NORTHERN ARIZONA UNIVERSITY
Mechanical Engineering

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Date: April 1, 2020

Subject: Implementation II Memo

The purpose of this memo is to discuss the Northrop Grumman Standoff Capstone Team's implementation of manufacturing the final prototype during weeks 7 to 11, address the standards, codes, and regulations relevant to the team's design, and to provide a risk analysis and mitigation to support design changes. Rocket motor integration activities at Northrop Grumman field sites currently bond standoffs, which are threaded mounting devices that are used for avionic electrical components, to rocket motor domes using adhesive and tape. These standoffs are mounted to metal brackets and are taped to the motor dome for 24 to 72 hours to allow the adhesive to cure. This method is unreliable and fails roughly 5% of the time which would cause an increase in man hours and money for reinstallation of these standoffs. As a result, the team was tasked to design, analyze, and build a prototype universal dome standoff bonding tool that can be mounted to the attached rings of variations of rockets that will hold standoff brackets while the adhesive cures. The NG Standoff Team has created the following design, as shown in Figure 1, as a solution to this problem.

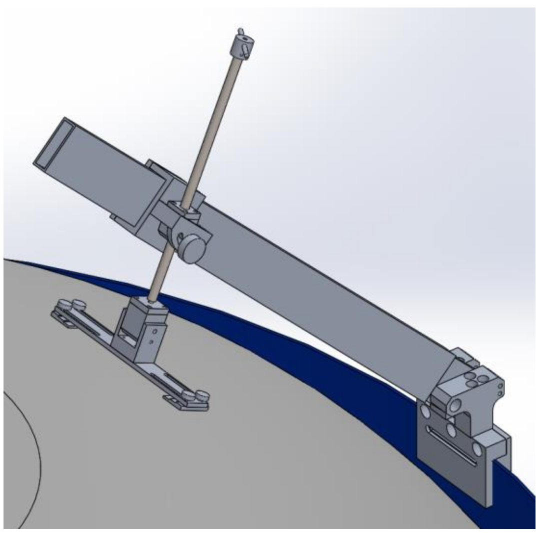

Figure 1. Final CAD Model

1 Implementation – Weeks 7-11

This section will go into detail on the steps taken to ensure that the device meets the engineering requirements and what types of manufacturing was implemented to complete the final product. The types of manufacturing methods used to create the final product include the CNC mill, vertical mill, and lathes located in the NAU Machine Shop. Design changes made to the device to ensure the functionality of the device have been justified through calculations and inspection.

1.1 Manufacturing

This section will focus on the manufacturing implemented for the production of the final product. This will include the machines utilized to fabricate the sub-assemblies as well as the methodologies utilized to ensure the quality of those parts. Previously, the team had strictly machined on the vertical mills and lathes that are located in the 98C machine shop. After the preliminary design presentation at the Northrop Grumman headquarters, the senior engineers working there informed the team that the assembly of the design should minimize the usage of the CNC parts to reduce cost and complexity of the design. However, due to attempting to complete the final product primarily before spring break, the CNC machine located in the 98C machine shop has been utilized due to its ability to provide highly accurate parts in less than an hour as opposed to about a week it would take the design team to machine on the vertical mills.

In the previous report, the design team had received an engineering requirement change which resulted in a change in the overall design. Since those changes were implemented, the team has been primarily focused on machining the entirety of the design. The team started with the rail cart as seen in Figure 2 below.

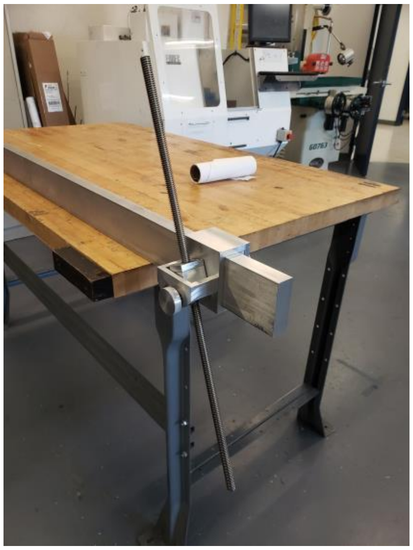

Figure 2. Manufactured Rail Cart

All of the design changes, discussed in the previous report, were implemented into the manufacturing of the rail cart system in Figure 2. The only aspect of the design that is displayed in Figure 2 that is not currently being used in the final product is the rectangular rail. The rail is solid in Figure 2, however it is actually hollow in the final design as seen in Figure 3 below.

Figure 3. Final Product

Seen in Figure 3, many of the other components of the design are completed. The rail system is now a hollow tube that is 3”x1”x1/8” thick. The rail cart slides onto the rail and is able to lock in place with a pressure plate that utilizes a capped screw which was created on the lathe. Two holes are drilled into the other end of the rail to lock the rails to the angling mechanism. The components on the left side of Figure 3 are now fully manufactured and can be seen as CAD parts in Figure 4 below.

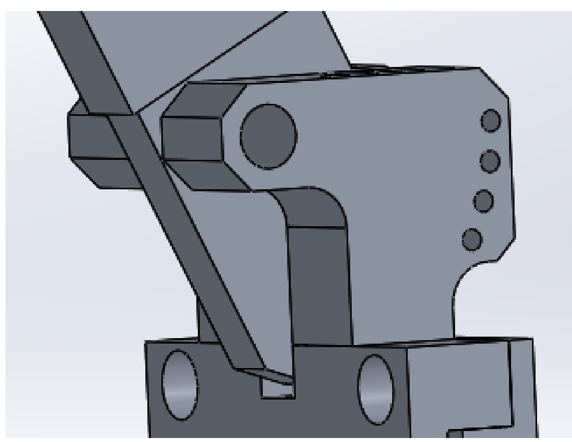

Figure 4. Angling Mechanism

The rail mount is inserted into the rail which locks the rail in place with two ¼” pins. The device is then able to angle as needed with 5 positioning holes placed 9 degrees offset from one another. Two p-pieces are then able to lock the angle with two pins that are inserted through the p-pieces and the rail mount. The ¾” hole works as the rotation axle while the smaller ¼” holes allow for the device to angle as needed and locked in place with a pin. There are four holes on the p-pieces to allow for additional angling positions for operators as needed. The p-pieces are then bolted onto the clamping mechanism that can be seen clearer in Figure 5 below.

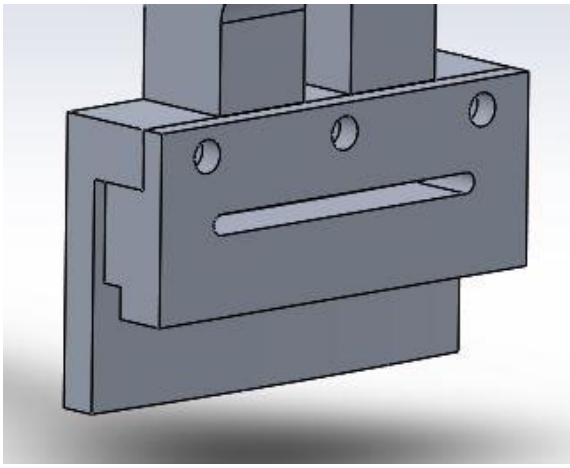

Figure 5. Clamping Mechanism

The inner and outer clamp pieces were created with a curvature that would match the 92" diameter rocket motor ring of the Castor 30XL which were created using the CNC to get accurate dimensions and proper fitment. The team also created a mock motor ring to rig the device to for testing procedures. The mock ring and clamp can be seen together in Figure 6 below.

Figure 6. Mock Motor Ring and Clamp

The mock ring was also created using the CNC to allow for the correct curvature of the Castor 30XL. The holes however were created using a 3D printed hole template that fit the dimensions and curvature of the Castor 30XL. This was built as the CNC in the machine shop is a 3-axis and wouldn't be able to rotate the piece to drill the holes in the correct placements. The team then drilled holes into the mock ring as seen in Figure 7.

Figure 7. 3D Hole Template Set-Up

In total, the final product is 95% finished from the CAD package. Due to the unforeseen events of COVID-19, the team is unable to perform any further manufacturing in the machine shop. However, work orders for the remaining parts have been submitted and completed by the 98C manufacturing shop. Due to the limited time the team can finalize the manufacturing of the parts, there will be some actions that will not be performed by the team. The team will not manufacture any of the pull test functions of the device as this was an optional manufacturing goal set by the client, instead focusing finalizing the push test for the final device. The torque wrench which was to be purchased for performing accurate pull and push tests on the device will not be completed and will instead be discussed in the final report in detail so Northrop Grumman will understand what was planned. The team will also not apply teflon coatings on various parts to reduce friction and load distribution throughout the design. The only part that still needs to be completed for the push test is the thumb screws shown in Figure 8 below.

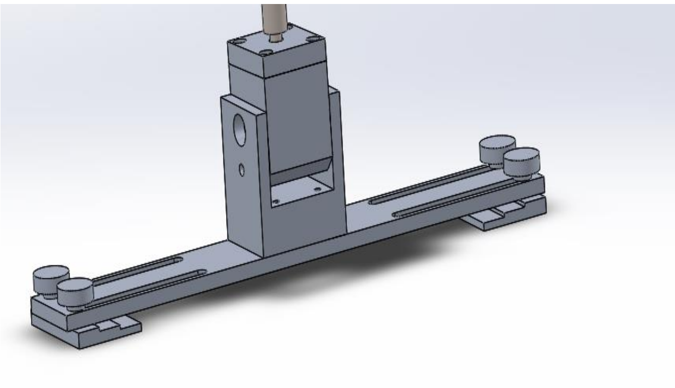

Figure 8. Bracket Clamp

The four thumb screws shown in Figure 8 are not and will not be completed by the end of the semester. Instead, an alternate design solution will be discussed. This could possibly be done with parts available at home depot, or just with an explanation on the final report at the end of the semester. In total, the entire design was completed using the mill and lathe machines available in the machine shop excluding the clamping mechanism which used the CNC to create the curvature present on the rocket motor ring.

1.2 Design Changes -Weeks 7-11

Through week 7-11, the entirety of the final design was manufactured. Through these weeks, no changes in the final design were made. The only edit that has been discussed was the inclusion of washers throughout the design. This would allow the team to fix tolerance problems the device was having on some subsystems while also allowing less contact area between various parts made out of aluminum 6061. Otherwise, the CAD designs that the team made in the previous report held true to this report with no changes worth mentioning.

2 Standards, Codes, and Regulations

The purpose of this section is to discuss the standards and regulations that are relevant to the project and how they would be applied in industry. The function of standards and regulations within manufacturing and design processes is to ensure safety, reliability, and efficiency. Most standards are promoted and maintained by engineering societies and regulatory agencies such as the Institute of Electrical and Electronics Engineers (IEEE) or the American Society of Mechanical Engineers (ASME) [3]. The codes and standards included within this section were procured from the ASME standards catalog. The standards that were chosen for this section include ASME Y14.5-2009 Dimensioning and Tolerancing, B30.2-2009 Overhead and Gantry, B18.29.1-2010 Helical Coil Thread Inserts, B5.48-1977 Ball Screws, B1.5-1997 Acme Screw Threads, P30.1-2014 Planning for Load Handling Activities, B107.3000-210 Torque Instruments, and B46.1-2009 Surface Texture.

2.1 Standards applied to project

This section will go over each individual standard that may be applied to this project in detail. The codes that were considered for the final design of the device were found using the American Society for Mechanical Engineers (ASME) codes and standards database. The codes and standards that were considered for this project can be referred to below in table 1.

Table 1. Codes and Standards

Standard Number or Code	**Title of Standard**	**Application to the Project**
ASME Y14.5-2009	Dimensioning and Tolerancing	This standard could help facilitate the creation of engineering drawings that effectively communicate design intent.
ASME B30.2-2009	Overhead and Cantilevered Gantry Cranes	Applies the operation and safety procedures associated with cantilevered gantry cranes which can be related to our product.
ASME B18.29.1 - 2010	Helical Coil Screw Thread Inserts--Free Running and Screw Locking	This standard relates to our project by providing information on threaded hole helical screw inserts which are included within the power screw assembly.

ASME B1.5 - 1997	Acme Screw Threads	This resource gives information related to acme screw threads which is the thread form which will be used for the power screw.
ASME P30.1 - 2014	Planning for Load Handling Activities	This standard establishes planning considerations and practices that apply to Load Handling Equipment (LHE), other associated equipment and activities when moving loads vertically or horizontally.
ASME B107.3000 - 2010	Torque Instruments	This Standard provides performance and safety requirements for manually operated torque instruments, commonly used for mechanical measurement of torque for control of the tightness of threaded fasteners.
ASME B46.1 - 2009	Surface Texture	This Standard is concerned with the geometric irregularities of surfaces. It defines surface texture and its constituents: roughness, waviness, and lay.

As seen in table 1 above, the first standard to be considered for this project was related to the aspect of dimensioning and tolerancing with respect to engineering drawings. The resource from which this standard originated from the AMSE and is denoted as Y.14.5-2009. This standard will help facilitate the creation and review of the engineering drawings in order to ensure their readability and design intent. The project includes the creation of an in depth CAD package which in order to be effectively communicated to the client must be transferred into drawing format. This standard will affect the project by influencing this process and changing the methods of dimensioning and tolerancing of these engineering drawings.

The next standard to be considered will be the ASME B30.2-2009 Overhead and Gantry standard which relates to the cantilevered gantry design of the device. This standard applies to the installation, operation, and maintenance of hand-operated gantry cranes. While the device is not a gantry crane it does share similarities, which include the bracket delivery system and the overhead rail design. This standard also applies to special circumstances such as non-vertical force delivery and guided loads which are consistent with the current design. This standard will help the project by allowing the team to comply with regulations of the industry while maintaining operational efficiency and safety.

The current design utilizes a power screw system to deliver pull and push forces at the appropriate angles to the brackets. This standard is denoted as ASME B18.29.1-2010 within the table above. This assembly will include components such as helical coil screws (lead screws) and screw locking mechanisms. This standard will help with the facilitation of the design of this assembly by providing information on the proper selection of Screw thread insert (STI) taps, installation, and dimensional data. This standard could influence the team's decision on the power screw that is chosen for the device as it would adhere to standards used in industry.

The thread form of the power screw is an important consideration to be had for the design of the rail cart assembly. This standard is denoted as ASME B1.5-1997. This standard will give information on the applications and general limits and tolerances of acme threaded screws. Due to the prolific occurrence of acme threaded power screws within force delivery systems, the team will heavily consider its use within the device. This resource will provide information on the three classes of general purpose acme threads as well as their alignment, clearances, major and minor diameters, and appropriate alignment. This will influence the team's discussion of the correct power screw to be utilized within the design due to the information provided within the standard.

The nature of the device as it was originally envisioned was to act as a force applicator to achieve specific conditions to aid in the curing of the adhesive on the bracket templates. There is a standard within the ASME database which focuses on load handling activities which is denoted as ASME P30.1-2014 which focuses on the preparations and practices which apply to load handling equipment such as our device. This resource will aid in the completion of the project by providing information regarding the device which can be included in the operation manual which will be created in the coming weeks. Other than benefiting the creation of the operation manual, this standard will also ensure that our device adheres to any regulations defined by this standard.

For the force application of the device, a torque instrument will be used to transfer axial loads through the power screw assembly onto the bracket template. A standard that can be applied to this procedure would be the ASME B107.3000-2010 standard which focuses on torque instruments and any performance or safety requirements that may be associated with them. For our device, the input torques required to achieve the expected axials loads were very minimal in comparison to the critical torque of the power screw. Other topics that this standard applies to would be mechanical measurement of torque loads which is a procedure that will be used on the power screw assembly.

The final standard included on the list would apply to the surface texture of the device which is significant to its proper operation. This standard is denoted as ASME B46.1-2009 and deals with geometric irregularities regarding surfaces. This applies to our device because the rail cart assembly must glide over the rails with little friction to allow for ease of operation by technicians. This standard could help identify surface irregularities which may affect the interfaces between components of the assembly. Using the standards and codes presented in this section, the team will be more knowledgeable in future endeavors on the applications and importance of codes and standards in industry.

3 Risk Analysis and Mitigation

This section discusses how the team mitigated potential failures in the system based on the design decisions. The first part of this section identifies potential failures identified in the fall semester and the second part addresses the design changes in order to mitigate the risks.

3.1 Potential Failures Identified Fall Semester

This section will focus on the potential failures identified during the fall semester. A Failure Mode and Effects Analysis (FMEA), as provided in Appendix A, was used to determine and quantify top potential failures in the team's design. The final product has seven sub-functions which include mounting to the ring, translating the brackets, holding the bracket, applying axial force, locking, angle bracket, and ESD compliance. These sub-functions were used as the possible function failures for the project. By evaluating the severity of the potential effects for failure, and the occurrence and detection of the potential causes for failure, the team was able to identify the top ten potential failures based on the risk priority number (RPN) as shown in Table 2. As shown in Table 2, ten critical failures were found based on their RPN values and provides the actions that the team should take to reduce the likelihood of these failures. The team had identified that the top ten potential failures include: bending of the ring, bracket joint pin shear failure, spline mounting screw shears, clamp slips off, force block slides during axial force test, unable to hold standoff bracket, lead screw breaks, bending of the rails, force block does not slide, and the fish scale does not read correctly.

Table 2. Top 10 Potential Failures FMEA

Product Name	Standoff Bonding Tool	Development Team	18F19				FMEA Number	3			
							Date	11/14/19			
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	
11	Angle Bracket	Bracket Joint Pin Shear Failure	Inability to carry out the pull test	7	Applied axial force	6	Visual Indicator	8	336	Material Selection Analysis	
5, 6	Angle Bracket	Spline Mounting Screw Shears	Device will be unsupported	8	Applied axial force	6	Audibe and Visual Indicators	5	240	Spline Shaft Gear Analysis	
2	Mount to ring	Clamp slips off	The device will be unsupported	8	Inefficient clamping force	3	Visual Indicator	8	192	Clamp force analysis	
4, 13	Locking	Force block slides during axial force tests	Device cannot be applied to a specific location	7	Applied force exceeds lock capacity	5	Audibe and Visual Indicators	5	175	Material Selection Analysis	
3	Bracket slips off	Unable to hold standoff bracket	Unable to hold standoff bracket	7	Incefficent clamping force	3	Visual Indicator	8	168	Clamp force analysis	
22	Apply Axial Force	Lead Screw Breaks	Unable to apply axial force	8	Force induced deformation of screw	3	Audibe and Visual Indicators	5	120	Lead Screw Stress analysis	
1	Translate the brackets	Bending of the rails	Device is not able to translate toward the standoff location	7	Overstressing the pivots	2	Visual Indicator	8	112	Deformation Test	
4	Translate the brackets	Force Block does not slide	Device is not able to translate toward the standoff location	7	Ball Bearing Breaks	2	Visual Indicator	8	112	Bearing Analytical Analysis	
15	Apply Axial Force	Fish Scale does not read correctly	Force will not display to operator	5	Spring does not function with the device	2	Visual Indicator	8	80	Spring Analysis	

3.1.1 Potential Critical Failure 1: Bending of the Ring

The standoff mounting arm will be attached to the rocket motor dome in order to hold the standoff brackets in place while the adhesive cures. However as seen in Figures 9 and 10, the standoff device will only have .2” x 1.25” to attach to the Castor 30 XL and .205” x 1.375” to clamp onto the Orion 50 rocket motor rings.

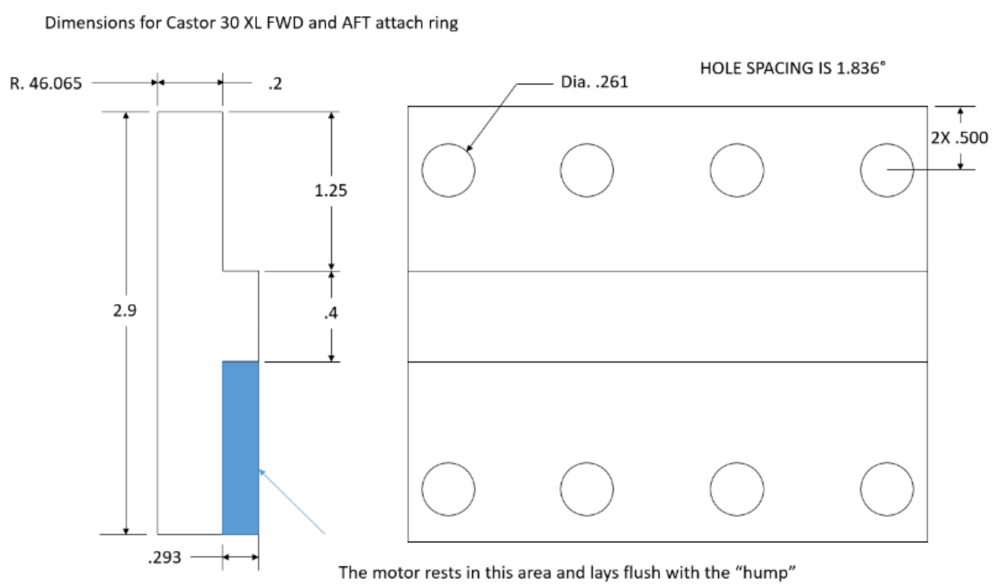

Figure 9. Castor 30XL FWD and AFT attach ring Dimensions

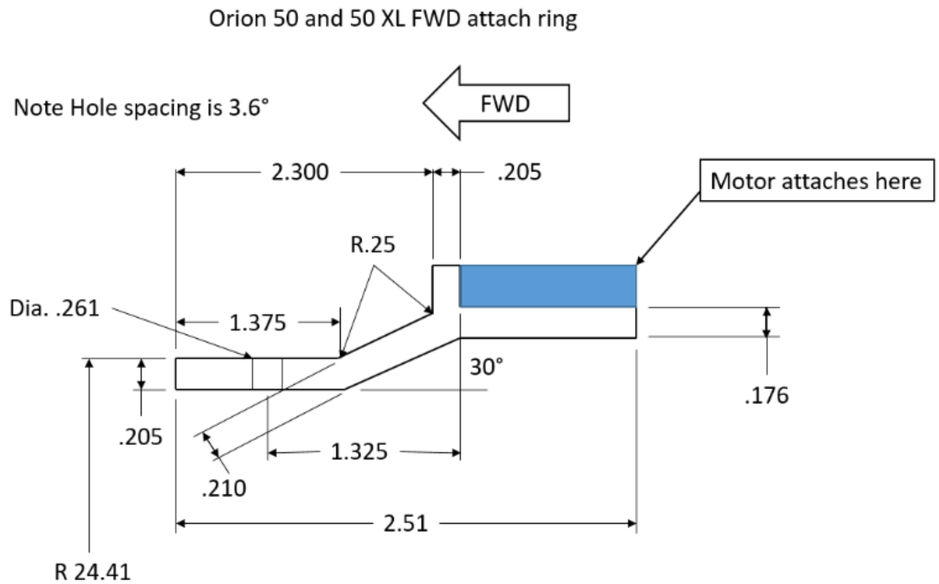

Figure 10. Orion 50 and 50XL FWD attach ring Dimensions

Due to the distance that the axial force will be applied from the rocket motor ring (4-36" inboard), a large moment will be applied to the thin rocket motor ring. Despite being made of Aluminum 7075, the moment could cause bending of the rocket motor ring. If this were to occur, the rocket motor ring would need to be replaced, which could delay usage and drain resources. This is the absolute worst case scenario for the design team and is deemed the most severe of potential failures of the device. That is why this potential failure has the highest RPN values shown in Table 2. To mitigate this failure from occurring, an analysis will be performed which considers the longest moment arm and maximum force to examine the worst case scenario for each ring geometry. The calculations will be performed with Solidworks FEA to visualize the stress concentrations and will be backed with hand calculations. These hand calculations will be used to ensure that the software is providing a reasonable output. The result of this analysis will allow the team to determine the necessary clamp width for load distribution while also ensuring that the maximum moment can be tolerated in all cases.

3.1.2 Potential Critical Failure 2: Bracket Joint Pin Shear Failure

In order to meet the 45 degree pull test requirement specified by Northrop Grumman, the bracket holding component that will mount to the bottom of the force gage will lock in two positions (90° and 45°). In order to lock the bracket in place, a pin will be used to lock between the two different positions. Due to the axial forces that will be performed on the device, a large amount of stress will be applied to the locking pin which could result in shear failure. To mitigate this from occurring, a material selection analysis will be performed to determine the best material and geometry for the pin. In the future, a further analytical analysis may be performed in order to verify that the pin will not suffer a catastrophic failure.

3.1.3 Potential Critical Failure 3: Spline Mounting Screw Shears

As described in the previous preliminary report and section 5 of this report, one of the primary designs that has been considered by the design team is a sliding rail system. The rail system will have two rails that will allow a force block to slide into position to apply the axial forces needed. Originally, the rail system was to move strictly horizontal across the rocket motor dome. However, the Castor 30 series' dome protrudes over the rocket motor ring plane shown in Figure 11 below.

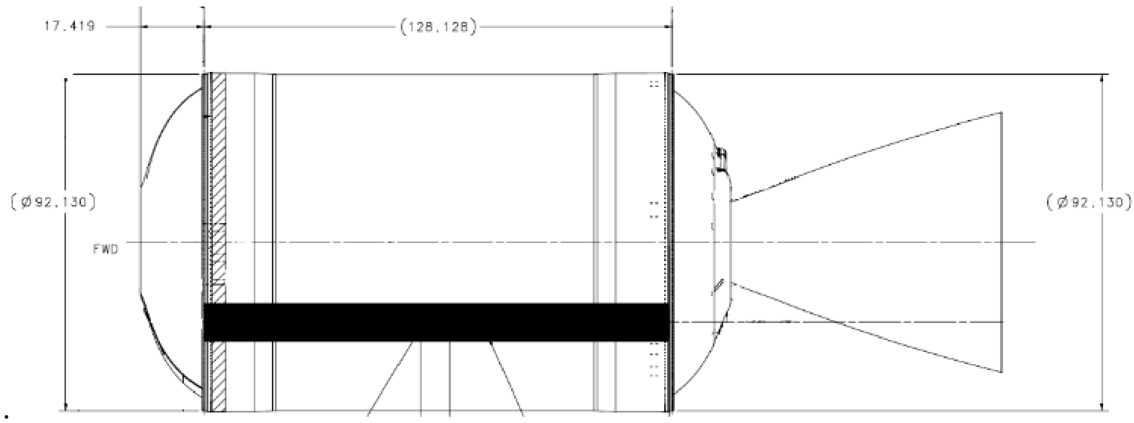

Figure 11. Castor 30 Series Drawing

Due to the dome protruding over the normal plane of the rocket motor ring, the device must be able to angle vertically to account for the profile of the dome. A splined shaft design was made to allow the device to angle the mounting arm vertically. This spline design can be seen in Figure 12 below.

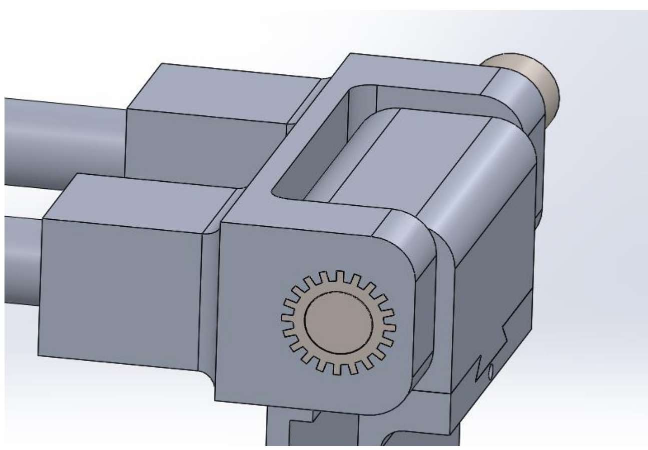
Figure 12. Spline Shaft Design

Due to the teeth of the spline, the axial force could cause damage to the design. This would make the design not lock in a vertical position. In order to prevent this from occurring, an in depth analytical analysis will be performed spring semester. This analysis will focus on mechanics of materials topics including gear teeth, and rotational locations. This analysis will allow the design team to safely select the amount of teeth the spline shaft should have. If the applied axial force is within the 3.0 factor of safety minimum described in the project description section, and whether the spline will be a suitable design for the project team to use. These analyses will be conducted with hand calculations along with an excel sheet that allows the user to change various design variables such as spline teeth and angle.

3.1.4 Potential Critical Failure 4: Rocket Ring Clamp Slips Off

In order to mount onto the rocket motor ring, a clamping device must be designed to secure the device in place. This will allow the mounting arm to hold in a locked position while the axial forces are applied.

However, as the axial force is applied, the grip the mounting arm has on the rocket motor ring could loosen and cause the clamp to slip off the locked position. This failure could result in the device, the rocket motor dome, or an operator to be damaged or hurt. In order to prevent this from occurring, a clamping analytical analysis will be made. The primary goal of this analysis, as described in section 3.2, is to solve the exact load distribution along the ring (how much clamp area should be used to disperse the force along the ring) and the necessary clamping force needed to support the design. Solid mechanics hand-calculations, Solidworks FEA, and physical experiments will be conducted by the team. The experiment will be conducted for ME495 lab with the primary purpose of solving the optimal load distribution along the ring which will utilize pressure sensors and strain gauges. Results from the solid mechanics hand-calculations and the experiment will be used to redesign the vise grip to the dimensions that best suit the team's current design along with a Solidworks FEA calculation to prove that the clamping mechanism is feasible.

3.1.5 Potential Critical Failure 5: Force Block Slides due to Axial Force

Described in section 4.1.3, a rail system has been a possible solution for this project. This design will allow the translation of the bracket to be easily performed, while eliminating the use of an articulating arms multiple locking positions. In order to secure the force block in place, a locking mechanism must be designed to secure the location of the axial force. As of now, four rail locking rings will be designed to lock the force block on each rail in each location. With the axial force that will be performed by the device, it is possible for these locking mechanisms to fail. This would cause the force block to slide during the axial force which would make the device not have the ability to be locked into place. In order to mitigate this from occurring, a material analysis will be made on the locking mechanism to verify that the lock will not break and perform as needed. Once this is performed, another FMEA will be made to determine the likelihood of this occurring and if the RPN is still relatively high another analytical analysis of the frictional coefficient and clamping forces will be made to determine if this design should be continued with in the final design or if another option should be made.

3.1.6 Potential Critical Failure 6: Bracket Clamp Slips Off

As the project description states, the standoff mounting device must firmly hold the standoff template brackets in place while the adhesive cures. In order to do this, a clamping device was designed by the project team to hold the brackets in place while the axial force testing is conducted. It is possible that while the axial force is done, the bracket clamp could slip off the bracket template. This would prevent the mounting arm from securing the brackets in place as the customer required. This is similar to the rocket ring clamp slipping off as stated in section 4.1.4, however less likely since a lesser moment will be applied to the bracket clamp. However in order to verify that this will not occur, the testing stated in section 3.2 will be referenced along with a lesser clamping force calculation that will be performed by the design team in the spring semester. An FEA analysis will be done with the designed clamp and bracket templates to verify that the hand calculations that were made were correct.

3.1.7 Potential Critical Failure 7: Lead Screw Breaks

In order to translate the axial forces required for the design, a lead screw is required. This power screw design will allow the operator to apply a force with a drive nut, and then keep that force locked in place by the thread position. Failure could occur from the axial force applied on the device which could cause the lead screw to deform. This would make the device unable to apply an axial force to the bracket templates, which in turn caused the device to be inoperable. In order to mitigate this failure from occurring, a power screw analytical analysis will be performed. This analysis will involve determining the right conditions for the screw to be self-locking as well as its ability to provide adequate push and pull force to meet the client's requirements. The objective of this analysis is to find which elements of the power screw directly benefit the project such as the thread form, pitch, efficiency, cost to procure, cost of maintenance and operability. The project could benefit from this analysis by the discovery of the weight incurred by the screw, as well as its ability to apply axial loads to the bracket holder at multiple angles. The length and width of the power screw will also be considered for this evaluation and help finalize the design of the rail cart sub-system.

3.1.8 Potential Critical Failure 8: Bending of the Rails

As described in section 4.1.5, a rail system has been considered by the design team, which would allow the translation of the bracket to be easily performed while eliminating the use of articulating arms with multiple locking positions. The drawback of this design, however, is the fact that a deflection or bend in the rails could occur during testing due to the axial forces being applied onto the rocket motor ring. This could cause the device to be unable to translate the brackets to the appropriate location thus making the device inoperable. In order to mitigate this failure from occurring, a rail deflection calculation will be performed as described in section 3.3. The project description requires a 20 lb push and 50 lb pull test conducted between 4" and 36" inward of the rocket motor ring. At the maximum 36", the 50 lb pull test will generate a large bending moment and shear force within the rails. This analysis will cover the force and bending analysis within the rails and will analyze different materials to predict actual movement and reactions within the rails. These tests will be conducted with hand calculations and backed by MATLAB code and Solidworks FEA analysis to verify the values. These calculations will greatly aid the team in determining what materials are used for the design and how the device will theoretically perform.

3.1.9 Potential Critical Failure 9: Force Block does not Slide

As described in the previous subsection, the rail system considered by the design team will allow operators to slide the force block into position much easier than that of an articulating arm. For this to work appropriately, the force block must be able to slide easily into the correct position. In order to do this, bearings will be installed into the force block to allow operators to easily position the device. As with many other failures described in this section, the axial force performed by the device could result in the bearings to break resulting in the force block not sliding into the correct position. This would cause the device to not meet the translating the bracket sub function. Since the bearings will be at a location where the max force will be applied to the device, it was determined an analysis should be conducted to determine if this can be applied to the final design. This analysis will compare bearing designs to determine: methods to applying bearings to the device, if the bearings would fail under the max load, what materials should be used for the bearings, and if the bearings will cause damage to the rail system under the load of the device. After these analyses it will be determined if bearings could be used on the device, and if so which ones. This analysis will be conducted with hand-calculations as well as MATLAB or an Excel worksheet to verify the values are correct, as well as to create visual aids on the force analysis of the bearings materials.

3.1.10 Potential Critical Failure 10: Fish Scale does not Read Correctly

Currently at Northrop Grumman to test that the brackets are placed in position and will not come off, a fish scale is used to pull the brackets with 50lbs of force to verify that the brackets are in place. The client has asked that the design team implement this into the final design. In order to do this, a fish scale will be placed on the mounting arm with a spring with a given k value. This force scale can be seen in Figure 13 below.

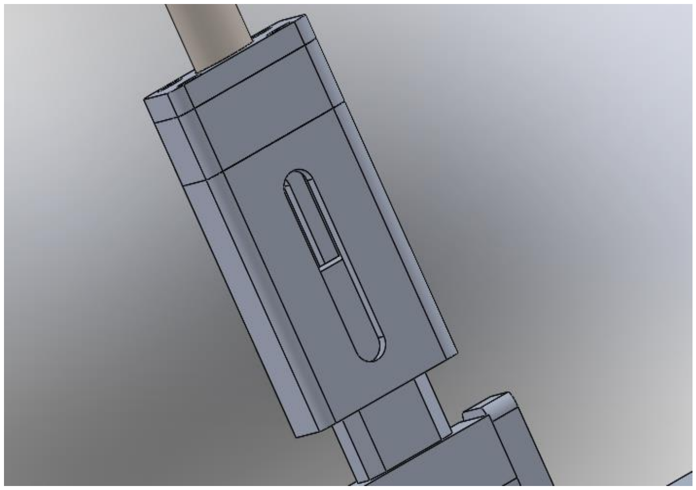

Figure 13. Force Scale Design

Currently the force scale will use the spring implemented inside to allow the reader to see exactly how much force is being applied to the brackets. The problem with this design is that if the spring used becomes deformed due to the axial force and regular use, the force reading would become inaccurate. This will make the operators possible apply a different force to the rocket dome either making the bracket become not secured onto the rocket motor dome, or damaging the rocket motor dome. In order to verify that this design will not have this failure occur, an analytical analysis of springs that could be used in the design will be performed. This analysis will take various spring lengths, coil counts, and materials placed against one another to see which spring would function the best in the final design. For this analysis, an excel sheet will be made to allow the user to change various design variables to verify which spring is the most applicable to the final design.

3.2 Risk Mitigation

The purpose of this section is to outline multiple potential concerns with the initial design, and how these concerns were mitigated with design changes and considerations. Below are examples of specific design elements that were altered due to the risk of potential failures, all of which attempt to improve on the usability of the design as well.

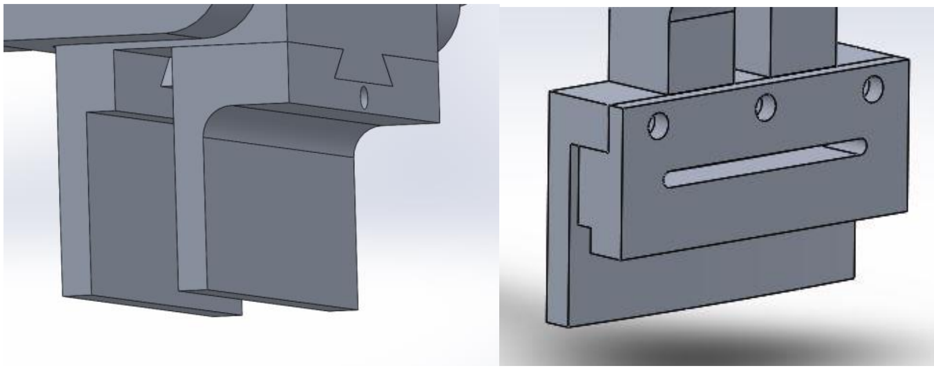

Figure 14. Previous Ring Clamp (Left) and New Design (Right)

When a load is applied to the end of the extended mounting arm, the reaction forces are translated to the rocket motor ring via the ring clamp. The initial design for this clamp, which is shown on the left side of Figure 14, included interchangeable jaws, which could interact with the different ring geometries. However, this design was complicated, difficult to physically handle, and did not allow for the mount to pass through the holes in the motor ring. The clamping mechanism also relied on the use of a dovetail, which would have added significant machining time.

The updated design, which can be seen on the right in Figure 14 replaces the previous design with entirely interchangeable clamp halves to operate with each specific motor ring. This simplifies the design, creating a system with less uncertainty that is both easier to machine and handle. The new design also allows for the ring clamp to accommodate fasteners that will pass through the holes in the rocket motor ring, eliminating any risk of the clamp sliding off of the ring during operation. A slot was utilized in this design change to allow for access to the holes without limiting the positioning of the clamp about the ring.

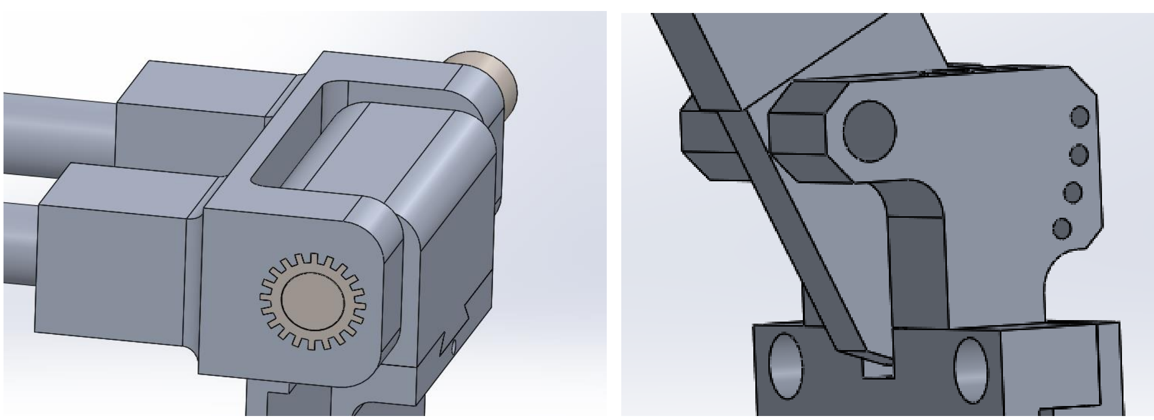

Figure 15. Previous Ring Angler (Left) and New Design (Right)

The initial design that would allow the system to change the angle of the rail relative to the ring is pictured in Figure 15. This concept relied on a spline shaft that could support the load induced about the ring during operation, while also allowing for the rail angle to be set at various positions. This design provided challenges in that the arm would not be secure while changing the angle, it would be difficult to machine, and that the moment about the splines would be large due to the small distance from the center of rotation. The large induced moment had the potential to shear the splines from the shaft, which could cause damage to the rocket motor itself.

The new iteration of this design is also shown in Figure 15, which utilizes pins to set the angle of the rail system. This provides a much longer moment arm to counterbalance the moment induced by loading the system. In turn, the factor of safety for the system is greatly increased. The design is now stable while changing angles as well, which improves the usability of the system. Machining the complicated splines is also no longer necessary, reducing manufacturing time significantly.

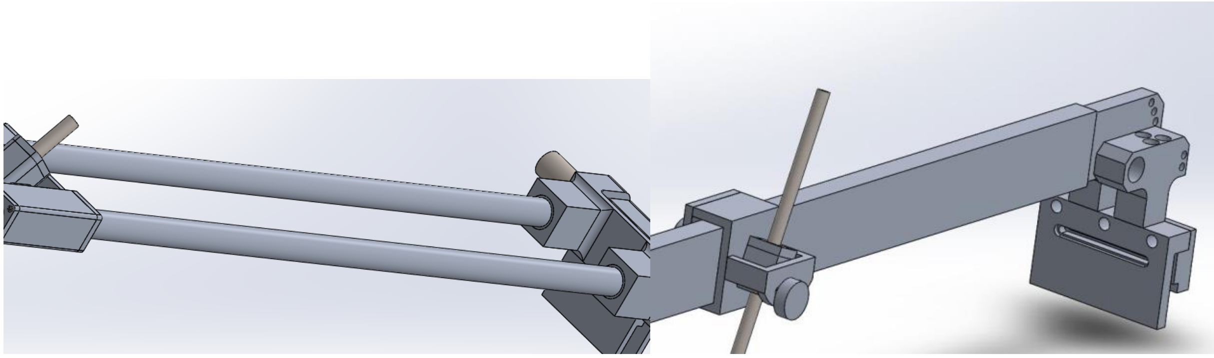

Figure 16. Previous Rail System (Left) and New Design (Right)

The original rail system was designed to translate the lead screw to different portions of the rocket motor dome. This design was simple and lightweight, but would have been cause for relatively high deflections of the rails under the operating load. Aligning the dual rail system with the cart could have also imposed a challenge for the end used, making the installation of standoffs more difficult.

In order to mitigate the issues imposed by the first iteration of this design, a new, single rectangular rail was proposed. With a much larger moment of inertia, the rectangular rail would undergo much less deflection during operation while maintaining a similar total weight. A single rail design is also an improvement from a user's perspective, as two rails do not need to be handled simultaneously while positioning the device. Overall strength and factor of safety for the design have also been improved with this change.

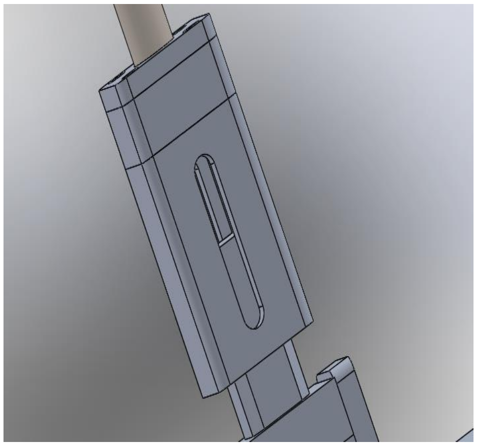

Figure 17. Spring Scale Design

In order to correctly install the standoffs and test the adhesion to the surface, the amount of force that is applied to the mounting bracket must be measurable. In order to meet this requirement, the design initially included a spring scale that was mounted in line with the lead screw, which would have provided a force reading for the operator when using the device.

However, this reading would have been difficult to check from many angles, and would have required extensive machining. The nature of the scale may have also provided unreliable readings, and would have added unnecessary bulk to the design. The new iteration will utilize a torque wrench to turn the lead screw and provide the necessary load on the standoff mounting bracket. This will also ensure more consistent force readings, as fatigue on the spring system will no longer be a concern.

4 Appendix

Appendix A: Complete Failure Mode 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
		Rocket Motor Ring is damaged			Overstressing the ring	1	Visual Indicator	8	80	
					Stress fractures occur due to regular use	1	Visual Indicator and assembly check	3	30	
		Clamp slips off	The device will be unsupported	8	Inefficient clamping force	3	Visual Indicator	8	192	Clamp Force Analysis
		Clamp Breaks			Overstressing the clamp	1	Visual Indicator	8	64	
					Sliding portion snaps	1	Visual Indicator	8	64	
		Clamp slide attachment is deformed			Overstressing of the clamp	1	Visual Indicator	8	64	
		Clamp attachments fracture			Attachments are maufactured poorly or stress fractures occur over regular use	1	Visual Indicator	8	64	
		Clamp teeth shear			Stress fracture occurs from manufacturing or regular use	1	Visual Indicator	8	64	
					Moment of the mounting arm causes severe stress on the teeth	1	Visual Indicator	8	64	

12	Translate the Brackets	Shear of center pivots in force block	Unable to apply axial force	7	Overstressing the rails	1	Audible and Visual Indicators	6	42	Factor of Safety Analysis
1		Bending of the rails	Device is not able to translate toward the standoff location	7	Overstressing the pivots	2	Visual Indicator	8	112	Deformation Test
4		Force Block does not slide			Friction force is too great	1	Audible and Visual Indicators	5	35	Bearing Analytical Analysis
					Ball Bearing Breaks	2	Visual Indicator	8	112	
1		Rails are damaged			Ball bearing would cause cracks or surface damage	1	Visual Indicator	8	56	
					Sliding would create scratches due to the metal frame of the force block	1	Audible and Visual Indicators	5	35	
					Weight of the rails cause deformation	2	Audible and Visual Indicators	5	70	Deformation Test
13		Force block locks are damaged	Force block is not able to be held in place	7	Formation surface damage of the rails	1	Audible and Visual Indicators	5	35	
					Force Block creates a greater sliding force than the locking force	1	Audible and Visual Indicators	5	35	Bearing Analytical Analysis
					Stress fracture occurs from manufacturing or regular use	1	Audible and Visual Indicators	5	35	Material Selection Analysis

9	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
					Thread shears off	1	Visual Indicator	8	64	Thread Material Properties Analysis
3		Clamp jaw deforms			Stress fracture occurs from manufacturing or regular use	1	Visual Indicator	8	64	Material Selection Analysis
					Clamp shape does not match the bracket template being installed	1	Visual Indicator	8	64	
		Clamp jaws break			Stress fracture occurs from manufacturing or regular use	1	Visual Indicator	8	64	
					Overstressing of the clamp	1	Visual Indicator	8	64	
		Mounting arm cannot be adjusted	Unable to hold standoff bracket	7	Bracket Template mass exceeding mounting arm maximum load	1	Visual Indicator	8	56	
		Bracket slips off			Incefficent clamping force	3	Visual Indicator	8	168	Clamp Force Analysis
		Bracket breaks	Standoffs are not secured in place	8	Clamping force exceeds material max force	1	Visual Indicator	8	64	
					Clamp and bracket contact is minimal causing deformation	1	Visual Indicator	8	64	

22	Apply axial force	Lead Screw breaks	Unable to apply axial force	8	Force induced deformation of screw	3	Audible and Visual Indicators	5	120	Lead Screw Stress analysis
					Moment induced deformation of the screw	1	Audible and Visual Indicators	5	40	
14		Assembly screws break			Overstressing of the device at the screw locations	1	Audible and Visual Indicators	5	40	Material Selection Analysis
					Stress fracture occurs from manufacturing or	1	Audible and Visual Indicators	5	40	
7		Shaft Collar disconnects	Bracket Clamp disconnects from force block	7	Deformation wear of the securing screw	1	Visual Indicator	8	64	Deformation Analysis
15		Lead Screw and Fish Scale box attachment breaks due to axial force testing			Attachment breaks due to continous use or manufacturing	1	Visual Indicator	8	64	Material Selection Analysis
		Fish Scale does not read correctly	Force will not display to operator	5	Spring does not function with the device	2	Visual Indicator	8	80	Spring Analysis
					Spring deforms over continuous use or from manufacturing	1	Visual Indicator	8	40	
					Fish Scale box deforms over continuous testing	1	Visual Indicator	8	40	

4, 13	Locking	Force block slides during axial force tests	Device can not be applied to specific location	7	Applied force exceeds lock capacity	5	Audible and Visual Indicators	5	175	Material Selection Analysis
					Force Block creates a greater sliding force than the locking force	1	Audible and Visual Indicators	8	56	Bearing Analytical Analysis
					Rail deformation is already present	1	Visual Indicator	8	56	
					Frictional Coefficent on rail clamping system is not sufficent for the device	1	Visual Indicator	8	56	
					Stress fracture occurs from manufacturing or regular use	1	Visual Indicator	8	56	Material Selection Analysis
12		Center Block moves rotationally			Applied force exceeds lock capacity	1	Visual Indicator	8	56	
					Side shearing occurs over regular use	1	Visual Indicator	8	56	
4		Center block cart attachments shear			Stress fracture occurs from manufacturing or regular use	1	Visual Indicator	8	56	
					Rotational movement creates deformation	1	Visual Indicator	8	56	
					Applied force exceeds lock capacity	1	Visual Indicator	8	56	
11	Angle Bracket	Bracket Joint Pin Shear Failure	Inability to carry out the pull test	7	Applied axial force	6	Visual Indicator	8	336	Material Selection Analysis
					Stress fracture occurs from manufacturing or regular use	1	Visual Indicator	8	56	
					Moment of the mounting arm	1	Visual Indicator	8	56	
3		Bracket Clamp to Arm attachment shears	Unable to hold standoff bracket	7	Applied axial force	1	Visual Indicator	8	56	
10		Spline Mounting Screw Shears	Device will be unsupported	8	Maufacturing or regular use	1	Audible and Visual Indicators	5	40	Spline Shaft Gear Analysis
					Axial force	6	Audible and Visual Indicators	5	240	
5, 6		Spline Hub breaks			Axial Force is greater than the gear material can experience	1	Audible and Visual Indicators	5	40	
		Spline Shaft breaks			Axial Force is greater than the pin material can experience	1	Audible and Visual Indicators	5	40	
		Spline Shaft Deforms			Axial Force is greater than the pin material can experience	1	Audible and Visual Indicators	5	40	
					Stress fracture occurs from manufacturing or regular use	1	Audible and Visual Indicators	5	40	
-	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	Create ESD Testing Procedure