Variable Angle Target Training System (V.A.T.T.S.)

Fall Final Report

Team 16
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Abstract

Stationary Infantry Targets (SIT) have been used in the past to give a more realistic training experience to military and law enforcement. Many of these targets employ the same overall target actions, but actions such as “pop-up” or rotation have recently been implemented in order to create a more robust training model. Specifically, Lockheed-Martin’s version of the SIT does not have the capability to rotate the attached target once in an upright position. The team’s objective is to create a lifting bracket to mount on Lockheed-Martin’s current SIT design. The newly designed and selected lifting bracket will accommodate various types of standard targets, as well as rotate the target using standard Future Army Systems of Integrated Targets (FASIT) regulations. Following the typical design process, the team has developed various bracket designs and with sponsor feedback has selected a final bracket with the use of a design selection matrix. The team has also designed and selected a suitable arm to lift the bracket and target. SolidWorks was used to perform flow analysis on two of the required targets. The results of the analysis provided the team with a better understanding of the system operation under the given wind constraint. Parts which the team will definitely employ in the final prototype will be ordered this semester, and other crucial parts, such as the motor and gearbox will be ordered early in the next semester to ensure the goal of producing a fully functional prototype.

1.0 Introduction

Military and law enforcement organizations have always attempted to simulate real life situations while training in order to be more prepared for real life situations. Targets that vary from simple paper and cardboard posters, to more complicated molded silhouette targets have been used to simulate real life situations where there is a need to distinguish between a hostile and a friendly entity. Coupling these target presentations with realistic spatial movements provides a robust model for what one might encounter in real life. There are various mechanisms available on the market that fully simulate an encounter where there is a need to discern friend from foe. One of those systems is the Stationary Infantry Target or SIT. The SIT system raises a concealed target up 90 degrees and presents the trainee with a target which can be either friend or foe. There are limitations of the SIT such as, the time to switch the physical target between a friendly target and a foe target, the manner in which the target is attached to the system is not universal for different, widely used targets, the target presented cannot rotate and is fixed in a fully presented position, limiting the realistic simulation of a quartering body.

The objective of this project is to implement a new target arm to the SIT, which alleviates many of the shortcomings of the original design. The new target arm shall make replacing used targets quicker and easier, accommodate various standard training targets, be able to rotate the target between a range of quartering angles once fully deployed in its upright position, as well as rotate a full 180 degrees to reveal a second, different presentation.

2.0 Project Scope

Team 16 plans is to develop a target turner for Lockheed Martin's Live Training organization for domestic and international militaries practices. An arm mechanism with turning function is for "pop-up/rotation" mechanism for various target presentationspictured below in Figure 3.

2.1 Background research

The Stationary Infantry Target, or SIT, has been used for many years and is a staple of live training equipment. They are primarily used in infantry platoon/squad battle courses but can also be used at gun ranges as well **[1]**. A picture of the mechanism can be seen below in Figure 1 **[2]**. The SIT mechanism has gone through many iterations over the years, making it more reliable, flexible, and simple to use. Therefore, the SIT systems that exist today are very robust. There are many different companies who design and market SIT systems, these companies include Strategic Systems, Meggitt, Lockheed Martin, and more. All the different SIT systems these companies produce essentially perform in the same way. Therefore, to incentivize organizations into buying their SIT systems, engineers are required to innovate and constantly improve their designs. These improvements are not just limited to the operation of the system but also to things such as portability, reliability, and cost **[3]**.

The competition between companies as well as increasing requirements from clients has given rise to complex SIT systems that provide more variable training. These variables add additional stress and also simulate real combat more closely giving rise to better trained personnel. Some examples include thermal targets which are used for night training, hit detection, and muzzle flash. However, the feature that the design team is primarily interested in is the rotation of a mounted target. Theissen already implements a friend/foe SIT on their MOUT (Military Operations in Urban Terrain) courses **[4]**. Also, Meggitt has a product called the MF-SIT which has the ability to raise and rotate the target a complete 360 degrees in less than a second **[2]**. This is of interest to the team since this feature is one of the goals of this project. Also, it can be seen that a rotating target has already been done and is currently in use.

It has been seen that SITs can vary in their combat simulation variability, but beyond these aspects, many systems follow a standard. For example, all SITs present the same basic targets. These include E-type, F-type, and Ivan-type targets. Also, all target systems run of FASIT 2.0 compliant firmware. FASIT is a set of regulations that helps simplify programming a training routine by keeping a universal set of commands among differing targets, and target manufacturer hardware on a range. More can be learned in the FASIT 2.0 Interface Control Document. The team will have to take these given factors into consideration in order to meet the project requirements.

Figure 1. Example of SIT

2.2 Need Statement

Lockheed Martin's Live Training organization specializes in training domestic and international ally militaries. Currently Lockheed supplies live fire "pop-up" targetry training systems for military target identification purposes. The new target training system requires the ability to rotate the target through various angles in either direction once the target has been lifted in order to present a friendly or foe target.

"Lockheed-Martin's current Stationary Infantry Target does not allow for suitable target presentations"

2.3 Goal Statement & Objectives

"To create a target system that can deploy a variety of targets from a resting position, and rotate to a friendly or foe position on command."

Objectives:

- Lift and rotate targets on command
- Firmware interface with FASIT
- Create a universal mount for variety of targets
- Easily attach and detach various types of targets
- Withstand 35 mph cross winds
- The motor may not be back driven
- Motor will be unaffected by heat, sand, dust, and rain
- Use "Type 11", "Ivan", "Type E" and "Type F" type targets

3.0 Constraints and Requirements

- The total cost may not exceed $3,000.
- Motor must meet FASIT requirements. **[5]**
- Distance from bottom of lifter to top of the arm shall be no more than 18 inches.
- Weight of lifter arm with turner motor shall be no more than 10 lbs.
- Time to install new target shall be less than 10 seconds
- Motor shall rotate the target up to 90 degrees in either direction within 1 second of receiving turn command.
- Motor housing shall be rated to at least IP67.
- Arm shall survive a loose cargo test (details TBD).
- Target arm shall operate -20^{o}C to 50^{o}C and shall have a minimum storage temperature range of -40^{o}C to 60^{o}C.
- Target arm shall accommodate an Ivan-style target (Figure 2a.), aType E (Figure 2c.) and Type F (Figure 2d.) target, and a Figure 11 target (Figure 2a.) without reconfiguration.
- Target arm shall fit on the new Lockheed Martin Stationary Infantry Target (SIT) – part number 15721510G1 (dimensions provided).
- Arm shall not impede functionality of muzzle flash feature on the SIT.
- The new bracket and arm must be able to hold the target in wind conditions up to 35 miles per hour
- Firmware shall be compatible with all applicable FASIT 2.0 commands (Refer to Table 1)

Figure 2a." Type 11" Target Face

Figure 2b. "Ivan" Type 3D Target

Figure 2c. “Type E” Style Target

Figure 2d. “Type F” Style Target

Figure 2. Target Examples

Table 1. FASIT 2.0 PD IDC calls out ASPECT field: values 0 through 6

FASIT 2.0 PD IDC Command	**Target Action**
0	Concealed
1	Simple Hostile
2	Restricted Hostile Left
3	Restricted Hostile Right
4	Simple Neutral
5	Restricted Neutral Left
6	Restricted Neutral Right

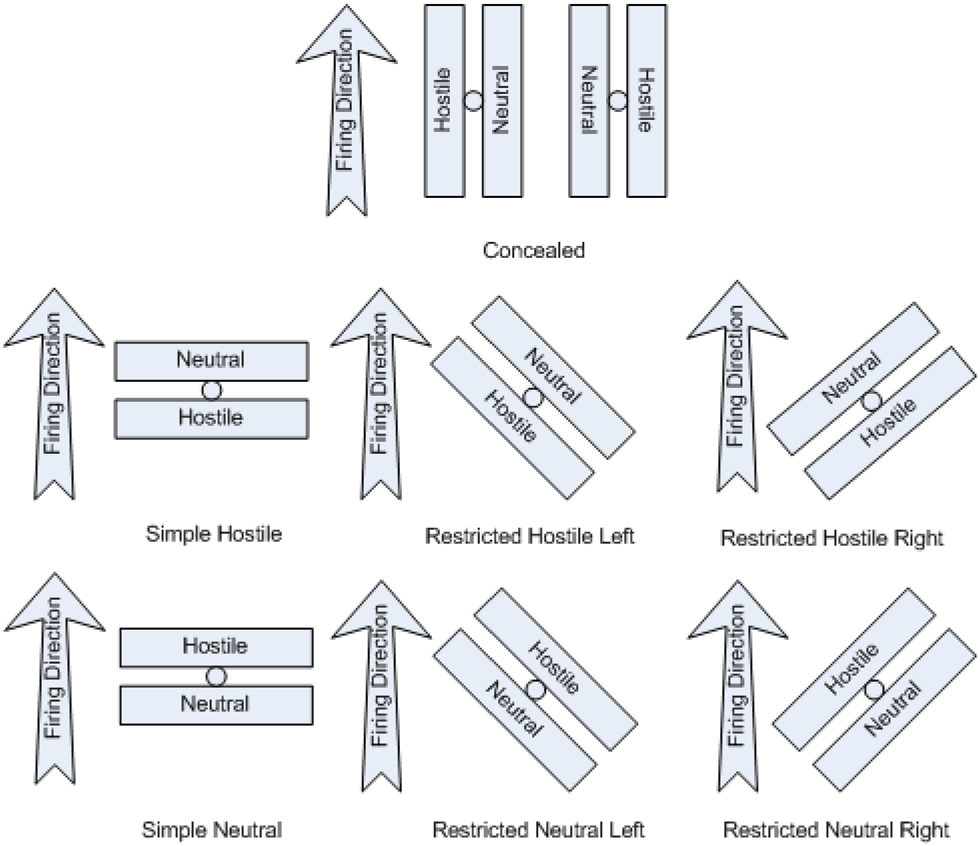
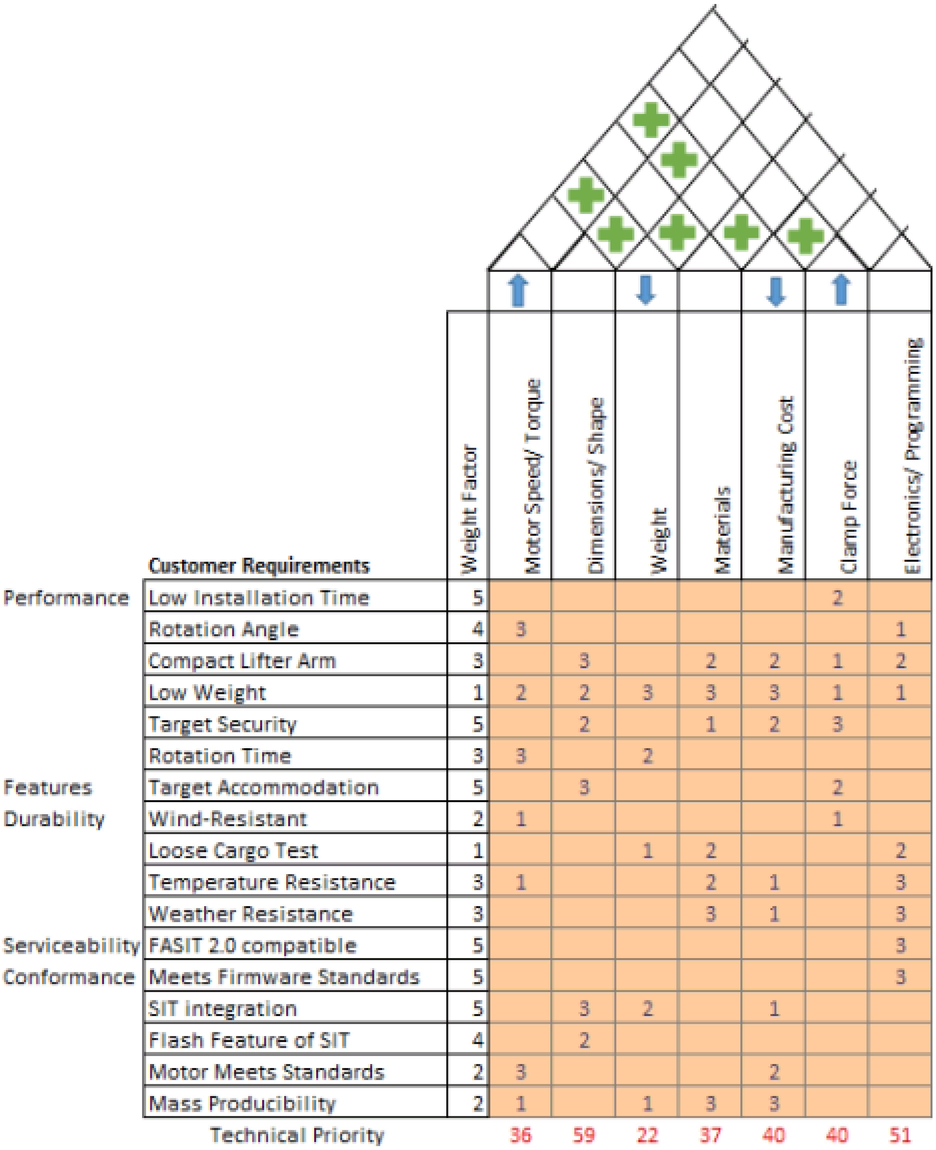


Figure 3. FASIT Target Actions

3.1 House of Quality

Based on the customer requirements and given project constraints a house of quality was constructed to better observe the importance of different needs for the project.



	Customer Requirements	Weight Factor	Motor Speed/ Torque	Dimensions/ Shape	Weight	Materials	Manufacturing Cost	Clamp Force	Electronics/ Programming
			↑		↓		↓	↑	
Performance	Low Installation Time	5						2	
	Rotation Angle	4	3						1
	Compact Lifter Arm	3		3		2	2	1	2
	Low Weight	1	2	2	3	3	3	1	1
	Target Security	5		2		1	2	3	
	Rotation Time	3	3		2				
Features	Target Accommodation	5		3				2	
Durability	Wind-Resistant	2	1					1	
	Loose Cargo Test	1			1	2			2
	Temperature Resistance	3	1			2	1		3
	Weather Resistance	3				3	1		3
Serviceability	FASIT 2.0 compatible	5							3
Conformance	Meets Firmware Standards	5							3
	SIT integration	5		3	2		1		
	Flash Feature of SIT	4		2					
	Motor Meets Standards	2	3				2		
	Mass Producibility	2	1		1	3	3		
	Technical Priority		36	59	22	37	40	40	51

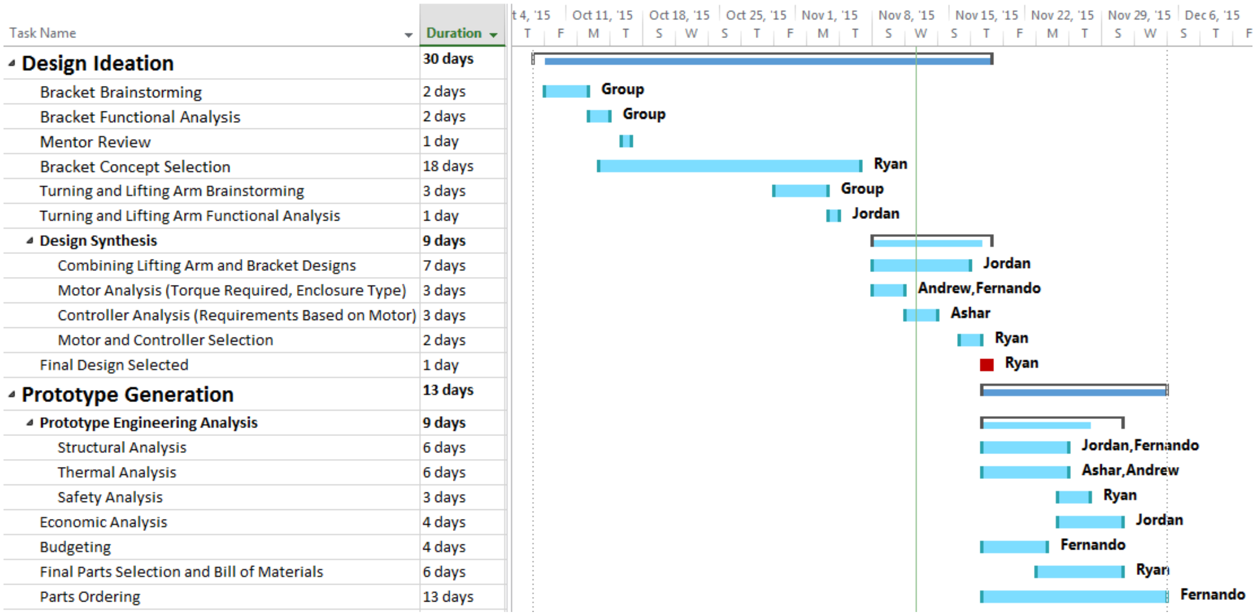
Figure 4. Constructed House of Quality

4.0 Methodology and Approach

Currently the team meets with each other on a weekly basis. The team also meets with the sponsor, Chris Isler, on a weekly basis via conference call. Anything that is discussed about in the meeting is written down by the historian, Andrew Bellstrom. Also, any documents that are given to us by the sponsor goes to the team leader directly who can then decide to delegate it among the members. This way, information sharing is more streamlined.

The team produced a Gantt chart to help plan out the nine months left to work on this project. The time allotted to work on deliverables are concrete due to deliverable deadlines. The time allocated to the design process is more flexible, but will be followed as stringently as possible. The Gantt chart should provide a general idea of the project's status on a given day. Assignment of responsibility for respective tasks can be found on the Gantt chart diagram.

4.1 GanttChart



Task Name	Duration
Design Ideation	**30 days**
Bracket Brainstorming	2 days
Bracket Functional Analysis	2 days
Mentor Review	1 day
Bracket Concept Selection	18 days
Turning and Lifting Arm Brainstorming	3 days
Turning and Lifting Arm Functional Analysis	1 day
Design Synthesis	**9 days**
Combining Lifting Arm and Bracket Designs	7 days
Motor Analysis (Torque Required, Enclosure Type)	3 days
Controller Analysis (Requirements Based on Motor)	3 days
Motor and Controller Selection	2 days
Final Design Selected	1 day
Prototype Generation	**13 days**
Prototype Engineering Analysis	**9 days**
Structural Analysis	6 days
Thermal Analysis	6 days
Safety Analysis	3 days
Economic Analysis	4 days
Budgeting	4 days
Final Parts Selection and Bill of Materials	6 days
Parts Ordering	13 days

Figure 5. Fall 2015 Semester Gantt Chart

5.0 Environmental and Safety Assessment

5.1 Risk Assessment

As with most any project, there is a risk element. The team has performed a risk assessment and submitted the document to the Senior Design Capstone advising faculty. In said risk assessment, the team outlined the potential risks presented by this specific project. The main risks were found to be in the Prototype Construction and Prototype Testing phase of this project. Where construction of the prototype would present risks such as machine tools, and prototype testing risk would involve potential bodily injury from moving parts on the prototype. In order to reduce the risk, the team will take appropriate steps to avoid injury. Steps include being certified for use of required machining tools, deferring to experts in the machine shop for majority of the machining process and following Lockheed-Martin’s safety guidelines for use of their provided Stationary Infantry Target system. All members of the group have understood proper emergency procedures and all potential risks will be reported to group mentors as well as senior design faculty. In the event of accident, or close call, the group understands that it has a responsibility to inform its project advisors.

5.2 Environmental Impact Assessment

This project involves the manufacturing of many different components that might eventually reach the end of their life cycle. It is important to ensure that the retirement of such a system is handled properly. The proposed components of the system, such as any battery used for the turning mechanism, must be disposed of in regulation with proper safety and recycling standards. The electrical components, such as the controller and motors should also be disposed of or recycled in a proper manner. At the end of this product’s life cycle it would be greatly suggested that the recycling of materials take place. The plastic housing of the lifter, as well as other aluminum parts may be recycled to lessen the impact on the environment to produce more of the same parts from scratch.

6.0 Design

6.1 Bracket Design

6.1.1BracketDesign A

This bracket design is based on minimum weight and cost. The first thought was to measure all the targets and put them together to visualize a pattern between them. As one can see from Figure 7, there is a pattern between the flat targets. The "Ivan" target can be seen with the small hole in the back at an estimate of 80 degrees from the other targets. The next step was to conceptualize the locking mechanism, which is a main challenge in this project. There are many locking mechanism to choose from, but only one will be chosen based on sponsor feedback and design constraints. Examples of these mechanisms are Line Actuators, clamps, Pneumatics or even motors with gears. Some of this will increase the price and/or the weight. The best choice in this case are clamps, specifically toggle clamps, pictured in Figure 8, or bicycle seat clamps, seen in Figure 9. The toggle clamp is better suited for the ability to lock after the rotation, making this the choice for this design. For Bracket Design A, three of these clamps will be placed on the target rack, one in the middle and the other two located seven inches from the center. The side clamps will have the ability to rotate 80 degrees inward in order to accommodate the Ivan style target. Design A can be seen in Figure 11. Figure 10 shows the maximum clearance for the turner bracket which must be met by this design. As one can see, the height up from the pinch point of this mechanism must be less than 3.8".

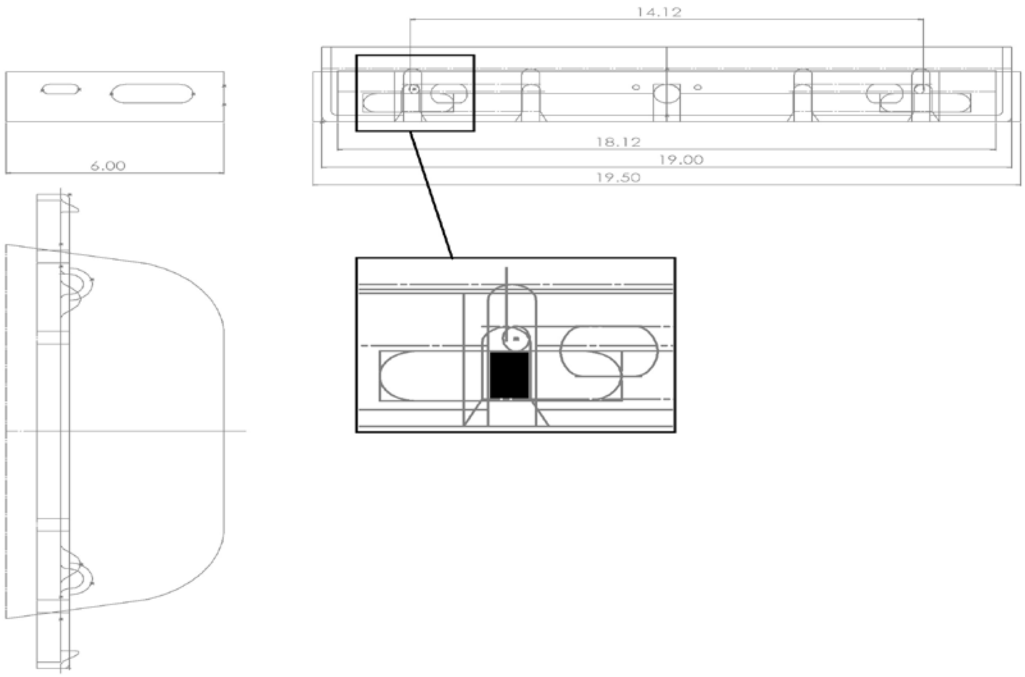


Figure 7: CAD of Overlapped Targets showing universal gap

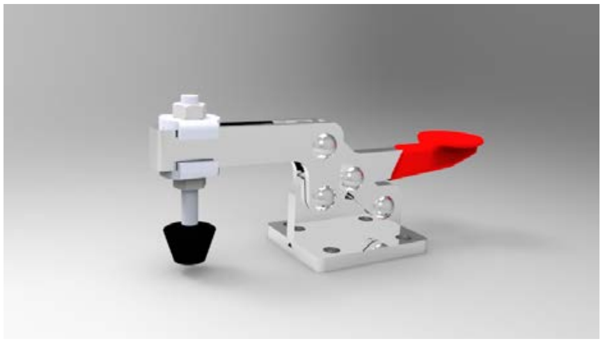


Figure 8: Toggle clamp CAD

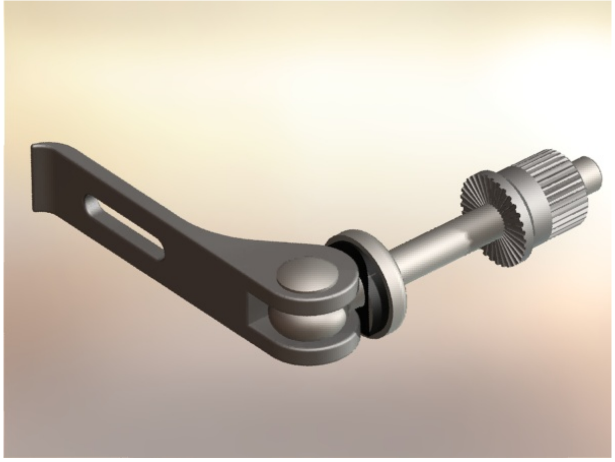


Figure 9: Bicycle seat clamp CAD

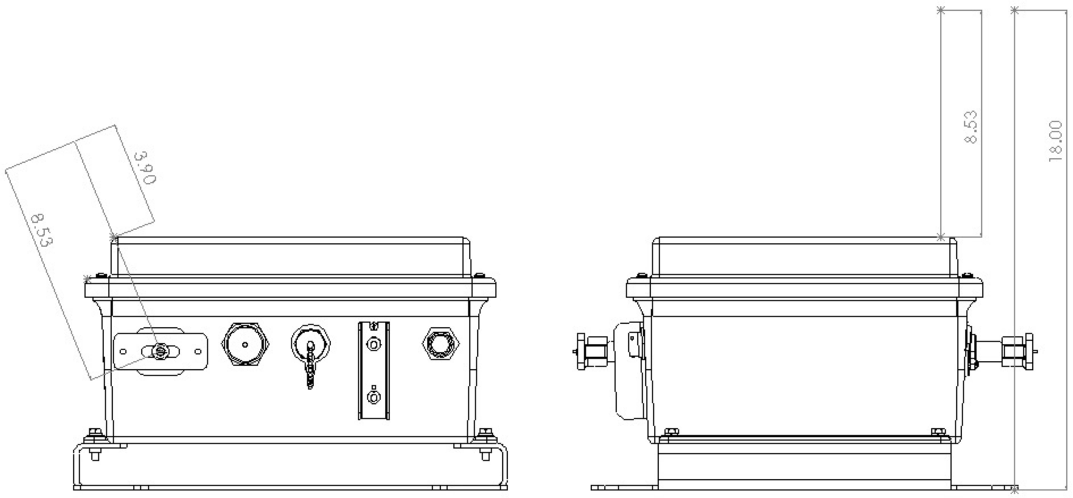


Figure 10: Limiting height of lifting arm on SIT

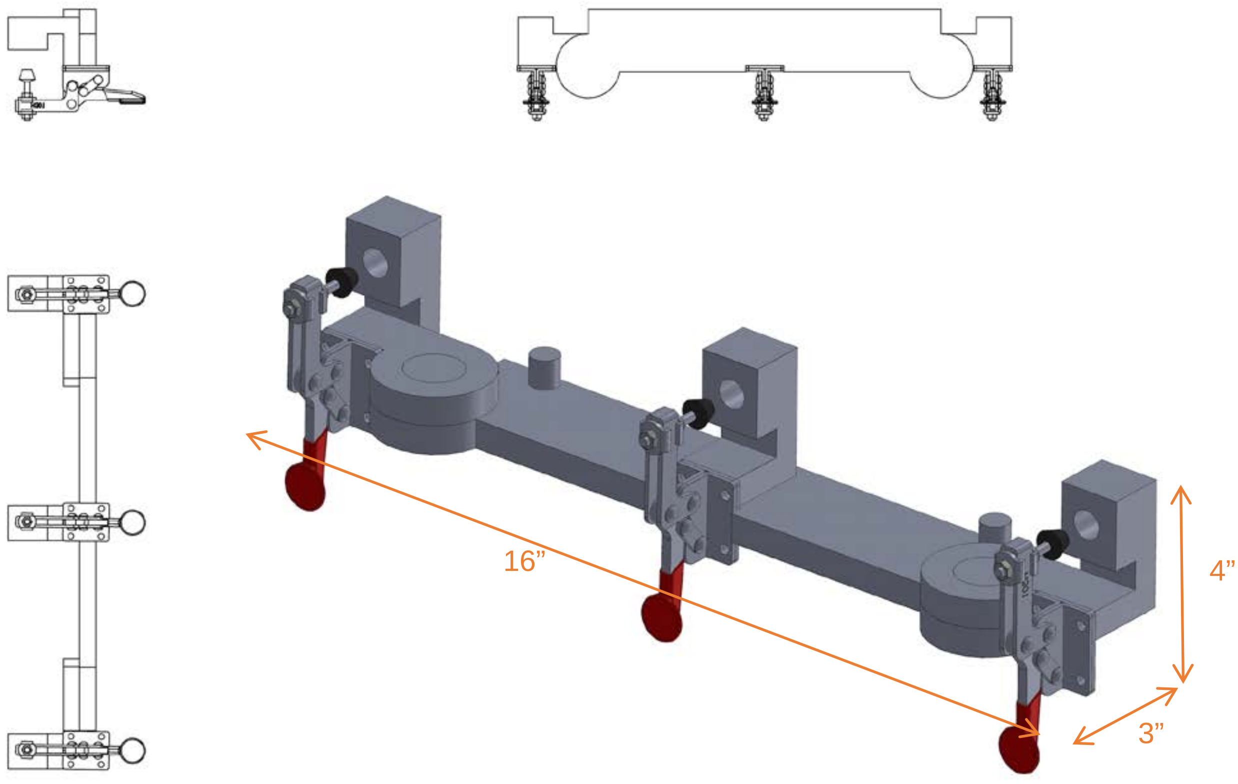


Figure 11. Design A

6.1.2 Bracket Design B

This a preliminary design concept of the target bracing mechanism. The goal of this design is to securely hold all 4 target types while the lifter operates. This design features a swinging gate attached by a hinge, which will rotate upward and be clamped to the back of the bracing mechanism. Bracket Design B will operate similar to the tailgate of a truck. To lock/unlock the system, a clamp can be utilized. To incorporate the Ivan, target the back of the target brace will be slotted to allow the Ivan to fit securely in place. In order to connect the brace to the motor/gearbox a pin and collar can be used on the bottom plate.

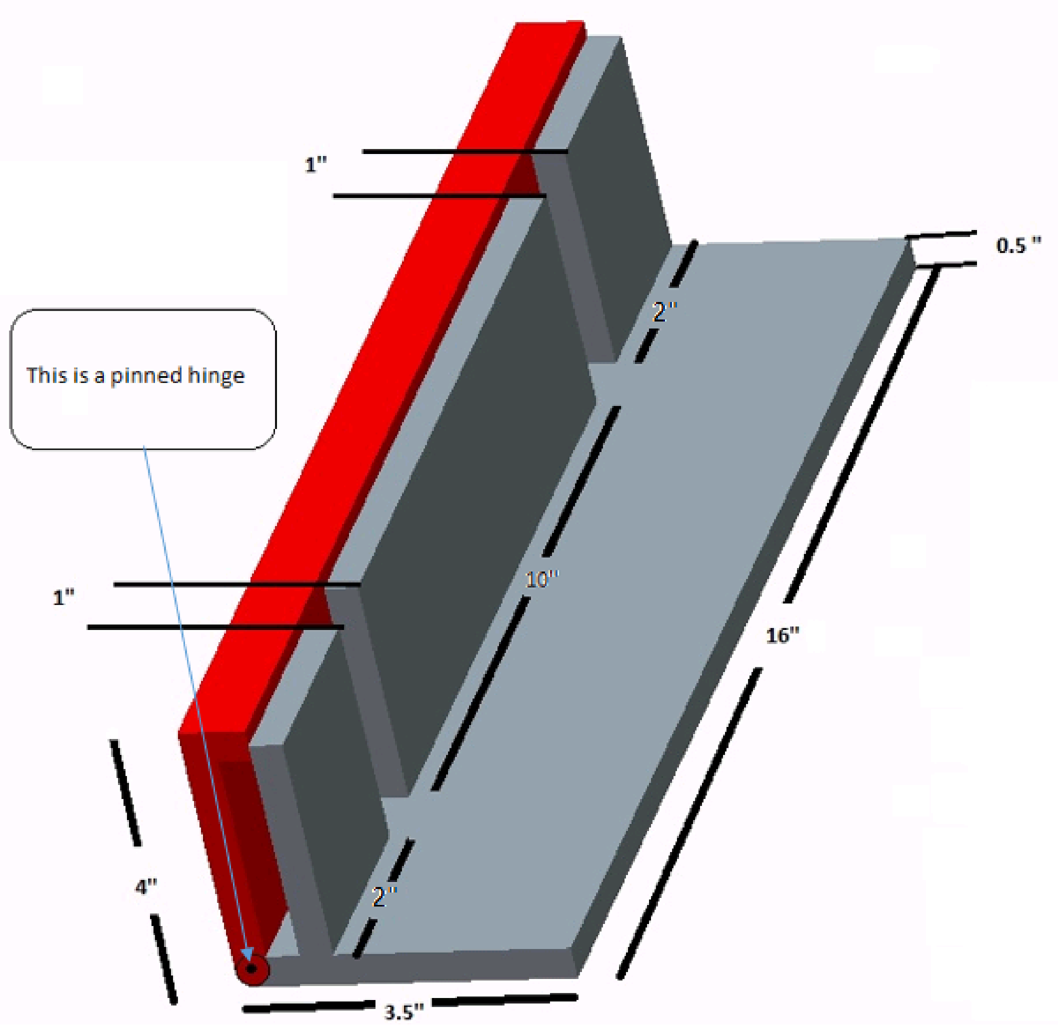


Figure 12. Bracket Design B

6.1.3Bracket Design C

Bracket Design C implements a toggle mechanism coupled with a simple one point bracing against a plate. The toggle mechanism used would be similar to that of vice grip pliers. The benefits of this include increased speed of interchanging targets and firm locking. However, the one-point brace may present a problem for ensuring a suitable target hold. This design would work of all targets utilized in the project by bracing only the front part of the target, not the sides, such as those on the “Ivan” style target.

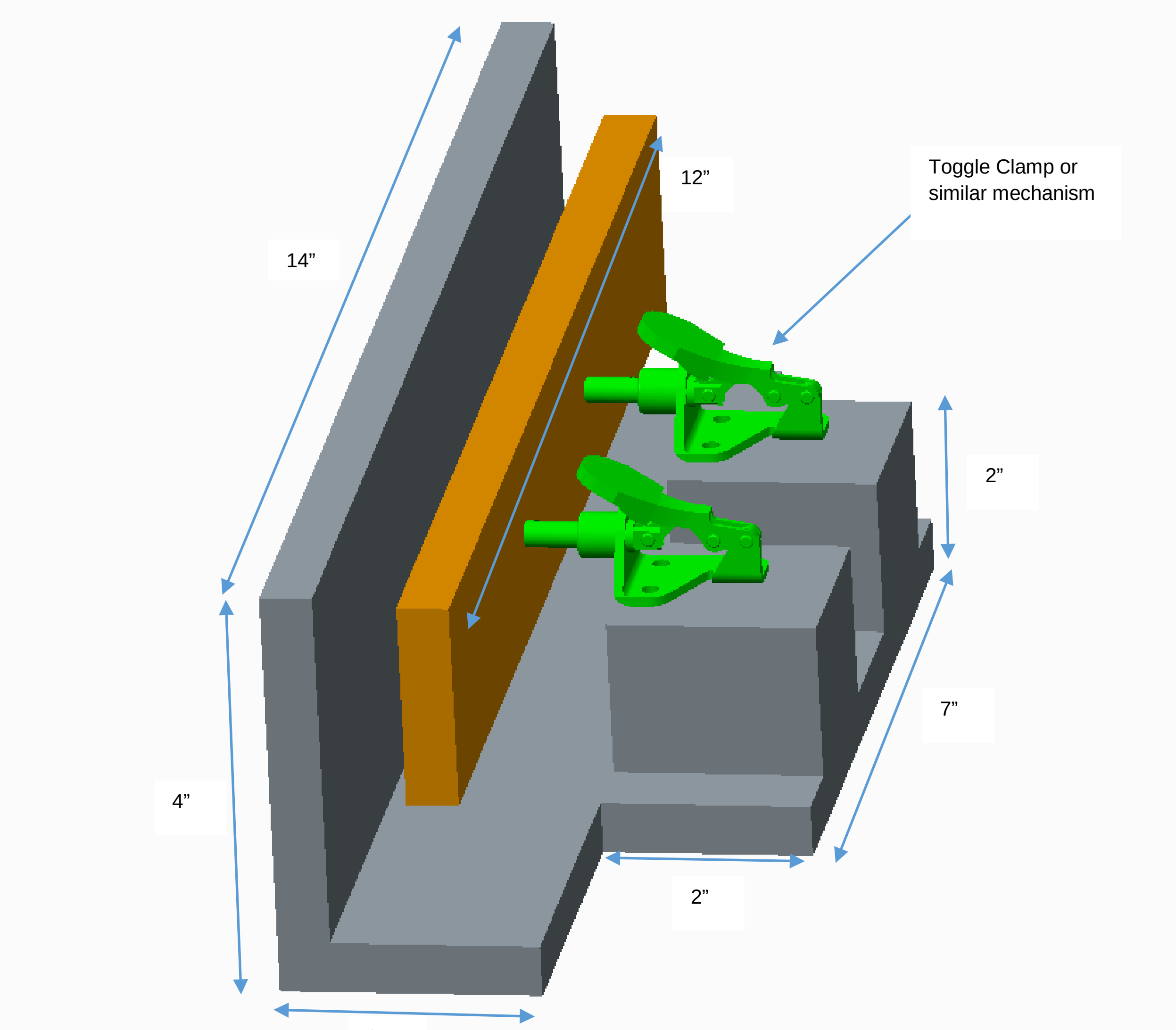


Figure 13. Bracket Design C

6.1.4Bracket Design D

Bracket Design D is very similar to Bracket Design C, but instead of a toggle mechanism, screw-in bolts are utilized to brace the target against the front plate. This design is simple, but the screw-in bolts increase the time to interchange targets. Also, the sponsor has communicated issues in the past systems where weathering of bolts contributes to difficulty of target removal.

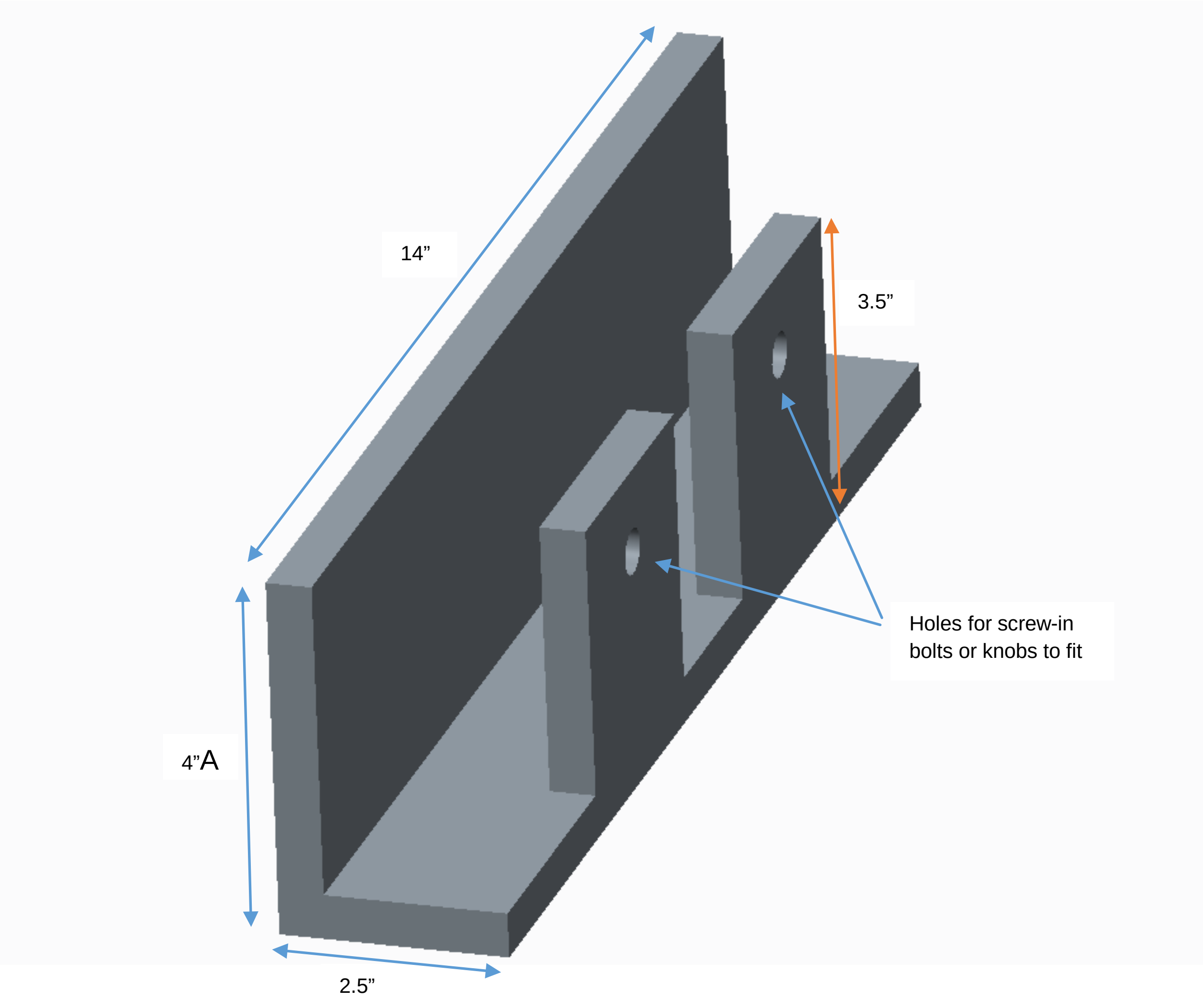
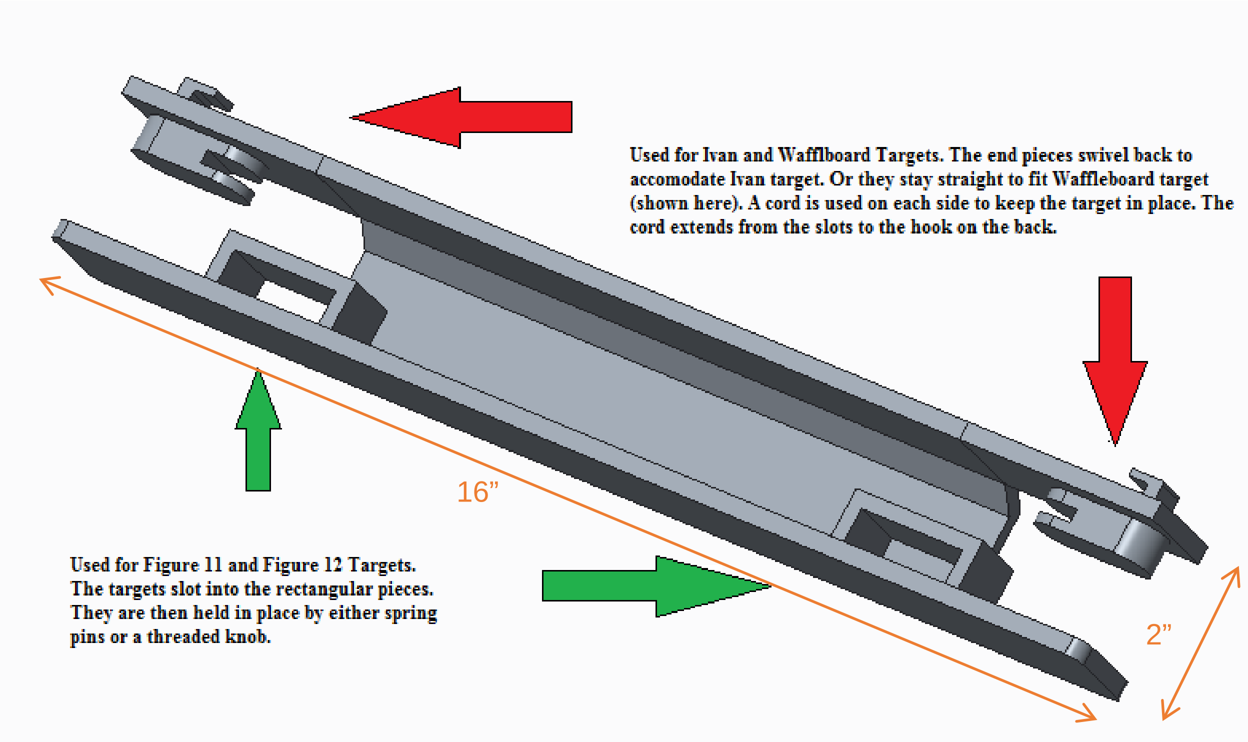


Figure 14. Bracket Design D

6.1.5 BracketDesign E

The below image in Figure 15is a conceptual idea more than a design. It pays no heed to any of the constraints but it does provide a possible solution to the problem at hand. Further iteration would require the design to be more viable.

This design accommodates all four targets without any reconfiguration. The Ivan and Waffle Board targets are held against the back plate with a help of a cord. The end pieces swivel back to accommodate the Ivan target. The “Type 11” and “Type12” standardtargets are clamped to the front plate and held in by the rectangular slots shown. The sprung pin/threaded knob would come in from the front and would hold the target against the back of the rectangular slot.



Used for Ivan and Wafflboard Targets. The end pieces swivel back to accomodate Ivan target. Or they stay straight to fit Waffleboard target (shown here). A cord is used on each side to keep the target in place. The cord extends from the slots to the hook on the back.

Used for Figure 11 and Figure 12 Targets. The targets slot into the rectangular pieces. They are then held in place by either spring pins or a threaded knob.

Figure 15. Bracket Design E

6.2 Revised Bracket Design

After review with the sponsor, it was determined that many of the previously shown designs were unsuitable due to the use of various types of a hinge. The sponsor indicated to the team that the use of a hinge has regularly caused problems on current systems they already employ. Given the feedback, the team modified and adjusted the previous designs to produce the following ideas.It was important to eliminate all moving and threaded parts from the previous bracket designs. Hinges, swivels, threaded fasteners, and rubber materials will not last when exposed to sand wind, rain and mud. Descriptions and illustrations of Bracket Designs F and G can be seen in the figures below.

6.2.1 Bracket Design F

Bracket Design F features a front plate that holds each of the targets in place with two bicycle seat clamps that force the adjustable front plate to the back of the bracket. This design is very simple and inexpensive, however the design doesn't allow for as easy of a secured universal fit when compared to Bracket Design G. Bracket Design F is also an all-aluminum bracket however its dimensions are a bit larger than Bracket Design G. The height of bracket Bracket Design F allows for a larger maximum clearance for the needed arm attachment.

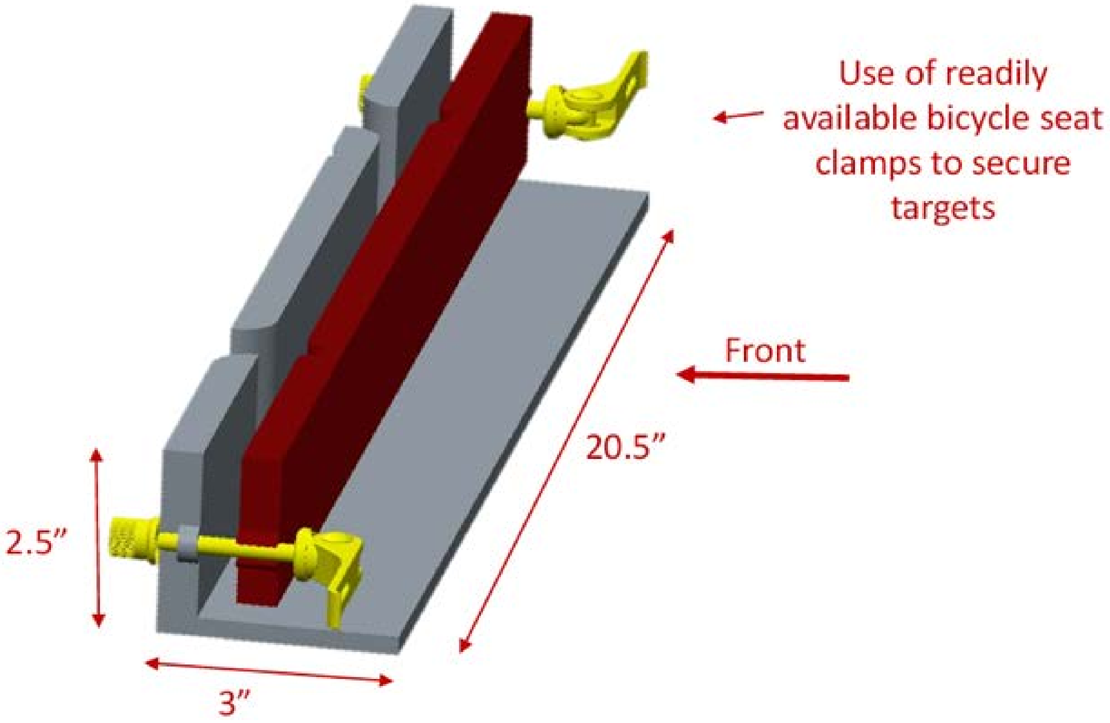
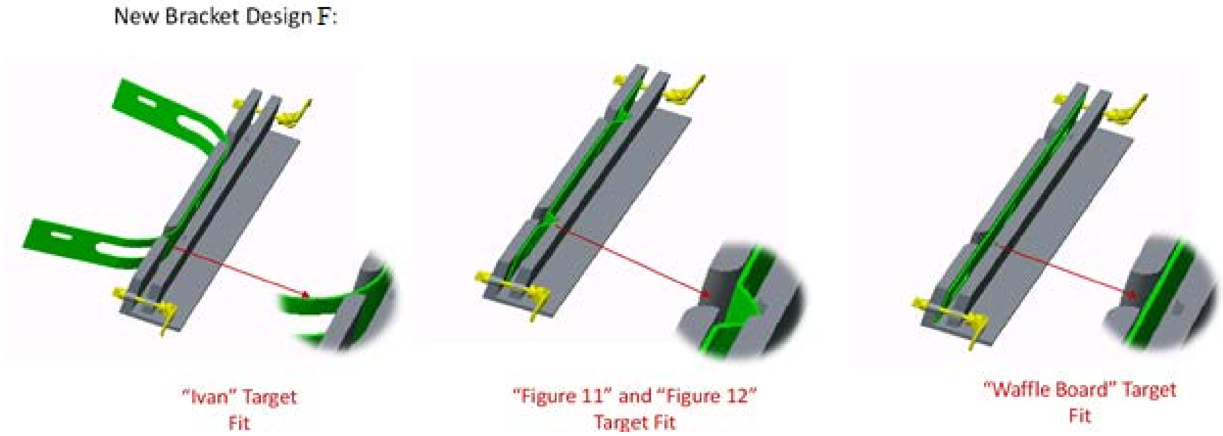


Figure 16. Bracket Design F

As seen below in Figure 17, the targets fit in between the adjustable front plate and the back of the bracket. The targets are held between these two plates using an applied friction force created from using two bicycle seat clamps. The concept is very simple, however the slight rivet difference between the “Type 11” and “Type 12” target may be enough to cause the smaller of the two to slip out when the lifter operates with the added rotational factor. An additional factor of concern with this design is that the adjustable front plate may not operate when the bracket becomes caked with mud or sand.


New Bracket Design F:

“Ivan” Target Fit

“Figure 11” and “Figure 12” Target Fit

“Waffle Board” Target Fit

Figure 17. How the various required targets fit into Bracket Design F

6.2.1 Bracket Design G

Bracket Design G shown in Figure 18 below is an all-aluminum bracket that uses two toggle lever clamps to brace the various targets against the front plate. This design allows for a maximum arm attachment height of 14 inches which can provide about a 5 inch clearance for the motor housing, when the arm is sitting above the lifter in the up position. This bracket is more complex than Bracket Design F but it allows for a more secure universal fit for each of the 4 targets. This design is also lighter in weight, smaller in size and has a fewer number of parts increasing both the reliability and loading time of the bracket.

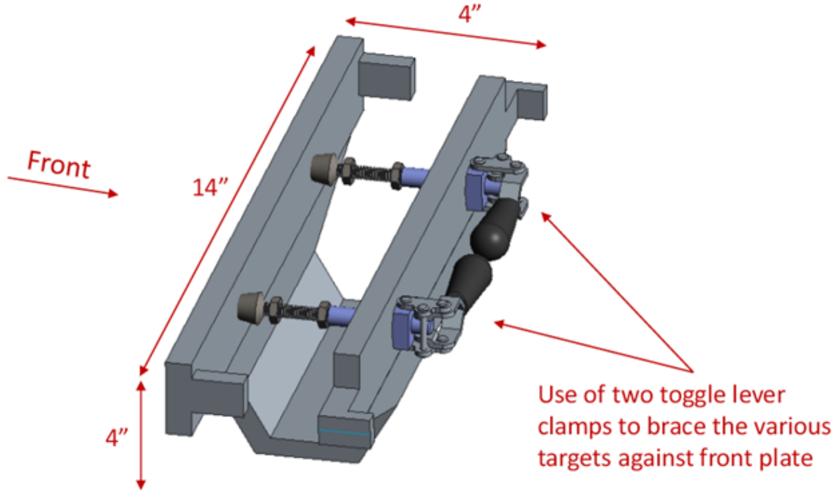


Figure 18. Bracket Design G

As seen below in Figure 19, the targets fit into the bracket design according to the shape and profile of the target. The targets are held between these two plates using an applied friction force created from using two toggle lever clamps. This bracket design is more complex than Bracket Design F, however this bracket allows for a more secure universal fit.

Figure 19. How the various required targets fit into Bracket Design G

6.3 Bracket Design Selection

Table 2. Design Matrix for Bracket Designs F and G

Target Bracket Design Matrix			
	Weighted	Bracket Design F	Bracket Design G
Simplicity	5	4	2
Cost	3	4	2
Size	1	2	4
Weight	2	3	4
# of parts	4	3	5
Loading time	4	3	3
Reliability	5	2	4
Total Point Value		74	80

The Design Matrix, seen in table 3 above, compares the two final bracket designs conceptualized by team 16. For this matrix each of the engineering factors have been weighted numerically from 1 to 5. A weight of 1 implies that the factor is of little concern and a weight of 5 indicates that the engineering factor is very important.

The goal of these two mechanical bracket designs isto hold each of the 4 standard targets securely while the lifter operates. The engineering factors have been weighted based on the customer's specifications and the lifters constraints. Lockheed Martin's current mechanical bracket is inefficient and inconvenient for the user when loading each of the four different types of targets into the lifter.

Simplicity, reliability, loading time, and number of parts were determined to be the highest weighted and most important factors of our preliminary designs. The loading time was presented to be one of the more important constraints, as our design must allow for each target to be changed and loaded within 10 seconds. Each Bracket Design F and G incorporate toggle clamps or bicycle clamps to securely hold the 4 standard target types.

Reliability is weighted as very important due to the fact that the mechanical bracket design must be able to withstand variable environmental elements including water, dust, wind, and sand. The design must also be reliable to ensure that the bracket will continually hold the targets as they are shot at repeatedly.Due to the greater number of parts and the adjustable sliding front plate, Bracket Design F received a lower score in the reliability section. The sliding front plate may allow for mud or other debris to prevent the plate from adjusting or functioning properly.

Weight, cost, and size are other factors that our team took into account while designing the mechanical target arm. These factors happen to be weighted lower than the previously discussed factors but are still necessary design elements to consider. Using all weighted factors, it was determined the best design was Bracket Design G.

6.4 Arm Design

In order to attach the bracket to the lifter an arm is needed, as seen in Figure 1. This arm must also house the motor, gearbox and micro-controller. As stated previously in the constraints, the top of the bracket must not be more than 18 inches above the ground. The motor or motor housing must also meet IP 67 requirements. These requirements state that the motor must be able to operate in dusty or wet conditions.With the final selected bracket, Bracket Design G, the arm must not extend more than 13 inches above the ground in order to provide the needed clearance for the lifter. During the lifting process, the arm must also clear the top of the lifter. The top of the lifter is 9.5 inches above the ground, this means that the motor housing and arm attachment must fit between a space of 3.5 to 4 inches if the arm is to sit over the top of the lifter. The arm may sit centered over the lifter or the arm can sit behind the lifter after the target is raised. In order to complete the arm design selection, the motor analysis must be completed and a motor must be selected to determine the dimensions of the motor housing and the placement of this motor housing on the arm attachment.

6.4.1Arm Design A

Arm Design A, as seen below in Figure 20 is a simple U-shaped arm that sits over the center of the lifter when raised. The arm houses the motor and its internals in an area that runs along the underside of the top of the arm attachment. In this design the back of the motor housing is left exposed for ventilation and easy access to the motor and gearbox. In order for this housing to work, the motor and electronics must meet IP 67 requirements individually. This is not cost effective so an alternative IP 67 housing should be used.

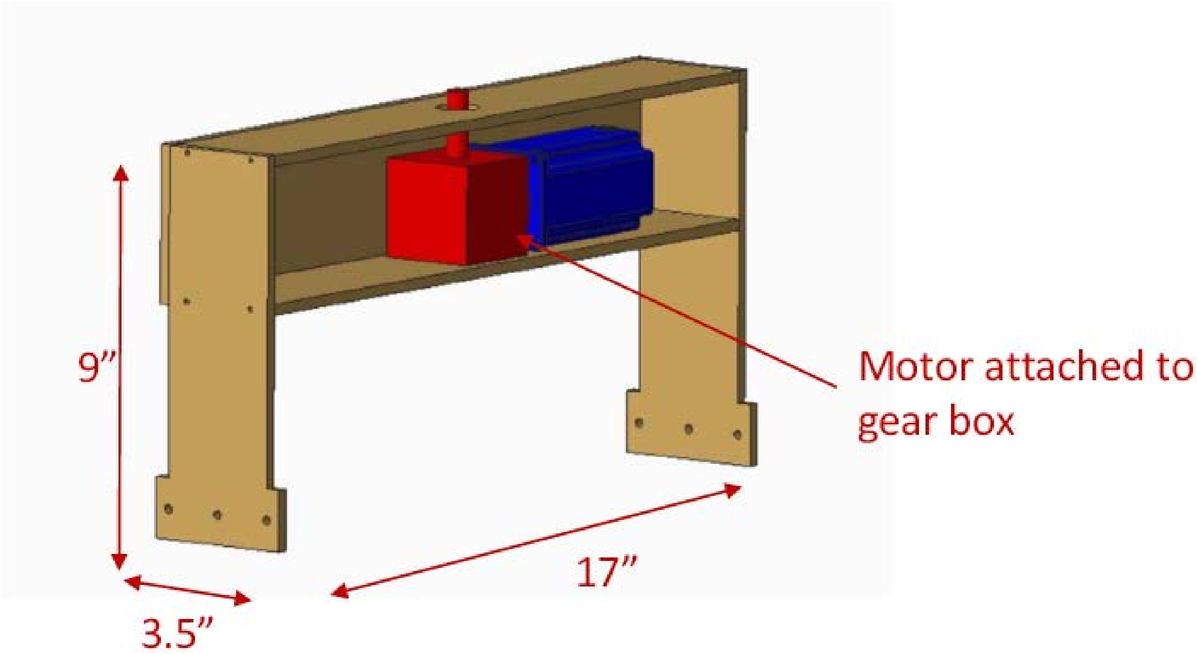


Figure 20. Arm Design A

6.4.2 Arm Design B

Arm Design B is very similar to Arm Design 1, however it has a curved profile and features a motor housing that sits on top of the arm attachment. The dimensions of the motor housing are still to be determined based upon motor selection. Depending on the selected motor, this design may or may not be suitable for the lifter. The motor housing in this design is fully enclosed and features a detachable plate that allows technicians to access the internals of the housing.

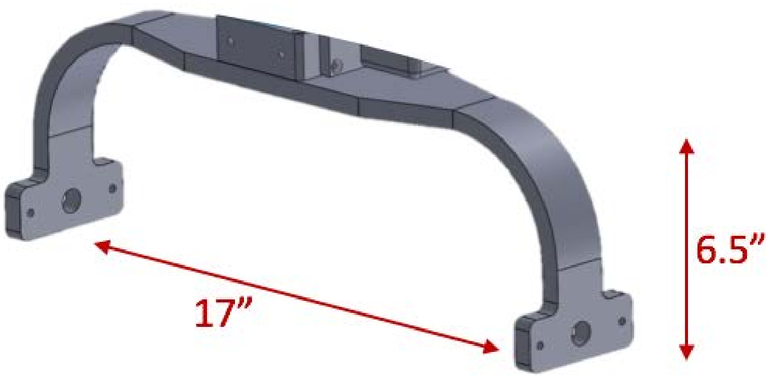


Figure 21. Arm Design B

6.4.3 Arm Design C

Arm Design C sits behind the lifter when the arm is raised. This design eliminates the pinch point problem that occurs when the arm sits directly over the lifter. In order to achieve the desired positioning behind the lifter, the arm is angled back to provide a gap between the arm and the lifter. The arm also holds the motor housing in this design. The motor housing is attached with two bolts from the top of the arm. This allows the motor housing to be taken off of the arm completely for maintenance. The motor housing also features vents and fins in order to keep the motor from overheating. Technicians can access the internals of the housing by simply removing the back plate with a Philips head.

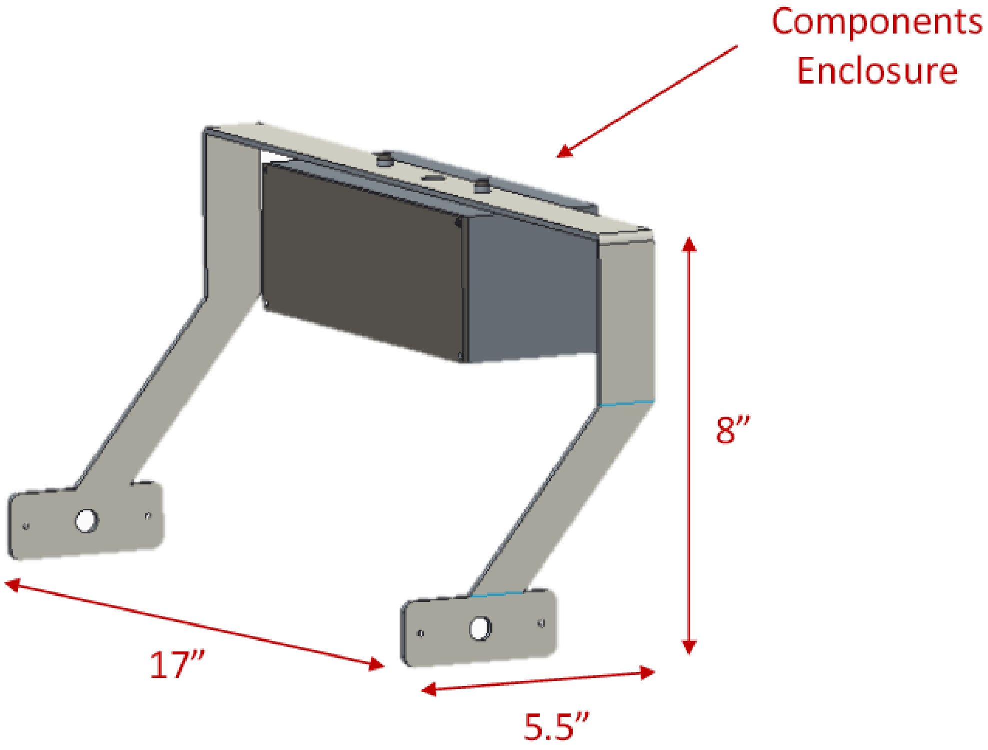


Figure 22. Arm Design C

6.5 Arm Design Selection

Table 3. Design Matrix for Arm Designs A – C

Target Arm Design Matrix				
	Weighted	Arm Design A	Arm Design B	Arm Design C
Simplicity	5	4	2	2
Cost	3	4	2	2
Size	1	2	3	3
Weight	2	2	4	3
# of parts	4	4	3	3
Reliability	5	4	3	4
TotalPoint Value		74	54	57

The Design Matrix, seen in table 3 above, compares the three preliminary mechanical arm designs conceptualized by team 16. For this matrix each of the engineering factors have been weighted numerically from 1 to 5. A weight of 1 implies that the factor is of little concern and a weight of 5 indicates that the engineering factor is very important.

The goal of these three mechanical arm designs is to hold the motor housing and its internals while lifting the bracket and each of the 4 standard targets. The engineering factors have been weighted based on the customer's specifications and the lifters constraints.

Simplicity, reliability, and number of parts were determined to be the highest weighted and most important factors of our preliminary designs. The simplest design with the fewest amount of parts is design 1. The problem with Arm Design A is having the motor housing meet the required IP 67 statute. This can be solved by combining the motor housing from arm design 3 with the arm from the first design.

The greater the number of parts, the less simple the design, and the higher the risk that the design will not withstand the elements or required testing. Arm Designs B and C were considered less favorable do to the number of parts associated with the motor housing and arm attachment.

Reliability is weighted as very important due to the fact that the mechanical arm design must be able to withstand variable environmental elements including water, dust, wind, and sand. The design must also be reliable to ensure that the bracket will continually hold the targets as they are shot at repeatedly the designs that scored well in this area were Arm Designs A and C.

Weight, cost, and size are other factors that our team took into account while designing the mechanical target arm. These factors happen to be weighted lower than the previously discussed factors but are still necessary design elements to consider. Using all weighted factors, it was determined the best designs were Arm Designs A and C.

Due to its simplicity, Arm Design A was selected. If future iterations of arm designs are needed, Arm Design C's principal design elements will be taken into account due to its high rating with respect to the team's weighting factors.

7.0 Results

7.1 Motor

7.1.1 Torque Analysis

In order to determine the required motor, the team must take into account many factors, such as the weight of components from the bracket, target weight and any wind forces that may act upon the bracket system during operation. The team calculated the motor torque required to turn the bracket with no wind force as 238 ozf*in with a factor of safety of 1.5. The calculations for this nominal stepper motor torque can be found in Appendix A.

7.1.2 Gearbox and Bracket to Arm Attachment

Due to the orientation of the motor in the selected arm and bracket designs, a gearbox will be required to change the output shaft orientation from the motor in order to turn the bracket. This gearbox is still to be determined. The output shaft from the gearbox will bear a large amount of force due to the wind and weight of the bracket, therefore the team has proposed the use of a bearing on the output shaft to alleviate any over-torqueing of the output, hindering rotation of the target. The output shaft will be attached to the bottom of the bracket with the use of a shaft fit to a flange which may then be fastened to the bottom of the selected bracket.

7.2 Wind Effects Analysis

SolidWorks was used to conduct flow analysis given the operational constraint of 35 mile per hour (about 16 meters per second) winds. Below are two cases which will be encountered.

7.2.1 Flat Target

A target modeled as a flat plate with dimensions 40in x 18in x 0.1in was analyzed and closest resembles the team's "Type 12" target. This target was tested at five different angle position,seen on Figure 23, to observe the highest force and torque values across the x, y and z directions. The first target angle of $0^{o}$was calculated and as expected the force on the x-axis is the highest due to the entire surface area of the 40 inch wide target being in the flow. In this flow configuration the force on the bracket was determined to have a magnitude of 70N, or about 16lb force. The torque in the y direction (out of the page) was determined to be at its maximum of 31Nm with this same 0^{o} target orientation. This torque is of particular interest because it is the maximum torque acting against our motor. It is also important to note that the target, while turning, will incur some lifting force due to a pressure differential at different angles. Due to this, when the motor calculations are complete, accounting for this simulated maximum toque, there will be a factor of safety included to account for the lifting. Analysis of angles from the other cases of 0^{o} to 90^{o} can be found in Table 4 in Appendix B.

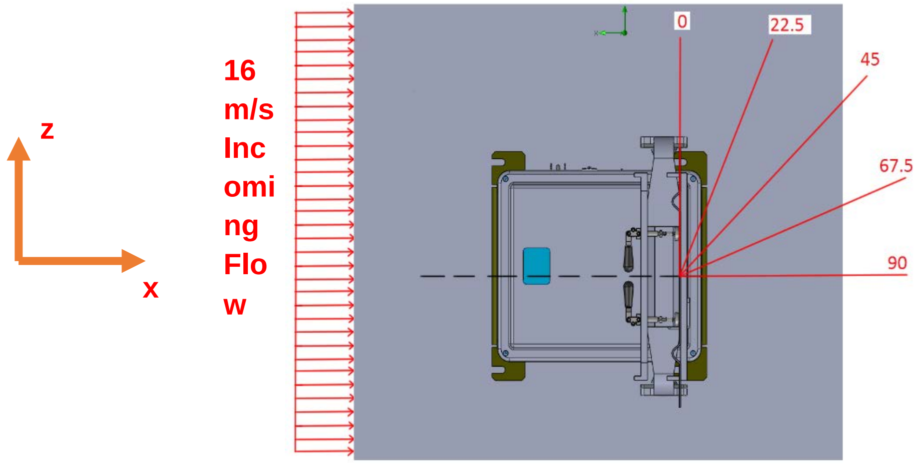


Figure 23: Flat Stationary Target flow direction, and testing 0-90 degree target orientation with respect to the front of the lifter

7.2.2 Curved "Ivan" Target

Computational Fluids Dynamics was complete on the "Ivan" type stationary infantry.As expected there was a difference between this curved target and the flat target analyzed previously.The testing region for this was from 0 to 180 degrees with respect to the front of the lifter. The maximum force that this setup encountered was found to be 51N in the x direction when in the 180^o target orientation, where the wind flow is fully acting into the "scooped", curved section of the Ivan target. The maximum torque was found to be 22Nm in the y direction (out of the page), also when in the 180^o orientation. The next two worst cases were found to be the 22.5^o and 157.5^o orientations. It was not expected that the "Ivan" target would have less force and torque on the motor in these various cases. This proves the importance of the flow simulations conducted. The analysis of angles from the other cases of 0^o to 180^o can be found in Table 4 in Appendix B.

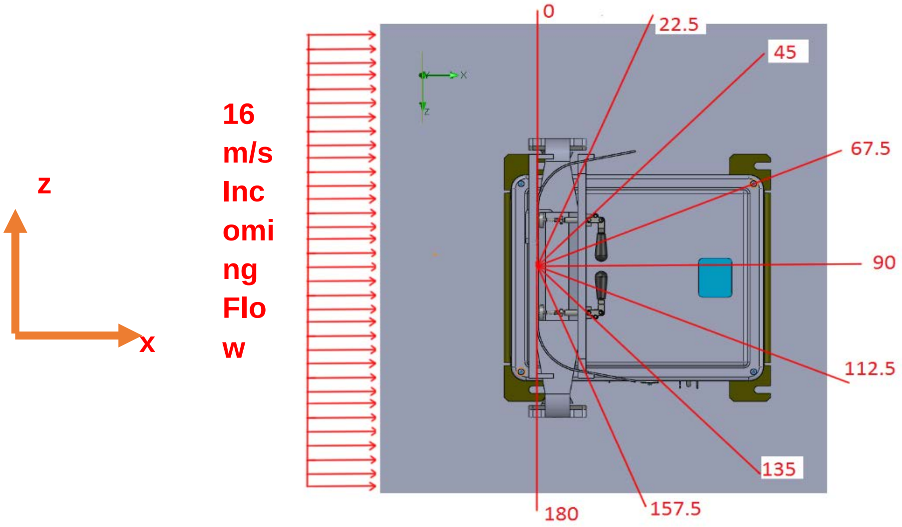


Figure 24: Curved "Ivan" target in target orientations from 0 – 180 degrees with respect to the front of the lifter in a 16 m/s flow

7.3 Bolt Tear Out Analysis

When assembling the bracket, it is important to consider the method of attachment. The most cost effective method is to use a plate of 6061 aluminum cut into smaller sections. After it is cut, one can drill and tap holes to allow the pieces to be screwed together. In order to determine if these screws can suitably withstand the various forces applied, failure analysis must be performed. There are multiple stresses being placed on the bracket, but the highest is from the selected toggle clamps. With each supplying a 100-200lbf based on user input. The worst case of 200lbf was assumed and placed directly over the bolt head. It was determined that the structure will feel a normal stress of 356 kPa, and a shear stress of 14 MPa. This is well below the operating limits of our base material of 6061 aluminum and it was determined that mating the plates via screws is a viable option. The calculations for this analysis can be found in Appendix C.

7.4 Projected Budget

The team plans to put in parts orders before the end of this semester for plate aluminum to construct the arm and for the selected clamps. The Motor cannot be selected until further analysis has been done with the wind forces as well as gearbox and bearing research. At this time there is no projected cost of these components, but from background research, these components will be well within the team’s given budget.

8.0 Conclusion

Using the aforementioned design criteria, the final design will consist of Lockheed Martin’s current SIT design with the following features to allow for a rotational effect and target implementation. Bracket Design G will allow for all targets to be fixed to the lifter while limited the number of moving parts to decrease the possibility of malfunction, while still providing adequate target retention. The material selected for the design was 6061 aluminum, it will provide the necessary strength and has the capabilities of being welded if needed. The motor and gearbox selection has yet to be finalized but the initial required torque has been analyzed and the selection process is ongoing. The final arm design was selected as Arm Design A, and any further revisions will refer to Arm Design C. The selected arm design provides the best way to meet the IP67 requirements and allows for a simple design to implement. SolidWorks was used to determine the various forces due to wind on two of the required targets. This analysis was meant to determine the worst case scenario for the torques and forces on the bracket in order to provide a more robust feasibility analysis of the future prototype. The team is still in the process of budgeting for the parts it will need. In the meantime, parts orders will be placed for items which have already been determined, such as clamps and aluminum plates. Once resuming the project in the next semester, the team hopes to take the previous analysis to order a motor, gearbox and other crucial parts early in the semester in order to ensure ample time to produce a functional prototype by the end of the semester.

9.0 References

[1] Infantry Squad Battle Course, Army Engineers
[2] Meggitt MF-SIT Specification Document
[3] MS Instruments Stationary Infantry Target Specifications
[4]Theissen GSA Federal Supply Schedule Price List
[5] Future Army System of Integrated Targets: Presentation Devices Interface Control Document 2.0

Acknowledgements

Team 16 from the FAMU - FSU College of Engineering would like to express the deepest appreciation to all those who helped us during fall semester on this senior design project. A special gratitude to our advisor Dr. Patrick Hollis whose advice and knowledgeable skill help guide us the right direction towards our goal. Another special thanks to Dr. Nikhil Gupta forproviding feedback, stimulating suggestions, and helping coordinate our presentations, reports and ideas. Furthermore, we would like to acknowledge Chris Isler the Lead Hardware Engineer for his many useful inputs as well as taking the time to speak with the team every early Monday morning. Last but not least, many thanks to our teaching assistantswho have provided helpful feedback on our presentations, assignments and deliverables.

Team Biography

Ashar Abdullah (Lead Programmer)

Senior at Florida State University majoring in Mechanical Engineering. He is currently involved with SAE and has been charged with designing Drivetrain/Ergonomic components. He is also involved with research in Ceramic materials, specifically for the purpose of creating a wireless Temperature sensor for use in nuclear reactors. Ashar hopes to go into industry after he graduates in May of 2016.

Andrew Belstrom (Web Design / Historian)

Andrew Bellstrom is a senior in mechanical engineering at Florida State University. He is going for a specialization in thermal fluid science track and is due to graduate Spring 2016 with a minor in physics and mathematics. Previous work experience includes an internship for Source Refrigeration where he contributed to optimization of components. His future plans include entering the work force in the field of fluid science.

Ryan D’Ambrosia (Team Leader)

A senior in the mechanical engineering department, Ryan has achieved his minor in both physics and mathematics and is due to graduate in April 2016. Ryan has participated in a variety of research at Florida State University’s Aeropropulsion Mechatronics and Energy Center (AME), and participated in the National Science Foundation (NSF) funded Research Experience for Undergraduates Program (REU-MASS) over the Summer 2015 term. As a Research Assistant, Ryan has been involved in various topics including the National Parks Service Penetrometer Capstone Project, Autonomous Quadcopter projects and Embedded Smart Material Sensing for Aerospace Structures, Wind Energy, and Legged Robotics Applications. Ryan has also been a Teaching Assistant for the graduation prerequisite Mechatronics 1 course, where students are introduced to the basics of C programming and hardware integration through integrated development environments (IDEs). Ryan intends to pursue a graduate degree in Mechanical Engineering after graduating from Florida State University.

Jordan Lominac (Lead Mechanical Engineer)

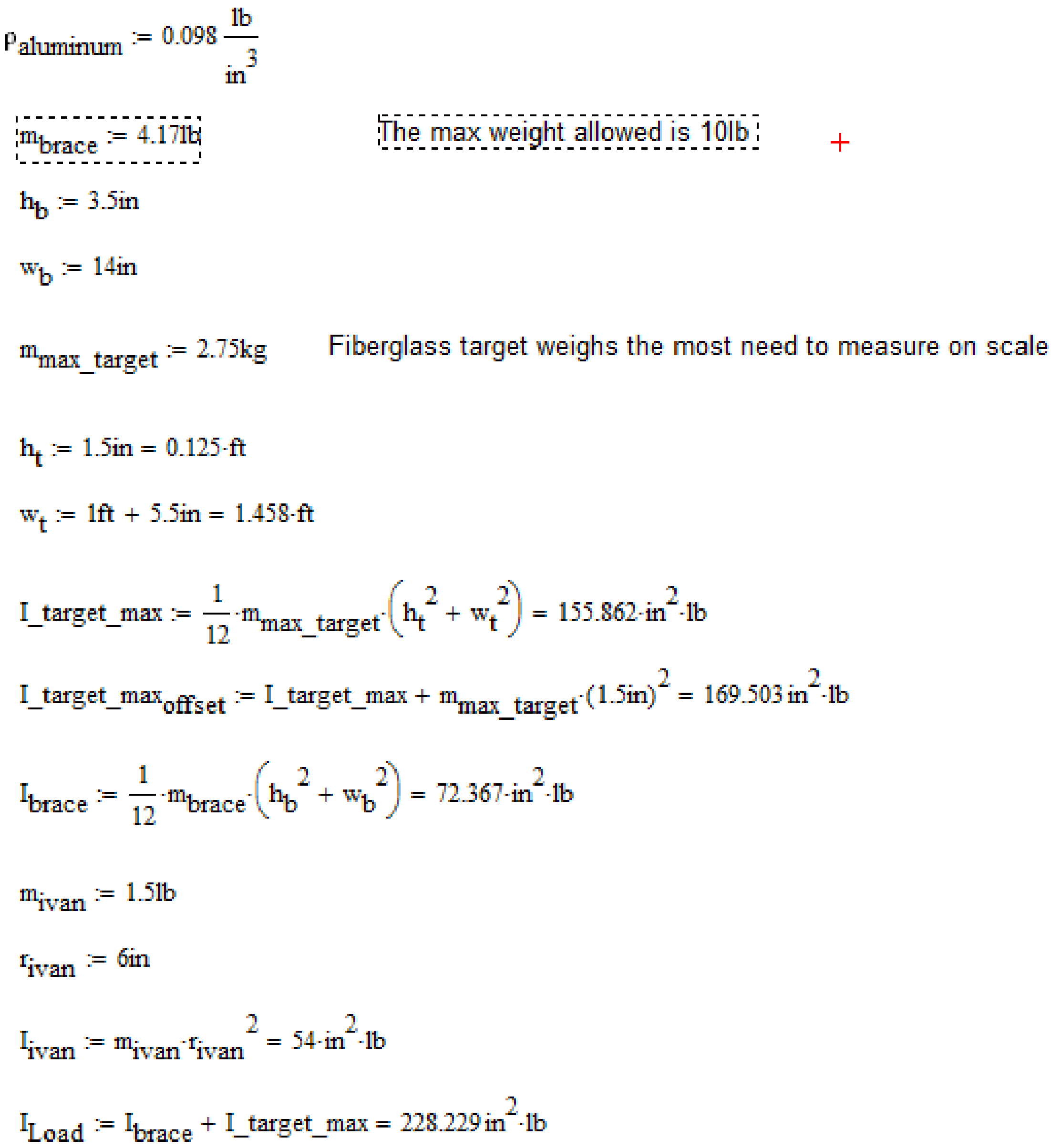
Jordan Lominac is a senior at Florida State University and will be graduating with his Bachelor's of Science Degree in Mechanical Engineering Spring of 2016. This past summer Jordan worked as a Supply Chain Engineer for Johnson&Johnson where he gained experience in project management and continuous improvement methodologies. Jordan focused on developing a round wire fixture to improve the efficiency of Cordis' Receiving Inspection and supported the Shelf Life Extension Project for Listerine and Reach Dental products. Jordan is currently in progress of receiving his Thermal Fluids Specialization from Florida State. After receiving his degree, Jordan plans to be working full time and plans on receiving his Professional Engineering License.

Fernando Rodriguez (Financial Advisor)

Fernando Rodriguez currently senior undergraduate student on Mechanical Engineering (ME) from Florida State University (FSU). Born and raised in Cuba, came to the United State of America at the age of fourteen. Pursuing his goal in science let him be a part of Miami Dade College from 2010 to 2012. Transfer to Florida State University to continue his studies as undergraduate ME from 2012 up to 2016. Had opportunity to be a part of Florida Center for Advanced Aero-Propulsion (FCAAP) as research assistance during the Summer 2015. Helped and learned from graduate students with new experiment with Particle Image Velocimetry (PIV) in the supersonic, and subsonic wind tunnel facility. As of Fall 2015 Fernando is working under Dr. Kumar's research for Asymmetric Vortex Control of Slender Body at High Angle of Incidence. Also, working on Variable Angle Target Training System (VATTS) for Senior Design, sponsored by Lockheed Martin.

Appendix A

Motor Torque Calculations:



$\rho_{aluminum} := 0.098 \frac{lb}{in^3}$

$m_{brace} := 4.17lb$ The max weight allowed is 10lb

$h_b := 3.5in$

$w_b := 14in$

$m_{max\_target} := 2.75kg$ Fiberglass target weighs the most need to measure on scale

$h_t := 1.5in = 0.125 \cdot ft$

$w_t := 1ft + 5.5in = 1.458 \cdot ft$

$I\_target\_max := \frac{1}{12} \cdot m_{max\_target} \cdot \left(h_t{}^2 + w_t{}^2\right) = 155.862 \cdot in^2 \cdot lb$

$I\_target\_max_{offset} := I\_target\_max + m_{max\_target} \cdot (1.5in)^2 = 169.503\,in^2 \cdot lb$

$I_{brace} := \frac{1}{12} \cdot m_{brace} \cdot \left(h_b{}^2 + w_b{}^2\right) = 72.367 \cdot in^2 \cdot lb$

$m_{ivan} := 1.5lb$

$r_{ivan} := 6in$

$I_{ivan} := m_{ivan} \cdot r_{ivan}{}^2 = 54 \cdot in^2 \cdot lb$

$I_{Load} := I_{brace} + I\_target\_max = 228.229\,in^2 \cdot lb$

1.8 Step Angle Chosen

$O\_P := \frac{180}{1.8} = 100$ Number of Operating Pulses

$t_0 := 1s$ Time Required to Preform Positioning

$t_1 := 0.25s$ Acceleration/Decleration Time

$f_2 := \frac{O\_P}{t_0 - t_1} = 133.333\,\frac{1}{s}$

$N_M := \frac{1.8 \cdot f_2 \cdot 60\,\frac{s}{min}}{360} = 40\,\frac{1}{min}$

Load Torque

No Friction, No Wind

$T_L := 0$

Acceleration Torque

$I_0 := 0$

$i := 1$

$T_a := \frac{\left(I_0 \cdot i^2 + I_{Load}\right) \cdot \left(N_M \cdot 60\right)}{9.55 \cdot t_1} = 158.46\,ozf \cdot in$

Required Torque

$S_f := 1.5$ Safety Factor

$T_R := \left(T_L + T_a\right) \cdot S_f = 237.691\,ozf \cdot in$

Appendix B

Degree		0	22.5	45	67.5	90
	X-axis					
Force	N	-70.05	-63.63	-47.92	-20.87	-0.44
Torque	N*m	-0.57	11.28	21.04	22.84	0.91
	Y-axis					
Force	N	-1.46	-1.6	-1.46	-0.83	-0.02
Torque	N*m	30.97	28.69	20.84	9.00	0.33
	Z- axis					
Force	N	0.03	25.94	49.61	51.57	2.01
Torque	N*m	31.27	28.41	21.38	9.55	0.27

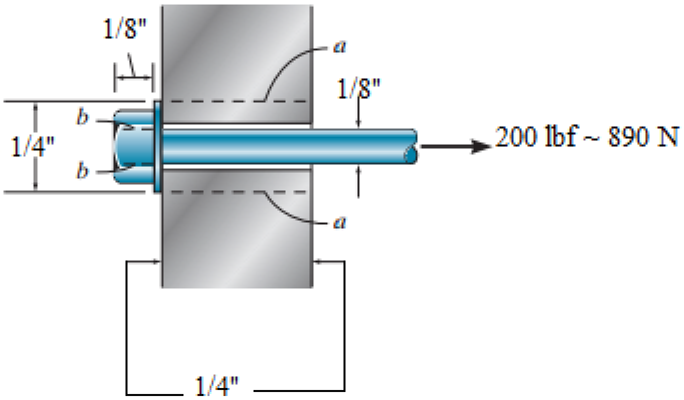
Table 4. Wind Torque Analysis on Flat Target for angles 0 – 90 degrees

Table 5. Wind Torque Analysis on Curved "Ivan" Target for angles 0 – 180 degrees

Degree		0	22.5	45	67.5	90	112.5	135	157.5	180
	X-axis									
Force	N	33.57	35.30	25.94	16.53	13.44	19.96	41.22	48.19	51.05
Torque	N*m	-0.33	-2.60	0.42	-2.15	0.00	4.83	9.83	6.16	0.04
	Y-axis									
Force	N	-0.28	-0.45	-0.31	-0.04	0.05	0.72	-0.90	-1.20	-1.07
Torque	N*m	-14.33	-17.17	-14.04	-9.13	-6.76	-7.77	-15.07	-18.52	-21.71
	Z- axis									
Force	N	-0.66	-8.41	-0.67	-8.21	-0.32	18.31	36.79	23.50	1.36
Torque	N*m	-8.49	-9.65	-7.31	-4.80	-3.96	-5.99	-11.34	-13.28	-14.21

Appendix C

Tear Out Analysis Calculations:



$$\sigma = \frac{F}{A} = \frac{890 N}{\frac{\pi}{4}(0.003175 m)} = 356 \text{ kPa}$$

$$\tau_a = \frac{V}{A} = \frac{890\ N}{\pi(0.00635\ m)(0.003175 m)} = 14\ MPa$$

$$\tau_b = \frac{V}{A} = \frac{890\ N}{\pi(0.003175 m)(0.003175 m)} = 2.8\ MPa$$