

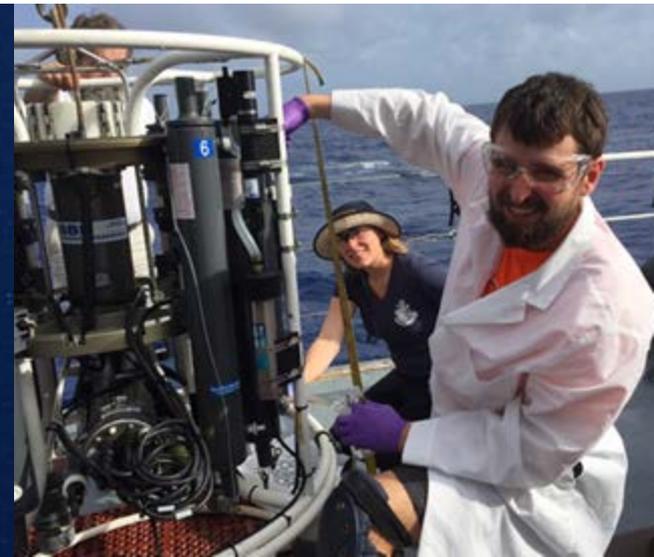


# Technology and Methodology Development

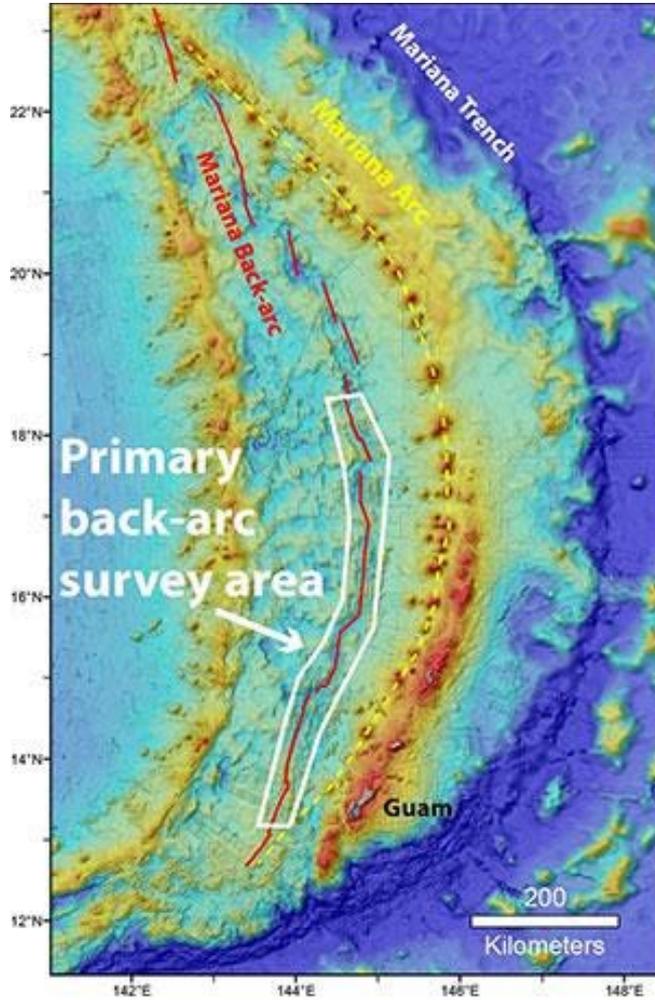
Steve Hammond, PhD  
Senior Science Advisor

# Technology Innovation, Application, and Program Use

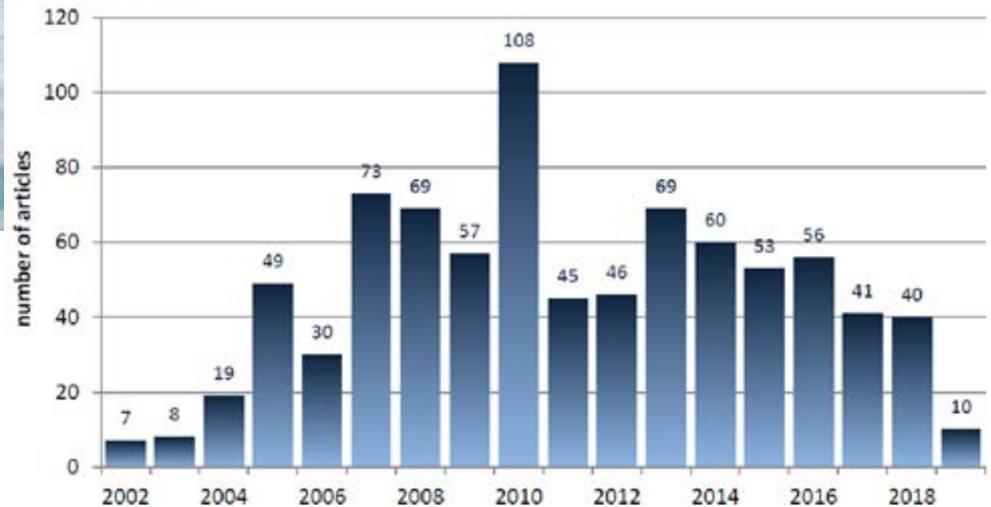
- Evolving technology innovation and development
- Evolving the scope of ocean exploration
- Enabling means for observations and sampling



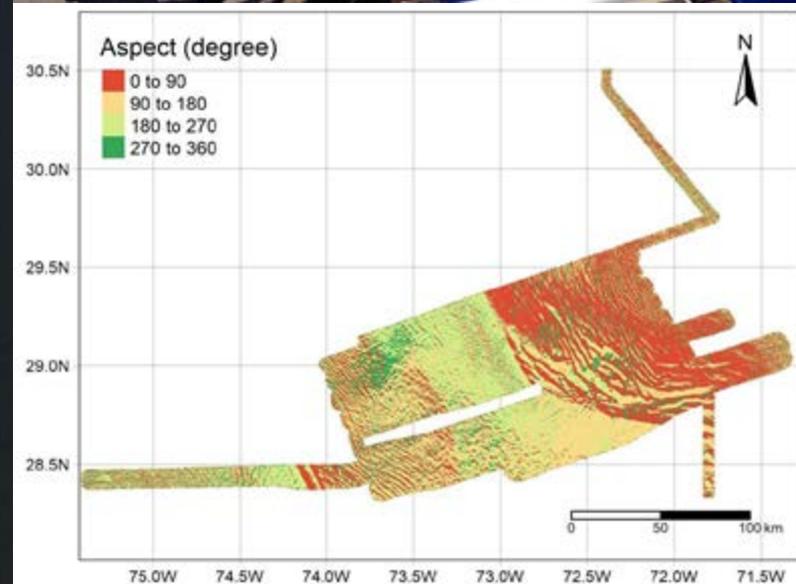
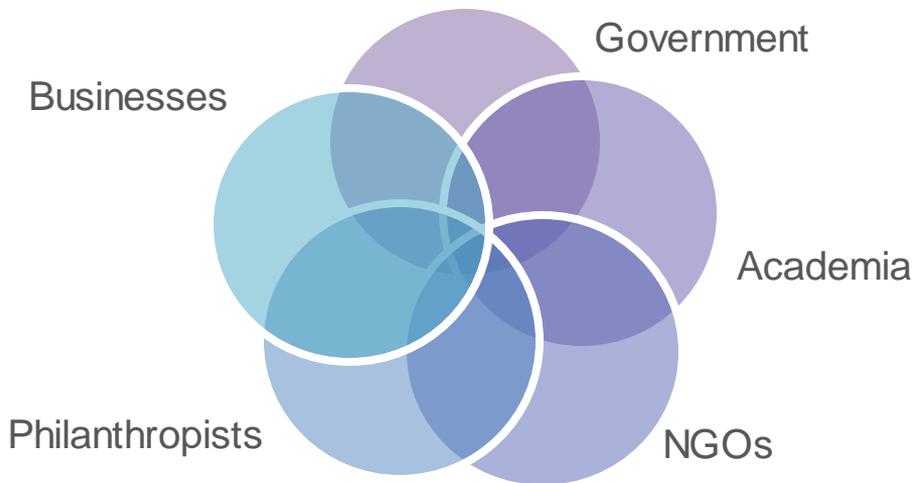
# OER Competitive Grants Program Impacts



Articles Per Year (as of July 2019)



# Evolving OER's Abilities to Explore and Characterize the Ocean





[OceanExplorer.NOAA.gov](http://OceanExplorer.NOAA.gov)



**Ocean Exploration  
and Research**

A blue robotic arm with a white corrugated hose is positioned over a diverse coral reef ecosystem. The reef is covered in various types of coral, including branching, table, and brain corals, along with other marine life like a red crab and a white fish. The scene is illuminated with a mix of natural and artificial light, creating a vibrant underwater environment.

# Advancing Technologies for Exploration

Chris Beaverson  
Science and Technology Division

# OCEAN EXPLORATION



Seafloor Mapping



Visual Surveys



Sampling



Inform traditional and renewable energy siting



Evaluate availability of critical minerals resources



Discover new species with biopharmaceutical/biotechnology potential



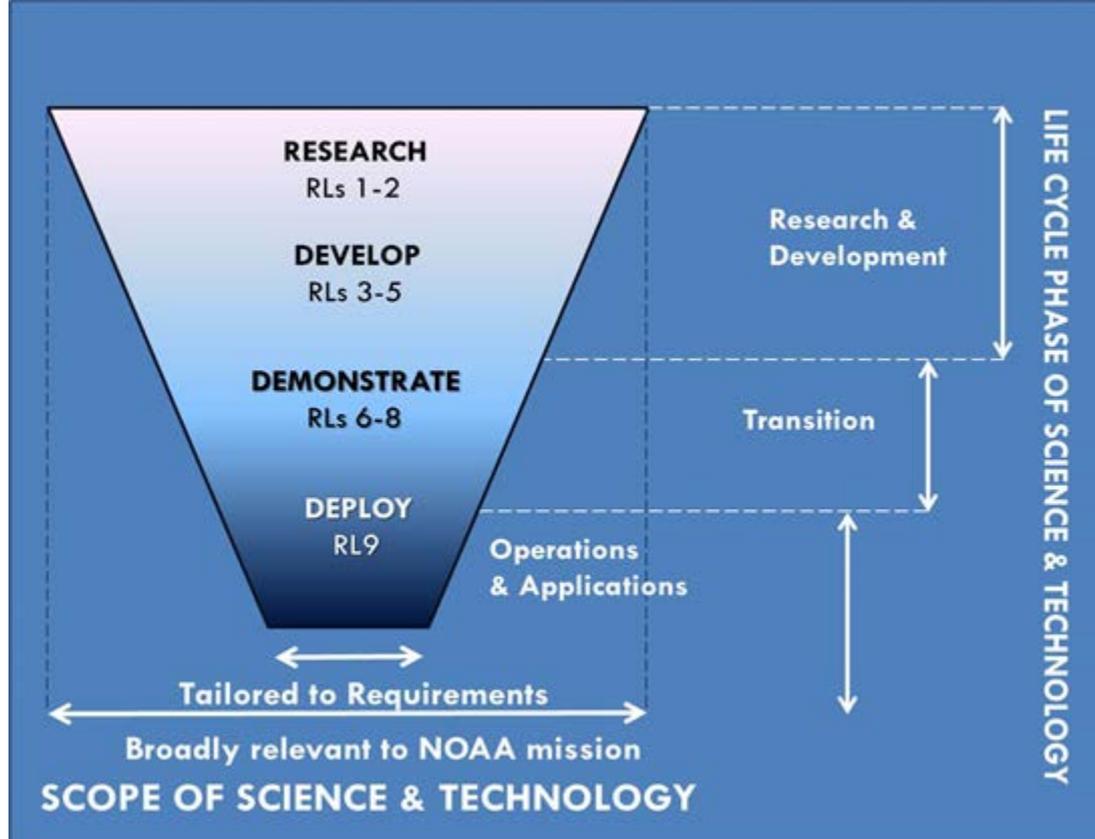
Assess populations and habitats of managed marine species



Drive innovation of novel technologies



Inspire and educate the next generation of STEM professionals



# Exploration Technology Priorities

## Strategic approach

- Transfer of new exploration and undersea research technology into applications
- Focus on testing/transfer of TRL 6+ ocean exploration technology
- Encourage partnerships for expertise and cost-sharing

	Capability gaps
1	Advanced sampling techniques and sensors
2	Power/batteries
3	Telepresence-enabled exploration and research
4	Under-ice exploration and sampling
5	Hadal > 4000m exploration and sampling
6	Advanced video imaging and processing (3D, mosaic, recognition)
7	Undersea vehicle autonomy and swarm behavior
8	Telemetry (through-water data transmission)
9	Ocean exploration data management technology
10	Outreach and engagement pathways

# OER Technology Investment Mechanisms

- Annual Federal Funding Opportunity
- Cooperative Agreements
  - Cooperative Institute for Ocean Exploration
  - Cooperative Institute for Ocean Exploration Research and Technology
  - Ocean Exploration Trust
  - Global Foundation for Ocean Exploration
- Interagency Partnerships – NOPP
- Cooperative Research and Development Agreements (CRADA)
- Small Business Incentive Research Program (SBIR)

# Technology Investments

## Community Assets

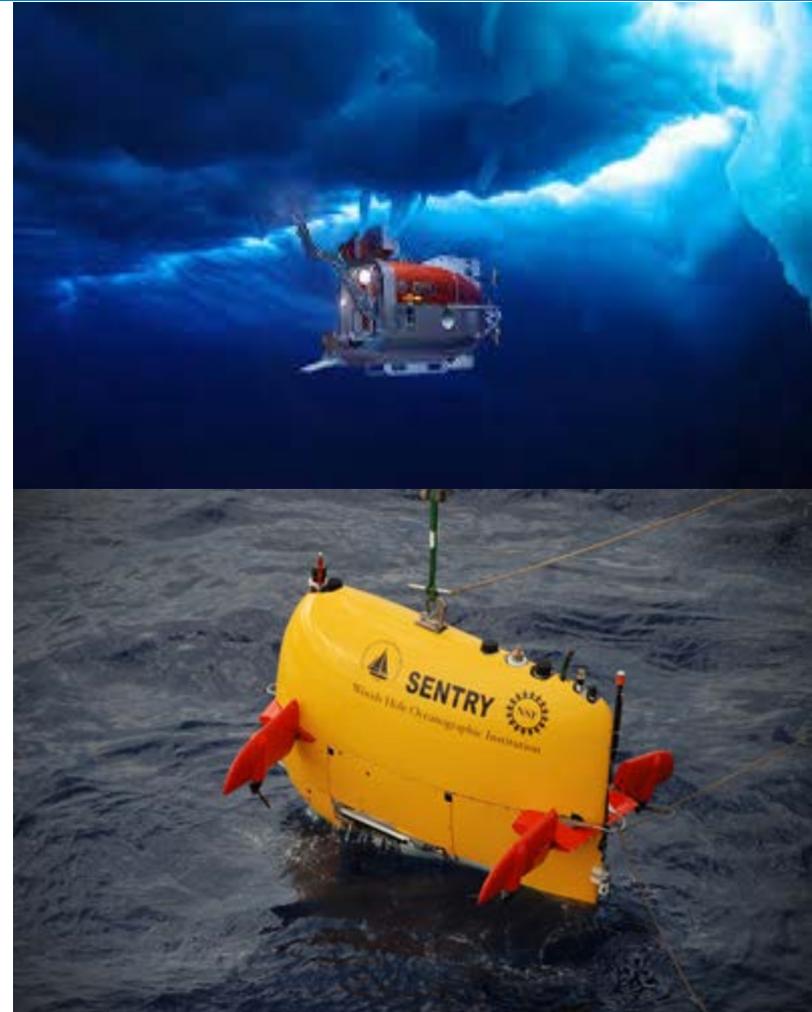
Nereid Under Ice, *Sentry*, NDSF

## Innovative Tools

Sensors, Platform applications

## Methods

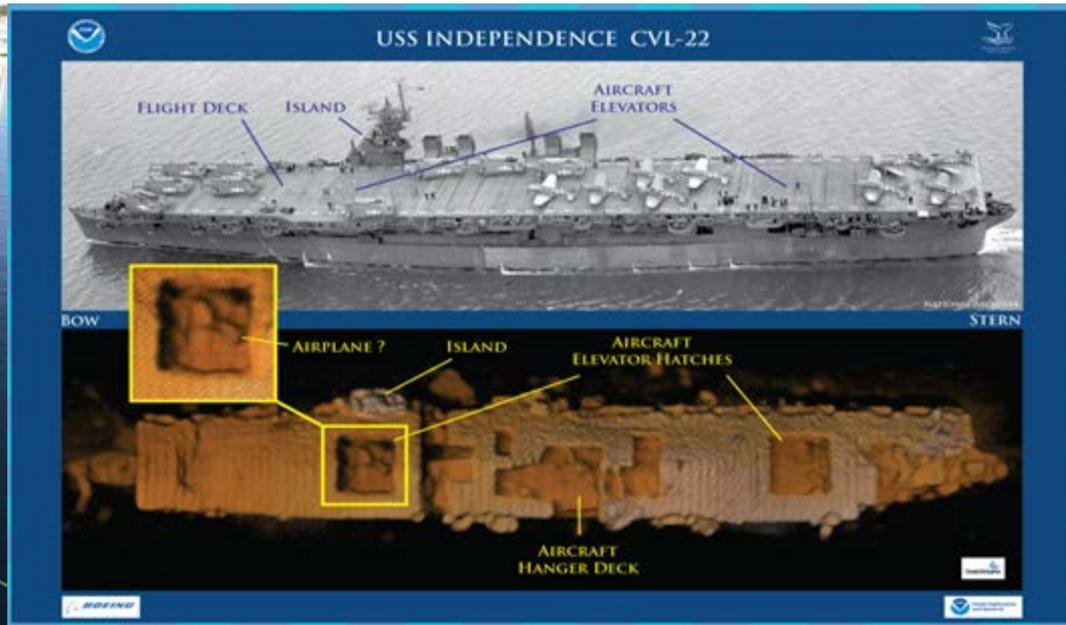
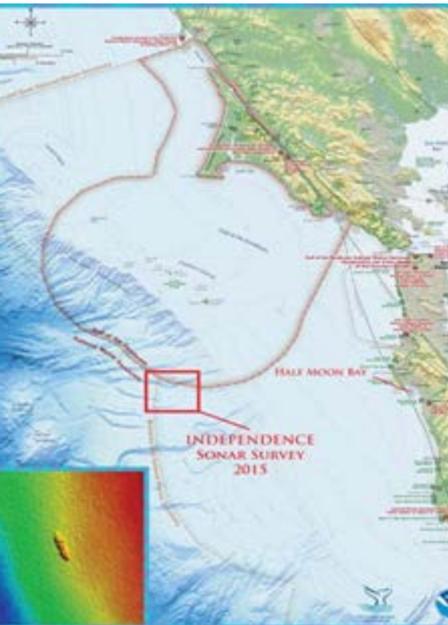
Data Analysis, Visualization



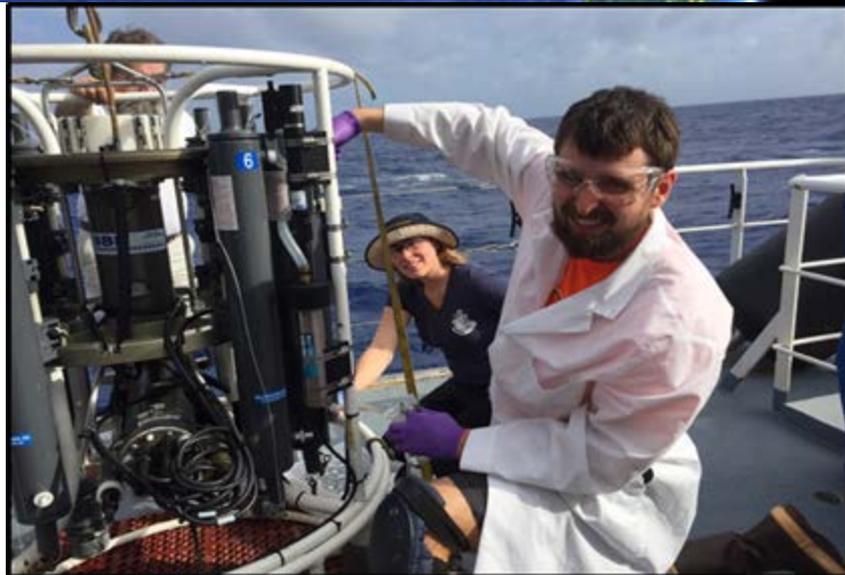
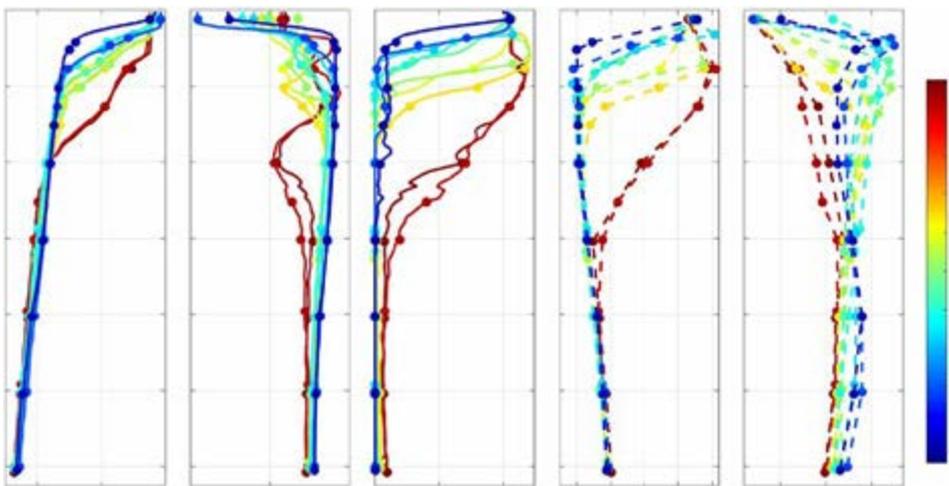
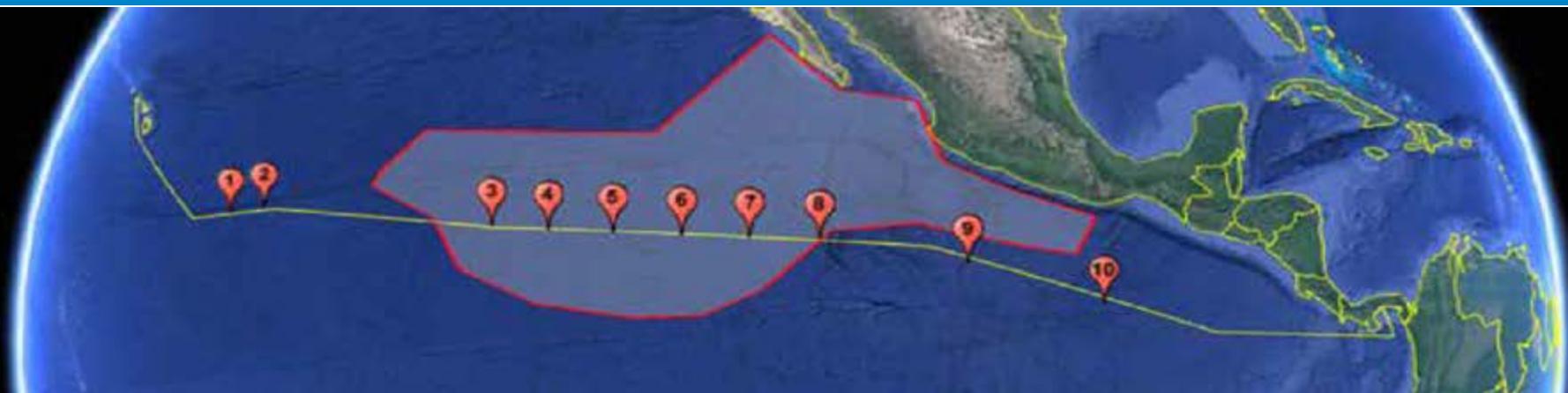
# AUV Demonstration

OER / Sanctuaries / BOEING / Coda Octopus USS *Independence*

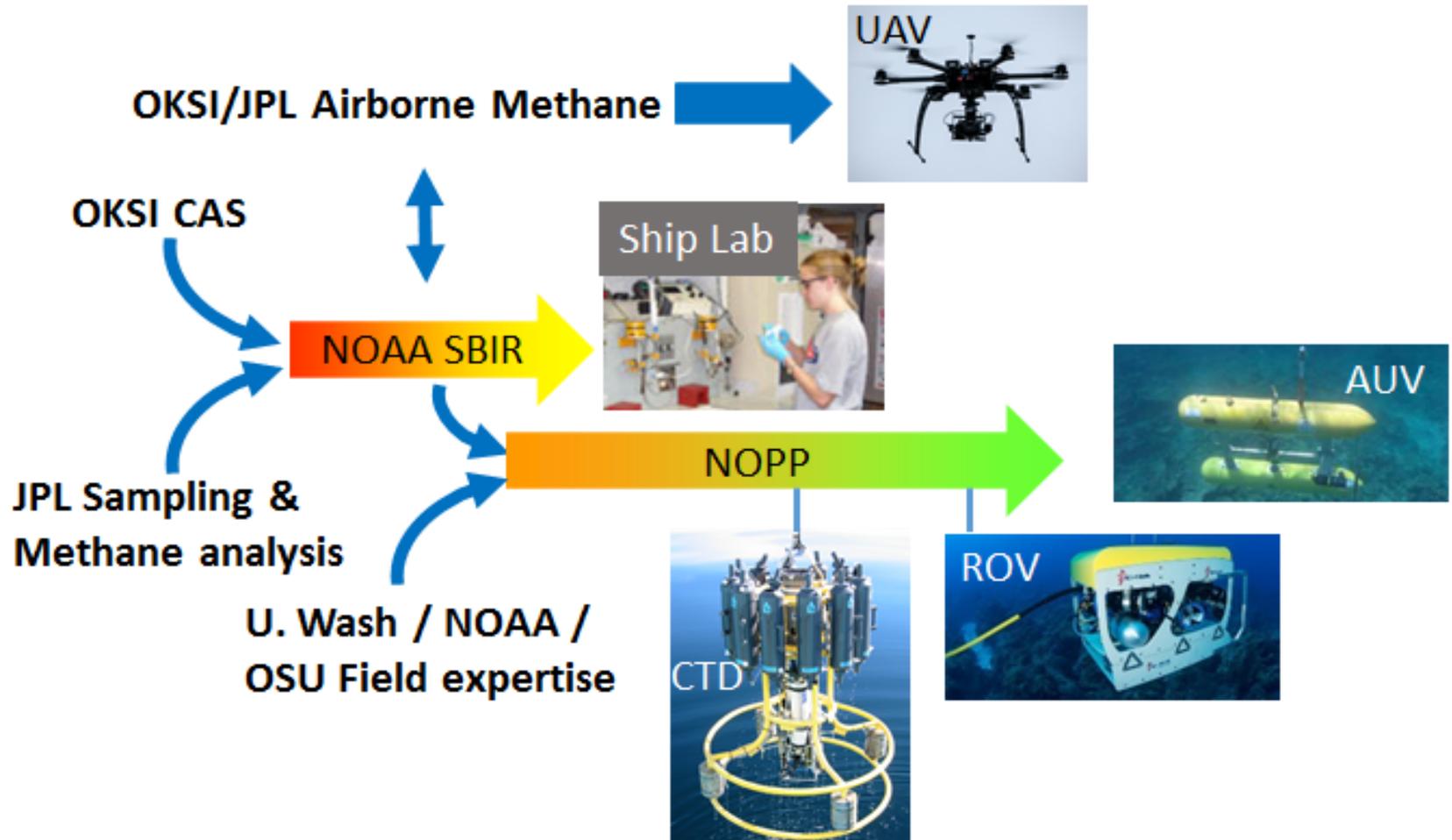
- CRADA
- Multi-partnership



# Nitrogen Sensor



# Isotopic Methane Sensor



# Prize Incentive



**Shell**  
OCEAN DISCOVERY **XPRIZE**<sup>®</sup>  
Getting to the Bottom of Our Ocean.

Ocean Mapping XPRIZE - NOAA \$1M Bonus Prize

# National Ocean Partnership Program



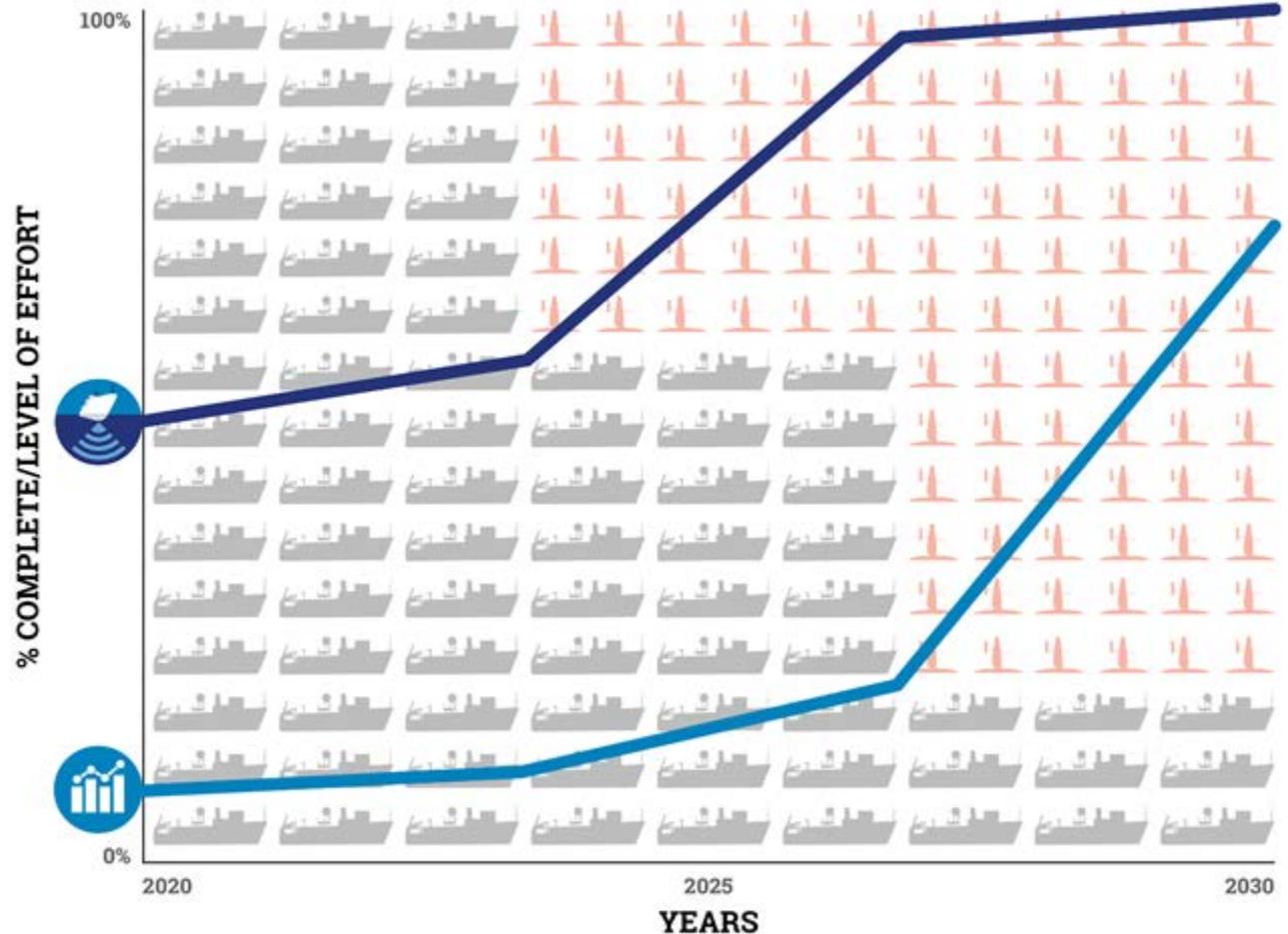
- **NOPP Broad Agency Announcement (BAA)**
  - ONR leads BAA process; Contributes \$6-8M
  - NOPP Agencies define solicitation topics
  - Partners bring money or other resources
- **NOPP Agencies Partner Outside BAA Process**
  - Partners agree on projects and level/type of support
  - Partners are generally federal and non-federal

# Autonomous systems to get us there



Mapping

Characterization

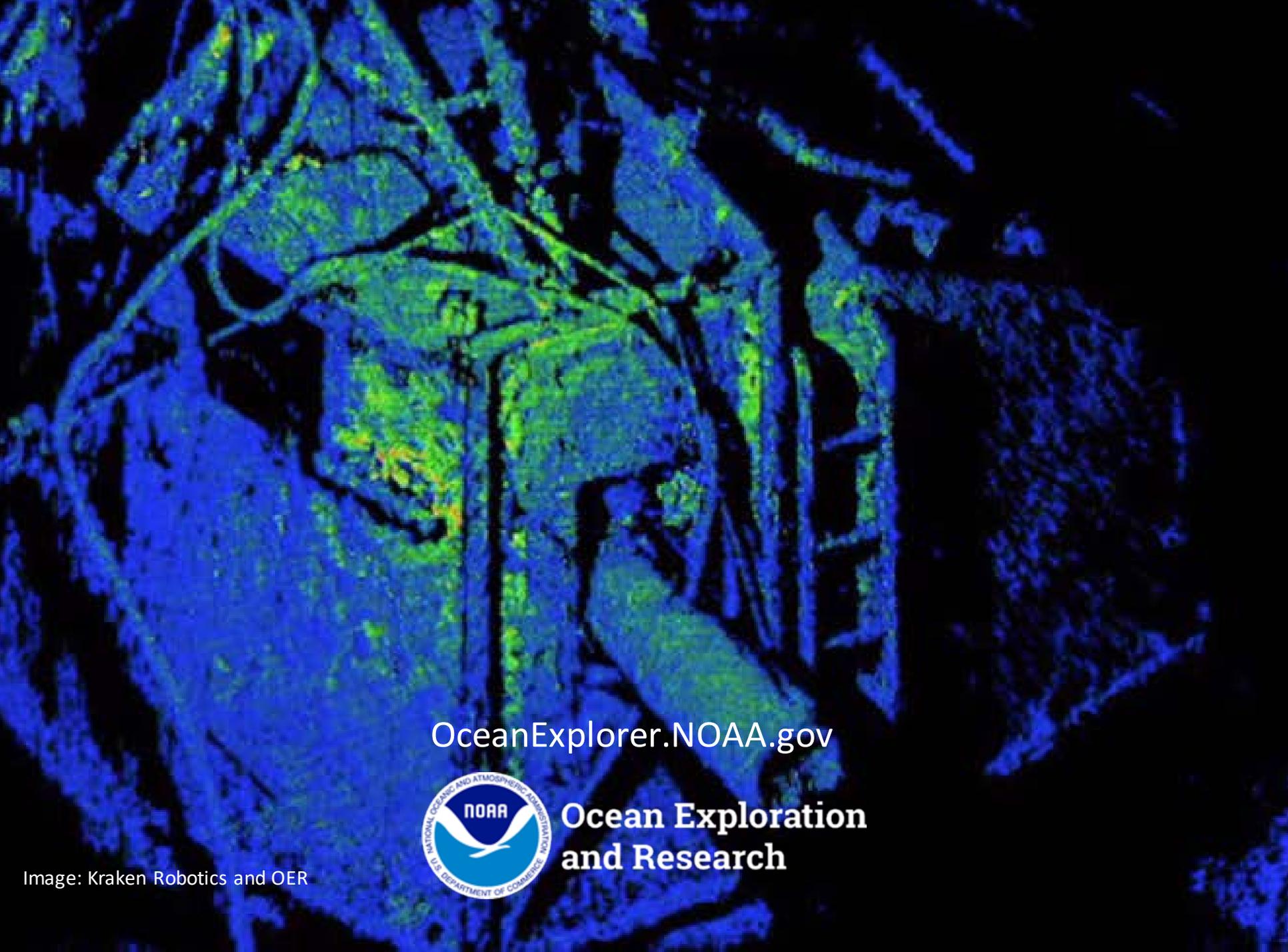


# FY19 Autonomous Mapping Awards

\$3M advancing autonomous mapping in the deep ocean

- OER leveraged \$1.5M of OAR NOPP funds
- 3 awards, three different platform types





[OceanExplorer.NOAA.gov](http://OceanExplorer.NOAA.gov)

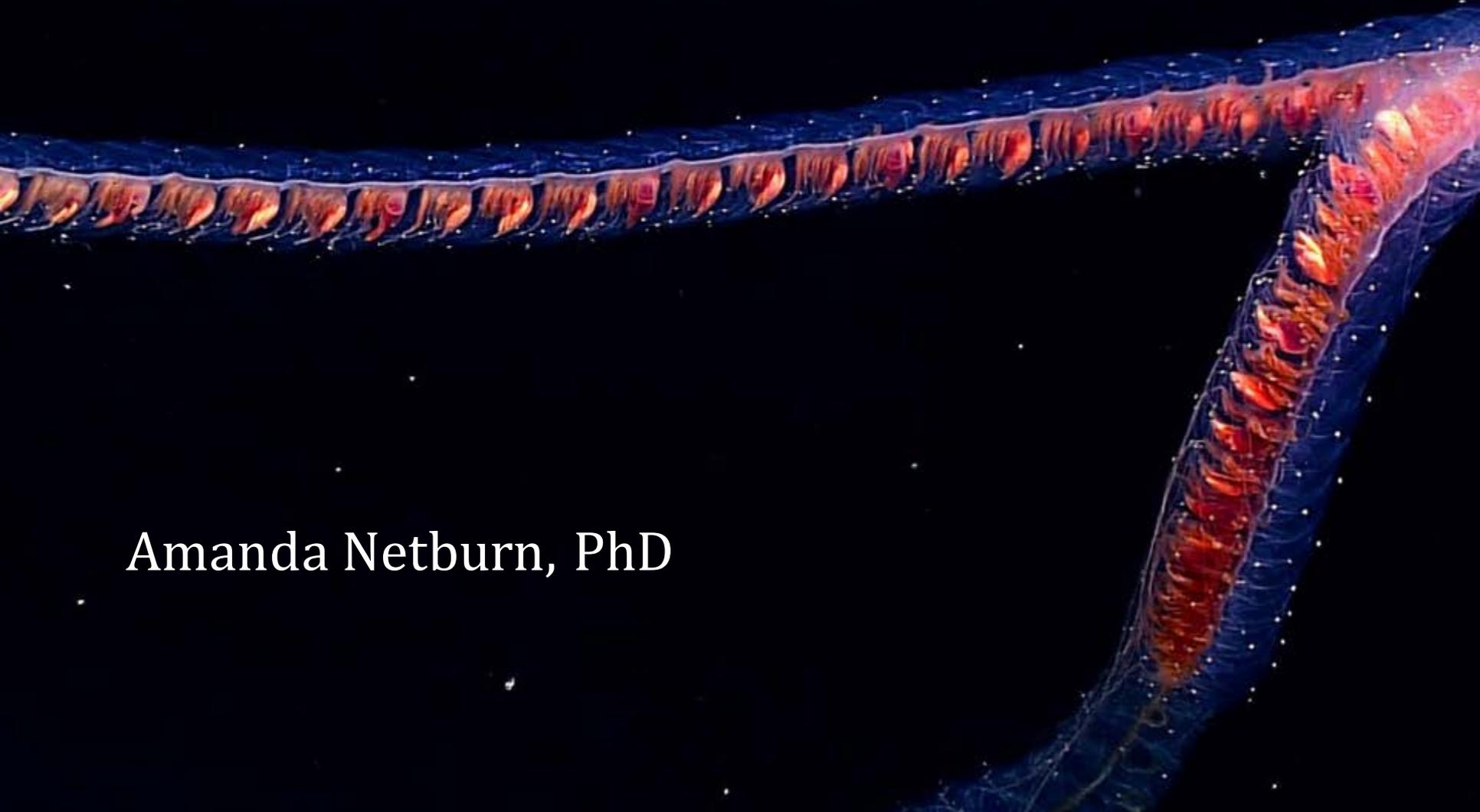


**Ocean Exploration  
and Research**

Image: Kraken Robotics and OER

# Ocean exploration in three dimensions: advancing water column exploration

Amanda Netburn, PhD



# Water column identified as gap



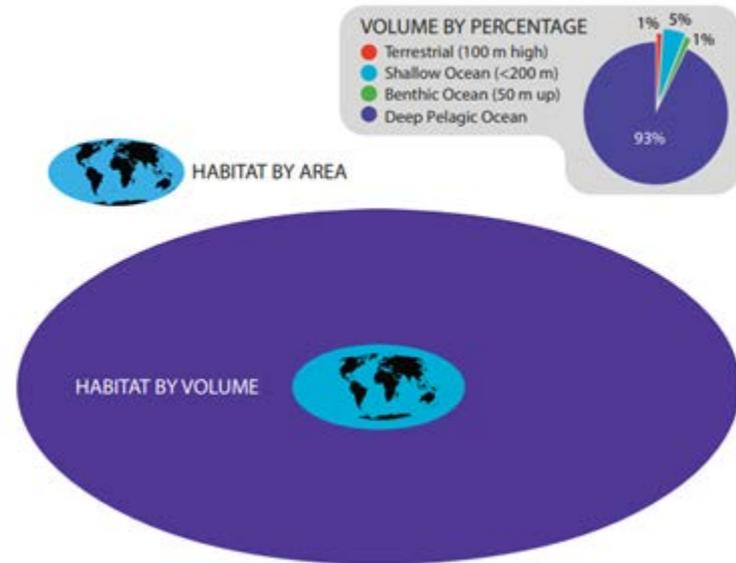
OE early focus on seafloor geology and biology



2013 and 2015 OE forums: water column identified as gap in program

# Why explore the water column?

- Largest inhabitable volume on the planet for multicellular life
- Important to: marine food webs, carbon sequestration, nutrient cycles, heat transfer



Haddock et al. 2017



# Why explore the water column?

- Gelatinous animals and behaviors are poorly observed by traditional means (e.g., trawls)
- Observations are rare throughout most of the ocean

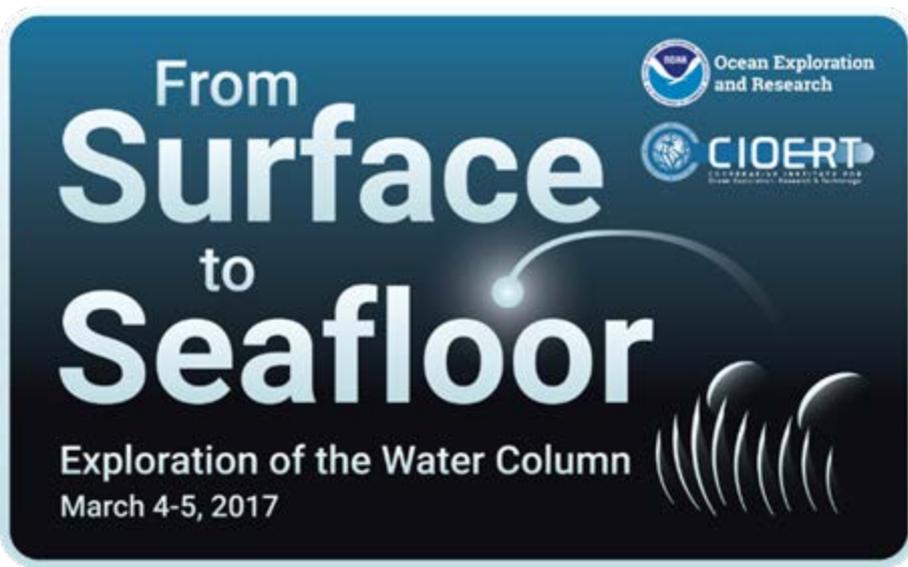


# 2017 Water Column Workshop

47 participants

25 institutions and programs

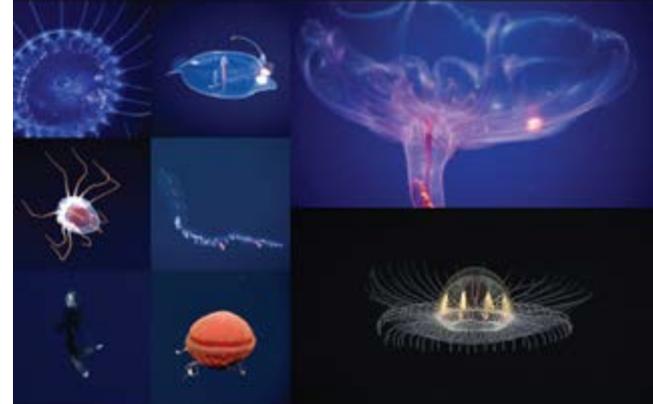
Multidisciplinary and international



# Workshop Outcomes

1. Review of past efforts
2. Identified unanswered questions
3. Recommendations
  - a. Geographic priorities
  - b. Community building
  - c. Opportunistic data collection
  - d. Technology development- Animals as sensor platforms and as sensors, Moorings for long-term monitoring (temporal recon), Autonomous systems to cover ground

From  
**Surface**  
to  
**Seafloor**  
Exploration of the Water Column  
March 4-6, 2017



U.S. Department of Commerce  
National Oceanic and Atmospheric Administration  
Oceanic and Atmospheric Research  
Ocean Exploration and Research

NOAA Technical Memorandum OAR OER, 003  
June 2018  
DOI: <https://doi.org/10.25923/tpjx-vv79>



# Recommendations: Use a “Toolbox”



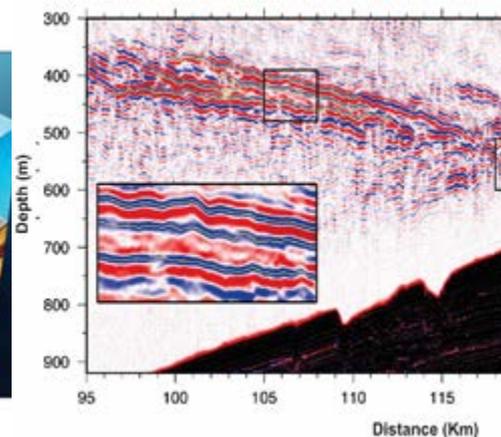
	Measurement	Platform/Sensor/Sample Type Required
<b>Physical/Chemical</b>		
<b>First tier</b>	Basic Hydrography- temperature, density, salinity, oxygen	CTD with oxygen sensor
	Chla Fluorescence	Fluorometer
	Bathymetry	Multibeam sonar (1st), Side Scan sonar (2nd)
	Irradiance/Light scattering	Light scattering sensor
	Light Transmission	Transmissometer
	Ocean color, SSH, temp, etc.	Imaging satellites
<b>Second tier</b>	Macro- and micronutrients/metals	Water
	DIC, POC/POM, pH/alkalinity	Water
	Dissolved gases	Water
	Currents	Acoustic Doppler Current Profiler (ADCP)
	Methane	Water
	Hydrogen	Water
	Resuspended sediment	Video, Water, Transmissometer
	Small-scale turbulence	Aquadopp® Profiler
<b>Biological - single cell</b>		
<b>First tier</b>	Genomics	Water, Tissue samples
	Single-cell imaging/sorting	Flow Cytometer
<b>Second tier</b>	ChlA/accessory pigments	Water
	Biological rates	Water
<b>Biological - multicellular</b>		
<b>First tier</b>	Specimens for physiology, morphological ids, genomics	Net trawls (mult. sizes), including optical tools
		ROV for fragile organisms
	In situ imaging	ROV, AUV (e.g., i2MAP), Low-light imaging, Microscopy
		Video Plankton Recorder, In Situ Ichthyoplankton Imaging System
<b>Second tier</b>	High resolution biological "mapping"	Active acoustics
	Bulk biodiversity	eDNA/Metabarcoding- from split net tow and water samples
	Food web analysis	Animal specimens (ROVs, nets)
	Biological rates	Animal specimens (ROVs, nets)
	Tracking of large animals	Hydrophone, Surface observations (megafauna)
	Bioluminescence	Splat screen, Low light camera, Photometers
	In situ responses	In situ experiments- light, metabolism, predation, flux

# Competitive grants – Water column theme (FY17)

Journey into Midnight: Light & Life  
Below the Twilight Zone



3D “Seismic Oceanography”: The New Frontier  
in Ocean Water-Column Exploration

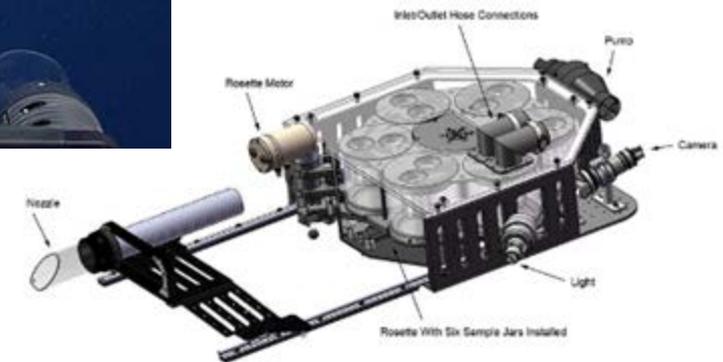
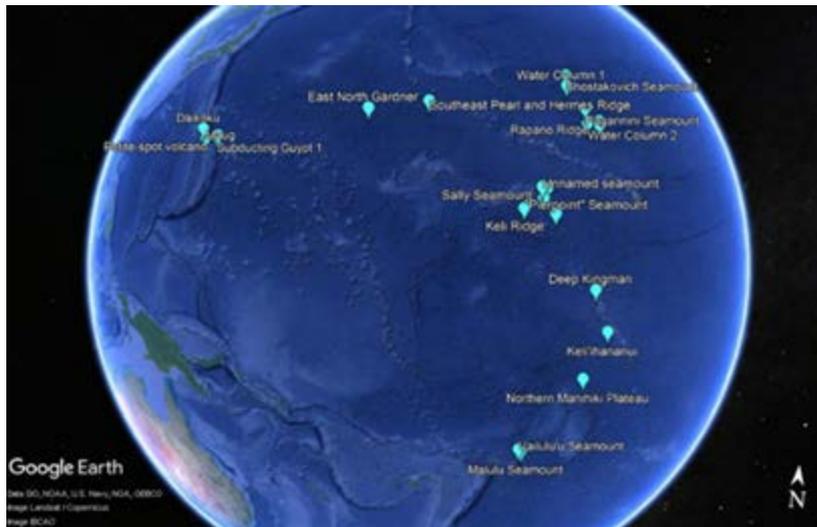


Integrating Echosounding into the  
Wire Flyer Profiling Vehicle



# Exploratory water column ROV transects

- 2013 - first midwater ROV survey on *Okeanos*
- Now typically 3-5 sites per expedition
- New capability to collect midwater animals



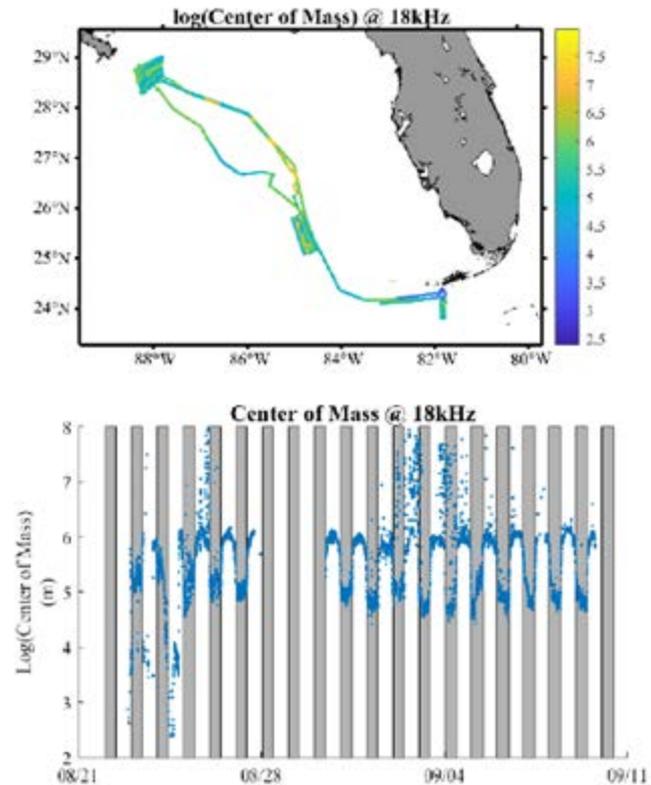
# NOAA Ship *Okeanos Explorer* EK60 Optimization Workshop (Sept. '17)

## Recommendations & Outcomes:

- Calibrate based on fisheries standards
- Solicit input for water column surveys in expedition planning
- NCEI partnership for data visualization

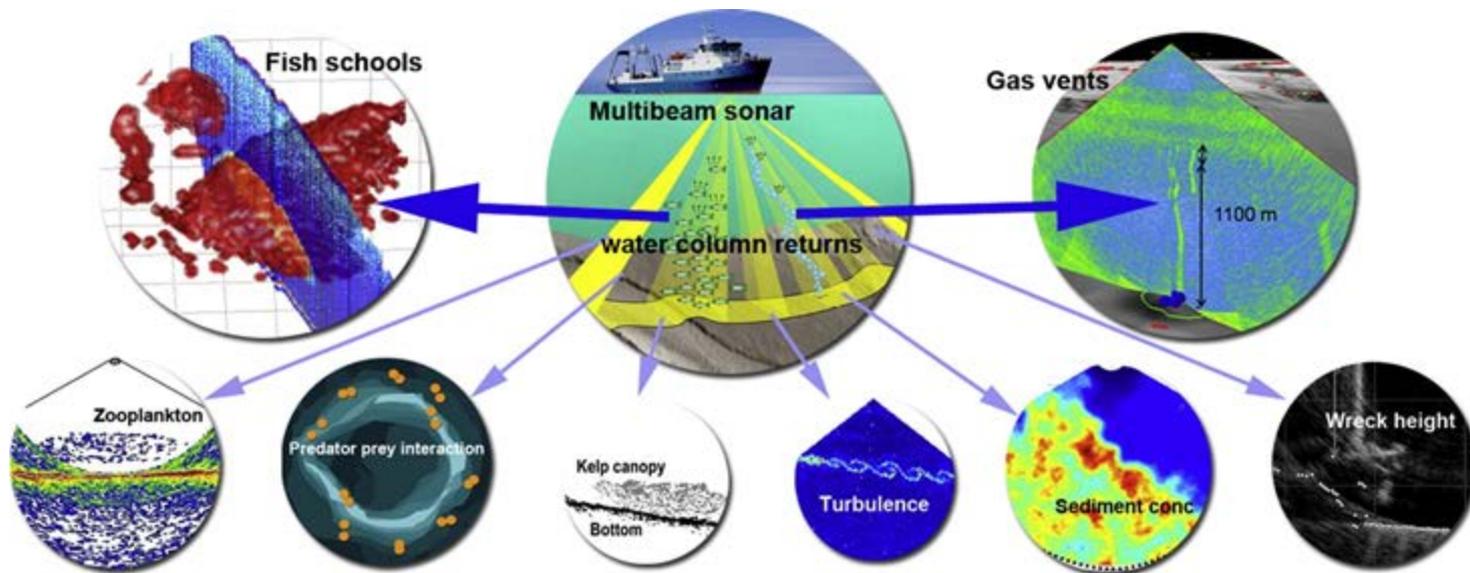


NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION



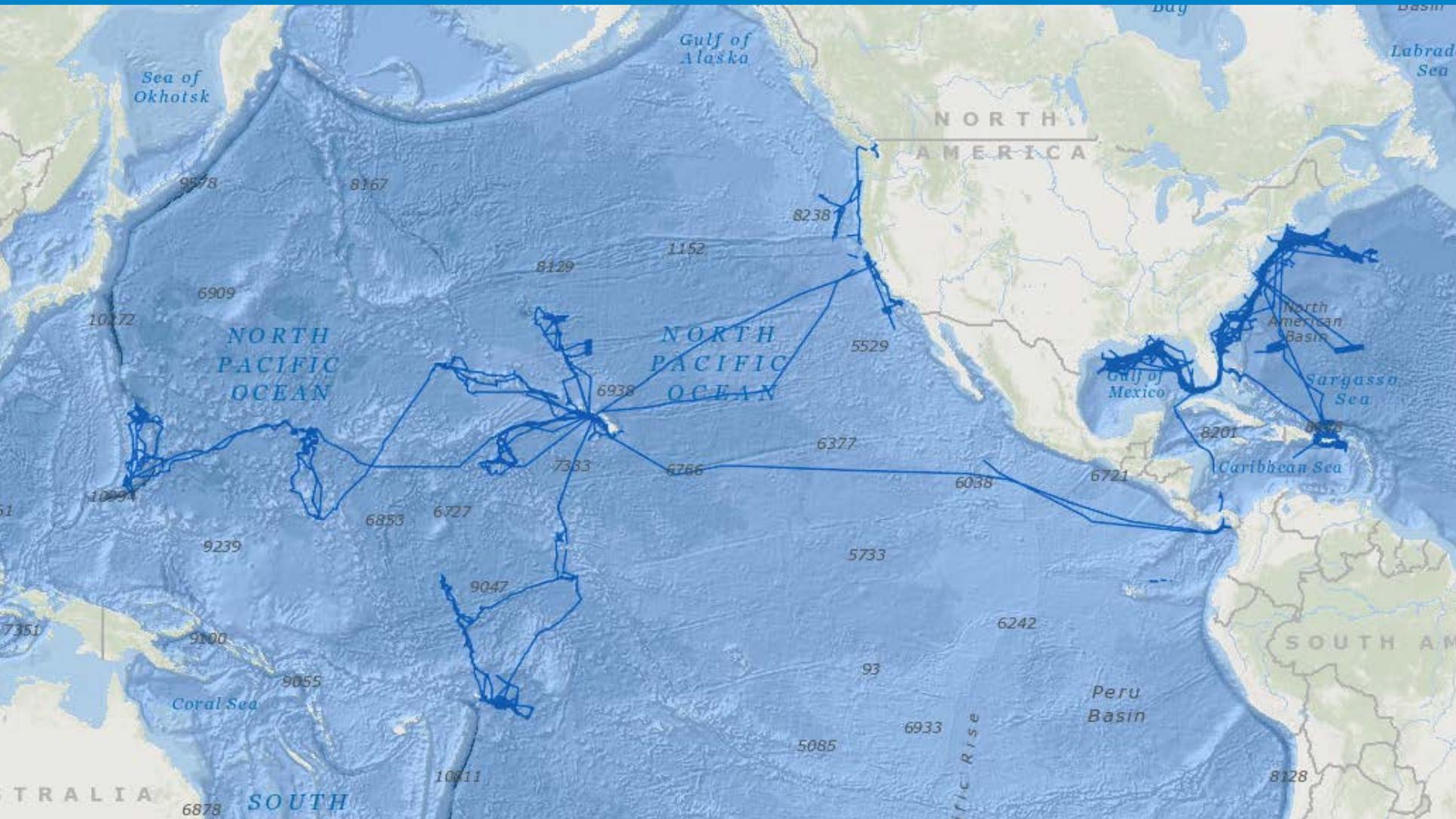
# NOAA Ship *Okeanos Explorer* water column sonar

- Simrad EK60/EK80: GPTs (18, 120, 200 kHz) and WBTs (38 and 70 kHz)
- Kongsberg EM302 Multibeam



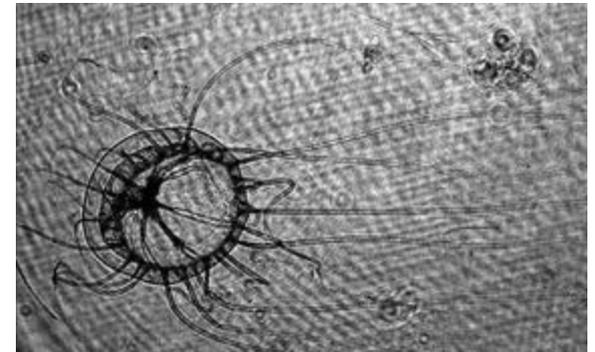
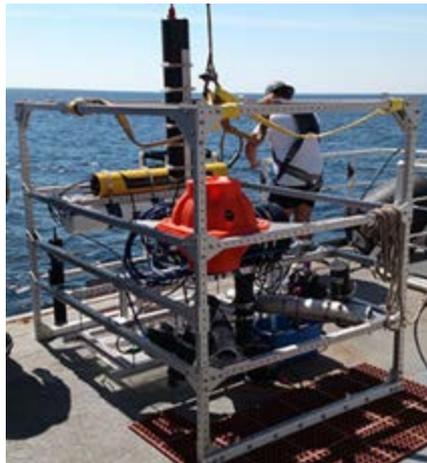
Calbo et al. 2014

# >8 TB water column sonar data in data archive



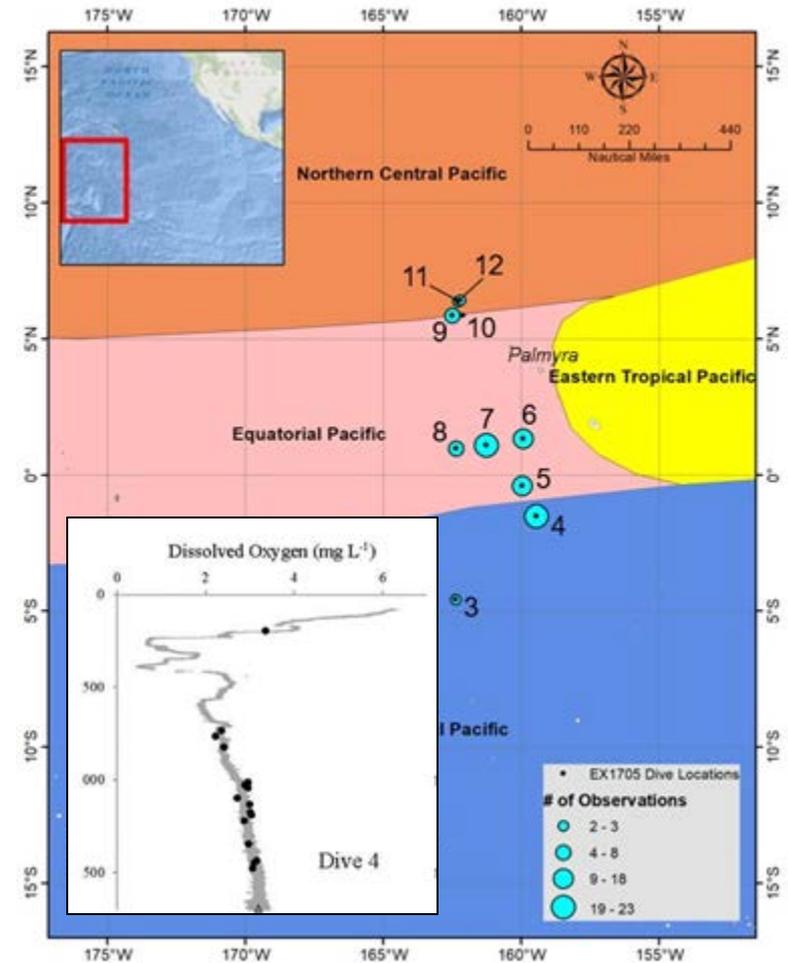
# *Okeanos Explorer* Technology Demonstration

- Spring 2018 in the Gulf of Mexico
- CIOERT/FAU Midwater Profiler
- Multi-scale imaging/acoustics

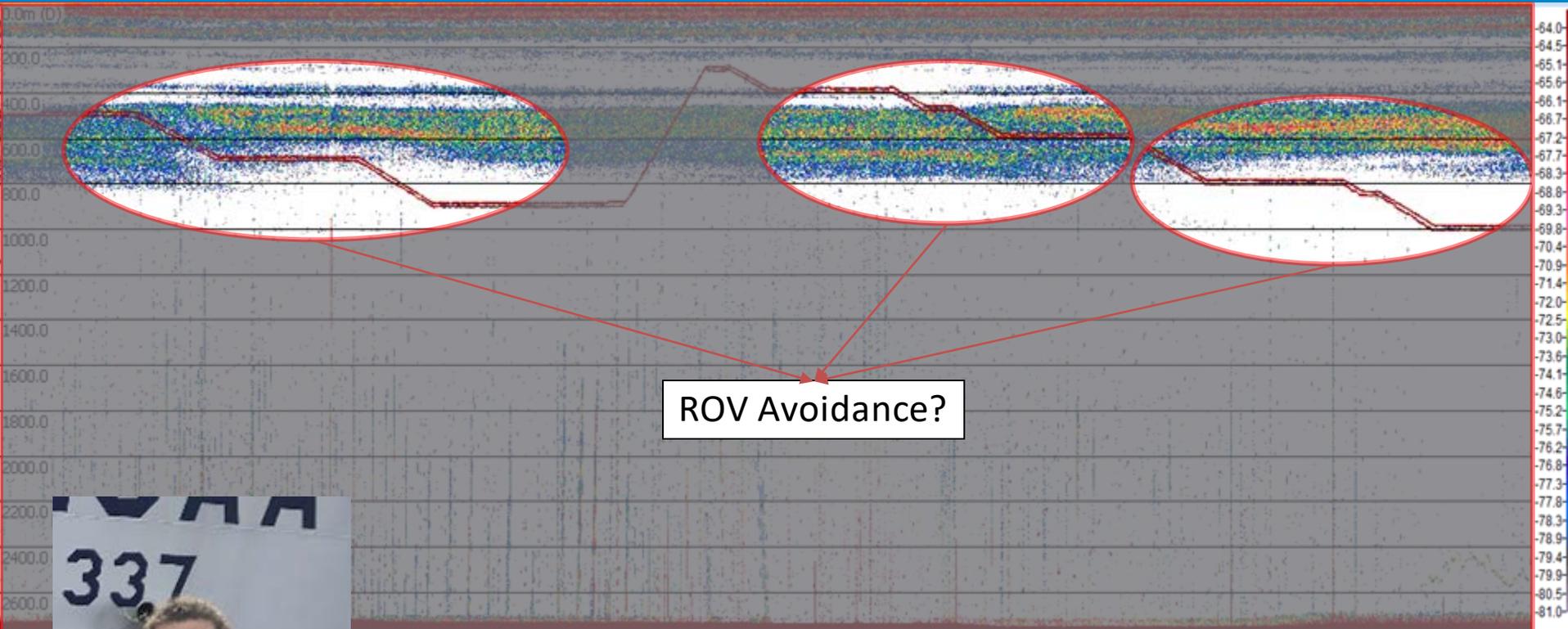


# Data Synthesis

- EPP/MSI Scholar -2018
- Distributions of *Pelagothuria* in the central Pacific ocean



# ROV Avoidance



Herbert Leavitt  
Eckerd College

- 2018 Hollings Scholar



[OceanExplorer.NOAA.gov](http://OceanExplorer.NOAA.gov)



**Ocean Exploration  
and Research**



Deep-sea data needs, measurements, and  
gaps for characterizing the U.S. EEZ

Katharine Egan  
Knauss Fellow



## ROV OPERATIONS

		HD VIDEO WITH LASERS FOR SCALE	ANNOTATIONS	DIVE SUMMARY FORM	DIVE PLANNING FORM	PRIMARY BIOLOGICAL SAMPLES	PRIMARY ROCK SAMPLES	ASSOCIATED BIOLOGICAL SAMPLES	ROV NAVIGATION	CTD	TURBIDITY & OXIDATION REDUCTION POTENTIAL
<b>FREQUENCY OF OPERATION</b>		ROV cruises only	ROV cruises only	ROV cruises only	ROV cruises only	ROV cruises only	ROV cruises only	ROV cruises only	ROV cruises only	ROV cruises only	ROV cruises only
<b>COLLECTION RATE DURING OPERATION</b>		continuous (turned off for close-up imaging)	variable	1/dive	1/dive	≤8/dive	≤3/dive	variable	1/sec	continuous	continuous
<b>WATER COLUMN</b>	BIOLOGICAL	X	X	X	X	X		X	X	X	X
	CHEMICAL/PHYSICAL							X	X	X	X
<b>SEAFLOOR/SUB-SEAFLOOR</b>	BIOLOGICAL	X	X	X	X	X	X		X	X	X
	CHEMICAL/PHYSICAL	X		X			X		X	X	X
	GEOLOGICAL	X	X	X	X		X	X	X	X	X
	ARCHAEOLOGICAL	X	X	X	X	X			X	X	X



## MAPPING OPERATIONS

		XBT	MULTIBEAM BATHYMETRY/BACKSCATTER	SUBBOTTOM PROFILER	EK60/EK80
<b>FREQUENCY OF OPERATION</b>		every cruise	every cruise	every cruise	every cruise
<b>COLLECTION RATE DURING OPERATION</b>		2 - 6 hours	continuous	continuous	continuous (based on sonar frequency)
<b>WATER COLUMN</b>	BIOLOGICAL		X		X
	CHEMICAL/PHYSICAL	X	X		X
<b>SEAFLOOR/SUB-SEAFLOOR</b>	BIOLOGICAL				
	CHEMICAL/PHYSICAL		X	X	X
	GEOLOGICAL		X	X	X
	ARCHAEOLOGICAL		X	X	



## CTD ROSETTE OPERATIONS

		CTD ROSETTE SUMMARY FORM	CTD-O	TURBIDITY & OXIDATION REDUCTION POTENTIAL AND FLUOROMETER	WATER SAMPLES
<b>FREQUENCY OF OPERATION</b>		if requested	if requested	if requested	if requested
<b>COLLECTION RATE DURING OPERATION</b>		1/cast	continuous	continuous	≤12/cast
<b>WATER COLUMN</b>	BIOLOGICAL		X	X	X
	CHEMICAL/PHYSICAL	X	X	X	X

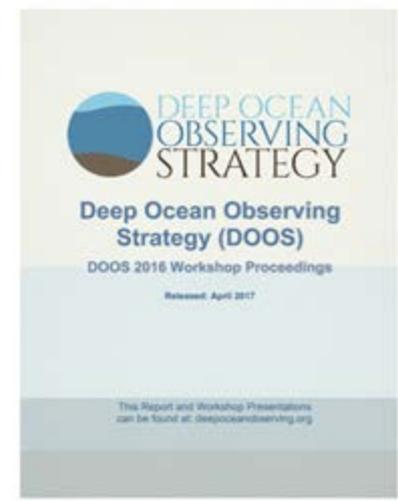
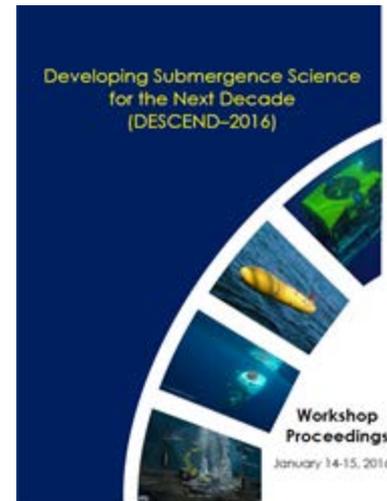


## SHIP-BASED MEASUREMENTS

		METOC SENSORS	THERMOSALINOGRAPH	ADCP
<b>FREQUENCY OF OPERATION</b>		every cruise	every cruise	every ROV cruise; if requested on other cruises
<b>COLLECTION RATE DURING OPERATION</b>				every ROV dive; As request
<b>ATMOSPHERE</b>	BIOLOGICAL			
	CHEMICAL/PHYSICAL	X	X	
<b>WATER COLUMN</b>	BIOLOGICAL			
	CHEMICAL/PHYSICAL			X

# Data Gaps - Identified through community recommendations

Literature review conducted of published community reports synthesizing deep-ocean data needs



# Data Gaps

- A list of observation types was compiled meeting the following criteria:
  - A deep-sea observation was identified as critical to measure
  - That measurement is not currently collected by OER
- Reports were also assessed for overlapping measurements (i.e. a measurement appeared in more than one report).

# Data Gaps

- Total: **53 data gaps** identified
- Ten data gaps were identified in three or more community reports



## DATA GAPS

		INORGANIC MACRONUTRIENTS, NITRATE/NITRITE, SILICATE, PHOSPHATE	MICROBIAL BIOMASS AND DENSITY	PHYTOPLANKTON & ZOOPLANKTON BIOMASS AND DIVERSITY	SUSPENDED PARTICULATES, PARTICULATE ORGANIC MATTER, DISSOLVED ORGANIC CARBON	DISSOLVED INORGANIC CARBON	OCCURRENCE AND DISTRIBUTION OF LARGE MARINE VERTEBRATES	PH, ALKALINITY, REDOX	FLUXES: GEOTHERMAL, BOTTOM BOUNDARY, PARTICULATE, SEDIMENT, NUTRIENTS	BULK BIODIVERSITY	MICROPLASTIC ABUNDANCE AND DIVERSITY
NUMBER OF REPORT MENTIONS		5	5	5	4	3	3	3	3	3	3
WATER COLUMN	BIOLOGICAL		X	X			X			X	
	CHEMICAL/PHYSICAL	X			X	X		X	X		X
SEAFLOOR/ SUB-SEAFLOOR	BIOLOGICAL		X							X	
	CHEMICAL/PHYSICAL							X			X
	GEOLOGICAL							X			



# Feasibility Assessment

- Used to evaluate the feasibility of incorporating new measurements, instruments, or processes into OER standard operations to fill data gaps
- Assessments are completed in consultation with experts in that field

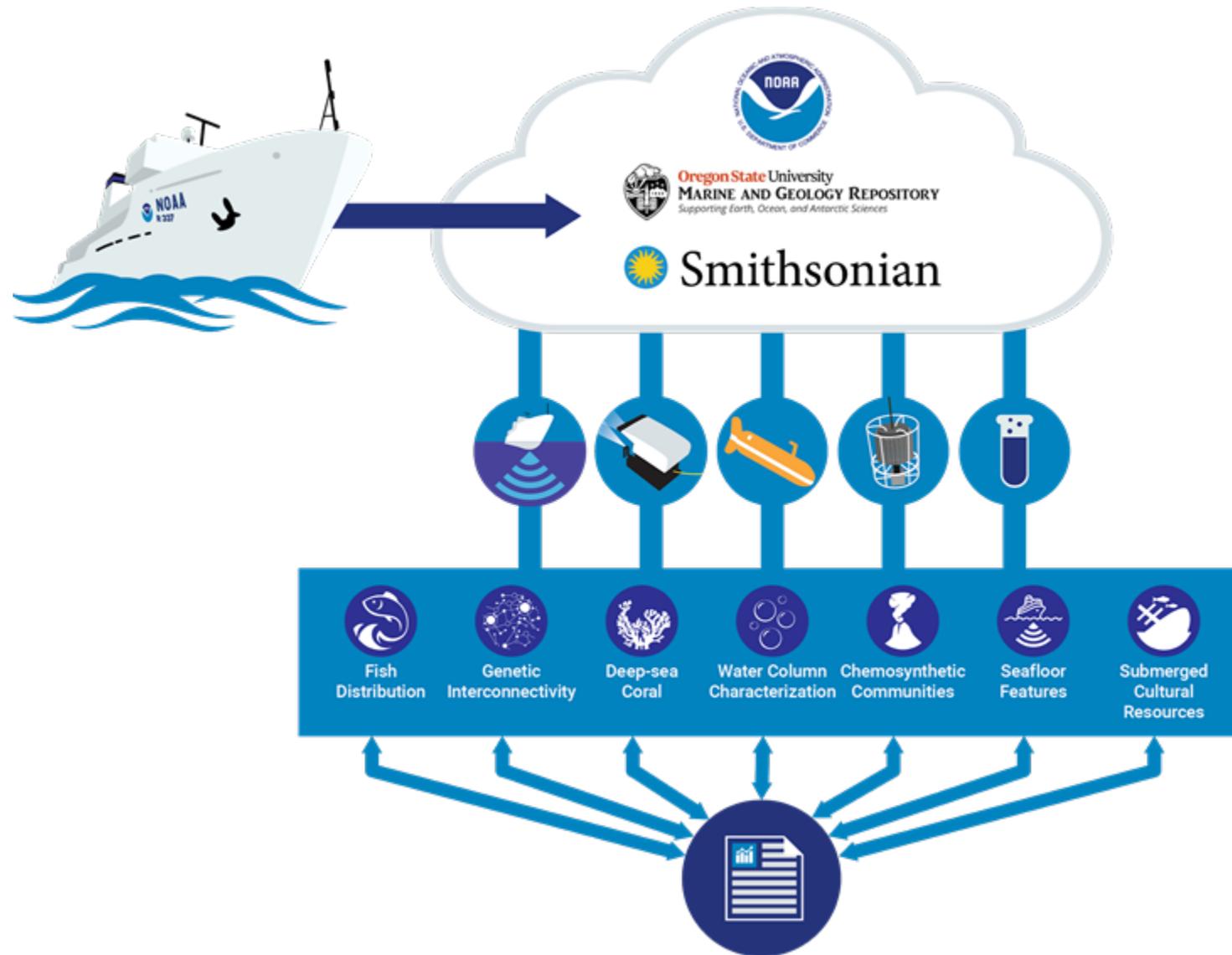
# Feasibility Assessment

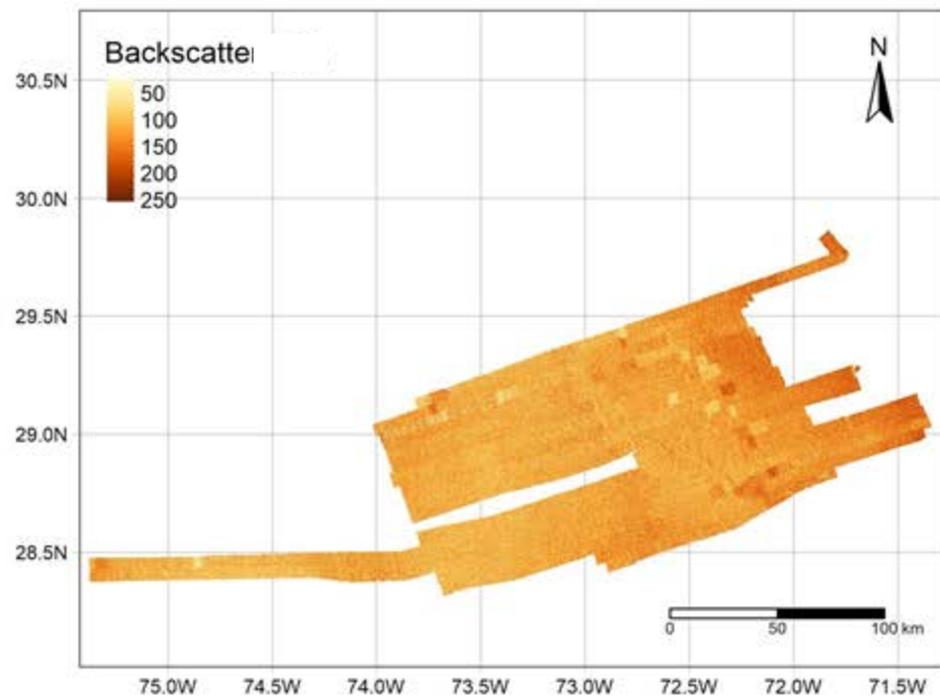
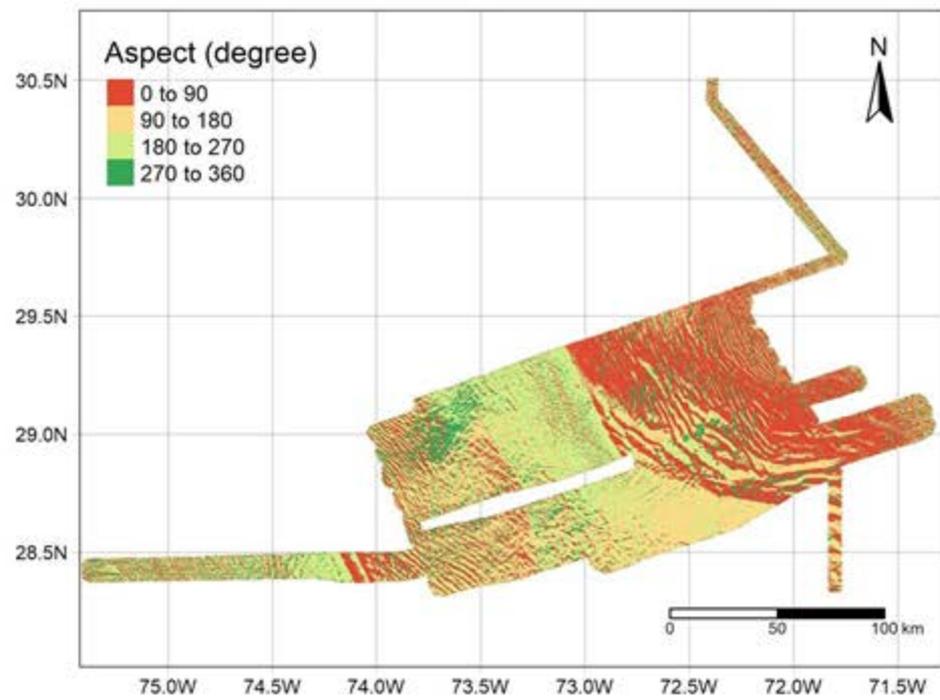
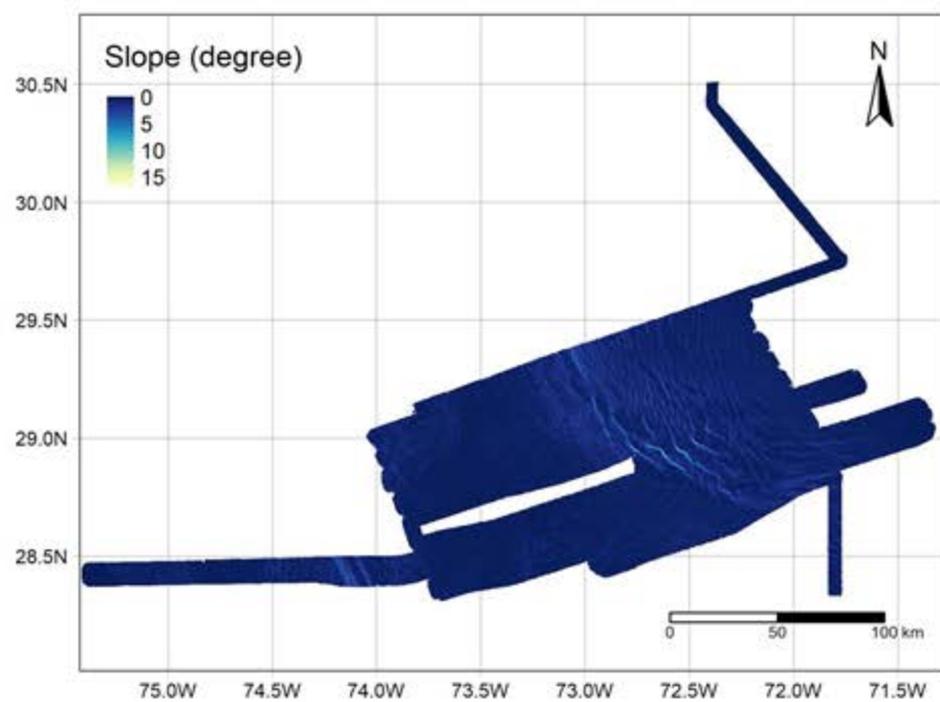
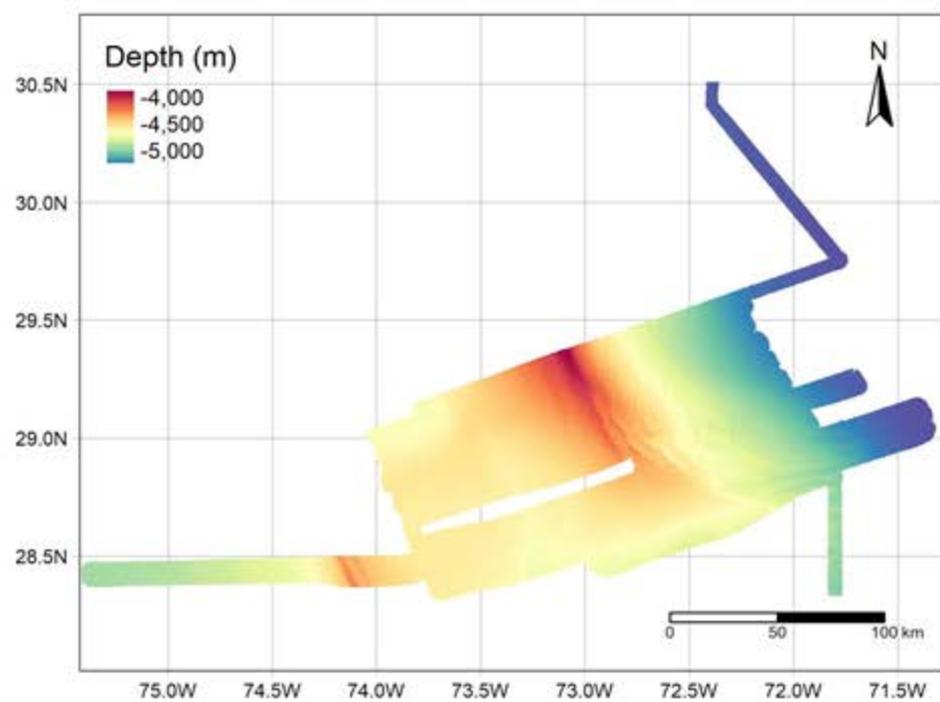
- Background and justification
- Relevance to NOAA and OER missions/strategic goals
- Materials
- Methods
- Cost
- Personnel
- Time
- Data management, processing, accessibility, summaries
- Permitting
- Environmental risk

# Feasibility Assessment: eDNA

- Equipment to collect water samples and lab space on the EX is adequate for filtering samples.
- Personnel time and identifying a repository to store the samples or conduct the analysis remain challenges.
- Team is making recommendations based on the assessment.

# Data Synthesis



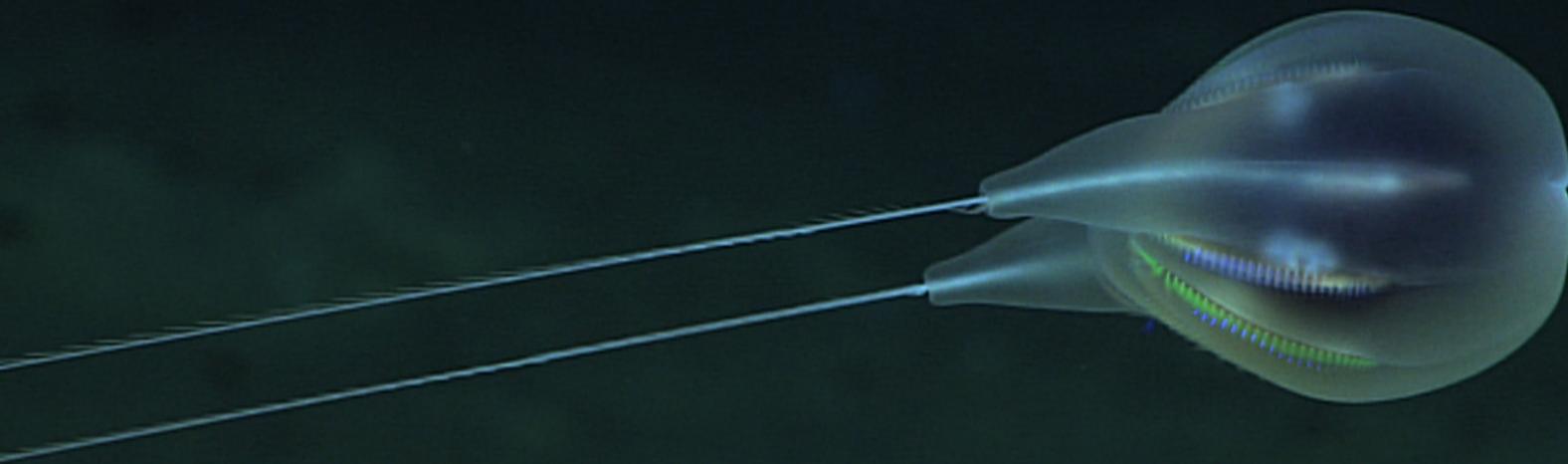


# Questions?

[OceanExplorer.NOAA.gov](http://OceanExplorer.NOAA.gov)



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