MARS EXPLORATION WITH A SELF-REFUELING HOPPER.

Geoffrey A. Landis[1] and Diane Linne[2], [1]Ohio Aerospace Institute, NASA John Glenn Research Center mailstop 302-1, 21000 Brookpark Road, Cleveland OH 44135; e-mail geoffrey.landis@grc.nasa.gov, [2] NASA John Glenn Research Center, mailstop 5-10, Cleveland, OH 44135; e-mail Diane.L.Linne@grc.nasa.gov

Introduction: A small reusable "hopper" vehicle, the Mars In-situ Propellants Rocket, is proposed to fly autonomously on Mars, using *in-Situ propellant production* to manufacture rocket propellant directly out of the Martian atmosphere [1]. The MIPR explores the Martian surface under rocket power and can repeatedly takeoff and land, carrying a suite of science instruments over a range of hundreds of meters per hop. The flight demonstration will accomplish a range of technology objectives important to both unmanned probes and to future human missions, including:

demonstration of a sub-orbital Mars launch vehicle

demonstration of a pressure-fed small propulsion system for Mars ascent vehicles

demonstration of a lightweight space engine

and

use for the first time of propellants manufactured in-situ on another planetary body.

In addition to these technology objectives, the MIPR vehicle can carry a science payload that will advance our understanding of the surface and atmosphere of Mars.

Discussion: The Mars Pathfinder mission convincingly demonstrated the value of mobility on a planetary surface, and even though the *Sojourner* rover crawled at less than half a meter per second, and wandered no more than a maximum of twelve meters from the lander, the scientific (and public outreach) value of the *Sojourner* rover was incalculable.

But surface rovers, limited by terrain, cannot explore many interesting territories. If a vehicle were to rise above the surface, it could traverse "impassible" chasms and hop over "uncrossable" cliffs.

A valuable surface explorer would be a rocket-powered hopper able to take off and land repeatedly, carrying a suite of science instruments over hundreds of meters per hop.

The rocket-powered hopper with these key features can achieve such objectives:

- refuels itself autonomously for multiple hops by using solar power to react atmospheric CO_2 into O_2 (oxidizer) and carbon monoxide (CO) (fuel);
- achieves an altitude of several hundreds of meters and traverses a distance of several hundreds of meters during each hop; and
- carries a suite of scientific instruments to a soft landing at the conclusion of each hop.

The hopper will be situated on the science deck of a Surveyor class Mars lander. Once the lander sets down on Mars, the solar arrays will begin to produce power to operate its propellant production plant. The available power will determine the production rate.

The propellant production system is based on the MIP demonstration unit, which is a flight-qualified production plant originally designed to fly on the [now postponed] Mars-2001 Surveyor mission [2]. Our preliminary designs indicate that the production plant will be at least half of the hopper's dry mass. The distance achieved during a hop is a function of launch angle, quantity of propellants, thrust, and dry mass. For initial planning purposes, we have assumed a launch angle of 45° to maximize range. As a technology goal, we want to demonstrate an engine large enough that it can be scaled up for a Mars sample-return mission, where required thrust is expected to be 1700 to 2200 N (400 to 500 lbf). However, it is also important to keep hopper thrust levels low—to minimize mass and to allow a soft landing after each hop. We anticipate engine thrust to be 200 to 700 N (50 to 150 lbf) and are using a thrust level of 350 N (75 lbf) for planning purposes.

Parameters for the candidate vehicle are shown in table 1.

The nature of the hop, therefore, can be described by the dry mass of the vehicle (i.e., the mass to be landed back onto the Martian surface), the O_2 and CO production rates (measured in standard cubic centimeters per minute (sccm)), and the length of time between hops. For example, we have estimated that for 20 kg of dry mass and a production rate of 20 sccm of O_2, the hopper can jump 500 meters every 25 days. For 30 kg of dry mass and a production rate of 40 sccm of O_2, the hopper can jump 1000 meters every 25 days.

Table 1
Mars In-Situ Propellant Ballistic Hopper

Single Hop Range:	0.50 kilometers
Engine Thrust:	335 N (75 lbf)
Engine I_{sp}:	250 sec
Propellants:	O_2/CO (gas)
Total Mass	20.3 kg
Duration Between Hops:	25 days

Sounding Rocket: A proposed alternate vehicle is the Mars sounding rocket. This would be a single-launch vehicle, but it might deploy several payloads to multiple locations. It could be designed for a semi-soft or hard landing but could not be refueled for a second flight. The sounding rocket would obtain the same aerial science data as the hopper (although for only a single flight) and surface information at a single or multiple sites. It could also demonstrate the use of in-situ produced fuel, although for this option the propellant production plant would not be carried onboard. This would greatly reduce its dry mass and thereby allow the single flight to achieve a higher altitude, a longer range, a larger payload, or some combination of all three.

Science: The vehicle serves as a science platform that complements ground and orbital observations. Possible science payloads for the vehicle include:

Aerial photography of landing site. The aerial view of the landing site will be invaluable for placing geological investigations in a proper context. We will get high-detail images at a different sun angle and from a different physical perspective than the images taken by the descent imager during landing. Thus, our aerial images will complement the science data obtained from other means. These images will also provide "aerial reconnaissance" for selecting traverse path and locating interesting targets for rover samples.

Meteorology. Studies of Martian climate and meteorology will benefit greatly from an expanded range of altitudes for temperature and wind measurements.

Vertical profile of aerosols. The aerosols suspended in the Mars atmosphere are a significant climate and meteorology driver; the hopper/sounding rocket scientific payload will measure the vertical profile and investigate the change in optical scattering properties of the dust as a function of altitude.

Geological measurements at isolated remote sites. Since the vehicle easily traverses obstacles that rovers cannot, we will be able to sample regions that are geologically interesting but too rugged for surface rovers to reach.

References:

[1] G. Landis, D. Linne, and D. Taylor, "A Mars Rocket Vehicle with In-situ Propellant Production," AIAA-2000-3120, to be presented at 36th Joint Propulsion Conference, Huntsville AL, July 17-19 2000. [2] D. Kaplan, J. Ratliff, R. Baird, G. Sanders, K. Johnson, P. Karlman, K. Juanero, C. Baraona, G. Landis, P. Jenkins, and D. Scheiman, "In-Situ Propellant Production on Mars: the First Flight Demonstration," presented 30th Lunar and Planetary Science Conf., Houston TX, Mar 15-19 1999.