MARS ISRU SAMPLE RETURN (MISR) — A MISSION DESCRIPTION

D. I. Kaplan, NASA Johnson Space Center, Houston, Texas

A team of scientists and engineers at the Johnson Space Center has been studying an innovative approach for a Mars sample return mission. The key concept in this new approach is to use *in-situ* resource utilization (ISRU) technology to manufacture at Mars the necessary propellants to return the samples to Earth. The mission is called the Mars ISRU Sample Return (MISR). The chief benefit of such an approach is that the total mission cost can be significantly reduced compared to alternatives where all propellants are transported from Earth to Mars. While on the surface, MISR will collect and containerize 2.5 kilograms of intelligently-selected Martian rock, soil, and atmosphere samples using a microrover that is teleoperated by scientists on Earth.

MARS ARRIVAL

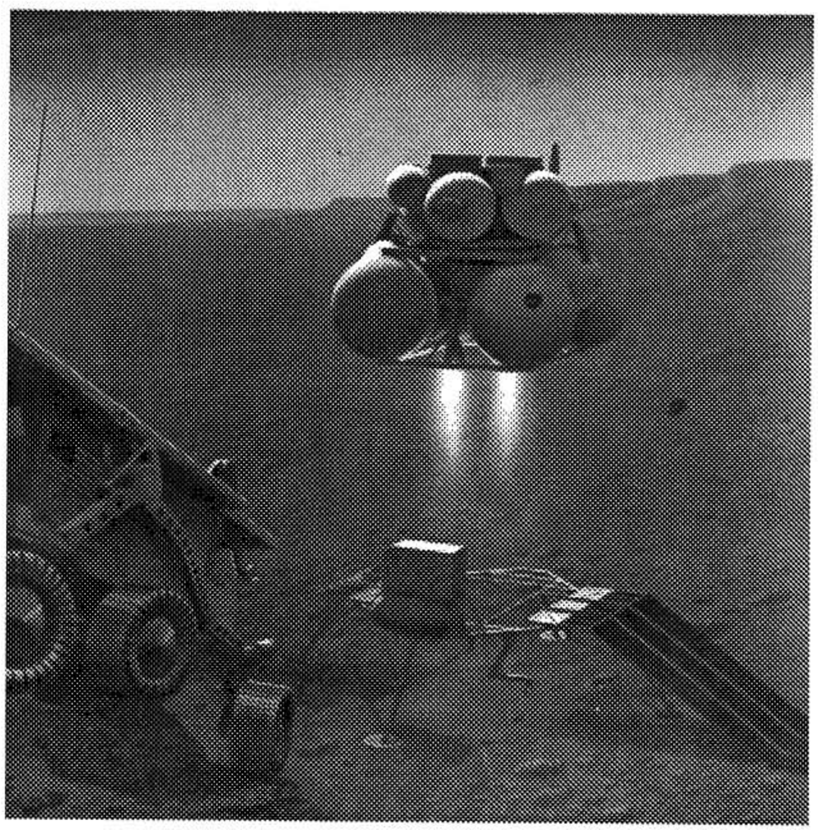
The entire MISR vehicle is launched to Mars on a single, expendable launch vehicle (ELV). Current spacecraft masses support using the Delta II or Atlas II. Launch on these smaller ELV's is possible because the Mars-ascent and Earth-return propellants are not onboard the vehicle. Instead, a much less massive propellant production facility is included.

Upon arrival at Mars, MISR enters directly into the atmosphere. No portion of the MISR vehicle is placed into orbit around Mars; hence, there is no expense for the design, construction, and operation of an orbiter. An aeroshell provides aerodynamic braking down to a velocity where a parachute can be deployed. Finally, small engines fire during terminal descent to slow the vehicle to a soft landing. An autonomous "hazard avoidance" guidance algorithm uses descent imagery to ensure that the touchdown occurs on a safe terrain.

Upon safe arrival, the vehicle transmits the nested descent images back to Earth, collects an atmosphere sample, deploys the microrover, and initiates the propellant production facility.

MICROROVER OPERATIONS

During the next sixty days, the microrover is teleoperated by Earth-based scientists to examine/analyze many rock and soil samples with the instrument set the rover carries. The microrover traverses an area approximately 100 meters in radius from the lander. The microrover is an enhancement of the JPL-developed Rocky 4, which is to be flown in 1996 on the MARS PATHFINDER mission. The most fundamental modification would be the addition of a sample collection mechanism.



Approximately 2.5 kg of soil, pebble, and rock fragments will be collected. Each sample will be separately containerized and deposited into the sample canister. The

MARS ISRU SAMPLE RETURN (MISR) — A MISSION DESCRIPTION : Kaplan, D. I.

sample canister will subsequently be closed and hard-sealed. The sample collection phase of the surface operations will be completed relatively quickly, and the NASA teleoperations team can stand-down. Control of the microrover will then be turned over to an education consortium which will continue the in-situ scientific investigations of the Martian surface.

PROPELLANT PRODUCTION

MISR will use a Sabatier-reactor/water-electrolysis/methane-pyrolysis-reactor to autonomously produce gaseous oxygen from carbon dioxide taken from the Martian atmosphere. The chemistry for the process is as follows: a small amount of water will be carried to Mars and electrolyzed into hydrogen and oxygen. The hydrogen will be mixed with carbon dioxide extracted from the atmosphere, and both will be fed together into a Sabatier reactor. The Sabatier reactor will produce methane (CH_4) and water. The water is electrolyzed; oxygen is refrigerated and stored cryogenically in propellant tanks, and the hydrogen is recycled back into the Sabatier reactor. The methane is fed into a methane pyrolysis reactor where it is broken up into carbon and hydrogen; the hydrogen is recycled back to the Sabatier reactor, and the solid carbon is discarded.

The fuel for the engines is propane. Propane is storable on Earth, during interplanetary transit, and on Mars. It does not need to be maintained cryogenically. Furthermore, propane has a very capable performance. To return the Sample Return Capsule to Earth, the two-stage Mars Ascent and Earth Return Vehicle (MAERV) will require a total of 970.5 kg of oxygen and 305.5 kg of propane. Consequently, 76% of the mass of the combination is oxygen. So there is a high-leverage payoff in terms of reduced Earth launch mass from manufacturing only oxygen at Mars.

For ten hours each sol*, there is sufficient sunlight to fully power the propellant production plant. During those ten hours, 4.7 kg of oxygen will be produced. Given this production rate and considerations of cryo boil-off, it will take nearly 500 sols to produce the 970.5 kg of oxygen required for Mars-ascent and Earth-return.

A minimum-energy return trajectory from Mars to Earth will occur 567 sols (583 Earth days) after landing. Consequently, 67 sols are "contingency" time for propellant production.

EARTH RETURN

After the 567 sols on the Martian surface, with the samples safely stowed away and the propellant tanks filled, the Mars Ascent and Earth Return Vehicle (MAERV) launches off the surface.

Throughout the entire return trip, the samples are maintained at Mars ambient environmental conditions; that is, temperature at or below -10°C, pressure at 0.01 atm. of carbon dioxide; and shielded from ionizing radiation.

Nearly seven months later, the Sample Return Capsule separates from the MAERV, and the MAERV fires its thrusters to pass beyond Earth into interplanetary space.

It is a mission constraint that no Martian materials come in contact with the Earth's biosphere. As the Sample Return Capsule separates from the MAERV, a combination of a protective bio-bag and a pyrotechnic outer skin layer will insure that no extraneous Martian materials are attached to the outside of the Sample Return Capsule.

The Sample Return Capsule enters the atmosphere, deploys a parachute, and is air-snatched by a helicopter. The helicopter delivers the vehicle to a waiting transport, which then takes it to the quarantine facility.

The return of Martian samples will be the preeminent accomplishment of the MISR mission. However, another important accomplishment should not be overlooked . . . the demonstration of *in-situ* resource utilization technology to produce propellants from indigenous resources. This demonstration will pave the way for a new approach to both robotic and human missions of exploration.

* A **sol** is one Martian day, which is equal to 24 hours, 39 minutes, and 35 seconds.