Burrowing Robot Test Apparatus for 1/6g Spaceflight

Sponsor: Professor Hawkes' Lab

Project Description

The Hawkes Lab at UCSB is developing a robot that uses tip-extension to burrow through the ground like a plant root. This device was recently featured in *Science Robotics* and on the YouTube channel *Veritasium.* Because the robot extends from the tip, there is no relative movement between the robot walls and the surrounding medium. This means that friction between the sides of the robot and its environment reduce the reaction force required to burrow, rather than increase it. This makes the device advantageous for low gravity environments where reaction forces are difficult to produce.

The Hawkes Lab has secured an opportunity to test their NASA sponsored burrowing research in Lunar conditions on a BlueOrigin New Shepard spacecraft. This will be BlueOrigin's first partial gravity mission, planned for early 2023. Once the New Shepard spacecraft has reached stable spaceflight, it will rotate to provide 1/6 Earth gravity for 2.5 minutes, before returning to Earth. The project has been allocated a double locker sized payload worth about $120k with a maximum payload mass of 50 lb (22.7kg).

The test apparatus must address numerous challenges to provide a reliable way to test burrowing in Lunar regolith simulants at 1/6g. The main goal of the test is to compare the reaction and anchoring forces of a rigid intruder and a pneumatic tip-extending device (Figure 1). Students will have the freedom to design a suitable test apparatus that meets the project scope described below. This opportunity for ME and EE students will span a multitude of engineering principles including spacecraft design, CAD, rapid-prototyping, structures, controls, sensing, actuators, pneumatics, granular physics, reliability and more.

Project Scope

- Design and build a test apparatus for the New Shepard 1/6g spaceflight that meets the following design challenges:
    - Experiment must work virtually 100% of the time, there is only one chance to go to space.
    - Reset Lunar regolith simulant after reaching stable 1/6g
    - Meet BlueOrigin payload requirements including: mass, center of mass, volume, vibration, acceleration, and more
    - 1/6g will be perpendicular to launch direction
    - Contain Lunar regolith simulant and pneumatic gas inside a secondary container
    - Mechanically and electrically interface with BlueOrigin test locker

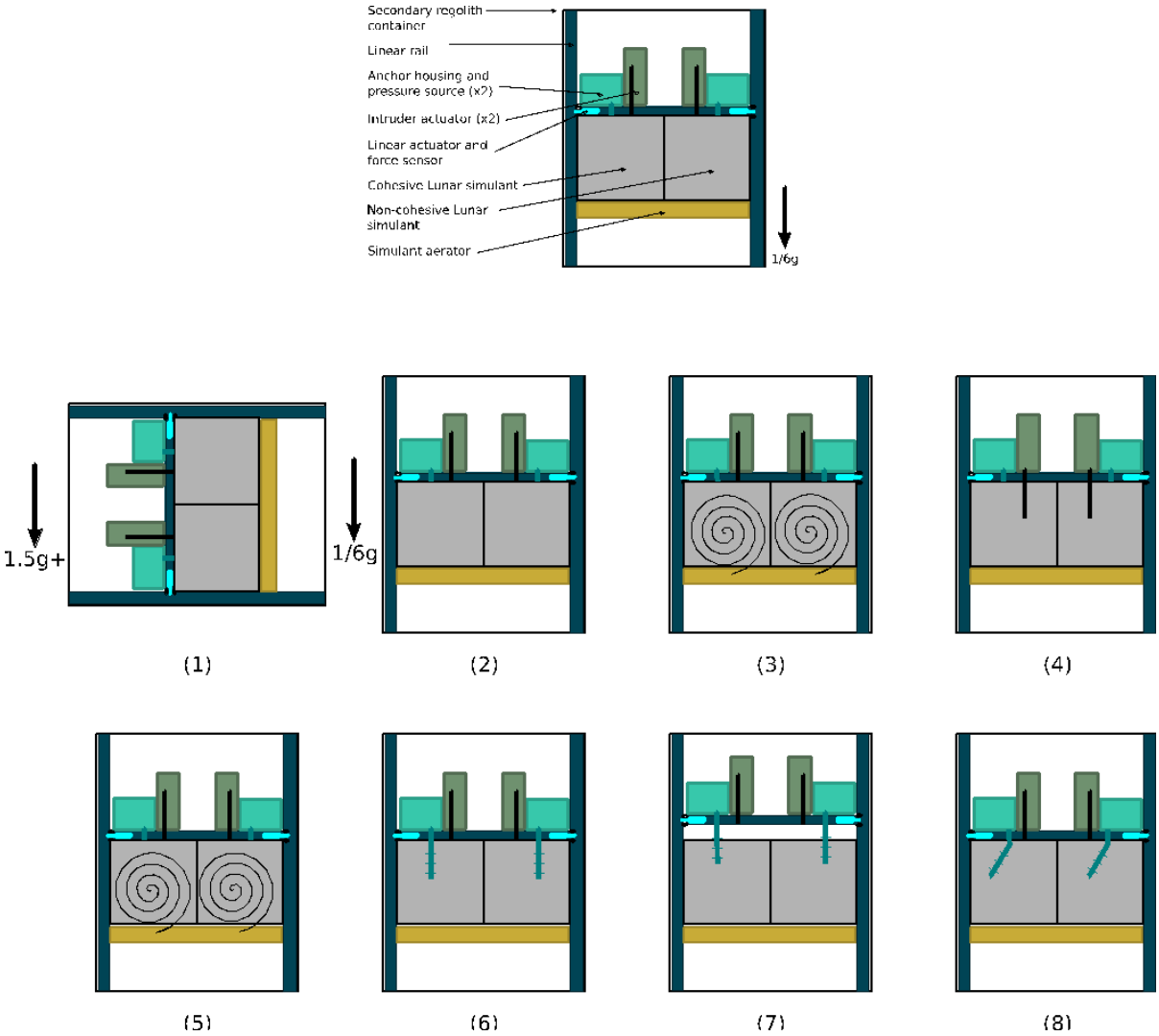

Figure 1: (Top) Proposed test apparatus components. (Bottom) Proposed test procedure. (1) Flight out, with regolith containers sealed. (2) 1/6g starts, direction of gravity changes. (3) Reset state of regolith containers via aeration. (4) Intrude and retract intruder while measuring force and depth. (5) Reset regolith state. (6) Grow tip-extending anchor into regolith by inflation while measuring reaction force and length. (7) Pull tip-extending anchor part way out of regolith to measure pull-out force. (8) Deflate anchor and reseal regolith container.

Potential Add-Ons

- Students may have the opportunity to continue working on the project with an engineering contractor to develop a space-ready test apparatus
- Students may have the opportunity to visit the BlueOrigin facility where the payload will be launched from
- Students will be included in any research publications that arise from a successful spaceflight

Project Requirements

- No citizenship requirements
- No invention assignment requirements