Design title: 2025 Human Lander Challenge (HuLC) Design Challenge

Challenge overview

Human Lander Challenge (HuLC) is made ofNASADiscovery Systems Development Task Manager (ESDMD) A program launched to explore solutions to human landing systems (HLS) Innovative solutions to known problems. The challenge encourages college students toNASAexistHLSContribute to advances in the field of technology, with a particular focus onNASACryogenic liquid storage and transfer systems involved in long-term lunar missions.

2025 Theme Background: Advanced Cryogenic Technology

Space propulsion systems using cryogenic liquidsNASAMissions to explore the moon and Mars are vital. Current technology is capable of storing cryogenic liquids for hours, but future missions will require storage capabilities that can last for months. This challenge aims to fill this technology gap by focusing on advanced cryogenic fluid technologies.

Challenge description and proposal category

Student teams will develop innovative, systems-level solutions aimed at understanding and mitigating potential issues associated with the storage and transport of cryogenic fluids in space. The proposed plan should be3to5Applicable during the year and shall fall into one or more of the following categories:

* **Cryogenic propellant transfer in orbit**: On the ground, the transfer of cryogenic fluids has become routine. In orbit, however, challenges arise due to a lack of experience in transferring large amounts of cryogenic fluids in environments dominated by microgravity or surface tension. Understanding the thermal fluid physics of cryogenic liquids during pipe cooling, tank cooling, and transfer filling operations is critical to developing efficient propellant transfer schemes.
* **Cryogenic liquid mass tracking in microgravity**: Existing mass measurement instruments often require higher accelerations to measure liquids within propellant tanks. These gauges perform well during engine firing or ground operations. But in a microgravity environment (HLSThe mission may last several months), and the liquid in the tank moves freely due to less restrictions, and existing instruments cannot effectively measure it. Propellant sloshing during landing or initial engine thrust phases can also affect the accuracy of mass measurements.
* **Large area radiant insulation**: In the cislunar space, most of the heat entering the propellant storage tank comes from radiative heat transfer, such as solar radiation, earth albedo, heat generated by other celestial bodies, other parts of the spacecraft, or engine operations. Since space vehicles require large-capacity cryogenic propellant storage tanks, usually diameter5-7meters, height10meters, therefore a large area of ​​radiant insulation is required to cover the entire tank to reduce the total heat entering the cryogenic liquid.
* **Advanced structural supports to reduce heat transfer**: Structural supports for conventional launchers are often made of highly thermally conductive materials such as metal, potentially allowing kilowatt-scale heat to be transferred into the propellant tanks. In addition to radiant insulation, new methods will need to be developed to reduce structural heat leakage, such as incorporating thermal breaks in the skirts to separate the dry mass from the vehicle, or using coatings that reflect heat into cislunar space.
* **Automated cryogenic coupler for propellant transfer**: To transfer large quantities of cryogenic liquids between aircraft, reusable automated couplers must be developed to support multiple cryogenic propellant refueling missions.
* **Low leakage cryogenic components**: Traditional launcher cryogenic valves, pressure reducing valves, check valves and other components have acceptable leakage rates over multi-hour missions. But on long-duration missions lasting several months, this leakage rate can cause stocks of cryogenic fluids to be depleted, necessitating improved valve performance.

Design constraints and guidelines

Proposed technologies and designs must comply with the following constraints:

* **Survivability in extreme environments**: The solution must be able to operate in the harsh environment of cislunar space and the moon.
* **rightNASAlowest barrier to adoption**: The design should have characteristics such as low quality, small size, and low power consumption.
* **No additional risk to crew**: Solutions should not pose new risks to mission crews.
* **Survivability during launch**: Technology must be able to withstand the mechanical stresses of launch.
* **mission life**: The design must support operations lasting several months.

Things to consider when proposing solutions

Proposals must be innovative and contain a clear description of the need, utilization or application, impacts, and outcomes to reduce and mitigate the risks associated with long-term storage and transfer of cryogenic fluids in unstable or low-stability states. Proposal teams should clearly identify their assumptions and provide sound engineering rationale to support these assumptions. The following are some suggested assumptions, but adjustments can be made if there are good engineering reasons.

* **Short-term applications toward the moon (3to5within the year)**
* **Cost-effectiveness and well-founded estimates**: The solution should be sufficiently economical to merit consideration for implementation.
* **Ease of implementation and operation**
* **Designed for cislunar space and lunar environments**:referenceSLS-SPEC-159 NASACross-project natural environment design specifications (DSNE) revised versionI。
* **Deployed in or applied toNASA/BusinessHLSlunar cryogenic vehicle**
* **Key technologies (if relevant)**:Includes technology maturity levels (TRL), and system engineering and architectural trade-off analysis to guide recommended solutions.
* **Technical value and rationality of task operations**: Support exciting and sustainable space exploration programs.
* **Support engineering analysis and reasonableness of assumptions**
* **Realistic assessment of project progress and milestones**: Include realistic development and annual operating costs (i.e. budget).
* **Comply with design competition requirements and constraints**