ASRG MARS GEYSER HOPPER. Geoffrey Landis[1], Steven Oleson[1], and Melissa McGuire[1], [1] NASA Glenn Research Center, Cleveland, Ohio, 44135, geoffrey.landis@nasa.gov.

Introduction: The Geyser Hopper is a design for a Discovery-class spacecraft using the Advanced Stirling Radioisotope Generator (ASRG) power source. This mission would land a spacecraft capable of rocket-powered hopping from a landed location at the Martian South Pole. The mission will study the geysers that appear near the South Pole in the Martian spring, with a stay of nearly one Martian year on the South Pole. This mission will, for the first time, demonstrate rocket take off from the surface of Mars, a necessary capability of a future sample return mission.

The design constraints were that the mission is to meet the Discovery-mission life-cycle cost cap, not including the ASRG, and incorporating adequate reserves in mass, power, and propellant. To reduce the cost and risk, the spacecraft concept was based on a previous design, the Phoenix lander, with flight heritage. The Phoenix incorporates soft landing capability with a restartable rocket propulsion system suitable to be repurposed for our requirements.

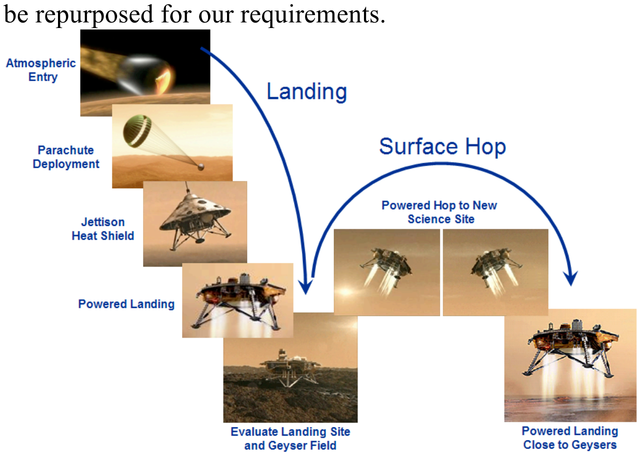

Figure 1: *Mission concept summary.*

Mars Geysers: Images from Mars Global Surveyor showed interesting dendritic features in the south polar regions, called “dark dune spots” or “spiders.” These occur in regions covered by the seasonal polar cap during the winter, but ice-free during the summer.

These features are the trace left on the ground of carbon-dioxide geysers. During the polar winter, the regions are glazed with a layer of carbon dioxide ice. The CO_2 ice is nearly transparent to sunlight, and when spring arrives, the sun heats the surface below the ice, causing the carbon dioxide to sublime from the bottome, where it is trapped by the overlying ice sheet. When sufficient pressure builds up, the ice sheet bursts, resulting in a brief “geyser” as the carbon dioxide trapped below the ice is released. Carbon dioxide flows beneath the ice to the rupture location at speeds of up to 160 km/hr, entraining debris, which is blown into the atmosphere along with the escaping gas. This debris plume (primarily dark basaltic sand) ejected into the air falls back onto the surface creates the dark fan pattern while erosion due to this flow carves radial patterns (“spiders”). As a phenomenon that is unseen elsewhere in the solar system, the Martian polar geysers are well worthy of further investigation. Such observation requires a high accuracy in placement. Further, the phenomenon occurs under harsh conditions, following an extended period of darkness, with temperatures in the range of -150°C, and sun angle only a few degrees above the horizon.

Mission: The mission concept is shown in figure 1. The Geyser Hopper design builds on the Mars Phoenix Lander as a heritage system, but uses a single ASRG as the power source. The ASRG is now undergoing space qualification and lifetime testing at NASA Glenn. The spacecraft is shown in Figure 2 and 3.

Science instruments include stereo cameras to view the geyser events and a robotic arm (from Phoenix5) to dig beneath the soil surface and gather soil samples for chemical analysis on the Hopper. A light detection and ranging instrument (LIDAR), a landing camera and a thermal spectrometer (for remote geological analysis as well as weather sensing) are included. The target-landing site is on the South Pole, a region where geysers exist over a stretch of several hundred kilometers with densities of at least a geyser every 1 to 2 km.

Design details of the spacecraft, along with a discussion of the mission criteria and the DRM design process, are found in references [1 and 2].

Mission conceptual timeline

1. The spacecraft enters the atmosphere, and make a rocket-powered soft landing in a geyser-dense region of the South Pole. This landing takes place in polar summer, when the surface is free of ice. The landing ellipse is 20- by 50-km, and hence the landing is targeted to a region, and not to a specific geyser location.

2. The science phase conducts science operations to characterize the site and understand the surface geology during the ice-free summer period. Images will identify the landing location precisely. From this, we identify a nearby location with a signature of a geyser.

3. The spacecraft will stow its science instruments and re-ignite the engines for a first hop of a distance of up to 2 km, to place the lander in a location where it

can directly probe the geyser region. The flight also will move the spacecraft closer to the winter-over site.

4. In the second landed science phase, the lander conducts science operations to characterize a geyser site during the summer period.

5. The spacecraft will stow its science instruments and re-ignite the engines for a second hop, a distance of ~100 meters. The hop places the lander on the winter-over site, hosen to be a relatively high elevation close to but not located on the site of a known geyser, and outside the fall-out pattern of the debris plume.

6. The spacecraft characterizes the area, then goes into "winter over" mode. ASRG waste heat allows that the lander itself to remain ice-free during the winter.

7. At polar spring, the lander observes the geyser from the location selected for optimum viewing.

8. Following geyser observations, extended mission operations could continue to a 2nd Mars summer.

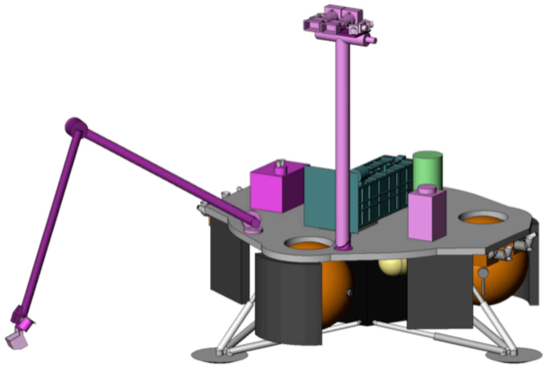

Figure 2: *Mars Geyser hopper shown as deployed on Martian surface, with sampling arm extended.*

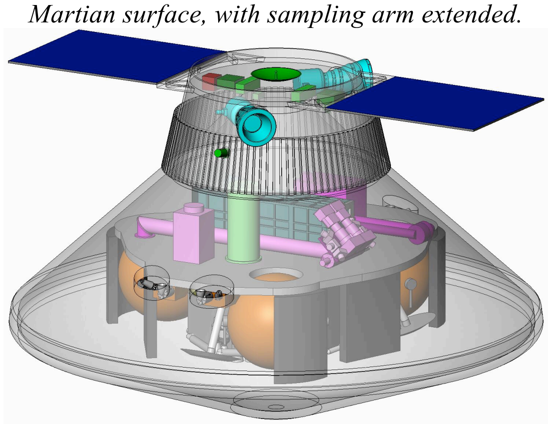

Figure 3: *Lander shown inside aeroshell with cruise stage attached (bioshield & insulation not shown).*

Hop Details: A key element of the spacecraft is that it will have the ability to hop to reposition close to a geyser site, and wait through the winter until the first sunlight of spring for the geyser phenomenon. The ability to "hop" after a propulsive soft landing was done once before, on the Surveyor-VI lander on the moon in 1967. The 300-kg landed mass of the Surveyor-VI is about 20% less than the mass of the lander assumed here.

The hop is done using the same engines used for the soft landing. Since the engines are pulsed hydrazine monopropellant engines, restart capability is already incorporated into the design. The spacecraft must be modified to ensure that the engines are preheated before the flight, and the thermal system is designed so that the hydrazine propellant is kept liquid at the approximately -75 °C ambient temperature of the polar summer.

The vehicle is designed for performing up to two hops, the first hop to bring the Lander to the region for characterizing geyser fields during the summer, and a second smaller hop to take the Lander to the "winter over" site in view of, but not directly on, a geyser site. In additional a "fine tune" hop to optimize the landing site may be done if fuel margins permit.

Each hop was modeled in the Mission Analysis and Simulation Tool in Fortran (MASTIF) program. The hops were modeled in 3 Degrees of Freedom with open loop control. The hops included:

- Two second vertical rise
- Thrust at a 35° angle relative to local vertical
- Ballistic coast
- Orient thrust to cancel horizontal velocity
- Vertical descent for soft landing

For each hop, an amount of propellant equal to the expected usage plus reserves is determined. Table 1 shows the hops that were modeled. These distances are the science minimum values. Since hop propellant is stored in the same tank as landing propellant, unused fuel from the landing is also available. Landing propellant requirements incorporate 30% reserves. If fuel margins are not used, a final hop can be added into the plan, to "fine tune" the site to the optimal location.

	Hop 1	Hop 2
Distance, km	2.0	0.1
ΔV (m/sec)	248	60
Mass-initial, kg	500	452
Mass-final, kg	452	440
Propellant, kg	48	12

Table 1—*Propellant consumed for each hop*

References:

[1] G.A. Landis, S. J. Oleson, and M. McGuire, paper AIAA-2012-0631, 50th AIAA Aerospace Sciences Conference,(2012). [2] NASA Glenn COMPASS team (S. R. Oleson, team lead), COMPASS Final Report: Radioisotope Power Systems, Design Reference Mission 1: Mars Geyser Hopper, CD–2009–37, NASA Glenn Research Center (2009).