SUPPORTING WATER ISRU IN LUNAR PSRs WITH THE SELF-ERECTABLE LUNAR TOWER FOR INSTRUMENTS (SELTI).

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Motivation and Summary: The permanently shadowed regions (PSRs) at the lunar South pole are believed to contain significant reserves of water ice and volatiles. As NASA and its international and commercial partners proceed with their plans for a sustainable return to the Moon, fleets of rovers, robots and infrastructural assets will be deployed to explore and develop these resources. However, the terrain in and around PSRs is uneven, limiting the lines of sight required by rovers and other far-flung assets to maintain communications, while also making navigation and mobility more difficult. One solution is to support these mobile assets with radio repeaters, stereo cameras and navigational aids situated at elevated vantage points (i.e. on towers). Here, we report on the development and testing at MIT of a lightweight 16.5m tall lunar tower – the Self-Erecting Lunar Tower for Instruments (SELTI). The SELTI project, first conceived and funded as a finalist and awardee at NASA's 2020 BIG Idea Challenge under the name MELLTT [1], is the subject of a Space Act Agreement collaboration with NASA LaRC's Deployable Composite Booms team.

SELTI System Overview: A CAD of SELTI and its subsystems is shown in Fig. 1.

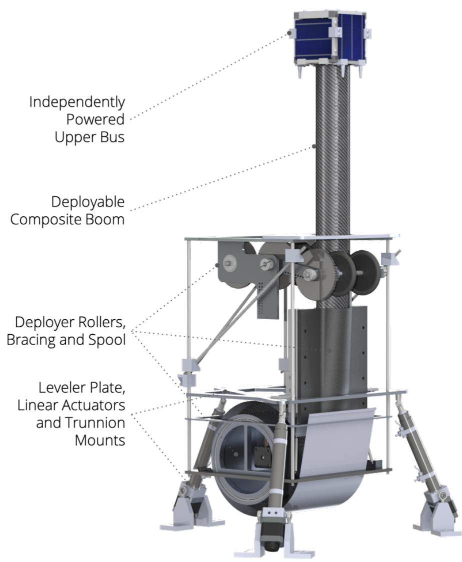

Fig. 1: SELTI CAD showing the key subsystems: Leveler, Deployer, 16.5m composite boom and Upper Bus. Value-added payloads such as radio transceivers, imagers and navigation beacons are hosted inside and on top of the CubeSat which serves as the upper bus.

Subsystem Descriptions: SELTI consists of a Leveler, a Boom with its Deployer and an Upper Bus. An optional Rigging subsystem is also under development.

Leveler: The deployer and boom are mounted onto a kinematic base, Fig. 2, consisting of three linear actuators and a mounting plate. The desired pose and attitude of the tower is fine-tuned using both open- and closed-loop feedback control based on accelerometer data.

The leveler has two primary functions: (1) Align long axis with lunar gravitational field (2) Re-align tower axis in event of boom bending. Key design considerations included: (1) Zero-power passive locking, (2) Simplicity, for reliability and low mass and (3) Strength to react to dynamic loads.

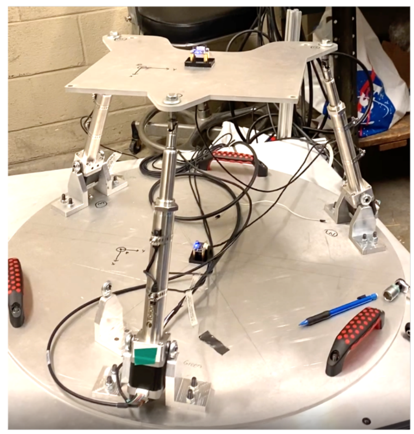

Figure 2: The Leveler subsystem, mounted on a mock lander deck, is capable of correcting up to 15º of inclination.

Boom and Deployer: A bi-stable carbon fiber composite boom [2,3] is rolled flat around a motorized spool, Fig. 3. During powered deployment, the boom is unrolled to form a lenticular cross-section that resists torsion, bending and buckling. A set of powered rollers assists deployment and retraction, and the deployed boom is braced to support loading under gravity. The deployer can be used with variable height booms. We are currently investigating higher-strength booms capable of larger payloads than the current 1U CubeSat.

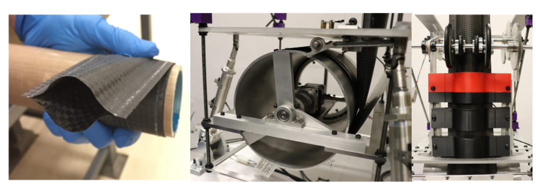

Figure 3: (a) bi-stable composite lenticular boom [2,3], (b) deployer spool (c) boom bracer with motorized rollers.

CubeSat-based Upper Bus: A payload platform at the top of the tower, Fig. 4, provides client payloads an elevated vantage point for service delivery. The first prototype was based on a 1U CubeSat to leverage COTS parts, and included four exterior solar panels, batteries, computer, pointer motor, radio and an imager. The platform's function is to provide mounting, power, communications (TT&C) and pointing to hosted payloads.

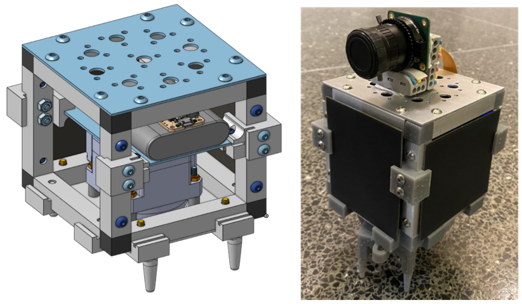

Figure 4: (a) upper bus CAD (b) as-built 1U prototype. The self-powered Upper Bus is a CubeSat, for ease of integration of a diverse set of potential application payloads.

Deployable Rigging Subsystem: A modular, deployable three-arm structure is anchored to the leveler plate, Fig. 5. The guy wires are deployed and tensioned using a motorized spool with feedback from an S-shaped load cell. A ratchet and pawl system sustains tension passively after deployment. The primary functions of the rigging system are to protect the tower against buckling and to provide operational flexibility for leveling and straightening under a variety of contingency modes.

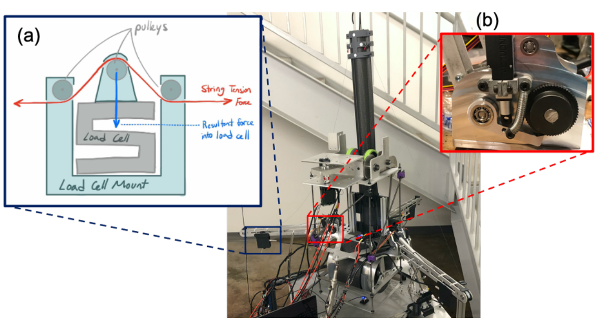

Figure 5: SELTI with the add-on rigging subsystem installed; Three guy wire arms spaced 120º apart are mounted to the leveler platform, with guy wires secured at the boom tip, next to the photogrammetry targets (white circles); (a) detail of load cell design; (b) ratchet and pawl for passive tensioning.

Testing Results: During Fall 2021, SELTI was deployed to heights of 8.5m and 11m inside a stairwell at MIT. A calibrated, sub-millimeter-accurate Optitrack V120: Trio photogrammetry system was used to measure tip deflections under a range of static wire tension loads. We found that dynamic deflections of up to 0.5m were passively attenuated and corrected by the tensioned guy wires and that tension adjustments to the opposing guy wire could correct ~75% of static deflections (boom bending), Fig. 6.

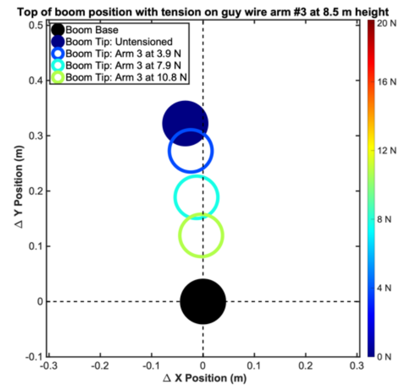

Figure 6: Results of guy wire testing from the 8.5m test. The results from the 11m test (not shown) were similar.

Applications and Conclusion: Depending on the size and payload capacity of the tower, a variety of ISRU–supporting applications may be enabled, Fig. 7, including power beaming, radio relay, navigation, remote prospecting, imaging and mapping services.

Acknowledgments: the authors wish to thank our collaborators at NASA LaRC DCB team. Thanks also NIA who organize the BIG Idea Challenge; to funding sponsors NASA and Massachusetts Space Grant; to the competition judges hailing from NASA LaRC & JSC, JHU APL, UCF, and Honeybee Robotics. Finally, we are grateful to past members of the MIT MELLTT team for their work on earlier versions of MIT's lunar tower.

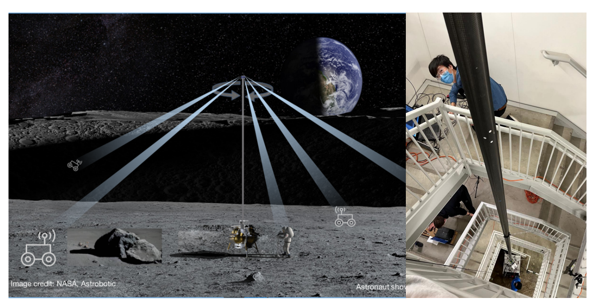

Fig. 7: Deployable tower supporting rovers exploring a PSR

References: selected references are shown below.

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