COSMIC

THE POWER OF COLLABORATION

COSMIC Capstone Challenge: Final Briefing

Free Flyer Grapple System, California State University, Los Angeles

Students: Michael Mireles, Jordan Socop, Antonio Gutierrez, Bryan Hernandez, Apryl Sperling, Brooklyn Jarvis, Hanneef Myvett
Advisor: Patrick Hartunian
Mentor: Edgar Herrera, Timothy P Woodard

April 14, 2025

Agenda

1.	Background and Objective	Bryan Hernandez
2.	System Overview	Michael Mireles
3.	Mechanical Design	Antonio Gutierrez
4.	Mechanical Design Subcomponents	Michael Mireles
5.	Computer Vision	Jordan Socop
6.	Electrical	Bryan Hernandez
7.	Data and Calculations	Antonio Gutierrez
8.	Conclusion	Jordan Socop

Team Overview

Left to Right: Jordan Socop (ME), Bryan Hernandez (EE), Michael Mireles (ME), Antonio Gutierrez (ME), Hanneef Myvett (ME), Brooklyn Jarvis (ME) & Apryl Sperling (ME)

Project Background

COSMIC
CONSORTIUM FOR SPACE MOBILITY AND ISAM CAPABILITIES

Objective

Design a payload, to be hosted about the BCT X-Sat Venus Class bus, that will demonstrate a chain of 3 or more operations that provide an on-orbit, autonomous ISAM capability

Determining Research

NASA ISAM Overview	NASA-STD-6016	Cosmic ISAM 101

Proposed Solution

Want to leverage In-space, Servicing, Assembly, and Manufacturing (ISAM) technologies to extend the operational lifespan of satellites and minimize space debris, promoting a more sustainable and efficient orbital environment

Project Overview

Deliverables

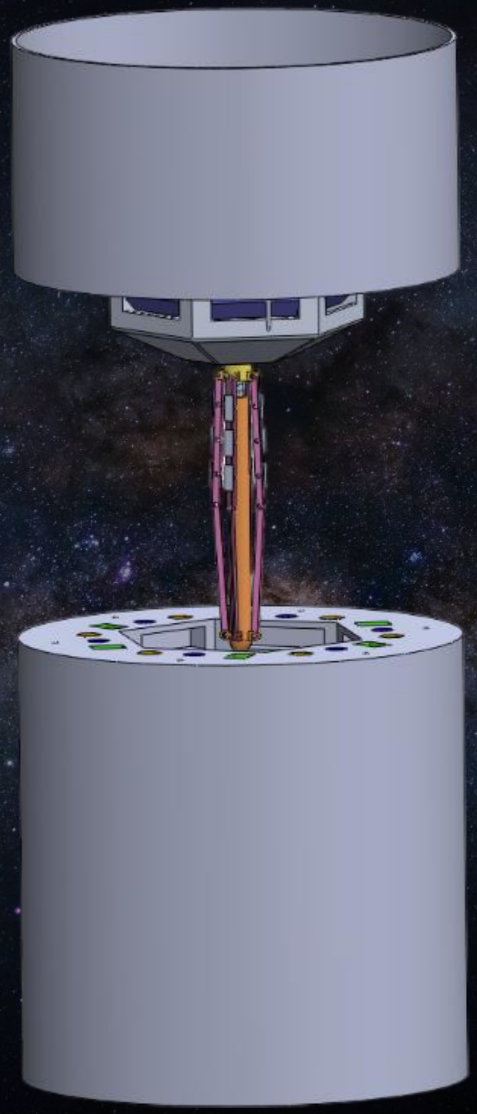
Research
- Conducted project background investigation
- Requirements for project

Concept Design Development
- Concept Sketches
- Design Concepts
- Trade Studies

Detailed Designed
- Final CAD
- Integration

Calculations
- Calculated torque for design purposes
- Calculated power
- Calculated spring rates

Computer Vision
- Target detection
- Tracking system



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System Overview

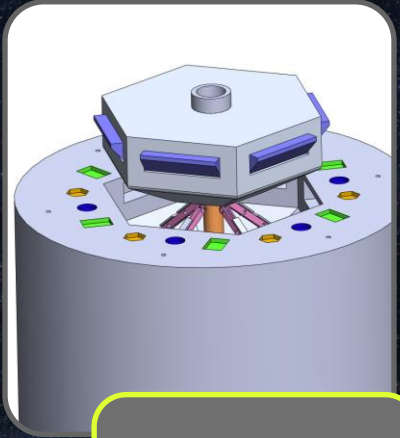
Requirements

#	Requirement Title	Objective	Source of Requirement	Method of Verification
		Functional Performance		
1	Locking Mechanism	The grapple system shall have a locking mechanism after grapple extension	Client	Design
2	Push off	The grapple system shall have a push off mechanism	Client	Design
3	Discharge	Upon capture phase, the grapple system shall be able to discharge up to 5,000 volts (1 Joule)	Client	Analysis and test
4	Tolerance	The grapple system shall have a material tolerance	Client	Analysis or test
5	Attaching	The grapple system shall mate a service vehicle and client vehicle	Client	Desgin
6	Autonomous	The grapple system shall mate autonomous	Client	Analysis or design
7	Capture envelope	The grapple system shall have a defined capture envelope comprising 12 specific parameters	Client	Analysis and test
8	Contact to capture	The grapple system shall have alignment features from initial contact to capture	Client	design
9	Capture to mate	The grapple system shall have alignment features from capture to mate	Client	Design
10	Pre-load	While the system is in the capture phase, the system shall pre load the infterface to provide a rigid inter- connection	Client	design and test
11	Release	The grapple system shall be able to release after capture phase	Client	design and test
12	Fiducial	The interface shall provide a fiducial	Client	test
13	Chain of operations	The grapple system shall perform a chain of three operations: capturing the client vehicle, aligning and stabilizing the connection, and performing diagnostic checks post-capture.	C3	Test

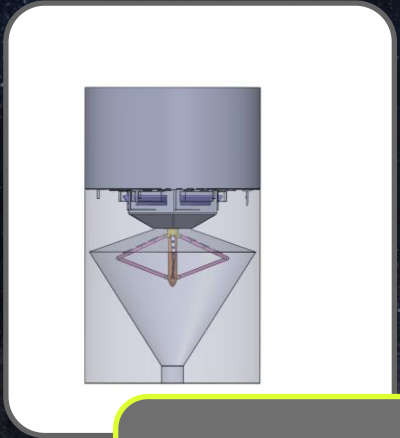
System Overview

Chain of Commands

Approach Phase

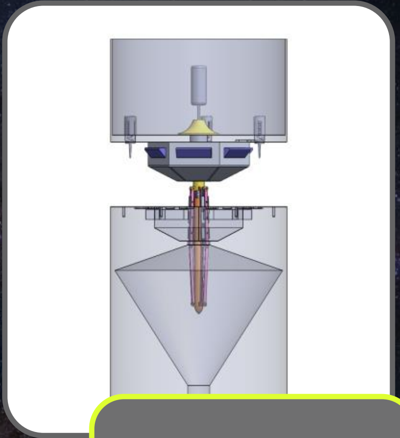


Alignment Phase



Capture Phase

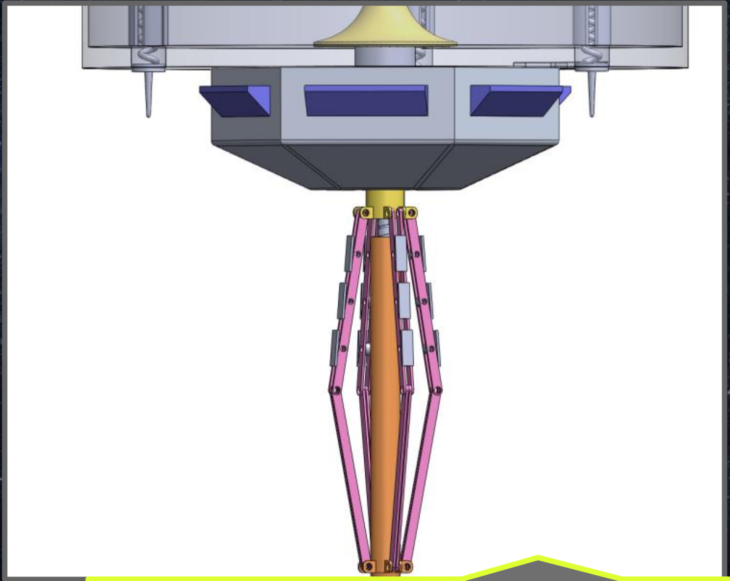
Post-Capture Phase



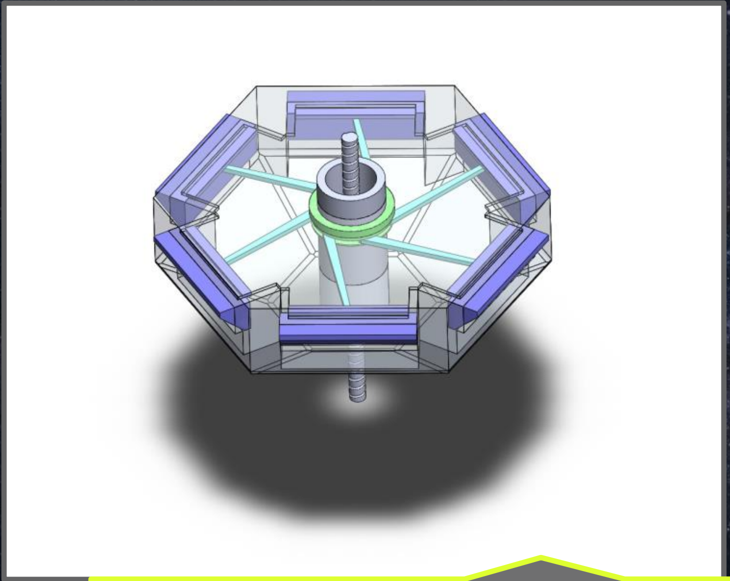
Release Phase

System Overview

Design Components



Umbrella



Locking Tabs

Springs

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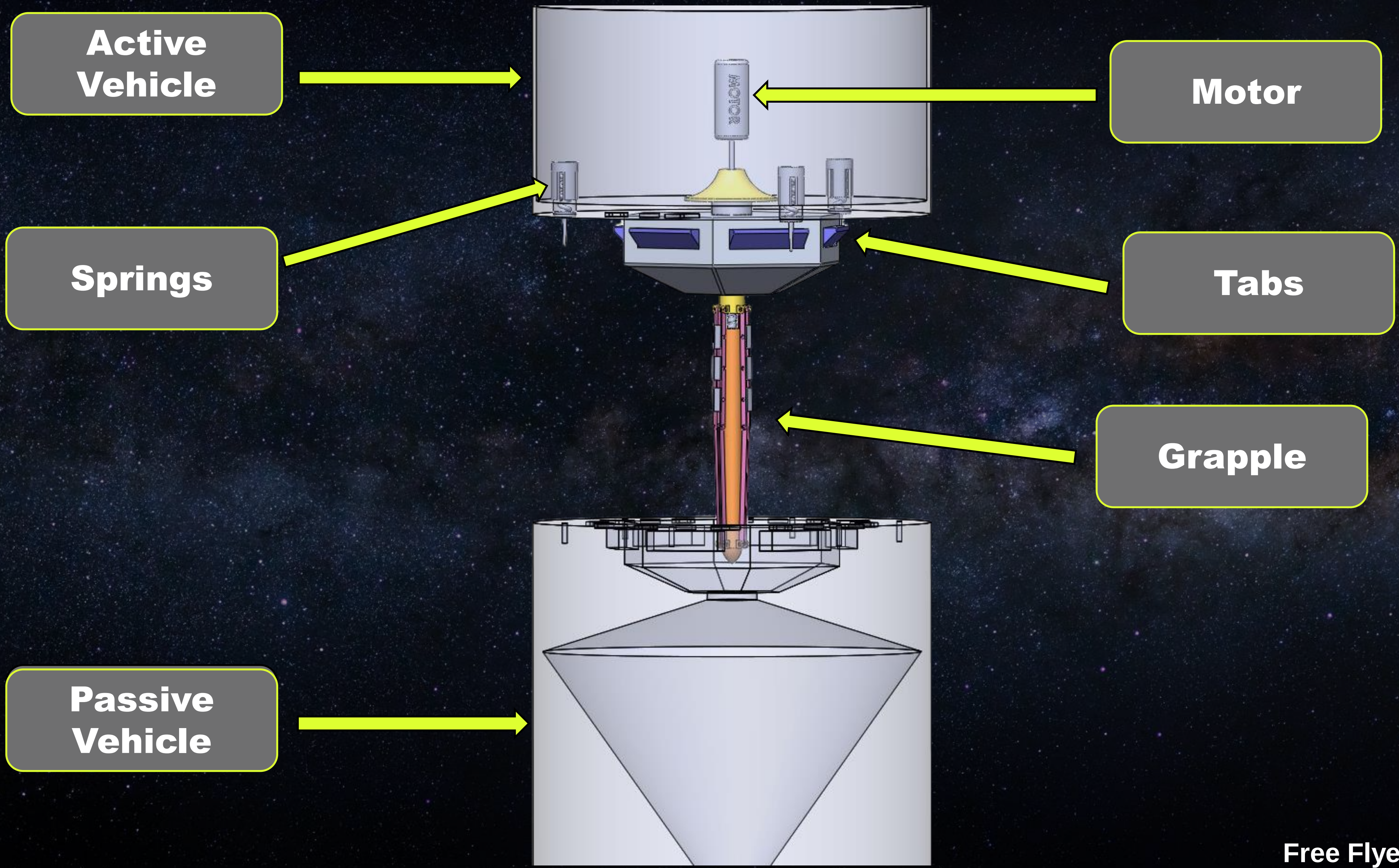
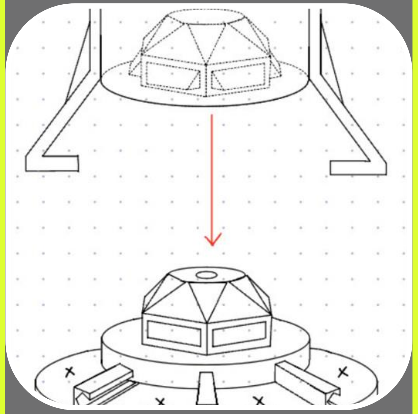
Mechanical Design

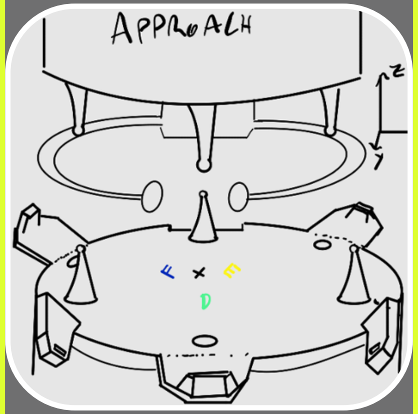


Mechanical Design

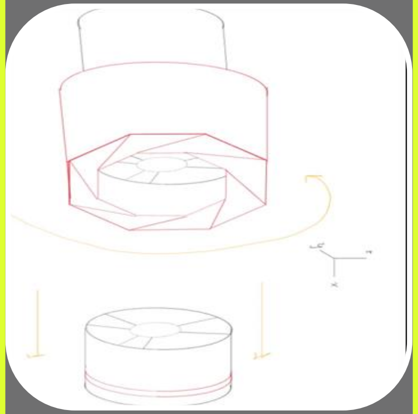
Concept Design for Grapple System



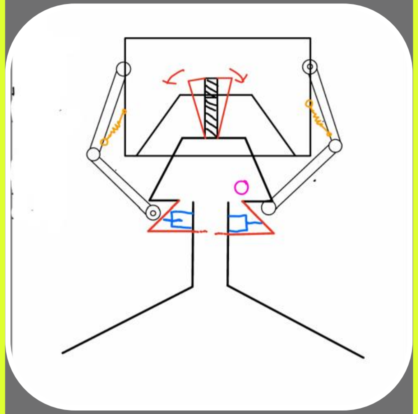
Concept Design 1



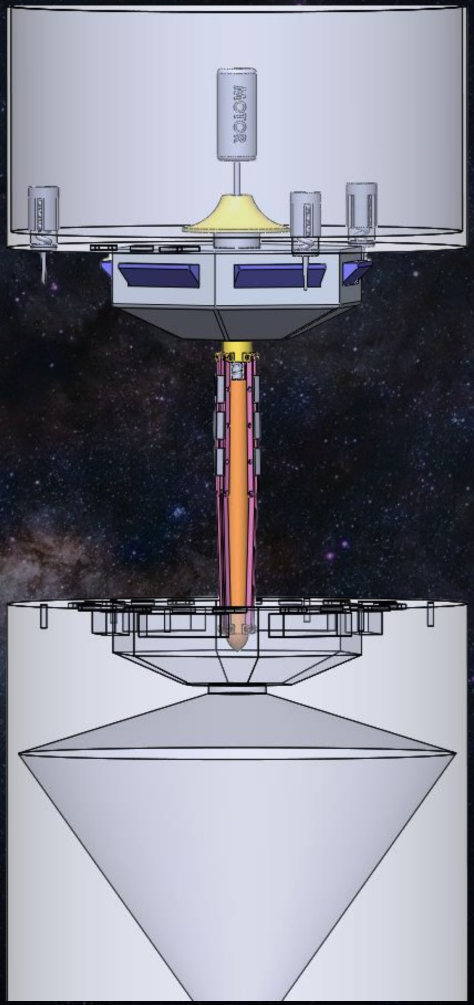
Concept Design 2



Concept Design 3



Concept Design 4



Mechanical Design

Trade Study for Grapple System

Requirement	Weight	Design 1	Design 2	Design 3	Design 4
6D Constraint	15	15	15	7.5	15
Alignment Geometry	10	10	5	5	5
Capture Envlope	7.5	3.75	7.5	7.5	7.5
Complexity	2.5	2.5	2.5	0	1.25
Discharge / Grounding	12.5	12.5	0	12.5	0
Load Capability	12.5	6.25	12.5	6.25	6.25
Reliability	5	2.5	2.5	2.5	2.5
Testability	7.5	0	0	3.75	3.75
Desirements	**Weight**	**Design 1**	**Design 2**	**Design 3**	**Design 4**
Androgynous	5	0	0	0	5
Zero Force Capture	5	5	5	2.5	5
Zero Force Disengage	2.5	2.5	2.5	2.5	2.5
TOTAL:	100	60	52.5	50	53.75

Key	Point Value
Green	1x
Yellow	0.5x
Red	0x

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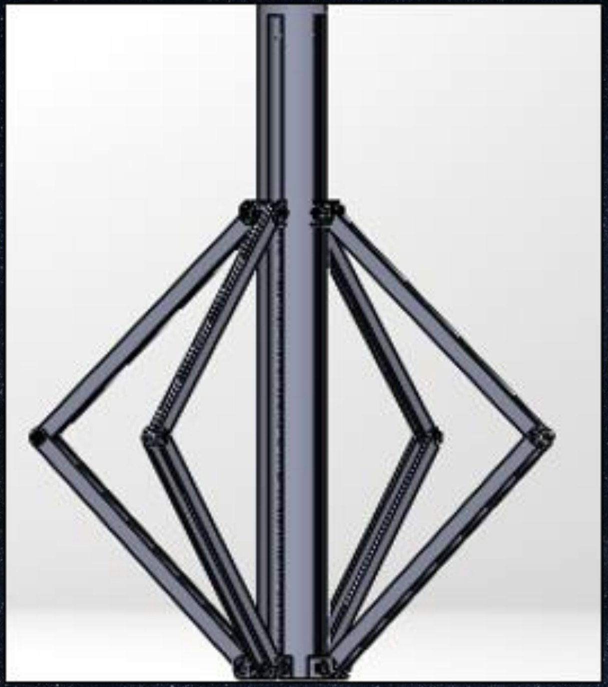
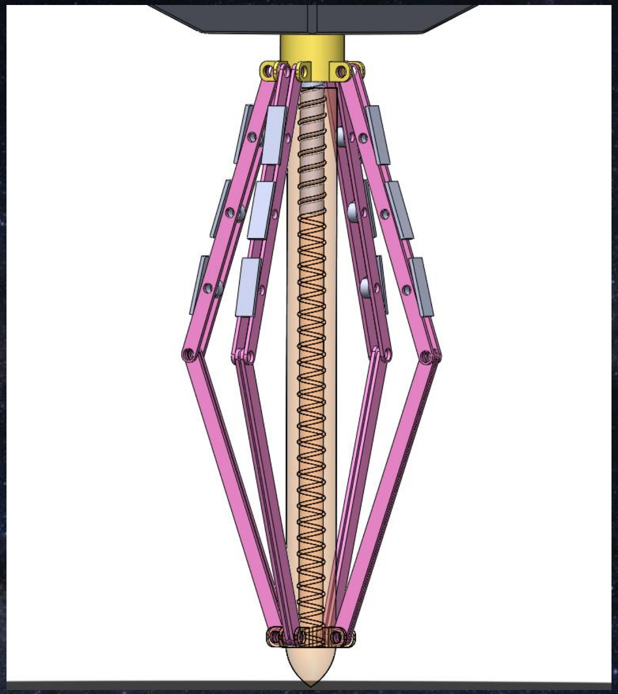
Mechanical Design

Design Iterations for the Umbrella Design



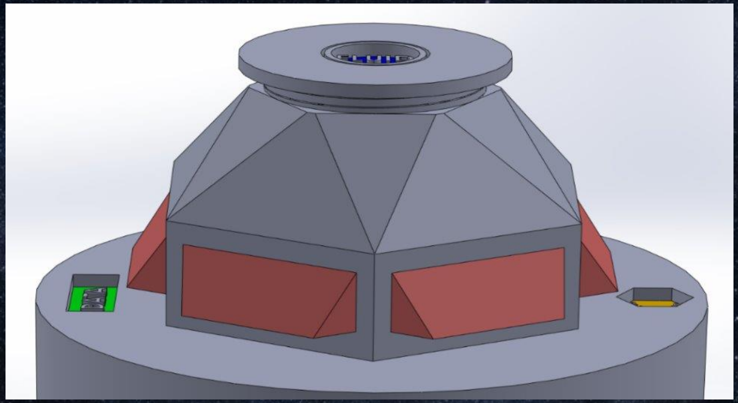
Design Concept for Umbrella Design 1



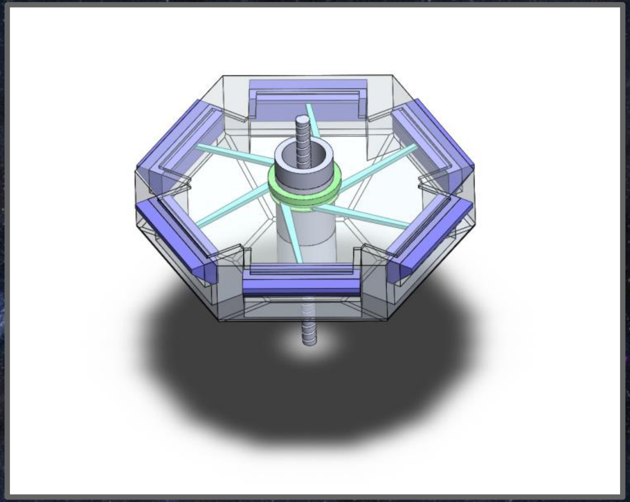
Current Design Concept

Mechanical Design

Design Iterations for the Locking Tabs



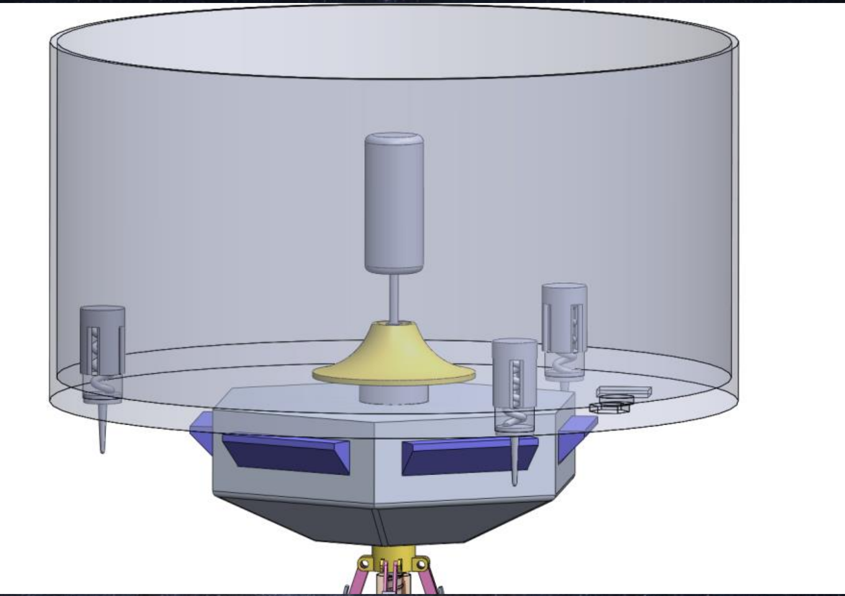
Design Concept for Locking Tabs Design 1



Current Design Concept

Mechanical Design

Design Iterations for the Springs



Design Concept for Spring Design 1

Current Design Concept

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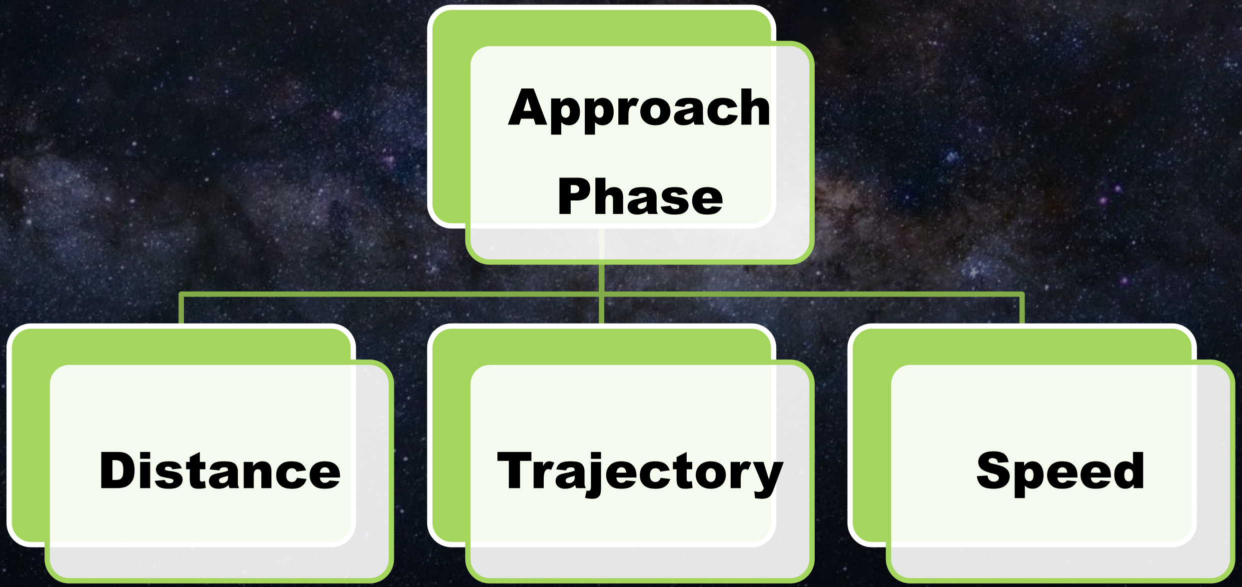
Computer Vision

Data Handling and Comms

- **Fully autonomous**
  - When approaching, capturing and releasing the Grapple System will operating without interference
- **ArUco Markers**
  - Simple, scalable, and not easily distorted



Computer Vision

Software

- Visual Studio
  - Code editor and Debugger

Python

- Python
  - Programming language

Open CV

- Open CV
  - Open source Computer Vision Library

ArUco

- ArUco
  - Library within Open CV

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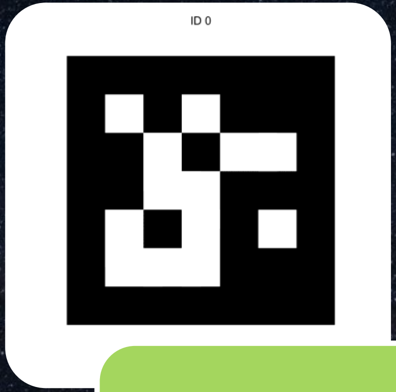
Computer Vision

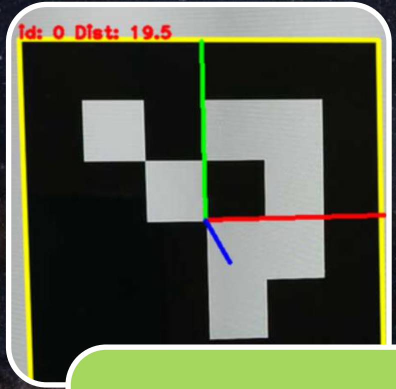
Target Detection



ArUco Marker ***Generator***

ArUco Marker ***Detection***

ArUco ***Camera Calibration***



ArUco Marker ***Distance Check***

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Electrical

Motor Selection

- The motor chosen for our project's reference point is the Nema 23 Stepper Motor
- This high torque motor was chosen for being twice the amount of torque needed
- This stepper motor is precise, has a simple control mechanism and can operate at low speeds despite the load

Nema 23 Stepper Motor

Electrical

Sensor

- To sense when our grapple has made first contact with the passive object, we are using a force sensitive resistor
- This was selected due to its simplicity over other options
- Other methods were also rejected due to placements or interference with the Sun being a factor

Force Sensitive Resistor

Electrical

Discharge

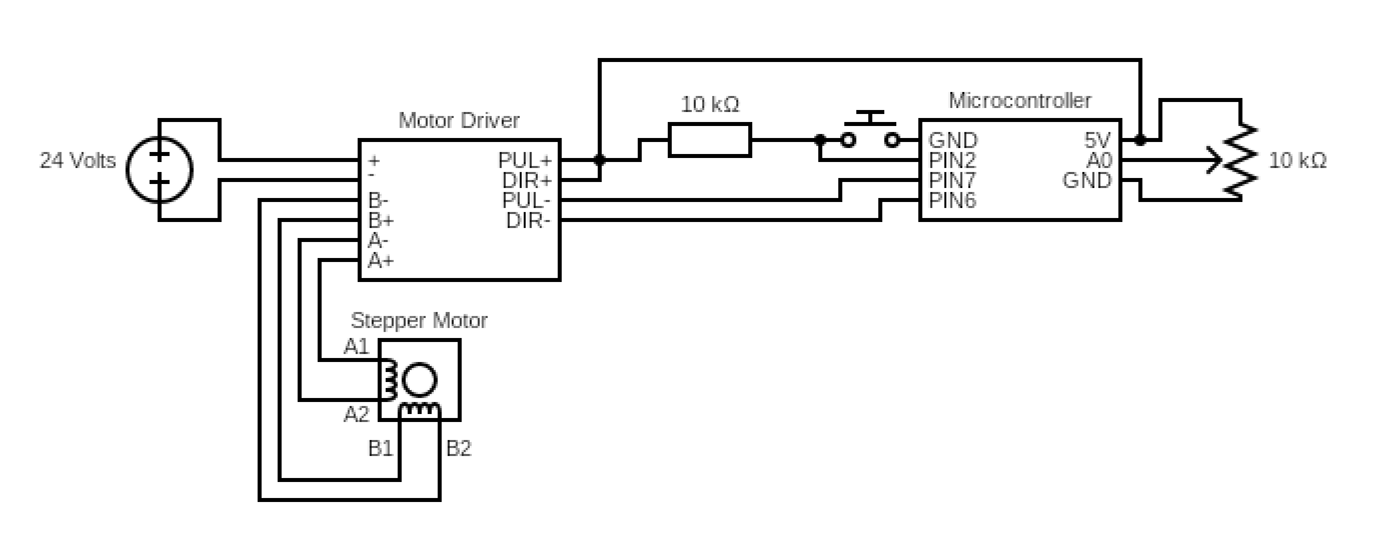
- To expel any built-up charge on the passive object, there are two methods that were explored
- The robust method is to direct the extra charge to the main body of the active object, thus grounding it
- The other method is to use the Plasma Contactor Unit (PCU), which discharges the control electrons

Plasma Contactor Unit

Electrical

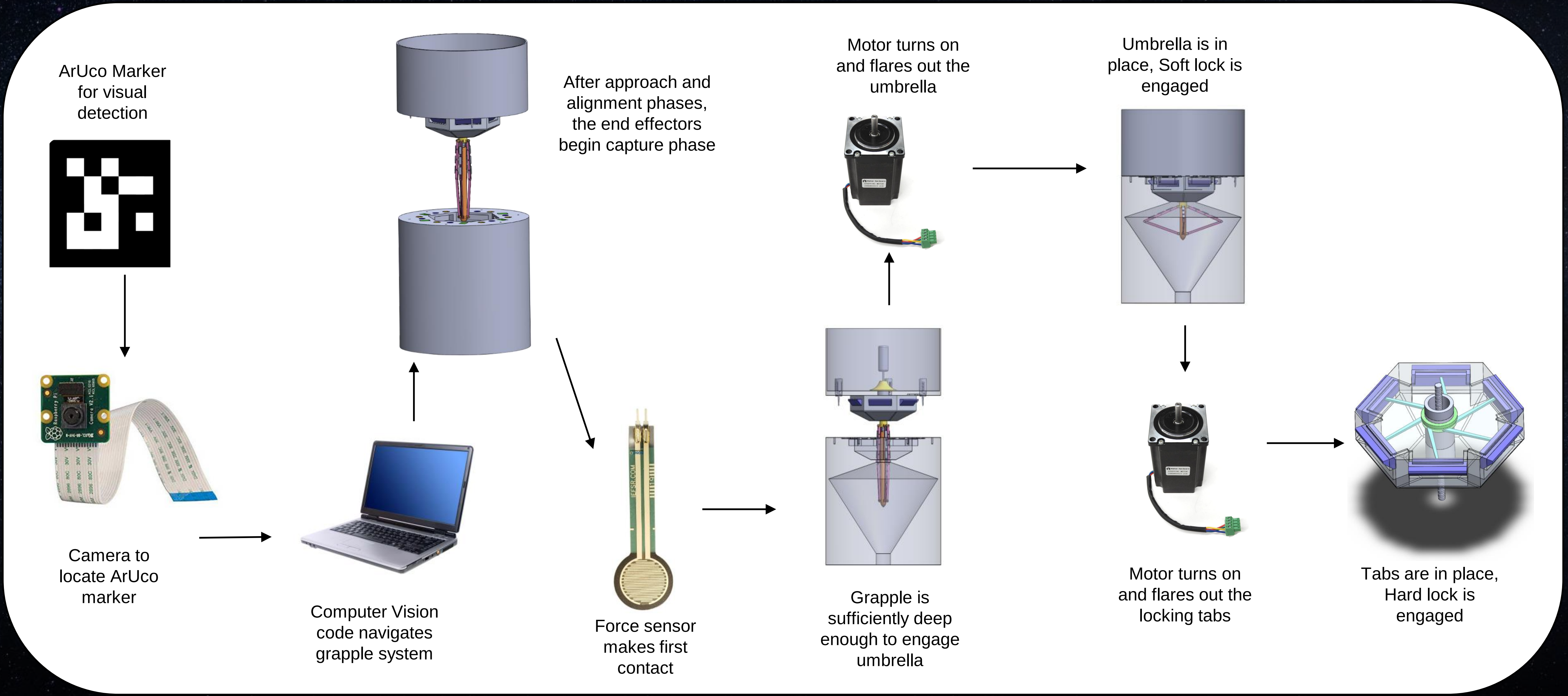
Schematic

- Using the battery on the Venus Satellite, our selected motor requires 24 Volts for best performance
- Button and Potentiometer represented here is controlled digitally by the microcontroller
- Their purpose is to activate the motor going clockwise or counter-clockwise and the rpm respectively



Motor Schematic

Systems Integration



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Data and Calculations

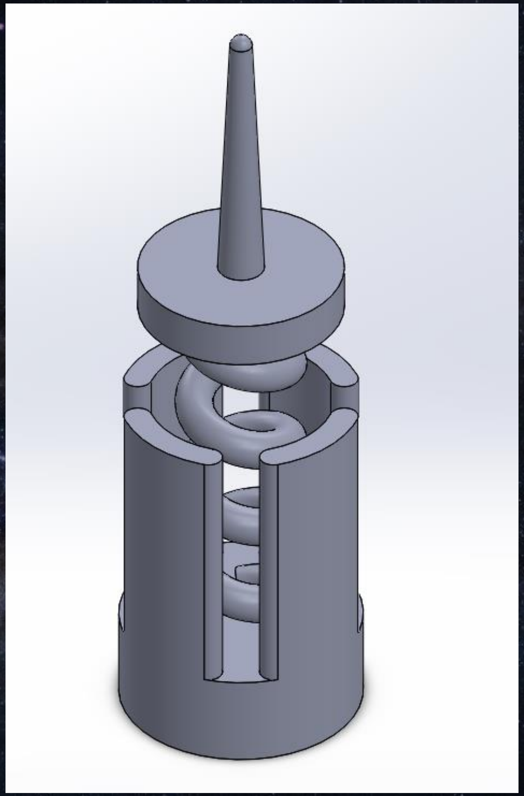
Spring Calculations

Maximum Compression

$$x_{max} = Nd$$

N = Number of coils 5
d = wire diameter 0.0318m (0.25 in)

$$x_{max} = 5 \times 0.00635m$$
$$x_{max} = 0.0318m$$



CAD model of spring separation system

Maximum compression of the spring is 0.0318m

Data and Calculations

Spring Calculations

Since energy is conserved, set $U=KE$
*there are no external forces in space, we assume all stored spring energy converts into kinetic energy of the object.

$$m_1 = 70\ kg$$

$$Venus = m_2 = 70\ kg$$

$$x_{max} = 0.03175\ m\ (0.25\ in)$$

$v_1 \& v_2$ = 1ft/s = 0.3048 m/s

$$k = \frac{m_1 v_1^2}{x^2} + \frac{m_2 v_2^2}{x^2} = \frac{(70)(0.3048)^2}{0.03175^2} + \frac{(70)(0.3048)^2}{0.03175^2}$$

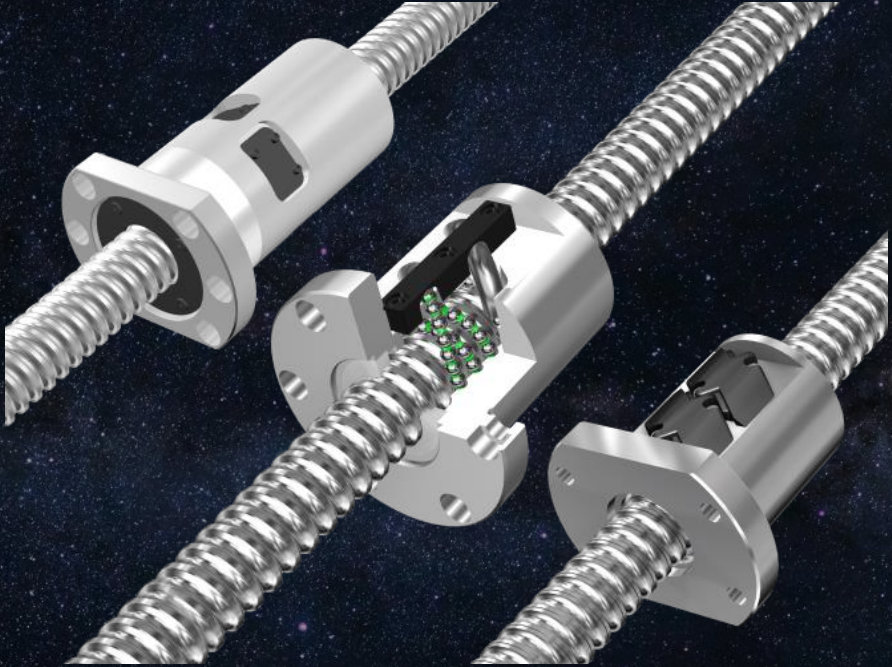
$$k = 12{,}902.4\ \frac{N}{m}$$

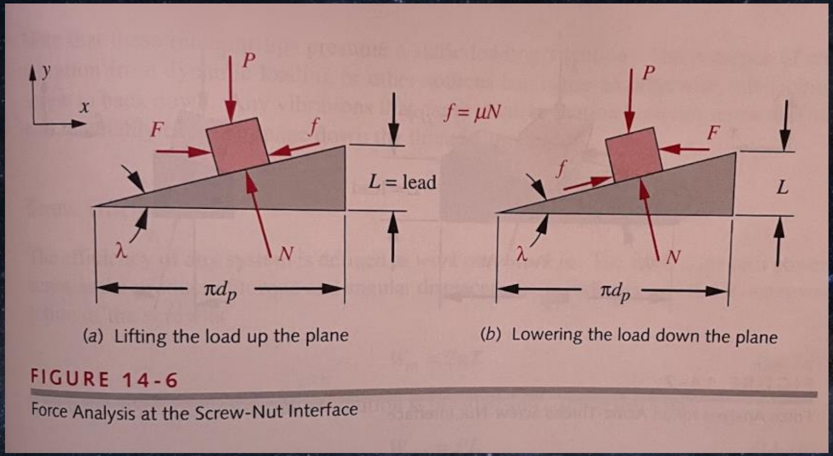
Spring Constant is approximately 12,902 N/m

Data and Calculations

Ball-screw Calculations

Ball-screw Dimensions, Major Diameter: M6 |Minor Diameter: 5.3 mm





(a) Threading | (b) Un-threading

Max Axial Force

$$P_{Axial} = m * g = 70\ kg * 9.81 \frac{m}{s^2} = 686.7\ N \sim 154.37\ lb * f$$

$$P_{Total} = P_{Axial} + F_{Spring} = 154.37\ lb * f + 354.7\ lb * f = 509.08\ lb * f$$

Data and Calculations

Ball-screw Calculations

The torque required to turn thrust collar

$$T_c = u_c * F_{max}\left(\frac{d_c}{2}\right) = 0.2 * (509.08\ lb * f) * \left(\frac{0.45\ in}{2}\right) = 1.018\ lb - in$$

Screw torque required to lift load

$$T_s = \frac{F_{max} * L}{2 * \pi * \eta} = \frac{(509.08\ lb * f) * (0.0394\ in)}{2 * \pi * 0.95} = 6.94\ lb - in$$

Total torque

$$\mathrm{T_u} = T_s + T_c = (6.94\ lb - in) + (1.018\ lb - in) = 7.97\ lb - in \sim 0.9\ N - m$$

Notations

η = Ball screw efficiency (0.85-95)

L = Same as pitch for a single start

u_c = Coefficient of friction, Dry: 0.15-0.20

d_c = Mean diameter of thrust collar

Agenda

Most Important Technology Gaps

- Better feedback system to instruct with more confidence the automated system whether a step has failed or succeeded
- Discharging at point of contact rather than routing to main body to ensure protection of electrical components
- Manage energy consumption of autonomous components that need to always be active
- Little to no remote communication between ground and space
- Accurate testing or simulation of autonomous grappling system in no gravity conditions

Conclusion

- The team has gone through countless concepts designs to land on the current umbrella capture system and locking tabs idea, taking hold of these features fully and attempting to realize what it would take to make them a reality
- One important lesson we learned very early on was communication, which was tested throughout the duration of this project and overcame to produce what we've shown here
- The next steps we'd like to began is 3 – D printing our prototype for the grapple system

Questions

Questions?

Backup Slides

CONSORTIUM FOR SPACE MOBILITY AND ISAM CAPABILITIES

Material considerations

- Material selection criteria for spacecraft were developed through research to form a decision matrix
  - Criteria follows: NASA-STD-6016

- Focus area:

Corrosion Resistance
Thermal Stability/ Protection
Resistance to Temp. Fluctuations
Strength-to-weight ratio
Radiation Resistance
Vacuum Compatibility

Material considerations

Material	Properties & Considerations
5000-Series Aluminum Alloys	Not suitable for temperatures above 66°C (150°F) due to stress-corrosion sensitivity and exfoliation. Includes 5083-H32, 5083-H38, 5086-H34, 5086-H38, 5456-H32, and 5456-H38. Consider using 6000-series aluminum alloys.
300-Series Stainless Steel (CRES)	Should not be used above 370°C (700°F) for extended periods. Austenitic stainless steels (higher chromium and nickel content) are more resistant to stress corrosion cracking than ferritic and duplex stainless steels.
Titanium 6Al-4V	Heat-treatable alpha-beta titanium alloy with high strength, good corrosion resistance, and temperature stability up to 399°C (750°F). Vulnerable to stress corrosion cracking in strong oxidizers, methanol, or hot-salt environments. Used in aerospace applications.
Ti-6Al-6V-2Sn	Similar to Ti-6Al-4V, tested for structural stability and strength in annealed conditions. Commonly used in aerospace structures.
High Nickel Content Alloys	Resistant to stress corrosion cracking. Suitable for extreme environments.
Thermal Control Materials	Used for passive thermal control via surface treatments, coatings, or multi-layer insulation blankets. Surface treatment is required to prevent corrosion before launch.