Midterm 1 Report

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 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.

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

2.2 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 4 below provides a visual for the main components mentioned above:

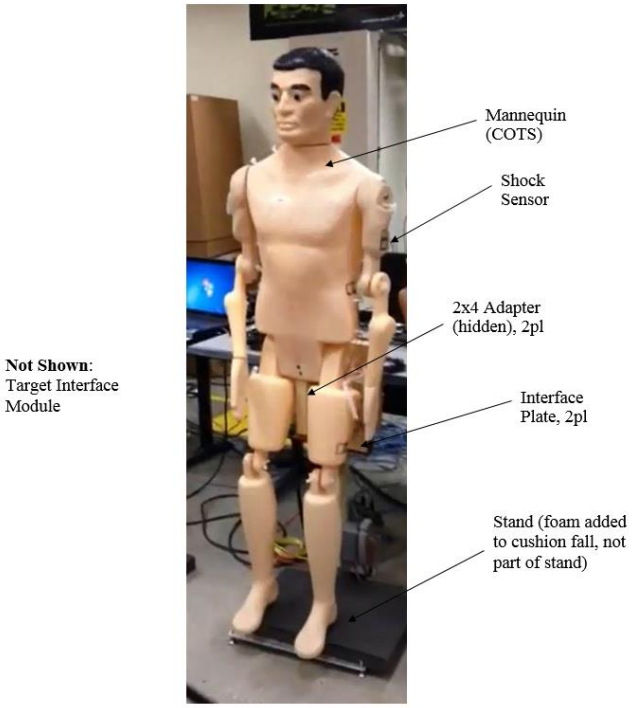

Figure 4: General layout of current prototype with main components noted

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 5: 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. Conceptual Designs

4.1 Interface Plate Designs

There are two interface plates present on the current prototype, these can be found 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 the mannequin is supported. 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 get the bolts back into the latching mechanism. Potential solution for this include guides or a larger latching area. Team #7 has two current solutions, each with their own pros and cons, which are discussed below.

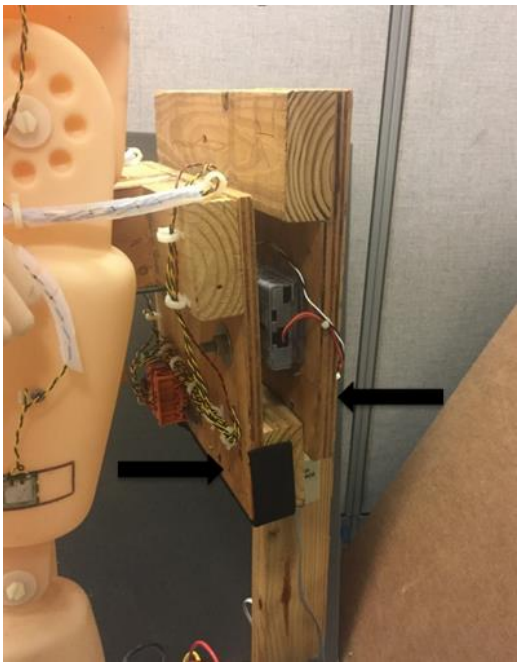

Figure 6: Human Type Target prototype (interface plates)

4.1.1Interface Plate Design A

The following figures represent a rough drawing of Design A. They will be used to communicate the direction Team #7 is moving with the design process. If this design is selected, significant modification of the designs will need to be done. The approximate dimensions of Design A are 14in wide by 10in tall.

Figure 7: Interface plate Design A

Figure 7 above shows a simple design of the interface plate. This design allows the latches (gold in Figure 8) to be mounted to the upper most holes on both the right and left side of the interface plate. Figure 8 below shows the assembly of the interface plate that would be attached to the stand. Located in-between the latches and the interface plate are the two proposed guides (red in Figure 8) for the pins (brown in Figure 9) to easily make contact with the latches.

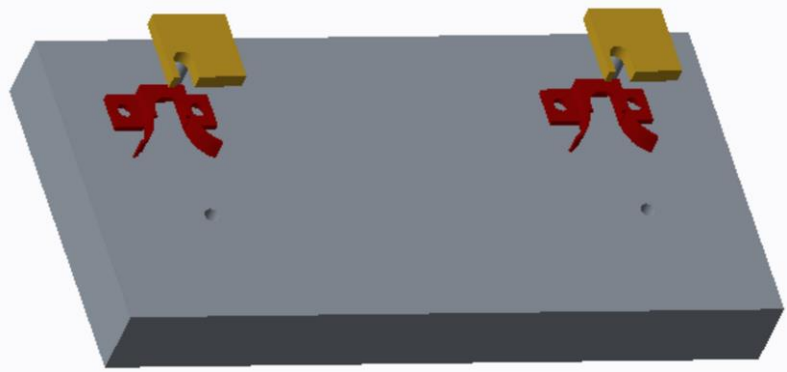

Figure 8: Interface plate Design A with latches and guides attached

In Figure 8, the assembly of the interface plate that will be attached to the mannequin can be seen. Each of the four proposed holes will have a bolt inserted into them. These will allow the

clamps to grasp the upper most bolts while the bottom most bolts will press off of the plate to reduce the torque on the latches.

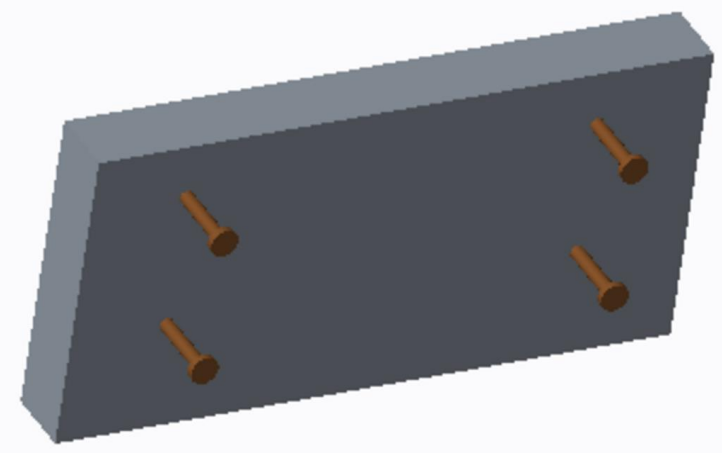

Figure 9: Interface plate Design A with bolts attached

The final figure for Design A can be seem below in Figure 10. This figure shows how the two plates are designed to come together. The picture provides a visual looking up from the bottom of the assembly.

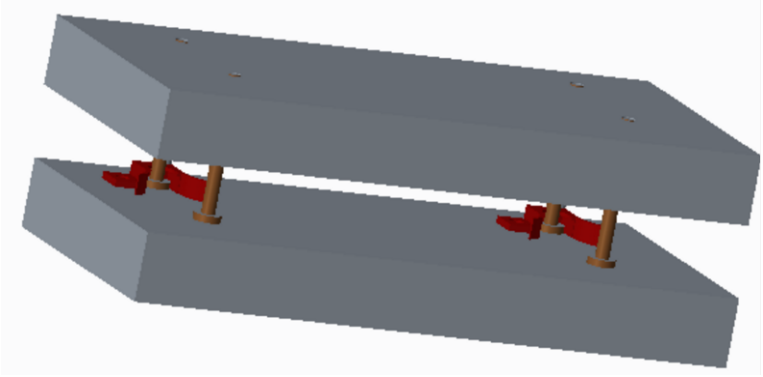

Figure 10: Interface plate Design A assembly

The main advantages of Design A are that it will be very simple to manufacture, easy to repair if damaged in the field, and it reduces the torque on the clamps. One of the main disadvantages of this design is that it requires a lot of parts for assembly. Lockheed Martin would rather the interface plate incorporate many of these features without the need for assembly. Lockheed Martin hopes is to injection mold the interface plate when a final design is selected, with this current design, it is not worth injection molding such a simple solution.

4.1.2 Interface Plate Design B

Concept Design B, Figure 11, is another design for the interface plate. Once again both the interface plate attached to the mannequin and the one attached to the stand would be the same. This design, unlike Design A, is one piece that can be made with one mold. From the front view there are two main components, the base and the hood. The hood protrudes off the base and creates a cavity, or hollow space, for the latch to be inserted. The balls at the bottom of the part are there for spacing purposes to keep the mannequin up right preventing the bolts from binding inside the latch. The guides are on the part to help the user place the bolts into the latches, the bolts will follow along the guide until they snap into the latches.

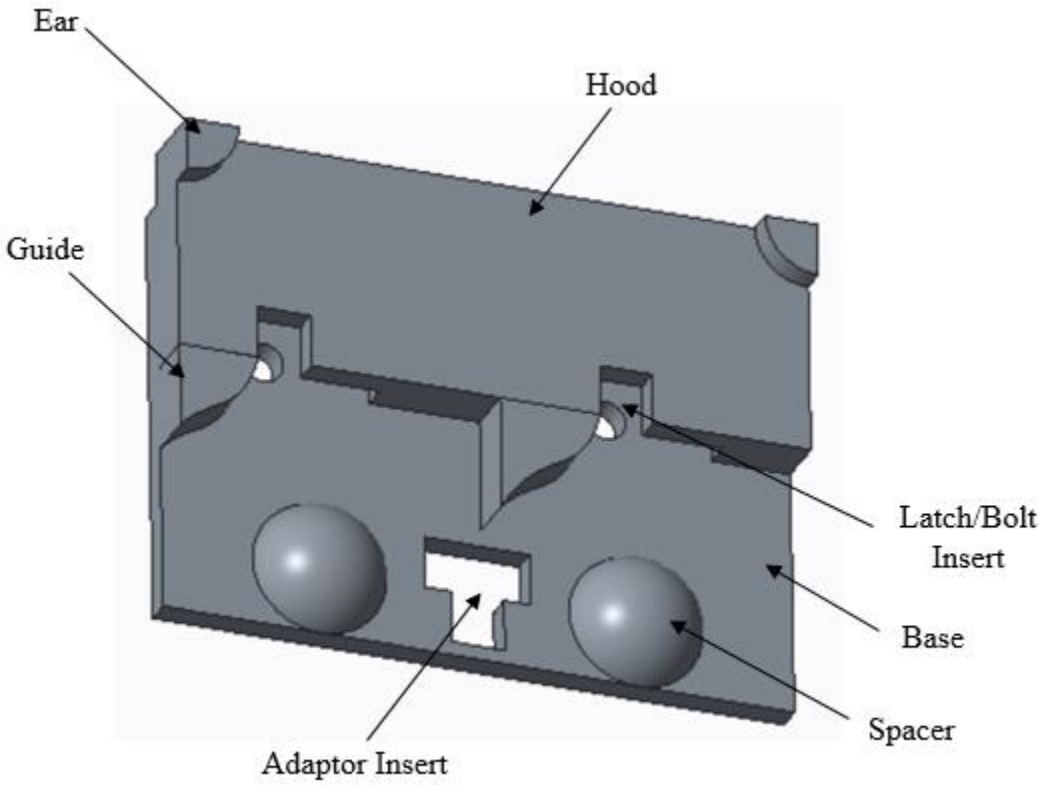

Figure 11: Interface plate conceptual design B (front view)

From Figure 11, one can also see the t-shaped hole in the bottom middle of the base, this is where the adaptor connected to the mannequin will be inserted. The bottom view, Figure 12,

gives a better visual of the separation between the hood and the base allowing the insertion of the latch. The holes seen near the guides on the base are for the bolts attached to the mannequin to go through because this is the same interface plate for both the stand and the human type target.

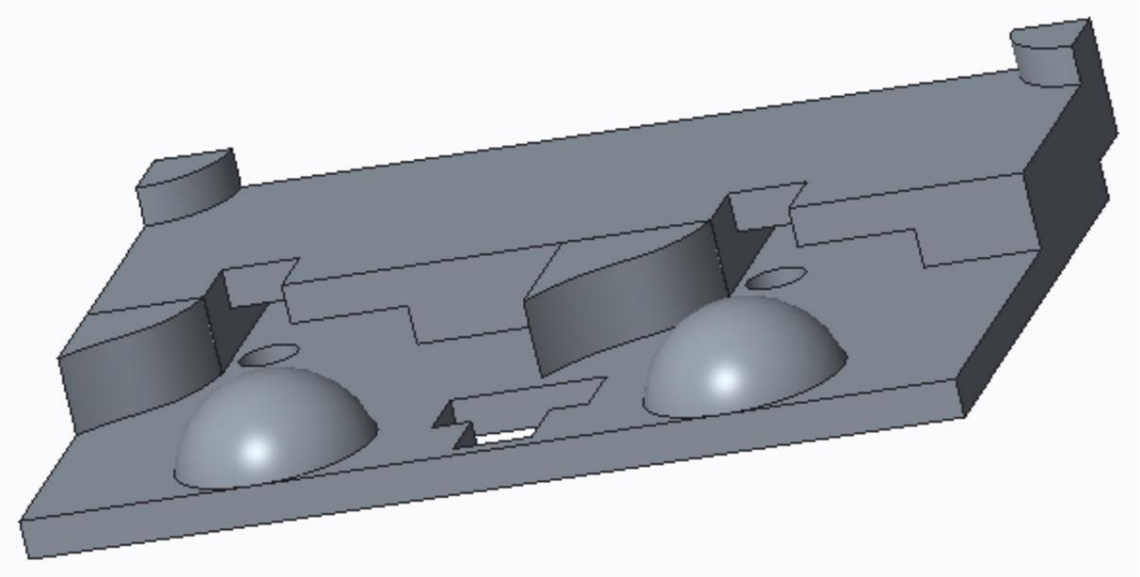

Figure 12: Interface plate conceptual Design B (bottom view)

Figure 13, gives the top view of the interface plate and shows two holes on the top. These holes are for wire routing, which is an important component of the system because keeping wires organized and protected will keep the target system running for the duration of its life span. Looking at both Figure 13 and the assembled figure, Figure 14, the two are assembled front to back. The ears fit into the slots on the back, seen in Figure 13, and the bolts coming from the mannequin go through the holes on the base under the hood and into the latches in the same spot on the back interface plate. The spacers keep the correct distance between the front plate and the back plate to prevent binding of the bolts in the latches.

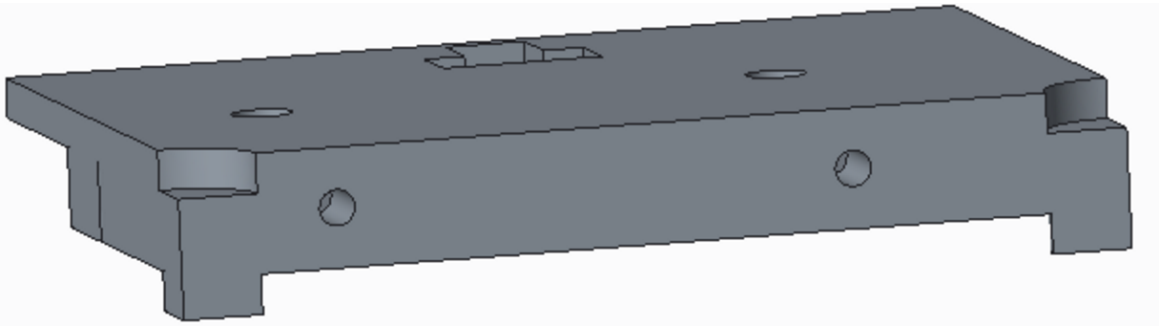

Figure 13: Interface plate conceptual Design B (top view)

There are many benefits to Design B that Lockheed Martin wants to keep. The main component that needs to be kept is the fact that it is one solid piece that can be made with one mold. This is beneficial from a manufacturing stand point, and in the long run will cut time and cost. With them being the same part and not needing multiple components the company will only need to make one mold then mass produce however many plates they need. Another benefit of this design is the ability to have the latch and wires protected under the hood. With these major components protected there is less of chance the will be damaged either by gunfire, by being dropped or being mishandled. Without those two components the mannequin would not be able to fall, and damaging the latch would prevent the target from being inserted.

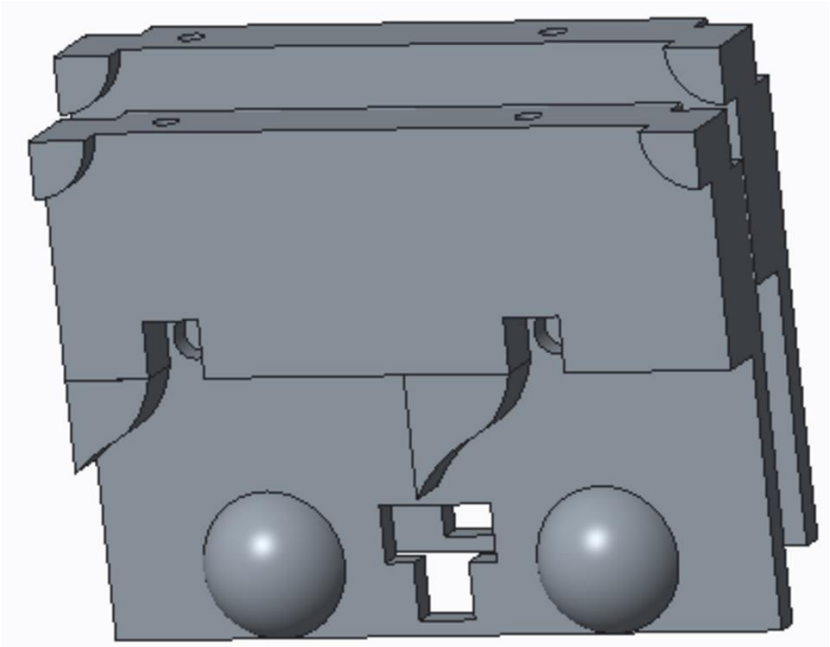

Figure 14: Interface plate conceptual Design B (assembled view)

While there are benefits to this design, there are also a few downsides. When doing injection molds, it is important to have uniform thickness, or close to uniform thickness, throughout the part. With this design the spacers and the guides are much thicker than any other components on the interface plate. This will cause those sections to form cavities due to the uneven cooling of material. A possible solution to this is to design the spacers and guides in such a way that the thickness is uniform. Another problem with this design is that if the mannequin system malfunctions and will not fall by hitting the sensors, the latches are in an unreachable spot. It will be impossible to unlatch the mannequin easily without either disassembling the latches from the interface plate or breaking the part. A possible solution to this is to make an access hole in the back of the interface plate so the latches can be reached.

Overall, Lockheed Martin liked Concept Design B over Concept Design A solely based on the fact that it is one part. Design A has many parts that have to be manufactured, bought and assembled, while Design B is just one part that uses a mold. Based on the manufacturing aspect Lockheed said to move in the direction of Design B.

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 15: 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.

5. Future Plans

In the coming weeks, Team #7 plans to continue brainstorming on the interface plate design, select a design, create detailed drawings, and then propose the design to Lockheed Martin. If these tasks can be completed in a reasonable time frame, and Lockheed Martin approves the design, a prototype will be constructed. Furthermore, Team #7 plans to order the above mentioned dolly, determine the modifications that need to be incorporated to it, implement those modifications, and then, eventually, mount the new interface plates to it. Once mounted, the new stand and interface plate design will be tested and analyzed for performance in regards to ease of resetting the mannequin and ease of mobility. If these categories meet Lockheed Martin's requirements, Team #7 will begin to pursue other aspects of the Human Type Target that Lockheed Martin would like revised.

Figure 16 below shows the Gantt chart Team #7 will use to try and remain on schedule with the future plans mentioned above.

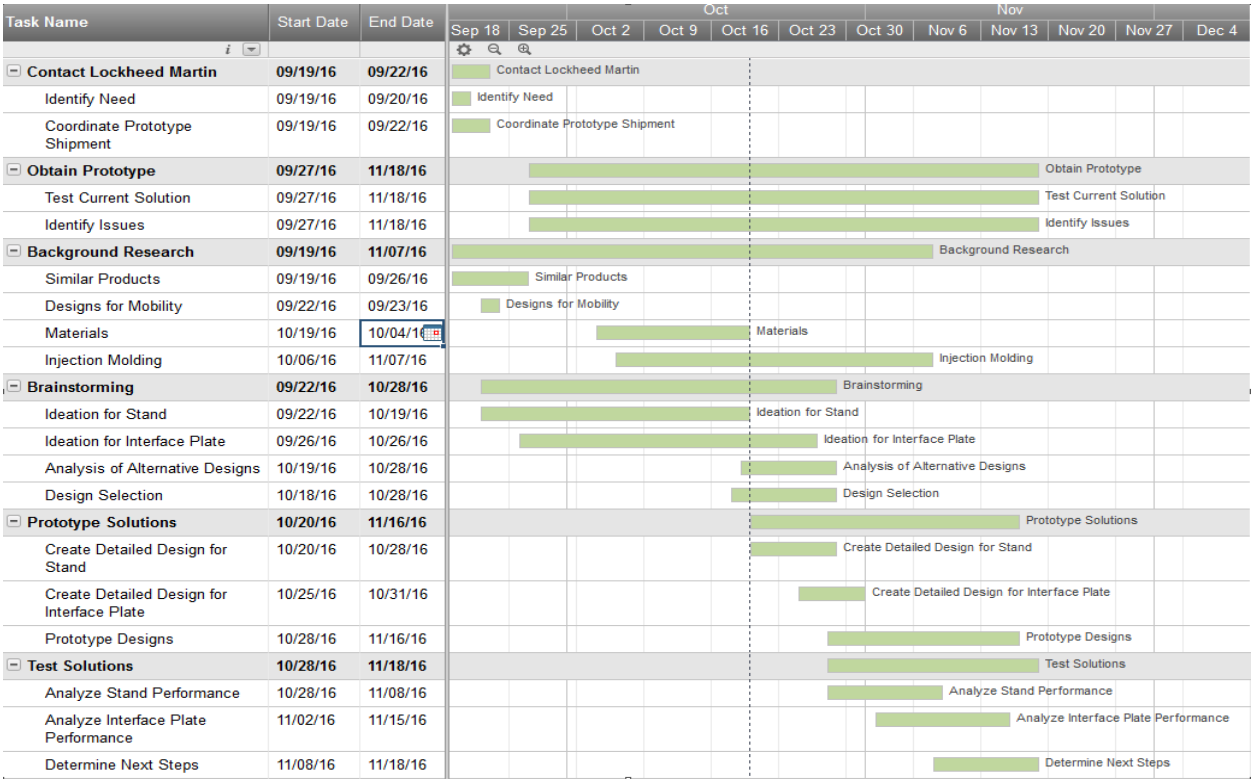

Figure 16: Gantt Chart

6. 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. Two designs for an interface plate have been proposed and critiqued giving a direction to head in when going through the next interface plate design. 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.

Appendix A

MIL-STD-1472F Department of Defense Design Criteria Standard, Human Engineering. Attached