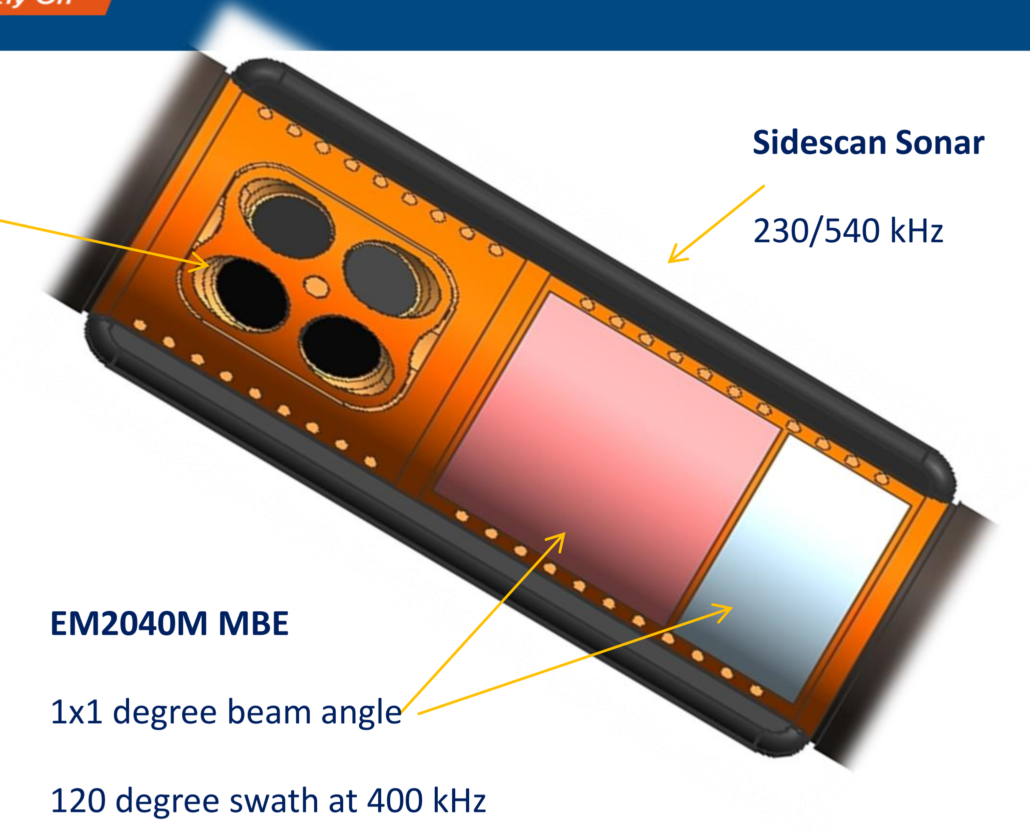






# Current Payload Module





**DVL**

Broadband 300/600 kHz

**Sidescan Sonar**

230/540 kHz

## MUNIN & REMUS 600

## Payload Module:

Honeywell HG9900 INS

With NavP

INS and DVL aligned with EM2040

UTP/DTM Compatible

**EM2040M MBE**

1x1 degree beam angle

120 degree swath at 400 kHz

140 degree swath at 200 kHz

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# Kongsberg MUNIN

KONGSBERG

**Nose Section**

Forward Looking Sonar

NBOS CT Sensor

Pop-off buoy and recovery line

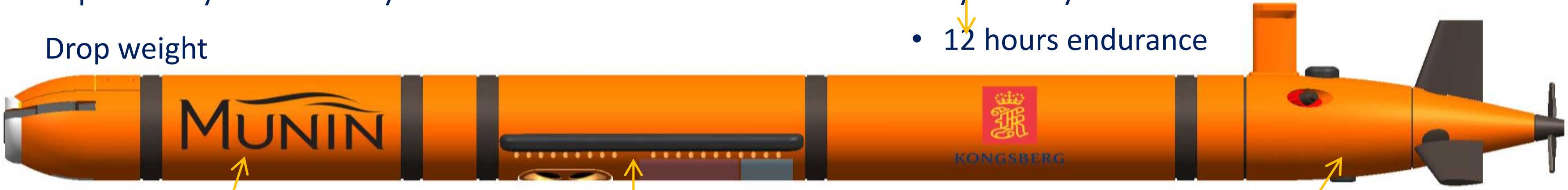
Drop weight

**Control Module**

Vehicle and Payload Electronics

Fixed Dry Battery

- 12 hours endurance




**Battery Module**

Swappable dry battery section

- 12 hours endurance

**Navigation and Payload Module**

INS

DVL

EM2040

Sidescan sonar arrays

**Tail Section**

Propulsion and steering

cNODE communications and

positioning transponder

RF/Wi-Fi/GPS antenna

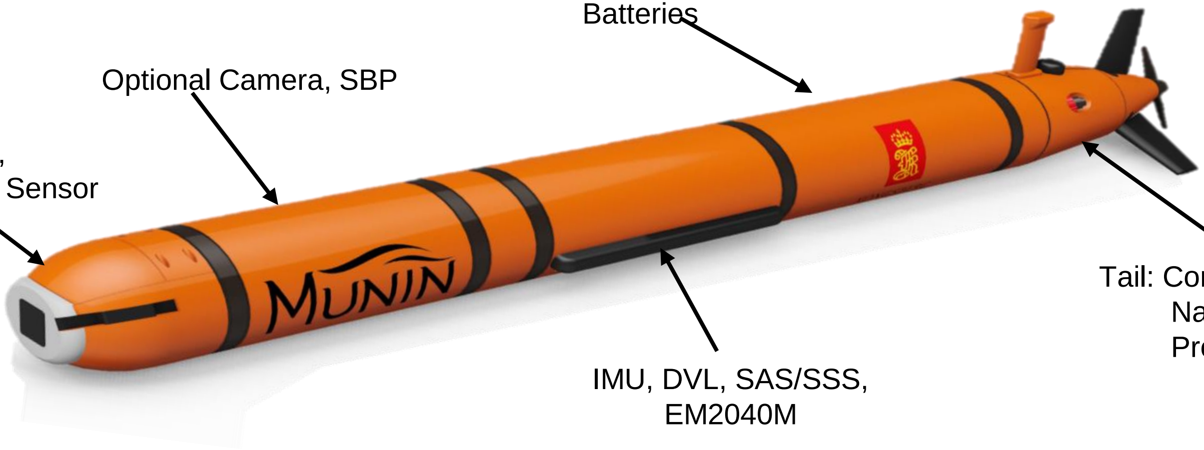
# Kongsberg HUGIN 1000 Multi-Purpose AUV




| Navigation | Payload | Other |
|---|---|---|
| INS (inertial navigation system) | MBE | FLS (forward looking sonar) |
| Acoustic positioning (USBL, UTP) | SAS (synthetic aperture sonar) | Forward altimeter |
| Surface GPS | SSS (sidescan sonar) | Downward altimeter |
| Pressure sensor | SBP (sub-bottom profiler) | Acoustic up and down links |
| DVL bottom-track | ADCP (acoustic Doppler current profiler) | Radio link |
| DVL water-track | CTD (conductivity-temperature-depth) | WLAN |
| Model aiding | Fishery research instrumentation | Iridium |
| DPCA micronavigation | Optical camera | |
| Terrain navigation | Turbidity sensor | |
| Feature based navigation | | |
| Compass (for redundancy) | | |


HYDROID

# Rental MUNIN AUV System




## Key Navigation System Components

Depth Sensor

Forward Looking Sonar

Inertial Measurement Unit

Doppler Velocity Log

cNODE Transponder

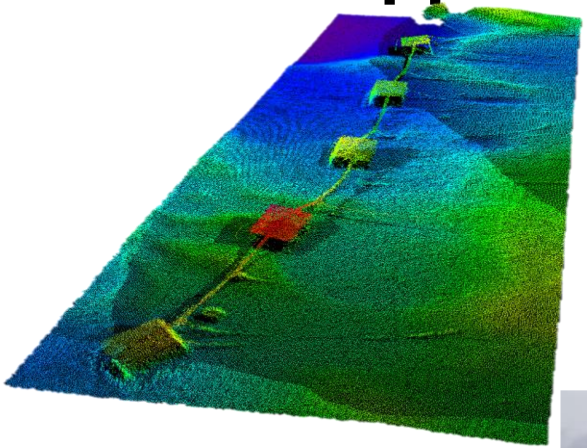
# Dedicated Launch and Recovery

- Stinger works with freeboards up to 2.5 metres
- Require small footprint on aft deck, 5 x 1.5 metre
- Self contained batteries and hyadraulics.
- Fast mobilisation

# Batteries

- Potential to run extra battery modules
- Internal Gives 9 hours+
- External Gives 9 Hours+
- Both Batteries together 18 Hours+
- Recharge time of 8 hours

# Commercial Applications

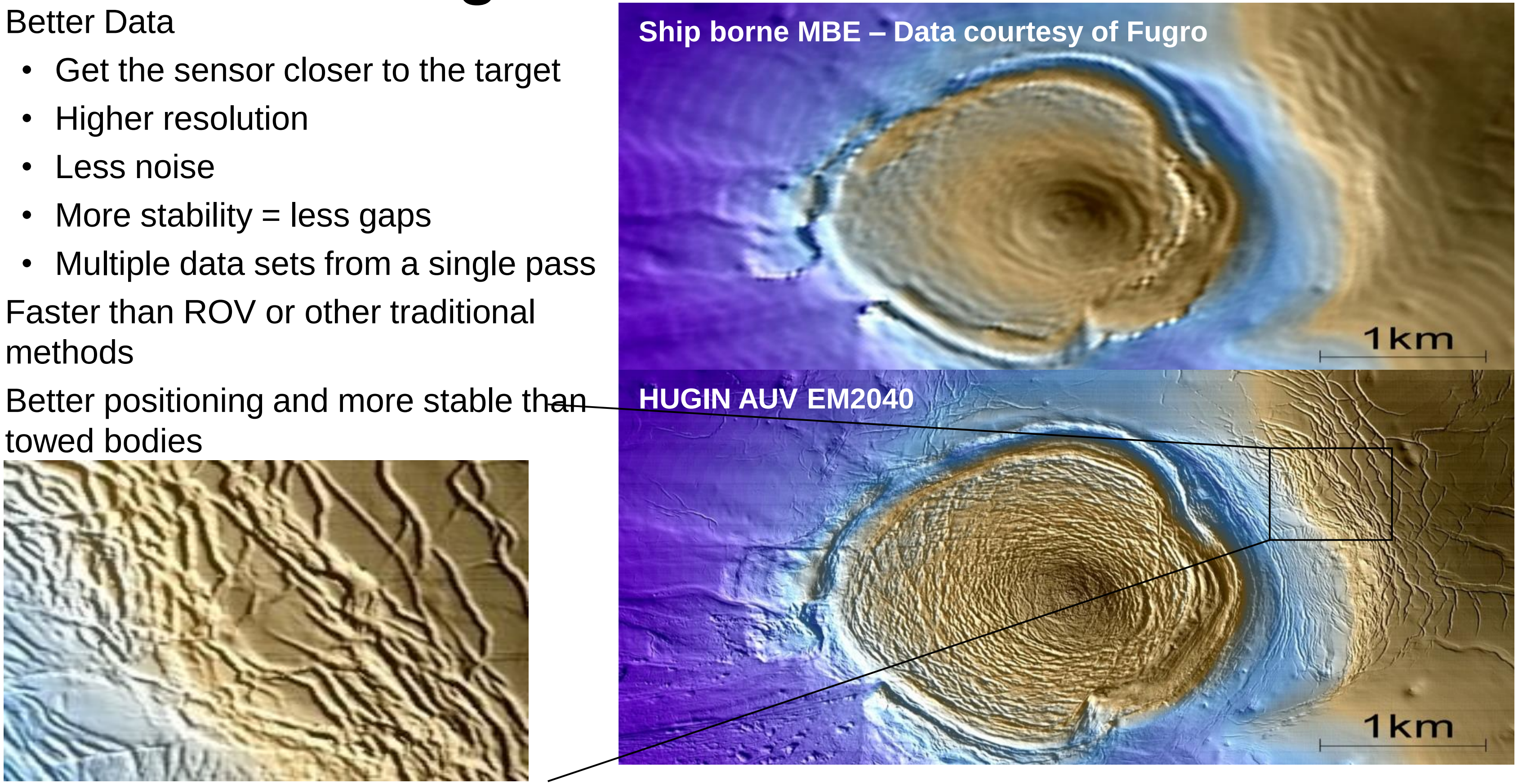


- Hydrography
- Oceanography
- Geohazard Surveys
- Pipeline Inspections
- Route Surveys
- As-Built Surveys
- 3D Micro Survey

- Environmental Monitoring
- Benthic Habitat Mapping
- Marine Archeology
- EEZ/UNCLOS Surveys
- Search and Salvage
- And more….

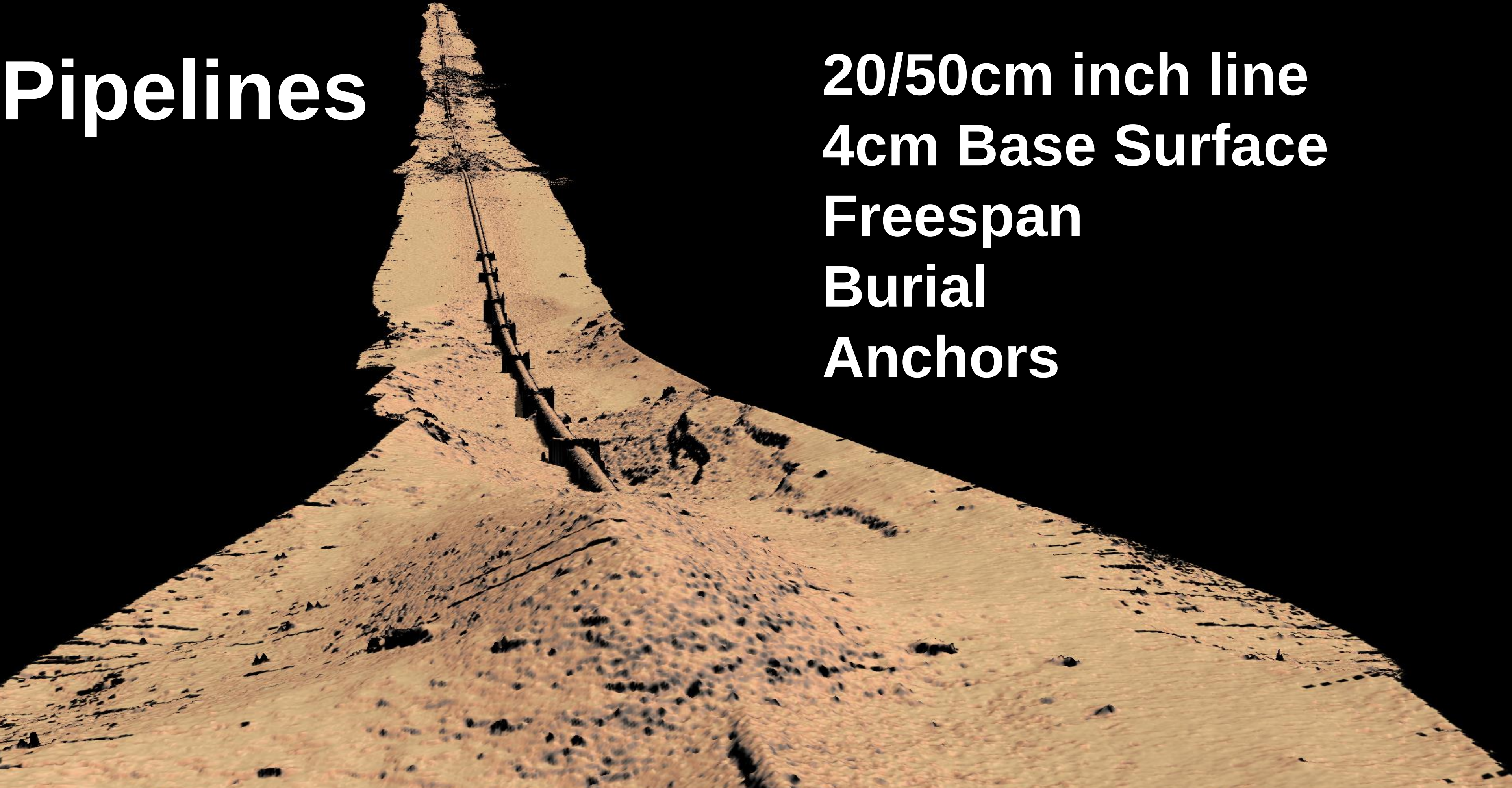
# Benefits of Using AUVs

- Better Data
  - Get the sensor closer to the target
  - Higher resolution
  - Less noise
  - More stability = less gaps
  - Multiple data sets from a single pass
- Faster than ROV or other traditional methods
- Better positioning and more stable than towed bodies



# Pipelines

20/50cm inch line
4cm Base Surface
Freespan
Burial
Anchors



# 7cm Power cable,

# High SS overlaid onto EM2040 Bathymetry

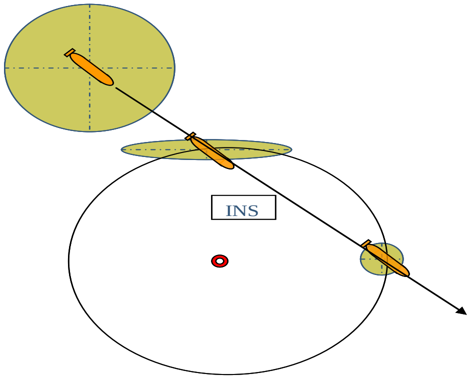
# IHO S44 guidelines

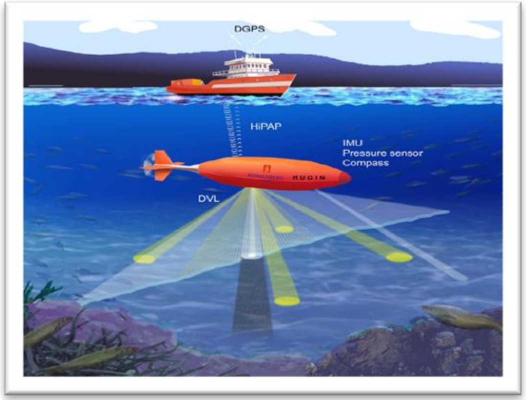
| Reference | Order | Special | 1a | 1b | 2 |
|---|---|---|---|---|---|
| Chapter 1 | **Description of areas.** | Areas where under-keel clearance is critical | Areas shallower than 100 metres where under-keel clearance is less critical but *features* of concern to surface shipping may exist. | Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area. | Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate. |
| Chapter 2 | **Maximum allowable THU 95% *Confidence level*** | 2 metres | 5 metres + 5% of depth | 5 metres + 5% of depth | 20 metres + 10% of depth |
| Para 3.2 and note 1 | **Maximum allowable TVU 95% *Confidence level*** | a = 0.25 metre<br>b = 0.0075 | a = 0.5 metre<br>b = 0.013 | a = 0.5 metre<br>b = 0.013 | a = 1.0 metre<br>b = 0.023 |
| Glossary and note 2 | ***Full Sea floor Search*** | Required | Required | Not required | Not required |
| Para 2.1<br>Para 3.4<br>Para 3.5<br>and note 3 | ***Feature Detection*** | Cubic *features* > 1 metre | Cubic *features* > 2 metres, in depths up to 40 metres; 10% of depth beyond 40 metres | Not Applicable | Not Applicable |
| Para 3.6 and note 4 | **Recommended maximum Line Spacing** | Not defined as *full sea floor search* is required | Not defined as *full sea floor search* is required | 3 x average depth or 25 metres, whichever is greater For bathymetric lidar a spot spacing of 5 x 5 metres | 4 x average depth |
| Chapter 2 and note 5 | **Positioning of fixed aids to navigation and topography significant to navigation. (95% *Confidence level*)** | 2 metres | 2 metres | 2 metres | 5 metres |
| Chapter 2 and note 5 | **Positioning of the Coastline and topography less significant to navigation (95% *Confidence level*)** | 10 metres | 20 metres | 20 metres | 20 metres |
| Chapter 2 and note 5 | **Mean position of floating aids to navigation (95% *Confidence level*)** | 10 metres | 10 metres | 10 metres | 20 metres |

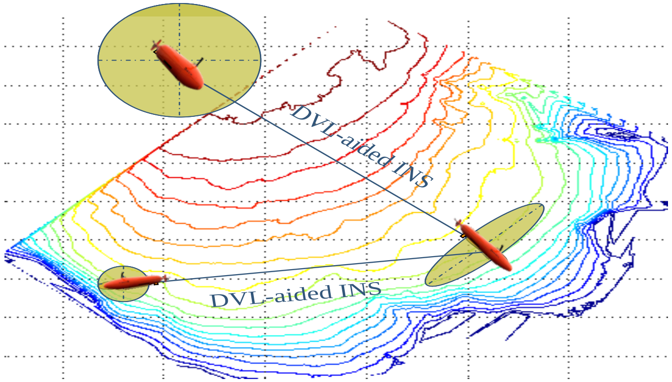
# Geo-Referenced Data

## NavP, HiPAP, UTP and Terrain Navigation

| Modes of Operation: | Navigation Error | |
|---|---|---|
| | Real-Time | Post-Processed |
| Autonomous: No updates, straight line | 0.1% of Distance Travelled | 0.1% of Distance Travelled |
| Autonomous: GPS fix every 1-2 hrs | 2 to 10 m | 1 to 4 m |
| Autonomous: NavP UTP ranging | 5 m | 2 m |
| Supervised: HiPAP USBL updates | 0.5 to 6 m (depending on depth and GPS accuracy) | 0.5 to 4 m |

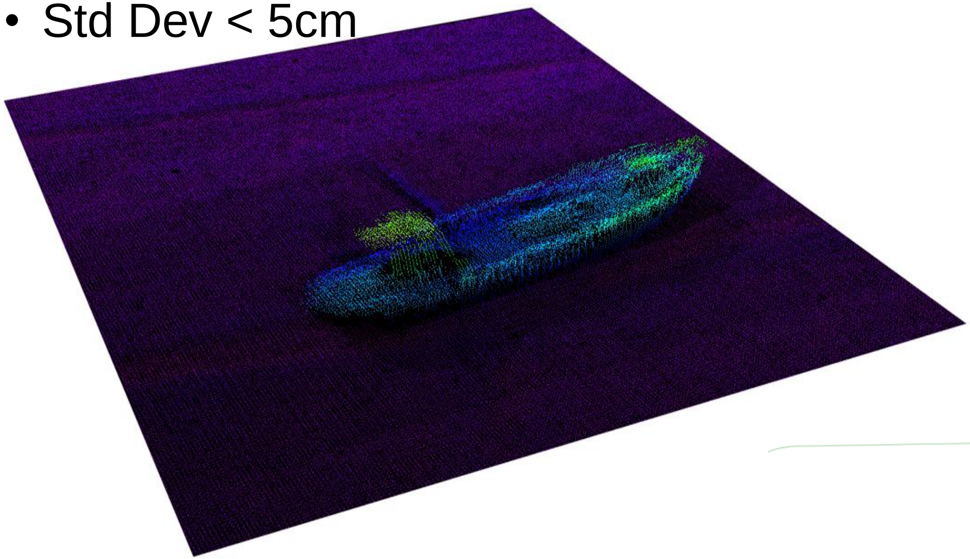


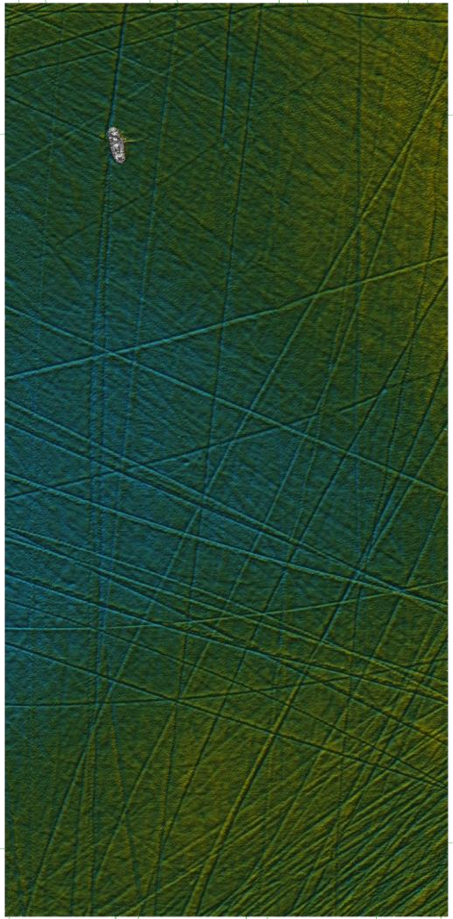



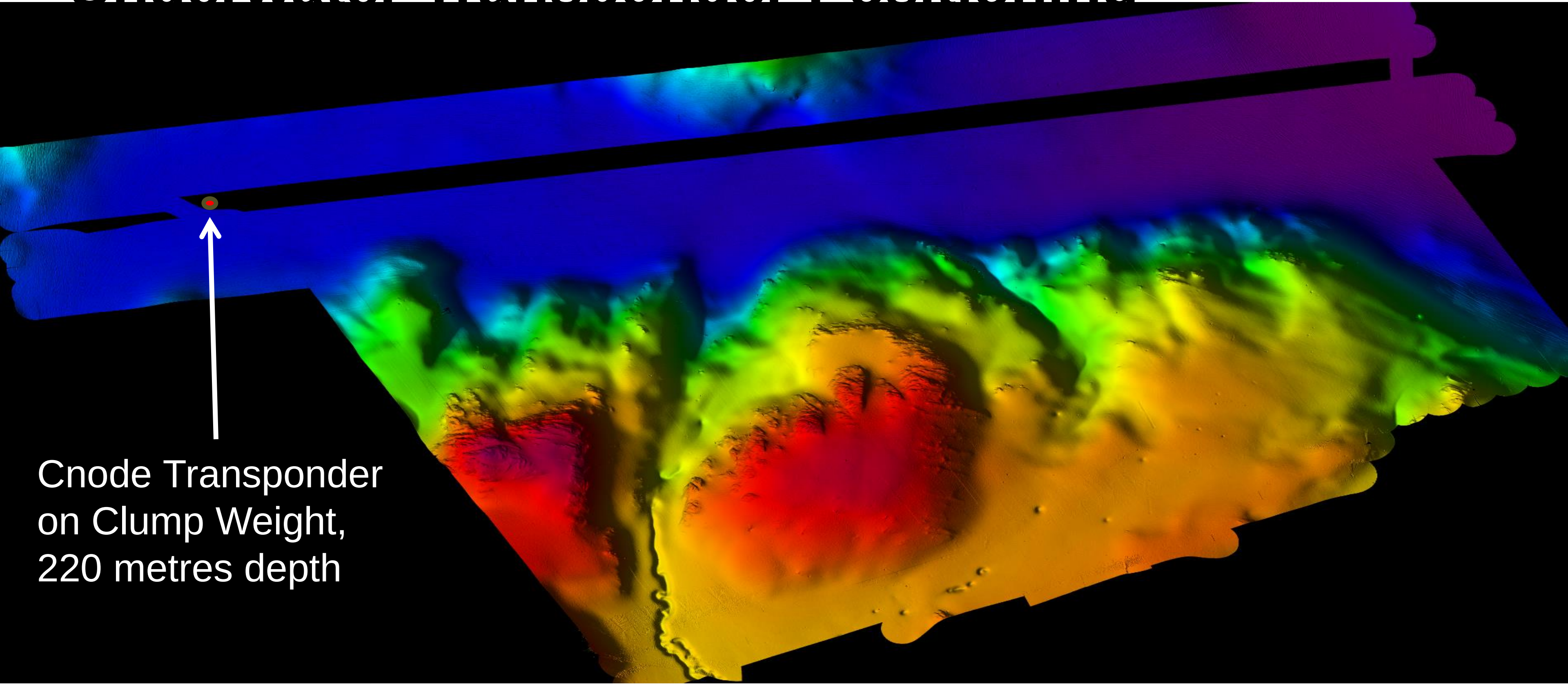
# Oslo Fjord

- USBL Aiding
- 200 metres depth
- Depth scale colours 25cm
- 4 passes < 15cm difference
- Std Dev < 5cm

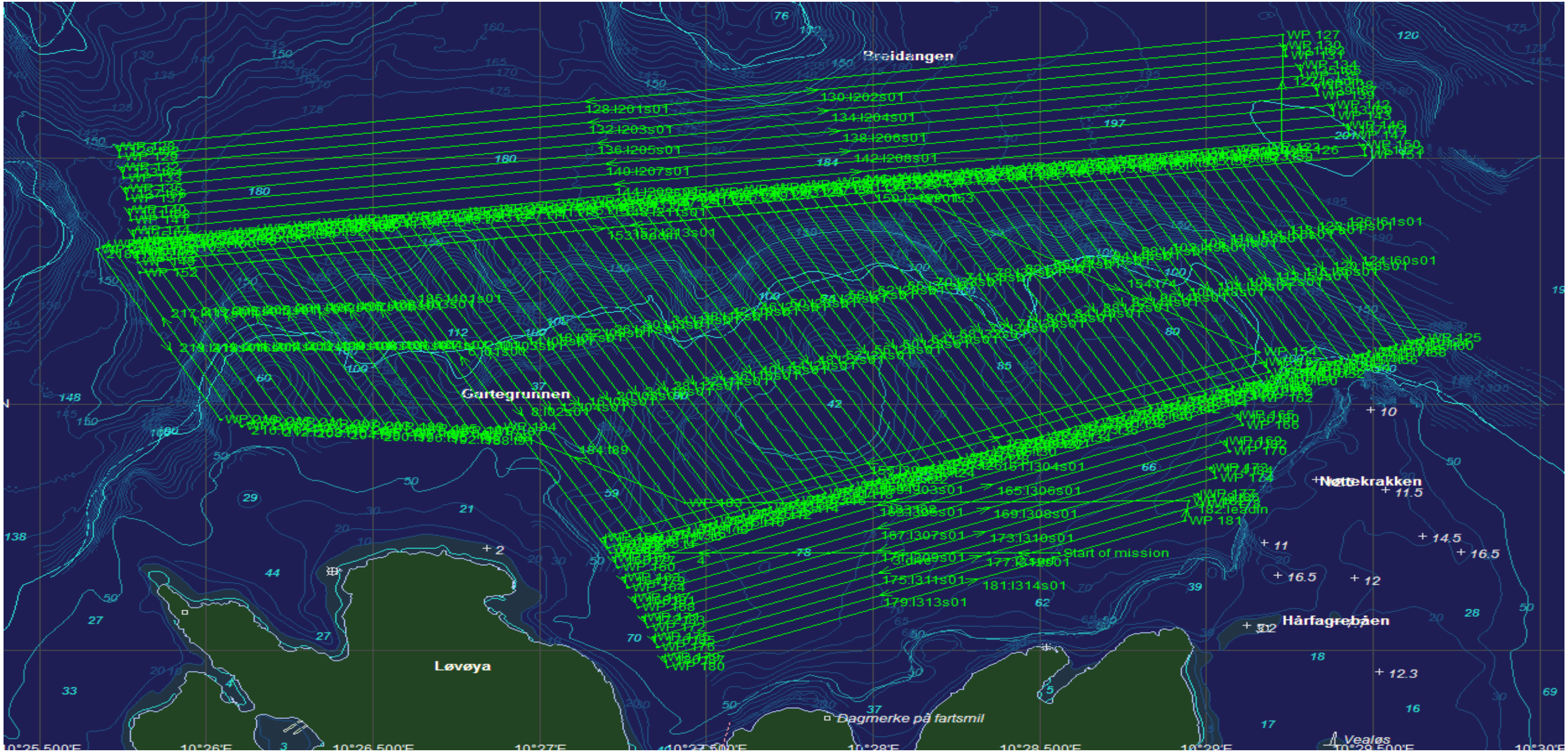


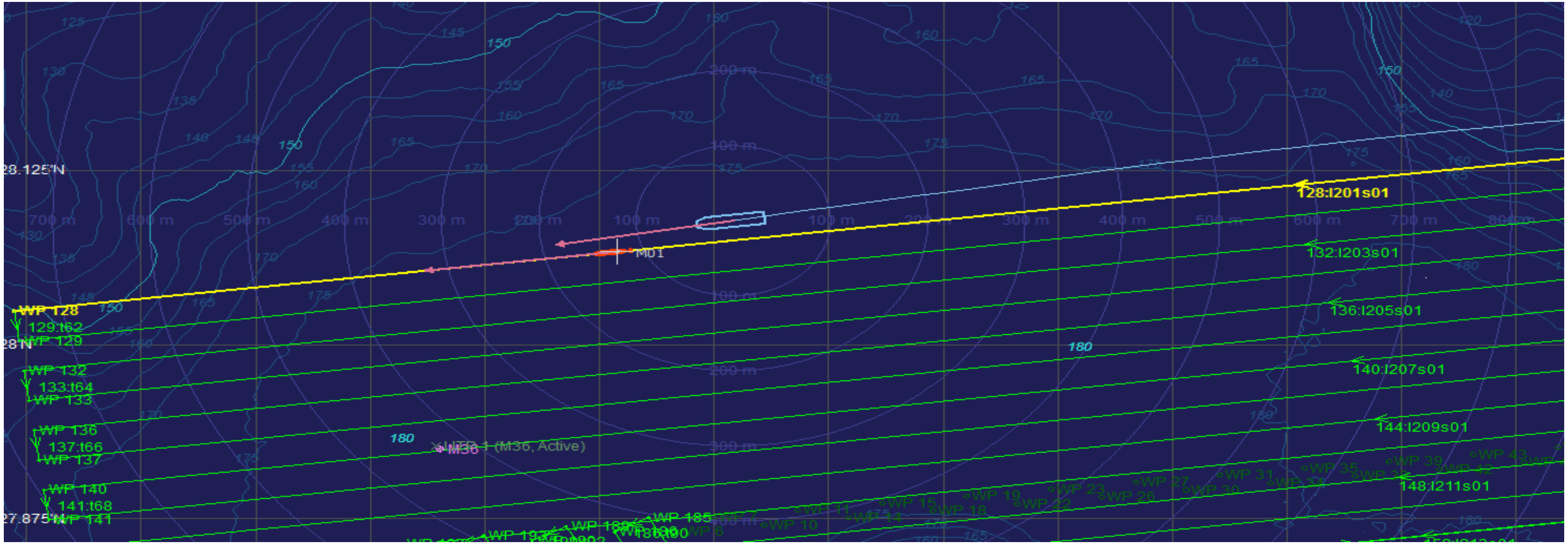


# UTP
# Underwater Transponder Positioning



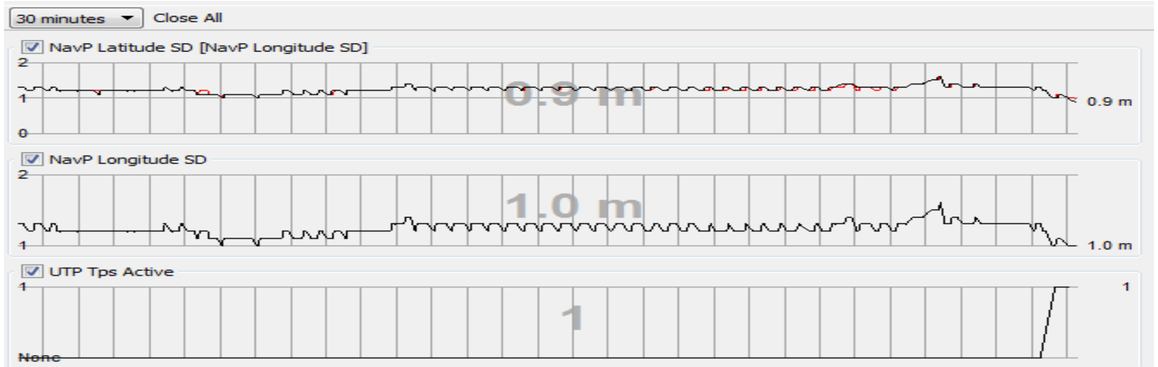
# Mission Plan

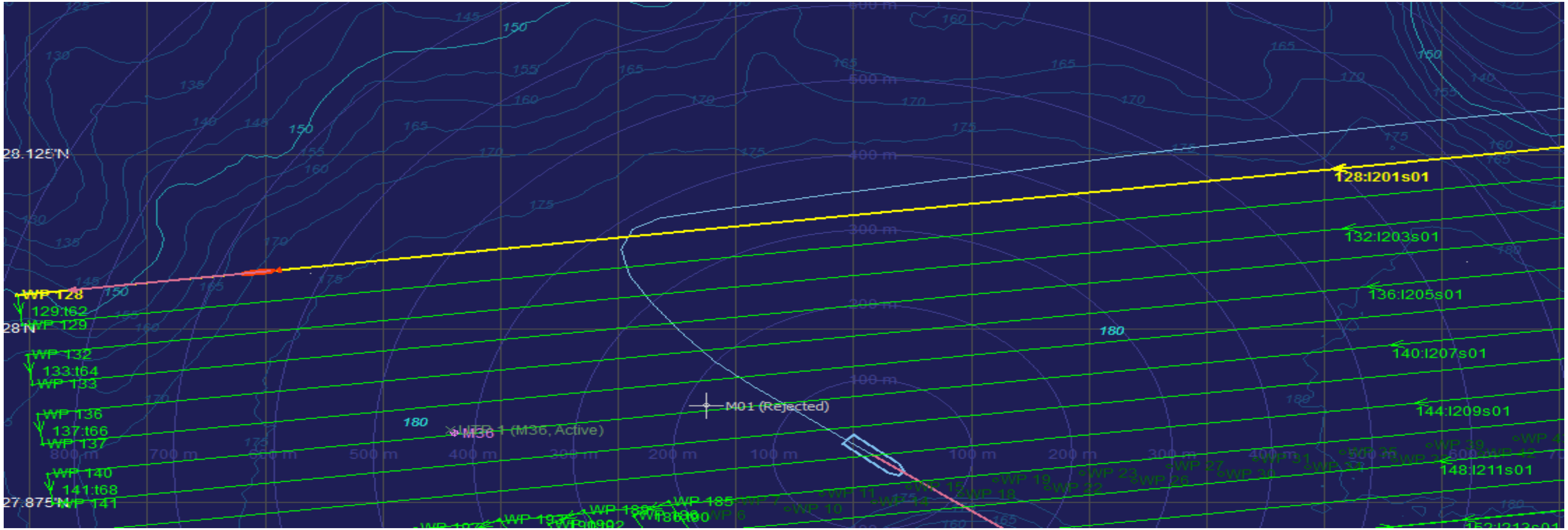




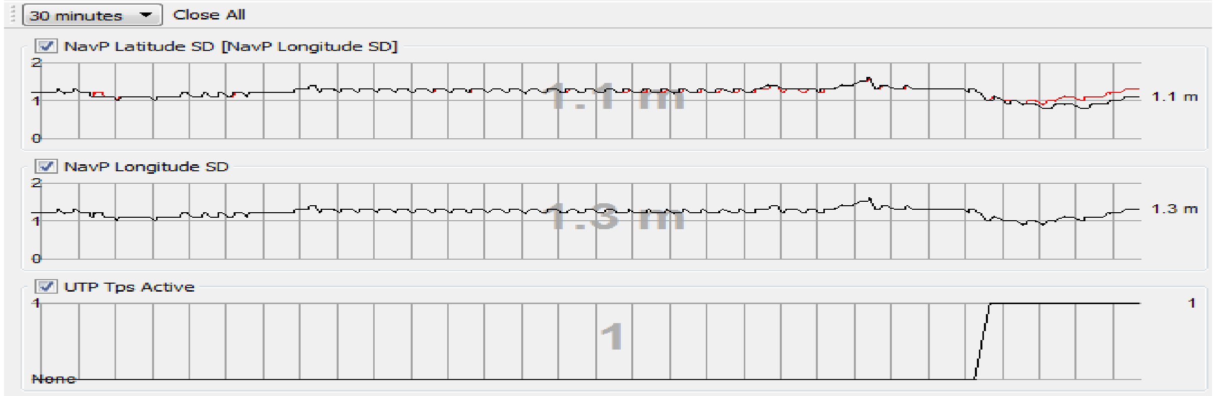

HiPAP Aiding, all good.

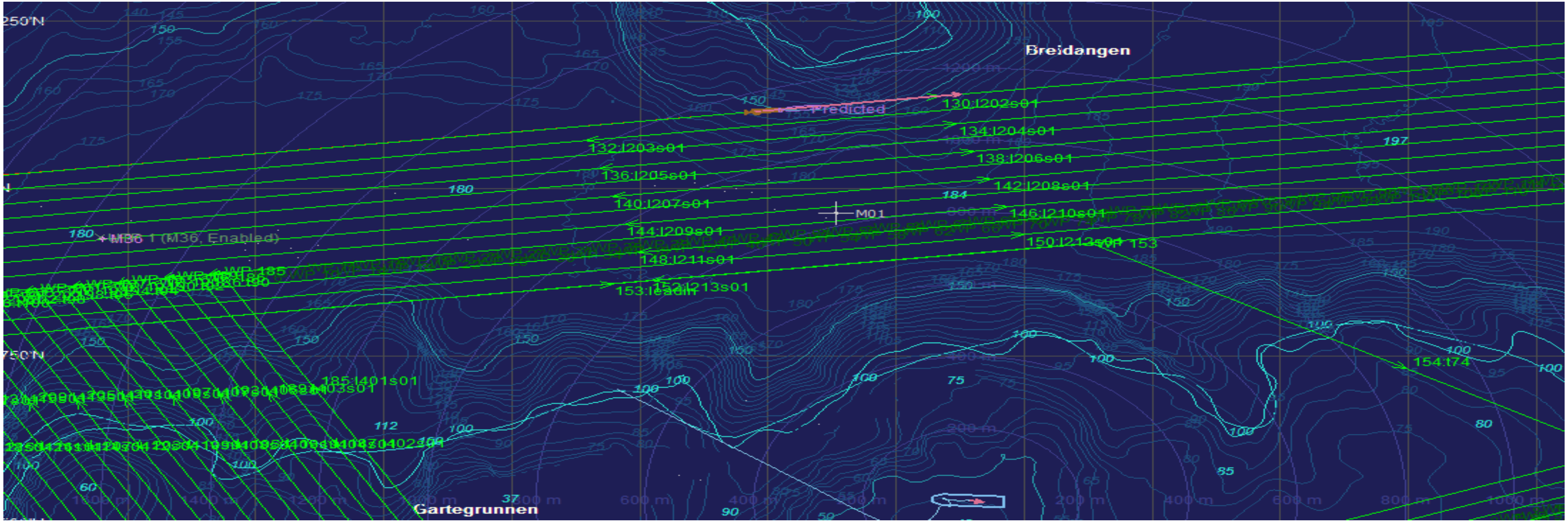
Expected 1m predicated error in 200 metres






# HiPAP Aiding Off, UTP Transponder Active.

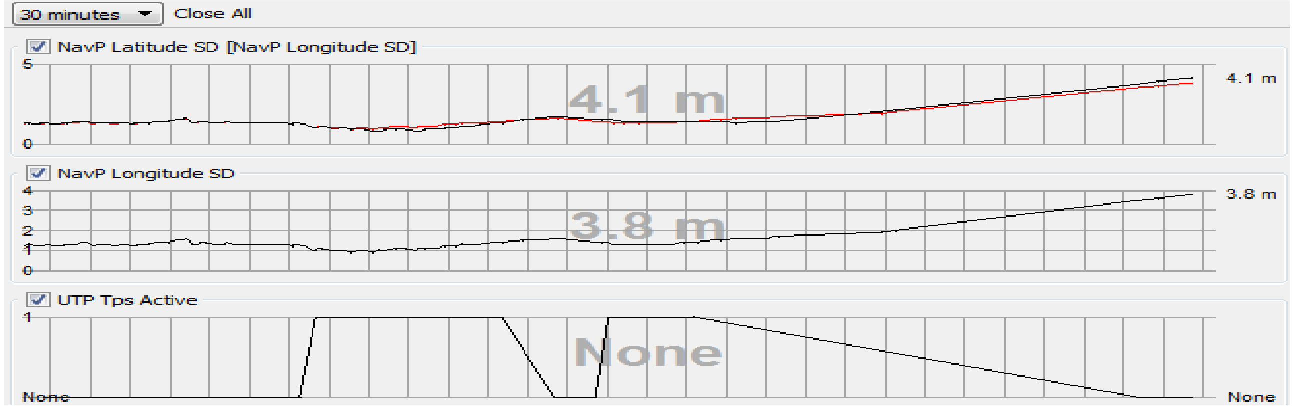


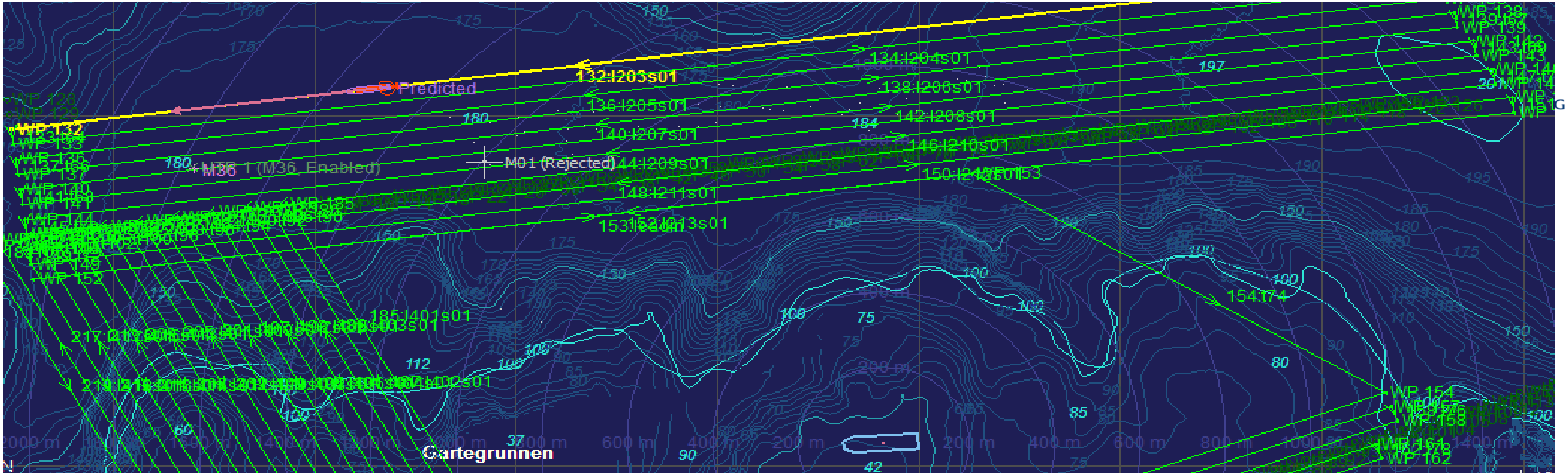



Gradual rise in Std Dev

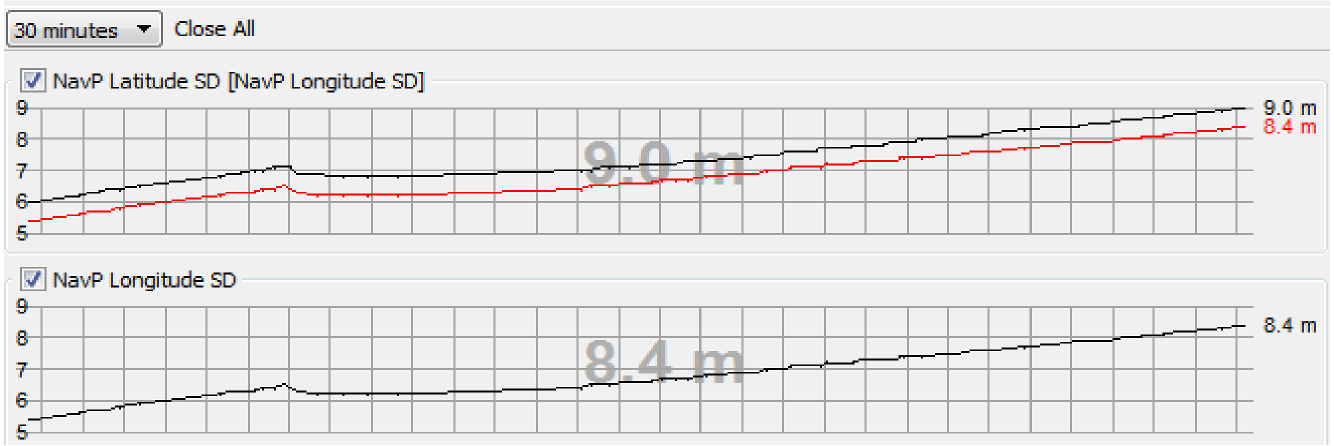
Both northing and easting.

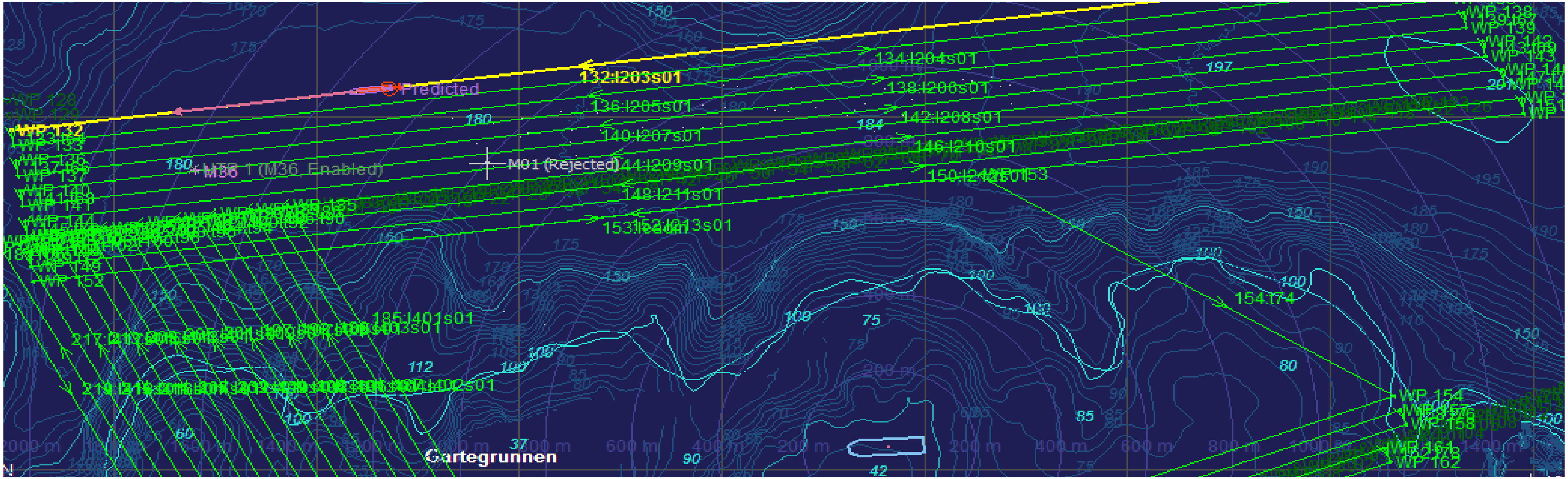
Note drop out due to range in turn



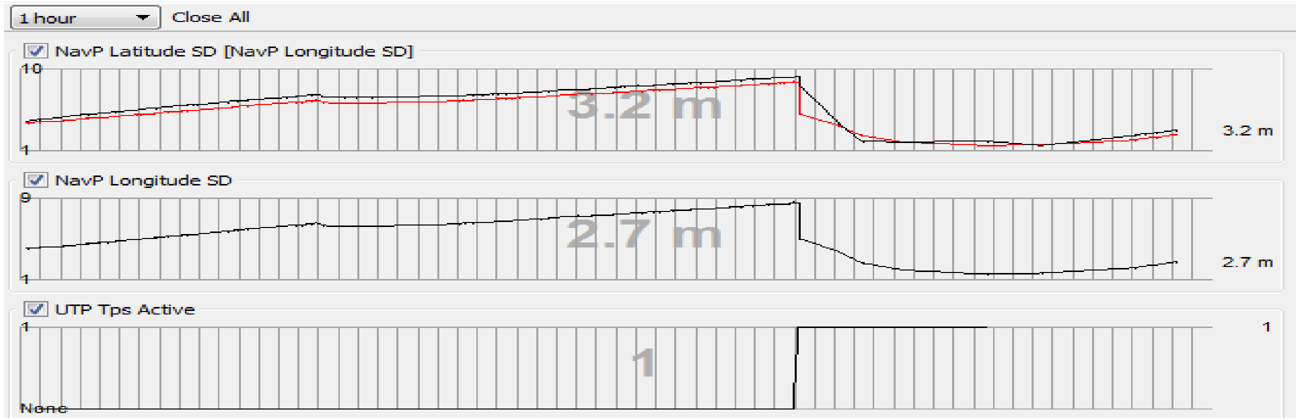


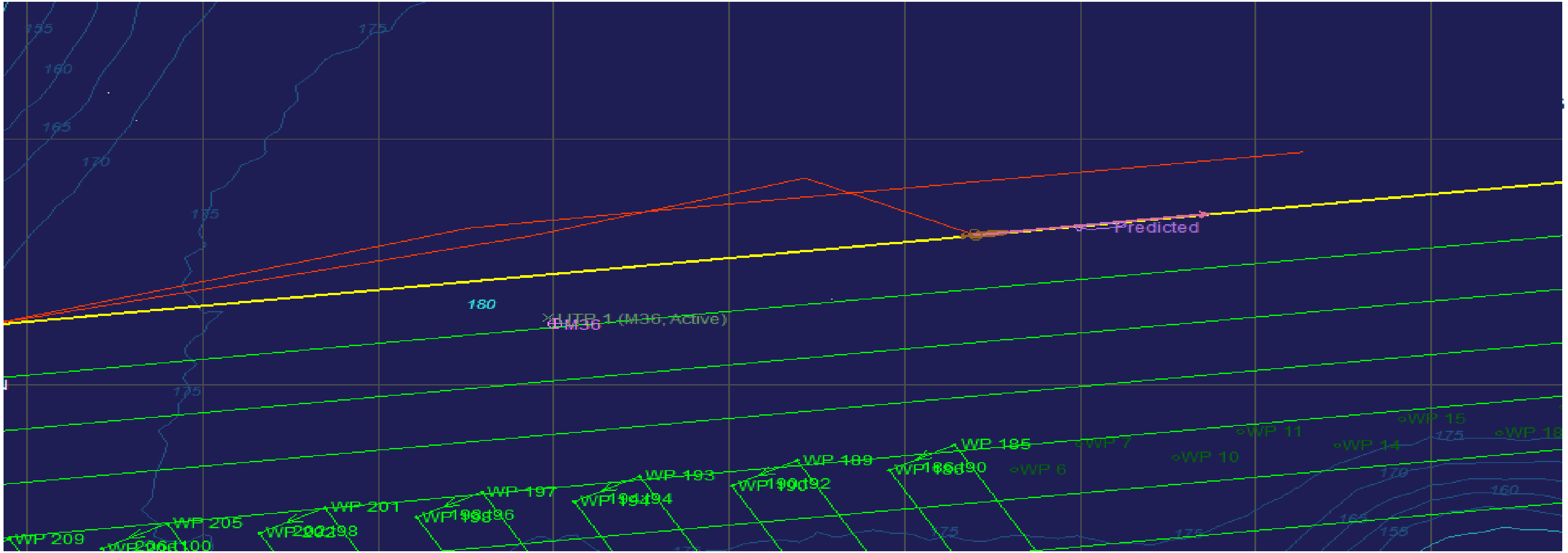
One hour after losing UTP, error estimated at 9 metres





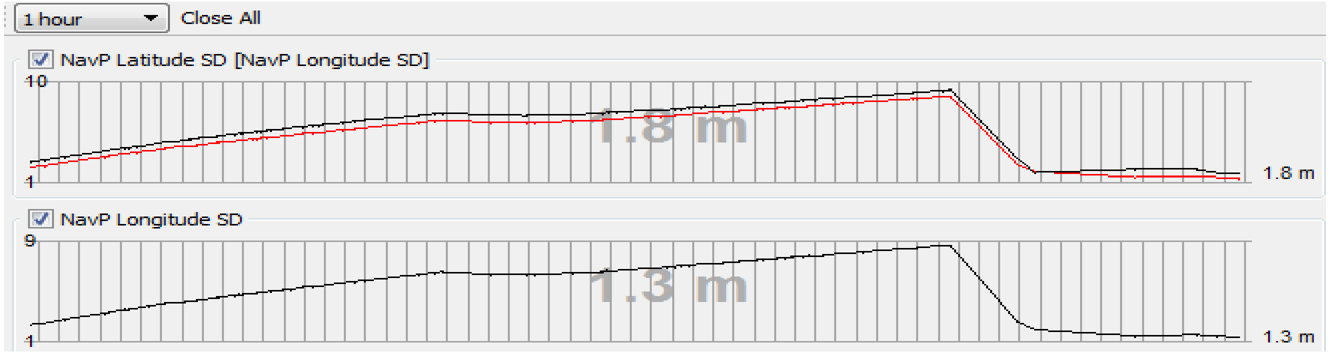

Regains UTP, drop off to 2.5 metres



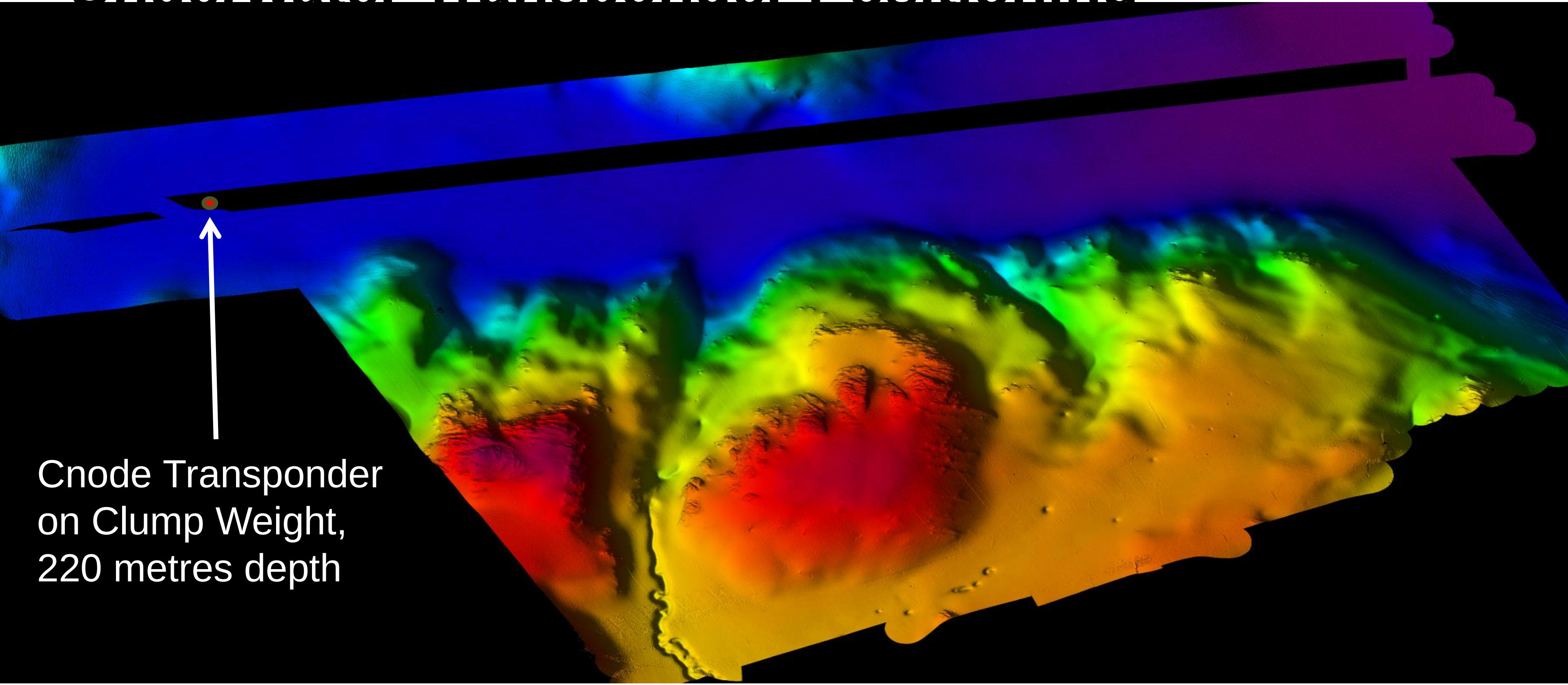



UTP Good but vehicle makes large corrections to track.

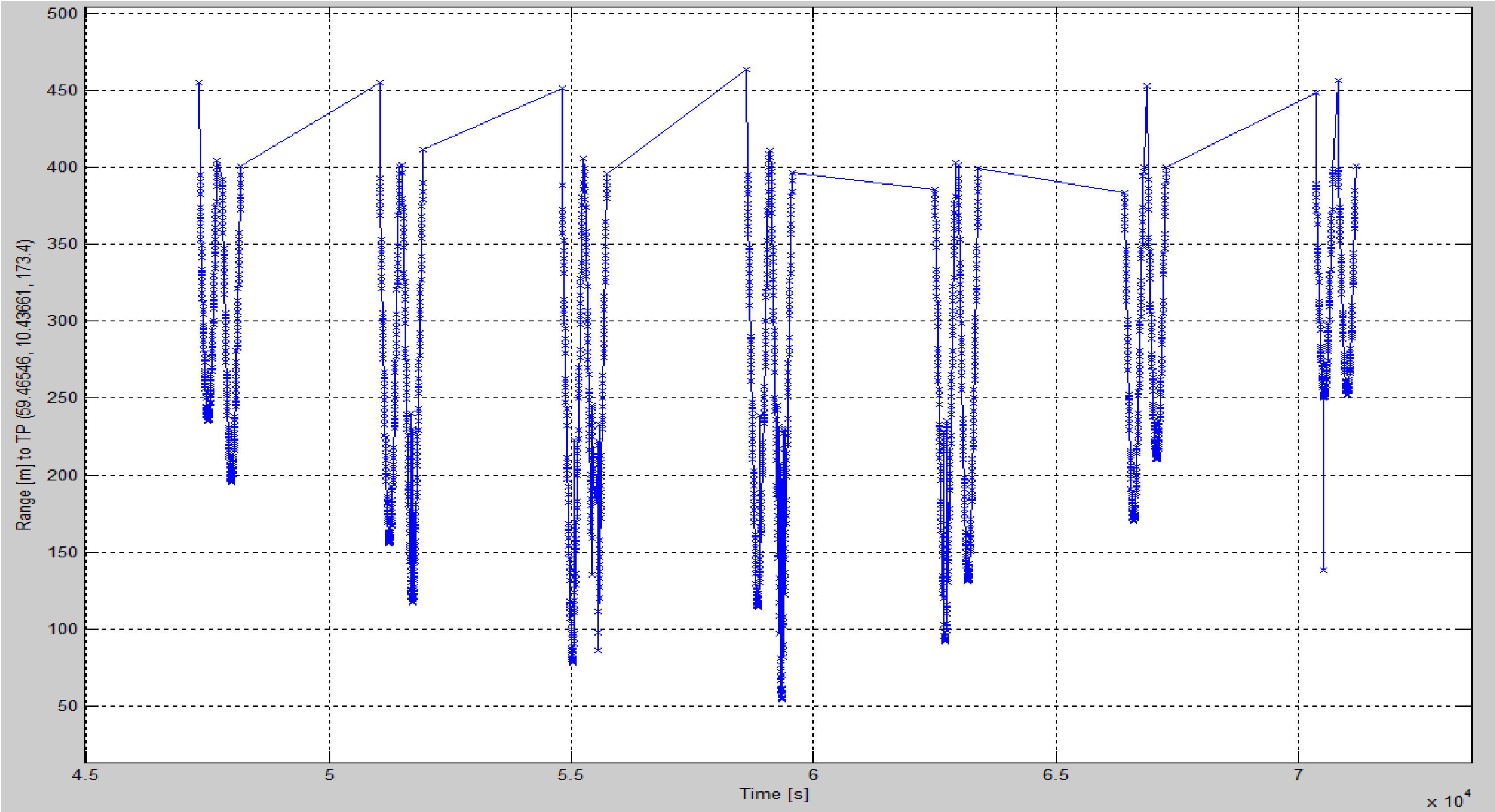
Problem?



# UTP
# Underwater Transponder Positioning

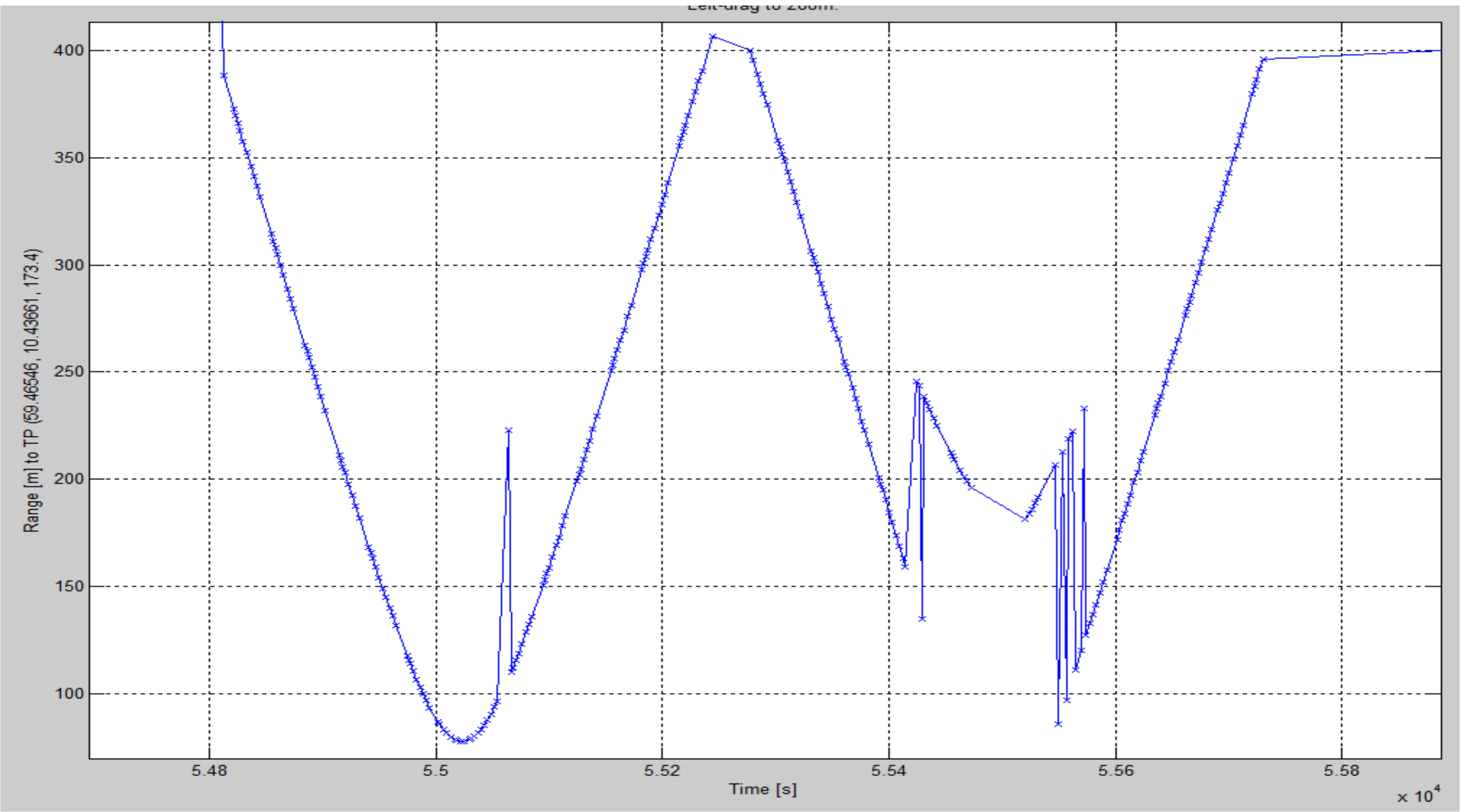


# Raw UTP



Range [m] to TP (59.46546, 10.43661, 173.4)
500
450
400
350
300
250
200
150
100
50
4.5
5
5.5
6
6.5
7
Time [s]
x 10^4

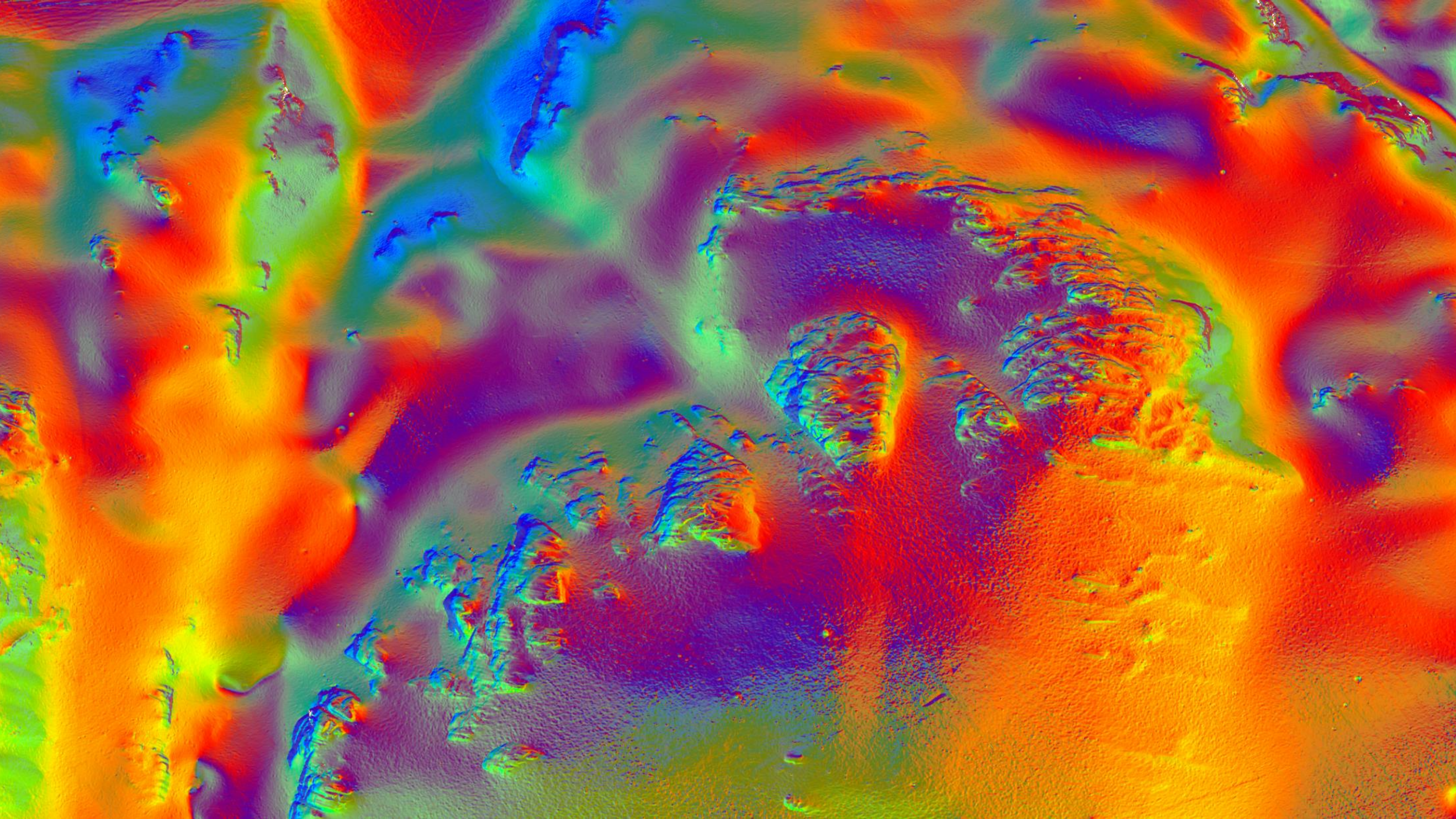
# Surface reflections taken as true



ERRPAR.INI - Notepad

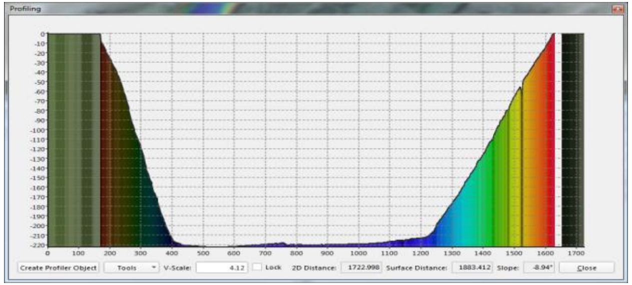
File Edit Format View Help

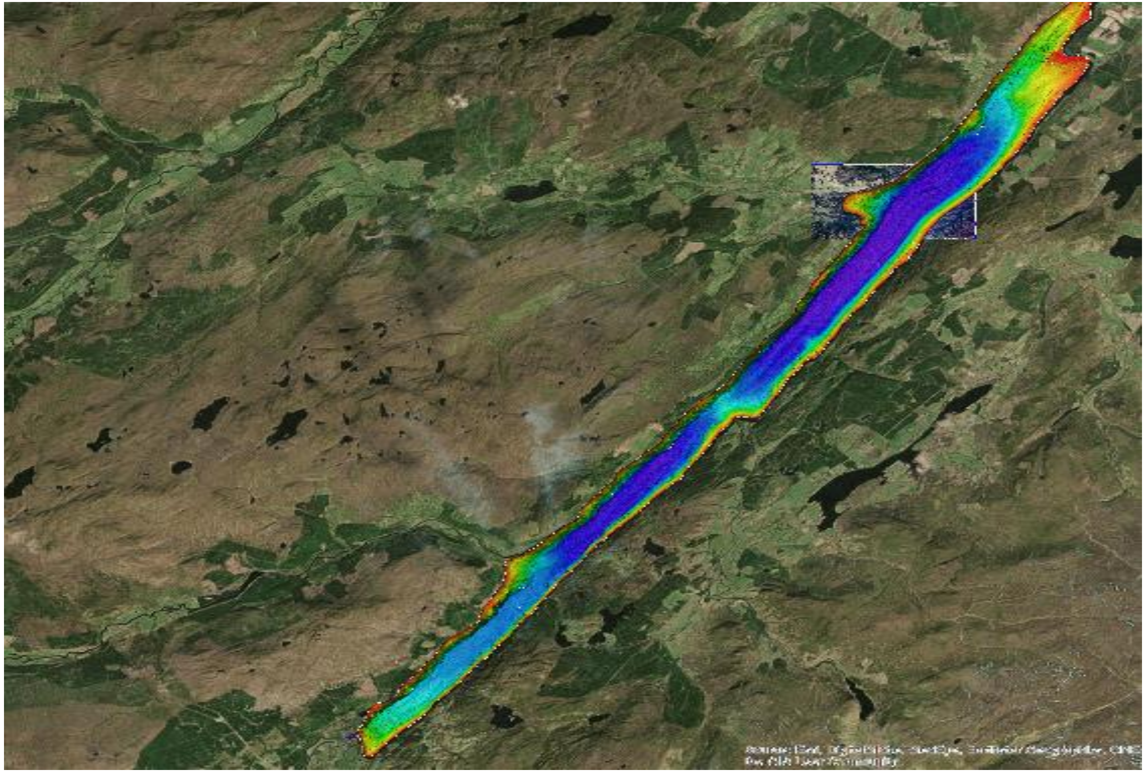
```
[Version]
FileVersion = 8.4.0        # Must match CP major and minor version, e.g. 7.2.x.
                           # Do not change this version before updating the file according to the s

[ErrorDetection]
#CP
DiveTimeLimit             =    300000   # ms
DiveDepthLimit            =    5.0      # m
CriticalStdDevLatitude    =    50.0     # m
CriticalStdDevLongitude   =    50.0     # m

#NavP
DvlSigmaTestLevel                = 5.0     # DVL sigma test factor, i e 5*sigma. sigma = std dev
MaxDvlSigmaTestRejects           = 10      # Max number of consecutive DVL sigma test rejects
VehicleGpsSigmaTestLevel         = 15.0    # Vehicle GPS sigma test factor
MaxVehicleGpsSigmaTestRejects    = 100     # Max number of consecutive Vehicle GPS sigma test rejects
UtpSigmaTestLevel                = 5.0     # UTP sigma test factor
MaxUtpSigmaTestRejects           = 10      # Max number of consecutive UTP range sigma test rejects
MaxShipGpsNavpTimeDifference     = 3000    # ms

[ErrorHandling]
MinErrmsgRetransIntv                = 5000                     #ms - min interval between error msg retran
ErrorBlockList                      =                          #Comma separated list of error numbers to b
MaxNoOfSmartMotorRestarts           = 3
SmartMotorRestartDelayInSurface     = 10000                    # ms
SmartMotorRestartDelaySubmerged     = 60000                    # ms
DepthChangeIfAltimeterFailure       = 40.0                     # m
MinDepthIfAltimeterFailure          = 0.0                      # m
HighControlContTempLimit            = 40.0 # [Celcius], CP high temperature limit
CritControlContTempLimit            = 50.0 # [Celcius], CP critical temperature limit
HighPayloadContTempLimit            = 40.0 # [Celcius], PP high temperature limit
CritPayloadContTempLimit            = 50.0 # [Celcius], PP critical temperature limit

[ErrorDetection]
DoDgpsHipapSigmaFiltering           = 1
DgpsHipapSigmaTestLevel             = 50
MaxDgpsHipapSigmaTestRejects        = 4
```



# So, Loch Ness.

- Its Big
- Its Deep
- And its been surveyed lots!
- Around 40km x 2km
- We believe 227 meters deep
- Just a bathtub



# Project Aims

- Waveforms

Discovered in Feb 2013 from Remus 100 Geoswath equipped

- The “Trench”

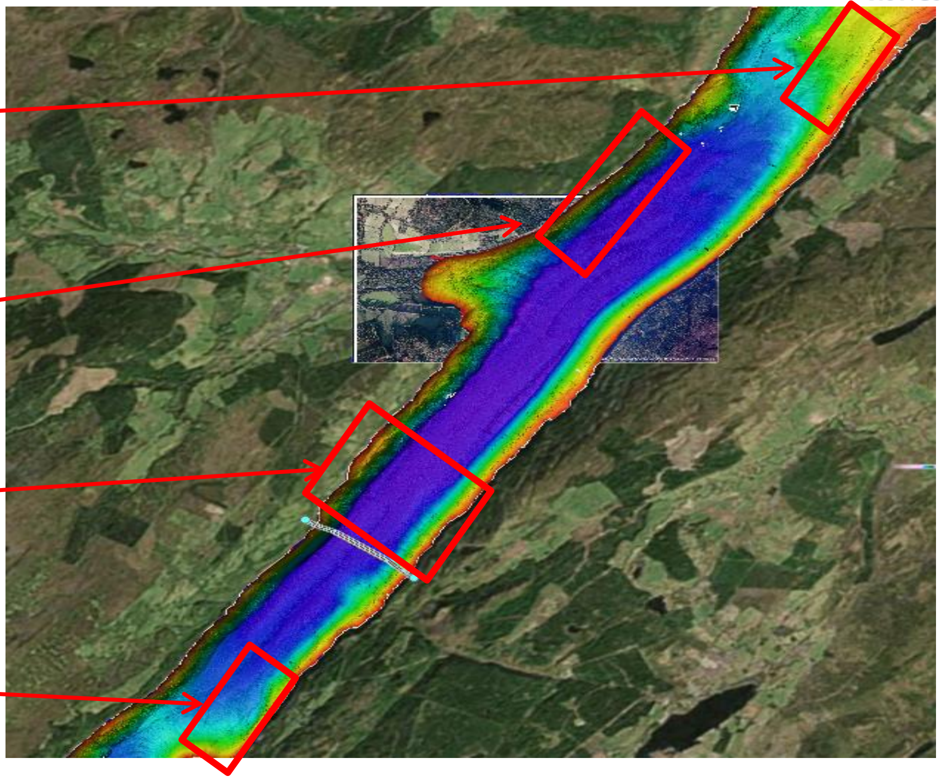
Discovered in Jan 2016, 270-290 metre trench discovered??

- Cobbs Engine

Tragic Speed record attempt 1952.

- Foyers Outlet

Large subsea Landslip



# Low Logistics



# Vessel of Opportunity

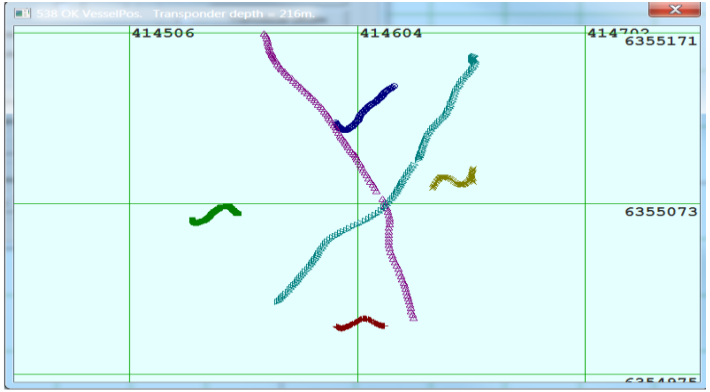


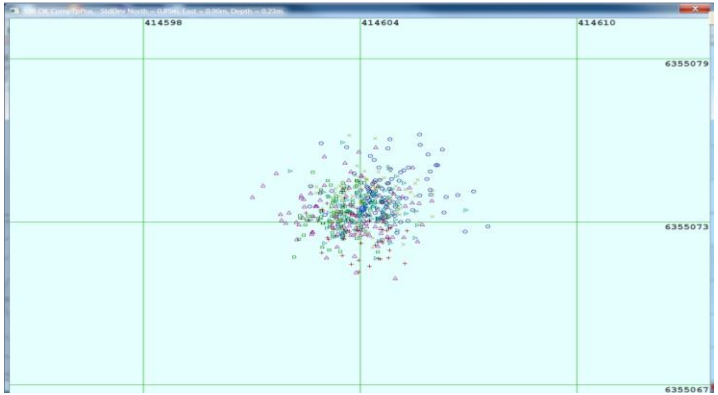
# Simple Launch and Recovery

# HiPAP Configuration/GPS

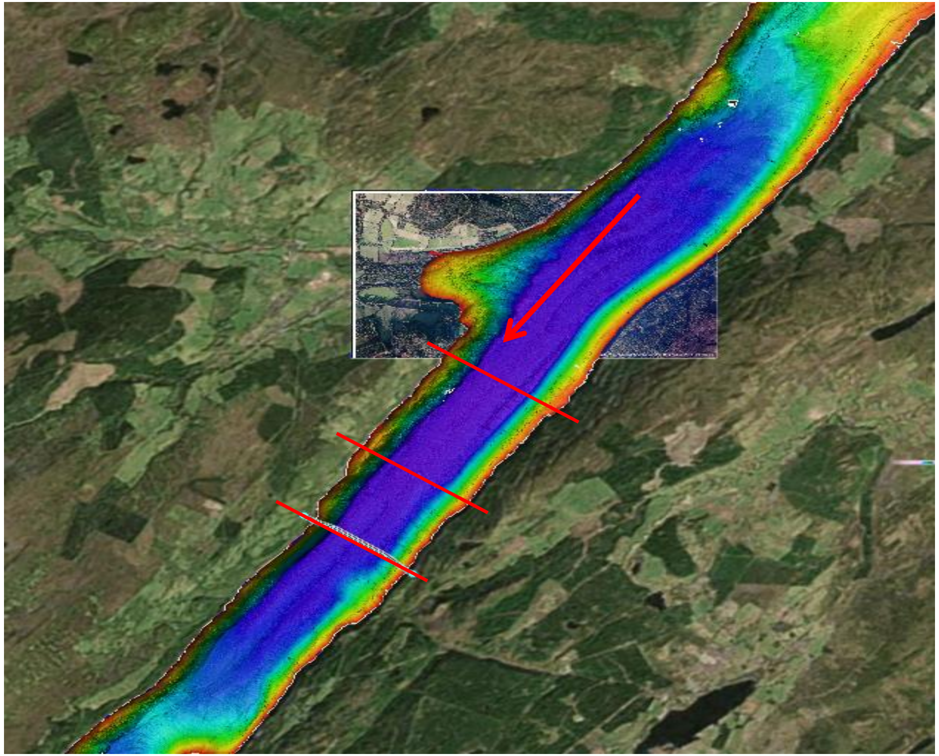
**Transponder boxed-in position**

| | |
|---|---|
| Northings | 6355073.48 m |
| Eastings | 414604.07 m |
| Depth | 215.95 m |
| 1-sigma error ellipse | 0.21 m, 0.19 m 106 ° |
| Depth 1-sigma accuracy | 0.09 m |

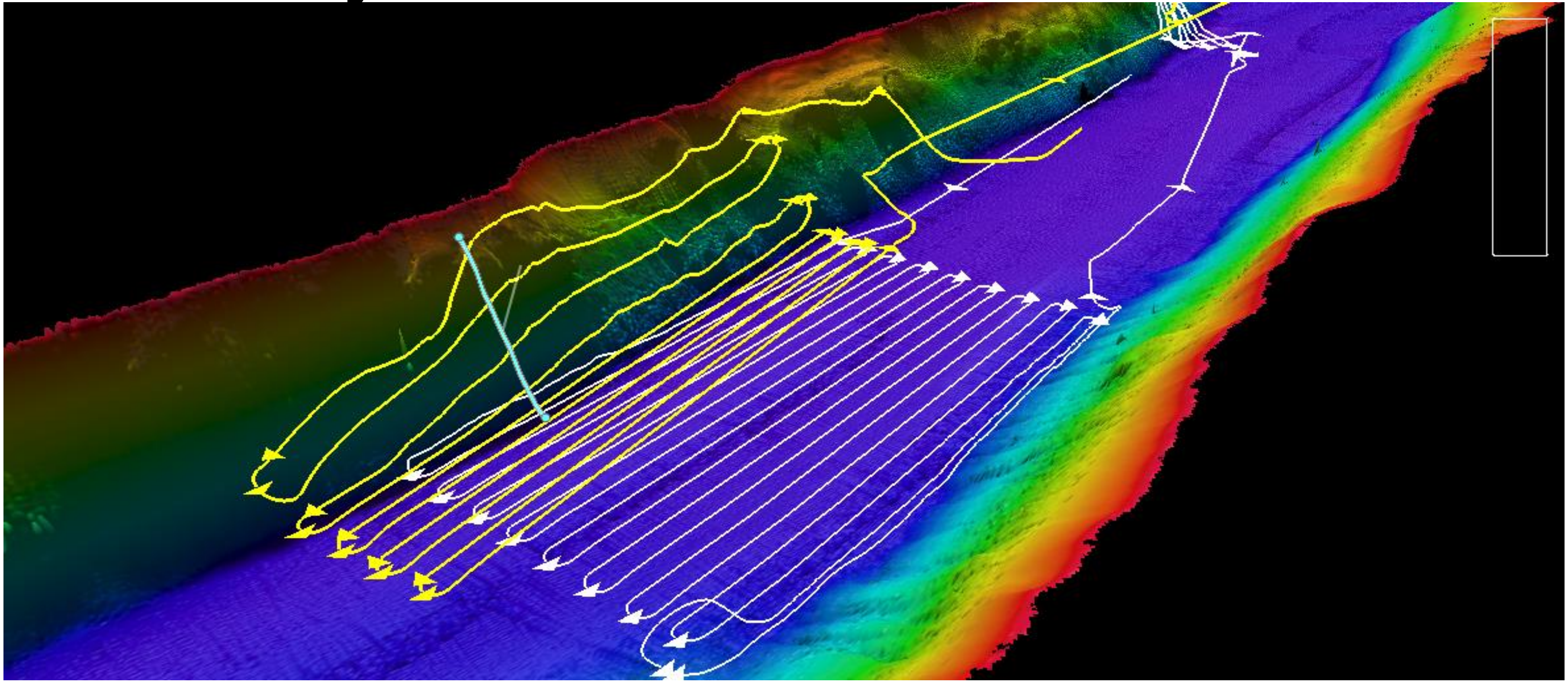


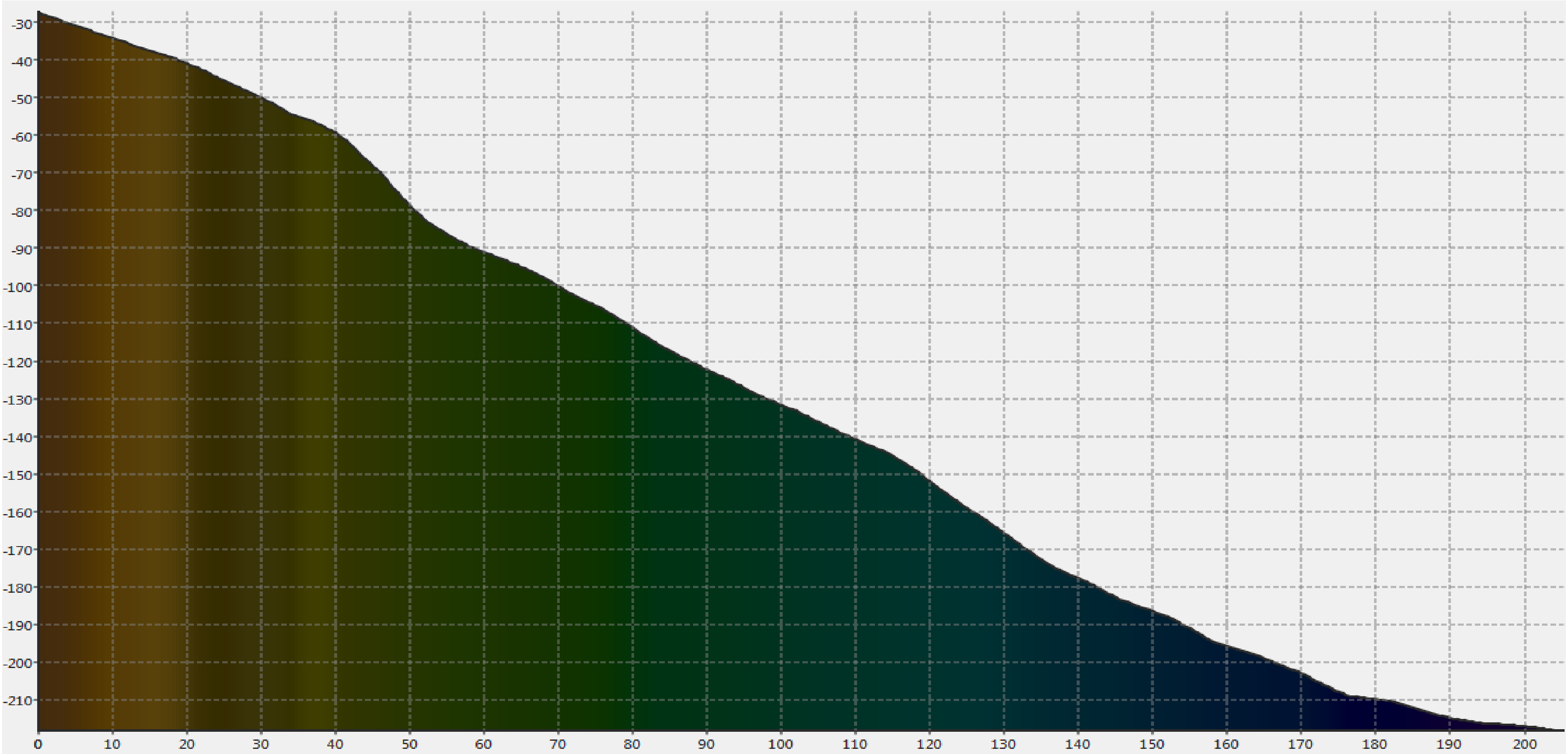
# John Cobb Surveys, JC1 and JC2



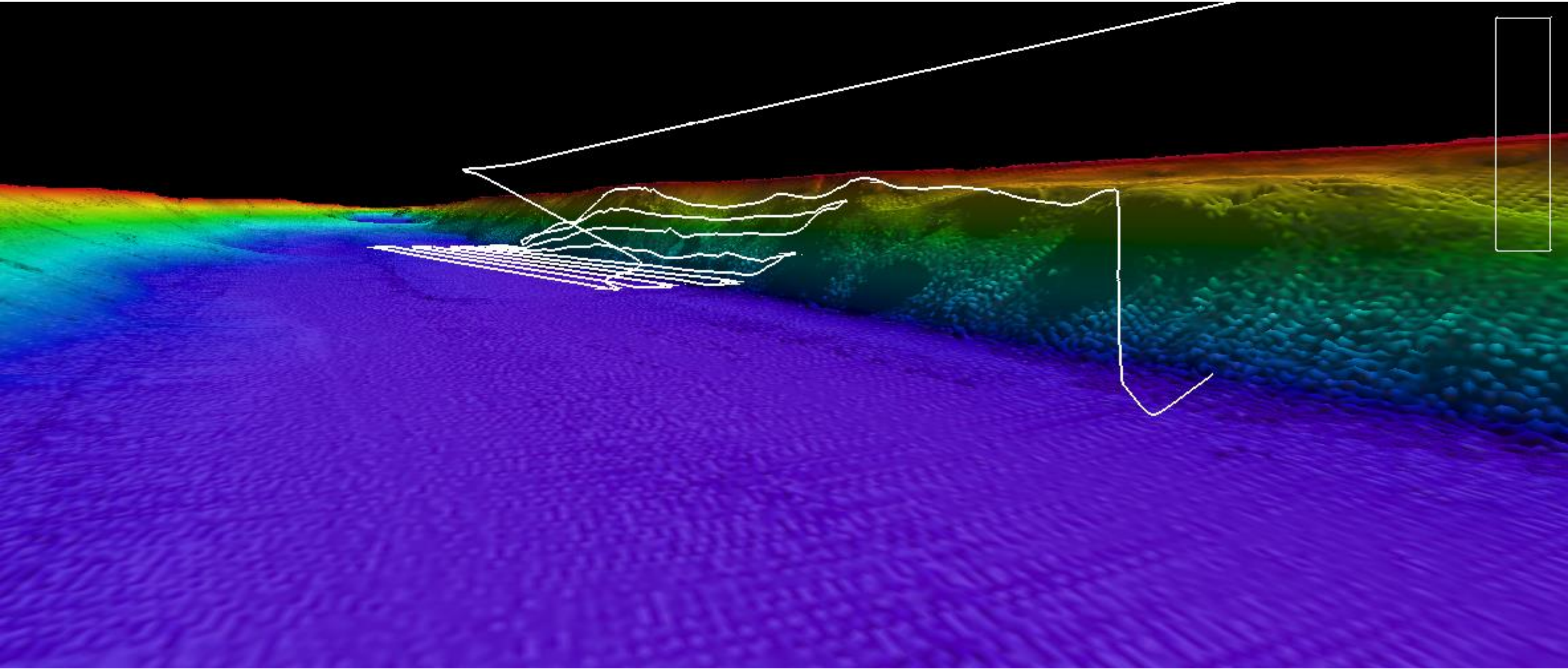
# Two surveys/missions



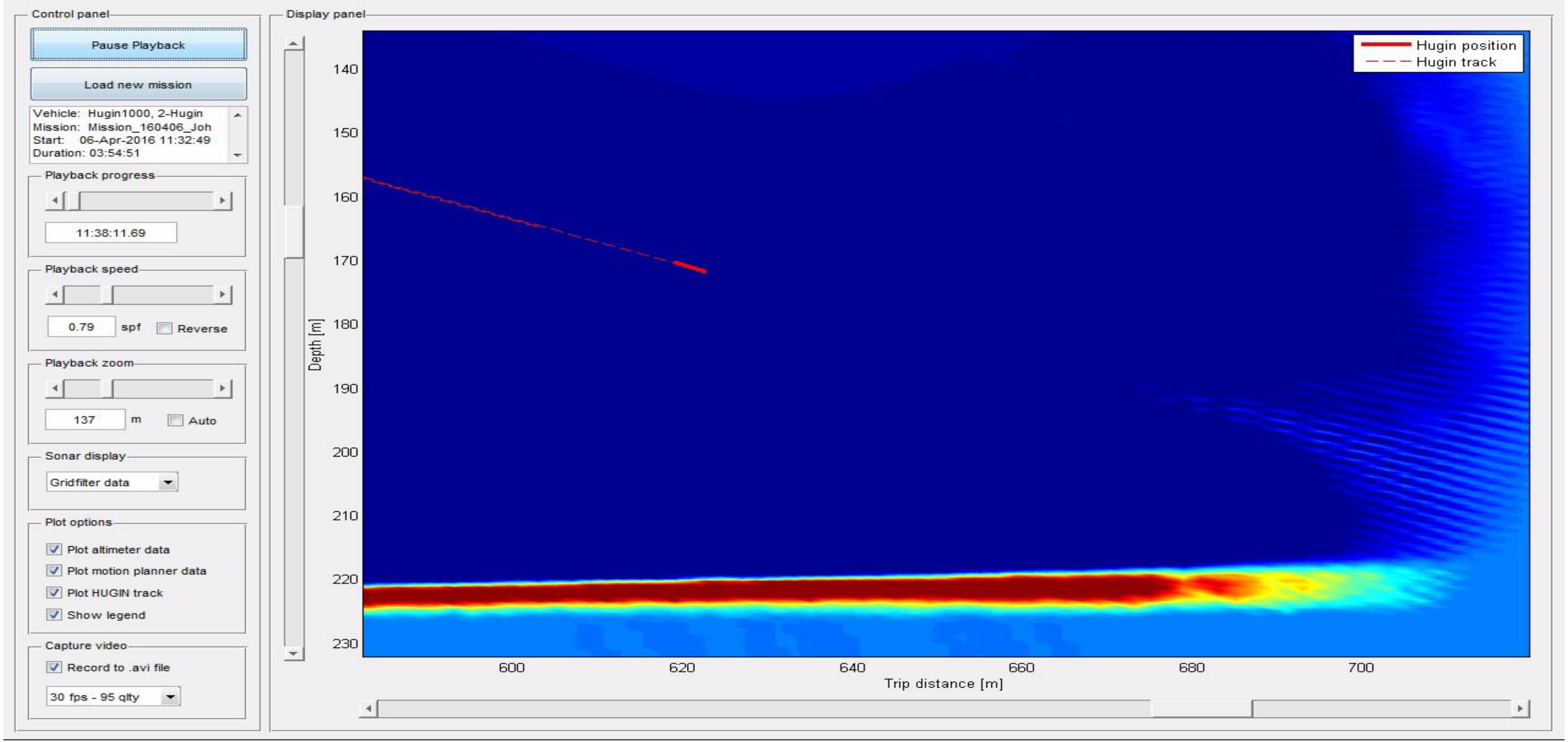
# Sides of 1:1


-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200

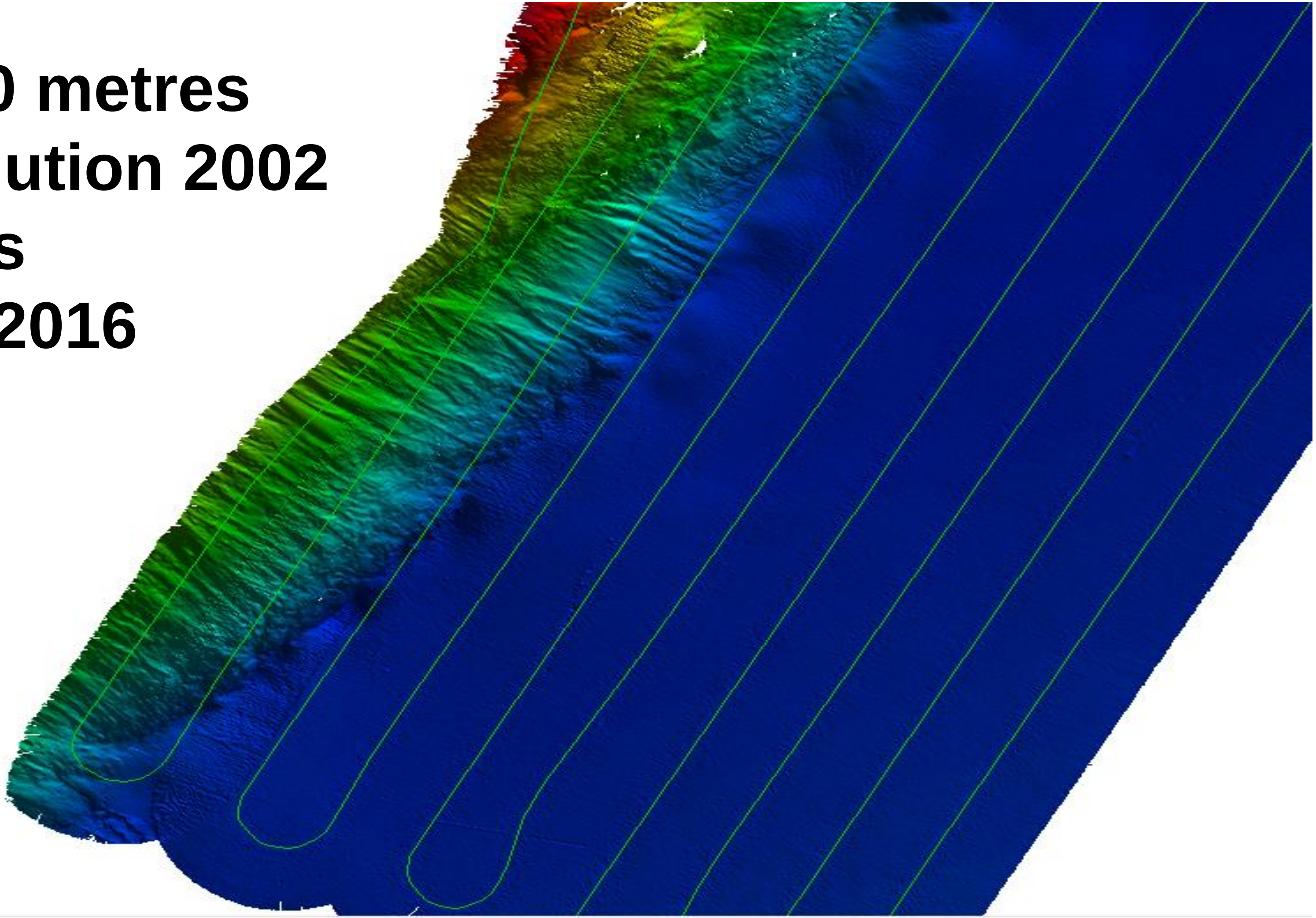
# No Vertical Exaggeration

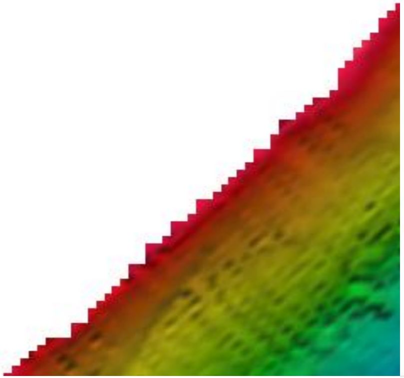


# Forward Looking Sonar

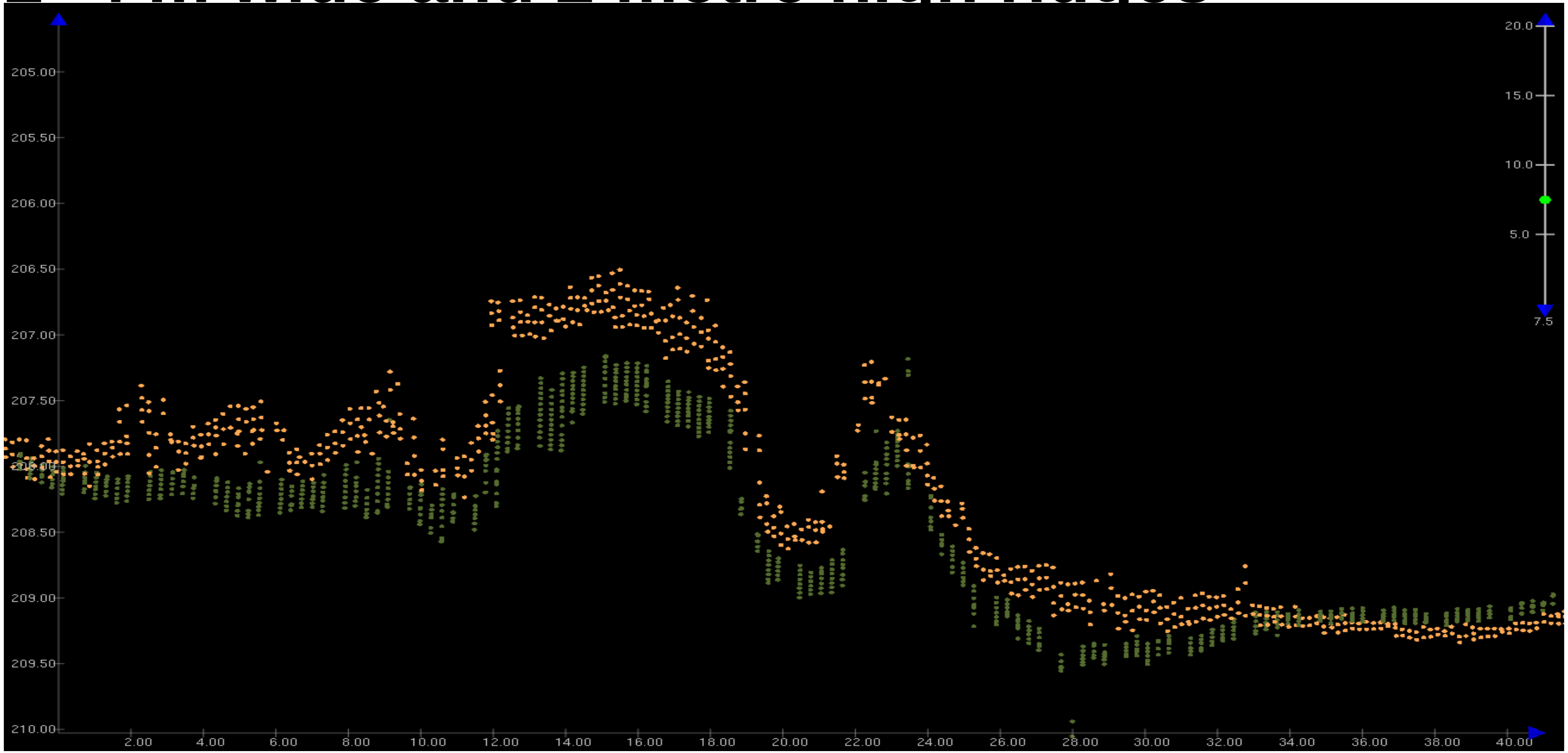


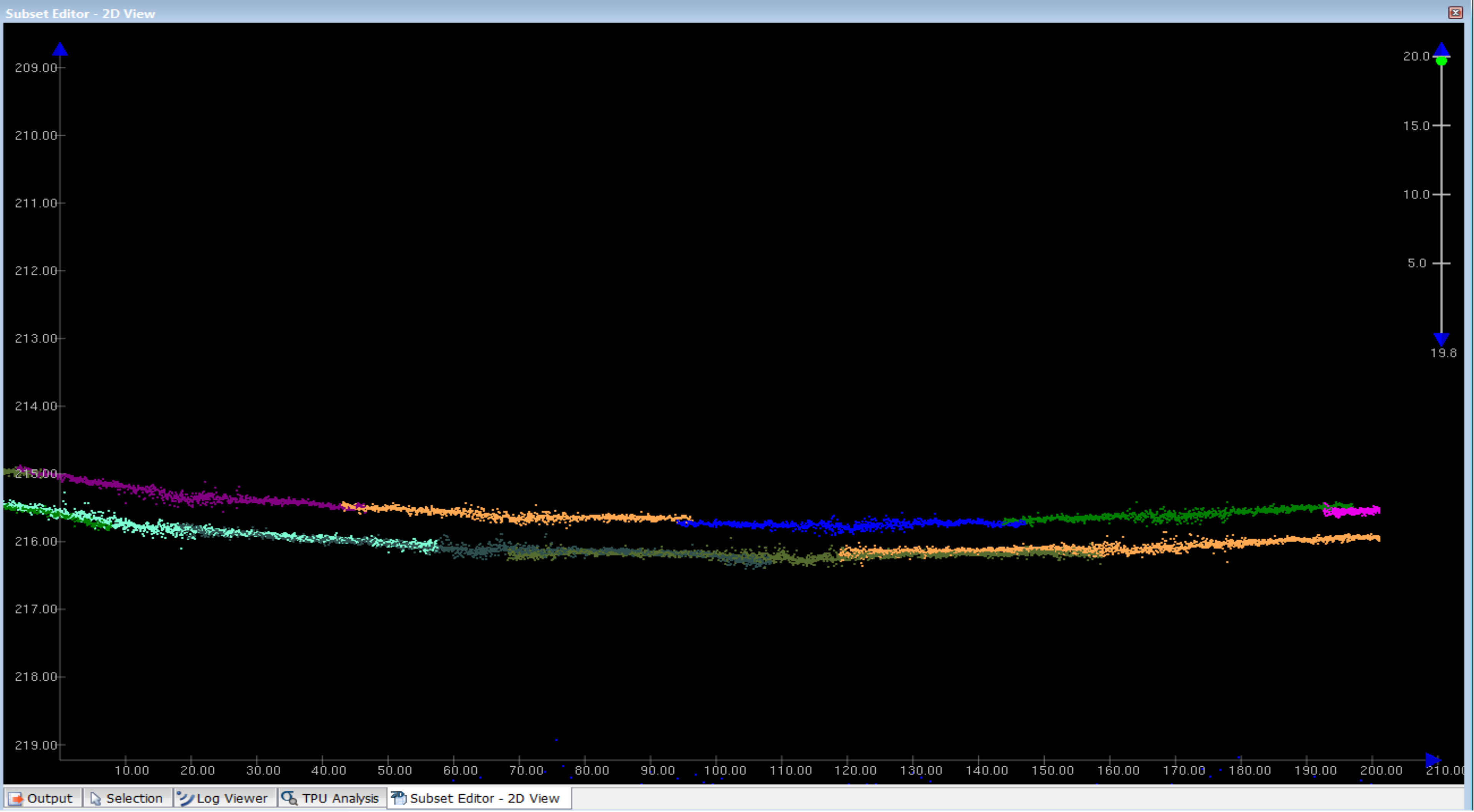
# 40 >> 210 metres
# Surface Solution 2002
# Vs
# AUV 2016





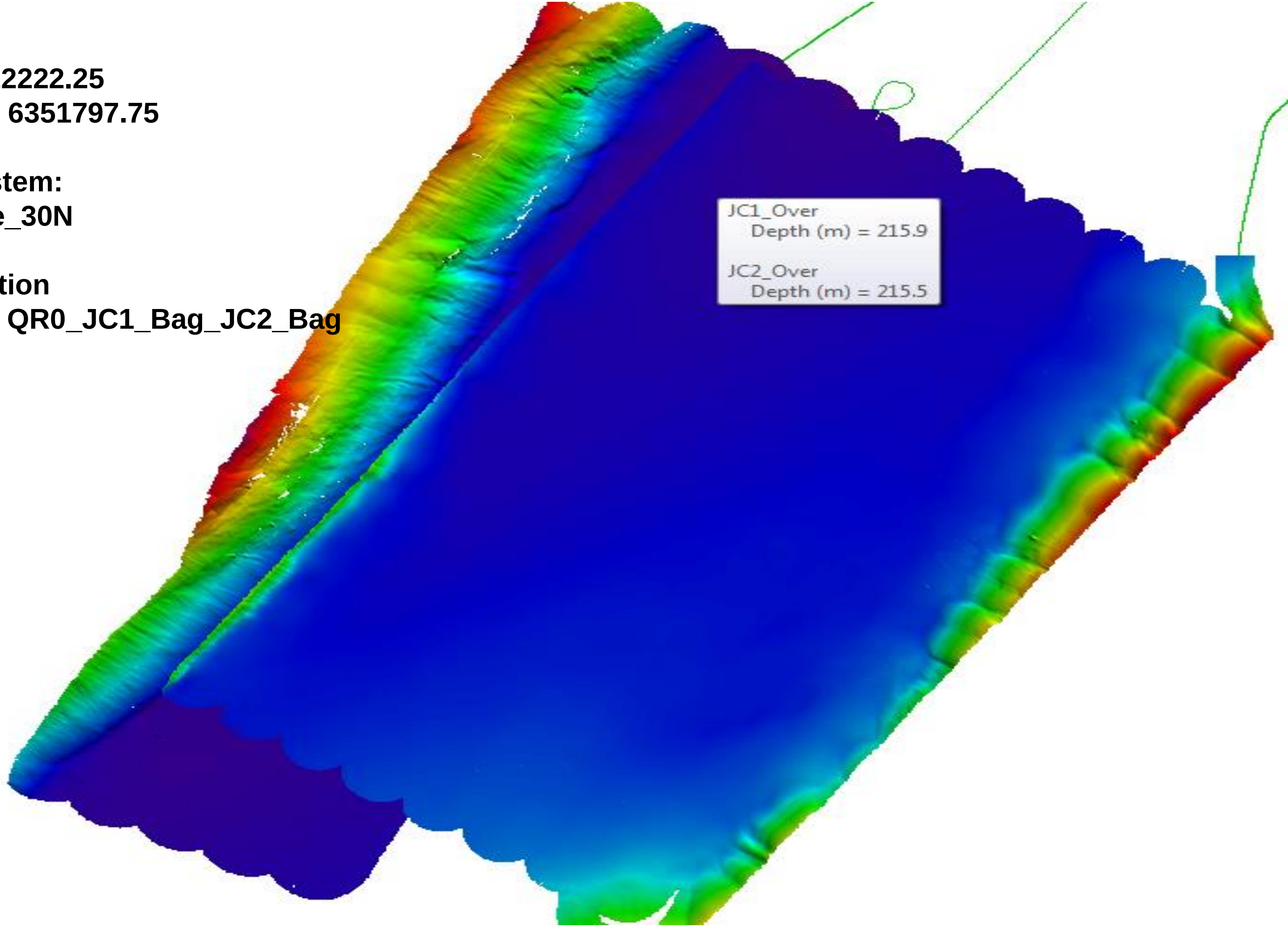
# JC1 and JC2
# 2- 4 m wide and 2 metre high ridges



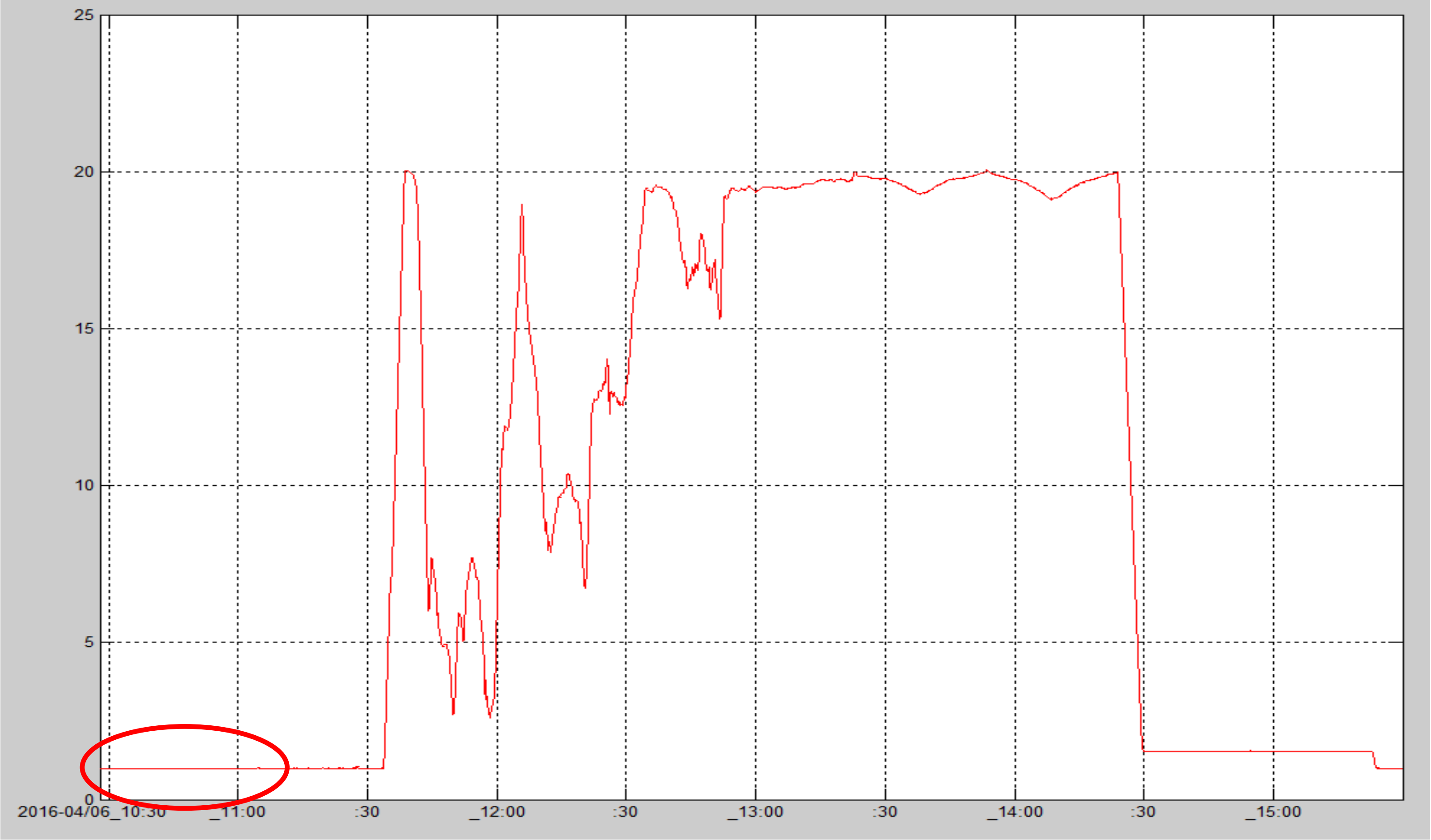

Subset Editor - 2D View
209.00
210.00
211.00
212.00
213.00
214.00
215.00
216.00
217.00
218.00
219.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
110.00
120.00
130.00
140.00
150.00
160.00
170.00
180.00
190.00
200.00
210.00
20.0
15.0
10.0
5.0
19.8
Output
Selection
Log Viewer
TPU Analysis
Subset Editor - 2D View

X Range: 411620.25 to 412222.25
Y Range: 6351149.75 to 6351797.75
Z Range: -8.17 to 4.91
Horizontal Coordinate System:
FP_WGS_84_UTM_zone_30N

Surface Statistics Information
Name: Selected Area from QR0_JC1_Bag_JC2_Bag
Median: -0.49
Mean: -0.48
Std Dev: 0.06



# Atmospheric Pressure

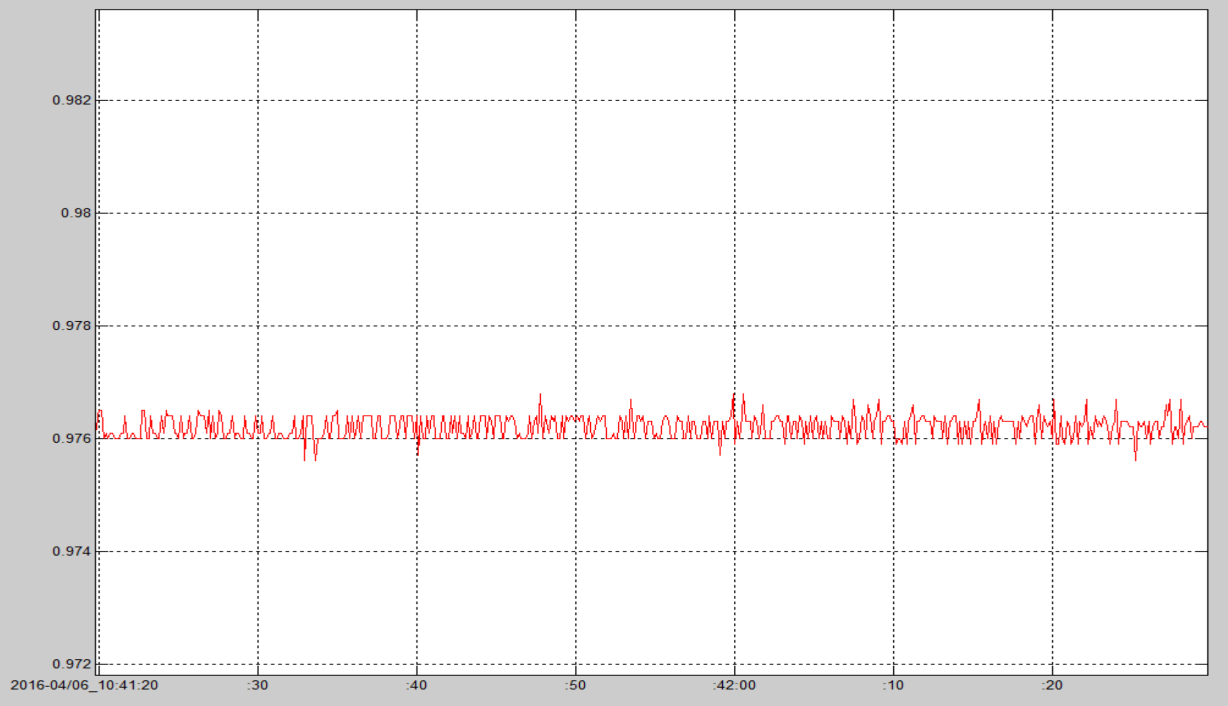


# Compensate for Atmospheric

## Depth =(Pressure*1e5/ (Water Density*Gravity)

**976mBar**
**Hence system**
**over reads pressure.**
**Need to add difference**

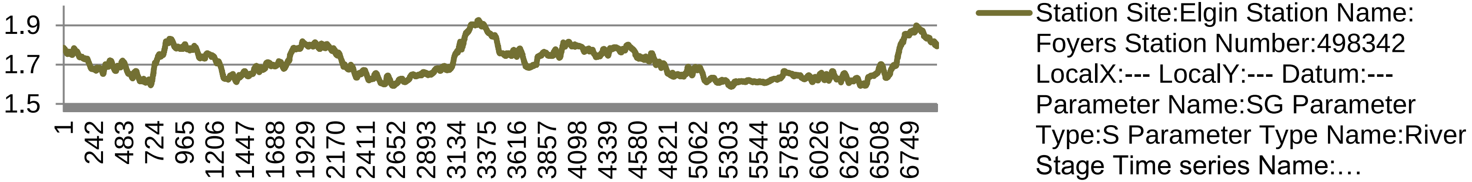
**1 Bar = 10.1844m**
**JC1 0.976 = 9.9298m**
**JC2 1.008 = 10.2659m**
**Change in depth, 34cm**
**Still missing 14 cm**



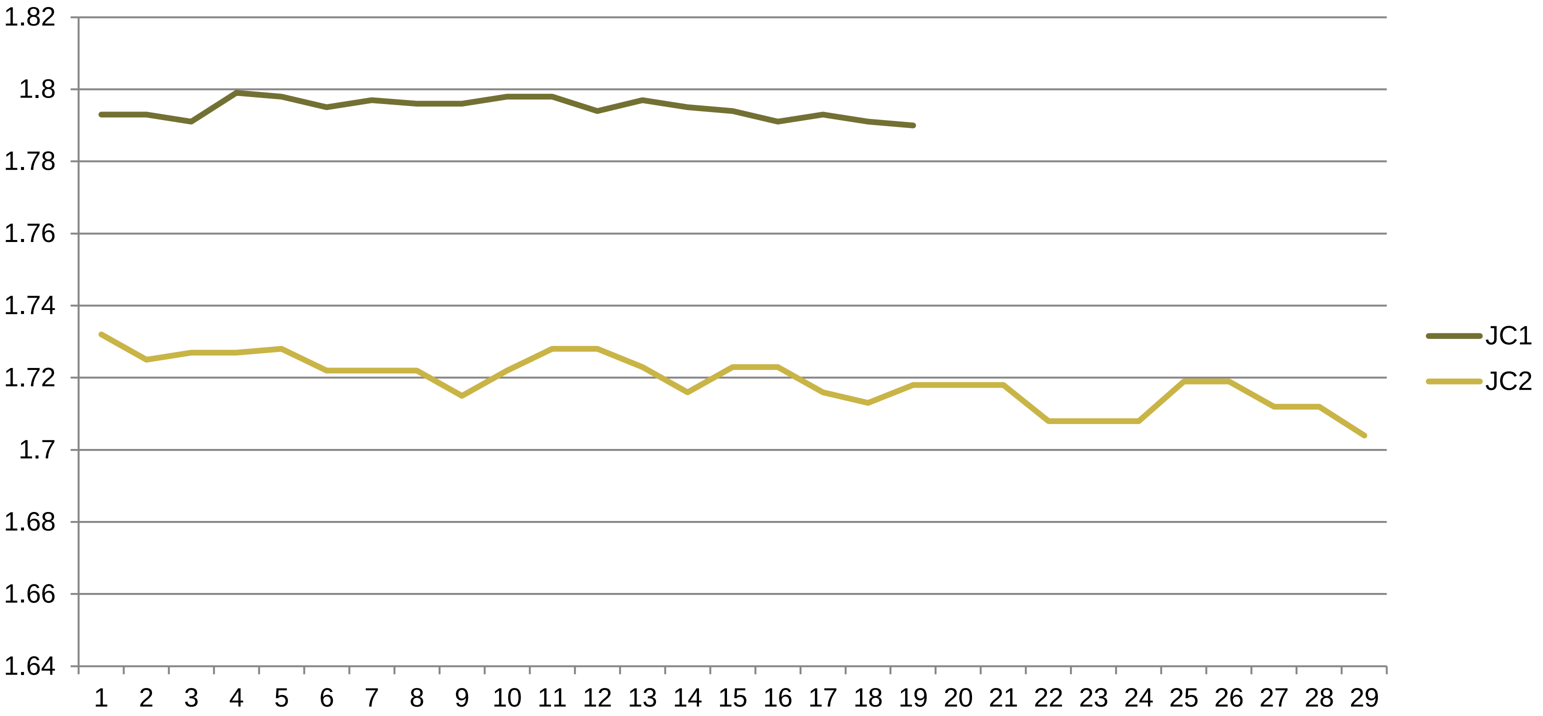
# Tide

## Loch Ness Tides peak around 1.5mm....

**Station Site: Elgin Station Name: Foyers Station Number: 498342 LocalX: --- LocalY: --- Datum: --- Parameter Name: SG Parameter Type: S Parameter Type Name: River Stage Time series Name: 6/498342/SG_n/15m.Cmd Time series Unit: m GlobalX: 250340.000000 Glo**

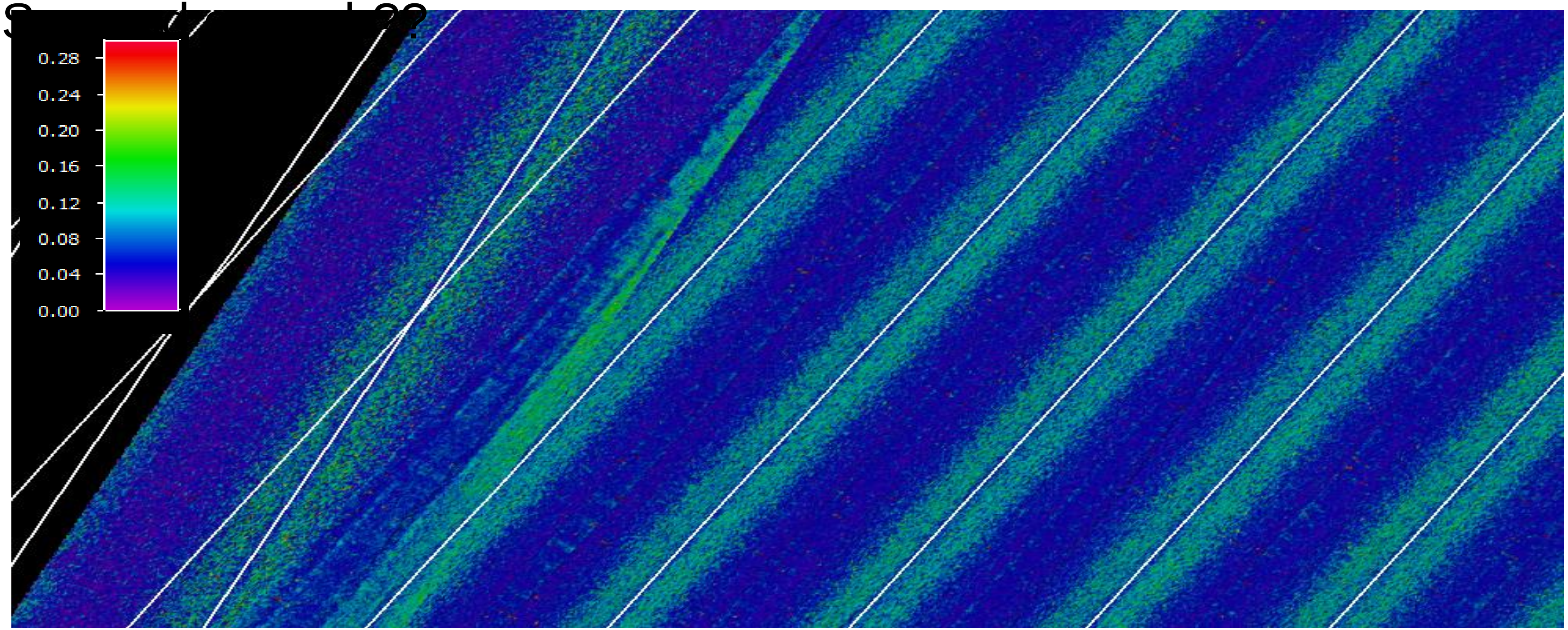


# Mean depth Difference 7cm
# 14 - 7, Error now 7cm

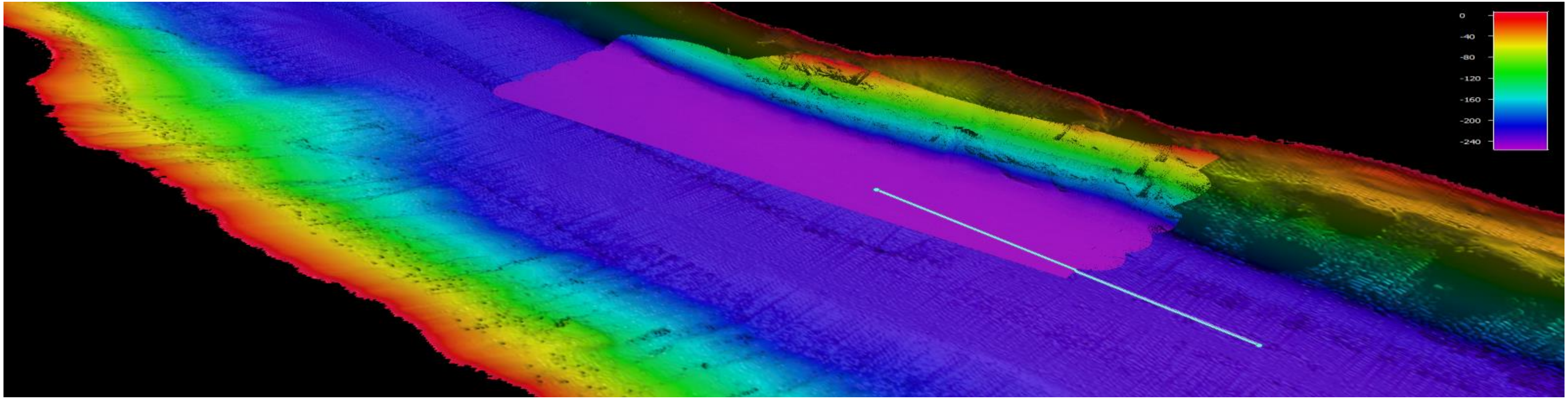


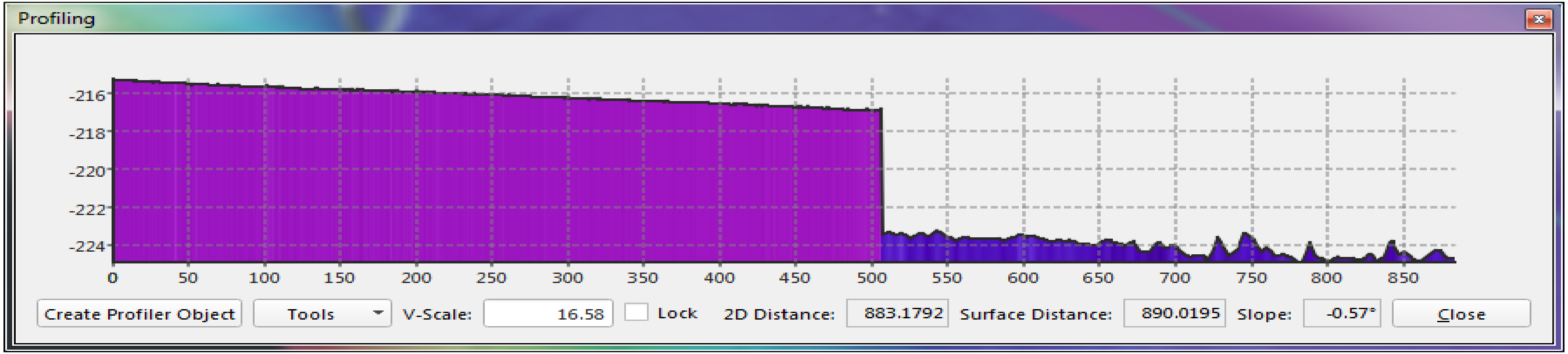
# Std Deviation on overlap ~ 10cm Pk

- Backscatter ~-40dB, EM Std Dev ~ 5 cm
- 700m Water Comp Digiquarz, 0.01% Full Scale Deflection >> 7cm
- S ??

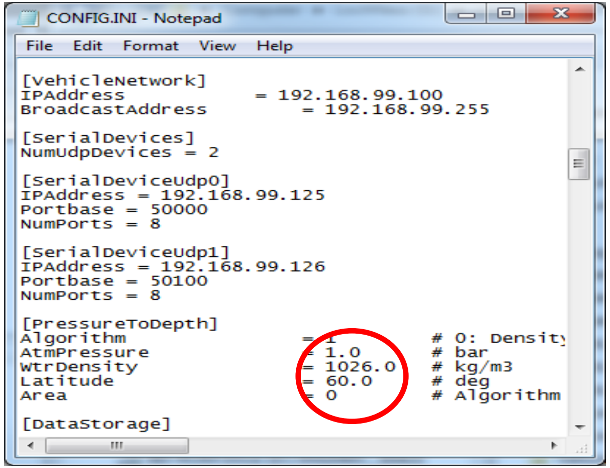


# 2002 data, 5/6 metres difference??



# Fresh Water vs Salt Water in 200 metres



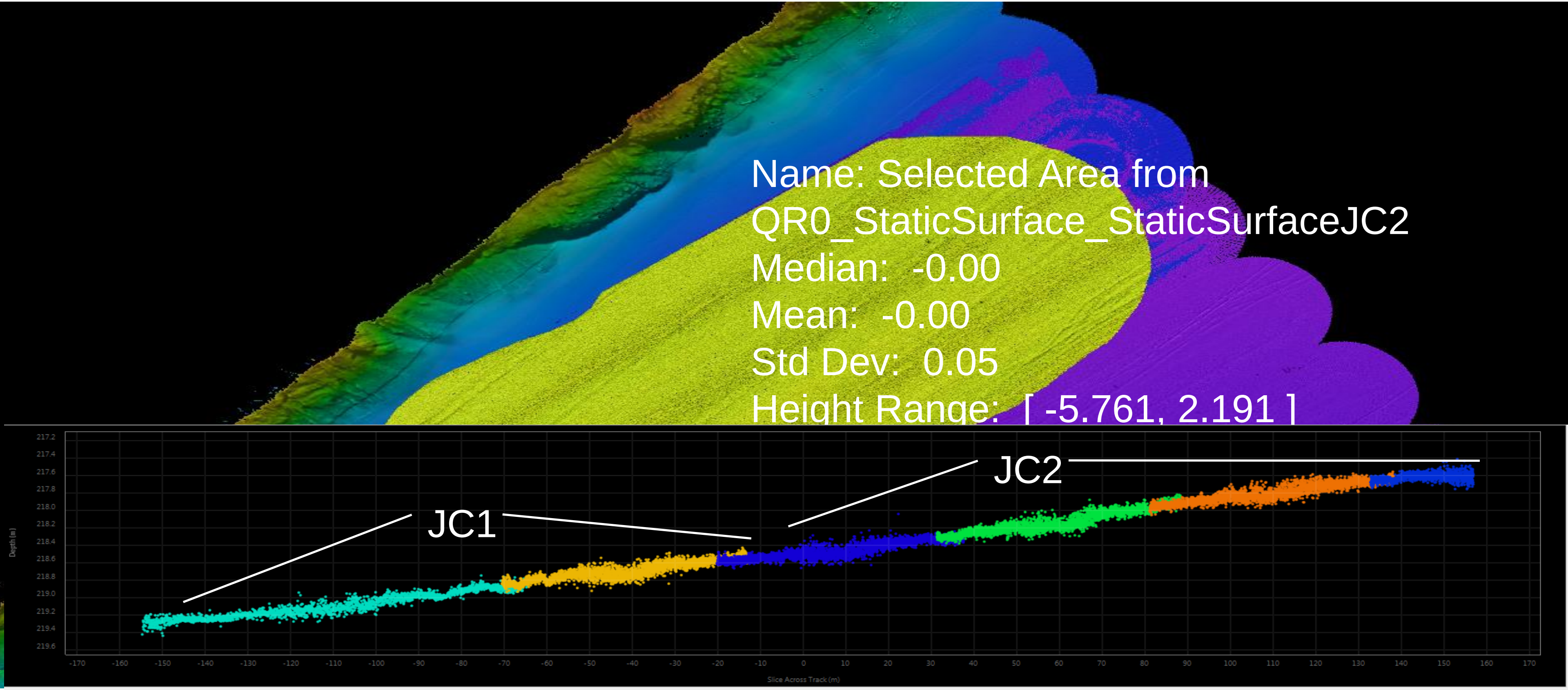

```
[VehicleNetwork]
IPAddress          = 192.168.99.100
BroadcastAddress      = 192.168.99.255

[SerialDevices]
NumUdpDevices = 2

[SerialDeviceUdp0]
IPAddress = 192.168.99.125
Portbase = 50000
NumPorts = 8

[SerialDeviceUdp1]
IPAddress = 192.168.99.126
Portbase = 50100
NumPorts = 8

[PressureToDepth]
Algorithm                    = 1        # 0: Density
AtmPressure                  = 1.0      # bar
WtrDensity                   = 1026.0   # kg/m3
Latitude                     = 60.0     # deg
Area                         = 0        # Algorithm

[DataStorage]
```

**20 Bar in Salt Water = 203.68**
**20 Bar in Fresh Water = 198.32**
**~5.5 metres**

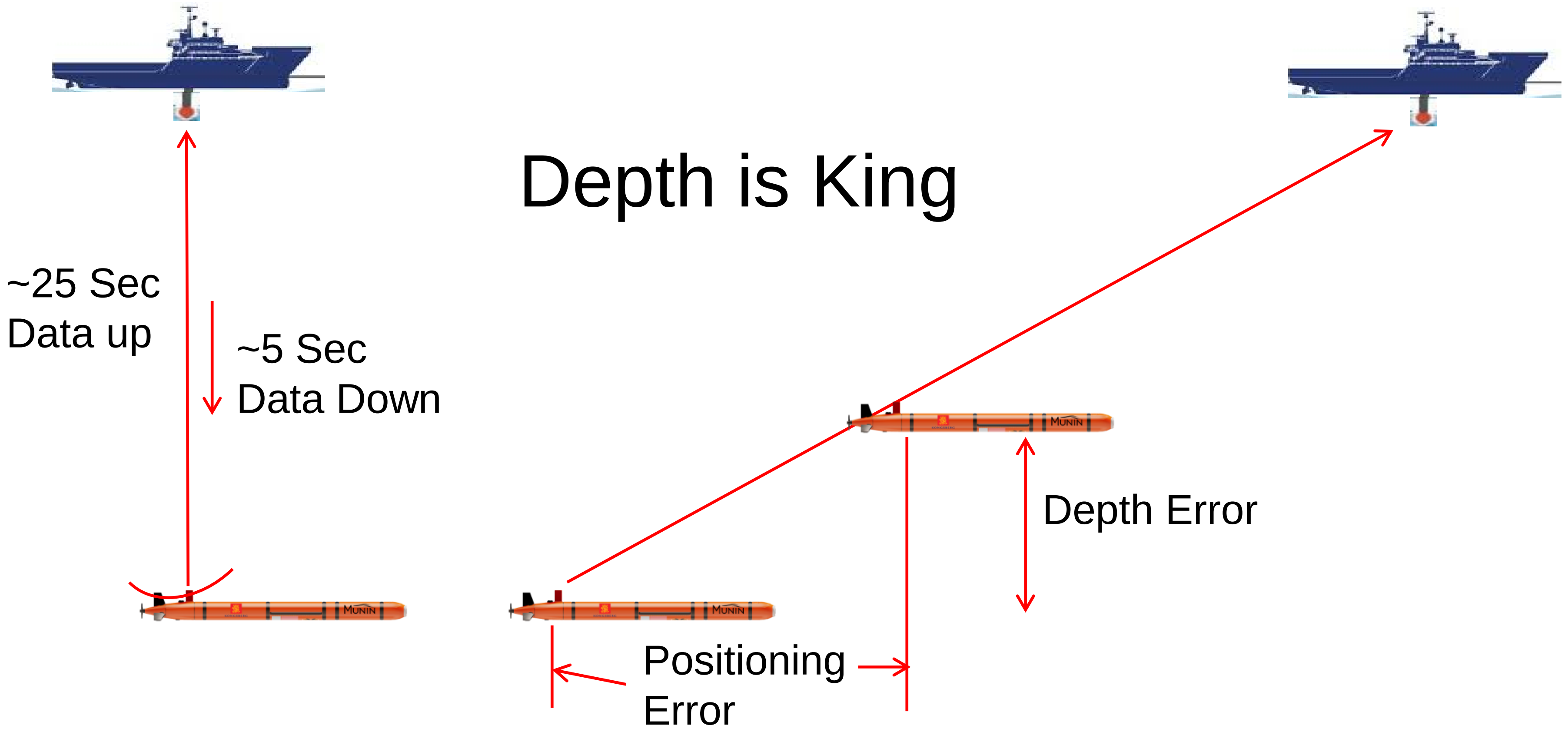
**Altitudes!! Scaled error for depth of vehicle**

**JC1 ran 20 metres altitude**
**JC2 ran 15 metres altitude**
**5 metres in 200 metres ~ 10cm different if salt or fresh**

# Final Surfaces Using Full Unesco



# So sorted, right??



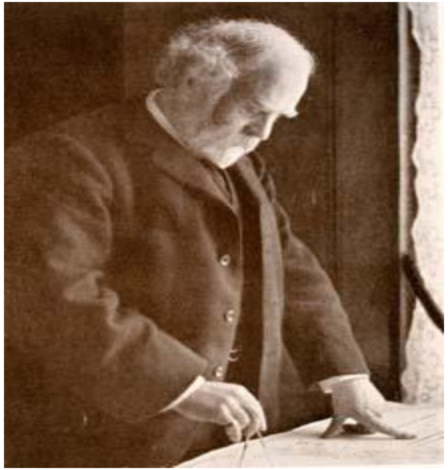
# Key Points



- Close coupled solution, depth can affect position
- Catch as many variables as possible
- Don’t really on post processing
- Atmospheric pressure, Log it
- SVP, preferably full CTD
- “TIDE” Lochs are not all stable

“Even the best artificial intelligence is no match for natural stupidity”

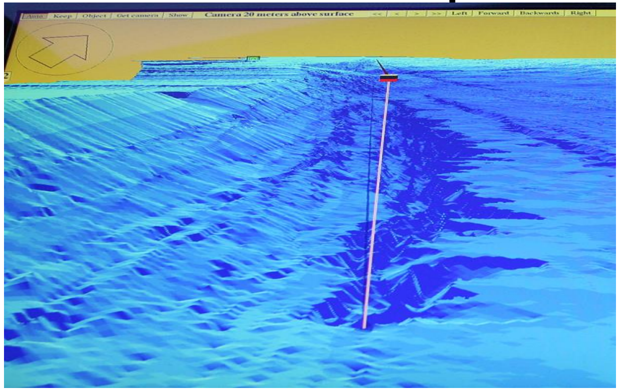
# The Trench, and Monster….



Sir John Murray 1903 Loch Ness
Maximum Depth 230 metres

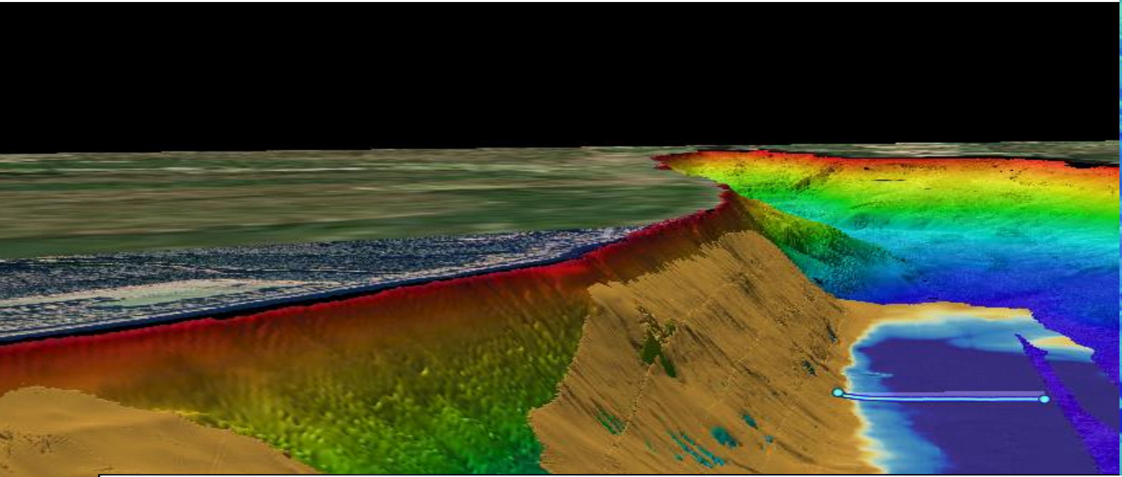
Kongsberg Survey 1991
Maximum Depth 226 metres

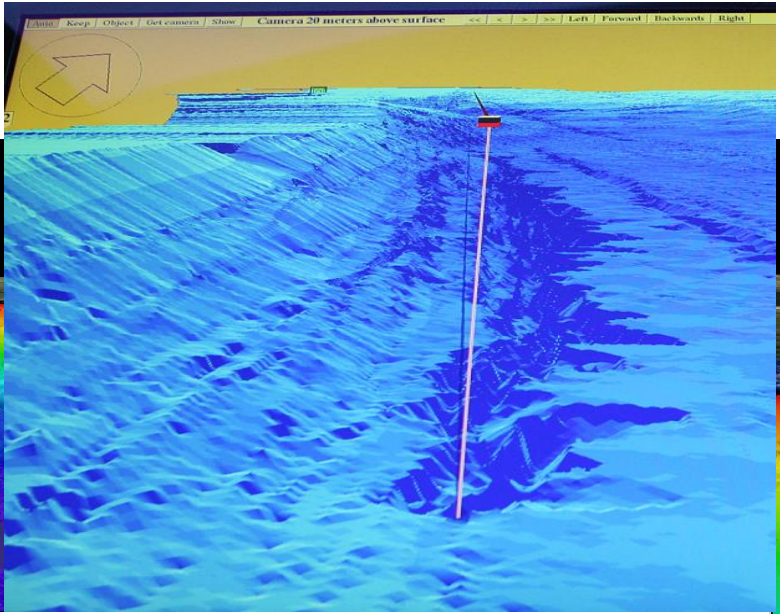
Kongsberg Survey 2002
Maximum Depth 227 metres

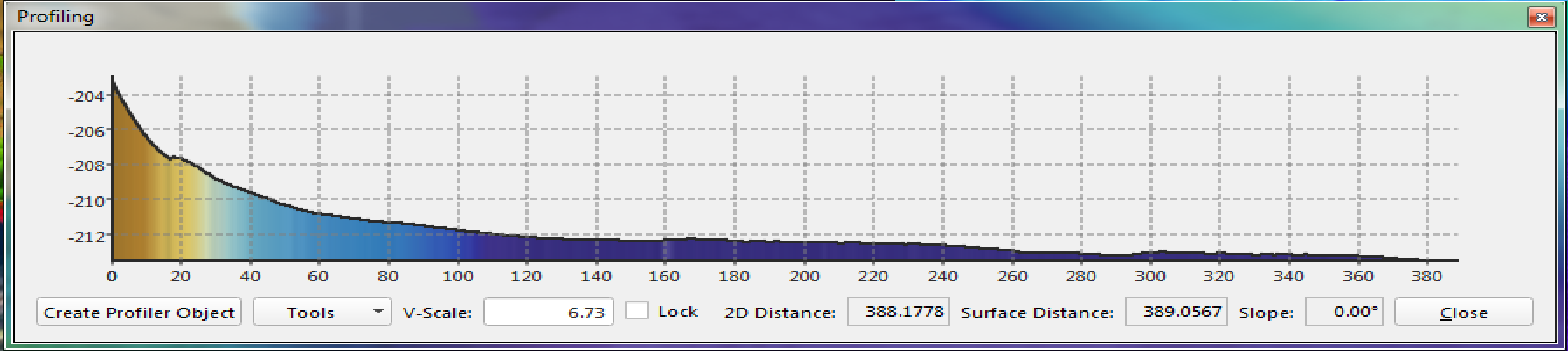


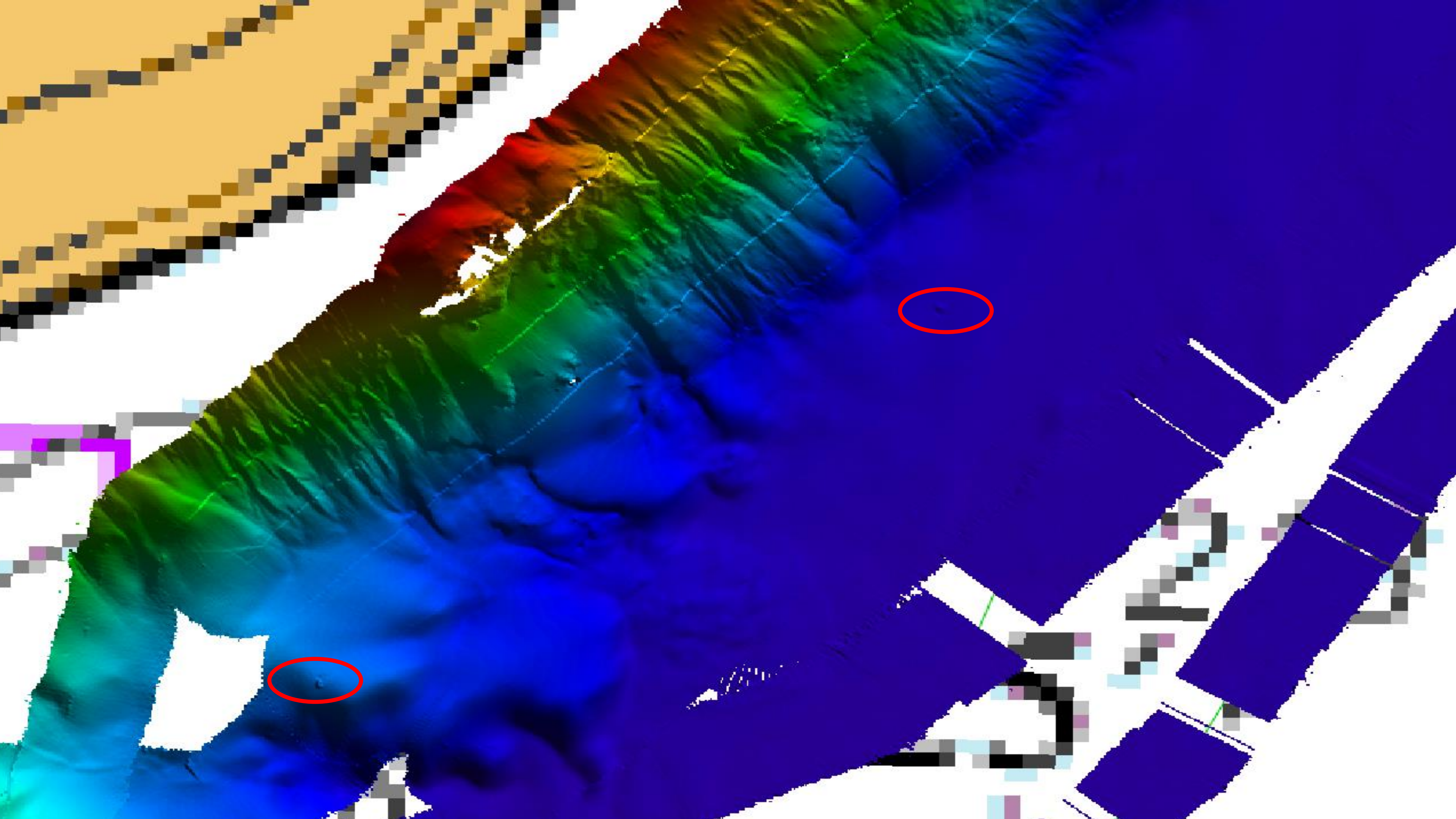

January 2016 Keith finds a 290 metre trench,
Known as Nessie's Lair

# Keith's Trench



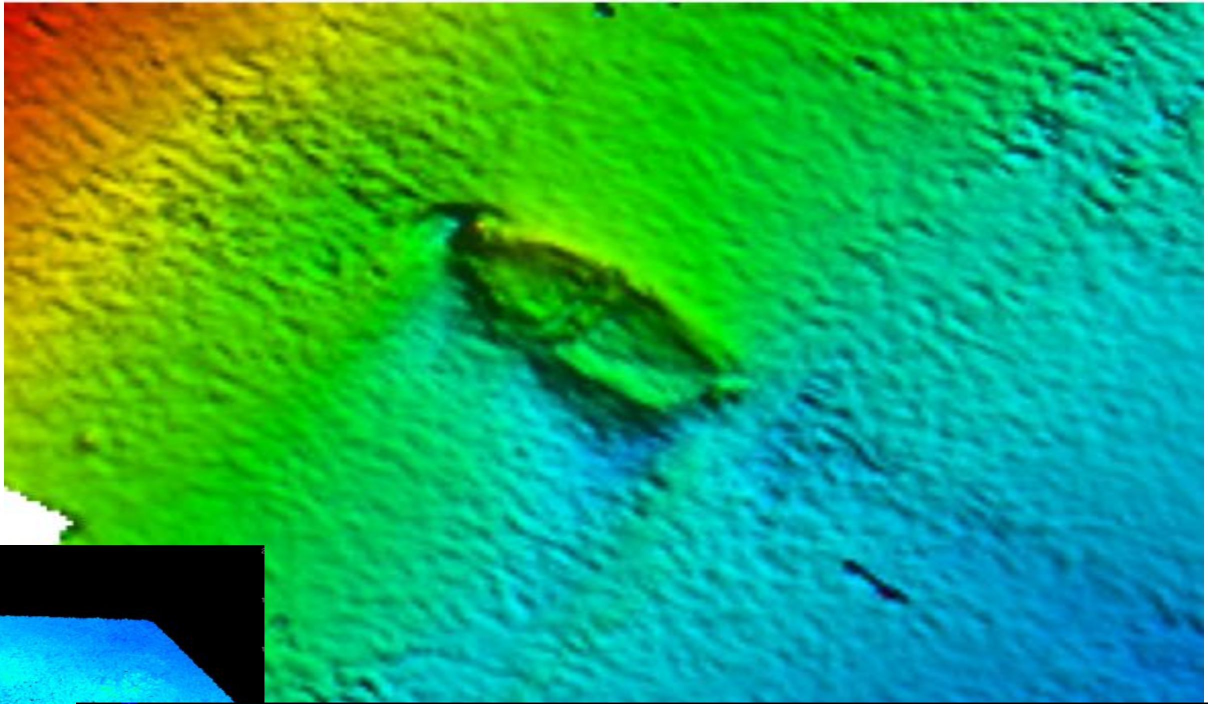


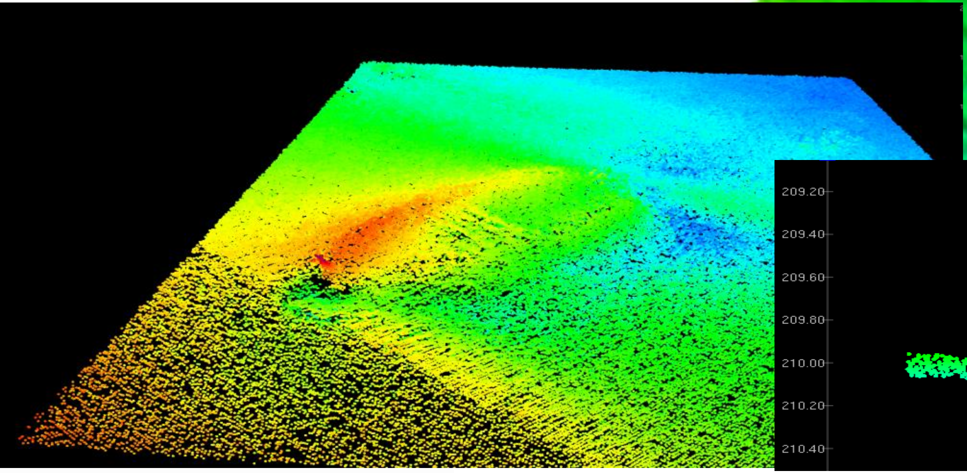



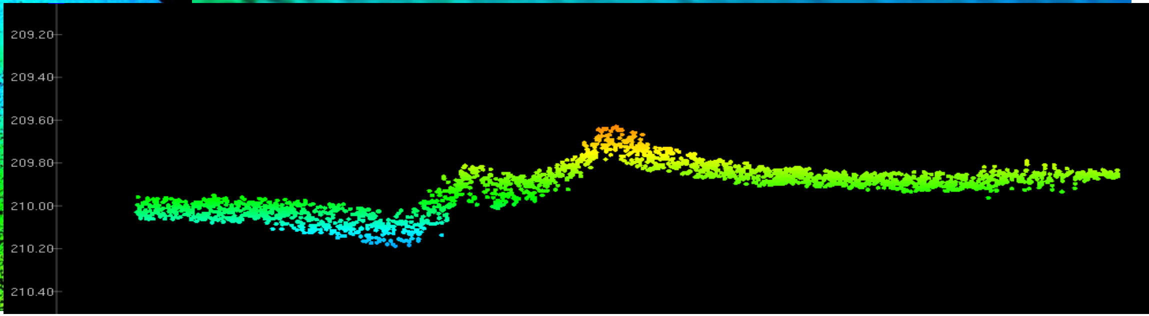


# Viking Longship?

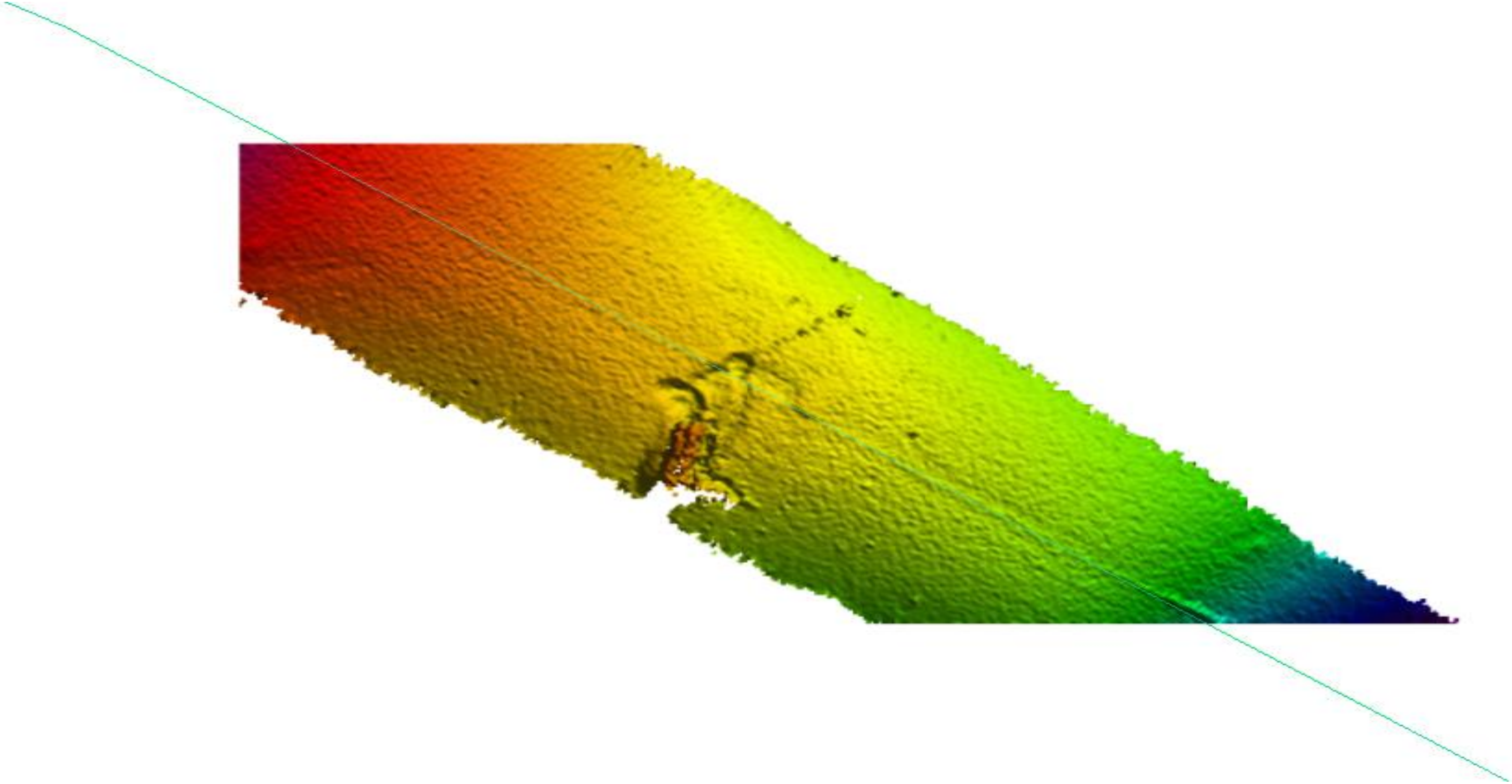
**10 metres long**
**2 metres wide**
**Only 30cm above neighbouring seafloor**

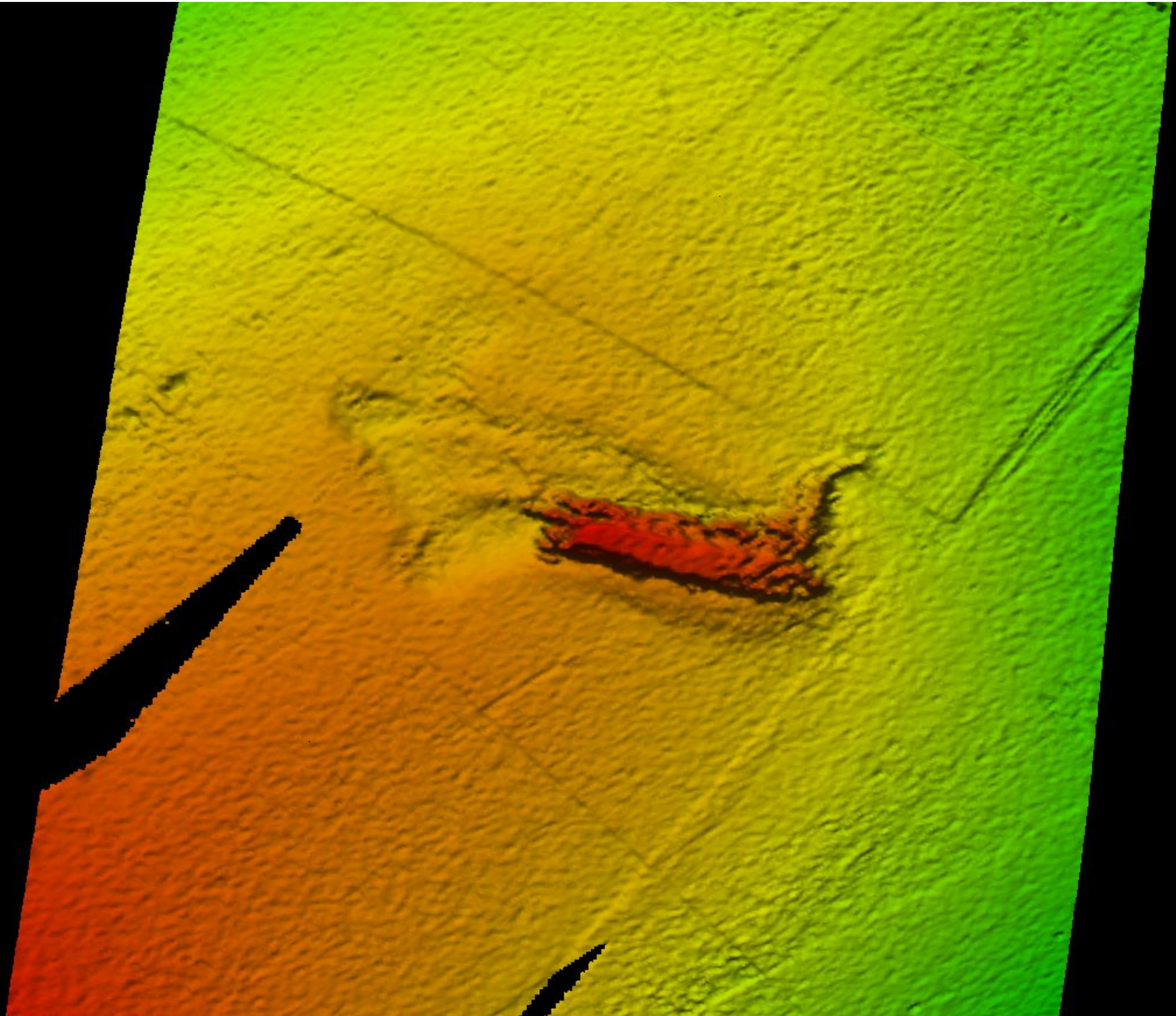




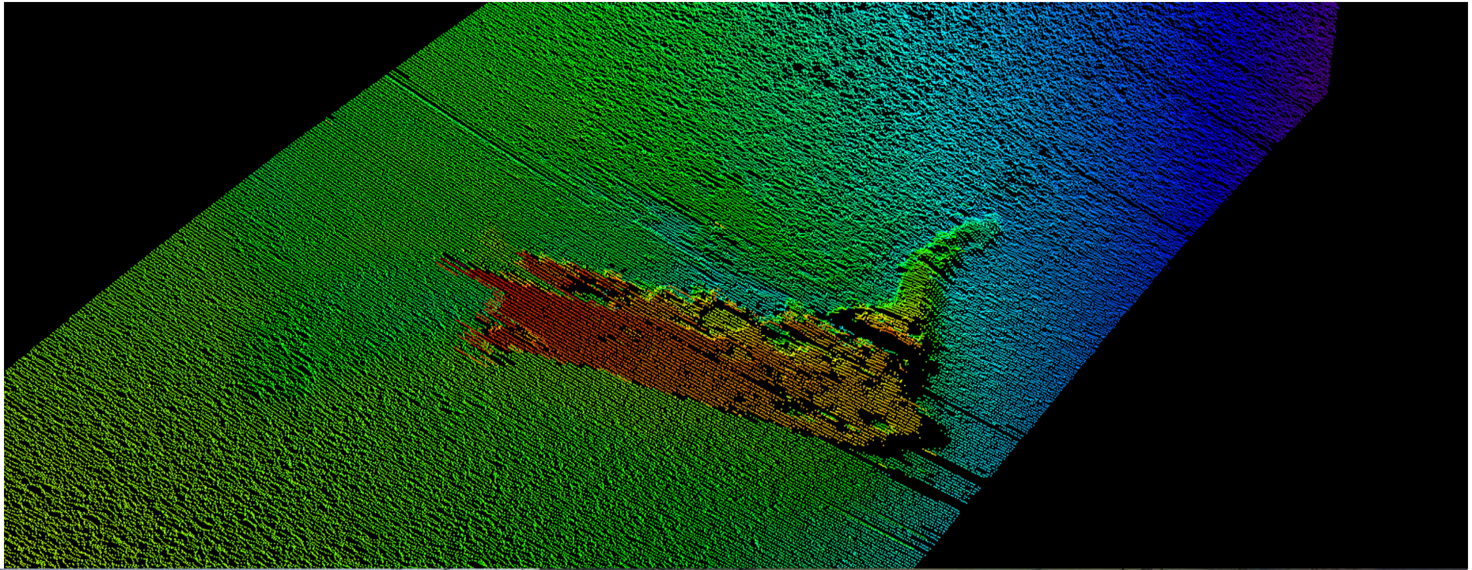


# Passing line on transit





# Sherlocks Monster

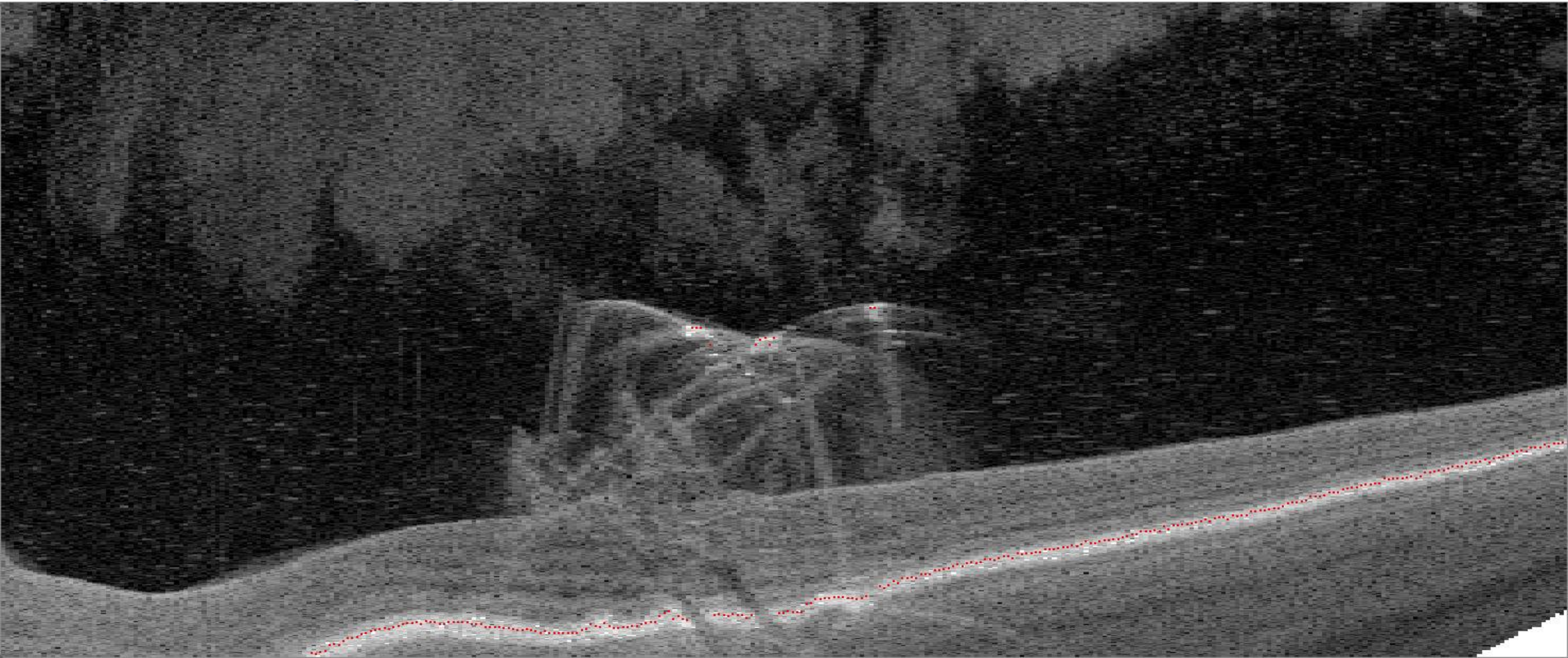



MUNIN
KONGSBERG

# Questions?

Craig Wallace
craig.wallace@kongsberg.com

Bungy Williams
rwilliams@hydroid.com



**Mr Dan Hook**

ASV

# Hydrographic Data Collection from an USV

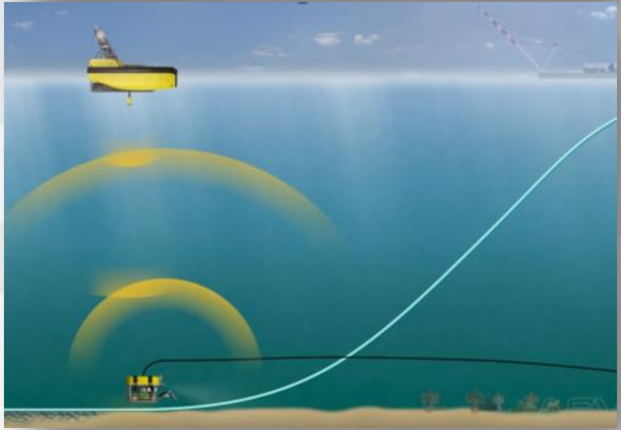
# ASVs for Hydrographic survey

November 2016

Dan Hook, CEng, MRINA
Managing Director

# ASVs in Defence

# ASVs in Oil and Gas



# ASVs in Science


C-Enduro

Autonaut


Waveglider


Saildrone

# ASVs in Hydrography

- Why

- How

- Proof

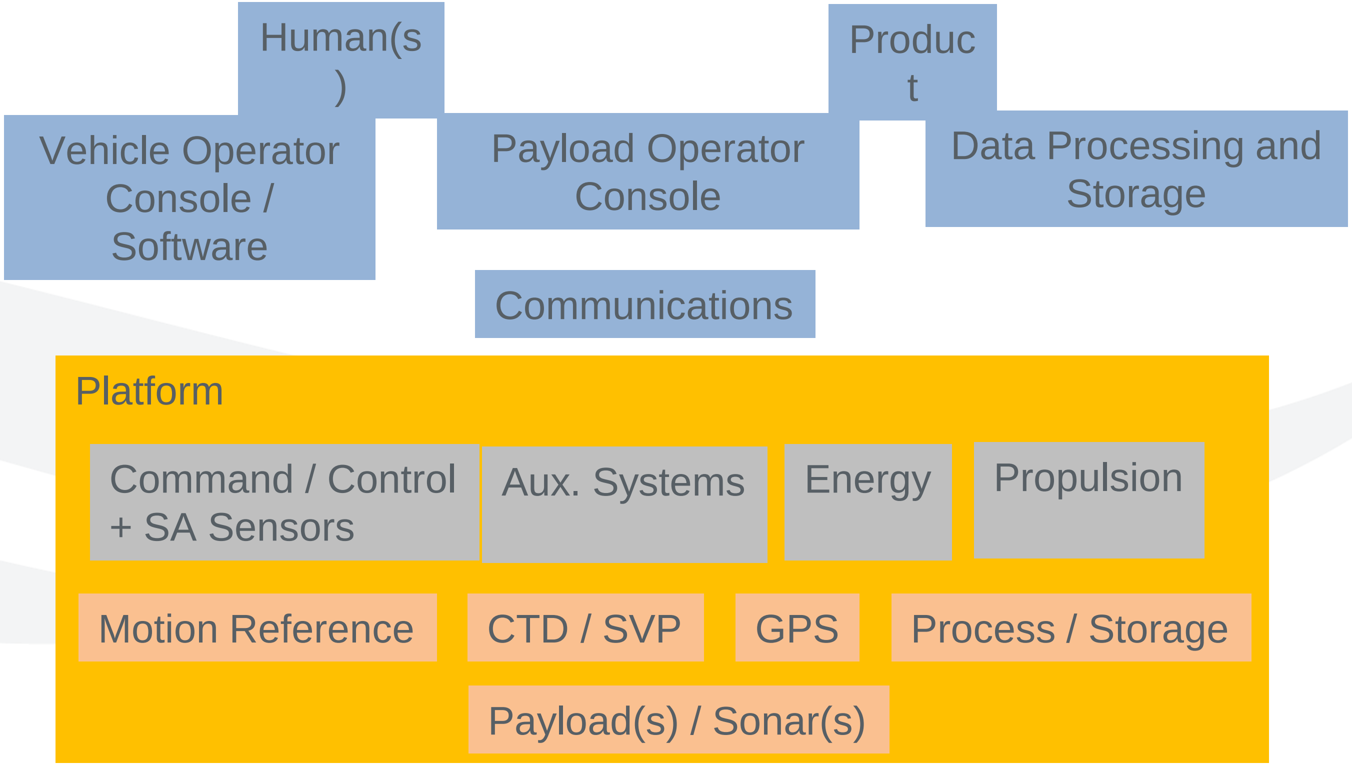
# The Why

Challenges;

- **Cost** (Fuel, people at sea, capital assets)
- Lack of **data and efficiency**
- **Dangerous** (Small boat operations)
- Weather **downtime**
- Vessel **availability/ mobilisation**
- Looking for **technical edge or** 'win themes' in bids

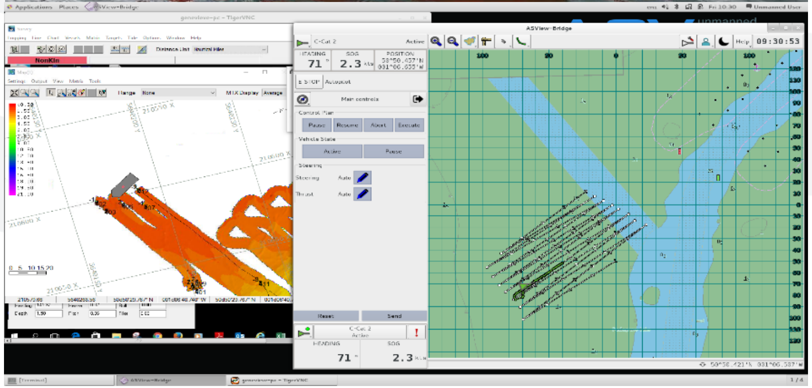
**ASVs** are making **disruptive** changes in **all** of these areas

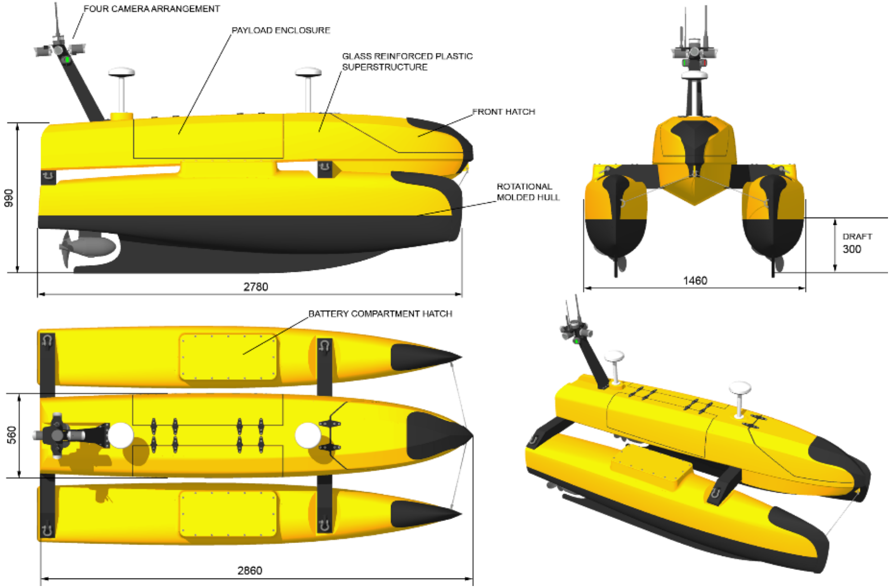
# The How – A system approach (simplified!)



# C Cat 2 + 3

# (Inshore waters, ports/harbours, lakes dams, day running)



# C-Worker 4
# (Estuaries, Coastal, Large lakes, shallow water)


# C-Worker 5

# (Large areas, parallel line running, week+ duration)

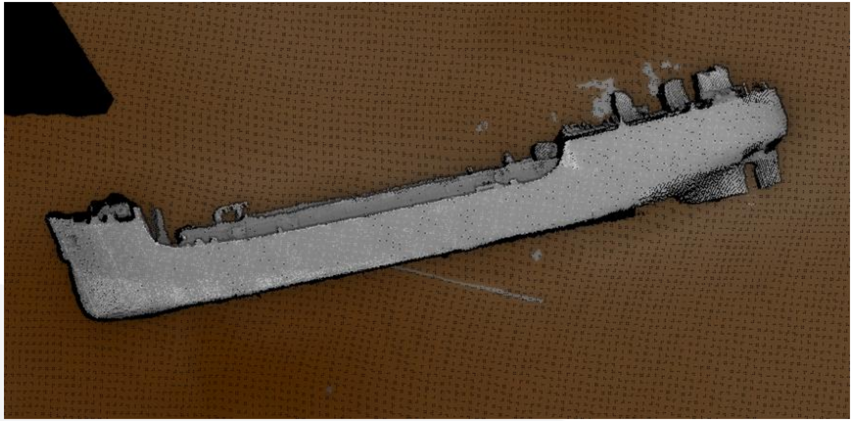

# C-Worker 6 and 7 and bigger…..
# (Multiple payloads, true open ocean operations)

# Conversions / Upgrades of Third Party Vessels


# R2Sonic Multibeam Payload Example

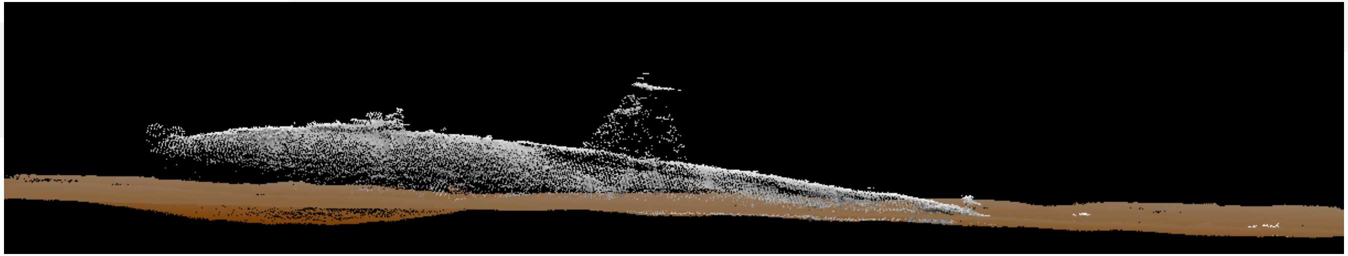

- R2Sonic 2022
- Integrated INS
- Payload provided by Swathe Services

# Initial Data Sets - Solent



Margaret Smith off Yarmouth

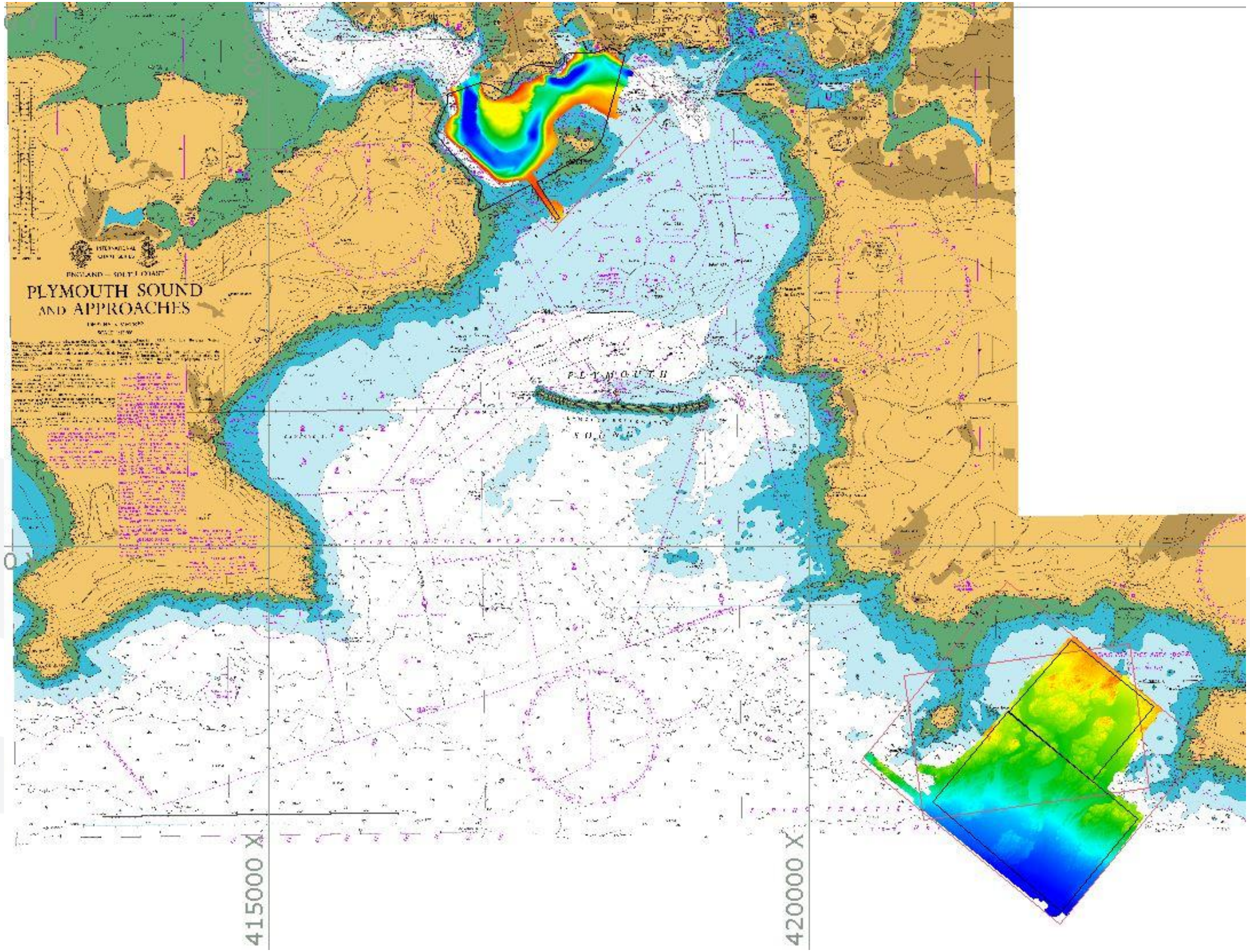
- Setup testing completed over 3 days in Solent
- Capture of 3 wrecks and area off Needles
- Demonstrated reliable operation of the system

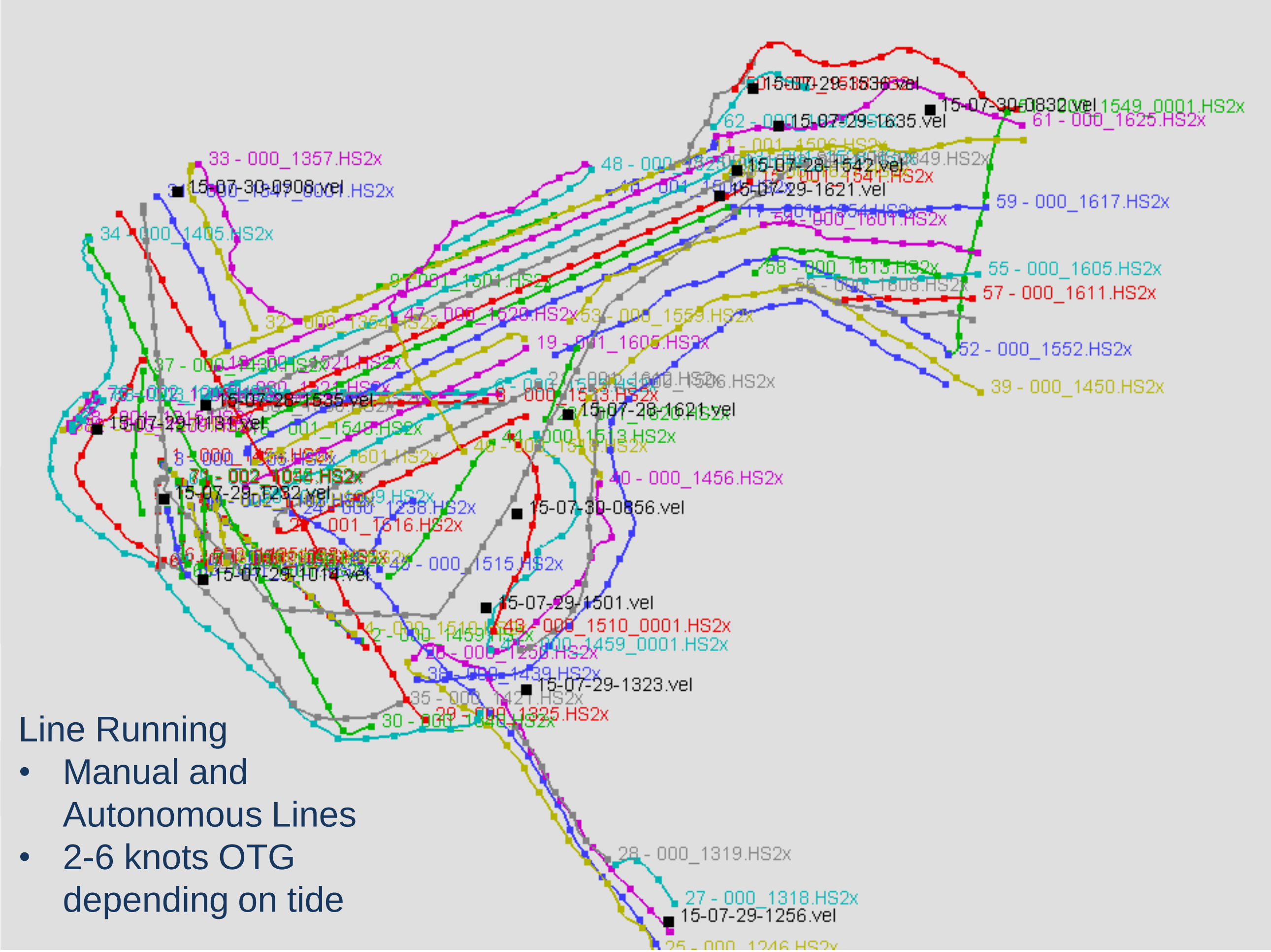


A1 Sub off Bembridge

# Shallow Survey 2015 Data Collection

- Common data set to enable the comparison of Multi beam data.
- Quick mobilisation
- Data set completed in 20hrs survey time
- Targets detected as required by spec


PLYMOUTH SOUND
AND APPROACHES
415000 X
420000 X

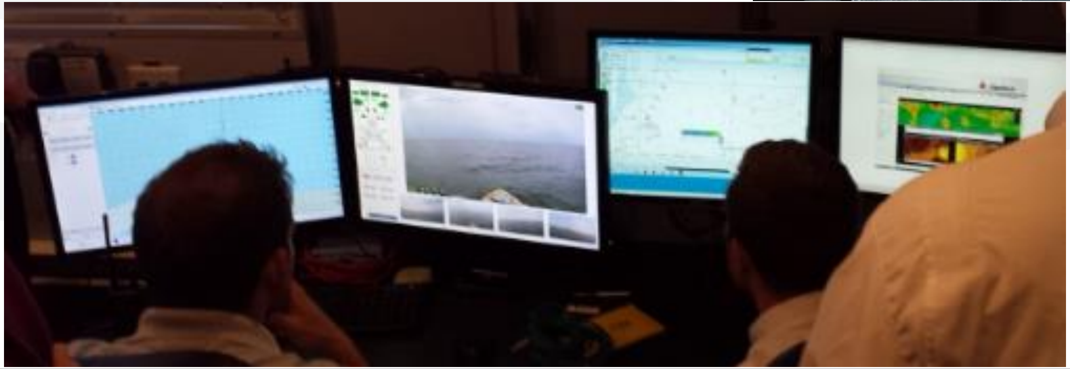


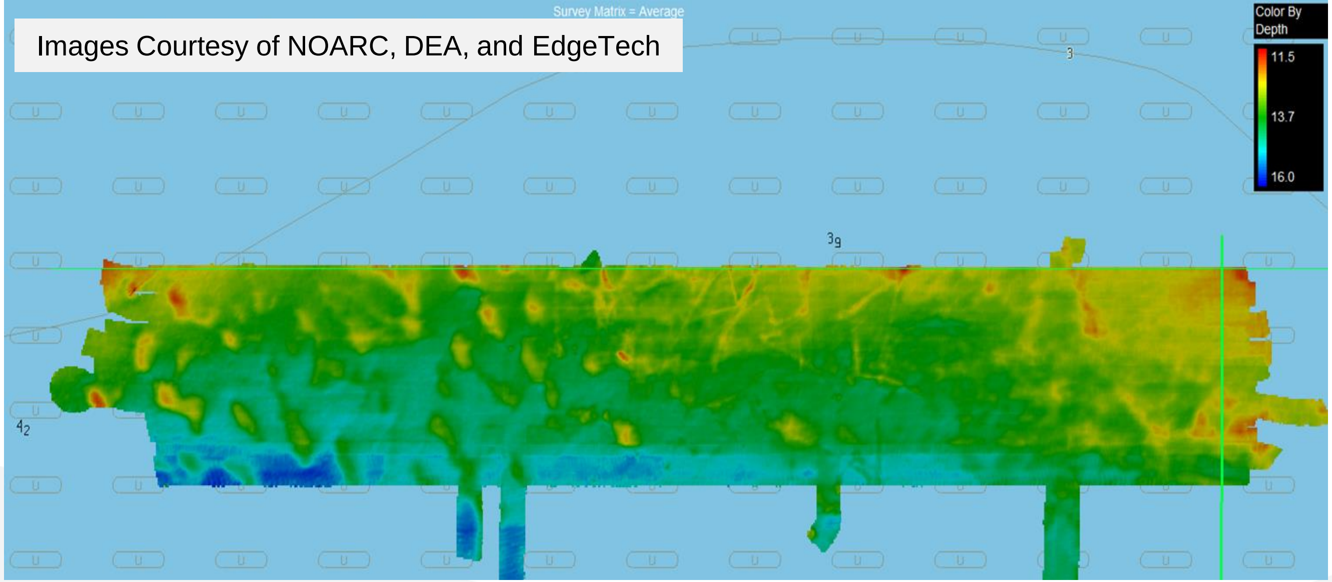

## Line Running

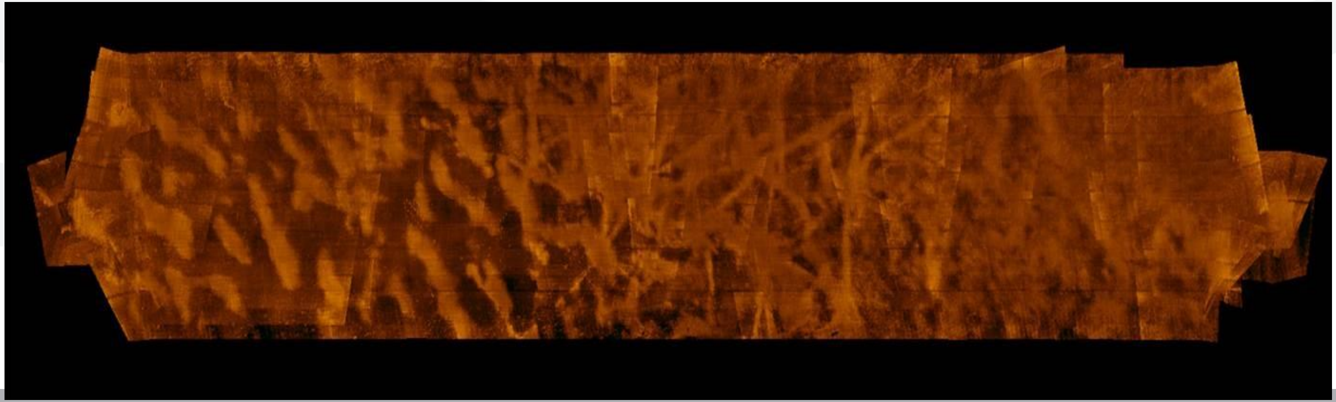
- Manual and Autonomous Lines
- 2-6 knots OTG depending on tide

# MBES Results – Mississippi Oyster Bed Test

- “Force Multiplier” program in parallel with DEA hydrographic survey vessel
- Excellent feedback from NOAA, US Army Corps of Engineers, others.
- EdgeTech 6205 MBE & Sidescan

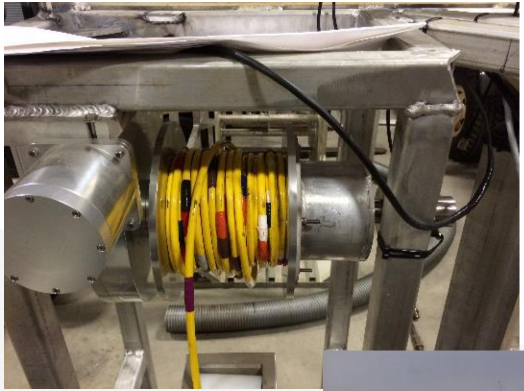



Images Courtesy of NOARC, DEA, and EdgeTech
Survey Matrix = Average
Color By
Depth
11.5
13.7
16.0



# Multi Beam & Sidescan Sonar Survey – GoM

- “Force Multiplier” program in parallel with Oceaneering hydrographic survey vessel
- Kongsberg 2040 Multi Beam Bathymetry, EdgeTech 4125 Sidescan with Tow Fish & winch
- First autonomous system to complete a whole NOAA chart sheet!



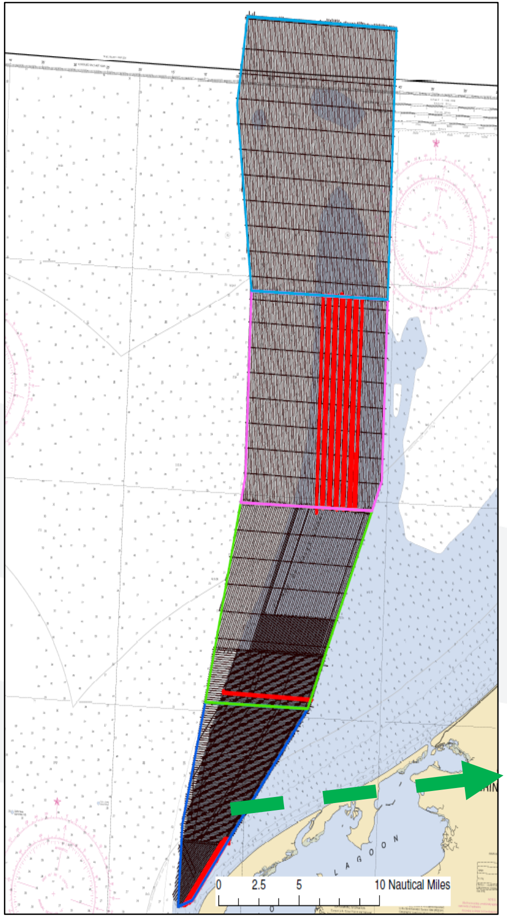
Sidescan towfish holder and winch

Up to 140 line kms production per day

# New Customer - Narrow Beam Survey PoC – Bering Sea (2015)

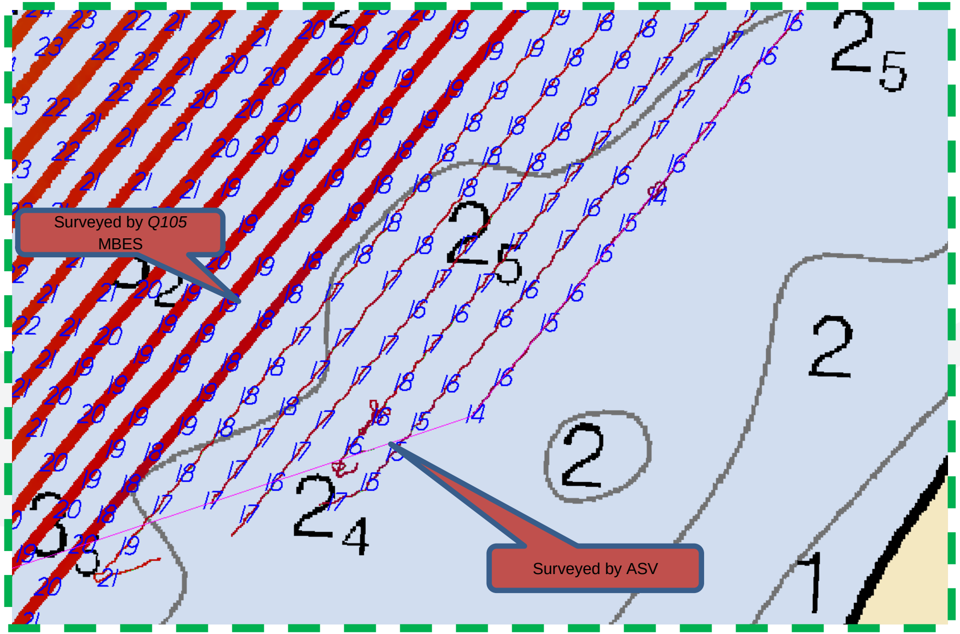
- "Force Multiplier" program in parallel with Terrasond hydrographic survey vessel
- SMBB200-3. 200kHz, 3 degrees. Used with an Odom CV100. "eChart" software was used to control the singlebeam and Hypack 2014 was used to collect all the data. Post-processed kinematic (PPK rather than RTK) GPS positioning with a Trimble system. Hemisphere V113 for heading, heave, pitch, and roll.

Image Courtesy of Terrasond




## Results

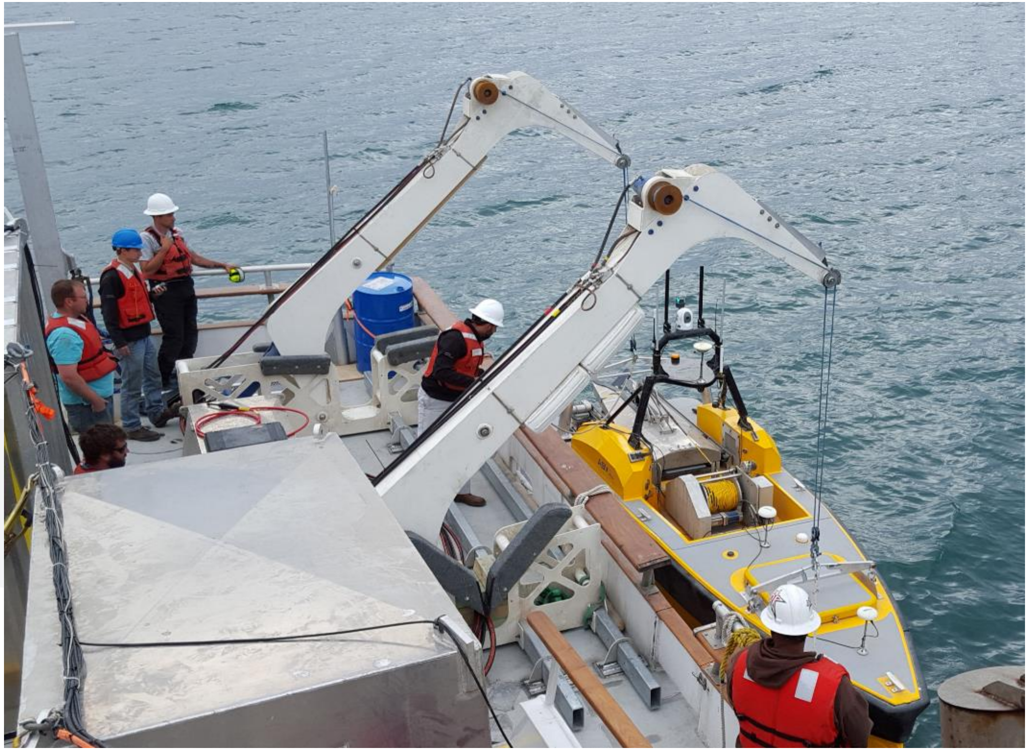
- Kept Q105 out of potentially dangerous shoal SE corner of survey area.
- Lets do more next season!



# Hydrographic Force Multiplier- C-Worker 5 (6 month development)

- Designed specifically to operate as a force multiplier
- Designed to operate upto SS4
- Reliability through simplicity
- Simple payload integration
- 4 systems being commissioned now

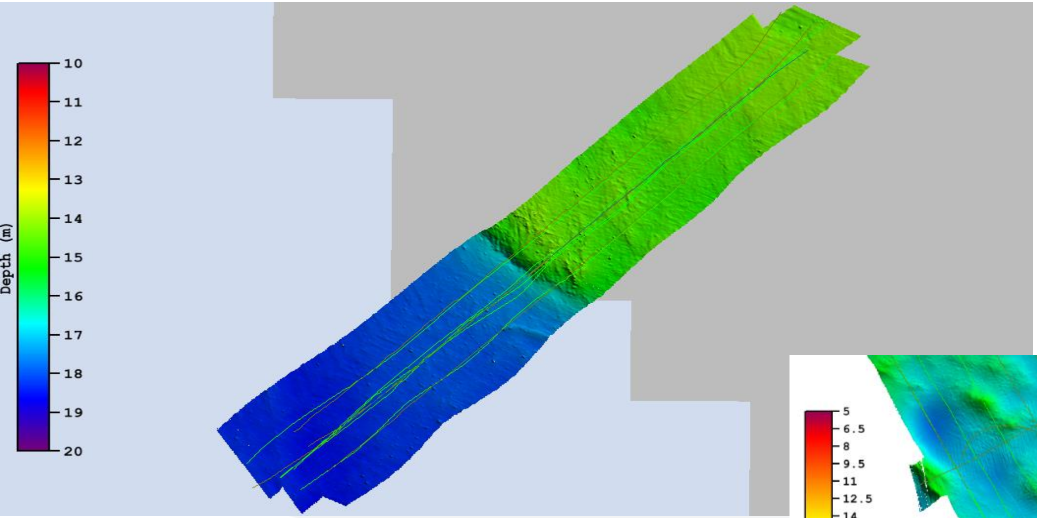

# LARS



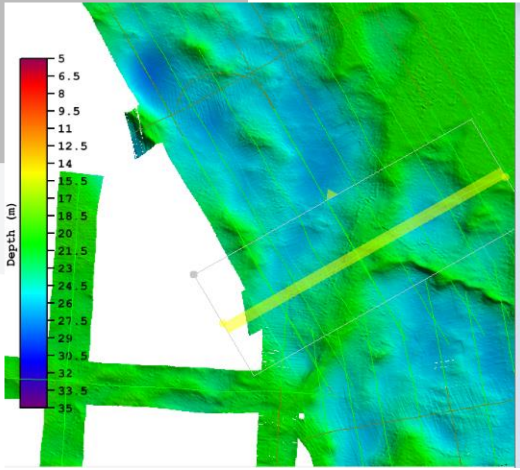

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

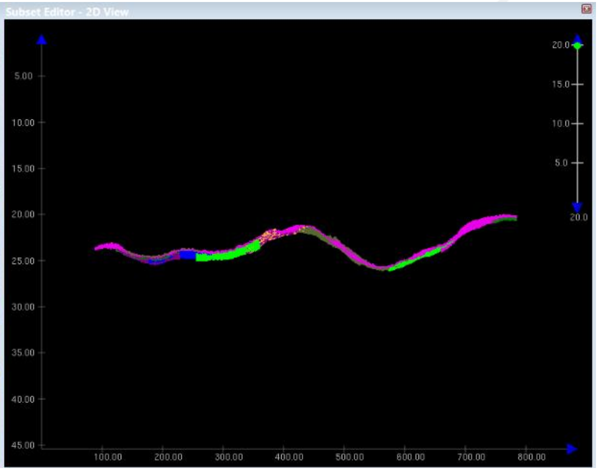
TERRASOND

# Patch Tests

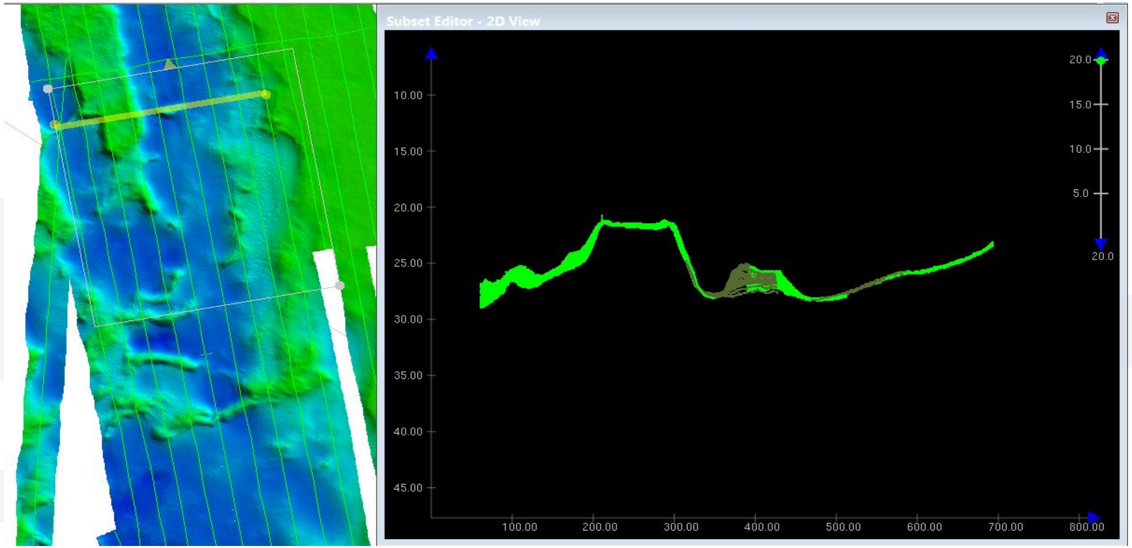



- Reson 7101 Multibeams
- POSmv motion sensor
- QPS and Caris Onboard Software
- Winch-towed EdgeTech 4200 Side Scan sonars
- ASV acquisition remotely viewed onboard Q105
- 6 Knots 24/7 operation



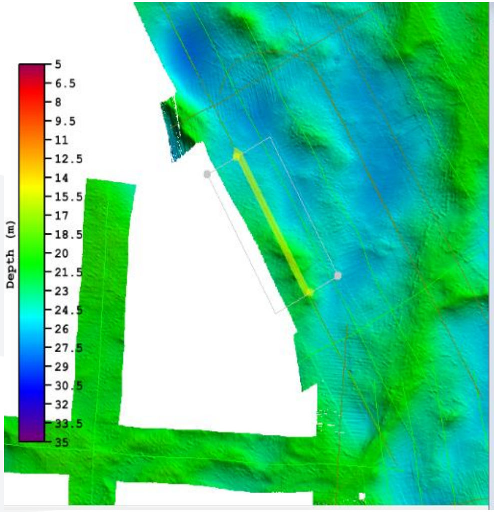



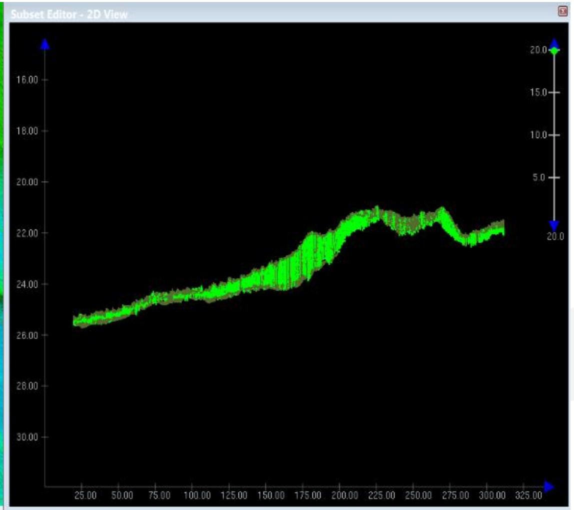
# Multibeams side-by-side in 25 m water depth



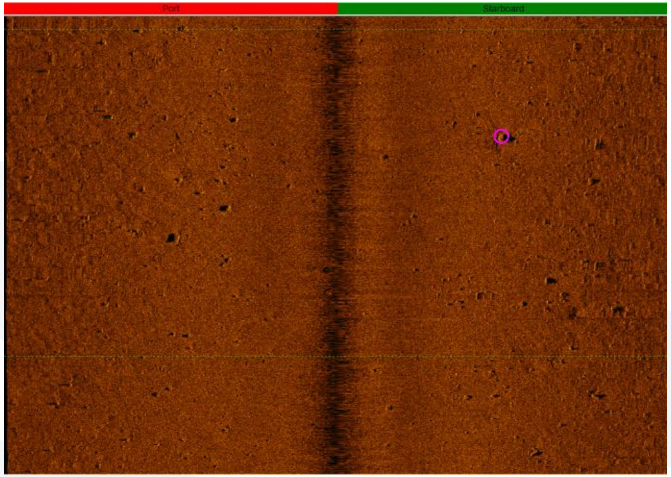

Q105 lines (Light Green), Two ASV lines (dark green),

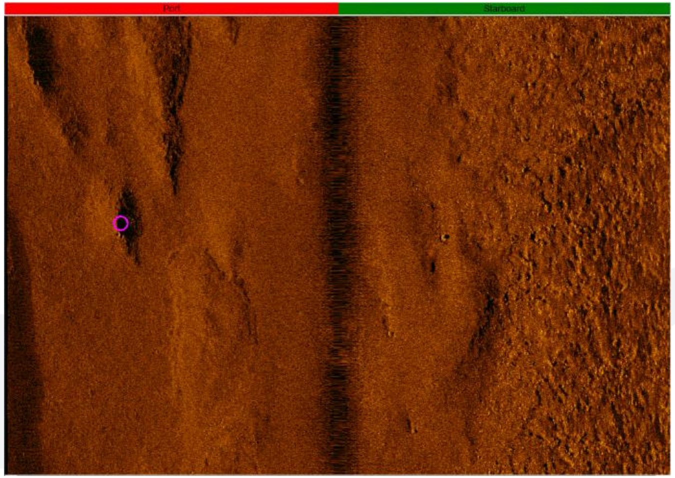
# Both vessels occasionally ran the same line for comparison purposes.



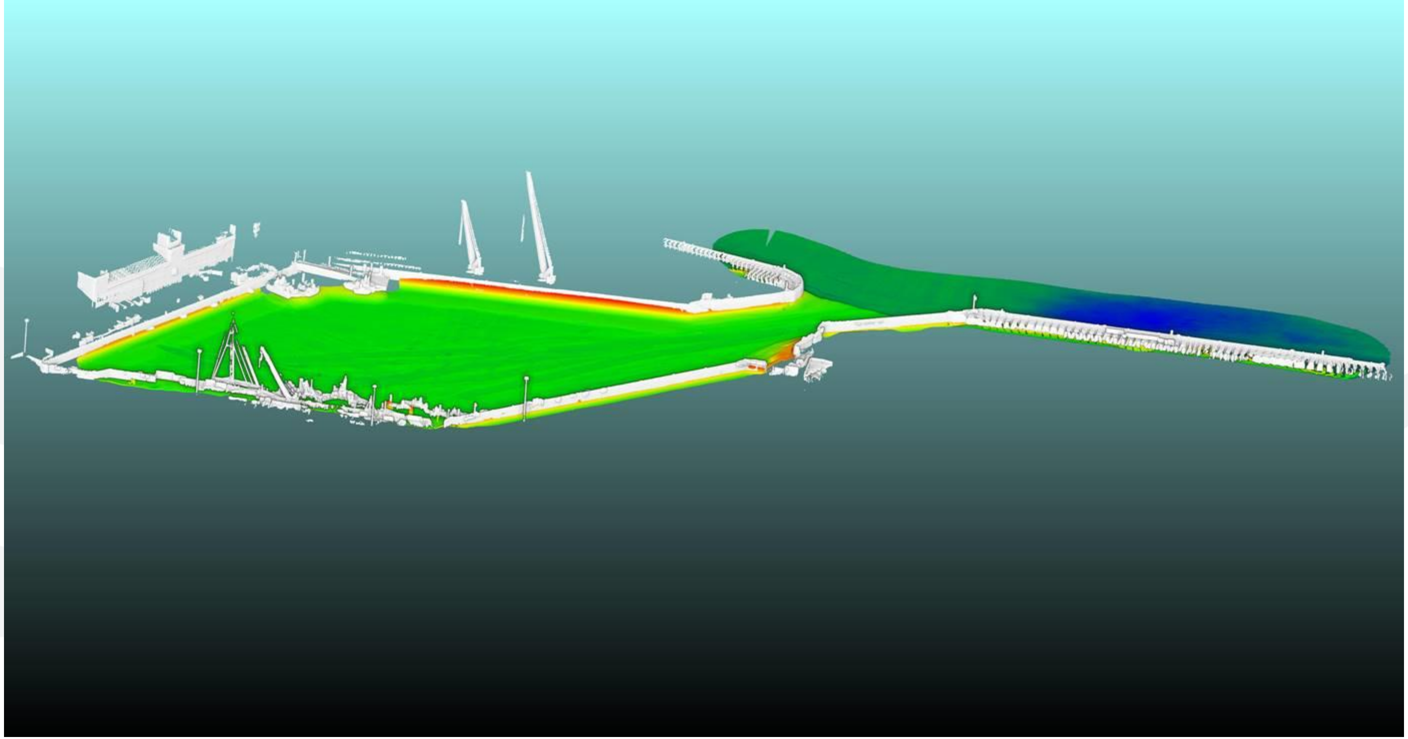



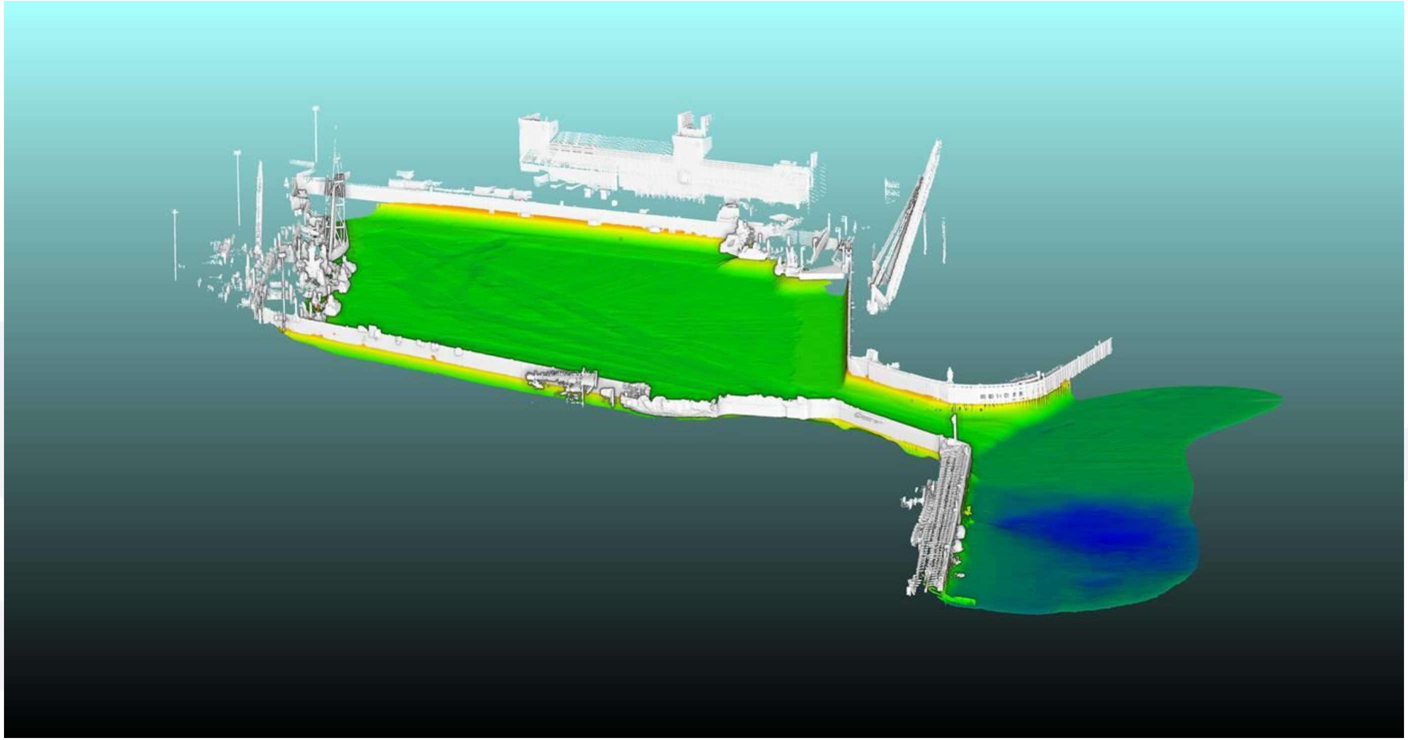

**Q105 line is virtually indiscernible from the ASV line (light green)**


Port
Starboard


Port
Starboard

# Combined MBES and LIDAR Payload





## Summary

- Thanks for listening to a Naval Arch. talking Hydrography!
- Now completed over 10 survey deployments (~100 days).
- Ultimate proof is in being asked back to do more work.
- Rely on input from the likes of NOAA, UKHO, MCA.
- Patch tests analysed, data validated and accepted.
- Encourage you to put ASVs on the proven options list.


ASV unmanned marine systems
www.asvglobal.com
@ASVLtd
ASV Global
dan@asvglobal.com

**Mr Geraint West**

Sonardyne

# Positioning and Communications

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# AUV Positioning & Communications

THE QUEEN'S AWARDS FOR ENTERPRISE: INNOVATION 2014

**Geraint West**

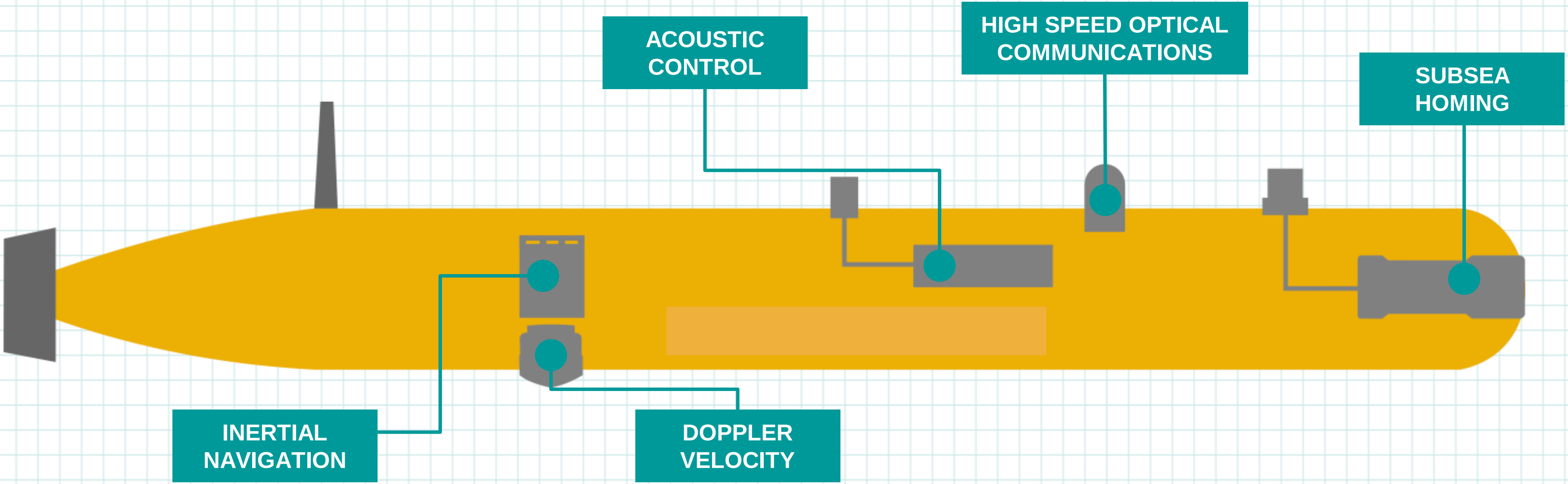
Global Business Manager - Oceanographic

## Outline

- Acoustic Positioning
- Acoustic Positioning & Communications
- Optical Communications
- Inertial Navigation System Aiding
- Doppler Velocity Log Aiding
- Docking
- Post-processing
- Simultaneous Location and Mapping (SLAM)

# AUV Positioning & Communications

## Overview




+ Post processing & SLAM

# AUV Positioning & Communications

## Wideband acoustic signal processing improvements

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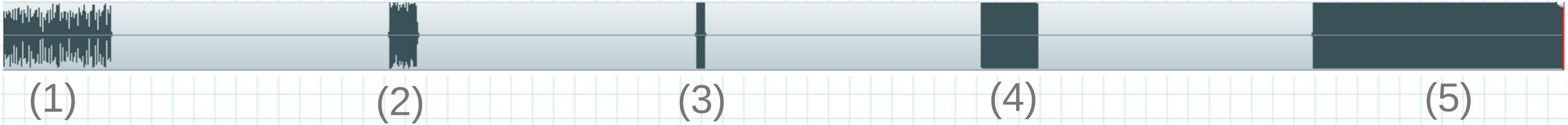
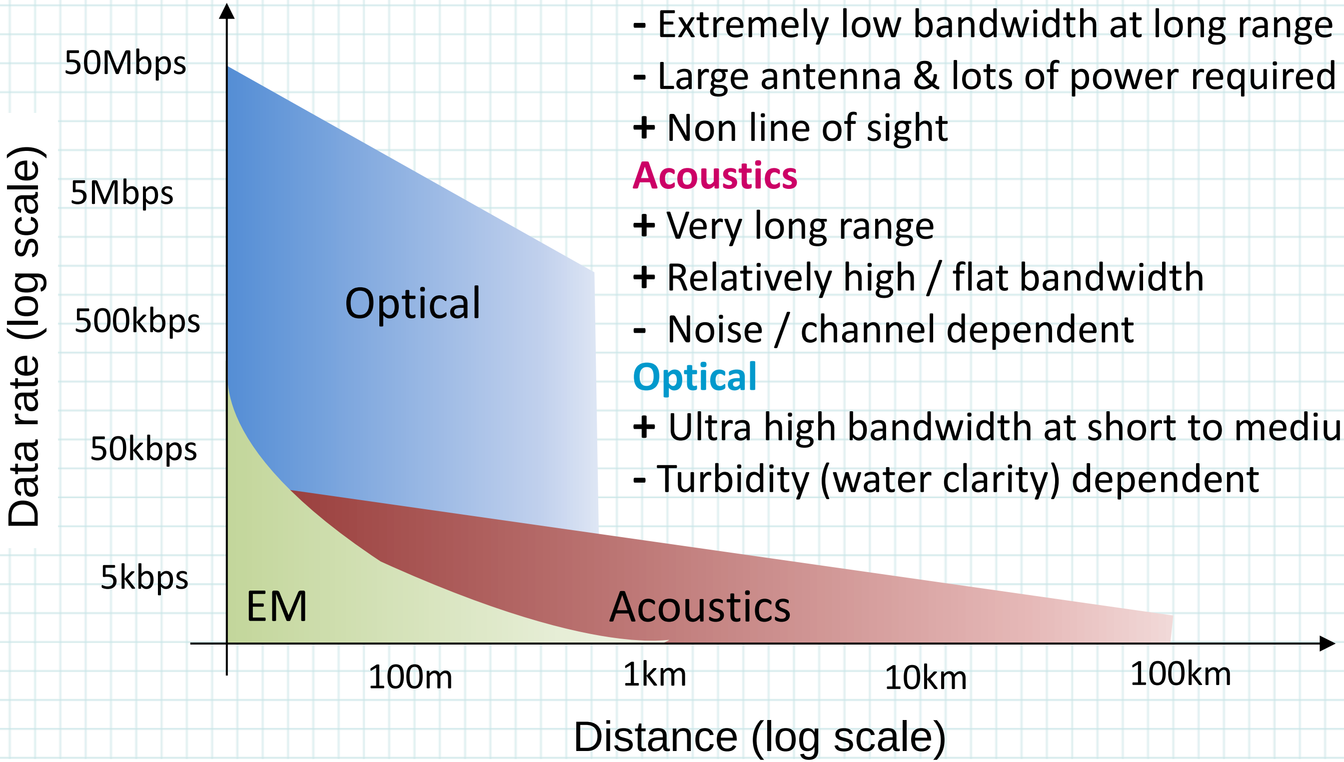
- Enabled through $Billions of investment in mobile phone tech …




Through water communications has got much faster and more reliable …

1) 80’s - Frequency modulated. 50 bits/sec ~2 secs to send **1 temperature**
2) 90’s - Frequency modulated. 200+ bits/sec ~0.6 secs to send **1 temperature**
3) 2005. Digital signal processing. 1,500 bits/sec 0.3 secs to send **1 temp** record, but more robust in all environments.
4) 2009 to now. 15,000 bits/sec. 1 secs to send **100** temp records
5) 2010 to now. 15,000 bits/sec 4.5 secs to send **500 multi-parameter data records** with timestamp or a days worth of recording temperature every few minutes.

## Through water wireless communications




**EM / Radio**

- Very high bandwidth but <u>only</u> at extremely short range
- Extremely low bandwidth at long range
- Large antenna & lots of power required for reasonable distances

\+ Non line of sight

**Acoustics**

\+ Very long range

\+ Relatively high / flat bandwidth

-  Noise / channel dependent

**Optical**

\+ Ultra high bandwidth at short to medium range

- Turbidity (water clarity) dependent

# AUV Positioning & Communications

## USBL Positioning from Ship – MH370

# AUV Positioning & Communications

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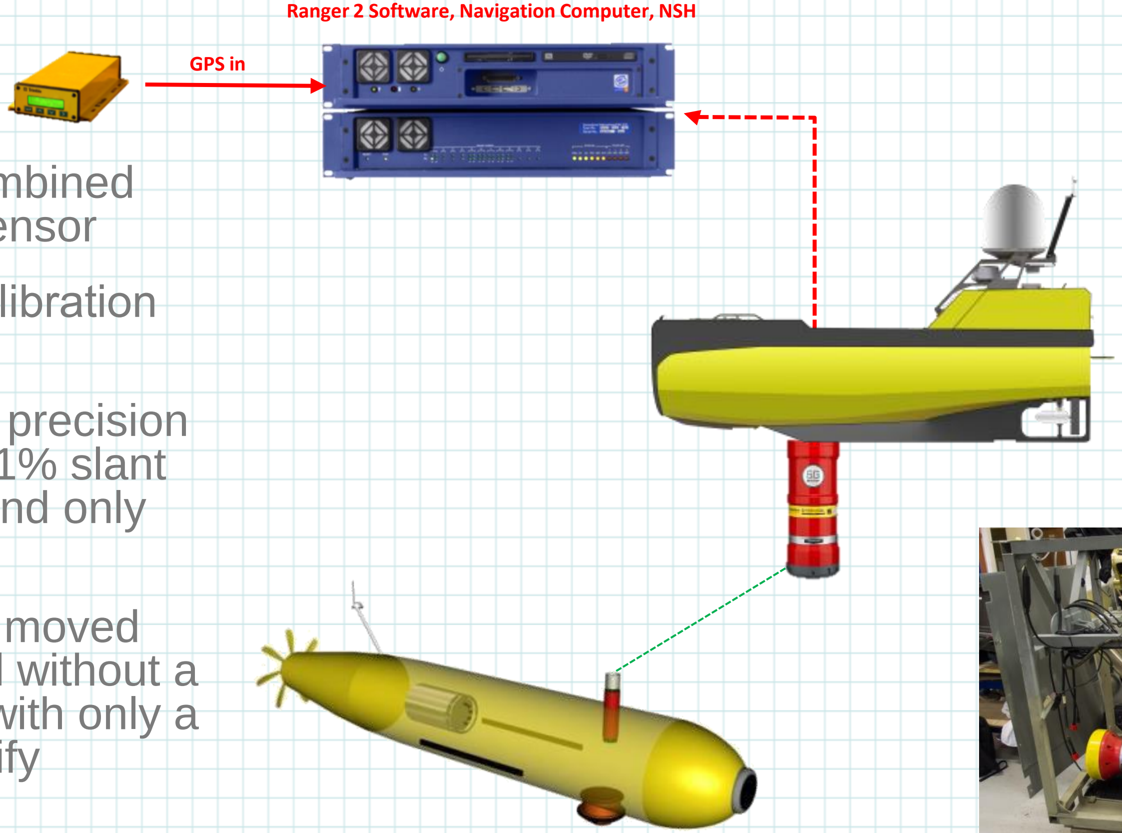
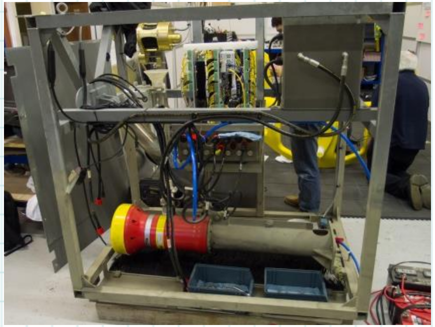
## Navigation – Ranger 2 GyroUSBL

- GyroUSBL is a combined USBL and attitude sensor
- Out of the box “Calibration free”
- ~0.3% slant range precision improving to up to 0.1% slant range after the first and only calibration
- GyroUSBL can be moved from vessel to vessel without a need to re-calibrate with only a quick spin test to verify alignment required







# AUV Positioning & Communications

## Positioning Transponders


WMT

Water depths up to 7,000m

- 3,000m rated with Omni-directional or semi-directional transducer
- 5,000m and 7,000m rated versions available with semi-directional transducer and higher source level (199dB re 1 µPa @ 1 m)
- Remote transducers available
- Li-ion battery charged from AUV power supply (0.5<50W)
- Integrated depth sensor options
- 2.2 kg in water


WSM 6+

Water depths up to 1,000 m

- 1,000 m rated with Omni-directional transducer
- Variants available with acoustically controlled output lines suitable for releasing ballast weights etc.
- Rechargeable NiMH battery for emergency recovery (loss of AUV power) 3 months life
- 4,000 m rated version with directional transducer also available
- Source level 199dB re 1 µPa @ 1 m
- 1.3 kg in water


Nano

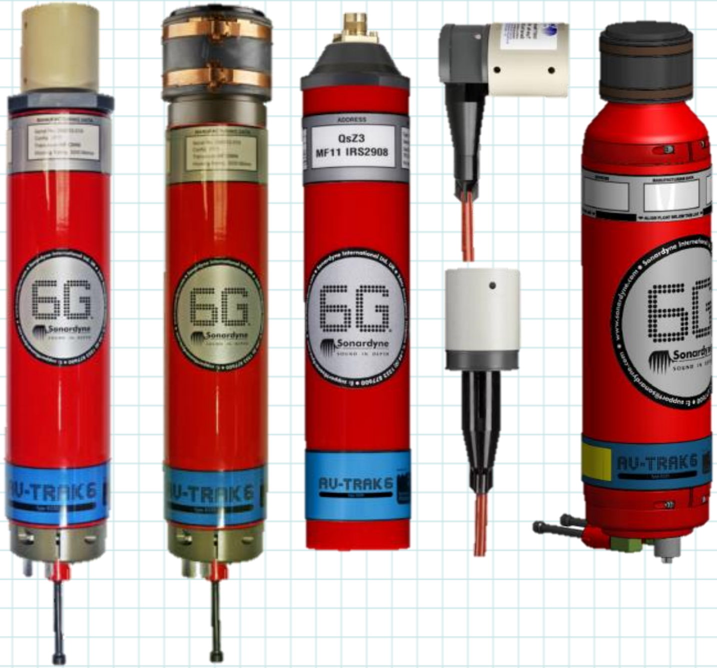
Water depths up to 500m

- Compatible with Mini Ranger 2 6G Wideband USBL
- 750m slant range
- Quiescent battery life >10 days
- 5 sec ping rate >15 hrs
- Docking station allows wireless configuration and charging
- Source level 183 dB re 1 µPa @ 1 m
- 140g in water

Full two-way 6G Wideband interrogation and reply

# AUV Positioning & Communications

## Integrated AUV navigation and comms




- Simultaneous USBL navigation with two way positon telemetry
- Simultaneously integrates on-demand data messages without loss in USBL tracking update i.e. send control commands, receive status updates, etc
- Measures ranges to reference transponders (LBL)
- Communicates with other AUVs
- Sends QC sidescan / images via high data rate (9kbps) acoustic modem
- Up to 7000m depth operation (Directional transducer version)
- Integrated re-chargeable battery for emergency relocation
- Direct control of emergency ballast, plus other IO lines

# AUV Positioning & Communications

## AUV to AUV Comms

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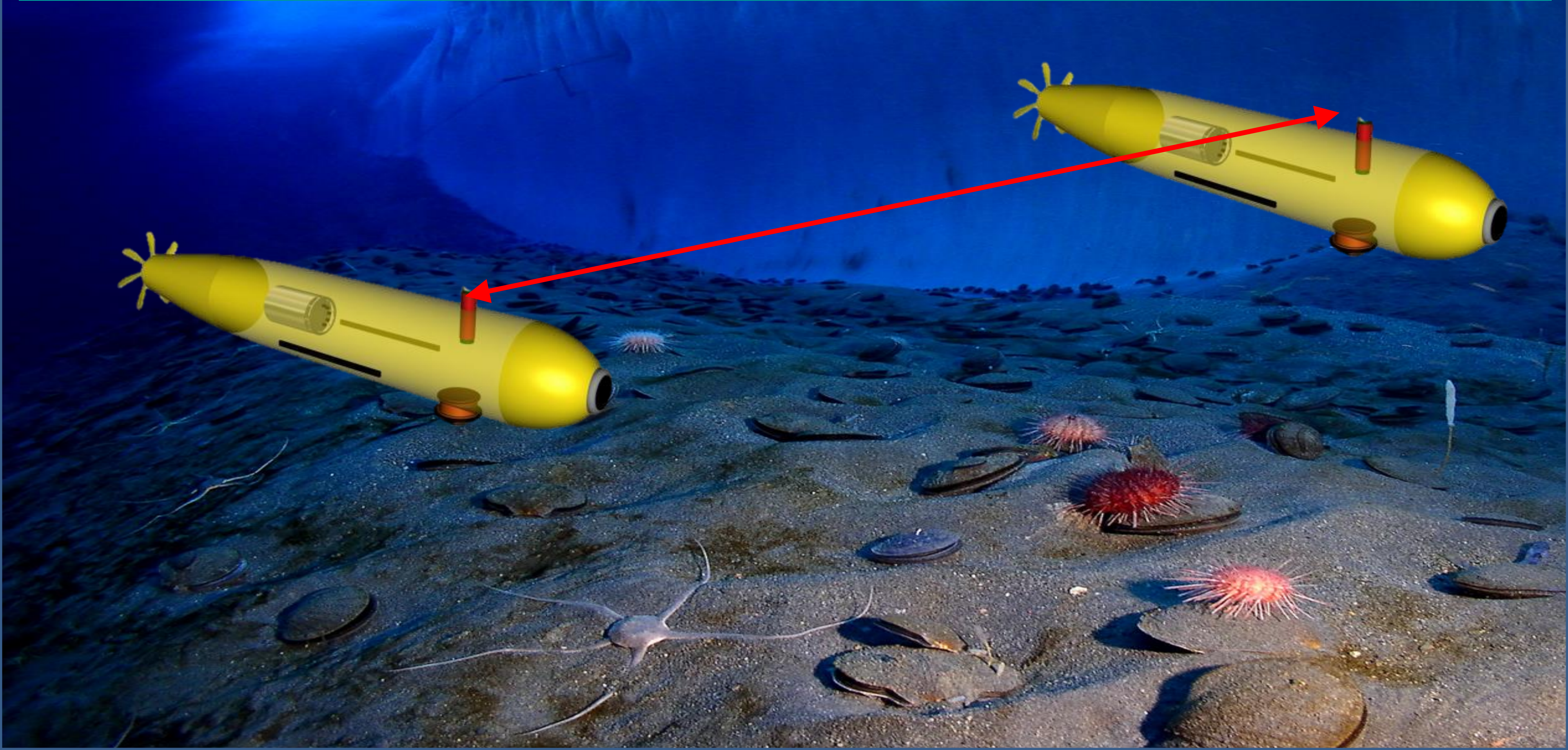
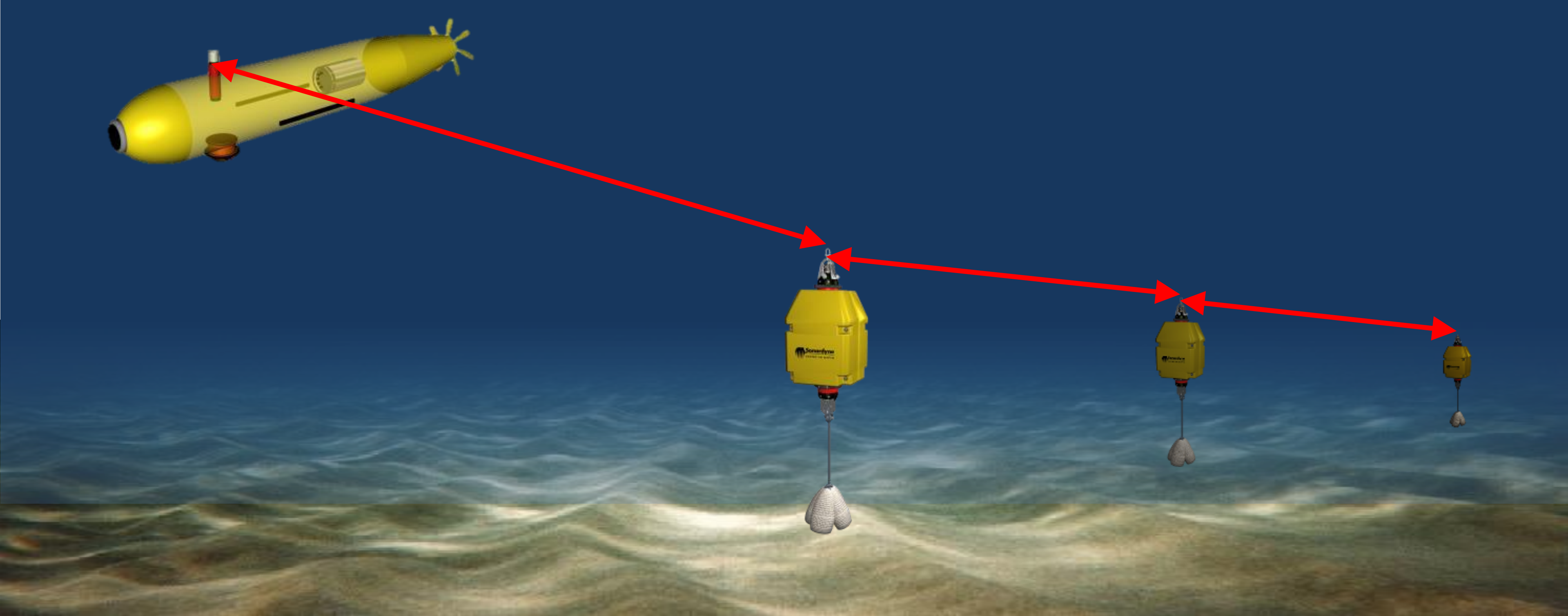


## AUV Seabed Transponder Relay

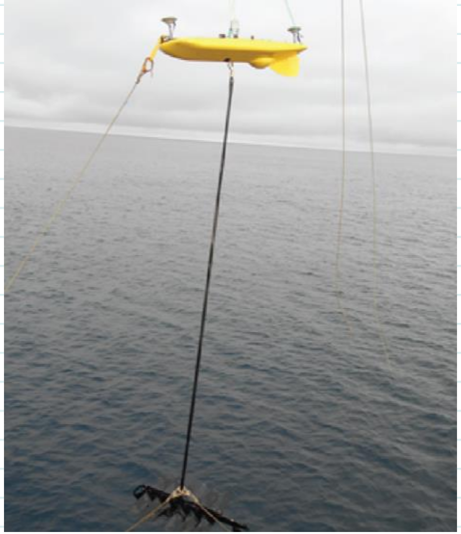


# AUV Positioning & Communications

## Integrated AUV Navigation and Comms

- Positioning & telemetry transponder board set
- Compatible with 6G Wideband USBL
- Active listening power < 60mW
- Input voltage 12.5 – 20Volts
- MF band
- Low / medium power
- Communications – RS232
- 500 m depth rating
- Operational range up to 995 m
- Telemetry schemes up to 9kbps

## WaveGlider Communications – Acoustic Comms Module

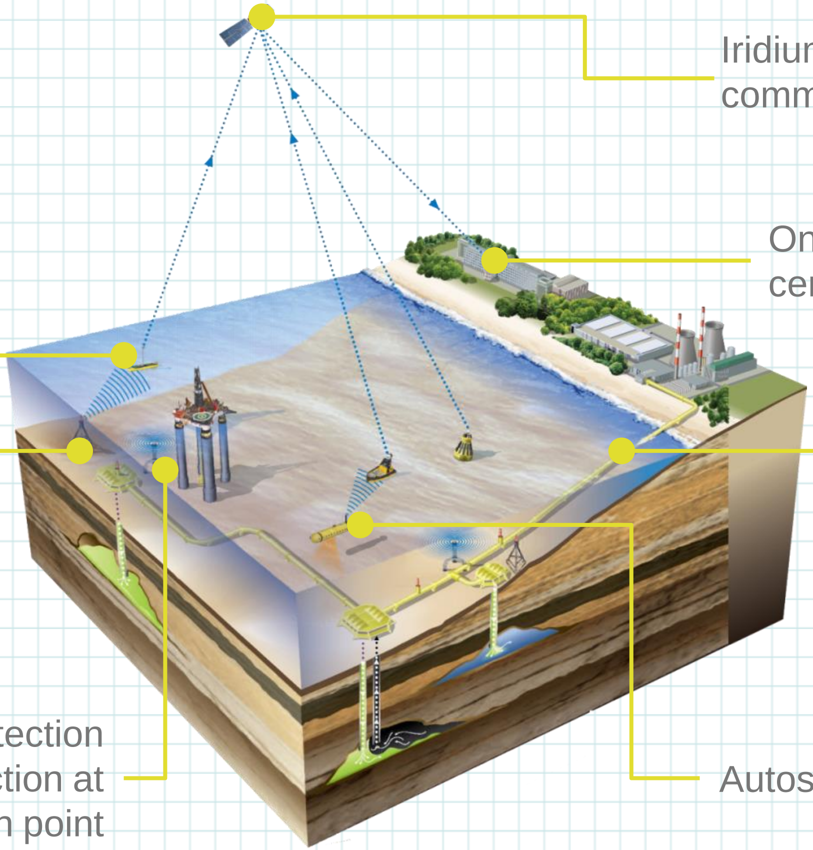


- Specifically designed for incorporation into Liquid Robotics Waveglider for:
  - Remote/wireless data harvesting from large arrays of seabed instruments
  - Deep ocean Tsunami sensor mobile gateway buoy
  - Precise GPS/acoustic positioning of seafloor reference sites for tectonic studies
  - Collection of pressure and temperature gauge data from Sonardyne acoustic data loggers;
- 6G Wideband 2 acoustic comms
- Telemetry < 9kbps
- MF (19–34kHz) and LMF (14-20kHz) versions

# AUV Positioning & Communications

## CCS - Concept of Operations





## Optical Comms Demonstration in NASA Neutral Buoyancy Tank

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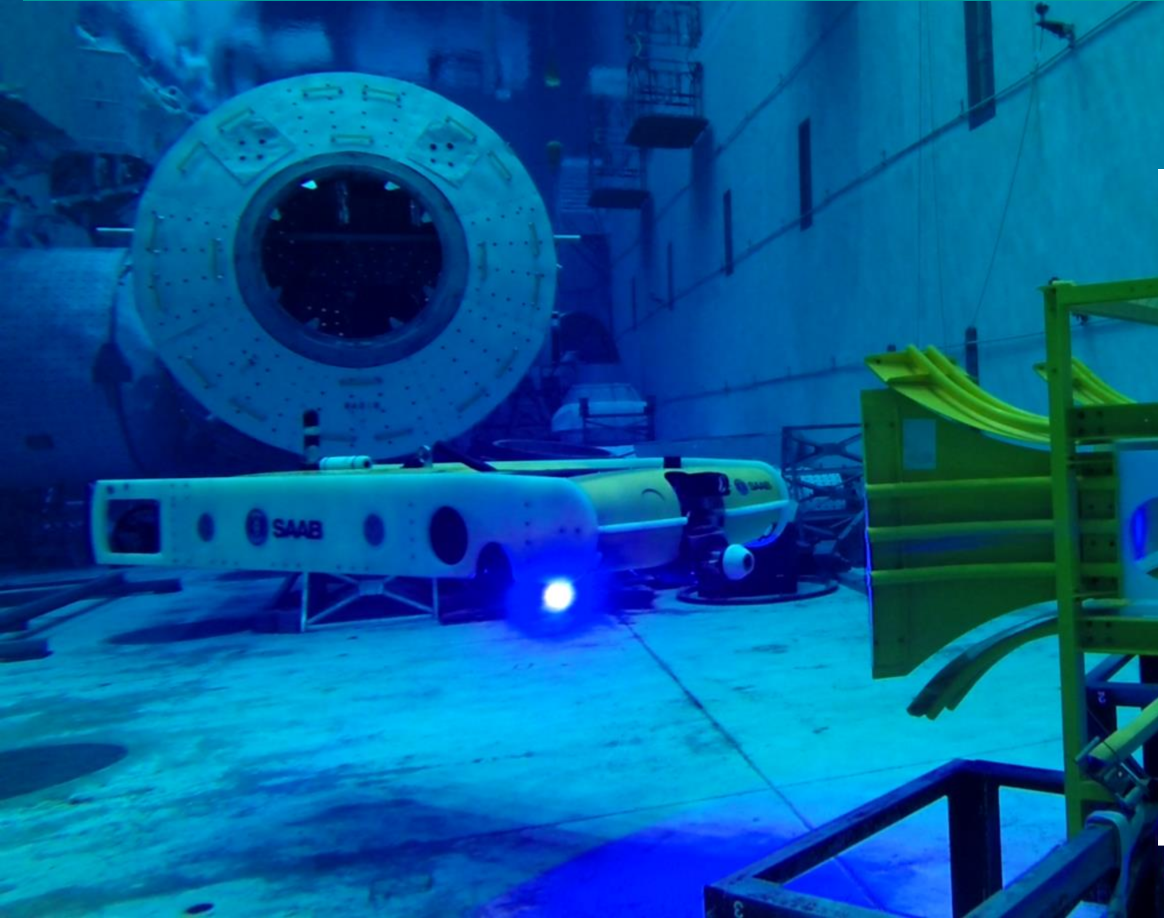
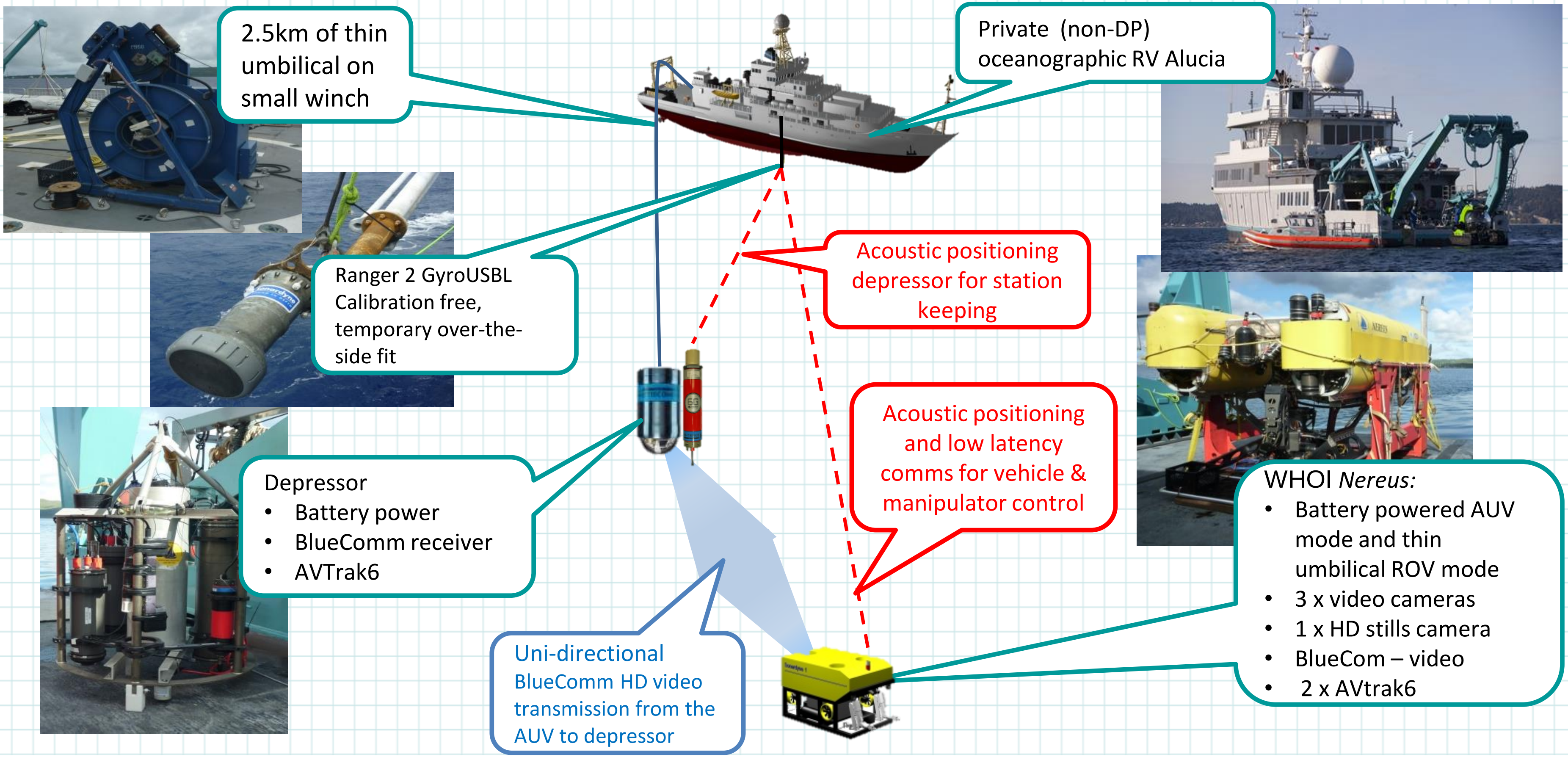



- 1 – 12.5 Mbps at up to 200m
- Suitable for low turbidity and dark conditions
- Housings up to 6,000m depth

# AUV Positioning & Communications

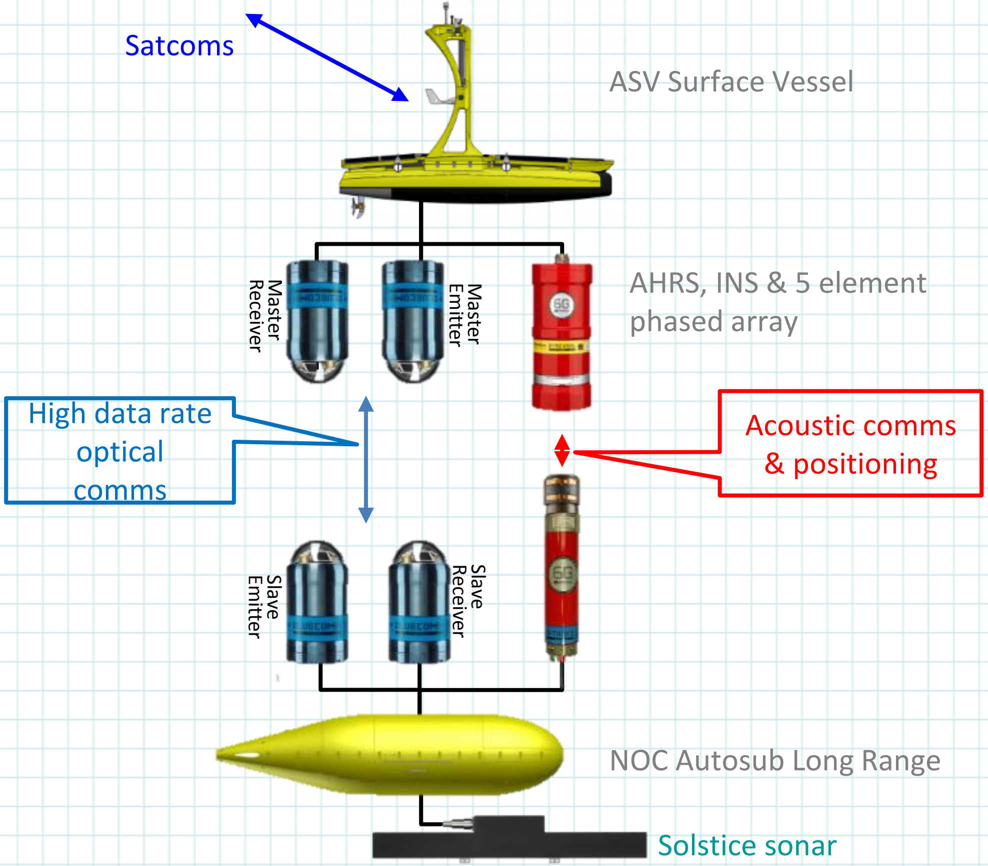
## BlurComm Case Study: RV Alucia/Nereus Trial



# AUV Positioning & Communications

## Autonomous Surface Subsurface Survey System





AUV Positioning & Communications

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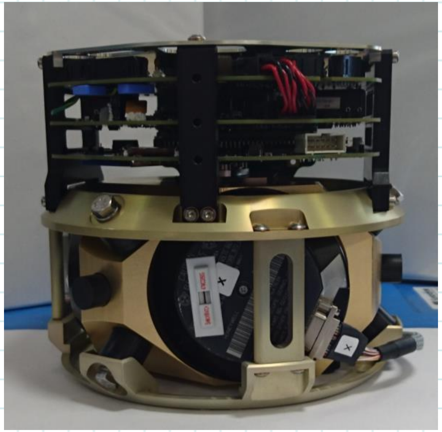
## Inertial Navigation System (INS)

| | SPRINT 300 | SPRINT 500 | SPRINT 700 |
|---|---|---|---|
| Linear mission (% distance travelled) | 0.25 | 0.15 | 0.08 |
| Site survey (% distance travelled) | tbc | 0.02% | <0.02% |
| Free Inertial (NMPH) | tbc | 2 | ~0.8 |
| Sparse LBL (% slant range) | n/a | 0.3% | 0.15% |
| USBL (reduction of noise) | 2–6 x | 4-10 x | 6-13 x |

- Honeywell Ring Laser Gyros (RLG) MTBF > 400,000 hours
- 100,000+ Honeywell IMUs in operation in most commercial aircraft
- Commerce rather than ITAR export controls
- Dual AHRS and INS
- 15 days internal storage
- 2hr battery backup

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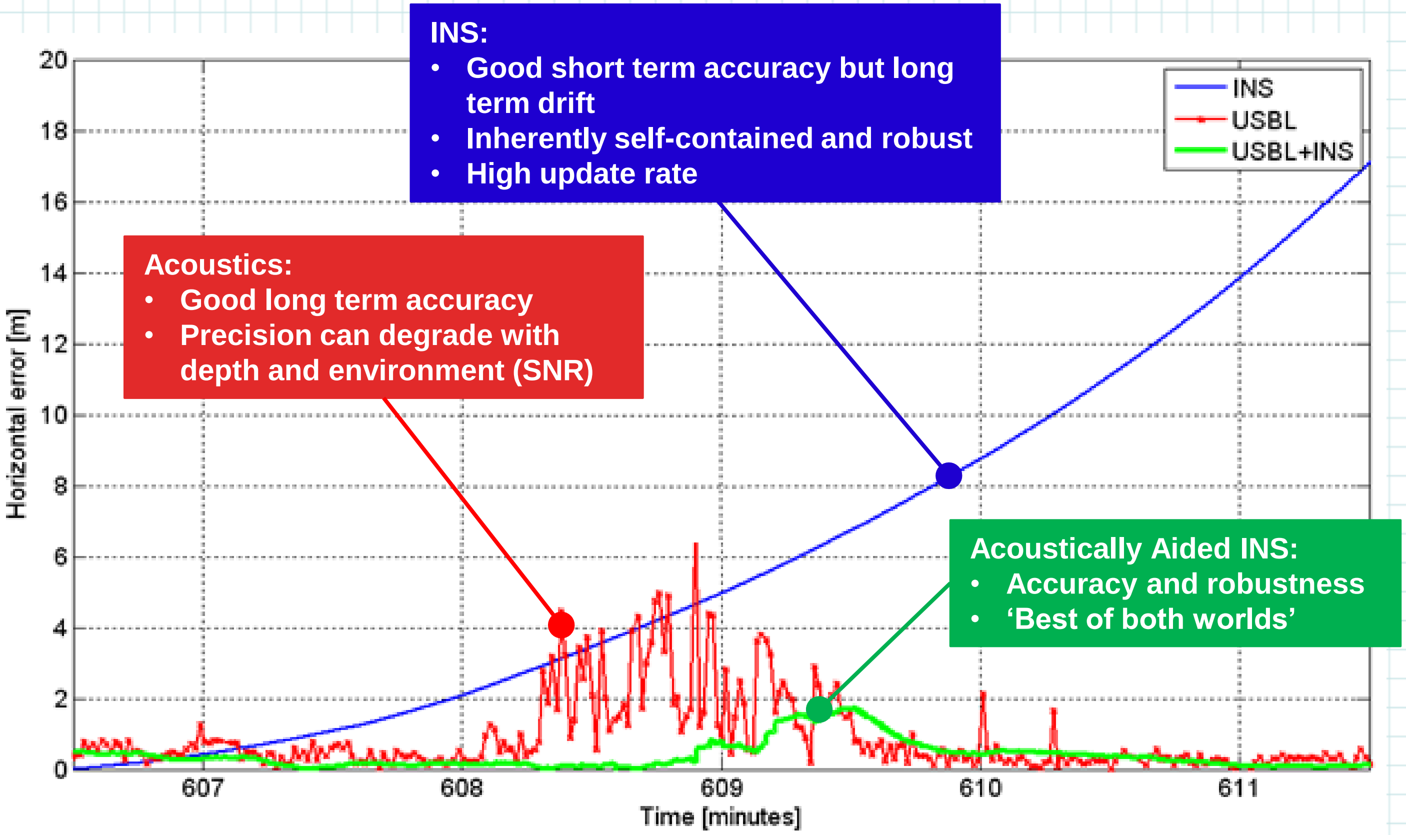
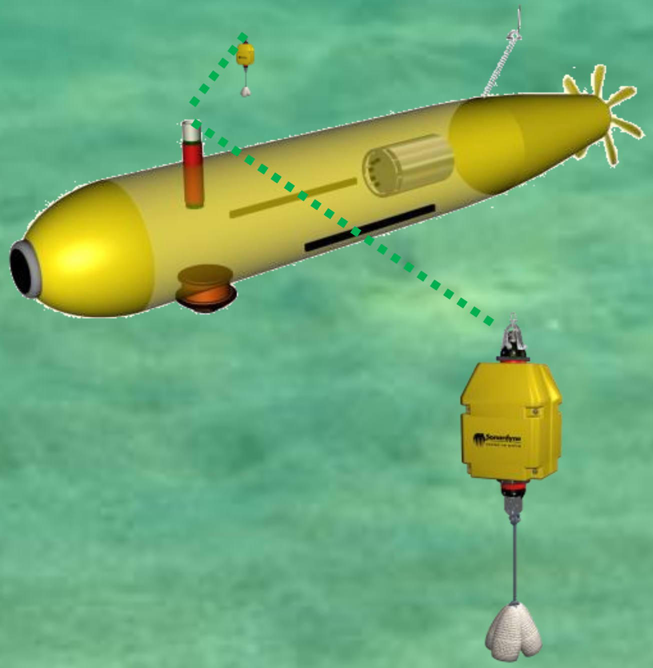
## Complementary characteristics of INS and acoustic positioning

Inertial Navigation determines a position by dead reckoning.

- An INS calculates position, velocity and attitude changes using gyros and accelerometers
- It is completely self contained and therefore inherently robust
- Earth gravity and rotation is not easily disturbed!
- Continuous output with very good short term accuracy
- But drifts with time
- Complementary to acoustic positioning

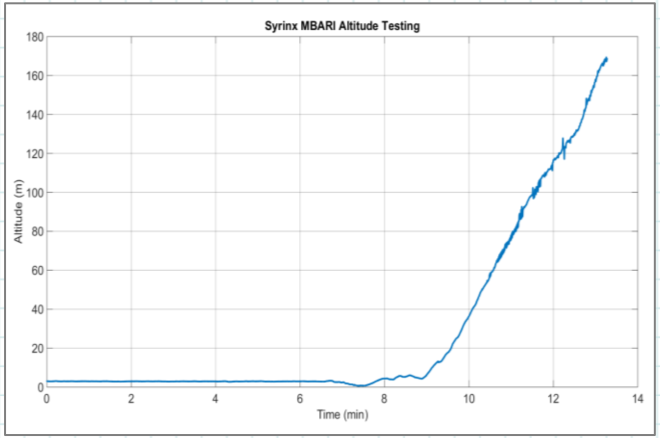


- AUV command and control software instructs the Avtrak 6 to measure acoustic ranges to Compatt transponders. These ranges are sent to the SPRINT INS system to generate a position of the AUV.
- Positioning to <5cm from full LBL array (≥4 Compatts)
- Positioning to <20cm from sparse LBL (1/2 Compatts)

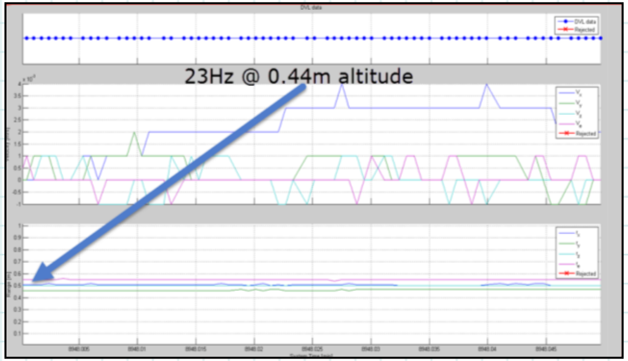


## Syrinx DVL Performance

### Altitude:
- Max 175m
- Min 0.4m

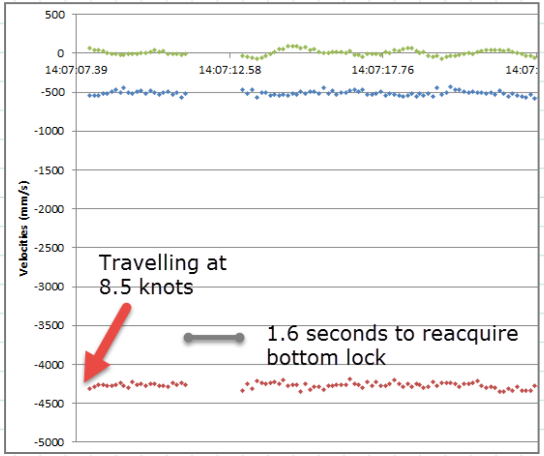



### Update Rate:
- >20Hz @ <0.5m altitude
- Also achievable at higher altitudes





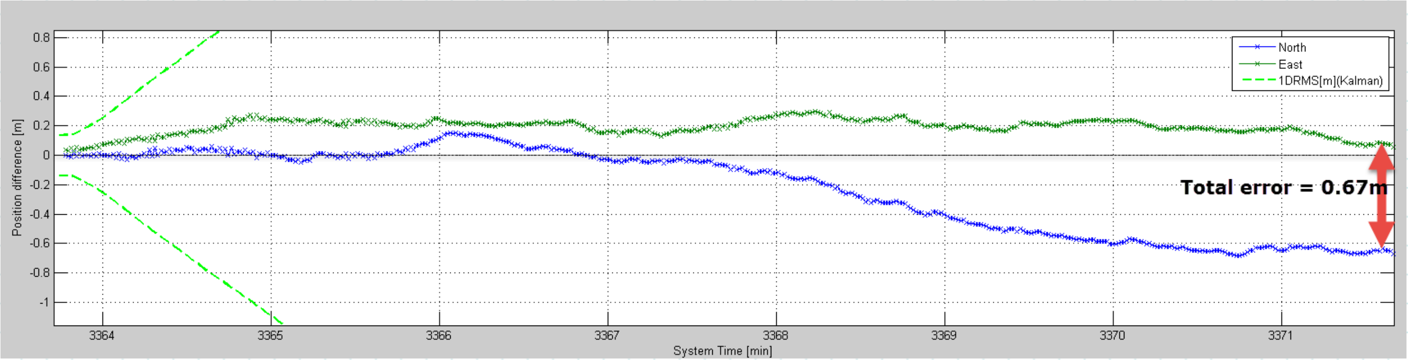
### Bottom Lock:
- Rapid Reacquisition
- 1-2 s even at >8kts




600kHz ADCP
- Concurrent Ethernet and serial connectivity
- Uses both Doppler and Correlation technology

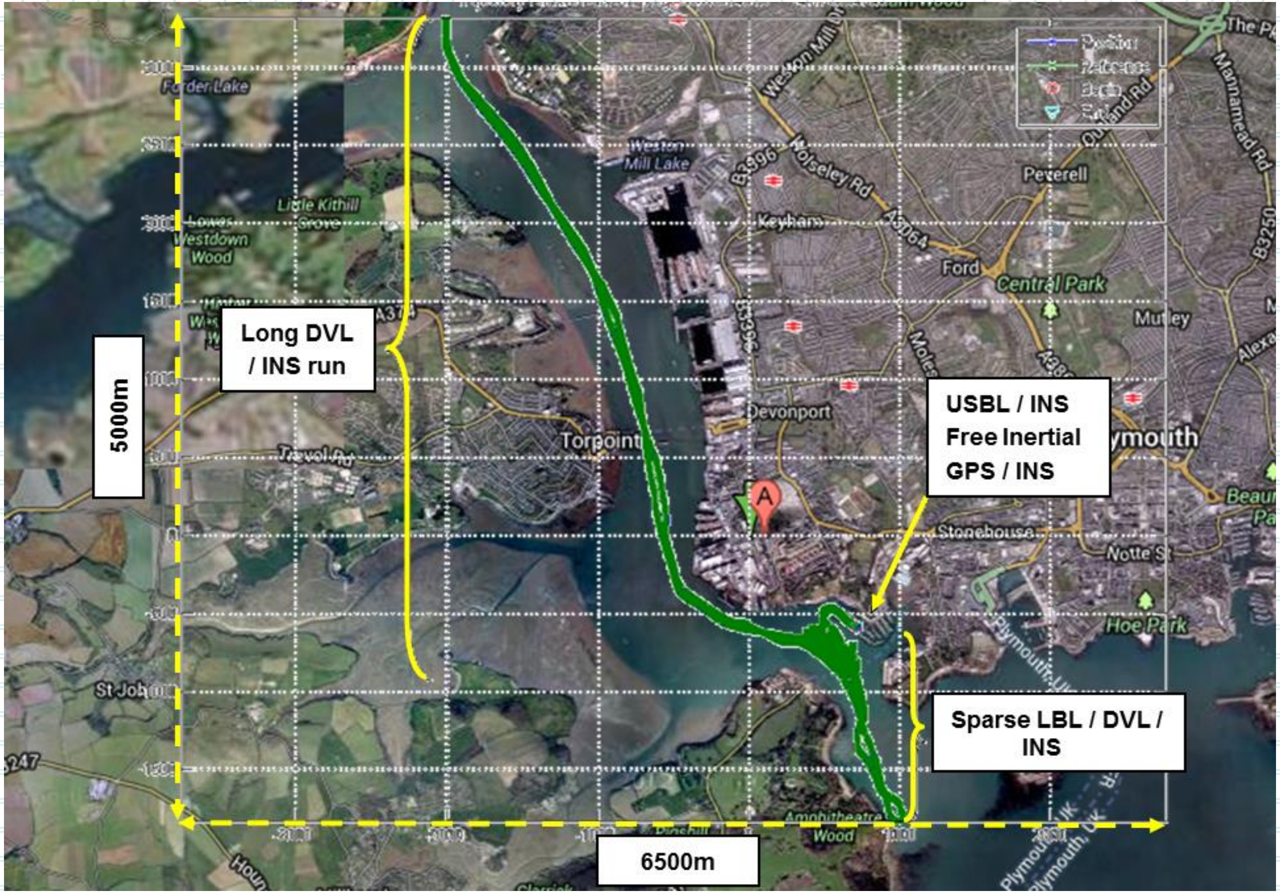
## Navigation – Tightly Integrated SPRINT/SYRINX

- All-in-one subsea navigation
- Integrated unit with fully water blocked DVL endcap
- 0.01% full scale intelligent pressure sensor
- Negates lever arm errors
- Typical DVL INS positioning error of 0.1% of distance travelled (observed error in trials 0.07%)
- Firmware – optimisation of data provided to DVL by Lodestar to aid in velocity prediction and outlier rejection
- Pre calibrated INS + DVL - Reduced deployment complexity

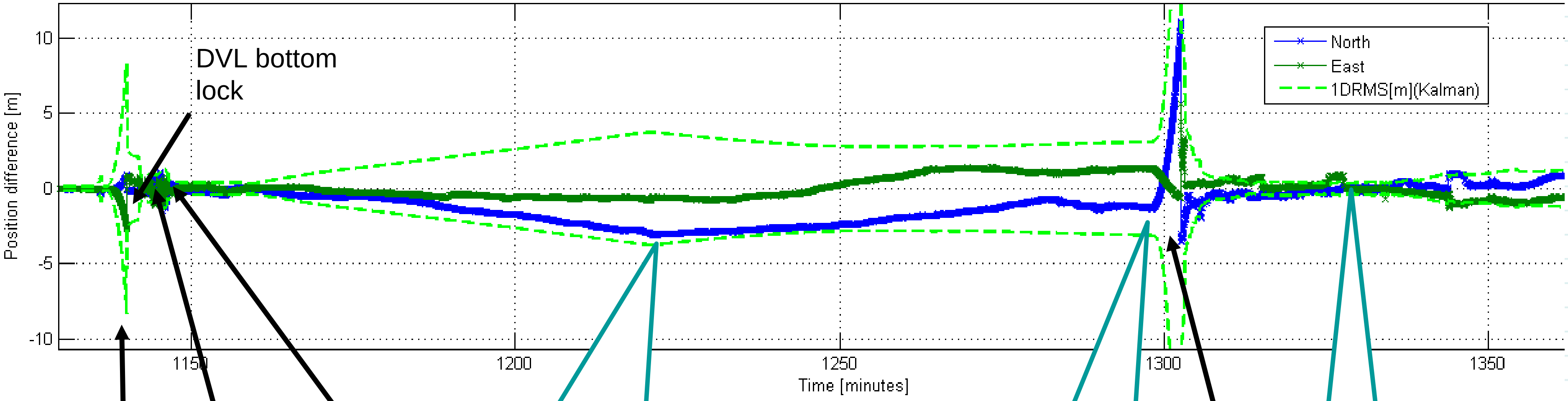
# AUV Positioning & Communications

## AUV Scenario with RTK GPS Truth



# AUV Positioning & Communications

## AUV Scenario with RTK GPS Truth




Free Inertial drift during deployment

USBL aiding enabled

USBL aiding disabled

Free inertial period

DVL aided INS after 1hr and max distance (5km) from origin:
2.85 m error (0.06% of distance travelled)
This is "worst case" (at turning point) with excellent integrity

DVL aided INS after 2hr (>10km) when returning to origin:
1.66 max error
Again excellent integrity.

Sparse LBL (1 transponder at 1 – 1.2km range) aiding
Error <1.0m
25m w.d.

## AUV Positioning & Communications

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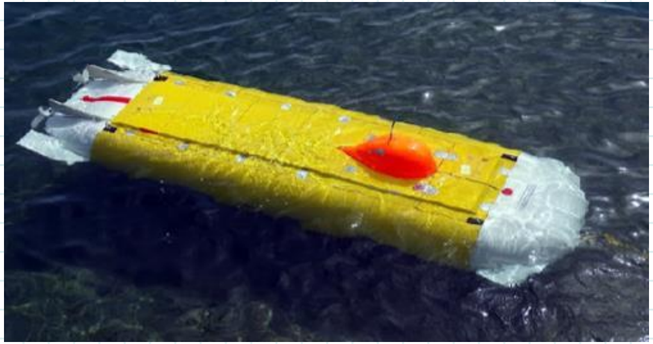
### Fraunhofer DEDAVE AUV – SPRINT Syrinx

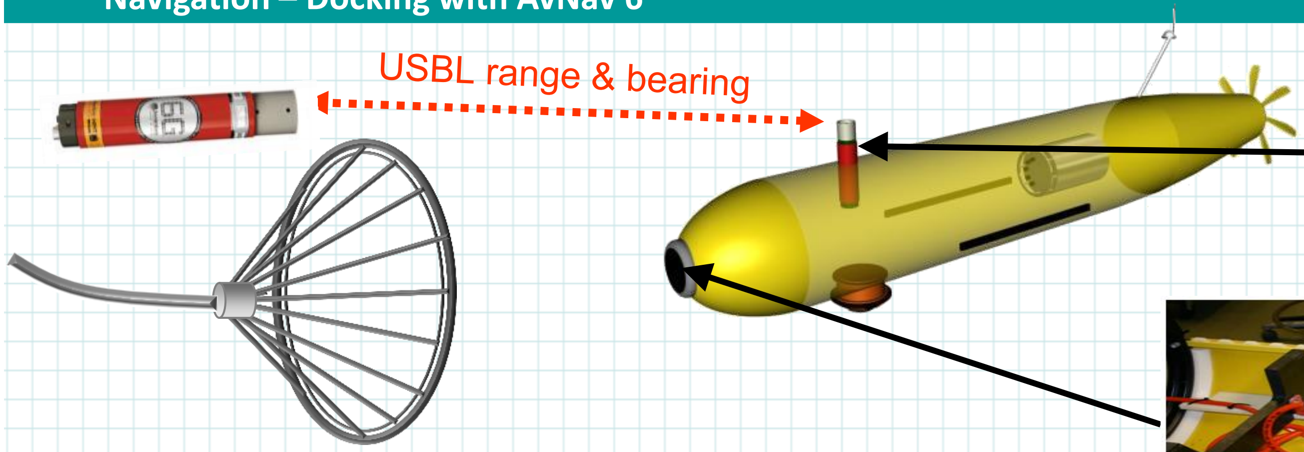


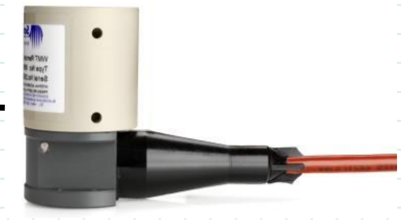


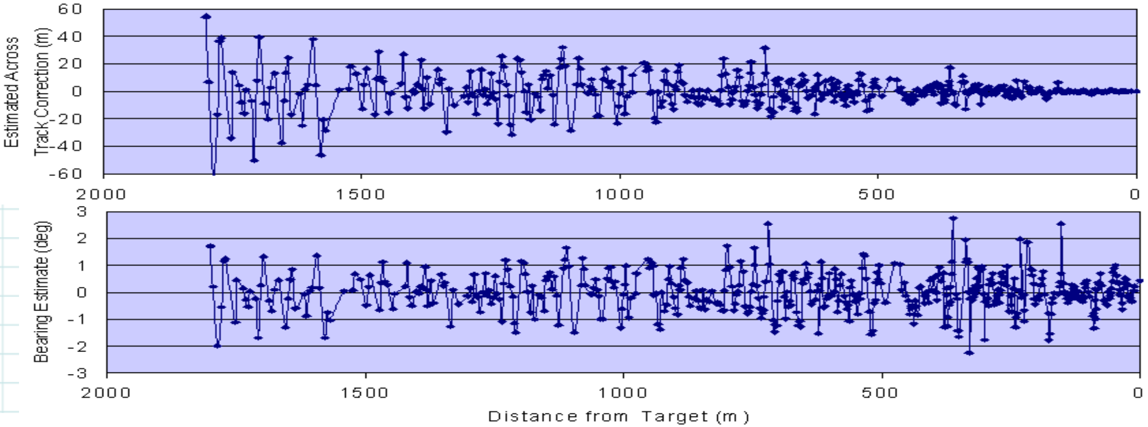
- SPRINT Syrinx all-in-navigation (INS,DVL,Depth)
- Integrated to DEDAVE 6000m AUV
- Modular design supported with SPRINT versions
- Single, simple interface via SPRINT INS
- Selected for ease of export (non ITAR)
- Evaluation underway in lake & sea trials

# AUV Positioning & Communications

## Navigation – Docking with AvNav 6



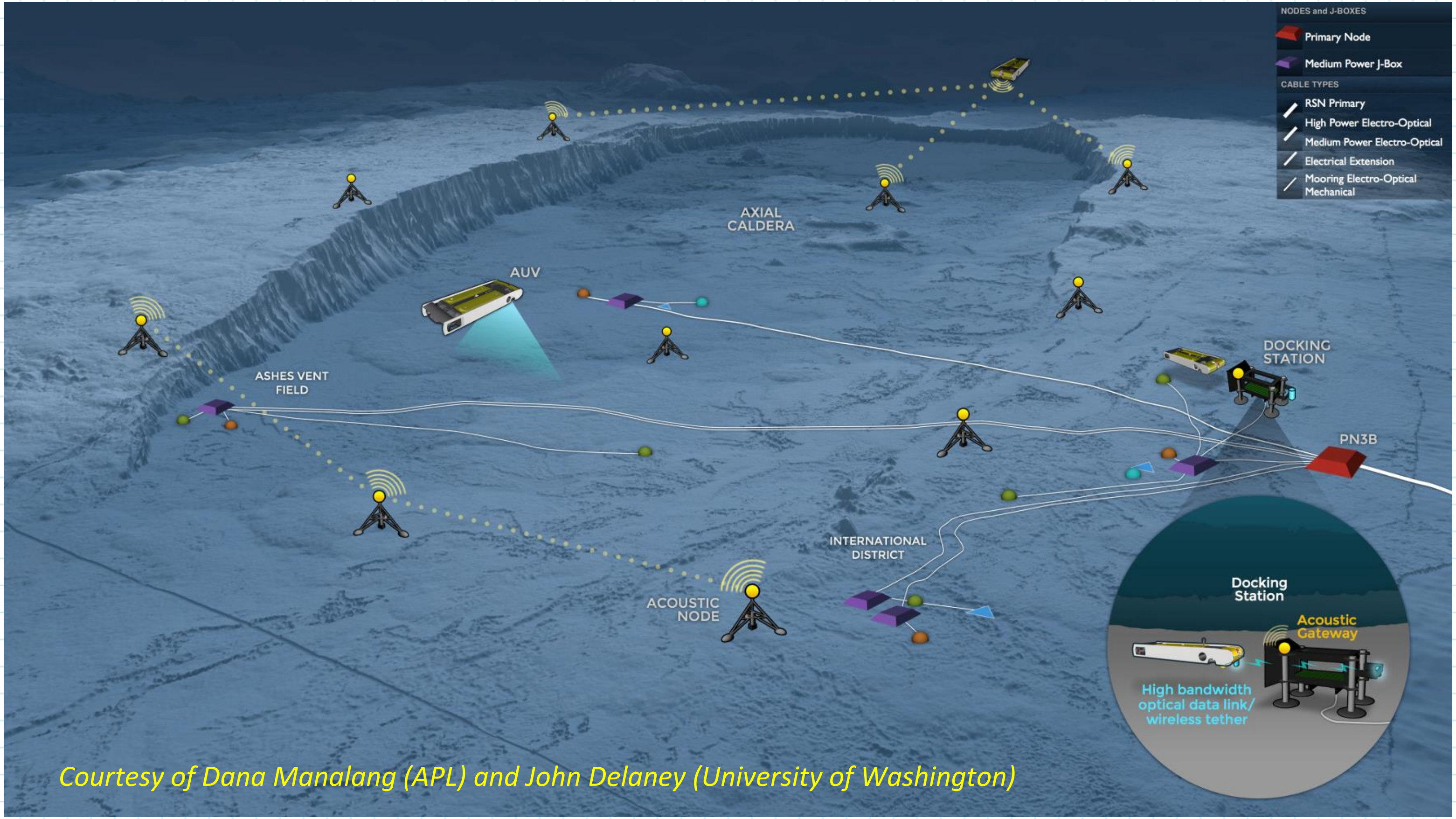



Cross track error

Bearing error

# AUV Positioning & Communications

## Axial Seamount Resident AUV and Seabed Monitoring Concept




*Courtesy of Dana Manalang (APL) and John Delaney (University of Washington)*

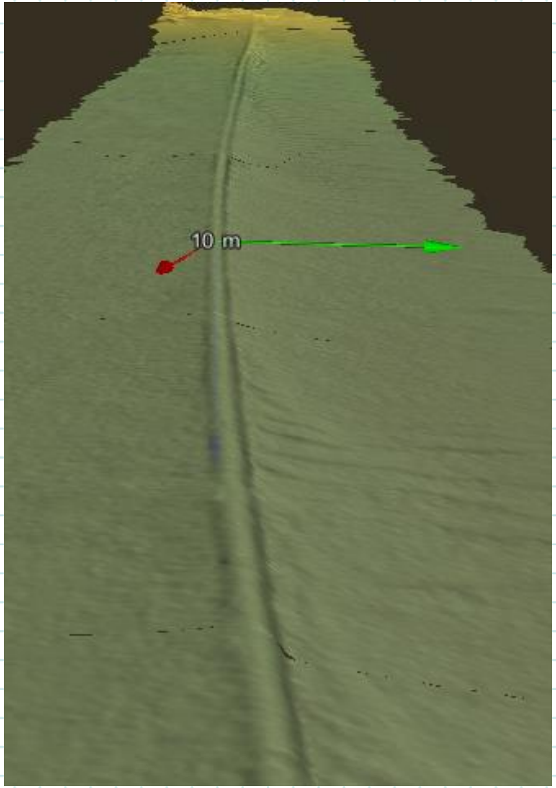
# AUV Positioning & Communications

## Post Processing

- SPRINT with 3000m Lodestar INS
- USBL, DVL and Depth aiding
- JANUS Post Processing
- Spec of 20cm relative accuracy in 50m easily achieved
- With USBL disabled for 10 minutes the real time DVL aided drift of 20cm was eliminated during post processing
- This means that even with a 10 minute USBL outage SPRINT and JANUS still achieved the required spec.

**SPRINT Real Time (coarse configuration)**


**JANUS Post Processed**



## SPRINT & Janus Case Study: Pipeline Out Of Straightness

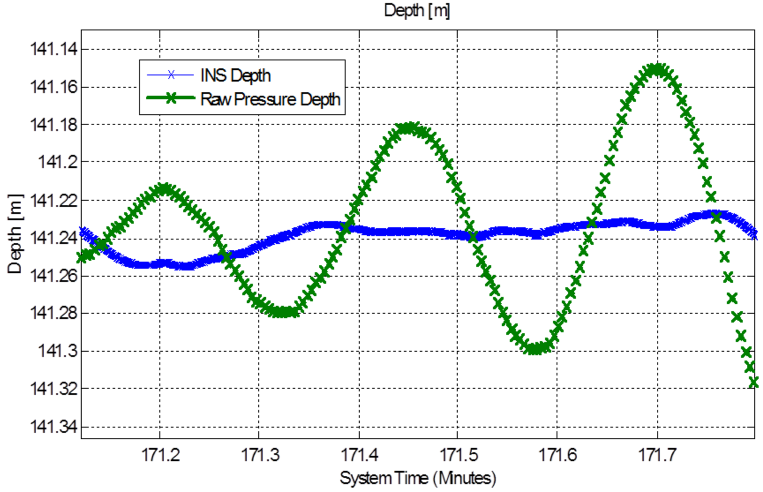
*South Africa - December 2012*

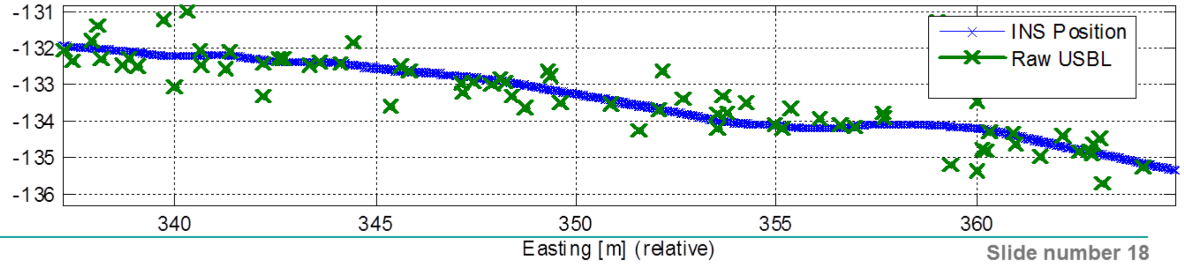
### Setup:

- SPRINT with 3000m Lodestar INS
- USBL, RDI DVL and Depth aided
- JANUS Post Processing

### Customer Benefit:

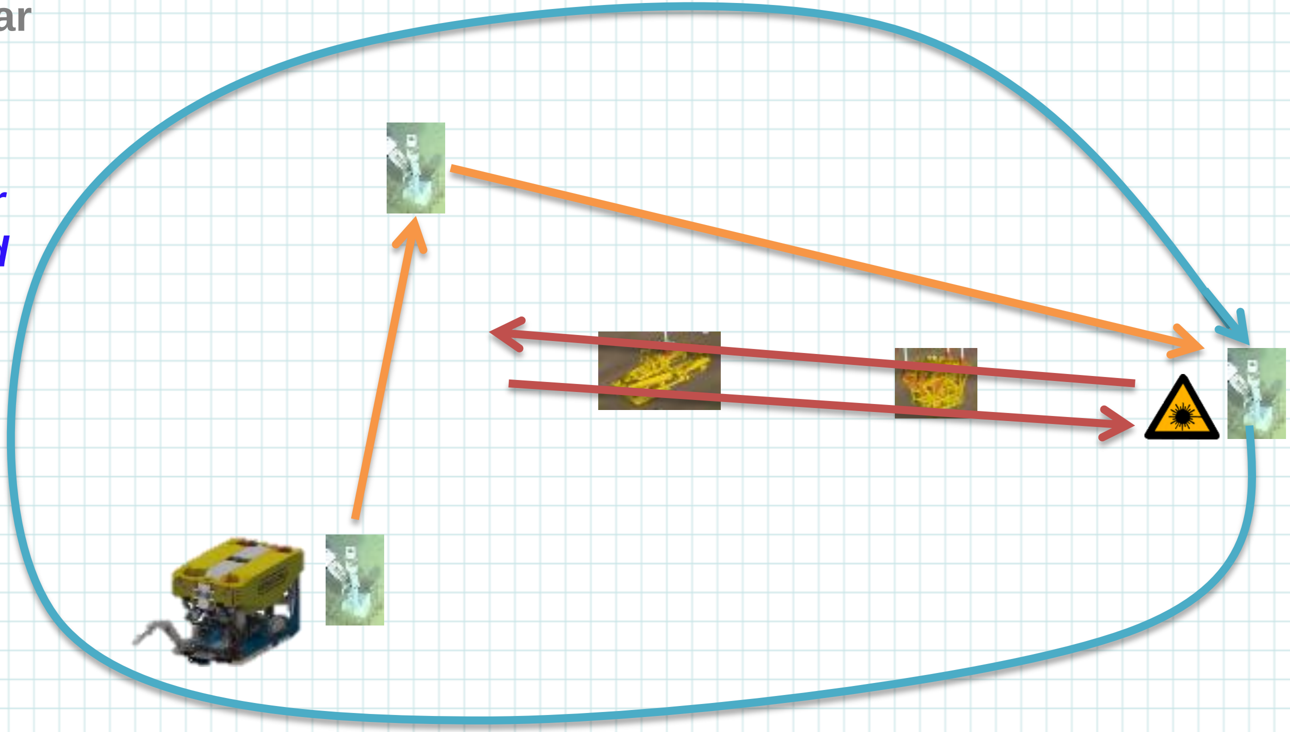
- **Ocean swell** effect on pressure depth removed by Janus post processing (see right)
- Post processing further removes effects of **USBL outliers** (see below)



## Hi-res wide area mobile mapping via INS + Laser/LIDAR

1. Deploy mini WB transponders
2. SLAM and Baseline calibrate (JANUS)
3. Enable Laser/Lidar
4. Map Baseline
5. *Janus post-proc*
6. *Merge Nav+Laser => 3D point cloud*
7. *Measure*



# AUV Positioning & Communications

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## Laser Mapping - U561

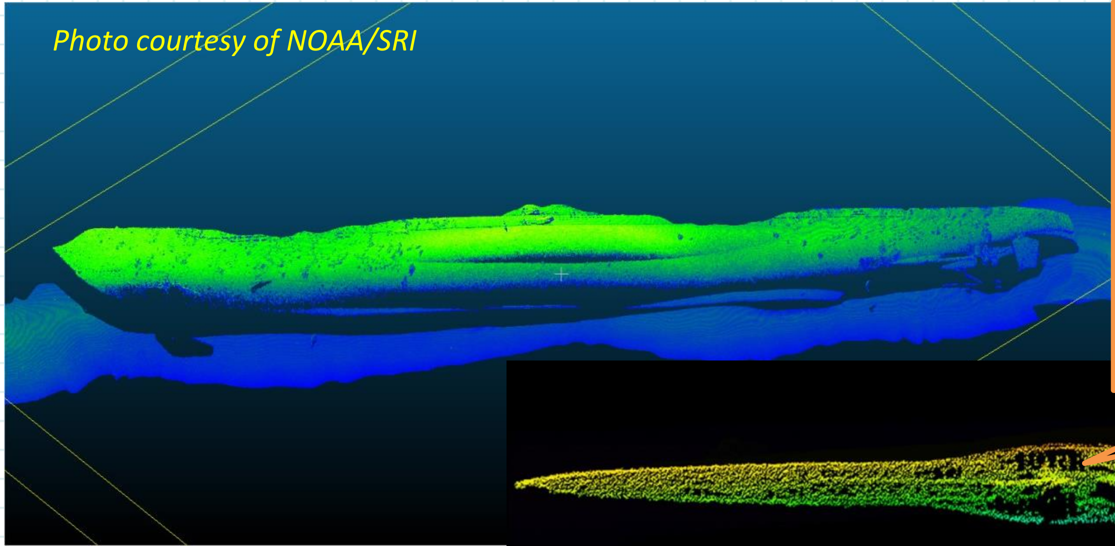

*Photo courtesy of NOAA/SRI*

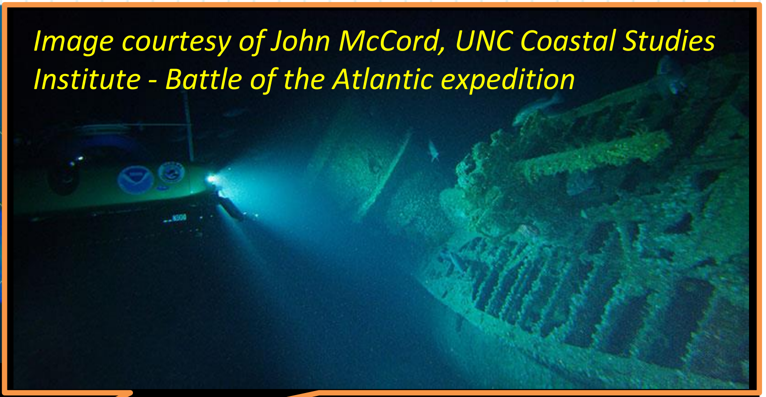

*Image courtesy of John McCord, UNC Coastal Studies Institute - Battle of the Atlantic expedition*

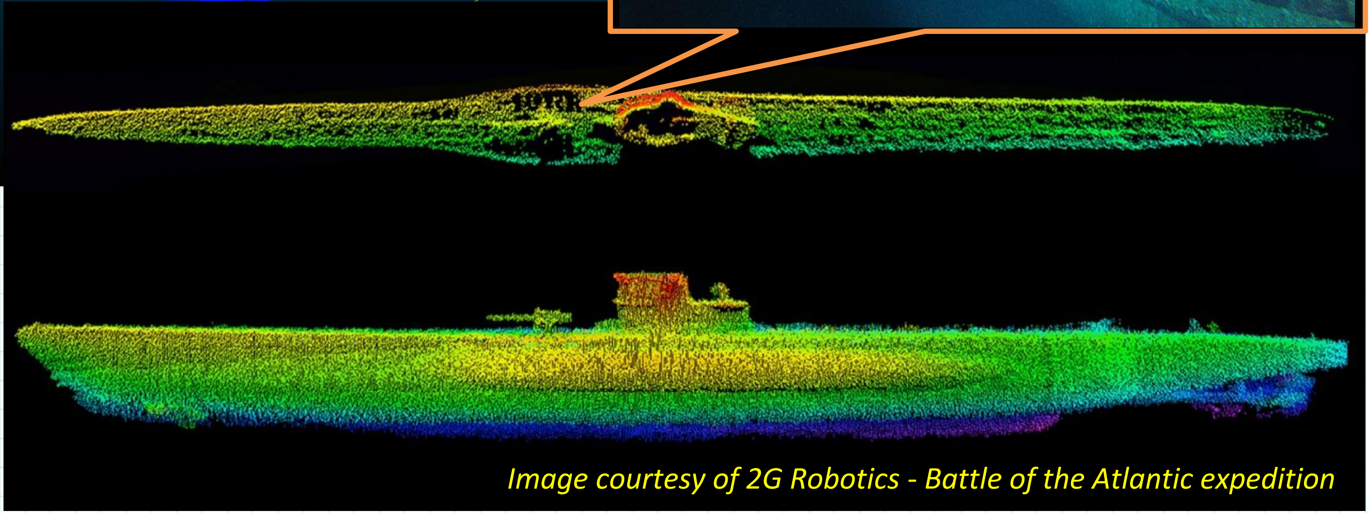

*Image courtesy of 2G Robotics - Battle of the Atlantic expedition*

- Sunk 13 July 1942
- Mapped 24 August 1916

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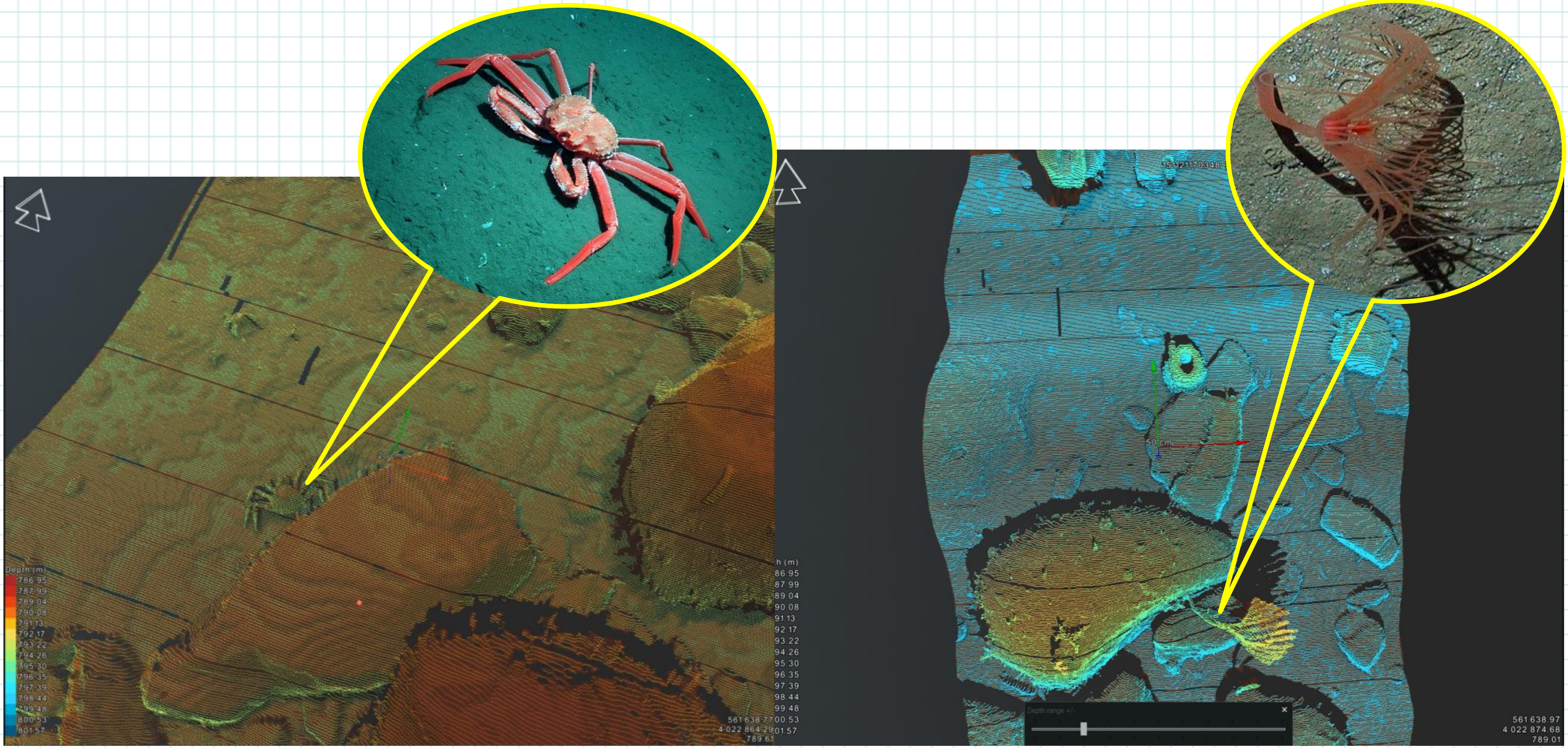
## Laser Mapping – Monterey Bay



# AUV Positioning & Communications

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Korea Polar Research Institute

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An institute of Nanyang Technological University

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UNIVERSITY of WASHINGTON

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NATURAL ENVIRONMENT RESEARCH COUNCIL

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# Any questions?

**Panel Discussion**

**Questions**

# Marine Autonomous Systems Bathymetric Survey Workshop

*"However, until the technology has matured, we have no plans to employ MAS under the programme.*

*As you might imagine, we are watching this area closely and are aware of a number of trials that have recently taken place.*
***We await the results with interest**."*

*What is the way ahead?*

*[1] Use SMI's Maritime Autonomous Systems (MAS) Council to lobby for acceptance that the technology is mature enough.*

*[2] Open a dialogue with IHO to see if the existing codes/standards need to be modified to include a MAS delivery capability*

*[3] MAS Community produces its own code/standard*

# Marine Autonomous Systems Bathymetric Survey Workshop


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# Panel Discussion

# Questions and the Way Ahead