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NORTHROP GRUMMAN

Standoff Project

Team:

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10/9/19

Project Description

- Objective:
  - Design and build a prototype that will hold standoff brackets while adhesive cures
- Problem:
  - Adhesive is applied and bracket is taped to help cure adhesive
  - Taping is unreliable and costs money and man hours when it fails

Figure 1: Castor 50XL [1]

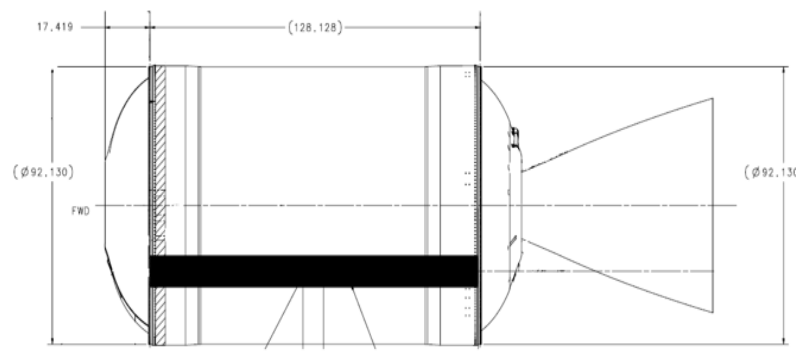

Figure 2: Castor 30 [1]

Design Description - CAD Model

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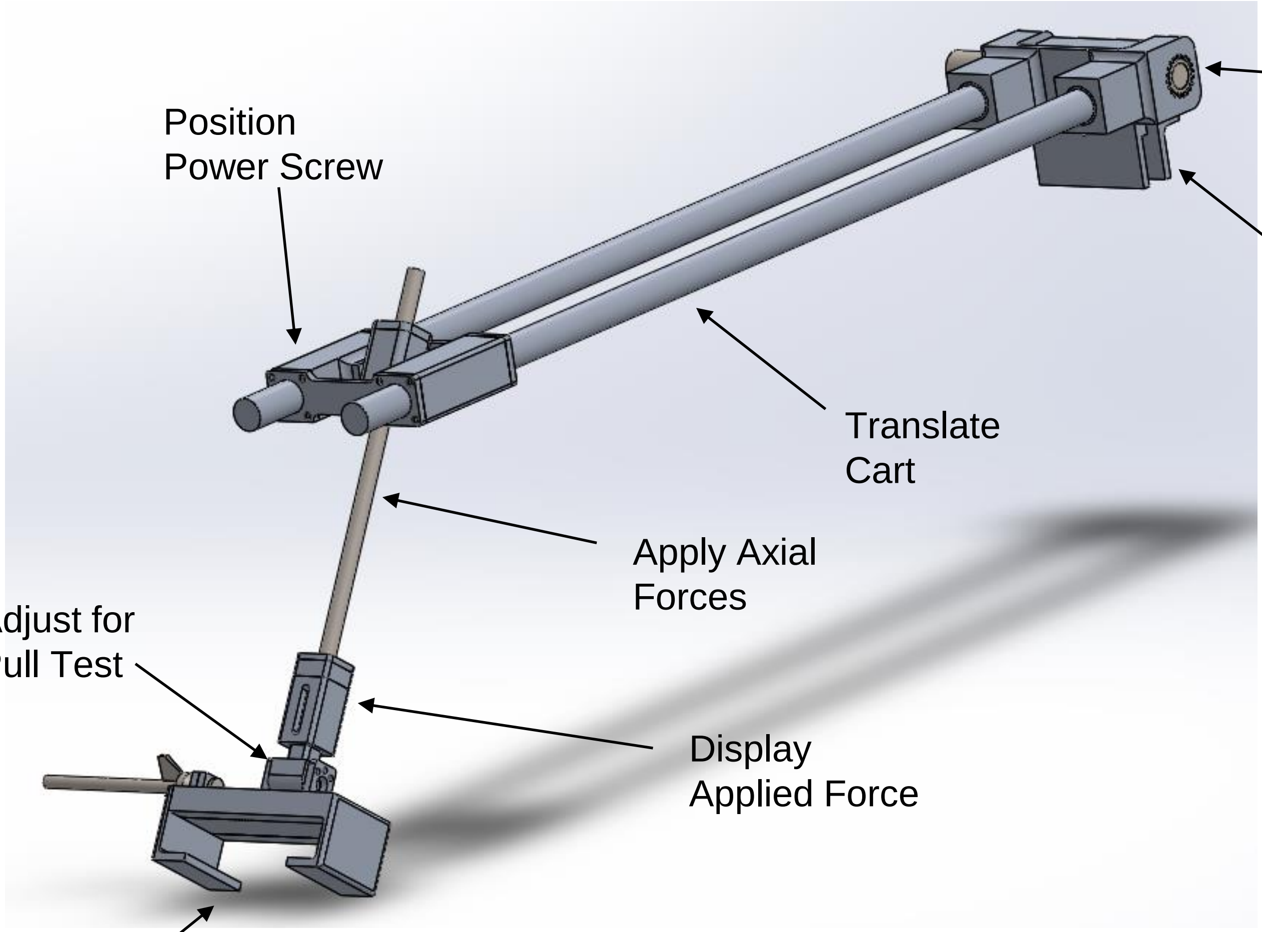

Figure 3. CAD Model

Design Description - CAD Model (2)

- Main body components of design will be constructed out of 6061 aluminum stock.
- The rail system will be made of 7075 aluminum round stock, as it will deflect less than the 6061 aluminum.
- The lead screw, splined shaft, spline nuts, and spring will all have to be purchased from outside sources.
- The current weight of the design is less than 20 lbs when implementing the theoretical material densities.

Design Description

- Clamping mechanism to the ring of the rocket motor, similar to the quick interchange part of a lathe. This component will have different templates that can slide in to adhere to the different rocket motor ring geometries.

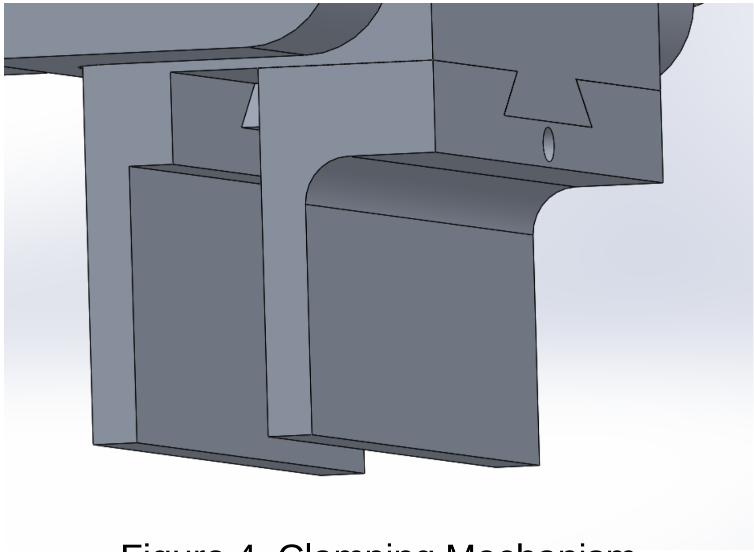

Figure 4. Clamping Mechanism

- Splined shaft that will allow the hinge section to adjust to multiple angles to conform to the rockets dome profiles.

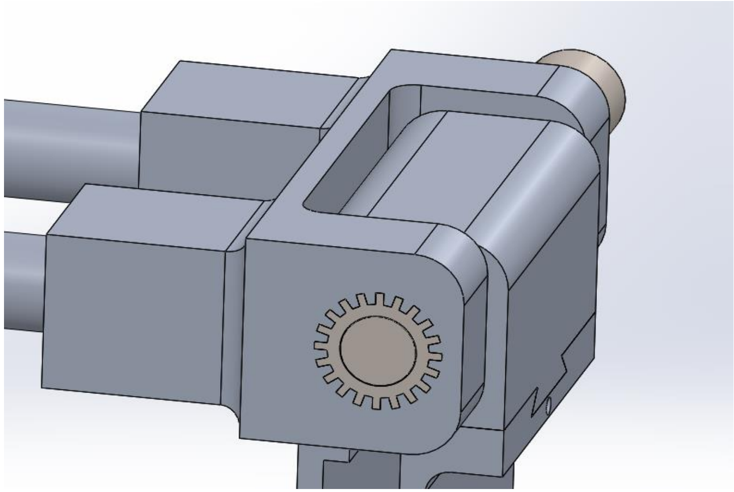

Figure 5. Splined Shaft

Design Description (2)

- Two sets of cylindrical rails allow the cart to slide inward from the hinge component.
- The cart component holds the power screw assembly and allows for a variety of applicable angles.

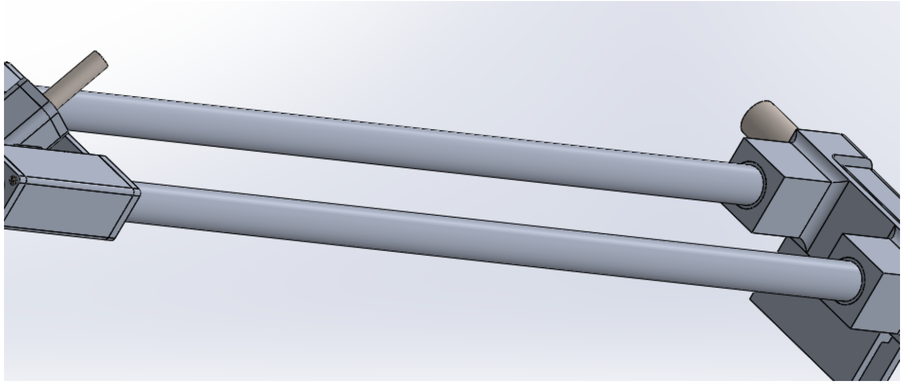

Figure 6. Cylindrical Rails

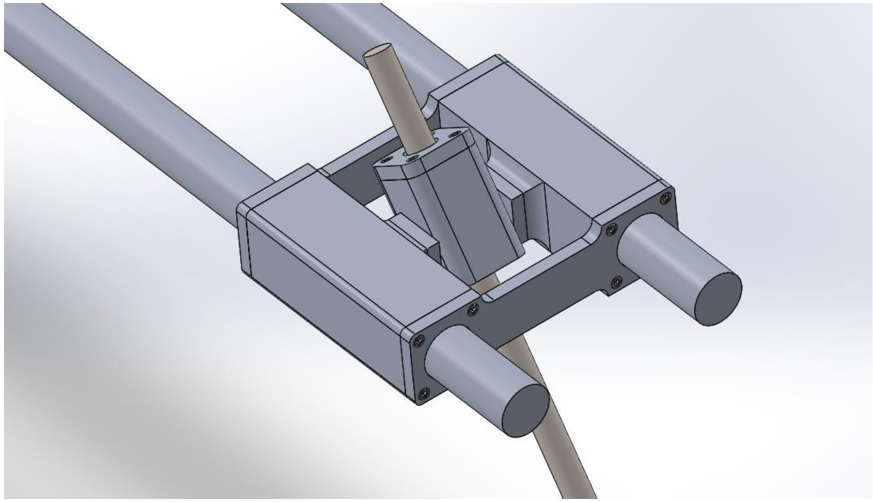

Figure 7. Cart Component

Design Description (3)

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- The power screw provides the axial force required to adhere the brackets to the dome. A knurled nut on top will move the screw up and down.

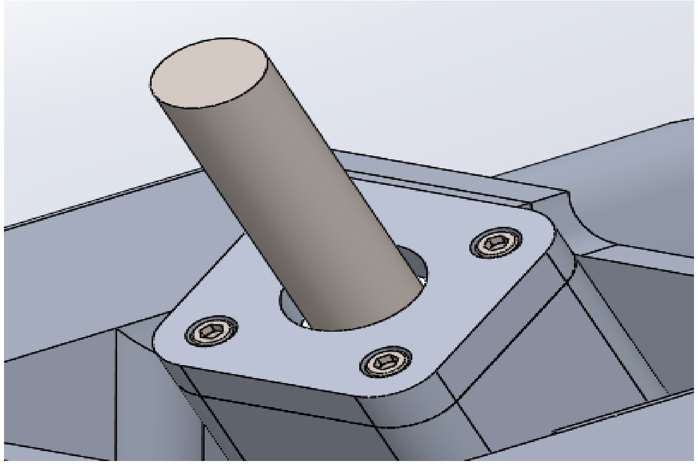

Figure 8. Power Screw

- The force gage spins freely around the end of the power screw allowing the bracket to remain in place. This gage will provide feedback on both the pushing and pulling force from the power screw.

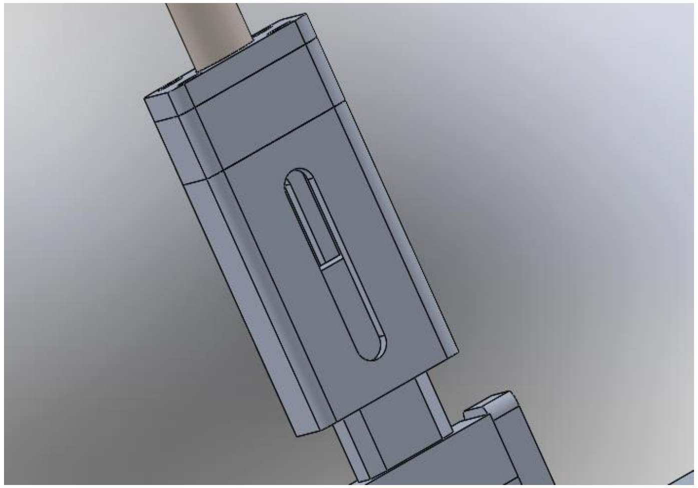

Figure 9. Force Gage

Design Description (4)

- The bracket holding component will mount to the bottom of the force gage and will lock in two positions (90° and 45°) to perform the pull test.

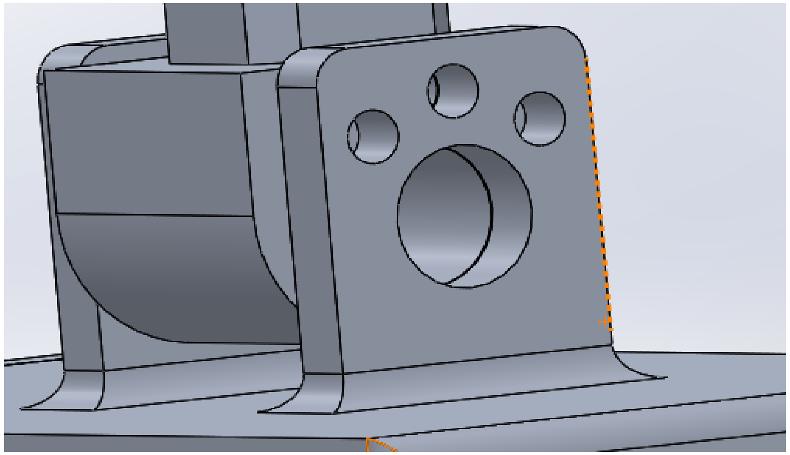

Figure 10. Bracket Holding Component

- The last component is the bracket holding mechanism itself. It will be adaptable to hold the different sized brackets provided by Northrop Grumman.

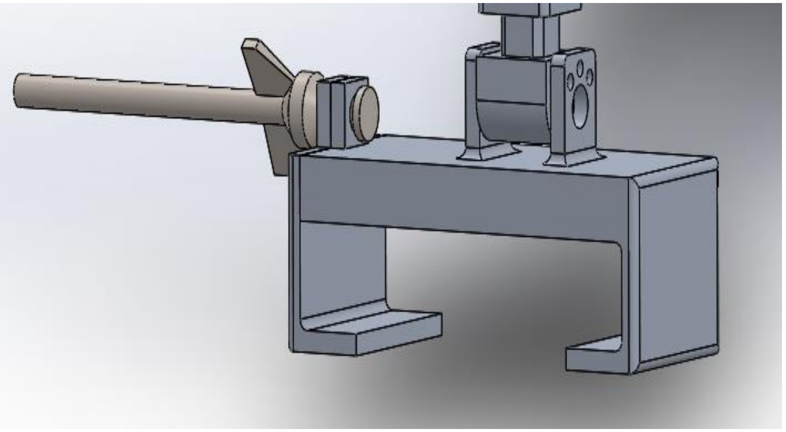

Figure 11. Bracket Holder

Design Requirements - Customer Requirements

- Customer Requirements
  - Electrostatic Discharge Compliant
  - Durability
  - Reliability
  - Adjustable Interfaces
  - Minimum 3.0 Factor of Safety

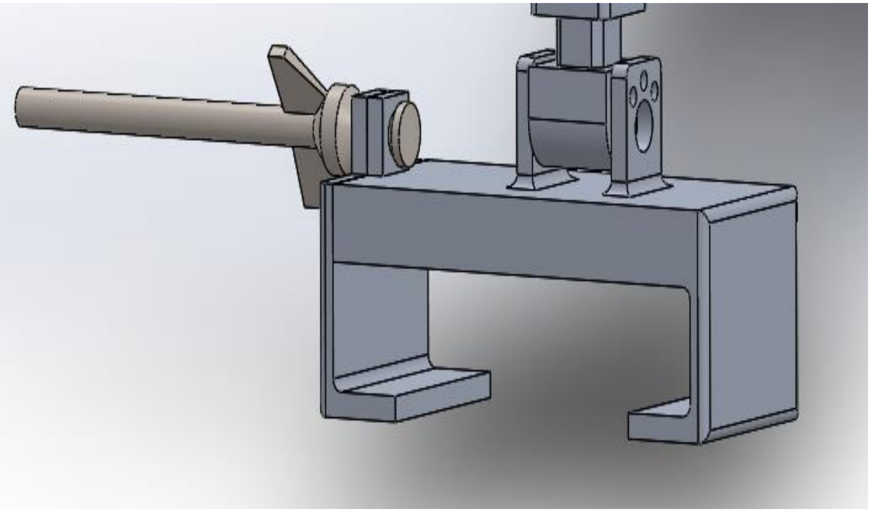

Figure 12. Bracket Holder

Design Requirements - Customer Requirements (2)

- Customer Requirements
  - 20 lbf Push Test
  - 50 lbf Pull Test
  - Six degrees of freedom in movement
  - Usable 4” - 36” inboard of ring
  - Transportability
  - Ease of operation
  - Support 10 lbs in locked position

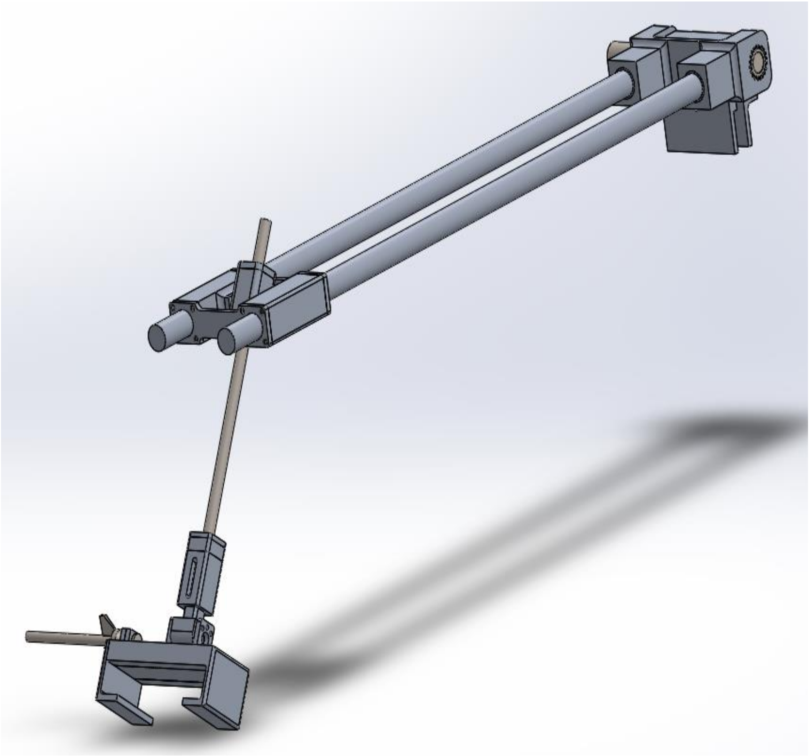

Figure 13. Current Design

Design Requirements - Clamping Force

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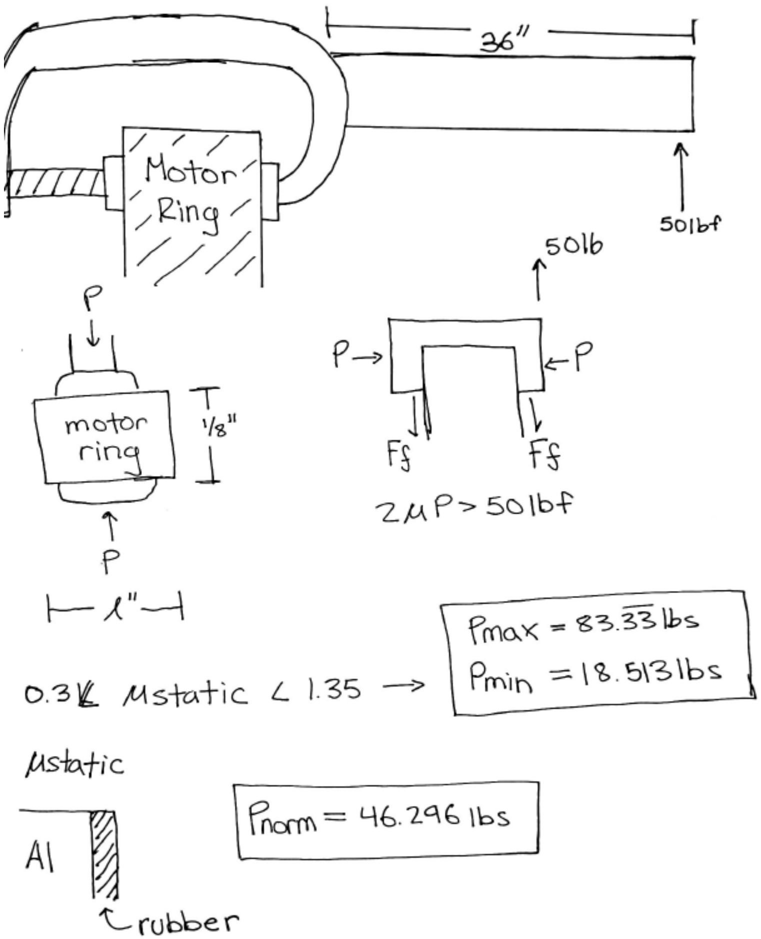

Figure 14. Clamping Force Hand Calculations

Design Requirements - Ring Moment Analyses

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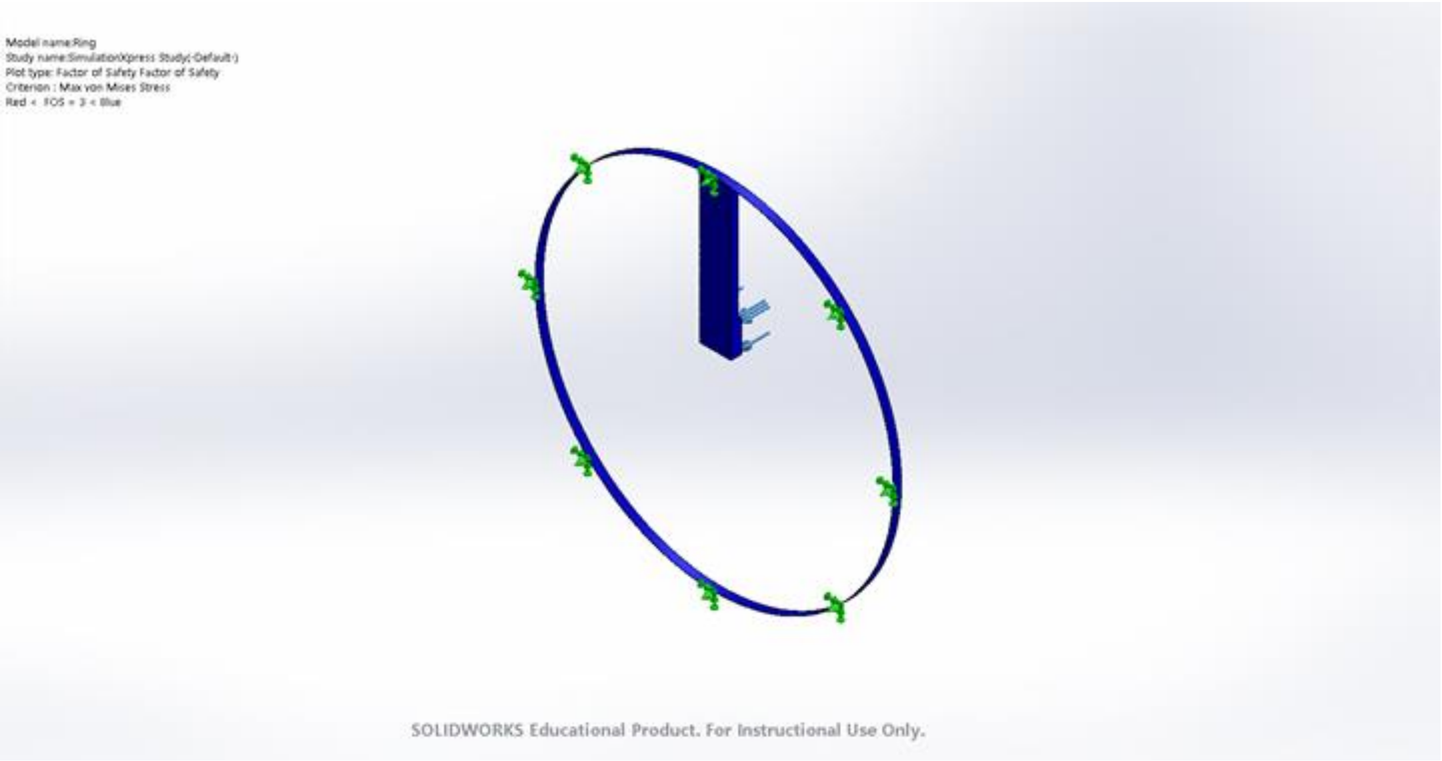

Figure 15. Finite Element Analysis of
Motor Ring

Design Requirements - Ring Moment Analyses

Stress distribution in the ring:

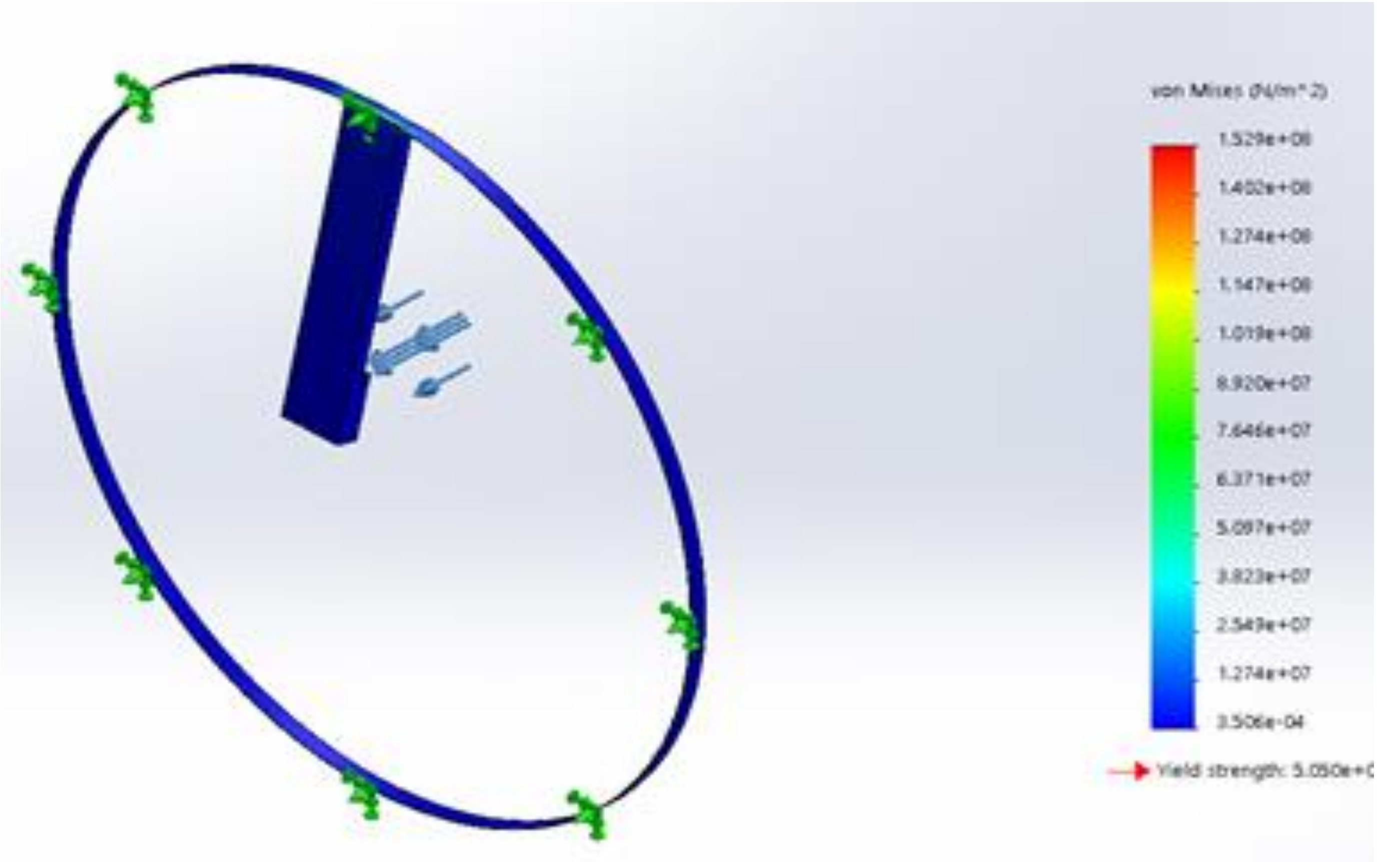

Figure 16. Ring Stress Distribution

Design Validation - FMEA (1)

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Table 1. Failure Modes and Effects Analysis

Part #	Function	Potential Failure Mode	Potential Effects for Failure	Severity (1-10)	Potential Cause(s) for Failure	Occurance (1-10)	Current Design Controls Test	Detection (1-10)	RPN (SxOxD)	Reccomended Action(s)
2	Mount to ring	Bending of the ring	Rocket Motor Ring will break	10	Overstressing the ring	5	Visual Indicator	8	400	Moment Ring Analytical Analysis
8		Clamp slips off	The device will be unsupported	8	Inefficient clamping force	3	Visual Indicator	8	192	Clamp Force Analysis
1	Translate the Brackets	Shear of center pivots in force block	Unable to apply axial force	7	Overstressing the pivots	1	Audible and Visual Indicators	6	42	Factor of Safety Analysis
4		Bending of the rails	Device is not able to translate toward the standoff location	7	Overstressing the rails	1	Visual Indicator	8	56	Deformation Test
6		Force Block does not slide			Friction force is too great	2	Audible and Visual Indicators	5	56	Bearing Analytical Analysis
12					Ball Bearing Breaks	1	Visual Indicator	8	56	
16		Rails are damaged			Ball bearing would cause cracks or surface damage	1	Visual Indicator	8	56	
3	Hold Bracket	Clamping screw breaks	Unable to clamp standoff bracket template	8	Stress fracture occurs from manufacturing or regular use	1	Visual Indicator	8	64	Mechanics of Materials Life Cycle Analysis
17					Thread shears off	2	Visual Indicator	8	128	Thread Material Properties Analysis
22	Apply axial force	Lead Screw breaks	Unable to apply axial force	8	Force induced deformation of screw	2	Audible and Visual Indicators	5	80	Lead Screw Stress analysis
7		Shaft Collar disconnects	Bracket Clamp disconnects from force block	7	Deformation wear of the securing screw	1	Visual Indicator	8	64	Deformation Analysis
13	Locking	Broken locks	Device can not be applied to specific location	7	Applied force exceeds lock material strength	5	Audible and Visual Indicators	5	175	Material Selection Analysis
11	Angle Bracket	Bracket Joint Pin Shear Failure	Inability to carry out the pull test	7	Applied axial force	6	Visual Indicator	8	336	
-	Does not carry electro static charge	Does not meet ESD Compliance	Damage electronic components	10	Material is non-conductive	1	ESD Test	1	10	Create ESD Testing Procedure
					Device does not have grounding capability	1		1	10	

Design Validation - FMEA (2)

- Critical Potential Failures
  - Bending the Circumferential Motor Ring
  - Device Losing Grip onto the Ring
  - Angled Bracket Joint Failure
- Proposed Design Solutions
  - Wider grip
  - Increase clamp force
  - Spline design to increase strength of locking mechanism
- Risk Trade-off Analysis
  - Increasing the complexity of the design adds more failure points
  - Proposed solutions increased the overall weight

Figure 17. Splined Shaft

Design Validation - ESD Compliance

Objective: To test the ESD Compliance of the device

Resources Required: Device prototype, multimeter, wires, ESD mat

Procedure:

Estimated Testing time - 15 minutes

1. Lay ESD mat flat on the table
2. Clamp device to the table and ensure that the device is placed on the mat
3. Use the multimeter to detect voltage between the device and the user.
4. If the multimeter reads 0V then the device is ESD Compliant

Design Validation - Clamping Test

Objective: To determine the optimal dimensions and materials of the clamp necessary to support the device without deforming the outer ring material

Resources Required: pressure sensor, strain gauge, multimeter, arduino, vise grips, wires, rubber, soldering kit, aluminum sheets

Procedure:

Estimated Testing time - 2 hours

1. Conduct mechanics of materials calculations on aluminum
2. Conduct analytical analysis on clamping force
3. Create a program(s) that will read pressure and strain
4. Attach pressure sensor and strain gauges to the aluminum sheet
5. Measure clamping force while the program runs
6. Compare data to analytical analysis

Design Validation - Rail Test

Objective: To determine the best material for the rails

Resources Required steel or aluminum rods, strain gauges, wires

Procedure:

Estimated Testing time - 3 hours

1. Apply strain gauges to both ends of the steel rod
2. Connect strain gauges to computer software
3. Apply axial forces to the end of the rod while the software is running
4. Compare data to analytical results
5. Repeat procedure for the aluminum rod

Design Validation - Axial Force Test

Objective: To verify that the device will pass the axial force tests under realistic conditions

Resources Required: fully functioning prototype, fish scale, bracket,

Procedure:

Estimated Testing time - 1 hour

1. Clamp device to simulated outer ring
2. Ensure ESD compliance
3. Position device for the pull test
4. Conduct pull test and record measurements

Schedule (1)

Fall Semester				
Final Report	Everyone	0%	11/6/19	11/15/19
Final BOM/CAD Package	Sage, Dakota	0%	10/14/19	11/20/19
PDR Presentation	Everyone	0%	10/28/19	11/18/19
Individual Analytical Report	Everyone	0%	10/14/19	11/28/19
Final Prototype	Everyone	0%	11/20/19	12/4/19
Website Check 2	Tyler, Brandon, Elaine	0%	11/6/19	12/9/19
Spring Semester				
Post Mortem	Everyone	0%	1/6/20	1/15/20
Self-Learning	Everyone	0%	1/6/20	1/24/20
Hardware Review	Everyone	0%	1/15/20	2/14/20
Website Check 3	Tyler, Brandon, Elaine	0%	2/1/20	2/21/20
Midpoint Presentation	Everyone	0%	2/17/20	3/4/20
Midpoint Report	Everyone	0%	2/17/20	3/6/20
Individual Analysis II	Everyone	0%	2/1/20	3/13/20
Final Product Finished & Device Summary	Everyone	0%	1/15/20	3/25/20
Drafts of Posters	Everyone	0%	3/1/20	4/1/20
Testing Proof	Everyone	0%	3/25/20	4/8/20
Final Poster and Operation Manual	Everyone	0%	4/1/20	4/15/20
Final Presentation (UGRADS)	Everyone	0%	4/1/20	4/24/20
Final Report and CAD Package	Everyone	0%	4/6/20	4/29/20
Website Check 4	Tyler, Brandon, Elaine	0%	4/29/20	5/4/20

Figure 18. Updated Schedule

Schedule (2)

- On schedule
- Distribution of the work
  - Sage
    - CAD Package
    - Ring Moment Analysis
    - Locking Methods
    - Manufacturing
  - Dakota
    - CAD Package
    - Rail Deflection Analysis
    - Rocket Motor Basics and Overview
    - Manufacturing
  - Brandon
    - Website Development
    - Power Screw Analysis
    - Axial Force Benchmarking
    - Testing

Schedule (3)

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- Tyler
  - Website Development
  - Bearing Analysis
  - ESD Compliance Research
  - Manufacturing
- Elaine
  - Website Development
  - Clamp Force Analysis
  - Clamping Literature Review
  - Testing

Budget (1)

Table 2. Bill of Materials Final Design

Part #	Part Name	Qty	Description	Functions	Material	Dimensions	Cost	Link to Cost estimate
1	Rail	2	41L40 Alloy Steel Round Rod 1/2" Diameter x 3' Length	Mode of translation for the Bracket Holder Mechanism (rail cart).	7075 Aluminum	1/2" x 1/2" x 3'	154.71	https://www.onlinemetals.com/en/search/results?q=aluminum+bar%3Aprice-asc%3AMaterial%3AAluminum%3AShape%3ARound%2BBar%3AAlloy%3A7075&checkbox=on&sort=price-asc#
2	36" Clamp	1	Adjustable Clamp 9133 Corner/Splicing Clamp	Secure the device to the motor ring.	6061 Aluminum	1.5" x 7.8" x 6"		
3	Bracket Holder	2	Custom made bracket holder, to be manufactured in machine shop.	Secure the bracket to the device.	6061 Aluminum	16" x 3" x 2"		
4	Rail Cart Rail Connectors	2	Custom made for fabrication at machine shop	Transports bracket holder across rail system.	6061 Aluminum	4" x 3" x 1"		
5	Spline Rail Connector	1	Custom made for fabrication at machine shop	Adjusts the angle of the device	6061 Aluminum	4" x 8"		
6	Spline Clamp Connector	1	Custom made for fabrication at a machine shop	Adjusts the angle of the device	6061 Aluminum	4" x 8"		
7	Shaft Collar	1	Custom made for fabrication at a machine shop	To prevent the bracket clamp from rotating while the handling arm is lowered onto the rocket dome	6061 Aluminum	1/2" x 4"	240.16	https://www.metalsdepot.com/aluminum-products/aluminum-square-bar
8	92 " Clamp	1	Adjustable Clamp 9133 Corner/Splicing Clamp	Secure the device to the motor ring.	6061 Aluminum	1.5" x 7.8" x 6"		
9	Bracket Clamp Screw	1	Custom made for fabrication at a machine shop	Tighten the bracket clamp around the bracket templates	6061 Aluminum	1/2" x 10"		
10	Spline Pin	1	Custom made for fabrication at a machine shop	Secure spline location in place	6061 Aluminum	1/2" x 2"		
11	Universal Joint Pin	1	Small metal rod	Lock joint in place	6061 Aluminum	1/4" x 2"		
12	Rail Cart Rotational Positioner	1	Custom made for fabrication at a machine shop	Allows team to move the location of the axial force on the rail cart	6061 Aluminum	4" x 4" x 8"		
13	Locking Rings	4	Circular Rubber stoppers that can clamp onto the metal rods	Lock the Force Block in place	Rubber	1/2" x 36"	2.99	https://www.rockler.com/non-skid-rubber-bumpers?sid=V9146?utm_source=google&utm_medium=cpc&utm_term=&utm_content=pla&utm_campaign=PL&gclid=EAIaIQobChMIz52AkMjW5QIVbxitBh39DQsrEAQYBSABEgJ_ePD_BwE

Budget (2)

Table 3. Bill of Materials Final Design

14	Design Screws	24	2" long screws	To assemble seperate parts together in the final assembly	Stainless Steel	#4 x 5/8"	8	https://www.amazon.com/Screws-Thread-Stainless-Self-Tapping-Quantity/dp/B01CRE76IK/ref=sr_1_2?keywords=%234+metal+screws&qid=1573076036&refinements=p_n_feature_nine_browse-bin%3A17426584011&rnid=17426558011&s=hi&sr=1-2
15	Hanging Scale	1	Klau Portable 150 kg / 300 lb Heavy Duty Crane Scale	Method of measuring force imparted onto bracket.	Stainless Steel	9.1" x 3.1" x 1.3"	23.99	https://www.amazon.com/Klau-Portable-Digital-Hanging-Backlight/dp/B07BHLR9DN/ref=sr_1_5?keywords=Hanging+Scale&qid=1570590867&s=industrial&sr=1-5-catcorr#customerReviews
16	Lubricant	1	Super Lube 51004 Synthetic Oil with PTFE, High Viscosity, 4 oz Bottle	Reduce friction of the rail system.	Synthetic PTFE Oil	2" x 2" x 6.5"	4.60	https://www.amazon.com/Super-Lube-51004-Synthetic-Viscosity/dp/B000UKUHXK/ref=sr_1_1?keywords=Synthetic+PTFE+Oil&qid=1570591173&s=industrial&sr=1-1
17	Fastener	3	Black Oxide Alloy Steel Socket Head Screw 1/4-20, 4" Long	Works with wing nut to secure bracket to the clamp.	Black Oxide Alloy Steel	3/8" x 4"	9.25	https://www.mcmaster.com/90044a131
18	Wing Nut	1	18-8 Stainless Steel Wing Nut 1/4"-20	Part of clamping mechanism to secure bracket to clamp.	Stainless Steel	31/64" x 1 1/8" x 5/8"	7.32	https://www.mcmaster.com/92001a321
19	Universal Joint	1	Custom made for fabrication at a machine shop	Universal joint to help position the bracket onto the rocket.	Vanadium Steel	6.5" x 5" x 1.1"	11.98	https://www.amazon.com/TEKTON-4964-Impact-Universal-3-Piece/dp/B000NPZ40I/ref=sr_1_21?keywords=Ball+and+Socket+Joint&qid=1570592342&sr=8-21
20	Drive Knob for Cart	1	Genuine Echo KNOB, FASTENER for driveshaft coupler assembly	Transmit force into the push/pull system.	Steel	4" x 1" x 2.5"	10.59	https://www.amazon.com/Echo-V299000160-Fastener-driveshaft-Assembly/dp/B07FDJSSFZ
21	Power Screw	1	Carbon Steel Acme Lead Screw Right Hand, 1/2"-10 Thread Size, 2 Feet Long	Translate force from the knob onto the bracket.	Steel	1/2" x 2'	5.93	https://www.mcmaster.com/98935a911
22	Lead Screw	1	Metal Screw	Drives the bracket toward the rocket dome	Stainless Steel	2' x 1/2"	178.36	https://www.mcmaster.com/lead-screws
Total Cost Estimate:							1391.83	

Budget (3)

- Expected Final Design Cost ≈ $1391.83
- Clamp Force Experiment ≈ $78.00
- Rail Test ≈ $154.25
- Travel ≈ $80.00
- Low Fidelity Prototype ≈ $13.00
- Prototype ≈ $200.00
- Remaining Budget ≈ 8,082.92
- Budget Uncertainties
  - Design Revisions
  - Machine Shop Costs
  - Component Failures

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References

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[1] G. Elert, “Coefficients of Friction for Rubber,” Coefficients of Friction for Rubber - The Physics Factbook. [Online]. Available: https://hypertextbook.com/facts/2005/rubber.shtml. [Accessed: 09-Oct-2019].

[2] “Friction and Friction Coefficients for various Materials,” Friction and Friction Coefficients for various Materials. [Online]. Available: https://www.engineeringtoolbox.com/friction-coefficients-d_778.html. [Accessed: 09-Oct-2019].

[3] R. C. Hibbeler, Mechanics of Materials. Harlow, England: Pearson, 2019.