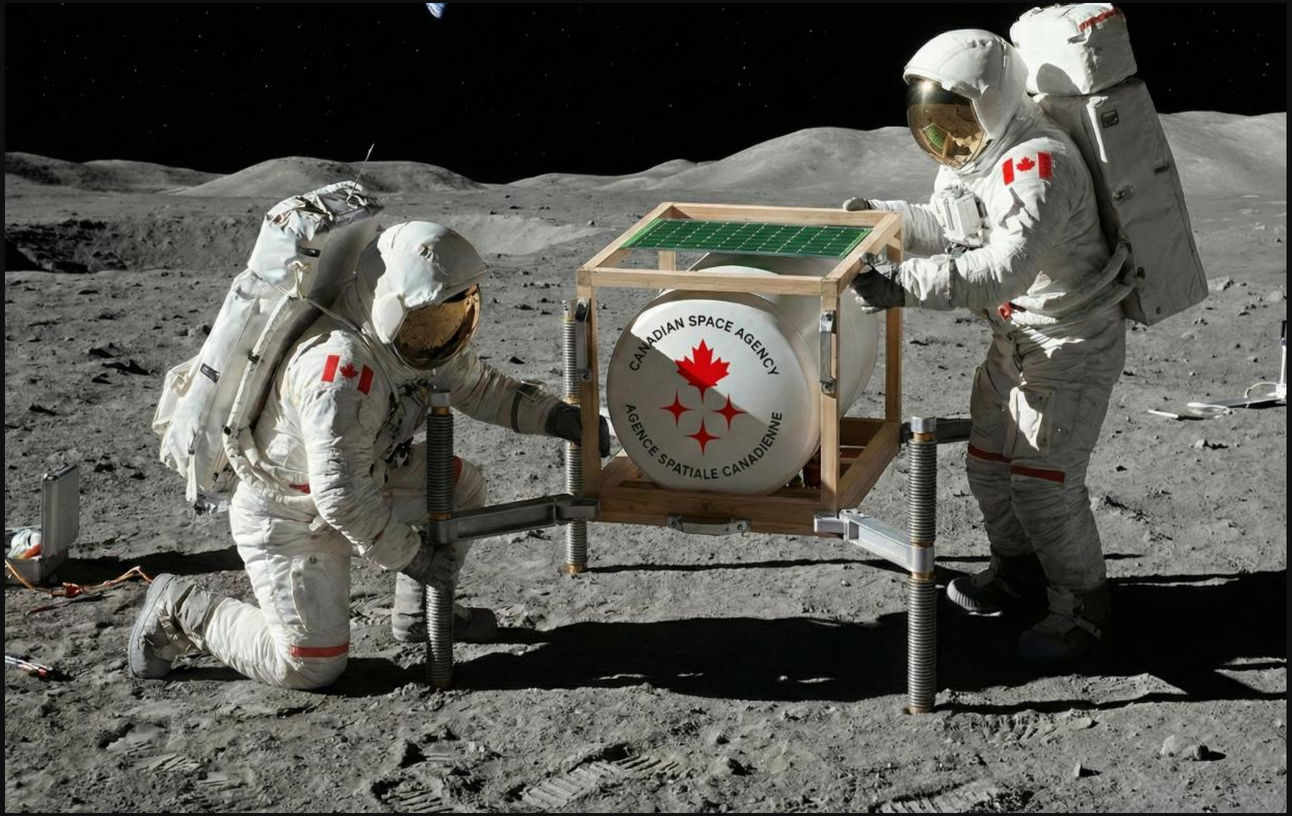


OASYS Leveling Mechanism

Engineering a stable foundation for lunar agriculture

Group 19

UBC
Engineering

Mission Overview

The Challenge

Design a support structure to level the OASYS greenhouse prototype on uneven lunar terrain, enabling bio-regenerative life support system testing.

The Client

Canadian Space Agency (CSA) - advancing astro-horticulture through collaborative student innovation across Canada.

Our Mentor

Egor Yaritsa
Engineer – Engineering Development & Capability Demonstration Program
Canadian Space Agency (CSA)

Critical Requirements

Terrain Compensation

Level platform on slopes up to ±15° from horizontal with ±1° accuracy.

Load Capacity

Support 130 kg distributed load under lunar gravity (1.62 m/s²).

Power Independence

Function without dedicated electrical supply; use external tools only.

Compact Storage

Fit within 1105 mm × 715 mm envelope when fully stowed.

Ground Clearance

Maintain minimum 1 meter clearance from ground to highest point when leveled.

Thermal Operating Range

Withstand thermal cycling from -200°C to +100°C throughout 6-week operational lifespan.

Lunar Dust Resilience

Prevent abrasive dust contamination of moving parts and maintain functionality in regolith environment.

Design Evaluation Criteria

System Mass

Minimized through I-beam selection and aluminum alloy—critical as launch costs scale with mass.

Ease of Use

Simple crank handle operation; large diameter for thick gloves; no complex sequences.

Design Simplicity

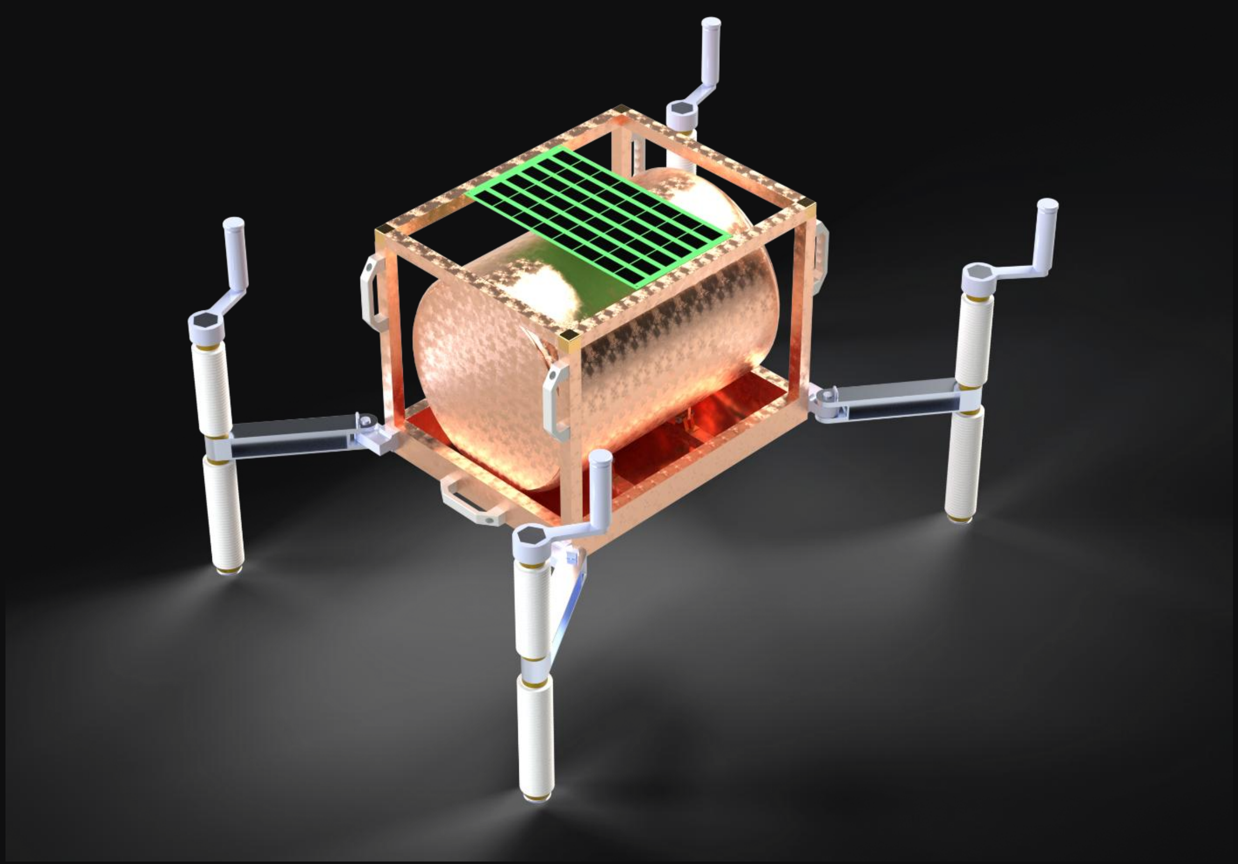
Symmetric four-leg design enables component reuse, reducing complexity and overhead.

Robustness

Self-locking screws, discrete hinge positions, and dust protection minimize failure modes.

Key Components

- Four-Leg System
- Hinge Locking Mechanism
- Lead Screw Actuation
- Dust Protection
- Ground Adaptation



Design Assumptions & Simplifications

Rigid Ground Assumption

Soil bearing analysis assumes a perfectly rigid lunar surface, simplifying interaction models.

Load Distribution

Center of gravity is assumed to be within 20% of its geometrical center.

Static Loading Conditions

Design accounts only for steady-state loads, excluding dynamic impacts or vibrations during operation.

Lead Screw Alignment

Preliminary calculations indicate that slight misalignment of the lead screw will not cause binding. Following calculations are done assuming this finding.

These assumptions are vital for simplifying complex analyses, providing a foundational basis for initial design validation.

Material Selection

Aluminum 2219-T87

- Density: 2840 kg/m^3
  - Lightweight - Nearly 2.75x lighter than wrought steel
- Yield Strength: 393 MPa
- Fatigue Strength: 103 MPa
- Brinell Hardness: 130 HB
- Creep: 0.4 Tm = 217.2°C
  - Subject to low stresses
  - 6-week long mission
- Thermal Operating Range: -200°C to 100°C
  - Gains strength at cryogenic temperatures
  - Aluminum – FCC Material – DBTT not an issue

Material Selection

Keronite Coating (Plasma Electrolytic Oxidation)

Cold Welding Prevention

The ceramic oxide layer has a low adhesion surface that resists metal-to-metal bonding typically responsible for cold welding.

Coefficient of Friction 0.5-0.6

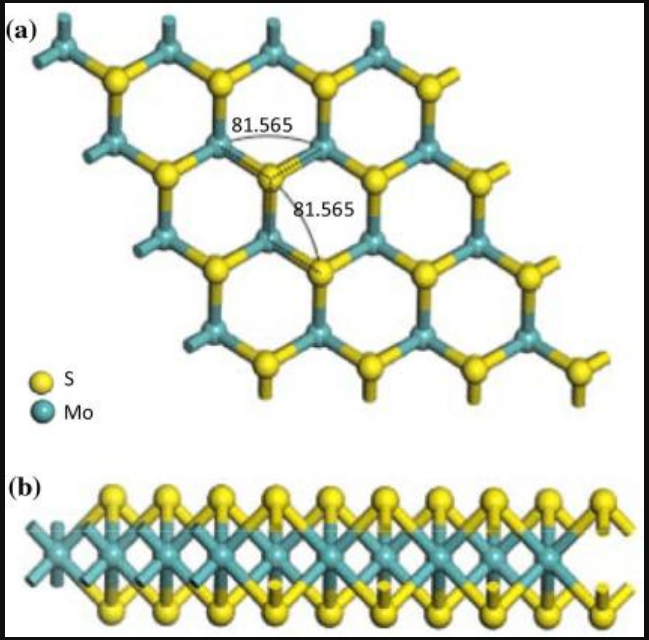
Provides self locking capability for the lead screw, enabling the system to stay raised without power input.

Hardness: 3-4 times more hard than hard anodizing

Dense and crystalline structure resists abrasion, fretting, and provides wear resistance.

Material Selection

MoS_2 Dry Lubricant



Low Coefficient of Friction

Dynamic CoF is typically between 0.03 and 0.06.
Provides excellent lubrication without outgassing.

High Load Capacity

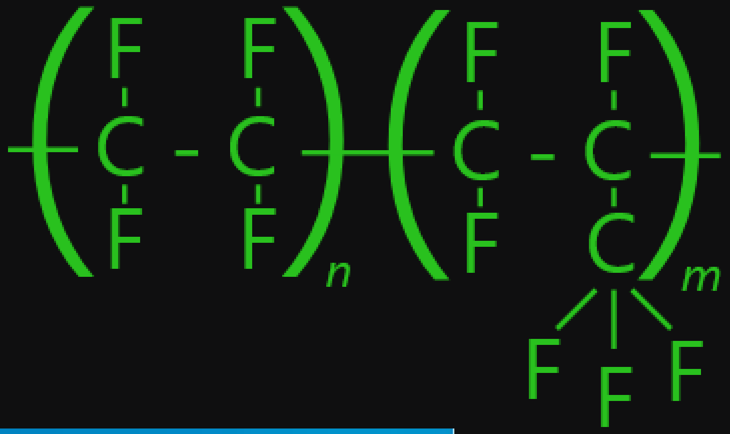
Has a load capacity around 1700 MPa.
Can handle high loads without wearing down.

Wide Operating Temperature Range

In vacuum environment, can operate between -200°C and +350°C, which fulfills the temperature requirement for a lunar environment.

Material Selection

FEP (Fluorinated Ethylene Propylene) Fluoro-Polymer for Dust Cover



Extreme Operation Temperatures

Working temperature is between -240 to 205 C,
so able to withstand required -200 to +100 C.

Good Mechanical Properties

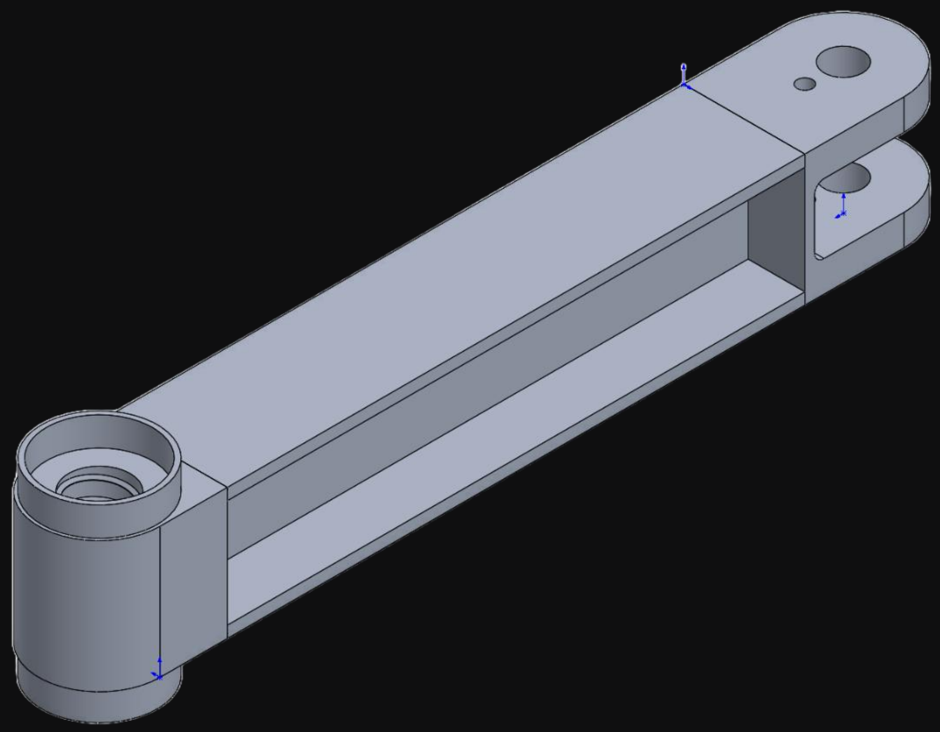
Elastic Modulus and Yield Stress are similar to LDPE, good candidate for folding accordion style dust cover which can transmit torque.

Minimal Outgassing and Radiation Resistant

FEP meets outgassing requirements, and its transparency to UV radiation stops it from degrading in harsh radiation environments (i.e. the Moon).

I-Beam Cross Section Analysis

Beam Type	Key Advantage	Selected
I-Beam	Excellent vertical bending strength, weight efficient	✓
Box Beam	High torsional rigidity	—
Circular Tube	Uniform stress distribution	—
Truss Beam	High stiffness-to-weight	—



I-Beam selected for superior performance in uniaxial bending loads with minimal mass—ideal for the outrigger's primary loading condition.

Experiences Bending Moment due to weight of system
Worst Case: System Mass being supported on one leg
(Peak Bending Stress: **3.64 MPa**, SF = **108.5**)

UBC Engineering

Hinge Lock Assembly

Pin-locking rotational mechanism with 20 mm diameter central shaft secured by M18 × 1.5 nut. Locking holes spaced at 37° increments enable 142° total swing, achieving required 32° deployment angle.

Robust Design

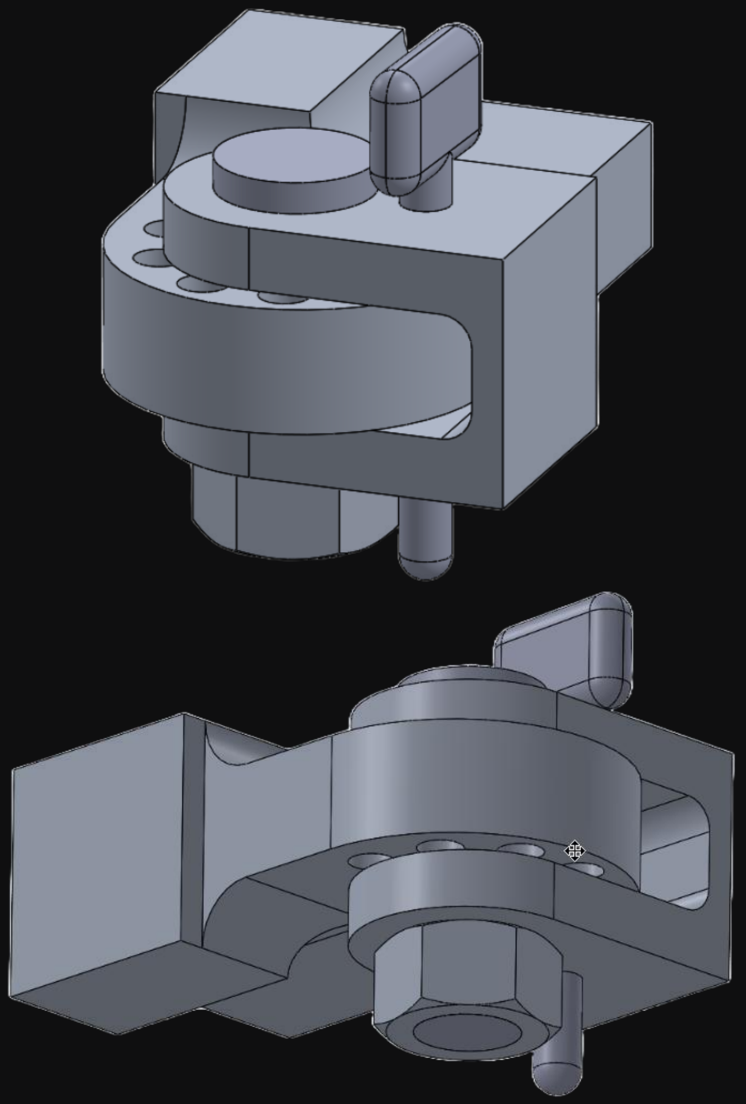
Single-axis rotation with direct load path through solid shaft.

Dust Tolerance

Sufficient clearance at non-loadbearing interfaces prevents regolith jamming.

Discrete Locking

Repeatable positions that don't degrade under wear; pin carries no axial load.



Experiences Bending Moment due to weight of system

Worst Case: System Mass being supported on one leg

(Peak Bending Stress: **3.64 MPa**, SF = **2.73**)

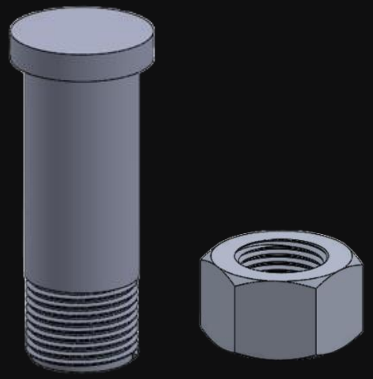
Hinge Pin and Bolt

Main Shaft Design – 20 mm Diameter

- Worst-case torsional load at joint: **190N**
- Resulting shear stress: **48MPa**
- Safety Factor (shear) = **4.1**

- Bearing Stress: **0.6 MPa**
- Safety Factor (bearing): **> 1000**
- S

Load transfer through the hinge is structurally secure, and the shaft is not a critical or high risk component.

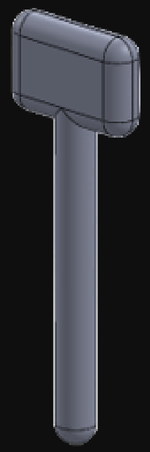


Locking Pin Design – 8 mm Diameter

- Worst-case torsional load: **3.8 kN** shear
- Resulting shear stress: **75** MPa
- Safety Factor (shear) = **3.3**

- Bearing stress : **13 MPa**
- Safety Factor (bearing) = **30**

Pin has significant margin, even though it normally carries zero structural load.



Lead Screw Specifications

TR32x10 Trapezoidal Screw

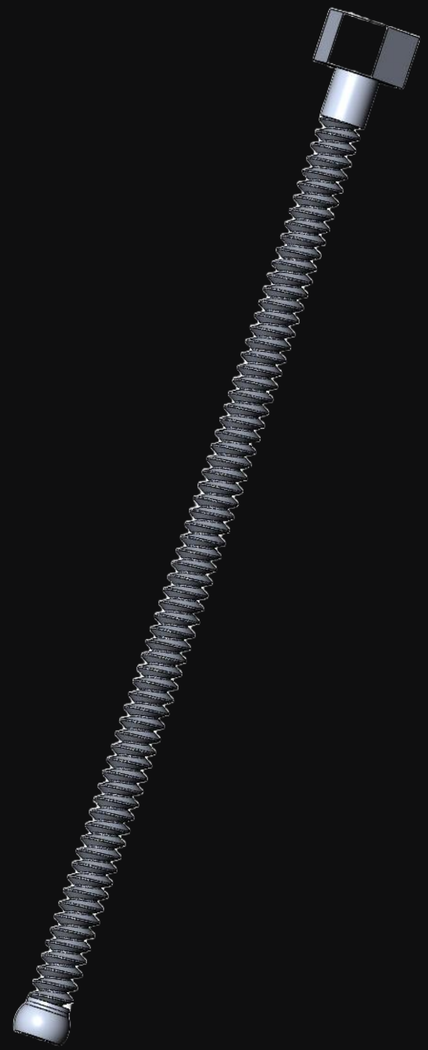
- 32 mm diameter, 10 mm pitch
- Keronite coating friction ensure self-locking
- 32 mm nut prevents thread binding

Loads experienced:

- Force (w/ SF) - 163.5N
- Von Mises Stress – 2.4 MPa (SF = 164.6)
- Critical Buckling Load – 22 kN (SF = 134.4)
- Bending Stress – 281 Mpa (SF = 1.4) **Limiting Factor

Assumptions:

- Worst case CG – 20% off center
- Worst case rod length - 700mm
- Bending treats screw as solid rod with root diameter



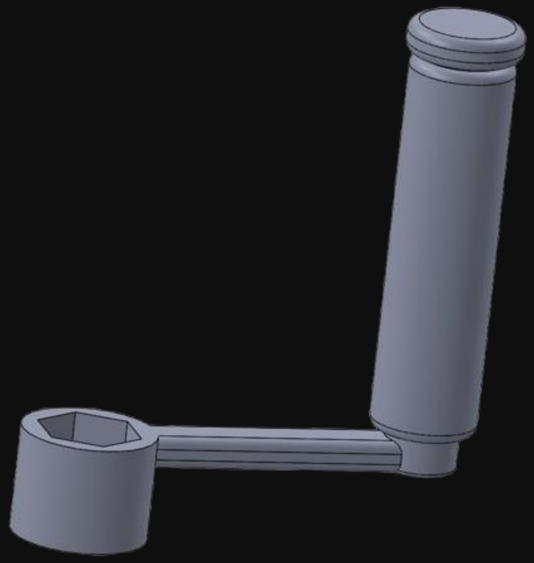
Power Requirements

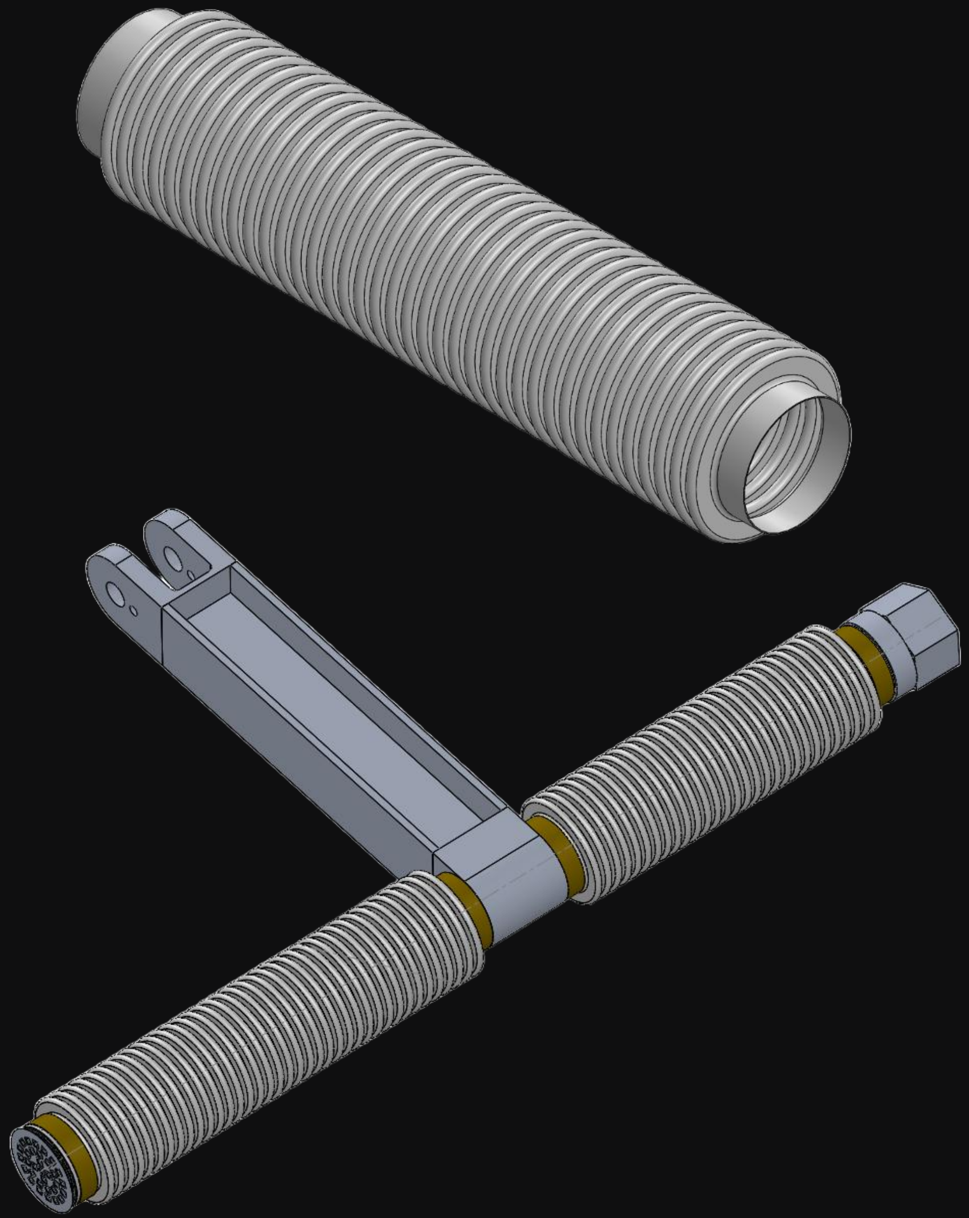
Key Considerations:

- Torque required: 1.5 Nm (raise), 0.8 Nm (lower).
- NASA Pistol Grip Tool can be used for automated deployment
- Max power: 17 Watt
- Leg deployment at 18.2 mm/s
- 4 legs deployed in 66s

> Alternative: Manual crank tool can be used.

- Oversized handle for space suit use.





Bearing & Dust Protection

Regolith Protection

Prevents abrasive particles from contaminating threads

Decoupling Function

Allows screw rotation while holding cover stationary

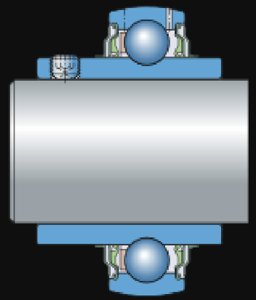
Customized Insert Bearing

Press-fitted between lead screw and dust cover

Radiation & Wide Temperature Tolerance

Allows screw rotation while holding cover stationary

UBC Engineering



Bearing Selection: Custom 206-Series Insert

(Baseline Geometry: SKF YAR 206-104-2F)

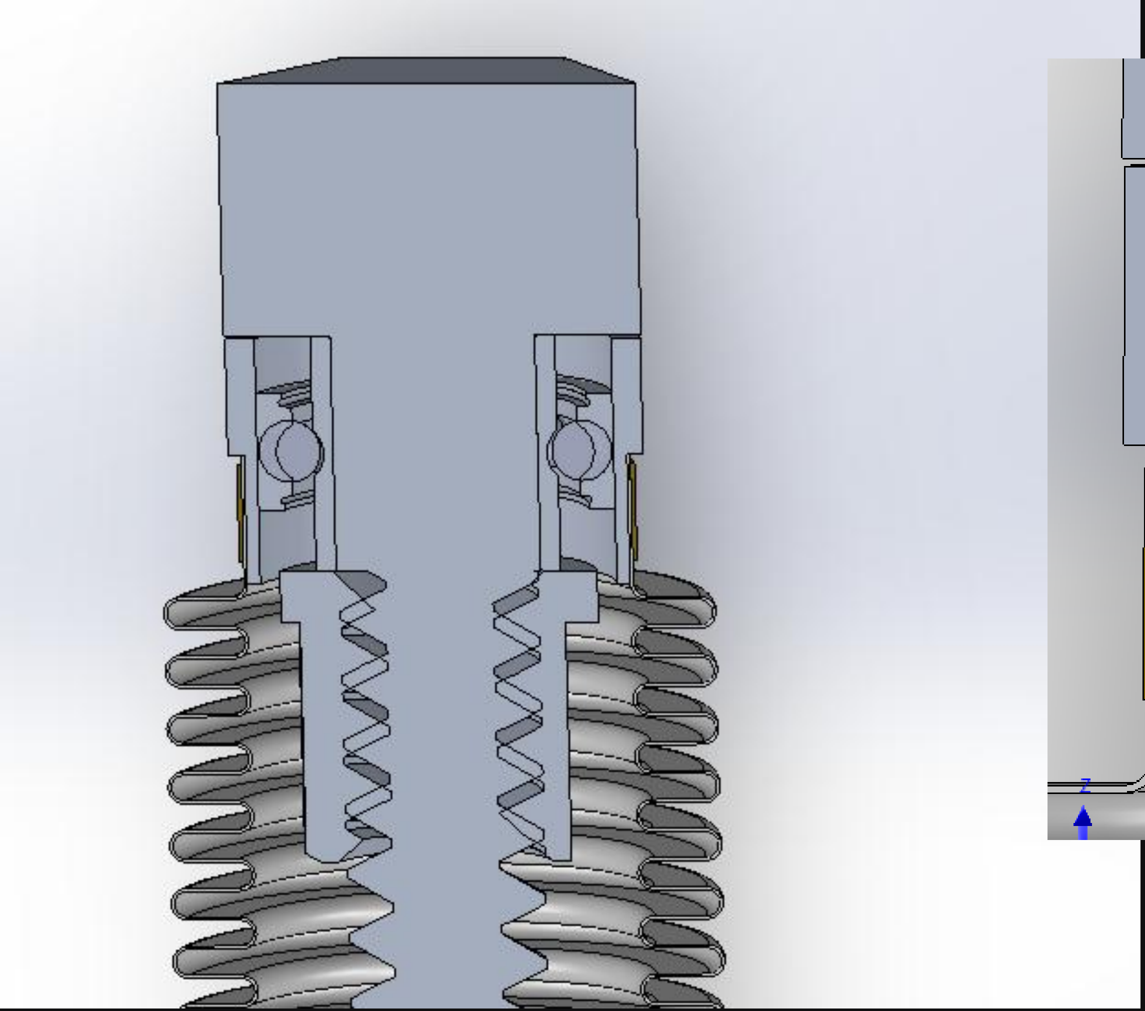
- Why Extended Inner Ring?
  - Provides mounting clearance for the lead screw interface.

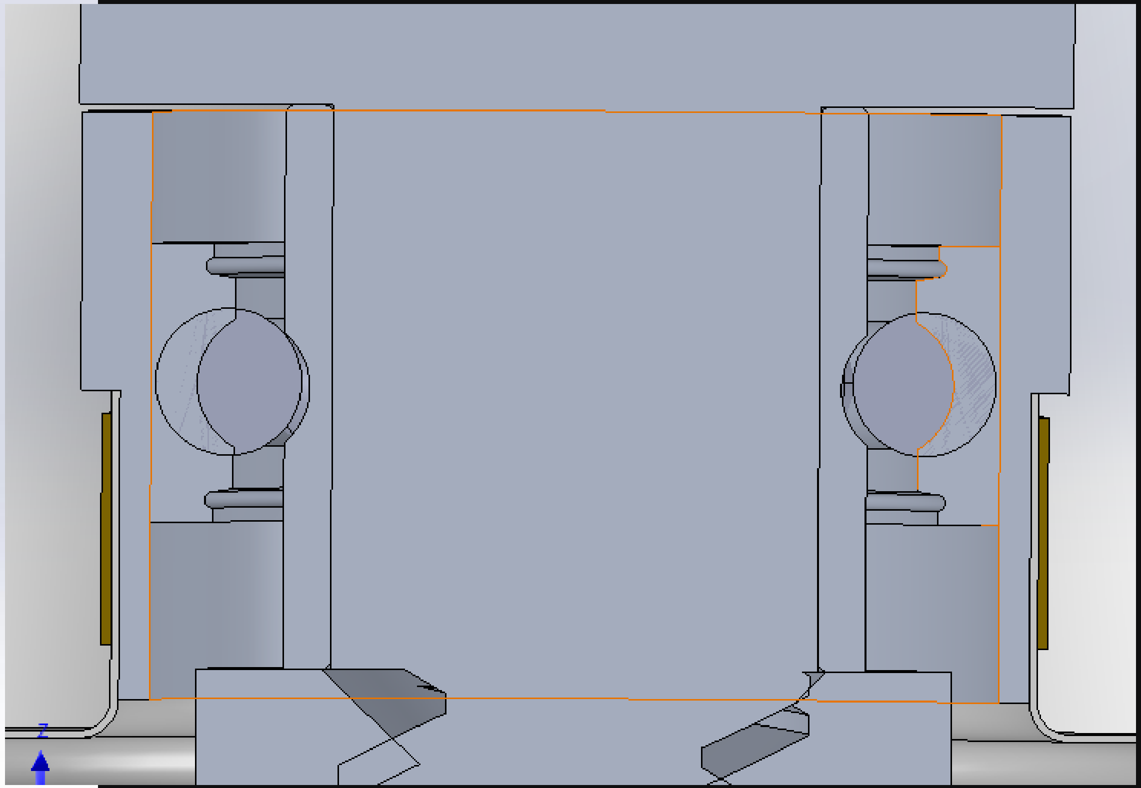
- Load Case (Low Stress Application):
  - Axial: < 50 N
  - Radial: Negligible

- Speed: 60 RPM (Max Operating) vs. 6,300 RPM (Rated Limit)

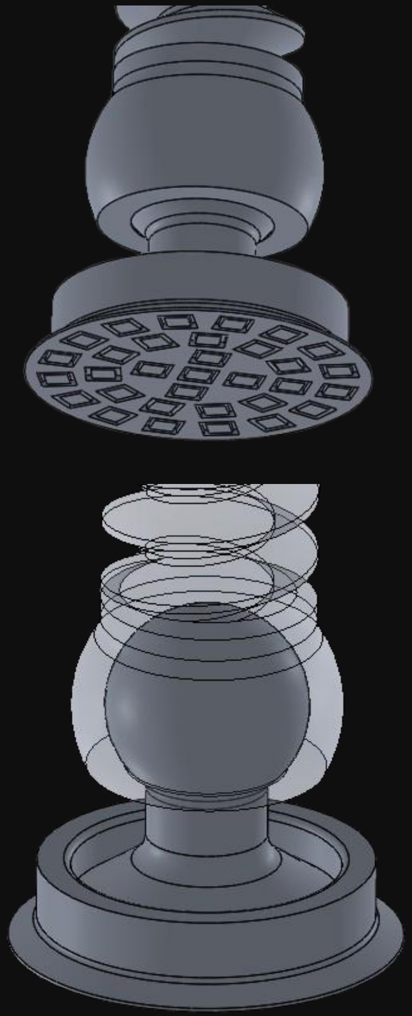
- Environmental Modifications:
  - Material: Al 2219-T87
  - Lubrication: MoS2 Dry Film
  - Cold Welding Treatment: Keronite Coating
  - Seals: Teflon FEP

- Static SF = 224
- Lifetime L_{10h} = $1.65 * 10^{10}$ hours (Infinite)
- Operating Speed @ 1% of Rated Speed





Ground Interface Design



Ball-and-Socket Joint

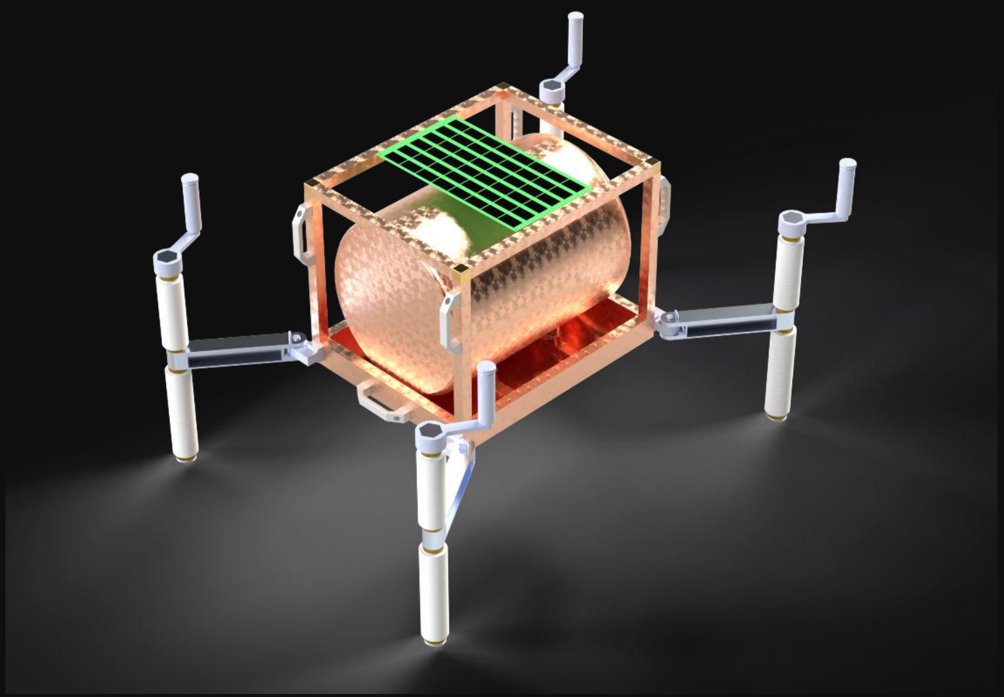
Inherently very robust: for Aluminum 2219-T87 joint with 30 mm ball, 23.5 socket opening diameter:

- Actual Load (Worst Case): 68 N
- Compressive failure load: 89 kN (SF = 1310)
- Tensile failure load: 48 kN (SF = 705)

Allows 15.2° of articulation at each footpad, meeting the ±15° slope requirement.

Isolates lead screw from bending moments that could cause failure or nut interference.

Macro-texturing on footpad bottom provides traction to keep lander static



Final Design Features

No In-Situ Assembly

System deploys fully pre-assembled, meeting RQMT-0017 requirement.

Independent Leg Control

Each outrigger adjusts separately for precise leveling on irregular terrain.

Self-Locking Mechanism

10 mm pitch prevents unintended descent; maintains position without power.

Thermal Management

Material selection and geometry minimize thermal stress without active systems.

UBC Engineering

Structural Safety Factors

1.4

Minimum Required

CSA specification for all structural components

1.4

Lead Screw

Von Misses Stress

108

I-Beam Assembly

Peak Bending Stress

2.7

Hinge Assembly

Peak Bending Stress

705

Ball and Socket Joint

Tensile Loading

224

Bearings

Static Loading

Deployment Sequence

1. Stowed Configuration

System compact within 1105 × 715 mm envelope for transport.

2. Outrigger Deployment

Swing beams outward to 32° angle; secure with locking pins.

3. Height Adjustment

Rotate lead screws sequentially to level platform within ±1°.

4. Final Verification

Confirm 1 meter ground clearance and stable footprint achieved.

Further Actions

Prototyping

Fabricate functional prototype of the assembly. Conduct physical testing to validate the manual adjustment workflow, verify torque requirements, and ensure mechanism does not bind under loads.

Soil Bearing Capacity

Replace rigid ground assumption with lunar regolith soil models. Perform soil bearing analysis to verify footpad surface area prevents sinking or slippage under full load.

Dust Cover Mechanics

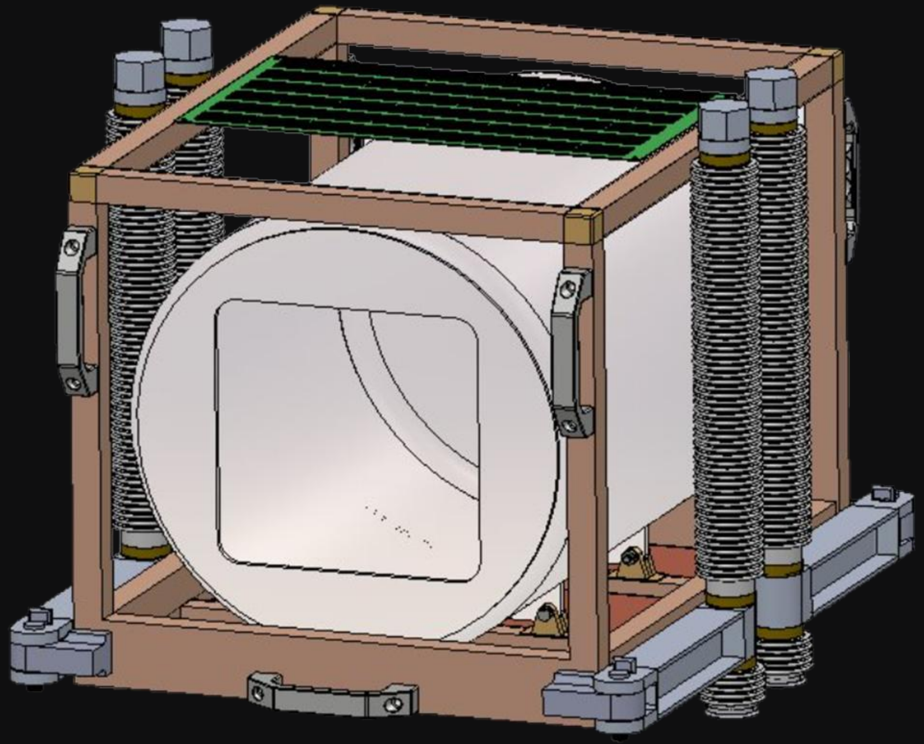
Exact mechanical properties of the dust cover are uncertain. Further analysis required to determine spring constant and torque transmission of bellows.

Sequential Adjustment

Astronaut must rotate around system multiple times to incrementally raise chassis. Next design iteration should implement a way to extend all four legs simultaneously.

UBC Engineering

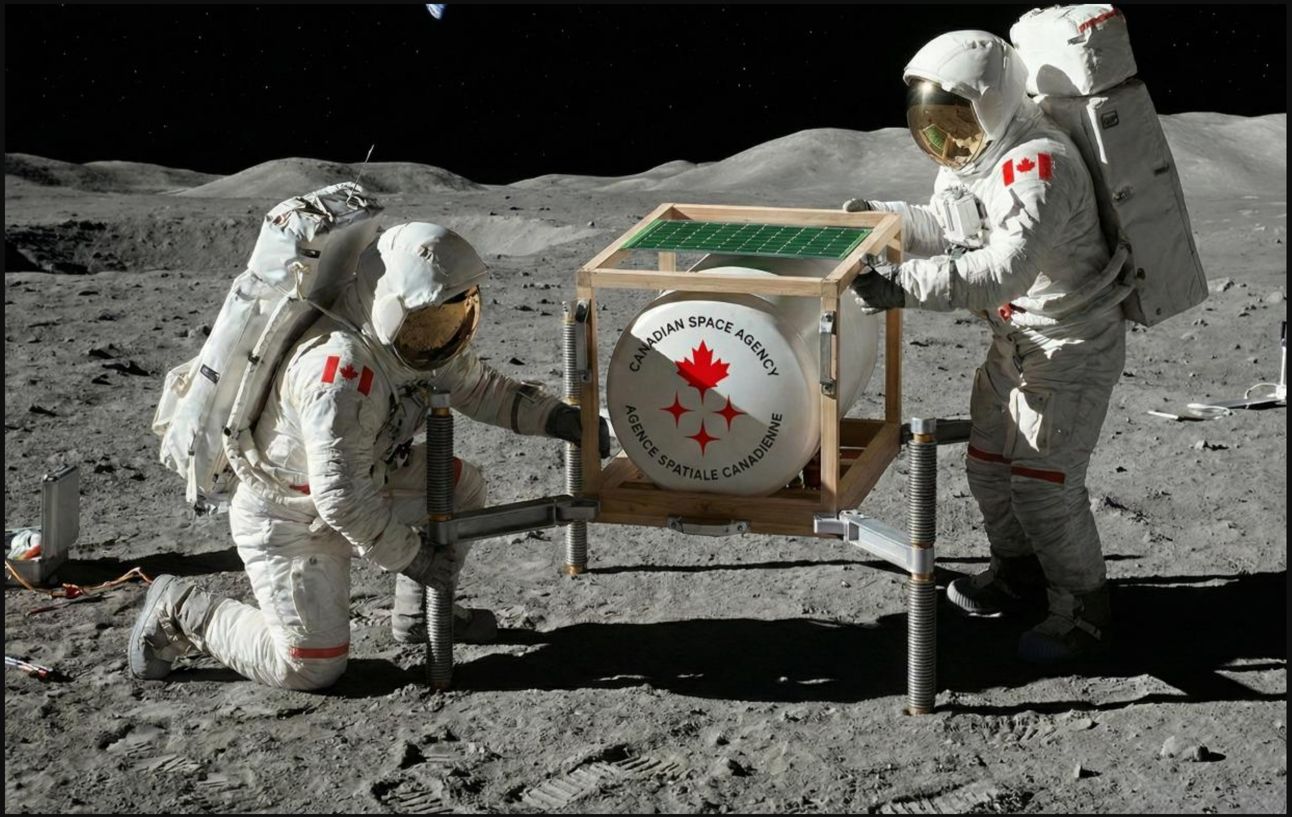
Mission Success



Requirements Met

- Levels platform on ±15° slopes with ±1° accuracy
- Supports 130 kg load with safety factors > 1.4
- Operates in vacuum, extreme temperatures, and abrasive dust
- Compact storage and manual actuation capability

The OASYS Leveling Mechanism provides a robust, lightweight foundation for lunar agriculture research, advancing the CSA's mission to enable sustainable space exploration.



Thank You

Q & A

UBC Engineering

Sources

- https://www.keronite.com/surface-technology/
- https://ws2coating.com/other-lubes-and-coatings/mos2-dry-film-lubricant/
- https://ntrs.nasa.gov/api/citations/19960025621/downloads/19960025621.pdf
- https://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA2219T87