# Deep Ocean Exploration on E/V *Nautilus*: Thirteen Years of Exploration with an EM302 and a 2026 Upgrade to an EM304 MKII

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Paul Johnson and Larry Mayer (University of New Hampshire Center for Coastal and Ocean Mapping)
Colleen Peters and Meme Lobecker (Kongsberg Discovery)



FEMME 2026

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**Explore** the ocean, seeking out **new discoveries** while pushing the boundaries of **technological innovation**, **education, & outreach**

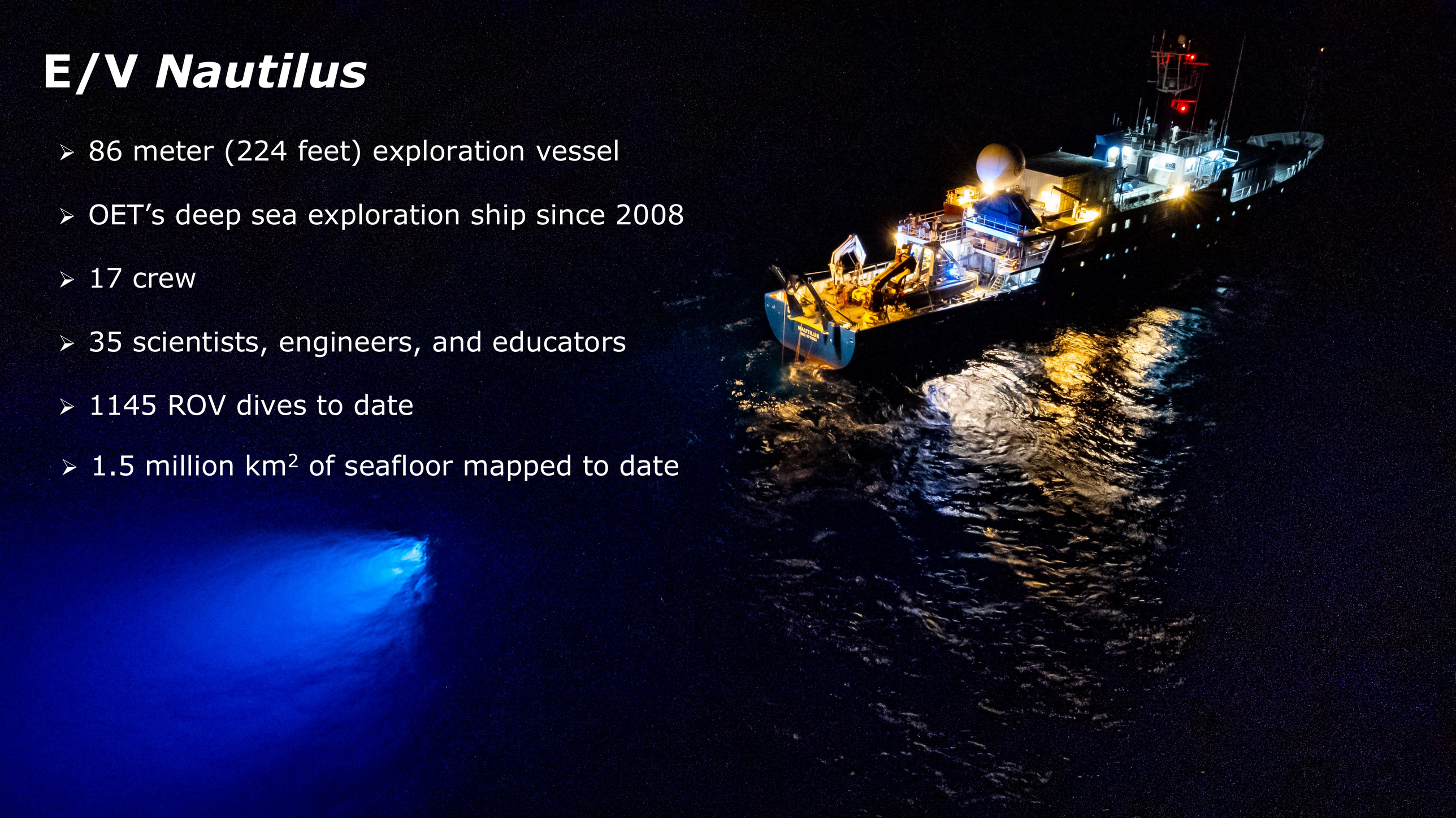
Founder: Dr. Robert Ballard

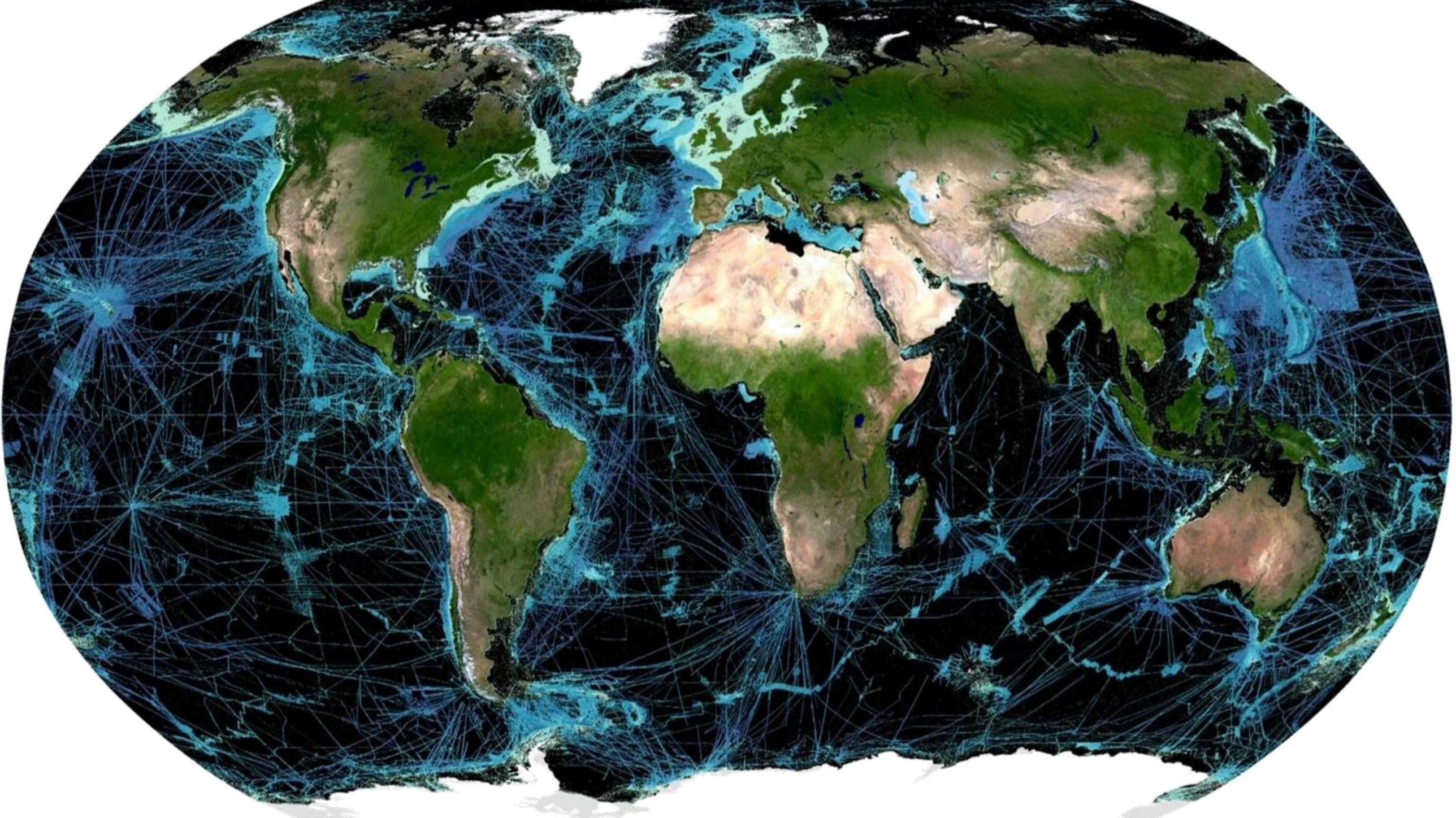



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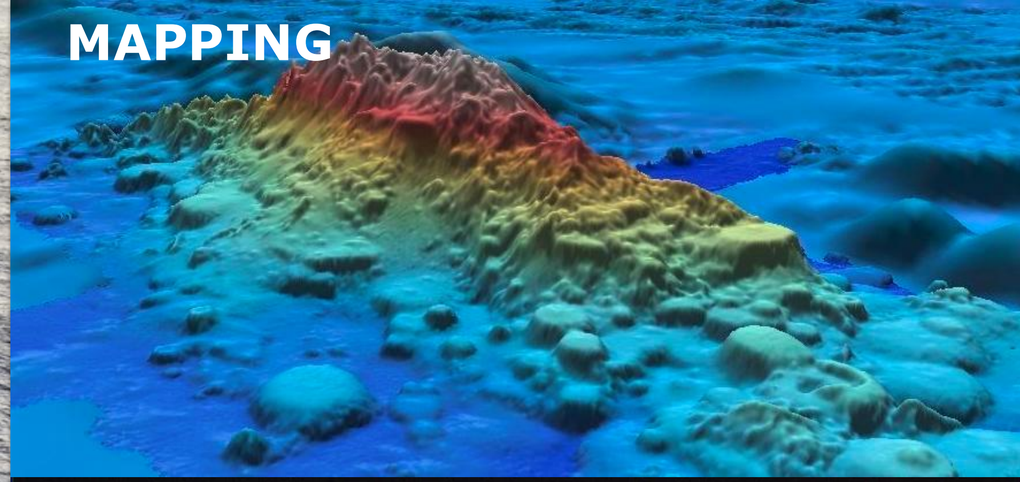
# E/V *Nautilus*

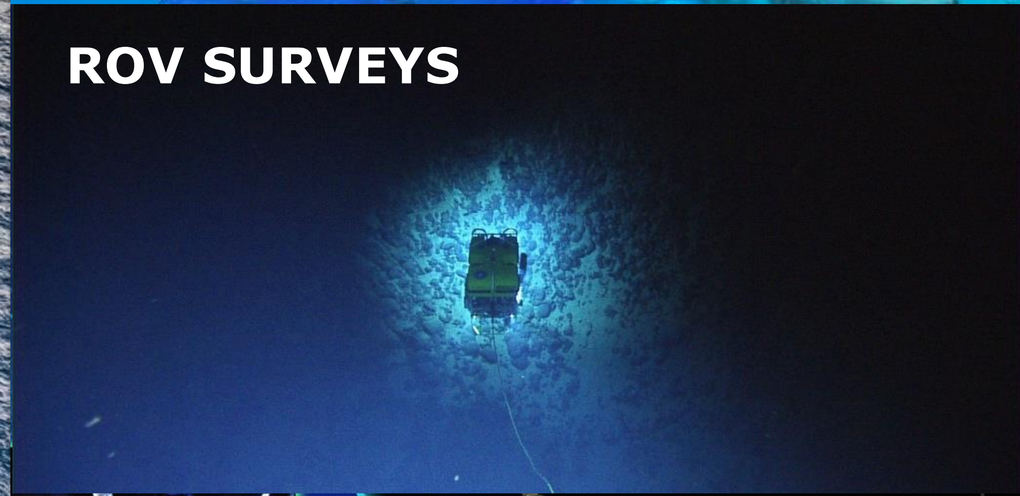
- 86 meter (224 feet) exploration vessel
- OET's deep sea exploration ship since 2008
- 17 crew
- 35 scientists, engineers, and educators
- 1145 ROV dives to date
- 1.5 million $km^2$ of seafloor mapped to date

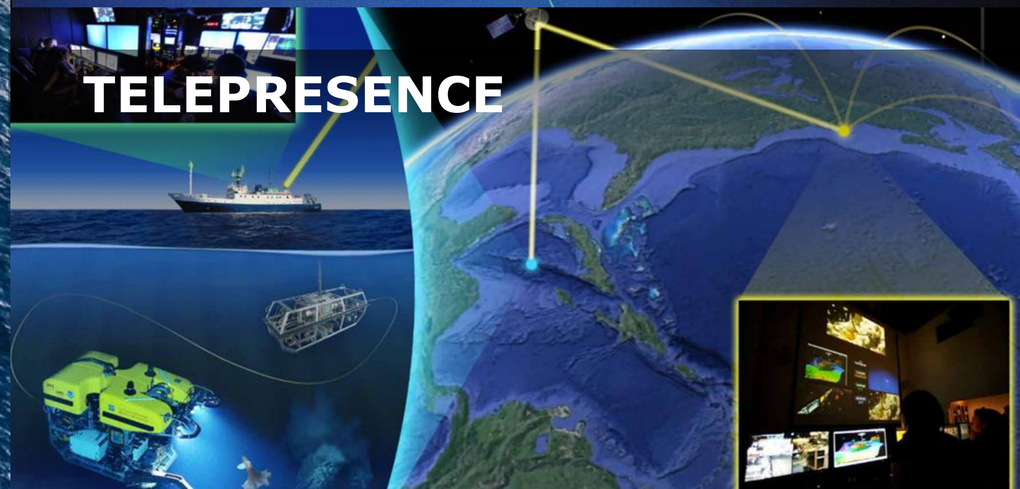






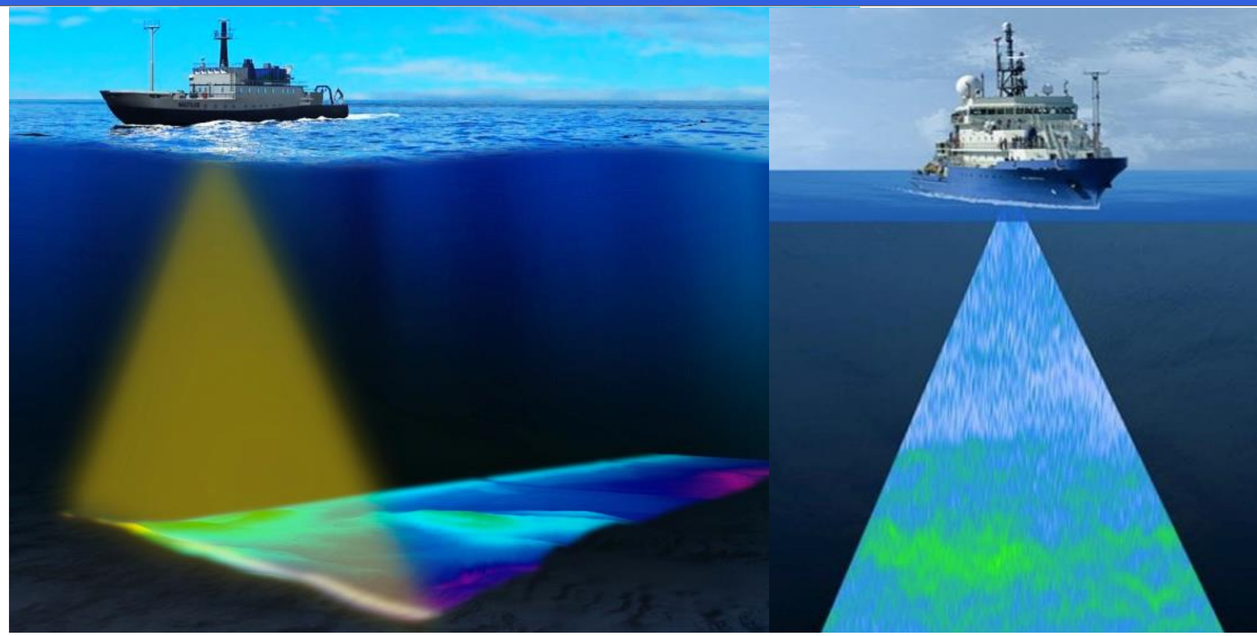

MAPPING

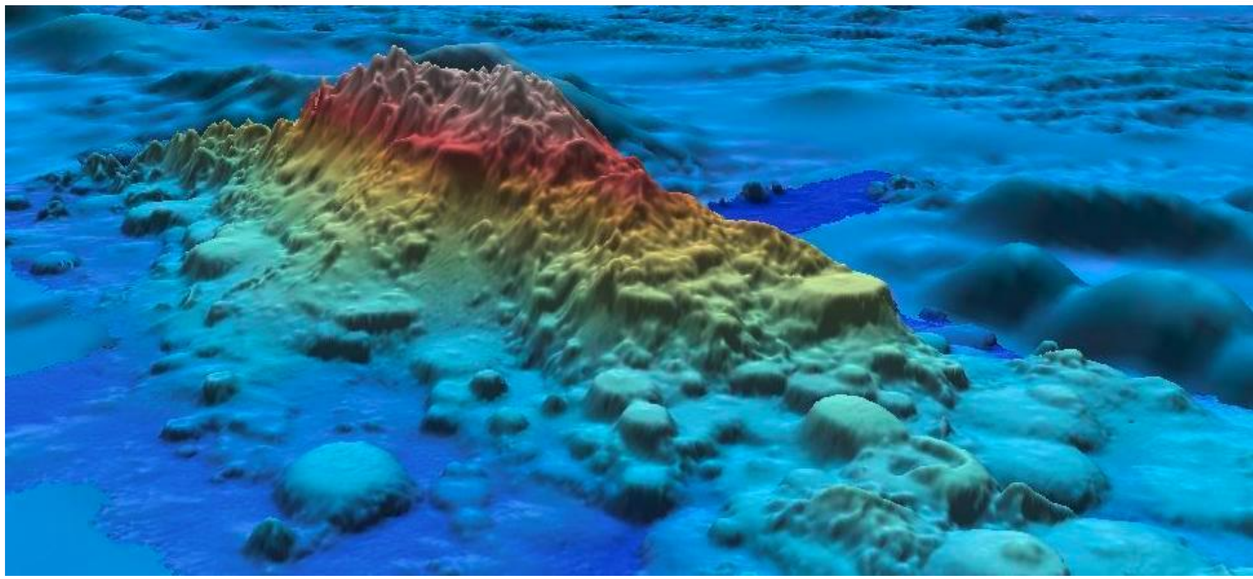

ROV SURVEYS

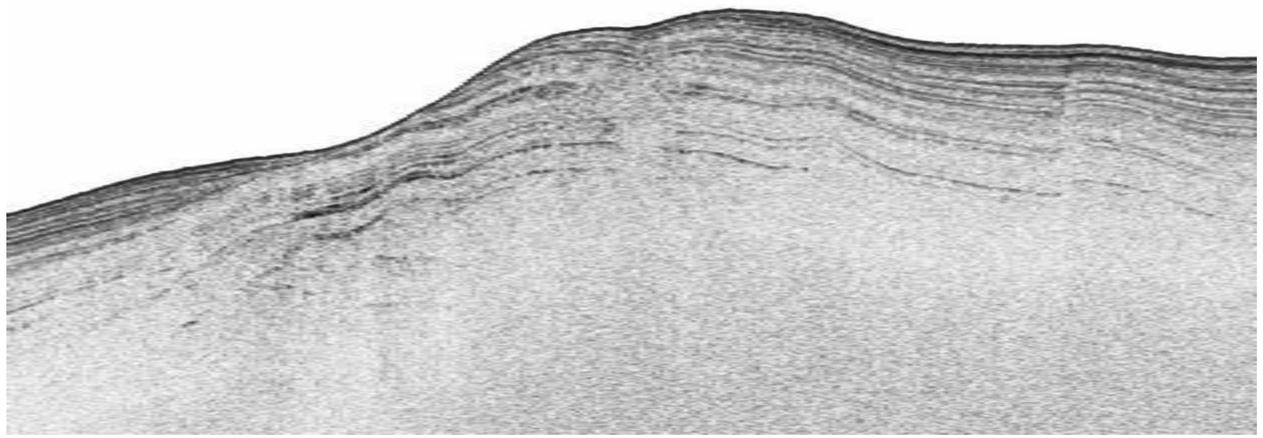

TELEPRESENCE

# E/V *Nautilus* Mapping Capabilities (through 2025)

- Kongsberg EM302 Multibeam
  - Seafloor bathymetry maps ~50 - 7,000 m (30 kHz)
  - Seafloor backscatter intensity
  - Water column backscatter
- Knudsen 3260 Sub-bottom Profiler
  - Subsurface maps <80 m (3.5 & 15 kHz)







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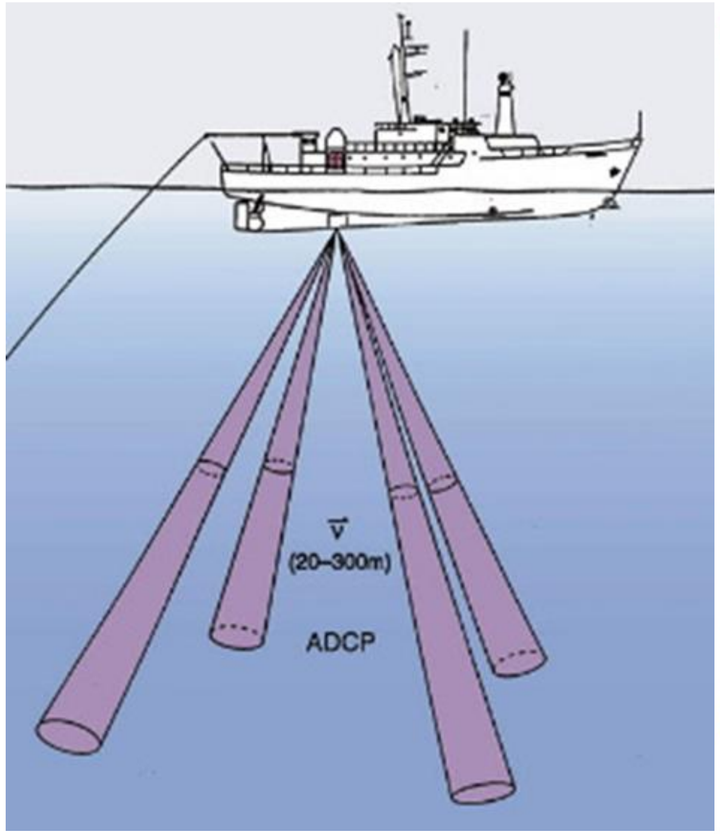
# E/V *Nautilus* Mapping Capabilities

Kongsberg EC150: EK80 & Acoustic Doppler Current Profiler (150 kHz)

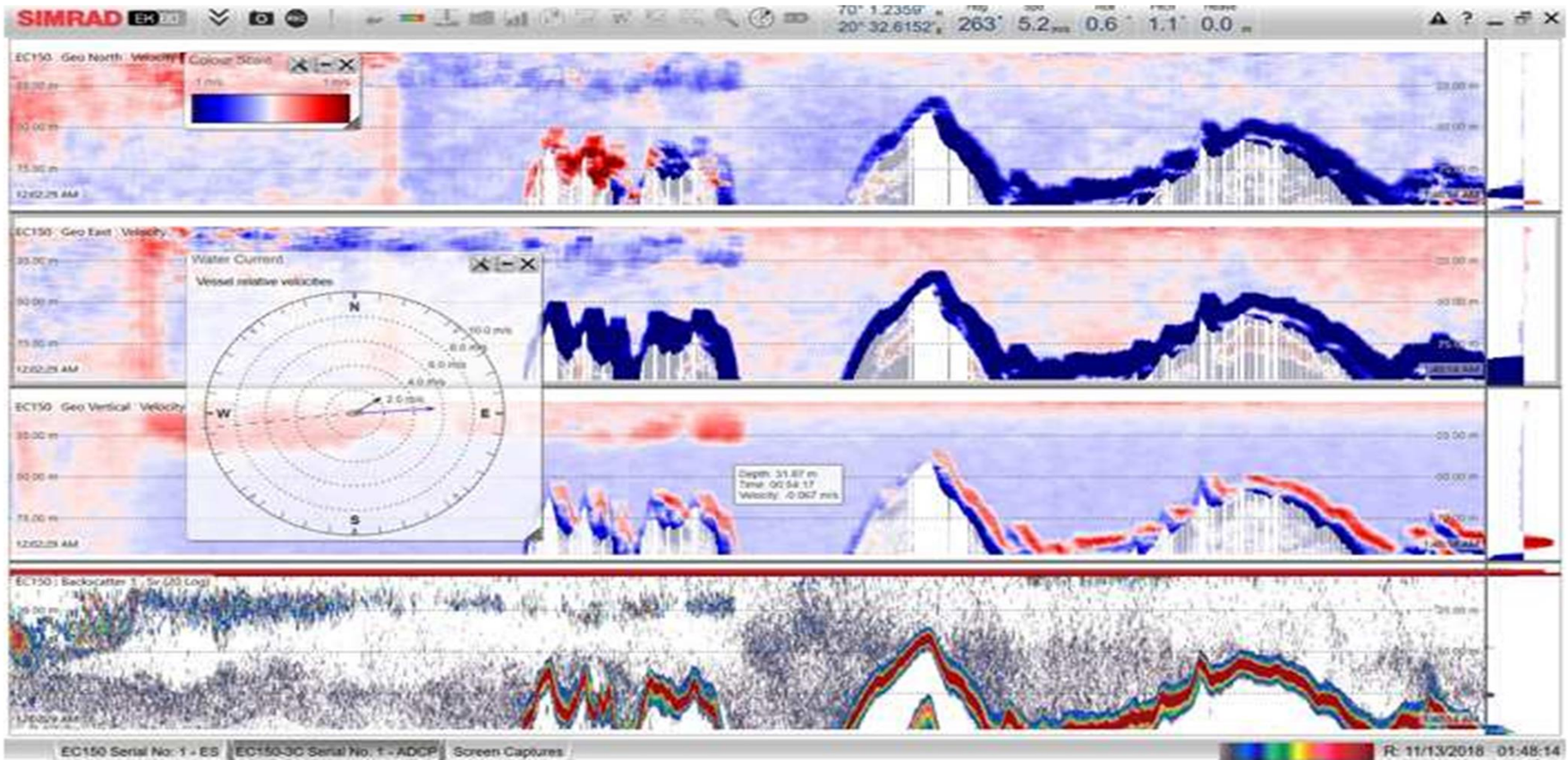


Image by Kongsberg






ADCP and EK80 data example, Image by Kongsberg

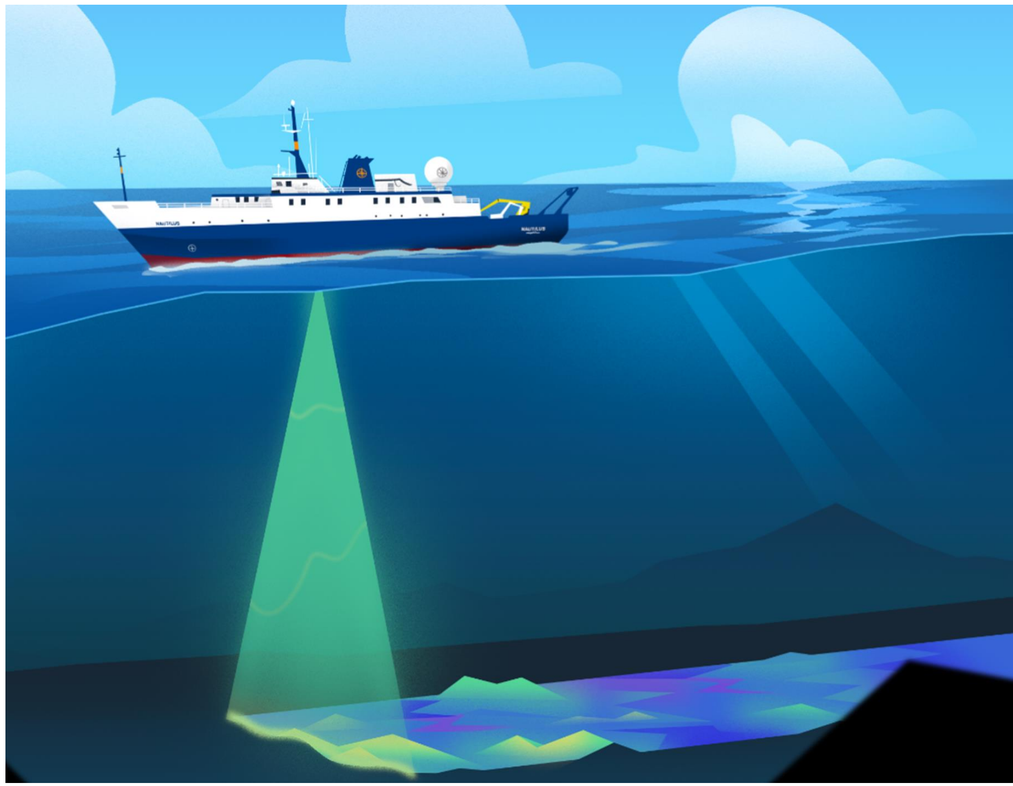


# Mapping Approach

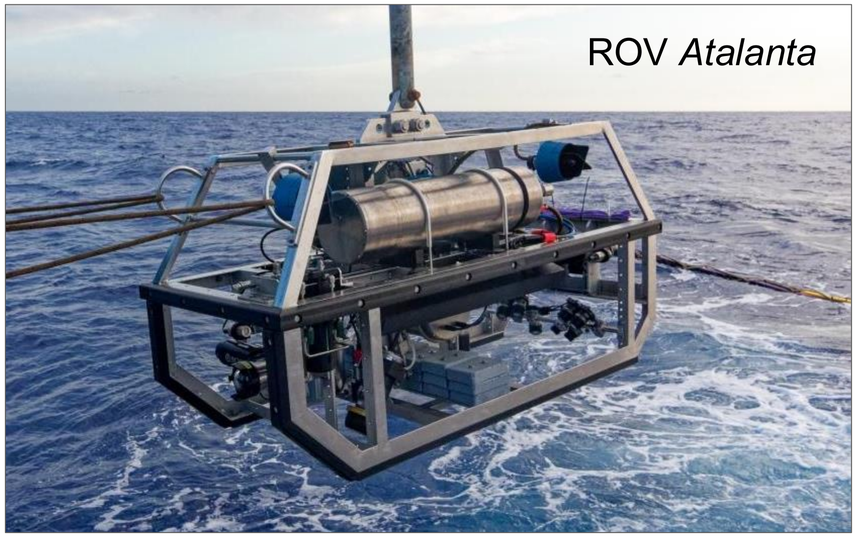
Collect data whenever possible over unmapped areas or areas with old/low resolution data (with a focus on deep ocean areas)

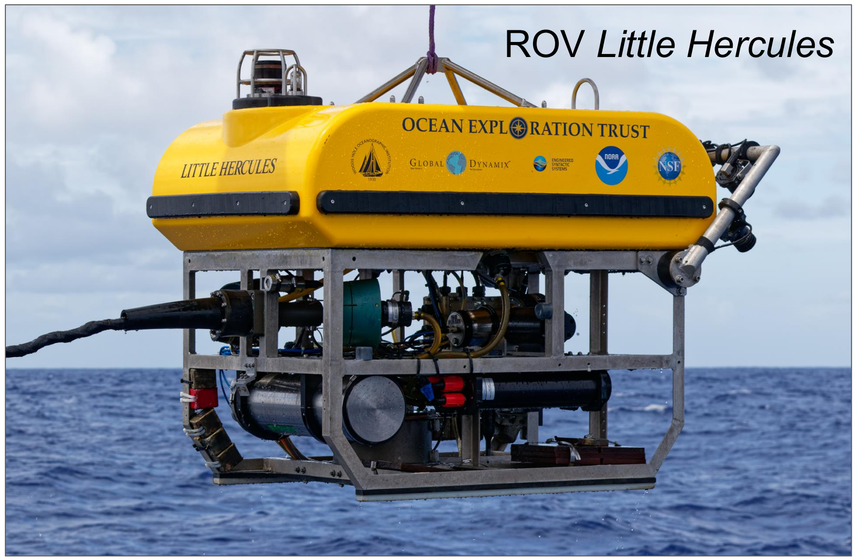
Contribute seafloor mapping data to publicly available archives / efforts:

- NOAA
- Global Multi-Resolution Topography (GMRT) synthesis
- Seabed 2030 Initiative
- National Strategy for Ocean Mapping, Exploring, and Characterizing the U.S. Exclusive Economic Zone (NOMEC)



# Remotely Operated Vehicles (ROVs)


ROV *Atalanta*



ROV *Little Hercules*



ROV *Hercules*

# NOAA OCEAN EXPLORATION COOPERATIVE INSTITUTE

oeci

THE UNIVERSITY OF RHODE ISLAND

OCEAN EXPLORATION TRUST

WOODS HOLE OCEANOGRAPHIC INSTITUTION

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

University of New Hampshire

NOAA OCEAN EXPLORATION

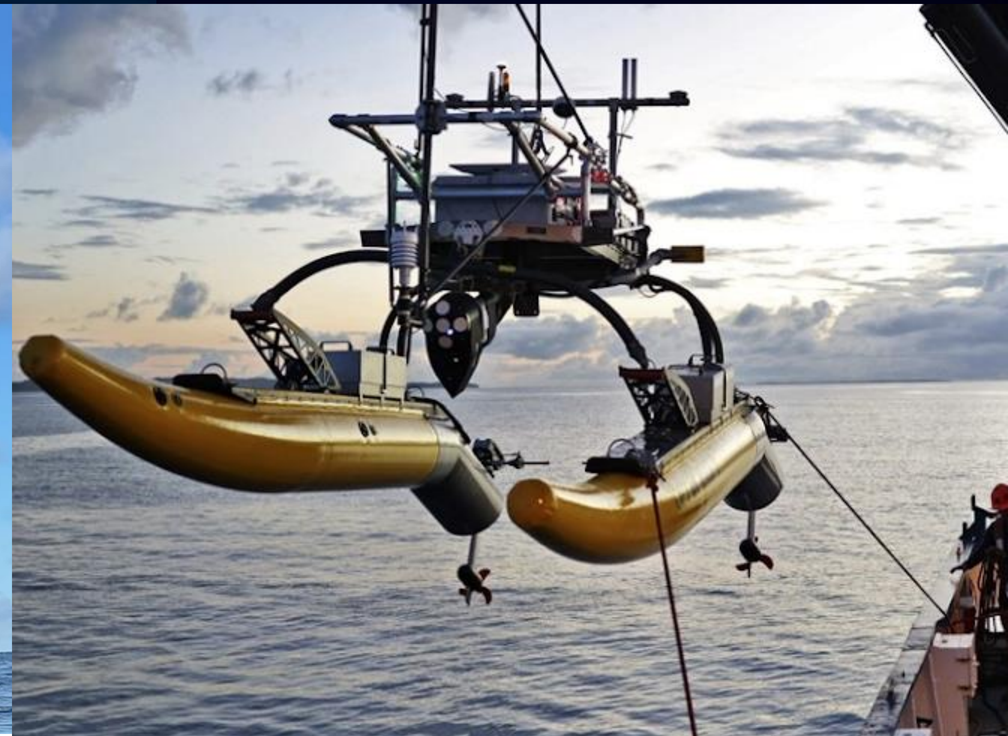

iXblue




SENTRY



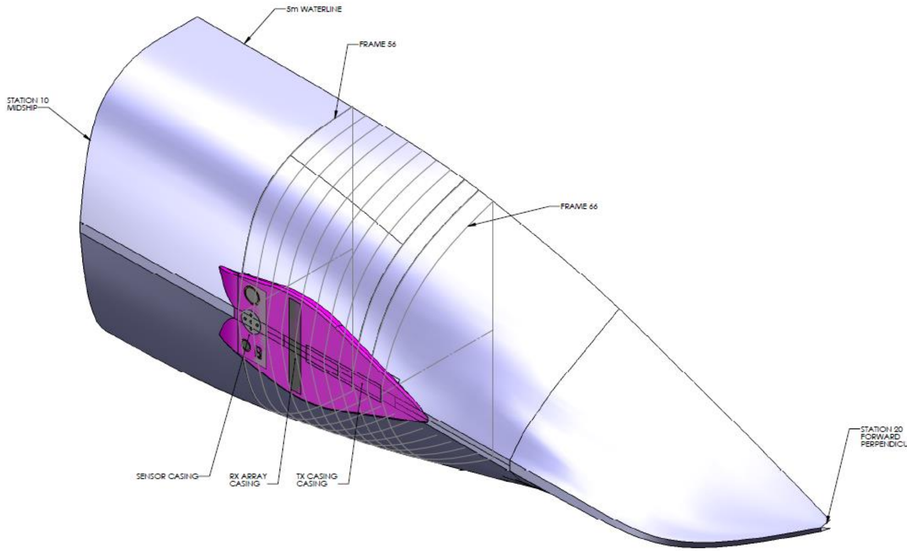

NAUTILUS
KINGSTOWN



# Our EM302 Multibeam on Nautilus (2013-2025)

- Installed in 2013
- 1x1 TX/RX angular resolution configuration
- 13 expedition seasons spanning the Mediterranean to the western Pacific
- Seapath 380 positioning system and MRU5 IMU
- XBTs and UnderwayCTD (UCTD) for sound velocity data
  - 2023 UCTD equipment no longer supported
  - Sippican WinMK21 system for XBT deck box (switched to Turo Quoll XBT-SV in 2025)
- Not compatible with SIS5 software improvements
- Used Fugro Marinestar for GNSS correction service

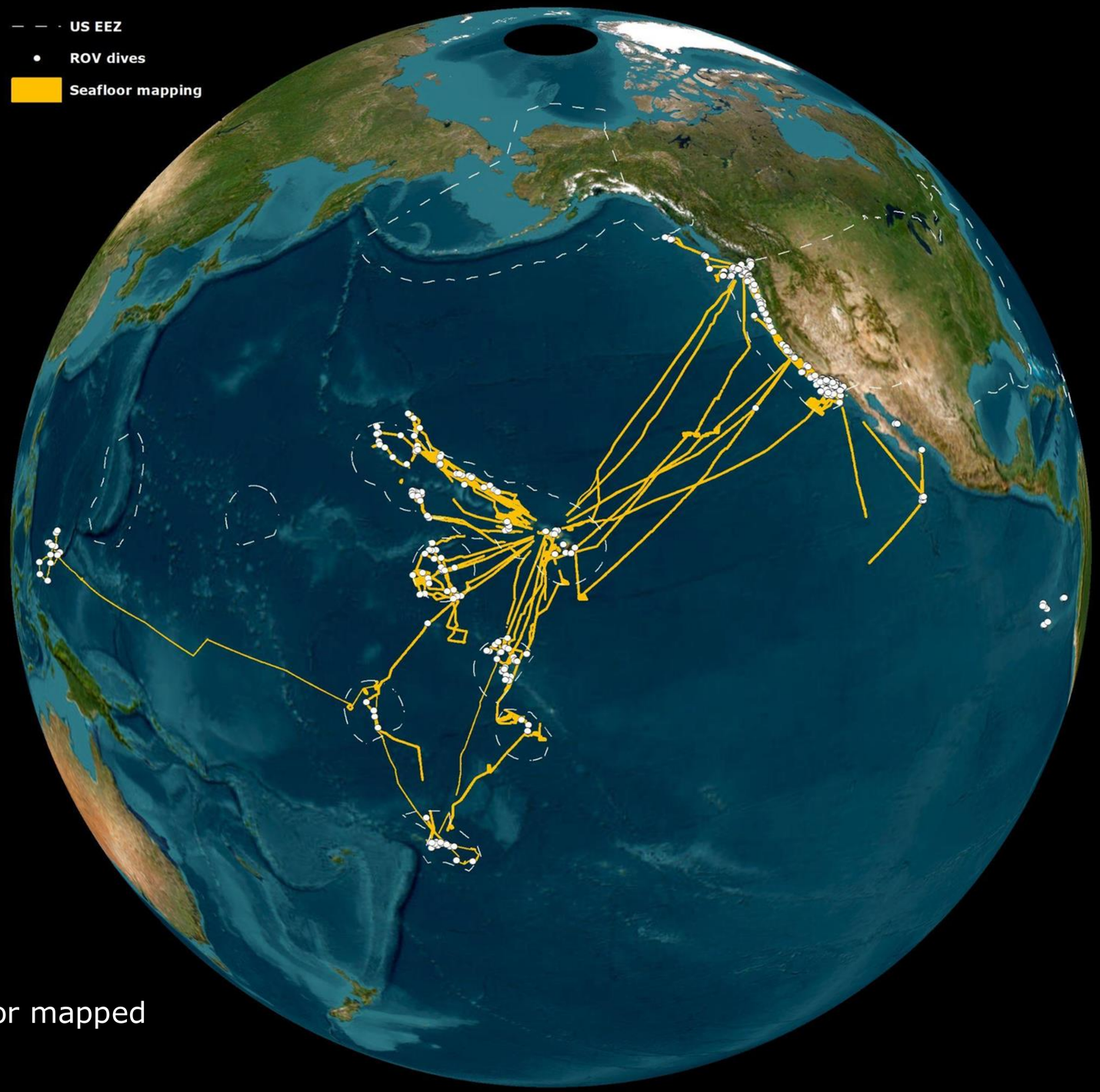





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# PACIFIC OPERATIONS

2015 – 2025
(EM302)




~ 1 Million Square KM of seafloor mapped
> 1000 ROV dive surveys

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# Tracking EM302 System Health Over 13 Years

## Annual Quality Assurance Testing (QATs): Paul Johnson

- Review and verification of system geometry
  - Lever arms
  - Angular offsets
  - Waterline
  - Verify signs with correct coordinate reference system depending on manufacturer and software conventions
- Patch test calibration and verification
- Noise testing (engine RPMs, propeller pitch, octagon tests)
- Accuracy tests at different depths and sonar modes
- Swath performance (swath width vs. depth)
- Evaluate data on the health of the arrays every year (2013-2025)





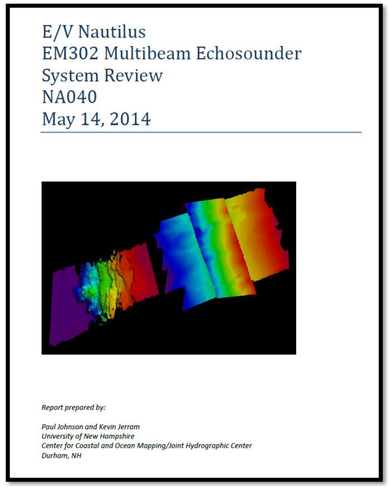


Nautilus

TECHNICAL REPORTS

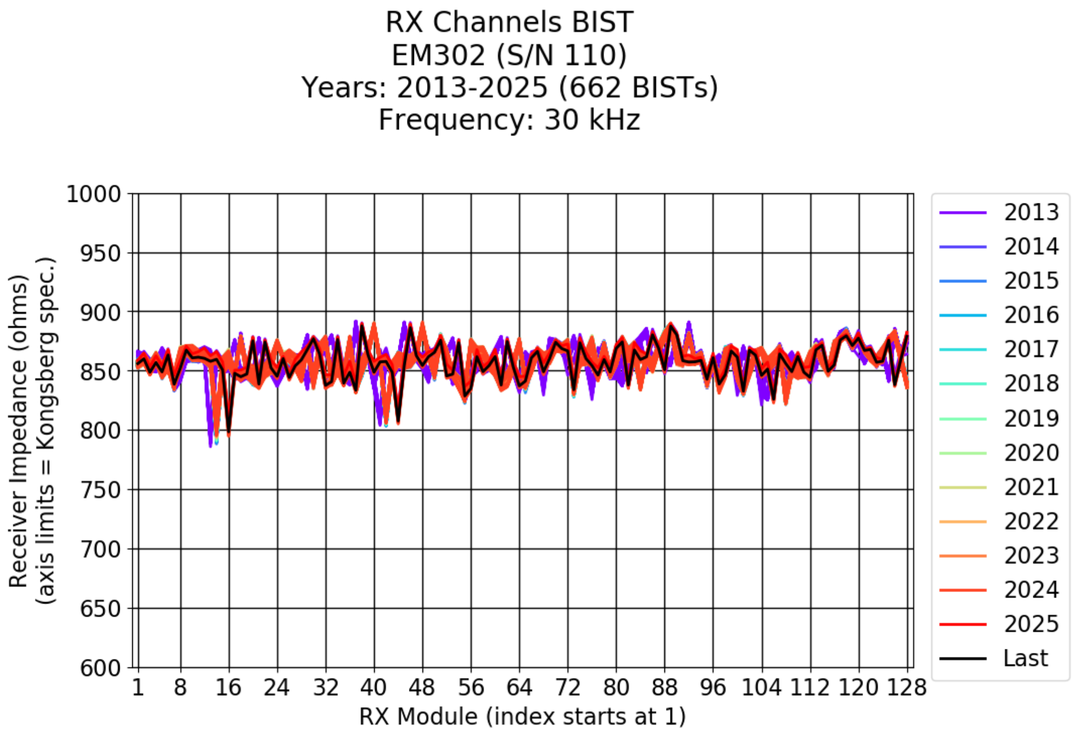
2022 Nautilus QAT Report

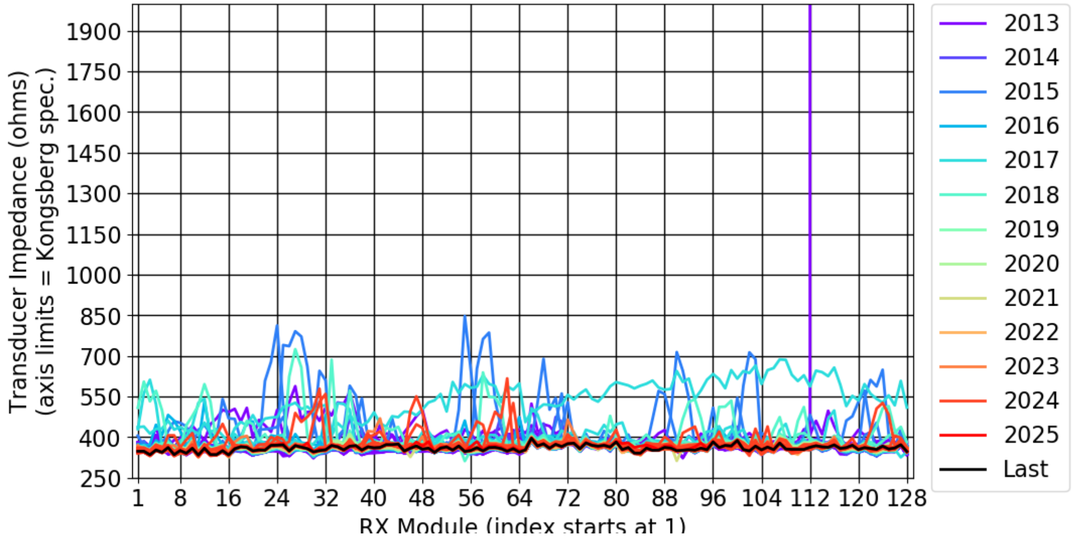





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# EM302 Transducer Health: Impedance – RX Channels & Receiver



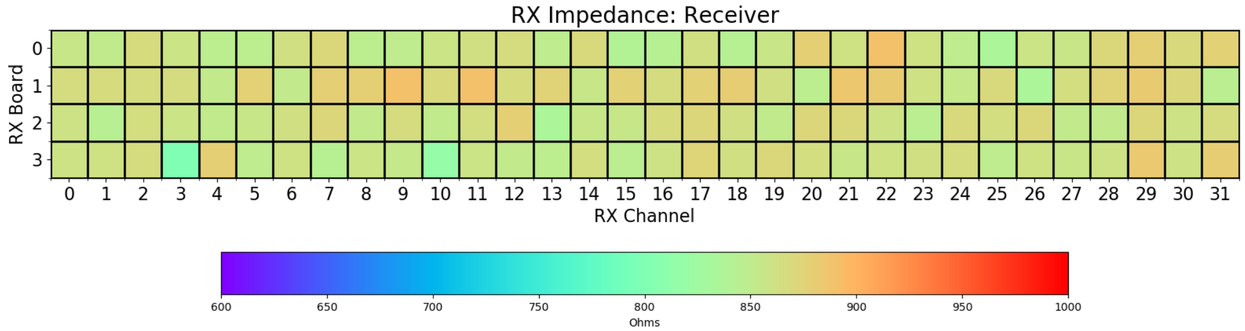



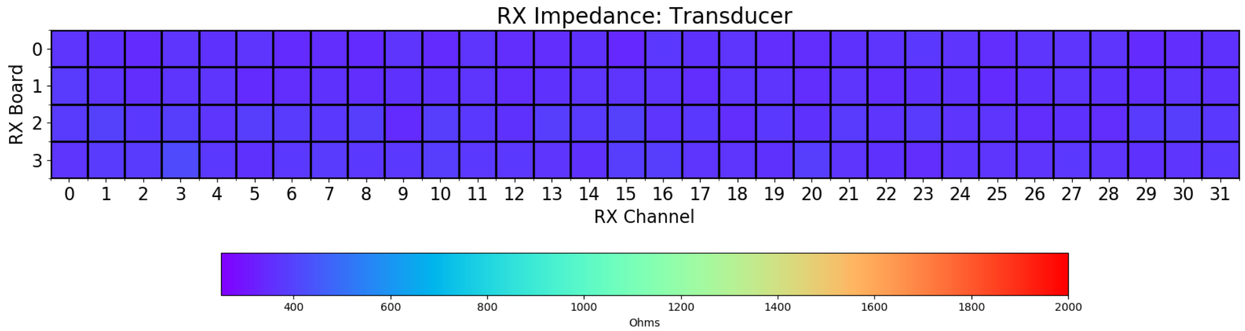

- Impedance levels for receiver and transducer collected by BIST tests from 2013 to 2025.
- 662 BISTs plotted.
- The most recent 2025 test shown as a thick black line.
- Y- axis represents acceptable impedance range to pass a BIST test as defined by Kongsberg.
- Impedance values showed relatively uniform levels across all channels and confirm no open or short-circuit conditions.
- There was very little change in amplitude or variation in pattern over the 13 years of testing.

# EM302 Transducer Health: Impedance – RX Channels & Receiver

## RX Channels April 2013 (SAT)

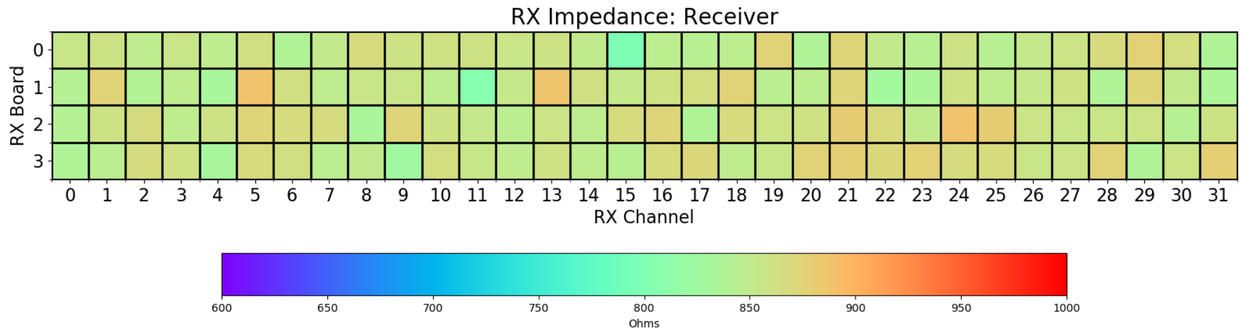
RX Channels BIST
EM302 (S/N 110)
2013/04/03 15:52:17.457
Frequency: 30 kHz

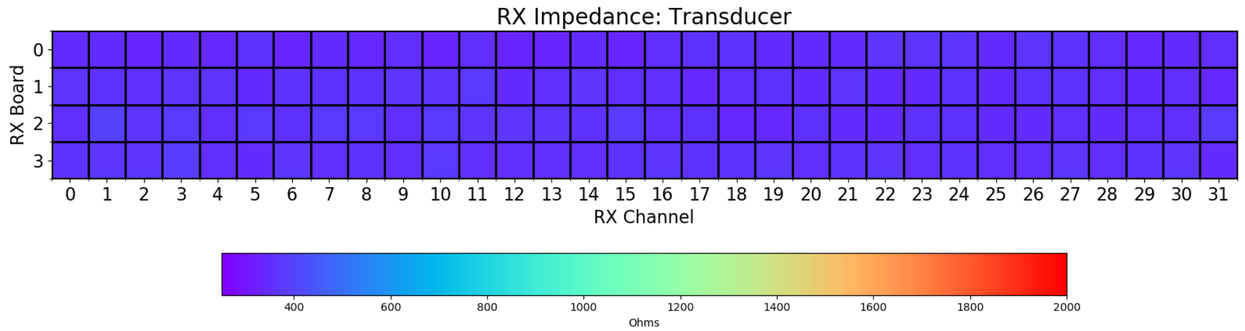



## RX Channels May 2025

RX Channels BIST
EM302 (S/N 110)
2025/05/01 06:10:14.783
Frequency: 30 kHz

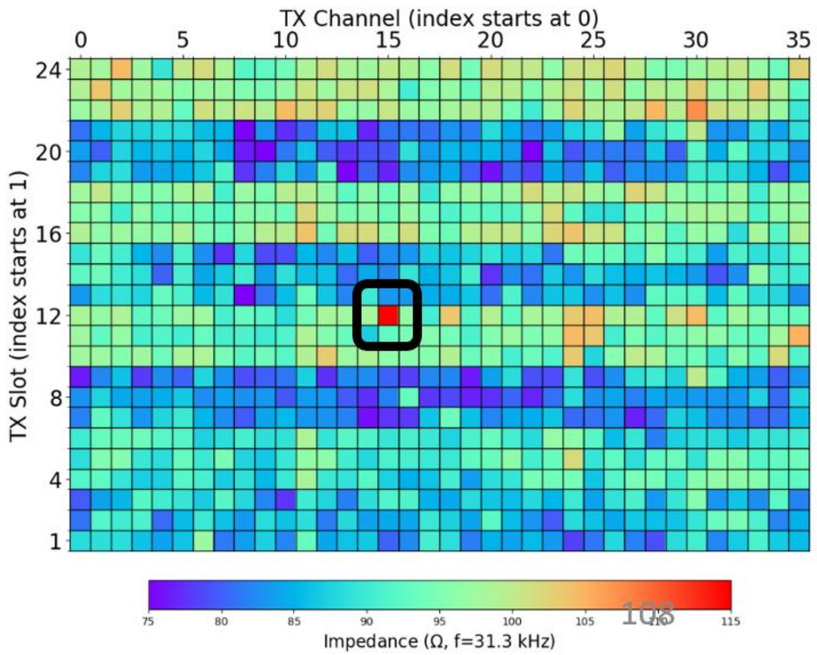


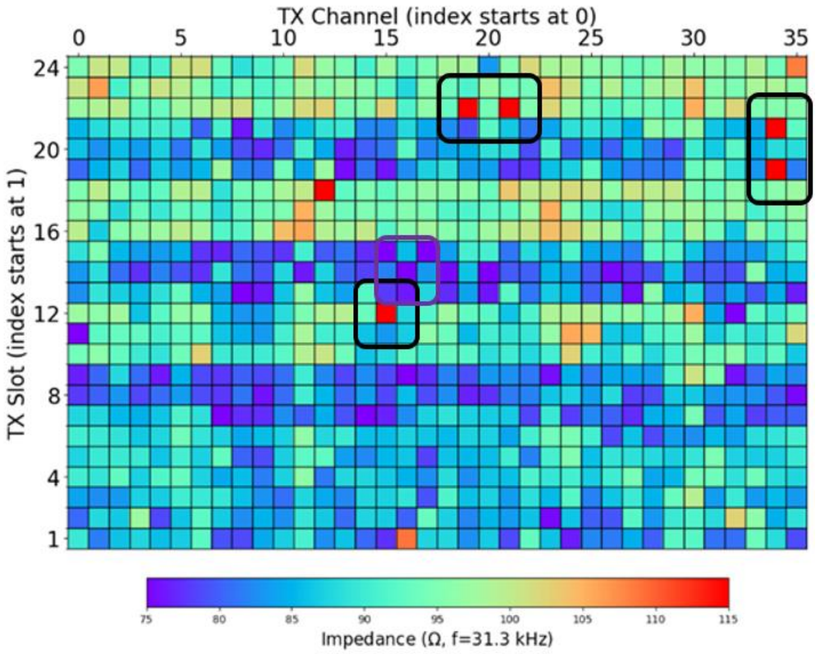



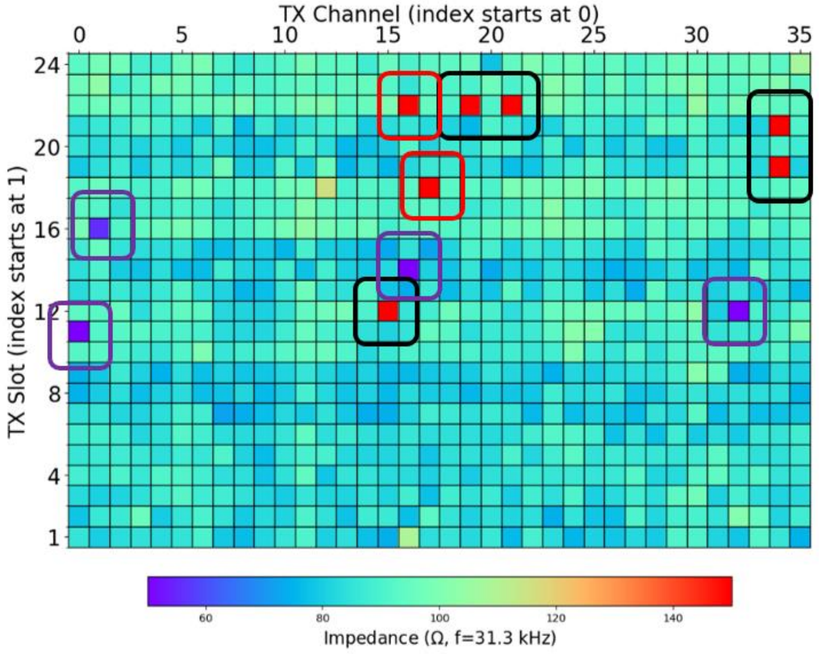

- All channels met specifications after 13 years

# EM302 Transducer Health: Impedance – TX Channels

2014 → 2024 → 2025

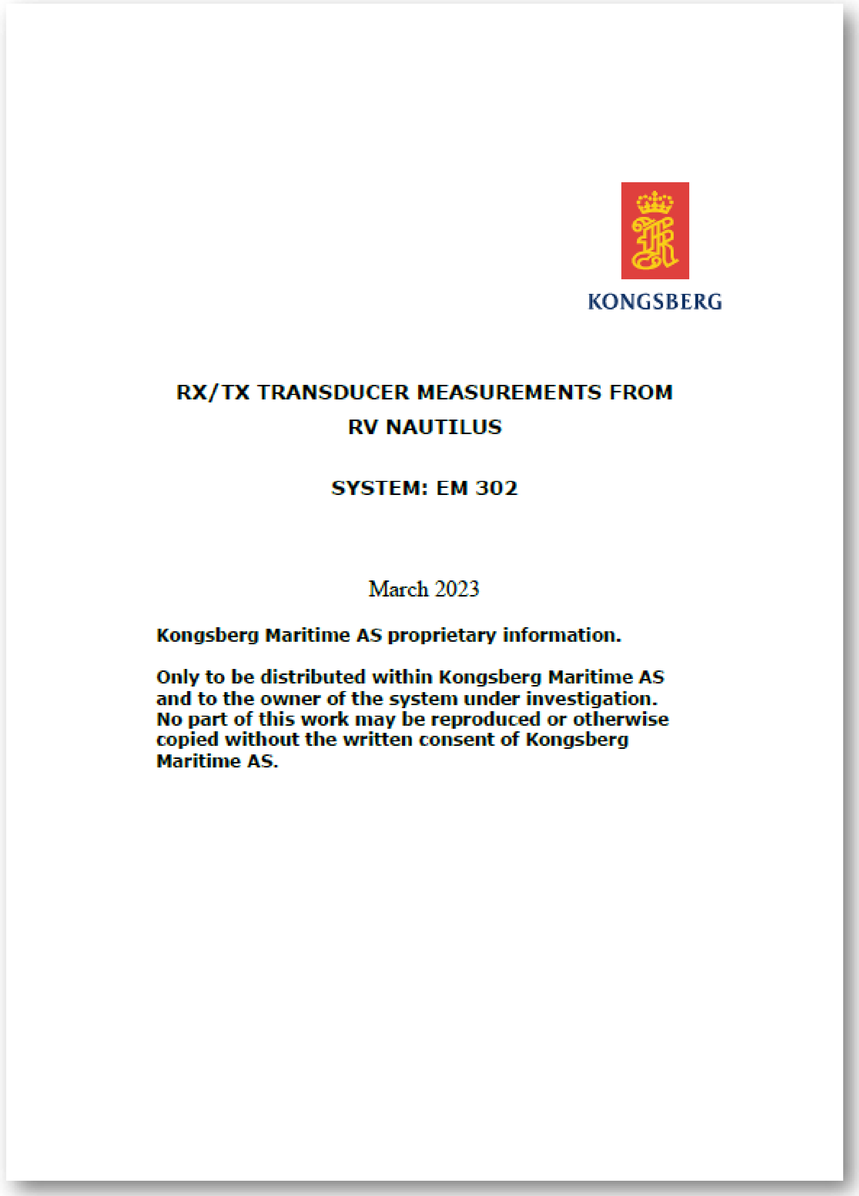



- The 2025 BIST impedance showed 7 bad elements (2 newly identified from 2024 - red boxes)
  - 1 bad channel in 2014
  - 1 additional bad channel in 2022
  - 1 additional bad channel in 2023
  - 2 additional channel in 2024.
- 4 channels showed borderline low impedance (purple boxes)
- Monitoring shows slow degradation over 13 years, but most channels still meeting specification

# EM302 Transducer Health: 2023 RX/TX Transducer Tests



KONGSBERG

**RX/TX TRANSDUCER MEASUREMENTS FROM RV NAUTILUS**

**SYSTEM: EM 302**

March 2023

**Kongsberg Maritime AS proprietary information.**

**Only to be distributed within Kongsberg Maritime AS and to the owner of the system under investigation. No part of this work may be reproduced or otherwise copied without the written consent of Kongsberg Maritime AS.**

To more directly evaluate just the health of the EM302 transducer arrays, OET asked Kongsberg to complete direct electrical measurement of the staves/elements in 2023.

Results

- RX Array:
  - 1 channel outside production specification out of 128 elements
- TX Array:
  - 3 channels outside spec out of 864 elements
  - Standard deviation a bit higher than the stated production specifications - can result in more noise
  - (Kongsberg accepts 10% of the TX array to be defective before proper action should be taken, i.e. 86 elements.)

For arrays 11 years old at the time, the condition was beyond expected. OET used these arrays for another two field seasons.

# Tracking EM302 System Health Over 13 Years

Trends in system performance as it aged:

- Increasing issues with bottom tracking – especially on slopes or in very low backscatter substrates in deep water

- “tearing” (gaps in bathymetry) at sector boundaries in outer sectors of the swath

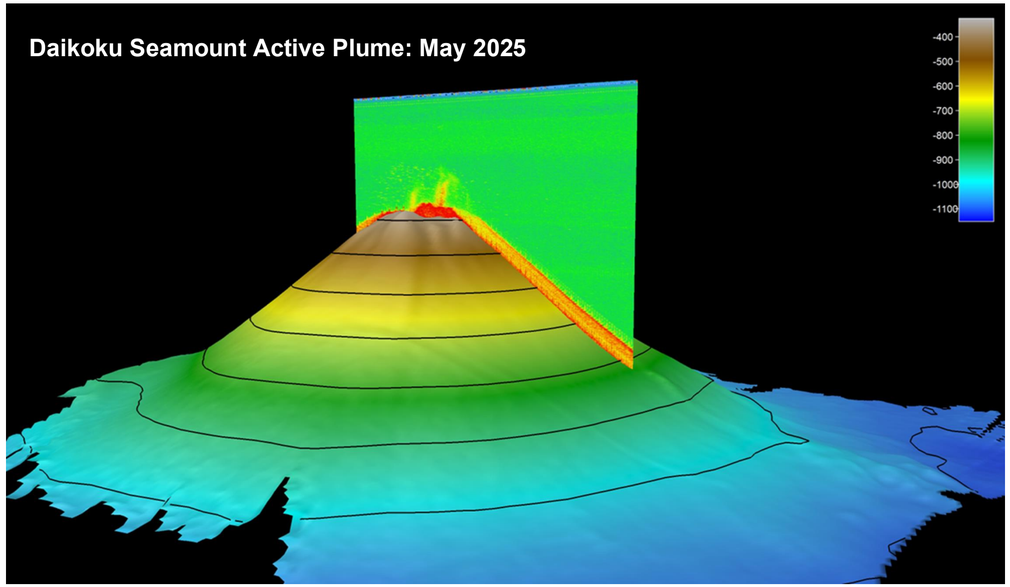
- Auto mode issues with transition from Deep to Very Deep at 3300 m – we had to keep moving this transition to a shallower water depth over time and change modes manually.
  (Impact: reduced swath width and losing alongtrack data density going from dual ping to single ping)

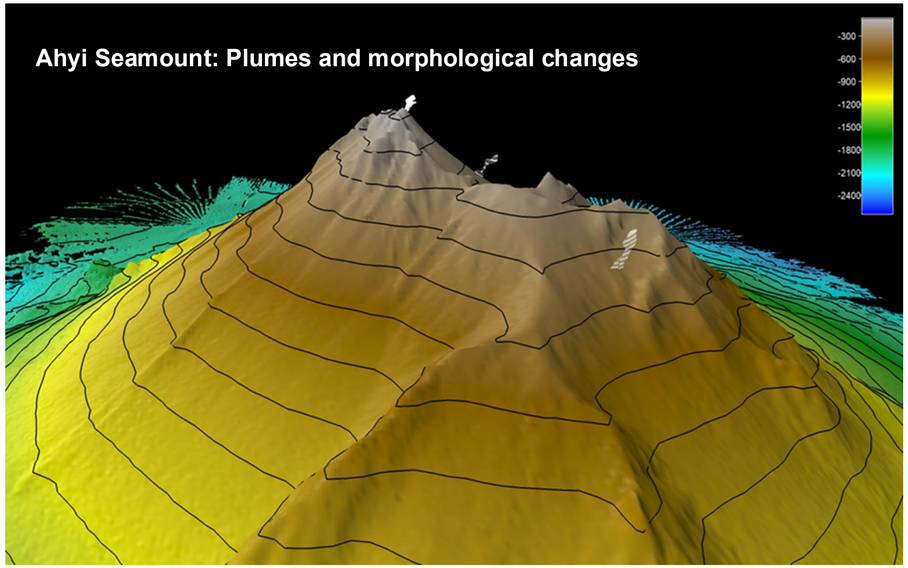
- 2024 and 2025 – noticeable problems in swath/tracking in Pacific abyssal plains (>4500 m) – at times would lose entire quarter of our swath on the port side, greatly reducing our mapping efficiency (exacerbated by louder ship noise over time)

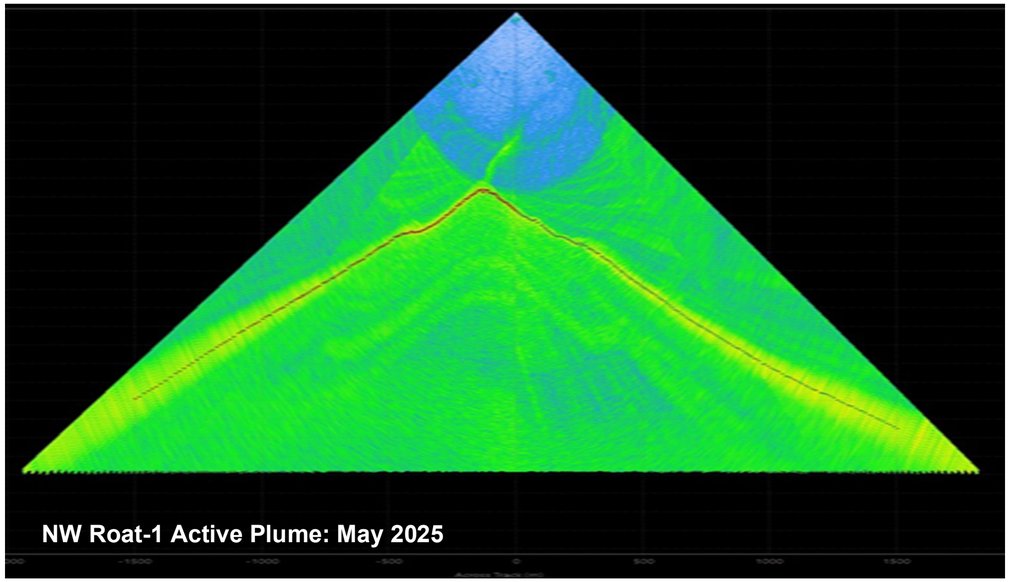
# EM302 (2013-2025): Highlights of Features Mapped/Explored

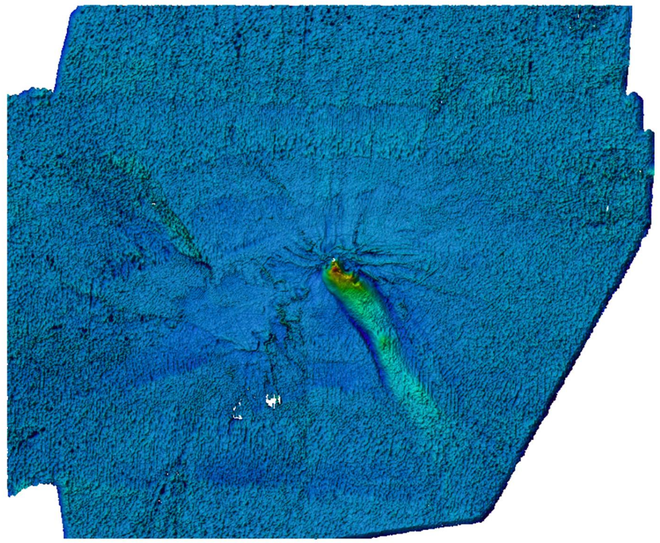
## Mariana volcanoes – tracking subsea volcanism, geomorphic changes

Credit: OET, Anna Coulson



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# E/V *Nautilus* Mapping and ROV Dives Reveal Hundreds of Vents Along the West Coast of the United States

Renato Kane[1], Nicole Raineault[1], Lindsay Gee[2], Robert Embley[3], Susan Merle[3,4], Peter Girguis[5], Onni Irish[6], Megan Lubetkin[7], Christopher German[8], Lisa Levin[9], Marie-Helene Cormier[10], Chris Caldow[11], Ryan Freedman[11]
1. Ocean Exploration Trust, 2. Acoustic Imaging, 3. NOAA Pacific Marine Environmental Lab, 4. Oregon State University 5. Harvard University, 6. University of New Hampshire, 7. Bates College,
8. Woods Hole Oceanographic Institution, 9. Scripps Institution of Oceanography, 10. University of Rhode Island Graduate School of Oceanography, 11. NOAA Channel Islands National Marine Sanctuary

## Overview

Examination of water column data collected in the 2015 and 2016 field seasons along the US west coast revealed hundreds of distinct vertical features, presumably plumes of methane gas released from the seafloor. While seafloor reservoirs of methane are thought to contribute 5-10% of the global discharge, inventories of seafloor methane seeps are poorly constrained due to the lack of data such as the distribution and abundance of seafloor gas plumes. The results of mapping efforts reveal an unexpected number of methane seeps (Fig. 1). ROV dives were then used to provide geological context to the seeps and associated unique biological communities.

*Figure 1: US west coast seep sites found by E/V Nautilus 2015-2016*

## Sensors and Systems

The Exploration Vessel (E/V) *Nautilus* has mapped more than 30,000 km² of seafloor off the west coast of the United States between July 2015 and September 2016. The 30 kHz Kongsberg EM302 multibeam mapping system collects water column data in addition to bathymetry and backscatter. The 1x1° beam width is fixed to 65° for seep detection surveys (Fig. 2). Remotely operated vehicles (ROVs) *Hercules* and *Argus* were used to examine and carry specialized equipment to sample the seep sites (Fig. 3).

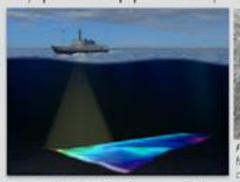


*Figure 2 (above): E/V Nautilus equipped with an EM302 multibeam mapping water depths from 10-7000 m*



*Figure 3 (above): ROV Hercules gathers seep bubbles with a funnel to collect in a gas tight chamber for gas composition analysis.*

## Water Column Data Analysis

The initial processing used the QPS Midwater tool to locate the seeps and determine their size and location. This was achieved using a number of different modes: the single fan, stacked fan (10-20 pings) to improve detection of faint seep returns in noisy environments, and stacked range mode for a chronological view (Figure 5). Each line of data was viewed in playback mode. When a seep was detected, the locus of the seep at the seafloor (bottom pick) and maximum height above the seafloor (rise) was geo-picked and saved (Figure 4). Geospatial distribution was reviewed during processing in 3D scenes (example to right) to relate the seeps to the multibeam bathymetry and backscatter.

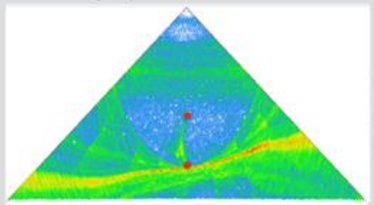


*Figure 4: Double seep in fanbeam view. Top is ocean, seep and rise of one seep marked with red circles.*

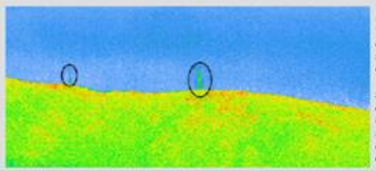


*Figure 5: Stacked view of beams helps identify seeps chronologically (X axis is time starting on left and Y is range from top). Two seeps are visible here (black on white).*

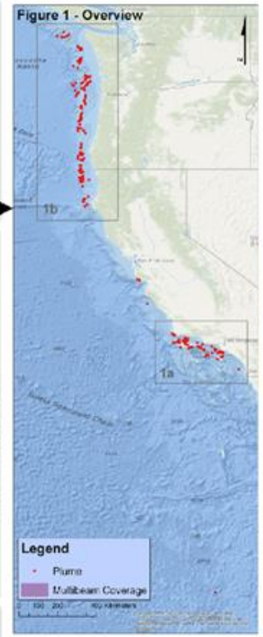
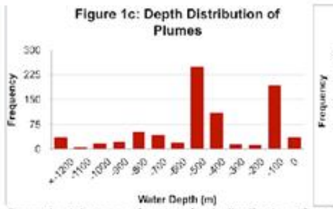



*Figure 1: Overview of gas plumes (red dots) detected in water column*



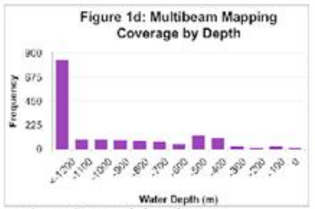




Figure 1c: Histogram showing depth distribution of gas plumes discovered along the coast.
Figure 1d: Histogram showing multibeam mapping coverage by depth.

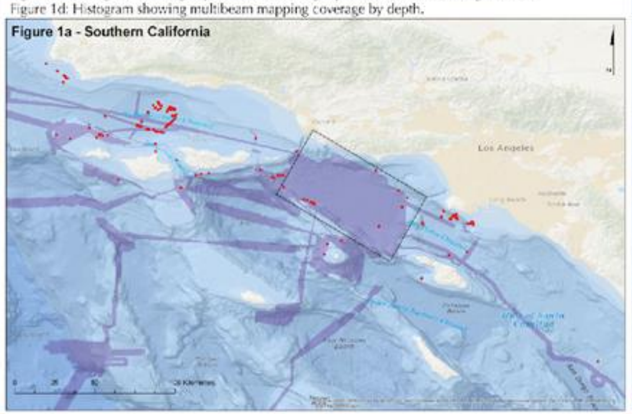



*Figure 1a: Highlight of gas plumes found around the Channel Islands.*

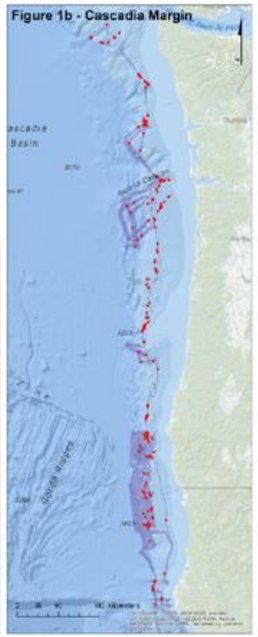
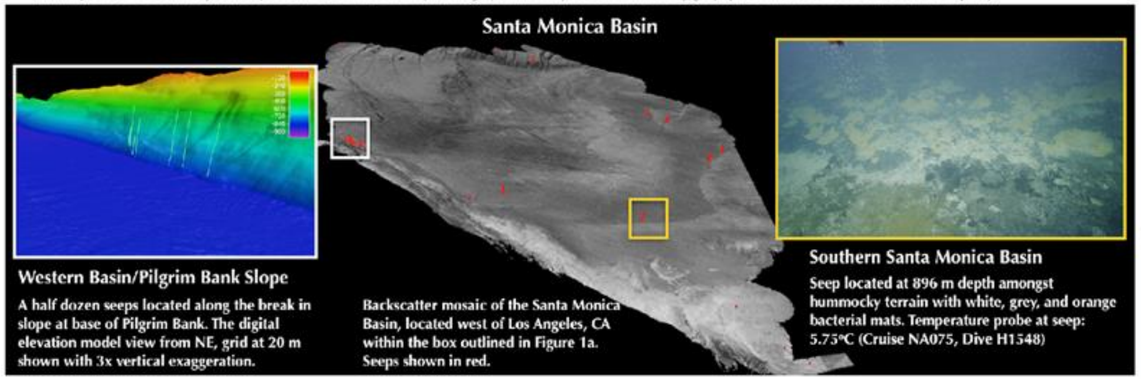



*Figure 1b: Highlight of gas plumes found off the coast of Washington and Oregon.*

Projection: WGS84 Mercator. Data: Ocean Exploration Trust. ESRI basemap

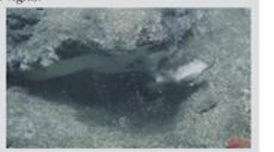
- Over 800 clusters of seeps were identified through our detection methods, from Washington to California off the US west coast.
- Most mapping efforts (defined here as area mapped) were concentrated along the Cascadia Margin and the Southern California region, and the majority of seeps were found in these locations.
- The majority of seeps were identified along the 500 m depth contour, which coincides with the upper limit of methane hydrate stability, but also represents greatest mapping effort depth zone apart from <-1200 m. Low mapping efforts in the 200-400m depth range (and in the central California region) may account for low seep discoveries.
- There were often fields of seeps found in the 100 m depth zone, but further research is required to identify the cause (perhaps increased water column resolution or higher seep concentrations/more diffuse vent sites).
- Similarly, there were relatively few seeps found in the <1200 m depth category, which may be accounted for by geophysical limitations but also resolution disparity.




## Astoria Canyon

Located off the Cascadia Margin, seeps detected at the mouth of the canyon (850 m) and at the head of the canyon (495 m) were studied. Methane hydrate was observed at the 850 m depth site (below right).





## Redondo Knoll

Redondo Knoll is 14 km across and rises 350 m above the seafloor 7 miles from the mouth of the Redondo Canyon. The knoll has seeps around the perimeter at 850-900 m depth, particularly on the NW side. The seep site is within the regional oxygen minimum zone and contains no vent fauna, just white, orange, and yellow microbial mats (Figure 6)

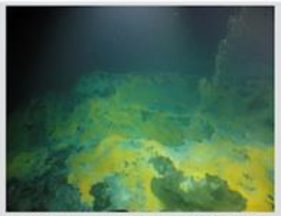


*Fig 6: A spray of bubbles emanates from the Redondo Knoll seep. (Image courtesy of GoPro camera provided by Daniel Fornari, WHOI).*

## Point Dume

Located 5 miles off the Malibu coast at 700-750 m depth, this 1.3 km long diffuse flow site is within an oxygen minimum zone. Aside from orange, yellow, and white microbial mats, this site is devoid of typical seep fauna (below).





The ROV used an in situ sensor to measure eH at the odd chimney concretions, with dark sulfidic sediments inside a thin outer crust. No advective flow or methane bubbles were observed.

## Significance & Conclusions

The results of mapping efforts reveal an unexpected number of methane seeps. ROV dives were then used to provide geological context to the seeps and associated unique biological communities. Altogether these findings contribute significantly to our baseline inventory of seeps along the continental margins of the United States. The presence of unexpectedly large numbers of methane seeps on the US Pacific, Gulf and Atlantic margins may influence the management of human extraction activities on the margin seabed. In future work, we hope to gain insight from this data through analysis of seep location in relation to backscatter, slope, depth, and geological setting, with the goal of more automated detection. We also hope to analyze the spatial distribution of seep clusters and what factors constitute a grouping.

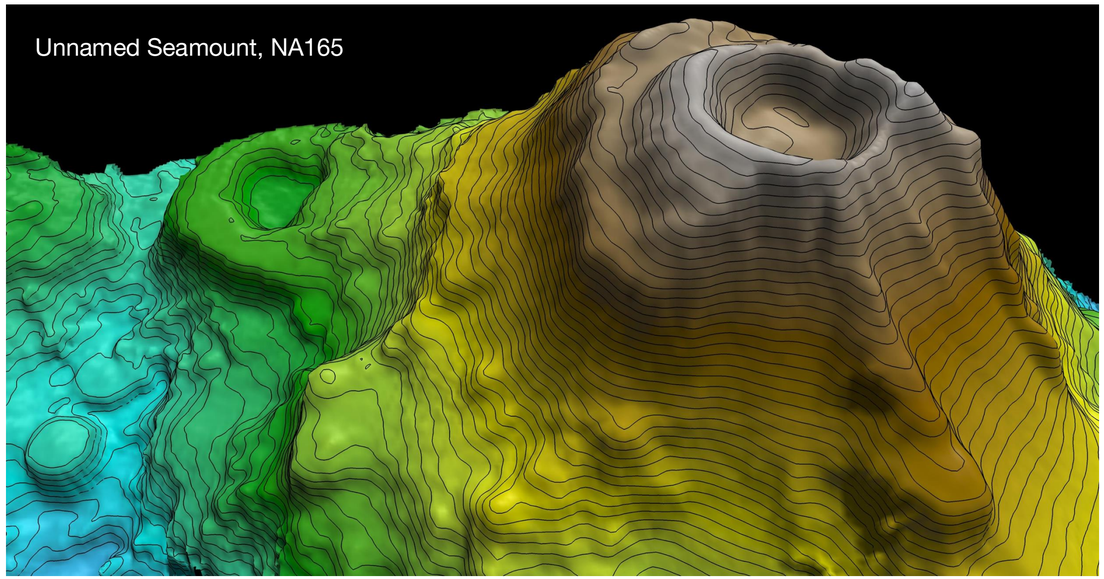
## Acknowledgements

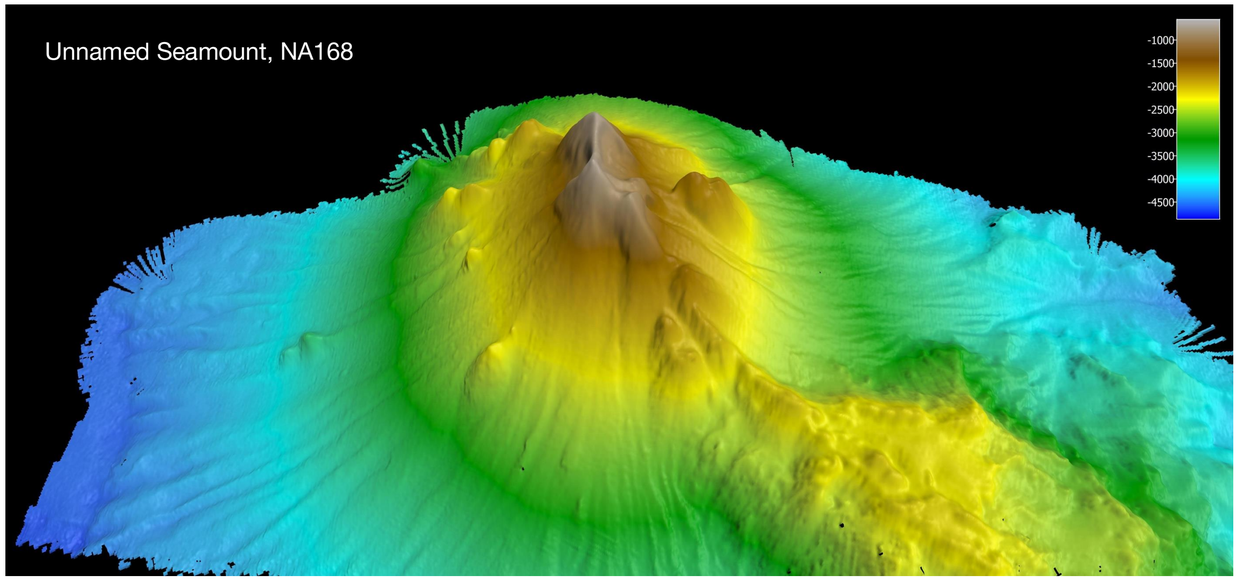
Research was conducted by the Ocean Exploration Trust on the E/V *Nautilus* cruises NA065, NA066, NA067, NA070, NA072, NA073, NA074, NA075, NA076, NA077 NA078. We would like to thank NOAA Office of Exploration and Research and the National Marine Sanctuaries for funding.

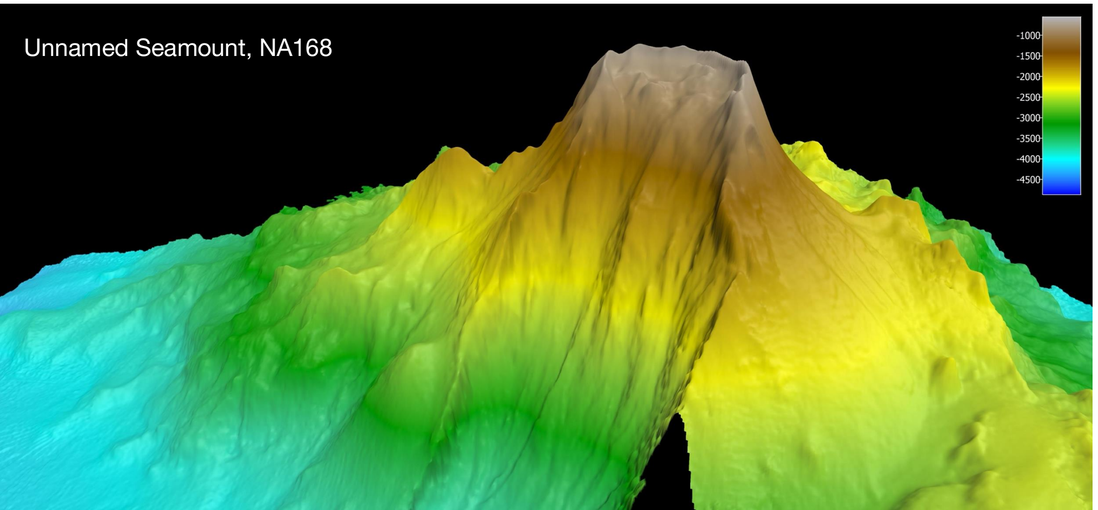
Contact Information: Nicole Raineault (nicole@oet.org)

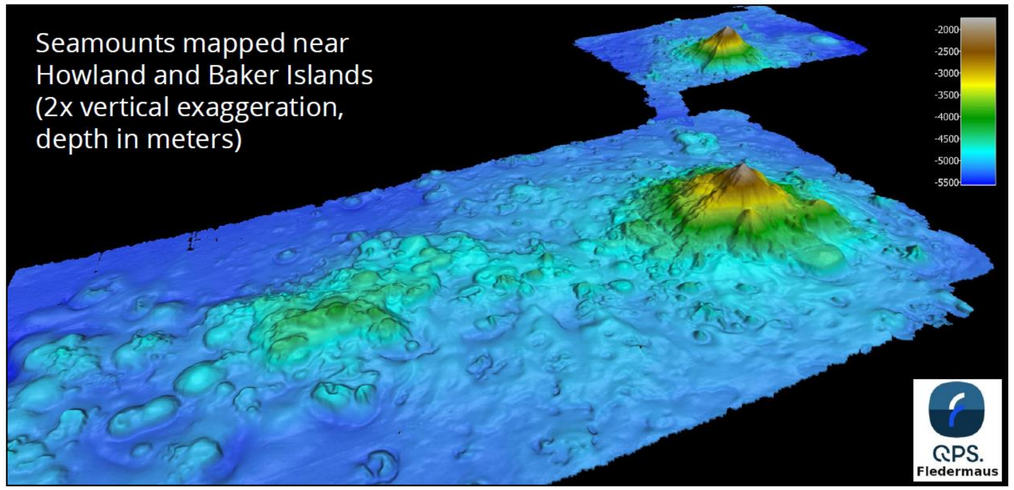
# EM302 (2013-2025): Highlights of Features Mapped/Explored

## Seamounts: Many too small to be detected by Satellite Bathymetry



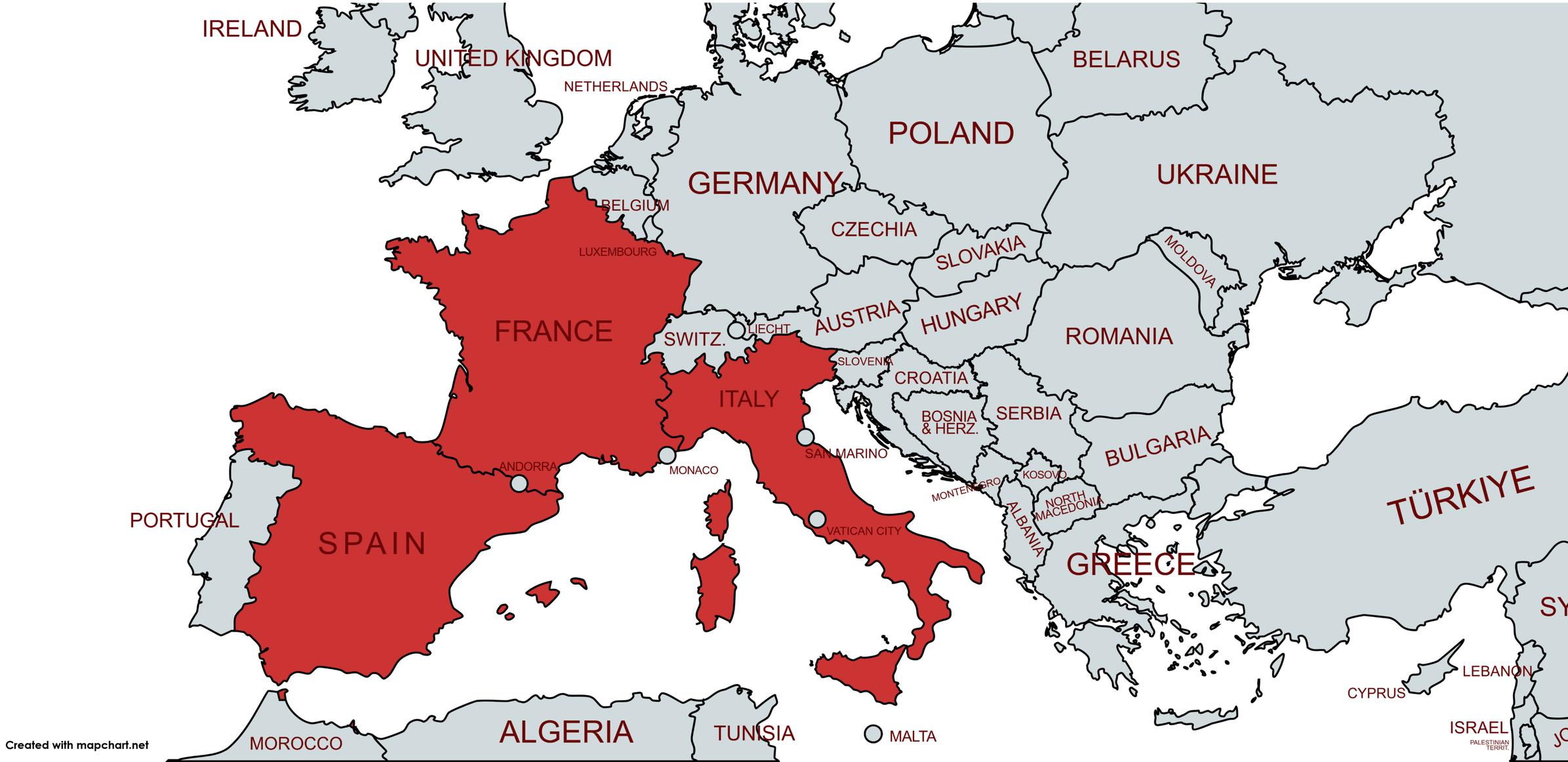




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# EM302 (2013-2025): 1.3 Million Square Kilometers Mapped

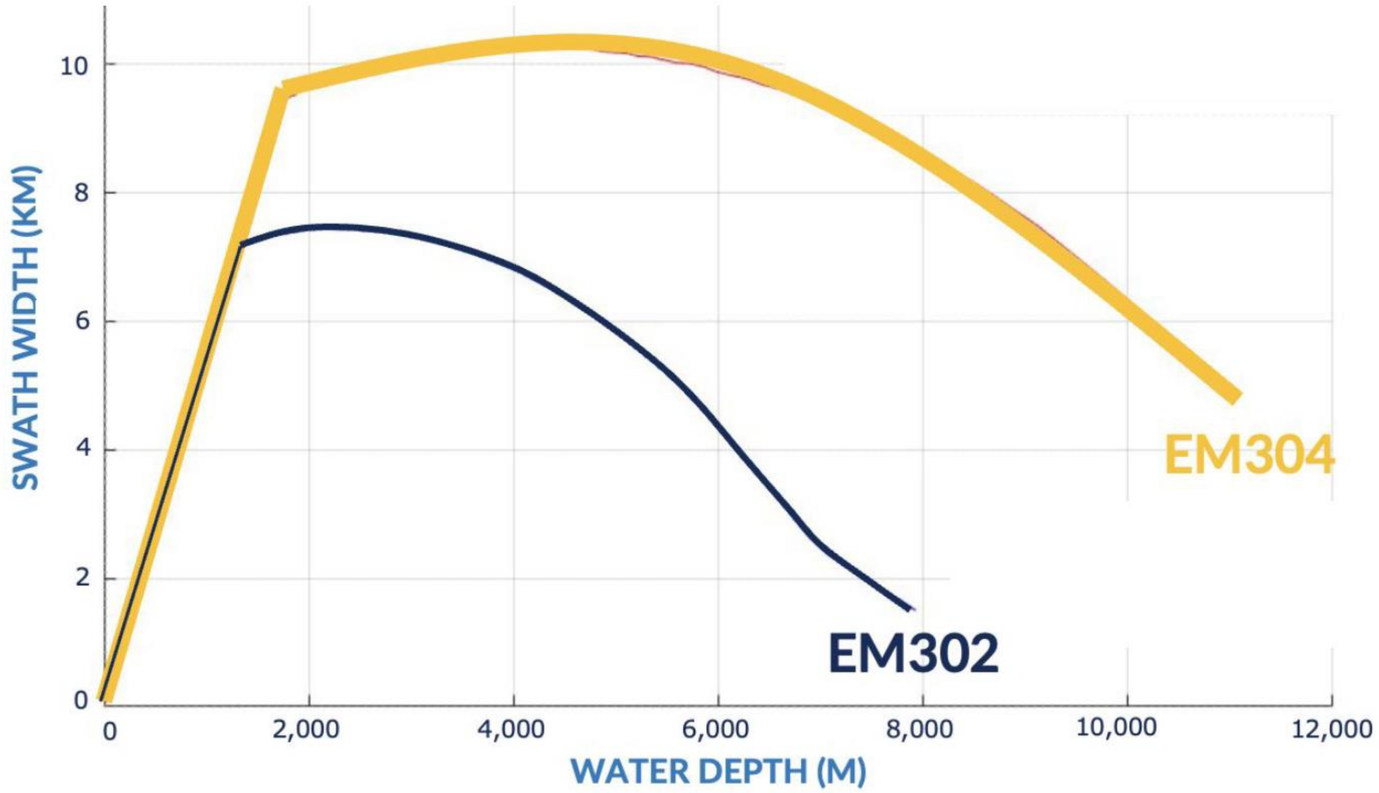
**Equivalent to mapping an area almost the size of Spain, France, and Italy combined**



# Why upgrade from EM302 to EM304 in 2026?

- 13 years of service life
  (typical lifespan 10-12 years)
- Usable swath width was becoming about 4500 m in depths over 5000 m.
  (less than half of an EM304)
- Next planned drydock for E/V Nautilus would not be for another 3 years
- EM302 not compatible with SIS5 software improvements
- Most unmapped areas in the Pacific lie at depths of 4,000-6,000 m; at these depths an EM304 would enable OET to double its mapping coverage or halve its survey times for the same area.

Image by Kongsberg




*Comparison of swath width by water depth for mapping using a EM302 and EM304. Below 1,500 m, the EM304 provides ~1.3-5.5 times higher swath widths compared to an EM302.*

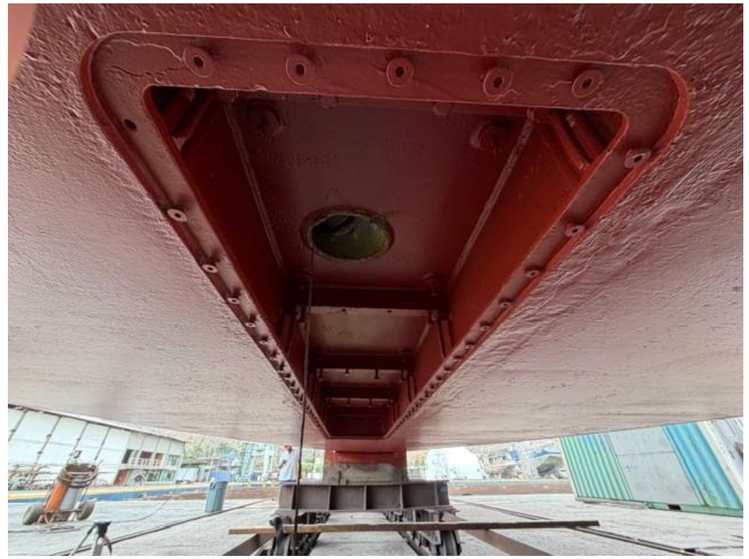
# 2026 New EM304 MKII Multibeam Sonar Approved and Funded

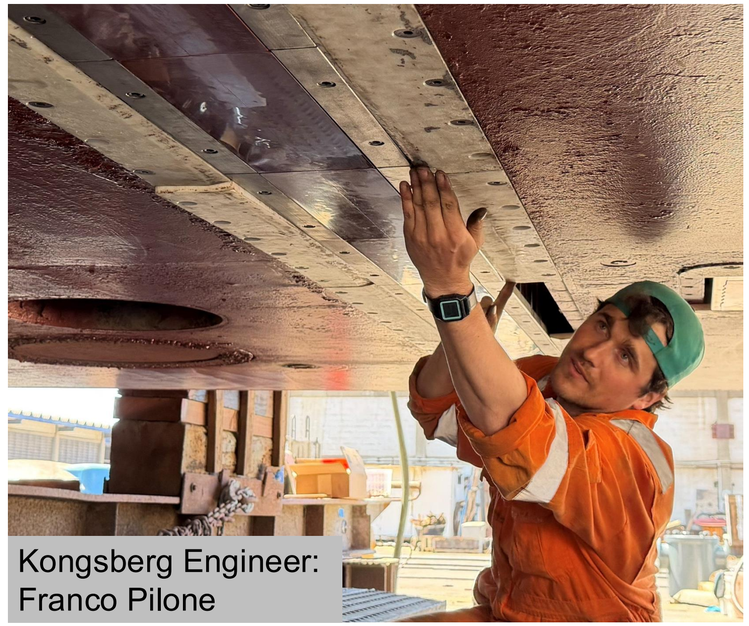
**Funded via a grant from the U.S. Office of Naval Research (ONR) awarded to the University of New Hampshire's Center for Coastal and Ocean Mapping (UNH/CCOM)**

- Partnership "test bed" for deep ocean mapping research with UNH/CCOM, OET, and Kongsberg
- Able to use same casement and sonar blister as EM302 – same form factor is a big deal for viability of upgrade and keeping shipyard costs reasonable (kept 1°x1° angular resolution of the array)
- EMSBP (sub-bottom profiler) option added
- Upgraded motion reference unit (MRU5+)
- Added AML-1 RT sound velocity sensor to the hull, back up flow through system with AML sensors.

# Installation of EM304 MKII in Ensenada Drydock: April 2026





Kongsberg Engineer:
Franco Pilone

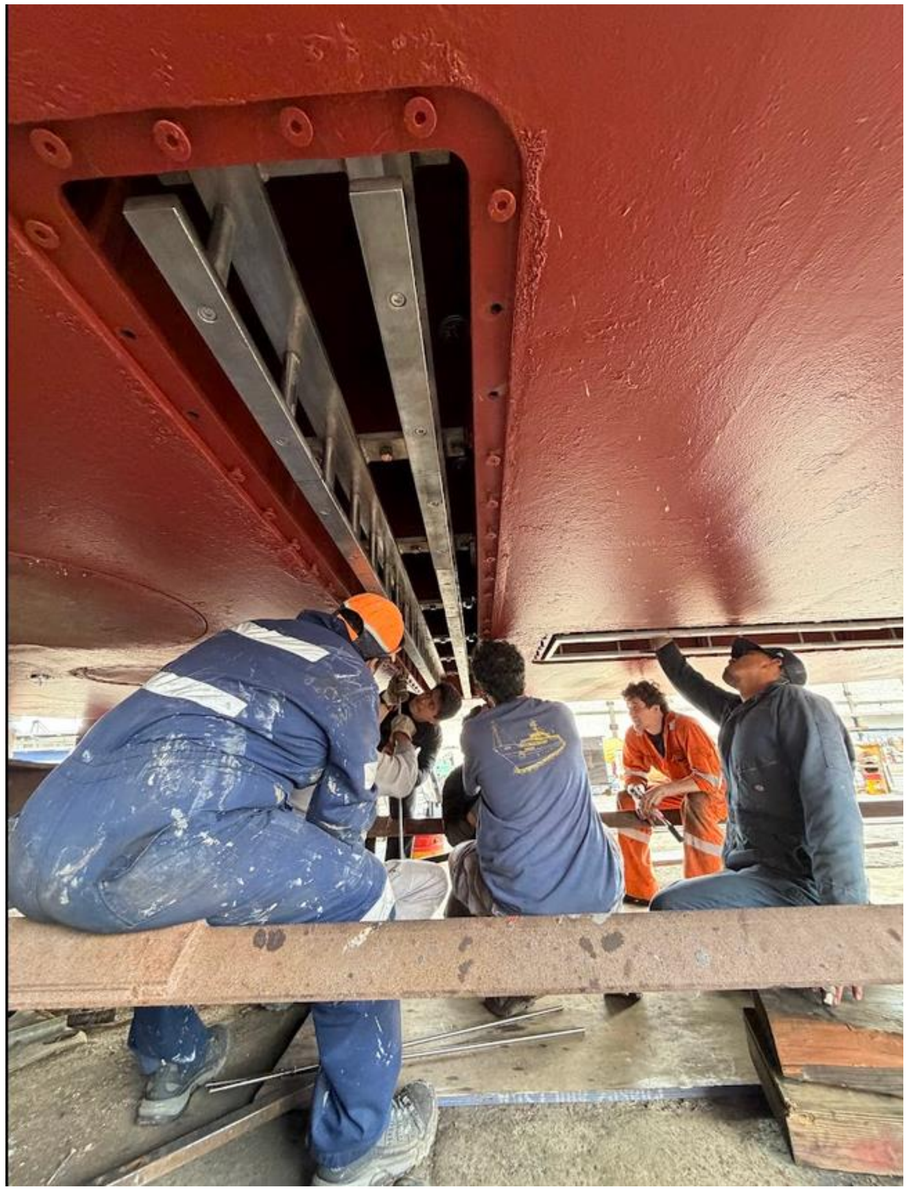
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# Installation of EM304 MKII in Ensenada Drydock: April 2026



Installation of new anodes and the Transmit (TX) and Receive (RX) frames that hold the sonar transducer modules.

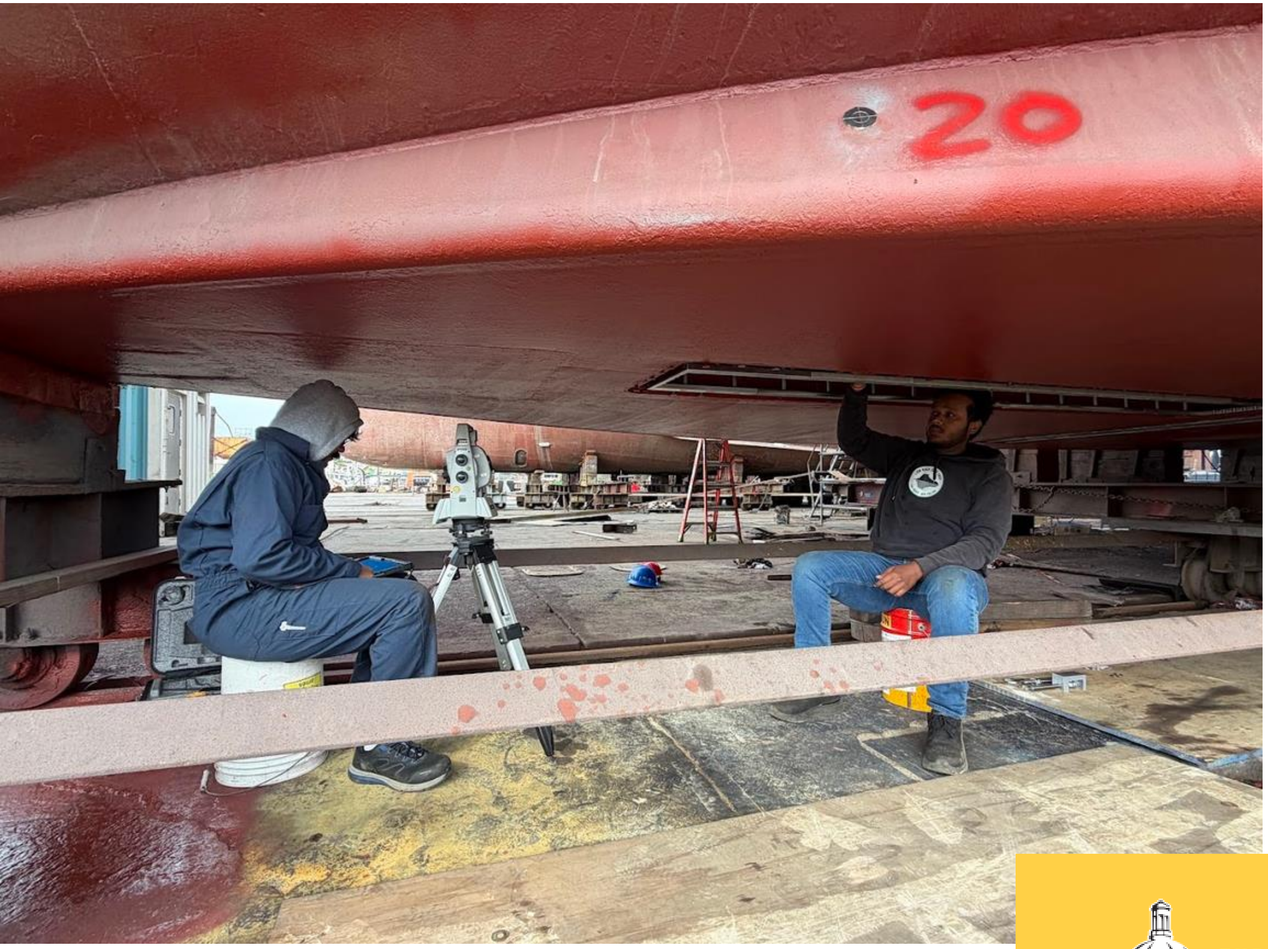




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# Installation of EM304 MKII in Ensenada Drydock: April 2026

Dimensional control survey and new transducer leveling work by Dr. Anand Hiroji and Rishabh Singh from OECI partner University of Southern Mississippi (USM)

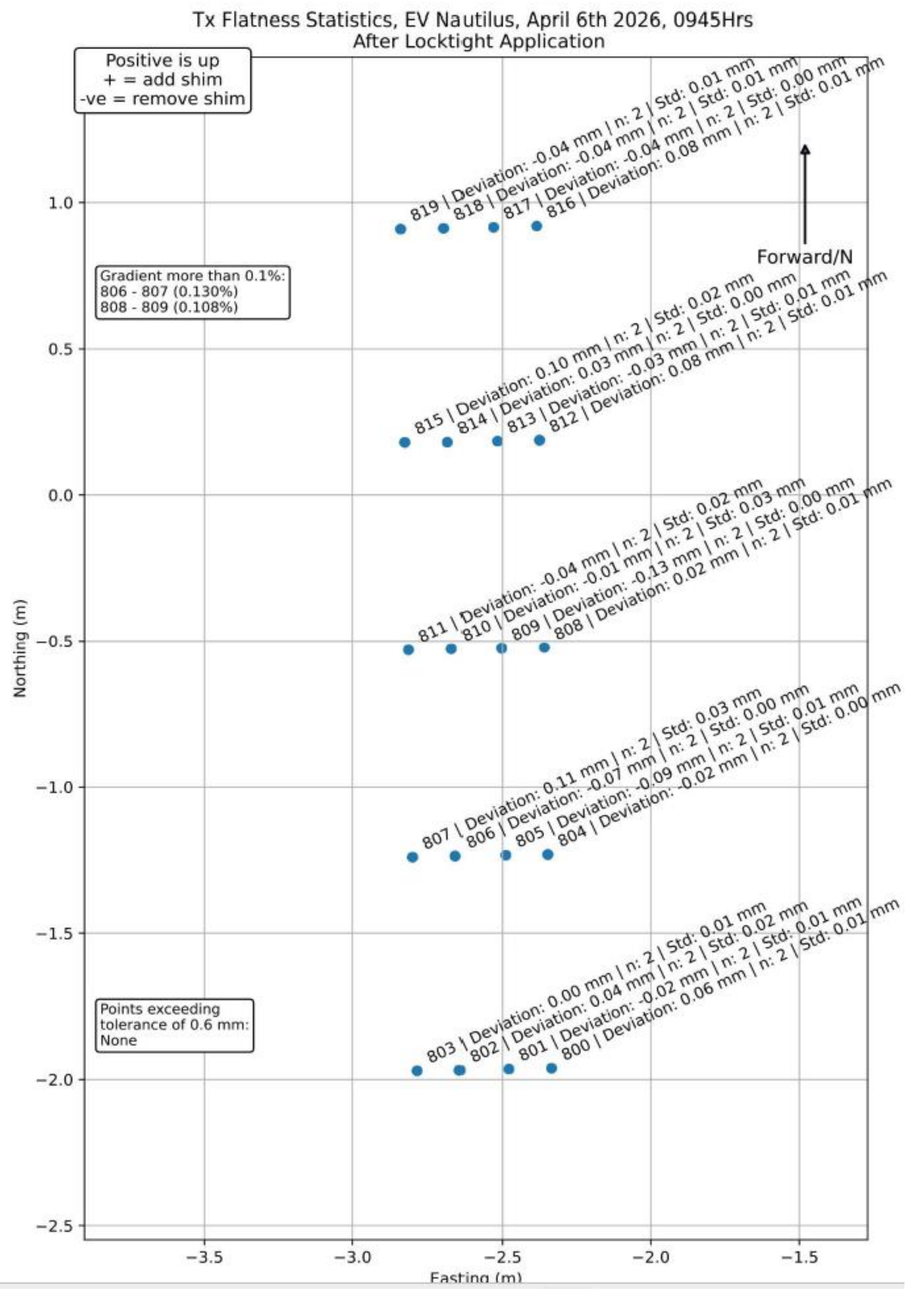





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# Installation of EM304 MKII in Ensenada Drydock: April 2026



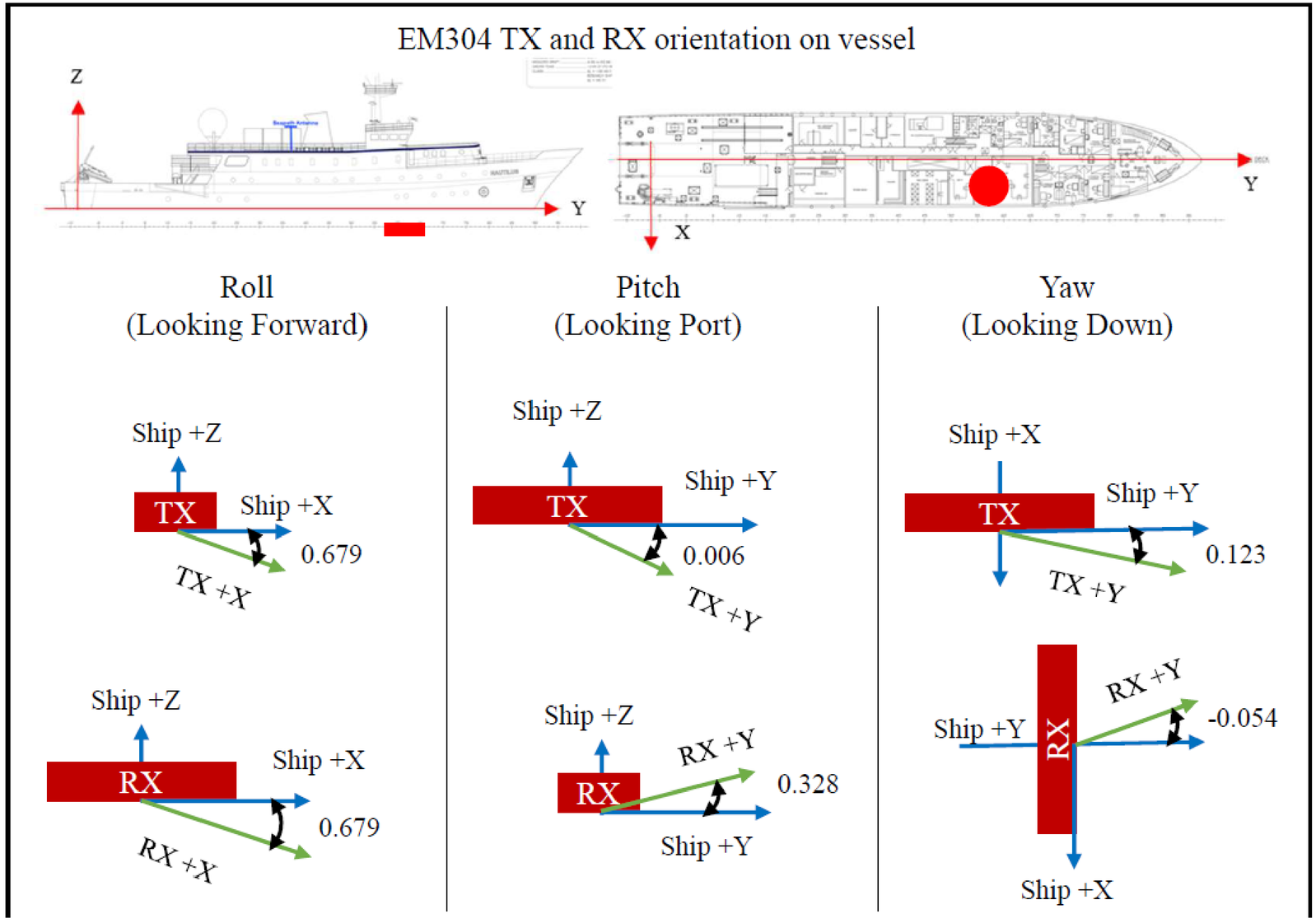




Figure Credits: Dr. Anand Hiroji, USM

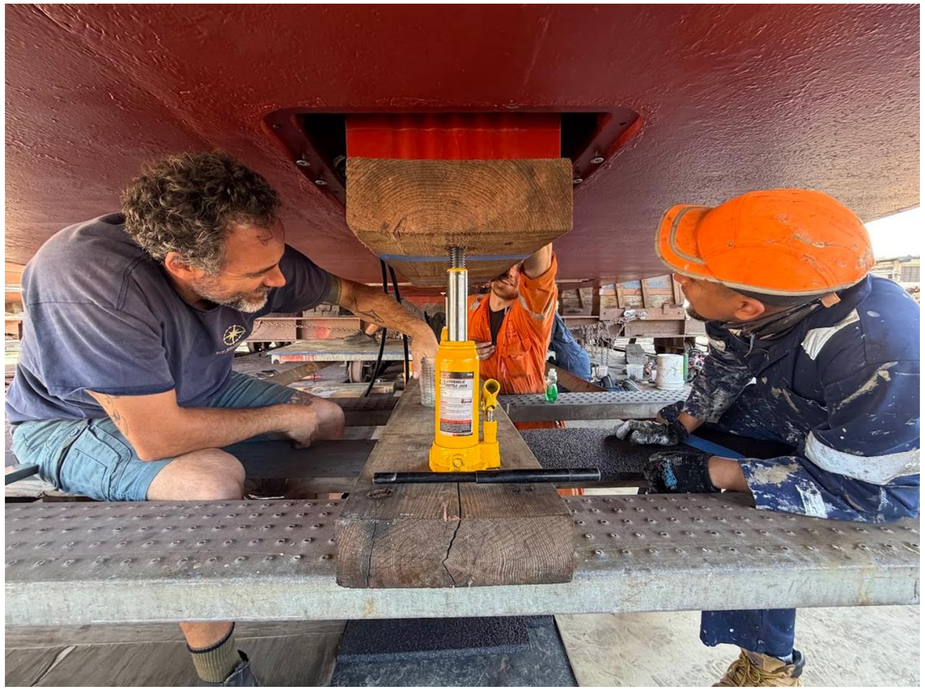
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# Installation of EM304 MKII in Ensenada Drydock: April 2026



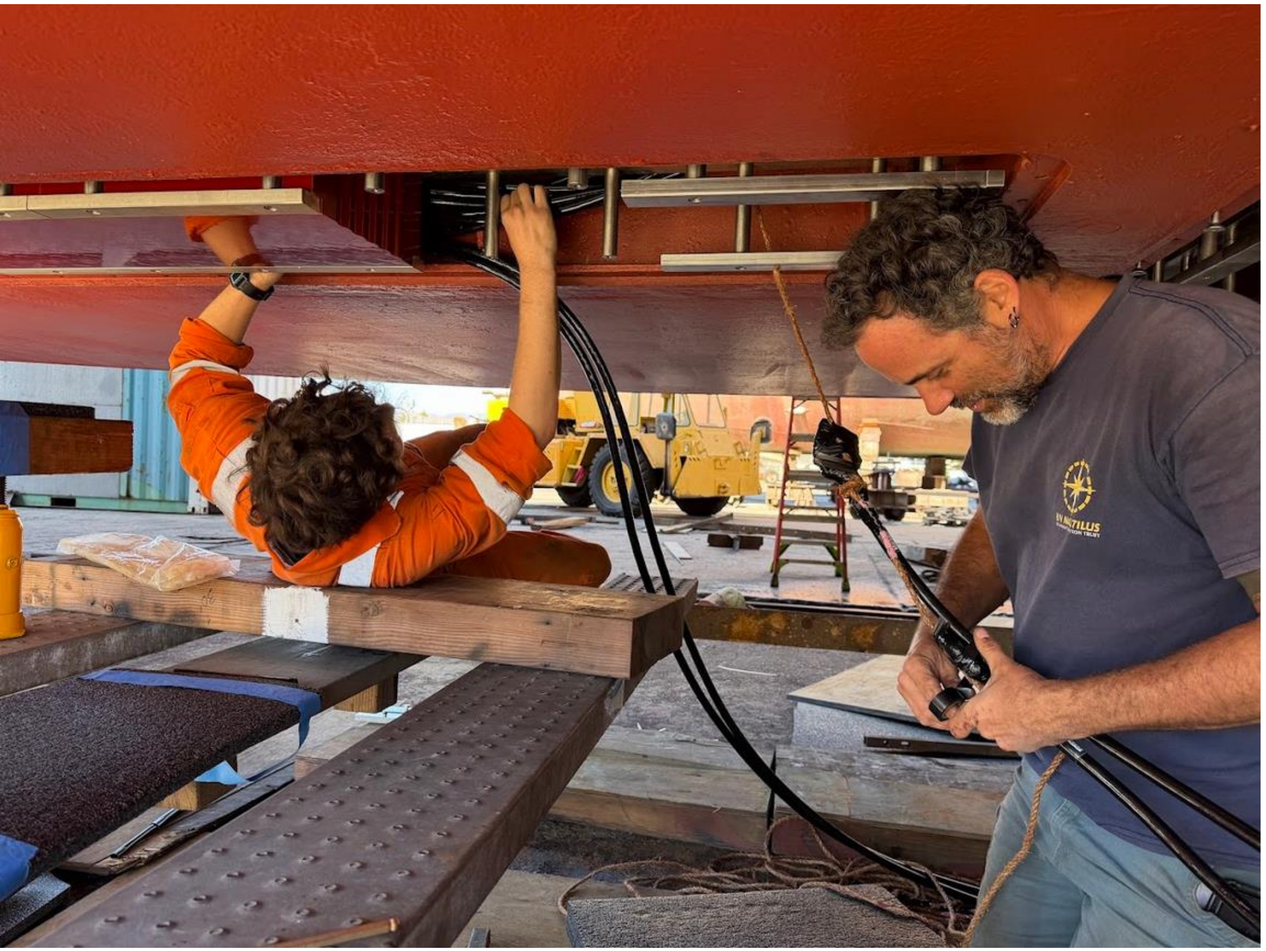
Installation of new Transmit (TX) and Receive (RX) sonar transducer modules into mounting frames

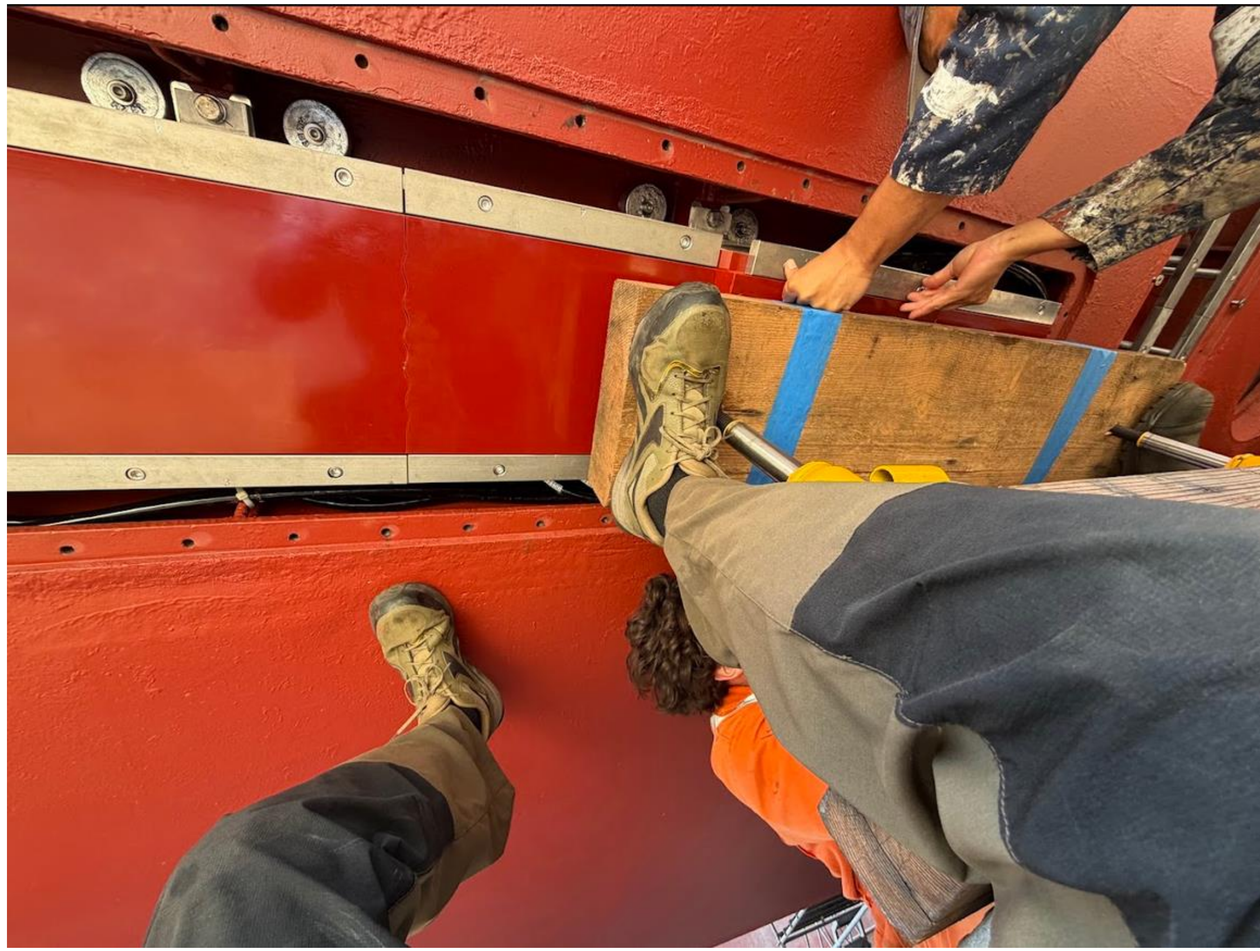




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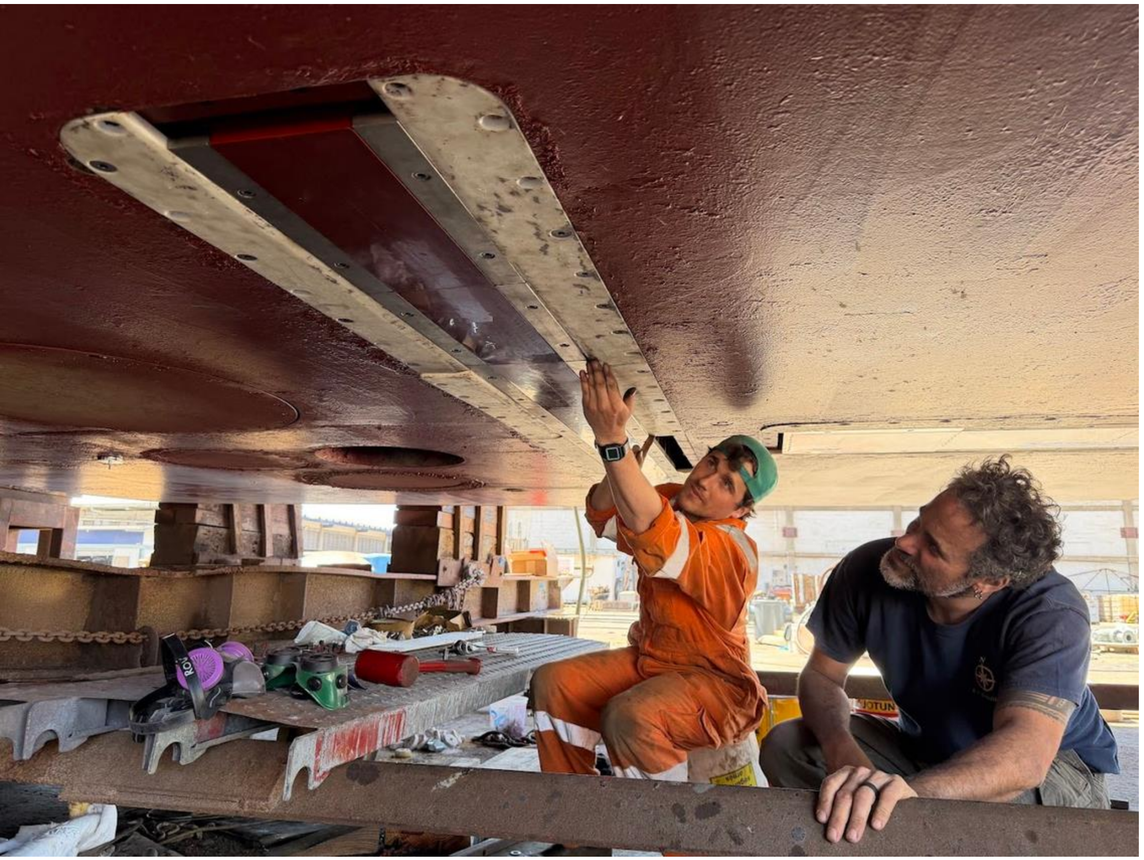
# Installation of EM304 MKII in Ensenada Drydock: April 2026

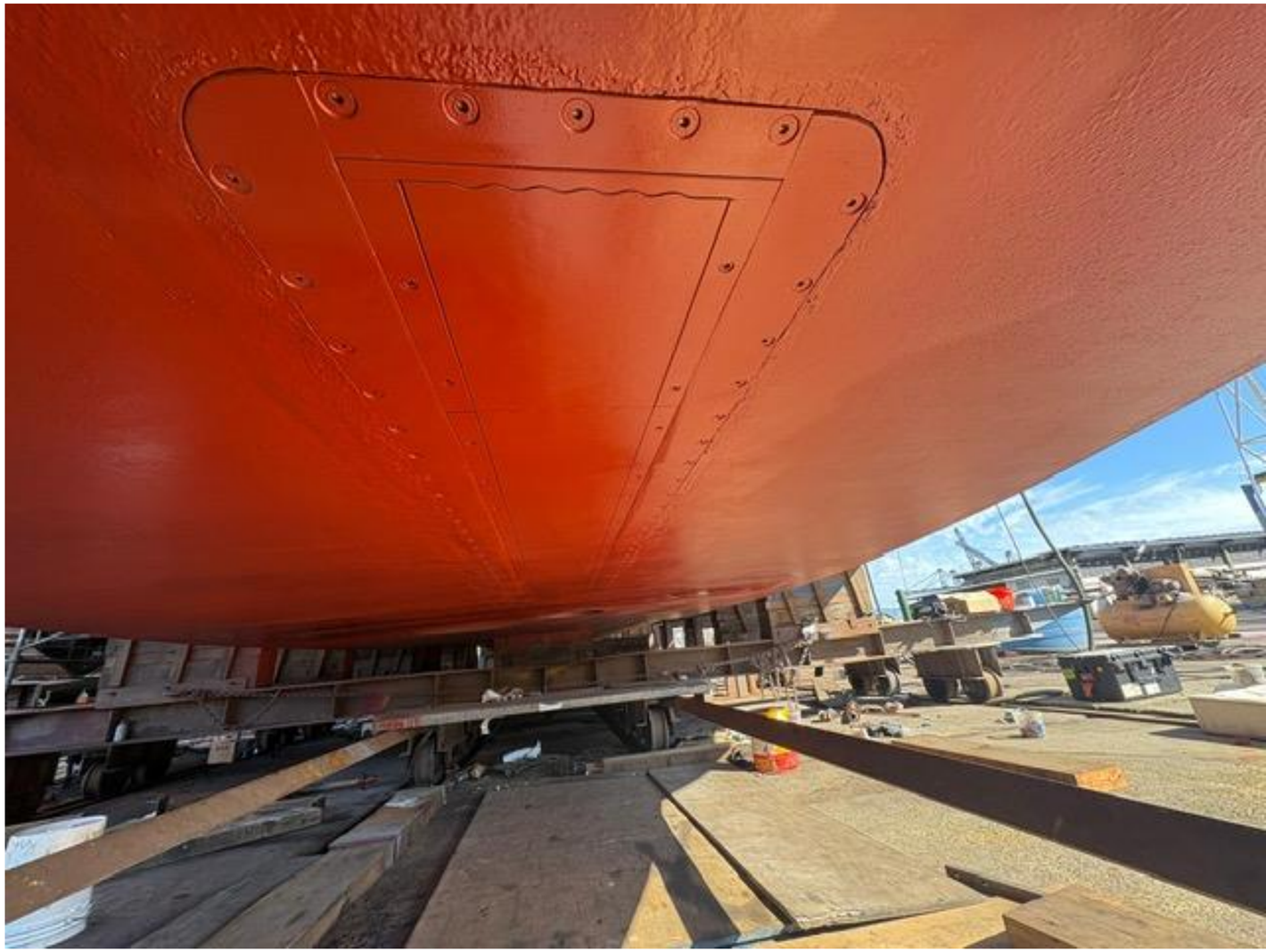




Pulling of transducer cables from the hull, through conduit, and into the sonar room. Final tightening of modules into place, survey to verify that the arrays are level and meet specifications.

# Installation of EM304 MKII in Ensenada Drydock: April 2026





Installation of fairing plates and final anti-fouling painting of the transmit and receive arrays.

# Installation of EM304 MKII in Ensenada Drydock: April 2026







Transducer cable management, watertight fittings over the pipe conduit, installation of transducer cables into the transmit and receive electronics cabinets, and installation of new AML-1 sound velocity sensor on the hull just aft of the sonar array.

# Sea Acceptance Tests & Shakedown: May/June 2026

- 3 days of validation trials with Kongsberg engineer (thank you Alissa Johnson)
- Rigorous system testing led by Paul Johnson (UNH/CCOM and the Multibeam Advisory Committee)
- Patch Test calibration – fine tuning of roll, pitch, and yaw offsets
- Noise tests - finding engine RPM and propeller pitch for our specific vessel that minimizes ship noise while maintaining efficient surveying speeds
- Swath coverage vs. depth tests
- Accuracy assessment of system at various depths

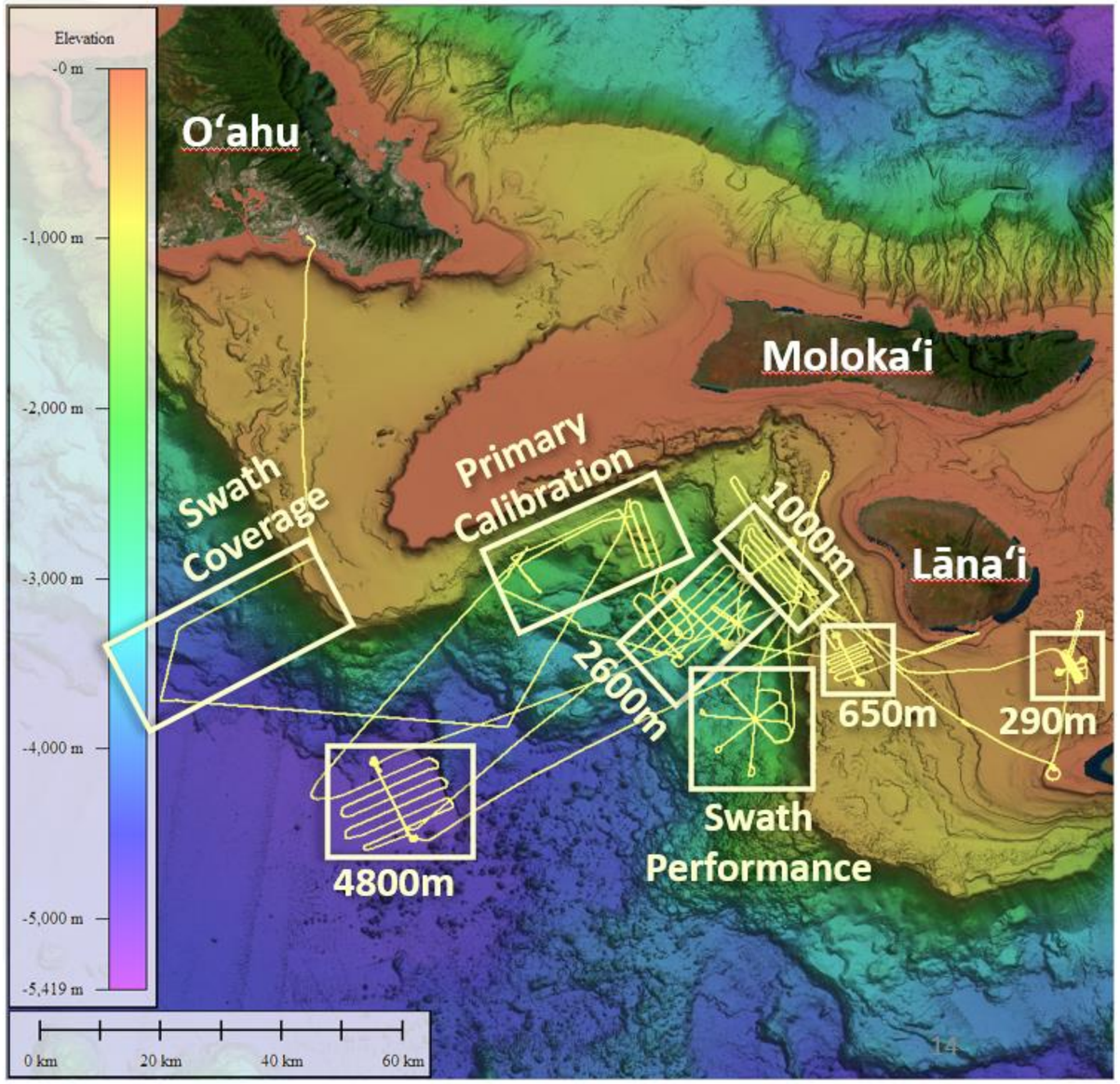
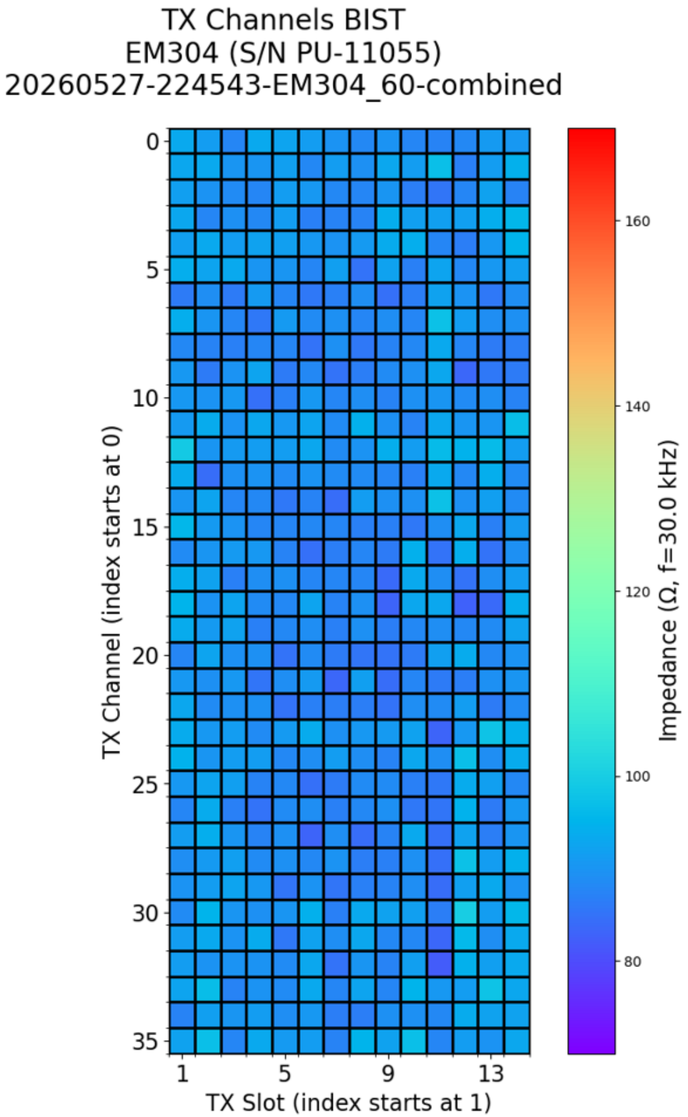



Figure Credit: Paul Johnson

# Sea Acceptance Tests & Shakedown: May/June 2026

- EM304 Baseline Evaluation of Transducer Health – all elements met specification



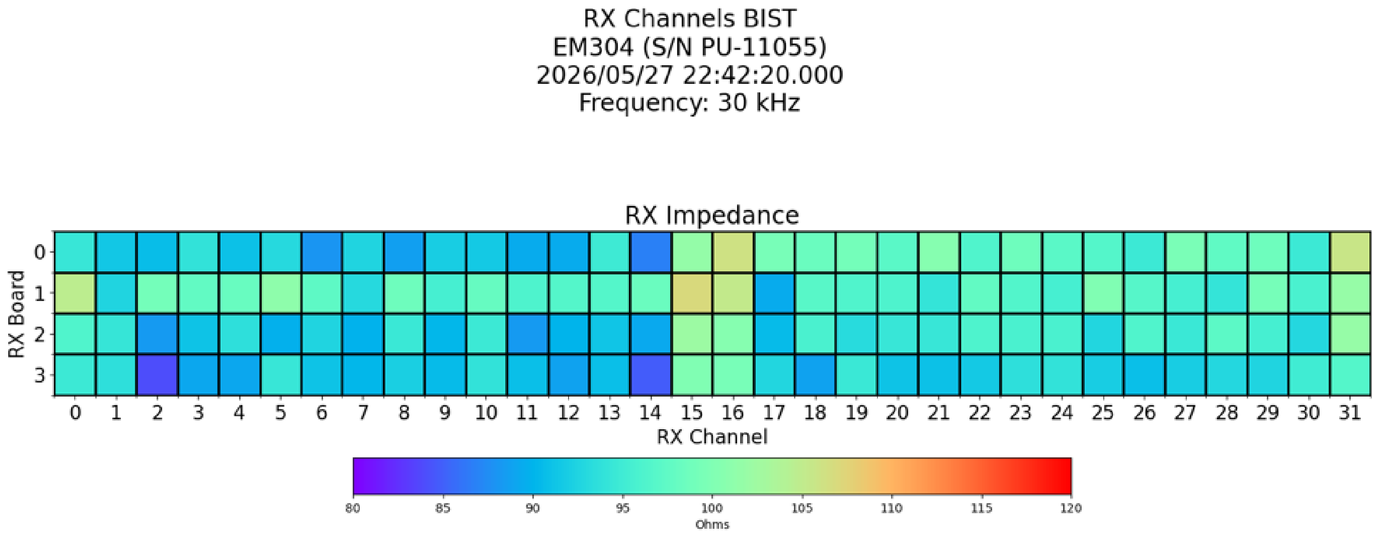



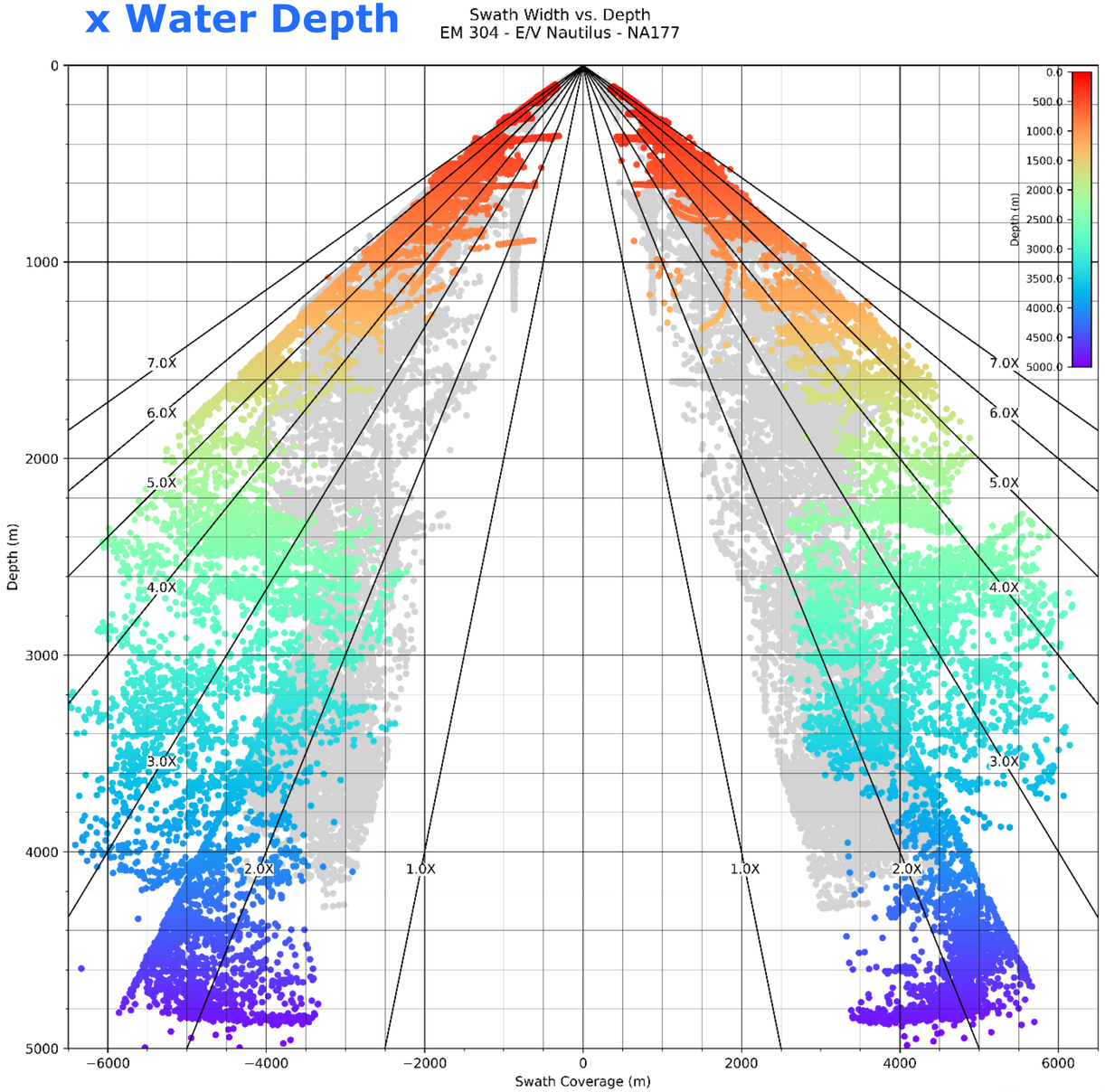

Figure Credits: Paul Johnson

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# EM304 Swath Coverage

## EM304 (rainbow) with EM302 underlay (grey)

### x Water Depth




### x Swath Angle

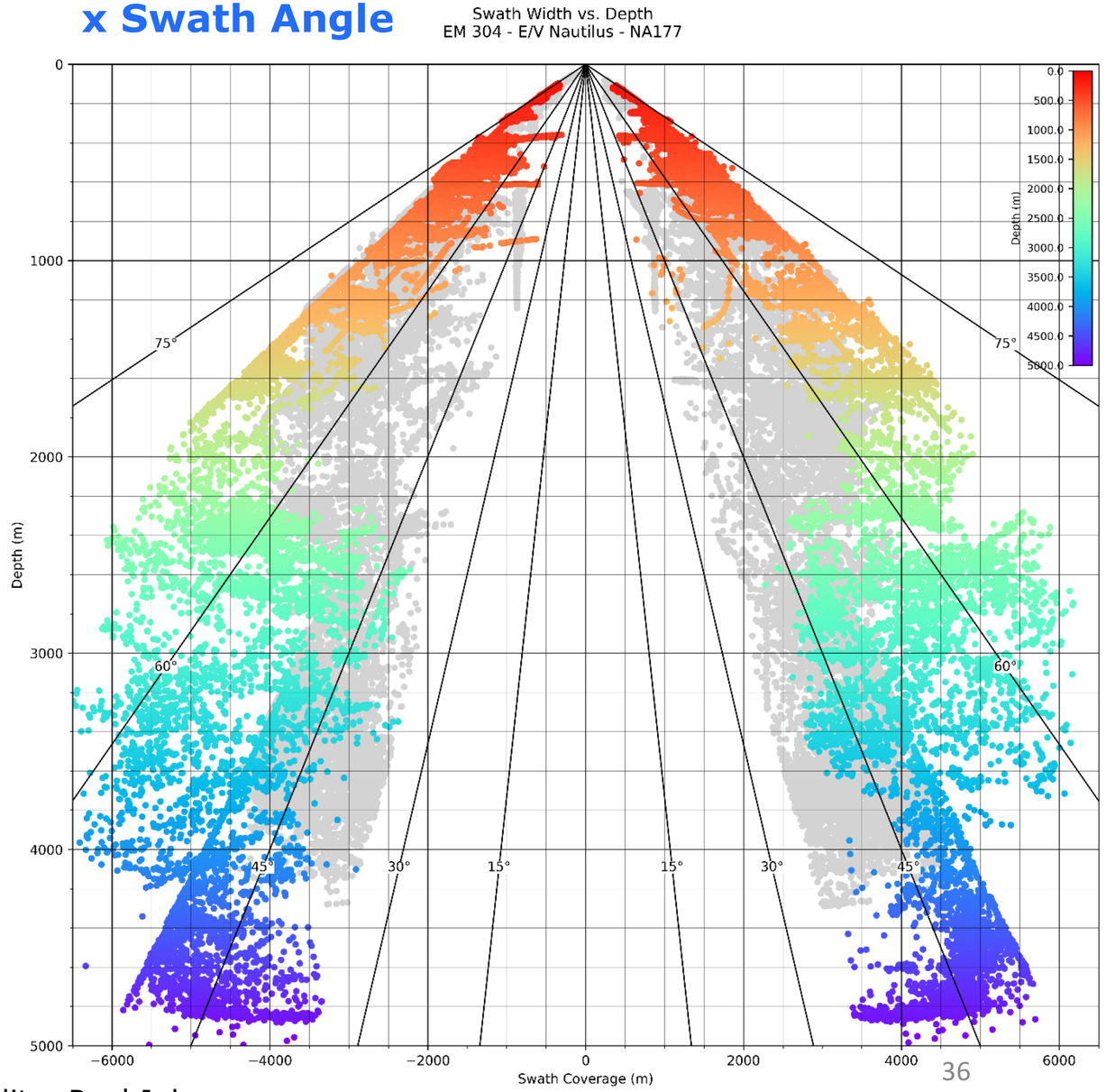
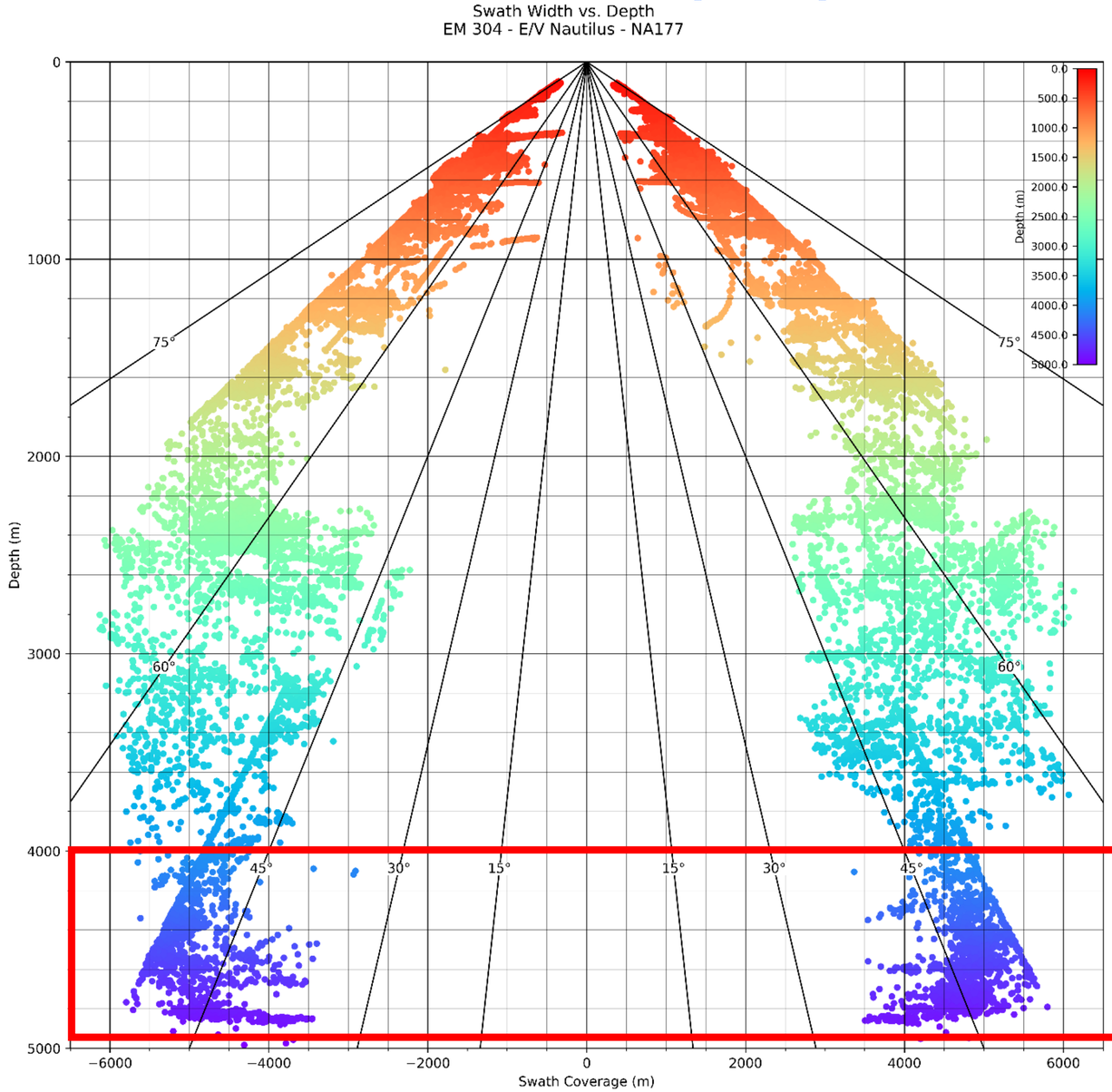



Figure Credits: Paul Johnson

# EM304 Swath Coverage

## EM304 – NA177 (2026)




## Comparison EM304 vs. EM302 on Nautilus

## EM302 – NA170 (2025)

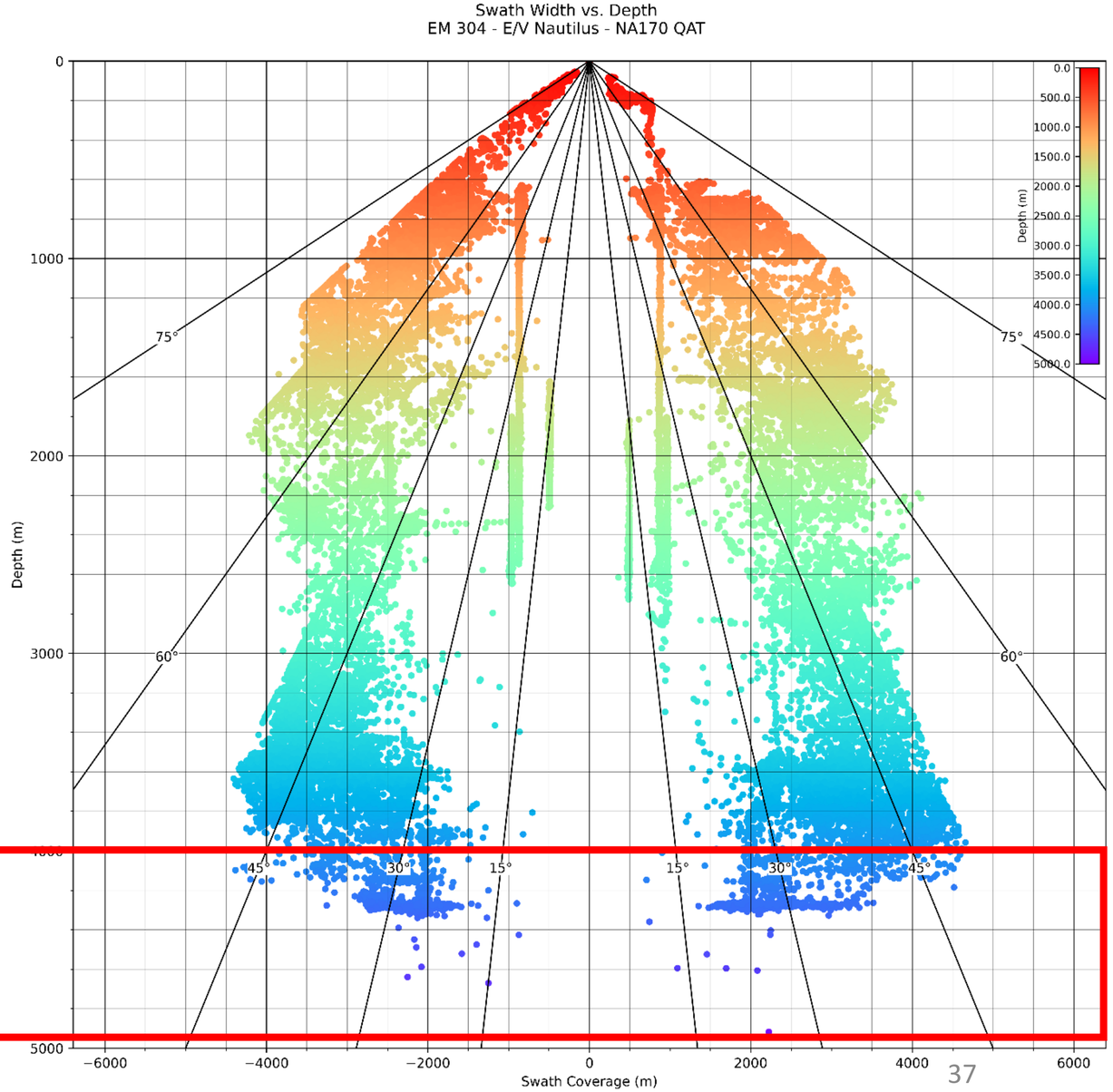



Figure Credits: Paul Johnson

# EM304 Swath Coverage

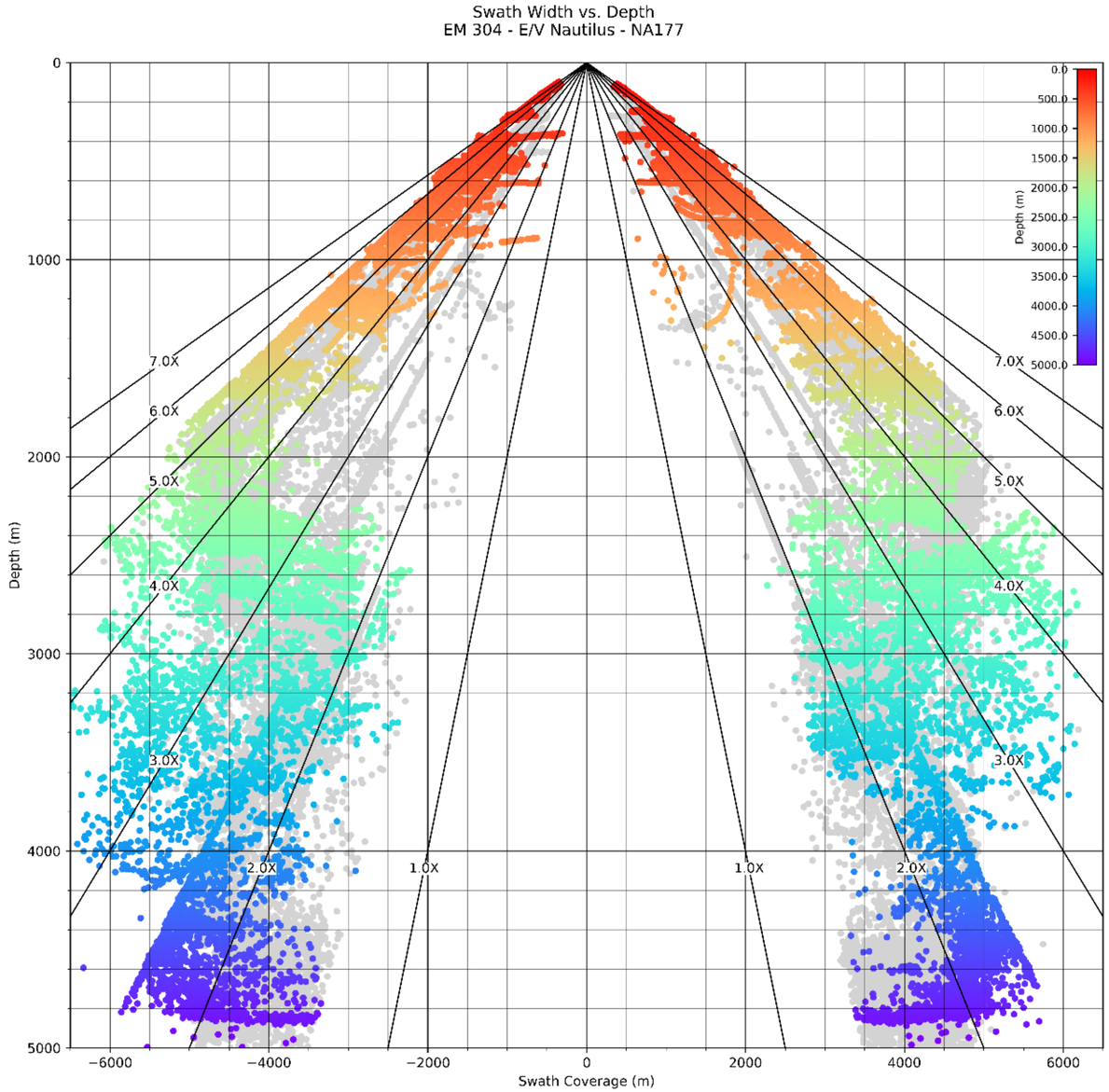



Figure Credit: Paul Johnson

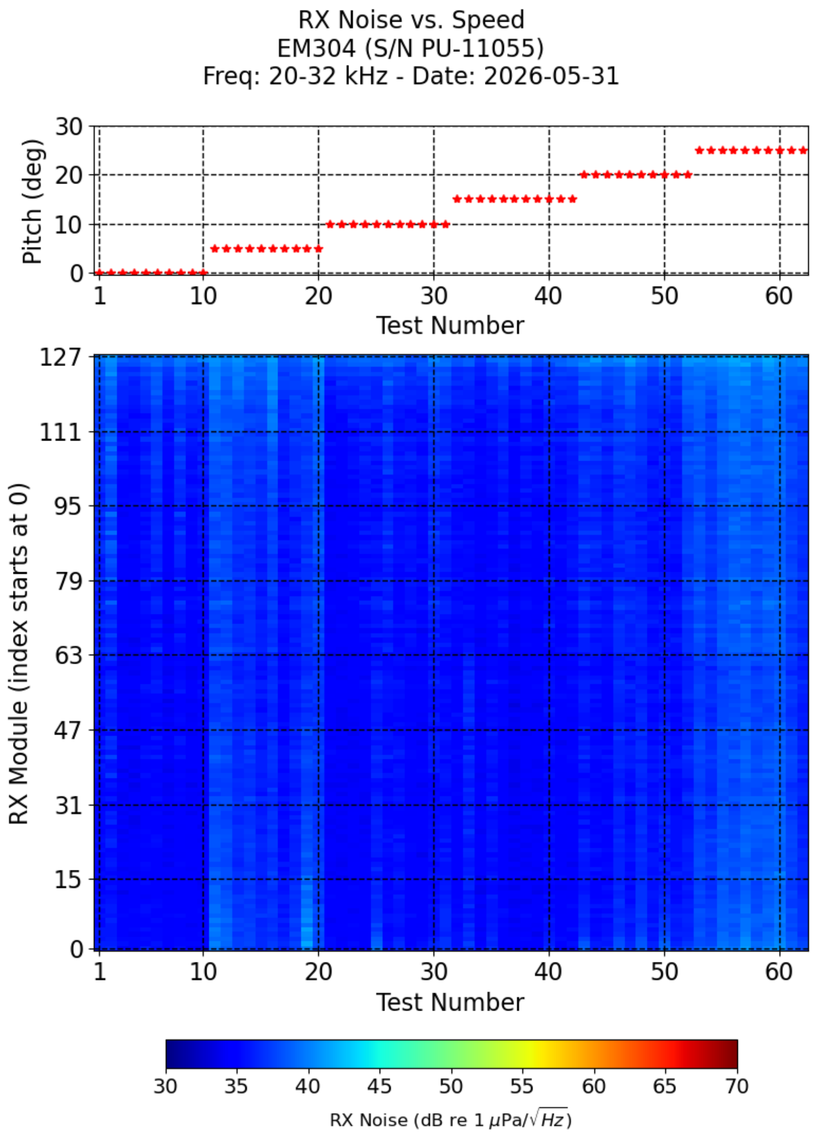
## E/V *Nautilus* EM304 (rainbow)
## NOAA Ship *Okeanos Explorer* EM304 (grey)

- When comparing swath coverage performance against the EM304 on NOAA Ship *Okeanos Explorer*'s EX2203 Puerto Rico trench coverage (grey), the new EM304 MKII on the Nautilus (rainbow) holds its own with similar swath coverage.

# EM304 Noise Level Assessment

## (770 RPM – With Seas)

### Pitch




### Speed

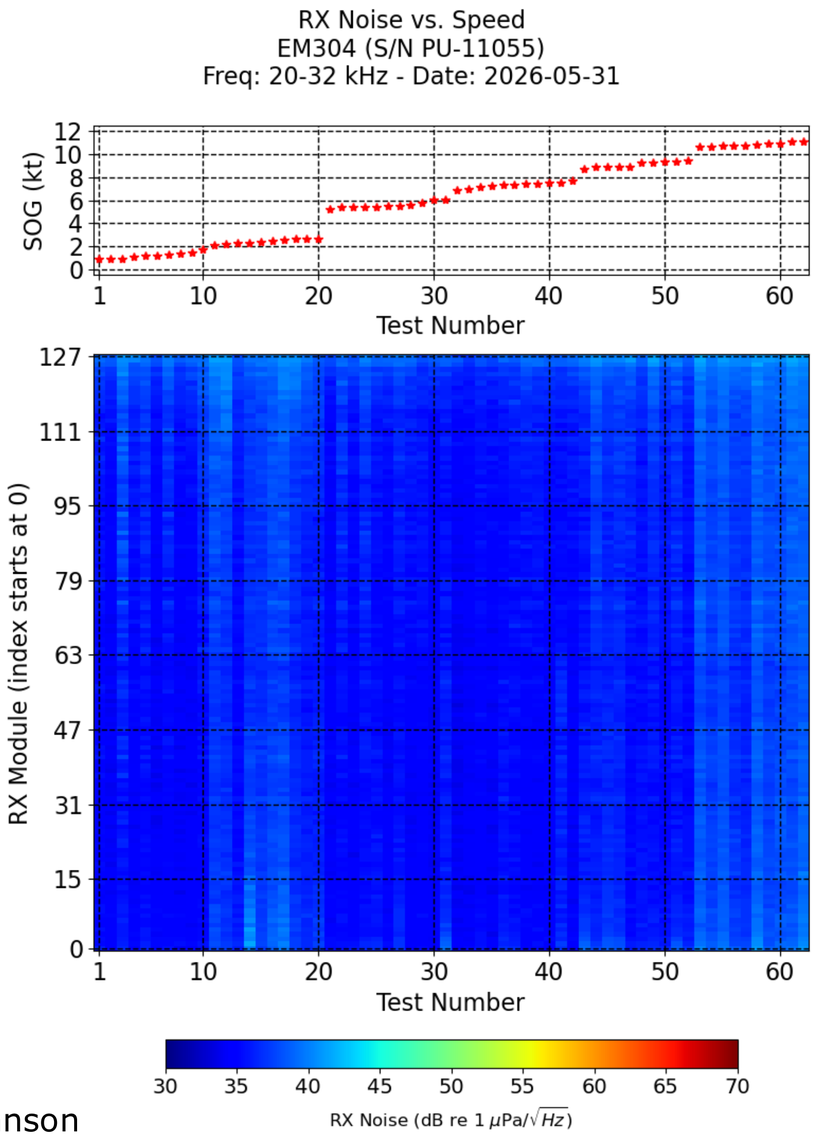



Figure Credits: Paul Johnson

# Sea Acceptance Tests & Shakedown: May/June 2026

Summary of Results

- The EM304 consistently collects more accurate data with a wider swath and less noise than our EM302

- Following drydock, the ship's self noise has dropped down to as low or lower ( < 40 dB) than all historic noise measurements that have been made
(likely due to main propulsion shaft overhaul and removal of all hull/prop biofouling)

- Sea Acceptance Trials for the new EM304 went very well and show a well integrated system that is collecting high-quality multibeam data

- Achieved mapping swath widths exceeding 12 km at speeds of 11–12 knots

# EM304 Performance on 2026 Expeditions thus far

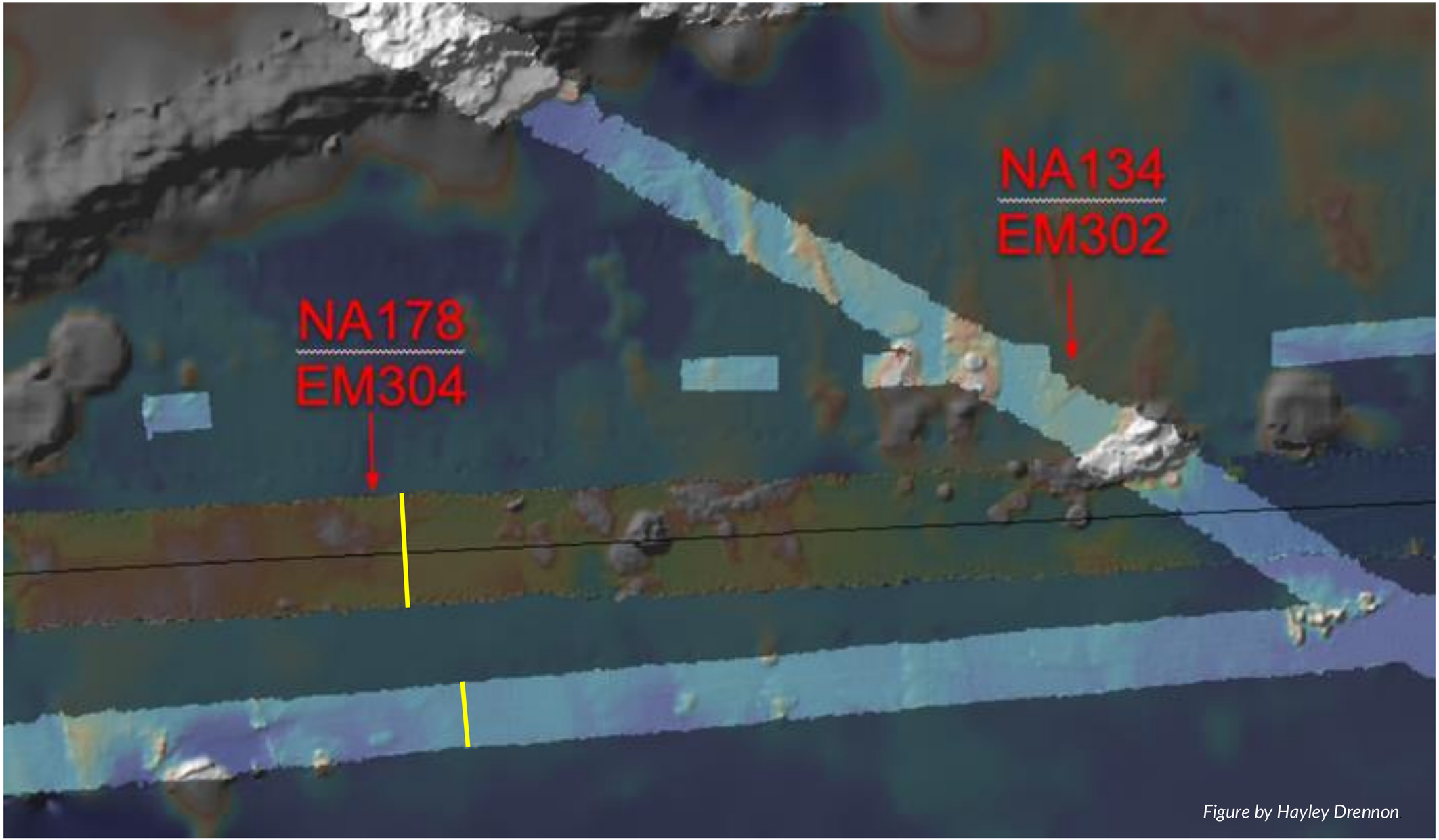



*Figure by Hayley Drennon*

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# EM304 Performance on 2026 Expeditions thus far

Why mapping on transits is so important…

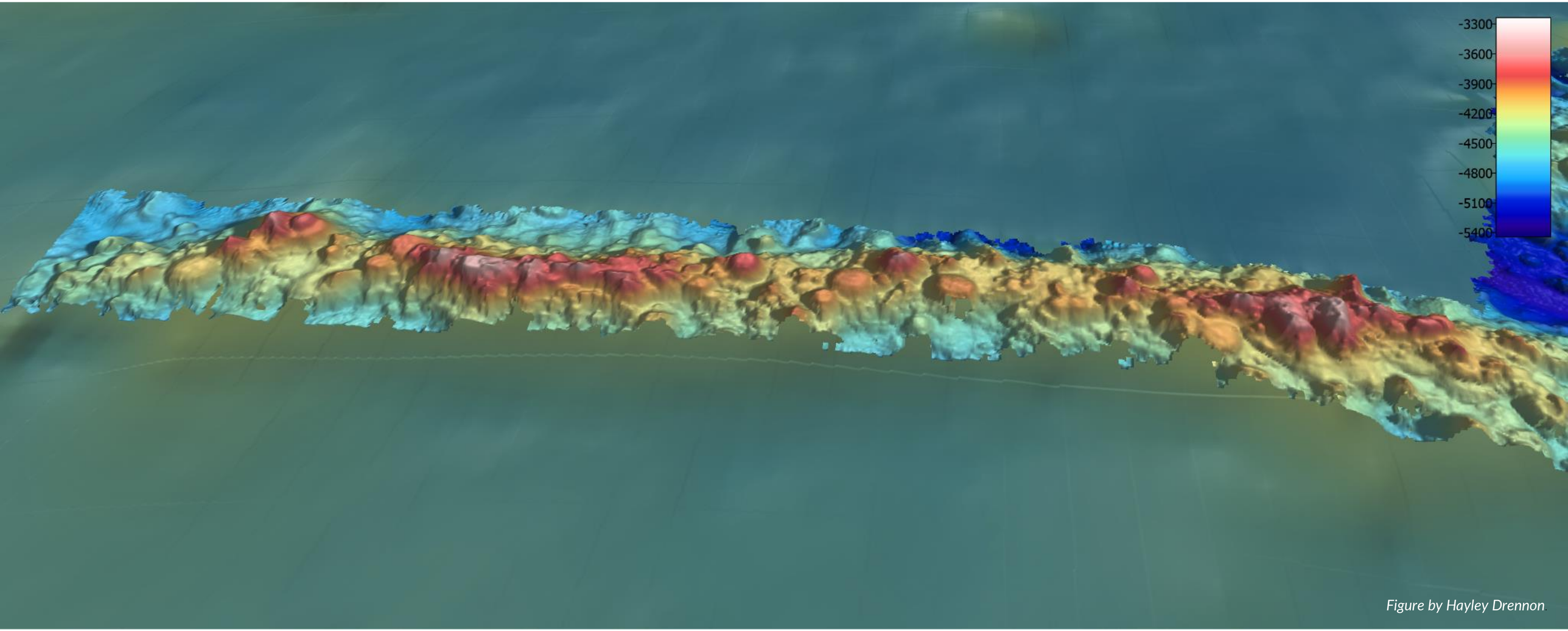



*Figure by Hayley Drennon*

E/V *Nautilus* Expedition: NA178

# KONGSBERG

Colleen Peters, Product Manager

Bjørnar Langli, Principal Engineer

FEMME




OET

NA178

# Objectives

KONGSBERG

Primary Goals:

- **Test SIS software v5.16**
  - Testing new fixes and features before the next release
  - Generally, tend to any issues/errors that may arise during the transit on the brand-new mapping system

- **EMSBP software v1.11**
  - Test a brand-new user interface - checking that all the improvements and fixes are properly implemented
  - Collect deepwater data that we can use for analysis and publication
  - Collect Knudsen data for comparison to EMSBP data
  - Collect data as we transit over the Mariana Trench to evaluate performance

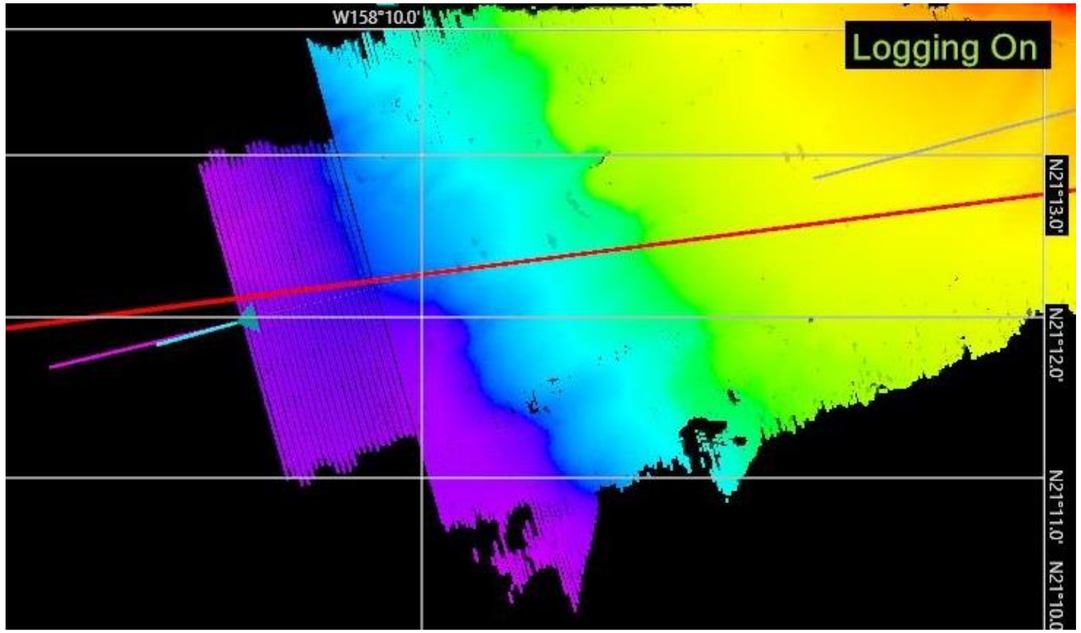
- **Figure out why there is a reduction in EM performance when EMSBP is in use**
  - On several other vessels, it has been observed that there are various issues in EM performance (reduced swath, strange depth modes, etc.) when operating EMSBP in deep water (>2000m). EM data quality should be consistent (or at least closely similar) whether you are operating the EM or EM + EMSBP.



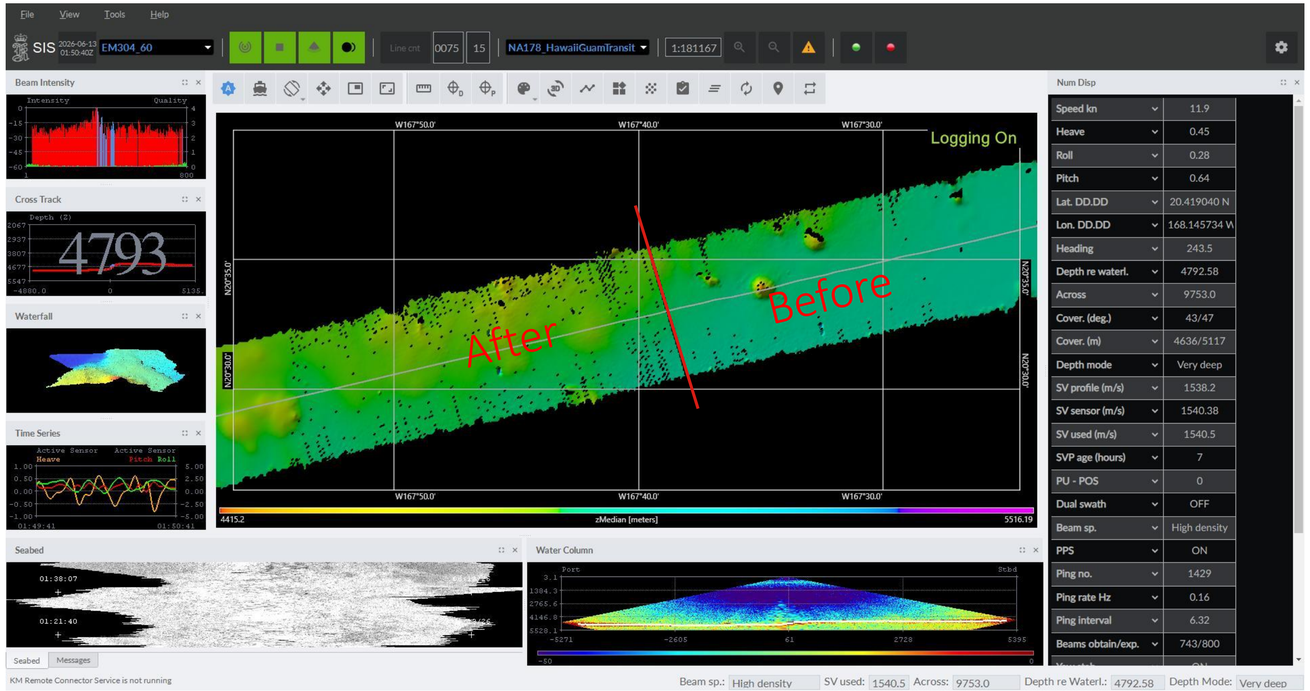
See Statement of Proprietary information

NA178

# EM Swath Correction




Problem: Swath reduces when EMSBP pinging.




Solution: Do not process and output pingdata as MRZ or MWC when this is an EMSBP ping. Do not allow EMSBP pings before the EM has gone into TRACK state.

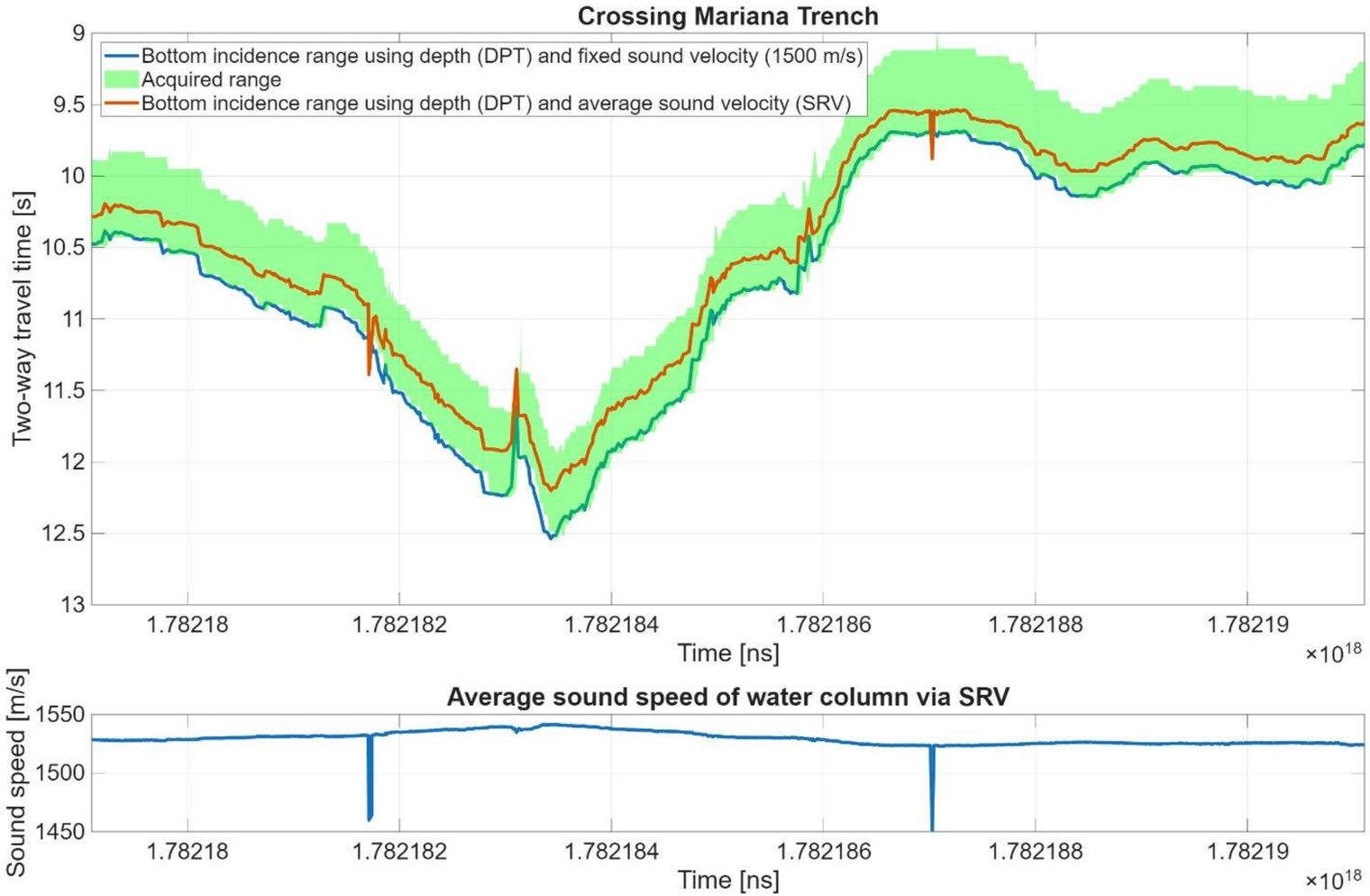
See Statement of Proprietary information

NA178

# Sound Velocity/Depth Error

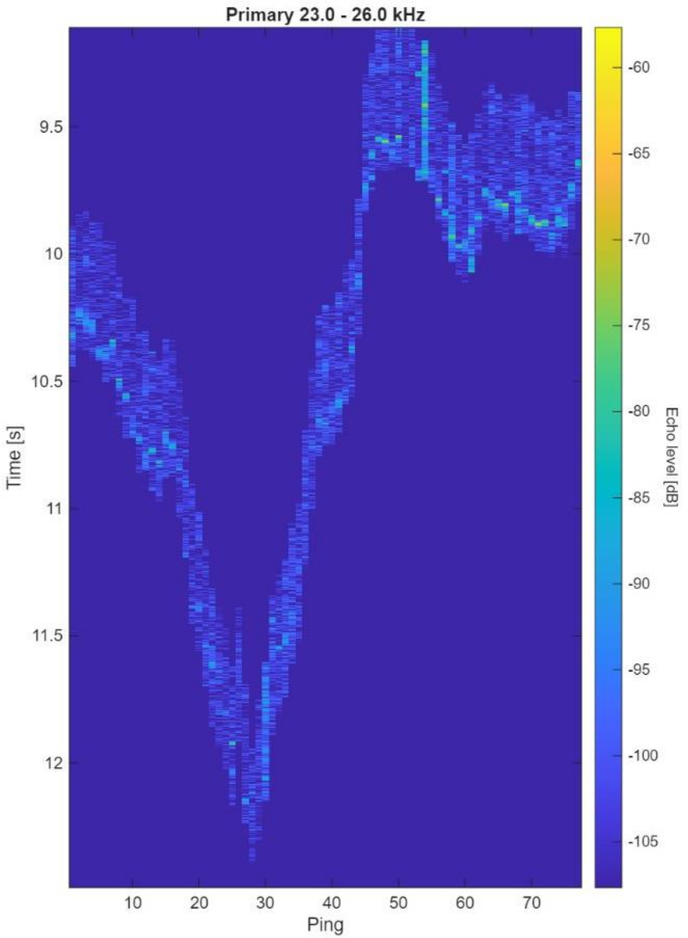
- EMSBP used constant sound velocity to convert from DPT (depth below transducer) to TWTT (two-way travel time), leading to overestimated TWTT which in deep water meant the water-seabed interface was not captured

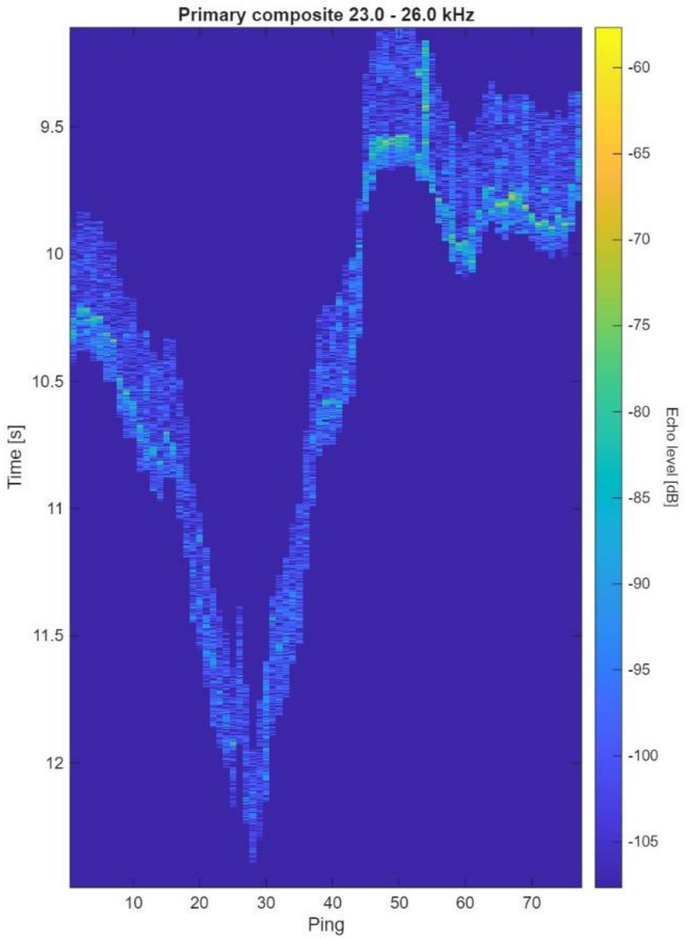
  *Note: This is corrected in the upcoming EMSBP release!*



NA178

# Mariana Trench




- EMSBP ping rate is 1 SBP:10 EM to favor bathymetry over the trench.
- Bottom returns are occasionally visible in the primary 20-32 kHz signal.
- No obvious bottom returns are visible in the parametric 2-11 kHz signal (not shown).
- In the composite echogram (right) there is a significant improvement in imaging of the seafloor.
- In the steep slopes, it is possible that the 600 ms acquisition window is too short

FEMME

*Note: All input data to EMSBP was logged, allowing reprocessing with SV corrected range*

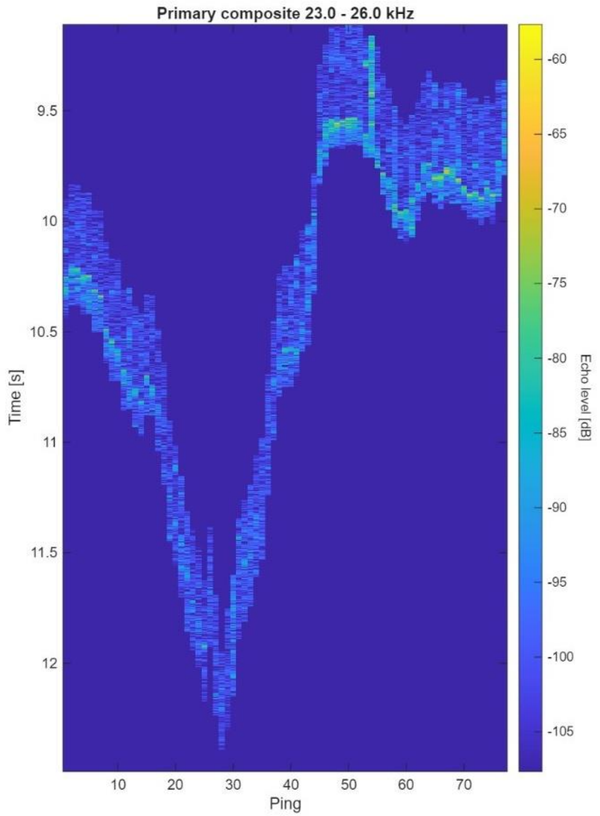
See Statement of Proprietary information

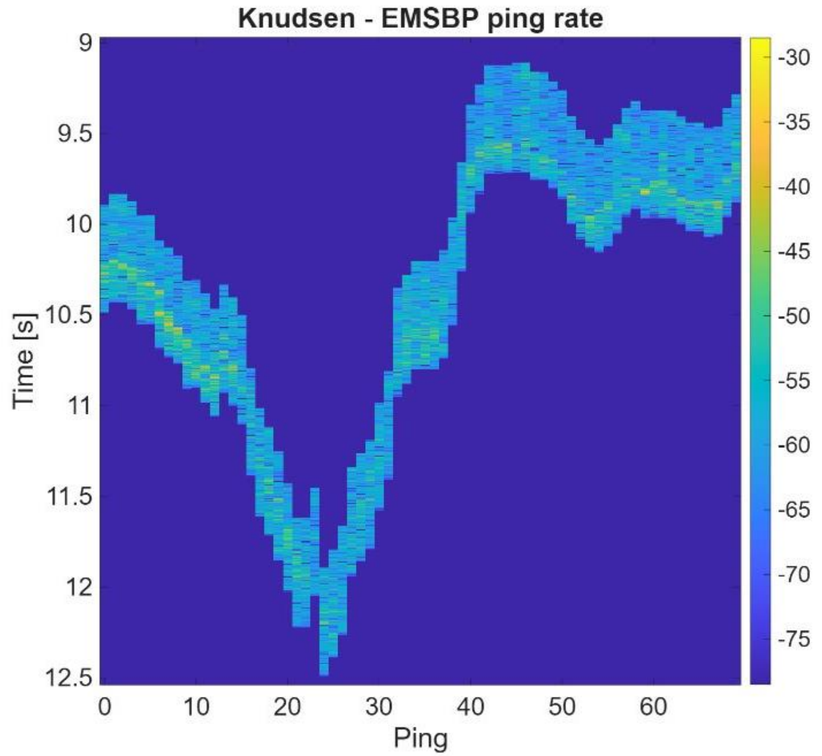
NA178

# Knudsen Comparison

KONGSBERG

- KNUDSEN is a 64 ms 2 - 6.125 kHz linear FM pulse
- Knudsen interfered with EMSBP until a fix was implemented
- Knudsen pinging at a faster rate, EMSBP pinging at 1 SBP to 10 EM pings for bathymetry focus
- Knudsen data at extreme depth was better




FEMME

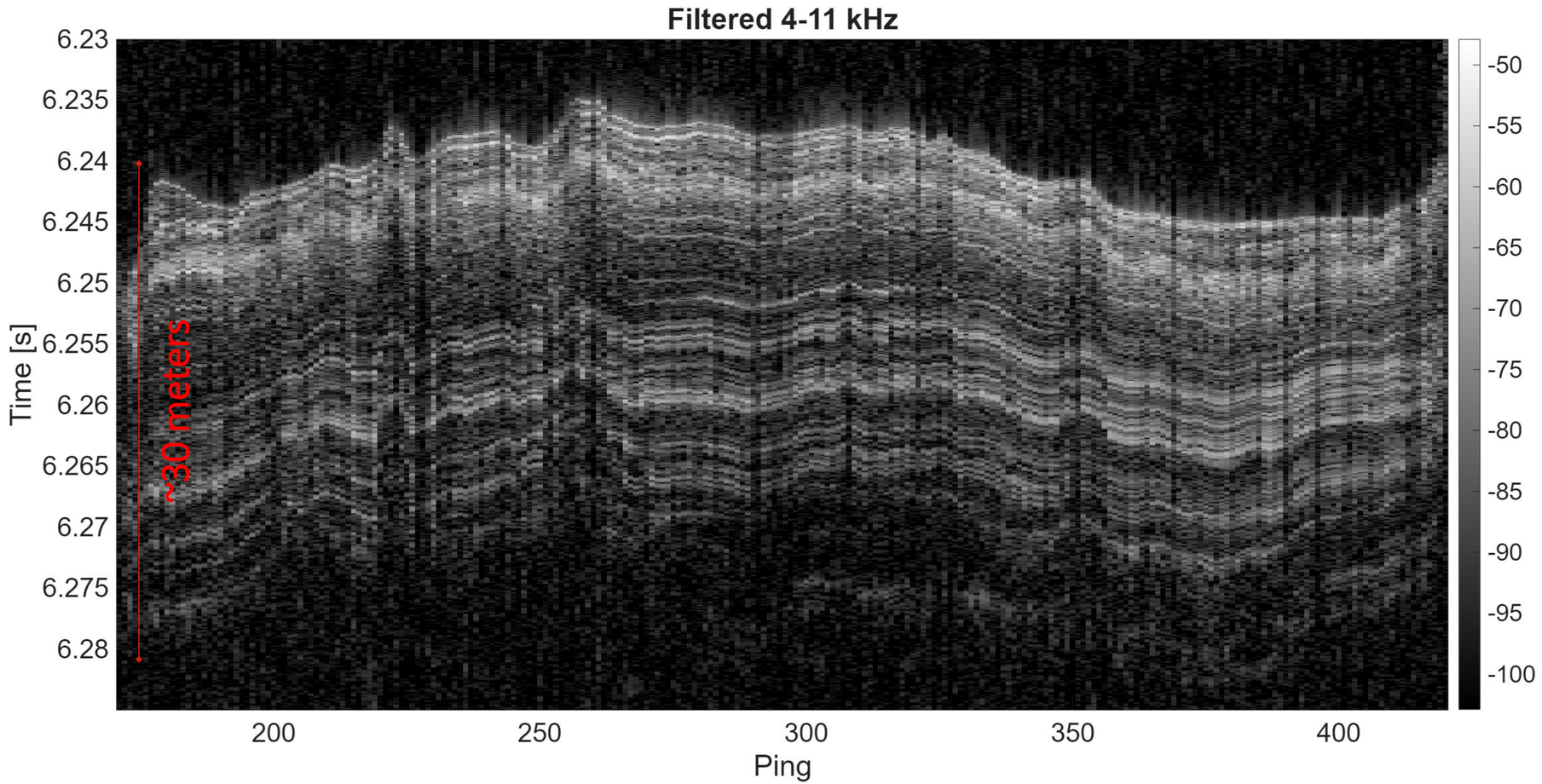
*Note: All input data to EMSBP was logged, allowing reprocessing with SV corrected range*

See Statement of Proprietary information

NA178

# EMSBP Examples

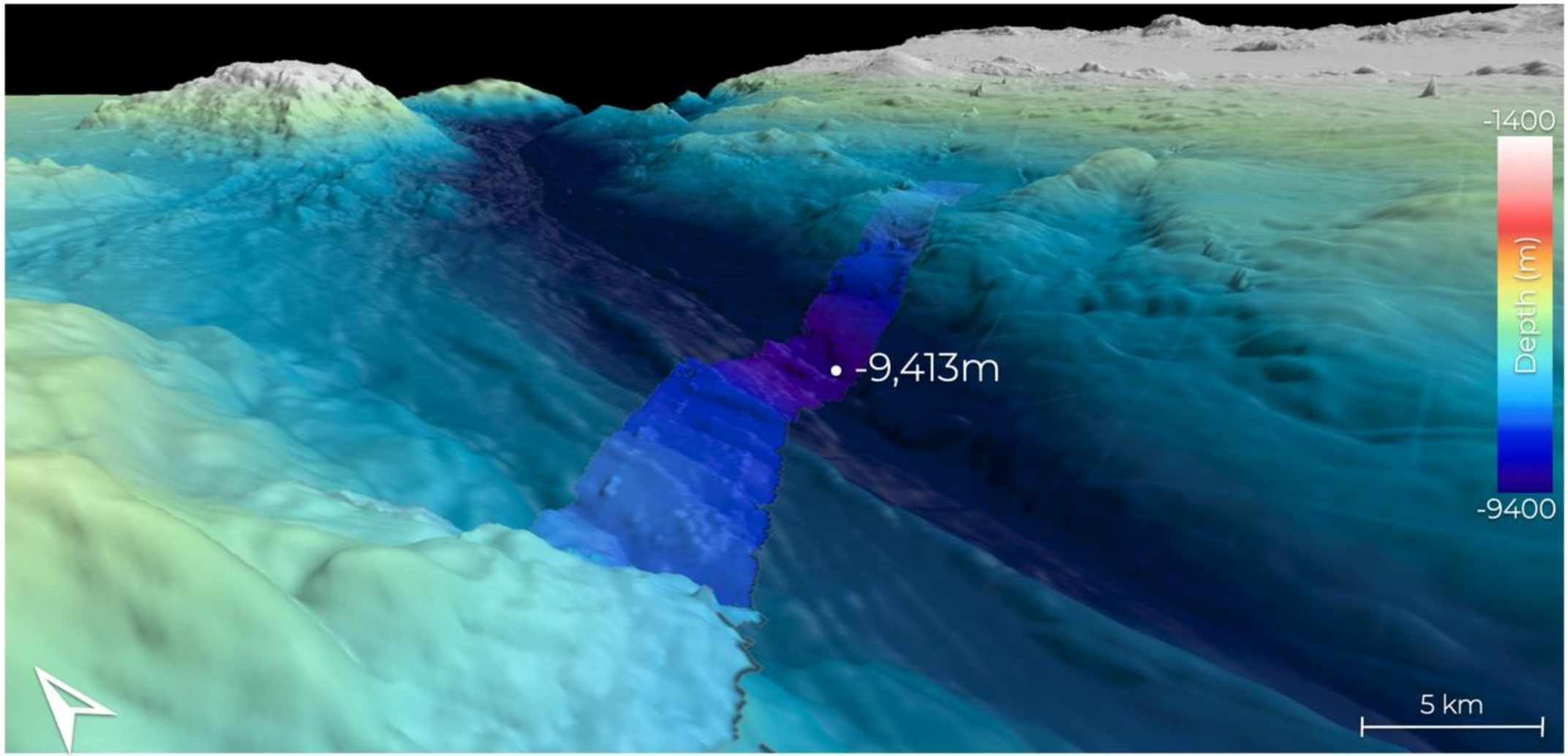
KONGSBERG




FEMME

See Statement of Proprietary information

# The ultimate extinction test – transiting over the Mariana Trench (NA178)




*With our new EM304 sonar, we were able to map a swath to the full depth of this section of the Mariana Trench, with the deepest depth observed being 9413m. Figure by Hayley Drennon*

# The ultimate extinction test – transiting over the Mariana Trench (NA179)

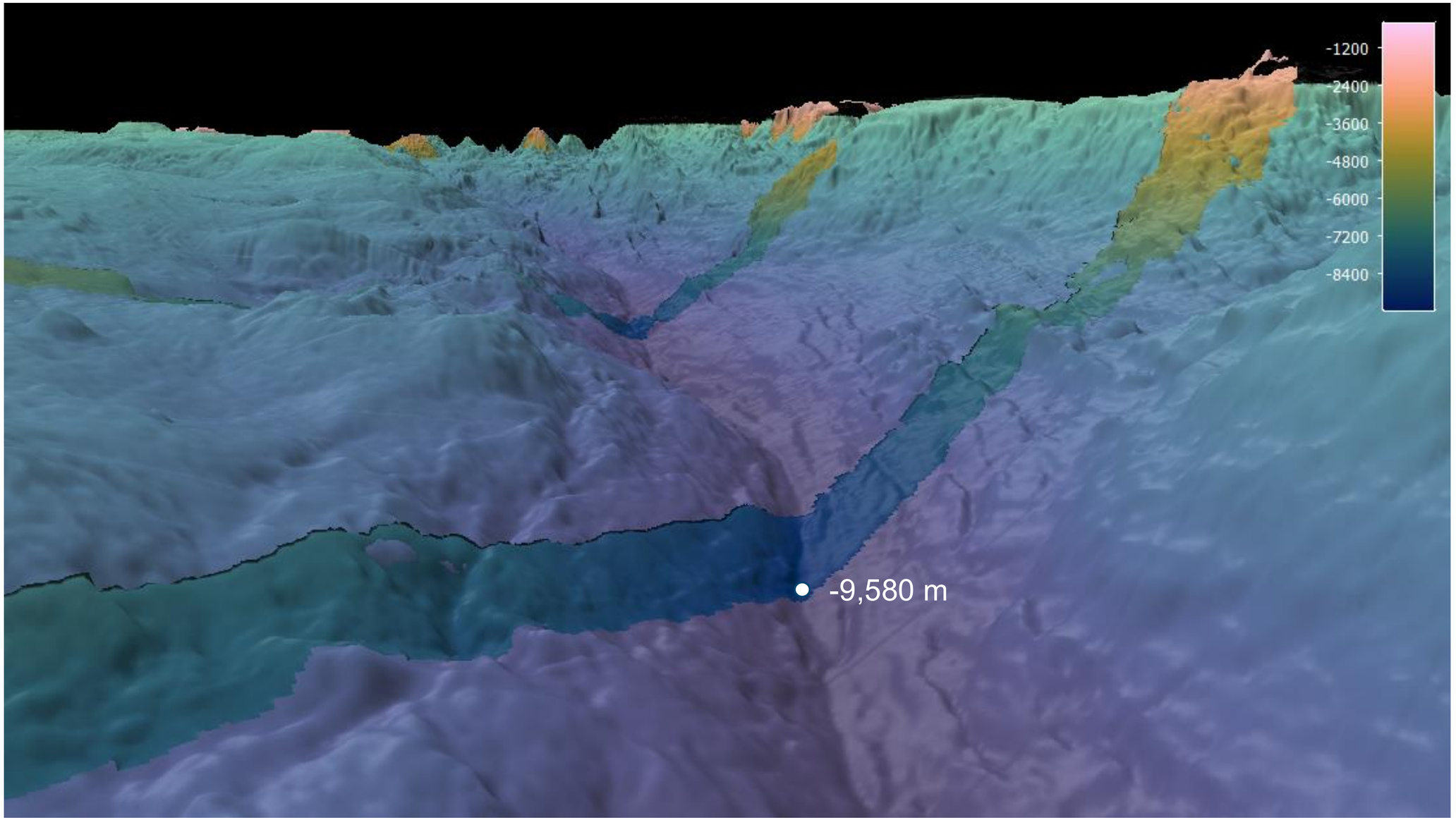
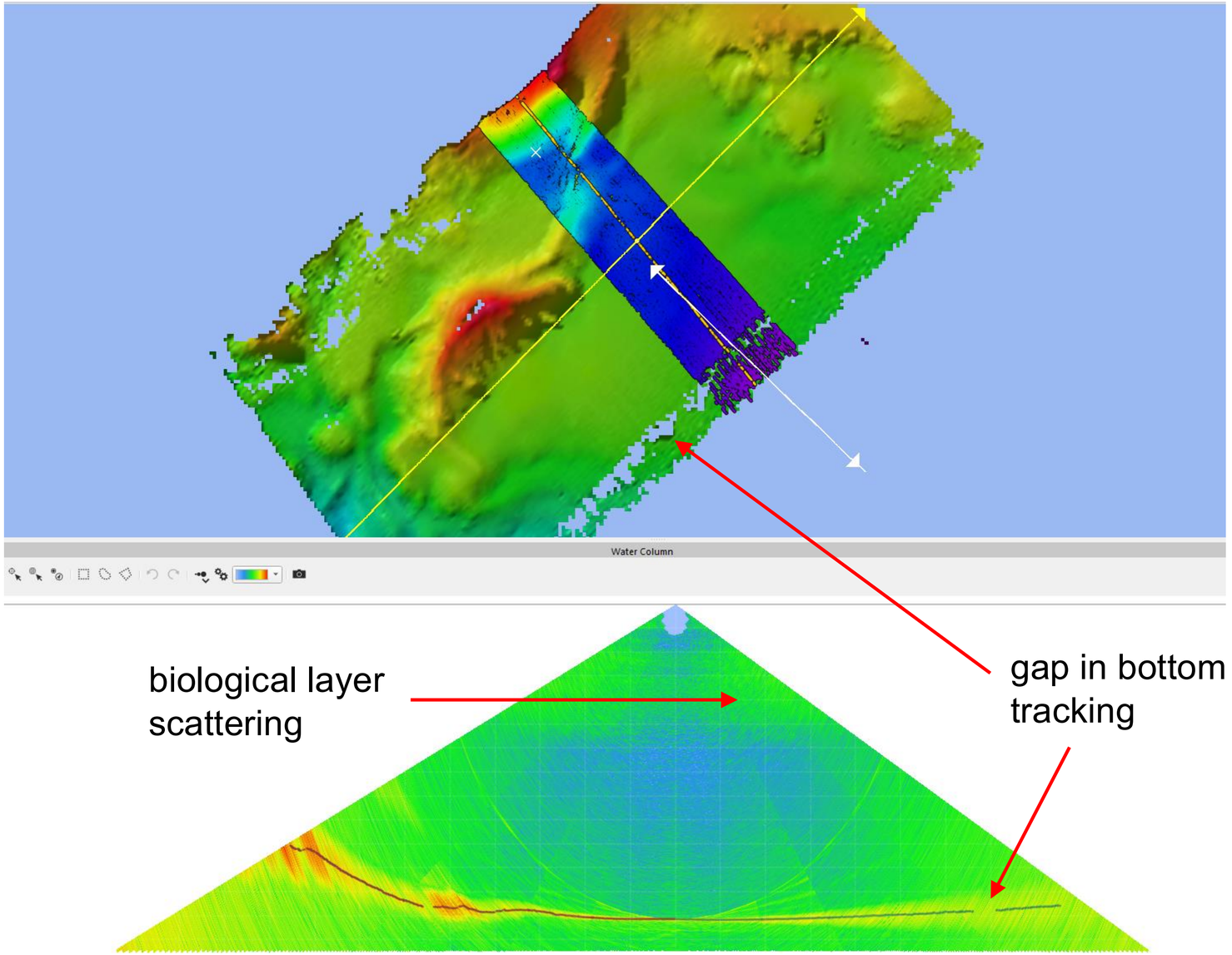



Figure: Derek Sowers

# EM304 Troubleshooting examples

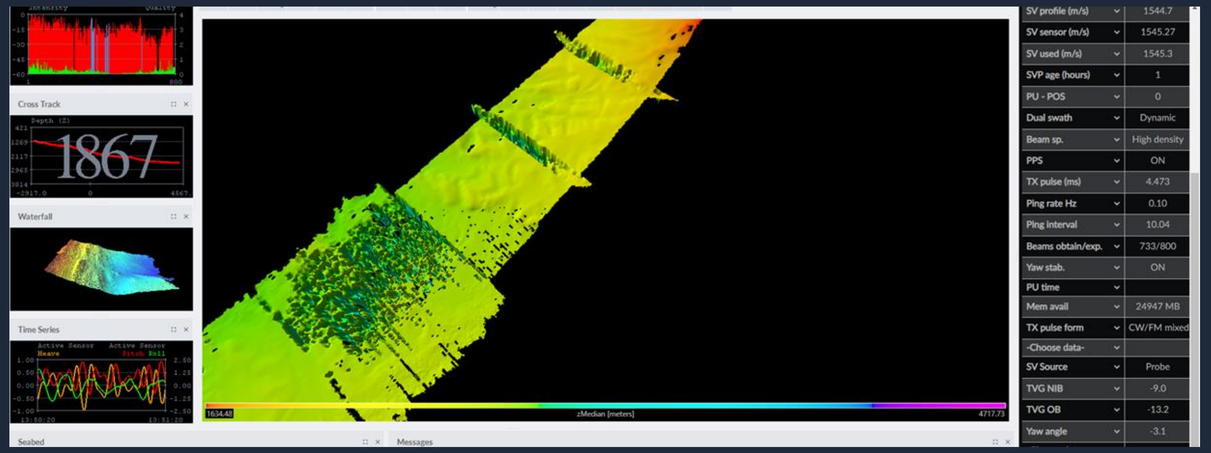
Occasional gaps in bottom tracking near the sector boundary of outer beams (Example is 2700 m)



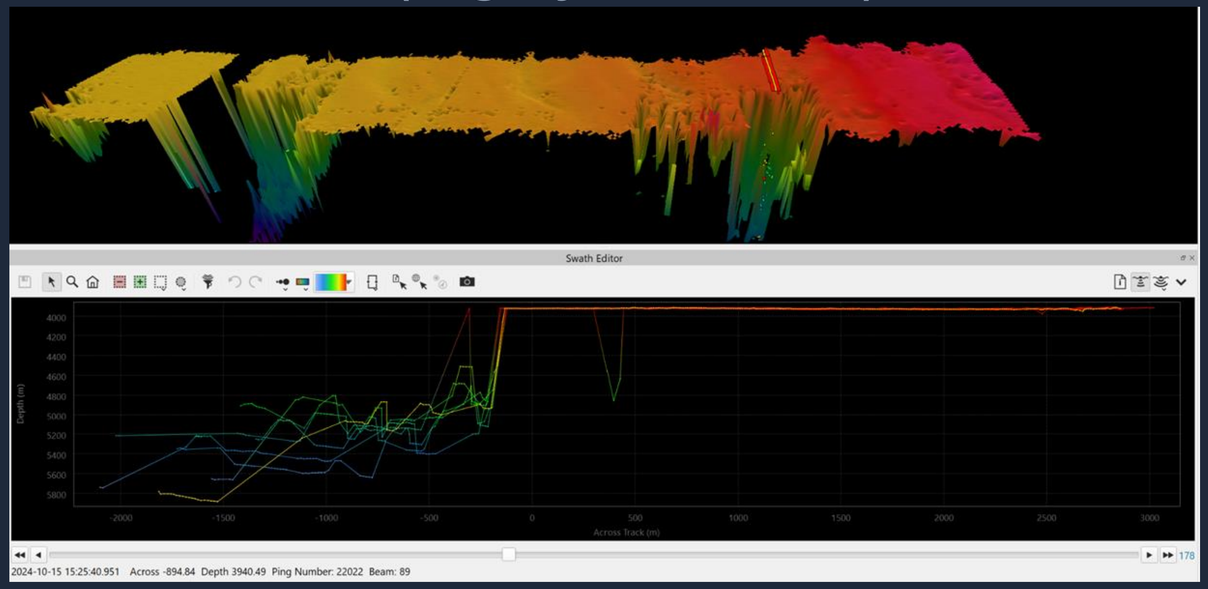

Solution: Manually force multibeam into deeper depth mode

# Persistent Port Side Noise Across Two Hardware Generations

## NA180 – EM304 MKII (Current Generation)




## NA166 – EM302 (Legacy Generation)




## KEY OBSERVATIONS & PATTERNS

### 1. Intermittent On/Off Pattern

**Elevated port-side noise episodes are on/off — never a constant bias.**

### 2. Hardware Generation Persistence

**Confirmed on both EM302 (NA166, legacy) and EM304 MKII (NA180, current).**

### 3. Low Relief Context

**Problem appears to occur in areas of low relief (may be coincidental).**

### 4. Depth Mode Switch Patch

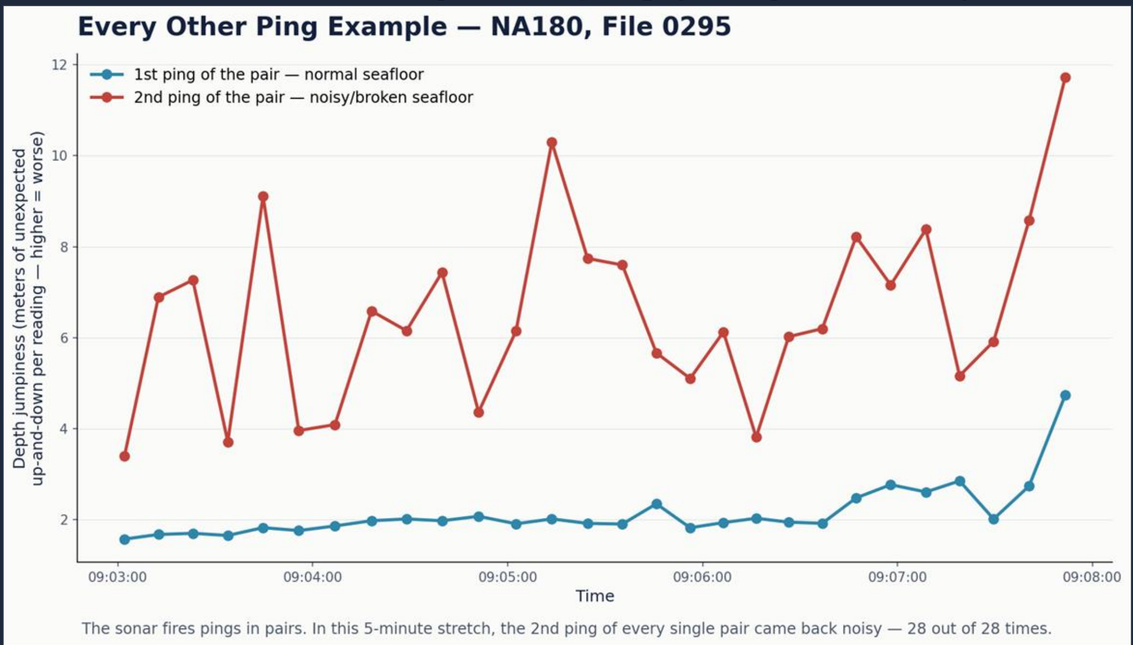
**Switching depth mode (Deep → Very Deep, or Very Deep → Extra Deep) appears to resolve the issue.**

*EM304 port-side sector frequencies — dual swath: 20 / 22.1 / 24.9 / 27.7 and 21 / 23.3 / 26.3 / 29.1 kHz; single swath: 20 / 21.25 / 23 / 24.0 kHz*

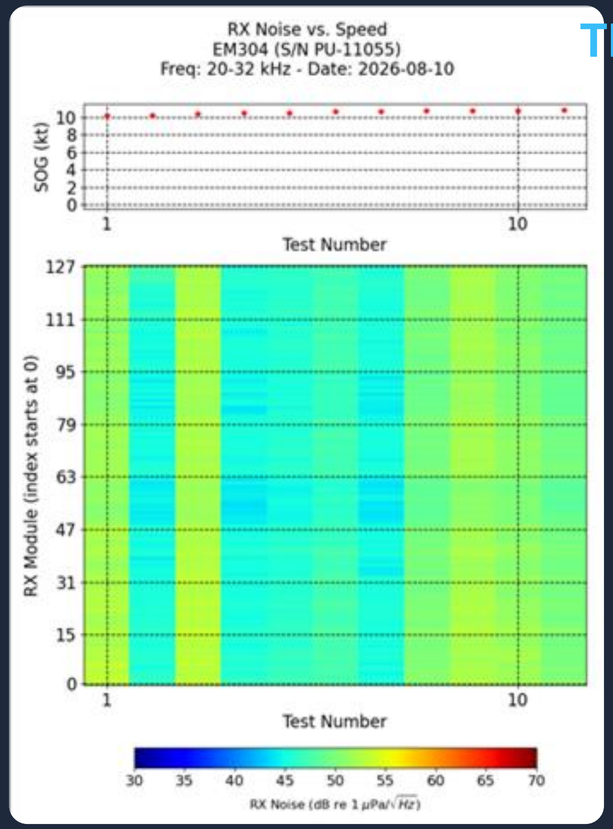
# Persistent Port Side Noise Across Two Hardware Generations

## TROUBLESHOOTING

- **No obvious operational cause:** speed shows no correlation, and engine room/bridge confirmed nothing running during episodes
- **Sea state doesn't appear to be a factor:** No correlation with roll, pitch, or heave in NA180
- **Inconsistent ping pattern:** In dual swath mode, artifact hits every other ping (always second) — or




## BIST & HARDWARE TESTS




*MAC Noise Analysis of BIST ran during NA180 episode*

- MAC team reports: **BIST taken during episodes differ dramatically (significantly noisier) from SAT tests**
- Dual swath: **Turning off had no effect**
- Sub-bottom profiler: **Turning off had no effect**
- Receiver cards: **Swapping was tried previously and didn't change results**

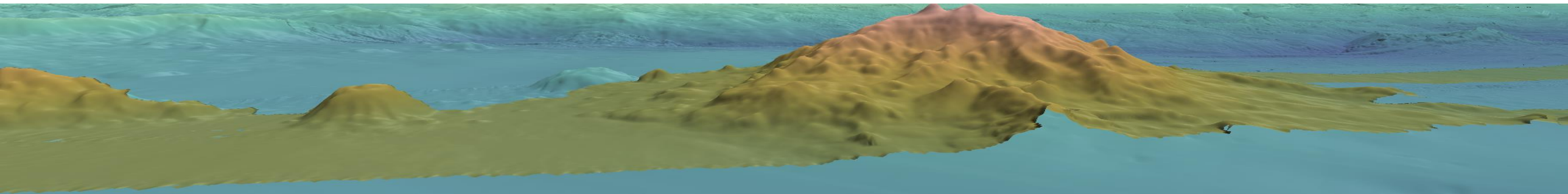
# EM304 MKII Benefits Moving Forward

- Our most recent expedition (Guam to Hawaii) mapped more seafloor than any previous *Nautilus* expedition.

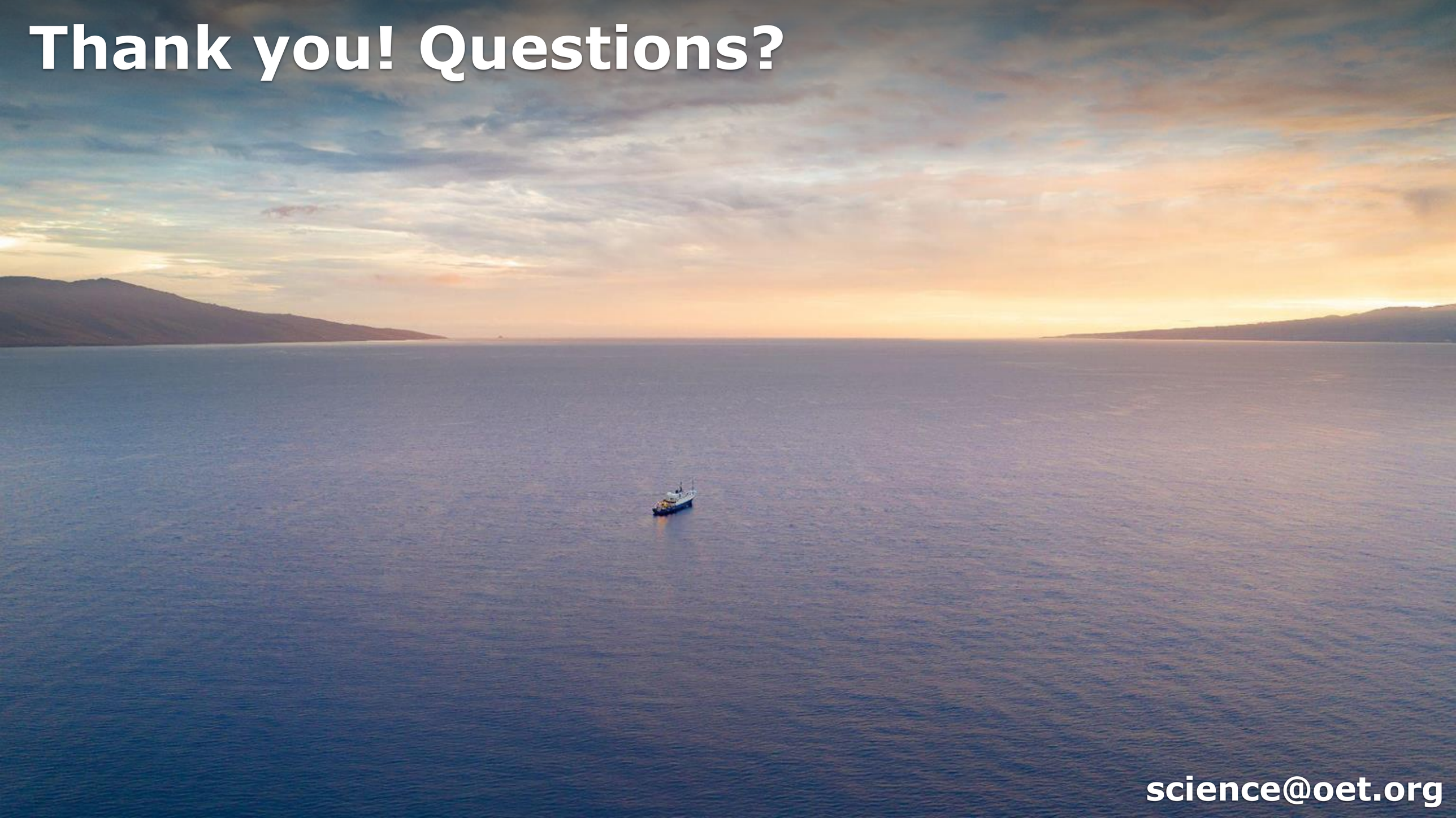
- So far for 2026, Nautilus has mapped a total of 181,305 $km^2$ of seafloor with the new EM304 during 96 days at sea.

- If we normalize our mapping statistics to days at sea, we are now mapping over 2,000 $km^2$ per day at sea, more than double what we mapped in the 13 previous years using our the EM302.

- Assuming similar efficiencies in the next 10 years (the expected minimum lifespan of the EM304 MKII), E/V Nautilus will map at least an additional 1.2 million $km^2$ over what was possible with the EM302
  - ~ twice as much area
  - ~ three more Norways



# Thank you! Questions?



science@oet.org