

# AEROSPACE SENIOR DESIGN: ADVANCING AEROSPACE TECHNOLOGY

## Conceptual Design of In-Space Orbital Reliable Printed Circuit Boards (ORCA)

Professor: Dr. Vijay K. Goyal  
Mentor: Matt Anderson

### Deep Interstellar Solutions

Max Starnes, Team Leader  
Keegan Jordan, Team Co-Leader  
Ian Griffith, Team Co-Leader  
Grant Pesqueira  
Vishal Patel



Mechanical Engineering  
Minor in Aerospace Engineering



KENNESAW STATE  
UNIVERSITY



# DEEP INTERSELLAR SOLUTIONS TEAM



**KENNESAW STATE**  
UNIVERSITY



**Max Starnes**  
**BS Mech Eng**  
Leader  
Project Manager

**Keegan Jordan**  
**BS Mech Eng**  
Co-Leader  
Simulation Expert



**Ian Griffith**  
**BS Mech Eng**  
FEA Expert

**Grant Pesqueira**  
**BS Mech Eng**  
Engineering Expert



**Vishal Patel**  
**BS Mech Eng**  
Report and  
Presentation Expert

**Minor in Aerospace Engineering**

**Develop a Conceptual Design of In-Space Orbital Reliable Printed Circuit Boards to manufacture custom PCBs using laser etching technology.**

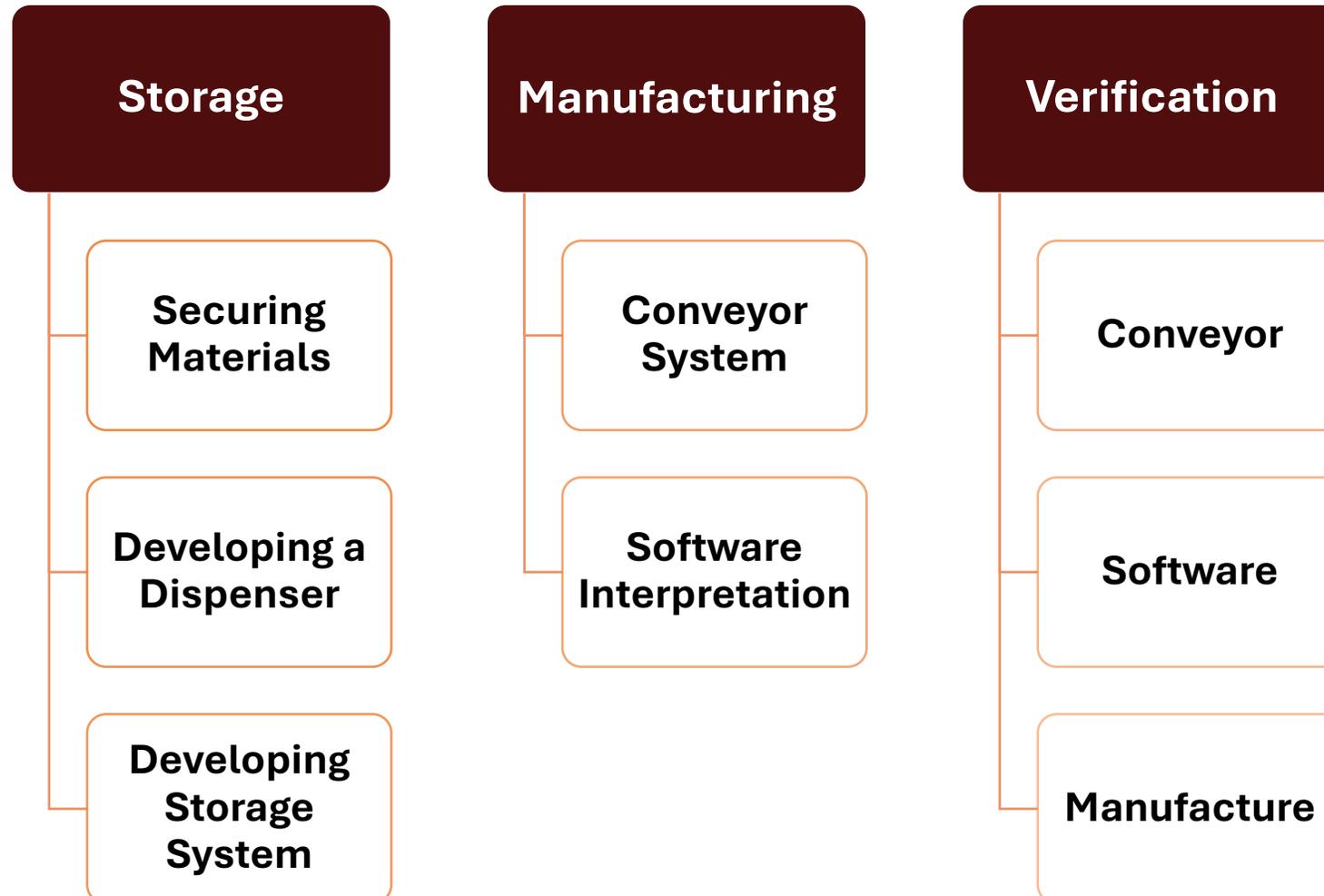
# COSMIC CHALLENGE



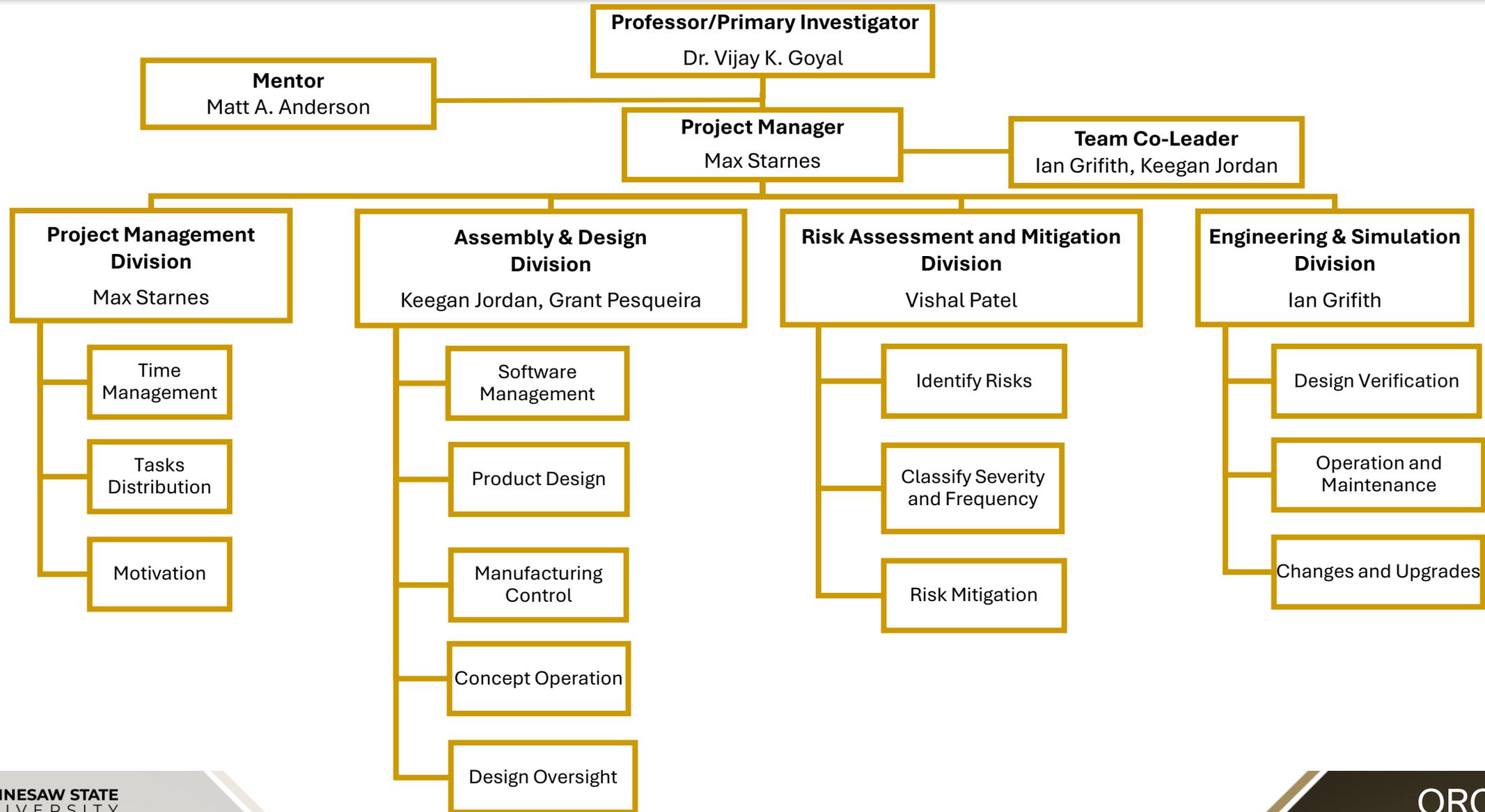
Track 1 Challenge:  
**Orbital Manufacturing and Assembly**  
(C3-Manufacturing)

# PROBLEM DESCRIPTION

Developing and demonstrating a process to manufacture PCBs in space is an important, currently absent step toward long-term human exploration of space.



# MANAGEMENT PLAN



# DESIGN CRITERIA



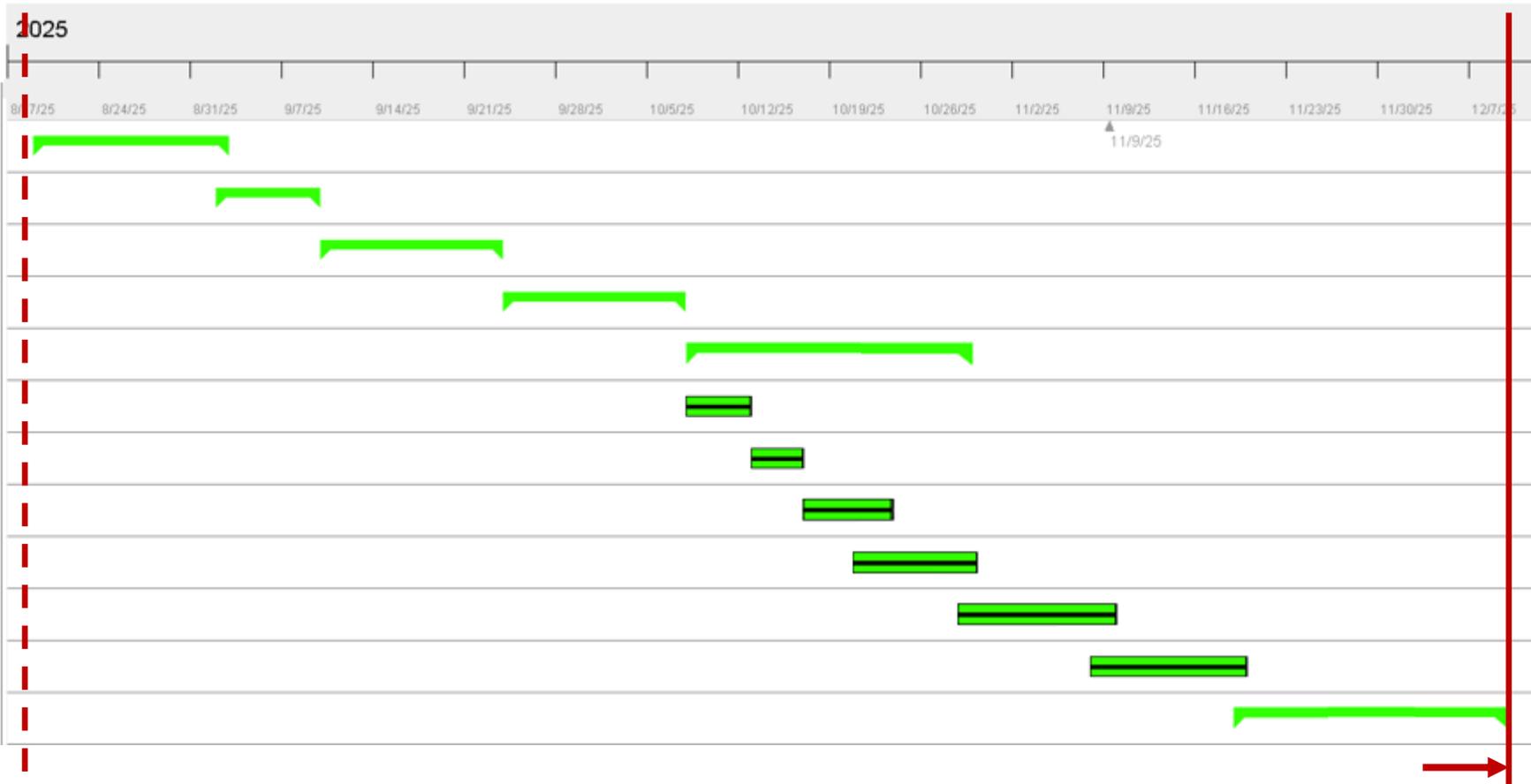
Design Criteria	Parameters
<b>Simplicity</b>	N/A
<b>Autonomy</b>	No. of Inputs: 2
<b>Size, Weight, and Power (SWaP)</b>	Max Mass: 400 kg Max Power: 300 W Max Vol: 144,145 cm <sup>3</sup>
<b>Price</b>	~20,000 USD
<b>Manufacturability</b>	N/A
<b>Durability</b>	Strength: 10 MPa Strain: 5 $\mu\text{m}/\text{mm}$
<b>Adaptability</b>	60% COTS No. of DOF: 3



# GANTT CHART

Aug 19

Dec 9



Name	Resources	Begin date	End date
> Mission Conce...		8/19/25	9/2/25
> System Requir...		9/2/25	9/9/25
> Conceptual De...		9/10/25	9/23/25
> In progress Re...		9/24/25	10/7/25
▼ In Progress Re...		10/8/25	10/29/25
Initial CAD D...	Keegan	10/8/25	10/12/25
Technology ...	Max,Grant	10/13/25	10/16/25
Trade Space...	All	10/17/25	10/22/25
Risk Assess...	Ian,Vishal	10/21/25	10/29/25
Preliminary De...	All	10/29/25	11/9/25
CAD Simulation	Keegan,Ian	11/8/25	11/19/25
> Deliverables		11/19/25	12/9/25

# F FORGE

Facility for On-Surface Refining, Gathering, and Extraction

## C3 Flash Talk

December 8th, 2025

# C3 Problem Statement

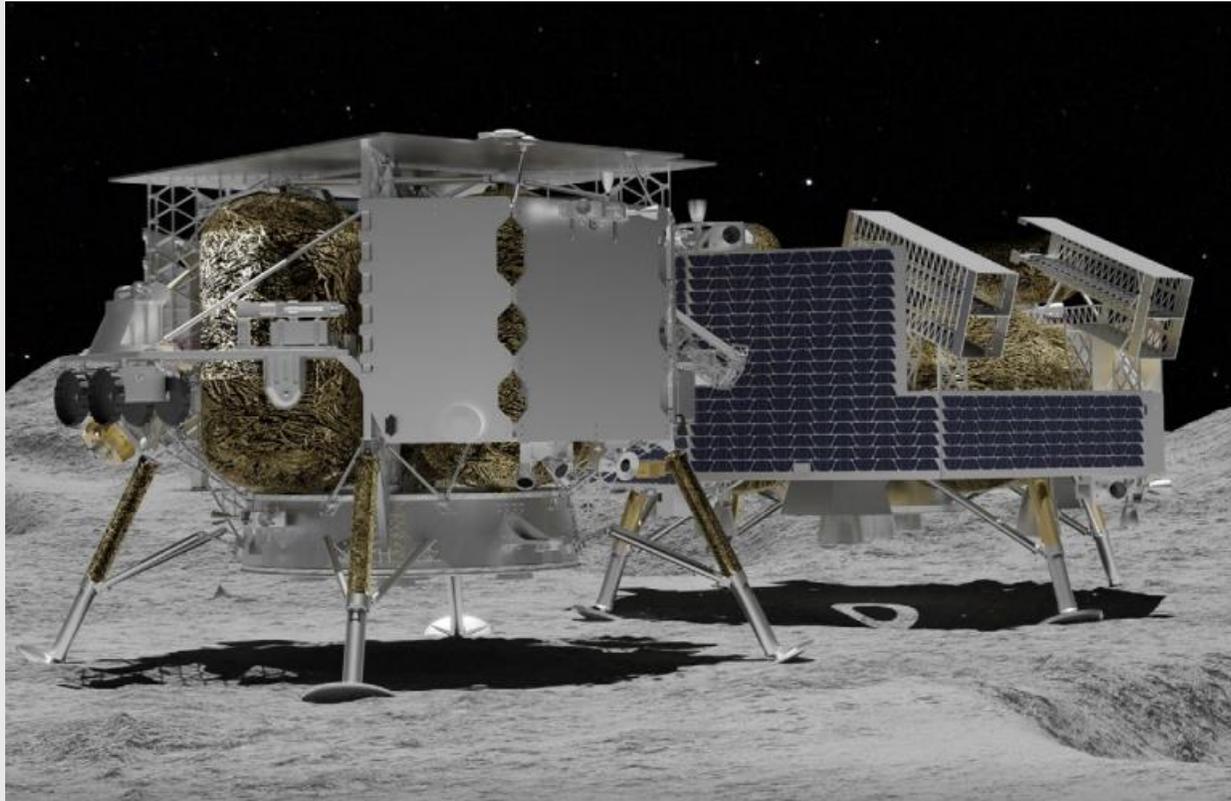


Image retrieved from: ASTROBOTIC LUNAR LANDERS:  
Payload User's Guide

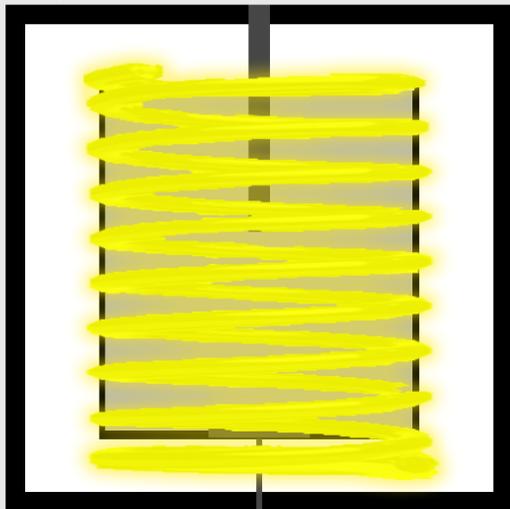
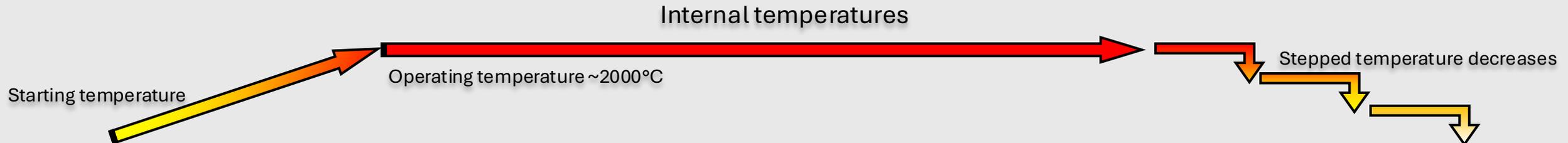
Design a payload, to be delivered by the Griffin lunar lander, that can create infrastructure for a permanent lunar outpost.

Focus on autonomous construction.

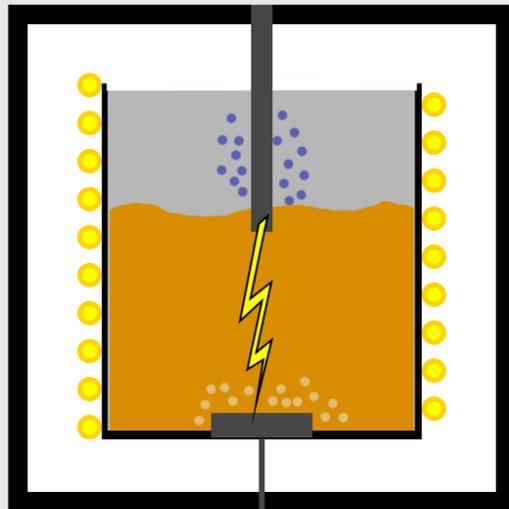
# FORGE Statement of Intent

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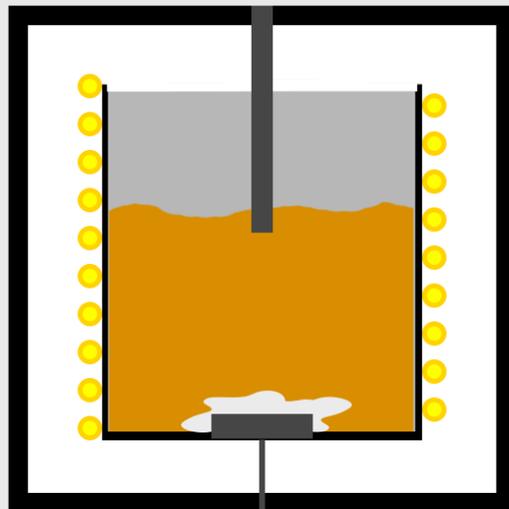
FORGE will melt lunar regolith to allow ease of access to raw materials on the lunar surface.



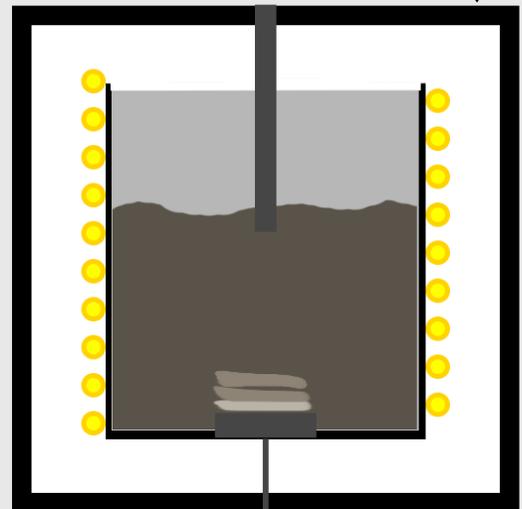
I. Induction coils fully melt the regolith sample in the crucible.



II. A current is passed between two electrodes. Oxygen atoms split from desired materials and gather on electrodes.

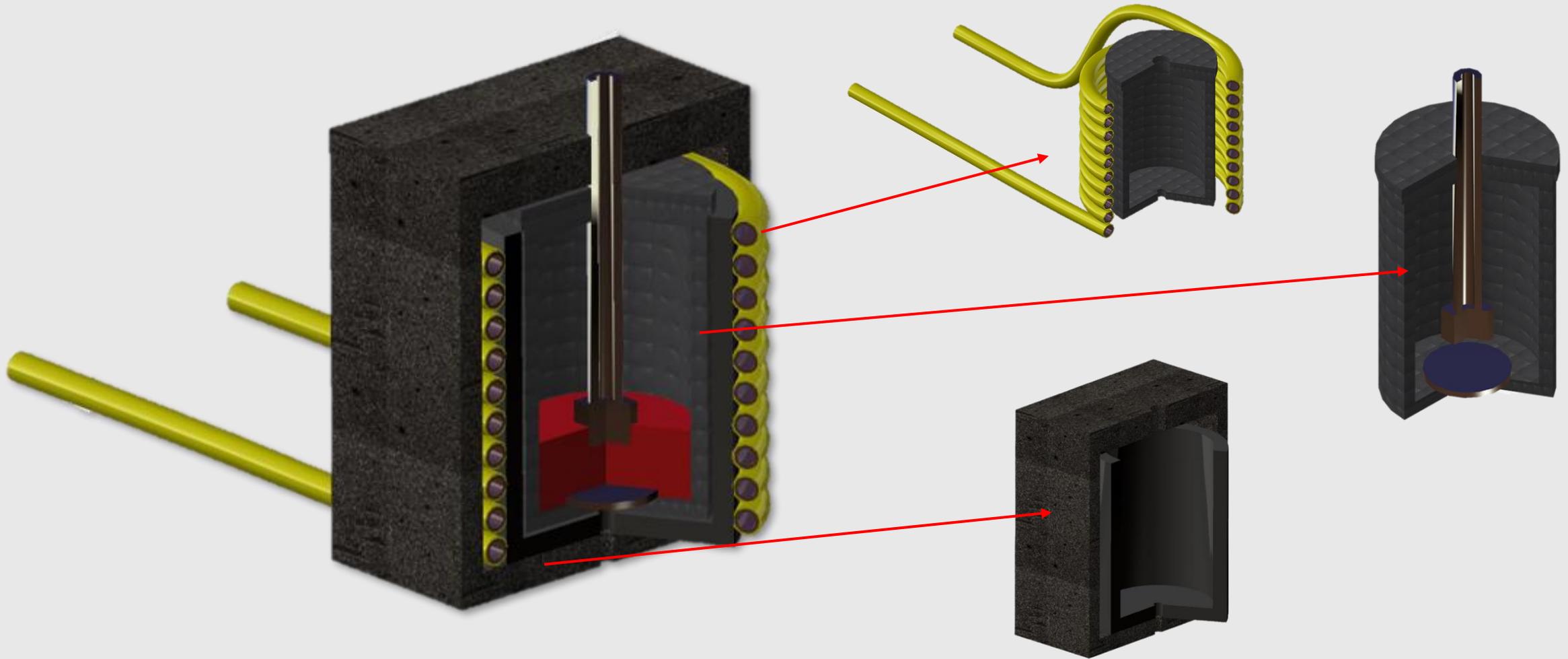


III. An alloy of molten metals gathers on the cathode as the electrolysis completes.



IV. Stepped temperature decreases crystallize and separate the metals within the cooled regolith.

# Design Overview



# Theoretical Mission Process

Launch → Arrival → Refine → Mission Proceeds

FORGE is on board the launch vehicle

Initial mission established with critical structures

Place FORGE in desired location, and refine the needed materials

Materials produced by FORGE are used to construct lunar settlement

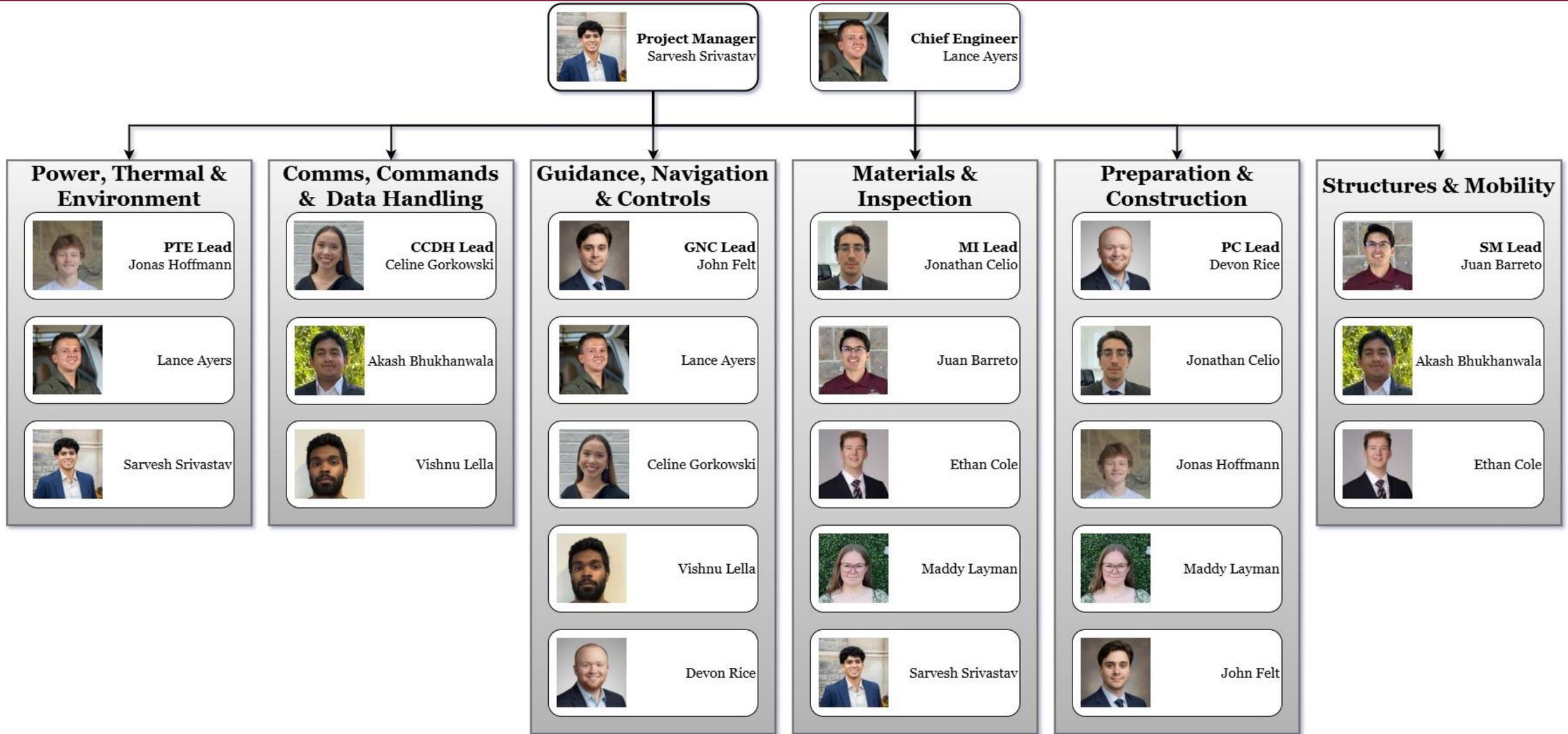


# C3 Lunar Track 2 Flash Talk

Team C3PO



# Organization Chart



**C3PO will develop an autonomous lunar system to produce, integrate, and inspect sintered lunar regolith for tile manufacturing.**



**1 Phase 1 - Launch**  
The Payload is launched from Earth and delivered to the Moon by a Falcon 9 Heavy

**2 Phase 2 - Landing**  
The Griffin Lunar Lander lands on the Lunar surface

**3**

**Phase 4 - Surface Preparation**  
All obstructions are removed from the Site, the surface is graded, compacted, and inspected for strength

**4**

**6**

**Phase 6 - ISRU Unit Placement**  
Finished ISRU Units are collected from ISRU Production and placed onto the Site. Placement is inspected and the Site is ready.

**5**

**Phase 5 - ISRU Production**  
Regolith is collected, sifted, and delivered to ISRU Processing. Regolith is then sintered into ISRU Units and inspected for strength.

**Phase 3 - Deployment**  
The Payload is deployed from the lander, ISRU Processing is setup, and the Site is mapped

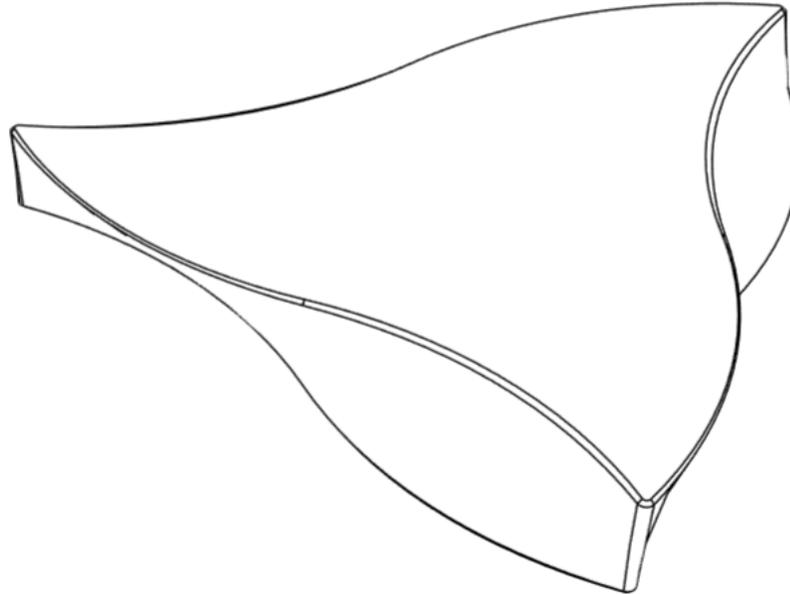
# Executive Summary

## Problem Statement

- Lunar launch/landing pads are the first point of interaction for any future lunar mission
- Dust plumes significantly increase abrasion and the potential for mechanical failures from dust jamming
- Landing pads can decrease dust plumes by compacting the surface therefore preventing a major concern for lunar systems at the source

## Solution

- Sintered tessellating tiles with high compressive strength properties.

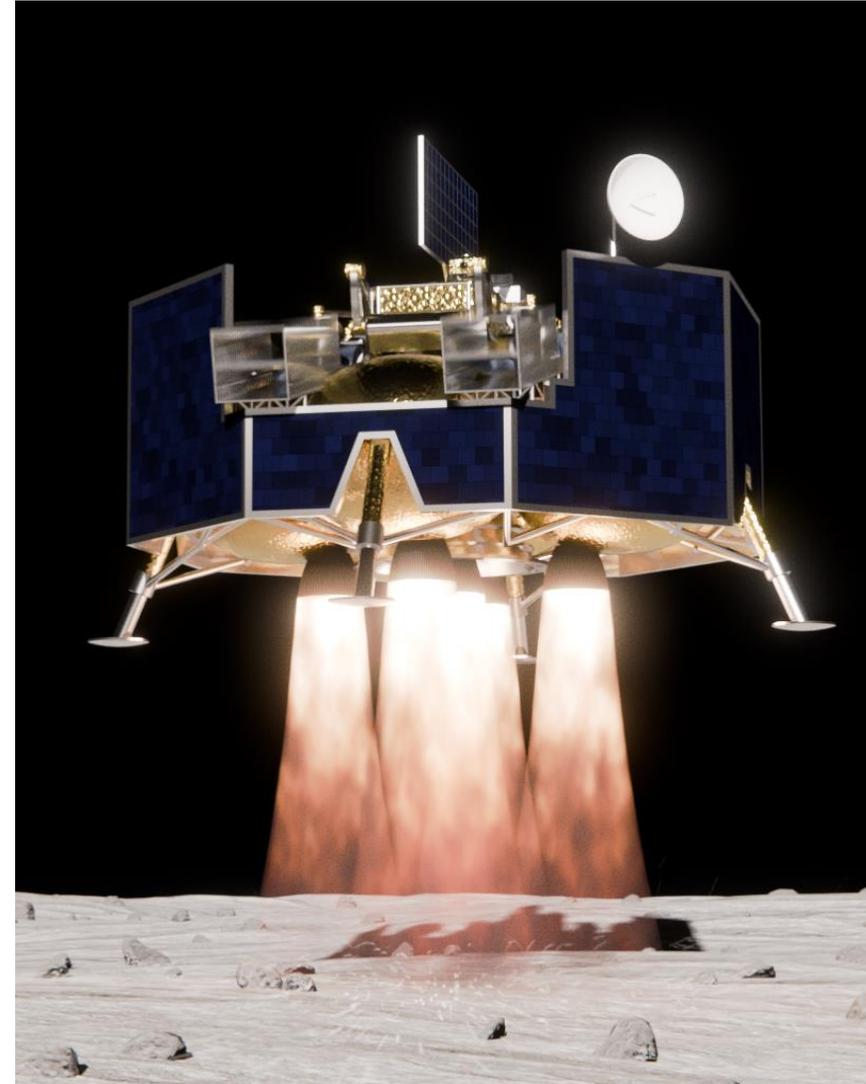


## Why Sintered Tiles?

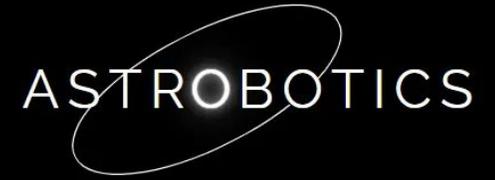
- Triangular shape is proven to be structurally advantageous compared to alternative shapes
- Tessellation allows for modularity, easy repairs, greater longevity
- Sintering is a reliable method that requires no additional resources from Earth while requiring easily attainable energy from existing lunar technologies

# Projected Path

- **Lunar regolith simulant sintering and stress testing**
  - **Will obtain lunar regolith simulant and sinter in a kiln to simulate the product we are planning on creating on the lunar surface**
  - **Test the resulting tile for defects and under a 3-point bend test and compression test for strength validation**
- **Finalize rover model, oven model, and components for all six subsystems**
- **Refining our CONOPS to include specifics about landing cite and our mission**



# Meta: Template Guidelines



- You can use any template you want— you can choose to use the COSMIC template, or you can use your own template
- Whichever template you use, include the key elements described here
- If you use this template, you may want to replace COSMIC logos with your own
  - For main body slides like this, replace the upper right COSMIC logo via “View: Slide Master” & go to slide marked 1
  - To edit the title slide, use “View: Slide Master” & go to slide marked 2
- Every slide should include the Short Name of your project to keep the audience oriented and in case of later arrivals

# Meta: Briefing Guidelines

- The primary goal is to help C3 organizers understand what you're doing and why you're doing it
  - What is the problem you're trying to solve?
- As you put together your charts, recall you have 5 minutes to brief
  - Recommend creating a “time budget” to allocate to various elements
  - Make decisions on what to include— while we have guidance, it is not cookie cutter
  - You're not limited to 3 charts, as images are often better if bigger, but don't get into too much detail
- Remember this is the first time the audience is seeing these, images are very helpful
- Focus on quality of presentation rather than how dense a slide can be packed
  - Many details should be reserved for the final presentation and/or paper/

# ASTROBOTICS

COSMIC Capstone Challenge:  
Mid Design Brief

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## **Astrobotics, Purdue University: VLA Robotic Arm Framework**

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Students: Elaine Lee, Ritwik Jayaraman, Ankur  
Senapati, Ekansh Agarwal, Ojas Chaturvedi  
Advisor: Elizabeth Kung  
Mentor: Harsha Malshe

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December 8, 2025



# Team Overview



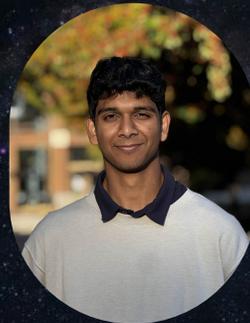
Ritwik Jayaraman



Elaine Lee



Ojas Chaturvedi



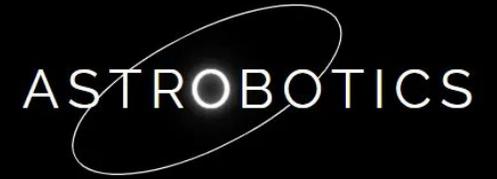
Ankur Senapati



Ekansh Agrawal

# Team Overview

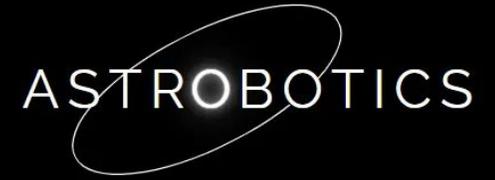
## *VLA Robotic Arm Framework*



- Purdue University, Astrobotics
- Team of students majoring in ECE, CS, Aerospace Engineering
- Developing a fully autonomous software platform that enables robotic systems to identify, align, join and verify structural components at orbital worksites, using low-power self-piercing riveting.



# Executive Summary



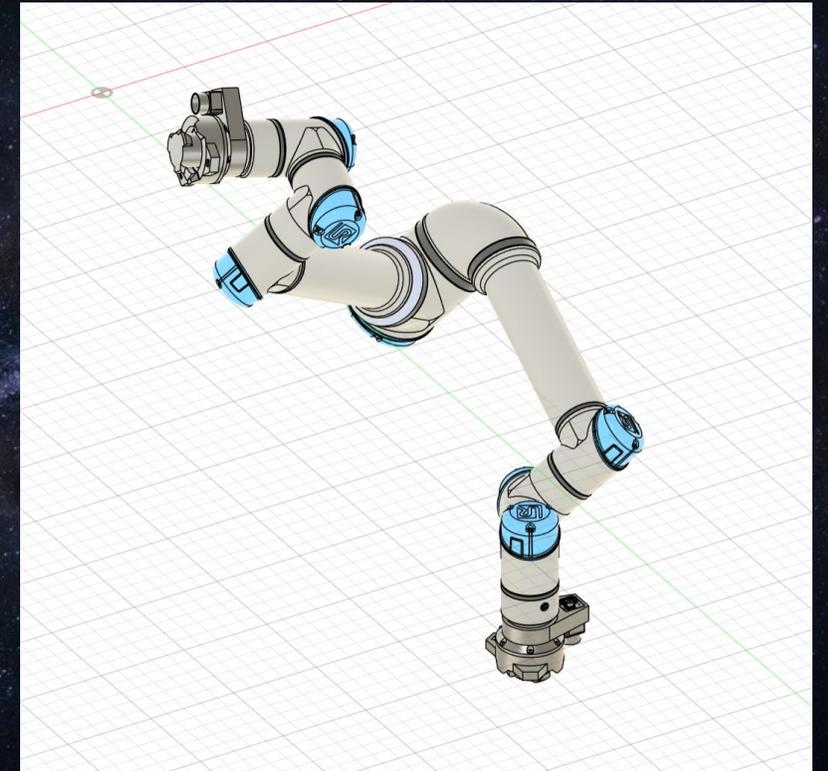
## *VLA Robotic Arm Framework*

### Problem Identified:

- Current ISAM systems require continuous astronaut intervention, causing major operational delays

### Proposed Solution:

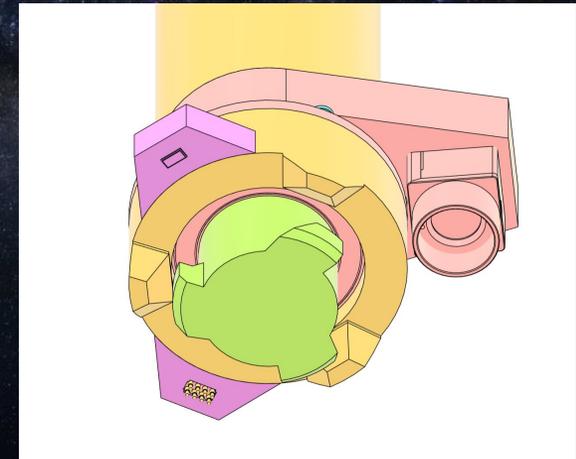
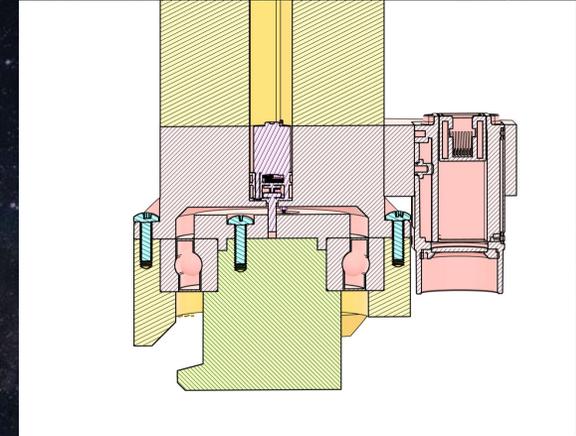
- Platform-agnostic software framework is needed for robotic manipulators to perform multi-stage tasks with minimal human supervision
- Fully autonomous software platform enabling robotic systems to identify, align, join, and verify structural components in orbit using precision riveting
- The solution combines Vision Language Action (VLA) Models, AI perception, motion planning, and process control for verifiable, high-precision assembly.
- The models are geared towards operating an autonomous inchworm robotic arm. The 3D assembly used consists of a 7-DOF inchworm arm with two identical end effectors equipped with a light, camera, and pogo pins for varied tool connection and implementation.



# Projected Path

## Future Direction:

- Implement VLA software for control robotic arm control
- Simulate robotic arm locomotion for a series of tasks
- Design and model tooling methods



# H2SPACE

Lunar Miner – C3 Track 2

Zachary Spencer, Lucas Wiedmann, Nathan Wei, Anthony Matteo, Joseph Long, Dorothy Vogel, Stephen Franke

# INTRODUCTION

- H2Space is taking a focus on the process of mining lunar regolith
- The team is working on adapting systems from mining operations on earth to work on the lunar surface
- With constrained weight and space on the griffin lander, it has become a primary focus to create systems that can reach needed performance without exceeding at extra costs

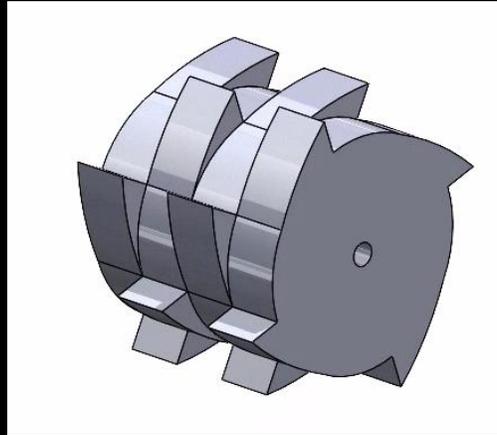


# CONTINUOUS MINERS

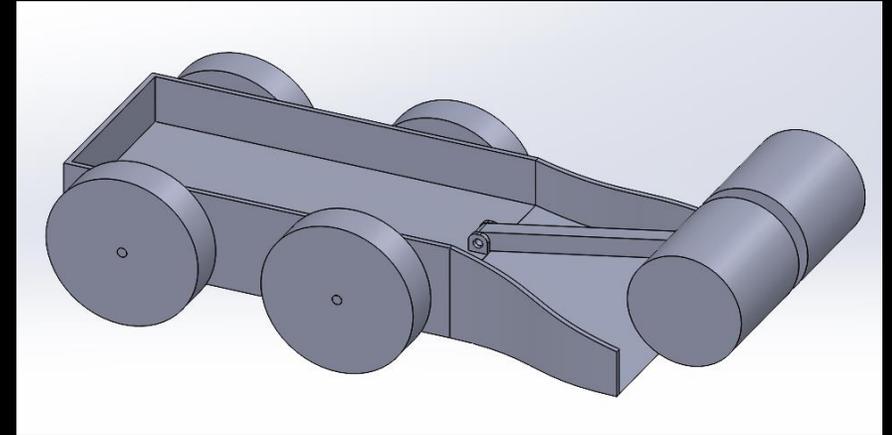
- We took inspiration from continuous mining machines on Earth



*Continuous Underground Miner [1]*



*Prototype Drilling Head*



*Prototype Rover Chassis*

# ADAPTING CONTINUOUS MINER FOR LUNAR ENVIRONMENT

- One of the main obstacles that we must work around while trying to design a continuous miner rover are the weight restraints set by the project requirements (max 200kg).
  - Continuous miners used in quarries are massive machines weighing upwards of 70 tons.
  - Luckily, the regolith we are moving is already in a powdered form and we do not need to move massive amounts of material, as is the case with industrial miners used in quarries.
- An additional obstacle while designing our rover is the corrosive environment created by the lunar dust.
  - Lunar regolith, unlike earth dust, is made of many jagged sharp particles due to the lack of an atmosphere. Additionally, these particles are electrostatically charged causing it to stick to many metallic surfaces.
  - To combat this wear resistant materials and ceramic coatings will need to be used for our rover parts



*Lunar Regolith Before/After Oxygen Extraction [2]*

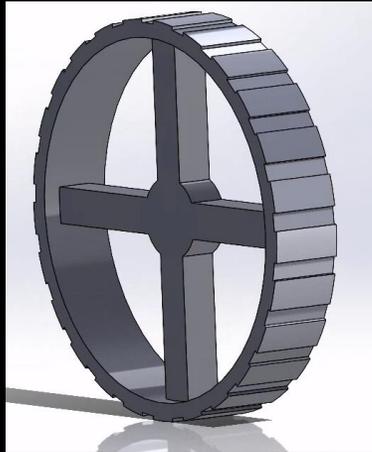
# ELECTRICAL HARDWARE

- C&DH Systems - Used as the main communication between the rover and the controllers on the ground
- GNSS – this includes the GPS that is included with the GNSS system, but provides data with high accuracy
- Telemetry Radio – collects and can receive data, can set waypoints for the rover while also collecting data, that includes temperature, altitude, etc.
- Distance sensors – protects the rover from damaging itself via obstacles or any debris
- Antennas – crucial for radio communication
- Ground station software – software that can be used on any device to track the rover from anywhere
- Arduino microcontroller



# SUPPORT SYSTEMS

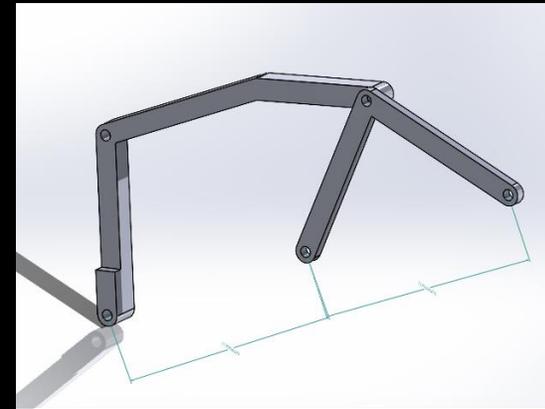
- Support systems on the rover are being created with previous space rovers and company prototypes in mind for design considerations



*First Wheel Prototype  
Modeled For Basic  
Testing*



*Bridgestone Lunar Wheel, Design  
Motivation For Future Wheel Designs  
[3]*



*Suspension System Modeled after  
Curiosity Rover*

# SOURCES

- [1] *A continuous miner above ground parked*. 9 Sept. 2021. *An Underground Miner*, <https://anundergroundminer.com/blog/how-continuous-miner-works>. Accessed 4 Dec. 2025.
- [2] *Oxygen and metal from lunar regolith*. *The European Space Agency*, [https://www.esa.int/ESA\\_Multimedia/Images/2019/10/Oxygen\\_and\\_metal\\_from\\_lunar\\_regolith](https://www.esa.int/ESA_Multimedia/Images/2019/10/Oxygen_and_metal_from_lunar_regolith). Accessed 4 Dec. 2025.
- [3] *Second Generation*. *Bridgestone's Lunar Rover Tire*, Bridgestone, [https://www.bridgestone.com/technology\\_innovation/moon\\_tires/](https://www.bridgestone.com/technology_innovation/moon_tires/). Accessed 4 Dec. 2025.



COSMIC Capstone Challenge:  
Mid Design Brief

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**VT LUNA, Virginia Tech:**  
**Full Name of Project**

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Students: Abinav Khadka, Duncan Foster, Timmey Curry, Jonah Bradley, Ty Brennan, Braeden Peterson, Eider Belda Cano, Robert Higinbotam, Juliana Evans, Hugh Young, Nicholas Harvey  
Advisor: Dr. Kevin A. Shinpaugh  
Mentor: Dr. Jessica M. Pines

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December 8, 2025

# Team Overview

VT LUNA

Virginia Tech



Project Lead



Abinav  
Khadka

Chief Engineer



Duncan Foster

Material	Communications, Griffin Lander	Power, Thermal, Energy	Rover Architecture	Stationary System Architecture
Timmy Currey	Jonah Bradley	Ty Brennan	Juliana Evans	Duncan Foster
Hugh Young	Braeden Peterson	Eider Belda Cano	Jonah Bradley	Timmy Currey
Ty Brennan	Eider Belda Cano	Nicholas Harvey	Braeden Peterson	Abinav Khadka
Robert Higinbotham	Nicholas Harvey	Juliana Evans	Robert Higinbotham	Hugh Young

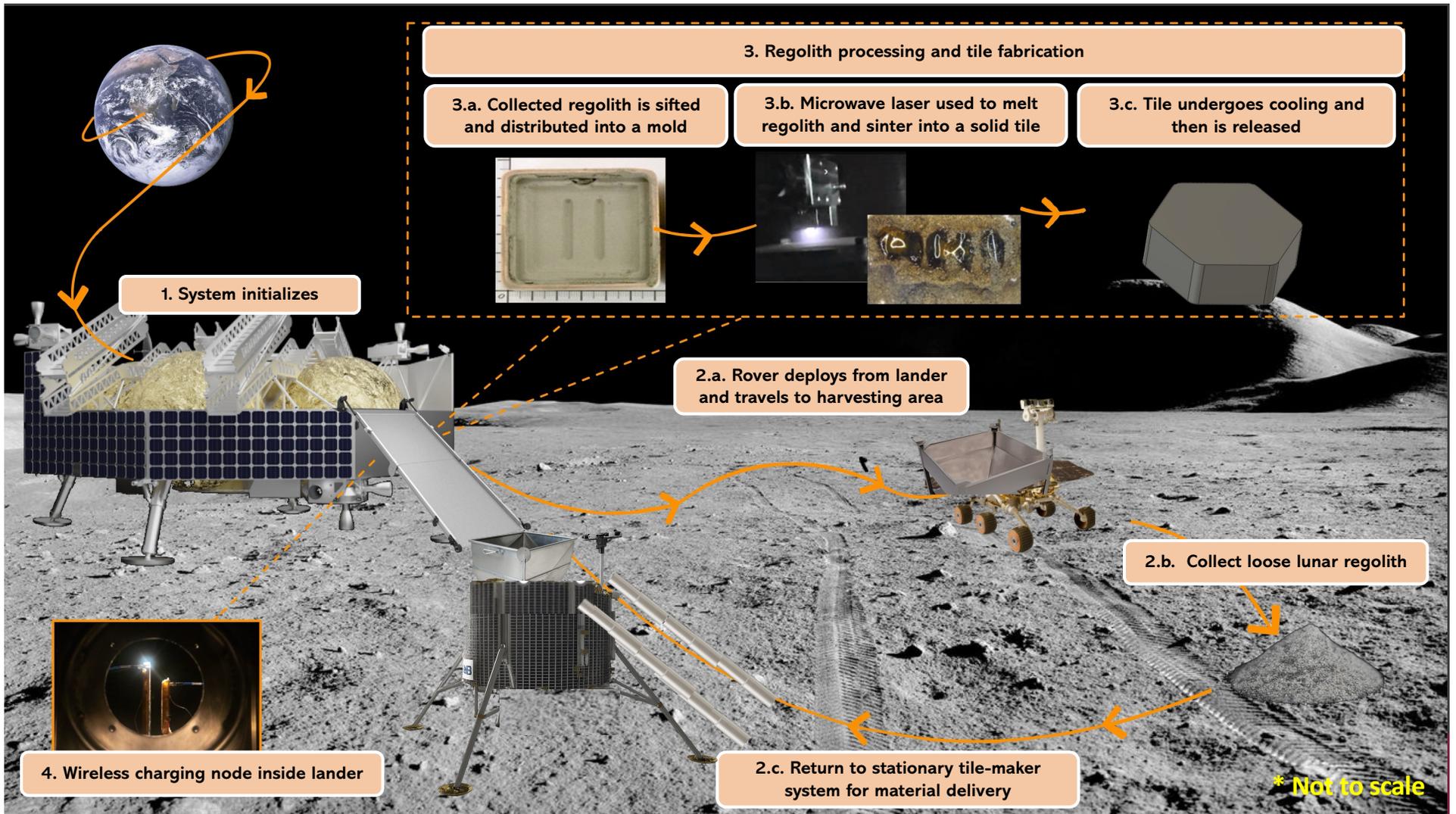
VT LUNA

# Executive Summary

*Full Name of Project*

- Problem statement
- Mission Timeframe
- Additive manufacturing and In-Site Resource Utilization (ISRU)
- Concept of Operations







## Projected Path

- Our current goal is a proof of concept, saying that tiles can be made on the Moon. In the future we want a full tile factory, building a fully usable landing pad.
- We will be looking into a more autonomous rover system. Finding the feasibility of adding in the ability of the rover to move tiles away from the factory for testing.
- We want to find a full proof way of testing the tile(s) on the Moon, in addition of shipping the tiles back to Earth.
- Perform Finite Element Analysis on different tile geometries to find an optimal solution.
- We want to add an interlinking geometry system for the tiles to connect with each other completely.
- We want to be able to terraform a suitable landing pad area.

# University of Washington

## Husky Satellite Lab

HuskySat-3 Mission

C3 Flash Talk - Mid Design Brief

Advisor: Alvar Saenz-Otero

Mentors: Tim Kienberger, Victor Lin

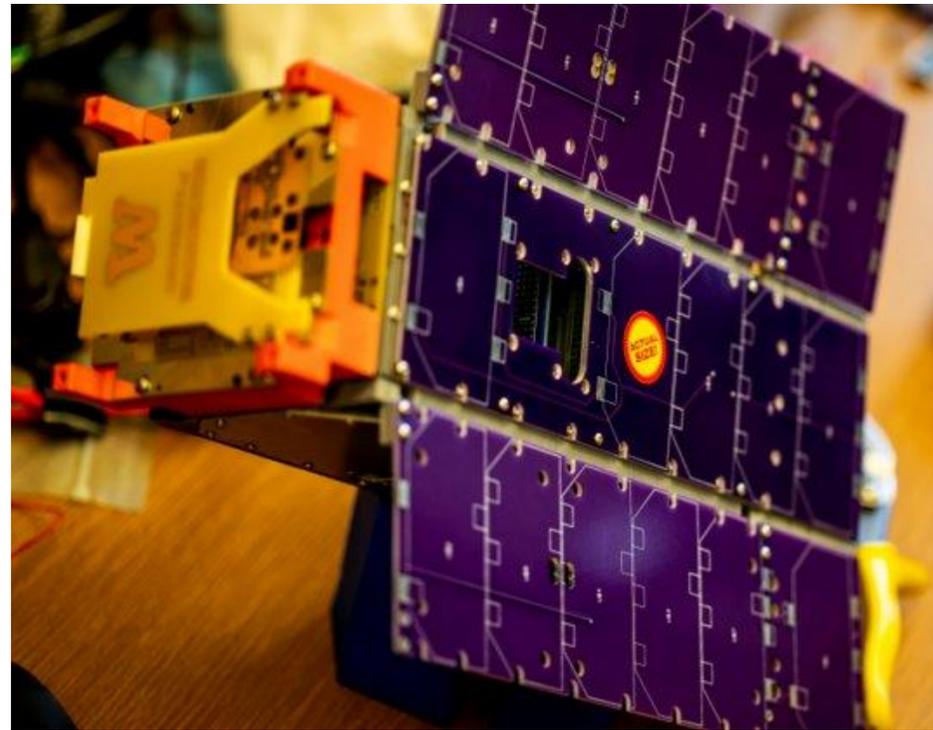
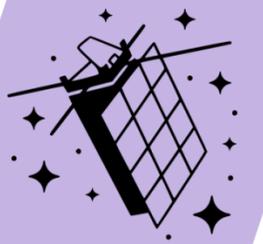
Dec 8, 2025

Students: Rassa Modares, Erika Wood, Madeline Beltran, Hayley Cox, Jasmine Huang, Mark Platonov, Alex Ross, Divya Rao, Odin Lindal



# HuskySat-3: A one of a kind Lunar CubeSat

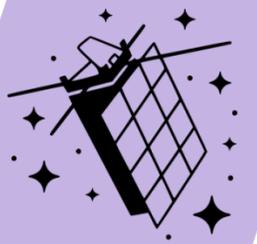
# Team Overview



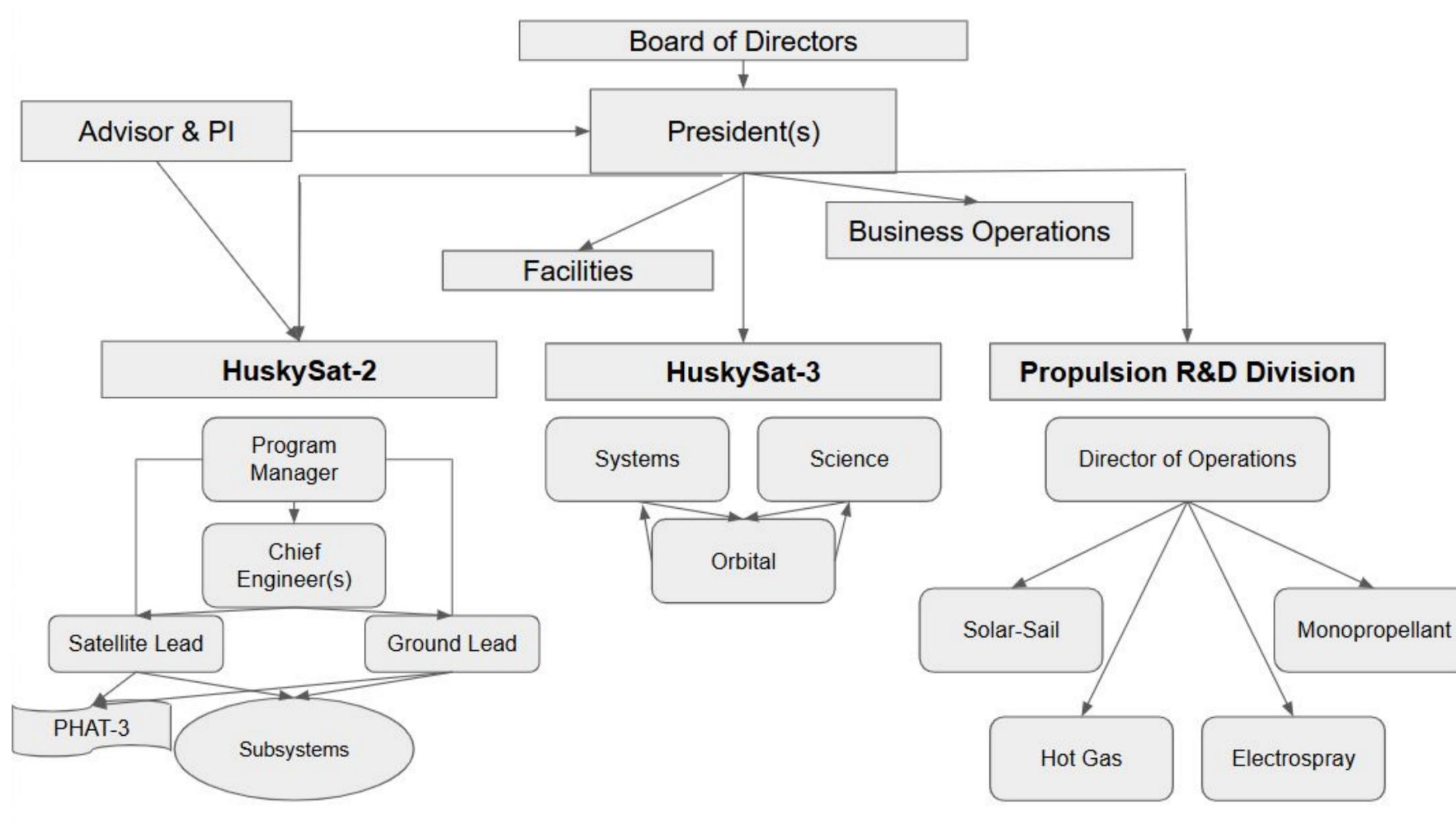
- HuskySat-3 is a Lunar CubeSat mission under development at the Husky Satellite Lab (HSL), a Research and Development laboratory set in the University of Washington. The HSL has long been dedicated to furthering the capabilities of Cube-Satellite (CubeSat) technologies and advancing efforts of scientific research and exploration.
- As it stands, HuskySat-3 is one of the most ambitious and top-of-the line CubeSat in development nationally.
- HuskySat-3 is the third mission in HSL's interplanetary technology “package”, intended to serve as the ultimate demonstration that a CubeSat is capable of conducting interplanetary novel scientific research and exploration.



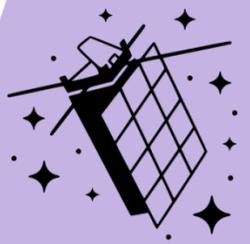
# Team Overview



## Husky Satellite Lab's structure:

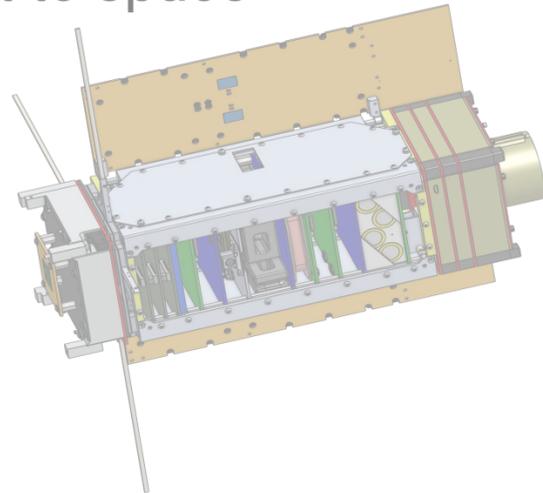


# HSL's Mission Flow



## *HuskySat-1 - 2020* (Low Earth Orbit)

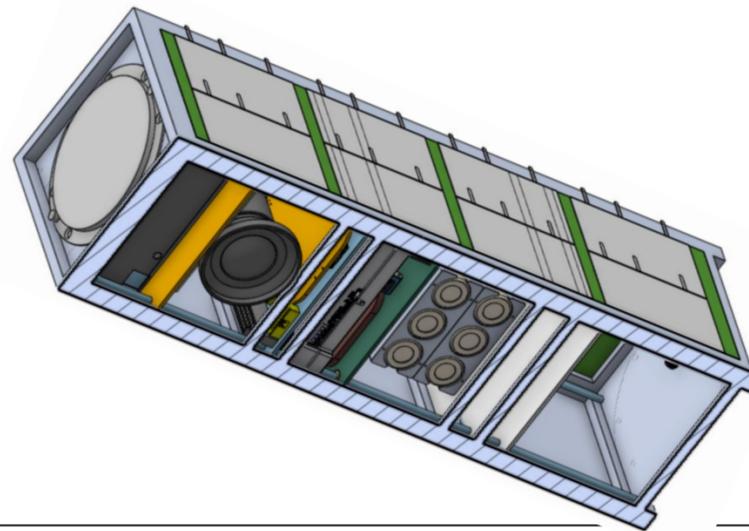
- 3U satellite
- Propulsion and Telemetry Payloads
- First WA-student-built satellite sent to space



- Successful Launch
  - Successful Operation in LEO
- Established Foundation of current HSL

## *HuskySat-2 ~2027* (Low Earth Orbit)

- 3U satellite
- Optical Navigation technology demonstrator
- Currently funded by the AFRL and the DOW

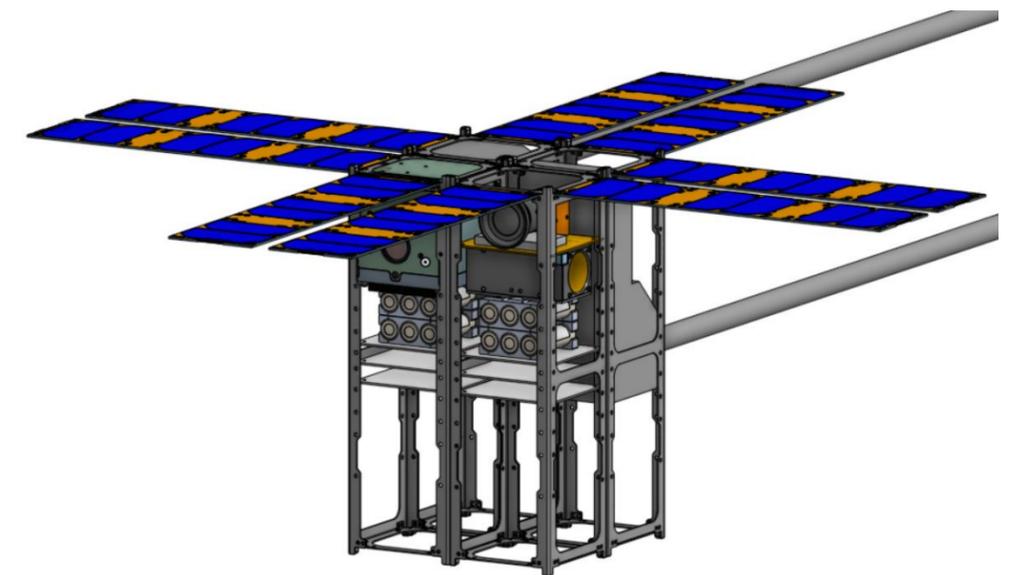


Lunar GNC for Small Satellites

## ***HuskySat-3 ~2030*** **(Low Lunar Orbit)**

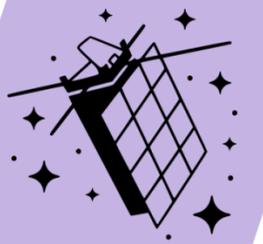
### **C3 Competition Satellite**

- 12U Scientific Research CubeSat
- Lunar Cubesat



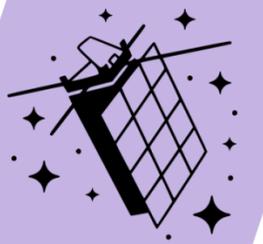
**Map lunar subsurface with ground penetrating radar as candidates for human habitation**

# HuskySat-3's Mission Statement

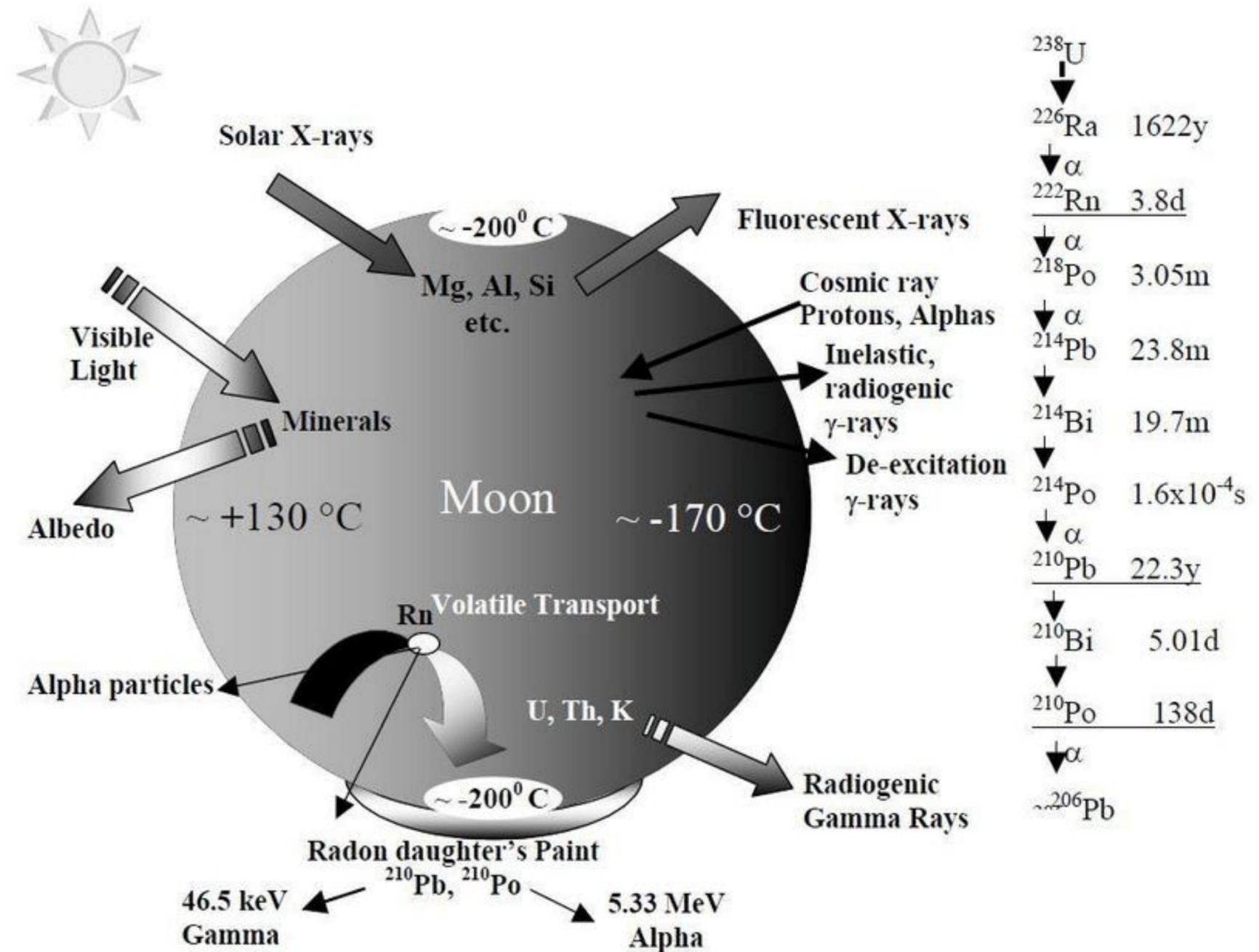


*HuskySat-3 shall obtain the **span, ceiling depth,**  
and **floor depth** of subsurface lunar lava tube  
caves within the **Basaltic Maria** regions*

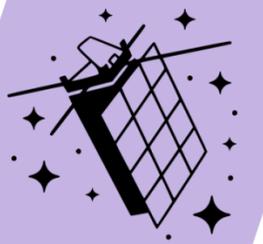
# Executive Summary



- 3 main issues** with long-term human settlements on lunar surface:
- Extreme thermal fluctuations as the moon rotates
  - Vulnerability to direct solar radiation
  - Vulnerability to natural phenomena such as meteorites or comets



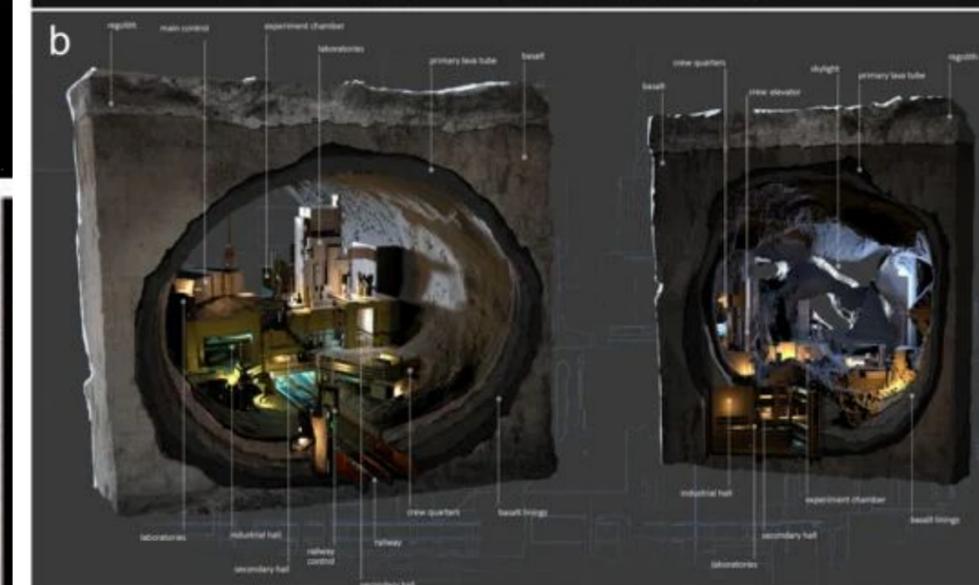
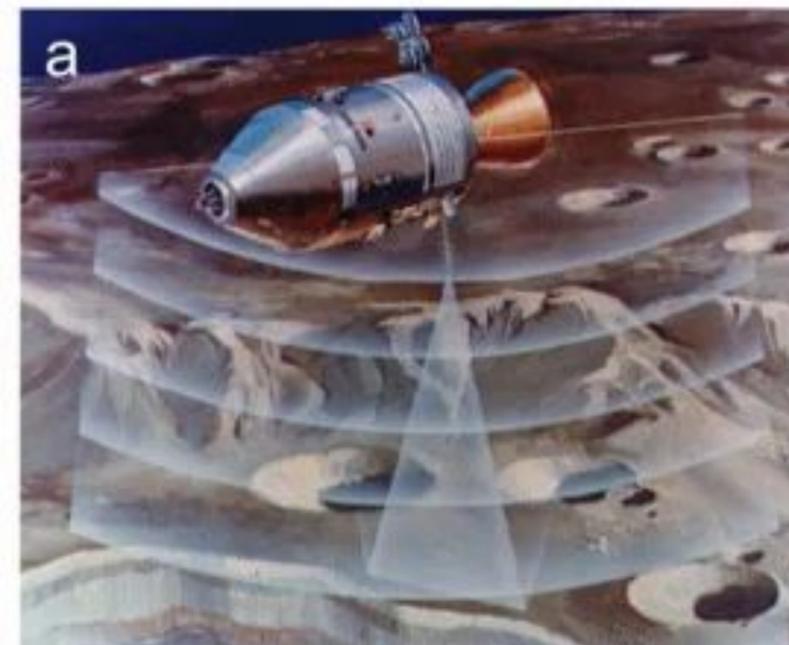
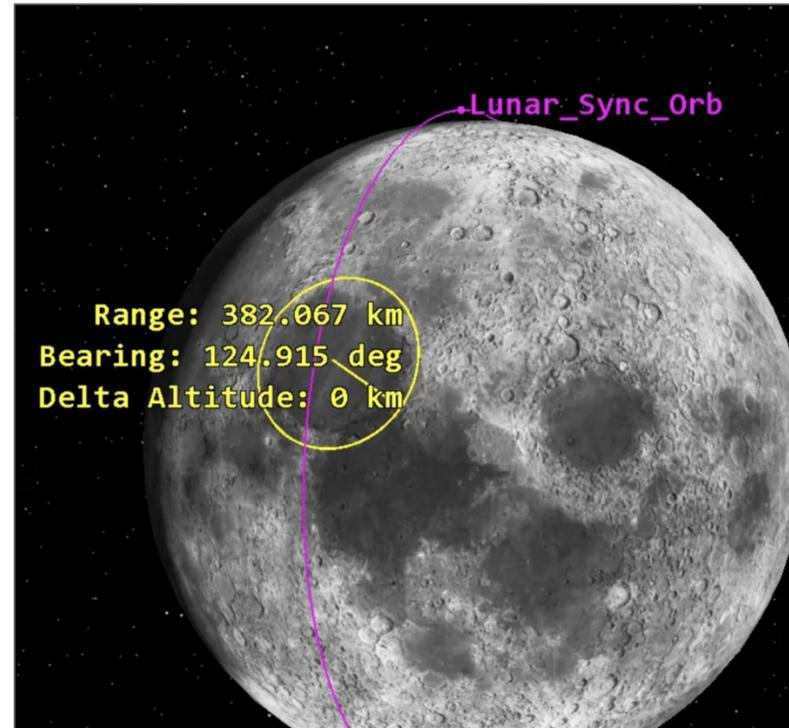
# Executive Summary



## Solution:

- Move underground!
- Subsurface lava tube caves provide:
  - Natural radiation shielding
  - A far more stable and nominal thermal environment
  - Protection from meteorite/comet impact

**HuskySat-3** is aiming to map these subsurface lava tube caves by using an orbital-based Ground Penetrating Radar (GPR)



# Path Forward

- Current state: Focus is on Systems Engineering and Mission Operations.
  - What's already done:
    - Requirements on the Satellite, GPR, Comms, as well as some on Controls, Avionics, and Propulsion.
    - Budgets on Power, Time, Thermal, Data, Link, and Error budgets.
    - CONOPS for the final stage of the mission
- Path forward: Continued development on the System and Subsystem requirements, Concept of Operations (CONOPS) of the mission, its State Machine, Interface Control Documents (ICD), and model (CAD)
  - In Spring quarter, preliminary subsystem designs and development will begin! This will bring the team to a PDR towards the end of 2026

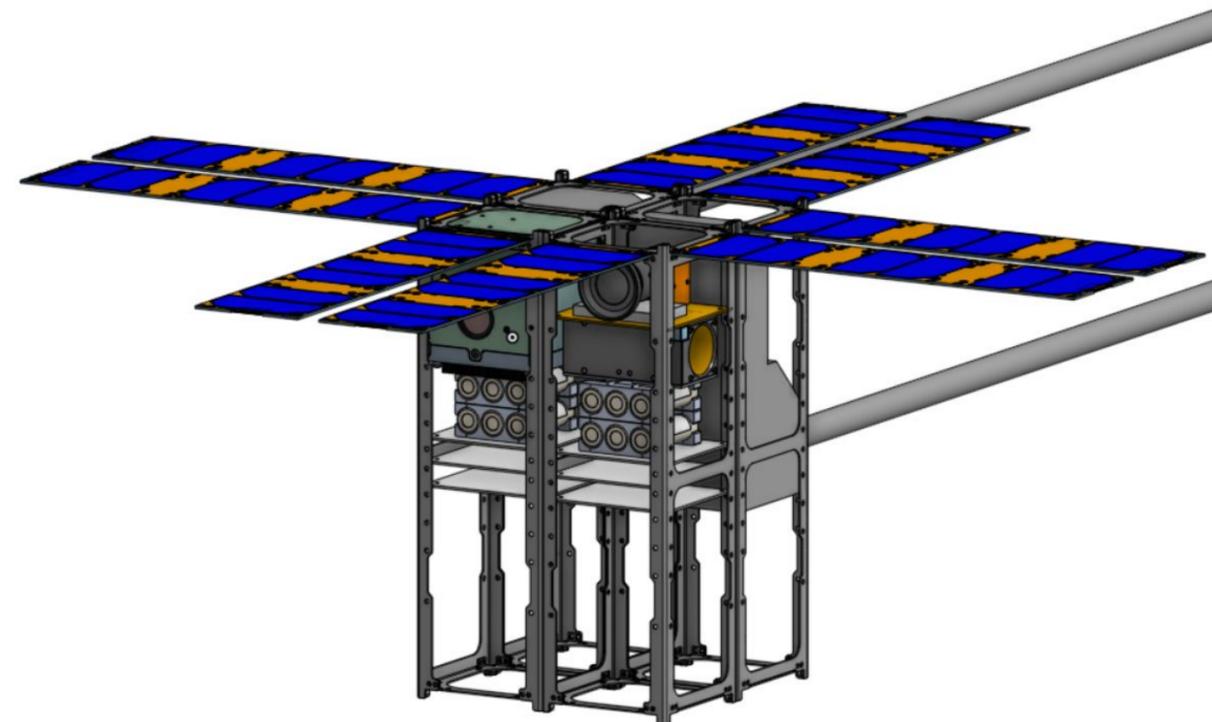
## Analysis Cycles:

- 1 Analysis Cycle #1
- 2 Analysis Cycle #2
- 3 Analysis Cycle #3
- 4 Analysis Cycle #4
- 5 Analysis Cycle #5

## Mission Operations

CONOPS

STATE MACHINE





*Missouri University of Science and Technology*

**Metal Maniacs**

# **The Lunar Iron Reduction System (LIRS)**

Jaden Carollo, Elijah Bracken, Elisha Haff, Evan du Manoir, Jacob Bellet, Sunshine Le, Talon Jones, Grant Baer

**Advisor:** Dr. Frank D. Han (Missouri S&T)

**Mentor:** Brian Nufer (NASA KSC)

# Team Members



**Jaden Carollo**  
Engineering Management  
*Project Manager*



**Elijah Bracken**  
Electrical Engineering  
*Electronics Lead*



**Sunshine Le**  
Engineering Management  
*Collections Lead*



**Evan Du Manoir**  
Aerospace & Mechanical  
Engineering  
*Rover & Processing Lead*



**Jacob Bellet**  
Physics  
*Processing & Electronics*



**Talon Jones**  
Metallurgical Engineering  
*Technical Writer*



**Elisha Haff**  
Aerospace & Mechanical  
Engineering  
*Rover & Collections*



**Grant Baer**  
Aerospace & Mechanical  
Engineering  
*Graduate Student Mentor*

# Projected Path

## *MS&T Metal Maniacs*

- ▶ There is a need for processing of raw materials from lunar resources in advance of the upcoming Artemis III missions.
- ▶ Lunar regolith is rich with iron oxides.
- ▶ The LIRS shall perform the collection, transport, thermal processing, and storage of sintered iron agglomerates derived from lunar regolith.
- ▶ To do this, the LIRS shall utilize four distinct subsystems:
  - Rover
  - Processing
  - Collection
  - Electronics

### Preliminary timeline:

- January -  
Build/test prototype
- Late February -  
Finalize EDU design
- Late March -  
Finalize writeup

# Level One Requirements

## Track 2 –Lunar Operations

- ▶ Establish a permanent facility or capability at a Lunar outpost that supports other operations.
- ▶ Provide “hard” infrastructure necessary to build larger structures.
- ▶ Have a payload less than or equal to 200 kg which occupies no more than 75% of the total Griffin Lander volume.
- ▶ Create a prototype hardware assembly demonstrating one or more key elements of the proposed design.

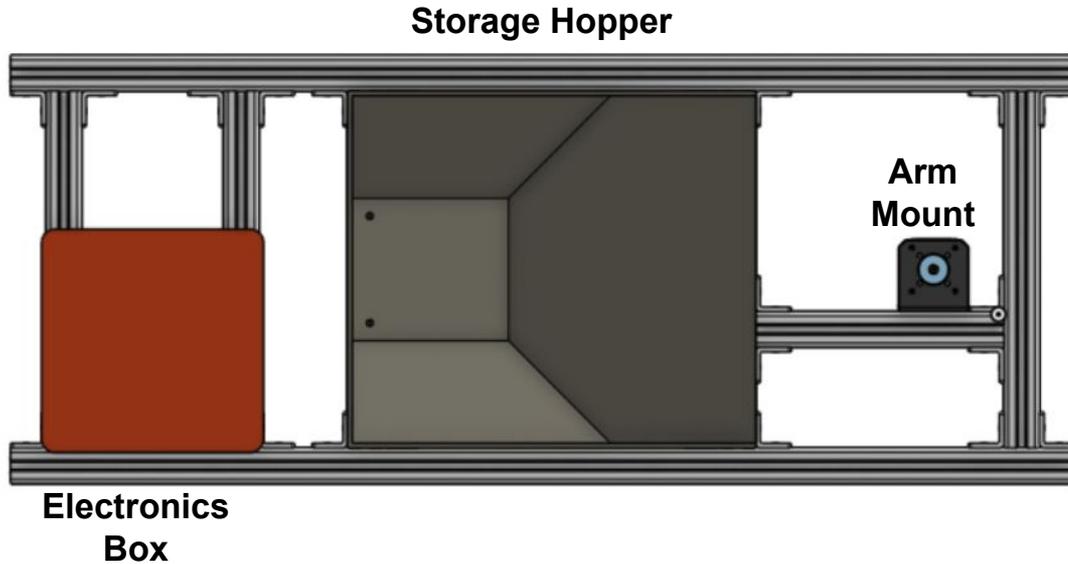
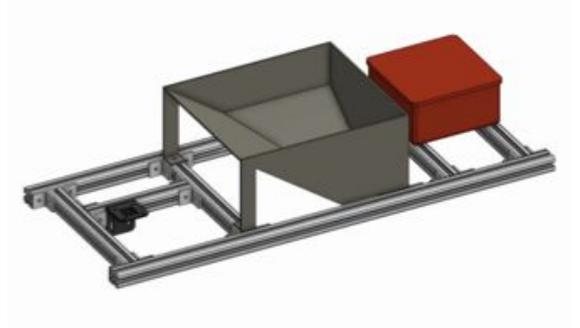
# Subteam Overview: Rover

## A Stable Platform for Lunar Operations

- ▶ The rover chassis shall consist of 80/20 extrusion aluminum.
- ▶ The rover shall house the required integrated oxide storage, power generation, and communication/control subsystems.
- ▶ The chassis shall have mounting points for:
  - The collection arm apparatus
  - A temporary mount for the deployable thermal processing subsystem.
  - Mounting locations for all required antennae and optical sensors.
- ▶ The processing subunit will be remotely detached at a chosen location after the rover has disconnected from the Griffin Lander.

# Subteam Overview: Rover

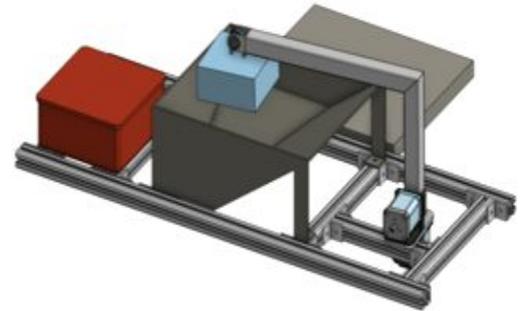
## A Stable Platform for Lunar Operations



# Subteam Overview: Collection

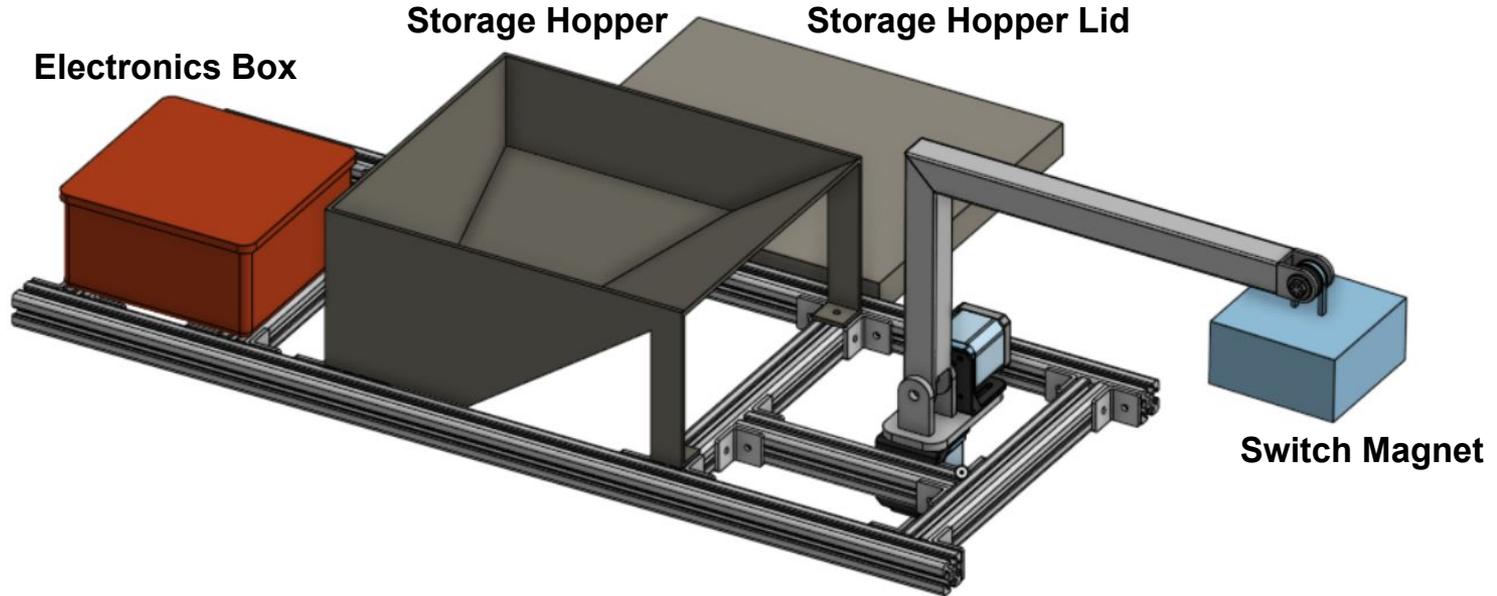
## LIRS Collection Arm

- ▶ Equipped with a switchable magnet, the arm shall be capable of:
  - Moving the metal cover of the storage unit.
  - Magnetically collecting oxides from surface regolith.
  - Navigating above the open storage and switching the magnet off to deposit the collected material.
    - This process shall be used to transfer oxides from the rover storage system into the processing subunit.
- ▶ The collection subsystem shall be able to operate both autonomously and via remote control.



# Subteam Overview: Collection

## LIRS Collection Arm

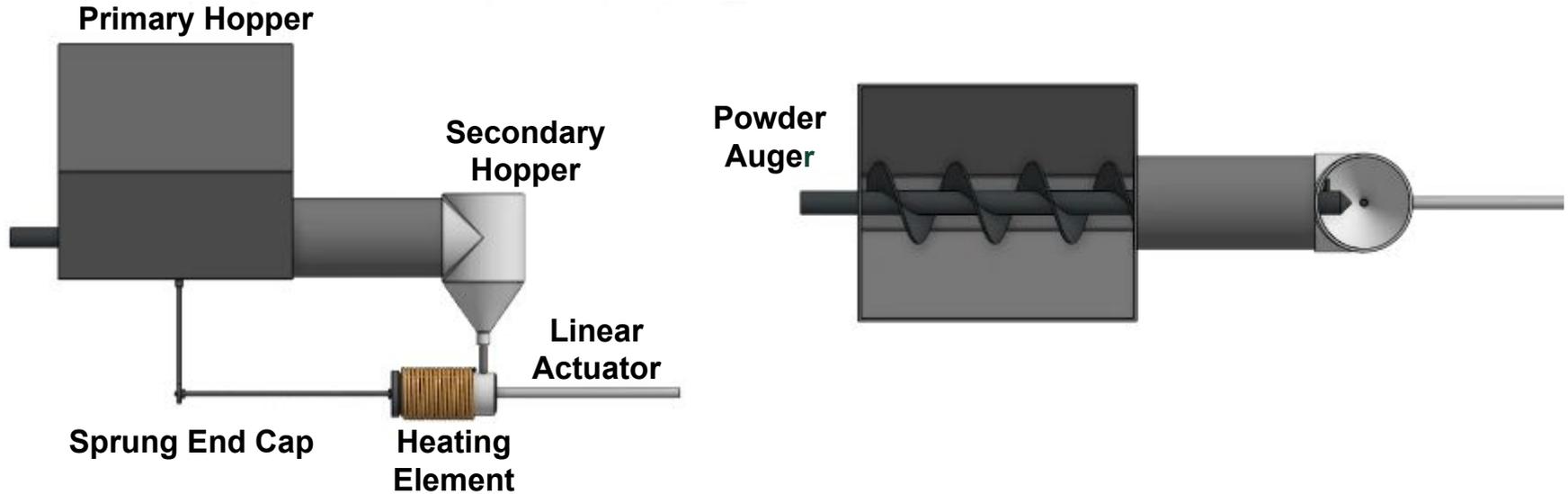


# Subteam Overview: Processing

## Processing via Thermal Reduction of Iron Oxide

- ▶ The system shall operate fully autonomously to produce ~1kg chunks of agglomerated iron for use in future in-situ manufacturing efforts.
- ▶ A measured amount of oxide powder shall be fed into a tube crucible of fused quartz through use of an auger and hopper system and compressed with a linear actuator against a spring-loaded backstop.
- ▶ The crucible shall then be inductively heated to 1250°C for 1.5 hours to undergo thermal reduction, producing a chunk of iron agglomerate.
- ▶ The linear actuator will then remove the chunk from the system, depositing it into an attached temporary storage receptacle.

# Subteam Overview: Processing The Reduction Process of Iron Oxide



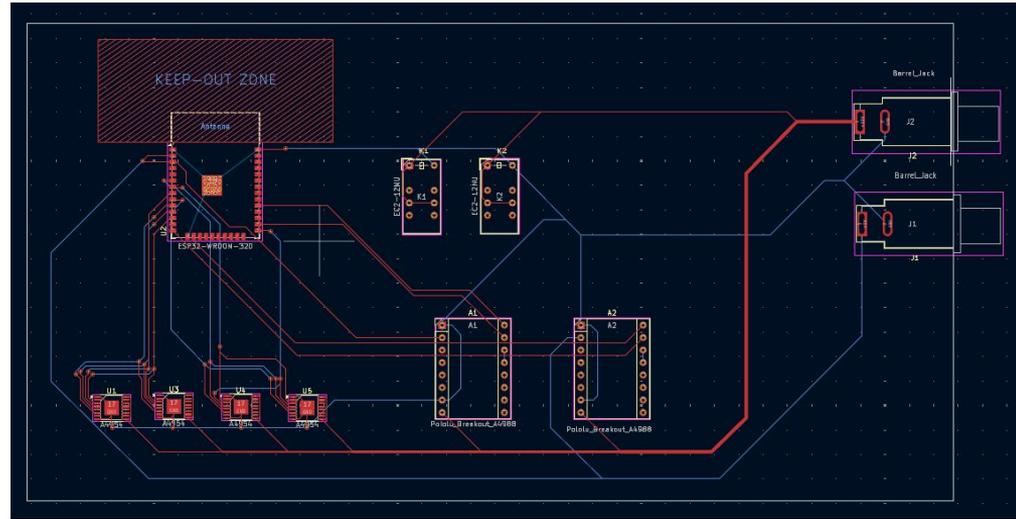
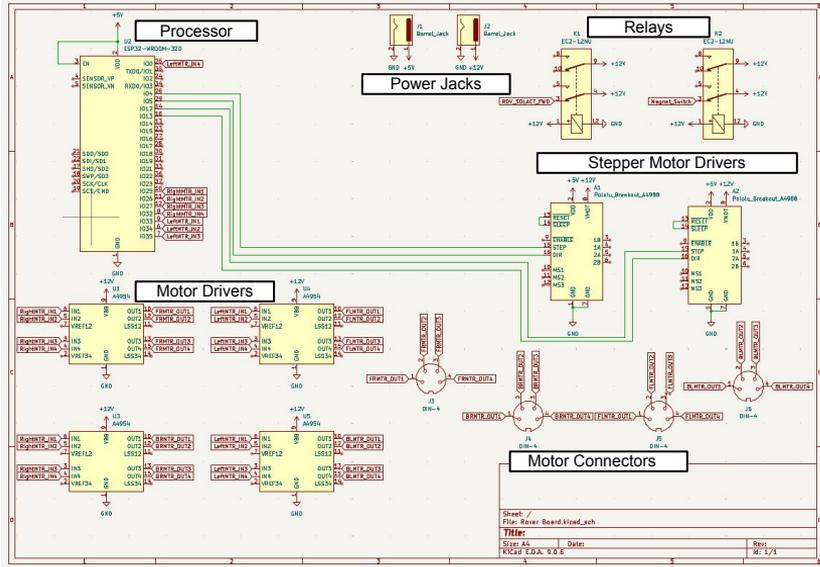
# Subteam Overview: Electronics

## Power & Electronics

- ▶ Power systems for the rover and processing stations shall use an linearly-expanding solar array and dual battery system to collect and store energy.
  - The dual battery system shall increase redundancy and reduce the operating temperatures of each battery.
- ▶ Sensitive electronics shall reside in radiation-shielded and dust-proof HDPE enclosures.
- ▶ Electronics for the rover and processing systems shall be controlled by dedicated PCBs, and communicate via medium-gain and WIFI antenna.

# Subteam Overview: Electronics

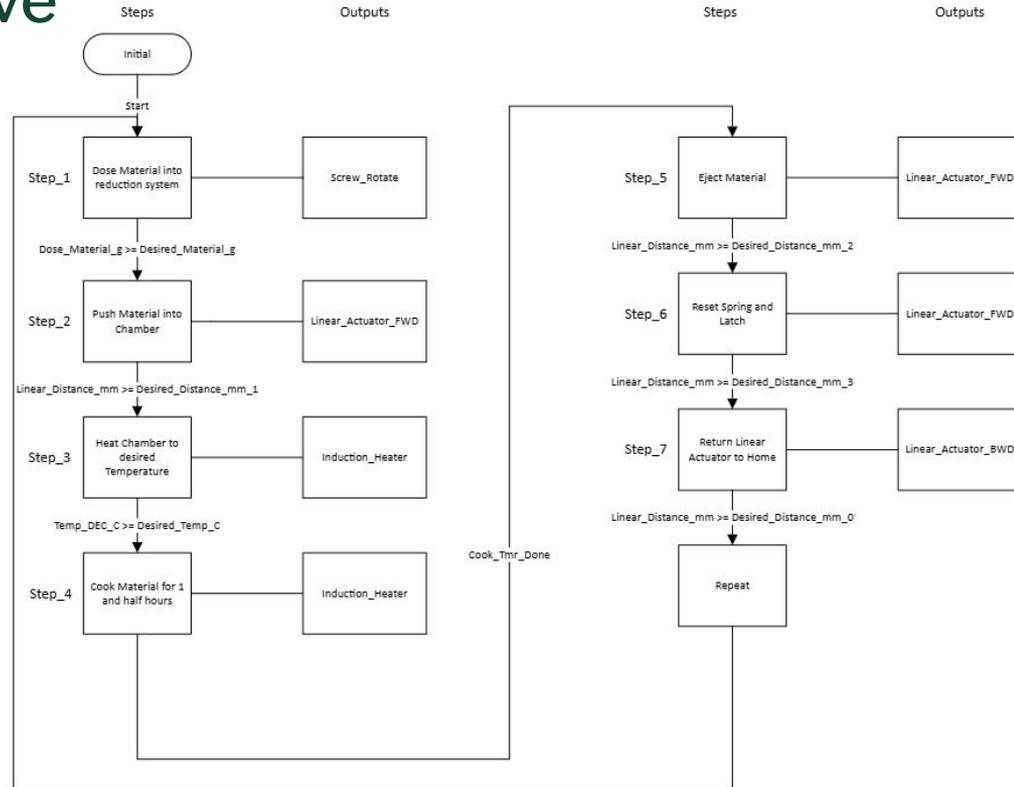
## Prototype Rover PCB



# Subteam Overview: Electronics

## Processing Control Narrative

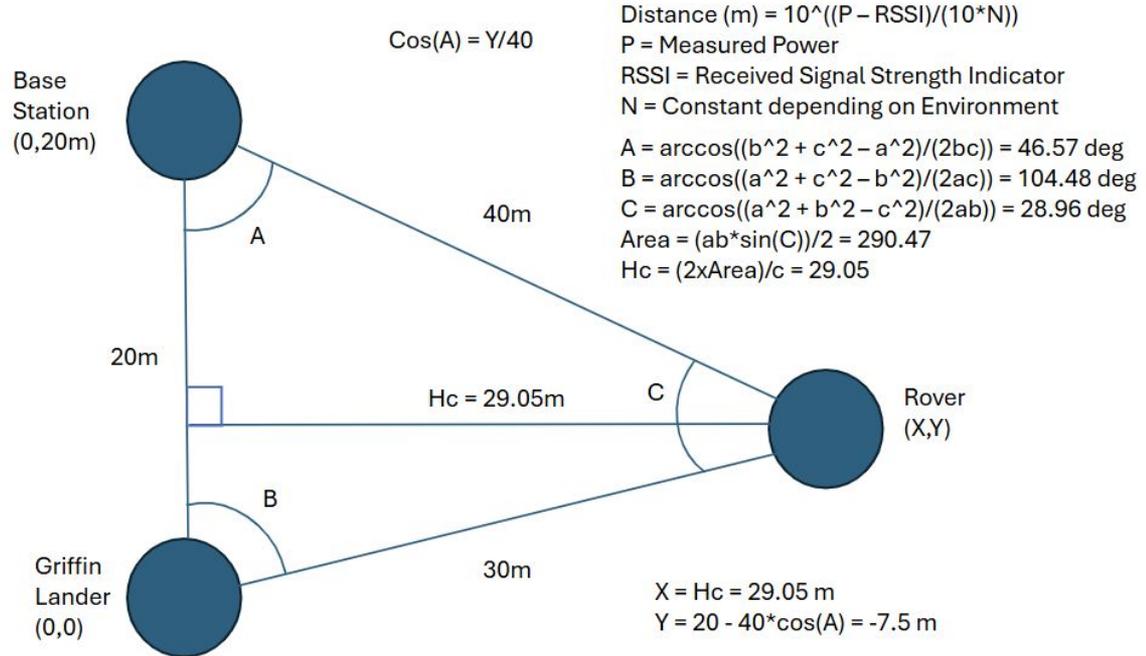
- ▶ The processing station shall have a control narrative to clarify the steps of the process with transition between steps and outputs for each step.



# Subteam Overview: Electronics

## Navigation

- ▶ The navigation system of the rover shall use the strength of the signals from the processing station and the Griffin lander to calculate the location of the rover in respect to the Griffin lander.



# Missouri S&T Resources

- ▶ Missouri S&T has several faculty with prior research in relevant fields, including prior lunar resource collection, which can be used as a resource for the team.
- ▶ Missouri S&T has several facilities to support development, including general manufacturing shops, furnaces, and vacuum chambers for determining the viability of our prescribed collection and reduction processes.

# MISSOURI S&T



CSUN ISAM R&D

# LUNARIS 2025/2026

Track 2 Challenge (C3-Lunar)

Brendan Williamson & Albert Chamoun

Faculty Advisor: Dr. Christoph Schaal

CSUN Department of Mechanical Engineering

# Problem: Infrastructure is Needed

- NASA's Artemis program aims to send humans back to the moon, but not for a brief visit
- Infrastructure is needed to support a **permanent lunar outpost**
  - Landing pads
  - Protective shelter
  - Storage for resources and hardware
- Launching construction materials from Earth is not sustainable
- The solution: **transform lunar soil into regolith building blocks**

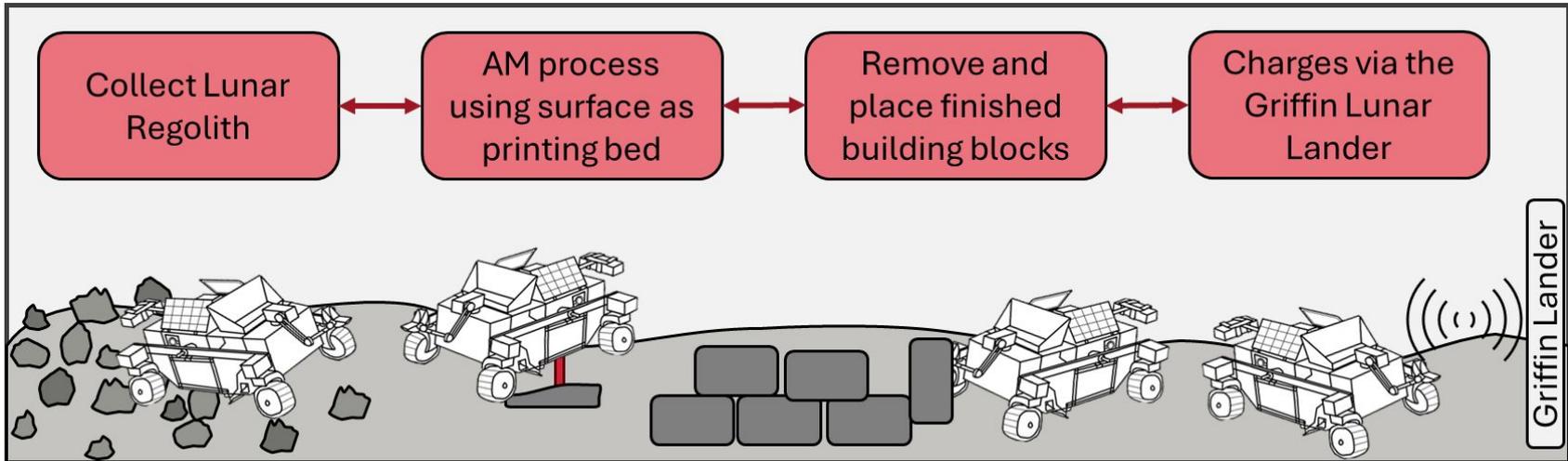
*L*unar  
*U*tilization and  
*N*ovel  
*A*ssembly via  
*R*egolith  
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*S*ystems



Credit: ESA - P. Carril

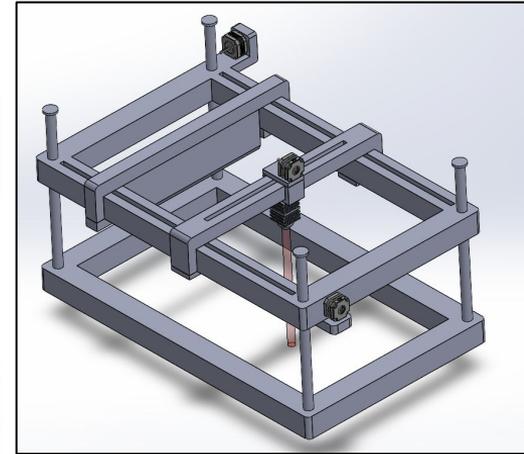
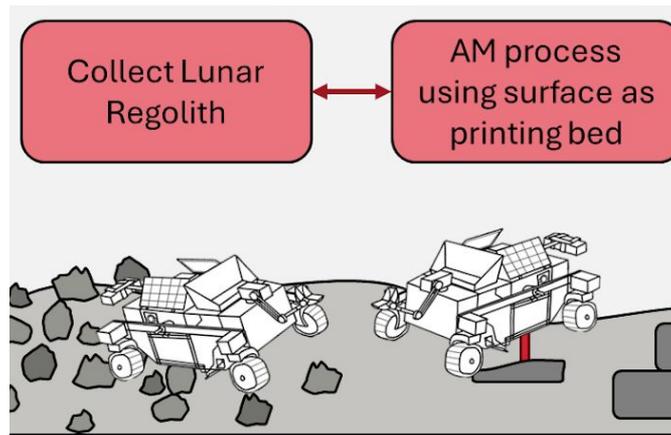
# Solution: Utilize the Environment

- **LUNARIS** is a payload delivered by the Griffin Lander
- It will autonomously create regolith building blocks
- Provides a way to enable construction of lunar infrastructure



# How Does LUNARIS Work?

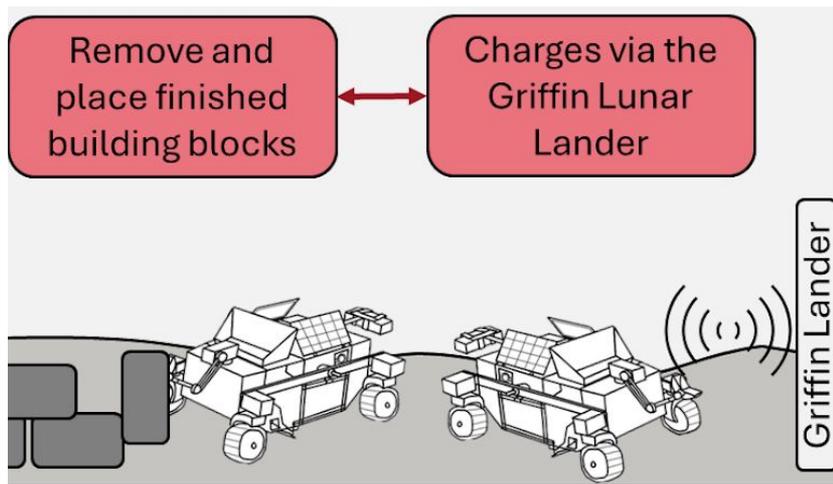
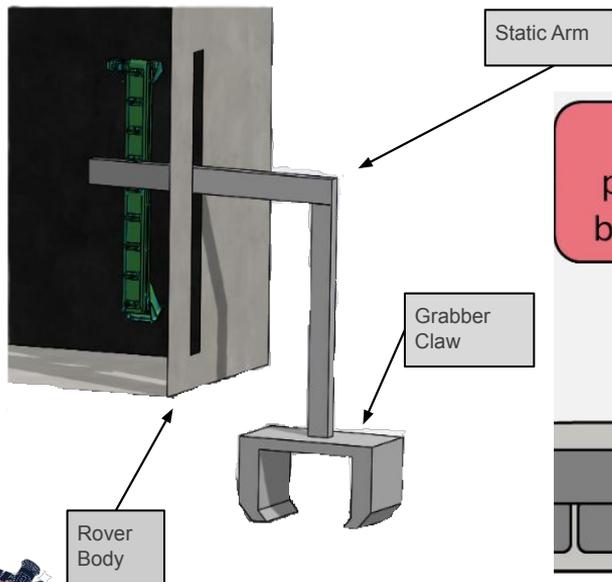
- **LUNARIS** is a rover that will harvest regolith, purify it through meshing and traditional sorting. In order to have a fine dust capable of being laser sintered in a way similar to SLS printing.
- 1. Collecting regolith
- 2. Sorting and Storing
- 4. Laser sintering and recoater work together to create the part.



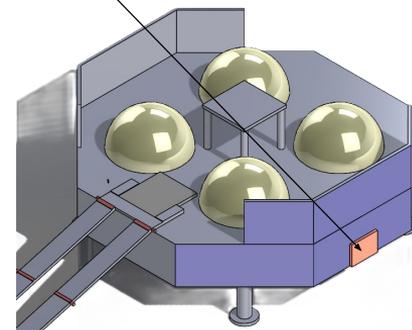
Conveyor belt elevation

# How Does LUNARIS Work?

- 5. Remove the finished part and place it where needed.
- 6. Charge via the griffin lander and then restart the cycle.

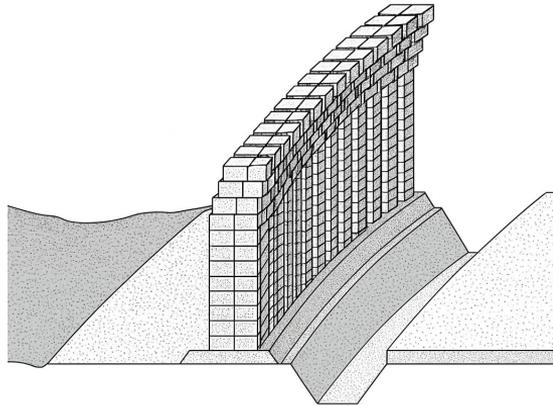


Griffin Lander induction charger



# Validation and Impact

- **LUNARIS Impact:**
  - Capable of creating large structures. For example **Blast Walls, Landing Pads, and Shelters.**
- Since it is a **SLS printer** the Geometry of the final product can be changed which achieves a high level of **Versatility**



Credit: Yashar et al. (2021), Project Olympus

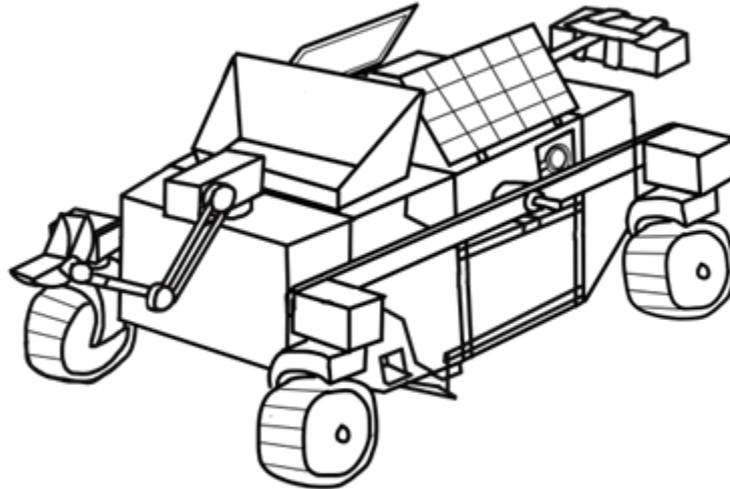


Credit: Port San Antonio/Tangram 3DS

# Project Wrap-up

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- LUNARIS solves a critical C3 Track 2 need: **lunar construction using local resources**
- Demonstrates full infrastructure development: **Harvest** → **Print** → **Place** → **Repeat**
- Fully aligned with C3-Lunar mission objectives
- **LUNARIS enables the first step toward permanent human presence on the Moon**



# **Orbital Gators – Lunar Subsurface Resource Characterization Mission (LSRCM)**

Team: Andrew Dishchuk, Max Caldwell, Paige DeMino, Jack Xu, Christian Szczeniak, Riley Cullingford, Benjamin Hamilton, George Rushevich, Nilson Bretas, and Arin Churi

## **Opening Statement**

**The 2025 Orbital Gators C3 team is developing a lunar resource-mapping concept that integrates spectroscopy and ground-penetrating radar to estimate the distribution of H<sub>2</sub>O and He-3 across the lunar surface with a 90% confidence level.**

**Our goal is to generate a high-fidelity resource model that guides future lunar In-Space Resource Utilization (ISRU), site selection, and early infrastructure development.**

# Mission Objective & Design Driver

- Produce a quantitative resource model for potential water and Helium-3 extraction
- Characterize lunar surface and subsurface composition
- Science driven, paves the way for future exploration

**Our mission is to establish a scientific baseline for lunar ISRU by characterizing surface and near-subsurface regions and producing a quantitative resource model that identifies areas with the highest potential for H<sub>2</sub>O and Helium-3 (He-3) extraction.**

# Concept Overview

Our mission aims to characterize the location of ilmenite and subsurface water reserves. Ilmenite ( $\text{FeTiO}_3$ ) has been found to be the best particle of trapping helium 3 on the lunar surface [1].

## Material Focus:

He-3 is a molecule used in nuclear fusion, medical imaging, and nuclear scanning, making it a sought-after commodity ~\$22 million per kg [2]. The Moon contains helium-3 in concentrations roughly three orders of magnitude higher than Earth, about 1–20 ppb in typical lunar soils compared to Earth's ~0.1 ppb [3].

Water, also proven present on the moon, can be used for mass-propellant systems, and life-support,

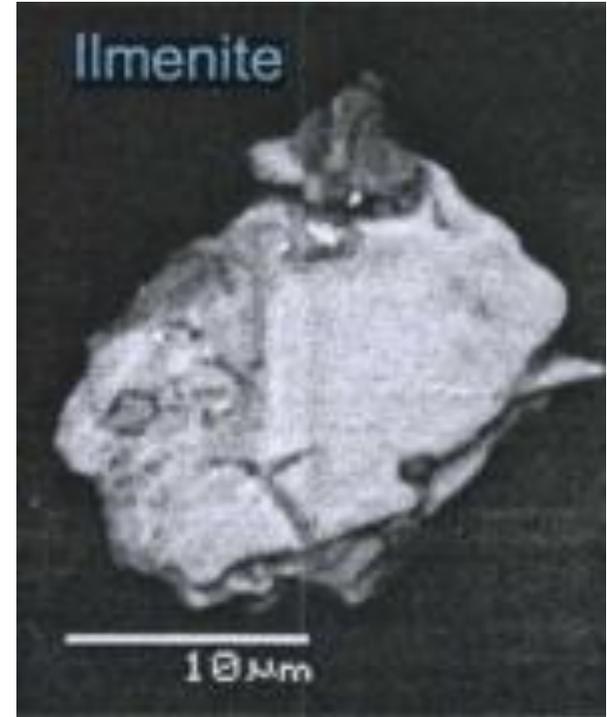


Figure 1. Depicted image of ilmenite, a component of lunar dust termed “regolith”. From *The Lunar Regolith*, by Sarah Noble, 2009. Retrieved from <https://ntrs.nasa.gov/api/citations/20090026015/downloads/20090026015.pdf>.

# Technical Reasoning

## Past Modeling Implementations:

Ilmenite and H<sub>2</sub>O research models already exist. Our objectives differ from those models because we aim to provide direct measurements for ilmenite and H<sub>2</sub>O reserves [4].

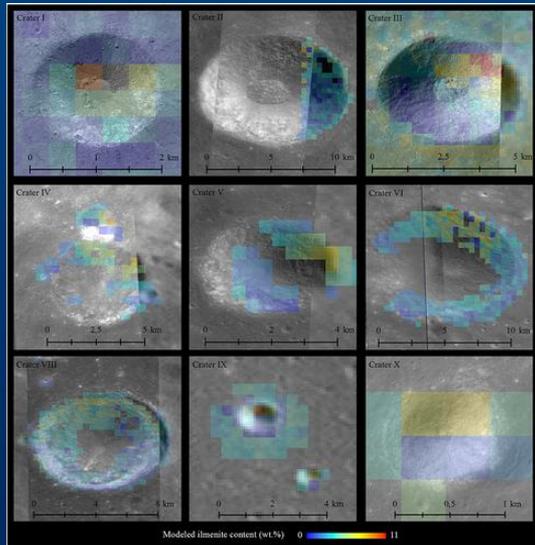


Figure 2. Ilmenite abundance (0–11 wt%) across Mare Australe craters, derived from spectral mapping. Data from Lemelin & Morisset (2013).

Other resource distribution maps use prior correlations to suggest resource quantities across lunar regions [5].

- Increased Optical Maturity (OMAT) displays less TiO<sub>2</sub> content.
- Greater solar wind flux displays greater TiO<sub>2</sub> content.
- Thinner regolith layers display increased TiO<sub>2</sub> content.
- Decreasing regolith grain size displays increased TiO<sub>2</sub> content.

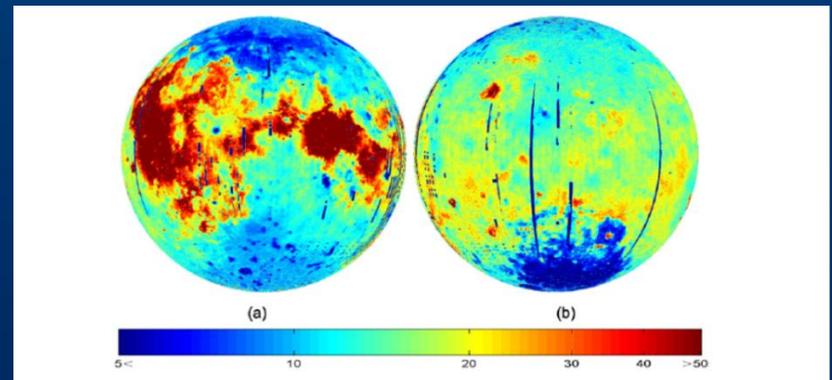


Figure 3. Modeled He-3 abundance (ppb) across the lunar surface, derived from Apollo soil data and Clementine multispectral reflectance. After Fa & Jin (2007).

## Regolith Property Data our Payload will Collect

### Helium-3:

#### Density

- Lunar Penetrating Radar (LPR)

#### Grain Size

- Automated Grain Size Analyzer, Multispectral Imaging Camera

#### TiO<sub>2</sub> content

- Alpha Particle X-Ray Spectrometer (APXS)

#### Magnetic Anomalies (Inverse Relation)

- Fluxgate Magnetometer

#### Solar Wind Flux

- Electrostatic Analyzer (ESA)

#### Neutral Gas Flux

- Neutral Particle Detector (NPD)

### Water:

#### Dielectric contrast

- Lunar Penetrating Radar (LPR)

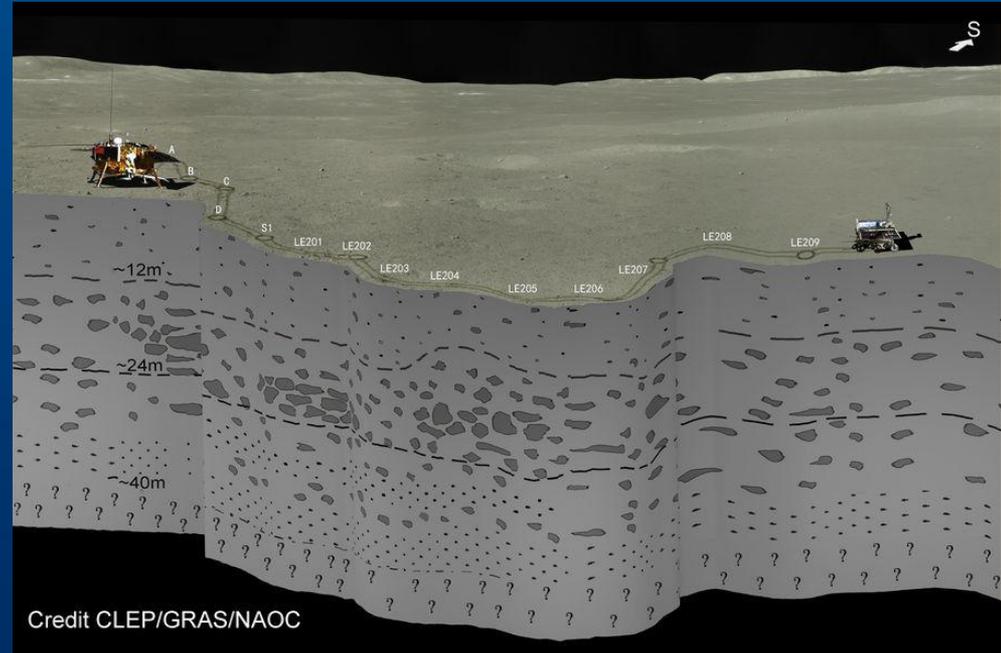


Figure 4. An LPR image of the subsurface stratigraphy of the far side of the moon. From CLEP/GRAS/NAOC provided to Xinhua (2020).

# Roadmap

## Current Status (2025):

- Completing final revisions of System Requirements.
- Finalizing the Conceptual Design.

## Mid-Term Plan (First quarter 2026):

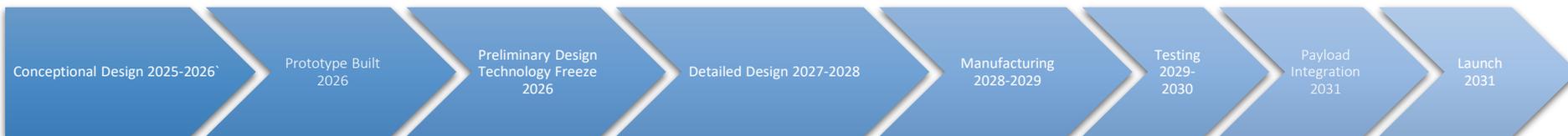
- Complete Preliminary Design
- Technology Freeze.
- Develop list of prototypes and intent.
- Purchase parts for first prototype.
- Begin initial prototyping.

## Second quarter 2026:

- Complete initial prototype.
- Develop plans for additional prototypes.
- Summarize success and plausibility of concept implementation.
- Present to C3

## Long-Term Roadmap:

- Progress into future detailed design process in 2027–2028, refining hardware interfaces, calibration strategies, and data-fusion pipelines.
- Manufacturing (2028–2029) of components for full-system integration.
- Testing and Verification (2029–2030) to ensure mission reliability.
- Payload Integration (2031) followed by Launch in 2031.



# Closing Statement

Our mission moves beyond mapping the Moon, we are building the foundation for future lunar industry. By validating He-3 and H<sub>2</sub>O resource models with a high-confidence architecture, we enable safer planning, lower risk, and more sustainable surface operations. As we finalize system requirements and advance toward prototype development, our intent is clear: deliver a practical, data-driven toolchain that accelerates humanity's permanent presence on the lunar surface.

# References

- [1]** H. Song, J. Zhang, Y. Sun, Y. Li, X. Zhang, D. Ma and J. Kou, “Theoretical study on thermal release of helium-3 in lunar ilmenite,” *Minerals*, vol. 11, no. 3, art. 319, Mar. 2021, doi:10.3390/min11030319.
- [2]** Interlune, “\$20 MILLION/KG...,” Accessed: Feb. 6, 2025. [Online]. Available: <https://www.interlune.space/>
- [3]** A. D. S. Olson, “Lunar Helium-3: Mining Concepts, Extraction Research, and Potential ISRU Synergies,” in *AIAA ASCEND 2021 Conference*, Las Vegas, NV, Nov. 2021, 20210022801.
- [4]** M. Lemelin, C.-E. Morisset, M. Germain, V. Hipkin, K. Goïta, and P. G. Lucey, “Ilmenite mapping of the lunar regolith over Mare Australe and Mare Ingenii regions: An optimized multisource approach based on Hapke radiative transfer theory,” *Journal of Geophysical Research: Planets*, vol. 118, no. 12, pp. 2582–2593, Dec. 2013, doi: <https://doi.org/10.1002/2013je004392>.
- [5]** W. Fa and Y.-Q. Jin, “Quantitative estimation of helium-3 spatial distribution in the lunar regolith layer,” *Icarus*, vol. 190, no. 1, pp. 15–23, 2007, doi: 10.1016/j.icarus.2007.03.014.



THE POWER OF COLLABORATION

COSMIC Capstone Challenge:  
Mid Design Brief

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**The Moonwalkers,**  
**Georgia State University:**  
*Autonomous Signal Transmission &  
Relay Rover (ASTRA)*

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Students: Paul Lichtenwalner, Vishesh Jain, Naomi  
Portilo, Kenna Lemon, Eden McKenzie  
Mentor: Bo Varga

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December 8, 2025

# Team Overview



## *Autonomous Signal Transmission & Relay Rover (ASTRA)*

- **Who We Are:**

An interdisciplinary team within the GSU Robotics Club, focused on advancing lunar communication and robotic systems.

- **Our Focus Areas:**

Robotics · Communication Systems · Embedded Hardware

- **Advisor & Mentor Support:**

We are guided by faculty and industry mentors to ensure technical rigor and mission relevance.

***"ASTRA - A mobile autonomous relay rover designed to extend communication coverage for lunar missions."***



# Executive Summary

## *Autonomous Signal Transmission & Relay Rover (ASTRA)*

- **Problem Identified**

- Lunar terrain (craters, ridges, etc.) blocks line-of-sight signals.
- Rovers can lose connection, interrupting data transfer and shortening mission duration.

- **Proposed Capability**

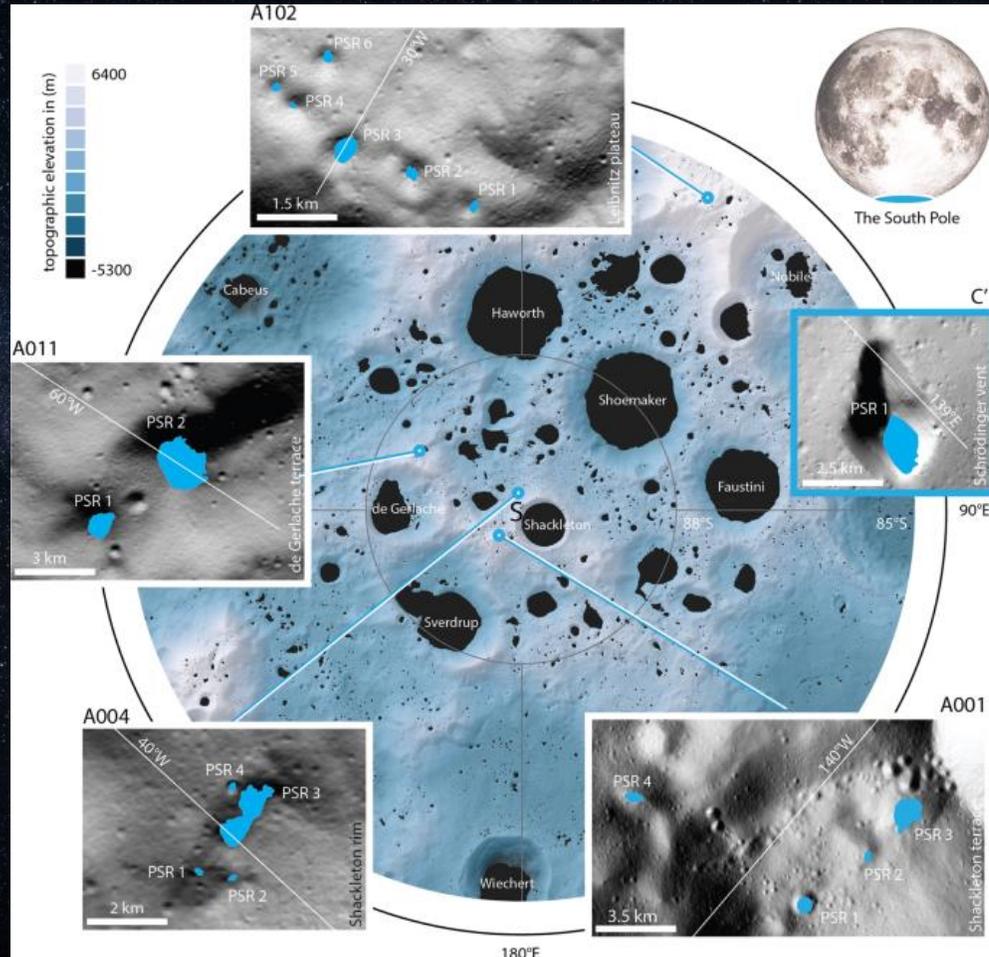
- ASTRA is a **mobile relay rover** that acts as a hotspot to extend surface communication.
- Provides flexible, terrain-adaptive coverage to keep rovers connected.

- **How does it solve the problem:**

- By mounting ASTRA on Hyundai's rover, it actively bridges communication gaps between rovers operating in PSRs and the existing communication network. Multi-robot teams stay coordinated even when terrain blocks their direct line-of-sight.

# Communication Dead Zones

## Autonomous Signal Transmission & Relay Rover (ASTRA)



- Communication within permanently shadowed regions (PSR) of the moon is difficult and limited to Line of Sight (LoS) Satellites.
- The rover's primary function is to eliminate signal loss caused by Line-of-Sight (LoS) obstructions, ensuring 100% communication reliability between Earth/orbit and mission assets operating within shadowed lunar regions.

**Key Point: Enabling sustained operations in permanently shadowed lunar regions**

# Line of Sight Communication

## Autonomous Signal Transmission & Relay Rover (ASTRA)

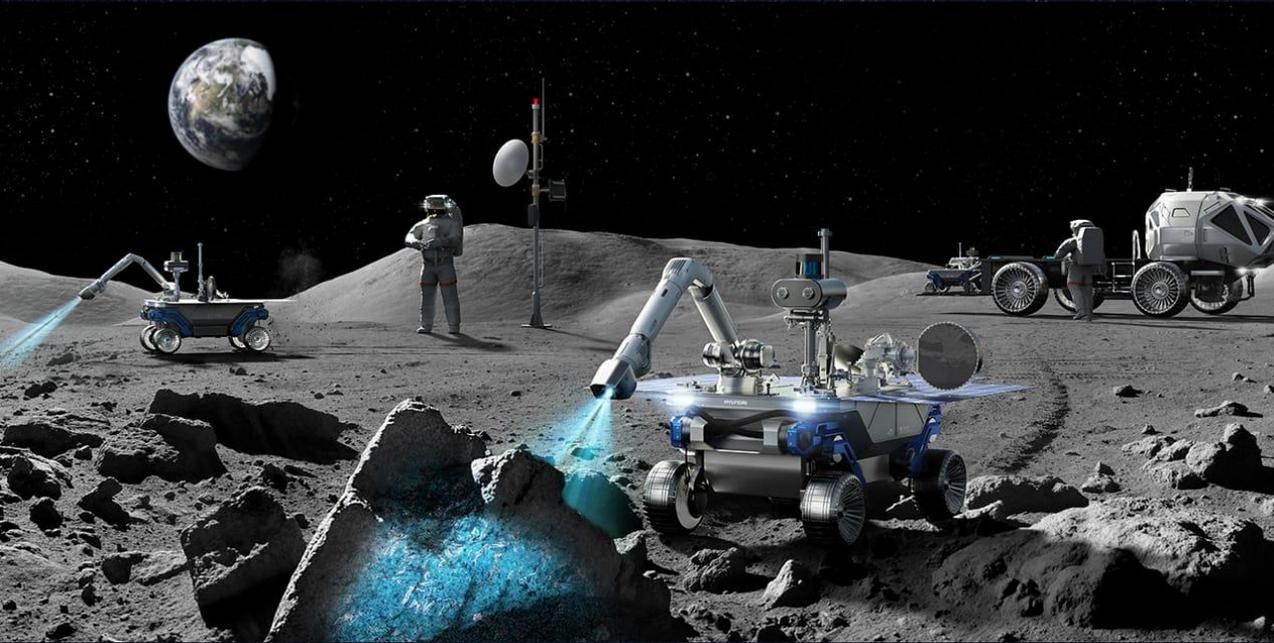


- The lunar South Pole, with its deep craters and high peaks, creates significant obstructions, frequently breaking the LoS and resulting in communication dead zones.
- Without a mobile relay asset, valuable data collected by rovers in PSRs cannot be continuously transmitted, severely limiting mission duration and data transfer.
- Our Relay Rover acts as an intermediary node, positioning itself to maintain a guaranteed LoS link between the asset in the dead zone and the Earth/Orbital network.

**Key Point: LoS communication will ensure robust, high availability data transfer**

# Hyundai Lunar Rover

*Autonomous Signal Transmission & Relay Rover (ASTRA)*



- Hyundai is working to produce a small rover for lunar exploration.
- The rover will be autonomous, solar powered, and weigh roughly 70kg.
- Our communications pod will attach directly to this rover in its mission to assist additional rovers.
- In our design, we will assume Hyundai has these lunar rovers operational on the moon.

**Key Point: Hyundai's rover will give our communications pod an operational platform**

Autonomous Relay Rover

# Projected Path

## *Autonomous Signal Transmission & Relay Rover (ASTRA)*

- Finalize System Requirements
- Contact Hyundai on the specifications of their lunar rover
- Complete Concept of Operations
  - Unloading from Griffin Lunar Lander
  - System Assembly with Hyundai Rover
  - Communication Testing
- Begin Concept Design
  - CAD Design
  - Communications Hardware

**Thank You**

# Bearcat Assembly C3 Midpoint Showcase

Diego Quevedo, Conrad Kent, James  
Talavage, Sarah Hudson, John Radey,  
Sophia Yu, Gerardo Martinez-Avila

University of Cincinnati

8 December 2025

next  
lives  
here

IASRL

University of  
CINCINNATI

# Concept

- ❖ Concept
- ❖ System Req.
- ❖ Orbital Mechanics
- ❖ Structure
- ❖ Electrical
- ❖ Thermal
- ❖ Communications

**The unmanned assembly of a modular, autonomous, and reconfigurable research station for experiments beyond LEO.** These experiments could be commercial in nature and will include biological, technological, or other deep space focused research payloads. The station concept takes advantage of existing technologies and concepts such as CubeSat scale factors. *The structure of the station will be constructed from the ARMADAS system, including power transfer, solar panel, and rail system voxels, which will allow the station to be self-maintained by a crew of autonomous robots.* The station will automatically handle experiments throughout their lifecycles, from docking to end-of-experiment (EOE) processing or disposal. Experiments will benefit from the shared resources offered by the station, including but not limited to power, communication bandwidth, thermal management, and station keeping.



Image credit: NASA/Roscosmos

The short version...  
the evolution of ISS  
scientific experiments.



Image credit: NASA

# System Requirements

## The space station shall...

- ✓ Provide berthing to customer experiments, plus accommodations such as power, communications to and from ground, and thermal regulation.
- ✓ Be constructed primarily of NASA ARMADAS cells to enable streamlined in-space assembly.
- ✓ Be autonomously self-maintained by a crew of robotic agents.
- ✓ Store replacement cells and equipment for regular maintenance operations.
- ✓ Have a docking ring for delivery of materials and experiments, as well as disposal (e.g., broken equipment, finished experiments).
- ✓ Provide protection to customer experiments from orbital kinetic hazards.
- ✓ Provide varied experiment berthing options, meaning a small berth (one Arkysis Bosun locker sized), a large berth (TBH # of Arkysis Bosun locker sized), and a radiation-hardened berth.

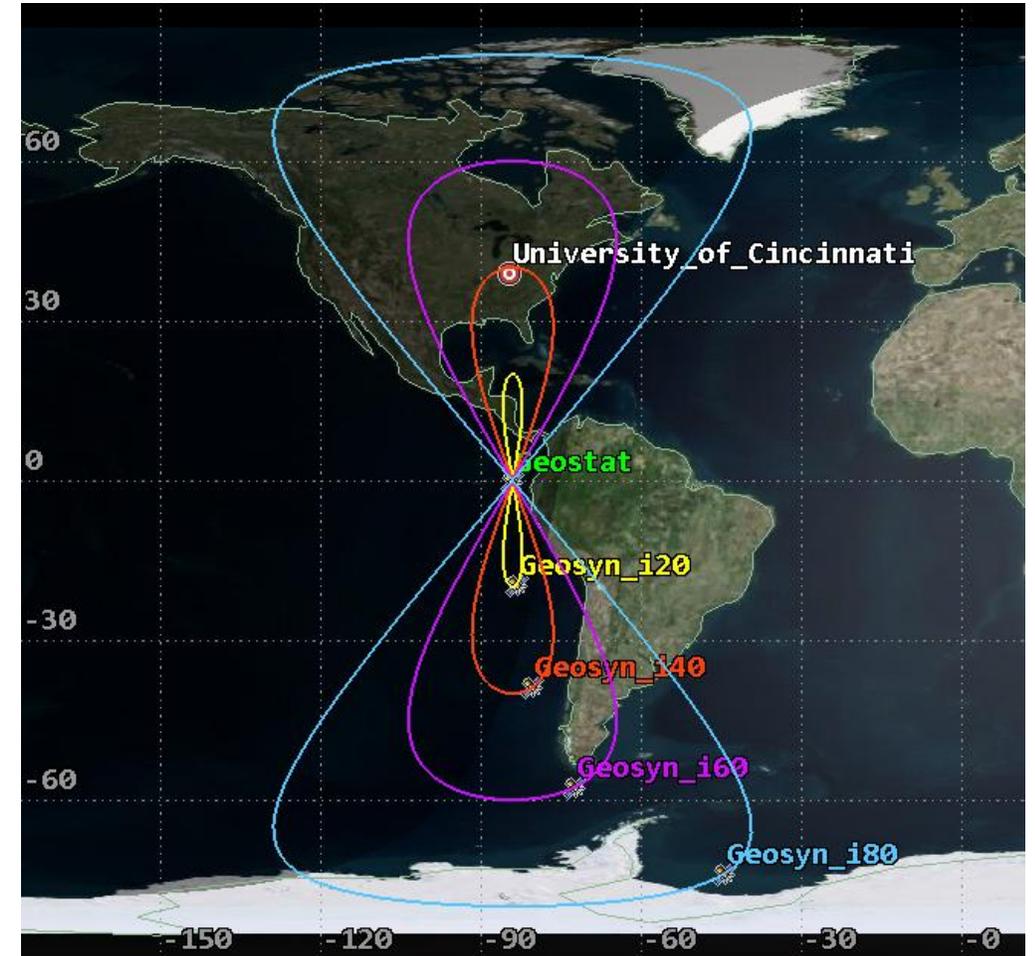
## The robotic crew shall...

- ✓ Be capable of assembling the station after orbit deployment.
- ✓ Dock supply spacecraft to the station.
- ✓ Move station materials, equipment, and experiments around the station.
- ✓ Be fully independent from human command beside being directed in overall task (e.g., no teleoperating).

# Orbital Mechanics

- ❖ Concept
- ❖ System Req.
- ❖ Orbital Mechanics
- ❖ Structure
- ❖ Electrical
- ❖ Thermal
- ❖ Communications

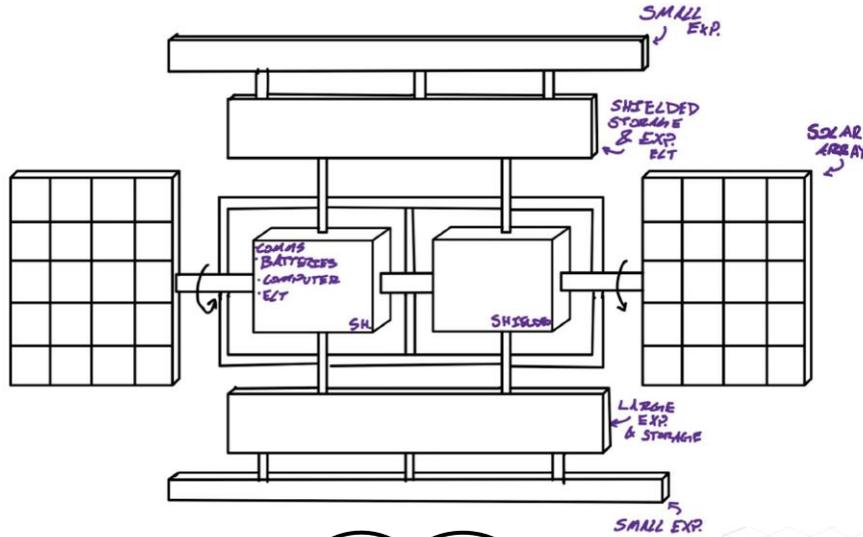
- ❑ The most popular in-space test facility is the International Space Station
  - Stays in a low-Earth orbit (~400 km)
  - End-of-life in 2030
  - Future is to transition to commercial stations
- ❑ The team is currently looking at geosynchronous orbits
  - ~35,786km with a period of one sidereal day
  - Untapped area for a test facility
  - Radiation hardened or high-latency sensors
  - Can test Earth observation, Space Domain Awareness, or deep space sensors



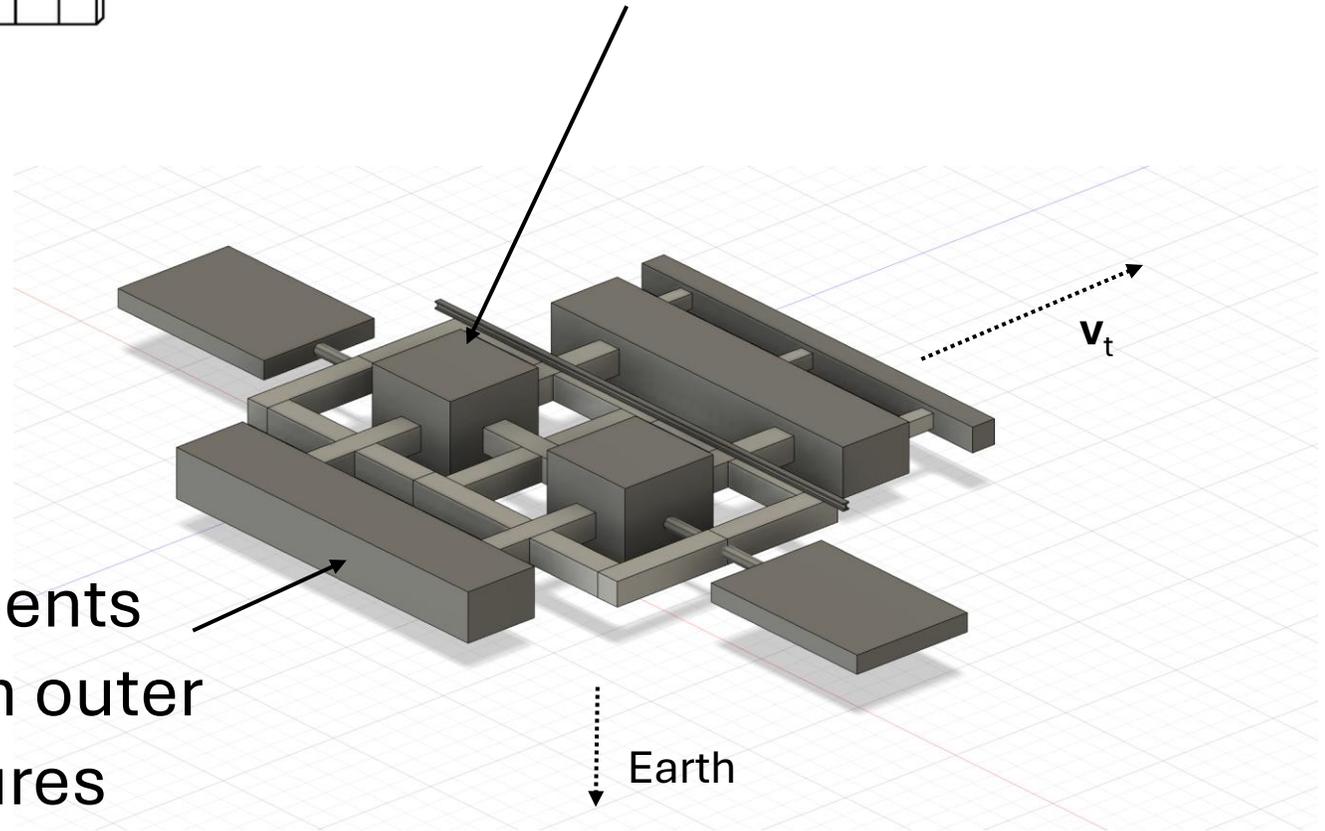
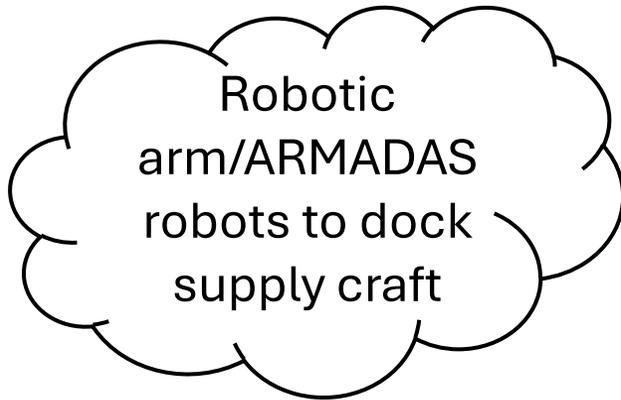
Geo-satellites at varying inclinations in Ansys STK (2D track)

# Structure

- ❖ Concept
- ❖ System Req.
- ❖ Orbital Mechanics
- ❖ Structure
- ❖ Electrical
- ❖ Thermal
- ❖ Communications



Communications,  
batteries, computers  
etc. in central  
compartments

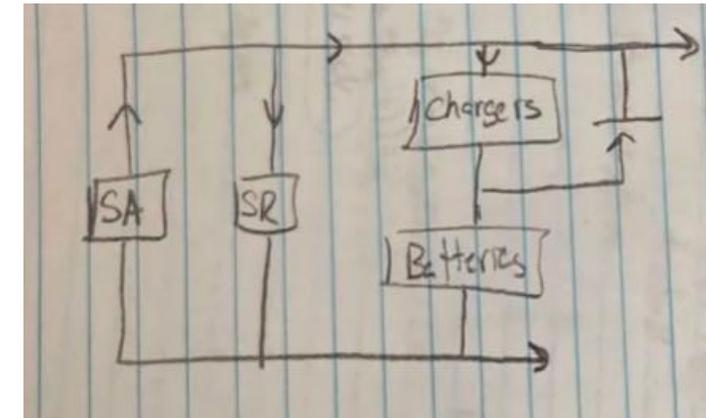
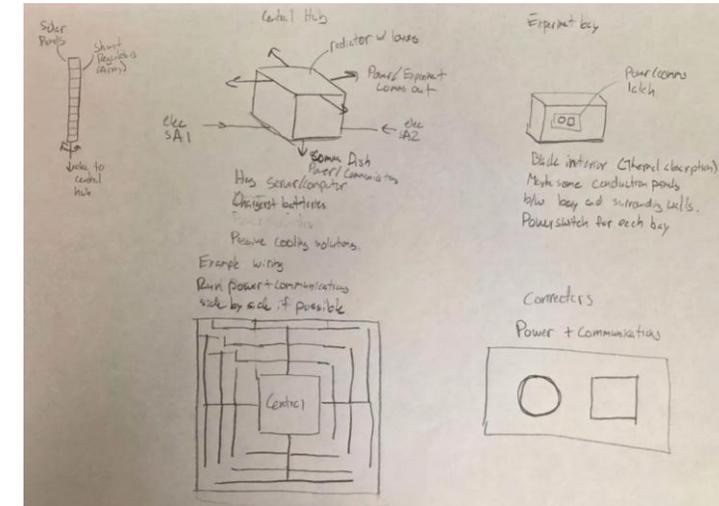


Experiments  
dock to on outer  
structures

# Electrical / Power Systems

- ❖ Concept
- ❖ System Req.
- ❖ Orbital Mechanics
- ❖ Structure
- ❖ Electrical
- ❖ Thermal
- ❖ Communications

- ❑ Central storage and computing
- ❑ Direct Energy Transfer (DET) power system
  - Quasi-regulated system with constant current chargers
  - Powered via solar panels
    - Shunt arrays on the back of
  - Lithium-ion batteries
    - High power density (70-110 W\*hr/kg)
  - Advantages over a Peak Power Transfer (PPT) system
    - Fewer parts
    - Lower mass
    - Higher efficiency at end of life



# Thermal Systems

❑ Maximum power dissipation:

$$q_{rad} = \sigma T_x^4$$

$$T_{stat, des} = 293 K, T_{sun} = 5800 K, T_{space} = 4K, q_{albedo} = 496.3 \frac{W}{m^2}$$

$$\alpha q_{sun} A + \alpha q_{Albedo} A + 6\alpha q_{space} A - 6\epsilon q_{surface} A + \dot{q} = 0$$

$$A = 17.4 m^2 \text{ per side} = 4.17 m \times 4.17 m$$

Assumed black bodies, the station is a cube, even temperature distribution.

❑ Externals coated with a white thermal coating/paint

➤ Z93

- Rho: 0.8
- Epsilon: 0.92

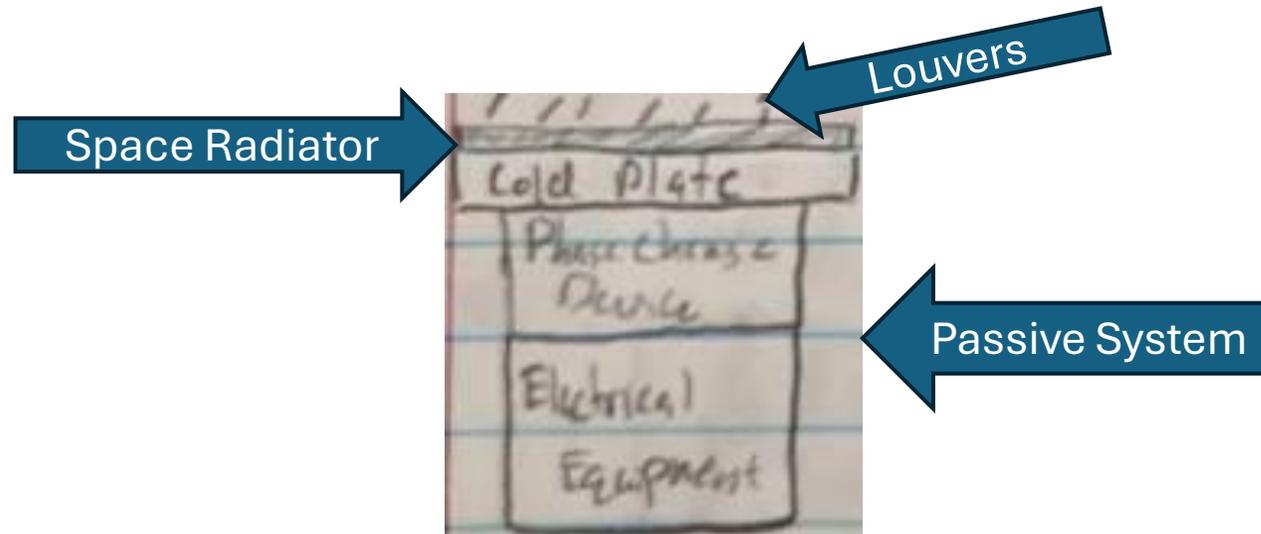
➤ Ultra-white paint from Purdue (Nano-paints values):

- Rho: 0.981
- Epsilon = 0.95

❑ Internals with black paint to facilitate heat transfer from the station internals to their externals

# Thermal Systems: Main Electronics

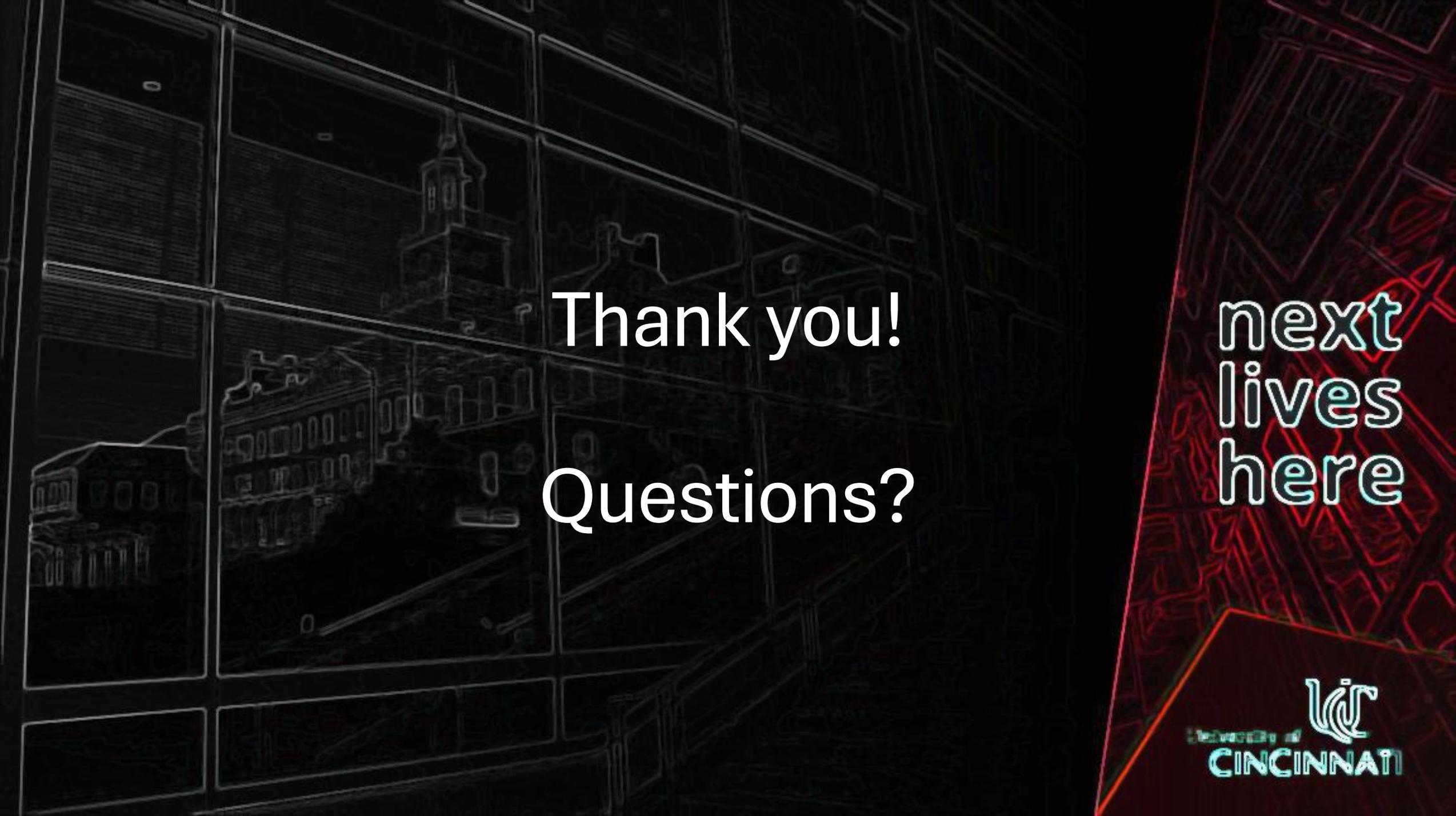
- ❑ Shunt arrays to help dissipate excess power generation
  - Located on other side of solar arrays
  - Decrease surface area needed for heat dissipation
- ❑ Passive heat discharger with phase change devices and cold plates
- ❑ Space radiator with louvers to help regulate passive heat discharge



# Communication

- ❑ The commercial persistent platform will handle most operations autonomously but will have capacity for remote operations, data downlinks and TT&C enabled by similar communication structure as the International Space Station (ISS).
- ❑ The platform, like the ISS, will rely on the NASA-managed Space Network which uses a constellation of TDRS satellites. This is used for the central control of the station.
- ❑ Additionally, each payload may have a smaller X-Band communication modules that each client may design an access independent from central control of the platform.
- ❑ Given Parameters:
  - 50 MBit/s data rate
  - Geostationary orbit

Parameter	Notional 50 Mbit/s Ku (This Design)	AAC Clyde PULSAR-XTX (X-Band Smallsat)
Band / freq.	Ku, ~15 GHz TX	X-band, 8.025–8.375 GHz ( <a href="#">Satsearch</a> )
Data rate (max)	50 Mbit/s (QPSK + FEC)	10–50 Mbit/s (OQPSK/QPSK) ( <a href="#">Satsearch</a> )
Required spacecraft EIRP	~54 dBW (from link budget)	~43 dBW with 2 W + ~11 dBi antenna (direct-to-Earth)
Antenna type & size	1.0 m Ku parabolic dish on 2-axis gimbal	Small X-band patch (~8–10 dBi)
RF output power (Tx)	~20 W RF	2 W RF (33 dBm) ( <a href="#">Satsearch</a> )
Peak DC power (Tx mode)	~150 W (HPA + baseband)	< 10 W (Tx electronics) ( <a href="#">AAC Clyde Space</a> )
Approx. comms hardware mass	~40–60 kg (antenna + RF electronics)	< 0.2 kg (Tx + patch antenna)



Thank you!  
Questions?

next  
lives  
here

Backup

next  
lives  
here

IASRL

University of  
CINCINNATI



# C3 Flash Talk

Bruce Noble, Brendan King, Connor Hall, Lawrence Tolentino,  
Parker Scribner, Paul Brich, Paytn Barnette

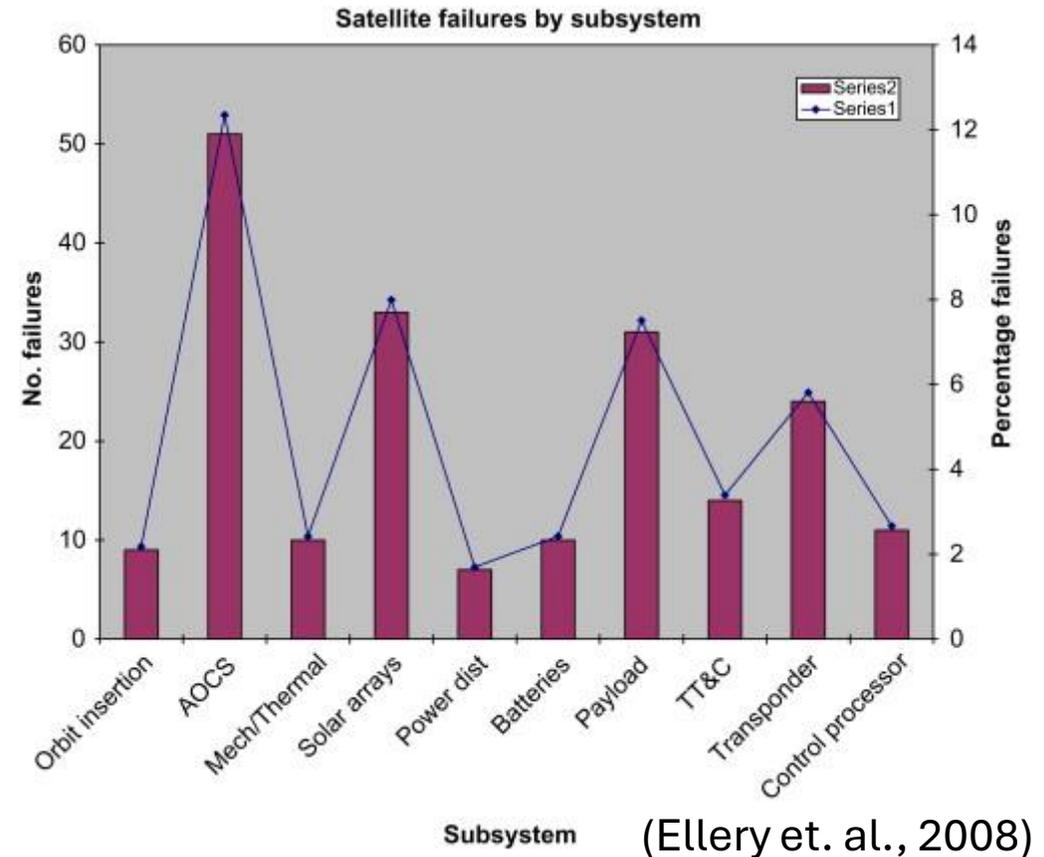
# Mission Goals

- Clients are GEO satellites
  - More cost savings
- Service multiple satellites in one launch
- Focus on servicing current satellites



# Satellite Failure Break Down

- Most common failures for satellites
  - Lack of propellant to maintain orbit and attitude (AOCS) (Ellery et. al., 2008)
  - Degradation of solar panels causing insufficient power generation (Ellery et. al., 2008)

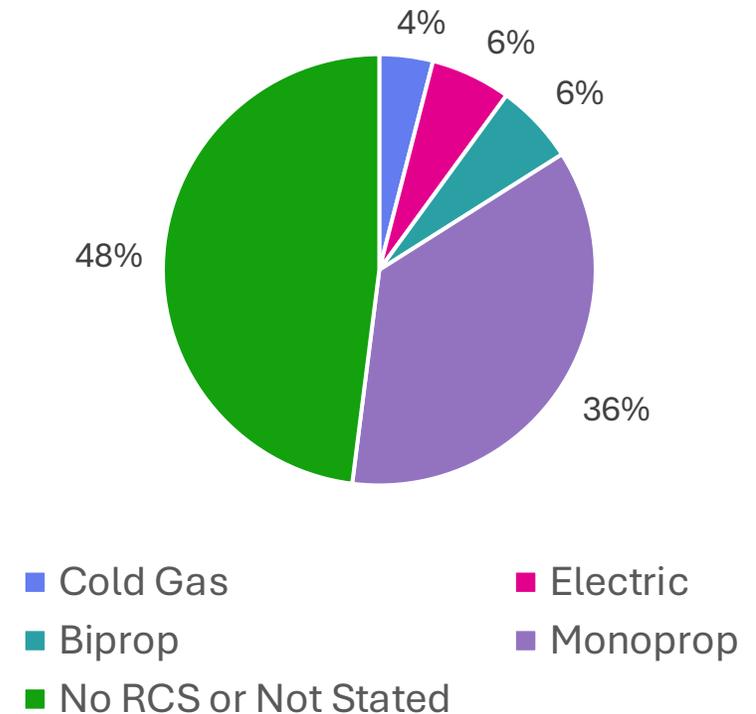


# Propellant Refill

# Propellant Refills are needed

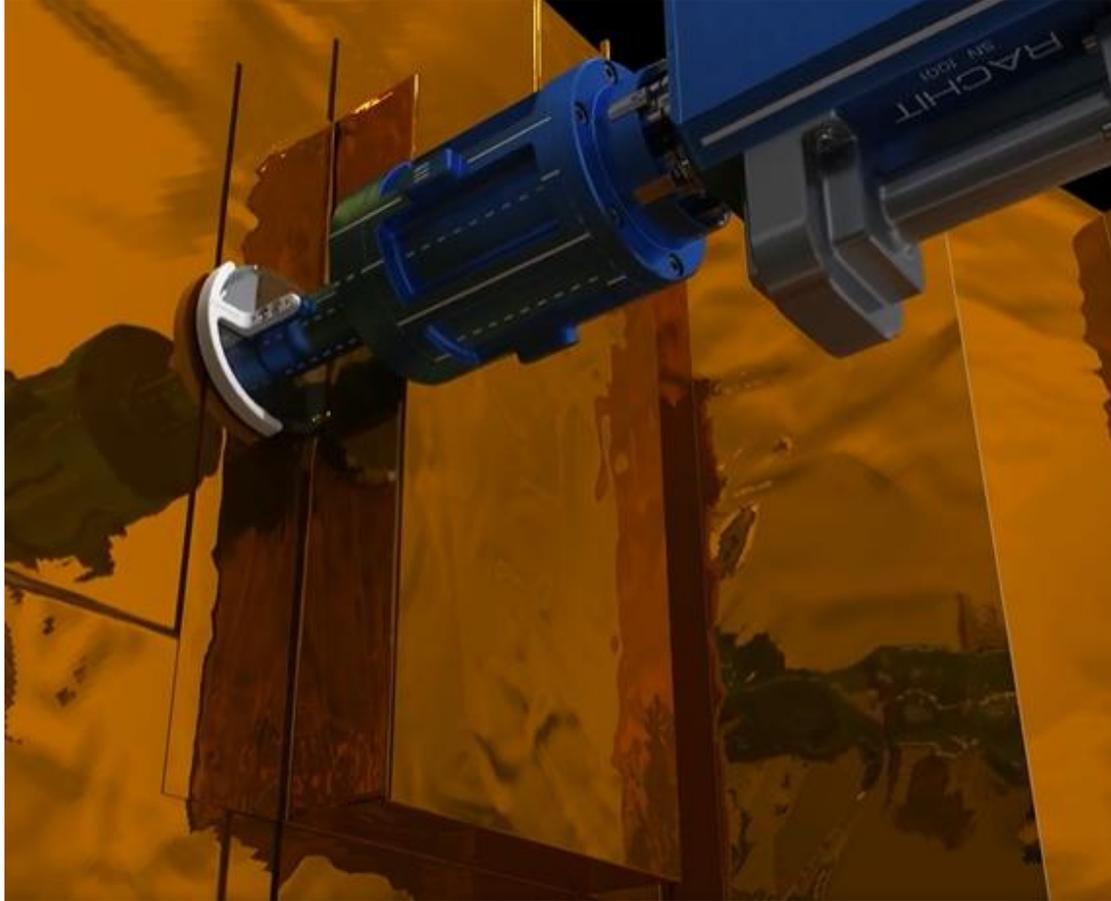
- Majority of satellites with a reaction control system (RCS) use single-component mono-propellant
- Majority of mono-propellant used is Hydrazine
- Need to manage the Catalyst

Types of Reaction Control Systems Used on Currently Active Satellites (Sept 2025)

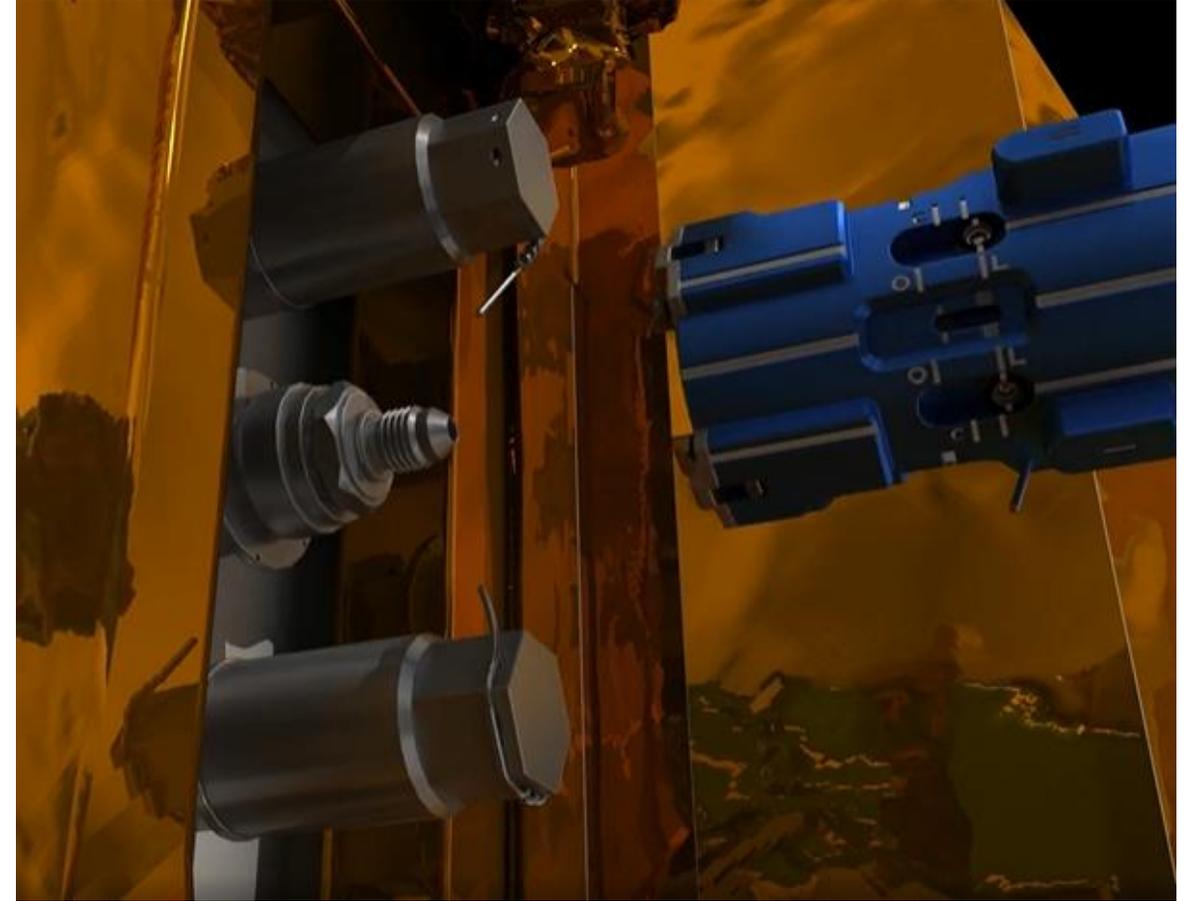


(OSCAR and eoPortal, 2025)

# Existing Methods to access the Refilling Ports are Complex

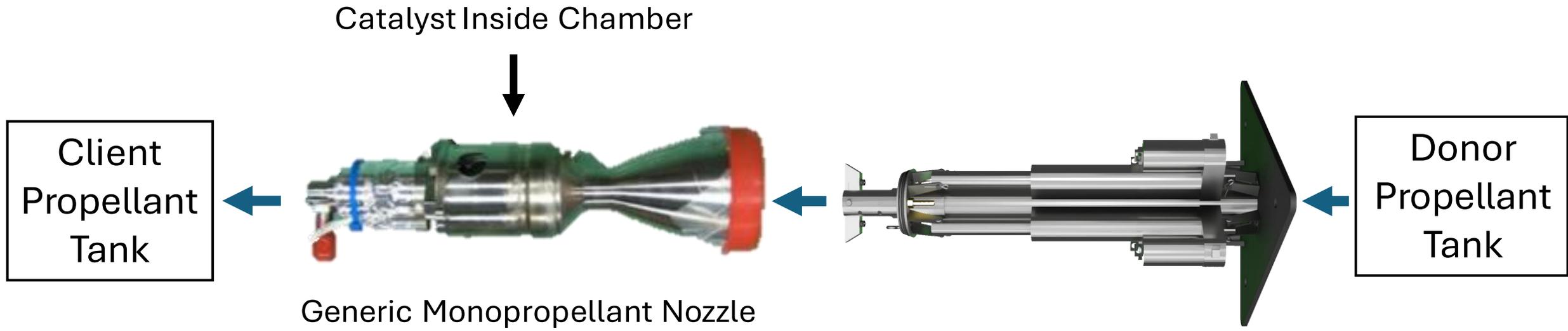


OSAM-1 Mission: Cutting MLI to access refuel port

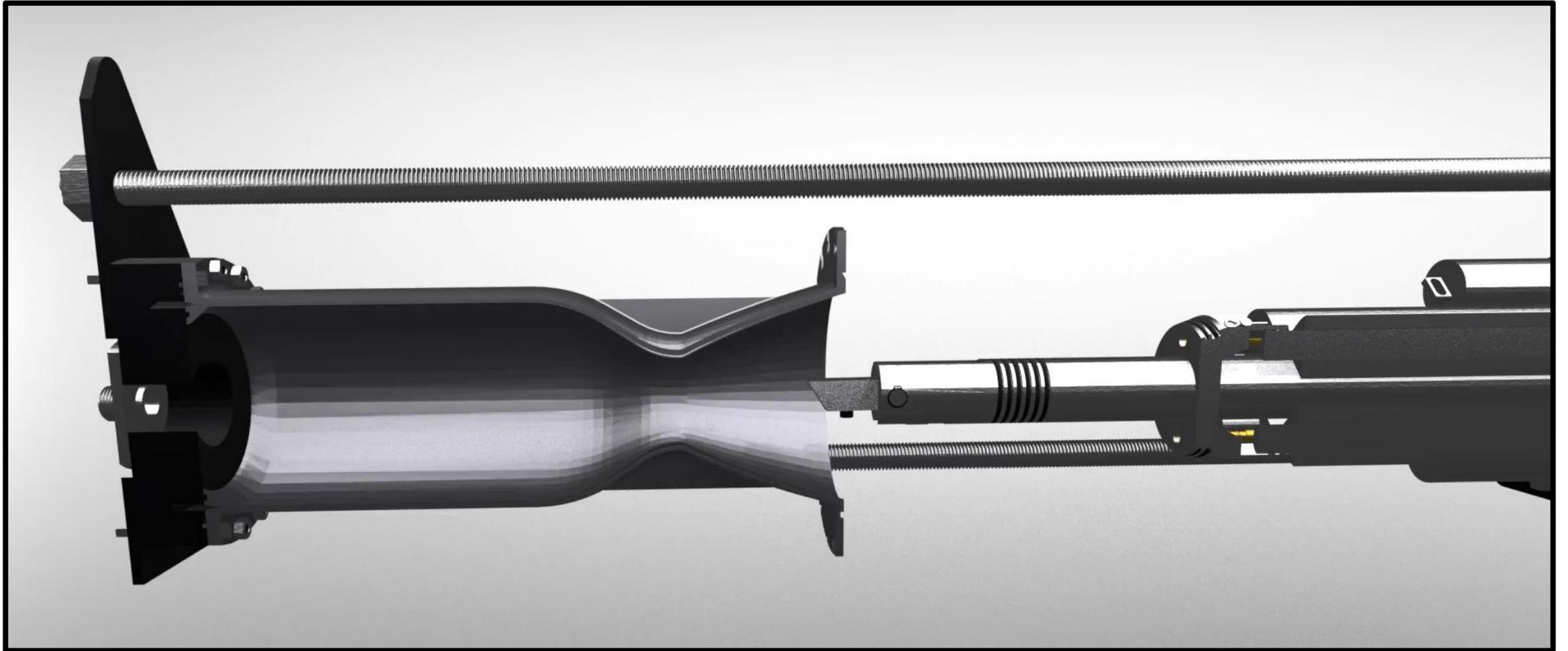


Uncapping port and then refueling spacecraft

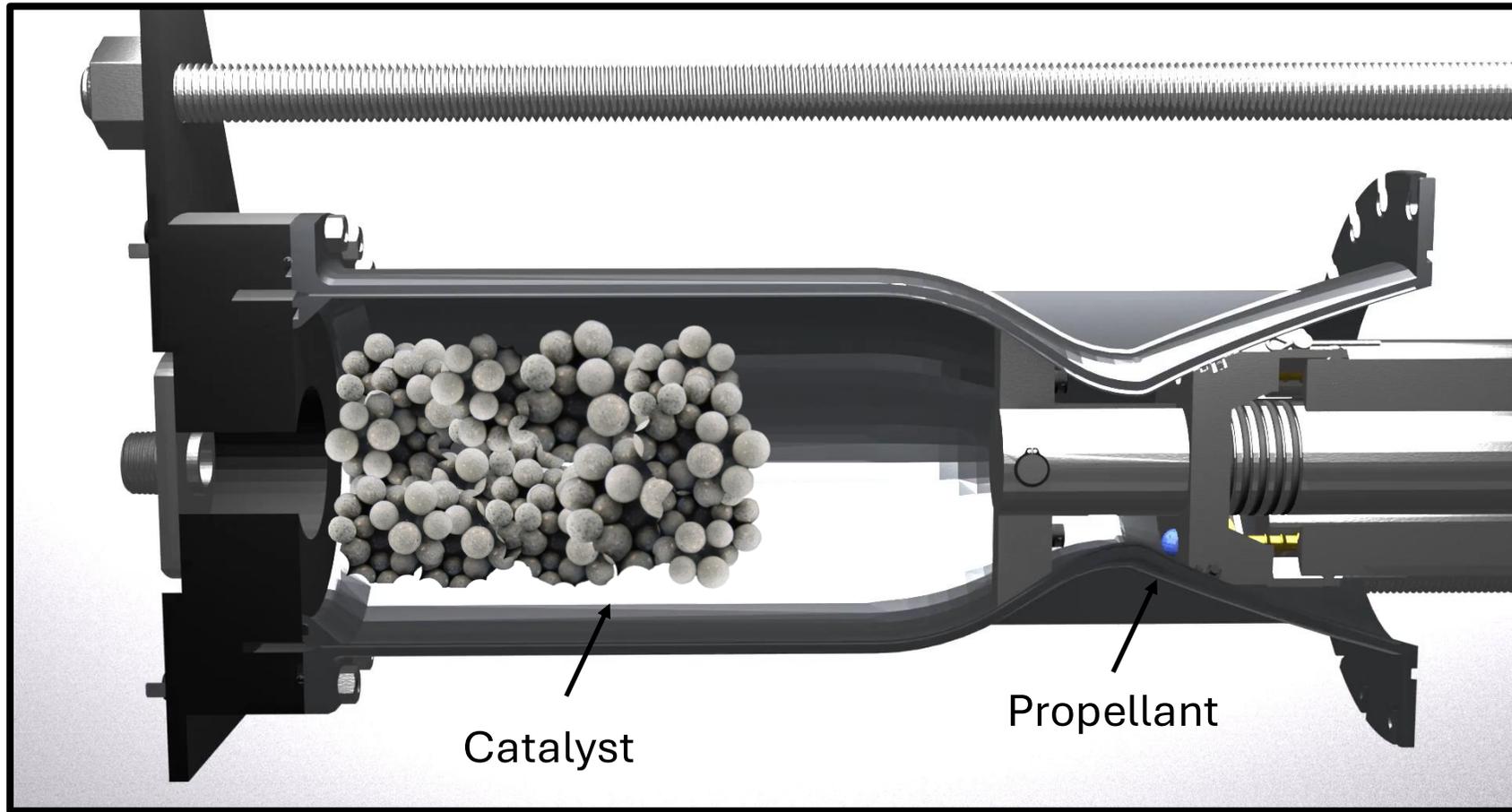
# How to Backflow



# Docking and Sealing Animation



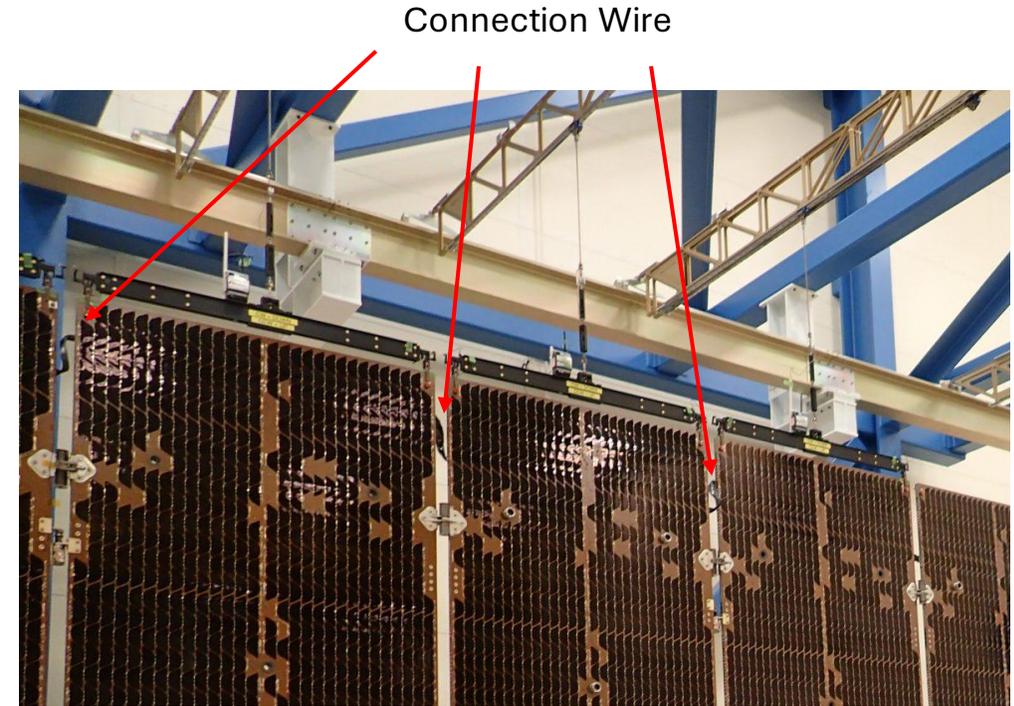
# Fluid Simulation Animation



# Solar Panel Repair

# Solar Panel Replacement is Complex

- Splicing into the power system requires complex robotics
- Wires are often small, requiring precision
- Integrating to installed electronics makes each mission unique



GOES-R Solar Panel in Assembly Bay

# External Concentrators are Easy to Implement

- Requires no electrical connection and integration
- Easily scalable
- Need to handle additional thermal loads



# Integration

# Both Solutions will be Integrated on One Satellite Bus

- Existing bus ESPASat
- Use a robotics arm for repair
  - Propellant refueling docking
  - Concentrator mounting
- Outfitted with its own refueling tank and solar concentrator storage



# Questions?



COSMIC Capstone Challenge:  
Mid Design Brief

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**PackNanoSat, North Carolina  
State University:  
Orbital Refueling – Track 3**

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Students: Mason Stimach, Nick Lawton, Will Bodnar  
Advisor: Felix Ewere  
Mentor: Uchechukwu Agwu

---

December 8, 2025

# Team Overview

*Orbital Replacement Unit for In-Orbit Refueling*

- PackNanoSat is NC State's first student-led experimental nanosatellite lab, focused on developing hands-on experience in satellite subsystems, in-space servicing technologies, and mission architecture through national competitions like COSMIC C3.
- Founded Fall 2025
- First major competition: COSMIC C3
- Student-led team
- Designing a modular spacecraft system capable of autonomously refueling client satellites using replaceable propellant ORUs.



Orbital Replacement Unit for In-Orbit Refueling

# Executive Summary

## *Orbital Replacement Unit for In-Orbit Refueling*



- Problem Identified
  - Many satellites lack modular servicing infrastructure for refueling.
  - Their lifetimes are limited by propellant depletion, leading to premature disposal and increased orbital debris.
  - Existing servicing methods are costly, complex, or non-autonomous.
- Capability We Are Proposing
  - An ESPASat-based servicing spacecraft equipped with:
    - Replaceable propellant Tank ORUs
    - A track-based internal handling system for ORU transfer
    - A standardized ISS-style docking interface for client satellites

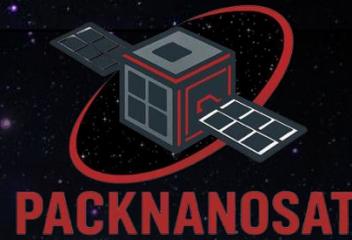


NASA Docking System

Orbital Replacement Unit for In-Orbit Refueling

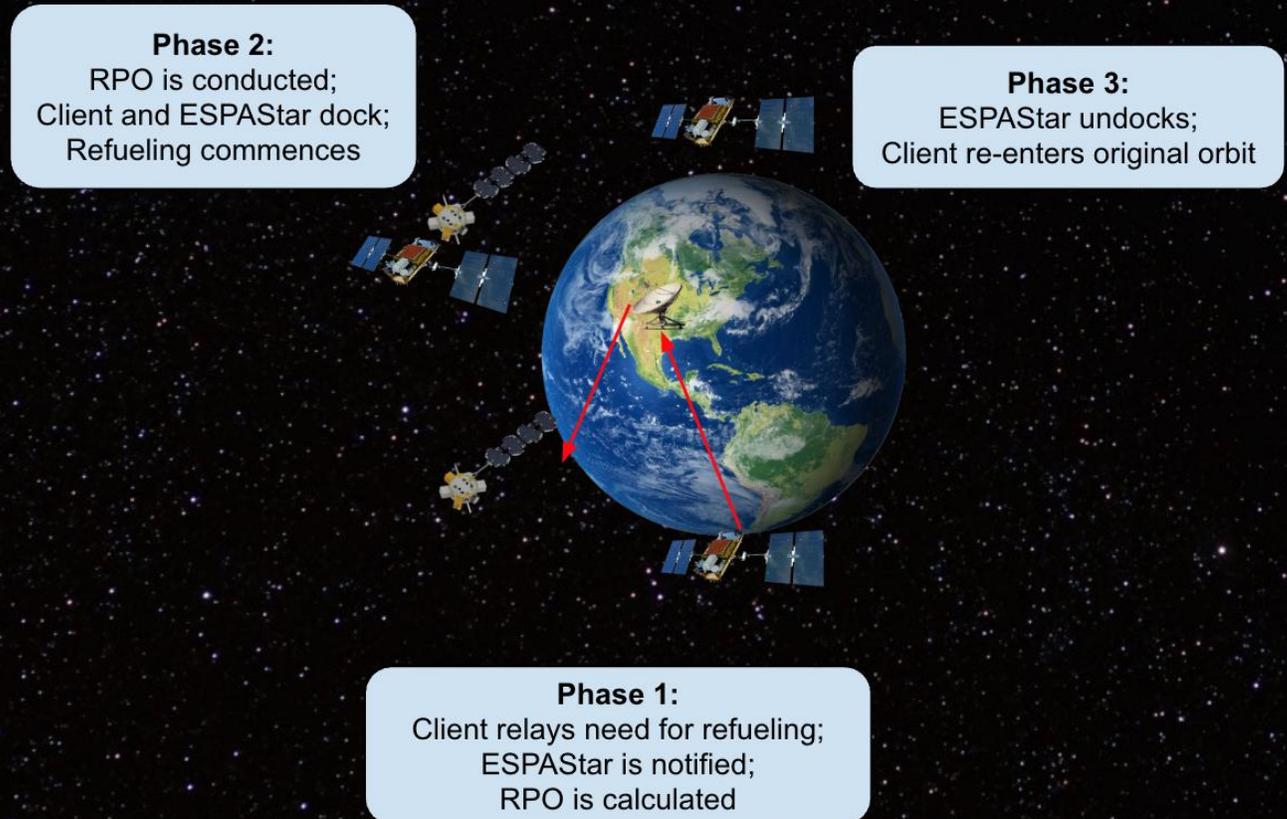
# Executive Summary

## Orbital Replacement Unit for In-Orbit Refueling



- How This Will Solve the Problem

- Enables autonomous refueling of multiple client satellites in LEO.
- Extends satellite lifetimes by reducing fuel-related end-of-life failures.
- Reduces orbital debris through life extension servicing.
- Demonstrates a modular ISAM architecture compatible with future missions.



# Projected Path

## *Orbital Replacement Unit for In-Orbit Refueling*



### Track System / ORU Transfer Mechanism:

- Goals:
  - Finalize concept trade between articulated arm vs. rail/track-based ORU exchange system
  - Define how ORUs will be moved internally once docking is complete
  - Identify physical constraints: tank size, storage layout, required clearances
  - Begin outlining operational sequence for tank removal/replacement
  - Sketch-level CAD or block-geometry models
- Funding Integration:
  - Space Grant funds will support initial prototyping materials and mechanism feasibility tests

# Projected Path

## *Orbital Replacement Unit for In-Orbit Refueling*



### Docking & Interface Mechanism:

- Goals:
  - Select docking approach (ISS-style mechanism is current baseline)
  - Define required alignment tolerances for transferring ORUs
  - Establish high-level fluid/propellant interface design requirements
  - Determine how modular docking must be to support multiple client satellites
  - Produce a preliminary interface process showing:
    - dock → secure → ORU removal → ORU replacement → undock
- Funding Integration:
  - Space Grant funding will support early interface mockups and latch-mechanism concept testing

# Projected Path

## *Orbital Replacement Unit for In-Orbit Refueling*



### Mission Analysis & System Integration:

- Goals:

- Select preferred orbit (e.g., 700–780 km LEO) and justify with  $\Delta v$  and servicing logic
- Build a detailed flowchart of the servicing sequence
- Draft preliminary CONOPS for SRR, including:
  - client request
  - rendezvous planning
  - tank exchange
  - undocking and return orbit
- Define communication handshakes between ESPASat bus, docking subsystem, and ORU transfer mechanism

- Funding Integration:

- Space Grant funds will support software/system modeling tools and early integration testing rigs

# Projected Path

## *Orbital Replacement Unit for In-Orbit Refueling*



Beyond This Semester:

- Expand PackNanoSat into a sustainable, long-term student satellite program.
- Build foundational infrastructure:
  - Small workspace / lab
  - Documentation repository for future teams
- Prepare to compete in C3 again next year with a more mature team.
- Grow multidisciplinary membership (MAE, ECE, CS) to support full spacecraft development.



# Manufacturing of Cold-Welded Assemblies COSMIC Capstone Challenge

Mid –Design Brief

Embry Riddle Aeronautical University  
December 8, 2025

Keven Duong, Ben Grieger, Cordelia Kohuth, Daniel  
Mount, Ela Ozatay, Manan Patel, & Abigail Storey

Advisor: Dr. Kaela Martin, Dr. Dawn Armfield

Mentor: Sara Mitran



# Organizational structure of team MOCA.

**Team Lead**



Manan Patel

**Co-Team Lead**



Daniel Mount



Keven Duong



Ben Grieger



Cordelia Kohuth



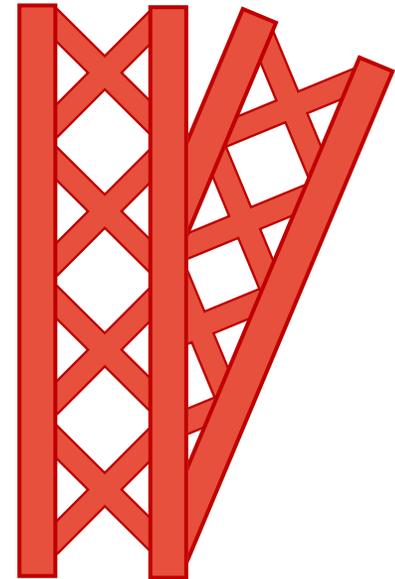
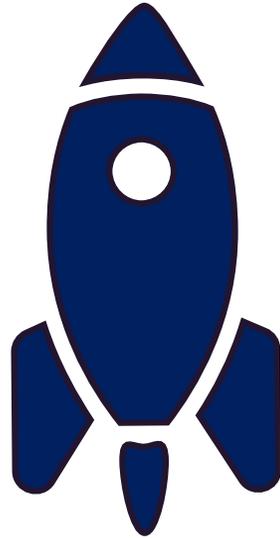
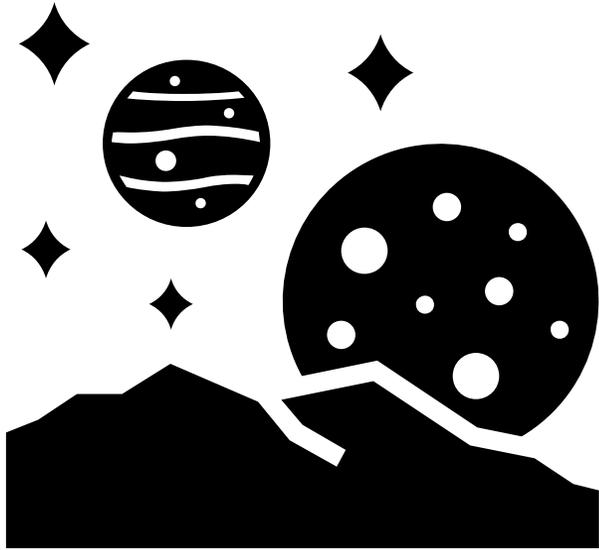
Ela Ozatay



Abigail Storey

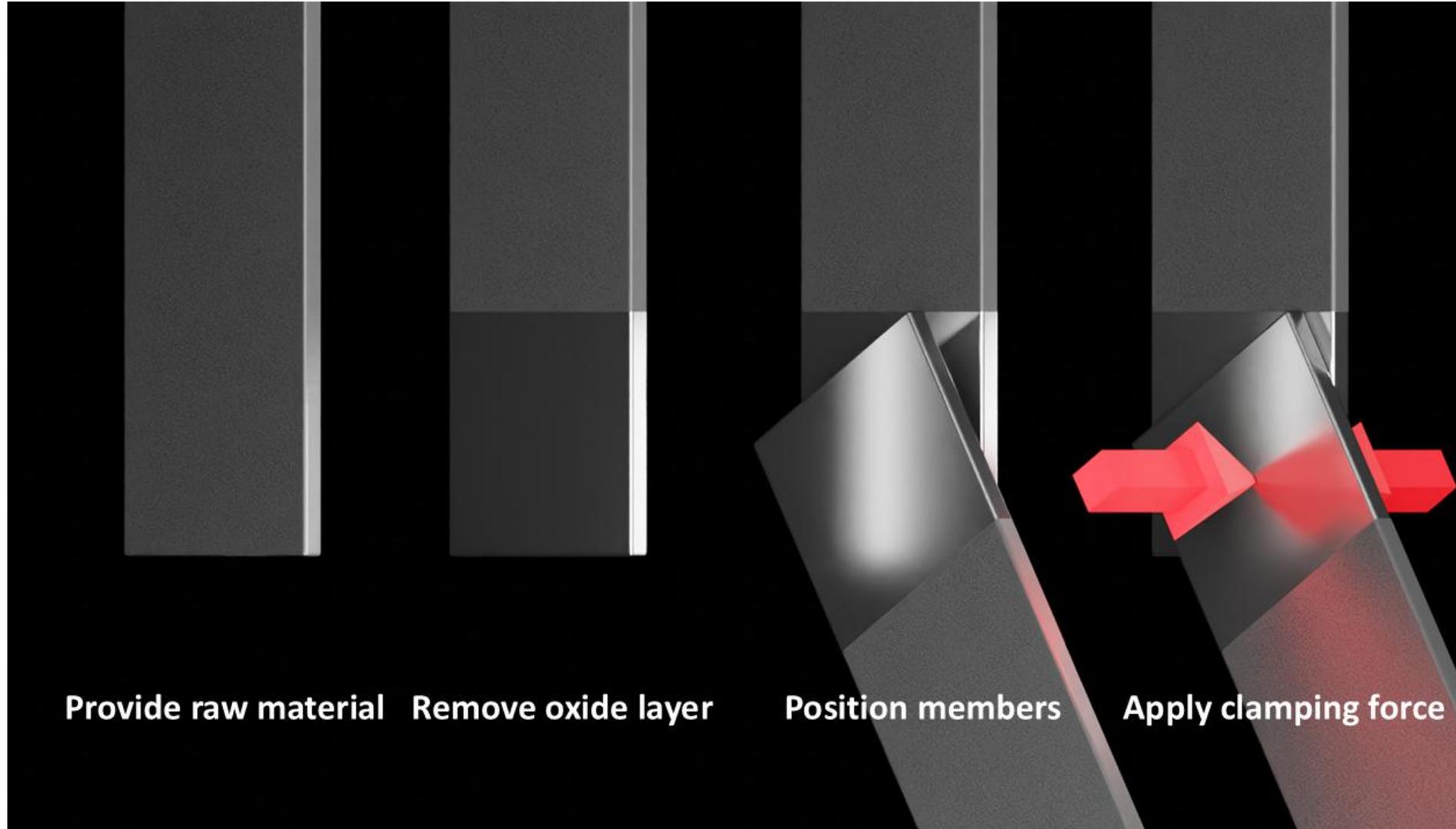


The size of space structures are constrained to modern payload restrictions.



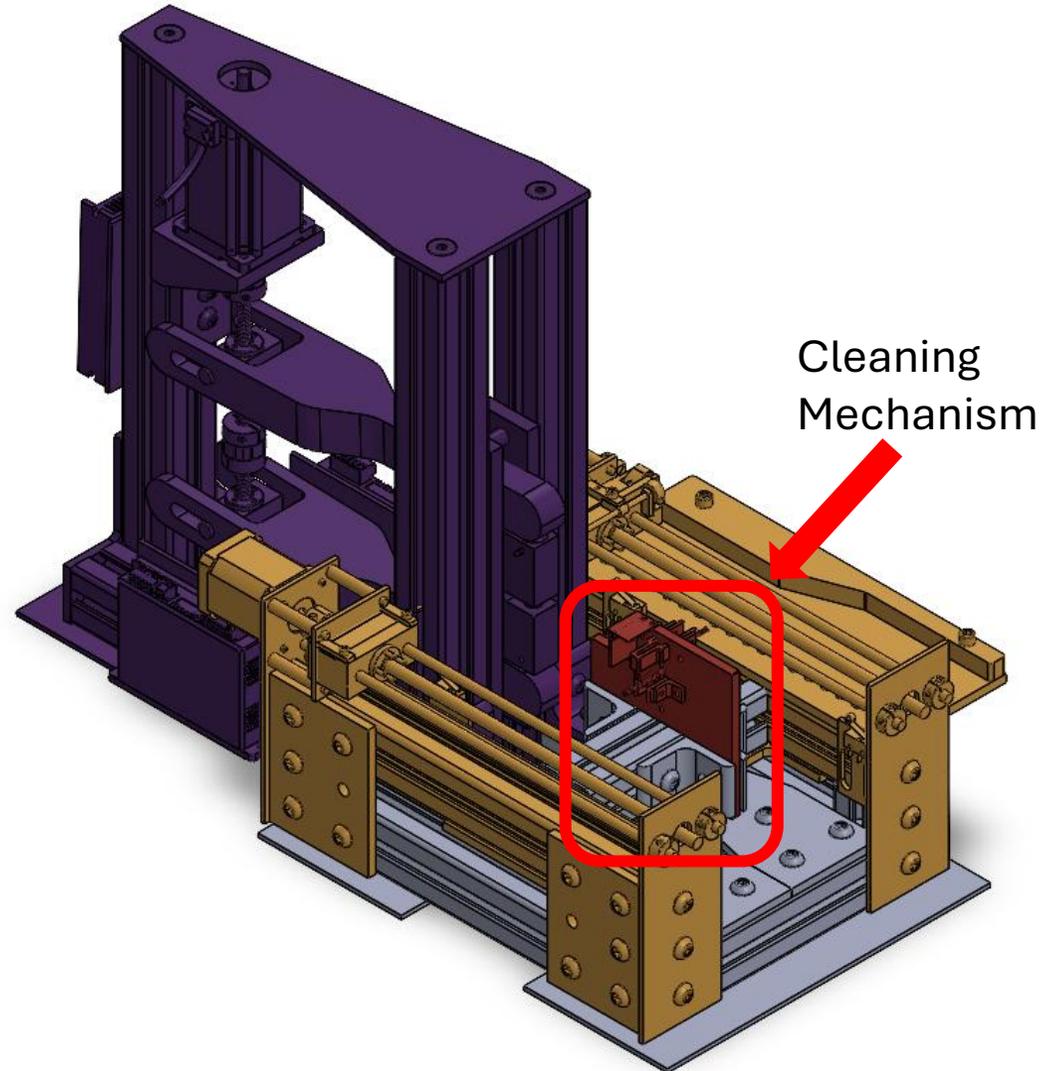


MOCA enables truss joints to be cold-welded by removing the oxide layer and applying pressure.



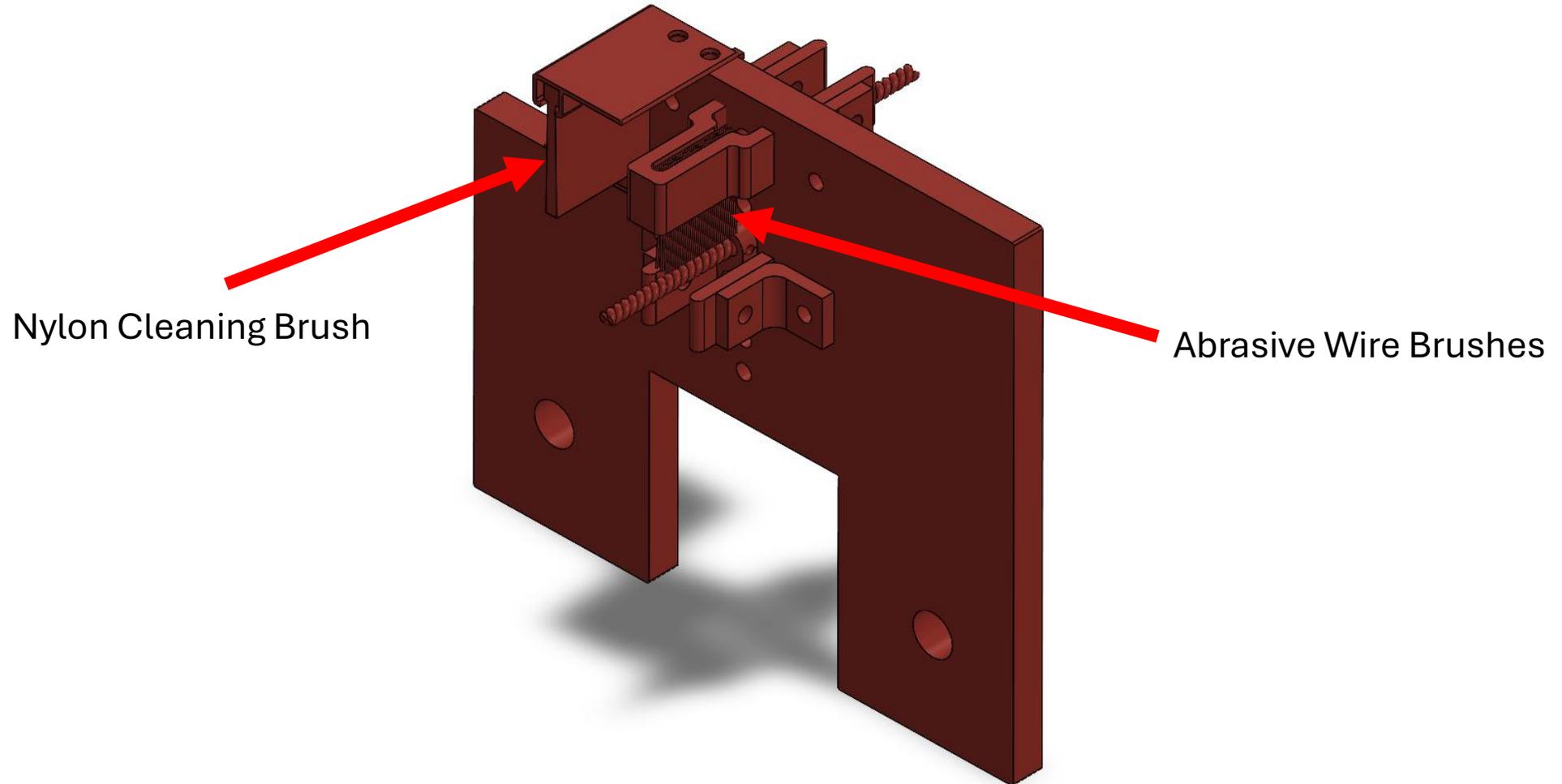


MOCA's cleaning mechanism removes the oxide layer and brushes off the contaminants.



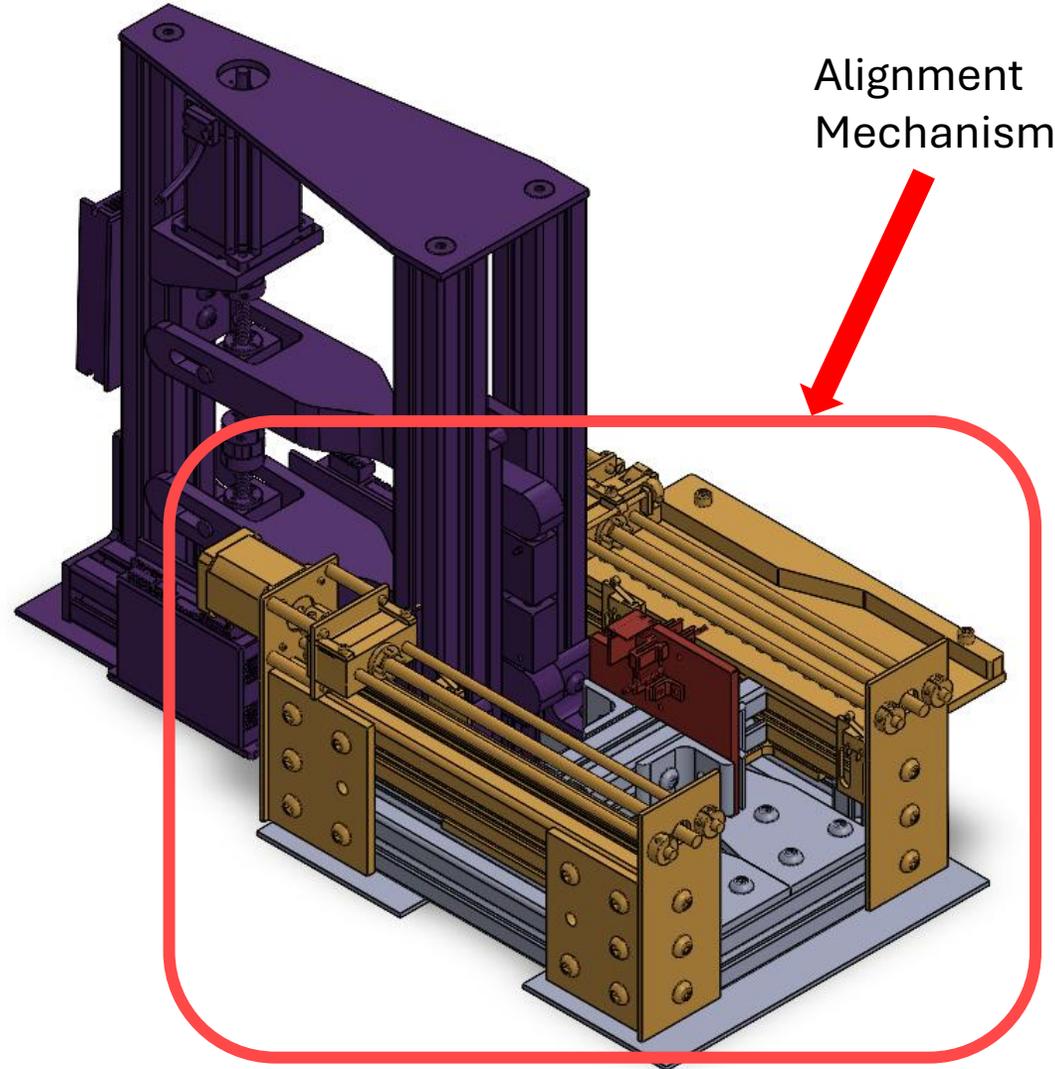


The cleaning mechanism has the required abrasiveness needed to scrap the oxide layer off.



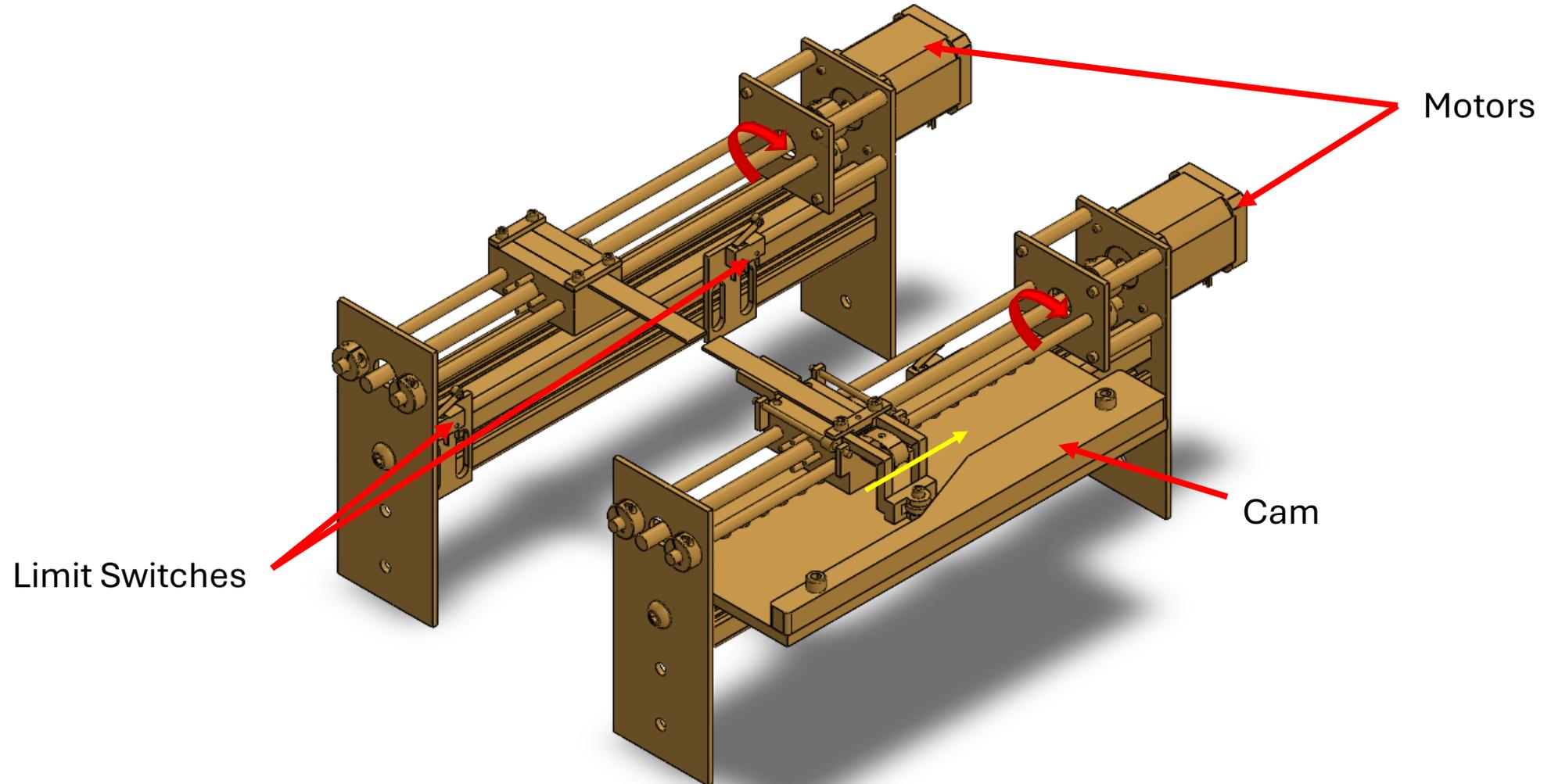


MOCA's alignment mechanism aligns the pieces into the pressure mechanism.



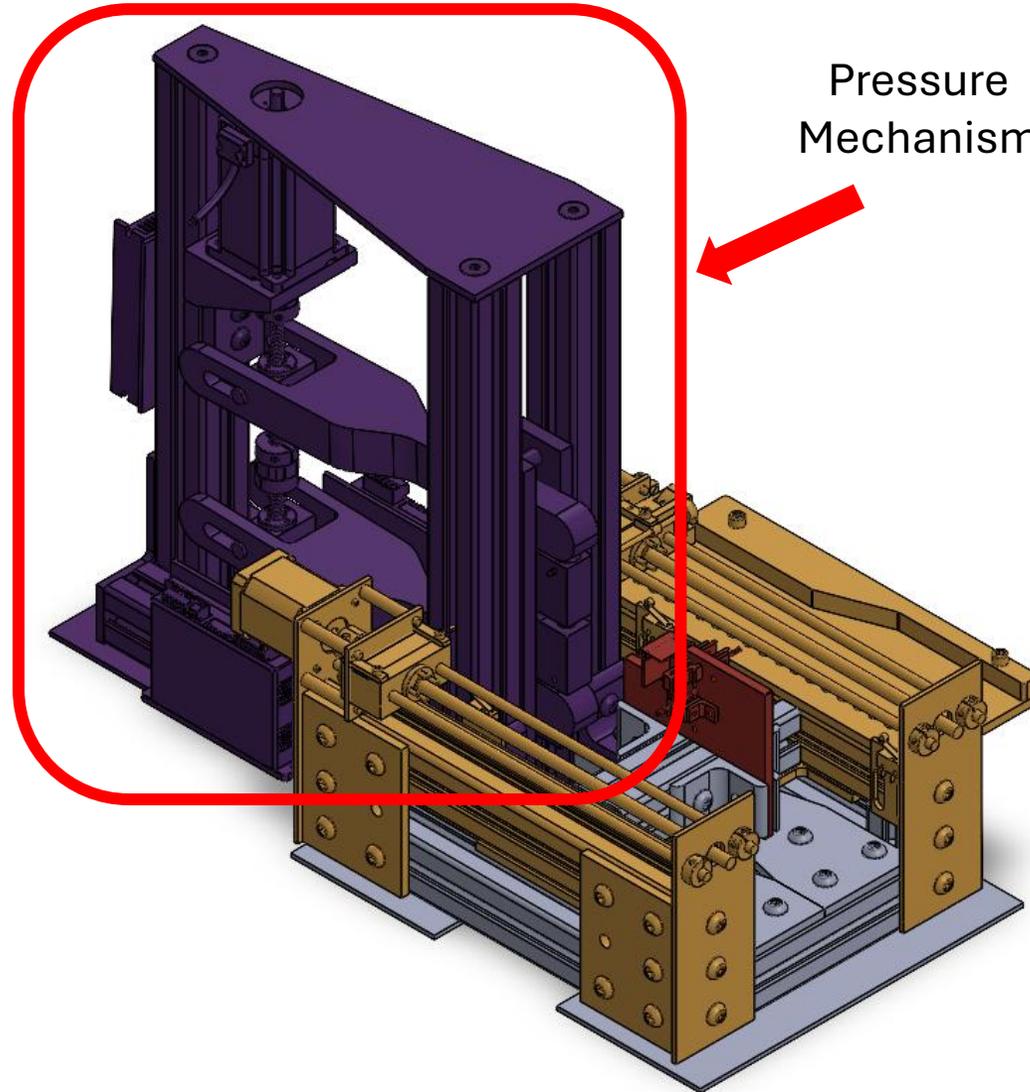


The alignment mechanism motor has the power to overcome all the friction forces.





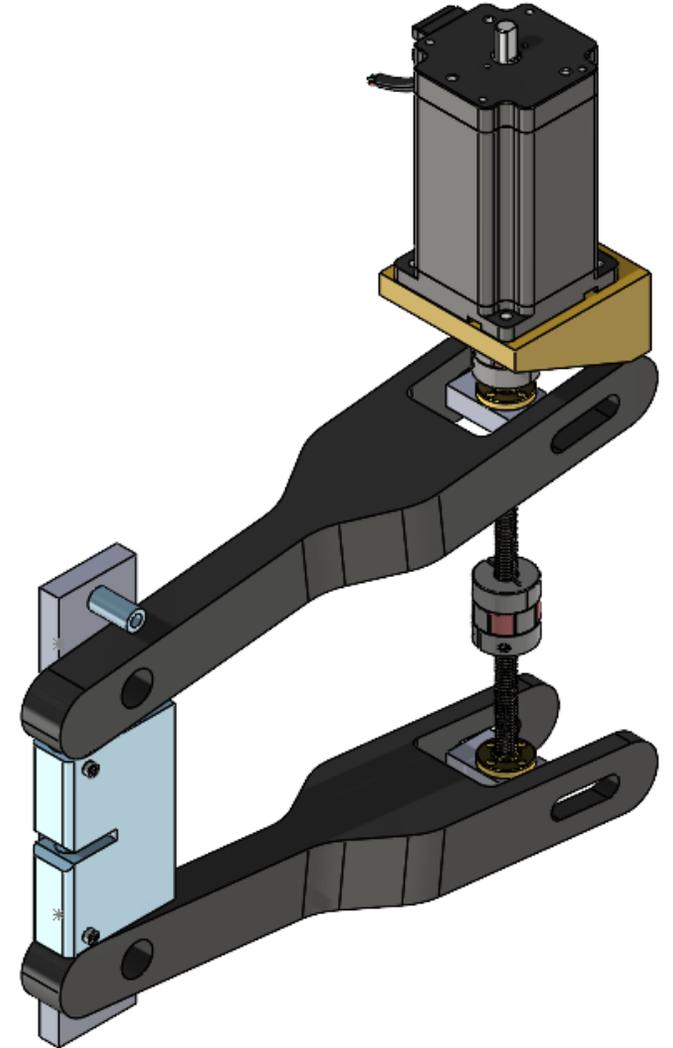
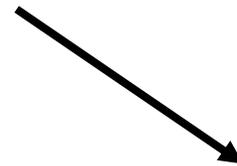
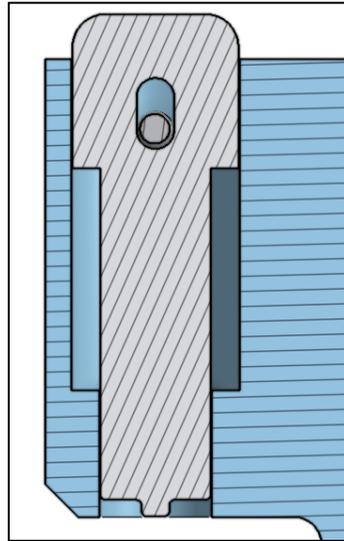
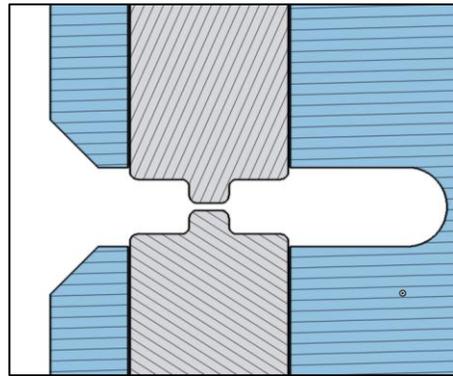
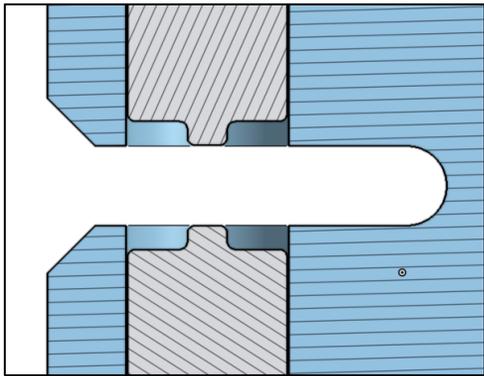
MOCA's Pressure Mechanism applies pressure to the members.



Pressure  
Mechanism

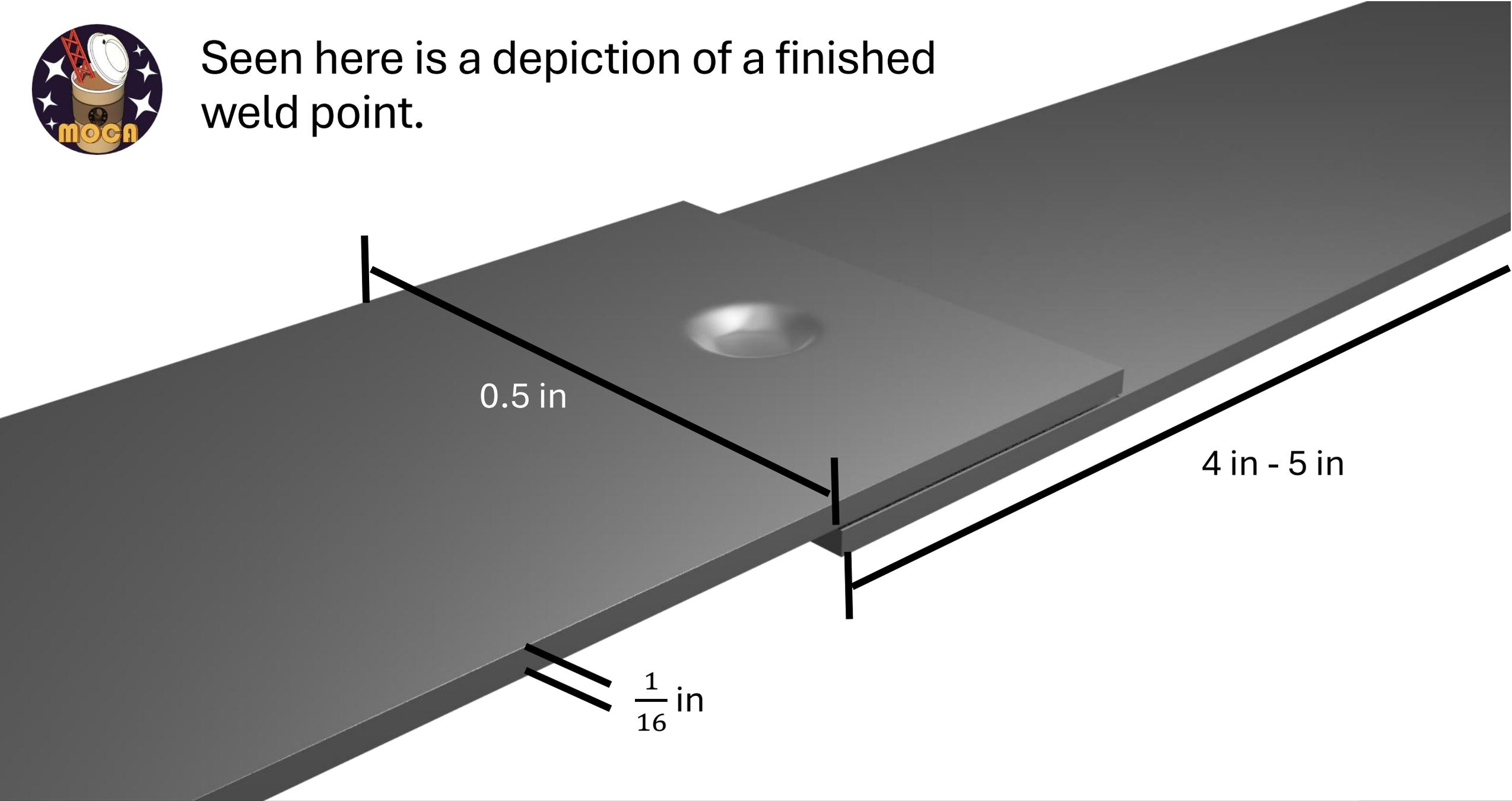


The pressure mechanism is a clamp that applies pressure to a very small point.



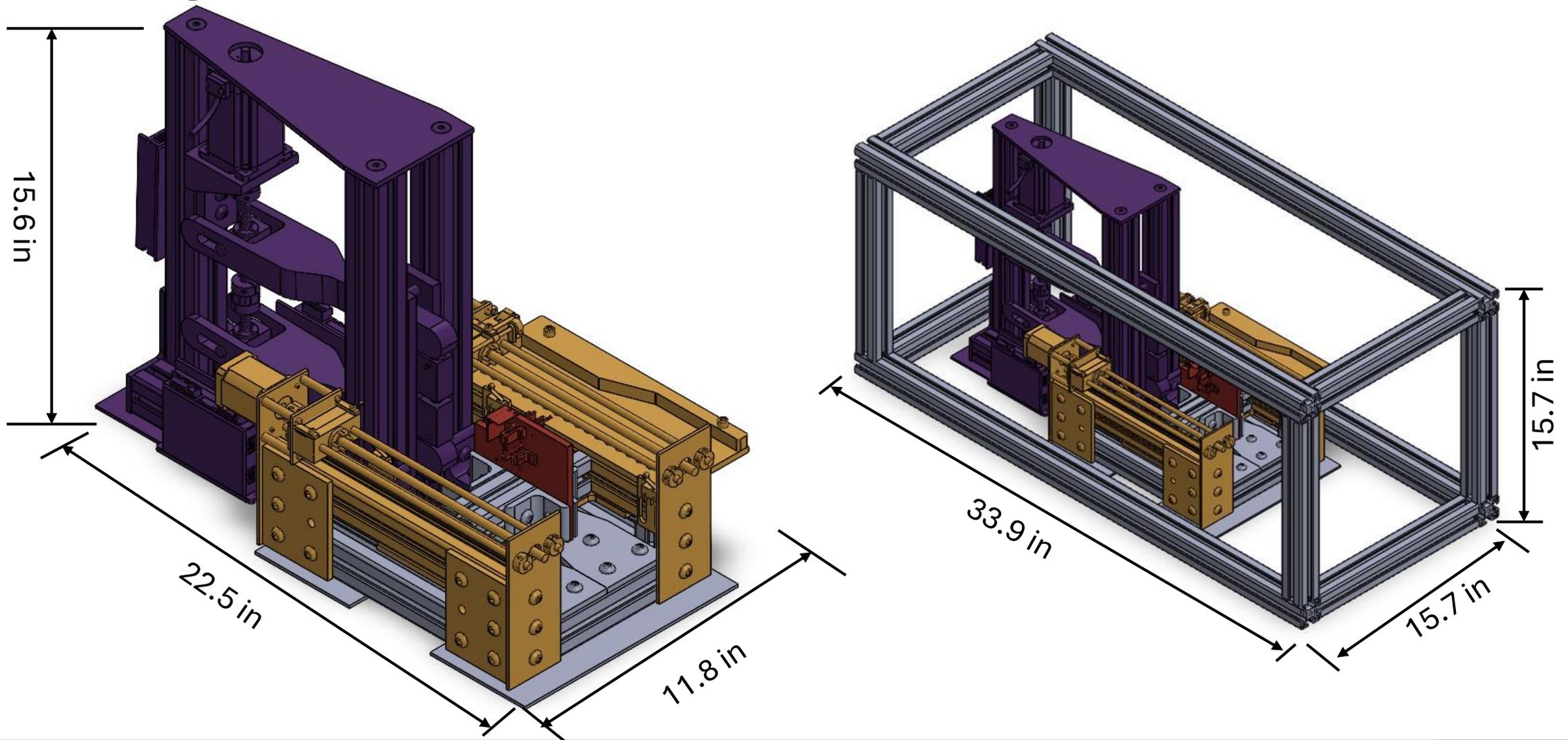


Seen here is a depiction of a finished weld point.



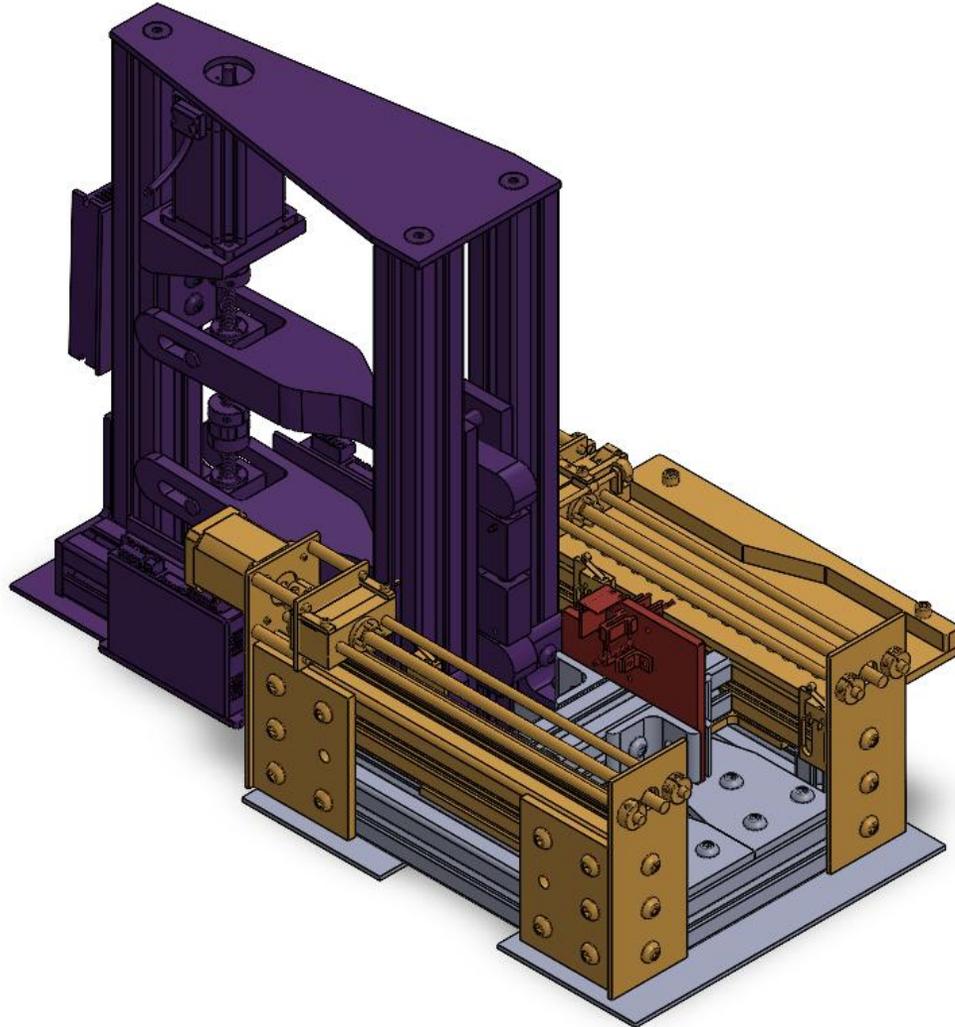


MOCA's will continue to build and test the finalized design.





MOCA will enable the construction of cold-welded truss joints while in orbit.



Questions?



# References

- [1] Chown, M., ‘Confused about gravity? Here are 12 facts about the force that keeps us grounded’ Available: <https://www.skyatnightmagazine.com/space-science/what-is-gravity-facts-about-force>.  
Orbit Pic - <https://www.skyatnightmagazine.com/space-science/what-is-gravity-facts-about-force>
- [2] Cosmicspace, ‘C3: COSMIC Capstone Challenge’ Available: <https://cosmicspace.org/c3/>.
- [3] Arkisys, “Arkisys – Enabling a New Space Infrastructure,” [Online]. Available: <https://www.arkisys.com/>.
- [4] Cosmicspace, ‘BOSUNS LOCKER Family: interface Control Document (ICD) V2.4’ Available: <https://cosmicspace.org/wp-content/uploads/2025/07/Bosuns-Locker-Prelim-ICD-7.9.pdf>.
- [5] STEPPERONLINE, “Digital Stepper Driver 1.8–5.6A 20–50VDC,” Amazon, [Online]. Available: <https://www.amazon.com/STEPPERONLINE-Digital-Stepper-1-8-5-6A-20-50VDC/dp/B074TBM7N>.
- [6] STEPPERONLINE, “Stepper Motor Driver 1.0–4.2A 20–50VDC Micro-step Resolutions,” Amazon, [Online]. Available: <https://www.amazon.com/STEPPERONLINE-1-0-4-2A-20-50VDC-Micro-step-Resolutions/dp/B06Y5VPSFN>.
- [7] Arduino, “Mega 2560 Rev3 Compatible Board,” Amazon, [Online]. Available: <https://www.amazon.com/Arduino-ATmega2560-Compatible-Advanced-Projects/dp/B0046AMGW0/>.



# References

- [8] Omron Electronics Inc. – EMC Div., “SS-01GL2-3T Microswitch,” Digi-Key Electronics, [Online]. Available: <https://www.digikey.com/en/products/detail/omron-electronics-inc-emc-div/SS-01GL2-3T/5236930>.
- [9] Avnet, ‘72-7245’ Available: <https://il.farnell.com/tenma/72-7245/power-supply-2ch-30v-3a-adjustable/dp/4911787>.
- [10] Flyrobo, ‘3d-printer-cnc-copper-lead-screw-nut-2x8mm’ Available: <https://www.flyrobo.in/image/cache/catalog/3d-printer-cnc-copper-lead-screw-nut-2x8mm/3d-printer-cnc-copper-lead-screw-nut-2x8mm3-1000x1000.jpeg>.
- [11] Tumblr, ‘Stepper Motor’ Available: [https://66.media.tumblr.com/a1f06c67e9e0ed4cd5b71c658d64a102/tumblr\\_miu2k9pWrv1rn2rmco1\\_1280.jpg](https://66.media.tumblr.com/a1f06c67e9e0ed4cd5b71c658d64a102/tumblr_miu2k9pWrv1rn2rmco1_1280.jpg).
- [12] Microlube, ‘Grease Lubrication’ Available: <https://www.micro-lube.com/wp-content/uploads/2022/09/Grease-Lubrication.jpg>.



Total mass of MOCA is 55 lbs, total power is 252 W, and costs \$1,450.

**Table 8.6:** Subsystem Mass Allocation

Subsystem	Mass [lbs]
Mechanical	50
Electrical	5
<b>Total System Mass</b>	<b>55</b>
Mass Requirement	882
<b>Leftover Mass</b>	<b>827</b>

**Table 8.7:** Subsystem Power Allocation

Subsystem	Power [W]
Mechanical	-250
Electrical	-20
<b>Total System Power</b>	<b>570</b>
Power Requirement	300
<b>Leftover Power</b>	<b>-270</b>

**Table 8.8:** Subsystem Cost Allocation

Subsystem	Cost [\$]
Mechanical	\$700.00
Electrical	\$300.00
Management Reserve (20%)	\$290.00
<b>Total System Cost</b>	<b>\$1,290.00</b>
Cost Requirement	\$1,450.00
<b>Leftover Cost</b>	<b>\$160.00</b>



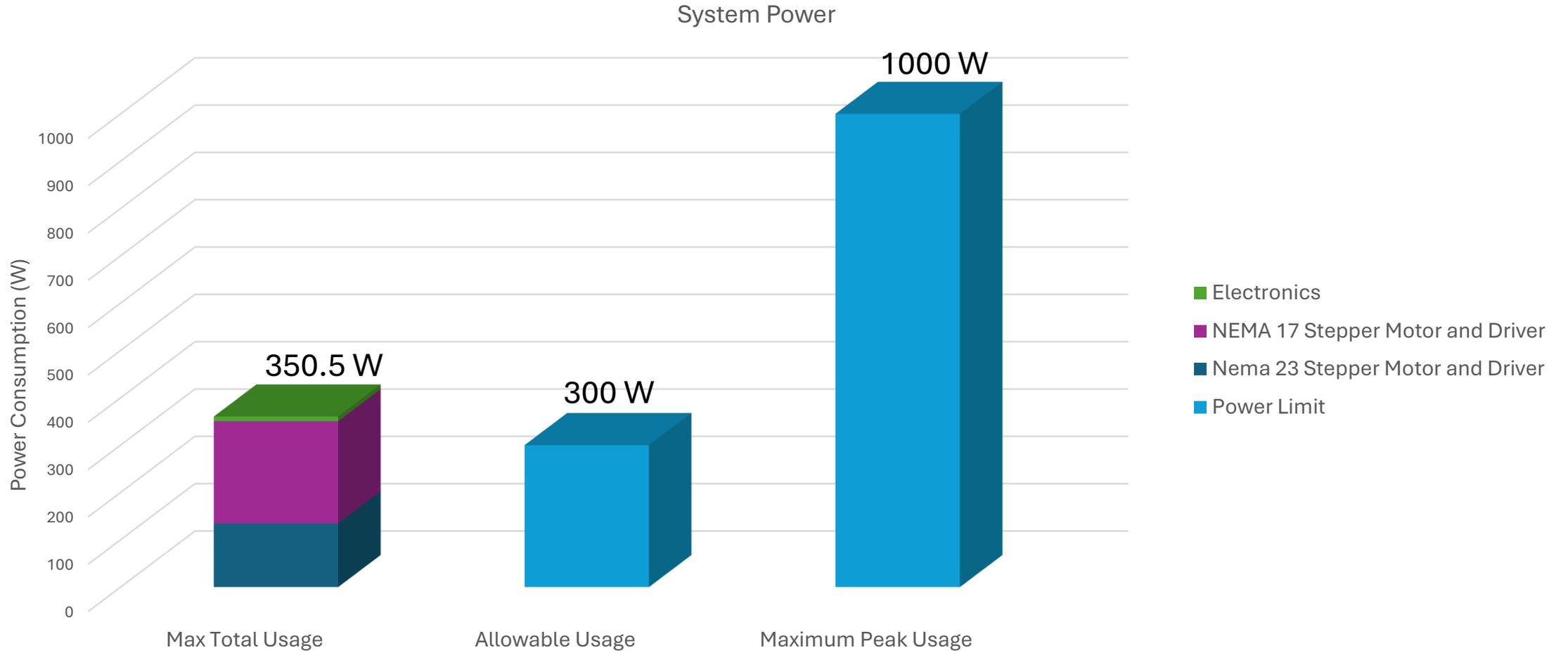
# MOCA's Risk Matrix and risks decreased impact after mitigation techniques are implemented.

		Consequences				
		Minimal	Minor	Moderate	Significant	Severe
Possibility of Occurance (%)	Level 5: 81-100 %					
	Level 4: 61-80%				Motor Damage*	Code Error*
	Level 3: 41-60%			Motors Skipping Bearing Grease Removal Tandem Motor Operations		Misalignment During Assembly*
	Level 2: 21-40%		Non-motor Related Carriage Stalling	Brush Binding Nuts Stripping <b>Motors Skipping</b> <b>Motor Damage*</b> <b>Tandem Motor Operations</b>	Lead Screw Stripping* Unintended Collisions	<b>Misalignment During Assembly*</b>
	Level 1: 0-20%		<b>Code Error*</b> <b>Non-motor Related Carriage Stalling</b>	<b>Brush Binding</b> <b>Nuts Stripping</b> <b>Bearing Grease Removal</b>	<b>Lead Screw Stripping*</b> <b>Unintended Collisions</b>	

Legend  
 Plain Text - Pre-Mitigation  
**Bold Text** - Post Mitigation  
 \* - Critical Risk



MOCA analyzed a worst-case power draw with all motors running at stall torque.



**Cal State LA**

Free Flyer Docking  
system



# Team Overview

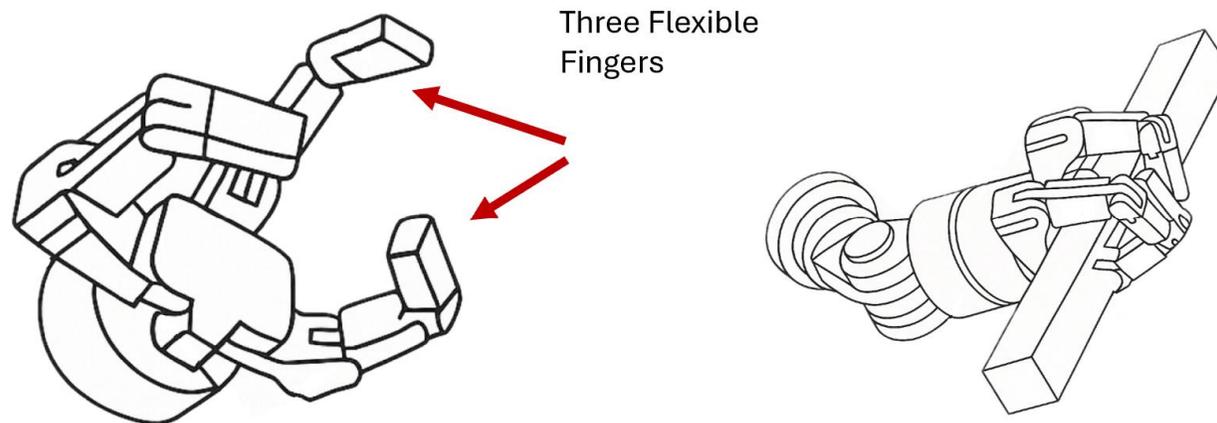
## *Free Flyer Docking System*

- California State University of Los Angeles, The Dockers
- Yousra Fakhro
- Kenny Ngo
- Edgar Avila
- Enrique Rosales
- Edgar Herrera
- Michael Thorburn
- A robust robotic claw that brings on-orbit servicing capability to satellites that were never designed to be serviced.

# Executive Summary

## *Free Flyer Docking System*

- Many satellites become unusable because they run out of fuel or experience minor failures.
- Without secure docking, in-orbit servicing, refueling, or repairs cannot be performed
- A scalable, autonomous docking mechanism capable of soft capture, alignment, and hard mate for vehicles ranging from 500 to 15,000 lbm
- Our system mates with satellites allowing repairs, reactivation, and retrieval. Extends satellite lifespan, reduces orbital debris, and supports future on-orbit servicing



Design	TRL (30%)	Complexity (20%)	Reliability (10%)	Manufacturable (20%)	Capture (15%)	Separation (5%)	Total
Inflatable nose	0.9	0.6	0.3	0.4	0.45	0.15	2.8
Bayonet capture	0.9	0.4	0.2	0.4	0.45	0.25	2.6
Anchor mechanism	1.2	0.4	0.2	0.6	0.6	0.15	3.15
Push latch	0.9	0.6	0.3	0.8	0.675	0.2	3.475
<b>Robotic Claw</b>	<b>1.2</b>	<b>0.6</b>	<b>0.3</b>	<b>0.8</b>	<b>0.525</b>	<b>0.1</b>	<b>3.525</b>
Gecko Skin	0.6	0.8	0.3	0.4	0.375	0.1	2.575

Each criteria ranked from 1-5, and then the score is multiplied by the weight.

example: Robotic Claw, TRL = 4  
 $4 * 0.3 = 1.2$

# Projected Path

*Free Flyer Docking System*



Calculations



Full 3D CAD model



Bill of materials



Begin prototype  
plan

Docking system