COSMIC
THE POWER OF COLLABORATION

COSMIC Capstone Challenge: Final Briefing

The Miners, University of Texas at El Paso:

Patcher-1

3D Printing Patch Antennas for LEO Applications

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Executive Summary

Patcher-1 | 3D Printing Patch Antennas for LEO Applications

- On-demand antenna manufacturing system
- Multipurpose robotic arm that 3D-prints and installs
- To restore, upgrade, or repurpose satellites that have failures or are underutilized

Team Overview

Past Team Members

Andres Lepe- Team Leader & CAD Designer
Daniel A Cruz- Lead Systems Engineer
Bryan Sifuentes- CAD Designer
Allison Kendrick- Materials Research Advisor
Evan M Griffin- Simulation Coordinator

Aida Chacon
Team Leader

Diego del Rio Reyes
Lead Animator & CAD Designer

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Materials & Technology Advisor

Joanne Arellano
Lead Budget & Materials Coordinator

Joshua Servantez
CAD Designer

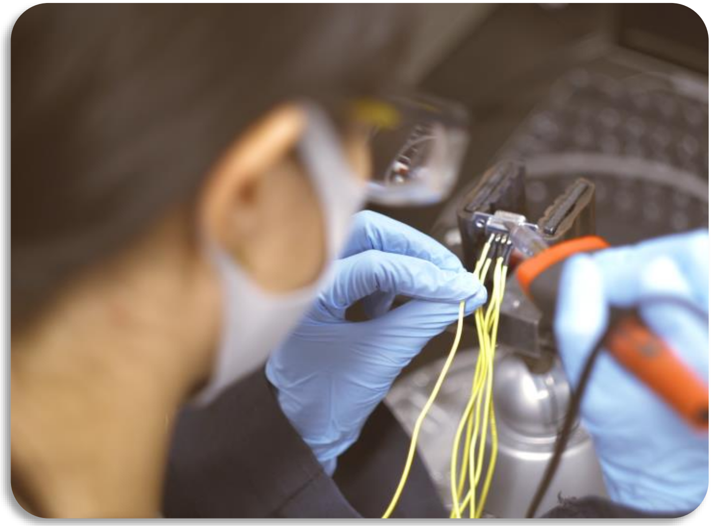
Joel Lujan
CAD Designer

Osmar Nolazco
CAD Designer

Danna Martinez
Budget & Materials Coordinator

1.1 Impact

Upgrades & Repairs

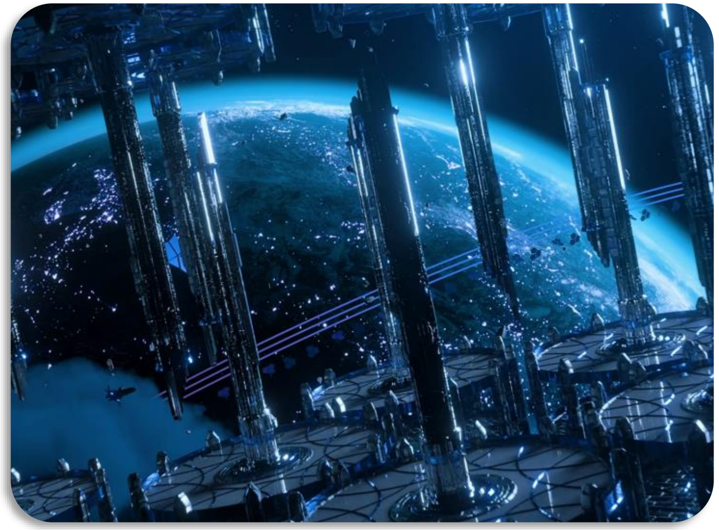


- On-demand production of components
- On-board manipulators assemble and install finished parts

Resupply Mission Reduction

- Reduce the frequency of resupply missions
- Cut cost and logistical challenges

Extended Mission Lifespan



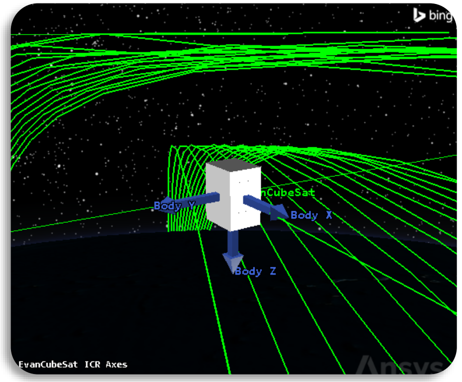
- Reduce early decommissioning
- Supports and extends long-term missions

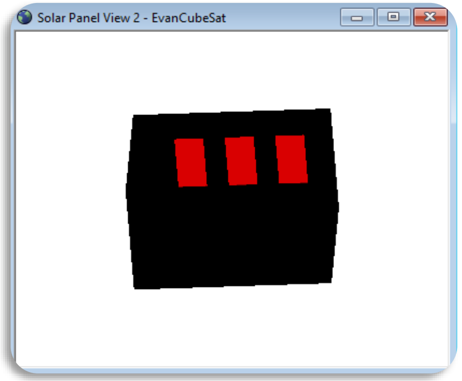
1.2 Feasibility

Power Budget

Total energy produced per day using a 444 W Double Solar Array:
E = Power*time = (0.444 kW)*(14.4 hours) = 6.4 kWh/day

Process	Power Required (kW)	Time (Hour)	Total Energy Consumption (kWh)
1. Ground Layer Deposition	0.15	1	0.15
2. Structural Layer Printing	0.3	1.5	0.45
3. Patch Layer Deposition	0.15	0.883	0.132
4. Sintering Process	0.2	1 - 2	0.2 - 0.4
5. Annealing Process	0.15	1 - 2	0.15 - 0.3
6. Sensors and Monitoring	0.05 - 0.1	5 - 6	0.25 - 0.6
7. Robotic Arm Operation	0.05 - 0.1	3 - 4	0.15 - 0.40
Approximately Total Energy Required per Patch = 1.96 kWh			





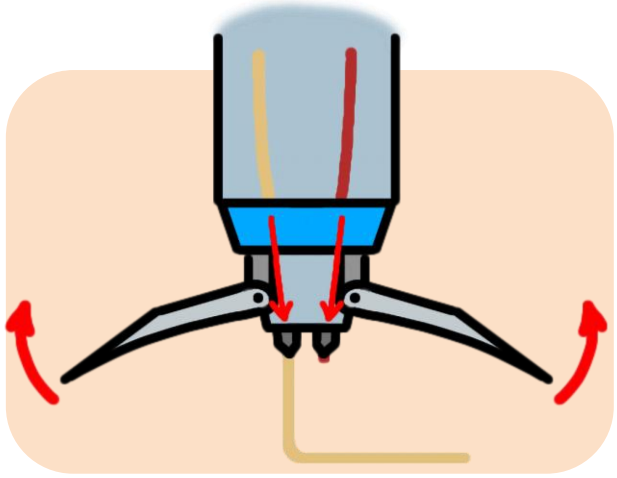
1.2 Feasibility

Bill Of Materials

Item	Quantity	Estimate Cost	Source
(ULTEM 1010)	1 kg	$337.00	https://top3shop.com/product/intamsys-ultem-1010-1-75-mm-1-kg
Copper Filament (Electrifi-conductive filament from multi 3D)	1 kg	$205.99	https://shop.thevirtualfoundry.com/products/copper-filament?variant=12352925237331
Vacuum Rated Stepper Motors	6	$1,800.00 - $2,400.00	https://www.linengineering.com/products
Build Plate (McMaster-Carr (custom high-temp templates)	1	$500.00 - $800.00	https://www.mcmaster.com/silicon-
Sensors (Thermocouples)	4	$100.00	https://www.omega.com/en-
Motor Controller	1	$200.00	https://www.adafruit.com/product/3099
Camera	2	$60.00	https://www.omega.com/en-
Electric Power System	1	$15,000.00	https://www.customcells.org/en/space-
Solar Cell	2	$4,000.00	https://www.azurspace.com
Misc (relays, wiring, etc)	-	$500.00	-
Structural Housing	-	$500.00	-
Total		**$23,500.00 - $25,000.00**	

Estimate payload cost: $22,000.00 - $25,000.00 Excluding custom treatments and future enhancements.

1.3 Innovation



Demonstrations

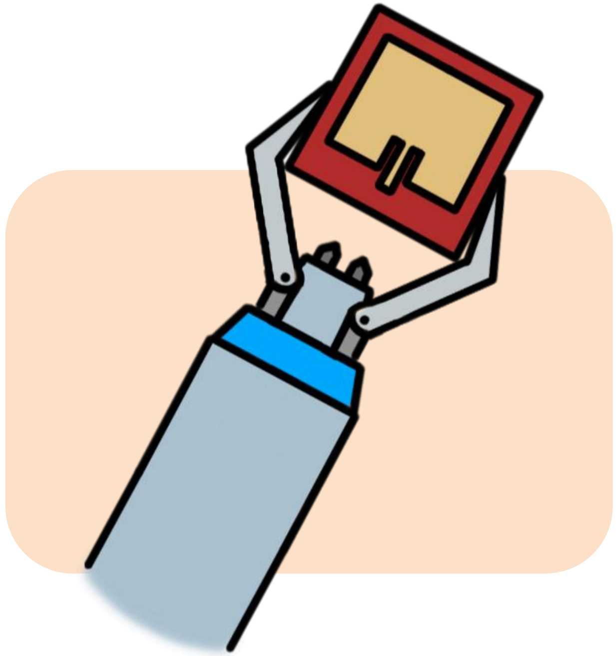
- Robotic Arm Manufacturing (RAM) 3D Printing. info
- Fully 3D printed patch antennas metal and fused filament
- In-orbit FFF 3D printer with high-temp capabilities. info

Proposals

- OSAM-2 to manufacture and assemble spacecraft components in low-Earth orbit. info
- Mitsubishi Electric's resin-based on-orbit freeform antenna manufacturing. info

Novelty

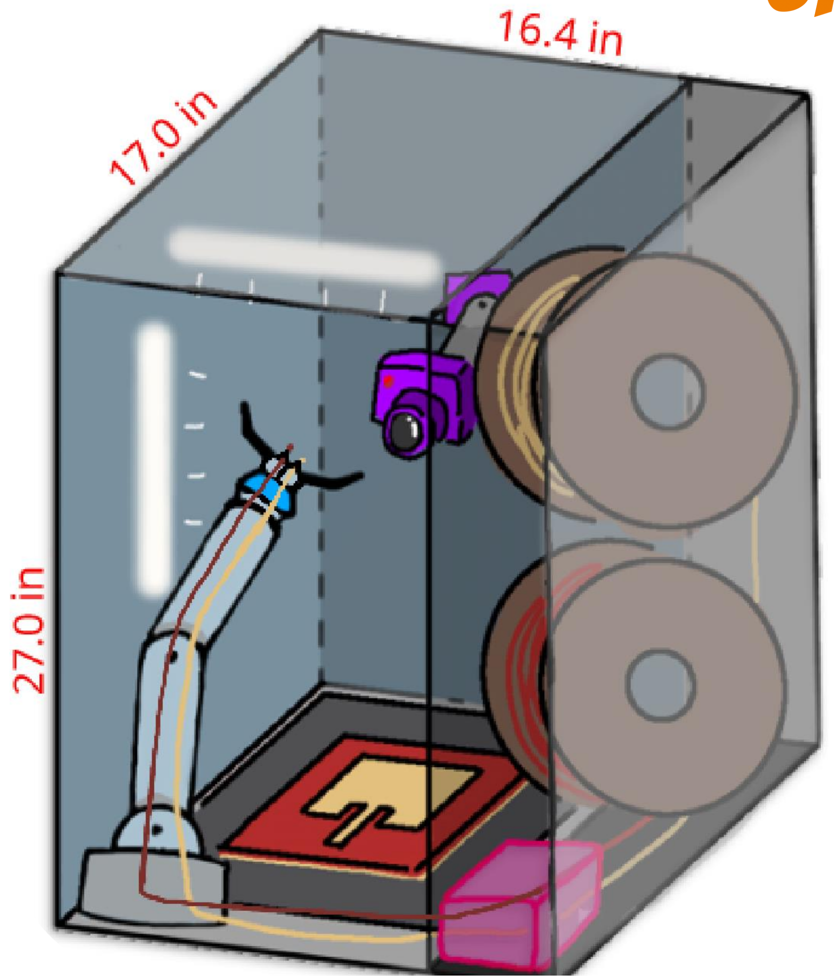
- Gripper and 3D Printing end effector on a robotic arm
- Print and install to existing orbiting satellites



1.4 Required Elements

- ✓ Payload size using dual arrays
  - 17.0” x 16.4” x 27”
- ✓ Mass < 70kg
- ✓ Power requirements confirmed with a power budget "dual array"
- ✓ Proposed bus supports operations
- ✓ Design considers launch environment
- ✓3 sequencing technologies
  - Printing
  - Gripping
  - Installing

CAD Model



General sketch layout for payload

1.5 Risks

Risk Analysis of General Satellite Survivability

Risk ID	Risk Description	Likelihood	Impact	Risk Score	Category	Mitigation Strategy	Owner
A	High G-forces during launch may damage payload.	Medium	High	9	Launch	Conduct vibration tests; use shock absorbers.	Structural Engineer
B	Thermal fluctuations in LEO may affect electronics.	High	Critical	20	LEO Environment	Design thermal insulation; incorporate active cooling.	Thermal Systems
C	Micrometeoroid or debris impact in LEO.	Medium	High	9	LEO Environment	Use shielding (e.g., Whipple shield); monitor debris.	Systems Engineer
D	Radiation exposure may degrade payload materials.	Medium	High	9	LEO Environment	Use radiation-hardened components; test materials.	Materials Team
E	Failure of deorbit mechanism could leave debris in orbit.	Low	Critical	4	Deorbit-ability	Design redundant deorbit system; verify reliability.	Propulsion Team
F	Communication loss during deorbit phase.	Medium	Moderate	6	Deorbit-ability	Develop robust telemetry systems; test during simulation.	Avionics Team
G	Payload functionality may degrade due to combined stressors from launch, LEO environment, and deorbit phases.	Medium	Critical	12	Cross-phase (Launch, LEO, Deorbit)	Perform integrated system testing under simulated conditions for all mission phases; build redundancies into critical subsystems.	Systems Integration Team

Likelihood	Description
Low	Rare occurrence, less than 10% more
Medium	Possible occurrence, 10-50% chance.
High	Likely to occur, over 50% chance.

Likelihood \ Impact	Minor	Mode-rate	High	Critical
Low	1	2	3	4
Medium	3	6	9	12
High	5	10	15	20

Impact	Description
Minor	Minimal effect on mission success.
Moderate	Partial loss of functionality or delays.
High	Significant effect; requires major mitigation.
Critical	Total mission failure if not addressed.

1.7 Trade Studies
Manufacturing Selection

FOMs	Weight	Nanojet Electrospray		Aerosol Jet Printing		Fused Filament Fabrication	
	1, 3, or 9	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Print Resolution & Feature Size	9	9	81	3	27	1	9
Material Compatibility	9	9	81	9	81	3	27
Print Speed	1	1	1	3	3	3	3
Ability to Layer Material	9	1	9	3	27	9	81
Energy Consumption	9	3	27	1	9	3	27
System Footprint & Integration	9	1	9	1	9	9	81
Robotic Arm Retrofit Capability	3	3	9	3	9	9	27
Weight Contribution	9	3	27	1	9	3	27
Vacuum & Thermal Stability	9	9	81	3	27	3	27
TOTAL			**325**		**201**		**309**

Fused Filament Fabrication (FFF) was **chosen**, despite not having the highest score, due to its simplicity in integration and setup in the payload, and ability to operate autonomously without requiring compressed gas, making it the most practical and efficient option for our payload.

1.7 Trade Studies

Antenna Selection

FoMs	Weight	Patch Antenna		Helix Antenna		Corrugated Horn Antenna	
		Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Ease of 3D Printing	9	9	81	3	27	1	9
Material Efficiency	9	9	81	3	27	1	9
Performance in Space Conditions	9	3	27	9	81	9	81
Structural Integrity	3	9	27	3	9	9	27
Ease of Assembly	3	9	27	3	9	3	9
Bandwidth and Frequency Range	3	3	9	9	27	3	9
Reusability	1	1	1	1	1	1	1
Manufacturing Time	1	9	9	3	3	1	1
TOTAL			**262**		**184**		**146**

The **patch antenna** emerged as the **best choice** due to its superior performance in ease of 3D printing, material efficiency, and adaptability to space conditions, resulting in the highest overall score.

Patch Antenna

- Three layers
- Tailored to satellites needs
  - Area of the patch affects the resonant frequency
  - Thickness of the substrate affects the bandwidth and impedance

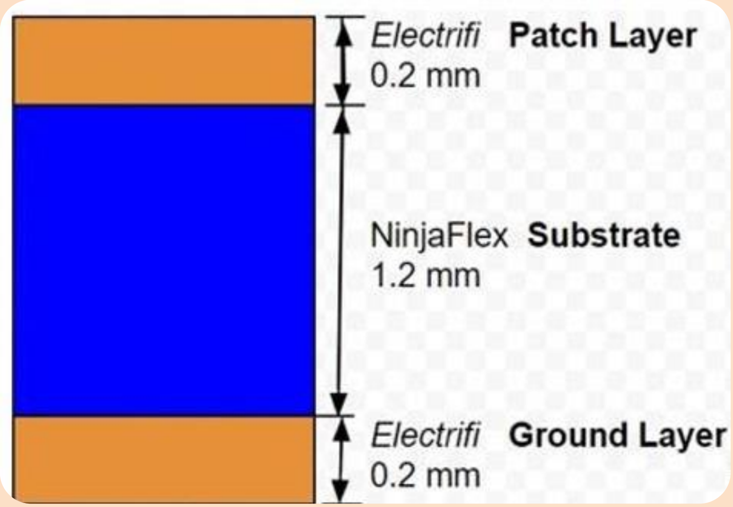
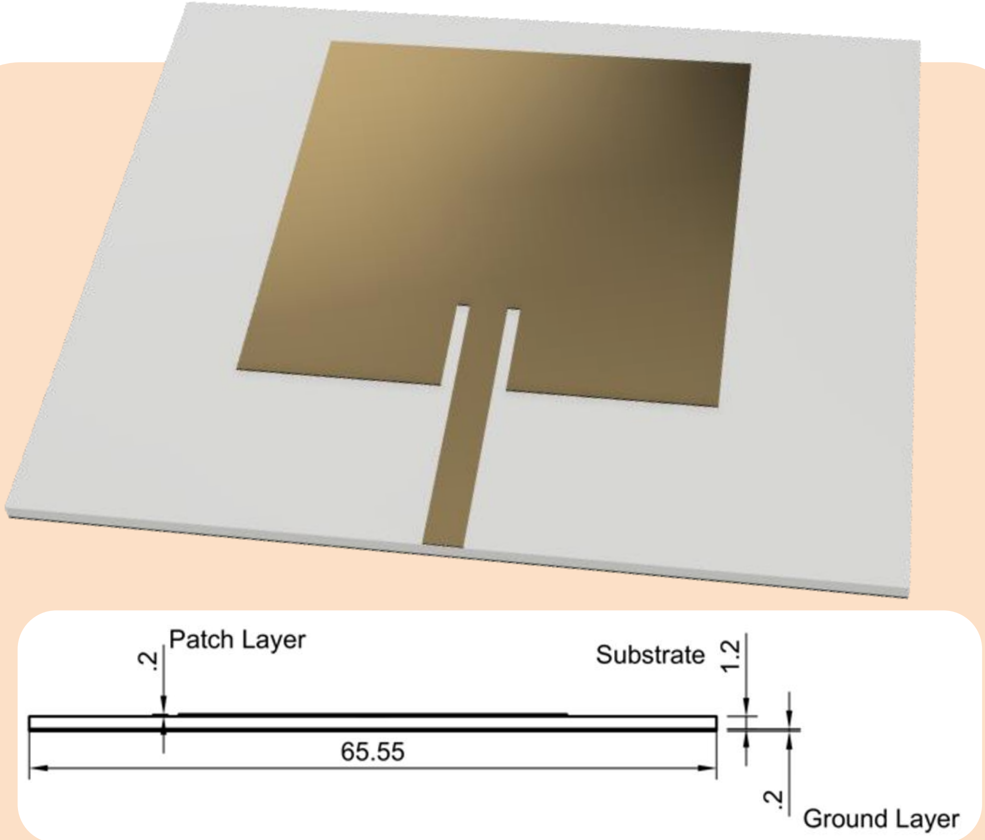


Diagram from [D. Mitra et al.]()



Patch antenna to be manufactured by the payload

1.7 Trade Studies

Substrate Material Selection

FOMs	Weight	PEEK		PEKK		ULTEM 1010	
	1, 3, or 9	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Termal Stability	9	3	27	9	81	9	81
Printability	3	3	9	9	27	9	27
Mechanical Strength	9	9	81	3	27	9	81
Space Suitable	9	9	81	9	81	9	81
Dielectric constant (3)	3	9	27	3	9	9	27
Coefficient expansion	3	3	9	3	9	9	27
Cost	1	3	3	1	1	9	9
TOTAL			**237**		**235**		**333**

ULTEM™ 1010 (a high-performance Polyetherimide - PEI) was selected as the **best** substrate material for the 3D-printed space antenna because it provides an optimal balance of dielectric properties, thermal stability, radiation resistance, and printability.

1.7 Trade Studies

Electrical Material Selection

FOMs	Weight	Copper		CNT-PEI		Graphene	
	1, 3, or 9	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Electrical Conductivity	9	9	81	9	81	3	27
Adhesion to Material	3	3	9	9	27	3	9
Oxidation resistance	9	3	27	9	81	9	81
Printability	3	9	27	3	9	3	9
Radiation Resistance	9	9	81	1	9	1	9
Space Suitability (Long-Term Stability)	3	9	27	3	9	3	9
Cost	1	9	9	3	3	9	9
TOTAL			**261**		**219**		**153**

Copper-PEI was selected as the **best conductive material** for the antenna due to its high electrical conductivity, radiation resistance, and space suitability.

1.7 Trade Studies

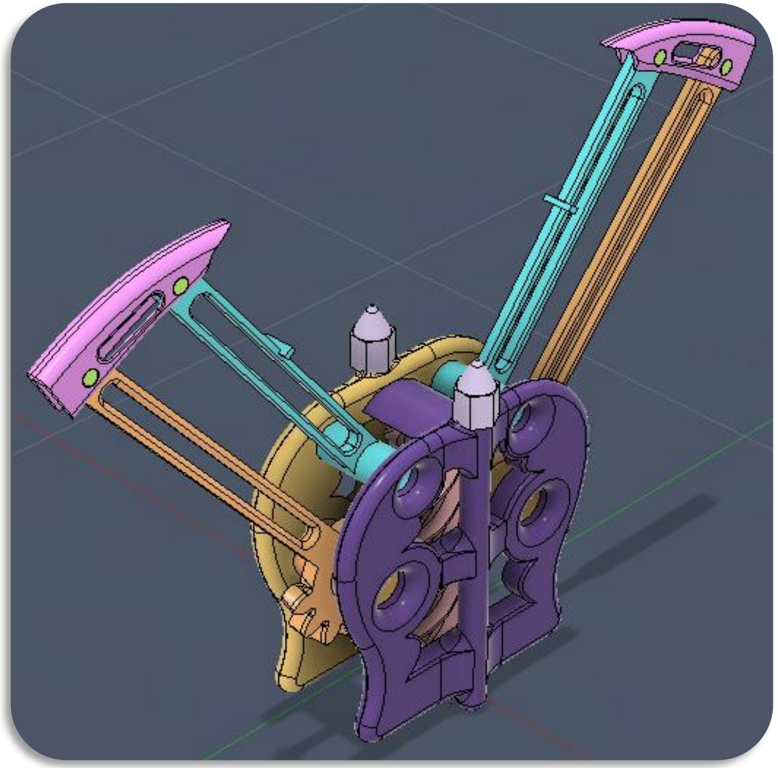
Gripper Selection

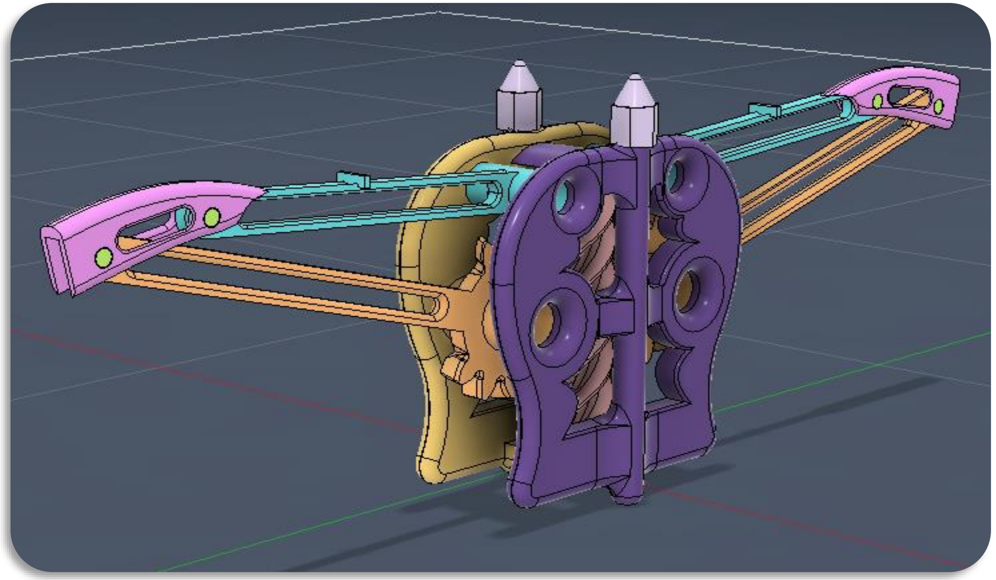
FOMs	Weight	Two-Finger Gripper		Three-Finger Gripper		Flexible Robot Gripper (Pneumatic)	
	1, 3, or 9	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
Dual Extrusion Capability	9	9	81	3	27	3	27
Object Removal Capability	3	3	9	9	27	1	3
Precision and Accuracy	3	3	9	9	27	2	6
Radiation Resistance	9	9	81	9	81	1	9
Lightweight Construction	3	3	9	1	3	3	9
Autonomous Operation	3	3	9	3	9	3	9
Strength-to-Weight Ratio	9	9	81	3	27	1	9
Robotic Arm Compatibility	3	3	9	3	9	3	9
Power Consumption Efficiency	1	9	9	1	1	9	9
TOTAL			**297**		**211**		**90**

Three-finger Gripper would have more advantages in some cases, **Two-finger Gripper** was selected due to high scoring and provides a good balance between weight and effectiveness.

Precision-Dual Purpose Gripper

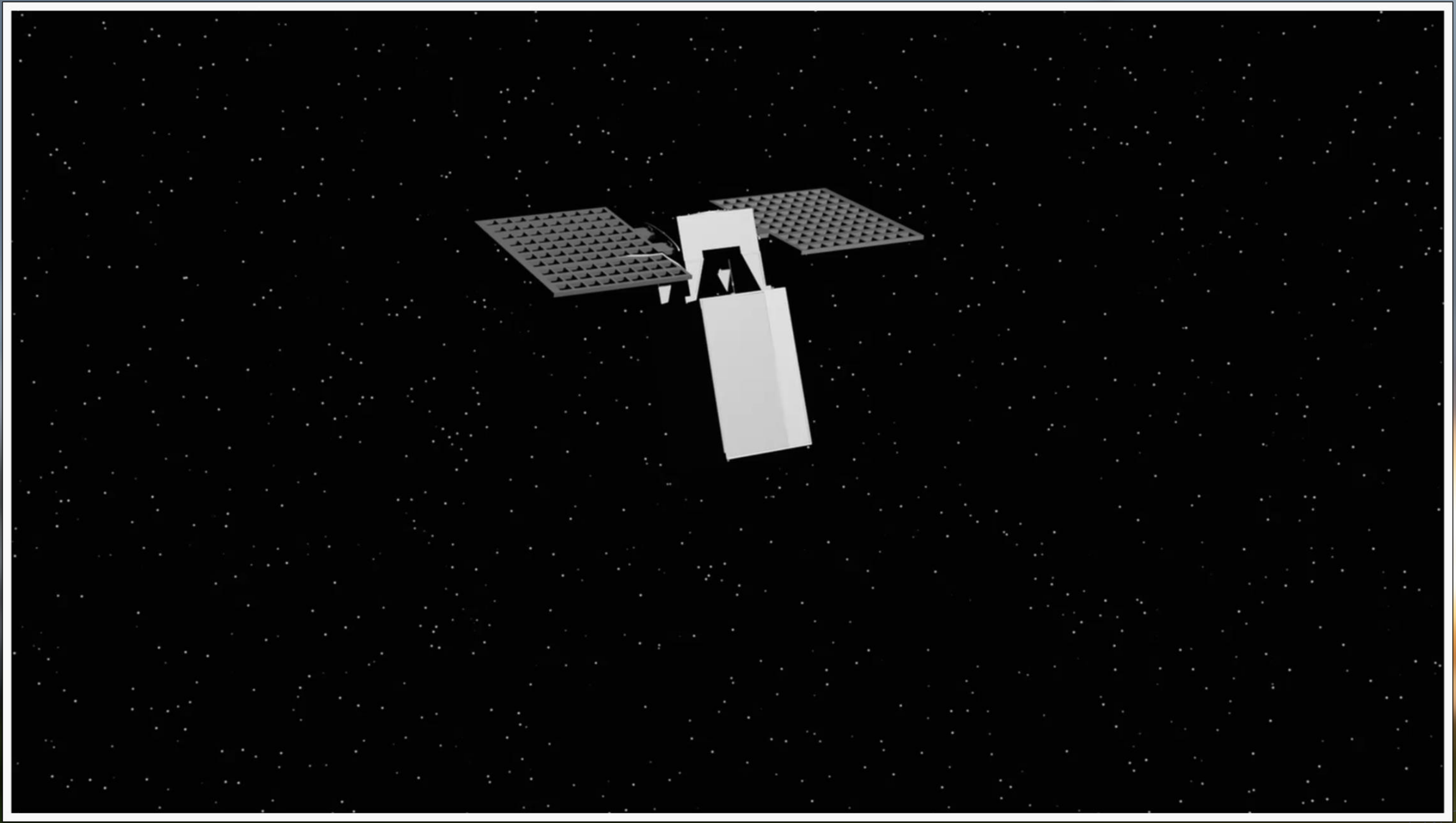
- Screw gear driven mechanism motor to operate.
- Dual extruders at the base for material selection
- Function: 3D print, and remove objects from bed
- Light Weight Design- removed unnecessary material
- Note: A scraper design at the head of each finger. Assist with removing print from bed



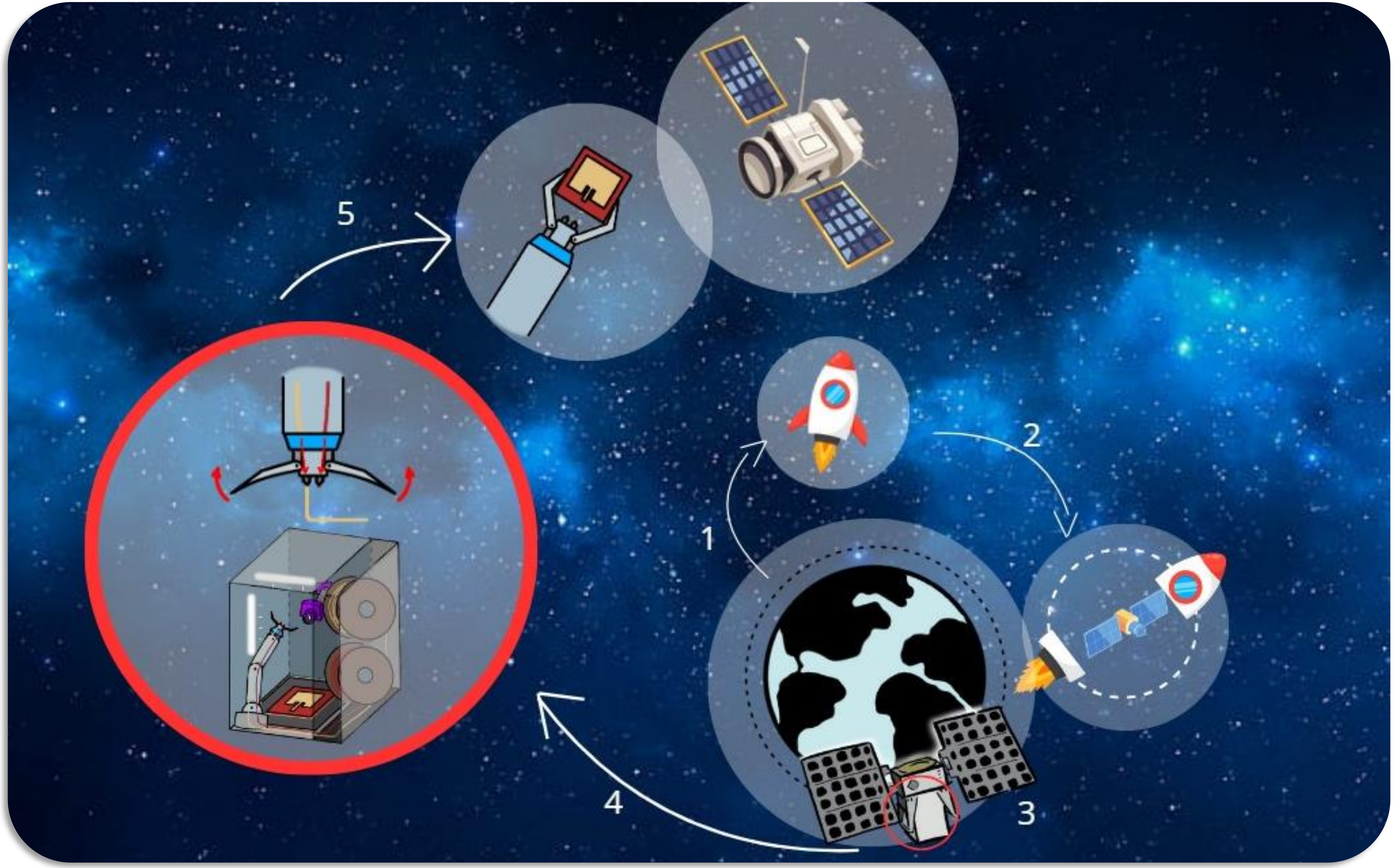


Modeling in Fusion360

2.1 Animation



2.2 Storyboard



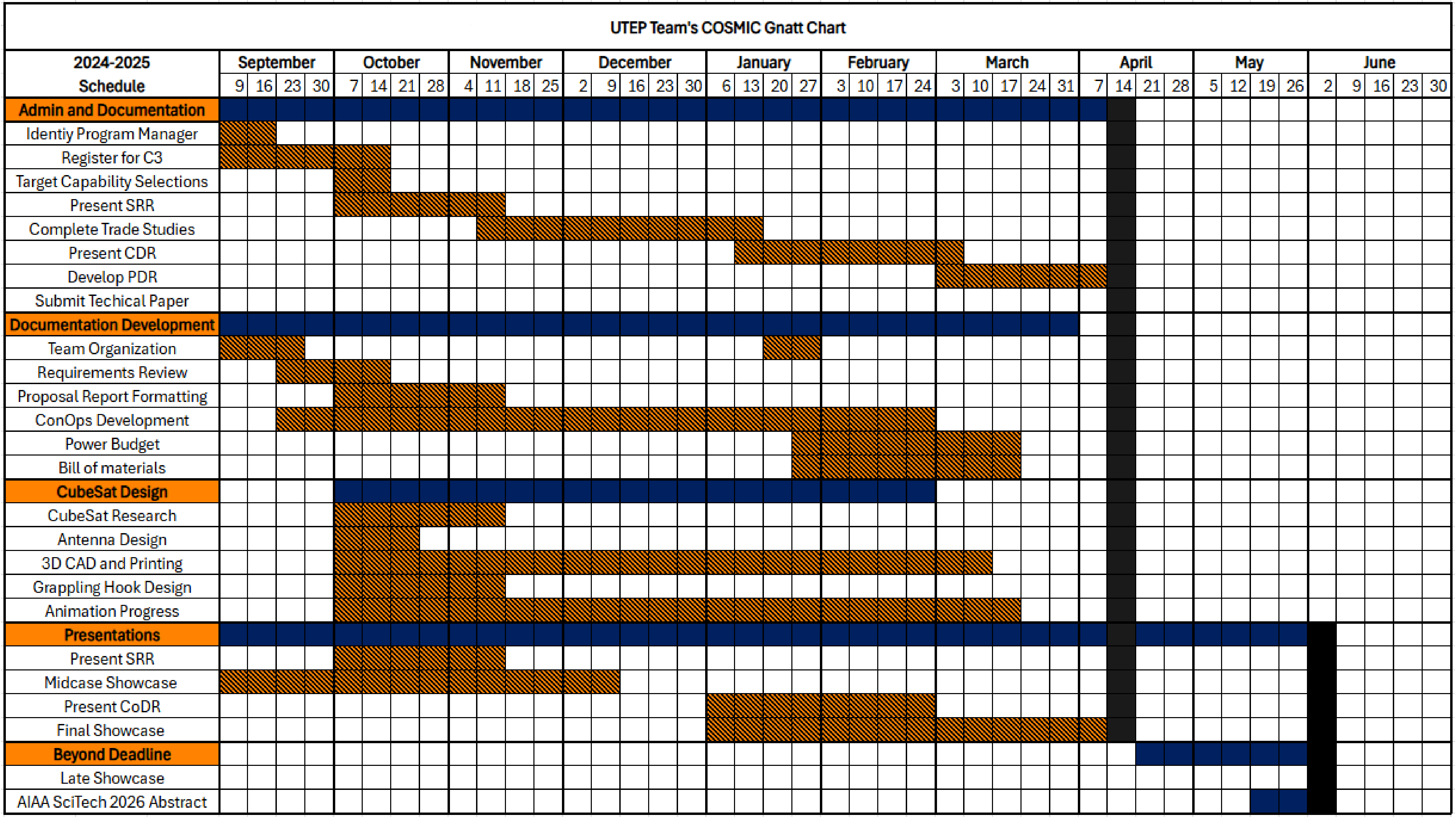
2.3 Data Handling & Comms

- Real-Time Downlink
  - ✅Required – Enables real-time monitoring of temperature, pressure, material alignment, and print quality. Supports camera and sensor data transmission to ground.
- Observer
  - ❌Not Required – Fully autonomous payload. Onboard systems handle all observation tasks.
- Operator
  - ❌Not Required - Ground operator only needed for pre-mission setup and troubleshooting. Autonomous during LEO operations.
- Bitrate Estimate
  - Estimate Total: ~1 Mbps during printing

2.3 Data Handling & Comms

- Comms System Requirements
  - Must buffer data during LEO blackouts
  - Support real-time downlink + command uplink
  - Operate with periodic LEO contact or relay coverage
  - Operate within 444W total power budget
  - Fit within 17.0” x 16.4” x 27” size
  - Operate across ~100°C to 120°C thermal extremes

2.4 Systems Engineering Milestones



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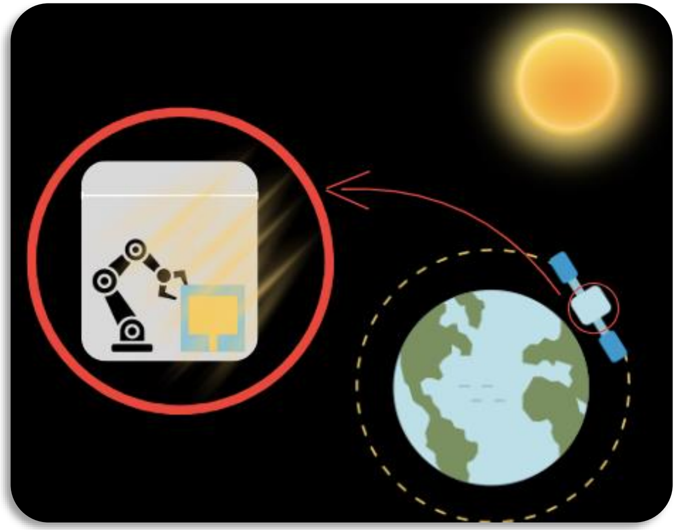
3.1 Innovative Concepts

Multipurpose Robotic Arm

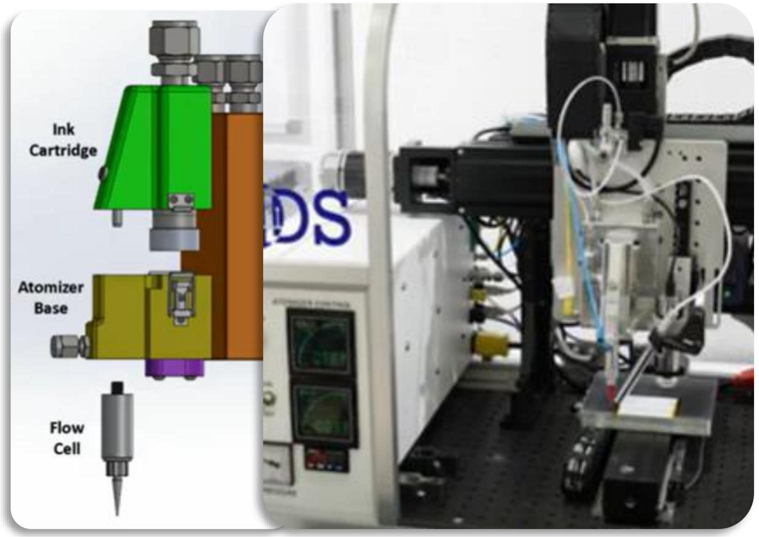
- Robotic arm manufacturing with FFF
- End effector grips to grab and install finished patch antenna

Solar Sintering



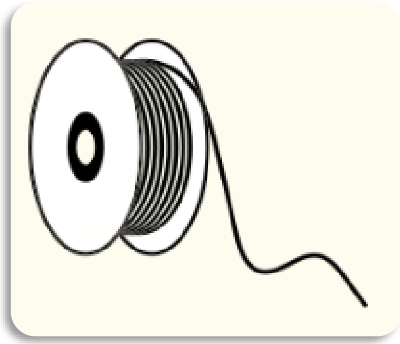
- Harnessing the suns thermal radiation to sinter antennas
- Higher quality signals

Nanojet Electrospray

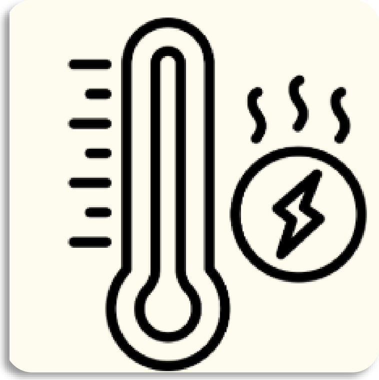


- Not polymer based
- High level precision/detail
- Comparably less off-gassing to FFF

3.2 Tech Gap Assessment



- Space grade filaments improvements

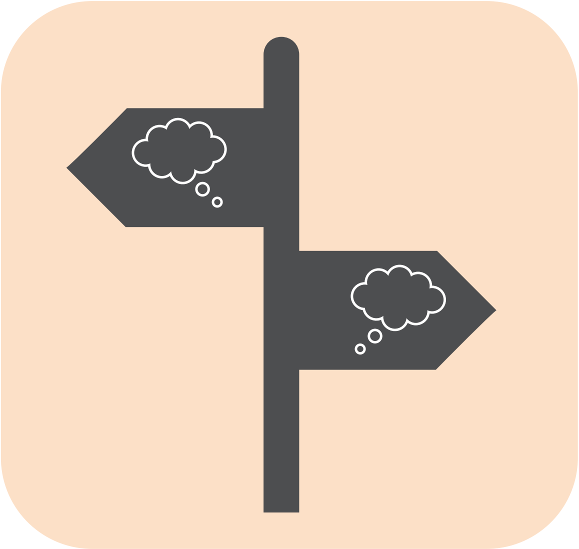


- Power & Thermal Management

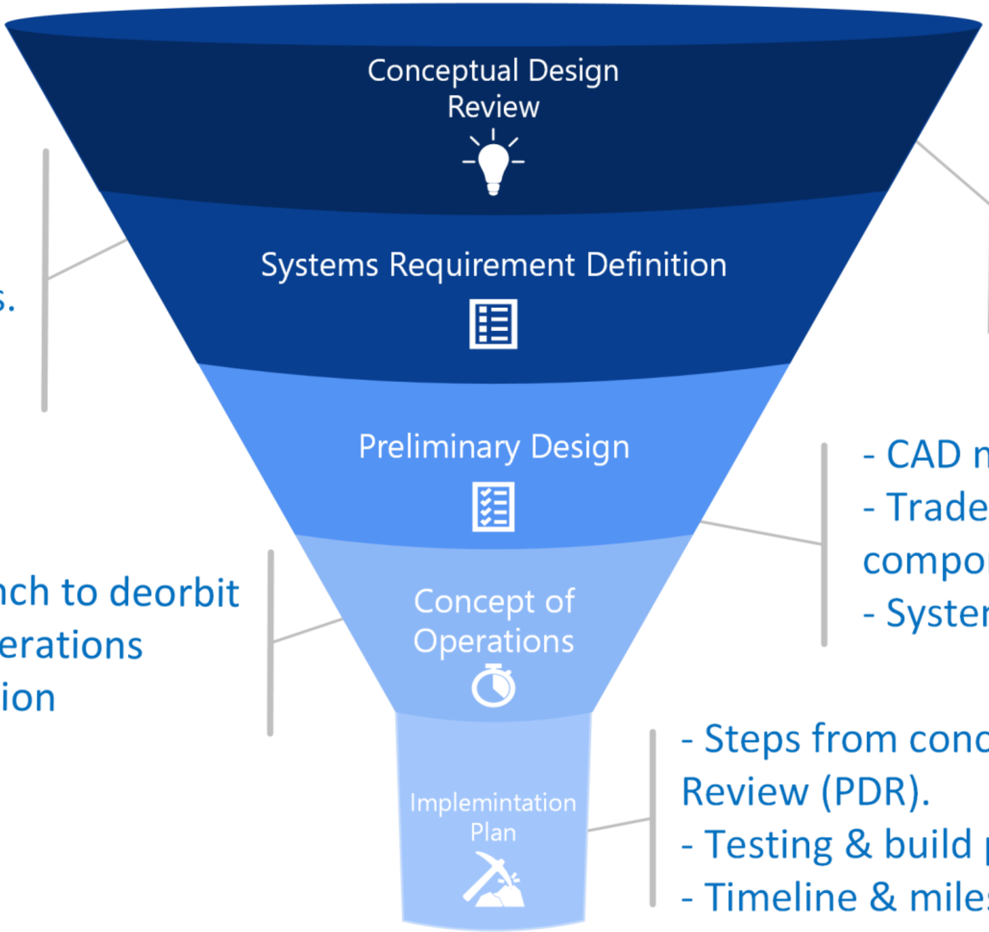
- In-Situ Antenna Performance Validation in Space

3.3 Biggest Challenges

- Deciding on a concept
- Making the idea innovative
- Balancing energy demands



1.6 Path to PDR



- Initial CAD designs & trade studies
- Data handling & communications flow
- Risk assessments & safety strategies

- Key Constraints: power, volume, mass
- Autonomy & command levels.
- Environmental & launch conditions

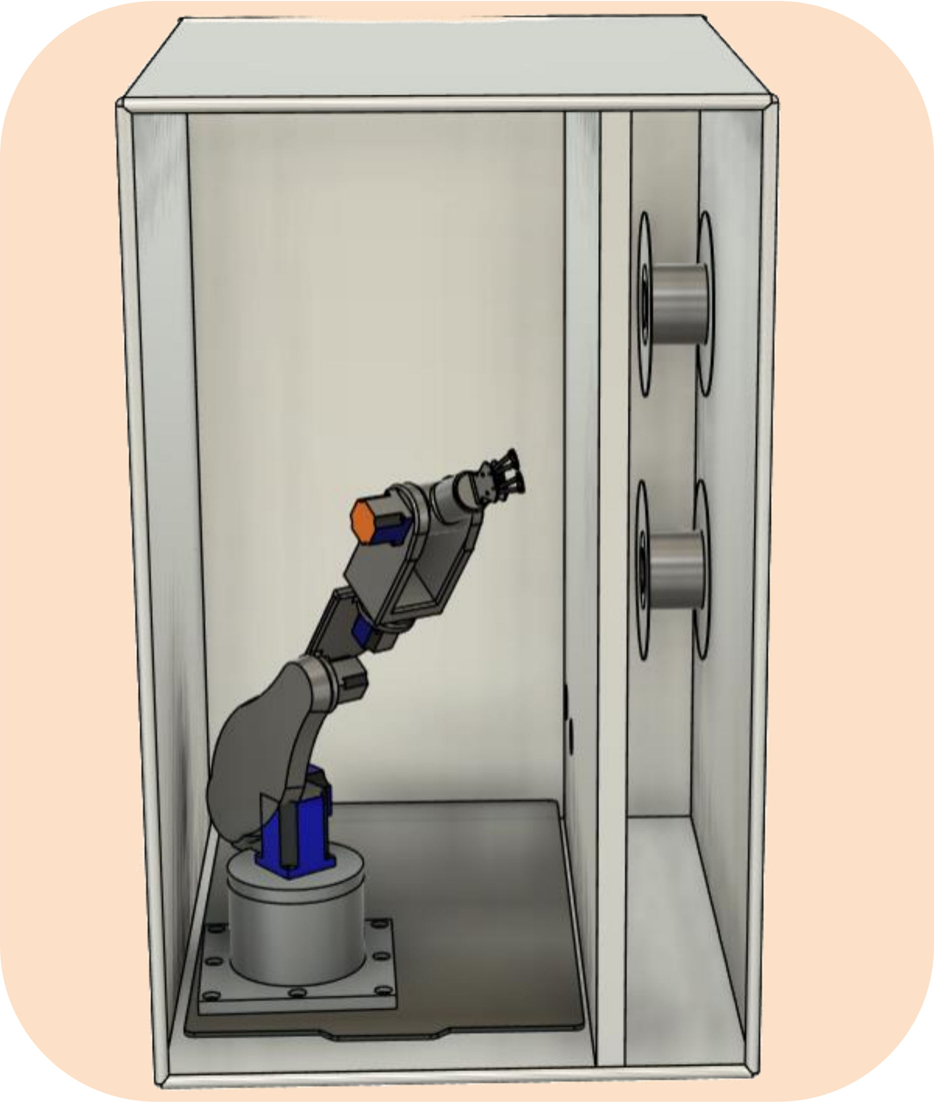
- CAD model of payload & ISAM operations
- Trade studies for best methods or components
- System safety & failure mitigation

- Mission lifecycle: launch to deorbit
- Sequence of ISAM operations
- Payload-host integration

- Steps from concept to a Preliminary Design Review (PDR).
- Testing & build path aligned with ISAM.
- Timeline & milestones (COSMIC guidelines)

Conclusion

- Autonomous 3D printing and installation of antennas in orbit
- Robotic servicing platform for in-situ satellite upgrades
- Extends satellite function while minimizing orbital debris
- Enables modular, scalable, and resilient space operations



Questions?

Thank You

The Miners, University of Texas at El Paso

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3D Printing Patch Antennas for LEO Applications

Technical Requirements Analysis

COSMIC Requirements		
Requirement	**Rationale**	**Subsystem**
CubeSat **shall** demonstrate the following operations, printing, grasping and monitoring, and installing.	The proposed payload will 3D print patch antennas, grab them and place them in another satellite. A camera will monitor the 3D printed part and inform when ready.	Full Satellite
Satellite **shall** be able to operate in vacuum space.	From general rules Pg.4	Full Satellite
Satellite **shall** operate in microgravity.	From general rules Pg.4	Full Satellite
The satellite mass **shall** not exceed 70 Kgs.	From Design Constraints	Full Satellite
Satellite **shall** survive several launch loads.	From general rules Pg.4	Full Satellite
Satellite **shall** perform in Lower Earth's Orbit	From general rules Pg.4	Full Satellite
Satellite shall survive launch loads	Satellite will be launched from Earth	Full Satellite
Satellite **shall** be able to operate in low earth orbit environment including vacuum and reduced gravity	Operational environment	Full Satellite
The robotic arm **shall** move and perform the 3D printing autonomously	To improve accuracy and reduce human errors	Payload
The payload design **shall** be autonomous with limited remote commands.	From General rules Pg.4	Payload

Technical Requirements

Payload **shall** use a single solar array power of 222W.	Chosen by team in order to have more space to move the robotic arm.	Payload
Payload **shall** be no bigger than 20.5" x 16.4" x 27.0".	From General rules Pg.3; Decision making	Payload
Electrical components **shall** not exceed 222W of power and 10.2 Ah.	From General rules Pg.3; Decision making	Payload
The 3D printing system and materials **shall** operate in a vacuum environment and withstand thermal cycling from -100°C to 120°C.	LEO temperatures are in this range and it ensures materials remain stable and functional when exposed to space vacuum and extreme temperature fluctuations.	Payload
All 3D printed materials **shall** have a Total Mass Loss (TML) <1% and Collected Volatile Condensable Material (CVCM) <0.1%, minimizing contamination risk.	Reduces the risk of contaminating sensitive systems by limiting outgassing in the vacuum of space	3D printing module
The 3D printing system **shall** incorporate stabilization methods to ensure precise material deposition, such as ADCs and vibration damping.	Ensures accuracy and integrity of printed parts, especially for critical components like antennas.	3D printing module
The 3D printing system **shall** be capable of printing a patch antenna in under 5 hours.	Supports rapid prototyping and on-demand manufacturing to enhance mission flexibility.	3D printing module
Minimum EIRP for patch antennas (neglecting FSL) **shall** be 30 dbW.	From STK Simulation Analysis	3D printing module

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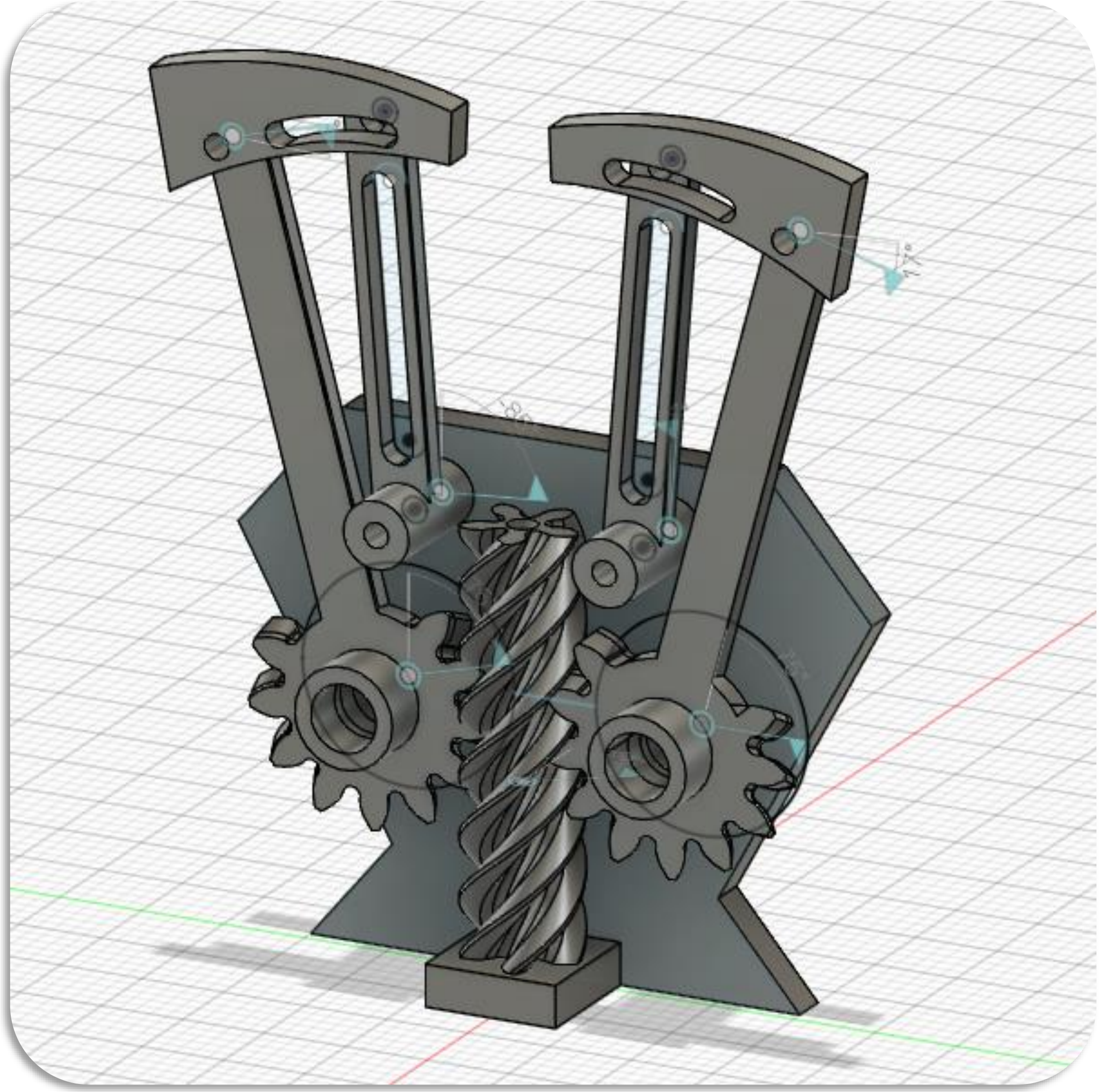
Model: Two finger Claw

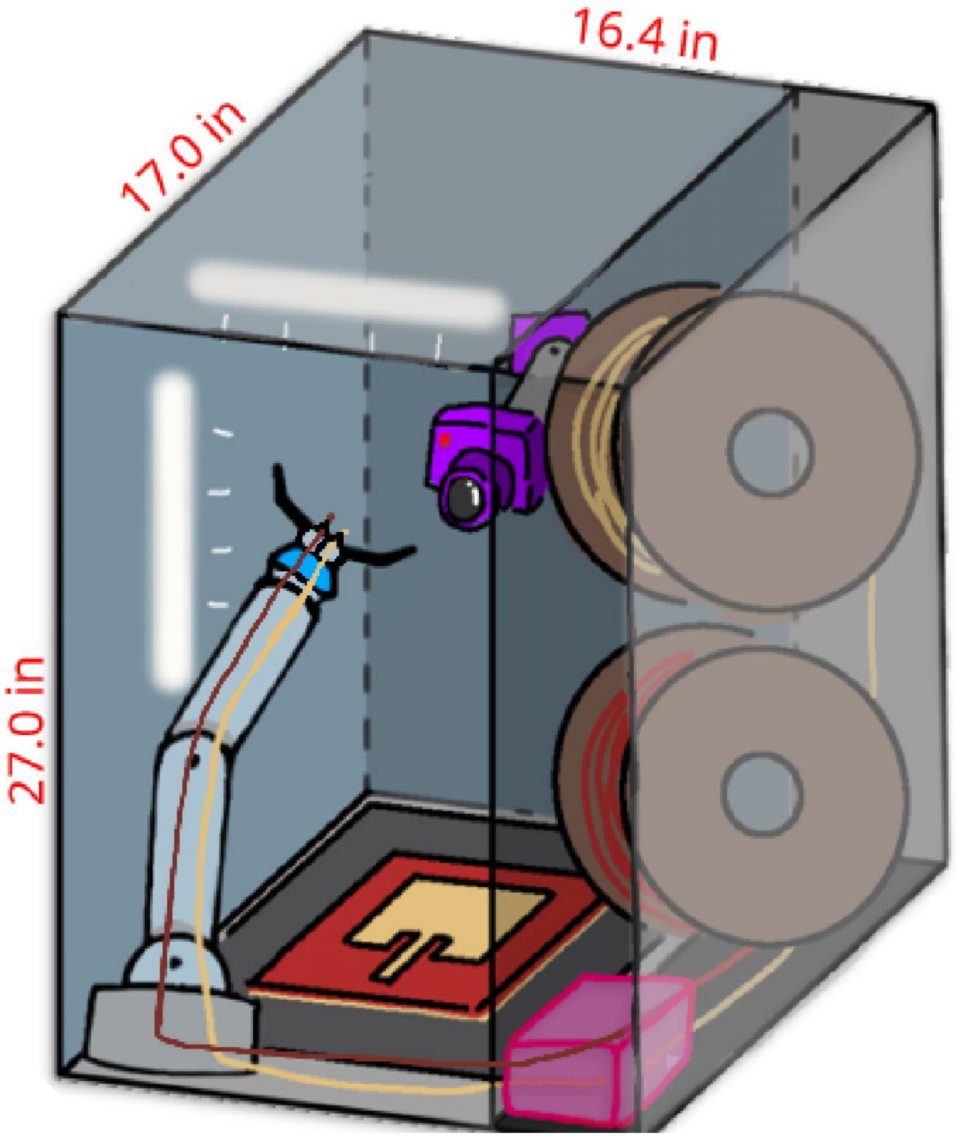


- One motor actuates the screw.

Payload

Components to be used:

- **Stepper motors** for the robotic arm 4118 Series rated for "space flight" by manufacturer (Nema 17 motors are generally used)
- **Cameras** can be used for **monitoring**
- Additional lighting for enhanced monitoring can be via LED integration
- Multi-purpose end effector actuation will require another motor that is to be determined based on the design
- The **extruder** is comprised of a hotend and an extruder motor (most likely another Nema 17)
- The build plate has to heat up, provide adhesion while printing, and have easy release after completion



General sketch layout for payload

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