Habitat On Mars Enabling Surface Testing And Refinement (HOMESTAR). D. M. Marcus, Senior Reliability and Systems Engineer, Orion MPCV Program (danielma@seas.upenn.edu).

Introduction: Many of the critical infrastructure elements required to send a crew of astronauts to Mars are currently in development by NASA- the Orion MPCV, the SLS heavy lift vehicle, ground support equipment, launch facilities, and more; however, there remain several critical pieces of infrastructure and technology that must be perfected prior to sending human beings to face the long voyage to Mars, the subsequent visit on the Martian surface, and the return trip. One of the most critical pieces of infrastructure required to send people safely to and from the red planet is a functioning habitat. A habitat for people visiting or living on Mars must be able to withstand a wide array of environmental factors including periods of high radiation, extreme temperatures, vacuum, reentry conditions, and more.

Architecture: This proposal is for a light weight, radiation shielded, temperature controlled, inflatable and deflatable habitat to be sent to Mars. It will be a test bed for critical technologies that will be required in order to send human beings on long space voyages. An array of sensors, a life support system, and a suite of tools for mining, resource gathering, production, and localized manufacturing of the building blocks for ad hoc colonization of the Martian surface will be tested. The knowledge gained from this platform and its embedded sensors will provide significant scientific benefit as well as critical benefits for human exploration.

Mission Profile: The Launch Vehicle for the HOMESTAR mission would be selected at a later date, once detailed requirements, mass, sizing, and other design elements have been defined. An ion propulsion system would be used as the primary means of transportation in space. The habitat would travel on a mission profile that could be used as a reference trajectory for future crewed missions. This will allow deeper insight to be gained into the environmental conditions that would be faced on such a mission.

On the way to Mars, the habitat would be inflated. The environmental control and life support equipment as well as propulsion and other subsystems would be operated in the same way they would be if there were humans on board. A robust set of sensors will measure radiation levels outside and inside the habitat, temperature, air, water, loading, shock and vibration, location, orientation, and other environmental and resource management conditions. An advanced Failure Detection, Isolation, and Response (FDIR) system will detect, log, and respond to software and hardware malfunctions. All sensor, FDIR, and other data will be streamed back to Earth in real time via the communications system.

Once the vehicle arrives at Mars, it will transform back into a small package for entry. The Thermal Protection System for this mission would test out a likely heat shield and back shell design that might be used to bring people to the Martian surface in the future.

Upon landing, the habitat will open up once again and establish a base where it will automatically deploy an array of equipment for drilling the Martian surface. It would mine raw soil in its landing site to produce valuable building materials, life-sustaining resources, and fuels that will be critical to people that will land there in the future. HOMESTAR will test drilling and sampling equipment, techniques for converting elements available on Mars into useful resources, and more.

To keep costs to a manageable level, the vehicle will remain on the Martian surface rather than returning home. This will enable the system to be tested to failure to gather valuable reliability data about equipment and integrated habitat systems for planning the design and redundancy scheme of future habitats. It also enables testing of some of the technologies that support a future sample return mission.

Scientific Benefits: The suite of sensors to be placed on HOMESTAR will enable extensive science to be conducted and great insights to be gained about the solar system and the space between Earth and Mars.

Improved radiation modeling of the Van Allen Belts around Earth and the equivalent radiation belts around Mars. Radiation exposure, over long mission durations, can be one of the most critical factors in determining the success of interplanetary missions, both for crewed and uncrewed vehicles. Long-term exposure to radiation can result in central nervous system damage and cancer in people and in critical hardware failures in electronic systems.

Today's radiation models of the Van Allen Belts around the Earth are still in large part based on data gathered in the 1950s and 1960s by the Explorer series of missions and other missions such as Pioneer 3 and Luna 1. Updated radiation data is both necessary and extremely valuable for ensuring the success of future crewed missions and all missions that go beyond Low Earth Orbit. It is also valuable for understanding the radiation hardening requirements for hardware.

The radiation belts around Mars have been explored to some extent already by missions such as the Martian Radiation Experiment (MARIE), which was part of the 2001 Mars Odyssey, and which ironically failed due to radiation from a solar flare in 2003. This shows how critical it is to better understand radiation levels from various environmental conditions, along with their associated failure modes. It also illustrates the criticality of further assessing radiation environments.

This setup will also allow radiation levels to be measured during the trip between the two planets, thus improving understanding of the total radiation levels that can be experienced on such a voyage.

Further detailed assessment of the chemical composition of Martian soil, atmosphere, and more. Since it will likely not be possible to transport a large amount of materials to the Martian surface from Earth, due to the cost-prohibitive nature of such transportation, it will be necessary to be able to convert local materials into resources. To this end, an extensive assessment of the composition of the local Martian soil, rocks, solar radiation levels, composition of the atmosphere, etc. will be required and will enhance overall understanding of Mars.

Exploration Benefits: There are a number of key benefits to human exploration for this proposed mission.

Inflatable habitat. As mentioned, extreme weight constraints exist for any mission launched into orbit, much less for missions launched to Mars, due to the high cost per pound of moving mass. Additionally, the requirement for humans to have sufficient living space for a long-duration mission due to physical, emotional and mental constraints results in the need for a relatively large, but also light weight, durable, and strong structure. The structure also needs to be resilient to micro-meteoroid orbital debris strikes, possibly with self-healing properties and the ability to prevent breaches and venting of critical commodities, such as air, into space.

Radiation shielding. Radiation exposure, over long mission durations, as discussed before, can be a primary cause of failure and upsets of electronic hardware if not properly shielded and radiation hardened. Additionally, the cumulative radiation dose that passengers on Mars-bound journeys will be subjected to needs to be kept at a level that does not pose a risk to the long-term health of astronauts. Given intense, long-duration radiation environments and extreme weight constraints, it will be necessary to develop and test innovative radiation shielding techniques to protect crews on the way to Mars, on the Martian surface, and again on the flight back to Earth.

Environmental Control and Life Support Systems. Efficient and reliable environmental control and life support systems are critical for long interplanetary journeys. The combination of limited resources that must be recycled, harsh environments, and long time durations mean that hardware must be both extremely efficient in recycling and reusing resources and extremely reliable without the need for maintenance that might require repairs and sparing.

Reentry systems. Uncrewed missions to Mars have relied on specialized heat shields designed for their mission characteristics and the low atmosphere density entry environment on Mars. Reentry systems will have to be optimized for humans to ensure that loading, temperatures, and other environmental factors do not exceed Brinkley criteria or other limitations. This will prevent injury and death caused by exceeding the load capability of the human body or other constraints. An array of accelerometers, load sensors, temperature/pressure sensors, and inertial measurement devices would be used to accurately assess environments seen during the mission and particularly during entry, descent, and landing.

Resource management and creation systems. Future crews, on missions to Mars, will require tools to leverage local materials and turn them into the critical resources needed to sustain their own existence on the planet. A number of techniques will be prepared, and important equipment will be designed, to extract materials from the Martian soil, rocks, atmosphere, and the sun to create the building blocks necessary to sustain life on Mars, all using a set of equipment crafted as part of the habitat.

Additional Information: If you have any questions or wish to speak with the author of this abstract, please call at 267-970-5671 (or send an e-mail message to danielma@seas.upenn.edu).