COSMIC

THE POWER OF COLLABORATION

COSMIC Capstone Challenge:
Mid Design Brief

AIAA University of South Florida: Telescoping Robotic Arm Module (TRAM)

Students: Ethan DeWild, Harshitha Madabhushani, Lucas Birnbrook-Palm, Matthew Hernandez, Yavuzalp Gulyurdu, Dulce Melendez
Advisor: Dr. Stephanie Carey
Mentor: Richard Nederlander, Molly Sullivan

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Team Overview

Telescoping Robotic Arm Module (TRAM)

- University of South Florida – American Institute of Aeronautics and Astronautics (AIAA) Student Section

Ethan DeWild

Harshitha Madabhushani

Lucas Birnbrook-Palm

Matthew Hernandez

Yavuzalp Gulyurdu

Dulce Melendez

- A compact, extendable robotic arm designed to perform autonomous drilling, screwing, and bolting operations essential for future in-space servicing and assembly.

Executive Summary

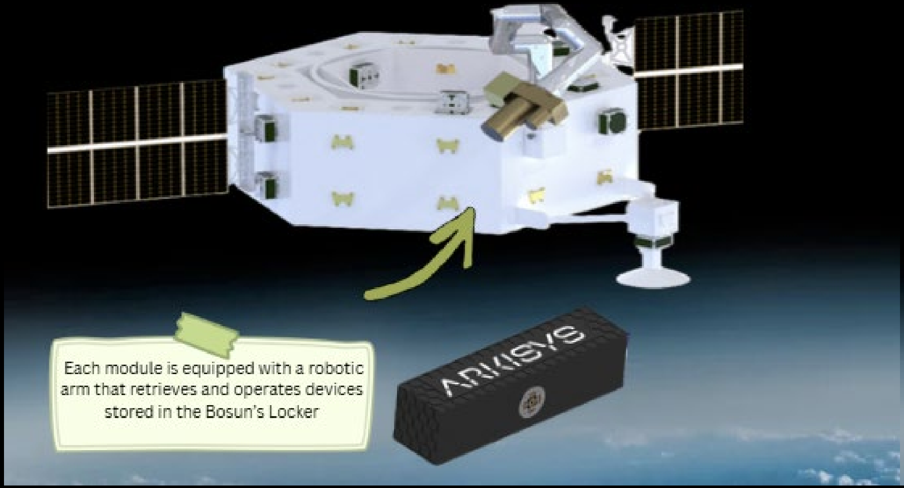
Telescoping Robotic Arm Module (TRAM)

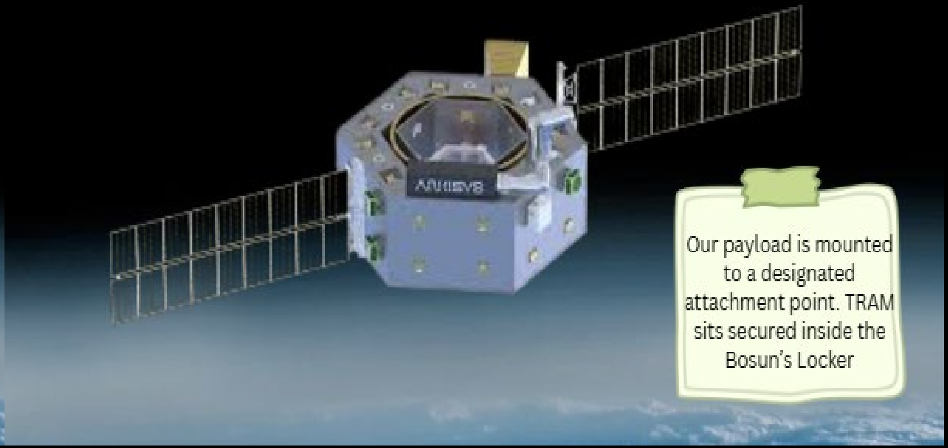
Vision & Infrastructure

- **Market Context:** Advancements in satellite technology are increasing mission frequency and expanding access to space exploration.
- **Arkisys Mission:** Reducing the cost and complexity of space missions through the Port Module, a spacecraft platform supporting up to 60 payloads.
- **The Bosuns Locker:** A specialized, sensor-equipped enclosure for payloads that require protection from the space environment while docked to the Port Module.

Arkisys Port Module

1.1 How does The Port Work





Impact

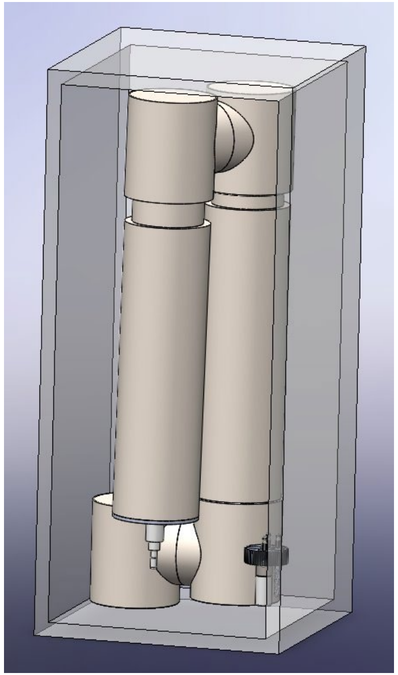
1.2 Impact of Servicing Missions

- **Operation Cost**
  - Eliminates the need for fully functioning satellites
  - Enables reuse of tools and hardware
  - Provides power, communication and thermal control across available attachment points
- **Debris and Sustainability**
  - Supports repair, reuse, and upgrade of hardware while in orbit
  - Reduces the number of discarded or single-use satellites
  - Helps prevent accumulation of abandoned materials
- **Mission Flexibility**
  - Robotic arms aboard The Port can assemble and modify payloads in a zero-gravity environment
  - Customers focus more on developing and testing their payloads rather than managing supporting systems such as power and data systems
  - Supports multiple payloads and missions from one platform

Technical Solution

The TRAM System: Our robotic arm provides a flexible, space-saving design for complex orbital tasks.

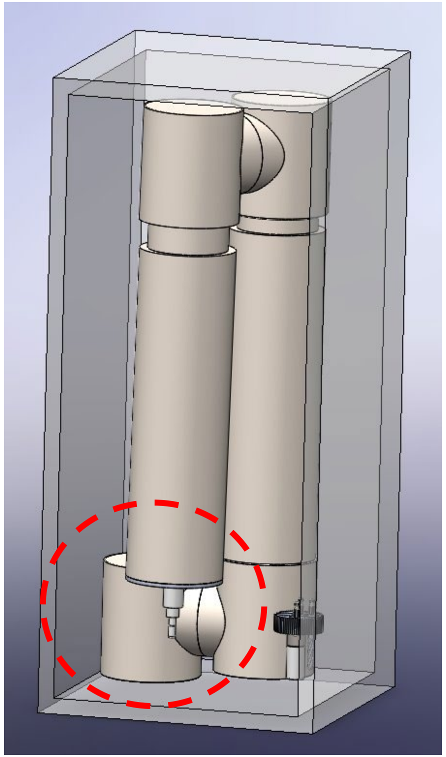
- **Primary Operations:**
  - **Drilling:** Precision hole creation in hardware.
  - **Screwing:** Securing components autonomously.
  - **Bolting:** Structural assembly and fastening.
- **Key Components:**
  - **Rotating Tool Holder:** A gear-driven mechanism housing a drill bit, screw bit, and socket.
  - **Actuation & Feedback:** Motor-driven functions guided by high-accuracy sensor feedback to ensure operational precision.
- **Strategic Impact**
  - The TRAM payload serves as a critical proof-of-concept for **autonomous orbital assembly**, proving that complex manufacturing tasks can be performed reliably within the modular environment of the Bosuns Locker.

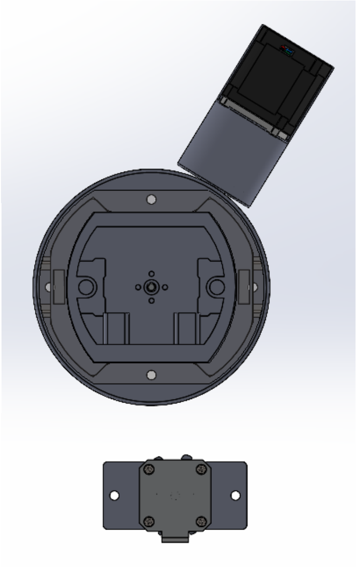


Systems Engineering Milestone

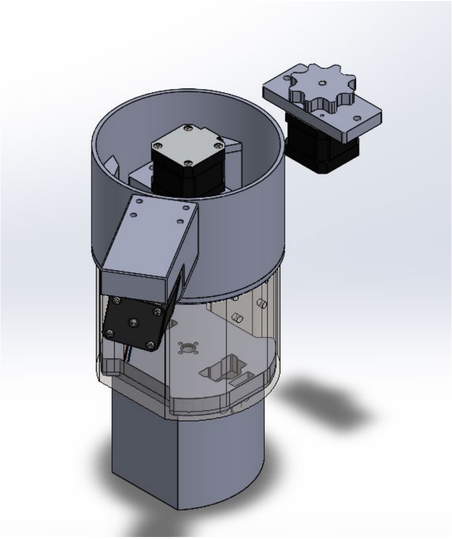
- 10/13/25 — Team Formed and Mentors Assigned
- 10/15/25 — Brainstorm operation and device capabilities
- 11/20/25 — System Requirements Review
- 12/11/26 — Finalized Concept Design/CAD
- 2/25/26 — Prototype Development Begins
- 3/30/26 — Developed Path to PDR
- 4/15/26 — Final Presentation

Mechanical Design





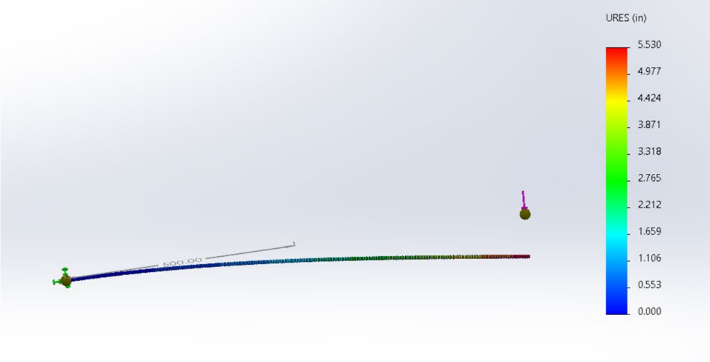
Top - Down View

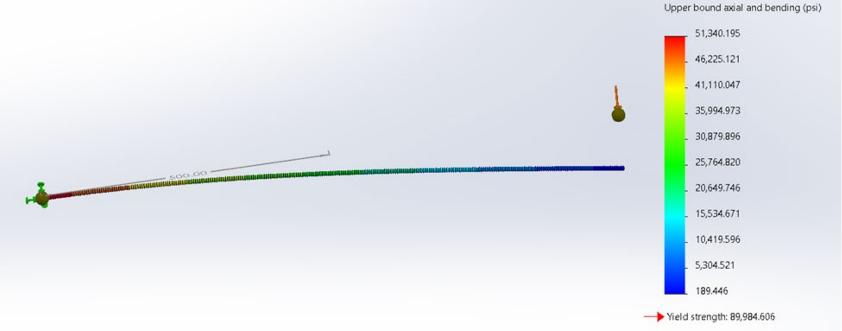


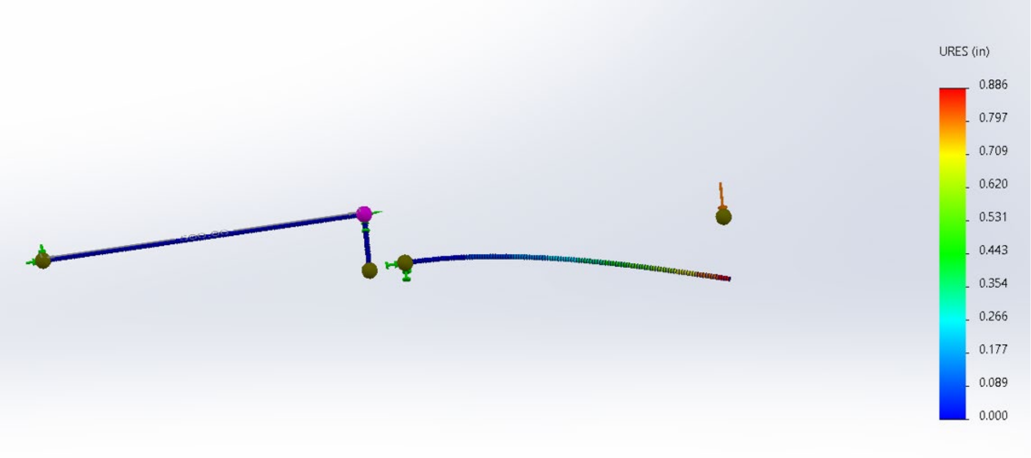
Isometric View

Figures showing components of the flexible telecscopic arm

Simulation


URES (in)
5.530
4.977
4.424
3.871
3.318
2.765
2.212
1.659
1.106
0.553
0.000


Upper bound axial and bending (psi)
51,340.195
46,225.121
41,110.047
35,994.973
30,879.896
25,764.820
20,649.746
15,534.671
10,419.596
5,304.521
189.446
Yield strength: 89,984.606


URES (in)
0.886
0.797
0.709
0.620
0.531
0.443
0.354
0.266
0.177
0.089
0.000

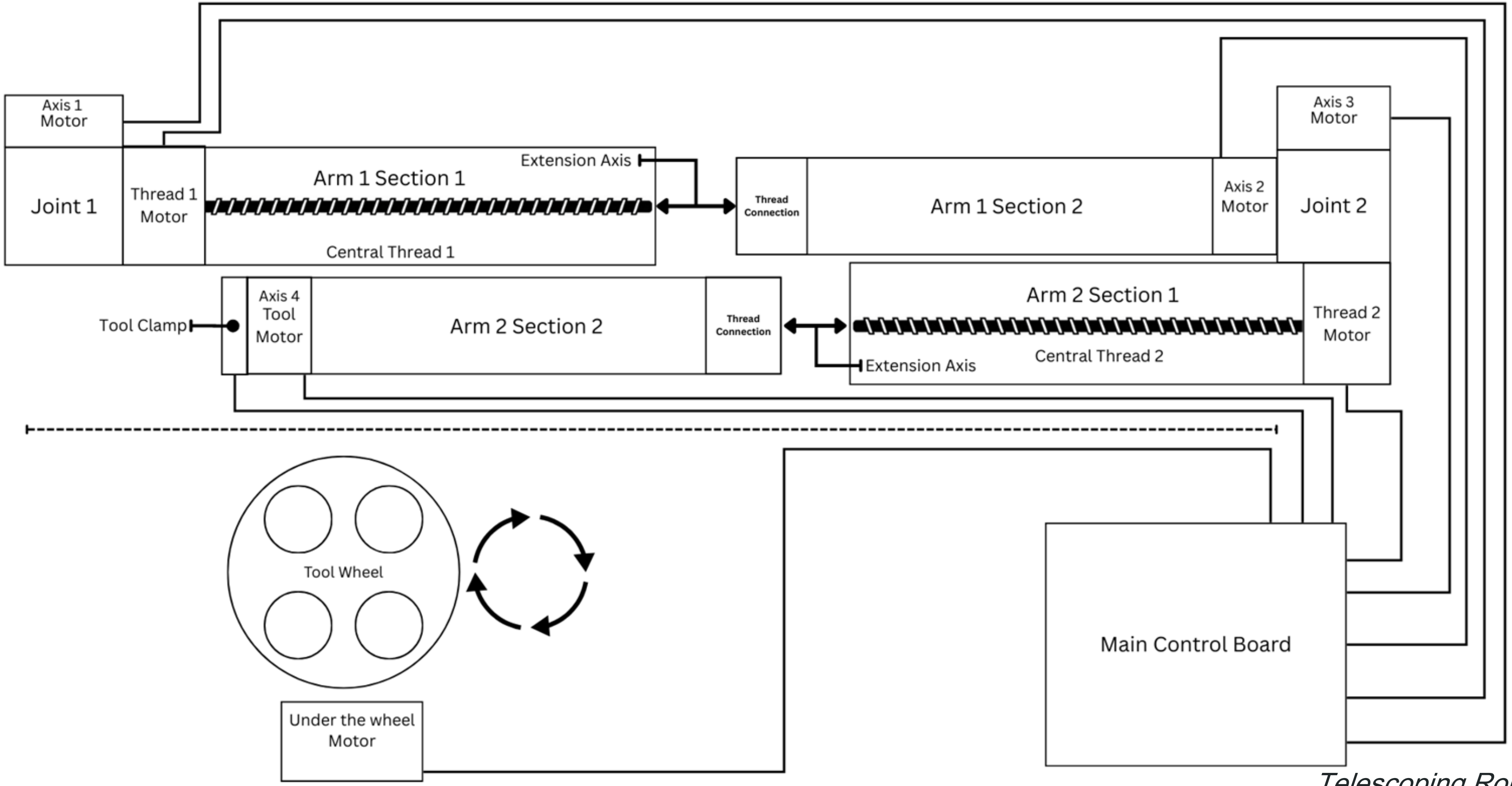
2.2 Storyboard of Complete Operation

Launch: Our payload will be enclosed in a Bosuns Locker that is to be hosted aboard Arkisys Port Module.

In Flight: In space TRAM will perform 3 in-space operations important for orbital manufacturing. TRAM will show its functionality by drilling into plates and securely fastening components by screwing and bolting. It will utilize its rotating tool holder to locate which tool is necessary for operation.

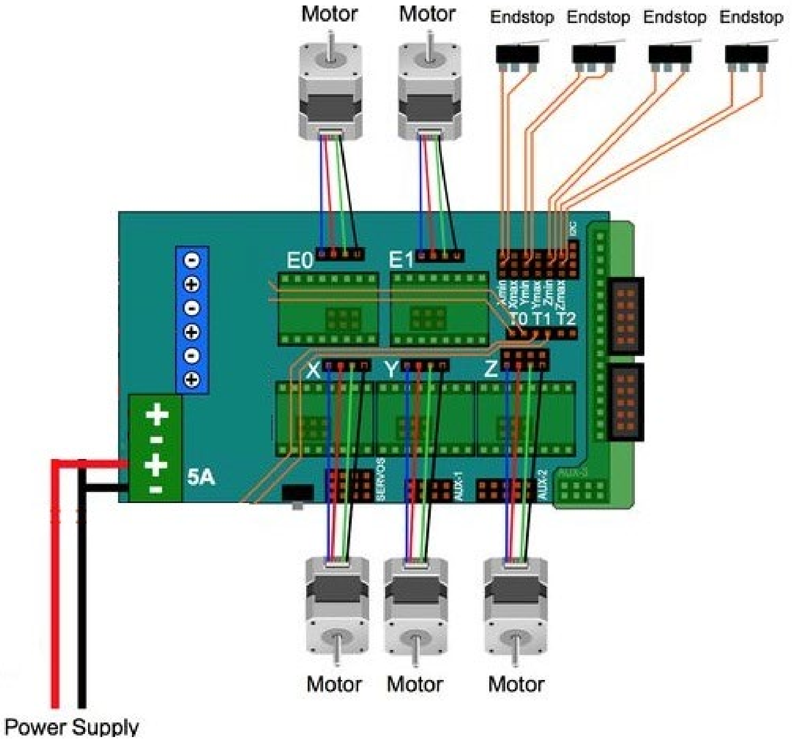
In Earth: The Bosuns Locker works to monitor and record the success of our 3 in-space operations. The sensors inside the locker will assist us in measuring TRAM in-space performance. Arkisys Port Module will have enabled us to perform a space mission at a low cost.

Wiring Diagram

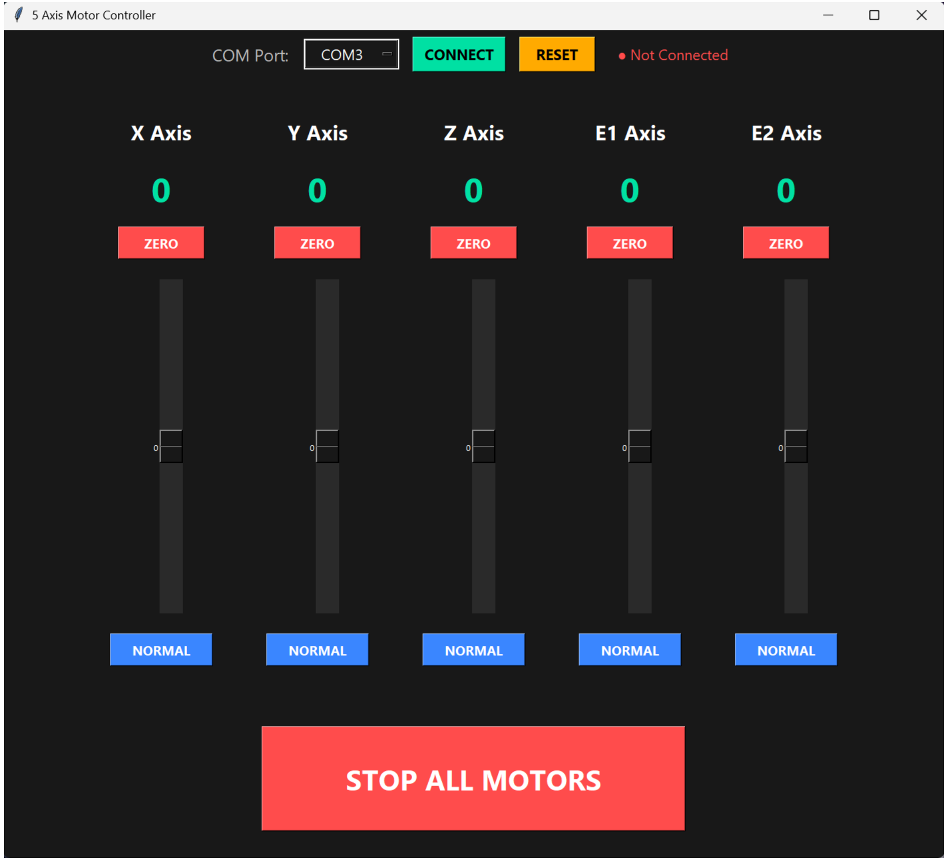


State of Electronics

RAMPS 1.4 Wiring



State of Software



Trade Study- Mechanical

TRAM Mechanical Systems						
Criteria	**Explanation**	**Grade**	**Weight**	**Lead Screws**	**Belt Drive**	**Rack and pinion**
Load Capacity & Precision	Must withstand operational loads and provide precise motion	10 = high, 5 = medium 1 = low 0 = Fail	25%	10	5	8
Reliability in Extreme Space Environments	Must be able to perform in vacuum, radiation, and extreme temperatures in space	10 = high, 5 = medium 1 = low 0 = Fail	25%	9	4	8
Compactness & Mass Efficiency	Must fit within the Bosun's Locker constraints	10 = high, 5 = medium 1 = low 0 = Fail	25%	8	9	6
Maintenance & Mechanical Complexity	Fewer moving parts and minimal wear preferred	10 = high, 5 = medium 1 = low 0 = Fail	25%	9	6	7
		TOTALS:	100%	90.00%	60.00%	72.50%

Risk Matrix

LIKELIHOOD \ CONSEQUENCES	1	2	3	4	5
5					
4					TRAM-01-M
3				TRAM-03-M TRAM-04-M	TRAM-02-M TRAM-05-M
2			TRAM-10-M	TRAM-06-M TRAM-07-M TRAM-09-M	TRAM-08-M
1					

Risk Log

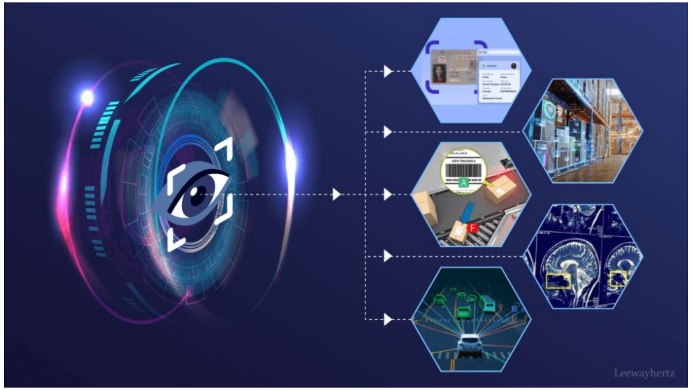
Risk ID #	Risk Owner	Risk Title	Risk Statement	L	C	Rating	Approach	Trend	Matrix Format
Unique ID	Which team member is assigned responsibility over seeing this risks closure	A short descriptive title of the risk	A more thorough description of the risk following the appropriate format of "Given that [CONDITION], there is a possibility of [DEPARTURE] adversely impacting [ASSET], which can result in [CONSEQUENCE]."	Likelihood of the risk to occur, see the Resources sheet for more information	Consequences if the risk occurs, see the Resources sheet for more information	High level indicator of the criticality of the risk	How the risk will be handled or not	Trend of any changes to the risk's LxC over its life cycle	
TRAM-01	Electrical Lead	Radiation Electronics Failure	Given that TRAM operates in a high-radiation space environment, there is a possibility of radiation-induced degradation or bit flips adversely impacting onboard electronics and control systems, which can result in mission failure.	4	5	High	Mitigate- use radiation-hardened components and incorporate shielding (M)	↑ Increase	-TRAM-01-M-↑
TRAM-02	Mechanical Lead	Arm Jamming	Given that the telescoping mechanism operates in extreme temperatures, there is a possibility of mechanical binding adversely impacting arm deployment, which can result in loss of functionality.	3	5	High	Mitigate- Use dry lubricants, precision tolerances, and thermal analysis (M)	→ Neutral	-TRAM-02-M-→
TRAM-03	Electrical Lead	Motor Failure	Given that multiple motors are used throughout TRAM, there is a possibility of motor degradation or failure impacting operational capability, which can result in system failure.	3	4	Moderate	Mitigate – Use space-rated/tested motors, redundancy methods, and continuous monitoring. (M)	→ Neutral	-TRAM-03-M-→
TRAM-04	Software Lead	Control Failure	Given that TRAM relies on autonomous control systems, there is a possibility of software errors adversely impacting operational accuracy, which can result in mission interruption or damage to hardware.	3	4	Moderate	Mitigate – Perform simulation and validation testing. (M)	↓ Decrease	-TRAM-04-M-↓
TRAM-05	Mechanical Lead	Thermal Failure	Given that TRAM is exposed to extreme temperature fluctuations in orbit, there is a possibility of thermal stress impacting structural and electronic components, which can result in reduced performance or failure.	3	5	High	Mitigate – Implement thermal coatings, insulation, and thermal analysis. (M)	→ Neutral	-TRAM-05-M-→
TRAM-06	Operations Lead	Locker Interface Failure	Given that TRAM must be integrated with the Bosun's Locker, there is a possibility of interface incompatibility impacting deployment, which can result in mission delays/failure.	2	4	Moderate	Mitigate – Perform thorough interface control testing. (M)	↓ Decrease	-TRAM-06-M-↓
TRAM-07	Electrical Lead	Wiring Failure	Given that TRAM contains complex electrical connections, there is a possibility of connector failure impacting power and signal transmission, which can result in system malfunction.	2	4	Moderate	Mitigate – Use space-grade connectors and relief mechanisms. (M)	→ Neutral	-TRAM-07-M-→
TRAM-08	Mechanical Lead	Deployement Failure	Given that TRAM must be able to contain launch loads, there is a possibility of structural damage impacting system integrity, which can result in deployment failure.	2	5	Moderate	Mitigate – Conduct vibration, shock, and FEA testing. (M)	↓ Decrease	-TRAM-08-M-↓
TRAM-09	Systems Lead	Communication Failure	Given that TRAM has communication with the host spacecraft, there is a possibility of signal loss adversely impacting command and control, which can result in operational issues.	2	4	Moderate	Mitigate – Use fail-safe modes and redundant communication pathways. (M)	→ Neutral	-TRAM-09-M-→
TRAM-10	Mechanical Lead	Misalignment	Given that TRAM performs precision tasks, there is a possibility of tool misalignment adversely impacting assembly accuracy, which can result in operational errors	2	3	Moderate	Mitigate – Implement calibration procedures and precision guides. (M)	↓ Decrease	-TRAM-10-M-↓

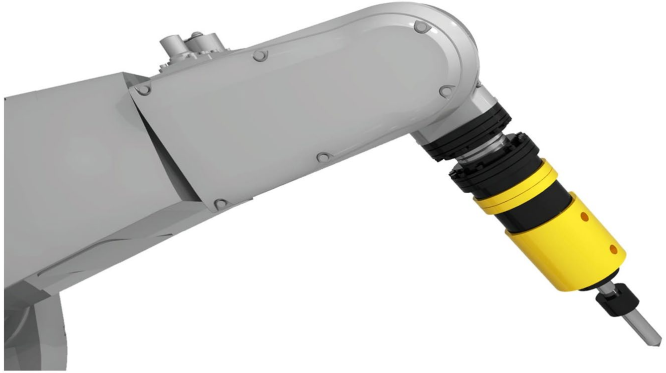
Challenges Encountered

- Concept Design
  - As a team, we listened to one another and shared ideas to develop unique solutions that helped us overcome challenges
  - Team members regularly would step in and and help others come up with a solution regardless if it was design, electrical, or hardware problem
- Electrical
  - There was difficulty identifying how much power and what type of motors would be needed throughout the device
  - We experimented and recorded which components worked the best in efficiently powering TRAM
- Computer Aid Design
  - Model challenges were overcome through different iterations until a design was chosen
  - Each member had the opportunity to practice their CAD skills

Future plans for Electrical Design

- Camera - Computer Vision Model (Autonous capabilitywithin prototype)
- End effector integration within prototype
- Pre-Programmed Motion





Paper

- Paper dives into the mechanical and electrical development of our device
- Detail figures of each component are provided with a explanation on functionality
- Risks are identified and briefed on
- Prototyping and development budget is included

Recommended Next Steps

1. Review Final Design
   a. Ensure all requirements are met and carefully examine details that could be improved
2. Test the Prototype
   a. Complete several tests to ensure the device works as intended
   b. Test and record with different scenarios in mind
3. Improve
   a. Review the electrical components and validate their success in powering our device
   b. Use the data and continue making improvements until device is ready for full integration

Conclusion

TRAM was developed by a multidisciplinary team committed to collaboration and shared learning, with the objective of expanding their understanding of orbital manufacturing to support in making space missions more achievable.

- Impact
  - TRAM transitions single-use systems to reusable and long-term sustainable ones by providing tools to maintain and repair while in orbit
  - Devices like TRAM reduce cost, minimize space debris, and increase mission efficiency
  - The Port Module is a key in making space missions more accessible
- Lessons
  - Learned about the importance of in-space servicing missions and how valuable devices that aid ISAM activities are
  - Members from different disciplinaries helped others understand and communicated with them

Resources

- NASA L'SPACE MCA Templates
- https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=5999&context=smallsat

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Capstone Challenge

Thank you, Questions?

TRAM
TELESCOPING ROBOTIC ARM MODULE