for the

Shell OCEAN DISCOVERY XPRIZE®

On behalf of the GEBCO-NF Alumni Team

Jaya Roperez

Modified presentation of Dr Rochelle Wigley

General Bathymetric Chart of the Oceans GEBCO

THE NIPPON FOUNDATION

The inspiration to enter as a team for the challenge:

Forum for Future Ocean Floor Mapping

15 to 17 June 2016 in the Principality of Monaco

- Opening speech by Mr Sasakawa – Argued for ongoing alumni development & projects
- Jyotika Virmani, Senior Director in Prize Operations, at XPRIZE said at the Forum "NF *GEBCO training program is probably the most successful unknown capacity-building global initiative*"

Forum for Future Ocean Floor Mapping

June 2016

Mr Sasakawa, Chairman of the Nippon Foundation Proposed '…to map 100% of the topography of the World Ocean by 2030'

THE OCEAN CONFERENCE
UNITED NATIONS, NEW YORK, 5-9 JUNE 2017

June 2017

Nippon Foundation - GEBCO Seabed 2030 Project announced

Mr Sasakawa – 1 of 8 IOC-UNESCO "Champions of Global Ocean Science"

Shell OCEAN DISCOVERY XPRIZE®

A $7 million global competition challenging teams to advance deep-sea technologies for autonomous, fast and high-resolution ocean exploration.

Create solutions that advance the autonomy, scale, speed, depths and resolution of ocean exploration

https://oceandiscovery.xprize.org

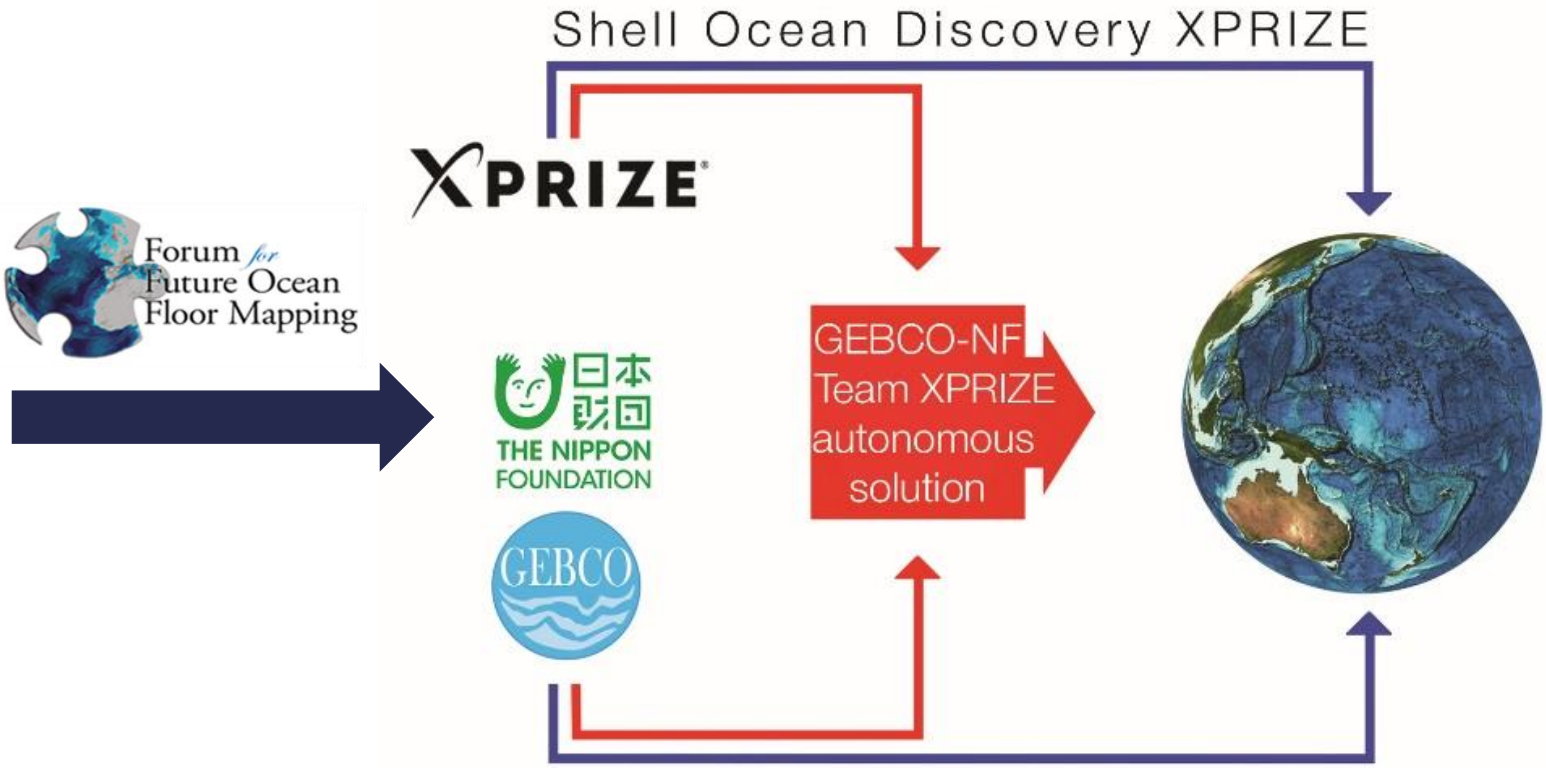
Shell OCEAN DISCOVERY XPRIZE®

The key elements of the challenge

1. Create an autonomous solution to collect data
2. All components used for data gathering must fit within a standard 40 ft shipping container
3. Produce a high-resolution bathymetric map of an area of 100 km^2
   (5 m horizontal and 0.5 m vertical resolution)
4. Produce images of a specified object
5. Identify and image five archeological, biological or geological features

Data collection must be completed in 16 hours with 48 hours for product generation

Meeting global challenges



Nippon Foundation - GEBCO Seabed 2030

Produce: Bathymetric grids where no features of the accessible parts of the World Ocean floor larger than 100 m remains to be portrayed.

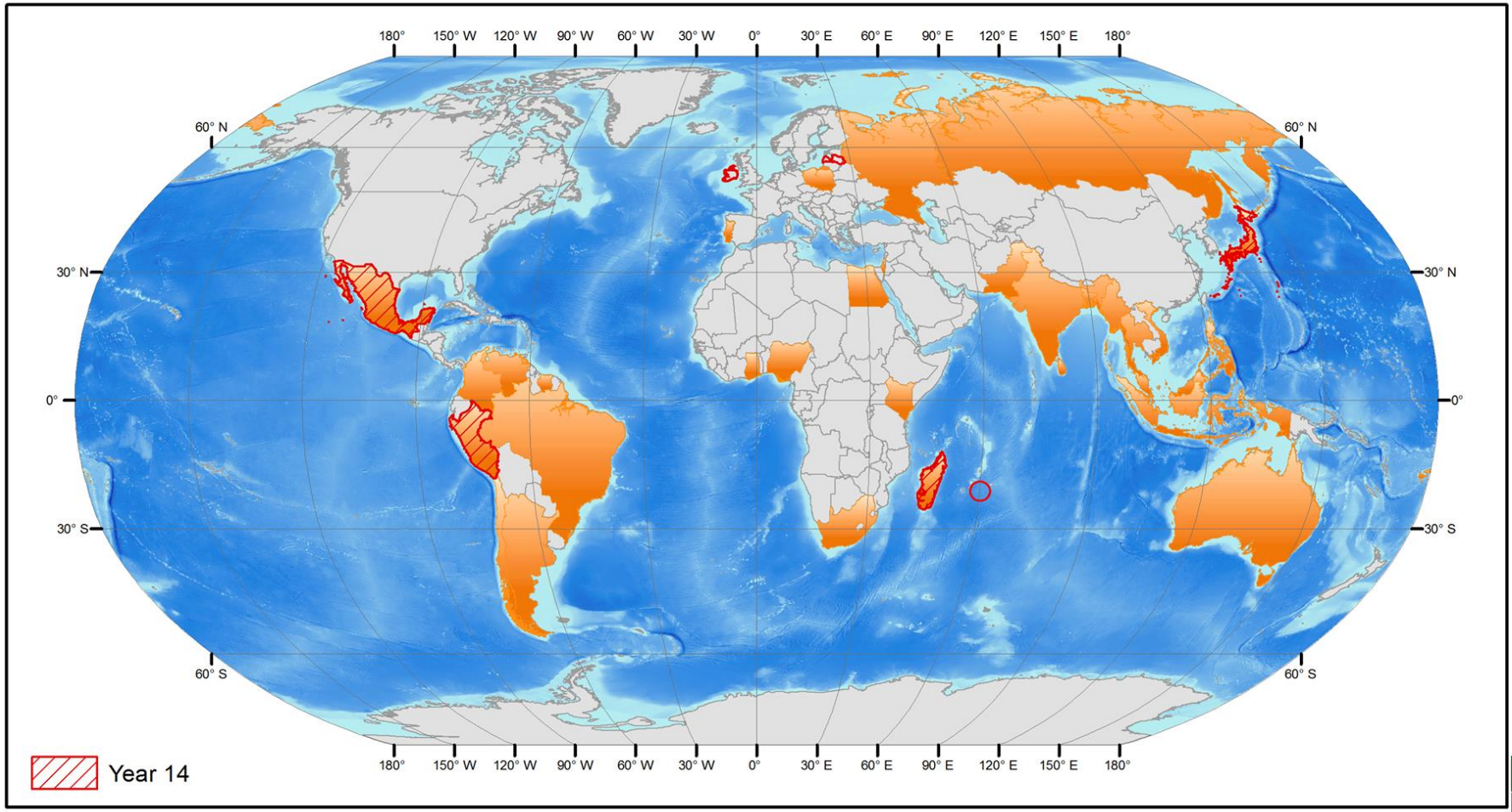
Challenges: Keeping up with technology

The Postgraduate Certificate in Ocean Bathymetry

Designed to train a new generation of scientists and hydrographers in ocean bathymetry

The Center for Coastal and Ocean Mapping /Joint Hydrographic Center
University of New Hampshire, USA

84 scholars from 37 coastal states over last 14 years



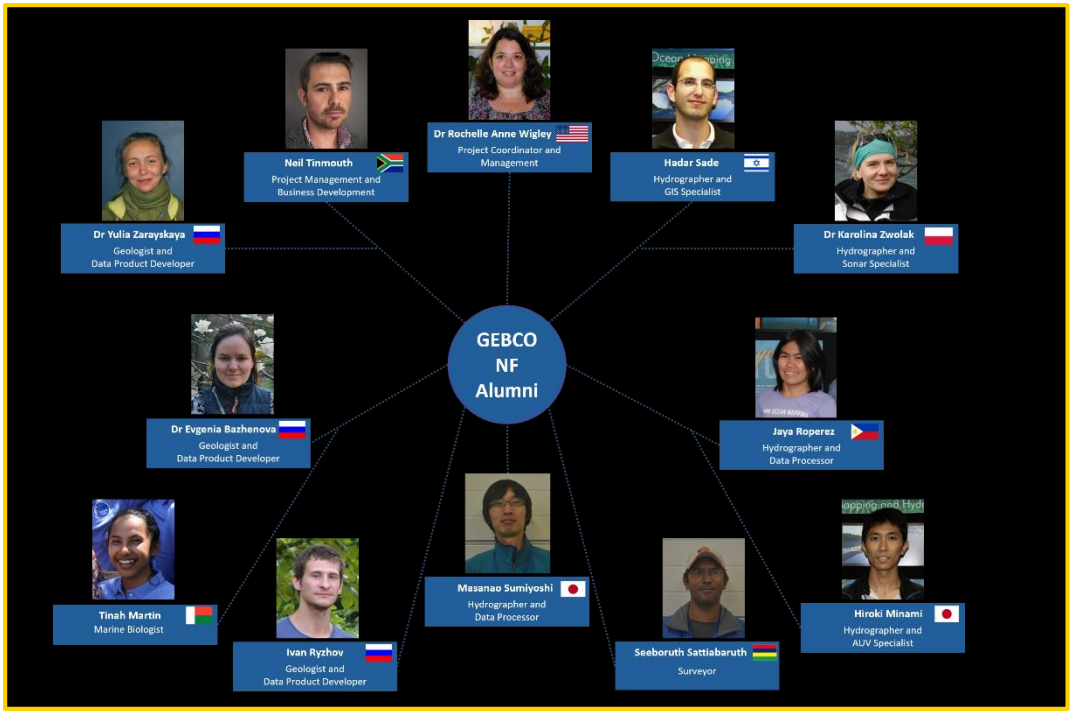
GEBCO-NF Alumni Team: 12 active alumni

10 different coastal states & 8 years of training program

Industry Partners:

- Kongsberg Maritime
- Ocean Floor Geophysics
- Hushcraft Ltd
- University of New Hampshire
- OceanAero
- Teledyne CARIS

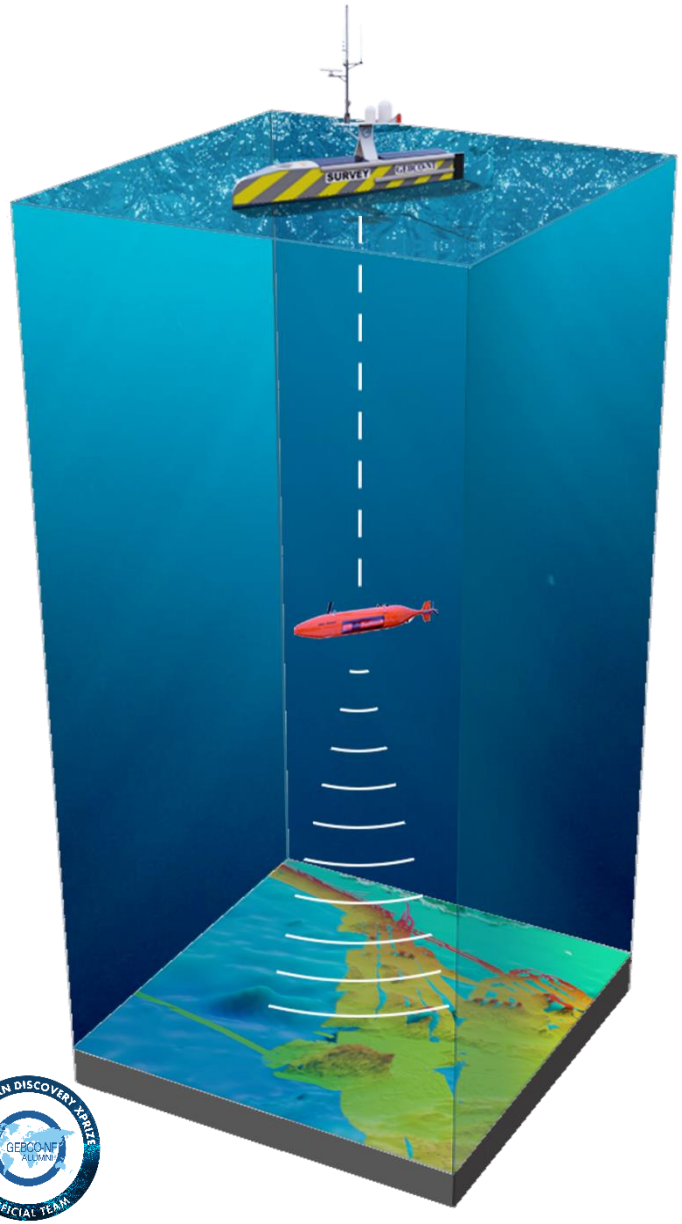
http://gebco-nf.com



4 technical advisors from within GEBCO

The GEBCO-NF Alumni Team concept

Integrates existing technology with innovative new ideas



Hushcraft Limited USV

- Sea-Kit XP with KM HiPAP 351P-MGC
- Unmanned operations by KM

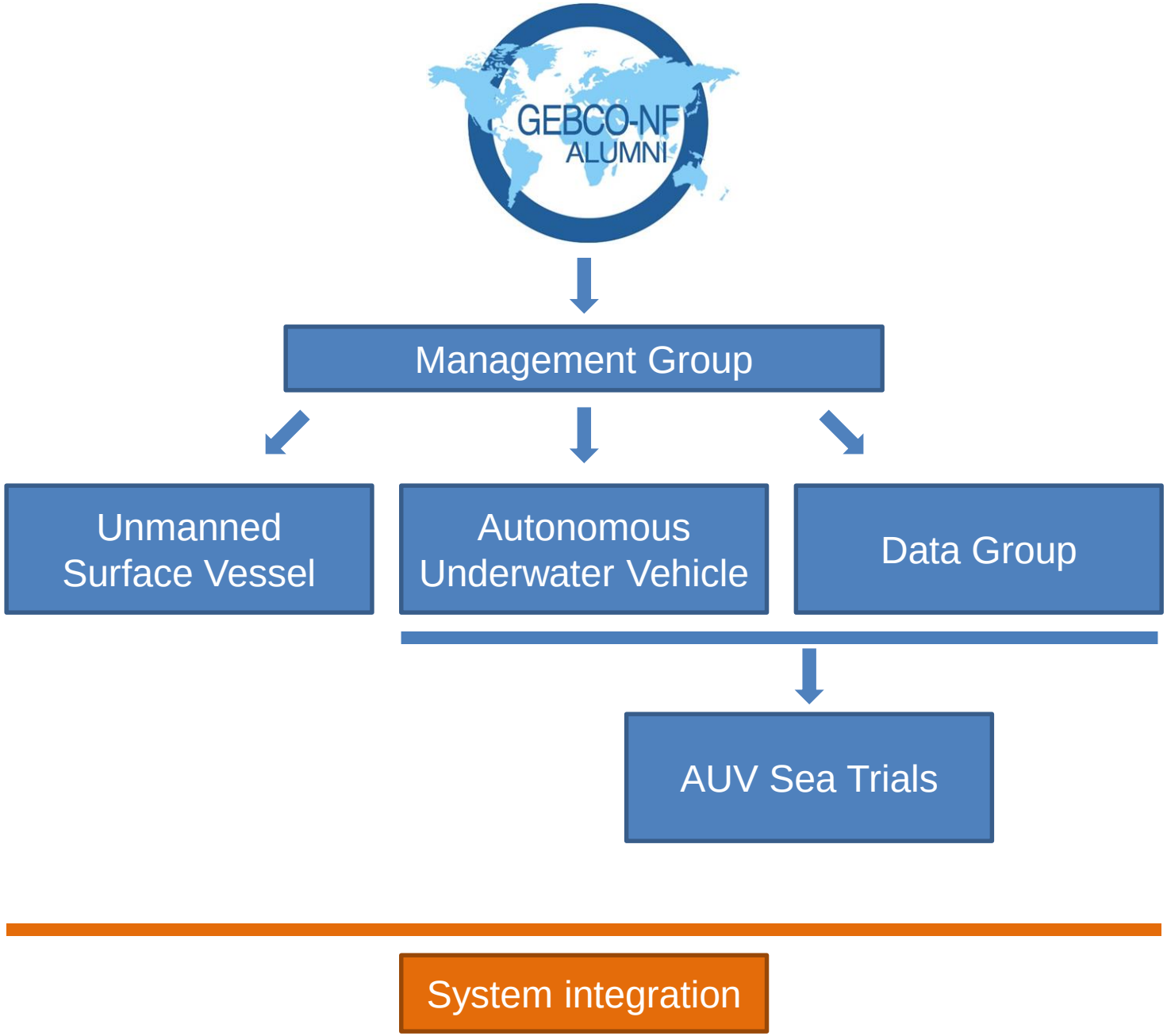
Kongsberg Maritime HUGIN 1000 AUV

- OFG Chercheur AUV (3,000 m)

TELEDYNE CARIS esri

High quality seafloor bathymetry and imagery

- Combination of EM2040 MBES, HISAS side-scan wide-area and HISAS bathymetry & spot-focused HiSAS imagery


GEBCO-NF
ALUMNI
Management Group
Unmanned
Surface Vessel
Autonomous
Underwater Vehicle
Data Group
AUV Sea Trials
System integration

Project Time Line

2016	Decision to register a XPRIZE team	June
	First discussion with boat designer	Sept
	meeting	5 Oct
	meeting	3 Nov
	Shell Ocean Discovery XPRIZE summit	11-14 Nov
	Submission of technical documents	17 Dec
	Through to Round 1 Shell Ocean Discovery XPRIZE	7 Feb
		27 Feb
	Submission to Nippon Foundation	16 March
	Round 1 funded by NF / SPF - $3.25M	22 March
	meeting OFG	**6 April ***
	meeting	11-14 April
	Metal cut for Boat Build	21 April
	First installment of funds	22 April
	meeting OFG	26 April
	meeting OFG	15-16 May
	K-MATE contract	2 June
	SEA-KIT delivered	28 June
	2nd installment of funds ($2,741,500)	30 June
	Data Group: 2 week visit TELEDYNE CARIS	24 July
	AUV arrives in Norway	7 Aug
	AUV tests with chase boat Storm	14 Aug
	AUV & Data Team sea-trials in Norway	19 Aug
	OFG contract OFG	24 Aug
	SEA-KIT christened USV Maxlimer	1 Sept
	USV Maxlimer's first wet test	2 Sept
	USV Maxlimer in Norway	14 Sept
	USV Maxlimer K-Mate development & trials	**18 Sept ***
	First USV– AUV trials: Testing HiPAP	27 Sept
	First AUV retrieval	3 Oct
	Start of final sea trials	3 Nov
2017	*Technology readiness test* Shell Ocean Discovery XPRIZE	20 Nov

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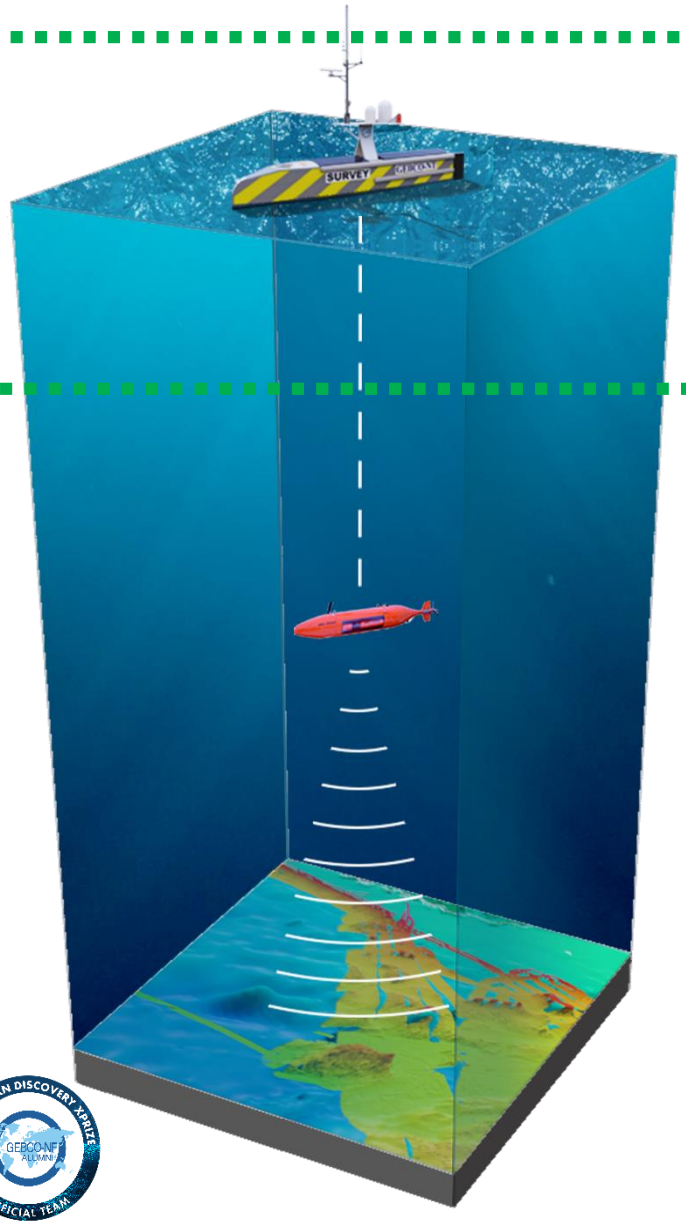

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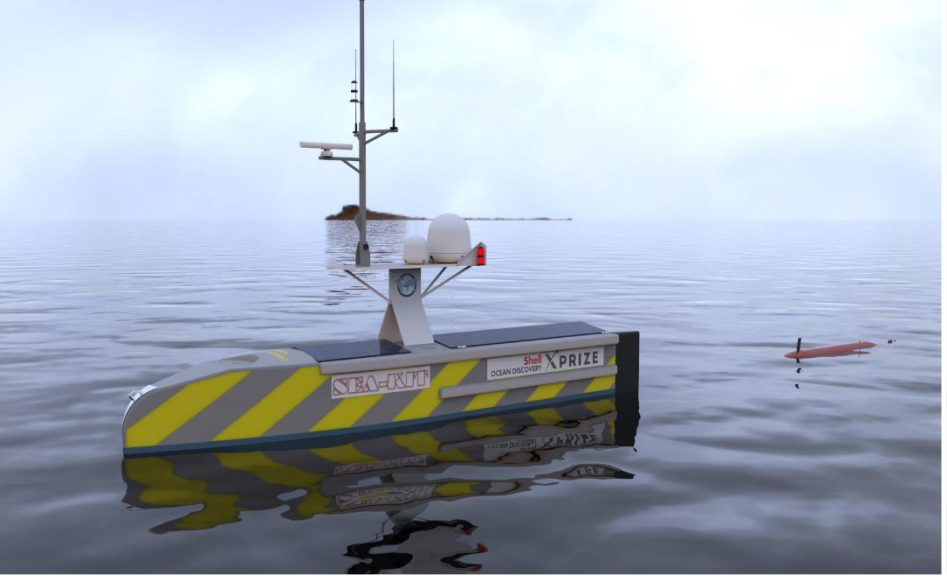
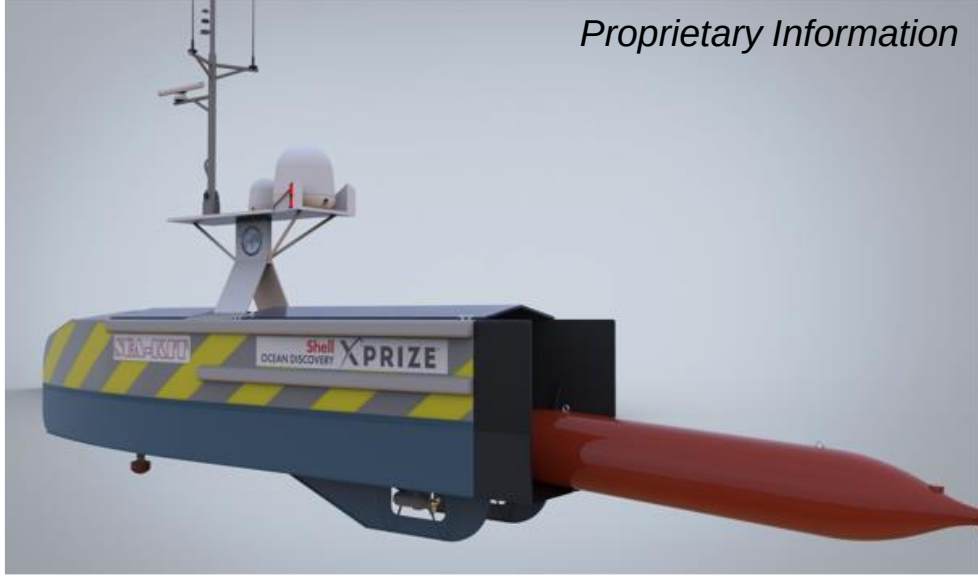
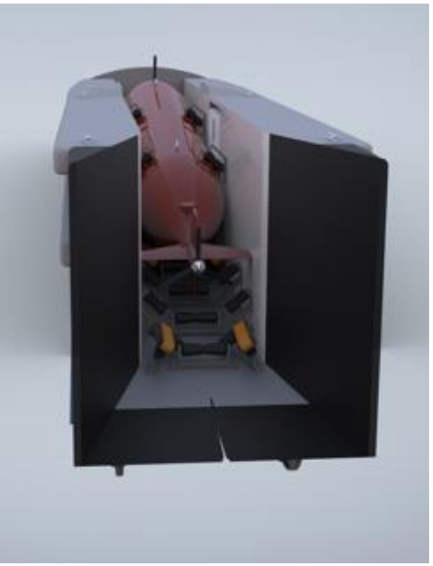
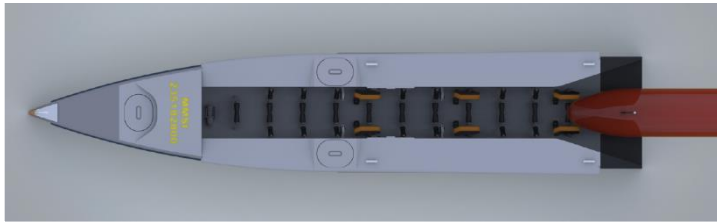




USV SEA-KIT: Unmanned surface utility craft



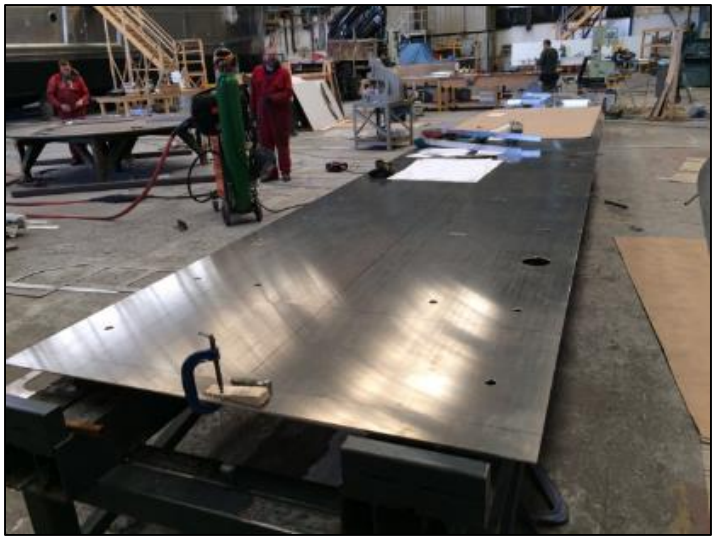
- Designed as mother vessel for AUV – fitting in 40 ft container
- Exclusion area safety vessel
- Border Safety / Patrol vessel
- Rapid survey deployment
- Passive Acoustic Monitoring
- Acoustic positioning USBL
- Ocean Data Collection Platform
- Communications Repeater Station



HUSHCRAFT

The start of construction with metal for the hull being cut (21 April 2017)

ALUMINIUM MARINE CONSULTANTS



Delivery of completed hull (28 June 2017)

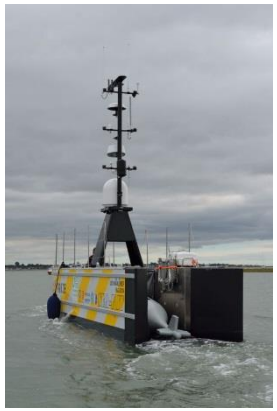
USV at work shop ready for wet test
(31 August 2017)

SEA-KIT 01 BUILD

FIRST WET TESTS IN UK

Christened USV Maxlimer - 1 Sept 2017

SEA-KIT for Shell Ocean Discovery XPRIZE





SEA-Kit Dimensions:	• Length: 11.75 m (38.55 ft) • Beam: 2.2 m (7.22 ft) • Transport Height: 2.0 m (6.56 ft) - Operational Height: 7 m (22.97 ft) • Weight: 11,200 kg (estimated)
Fully redundant propulsion and communication systems	• Propulsion: 2 X 10 kW / 1200 rpm electric directional thrust motors • Communication: Wi-Fi, Radio, Satellite (Iridium and Inmarsat) and Kongsberg Maritime Broadband Radio (<45 km offshore) • CCTV: 2 interior and 6 fore and aft cameras, 1 night-vision camera
Two independent power supplies and power charge	• Generator 2 X 18 kW 48 V DC • Fuel 2,000 L • 56 Gel and Absorbent Glass Mat (AGM) types of valve-regulated lead-acid battery (VRLA) Marine Batteries, 12 V – 214 Ah capacity • 4 dry cell Absorbed Glass Matt (AGM) VRLA 12 V 100 Ah Marine Dual Purpose Batteries for the engine and propulsion

SEA-KIT Communication & Navigation

Remote control antennae

Kongsberg Seapath 130 GPS antenna

Wind Sensor & AIS antenna

Kongsberg MBR

Wifi and Radio antennae for AUV (OFG) & Iridium antenna

HS70 GPS compass

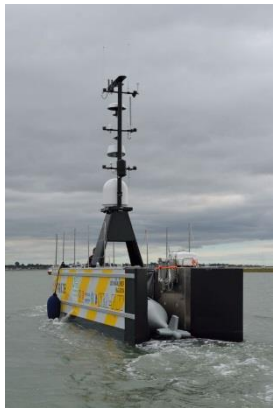
Simrad 4G radar & GPS for Iridium

Loud hailer: anti-hijack!

Inmarsat SAILOR 500
FleetBroadband

HIPAP 351P-MGC
Transducer

SEA-KIT for Shell Ocean Discovery XPRIZE





Modes of Operation

1. Unmanned, partly autonomous
   (Kongsberg Maritime AS K-MATE)
2. Remote control (joystick)
3. Manned

USV Maxlimer on her way to Norway

8 Sept 2017

Unpacking SEA-KIT container in Horten, Norway

14 Sept 2017

The GEBCO-NF Alumni Team concept

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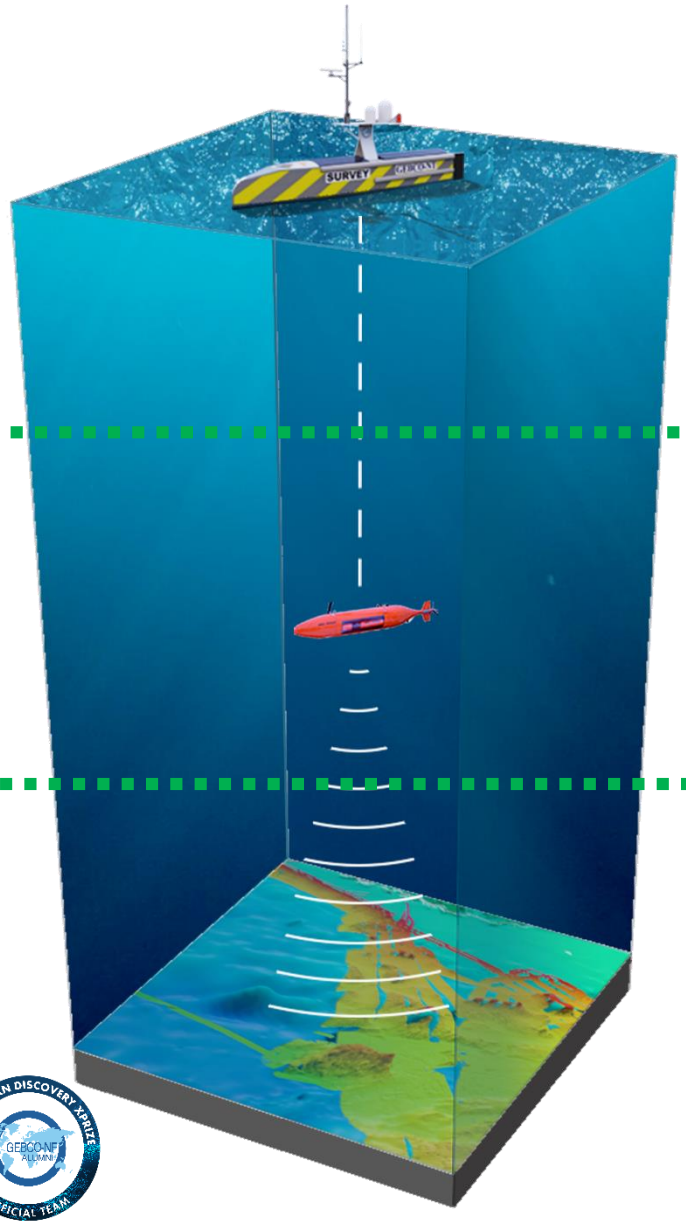

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OFG Ocean Floor Geophysics

Ocean Floor Geophysics Capabilities:

- Deep water **AUV** operations and data acquisition for **infrastructure inspection** and **survey**

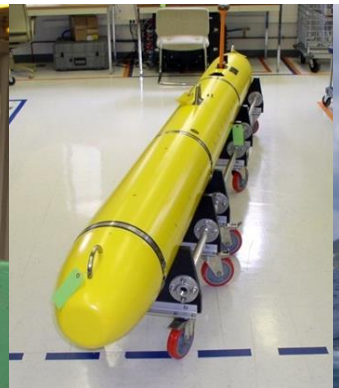
*** Route and Site Surveys * Pipeline Inspection *Mineral Exploration**
*** Decommissioning Survey * Archeology and Salvage**
*** Seafloor Search * Environmental Baseline Studies**
*** Seafloor Classification * Unexploded Ordinance * Physical Oceanography**

- Electromagnetic mapping and Magnetic 2D & 3D surveys
- Geo-chemical prospecting and mapping surveys
- Gravity and inversion post processing (ROV/AUV borne)
- Sensor Development - Self Compensating Magnetometer (SCM) System for **real-time** compensated magnetic data.

OFG Ocean Floor Geophysics

WHY OFG:

- OFG Personnel have diverse AUV Experience - Operations, System Integration and Design
- Mission Planning
- Selection, Design, and Integration of Sensors
- R&D background
- Similar philosophical approach



OFG Ocean Floor Geophysics

“Chercheur” HUGIN 1000 AUV Specs

General	• Rating: 5 - 3,000 m • Length: 5.5 m • Weight in Air: 1,200 kg • Neutrally buoyant 
Sensors	• SAS: Kongsberg Maritime HISAS 1032 • MBES: EM2040 200-400 kHz (0.7° x 0.7° beam width) • Sub-Bottom Profiler: EdgeTech DW 106 SBP
Navigation Sensors	• IMU: Honeywell HG9900 • Compass: Leica DMC • DVL: Teledyne RDI Workhorse Navigator 300 kHz • Altimeter: Kongsberg Mesotech 675 kHz down looking • Forward Looking Sonar: Imagenex MBES sonar • CTD: SAIV CTD • USBL: HiPAP Transponder • Depth Sensor: DigiQuartz 8CB4000 • GPS Receiver: Novatel
Power	• 3 batteries (24 kWh) • Endurance estimates: 37 hrs @ 3 kts & 27 hrs @ 4kts

KONGSBERG

THANK YOU

to

Kongsberg Maritime in Horten, Norway for supporting us through 2 months of sea-trials

AUV Sea-trials:
To maximize coverage and resolution

Data group and OFG operators acquired bathymetric and side-scan data, as well as sub-bottom profiles.

The data was collected during 12 dives in 4 weeks.

Included:

- DVL calibrations
- Patch tests separately for EM2040 and HISAS 1032
- Various operational modes: getting wide-area side scan bathymetry operational (KM input), testing standard HISAS bathymetry and HISAS imagery
- Data collection different altitudes and speeds


Horten Havn


Horten Havn

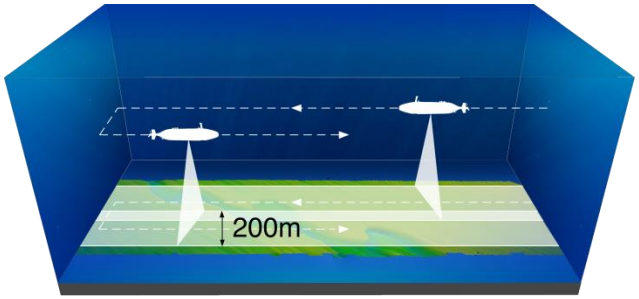

Horten Havn

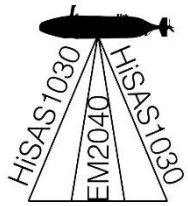
Data Group

Focus on Automated Data Flow

- Masa worked with Teledyne CARIS to understand:
  1. AUV work flow in processing HISAS data & EM2040 data (Ms. Fernanda Viana Da Conceicao)
  2. Developed automated work flow based on CARIS processing tools
- Fine-tuned and further developed during sea trials at Kongsberg Maritime
- CARIS output will be imported into ArcGIS
  1. Analysis of bathymetric data (contours, slope etc.)
  2. Publishing of image services in ArcGIS Online
  3. Collection of bathymetric data available from internet sources

HUGIN 1000 with HISAS 1032
Data Collection

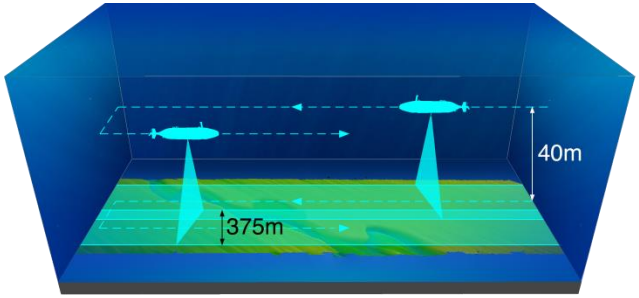


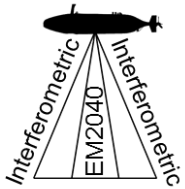


STANDARD HISAS MODE:

Distance-triggered

- Swath width: ± 200 m (400 m)
- Side scan image: = ~ 4 cm
- HISAS Bathymetry Resolution: = 1 m
- HISAS Spot Bathymetry Resolution: = 10 cm
- Speed: = 3.9 knots (2.0 m/s)



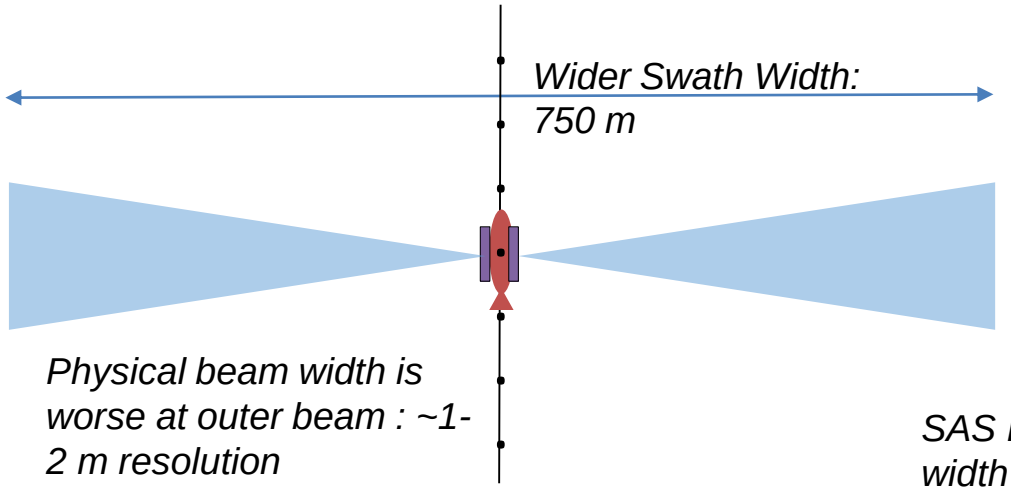


WIDE-AREA (SIDE-SCAN) MODE:

Time-triggered

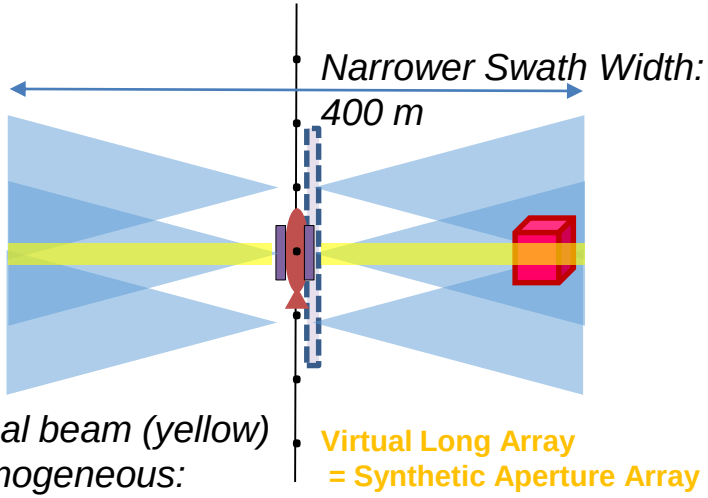
- Swath width: ± 375 m (750 m)
- Side scan image: = ~ 1 - 2 m
- Bathymetry Resolution: = ~2 m
- Speed: = 4.3 knots (2.2 m/s)

WIDE AREA MODE
Bathymetric Side-Scan Method



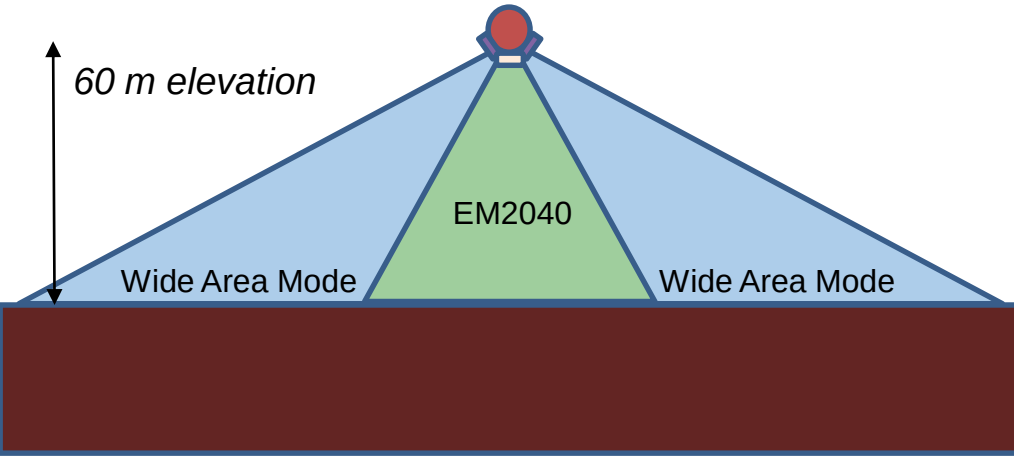
Physical beam width is worse at outer beam : ~1-2 m resolution

Standard HISAS MODE
Synthetic Aperture Sonar (SAS) Method

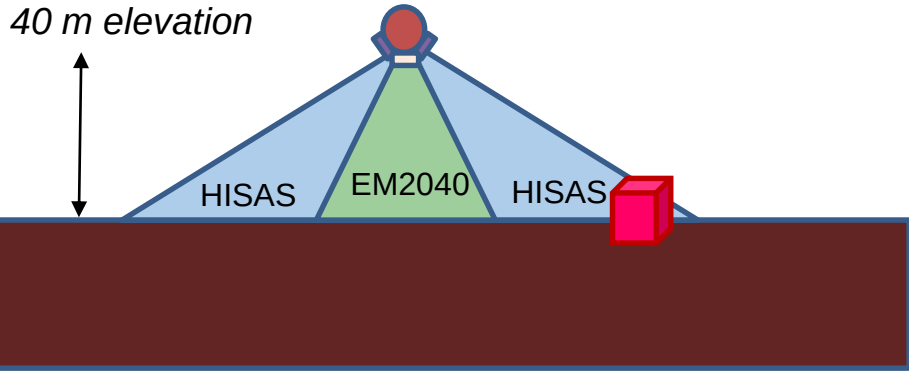


SAS Physical beam (yellow) width is homogeneous: ~4 cm resolution

For wide area bathymetry



For seafloor feature detection

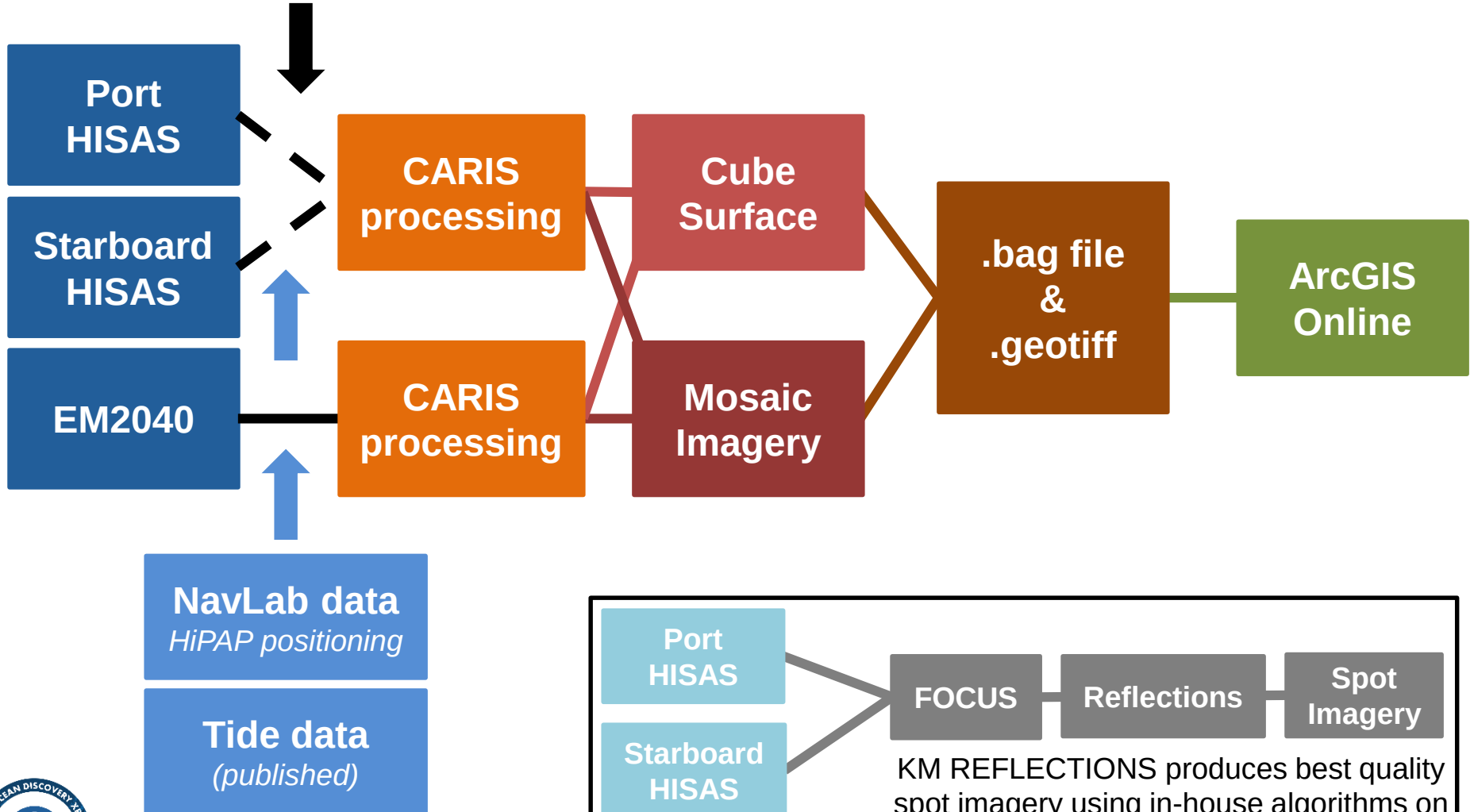


AUV “Chercheur” Data types

Sonar	File type	Data	Resolution
EM2040	*.all	Bathymetry & Imagery	<1 m
HISAS (Standard)	*.all	Port and Starboard Bathymetry	1 m
HISAS (Standard)	*.xtf	Imagery	4 cm
HISAS (Standard)	*.all	Port and Starboard Spot Bathymetry	10 cm
HISAS (Standard)	raw data	Port and Starboard Spot Imagery	~2-4 cm
HISAS (Wide-area)	*.all	Port and Starboard Bathymetry	2 m
HISAS (Wide-area)	*.xtf	Imagery	1-2 m

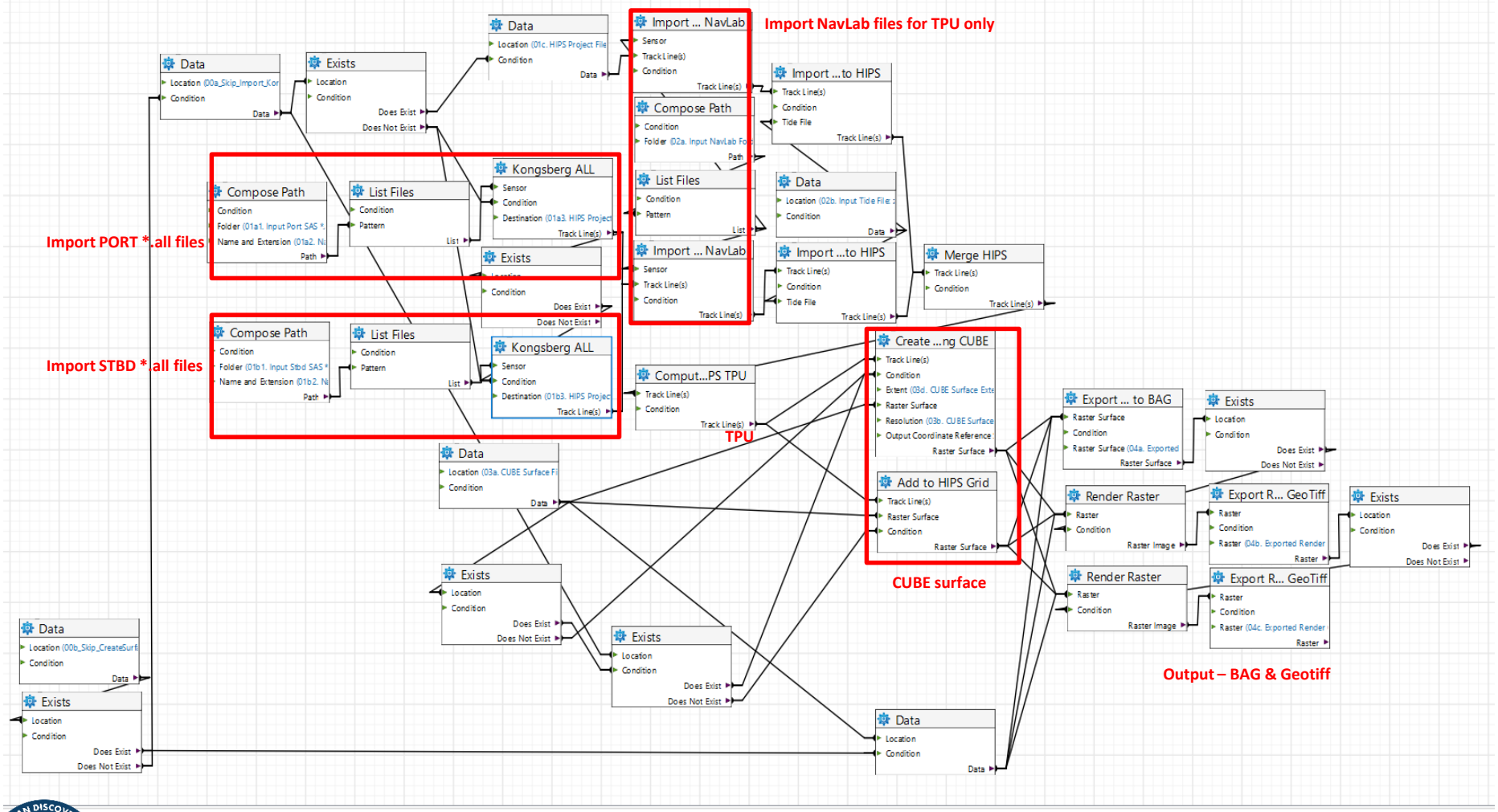
Simplified data work flow

Kongsberg Proprietary software FOCUS & REFLECTIONS takes raw HISAS data and produces .all & .xtf for input into CARIS



KM REFLECTIONS produces best quality spot imagery using in-house algorithms on raw data files (for 20, 50 or 100 m^2 areas)

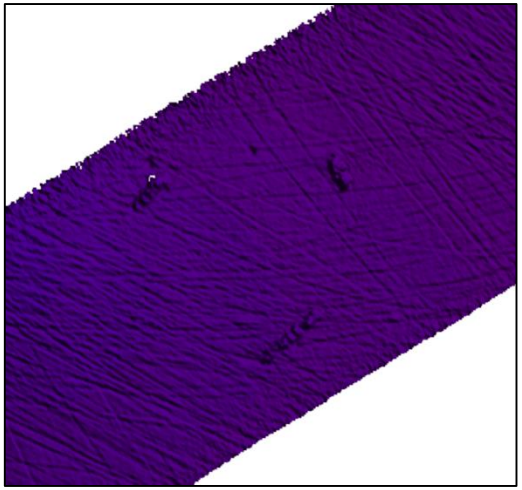
DETAILED EXAMPLE:
HISAS wide-area mode work flow

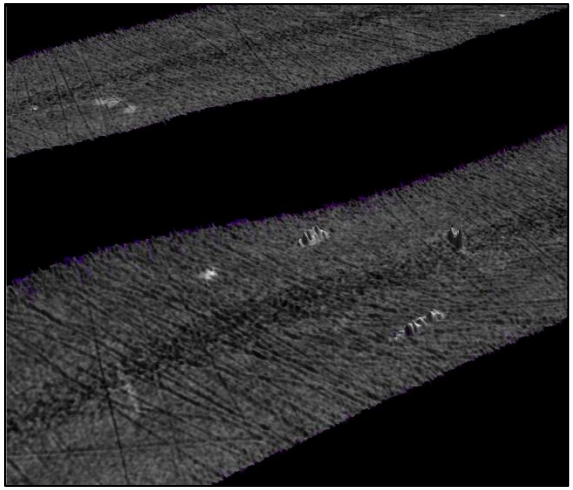


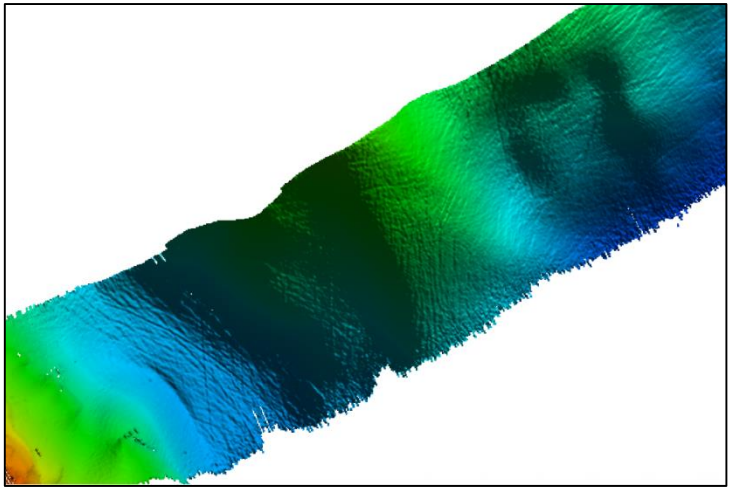
Want to know more… speak to Masanao Sumiyoshi

EM2040 data

- Nadir fill
- Approximate total swath width = 200 m (120° swath & 400 beams at 60 m altitude)
- Data resolution ≤1 m



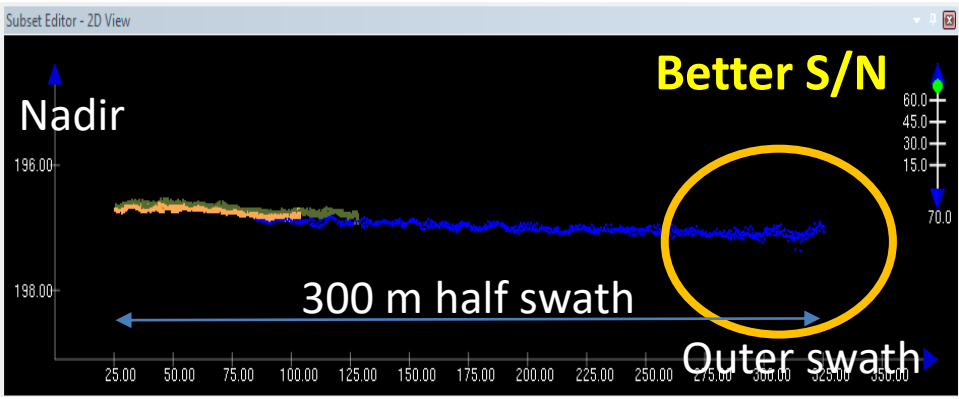


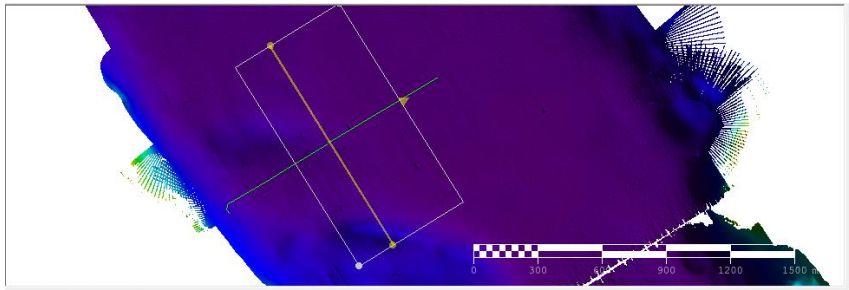


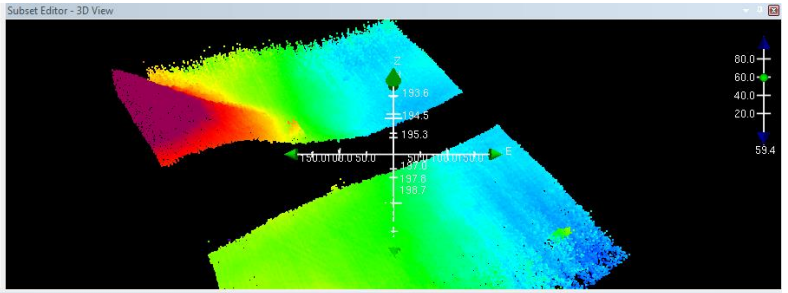
HISAS Wide-Area Test

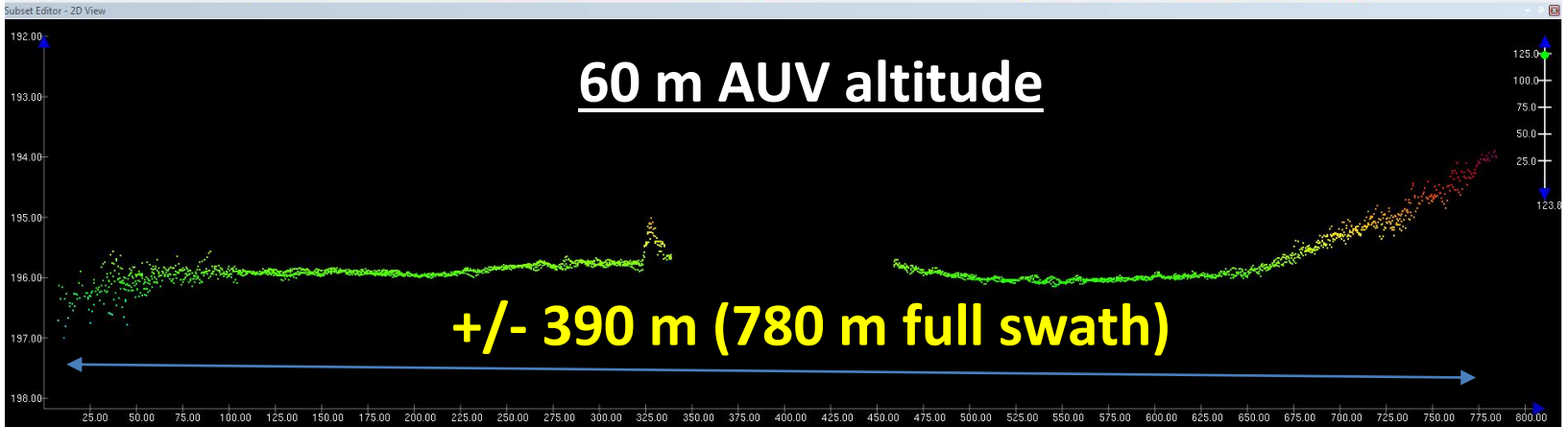
30 m AUV altitude

60 m AUV altitude



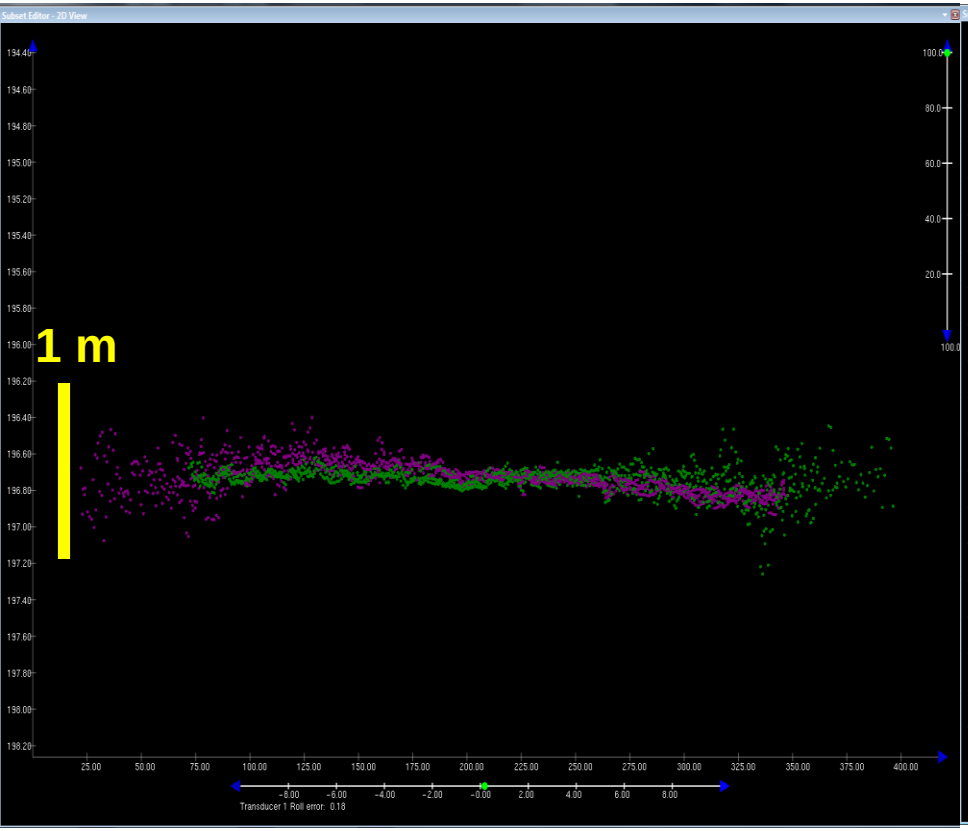




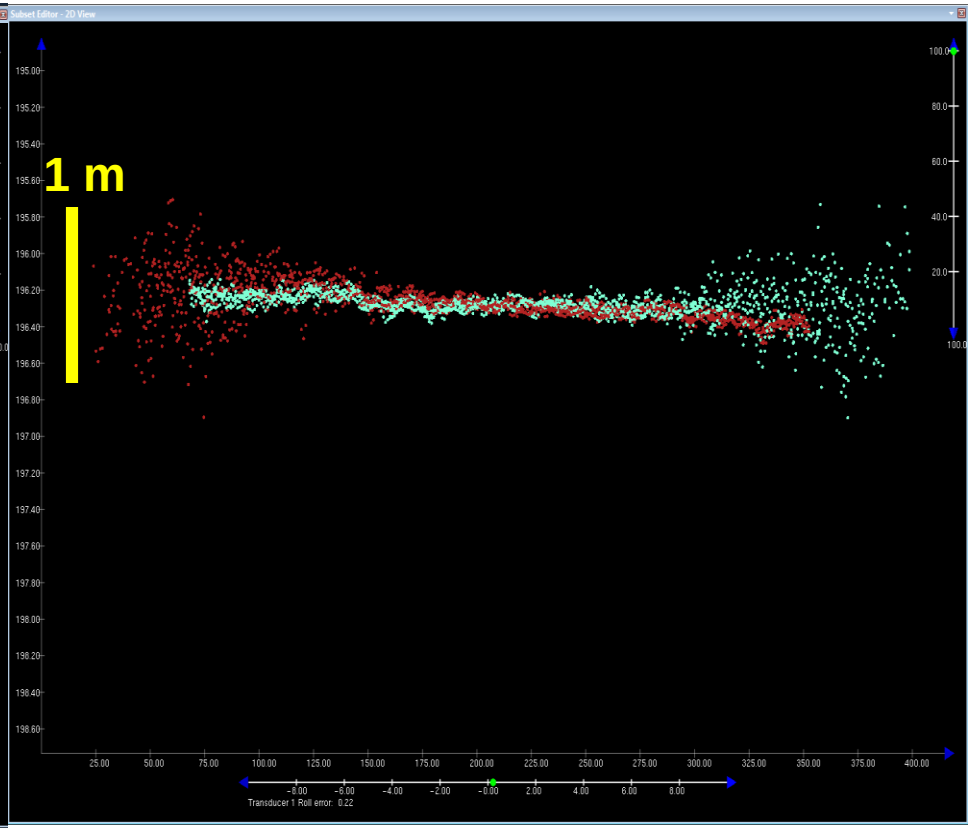


Patch Test for HISAS Wide-Area

[PORT] Roll: +0.225 degree



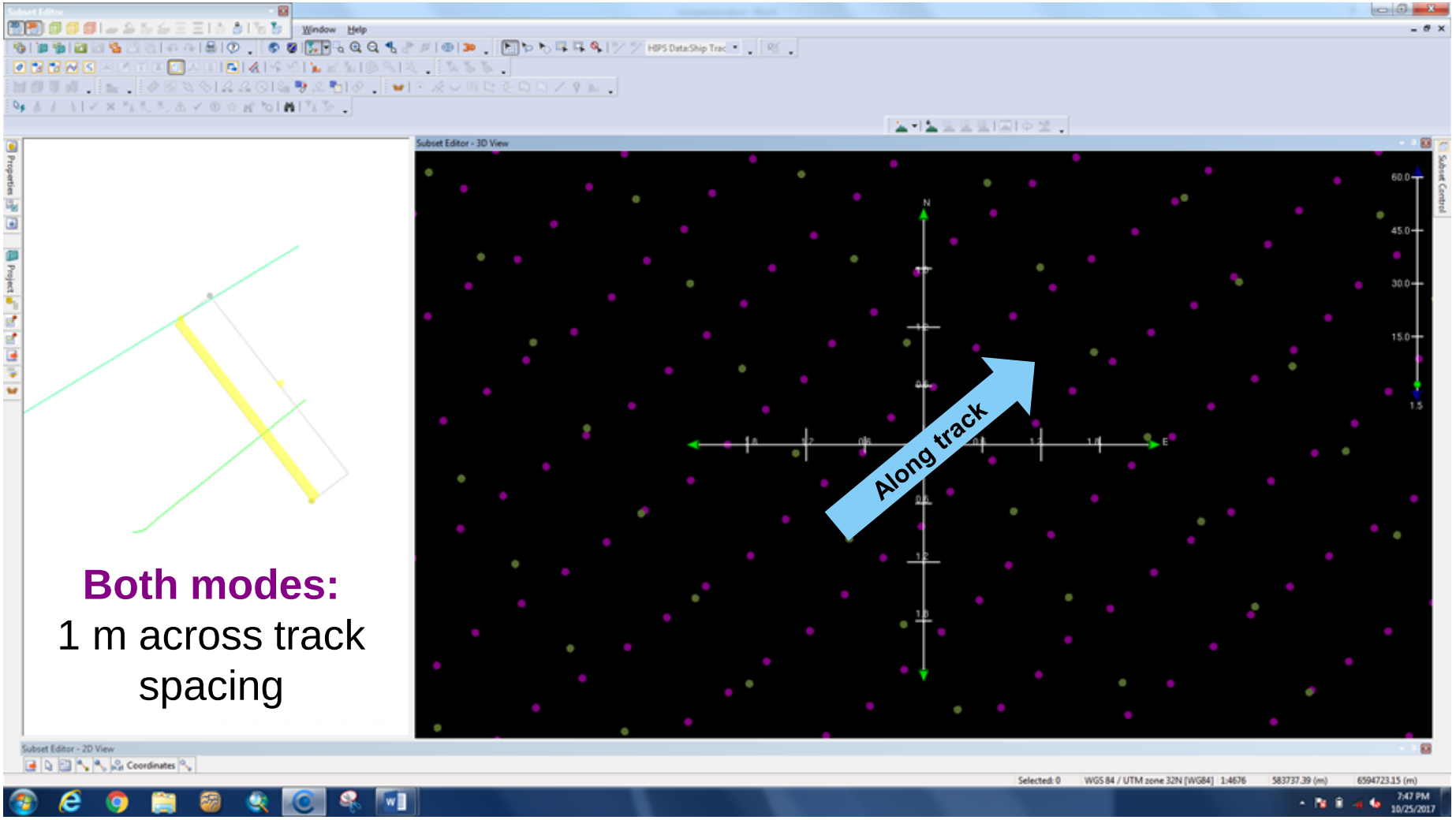
[STBD] Roll: +0.185 degree



Data density: Different HISAS modes

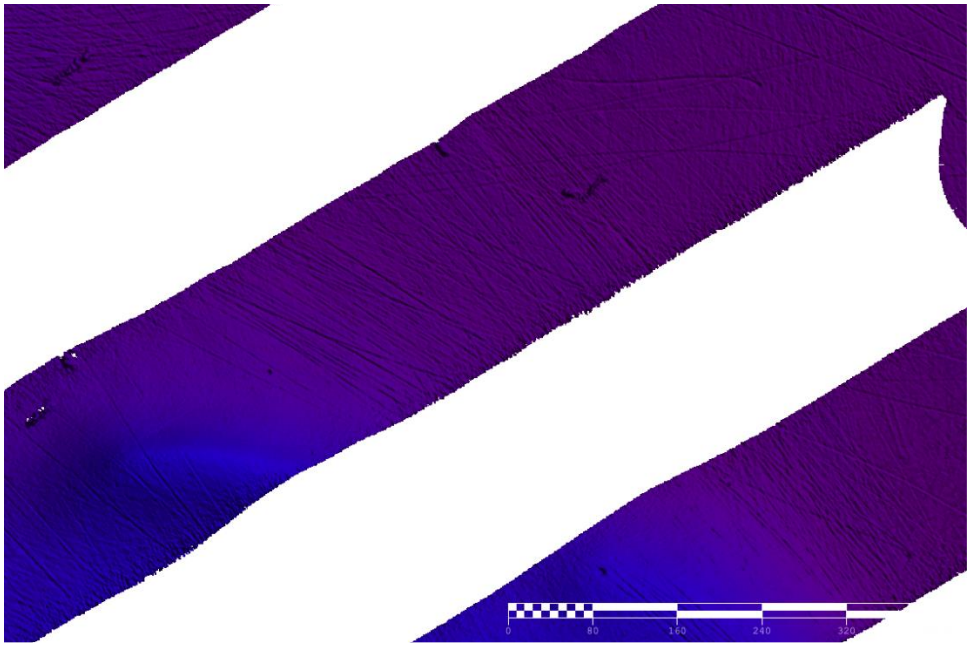
Standard HISAS
0.5 m along track spacing

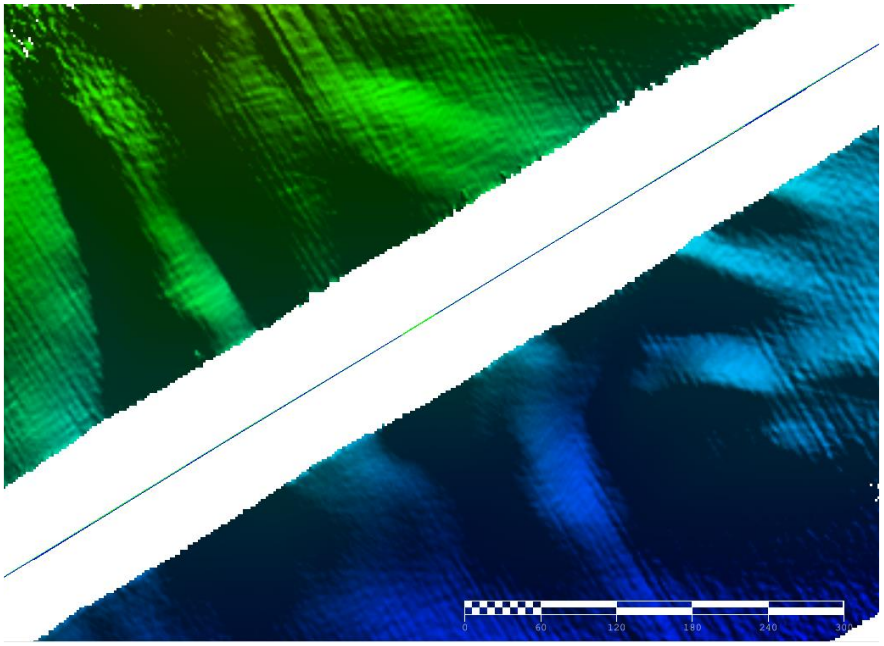
Wide-area mode
~1.5 m along track spacing

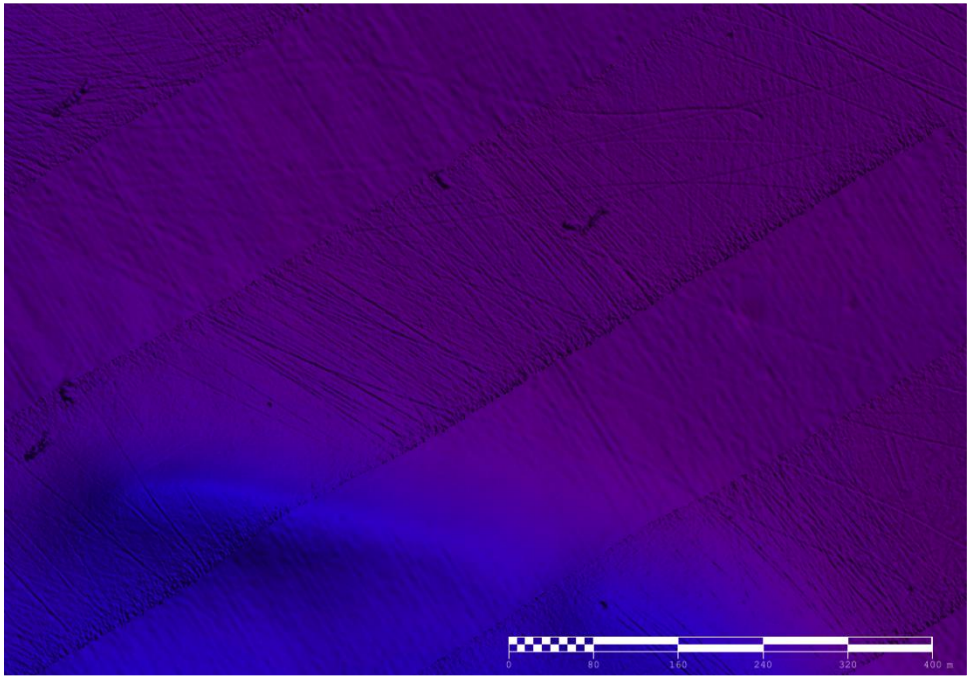


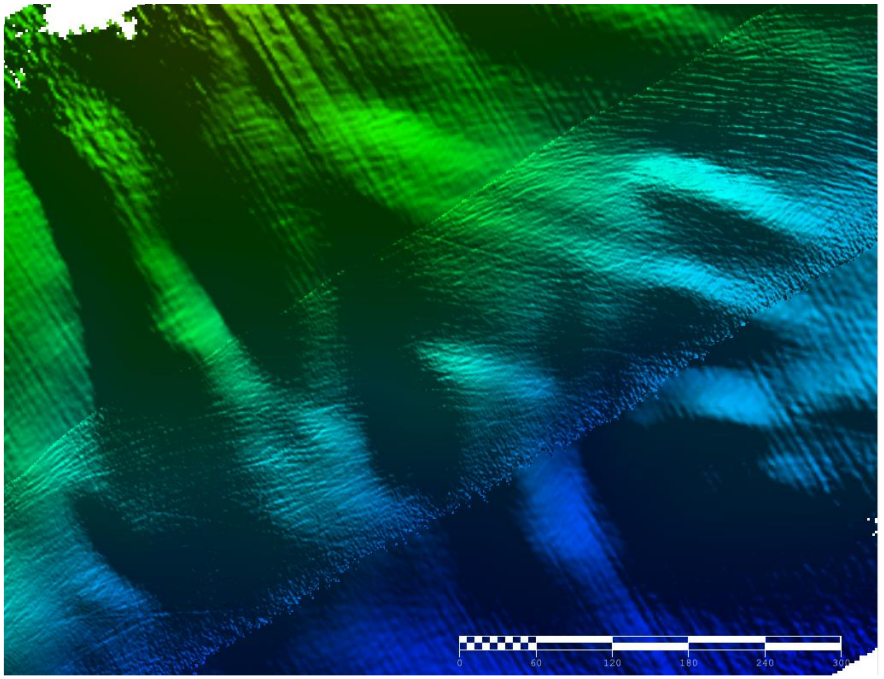
Both modes:
1 m across track spacing

HISAS wide-area mode with EM2040 nadir gap filling









Coverage Estimates

- Standard HISAS: 2.7 km^2/hour
- HISAS wide-area side-scan: 6.2 km^2/hour

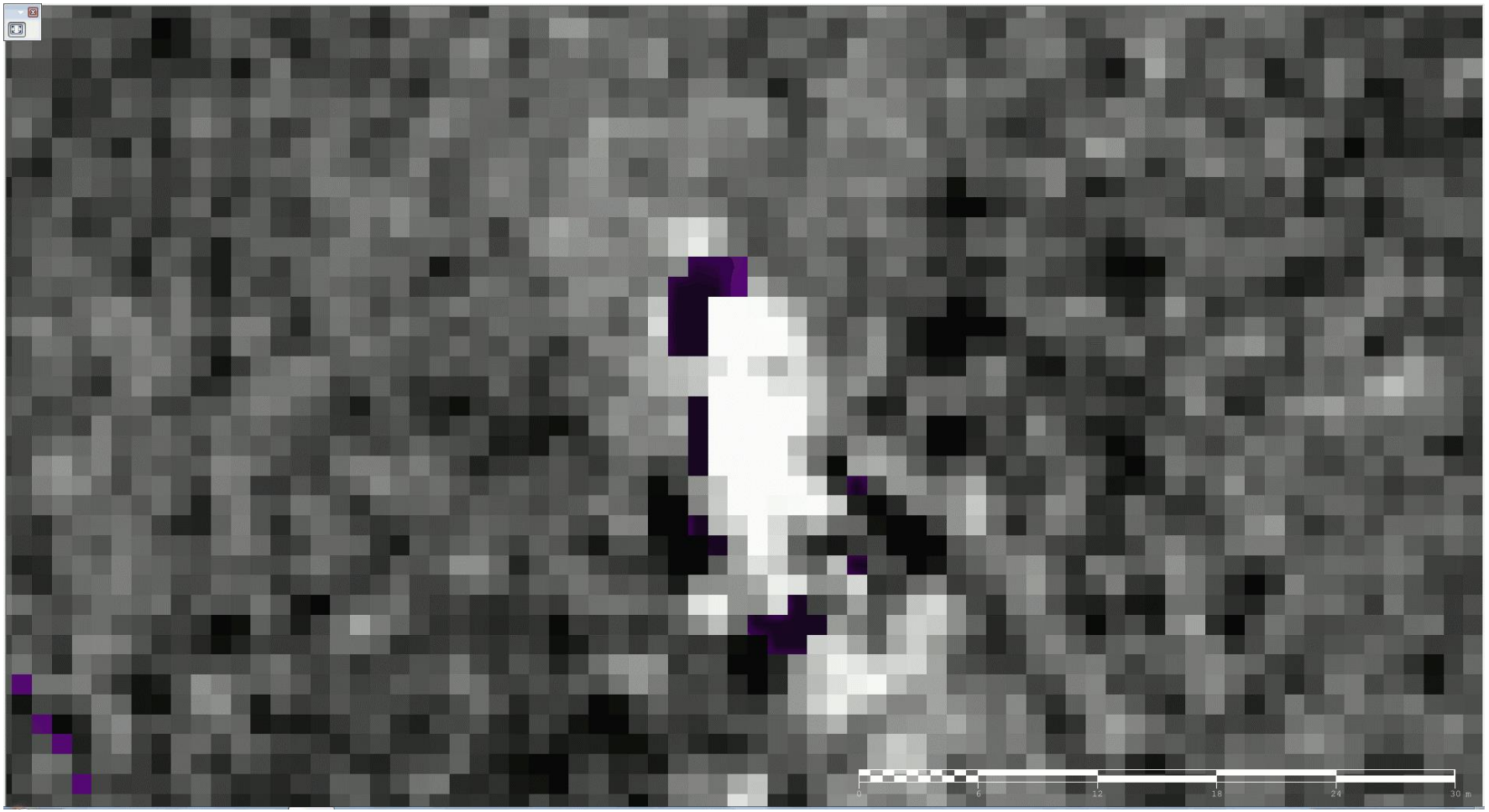
This includes EM2040 nadir gap data

The Team plan for XPRIZE was to run various AUV modes:

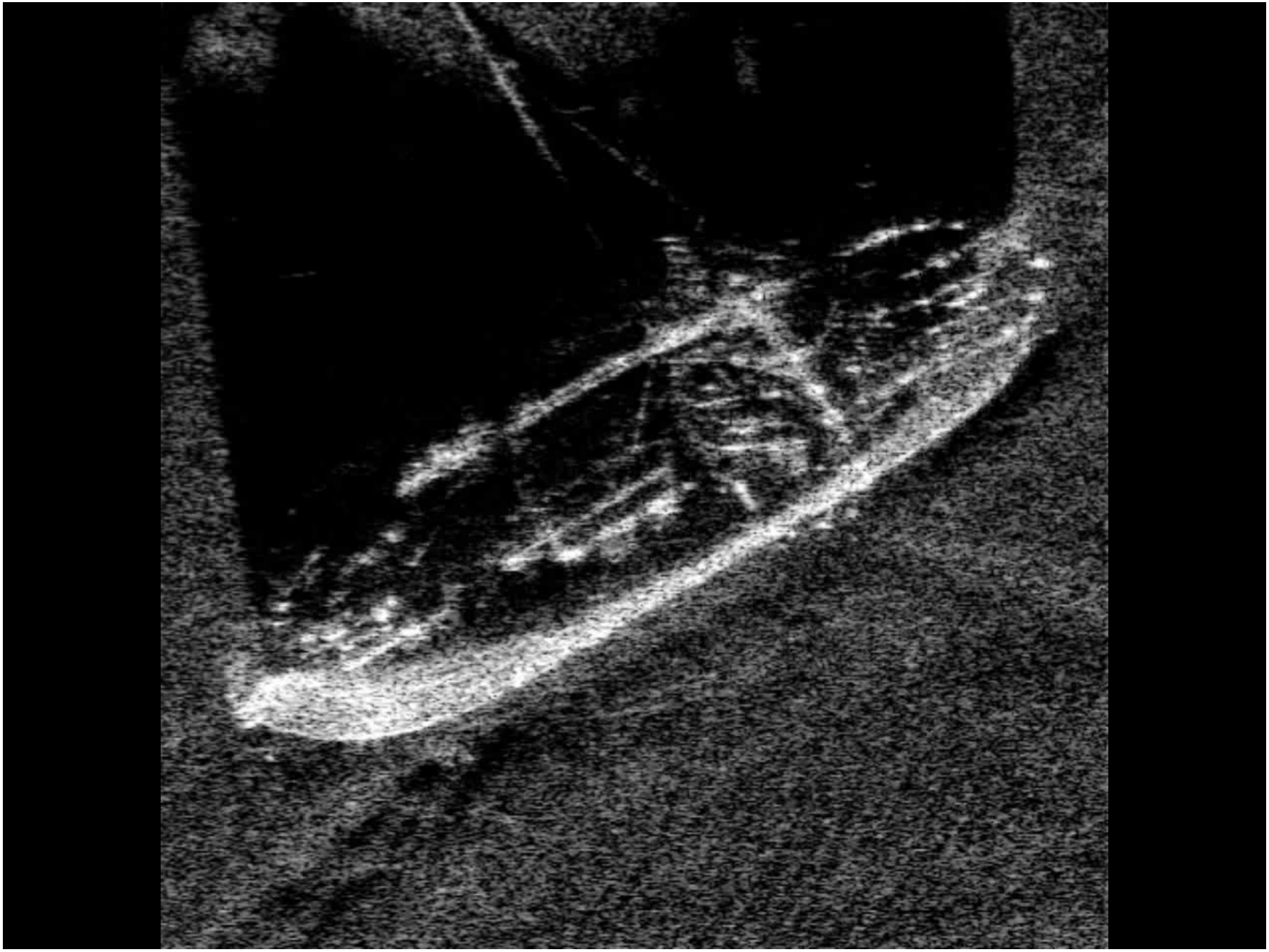
- 13 hours of HISAS wide-area mode (80.3 km^2)
- 2 hours of standard HISAS mode (5.4 km^2)

= ~86% of required coverage

EM2040 backscatter *vs.* HISAS imagery

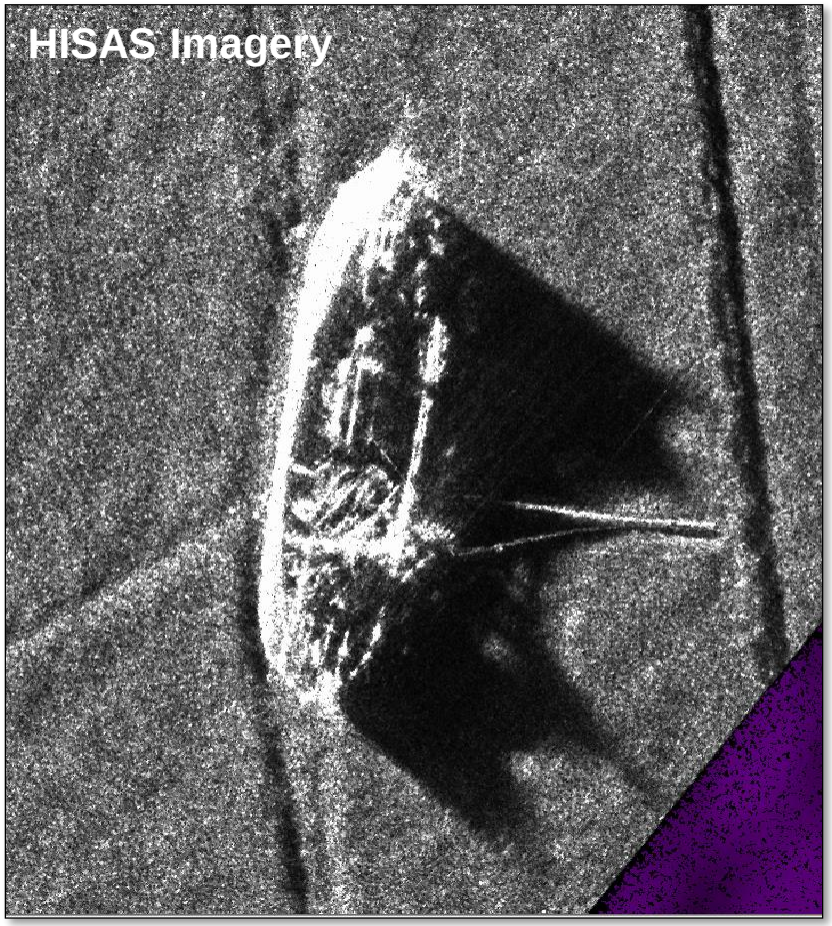


XP_Shipwreck.gif

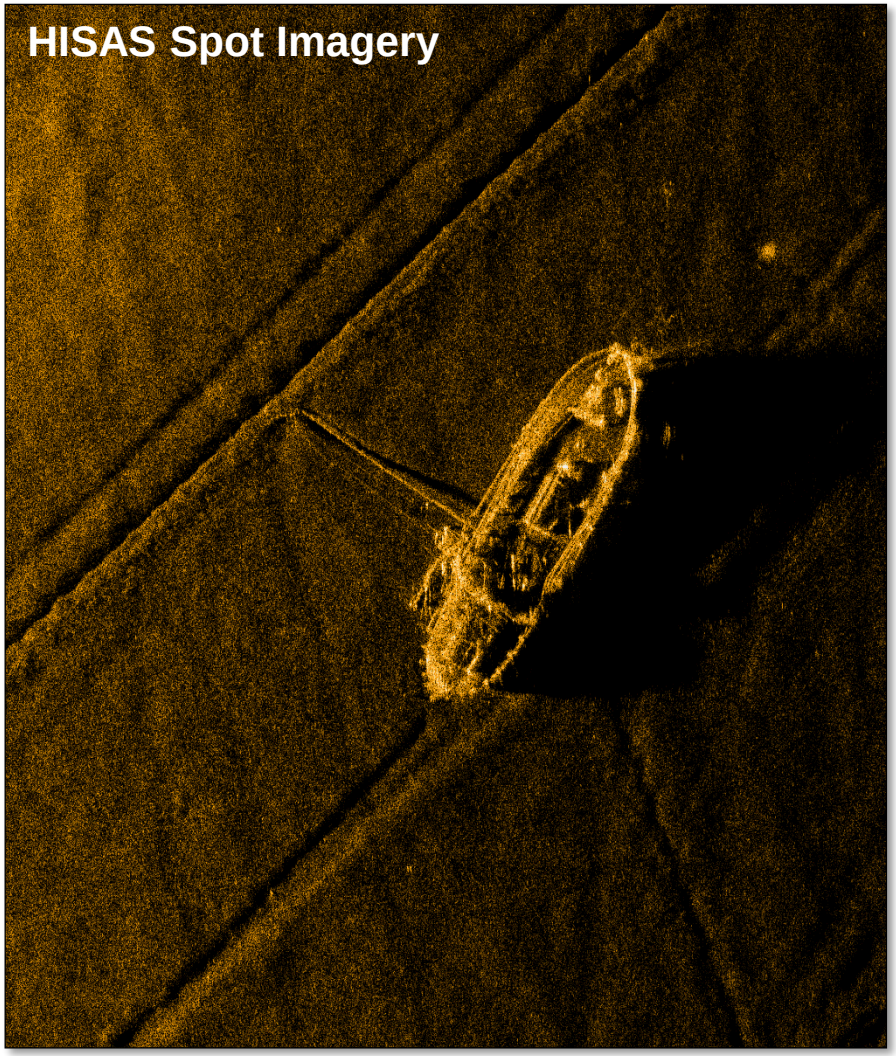


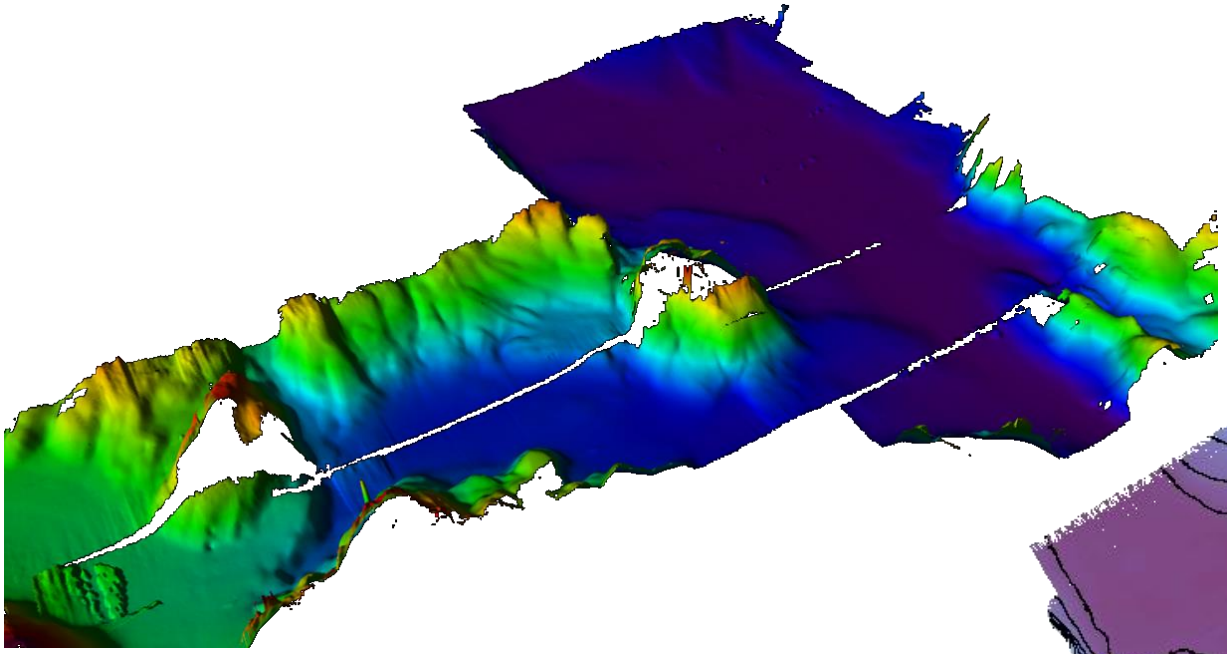
XP_Wreck_sasi.gif

Only wreck covered using HISAS mode – more to come…..

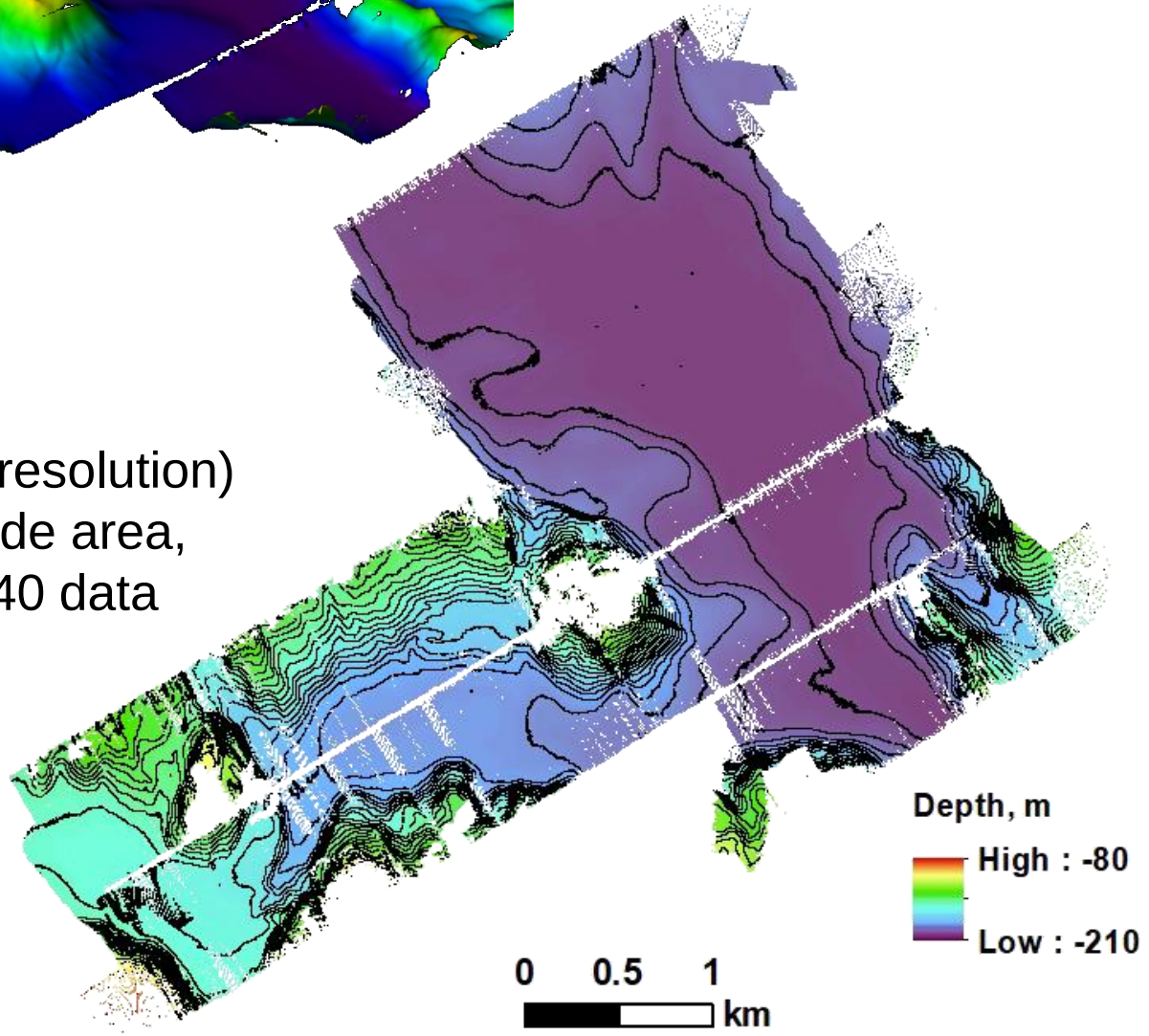


Shipwreck 20 m Length; 5 m Beam
in ~200 m water depths



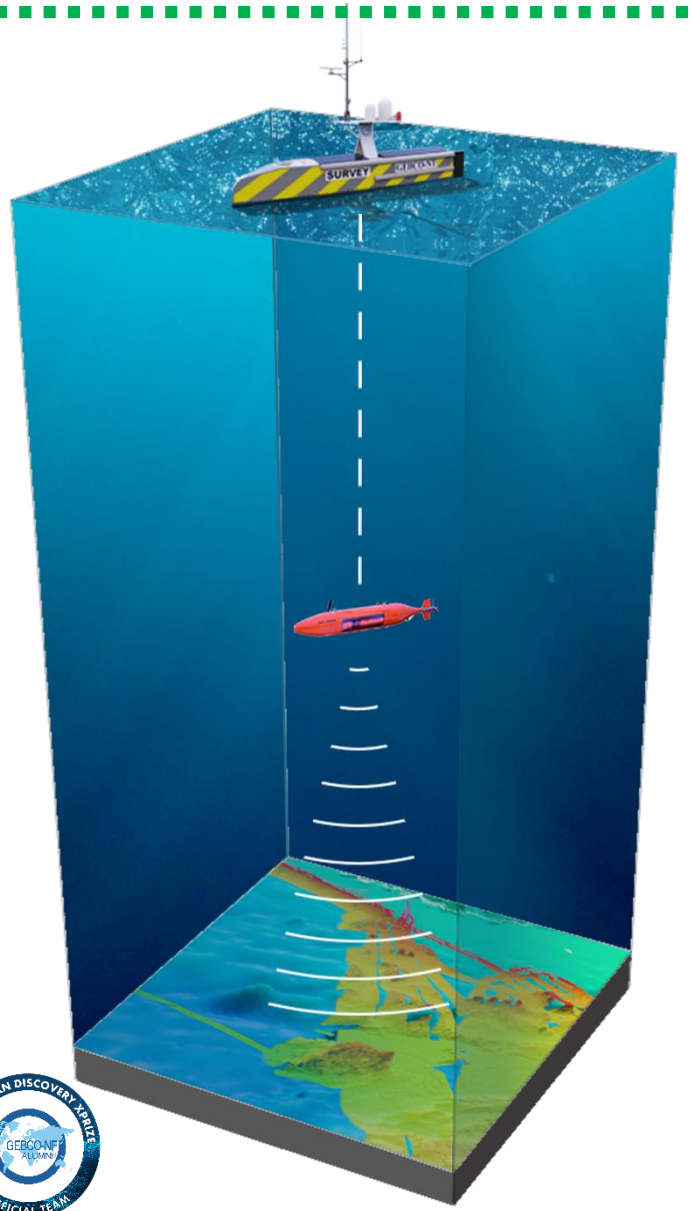


Dive 12 surface (1 m resolution) based on HISAS wide area, HISAS and EM2040 data



The GEBCO-NF Alumni Team concept

Integrates existing technology with innovative new ideas



Hushcraft Limited USV

- Sea-Kit XP with KM HiPAP 351P-MGC
- Unmanned operations by KM

Kongsberg Maritime HUGIN 1000 AUV

- OFG Chercheur AUV (3,000 m)

TELEDYNE CARIS esri

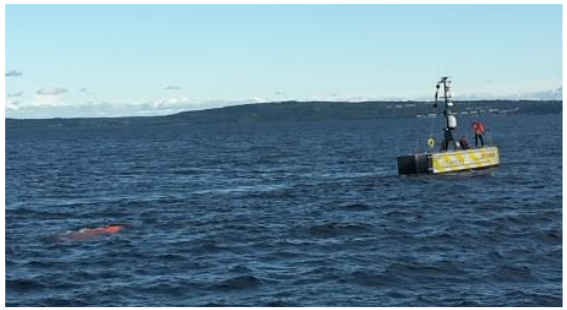
High quality seafloor bathymetry and imagery

- Combination of EM2040 MBES, HISAS side-scan wide-area and HISAS bathymetry & spot-focused HiSAS imagery


WLL 2000 KG


WLL 2000 KG


XPRIZE
Horton

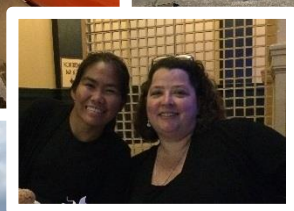



10-03-2017 14:31:29
10-03-2017 14:31:30
STERN DECK
10-03-2017 14:31:29
MAST HEAD STBD












An unmanned seafloor mapping system
the concept of an AUV integrated
with the newly designed USV SEA-KIT




OFG

THANK YOU


MÅLFRID