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

TEAM #16

DESIGN REVIEW #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
  - Arm
- Analysis
  - Structural Analysis
  - Wind Simulation
  - Motor & Gearbox Specifications
- Current Parts Selection
  - Budget
- 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

Fig. 1

Background

"E" Style
(Waffle Board)
Fig. 2

"Figure 12"
Style
Fig. 3

"Figure 11"
Style
Fig. 4

"Ivan"
Style
Fig. 5

Terminology

Target Bracket

Arm

Lifter

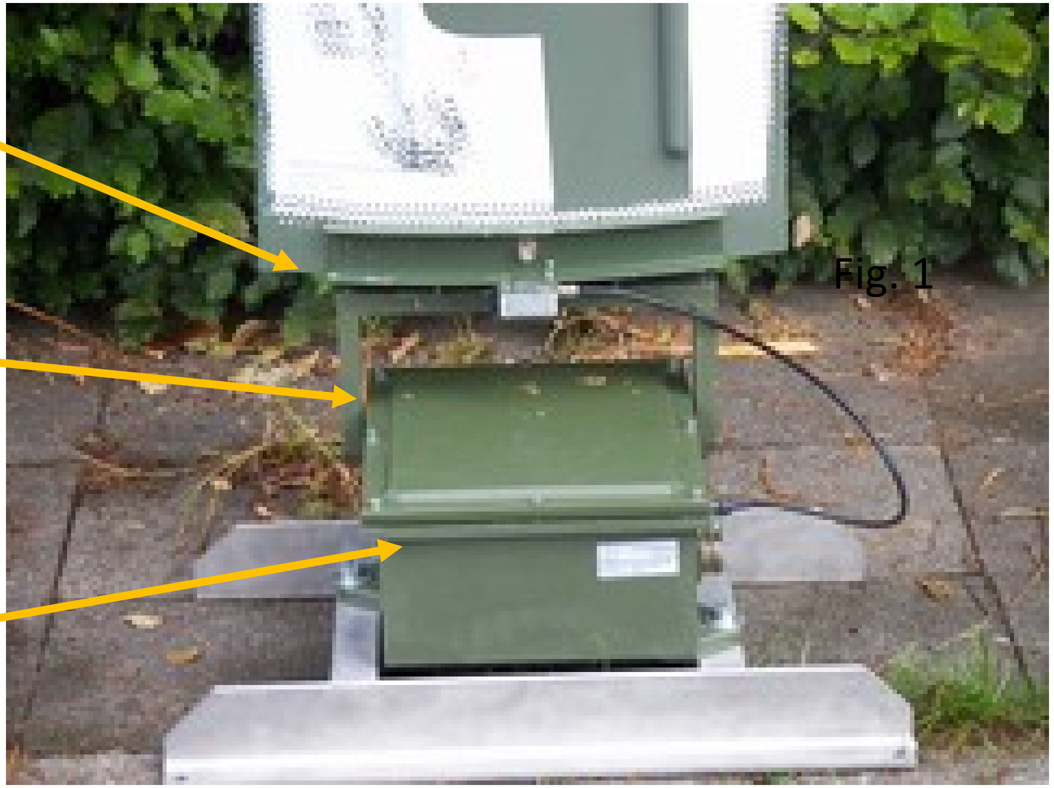


Fig. 6

Friend & Foe

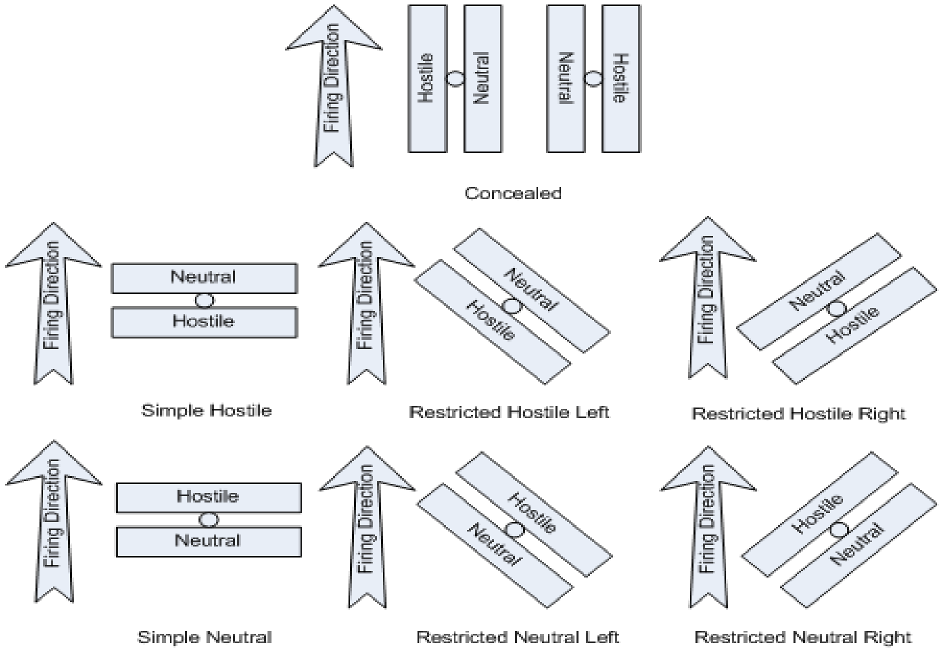


Fig. 7

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."

Fig. 8


Soldier practicing on a SIT

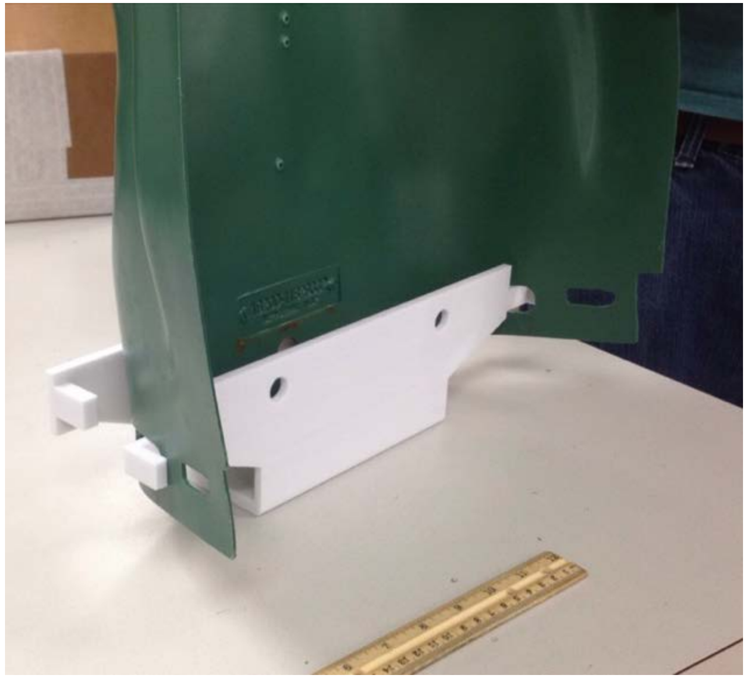
Fig. 9

Design Progress

- The 3D printed bracket has been received from Lockheed
- Arm and Bracket Design changed based on our 3D printed prototype

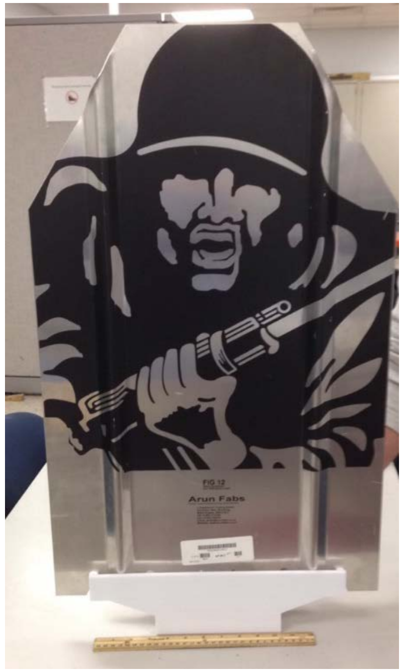
"E" Style (Waffle Board)

Fig. 10



"Ivan" Fit

Fig. 11



"Figure 12" Fit

Fig. 12

Bracket Design Update

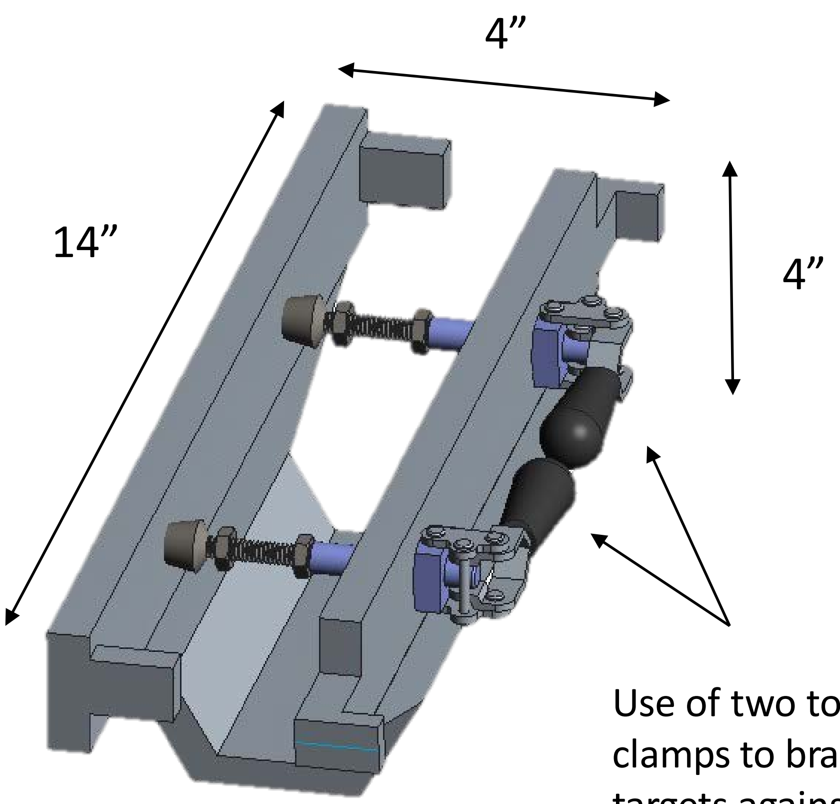


Fig. 13

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

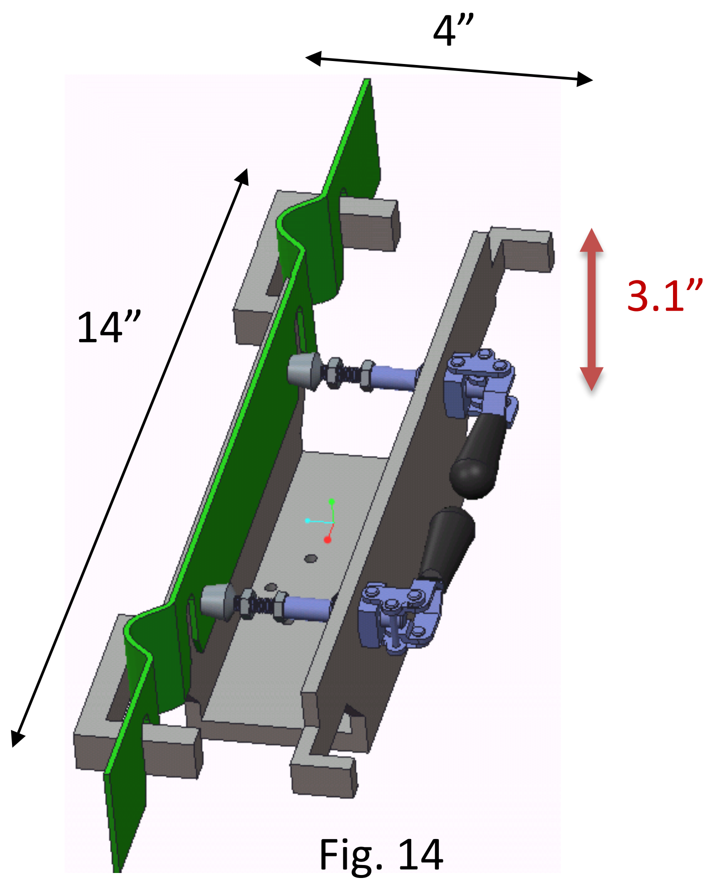


Fig. 14

Bracket Design and Target Fit

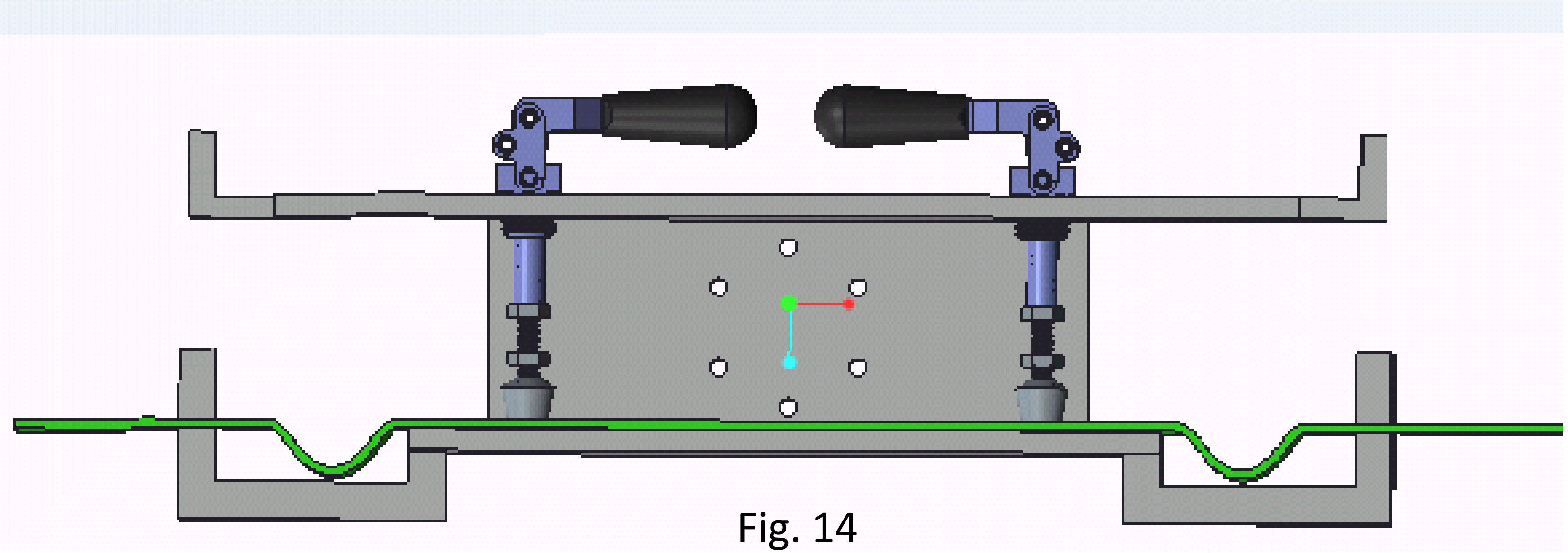


Fig. 14

Exaggerated hooks to allow the target ridges to fit

Previous Arm Design

* All Material is Aluminum 6061

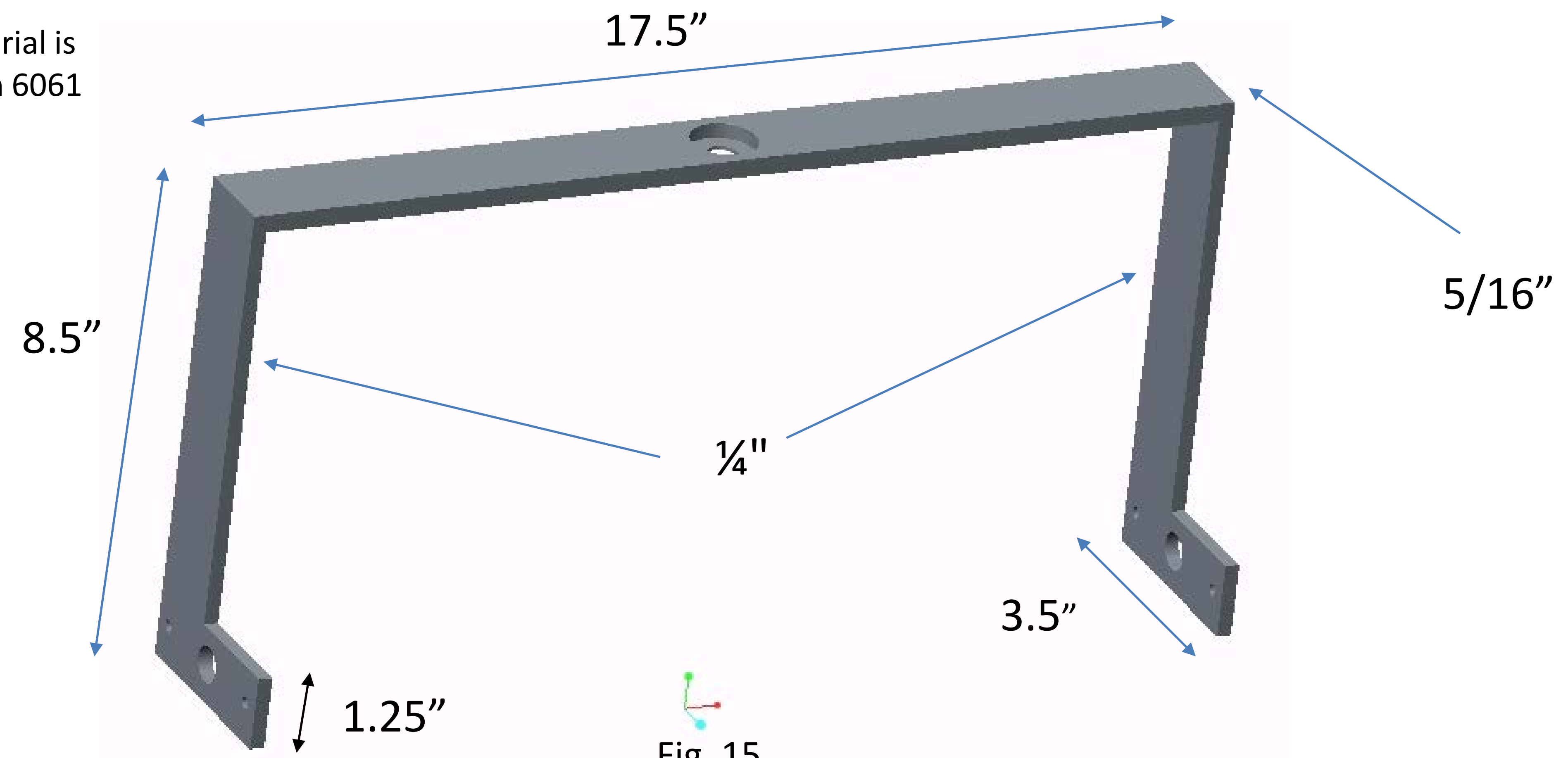


Fig. 15

Arm Design Update

* Welded to top of the arm to allow space for bearings

* All Material Aluminum 6061

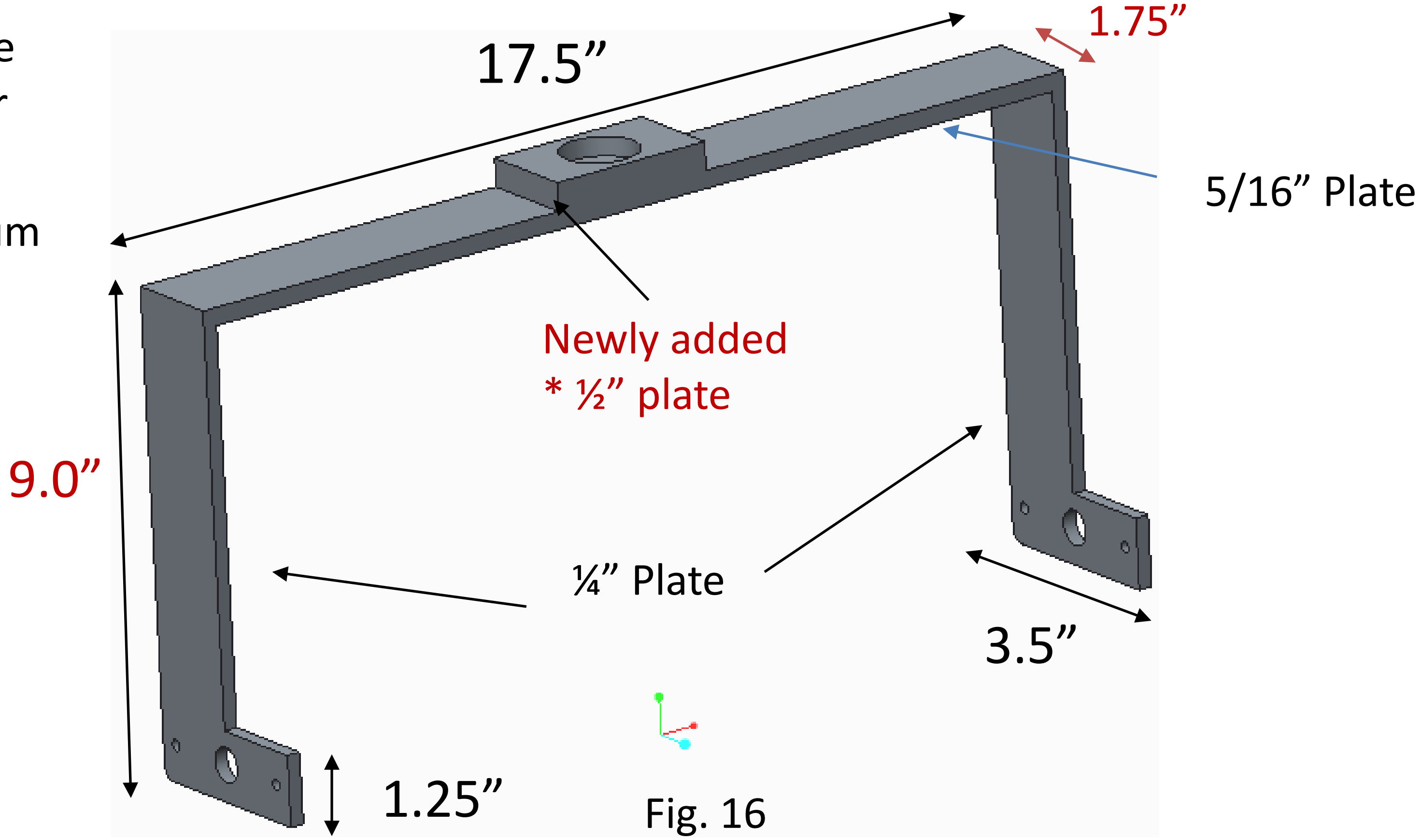


Fig. 16

Design Analysis

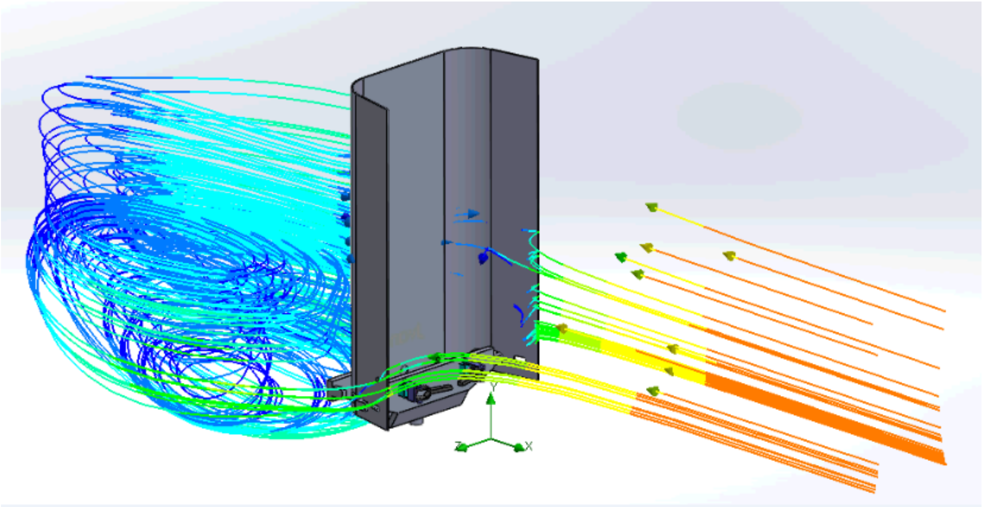


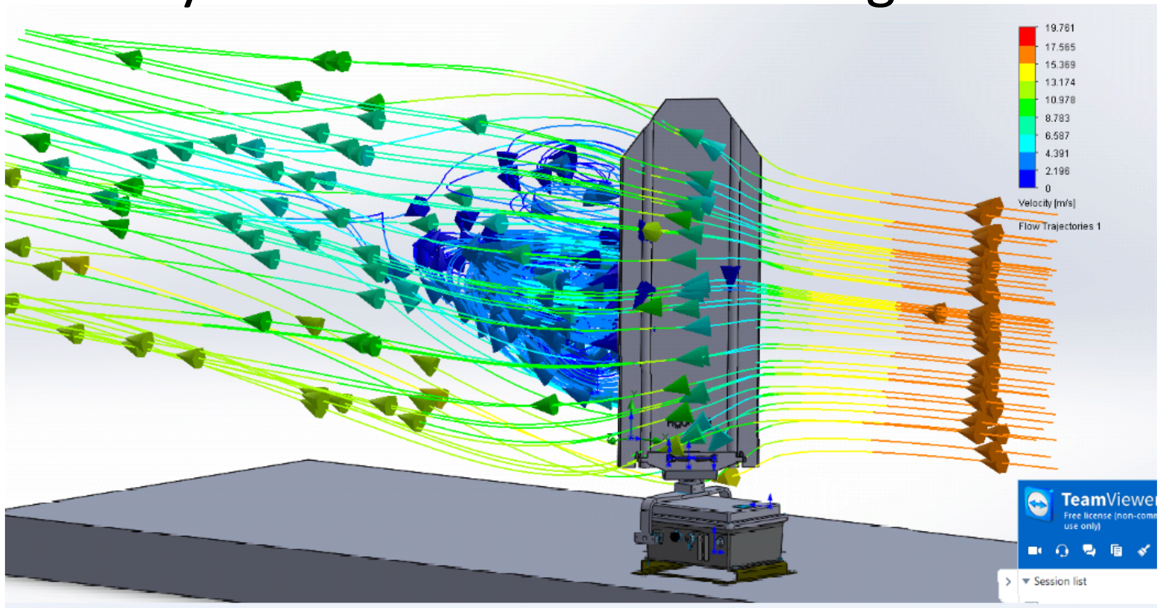
Fig. 17

$\rho := 1.225 \frac{kg}{m^3}$	Density of Air
$v := 35mph$	Velocity of Wind
$A := \pi \cdot 6in \cdot 3ft = 4.712 ft^2$	Area of Ivan
$C_d := 1.45$	Drag coefficent of Ivan
$F_d := 0.5 \rho \cdot v^2 \cdot A \cdot C_d = 21.399 lbf$	Resultant Force

- Worst case scenario: 35 mph wind blowing on the back of the Ivan

Design Analysis

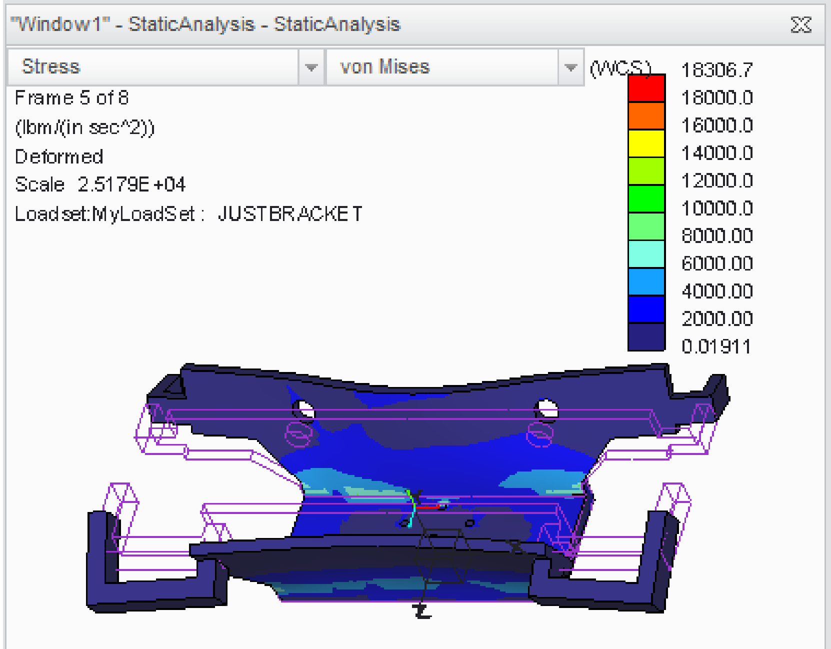
- Max torque generated from the distributed wind force **= 11.5 ft*lbf (15.592N*m)**
- Our bracket currently secures each of these targets with clamps rated for 100 lbf



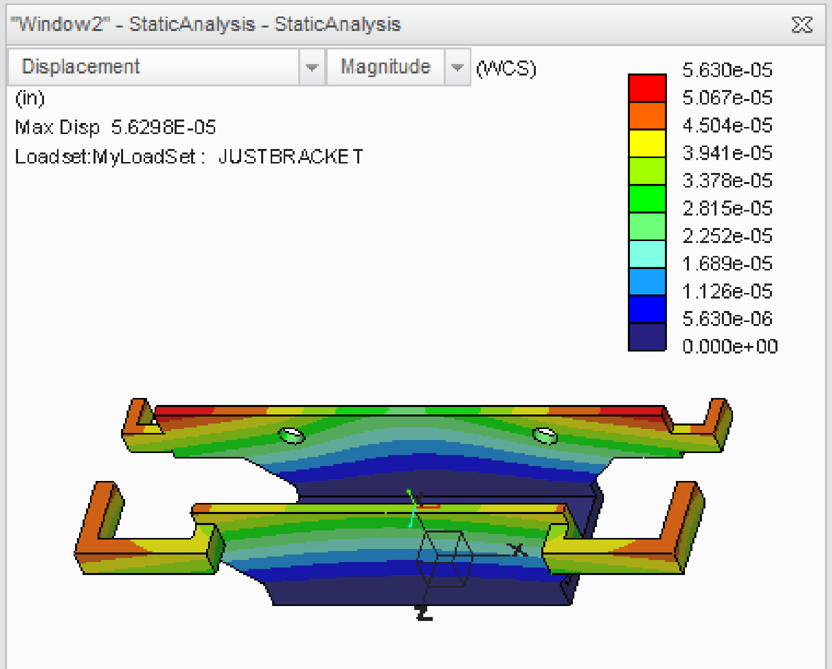
all other targets can be assessed from largest target (fig 11)

Fig. 18

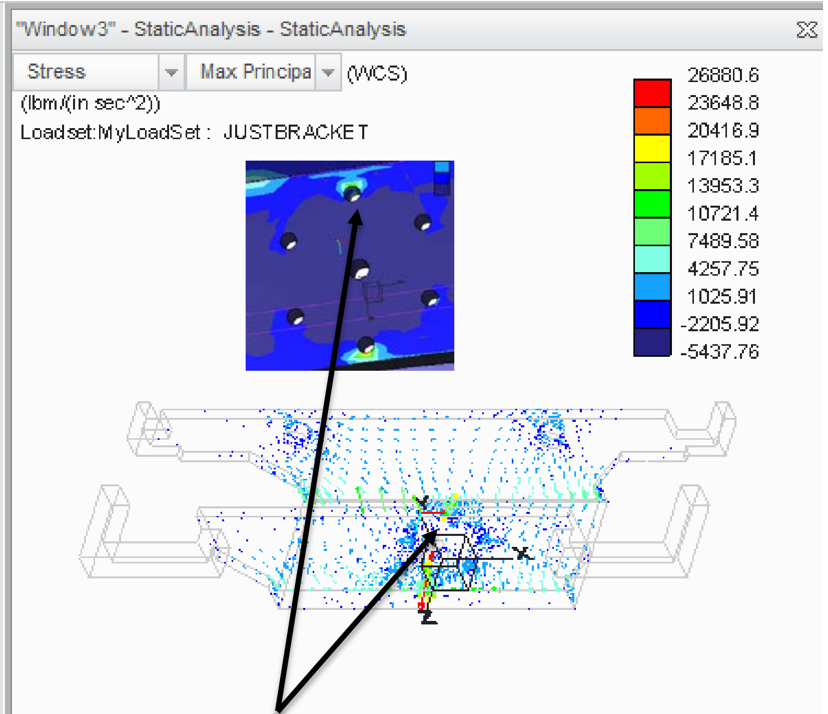
Bracket Analysis



Max Stress = 18,300 psi



Max Displacement = 0.0001 in.



Max Principal Stress locations (26,880 psi)

Yield Strength = 40,000 psi

Cyclic Loading = 14,000 psi

Fig. 19

Fig. 20

Fig. 21

Arm Analysis

Worst case scenario causing torsional effects on arm

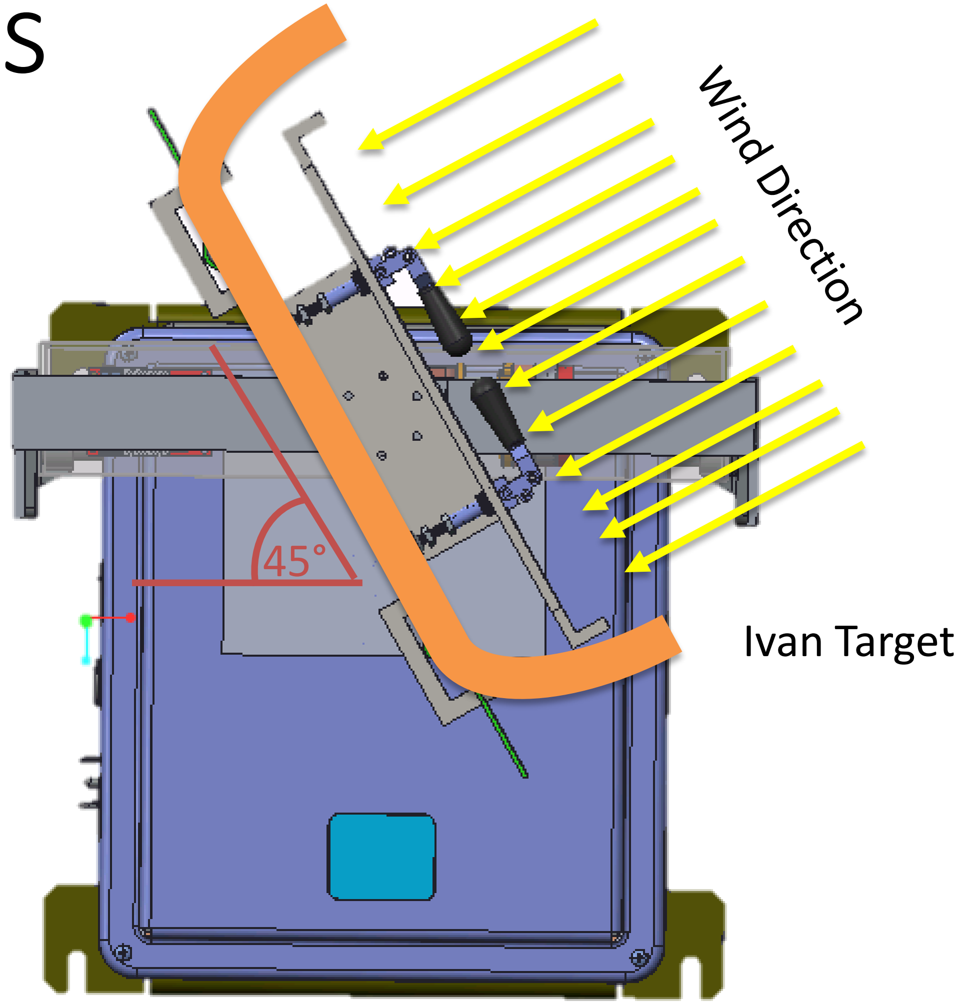
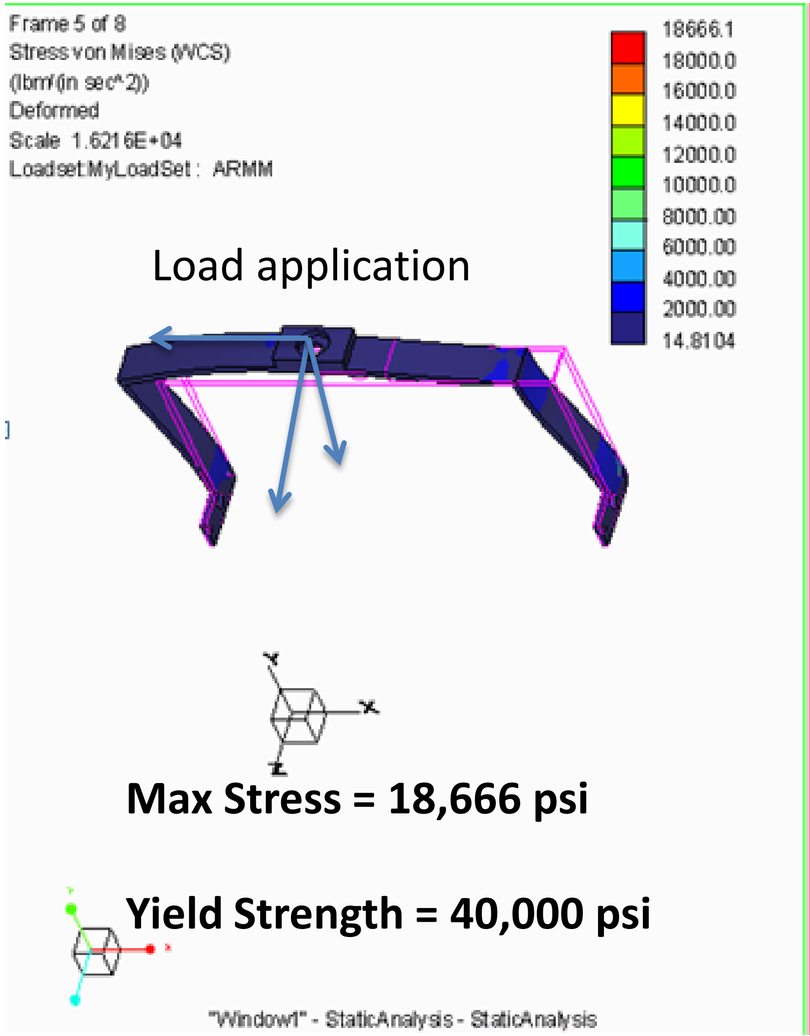


Fig. 22

Arm Analysis

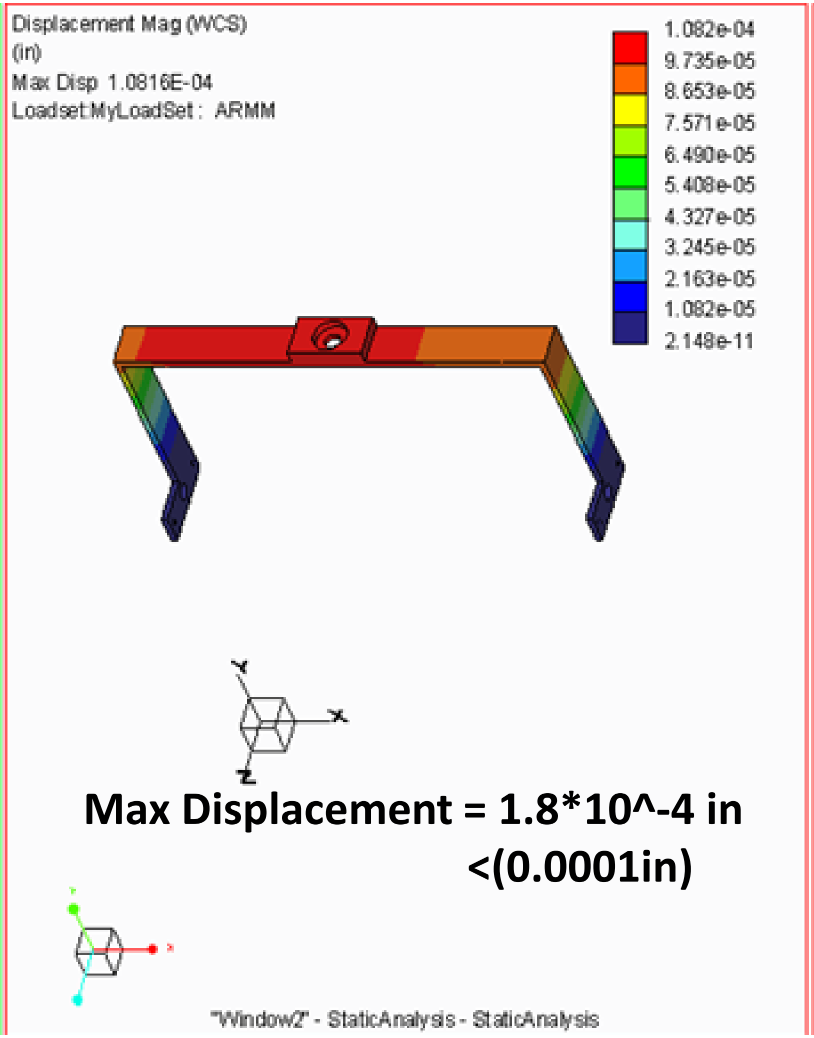
LOCKHEED MARTIN



Max Stress = 18,666 psi

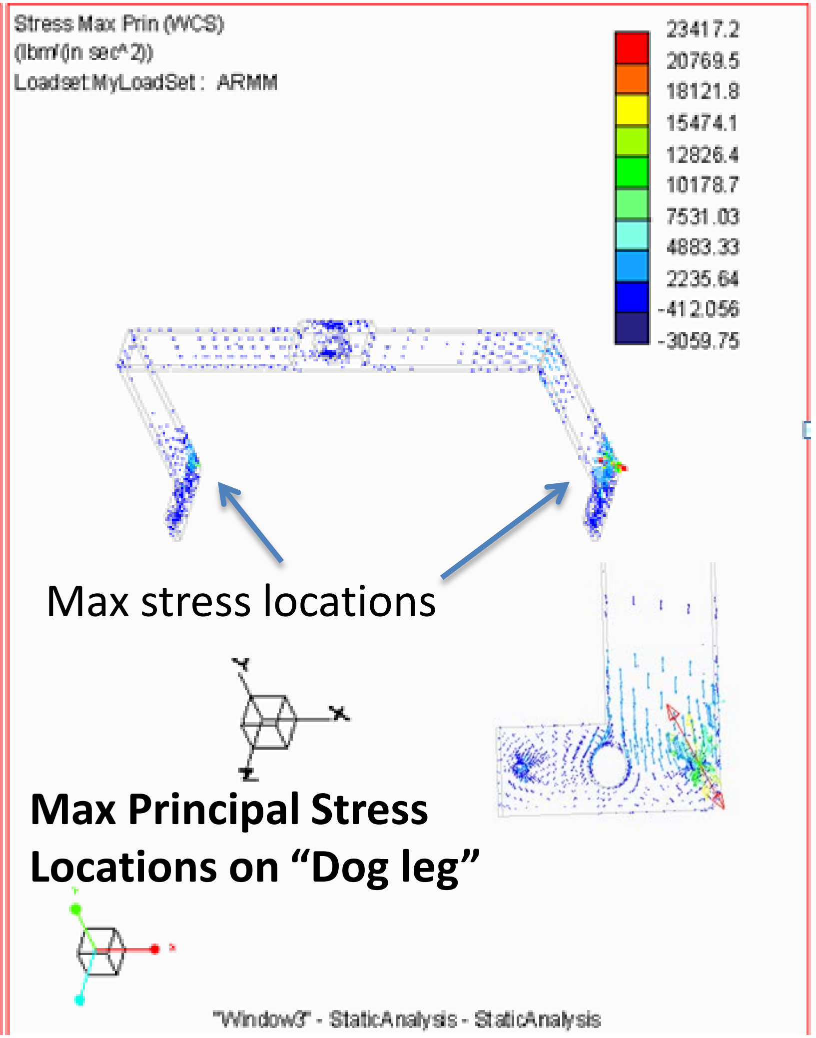
Yield Strength = 40,000 psi

Fig. 23



Max Displacement = 1.8*10^-4 in <(0.0001in)

Fig. 24



Max Principal Stress Locations on "Dog leg"

Fig. 25

CFD Simulation for Wind

- Solidworks was used to provide a basic simulation of gust winds on target
- This was done to achieve reliable numbers to base motor specs and structural analyses on
- The simulation was done for both the Ivan target and the biggest flat type target
- Simulation was run multiple times for the multiple angles the wind could be blowing on the target

CFD Simulation for Wind

- The maximum torque on the motor due to wind was 11.5 ft*lbfs
    - Generated on Ivan with wind attacking at 135 degrees (Fig. 26)
- The maximum forces seen on any target was 21.3 lbfs
    - Generated on flat target with angle of wind straight on (Fig. 27)

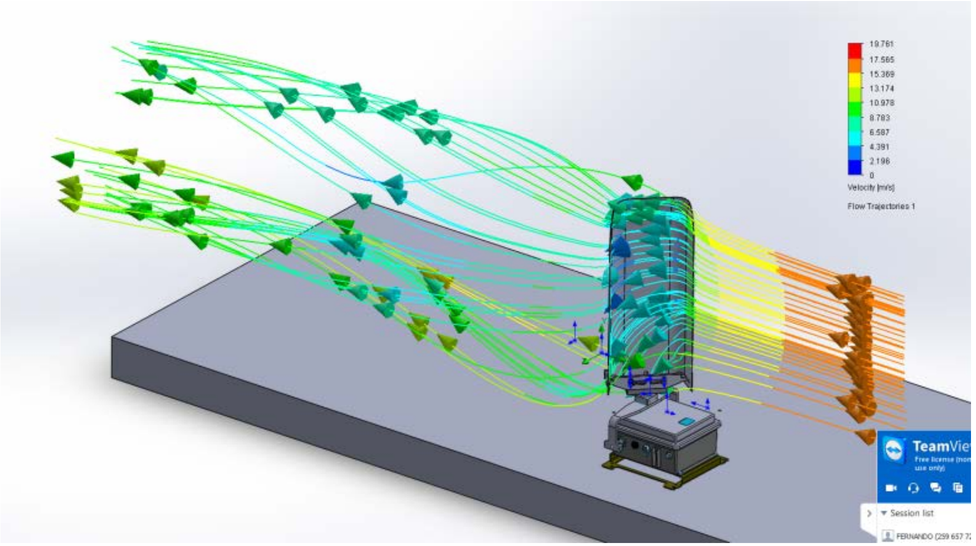


Fig. 26

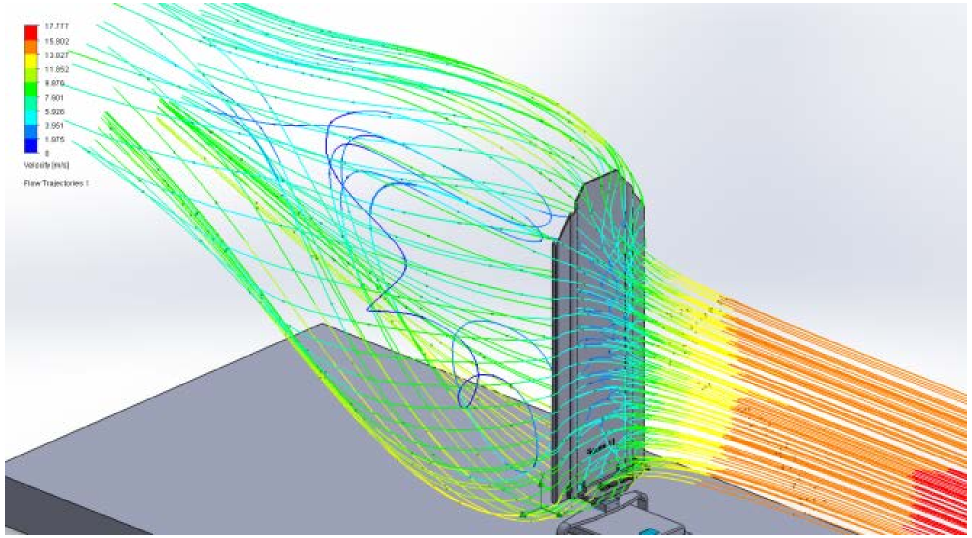


Fig. 27

Turning Mechanism Specs

- Needed to be able to select Motor/Gearbox
- Main values of interest to find Torque is inertia of the bracket and attached target as well as any forces generated by gust winds
- With a safety factor of 1.25 we found that we needed **3000 ozf-in @ 40 rpm**

Motor Selection

CCL-9015 12VDC Brushed Motor

Fig. 28

- Length: 3.19 inches
- Weight: 0.5 pounds
- At max power of 179.3W:
  - 32.5 amps
  - **Torque: 30.32 oz-in**
  - 8000 RPM

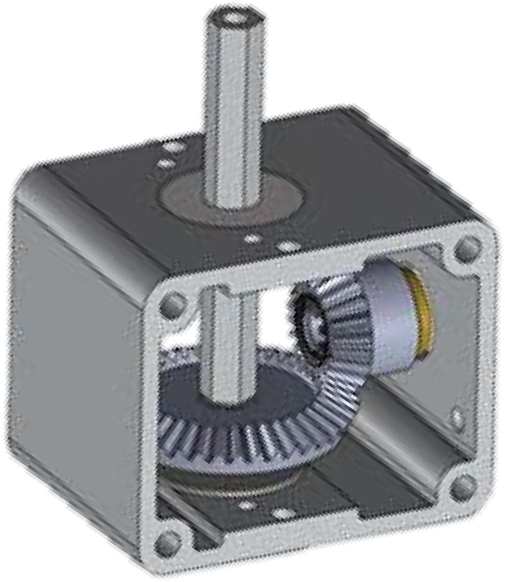
Gearing Selection

AM-0002 Planetary Gearbox

Fig. 29

- Length: 2.5 inches
- Weight: 0.63 pounds
- Reduction: 3.67:1
  - 2 additional gear stages will be added to help meet the required torque

Gearing Selection



LJ Bevel Right Angle Gearbox

Fig. 30

- Dimensions:
  3 x 2.5 x 2.25 in
- Weight: 0.95 pounds
- Reduction: 2:1

Turning Mechanism Selection

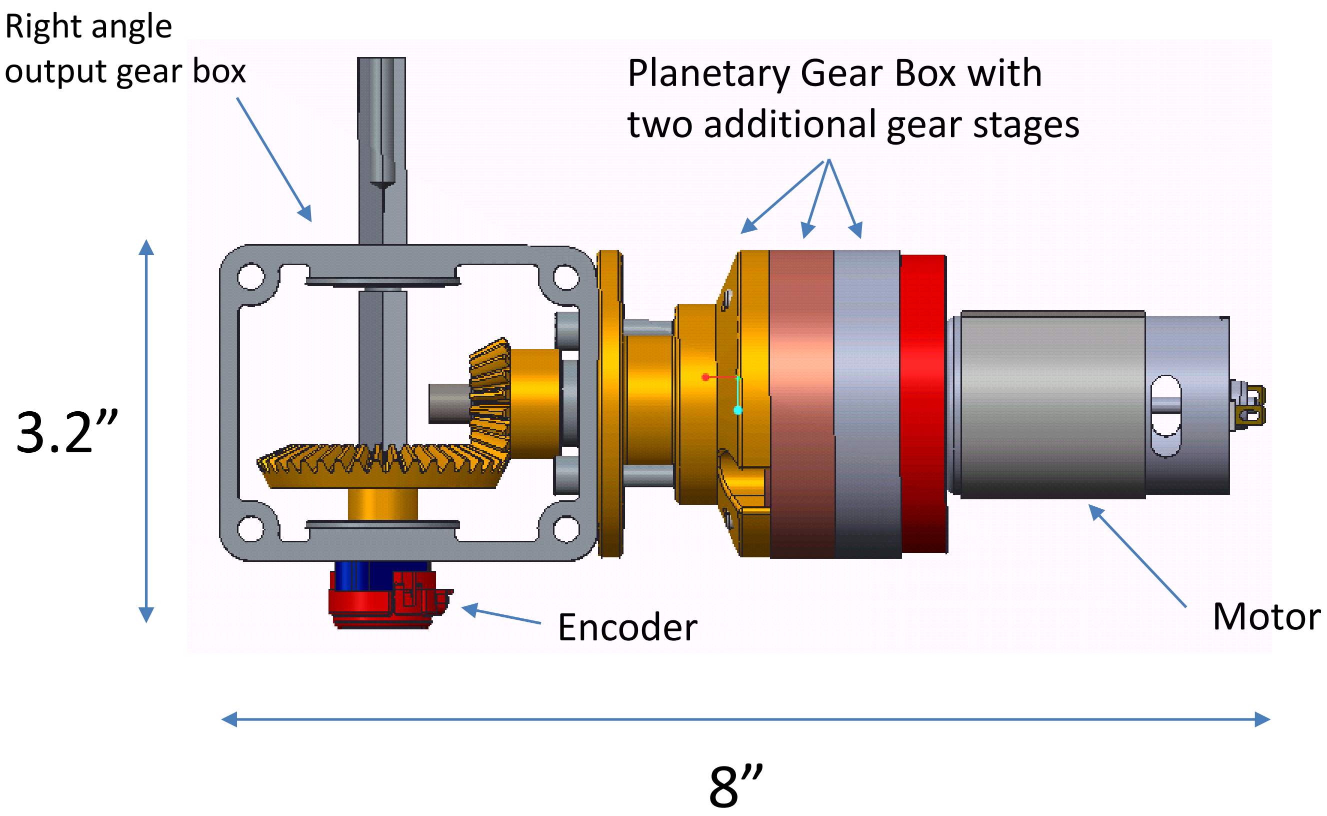
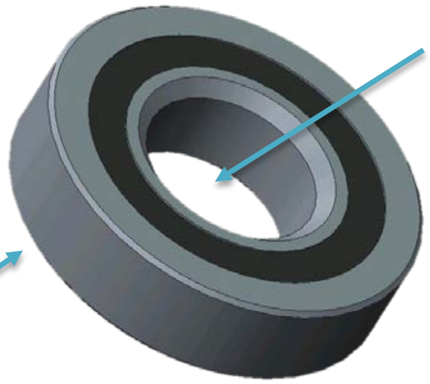


Fig. 31

- Total Weight: 2.6 pounds
- Output of the right angle gear box:
  - **Torque: 3000 oz-in**
  - **80 RPM**

Bearing Selection

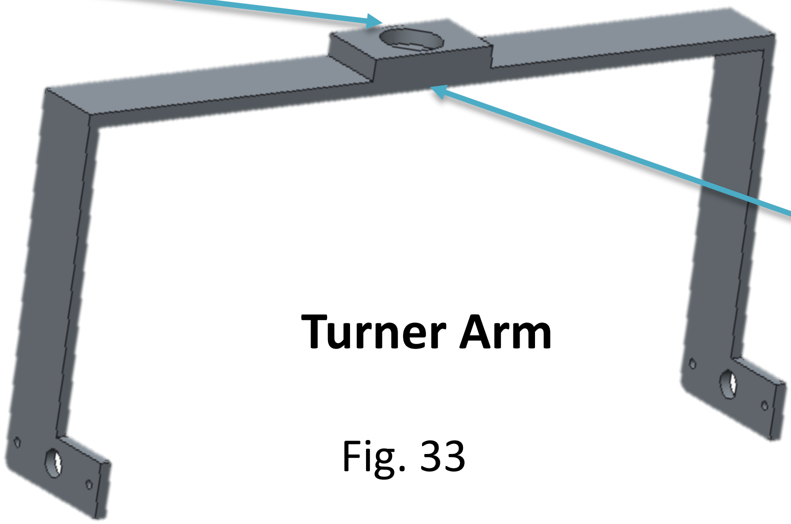


5/8” ID

1 3/8” OD

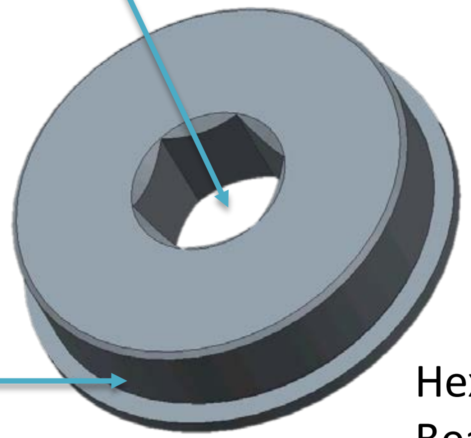
Double Sealed and Permanently Lubricated ball bearing

Fig. 32



Turner Arm

Fig. 33



3/8” Hex Inner Dimension

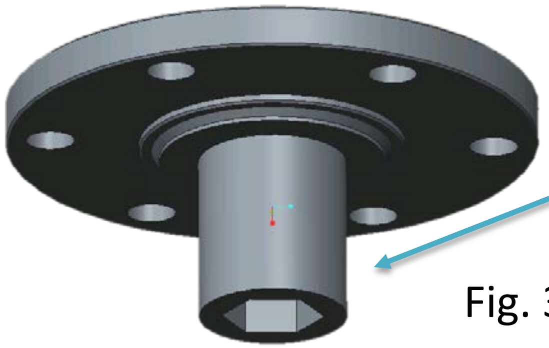
1 1/8” OD

Hex Ball Bearing

Fig. 34

Turning Mechanism to Bracket Coupling

3/8" Inner Dimension Hex Motor Hub



5/8" OD to fit bearing in Arm

Fig. 35

Hex Shaft is threaded for ¼ - 20 Screw

3/8" Hex Shaft from Right Angle Gear Box

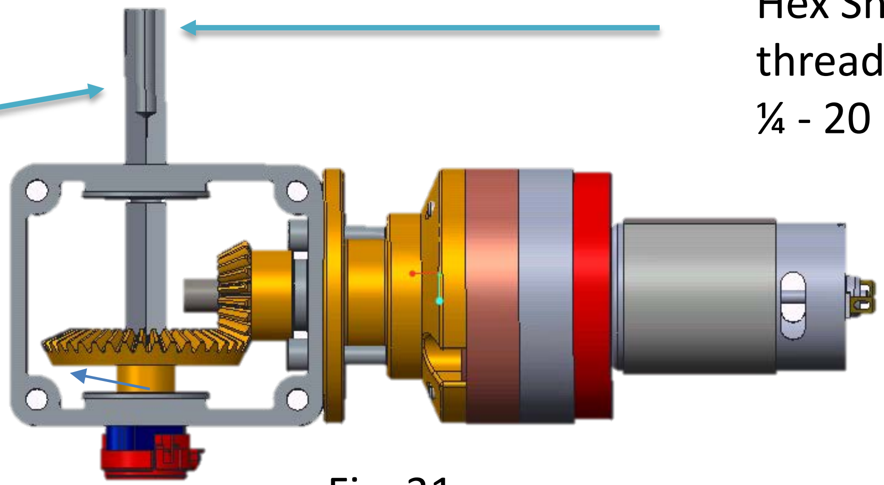
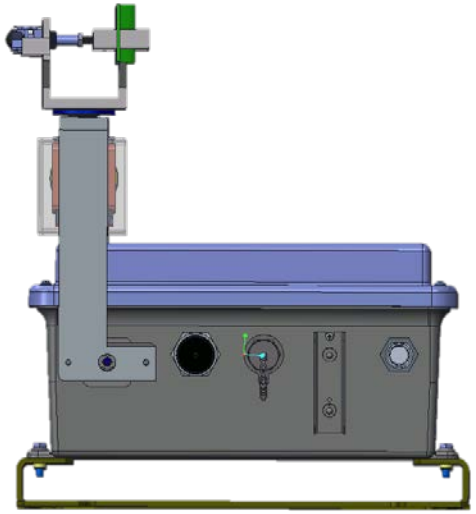


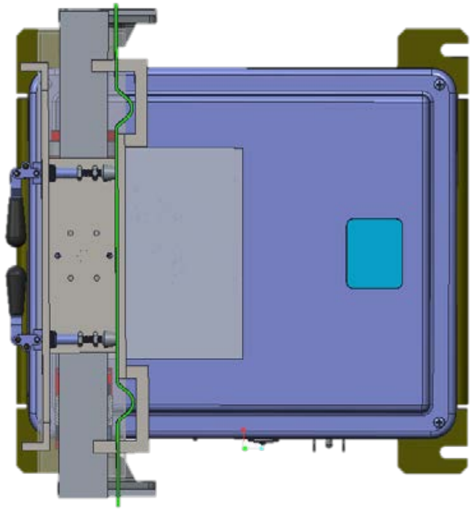
Fig. 31

Finalized Design



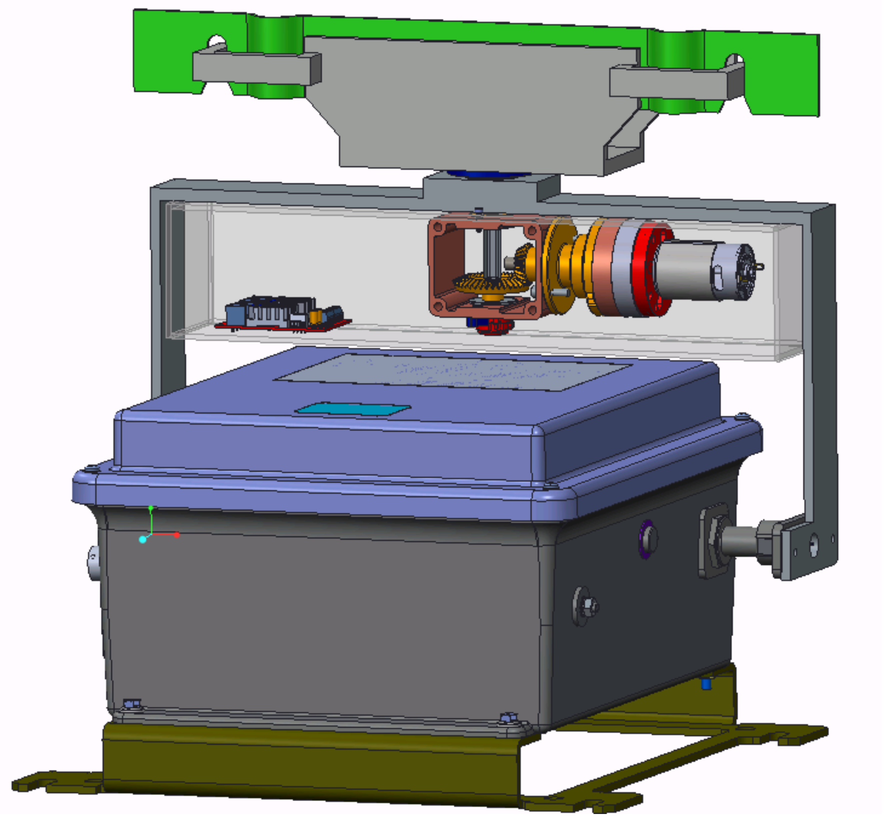
Side View

Fig. 36a



Top View

Fig. 36b



Parametric View

Fig. 36c

Finalized Design

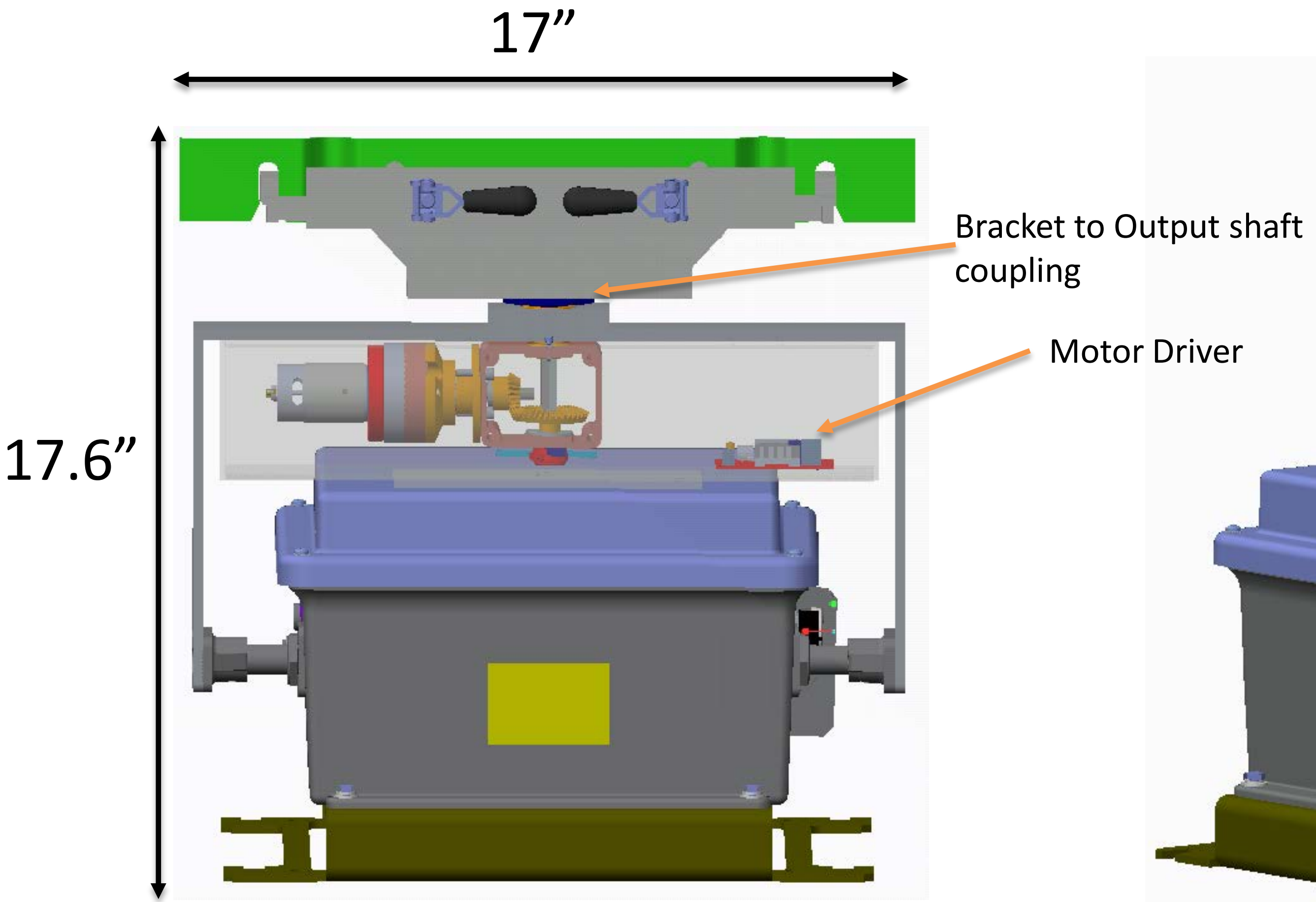


Fig. 36d

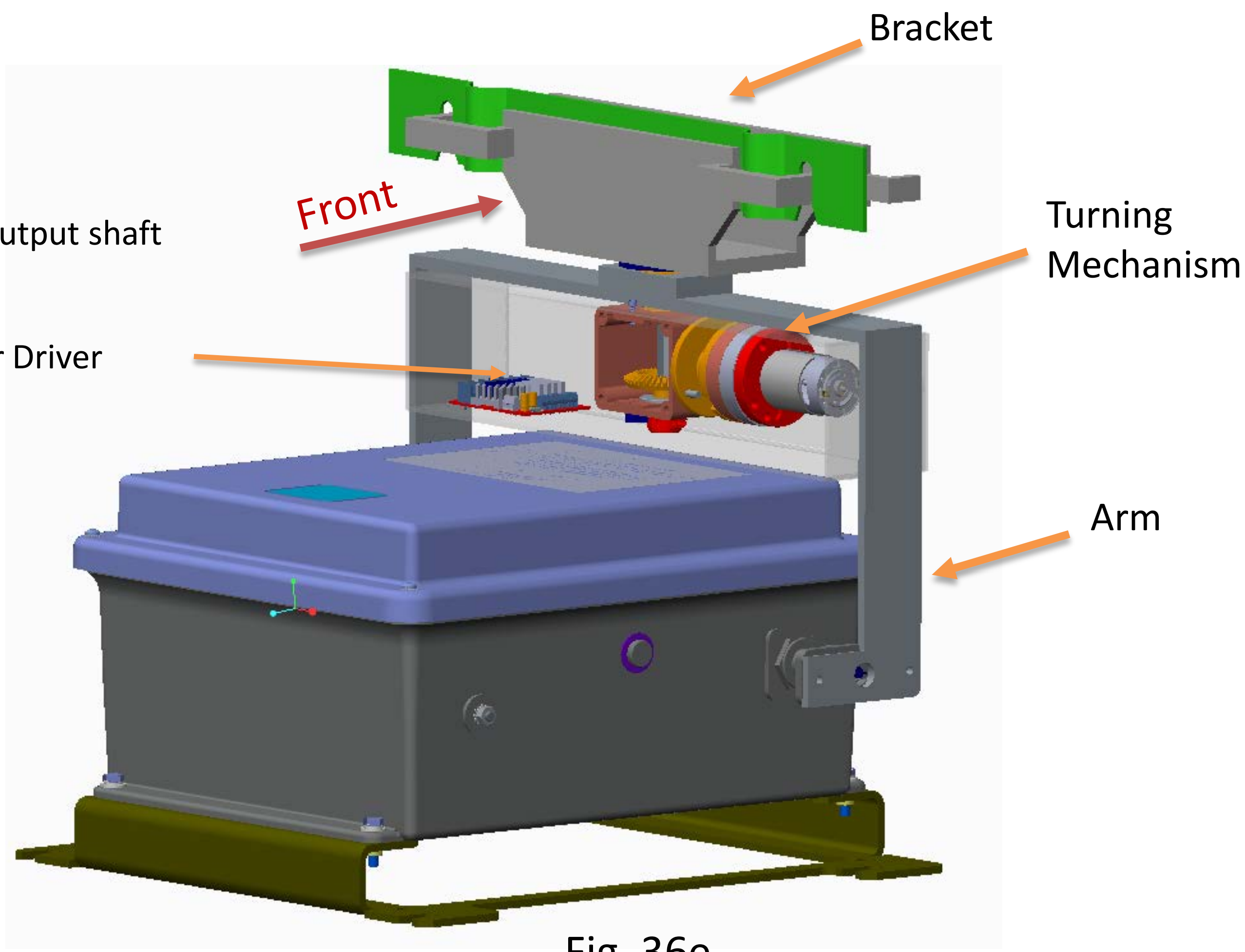


Fig. 36e

Purchases

OnlineMetals

- Sheet Metal for construction of arm and bracket
- Status: Delivered
- Total: **$164.99**

McMaster-Carr

- Bearing and Clamps
- Placed: 02/09/16
- Status: In Transit
- Total: **$75.36**

AndyMark

- Turner Mechanism Components
- Placed: 02/10/2016
- Status: In Transit
- Total: **$439.22**

Budget: $2000

Total expenses thus far: $679.57

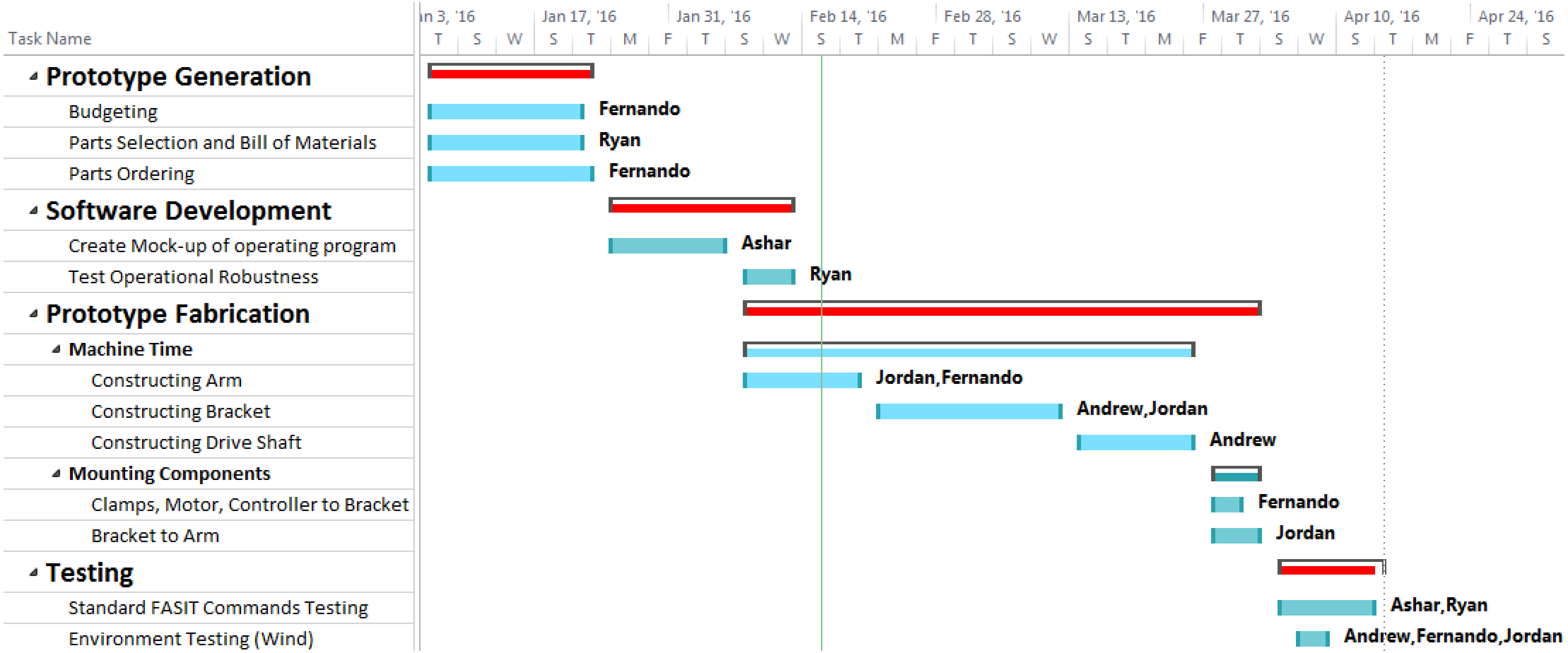
Remaining Funds: $1320.43

Summary

- Amended Bracket and Arm Design based off of 3D Printed Bracket received from Lockheed-Martin
- Analysis performed on the new bracket and arm
- Structural and target turning components selected and ordered

Future Work

Schedule:



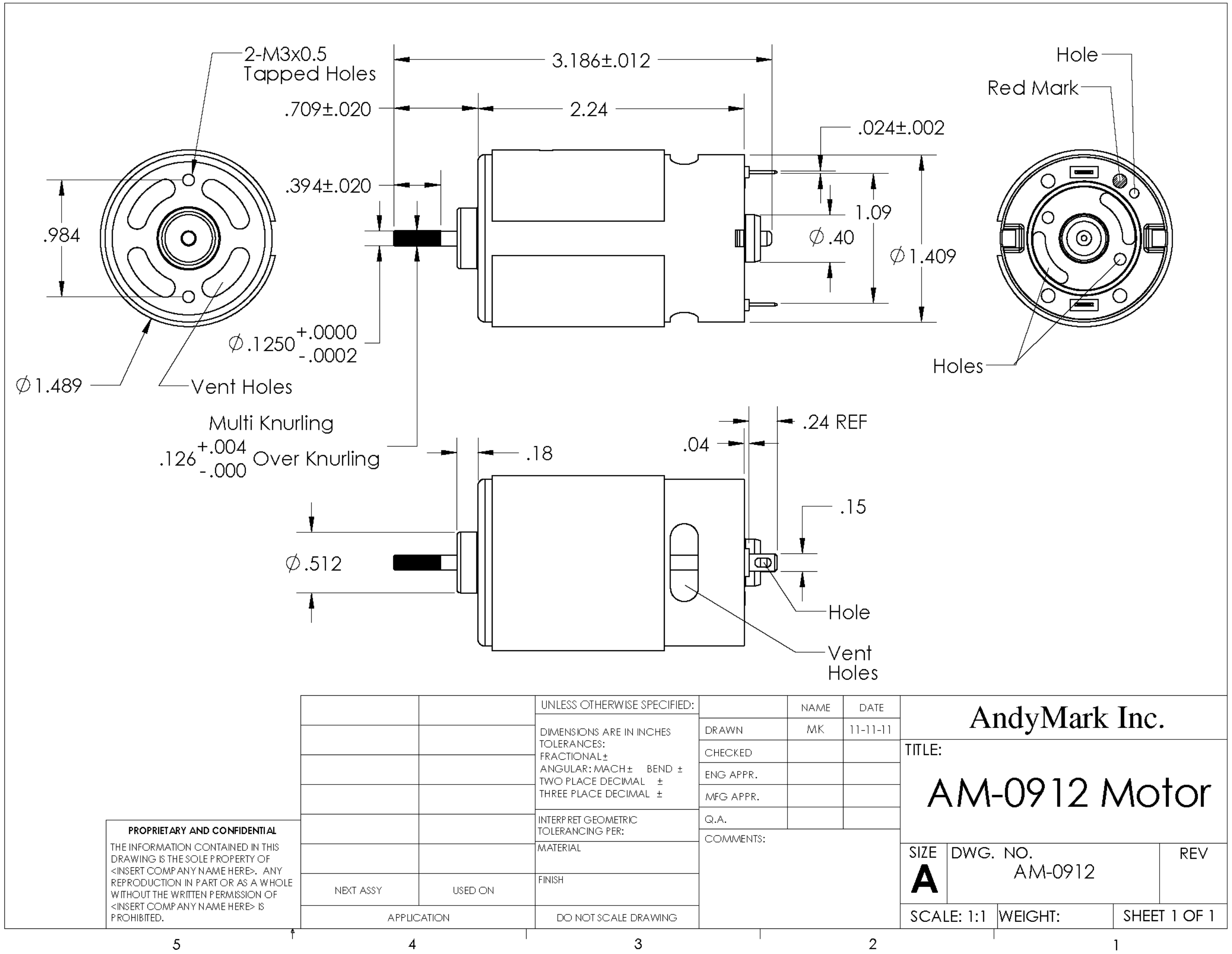
Future Work

- Ordering Components:
  - Motor Driver
  - Motor Controller
  - New Aluminum 6061 Pieces
  - Hardware (Screws, Bolts, Fasteners)
- Software Development
- Machining raw material

Fig. 37

Questions / Comments

Fig. 38


2-M3x0.5
Tapped Holes
3.186±.012
.709±.020
2.24
.394±.020
.984
∅.1250 +.0000 -.0002
∅1.489
Vent Holes
.024±.002
1.09
∅.40
∅1.409
Hole
Red Mark
Holes
Multi Knurling
.126 +.004 -.000 Over Knurling
.18
.04
.24 REF
.15
∅.512
Hole
Vent
Holes
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC
TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
MK
11-11-11
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AndyMark Inc.
TITLE:
AM-0912 Motor
SIZE
A
DWG. NO.
AM-0912
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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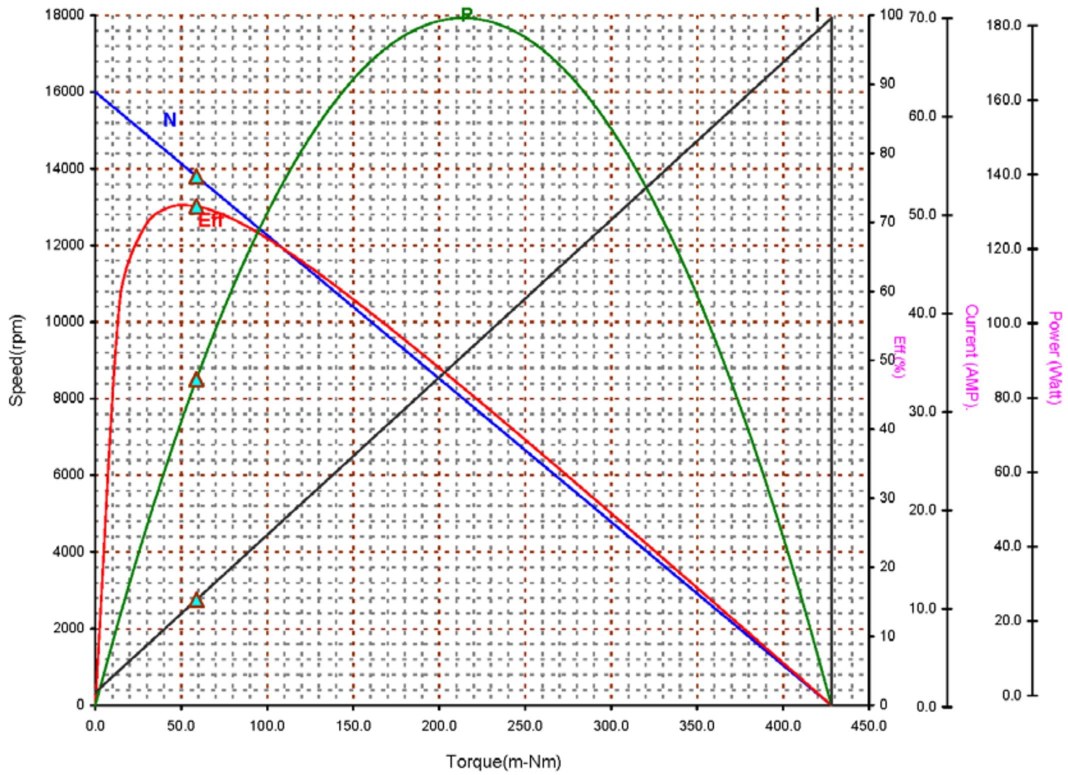
USED ON
APPLICATION
5
4
3
2
1

Chiaphua Components
Group of Companies

http://www.cclmotors.com

Project No : DB-30F-2005
Proposal No:
Winding : 0.00 - 0
Motor test reference no : (CCW)
Operator : JACKY
Date : 2011/11/10



Performance (In an ambient temperature of 25 -30 C)
Motor tested rapidly to prevent significant temperature rise.

At a constant voltage of	12.00	Volts
With a circuit resistance	0.000	Ohms

AT No Load

Speed :	16000	Rpm
Current:	1.200	Amp

At stall (Extrapolated)

Torque :	428.073	m-Nm
Current:	63.745	Amp

At maximum efficiency

Efficiency :	72.50	%
Torque :	51.647	m-Nm
Speed :	14070	Rpm
Current :	8.746	Amp
Output :	76.095	Watts

At maximum power

Torque :	214.036	m-Nm
Speed :	8000	Rpm
Current :	32.473	Amp
Output :	179.311	Watts

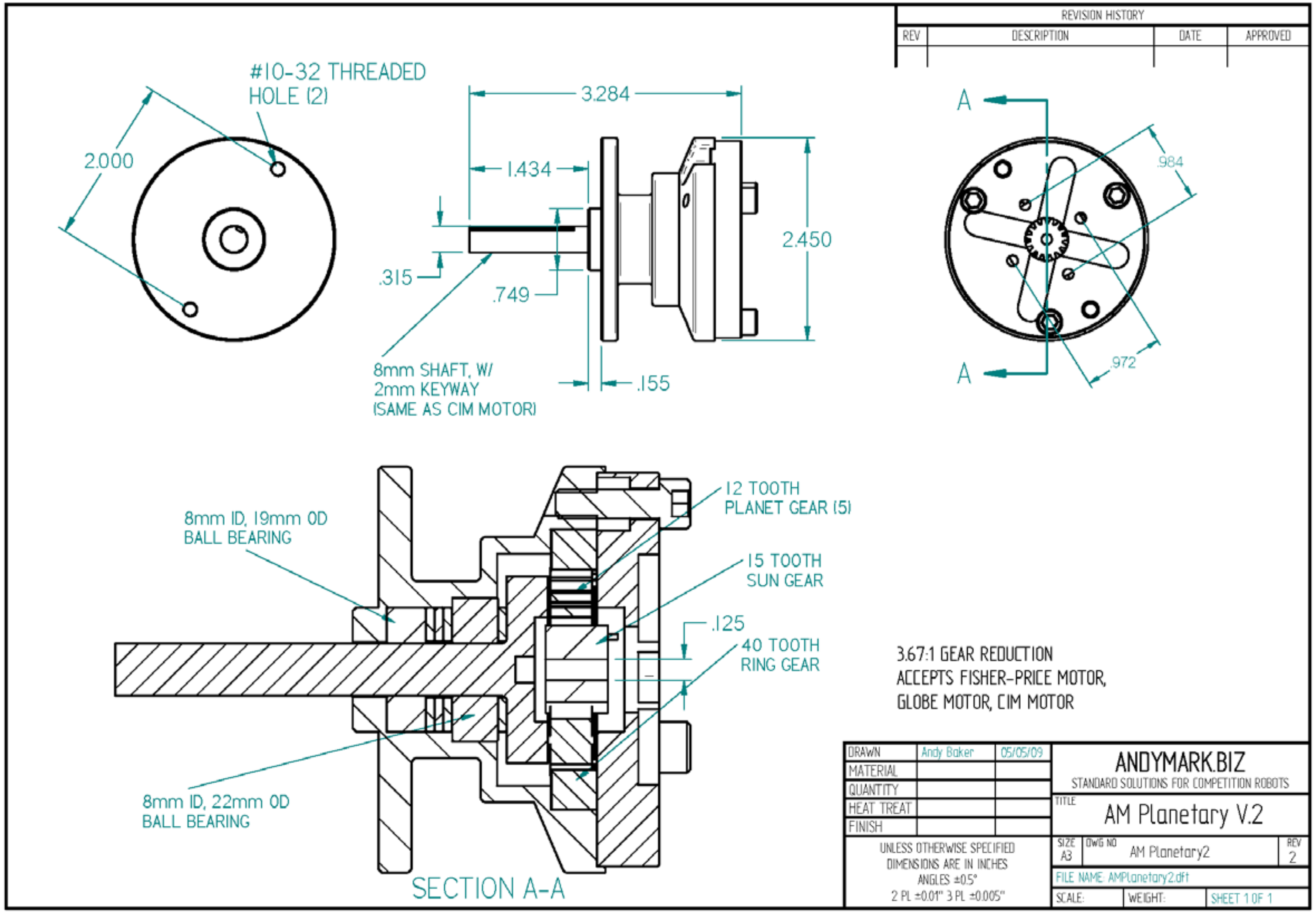
Characteristics

Torque Constant :	6.844	m-Nm/Amp
E.M.F Constant :	6.844	mV/rad/sec
Dy. Resistance :	0.188	Ohms
Motor Regulation:	37.377	Rpm/m-Nm

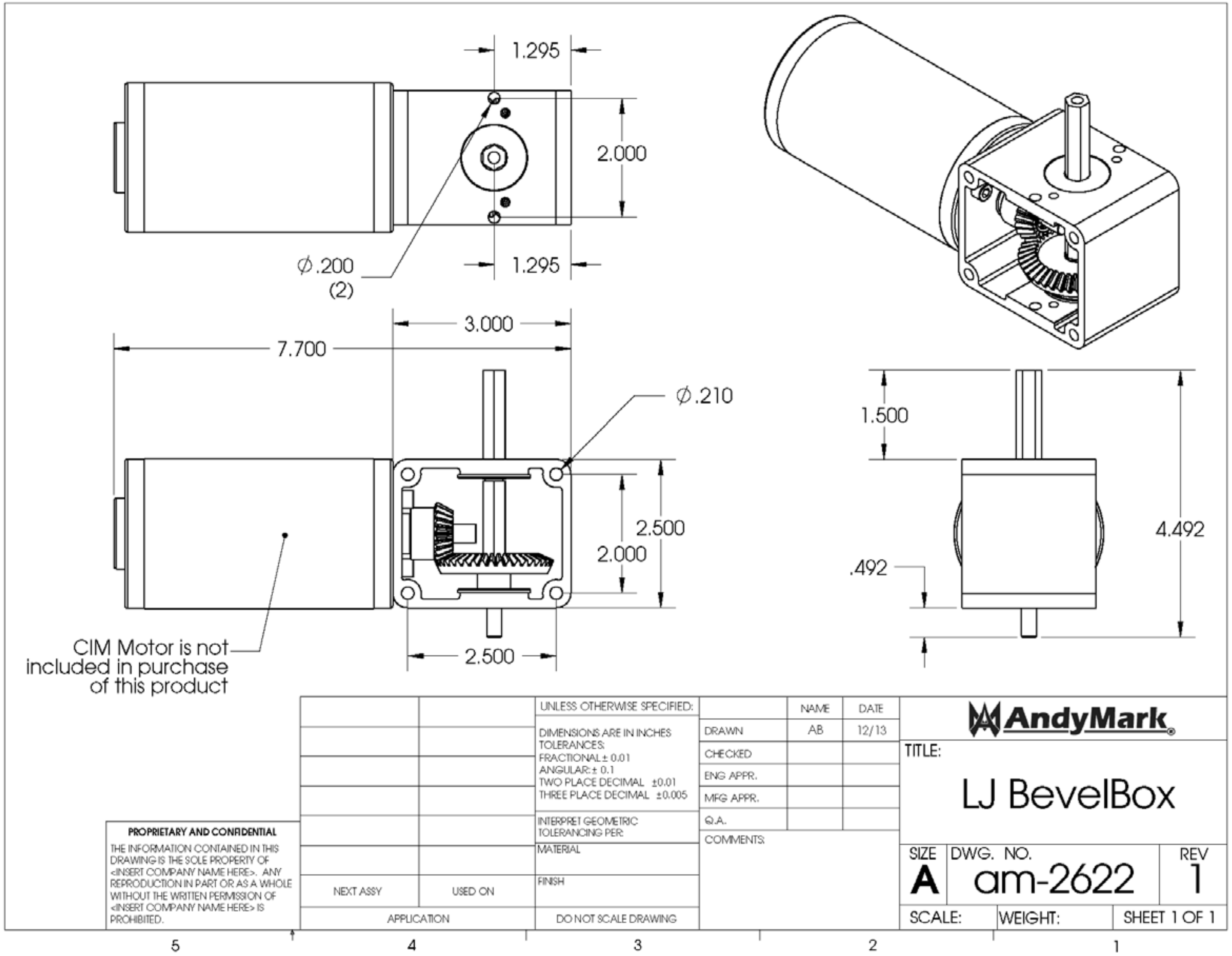
Calculation

At Torque Level:			At Fan:		
Torque:	58.860	m-Nm	Torque:		m-Nm
Speed:	13800	Rpm	Speed:		Rpm
Current:	9.800	Amp	Current:		Amp
Efficiency:	72.33	%	Efficiency:		%
Output:	85.061	Watts	Output:		Watts

COMPUTER PRINT-OUT
NORMINAL MOTOR CURVE
Performance and characteristics are measured based on limited motor sample only



#10-32 THREADED HOLE (2)
2.000
3.284
1.434
.315
.749
2.450
.155
8mm SHAFT, W/ 2mm KEYWAY (SAME AS CIM MOTOR)
REVISION HISTORY
REV
DESCRIPTION
DATE
APPROVED
A
.984
.972
12 TOOTH PLANET GEAR (5)
8mm ID, 19mm OD BALL BEARING
15 TOOTH SUN GEAR
.125
40 TOOTH RING GEAR
8mm ID, 22mm OD BALL BEARING
SECTION A-A
3.67:1 GEAR REDUCTION
ACCEPTS FISHER-PRICE MOTOR, GLOBE MOTOR, CIM MOTOR
DRAWN Andy Baker 05/05/09
MATERIAL
QUANTITY
HEAT TREAT
FINISH
ANDYMARK.BIZ
STANDARD SOLUTIONS FOR COMPETITION ROBOTS
TITLE AM Planetary V.2
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES ANGLES ±0.5° 2 PL ±0.01" 3 PL ±0.005"
SIZE A3
DWG NO AM Planetary2
REV 2
FILE NAME: AMPlanetary2.dft
SCALE:
WEIGHT:
SHEET 1 OF 1


1.295
2.000
⌀.200
(2)
1.295
3.000
7.700
⌀.210
1.500
2.500
2.000
4.492
.492
CIM Motor is not included in purchase of this product
2.500
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 0.01
ANGULAR: ± 0.1
TWO PLACE DECIMAL ±0.01
THREE PLACE DECIMAL ±0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
AB
12/13
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AndyMark
TITLE:
LJ BevelBox
SIZE
A
DWG. NO.
am-2622
REV
1
SCALE:
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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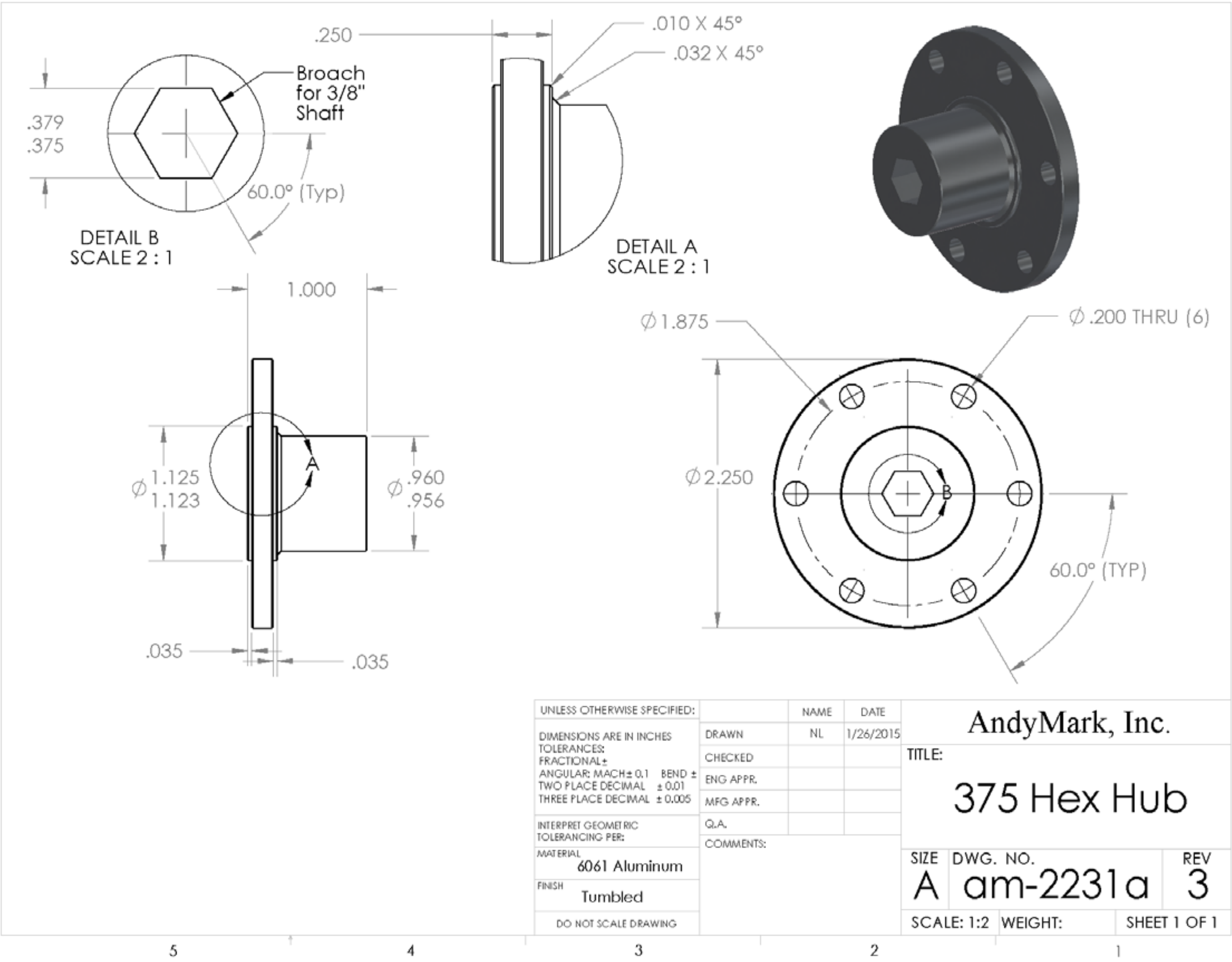

.250
.010 X 45°
.032 X 45°
Broach for 3/8" Shaft
.379
.375
60.0° (Typ)
DETAIL B
SCALE 2 : 1
DETAIL A
SCALE 2 : 1
1.000
Ø 1.875
Ø .200 THRU (6)
Ø 1.125
1.123
A
Ø .960
.956
Ø 2.250
B
60.0° (TYP)
.035
.035
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± 0.1 BEND ±
TWO PLACE DECIMAL ± 0.01
THREE PLACE DECIMAL ± 0.005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Aluminum
FINISH
Tumbled
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
NL
1/26/2015
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
AndyMark, Inc.
TITLE:
375 Hex Hub
SIZE
A
DWG. NO.
am-2231a
REV
3
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1

Online Metals Purchase Order Form

Vender Information

Name: Online Metals

Item Description	Item Number	Qty*	Price	Total Cost
Aluminum 6061T651 Plate 0.3125" Cut to: 1.75" x 18"		1	12.92	12.92
Aluminum 6061T651 Plate 0.375" Cut to: 7.25" x 3.25"		1	8.01	8.01
Aluminum 6061T651Plate 0.25"Cut to: 4" x 15"		3	13.20	41.1
Aluminum 6061T651Plate 0.5"Cut to: 1" x 1"		6	0.45	8.7
Aluminum 6061T6Sheet PVC 1 side 0.125"Cut to: 16.25" x 5.25"		4	13.65	57.6
Aluminum 6061T6Sheet PVC 1 side0.125"Cut to: 5" x 3"		3	2.4	8.7
Aluminum 6061T651BarePlate 0.25"Cut to: 9" x 8"		1	15.84	15.84

SUB TOTAL: 152.87

McMaster-Carr Purchase Order Form

Vender Information

Name: McMaster

Item Description	Item Number	Qty*	Price	Total Cost
Push/Pull Action Toggle Clamp, Hole Mounted, 200 lb Maximum Holding Capacity, 3-1/8" Height	5093A56	2	16.51	33.02
Replacement Holding Screw for Toggle Clamp, Nonmarring Flat-Tipped, 1/4"-20x 1-5/8" Screw Size, Steel	5147A63	2	3.34	6.68
Permanently Lubricated Ball Bearing	2342K187	1	20.66	20.66

SUB TOTAL: 60.36

AndyMark Purchase Order Form

Vender Information

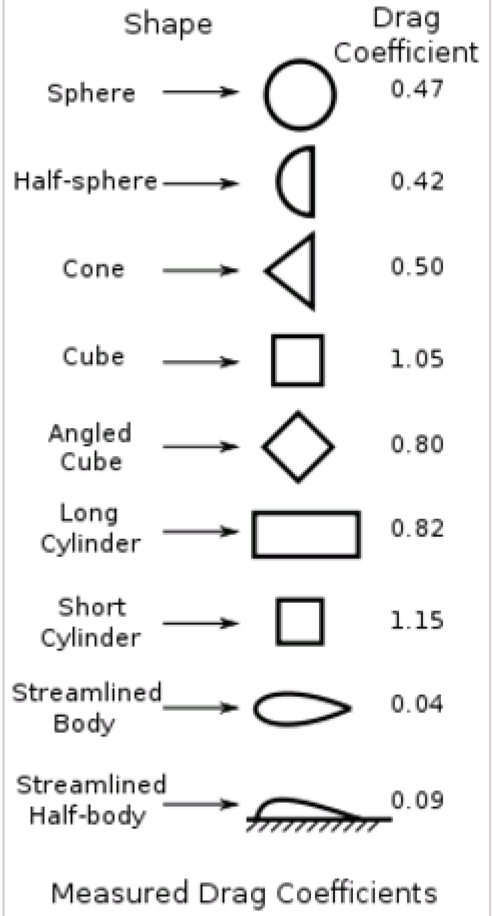
Name: AndyMark, Inc

Item Description	Item Number	Qty*	Price	Total Cost
AM Planetary Single Stage	Am-2491	1	45.00	45.00
AM Planetary Gearbox, 3 Stage, 49.4:1 Ratio	am-2547	1	180.00	180.00
Sun Gear, 15 Tooth, 32 dp	am-0040	1	9.00	9.00
LJ Bevel Box with 3/8 Hex Output Shaft	am-2622	1	129.00	129.00
Encoder Mount Pad	am-0208	1	4.00	4.00
E4T OEM Miniature Optical Encoder Kit	am-3132	1	42.00	42.00
FR6ZZL-hex Bearing	am-0692	1	5.00	5.00
1/4-20 x 5/8" SHCS [Qty-10]	am-1203	1	2.00	2.00
AndyMark 9015 Motor	am-0912	1	14.00	14.00

SUB TOTAL: 430.00

Appendix

LOCKHEED MARTIN



Drag coefficients in fluids with Reynolds number approximately 10^4

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

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

$$C_{d2} := 0.82$$

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

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

NATO Style Figure 11 Target

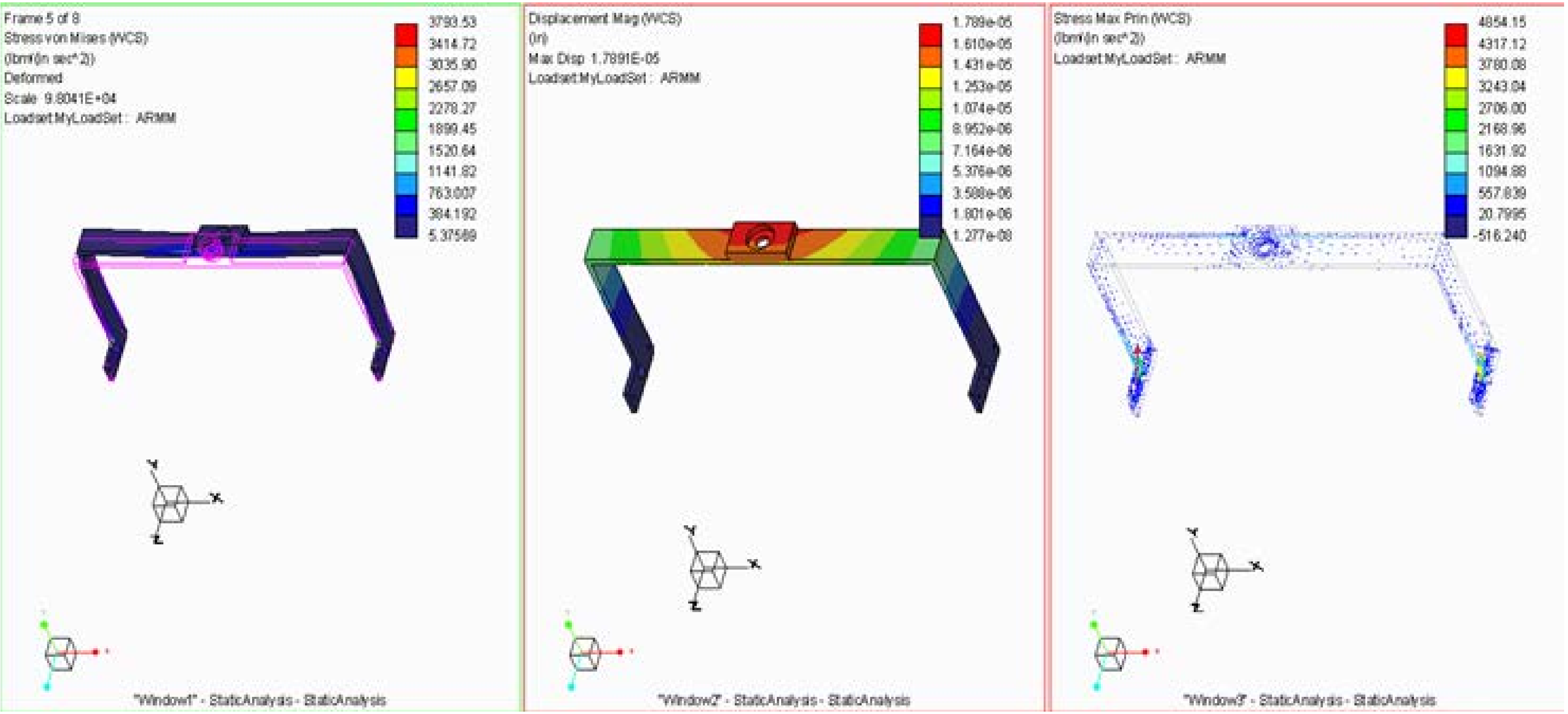
It can be assumed the largest force felt is 50lbf*ft

$$50lbf \cdot ft = 67.791 \cdot N \cdot m$$

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

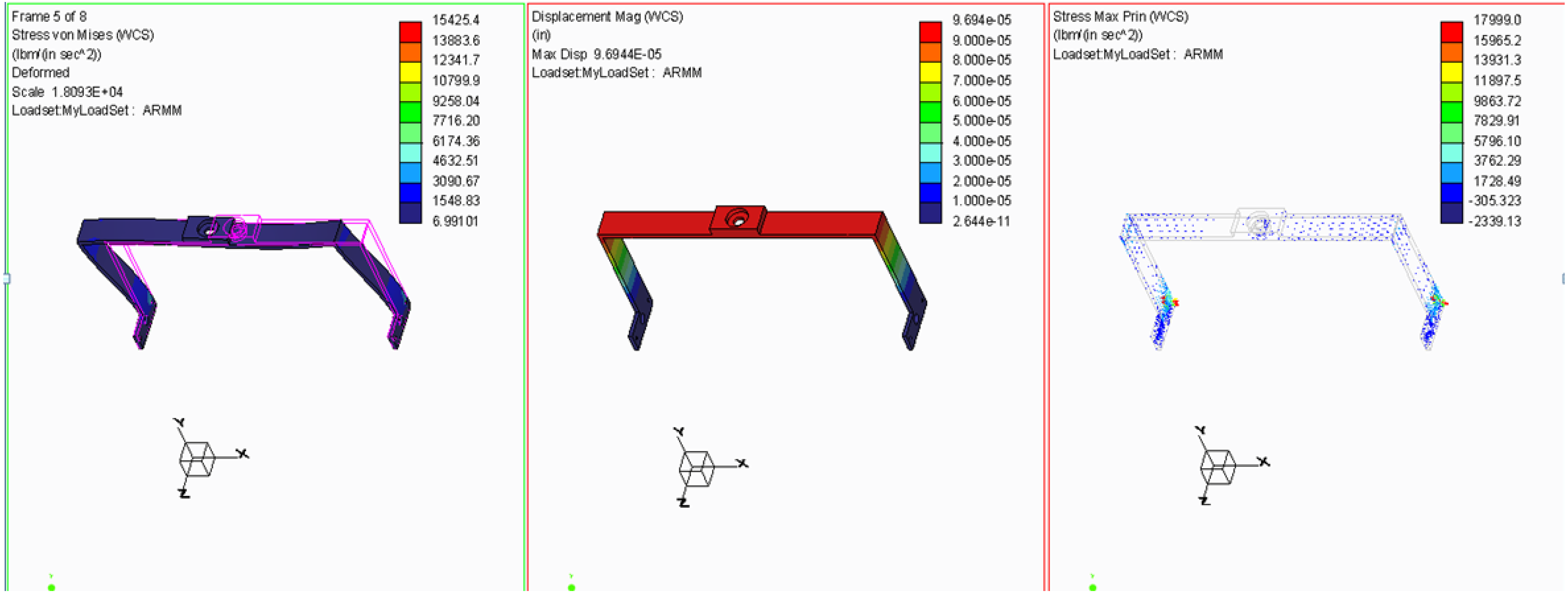
$$\frac{(50lbf \cdot ft)}{\pi \cdot 0.5in} = 381.972 \cdot lbf$$

Appendix

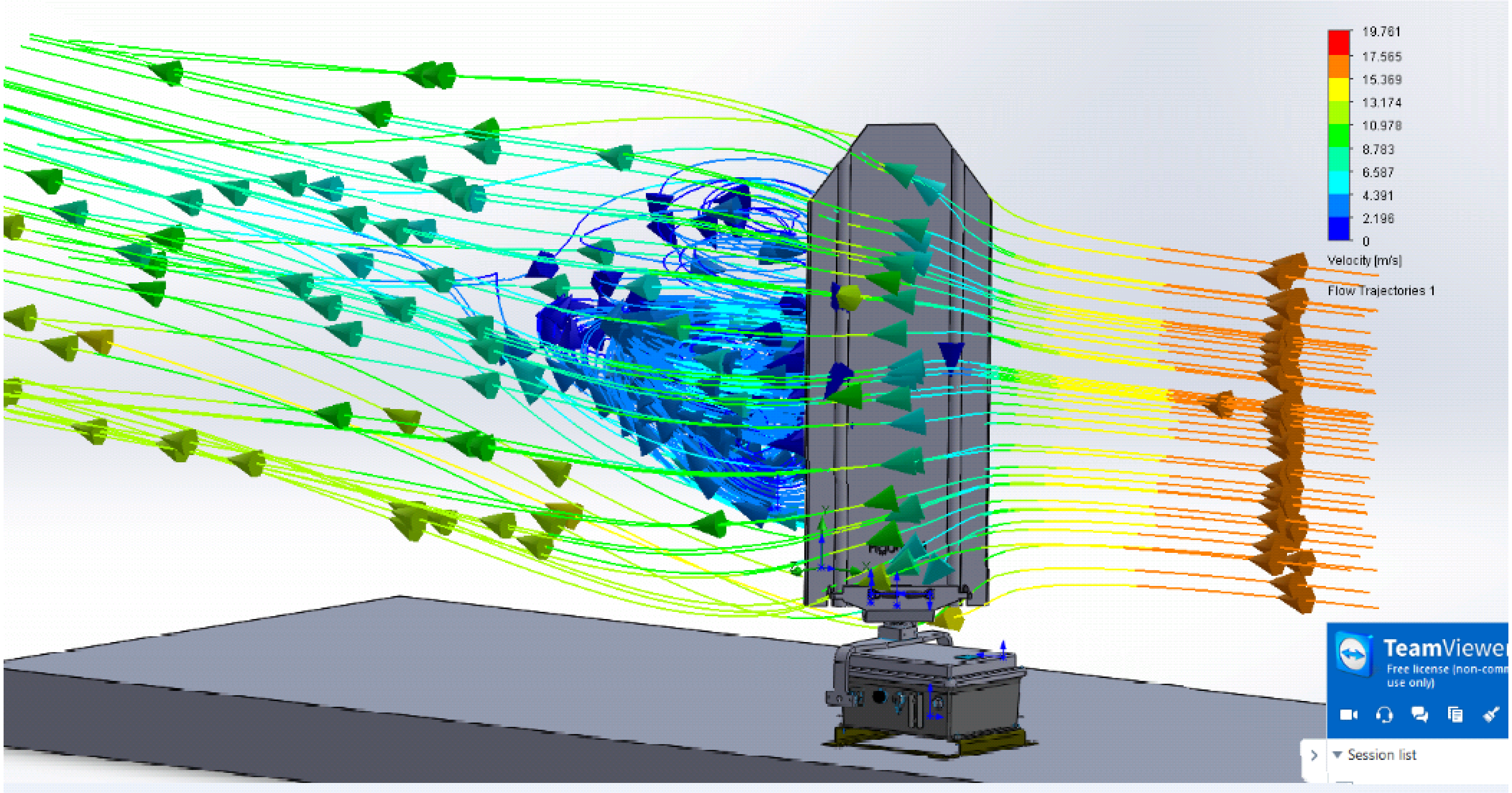


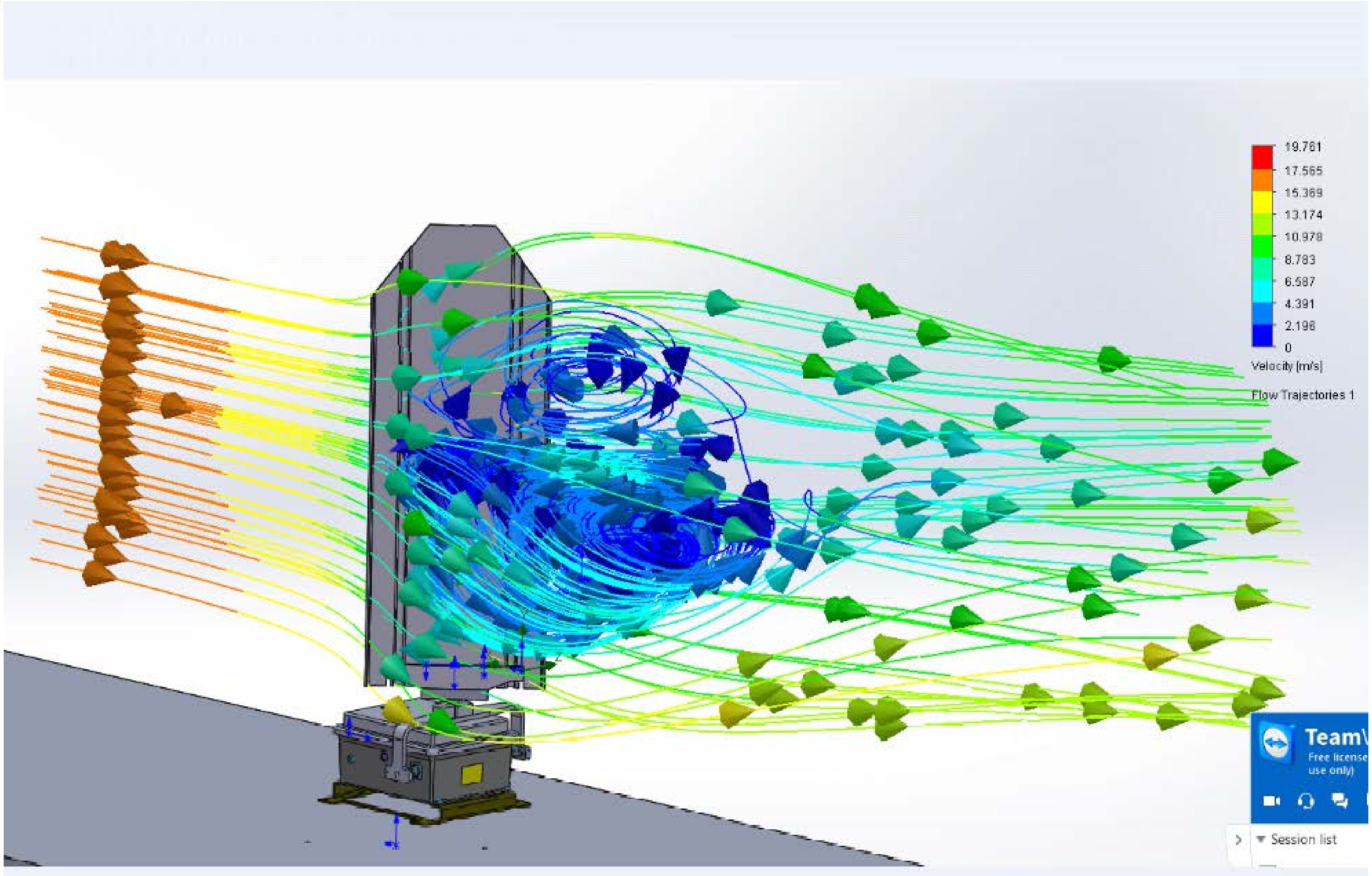
- Applied force only in the “Z” Direction

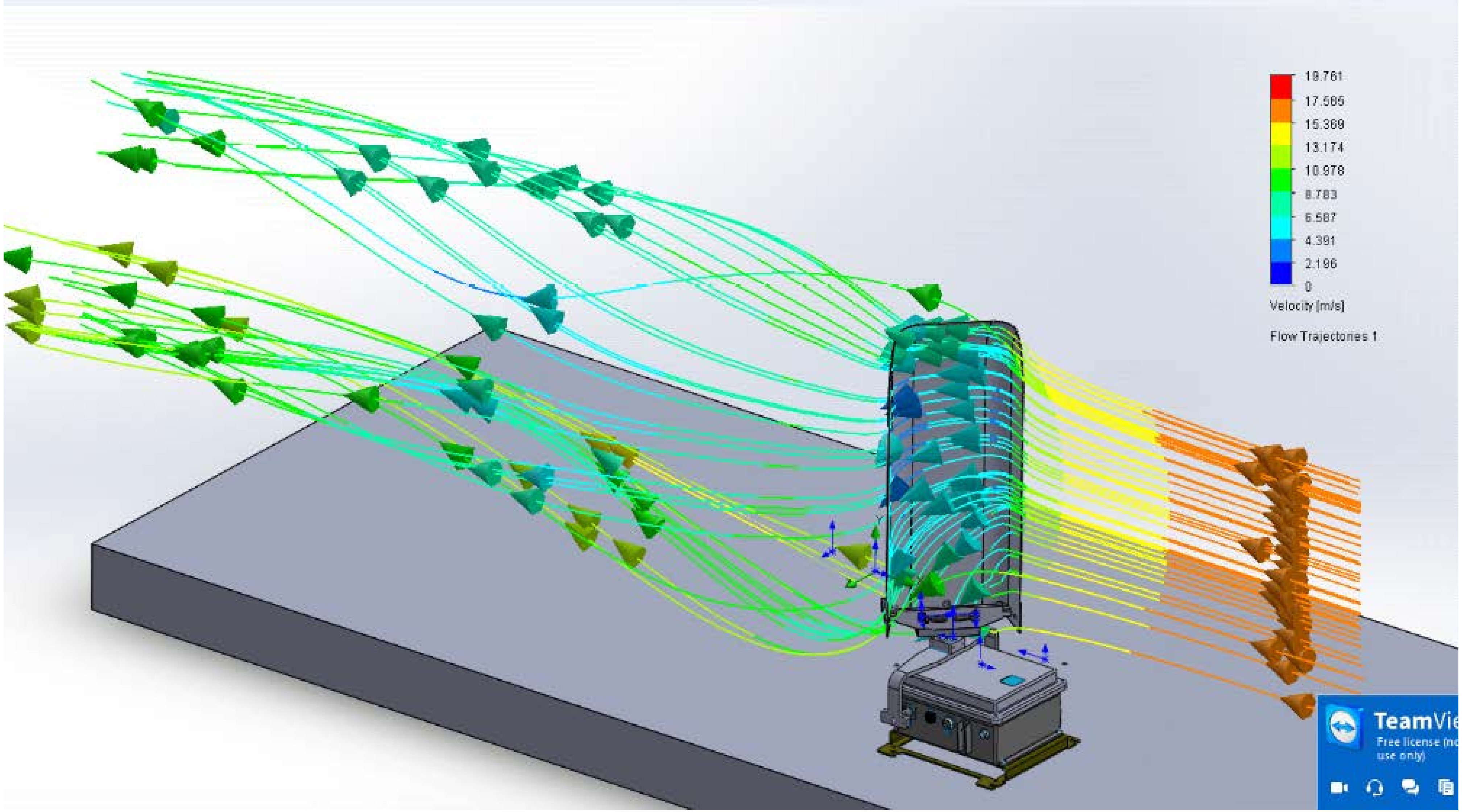
Appendix

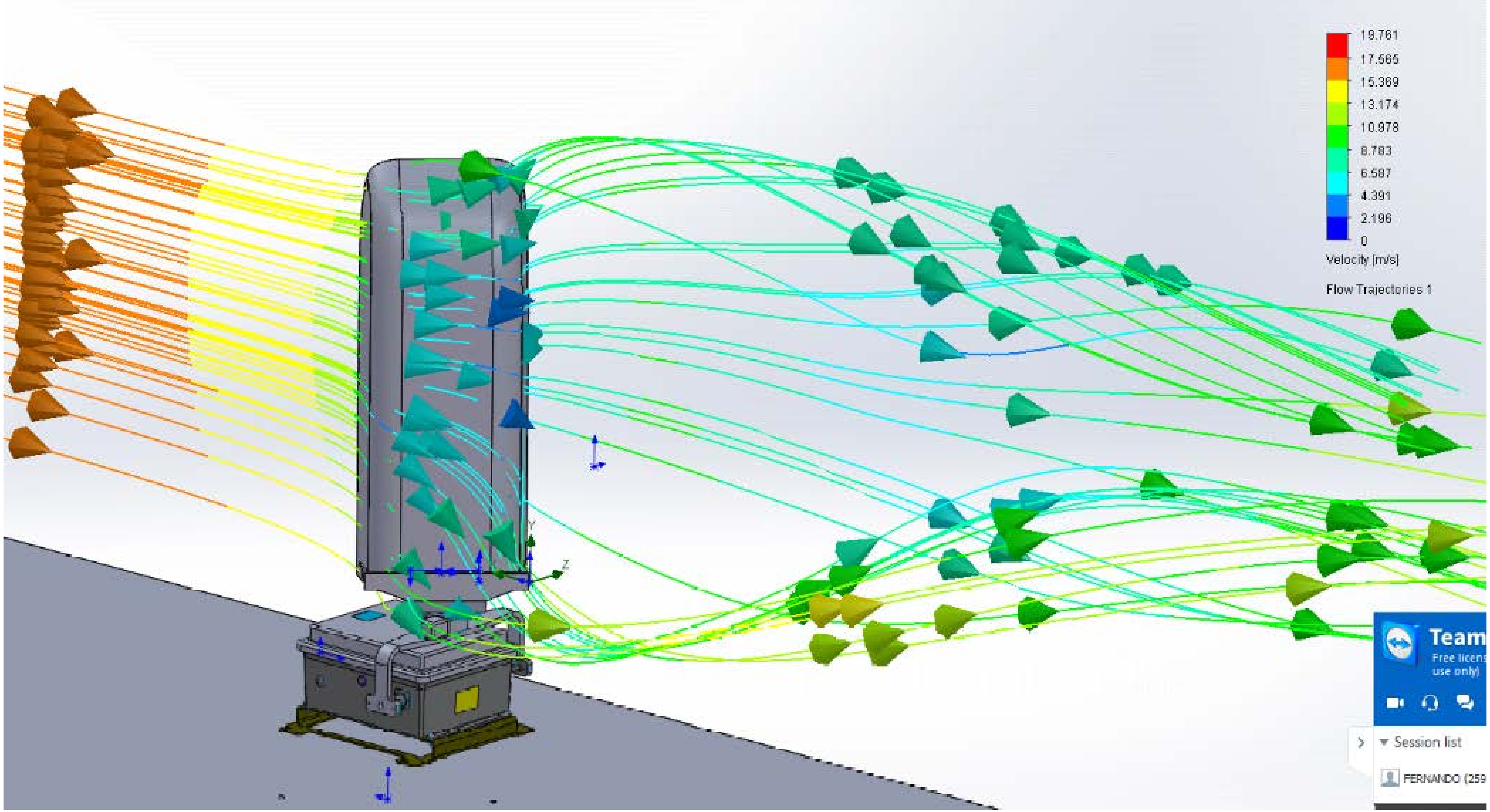


- Applied force only in the “x” Direction (not designed for)


19.761
17.565
15.369
13.174
10.978
8.783
6.587
4.391
2.196
0
Velocity [m/s]
Flow Trajectories 1
TeamViewer
Session list


19.761
17.565
15.369
13.174
10.978
8.783
6.587
4.391
2.196
0
Velocity [m/s]
Flow Trajectories 1
Session list


19.761
17.565
15.369
13.174
10.978
8.783
6.587
4.391
2.196
0
Velocity [m/s]
Flow Trajectories 1
Free license (no
use only)



19.761
17.565
15.369
13.174
10.978
8.783
6.587
4.391
2.196
0
Velocity [m/s]
Flow Trajectories 1
Session list

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

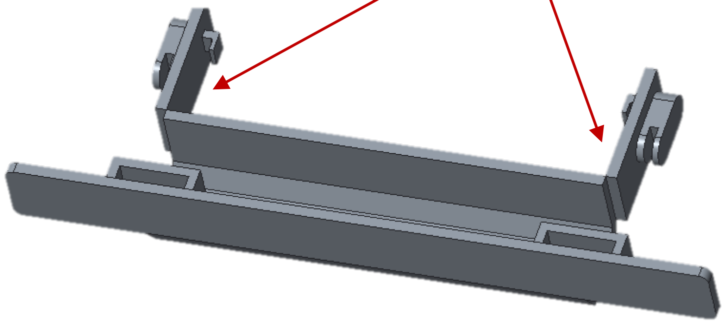
Design Specifications

- **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

FASIT
Future Army System of Integrated Targets

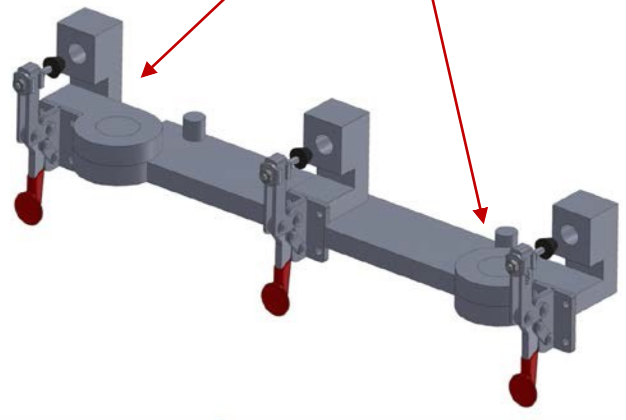
Previous Target Brackets

Hinge



Example of
Previous Bracket 1

Swivel Connection



Example of
Previous Bracket 2

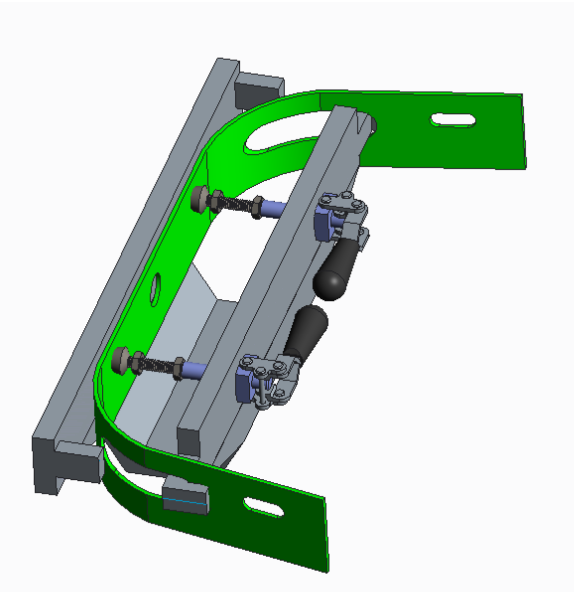
Target Bracket Progress

New Developments:

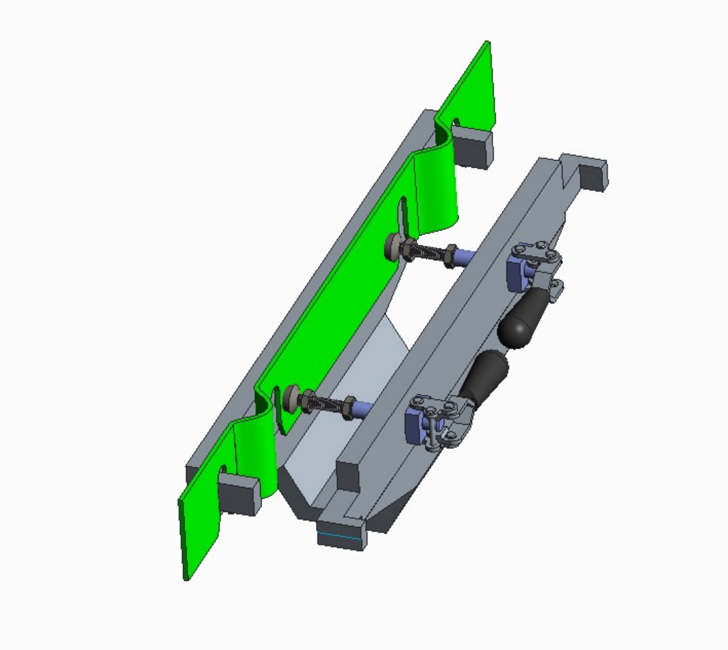
- From sponsor feedback, many of the team's previous designs were inadequate due to various uses of a hinge or other similar moving parts
- Hinges inadequate due to operational conditions, specifically the SIT's environment
- Previous designs were amended to incorporate an alternate form of latching/locking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

Amended Turning Bracket Designs

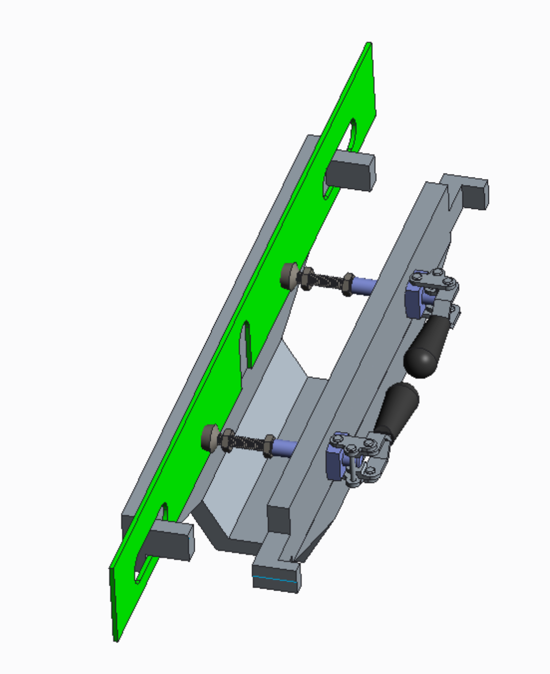
New Bracket Design 1:



"Ivan" Target Fit



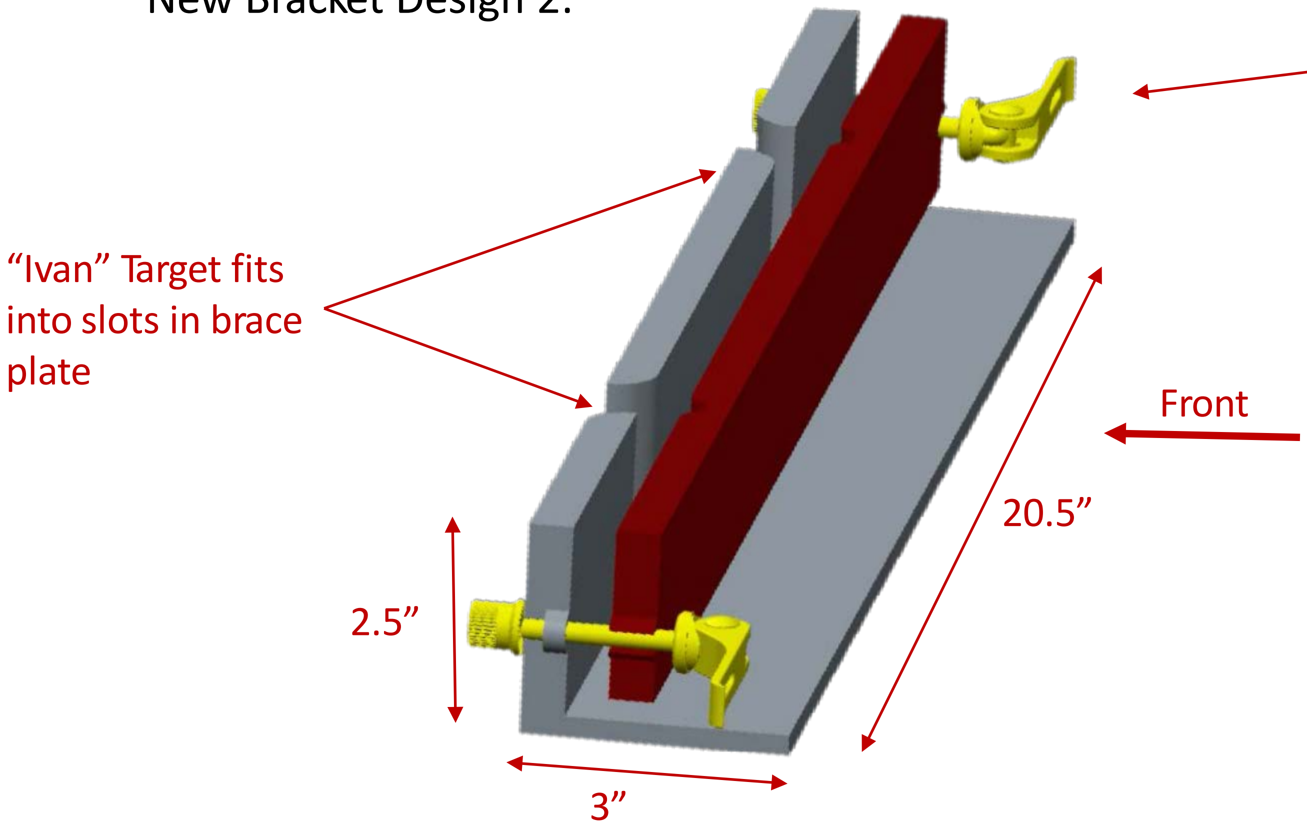
"Figure 11" and "Figure 12" Target Fit

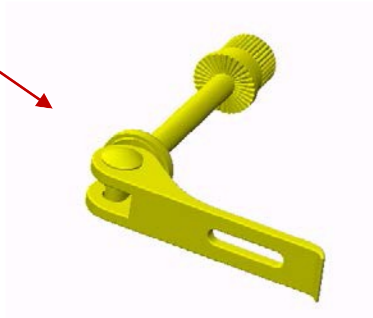


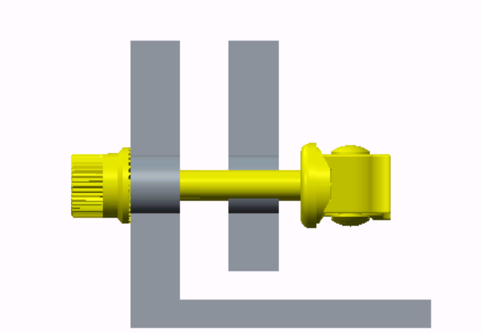
"Waffle Board" Target Fit

Amended Turning Bracket Designs

New Bracket Design 2:



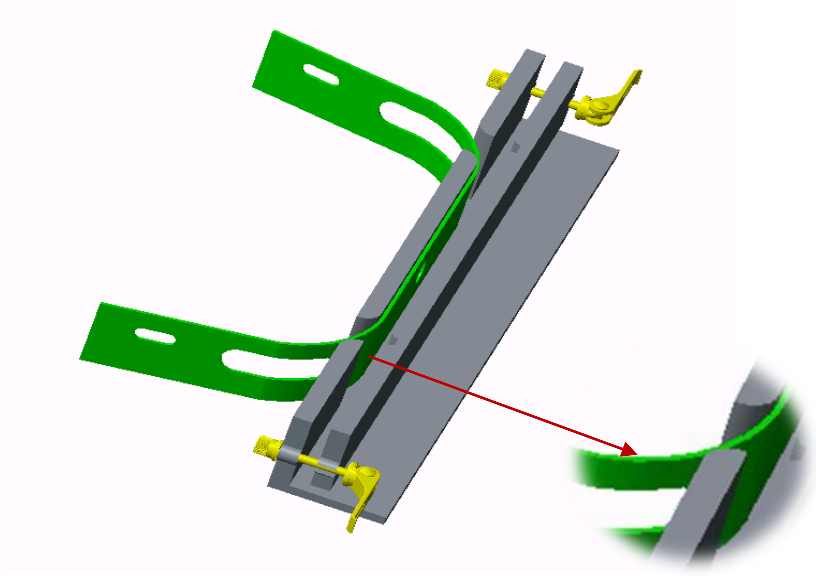




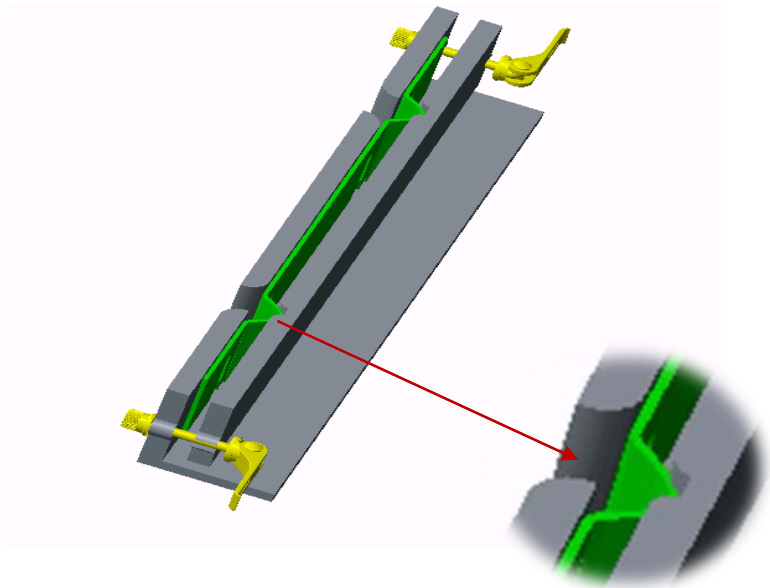
Side Profile of Bracket Design 2

Amended Turning Bracket Designs

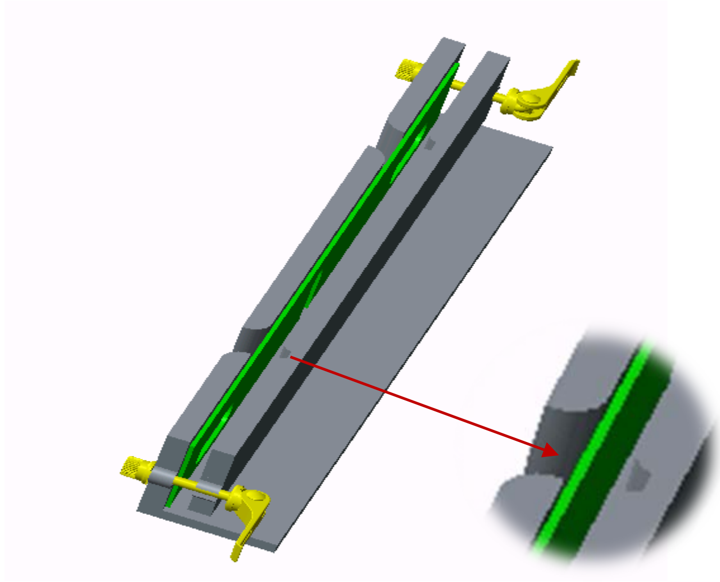
New Bracket Design 2:



"Ivan" Target Fit



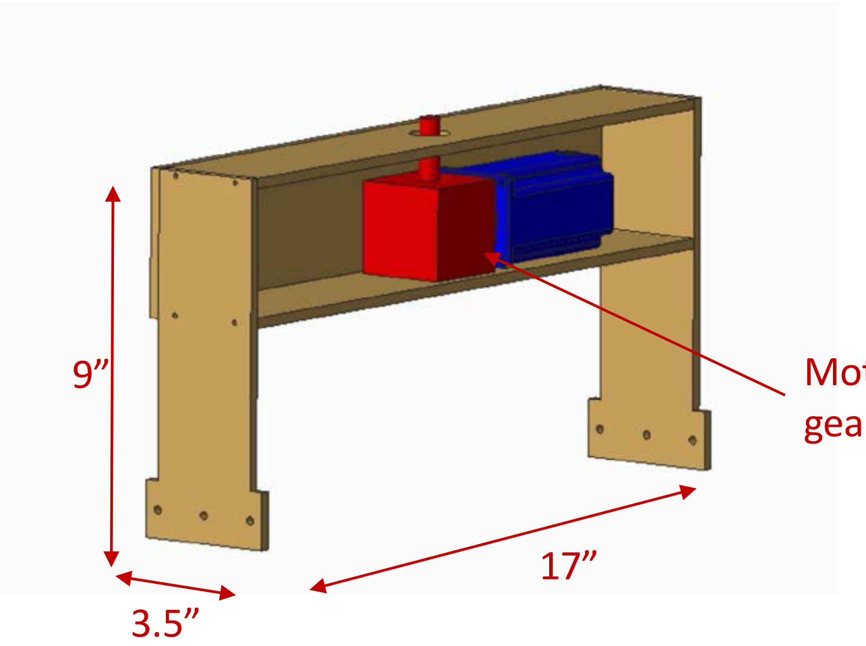
"Figure 11" and "Figure 12" Target Fit

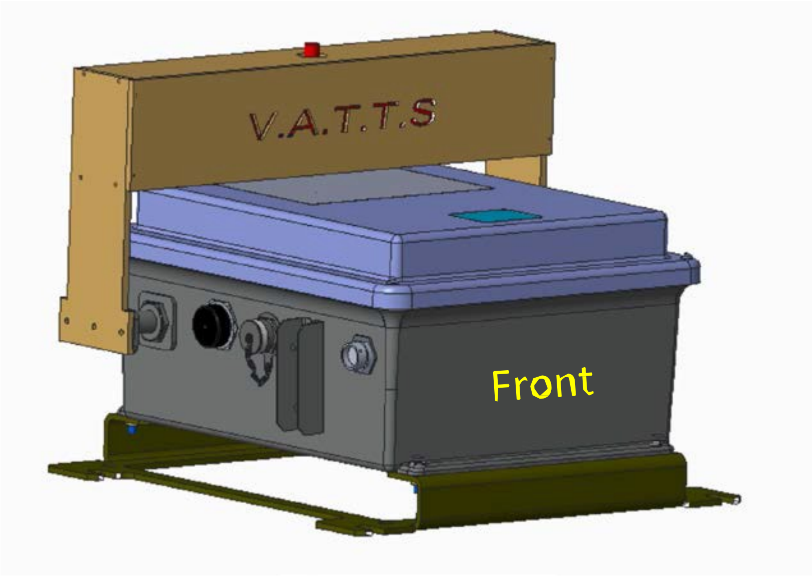


"Waffle Board" Target Fit

Lifting and Turning Arm Designs

Arm Design 1:

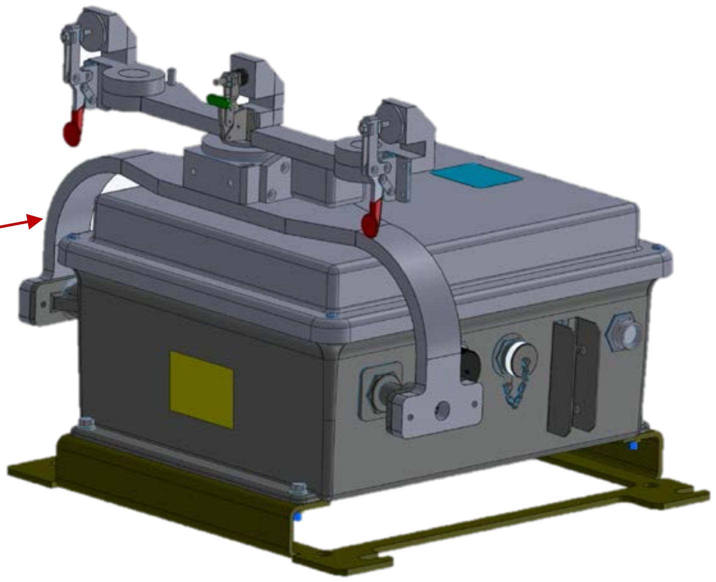


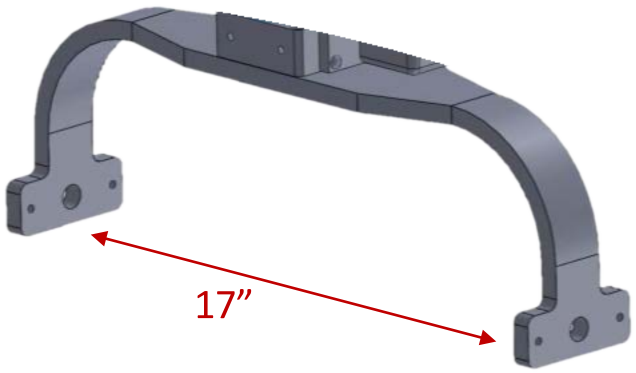


Arm Design Attached to Provided Lifter

Lifting and Turning Arm Designs

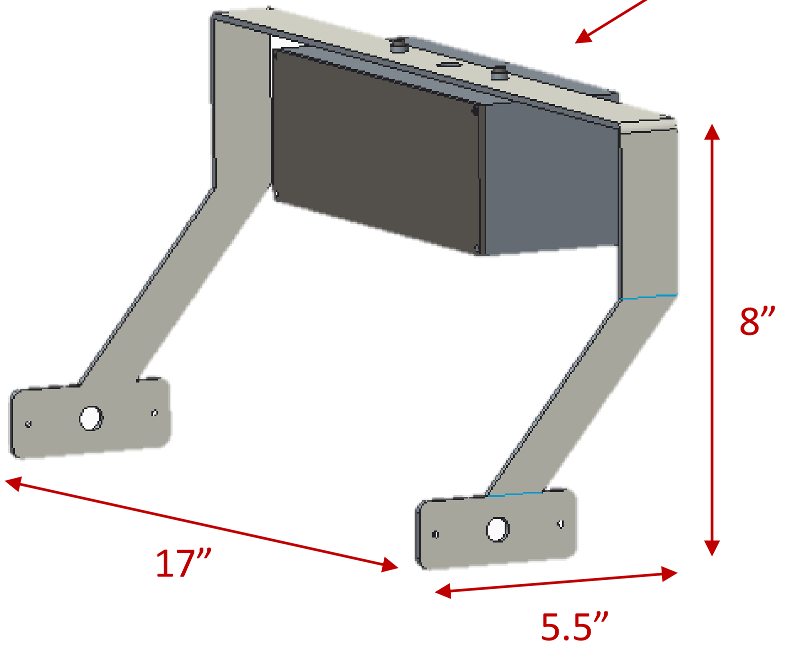
Arm Design 2:

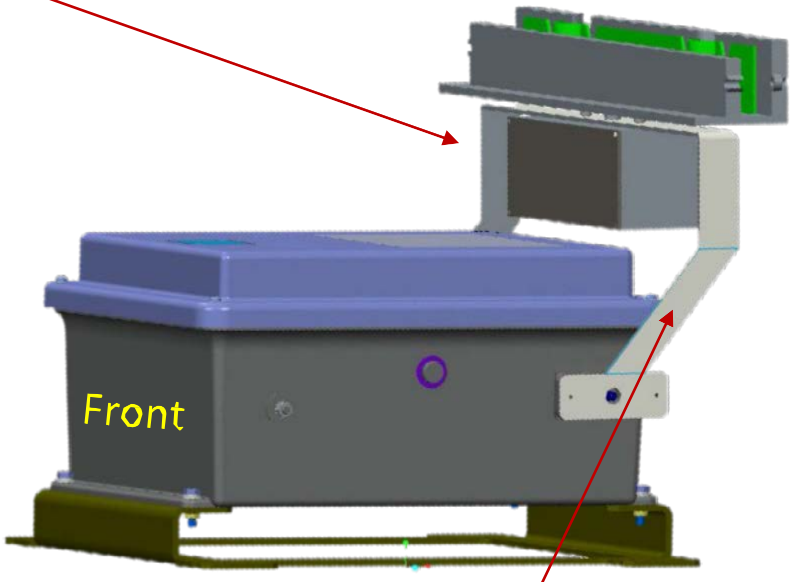




Lifting and Turning Arm Designs

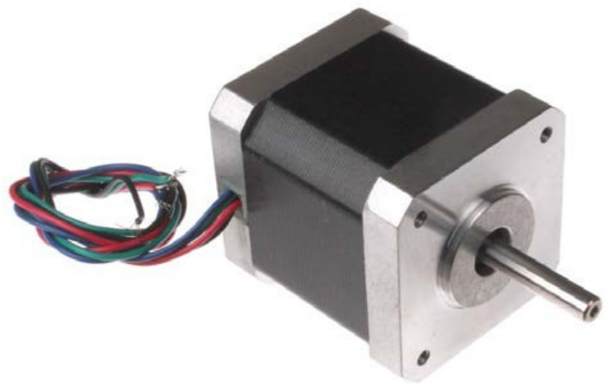
Arm Design 3:





Target Turning Motor Selection

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

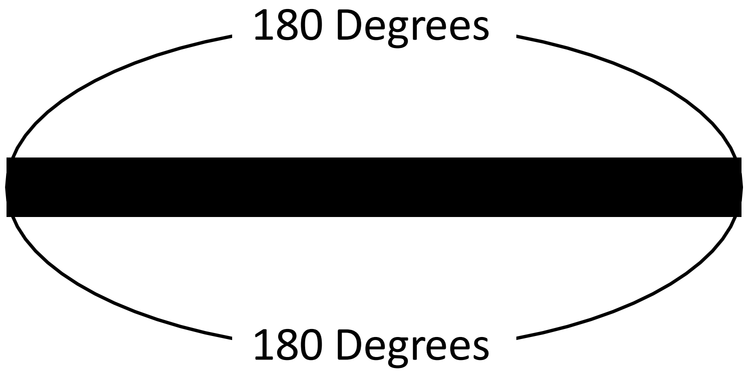


- Ideal for quick and accurate positioning over short distances

- 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

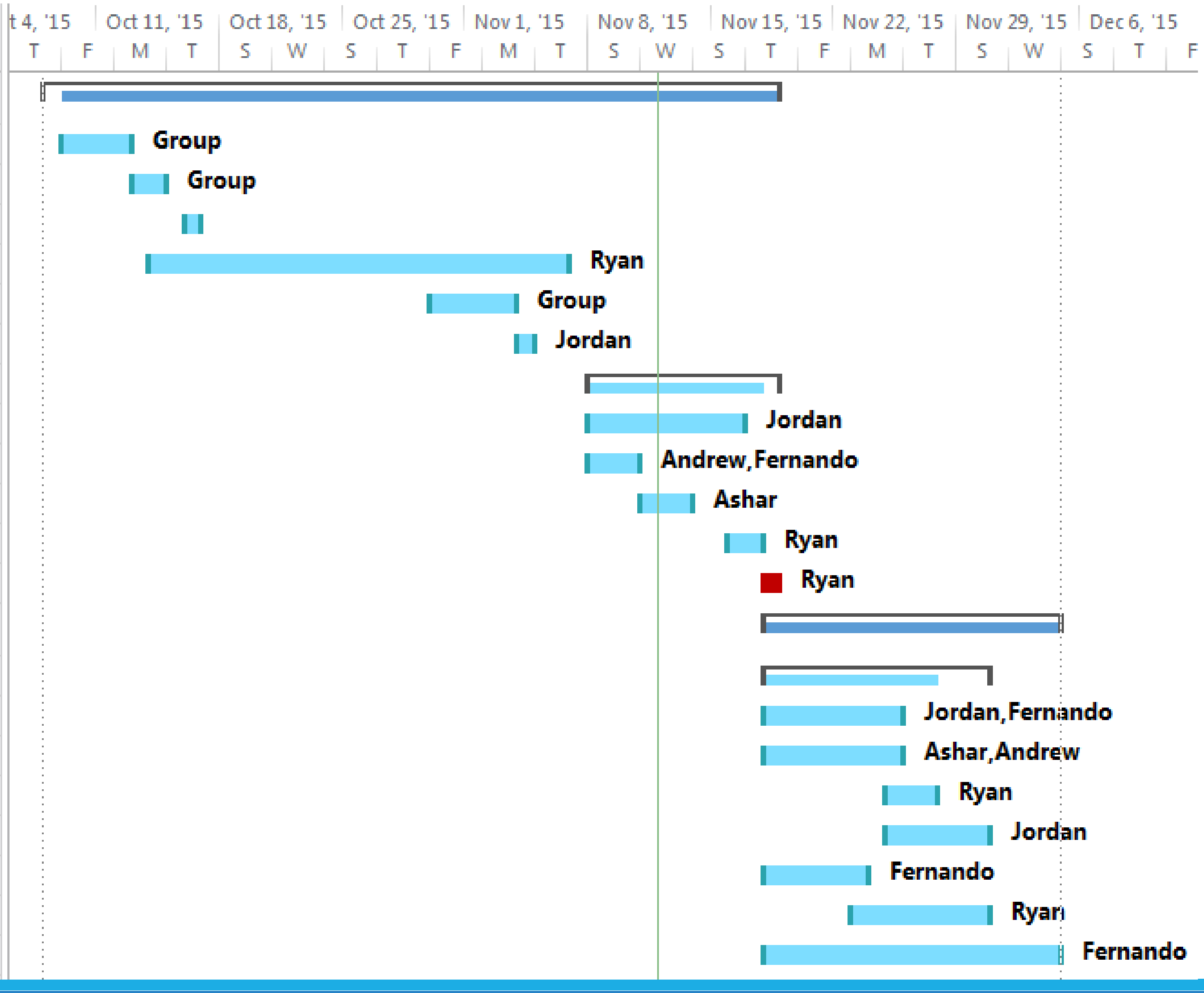


Bracket: 180 Degree Positioning

Gantt Chart

LOCKHEED MARTIN

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

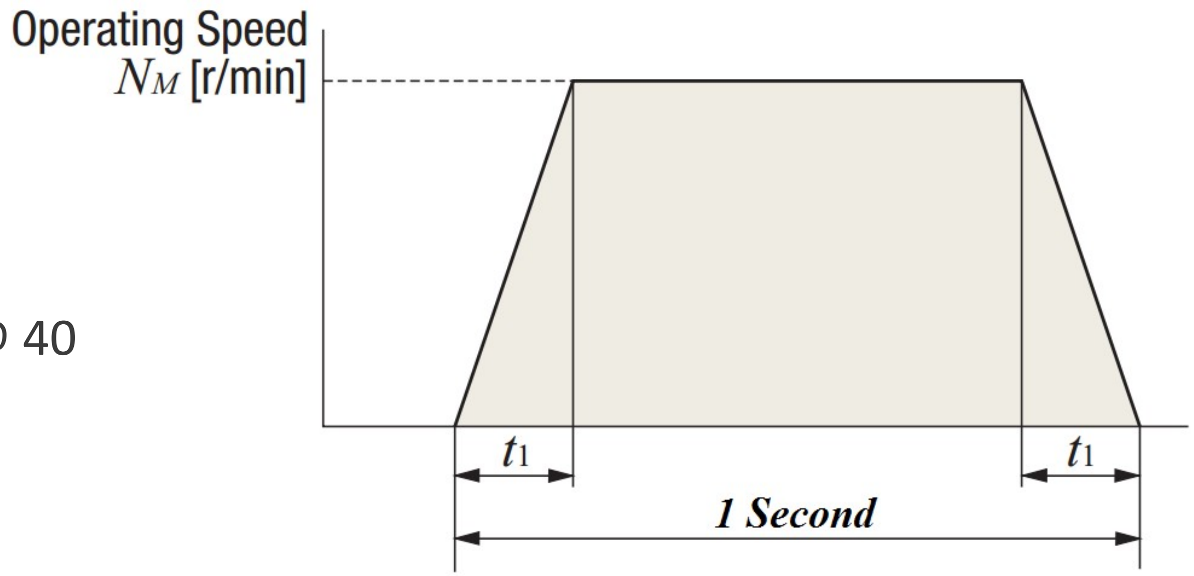
References

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

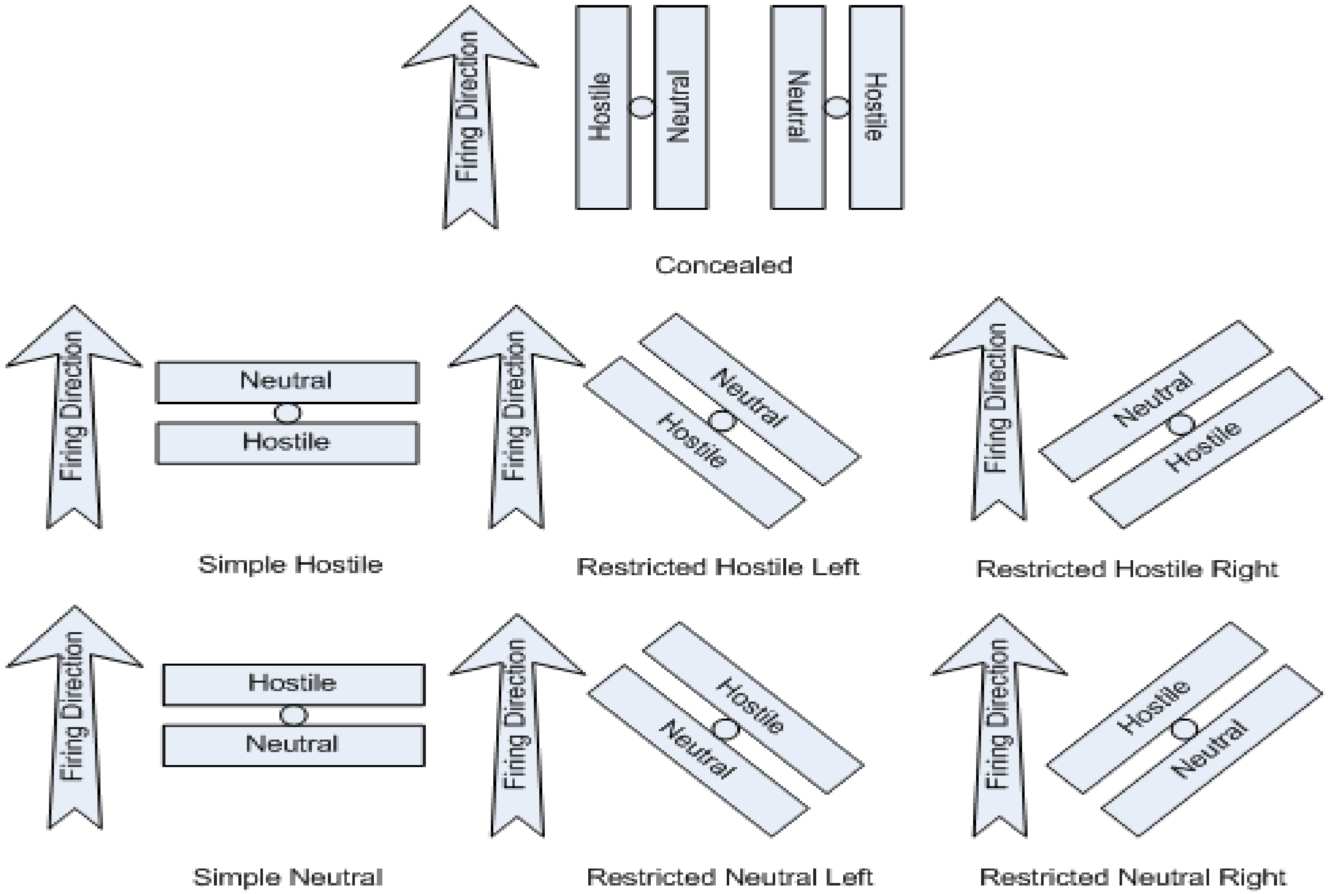
References

- 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
Neutral
Hostile
Simple Hostile
Neutral
Hostile
Restricted Hostile Left
Neutral
Hostile
Restricted Hostile Right
Hostile
Neutral
Simple Neutral
Hostile
Neutral
Restricted Neutral Left
Hostile
Neutral
Restricted Neutral Right

References

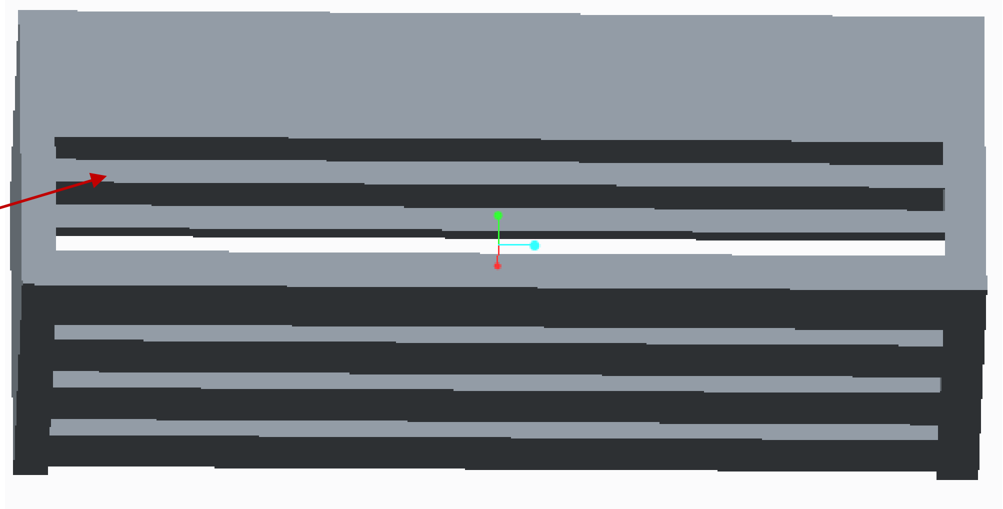
FASIT 2.0 PD IDC Command	Target Action
0	Concealed
1	Simple Hostile
2	Restricted Hostile Left
3	Restricted Hostile Right
4	Simple Neutral
5	Restricted Neutral Left
6	Restricted Neutral Right

References

References

Arm Design 3:

Ventilation of Components Enclosure



Forces generated with tailwind

DRAG COEFF SHOULD BE 1.5

Drag Force:

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

$$v := 35mph$$

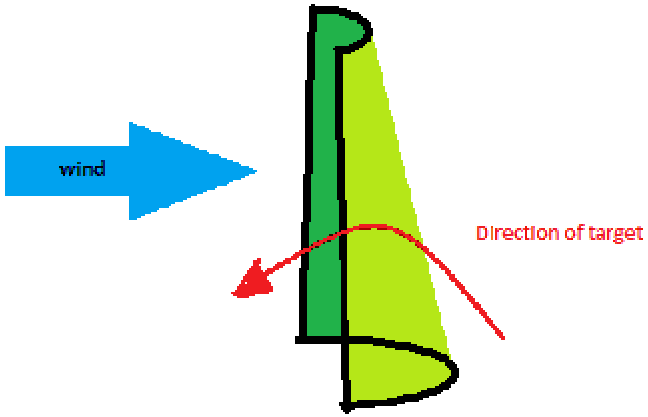
$$A := \pi \cdot 6in \cdot 3ft = 0.438\,m^2$$

$C_d := 2$ 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

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

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

$m_{max\_brace} := \rho_{aluminum} \cdot V_{max} = 15.876 \cdot lb$ 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

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

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

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

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

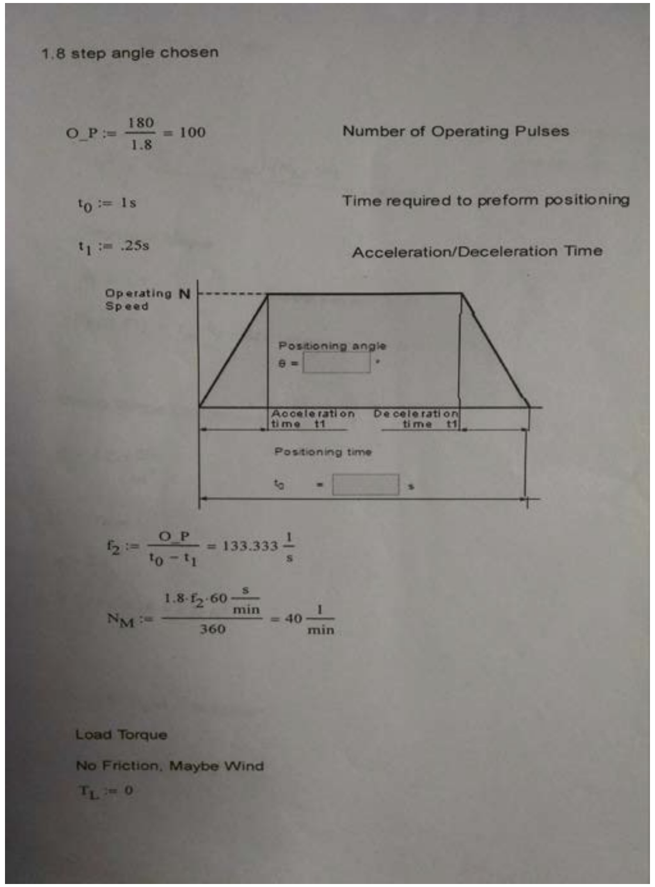
$m_{ivan} := 1.5lb$

$r_{ivan} := 6in$

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

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

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

$I_0 := 0$

$i := 1$

I.0 is motor inertia

i is gear ratio

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

Required Torque

$S_f := 1.5$ Safety Factor

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