Release Lanyard Design

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Team05

Document

Project Proposal

Submitted towards partial fulfillment of the requirements for
Mechanical Engineering Design – Fall 2012

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NAU Capstone Team 5
South San Francisco Street
Flagstaff, AZ 86011
December 7, 2012

Steve Larimore
Department Manager
Tactical Systems Mechanical Design/Mechanical Systems Design Center
Raytheon Missile Systems
1151 Hermans Road
Tucson, AZ 85756

Dear Steve Larimore and Raytheon Associates:

First off, we would like to thank you for the opportunity to work with you on this release lanyard project. We understand that on occasion, the lanyard is failing to activate the device due to icing, poor installation, and contaminates (sand, dust, etc.). As a result we have worked to find a new design that is more reliable and less susceptible to these modes of failure. We recently had a change of design focus, and are currently proposing the housing concept with a strictly mechanical activation system to follow. The final activation design concept is in the works and will be designed so that the casing and the mechanism are one entity.

Casing Concept:

1. Addresses the issues of contamination causing failure which will improve the performance
2. Decrease installation time
3. Increased reliability
4. Maintains current device locations

Since the entire final design has not been identified, the exact cost of the design is yet to be determined. With the necessary engineering analysis and research carried out, the material cost, manufacturing cost, and installation time will be quantified. The primary task over the holiday break is to identify which mechanical activation system to proceed with. Once the dimensions have been identified, our current casing prototype can be updated to accommodate the design. We understand there is quite a bit of work left to complete and are working to stay on top of it all.

Again we thank you for the opportunity and look forward to meeting with you.

Sincerely,

Christopher Temme
Carly Siewerth
Timothy Haynes
Styson Koide
Andrew Baker
David Lofgreen

Problem Statement:

1.1 Introduction

Many weapons constructed by Raytheon use a lanyard device to activate the weapon after it has been released. Unfortunately on a few occasions the lanyard has failed to activate the weapon due to icing, poor installation, and contaminates such as sand and dust. Raytheon has proposed this project to our team to find a new design that is more reliable and less susceptible to these modes of failure.

1.2 Background Research

Raytheon was established on July 7, 1922 in Cambridge Massachusetts as the American Appliance Company. Raytheon became a major national defense company during World War II where they supplied 80% of the magnetron tubes used in radars. With these strong foundations Raytheon now specializes in defense and homeland security in the Unites States as well as government markets throughout the world. One of Raytheon's divisions specializes in military weapon systems. Some of these systems experience extreme environmental conditions during use, which causes a fraction of them to fail.

1.3 Needs Identification

The current lanyard design does not address issues relating to extreme temperatures and environmental effects, which leads to system malfunction. This project will consist of developing a new design for an arming system lanyard and a functional prototype.

1.4 Project Goal

Our goal is to design a reliable, low cost system that can withstand extreme temperatures and environmental effects. After talking with our client, the emphasis of our design analysis has changed to focus primarily on the activation area instead of the entire lanyard system. This changed the original design problem from redesigning an entire lanyard system to redesigning the activation arm, which disregards the cable and cable guide components.

1.5 Objectives

With the information provided by our client, the following table was constructed based on the most important criterion.

Table 1: Objectives

Objectives	Basis for Measurement	Units
Inexpensive	Manufacturing Cost Based on Current Design	$$
Maintain Current Location of Devices	Location Based on Current Design	Meters
Installation and Assembly	Timed Trial	Seconds
Successful Activation of Devices	Minimum Force Required	Newtons
Low Susceptibility to Contamination	Amount of Contamination Required to Induce Failure	Kilograms
High Performance Reliability	Number of Successful Attempts vs. Failed	%
Increase Maneuverability	Pivot Radius of Device	Meters

As seen in Table 1, the team hopes to achieve all of these objectives. However, the main objective that needs to be achieved is the successful activation of the device. This will be achieved by meeting the objective of low susceptibility to contamination, which will in turn create high performance reliability.

1.6 Constraints

Based on the information provided by Raytheon the following constraints were generated. These constraints are:

i. The device must fit within the current space requirements as dictated by the weapon system and government specifications.
ii. The placement of the lanyard mounts and associated devices have already been predetermined.
iii. The allowable cost must not exceed that of the current design of $300 in material cost.
iv. Must be easily assembled within 30 minutes.
v. Must use a mechanical force to activate the device. This force must be at least 50N.
vi. The device must contain a safety mechanism for inactive use and mounting.
vii. The use of the current power system is not possible.
viii. Device must have a flight time of 2 days for battery powered systems.

1.7 Criteria Tree

Based on the information provided in Table 1the following criteria tree was produced. This criteria tree shows the relationship that each criterion shares with the others.

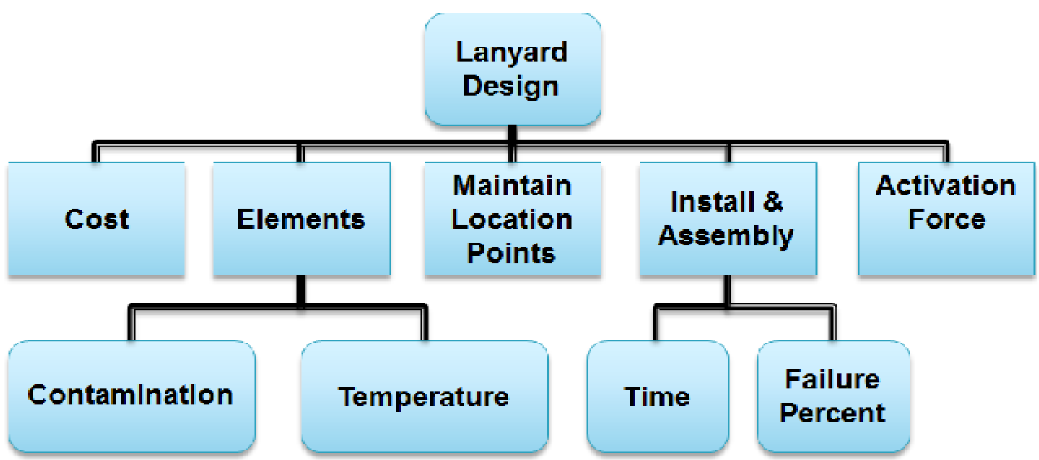

Figure 1: Criteria Tree

1.8 Quality Function Deployment

The customer requirements and quantifiable engineering requirements have been compared in Figure 2 below. The engineering targets below have been determined after speaking with the client. However, material thickness will be determined once a suitable material is chosen and thus it is listed as to be determined (TBD) in the figure below.

The house of quality pictured in Figure 3 relates the engineering requirements to one another with a directly or indirect relationship. This is shown at the top of the table indicating a "+" for a positive relationship and a "-" for an inverse relationship.

Customer Requirements	Engineering Requirements					
	Cost	Weight	Material Thickness	Size Dimensions	Force Requirement	Yield Strength
Activates Weapon					X	
Inexpensive	X		X			
Ease of Assembly	X					
Ease of Installation	X					
Impervious to Environmental Conditions		X	X			X
Set Installation Locations	X			X		
Units	$	kg	m	m^2	N	Mpa
Engineering Targets	~300	2.27	TBD	~2	50	276

Figure 2: Quality function development

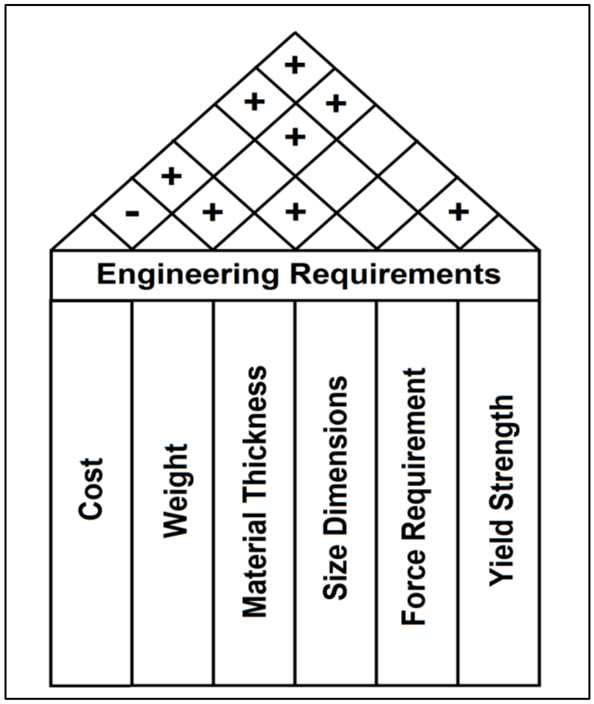

Figure 3: House of quality

Concept Generation:

According to the requirements provided by our sponsor, there are certain components of the current design that cannot be altered. This pertains to the lanyard attachment point on the aircraft, ground safety pin preventing early activation, and the location of the battery and switch. With this in mind, our team identified the potential areas of redesign. The categories of redesign pertain to the:

1. Cable options
2. Cable guide components
3. Activation system

A few desired features that needed to be considered in this concept generation process include:

1. Easy to assemble correctly and install external cable, guides, and activation system while in the field
2. Cost less than the current design

With the design criteria identified, the team began the concept generation process and produced the following designs. Our cable option designs include cable coating or eliminating the cable and switching to a rigid rod or electrical system. The cable coating would be a Teflon/Tyvek tubing material. This feature would protect the cable from fraying and being damaged by the potentially sharp edges of the guide pipe.

There were two design ideas that could potentially eliminate the cable. The first idea was to replace the cable with a rigid rod. This would ideally eliminate the failure due to the cable “locking-up” within the guide pipe. However, after further discussion we realized that this design had the potential of compromising the integrity of the vehicle or the device it was attached to. This may also interfere with the allowable space requirement mentioned in the previous section. The second idea reduced the length between the activation pin and the cable attachment point to the vehicle. When considering the force transferred from one location to the other to activate the switch, the electrical wire design incorporates a different thought process of moving the mechanical force needed to activate the mechanism much closer to the clip-in point pin and thus greatly reducing the distance of transferred force. This would be accomplished by almost completely removing the cable wire and replacing the battery slider assembly to an electrically based system by breaking/opening the loop via the two pull pins which will close/open the electrical loop and arm the mechanism as it would normally.

Our cable guide component designs include a cap over the guide pipe opening, lubrication, creating radius edges, creating a funnel opening (Figure 21, Appendix), a rubber guide within the pipe, and reducing the guide pipe to an array of steel rings. The cap would be manufactured from a durable plastic or rubber to prevent water and contaminants from entering the guide pipe system. This would be applied to the current guide design, Figure 4, and could be paired with the lubrication idea.

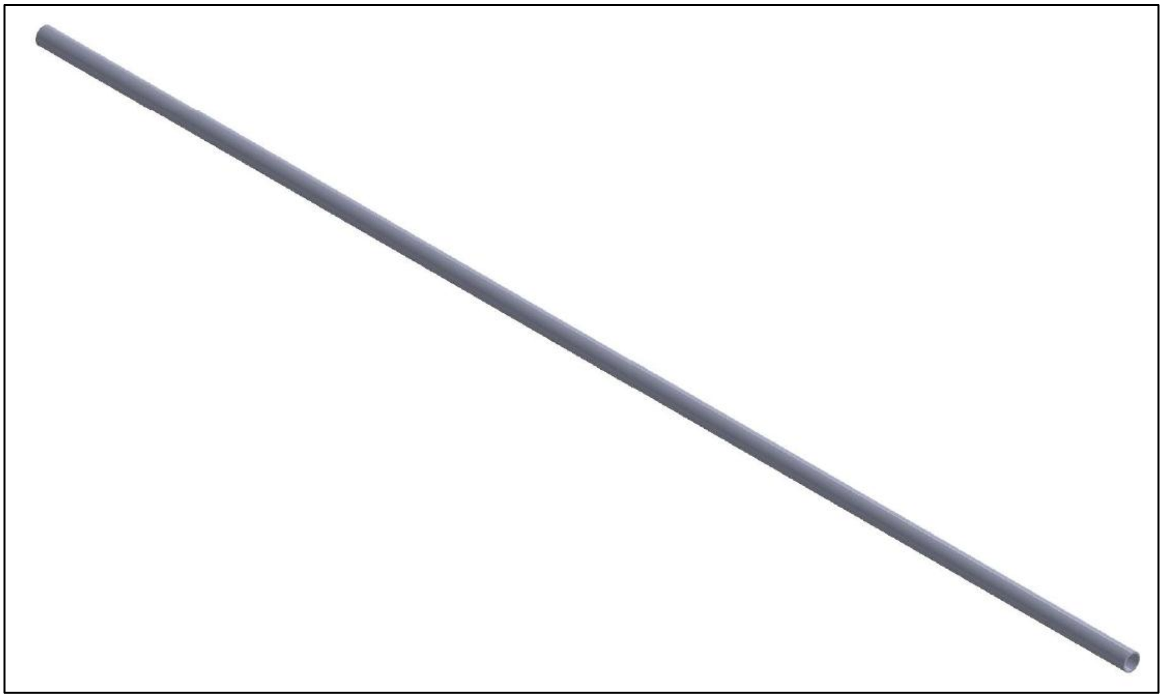

Figure 4: Current guide pipe

There are several lubricating products that work at extreme temperatures and could fill the inside of the pipe system to prevent compromise. Creating radius edges on the ends of the guide pipes would eliminate the sharp turns of the current guide pipe system. The funnel opening feature would remove the sharp edges that are leading to the cable fraying, but has the potential of increasing contaminant buildup at the opening. The last two design features are paired together. The rubber guide would lie at the bottom of the array of steel rings pictured in Figure 5.

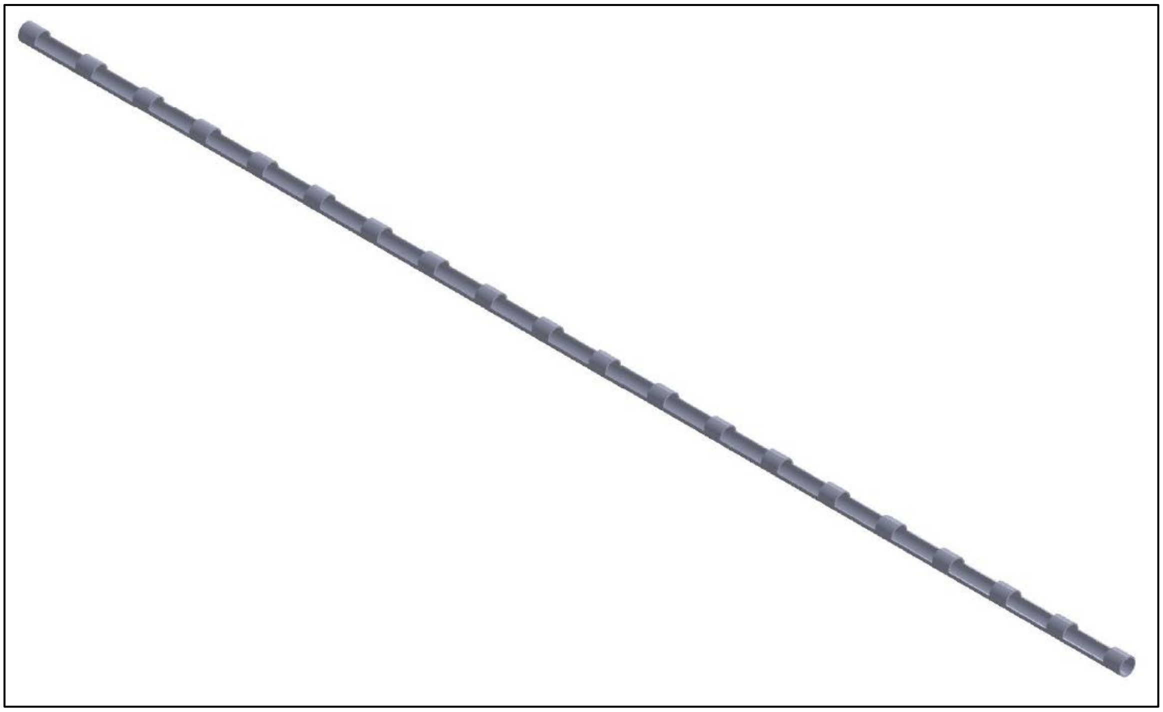

Figure 5: Steel ring array guide

This allows the cable to glide smoothly when a force is applied to one end. The final guide alteration consists of an array of steel rings and can be seen in Figure 5. These steel rings may be circular or even horseshoe in shape.

This last group of designs pertains to the actual activation system. The 3D sketch below depicts the current lanyard system.

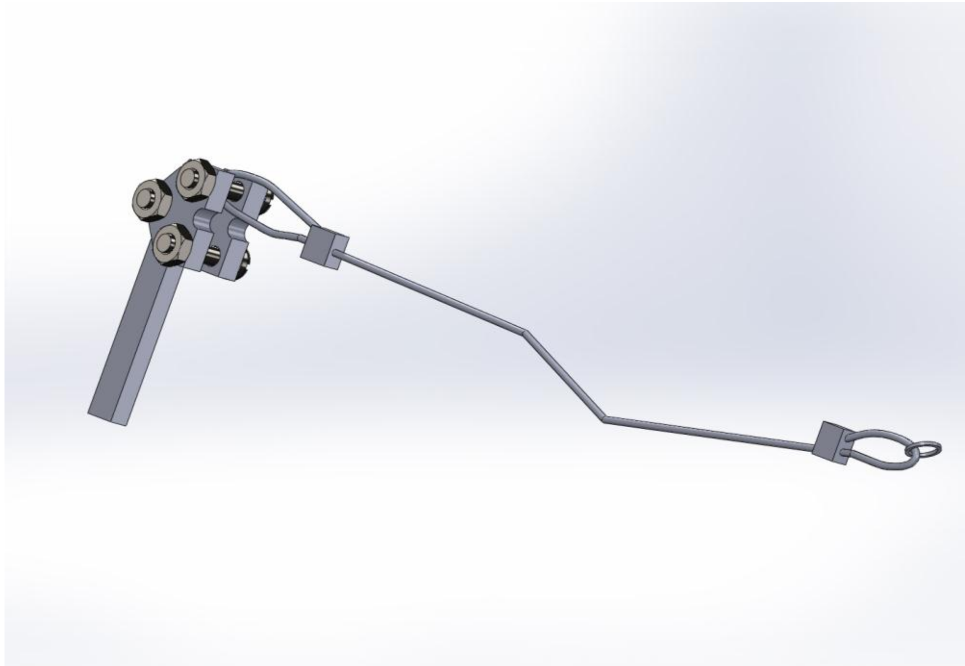

Figure 6: Current activation system

The first design considered simply extends the activation arm and repositions the connection point of the cable to create a greater torque. The second design utilizes a spring and a pull pin. Once the safety pin is removed, the operation is ready to be carried out. As soon as the force is transmitted to the holding pin, the pin would be removed from its resting position and a spring would in turn force the activation pin out of the crevice. The final design pertaining to the activation system converts the pivot assembly (Figure 23, Appendix) to a slider switch (Figure 24, Appendix). The principles of this design are the same as the current design. When the cable experiences a force, it is translated to the activation assembly, but rather than causing a pivot action the system slides. Each of the concepts produced attempts to address the environmental conditions experienced while the weapon is attached to the aircraft (vibration, sand and dust, icing, etc.).

Concept Selection:

Based on the criteria provided to us by our client, the following decision matrices were constructed. As mentioned before, our team identified three primary areas of redesign. The scale used for the matrix values can be found below. It was constructed with 5 being a moderate improvement to the current design and 1 being much worse.

Based on the decision matrix found below, the switch slider assembly appears to be the best design option for the activation system. The switch slider can be found in Figure 23 of Appendix A.

Table 2: Activation Arm

Scale	
1	Terrible
2	
3	
4	
5	Moderate
6	
7	
8	
9	
10	Excellent

Activation Arms				
Criteria	Weight	Switch Slider	Extended Arm	Spring Loaded Arm
Cost	0.1	2	3	2
Contamination	0.4	6	5	3
Temperature Range	0.2	5	5	4
Installation Time	0.1	5	5	4
Ease of Installation	0.1	4	5	3
Dimensions	0.1	8	3	7
Weighted Sum	1	5.3	4.6	3.6

Once the cable options were sifted through, the team was able to construct the decision matrix below. According to the weighted values, cable coating appears to be the best feature for this design category.

Table 3: Cable Options

Cable Options				
Criteria	Weight	Cable Coating	Electrical Wires	Rigid Rod
Cost	0.1	3	2	4
Contamination	0.4	8	6	6
Temperature Range	0.2	5	5	5
Installation Time	0.1	3	4	6
Ease of Installation	0.1	4	4	6
Dimensions	0.1	5	8	2
Weighted Sum	1	5.7	5.2	5.2

With two of the three areas of design addressed, the final decision matrix provides an analysis for the cable guide components. After performing the appropriate calculations, it can be seen that the cap feature would address the necessary criterion.

Table 4: Cable Guide Components

Cable Guide Components					
Criteria	Weight	Array	Radius Edges	Cap	Lubrication
Cost	0.1	4	4	3	3
Contamination	0.4	7	5	8	4
Temperature Range	0.2	5	5	5	7
Installation Time	0.1	4	5	5	3
Ease of Installation	0.1	4	5	5	3
Dimensions	0.1	5	5	5	5
Weighted Sum	1	5.5	4.9	6	4.4

Based on the results of the previous decision matrices the design concepts were combined to configure a possible final design. According to the results, this final design would utilize a Teflon/Tyvek coating on the current cable containing the fusible link. This cable would weave through the current guide pipe system, but include a cap to prevent contaminants from entering the piping. One end of the cable would be attached to the vehicle and the other end would be attached to the switch slider assembly.

Engineering Analysis:

Previously, our team identified the potential areas of redesign. The categories of redesign pertained to the:

1. Cable Options
2. Cable Guide Components
3. Activation System

4. Device Casing
5. Servo Mechanism

- **Lubrication Concept**

One concept that was researched pertained to lubrication. The concept of lubrication seems rudimental, but was an idea that could possibly be the key to a reliable mechanism. Lubrication not only reduces friction, but reduces the amount of wear, minimizes corrosion, and assists in keeping contaminants out of the system.

This concept required a lubricant that would maintain its lubricity and viscosity despite being exposed to extreme temperatures. After research, it was discovered that lubricants developed by DuPont™ Krytox® could meet these requirements. These lubricants were developed precisely for lubrication needs in the aerospace industry. Research revealed that their current products met the safety, reliability, and were in compliance with the specifications of the military. The DuPont™ Krytox® perfluoropolyether- (PFPE-) based oils and greases feature properties ideal for aerospace applications. These properties include:

- Wide Temperature Range (in which lubricity and viscosity aren't affected): -70 °C to 399 °C (-100°F to 750 °F)
- Stable Physical Properties Over Time
- Unaffected by Harsh Environments (vibration, heat, pressure, corrosive chemicals and radiation resistant)
- No Vapor Loss in a Vacuum (high altitude)
- High Compatibility for Most Materials (metals, plastics, finishes, etc.)
- Non-flammable, Nontoxic, Inert, and Non-evaporative

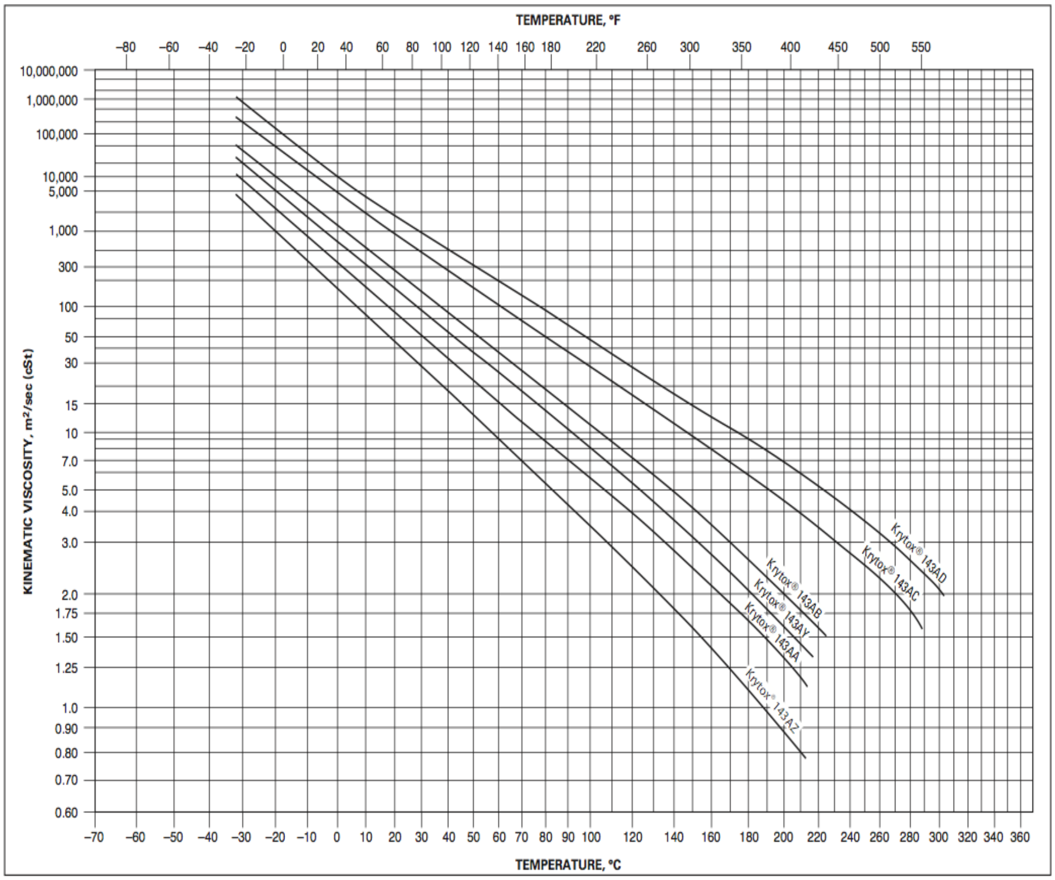

Figure 7: Lubricant Kinematic Viscosity vs. Temperature [3]

The figure above shows how the kinematic viscosity of the lubricants varies in relation to the temperature it operates in. Viscosity is defined as the resistance of a fluid to deformation. As can be seen, the kinematic viscosity has a negative correlation with respect to temperature. When the temperature is at the lower end of the spectrum, viscosity is rather high, but as temperature increases, the viscosity decreases.

Some of the current applications of this aerospace lubricant included the usual bearing applications, O-ring applications, but also utilized in wing flap actuators, lunar rover, rocket engine assemblies, and Oxygen breathing systems. The team was about to request a sample from the company to perform additional analysis, however after speaking with our client it was discovered that lubrication had recently been applied. Unfortunately, the lubrication concept was merely a temporary fix. There were concerns with how the lubrication would be affected if contaminants were encountered, how it might affect the mechanisms scheduled maintenance and maintenance costs.

- **End Cap Design**

The primary purpose of the end cap design is to prevent the accumulation of ice and other debris from forming within the cable guides. To achieve this, lightweight deformable caps will be located at one or both ends of the guide tubes. This will essentially block most moisture and other material from entering the guide tubing. A SolidWorks image of this design is displayed in Figure 8.

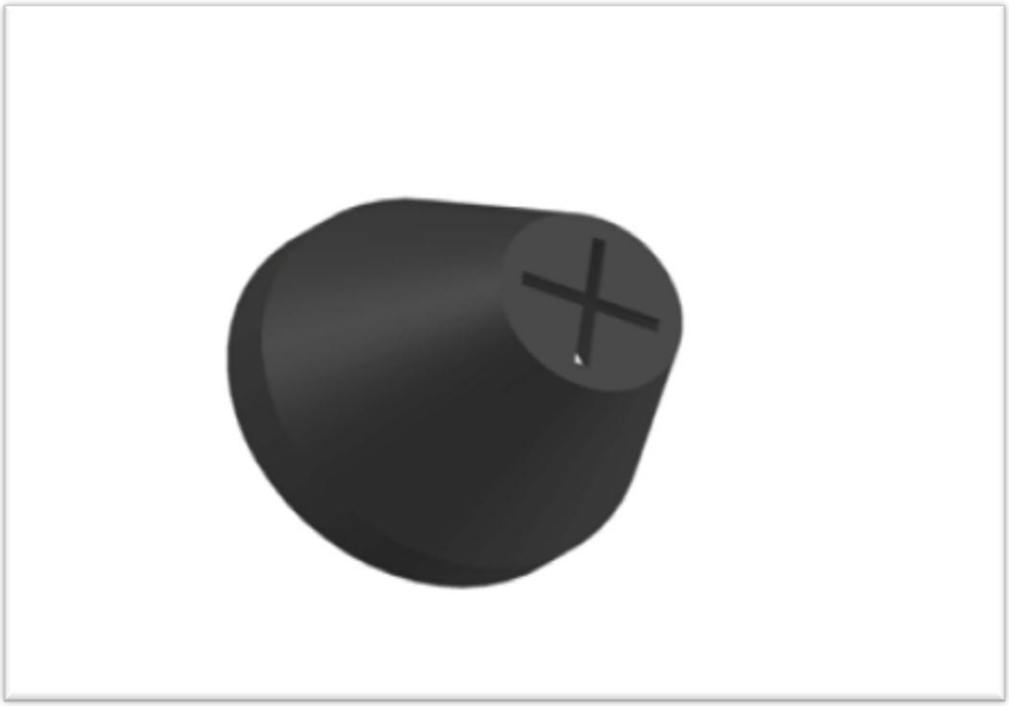

Figure 8: End cap design

Based on the information provided by Raytheon, the release lanyard system must demonstrate a temperature range from –50°C to 150°C which means that the end cap material needs to have a working temperature that encompasses this range. Three materials considered were flurosilicone rubber, silicone and Teflon PolyTetraFluoroEthylene (PTFE). The first two materials considered, flurosilicone rubber and silicone, have working temperature ranges of -74°C to 175°C and -60°C to 200°C respectively. Both of these materials are resistant to most fuel emissions, which show that either choice would be ideal for this application. However, these materials are primarily used for static situations due to poor abrasion resistance [2]. The last material considered, Teflon PTFE, was found to have a working temperature range of-73°C to 204°C. This material is also resistant to most fuel emissions and works well under dynamic situations [1].

Based on these specifications, Teflon PTFE appears to be the most suitable choice for this application. However, more research must be done to determine if this material will perform normally when exposed to particular types of fuel emissions. This material must also be evaluated to determine if it is a suitable choice for manufacturing.

- **Cable Coating Design**

The main purpose of coating the cable is to eliminate the cable from exposure to the elements that it will be exposed to. Some of the possible coatings that could be used are Tyvek® and Teflon® tubing seen in the following image.

Figure 9: Teflon tubing [4]

The working range for the lanyard the tubing must withstand the temperature range as noted previously. The Teflon tubing has a working range of -270°C to 260°C, and the Tyvek® has a working range of -73°C to 132°C [5]. Due to the working range of the lanyard the Tyvek® is not suited for the lanyard design and consideration on the Teflon® tubing will be pursued.

When looking at the working ranges that the lanyard is exposed to the Teflon® tubing seemed a viable option for consideration. However, based on information given to us by Raytheon and a few studies done previously on this application of stainless steel wire coated by Teflon® tubing corrosion occurred and cannot be used as a solution [6].

After generating the ideas listed above, Raytheon informed the team that many of these designs have been tested in the past or have already been implemented. This required the team to generate the new concepts listed below.

- **Device Casing**

  The top two designs that we are looking into prototyping for our client, Raytheon, consist of a casing concept and a servo activation device. For any design our team pursues in it will involve a casing device, which can be viewed in Figure 10 below. By using the casing concept we can decrease the amount of condensation that will build up on the activation mechanism by providing a shielding over the entire activation area. By keeping the activation device free of ice and debris, contamination will decrease and the failure rate of the device will also decrease. Installation of the casting will only add a very small amount of time to preexisting procedures, since this component is designed to use the same mounting points as the previous design. The pieces that will change in the assembly process will be the screws, which will hold the casing and activation mechanism in place. The only reason for changing the screws is that they need to be longer in order to hold the casing and activation mechanism to the weapon.

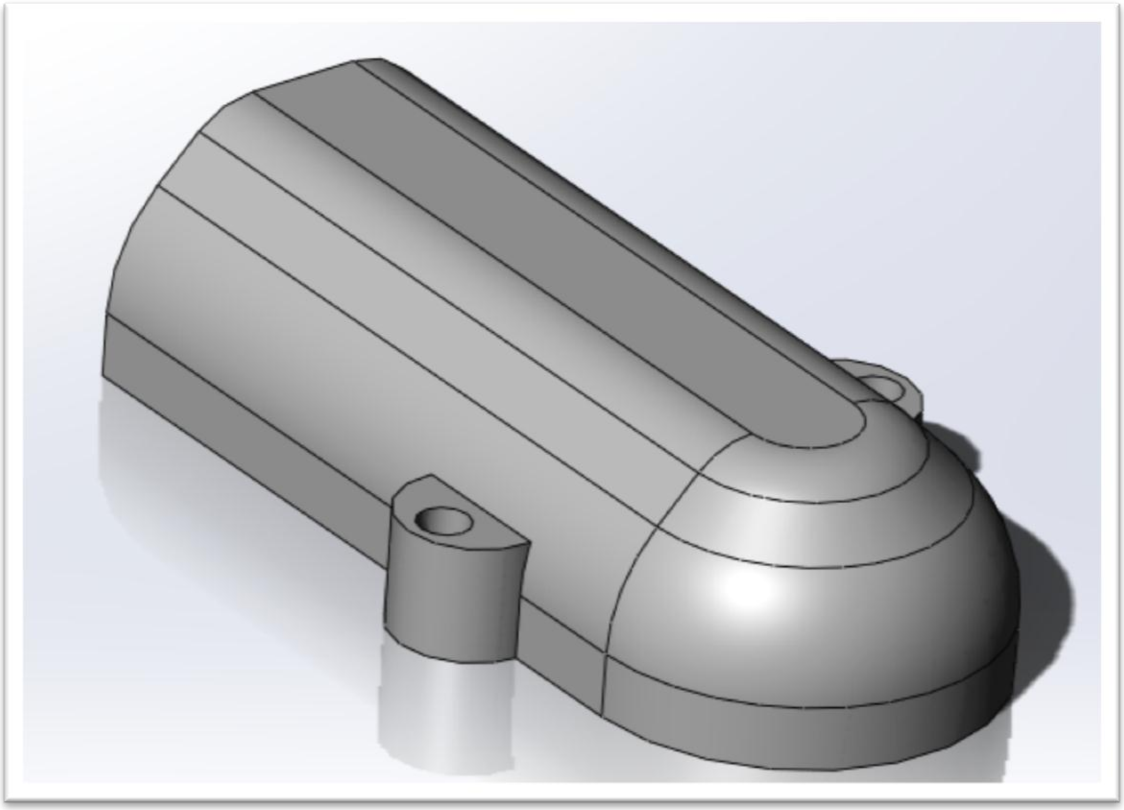

Figure 10: Casing

- **Servo Mechanism**

  The servo activation device was thought of to eliminate as many mechanical parts as possible. This would help prevent ice and debris from building up on the device with changing environmental conditions. A servo is made up of three main parts the first being a computer processor that communicates a signal back and forth from the motor and a secondary computer. The second key component of a servo is the motor that turns a set of gears a certain degree clockwise or counter clockwise, which is the only mechanical aspect to the activation device. The computer processor and motor components can be viewed in Figures 11 and Figure 12 below respectively. To protect these key components, the servo contains its own housing to protect it from the environment. Having the gears already in a case will keep ice and debris off the gears improving the mechanical aspect and allow us to place a safety pin in the activation design. The servo will only be replacing the mechanical activation mechanism that is currently being used, and all the existing cable, cable housing, and attachment points will still be in used. To have the weapon activate, the servo will be hooked up to a small battery pack that will send the current to the weapon's battery once activated. To activate the servo a cable will be pulled and turn the gears of the servo an arbitrary amount before the cable breaks. Once the servo has turned the required amount the servo will allow the current in the extra battery package to follow freely down to the weapon's battery. With this the weapon will now be activated and ready to be used.

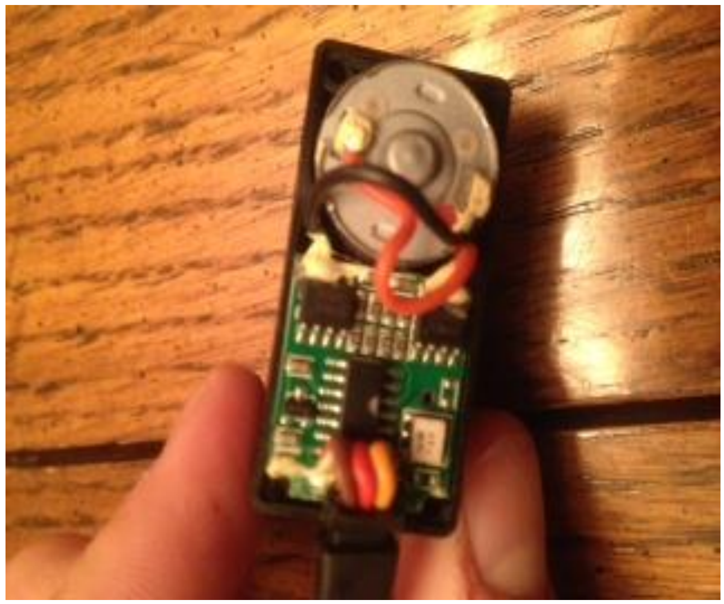

Figure 11: Computer and motor components of a servo

Figure 12: Gears of a Servo

A method of analysis for our design will include physical testing. The first test will be performed with the servo at room temperature to verify that it will be able to perform the required tasks. Another test will be performed to the servo at varying temperatures between -50° Celsius to 150° Celsius to determine how the servo responds at the extreme temperatures. The material of the housing and casing for the servo will also be tested to understand how they react to the exhaust fumes of the vehicle. To test this, the parts will first be weighed and then soaked in the fuel used by the vehicle. After soaking we will allow the material to air dry and then reweigh the material and calculate any change in the weight.

Final Design:

There were several designs considered for the design to proceed with going forth. The main feature of the design is housing/casing element. The casing is a design feature focused primarily on decreasing the amount of condensation that will build up on the activation mechanism. By providing a shielding over the entire activation area, the failures due to contamination and ice buildup on the mechanism will ideally be eliminated. By keeping the activation device free of ice and debris, contamination will decrease and the failure rate of the device will also decrease. Figure 13 is an example of what the casing is designed to look like (accompanied with an activation system similar to the current design).

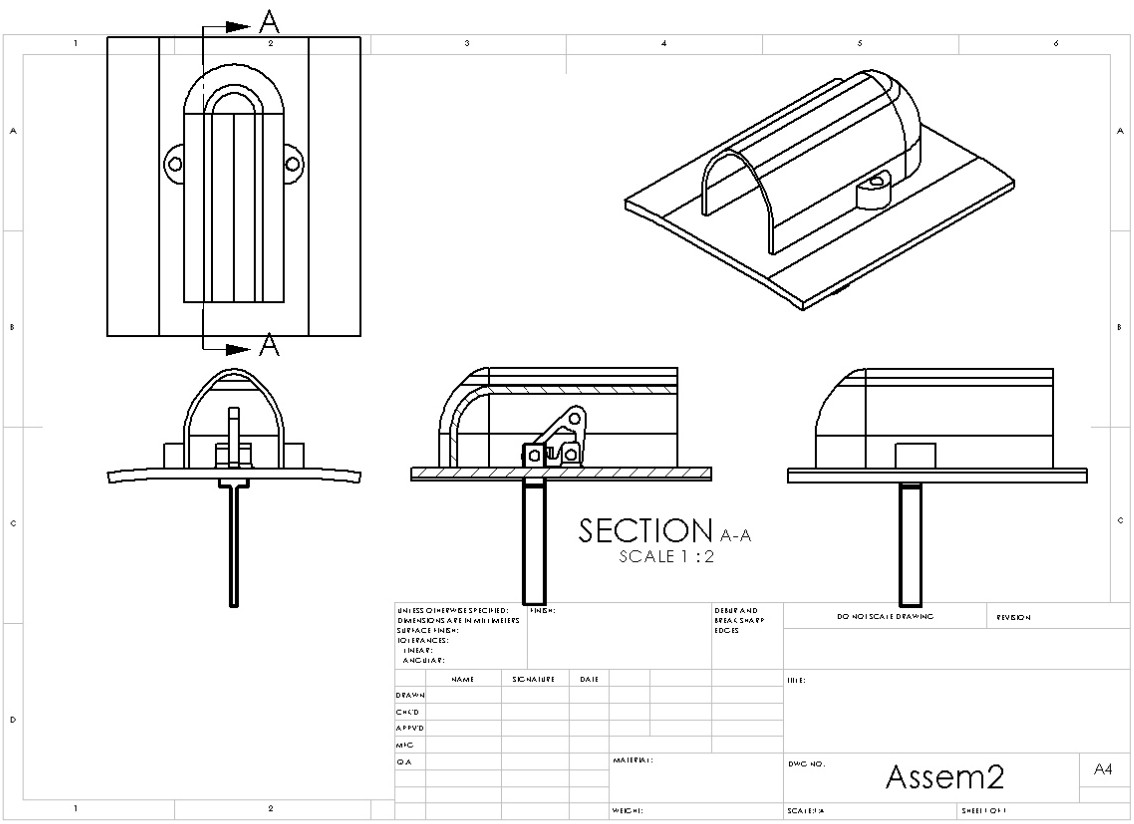

Figure 13: 2D orthographic view of the full assembly

The drawings above do not reveal the shape of the tail end of the casing. The tail of the end is designed to be a mirrored image of the front end. It features a slot to allow the cable to enter and attach to the activation arm. The dimensions used for the prototype seen in Figure 14 can be found in the Appendix. In order to prevent contamination through this slot, a rubber cap similar to the concept design mentioned previously.

Originally, the activation system was going to utilize a servo to eliminate as many mechanical parts as possible. Again, this would help prevent ice and debris from building up on the device with the changing environments Raytheon has asked us to consider into our design. To have the weapon activate, the servo will be hooked up to a small battery pack that will send the current to the weapon's battery once activated. To activate the servo a cable will be pulled and turn the gears of the servo an arbitrary amount before the cable breaks. Once the servo has turn an arbitrary amount the servo will allow the current in the extra battery package to follow freely down to the weapon's battery. With this the weapon will now be activated and ready to be used.

However, one issue the servo did not address in full was the maintenance aspect. The servo as mentioned requires its own battery source. In order for the system to be activated, the battery would need to hold the minimum charge to complete the activation process. After speaking with our client and learning the worst case scenario (i.e. flight time, time inactive, etc.), it was decided that we may need to focus once again on a strictly mechanical activation system. Due to the recent alteration in design focus, research and engineering analysis have not been carried out on the final concept.

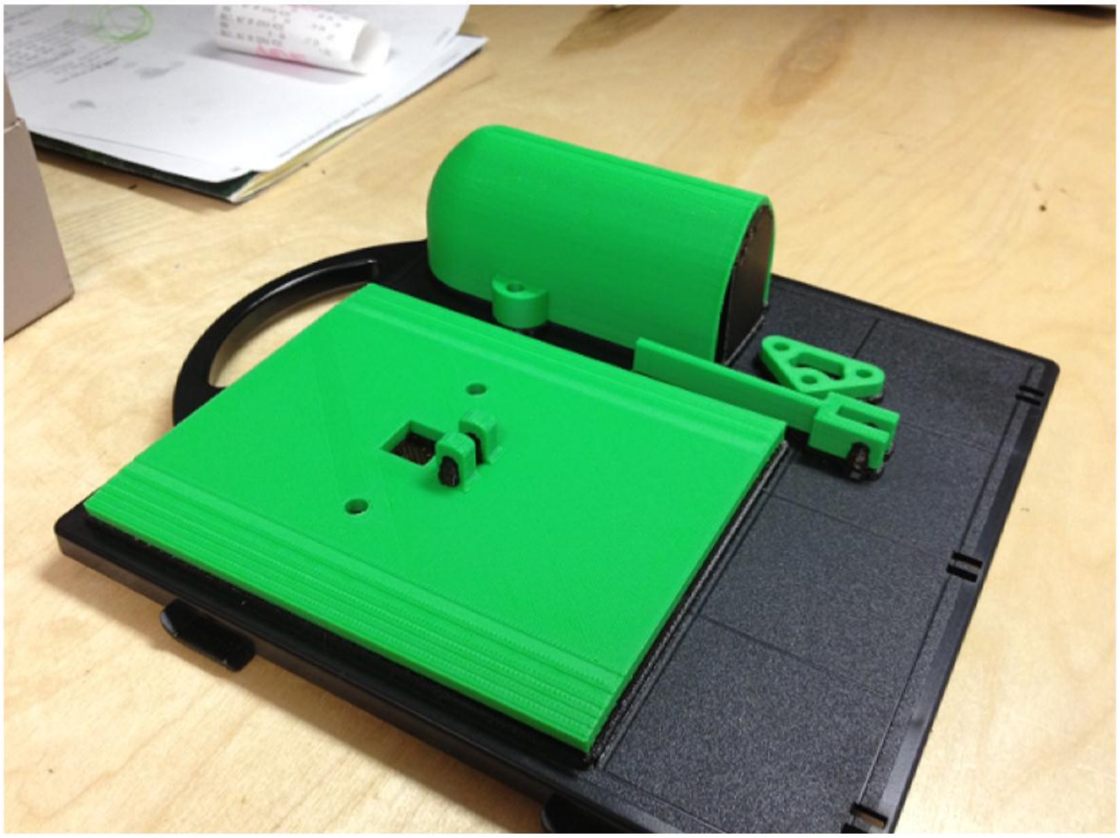

Figure 14: All four pieces after being made using the FDM

The final design concept will however utilize the casing concept and integrate our final activation mechanism design into it. The overall design will feature a mechanical activation system housed completely within the casing. The material settled on at this point (without extensive testing completed, i.e. corrosion tests, stress tests, etc.) is Aluminum 6061. It has a yield strength of 35,000psi and a Brinell Hardness between 60-95. For approximately $50, enough raw materials to produce about four prototype designs of the casing can be obtained. The manufacturing of the casing will be carried out in house by members of the team. Once the final activation mechanism design has been identified, a more accurate cost analysis will be carried out.

Utilizing the casing concept will address several of our objectives while keeping within the constraints. The casing will have a low susceptibility to contamination which will improve the performance reliability by eliminating the likelihood of the mechanism failing as a result of contamination. The elimination of the failure indicates a successful activation of the device which is the ultimate object. As mentioned before, whether the cost of the entire design will be below that of the current design manufacturing cost will be determined after the activation mechanism is determined. Having everything contained within the casing should decrease installation time while still addressing the issues of contamination.

Future Tasks:

Our future task will include the following: finalizing activation mechanism, receive client approval and budget, rapid prototyping, scaled designs, and testing of designs and possible materials. To rapid prototype, the team will be using Fused-Deposition Modeling (FDM) and CNC Milling. Before coming up with our final design that will be presented at the end of the year, the rapid prototypes that the team plans to produce will be scale down. The device and material testing mentioned in the previous section, will be performed throughout the semester and completed before the final presentation. The testing conditions that will be implemented on the design will be the same conditions that are in the constraints of this report. To test different materials for our final design the team will use corrosion, strength, and yield testing. The timeline for these tasks can be viewed in Figure 16.

Project Plan:

Looking at the Gantt Chart in Figure 15, the team kept close to the original dates set at the begin of project, which are viewed by the green bars. The gray bars designate the different sections of our project phase and the time aloud for each section. The actual time spent on specific sections of our project can be identified by the yellow bars. Below in Figure 16 is our projected Gantt chart of our future task.

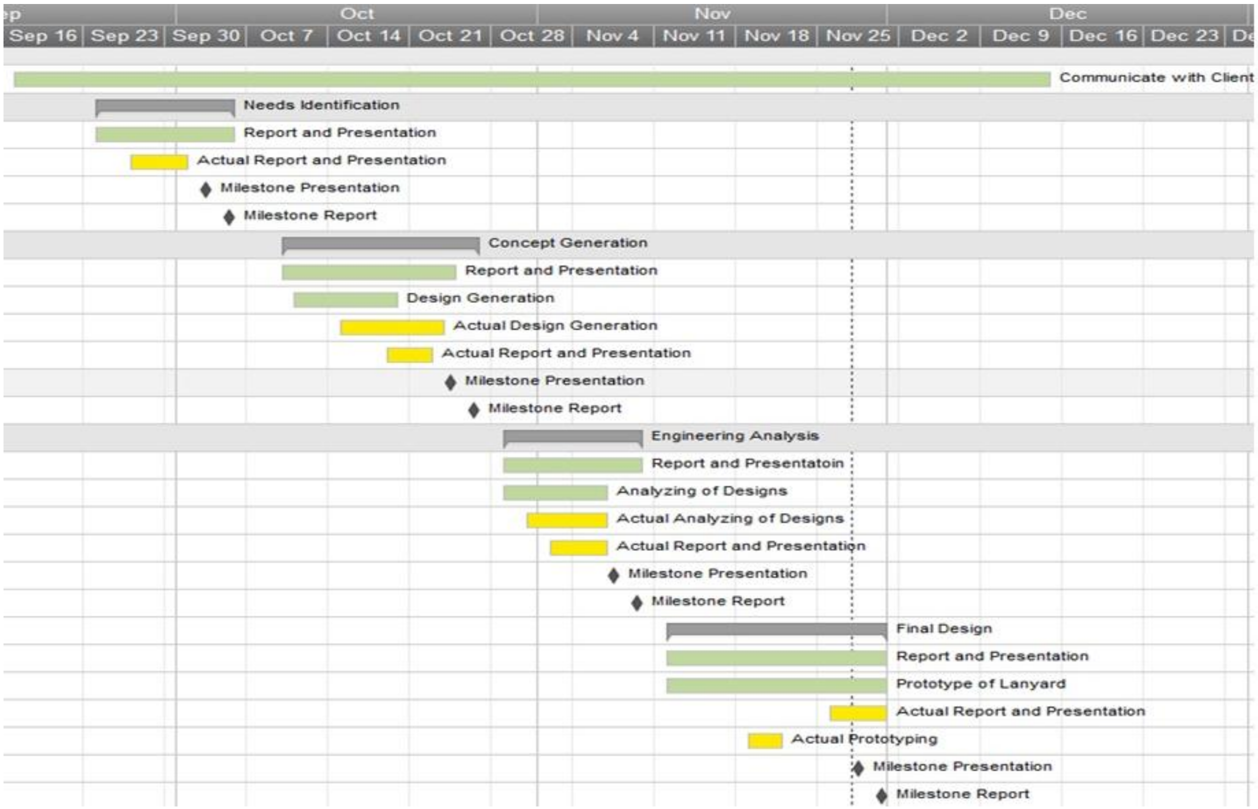

Figure 15: Latest Gantt chart for fall 2012

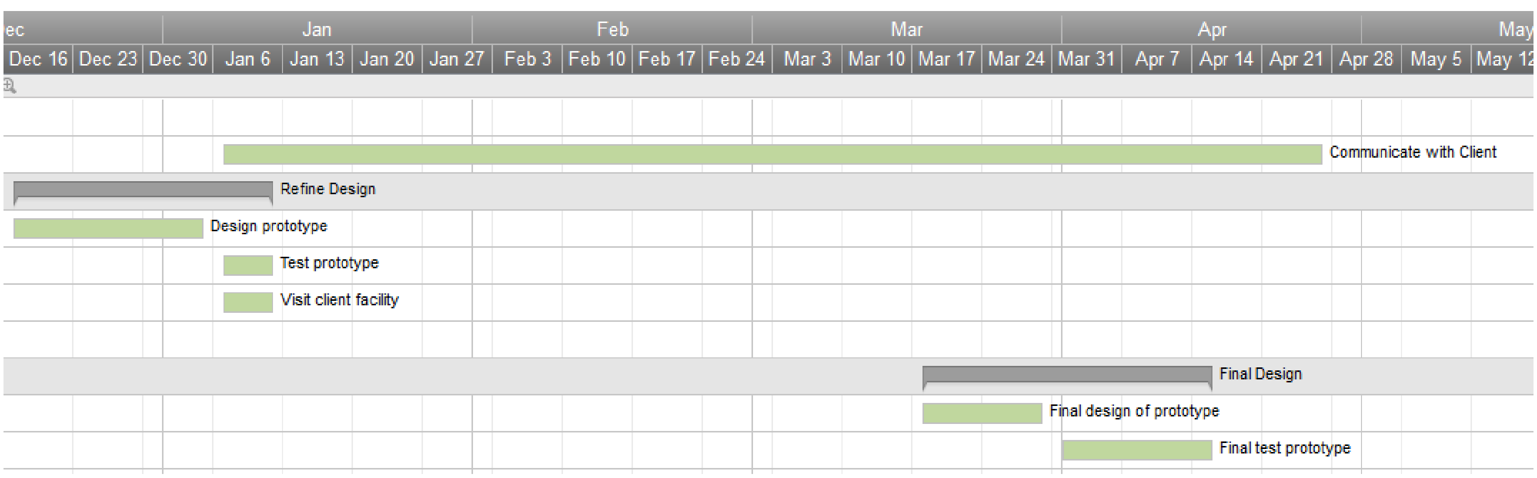

Figure 16: Future tasks planned

Conclusion:

After reviewing the criteria that our customer provided to us, we began our concept generation by determining categories of the release lanyard to be redesigned. We decided on three main categories for redesign which were cable options, cable guide components, and the activation arm. Three separate designs for each category were then constructed. To evaluate these design ideas three design matrices were used to select a final concept. After selecting the final concepts, research and analysis was performed to see if these ideas proved valid.

After carrying out the necessary calculations, the most appropriate final design would utilize a Teflon/Tyvek coating on the current cable. This cable would weave through the current guide pipe system, but include a cap to prevent contaminants from entering the piping. This cable would then attach to a switch slider to activate the weapon.

After speaking with our client, we were informed that the proposed concepts had already been tested or used in the past. Our client chose to keep this information from us since they wanted a new outlook on the project and didn't want to limit our creativity. With this information, the team took a new direction and came up with a design that would involve the activation device to be incasing in a metal housing. The second design that the team came up with was to use a servo in the place of the mechanical activation device currently used. After speaking with our client and professor at Northern Arizona University the team decided to go forward with the casing design. Having already made a prototype of the casing, the team will present this design in the proposal submitted to our client.

References:

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Appendix:

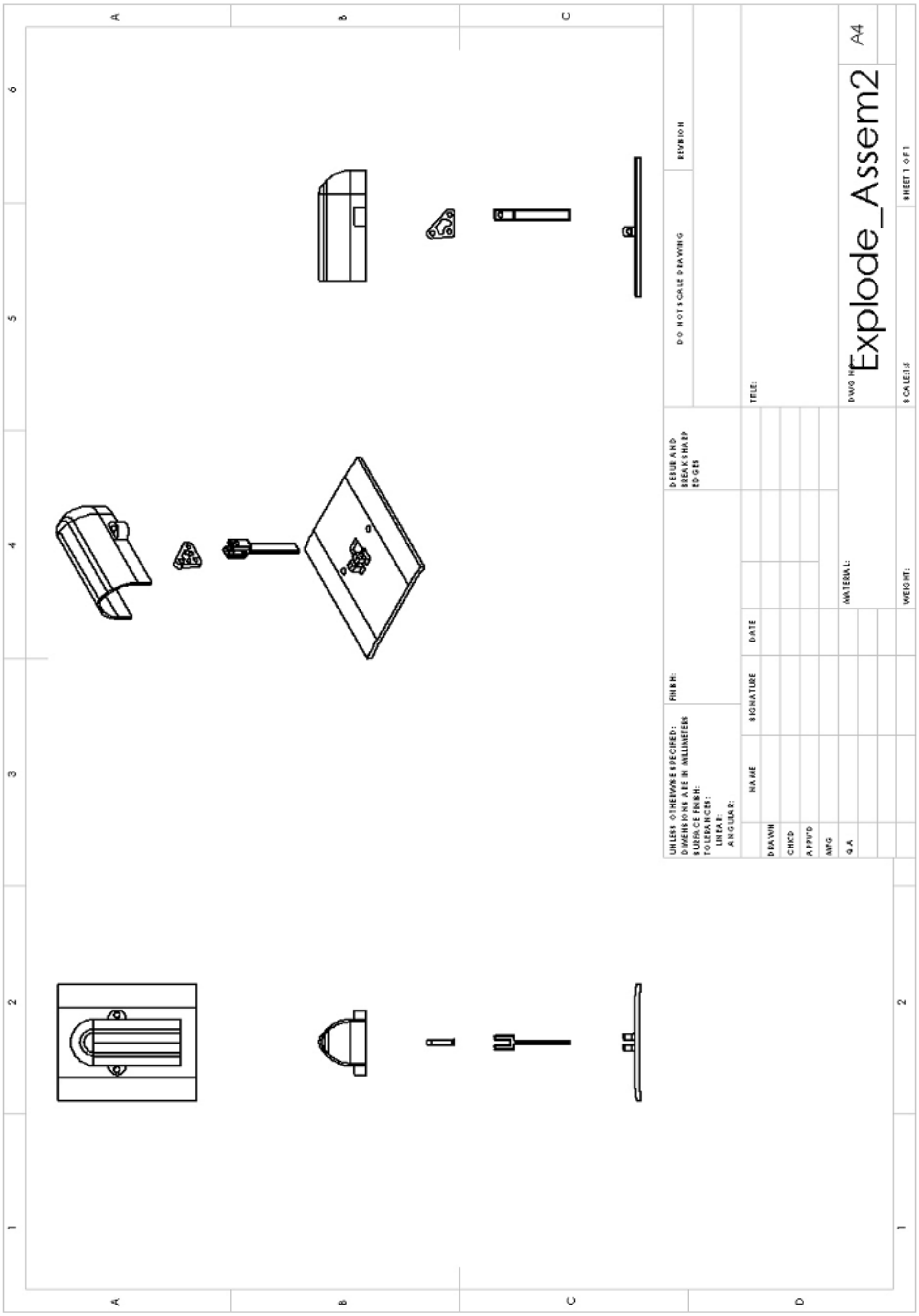

Figure 17: Exploded view of assembly

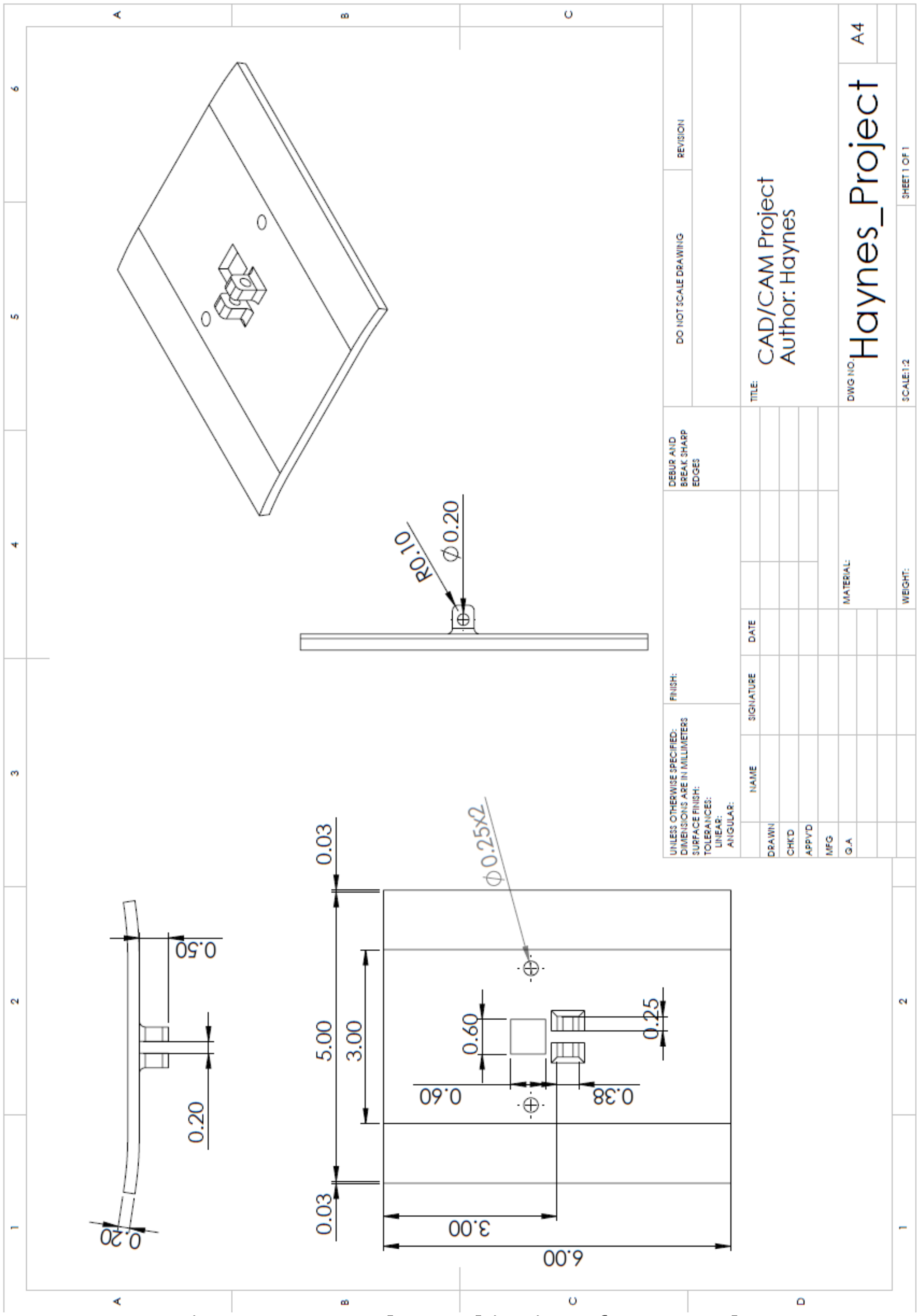

Figure 18: 2D orthographic view of weapon plate

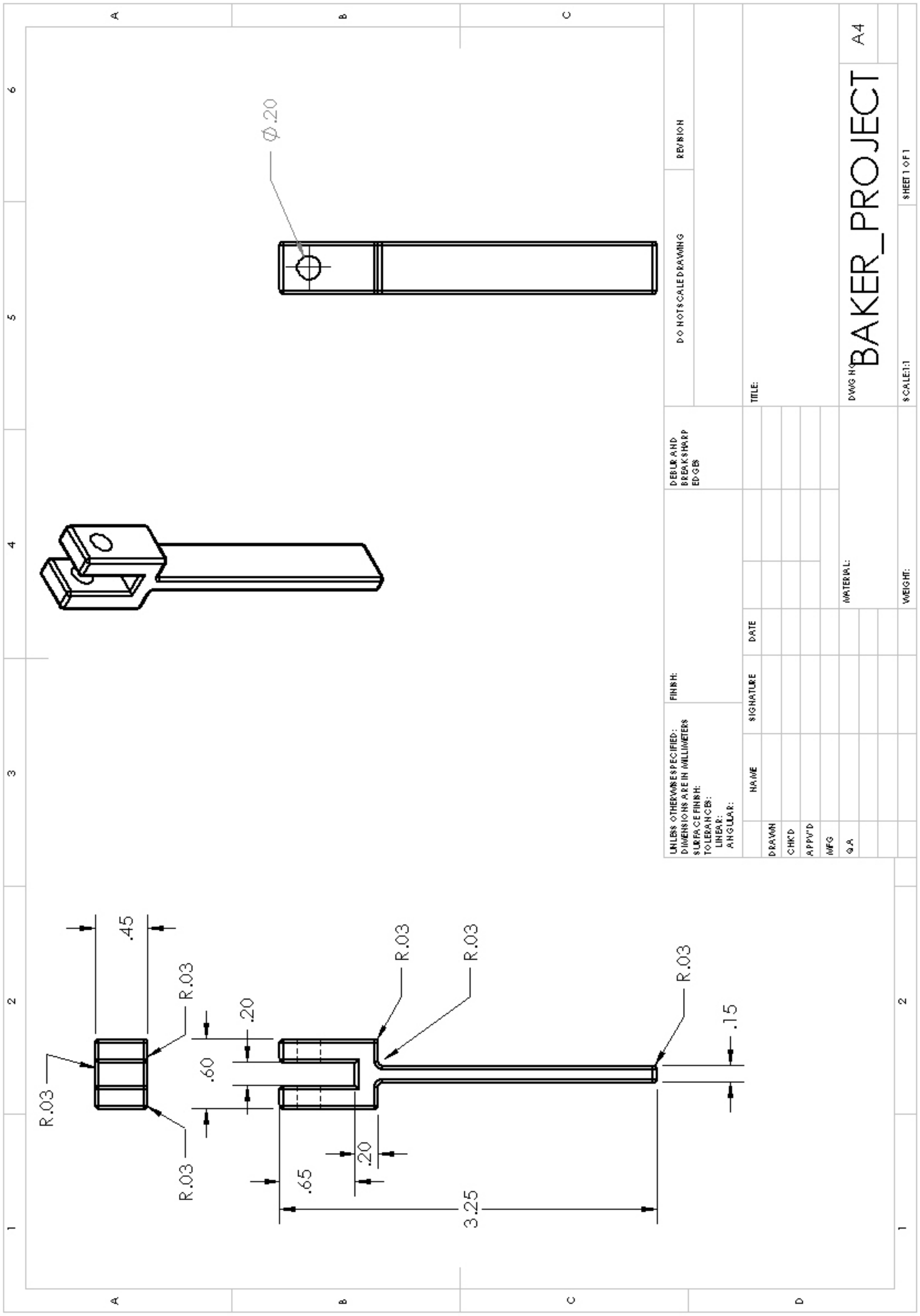

Figure 19: 2D orthographic view of activation arm

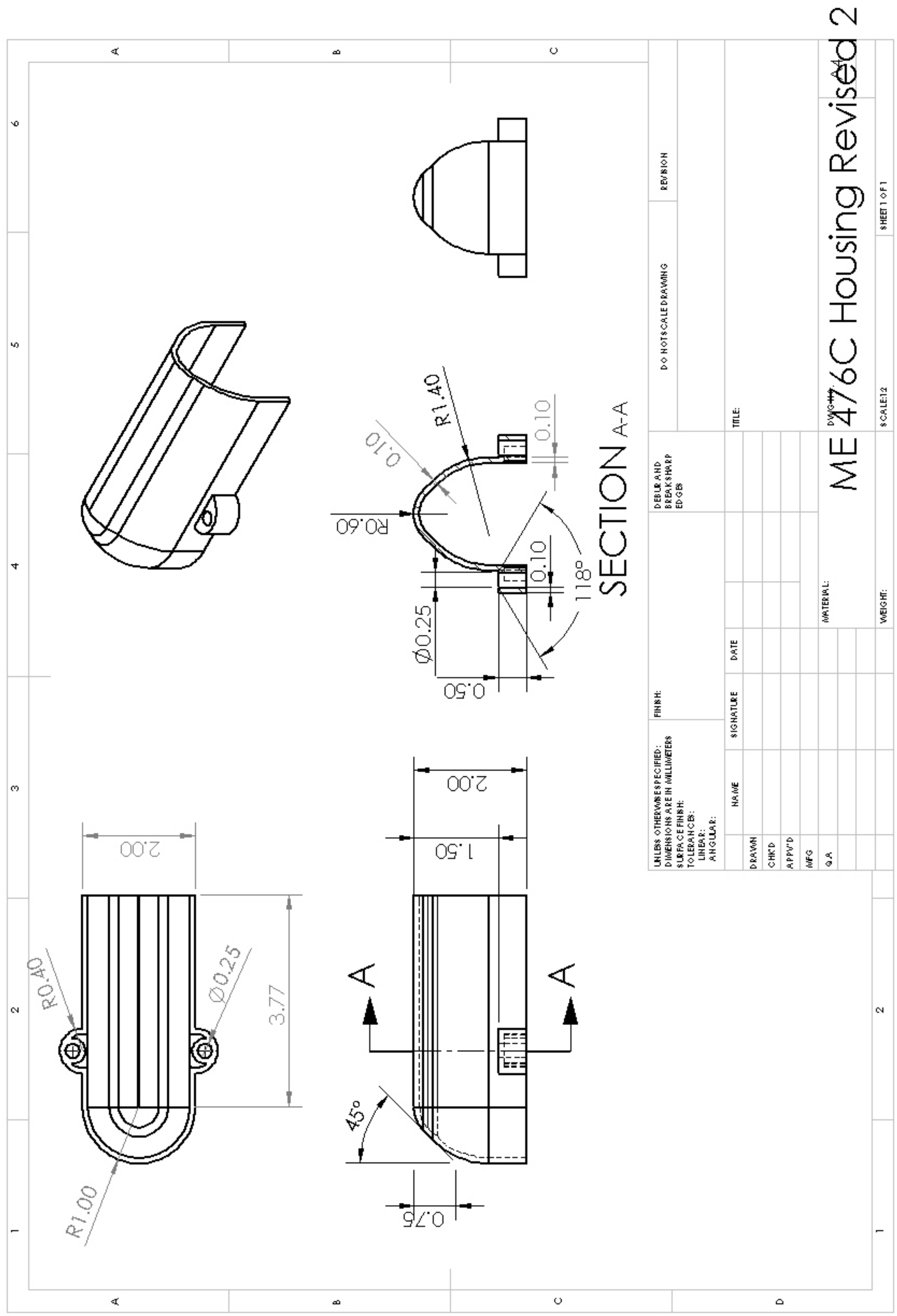

Figure 20: 2D orthographic view of Housing

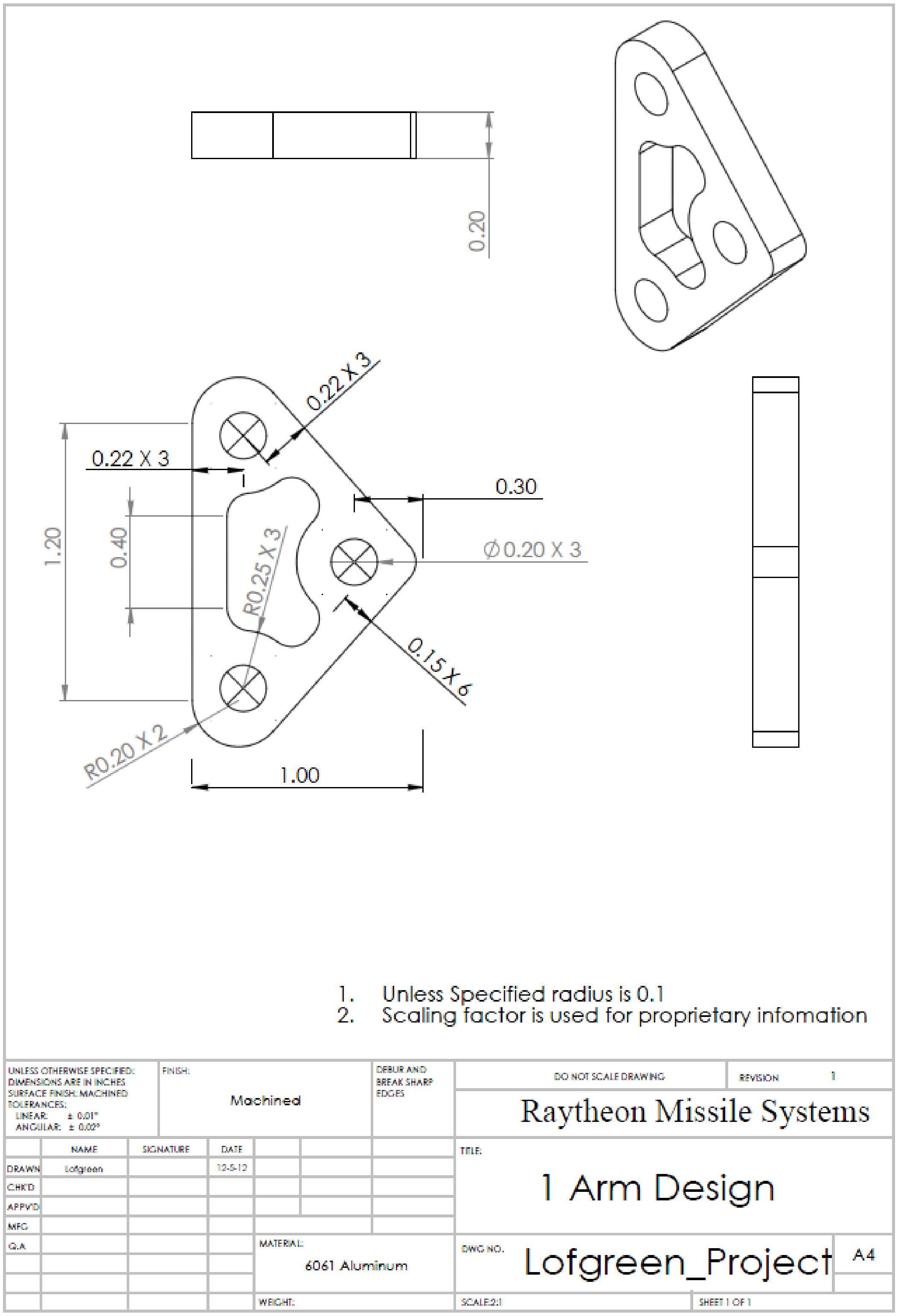

Figure 21: 2D orthographic view of pivot arm

Figure 22: Funnel opening for guide pipe

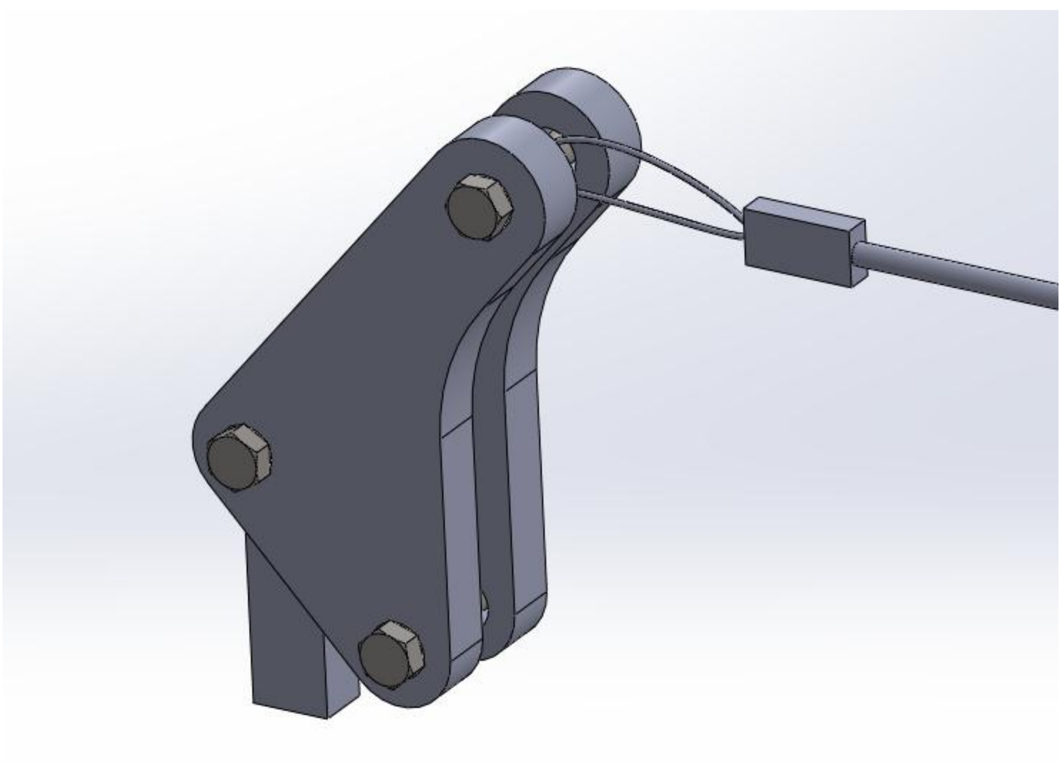

Figure 23: Pivot arm

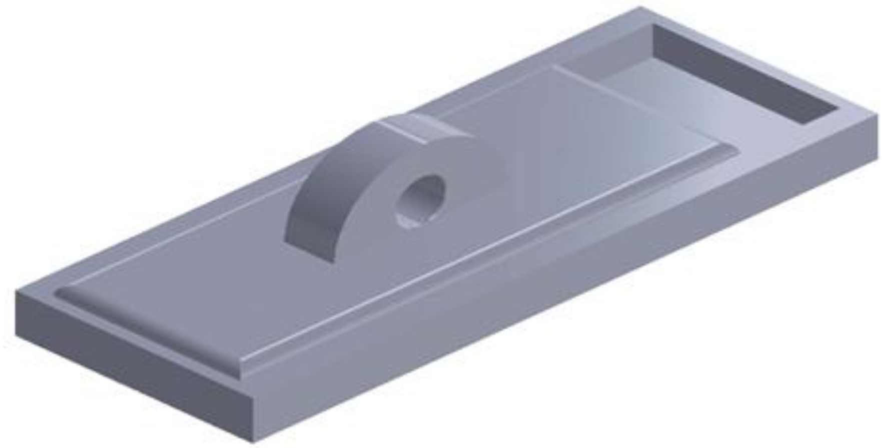

Figure 24: Switch slider assembly