Below are the abstracts of proposals selected for funding for the Discovery and Scout Mission Capabilities Expansion program. Principal Investigator (PI) name, institution, and proposal title are also included. 40 proposals were received in response to this opportunity, and 9 were selected for funding.

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**Kevin Baines/Jet Propulsion Laboratory**  
**Polar VALOR: The Feasibility of A Nuclear-Powered Long-Duration Balloon Mission to Explore the Poles of Venus**

We propose to determine the feasibility of using the Advanced Stirling Radioisotope Generator (ASRG) technique as the prime power source for a long-duration balloon mission to investigate, in-situ, the chemistry, meteorology, and dynamics of Venus's polar regions. Riding the powerful polar winds, two balloons and their scientific payloads of six instruments will circumnavigate both polar regions several times over a four-week period, thoroughly analyzing the dynamics, chemistry, and meteorology of Venus's polar dipoles which are the end points of Venus's global circulation system.

Due to the dearth of sunlight at the Venus poles, this type of long-duration mission is only enabled with the use of ASRGs. Based on the capabilities and design of our previously proposed Venus Aerostatic Lift Observatories for in-situ Research (VALOR) Discovery Mission, we will assess the mission impact of using ASRGs through all mission phases, including Earth storage, launch, cruise, atmospheric entry and in-situ operations. In the end, we hope to provide NASA and the Nation a feasible means for the long-term exploration of the dynamic skies of our neighboring world, Venus.

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**Richard Elphic/Los Alamos National Laboratory**  
**Locating and Characterizing Lunar Polar Volatiles: Feasibility of a Discovery-Class Mission**

We know almost nothing about the lunar polar environment, but the Moon's orbital obliquity has been very low for the past two billion years. Consequently regions of permanent shadow exist near the poles, regions that can cold-trap volatiles for very long times. Analyzing these volatiles at the Moon's poles will help us understand the processes by which exogenic water and other species have contributed to the terrestrial planets' volatile inventory over the history of the solar system - a contribution that could well have influenced the development of biology on Earth. But the Moon's cold traps are also sinks for the present-day tenuous lunar exosphere, which has both endo- and exogenic contributions.

A Discovery mission that addresses these questions must land within striking distance of permanent shadow in order to access the cold traps themselves. Non-nuclear power systems for robotic lunar exploration would require one-time use of batteries (severely
limiting mission lifetime), or periodic return to sunlight for recharging (increasing risk of mission loss if the mobile element cannot reach sunlight). Fortunately, Advanced Stirling Radioisotope Generators make extended operations within permanent shadow plausible. We propose to carry out a feasibility study for a landed Discovery-class mission to a lunar polar cold trap. We will perform trade studies involving mission design, including flight from the Earth to the Moon, and powered descent and landing. We will critically examine the science advantages and/or drawbacks of all modes of surface mobility, subsurface access and long mission duration (\(\geq 1\) yr) enabled by the ASRGs. ASRG waste heat may provide a means of staying alive in the ultra-low temperatures of permanently shadowed locales. Finally, understanding the effects of cryogenic temperatures on mechanisms and materials will be of critical importance. This study will result in a preliminary mission and system description.

**Michael Hecht/Jet Propulsion Laboratory**

**A tour through martian history: An ASRG-powered polar ice borehole.**

We propose Kuklos, a Mars polar drilling mission to explore the record of martian climate history encoded in the stratigraphy of the North Polar Layered Deposits. Life as we understand it requires a source of liquid water. Gullies and related features on Mars hint at a contemporary hydrological cycle, fueled by periodic climate changes driven by orbital and spin axis oscillation of the planet. On earth, such periodic changes are studied by optical and isotopic analyses of polar ice cores. Kuklos will perform such an assessment on Mars using an electrically-powered thermal drill. Kuklos builds on the proposed solar-powered Chronos mission, which is capable of accessing one or two recent climate cycles during a short, polar summer mission. ASRG-powered Kuklos will plumb many such cycles. Moreover, ASRG waste heat will warm the lander during the winter months, enabling an year-round assessment of present-day climate and a coordinated seismological investigation with ExoMars.

**Bradley Jolliff/Washington University**

**Journey to the land of Eternal Darkness and Ice (JEDI): A Lunar Polar Volatile Explorer**

The polar regions of Earth's Moon contain areas of permanent shadow that experience extremely low temperatures, which may form highly effective cold traps for volatile elements that migrate into them. Results from the Lunar Orbiter neutron spectrometer showed that concentrations of hydrogen are greatest at the poles. If hydrogen (potentially present as water-ice) and other volatile elements such as C, N, and organic compounds are enriched in deposits in the permanently shadowed regions, the deposits would be an important scientific target and a potentially exploitable resource for future exploration. JEDI is a lunar polar lander/rover that would conduct a geochemical traverse in a permanently shadowed polar crater. Use of an Advanced Stirling Radioisotope Generator (ASRG) will enable the rover to operate in this thermally challenging environment for sufficient time (6 months) to cover a meaningful distance (15 km) to determine the distribution of volatiles on local to regional scales and their relationship to the area of permanent shadow. The science payload is designed around detectors that are sensitive to...
H, ice compounds, and other potential volatile compounds, including an auger drill to investigate ice deposits buried within the upper meter of regolith. The analytical payload elements that will be further evaluated in the mission concept study include a neutron detector for H geochemical survey along the traverse, a laser Raman spectrometer (LRS) and a laser-induced breakdown spectrometer (LIBS) to determine speciation and composition of materials excavated by the auger, a neutral mass spectrometer to detect volatiles evolved at the auger tip by heating, and an alpha-particle x-ray spectrometer (APXS) for surface geochemical context. The proposal team includes experts for the analytical methods and partner Lockheed Martin (LM), which has broad experience and heritage in spacecraft design, sampling, and instrumentation.

Alfred McEwen/University of Arizona
Mission Concept: Io Volcano Observer (IVO)

Jupiter's moon Io is covered by hundreds of active volcanoes, many with erupting plumes of dust and gas up to 500 km high, and it is surrounded by the Io plasma torus and a neutral cloud of sodium and other elements. Previous attempts to fit a capable Io mission into the Discovery program have been hampered by the need for a large power system based on solar energy, because sunlight at Jupiter is 1/27 the intensity at Earth. The ASRGs combined with Ka-band downlink will enable a small satellite (~600 kg dry mass), which can be launched with 50% mass margin on an Atlas V 501, VEEGA trajectory, and inserted into a 30-day polar orbit about Jupiter. It is essential to make many (>10) Io passes in order to understand this highly dynamic system. We are planning a <50 kg payload including UV-through-mid-IR remote sensing and a neutral mass spectrometer. The total data volume to be returned in a 1-year nominal mission is at least 200 Gb, compared to the 0.2 Gb of Io data returned by Galileo. Key science objectives are (1) measure the eruption rates and lava mineralogy at volcanic centers; (2) improved understanding of Io's internal structure; (3) directly measure neutral composition of the torus, atmosphere, and plumes; (4) topographic mapping of key locations to model tectonic and volcanic processes; (5) monitoring of surface-plume-atmosphere-torus dynamics and mass loss; and (6) improved understanding of tidal heating and coupled orbital evolution.

Andrew Rivkin/Johns Hopkins / Applied Physics Lab
Ilion: An ASRG-Enabled Trojan Asteroid Mission Concept

We propose a study to explore a Jupiter Trojan asteroid mission concept, utilizing ASRGs as a power source. The Trojan asteroids are thought to be transitional objects between main-belt asteroids and Kuiper Belt objects, and are believed to have primitive, ice- and organic-rich compositions. However, recent dynamical work suggests they might originate from much further from the Sun than their current orbits near 5 AU. A mission to a Trojan asteroid was the second-ranked primitive bodies mission by the Primitive Bodies panel of the New Frontiers study by the NRC (not counting the already-flying New Horizons mission). The study will focus on a rendezvous and landing on a Trojan asteroid, with remote sensing instruments characterizing its structure and landed instruments to measure its surface composition. Preliminary orbit calculations have
shown that several of the Trojans can be reached with Discovery-class missions and reasonable travel times. The choice of payload, specific target, and the best approach to answering Decadal Survey and NASA goals will be the subject of the study as well. While solar power is being planned for missions out to 5 AU, large solar panels make it extremely difficult to land on a Trojan and they can not provide the required power during long nights at the landing site. ASRG-derived power enables this mission.

Scott Sandford/NASA Ames Research Center
Concept Study for a Comet Coma Rendezvous Sample Return Mission

We propose to carry out a concept study for a Comet Coma Rendezvous Sample Return (CCRSR) Mission as part of the Discovery and Scout Mission Expansion (DSMCE) program. This mission utilizes the Advanced Stirling Radioisotope Generator (ASRG) on a spacecraft designed to rendezvous with a comet, make extended observations within the cometary coma (but not land on the comet), collect coma samples, and return them to Earth for study. The returned samples would be studied in terrestrial laboratories using a wide variety of state-of-the-art analytical techniques in the manner of returned Stardust samples. Samples returned by CCRSR would have a number of major scientific advantages over those returned by Stardust. First, these samples will not have undergone hypervelocity impact during collection as occurred for Stardust samples, but will instead be captured at far lower velocities. This will eliminate sample destruction and alteration during the collection process and result in the return of much more pristine cometary material. Second, since this material will be collected over a period of time while the spacecraft is in the vicinity of the comet, it will sample a more extended period of cometary activity. Stardust’s exposure to cometary material lasted only ~10 minutes, and the majority of the material it captured is thought to have come from only a limited number of jets. CCRSR will obtain samples spanning months of cometary activity (both jets and the general coma) and will, therefore, provide a more representative sampling of the entire comet. Finally, CCRSR will collect many orders of magnitude more sample than Stardust, thereby vastly improving statistics and increasing chances of collecting rare materials that may be of high diagnostic value. This mission would greatly expand our knowledge of cometary activity and provide the study of the most pristine samples of primitive Solar System materials available.

Ellen Stofan/Proxemy Research
Titan Mare Explorer (TiME)

The Titan Mare Explorer (TiME) provides a unique opportunity to return affordable, fundamental science while demonstrating ASRGs in deep space and surface environments. The scientific objectives of TiME are to determine the chemistry, depth, surface morphology, and ambient surface conditions of a Titan lake. This will be accomplished with a payload that includes sonar, an organics analyzer, descent and surface imagers, and an environments-analysis package. TiME provides key scientific data unobtainable by Cassini, and yet are critical to understanding the unique liquid hydrocarbon cycle on Titan. Both the Decadal Survey and the Roadmap highlight the importance of understanding organics in the solar system, as well as planetary processes:
TiME directly measures the organic chemistry of a Titan lake and provides the first in situ data of a body of liquid on a planetary surface other than Earth. The mission remains in the cost cap by performing extremely focused science measurements and minimizing operations of the flight system. The mission launches on an Atlas 531 in January, 2014, arriving at Saturn in July, 2022. The spacecraft consists of a lander/floater derived from the Genesis capsule, and a carrier spacecraft that doubles as a communications relay. Following SOI, the spacecraft will target a northern hemisphere entry for the lander, with a splashdown on 8-8-2022 at 80°N, 250° longitude. The nominal mission consists of six passes (192 days), including the initial descent and landing, with the relay spacecraft encountering Titan once per relay orbit. ASRGs enable the mission by providing power for communications on the relay in a deep space environment where solar power is not viable, and power on the haze-shrouded surface of Titan where neither batteries nor solar power are options for long term survival. This mission benefits from strong inheritance of mission components and the experience of the combined team.

Jessica Sunshine/University of Maryland
Comet Hopper

CComet Hopper (CHopper) is a mission to explore the compositional and morphologic heterogeneity of a comet. Recent cometary flybys (Deep Impact at 9P/Tempel 1, Stardust at 81P/Wild 2, and Deep Space 1 at 19/P Borrelly) have revealed that there is both a great deal of diversity among comets and significant variation within individual bodies. Understanding the inherent diversity of a comet nucleus and the origins thereof are now a clear objective of future cometary exploration. Building on the results of these recent missions we propose Comet Hopper, an instrumented lander that will examine in detail the inner coma and surface of comet P/McNaught 2 (P/2004 R1). CHopper takes advantage of the low cometary gravity field to take off and land ('hop') multiple times. Six 'sorties' to the surface are envisaged as CHopper flies in loose formation with the comet over one orbital cycle. During each sortie, two hops will enable landings at three different sites to explore the comet's inner coma and surface at a variety of locations and heliocentric distances. The operational scenario of CHopper is simply not achievable with traditional solar energy sources because the large solar panels that would be needed are not amenable to prolonged exposure to the inner coma or landing on unknown terrain. Consequently, the success of CHopper in determining the heterogeneity of a comet and in separating the primordial state from subsequent evolution requires the use of non-solar power sources such as the Advanced Stirling Radioisotope Generator.