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December 7, 2012

Steve Larimore
Raytheon Company
870 Winter Street
Waltham, MA 02451-1449

Dear Mr. Steve Larimore,

Attached is our final proposal report, which discusses in detail our final design option for your approval. Our team for the Quick Change Electrical Connector has chosen a design that will mate if any misalignment were to occur from the nose and body of the missile and will be able to withstand the prescribed operating conditions.

The material we have chosen is AISI 303 Stainless Steel. We believe this material will provide a good corrosive resistance, as well strength to withstand the forces on the system. The estimated cost of this design is provided by the following list for one unit:

- Material Cost: $7.20
- Manufacturing: $80
- Production Cost: $40
- Electrical Connector: $40
- Total: $167.20

We believe that this design, material selection, and cost is a great solution to self-align the electrical connector and upon your approval we will prototype and test our design. On behalf of the Quick Change Electrical Connector Team I thank you for reading our attached proposal.

Sincerely,

Lauren Campbell

Enclosure: Final Proposal Report

Quick Change Electrical Connection

By
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Team 9

Final Proposal

Document

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

Department of Mechanical Engineering
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Flagstaff, AZ 86011

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1.1 Introduction

Quick change nose assemblies are used for various applications in today's world. Such designs are currently used for things such as Formula1 and Indy race cars. Yet these designs are purely mechanical connections that simply connect the nose to the desired structure and have no electrical components. In this project, our team wants to bridge this gap and create a design that will allow for electronics to be connected as well. This connection would allow our client to mechanically attach a nose assembly to the body of a structure without having to worry if the electrical components are attached correctly, because our design should insure that this happens. This connection should be able to withstand the operating conditions of the structure and provide proper electrical performance through its entire use.

1.2 Background Research

Our client for the Quick Change Electrical Connection (QCEC) is Raytheon Missile Systems. Raytheon is the world leader in design, development and production of missile systems. The company was started over 90 years ago, originally producing household items. During World War II, Raytheon came up an electron tube that could detect enemy aircraft and ships. Raytheon also made the computer that allowed Apollo 11 to be the first successful moon landing. Since then, Raytheon has expanded out into missile production which allowed them to create a branch just for defense contracting, Raytheon Missile Systems.

1.3 Needs Identification

The current electrical connection design for the missile system by Raytheon does not allow for a simple and effective connection between the nose and body of the missile. As the design stands, the electrical connection must be manually connected, which both is inefficient and does not assure that the connection is properly made. This also requires two individuals to work together on the assembly – one to connect the electrical connection while the other holds the nose until the connection is made.

1.4 Project Goal and Scope of Project

Raytheon desires an assembly of the missile nose to the body with only one individual and assurance that the electrical connection is secure between the two components. To do so, the connection must be self-aligning, endure numerous environmental factors without failing, and must not disconnect during use or otherwise compromise the functioning of the missile. The design of the connection is limited solely to a given volume on the bottom inner area of the nose and body of the missile and not the physical connection of the two components of the missile.

1.5 Objectives

The objectives of the QCEC project that the team is trying to accomplish are to make the connection and its zone as cheap as possible, to make the connection last as long as possible before failing, to make the connection easily replaceable or repaired, and to make sure the area is within the approved dimensions. The point of making the connector and its zone inexpensive is to make sure that when it is mass-produced that it doesn't end up costing Raytheon a lot of money. Although the long life may not be as big of a concern since missiles are not reused, they are mass-produced and do tend to sit around for a while beforehand. Making sure the part is easy to replace if it cannot be repaired is also necessary so that a small amount of time is used up changing out the nose cone if needed. The objectives along with their basis of measurement and units used in these measurements can be found below in table 1.

Table 1: Objectives

Objective	Basis of Measurement	Units
Inexpensive	Cost of producing 200 per year	$
Long Life	Time before failure	Years
Field Replaceable	Time taken to replace	Minutes
Easily Repaired	Distance part is deformed	Inches
Size	Area we have to work with	Inches

1.6 Constraints

Raytheon has a specific set of criteria for the Quick Change Electrical Connection to meet in order to function properly. The constraints include operation at:

- A temperature range of -34 to 51 °C
- Sand particle size between 47.7 and 645 micrometers at a concentration of .684 gram/m^3 at a velocity of 25mph

- Dust less than 96 micrometers in size at a concentration of 6.84 ± 3 grams/m^3 at a velocity of 25mph
- Water and ice at 0.7 inches per hour at a velocity of 556 feet per second and with an average droplet size of .045 inches with no failure during icing conditions
- Corrosion resistance to a salt solution with a 3% atmospheric salt solution
- Transportation loads of 19 G's of force
- Bomb rack ejection shock of 32 G's of force
- No material reaction in the presence of JP-10 jet fuel in both its vapor and liquid forms

Physical constraints are also a major factor given by Raytheon. The volume that the connection can be within is 1" by 2.5" by 1.25", which is shared between the nose and body of the missile. Additionally, the connection must make the mating tolerance in order to ensure the connection is made successfully without any doubt and does not affect the physical connection of the two components. The components must have a warranty of 15 years and a service life of 20 years. The overall cost should not exceed $1,000, be field replaceable, and take into account support issues that ensure damage to hardware can easily be repaired.

1.7 Criteria Tree

The criteria tree shows how all of the criteria of the project relate to each other and this can be seen below in figure 1. The size of the zone the group is working in and the lifetime of the missile are independent of the overall design factors. Whether or not it would be easy to repair, inexpensive and easy to replace parts in are all linked to the design of the QCEC.

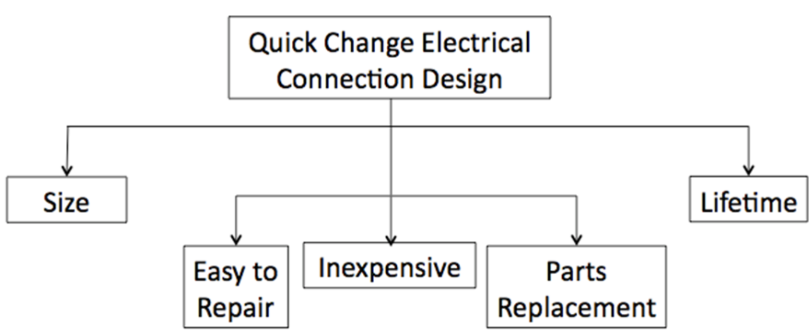


Figure 1 – Criteria tree

1.8 Quality Function Deployment

The quality function diagram shows any positive or negative correlation between each of the engineering requirements. As seen in figure 2, the bigger the connector width is, the more difficult the alignment becomes. Even though the connector has a predetermined size, this is still a valid statement since our group has to worry about breaking off any of the connector pins during the aligning phase. Also, as seen from figure 2, the cost has a positive correlation with everything except the alignment. The higher strength of the material, the bigger size and width of the connector, the higher weight of the missile, the material used, the durability, and the life and add to the cost and make it higher.

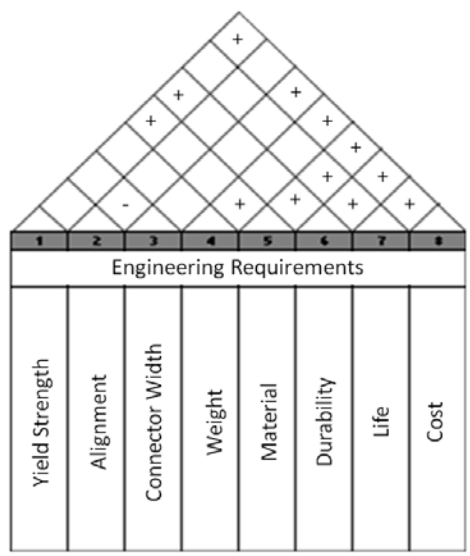


Figure 2 – House of Quality diagram.

2.0 Concept Generation

In this section, the six initial designs will be discussed. Each meet the requirements specified by Raytheon, however some are more plausible than others.

Solid Guided Connection

The first concept of the six unique designs created in our team is the Solid Guided Connection. The biggest part of this design, shown in figure 3, is the self-aligning slant that the connection has, which would allow the chosen port connection to slide into the other half of the connection effectively and automatically. This meets the requirement by Raytheon to have a self-aligning electrical connection that will mate when the nose and body of the missile come together. No matter how far off the aligning of the nose to the body of the unit is, the connection is sure to always align and connect. Additionally, with a gasket or similar material around the outer edge of the connector, as the two parts are mated, the gasket is pushed against the opposing face, making a tight seal immediately next to the connector to avoid contamination by moisture or dust.

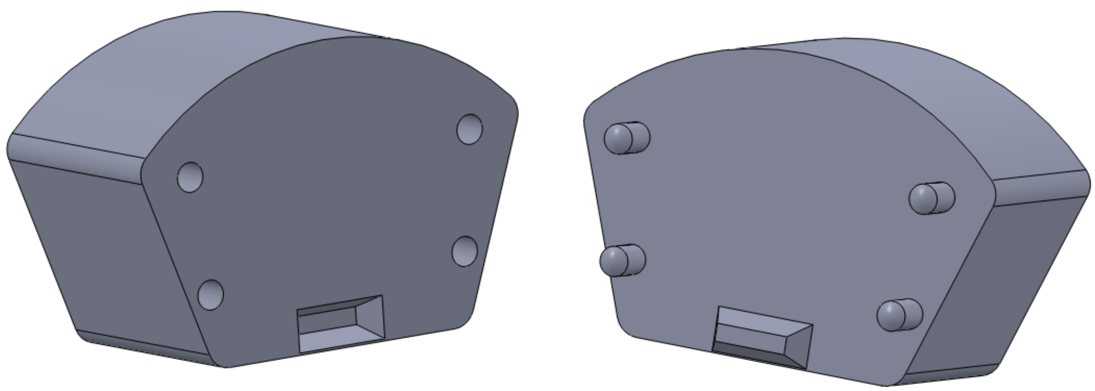


Figure 3 – The Solid Guided Connection

Indented Guided Connection

The second concept generated by the team includes the Indented Guided Connection, as shown in figure 4. This design is very similar to the Solid Guided Connection listed above, but instead of integrating the connection into the alignment guides as in that design, the connection is isolated and the alignment guides are to either side of it.

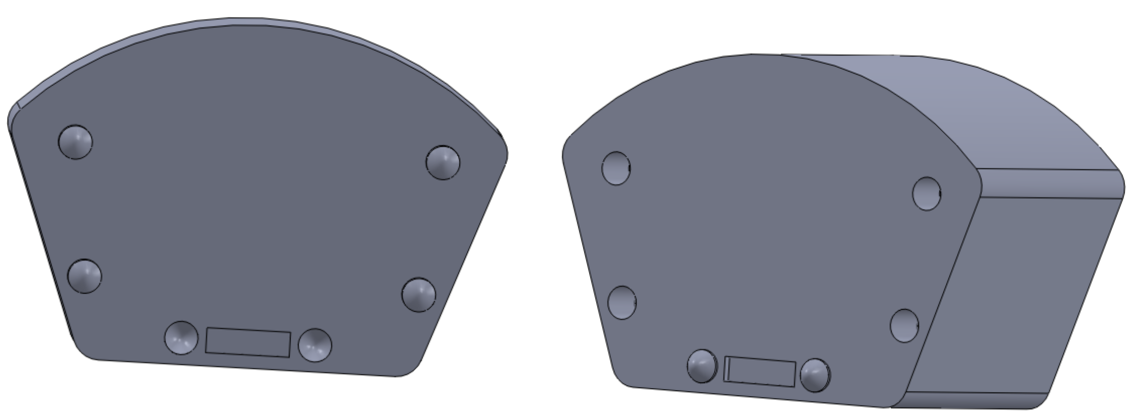


Figure 4 – The Indented Guided Connection

In this design, there are two half-spheres mounted to the nose part of the unit and two indents on the body side of the unit. The use of two spheres to align the connection puts less stress on the parts, including the threat of damaging the electrical connector, due to the mounting of the connections mostly on the body and not on an added part that could break off. Additionally, field repair of this connection is much easier than the first concept due to the usability of the unit. If one or both of the half-spheres break off an easy substitution of another similar part (half-sphere) to use the guides can be made. However, this connection is not as secure as the Solid Guided Connection and does not provide a solid seal between the two sides of the connection to keep out any stray dust or moisture, despite the use of a gasket.

Alignment Flange

This design incorporates a flange that attaches to the back of the electrical connector and the bottom of the connector keep in zones. This design is relatively cheap however, it may deform under high stress situations. Although this design keeps the electrical connector within mating tolerance, it does not ensure perfect alignment if the nose and body were of center. The aspects of the design are in figure 5.

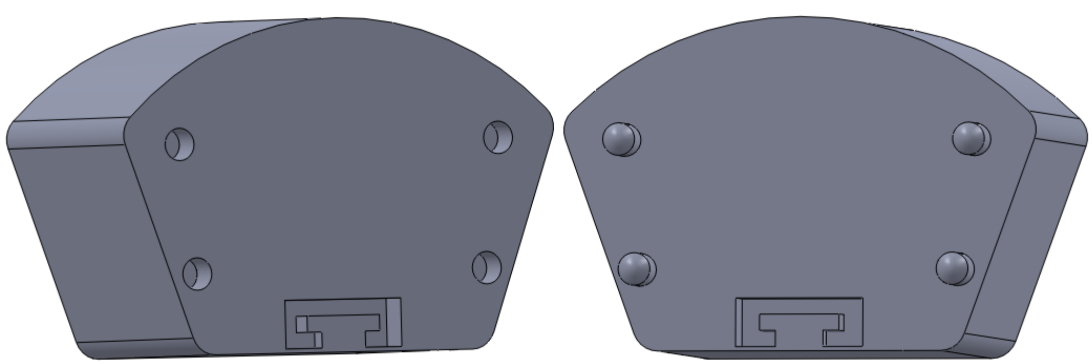


Figure 5 – Alignment Flange Assembly

Stabilizing Bars

This design is optimum for securing alignment in all coordinate directions. However, just like the design before, it does not guide the electrical connector in place, and therefore the nose and body alignment must be perfect. The four bars will be connected to the keep in zone by screws or adhesive, and will be connected to the electrical connector by some form of adhesive as well. This design however, does not do a great job of shielding the wires from any debris that could potential harm the system. The details of the design are shown below in figure 6.

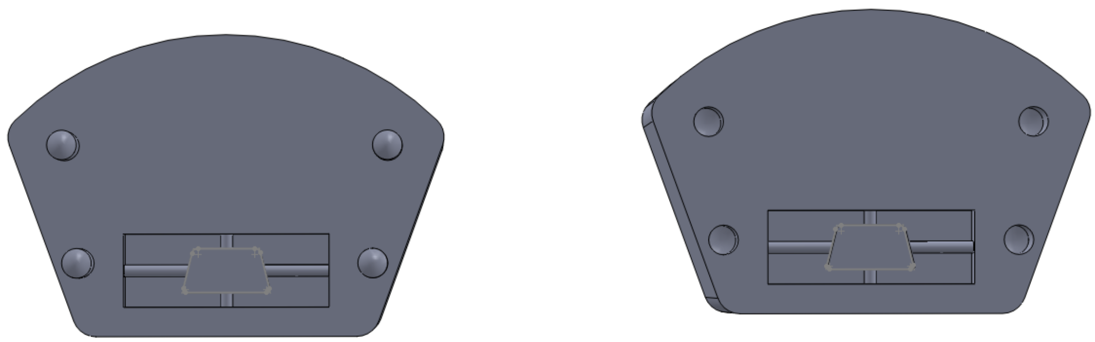


Figure 6 – Stabilizing Bars Assembly

Flexible Material

This design conceals the wiring with a flexible material like rubber to capture any debris that may occupy the system. The material will be held in place by fasteners into the keep in zone, and will prevent any movement from the electrical connector. This allows for maximum mating tolerance.

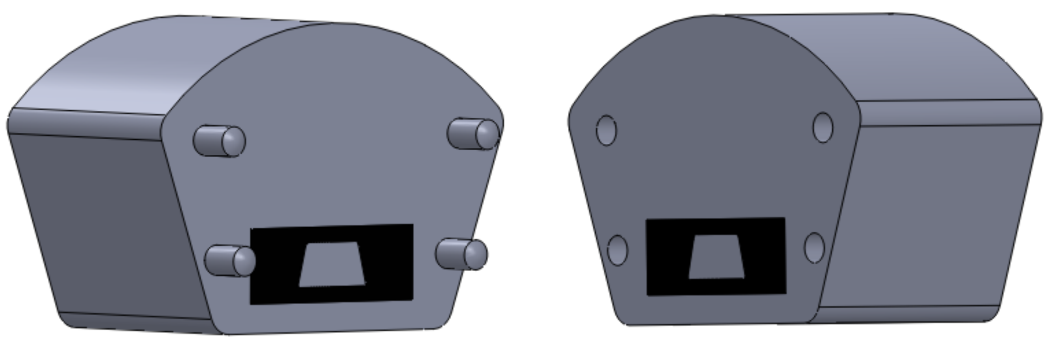


Figure 7 – Flexible Material Front View

Hooks and Fasteners

The final design was developed around the idea to keep the electrical connector in place. The hooks in this design will latch onto the opposing electrical connector securing the mate. This will prevent any separation due to missile movement. The details of this design are shown in figure 8, below.

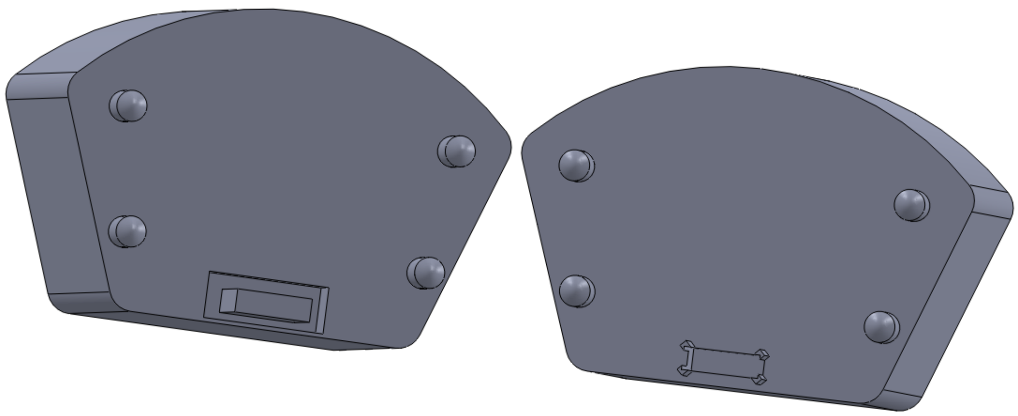


Figure 8 – Hooks and Fasteners Assembly

3.0 Concept Selection

The tables below represent or initial concept selection process. The first step in the process is to define the weights for each of our main categories. The main categories for our project are operating conditions, power loads, cost and maintenance. Table 2 is an arbitrary numerical system that rates the criteria based on relative importance. These numbers where then tabulated in Table 3 to get the pair wise comparison matrix. By using the values in the pair wise comparison matrix, we were able to calculate the normalized values for each of the four categories. The weights are shown in the green column of Table 4 where highest weight value is the operating conditions criteria at 44.5%

Table 2: Numerical Ratings

Judgment of Importance	Numerical Rating
Extremely more important	9
	8
Very strongly more important	7
	6
Strongly more important	5
	4
Moderately more important	3
	2
Equally important	1

Table 3: Pair Wise Comparison Matrix

Criteria	Power Loads	Cost	Maintenance	Operating Conditions
Power Loads	1	7	5	1
Cost	0.143	1	0.333	0.143
Maintenance	0.2	3	1	0.143
Operating Conditions	1	7	7	1
Totals	2.343	18	13.333	2.286

Table 4: Normalized Values and Overall Importance

Criteria	Power Loads	Cost	Maintenance	Operating Conditions	Overall Importance
Power Loads	0.427	0.389	0.375	0.438	**0.407**
Cost	0.061	0.056	0.025	0.063	**0.051**
Maintenance	0.085	0.167	0.075	0.063	**0.097**
Operating Conditions	0.427	0.389	0.525	0.438	**0.445**

Weighted Criteria Tree

Our criteria tree located below shows the relative weights for each of our main criteria that were calculated using the tables above. Starting with the left side our second rated criteria, Power Loads, has a weighting of 40% because we believe that the forces impacted on our alignment devise are crucial to how successful our design will be. Between the two sub categories, Transportation Loads, and Bomb Rack Ejection, Transportation Loads is ranked higher because these loads are throughout any given flight path of the missile, where the loads associated with bomb rack ejection are only once in the missiles lifetime. The next category, cost, is ranked the lowest. Although cost is important, a significantly better design would be worth the cost. Next, operating conditions has the greatest weight. This category was broken down into five sub categories, temperature, sand/dust, water/ice, corrosion, and fuel. All of these conditions must be met and therefore have a high importance but the same relative weight. Lastly, maintenance is broken down into three subcategories: field replaceable, reparability, and life. The life time of the design is weighted the most out of the three sub criteria because our designs must be able to withstand the life of the missile.

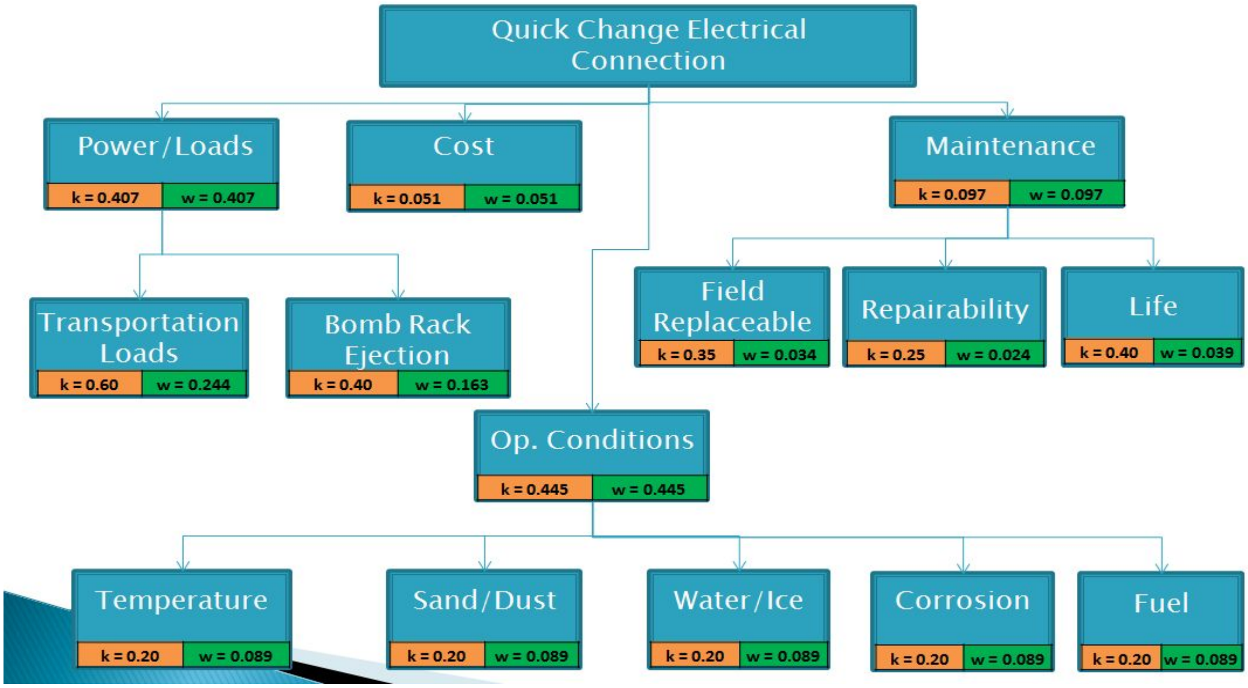


Figure 9 – Weighted Criteria Tree

Decision Matrix

As for our concept selection, the use of a decision matrix allowed the team to match the four major features of the connection versus the six designs mentioned earlier in this report. Power Loads, Cost, Maintenance, and Operating Conditions match against the six designs, with given weights of each category of interest calculated from the calculations in the Concept Tree. Using a rating scale of 1 to 6, with one being the least favorable design for the given category and six being the most, the four categories scaled against the six designs as shown in Table 5 below.

Table 5: Decision Matrix

	Power Loads		Cost		Maintenance		Operating Conditions		Totals
	0.407		0.051		0.097		0.445		
Solid Guided Connection	4	1.628	4	0.204	6	0.582	6	2.67	**5.084**
Indented Guided Connection	1	0.407	6	0.306	5	0.485	3	1.335	**2.533**
Alignment Flange	2	0.814	5	0.255	3	0.291	2	0.89	**2.25**
Stabilizing Bars	5	2.035	2	0.102	2	0.194	4	1.78	**4.111**
Flexible Material	3	1.221	3	0.153	4	0.388	5	2.225	**3.987**
Hooks and Fasteners	6	2.442	1	0.051	1	0.097	1	0.445	**3.035**

Upon scoring each of the six designs, each score was weighted based on the category weight listed above. For example, for the Solid Guided Connection, the score of 4 assigned to the Power Loads category was multiplied by 0.407 to get the weighted score of 1.628 for that category. These weighted values were then added in the far right column labeled "Totals" to achieve a final score for each of the six concepts.

Analyzing the total score for all the concepts, the Solid Guided Connection came out far ahead of the other five designs with a final score of 5.084. Following nearly one whole point behind, the second best concept was the Stabilizing Bars with a score of 4.111. The Flexible Material concept came in third best with a score of 3.987. After that, the Hooks and Fasteners design was our fourth-best design, the Indented Guided Connection was our fifth-best design, and lastly the Alignment Flange was our sixth-best design.

The top three designs, the solid guided connection, stabilizing bars, and the flexible material, will be analyzed in the following section. These designs will be evaluated on their material properties and other engineering aspects to choose our final design proposal.

4.0 Engineering Analysis

The focus for evaluating the materials used in our concepts will be the specified operating conditions that were previously discussed. These are the most important because if the developed design cannot meet all of the given criteria, then it will be considered to have failed. Based upon the different conditions that the design must operate under, the team has comprised a list of material properties that will allow for the final design to withstand these conditions. This list of properties includes:

- Have a low thermal conductivity
- Be corrosion/rust resistant
- High ductility
- High hardness
- High tensile strength

Though for many of these properties there is often a decrease in one when another property becomes higher. Due to this the team is trying to find the best balance in these properties so that the final design can be constructed, and materials chosen, as best as possible. For the previously mentioned design the team decided on a property that is considered highly, if not most, important for that design.

For the solid guided connection it was decided that the materials modulus of elasticity is the most important. This was decided because the team feels that a strong ductile material would fit the needs and goals of this design the best. Two materials being considered that have higher values are carbon and stainless steels, with modulus of elasticity values of 30.0 Mpsi and 27.6 Mpsi respectively. Another material that is being considered is airplane grade aluminum. Though it has a modulus of elasticity value of only 10.4 Mpsi, this material is still being considered due to its other properties, such as weight and ductility.

The power loads in which our design will be operating under are the most important criteria for the stabilizing rods design discussed above. This is because the design must be able to handle the forces that will act on the rods. If the design cannot resist these loads then it will render the design useless in holding the connection in place. To be sure that the design and material selected will be able to withstand these power loads, the team will calculate the axial and normal bending stresses with consideration to temperature effects. From these calculations the team will be able to determine if the design is acceptable for these power loads. This design was later discounted due to the inability to realign if the nose and base were connected out of position.

A most important criterion has yet to be chosen for the flexible material design. This is because of the lack of experience within the team in working with these types of materials. Materials being considered and researched are things such as those with rubber and silicon bases. While these materials will be able to meet many of the constraints that have been put in place, but there are a few constraints that it is unknown to the team if there are any flexible material options that will be suitable. However, this design cannot be used due to the material properties associated with the jet fuel.

5.0 Final Design

Our final design proposal is the solid guided design based on our engineering analysis and our concept selection.

Description

The solid guided design as previously stated is a self-aligning mechanism which allows the electrical connector to mate within the specified tolerance. This allows for any misalignment between the nose and body to still create a good bond between the two electrical pieces. A gasket allows for a tight seal to block any outside contaminants.

Dimensions

In figure 9 below, there are the proposed dimensions to meet the requirements stated above.

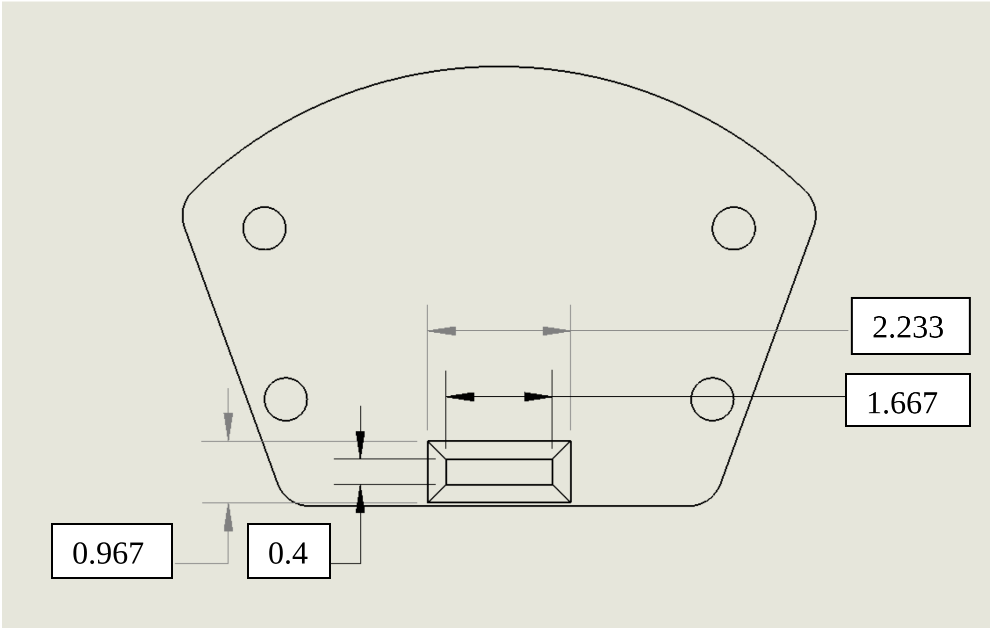


Figure 9 – Final Proposal Dimensions

Material Selection

The material we have chosen is AISI 303 Stainless Steel. This is due to its unique properties that make it optimum for the specified operating conditions. This type of steel is less brittle at low temperatures with a modulus of elasticity of 27.6 Mpsi. It also will withstand the forces on the system with a yield strength of 35 kpsi and ultimate strength of 87.3 kpsi. This material is resistant to corrosion and is able to operate in the temperature conditions.

Cost Analysis

The cost analysis is split up into two sections, what it would cost our team to prototype the design and our predicted cost for manufacturing at Raytheon.

Table 6: Cost of Prototyping

Category	Units	Cost
Material	$3-6 kg	$7.20
Manufacturing	Free (Machine Shop)	
Electrical Connector	$20 per unit	$20
Totals		$27.20

The estimated cost for Raytheon was calculated below, in table 7, for one unit.

Table 7: Estimated Cost Analysis

Category	Units	Cost
Material	$3-6 kg	$7.20
Manufacturing	Man Hours	4 hours ~ $80
Production Cost	Man Hours	2 hours ~ $40
Electrical Connector	Glenair Unit Price	$40
Totals		**$167.20**

This shows the estimated unit cost is under the desired cost as specified per Raytheon's request. This allows for some of the budget to be left for any repairs if needed.

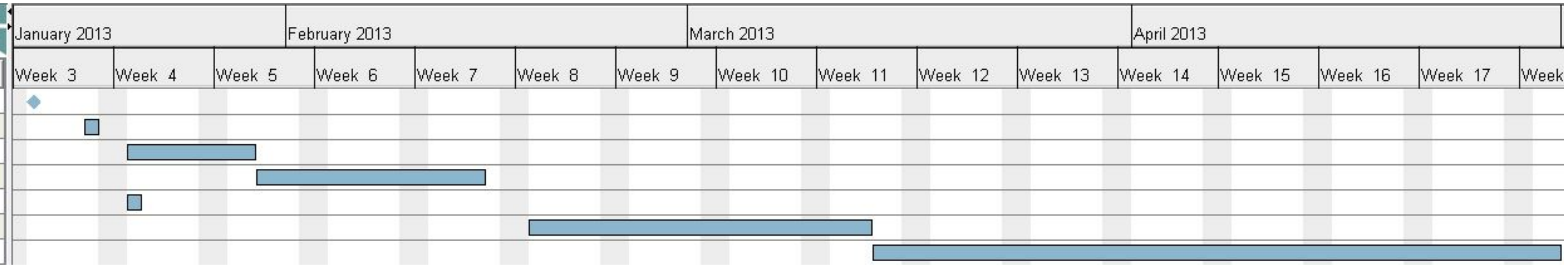
6.0 Future Tasks

Our plans for next semester are to build and test a prototype of our final design following approval from Raytheon. The first step in constructing our prototype will be to obtain the necessary materials for our design. After this will be the actual construction of our design, we will work with the machine shop at Northern Arizona University to accomplish this. The team will then place the electrical connector within the design so that testing can begin. We also plan to build makeshift missile body and nose parts so that basic testing can be as correct as possible. The things the team will be testing are the mating alignment and our design against the constraints that the team is able to perform without Raytheon assistance.

In the early stages of working on the construction and testing of our design, we plan to tour Raytheon's facilities. This will give us insight into the testing environment, and face to face discussions with the Raytheon team. Shortly after this meeting is when we want to have our first prototype built and begin fully testing the design. We also hope to find a solution to connecting our design to the main missile components while performing this testing. This testing will allow us to fix any issues within our design. If any problems arise from the testing, the team will edit our design as needed and begin additional rounds of testing. This process will continue until the team and Raytheon are fully satisfied with our design as well as the design meeting all of the given constraints.

7.0 Project Plan

Name	Begin date	End date
School Starts	1/14/13	1/15/13
Take Tour	1/18/13	1/19/13
Obtain Materials	1/21/13	1/30/13
Work in Machine Shop	1/30/13	2/15/13
Find Solution to Attach	1/21/13	1/22/13
Test Material	2/18/13	3/14/13
Fix Problems	3/14/13	5/1/13



8.0 Conclusion

The Quick Change Electrical Connection project is one in which our team was given the task to develop a design that allows for electronics to be securely connected when the nose assembly is attached to the body of a missile. Our team has been working with Raytheon Missile Systems to accomplish this task. The current design being used by Raytheon requires that both the mechanical alignment and electrical connection are made manually. Our design intends to take out the need to manually make the electrical connection and for it to happen alongside the mechanical alignment of the missile.

Along with developing the design for this, the team has a set of goals that are desired for the design to achieve. The main objectives are for the design to have a long life cycle, for it to be easily repaired and even field replaceable if the design were to fail before its expected life cycle is over. Due to volume restrictions, it is necessary that the design be made small enough to fit into the area provided. The final objective that the team would like to accomplish is to have the design be as inexpensive as possible, while still achieving our other goals. As discussed there are a few constraints that the team will have to work with for these goals to be achievable.

The list of constraints provided to our team by Raytheon Company for this project is very extensive. All of these restrictions must be met before any of our team's goals can be achieved. While being able to fit into the prescribed area the design must have resistance to an extreme temperature range and to very small particles of sand, dust, water, and also ice. Additionally our design should be corrosion resistant and be compatible with the jet fuel currently used at Raytheon. The final constraint of our design is one that will always be a factor; the Quick Change Electrical Connection must be able to withstand large forces from its transportation and bomb rack ejection.

Originally our team came up with six original designs that would meet all of the requirements specified by Raytheon. Though there were a few that would be meet our goals better than the others. Because of this our team developed various charts and methods to determine with criteria and goals were the most important. These six designs were then compared to each other with these charts and methods in mind. This allowed the team to find that the three of our designs would meet the criteria and achieve our goals the better than the others. These three designs were then analyzed against what the team decided would be most important about each design. After this was done it was determined that the solid guided design would be the best choice for our Quick Change Electrical Connection project.

This design is a self-aligning mechanism that allows for the electrical connection to be made when the nose of the missile is mechanically aligned with the body and will meet the mating tolerances. This design will ensure that any misalignment between the nose and the body of the missile will not affect the electrical connection. As of now the team has decided to create this design from AISI 303 Stainless Steel. This is because we feel it will be able to handle all of the constraints and accomplish all of goal as best as possible. The team will be moving ahead with this design upon full approval and will then proceed with our future tasks and project plan.

9.0 References

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[3]. Larimore S, Bliss S, Morzinski M, and Concilio A, 2012, "2012-2013 University Design Project: Quick Change Electrical Connect Project Package," Revision A, Raytheon Missile Systems.Raytheon official website. Web. 3 December 2012.