

SUBSEA



- Funded July 2017 by NASA SMD ROSES-2016 Program Element C.14 Planetary Science and Technology Through Analog Research (PSTAR)
- In-Kind support from NOAA OER and OET

PRESENTING: Drs. Darlene Lim (NASA Ames) & Chris German (WHOI)

Systematic Underwater Biogeochemical Science and Exploration Analog

SUBSEA team





SUBSEA research



Science – SUBSEA is anchored by a Science program that will both:

1. Broaden our understanding of the potential habitability of other Ocean Worlds in our Solar System, and
2. Characterize novel deep sea environments on our own planet.

Science Operations: SUBSEA will leverage the high-fidelity Low-Latency Telerobotics analog environment of the *Nautilus* tele-presence mission architecture and the real (non-simulated) SUBSEA science activities to evaluate and identify specific concepts of operations (ConOps) and capabilities that will have enabling and enhancing value for science-driven LLT exploration of Deep Space and Mars

Technology: SUBSEA will use prototype information technologies that will be evaluated and iterated upon based on their ability to support science-driven LLT operations. We will achieve this by integrating our Exploration Ground Data Systems (xGDS) software with *Nautilus* telepresence mission support systems, and then systematically evaluating the technology during our SUBSEA field campaigns. xGDS will provide human/robotic software functionality to support integration and visualization of diverse data products relevant to future human exploration of deep space.



SUBSEA IMPACT

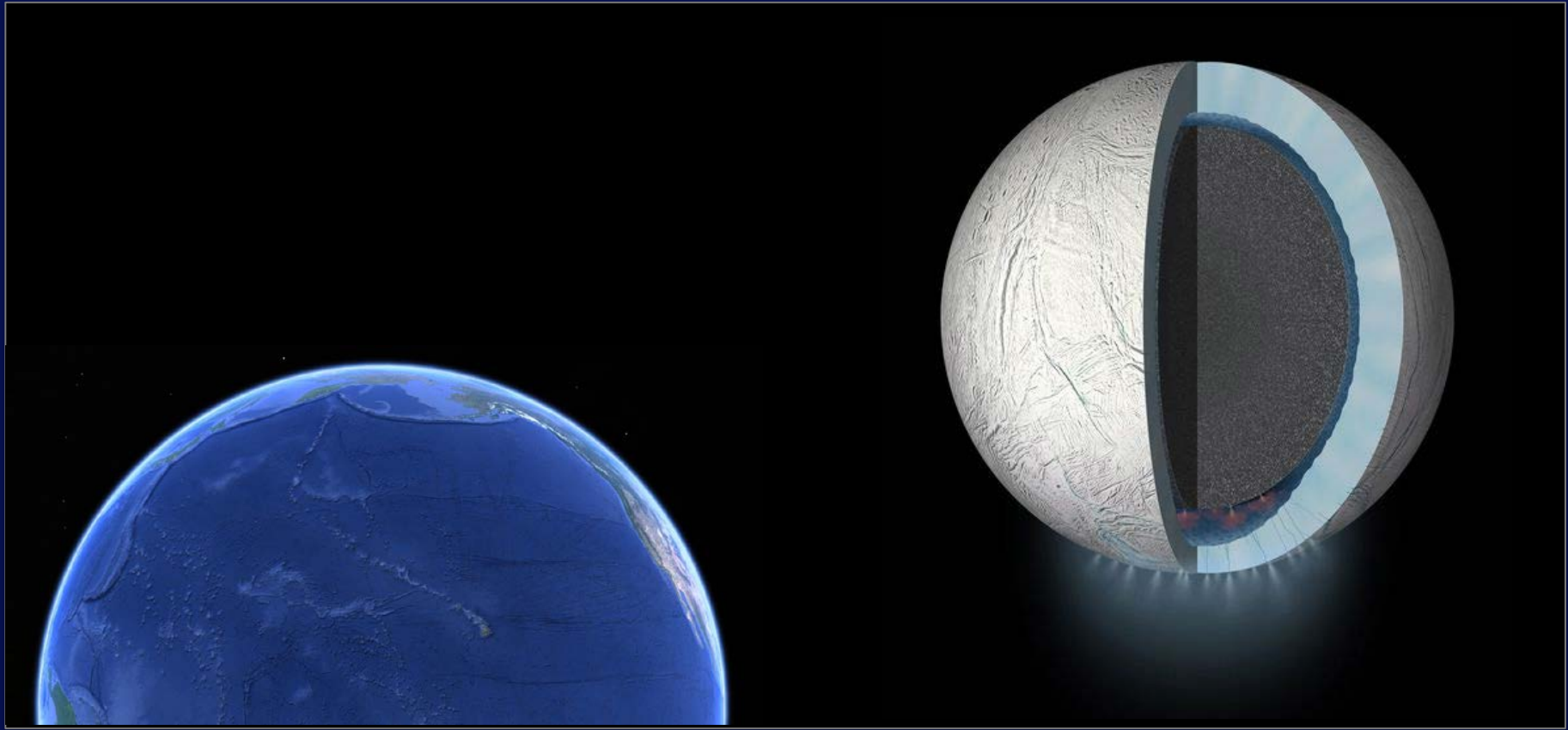
Ultimately, the results of SUBSEA's research will inform both strategies for conducting science via teleoperations at deep-space destinations and scientists' understanding of a wider range of deep-sea analogs for Ocean Worlds.

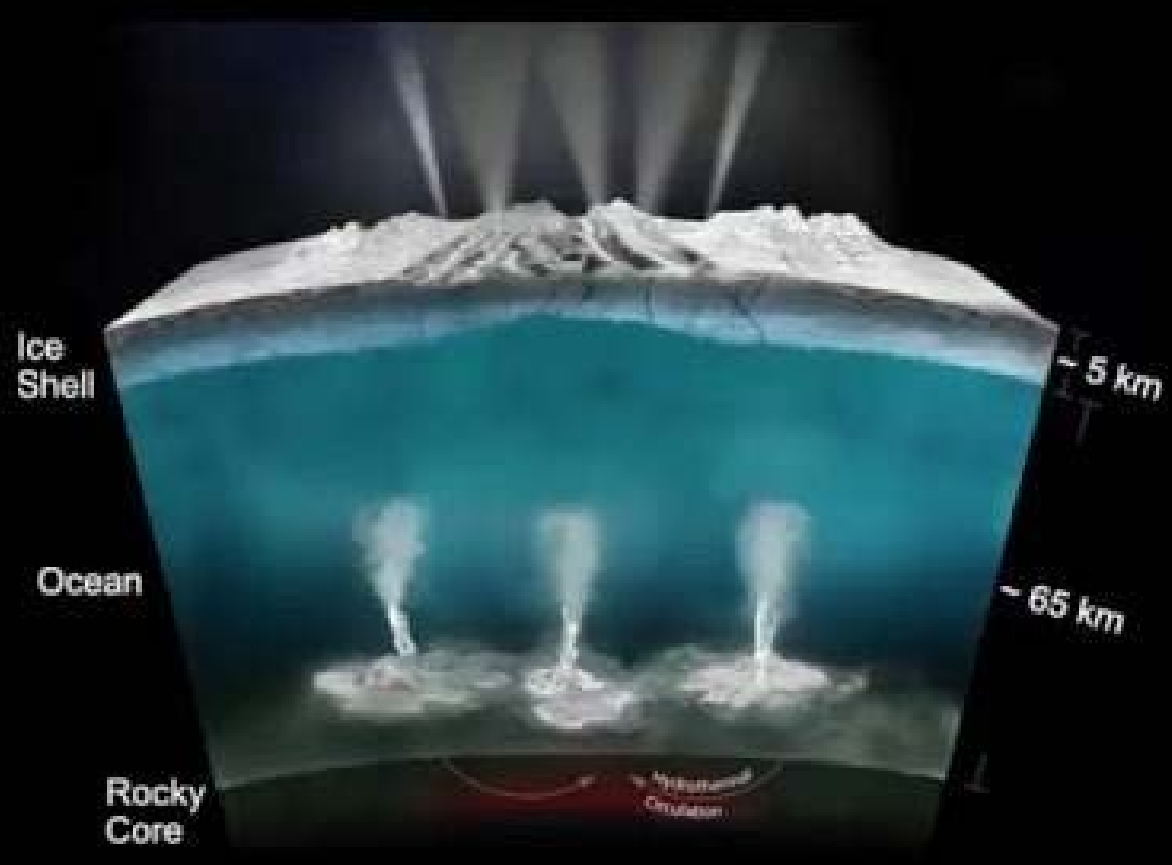
SUBSEA's science results will broaden our understanding of the potential habitability of other Ocean Worlds in our solar system by examining how a range of water-rock reactions can drive the availability of energy sources to sustain microbial metabolisms, and where and for how long such conditions are most likely to persist.

The transfer of knowledge from the project's findings will allow mission design teams to develop methods for efficiently, productively and safely conducting science-driven low-latency telerobotic operations in deep space environments such as Mars. This includes supporting the distributed science teams of such missions with visual observation, instrument data and sample collection information under a significant time delay.

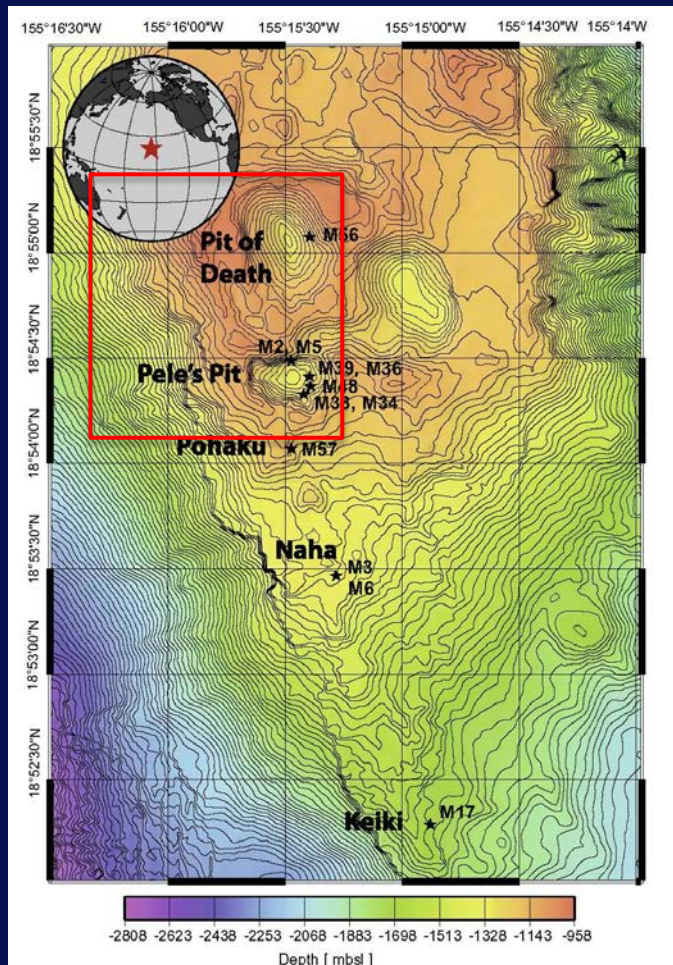
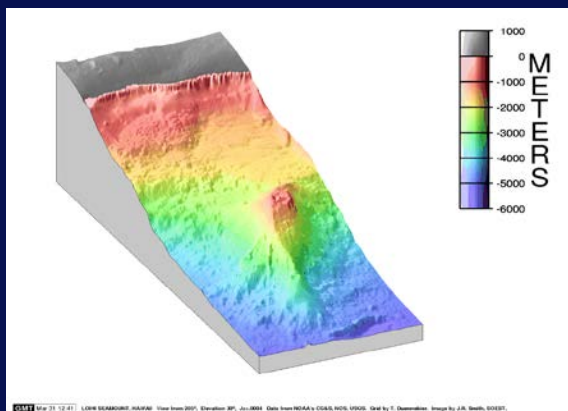
SUBSEA SCIENCE

NASA: Isolated Volcanism + Shallow Ocean

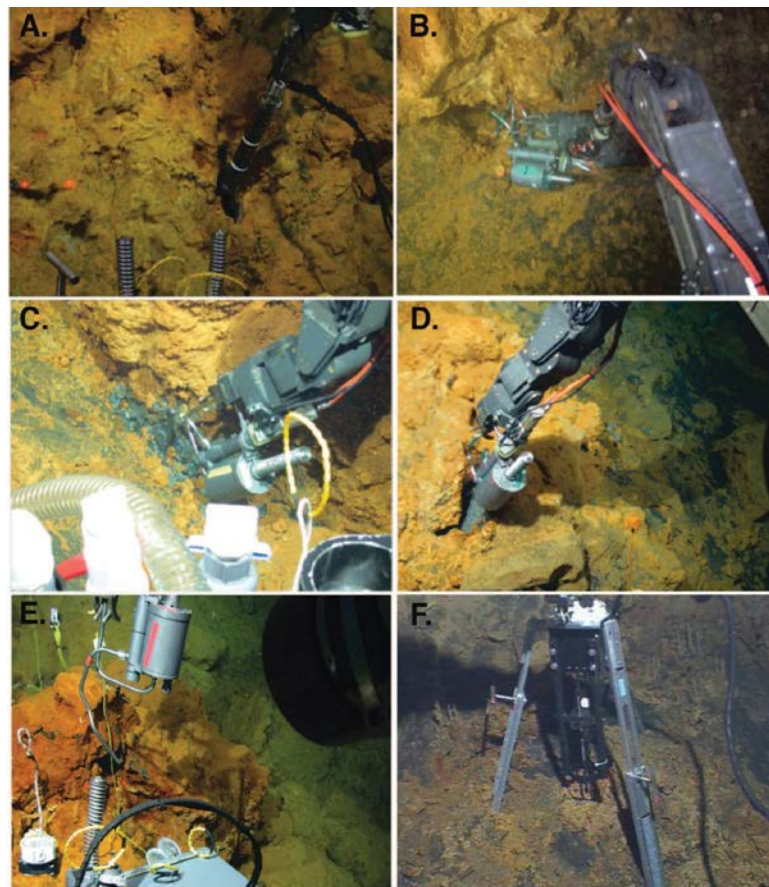
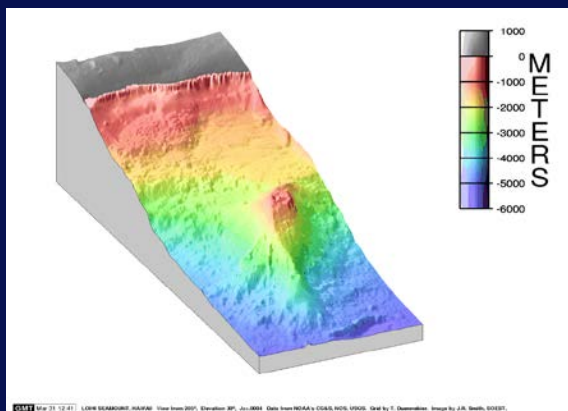




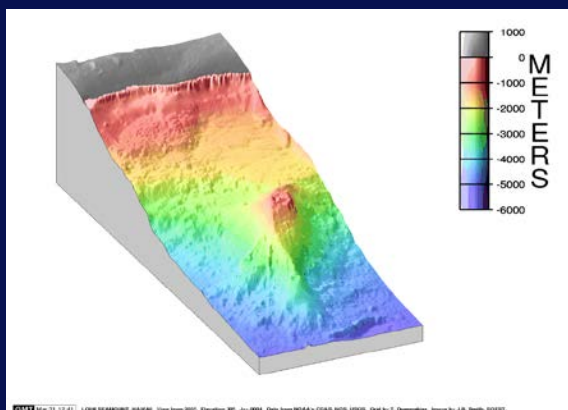
Lo'ihi: the next "Big Island" SUBSEA focus on the Summit



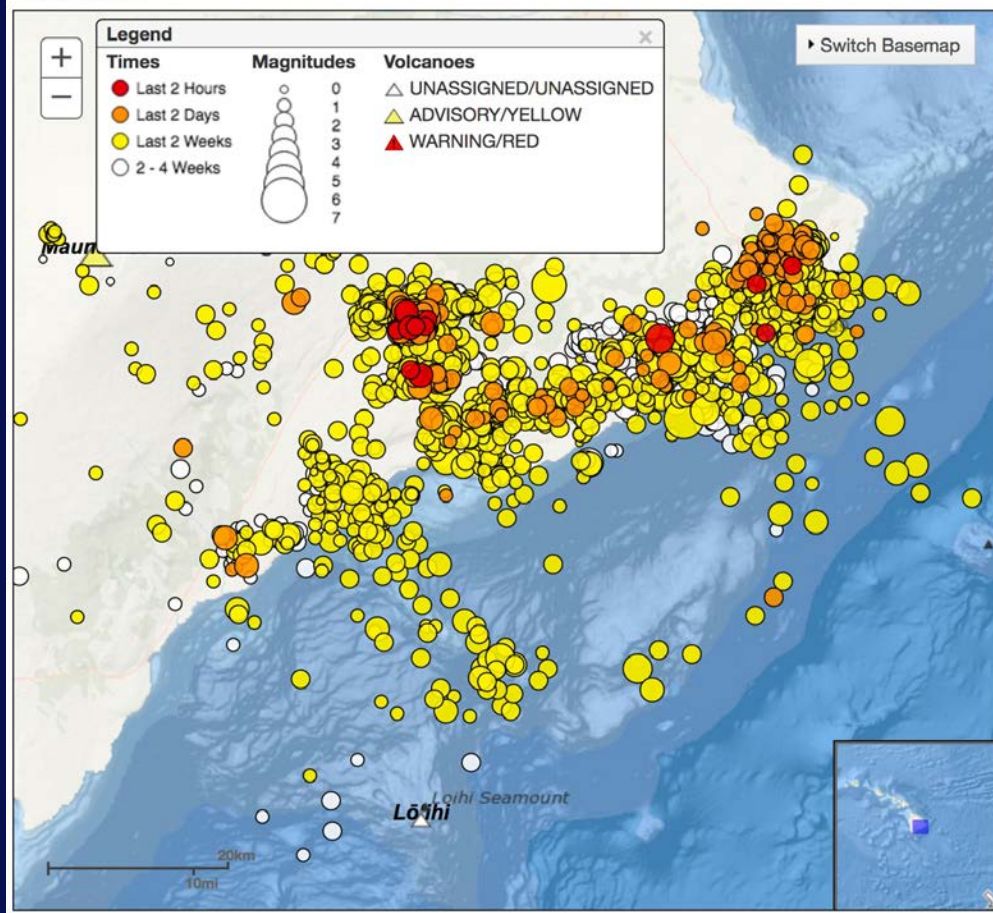
Low-T fluid flow



On-going seismicity



Earthquakes





SUBSEA SCIENCE PRIORITIES

- ★ **Seafloor Morphology**
- ★ **Seafloor Fluid Flow**
- ★ **Fluid biogeochemistry**
- ★ **Fluid microbiology**
- ★ **Robotic Oceanography**

SUBSEA SCIENCE OPERATIONS



Courtesy: OET/Nautilus Live

Directing Science via Telepresence

- Two dive types, alternating dives (sampling/survey)
- Deliberately imposed 24h repeat cycles (EST)

A	B	C	D	E	F	G
HAWAII TIME	EASTERN (+6HRS)	TYPE 1 - SUPR & IGT Sampling	HAWAII TIME	EASTERN (+6HRS)	TYPE 2 - Exploration dives	
0000	0600	Launch/Descend	0000	0600	Commence Exploration, Mapping, Geological Characterization & Rock Sampling	
0100	0700	Descend; Science briefing btw E/V Nautilus-ISC	0100	0700	Geo-Transects/Mapping/Rock Sampling (Shannon); Opportunities for 2 IGT Samples (Everett) & SUPR (Chip)	
0200	0800	Descend/On Bottom/Positioning; Start SUPR & IGT Sampling	0200	0800	Geo-Transects/Mapping/Rock Sampling (Shannon); Opportunities for 2 IGT Samples (Everett) & SUPR (Chip)	
0300	0900	SUPR (Julie) & IGT (Everett)	0300	0900	Geo-Transects/Mapping/Rock Sampling (Shannon); Opportunities for 2 IGT Samples (Everett) & SUPR (Chip)	
0400	1000	SUPR (Julie) & IGT (Everett)	0400	1000	Geo-Transects/Mapping/Rock Sampling (Shannon); Opportunities for 2 IGT Samples (Everett) & SUPR (Chip)	
0500	1100	SUPR & IGT; Start repositioning	0500	1100	Geo-Transects/Mapping/Rock Sampling (Shannon); Opportunities for 2 IGT Samples (Everett) & SUPR (Chip)	
0600	1200	In position; Start SUPR Sampling	0600	1200	Geo-Transects/Mapping/Rock Sampling (Shannon); Opportunities for 2 IGT Samples (Everett) & SUPR (Chip)	
0700	1300	SUPR (Julie)	0700	1300	Geo-Transects/Mapping/Rock Sampling (Shannon); Opportunities for 2 IGT Samples (Everett) & SUPR (Chip)	
0800	1400	SUPR; start repositioning	0800	1400	Geo-Transects/Mapping/Rock Sampling (Shannon); Opportunities for 2 IGT Samples (Everett) & SUPR (Chip)	
0900	1500	In position; Start SUPR Sampling	0900	1500	Geo-Transects/Mapping/Rock Sampling (Shannon); Opportunities for 2 IGT Samples (Everett) & SUPR (Chip)	
1000	1600	SUPR (Julie)	1000	1600	Geo-Transects/Mapping/Rock Sampling (Shannon); Opportunities for 2 IGT Samples (Everett) & SUPR (Chip)	
1100	1700	SUPR; Commence Exploration and Opportunistic Rock Sampling	1100	1700	Geo-Transects/Mapping/Rock Sampling (Shannon); Opportunities for 2 IGT Samples (Everett) & SUPR (Chip)	
1200	1800	Exploration & Opportunistic Rock Sampling (Shannon & SUBSEA Team)	1200	1800	Geo-Transects/Mapping/Rock Sampling (Shannon); Opportunities for 2 IGT Samples (Everett) & SUPR (Chip)	
1300	1900	Exploration & Opportunistic Rock Sampling (Shannon & SUBSEA Team)	1300	1900	Geo-Transects/Mapping/Rock Sampling (Shannon); Opportunities for 2 IGT Samples (Everett) & SUPR (Chip)	
1400	2000	Exploration & Opportunistic Rock Sampling; begin ascent	1400	2000	Geo-Transects/Mapping/Rock Sampling (Shannon); Opportunities for 2 IGT Samples (Everett) & SUPR (Chip)	
1500	2100	Ascend	1500	2100	Geo-Transects/Mapping/Rock Sampling (Shannon); Opportunities for 2 IGT Samples (Everett) & SUPR (Chip)	
1600	2200	On Deck; Start Turn Around Process (6 hours)	1600	2200	Geo-Transects/Mapping/Rock Sampling; begin ascent	
1700	2300	Turn Around	1700	2300	Ascend	
1800	0000	Turn Around	1800	0000	On Deck; Start Turn Around Process (6 hours)	
1900	0100	Turn Around	1900	0100	Turn Around	
2000	0200	Turn Around	2000	0200	Turn Around	
2100	0300	Turn Around	2100	0300	Turn Around	
2200	0400	Turn Around Complete; begin launch and descent	2200	0400	Turn Around	
2300	0500	Descend	2300	0500	Turn Around	
0000	0600	Descend/On Bottom/Positioning; Science briefing btw E/V Nautilus-ISC	0000	0600	Turn Around Complete; begin launch and descent	

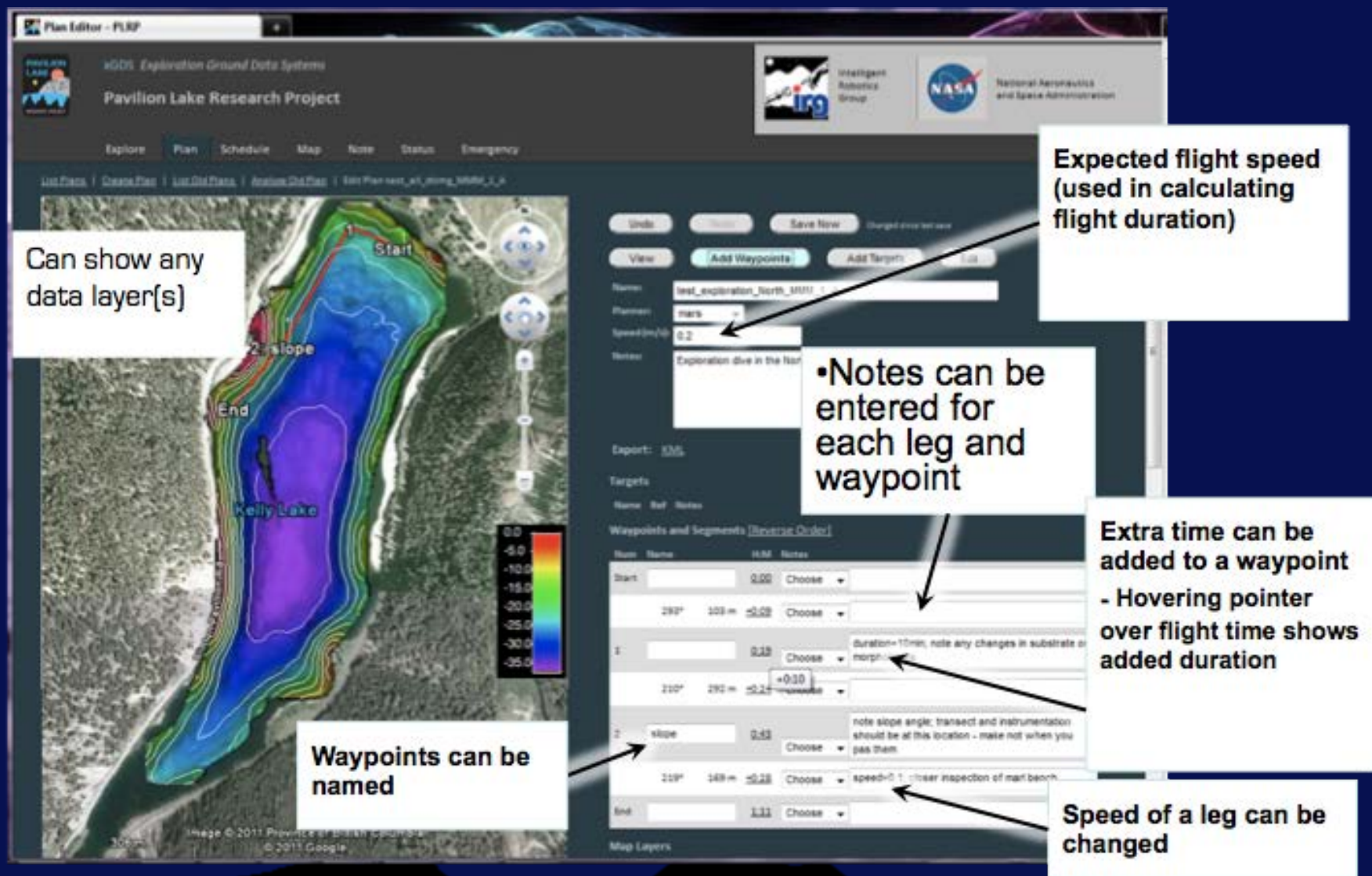


SUBSEA TECHNOLOGY

Scientific research under teleoperation mission conditions will require software tailored to the different space exploration contexts that may arise, with their own unique requirements. SUBSEA will use prototype information technologies to evaluate which software capabilities are required for missions with long communication delays and to improve upon these tools based on their ability to support science-driven LLT operations.

The Exploration Ground Data Systems (xGDS) software developed at NASA Ames will be integrated with the *Nautilus*'s own telepresence mission support systems. The researchers will then systematically evaluate the technology during the SUBSEA field campaigns. xGDS will provide software functionalities that allow integration and visualization of diverse data relevant to future human exploration of deep space.

xGDS for Planning



Can show any data layer(s)

Waypoints can be named

Expected flight speed (used in calculating flight duration)

Notes can be entered for each leg and waypoint

Extra time can be added to a waypoint - Hovering pointer over flight time shows added duration

Speed of a leg can be changed

Plan Editor - PLRP

xGDS: Exploration Ground Data Systems

Pavilion Lake Research Project

Explore Plan Schedule Map Home Status Emergency

Use Data | Create Data | Use Old Data | Archive Old Data | Set Plan next, all, home, Model, X, Y

Start

End

Kelly Lake

0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0

Export: KMZ

Targets

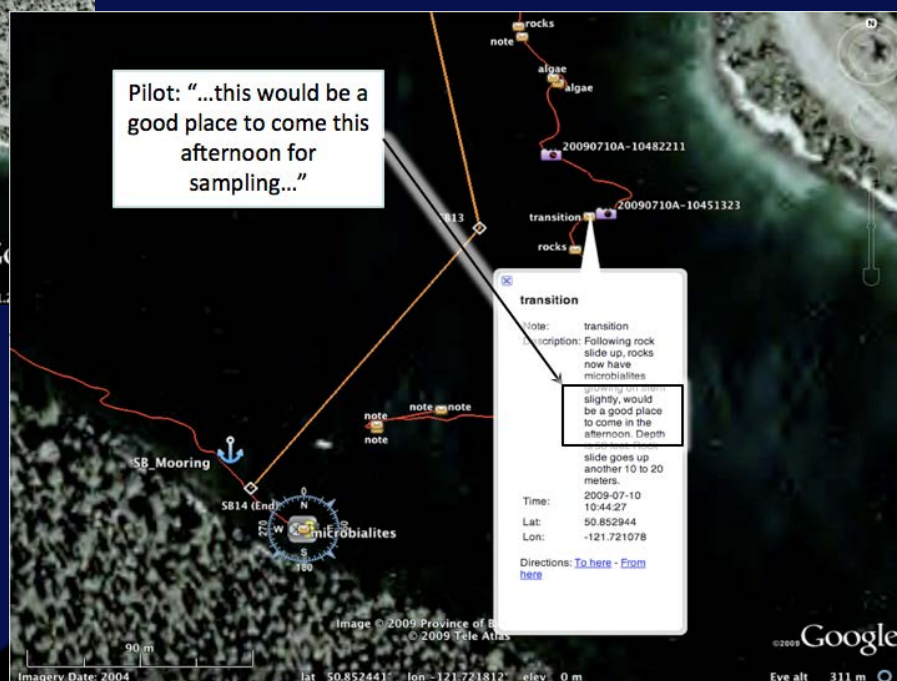
Name Set Notes

Waypoints and Segments [Reverse Order]

Row	Name	Alt	Notes
Start		0.00	Choose
292'	103'	-0.00	Choose
1		0.10	Choose
210'	292'	-0.10	Choose
2	slope	0.10	Choose
210'	168'	-0.10	Choose
End		1.11	Choose

Map Layers

xGDS for execution





SUBSEA Milestones

2018 – SUBSEA's first field campaign will focus on characterizing the geology, energetics, and microbial communities associated with the Lō'ihi seamount. The OET's telepresence architecture will be studied as a model for designing future LLT architectures for NASA

2019 – In SUBSEA's second deployment, the project will add a Mars-like communications delay to its mission simulation. The team's 2019 fieldsite will be complementary to Lō'ihi – stay tuned for the destination .



SUBSEA OUTREACH RESOURCES



Systematic Underwater
Biogeochemical Science
and Exploration Analog



Home

Mission Overview ▾

Our Team

News and Outreach

<https://spacescience.arc.nasa.gov/subsea/>



EXTRA SLIDES

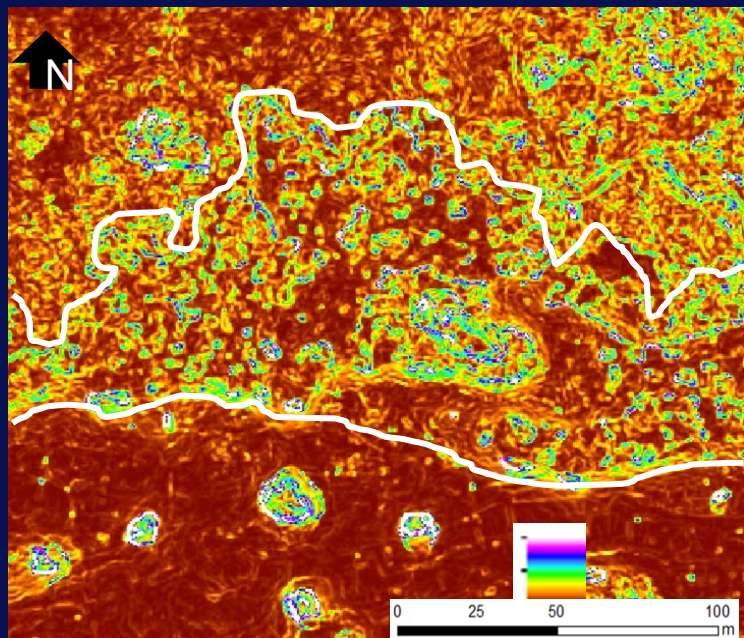
Seafloor Morphology (Idaho State)

Survey: lava morphologies

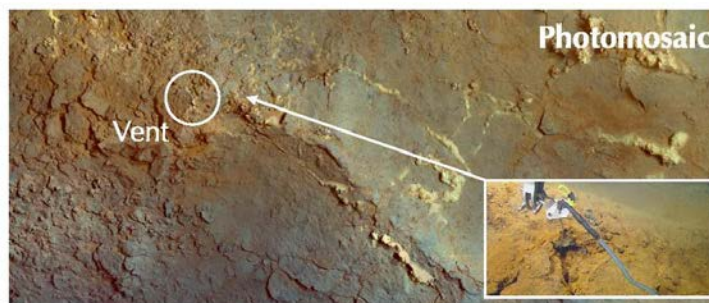
- Reactive surface areas
- Potential habitat volumes

Samples: different flow types

- Petrology & geochemistry
- Microtextural analysis



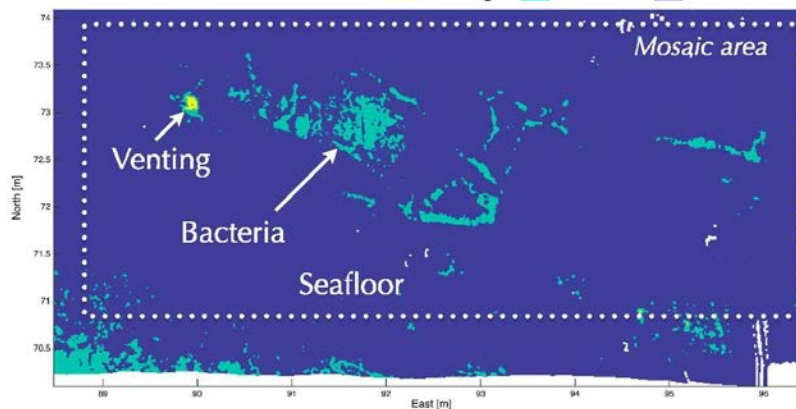
Mapping fluid flow



(a)

Classification Results

■ Venting
 ■ Bacteria
 ■ Seafloor



(b)

Smart et al.,
2017

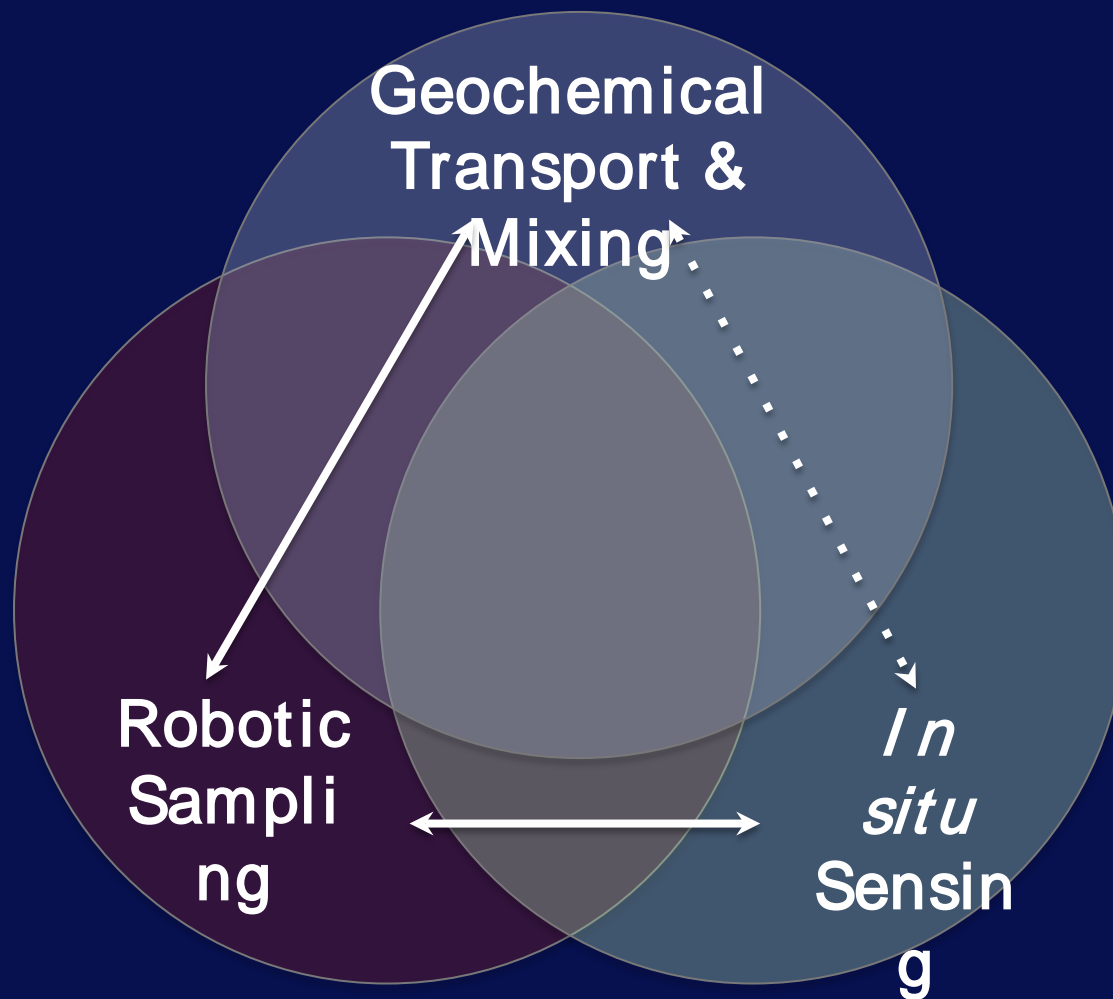
Fluid Geochemistry

- Fluid-rock energetics modelling
 - Gas-tight fluid sampling (IGTs)
- Shipboard and shore-based analyses
 - Emphasis on volatiles (incl. H₂)

Fluid Microbiology

- Quantify the standing stock of microbial biomass in venting fluids
- Determine the metabolic capabilities of subseafloor microbial communities in venting fluids
- Determine potential activity for targeted metabolic groups in venting fluids
- **SUPR sampler: link complementary fluid biogeochemistry to microbiology**

Robotic Oceanography



Using dispersing Fe as a “currency” to develop adaptive sampling