CSUN

COLLEGE OF
ENGINEERING AND
COMPUTER SCIENCE

CSUN ISAM

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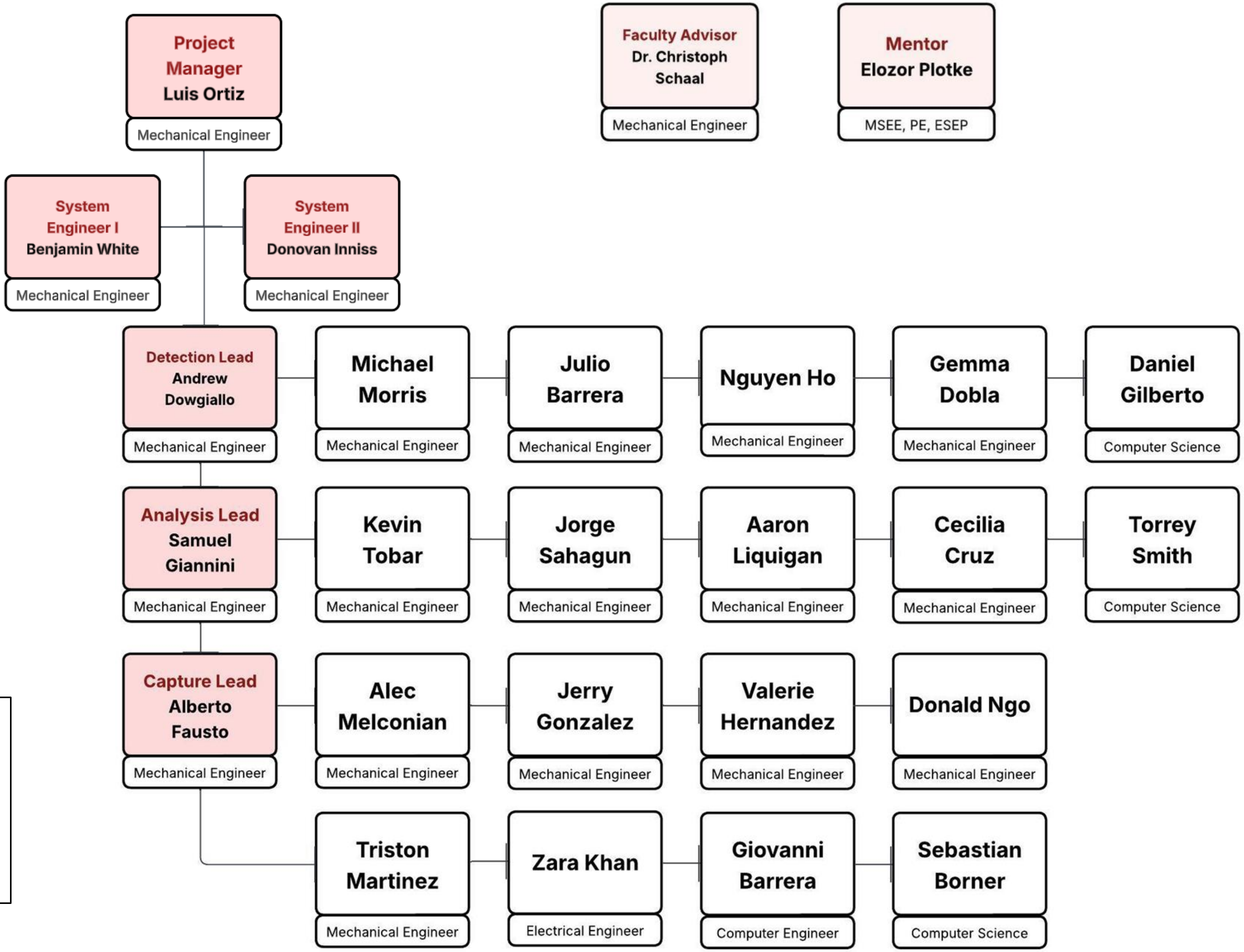
Alberto Fausto

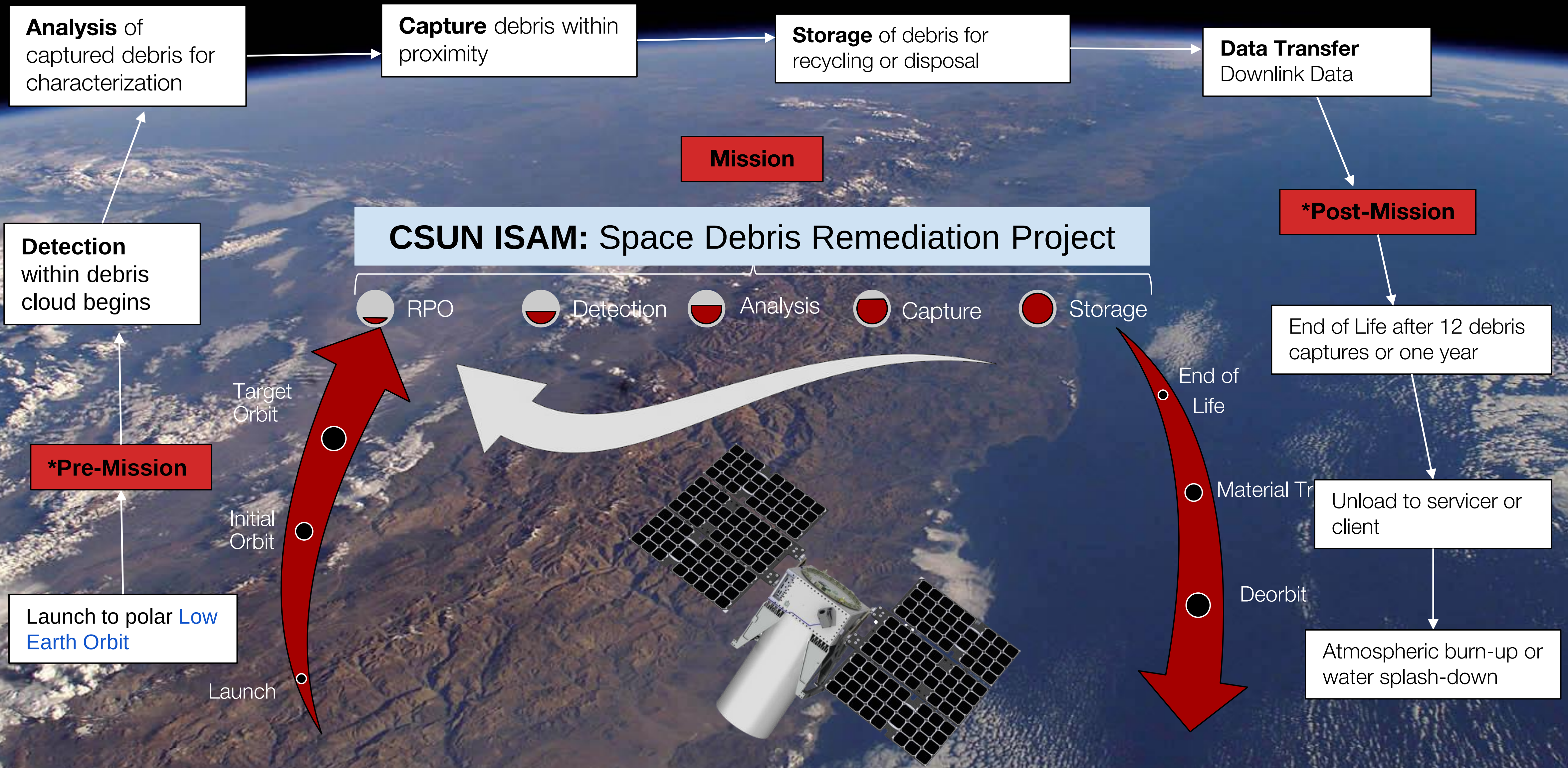
Team Overview



Team:

Mechanical Engineers: **19**
Computer Science: **3**
Computer Engineers: **1**
Electrical Engineers: **1**

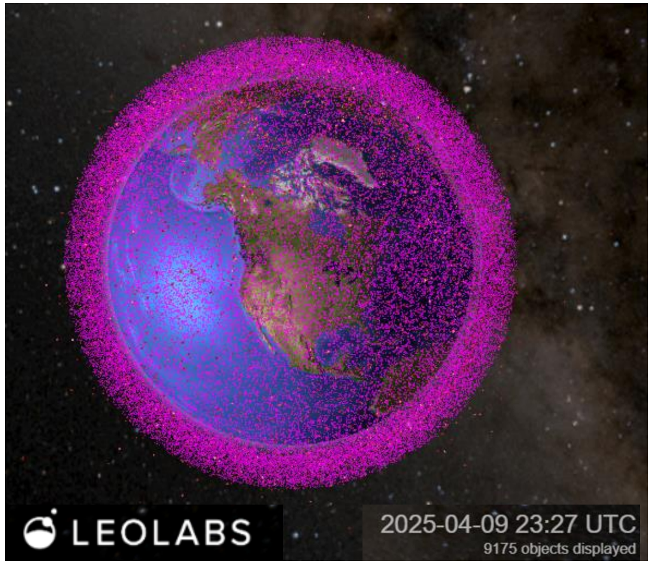
2.2 Storyboard of Complete Operation



1.1 Impact

Technical Impact:

• Prototype demonstrates ability to track Lethal Non-Trackables (LNTs), broadening operating ranges of future and current spacecraft and decreasing catastrophic collisions
• Eliminates LNTs in debris clouds thus allowing more robust satellites to be deployed in these clouds
• Autonomous servicing can reduce cost and increase lifetime of satellites
• Allows for future development of advanced spacecraft with In-Space Manufacturing Capabilities (ISAM) that can lead to a reduction of required missions to send materials to space thus reducing fuel consumption, material waste, and cost

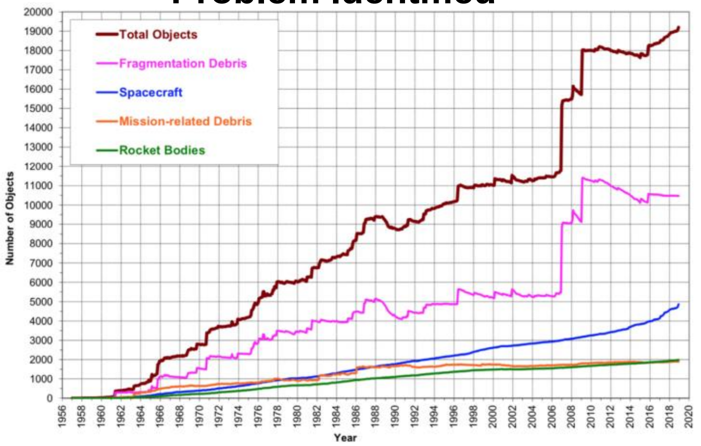


* LEOLABS

Executive Summary

CSUN In Space Debris Remediation Project

Problem Identified



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Proposed Capability

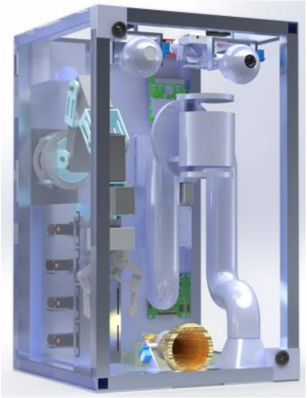
- Developing a space vehicle capable of autonomously detecting, capturing, analyzing and categorizing Lethal Non-Trackable (LNTs) objects to reduce collision risks and provide a positive impact for future space missions.

Solving The Problem

- Design a payload to be hosted upon a Blue Canyon Technologies Venus Class bus that will autonomously collect LNTs within a densely populated debris cloud and nondestructively analyze them for categorization and recycling purposes.

Project Status

- Pre-Phase A: Complete ✓
- Phase A: Complete ✓
- Phase B: In-Progress



[*] Maclay 2020

Design Specification

Venus Class Satellite Bus

- **Available volume:** 17.0” x 16.4” x 27” (dual solar array)
- **Payload mass capability:** 70kg
- **Solar array power:** 444W (dual array)
- **Energy storage:** 10.2 Ah

[BCT X-Sat Venus Bus]

Design for Space: **Low Earth Orbit**

Temperature Range	-65 ℃ to 150 ℃
Thermal Cycle (Orbit Duration)	90 mins
Pressure (High Vacuum)	10-700 nPa
Ionizing Radiation	25-54 µSv/d
UV Radiation	100-200 nm
Atomic Oxygen	109 atoms/cm^3

[LEO]

1.4 Required Elements

Technical Budget

Payload power budget (W)				
	Phase 1	**Phase 2**	**Phase 3**	**Phase 4**
Detection	400	60	100	60
Capture	0	0	250	200
Analysis	0	300	0	50
Heating	0	40	50	90
Total	**400**	**400**	**400**	**400**
Total Allowable	444	444	444	444
Efficiency Losses	**44**	**44**	**44**	**44**

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1.4 Required Elements

Technical Budget

Payload mass budget			
	Distributed Percent Allowed (%)	**Mass (kg)**	**Volume (m^3)**
Detection	10	7	0.0012
Capture	60	42	0.0740
Analysis	15	10.5	0.0185
Hardware	10	7	0.0123
Total	**100**	**70**	**0.1123**
Total Allowable	95	66.5	0.1061
Efficiency	**5**	**3.5**	**0.0062**

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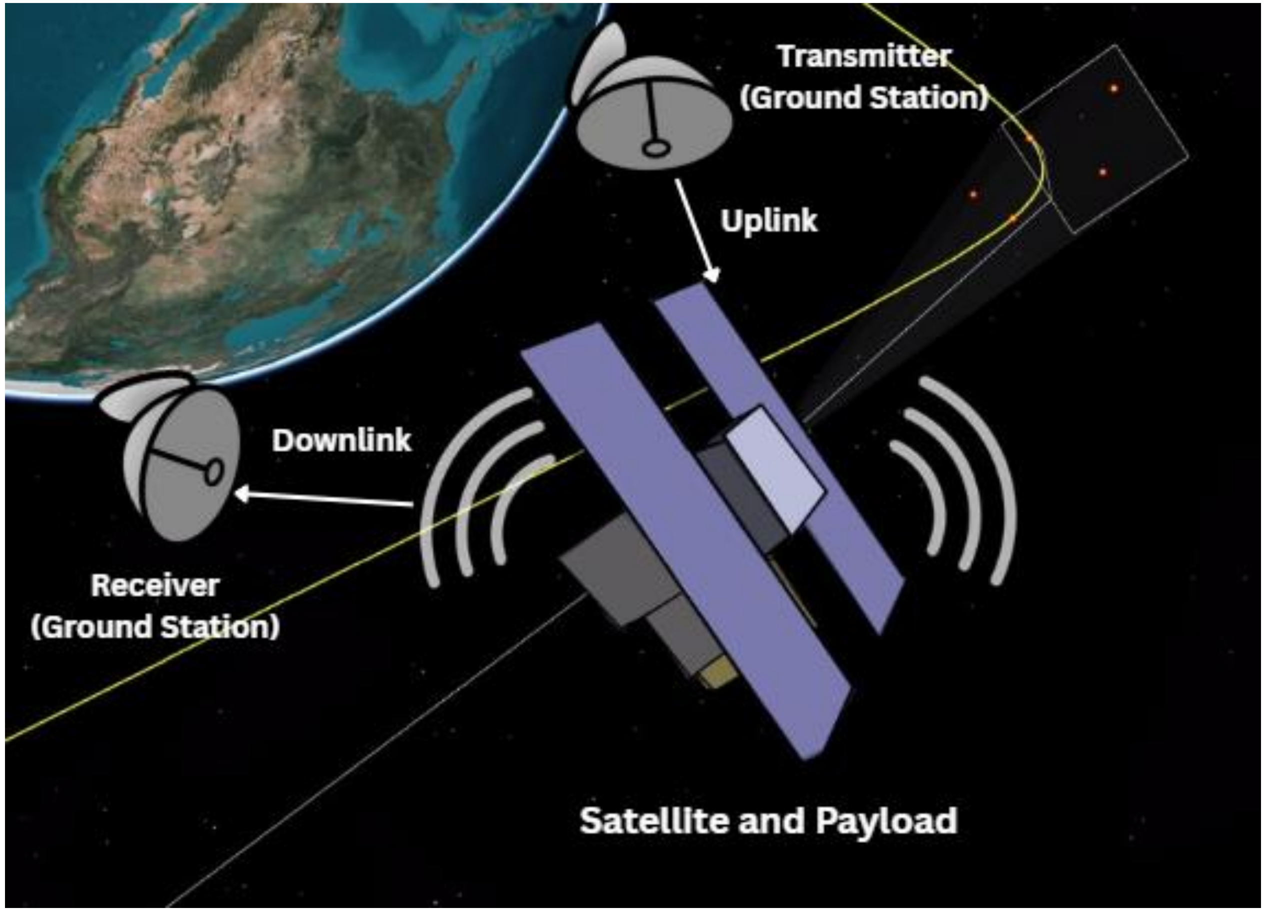
2.3 Data Management and Communications

Required Downlink data	Desired Downlink Data
Two Line Element Data (TLE) of Sighted Debris	Images from Photogrammetry
Volume Estimation Data of Captured Debris	3D Model of Captured Debris
Material Results from Spectroscopy	Spectroscopy Photos



Communication Requirements

- Information data of other debris clouds to avoid collisions.
- The ground station requires an operator to validate measured data occasionally
- Satellite communications system needs on-board storage
- Real time data downlink not required

2.5 Systems Engineering Milestones

Sep. — **Preliminary Research of Topics**

General research on topics and operations that are aligned with C3 and ISAM operations

Oct. — **Development of Concept of Operations**

Refining the general mission scope of the payload and its operations

Oct. — **Trade Studies**

Analysis of alternatives and capabilities of current technologies for Space Debris Remediation

Nov. — **System Requirement Review**

Full definition and review of system requirements that result in a successful mission

Mar. — **Conceptual Design Review**

Completed design of payload and compilation of individual subsystem operations in the fully formed payload

Apr. — **Prototyping Demonstration**

Development, creation and judging of each subsystem prototype

Pre-Phase A

Phase A

Phase B

2.5 Systems Engineering Milestones

Year 1

Concept Development, Mission Planning, & System Design

- Includes formulating in M.C.R.
- Research and technology feasibility
- Includes developing the S.R.R.
- Subsystem prototypes and testing

Year 2

Detailed Design & Model Testing

- Formulate P.D.R.
- Develop engineering model
- Integrate subsystem prototype

Year 3

Qualification & Flight Model Development

- Final flight model
- Develop engineering model
- Integrate subsystem prototype

Year 4

Pre Launch Preparations

- Complete final pre launch preparations
- Launch site testing and integration
- Final safety review
- Launch rehearsal and simulation

Year 5

Launch & Early Operations

- Launch and deployment
- Establish initial contact
- Payload activation
- Initial debris detection and tracking

Year 6

Full Mission Operation & Data Collection

- Routing operations
- Data transmission and analysis
- Periodic system diagnostics
- Subsystem prototype and testing
- Formulate mid mission review

Year 7

End of Mission & Deorbit

- Final data collection and transmission
- End-of-mission procedure
- Controlled deorbit

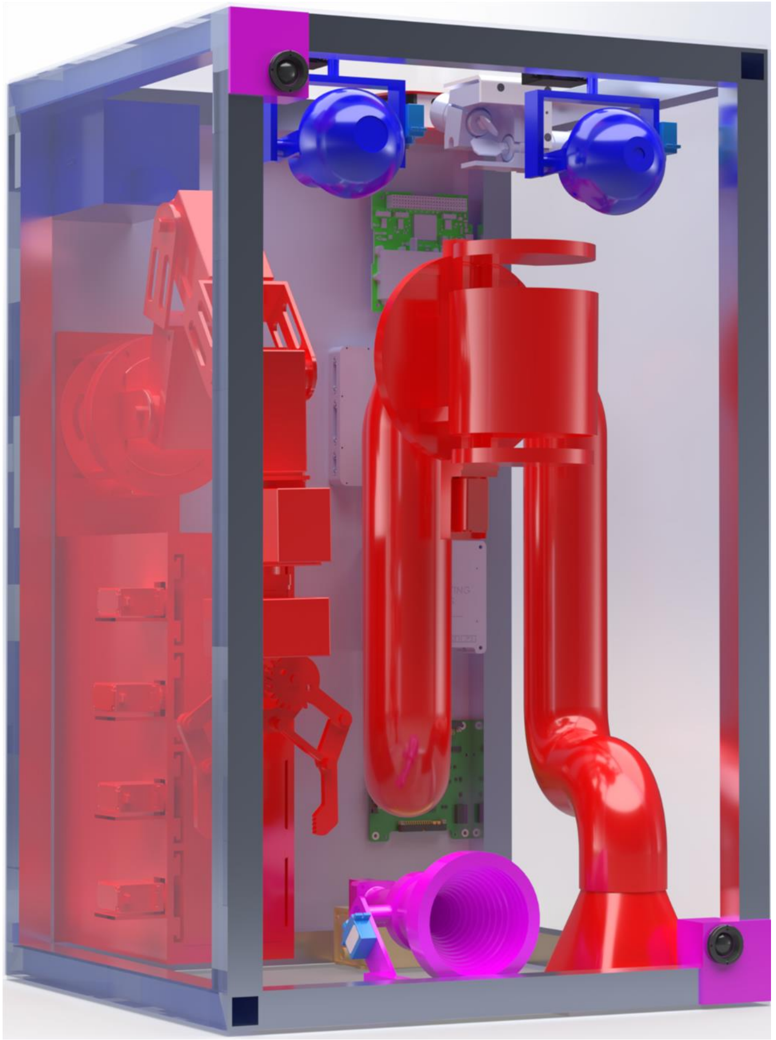
Conceptual Design

Capture Sub-system

Hardware:
- Capture Mechanism
- Robotic Arm
- Storage Housing

Detection Sub-system

Hardware:
- Horn Radar Antenna
- Actuating Antenna Arm
- Infrared Cameras



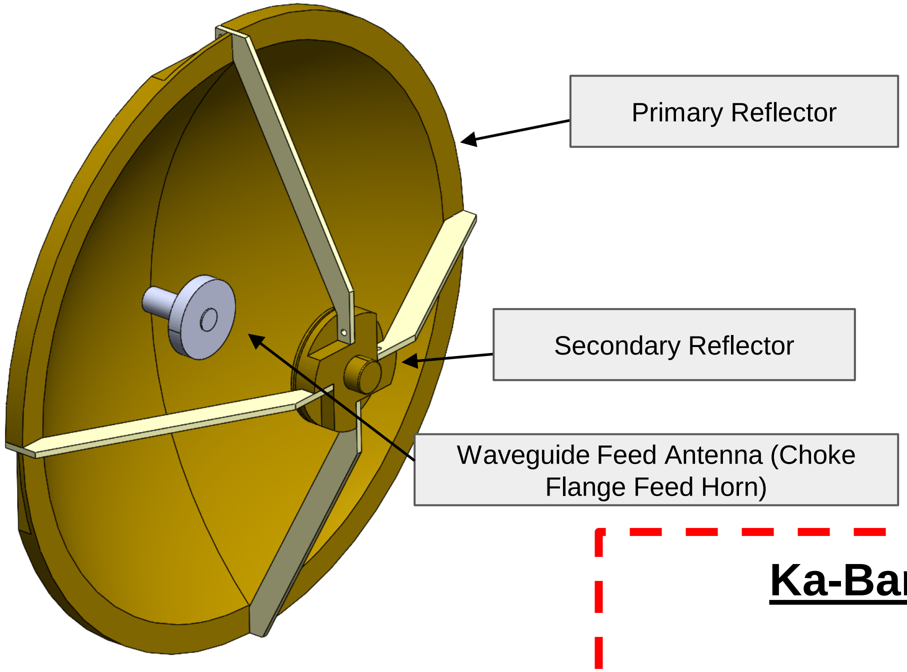
Analysis Sub-system

Hardware:
- Photogrammetry and LIBS (Laser Induced Breakdown Spectroscopy)
- Spectrometer
- Optic system

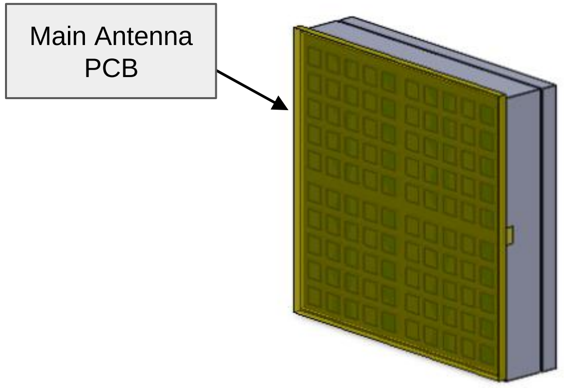
Trade Studies - Detection

Radar, Visible and Infrared Optics

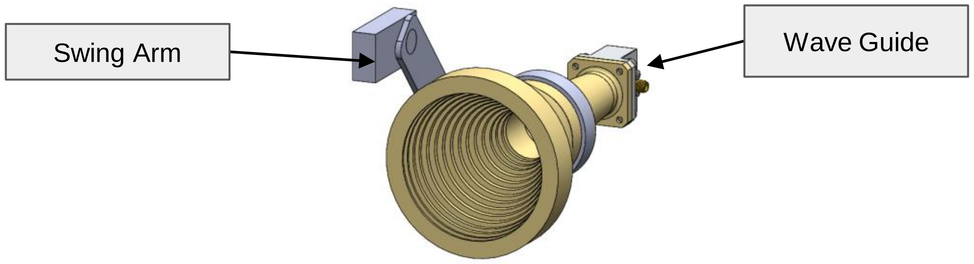
Radar - Cassegrain Antenna



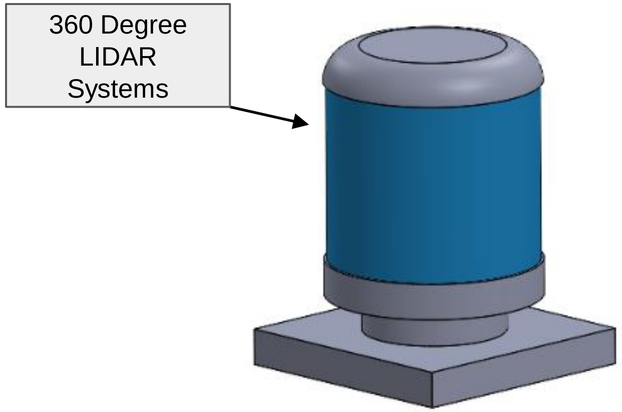
Radar - Phased Array Antenna



Ka-Band Horn Emitter



LIDAR (light detection and ranging)



Selection Criterion
- SWaP-C
- Range
- Gain

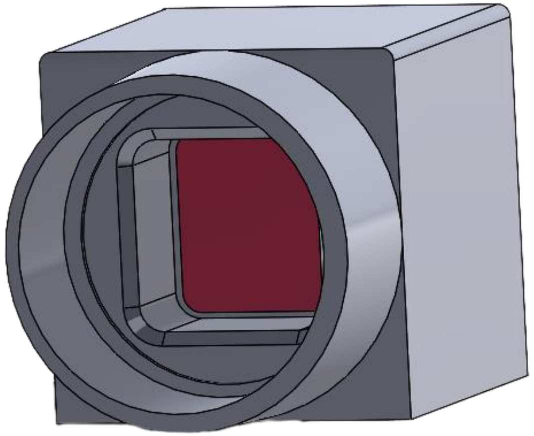
Trade Studies - Detection

Cameras and Rangefinder

Single-Point Laser Rangefinder

IR (Infrared) Cameras

Visible Light Cameras



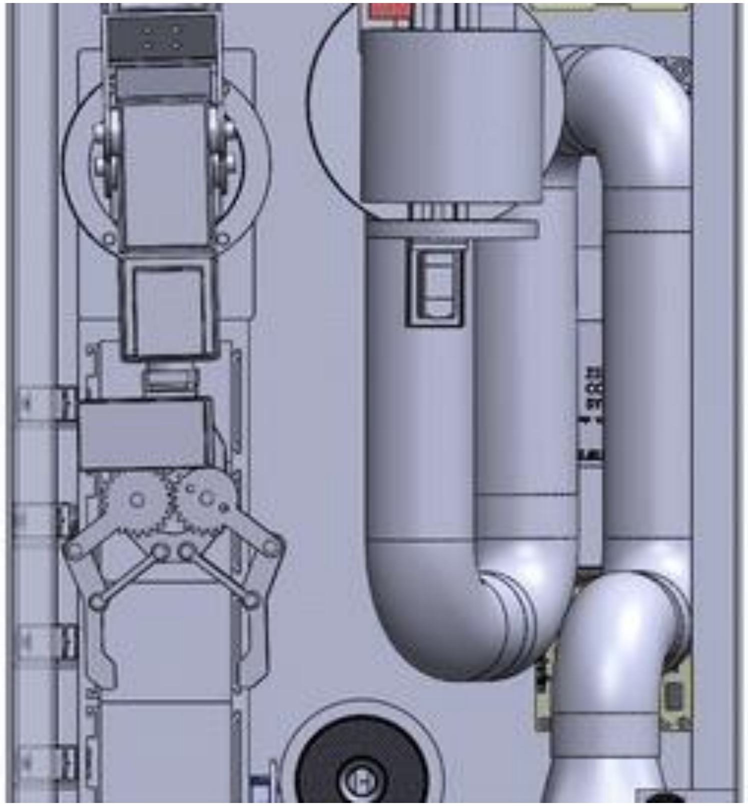
Selection Criterion

- SWaP-C
- Attenuation Rate
- hFOV

2.1 Animation of Key Operation Sequence

Detection: Ka-Band horn emitter

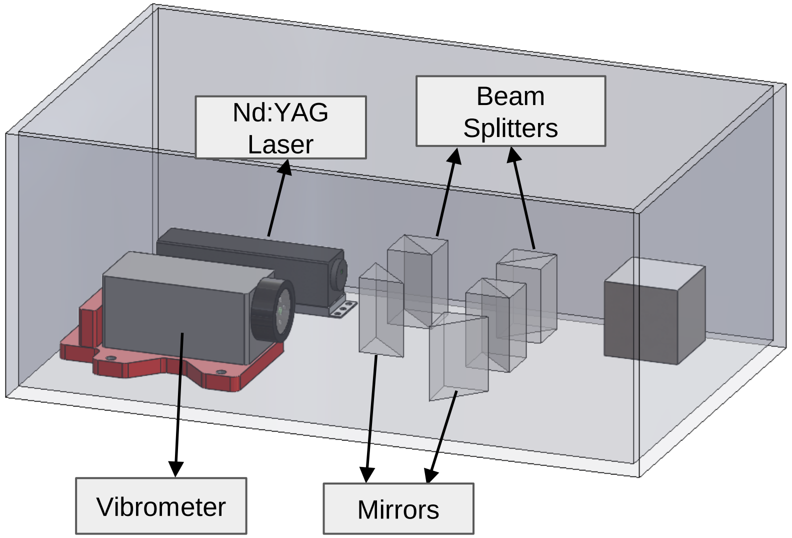
- Designed for precision and efficiency
- Uses a standard waveguide interface WR-28
- Standard flange (UG-599/U)
- Frequency: 37.5 GHz



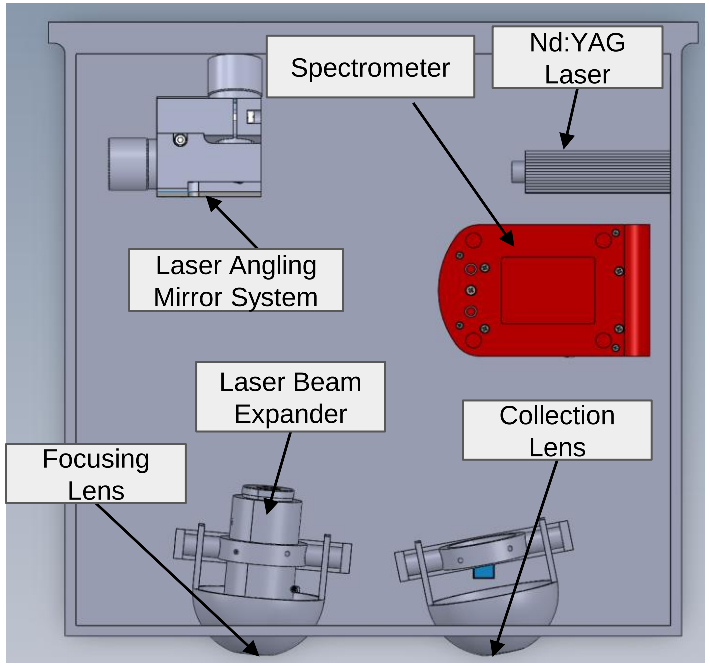
Trade Studies - Analysis

LIBS, EDDY Currents, Laser Ultrasound

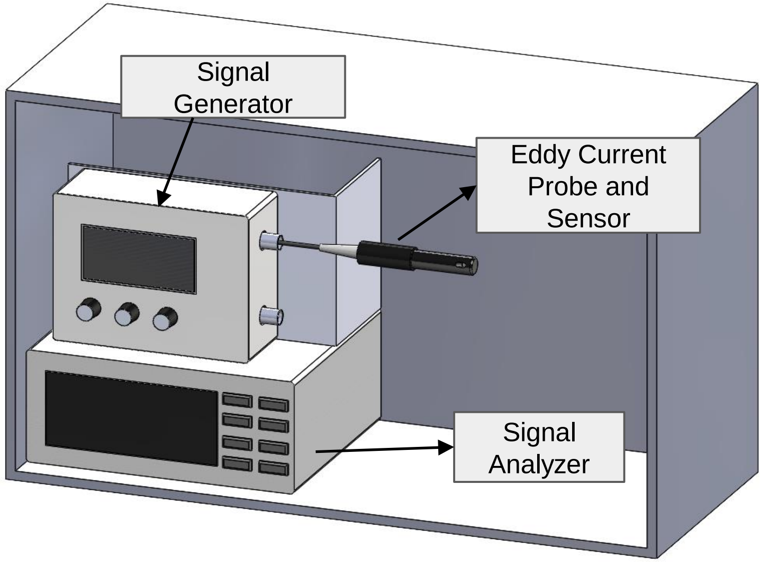
Laser Ultrasound



Laser Induced Breakdown Spectroscopy



EDDY Currents



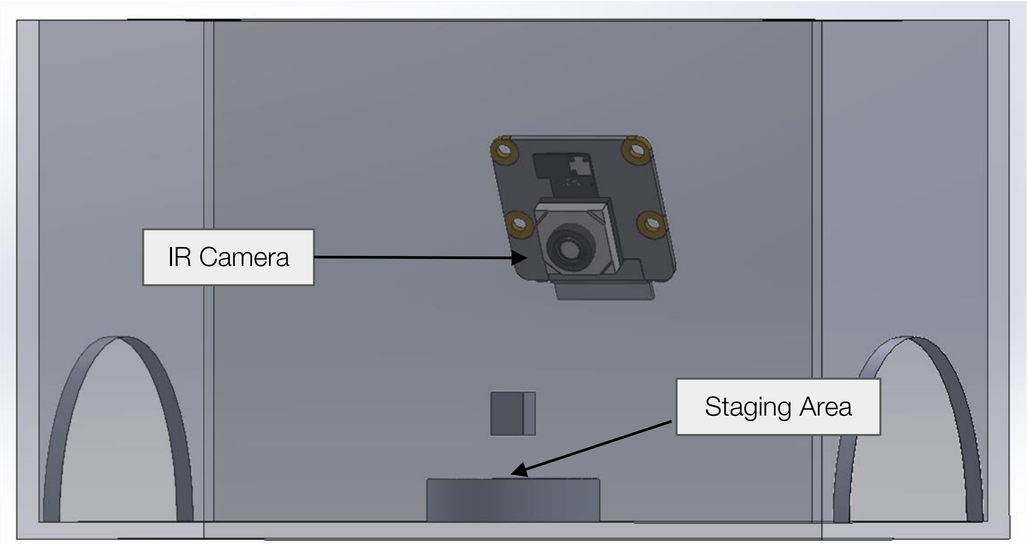
Selection Criterion

- SWaP-C
- Testing Range

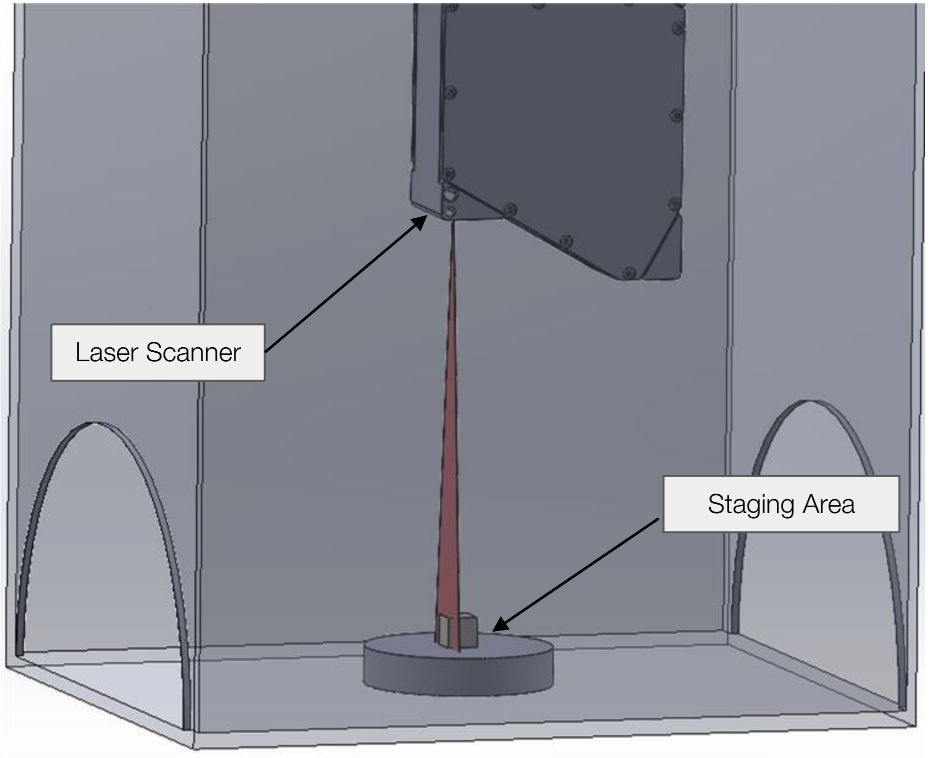
Trade Studies - Analysis

Photogrammetry and 3D Laser Scanning

Photogrammetry



3D Laser Scanning



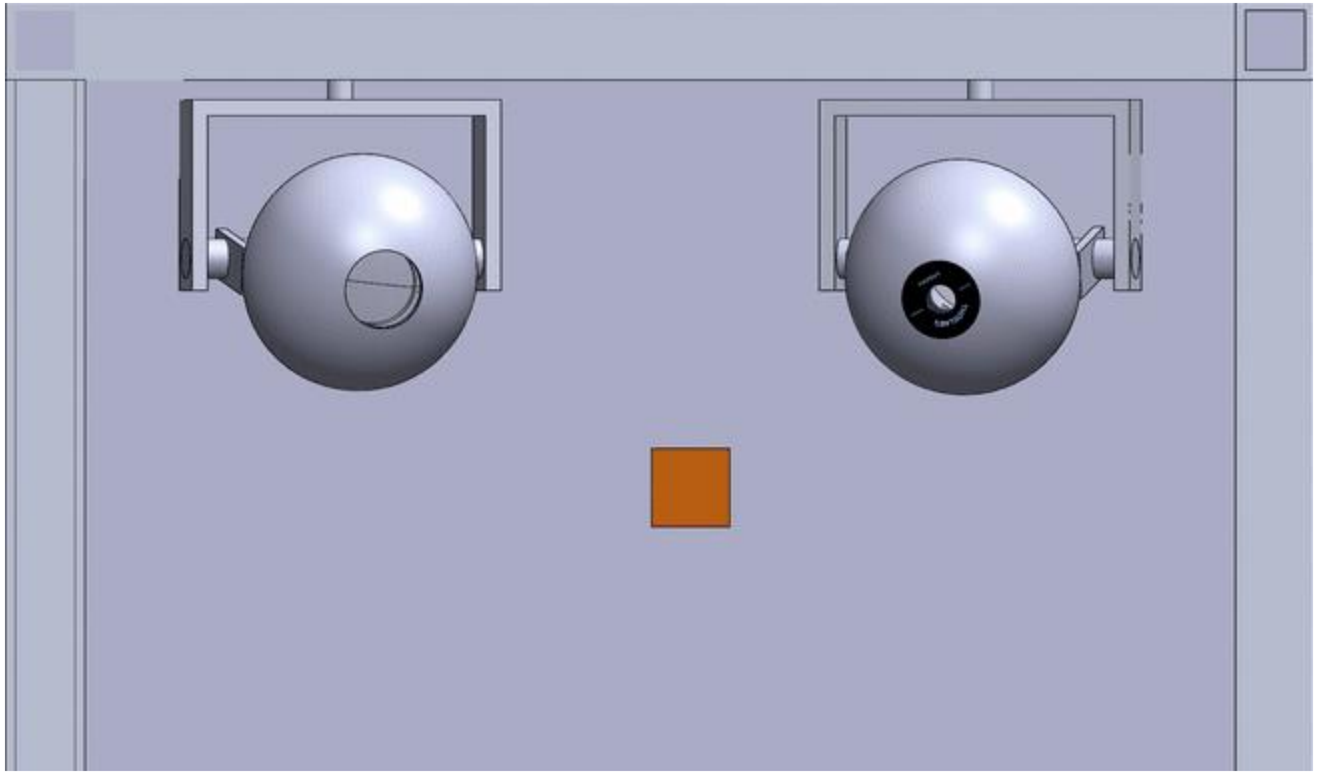
Selection Criterion

- SWaP-C
- Computing Power

2.1 Animation of Key Operating Sequence

Analysis: Laser Induced Breakdown Spectroscopy (LIBS)

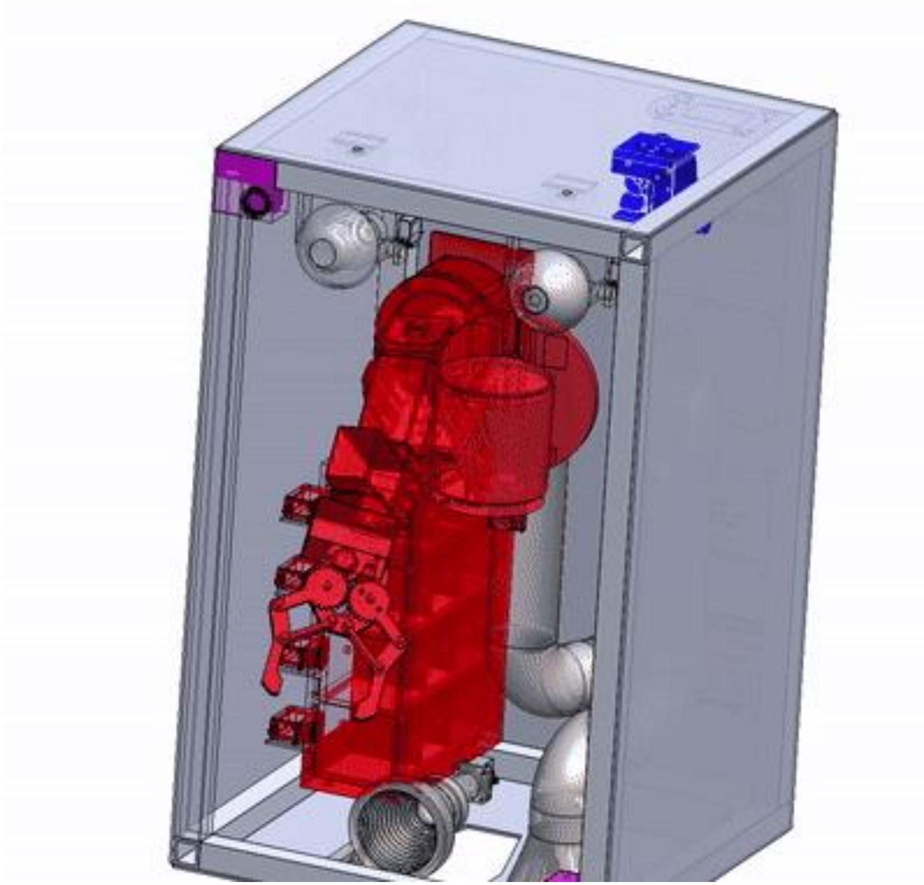
- MicroJewel DPSS Laser
- THORLABS CCT11 Compact Spectrometer
- Optic system: Edmund 10x Laser Beam Expander
- Focusing Lens: THORLABS N-BK Plano Convex lens



2.1 Animation of Key Operating Sequence

Analysis: Photogrammetry

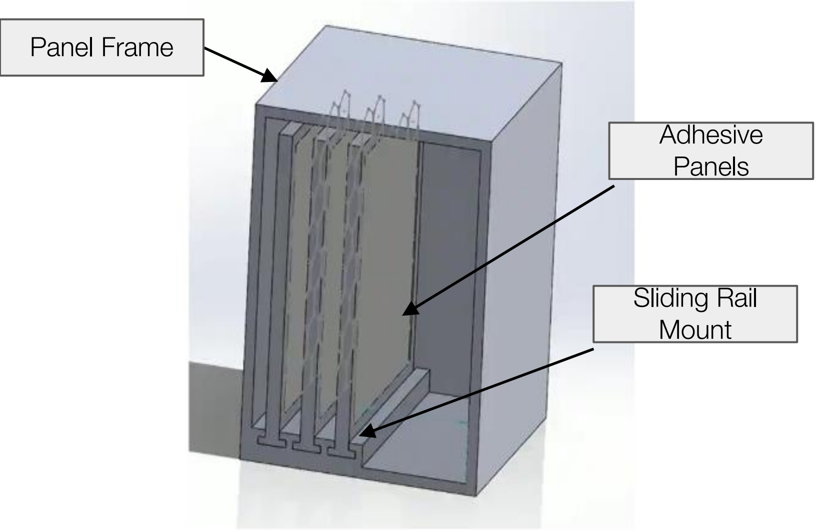
- Camera
- Raspberry pi
- Point Cloud Generation



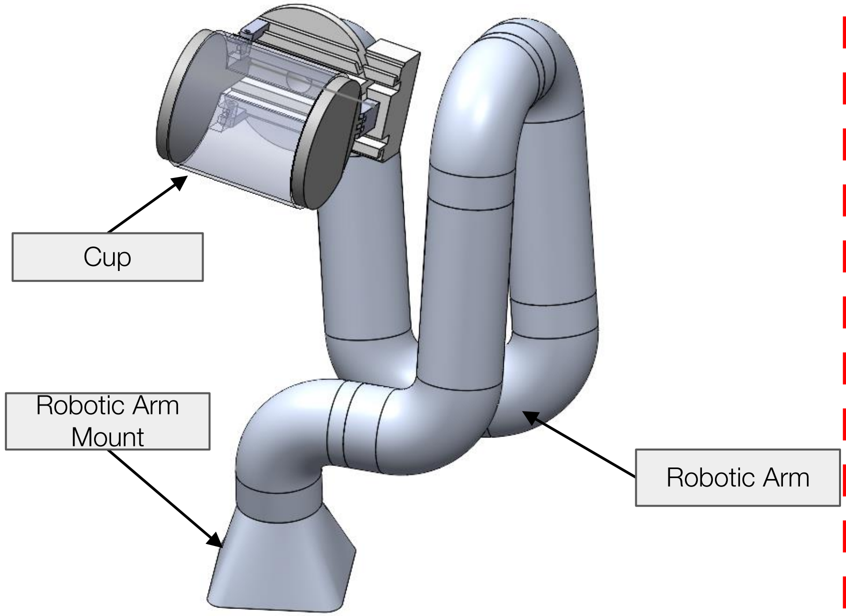
Trade Studies - Capture

Capture Mechanism

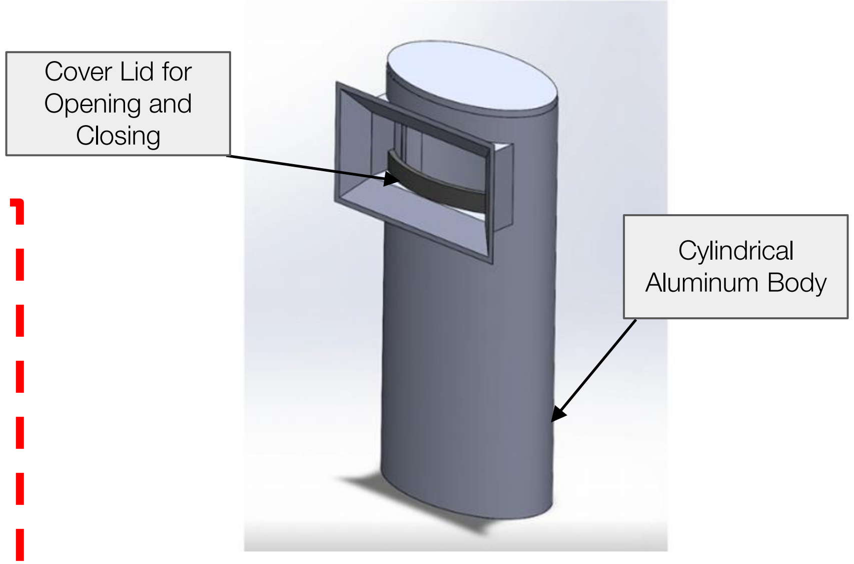
Capture & Storage Mechanism: “2 Layer Adhesive Panels”



Capture Mechanism: “The Cup”



Capture Mechanism: “The Bullet Catcher”

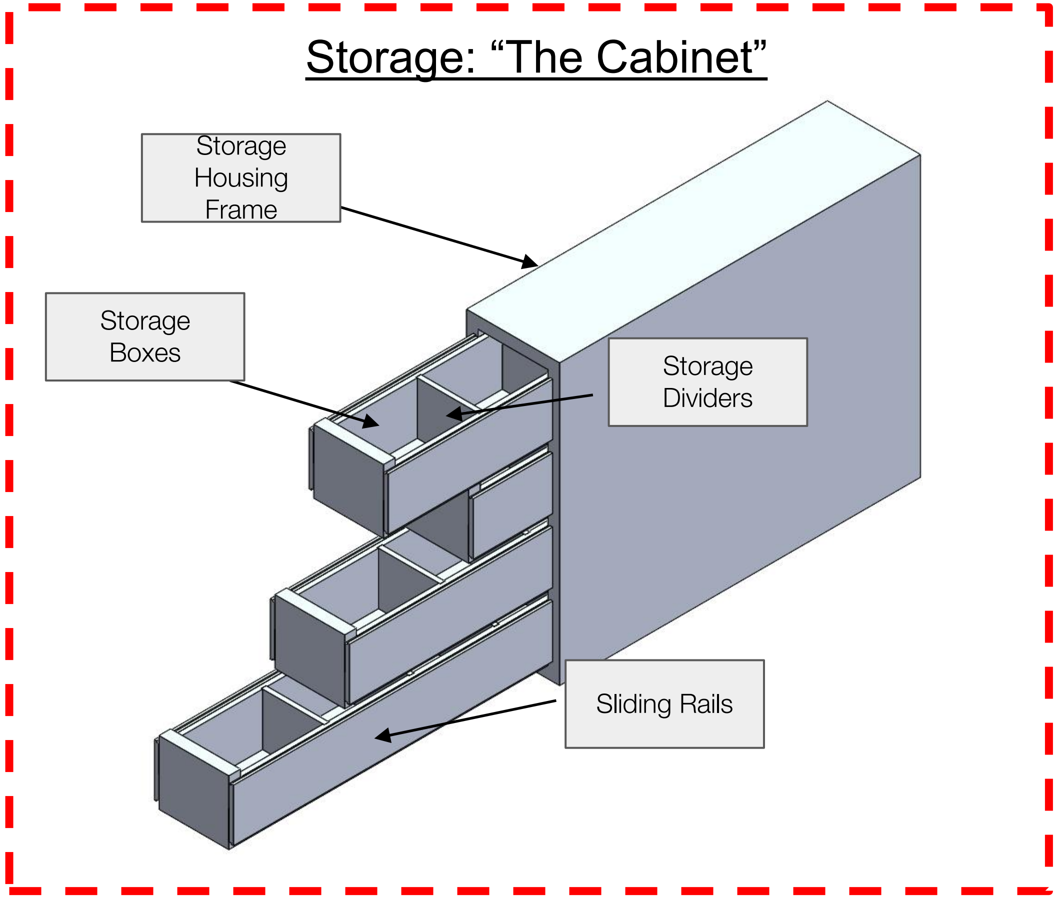


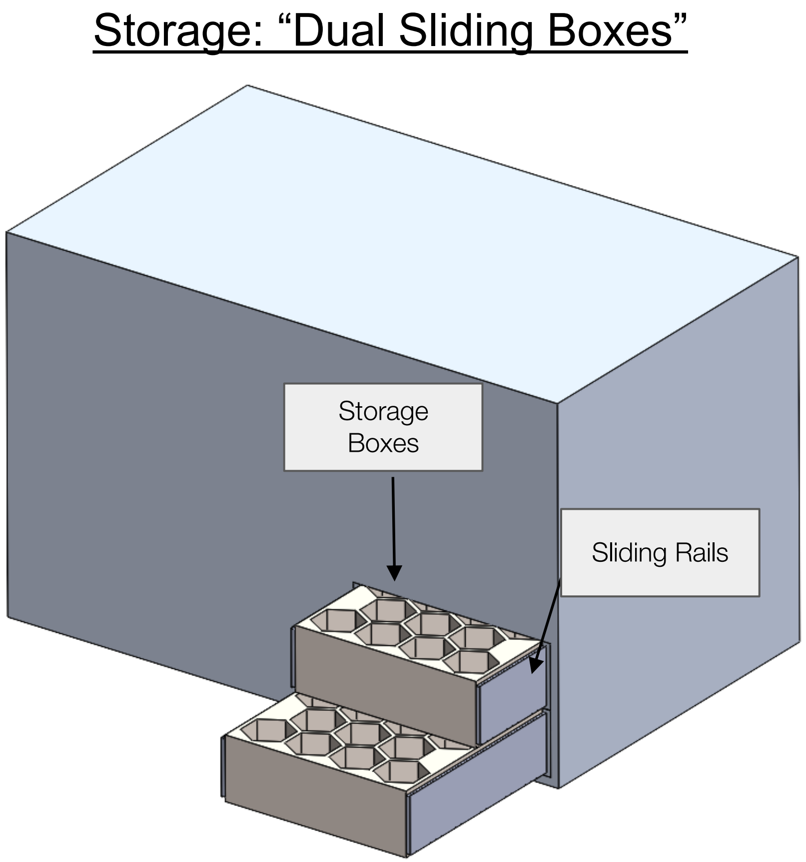
Selection Criterion

- SWaP-C

Trade Studies - Storage

Storage





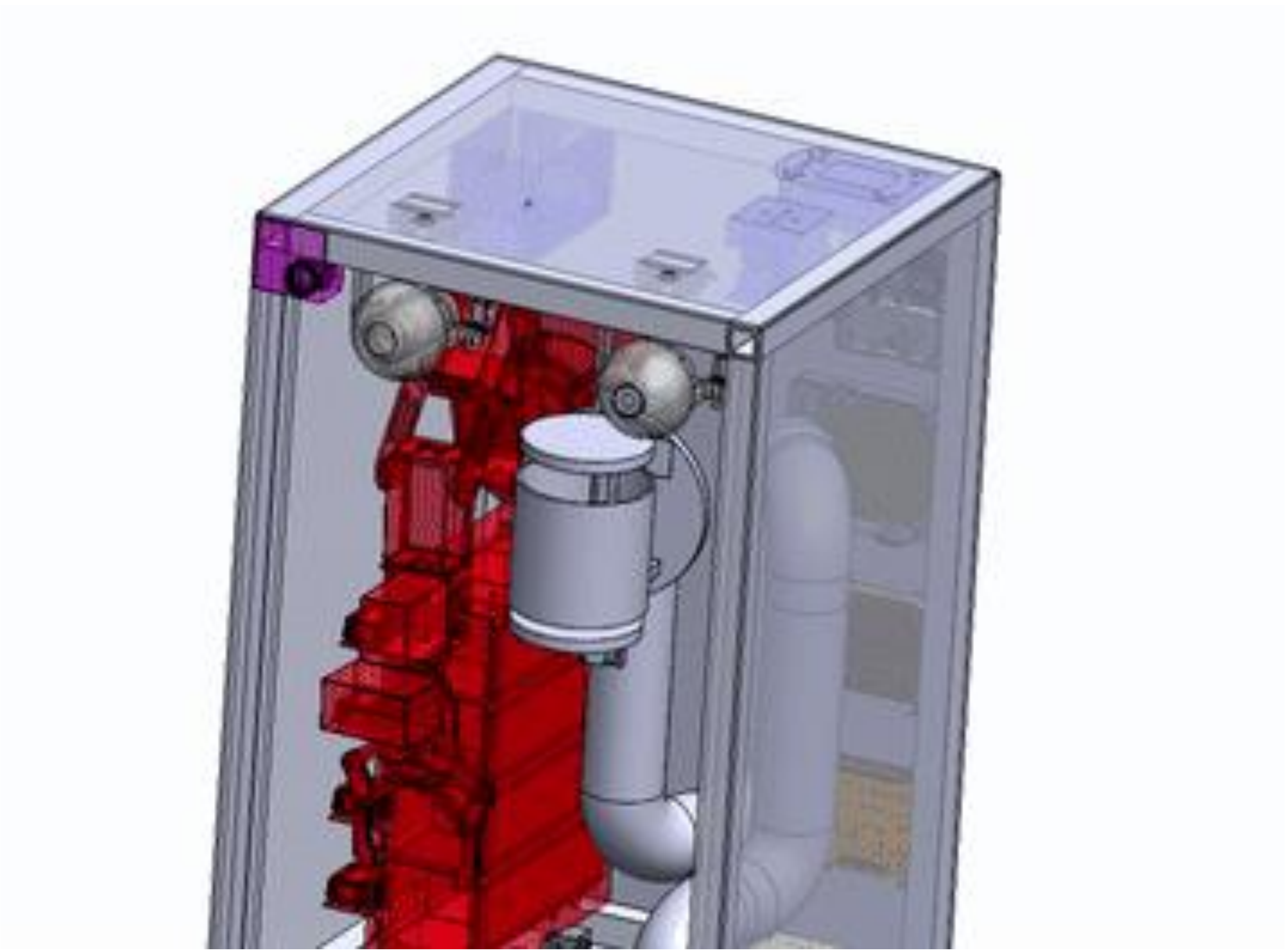
Selection Criterion

- SWaP-C

2.1 Animation of Key Operating Sequence

Capture: Main Robotic Arm and The Cup

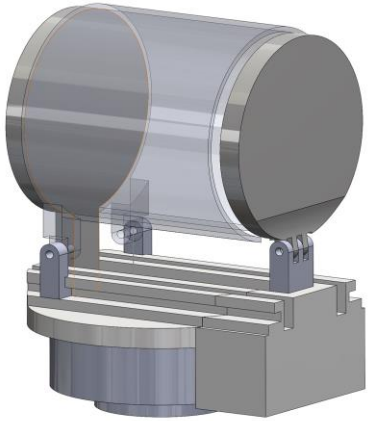
- Raspberry pi-powered robotic arm
- Servo motors
- Highly flexible 6 Degrees of Freedom (DOF) design
- 11.42 x 9.06 x 12.99 in



3.1 Most Innovative Concepts Considered

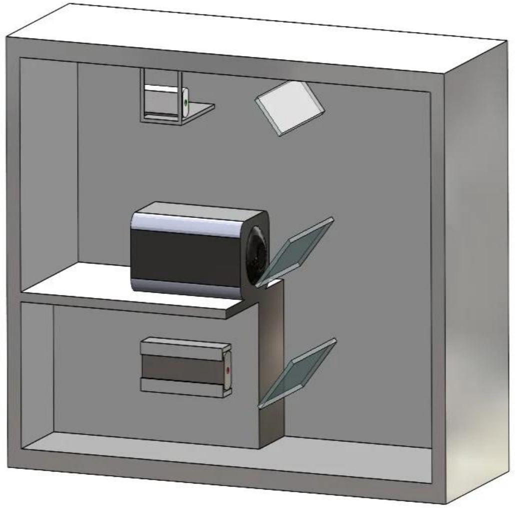
The Cup

- Consists of two Parallel Plates with Cylindrical Shell Section
- Closes the Manipulatable plate after debris fully enters the Shell
- Soft lining inside the can to reduce damage and rebound from incoming debris



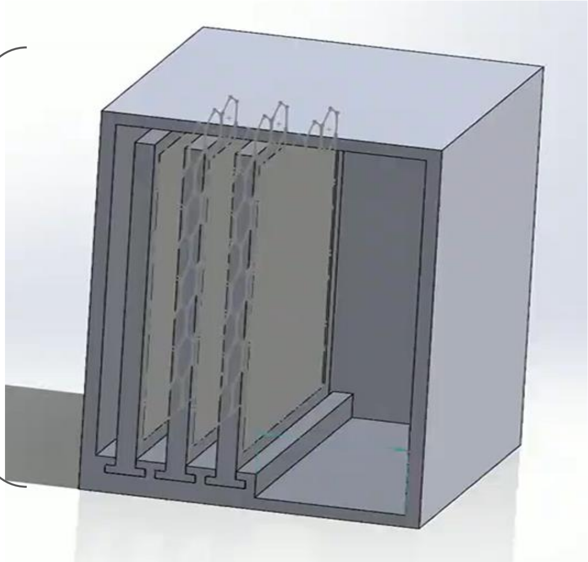
Laser Ultrasound

- Contains: Pulsed Laser, Continuous Wave Laser, Laser Ultrasonic Receiver, and Mirrors
- Debris shot with intense bursts of lasers from Pulsed Laser, generating Ultrasonic Waves
- Receiver absorbs and converts waves to electrical signals to Determine Material Properties



Two Layer Adhesive Panels

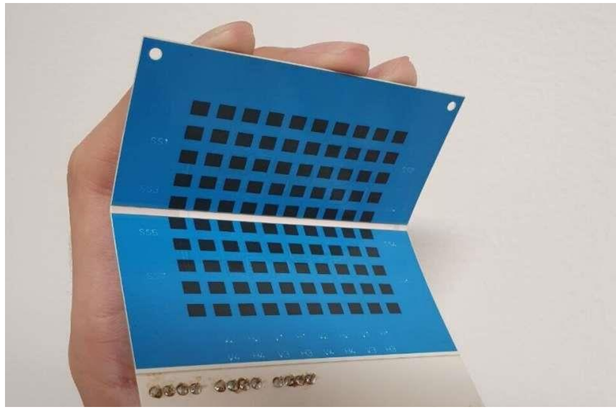
- Can capture multiple debris at once
- Dual-purpose functionality as it also works as storage
- Sliding rail mounts to slide panels in and out of payload



3.2 Most Important Technology Gaps

Phased Array Radar Antenna Development

- Components and concepts of the phased array antenna significantly raised the complexity of the detection sub-system design
- Limited availability of easily understandable resources for non antenna engineering experts

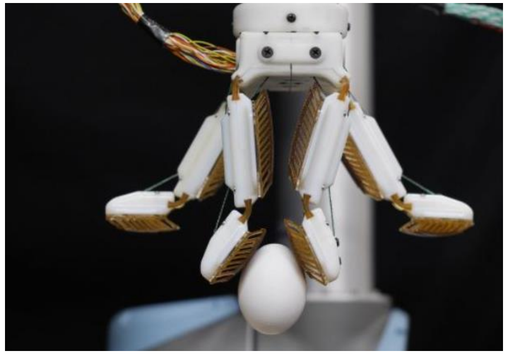


Sensor for Capture Mechanism

- Limited space on platform of capture device
- Difficulty of integration of sensors and components

Manipulator Arm for Debris Transfer

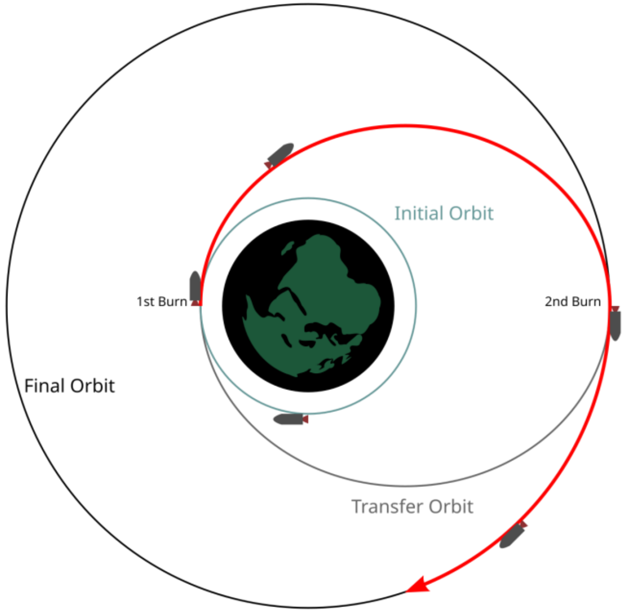
- Complexity of mechanics for precise handling of space debris transfer

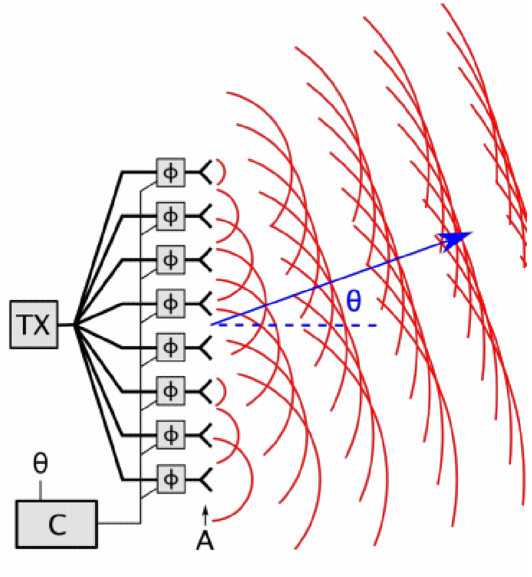


3.3 Biggest Challenges Encountered

RPO and Orbital Mechanics

- Identifying debris cloud to operate in
- Calculating efficient successive rendezvous operations



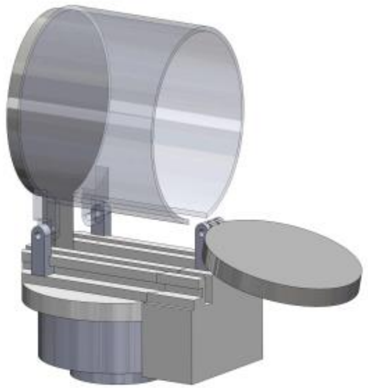


Phased Array Radar

- Power-intensive making integration difficult given power budget
- Highly complex as a solution for detection operation

Reliable Capture Mechanism

- Maintaining reliability and integrity when capturing fast-moving, tumbling debris
- Designing deployable mechanism capable of autonomous operation



1.5 Risks

Risk Identification Categories

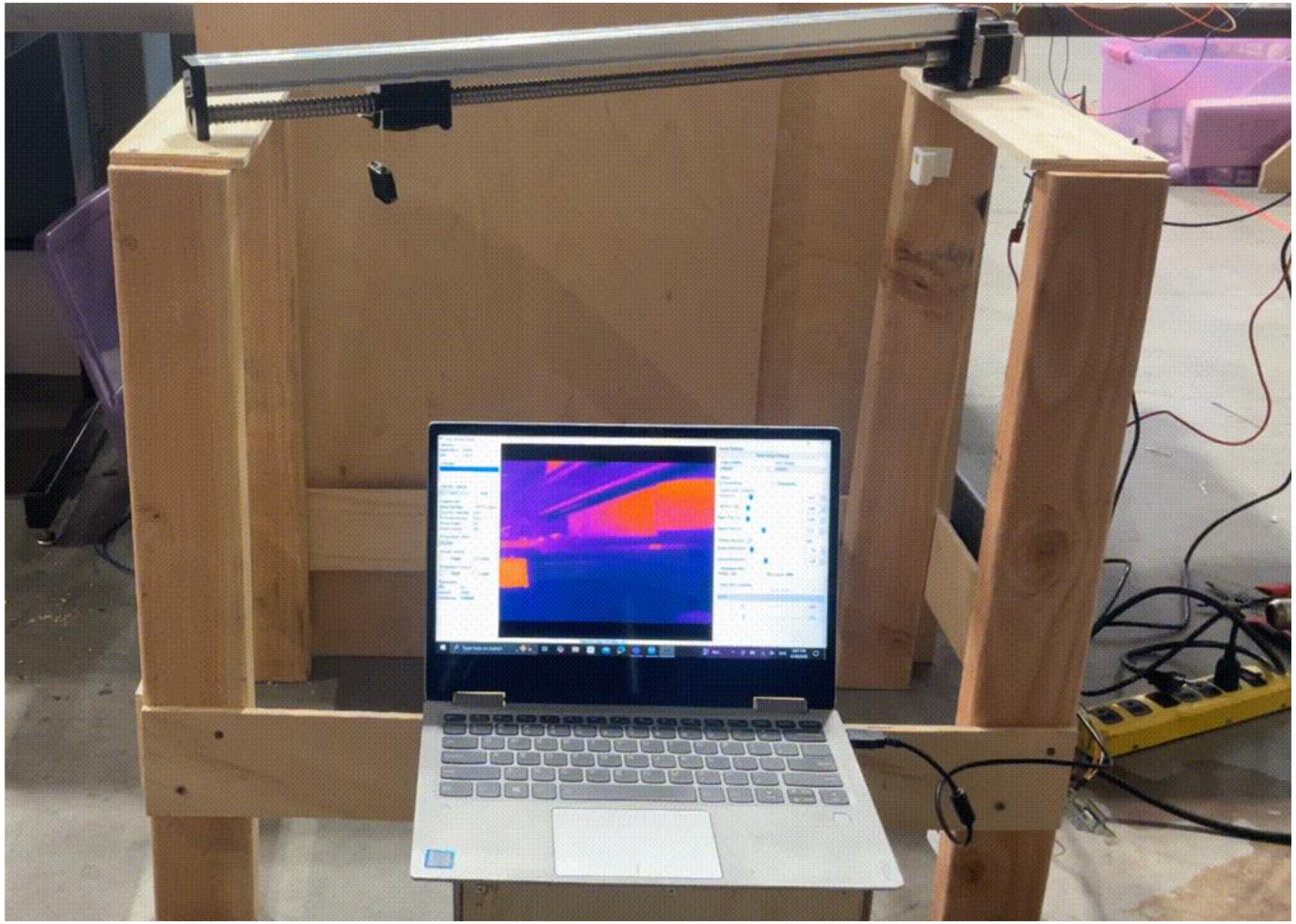
- **Technical Risks**
  - Payload instrument failure
  - Orbital insertion error
- **Environmental Risk**
  - Space debris collision
  - Solar activity
- **Operational Risk**
  - Scheduling delays
  - Budget shortfall

#	Risk	Likelihood	Severity	Mitigation Strategy
R.3.1.1	Complete loss of detection system.	Medium	High	Implement redundancy in key detection components.
R.2.1	Payload temperature outside components operating range	Medium	High	Ensure thermal dissipation system functionality
R.3.3.1	Debris damaging capture device	Medium	Medium	Conduct debris impact risk assessments and develop a debris avoidance strategy.
R.1.1	Project fails to meet timeline / budget constraints.	Low	High	Establish clear project milestones

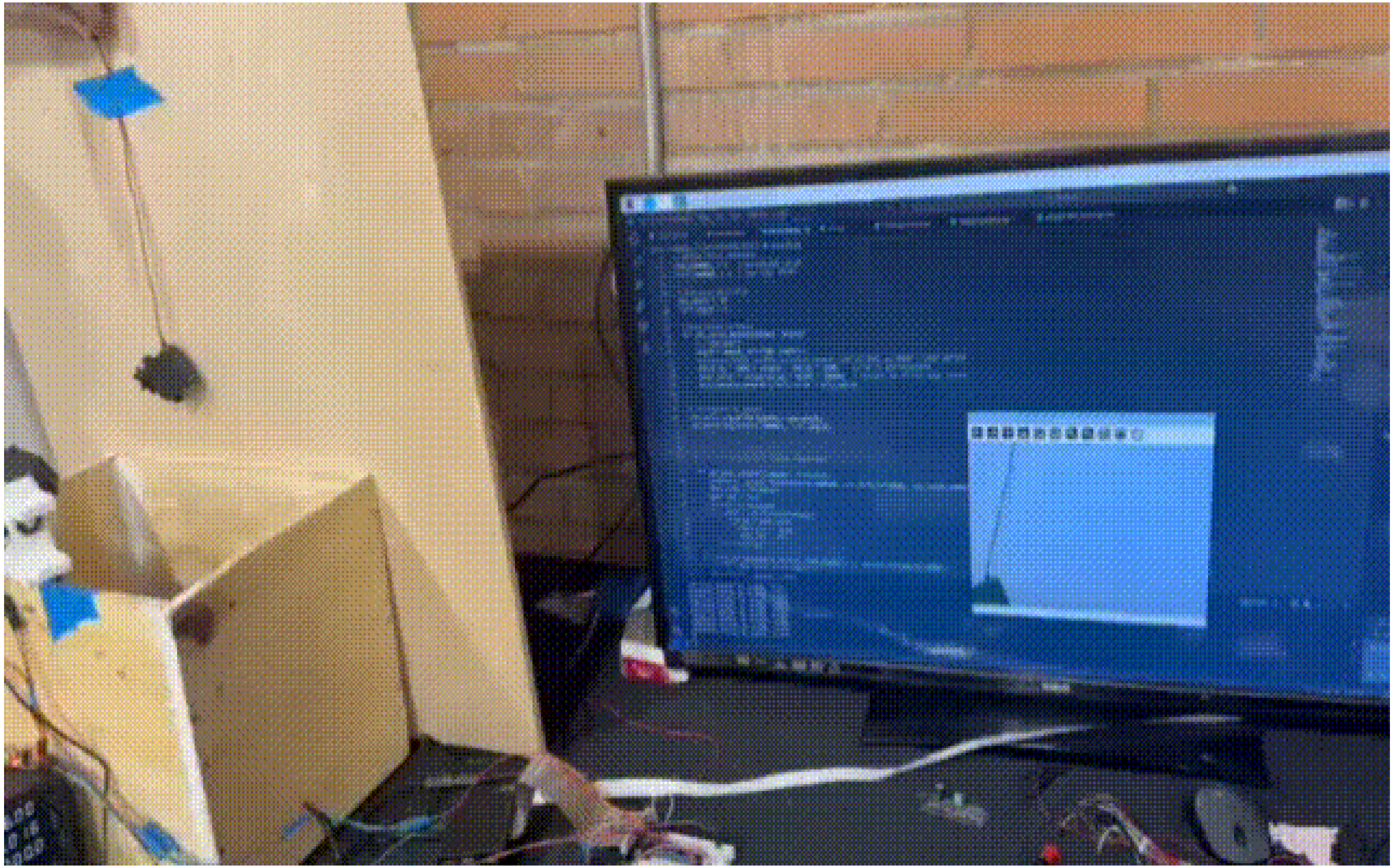
1.6 Path to PDR

1. Design docking and connection system to the host bus
2. Finalize the specific components for each subsystem
3. Finalize supporting accessories (fasteners, connectors, etc.)
4. Finalization of subsystem circuit design
5. Finalization of data budget and network protocols
6. Geometric Dimensioning & Tolerancing of mating parts
7. Conduct FEA analysis of each subsystem (vibration, heat, static)
8. Determine Thermal Coatings for Payload or Multi layer Insulation and heat dissipation

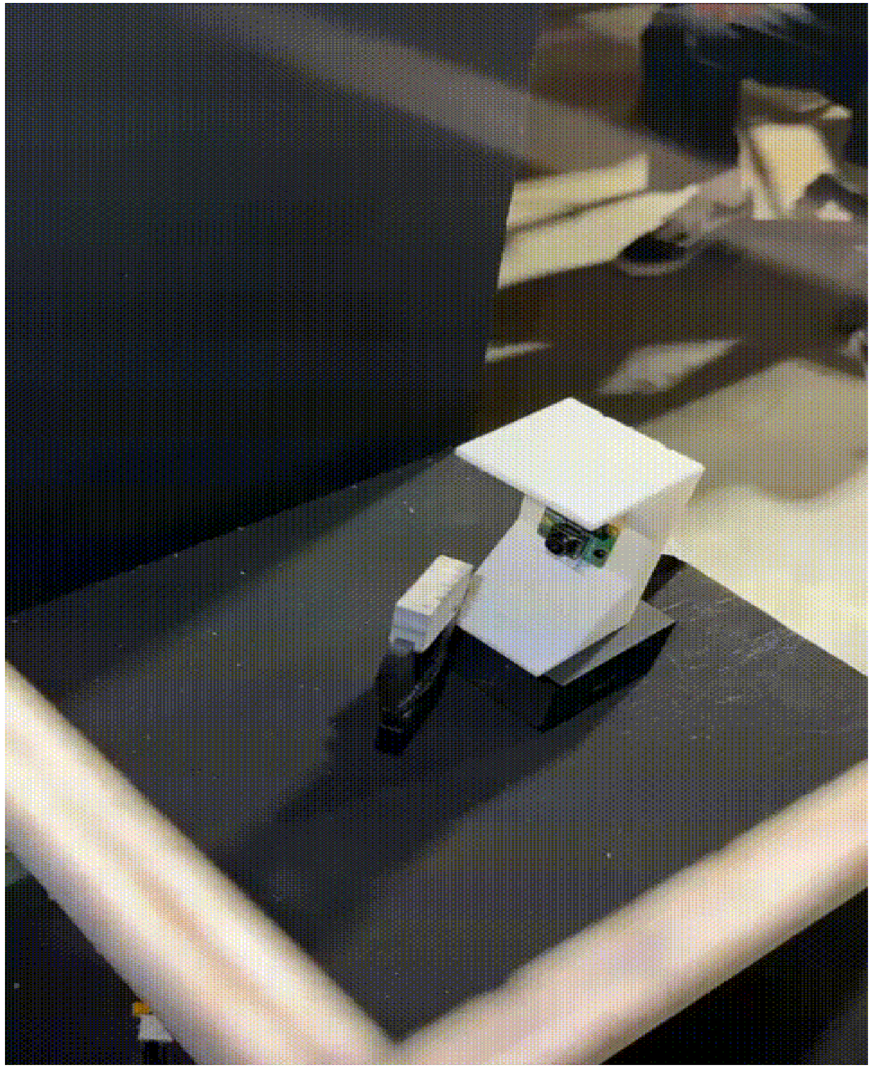
Prototype - Detection

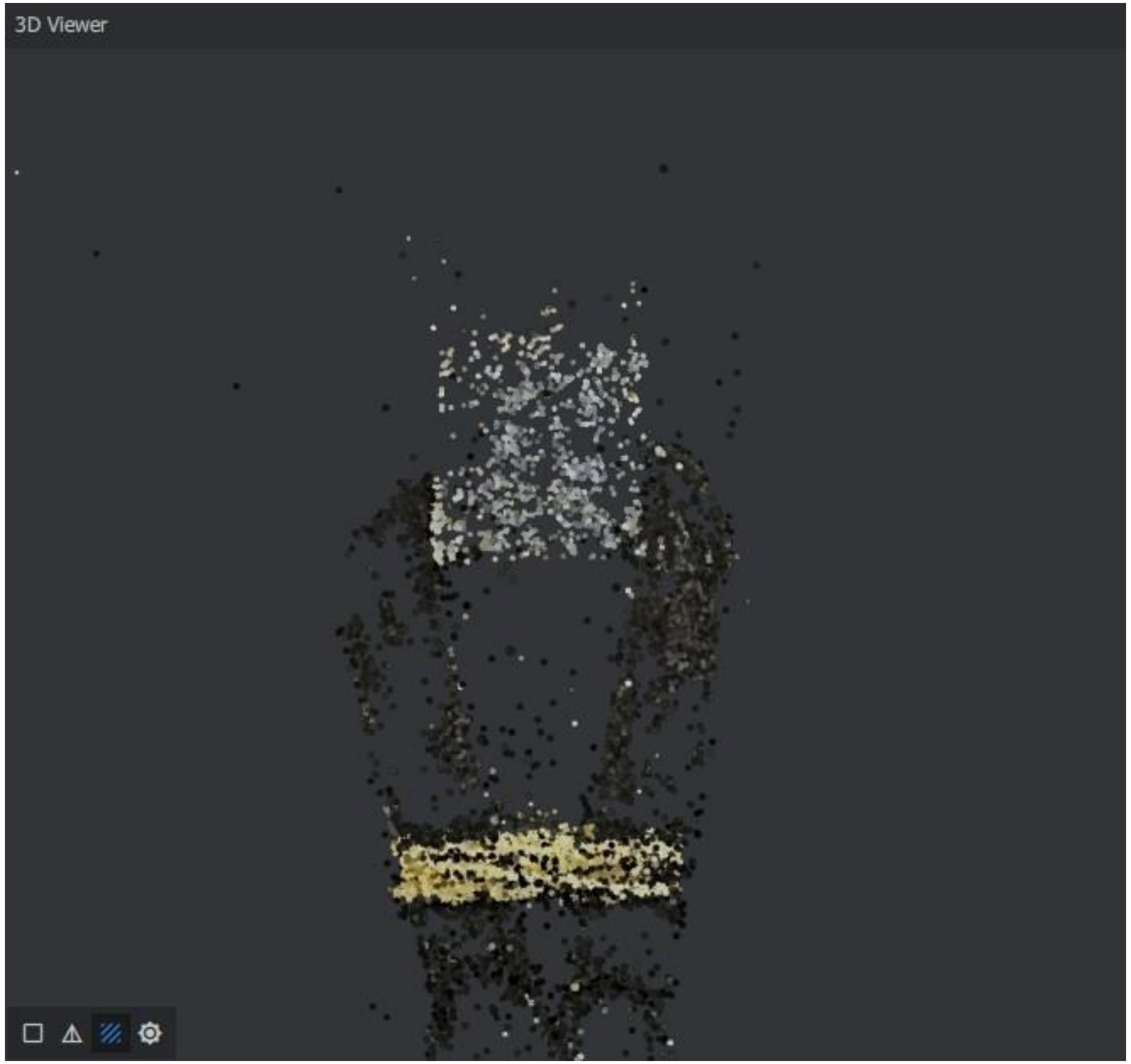


Prototype - LIBS

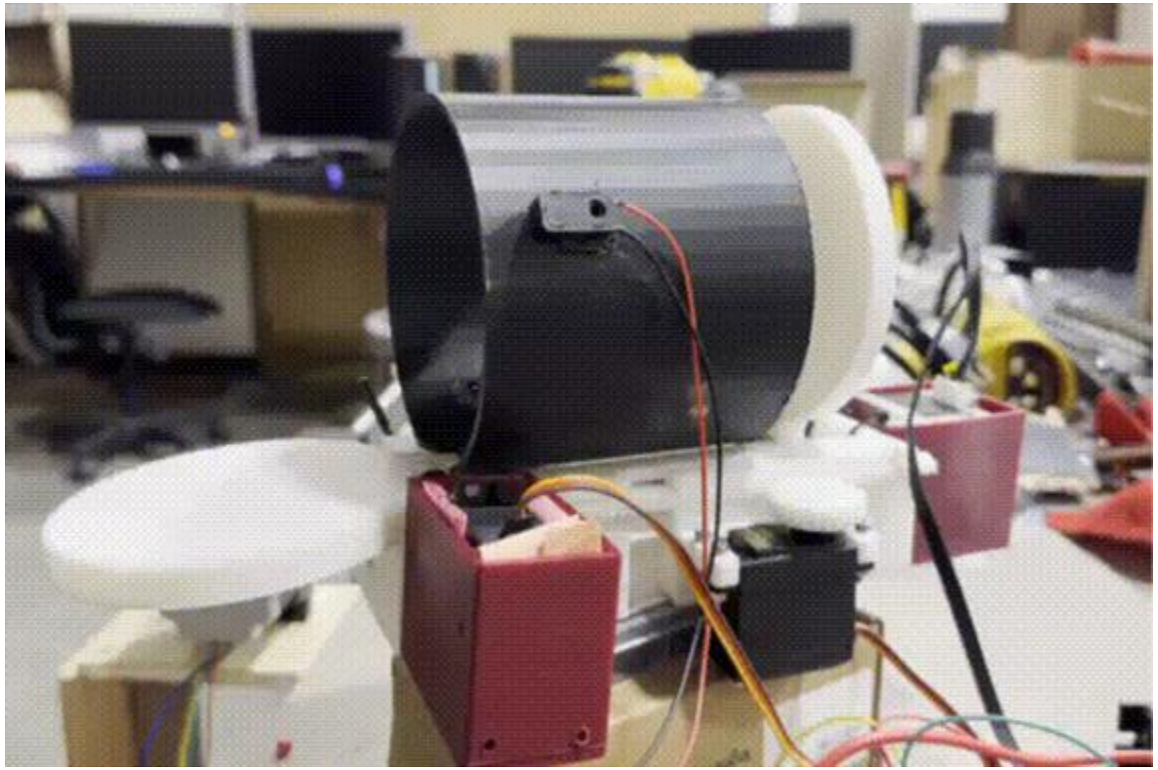


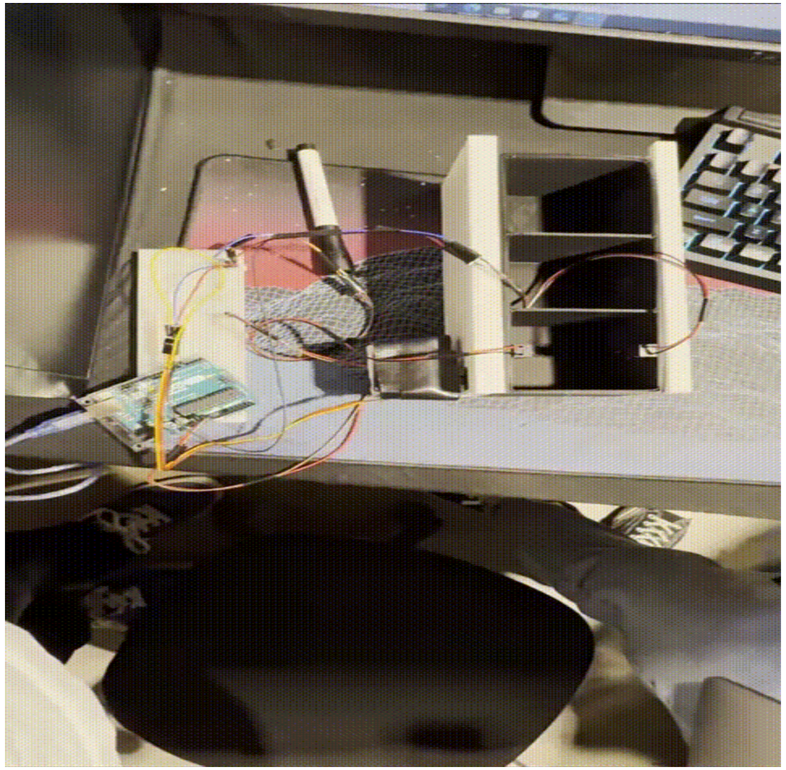
Prototype - Photogrammetry





Prototype - Capture Cup





4.1 Paper

- Comprehensive work which details work on space debris mitigation project
- Problem Definition
- Project Scope
- General requirements, mission requirements, sub-system requirements
- Project Innovation through sub-system operations

Detection, Analysis, and Capture of Lethal Non-Trackable Space Debris

Benjamin M. White-Blakesley*

California State University, Northridge (CSUN) has started its second year exploring In-Space Servicing, Assembly, and Manufacturing (ISAM) capabilities through its collaboration with the Aerospace Corporation and participating mentors in the Consortium for Space Mobility and ISAM Capabilities (COSMIC) Capstone Challenge (C3). This challenge was a direct response to the president's call for a national increase in studies and work done towards advancing ISAM capabilities. This cohort was led by Project Advisor Dr Christoph Schaal and mentored by LinQuest Corporation, Corporate Engineer II, Elozor Plotke. CSUN ISAM (2024-2025) sought a conceptual design solution to aid space debris remediation by improving tracking, categorization, and collection of lethal non trackable objects in low-earth orbit.

"Design a payload to be hosted upon a Blue Canyon Technologies Venus Class bus that will autonomously detect lethal non-trackables within a densely populated debris area, robotically capture potential specimens, and non-destructively analyze them for categorization and storage for future use."

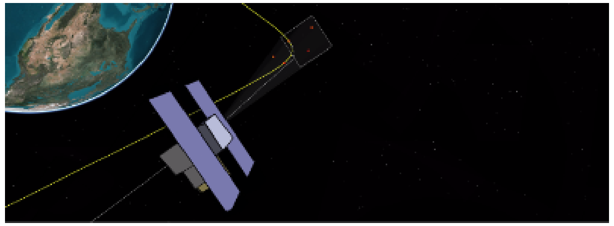


Fig. 1 Lethal non-trackable space debris by size and damage potential.

I. Introduction

THE population of the space domain is constantly increasing. From new constellations being launched to the rapid expansion of research and technology looking to take to the stars, Kessler syndrome is looking even more real as the years go by. Once space becomes too crowded, even the slightest disturbance in an orbit may wreak havoc on the entire space domain. The future of space exploration and advancements is dependent on the ability to do such activities safely in one of the most unsafe environments. Many recent developments and emerging projects have begun to take the initiative to tackle the space debris problem. Some target the largest of these debris objects, which are relatively predictable in terms of where they may be located at any given time in their orbit. Removing these larger objects is often seen as the easiest way to reduce the risk of Kessler syndrome. However, a serious risk to space mission safety still exists from the small debris population as well. These fragments fall into the size range where they bypass full protection by standard spacecraft shielding yet still retain enough kinetic energy to potentially cause catastrophic damage upon impact. What makes these debris objects more of a risk is the fact that current ground- and space-based technologies cannot detect such small objects. The next forefront of debris remediation may very well begin with these small debris objects if we wish to continue safe explorations in the future. Because these debris still contain lethal amounts of energy and happen to be too small for current tracking methods, they have become known as lethal non-trackables.

*Systems Engineer, California State University Northridge - In-Space Servicing, Assembly, and Manufacturing

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Summary/Conclusion

	Key Aspects
Summary	✓ Detect debris 1-5 cm in diameter ✓ Capture debris using Containment Cup ✓ Analyze debris and categorize according to material ✓ Store material with Intention of recycling material
Lessons Learned	● Order parts early/ order extra parts: Delayed prototype production ● Line-of-Sight challenges: Arm or Cup can momentarily block sensors ● Environmental Gaps: No vacuum/thermal testing yet. Ground conditions do not match orbits ● Time management and collaboration is crucial for mission success
Future Improvements	● Potentially add secondary sensor for uninterrupted tracking ● Test in thermal/vacuum chamber to assess real-world viability ● Explore autonomous recovery/ reset for rapid multi-capture capability

Questions

Discussion Points

- Technical Feedback
    - Design Improvements?
    - Action Items?
- Critical Considerations
- Other Questions