MARS ISRU SAMPLE RETURN (MISR) — A MISSION OVERVIEW

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The laboratory analysis of pristine Martian rock, soil, and atmosphere samples will lead to a major advancement in our understanding of that planet. 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.

MARS ARRIVAL

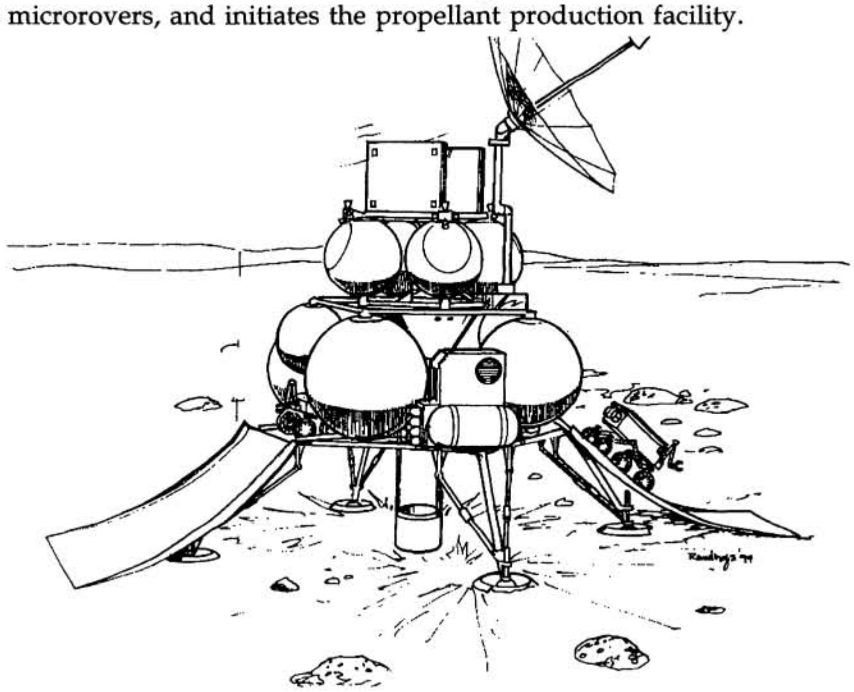
The entire MISR vehicle is launched to Mars on a single, expendable launch vehicle (ELV). Current spacecraft masses support using the Delta II or Atlas II. Launch on these smaller ELV's is possible because the Mars-ascent and Earth-return propellants are not onboard the vehicle. Instead, a much less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

Upon arrival at Mars, MISR enters directly into the atmosphere. No portion on 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, a small propulsive burn controls the terminal descent 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 microrovers, and initiates the propellant production facility.

MICROROVER OPERATIONS

During the next sixty days, two microrovers are teleoperated by Earth-based scientists to examine/analyze many rock and soil samples with the instrument set each rover carries. The microrovers traverse an area approximately 100 meters in radius from the lander. These microrovers could be 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.



During this time, approximately 2.5 kg of soil, pebble, and rock fragments will be collected. Each sample will be sealed in a plastic bag and deposited into the sample canister. The sample canister will subsequently be closed and hard-sealed. Thus, the sample collection phase of the surface operations will be completed rather quickly, and the teleoperations team can stand-down.

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PROPELLANT PRODUCTION

A minimum-energy return trajectory from Mars to Earth will occur some 500 days after landing. (This type of trajectory will require the least amount of fuel and oxidizer.) The propellant production facility is designed to operate autonomously throughout the 500-day surface stay in order to fill both the fuel and oxidizer tanks. There are three main options currently being investigated. All three options utilize carbon dioxide from the Martian atmosphere as the feedstock.

The first option is to manufacture at Mars methane as the fuel and oxygen as the oxidizer. Methane is a high performing fuel. However, this process requires cryogenic hydrogen to be transported from Earth to Mars. The hydrogen and carbon dioxide are mixed in a Sabatier reactor to produce methane (CH4) and water. The water is then cracked in an electrolysis cell; the oxygen is stored and the hydrogen is circulated for re-use in the Sabatier reactor.

A second option is to produce carbon monoxide (fuel) and oxygen (oxidizer) from the carbon dioxide using zirconia cell technology. The principal advantage of this approach is to eliminate the need to import any material from Earth. The major disadvantage is the lower performance of carbon monoxide as a fuel.

A third option is to manufacture only oxygen at Mars and to carry the fuel from Earth. Certain energetic fuels, such as ethane and propane, are easily storable at both Earth and Mars. In the case of ethane and propane, 80% of the mass burned in the ascent vehicle engines is oxygen. Thus, producing oxygen at Mars would save 80% of the imported propellant mass.

Regardless of the chemical option chosen, the lengthy surface stay is advantageous. The longer the time spent on the surface manufacturing propellants, the smaller the daily production rate needs to be. This implies that the power supply can be scaled down with lengthy stays. (And while an opportunity to return from Mars does exist after a 30 day surface stay, the power system required to manufacture the return propellants in such a short time would be prohibitive.)

EARTH RETURN

After the 500 days on the Martian surface, with the samples safely stowed away and the propellant tanks filled, the return vehicle launches off the surface. The first stage places the vehicle into Mars orbit. After receiving a state vector update, the second stage fires to sent the vehicle on its trans-Earth cruise.

Seven months later, the Earth Entry Vehicle separates from the rest of the return vehicle, and the return vehicle fires its thrusters to pass beyond Earth into interplanetary space.

The Earth Entry Vehicle 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 the samples to the curatorial facility.

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.

Great care will be taken to ensure that the Earth's biosphere is not exposed to Mars materials. Several design options are under consideration to assure that no extraneous Mars material is attached to the external surface of the Earth Entry Vehicle. Also, plans for mission contingencies—such as a failed parachute—are being addressed to prevent exposure of the terrestrial environment to the Mars samples.

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.