Fall Final Report

Team # 7

Revision of Lockheed Martin's Human Type Target for Manufacturing

Members:

Joe Nowicki	jdn14
Raymond Lessig	rtl12c
Daniel Kozell	djk12c
Kraig Williams	kmw12g

Faculty Advisor

Dr. Patrick Hollis

Sponsor

Lockheed Martin

Instructor

Dr. Nikhil Gupta

December 5, 2016

Table of Contents

Table of Figures

ABSTRACT

Lockheed Martin desires to produce a human type target system, resembling a human in size, shape, and appearance, which will react appropriately to being hit with small arms fire. This will be done via hit sensors on the target, which will be able to detect vibrations caused by a bullet being fired into the target. The target itself will be a commonly available mannequin, sold for use specifically as a small arms target. Seeing as the mannequin is indeed commercially available, and the fall mechanism itself has already been invented by Lockheed Martin and is currently patent pending, Team #7 is tasked with revising the prototype and making improvements on it to bring it to a production ready state. This will include designing, at a minimum, a stand for the target, an interface plate between the target and stand, interface adapters, and a test stand to activate the fall mechanism. The final outcome of this project will be an operational human type target which will fall when hit with an appropriate sequence of small arms fire, including ready for manufacturing designs of the aforementioned components. Team #7's prototyping components have been designed and analyzed and are soon ready for production and testing.

1. Introduction

Lockheed Martin has begun to take action with the final goal of producing a human type target system, resembling a human in size, shape, and appearance, which will react appropriately to being hit with small arms fire. Lockheed Martin already has a patent pending on a fall mechanism which they desire to use, and the mannequins which will be used for the target are commercially available as targets for law enforcement and military applications. The mannequin comes already equipped with a hole by which can be mounted to a simple 2x4. Consequently, Team #7 has been tasked with redesigning the stand, interface plate, and 2x4 adapters for manufacturability. These will be designed in such a manner as to facilitate performance up to the standards and constraints given by Lockheed Martin concerning the final product.

Since this product is to be manufactured for mass production by Lockheed Martin, the design team must consider the basic rules of design for manufacturing and design for assembly. Additionally, the team has target prices for each of the pieces. Producing in batches of 100, the cost of the interface plate is not to exceed $50/each, the 2x4 interface adapter is not to exceed $25/each, and the stand is not to exceed $70/each. Lockheed Martin has provided an early wood-based prototype for the design team to use as a starting point for their progression.

2. Project Definition

Lockheed Martin has produced a human type target system, resembling a human in size, shape, and appearance, which will react appropriately to being hit with small arms fire. This is done via hit sensors on the target, which will be able to detect vibrations caused by a bullet being fired into the target. Lockheed Martin is now ready to move the product to a production ready state and has asked Team #7 to redesign the prototype for manufacturability.

2.1 Background Information

Military and law enforcement departments all over the world use a variety of human-like targets in order to provide effective, realistic combat training to their personnel. Aside from the shape and size provided by human-like targets, a great deal of development has been done to make them react to ballistic impacts and indicate accurate marksmanship from the shooter. Enhancing combat target training even further requires that targets not only indicate impacts, but also accurately respond to the different magnitudes of damage, further demonstrating the lethality of the firearms utilized. Currently there are a number of different products seeking to meet this level of simulation.

2.1.1 Rubber Dummies

Rubber dummies are generally 3D models of a human torso characterized by their ability to withstand a significant amount of repeated damage with their self-healing properties. Contacting bullets are allowed to pass through the material while also leaving an indication of the impact location on the outer skin. This skin can be replaced between simulations or shooting sessions to give the marksmen a clean target to only indicating his/her immediate hits (shown below in Figure 1) [1].

Figure 1: Rubber dummy with impact indication [2]

2.1.2 Reactive Stand Targets

Other targets commonly used for law enforcement training, specifically SWAT team members, react to a certain amount of hits by falling backward slightly to simulate a neutralized target (Figure 2). These models are made of a self-sealing poly urethane compound that is designed to withstand anywhere from 5,000 to 10,000 live rounds. These models are also helpful for “Shoot/No Shoot” drills and can be customized to different appearances and sizes. They do not, however, indicate the specific impact locations without inspecting the target up close [3].

Figure 2: Reactive dummy representation showing fall-down mechanism [3]

2.1.3 Autonomous Robot Targets

Combining the effects of the reactive fall-down targets with simulated target movement, robotic targets have been manufactured for more authentic marksmanship training. These targets also utilize self-sealing materials to prolong the target life, while also neglecting to indicate a specific impact location. To make up for this potential shortfall, the dummies are designed with integrated sensors in specific locations termed “kill zones”. These sensors, when triggered, communicate with the fall-down mechanism to cause the target to tilt backward. After a set amount of time, the target will reset to its upright position while continuing its autonomous movement for continuous target practice [4].

Figure 3: Robotic dummy with integrated fall-down mechanism upon “fatal” ballistic impacts

2.1.4 Injection Molding

Lockheed Martin would like Team #7 to design two components of this human type target so that they can be manufactured using injection molding. These components are referred to as the interface plates and 2x4 adapters.

Injection molding is simply the shaping of rubber or plastic articles by injecting heated material into a mold. With this process, there are several conventions in which Team #7 plans to follow when designing the specified components. A visual is provided below in Figure 4 to aid in the description of some of these conventions.

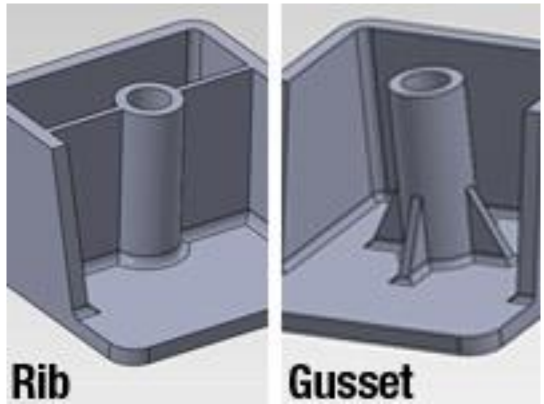

Figure 4: Ribs and Gussets

The figure above provides a visual aid of the components that are important to be considered when designing something for injection molding. One of the major ideas to keep in mind when designing for injection molding is that the thickness of the part designed must remain relatively constant. At the same time, the wall thicknesses should remain pretty thin; around 1/8” is fairly common. This can result in issues when attempting to provide good strength to thin plastic parts. This is where the use of ribs and gussets comes into play.

A depiction of a rib design is shown to the left of Figure 4; these ribs serve as structural supports that extend out from the walls of the design to provide strength. The convention Lockheed Martin uses when designing injection molding is that the base thickness of a rib is 60% the nominal wall thickness. The ribs are also design with what is referred to as a draft angle; a draft angle allows the part to easily be removed from its mold once it is set. A picture showing draft angle as well as several other common standards can be seen below in Figure 5.

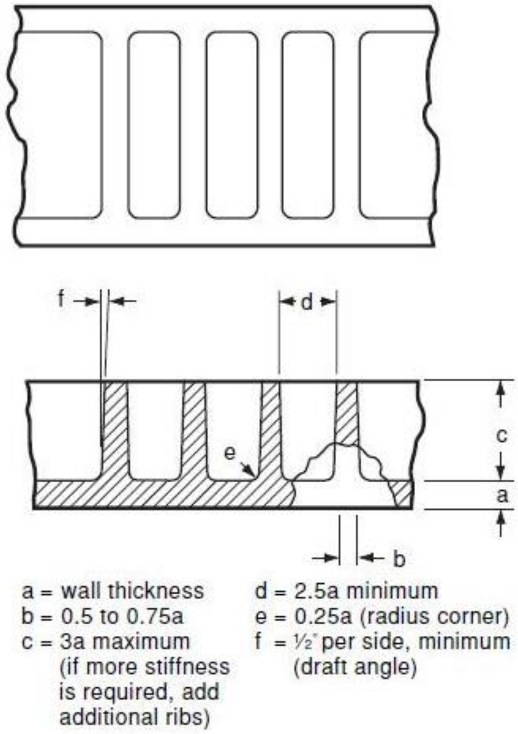

Figure 5: Picture showing good rib design standards

These standards will be considered and implemented into Team #7's designs moving forward. Furthermore, gussets (shown right in Figure 4) are used to support locations in which bolts or screws would be attached to a part. They also serve as a method of support to strengthen the area without causing a large increase in wall thickness. Gussets are also designed with a base thickness of 60% the nominal wall thickness. The Design Selection section of this report will touch on how exactly these standards are applied.

2.2 Need Statement

Lockheed Martin desires to move forward with a design for a Human Type Target (HTT) System, utilizing a commercially available mannequin and ensuring that it falls appropriately when hit. In order to bring this product to market, Team # 7 has been tasked with designing and preparing the interfacing components and stand for manufacturing as well as enhance the mobility of the target. The team needs to prepare these components for manufacturing, ensuring their durability as well as keeping their mass production costs below the given values. Finally, Team # 7 needs to test the device under the various conditions, including gunfire, to determine the suitability of the device to meet these needs and requirements.

“Lockheed Martin’s current human type target system is incomplete and requires further design for manufacturability and durability.”

2.3 Goal Statement and Objectives

“The goal of this project is to revise a prototype human type target system, that falls automatically when hit with a series of lethal shots, and take it to a production-ready-state.”

Objectives:

- Stand-to-Target Interface Plates
- Interface Adapters
- Target Stand
- Test Stand to Activate the fall mechanism (electrical/firmware interface needed)
- Stand to be movable by 1 person
- Stand to take up no more floor space than 2ft x 2ft and mannequin
- The interface plate, adapter, and stand shall be capable of surviving no less than 1000 target drops.
- The interface plate, adapter, and stand shall be capable of being exposed to the elements
- Items above 6” from the floor shall be made of non-ricocheting material (e.g. plastic) or shall be protected in a way such that bullets will not ricochet back to the shooter (e.g. bullet guards).

Figure 6 below provides a visual for the main components mentioned above:

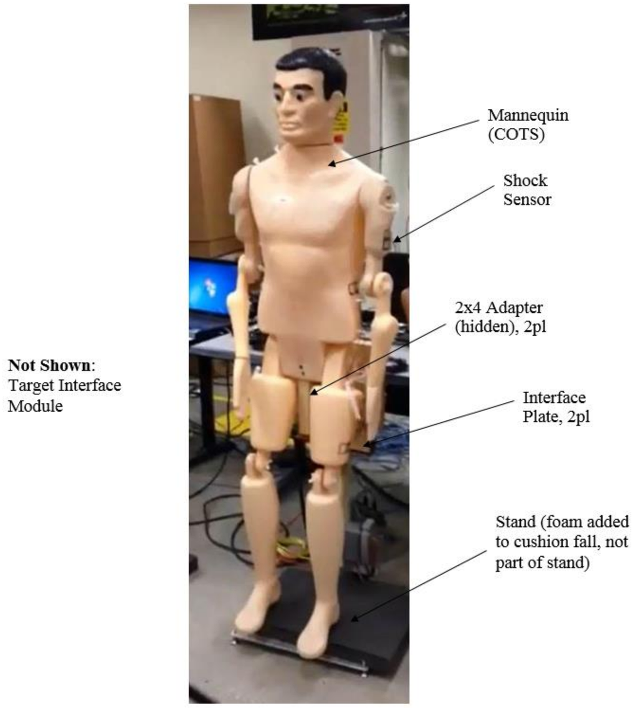

Figure 6: General layout of current prototype with main components noted

2.4 Constraints

As with any project, there are a whole host of constraints which apply to the design and construction of the human type target system. The majority of these constraints have been provided to Team # 7 by Lockheed Martin. The stand must be able to be moved by one person, according to MIL-STD-1472 [Appendix A, page 147]. This same stand must not take up more than a 2ft x 2ft square of floor space for the footprint, as well as necessarily interfacing with the Lockheed Martin Target Interface Module, dimensions and sizing of which will be provided at a later date. The stand must be able to withstand direct hits from 5.56mm, 7.62mm, and airsoft ammunition without toppling, either during the hit or the sequence which involves the fall mechanism. While the 5.56mm NATO round is very small and carries relatively little energy, the 7.62 NATO round (also known as 7.62x51mm or .308) carries significantly more force. These same three rounds must trigger the fall mechanism. Seeing as an airsoft round carries so little energy, it is crucial to note that the mechanism must be very sensitive, while also rugged enough to withstand the forces of the 7.62 NATO and the rapid fire nature of the 5.56 NATO round. In the same vein as ruggedness is the lifetime criteria—the interface plate, adapter, and stand must be able to survive at least 1000 target drops before failure. Due to the varying conditions in which the system shall be deployed, it is also crucial that all components are able to withstand various harsh environments, ranging from the heat and dryness of Saudi Arabia, to the freezing cold of Alaska, to the salt air and humidity of coastal regions across the globe. While many of the materials shall be chosen by the design team with a relatively high level of freedom, safety is still a concern. Since bullets tend to ricochet upon contact with metal, any and all components which will be more than six inches above the ground shall be made of a non-ricocheting material, such as plastic, or covered with an appropriate guard in order to ensure the safety of the operators and prohibit a bullet from ricocheting back into the shooter.

3. Methodology

3.1 House of Quality

Customer Requirements	Priority	Weight	Interchangable Parts	Sensor Protection	Stand Design	Material	Ease of Production	Ease of Assembly	Size of Stand
Performance	5	3		9	9				
Ease of Repair	4	3	9		3	9		9	1
Stability	5	9			9				9
Environmental Adaptivity	3			3		9			
Manufacturability	4	1	9		3	3	9	9	1
Cost	4	1	9		3	9	3	3	3
Mobility	3	9			3			9	9
Safety	5	3		3	9	9			1
Bullet Resistant	5			9	3	9			
Durability	4	1		3	3	9			1
Priority		3	5	3	5	5	3	4	2
Absolute Weight		20	27	27	45	57	12	30	25
Relative Weight		60	135	81	225	285	36	120	50
Relative Importance		6	3	5	2	1	8	4	7

Figure 7: House of Quality representation of different project aspects and relative importance

This House of Quality (Figure 7) allows one to assign a value to the relationship between the customer's needs and the design requirements; by doing this, Team #7 was able to rank the most important aspects of the design. Each customer requirement was given a priority based on the importance given by Lockheed Martin. The ability for the target to fall using the patent pending latches is the main function of the project, hence it was given a priority rating of 5. This goes along with the stability of the mannequin and stand, since if the stand is not stable when being shot impedes the function of the target it was also given the highest priority rating. Safety was given the upmost priority, along with bullet resistance, as well because it was stressed by Lockheed Martin that this target not ricochet bullets to avoid injury to the shooter.

The customer requirements were correlated with the engineering characteristics deemed important to Team #7, 1 being the least correlated and 9 being the most. For example the materials chosen in the design have a high correlation with the environmental adaptability of the target, therefore it was given a correlation of 9. This allowed relative importance to be found with giving priority to each engineering characteristic. It was found that the most important aspect to keep in mind while designing the different components of the target system is the material chosen, followed by stand design and interchangeable parts respectively. This makes sense because the material chosen will greatly affect many different customer requirements presented by Lockheed Martin, including two of the highest priority requirements, safety and bullet resistance. Stand design will clearly be one of the largest aspects of this project because it includes all of the stand, adaptors and interface plates. These components make up almost the entirety of the design work and will be where much of the cost comes from and directly impacts the performance of the target. Overall, this house of quality clearly states the most important aspects of this project and gives Team #7 an idea of where to start.

4. Design Selection

4.1 Interface Plate Designs

There are two interface plates present on the current prototype; these are shown below in Figure 8. The arrow on the left of Figure 8 points to the interface plate that connects to the mannequin and the arrow to the right points to the interface plate that connects to the stand. The objective is to create two identical interface plates that can connect to the mannequin and stand. Some of the current issues are binding in the latches as well as difficulty setting the mannequin back up once it has fallen. The binding in the latches comes from torque on the bolts that support the mannequin's weight. Potential solutions to this include better distribution of weight as well as better support for the interface plate. The main reason setting the mannequin back up is difficult is because it is hard to accurately align the bolts with the latching mechanism. Guides will be added into the design to allow the bolts to be more easily set.

The interface plates have gone through several stages of design. For the purposes of this report, Team #7 will briefly discuss two preliminary designs as well as the final selected design which will be 3D printed for testing purposes in the coming weeks.

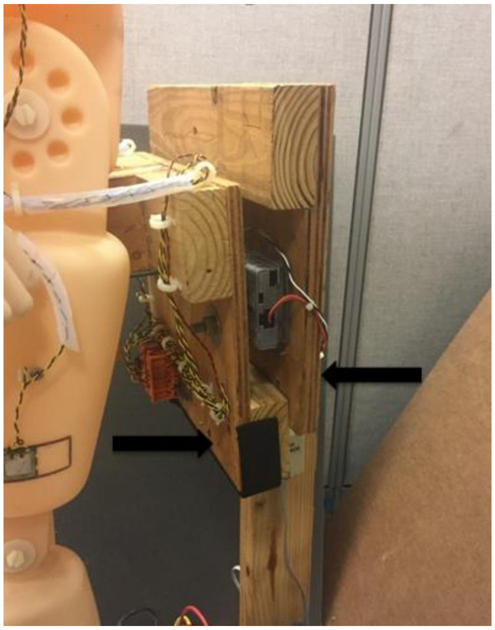

Figure 8: Human Type Target prototype (interface plates)

4.1.1 Interface Plate Design A

The following figures represent a rough drawing of the first design Team #7 came up with, Design A. This design was very simple with minimal features built into the mold itself. The approximate dimensions of Design A were 14in wide by 10in tall.

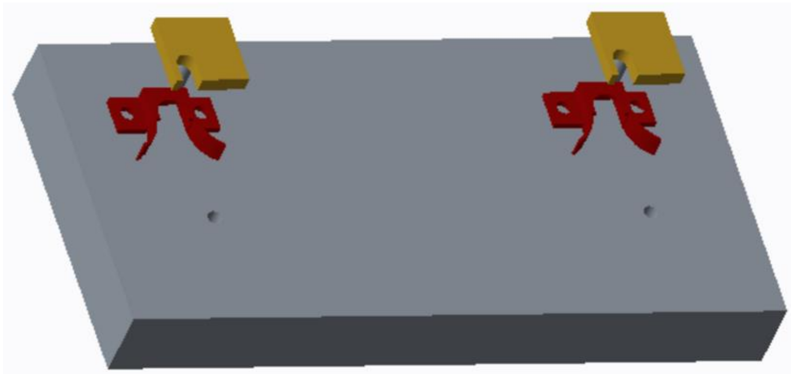

Figure 9: Interface plate Design A with latches and guides attached

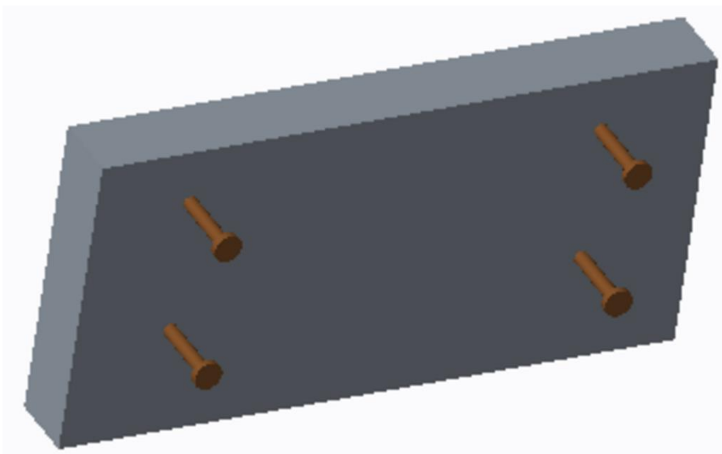

Figure 10: Interface plate Design A with bolts attached

The idea of this design was to have two clips (red in Figure 9), which serve as guides for the bolts (shown brown in Figure 10) to help the latches get set. The upper two bolts would get sent into the latches while the bottom two bolts would serve to hold the two plates parallel to one another.

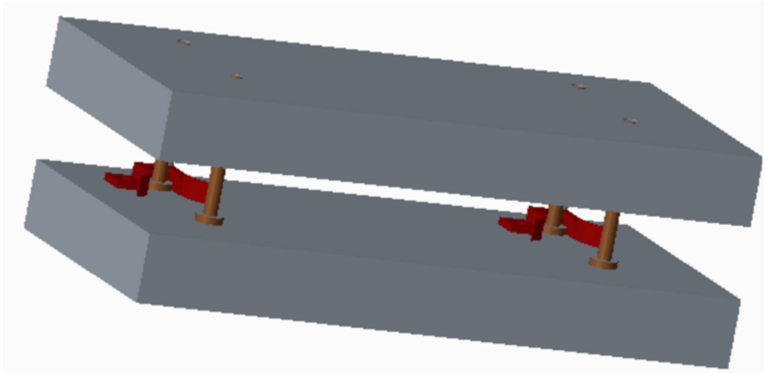

Figure 11: Interface plate Design A assembly

The full assembly of Design A is shown here in Figure 11. Design A was a very simple approach to solving Lockheed Martins problem. While a simple solution is good, this solution had several pressing issues that needed to be addressed.

One issue with this design is that it is not designed with injection molding in mind. The base thickness is too large and would likely result in warping of the material. Another issue with this design is that Lockheed Martin wants minimal assembly required. This design requires several of the major features to be assembled after the part is removed from the mold.

4.1.2 Interface Plate Design B

Concept Design B (shown below in Figures 12 and 13) is another design for the interface plate that did not quite meet the full needs Lockheed Martin set forward. While this second design incorporates many features that are pre molded in, as opposed to needing assembly, it is also not designed with injection molding in mind. This design would not be possible to injection mold in its current state and also does not practically allow the two plates to mesh together fully.

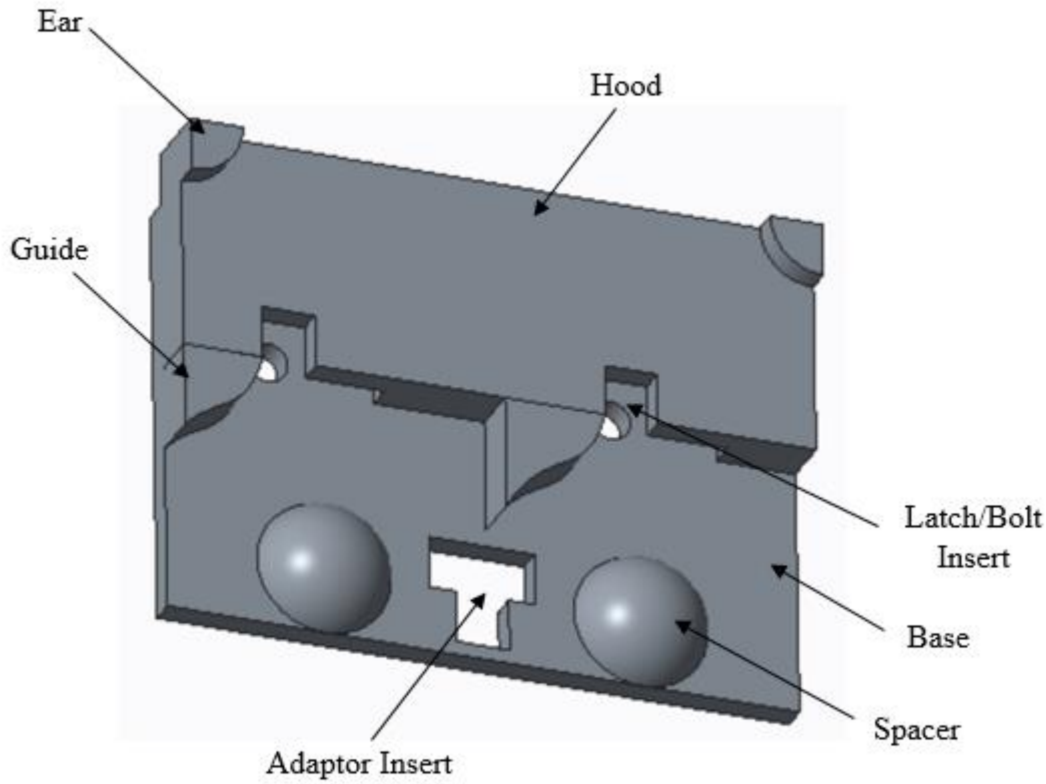

Figure 12: Interface plate conceptual Design B (front view)

The idea with this design was that that guides previously found in Design A are now built into the mold of Design B. Similarly, the bolts used to hold the plates parallel in Design A have been replaced by the Spacer in Design B.

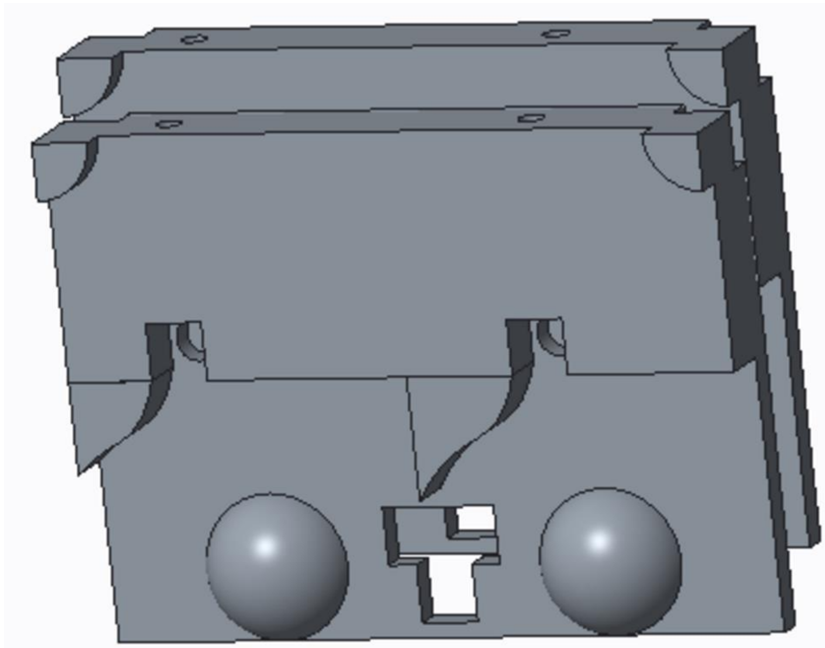

Figure 13: Interface plate conceptual Design B (assembled view)

Figure 13 shows the full assembly of Design B and how the plates would mesh together.

4.1.3 Selected Interface Plate Design

Taking into consideration the advantages and disadvantages of both Design A and B of the Interface Plate, the Interface Plate shown below in Figure 14 was designed.

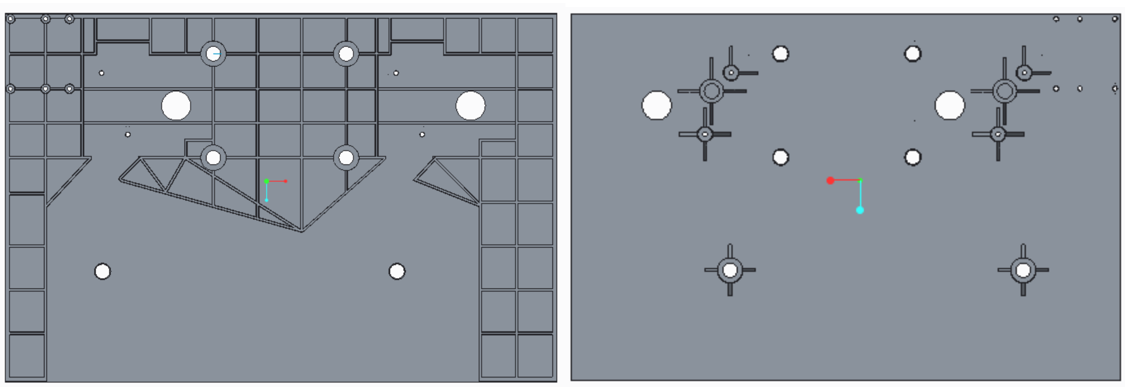

Figure 14: Interface plate designed for injection molding

The two images shown above in Figure 14 are the front (left) and rear (right) of the interface plate design. This design has successfully taken into account all the features Lockheed Martin requires; it has minimal assembly required, it is designed for injection molding, and the interface plate can be used for both the stand side of the assembly and the dummy side of the assembly. Images showing the full assembly will be found below in the Stand Design Section.

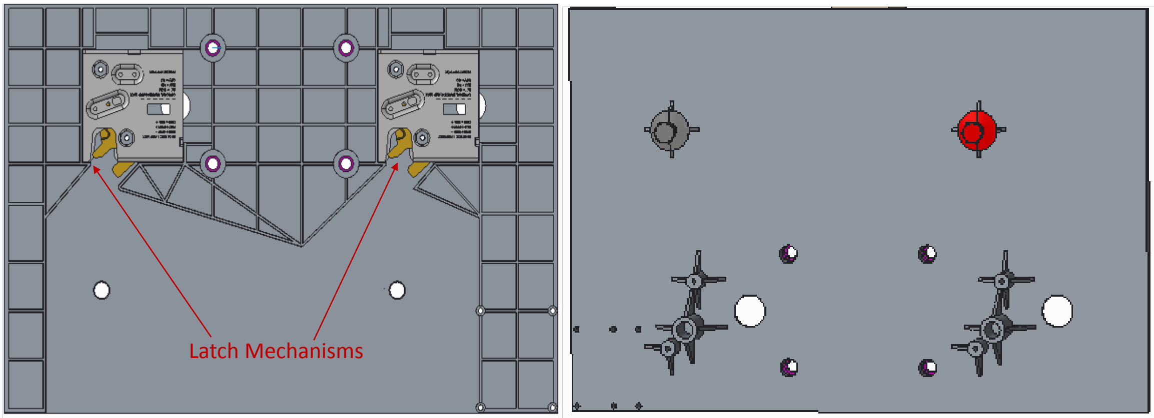

Figure 15: Interface Plates with components attached

Figure 15 above shows the final Interface Plate design with the latches and bolts attached. In the left image of Figure 15, the latch mechanisms can be seen. The ribs we have designed also serve as the rails that guide the bolts into the latches. The right image shows the rear of the plate where the bolts will be inserted.

After speaking with the sponsor, Team #7 has received positive feedback on this design and hopes to soon 3D print this design to begin testing and analyzing its performance. The team is hopeful that the first few weeks of the next semester will consist of ordering parts and assembling a new prototype with the improved Interface Plate design.

4.2 Stand Design

After speaking with the contact at Lockheed Martin, Team #7 learned that the base was not to be injection molded like the plates. Lockheed Martin has also made it clear that they wish for the base to be reasonably mobile, stable, and light, while keeping with the other restrictions for the project, including ricochet resistance. With these desirable characteristics in mind, Team #7 came up with concepts similar in style to a dolly, or hand truck. Discussion with Lockheed Martin proved their acceptance of this concept. Though the final design needs to be markedly different from a dolly in certain aspects (for example, Lockheed Martin has specified that they do not want excessively large wheels, or a metal construction), the dolly shall be used as the base from which to continue innovation and ideation. The model referred to is the Harper Nylon Dolly, which meets the necessary requirements for low tendency to ricochet (shown in Figure 16 below).

Figure 16: Harper Nylon Dolly

As has been previously stated, this is not the final solution, however it is a viable first step towards the next generation prototype for the base and stand. It is also worth noting that the base may require further revision in order to meet the stability requirements. Discussion with Lockheed Martin clarified that the constraint of a 2' x 2' baseplate is not necessarily a hard and fast constraint, rather a guideline for the relative desired size of the baseplate. Team #7 also proposed the concept of utilizing pop out stabilizers for the stand, which would fold to be inside of the desired footprint for transportation and storage, but could possibly flip out for field use, adding a higher level of stability and adaptability to the platform. Lockheed Martin showed interest in the concept, especially as a possible "expansion pack", which could be offered separately, and would be able to easily attach to the existing stand and base. This would have little implication on the actual design of the base and stand, except for perhaps designated attachment points, and would instead be a simple addition which may be worked on separately. Since these additions would be necessarily planned to be very low to the ground, their material is much more flexible. For the time being Team #7 has kept the same aluminum base plate and will add the necessary holes required to mount the control box and 2x4 adaptors which will be discussed in the next section. Further discussion will take place to incorporate this mobility aspect as well as structural stability as we finalize our design plans in the near future.

4.3 2x4 Adaptor

Similar to the interface plate requirements, the 2x4 adaptor needs to be standardized for all necessary locations on the stand. Meaning there needs to be one adaptor to serve many purposes. The selected 2x4 adaptor design is shown in Figure 17. The adaptor will need to accomplish the following requirements: connect the stand to the base, connect the stand to the back interface plate, and connect the mannequin to the front interface plate. The placement of the adaptors is depicted in Figure 18.

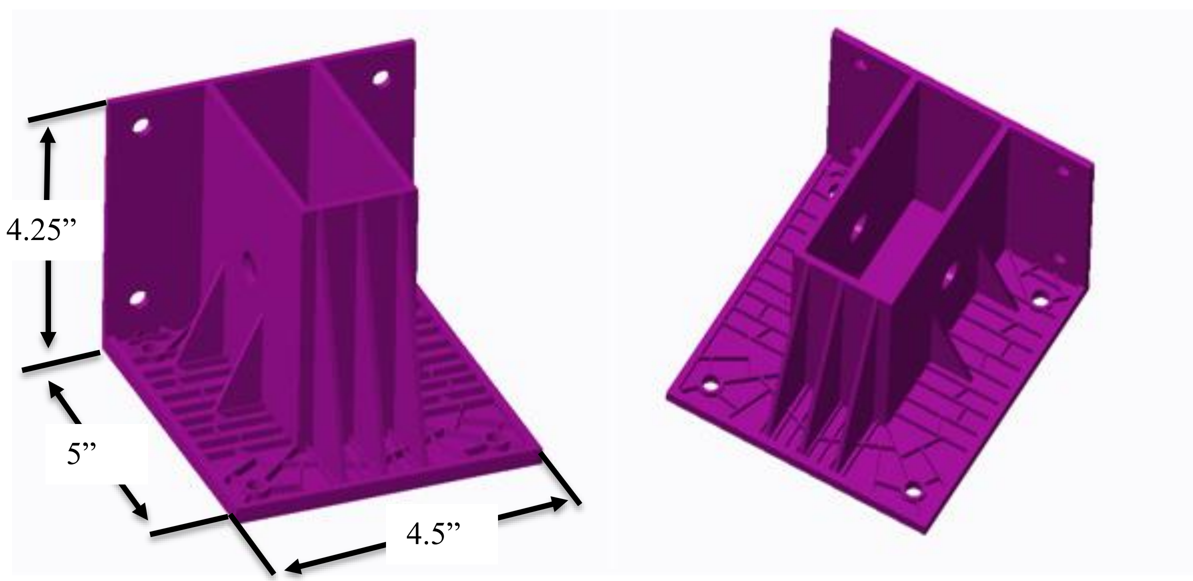

Figure 17: Selected 2x4 adaptor design with ribbing support structures included

The design of the adaptor is acceptable for all necessary requirements because it allows mounting in two separate directions. Having mounting holes on two surfaces 90 degrees apart allows 2x4 wood to be inserted from any direction that will be required. Since this part will be made with injection molding there are specific design aspects that had to be met. To increase the strength of the part ribs were added to diffuse stress on that face. Ribs were added at angles to improve strength from stresses in all directions since this is a multi-purpose part. Gussets were added to the sides to resist stresses especially on the front where long gussets were placed. Long gussets were placed on the front because when the dummy sits in the adaptor most of the stress from the resulting torque will be on that side's edge. The hole in the middle is to pin the 2x4, if necessary a bolt can be drilled through holding the wood in place.

4.4 Full Assembly

Figure 18 shows the full assembly of all the components necessary for this project. This includes the newly designed interface plate and 2x4 adaptors. However, also includes the placement of the control box on the base plate.

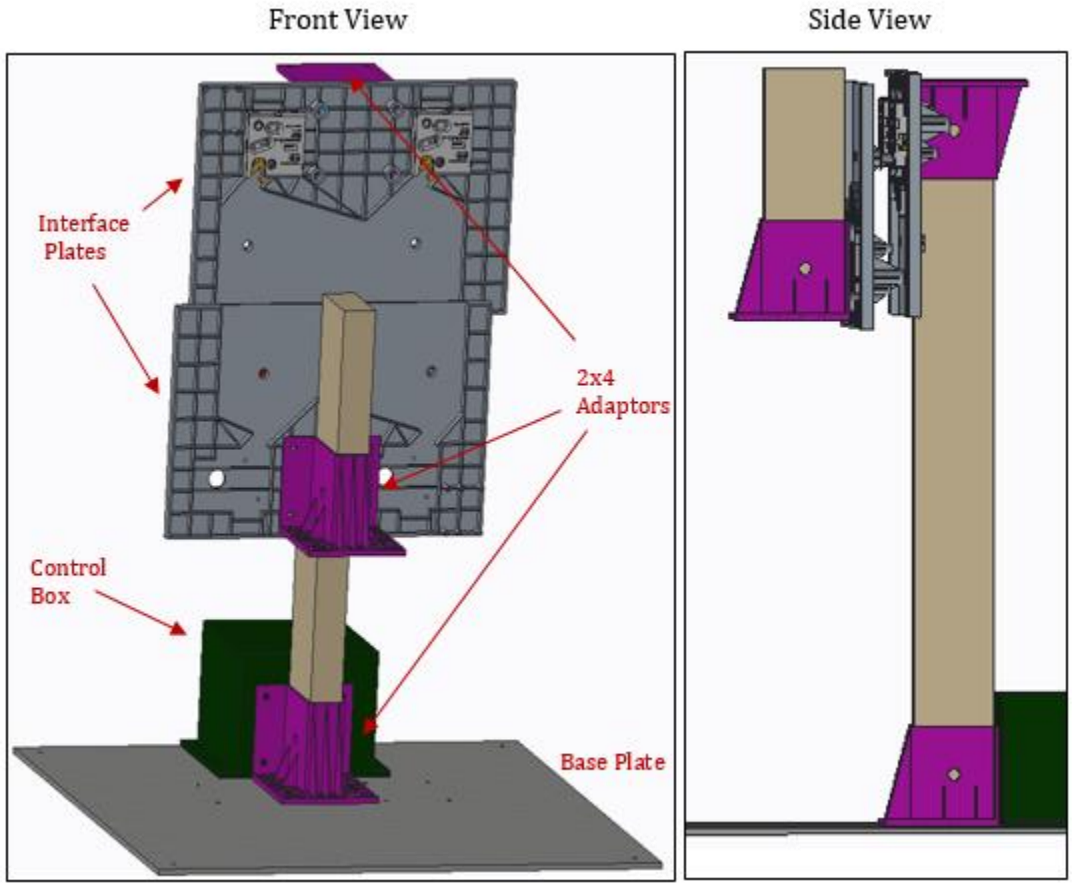

Figure 18: Assembly of current stand, 2x4 adaptors, and interface plates

The mannequin has been removed from this assembly to enable better views of the designs assembly, but the dummy will sit on the 2x4 attached to the front interface plate. The front interface plate is the same as the back interface plate, but when assembling the components it is flipped upside down and the bolts on the back slide into the clamps using the guides designed on the plates. The 2x4 adaptor on the front and back plate are drilled into the same holes respectively and are oriented in different directions. Another 2x4 adaptor connects the 2x4 of the stand to the base plate. The control box is place behind the 2x4 giving it a little more protection.

5. Stress Analysis

Upon viewing the assembly with the updated components, one can see that the 2x4 adaptors are utilized in three different location, each with their own load bearing conditions. Depending on their location, they will have multi-directional stresses on multiple or isolated areas of the adaptor. To verify that the material and structure can support the various stresses applied from the weights of the mannequin, 2x4s, and interface plates the adaptors were tested through Pro Engineer's Finite Element Analysis (FEA) feature.

Starting with the 2x4 adaptor's bolt hole feature used to mount the part to the interface plates and stand, the FEA was conducted assuming all the stress was placed on said holes. This includes the weight of the mannequin and other components as the entire structure is lifted off the ground, simulating a condition in which the maximum vertical stressed is placed on the part. The maximum stress came to just under 10.8 MPa, well below the material yield stress of approximately 79 MPa. This FEA with the representative color-coded stress value can be seen below in Figure 19.

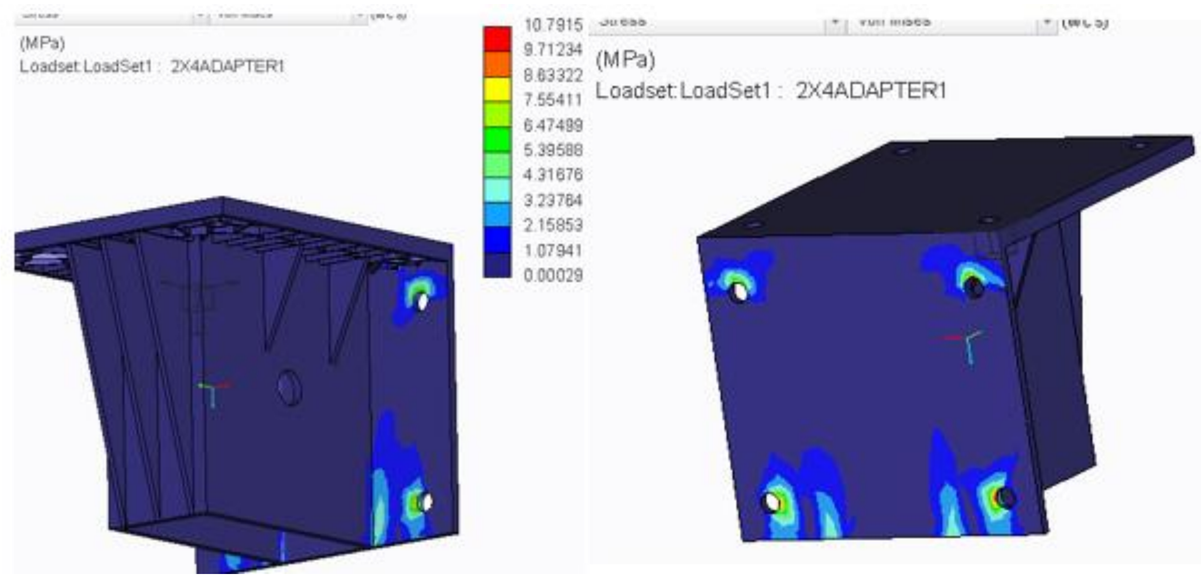

Figure 19: FEA of 2x4 Adaptor bolt holes

This same method was applied with a focus on the beam slot of the 2x4 adaptor. This is the larger opening of the part that the 2x4 board would slide into. The most significant stress applied to this section would come from the torque generated by the 2x4 that attached to the mannequin. This 2x4 adaptor would be attached to an interface plate the supports the full weight of the mannequin, suspended approximately 6 inches away from the vertical beam of the stand. This torque was taken into consideration with a mannequin and interface plate weight of approximately 22 lbs. As seen in Figure 20 below, the torque would apply a load in the opening of the slot near the corners. The maximum stress in this region was shown to be just under 22 MPa, the highest stress value on the whole structure. Thanks to the tall fin structures on the outside of the beam slot, this stress is dissipated and deemed non-threatening to the structural integrity during operation.

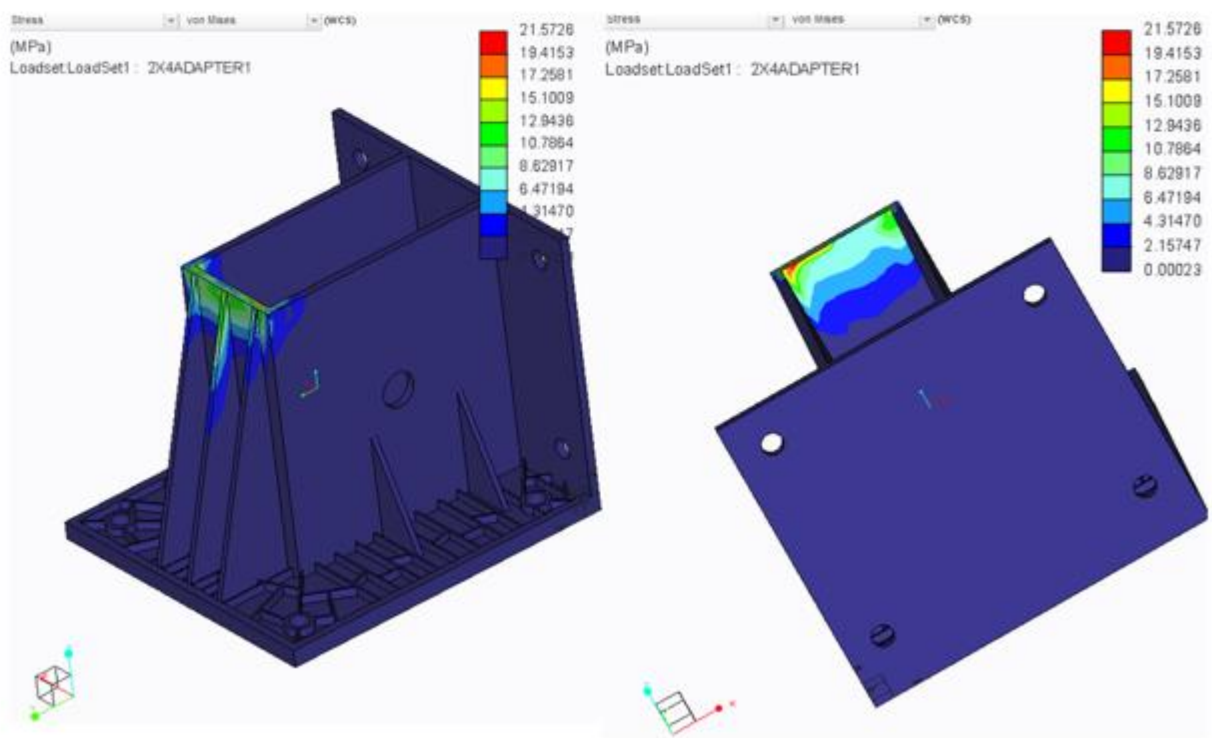

Figure 20: FEA of the 2x4 Adaptor beam slot

Lastly the 2x4 adaptor underwent FEA with the focus on the flat surface containing the ribbing structures. This would simulate the applied weight of the device placed on the 2x4 adaptor located on the top of the vertical beam. To ensure the part could withstand the bending forces always present in the device, the mannequin and interface plate weight of 22 lbs. was used again as the applied load. As seen in Figure 21 below, the ribbing structures do a phenomenal job of preserving the integrity of the structure, reducing the maximum stress of the area to around 11 MPa.

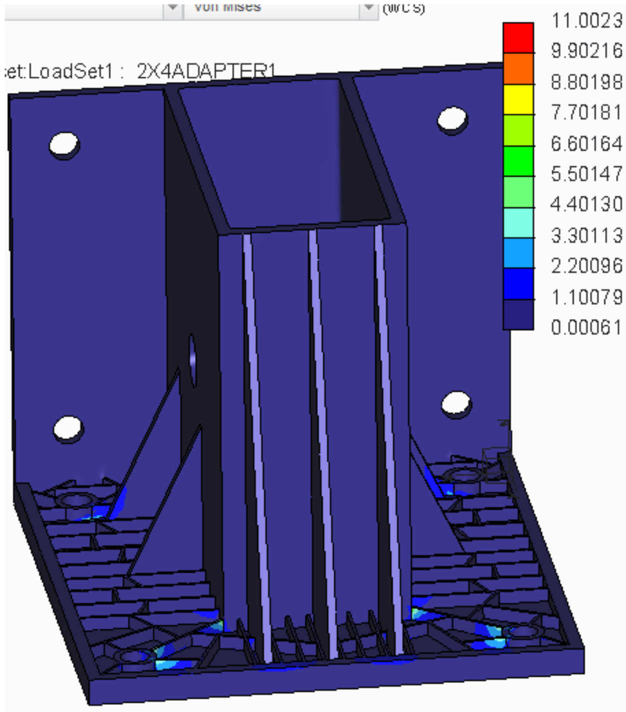

Figure 21: FEA of 2x4 Adaptor flat structure

6. Future Plans

The next step of the design process is to finalize designs and get them completely approved by both Lockheed Martin and the team's sponsor. This includes complete models and analyses. Once the design of both the interface plate and 2x4 adaptors are approved prototypes will need to be made. This will be done using 3-D printing either provided by Florida State University or Lockheed Martin. Testing the durability of both the adaptor and plate will commence after prototypes are procured and a mock assembly made, the mannequin will be mounted and then dropped a minimum of 1000 times. The results will be gathered and passed on to Lockheed Martin. During this time the final design of the stand will be made, preferably with mobility in mind, either adding wheels or implementing the dolly idea. Figure 19 below shows the current Gantt chart Team #7 will use to try and remain on schedule with the future plans mentioned above.

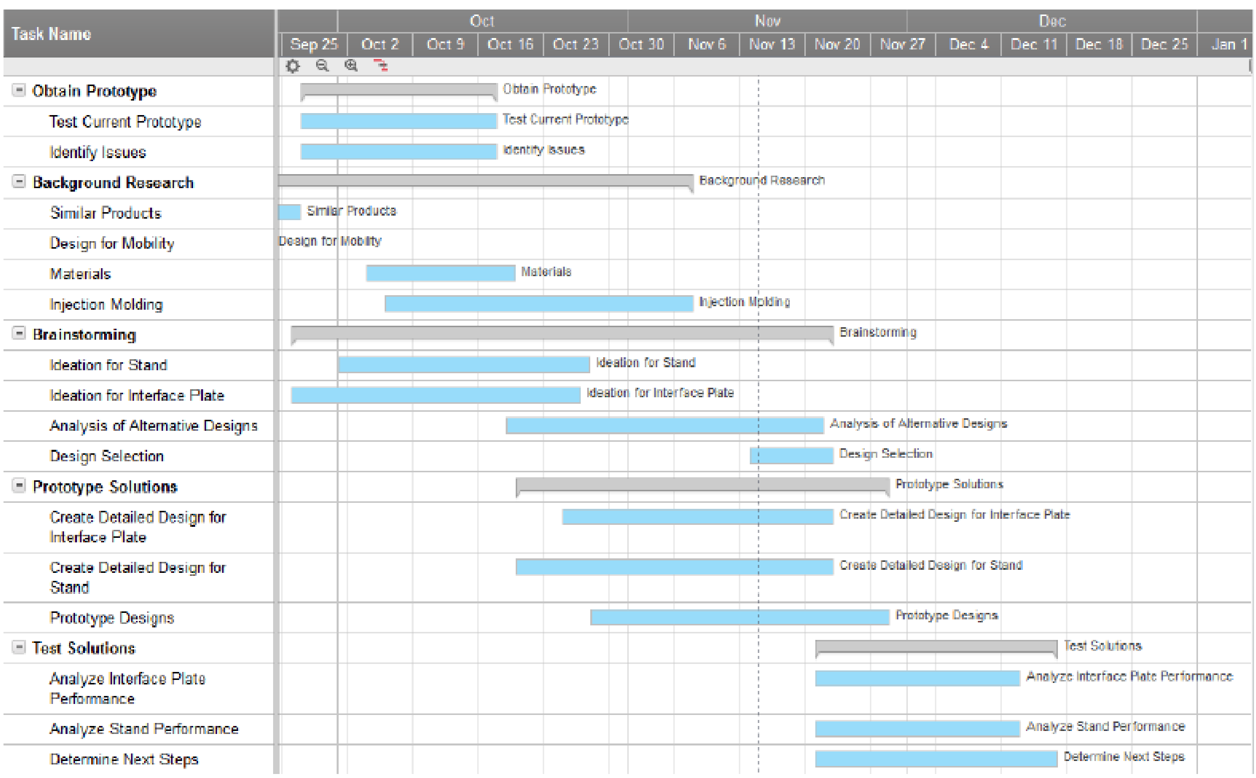

Figure 22: Gantt Chart

7. Conclusion

Lockheed Martin provided Team #7 with their current Human Type Target prototype. The main objectives of the team will be to design a new stand, interface plate and adaptors for manufacturing. When the design is complete for each component it will need to be at market quality level and easily manufactured, meaning that each component needs to be cost and time effective when being made. The aspects of this project that have been most challenging include designing interchangeable interface plates for ease of manufacturing and designing a durable stand that is not only mobile and durable, but stable when shot with a series of bullets. A design for the interface plate and 2x4 adaptor has been selected and is close to approval. This plate and adaptor meet all the design requirements, are interchangeable and are designed with injection molding in mind. An initial prototype of the stand will be constructed using a commercially available dolly as a base to model after. Once prototypes are made and tested for both the interface plates and test stand the next step will be to assemble the two and test the target system as a whole. The project scope and budget are reasonable parameters to work with and the Human Type Target will be able to provide realistic training for law enforcement and the military.

References

[1] Target, "'RUBBER DUMMY' – self healing LE training target," 2014. [Online]. Available: https://www.mrtargetonline.com/shop/rubber-dummy/. Accessed: Oct. 20, 2016.

[2] J. S, "Gear review: ZeroBravo REOS (rapid engagement offset sights)," in *Gear Review*, The Truth About Guns, 2015. [Online]. Available: http://www.thetruthaboutguns.com/2015/12/jeremy-s/gear-review-zerobravo-reos. Accessed: Oct. 20, 2016.

[3] "Dummies unlimited," Dummies Un. [Online]. Available: http://www.dummiesunlimited.com/3d-swat-target?lightbox=c6yq. Accessed: Oct. 20, 2016.

[4] Stars, "A GI's next target? That autonomous moving robot at 50 yards," Stars and Stripes, 2013. [Online]. Available: http://www.stripes.com/news/a-gi-s-next-target-that-autonomous-moving-robot-at-50-yards-1.239194. Accessed: Oct. 20, 2016.

[5] G. Equipment, "Harper™ PGCSK19 ultra Lite nylon hand truck 10" pneumatic wheels," Global Industrial, 2016. [Online]. Available: http://www.globalindustrial.com/p/material-handling/hand-trucks-dollies/hand-trucks-convertible/harper-ultra-lite-nylon-hand-truck-10-pneumatic-wheels?infoParam.campaignId=T9F&gclid=CPr42sSn6s8CFccehgod46QMnA. Accessed: Oct. 20, 2016.sss