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

TEAM #16

SPRING UPDATE PRESENTATION #1

ASHAR ABDULLAH

ANDREW BELLSTROM

RYAN D'AMBROSIA

JORDAN LOMINAC

FERNANDO RODRIGUEZ

CONTACT: CHRIS ISLER

ADVISORS: DR. PATRICK HOLLIS

DR. CHIANG SHIH

INSTRUCTOR: DR. NIKHIL GUPTA

Overview

- Background
- Design Progress
    - Bracket Progress
    - Lifting and Turning Arm Design
- Design Analysis
    - Structural Analysis
- Future Work

Background

- Stationary Infantry Targets (SITs) are used to train military in combat situations
- Include many features that help provide a more realistic experience
  - Muzzle Flash
  - Hit Detection
- Flips targets up and down
- A variety of targets can be used with the SIT

Background

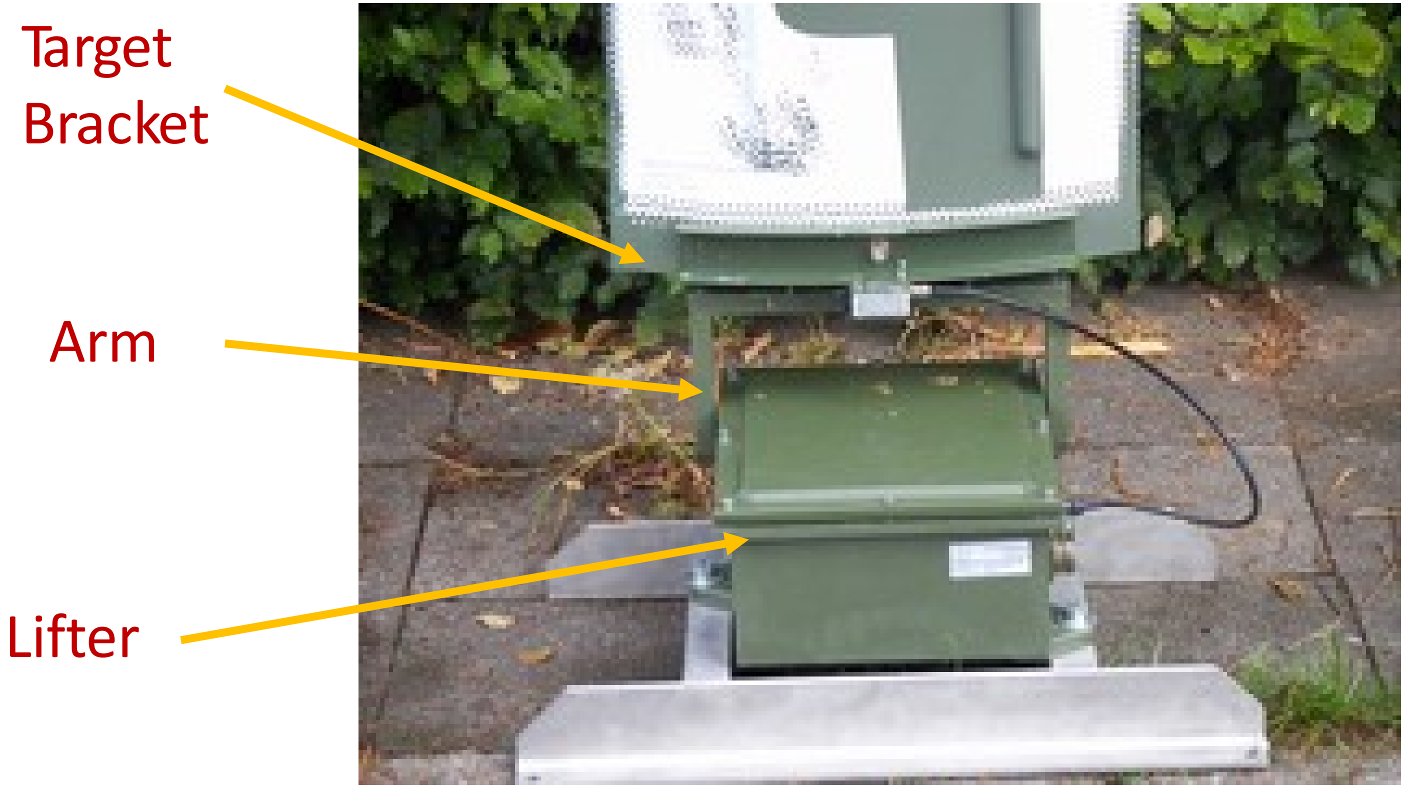
"E" Style
(Waffle Board)

"Figure 12"
Style

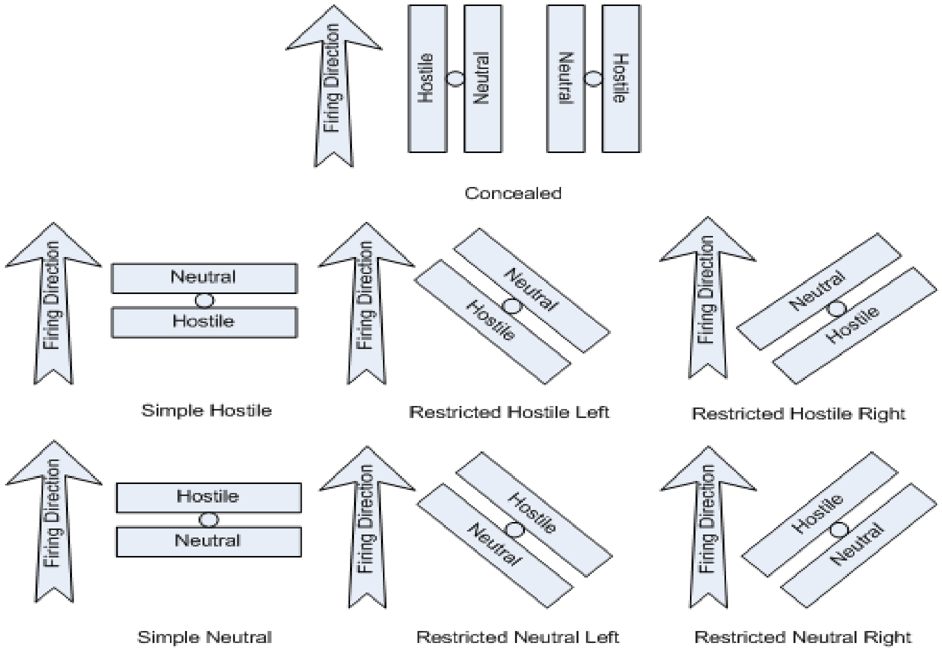
"Figure 11"
Style

"Ivan"
Style

Terminology



Friend & Foe



Needs and Goal Statement

- Needs Statement:

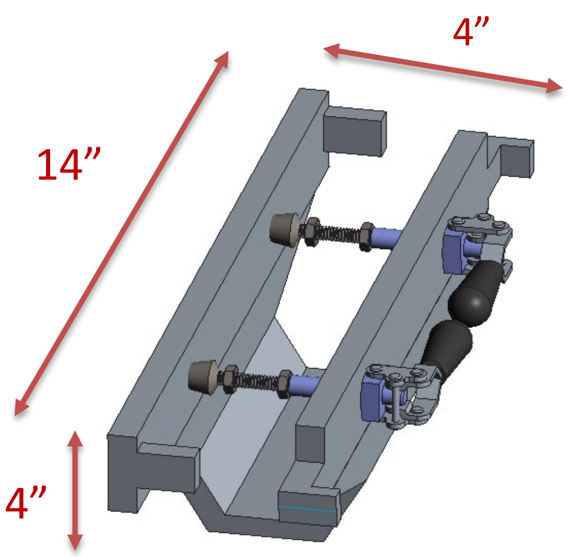
"Lockheed-Martin's current Stationary Infantry Target does not allow for horizontal rotation."

- Goal Statement:

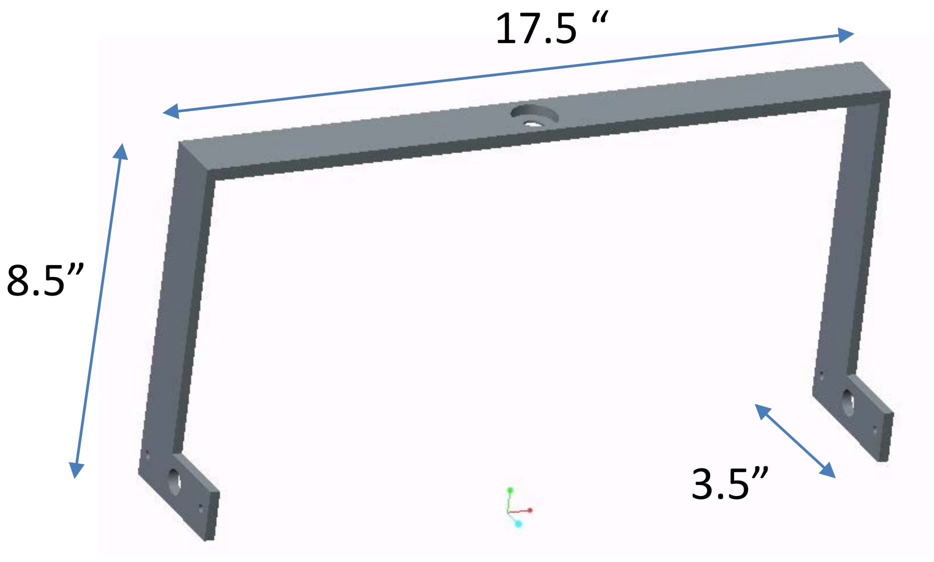
"To create a target system that can deploy a variety of targets from a resting position, and rotate to a desired angular position."

Design Progress

- The Bracket has been selected and is currently being 3D printed by Lockheed
- Final Arm design has been selected

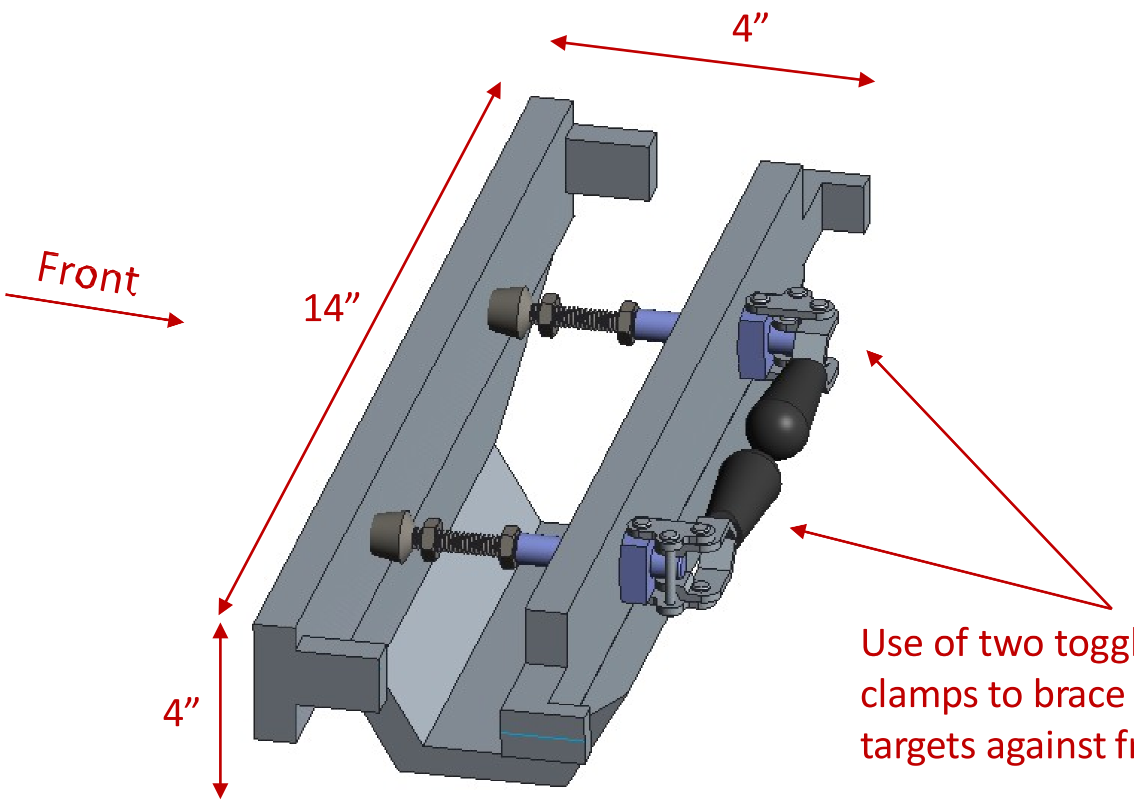


Bracket



Arm

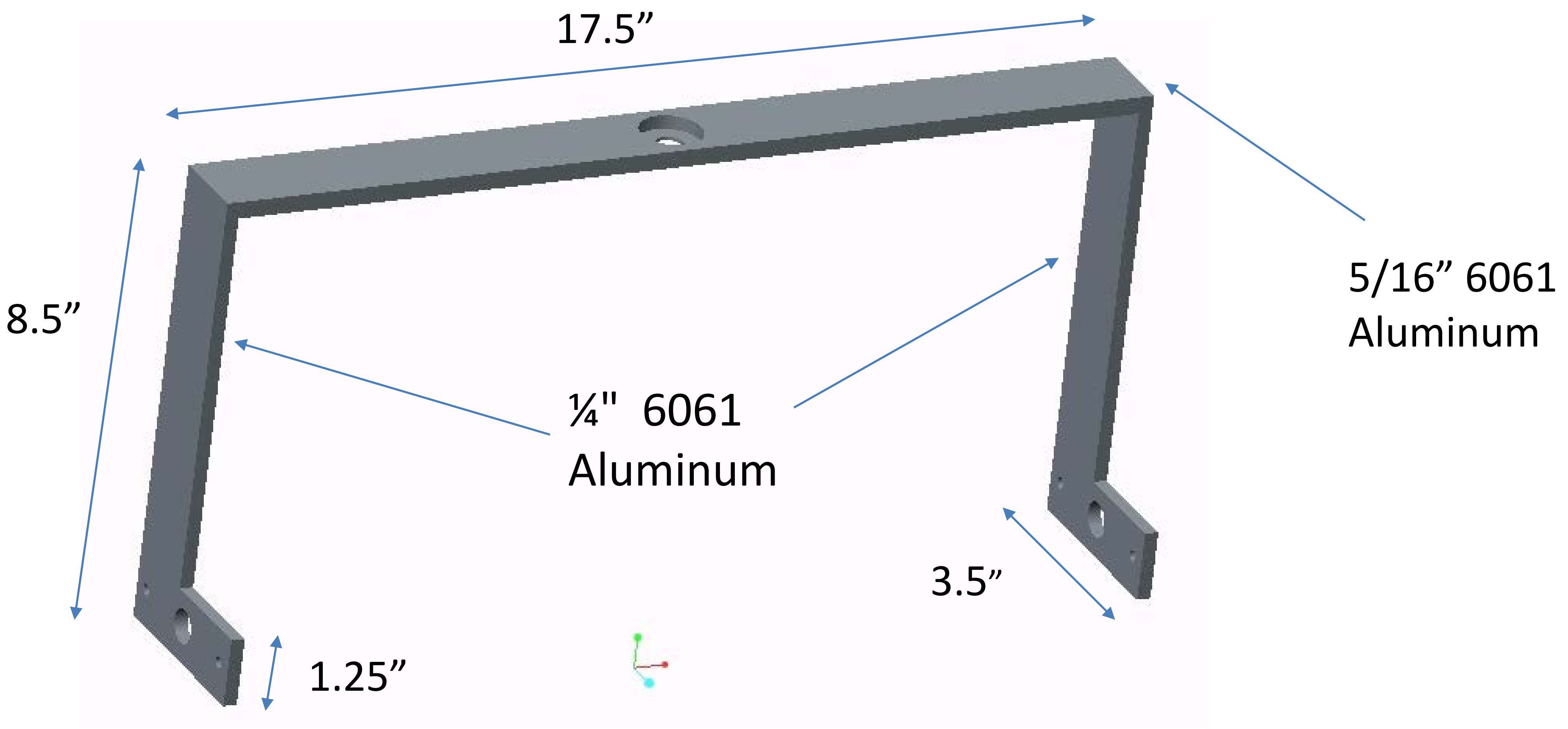
Selected Turning Bracket Design



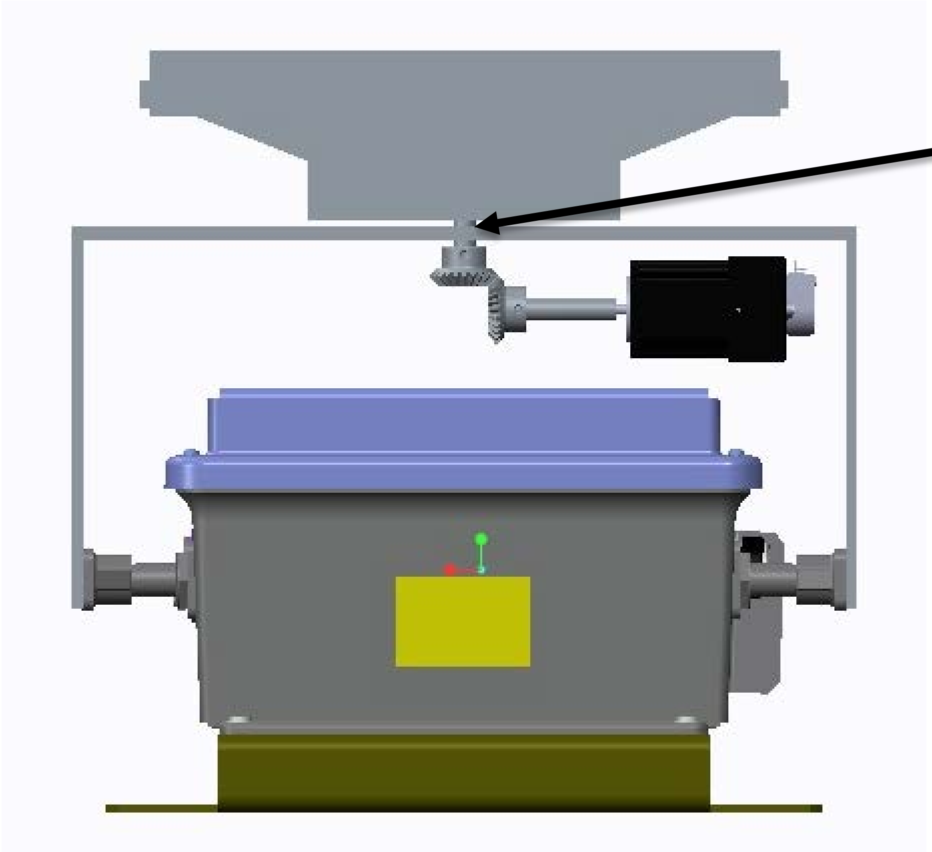
Use of two toggle lever clamps to brace the various targets against front plate

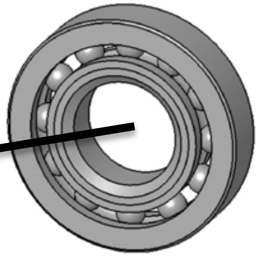
Example of clamp utilized

Selected Arm Design

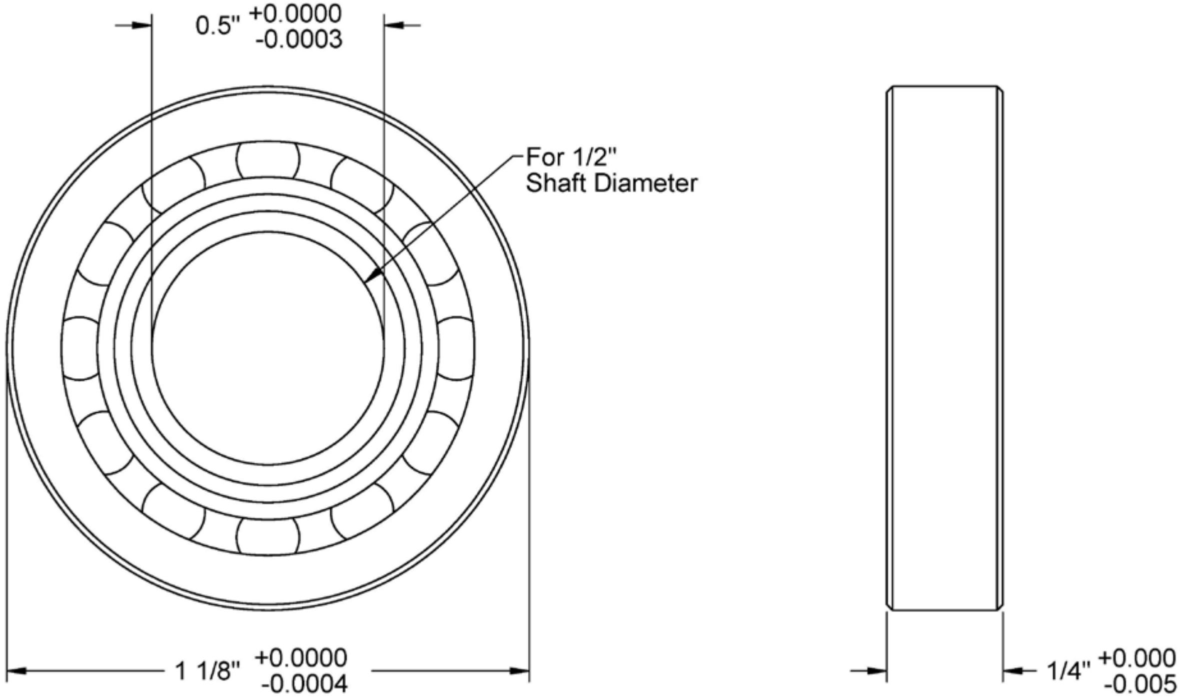


Bearing Design

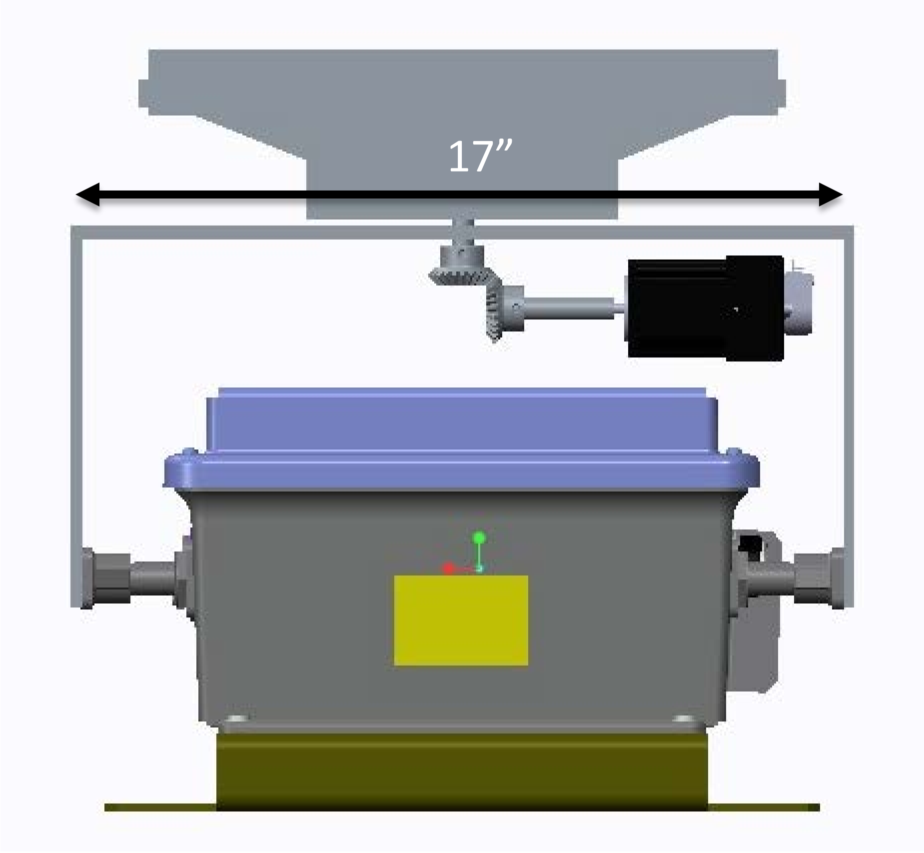


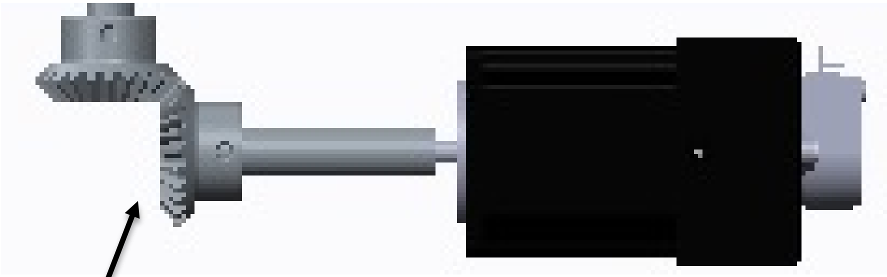


2 permanently lubricated bearings to distribute



Motor Output Design

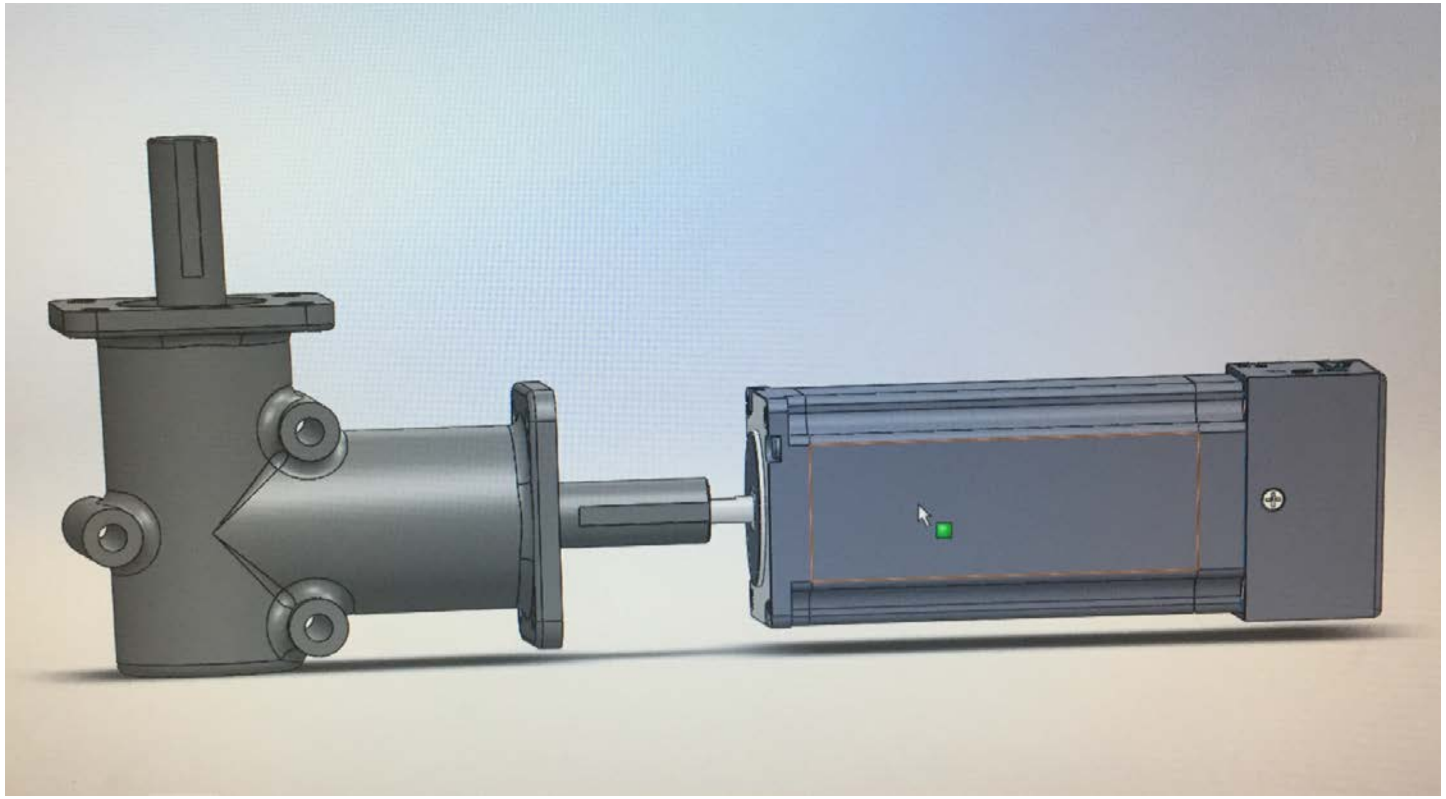




Bevel Option

Motor with Gearbox

Motor Output Design



Motor with stock Gearbox

Design Analysis

- Structural Analysis has been completed for both the arm and bracket
- Worst case scenario
  - 35 mph wind blowing on the back of the Ivan

$\rho := 1.225 \frac{kg}{m^3}$ density of air

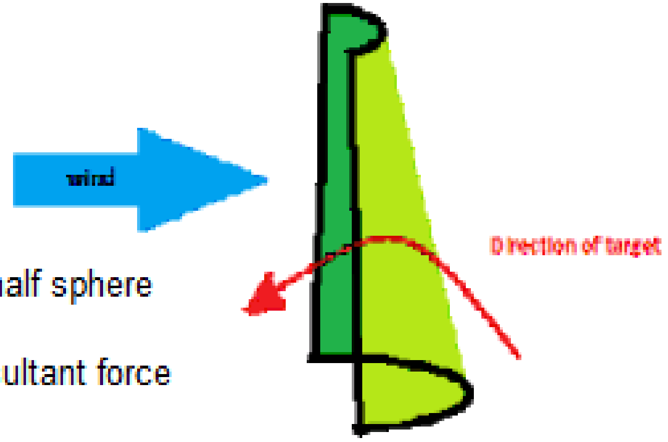
$v := 35mph$ velocity

$A := \pi \cdot 6in \cdot 3ft = 4.712 \cdot ft^2$ area

$C_d := 2$ This is drag coff for half sphere

$F_d := 0.5 \rho \cdot v^2 \cdot A \cdot C_d = 131.291N$ Resultant force

$131.291N = 29.515 \cdot lbf$



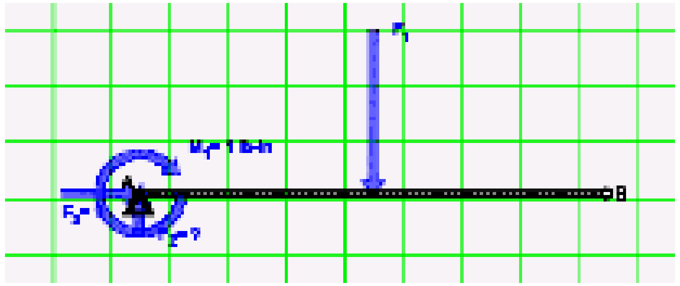
Design Analysis

- Max torque generated from the distributed wind force **= 50 ft*lb (67.79N*m)**
- Our bracket currently secures each of these targets with clamps rated for 100 lbf

$$F_x := 0$$

$$F_y := 30\text{lbf}$$

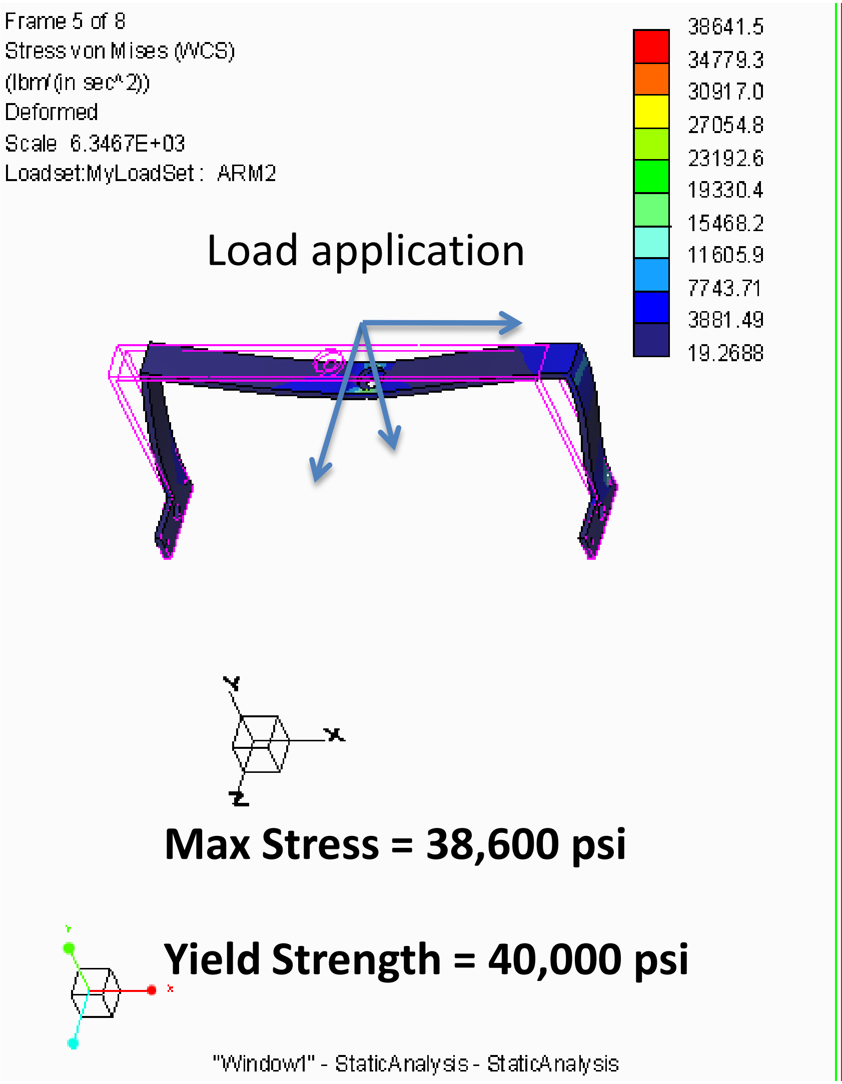
$$F_m := 30\text{lbf}\cdot 20\text{in} = 50\cdot\text{lbf}\cdot\text{ft}$$



all other targets can be assessed from largest target (fig 11)

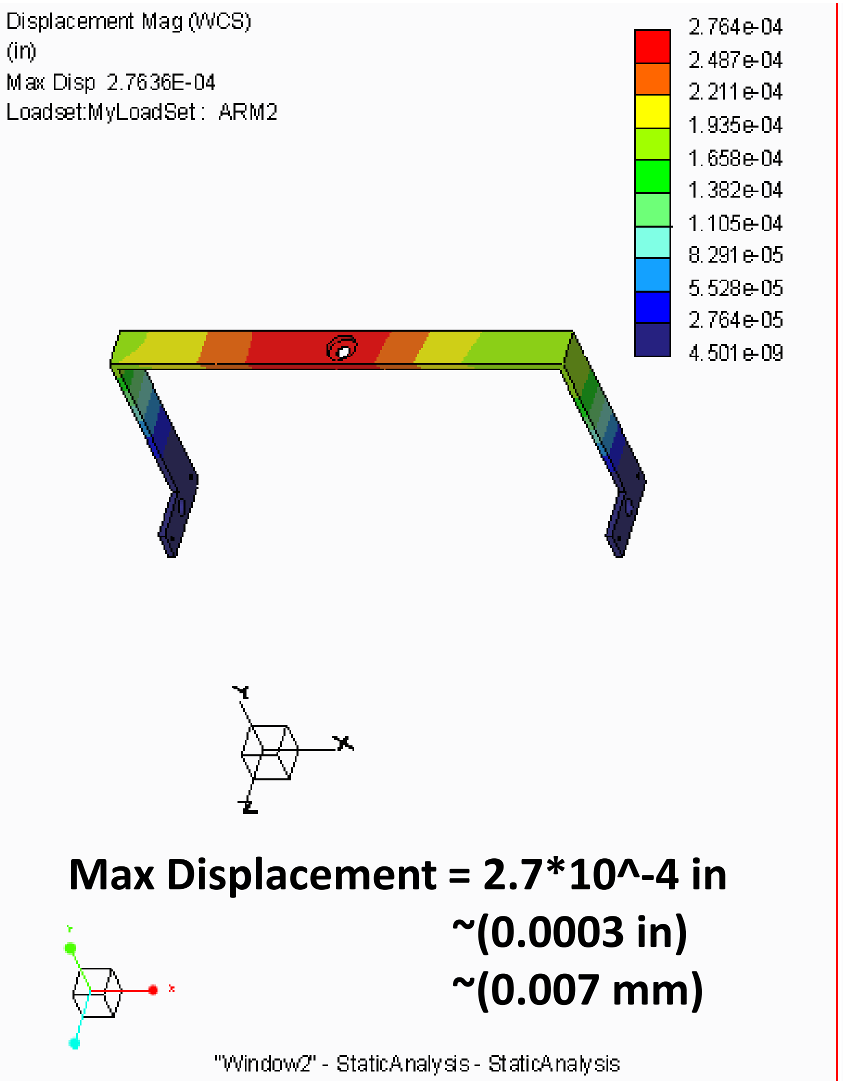
Arm Analysis

LOCKHEED MARTIN

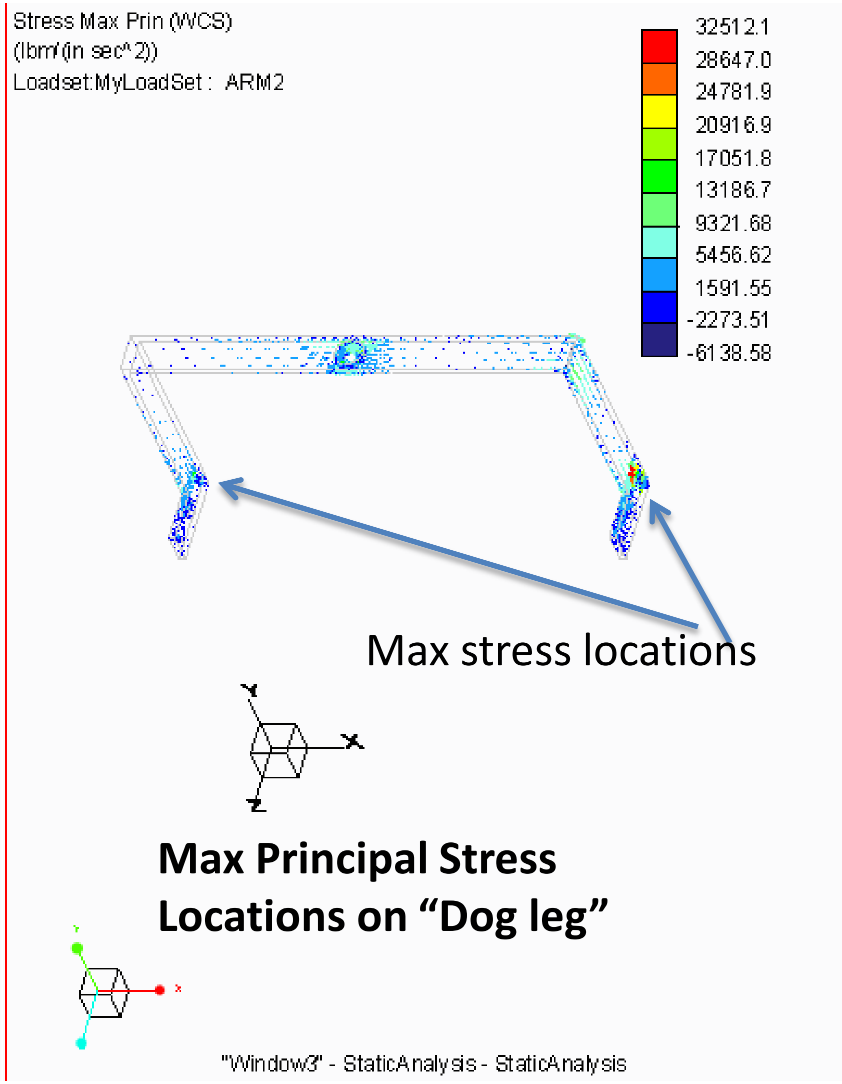


Max Stress = 38,600 psi

Yield Strength = 40,000 psi

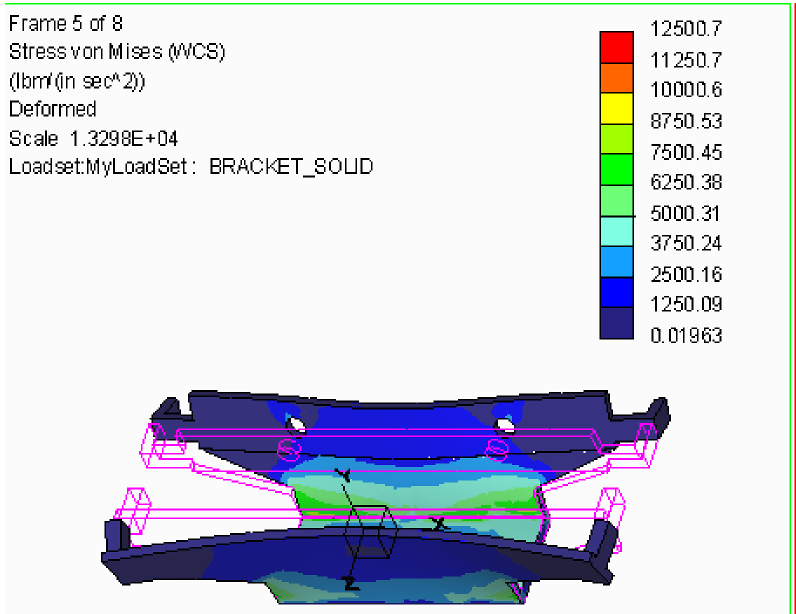


Max Displacement = 2.7*10^-4 in
~(0.0003 in)
~(0.007 mm)



Max Principal Stress Locations on "Dog leg"

Bracket Analysis

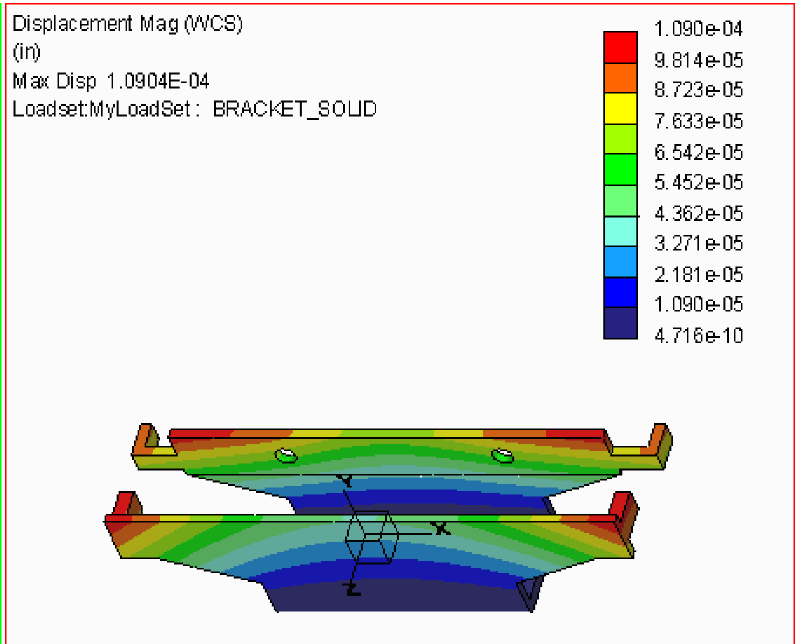


Max Stress = 12,500 psi

Yield Strength = 40,000 psi

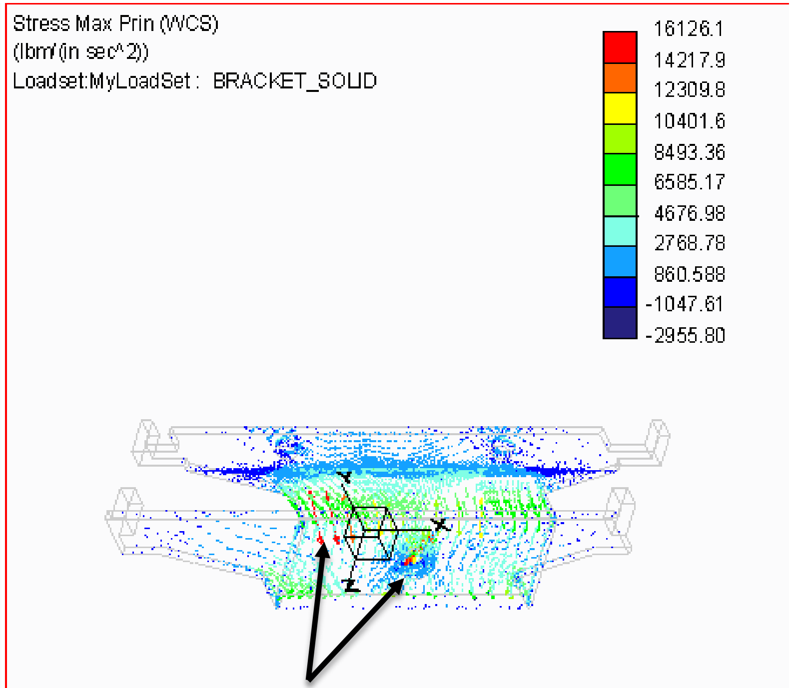
Cyclic Loading = 14,000 psi

"Window1" - StaticAnalysis - StaticAnalysis



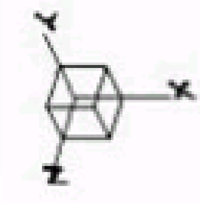
Max Displacement = 0.0001 in.
~(0.0025 mm)

"Window2" - StaticAnalysis - StaticAnalysis



Max Principal Stress locations

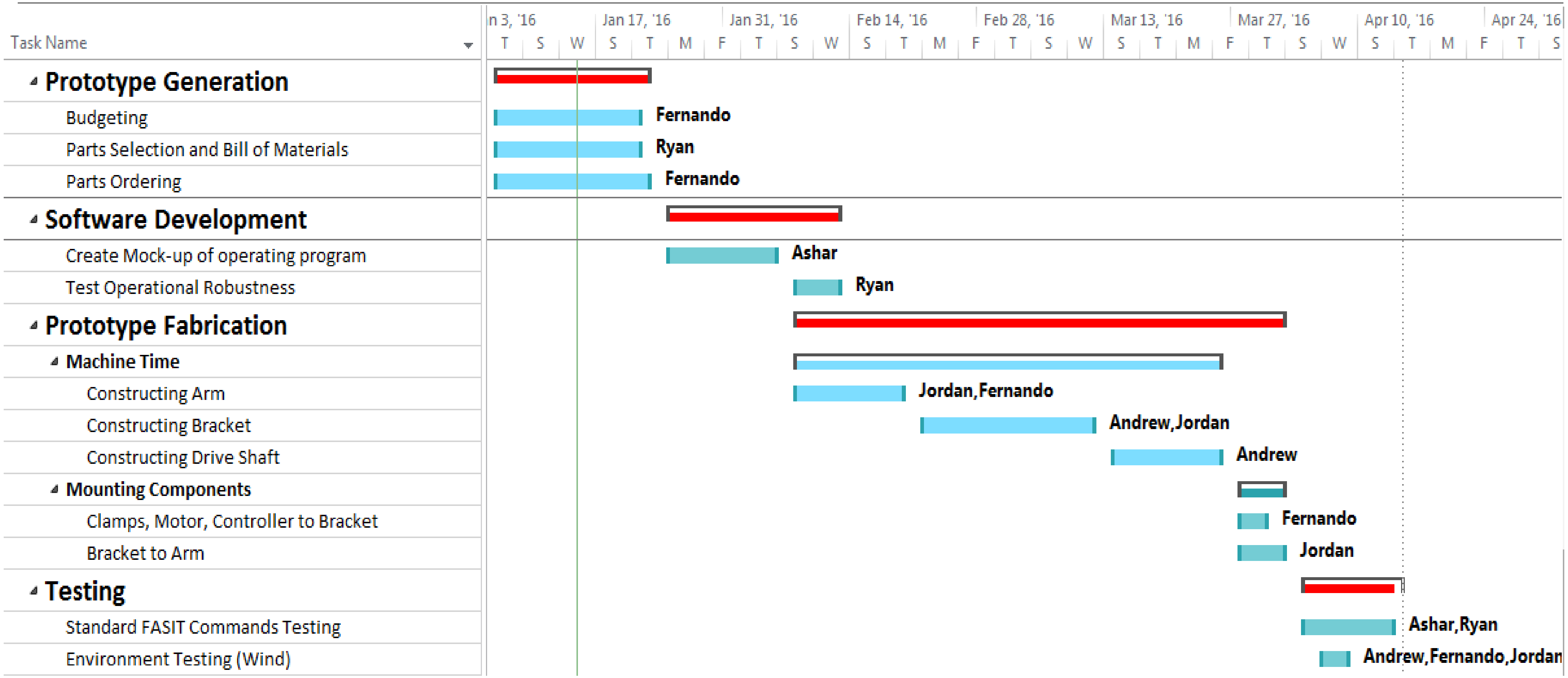
"Window3" - StaticAnalysis - StaticAnalysis



Summary

- Final Bracket and Arm Design Selected
  - Full-scale Bracket currently being 3D printed by sponsor
- Motor to be selected based on torque due to wind force
- Motor output will be connected to a gearbox or series of gears

Future Work



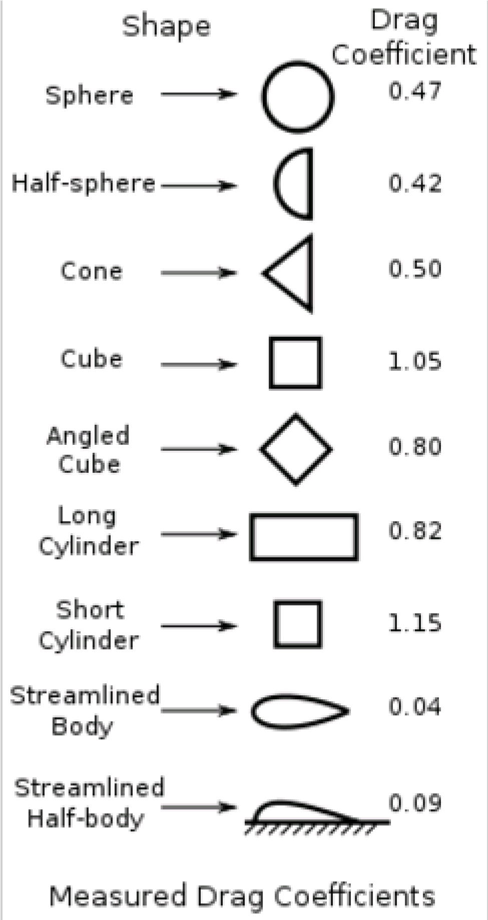
Task Name
n 3, '16
Jan 17, '16
Jan 31, '16
Feb 14, '16
Feb 28, '16
Mar 13, '16
Mar 27, '16
Apr 10, '16
Apr 24, '16
T S W S T M F T S W S T M F T S W S T M F T S W S T M F T S
Prototype Generation
Budgeting
Parts Selection and Bill of Materials
Parts Ordering
Software Development
Create Mock-up of operating program
Test Operational Robustness
Prototype Fabrication
Machine Time
Constructing Arm
Constructing Bracket
Constructing Drive Shaft
Mounting Components
Clamps, Motor, Controller to Bracket
Bracket to Arm
Testing
Standard FASIT Commands Testing
Environment Testing (Wind)
Fernando
Ryan
Fernando
Ashar
Ryan
Jordan,Fernando
Andrew,Jordan
Andrew
Fernando
Jordan
Ashar,Ryan
Andrew,Fernando,Jordan

Future Work

- Ordering Components:
  - Motor and Encoder
  - Gearing (Based on selection)
  - Bearings
  - 6061 Aluminum (Arm, Bracket, Drive Shaft)
  - Motor Controller
- Software Development
- Machining raw material

Questions / Comments

Appendix



Drag coefficients in fluids with Reynolds number approximately 10^4

all other targets can be assessed from largest target (fig 11)

$$A_2 := 17.25\text{in}\cdot 45\cdot\text{in} = 0.501\,\text{m}^2$$

$$C_{d2} := 0.82$$

$$F_{d2} := 0.5\cdot\rho\cdot v^2\cdot A_2\cdot C_{d2} = 13.843\cdot\text{lbf}$$

$$F_{m2} := F_{d2}\cdot 22.5\text{in} = 25.956\cdot\text{lbf}\cdot\text{ft}$$

NATO Style Figure 11 Target

It can be assumbed the largest force felt is 50lbf*ft

$$50\text{lbf}\cdot\text{ft} = 67.791\cdot\text{N}\cdot\text{m}$$

Since the student edition cant do moments i am substuting it as a force by deviding by the parameter

$$\frac{(50\text{lbf}\cdot\text{ft})}{\pi\cdot 0.5\text{in}} = 381.972\cdot\text{lbf}$$

Appendix

Current Design:

Down Position

Up Position

Appendix

Proposed Design:

Down Position

Up Position
with Rotation

Appendix

- Adding to Lockheed-Martin’s current SIT to allowing for rotation of the of the target

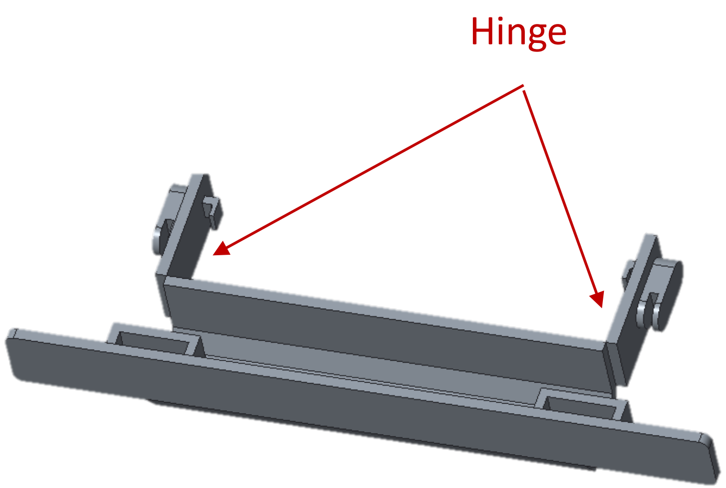
- Create a universal bracket for variety of targets

- Produce a functional prototype of our selected design

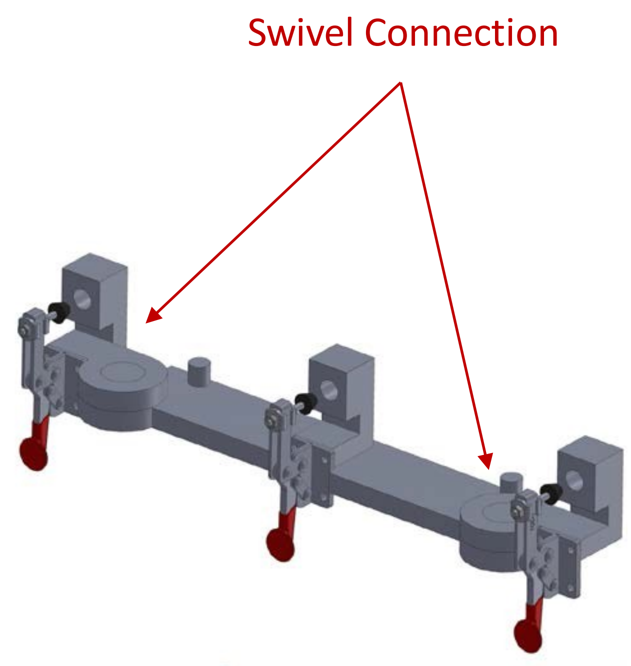
Design Specifications

- **Time to install new target shall be less than 10 seconds**
- **Motor housing shall be rated to at least IP67**
- **Motor shall rotate target 90^{o} in either direction within 1 second of receiving command**
- Distance from bottom of lifter to top of the bracket shall be no more than 18”
- Weight of lifter arm with turner motor shall be no more than 10 lbs.
- Arm shall not impede other integrated SIT functionalities
- Firmware shall be compatible with all FASIT 2.0 commands
- Bracket and arm must be able to hold the target in 35 mph winds
- Combined operational and storage temperature: $-20^{o}C$ to $60^{o}C$

Previous Target Brackets



Example of
Previous Bracket 1



Example of
Previous Bracket 2

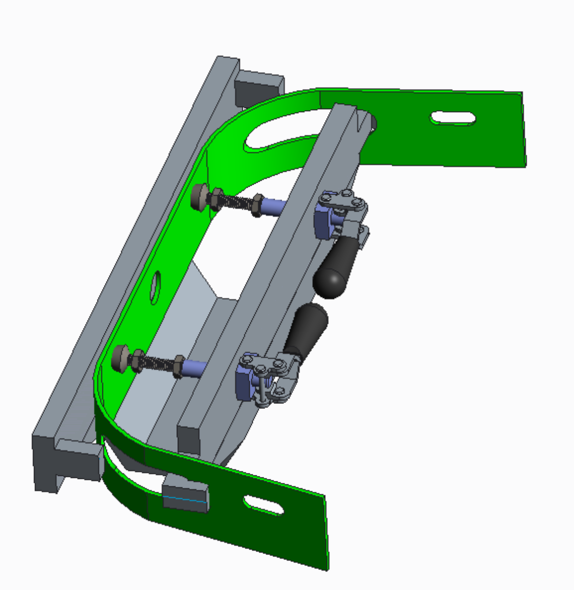
Target Bracket Progress

New Developments:

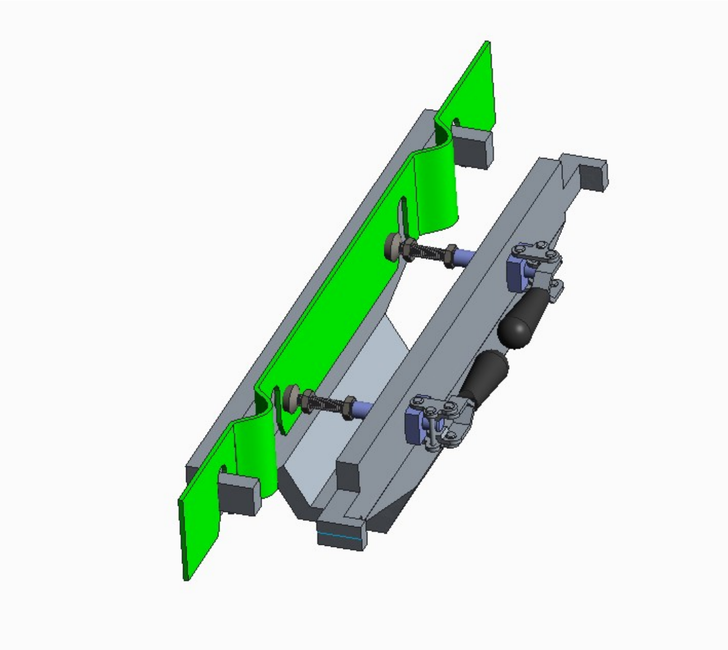
- From sponsor feedback, many of the team's previous designs were inadequate due to various uses of a hinge or other similar moving parts
- Hinges inadequate due to operational conditions, specifically the SIT's environment
- Previous designs were amended to incorporate an alternate form of latching/locking mechanism

Amended Turning Bracket Designs

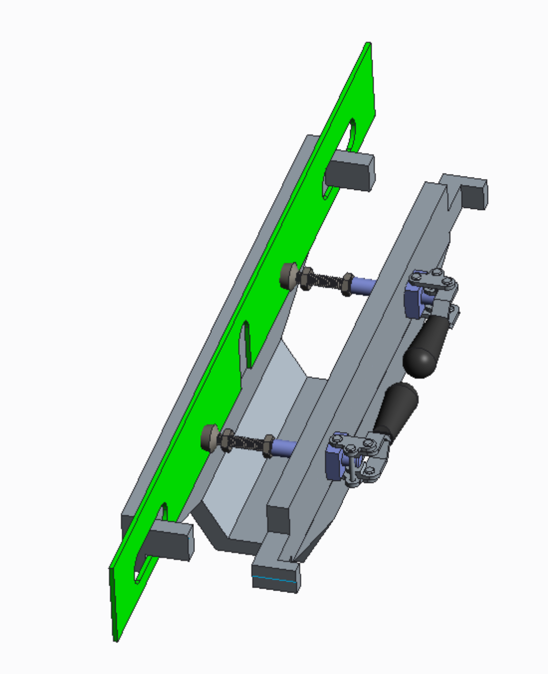
New Bracket Design 1:



"Ivan" Target Fit



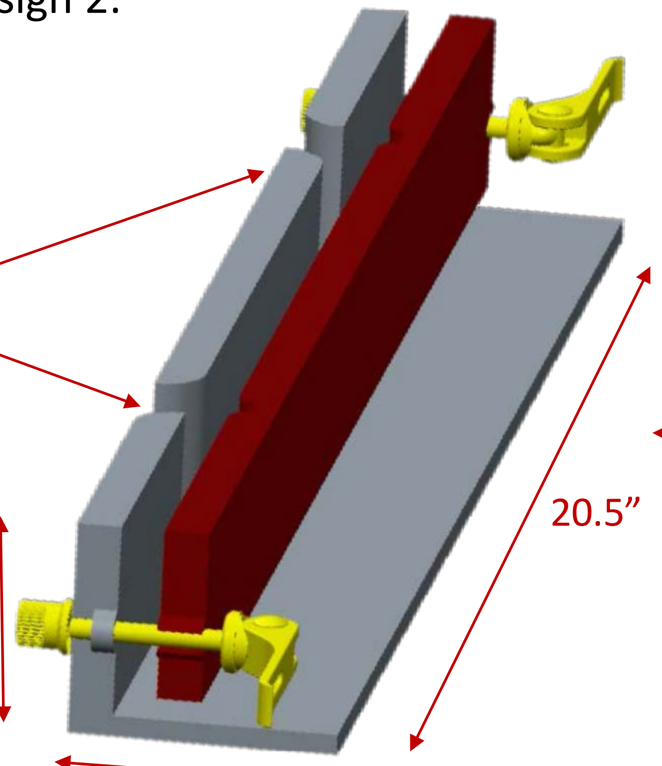
"Figure 11" and "Figure 12" Target Fit



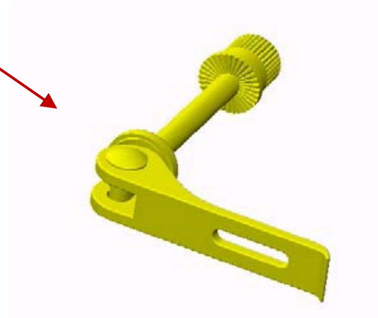
"Waffle Board" Target Fit

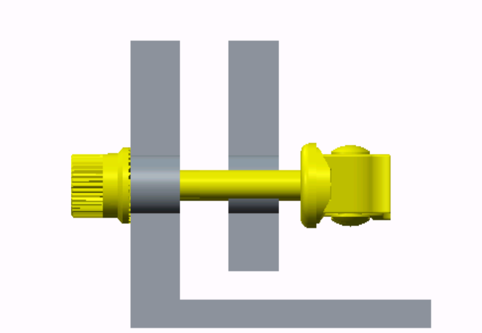
Amended Turning Bracket Designs

New Bracket Design 2:



Use of readily available bicycle seat clamps to secure targets

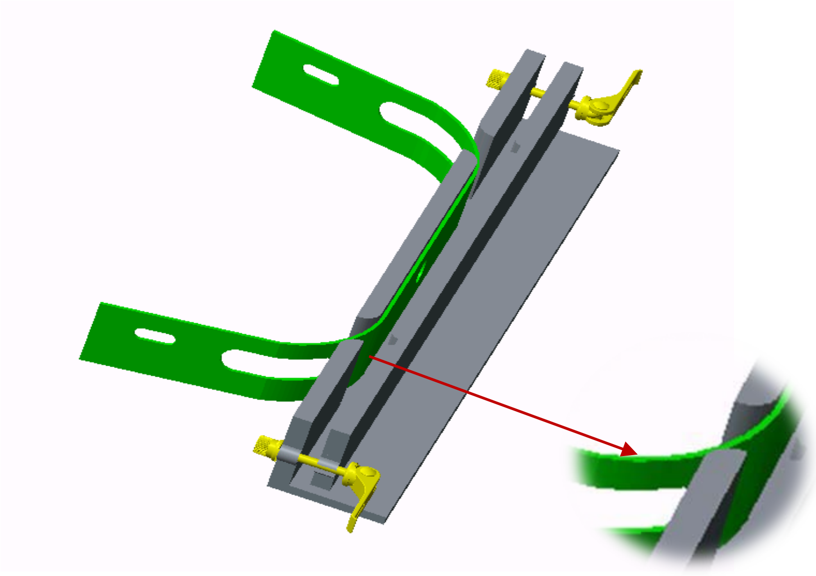




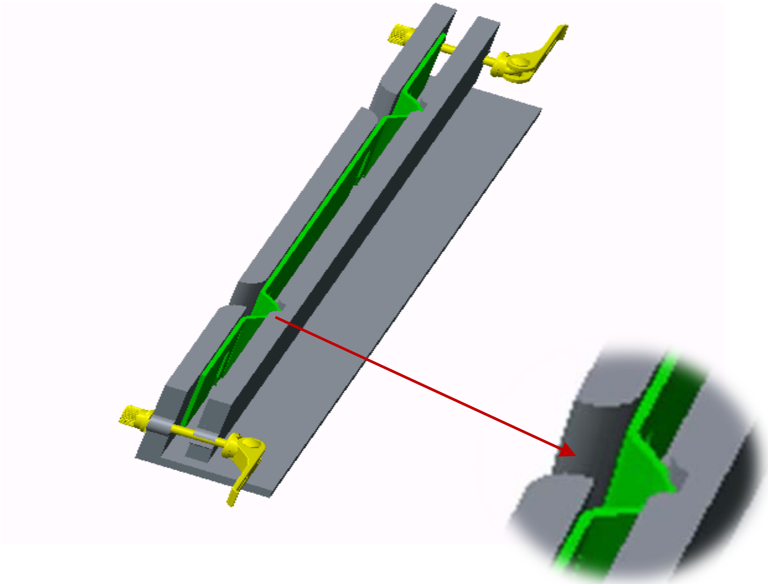
Side Profile of Bracket Design 2

Amended Turning Bracket Designs

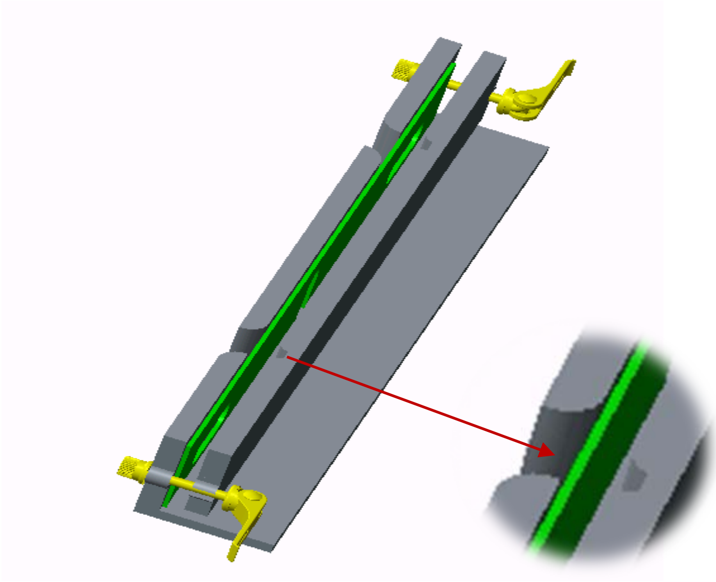
New Bracket Design 2:



"Ivan" Target Fit



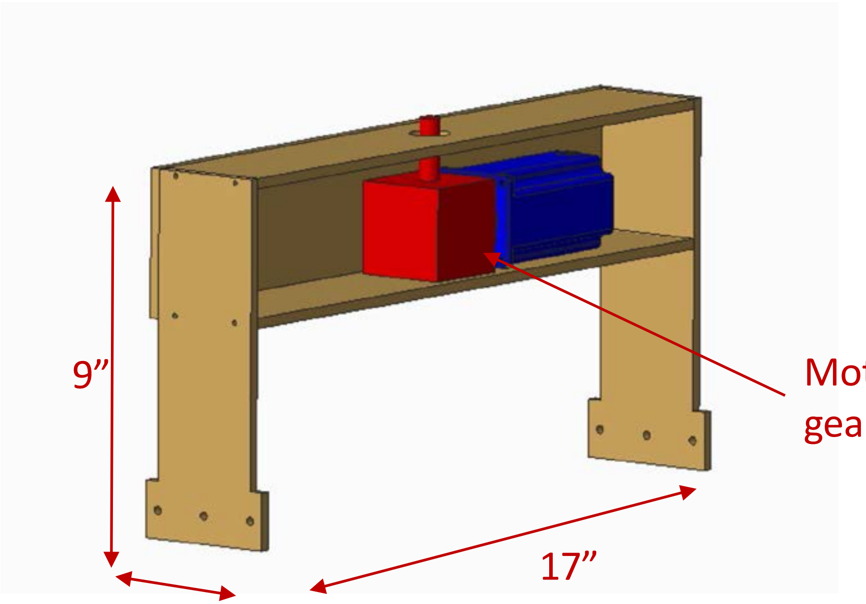
"Figure 11" and "Figure 12" Target Fit

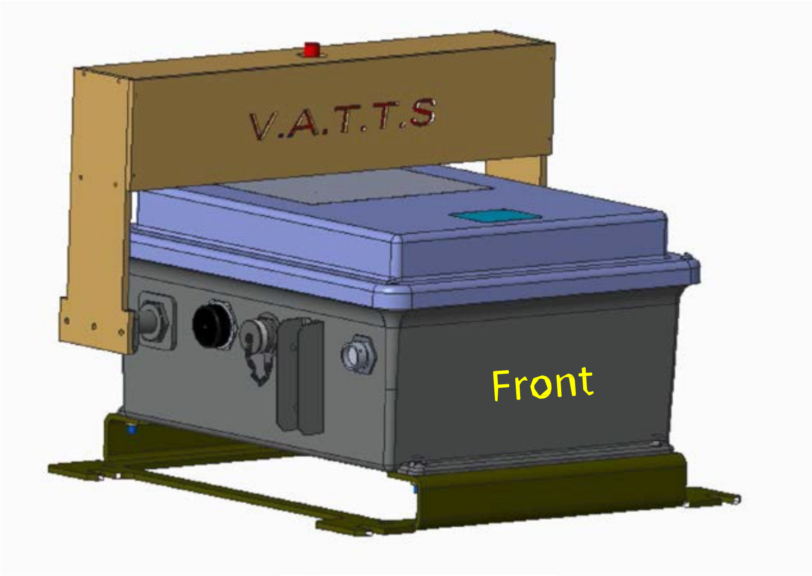


"Waffle Board" Target Fit

Lifting and Turning Arm Designs

Arm Design 1:

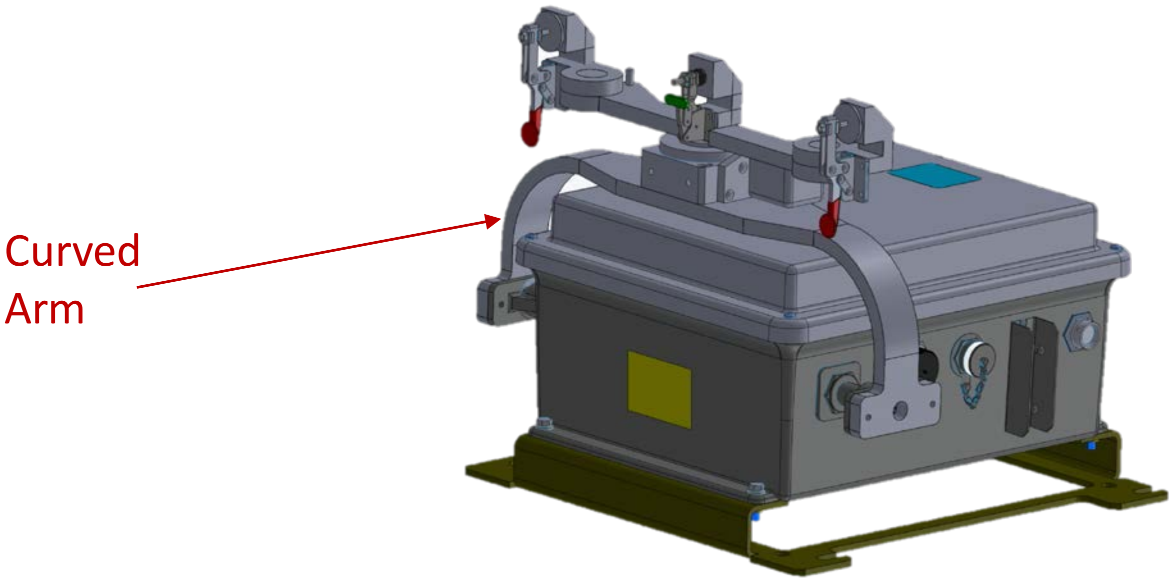


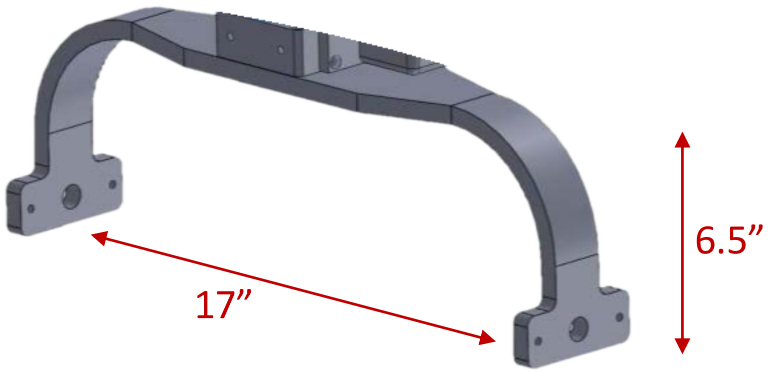


Arm Design Attached to Provided Lifter

Lifting and Turning Arm Designs

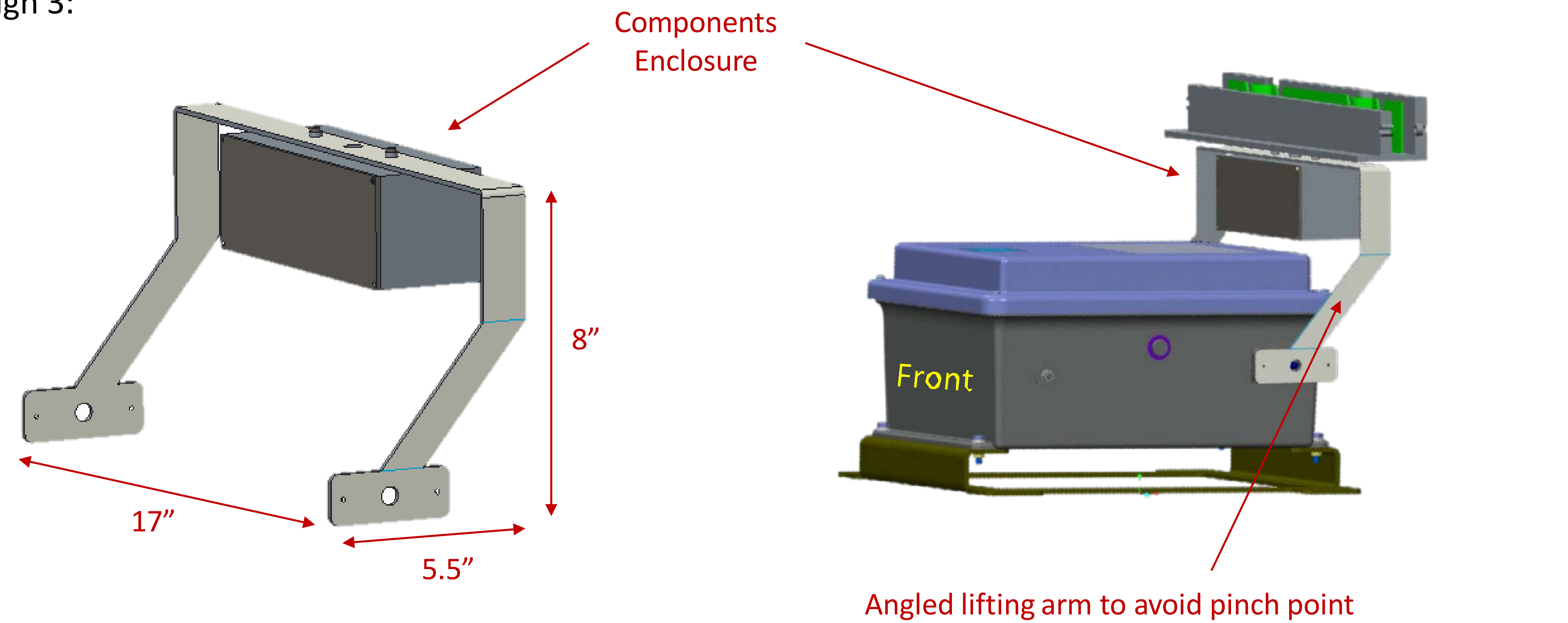
Arm Design 2:





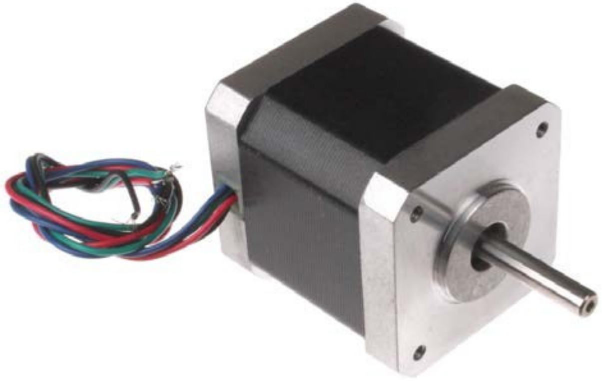
Lifting and Turning Arm Designs

Arm Design 3:



Target Turning Motor Selection

- Stepper Motor
  - Provides a Full Range of Motion
  - Precision Control
  - Open-Loop Feedback
  - High Holding Torque

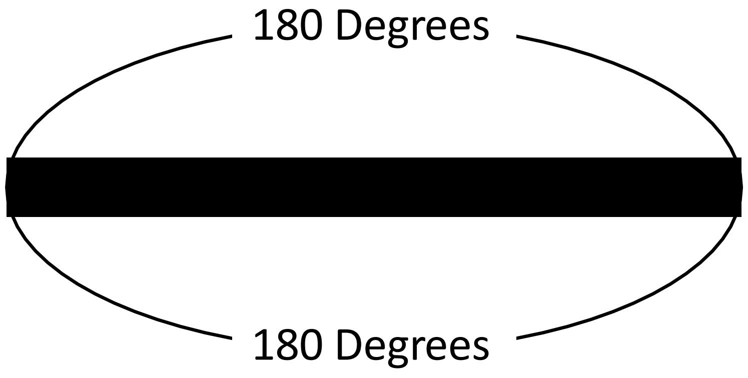


- Ideal for quick and accurate positioning over short distances

- Team has experience working with stepper motors

Target Turning Motor Selection

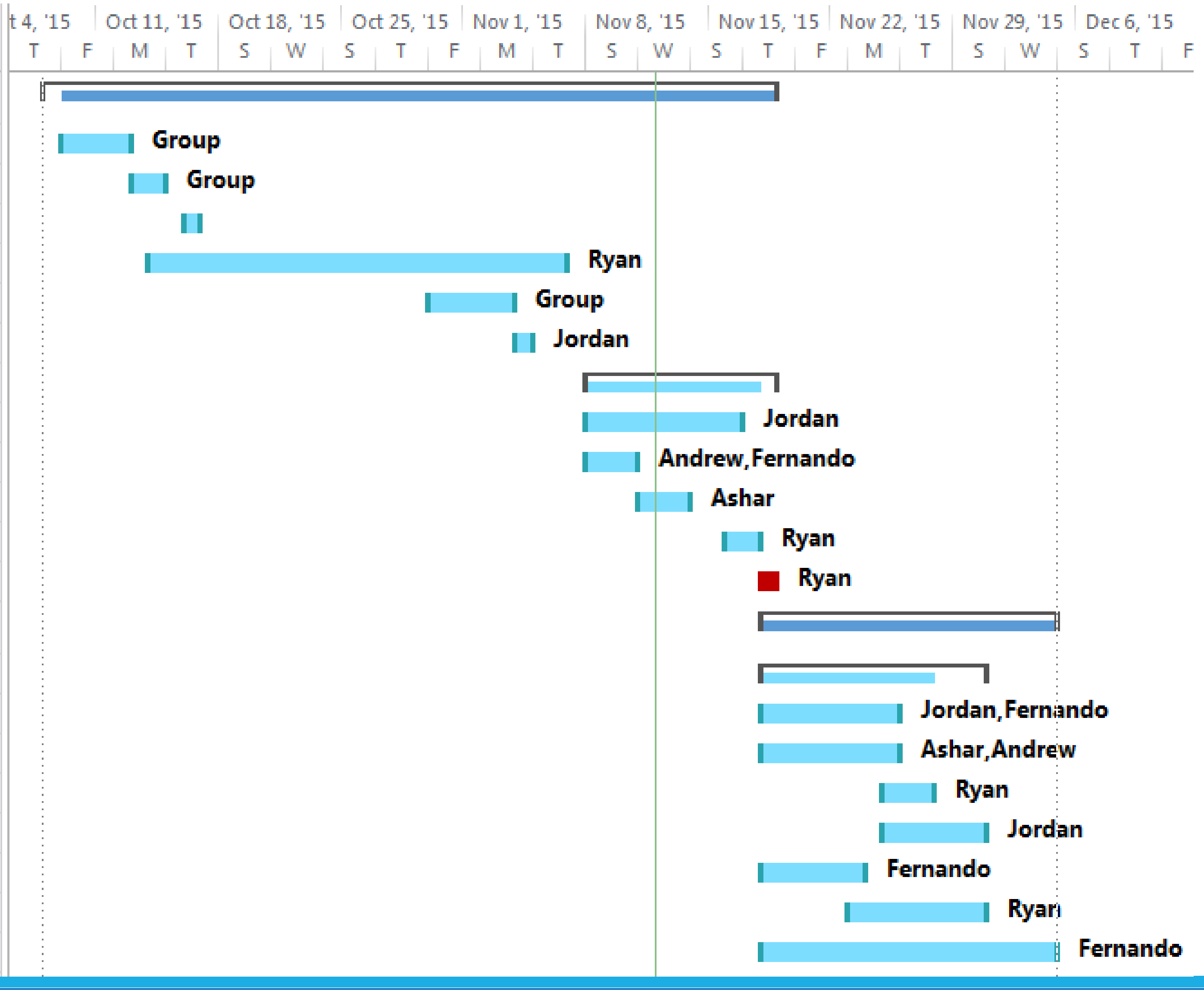
- Bracket needs to be able to turn **180** degrees in **1** second
- Required Operating Speed is **40** RPM
- To Find Required Torque from Motor
  - Assumed a very bulky bracket
  - The biggest target is attached
  - Frictionless
- Required Motor Torque: **620** ozf*in @ **40** RPM
  - Safety Factor: 1.5



Bracket: 180 Degree Positioning

Gantt Chart

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



Future Challenges

- Mating of the Bracket and the Arm assemblies
- Developing a suitable enclosure for the motor and control board
- Synthesis of all design components
- Engineering analysis of all design components

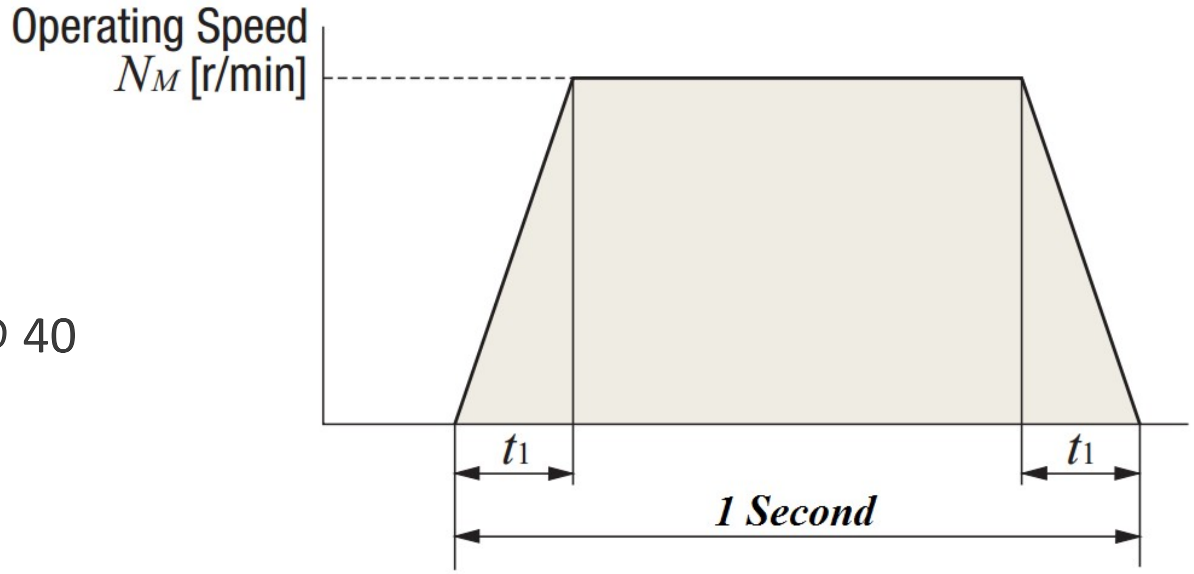
References

1. Infantry Squad Battle Course, Army Engineers
2. MS Instruments Stationary Infantry Target Specifications
3. Theissen GSA Federal Supply Schedule Price List
4. Future Army System of Integrated Targets: Presentation Devices Interface Control Doc. 2.0
5. http://www.orientalmotor.com/products/pdfs/2015
2016/H/Technical_Reference_Overview.pdf
6. McMaster Carr

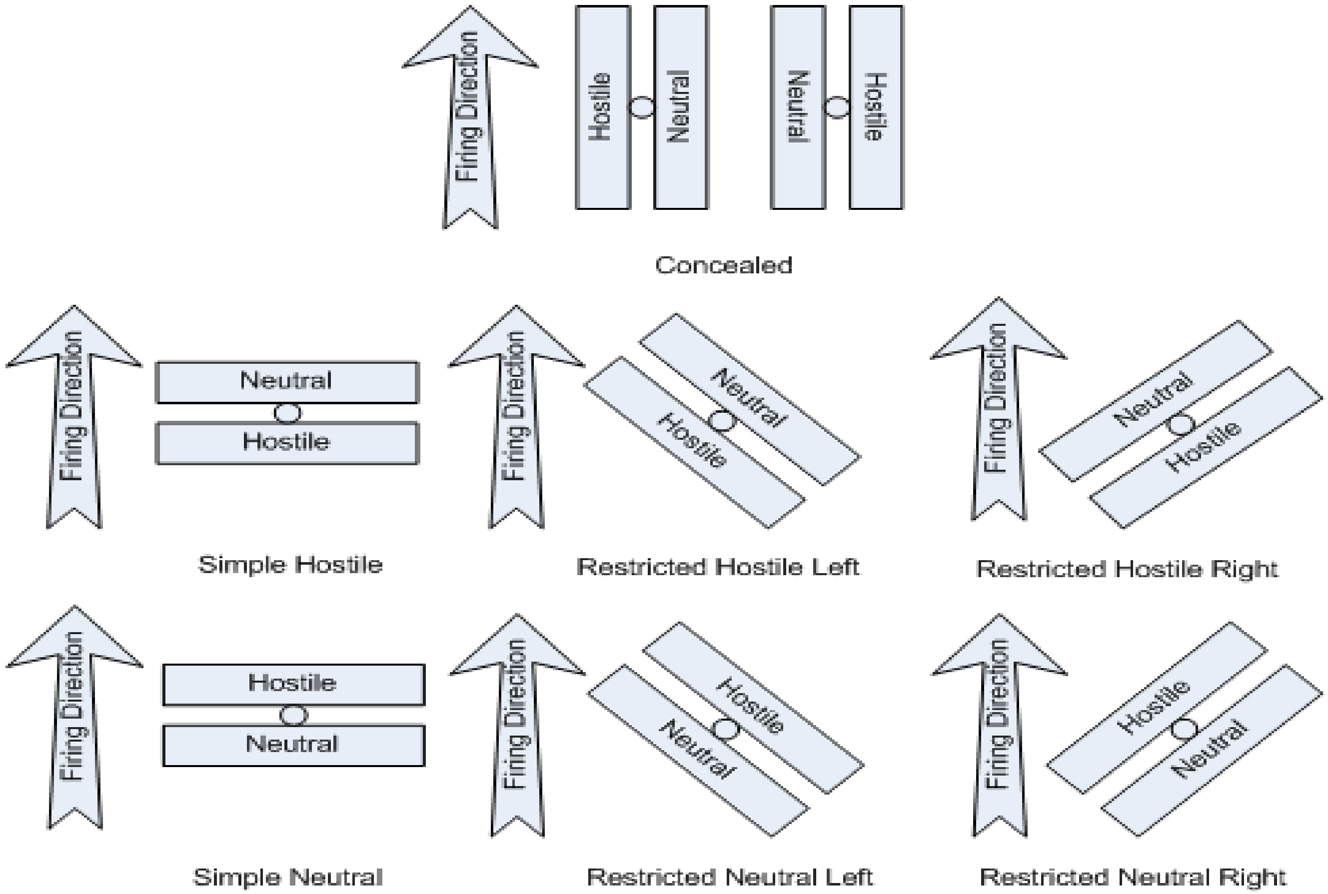
References

- Bracket needs to be able to turn **180** degrees in **1** second
- Acceleration/Deceleration time t_1 is **0.125** seconds
- To Find Required Torque from Motor
  - Assumed a very bulky bracket
  - The biggest target is attached
  - Frictionless
- Required Motor Torque: 620 ozf*in (32 lbf*in) @ 40 RPM
  - Safety Factor: 1.5

Motor Speed vs Time



References


Firing Direction
Hostile
Neutral
Neutral
Hostile
Concealed
Firing Direction
Neutral
Hostile
Simple Hostile
Firing Direction
Neutral
Hostile
Restricted Hostile Left
Firing Direction
Neutral
Hostile
Restricted Hostile Right
Firing Direction
Hostile
Neutral
Simple Neutral
Firing Direction
Hostile
Neutral
Restricted Neutral Left
Firing Direction
Hostile
Neutral
Restricted Neutral Right

References

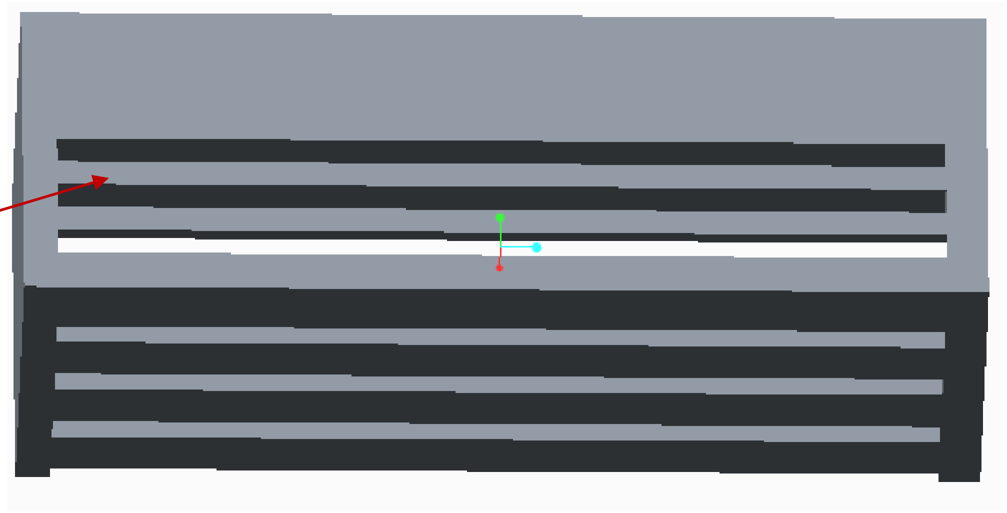
FASIT 2.0 PD IDC Command	Target Action
0	Concealed
1	Simple Hostile
2	Restricted Hostile Left
3	Restricted Hostile Right
4	Simple Neutral
5	Restricted Neutral Left
6	Restricted Neutral Right

References

References

Arm Design 3:

Ventilation of
Components
Enclosure



Forces generated with tailwind

Drag Force:

$\rho := 1.225 \frac{kg}{m^3}$

$v := 35mph$

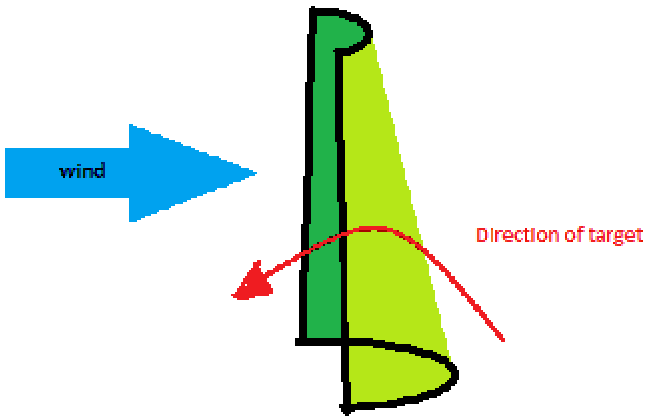
$A := \pi \cdot 6in \cdot 3ft = 0.438\,m^2$

$C_d := 2$ this is the drag coefficent for a half sphere

$F_d := 0.5 \cdot \rho \cdot v^2 \cdot C_d \cdot A = 131.291\,N$

$131N = 29.451\,lbf$

Note this is the force required to lower the target when a 30 mph tailwind is blowing on the back hollowed out portion.



References

Motor Selection Calculations

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

$V_{max} := 3in \cdot 3in \cdot 18in = 162 \cdot in^3$

$m_{max\_brace} := \rho_{aluminum} \cdot V_{max} = 15.876 \cdot lb$ The max weight allowed is 10lb

$h_b := 3in$

$w_b := 18in$

$I_{brace\_max} := \frac{1}{12} \cdot m_{max\_brace} \cdot \left(h_b^2 + w_b^2\right) = 440.559 \cdot in^2 lb$

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

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

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

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

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

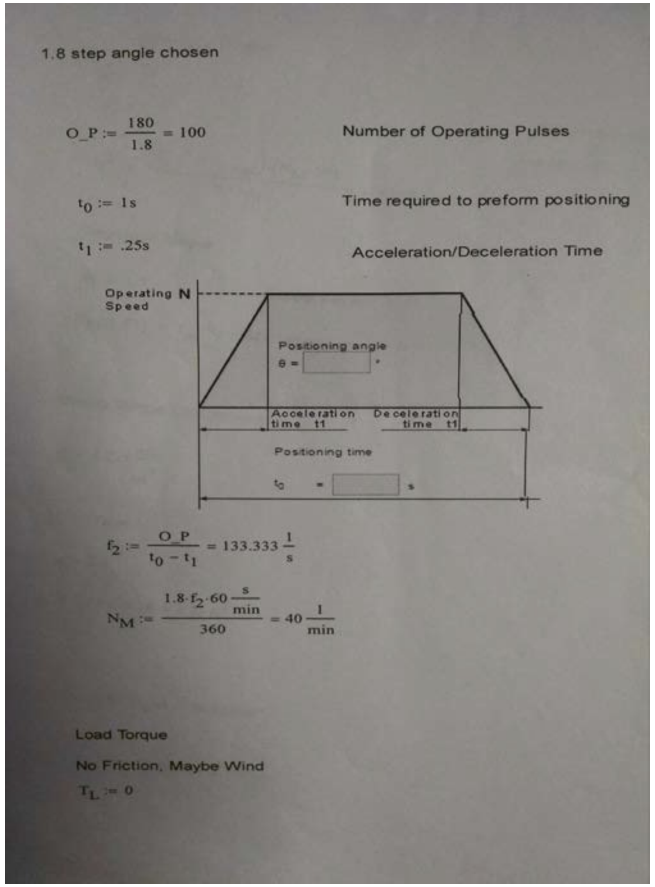
$m_{ivan} := 1.5lb$

$r_{ivan} := 6in$

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

$I_{Load} := I_{brace\_max} + I\_target\_max = 596.421 \, in^2 lb$

References



1.8 step angle chosen

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

$t_0 := 1s$ Time required to preform positioning

$t_1 := .25s$ Acceleration/Deceleration 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, Maybe Wind

$T_L := 0$

References

Acceleration Torque

$I_0 := 0$ — I.0 is motor inertia

$i := 1$ — i is gear ratio

$$T_a := \frac{\left(I_0 \cdot i^2 + I_{Load}\right)\cdot\left(N_M \cdot 60\right)}{9.55 \cdot t_1} = 414.098\ \text{ozf}\cdot\text{in}$$

Required Torque

$S_f := 1.5$ — Safety Factor

$$T_R := \left(T_L + T_a\right)\cdot S_f = 621.146\ \text{ozf}\cdot\text{in}$$