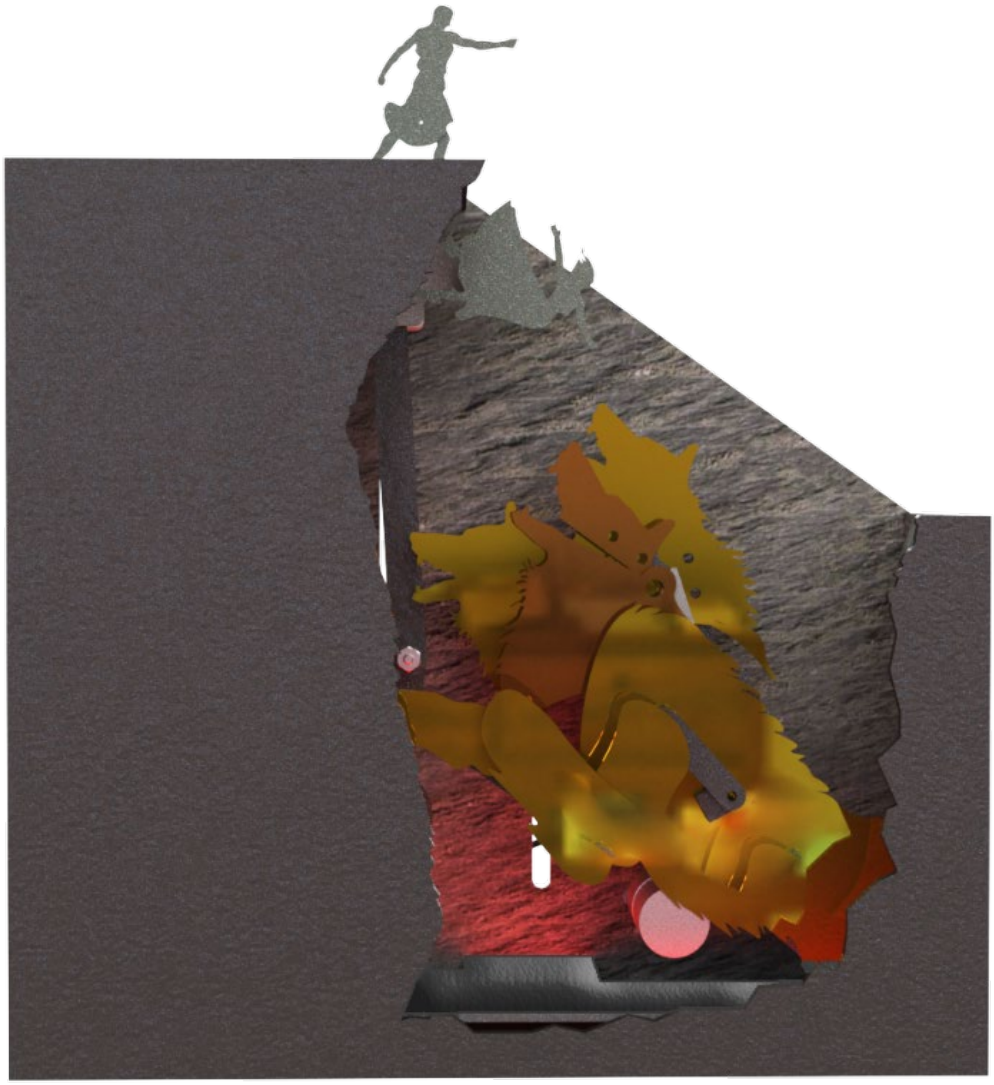


Welcome to Hell

ENGR 2330 – Mechanical Prototyping
May 9, 2019

Benjamin Ziemann
&
Amy Phung, Everardo Gonzalez, Eric Elder Jacobsen

Summary:

The story of Eurydice and Orpheus is myth takes a twist on the classic love story to explore, as Hades wanted to know, whether true trust in love exists. The answer, from this story at least, is a resounding no. After Eurydice enters underworld by choice but soon regrets it. Her lover, Orpheus sneaks through its many guardians and traps to save her. Captured by Hades but impressed by his gall, Hades makes a deal that if Orpheus can sneak back out with Eurydice, without ever looking back to make sure she is actually following him, he will let them both go. If he fails though, he claims Eurydice forever. Successfully navigating back, Orpheus has one step left before returning to the surface world, when unsure if Eurydice is truly following him, turns back. Just steps behind him is Eurydice though, who he sees for one last moment before she is pulled back into the underworld forever.

In our version, set in the ominously lit underworld, Orpheus stands upon the cliff just before the surface world. He looks back down over the cliff for his beloved as she climbs up after him and in doing so he loses Hades' deal. Eurydice falls back down into chomping jaws of Hade's pet Cerberus and she is lost forever as the underworld claims another soul. Using a variety of mechanisms from four bar linkages and multiple cams to make Cerberus move, and a slot slider, gear and chain drive to depict the betrayal of trust by Orpheus, we bring this scene to life in our kinetic sculpture: Welcome to Hell.

Figure 1: The assembled sculpture

Detailed Design:

Our mechanisms were split between two major subassemblies: the betrayal of trust by Orpheus and the intimidating Cerberus that waits below.

The power transmission is fairly simple. The main drive shaft drives a chain and helical gears train. The chain drive rotates the slot slider that holds Eurydice on the other side of the sculpture, with the chain allowing us to cover the greater distance without needlessly many gears. The helical gear turns the cams found behind Cerberus' body as well as the driven bar of the four bar linkage. We chose helical gears for their greater contact area and being easier to work with since we have access to a 3D printer to make them.

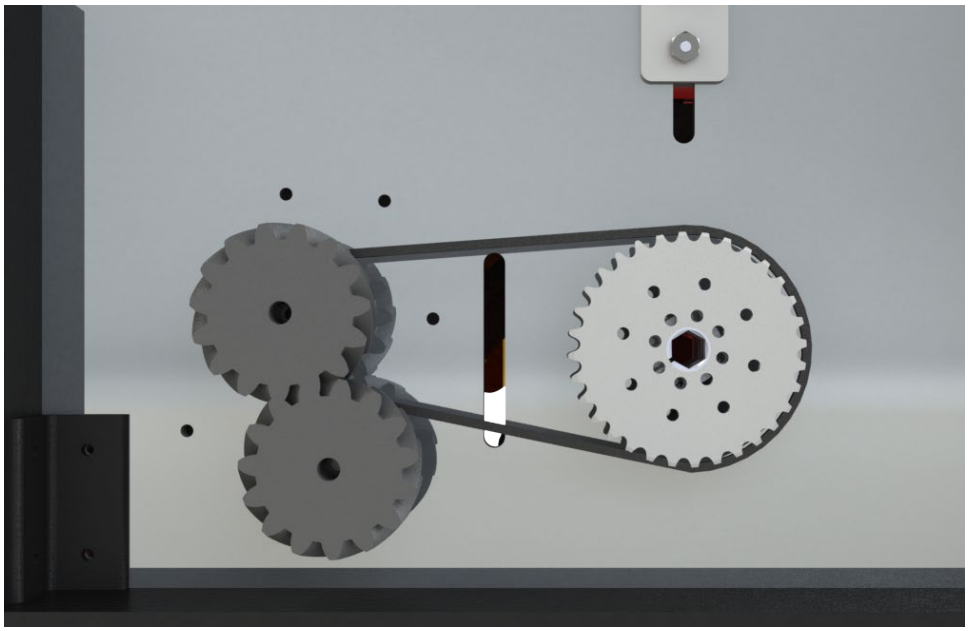


Figure 2: The Power Transmission

The chain and sprocket driven slot slide is a simple vertical slot with a slider moving along it to allow Eurydice to rise and fall as well as tip Orpheus over so he looks down at her. We chose a slot slider for this action because we knew we wanted a dramatic fall and needed distance for it so getting the fall distance of the diameter of the driven arm of the slot slider was great and could be made rather discreetly against the back wall of the sculpture. The Orpheus movement was achieved by simply having a small post that would push on his back leg, tilting him on his hip pivot so he looks down. Made primarily of Delrin plates and acrylic links is both light weight and low friction, allowing to better function as we intended. This subassembly did not change much from our initial planning due to its overall simplicity.

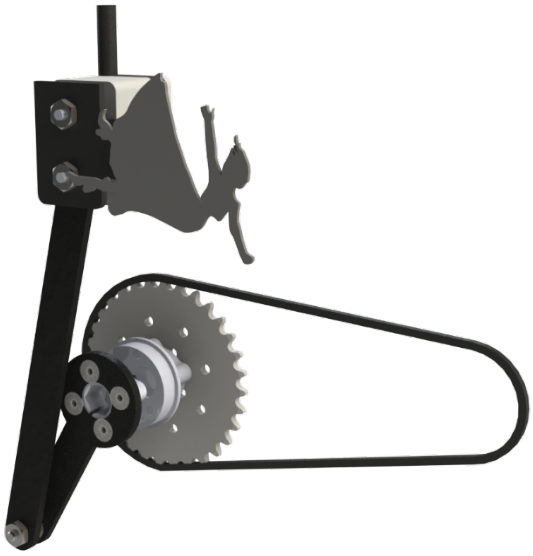


Figure 3: The Eurydice Slot Slider

Cerberus is comprised of two main mechanisms: the four bar linkage and the head cam followers. The three separate cams, each producing a different motion for each of the three heads is actually all one part, 3D printed and driven by the shaft connected the helical gear from the motor. Two of the heads use acrylic arms to ride along the cams, causing a bobbing motion while the chomping head utilizes a shaft through another 3D printed parts. These are all supported to fall back into place and remain on the cams by a series of rubber strung discretely through the body, covered by Cerberus' out brass plating.

Figure 4: Cerberus Cams

Of any of the mechanisms, the cams went through the most iterations as we discussed what motions we wanted for each of the heads and how to work around and integrate other shafts, the motor, and standoffs in and around the “coffin” body.

The four bar linkage acts to move the beast’s paw as he scratches at the cliff as he chases Orpheus and Eurydice. It’s powered through the same shaft the cams are on. This went through a few minor changes, with us originally wanting to do two legs that were the same but realizing this would needlessly complicate the build by cause interference and by only having one we better obtain the shadow theater look we were going for.

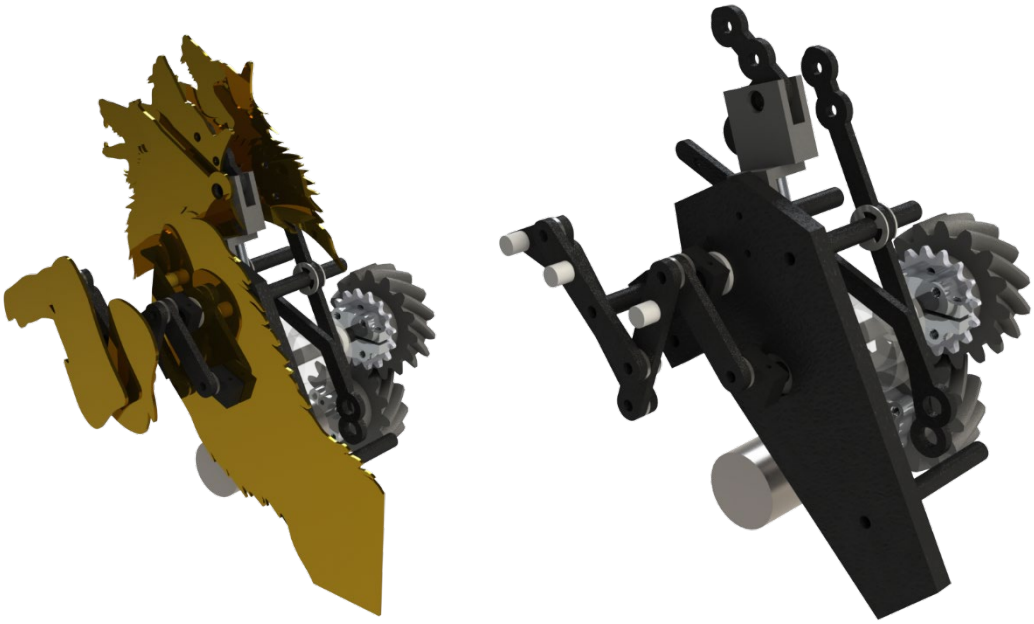


Figure 5: Cerberus Outer Plates (left) and Four Bar Linkage Structure (Right)

Finally there was the main structure which is where I designed the most. Taking place just as they are getting out of the Underworld, we thought it would be much more dramatic, a better use of space, and easier for the eye to follow the action if we used a cliff as the moment Orpheus decides to look back. Learning from my last project, I made sure the structure was easy to take apart and that any part could be openly worked on, even after it was mostly assembled, with the possibility of disassembly if needed. We added lights underneath the river plate to add an eerie atmosphere when Eurydice was climbing and change to a dramatic red as she fell back down to the Underworld through the use of a normally closed limit switch. The lights were covered in fabric to better diffuse the light. Finally as a design choice and after a bit of experimenting, we decided to complete the look of a cave with mixing dirt with glue and painting it onto the back walls for a realistic and creepy look. The outside was kept black and thin though to preserve the shadow theater look and feel.

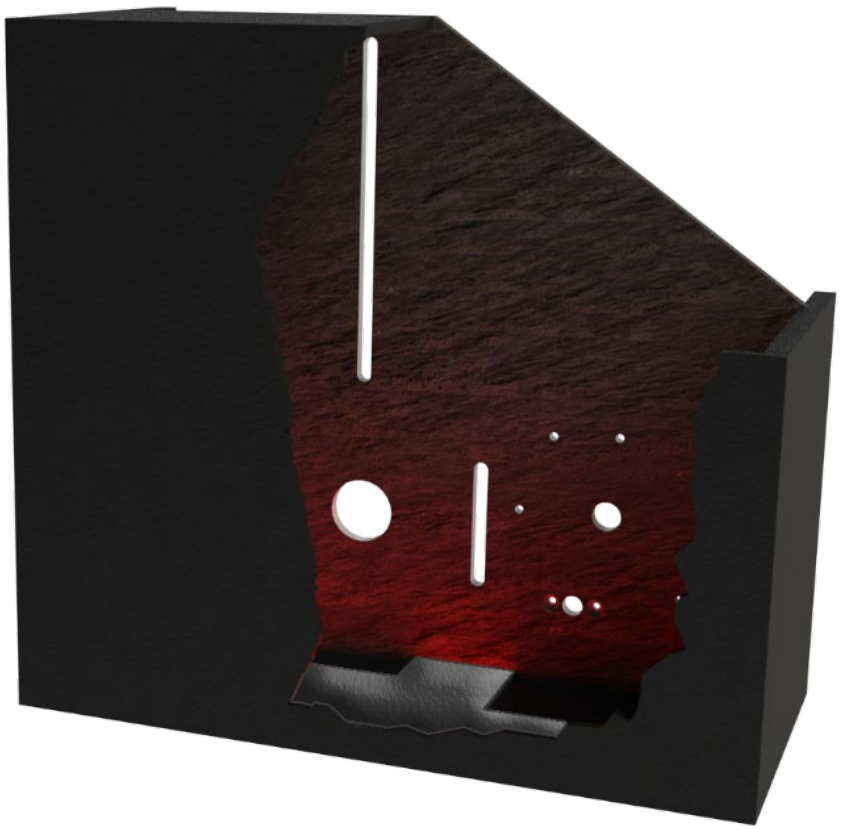


Figure 6: The Main Structure of the Sculpture

Reflection:

I think this project went really well, both for myself and for the rest of the team. We all came into it knowing we wanted to put a lot of effort in and we came out with a great sculpture that I think we are all pretty proud of. With all of us being non-first years we've all been on major project teams so the workflow was really nice and having known and worked with each other before really helped the entire project. Throughout the project I know there were definitely choices and designs I was very conscious about coming out of the last project, namely the design of the main cave structure which for this project I took the lead on. I knew I wanted it to be easily assembled and accessibility so we were constantly assembling and disassembling it, and if we were it wouldn't be a huge deal. Overall I think this came through and worked well, saving us a lot of time especially towards the end when there were somethings we changed as well as applying the glue dirt all while it was fully assembled. As far as the story of the project goes the changes we made to the story were smart both in terms of design and aesthetic. Having a vertical cliff meant we could make Cerberus fairly long while still making effective use of the vertical space. It also better helped draw the viewer's eye from Orpheus down to Cerberus through Eurydice falling, even if it isn't totally accurate to the original myth.

If I were to change anything I think it might have been not letting ourselves slow down towards the middle. With great feedback from the class and feeling like we were ahead with a lot of our manufacturing down, assembly still took a long time and we did end up working up until late Monday night/early Tuesday. This was partly because there was a stretch of 3 or 4 days where we didn't really meet, thinking we were in the clear. Again the rule of pi is important to remember, especially because if something had gone wrong we might have spent a lot more time through Tuesday morning fixing 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. I felt I was able to apply a lot of the lessons I learned throughout the class and especially from the previous sculpture to make the most out of the time and resources we had for this one, especially because the timeline was so much shorter. Speaking of resources I loved the aesthetic we decided on of the shadow puppet theater mixed with realistic setting, giving it, in my mind, a really unique look and made it stand out. This sculpture was definitely much more experimental for me, in large part because I had confidence in myself and my team that we would get done well so we had the time to try new things we might not have otherwise wanted to try due to time or stress on the previous one.

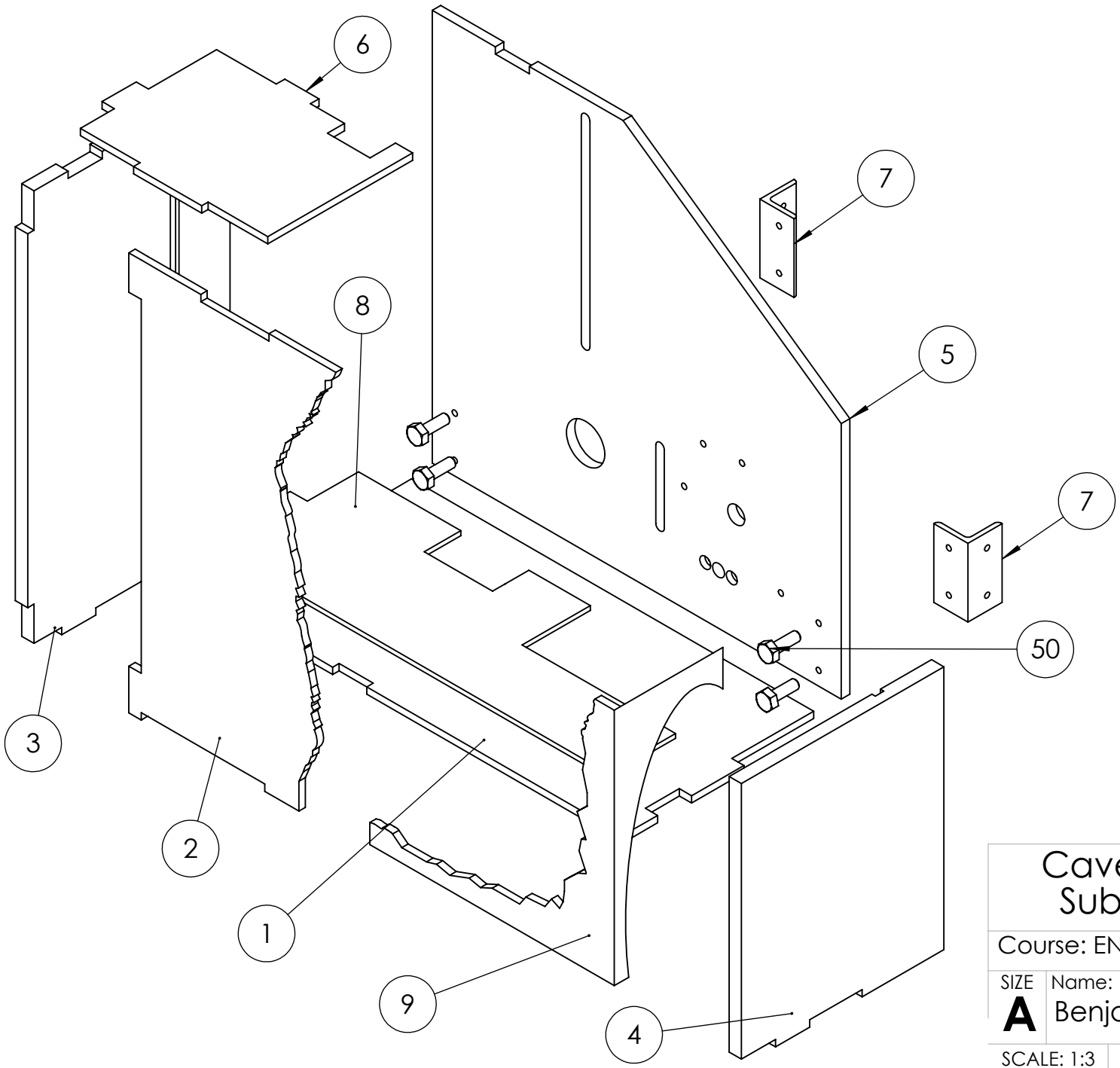
Time/Labor Breakdown:

Ben – I worked primarily on the clockcage and non-metal aesthetic design. For the clockcage I designed it in CAD and Illustrator, shopbot carved the main walls including the dado cut and laser cut the sharper cliff faces. The dirt wall in the back was also a product of my experimentation as I wanted to try to give the sculpture an unusual and stylized look from the shadow box plasma cuts and the real dirt.

Amy - Amy put a huge amount of work into this project. From designing and manufacturing the four bar linkage, to turning down all our shafts on the lathes to just making sure integration went smoothly. Of any of us she put in the most time. She also made sure we were always on track and moving towards a goal, taking on tasks as needed if someone knew they couldn't make it due to other classes.

Ever - Ever primarily worked on the cam and cam follower designs used in Cerberus and his three heads. He also milled the back plate out. He, with help from Amy, put together the overall structural design of Cerberus and integrated it into the overall clockcage. His designs went through a lot of iterations and he dealt with it really well.

Eric – Eric did a lot of the metal design aesthetic work, including making Cerberus, Eurydice, and Orpheus in Illustrator and then plasma cutting them. He also designed the slot slider. He did a really great job making sure we were seeing the bigger picture and making sure things weren't interfering, especially when it came to attaching the aesthetic plates.



Cave Structure Subassembly

Course: ENGR 2330 - Mech Proto

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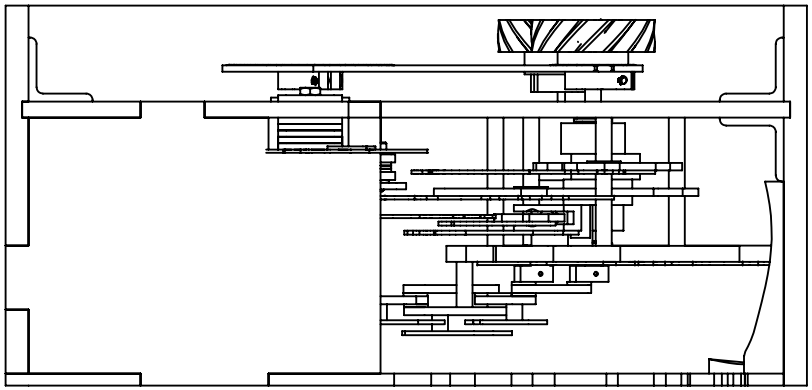
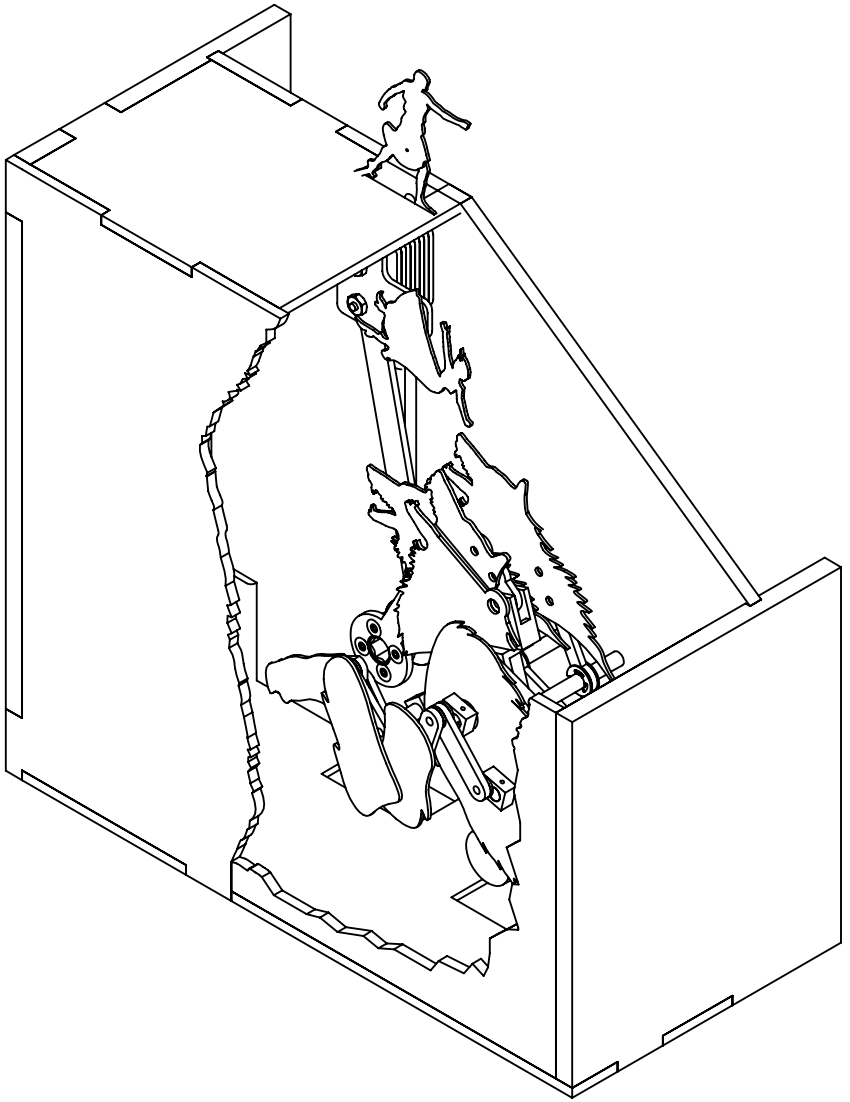
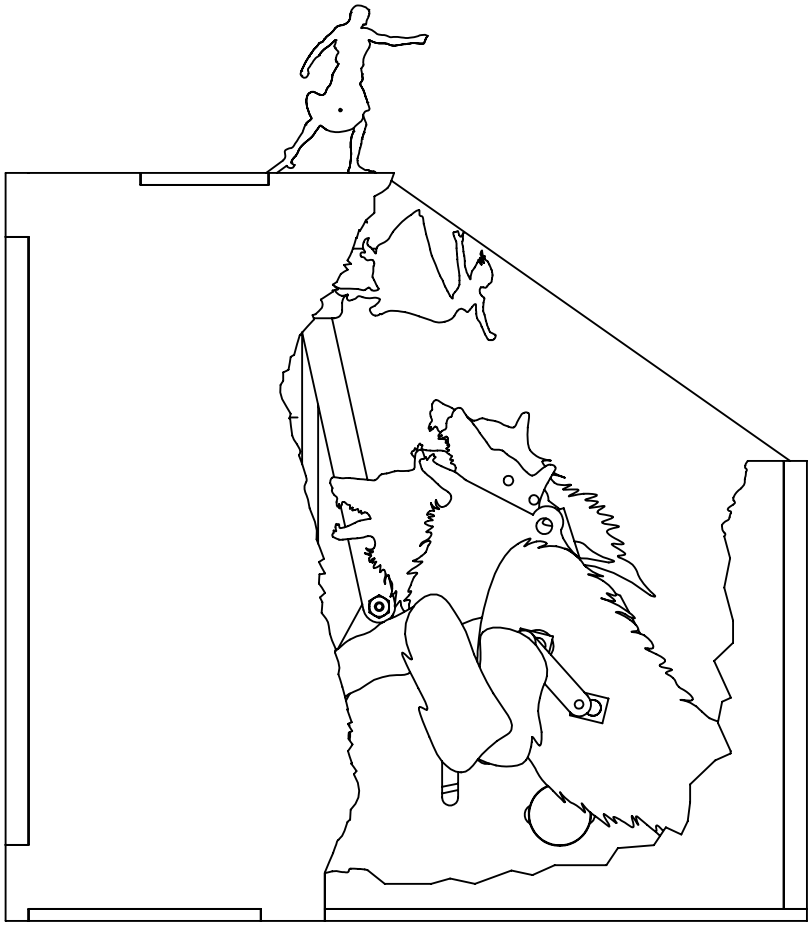
SCALE: 1:3 | Team: Welcome to Hell







Full Assembly

Course: ENGR 2330 - Mech Proto

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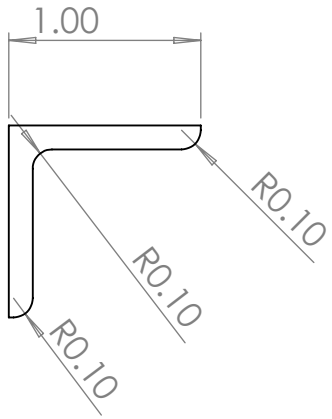
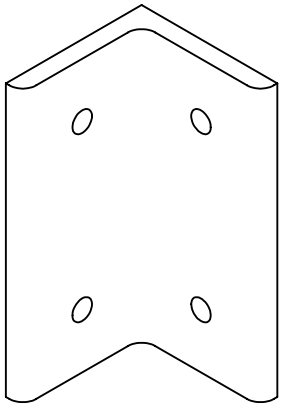
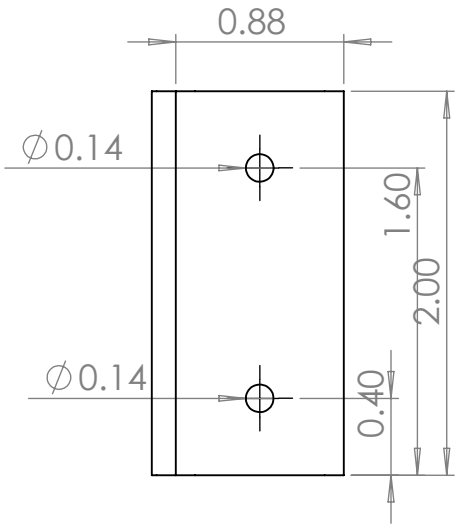
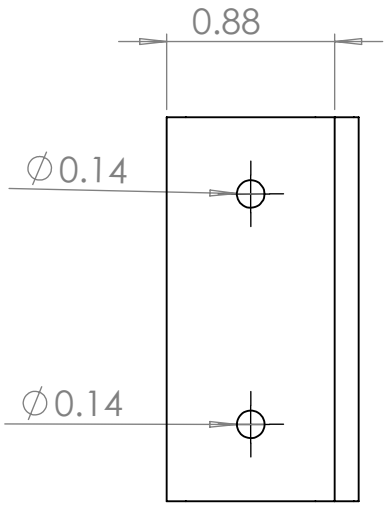
SCALE: 1:3 | Team: Welcome to Hell









Clockcage Bracket

Course: ENGR 2330 - Mech Proto

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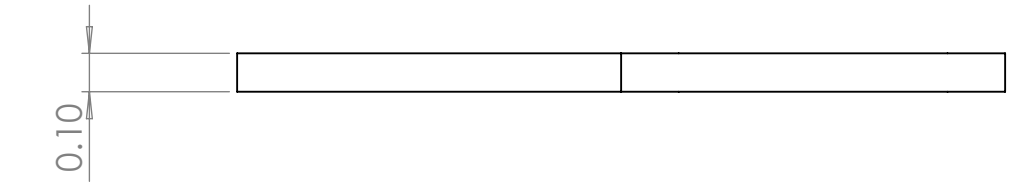

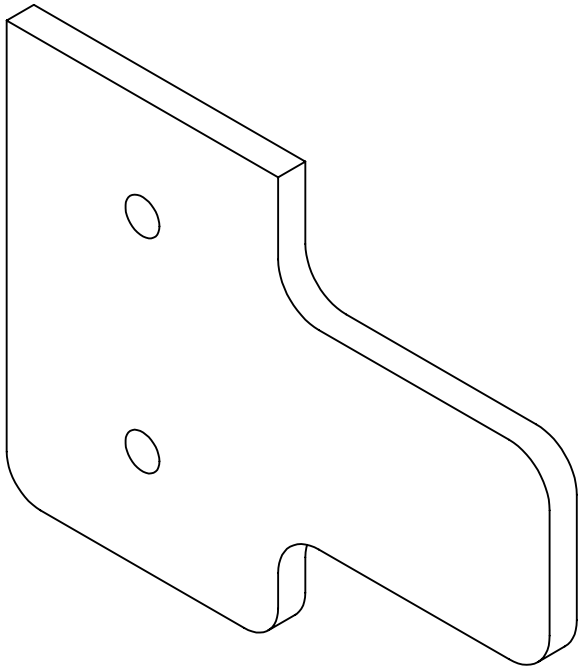

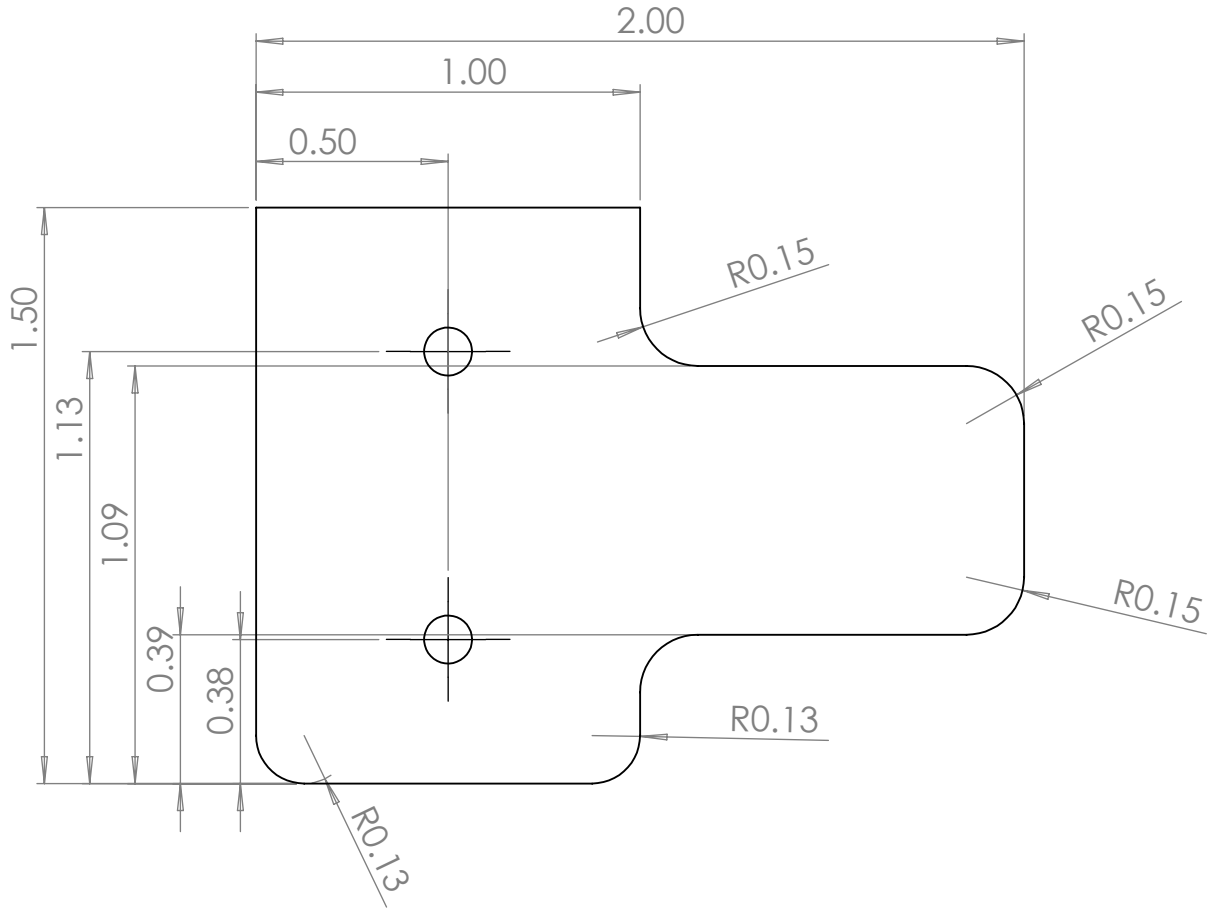

PLA Slider Plate

Course: ENGR 2330 - Mech Proto

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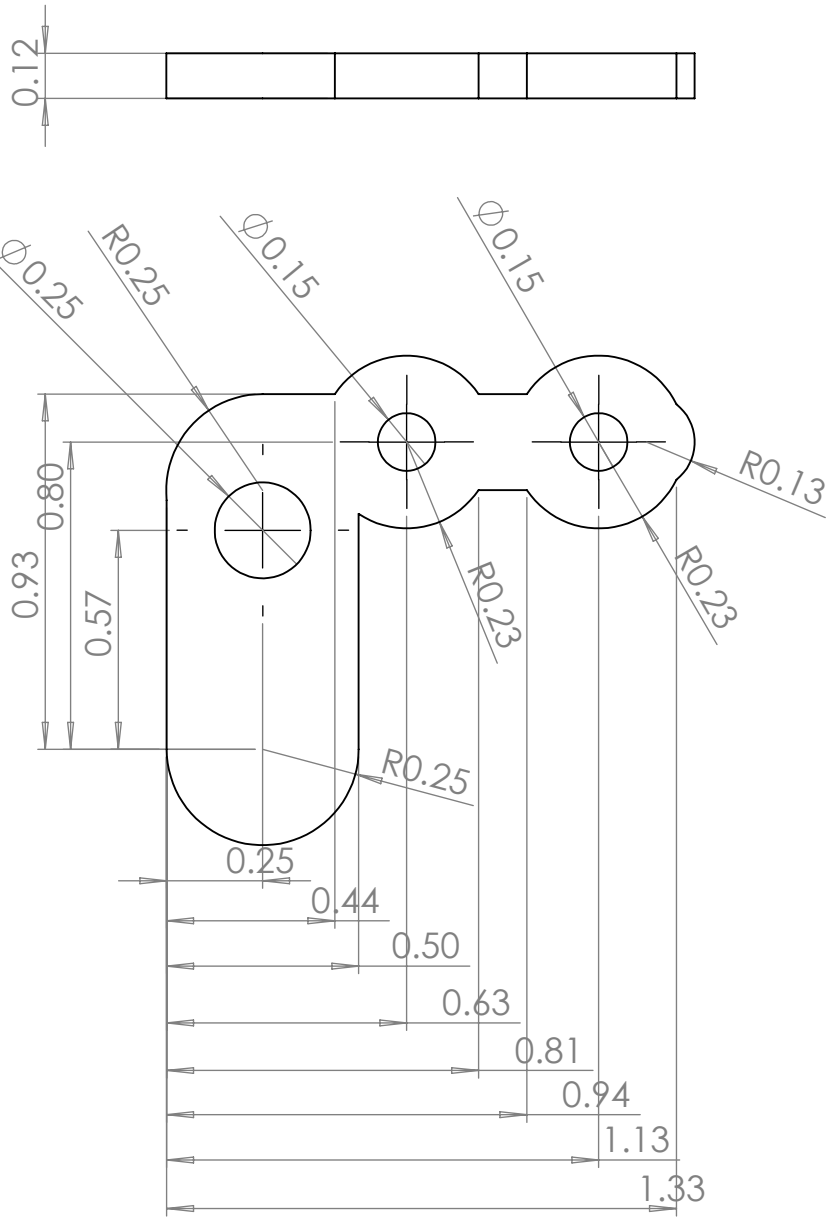
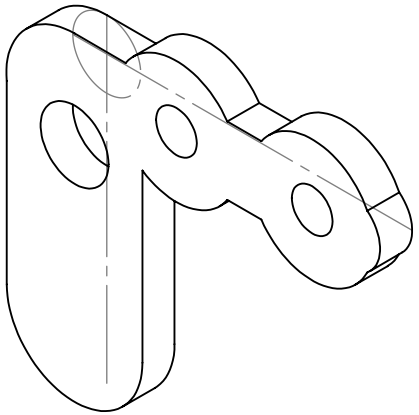
SCALE: 2:1 | Team: Welcome to Hell





Head Link

Course: ENGR 2330 - Mech Proto

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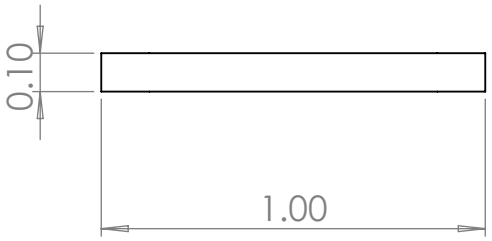
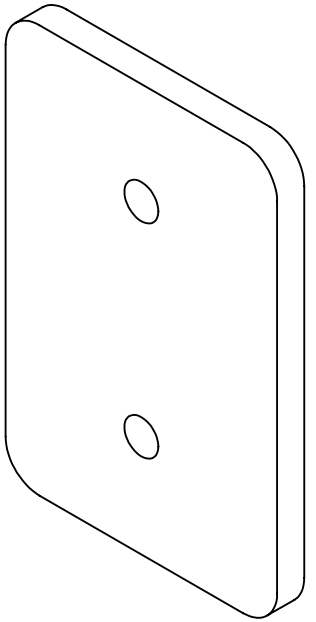
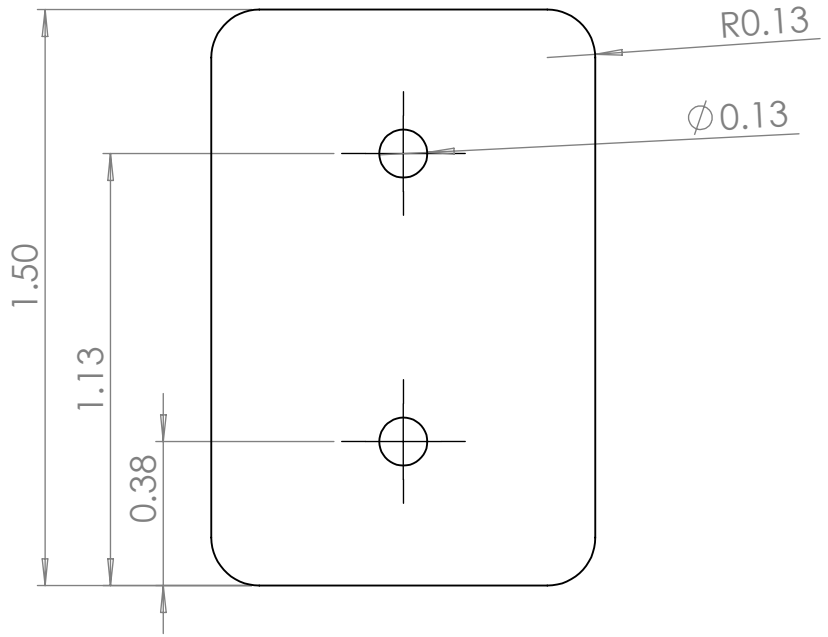
SCALE: 2:1 | Team: Welcome to Hell







Slider_Plate

Course: ENGR 2330 - Mech Proto

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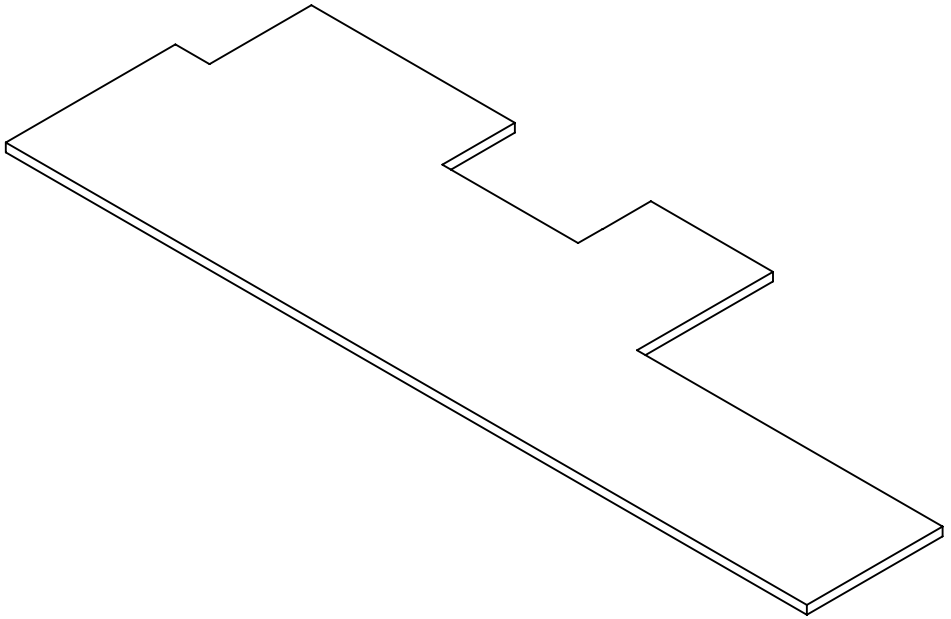
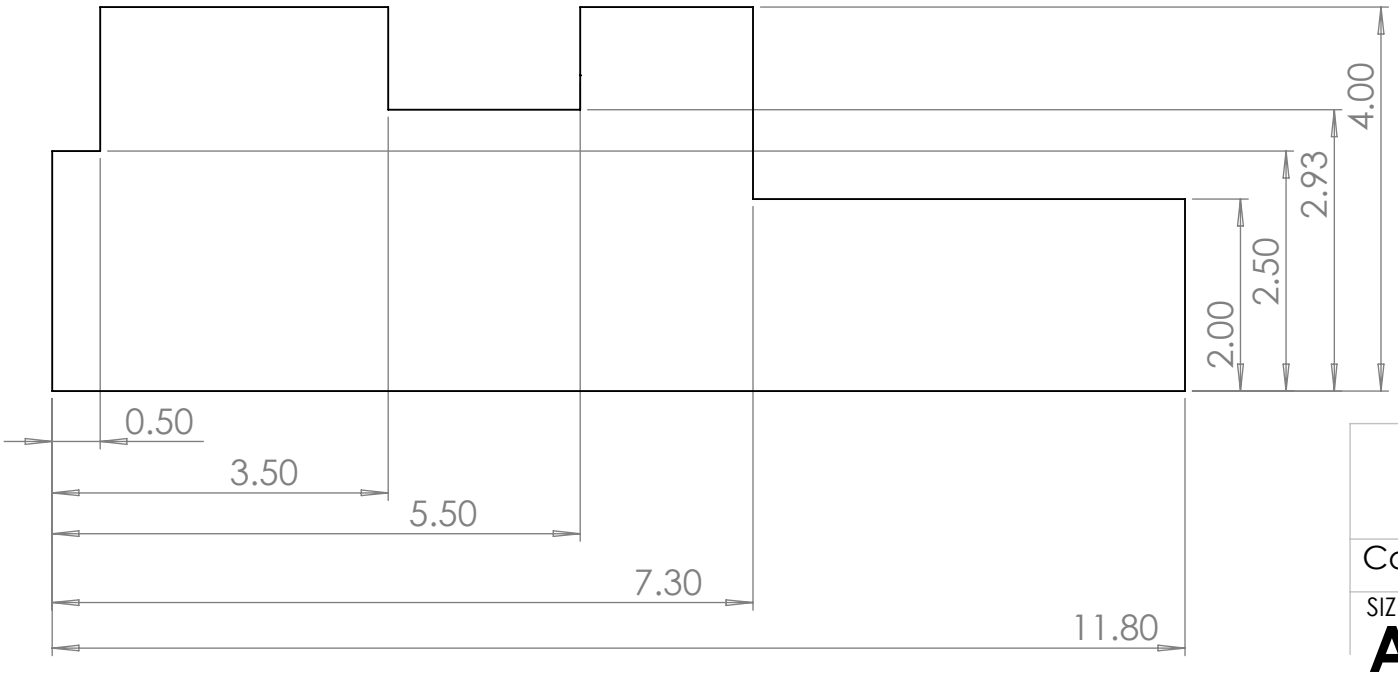
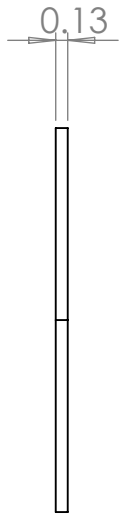
SCALE: 2:1 | Team: Welcome to Hell







River

Course: ENGR 2330 - Mech Proto

SIZE	Name:	QTY:
A	Benjamin Ziemann	1

SCALE: 1:2 | Team: Welcome to Hell

ITEM NO.	PART NUMBER	FABRICATION METHOD	MATERIAL	QTY.
	CLOCKCAGE			
1	clockcage_bottom	Laser Cut	Hardboard	1
2	clockcage_cliff	Laser Cut	Hardboard	1
3	clockcage_leftwall	Laser Cut	Hardboard	1
4	clockcage_rightwall	Laser Cut	Hardboard	1
5	clockcage_backwall	Mill	Aluminum	1
6	clockcage_platform	Laser Cut	Hardboard	1
7	clockcage_bracket	Bandsaw + Drill Press	Aluminum	3
8	dirtwall	Glue	Dirt + Wood Glue	1
9	clockcage_cliff2	3D Print	PLA	1
	SLOT SLIDER			
10	wheel_link	Laser Cut	Acrylic	1
11	Arm	Laser Cut	Acrylic	1
12	Slider_Plate	Bandsaw + Drill Press	Delrin	9
13	Spacer	Laser Cut	Acrylic	2
14	arcylicSpacer	Laser Cut	Acrylic	1
15	pla_slider_plate	3D-print	PLA	1
16	0.125 Aluminum Shaft^Eurydice_Slider	Bandsaw	Aluminum	2
17	orpheus_final	Plasma Cut	Steel	1
18	leg_final	Plasma Cut	Steel	1
19	body_final	Plasma Cut	Steel	1
20	eurydice	Plasma Cut	Steel	1
	CERBERUS			
21	outer_structural_plate	Mill	Aluminum	1
22	mill_power_transfer	Mill	Aluminum	2
23	acrylic_power_transfer _link	Laser Cut	Acrylic	1
24	Cams	3D Print	Onyx	1
25	chompCamSupport	3D Print	Onyx	1
26	transferRodChompy	Laser Cut	Acrylic	1
27	headLink	Laser Cut	Acrylic	1
28	dog Head 2 TransferRod	Laser Cut	Acrylic	1
29	dog head 3 transfer rod	Laser Cut	Acrylic	1
30	camRod	Bandsaw	Aluminum	1
31	camRod1	Bandsaw	Aluminum	1
32	camRod2	Bandsaw	Aluminum	1
33	camRod-Support	Lathe	Steel	2
34	support-rod	Lathe	Steel	1
35	link3	Laser Cut	Acrylic	1
36	link4	Laser Cut	Acrylic	1
37	link1	Laser Cut	Acrylic	1
38	link2	Laser Cut	Acrylic	1
39	Standoff	COTS	Delrin	3
40	Upper_Leg_Plate	Plasma Cut	Brass	1
41	Lower_Leg_Plate	Plasma Cut	Brass	1
42	Paw_Plate	Plasma Cut	Brass	1
43	Head_Plate_One	Plasma Cut	Brass	1
44	Head_Plate_Two	Plasma Cut	Brass	1
45	Upper_Jaw_Plate	Plasma Cut	Brass	1
46	Lower_Jaw_Plate	Plasma Cut	Brass	1
47	Body_Plate	Plasma Cut	Brass	1
48	Helical gear 12DP 15T 45HA 20PA 0.5FW	3D Print	Onyx	2
49	0.25 Clamping Hub	3D Print	Onyx	2
	COTS COMPONENTS			
50	Steel Washer #6 Screw, 0.156" ID, 0.375" OD	COTS - McMaster 98023A112	Steel	19
51	Steel Hex Nut, 6-32 Thread Size	COTS - McMaster 90480A007	Steel	7
52	4mm Clamping Hub	COTS	Aluminum	1
53	0.375 Hex Clamping Hub	COTS - ServoCity 545672	Aluminum	1
54	24T Sprocket	COTS - ServoCity 615106	Aluminum	1
55	16T Sprocket	COTS - ServoCity 615102	Aluminum	1
56	56 RPM Econ Gear Motor	COTS - ServoCity 638348	motor	1
57	Hex Bearing	COTS - VexRobotics 217-2735	Aluminum	1
58	Flanged Sleeve Bearings 1/4" Shaft Diameter, 1/4" Long	COTS - McMaster 1677K1	Bronze	1
59	Two-Piece Rivets 0.112" Diameter	COTS - McMaster 96082A100	Brass	4
60	Stainless Steel Slotted Spring Pin 1/16" Diameter	COTS - McMaster 92373A113	Stainless Steel	3
61	1/4" ID X 1/2" OD Flanged Ball Bearing	COTS - ServoCity 535198	Metal	3
62	Chain	COTS - ServoCity 615146	Metal	1
63	Side-Mount External Retaining Ring for 1/4" Shaft	COTS - McMaster 98398A134	Steel	6