Self-Erecting Lunar Tower for Instruments (SELTI)
Multifunctional Expandable Lunar Light Tall Tower (MELLTT)

The MIT Lunar Tower Team

Massachusetts Institute of Technology

Space Resources Roundtable

Jun 8, 2022

MIT AEROASTRO


M E L L T T

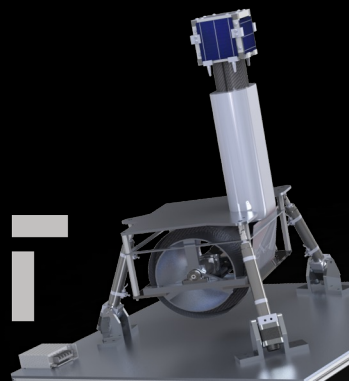
Self-Erecting Lunar Tower Value Proposition

Autonomously deploy a flight-proven composite boom in a gravity field

Provide lines of sight in and around Permanently Shadowed Regions (PSR)

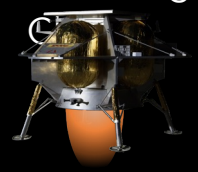
Support robotic and human distributed exploration ecosystems

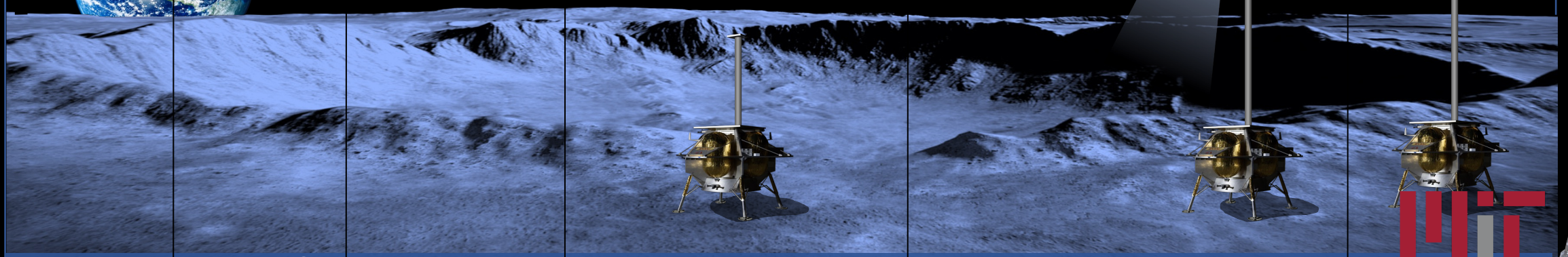
Notional - Astronaut shown for scale

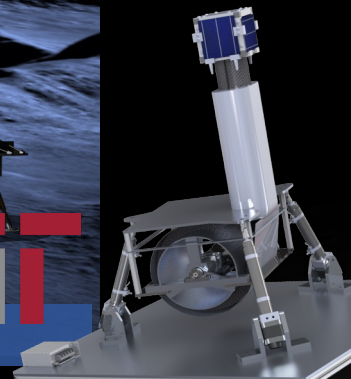


Concept of Operations of Self-Erecting Lunar Tower

LAUNCH	TRANSIT	LANDING	DEPLOYMENT	OPERATIONS	END OF LIFE
Packaging locked Systems OFF	Power ON System Checks	Packaging Locked Systems OFF Land near PSR Post-landing	Initial Leveling Incremental Boom Deployment Re-Leveling Final Deployment to 16.5m Photogrammetry, Motor and Accelerometer Data Collected	Upper Payload Power Test Upper Payload Avionics and Radio Activation Imager and Pointer Motor Activation Photogrammetry, Motor and Accelerometer Data Collected	Engineering and Science Data Return Systems OFF

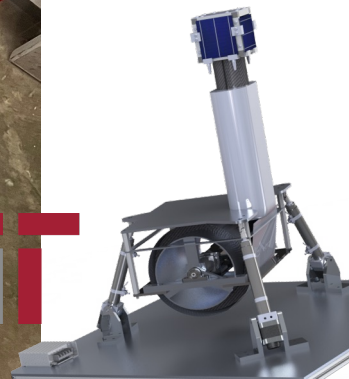






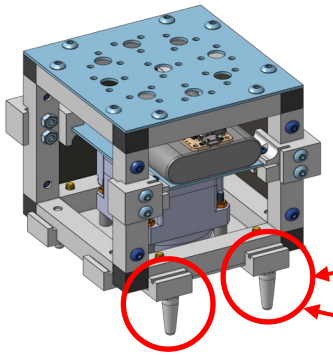
3 DAYS | 3 HOURS | 1 DAY | 13 DAYS (LUNAR POLAR DAY)

Deployment testing to 11m

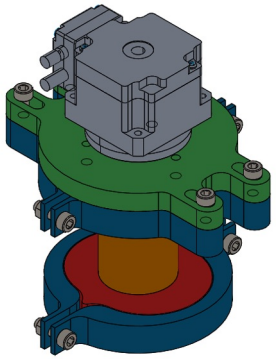


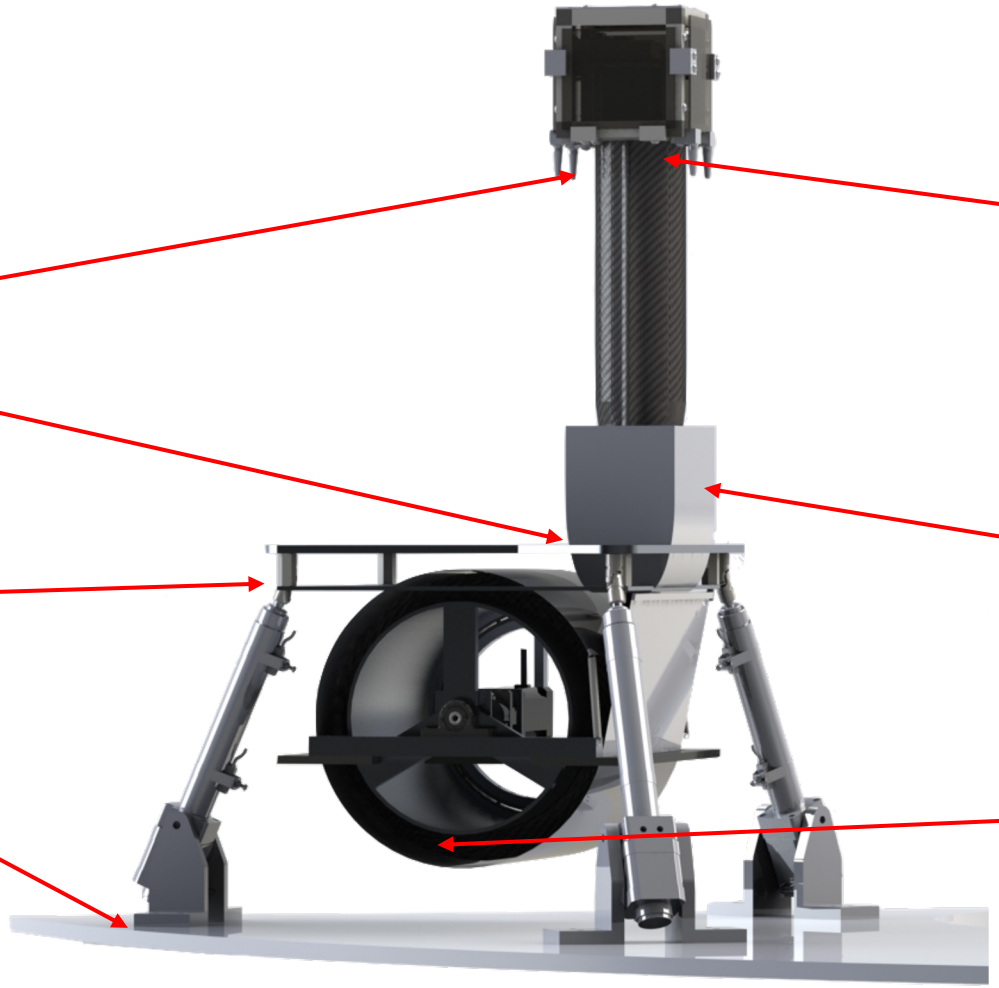
Overview of lunar tower system and interfaces

Deployer Interface with Upper Platform

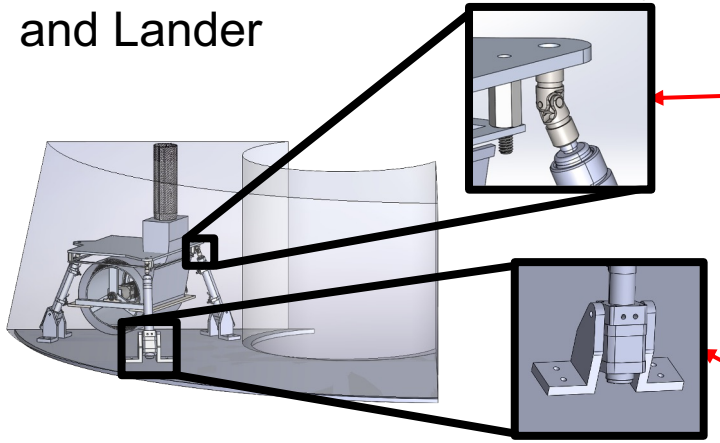


Boom Interface with Upper Platform

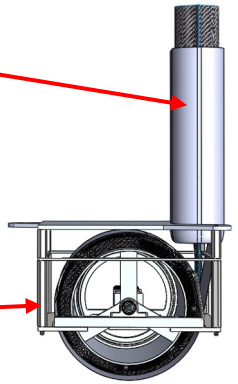


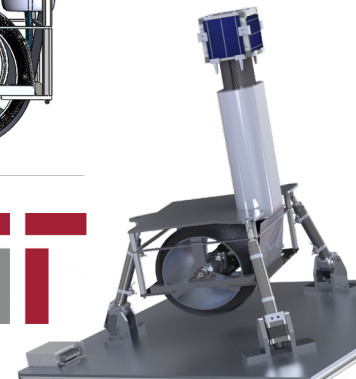


Leveler Interfaces with Deployer and Lander

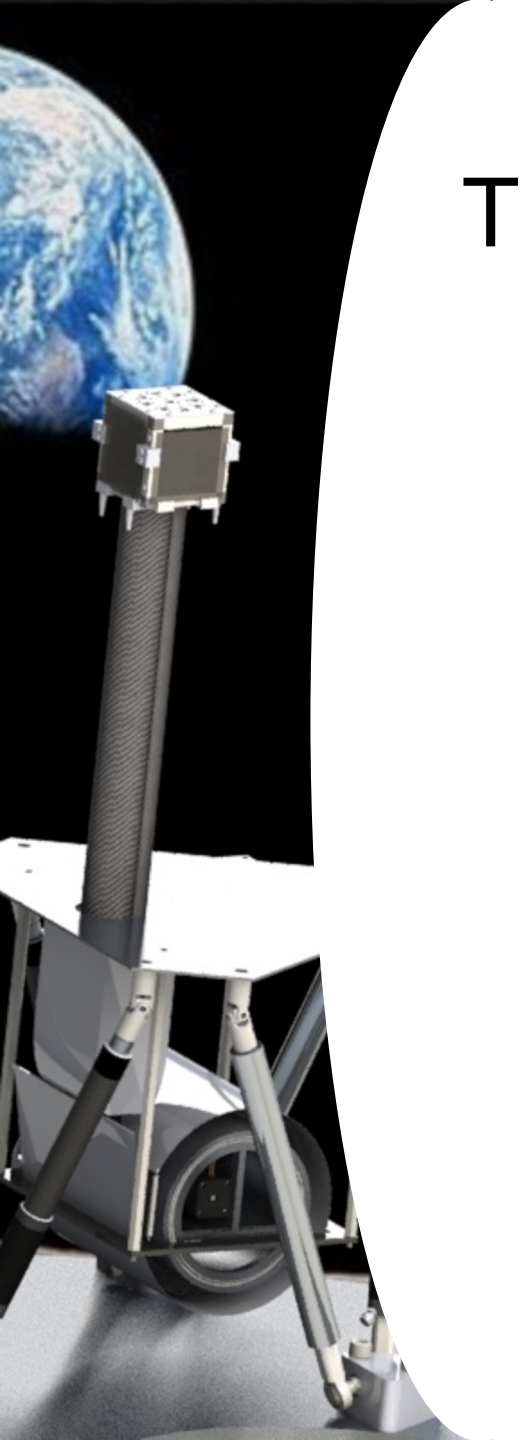


Boom Interfaces with Deployer

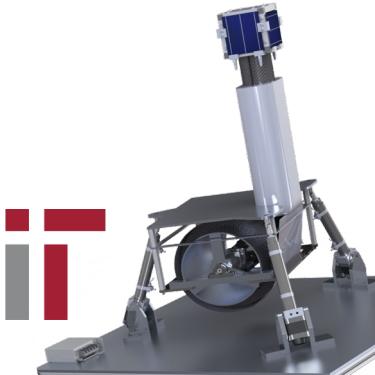




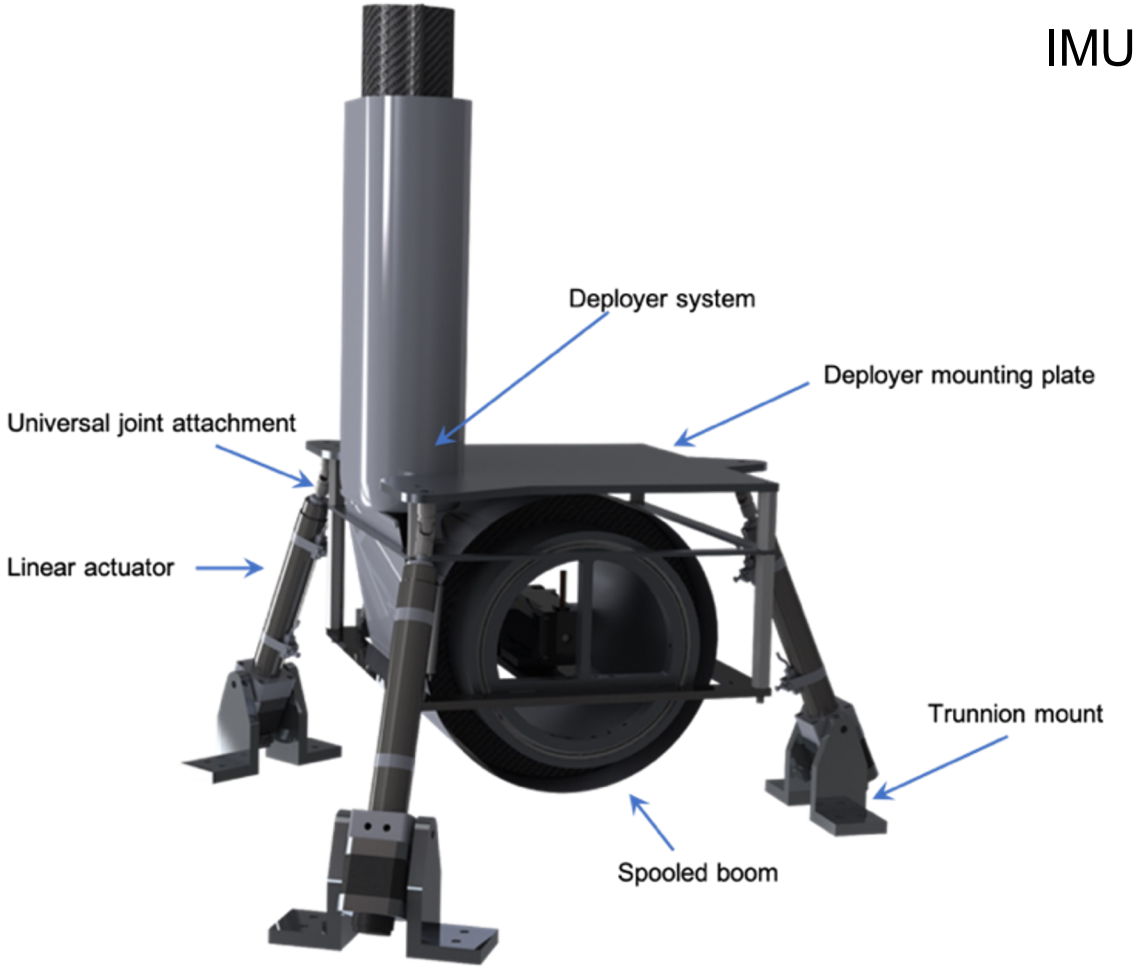
Contact: bigidea2020@mit.edu



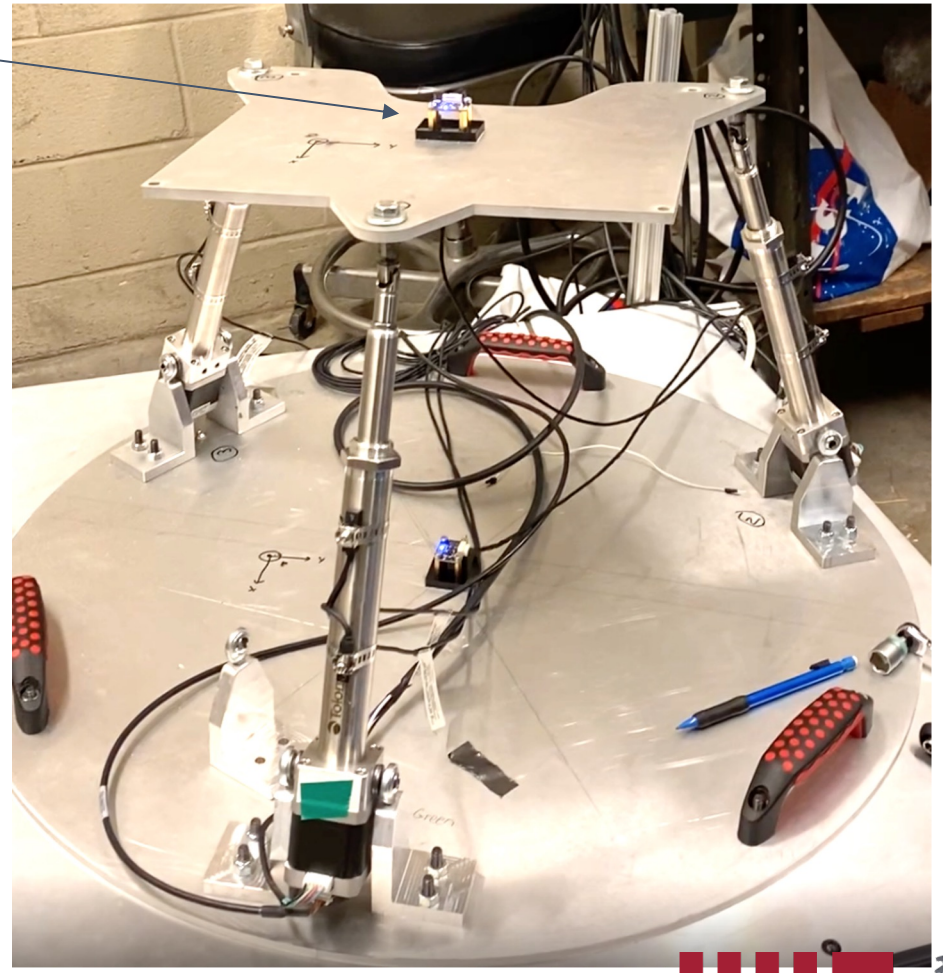
Tower Leveling Subsystem



The leveler subsystem offers redundant 2 DOF tip/tilt **correction up to 12°**



IMU



Leveler Control Architecture

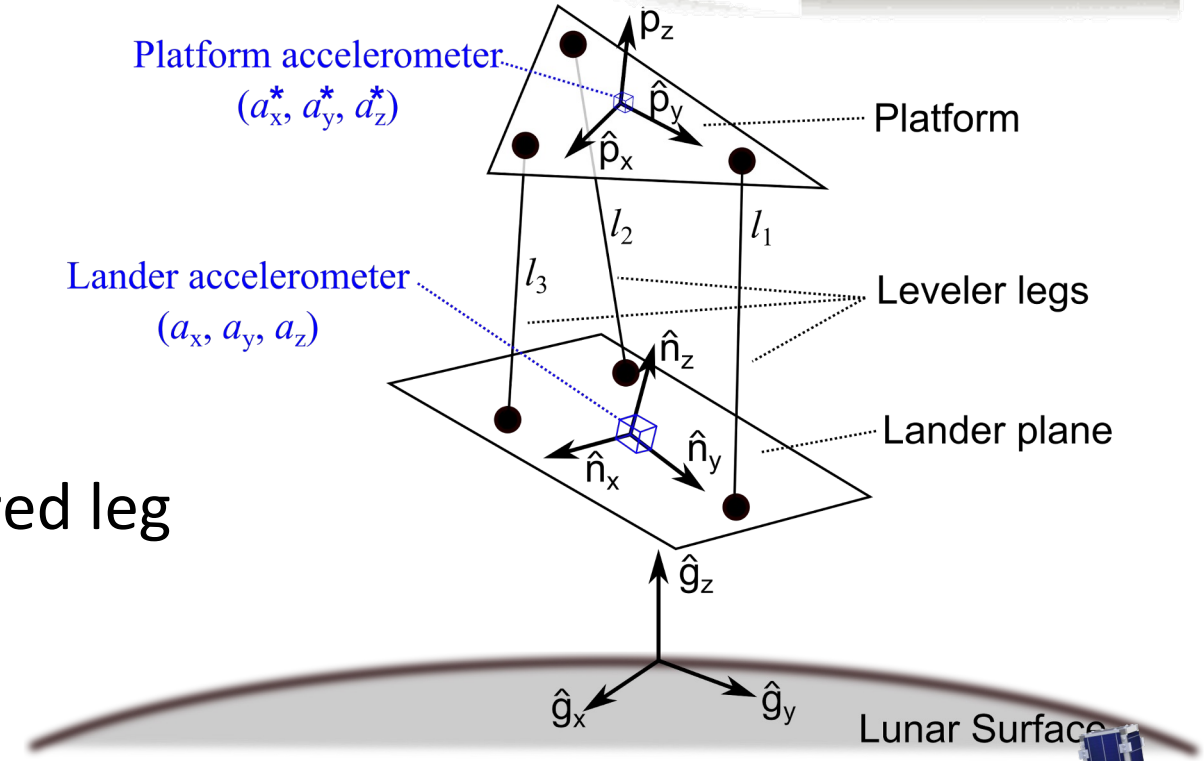
Step 1. **Open-loop** leveling

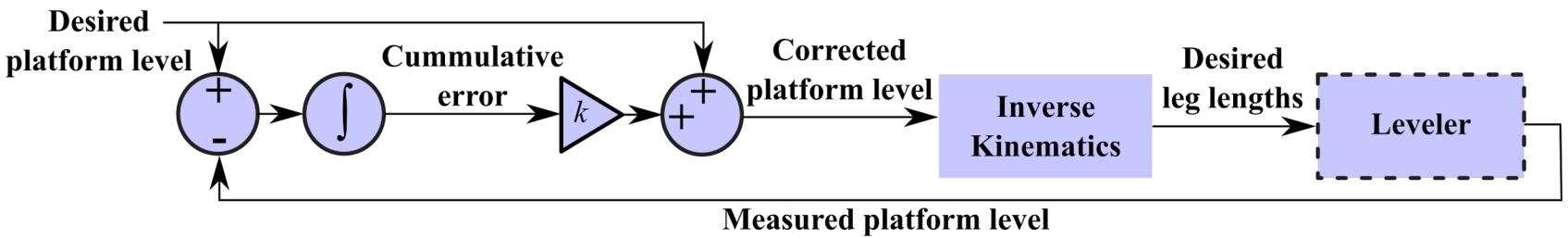
Given

1. Desired platform height
2. Measured lander orientation
3. Desired platform orientation
4. Kinematic constraints

Solve nonlinear equations for required leg lengths

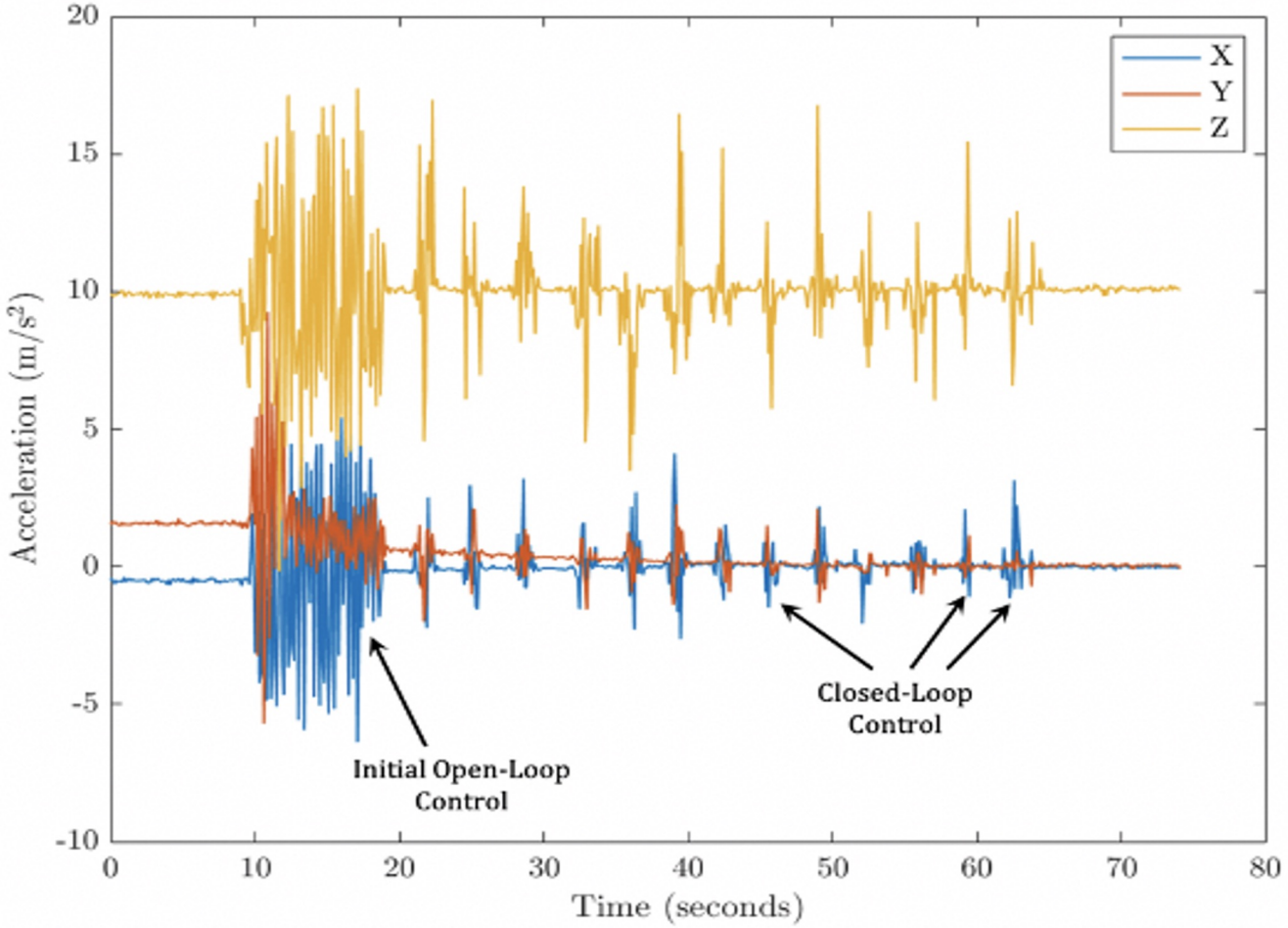
Step 2. **Closed-loop** fine tuning



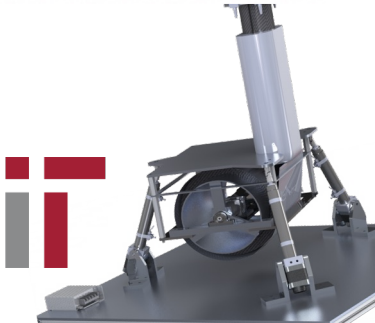


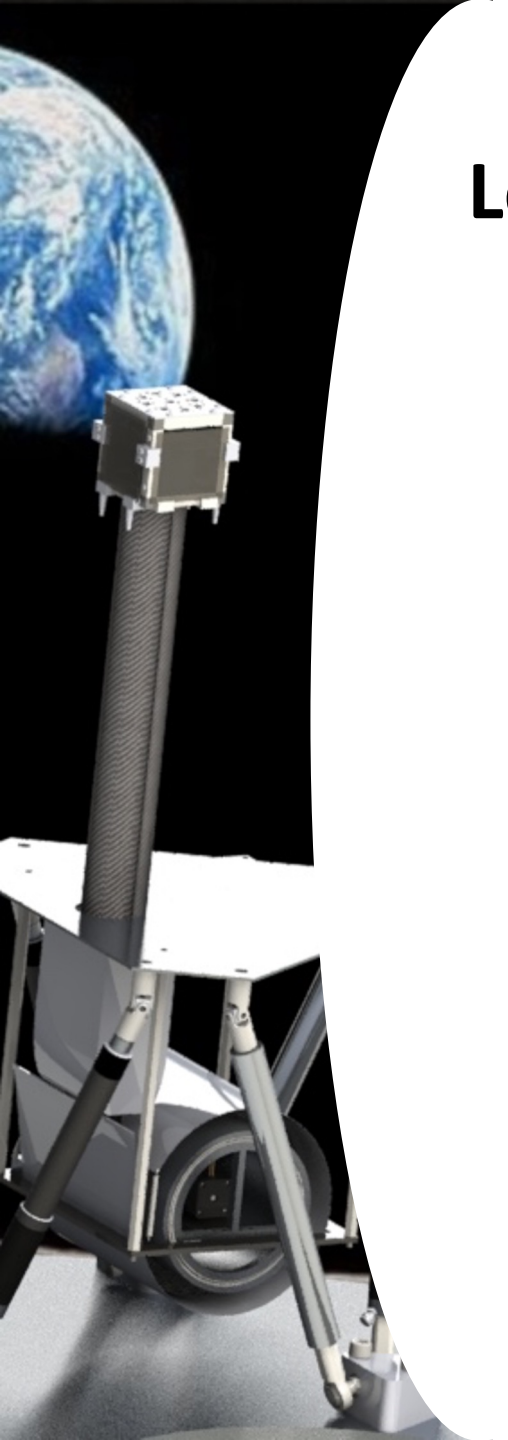
Leveler Test Results

Static load test

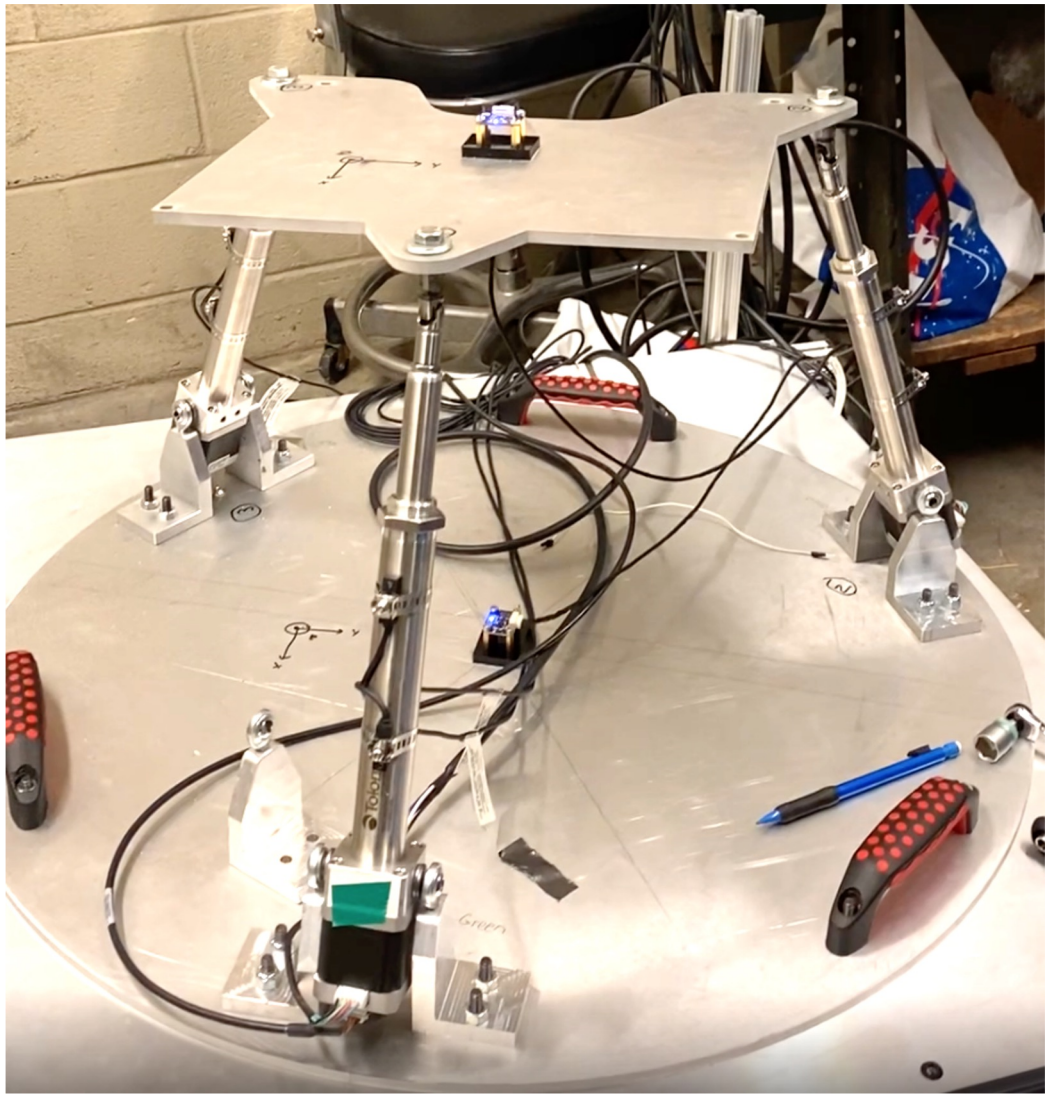


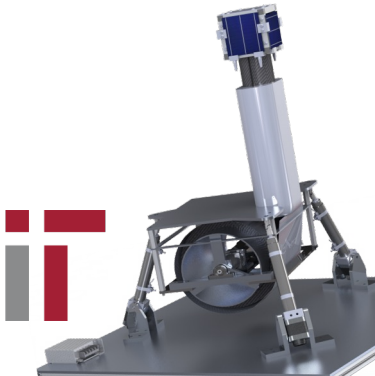
Open and Closed-Loop control tests

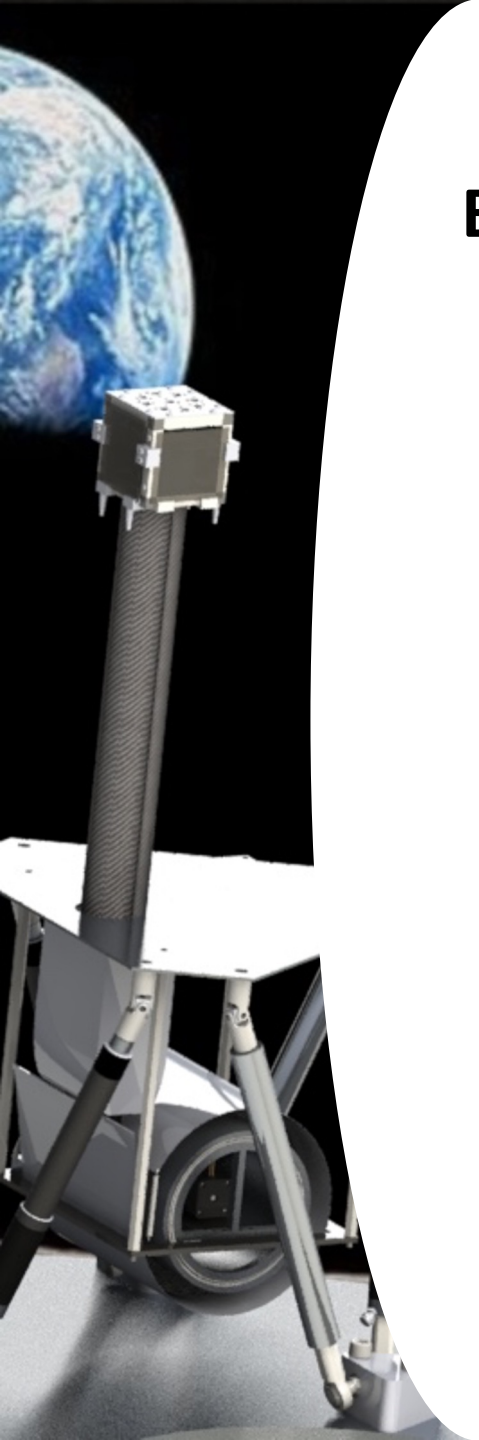




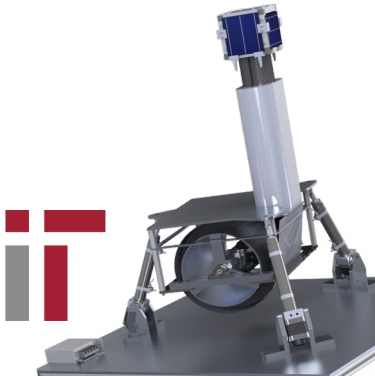
Leveler as-built

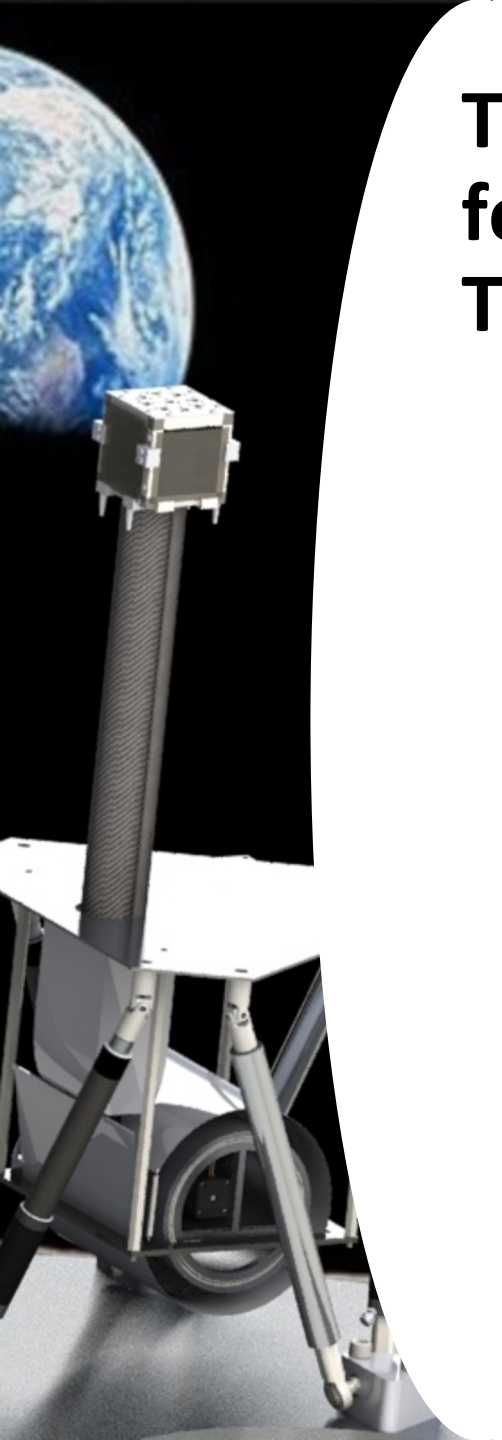






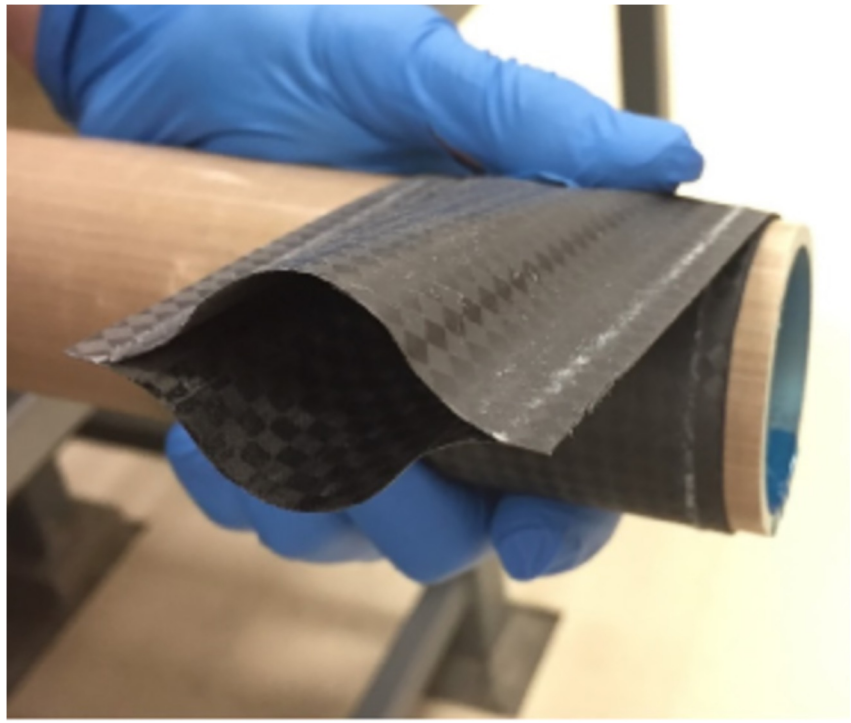
Boom Deployer Subsystem





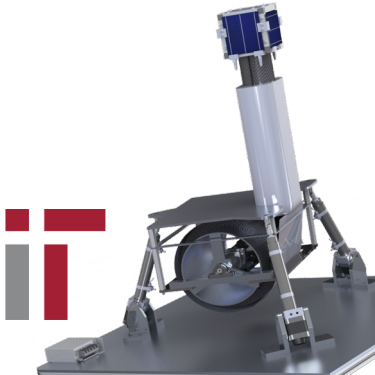
The deployable composite boom, originally developed for microgravity applications, was provided by DCB Team at NASA LaRC

Lenticular Cross-section bi-stable boom

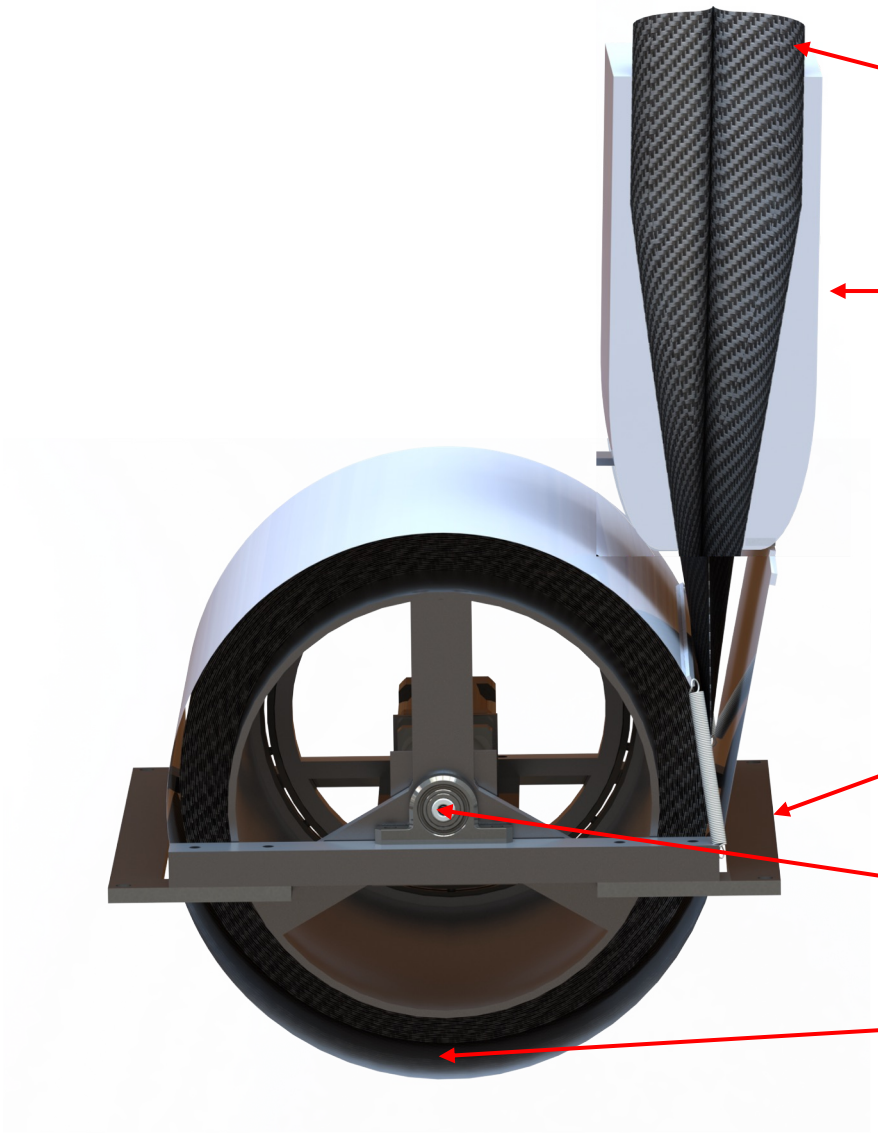


Material: Carbon Fiber Reinforced Plastic (CFRP)
Thickness: ~ 0.2 mm
Mass: < 1 kg

J. M. Fernandez, S. A. Krizan and E. R. Dyke (2019), "Thin-shell composite booms for solar sails: De- sign, manufacturing, and qualification," in 5th Interna- tional Symposium on Solar Sails, Aachen, Germany



Deployer system to support leveler / outrigger testing



Deployed Boom

Modular Custom Brace

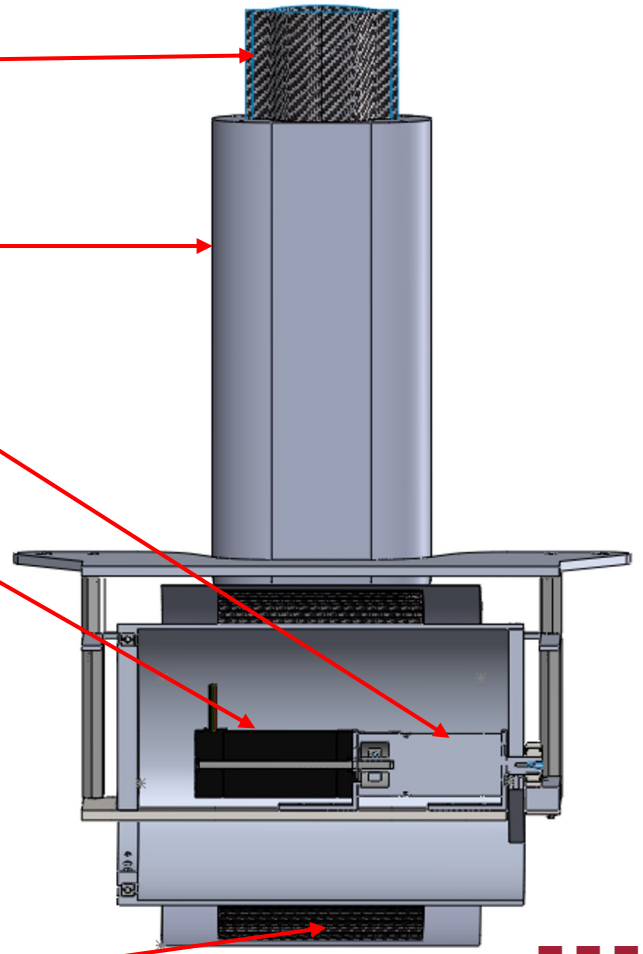
256:1 Gearbox

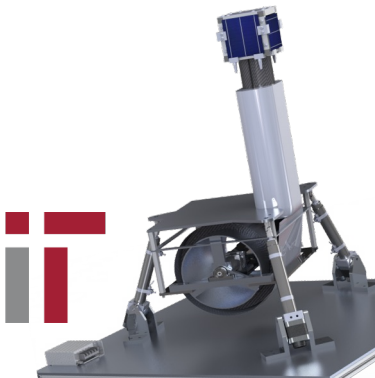
0.4Nm Motor

Fixed Steel Plate

Radial Bearing

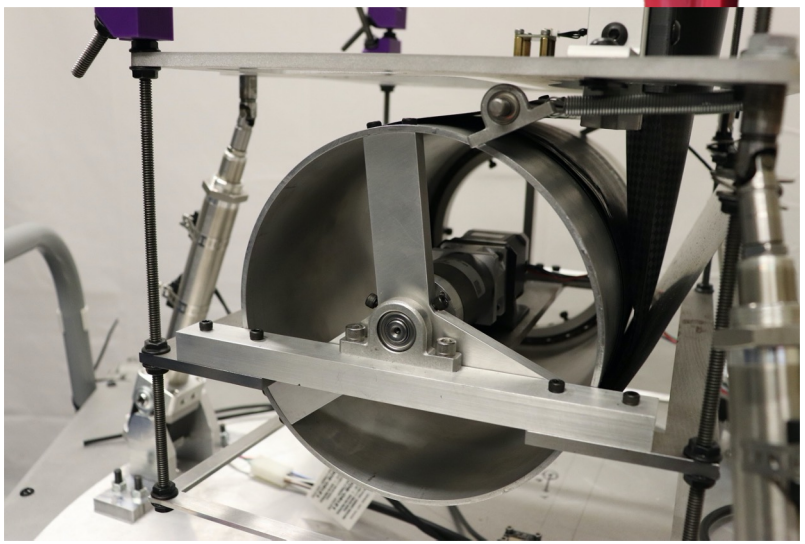
Boom Wrapped on Spool

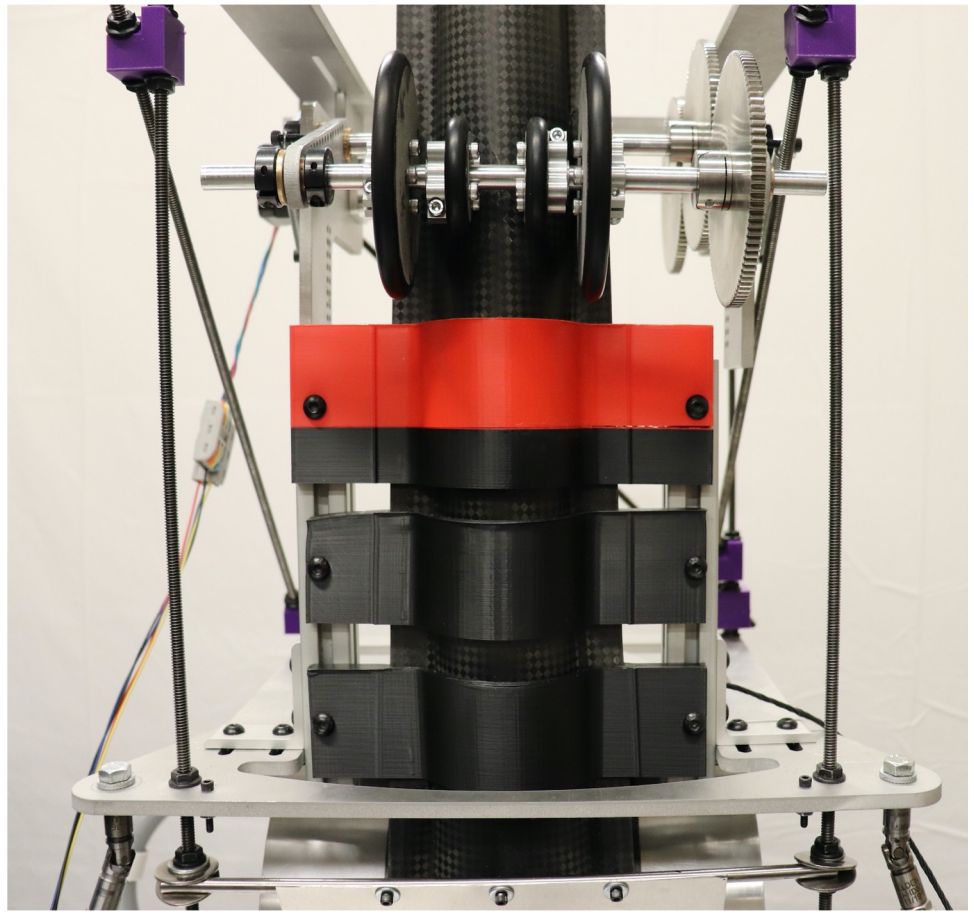




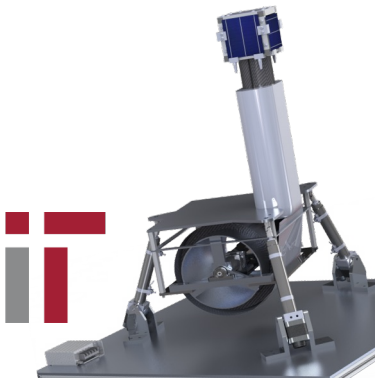
Deployer as-built

Deployer Mk1
(original design)

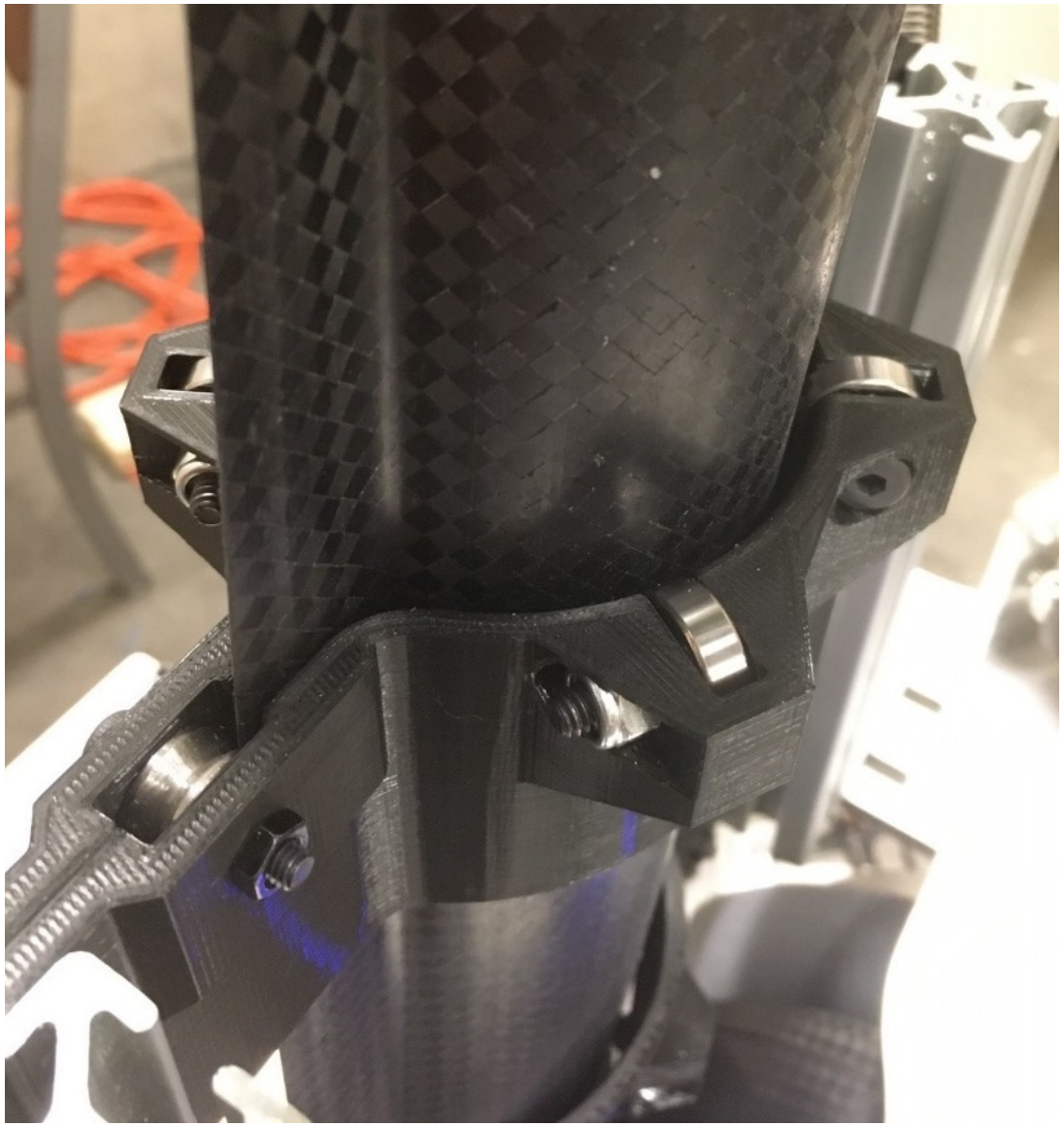


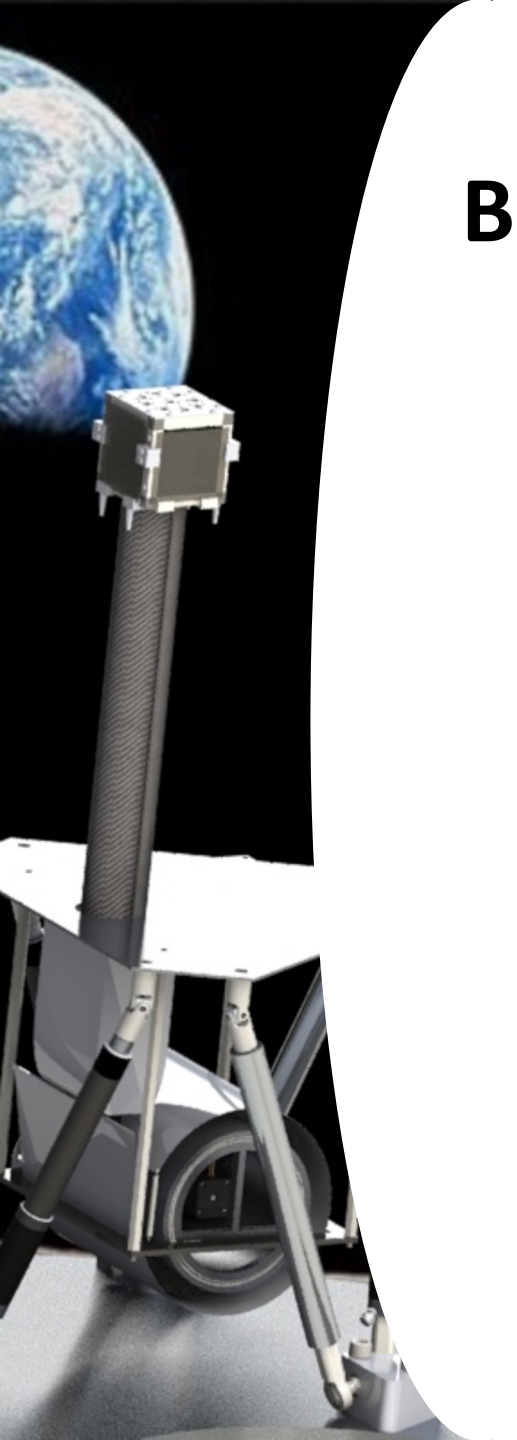


Deployer with powered rollers to mitigate boom blooming (iterated design)

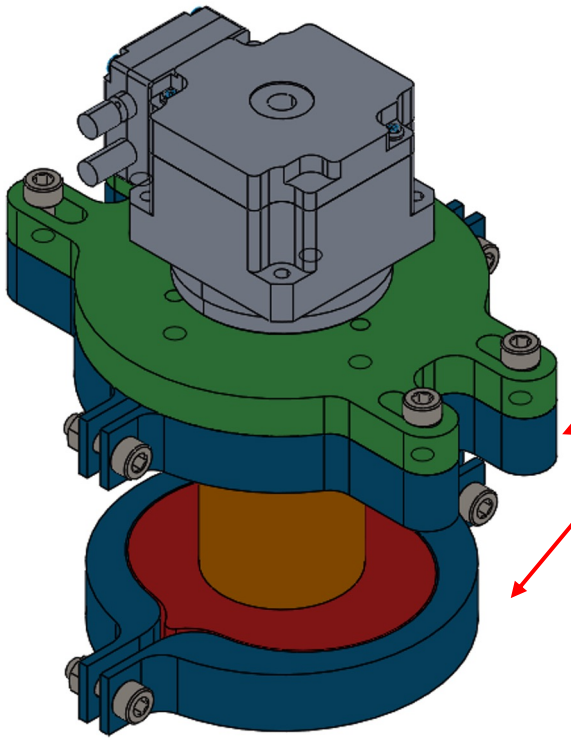


Bearing bracer detail



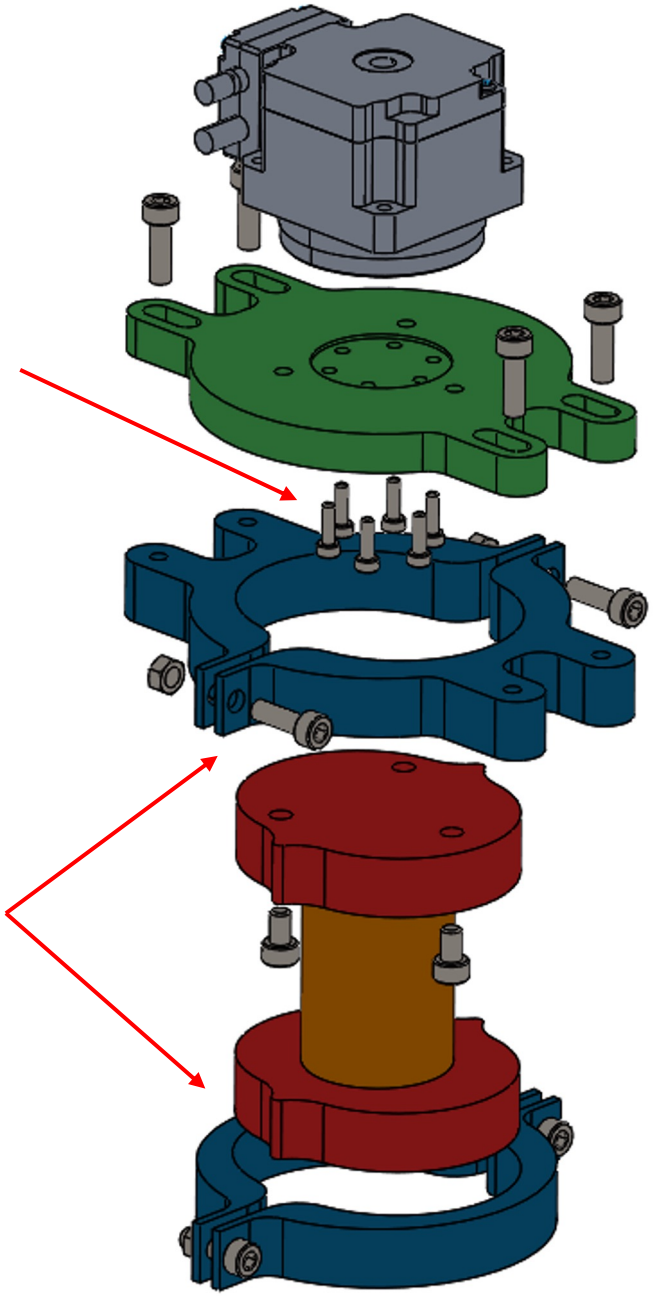


Boom-Payload Interface



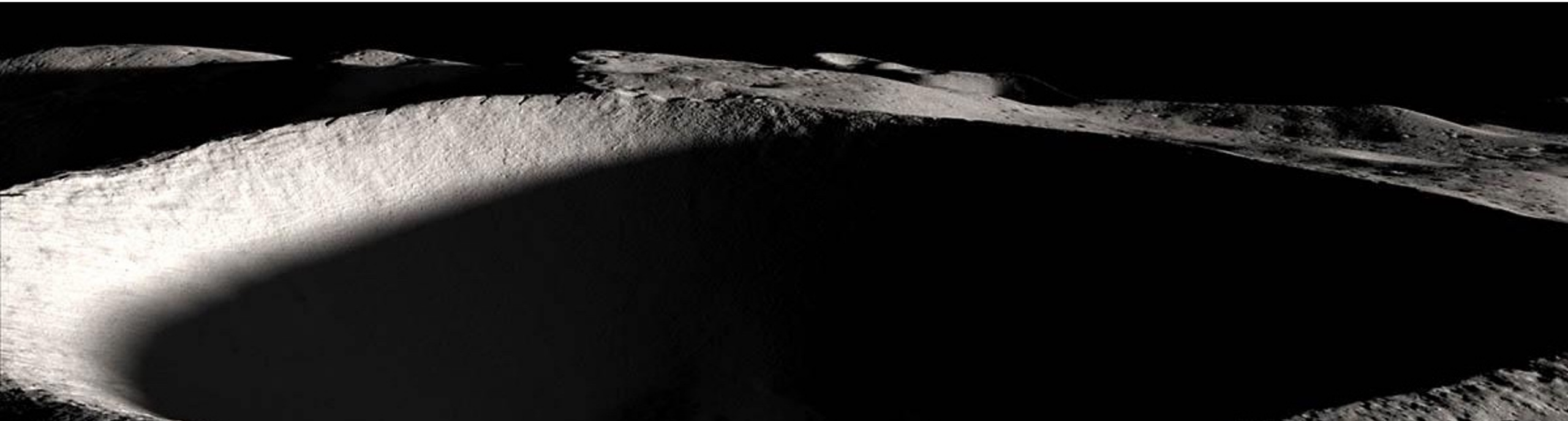
6 M3 screws attach the motor to the boom mount

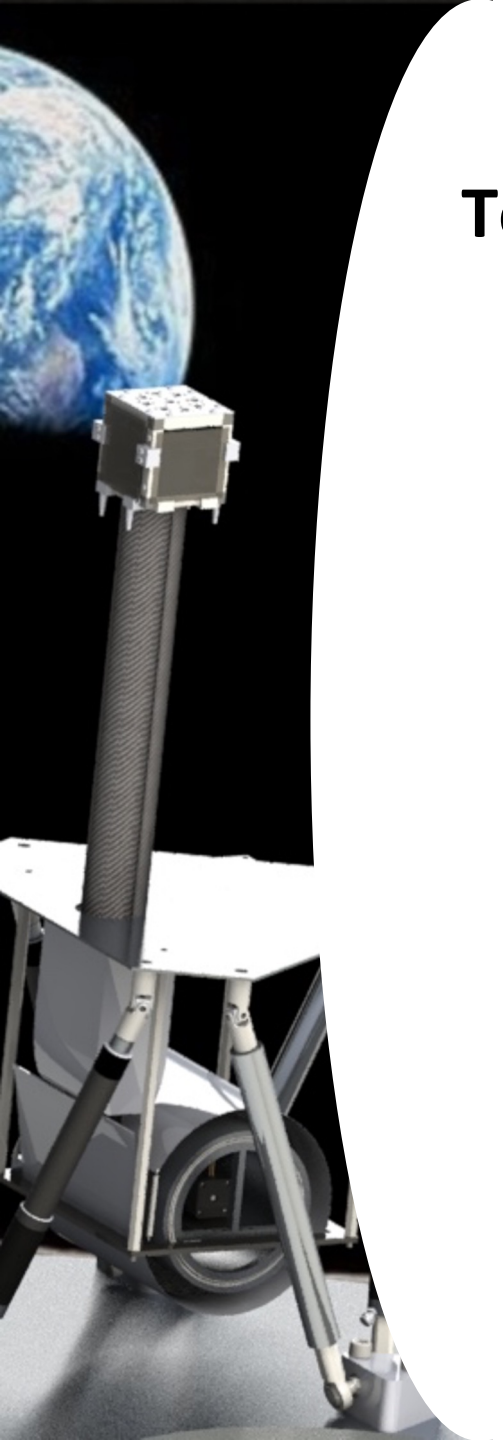
A “sleeve” clamps the mount to the boom



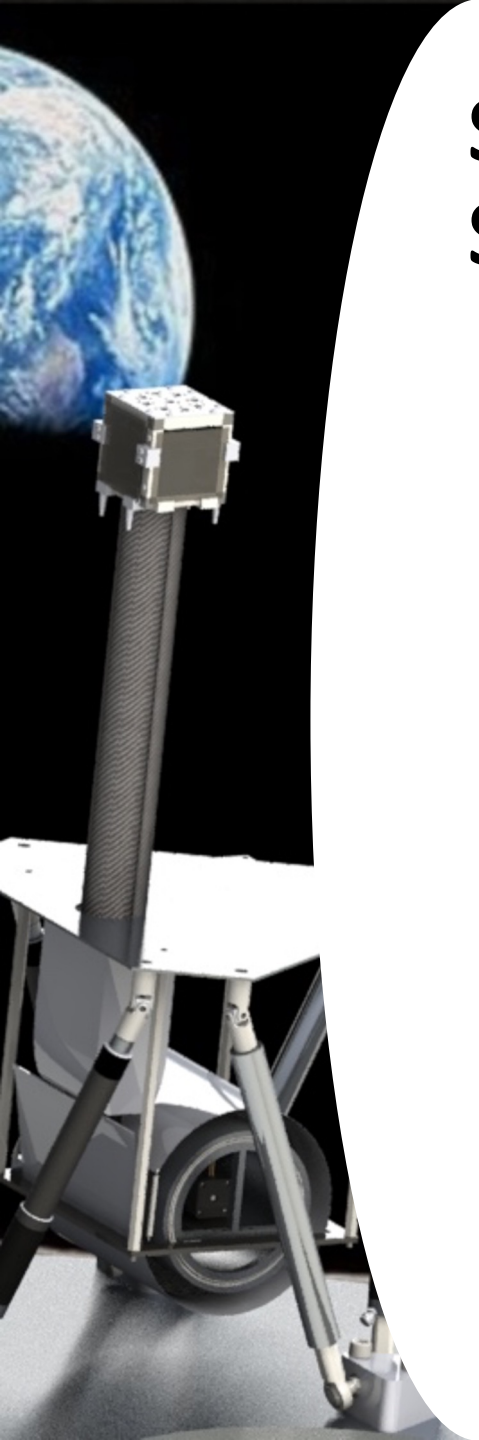
Mass: 800g

UPS – Upper Platform Subsystem





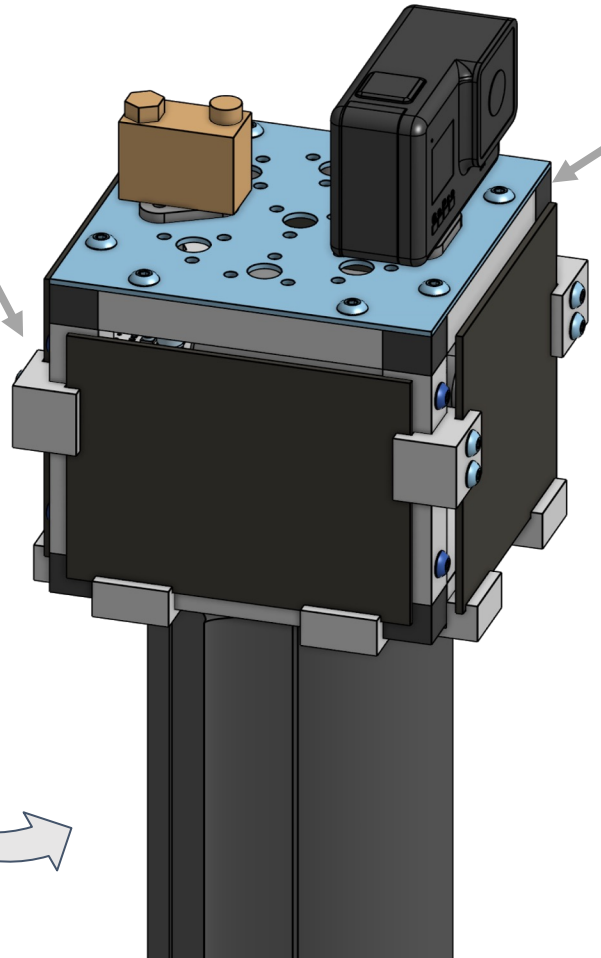
Tower Upper Platform



Self-Powered Upper Platform Provides Lines of Sight and Full Service to Elevated Payloads

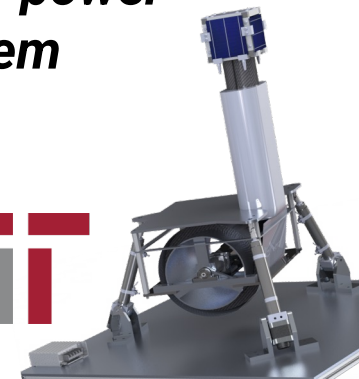
Internal control, power, pointing and data handling (payload services)

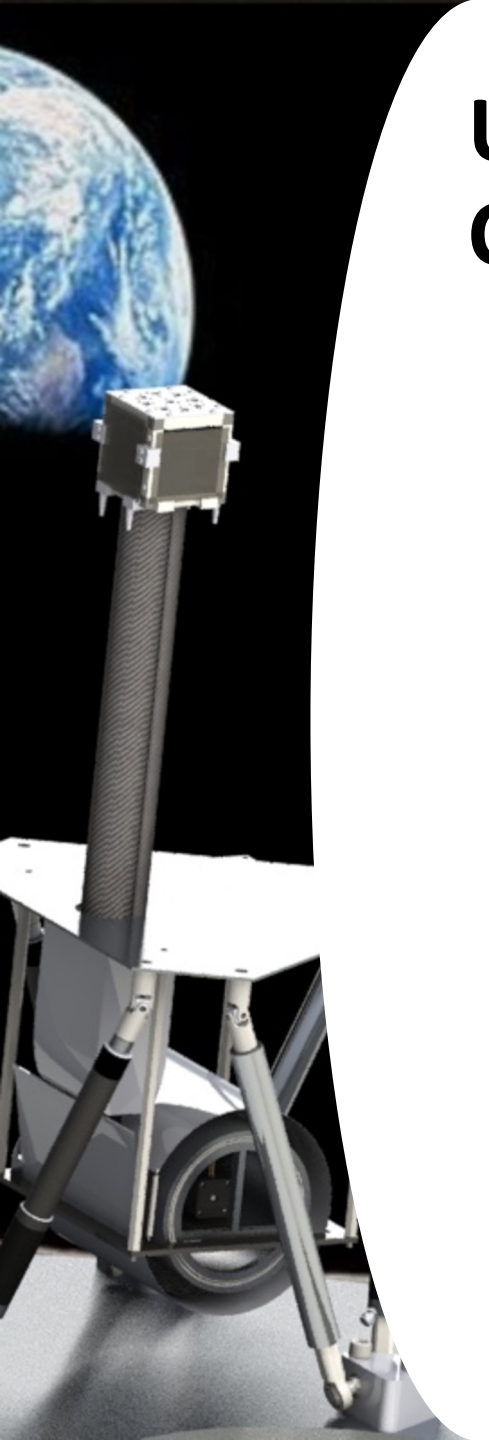
CubeSat form, standardized payload hosting



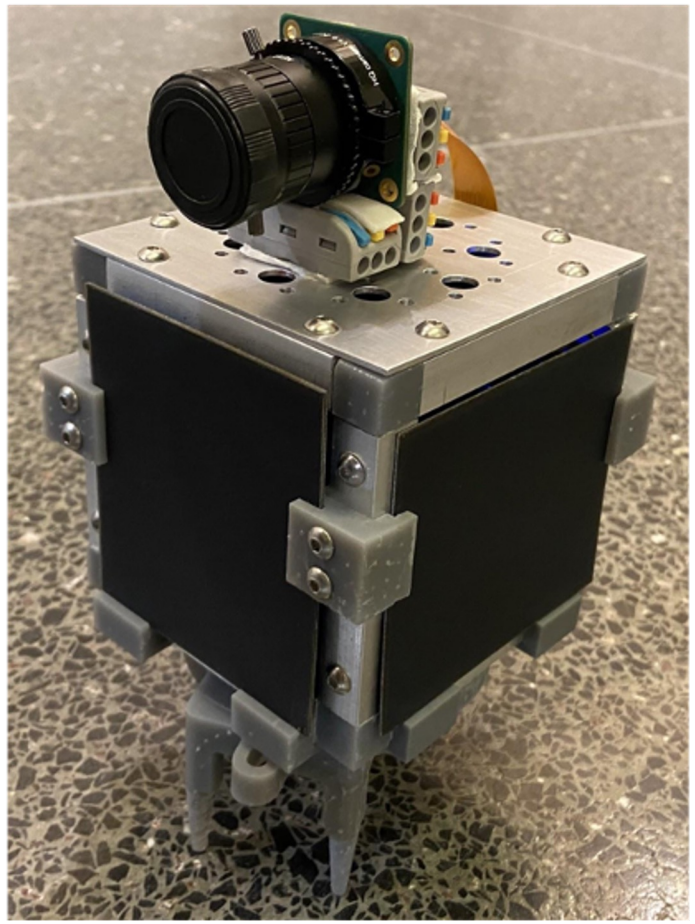
Independent solar power system

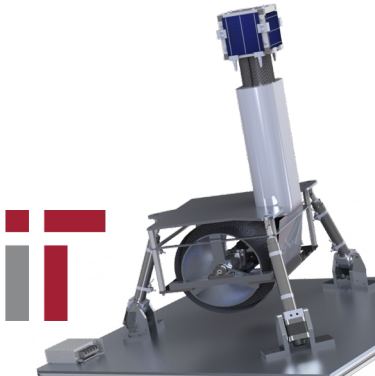
Azimuthal pointing control



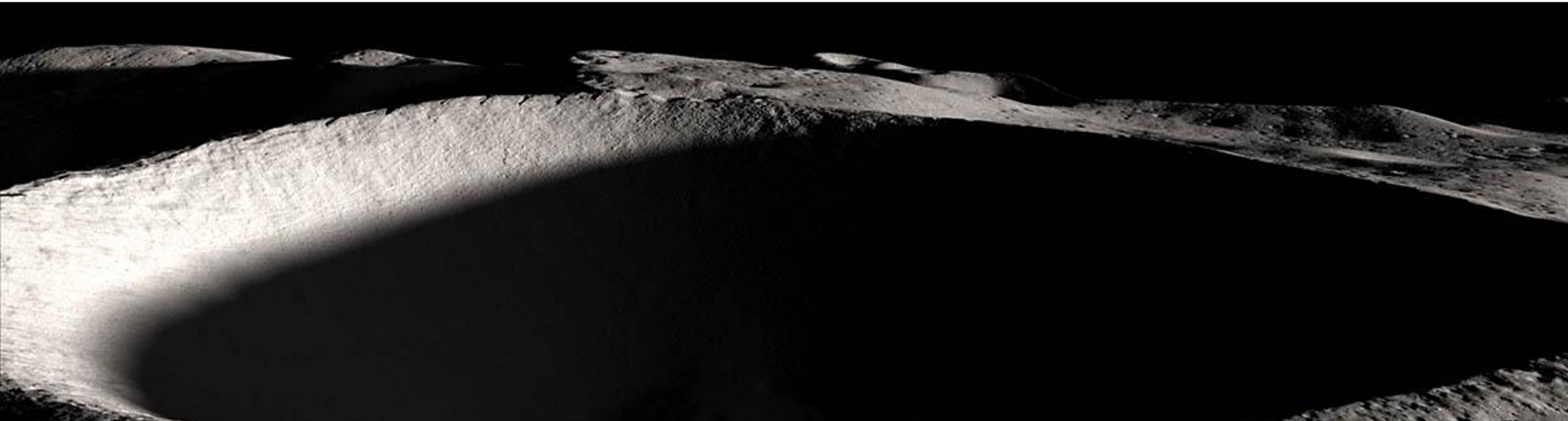


Upper Platform as built for NASA's BIG Idea Challenge demo, January 2021

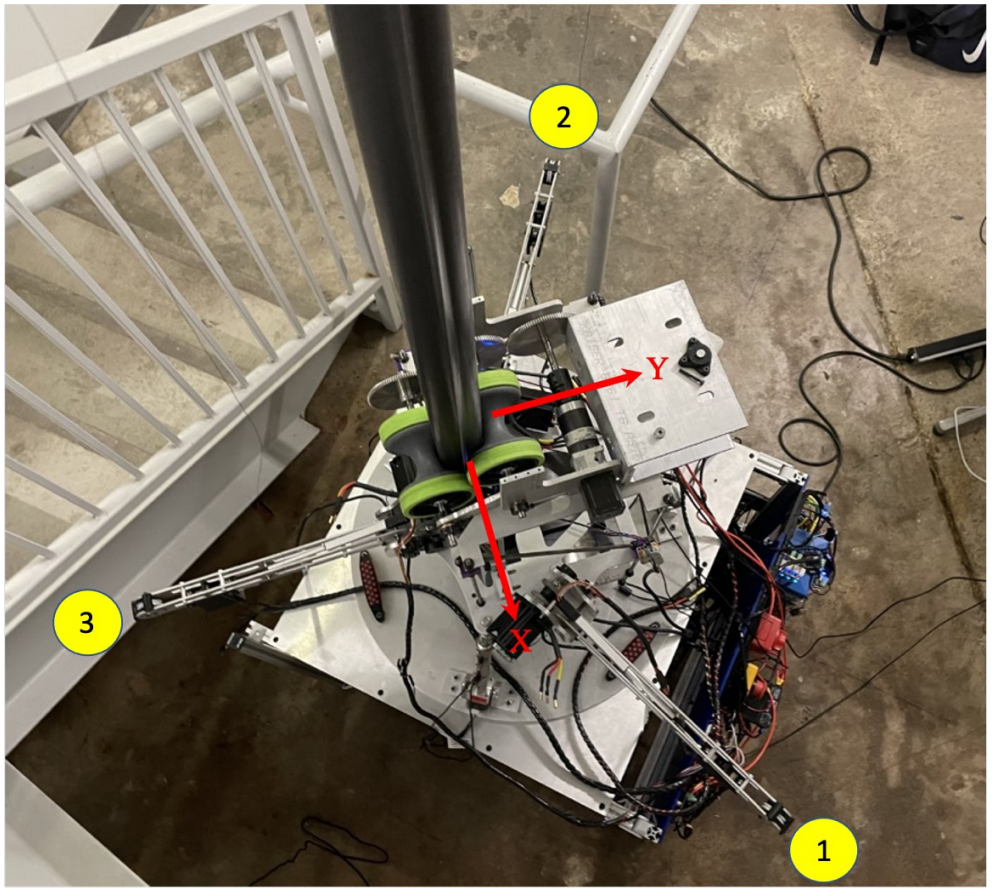




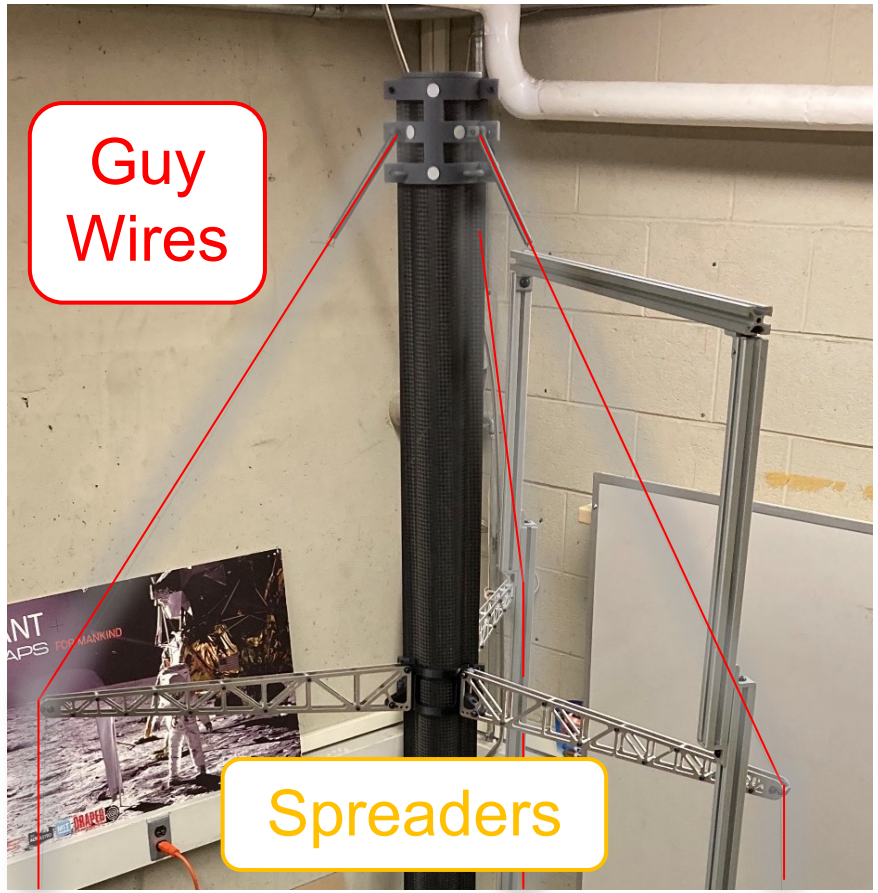
TRS – Tower Rigging Subsystem



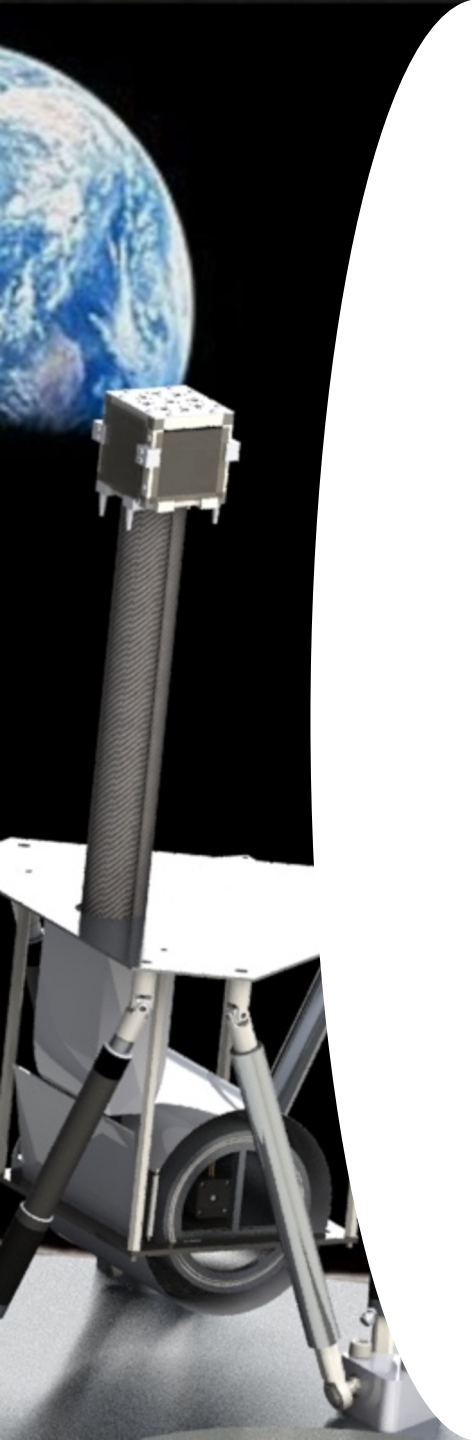
Components of Tower Rigging System



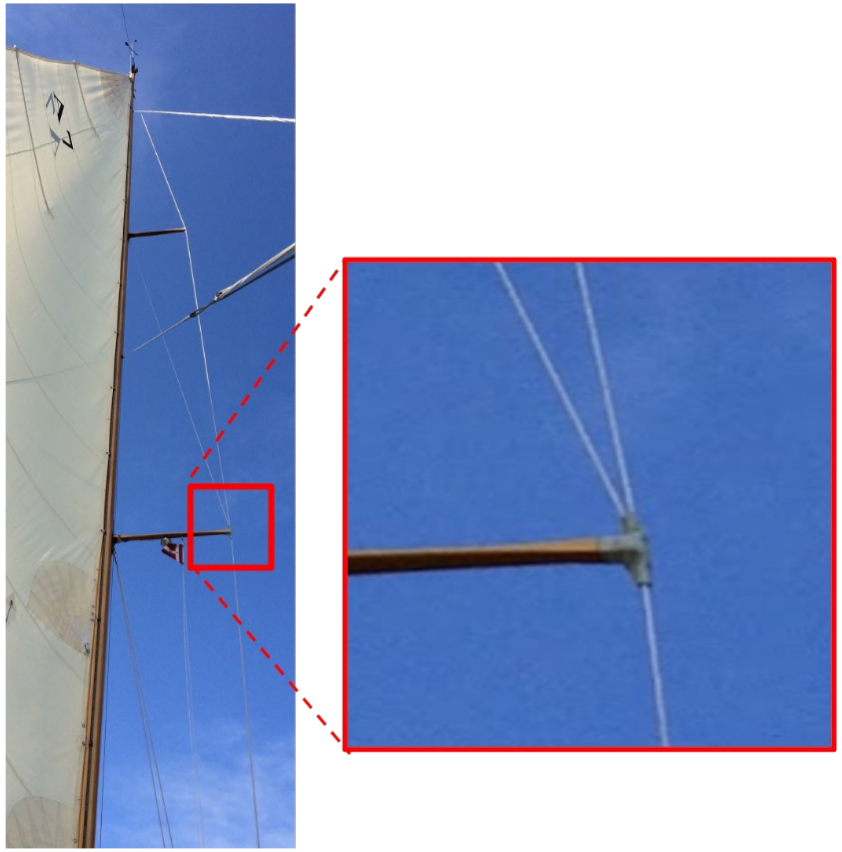
Three deployable base arms
with spools and load cells



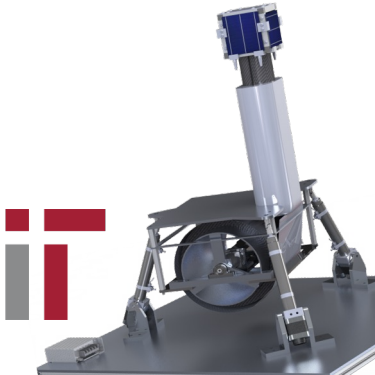
Guy wires and spreaders



Inspiration from antenna and sailing boat masts

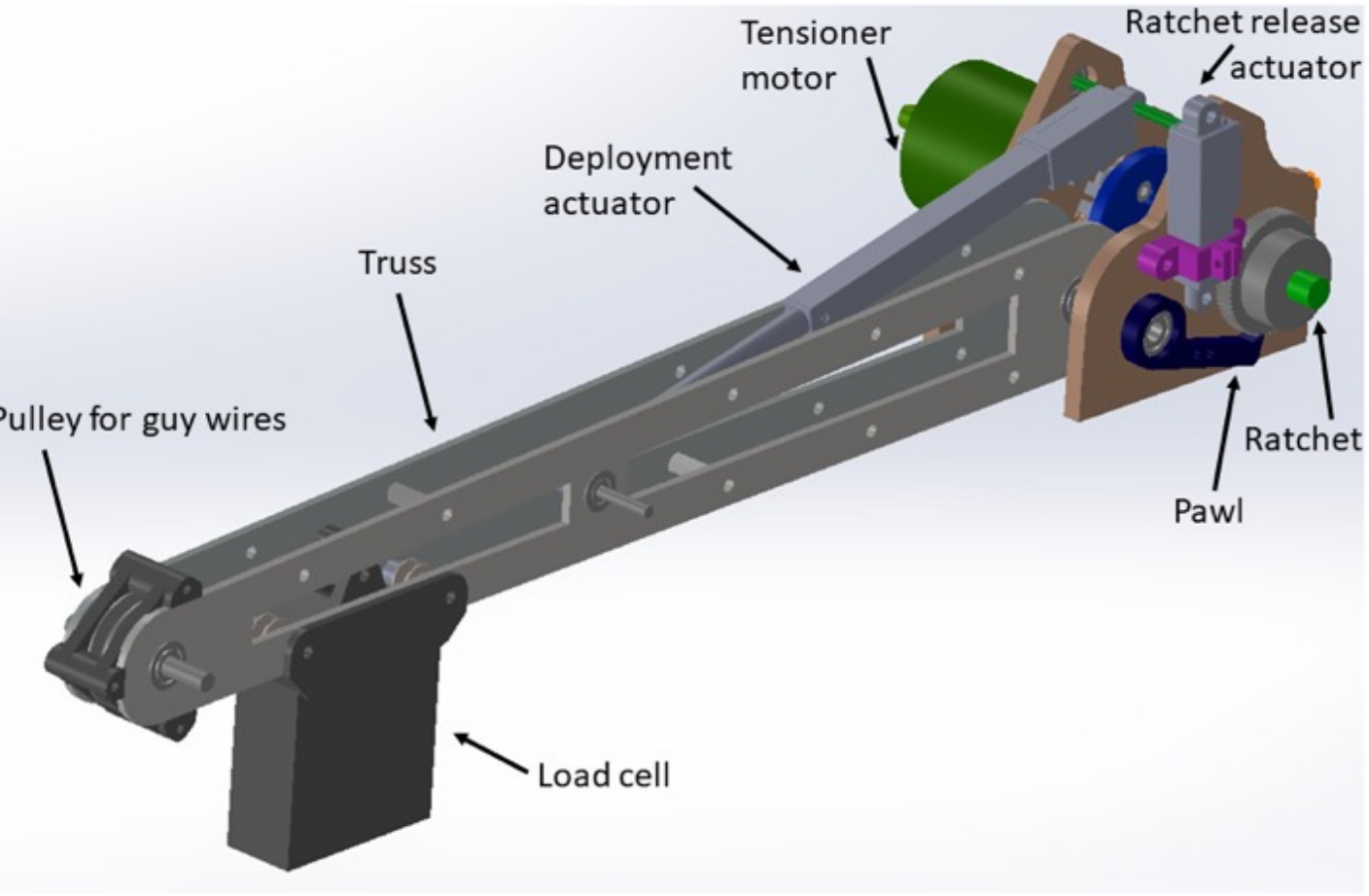


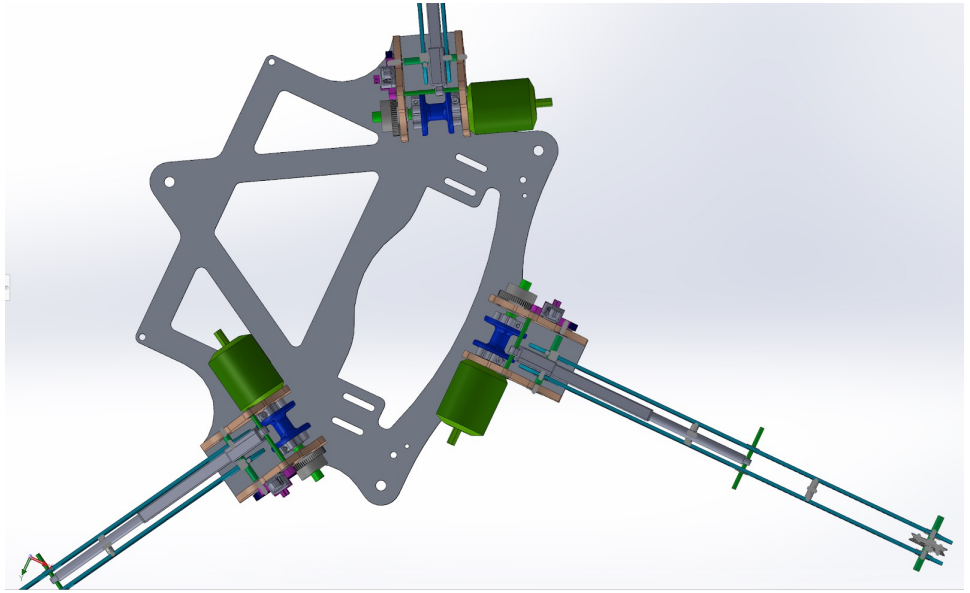
Rigging systems are used for many static and dynamics load cases.

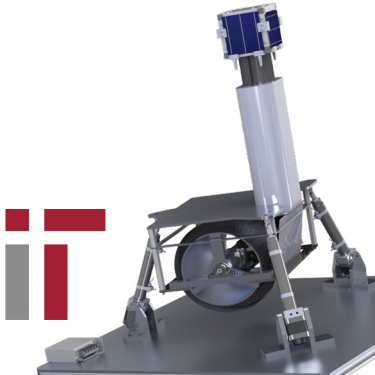


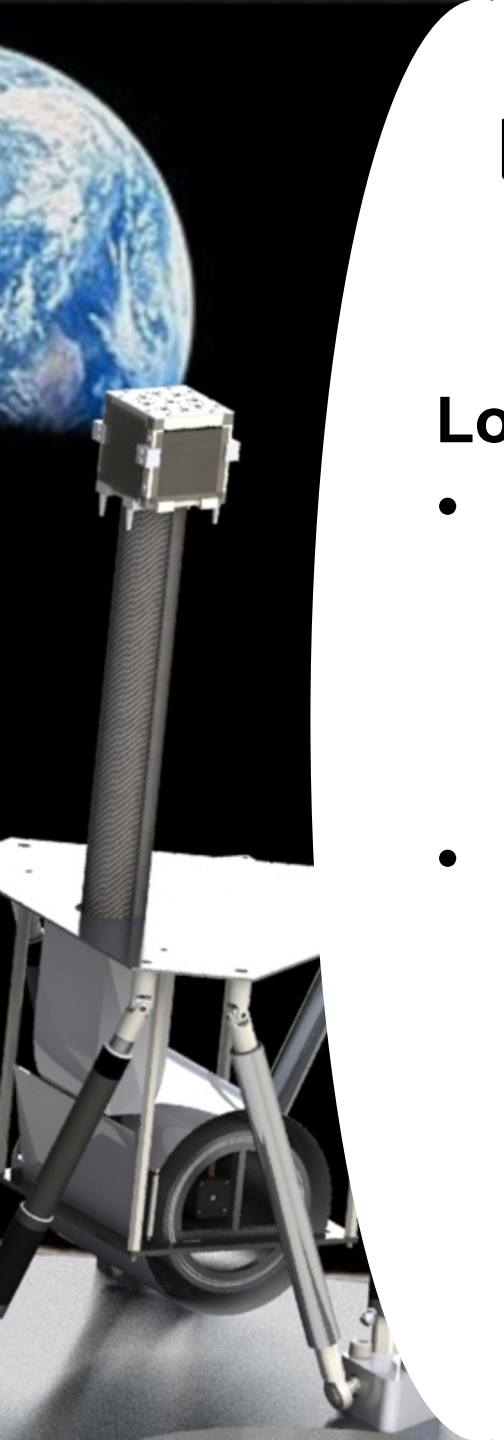
Deployable Rigging Arm Prototype Detail

- Linear actuator deployment
- Passive locking, with release actuator.
- Encoder and servo motor for tensioning
- Spectra HDPE low-stretch guy wire line.







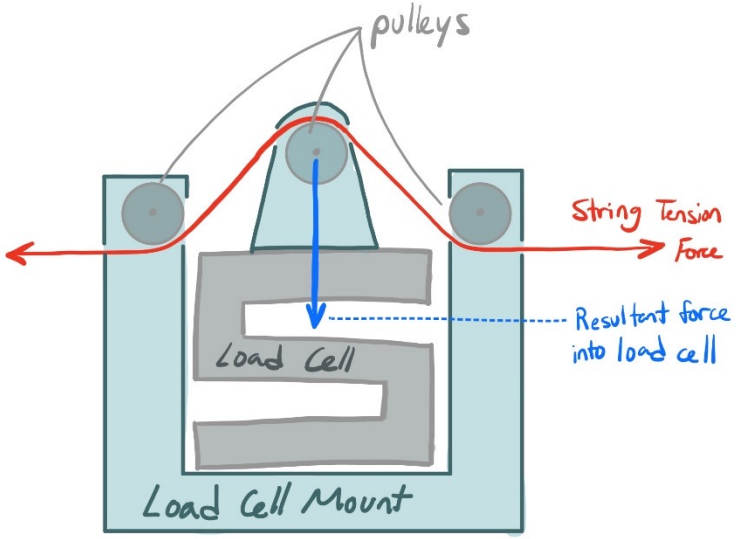


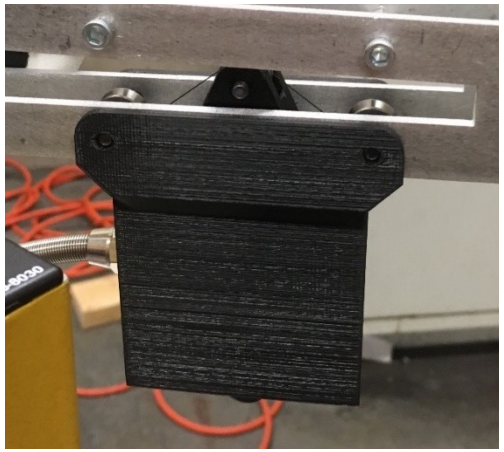
Load Cell Subsystem Detail

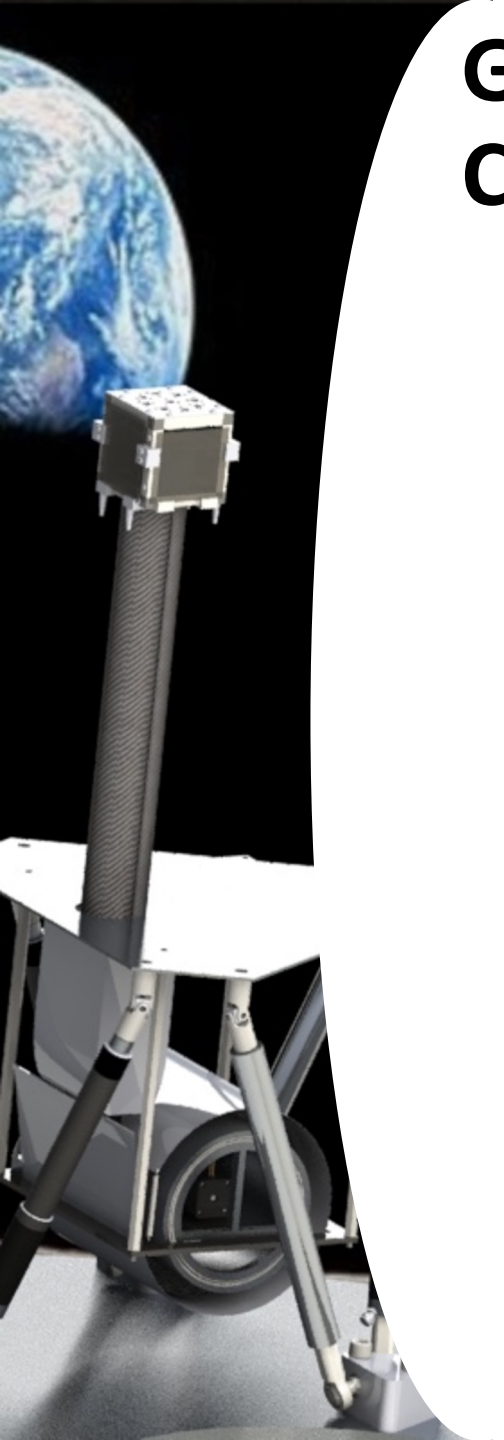
Load Cell design

- Measures inline tension of guy wires for experimental data collection

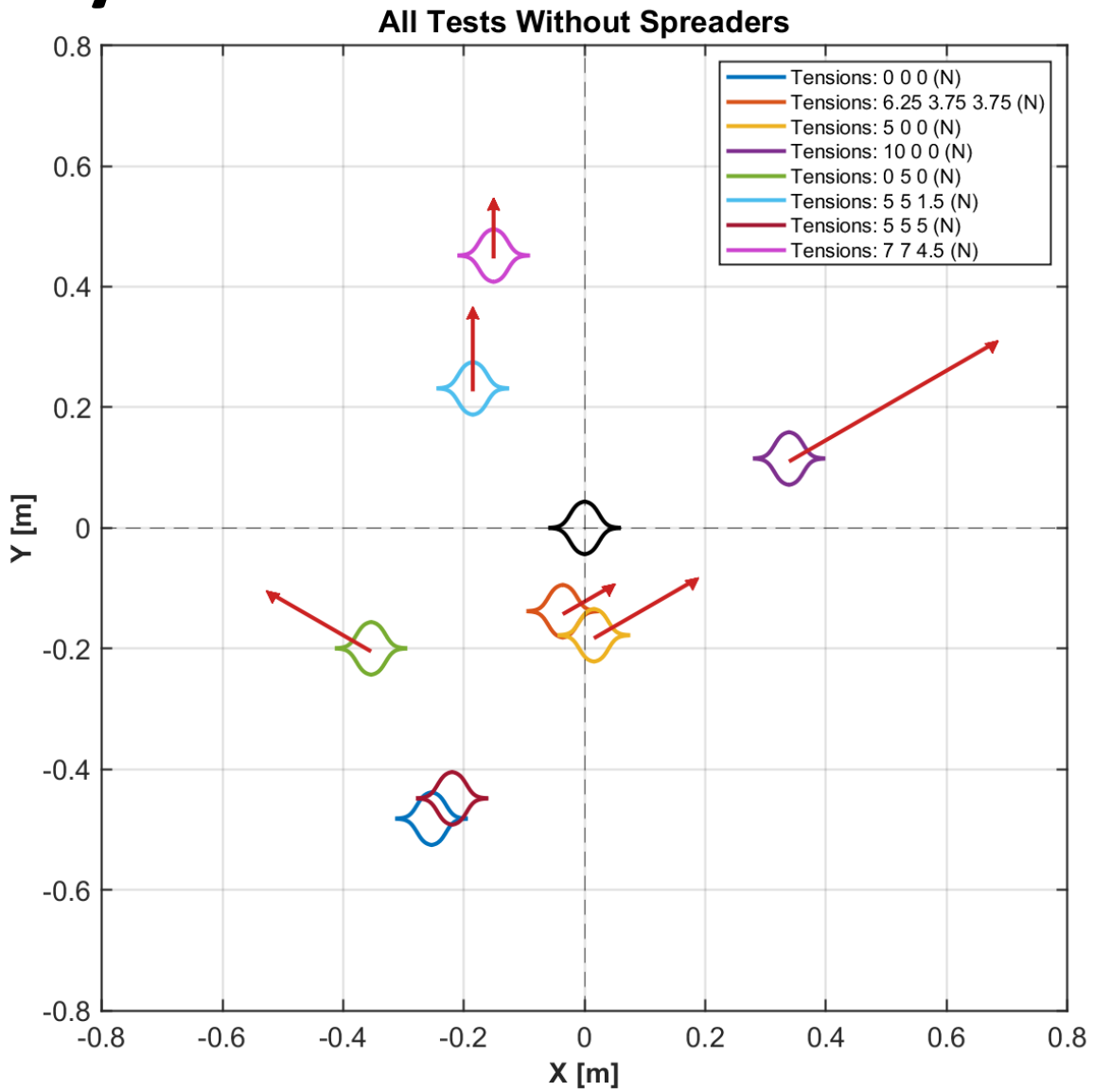
- Bulky load cells are located at base of tower, not on top payload.

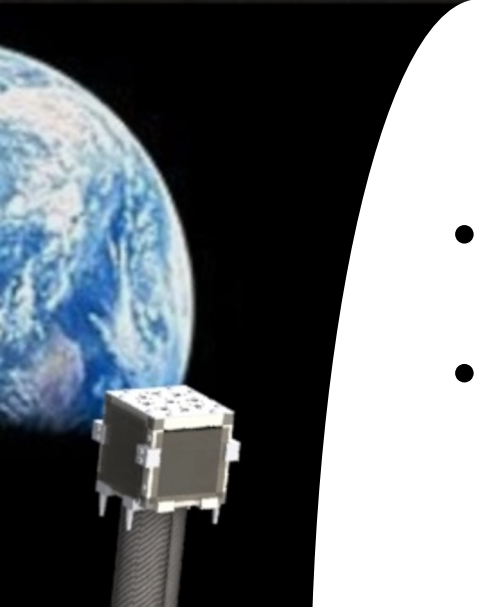






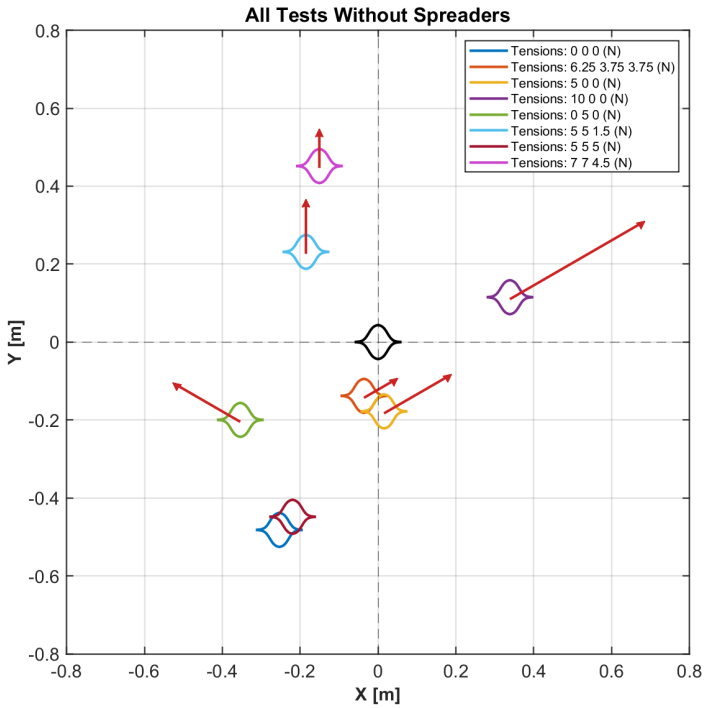
Guy Wires Add Significant Control Capability in 8.5m Test

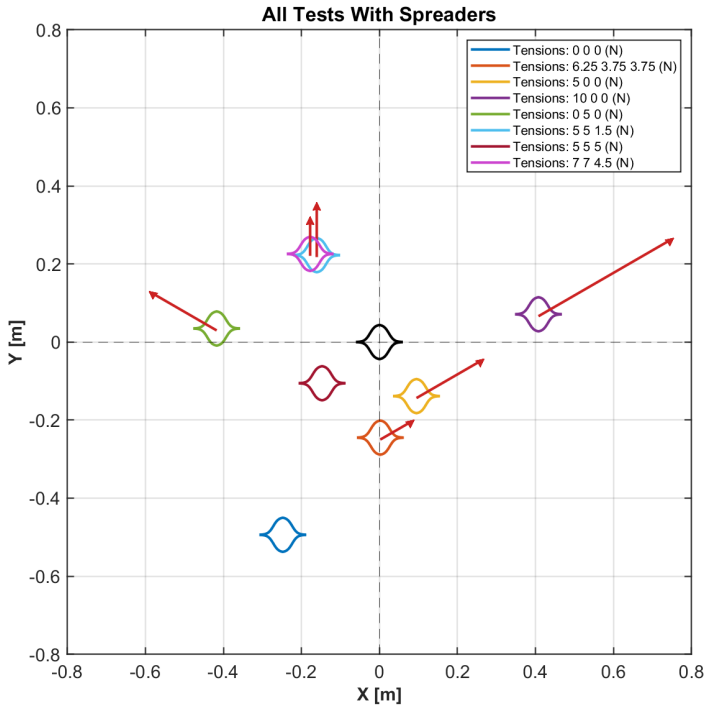




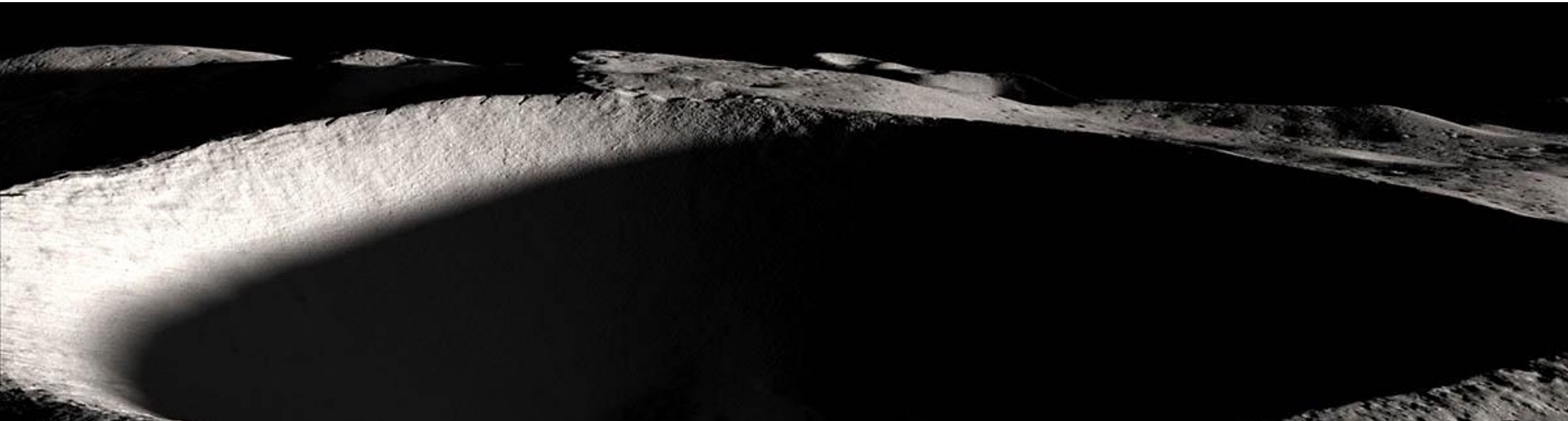
Mid-boom spreader arms: testing inconclusive

- Early results with spreader arms (right) show no significant improvement over tower without spreaders (left).
- Future testing with Gen2 SELTI system will include different spreader arm positions, including much closer to boom tip.





Tower Power and Data Design



Tower Software Design

Payload

- Pi Zero computing module to capture images from a servo-articulated camera, thereby enabling high resolution panoramic footage.

Leveler and Deployer

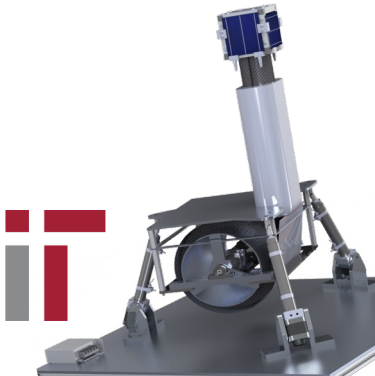
- Robot Operating System (ROS) framework on Pi4
- Closed loop motor controllers controlled via Modbus
- State Machine
- Leveling Controller
  - Inverse Kinematics
  - Accelerometers

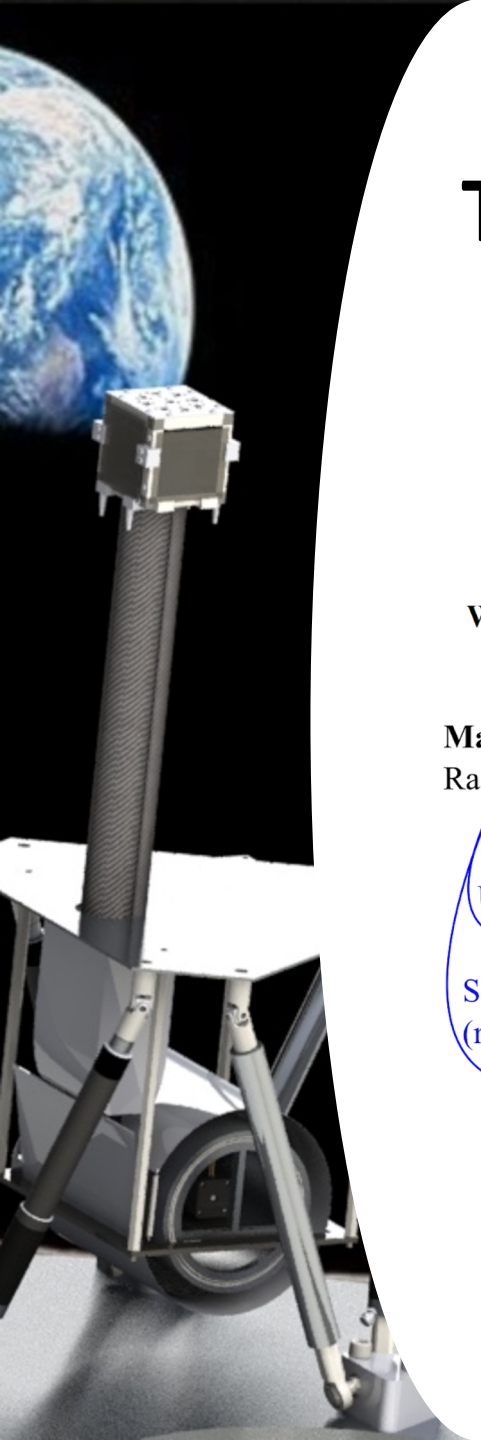
Photogrammetric Method to estimate pose

  - COTS OptiTrack Trio hardware and software

Outriggers

  - Real-time tension readout from 3 S-shaped load cells





Tower Software Design

Payload

Wifi — Serial bus (ribon cable) — **HD camera**

Radio — USB — **Raspberry Pi Zero**

(Direct header connection) — **TKF Pi Hat**

Tinkerforge bricklets (stacked or seperate)
- TKF Voltage/Current Measuring Bricklet
- TKF Accelerometer Bricklet
- TKF RS232 Bricklet (for TTL comm with motor controller)
- TKF 4 digital outputs bricklet (for LEDs)

Wifi — USB — **Main Computer**
Raspberry Pi 4, 8 GB RAM

USB — **TKF Master Brick**

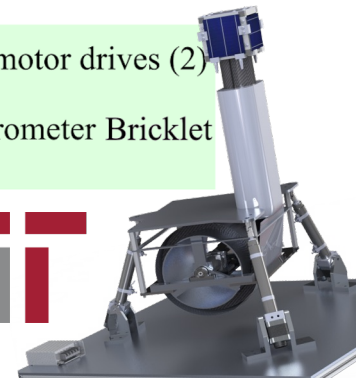
Serial bus (ribon cable) — **Camera staring at LEDs**

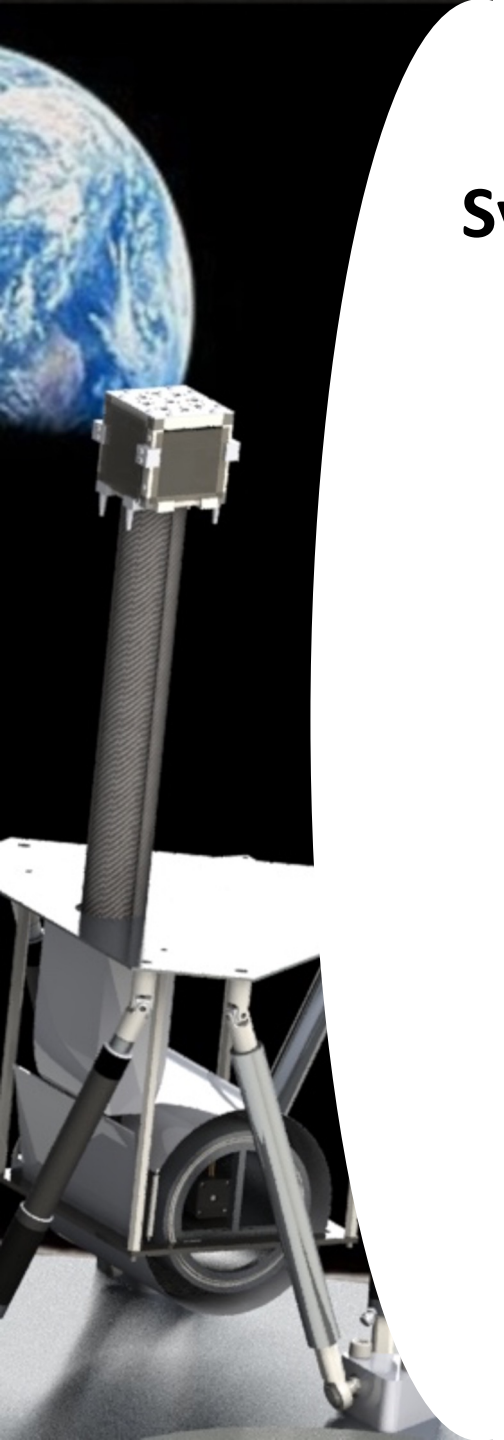
Serial (TKF standard connectors) — **Tinkerforge bricklets**
- TKF Current-Voltage Bricklet
- TKF RS485 Bricklet

Leveler
- TKF accelerometer Bricklet
- Modbus (RS485) — Leveler motor drives (3)

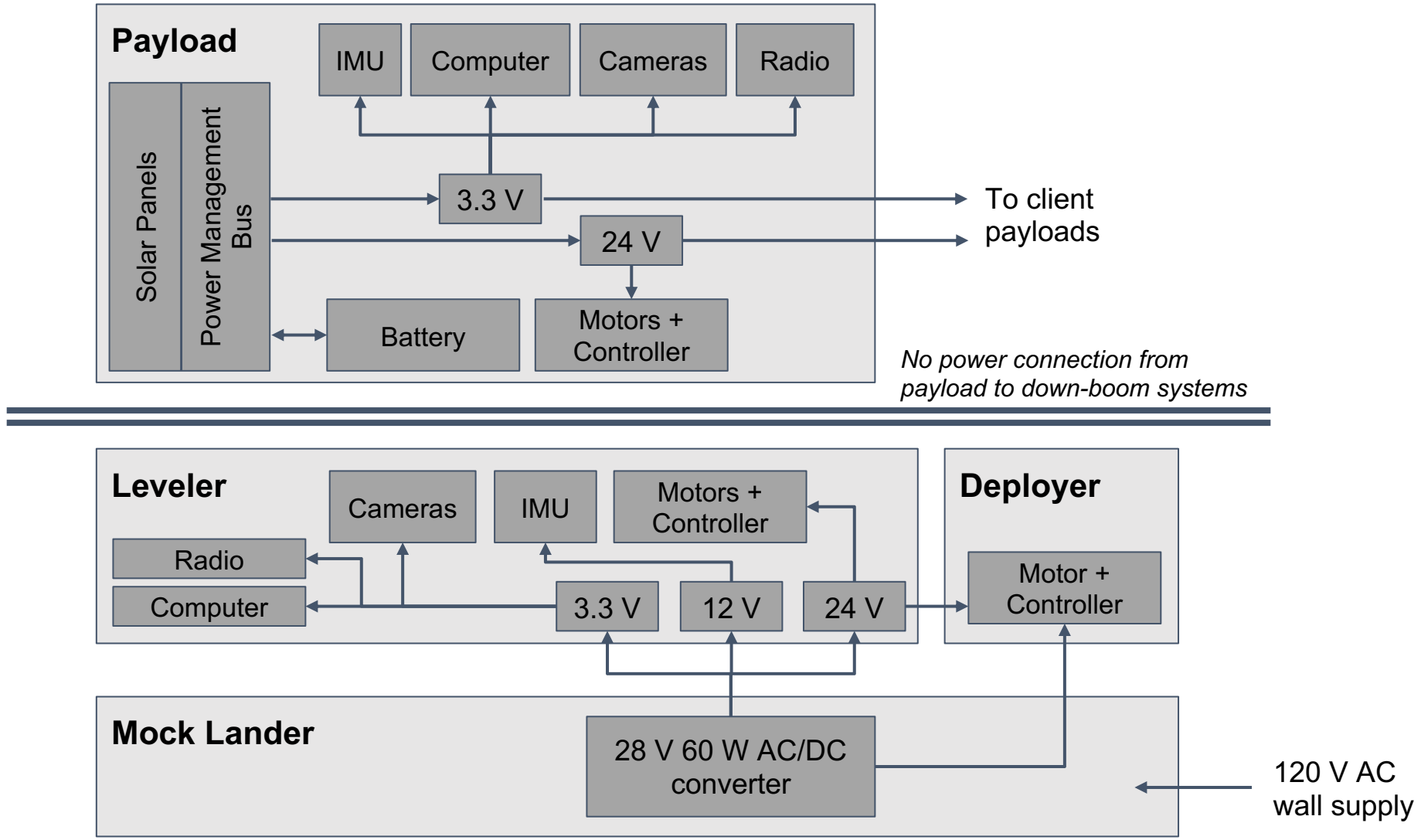
Deployer
- Modbus (RS485) — Deployer motor drives (2)
- TKF accelerometer Bricklet

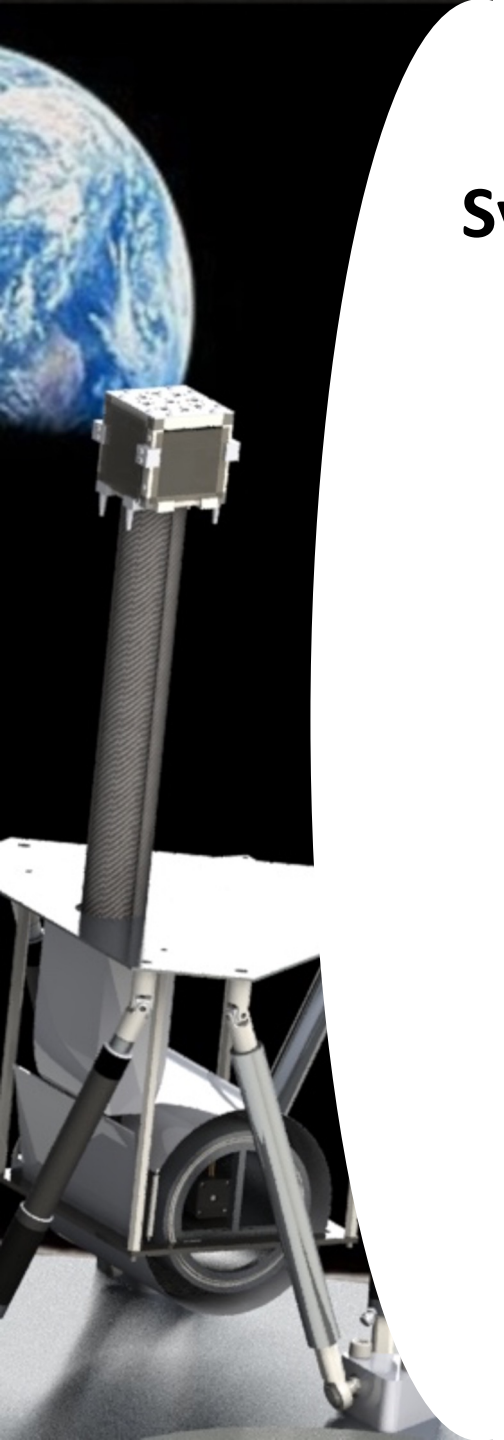
List of accronyms:
TKF - Tinkerforge



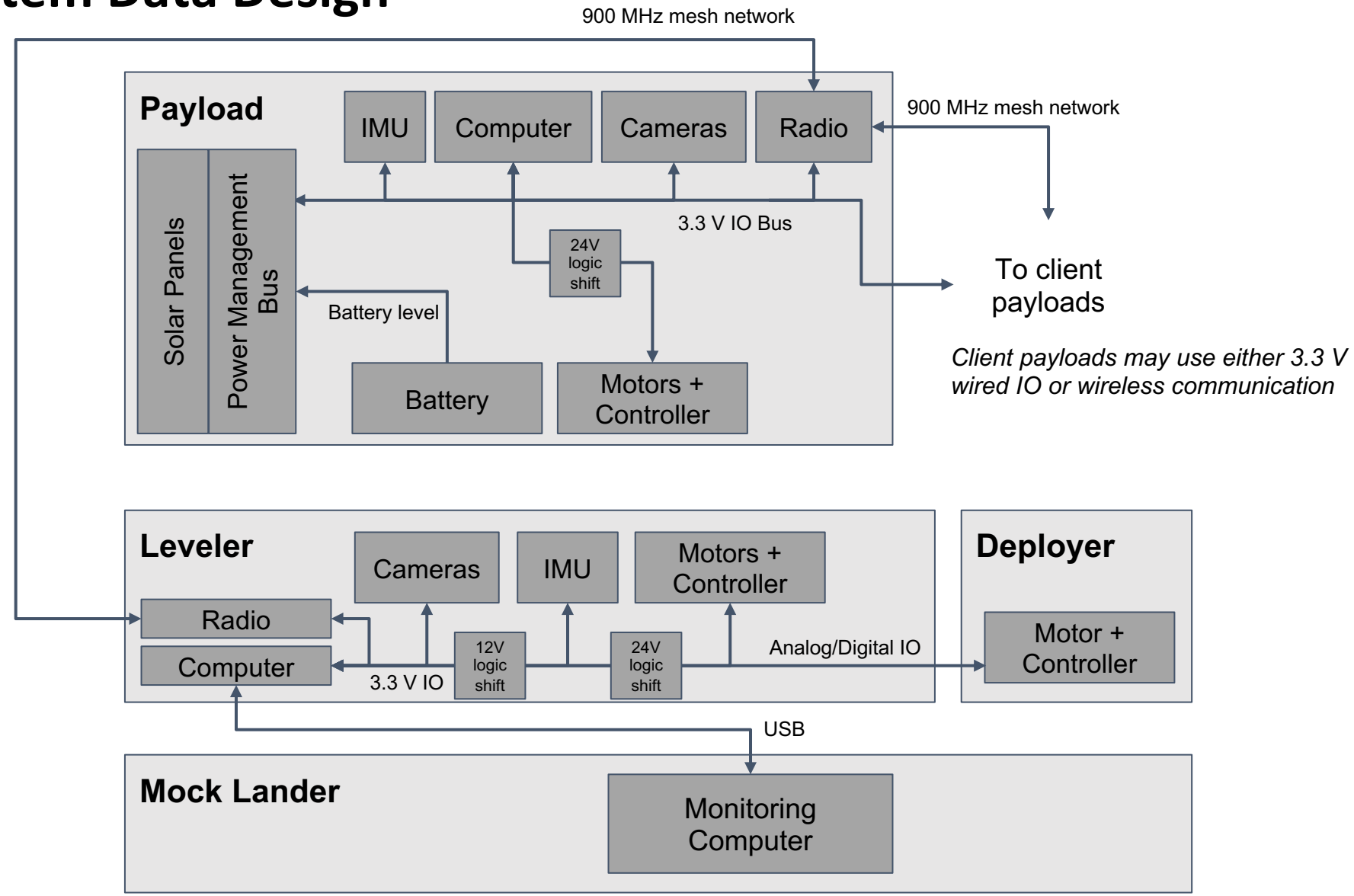


System Power Design

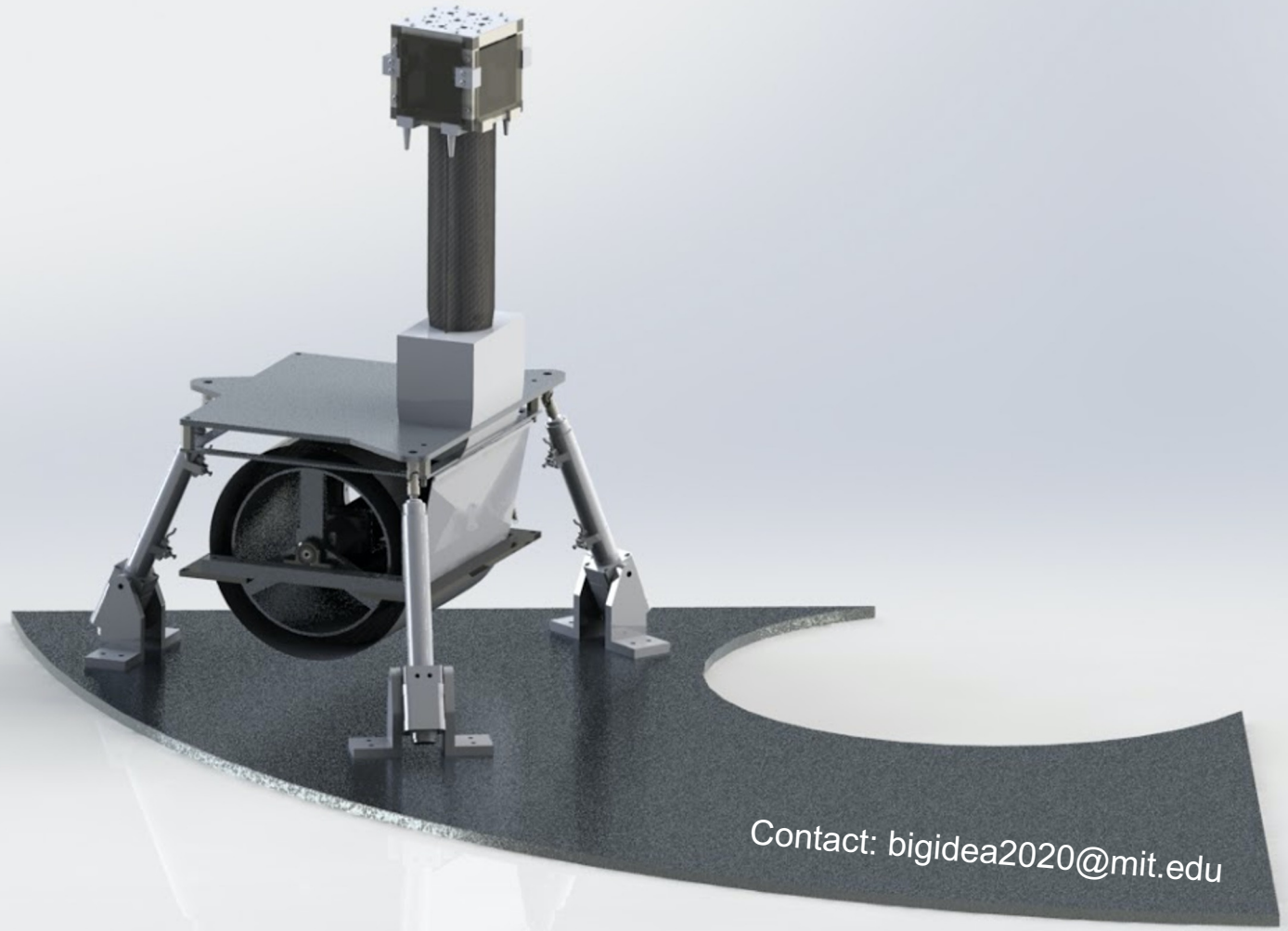




System Data Design

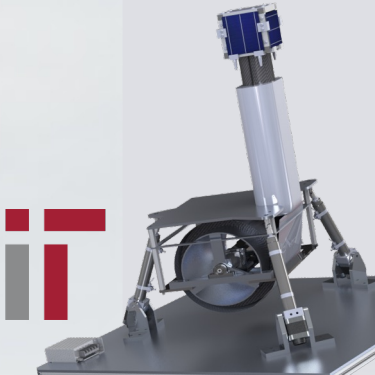


Next Step for MIT/LaRC Lunar Tower: aiming for TRL 6



Self-Erecting Lunar Tower for Instruments

Contact: bigidea2020@mit.edu

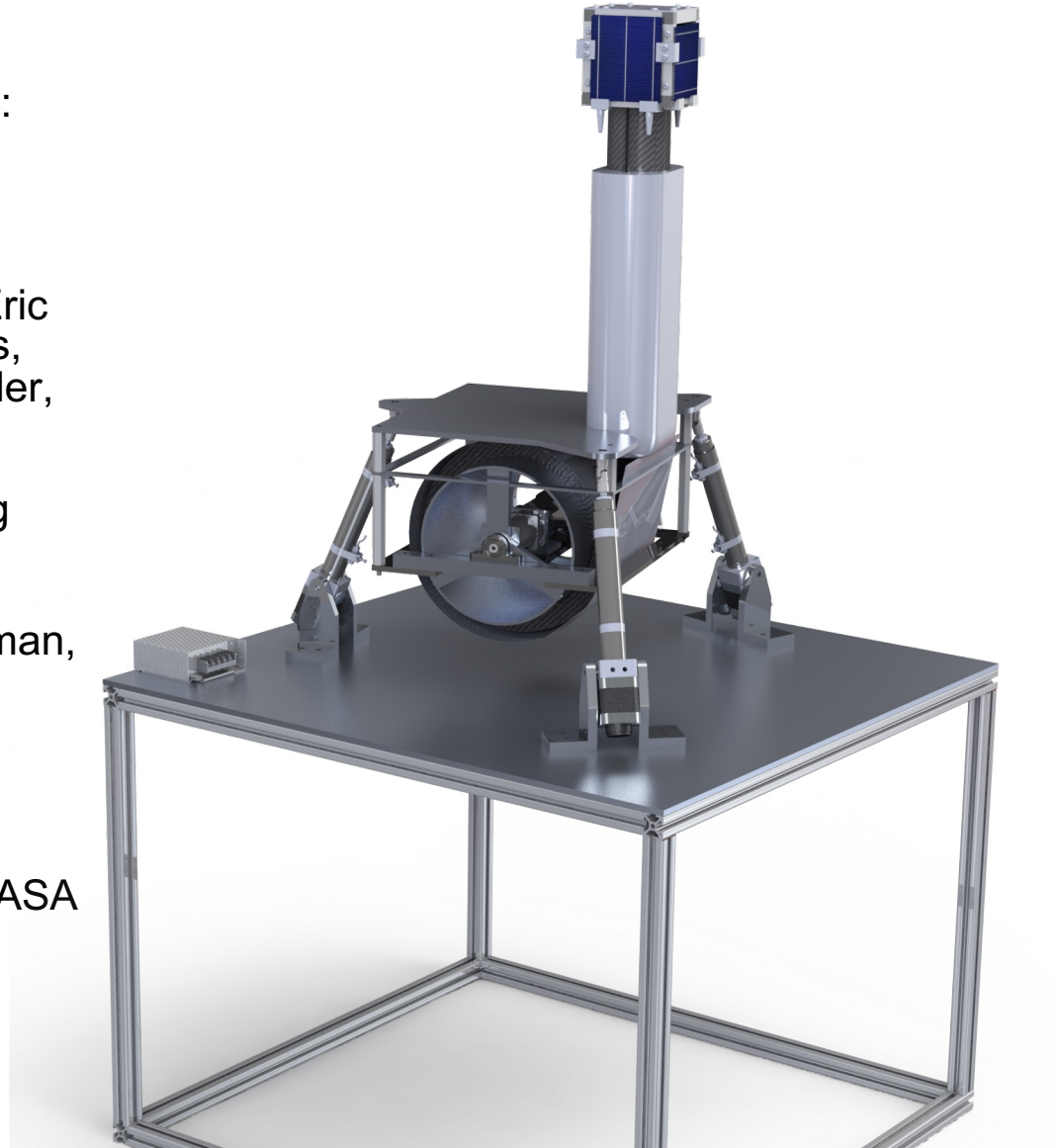


Our Lunar Tower Team

2019-2020 BIG Idea Challenge MELLTT team: Caleb Amy , Marc-André Bégin, Becca Browder, Manwei Chan, Charles Dawson, Paula do Vale Pereira , Travis J. Hank, Eric Hinterman, George Lordos, Benjamin Martell, Alex Miller, Cormac O'Neill , Vineet J. Padia, Natasha Stamler, Jessica Todd, Nieky Wang

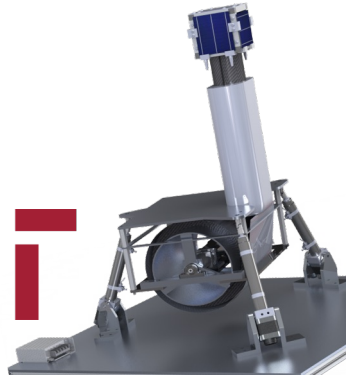
Advisors: Jeffrey A. Hoffman, Olivier L. de Weck, Dava J. Newman.

SAA Partner: Deployable Composite Boom team, NASA Langley Research Center Dr. Juan M. Fernandez



2021-2022 Space Act Agreement SELTI team: George Lordos, Benjamin Martell, Alex Miller, Palak Patel, Natasha Stamler, Joshua Rohrbaugh, Emma Rutherford, John Zhang

Summer 2022 on-campus team: George Lordos, Alex Miller, Palak Patel, Paul Portmann, Will Schoeman, Avril Studstill, Christian Williams, John Zhang



Contact: bigidea2020@mit.edu