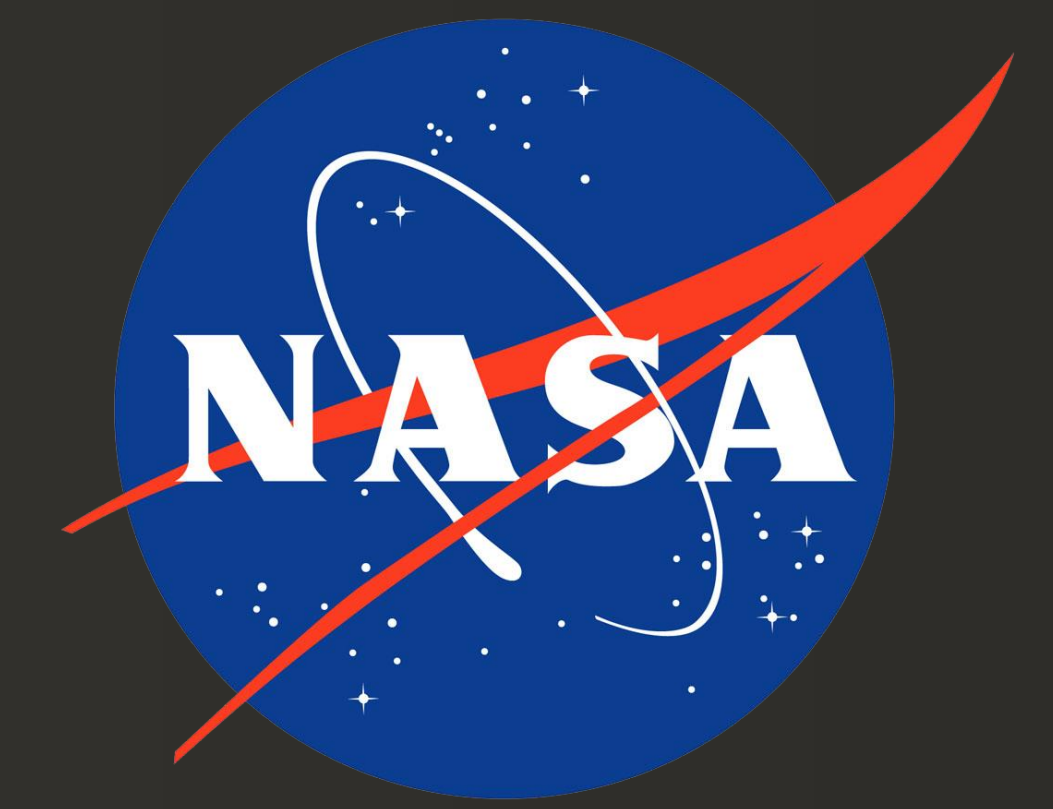
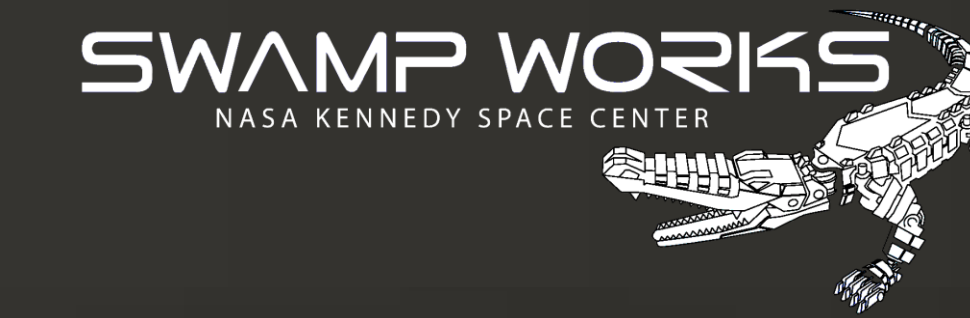


Vertical Lunar Regolith Conveying as a Flight Experiment in Simulated Lunar-Gravity



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Background

Regolith conveying will be an essential task for supplying regolith feedstock to In-Situ Resource Utilization (ISRU) reactor systems (Fig. 1) on the Moon and Mars [1-3]. The Vertical Lunar Regolith Conveyor (VLRC) is a technology being developed at NASA Kennedy Space Center (KSC) as a regolith transport task for the GCD ISRU FLEET project led by NASA Glenn Research Center (GRC).

- **Technology Product Capability**
 - Demonstrate feasibility of a vertical lunar regolith conveyor (VLRC) for transferring regolith (including icy regolith) from the lunar surface to an ISRU processing plant on a lander deck
- **Technical Capabilities**
 - Aims to understand the effects of particle size sorting and heat transfer during regolith transport along the conveyor
- **Exploration & Science Applicability**
 - Applicable for moving regolith from the ground to the inlet of ISRU processing plants that extract oxygen (O₂) from regolith or for extracting water from icy regolith

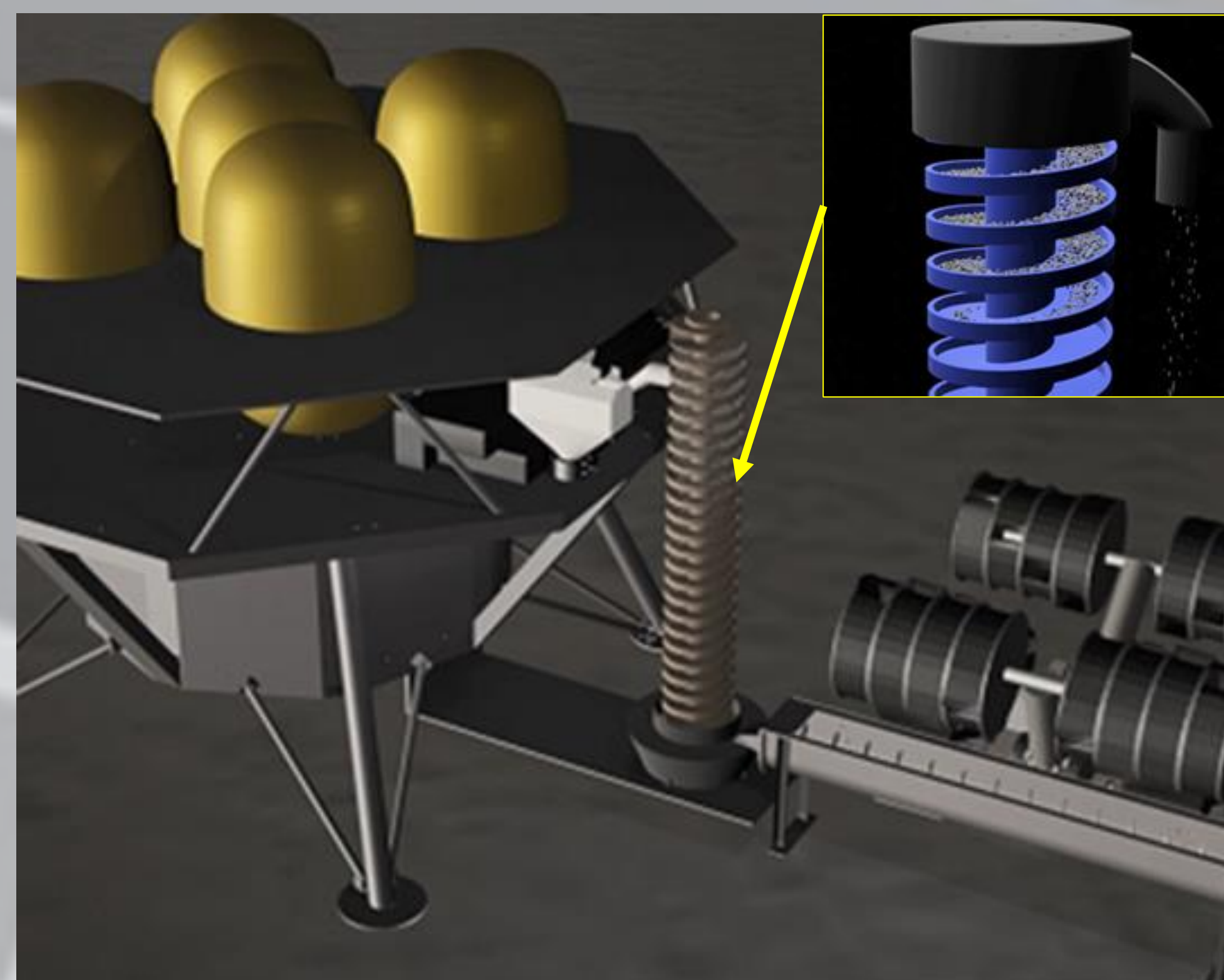


Figure 1: Concept of operations of a continuous vertical lunar regolith conveyor. (NASA KSC graphic)

Goals & Objectives

- **Goal: Determine the optimum method of conveying regolith vertically around a helical surface under lunar gravity conditions in vacuum**
- The NASA Flight Opportunities program selected the VLRC to fly on a future Blue Origin New Shepard suborbital launch vehicle to study regolith transport physics in a relevant vacuum environment in a vacuum chamber under simulated lunar gravity conditions and to advance its technology readiness level (TRL) for future space applications.
- NASA KSC developed multiple single-loop versions of the VLRC for the flight experiment to study the effects of test loop geometry on different granular materials under identical conveyance conditions simultaneously.
- A conventional two degree of freedom helical vibratory approach using eccentrically weighted rotors and a stick-slip approach are being evaluated

VLRC Flight Experiment Approach

- The experiment uses test loops of two helical inclinations that recirculate regolith flow
- Regolith flow behavior is captured with a camera and custom mirror and lens assembly

Figure 2: (Above) A VLRC single-loop helical surface includes inner and outer tracks for conveying two granular material samples separately, but simultaneously under the same conditions of motion. (Right) Particle image velocimetry will be used to analyze the video of regolith flow on the test loops. (NASA KSC graphics)

Flight Experiment Design Overview

- Experiment Objectives:**
1. Convey different lunar regolith simulants at different inclinations in simulated lunar-gravity
 2. Record regolith flow using tracer particles and COTS cameras to calculate mass flow rates
 3. Measure power consumption usage for two conveyor stack methods (stick/slip and eccentric)
 4. Conduct the experiment in a vacuum environment (< 10 Torr).

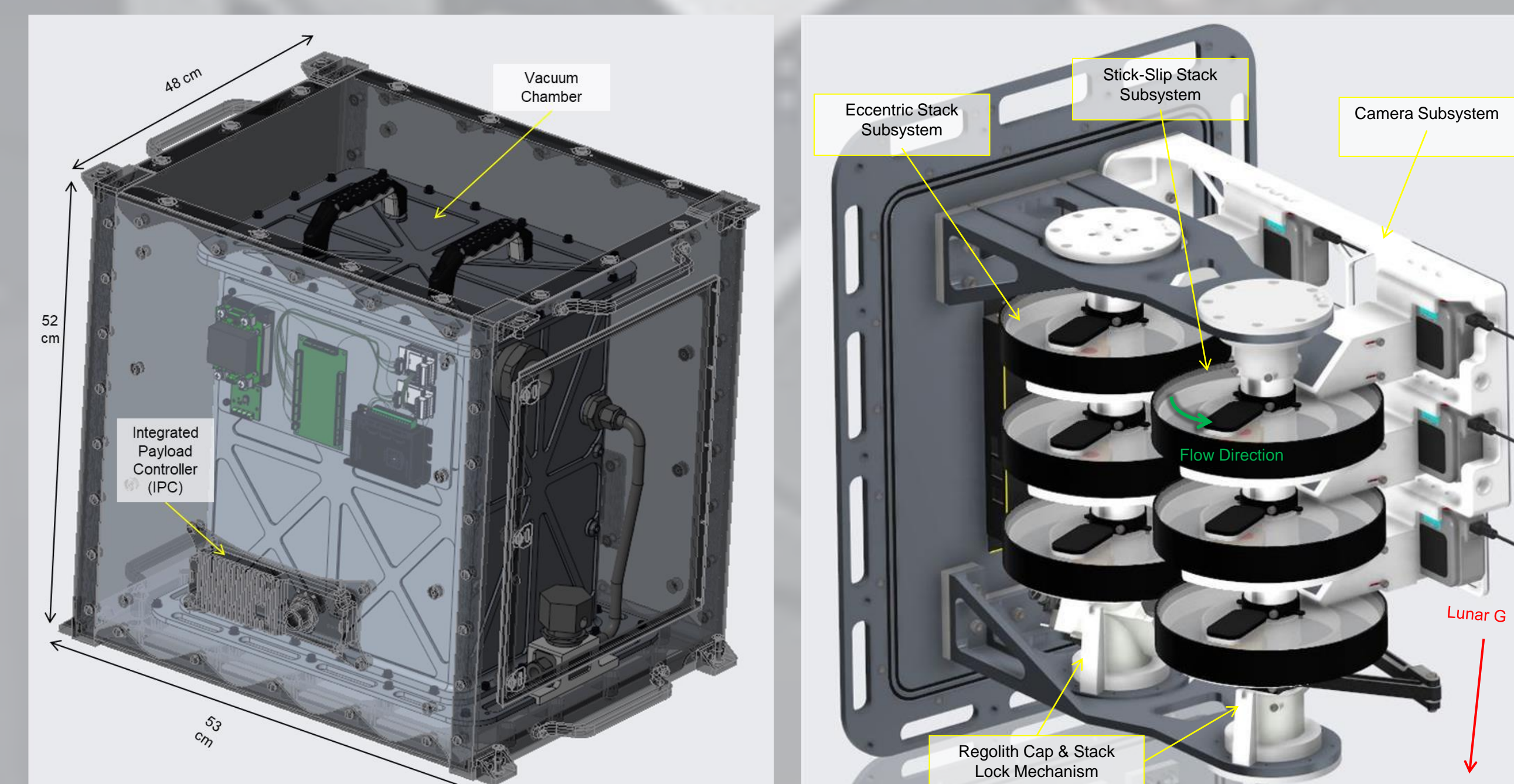


Figure 3: (Left) The experiment, mounted inside of its payload locker. (Right) The two types of VLRC conveyor stacks (attached to the vacuum chamber base plate) are shown in their orientation when operating in a simulated lunar-gravity environment with each stack containing three single-loop helical surfaces (NASA KSC graphic)

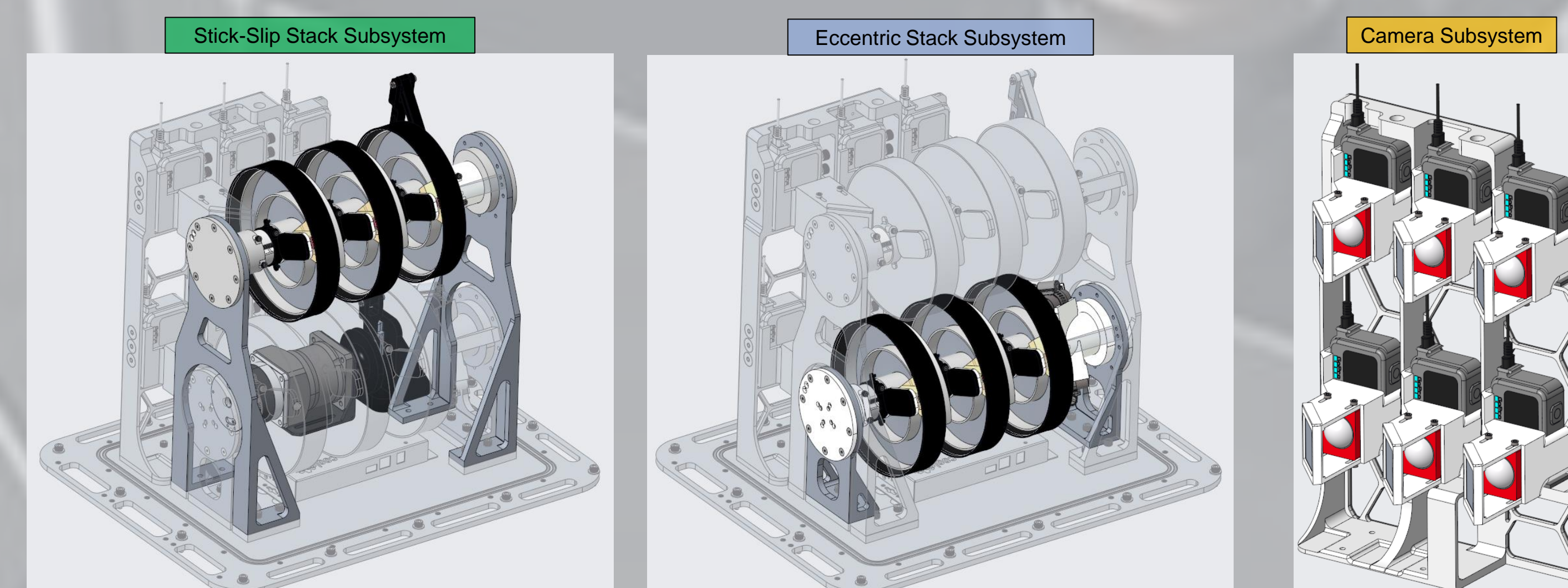


Figure 4: The primary subsystems of the experiment are shown above: (left) the stick-slip VLRC stack subsystem, (center) the eccentric VLRC stack subsystem, and (right) the six-camera assembly for recording particle motions within each track per single-loop. (NASA KSC graphic)

Assembly & Integration

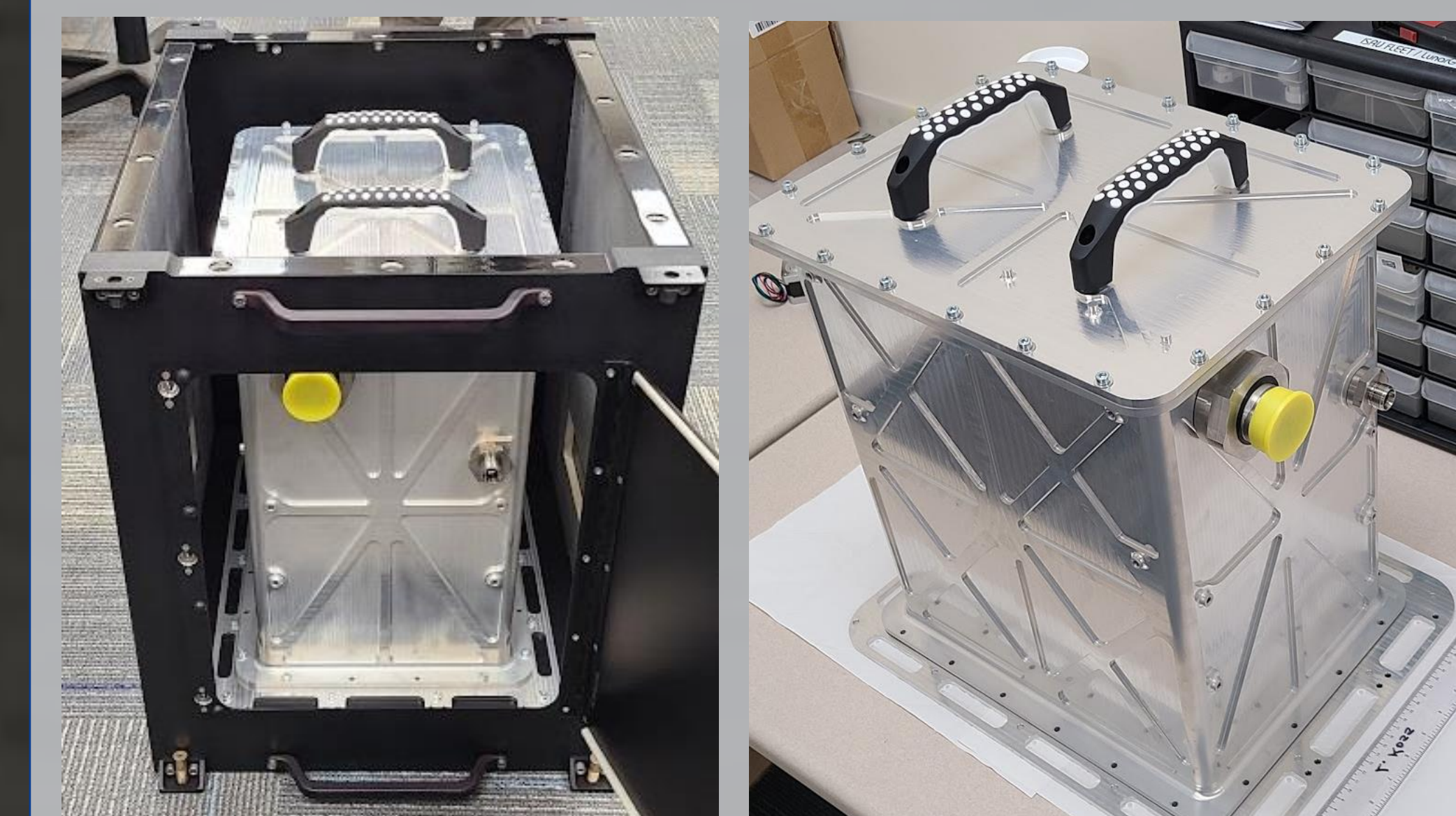


Figure 5: VLRC Vacuum Chamber designed to fit inside a Blue-Origin Double-Locker. The custom designed vacuum chamber was found to maintain 100 mTorr after 12 hours being isolated from its pumping system (NASA KSC graphic)

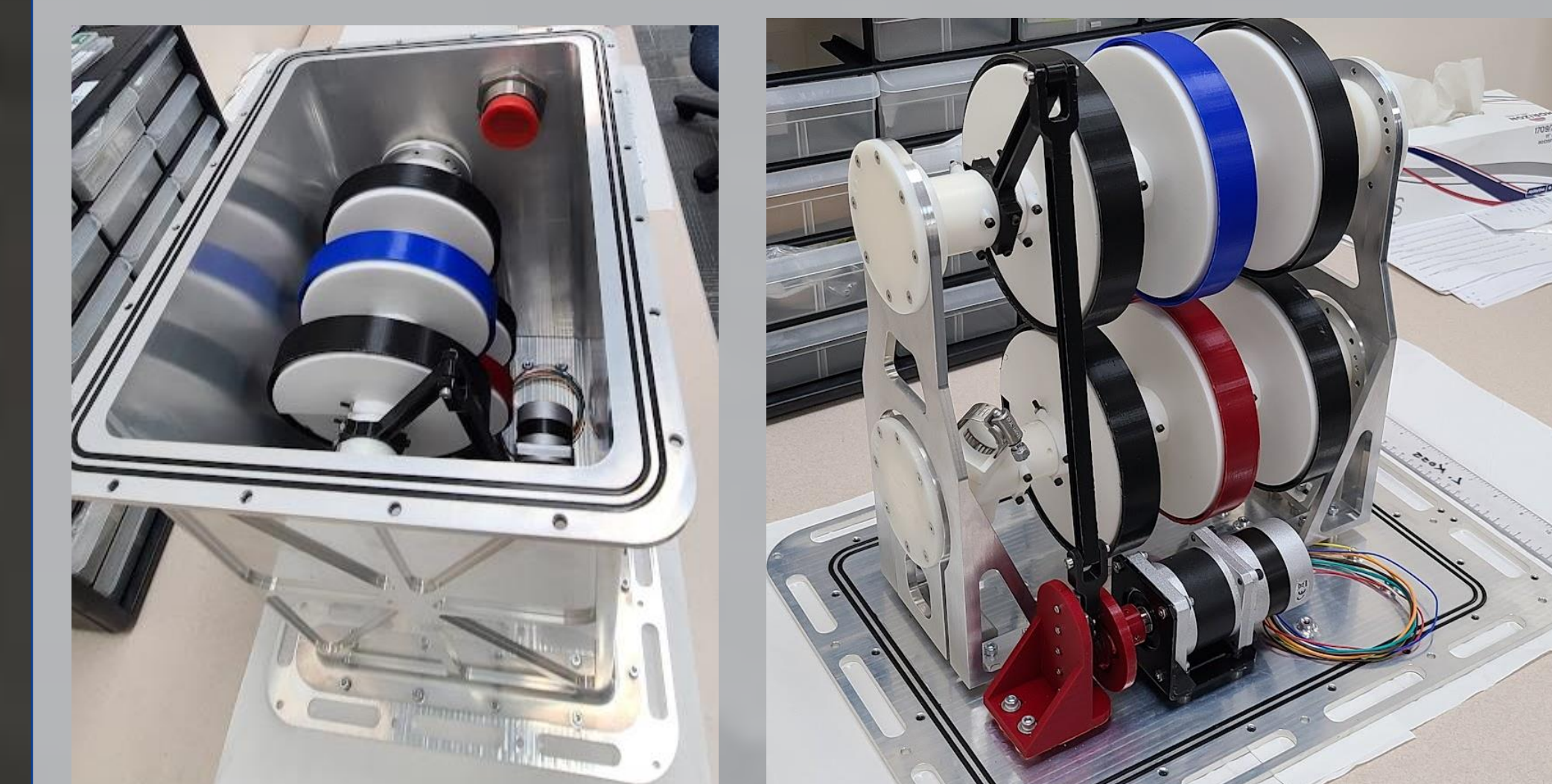


Figure 6: Actual VLRC conveyor stacks attached to baseplate of the LunarG vacuum chamber. Prototypes of the experiment's vibrating stacks were assembled for regolith flow rate testing (NASA KSC graphic)

Future Work

- Demonstrate full scale VLRC conveying icy regolith simulant in the thermal vacuum ASSIST chamber at KSC that provides an Atmospherically Sealed Simulator for In-situ System Testing.
- Results of VLRC testing in simulated lunar gravity is directly comparable to in-lab testing at one-G and will inform follow-on Discrete Element Modeling (DEM) by grounding the modeling analyses with test data.

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