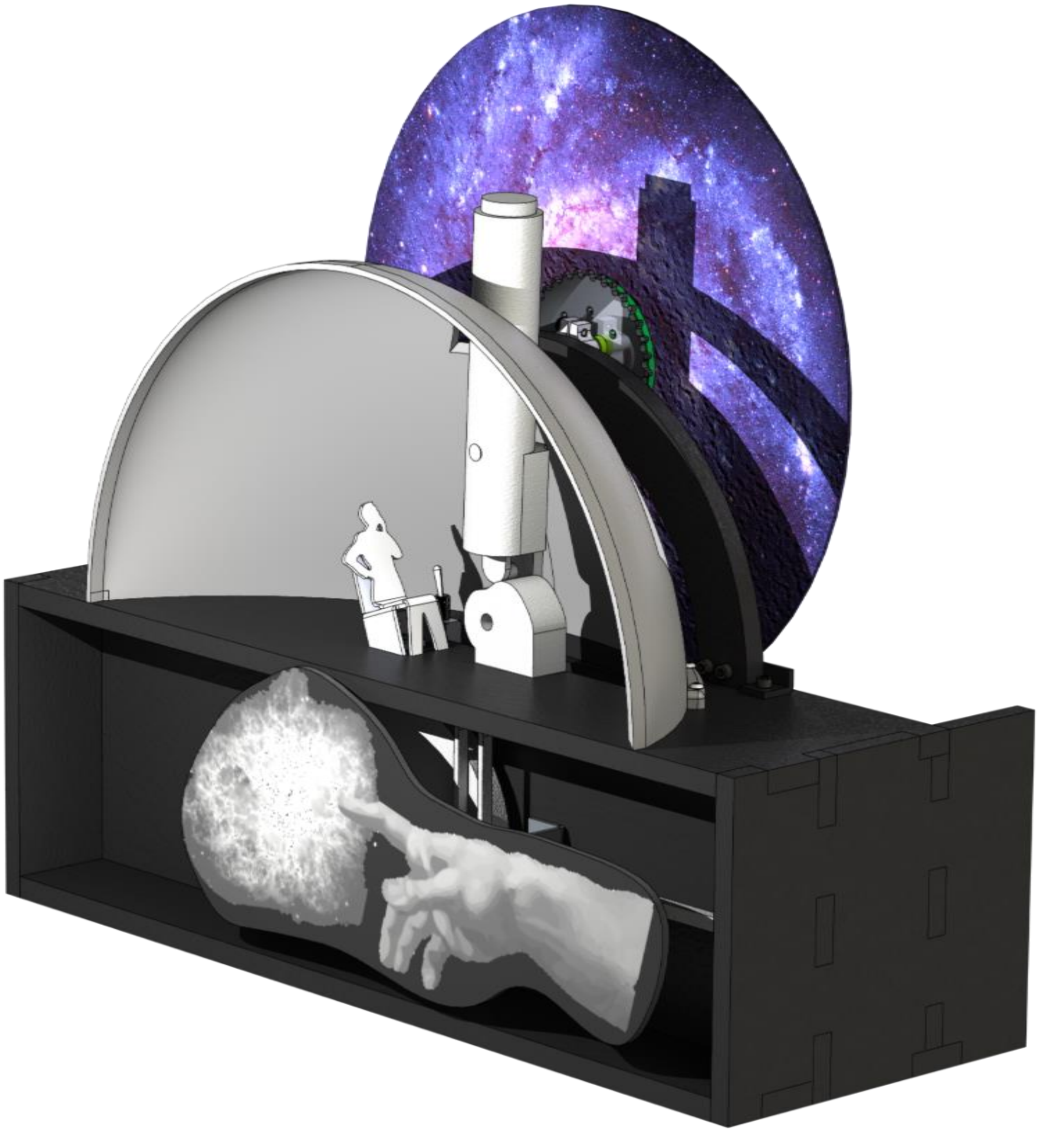

Astral Observations

ENGR 2330 – Mechanical Prototyping
April 15, 2019

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&
Julia Benton, Deborah Bowen, Griffin DiParlo, Carlos Godinez

Summary:

The Renaissance was a time of not just many new inventions, but also new ideas and ways of thinking. This is represented in my team's sculpture built for Mechanical Prototyping Spring 2019: Astral Observations in which a man looks through a telescope in a more modern looking observatory, gazing at the beauty, mystery, and immensity of the universe around him. This is representative of the more tangible advancements of Galileo's improved telescope as well as more conglomerations and centers of science. Meanwhile at the forefront of the box god's hand from "The Creation of Adam" is in a constant back and forth motion against a nebula, representing the paradigm shift in thinking about why the universe exists and our place in it, from religious to scientific.

All this was achieved through a number of mechanisms including a cam and follower and four bar linkage for the telescope, a scotch yoke for the motion of the nebula and god's hand, a belt drive for the rotation of the universe disk in the background, and finally various sets of gear to transmit power throughout the system. Of these, I worked the most on the cam and four bar linkage for the telescope setup, though by the end had helped out in each area including in large part bringing it all together into our final kinetic sculpture.

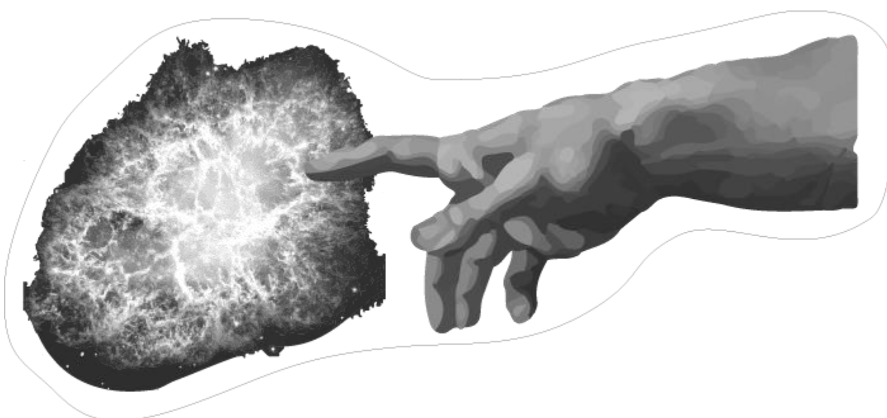


Figure 1: The rastered image on the front of the sculpture, depicting the god's hand and a nebula to represent the big bang. The beginning of the transition from religion to science was a major development during the Renaissance and the idea that we designed our sculpture around.

Detailed Design:

For each of our mechanisms we tried to have a different take on it that what traditionally comes to mind.

The power transmission was one of the last of the major design decisions we made and it definitely showed in some of our mechanisms and how we got power to them. Our first choice was not having the motor be the main drive shaft. Instead we offset it and powered the main drive shaft with a gear set. Being a 1:2 ratio, this meant all the other mechanisms were driven more slowly, a motion we liked due to how immense and timeless the concepts we were trying to convey are. This drive shaft then brings power through various means to our three main subassemblies.

The subassembly I am most proud of, partly because I was the one who designed and worked on it, was the combination of a four bar linkage and an inversion on the typical cam to create both the back and forth motion of the telescope through the observatory and the in-and-out "focusing" motion of the inner barrel of the telescope.

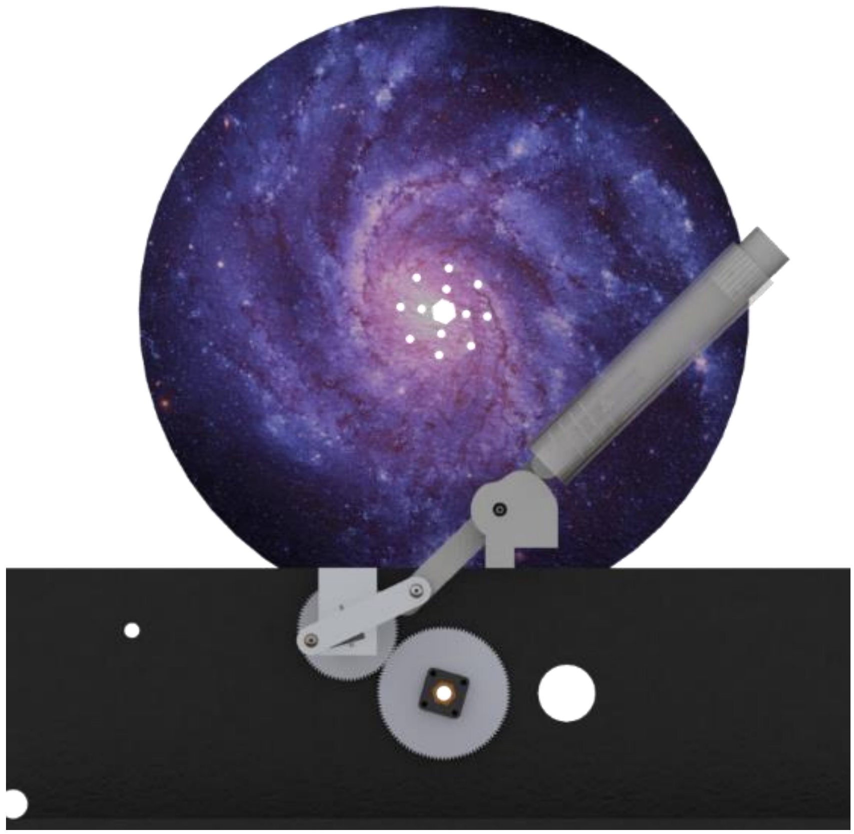


Figure 2: Isolated view of the four bar linkage and cam mechanisms in the telescope

Note that the four bar linkage actually uses the cam as one of its anchor points, with the other being an upside down bracket mounted discretely under the top of the clockcage box. The power for this system is derived from a gear which is on the back of the shaft that drives the back disk, with the second bar held in place with a spring pin while the others are held in in-plane by using fasteners between the bars as pins. Drawing from traditional windshield wiper motion, the four bar linkage sweeps the main barrel of the telescope through the channel in the observatory's dome.

Meanwhile the cam is a bit of a deviation from normal. Instead of the cam revolving, here it is stationary, press fit into the top of the box, while the cam follower, the inner barrel of the telescope, is what revolves around the cam. While originally we were going to have the cam follower be dependent on gravity and the cam having a shallow enough gradient to allow the follower to revolve around it smoothly, we were worried about it not being enough, especially not knowing what friction would be like between the inner and outer barrels. To assuage this, Deb added a spring and pin within the telescope to help the telescope's inner barrel drop back down as needed. While gravity did end up working, having the spring made it much more reliable as well as produced a smoother, cleaner looking motion.

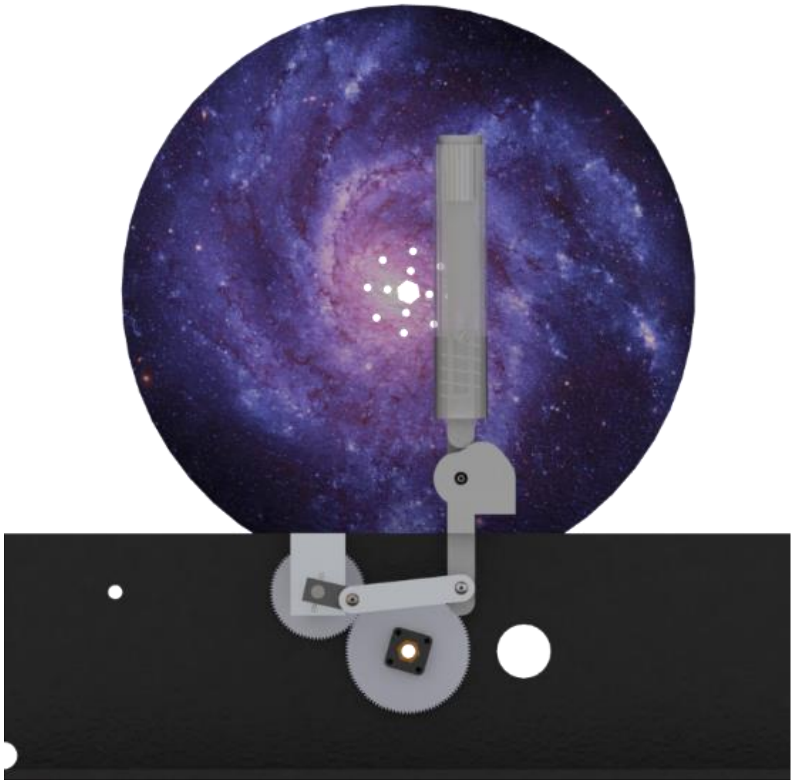


Figure 3: Compare the Figure 2 and Figure 3. Note the retracted inner barrel of the telescope

Next up we have one of the smoothest motions, the scotch yoke, producing horizontal motion to the acrylic rastered nebula and god's hand. With spray-painted 3D Printed PLA running between sheet metal brackets and enough tolerances, the light weight PLA moves between the two very cleanly. Originally we planned to have two scotch yokes, one to each side and both of them rotating in different directions, allowing the hand and nebula to move separately against on another. Due to budget and over-scoping constraints however we reduced it to a single scotch yoke. This is driven directly the drive shaft, with the yoke wheel is locked rotationally and translationally by a spring pin. The acrylic is held on through heat pressed TIG wire, of which we were surprised by the strength of when we were testing with it before assembly.

Because they were always on our minds, being such a problem we were trying so hard to solve when we were planning for two, in addition to this being our first exposure to the term, our team name, the Scottish Yokes, is derived from our constant mispronunciation of them.

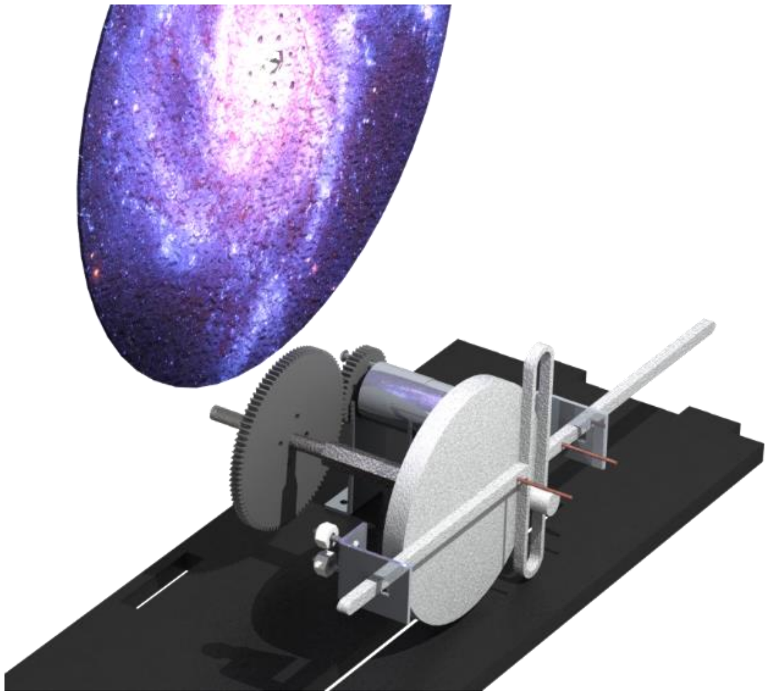


Figure 4: Our “Scottish” yoke

Finally our last major subassembly is the back rotating disk, which we used the chain to drive from the main drive shaft. This worked out nicely as almost all the mechanisms are hidden behind the disk itself or the large dome, allowing only the beautifully painted galaxy to be seen when viewed head on.

This was the part that went through the most iterations. While we knew we wanted a large rotating background, we were more unsure about how to power it and what should be going on it. Limited to 12”x12” due to material size, we instead ended up painting it which came out beautifully as a rotating galaxy. To solve the power issue we used the chain, allowing us to bridge the large distance. When it came down to assembly, this was what gave us the most trouble due to the need for a tensioner as the chain ended up being half a link off come assembly time. While we initially scrambled to try different sprocket combinations, after taking a walk and looking at past mechanical prototyping projects, we saw that a tensioner in our low stakes situation could be as simple as a brass tube spacer, which we ended up doing in just a few minutes.

The chain driven back assembly

Reflection:

Overall the design worked incredibly well however it wasn't without correcting several issues along the way, mainly in the assembly phase that might have been seen and resolved had we thought about them in the design phase. First was the order of operations it took to put the sculpture together. While the final product is able to be disassembled, it has to be done and put back together in a very specific, and sometimes jarring way. Figuring this out the first time through definitely took up a lot of time as well as provided some close calls in thinking we couldn't actually put it together. Second was accounting for space for fasteners. We didn't actually put most of our bolts in the CAD, just enough space as we thought we might need or what looked good. Unfortunately this does not translate to reality where our access to bolts is mostly in various increments, meaning there were a few places where things are much tighter than they should be or are sanded down.

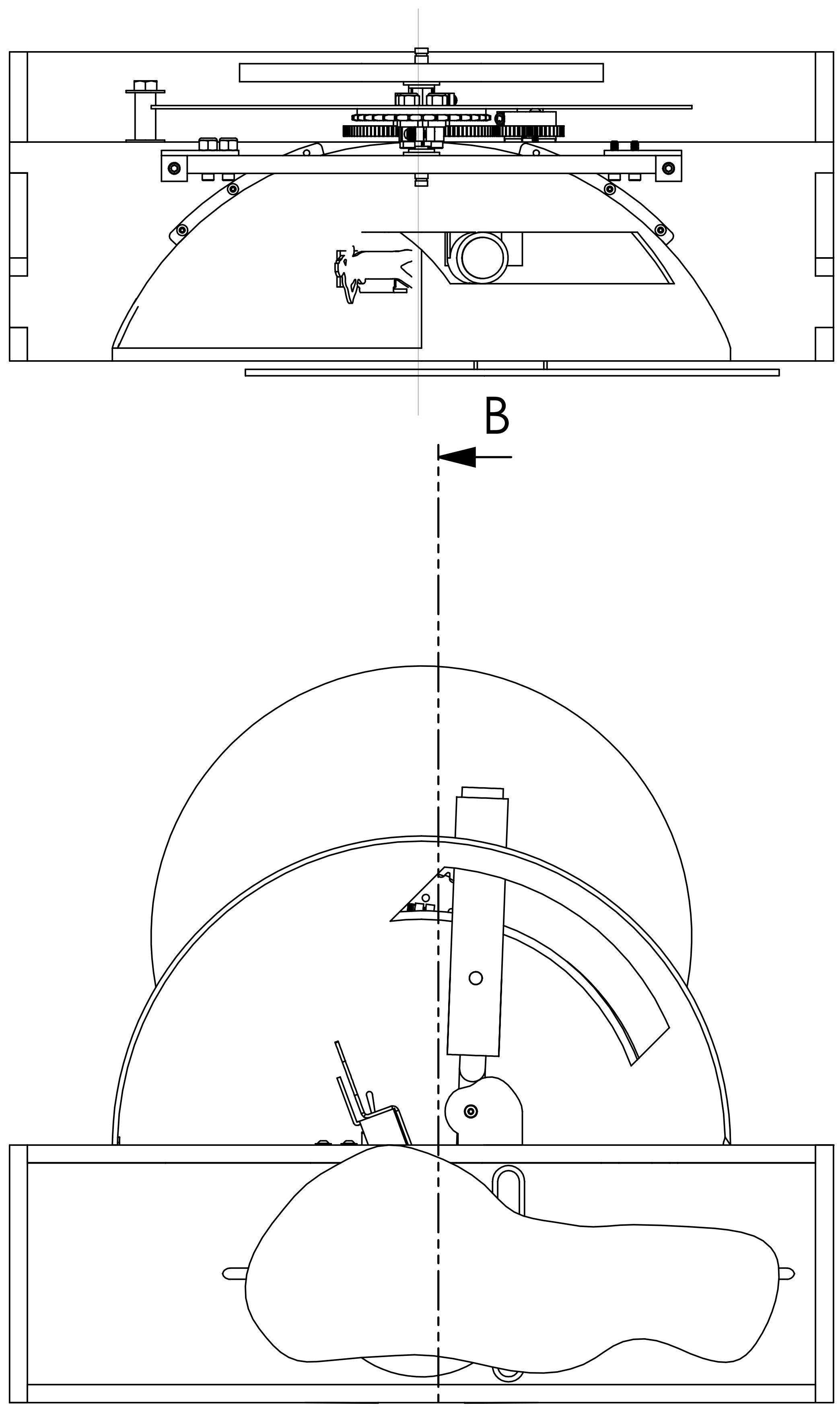
Both of these is issues might have been able to be caught if we sat down and thought about how everything would come together in the CAD assembly, rather than letting parts pass through each other to get where they needed to go. In doing so, we also would have recognized where fasteners needed more space or the way in which it would all have to come together. Individually I know I left the telescope's four bar linkage up in the air for how we were going to keep it together for a long time and ended up having to take some liberties while designing and making spacers and accounting for tolerances because of it.

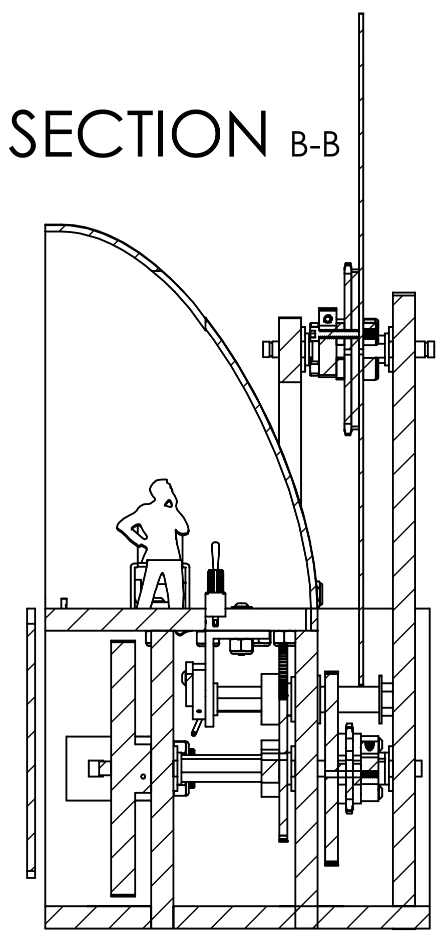
Conclusion:

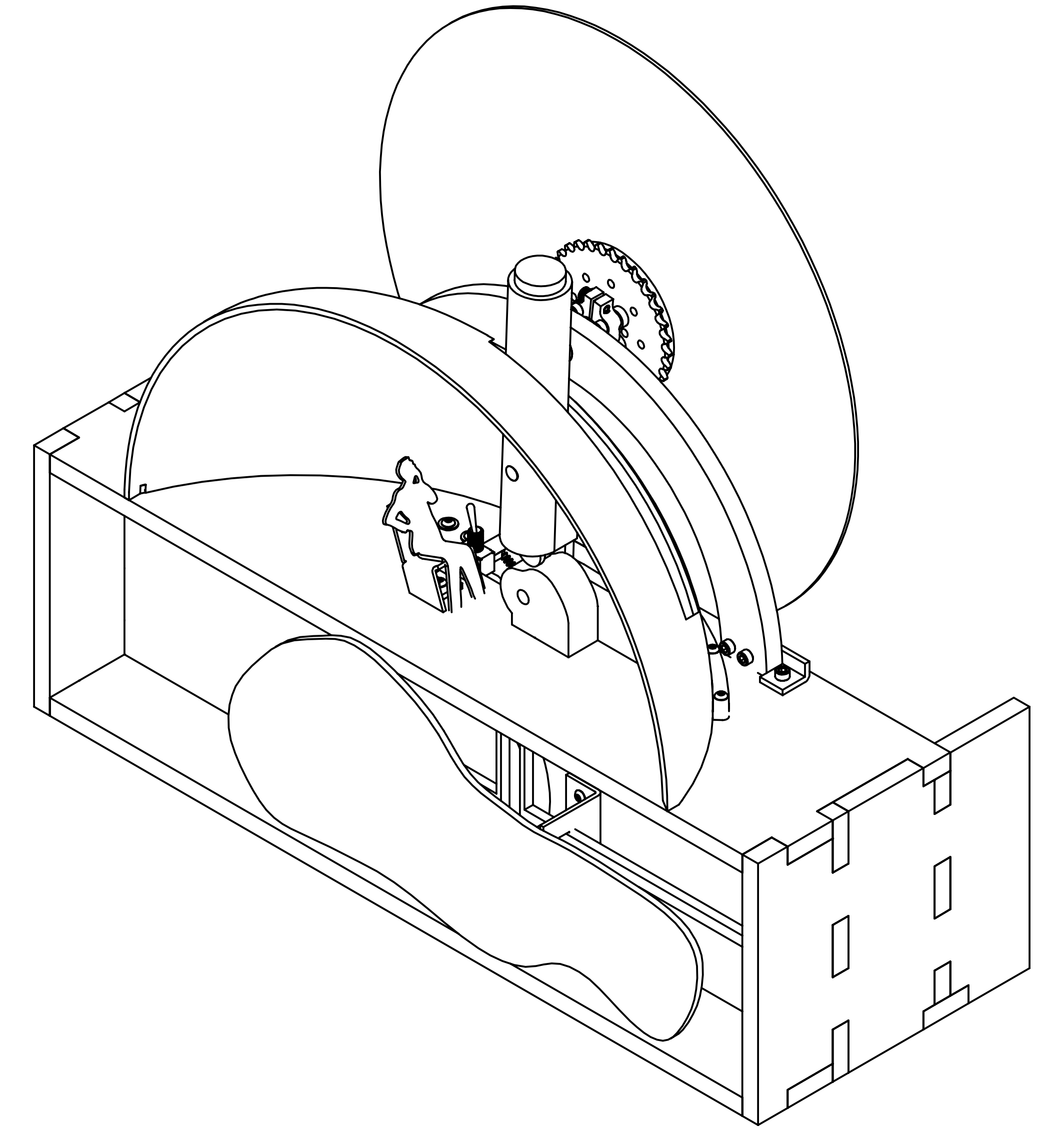
Overall I was incredibly proud of how the project turned out and how much we as a team accomplished. Many of our original designs and ideas went all the way through from our first design review to working on our final sculpture. This included the telescope's motions, both the outer barrel and the inner focusing barrel, the rotating disk on the back and the usage of a scotch yoke. We took a few risks, especially when setting up the telescope, using an inversion on the traditional cam setup and not knowing how well the inner barrel would move but we made it work in the end. While we successfully implemented each of the mechanisms, putting them together proved to be the hardest and it was the smaller details that ended taking the most time to resolve. Going forward we are better prepared to meet these factors, like spacing for fasteners, and think about them well in advance. Through this process I felt I hit many of my learning goals, from getting better about integration in final assemblies to making a finished, good looking, working product.

Time/Labor Breakdown:

Total Time (Hours):	250	
Team Member Breakdown Estimate:	**Hours**	**Percentage Time Spent**
Carlos	65	26%
Ben	55	22%
Julia	50	20%
Deb	40	16%
Griffin	40	16%
Process Breakdown:	**Hours**	**Where/when it was spent**
Conceptual Development:	25	Classtime
SolidWorks	75	Classtime, NINJA Hours
Fabrication	25	Shop
Assembly	50	Three nights leading up to demo
Repair/Redesign	75	NINJA Hours Three nights leading up to demo





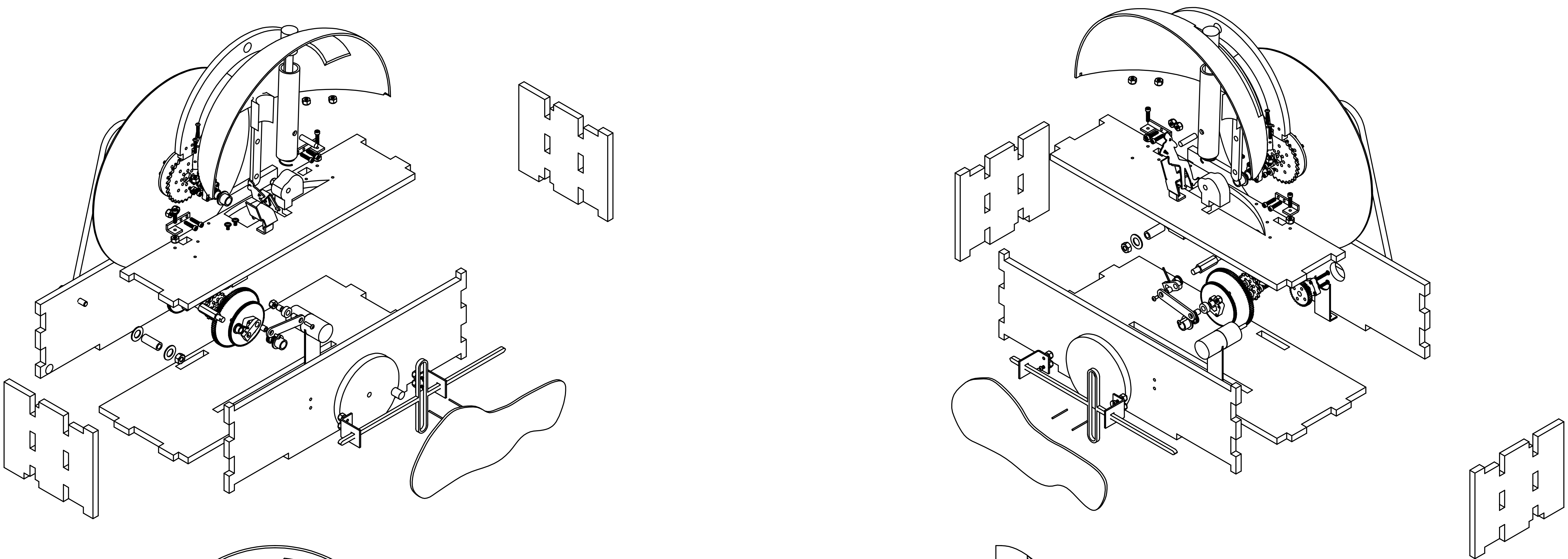


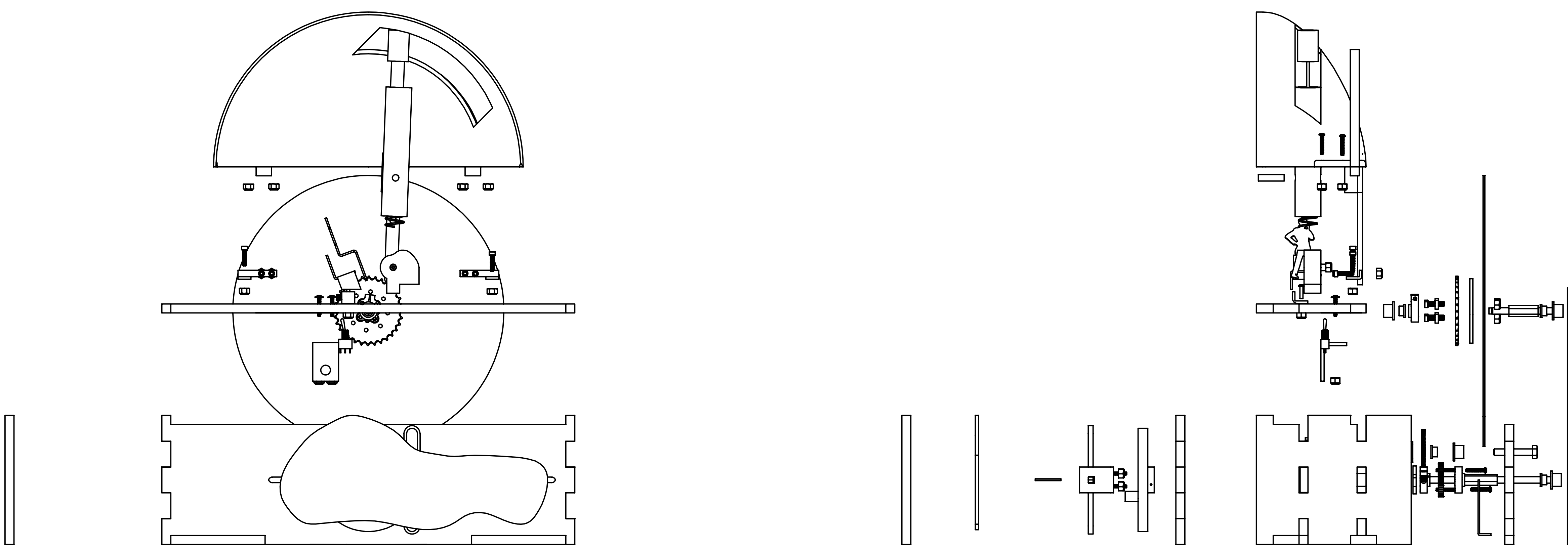
Assembly

Course: ENGR 2330 - Mech Proto

SIZE	Name:	QTY:
B	Benjamin Ziemann	1

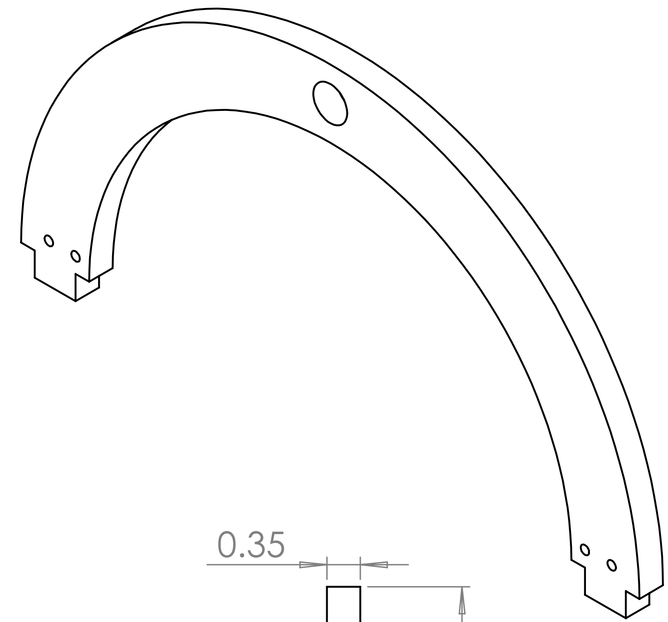
SCALE: 1:3 Team: Scottish Yokes

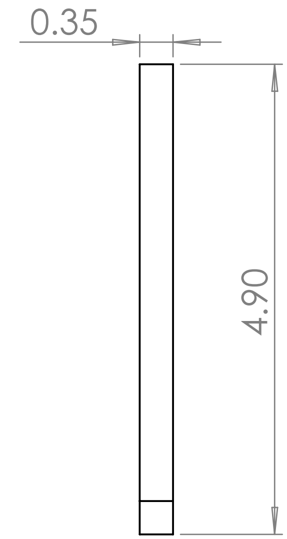


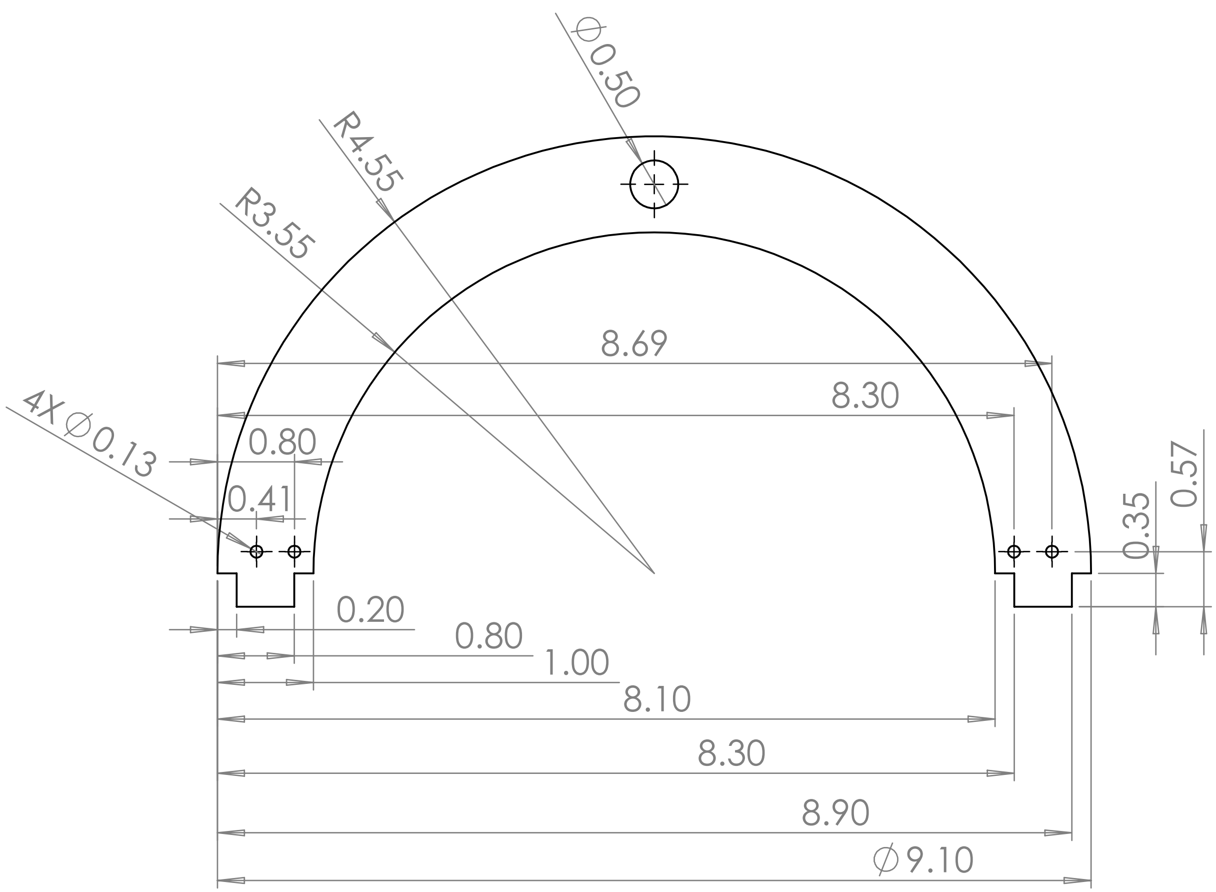


Exploded

Course: ENGR 2330 - Mech Proto		
SIZE **B**	Name: Benjamin Ziemann	QTY: 1
SCALE: 1:5	Team: Scottish Yokes	







Arch

Course: ENGR 2330 - Mech Proto

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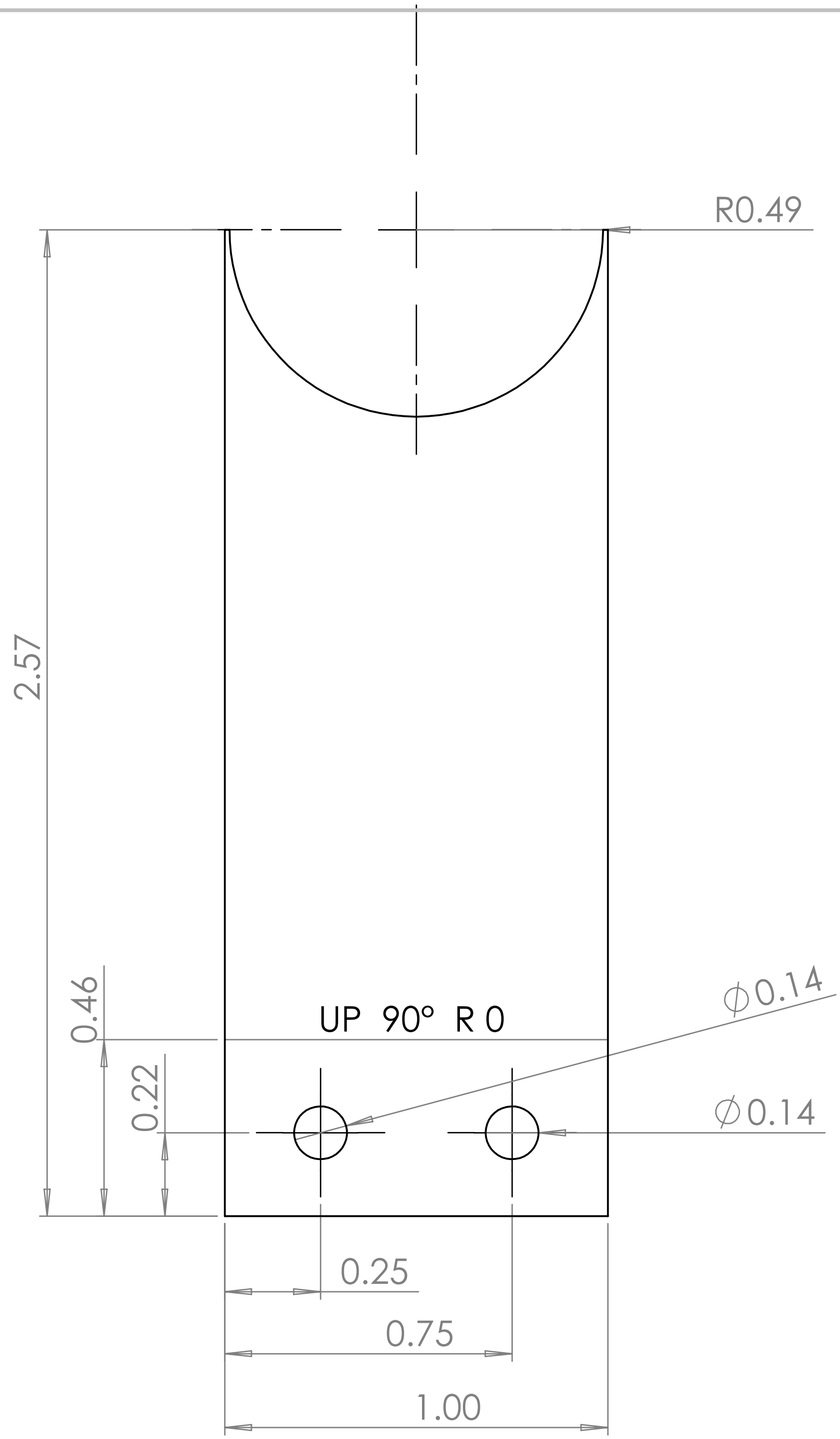
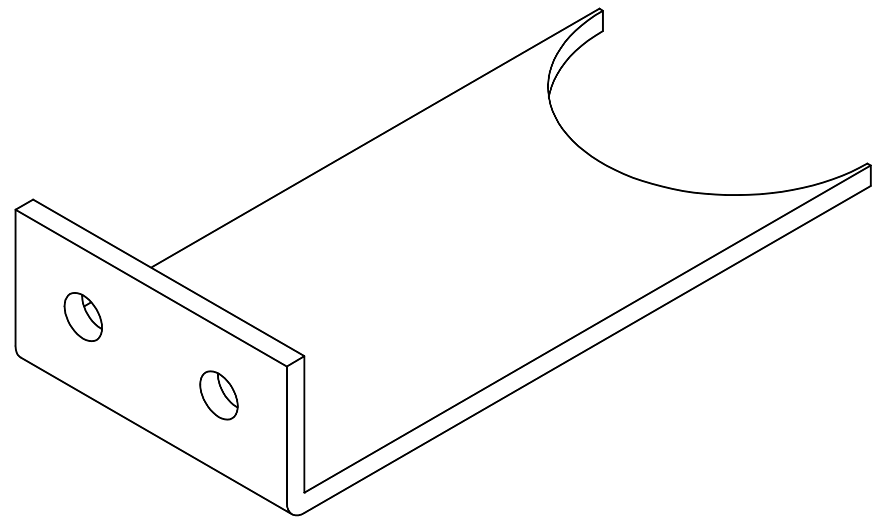
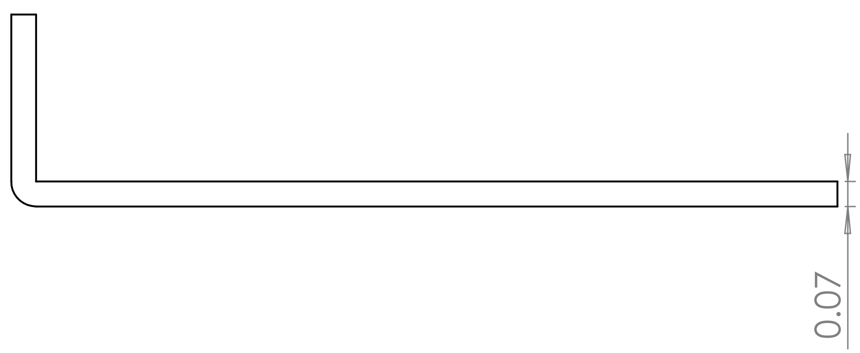
A	Benjamin Ziemann	1

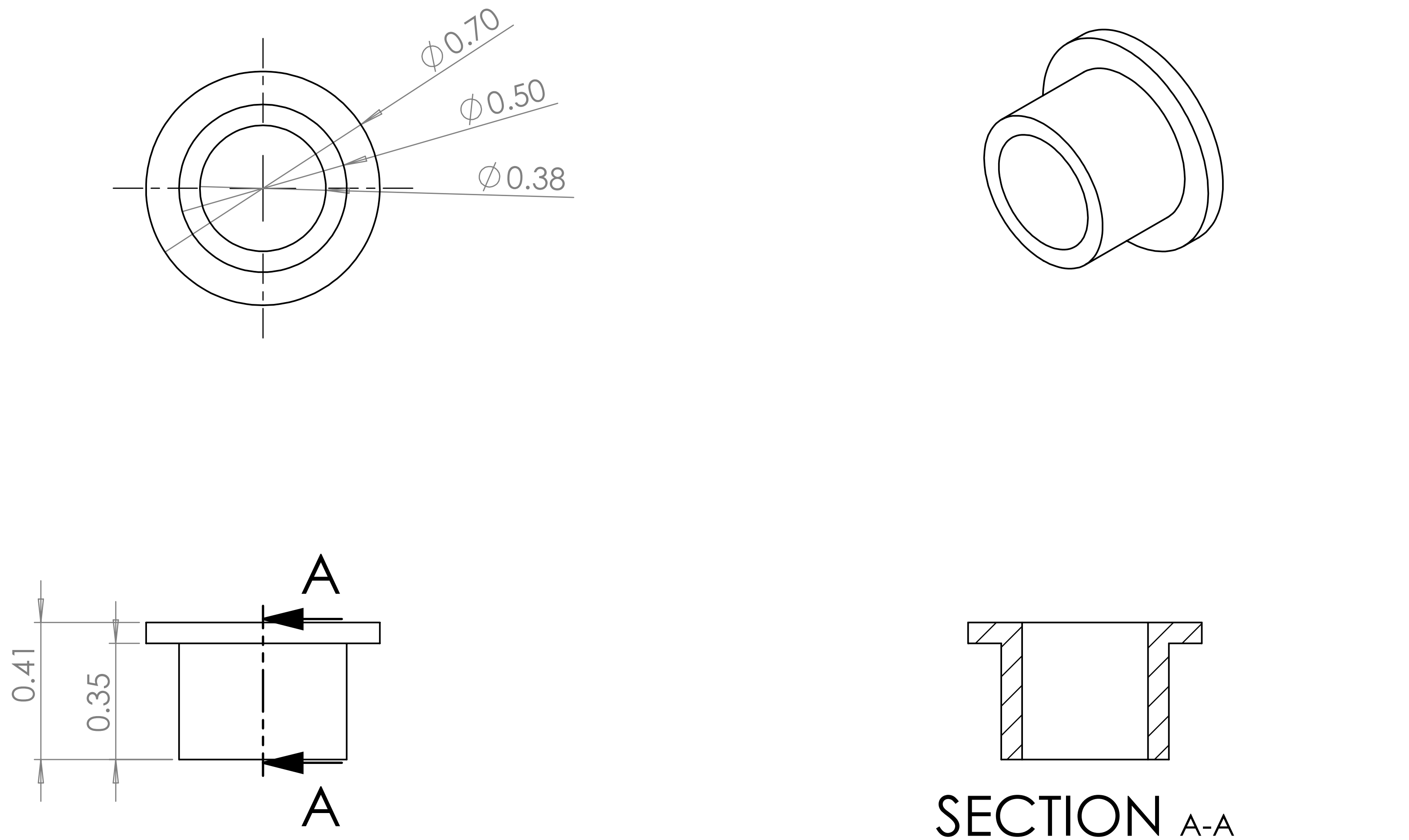
SCALE: 1:2 | Team: Scottish Yokes



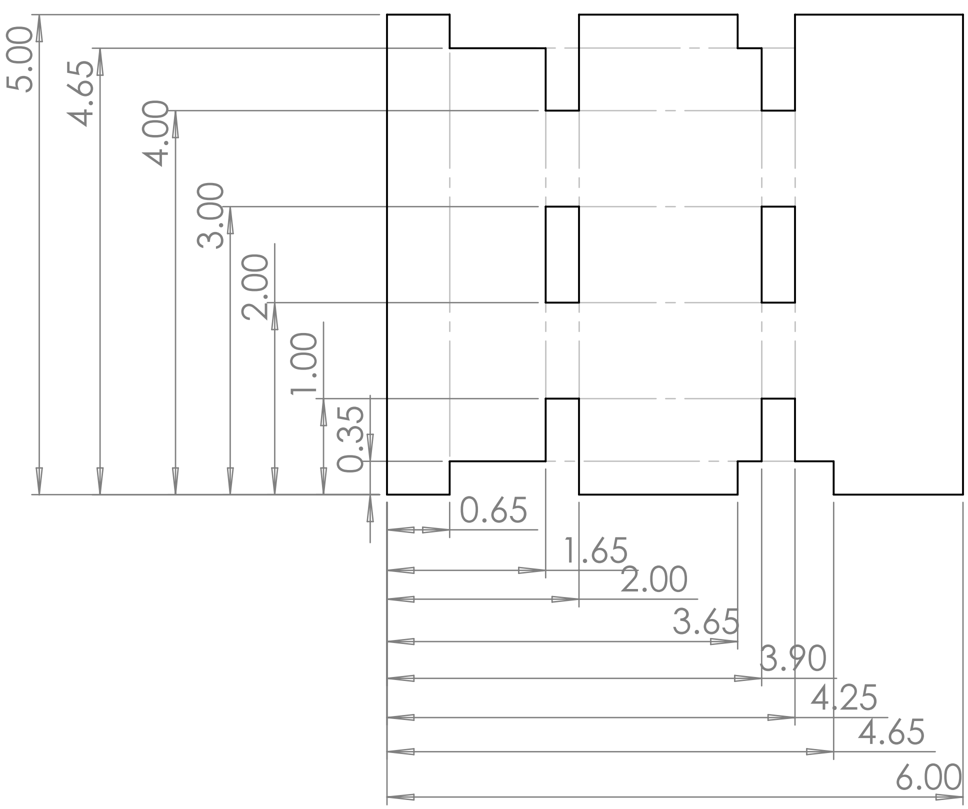


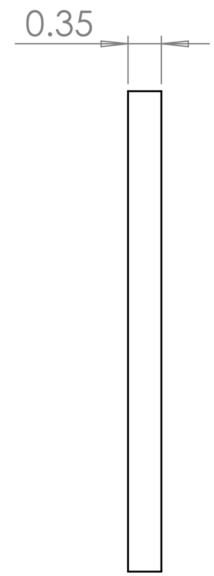


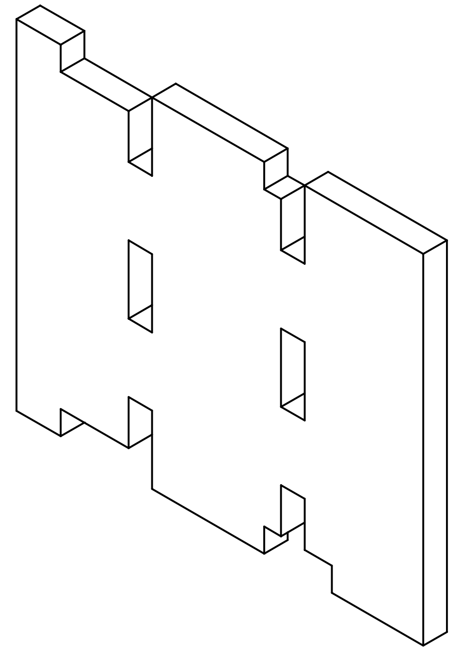
Motor Support		
Course: ENGR 2330 - Mech Proto		
SIZE A	Name: Benjamin Ziemann	QTY: 2
SCALE: 2:1	Team: Scottish Yokes	



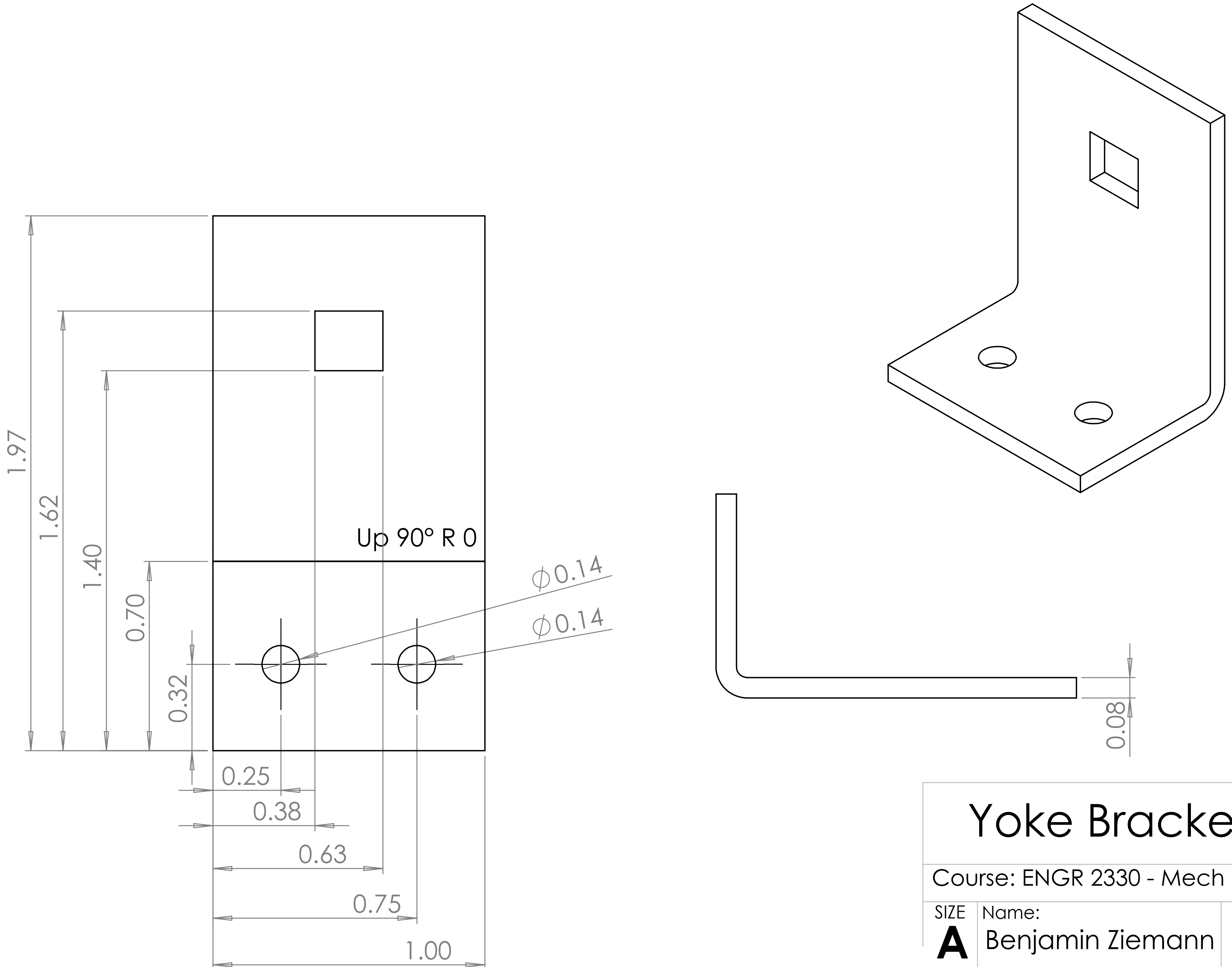
PLA Bushing		
Course: ENGR 2330 - Mech Proto		
SIZE A	Name: Benjamin Ziemann	QTY: 6
SCALE: 2:1	Team: Scottish Yokes	







Side		
Course: ENGR 2330 - Mech Proto		
SIZE A	Name: Benjamin Ziemann	QTY: 2
SCALE: 1:2	Team: Scottish Yokes	



Yoke Bracket

Course: ENGR 2330 - Mech Proto		
SIZE A	Name: Benjamin Ziemann	QTY: 2
SCALE: 2:1	Team: Scottish Yokes	

ITEM NO.	PART NUMBER	QTY.	Material	Manufacturing Method
1	Bottom	1	Plywood	Shopbot
2	Top	1	Plywood	Shopbot
3	Side	2	Plywood	Shopbot
4	Back Wall	1	Plywood	Shopbot
5	Telescope Cam	1	PLA	3D Printed
6	Telescope Holder	1	PLA	3D Printed
7	4Bar - Short	1	PLA	3D Printed
8	Telescope Bracket	1	Sheet Metal	CNC Plasma / Folded
9	4Bar - Long	1	Sheet Metal	CNC Plasma
10	Flanged Sleeve Bearings 1/4" Shaft Diameter, 1/4" Long	8	Bronze	Purchased
11	Dome Left	1	PLA	3D Printed
12	Dome Right	1	PLA	3D Printed
13	Telescope Outer Barrel	1	PLA	3D Printed
14	Telescope Inner Barrel	1	PLA	3D Printed
15	Spring	1	Spring Wire	Purchased
16	Telescope Pin	1	Steel Dowel	Purchased
17	Yoke Wheel	1	PLA	3D Printed
18	Yoke Slider	1	PLA	3D printed
19	Yoke Wall	1	Plywood	Shopbot
20	Yoke Shaft	1	Steel Hex Shaft	Lathe
21	4Bar Linkage Shaft	1	Steel Hex Shaft	Lathe
22	Motor	1		Given
23	0.375" Hex Clamping Hub 0.770" PATTERN	1	Aluminum	Purchased
24	Hex Hub Clamping Bolt	3	Aluminum	Purchased
25	Arch	1	Plywood	Shopbot
26	Drive Gear Large	1	PLA	3D Printed
27	Drive Gear Small	1	PLA	3D Printed
28	16T Sprocket	1	Aluminum	Given
29	Backbone	1	Plywood	Shopbot
30	Disc Shaft	1	Steel Hex Shaft	Lathe
31	PLA Bushings	6	PLA	3D Printed

32	32T Sprocket	1	Aluminimum	Given
33	Disk	1	Aluminum Sheet Metal	CNC Plasma Cut
34	Plate Spacer	1	Acrylic	Laser Cut
35	Acrylic Spacer	12	Acrylic	Laser Cut
36	Motor support	2	Sheet Metal	CNC Plasma Cut
37	Yoke Bracket	2	Sheet Metal	CNC Plasma Cut / Folded
38	Spring Pin	2	Steel	Given
39	PLA Hex Hub	2	PLA	3D Printed
40	Large Spur Gear	1	Acetal	Given
41	Small Spur Gear	1	Acetal	Given
42	Man	1	Aluminum Sheet Metal	CNC Plasma Cut / Folded
43	Chair	1	Aluminum Sheet Metal	CNC Plasma Cut / Folded
44	Chair Gusset	1	Aluminum Sheet Metal	CNC Plasma Cut / Folded
45	Switch	1	Aluminum	Given
46	Arch Gusset Right	1	Aluminum Sheet Metal	Folded
47	Arch Gusset Left	1	Aluminum Sheet Metal	Folded
48	Bronze Bushing	5	Bronze	Given
49	Bronze Tube Spacer	1	Bronze	Given
50	TIG Wire	2	Steel	Given
51	Hand-Nebula Acylic Piece	1	Acrylic	Laser Cut
52	#8-32, 5/8" Stainless Steel SHCS	10	Steel	Purchased
53	Chain	1	Steel	Given
54	#4-40, 3/4" Stainless Steel BHCS	14	Steel	Purchased
55	Washer ID .25"	2	Aluminum	Purchased
56	Washer ID .125"	2	Aluminum	Purchased
57	#4-40 Nylon Locknut	21	Aluminum	Purchased
58	#4-40, 1/2" Stainless Steel BHCS	3	Steel	Purchased
59	#4-40, 1/4" Stainless Steel BHCS	1	Steel	Purchased
60	Bronze Tube Tensioner	1	Bronze	Bandsaw
61	#1/4-20, 1.5" Stainless Steel BHCS	1	Steel	Purchased
62	#1/4-20 Nylon Locknut	1	Aluminum	Purchased