

Restated Project Definition and Scope/Project Plans

Team # 7

Revision of Lockheed Martin's Human Type Target for Manufacturing



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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 a mannequin, which will be able to detect vibrations caused by a bullet being fired into the 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 includes designing, at a minimum, a stand for the target, an interface plate between the target and stand, and 2x4 adaptors. Currently Team#7 has finalized and received the designs for the adaptors and interface plates, both of which were 3D printed by Lockheed Martin. Team #7 has also ordered or received all other necessary components to complete assembly of the prototype. The next steps include testing, potential design modifications for mobility, and production cost optimization through improved material selection if necessary.

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 it is able to 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 [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. 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.

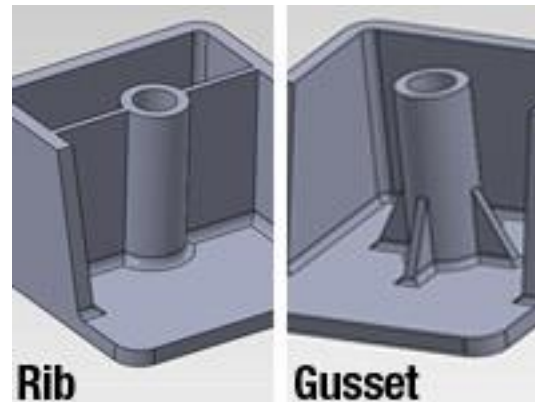


Figure 4: Ribs and Gussets

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.

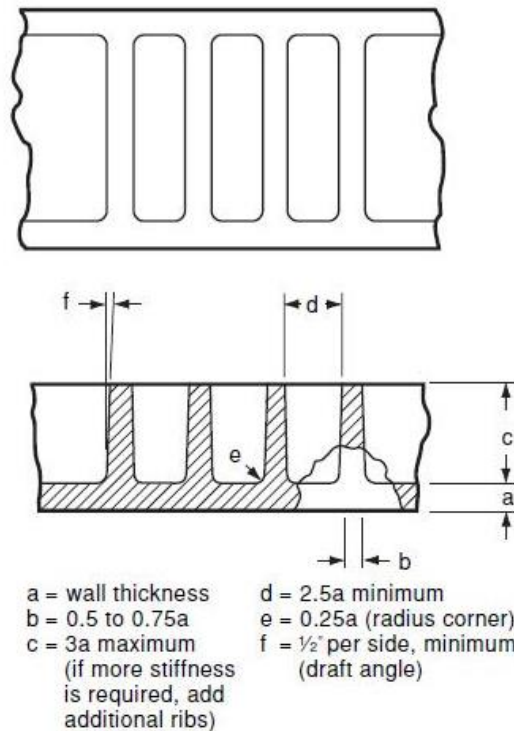


Figure 5: Picture showing good rib design standards

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 5 below provides a visual for the main components mentioned above:

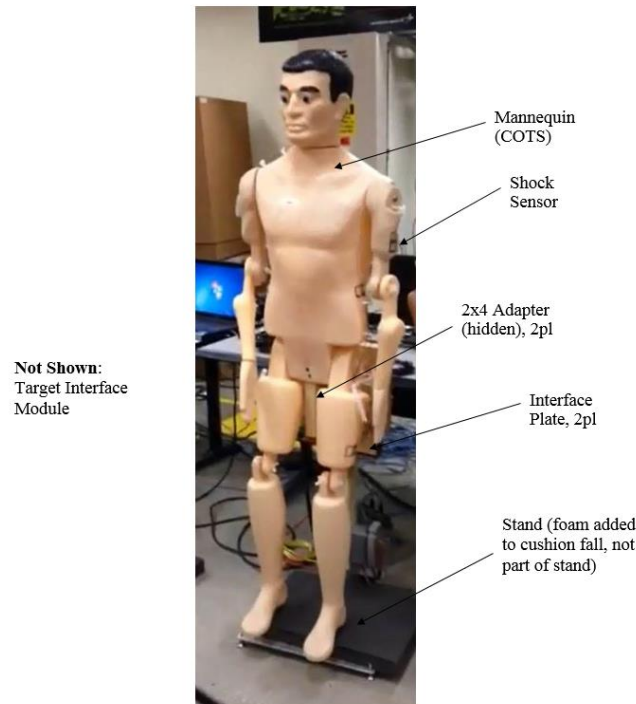


Figure 6: General layout of current prototype with main components noted

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	Interchangeable 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 4) 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 6. The arrow on the left of Figure 6 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.

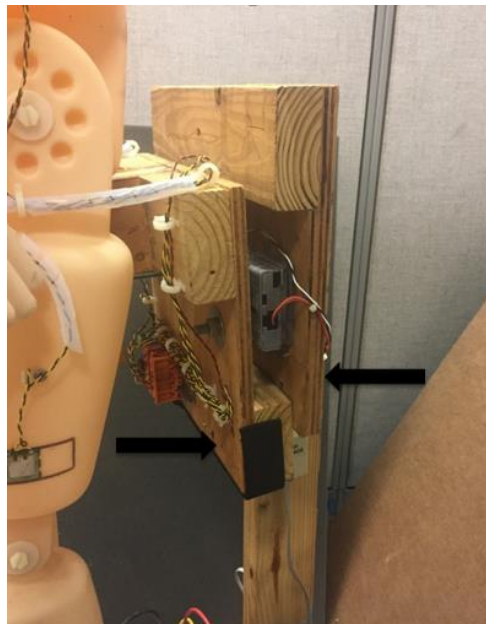


Figure 8: Human Type Target prototype (interface plates)

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.

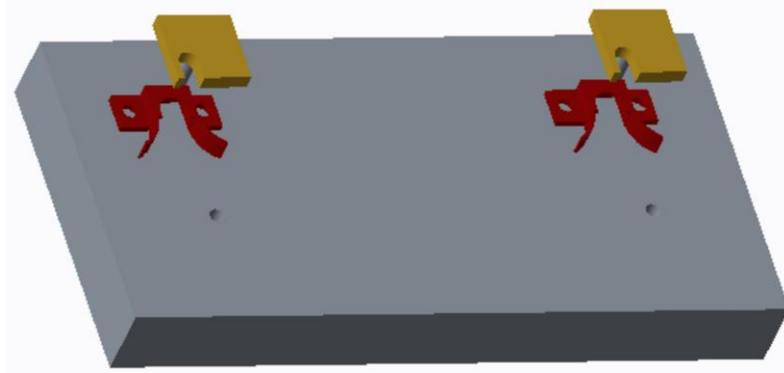


Figure 9: Interface plate Design A with latches and guides attached

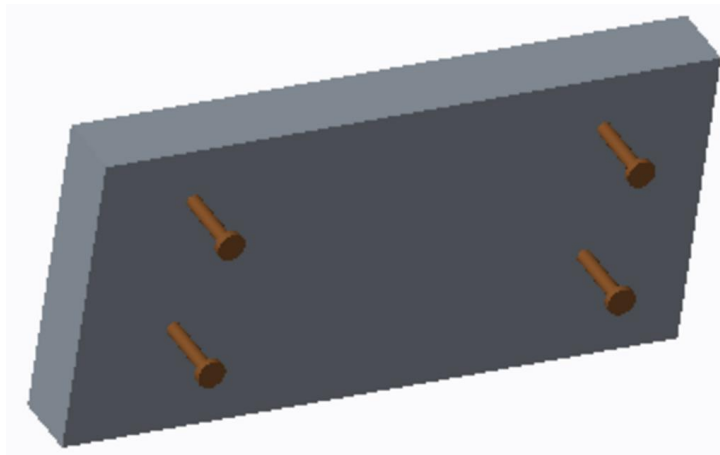


Figure 10: Interface plate Design A with bolts attached

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.

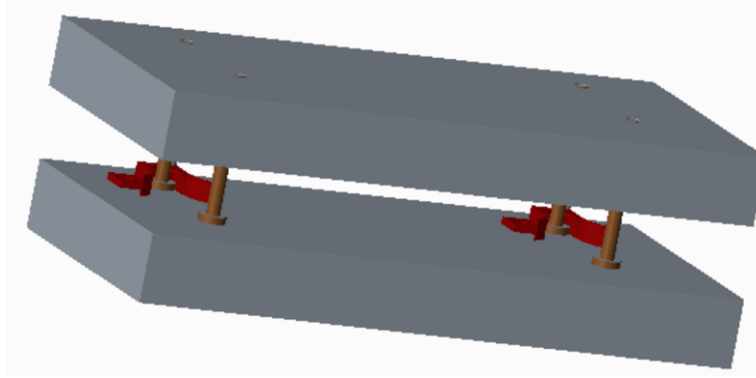


Figure 11: Interface plate Design A assembly

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 13 to __) 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.

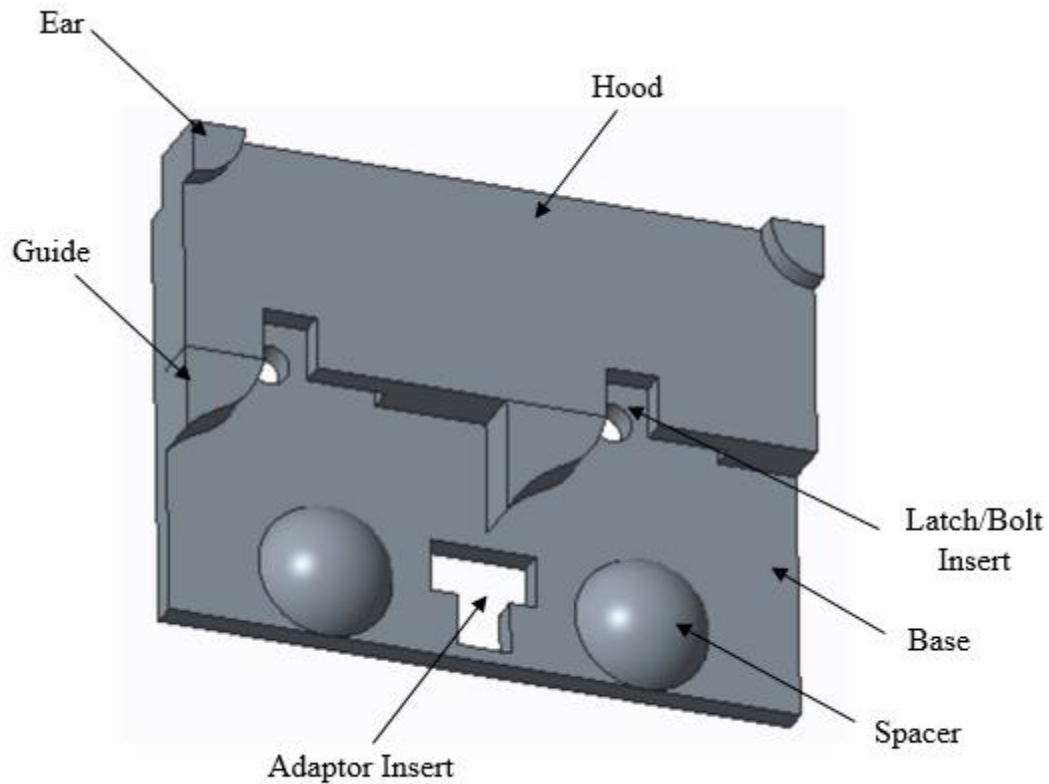


Figure 12: Interface plate conceptual Design B (front view)

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.

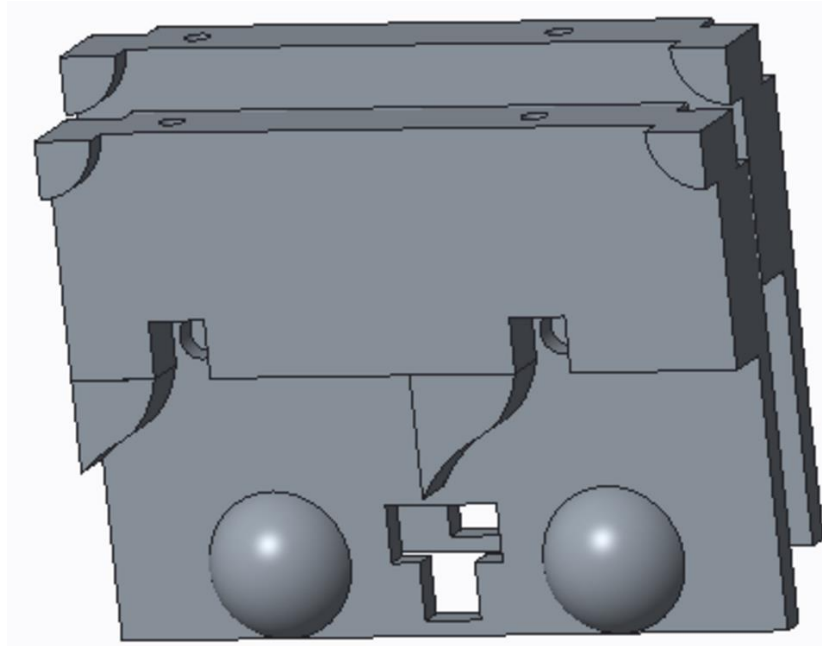


Figure 13: Interface plate conceptual Design B (assembled view)

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.

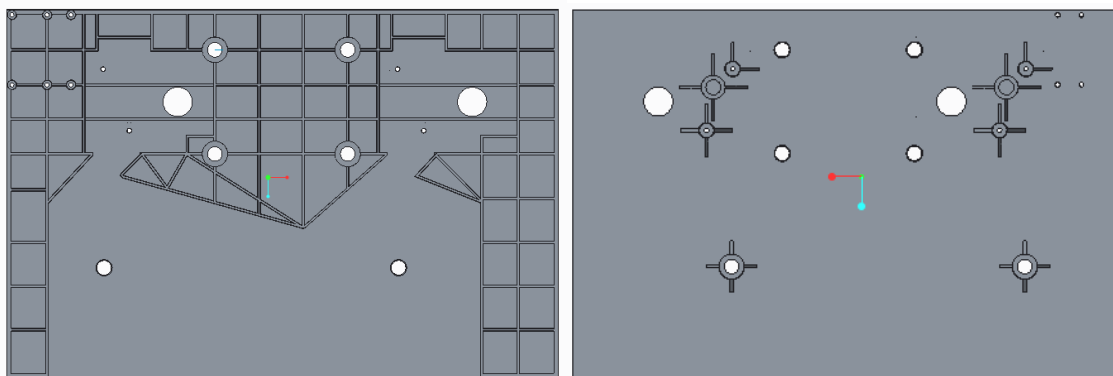


Figure 14: Interface plate designed for injection molding

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.

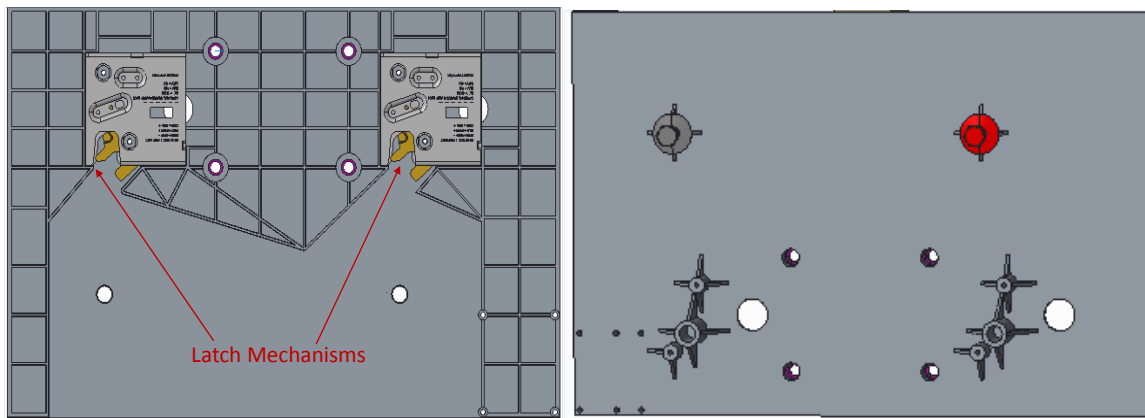


Figure 15: Interface Plates with components attached

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. The attachment of the two plates together can be seen below in Figure 16.

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. As a means to this end, Team #7 shall be purchasing a dolly to make a revised prototype off of. This model shall be the Harper Nylon Dolly, which will meet the necessary requirements for low tendency to ricochet (shown in Figure 15 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.

As of right now the current stand design can be seen in Figure 17. This design is currently incomplete, but shows the basic concept of the stand. When finalizing the design for mobility a couple of designs are being considered.

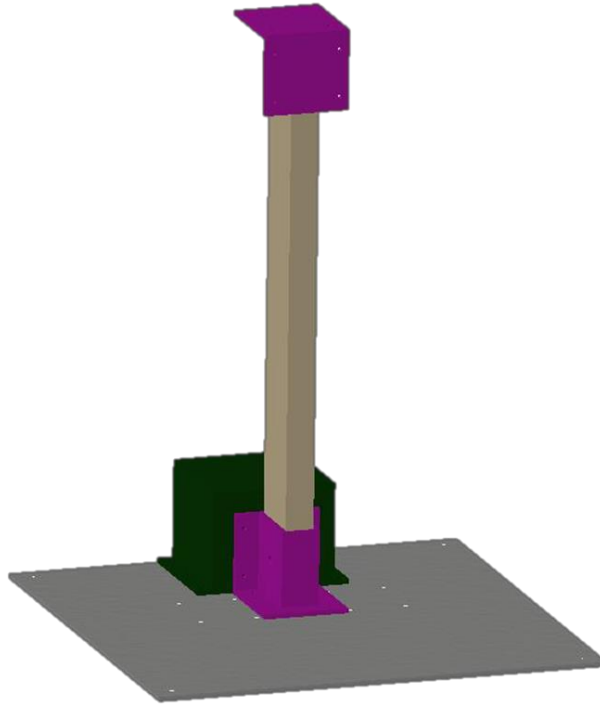


Figure 17: Current stand design

The dolly idea as previously discussed is under consideration, however now a swivel caster with a brake is a viable option upon discovery of most transportation being on concrete. These wheels would replace two or four of the leveling feet and when put in the desirable spot the wheels would be able to be locked with the brakes keeping it stable in the position. Another idea being considered is making the wheels similar to those of a suit case in a sense that the stand would be tilt back to engage the wheels to allow the dummy to move. This has potential to be cumbersome due to the bulky nature of the stand and mannequin. Team #7 will be discussing the appropriate course of action in the upcoming weeks.

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 18. 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 20.

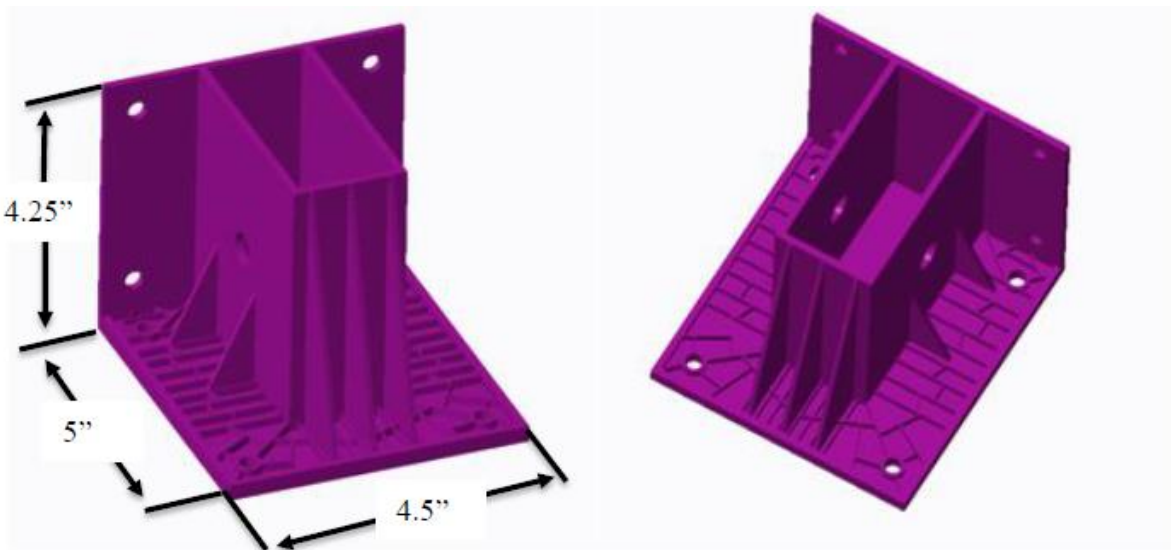


Figure 18: Selected 2x4 adaptor design with ribbing support structures included

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.



Figure 19: Different views of the 3D printed 2x4 adaptor

Figure 19 displays the final 2x4 part which was 3D printed by Lockheed Martin. This part is ready for assembly and test. The factors that will be monitored the most are the edge where most of the stress will be seen and the back wall without ribbing because it is the most flexible aspect of the entire part. If the back wall without ribbing fails an easy way to fix it is adding ribbing on the side which will not cause 90° ribbing with the bottom.

4.4 Full Assembly

Figure 20 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.

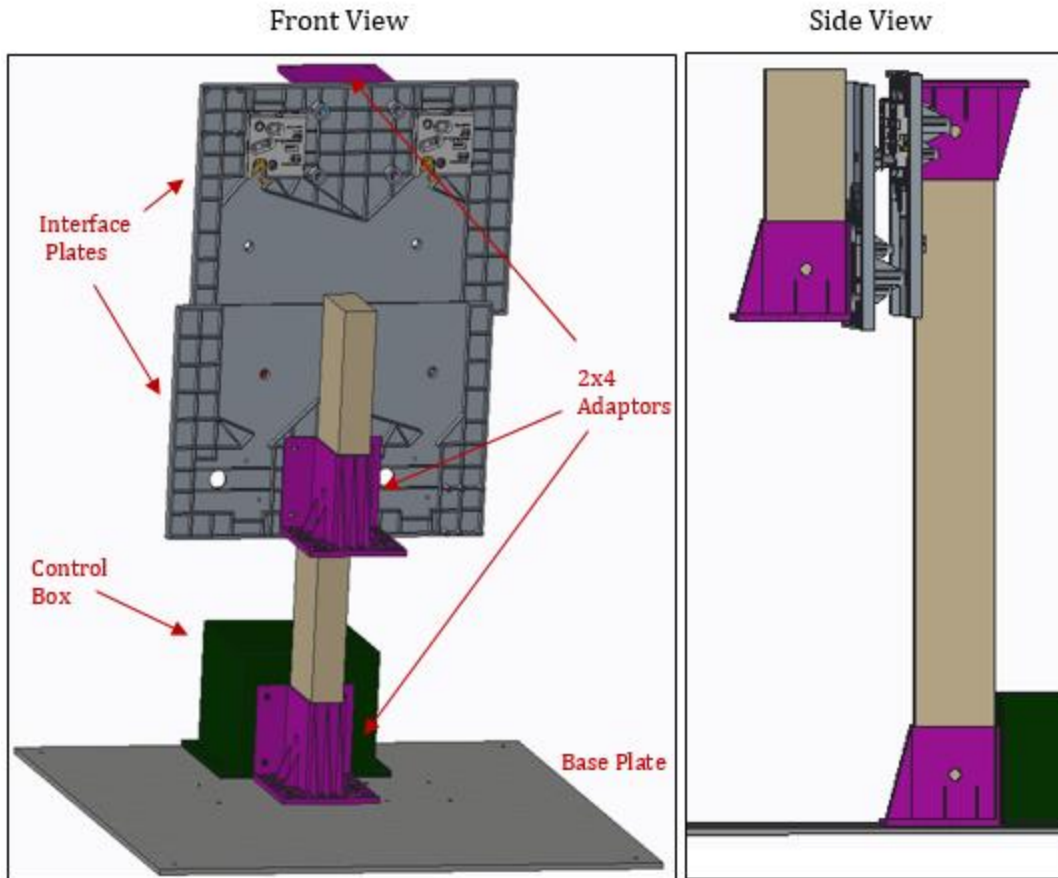


Figure 20: Assembly of current stand, 2x4 adaptors, and interface plates

The mannequin has been removed from this assembly to enable better views of the design 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 placed behind the 2x4 giving it a little more protection.

5. Future Plans

Team #7 is on track to finish the objectives of the project before the end of the semester. As of right now all parts, electronic and mechanical, have been ordered and are set to be delivered by the end of February. The 3D printed 2x4 adaptor has been received and the interface plate will be here next week. Once the interface plate is received assembly can begin. The adaptors will need to be attached to the interface plates and then to the aluminum base of the stand. Machining will be needed for the base of the stand and soldering will be needed to place the inserts in the aluminum for either wheels or leveling feet. This may take a little time, but overall the mechanical assembly of the target will not take longer than two weeks. Upon completion of assembly, Team #7 will be receiving the electronic components. Once the arduino board and clamps are in hand, the programming aspect will begin. This is needed to test the prototype so the team can press buttons to simulate certain “gun shots’ enabling the dummy to fall. This will need to be done a minimum of 1000 times to see if the design meets Lockheed Martin’s standards. Once testing is completed all information will be passed on to Lockheed and the project objectives will be completed. Figure 21 gives a visual representation of Team #7’s time frame.

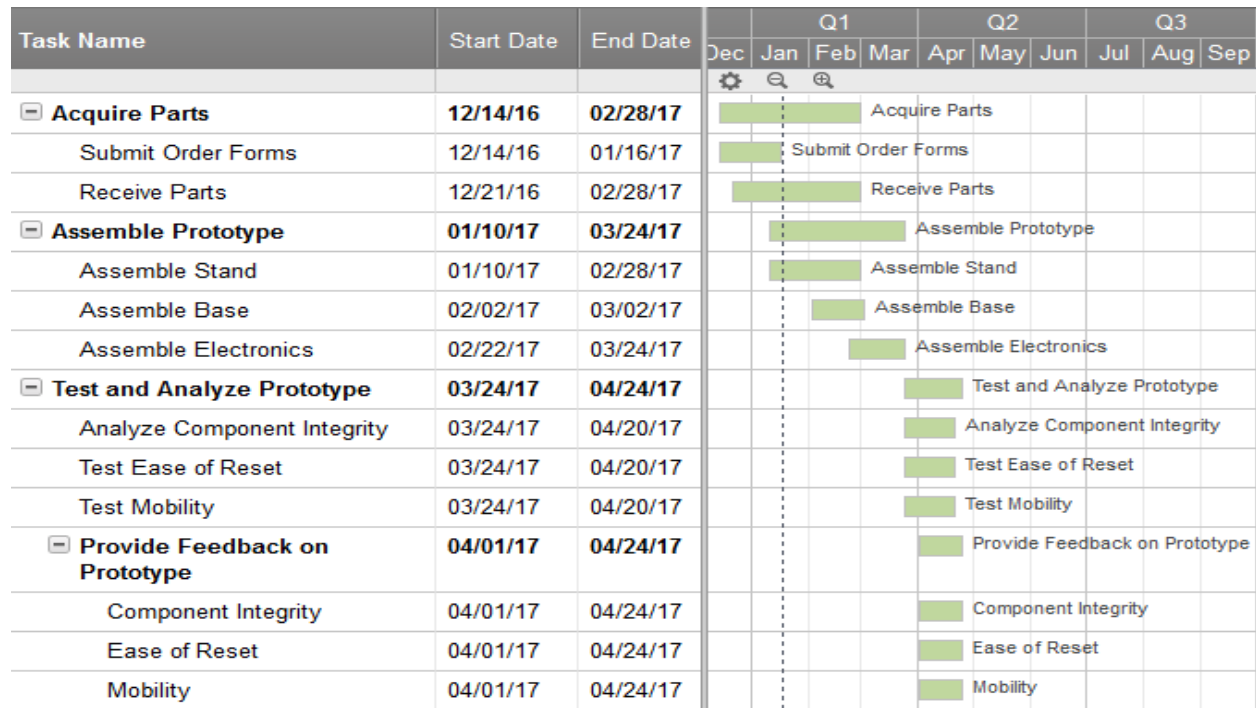


Figure 21: Gantt Chart

6.Challenges/Future Problems

There are a few problems that Team #7 anticipates to encounter while attempting to complete this project. Some are minor problems, while some could present significant challenges. A major problem that could occur is if one of the parts being 3D printed by Lockheed Martin, 2x4 adaptors and interface plates, fail and break. This would present a challenge for many reasons. First, this means the design is flawed and a new part will have to be designed, then the team would have to find a vendor to attempt to 3D print the part quickly so testing can continue. This would drain both time and money, both of which are fixed and essential. In preparation for this occurrence Team #7 has continued thinking about different designs and locating places that could possibly 3D print parts. However, if this situation does occur it will be a major setback.

A few minor challenges the team will face includes the machining and electronic aspects of the project. As a whole the team is very inexperienced when it comes to machining and working with electronic components. This could increase the time it takes to cut the aluminum base and insert the press in inserts. This could also prove time consuming when hooking up and programming the arduino board. While the program should be relatively simple it may still have a learning curve. Overall, these challenges are minor and shouldn't present too much of a problem for Team #7.

Another aspect of the projects that could prove to be challenging is designing the stand for mobility. This has been overlooked before and it is now time to consider how to make this stand more mobile. The team has discussed a few options as stated earlier in this paper, but implementing the ideas could give rise to new problems unforeseen by the team. However, even with these challenges the team is confident in completing the goals and objectives of this project by the given completion date.

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 produced and received. This plate and adaptor meet all the design requirements, are interchangeable, and are designed with injection molding in mind. Once the remaining components are received by mail, full assembly of the prototype will take place. After assembly, Team #7 will proceed to test the prototype for a goal of 1000 intact drops utilizing simple programming for the simulation of sensor feedback. Overall, the project scope and budget are reasonable parameters to work with and the finalized Human Type Target will be able to provide realistic training for law enforcement and the military.

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