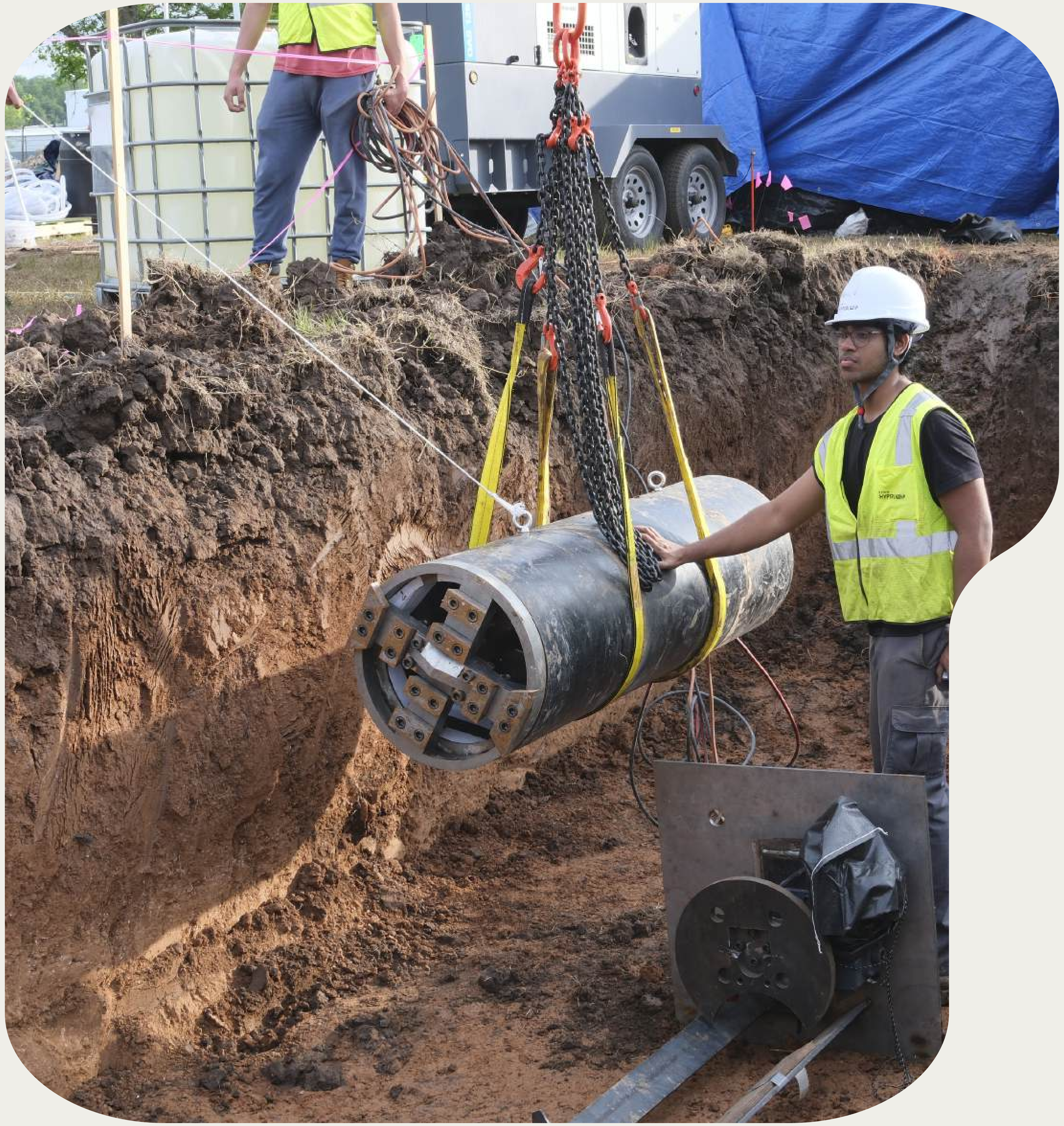
Mehul Vemareddy

Engineering Portfolio

Projects

Penn Hyperloop	NoDiggity V2
Penn Hyperloop	NoDiggity V1
UPenn MEAM Curriculum	Stirling Engine Model (MEAM 2010)
UPenn MEAM Curriclum	Undergraduate Lab Projects (MEAM 1010, 2470, 2480)



PENN HYPERLOOP

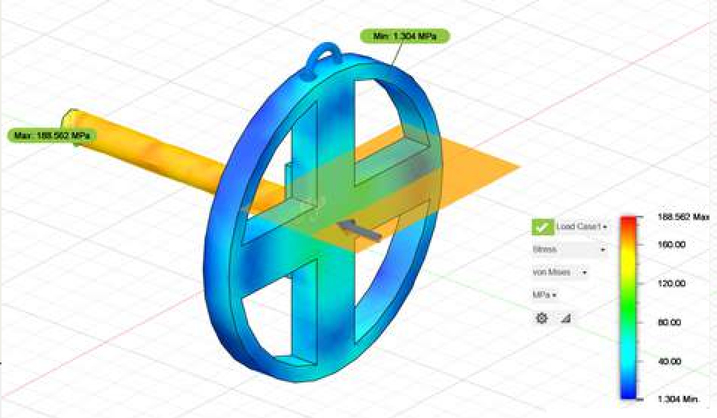
NoDiggity V2

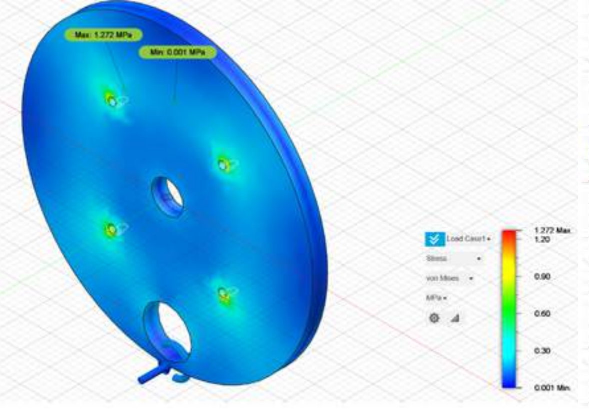
Overall goal was to dig a 30m long horizontal tunnel of 0.5m diameter. I was the Cutterhead and Main Drive systems RE (responsible engineer) for a system that generated 2.2 kNm of torque. Was the de facto mechanical–side team lead and coordinated between the propulsion system, soil removal and ground conditioning systems, to ensure delivery on the machine.

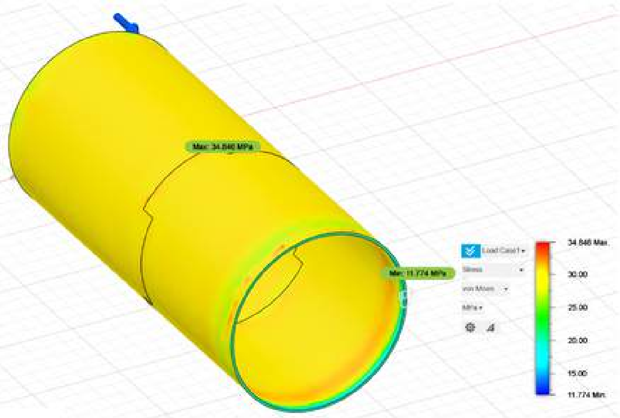
Not mentioned in this portfolio are the numerous hours (~50% of my time) spent planning the logistics of moving and testing ops, organizing a temporary build space, and fighting with school management for recognition, and fundraising talks.

Official dig length of 1.5m to win Rookie Award with smallest team and simplest TBM design (as per judges).

Excavation Systems - NoDiggity V2 - Penn Hyperloop





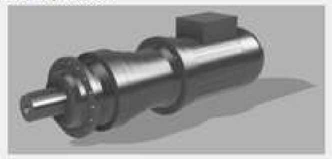


<u>Meain Drive Torque Calculation</u>
Utilizing the findings of Hu's 2011 paper* we can split up our torque contributions as seen below.

Torque Contribution	Torque (kNm)
T1 (Front)	1.169910308
T2 (Lateral)	0.5114362
T3 (Back)	0.389970103
T5 (Opening Shear)	0.13847143
T6 (Agitating torque)	0.2662796
Total Torque	2.476067639

Using a FOS of 2 we get a recommended Torque of **~5 kNm**

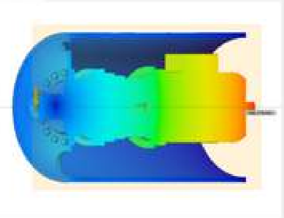
<u>Key System Metrics</u>: (Rossi Group motor: **HB3 132 S 4**, Rossi Group planetary gear reducer: **EP R 3EL**)



- Estimated Output Torque: 4780 Nm
- Nominal Output Speed: 8.1-11.9 rpm
- Mass: 221 kg
- Effective reduction ratio: 142.56-209.44
- Gearmotor configured for expected axial/thrust loads from manufacturer.

<u>Coupling</u>:

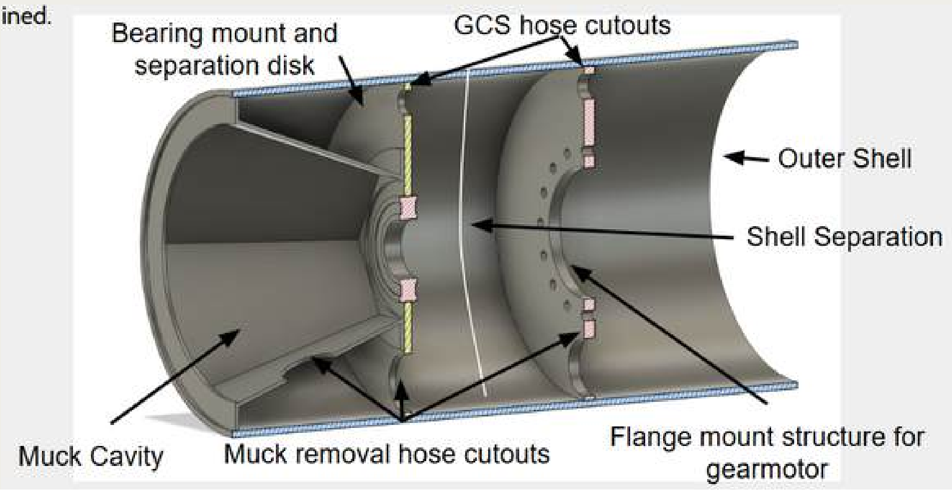
- Custom machined keyway two-piece coupling (Stafford)
- 316 Stainless Steel (for corrosion protection)
- 6 screws on each side
- Holding Torque: 3723 Nm

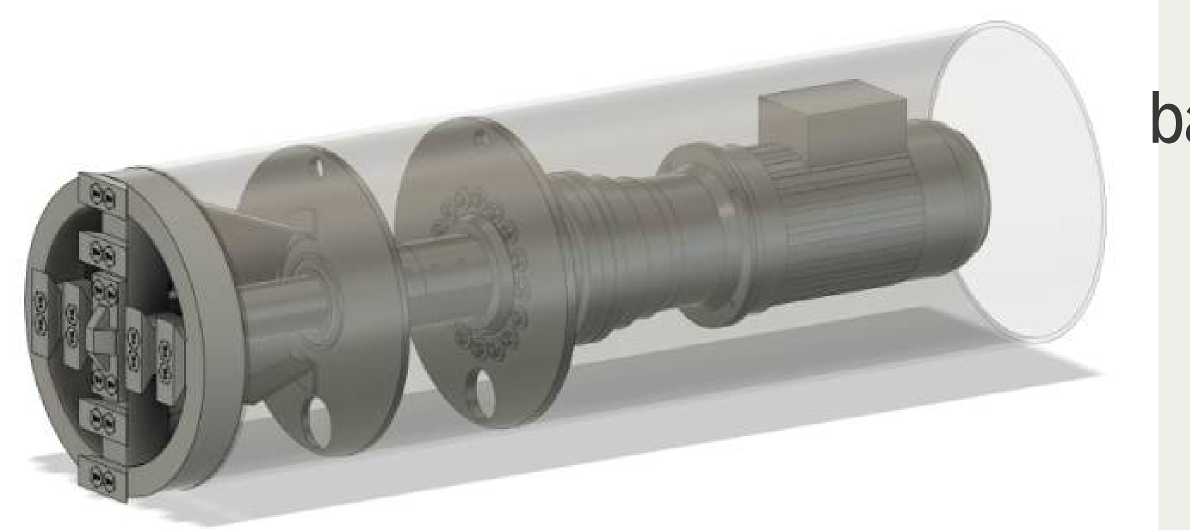


<u>Mounting Plate</u>:
- Assuming AISI 4340 242 HR steel with a Young's modulus a plate thickness of of 33mm would be needed to support the system. Considering a safety factor of 1.5, a plate thickness of 49.5mm (50mm) would be desirable.
- Mounting Strategy: Weld ring plate to outer body casing to create a flange mounting system for plate to be bolted to. This allows for removal of plate to make other components accessible.

ined.

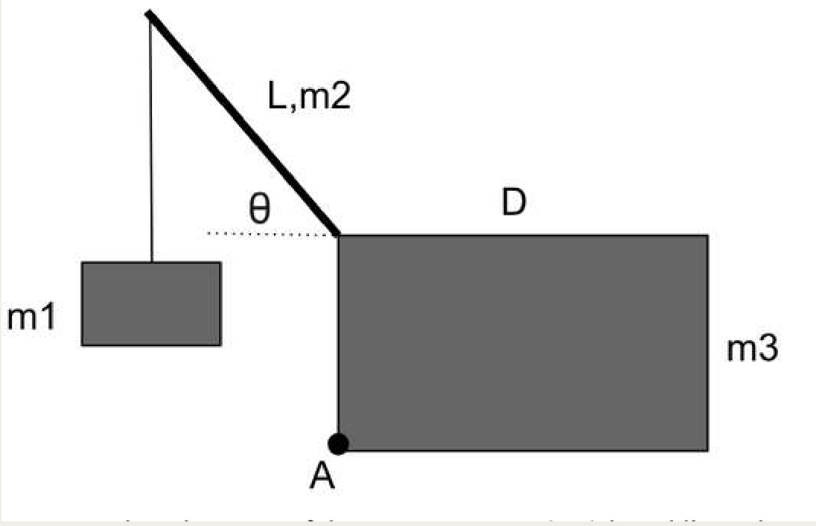
Initial Design – Started off with main physics requirement of torque needed. Accordingly, sourced sized a gearmotor + custom coupling system that fits into CAD modeled outer structure.

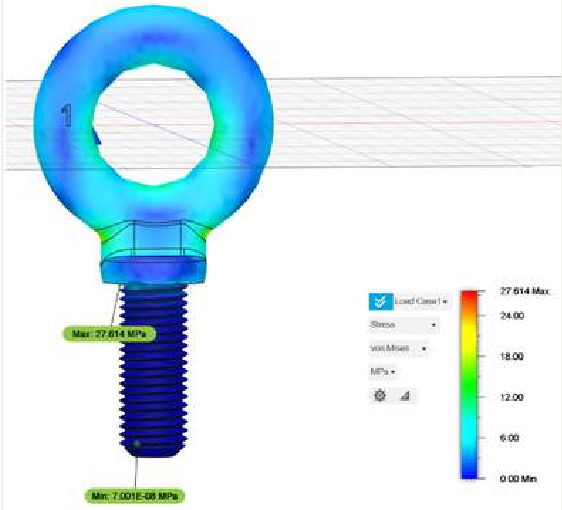


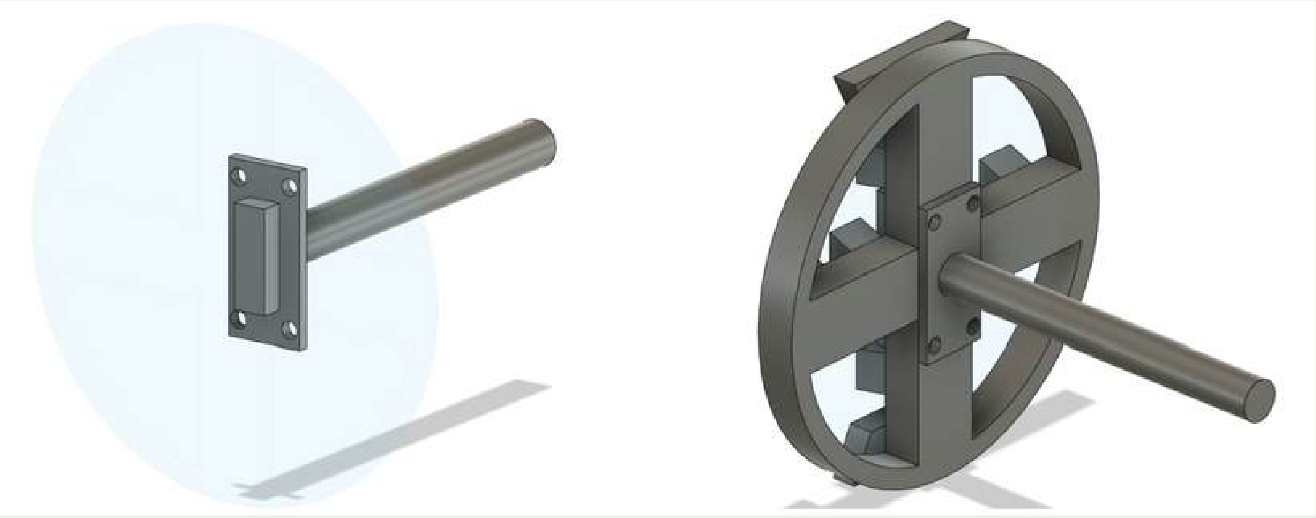


Improved design: Overall structural analysis shown for various failure modes.

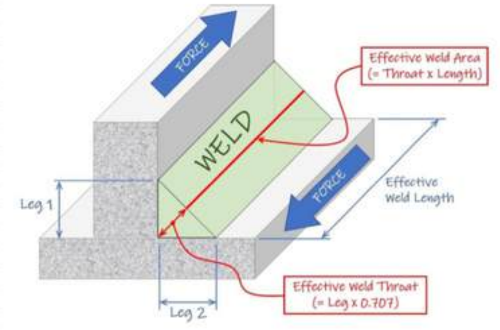
<u>Added</u>: lifting points, alignment peice to achieve concentrictiy and better torque transfer, switched out gearmotor based on updated assumptions.

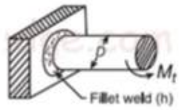






	A	B
1	**Torsional Shear**	
2	Applied Torque (Nm)	2700
3	Shaft Radius (m)	0.0508
4	Weld thickness (m)	0.00635
5	Polar moment of inertia (m^4)	0.000006274
6	FOS	5
7	Torsional shear stress (N/m^2)	109311612.5
8		
9	**Normal Shear**	
10	Applied Force (N)	265748.0
11	Weld area (m^2)	0.001170
12	Normal shear stress (N/m^2)	227098227.4
13		
14	Filler material required max stress (psi)	36554.8574
15		
16	**Online model (w/ safety factor)**	
17	Weld fillet radius (m)	0.003175
18	Filler material required max stress (psi)	43053.69067
19		
20	ER 4340 max stress (psi)	168,000
21	FOS	3.902104497
22		
23		
24		
25		
26		



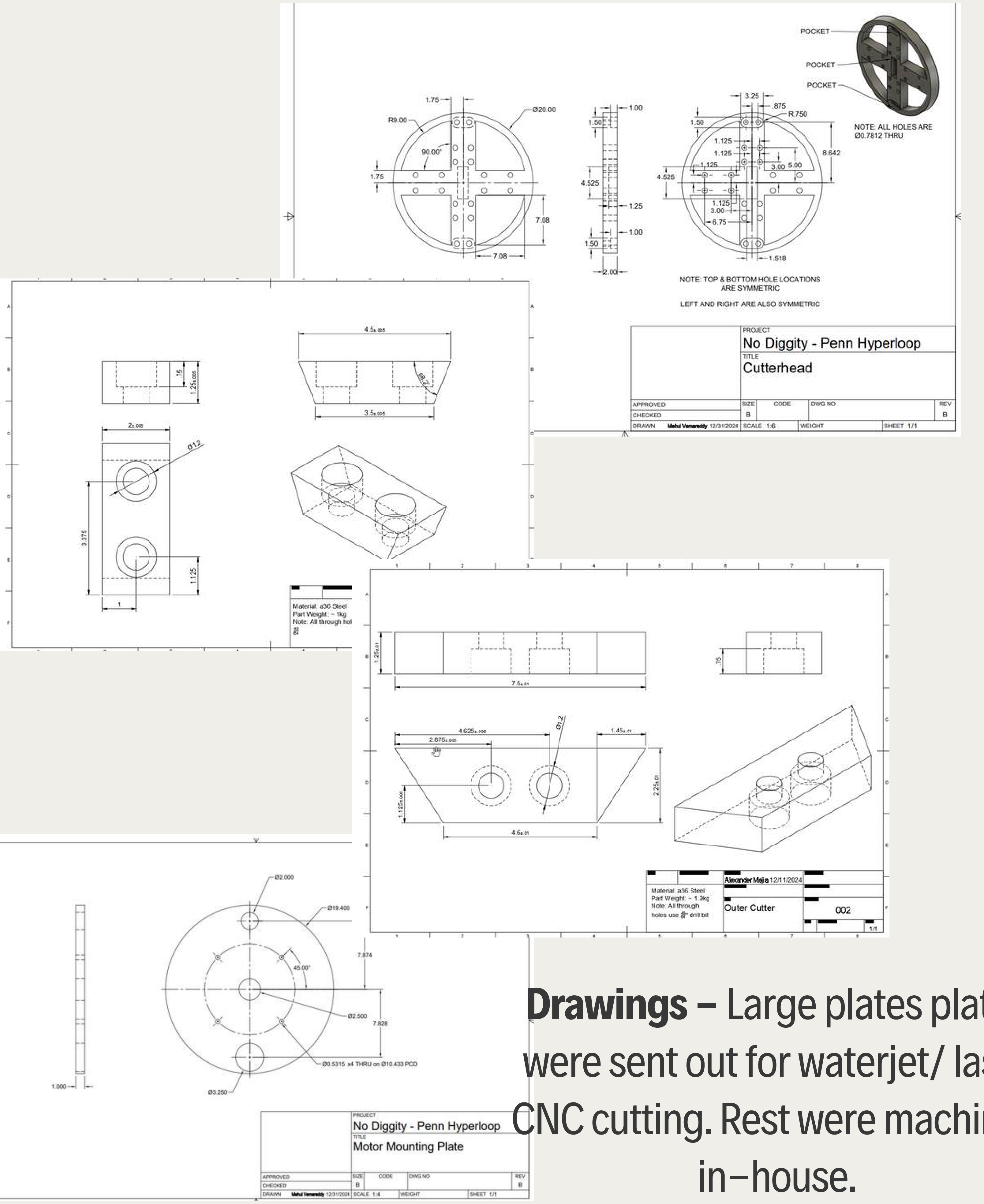


$$\tau = \frac{2.83\, M_t}{hD^2\pi}$$

τ = Shear Stress, MPa (psi)
M_t = Torque N-m (lbf-in)
D = Diameter, m (in)
h = Size of Weld, m (in)
π = 3.14157 (PI)

$$J = 2\pi a (r + a/2)^3$$

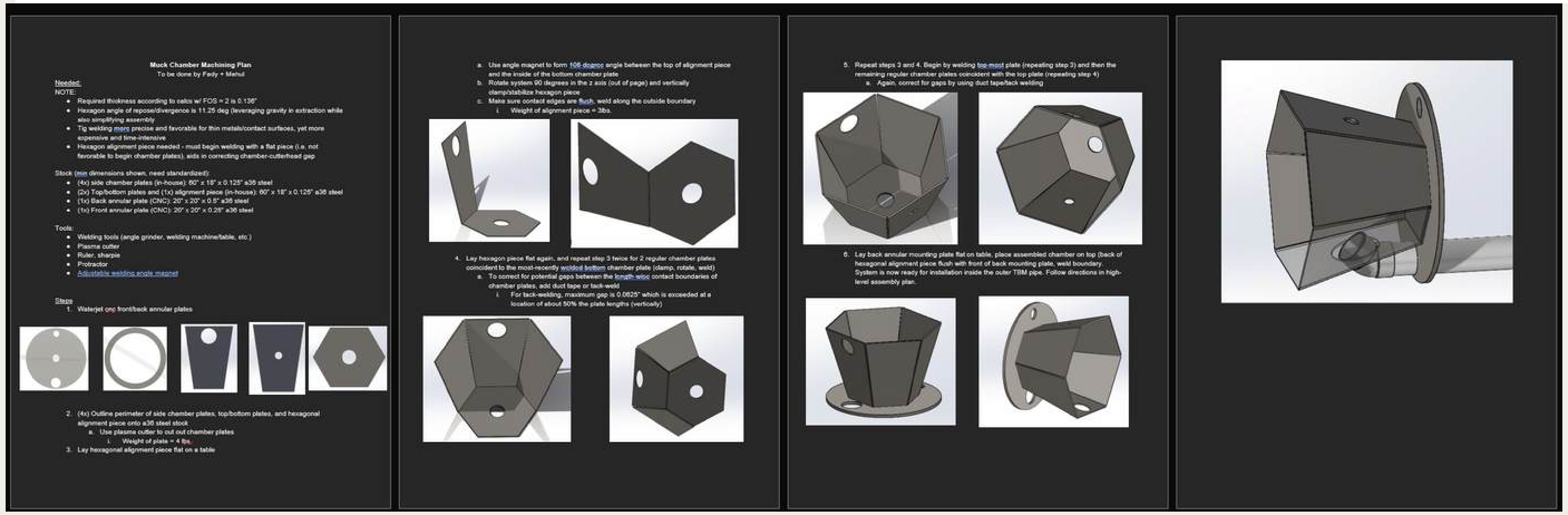
Excavation Systems - NoDiggity V2 - Penn Hyperloop



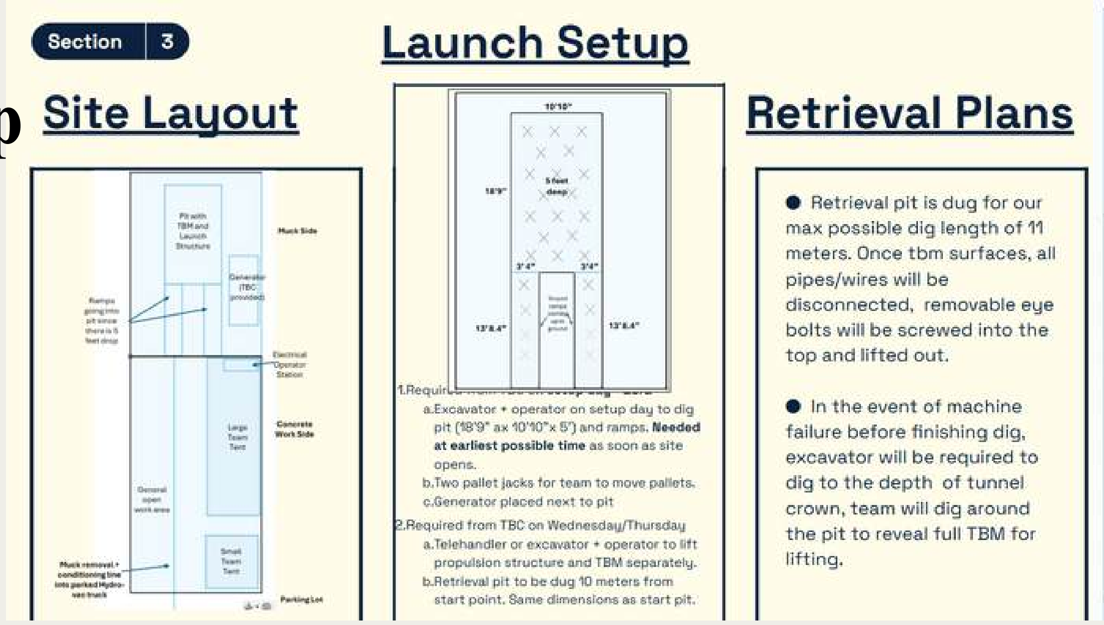
Drawings – Large plates plates were sent out for waterjet/ laser CNC cutting. Rest were machined in-house.

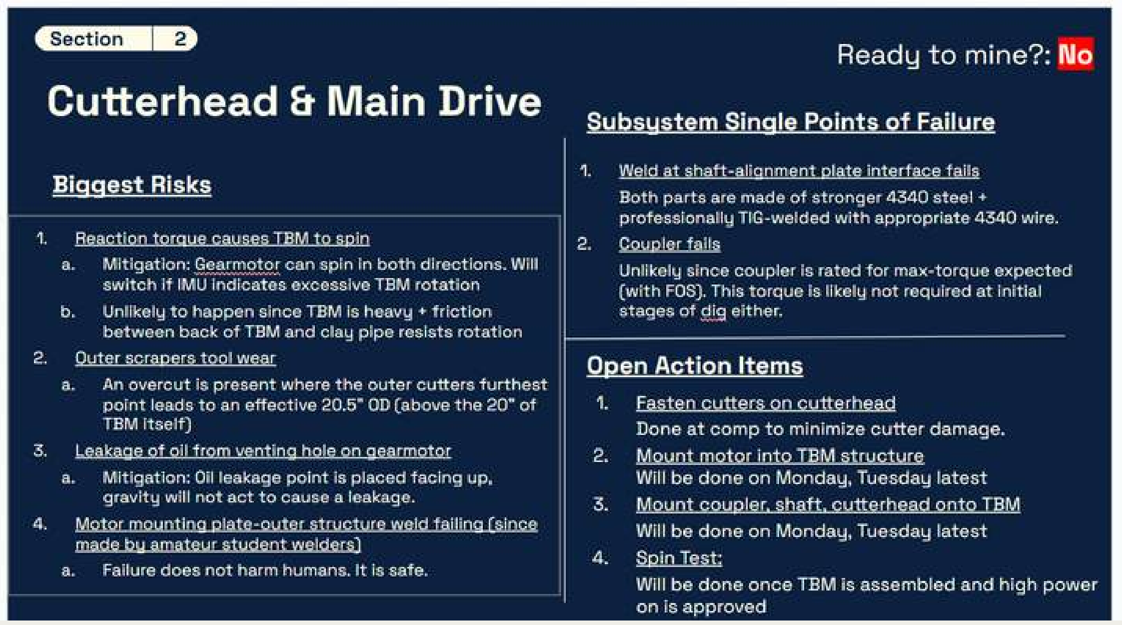
Assembly and Machining Plans generated:

(Test Plans were skipped due to lack of funding early enough into our process.)



Excavation Systems - NoDiggity V2 - Penn Hyperloop



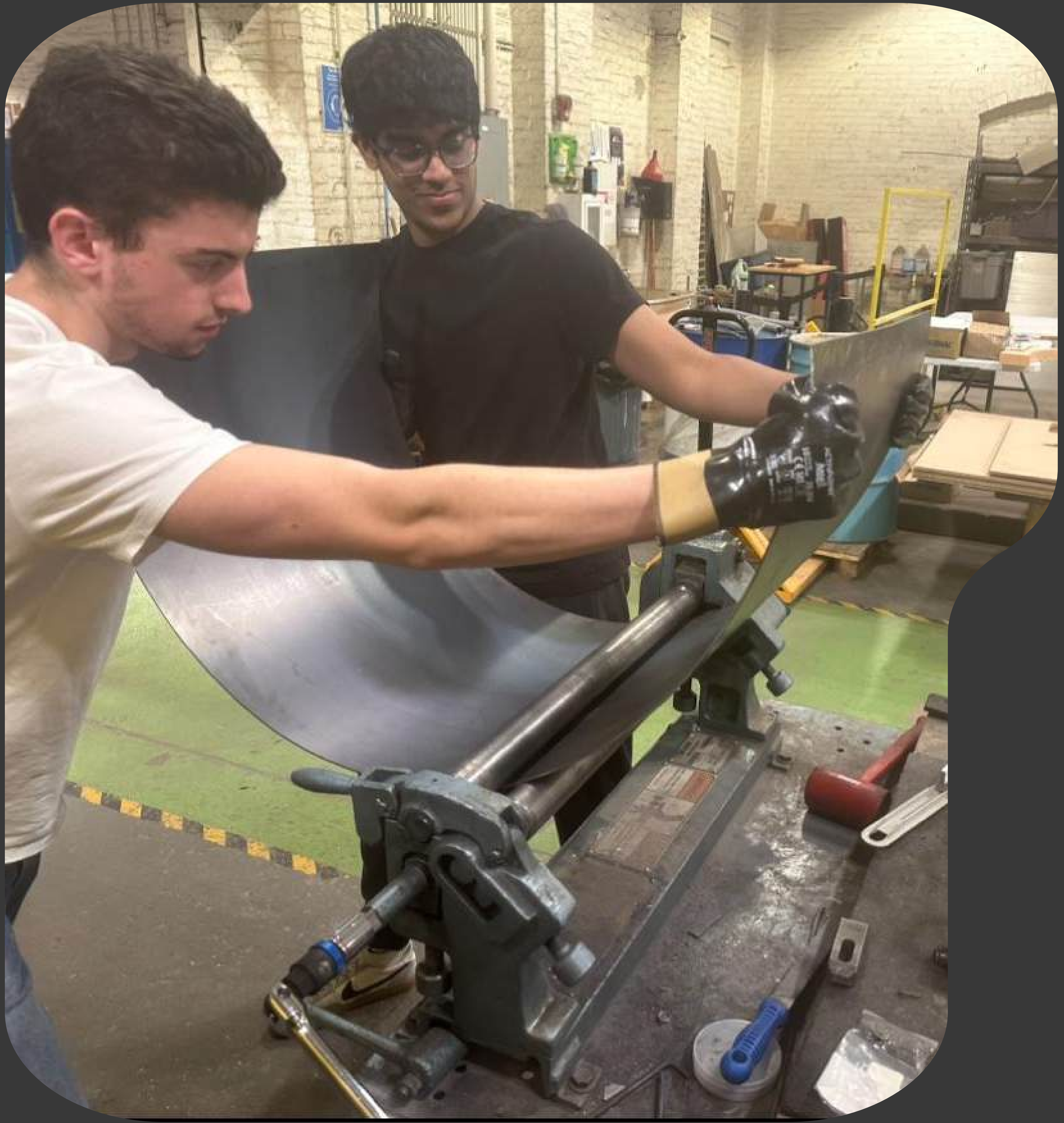


Evaluated mining readiness across mechanical systems to present to overseeing organization (Boring Company)

Manufacturing + Assembly at Nextfab (makeshift workspace for the machine)

Learnt and applied flux–core MIG Welding up to 1/4" thickness on Mild Steel.

Coordinated site prep, lifting ops, troubleshooting dig/ demo day failures



PENN HYPERLOOP

NoDiggity V1

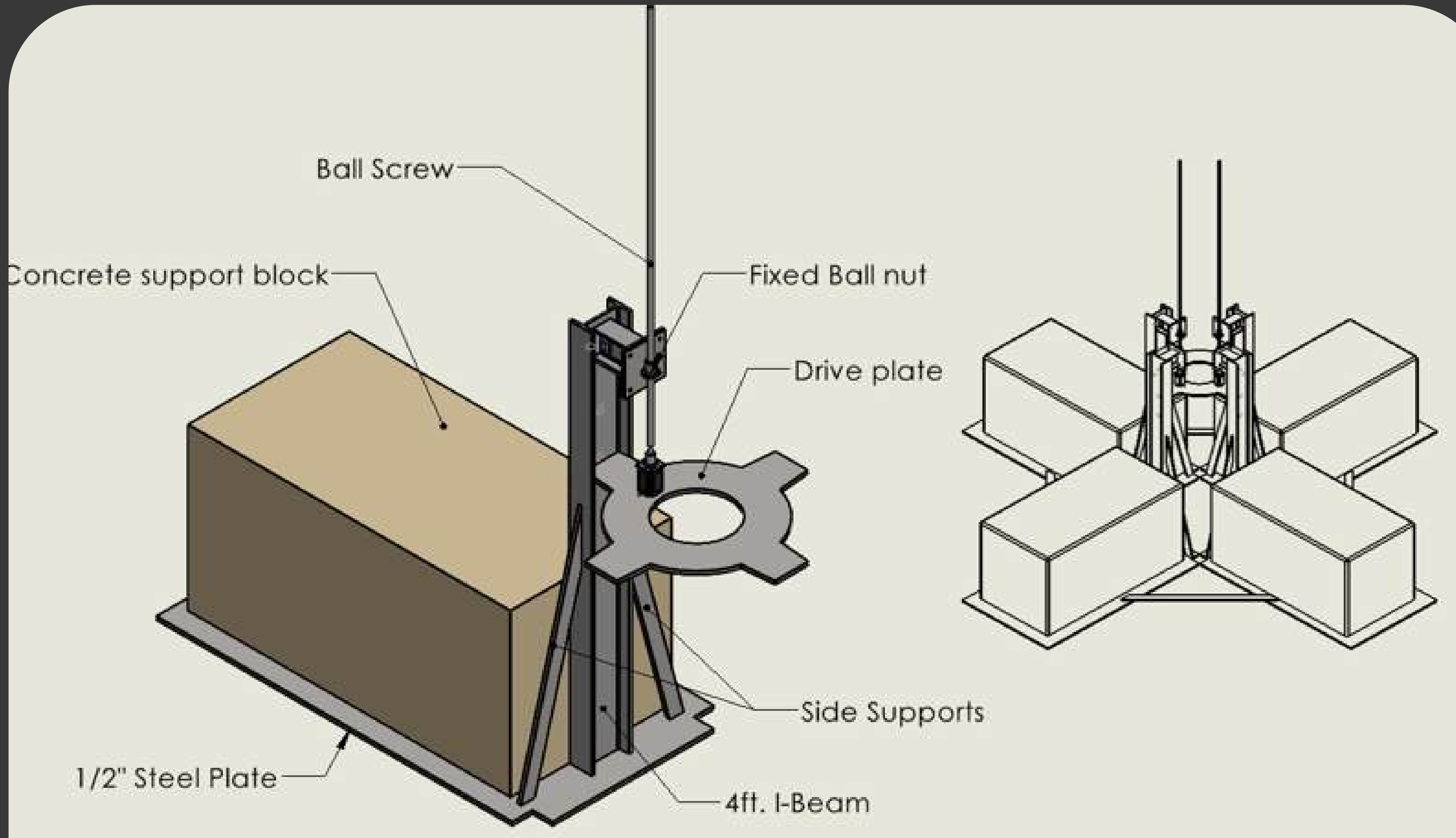
Founding member of what came to be the Penn Hyperloop team later. Our goal was to dig a 1 meter hole with a 0.5 meter diameter in Bastrop, Texas soil. I was the Propulsion System RE (responsible engineer) – an independent on–ground structure that would push the TBM vertically downwards as it excavated.

In addition, as 1 of 3 mechanical team members, I assisted in the machining of custom gearmotor keys, forming the machine's outer shell, and troubleshooting a host of competition safety related requirements.

Aggressive 2 month design phase + 3 week construction phase to win 1st place in our Digging Mini–Event at NaBC '24 (for the Boring Company).

Propulsion System - NoDiggity V1 - Penn Hyperloop

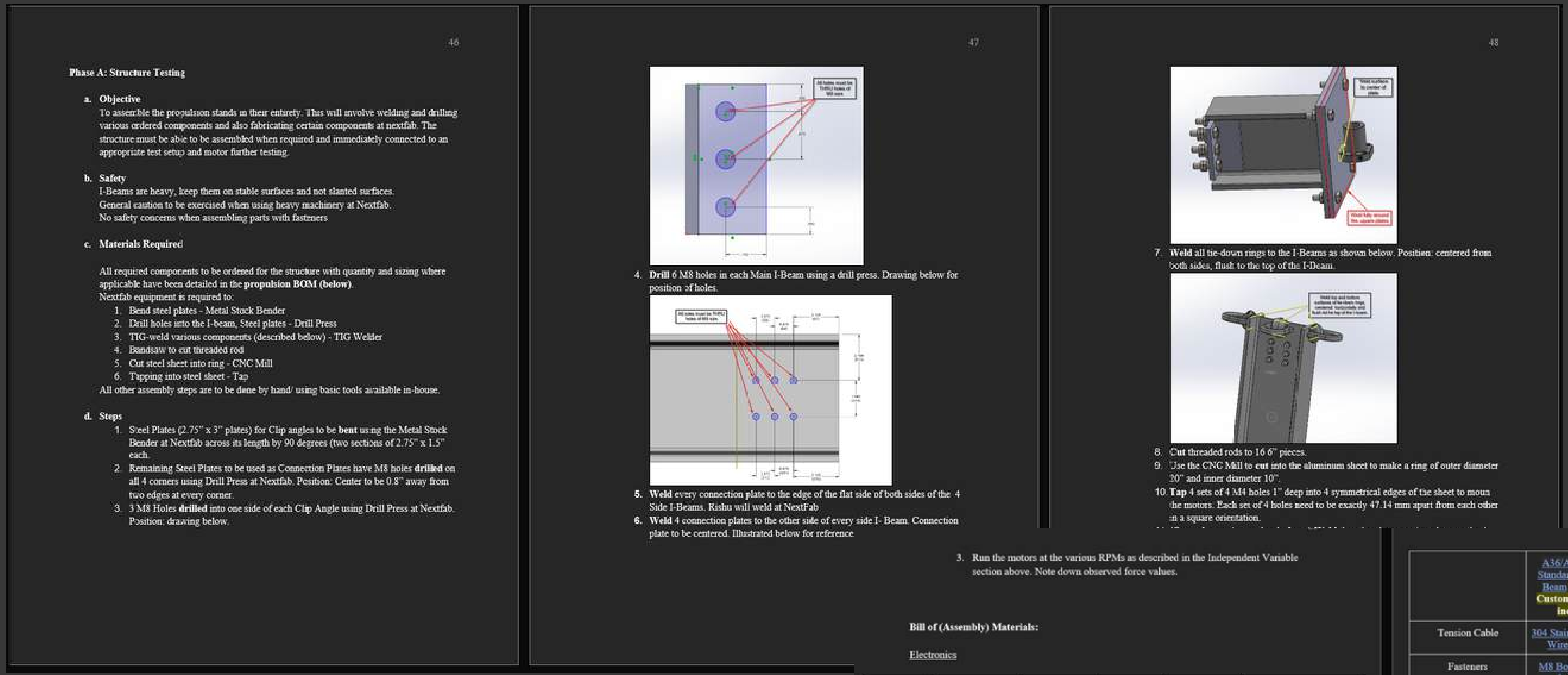
- Designed force reaction and torque reaction into the structure
- Switched from traditionally preferred linear actuators to ball screws to make a 5x cost reduction in this system.
- Learnt and performed weld shear calculations for key joints
- Conducted bolt shear analysis at fastened joints
- Identified and sourced metal from local vendors at discount rates and <1 week lead times.
- Attempted force testing to characterize ball screw movement as an actuator (with help of controls team)



- Propulsion Method: SFU1605 Ball Screw Linear Actuator
- Maximum Thrust Force: >1600 lbf
- Motor Type: NEMA23 DC Stepper Motors
- Torque Reaction Method: Slotting into I-Beam Webs and Ground Screws
- Thrust Reaction Method: Four Concrete Bunker Blocks on ½” thick steel plates

PROPULSION

Propulsion System - NoDiggity V1 - Penn Hyperloop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Phase A: Structure Testing

a. Objective
To assemble the propulsion stands in their entirety. This will involve welding and drilling various ordered components and also fabricating certain components at nextfab. The structure must be able to be assembled when required and immediately connected to an appropriate test setup and motor further testing.

b. Safety
I-Beams are heavy, keep them on stable surfaces and not slanted surfaces.
General caution to be exercised when using heavy machinery at Nextfab.
No safety concerns when assembling parts with fasteners

c. Materials Required
All required components to be ordered for the structure with quantity and sizing where applicable have been detailed in the propulsion BOM (below).
Nextfab equipment is required to:
1. Bend steel plates - Metal Stock Bender
2. Drill holes into the I-beam, Steel plates - Drill Press
3. TIG-weld various components (described below) - TIG Welder
4. Bandsaw to cut threaded rod
5. Cut steel sheet into ring - CNC Mill
6. Tapping into steel sheet - Tap
All other assembly steps are to be done by hand/ using basic tools available in-house.

d. Steps
1. Steel Plates (2.75" x 3" plates) for Clip angles to be bent using the Metal Stock Bender at Nextfab across its length by 90 degrees (two sections of 2.75" x 1.5" each.
2. Remaining Steel Plates to be used as Connection Plates have M8 holes drilled on all 4 corners using Drill Press at Nextfab. Position: Center to be 0.8" away from two edges at every corner.
3. 3 M8 Holes drilled into one side of each Clip Angle using Drill Press at Nextfab. Position: drawing below.

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4. Drill 6 M8 holes in each Main I-Beam using a drill press. Drawing below for position of holes.
5. Weld every connection plate to the edge of the flat side of both sides of the 4 Side I-Beams. Rishu will weld at NextFab
6. Weld 4 connection plates to the other side of every side I- Beam. Connection plate to be centered. Illustrated below for reference

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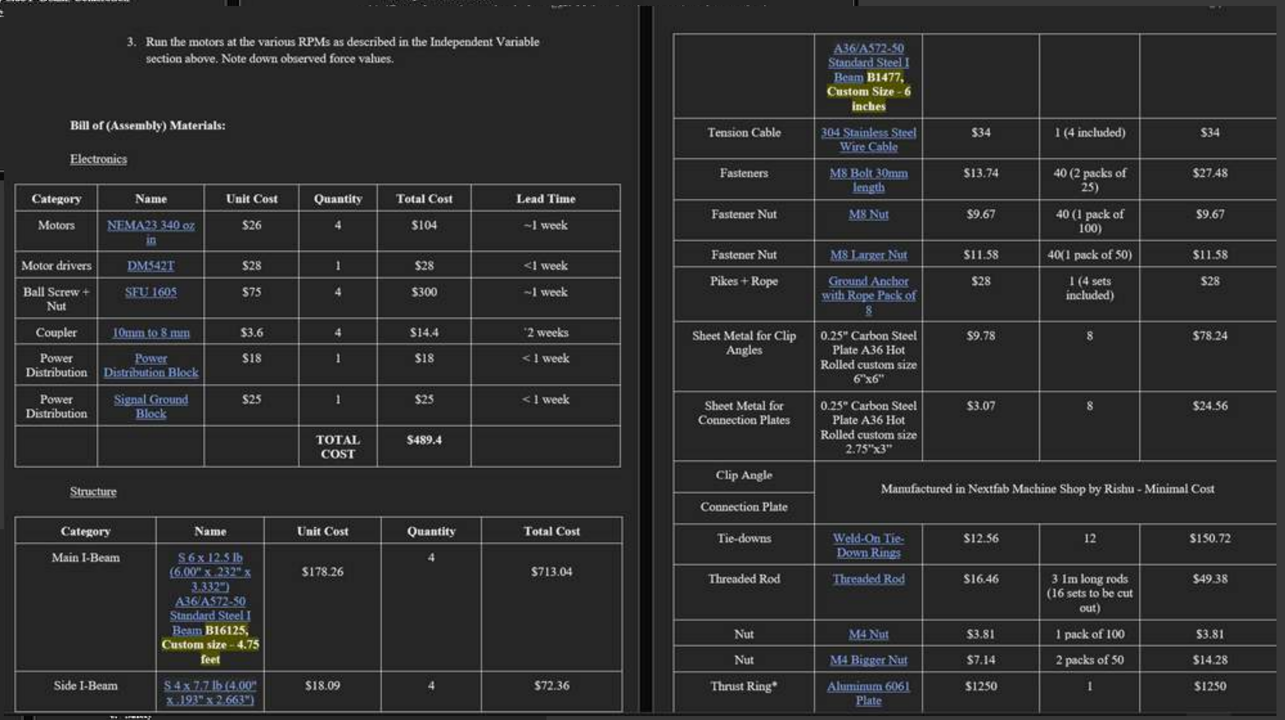
7. Weld all tie-down rings to the I-Beams as shown below. Position: centered from both sides, flush to the top of the I-Beam.
8. Cut threaded rods to 16 6" pieces.
9. Use the CNC Mill to cut into the aluminum sheet to make a ring of outer diameter 20" and inner diameter 10".
10. Tap 4 sets of 4 M4 holes 1" deep into 4 symmetrical edges of the sheet to mount the motors. Each set of 4 holes need to be exactly 47.14 mm apart from each other in a square orientation.


3. Run the motors at the various RPMs as described in the Independent Variable section above. Note down observed force values.

Bill of (Assembly) Materials:

Electronics

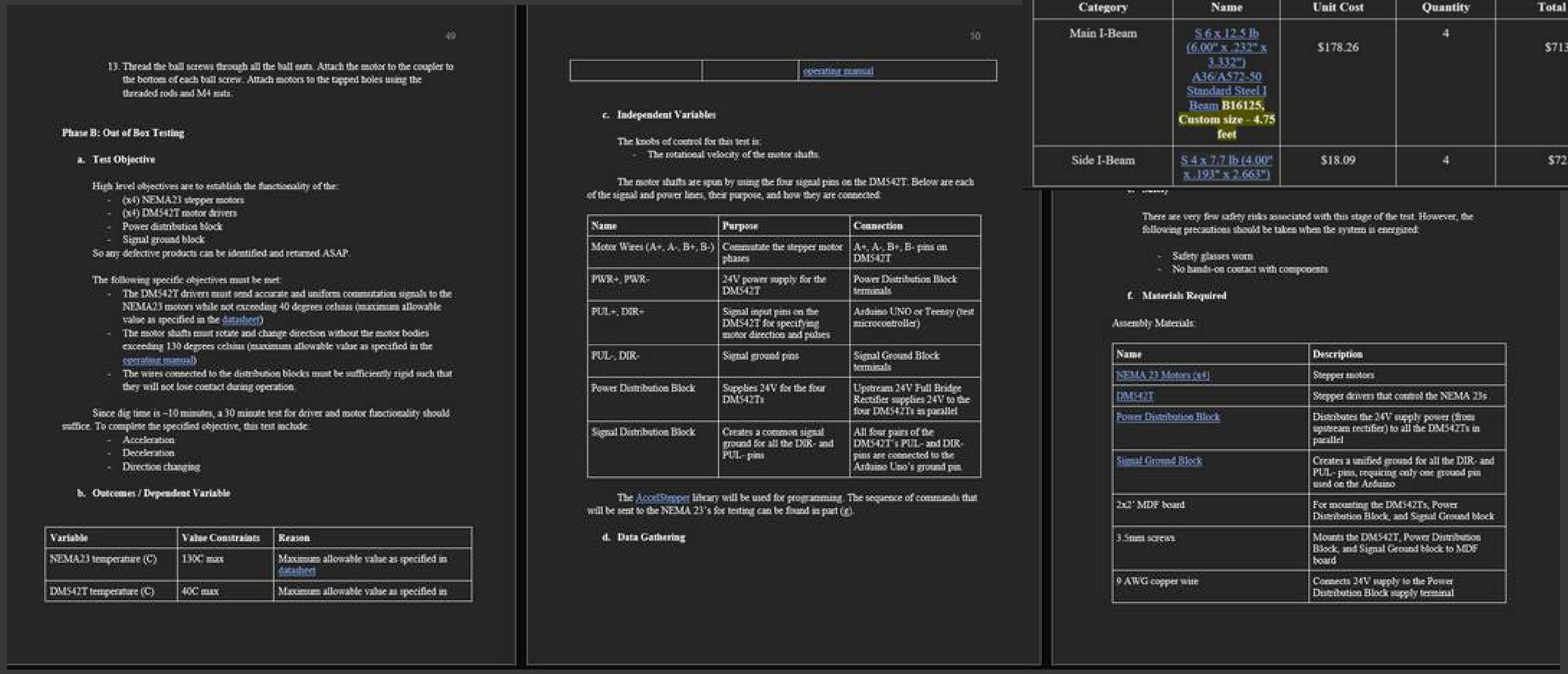
Category	Name	Unit Cost	Quantity	Total Cost	Lead Time
Motors	NEMA23 340 oz in	$26	4	$104	~1 week
Motor drivers	DM542T	$28	1	$28	<1 week
Ball Screw + Nut	SFU 1605	$75	4	$300	~1 week
Coupler	10mm to 8 mm	$3.6	4	$14.4	~2 weeks
Power Distribution	Power Distribution Block	$18	1	$18	< 1 week
Power Distribution	Signal Ground Block	$25	1	$25	< 1 week
			TOTAL COST	$489.4	

Structure

Category	Name	Unit Cost	Quantity	Total Cost
Main I-Beam	S 6 x 12.5 lb (6.00" x .232" x 3.332") A36/A572-50 Standard Steel I Beam B16125, Custom size - 4.75 feet	$178.26	4	$713.04
Side I-Beam	S 4 x 7.7 lb (4.00" x .193" x 2.663")	$18.09	4	$72.36

	A36/A572-50 Standard Steel I Beam B1477, Custom Size - 6 inches			
Tension Cable	304 Stainless Steel Wire Cable	$34	1 (4 included)	$34
Fasteners	M8 Bolt 30mm length	$13.74	40 (2 packs of 25)	$27.48
Fastener Nut	M8 Nut	$9.67	40 (1 pack of 100)	$9.67
Fastener Nut	M8 Larger Nut	$11.58	40(1 pack of 50)	$11.58
Pikes + Rope	Ground Anchor with Rope Pack of 8	$28	1 (4 sets included)	$28
Sheet Metal for Clip Angles	0.25" Carbon Steel Plate A36 Hot Rolled custom size 6"x6"	$9.78	8	$78.24
Sheet Metal for Connection Plates	0.25" Carbon Steel Plate A36 Hot Rolled custom size 2.75"x3"	$3.07	8	$24.56
Clip Angle	Manufactured in Nextfab Machine Shop by Rishu - Minimal Cost			
Connection Plate				
Tie-downs	Weld-On Tie-Down Rings	$12.56	12	$150.72
Threaded Rod	Threaded Rod	$16.46	3 1m long rods (16 sets to be cut out)	$49.38
Nut	M4 Nut	$3.81	1 pack of 100	$3.81
Nut	M4 Bigger Nut	$7.14	2 packs of 50	$14.28
Thrust Ring*	Aluminum 6061 Plate	$1250	1	$1250

Assembly Plans, Test Plans and BOM's generated for owned system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13. Thread the ball screws through all the ball nuts. Attach the motor to the coupler to the bottom of each ball screw. Attach motors to the tapped holes using the threaded rods and M4 nuts.

Phase B: Out of Box Testing

a. Test Objective

High level objectives are to establish the functionality of the:
- (x4) NEMA23 stepper motors
- (x4) DM542T motor drivers
- Power distribution block
- Signal ground block

So any defective products can be identified and returned ASAP.

The following specific objectives must be met:
- The DM542T drivers must send accurate and uniform commutation signals to the NEMA23 motors while not exceeding 40 degrees celsius (maximum allowable value as specified in the datasheet)
- The motor shafts must rotate and change direction without the motor bodies exceeding 130 degrees celsius (maximum allowable value as specified in the operating manual)
- The wires connected to the distribution blocks must be sufficiently rigid such that they will not lose contact during operation.

Since dig time is ~10 minutes, a 30 minute test for driver and motor functionality should suffice. To complete the specified objective, this test include:
- Acceleration
- Deceleration
- Direction changing

b. Outcomes / Dependent Variable

Variable	Value Constraints	Reason
NEMA23 temperature (C)	130C max	Maximum allowable value as specified in datasheet
DM542T temperature (C)	40C max	Maximum allowable value as specified in

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c. Independent Variables

The knobs of control for this test is:
- The rotational velocity of the motor shafts.

The motor shafts are spun by using the four signal pins on the DM542T. Below are each of the signal and power lines, their purpose, and how they are connected:

Name	Purpose	Connection
Motor Wires (A+, A-, B+, B-)	Commutate the stepper motor phases	A+, A-, B+, B- pins on DM542T
PWR+, PWR-	24V power supply for the DM542T	Power Distribution Block terminals
PUL+, DIR+	Signal input pins on the DM542T for specifying motor direction and pulses	Arduino UNO or Teensy (test microcontroller)
PUL-, DIR-	Signal ground pins	Signal Ground Block terminals
Power Distribution Block	Supplies 24V for the four DM542Ts	Upstream 24V Full Bridge Rectifier supplies 24V to the four DM542Ts in parallel
Signal Distribution Block	Creates a common signal ground for all the DIR- and PUL- pins	All four pairs of the DM542T's PUL- and DIR- pins are connected to the Arduino Uno's ground pin.

The AccelStepper library will be used for programming. The sequence of commands that will be sent to the NEMA 23's for testing can be found in part (g).

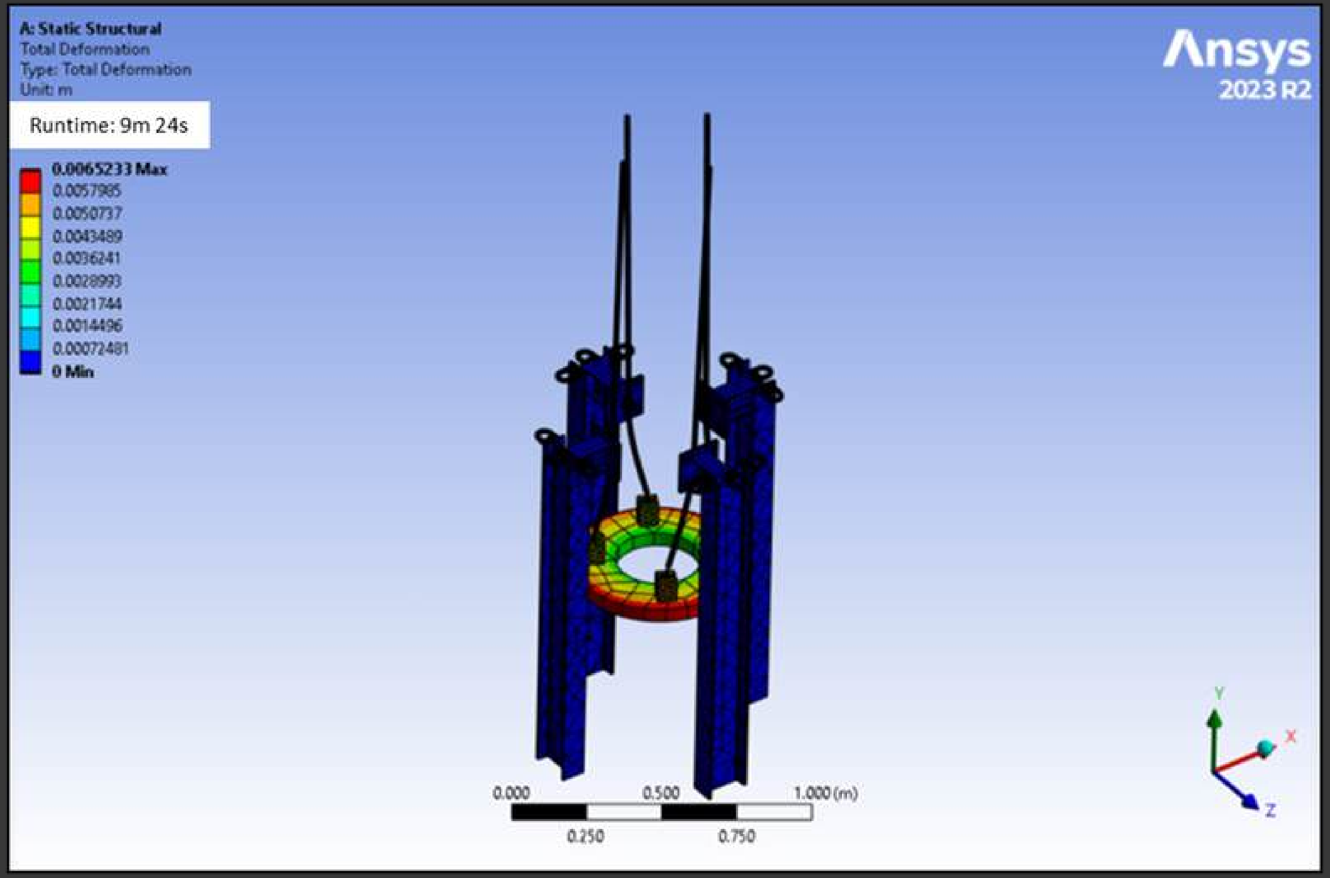
d. Data Gathering

There are very few safety risks associated with this stage of the test. However, the following precautions should be taken when the system is energized:
- Safety glasses worn
- No hands-on contact with components

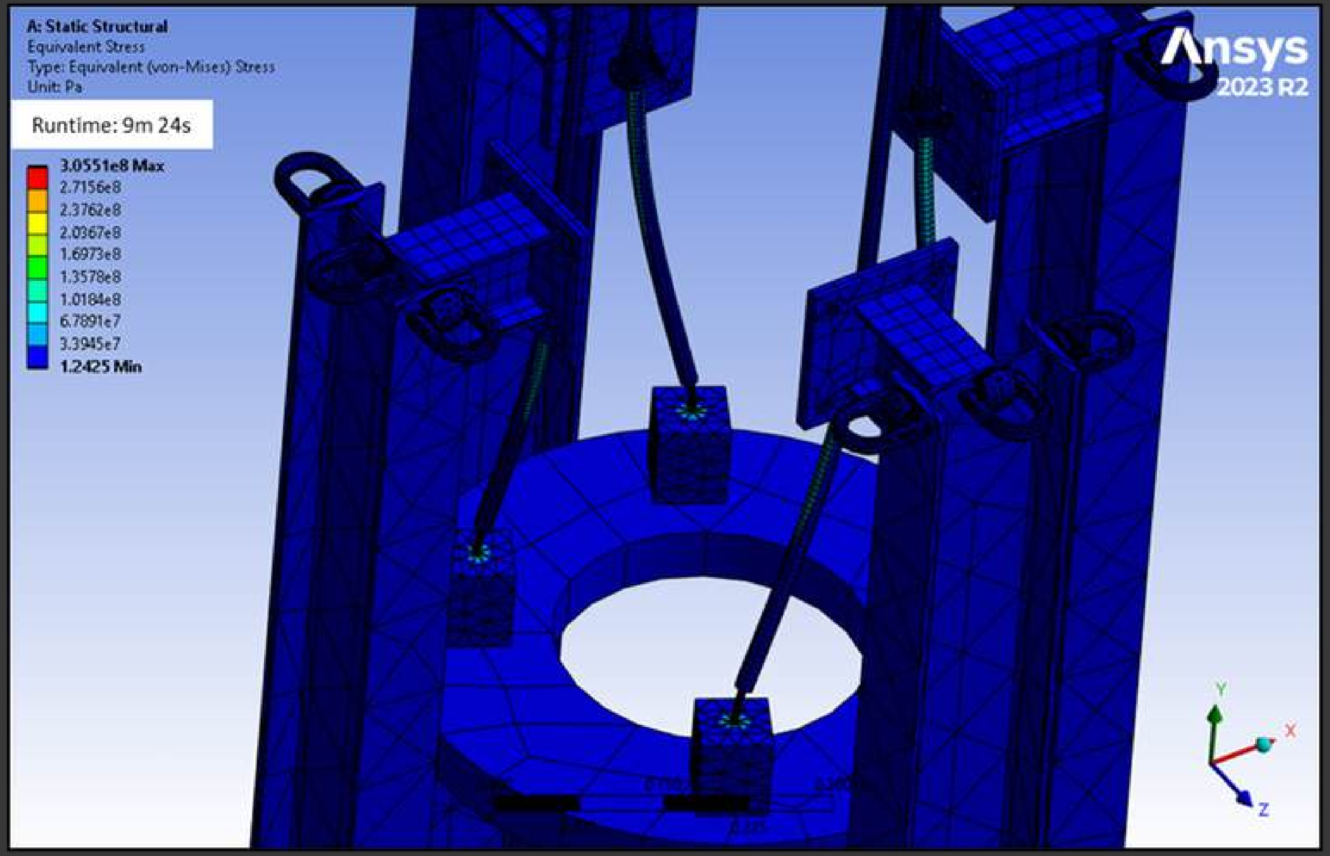
f. Materials Required

Assembly Materials:

Name	Description
NEMA 23 Motors (x4)	Stepper motors
DM542T	Stepper drivers that control the NEMA 23s
Power Distribution Block	Distributes the 24V supply power (from upstream rectifier) to all the DM542Ts in parallel
Signal Ground Block	Creates a unified ground for all the DIR- and PUL- pins, requiring only one ground pin used on the Arduino
2x2' MDF board	For mounting the DM542Ts, Power Distribution Block, and Signal Ground Block
3.5mm screws	Mounts the DM542T, Power Distribution Block, and Signal Ground block to MDF board
8 AWG copper wire	Connects 24V supply to the Power Distribution Block supply terminal



ANSYS FEA – Stress and Deformation analysis to ensure viability of structure and associated FOS.



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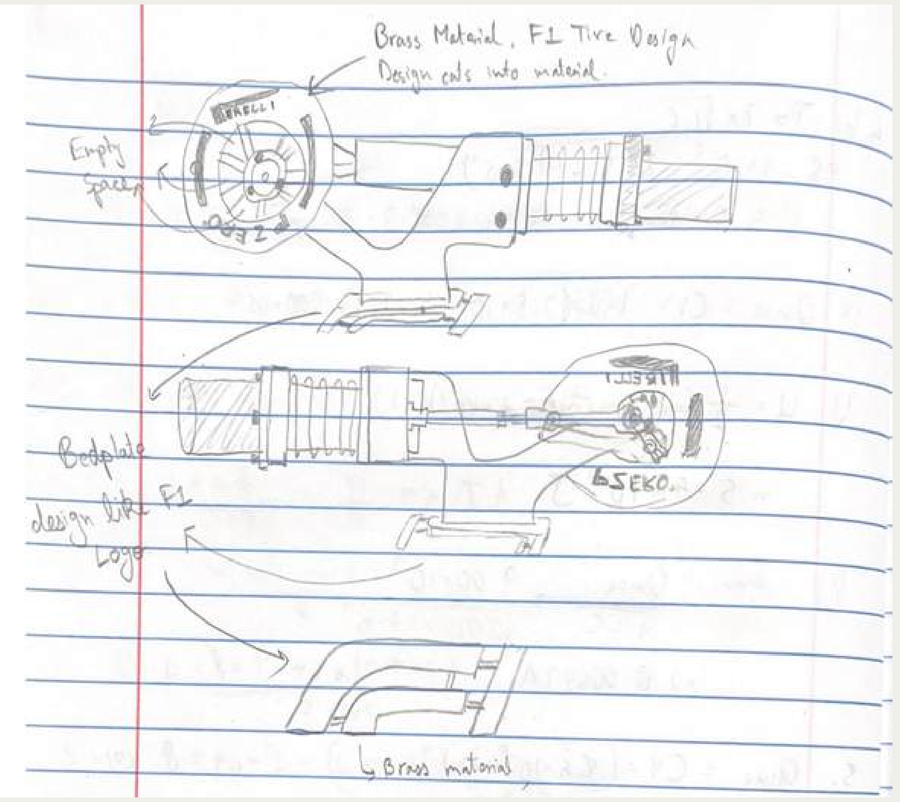
Stirling Engine Model

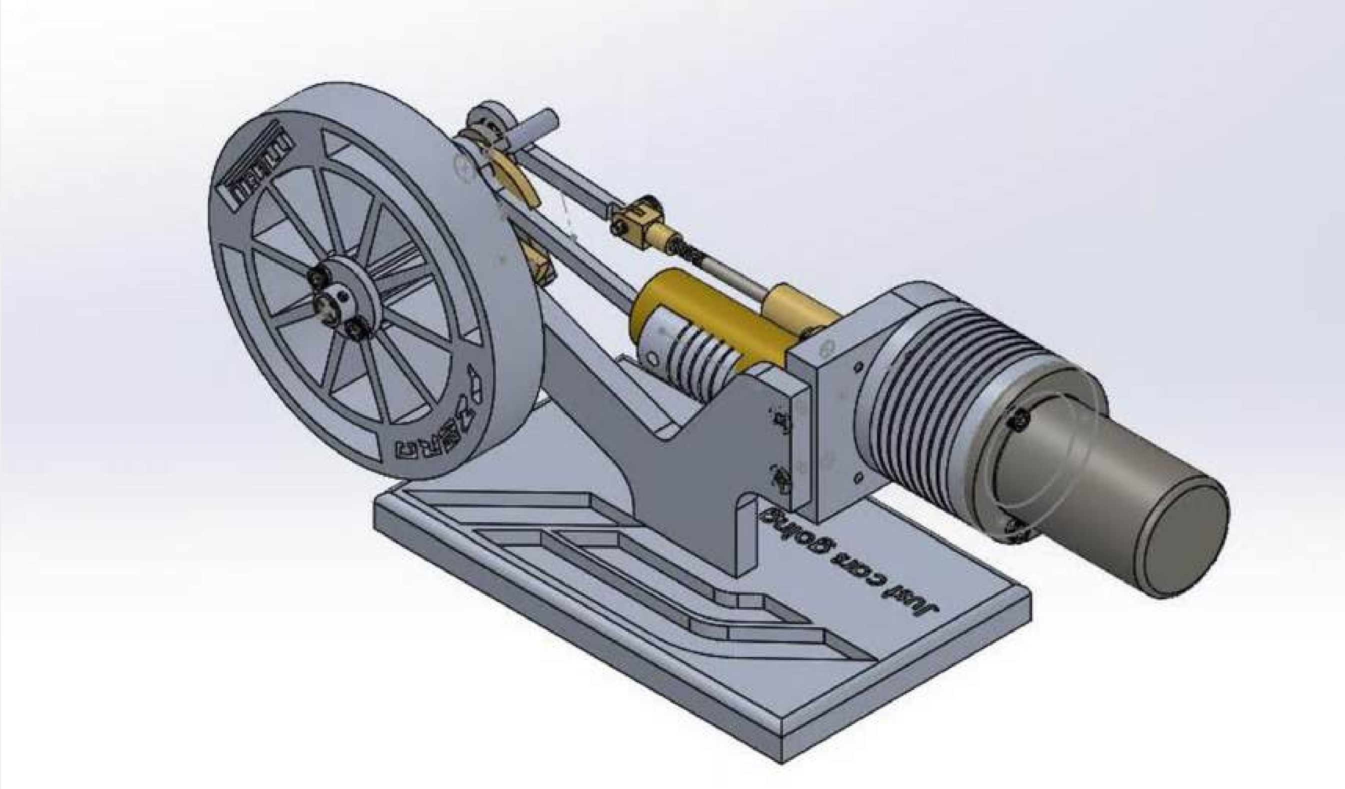
Designed on Solidworks and made using aluminum, brass, stainless steel. This working modeal was my introduction to manufacturing methods, the Machinist’s Handbook, and GD&T.

Stirling Engine Model - UPenn MEAM Curriculum

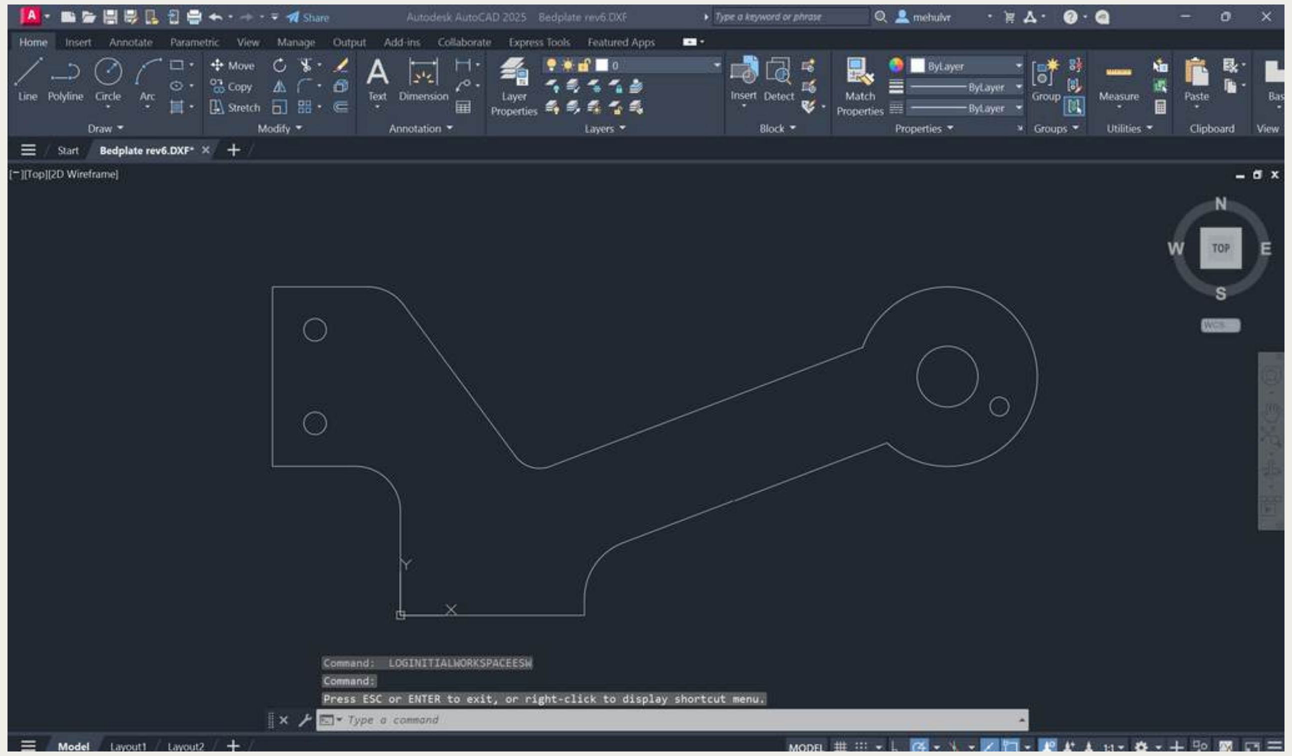


Inital Sketch of Design Idea

- Used 3–axis Prototrak Vertical Mill with CNC capabilities (toolpaths generated using Mastercam)
- Used horizontal lathe for drilling, boring and tapping operations on cylindrical parts.
- Assembled engine ran at ~950 rpm powered by butane torch lighter

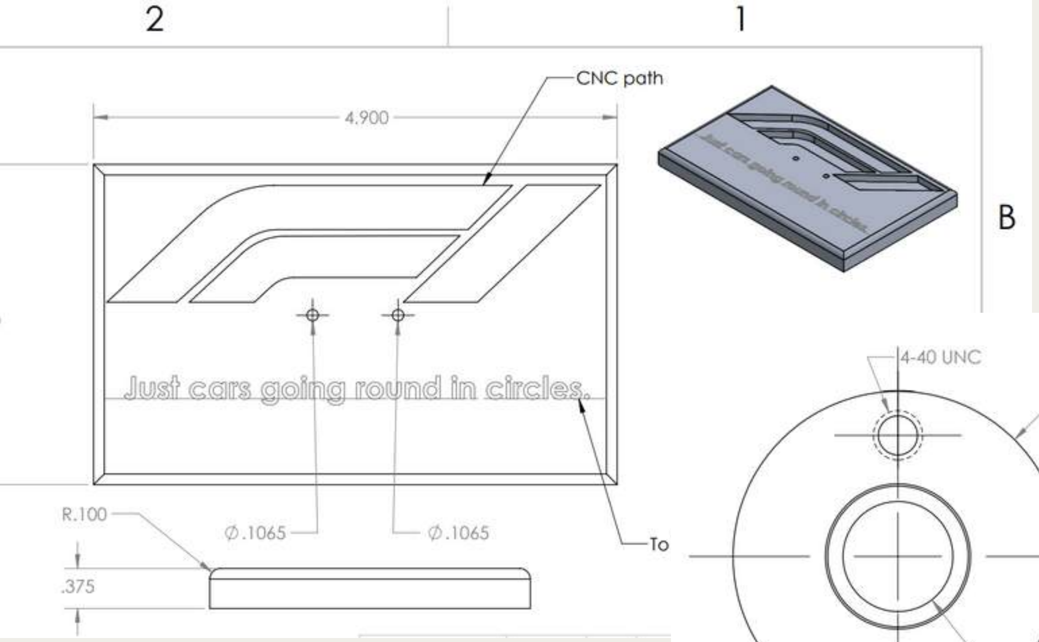


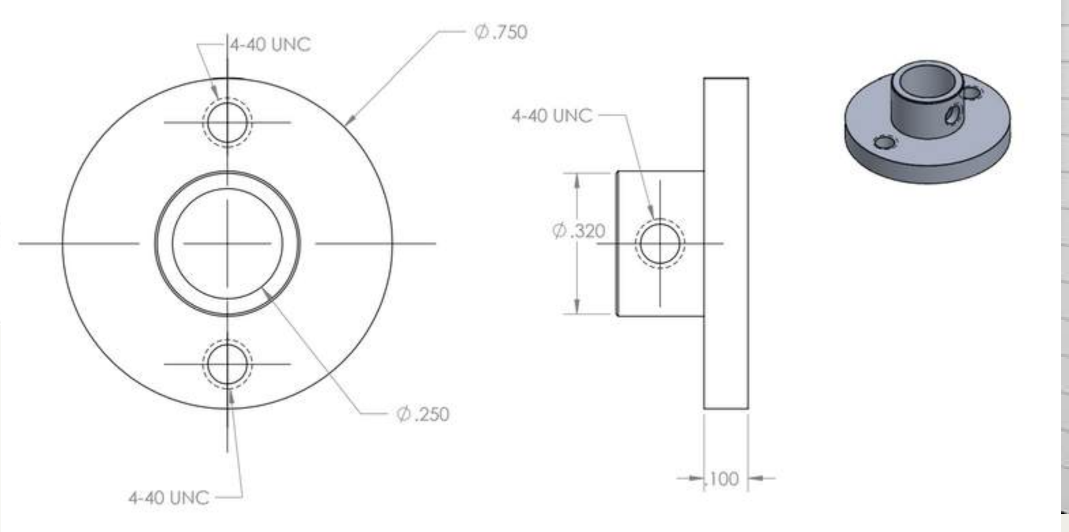
CAD Render – Solidworks assembly of parts (designed from drawings) with working gear mates

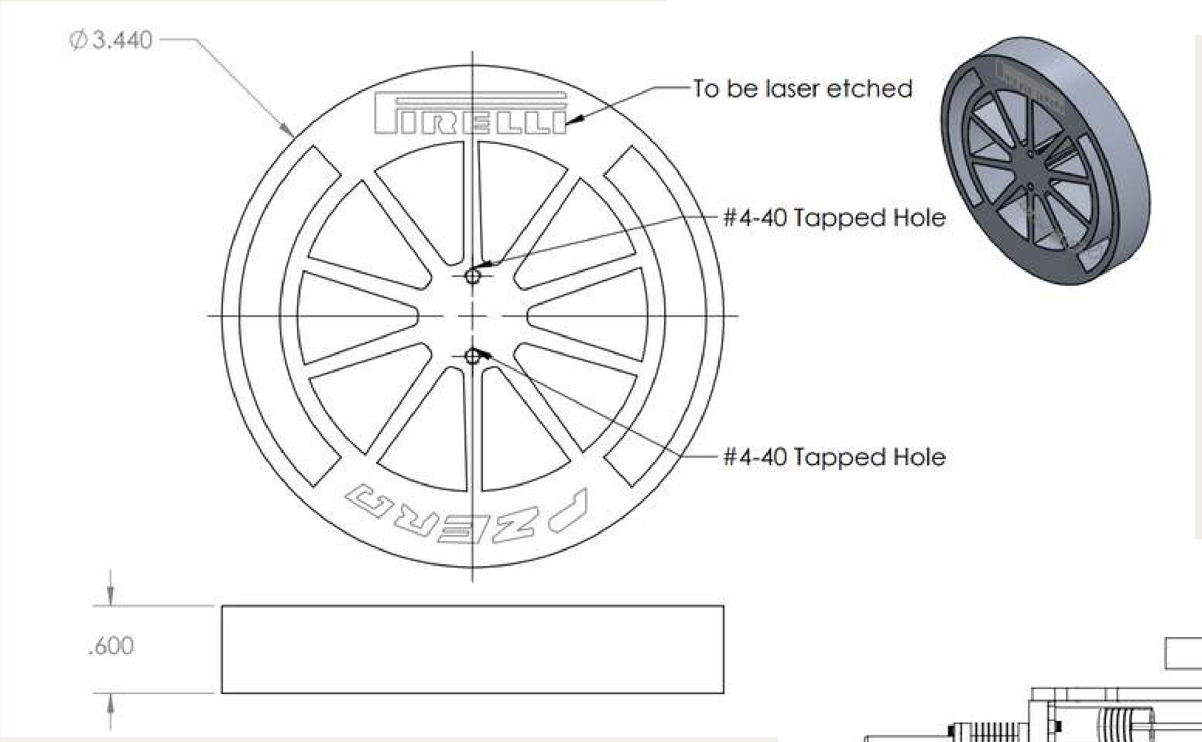


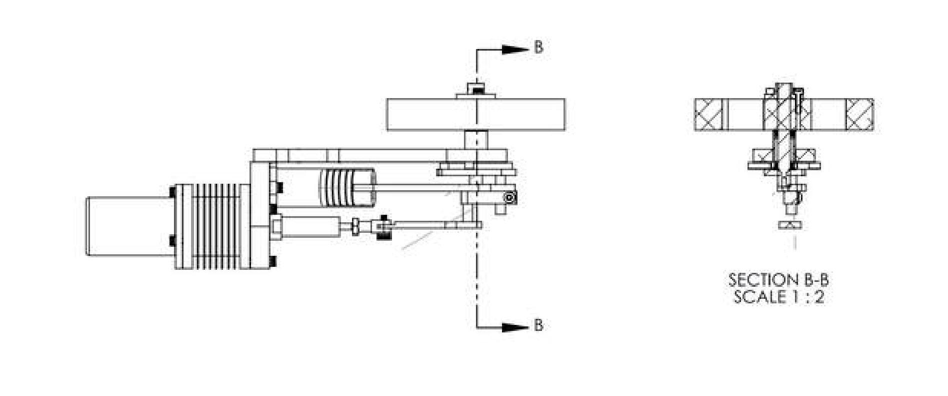
DXF drawings generated for outside vendors

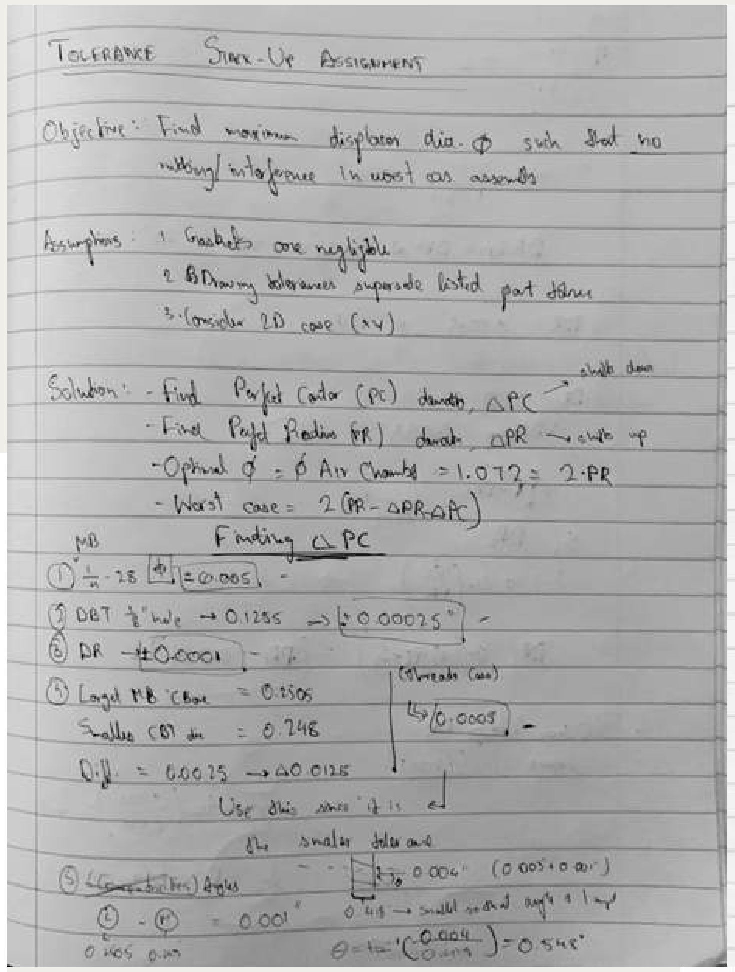
Stirling Engine Model - UPenn MEAM Curriculum

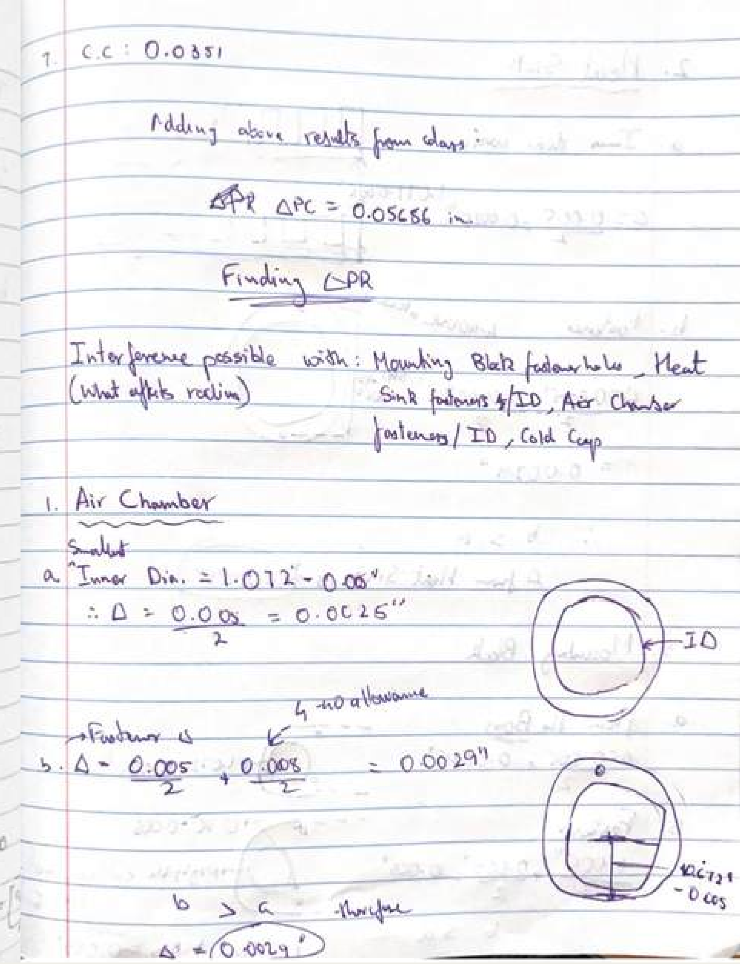




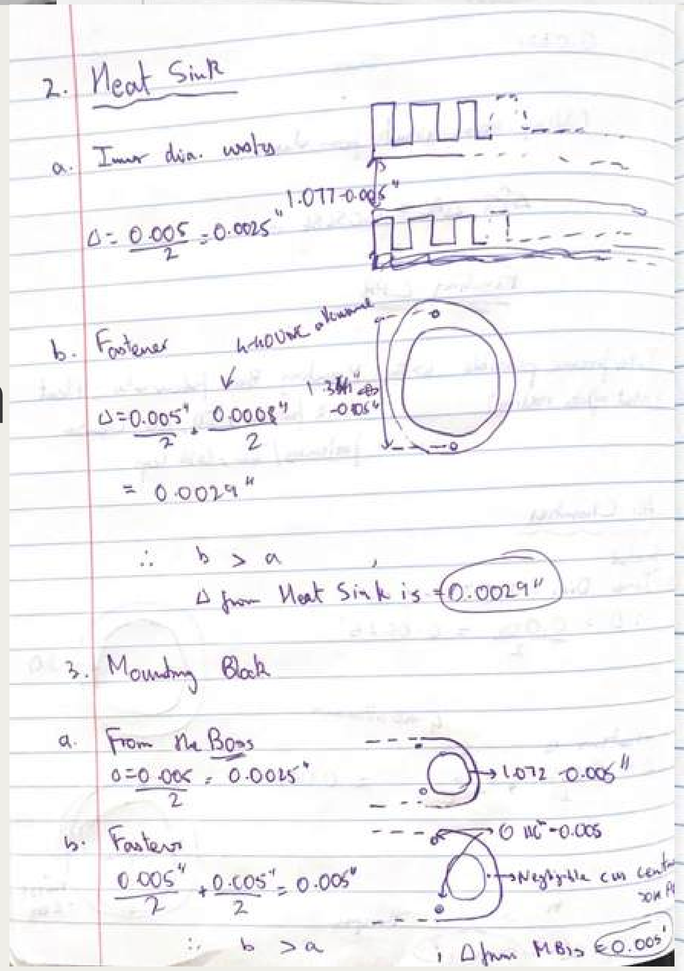


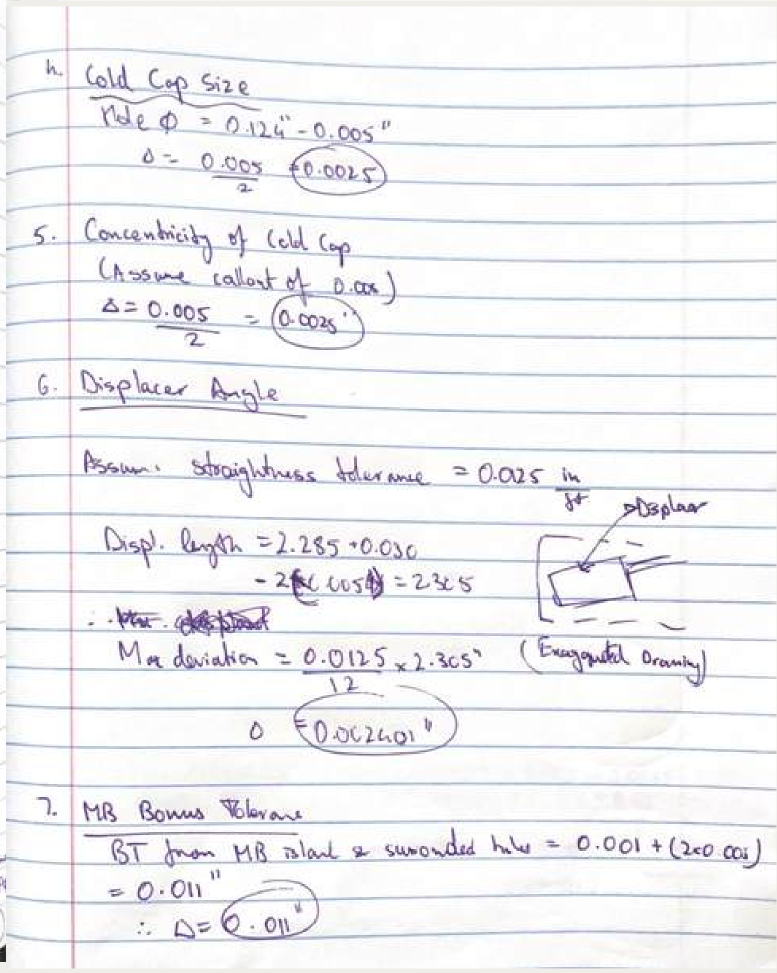






Tolerance Stackup – Exercise in GD&T to find max allowed deviation from Perfect Radius and Perfect Center positioning





Drawings – Solidworks drawings for parts and assemblies

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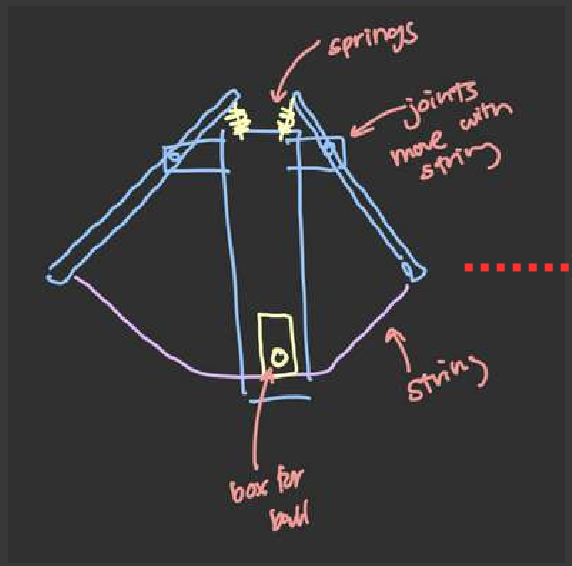
Undergraduate Lab Projects

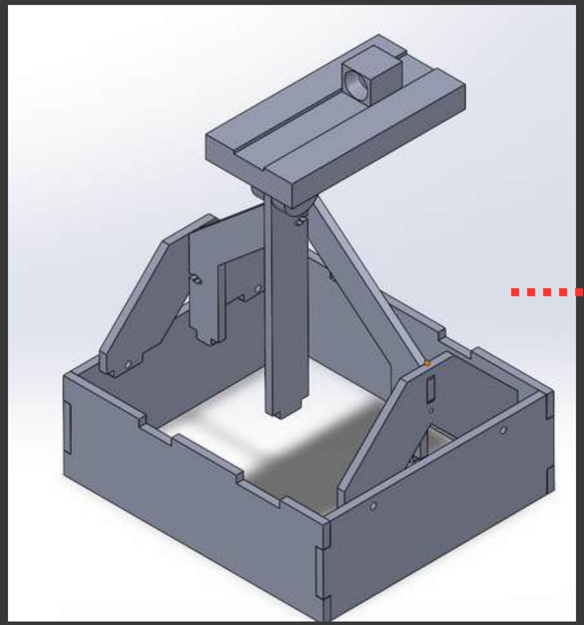
Trained in the traditional engineering and experimentation methodology through structured lab projects as a Mechanical Engineering undergraduate. Key projects include: Seige machine, Kinematics Launcher, Bridge, and Bottle Rocket.

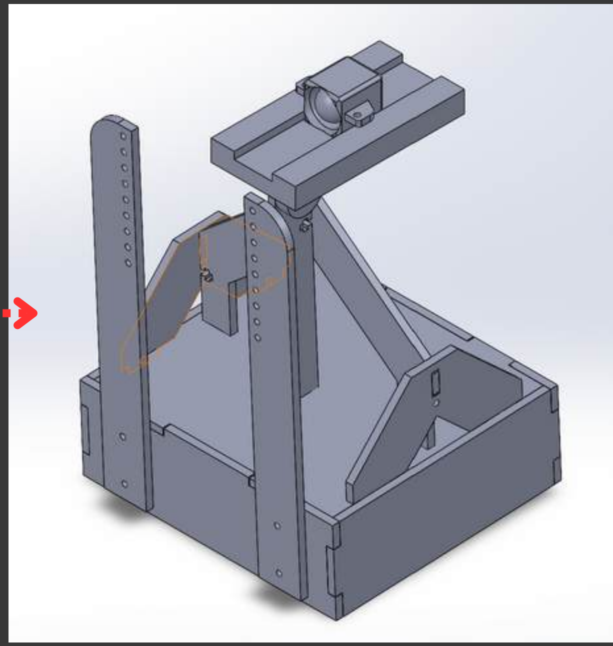
Made use of the school's Rapid Prototyping Lab to laser cut MDF, Acryclic and FDM 3D printers to extrude small PLA structures.

MEAM 1010: Intro to Mechanical Design

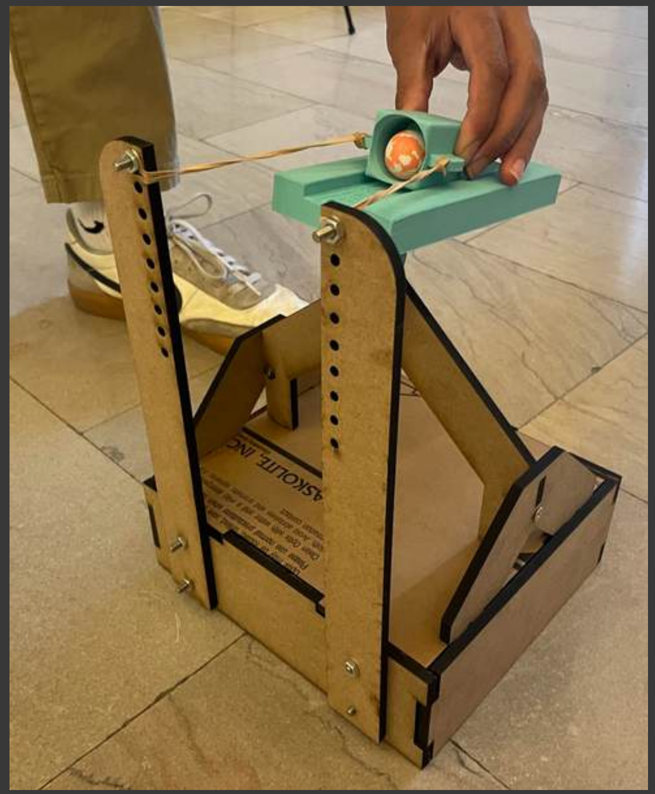
Seige Machine



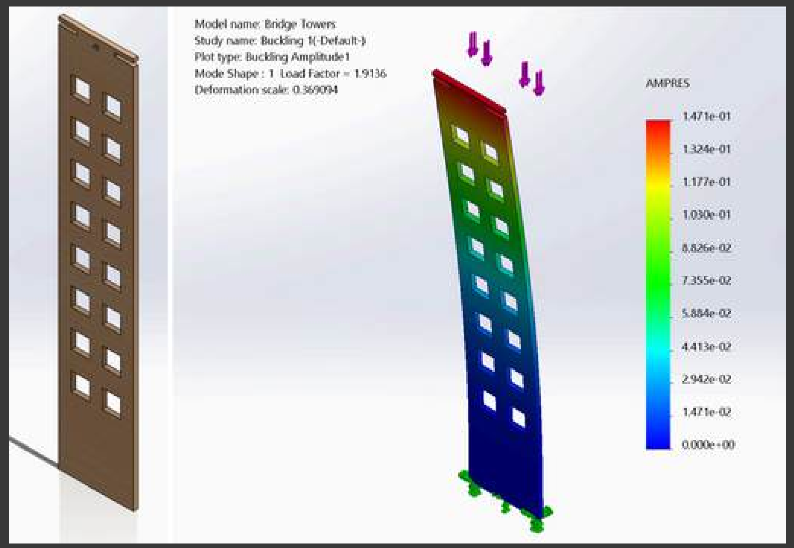




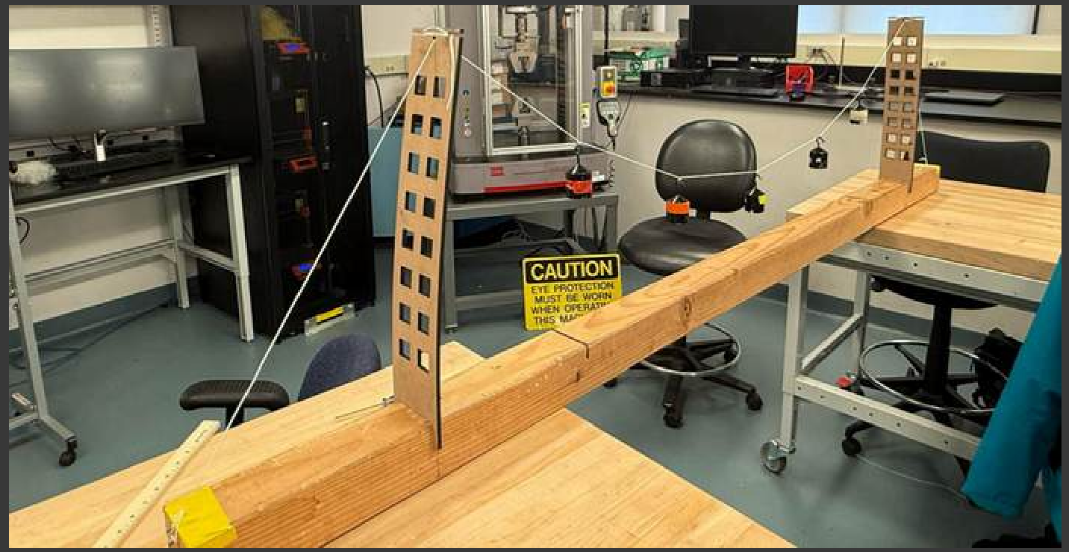
- Inspired by spring-loaded crossbows
- Utilized press fits for crossbow to attach to the large structure
- Fastener t-slot joints at the edges of the large structure
- Fastener lap joints on the crossbow itself
- Iterated on base design to manage reaction force generated by elastic rubber bands

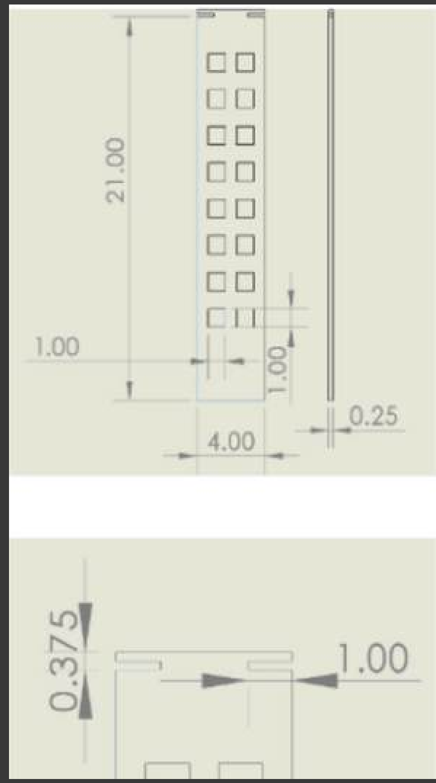


MEAM 2470: Mechanical Engineering Lab 1



Bridge Project

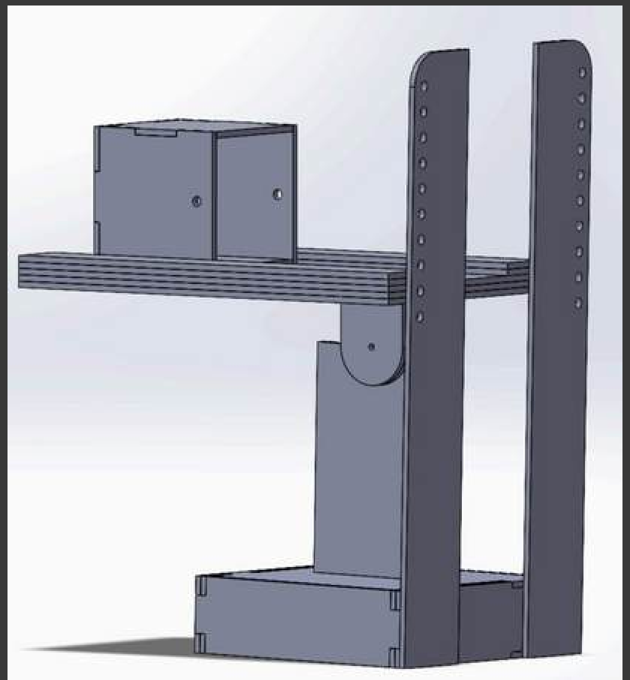




- Designed and built wide-span suspension bridge with 21″ MDF towers; FEA validated tower safety factor of 1.91 under 25 N load.
- Modeled cable sag via parabolic arc-length integration, calculated required pre-load cut length (75.7″) and hanger tensions (20–25 N range).
- Derived tension–elongation model from MTS tensile tests to predict cable stretch; total elongation measured at 4.7″.
- Implemented bowline knots + cleated loops for secure cable anchoring; optimized for cost.
- Final bridge passed test with 7.5″ sag clearance (vs. 6″ minimum), validating calculations and fabrication.

MEAM 2480: Mechanical Engineering Lab 2

Launcher Project



- Designed and manufactured adjustable slingshot–style launcher in SolidWorks; tunable angle (0–40°) and variable pullback energy.
- Iteratively improved design (track extension, kicker mechanism, structural backplate) to reduce friction and stabilize launches.
- Built Python model of projectile motion with drag; optimized launch angle and energy via numerical simulation.
- Calibrated model with experimental testing; derived correction multipliers for angle (0.66) and pullback (2.65).
- Validated energy transfer with onboard acceleration sensors; achieved >5 m launch distance.

MEAM 2480: Mechanical Engineering Lab 2

Model Rocket Project

- Designed and fabricated a pressurized water–butane rocket with 3D–printed PLA nosecone (optimized 0.08″ wall thickness) and MDF fins (sealed for water resistance) to minimize drag and maximize stability.
- Conducted 7+ experimental launches across varied angles (40–75°) and fill volumes (100–750 mL), recording trajectory outcomes under different wind conditions.
- Simulated two–phase flight (thrust + coasting) using ideal gas law, Antoine equation for butane vapor pressure, and drag modeling, implemented in Python.
- Applied OpenRocket aerodynamic modeling to determine center of pressure (6.76″) and center of mass (5.33″) for static stability margin analysis.
- Optimized launch parameters via brute–force grid search over angle and water fill volume; trade off accuracy vs. robustness for demo day.