LuVESS: Lunar Vacuum Enabled Sample Solution

Christopher Clyne (Honors Capstone), Kaylee Bell, Karthik Bijoy, Raquel Tejera Hernandez, Prachet Jain, Sidharth Prasad, Kriti Rathi, Krishen Ratnayaka, Firuz Sharipov, Catalina Garza, Anish Rajesh

Faculty: Prof. George Halow (Advisor), Prof. Steve Battel, Dr. Jonathan Van Noord

ENGINEERING HONORS PROGRAM
UNIVERSITY OF MICHIGAN

MBSE LEADERSHIP LAB

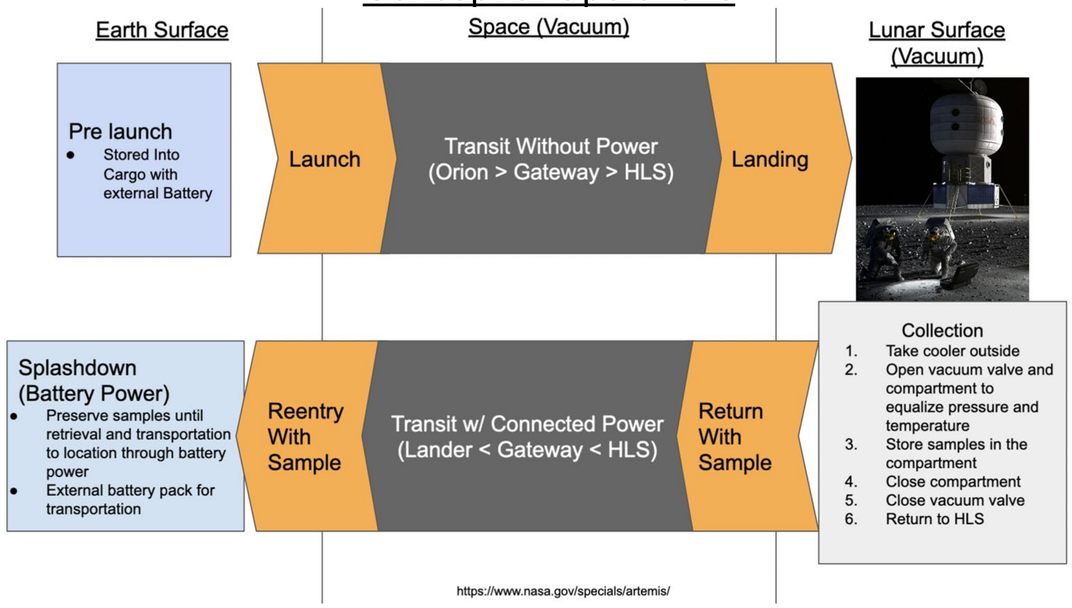
RASC-AL Revolutionary Aerospace Systems Concepts Academic Linkage

Overview

Renewed interest in human space exploration of the Moon and Mars will require innovative approaches to support astronauts in their objectives to study their environments. LuVESS is a universal sample containment solution for the NASA Artemis Mission and beyond, which is one of the themes for the 2022 Revolutionary Aerospace Concepts Academic Linkage (RASC-AL) competition. The solution will expand understanding of solar system processes by enabling sample collection at a wide range of temperatures on the lunar surface. It will also aid human spaceflight through collection of biological samples in crewed modules. The solution will provide stable, controlled storage for all samples during the journey back to Earth.

- Portable and lightweight 60kg briefcase design allows mobility on the lunar surface and maximizes available mass (40kg) for samples
- Lunar vacuum is harnessed and used as insulation for two cold storage containers to minimize heat loss and system mass
- Sun-shield lid ensures shading of samples and containers during collection
- Minimizes power usage on lunar surface through vacuum insulation and sun shielding
- Eggshell shaped containers optimize thermodynamic transfer between samples and coolers.
- Cryogenic and thermoelectric coolers are used strategically to minimize power and overall system cost.

Concept of Operations



Subsystem Design Details

All design choices made reflect high Technological Readiness Level, affordability, and robustness.

Structures:
- ¼" 7075 Al structure provides strength/protection from environment
- 25" x 16" x 8" tall maximizes trade of sample mass/system size
- Handles allow carrying by two astronauts in full EVA suits
- Lids for evacuated compartments sealed via external air pressure
- Vacuum throughout cryo-container provides optimal insulation

Cryogenics:
- System absorbs 1.81W of heat, coolers can counter this
- C1 cooled by CryoTel DS Mini cryocooler due to low mass and 2.5W cooling power
- C2 and C3 cooled by thermoelectric coolers, with induced temperature difference of 70K
- Gold plating on outer shell reduces heat loss of entire system

Controls and Power:
- Designed for astronaut ease-of-access and monitoring
- Monitors temperature of each compartment, humidity of electronics bay, and pressure of evacuated areas. Data stored in SSDR
- Controls power supplied to cryocooler and thermoelectric coolers
- Combination of thermistors, thermal diodes, and RTDs for temperature
- 8 space batteries provide over 8 hours of 175W peak power

Specification Flow

Stakeholder Objectives

Mission Objective: support Artemis activities and science objectives

Top Level Requirements

- Sample Temp Range: 43K-277K
  C1 Temp: 60-80K
  C2 Temp: 147-240K
  C3 Temp: 277K
- Total Mass: ≤100kg
- Sample Mass: ≥35kg
- On battery 6 +/- 2 hours
- Externally powered 25-34 days
- 2-5 EVAs
- Astronaut-managed
- Contamination Control (Planetary Protection

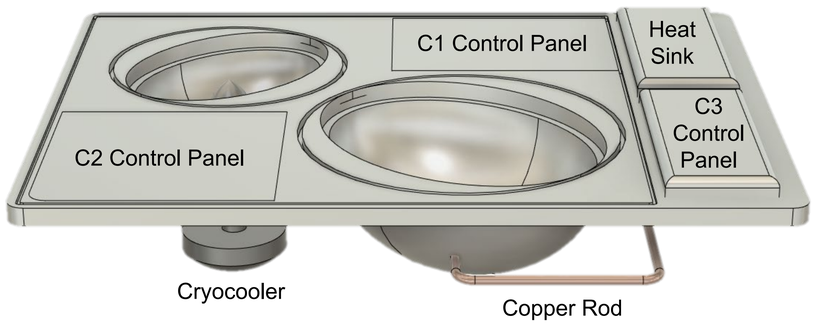
Subsystem Requirements

Controls
- Collect data on system/sample temperature
- Control coolers
- Monitor vacuum

Structures
- System mass ≤ 65kg
- 3 sample containers
- Withstand loads along chain of vehicles

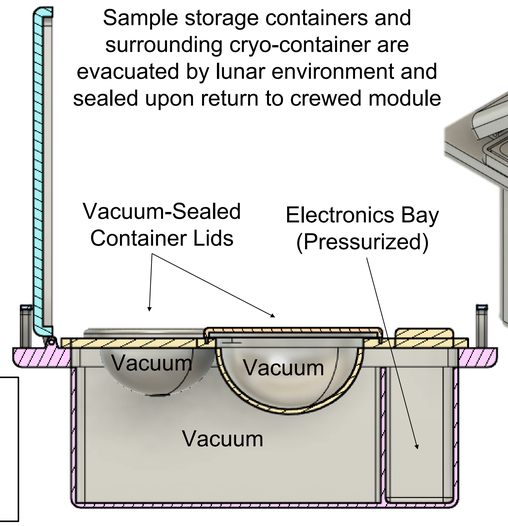
Cryogenics
- Cool samples in desired temperature ranges

Functional Design

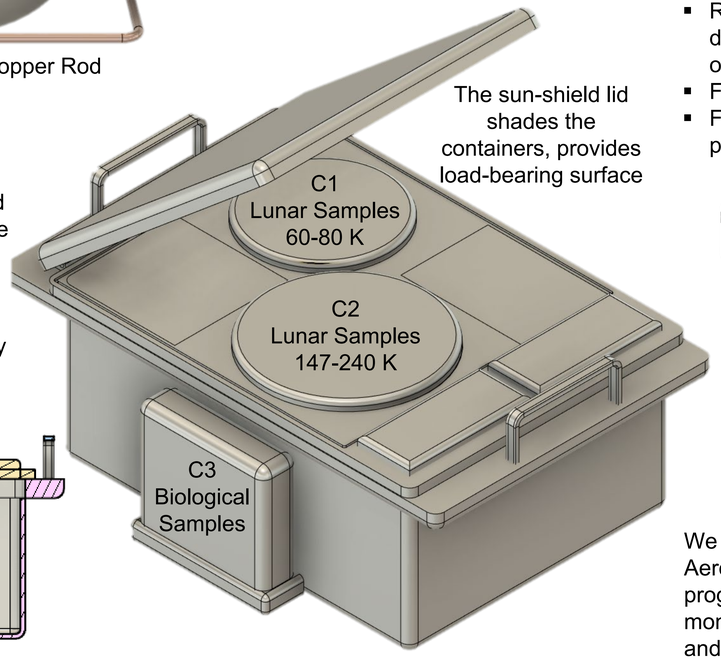


Heat is conducted away from storage containers via copper rods through the Electronics Bay to a gold-plated heat sink

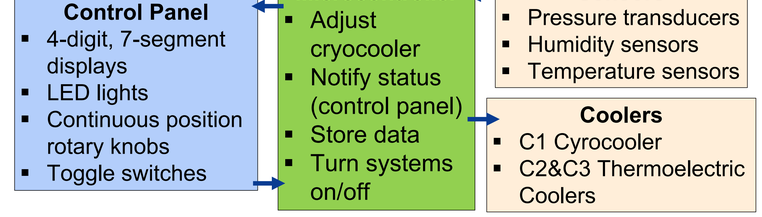
Individual samples are isolated in special ECTFE storage bags.



Sample storage containers and surrounding cryo-container are evacuated by lunar environment and sealed upon return to crewed module



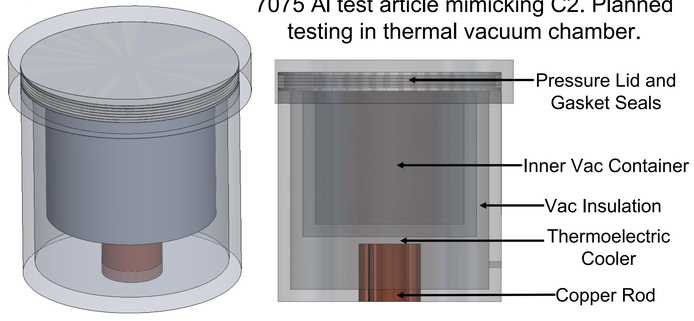
The sun-shield lid shades the containers, provides load-bearing surface



Further Study

- Risk of lunar dust compromising seals, valves, and sample storage is difficult to eliminate. We are currently examining electrostatic and operations-centric mitigation options.
- Further structural simulations and tests required to validate structure
- Full-structure simulations and component level tests to verify thermal properties

7075 Al test article mimicking C2. Planned testing in thermal vacuum chamber.



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