Marshall Problem Statement/ Senior Design Topic

Problem Title: **Thermally Conditioned Lunar Sample Return Vessel**

MSFC Mentor Name and Organization: **Travis Belcher, EV34 Thermal Analysis and Control**

Mentor's Contact Information: E: **travis.w.belcher@nasa.gov W: (256) 961-3155**

Indicate which discipline /s is/are most appropriate to work on this problem, e.g., aerospace, mechanical, electrical, chemical, industrial, civil, computer, physics, materials, test, nuclear, earth science, other **Mechanical (with potential collaboration with Chemical, Material disciplines)**

Marshall Problem Statement

Background: The big picture with references to previous work (Why would a senior design student be excited about this work?)

This is your chance to aid NASA in bringing moon rocks back to Earth! With future human exploration of the lunar surface through the orbiting Deep Space Gateway, NASA will need a way to transport lunar water-ice and frozen regolith samples back to Earth. These samples will need to be maintained in pristine condition for analysis which results in a temperature requirement below the triple point of water (< 32F) and hard vacuum (<10/^-6 torr). With resource limitations for the transport of cargo to/from the lunar surface, the vessel design should minimize mass and draw no power. Instead of removing heat leak into the container via a refrigeration cycle, an unpowered passive thermal storage solution utilizing Phase Change Materials (PCM) is desired. PCMs have previously been used for passive thermal control on spacecraft electronics, where the temperature of the thermal load is maintained at the melting point of the phase change material as heat is absorbed as heat of fusion. NASA is interested in further utilizing thermal storage via phase change to passively maintain scientific samples at a low temperature for relatively long durations. The specific durations of interest would be 3-4 days for transport from the lunar surface to the orbiting Gateway, and 15+ days for return to Earth. The design will also take into consideration the regeneration of the PCM.

Recent/on-going research on the problem (What resources, if any, are available to the senior design team, such as equipment, software, facility utilization)

- **NASA performed extensive research into Phase Change Materials in the 1970s and many publications are available, such as https://ntrs.nasa.gov /archive/nasa/casi.n trs.nasa. gov/19780007491.pdf**
- **The use of phase change materials for passive thermal control is widespread in industries such as construction, textiles, and pharmaceutical transportation**
- **NASA recently flew a phase change material heat exchanger experiment on ISS, which is conceptually similar to a phase change heat capacitor (https: //www.nasa.gov /mission pages /station /research/experiments /2077.html)**

Details of the problem; design constraints, requirements (if any), outcome expected (one semester Senior Design course lasts 15 weeks; two semester course lasts 30 weeks.) (What do you expect the senior design team to accomplish?)

- **The team will design, model, and analyze a lunar sample return vesse1 using their preferred design and analysis tools. The detailed assumption to be used**

for the volume, timeline and thermal environment will be coordinated with the mentor. Published data for thermo-physical properties of PCMs will be used as inputs to the model

- **If practical for the University given existing labs, student schedules and available funding from this activity; design and build, or purchase a test apparatus to measure the relevant thermo-physical properties of several candidate PCMs. These thermo-physical properties include, but are not limited to:**
  - **The therma1 expansion (change in density) across the material's solid/liquid phase change**
  - **The material's liquid and solid specific heat vs. temperature**
  - **The material's liquid and solid thermal conductivity vs. temperature**
  - **The material's heat of fusion**

- **Project Deliverables:**
  - **Geometric model of the proposed design**
    - **Design constraints of the model wil1 be based on ca1culations made by the team o Thermal Math Model (TMM) of the proposed design**
      - **TMM will be based on the dimensions of the CAD model and the physical properties from published sources or testing**
  - **Database of the physical properties of the phase change materials tested**
    - **Materials tested will be based on several criteria**
      - **Cost**
      - **Commercial availability**
      - **Compatibility with other materials**
      - **Melting point**

Senior Design Project Rules:

1. Weekly telecons will be scheduled to maintain proper progress and prevent dead-end ventures.

2. Deliverable/s required (e.g. one semester course - a written final report; two semester course - written final report and a prototype/model (if practical)