IN-SITU PROPELLANT PRODUCTION ON MARS: THE FIRST FLIGHT DEMONSTRATION.
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Introduction: Strategic planning for human missions of exploration to Mars has conclusively identified in-situ propellant production (ISPP) as an enabling technology [1]. A team of scientists and engineers from NASA's Johnson Space Center, Jet Propulsion Laboratory, and Lewis Research Center is preparing the **MARS ISPP PRECURSOR** (MIP) Flight Demonstration. The objectives of MIP are to characterize the performance of processes and hardware which are important to ISPP concepts and to demonstrate how these processes and hardware interact with the Mars environment. Operating this hardware in the actual Mars environment is extremely important due to both uncertainties in our knowledge of the Mars environment as well as because of conditions that cannot be adequately simulated on Earth.

The MIP Flight Demonstration is a payload onboard the MARS SURVEYOR Lander and will be launched in April 2001. MIP will be the first hardware to utilize the indigenous resources of a planet or moon. Its successful operation will pave the way for future robotic and human missions to rely on propellants produced using Martian resources as feedstock.

MIP Overview and Objectives: MIP is comprised of five distinct experiments; their names and key objectives are:

- Mars Atmospheric Acquisition and Compression (MAAC): to selectively absorb and compress carbon dioxide from the Martian atmosphere;
- Oxygen Generator Subsystem (OGS): to produce propellant-grade, pure oxygen;
- Mars Array Technology Experiment (MATE): to measure the spectrum at the Mars surface and to test several advanced photovoltaic solar cells;
- Dust Accumulation and Repulsion Test (DART): to investigate the properties of dust and to test techniques to mitigate the settling of airborne dust onto solar arrays; and
- Mars Thermal Environment & Radiator Characterization (MTERC): to measure the night sky temperature and to demonstrate the performance of radiators.

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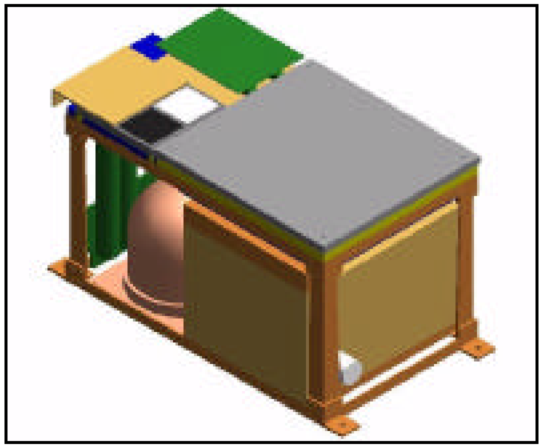
The MIP package will be small and light weight. Its overall external envelope is approximately 40 x 24 x 25 cm (15.7 x 9.4 x 9.8 inches), and its mass is 8.5 kg (18.7 lbm).

The long-term effects of operating in the Martian environment is key information being sought by MIP. Therefore, MIP would like to operate for a lifetime of 90 sols or more on Mars.



Mars ISPP Precursor (MIP) Flight Demonstration

Mars Atmospheric Acquisition and Compression (MAAC): The most readily available resource on Mars is the atmosphere. Hence, carbon dioxide (CO_2), which makes up more than 95% of the atmosphere, is the primary resource being considered for early Mars missions. However, the Mars atmospheric pressure is only 6 to 10 torr (0.1 to .15 psi), while most ISPP processes operate at approximately 760 to 3800 torr (1 to 5 atm.). Therefore, a CO_2 collection and compression device is required that is relatively small, lightweight, power efficient, tolerant to dust contamination, rugged and reliable enough to operate for long periods under the severe daily and seasonal temperature variations.

The primary objective of the MAAC experiment is to demonstrate and characterize the performance of a sorption compressor. A sorption compressor contains virtually no moving parts and achieves its compression by alternately cooling and heating a sorbent bed comprised of materials which absorb low pressure gas at low temperatures and desorb high pressure gas at higher temperatures. The characteristics of the material in the sorption pump define how much gas can be absorbed and which species are more readily absorbed over others. Due to the lack of rotating/moving parts, it has significant potential for high lifetime, reliability, and robustness.

MAAC acquires CO_2 during the cold Mars night when temperatures are typically 200°K. To facilitate cooling, the sorbent bed is attached to a horizontal radiator facing the night sky. Once an adequate amount of CO_2 has been absorbed (~12.5 g), the sorbent bed is heated and pressure in the sorption pump rises until 815 torr of pressure is reached. At this point, CO_2 can now be feed to the OGS experiment.

Oxygen Generator Subsystem (OGS): The ultimate objective of any ISPP demonstration is the production of oxygen and/or fuel from in-situ resources. The primary objectives of the OGS experiment are to demonstrate the production of oxygen from Martian atmospheric carbon dioxide (CO_2) as well as to investigate the basic performance of zirconia solid-oxide oxygen generator hardware in the Mars environment. The zirconia solid-oxide oxygen generator produces oxygen by electrolyzing CO_2 at elevated temperatures (750°C) to strip off an oxygen ion from the molecule. Once the oxygen ion has been removed from the CO_2 molecule, the zirconia material acts as an oxygen pump and separator by allowing only the oxygen to pass through it's crystal lattice when a voltage is applied across the zirconia material. The OGS is sized to produce 0.5 standard cubic centimeters of O_2 per minute (sccm) while operating. We desire to run the OGS about ten times on the Martian surface

Mars Array Technology Experiment (MATE): Until Mars PATHFINDER landed in July 1997, no solar array had ever been used on the surface of Mars. PATHFINDER was designed for a relatively short duration mission compared to a 500 sol surface stay for a Mars sample return mission that would incorporate ISPP. Since making propellants and storing them cryogenically requires significant power, power generation over a long period of time is critical for mission success.

MATE will incorporate five different individual solar cell types, two different solar cell strings, and temperature sensors to characterize promising solar cell materials and designs. MATE will also incorporate two radiometers and a dual spectrometer. The dual spectrometer will measure the global solar spectrum from 300 to 1700 nm by incorporating two separate photodiode arrays each with its own fiber optic feed and grating. Besides measuring the solar spectra on Mars, the dual spectrometer will also identify dust absorption and reflection bands, quantify daily variations in spectra and intensity, and improve atmospheric modeling.

Dust Accumulation and Repulsion Test (DART): Measurements from the PATHFINDER mission showed a dust deposition rate of 0.3% per day during a relatively clear (no dust storms) season. This accumulation could be catastrophic for a 500 sol lifetime mission.

DART will utilize a microscope, a dust accumulation monitor, and a sun position sensor package. The microscope will measure the amount and the properties of settled dust, and determine the rate of dust deposition, the particle size distribution, the particle opacity, the particle shapes, and possibly information about the particle composition through measurements of the optical properties.

DART will also incorporate tilted solar cells and an electrostatic dust repulsion device. Instead of attempting to remove settled dust, the DART experiment will use high-voltage to attempt to repel the dust before it settles.

Mars Thermal Environment & Radiator Characterization (MTERC): Thermal management is critical for efficient operation of an ISPP plant. Heat removal radiators will be required for such operations as cooling down a sorption pump sorbent bed, and cooling oxygen and fuel before liquefaction and storage.

The MTERC experiment will include four radiator plates: two with high emmisivity and two with low emmisivity. One high and one low emmisivity plate will be protected by a movable cover and will serve as the experiment control radiators. These control radiators will experience the least degraded measurement of the effective Mars night sky temperature and will serve as comparisons for the two continuously exposed radiators in order to examine the impact of dust accumulation, wind abrasion, etc. on long-term radiator performance.

Conclusion: The successful performance of the five individual demonstrations of MIP will provide both knowledge of and confidence in the reliability of this technology. At the completion of this flight demonstration, the MIP Team will be able to:

- recommend preferred hardware configurations for the intake and adsorption of carbon dioxide from the Martian atmosphere;
- understand the performance characteristics of zirconia cells to generate propellant-grade oxygen;
- understand long-term performance degradation characteristics of advanced solar array and radiator concepts operated in the actual Mars environment;
- evaluate the functionality of electrostatically repelling airborne dust from landing on a solar array; and
- recommend preferred hardware designs for innovative thermal management including the radiation of heat to the outside environment.

References:

[1] Hoffman, S.J. and Kaplan, D.I. (editors) (1997) "Human Exploration of Mars: The Reference Mission of the NASA Mars Exploration Study Team" NASA Special Publication 6107.