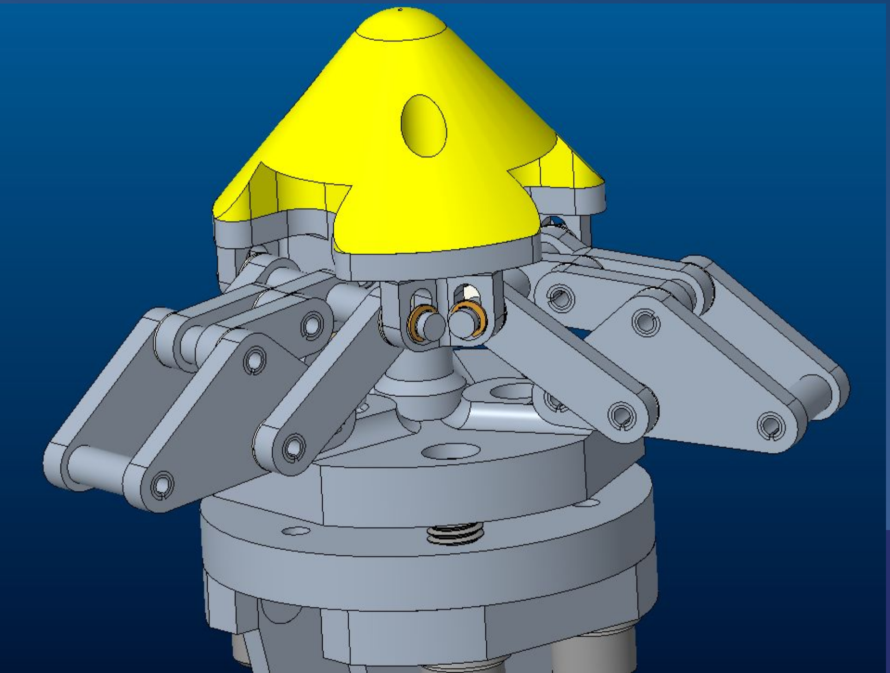
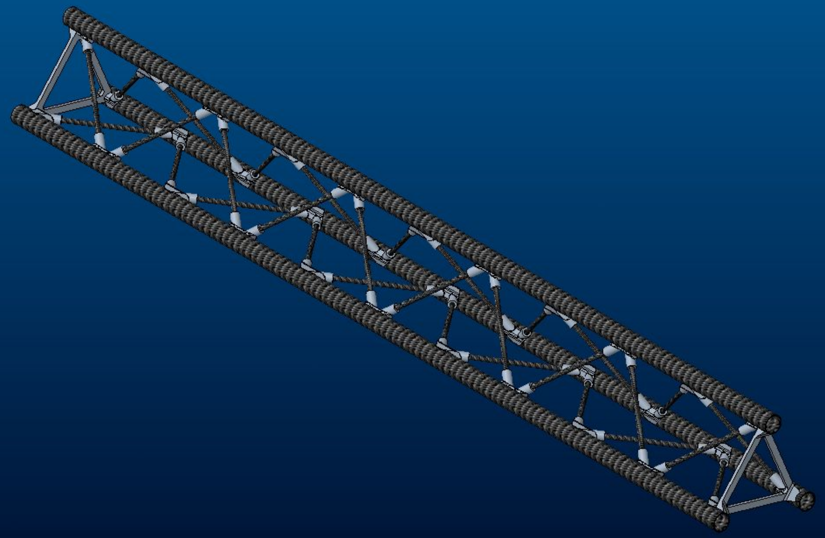
ASSEMBLERS – Mechanical Design of Modular Coupler

Intern: John Merila

Mentors: Matthew Mahlin, Jim Neilan, and John Mulvaney

Session: Summer 2021





Overview

- Bio
- ASSEMBLERS Overview
- Truss Redesign Project
- Modular Coupler System
- Concluding Remarks
- Lessons Learned
- Academic and Career Goals

Bio – John Merila

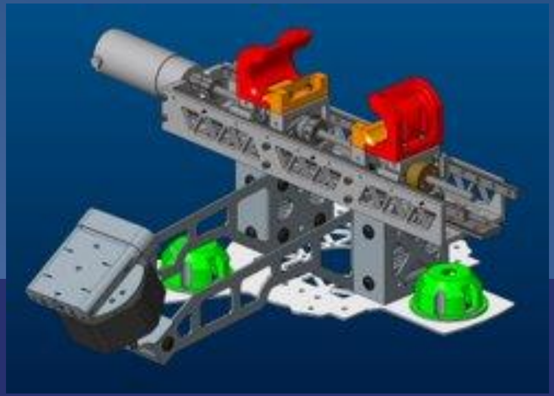
- Senior at the University of North Dakota studying mechanical engineering and minoring in electrical engineering
- President of the University of North Dakota Advanced Rocketry Club, and Robotics Club
- Previously a Student Researcher in the Mechanical Engineering and Space Studies departments
  - Designed mechanical components for vehicle mounted augmented reality system
  - Performed design and construction of space suits using 3D printing
- Currently working on the ASSEMBLERS project as a mechanical systems intern

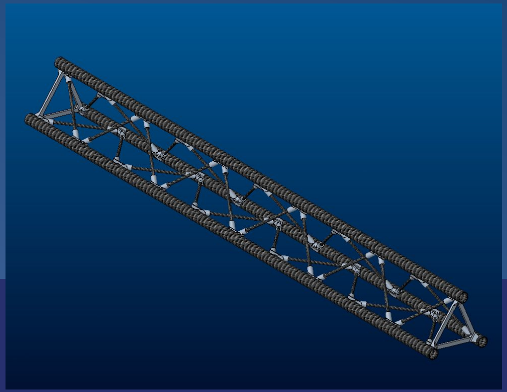
ASSEMBLERS

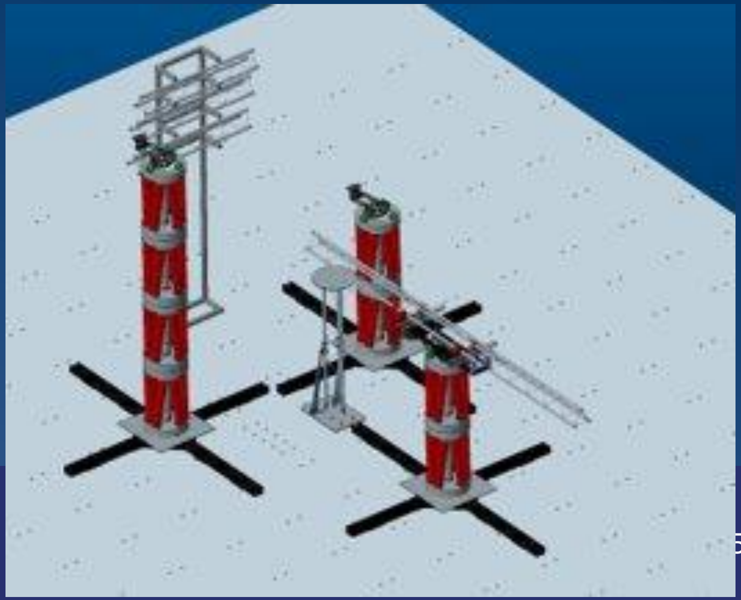
- Stewart Platform Robot
- Scalable system with high precision modules
- In space assembly of complex structures

ASSEMBLERS

- Reconfigurable system to allow for assembly of larger structures using multiple stacked platforms
  - Coupler mechanism will allow for live reconfiguration of system during operation
  - Coupler system needs to operate beyond the maximum loading of the actuators
- Testing will include assembly of truss segments
- Lower mass truss to simplify testing process



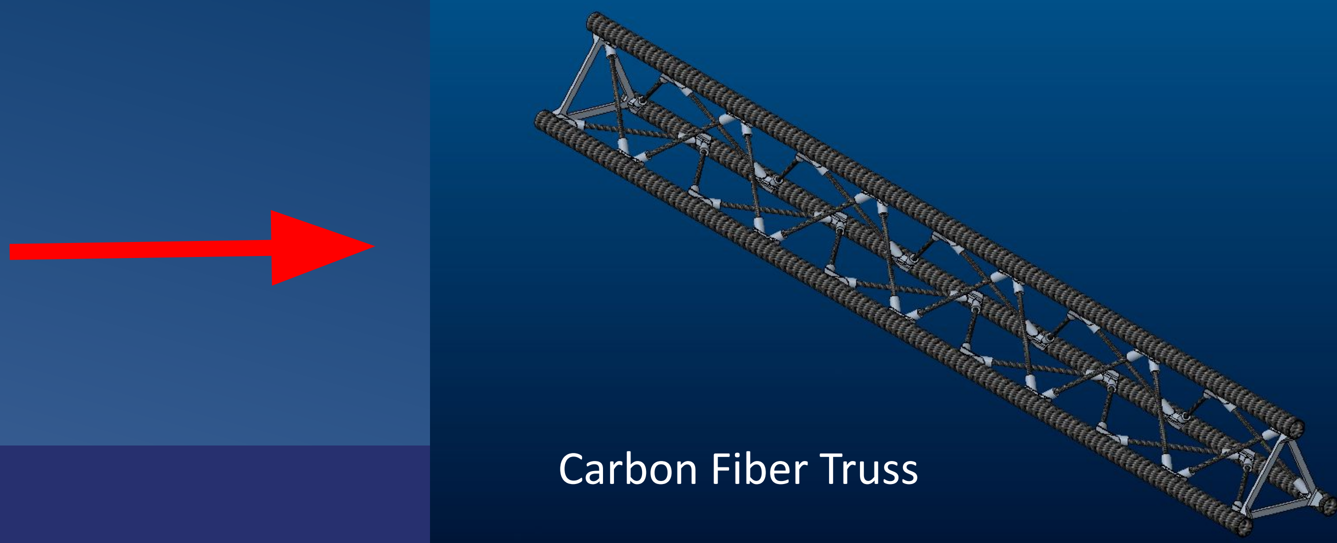




Truss Redesign Project

- Design new truss test article
- Original truss commercial off the shelf (COTS) constructed from aluminum
- Requirements:
  - Reduce weight compared to COTS
  - Similar flexural characteristics
  - Compatible with existing manipulators

COTS Aluminum Truss

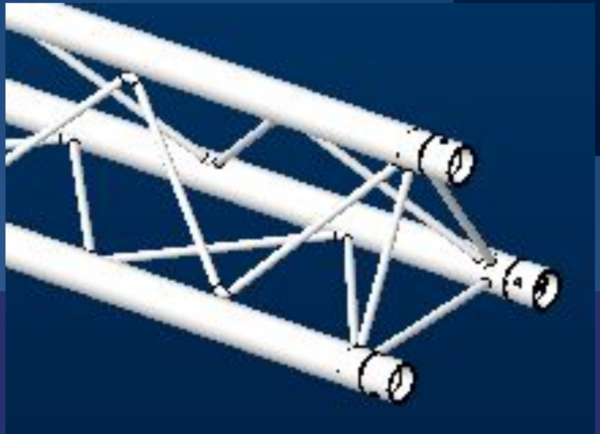


Carbon Fiber Truss

General Design & Material Selection

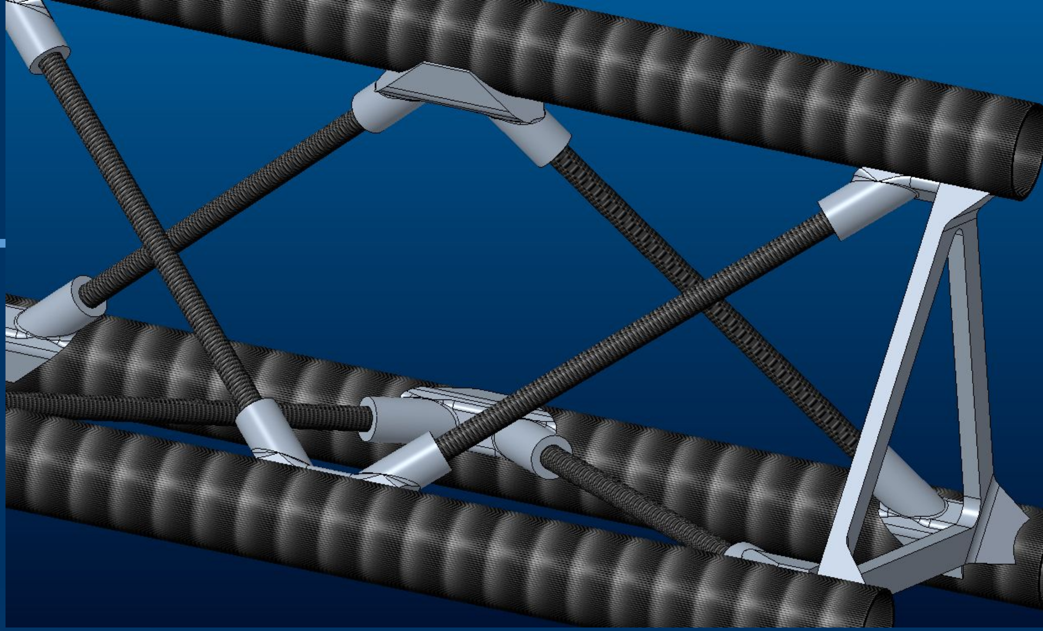
- Carbon fiber composite meets design requirements
- Replace outer tubes with tubes of equivalent outer diameter
- Maintained similar truss geometry with struts also made from carbon fiber tubing
- Increased specific Youngs Modulus allowed for reduced mass of truss while maintaining rigidity

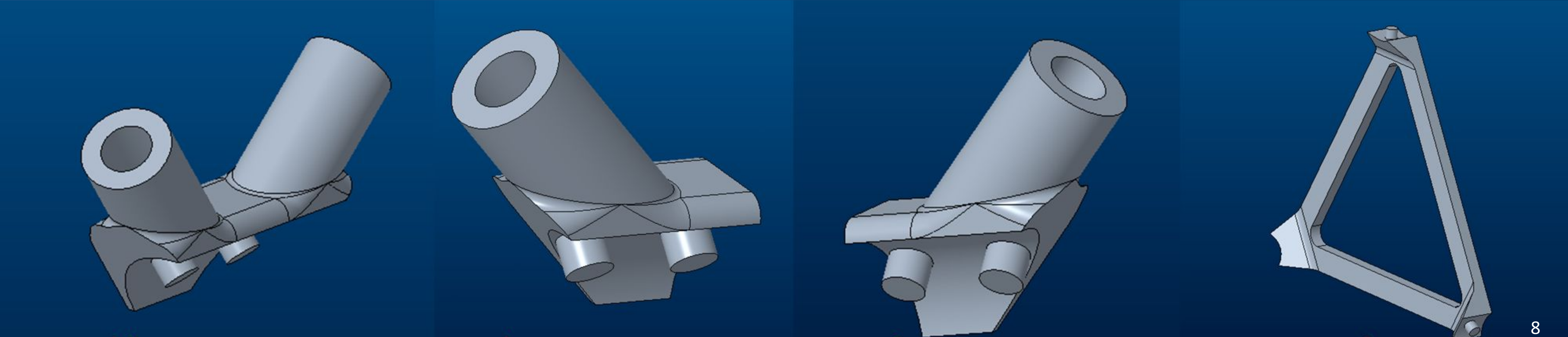
Material	Aluminum	Carbon Fiber
Youngs Modulus	3.5x10^6 Psi	35x10^6 Psi
Density	.0975 lbs/in3	.06 lbs/in3



Design

- Designed 3D printed brackets to mount struts to structural tubing
- 3D printed end spacer to aid in alignment and construction
- Nylon 12CF filament used for increased flexural and tensile strength





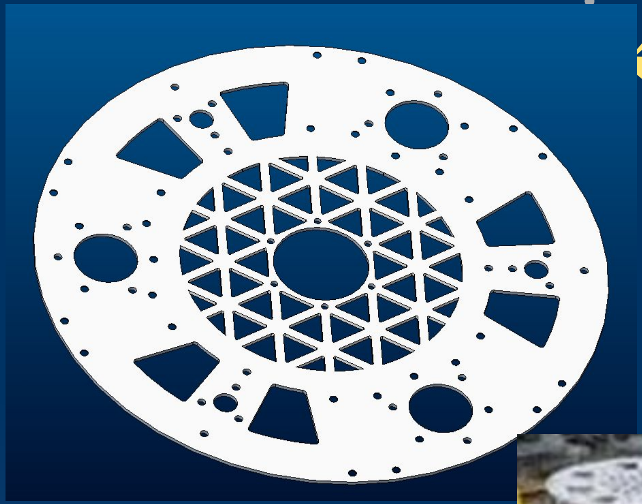
Middle Connector　　Right Connector　　Left Connector　　End Spacer

Conclusions and Future Work

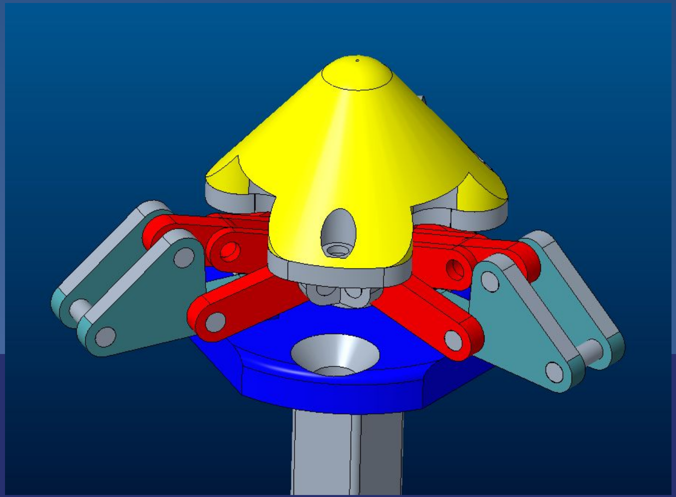
- Design successfully reduced deflection
  - Original truss calculations: 1.29”
  - New truss simulation: 1.21”
- Weight of truss reduced by 50% (calculated mass without weight of adhesive)
- 3D printed and carbon fiber components will expedite assembly process
- CF truss will be used in testing of ASSEMBLERS

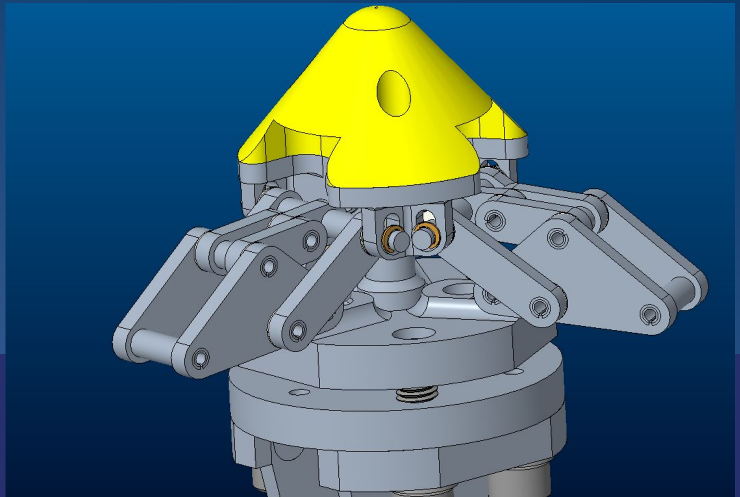
Modular Coupler System

- Given design for 6-bar linkage as starting point
- Requirements:
  - Work with existing machined plates
  - Create unlocking mechanism for links
  - Simulate system to ensure it can handle the forces applied
  - Maximize accuracy range



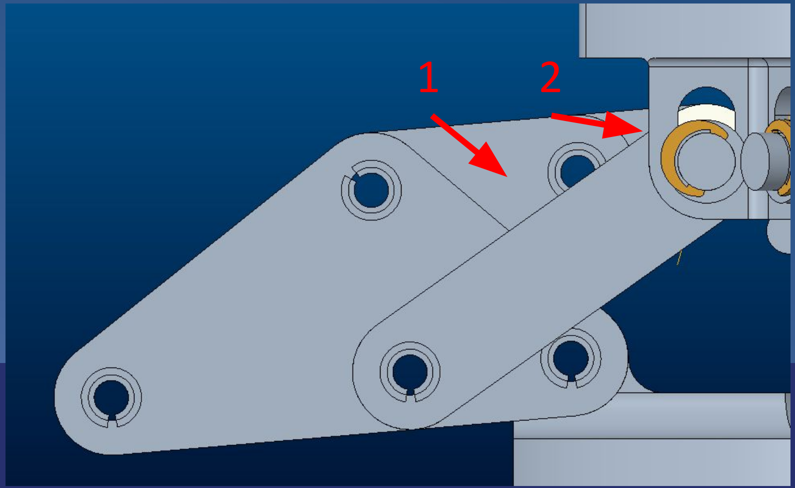
Stewart Platform Plate

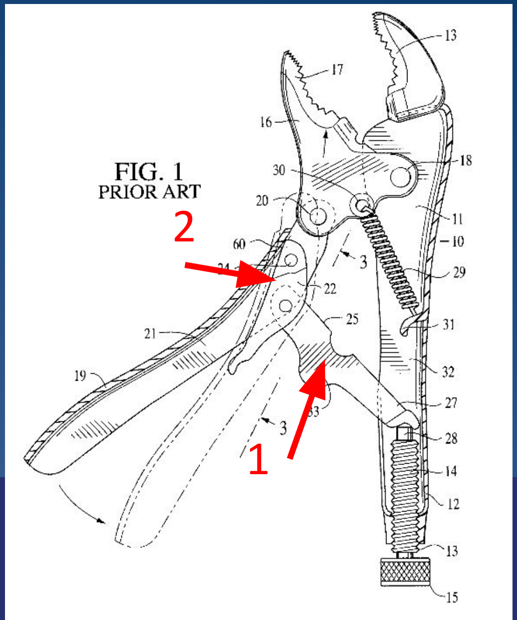


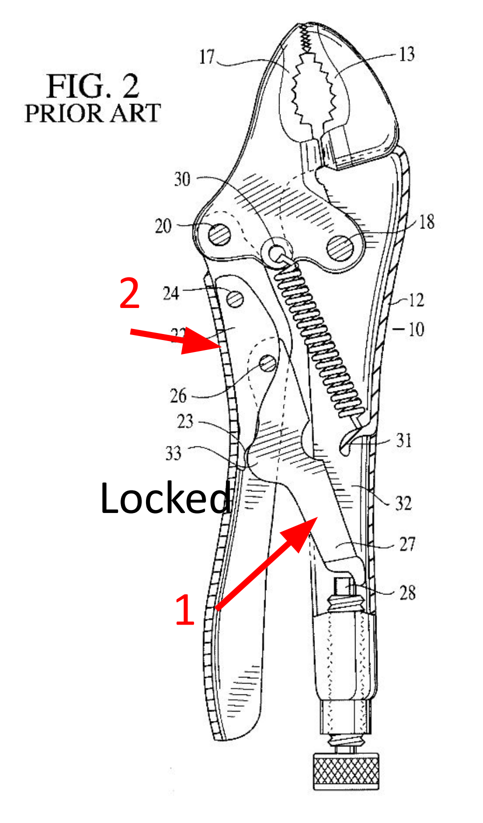


Toggle Locking Mechanism

- When aligned the top links (1 & 2) act as a single link which would require infinite force applied at the ends of the links to cause rotation
- Vise-Grip pliers uses same mechanism
- The parallel links are desired to be unlocked via same actuator that initially locks the links

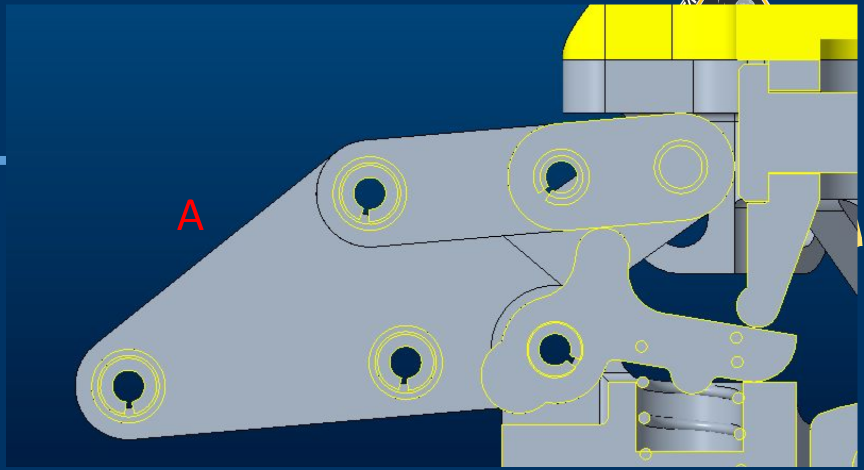


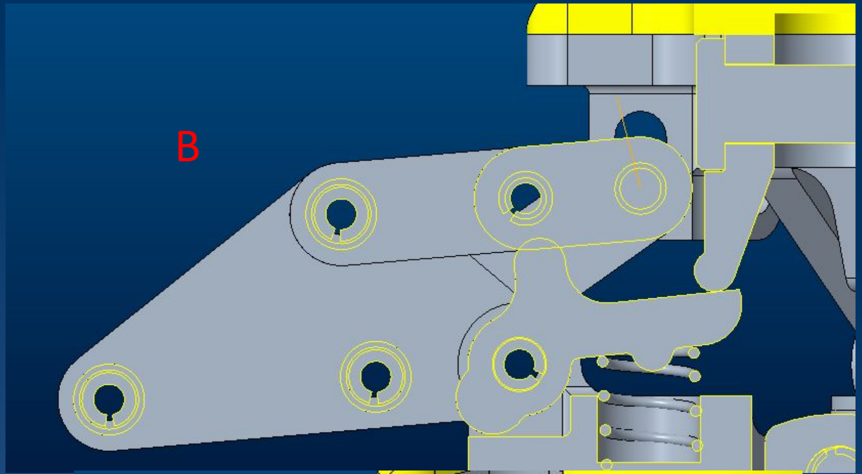


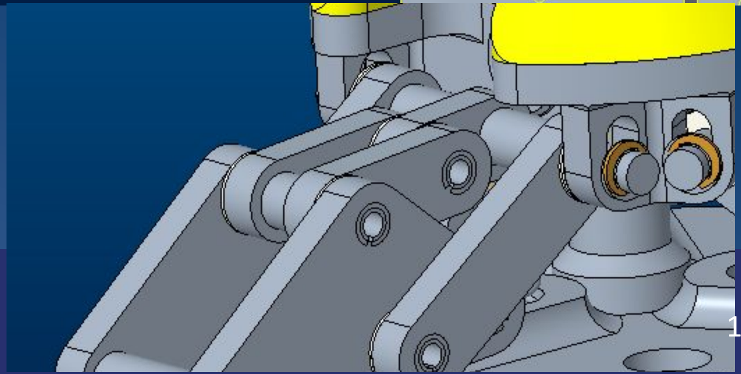


Unlocking System

- System uses a similar pusher lever to a vice grip to unlock the mechanism
- By having the moving pivot inside a slot, the top plate can actuate the mechanism
- A) mechanism is fully locked with spring compressed
- B) mechanism is unlocked, spring force is applied to links
- Future testing will be done to experimentally determine the distance the system needs to be unlocked to allow the actuator to continue the motion

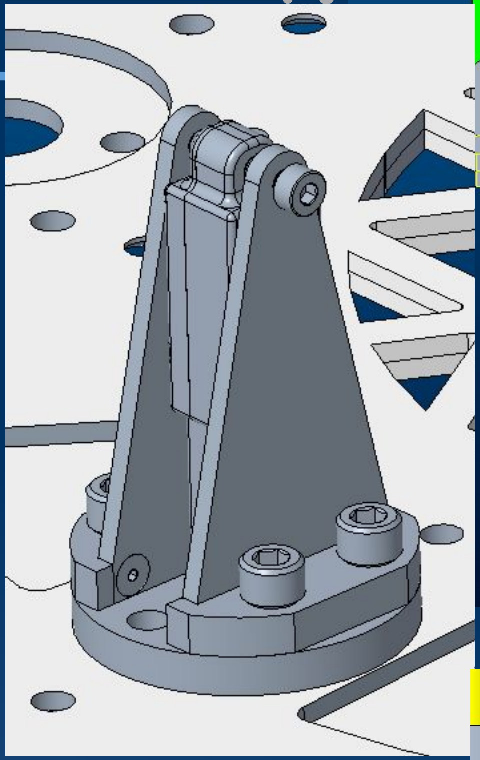


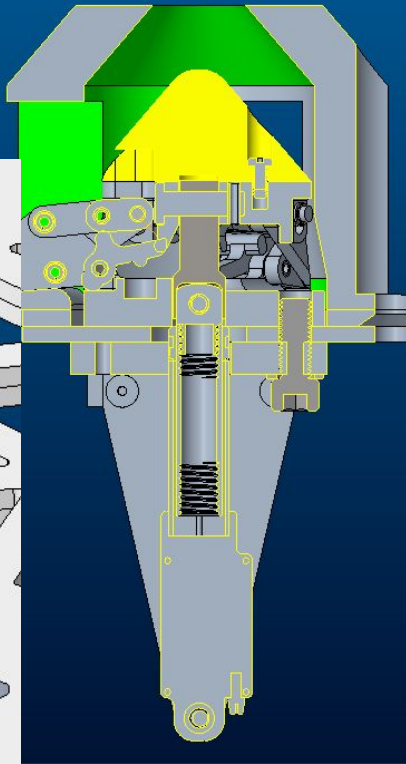


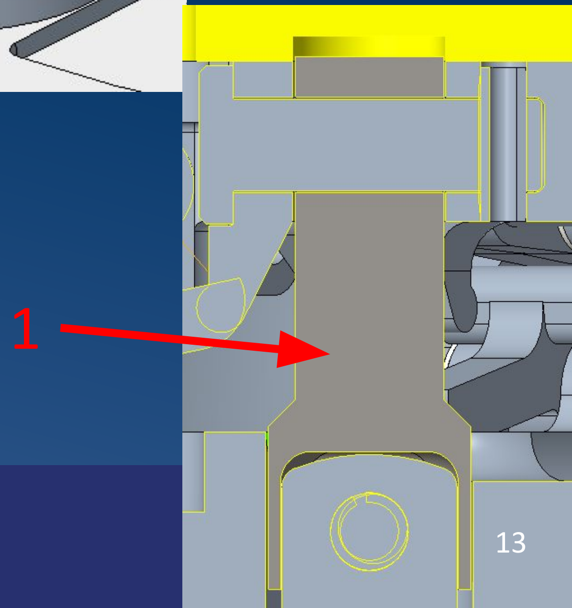


Linear Actuator System

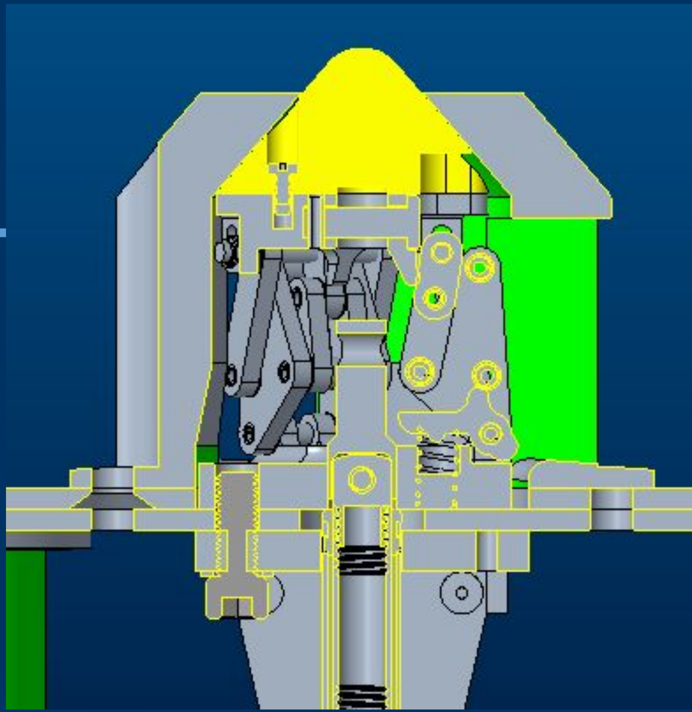
- Linear actuator mounted via CNC machined and waterjet plates
- Designed to minimize cost
- Standoff (1) couples linear actuator with top plate
    - Designed for easy installation and removal from linear actuator with set screw
    - Mounted to top plate via clevis pin and roll pin



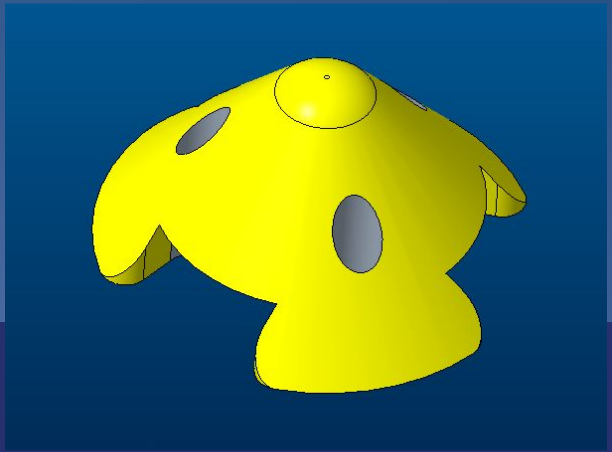


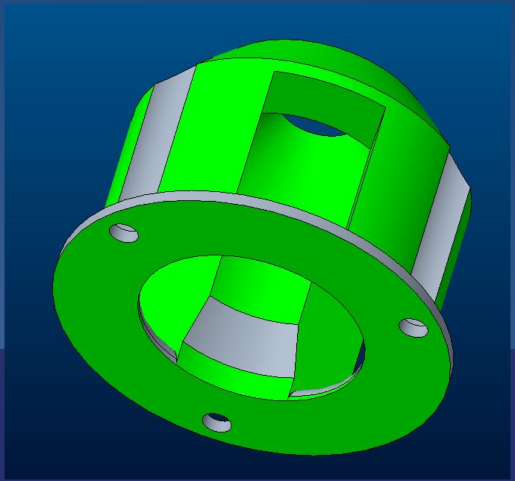


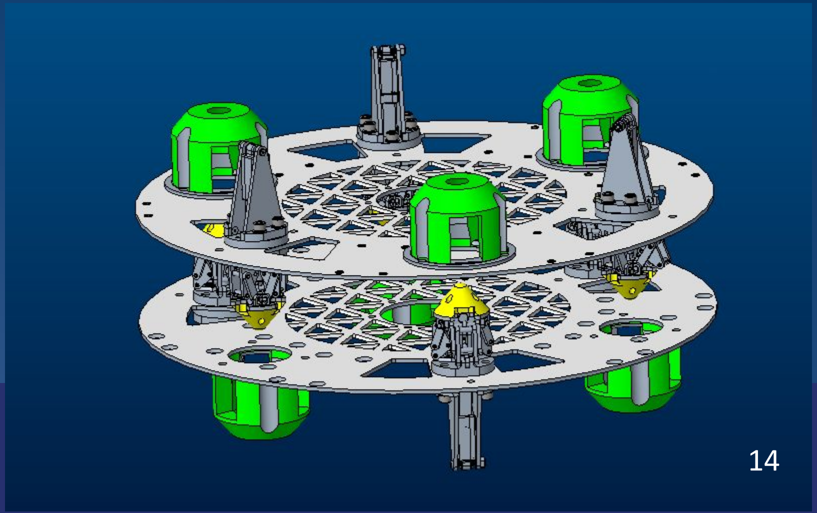
Cone and Receptacle



- Cone designed to allow for low friction adjustment into receptacle
- Receptacle designed to center the cone and allow ample room for the mechanism to actuate
- Designed to minimize accuracy requirements

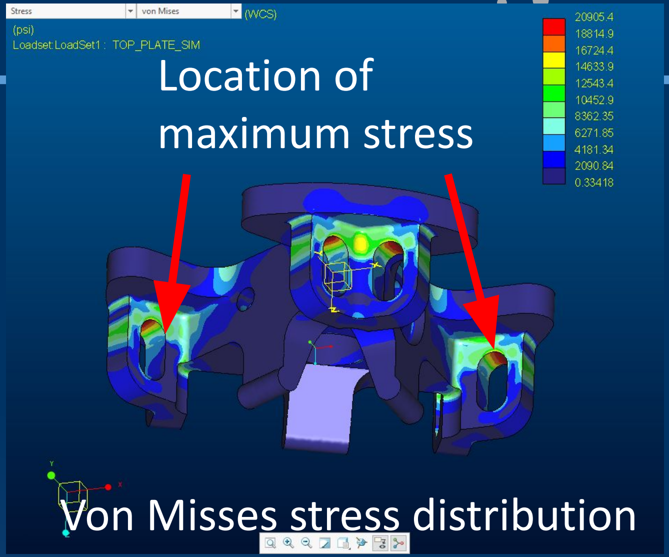


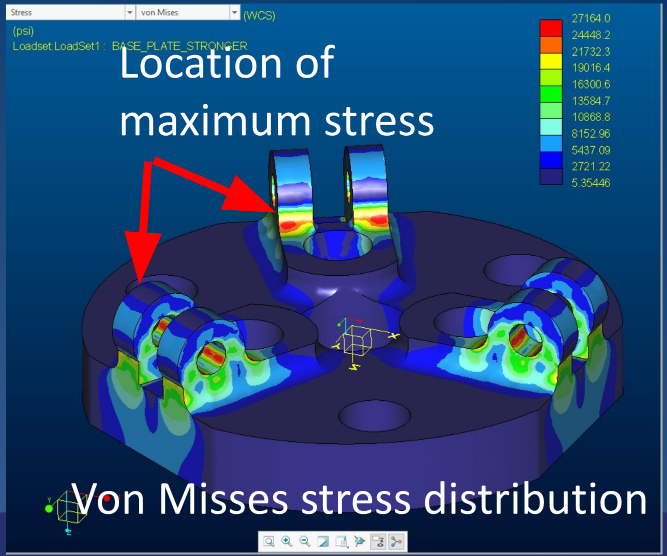


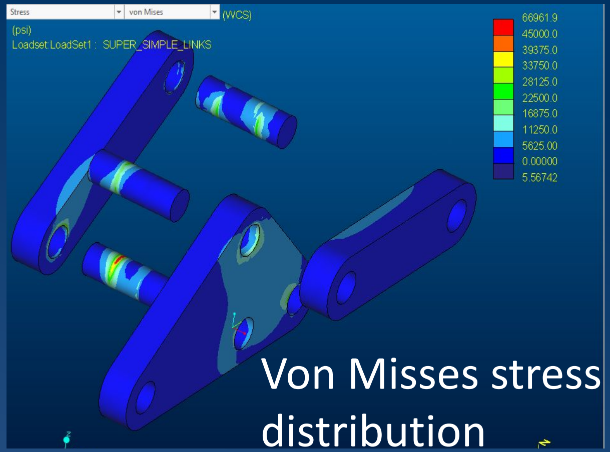


Design and Simulations

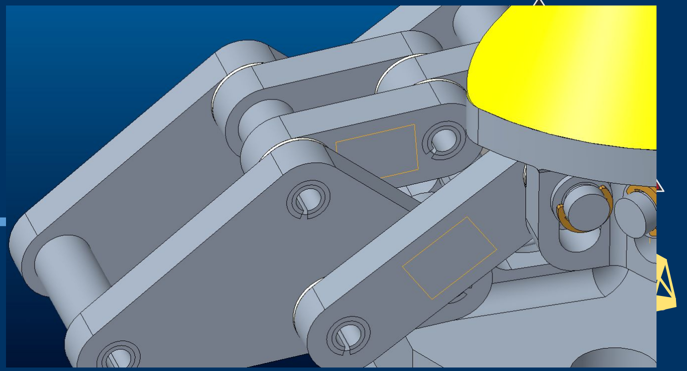
- Simulation performed to validate design could handle design load and iterated the design to meet requirements
- Simulation results compared with hand calculations to ensure accurate results





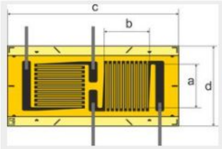


Future Work

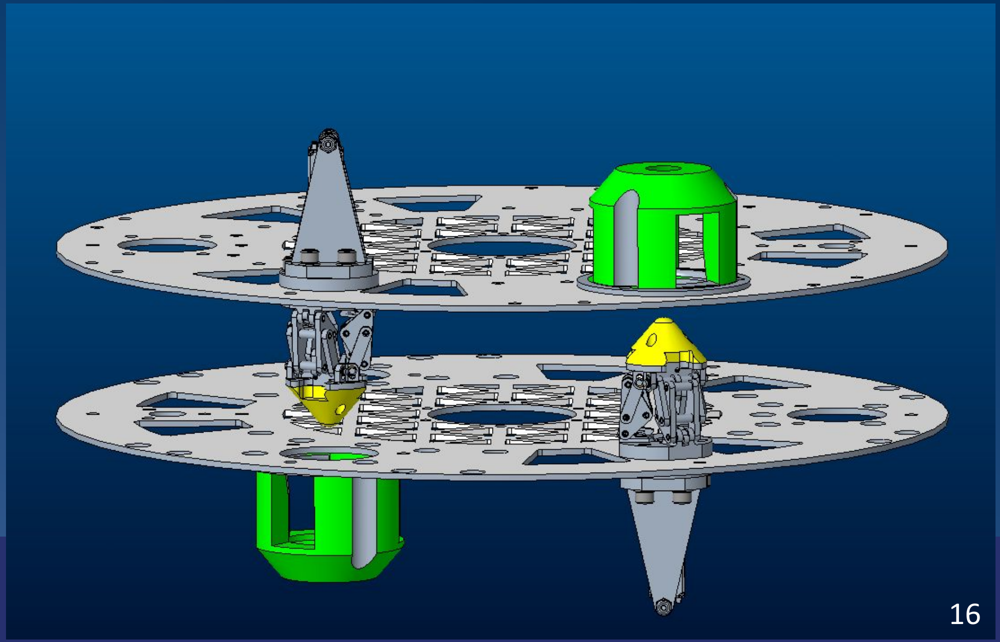


- Construction of test article and testing of system
  - Addition of strain gauges to system to experimentally find forces to refine design
  - Testing of unlocking system to determine forces required to unlock system
  - Destructive testing to identify failure points
- Addition of sensors to aid alignment
  - Optical
  - Magnetic
- Investigation into other application areas

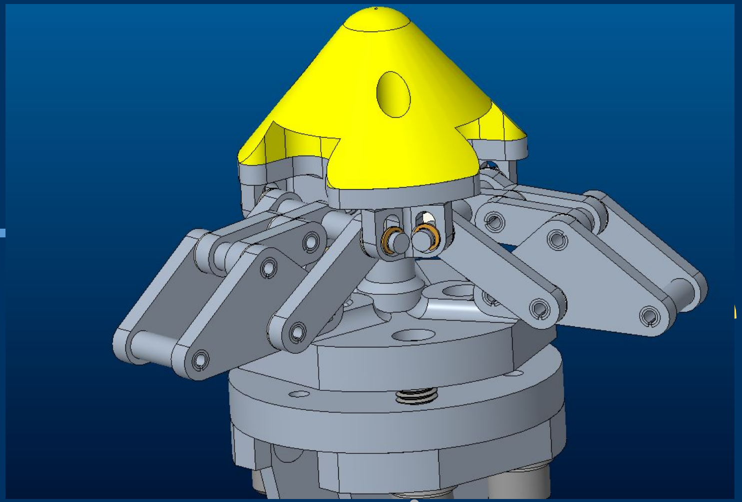
XY1 Leads on left and right side



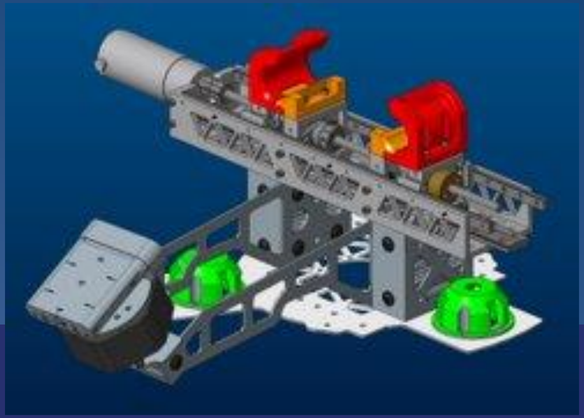
	Ordering number	Nominal (rated) resistance	Dimensions [mm/*inch*]				Solder terminals	Preferred types
			Measuring grid		Carrier			
		[Ω]	a	b	c	d		
	1-XY1x-0.6/120#	120	0.6 *0.024*	1.1 *0.043*	6 *0.236*	4 *0.157*	LS7	1

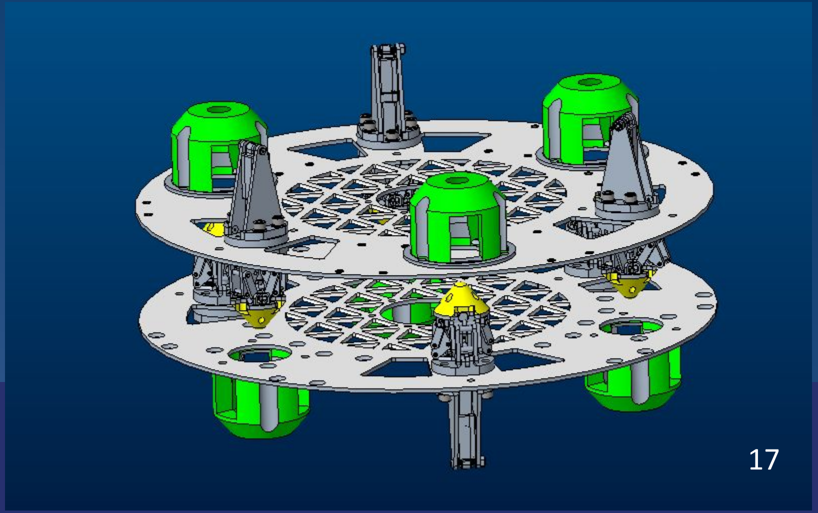


Conclusion



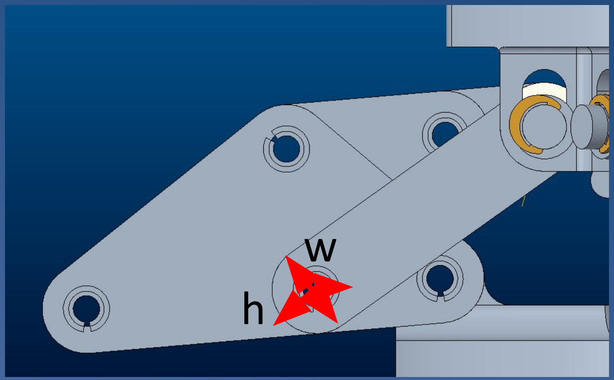
- Design Phase Complete
  - Verified system meets design requirements
  - Manufacturing drawings and documentation produced
- Will allow for the ASSEMBLERS robotic systems to autonomously reconfigure and change end effectors
- Can be applied to other modular systems

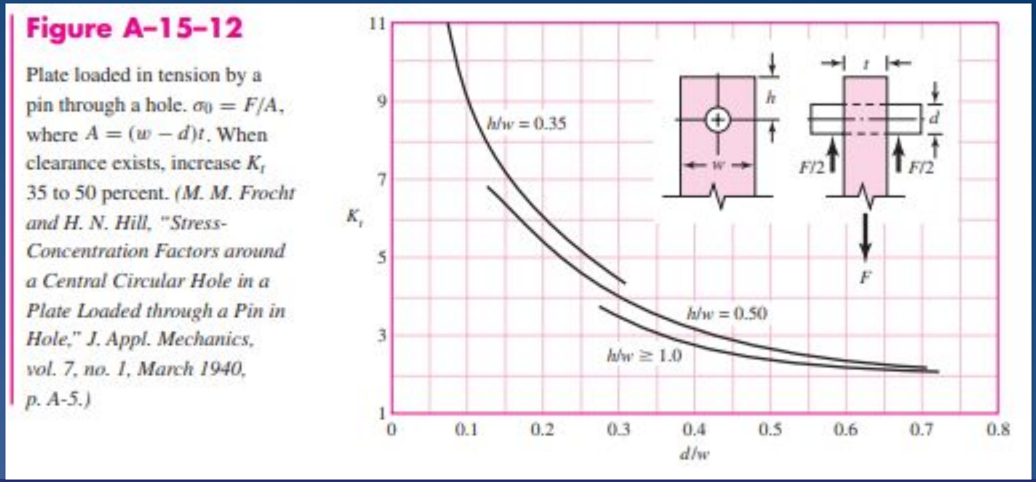




Lessons Learned

- FEA analysis is a great tool to optimize designs
- Design analysis using hand calcs is necessary to ensure FEA is accurate
- Using the motion tools in PTC Creo is super useful for designing mechanisms





Academic and Career Goals

- Greatly enjoyed the design and optimization for a space system
- Solidified intention to pursue graduate degree to enter more research-oriented position relating to robotics
- Working for NASA was a great experience and if I have another opportunity, I would love to do it again!