**MATERIAL RADIATION DEGRADATION STUDY (MARA-DS): A PAYLOAD CONCEPT TO PREPARE FOR HUMAN MISSIONS TO MARS** M. C. Bouchard,[1] F. E. Marshall[2], C. H. Parrish II[3], N. P. Orenstein[4], and I. A. Lee[3]. [1]Washington University in St. Louis (mcbouchard@wustl.edu), [2]Missouri University of Science and Technology (fem33@mst.edu, ial7c9@mst.edu), [3]North Carolina State University (chparris@ncsu.edu), and [4]University of Southern California (norenstein@usc.edu)

**Introduction:** NASA has set the target for a human mission to Mars in the mid-2030s, and the need to solve many of the remaining technology gaps grows. One of the challenges in sending a manned mission to the Red Planet is the harsh radiation environment that the crew will have to endure. The proposed payload instrument, the MAterial RAdiation Degradation Study (MARA-DS), will address this technology development so that structures and habitats may be designed for any future human mission to Mars.

The payload was developed as part of a university competition hosted by the non-for-profit foundation Mars One. Mars One seeks to establish a permanent human settlement on Mars and their first goal is to send a lander to the Martian surface in 2018. The mission's primary objective is a technolgoy demonstration for the subsequent human missions. Based on a written proposal process, the MARA-DS proposal was one of ten finalists in the university competition.

MARA-DS is designed to record the energy and impact events of Galactic Cosmic Ray and Solar Energetic Particle flux at the surface of Mars. The payload is designed to establish a baseline for the radiation environment on Mars while also measuring the radiation flux through a simulant of Martian regolith, which Mars One plans to utilize *in situ* as the primary sheilding material for the settlement.

**Science Objectives:** MARA-DS is a static payload designed to record the energy and impact events of Galactic Cosmic Ray and Solar Energetic Particle flux at the surface of Mars. Solar Energetic Particles are generated by high energy solar events while Galactic Cosmic Rays originate primarily outside of the solar system in events such as supernovae [1]. These two forms of radiation both provide high energy protons and elemental nuclei bombardment to the space environment [1]. For the purpose of this proposal, both radiation sources will be referred to as Galactic and Solar Radiation (GSR).

Sensors will collect information on the GSR energy and impact event environment near the surface of Mars. Ionizing radiation in the form of X-rays and gamma rays are near massless high energy photons and will not be measured by MARA-DS. The payload will establish a baseline for the radiation environment of the landing site while also measuring the GSR flux through JSC Mars-1: a Martian regolith simulant and analog for Mars One's proposed principal radiation protection. As GSRs penetrate the material shields a percentage of the primary GSR energy will be transferred into secondary radiation proportional to the interaction length and the thickness of the shields [1].

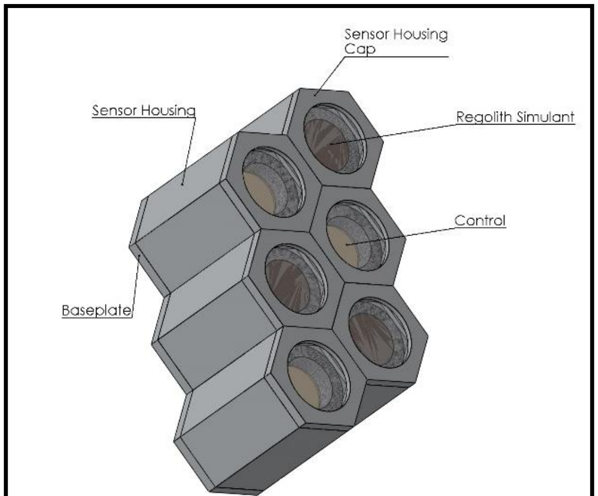

***Figure A:*** *MARA-DS Honeycomb Housing Design*

The primary science objectives of MARA-DS are to investigate the Galactic and Solar Radiation (GSR) energy and impact event frequency at the surface of Mars; to compare the degradation of GSRs through a Martian regolith simulant to determine the material's potential as radiation protection for human beings; and to provide input to the body of knowledge of the radiation influences to past, present, and future life on the Martian surface.

**Design of Experiment:** The MARA-DS layout consists of a stationary, zenith directed array of six silicon-lithium detectors for charged particle spectroscopy. Each of the first three sensors will be covered with a one centimeter thick shield of JSC Mars-1. Each shield diameter will be 31.5 mm and will completely cover its respective sensor. The final three sensors will serve as the control group and will not be shielded in order to act as a radiation environment baseline. All six sensors will be encased on their other five sides by the payload housing which will be Al-7075. When the sensors interact with a charged particle a current is created and emitted. Charged particles of different energies will create currents of varying amplitude when interacting with the sensors. By tracking the amplitudes of the generated currents, it is possible to determine the total energy absorbed by the sensor.

The data will be pulled from the sensors and stored in the redundant onboard memory which can be queried upon request by the payload. Due to power and

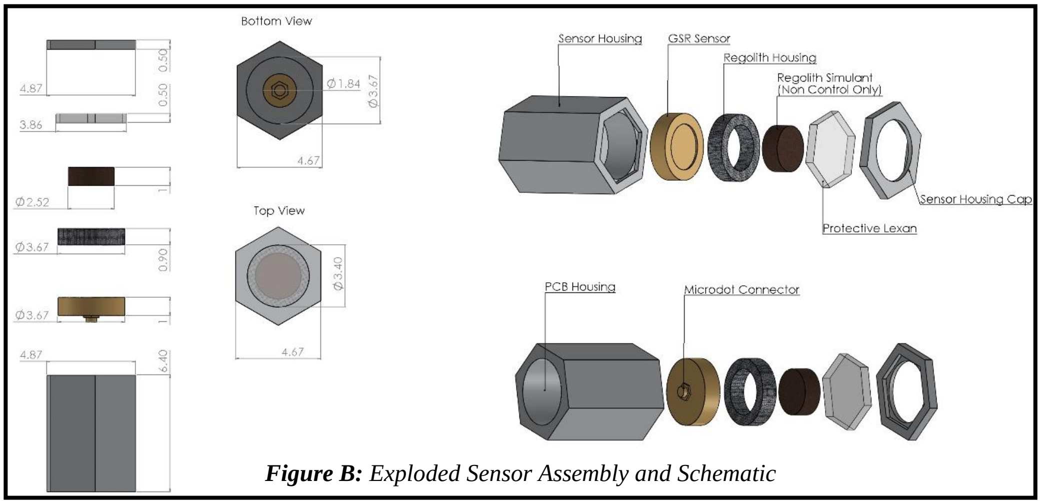

***Figure B:*** *Exploded Sensor Assembly and Schematic*

data constraints, the payload will be operated for a fifteen-minute period hourly over the course of the primary mission of two years which is a comparable sampling size to the Radiation Assessment Detector on Mars Science Laboratory [2].

Since this payload does not have the capability to detect the angle of incidence of the particle impedance, the mass and type of particle will not be discernable; however, the bulk energy flux and interference count for each sensor will be recorded. The detectors can measure energy events on the scale of up to 3 MeV for β-particles, 30 MeV for protons, and 140 MeV for α-particles. The sensors are capable of a 45 KeV resolution for α-particles and 40 KeV for β-particles.

This collected data can be used to extrapolate the absorbed radiation dose (RAD) at the landing site as well as the anticipated radiation environment at similar latitudes [3]. The team predicts that over the course of two years, the daily readings will create a baseline for the radiation environment of the selected landing site, and expects to see degradation in the particle count in the sensors protected by the JSC Mars-1 on the order of a few percent [1].

**Technical Design:** The static payload has been designed to minimize connection points, thereby reducing potential sources of structural failure, and the entire housing will be CNC mill-ed from a single block of Al-7075, a standard space-grade Al alloy that has an appropriately high strength-to-weight ratio.

The housing structure is a parallelogram-shaped honeycomb design that consists of six hollow, hexagonal prisms (Fig A). The total volume required by MARA-DS is only 338 $cm^3$. The payload mass totals 1.49 kg, which is less than 75% of the maximum allowed mass. Each prism, or column, contains an air-tight 5-mm thick hexagonal Lexan™ polycarbonate sheet to prevent dust from entering the hardware. Under this sheet, the sensor shield is encircled by a light-weight o-ring to prevent movement. Below the sensor shield, the sensor is inserted, followed by another o-ring. This second o-ring allows wiring from the sensor to the PCB to be semi-contained to reduce risk of disconnections (Fig B).

The electrical systems will be powered using power supplied by the lander and will be stepped down appropriately to power the processors and memory. The sensors, however, will require the voltage to be amplified to an estimated 700V. Canberra LEC 300-5000 sensors will serve as the Si-Charged Particle Detectors. A single circuit board will incorporate the processors, memory, and Microdot connectors to interface with the sensors, with all components in triplicate. Coulomb counters will be able to track both the events observed as well as the amplitudes of the energy.

Radiation fins for passive cooling require no power and no moving parts and were selected for thermal protection [4]. The honeycomb design incorporates the hexagons as fins that can radiate internal heat and add no addtional weight.

MARA-DS has been designed using only commercial off-the-shelf technologies with high Technology Readiness Levels. Since the team has limited capital and resources, radiation-hardened parts were not selected. Insted all electrical and computer elements are integrated with intelligent triple redundancy, a method employed by some aerospace companies such as SpaceX.

The MARA-DS team adopted the best practices of the systems engineering and architecture fields in the design of the payload, and the technical requirements were derived from the information provided by Mars One, as detailed in their Request for Proposal and the Proposal Information Packet of the spacecraft contractor, Lockheed Martin. The basic design for the Mars One 2018 lander will utilize much of the hardware and heritage of the successful NASA Phoenix mission.

**References:** [1] Hellweg C.E., and Baumstark-Khan C. (2007) *Naturwissenschaften, 94*, 517–526 [2] Hassler D.M., et al. (2012) *Space Sci Rev 170*, 503-558 [3] Kim M.Y., et al. (2014) *JGR, 119*, 1311–1321 [4] R.N. Krikkis (2002) *Journal of Heat Transfer, 124*, 805. The MARA-DS Team would also like to ackowledge Professor W. R. Binns of Washington University in St. Louis for his support and advice throughout the project.