Astrobiology Science and Technology for Exploring Planets
Abstracts of selected proposals
(NNH10ZDA001N-ASTEP)

Below are the abstracts of proposals selected for funding for the Astrobiology Science and Technology for Exploring Planets program. Principal Investigator (PI) name, institution, and proposal title are also included. 37 proposals were received in response to this opportunity, and 5 were selected for funding.

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**Don Banfield/Cornell University**
**Mars Methane Plume Tracer**

Recently reported observations of spatially and temporally variable methane on Mars raise the possibility that these discrete sources may be from extant Martian life. Whether or not the recent claims withstand further study, the problem of Martian atmospheric plumes of relatively short-lived chemical species remains important. Possible localized sources could include volcanic, areothermal and hydrothermal vents, as well as the more controversial possibility of biogenic sources. Atmospheric plume sources are crucial places for improving our understanding of Mars past and present climate and biologic history and thus important to locate and characterize. Identifying a plume source on Mars would make it a high priority target for future missions, warranting further in situ study regardless of the source type. Pinpointing its location will require new observational techniques and exploration strategies beyond the current arsenal. To even consider the feasibility of detecting and precisely locating such a target, we need to more fully understand the nature of Martian atmospheric plumes, how and when one might expect to detect them, and how plume dispersal properties can guide us to their sources. This is the focus of our study.

We propose to study methods of plume detection and characterization from orbital and in situ instruments. This includes understanding the influence of various plume source and atmospheric properties as well as instrument design trades on our ability to localize and characterize plumes from orbit. We also propose to extend that study further to in situ measurements, and also to develop and field-test conceptual instrument suites and navigational algorithms to guide a relatively slow-moving Martian rover to a plume's source.

We expect that this project will have significant strategic impact on the Mars exploration program, as well as having possible applications for exploration on other planetary bodies, including Earth (e.g., life detection in the Atacama, homeland security, pollution detection/enforcement, etc.), Titan's surface and even in Europa's subsurface ocean.
Our three-year field campaign will deploy a lake lander at lake Teno in the Central Andes of Chile where ice is melting at an accelerated rate. Deglaciation subjects lakes to interannual variability and key questions must be addressed to understand its impact: What are the disruptions associated with deglaciation, their frequency and magnitude? What is their impact on metabolic activity and biogeochemical cycles? What is the response of lake habitat, ecosystem, and biodiversity? Addressing these questions will contribute to a better understanding of the changes currently affecting Earth's glacial lake ecosystems, and shed light on how life and habitats adapted during past deglaciations. It will also bring new insights into Mars habitability and life potential during comparable geological periods. Further, the investigation of lake Teno will confront us with challenges analogous to those that will be faced by future missions to Titan planetary seas. In response, we have designed a field campaign that will deliver the first field demonstration of a planetary lake lander with complete system and analog payload. An alien seaward-bound mission will be a first, with no background data. Our project will further science and technology productivity of such mission by: (1) providing critical background to help reach best science and mission performance through hands-on experience, (2) realistic simulations, and (3) the production of science operational templates for various stages of this new type of missions. Operational scenarios will be tested, critically reviewed, and validated over hundreds of continuous hours of field demonstrations. The end-product will be a unique reference operational dataset for future missions to Titan. Concurrently, this dataset will provide critical data on the severe impact of deglaciation on Earth by simultaneously quantifying the domino effect of environmental changes from the atmosphere to the water column. Finally, the three-month duration of each of our field campaigns will enable the testing of adaptive science operations and demonstrate gain in science return using a lake lander with ever increasing decision-making capabilities.

Lisa Pratt/Indiana University
Shallow-Borehole Array for Measuring Greenland Emission of Trace Gases as an Analogue for Methane on Mars (GETGAMM)

During three years of sequential field campaigns in southwestern Greenland, we propose to measure seasonal and diurnal variation in concentration and isotopic composition of methane in bedrock boreholes (0.5 to 2 meters in depth) and soil pipe wells (1 to 1.5 meters in depth) intersecting permafrost environments across a study site of about 1 square km. Three instruments will be deployed for the measurement of methane isotopic compositions in the field: a multi-path tunable laser spectrometer that is optimized for carbon isotope discrimination will be contributed by the Jet Propulsion Laboratory; a cavity ring down spectrometer capable of both carbon and hydrogen isotopic measurements will be contributed by a collaboration between Goddard Space Flight Research Center and Princeton University; and a commercially produced integrated cavity output spectrometer from Los Gatos designed for carbon isotopic measurements will be operated by Indiana University. Isotopic compositions determined in the field will
be validated using duplicate flask samples and injection into conventional gas-source isotope ratio monitoring mass spectrometers in the Stable Isotope Research Facility at Indiana University. Drilling in the first two field campaigns will be progressively more robotic, leading to a technology demonstration in the third year of semi-autonomous drilling to depths of 2 meters with an integrated compression packer to seal the borehole and install one fiber optic and two capillary tubes. At time intervals of days to months, gas in the sealed boreholes will be transferred without atmospheric contamination to a suite of above ground instruments using the capillary tubes. The proposed GETGAMM campaign directly addresses the challenge of determining concentrations and isotopic compositions for methane in soil-gas or fracture-gas samples as a means to ground truth reports of methane plumes in the Martian atmosphere. A coordinated field test of three methane instruments will allow on-site comparison of analytical sensitivity and reproducibility as well as assessment of setup and calibration complexity for each instrument. Thus, results of the proposed study in Greenland are fundamental to engineering and scientific preparation for a proposed dual landing in 2018 of a NASA rover designed to explore and cache samples and a European Space Agency rover designed to drill down to depths of 2 meters.

Access to the proposed study site is possible year-round at reasonable cost due to the presence of a former U.S. military airbase with re-purposed buildings serving as the Kangerlussuaq International Scientific Support Facility. Continuous permafrost is present down to 300 meters depth with temperatures dropping to -3 degrees centigrade at a depth of about four meters, providing a relatively shallow and pristine setting for an instrumented study of reduced trace gases released by weathering and by microbial metabolism in super-permafrost bedrock and soil. There are mafic rock units and fracture zones within the proposed Greenland study site that are excellent targets for drilling Mars-analogue boreholes.

William Stone/Stone Aerospace

VALKYRIE: Phase 2

Laboratory research is underway on Phase 1 of the VALKYRIE cryobot project under ASTEP funding. We are investigating high power laser transmission through optical fiber waveguides; gaining empirical data on fiber power loss as a function of bend radius and turn count; and brass-boarding initial hardware concepts for the thru-ice SAR obstacle avoidance system. Here we propose three mid-stage field campaigns which, if successful, will significantly raise the TRL level for the concept and make possible the full-scale Phase 3 South Pole Lake cryobot sample return mission originally proposed as the VALKYRIE end objective. This latter mission will be a dress rehearsal for Europa. Further, if successful, VALKYRIE makes possible direct access to sub-glacial Antarctic lakes without the multi-year environmental protection process: the vehicle can be sterilized to internationally accepted planetary protection levels prior to deployment and the melt path freezes behind the vehicle, thus preventing forward contamination. The VALKYRIE concept uses fiber-guided laser power and SAR obstacle avoidance to emulate a fission-thermal-powered cryobot that would deliver an AUV science payload to the sub-surface oceans of Europa and Enceladus, as well as deep investigations into the Martian ice cap. In Phase 2 we propose to field test a sub-scale variant of
VALKYRIE in Great Slave Lake during February 2012 and on selected glaciers in Svalbard in the fall of 2012 and 2013. Arrangements have been made with UNIS, the Governor of Svalbard, and the Polish research station there for logistics support. VALKYRIE will penetrate a series of selected glaciers beginning with ice depths between 10 to 50 meters in 2012 and proceeding to as much as 200 meter penetrations in 2013. Svalbard provides a unique element of risk reduction in the development of VALKYRIE in this respect because it harbors a series of stable post-summer ice caves that extensively underlie certain glaciers there. It is our plan to map these features and to target each VALKYRIE mission so that the vehicle can be safely recovered through the roof of the ice cave at the conclusion of each mission. The sub-scale system will operate on a one kilometer bare silica spooler using a 5 kW laser power source. The vehicle will be equipped with an astrobiology sensor suite that will be calibrated against a ground truth ice core. Onboard algorithms will be developed to key off calibrated sensors and make an autonomous decision to collect a physical wall core sample from within the ice column. Follow up laboratory microbiology assays will confirm the efficacy of the vehicle’s science autonomy approach. Additional experiments will be conducted in which cryobot-deployed line sensors are embedded in the ice cap. If successful this may provide a completely new method of long term autonomous glacial monitoring.

David Wettergreen/Carnegie Mellon University
Robotic Investigation of Subsurface Life in the Atacama Desert

We propose to explore and measure the gradients of subsurface life and habitats in the Atacama Desert in a field campaign involving the first operation of a drill by an autonomous survey rover.

Our goal is to document subsurface ecosystems that demonstrate adaptation strategies in increased aridity, oxidation, and salinity conditions. The individual and combined role of hyperaridity, high UV high daily thermal amplitude, oxidation, wind, and desiccation on the surface and their impact on subsurface habitability, if any, will be quantified.

Our investigation will provide mission relevant, comparative, datasets by assessing the range of subsurface habitable conditions at depths equivalent and superior to MSL in an environment uniquely analogous to early Mars.

Our research will enable subsurface exploration by developing the necessary techniques and technologies for access and sampling. We will establish drilling as a field-proven capability for science rovers. A field campaign over three years will make spatial and stratigraphic transects of the desert. The versatile rover will incorporate a range of sensors for biogeologic survey and a drill capable of collecting samples and making measurements at various depths to characterize subsurface habitats.

The astrobiology questions to be addressed during the investigation are:

- What are the surface and subsurface physical, chemical, geological and mineralogical signatures of habitats?
- What is the spatial diversity, gradients, and types of habitats and life along transects and vertical profiles?

- What are the boundary conditions for survival in these habitats?

NASA Ames Research Center will provide leadership in astrobiology and science operations. Carnegie Mellon will integrate robotics technologies, collaboration with JPL and Honeybee Robotics, and will lead the field experiment. Our team possesses deep experience in the component disciplines, been successful together in prior field investigations, and has a proven record of delivering on science and technology objectives.