SYSTEMATIC AND WIDESPREAD EXPLORATION WITH AEROCOASTING AND RECONNAISSANCE OF THE MARTIAN SUB-ATMOSPHERE (SWARMS). M. N. Thornblom[1] , J. N. Lukas[2], and R. A. Lugo, [1]University of Maryland, mark.n.thornblom@nasa.gov, [2]University of Maryland, joseph.n.lukas@gmail.com, [3]North Carolina State University, ralugo@ncsu.edu.

Introduction: The atmospheric exploration of Mars has historically been relegated to orbital assets and entry vehicles. These platforms offer only the two extremes of atmospheric exploration: orbiters are limited to downward-facing sensors that cannot enter the atmosphere, and entry vehicles are limited to a single atmospheric profile that lasts only minutes. In-situ measurements of the atmosphere are desirable on both regional and global scales. To that end, an innovative exploration technology is proposed that utilizes "aerocoasting," or low-drag aerobraking, with a orbiting vehicle that periodically deploys robotic aerial explorers that "swarm" to measure and characterize the Martian atmosphere.

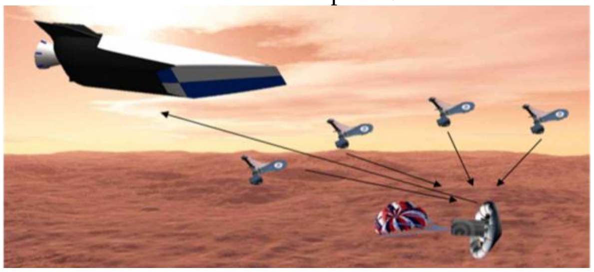

Figure 1: Mars swarming mission concept

Science Goals and Objectives: The science goals and objectives for this mission are derived directly from the Mars Science Goals, Objectives, Investigations, and Priorities report. In a general sense, the science objectives are to measure and characterize atmospheric water, dust, winds, density, and temperature. These objectives contribute to the achievement of three of the four MEPAG goals: I. Determine if life ever arose on Mars, II. Understanding the processes and history of the climate on Mars, and IV. Prepare for human exploration [1].

Mission Requirements: The mission requirements are derived from the science objectives, and are as follows:

- Achieve Mars aerocoasting orbit and collect atmospheric data between 60 km and 100 km
- Conduct in-situ, long-term global atmospheric science surveys (atmospheric water, dust, winds, density and temperature)
- Deploy at least 300 atmospheric sensing platforms through the Mars atmosphere
- Collect Pressure and Temperature data from 0-125 km from -30° to +30° lat and -180 to +180° long
- Recover and blend regional-scale data into useful global-scale trends

Regional flight coverage is dependent on winds, but is expected to be between within a 25-50 km radius, and mission duration is expected to be at least six months.

System Architecture: The system architecture is composed of three distinct exploration platforms: The Orbiter, the Deployment Module, and the Explorer. The combination of these platforms ensures coverage on both regional and global scales.

Orbiter. The Orbiter is styled as a hypersonic vehicle, with chemical rockets for propulsion and a 10 cm nose radius. It will perform aerocoasting maneuvers and science surveys at altitudes between 60 and 100 km. It carries 25 Deployment Modules that are deployed from its underbelly using a cold-gas ejection mechanism, just prior to entering the atmosphere.

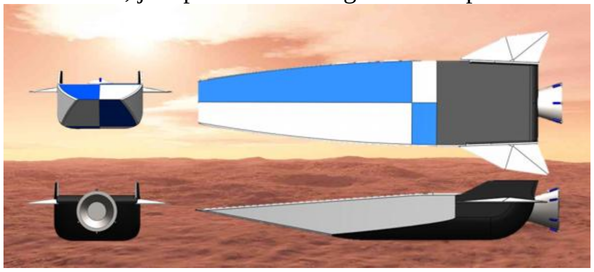

Figure 2: Orbiter design

Deployment Module. The Deployment Module is a cylindrical canister containing a payload of 15 Explorers, equipped with a hypersonic inflatable aerodynamic decelerator (HIAD) entry system. After deployment and peak entry heating rate, it ejects Explorers at a specified altitude. After landing, the Deployment Module acts as a data transceiver, receiving and storing data telemetered from Explorers before sending it up to orbital assets for subsequent telemetry to Earth.

Explorer. The Explorer is a maple seed-inspired, Samara-styled [2] miniature air vehicle designed to conduct science surveys as it descends. It carries only a science sensor and a communications package to telemeter data back to its Deployment Module.

Mission Design: A mission profile was designed to achieve the prescribed science goals and objectives. A primary mission duration of six months is predicted.

Orbit design. The design of the mission orbit is constrained primarily by the density of the atmosphere, which contributes directly to the change in velocity per pass and the heating rate experienced by the orbiter. In traditional aerobraking missions, a single periapsis altitude is selected to provide benign thermal environments, while still providing an appreciable change in velocity to circularize the orbit within an acceptable time. In the aerocoasting concept, the orbiter will have multiple periapsis altitudes, and therefore experience a range of changes in velocity. The final orbit design is complete when an acceptable number of passes have been made, and the total sum of all ΔV's is the required ΔV to circularize the orbit.

Heating. Atmospheric entry and associated heating rates typically present engineering challenges. However, the Mars atmosphere is sparse even down to a 60 km altitude, so heating predictions on the orbiter using Sutton-Graves [3] approximations are within 60 W/cm^2. This is a heating rate that can be withstood using current hot-structure thermal protection materials. The maximum heating predictions are a function of periapsis altitude, apoapsis altitude, atmospheric density, and nose radius. Mars atmospheric densities were obtained using a standard scaled-height approximation.

Communications. Vehicle-to-vehicle data transfer is expected to be a critical design issue, as the Explorers will have insufficient payload capabilities to store or transmit data directly to orbital assets. Therefore, the design includes "Deployment Modules" that are ejected from the Orbiter and will deploy the Explorers at a specified altitude. After Explorer deployment, the Deployment Modules will continue their descent and serve as a communications hub upon landing. Explorers will transmit their science data to the landed Deployment Module, which will in turn store and transmit the data to orbital assets. It is assumed that the Explorer-to-Deployment Module distance will not exceed 50 km, that the contemporary orbiting assets can be used to telemeter data back to Earth, and that existing hardware (such as the Small Deep Space Transponder [4]) can be used for Deployment Module-to-orbit communications.

System Design: In general, a 15-20% improvement in mass and power efficiency is projected due to technology and manufacturing improvements.

Mass budget. A maximum mass of 5000 kg for the Orbiter with 25 Deployment Modules was imposed. A ground-up mass budget was produced for each of the vehicles, resulting in an estimated 75 kg and 3 kg for a Deployment Module and Explorer, respectively.

Communications. Communications from Explorers to the Deployment Module are achieved using the UHF band antenna that is embedded in the Explorer's monowing. The signal is picked up by the receiving antenna on the Deployment Module, which is deployed after landing. Telemetered data is then stored aboard the Deployment Module until an uplink to an orbital asset can be established.

Communications from the Deployment Module to orbital assets are achieved by utilizing the same data transmission system aboard the MSL Curiosity rover [5]. This system is able to interface with MRO, ODY, and any other contemporary orbital assets.

Science instrumentation. Instruments on the Orbiter include a context camera, weather camera, coherent LIDAR, and infrared radiometer [6]. The Deployment modules carry a MSL-type flush air data system, and the Explorers can carry cameras, pressure transducers, thermocouples, and magnetometers.

Power. Vehicle power requirements and solutions were determined using parametric relations derived from previous missions. Specifically, an equation relating the science power to total power requirements was derived using ODY, MGS, and MRO, and used to extrapolate the total required power for the Orbiter.

Power is generated onboard the orbiter using multiple MSL-style MMRTGs, which nominally generate 120 W of electrical power each [7]. The Deployment Modules are powered by deployable solar panels that will supply <100 W. The Explorers are be powered by a lithium-polymer battery, which only needs to supply <20 W and last 30-60 minutes.

Summary: An innovative Mars exploration technology is presented that combines both regional and global atmospheric characterization. This exploration technology consists of "swarming" micro-vehicles that are periodically deployed from an orbiter which periodically performs modified aerobraking maneuvers. The micro aerial vehicles perform regional-scale atmospheric scans as they descend, while the orbiter performs global-scale atmospheric scans. The types of science data received from the vehicles are in accordance with current Mars science requirements set forth by MEPAG.

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