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OCEANIDS

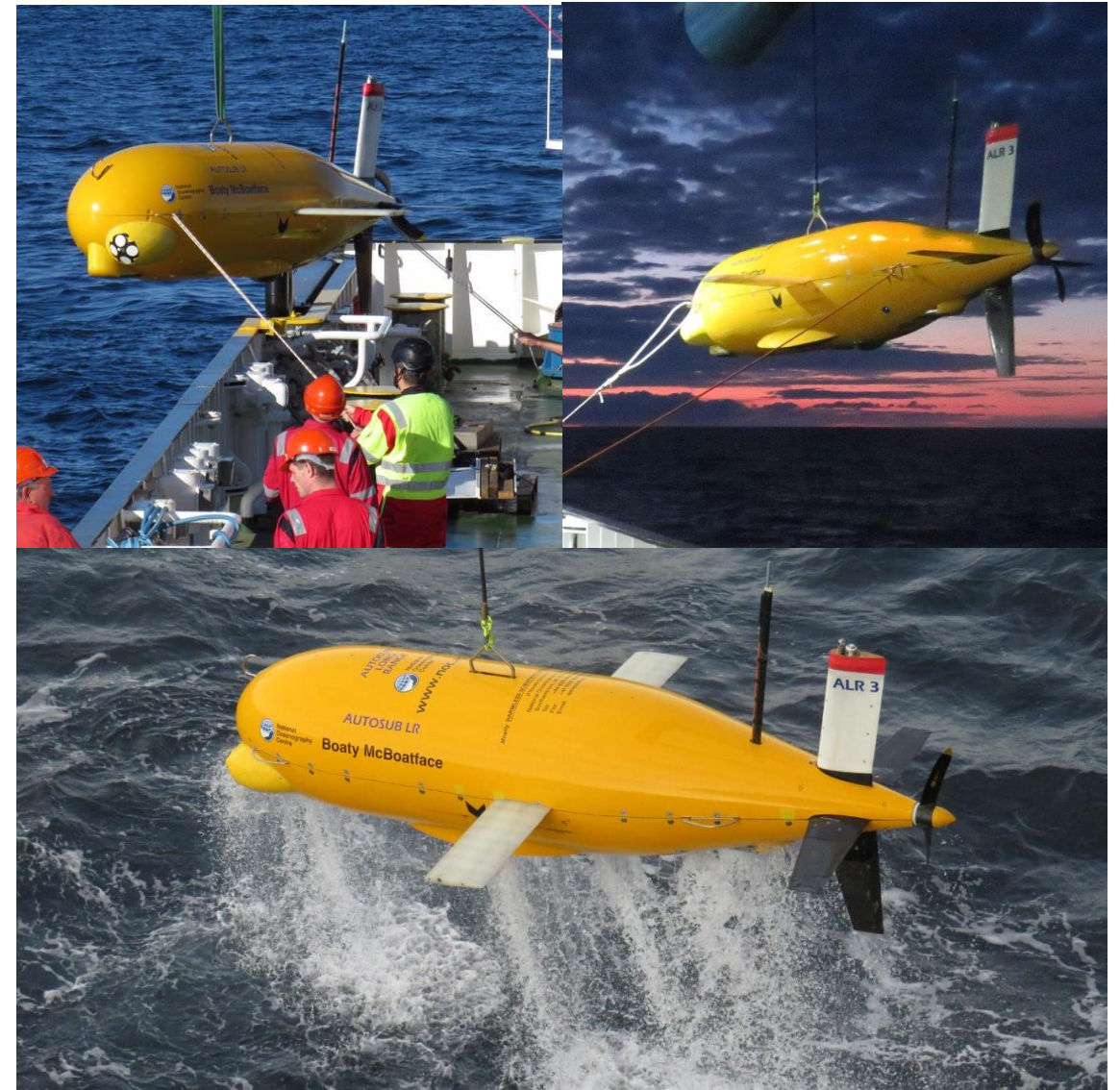
# Autosub Long Range: towards a shore launch shore recover AUV capability

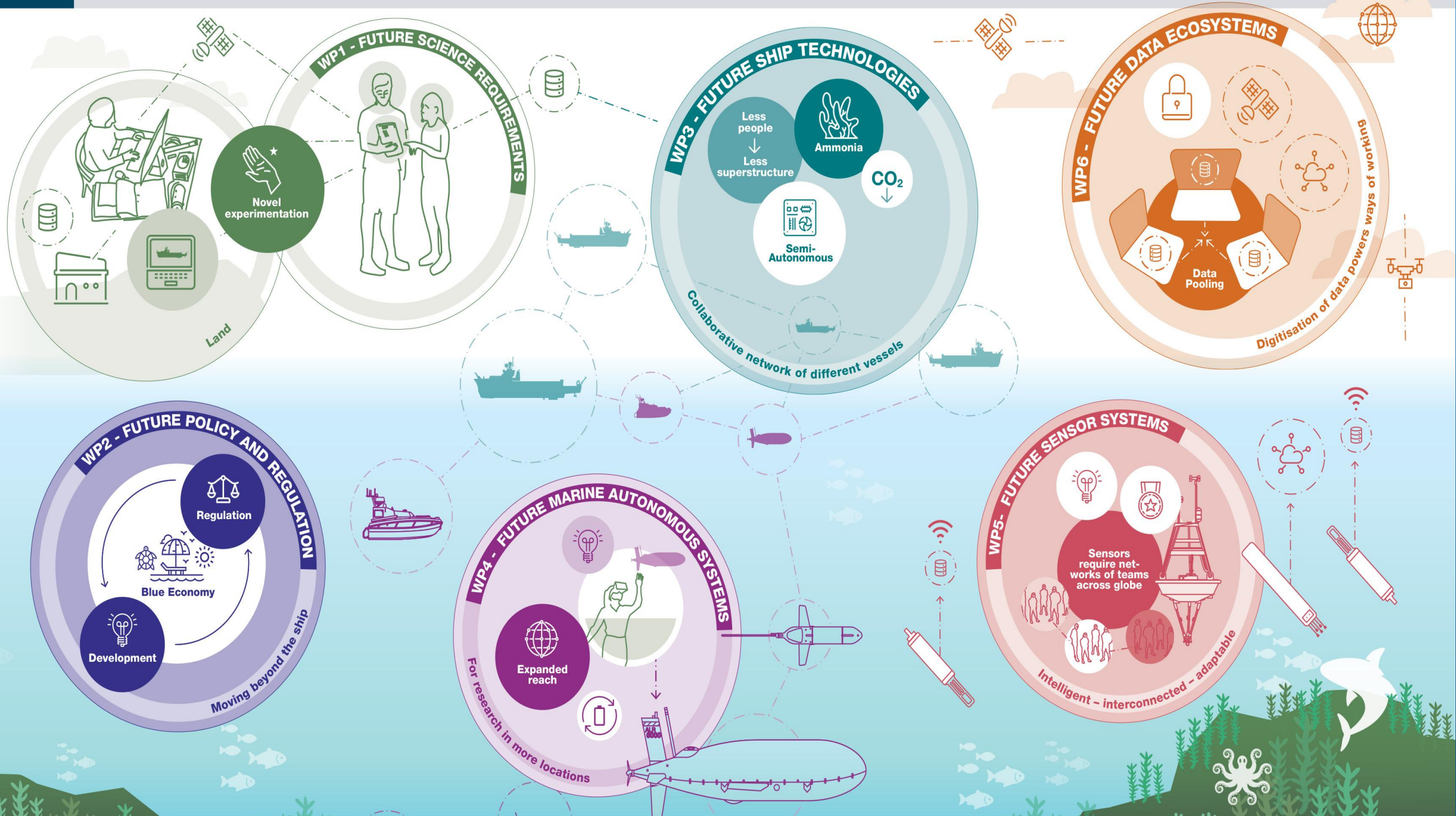
Dr Alexander Phillips  
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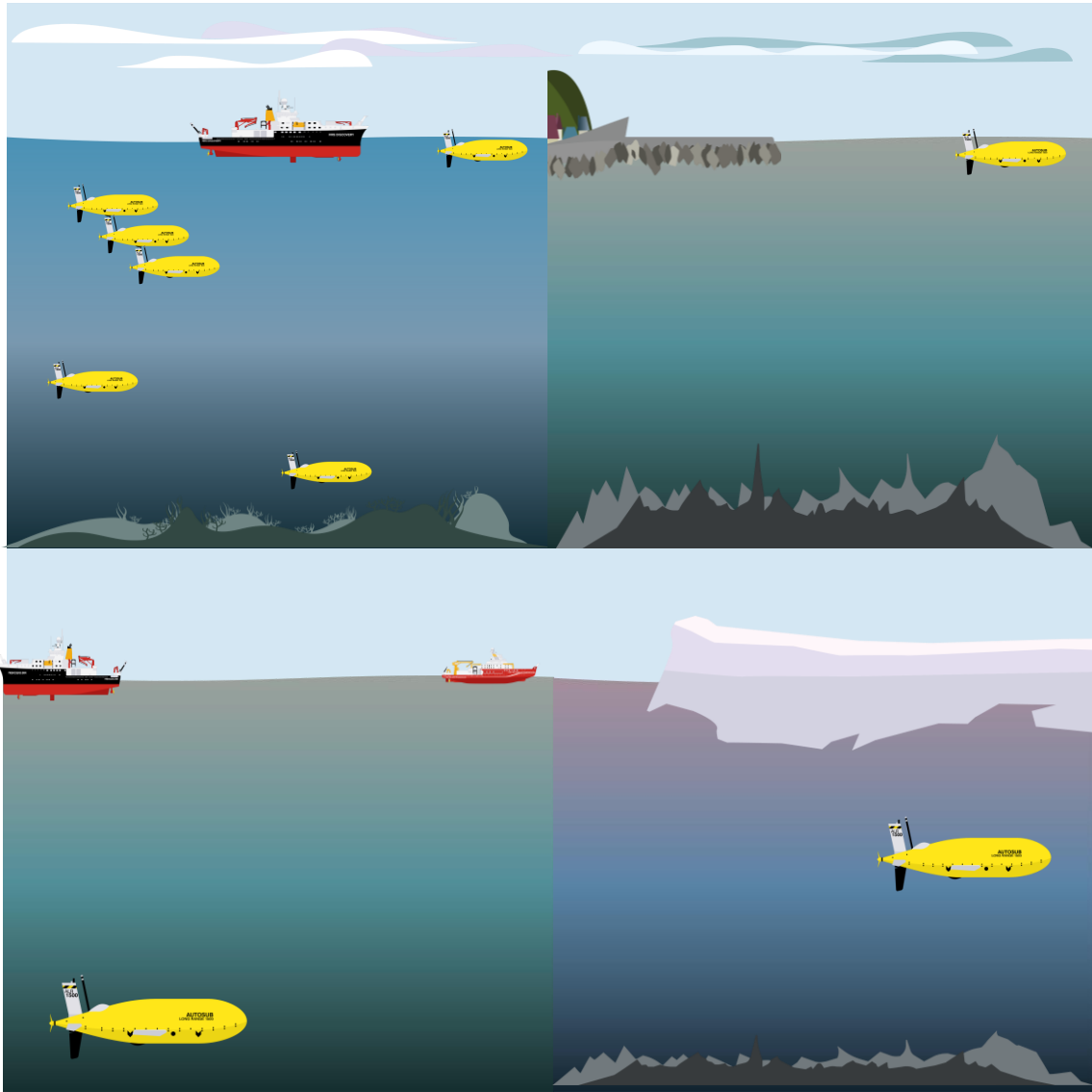
# Contents

- Long range platforms as part of a NZOC Capability
- Autosub Long Range
- Deployments so far from 2022
  - TARSAN: Under the Dotson Ice Shelf
  - Oceanids Sensors: DY149 Southwest Approaches
  - Long Distance Proving Trial: 2000km from Plymouth to the Shelf break and back again
  - DY152: Benthic Imaging in the Greater Haig Fras and South West Deeps (East) MPA
- Future Developments
- Final Thoughts





## Long range platforms as part of a NZOC Capability



Long Range MAS platforms can be in the water for weeks, months or even a year providing temporal coverage not typically available with a conventional research ship

### Potential Concepts of Operation

- Force Multiplication
- Shore Launch Shore Recover
- Vessels of Opportunity
- Persistent Presence

## Motivation for Autosub Long Range – DOLPHIN (1987)



DOLPHIN (Deep Ocean Long Path Hydrographic Instrument) to gather water column data beneath Antarctic ice sheets. (Polly Williamson)

Parameter	Target Specification
Range	7000km
Speed	2.5m/s
Length	5m
Depth Range	0-6000m
Payload	Triplicated Neil Brown CTD
Navigation	Dead Reckoning with Compass and Prop RPM

## 3 x Autosub Long Range 6000 (ALR6000)

- 2 x Pressure Vessel
- 38kWhrs Primary LTC Batteries
- 6000m depth rating
- Mass  $\approx$  800 kg
- Length  $\approx$  3.5m
- Top Speed  $\approx$  1m/s
- Max Range  $\approx$  **2000km**



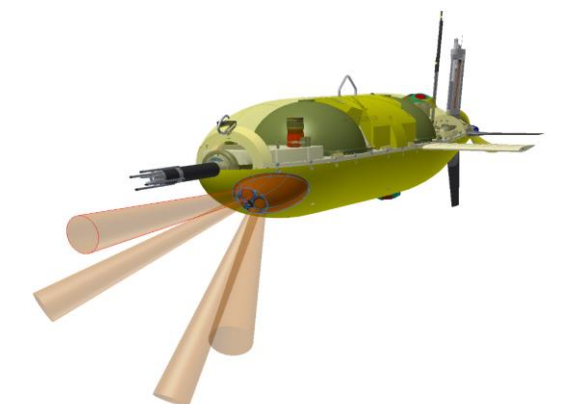
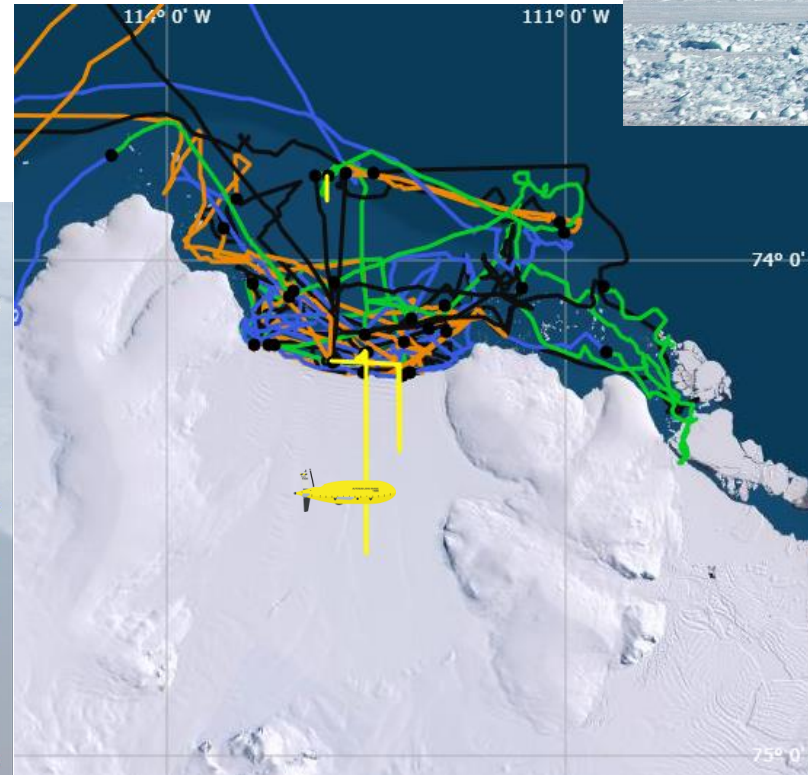
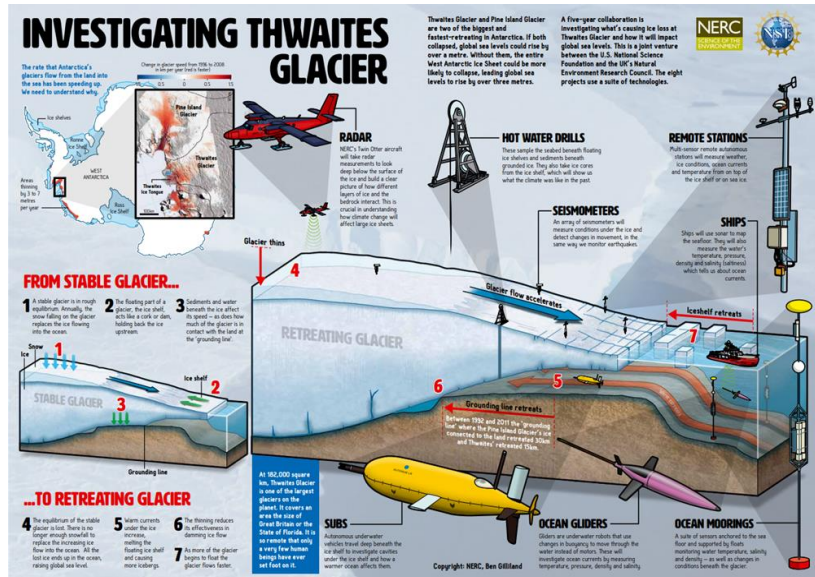
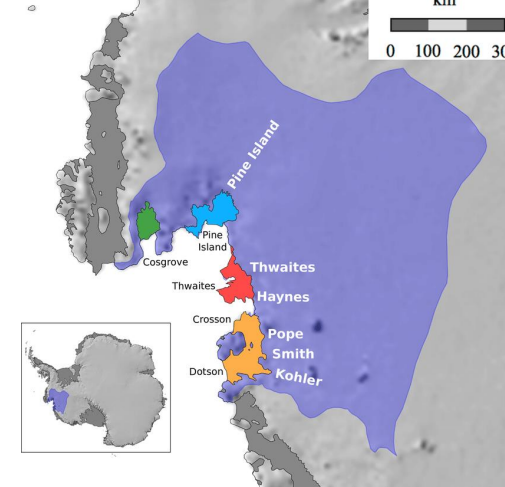
- 1 x Pressure vessel
- 95kWhrs Primary LTC batteries
- 1500m depth rated
- Mass  $\approx$  800 kg
- Length  $\approx$  3.5m
- Top Speed  $\approx$  1m/s
- Max Range  $\approx$  **6000km**

## 3 x Autosub Long Range1500 (ALR1500)

# Force Multiplication (TARSAN – Q1 '22)

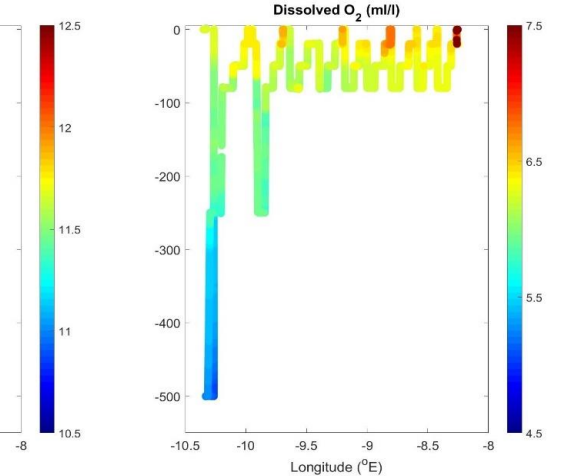
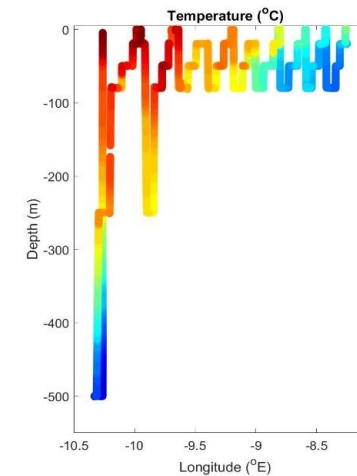
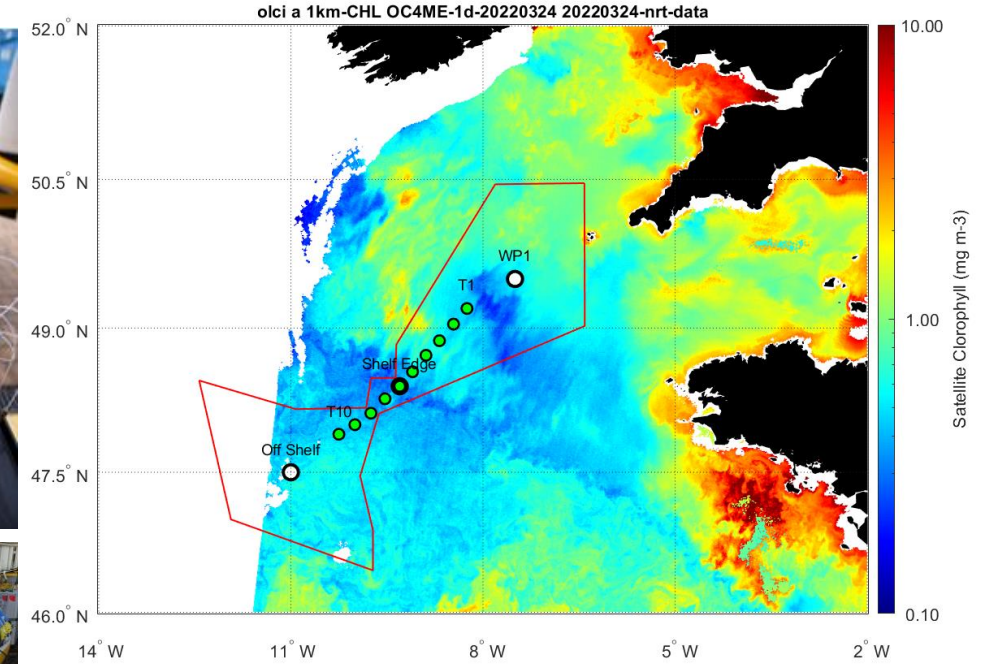
Multi-day deployment of ALR1 from the Nathaniel B Palmer under Dotson Glacier as part of TARSAN International Thwaites Glacier Collaboration

Longest track was 40km in under the ice flying at circa 100m altitude



# Force Multiplication (Biogeochemistry Q1 '22)

AUV	ALR2
Depth Rating	6000 m (Nominal) Currently de-rated to 600 m for sensor payload
Energy	Lithium Thionyl Chloride (~10 Days)
System sensors	<ul style="list-style-type: none"> <li>300 kHz RDI ADCP</li> <li>PNI Magnetic Heading Sensor</li> <li>CTD SBE 52</li> </ul>
Science sensors	<ul style="list-style-type: none"> <li>CTD SBE 52 MP + DO</li> <li>ADCPs as per system ADCPs</li> <li>DO SBE 43F</li> <li>AutoNuts – Nutrients                             <ul style="list-style-type: none"> <li>LOC Nitrate</li> <li>LOC Silicate</li> <li>LOC Iron (Chemiluminescent)</li> <li>LOC Iron</li> <li>LOC Nitrite</li> <li>LOC Phosphate</li> </ul> </li> <li>Carcass – Carbonate                             <ul style="list-style-type: none"> <li>LOC pH</li> <li>LOC TA</li> <li>LOC DIC</li> <li>ANB pH</li> </ul> </li> <li>Stafes-App – Primary Productivity</li> </ul>



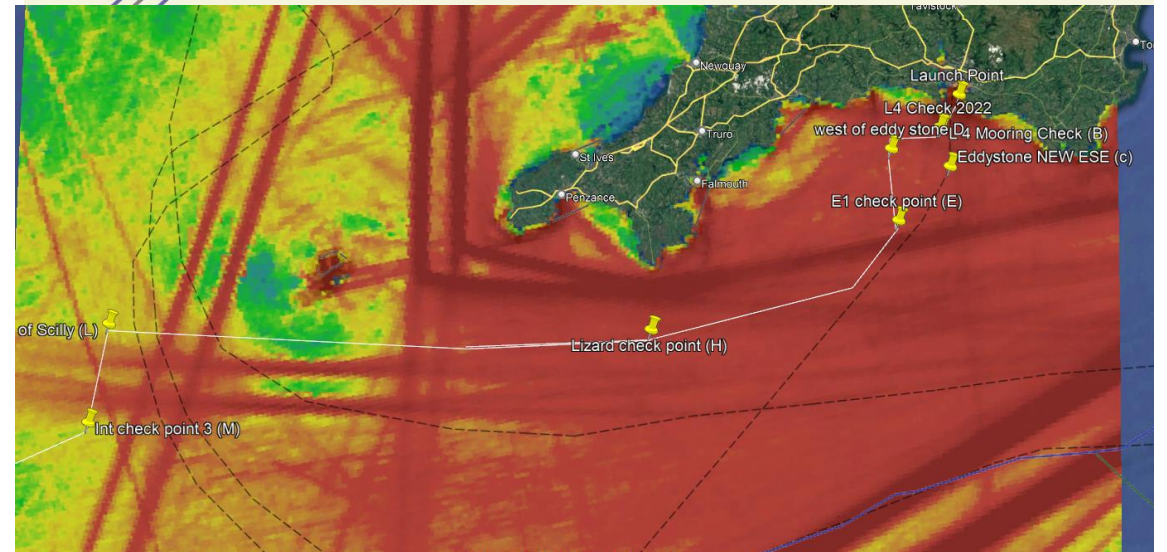
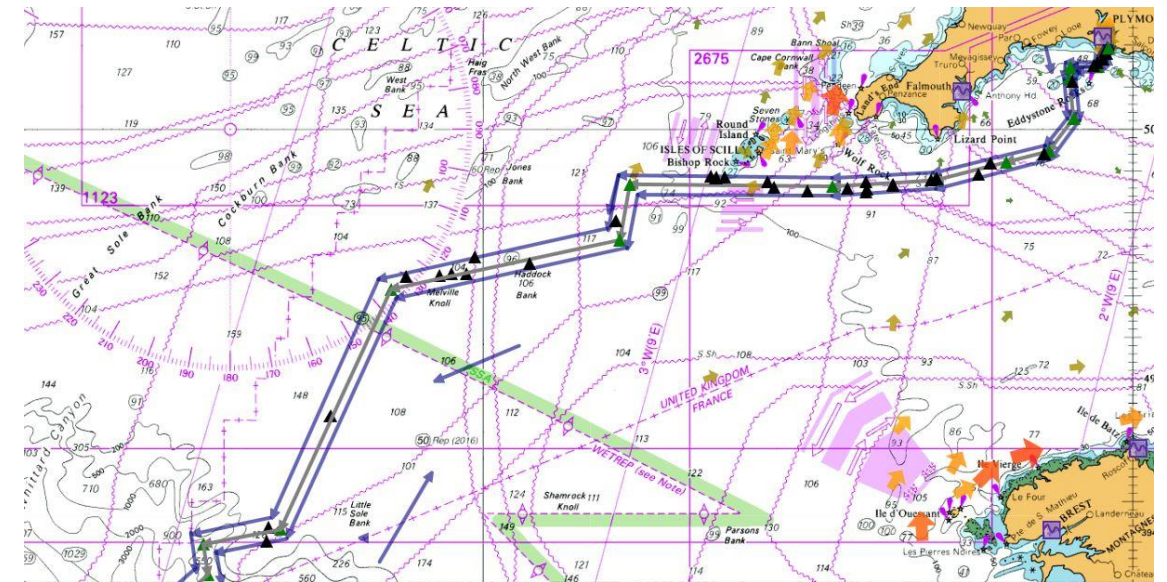
5 day continuous mission traversing across spring bloom and front features from shelf to deep water with collocated ship based CTD measurements



# Shore Launch Shore Recover (ALR4 Long Distance Proving Trial (LDPT) April 22)

## Objectives:

- Proof of concept of long range over the horizon operations with an ALR over a distance of 2000km and over a month
- Quantify real world performance (e.g. straight line navigation)
- Demonstrate a range of potential sampling approaches
- Better understand our needs for near real time data transmission



# LDPT Vehicle Configuration

Battery: 74kWh LTC

Payload Sensor Fit:

- An upwards and downwards Nortek 500kHz ADCP,
- Seabird 52MP CTD with Seabird 43F DO,
- Wetlabs CDOM Fluorometer (ECO-FLCDRTD)
- NOC 4000m range echosounder
- Octans Fibre Optic Gyro
- Self contained NOC pH LOC,
- Self contained Seabird SeapHOx,

Secondary Beacons:

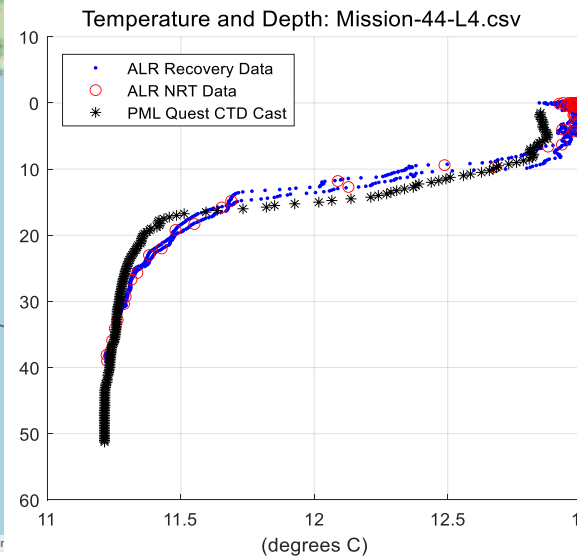
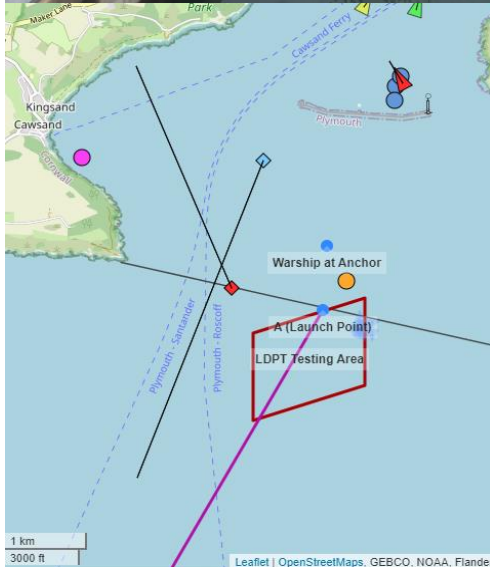
- Xeos Iridium
- Marker 6 Acoustic
- Argos



# LDPT Launch and calibration



- ALR4 Shipped to Plymouth from Southampton then fitted with batteries and final checks completed
- ALR4 was launched from Thales Turnchapel Facility on the 10<sup>th</sup> May
- Towed South of the Plymouth Breakwater by Thales RHIB
- Compass Calibration South of Plymouth Breakwater (M41)
- Compass/DVL Alignment South of Plymouth Breakwater (M42 & M43)
- CTD Cross Calibration with PML Quest at L4 Station 10Nm South-West of Plymouth (M44)

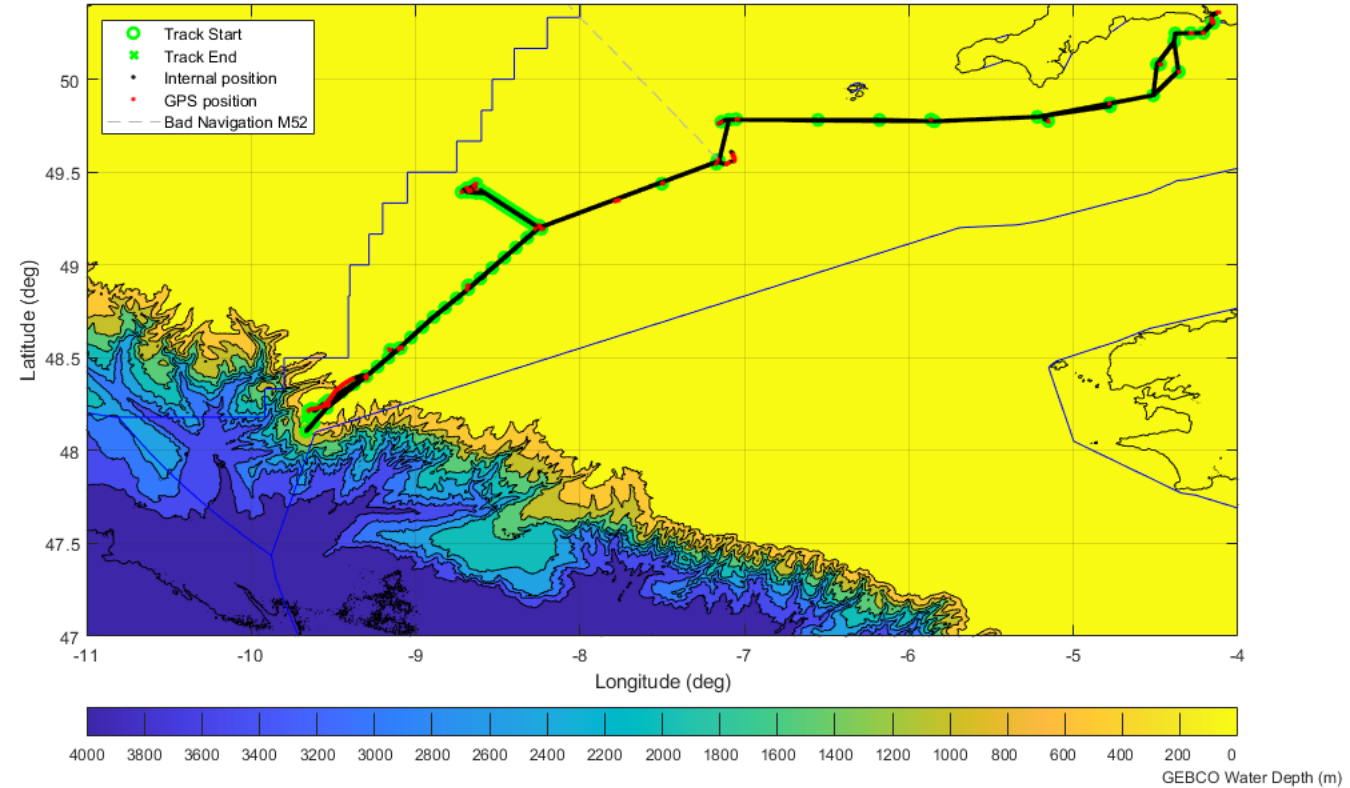


**PML** | Plymouth Marine Laboratory

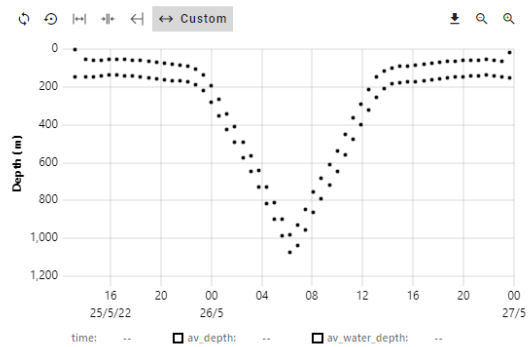
**THALES**

# LDPT Deployment Overview

- 5 weeks of unaccompanied operation in South West Approaches
- Piloted remotely from Southampton surfacing roughly every 24hours
- Deep Dives Down the Brenot Spur – max depth 1011m
- Range of sampling strategies undertaken during the transit and at the Candyfloss site

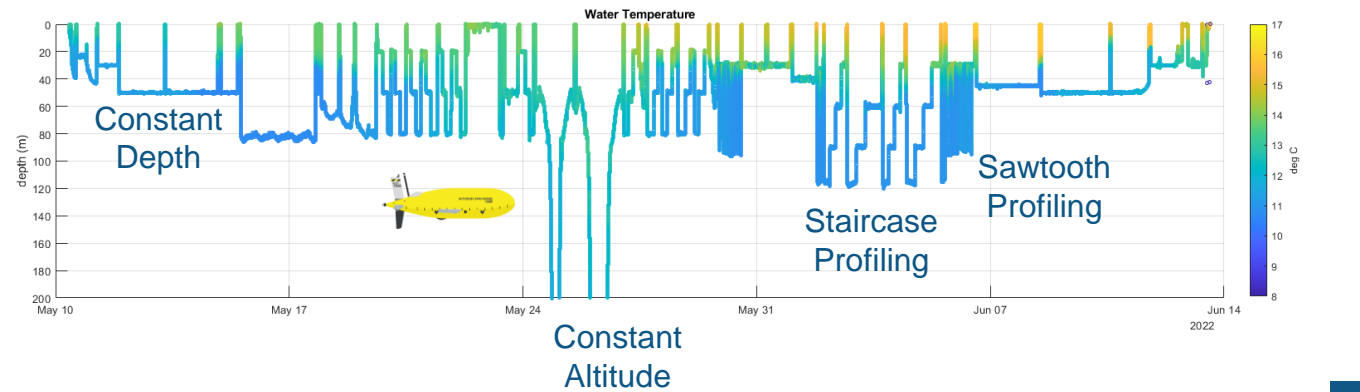
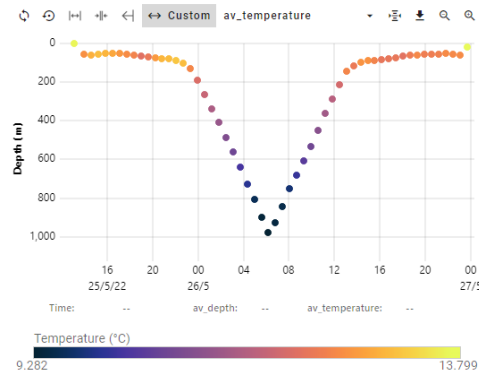


Average Depth



CTD

Conductivity, temperature and density

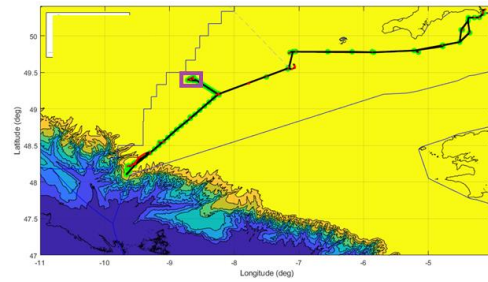
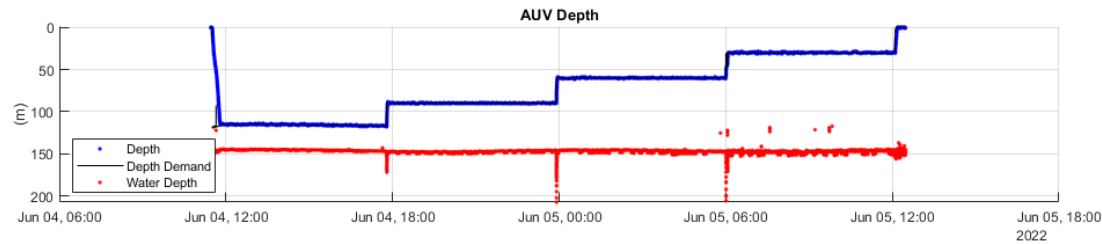
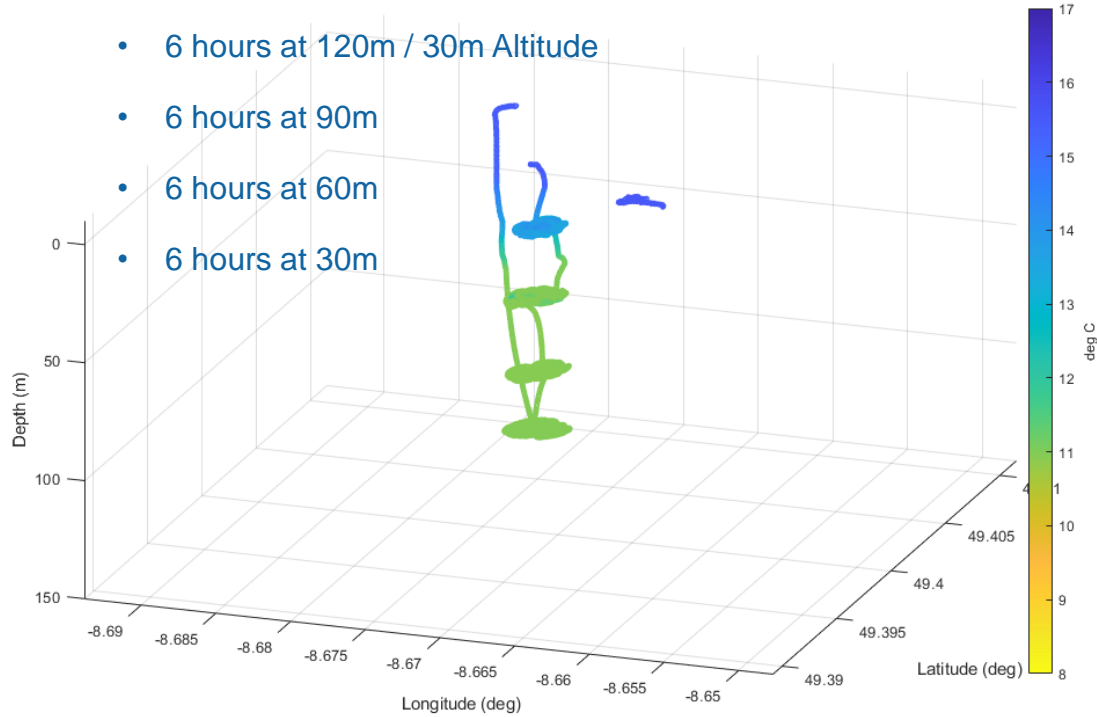


# LDPT Survey Modes at Candyfloss Site

## Virtual Mooring

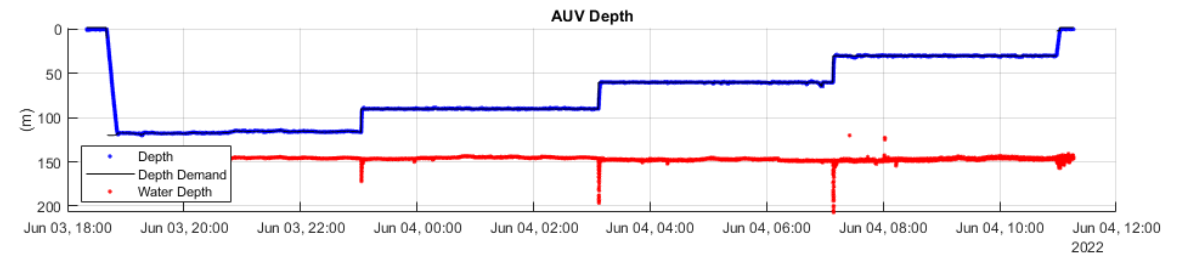
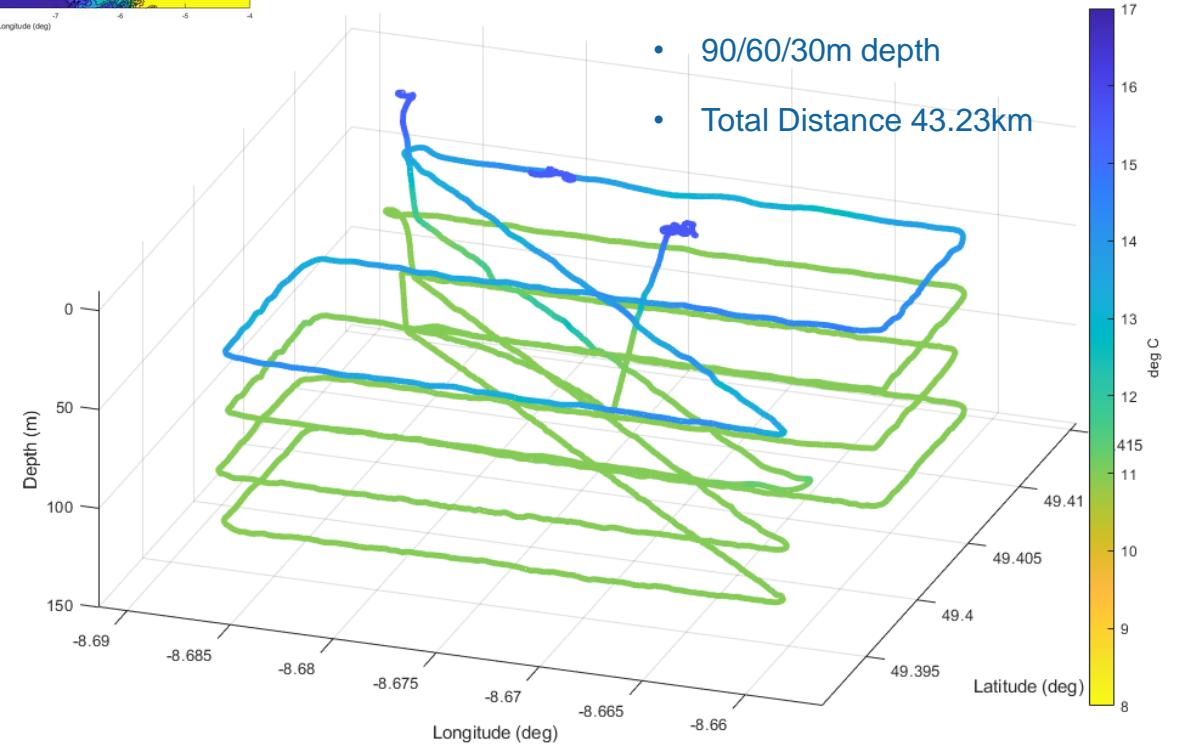
- Hold at Depth Virtual Mooring

- 6 hours at 120m / 30m Altitude
- 6 hours at 90m
- 6 hours at 60m
- 6 hours at 30m



- Lawnmower

- 1km legs
- 500m line spacing
- 30m altitude / 120m depth
- 90/60/30m depth
- Total Distance 43.23km



# LDPT Recovery

AUV was recovered to Plymouth on the 13<sup>th</sup> June having travelled circa 2000km maximum dive to 1011m

- Used circa half of the 74kWh installed
- No evidence of collision or damage during towing
- Minimal biofouling
  - initial colonisation by hydroids on the external surfaces originating at seams and panel joints
  - Initial Colonisation by hydroids inside the hydrodynamic fairing
  - No evidence of barnacles
- Limited Corrosion
  - Main pressure vessel appears well protected by anodes and anodising
  - Visible corrosion of bulkhead connectors
  - Minor corrosion of some stainless steel components
  - Titanium components look unaffected
- Silt and detritus inside the hydrodynamic fairing



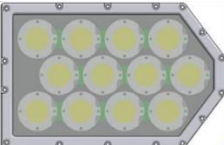


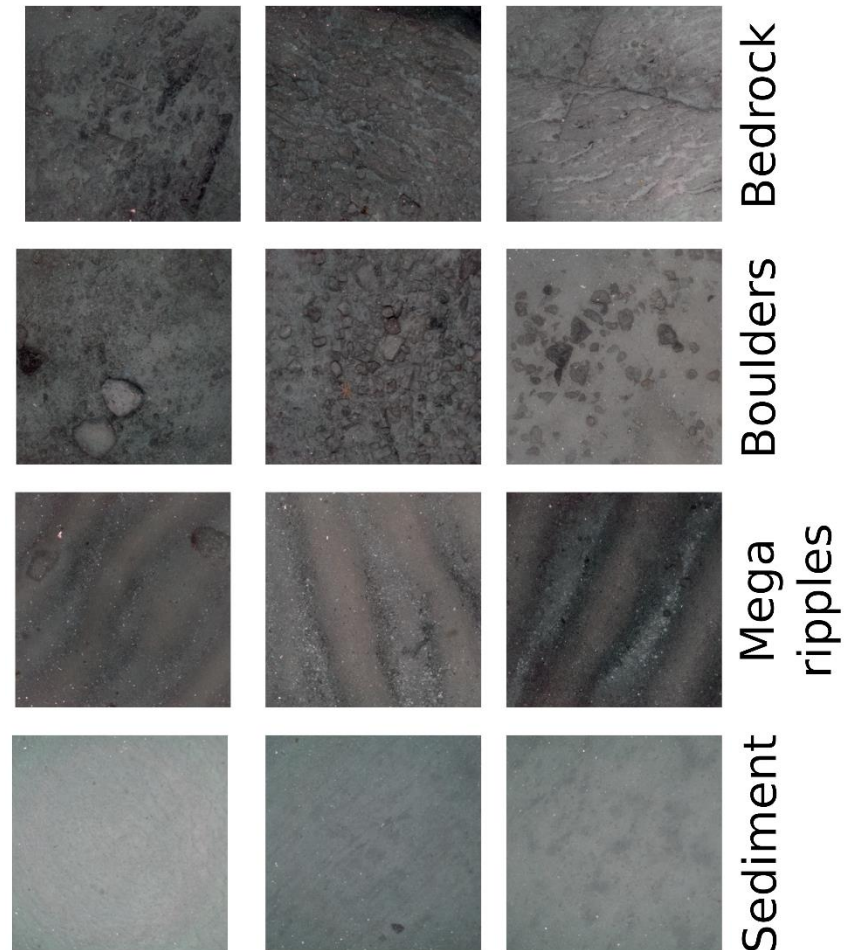
# Force Multiplication (DY152 ALR3/BioCam July 22)



- NMEP Trials Cruise to Greater Haig Fras and Whittard Canyon
- 2 Multi-day deployments, 15 Missions in Greater Haig Fras in vicinity of RRS Discovery
- 85km BioCAM survey at 4m or 5m altitude

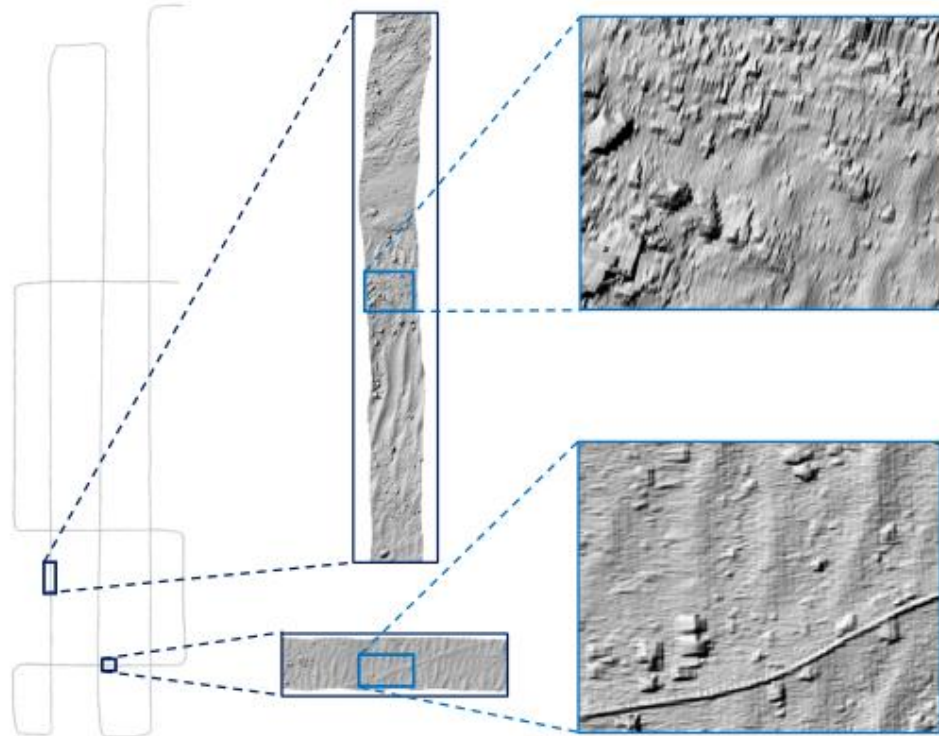


<p>Laser safety switch</p> 	<p>Camera unit</p> 	<p>Strobe x2</p> 	<p>Laser x2</p> 
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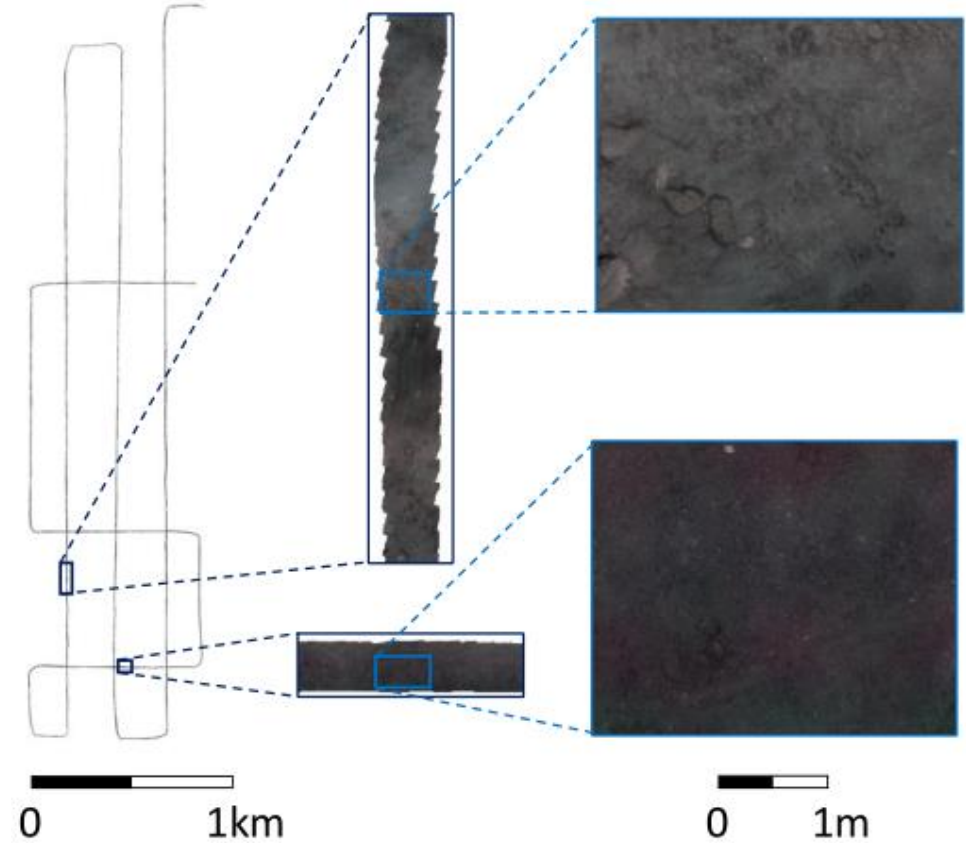


Images courtesy of: Adrian Bodenmann and Jose Cappelletto

### laser-line-based bathymetry maps



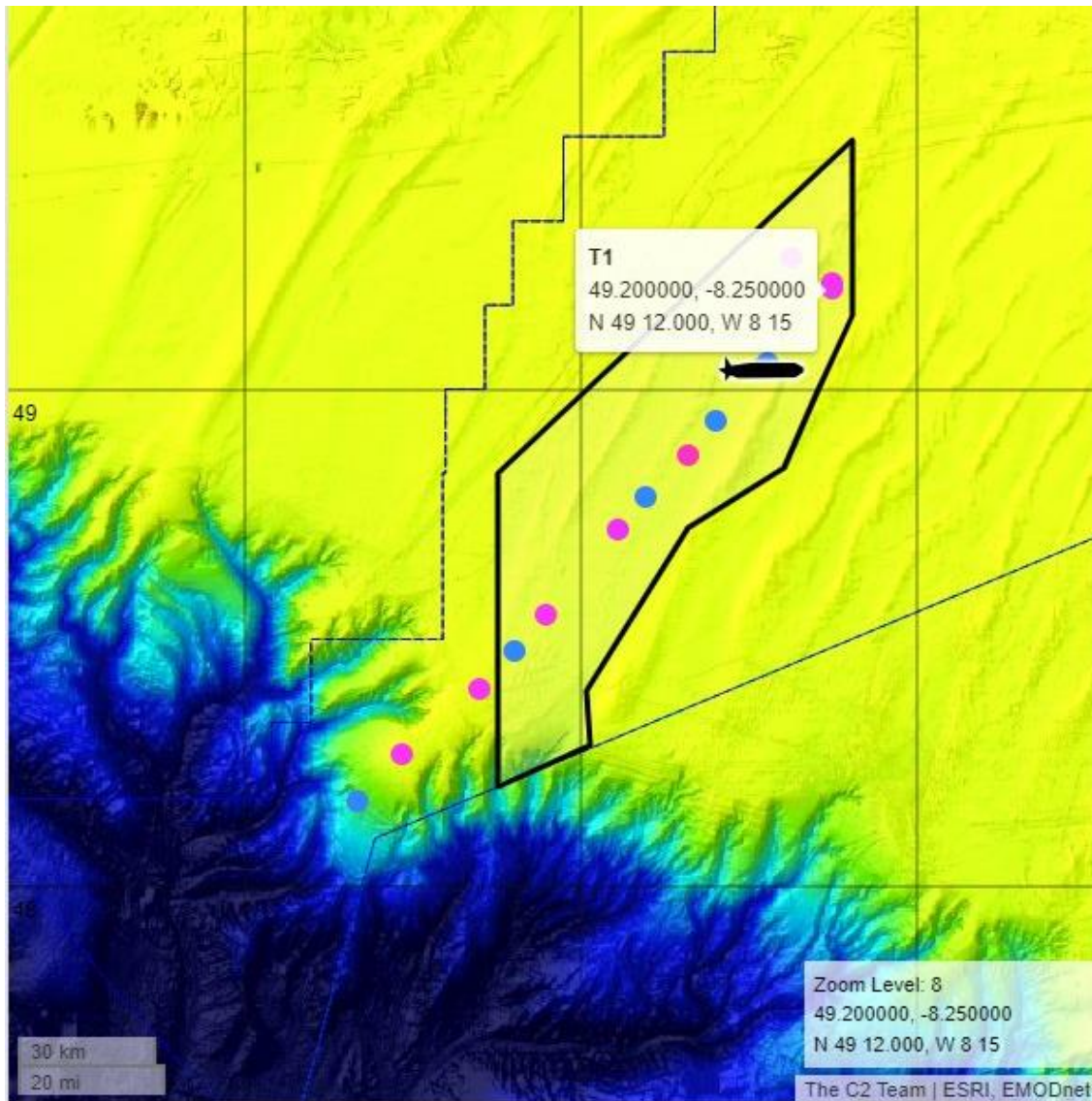
### texture maps



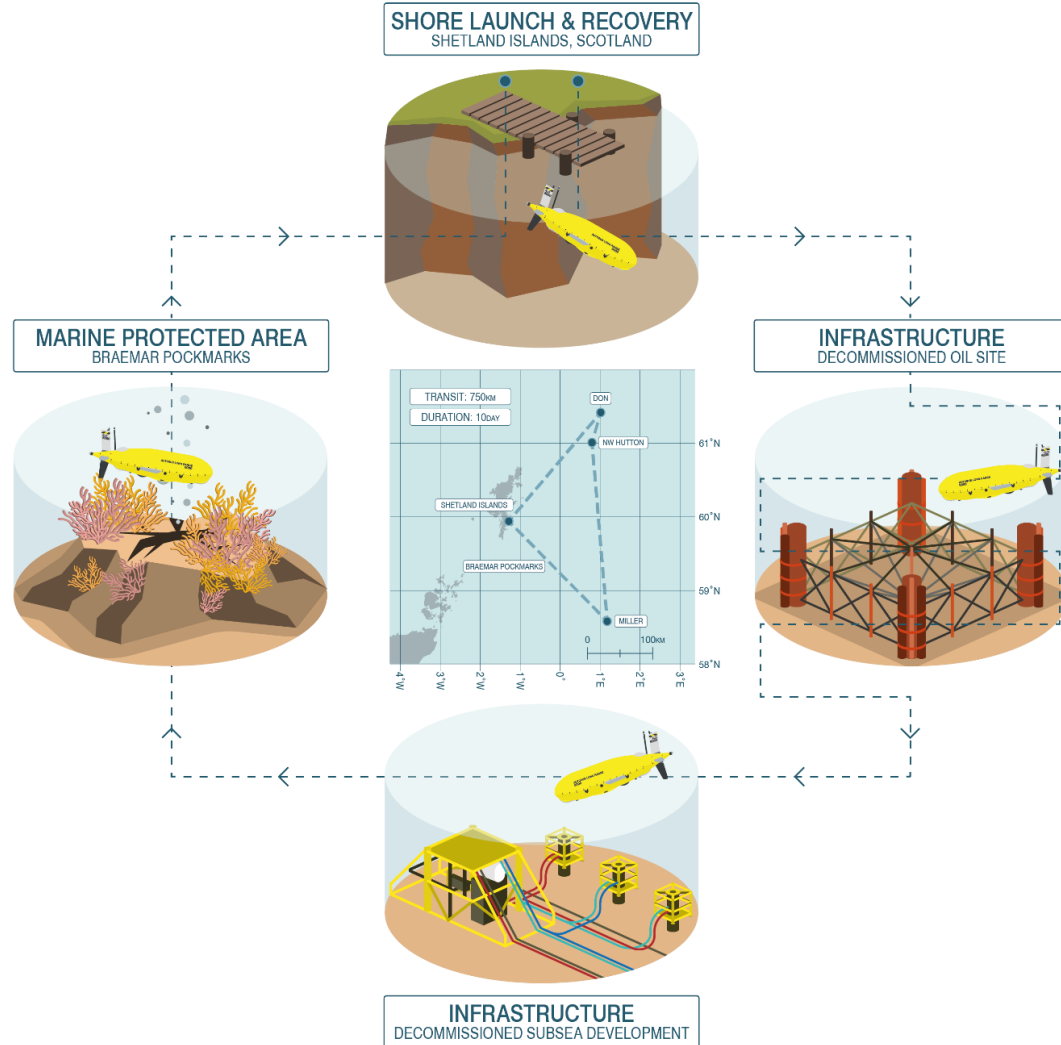
Images courtesy of: Adrian Bodenmann and Jose Cappelletto



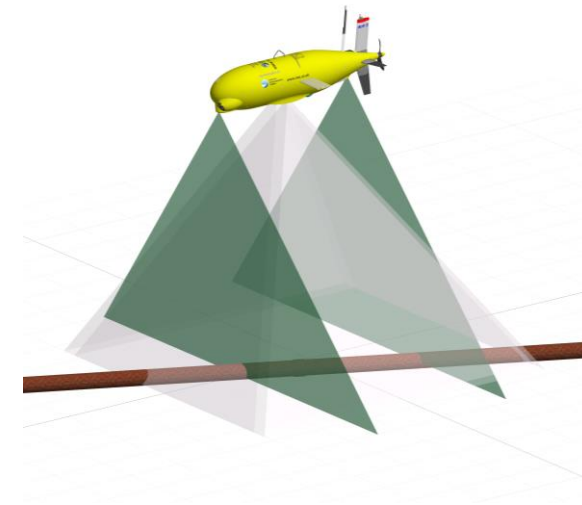
# Ships of Opportunity (DY152 Over the Horizon Operation of Autosub Long Range / BioCAM)



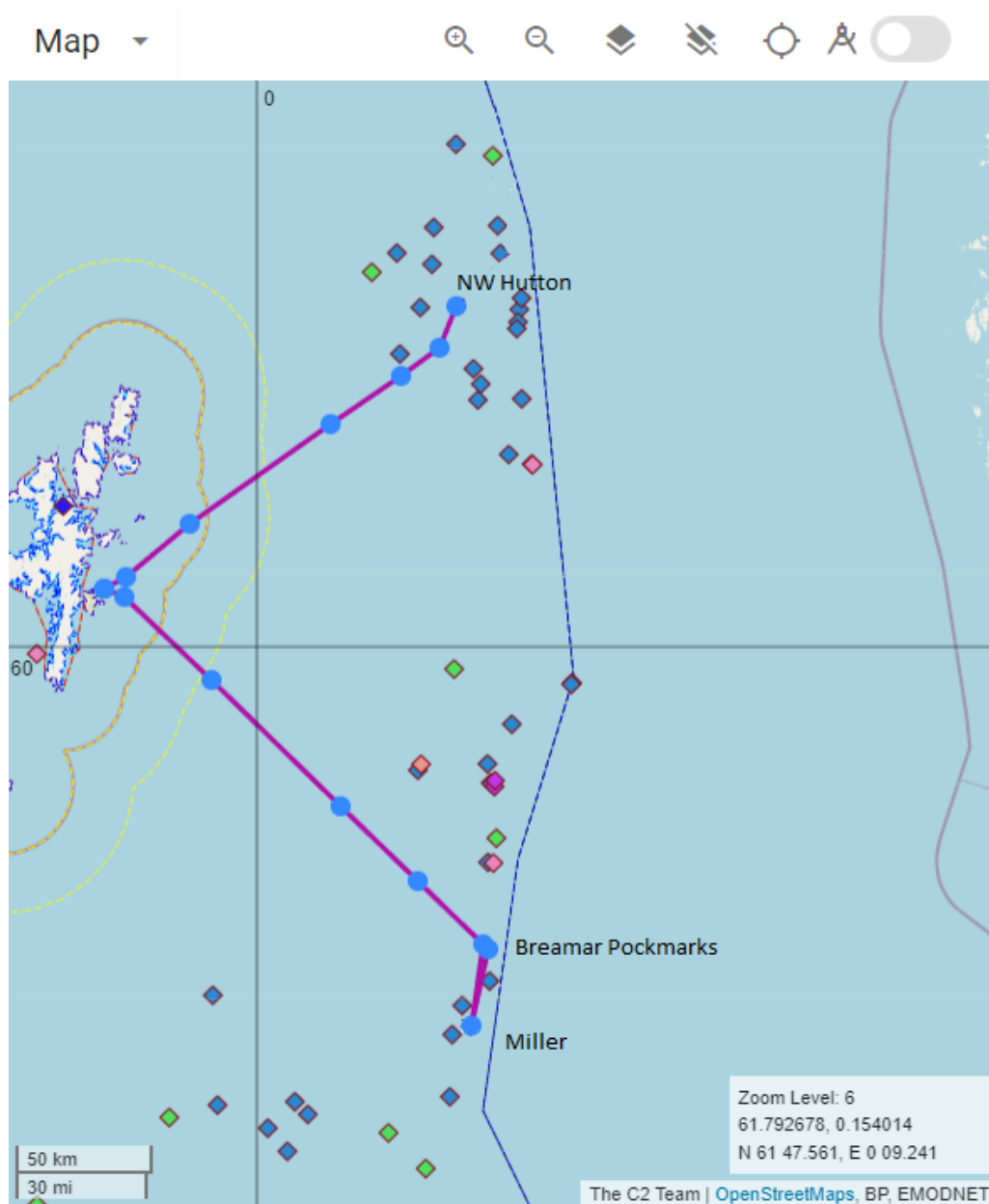
- Opportunistic deployment of ALR3/BioCAM in the South West Deeps (East) MPA whilst the RRS Discovery was operating at Whittard Canyon
- ALR3 deployed from the Discovery on route. Following a short test period with the ship on station the rest of the 5 deployment was piloted remotely via Iridium
- Missions were a mixture of:
  - 80m and 25m altitude transects
  - OAS testing over sand ridges
  - Virtual mooring at 80m altitude to gather ADCP data
  - 3 BioCAM missions covering a distance of 95km mapping circa 47ha at 5m altitude
- Key to improve:
  - Quantity and quality of near real time data



- INSITE is an independent science programme examining the effects of man-made structures in the North Sea
- The Autonomous Techniques for anthropogenic Structure Ecological Assessment ATSEA project is aiming to assess the feasibility and efficacy of fully autonomous monitoring of multiple decommissioning-related sites without the aid of a support vessel by demonstrating the use of an existing shore-launched, long-range, fully autonomous underwater vehicle for marine environmental survey.

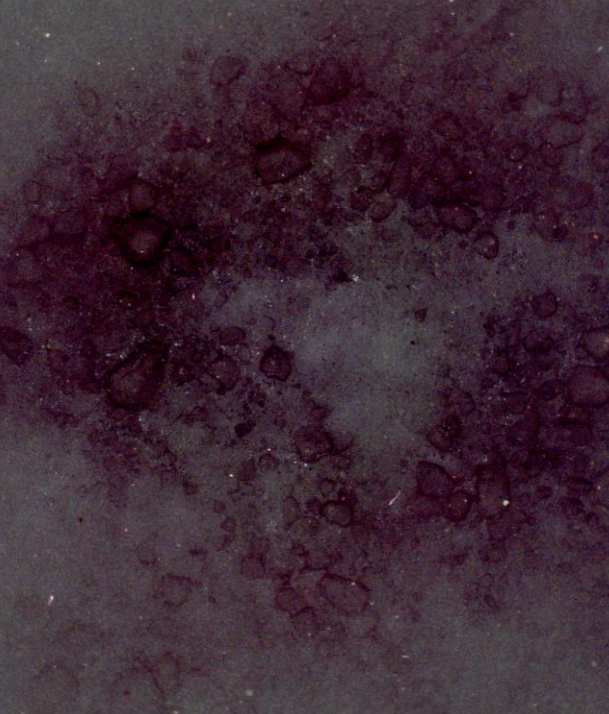
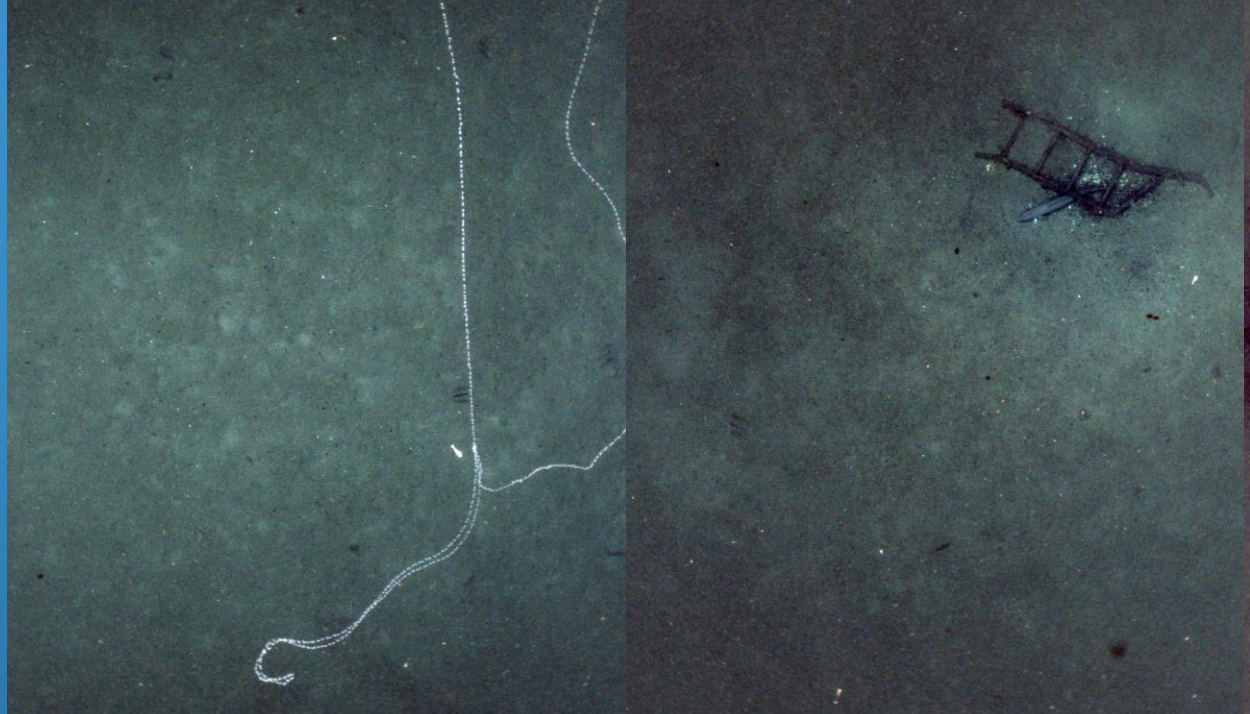


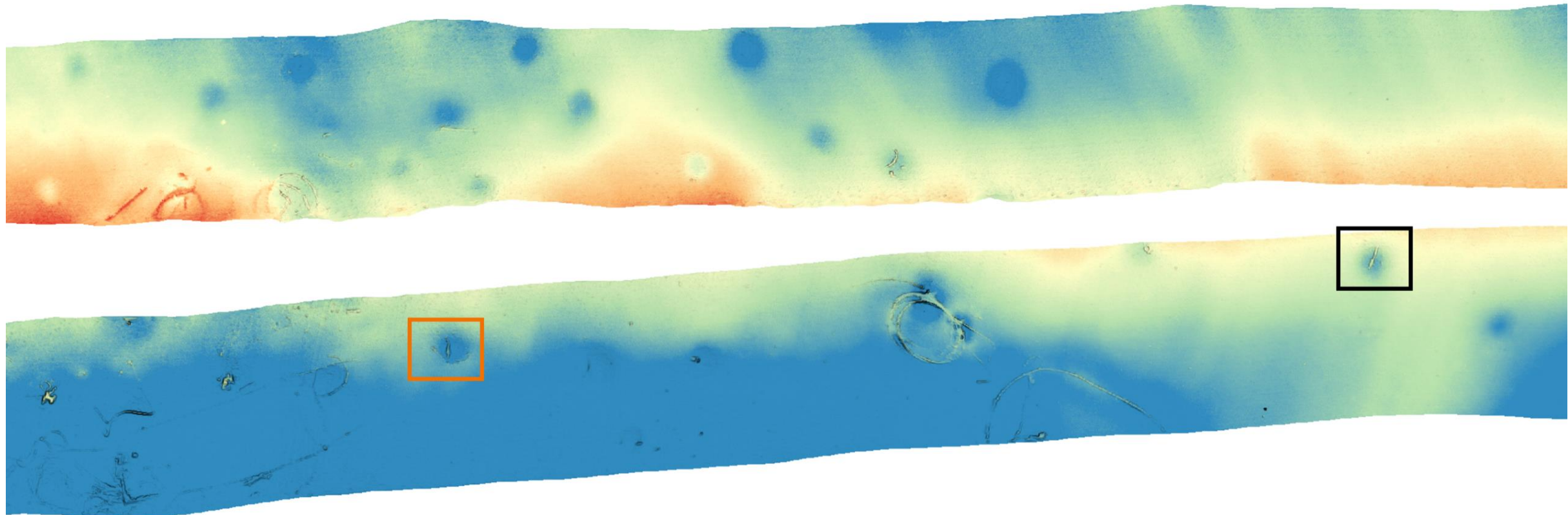
## Current Status



- ALR3 launched from Lerwick Monday 19<sup>th</sup> September for Northern Leg
- ALR3 arrived at the North West Hutton decommissioned oil and gas field Friday 23<sup>rd</sup> having transited 170km from shore unaccompanied
- At the decommissioned NW Hutton ALR3 performed a mixture of water column and camera surveys around the remaining infrastructure generating 50km of benthic imagery
- On Sunday 25<sup>th</sup> ALR3 began the return leg back to Lerwick
- ALR3 was recovered on 26<sup>th</sup> back at Lerwick
- ALR3 was deployed for the Southern leg on the 27<sup>th</sup> September
- ALR3 reached Miller Site 4<sup>th</sup> October conducting 3 15km imaging surveys at a range of altitudes
- ALR3 undertook a short survey on the Breamar pockmarks MPA 6<sup>th</sup> November
- ALR3 recovered 11<sup>th</sup> November

Images and micro-bathymetry being processed but preliminary results to follow:





10m

Depth, m

144.3

143.8

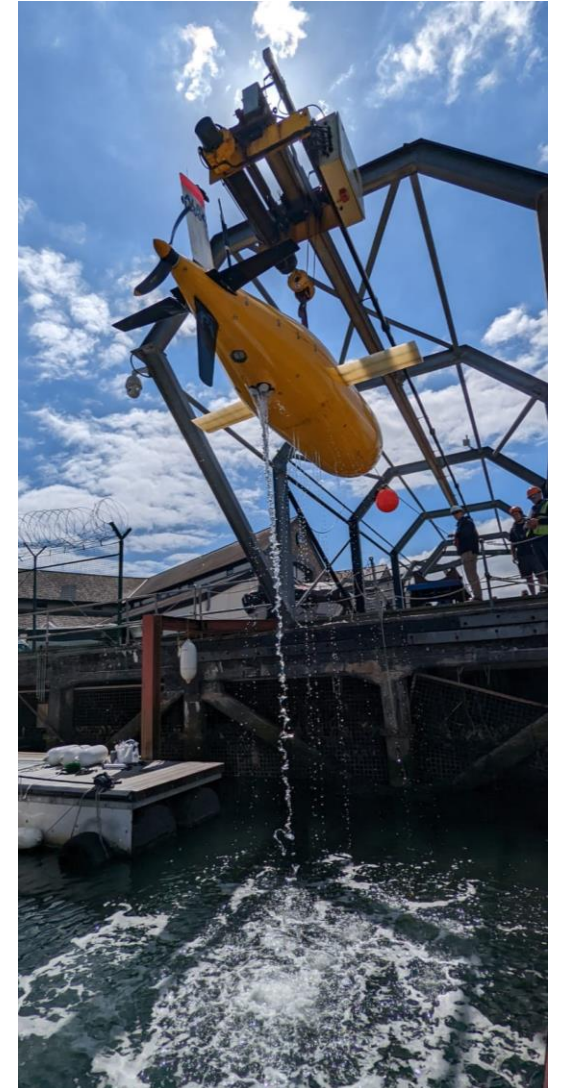
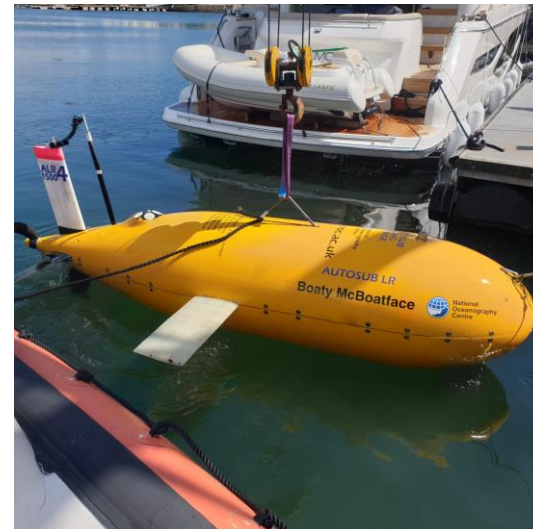
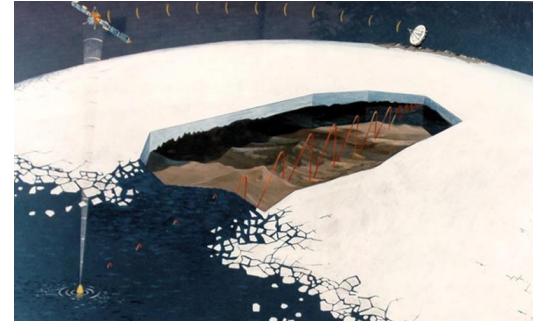
# Future Developments

- Future sensor fits
  - Integration of multibeam echosounder
  - Integration of benthic and pelagic camera systems
  - Integration of a scientific echosounder
  - Integration of samplers
  - Integration of PAM
  - ...
- Enhanced low power navigation and data fusion
- Stretch ALR – extended endurance shore launch – shore recover capability
- Improved near real time data transmission
- Adaptive sampling
- Drift/glide/listen mode
- Mooring system for persistent presence



## Closing Thoughts

- 35 years since the initial DOLPHIN concept and we are finally edging towards delivering that vision
- Operations in 2022 have demonstrated the flexibility of the ALR platform and its ability to act as both a force multiplier for research vessels or act alone shore launch shore recover.
- We believe at circa 2000km and 5 weeks LDPT is the longest deployment of a Large AUV and there is clear potential and aspiration to go for longer
- Increasing option in terms of sensor payloads coupled with an increasing need to enhance autonomy to ensure measurements made in the right place at the right time
- Looking forwards, its clear that long range autonomous systems (AUVs, Gliders, USVs) operating over the horizon will play an important role in delivery of a global ocean observing system and a net zero oceanographic capability



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