A MARS ATMOSPHERIC SENSOR SYSTEM FOR ENTRY, DESCENT AND LANDING. W. A. Sellers. Embry-Riddle Aeronautical University (sellerw1@my.erau.edu, Candidate for the Master of Aeronautical Science degree).

Introduction: NASA has identified strategic knowledge gaps in the understanding of atmospheric conditions on Mars that affect aerobraking, aerocapture and entry, descent and landing (EDL) and launch from Mars surface. The lack of observational data and uncertainty in modeling the atmospheric density and winds increases mission cost and risk and decreases performance as demonstrated in the need to accommodate larger landing ellipses than desired.[1]

This paper outlines a concept for Mars exploration that specifically addresses the gap in atmosphere knowledge while demonstrating technologies that may enable human exploration of the planet.

Mission Concept: A scientific payload of 8 small landers and an orbiter are delivered to Mars. To reduce mission risk, 4 landers are released from the arrival configuration prior to aerocapture using 8 m diameter 65 deg Hypersonic Inflatable Aerodynamic Decelerator (HIAD) (approximately 2000 kg). Aerocapture places the payload into a 500 km circular orbit. The aerocapture trajectory configuration is similar to that presented in the EDL-SA Year 2 Exploration Feed Forward Study.[2] The spacecraft is a MAVEN class data relay and meteorologically instrumented orbiter (900 kg). The landers (25 kg each), in a 0.5 m diameter 70 deg sphere cone aeroshell with MEDLI like instrumentation, are equipped with a surface meteorological payload.

Following post-aerocapture separation from the HIAD, a propulsive maneuver or a demonstration of autonomous aerobraking capabilities place the orbiter in the correct relay and science orbit and the remaining net landers are jettisoned at the appropriate locations and times to complete the ground matrix.

The concept addresses several Challenge areas: Challenge Area 1, Item 6-returning lower atmospheric data measurements at specific sites of interest; Challenge Area 2, Item 8,-providing a low cost platform for demonstrating aerocapture, aerobraking, aeroassist and EDL technologies, and Challenge Area 2, Item 11-a low mass, low cost multiprobe concept for landed missions carried by a larger orbital vehicle.

This concept is different from the ESA NetLander project because the goal is focused on atmospheric data collection, without a study of the Mars internal structure or the sub-surface. The simplification reduces mission risk, lowers cost, and reduces the technical challenges for mission actualization.

The successful Pioneer Venus 2 Multiprobe mission demonstrates that an orbiter and multiple landers can be deployed. See figure 1.

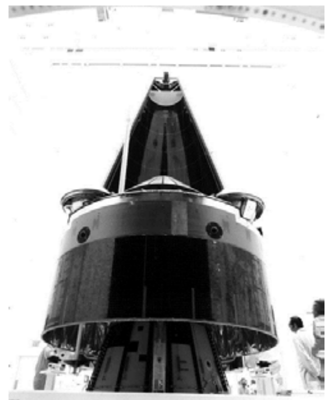

Figure 1. Pioneer Venus 2 Multiprobe
Source: NASA

Science goals: The goal of this concept is to gather atmospheric data in sufficient quantity and duration to discover the atmospheric processes on Mars. Current orbiters and landers do provide some data, but in general the atmospheric dataset of the lowest 5 km is limited, the orbiter data is typically confined to two local solar times and it is not correlated with surface measurments. The "dust" in the Mars atmosphere and low atmospheric pressure make common methods of remote sensing a challenge.

A standard suite of atmosphere instrumentation would be located on each lander retrieving measurements of temperature humidity, carbon dioxide, pressure, and wind direction and velocity. However, more advanced sensors like a Doppler Light Detection and Ranging (LIDAR) or a phased array Sonic Detection and Ranging (SODAR) pointed up into the atmosphere would provide the essential atmospheric conditions aloft if technical challenges can be addressed.

Pulsed Doppler LIDAR uses light energy to measure wind profiles, while SODAR uses acoustic energy. Each has trade-offs which could prove beneficial. Highly accurate LIDAR can determine atmospheric density, turbulent kinetic energy and estimate CO_2 column aerosols, but suffers from the poor optical situation on Mars with particulates limiting the range. SODAR suffers similarly on Mars with a low atmospheric pressure (mean of 600 Pa) and high sound attenuation profile compared to Earth's atmosphere.

However, SODAR has the advantage of being electronically steered providing a wide coverage in proximity of the instrument. The author's search for sound data on Mars discovered only the EDL microphone of the Phoenix lander[3], making the above acoustical claims not verified by actual data, but derived by acoustics calculations[4]. Instrumenting a LIDAR on one lander and a SODAR on another would give actual data to confirm or refine our understanding of the atmospheric dynamics. The other primary method of in-situ meteorological data, sonic anemometers on a tower, is impractical for a Mars robotic mission. Both LIDAR and SODAR would consume a significant part of the power budget, making multi-parameter sensors desirable. A data logger would be needed to store the data between orbiter passes. The power is provided by a battery with solar cell. The solar cell would need a wiper or vibration inducer to remove surface particulates.

A major advantage of the atmosphere data collection in this concept is that is allows for direct correlation of ground measurements with simultaneous measurements from orbit.

Lander EDL: The weather sensor lander is a 70 degree sphere cone aeroshell of the Viking vintage, but scaled to package the sensors. An initial estimate would be 0.5 m diameter and an entry mass of 25 kg. The ballistic coefficient for this configuration is roughly 21 kg/m^2, giving a subsonic landing capability.[5] The aeroshell size and mass limit can be adjusted for mission requirements.

In place of a supersonic disc gap band parachute, a small, towed, 80-degree, rigid cone could provide the aeroshell the correct orientation and stability.[6] The tow cable length and harness will need to be tuned for the specific vehicle. The tow cable and the cone will be deployed prior to hypersonic entry, and will need to be made from materials that can withstand the load and temperature extremes, i.e. Kevlar. The aeroshell will impact the surface and is designed to absorb the landing energy with a crushable region. EDL without a parachute is feasible when the payload is hardened electronics. Possible materials for the crushable aeroshell layer include carbon fiber composites and carbon foam.[7] Specific thickness of the crushable area is max velocity dependent and described in a NASA Contractor Report.[8] Adaptation would be needed for a Mars landing.

Each lander would be equipped with the Mars Entry, Descent and Landing Instrument (MEDLI) to obtain further EDL data.

Because the weather sensor landers are intended to be low cost, a set of landers, distributed in near-equatorial regions, could be deployed direct from cruise at each Mars launch opportunity. It is possible to use the Deep Space Network, existing orbital relay assets or a new relay orbiter for data telemetry depending on the lander power budget, data bandwidth and mission cost objectives. The MER Telecommunications architecture could be utilized without significant changes. Follow on years could send a new set of landers to replace failed landers and to increase data density at selected locations. Likely landing locations for future rovers would benefit from a weather sensor lander in the region. In this manner, atmospheric data would be available prior to rover arrival, and an atmospheric dataset for the prior 2 years would be available for mission planning and entry design.

Summary: A concept for a Mars atmospheric sensor system is presented with options for mission profiles, sensor systems and EDL concepts. The system if implemented would provide an improved understanding of the atmospheric conditions on Mars, a demonstrator platform for EDL technologies and testbed for low mass, low ballistic coefficient vehicles on Mars. The adoption of this concept will enable robust numerical weather prediction on Mars and increase the safety of Mars EDL operations.

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