Below are the abstracts of proposals selected for funding for the PSTAR program. Principal Investigator (PI) name, institution, and proposal title are also included. 48 proposals were received in response to this opportunity. On March 21, 2016, 7 proposals were selected for funding.

**Rosalyn Hayward/USGS**  
**Measuring Sediment Flux at a Mars Analog Site Using Multilayer Solid-State Saltation Sensors**

Description of the science goals and objectives: This proposal will determine the utility of using multi-layer solid-state saltation sensors (e.g. SENSIT(tm) Saltation Sensor) to measure sediment flux at a Mars analog site in lieu of sediment collectors. We will use previously funded sediment collectors (BSNEs) and anemometers to calibrate the sediment flux from the multi-layer solid-state saltation sensors (MLS4) as a function of kinetic energy and particle counts. In addition to measuring sediment flux, we will characterize the thermal stability of the boundary layer by using a series of temperature sensors mounted on a pole. Instabilities within the boundary layer may cause changes to the vertical distribution of the sediment flux.

Brief description of the methodology:  
This proposal will augment a previously (and ongoing) Mars analog study site with two additional pieces of instrumentation: (1) MLS4 and (2) a set of multi-layer temperature sensors. We plan to extend the collection of field data from the previously funded instrumentation (sediment collectors and anemometers) to calibrate an algorithm to convert the MLS4 kinetic energy and particle count rates into sediment flux. We will monitor the atmospheric temperature profile to determine if thermal instabilities affect this calibration algorithm.

Relevance of the proposed research: This proposal is relevant to two of the three areas of fidelity. Science: The Grand Falls dune field site is a local area (40 miles from the PI's institution) with high winds, active dunes and a range of precipitation and temperatures. This proposal will continue the collection of an additional year of sediment flux measurements. This additional year of data will allow for the analysis of interannual variability. The additional instrumentation to measure the near-surface atmosphere temperature profile will help determine the air stability and compare that to sediment flux rates.  
Technology: This proposal will test the deployment, feasibility, and calibration of MLS4 as an instrument package to measure sediment flux rates with no moving parts. We will develop the necessary protocols and procedures that will be needed to calibrate the data under conditions when concurrent sediment collectors and wind observations are not available. This instrument package could either be deployed to Mars (or perhaps Titan) on a rover (e.g. as part of the mast) or as a lander.
The Apollo Missions to the Moon are the only direct experience of humans with exploration of another planetary body, providing us with a critical set of in situ data that has led to a complete revolution in our understanding of lunar geology, the lunar interior, and lunar evolution. To date, the deployment of the geophysical instrumentation packages during the Apollo missions remain our only data points for evaluating the efficacy of human-placed geophysical instrumentation on another world. It is difficult to ascertain what parameters in these astronaut-deployed instrumentation packages could have been modified to improve and increase the scientific return of these geophysical investigations, particularly investigations of subsurface structure in combination with geological information. The effectiveness and success of future missions of human exploration and subsequent habitation of the inner Solar System will depend on characterizing both the practical and scientific value of subsurface materials, including physical properties, geological structures, mineral and ground water resources, hazard assessments, and habitation potential/accessibility.

To assess the fidelity of future human-deployed geophysical instrumentation packages and increase the integration of both geological and habitation assessments for planetary targets, we propose a multi year field deployment to evaluate the use of geophysical instrumentation on traverse design during human or robotic missions and different instrument deployment strategies for solving existing science questions about subsurface structure and stratigraphy in the San Francisco Volcanic Field (SFVF), AZ. We will build upon prior investments in the NASA Desert Research and Technology Studies (RATS) to study the human exploration aspects and logistical planning required for deploying geophysical instrumentation concurrently with geological field traverses. These studies will also serve as a stepping-stone for using geophysical methods to identify subsurface environments conducive to life, such as aquifers and geothermal sources of heat.

The project is relevant to the Planetary Science and Technology Through Analog Research program in that it integrates across field disciplines (geology, volcanology, geophysics) in preparation for future human and robotic mission deployed geophysical instrumentation. The proposed research will deploy instrumentation that is capable of operating on lunar, asteroid, and planetary surfaces in a lava flow environment that is commonplace across terrestrial bodies of the Solar System. The proposed research will result in new science as well as operational and technological capabilities that will enable the next generation of planetary exploration. The proposed activities will include training of graduate students, outreach to the public, and collaboration of academic institutions (UMD, NAU) with a NASA center (GSFC).
Lava tubes have been studied on Earth since the late 1960s when geologists observed active lava tubes on Hawaii. Tubes on other planetary bodies, however, have only been studied through remote sensing. In as early as the mid 1970s, it was postulated that these planetary tubes could provide safe havens for human crews and protect their life support equipment from harmful radiation, rapidly fluctuating surface temperatures, and even meteorite impacts. What is not clear, however, is how a human crew will characterize a tube-rich environment in preparation for habitation. The proposed work will address this knowledge gap using a suite of instruments in an analog study. Ground Penetrating Radar (GPR), Light Detection and Ranging (LiDAR), and handheld X-ray fluorescence spectroscopy (hXRF) are all techniques that have been deployed on Earth in a variety of geologic contexts with great success. They have never before been combined in a volcanic setting to investigate lava flow emplacement processes nor have any of them been applied to develop human exploration strategies for the examination of another planetary surface.

We propose to both investigate the combination of these field technologies in the development of a strategy for the exploration of lava tube and pit-rich environments as well as to advance GPR processing techniques in an effort to aid in detailed characterization of these subsurface features.

In order to develop this concept of operations for tube exploration, we will deploy GPR, LiDAR, and hXRF field instruments at the Lava Beds National Monument (Lava Beds NM), California. Lava tubes at Lava Beds NM range in length, depth and complexity. This range of complexity is particularly well-suited to this project as tube geometry present on other planetary surfaces is completely unknown. We will accomplish this work through the completion of five tasks in two PSTAR fidelity areas:

1. Define the instrumentation suite necessary for lava tube exploration and characterization (Science Operations)
2. Develop a GPR library of what different tube and pit geometries will look like (Science Operations)
3. Develop an exploration strategy for how a rover should characterize a tube/pit-rich environment (Science Operations)
4. Identify optimal GPR antenna parameters (Technology)
5. Identify optimal GPR data processing methods (Technology)

Together, these Science Operations (decision-making protocols, traverse planning, and navigation unique to science support) and Technology objectives (the use of mobile science platforms, intelligent systems and human/robotic interfaces, and instrument packages) directly apply to the PSTAR call and are therefore relevant to both this program call and to NASA. We also note that caves on other planetary surfaces have been highlighted as a potential place to preserve signatures of life, making this student applicable to NASA's current high priority objective of locating signs of life on other planetary surfaces.
Christopher German/Woods Hole Oceanographic Institution
Oases for Life Beneath Ice-Covered Oceans: Bio-Signature Pathways From Seafloor Ecosystems to the Overlying Ice-Shell

NASA's Mission to Europa plans fly-bys of Europa to investigate its habitability. We seek to support that and future missions through an analog, interdisciplinary field experiment to the Arctic Ocean that will explore for and investigate seafloor chemosynthetic ecosystems, and the fate of any bio-signatures they generate as they are transported up into the water column to the overlying ice. Our field program will include use of an icebreaker, ice-stations and, uniquely, a novel under-ice robot, Nereid Under Ice (NUI) designed specifically for long-range investigations, in both autonomous and remotely operated (human directed) modes, in ice-covered oceans. Shiptime for the project has already been awarded to our international collaborator, Prof. Antje Boetius (Alfred Wegener Institute, Germany) providing essential capabilities for our field program that will explore for and characterize new, isolated, hydrothermal ecosystems on the Arctic seafloor in Year 1. That field program will provide key sample and data sets from which we will derive new scientific and technologic capabilities, essential to planning future space missions. Our science-driven exploration program will be relevant to two key objectives of PSTAR:

Science: We will explore for and characterize (geochemically & microbiologically) new sites of seafloor venting at the Karasik Massif which rises from 4700m to 566m at the Gakkel Ridge (87°N, 61°E) and hosts chemosynthetic ecosystems at the seafloor of a permanently ice-covered ocean basin. We will seek to identify biosignatures generated by these chemosynthetic ecosystems and investigate their fate as they are transferred upward into the water column to the overlying ice-cover. We will also assess the potential for such tracers, indicative of chemosynthetic life, to persist and be detectable on the outer shells of other icy moons that host global-scale oceans (e.g. Europa, Enceladus) through remote sensing - using techniques already in use on multiple space missions and as planned for NASA's Mission to Europa. Our field program will use NUI in a range of fully autonomous to real-time human-directed modes for survey and sampling missions: at the seafloor, up through the water column, and at the under side of the overlying ice. Complementary ice-station work will allow us to collect a complete continuum of samples, from the ocean floor to the outer surface of the ice.

Technology: Beyond NASA's Mission to Europa, follow-on missions to any ocean world will require mobile robotic systems capable of searching for life and life-related chemistry. WHOI has demonstrated robotic exploration for seafloor chemosynthetic ecosystems including using acoustic communications to transmit data to humans, allowing them to intermittently re-task the robot based on information provided within a high-latency telerobotic framework. JPL has flown and demonstrated autonomous operations technologies on Mars Rovers and Earth Orbiters. Here we will forge this relevant experience into a new partnership and develop autonomous systems to perform scientific exploration under engineering constraints (e.g., communications, energy, payload, navigation, vehicle safety). We will develop a balanced autonomy that optimizes operations despite a 2-3h round trip communications delay while still allowing for expert scientific input to on-going high level mission planning. Building from joint participation in Y1 fieldwork that will establish the current terrestrial state of the art, we will (i) identify a viable level of autonomy between the vehicle, shore/ground, and the science/operations team; (ii) develop and implement autonomous operations algorithms and processes suitable for future planetary exploration missions; (iii) test these algorithms using archived field-data coupled with simulated communication and light time delay constraints and (iv) validate the autonomous operations technology we develop, on environmental simulations and in the field.
Cooperative Exploration With Under-actuated Autonomous Vehicles in Hazardous Environments

Our proposal seeks to demonstrate new methods for exploration using coordinated heterogeneous vehicle platforms. These methods rely on real-time automated mission re-planning, incorporating environmental and vehicle state data to maximize information gain while responding to risk/uncertainty and evolving science goals. This research is relevant to NASA because it decreases the need for human intervention, enabling under-actuated robotic platforms to complete survey and manipulation tasks in complex or hazardous environments which have previously required human teleoperation of highly maneuverable vehicles. This mode of operation is particularly important for robotic exploration in dynamic environments that, like Earth’s subsea, are not amenable to radio-frequency teleoperation because of electromagnetic signal attenuation, or excessive communications latency. Our research will emphasize minimalist hardware through increased reliance on autonomous analysis, navigation, and planning. This is directly transferable to planetary explorers which must operate under similar power, size, and telemetry constraints.

We will demonstrate these new capabilities at Kolumbo, the most active submarine volcano in the Mediterranean basin. This underwater caldera is a complex, hazardous environment that is a suitable analog for autonomous risk-aware exploration of other planetary bodies containing liquid water. As part of this demonstration we will explore for life forms in and around carbon-dioxide accumulating subsea pools. These pools represent a previously unknown type of marine habitat recently discovered by our team (Camilli, Nomikou, et al, 2015). The extent and composition of these acidic pools, as well as their associated chemolithoautotrophic communities are poorly understood. Our demonstration operations will provide a unique opportunity to characterize life which flourishes in extreme hypercapnia. Insights gained here will provide new perspectives on the biological context of Earth’s precambrian evolution to an oxidizing atmosphere and possible life on other planetary bodies where photosynthetic carbon fixation is not possible.

We propose to use heterogeneous oceanographic platforms analogous to those used in planetary exploration: a surface vessel (comparable to a remote sensing orbiter), an AUV glider (a long-range reconnaissance drone) and nUI, a light tether remotely operated vehicle (lander analog). The volcanic crater will be initially mapped using acoustic remote sensing from the surface vessel. Automated planners will assimilate these data (including potential areas of interest and hazards) to generate a mission plan for a hybrid AUV glider. The glider will be equipped with an underwater mass spectrometer to identify and localize chemical anomalies. The glider’s limited payload and maneuverability motivates the use of onboard terrain aided navigation to maintain a safe distance from collision hazards while hunting for chemical signatures of interest. Autonomously interpreted water column data from the glider will inform spatially focused investigations using nUI equipped with an extensive science payload that includes stereo imaging cameras, sonar, and chemical sensors. Mission path planning/replanning and task scheduling of vehicles will be performed by a risk-aware planner that ensures safe operation by bounding mission risk at operator specified levels. Technology development will also focus on enhanced perception and autonomy for imaging and precise spatial measurements in complex natural terrain that reduces the requirement to communicate state and science payload data during operations. nUI will apply real-time visual and acoustic mapping for risk-aware path planning in order to enable safe autonomous investigation of biological assemblages and geologic features in close proximity to hazardous areas. A robust education/outreach program will involve high school, undergraduate and graduate students.
Britney Schmidt/Georgia Institute of Technology
RISE-UP: Ross Ice Shelf and Europa Underwater Probe

Proposal Goals:
On Jupiter’s innermost icy moon Europa, the unique combination of an active ice shell and rocky, possibly magmatic interior may give rise to a geochemical system suitable to life [e.g. Hand et al 2009]. To study Europa, we turn to the Earth’s ice shelves since the ice-ocean interactions and environmental processes are analogous between the two environments [e.g. Schmidt et al 2011, Soderlund et al 2013]. Despite permanent darkness under Earth’s ice shelves, evidence of life persists. Processes at the ice-ocean interface are hypothesized to provide a substrate and nutrients to ice-borne or dependent life including raised concentrations of limiting nutrients [Lin et al 2011, Raiswell 2011, Shaw et al 2011]. The issue in further advancing knowledge of under-ice habitability and biological activity both on Earth and Europa is this: we just can’t get there! RISE-UP will advance a capable, small form factor Autonomous Underwater Vehicle for long-range exploration under the Ross Ice Shelf in order to develop a vehicle that could, realistically, be flown in the future to Europa or another icy satellite.

In this PSTAR project, the RISE-UP team will satisfy the following objectives:
Science- We will investigate the ice-ocean system for evidence of its impact on biological activity by 1) addressing how oceanographic conditions such as temperature, pressure, and salinity affect the characteristics of the ice-ocean interface; 2) characterizing the habitability of the ice, ocean and sea floor to determine what properties of and processes within this terrestrial environment are relevant to Europa; and 3) discovering whether the shelf environment is actively supporting organisms and understanding their adaptations.
Science Operations- This science is made possible by treating the Ross Ice Shelf, a scientifically compelling target in its own right, as an analog environment and its exploration and analog mission architecture for future astrobiology missions. We will investigate the Ross Ice Shelf where the ice is nearly 0.5km thick, and at the grounding line, where the ice is up to 1 km thick. Technology- We will develop a stable implementation of the Icefin vehicle to 1) deploy through up to 1 km of ice and operate over a 4 km range, at up to 1.5 km depth; 2) use onboard sensors for autonomous navigation; 3) charge itself at a deployable base station at the base of the shelf; 4) detect life in situ using custom microfluidic devices; and 5) sample ice, sediment and water.

Proposed Methodology: To characterize under-ice environments and test biological hypotheses, we will use the Georgia Tech hybrid ROV-AUV vehicle Icefin, to search in-situ for biological communities, understand the ice and seafloor, and map ocean water currents; each of these represents transformative observations for climate and planetary science. The vehicle is uniquely instrumented, with a variety of sensors for scientific analysis of the under ice region including sonar sensors for topographic ice mapping, a CTD (current temperature depth) sensor, a Doppler velocity log sensor, and imaging cameras. The autonomy built into Icefin will allow for more efficient data collection of the scientific data. Because the field deployment of AUV and ROV vehicles is complicated both logistically and from a science perspective, it is critical that scientists and engineers for such a project are integrated as proposed here. No other existing system can meet the requirements of the science investigations described in this proposal.

Relevance: This project will enhance our understanding of the evolution of Europa’s ice shell, a prime target in NASA’s search for life beyond Earth and the limits of life here while developing techniques for future exploration of ice-ocean ecosystems. Thus this project is relevant to NASA and to PSTAR program by developing technologies and achieving science relevant to planetary science and exploration in an analog environment.
Extraterrestrial missions must, inherently, down-select the vast array of possible samples due to limited on-board consumables for in situ analyses or limited caching capability for sample-return missions. Therefore, an informed choice of a sampling site is crucial for the success of such endeavours. Previous studies (Amador, et al., Planet. Space Sci., 2014, Gentry, et al., Astrobiology, in prep) indicated that biodiversity varies over spatial scales in apparently homogenous locations. The proposed research advocates a study of the long-range and short range biological and chemical diversity of volcanic tephra sites, lava fields and other landscape features in Iceland that are similar to those encountered on Mars. Here, we propose to continue our student-initiated field work in Iceland by expanding our science via new field sites and new scientific techniques, and build upon our past work by adding temporal resolution to our spatial studies in biodiversity and missions operations. The Hóluhraun lava field created by the Bárðarbunga eruption offers a particular interesting and comparatively accessible site for such studies.

OBJECTIVES:
Objective 1: Determine Spatial and Temporal Resolution of Biodiversity in Otherwise Homogenous Locations. We seek to understand how representative the biology and chemistry of a single sample is of its local and distant environment, particularly when that environment appears to be homogenous geologically, morphologically, and contextually. We also seek to understand how the biology and chemistry of that sample change over time, particularly with respect to re-colonization of terrestrial biome after a catastrophic geological event like a lava flow or ash cover. This objective not only has a strong stand-alone science aspect, but also informs mission operations in terms of selection of samples for analysis or return.

Objective 2: Experimental Coordination of Multiple Field, Field Lab, and Home Laboratory Analytical Techniques. Extraterrestrial missions, like field expeditions, are limited in field techniques to what can be carried and deployed given the constraints of the mission. Therefore, ascertaining the relationships between scientific return from multiple levels of field techniques, field lab techniques, and home laboratory techniques is critical not only for successful field science campaigns on Earth but also for extraterrestrial missions.

Objective 3: Field Testing New Analytical Instrumentation. This PSTAR effort would enable low-TRL preliminary field testing of technologies as they are developed under other awards (e.g. a microfluidic organic detection instrument for a Europan kinetic penetrator mission currently funded under PICASSO), which would additionally support Objectives 2 and 3.

RELEVANCE OF THE PROPOSAL TO THE EXOBIOLOGY SOLICITATION:
The proposed work includes a science component, a science operations component, and a technology component. The science investigation is designed to further planetary research in terrestrial extreme environments that may be analogous to those found on other planets, specifically to understand how to seek, identify, and characterize life and life-related chemistry. Our science operations study focuses on: decision-making protocols and sample acquisition and storage. Our technology is an instrument package that enables remote searches for and identification of life and life-related chemistry in extreme environments.