Scientific Exploration Subsurface Access Mechanism for Europa (SESAME)
Abstracts of selected proposals
(NNH18ZDA001N)

Below are the abstracts of proposals selected for funding for the Scientific Exploration Subsurface Access Mechanism for Europa (SESAME) Program. Principal Investigator (PI) name, institution, and proposal title are also included. Nine proposals were received in response to this opportunity. On January 29, 2019, five proposals were selected for funding.

Kate Craft/ Johns Hopkins University

Europa STI - Exploring Communication Techniques and Strategies for Sending Signals Through the Ice (STI) for an Ice-Ocean Probe

Below the icy crust, Europa contains more water within its ocean than all the surface water on Earth. Additionally, that ~ 100 km thick ocean has likely lain in contact with a silicate seafloor and water-rock interactions may be supplying chemically-reduced species into the ocean. In parallel, subduction of surface ice shell material could provide a steady flux of oxidants (notably oxygen) from above, leading to redox reactions that could provide the energy as well as the essential CHNOPS for carbon-based life. All these factors make Europa one of the most geophysically, chemically and potentially biologically interesting environments in our solar system and as such, drives our interest to explore and sample its ice and ocean below.

To reach Europa's ocean, an ice-probe must be able to travel and communicate through a layer of ice overlying the ocean, potentially several kilometers thick that varies in its properties with depth. The uppermost few kilometers will be radially flexing due to the forces of Jupiter, Io and Ganymede. This tidal motion induces fracturing and faulting that any means of communication from a robot sending signals interior-to-surface must endure. The Europa STI project will test multiple communication tether designs with a goal of bringing one (or more) to TRL 4/5 and will evaluate the performance of multiple free-space communication architectures that could be coupled with, or alternatives for, tethers to a subsurface probe. A strategic communication report will be provided to NASA as a final deliverable.

Tom Cwik/ Jet Propulsion Laboratory

Cryobot For Ocean Worlds Exploration

The Cryobot initiative enables NASA's search for life by maturing the system architecture and technologies necessary for accessing Europa's ocean. The project will begin with requirements to develop key technologies enabling a Cryobot to reliably penetrate 15 km of ice sheet within three years with a mass of less than 200 kg. Key to project success is a highly complementary partnership of seven institutions, synthesizing experience from five prototype ice probe systems, rapid prototyping of hardware, fluidics and thermal modeling, and testing in cryogenic ice chambers and the Arctic. The team's recent proof-of-concept study detailed a baseline architecture enabling all operational phases of a SESAME-type mission and identified technology gaps.

This architecture is centered on incorporating a Radioisotope Power Source into a high pressure vessel and effectively using its waste heat. In order to mitigate the risks presented by unknown ice shell contaminants and the vacuum/ice and high-pressure ice/water interfaces, the Cryobot frontend will combine multiple ice penetrating technologies (melting, water jetting, cutting, and mechanical drilling). Other identified needs include a hazard detection and avoidance system to navigate inclusions/voids, and a through-ice discrete telecommunication system of small radioisotope-powered transceiver relays.

After two years, the system architecture and Cryobot frontend will be matured from TRL 3 to 5, while power, telecom, and hazard avoidance systems will be better refined in anticipation of subsequent funding. Reports will detail the end-to-end architecture and numerical model, with laboratory validation and extrapolation to operation through the full Europa ice sheet profile. A development plan for key systems will be furnished, outlining current maturity, schedule, mitigation strategies, and interfaces to the Cryobot architecture. A terrestrial field test will provide a proof-of-concept demonstration and public outreach opportunity.

Britney Schmidt/ Georgia Tech Research Corporation

Vertical Entry Robot for Navigating Europa (VERNE)

We propose a deep subsurface access vehicle system for Europa. The concept is a platform that would enable access to a subsurface water volume within five kilometers of the surface, but capable of deeper penetration to 15km. We envision a three stage mission with a surface station, self-drilling vehicle with a breakable mechanical/data tether that deploys acoustic communications stations in the ice as it descends, and a base station that remains in the ice to relay communications with the mobile vehicle platform to the surface station.

We will leverage previous experience developing Icefin, a two kilometer (on Earth) depth-rated vehicle that is nine inches in diameter, tailored to through-ice exploration, as well as the new Deep Ocean Robotic Astrobiologist (DORA) vehicle under development for deep hypersaline anoxic basins through the NASA Astrobiology program. Icefin is an ~TRL 5 concept, built and tested in sub-freezing and underwater conditions in Antarctica. DORA is TRL 2 concept system following Icefin designed to deal with heavily corrosive, high pressure environments. Part of our study will be to evaluate migrating the current vehicle hardware to flight-tested or more flight-appropriate implementation.

During the vehicle system development, we will identify promising technologies as well as the technical risks associated with each in order to validate the materials list and integration plan. At the end of the work, we will emerge with TRL-4 ready realistic subsurface access drill design and TRL-4 ice communication pucks. We will achieve a model base station module at TRL 5 powered by batteries as an analog for the eventual RTG implementation. We will also complete a bill of materials and design adaptations to migrate Icefin to a flight-ready TRL 6 vehicle system, including integration of science sensors adapted for Europa conditions.

William Stone/Stone Aerospace, Inc.

PROMETHEUS: nuclear-Powered RObotic MEchanism Technology for Hot-water Exploration of Under-ice Space

We will advance a cryobot design that uses closed-cycle hot water drilling (CCHWD) technology as the primary means of penetrating ice. The primary role of the PROMETHEUS (nuclear-Powered RObotic MEchanism Technology for Hot-water Exploration of Under-ice Space) vehicle will be to enable actively controlled descent through the ice shell into Europa's subsurface ocean. In PROMETHEUS we will design, develop, and test a CCHWD cryobot that is compatible with a small fission reactor and which can be developed, by 2022, into a realistic flight cryobot. The design is a nuclear fission powered successor to Stone Aerospace's VALKYRIE and SPINDLE cryobots, capable of achieving a 15 kilometer descent through a Europan ice profile in under a year and under 200 kg vehicle mass. Based on analyses and design work from prior and on-going Stone Aerospace cryobot projects we anticipate the flight cryobot to have a 37 cm diameter and 4 m length.

We will test a functional sub-scale CCHWD cryobot and various PROMETHEUS subsystems, both in pure water ice and dirty ice, in the Stone Aerospace Europa Tower cryogenic/vacuum facility. The internal volume of the Europa Tower cryovac chamber is 0.75 m in diameter and two meter tall, and the chamber can simulate the temperatures and vacuum conditions believed to exist in Europa s surface, brittle, and ductile ices.

Kris Zacny/ Honeybee Robotics, Ltd.

SLUSH: Search for Life Using Submersible Heated drill

Europa is a primary target in the search for past or present life because it is potentially geologically active and likely possesses a deep global ocean in contact with a rocky core underneath its outer ice shell.

To reach the subsurface ocean, where life may be most prevalent, a probe would need to penetrate the icy formation while moving the excavated material behind it. This operation can be achieved via two methods: thermal (melting) or mechanical (cutting). Mechanical systems break the icy material efficiently, but transport ice chips inefficiently. Thermal systems have an effective chip removal approach, but a power intensive ice-melting step. The Search for Life Using Submersible Heated (SLUSH) drill is a hybrid, thermo-mechanical drill probe system that combines the most efficient aspects of these two techniques. SLUSH is five meter long, 57 cm diameter probe with a heated drill bit in front, antitorque cutters on the side, and several tether bays on top. The probe is partially flooded and only critical subsystems are inside a pressure vessel; this allows the probe to sink rather than float. SLUSH utilizes a mechanical drill to break the formation and partially melts the fragments to enable the efficient transport of material behind the probe. The resulting slush behaves like liquid despite being partially frozen, enabling a significant reduction of the power required for melting the full volume of ice. Further, because a mechanical approach generates higher penetration rates, SLUSH can reach the ocean in a much shorter time than a pure melt probe. Once SLUSH passes through the hazardous cryogenic ice, it could use a purely thermal approach to melt through the warmer ice without the need for mechanical cutting.

SLUSH incorporates the Kilopower reactor for both thermal and electrical needs. The fission reactor can be turned on/off and is self-moderating, significantly simplifying thermal management. The probe is physically connected to a surface lander by a communications tether, housed in several spool bays that are left behind in the ice once the spool is depleted. This allows each tether section to be purpose-designed. RF and acoustic communication will be investigated as backup systems, potentially incorporating transceivers into each spool section.