Robotic Walking Training Device

Internal Project

THE TEAM - TYL4:

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THE SPONSORS:

Dr. Yong Tai Wang, Dr. X. Neil Dong

THE ADVISOR:

Dr. Chung Hyun Goh

EXPERT GUESTS:

Dr. Indic, Dr. Brown, Dr. Fumo, and Dr. Ibrahim

November 21, 2019

Executive Summary

- Partial paralysis caused by SCI or Stroke are two of the most prevalent forms of physical disability in the world
- Presentation seeks to detail material selection process
- Garner approval for component selections and to begin manufacturing and construction process

Goal of Design Review

GAIN APPROVAL FROM FACULTY, SPONSORS, AND ADVISOR TO ORDER PARTS FOR ASSEMBLY

CONFIRM DESIGN FEASIBILITY

ENSURE SPONSOR SPECIFICATIONS ARE MET

AGENDA

Background

- Two leading disabilities around the world are Spinal Cord Injuries and partial paralysis caused by Stroke.
- The predominant form of rehabilitation is the use of a harness suspended over a treadmill or floor.
- This form is physically taxing for therapists; to ease the therapist's labor, Robotic Assisted Gait Rehabilitation systems have been produced.
- The current market lacks a device that accurately recreates the human gait path motion of the knee and ankle, nor do these devices provide additional neurological stimulation with F.E.S. systems.

PURPOSE

To build and optimize a set of robotic legs which recreate the motion of a natural gait cycle in conjunction with proper timing of a functional electro-stimulator (F.E.S.), used to contract muscle groups through external stimulation, with the goal of rehabilitation for individuals with minor spinal cord injuries or who are victims of a stroke.

Specifications

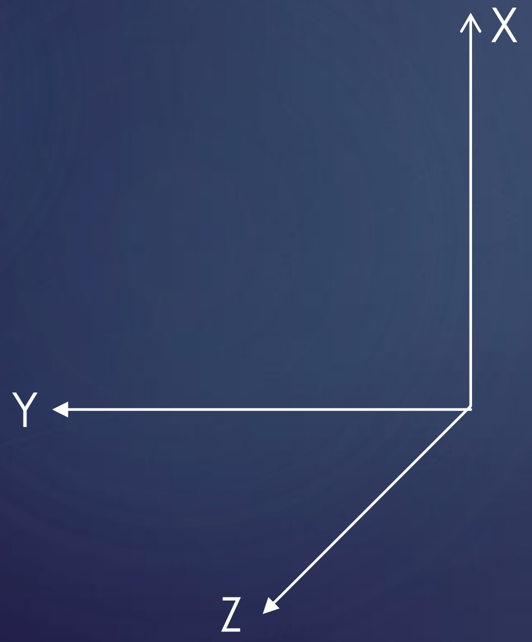
Description	Value/Limit or YES/NO	Units	Acceptance Tests or Method
Reproduce natural gait motion path of knee and ankle	Yes	N/A	Compare to Motion Capture
Adjustable for varying leg lengths	5'4" – 6'4"	ft./in.	SolidWorks Design and FEA
Electro-stimulate thigh muscle in time with walking motion	Yes	mA	Calculate motion path with linkage position and determine appropriate timing
Able to hold various body types	120 – 300	lb.	FEA testing

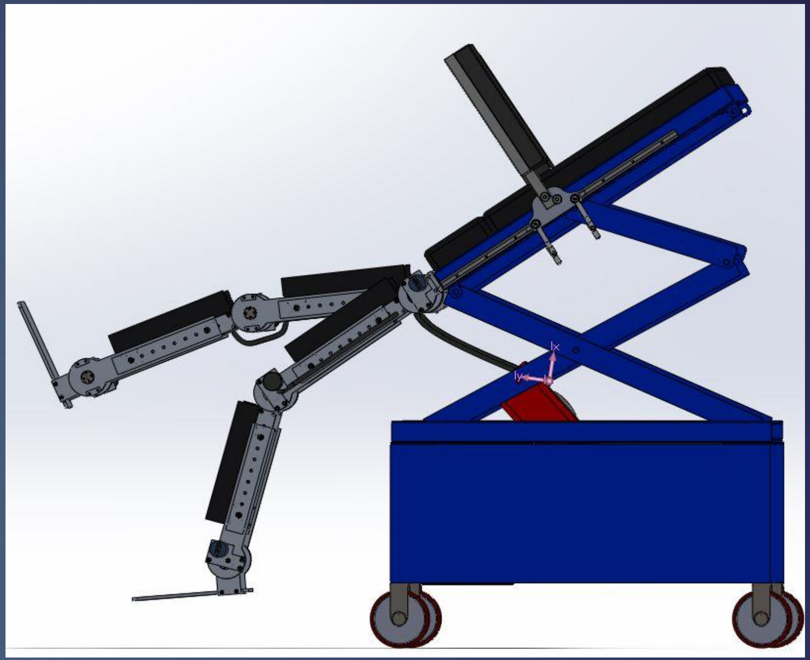
System Integration

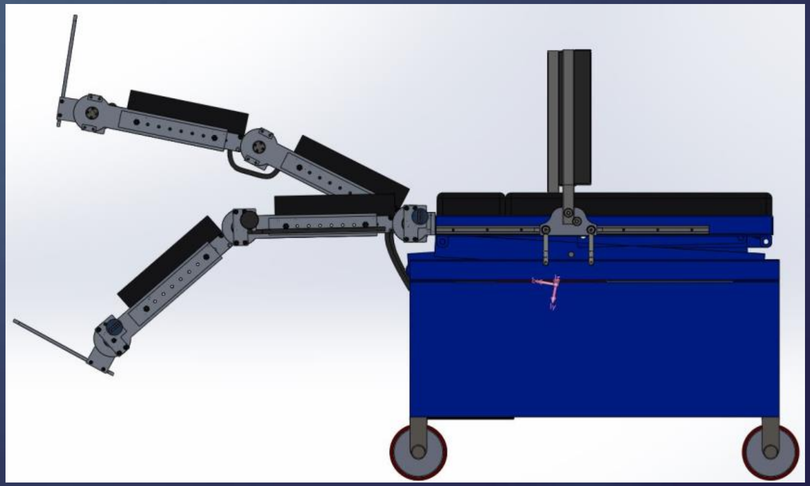
- The F.E.S. will be used in tandem with Robotic Legs
- Legs have been mounted to an adjustable frame
- The movement of the Legs will accurately reproduce a natural walking gait using Motors affixed at each joint
- F.E.S. will initiate muscle contractions on the appropriate muscle groups in time with the corresponding leg movement
- Foam padding added for comfort

Global Center of Mass

- Fluctuates minimally in X and Z direction
- Fluctuates ~ +6" in Y direction when fully raised relative to lowered position
- Typical load applied in Y direction and above CoM





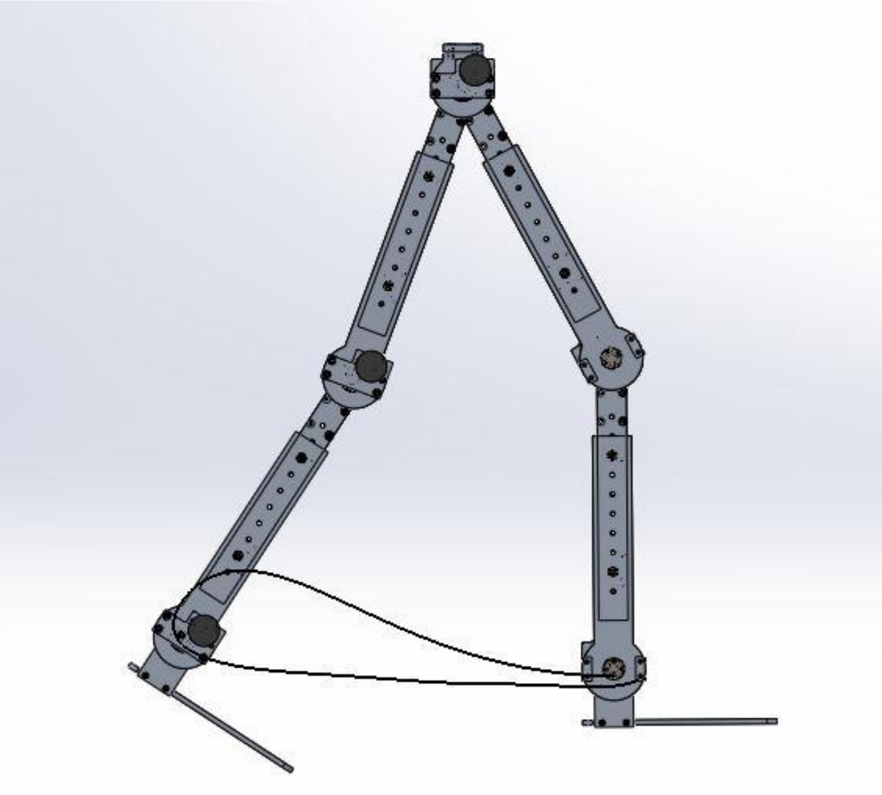


Safety Considerations

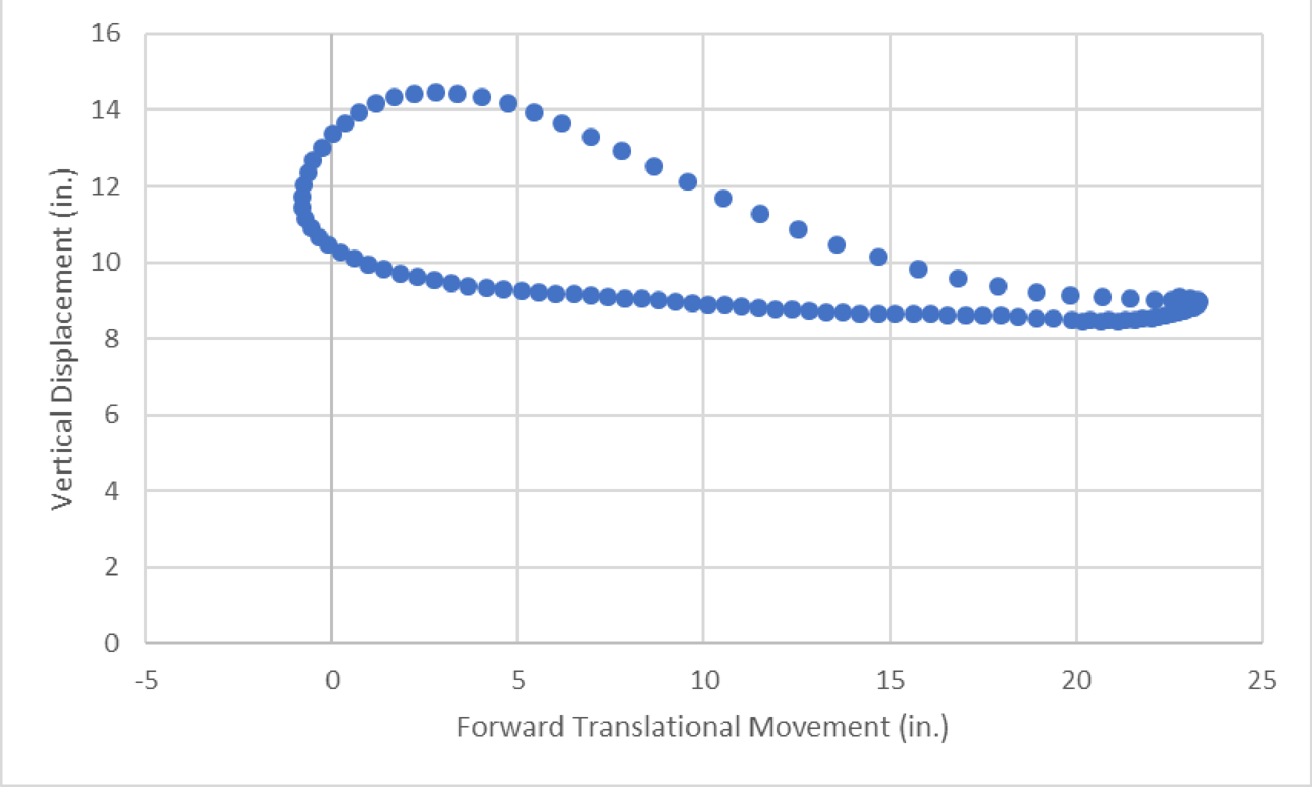
- Limit Switches
- Physical Limitations
- Kill-Switch
- Abdomen Strap
- Leg Straps

Feasibility Analysis

- Linkage Material
  - Low weight, durability, availability
  - 6061 Aluminum meets requirements
- Motor Torque and Speed
  - Selected motor for excess torque
  - Speed not as important as accuracy of movement
- Linear Actuator
  - Needed lift capacity of ~370lb
  - 2" stroke length
  - Small footprint
- Pivot Pin
  - Hip location
  - Durable Material



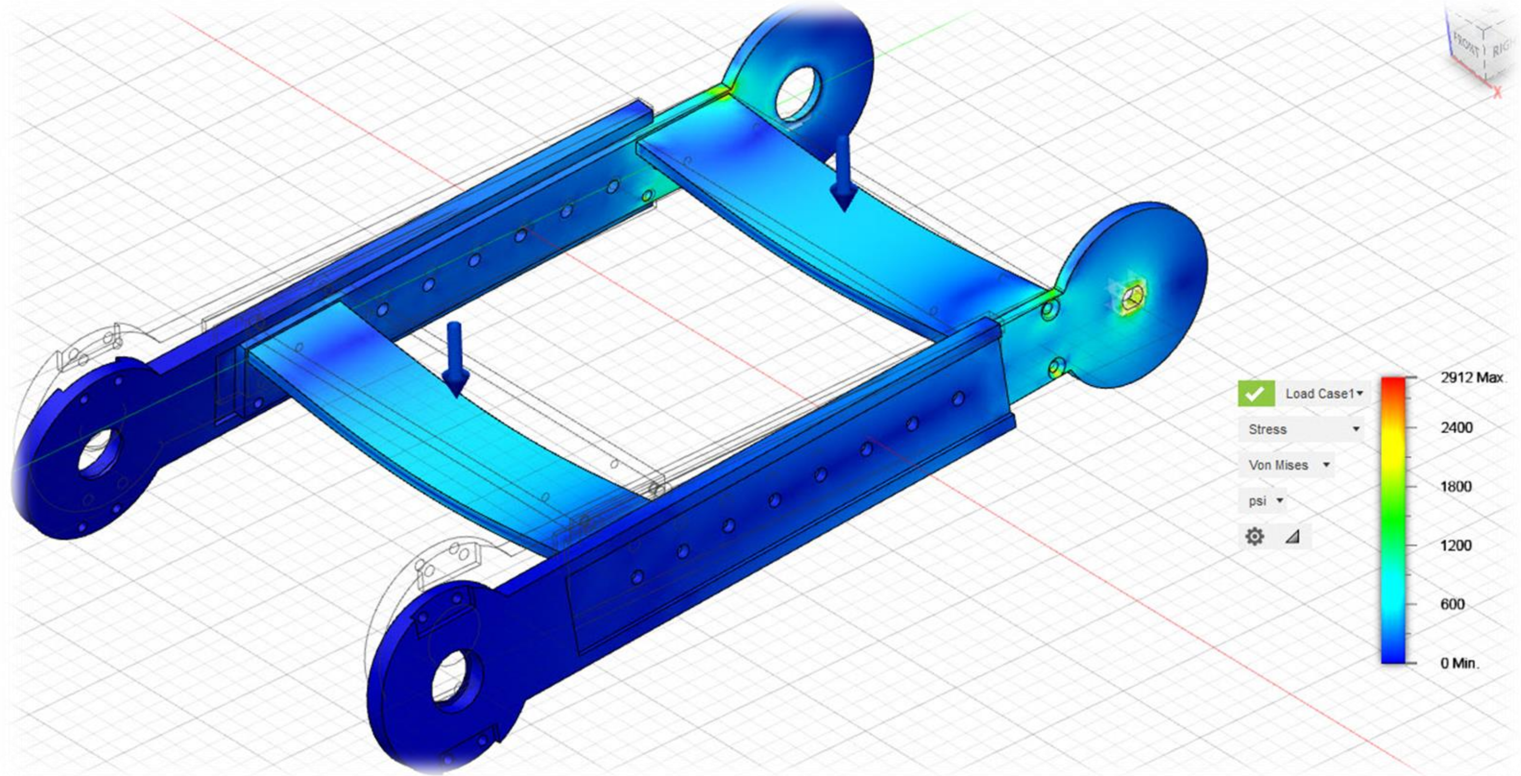
Motion Analysis of Gait Path



Vicon Motion Capture of Natural Gait

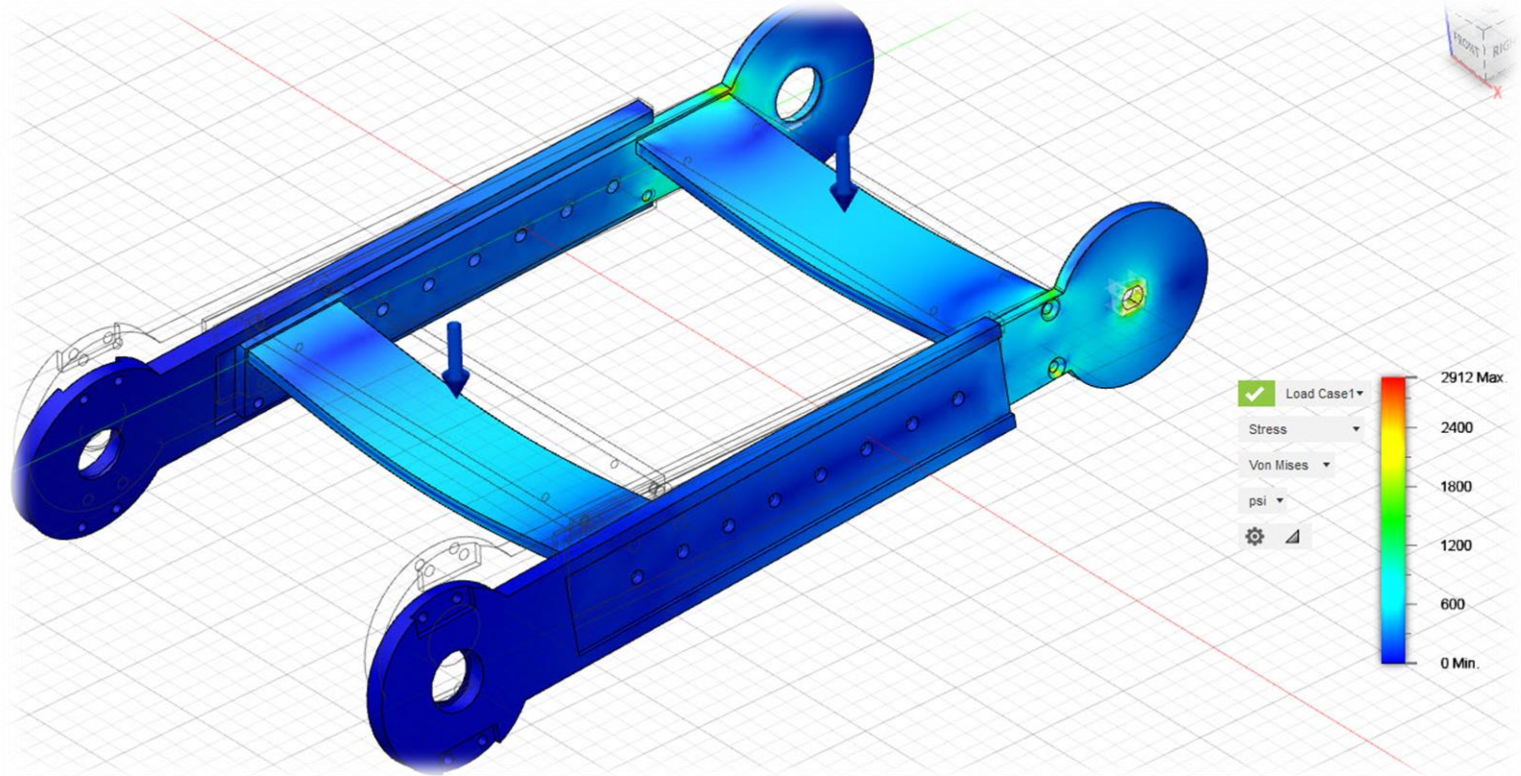
Motion Analysis – Gait Path

Simulation/Motion Analysis

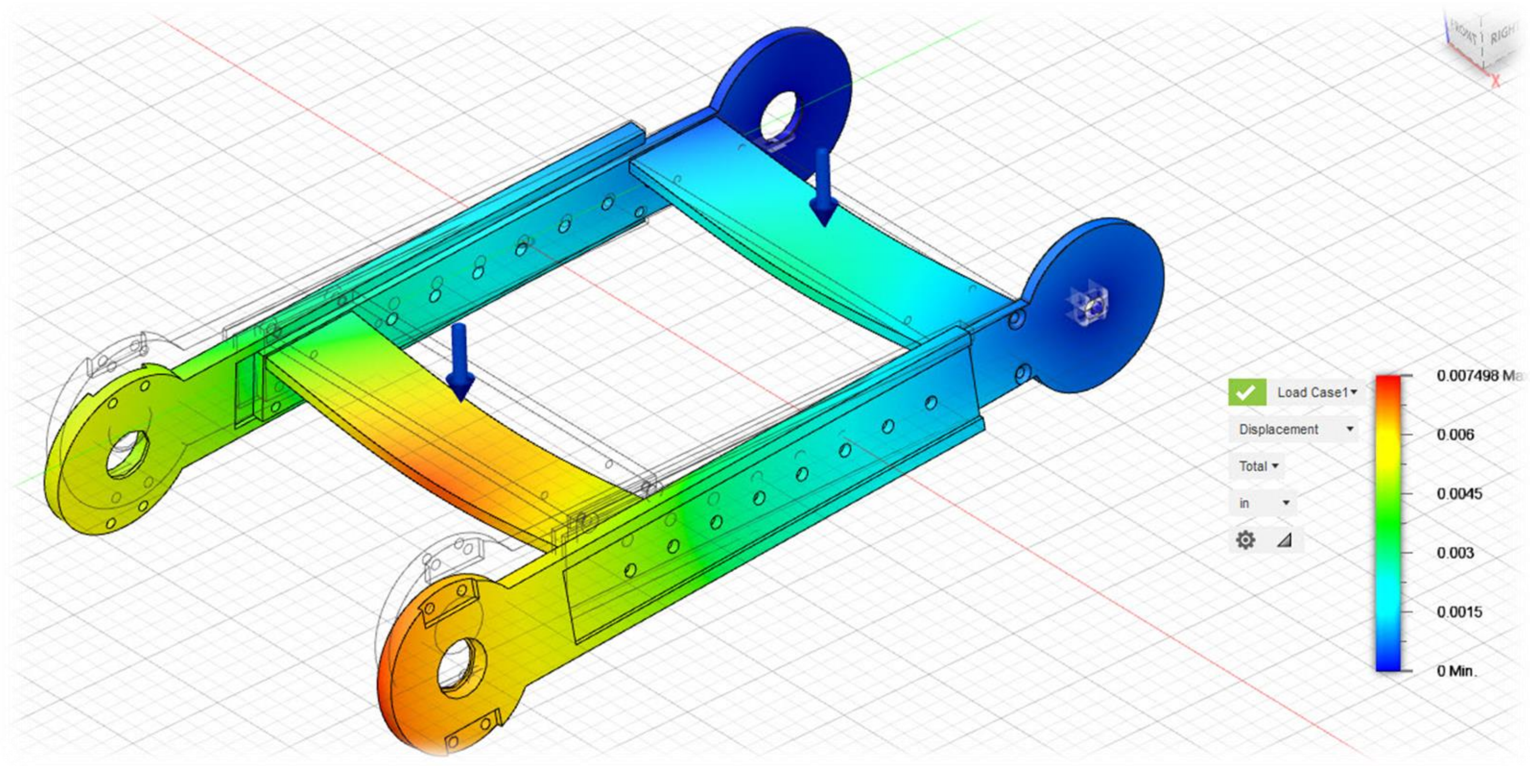


Finite Element Analysis

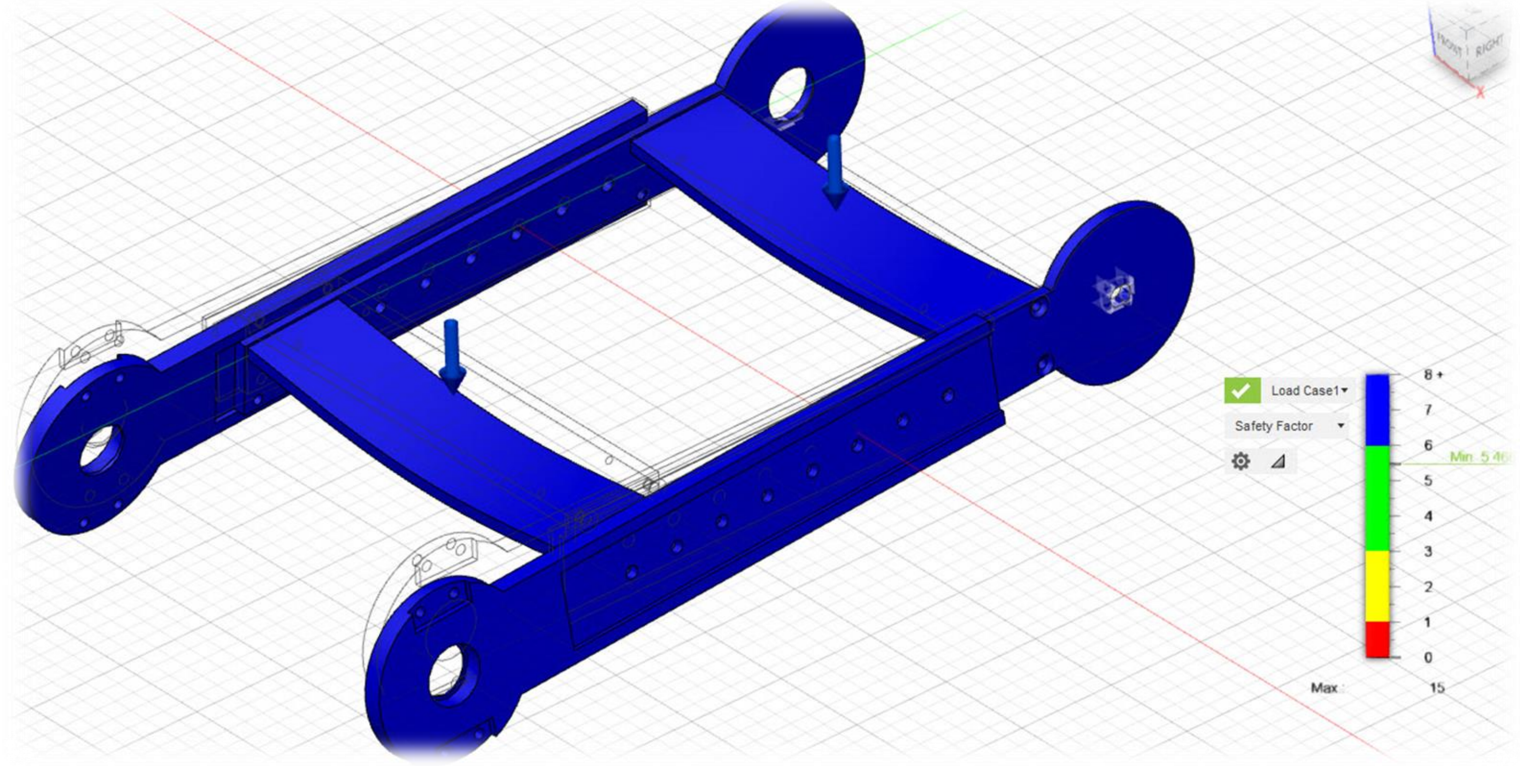
Von-Mises Stress on Thigh Sub-Assembly

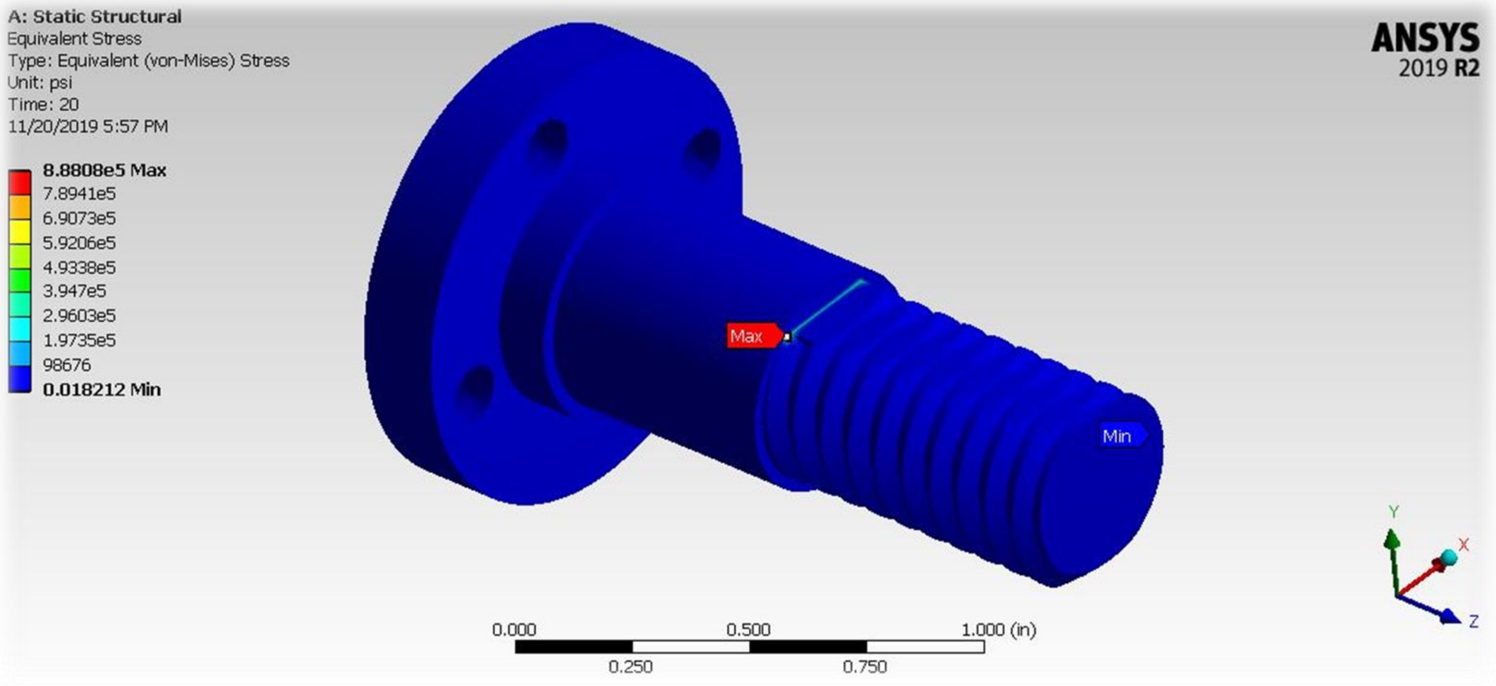


Total Deformation of Thigh Sub-Assembly

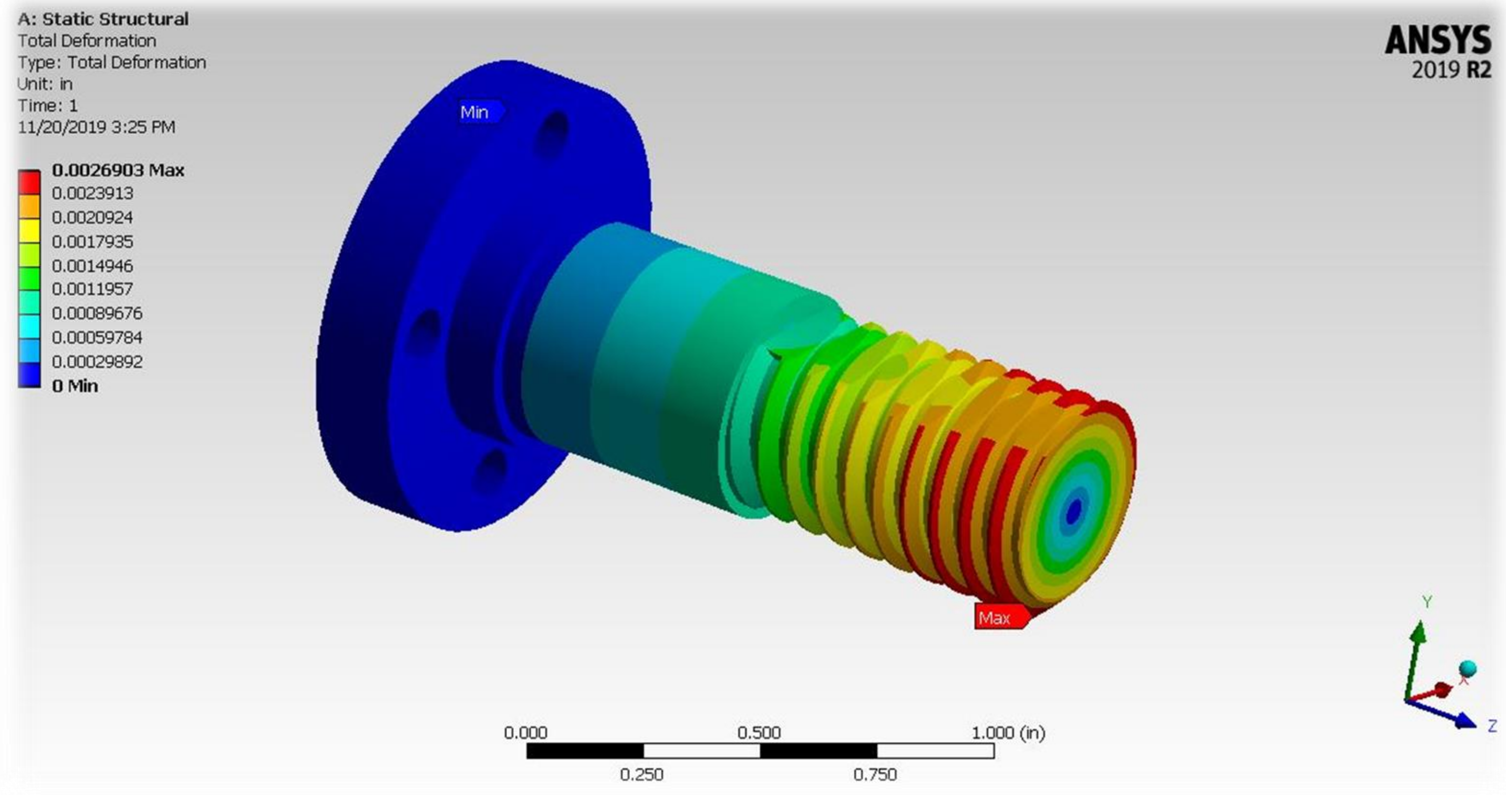


Safety Factor of Thigh Sub-Assembly



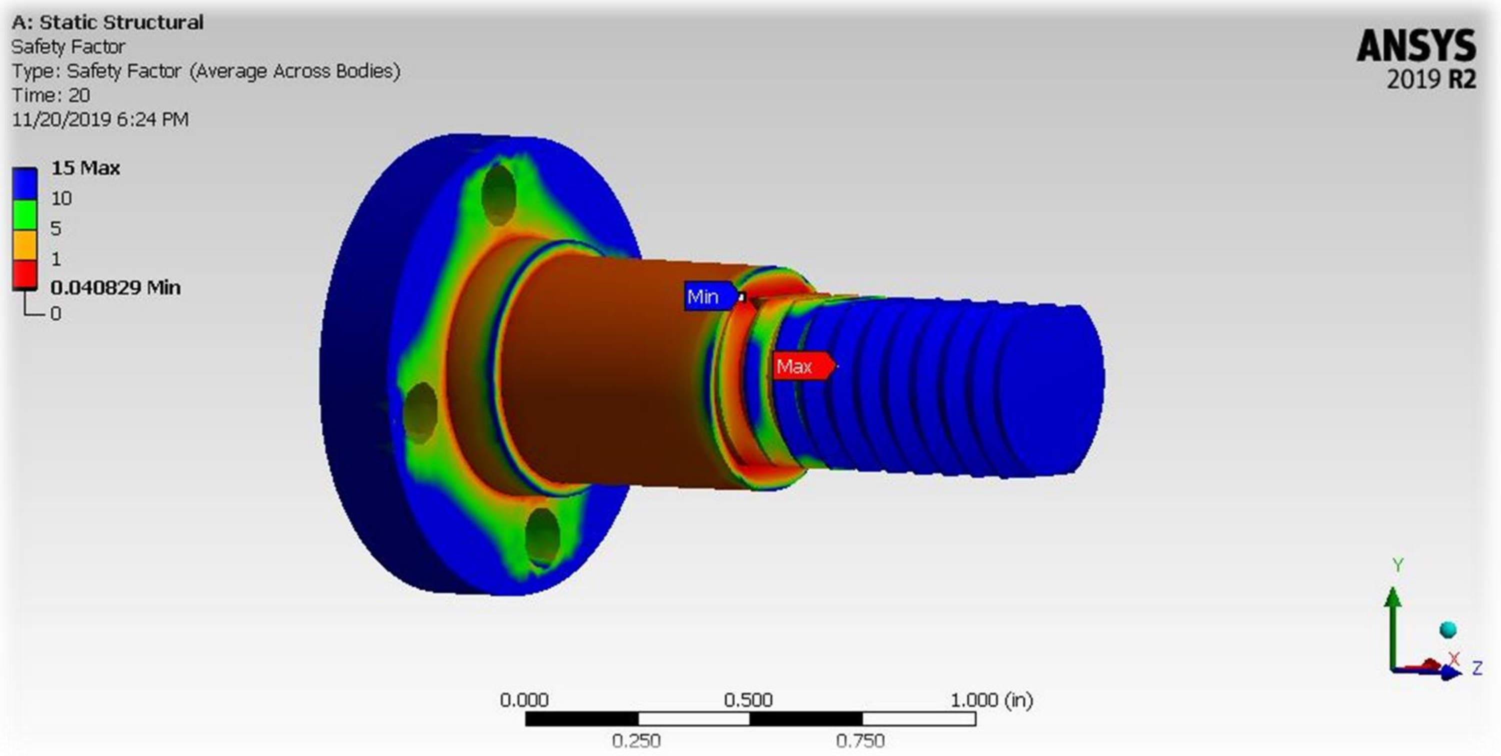


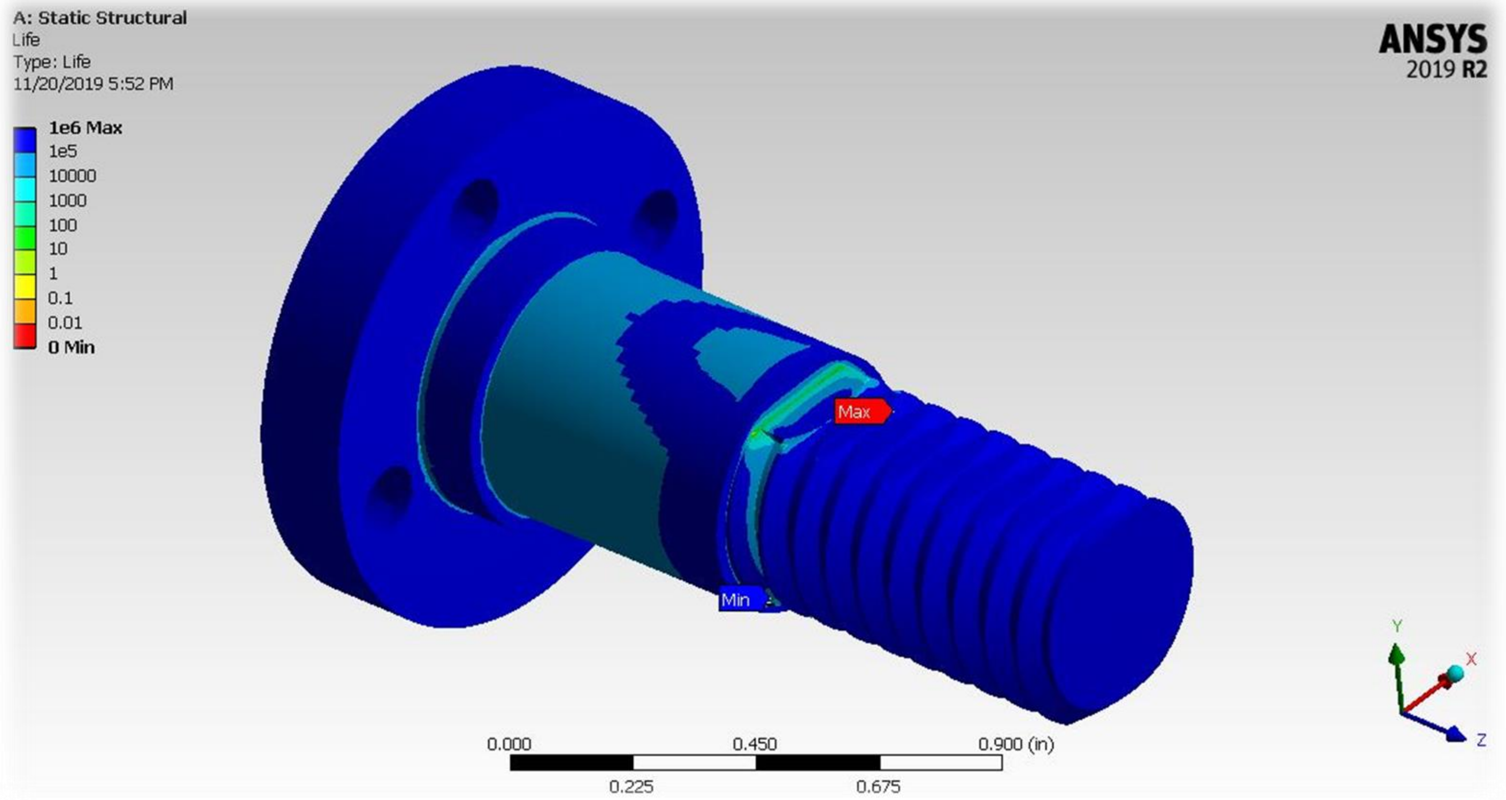
Von-Mises Stress on Joint Pin



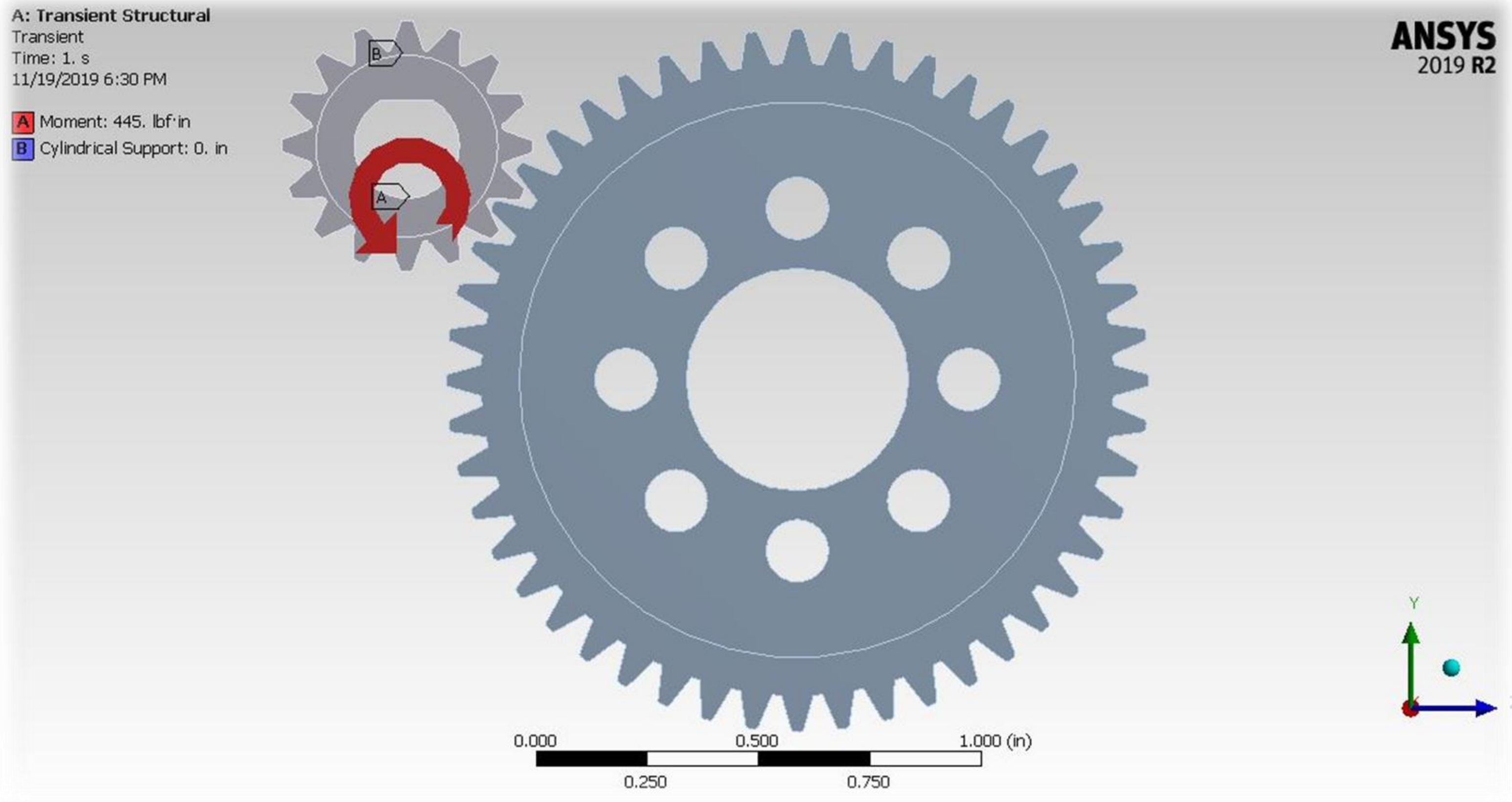
Total Deformation of Joint Pin

Safety Factor of Joint Pin

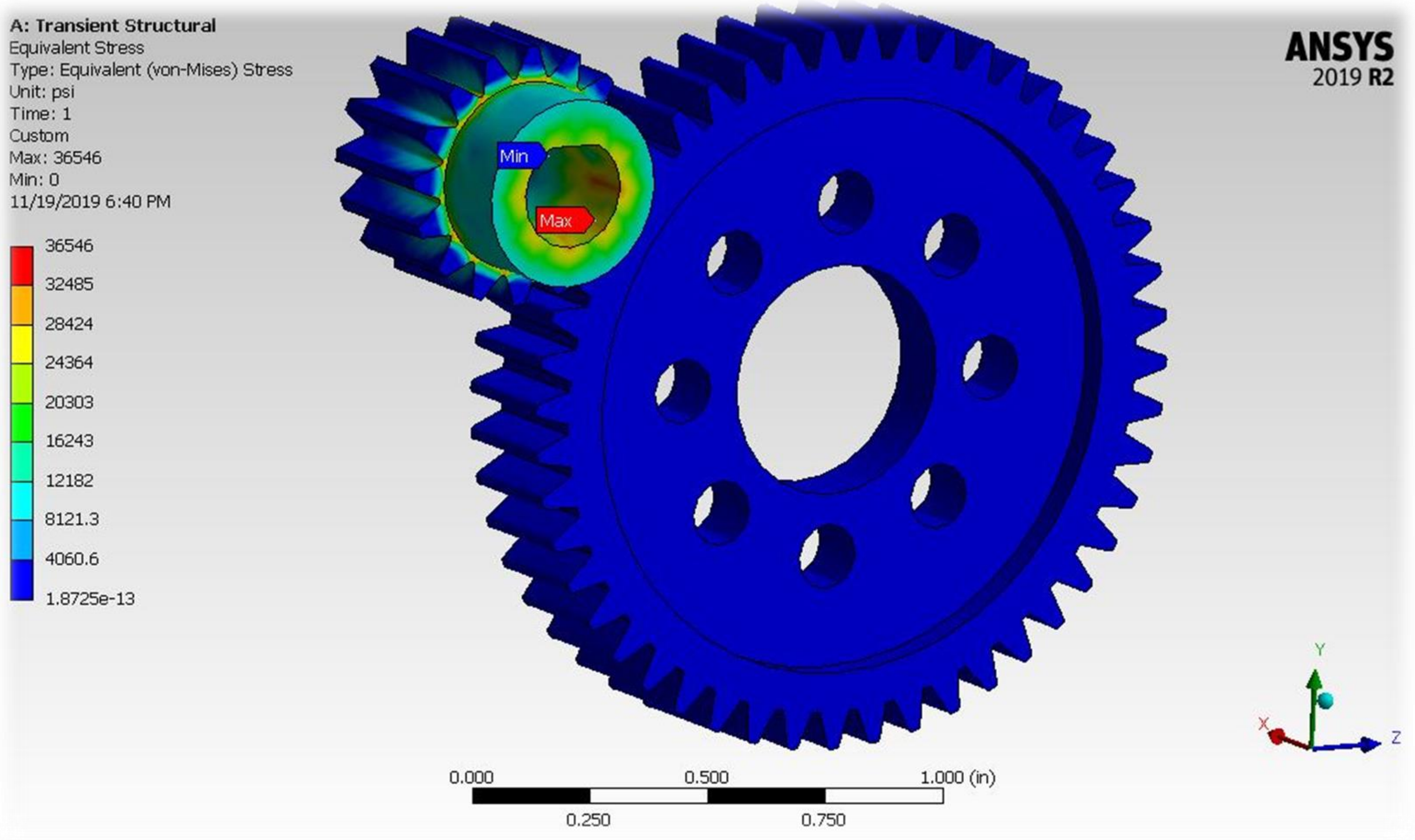




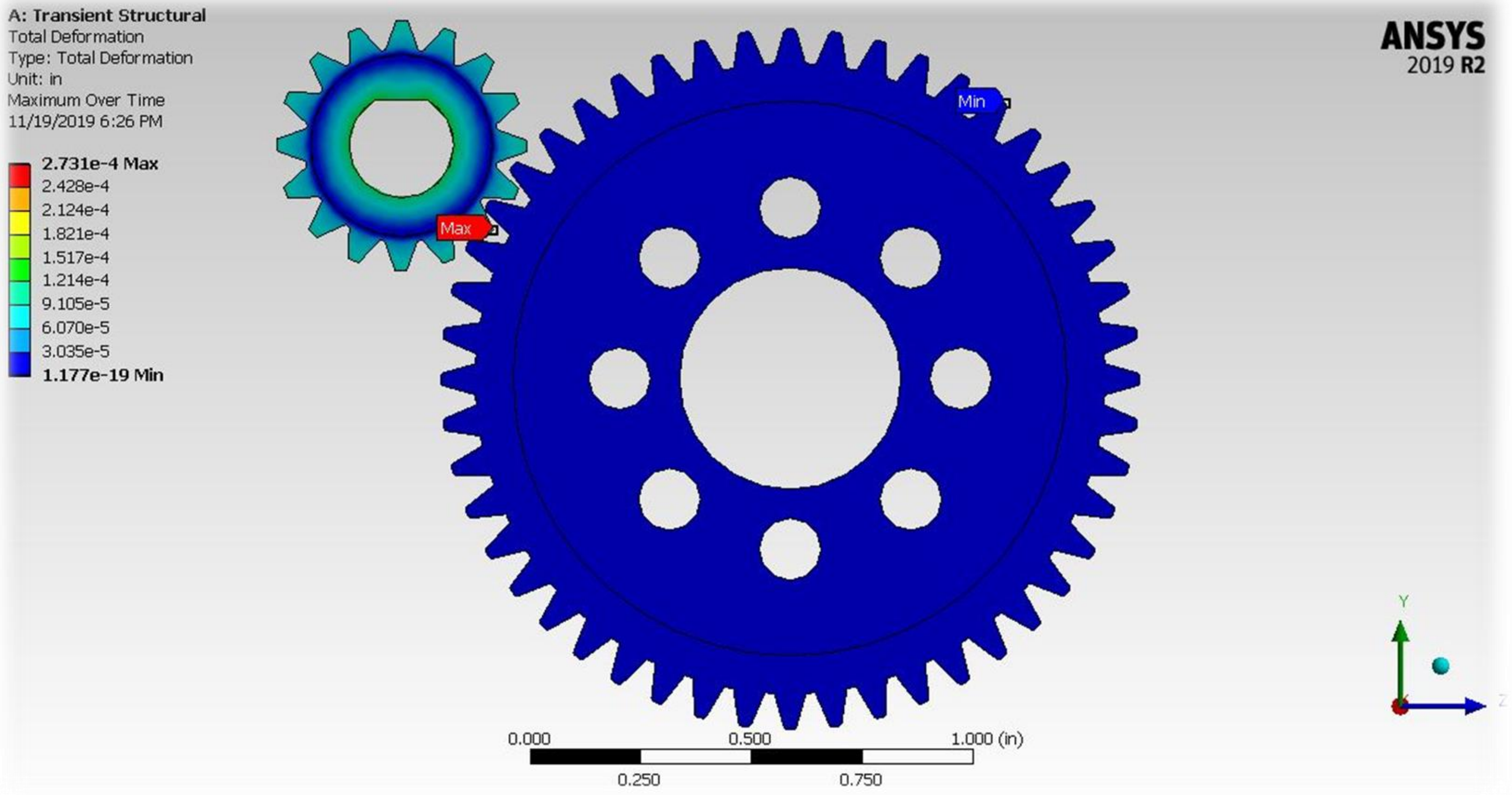
Life Cycle of Joint Pin



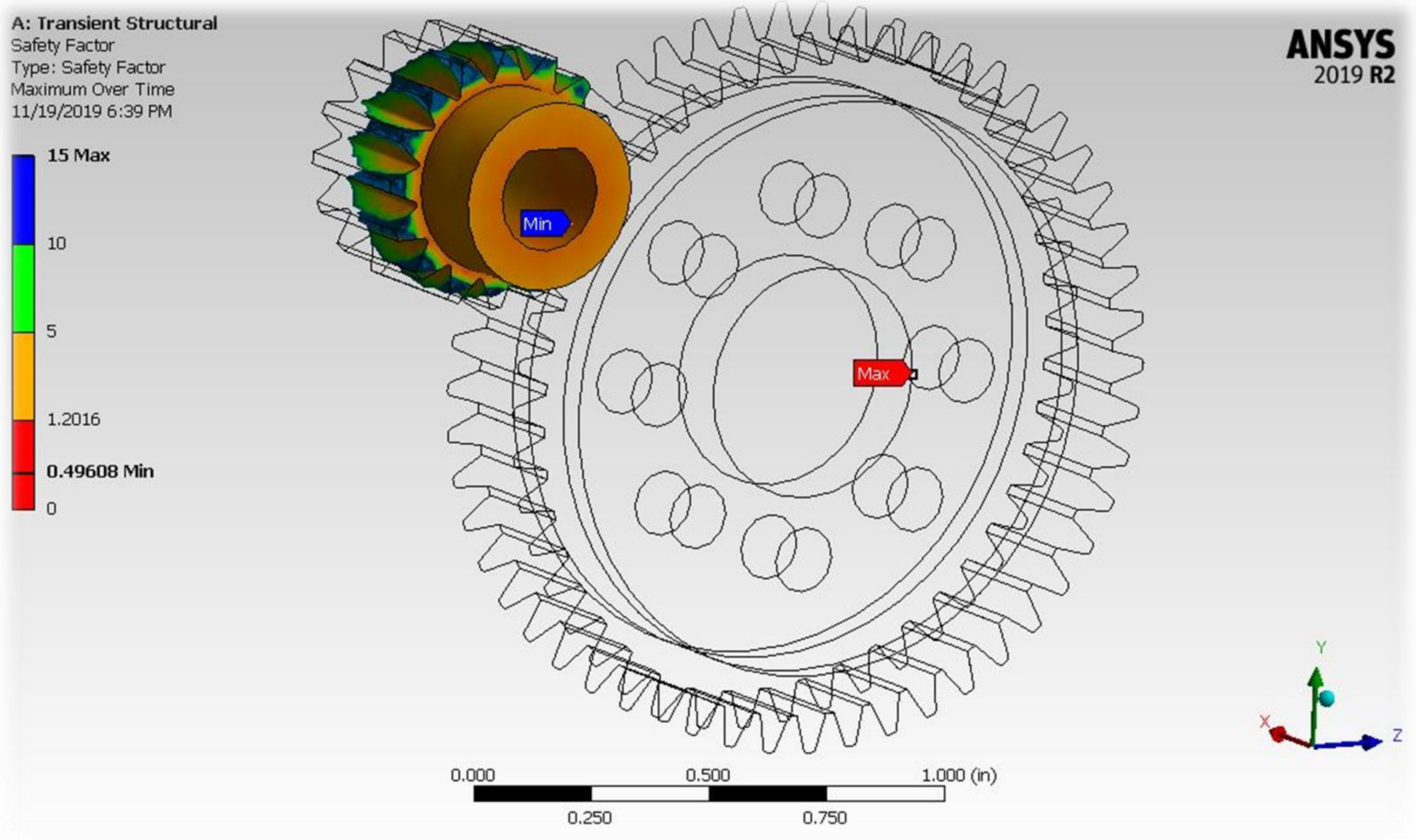
Setup of Gear Sub-Assembly



Von-Mises Stress on Gear Sub-Assembly

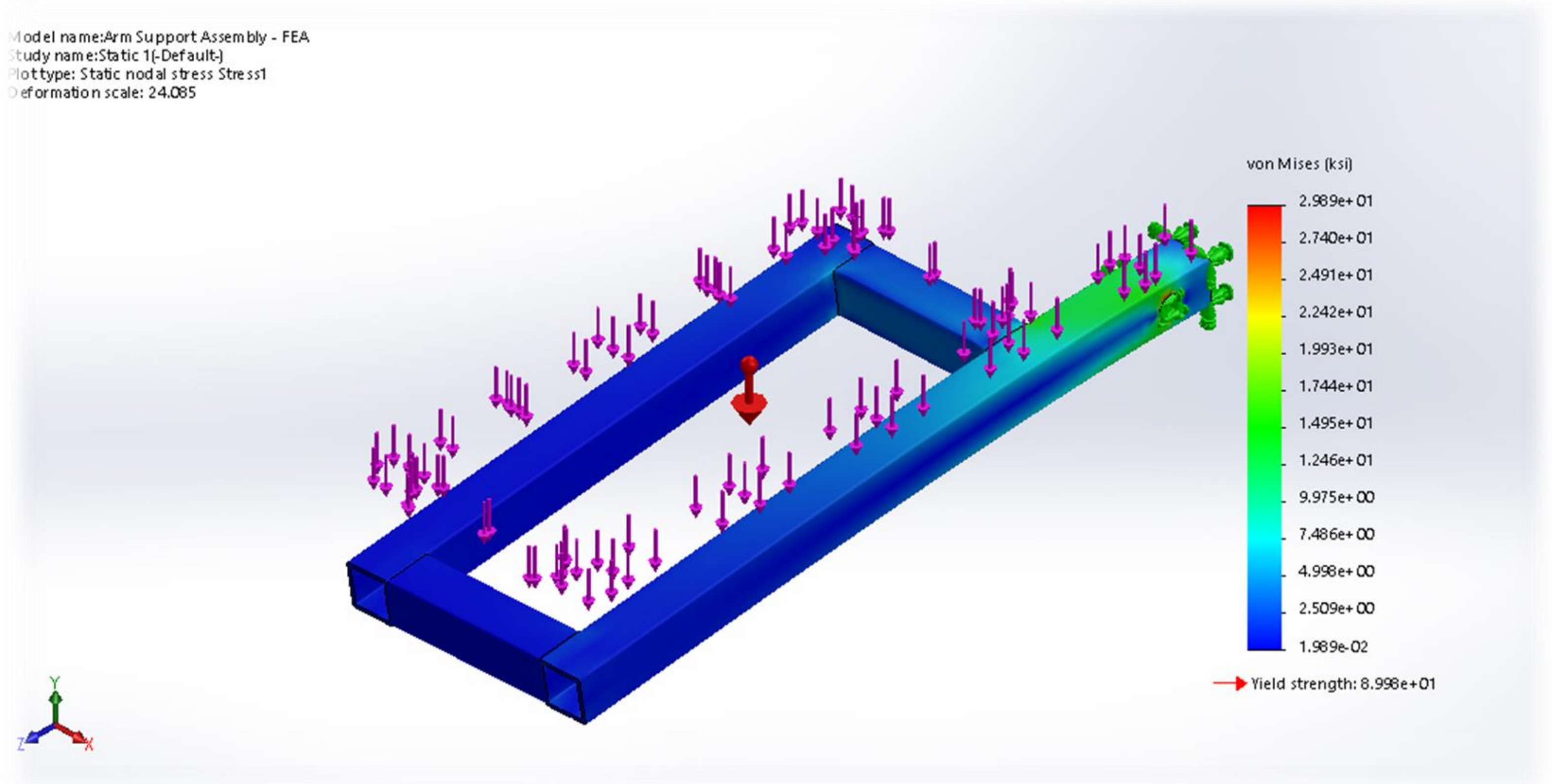


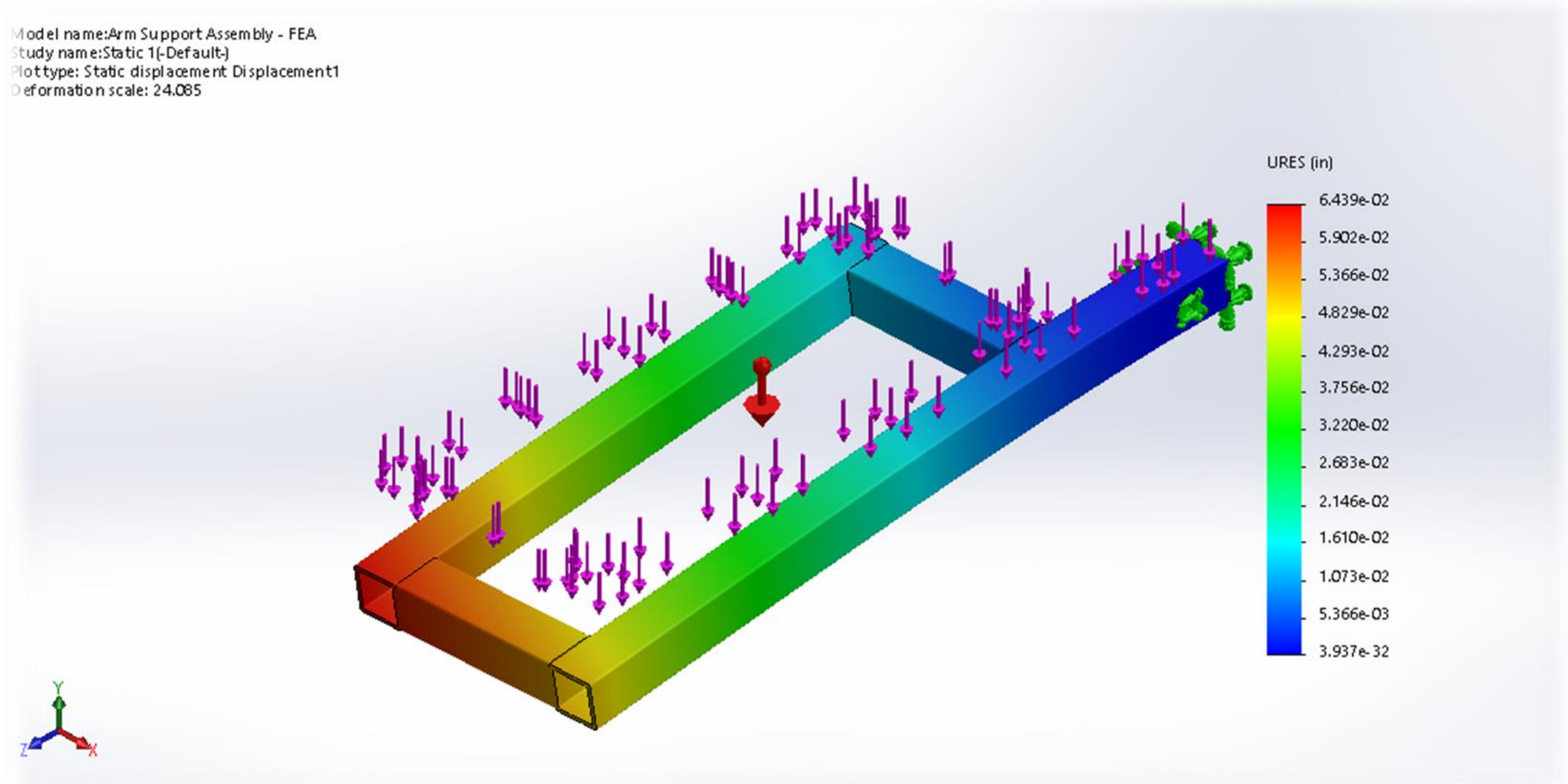
Total Deformation of Gear Sub-Assembly



Safety Factor for Gear Sub-Assembly

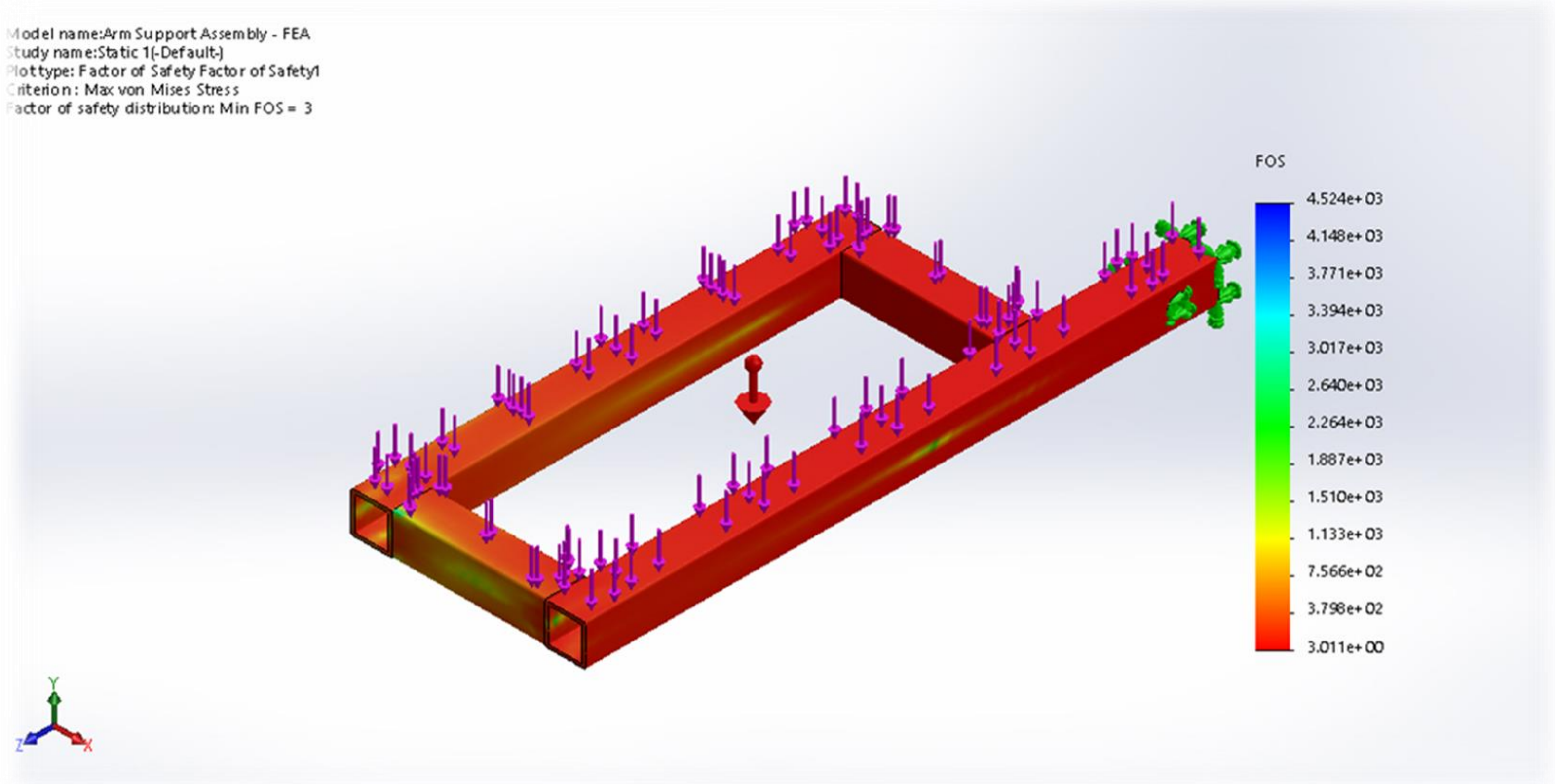
Von-Mises Stress on Arm Sub-Assembly





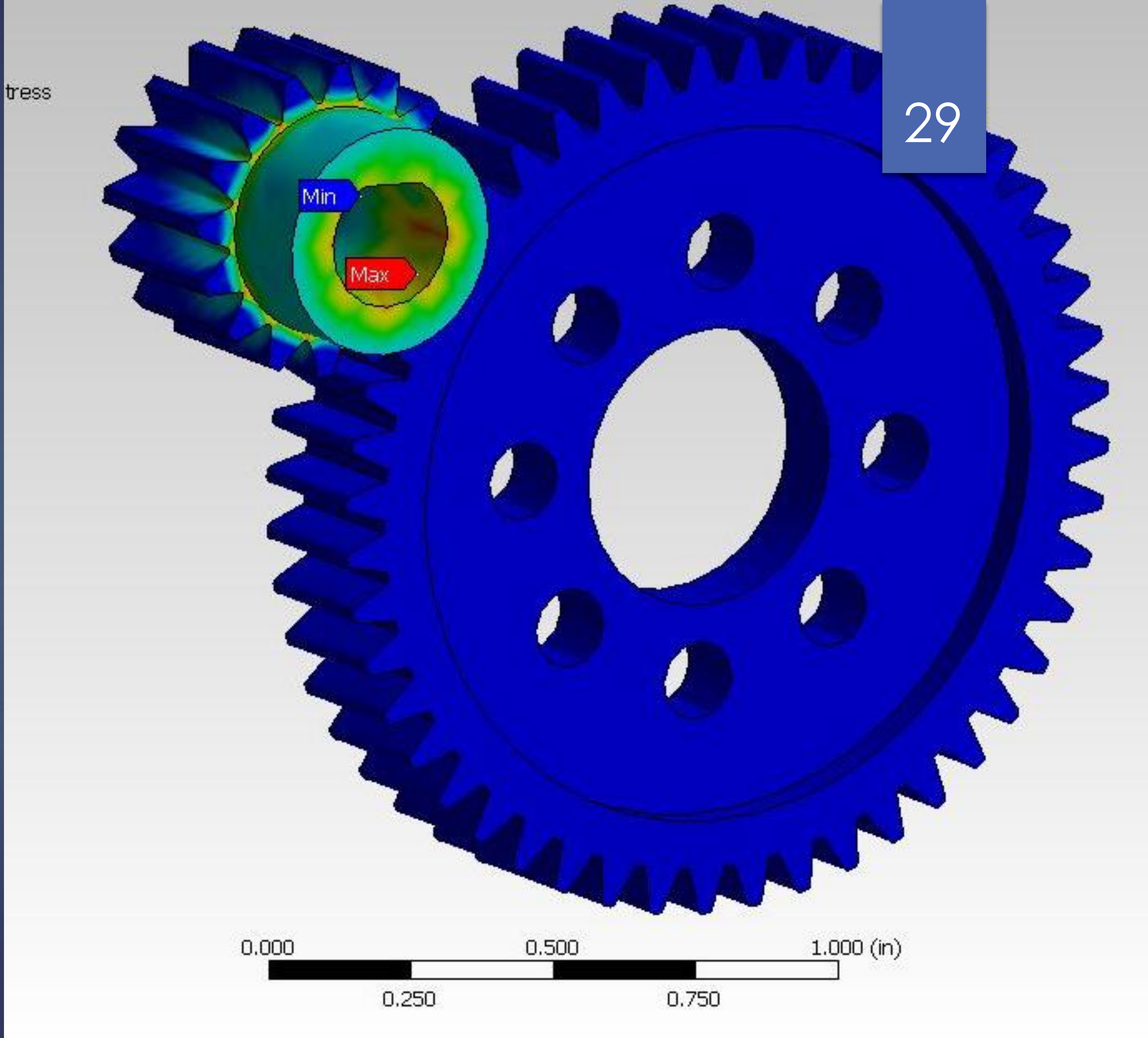
Total Displacement of Arm Sub-Assembly

Safety Factor of Arm Sub-Assembly



Failure Mode

- Locations of probable wear:
  - Driver Gear
    - Cost effectiveness
  - Linkage Connections
    - UHMW Wear Plate
  - Padding

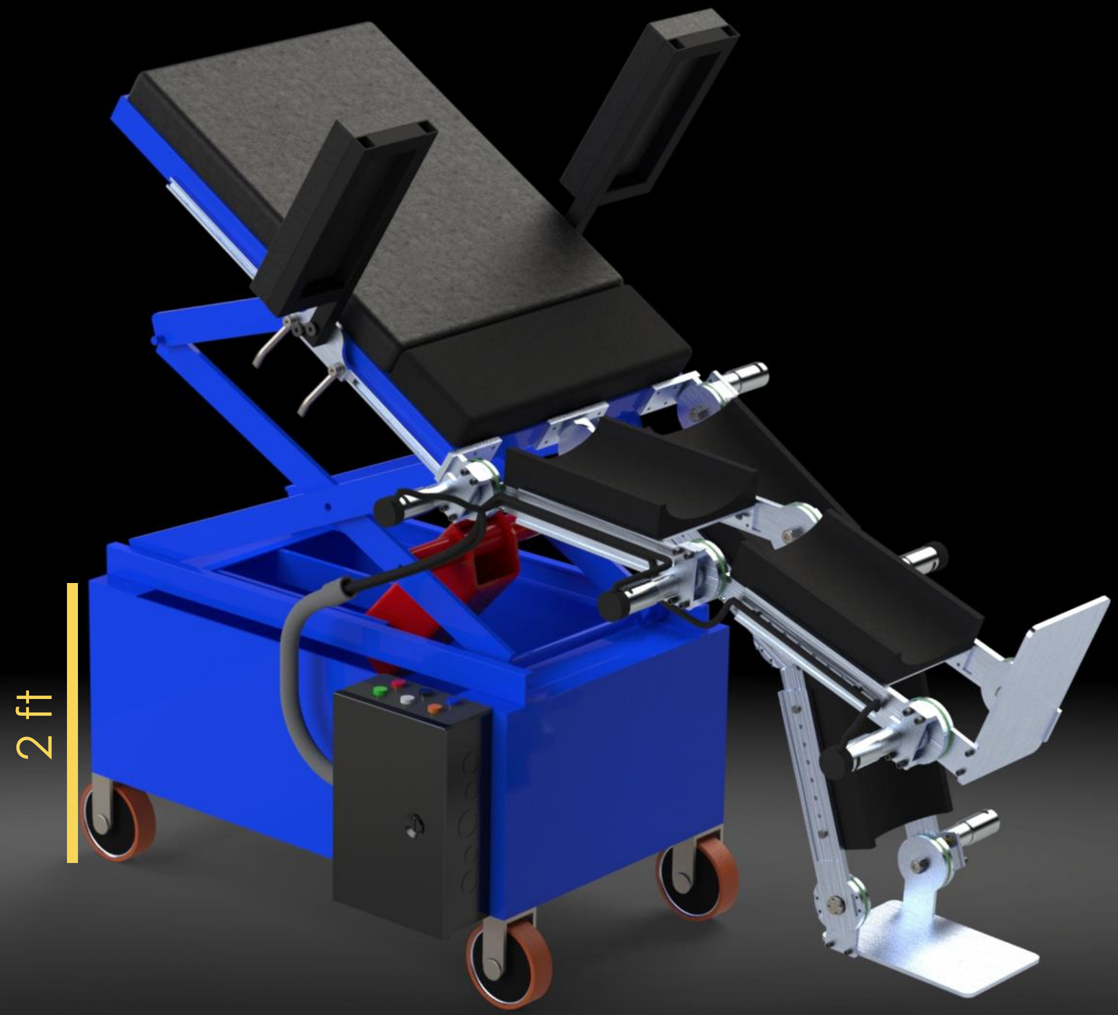


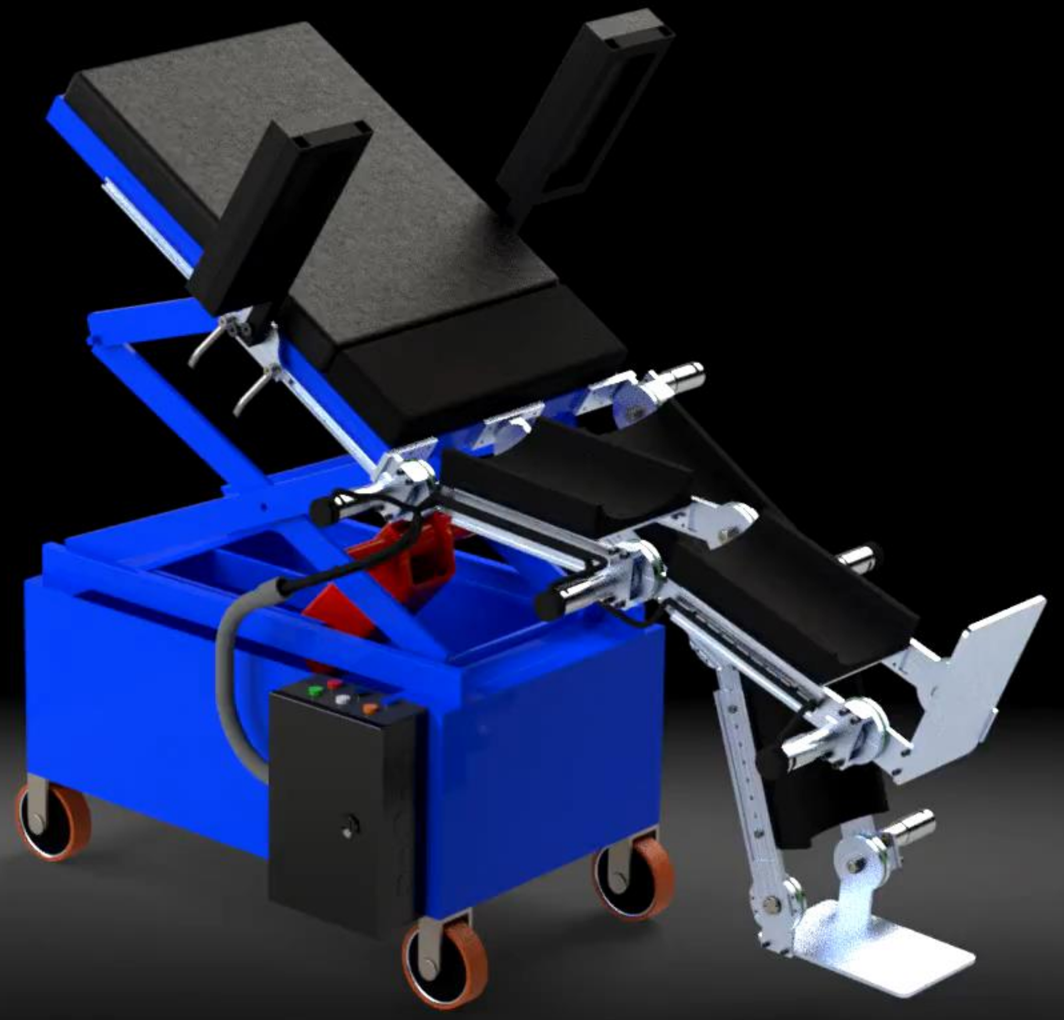
Risk Assessment

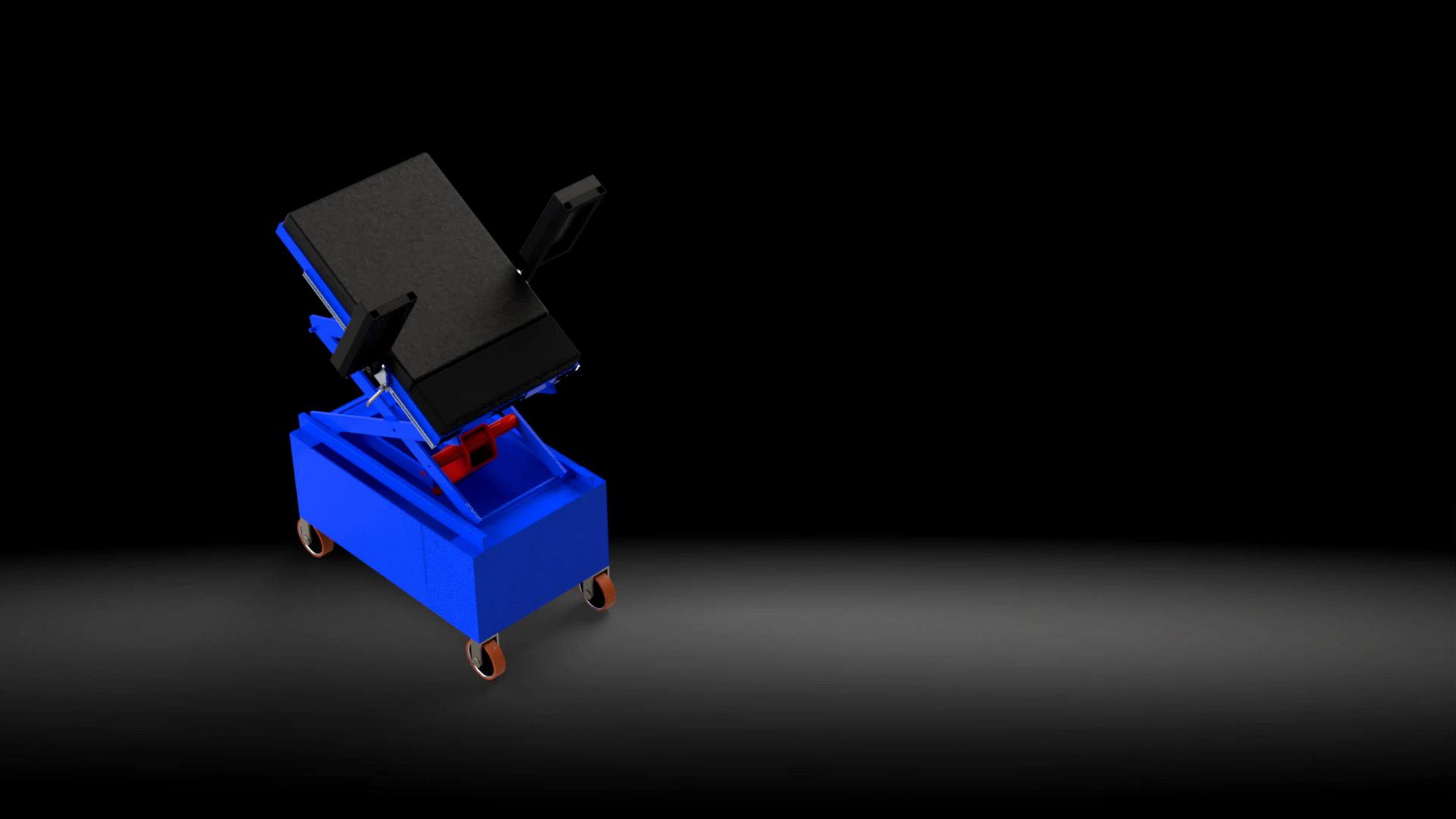
Probability of Occurrences			Catastrophic	Critical	Moderate	Minor	Negligible
Definition	**Meaning**	**Value**	**(A)**	**(B)**	**(C)**	**(D)**	**(E)**
Frequent	Occurs frequently	**5**	**5A**	**5B**	**5C**	**5D**	**5E**
Likely	Occurs less frequently	**4**	**4A**	**4B**	**4C**	**4D**	**4E**
Occasional	Occurs sporadically	**3**	**3A**	**3B**	**3C**	**3D**	**3E**
Seldom	Unlikely to occur	**2**	**2A**	**2B**	**2C**	**2D**	**2E**
Improbable	Highly unlikely to occur	**1**	**1A**	**1B**	**1C**	**1D**	**1E**

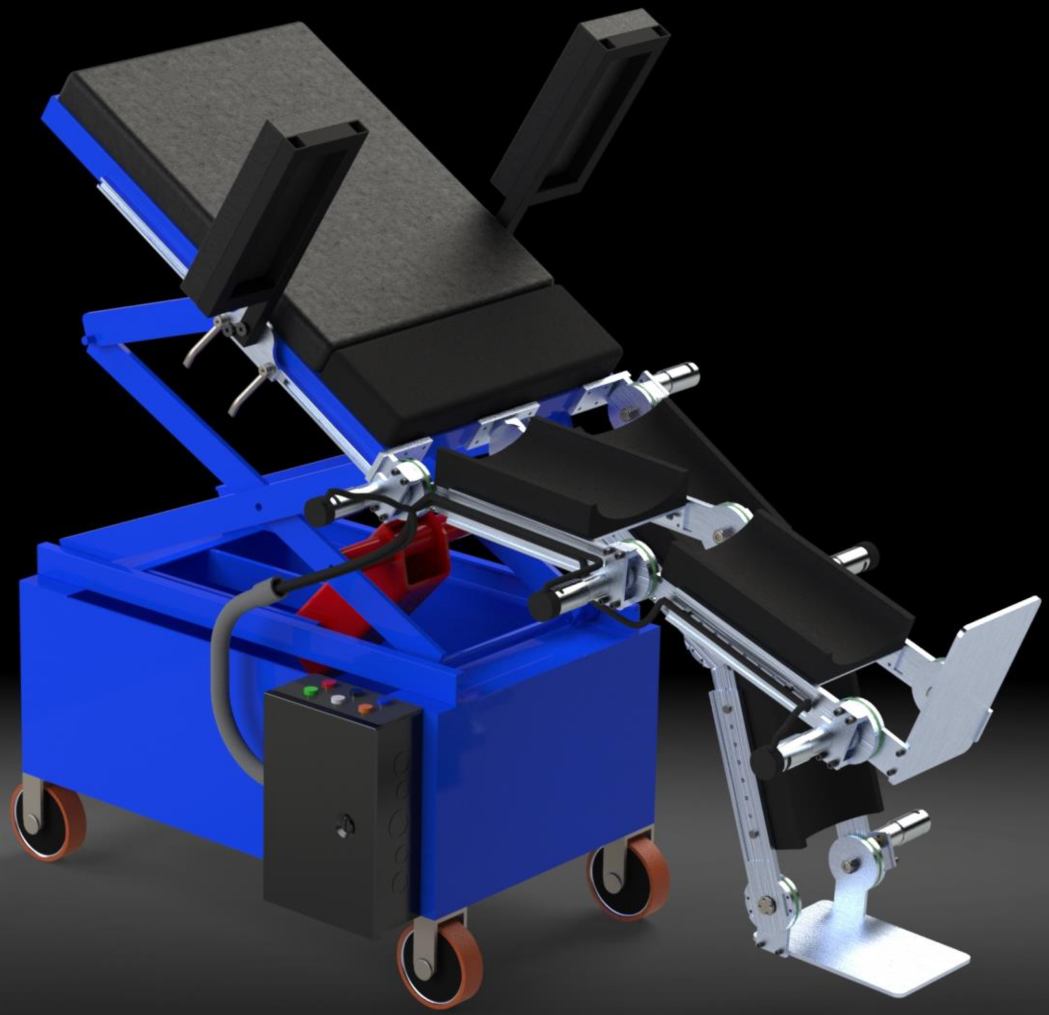
High Risk	
Medium High Risk	
Medium Low Risk	
Low Risk	

Complete Assembly



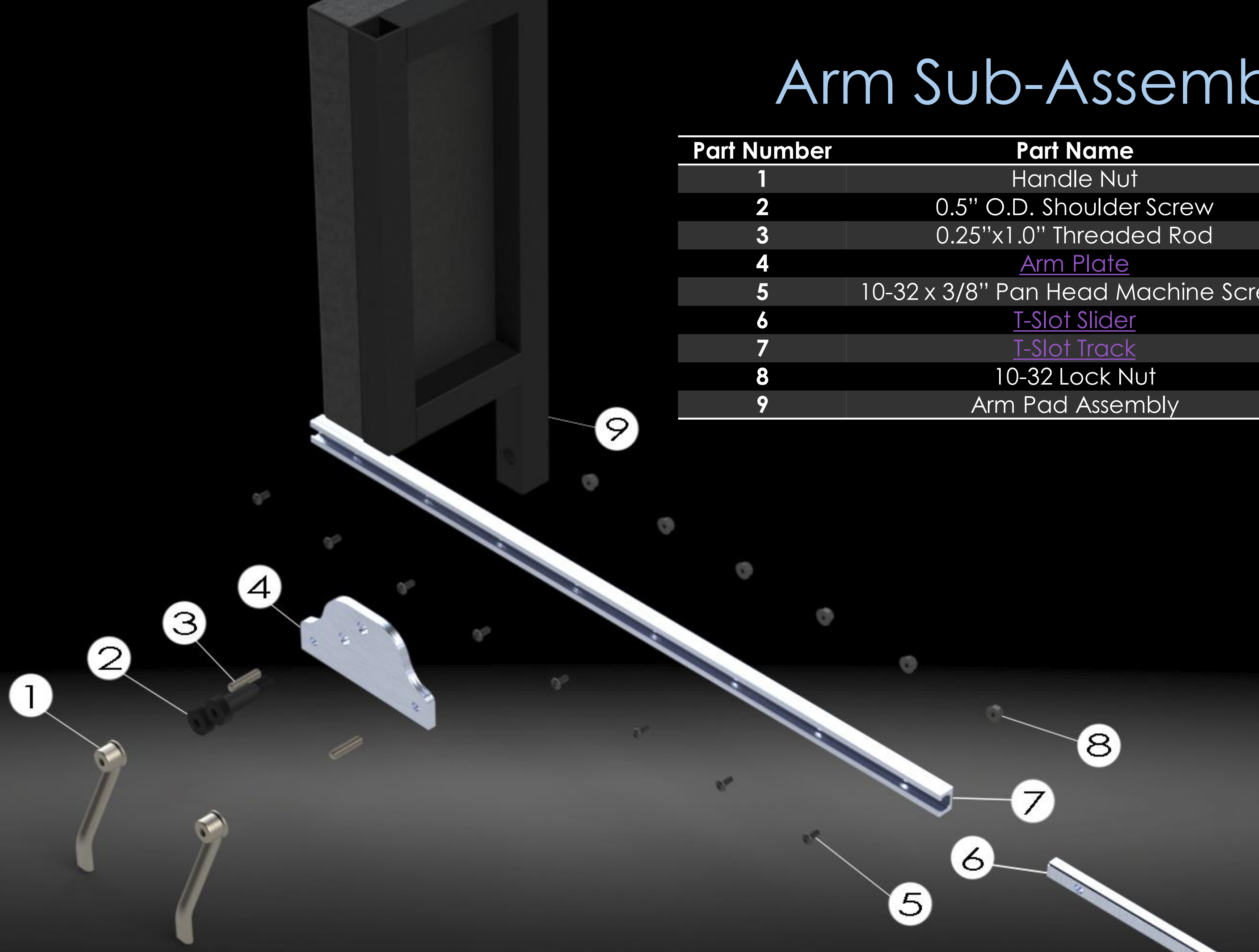


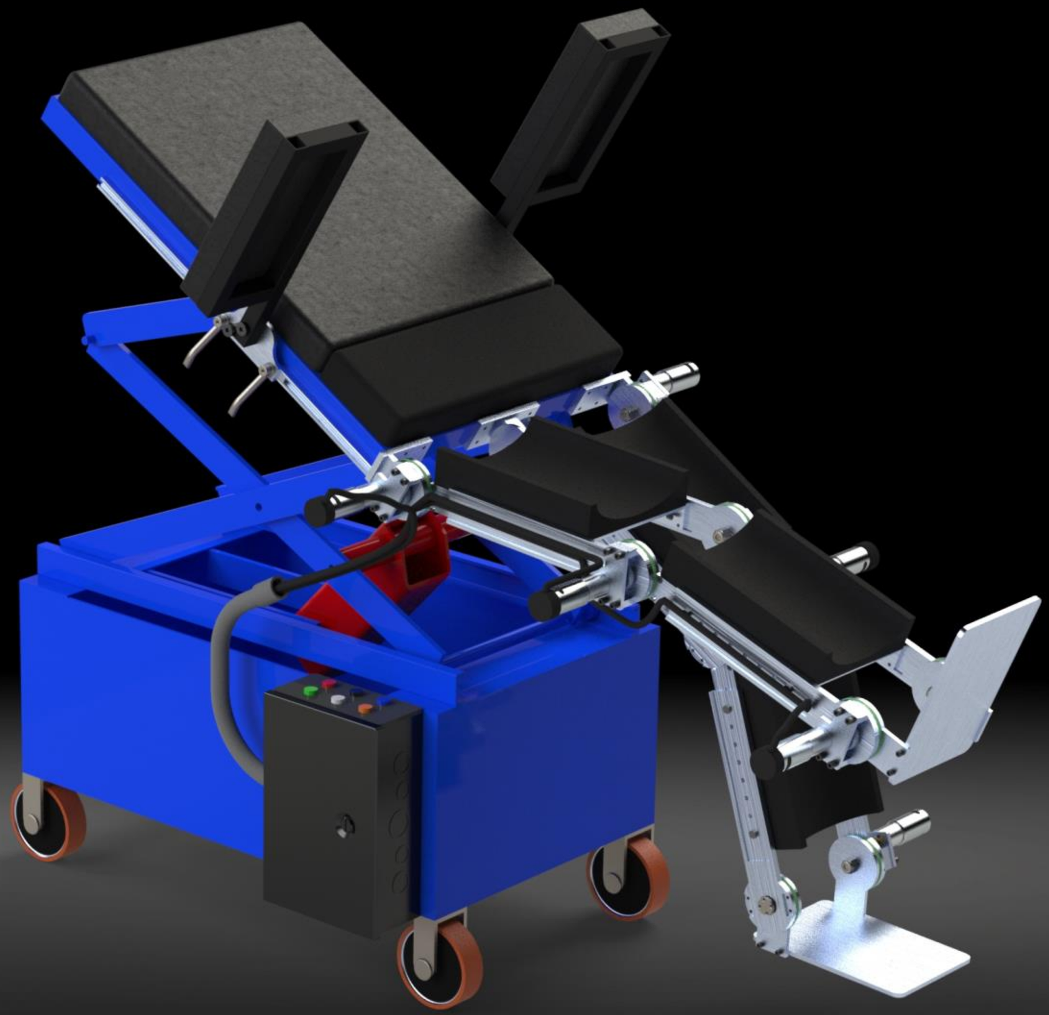




Arm Sub-Assembly

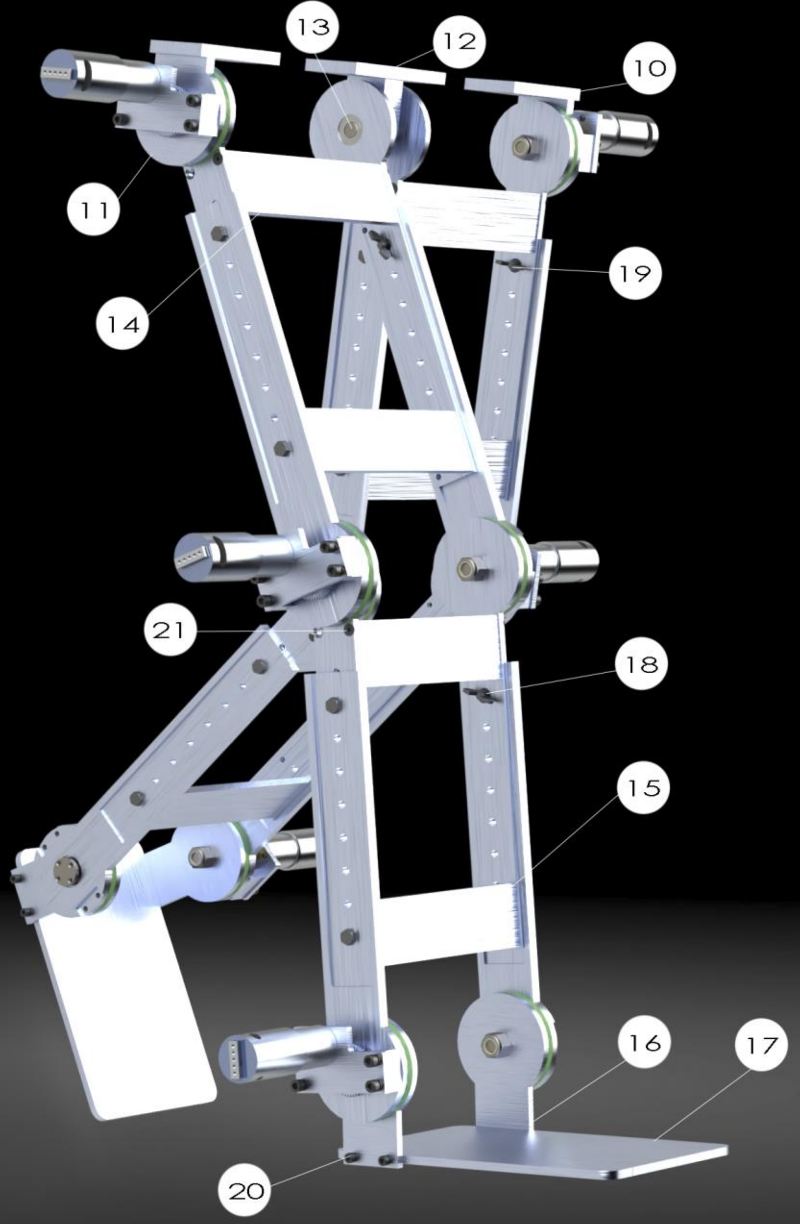
Part Number	Part Name	Quantity
1	Handle Nut	2
2	0.5" O.D. Shoulder Screw	2
3	0.25"x1.0" Threaded Rod	2
4	Arm Plate	1
5	10-32 x 3/8" Pan Head Machine Screw	8
6	T-Slot Slider	1
7	T-Slot Track	1
8	10-32 Lock Nut	8
9	Arm Pad Assembly	1





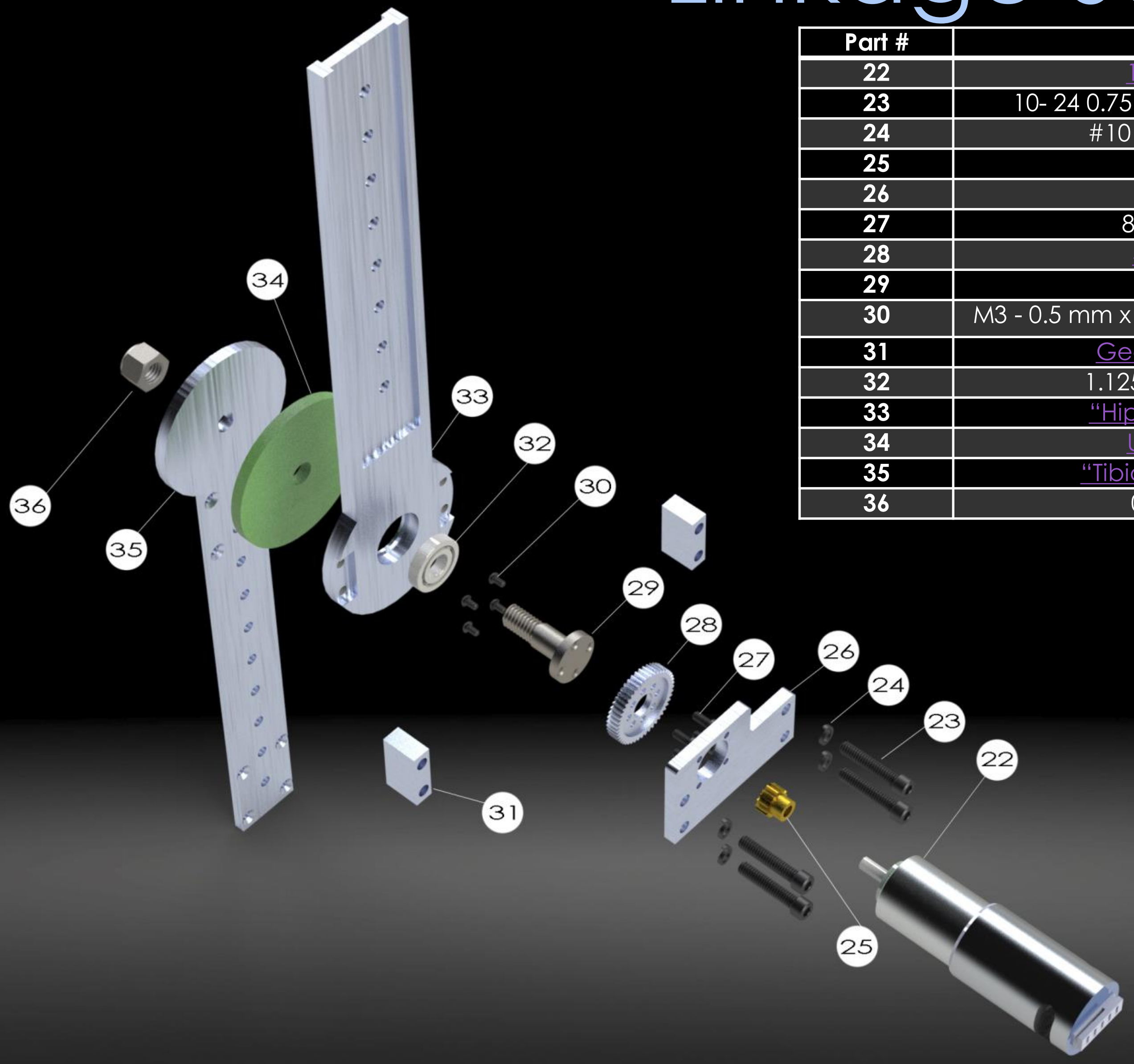
Leg Sub-Assembly

Part Number	Part name	Quantity
10	Hip Mount Plate	2
11	Hip Motor Mount	2
12	Groin Pin Mount	1
13	Groin Pin	1
14	Frame Spacer L	4
15	Frame Spacer Short	4
16	Ankle Swivel	4
17	Foot Platform	2
18	0.25" Hi-Collar Lockwasher	16
19	0.25"- 20 Wingnut	16
20	0.25"- 20 x 0.75" Hex Drive Flat Head Screw	4
21	10 - 24 x 0.75" SHCS	16



Linkage Sub-Assembly

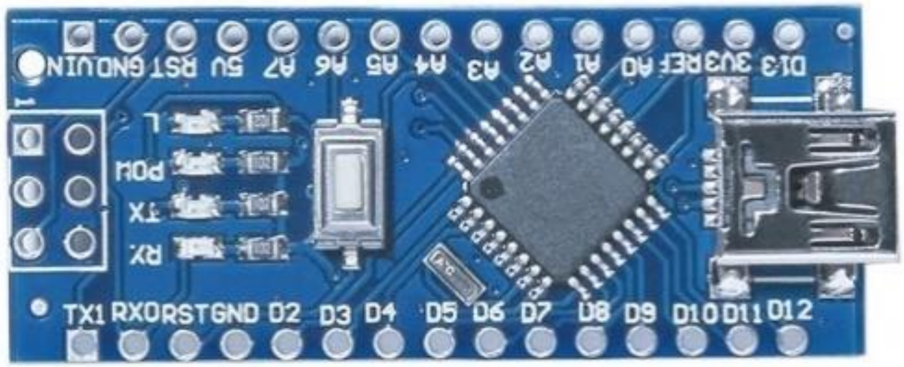
Part #	Part Name	Quantity
22	12 RPM P.G. Motor	1
23	10- 24 0.75" Hex Drive Flat Head Screw	4
24	#10 Hi-Collar Lockwasher	4
25	16T Driver (Gear)	1
26	Motor Mount	1
27	8 - 32 x 0.375" SHCS	4
28	48T Driven (Gear)	1
29	Pivot Pin	1
30	M3 - 0.5 mm x 10 mm Button Head Hex Screw	4
31	Gear Motor Mount Riser	2
32	1.125"x 0.500" I.D. Bearing	1
33	"Hip Tib" – Outer Linkage	1
34	UHMW Wear Plate	1
35	"Tibia Link" – Inner Linkage	1
36	0.5"- 13 Nylon Nut	1



ServoCity
12 RPM HD Premium Planetary Gear Motor with Encoder

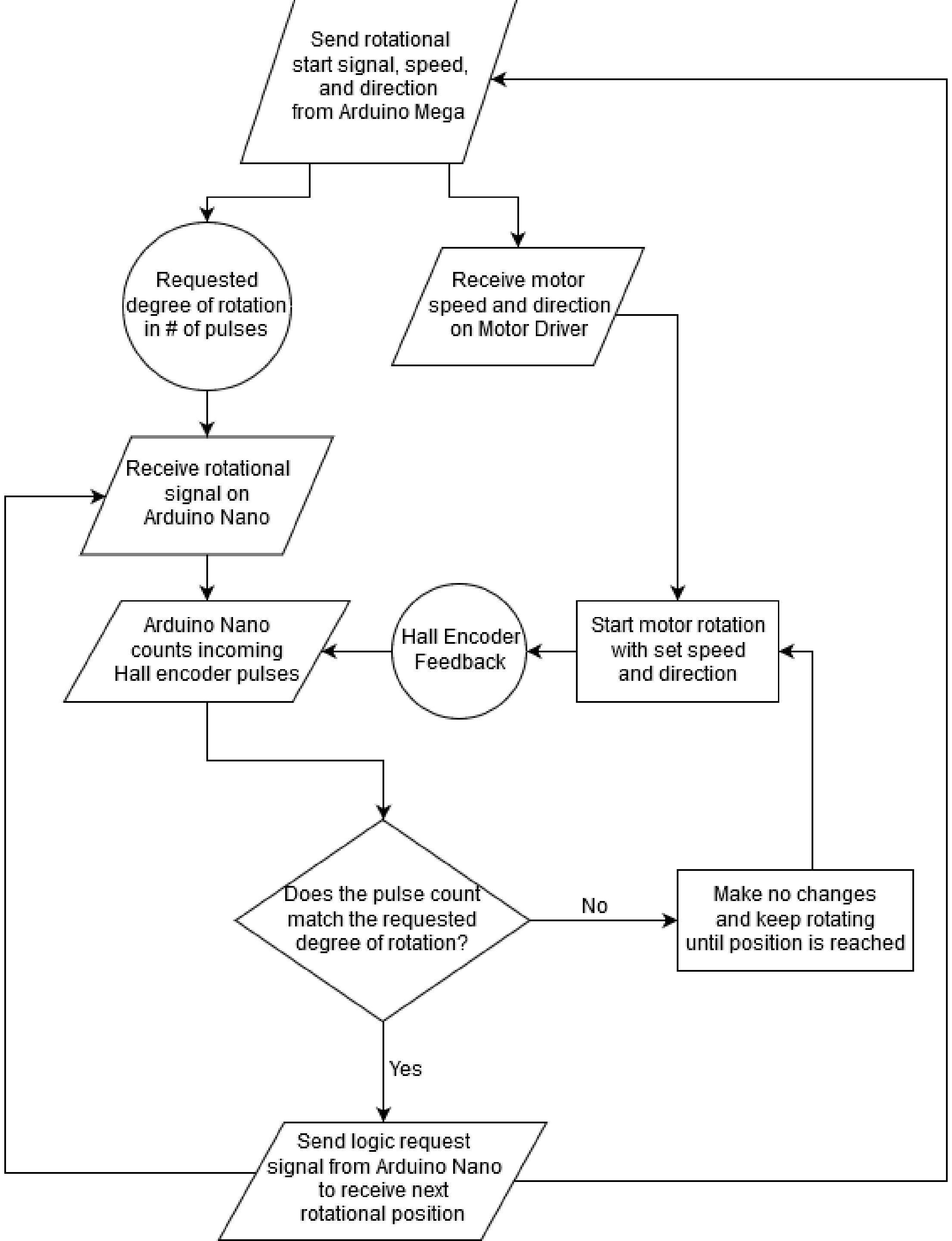
Arduino Micro-controllers

Arduino Mega 2560



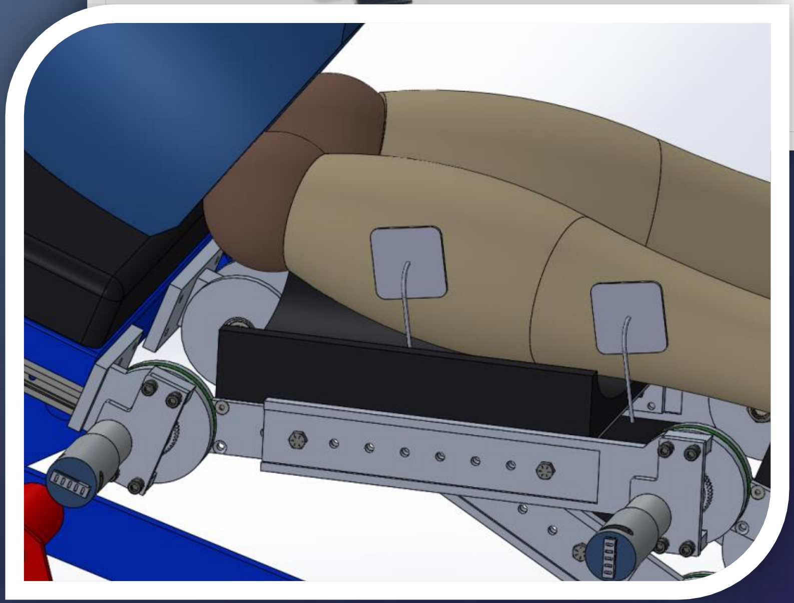
Arduino Nano

Program Overview

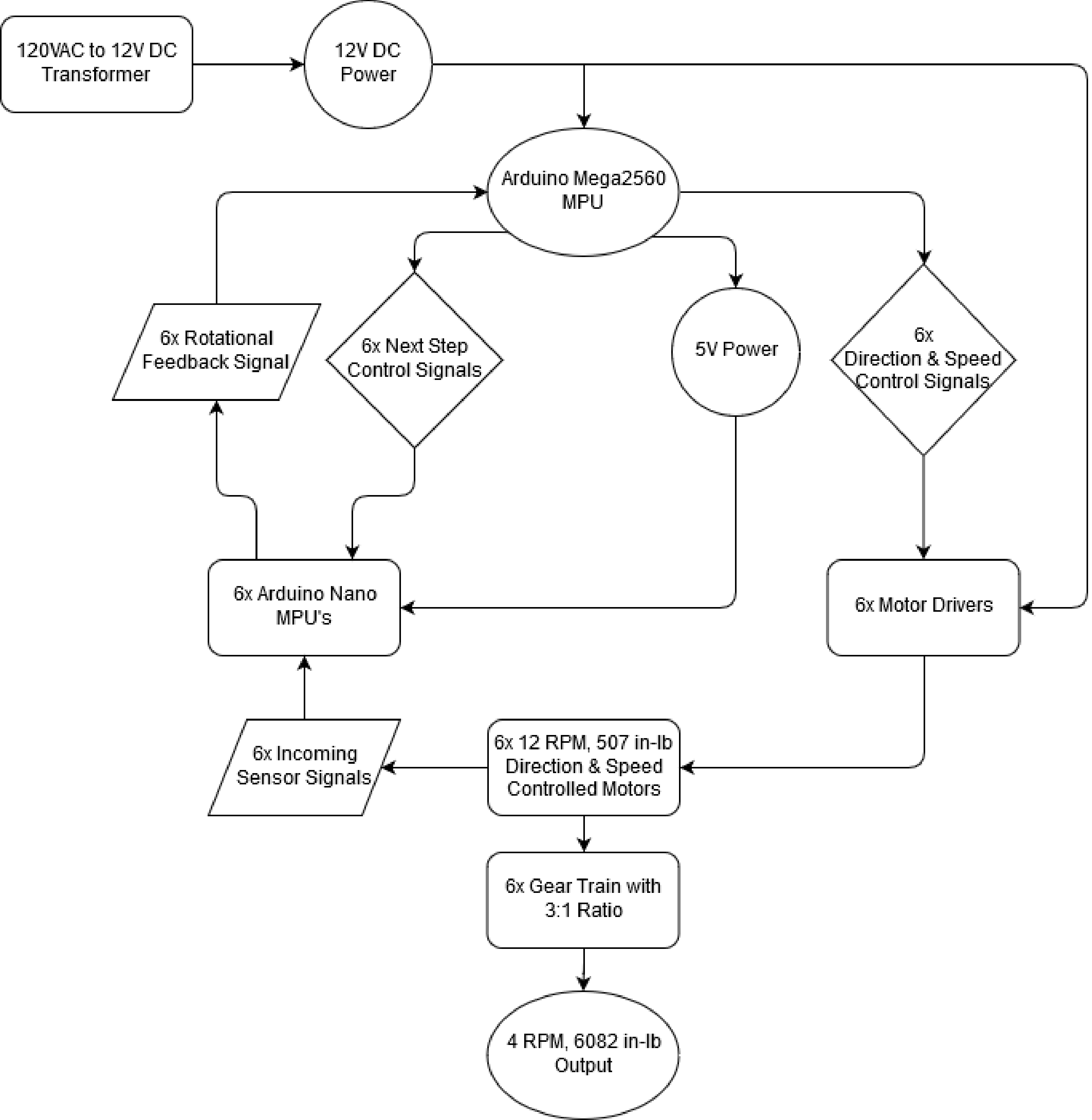


Functional Electrical Stimulation [FES]

- Used in conjunction with device
- Provides outside stimulation to muscles
- Programmed to stimulate the correct muscle group in time with motion of robotic Legs.



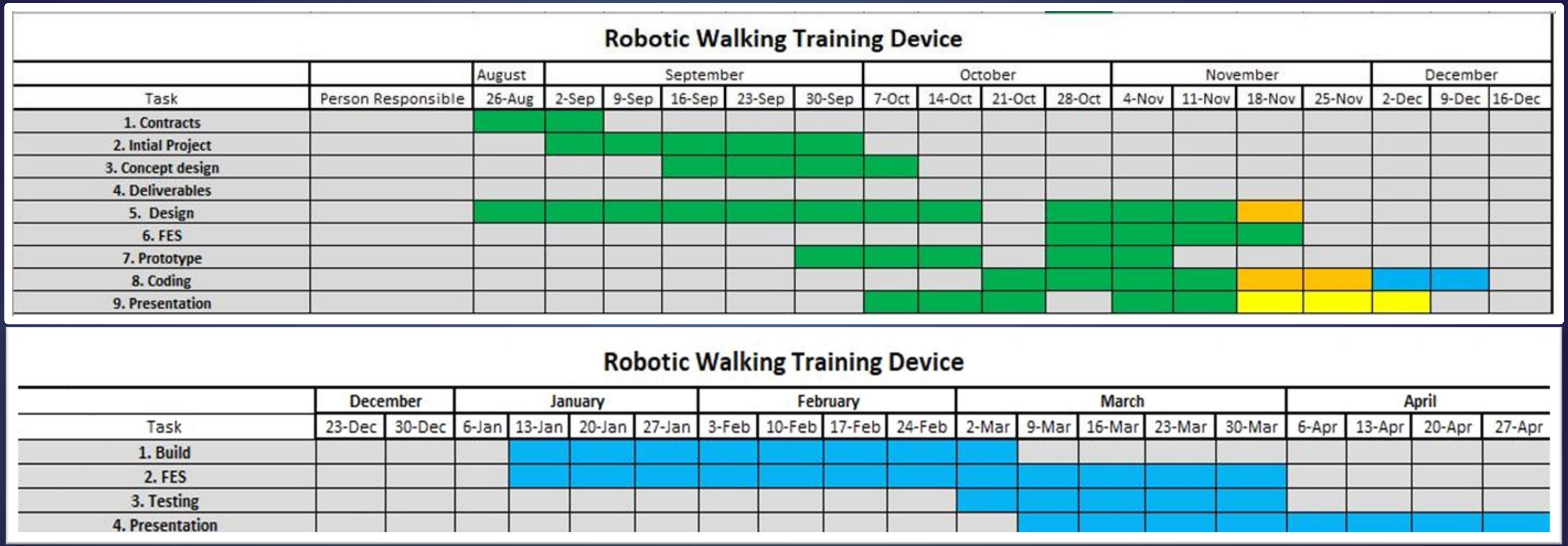
Electrical Design Flow Chart



Test and Evaluation Plan

- 3D Printed Prototype
- Upon completion of manufacturing and assembly of complete system, and implementation of program, the produced gait path will be compared with a natural gait through the Vicon Motion Capture system
  - This path will be compared to the original natural gait and the coordinates analyzed in Excel to determine that the produced path is within 10% of the human path.
- The F.E.S. will be wired with LED lights to illustrate when a therapy pulse is being administered until such time that the appropriate timing has been established.
  - After, the electrodes will be connected under the supervision of Dr. Dong for further testing.

Timeline


Robotic Walking Training Device
August
September
October
November
December
Task
Person Responsible
26-Aug
2-Sep
9-Sep
16-Sep
23-Sep
30-Sep
7-Oct
14-Oct
21-Oct
28-Oct
4-Nov
11-Nov
18-Nov
25-Nov
2-Dec
9-Dec
16-Dec
1. Contracts
2. Intial Project
3. Concept design
4. Deliverables
5. Design
6. FES
7. Prototype
8. Coding
9. Presentation
Robotic Walking Training Device
December
January
February
March
April
Task
23-Dec
30-Dec
6-Jan
13-Jan
20-Jan
27-Jan
3-Feb
10-Feb
17-Feb
24-Feb
2-Mar
9-Mar
16-Mar
23-Mar
30-Mar
6-Apr
13-Apr
20-Apr
27-Apr
1. Build
2. FES
3. Testing
4. Presentation

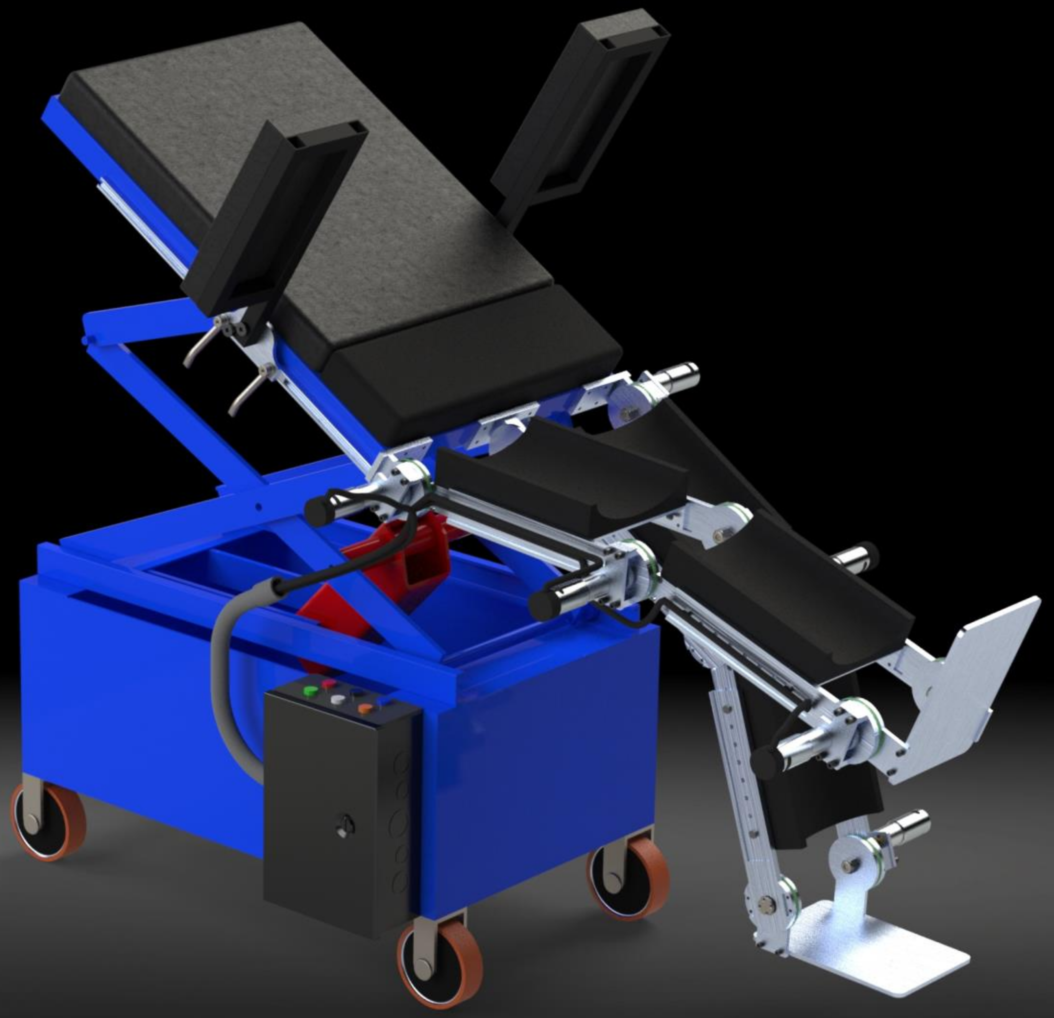

Done
IP
Scheduled
At Risk
Failed

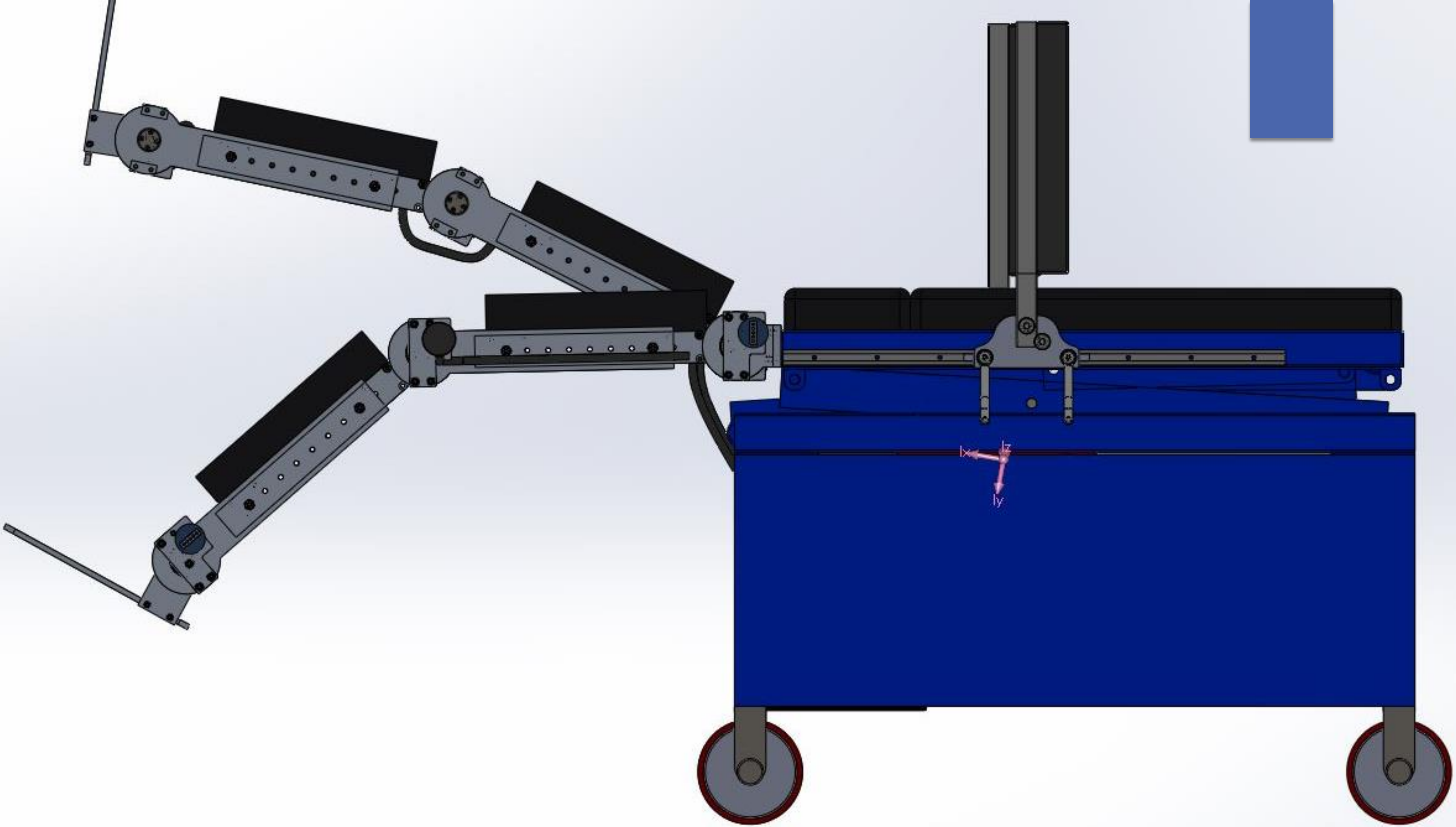
Budget

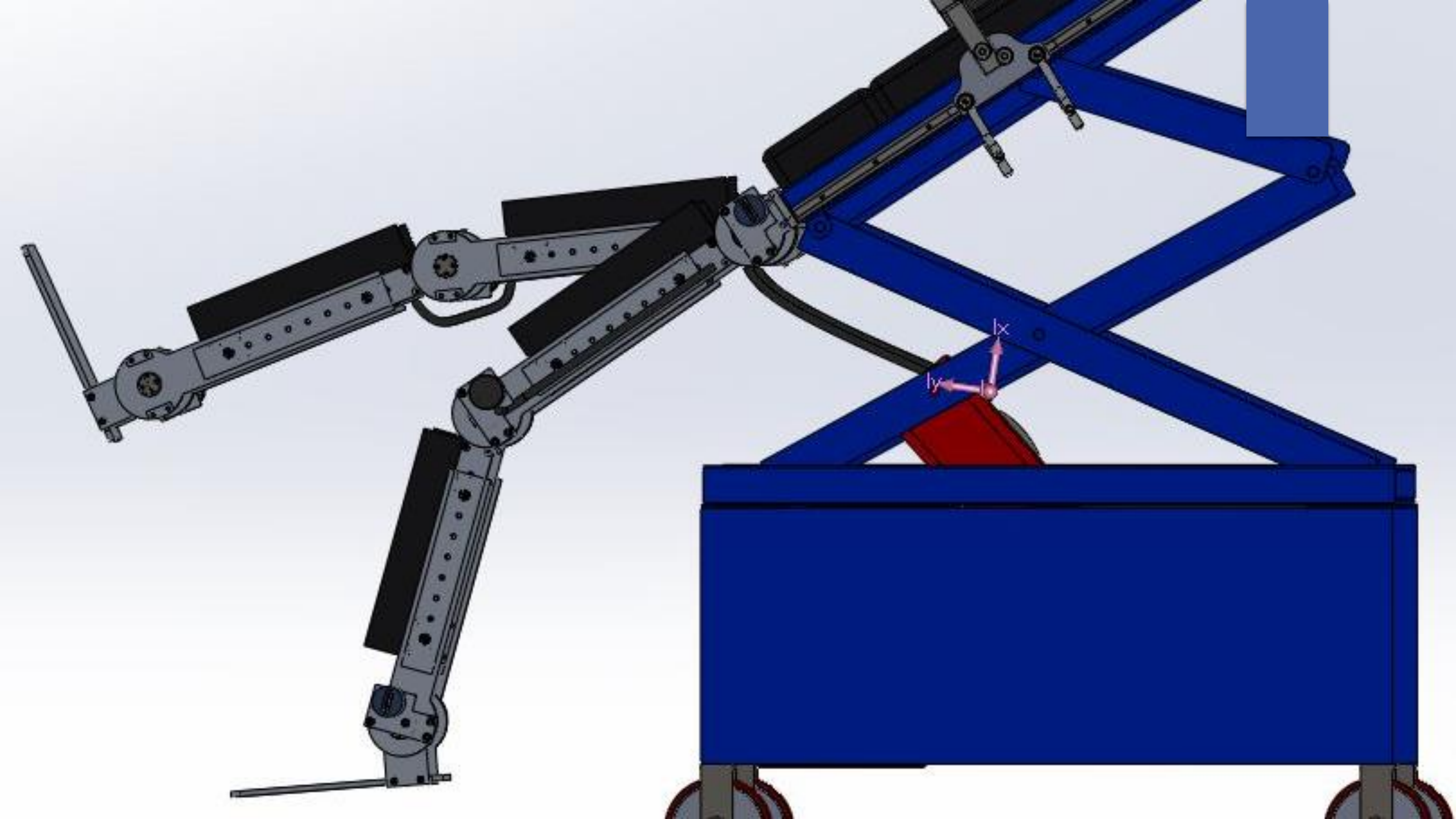
Part Name	Qty	PPU	Total Price
Aluminum Material	-	-	$93.84
24" Long Fixturing Track for Hex Head Screws	2	$7.10	$14.20
10-24 x 0.750" Hex-Drive Flat Head Screw	32	$8.56	$8.56
1/4 - 20 x 1.25" SHCS	24	$12.48	$12.48
8-32 x 0.375" SHCS	24	$10.89	$10.89
M3 - 0.5mm x 10mm Button Head Hex Screw	24	$7.77	$7.77
1/4 - 20 x 0.750" Grade 5 Hex Bolt	16	$8.53	$8.53
1/4 Hi-Collar Lockwasher	16	$10.38	$10.38
1/4 - 20 Wingnut	16	$10.94	$10.94
1/4 - 20 x 0.750" Hex Drive Flat Head Screw	4	$8.54	$8.54
10-24 x 0.750" SHCS	8	$12.07	$12.07
#10 Hi-Collar Lockwasher	8	$8.41	$8.41
1/2 - 13 Nylock Nut	10	$10.07	$10.07
Zinc-Plated Cast Iron Easy-Grip Handle with 3/8"-16 Thread	4	$3.79	$15.16
1/2" O.D. Shoulder Screw - 1.0" Shaft Length	4	$2.61	$10.44
1/4" - 20 x 1.0" High Strength Steel Threaded Rod	4	$3.13	$12.52
10-32, 3/8" Pan Head Phillips Screw	16	$13.88	$13.88
10-32 Medium-Strength Steel Nylon-Insert Flange Locknut	16	$6.85	$6.85
UHMW Wear Plate	10	$8.14	$8.14
12 RPM Motor (12VDC)	6	$59.99	$359.94
32 Pitch - 48 Tooth x 0.500" Gear	6	$12.99	$77.94
32 Pitch - 16 Tooth x 6mm D-Shaft Gear	6	$7.99	$47.94
1.125" x 0.500" ID Ball Bearing	12	$6.27	$75.24
FA-400-12-2-P	1	$139.00	$139.00
Cytron MD20A	6	$19.80	$118.80
Transformer	1	$17.99	$17.99
Arduino Nano	6	$4.29	$25.74
Arduino Mega2560	1	-	-
Eaton Neutral Bar	1	$6.55	$6.55
4x 100' - 18 AWG Wire	1	$15.95	$15.95
Memory Foam	1	$34.99	$34.99
		Total:	$1,203.75

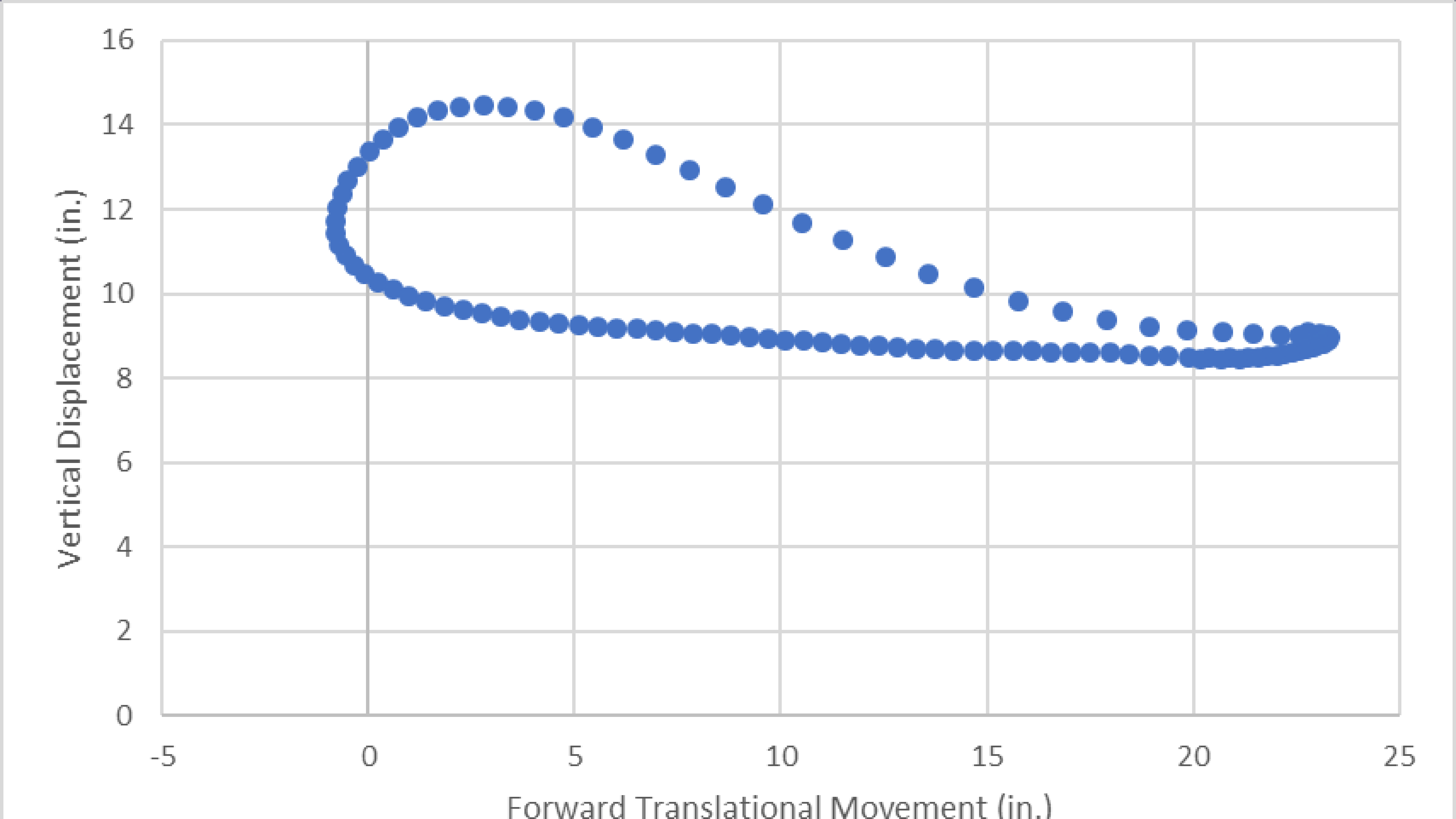
Questions?

Appendix

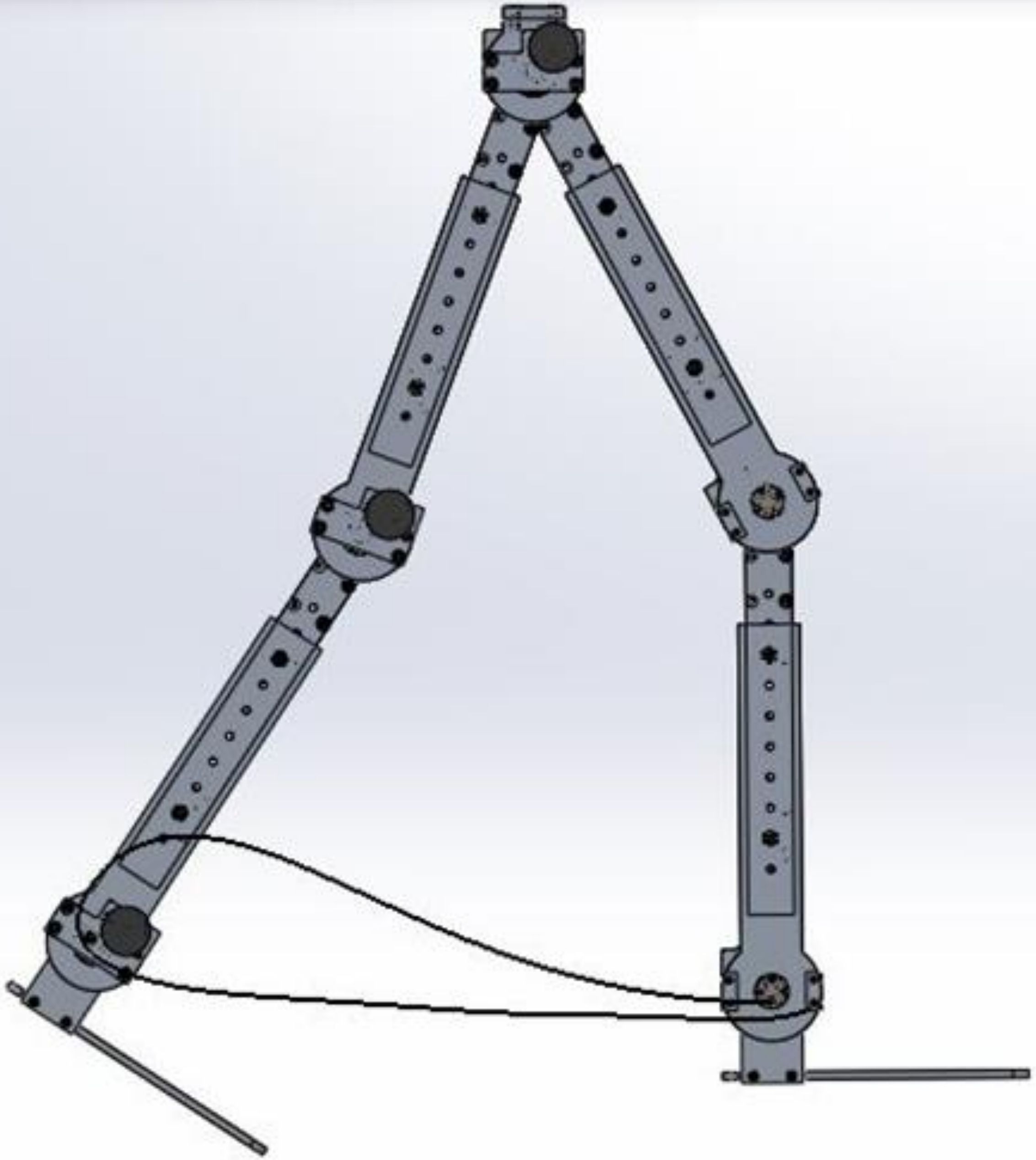


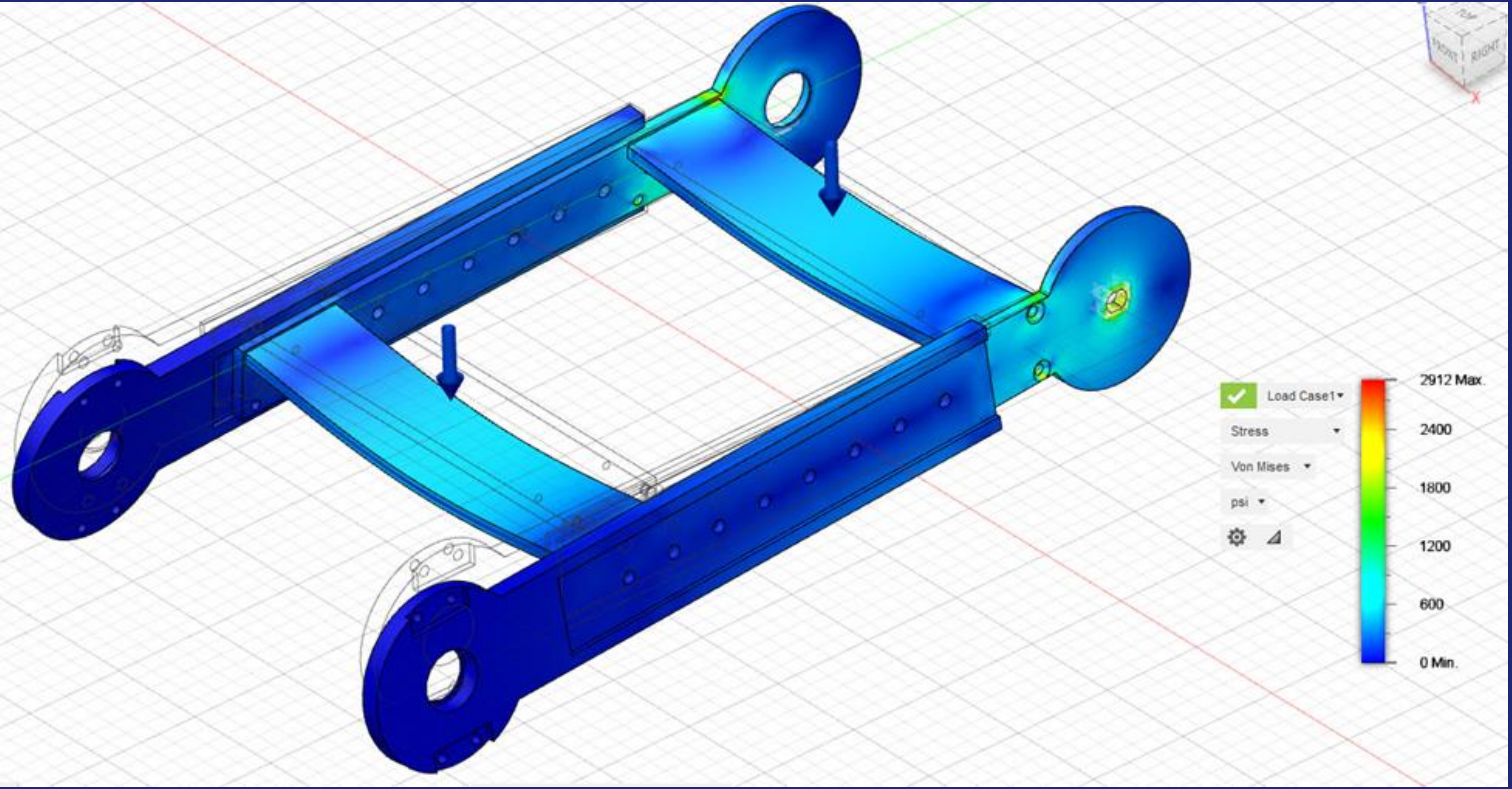

Ix
Iz
Iy


lx
ly

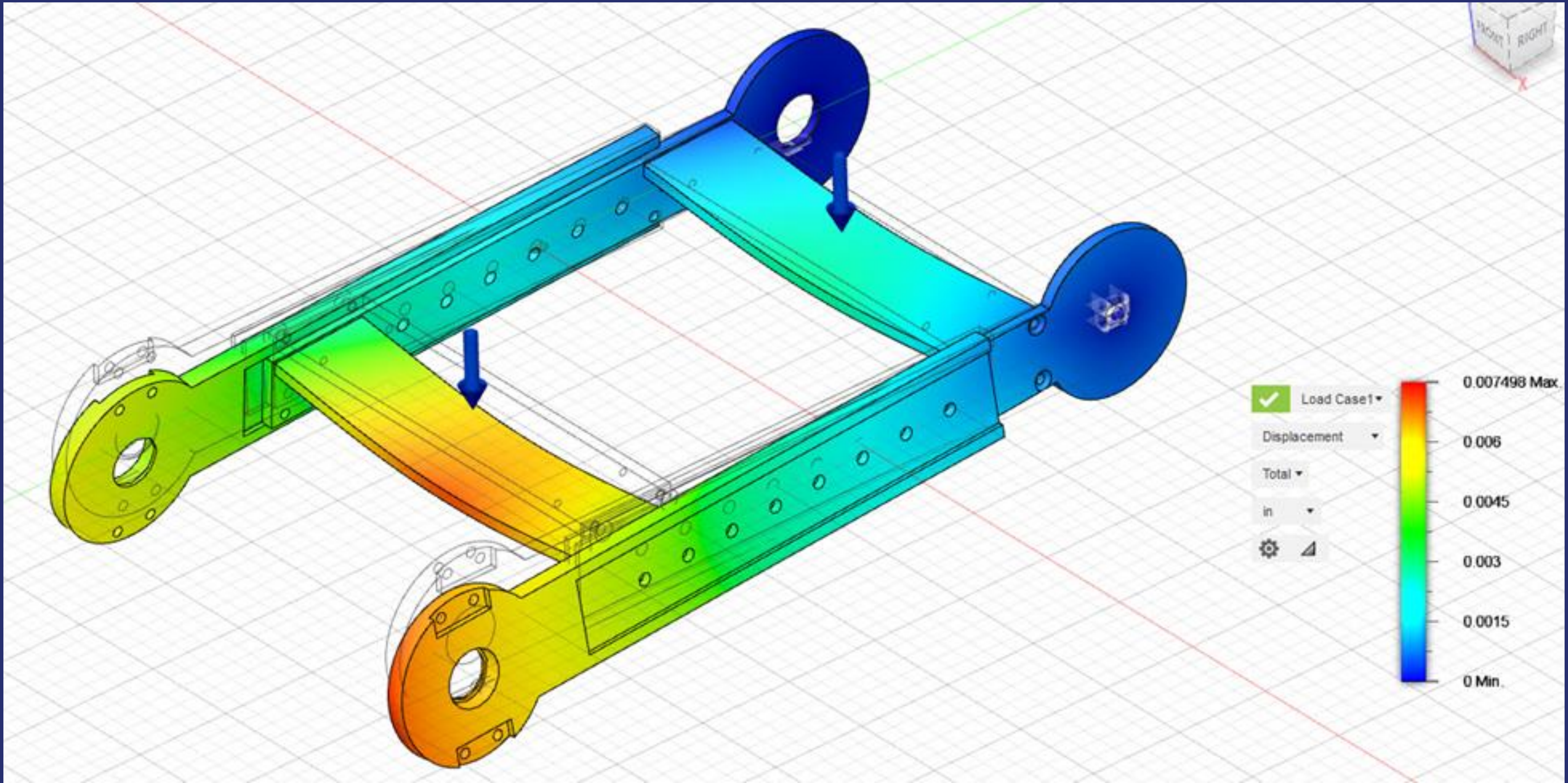


16
14
12
10
8
6
4
2
0
-5
0
5
10
15
20
25
Vertical Displacement (in.)
Forward Translational Movement (in.)

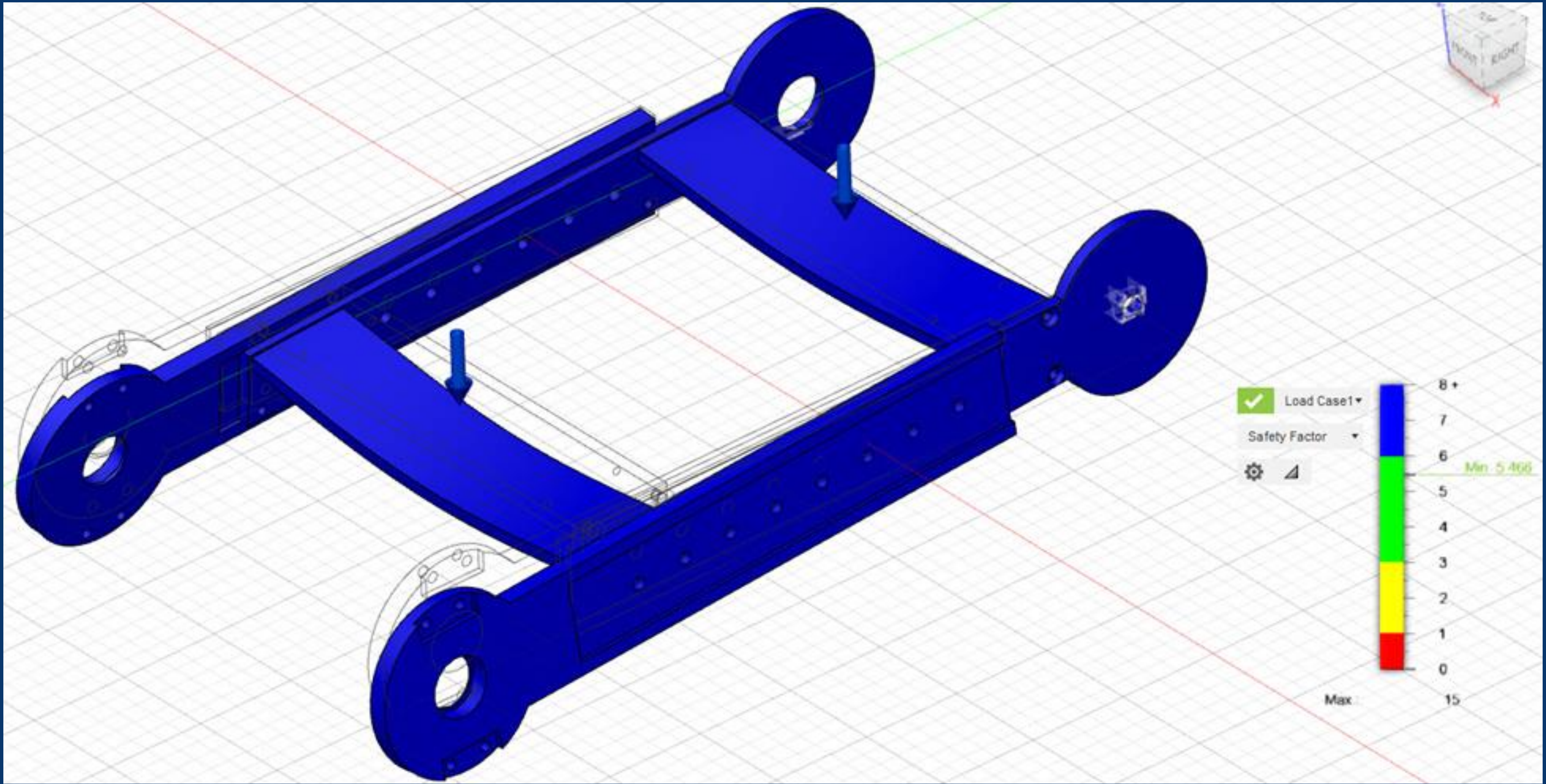


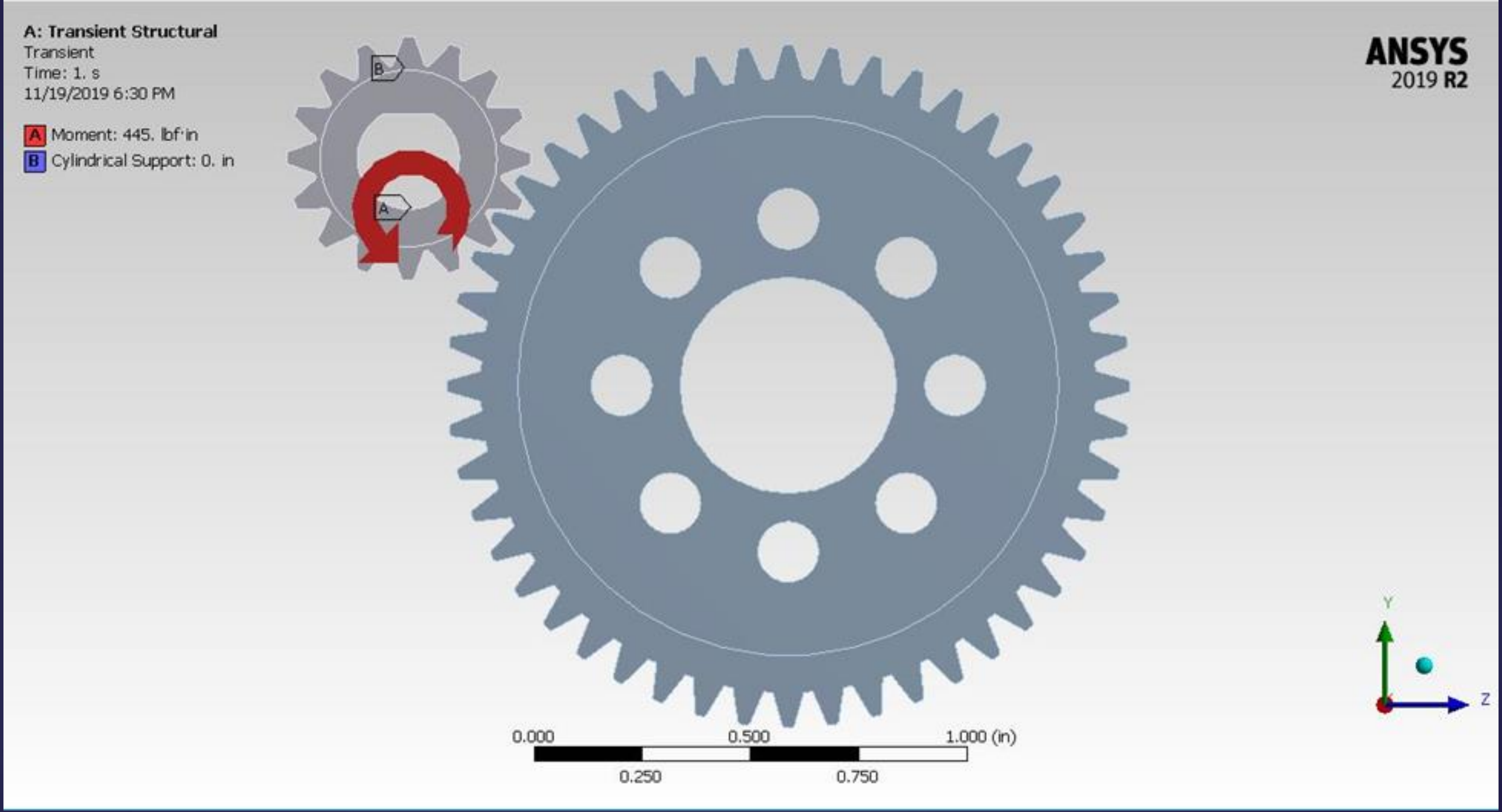


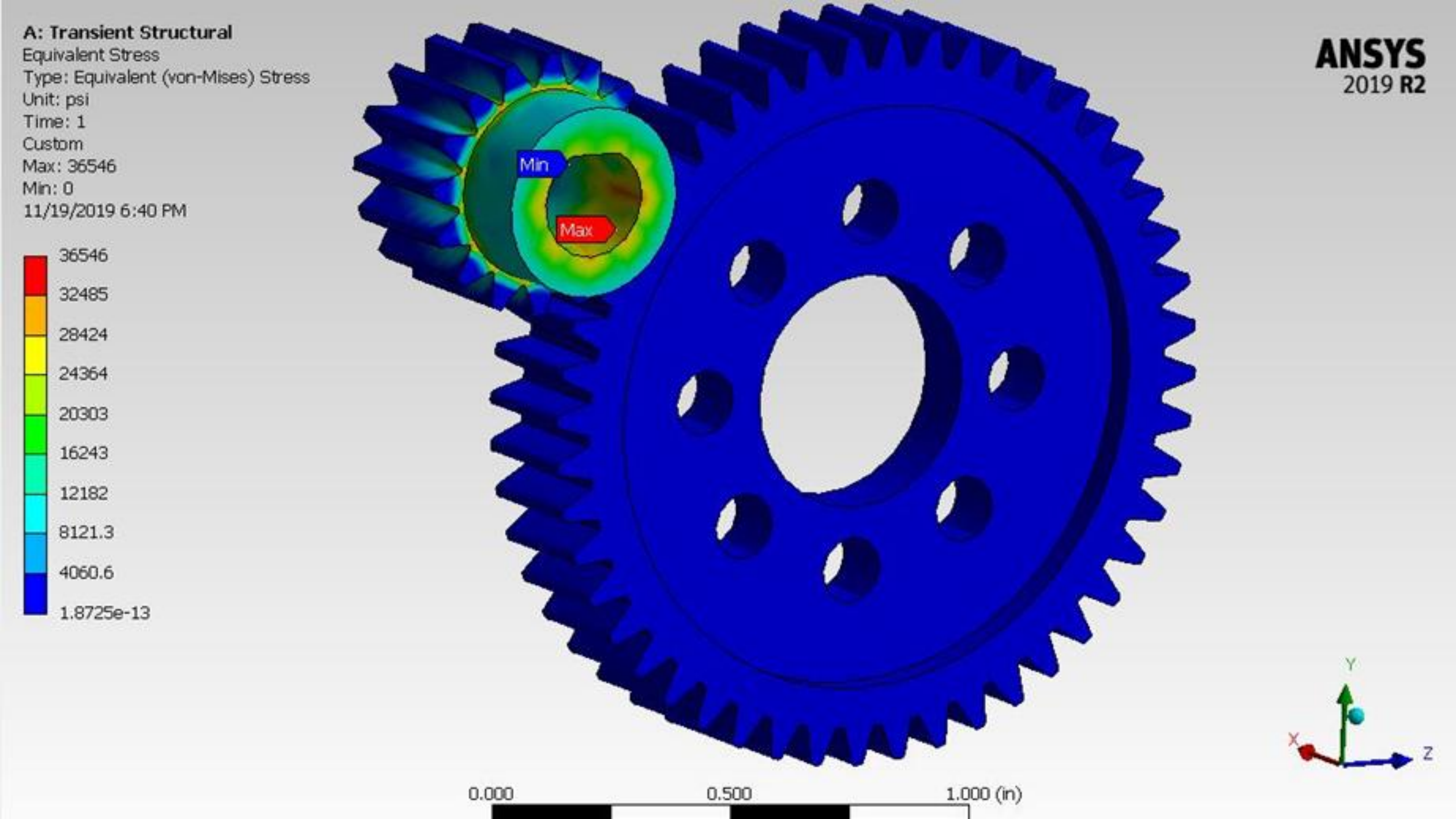
Load Case1
Stress
Von Mises
psi
2912 Max.
2400
1800
1200
600
0 Min.

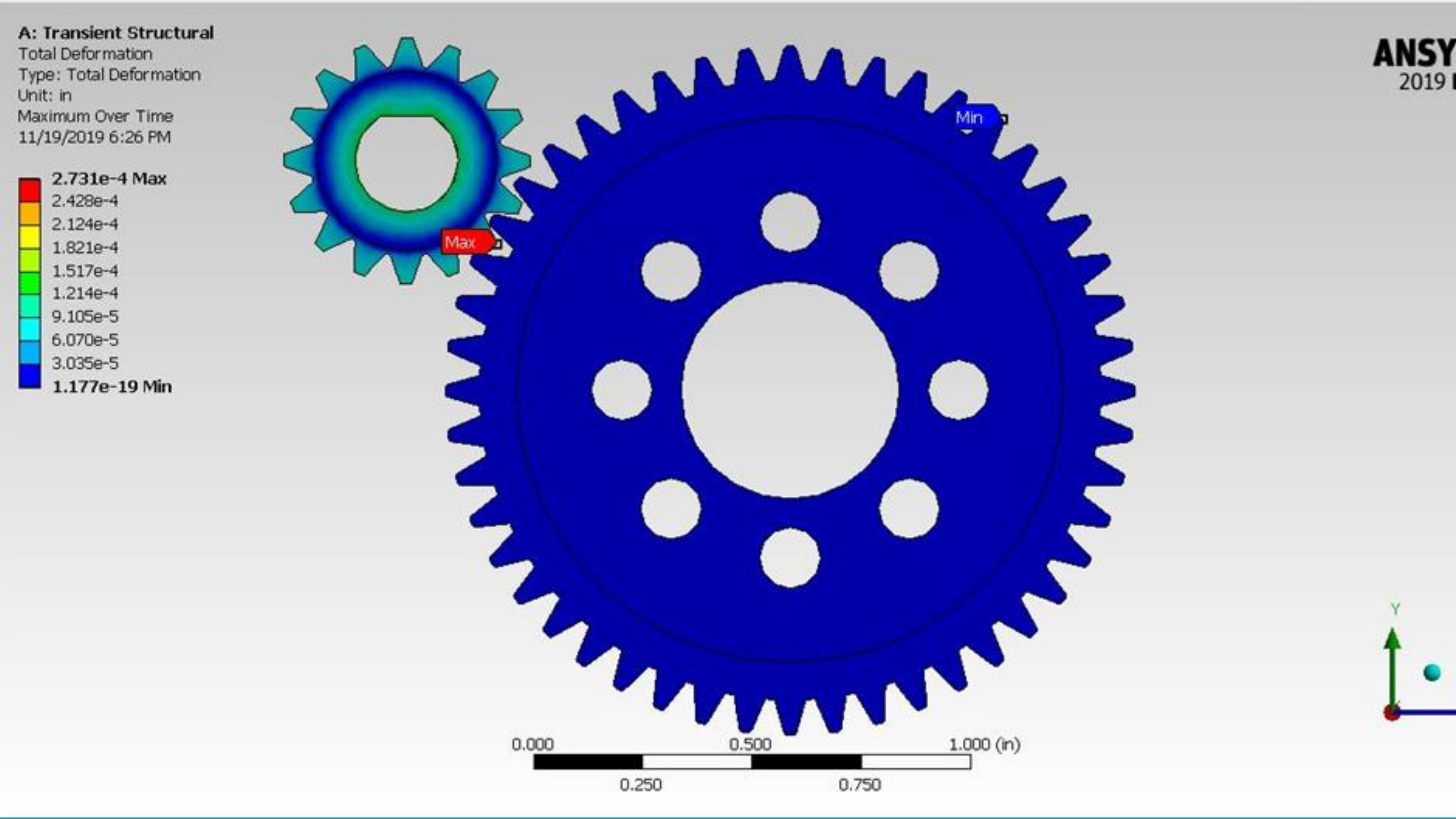


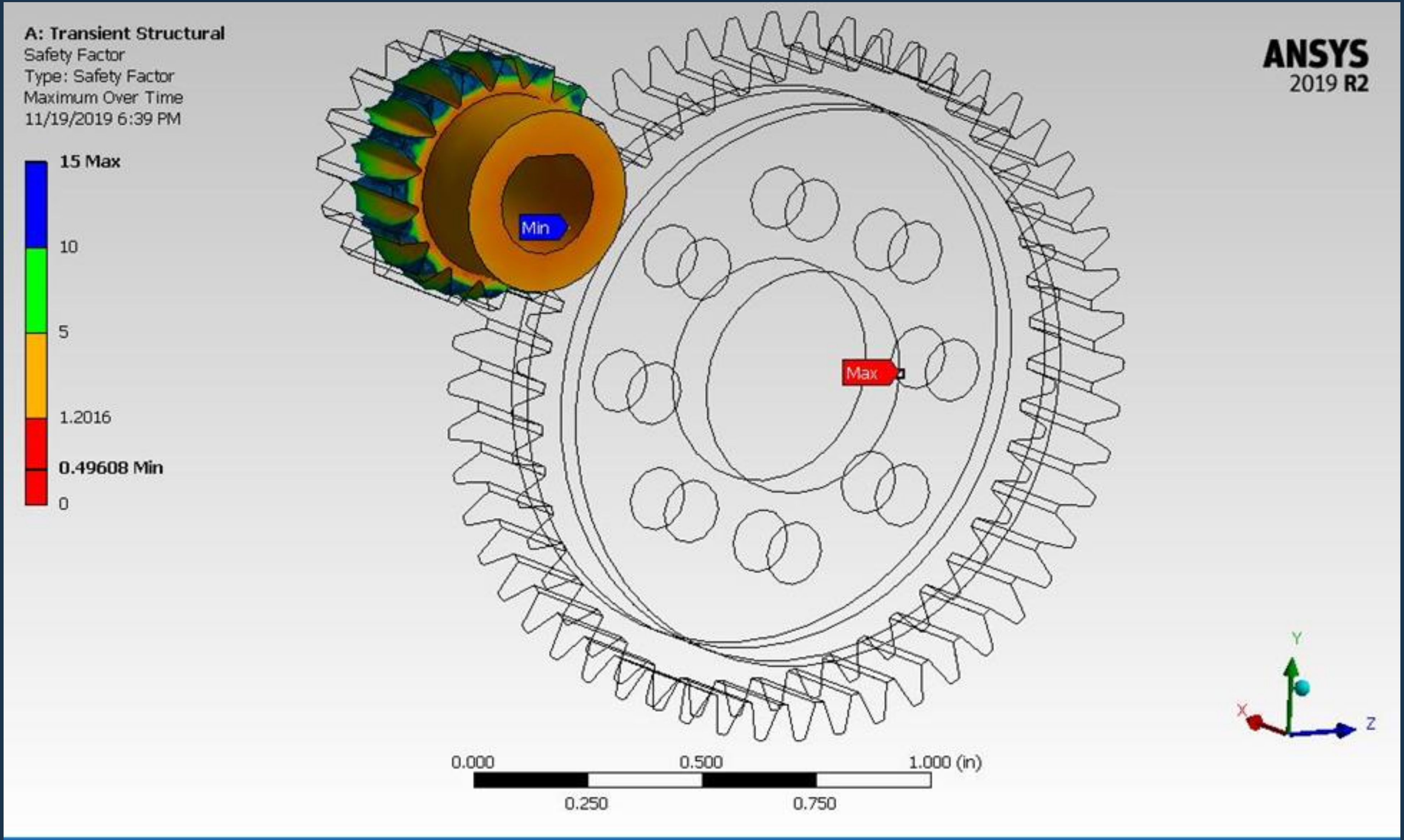
Load Case1
Displacement
Total
in
0.007498 Max.
0.006
0.0045
0.003
0.0015
0 Min.
FRONT
RIGHT


Load Case1
Safety Factor
8 +
7
6
5
4
3
2
1
0
Min: 5.466
Max: 15


A: Transient Structural
Transient
Time: 1. s
11/19/2019 6:30 PM
A Moment: 445. lbf·in
B Cylindrical Support: 0. in
ANSYS
2019 R2
0.000
0.500
1.000 (in)
0.250
0.750
Y
Z

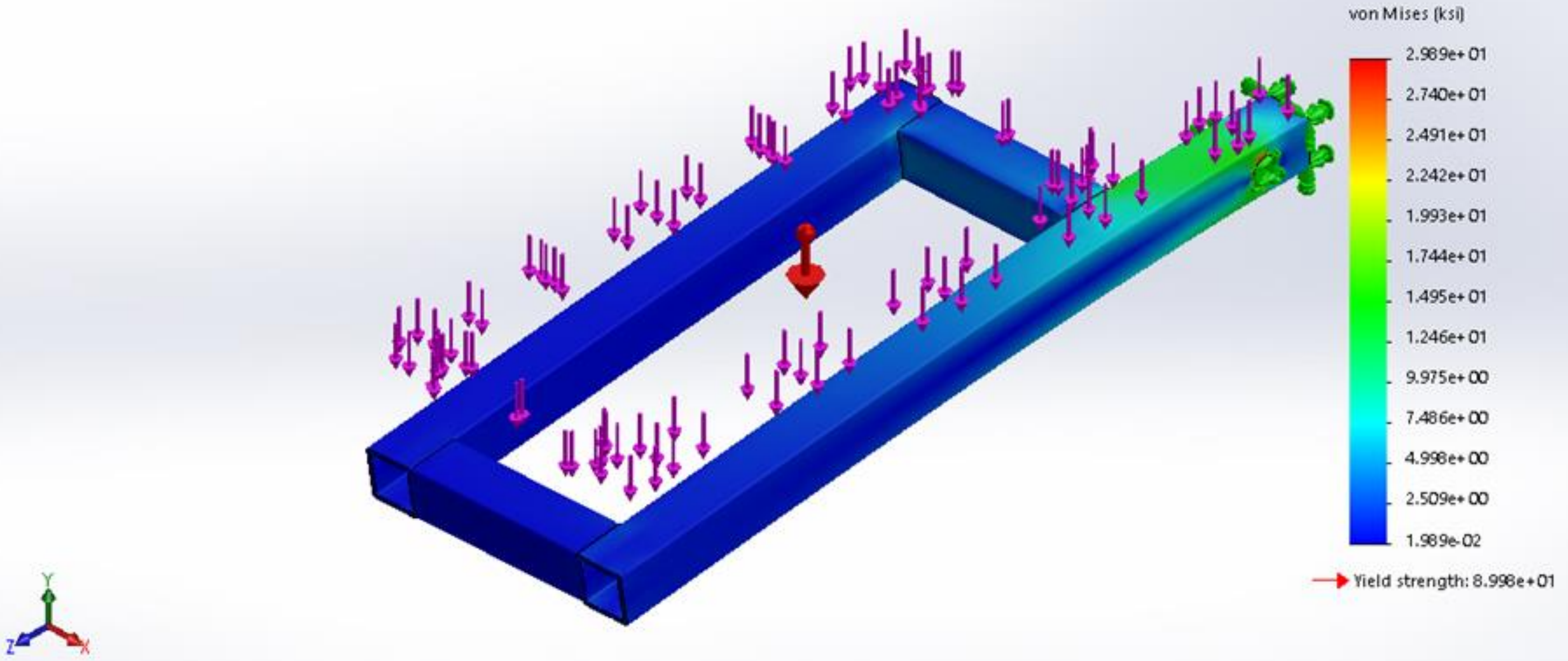

A: Transient Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: psi
Time: 1
Custom
Max: 36546
Min: 0
11/19/2019 6:40 PM
36546
32485
28424
24364
20303
16243
12182
8121.3
4060.6
1.8725e-13
Min
Max
ANSYS
2019 R2
Y
X
Z
0.000
0.500
1.000 (in)

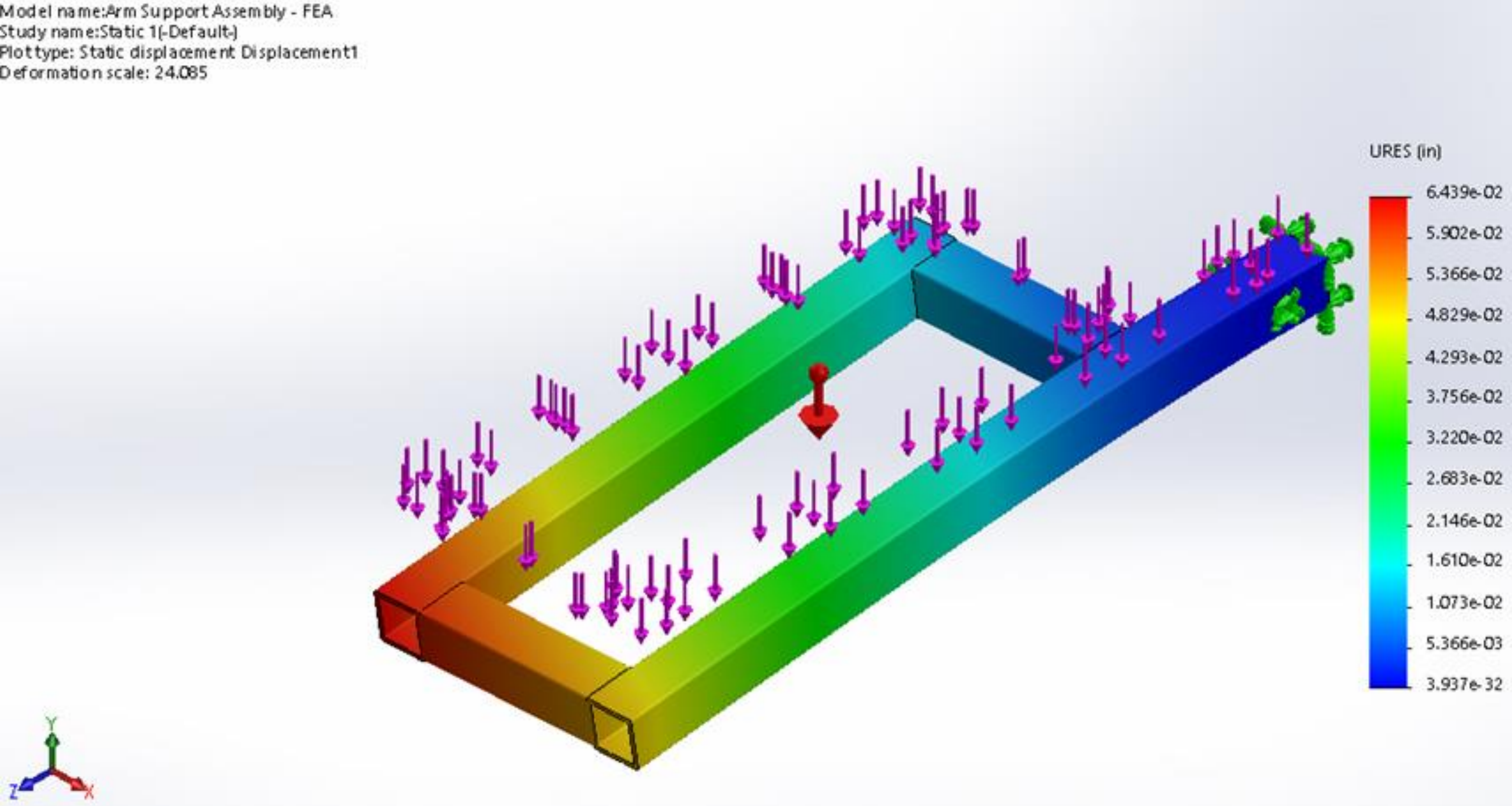

A: Transient Structural
Total Deformation
Type: Total Deformation
Unit: in
Maximum Over Time
11/19/2019 6:26 PM
2.731e-4 Max
2.428e-4
2.124e-4
1.821e-4
1.517e-4
1.214e-4
9.105e-5
6.070e-5
3.035e-5
1.177e-19 Min
Max
Min
0.000
0.250
0.500
0.750
1.000 (in)
Y

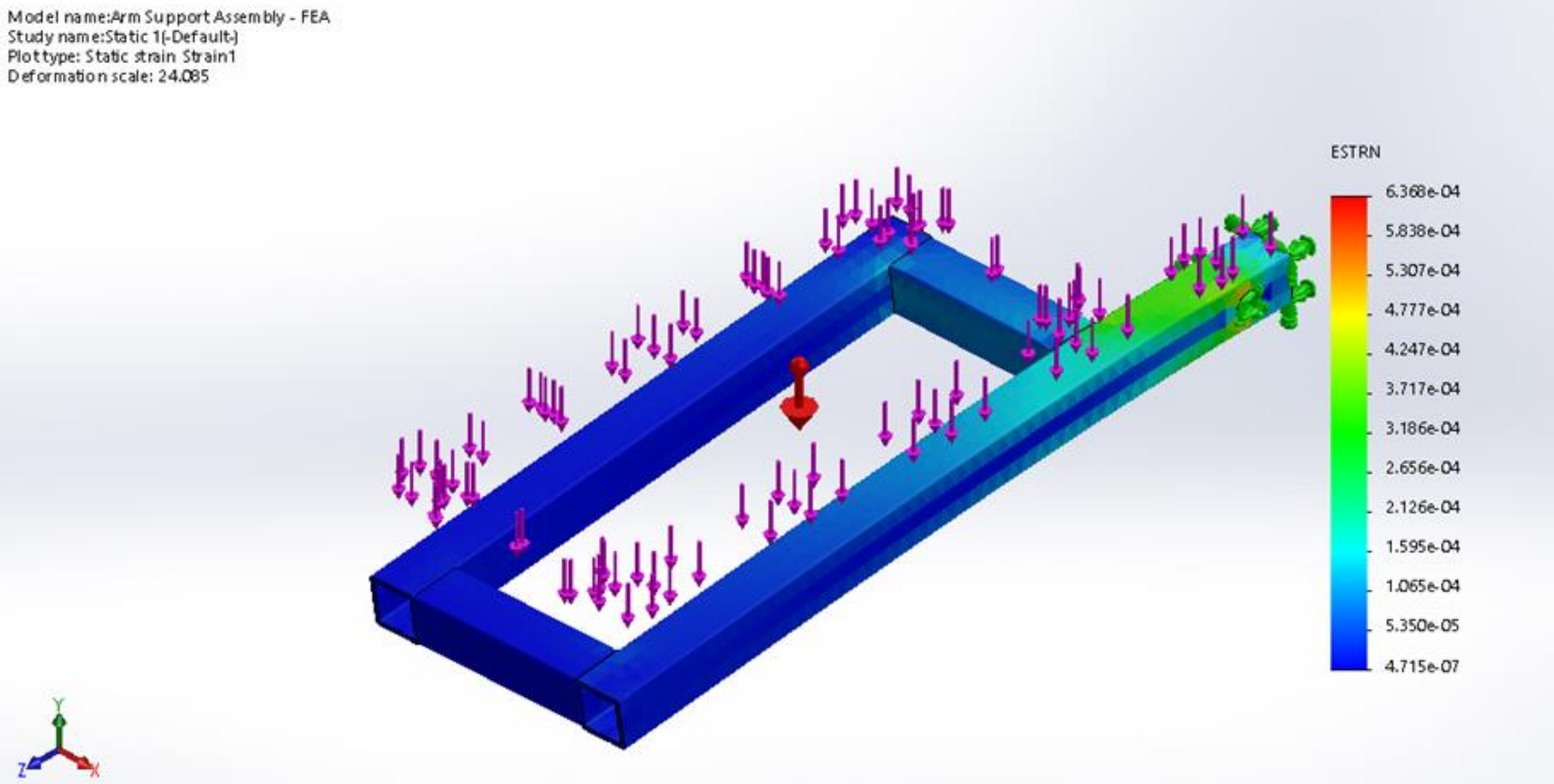


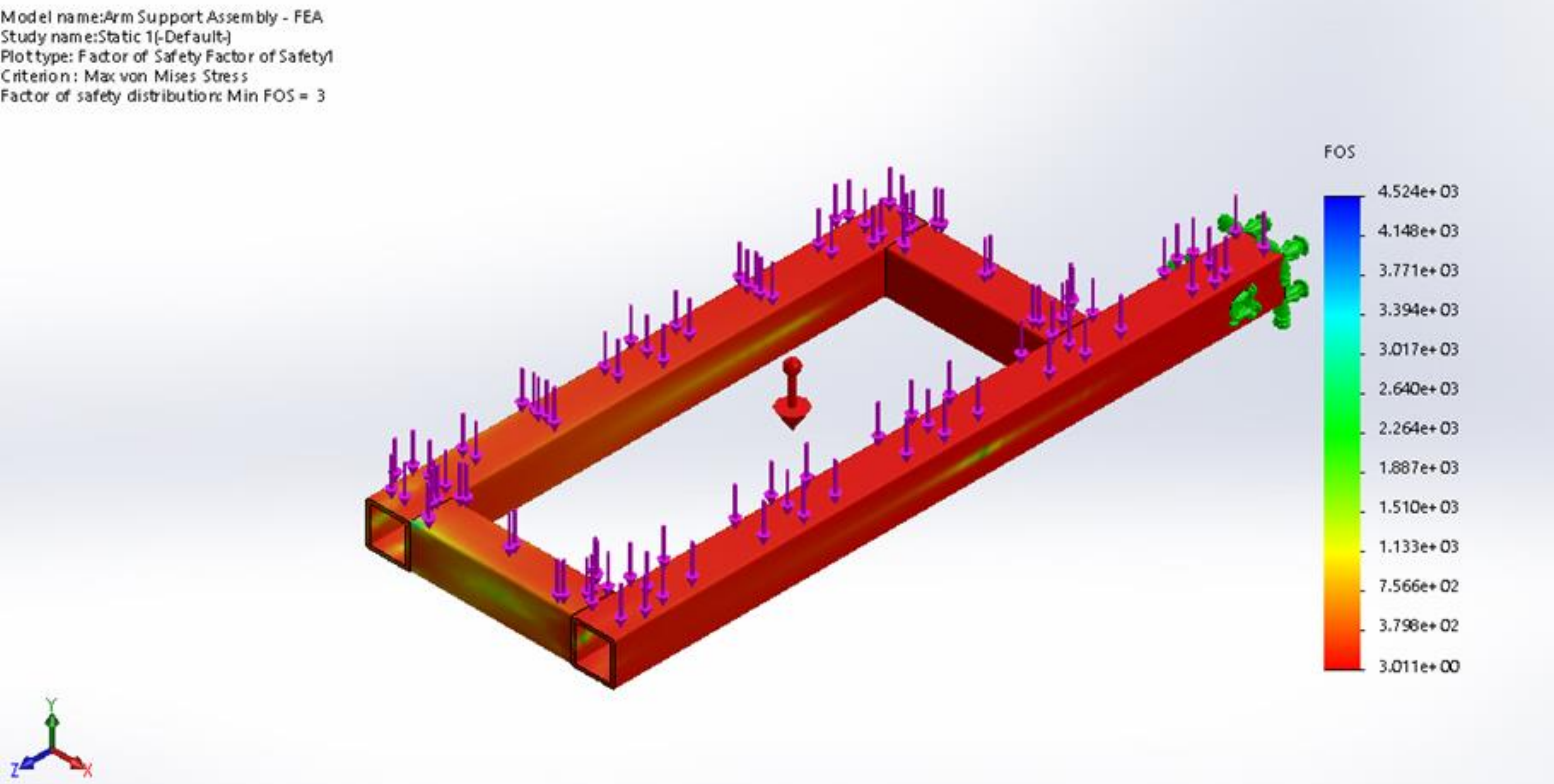
A: Transient Structural
Safety Factor
Type: Safety Factor
Maximum Over Time
11/19/2019 6:39 PM
15 Max
10
5
1.2016
0.49608 Min
0
Min
Max
ANSYS
2019 R2
0.000
0.500
1.000 (in)
0.250
0.750
Y
X
Z

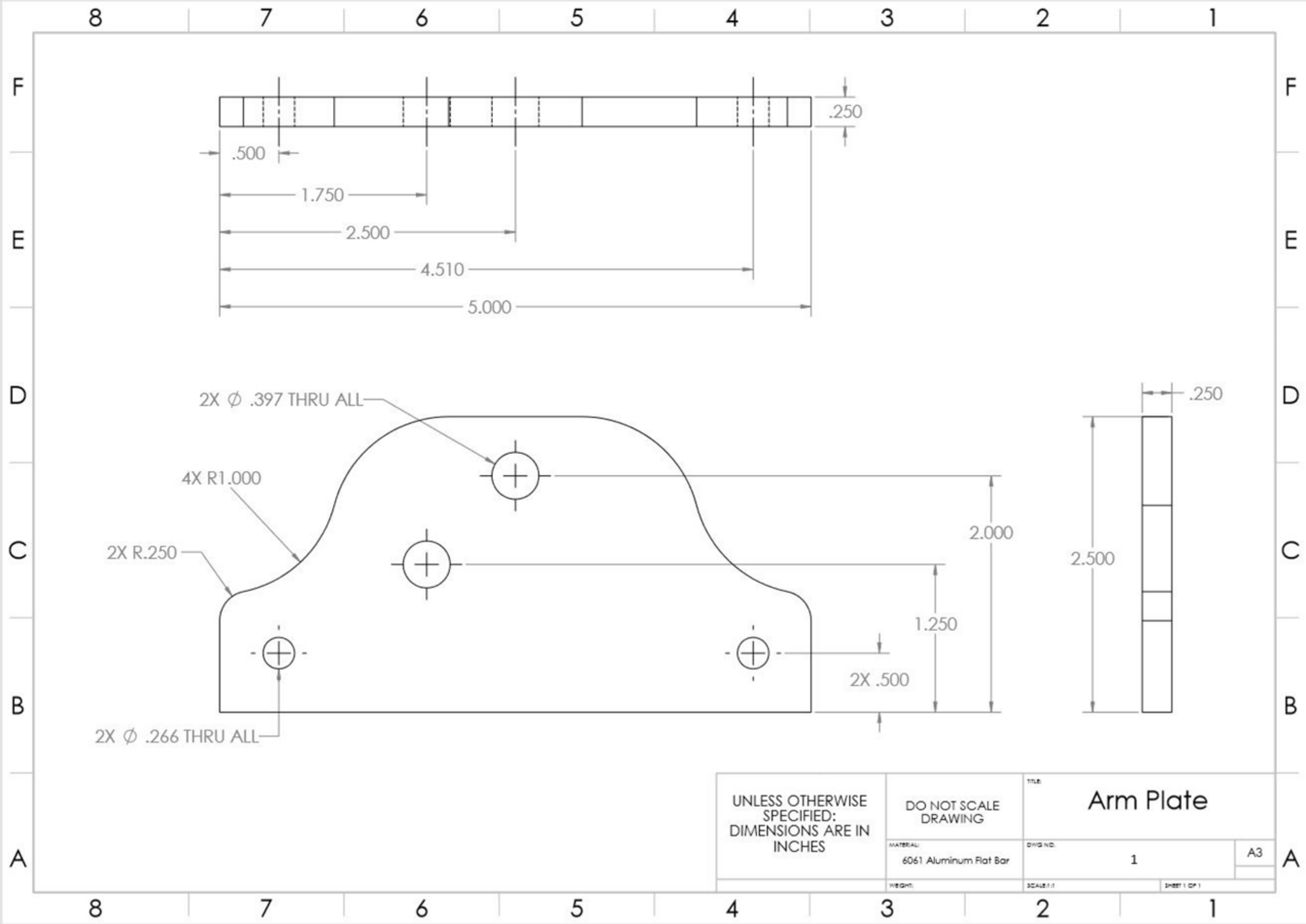
Model name:Arm Support Assembly - FEA
Study name:Static 1(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 24.085

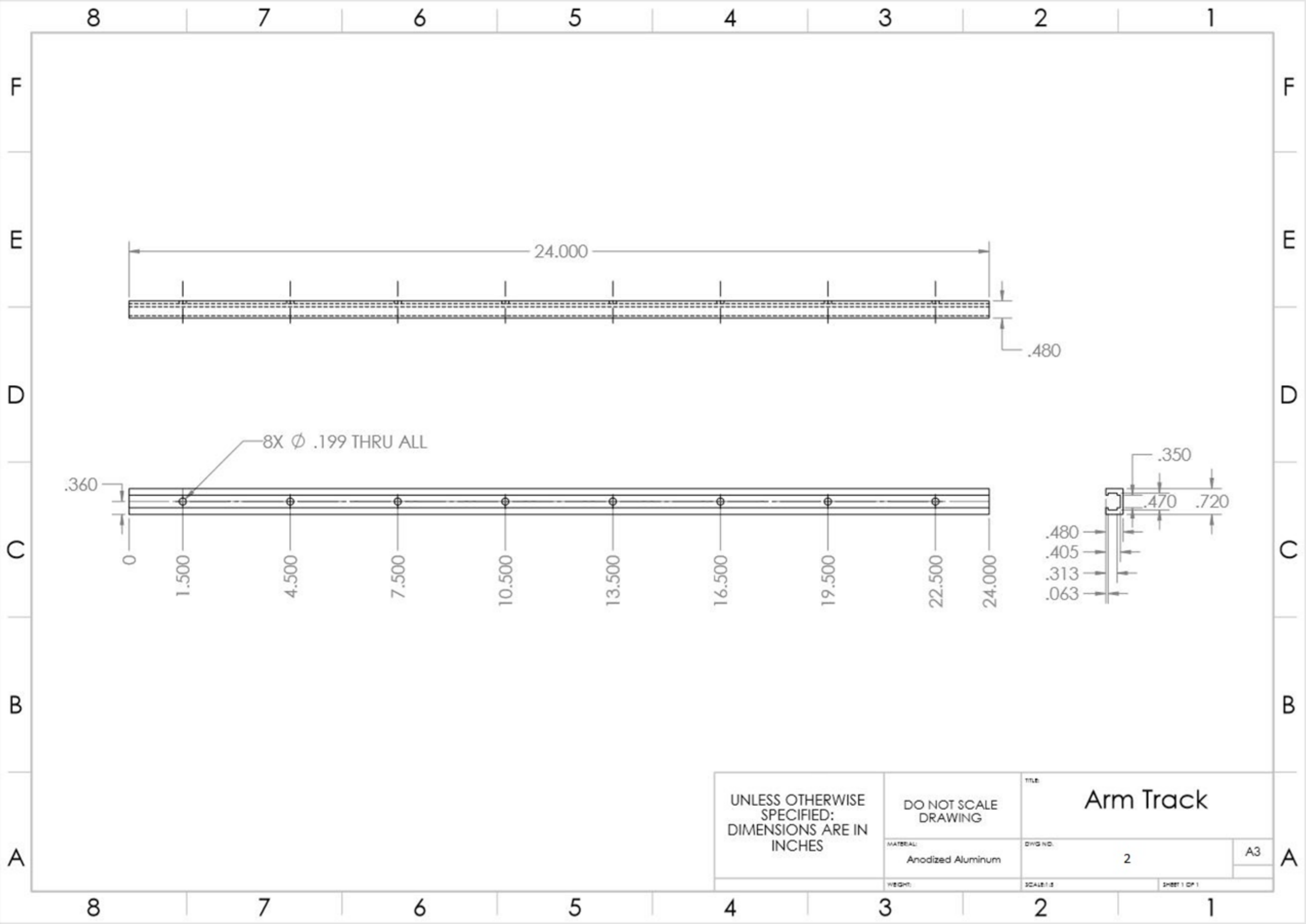


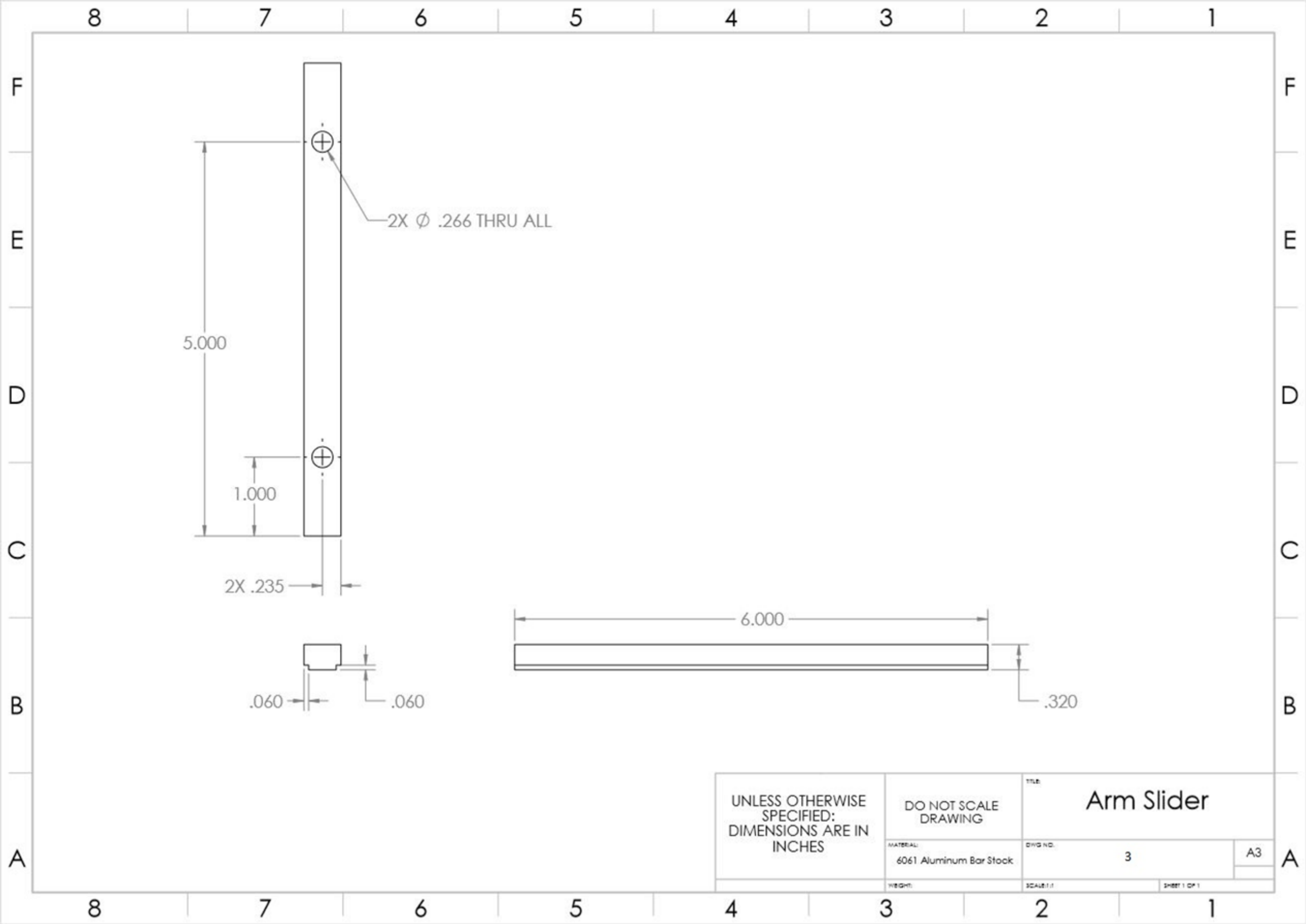

Model name:Arm Support Assembly - FEA
Study name:Static 1(-Default-)
Plot type: Static displacement Displacement1
Deformation scale: 24.085
URES (in)
6.439e-02
5.902e-02
5.366e-02
4.829e-02
4.293e-02
3.756e-02
3.220e-02
2.683e-02
2.146e-02
1.610e-02
1.073e-02
5.366e-03
3.937e-32
Y
Z
X

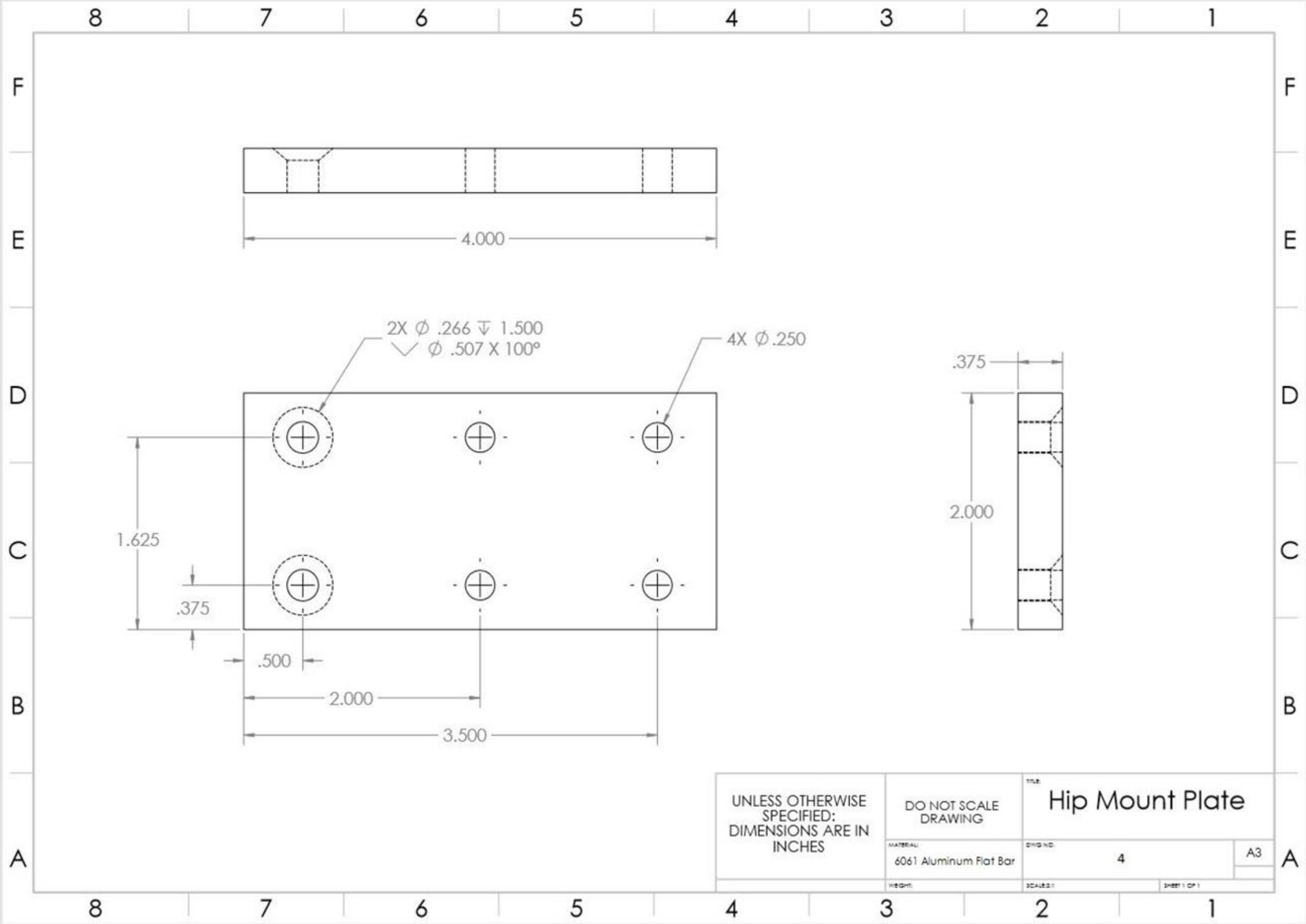

Model name:Arm Support Assembly - FEA
Study name:Static 1(-Default-)
Plot type: Static strain Strain1
Deformation scale: 24.085
ESTRN
6.368e-04
5.838e-04
5.307e-04
4.777e-04
4.247e-04
3.717e-04
3.186e-04
2.656e-04
2.126e-04
1.595e-04
1.065e-04
5.350e-05
4.715e-07
Y
Z
X


Model name:Arm Support Assembly - FEA
Study name:Static 1(-Default-)
Plot type: Factor of Safety Factor of Safety1
Criterion : Max von Mises Stress
Factor of safety distribution: Min FOS = 3
FOS
4.524e+03
4.148e+03
3.771e+03
3.394e+03
3.017e+03
2.640e+03
2.264e+03
1.887e+03
1.510e+03
1.133e+03
7.566e+02
3.798e+02
3.011e+00
Y
Z
X

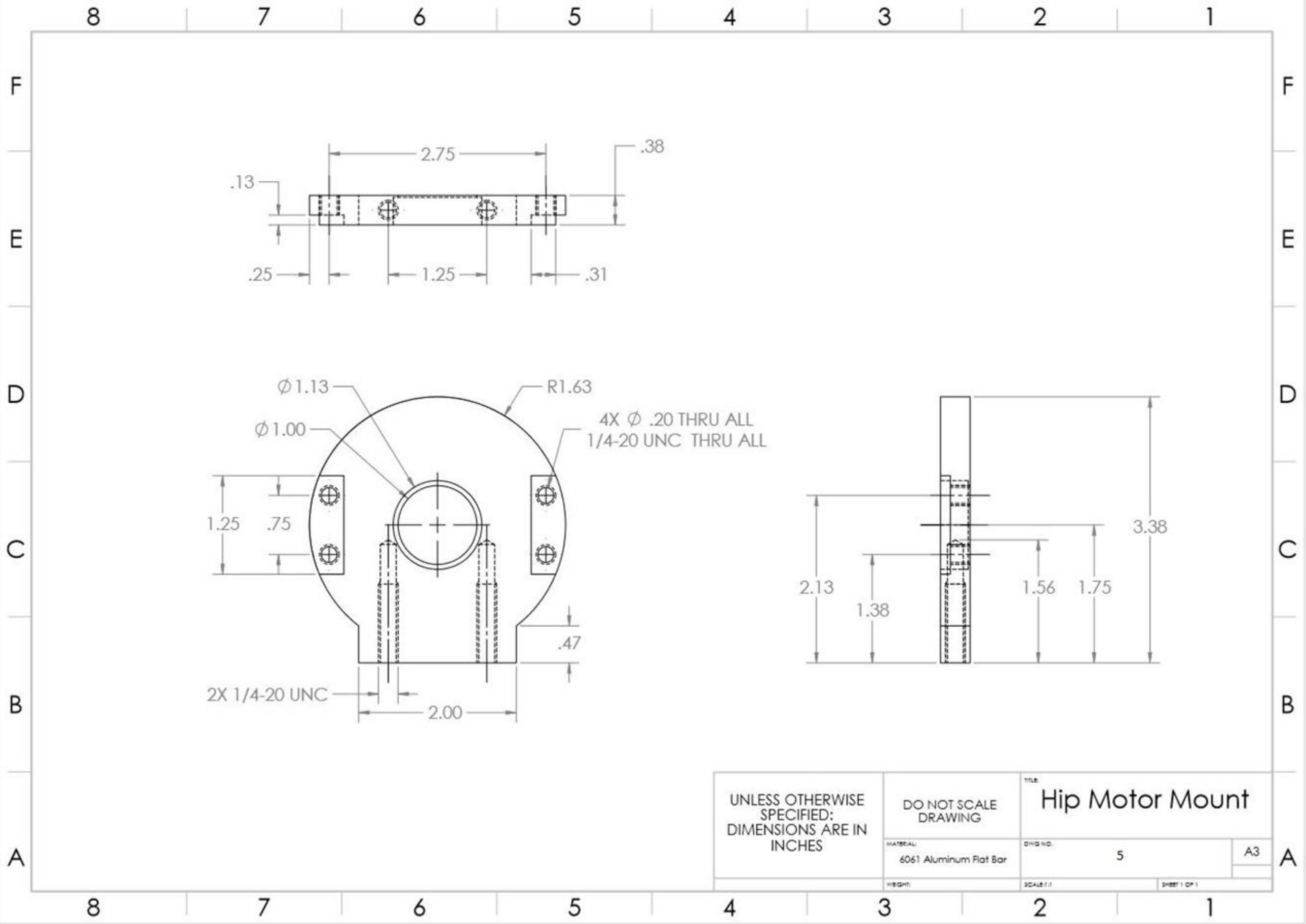

.250
.500
1.750
2.500
4.510
5.000
2X ∅ .397 THRU ALL
4X R1.000
2X R.250
2X ∅ .266 THRU ALL
2.000
1.250
2X .500
.250
2.500
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
Arm Plate
6061 Aluminum Flat Bar
1
A3


24.000
.480
8X ∅ .199 THRU ALL
.360
0
1.500
4.500
7.500
10.500
13.500
16.500
19.500
22.500
24.000
.350
.470
.720
.480
.405
.313
.063
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
Arm Track
Anodized Aluminum
2
A3

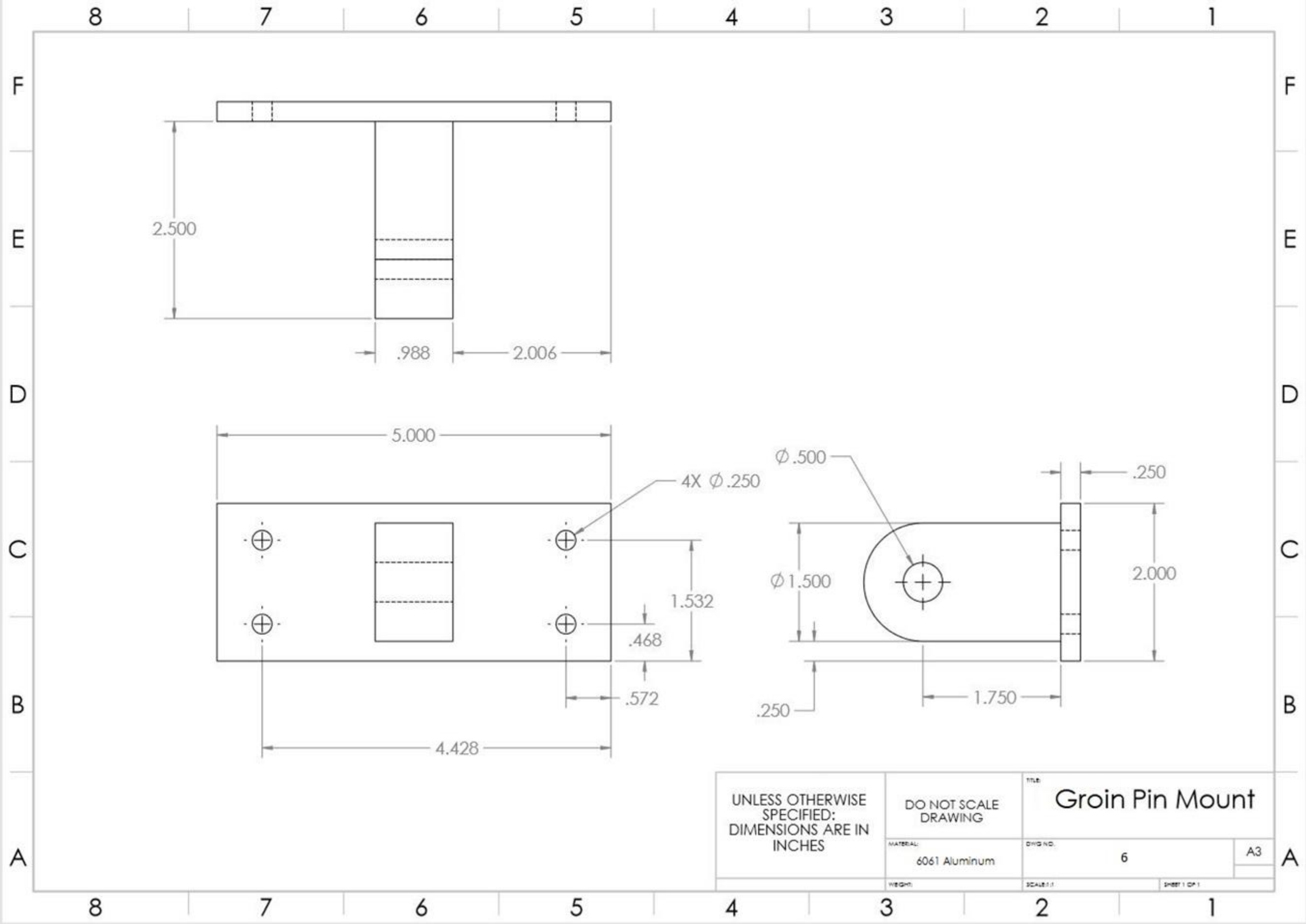

2X ∅ .266 THRU ALL
5.000
1.000
2X .235
6.000
.060
.060
.320
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
TITLE:
Arm Slider
MATERIAL:
6061 Aluminum Bar Stock
DWG NO.
3
A3
WEIGHT:
SCALE:1:1
SHEET 1 OF 1

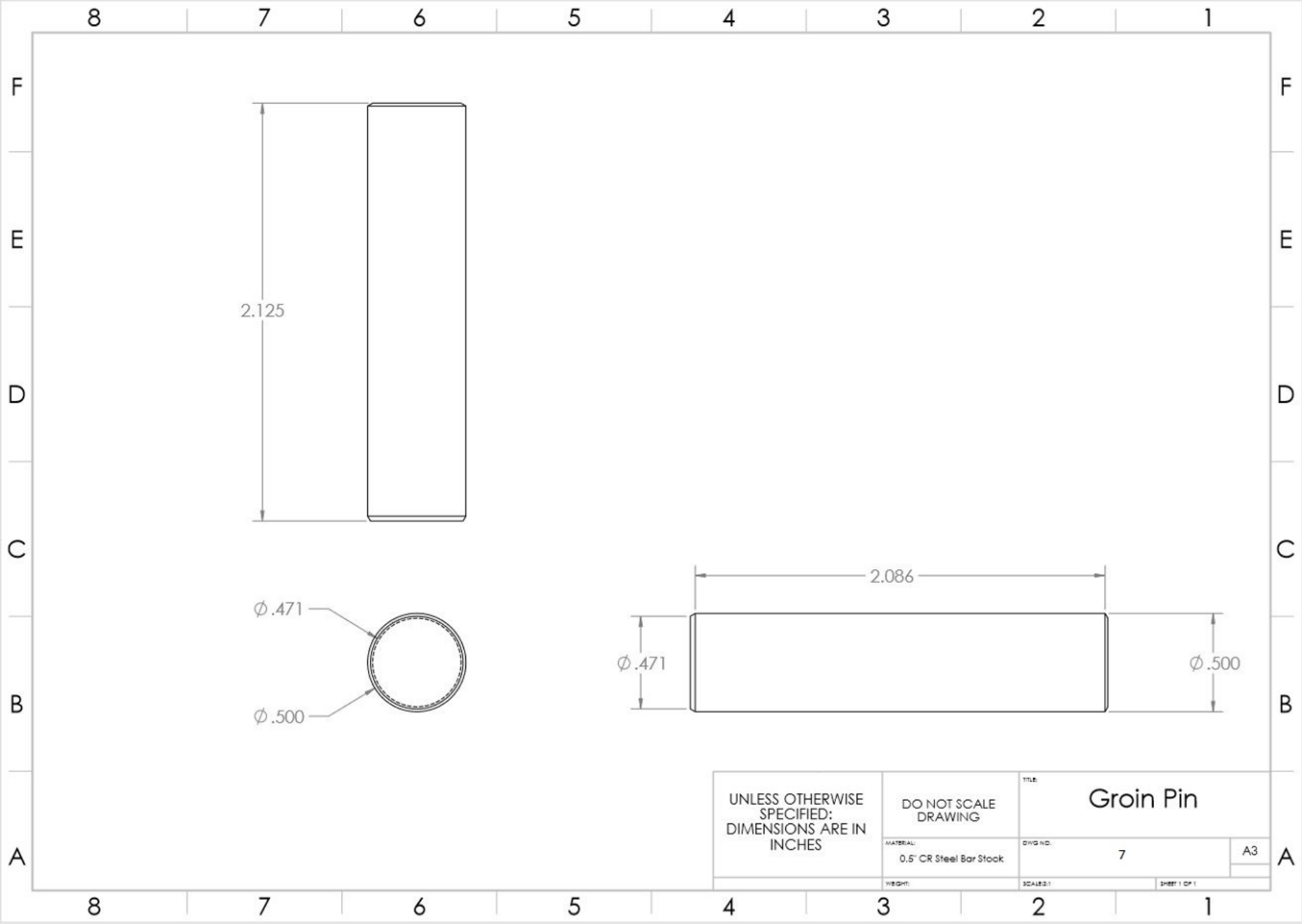


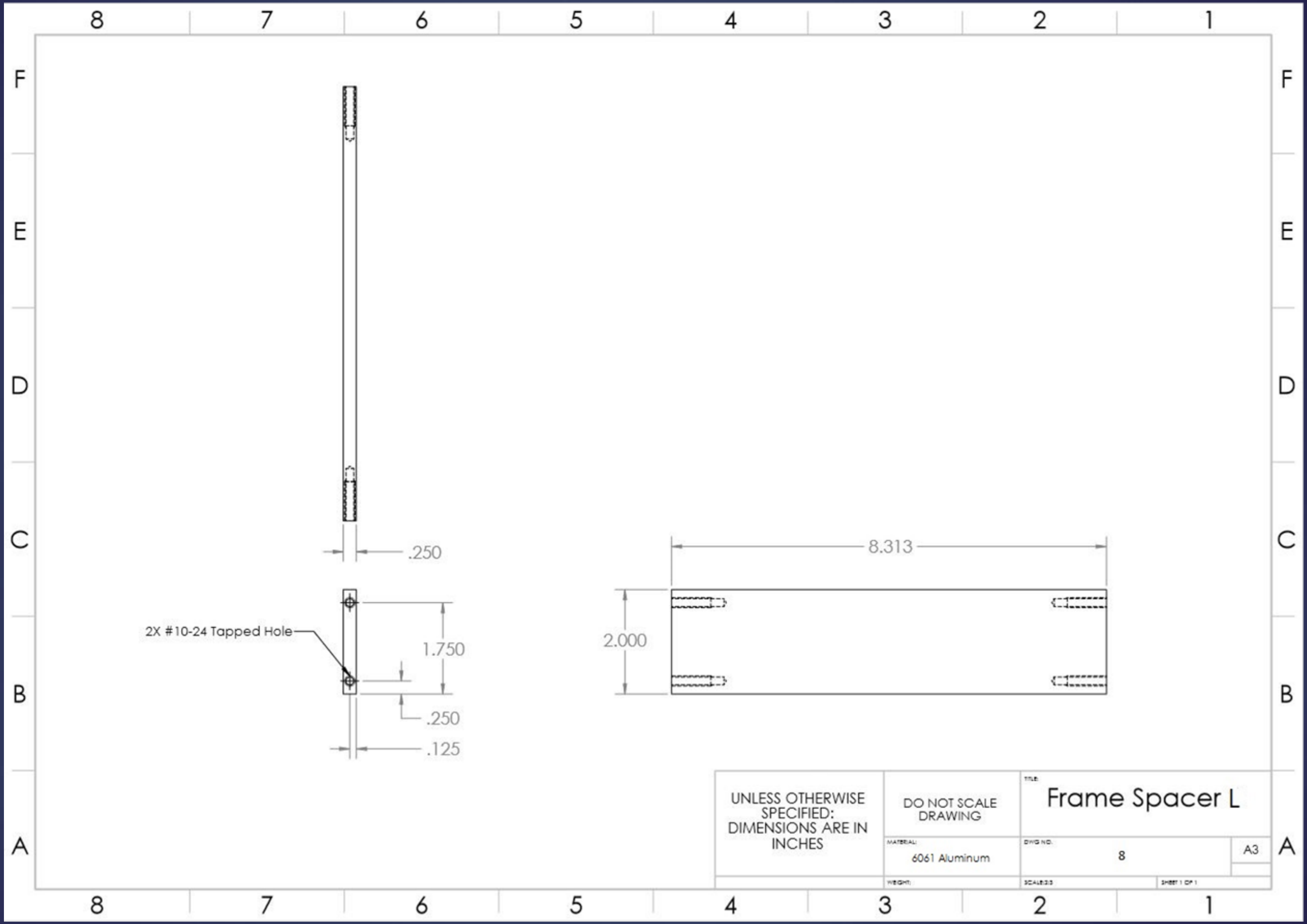
4.000
2X ∅ .266 ↧ 1.500
⌵ ∅ .507 X 100°
4X ∅ .250
1.625
.375
.500
2.000
3.500
.375
2.000
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
Hip Mount Plate
6061 Aluminum Flat Bar
4
A3



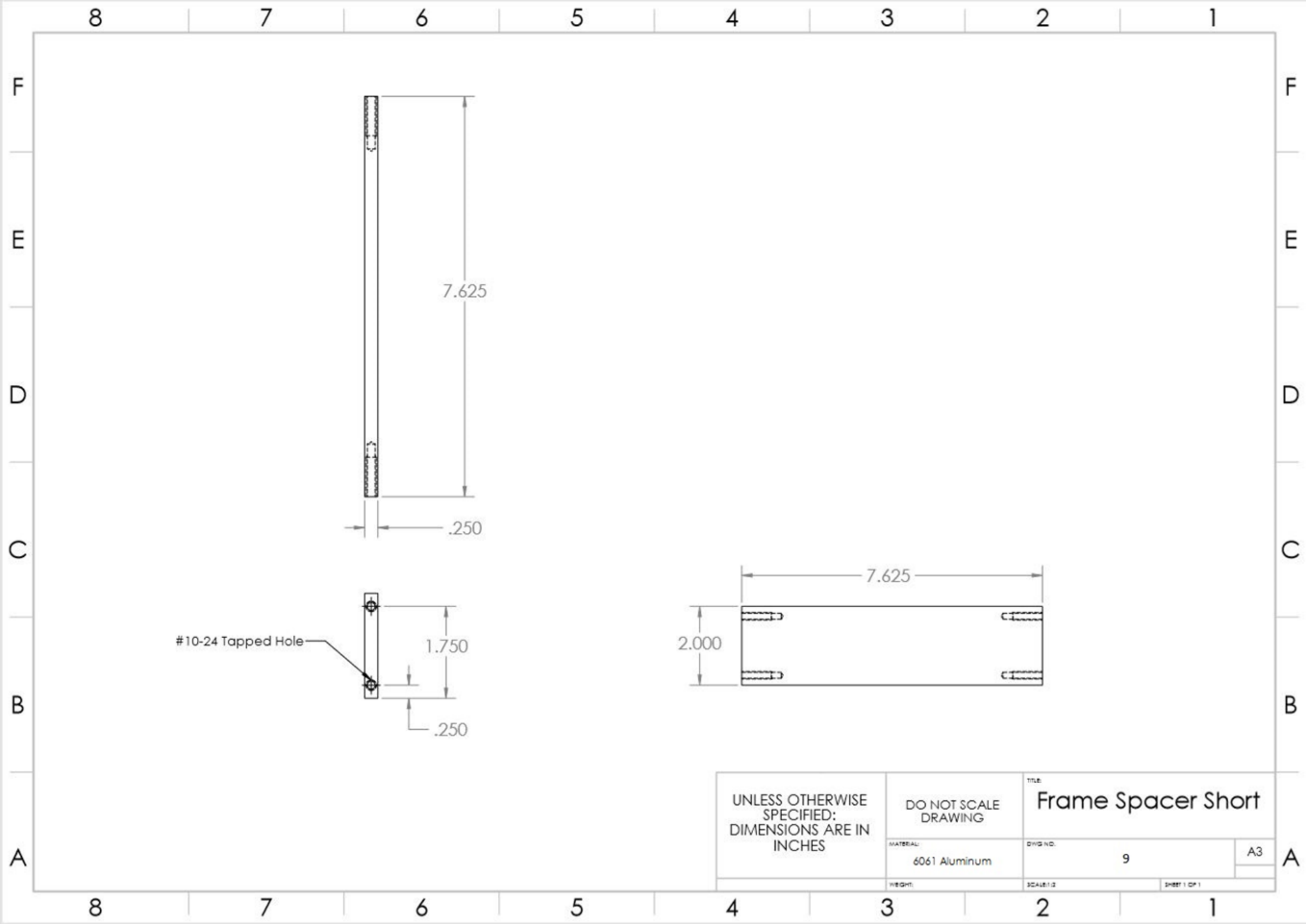
2.75
.38
.13
.25
1.25
.31
Ø1.13
R1.63
Ø1.00
4X Ø .20 THRU ALL
1/4-20 UNC THRU ALL
1.25
.75
.47
2X 1/4-20 UNC
2.00
3.38
2.13
1.38
1.56
1.75
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
Hip Motor Mount
6061 Aluminum Flat Bar
5
A3


2.500
.988
2.006
5.000
4X ∅ .250
1.532
.468
.572
4.428
∅ .500
.250
∅ 1.500
2.000
1.750
.250
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
Groin Pin Mount
6061 Aluminum
6
A3

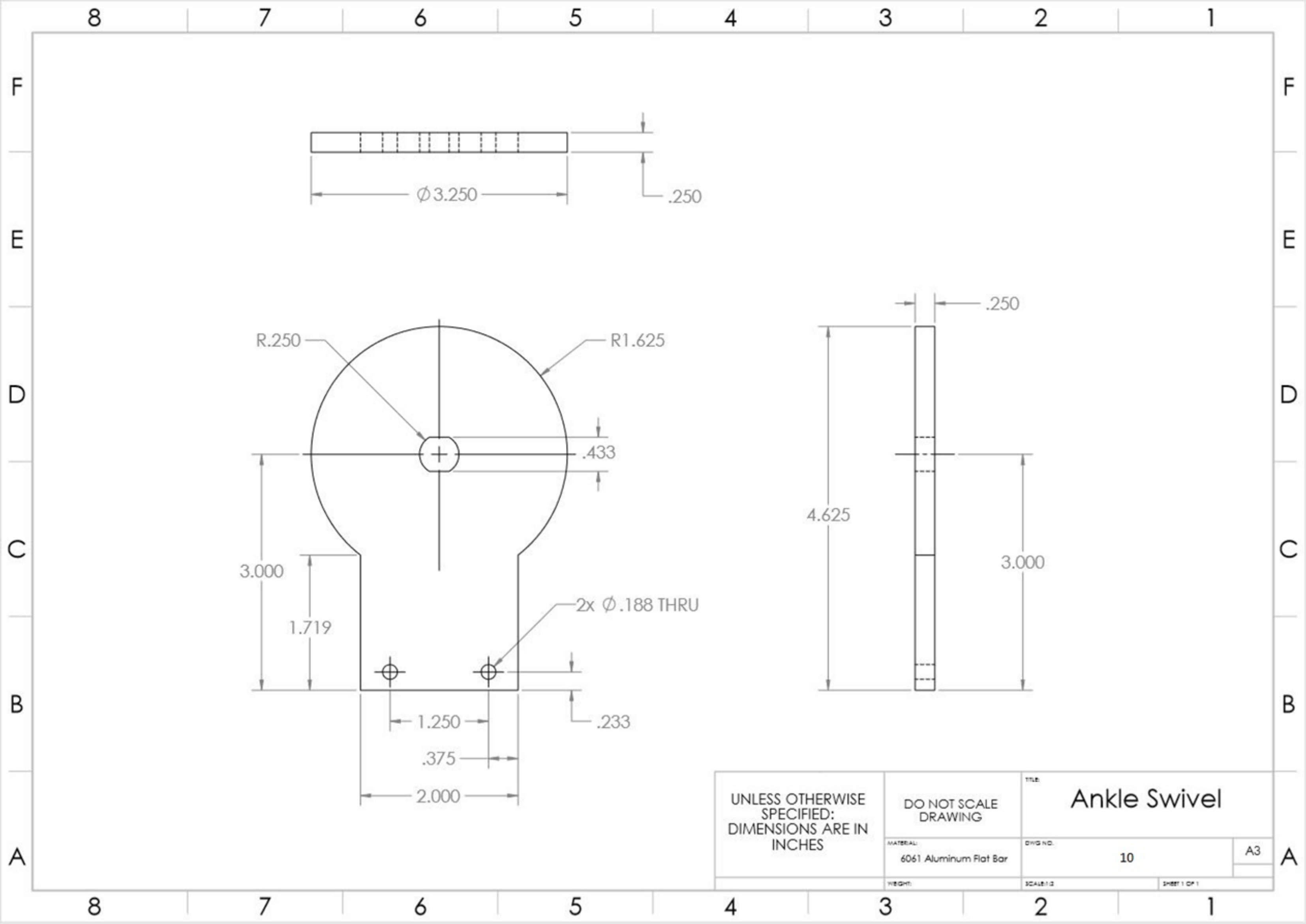

2.125
Ø .471
Ø .500
2.086
Ø .471
Ø .500
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
TITLE:
Groin Pin
MATERIAL:
0.5" CR Steel Bar Stock
DWG NO.
7
A3
WEIGHT:
SCALE:2:1
SHEET 1 OF 1



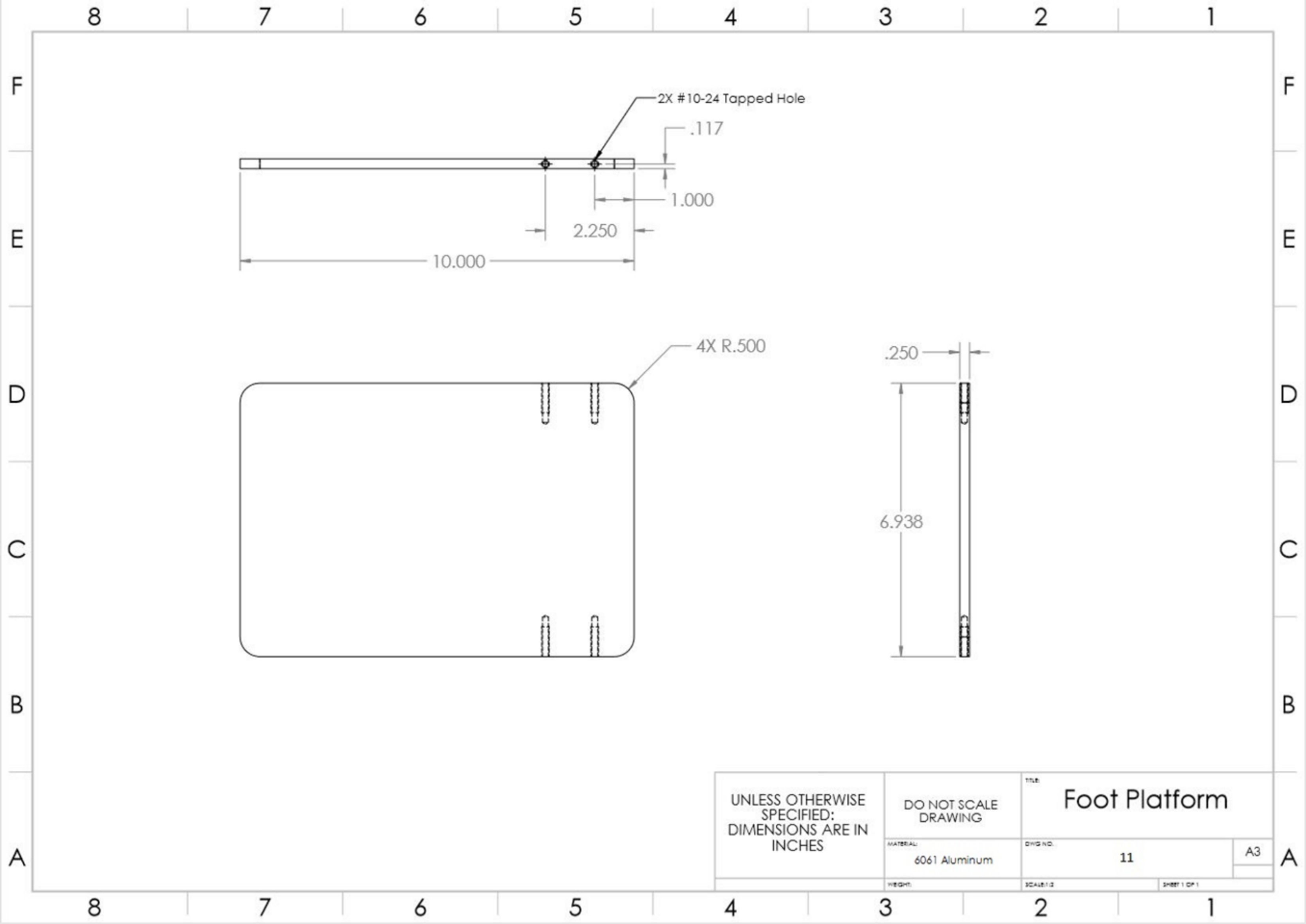
8
7
6
5
4
3
2
1
F
E
D
C
B
A
.250
2X #10-24 Tapped Hole
1.750
.250
.125
8.313
2.000
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
Frame Spacer L
6061 Aluminum
8
A3

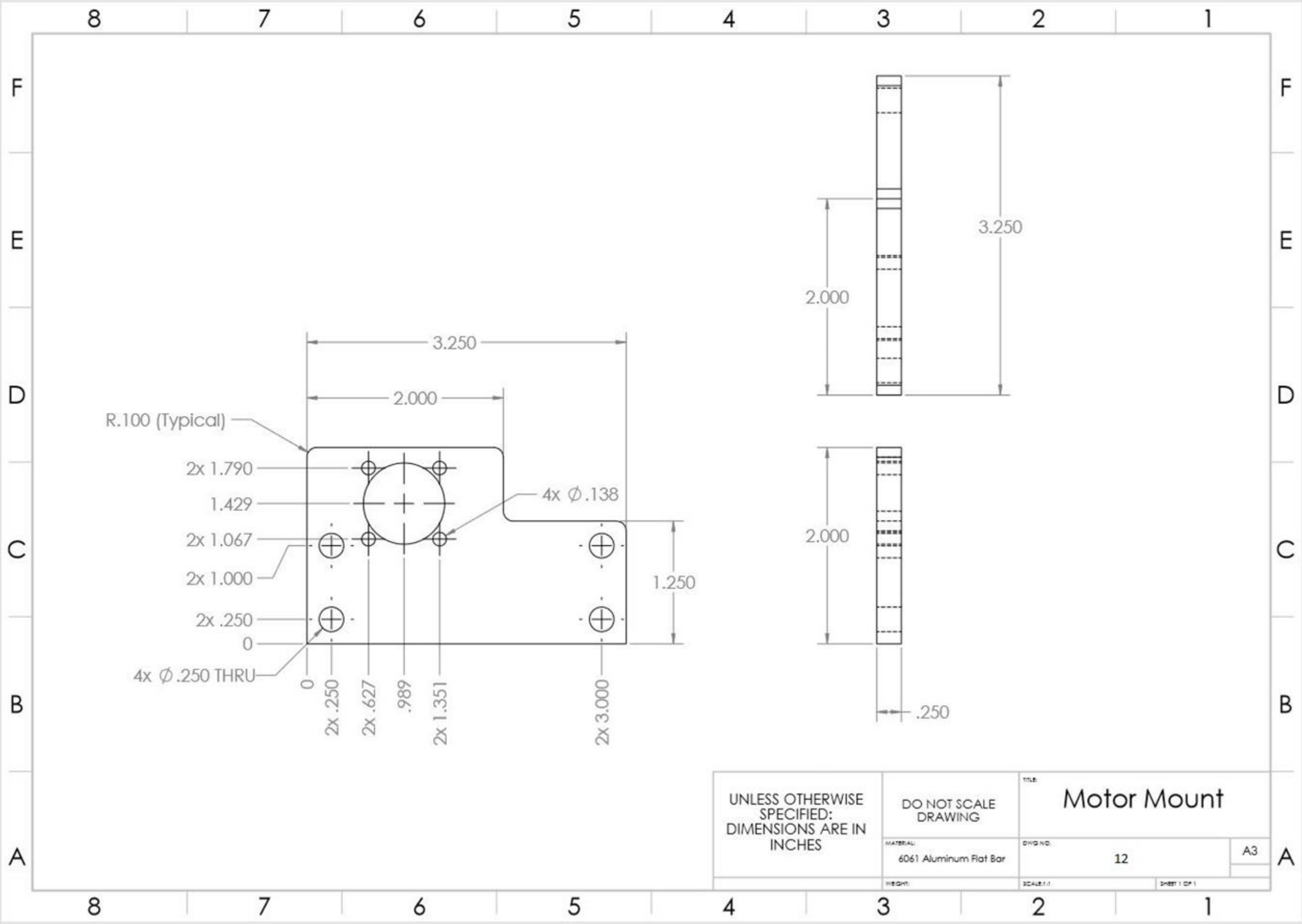


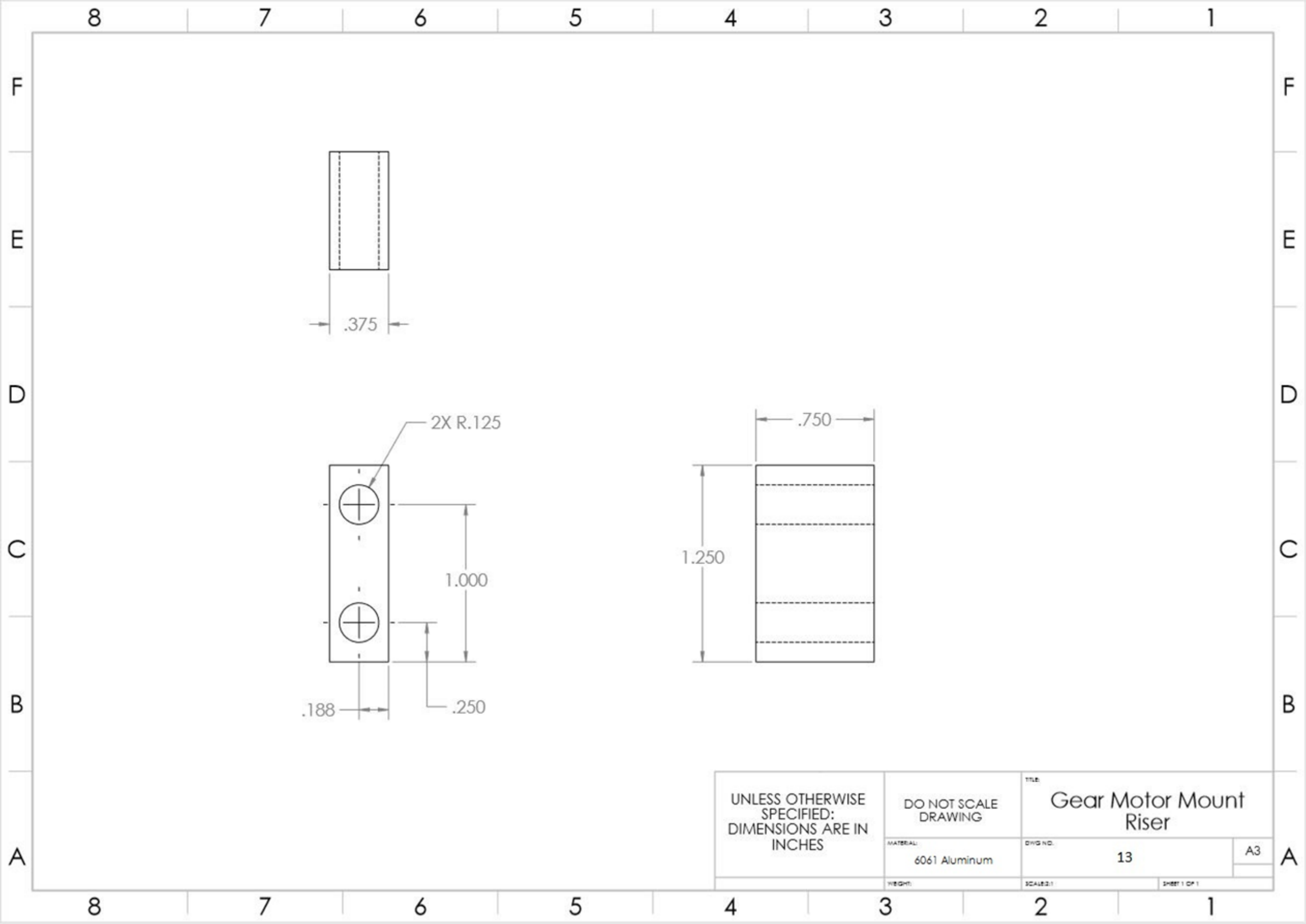
7.625
.250
#10-24 Tapped Hole
1.750
.250
7.625
2.000
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
Frame Spacer Short
6061 Aluminum
9
A3



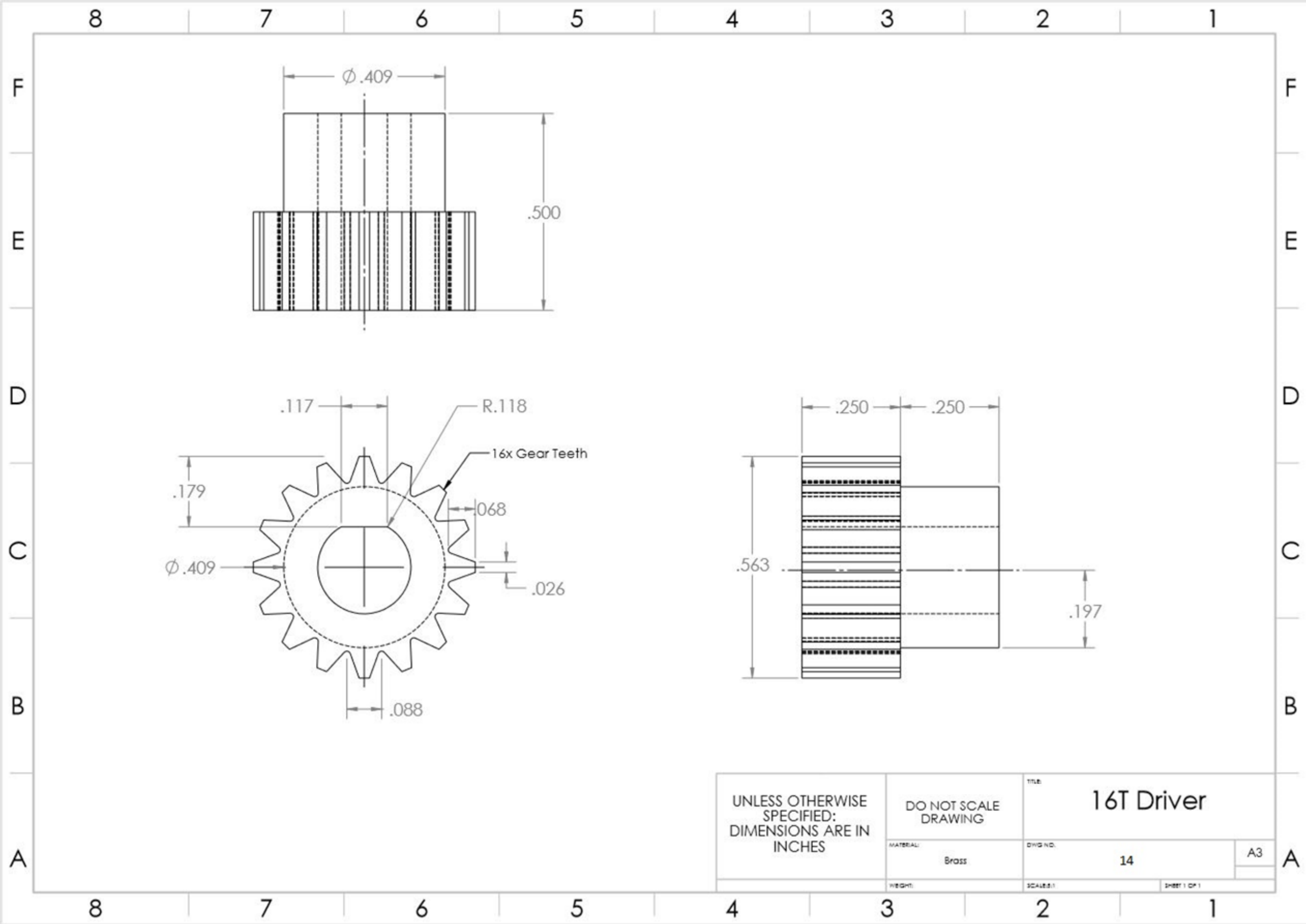
Ø3.250
.250
R.250
R1.625
.433
3.000
1.719
2x Ø.188 THRU
1.250
.233
.375
2.000
4.625
.250
3.000
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
Ankle Swivel
6061 Aluminum Flat Bar
10
A3


2X #10-24 Tapped Hole
.117
1.000
2.250
10.000
4X R.500
.250
6.938
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
Foot Platform
6061 Aluminum
11
A3

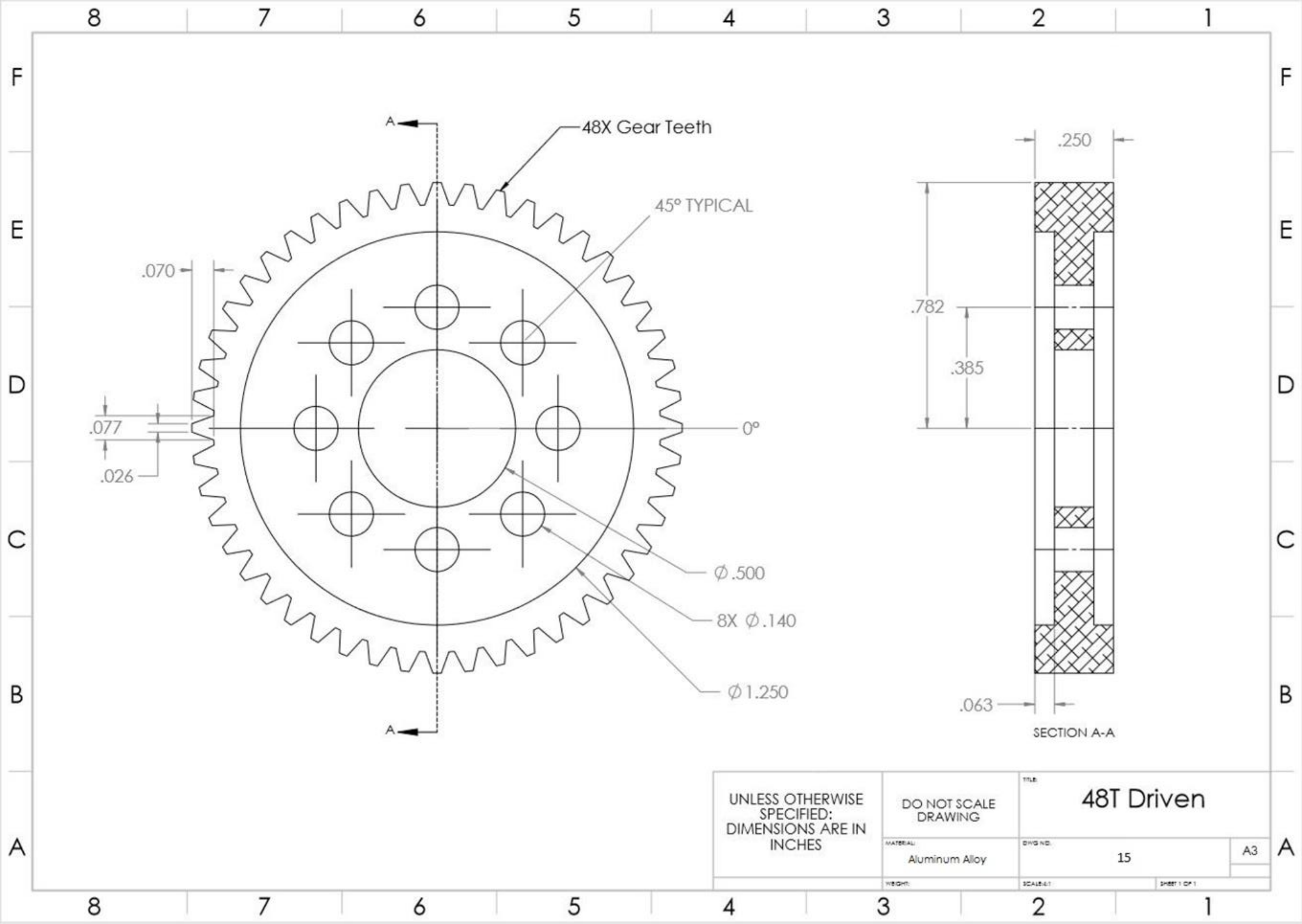

3.250
2.000
R.100 (Typical)
2x 1.790
1.429
2x 1.067
2x 1.000
2x .250
0
4x Ø.250 THRU
4x Ø.138
1.250
0
2x .250
2x .627
.989
2x 1.351
2x 3.000
3.250
2.000
2.000
.250
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
Motor Mount
6061 Aluminum Flat Bar
12
A3

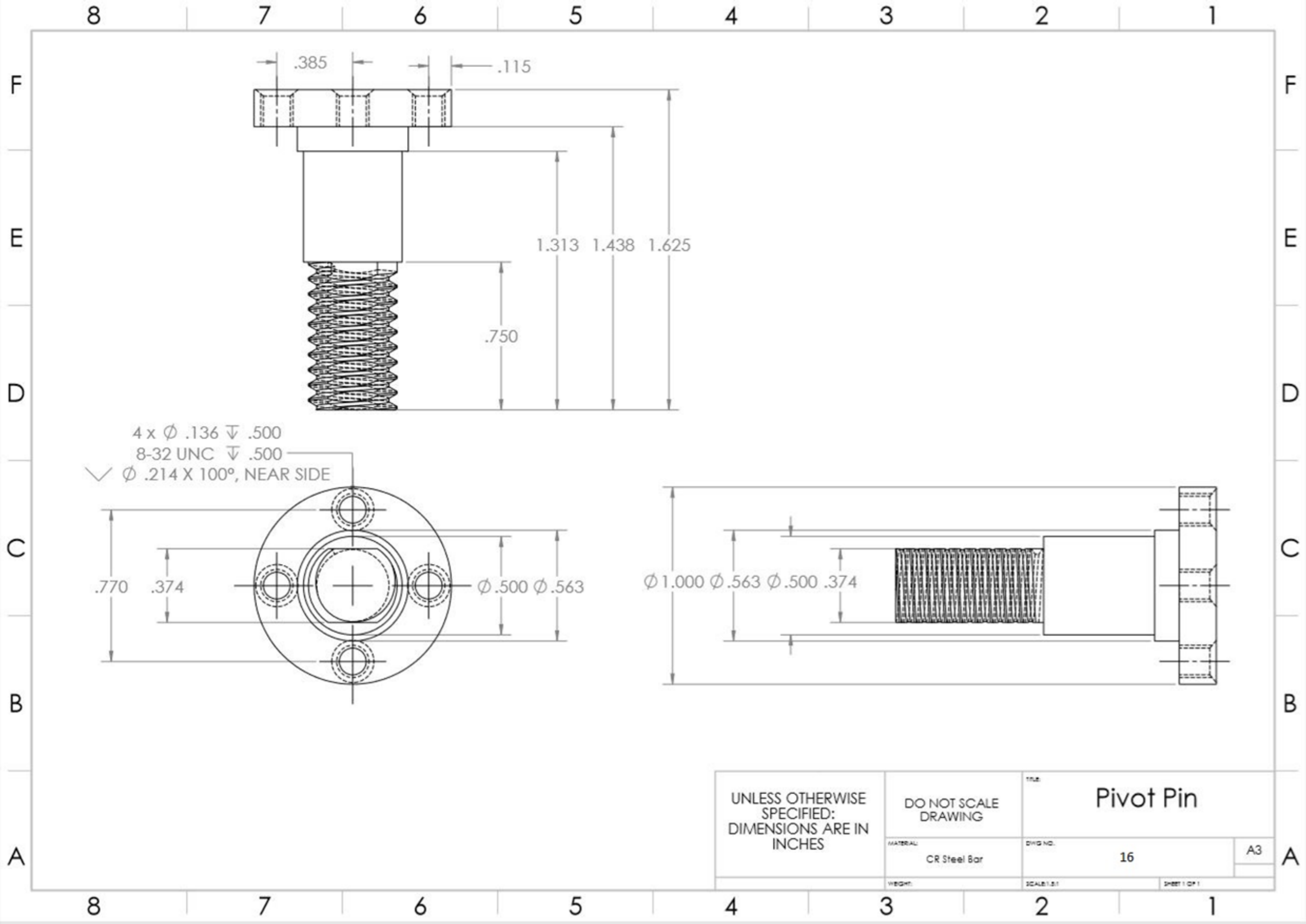


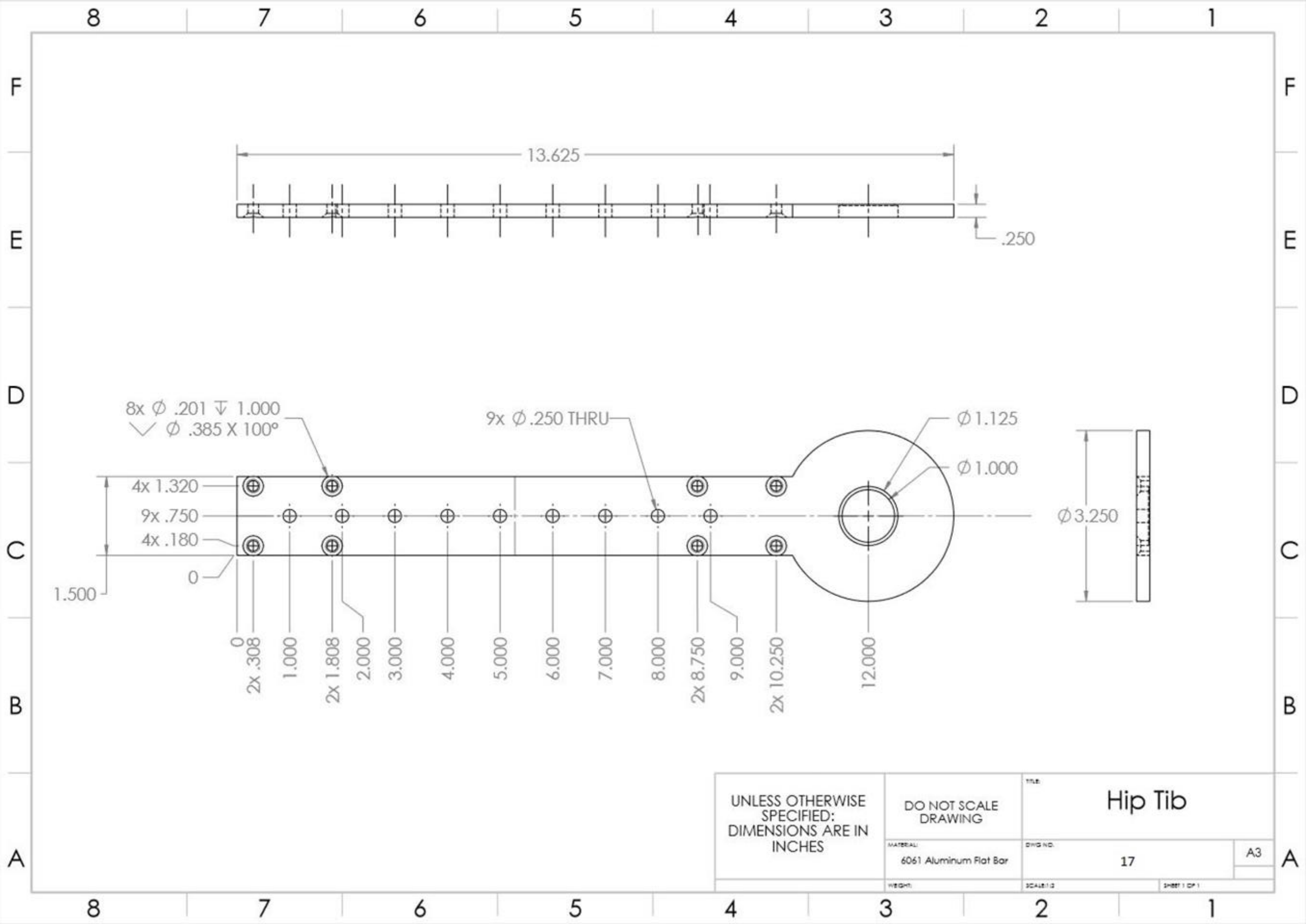
.375
2X R.125
1.000
.188
.250
.750
1.250
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
Gear Motor Mount Riser
6061 Aluminum
13
A3

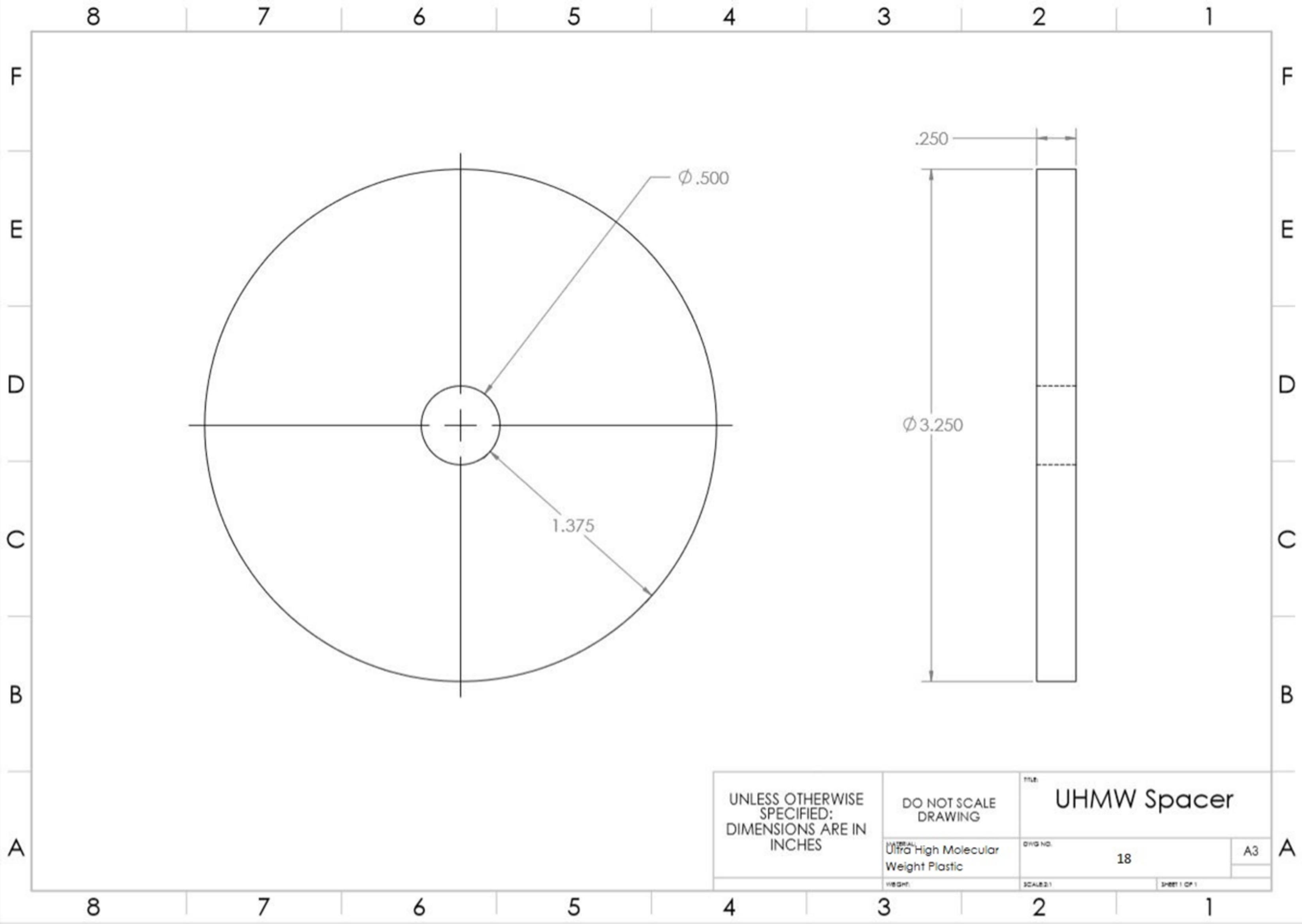


Ø .409
.500
.117
R.118
16x Gear Teeth
.179
.068
Ø .409
.026
.088
.250
.250
.563
.197
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
16T Driver
Brass
14
A3

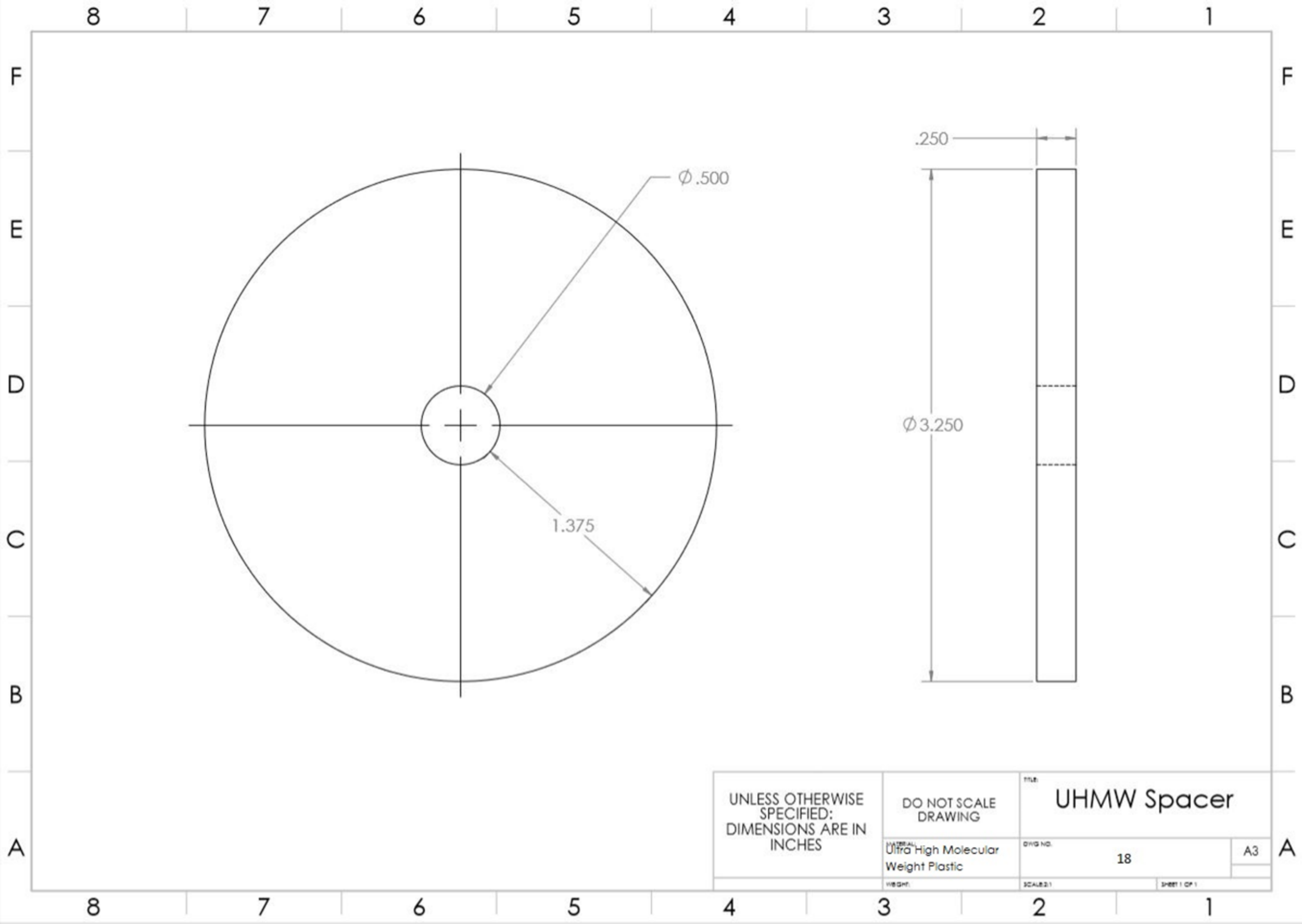

48X Gear Teeth
45° TYPICAL
.070
.077
.026
0°
∅.500
8X ∅.140
∅1.250
.250
.782
.385
.063
SECTION A-A
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
48T Driven
Aluminum Alloy
15
A3


.385
.115
1.313
1.438
1.625
.750
4 x Ø .136 ↧ .500
8-32 UNC ↧ .500
Ø .214 X 100°, NEAR SIDE
.770
.374
Ø .500
Ø .563
Ø 1.000
Ø .563
Ø .500
.374
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
Pivot Pin
CR Steel Bar
16
A3

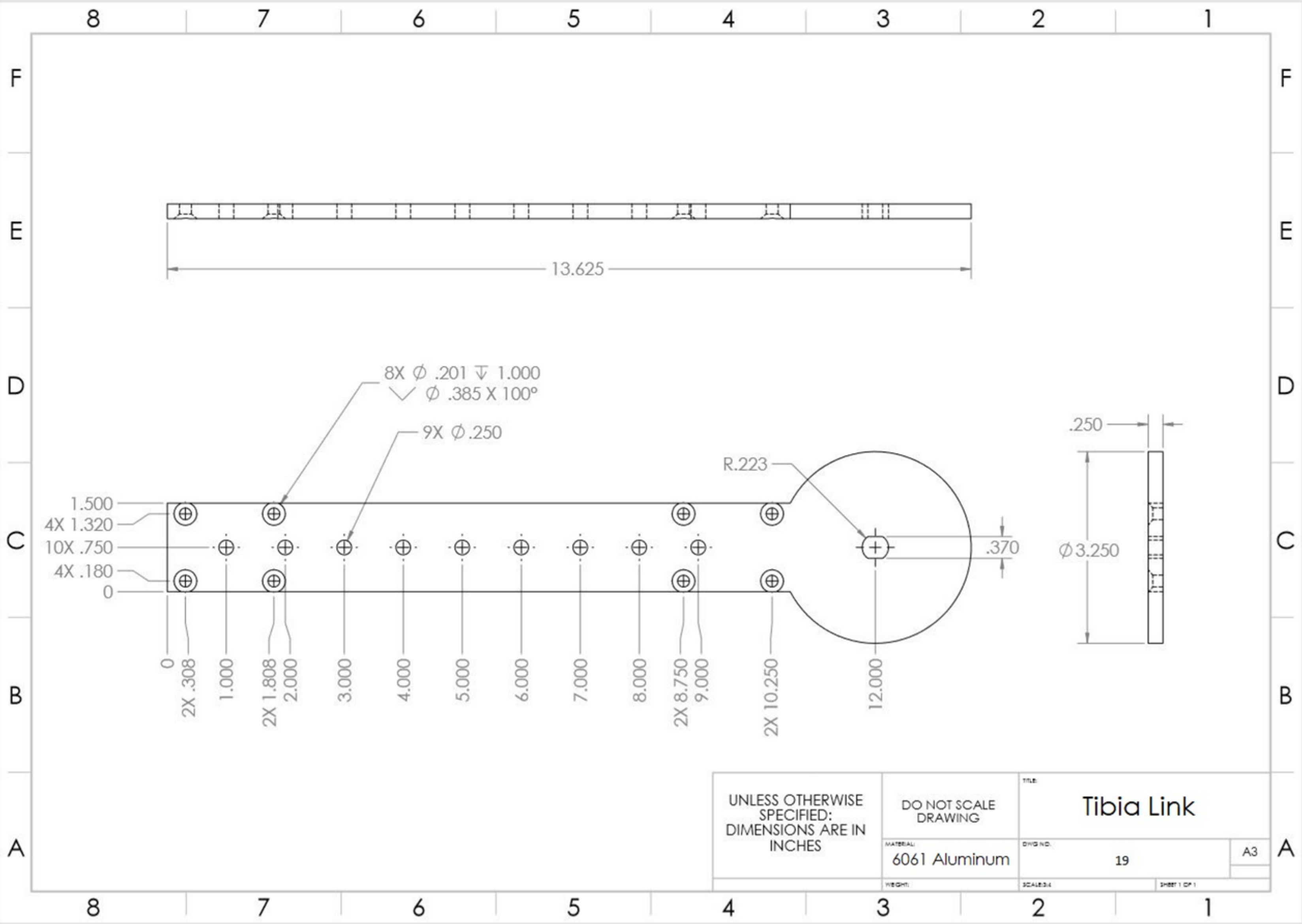

13.625
.250
8x ∅ .201 ↧ 1.000
⌵ ∅ .385 X 100°
9x ∅ .250 THRU
∅ 1.125
∅ 1.000
∅ 3.250
4x 1.320
9x .750
4x .180
0
1.500
0
2x .308
1.000
2x 1.808
2.000
3.000
4.000
5.000
6.000
7.000
8.000
2x 8.750
9.000
2x 10.250
12.000
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
Hip Tib
6061 Aluminum Flat Bar
17
A3



8
7
6
5
4
3
2
1
F
E
D
C
B
A
Ø .500
1.375
.250
Ø 3.250
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
UHMW Spacer
Ultra High Molecular Weight Plastic
18
A3

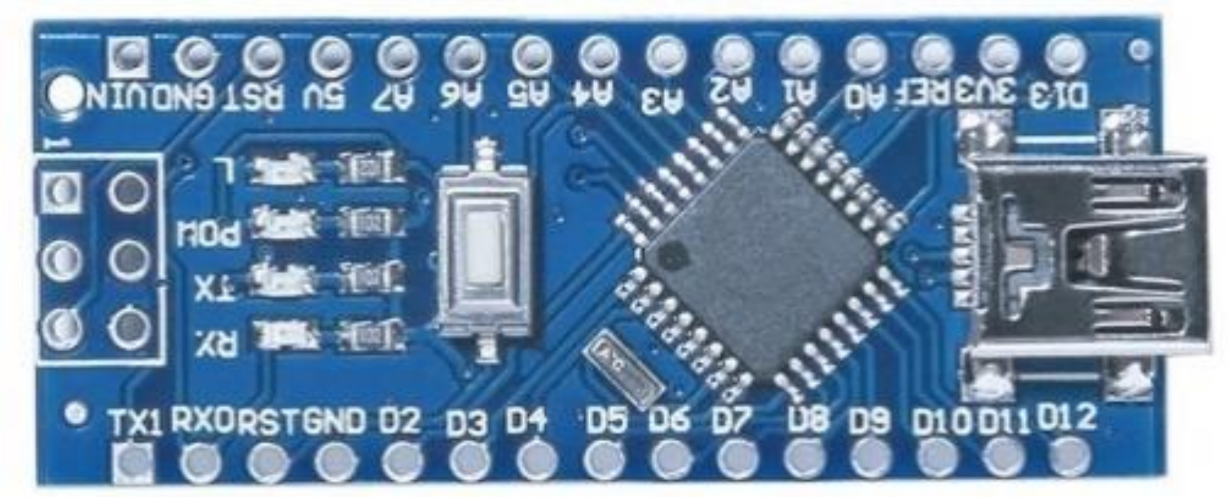


8
7
6
5
4
3
2
1
F
E
D
C
B
A
∅ .500
1.375
.250
∅ 3.250
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
UHMW Spacer
Ultra High Molecular Weight Plastic
18
A3

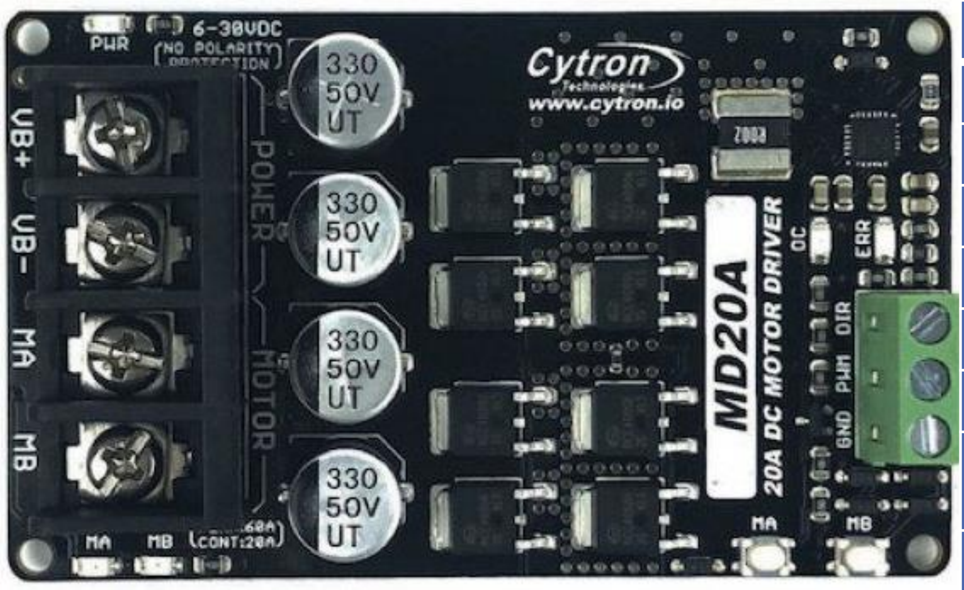

13.625
8X Ø .201 ↧ 1.000
⌵ Ø .385 X 100°
9X Ø .250
R.223
.250
1.500
4X 1.320
10X .750
4X .180
0
.370
Ø 3.250
0
2X .308
1.000
2X 1.808
2.000
3.000
4.000
5.000
6.000
7.000
8.000
2X 8.750
9.000
2X 10.250
12.000
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
Tibia Link
6061 Aluminum
19
A3

Model	ServoCity 12 RPM HD Premium Planetary Gear Motor w/ Encoder
Part Number	638310
Input Voltage Nominal	12 V
Input Voltage (recommended)	6 V – 12 V
Speed (No Load)	12 RPM
Current (No Load)	0.54 A
Current (Stall)	20 A
Torque (Stall)	8,110.2 oz-in (584 kgf-cm)
Gear Ratio	720.989:1
Gear Material	Brass primary, nylon secondary, steel tertiary
Gearbox Style	Planetary
Motor Type	DC
Motor Brush Type	Graphite
Output Shaft Diameter	6 mm
Output Shaft Style	D-shaft
Output Shaft Support	Dual Ball Bearings
Electrical Connection	PH Series JST 6-pin Connector (2 mm Pitch)
Operating Temperature	$-10° C \sim +60° C$
Mounting Screw Size	M3 x 0.5 mm
Weight	380 g
Encoder: Cycles Per Revolution (Motor Shaft)	12
Encoder: Cycles Per Revolution (Output Shaft)	8,651.868
Encoder: Countable Events Per Revolution (Motor Shaft)	48
Encoder: Countable Events Per Revolution (Output Shaft)	34,607.427
Encoder Type	Relative, Quadrature
Encoder Sensor Type	Magnetic (Hall Effect)
Encoder Sensor Input Voltage Range	2.4 V – 26 V
Encoder Sensor Output Pulse Amplitude	≅ Sensor Input Voltage

Model	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	54 (15 of which are PWM)
Analog Input Pins	16
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB (8 KB used by bootloader)
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz
Operating Temperature	−25° C ~ 50° C
Dimensions	101.52 mm x 53.3mm



Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (6 are PWM)
Analog Input Pins	8
DC Current per I/O Pin	40 mA
Flash Memory	32 KB
SRAM	1 KB
EEPROM	1 KB
Clock Speed	16 MHz
Operating Temperature	−25° C ~ 50° C
Dimensions	43.18 mm x 18.54 mm

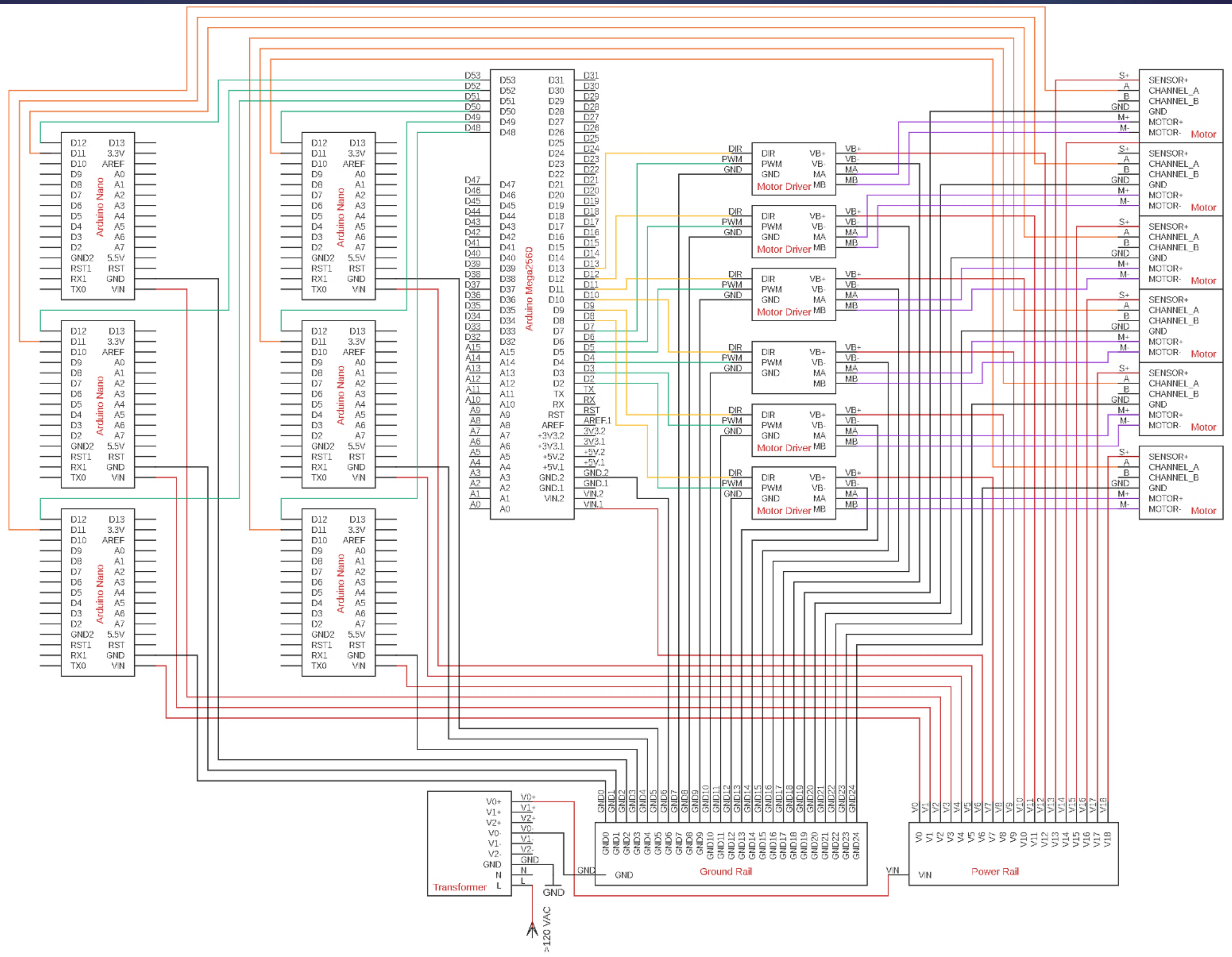


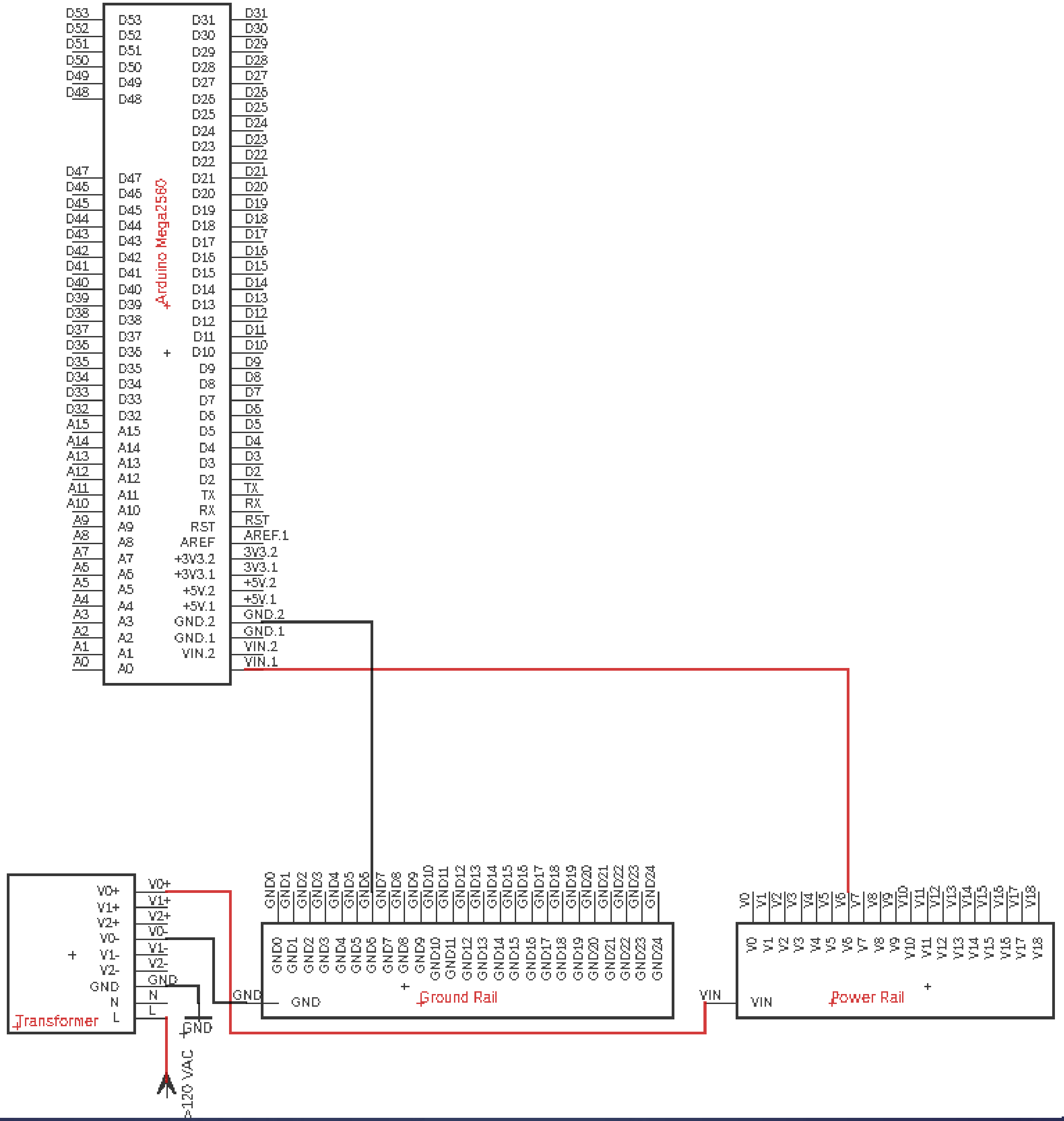
Model	Cytron MD20A
Logic Operating Voltage	0 V - 1.5 V
Motor Input Voltage	6 V - 30 V
Max Continuous Motor Current	20 A
Peak Motor Current	60 A
Digital Input Pins	3
DC PWM Frequency	20 kHz
Continuous Current Operating Temperature	25° ~ °30 C
Dimensions	86 mm x 52 mm

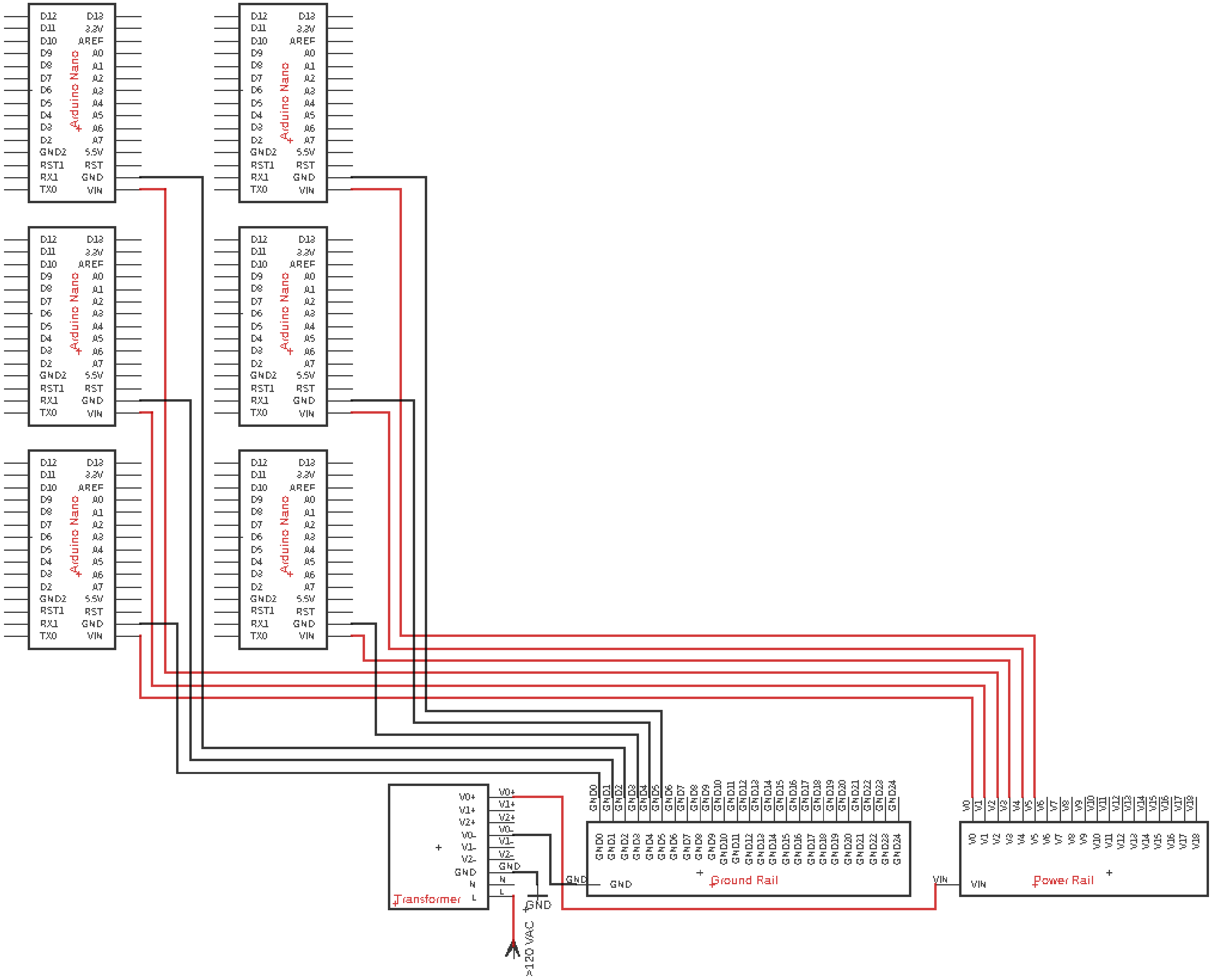
Model	MINZO S-120-12
AC Input Voltage	100 V – 240 V
Input Voltage Frequency	50 Hz – 60 Hz
DC Output Voltage	12 V
Output Current	0 A – 30 A
Output Voltage Adjustable Range	$\pm 10\%$
Output Voltage Tolerance	$\pm 1\%$
Nominal Power	360 W
Fan Temperature Control	45° C
Dimensions	215 mm x 115 mm x 50 mm

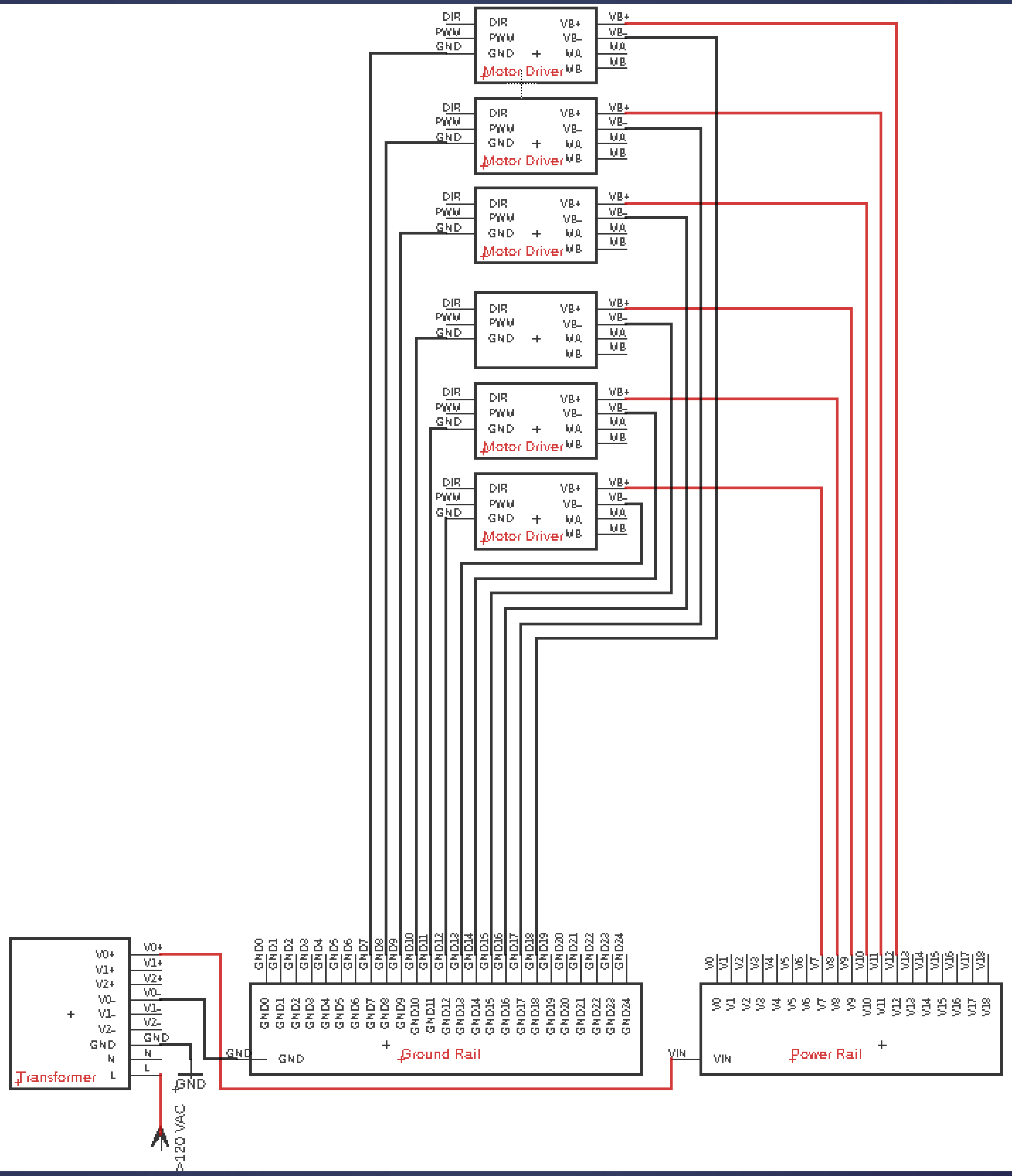
Model	ScripHessco Reusable & Self-Adhering Electrodes
Part Number	672 0106
Adhesive	0.889 mm Hydrogel
Conductor	2 mil carbon conductive film
Square Dimensions	50.8 mm x 50.8 mm
Rectangle Dimensions	50.8 mm x 82.55 mm
Round Dimensions	34.925 mm
Oval Dimensions	38.1 mm x 63.5 mm

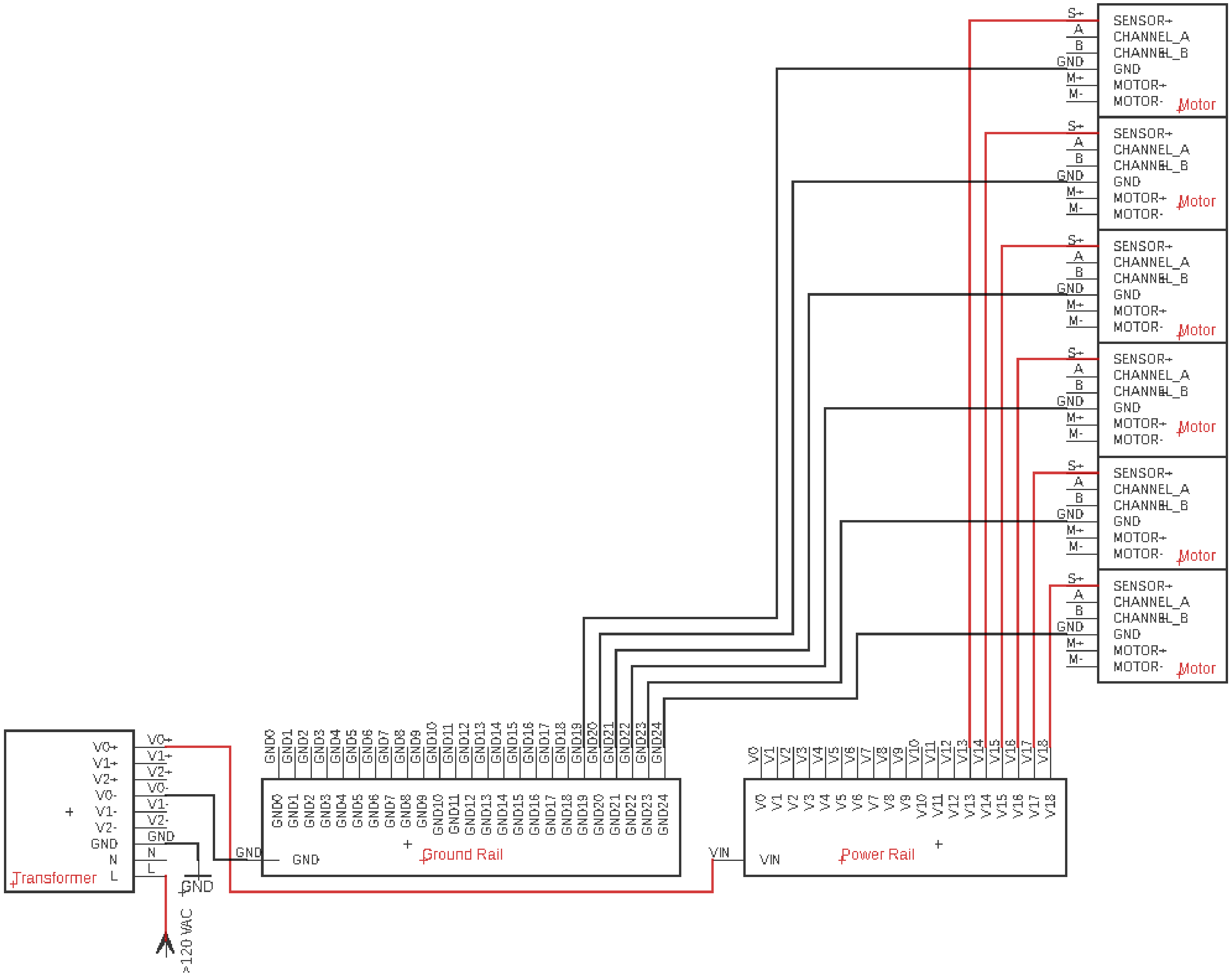
Model	Digitimer Constant Current Stimulator
Part Number	DS7A
Input Voltage	100 VAC to 240 VAC
Input Frequency	47 Hz to 63 Hz
Apparent Power	12 VA
Output Voltage	100 V to 400 V
Output Current	0 A to 1 A
Pulse Duration	50, 100, 200, 500, 1000, 2000 μs
Pulse Polarity	+ve, -ve, and alternating polarities
Connections	4mm shrouded, touchproof sockets on 19.05mm centers
Dimensions	225 mm x 100 mm x 255 mm


Arduino Nano
Arduino Mega2560
Motor Driver
DIR
PWM
GND
VB+
VB-
MA
MB
SENSOR+
CHANNEL_A
CHANNEL_B
GND
MOTOR+
MOTOR-
Motor
Transformer
Ground Rail
Power Rail
>120 VAC

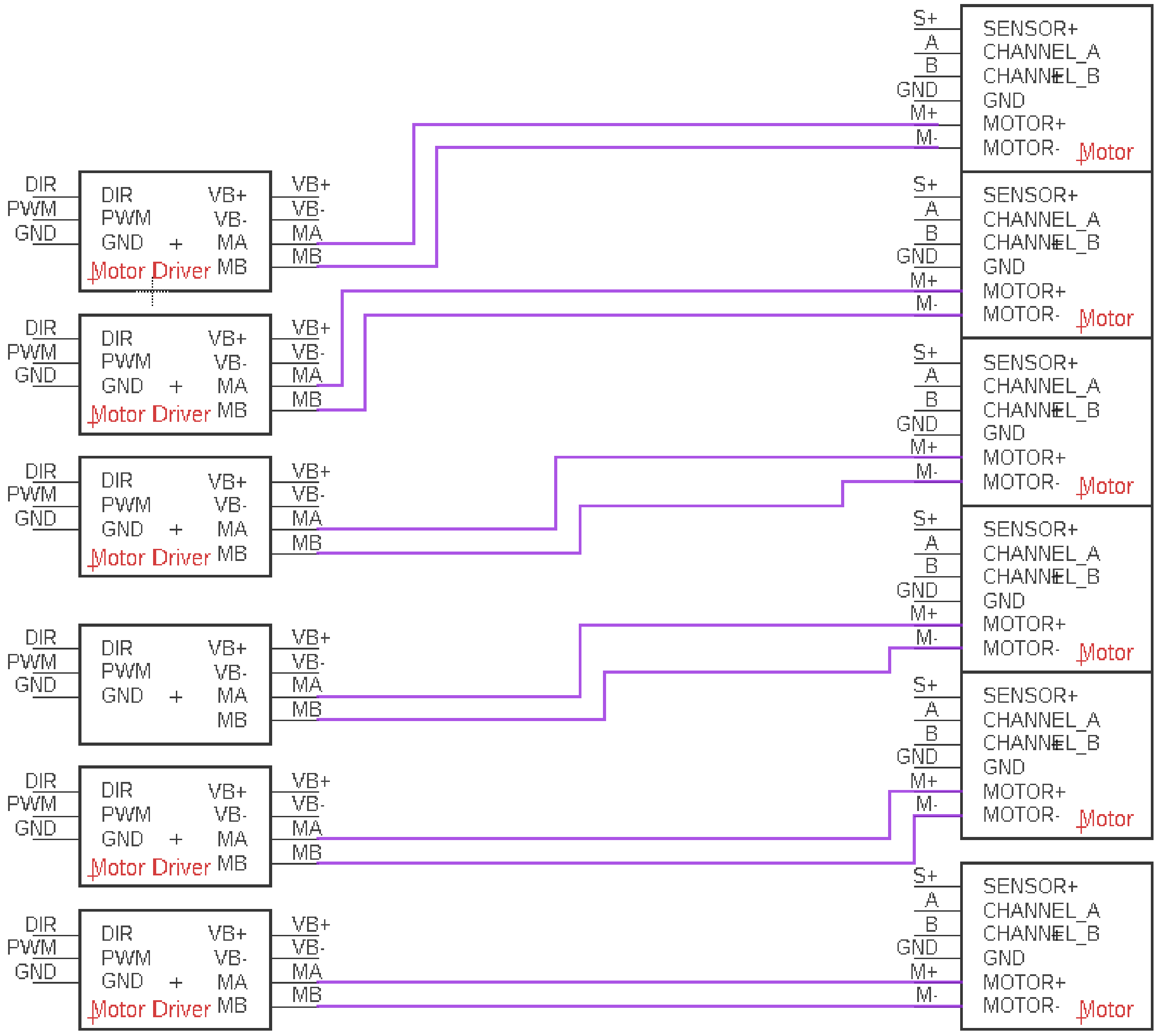

Arduino Mega2560
GND.2
GND.1
VIN.2
VIN.1
Transformer
V0+
V1+
V2+
V0-
V1-
V2-
GND
N
L
120 VAC
Ground Rail
GND
Power Rail
VIN

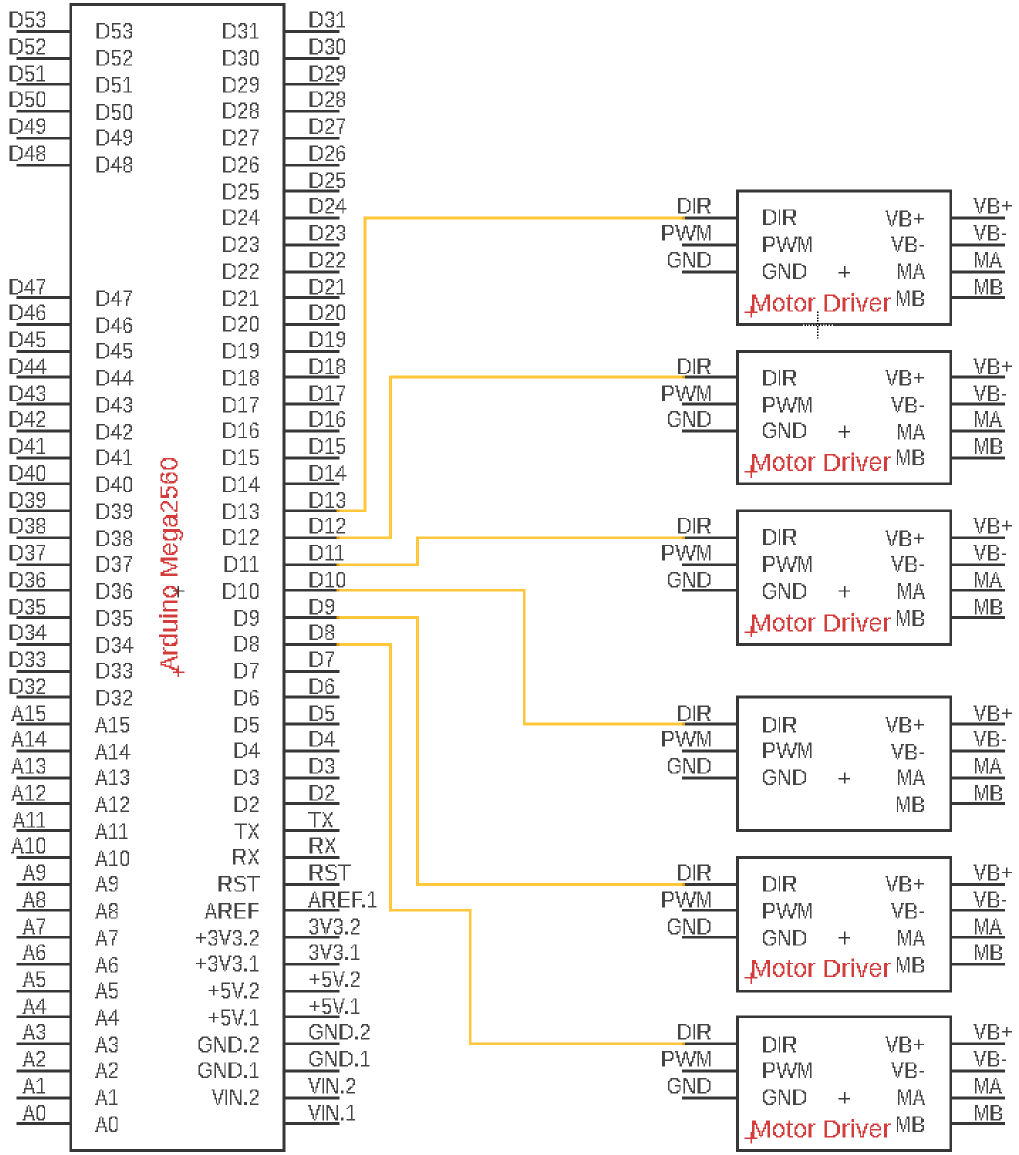

Arduino Nano
D12 D11 D10 D9 D8 D7 D6 D5 D4 D3 D2 GND2 RST1 RX1 TX0
D13 3.3V AREF A0 A1 A2 A3 A4 A5 A6 A7 5.5V RST GND VIN
Transformer
V0+ V1+ V2+ V0- V1- V2- GND N L
GND
>120 VAC
Ground Rail
GND
Power Rail
VIN

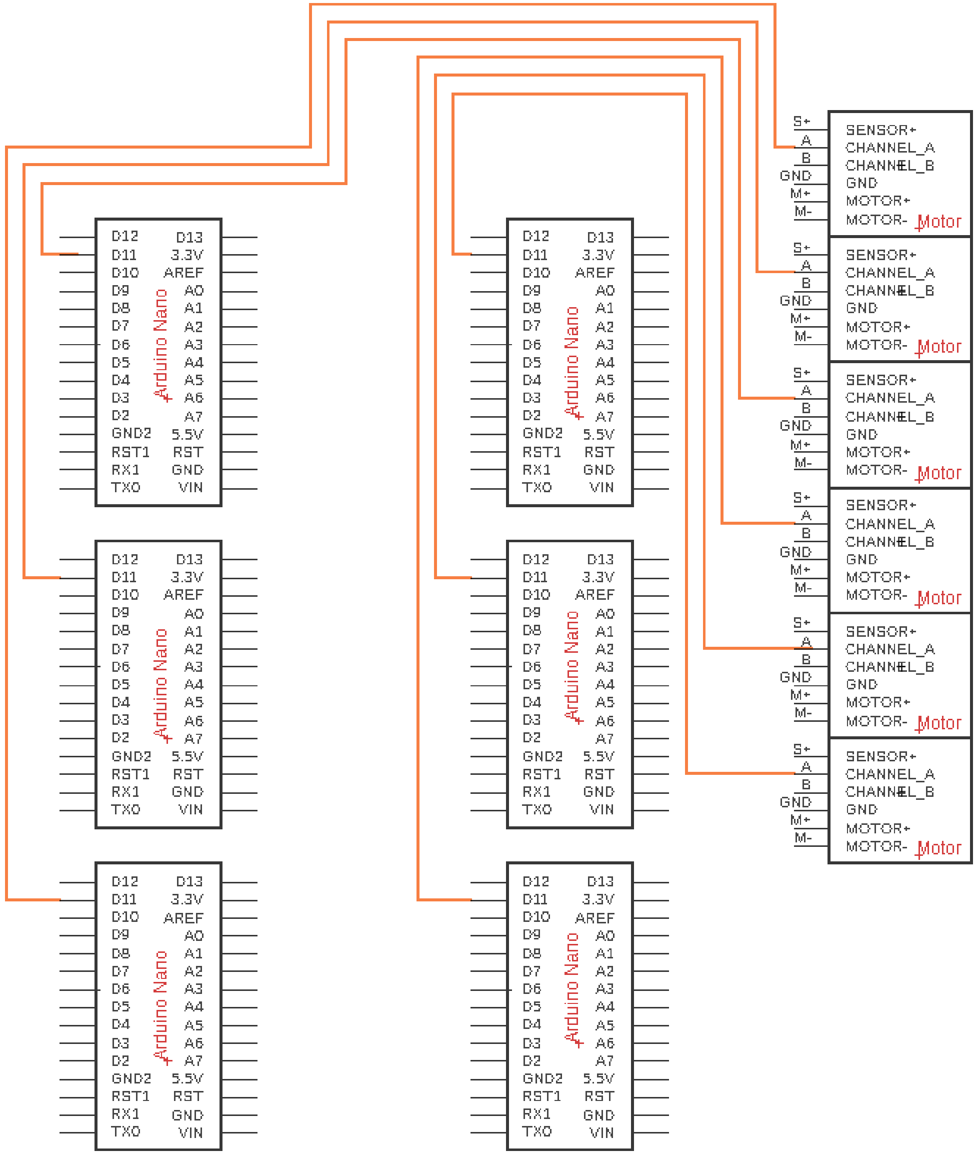

Motor Driver
DIR
PWM
GND
VB+
VB-
MA
MB
Ground Rail
Power Rail
Transformer
V0+
V1+
V2+
V0-
V1-
V2-
GND
N
L
VIN
>120 VAC



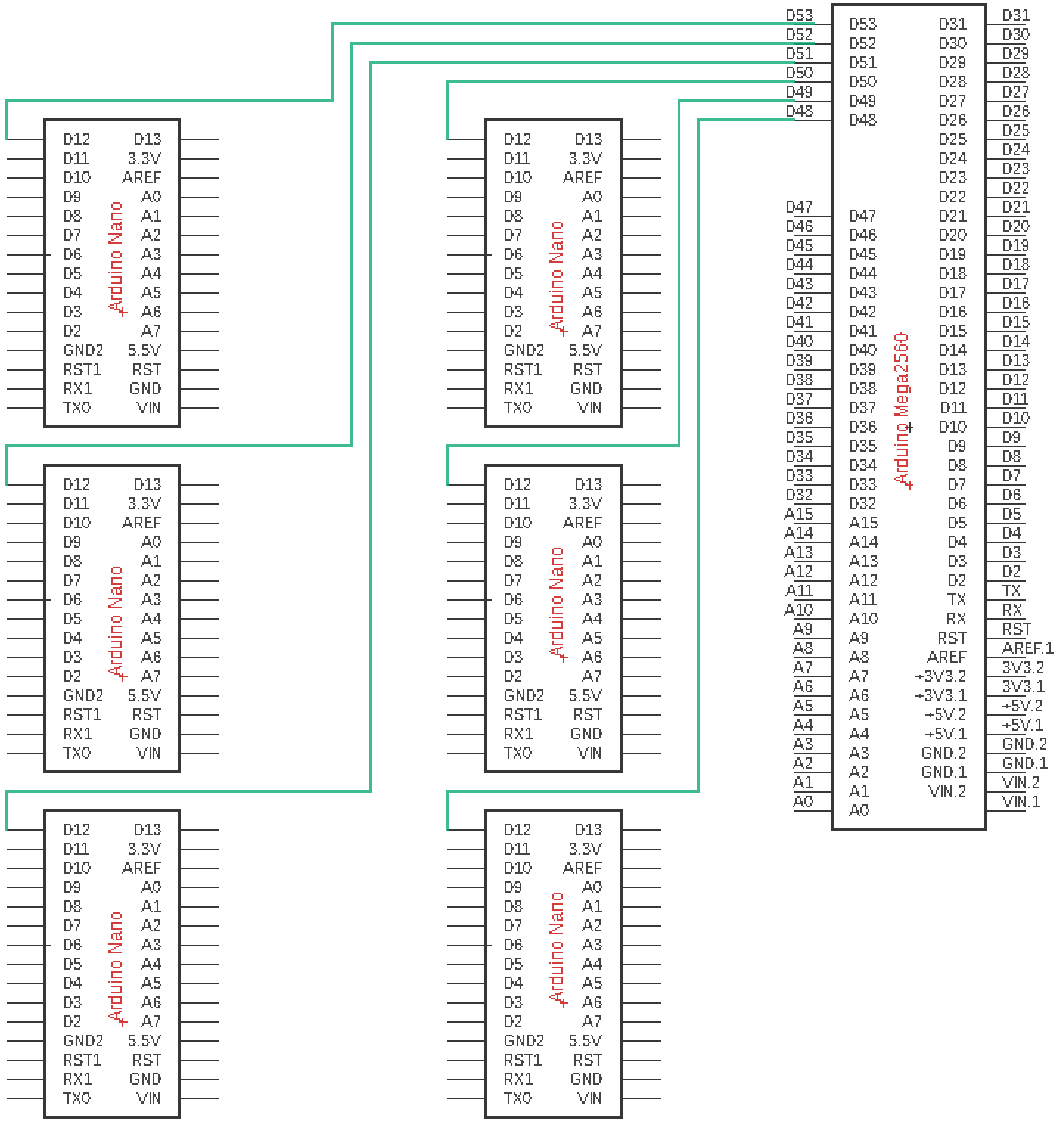
Transformer
V0+
V1+
V2+
V0-
V1-
V2-
GND
N
L
GND
>120 VAC
Ground Rail
GND0 … GND24
Power Rail
VIN
V0 … V18
SENSOR+
CHANNEL_A
CHANNEL_B
GND
MOTOR+
MOTOR-
Motor
S+
A
B
M+
M-

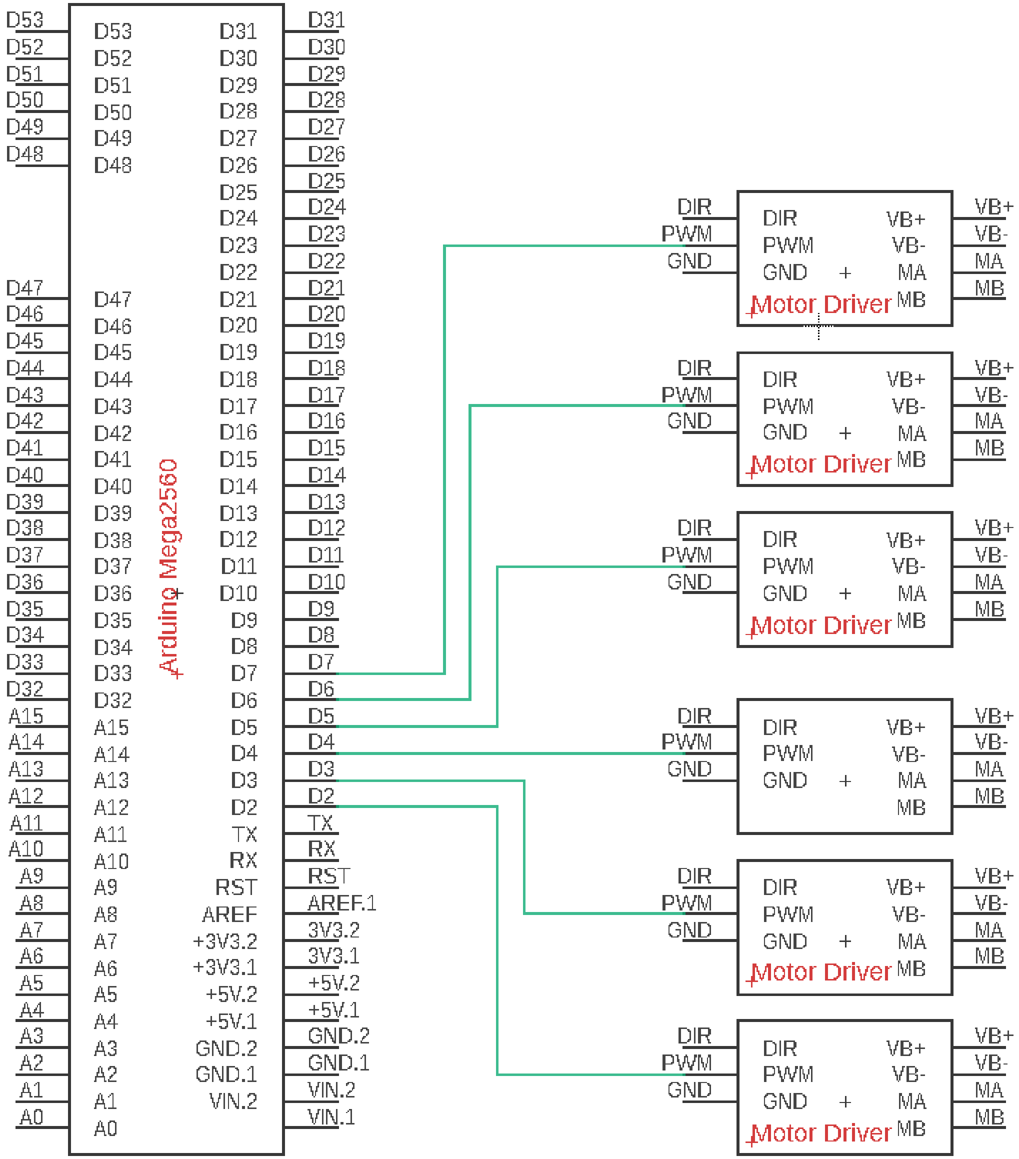

DIR
PWM
GND
DIR PWM GND +
VB+ VB- MA MB
Motor Driver
VB+
VB-
MA
MB
DIR
PWM
GND
DIR PWM GND +
VB+ VB- MA MB
Motor Driver
VB+
VB-
MA
MB
DIR
PWM
GND
DIR PWM GND +
VB+ VB- MA MB
Motor Driver
VB+
VB-
MA
MB
DIR
PWM
GND
DIR PWM GND +
VB+ VB- MA MB
VB+
VB-
MA
MB
DIR
PWM
GND
DIR PWM GND +
VB+ VB- MA MB
Motor Driver
VB+
VB-
MA
MB
DIR
PWM
GND
DIR PWM GND +
VB+ VB- MA MB
Motor Driver
VB+
VB-
MA
MB
S+
A
B
GND
M+
M-
SENSOR+ CHANNEL_A CHANNEL_B GND MOTOR+ MOTOR-
Motor
S+
A
B
GND
M+
M-
SENSOR+ CHANNEL_A CHANNEL_B GND MOTOR+ MOTOR-
Motor
S+
A
B
GND
M+
M-
SENSOR+ CHANNEL_A CHANNEL_B GND MOTOR+ MOTOR-
Motor
S+
A
B
GND
M+
M-
SENSOR+ CHANNEL_A CHANNEL_B GND MOTOR+ MOTOR-
Motor
S+
A
B
GND
M+
M-
SENSOR+ CHANNEL_A CHANNEL_B GND MOTOR+ MOTOR-
Motor
S+
A
B
GND
M+
M-
SENSOR+ CHANNEL_A CHANNEL_B GND MOTOR+ MOTOR-
Motor


Arduino Mega2560
D53 D52 D51 D50 D49 D48
D47 D46 D45 D44 D43 D42 D41 D40 D39 D38 D37 D36 D35 D34 D33 D32
A15 A14 A13 A12 A11 A10 A9 A8 A7 A6 A5 A4 A3 A2 A1 A0
D31 D30 D29 D28 D27 D26 D25 D24 D23 D22 D21 D20 D19 D18 D17 D16 D15 D14 D13 D12 D11 D10 D9 D8 D7 D6 D5 D4 D3 D2
TX RX RST AREF +3V3.2 +3V3.1 +5V.2 +5V.1 GND.2 GND.1 VIN.2
AREF.1 3V3.2 3V3.1 +5V.2 +5V.1 GND.2 GND.1 VIN.2 VIN.1
DIR
PWM
GND
VB+
VB-
MA
MB
Motor Driver



D12 D13
D11 3.3V
D10 AREF
D9 A0
D8 A1
D7 A2
D6 A3
D5 A4
D4 A5
D3 A6
D2 A7
GND2 5.5V
RST1 RST
RX1 GND
TX0 VIN
Arduino Nano
S+
A
B
GND
M+
M-
SENSOR+
CHANNEL_A
CHANNEL_B
GND
MOTOR+
MOTOR-
Motor


Arduino Nano
D12 D13
D11 3.3V
D10 AREF
D9 A0
D8 A1
D7 A2
D6 A3
D5 A4
D4 A5
D3 A6
D2 A7
GND2 5.5V
RST1 RST
RX1 GND
TX0 VIN
Arduino Mega2560
D53 D52 D51 D50 D49 D48
D47 D46 D45 D44 D43 D42 D41 D40 D39 D38 D37 D36 D35 D34 D33 D32
A15 A14 A13 A12 A11 A10 A9 A8 A7 A6 A5 A4 A3 A2 A1 A0
D31 D30 D29 D28 D27 D26 D25 D24 D23 D22 D21 D20 D19 D18 D17 D16 D15 D14 D13 D12 D11 D10 D9 D8 D7 D6 D5 D4 D3 D2
TX RX RST AREF
+3V3.2 +3V3.1 +5V.2 +5V.1 GND.2 GND.1 VIN.2
AREF.1 3V3.2 3V3.1 +5V.2 +5V.1 GND.2 GND.1 VIN.2 VIN.1


Arduino Mega2560
D53 D52 D51 D50 D49 D48
D47 D46 D45 D44 D43 D42 D41 D40 D39 D38 D37 D36 D35 D34 D33 D32
A15 A14 A13 A12 A11 A10 A9 A8 A7 A6 A5 A4 A3 A2 A1 A0
D31 D30 D29 D28 D27 D26 D25 D24 D23 D22 D21 D20 D19 D18 D17 D16 D15 D14 D13 D12 D11 D10 D9 D8 D7 D6 D5 D4 D3 D2
TX RX RST AREF +3V3.2 +3V3.1 +5V.2 +5V.1 GND.2 GND.1 VIN.2
TX RX RST AREF.1 3V3.2 3V3.1 +5V.2 +5V.1 GND.2 GND.1 VIN.2 VIN.1
DIR PWM GND
VB+ VB- MA MB
Motor Driver