Project Introduction for SUBSEA: Systematic Underwater Biogeochemical Science and Exploration Analog.

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Introduction: The NASA SUBSEA (Systematic Underwater Biogeochemical Science and Exploration Analog) research project, begun in late 2017, is a multi-institutional effort to investigate potential habitability of Enceladus through the use of analog seamounts in the Pacific Ocean. In 2018, we will use the Exploration Vessel *Nautilus* and its associated remotely operated vehicles (ROVs) to study the geology, rock-water chemical exchange, and microbial communities associated with Loihi seamount near Hawai'i. Our science will be conducted as a high fidelity space exploration analog, allowing us to test and improve concepts of operations for future low-latency telerobotic exploration of the solar system.

Science themes: Discovery of silica nanoparticles by *Cassini* has been used to infer hydrothermal circulation on Enceladus' seafloor, with anticipated low pressures and temperatures of ~50-200°C [1,2]. These conditions are consistent with seamount volcanism [3-6], raising the importance of investigating fluid exchange and microbiology associated with hot spot volcanism as opposed to much hotter and higher pressure mid-ocean ridge volcanism.

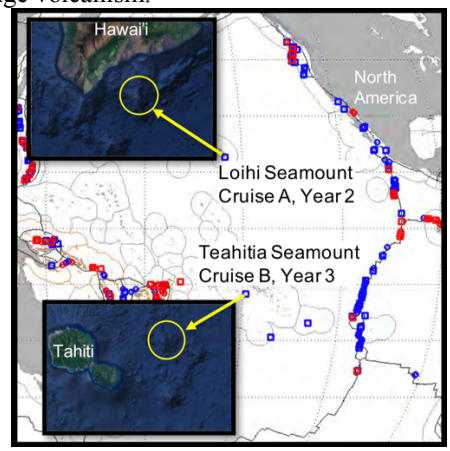

Figure 1. Seamount field targets. We will visit Loihi in August-September 2018. While we originally targeted Teahitia seamount for the second cruise, we are now considering other locations in coordination with Nautilus scheduling.

The science program of SUBSEA has 3 branches: volcanology, geochemistry, and microbiology. The volcanology team will investigate the role of lava morphology in determining reactive volumes, using high resolution topographic analysis and petrographic/geochemical measurement across alteration gradients. The geochemistry team will use the results from volcanology and direct water sampling to characterize the vent fluid and develop new models for fluid flow and energetics. The microbiology team will characterize the microbial communities associated with the fluid flow areas, emphasizing the standing stock of biomass, metabolic capability, and potential activity. These threads of investigation combine to provide an analog view of the physical, chemical, and biological possibilities on Enceladus, indicating habitability potential.

Operations and technology themes: SUBSEA uses science as a foundation for simultaneously investigating operational concepts and technology for low-latency telerobotic exploration of the solar system. The scientific leads will be situated at the Inner Space Center in Rhode Island where they will operate as a mission control science team making interdisciplinary strategic and tactical decisions to guide ROV activity. The interactions in the mission control science team will be studied as part of SUBSEA, as will the use of current and evolving technology designed to support the mission.

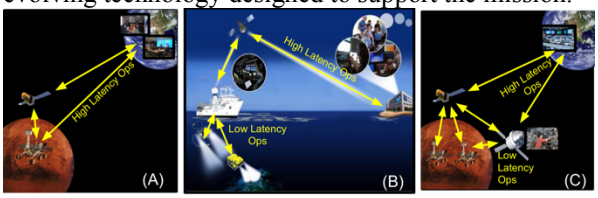

Figure 2. Concepts of operations (ops) for science operations driven telerobotics. A) Current high latency robotic Martian science ops; B) SUBSEA hybrid latency science ops; C) proposed low latency Martian ops.

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