19F18
Northrop Grumman Standoff Team

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Subject: ERs and TPs Revamp Memo

This memo will serve to review any changes that have been made to the project since the fall semester. Northrop Grumman's Flight Systems Group has requested for a team to design, analyze, and build a prototype universal dome standoff bonding tool that can be mounted to the attach rings of variations of rockets that will hold standoff brackets in place while the adhesive cures. The topics covered in this memo will include the customer requirements, engineering requirements, and testing procedures subject to modification. During the final weeks of the fall semester and winter break, the Northrop Grumman capstone team received a number of design considerations as related to the standoff attachment arm. This new information affected the project in various ways; the considerations included clarification of the dome protrusion of the CASTOR 50XL rocket (forward and aft), a maximum rail deflection of 0.1", pulling individual standoffs to 50lbs, push force of 20lbs per standoff (multiple per bracket), and the priority of hand calculations over SOLIDWORKS FEA. Due to this newfound information, the team will make modifications to the existing design. The changes made to accommodate these considerations will be explained in detail throughout the body of the memo.

1 Customer Requirements (CRs)

The customer requirements for the Northrop Grumman standoff project were collected from the project description and through client interactions. Some design aspects of the project have changed following the conclusion of last semester, these changes have come about through modifications of past customer requirements in accordance with the clients input. This section will note the changes that have been made to the projects and those that have remained unmodified. Table 1 below presents the customer requirements as of last semester along with their assigned weights.

Table 1: Customer Requirements

	Customer Requirements	Weight
1	ESD Compliance	0.09
2	Apply Axial Forces	0.09
3	6 DOF Movement	0.09
4	Range of 4-36"	0.09
5	Transportability	0.04
6	Ease of Operation	0.07
7	Durability	0.08
8	Reliability	0.08
9	Adjustable Interfaces	0.09
10	Support 10lb (Fixed Position)	0.09
11	Minimum 3.0 FOS	0.06
12	Budget	0.03
13	Size	0.05
14	Operator Safety	0.05
		1.00

The weights of the customer requirements, as seen in table 1 above, shows their priority within the project. Customer requirements that have changed as a result of the design considerations provided by Northrop Grumman include the size, transportability, force application, ease of operation, and operator safety. These changes have been noted as a result of design changes made to accommodate the new considerations. The overall size and robustness of the device had to be increased to meet the operator safety requirement which stated a deflection distance of 0.1" to not be exceeded. These design modifications both directly and indirectly affected the size, transportability, and safety of operation of the device. Another consideration included the change from applying 20lb to a single standoff to per each standoff. This requirement along with the information stating at max six standoffs per bracket meant the device capabilities should exceed a 120lb push force. The modifications made to meet this new requirement involved changing the rail design from circular to square tubing. The customer requirement affected by this design modification would again be the size and transportability of the device. Re-evaluation of the engineering requirements will be necessary as a result of the change to the customer requirements. The engineering requirements and their modifications as a result of the changes will be expanded upon further in the next section.

2 Engineering Requirements (ERs)

The engineering requirements of the project were determined from the customer requirements. As a result of the new project considerations from Northrop Grumman, the existing engineering requirements will need to be re-evaluated. This re-evaluation will involve stating the new target value, tolerance, and justification of the requirement as it relates to the project. While none of the requirements have changed explicitly, their tolerances and target values will have to be modified.

2.1 ER #1: Electrically Conductive

2.1.1 ER #1: Electrically Conductive - Target = Yes

The electro-static discharge (ESD) compliance requirement of our design has not been affected by the new considerations provided by the client. ESD compliance is a quantifiable aspect of the design where the target value for static buildup on the device is required to be zero. This circumstance allows the ESD compliance of the device to be denoted as either true or false based upon whether the surface static of the device is greater or less than zero. As a result our target value to meet for this requirement has been set to true (yes) which implies surface static of zero.

2.1.2 ER #1: Electrically Conductive - Tolerance = 0

Electro-static discharge (ESD) occurs when two electrically charged objects make contact or when the dielectric material between them meets the right conditions for spark. For this project, the electrical buildup on the device is expected to be null as it will be grounded. Due to the requirement of the electrical buildup to be zero, the tolerance for the design has also been set to zero.

2.2 ER #2: Mass

2.2.1 ER #2: Mass - Target = 25 lbm

The target mass for the design is dictated by the material of the rocket motor ring. Northrop Grumman have stressed that the motor ring should not be deformed from the application of our device. Back-of-the-envelope calculations were used to determine a target weight where our device would insignificantly impact the form of the motor ring. From these calculations, it was concluded that the target for the weight of the device should be around 25lbm distributed across the design. Applying these conditions to the motor ring, which has been idealized as a fixed cantilever beam with dimension of 1" x 5", the resulting in 0.005" deflection at the total length.

2.2.2 ER #2: Mass - Tolerance = +/- 5 lbm

The tolerance for this requirement was determined to be +/- 5lbm due to the deflection of the ring surpassing our self-assigned deflection constraint of 0.005". We would not want to go past this tolerance as the added forces from the pull or push test will need to be taken into consideration for the deflection.

2.3 ER #3: Working Length

2.3.1 ER #3: Working Length - Target = 32"

The working length for the design was determined through the project description and from client interactions. The device must be capable of delivering force between the range of 4-36" inward of the motor ring. This was used to set the target value of the engineering requirement as 32" which is in reference to the length of the rails mounted on the device.

2.3.2 ER #3: Working Length - Tolerance = TBD

The tolerance of the length would be determined by the size range of the mountable brackets. Since we are attaching to the bracket at its center, we would be the length of the bracket halved away from the extent of the aforementioned range. So the tolerance of this engineering requirement would be dependent on the smallest size of bracket. The team is currently in contact with Northrop Grumman over the dimensions of the bracket, and upon receiving the specific details will determine the tolerance for this requirement.

2.4 ER #4: Working Angle

2.4.1 ER #4: Working Angle - Target = 36°

The working angle of the device serves to meet the articulating arm requirements of the project. These requirements include six degrees of freedom, and the ability to mount anywhere between the range mentioned in the previous requirement. To fulfill this requirement, the team has implemented pin-located hinges onto the clamp, rail cart, and bracket head assemblies. This allows us to meet the 45 degree pull test as well as to clear the angle of the dome on the CASTOR 50XL motor. The hinge on the clamp portion of the device is set to 36 degrees to clear the dome, with the pin holes at increments of 9 degrees.

2.4.2 ER #4: Working Angle - Tolerance = 9°

The tolerance of this requirement was determined to be 9 degrees to meet the dome angles of the motors specified in the project description. The main concern lies with the CASTOR 50XL motor dome which requires a inclined angle of 36 degrees. Pin-holes have been implemented into the design to allow for the device to work at angles lower than 36 degrees at increments of 9 degrees. As a result, the tolerance for this requirement was determined to be 9 degrees.

2.5 ER #5: Modulus of Elasticity

2.5.1 ER #5: Modulus of Elasticity - Target = 9.9 x 10E06 Psi

The modulus of elasticity is an engineering requirement to prevent the deformation of the motor ring. The constraint of this requirement dictated that the devices material would deform before the motor ring specifically at the interaction point between the ring and the clamp. The material chosen for the device is aluminum 6061 with a modulus of elasticity of 9.9 x 10E06 Psi. This modulus of elasticity is lower than the motor ring by 0.5 x 10E06 Psi.

2.5.2 ER #5: Modulus of Elasticity - Tolerance = 0.5 x 10E06 Psi

Using hand calculations, the tolerance for the modulus must be lower than the rings modulus. The motor ring is made from aluminum 7075 with a modulus of 10.4 x 10E06 Psi. The chosen material for the device is made from aluminum 6061 with a modulus of 9.9 x 10E06 Psi. The difference between the two materials was used for the tolerance of this engineering requirement which equated to 0.5 x 10E06 Psi.

3 Testing Procedures (TPs)

This section discusses the testing procedures developed by the team to prove that all components of the design meets each engineering requirement. The purpose of these test procedures is to prove that the team's final design and product meets all engineering requirements: electrically conductive, mass, working length, working angle, and modulus of elasticity. The team plans to conduct a total of three test procedures which are "ESD Compliance", "Working Angle and Modulus of Elasticity", and "Mass and Working Length". Based on these test procedures, the team will be required to purchase $924.63 worth of testing equipment prior to conducting these tests. All tests will be conducted during the week of March 23, on a Thursday or Friday at noon in 98C.

3.1 Testing Procedure 1: ESD Compliance

This section outlines the ESD Compliance testing procedure which works to prove that the team's design meets the electrically conductive engineering requirement. The primary objective of this test procedure is to verify that the product will not carry static electricity into any of the electrical components of the rocket motor. This test requires the entire team, an anti-static table mat with a common ground cord, anti-static mat, a digital static field generator and a multimeter. Upon retrieving all necessary equipment, the team will meet during the week of March 23 on a Thursday or Friday at noon in 98C for approximately 30 minutes to conduct the test.

3.1.1 Testing Procedure 1: Objective

The purpose of this test procedure is to verify that the team's device is electrically conductive which is an engineering requirement. The team will test this particular aspect of the project because it is important that the final device, when functioning, will not carry static electricity into any of the electrical components of the rocket motor. How this test procedure will run is that the entire device will be placed on an anti-static table mat which would be grounded by a common ground cord. An anti-static mat will be placed on the floor to ground the user. A multimeter would be used between a team member (red wire) and the device (black wire) and is expected to read 0V to prove ESD compliance. To further verify that the device meets this engineering requirement, the team will use a digital static field generator on the device to provide the same expected 0V.

3.1.2 Testing Procedure 1: Resources Required

For this test, the entire team will be involved and the necessary equipment includes an anti-static table mat, common ground cord, a multimeter, and the completed device. All equipment necessary for this test procedure will be purchased by the team. The Anti-Static table mat, anti-static mat, and the common ground cord will be ordered online at uline.com. the multimeter will be purchased at Home Depot. These items will cost a total of $826.81. Since the ESD compliance requirement is weighted heavily by the customer, it is imperative that the team invests in the appropriate equipment to follow the ANSI/ESD 6.1 standard.

Table 2: ESD Resources Needed

Index	Tool	Dimensions	Reference	Price ($)
1	Anti-Static Table Mat	2'x4'	https://www.uline.com	85.00
2	Common Ground Cord	15'	https://www.uline.com	17.00
3	Multimeter	n/a	https://www.homedep	40.00
4	Digital Static Field Generator	n/a	https://gokimco.com/de	634.81
5	Anti-Static Mat	2'x3'	https://www.uline.com	50.00
				826.81

The resources required to carry out the ESD compliance testing are presented in table 2 above. The total cost of these materials is shown on the right side of the table along with the website where they were located.

3.1.3 Testing Procedure 1: Schedule

This test will likely occur on the week of March 23.The team will likely meet on a Thursday or Friday at noon in 98C to conduct this test. This test is estimated to take approximately 30 minutes. Additionally, before the test can be conducted all equipment must be ordered prior to testing. Shipping of the anti-static table mat, anti-static mat, and common ground cord is estimated to take 1-2 business days.

3.2 Testing Procedure 2: Working Angle and Modulus of Elasticity

This section discusses the second test procedure which works to prove that the team's design meets the working angle and modulus of elasticity engineering requirements. Additionally, this test will also be used to verify the reliability and robustness of the device. This procedure will test the functionality of the entire device, with a specific focus on the ring clamp, bracket holder, and power screw. The team will observe for deflections on the motor ring and rail components when applying the maximum force of 120lbf. This test will be repeated three times to test the reliability and robustness of the device. The entire team will be involved in this test procedure and will utilize a protractor, mock motor ring, and the complete device. This test will occur during the week of March 23 on a Thursday or Friday at noon in 98C and will approximately take 1 hour.

3.2.1 Testing Procedure 2: Objective

The purpose of this test is to prove the functionality and reliability of the angling mechanisms of both the ring clamp and bracket holder while applying a maximum force of 120lbf. This test will prove that the team's design meets both the working angle and modulus elasticity engineering requirements by providing physical proof that the device successfully functions in various angles from the motor ring ranging from 9 to 36 degrees. This test will require the entire team, complete device, a mock motor ring, and a protractor and would be conducted in 98C.

3.2.2 Testing Procedure 2: Resources Required

The entire team will be involved in this test procedure. Additionally, the equipment required includes a protractor, a 0.19" aluminum 7075 sheet cut into the appropriate dimensions of the ring, and the completed device. In order to create a mock motor ring, the team must purchase a 0.19" aluminum 7075 sheet online at onlinemetals.com and submit a work order to 98C in order for them to cut the sheet and round it. The protractor will be purchased in store at Target. The total cost of the testing equipment is $89.27 and the team will allocate an additional $200 for the work order. The resources needed are presented in table 3 below.

Table 3: Working Angle Resources

Index	Tool	Dimensions	Reference	Price ($)
1	Protractor	n/a	https://www.target.co	3.39
2	Aluminum 7075 Sheet (0.19" THK)	12"x24"	https://www.onlinemet	85.88
				89.27

The resources required to carry out the working angle testing are presented in table 3 above. The total cost of these materials is shown on the right side of the table along with the website where they were located.

3.2.3 Testing Procedure 2: Schedule

The test will occur during the week of March 23, most likely on a Thursday or Friday at noon in 98C, and is estimated to take 1 hour. Prior to testing, the team must submit a work order for the mock motor ring to 98C at least three weeks before the test. This timeframe will give the 98C shop managers enough time to discuss any potential issues with the work order with the team. Additionally, the 7075 aluminum sheet must be purchased and received prior to placing the work order. Onlinemetals.com provides 1-2 ground day shipping, so the team will factor this when preparing for this test procedure.

3.3 Testing Procedure 3: Mass and Working Length

This section discusses the test procedure required to prove that the team's device meets the mass and working length engineering requirements. The overall objective of this test procedure is to verify that the device meets the mass and working length engineering requirements by weighing and measuring the length of the device. The resources required include a digital scale, ruler, measuring tape, calipers, meter stick, and a laptop. The team will use the scale in the Soil Lab classroom, a meter stick will be purchased online, and the rest of the measuring devices will be borrowed from 98C. This test procedure requires the entire team and will be conducted during the week of March 23 on a Thursday or Friday at noon at 98C.

3.3.1 Testing Procedure 3: Objective

The objective of this test is to verify that the device meets mass and working length engineering requirements. The test will require the measurement of all device components using either a ruler, measuring tape, calipers, or a meter stick. Additionally, each component will also be weighed using a digital scale. In order to achieve this, the device will be completely unassembled to weigh each component. Through this test, the physical measurements should closely match the final CAD which would verify that the device meets the principal dimensions and mass engineering requirements. The reason why this test is important is because the team must meet specific dimensions in order to ensure that the device will be able to function on various types of rocket motor domes with varying diameters.

3.3.2 Testing Procedure 3: Resources Required

In order to be able to conduct this test, the team will need to acquire a digital scale, ruler, measuring tape, calipers, and a meter stick. To weigh the device, the team will use the digital scale found in the soils lab room. Additionally, the ruler, measuring tape, and calipers will be found in 98C and the team will check these equipment out on the day of the test. The meter stick will be purchased online. All team members will be present and will record the measurements on a shared google document or spreadsheet.

Table 4: Mass and Working Length Resources

Index	Tool	Dimensions	Reference	Price ($)
1	Digital Scale	n/a	Soils Lab	n/a
2	Ruler	n/a	98C	n/a
3	Measuring Tape	n/a	98C	n/a
4	Calipers	n/a	98C	n/a
5	Meter Stick	n/a	https://www.amazon.c	8.55
6	Laptop	n/a	Team Member	n/a
				8.55

The resources required to carry out the mass and working length testing are presented in table 4 above. The total cost of these materials is shown on the right side of the table along with the website where they were located.

3.3.3 Testing Procedure 3: Schedule

This test will be conducted on the week of March 23, when the device is required to be completed. The team will most likely meet on that Thursday or Friday to measure each component. Prior to conducting the test, the team will be required to check when the Soils lab is available or schedule to use the digital scales and check 98C to verify that it has a ruler, measuring tape, and calipers. Additionally, the meter stick must also be purchased prior to testing.
Resources

3.4