COSMIC Challenge

Free Flying Docking System

Team members:

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Advisor:

Michael Thorburn

Client:

Edgar Herrera

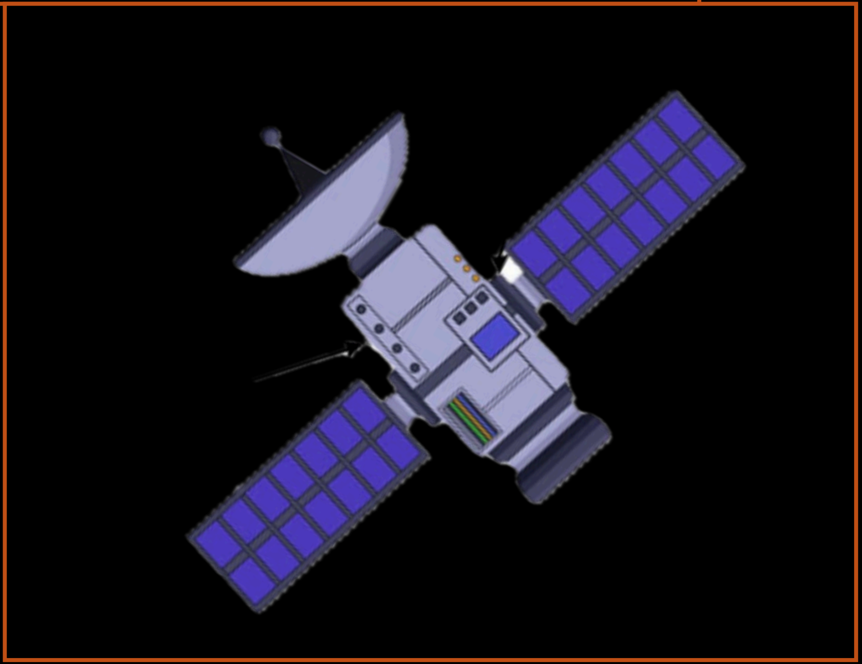
CAL STATE LA

Meet the Team

Yousra Fakhro	**Sabrina Barbosa**	**Kenny Ngo**	**Edgar Avila**	**Enrique Rosales**
Responsibilities • Team Lead • System Integration • End-Effector Design	Responsibilities: • Assistant Team Lead • CAD Modeling • End-Effector Design	Responsibilities: • Palm Design • Assembly Support • Analysis	Responsibilities: • Engineering Analysis • System Modeling	Responsibilities: • Engineering Analysis • Requirements Verification

Background

- 10,000+ satellites currently in orbit
- ~75% lack docking interfaces
- Satellite replacement costs $200M–$500M
- Servicing extends life 5–10 years
- Robotic servicing missions now appearing

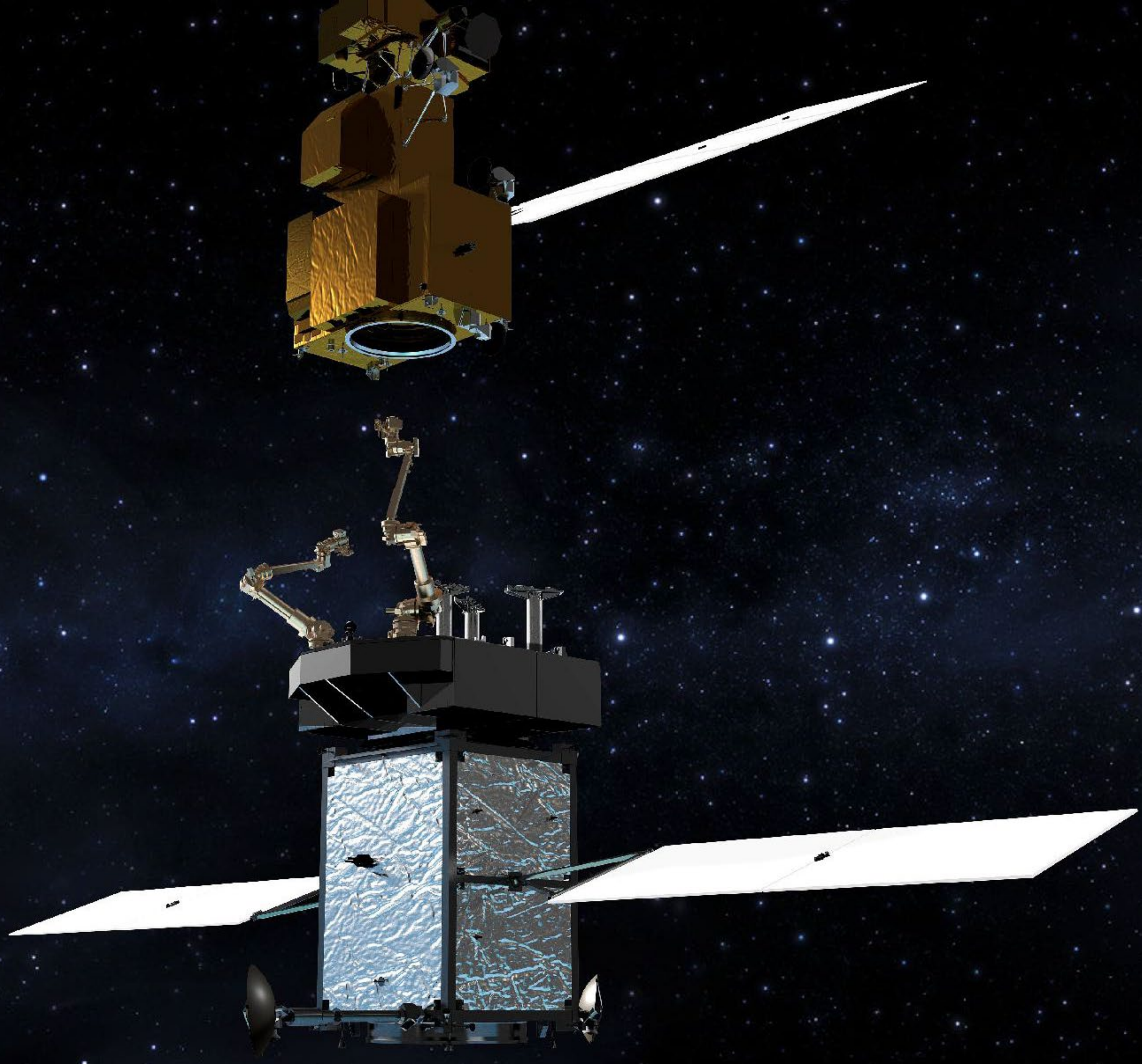


Problem

- Most satellites lack docking interfaces
- Standard docking requires cooperative vehicles
- Unknown geometry and moving targets
- Limited on-orbit servicing capability
- Growing number of aging satellites

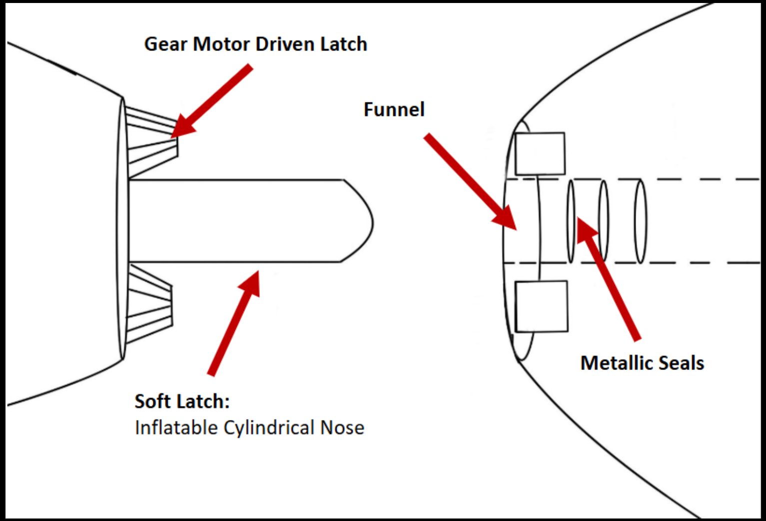
Objective

- Autonomous satellite rendezvous and approach
- Capture existing satellite structural features
- Establish rigid mechanical connection
- Enable servicing or inspection operations

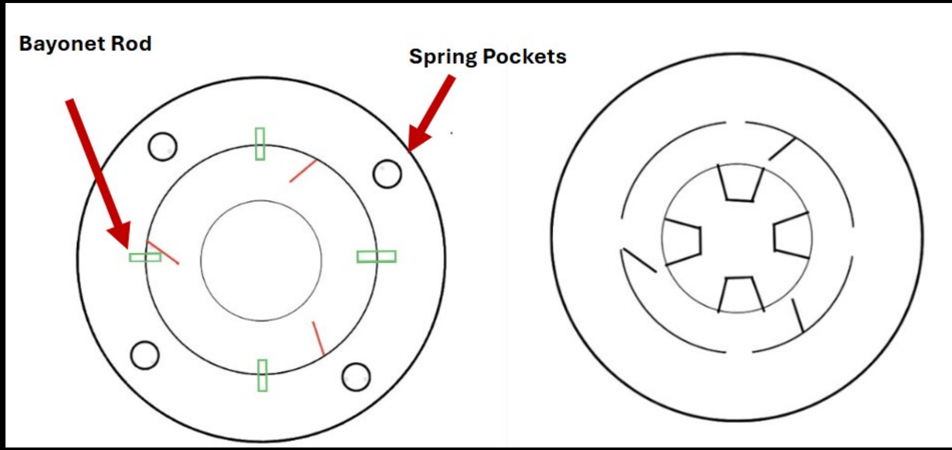


All Concepts

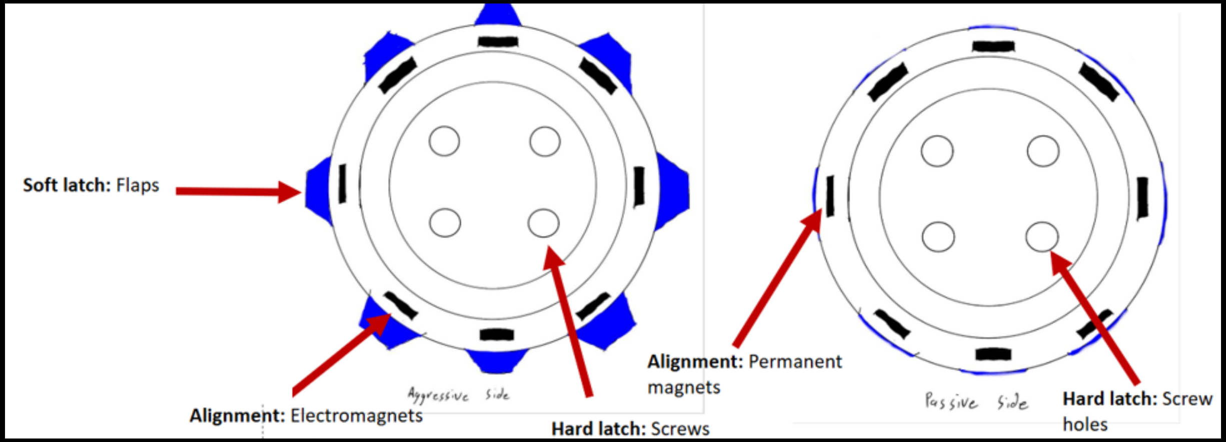
Concept 1: Inflatable nose



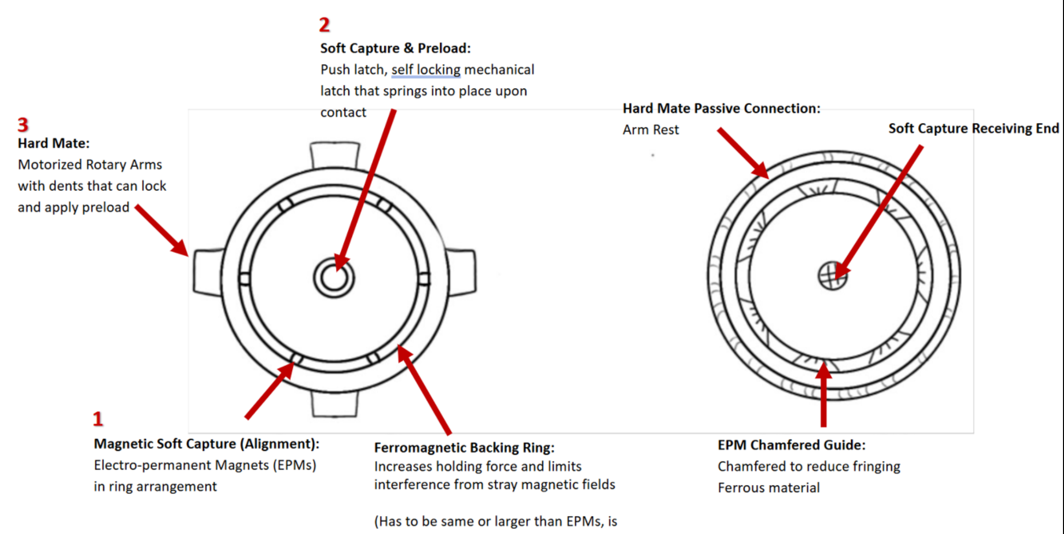
Concept 2: Bayonet capture



Concept 3: Anchor mechanism

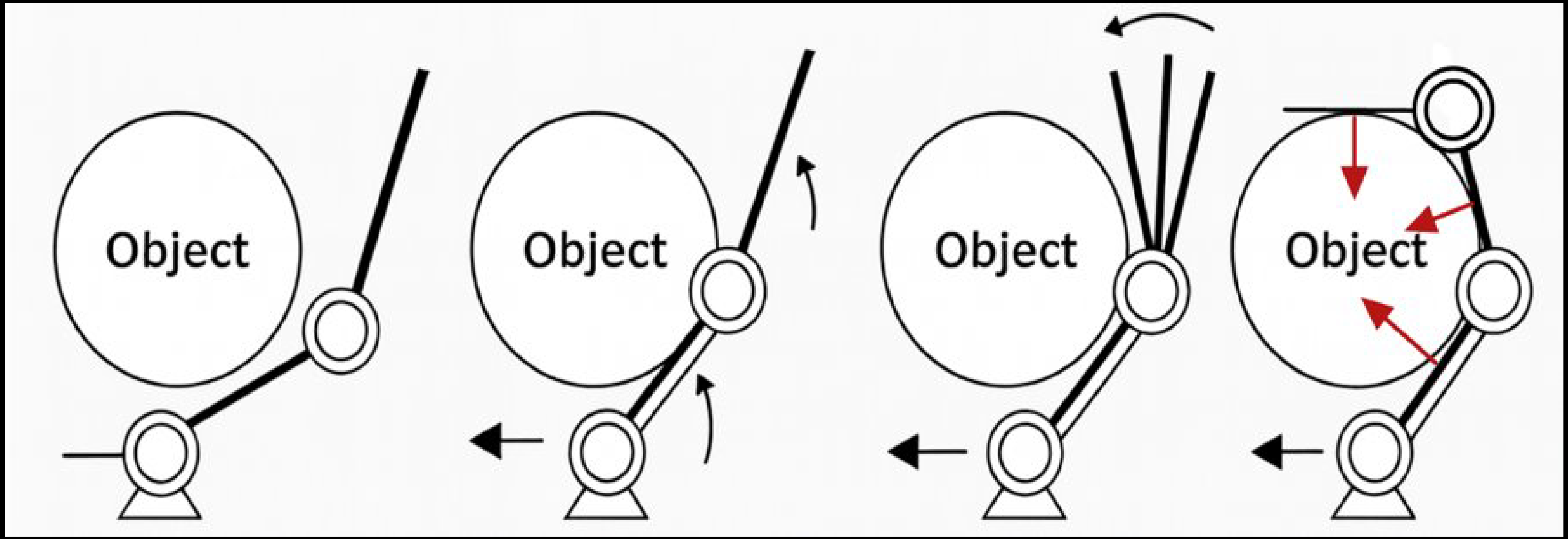


Concept 4: Push latch



Final Concept

Concept 5: Robotic Claw



Selected due to:
- Highest trade score
- Works with non-cooperative targets
- Flexible geometry capture

All Concepts - Trade Study

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
Robotic Claw	**1.2**	**0.6**	**0.3**	**0.8**	**0.525**	**0.1**	**3.525**

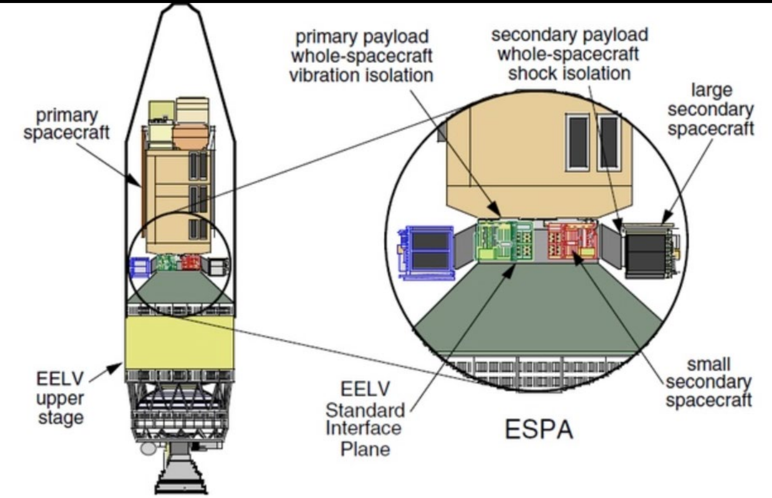
Each criteria ranked from 1-5, and then the score is multiplied by the weight.

Example: Robotic Claw, TRL = 4
4 * 0.3 = 1.2

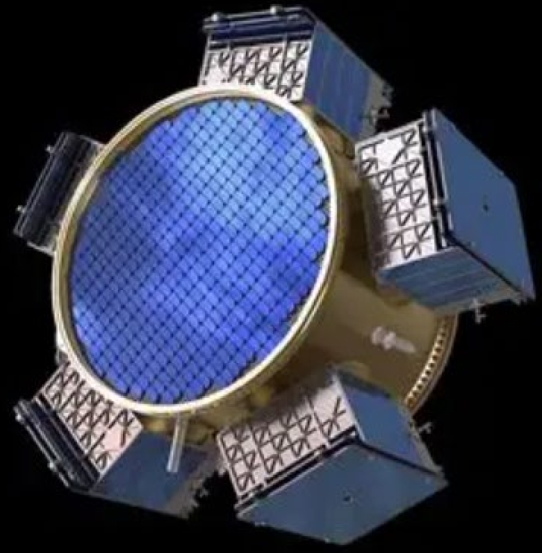
Capture Target

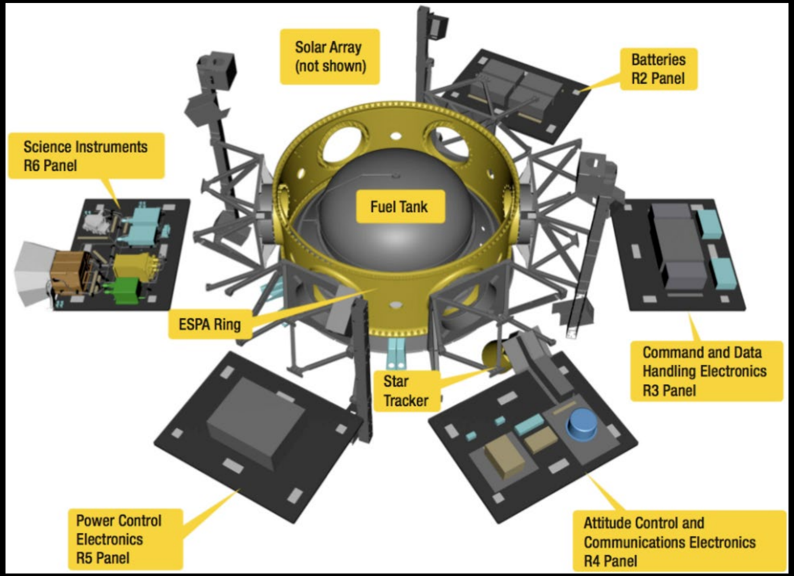
Focus on ESPA (EELV Secondary Payload Adaptor)

- Load bearing structure
- Used in satellite deployment
- Withstands launch loads, high structural integrity
- Aluminum 7050-T7451
- Diameter 62.01 inches
- Secondary satellites separate from ESPA leaving it exposed



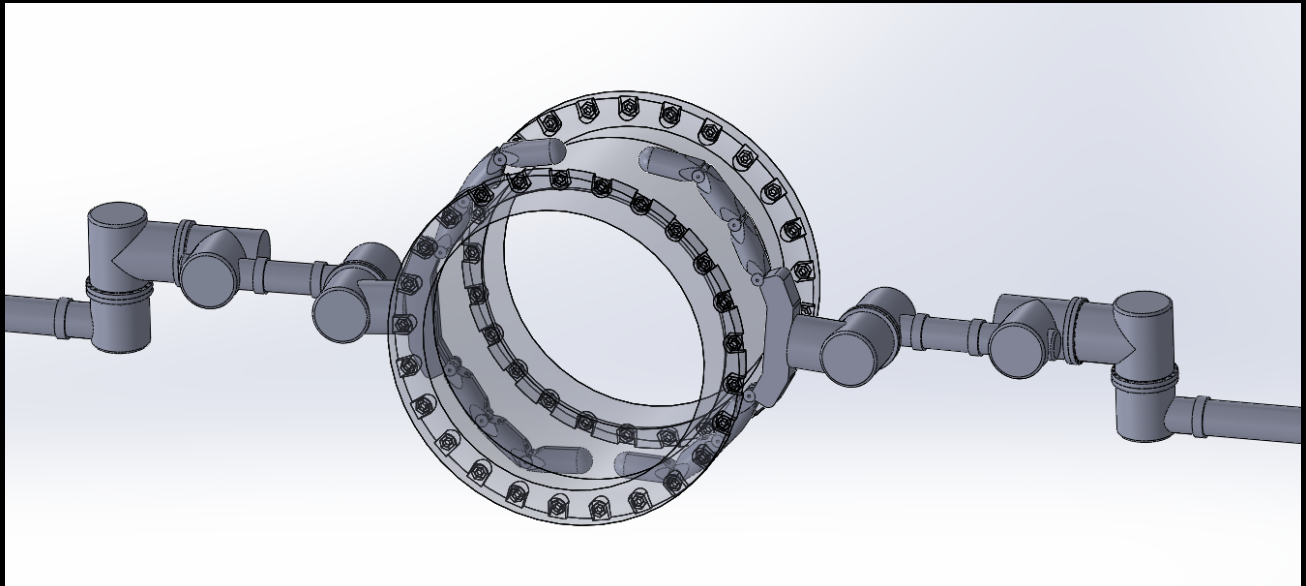
ESPA ring schematics, from â€œESPA: EELV Secondary Payload Adapter with whole-spacecraft isolation for primary and secondary payloadsâ€ Maly, Haskett, et al.





Design Concept - Approach

- 6-DOF robotic arm
- Finger based end effector
- Tendon driven actuation
- Grabs:
  - Rings
  - Rails
  - Brackets



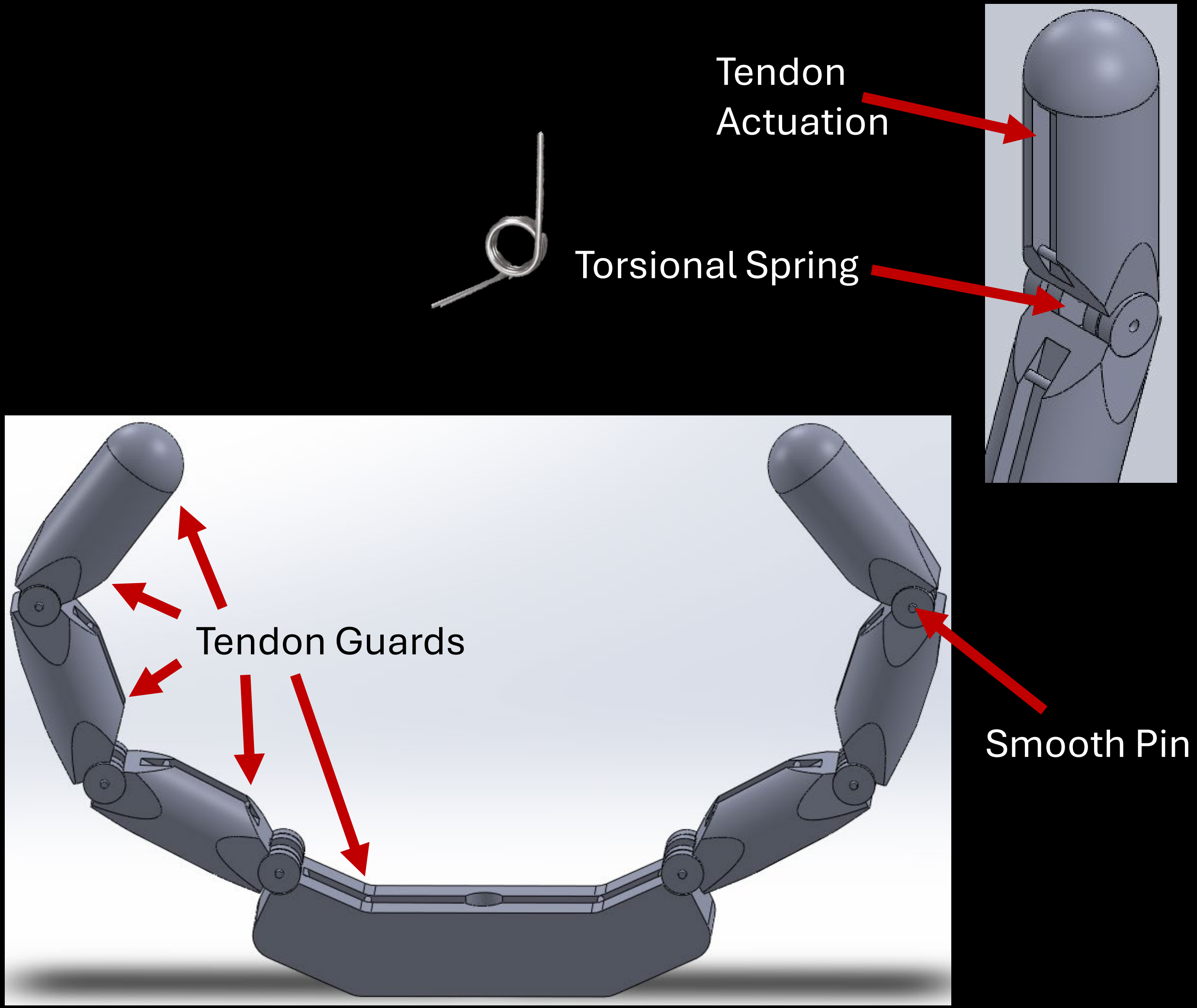
End Effector Design

Finger links: Ti-6Al-4V

Pins : 316 stainless steel

Torsion springs: Ti-15V-3Cr-3Sn-3Al

Tendon: fine stainless-steel cable



Testing & Results

Tested gripping capability on multiple geometries:

- Cylindrical object (water bottle)
- Linear object (rod)
- Irregular geometry object

Results:

- Successfully achieved stable grip on all test objects
- Maintained contact without slipping
- Adapted to varying shapes and sizes
- Demonstrated compliant grasping behavior

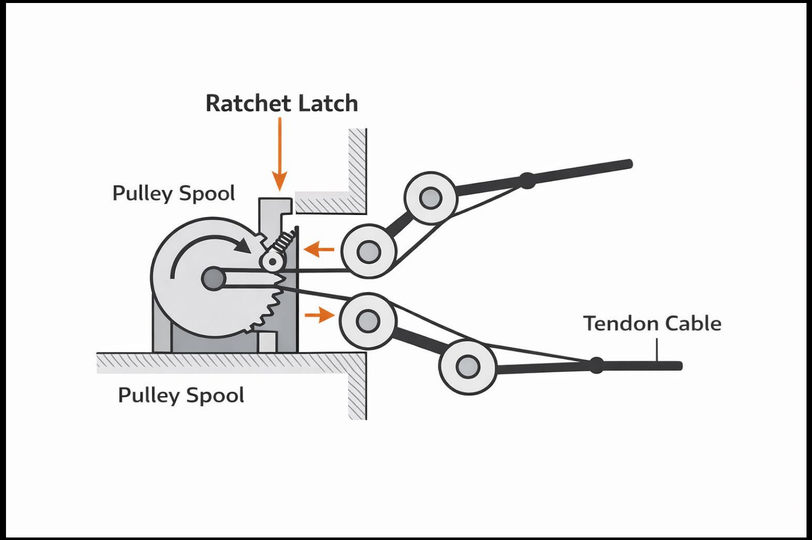
End Effector Design

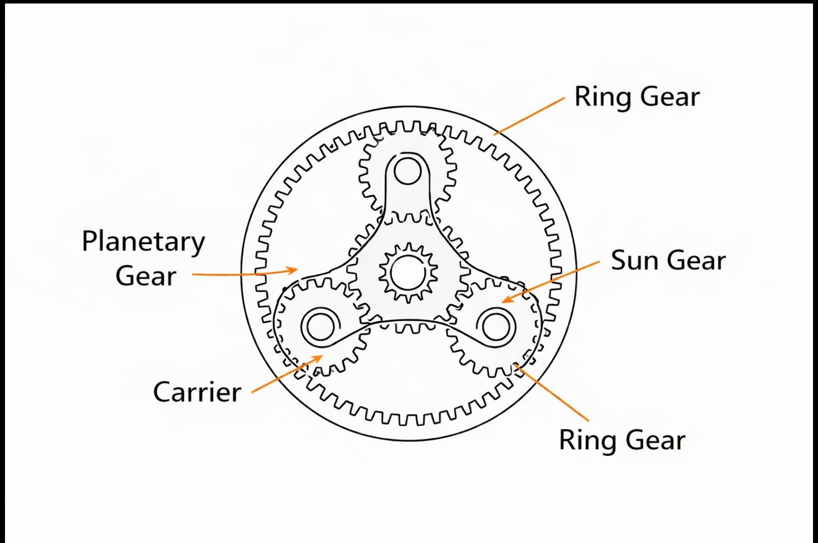
Planetary Gear System

- Sun Gear = input (motor)
- Ring Gear = fixed
- Carrier= output

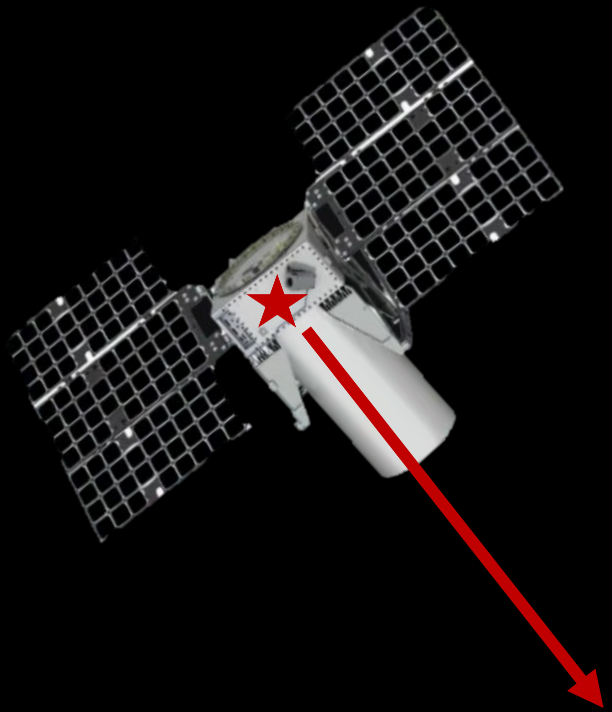
Ratchet Latch

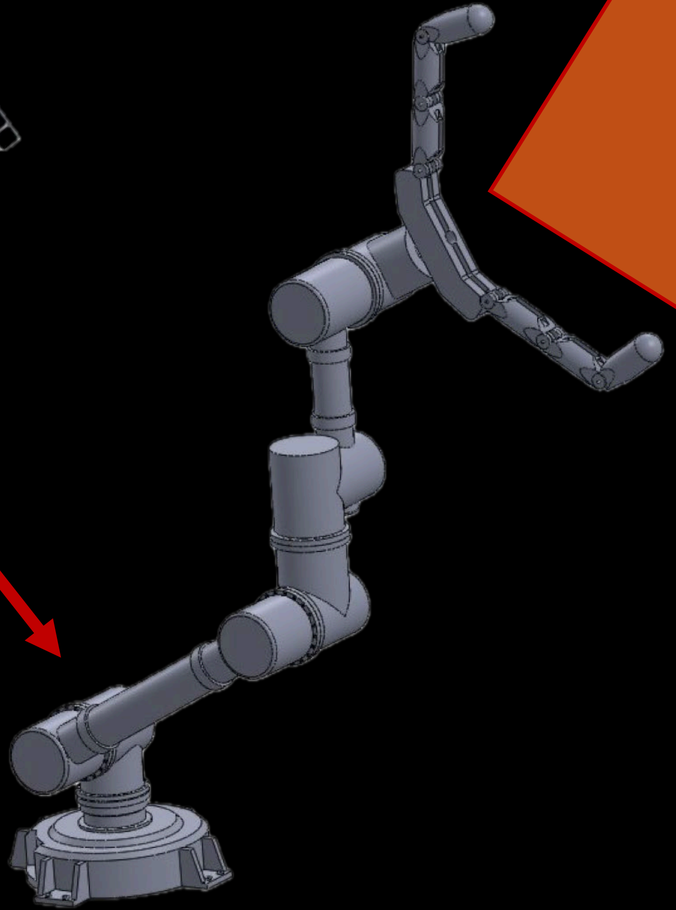
- Maintains cable tension without continuous motor input

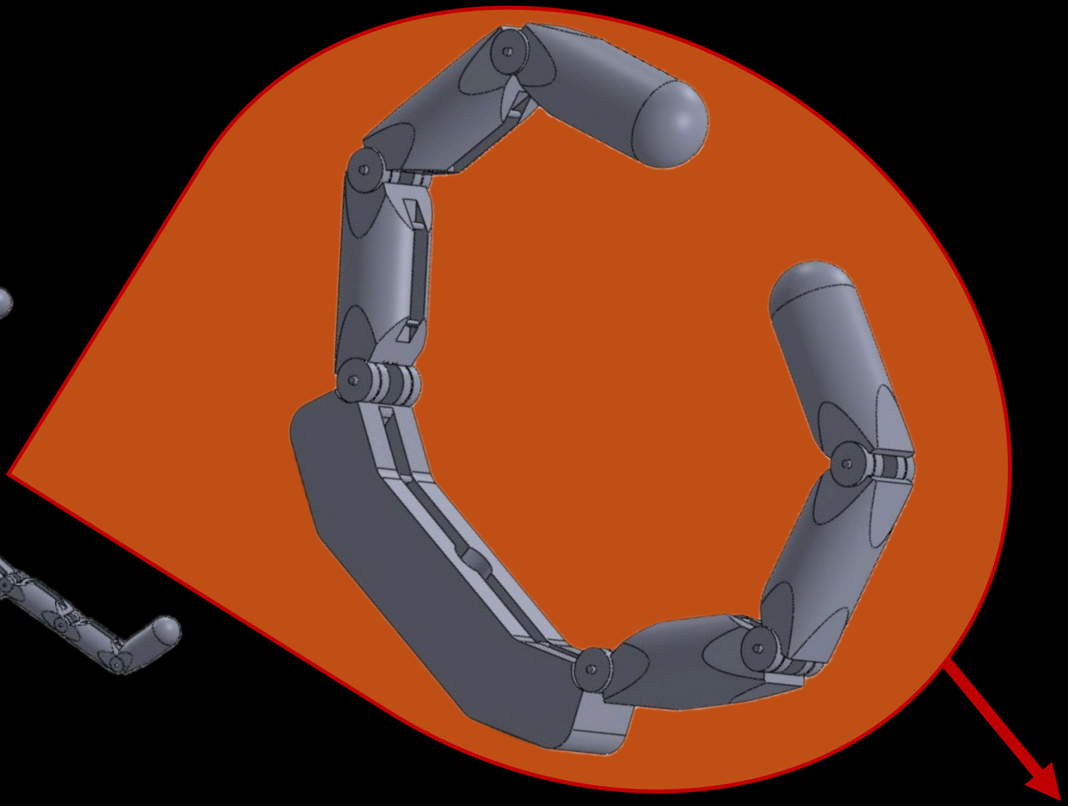




System Overview



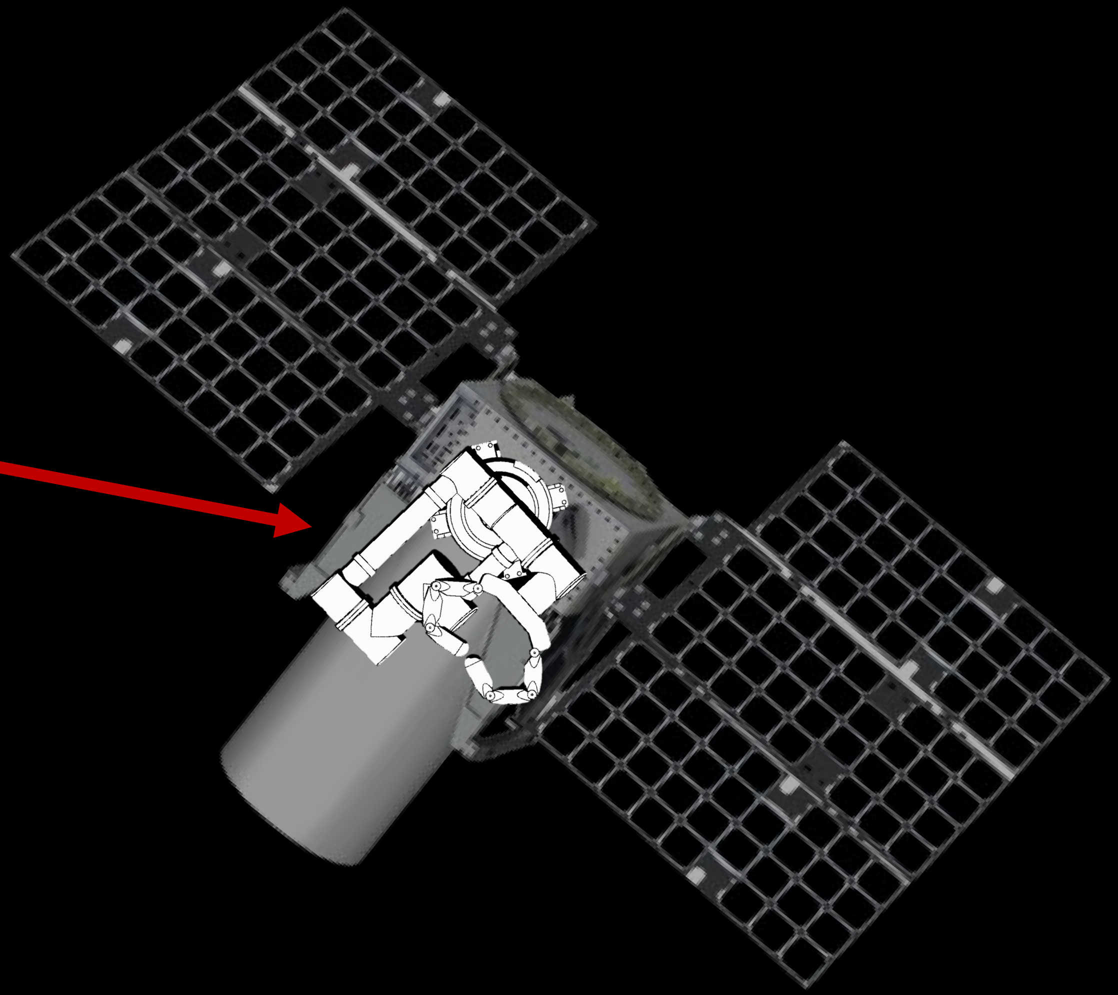




X Sat Venus Class Satellite → Multi-DOF Robotic Capture Arm → Finger-based End Effector → Target Satellite Structural Interface

System Integration & Mounting

- Robotic arm mounted to spacecraft structural panel
- Stowed configuration during launch
- External placement enables full range of motion
- Multi-DOF arm provides precise positioning and alignment
- End effector interfaces with target structural features



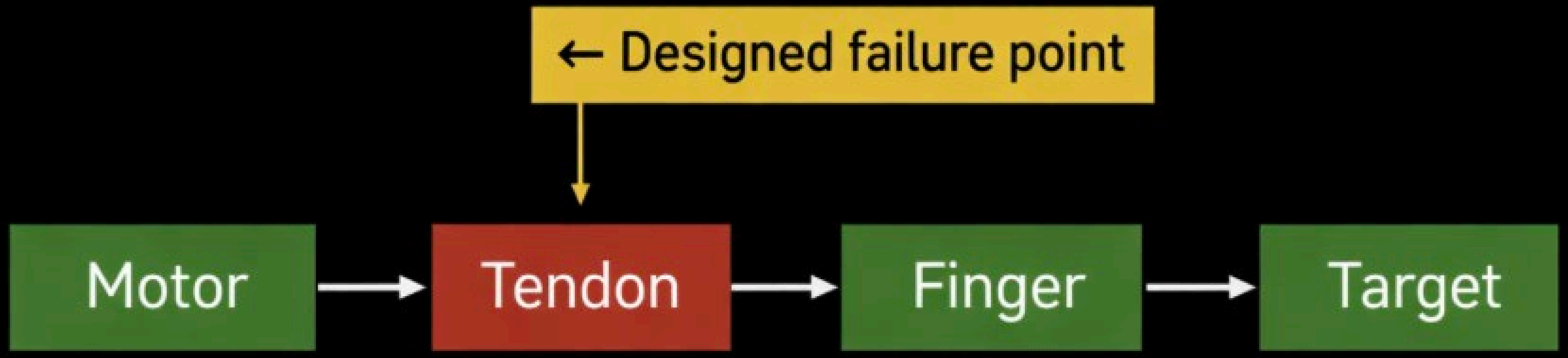
Risk

Tendon Failure During Capture:

- Failure would result in loss of gripping capability
- Could lead to incomplete capture or release of target

Mitigation Strategy:

- Tendon is intentionally selected as the first failure point
- Prevents damage to: motor joint, structural links
- Tendon is: easily replaceable low cost externally accessible



Conclusion

- Robotic capture is a viable alternative to traditional docking systems
- Successfully captures non-cooperative satellites without docking interfaces
- Demonstrated through a functional tested prototype
- Scalable to a full robotic servicing system
- Supports future mission in satellite servicing and debris mitigation

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Questions?

Backup Slides

Analysis

- Approach Velocity
- $v = 0.5 \frac{ft}{s} = 0.1524\ m/s$
- Impact Impulse
- $J = 10{,}000\ kg\ x\ 0.1524 \frac{m}{s} = 1{,}524\ \text{Ns}$
- Kinetic Energy
- $E_k = \frac{1}{2}\ x\ 10{,}000\ kg\ x\ (0.1524 \frac{m}{s})^2 = 116.13\ J$
- Compliance Stiffness
- $k = 2\ x\ 116.13\ J/(0.010)^2 = 2.3\ x\ 10^6\ \text{N/m}$
- Contact Force
- $F_{Contact} = \sqrt{2\ x\ 116.13\ J\ x\ 2.3\ x\ 10^6\ \text{N/m}} = 23{,}225.76\ N = \boxed{23.2\ kN}$
- Force of each arm
- $F_{Arm} = 23{,}225.76\ N/2 = 11{,}612.88\ N = \boxed{11.6\ kN}$
- Force of each finger
- $F_{Finger} = 11{,}612.88\ N/2 = 5{,}806.44\ N = \boxed{5.8\ kN}$

Givens:
m= 10,000 Kg
v= 0.5 ft/s
Allowable Compliance travel = 0.01 m