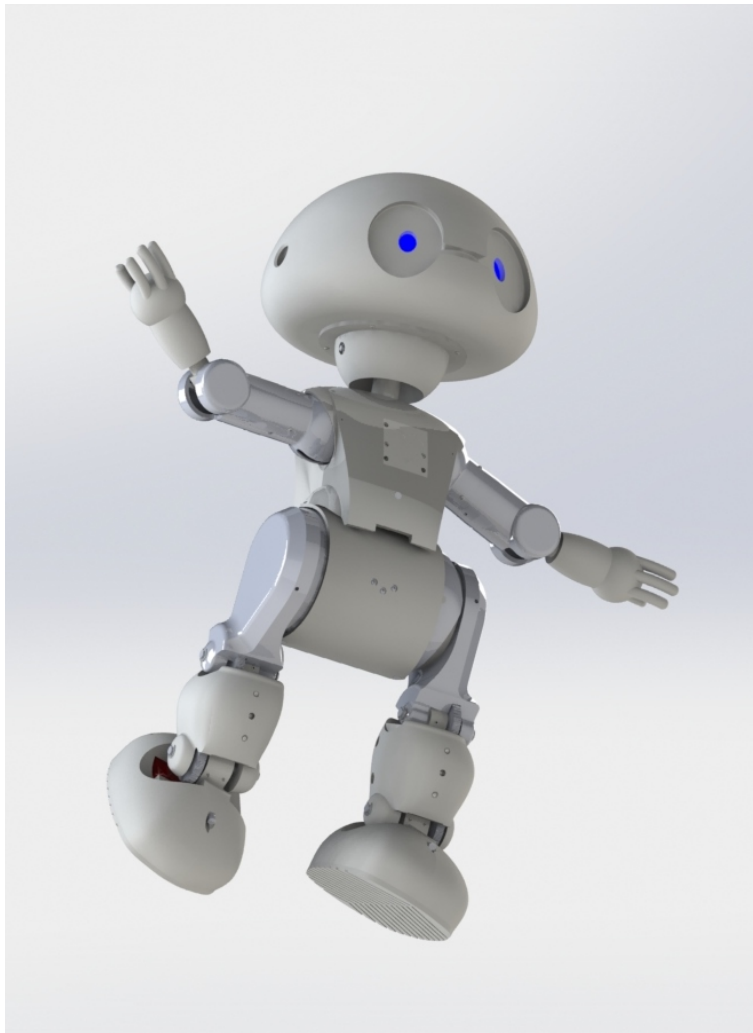


Olin College Jimmy X Project

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December 10, 2013



Contents

1	Executive Summary	5
2	Bill of Materials	6
3	Assembly Instructions	7
3.1	Arm Assembly	7
3.2	Leg Assembly	14
3.3	Shoulder Assembly	31
3.4	Head Assembly	44
3.5	Hip Assembly	55
3.6	Final Assembly	71
4	Printing Instructions	75
5	Assembly Drawings	76
6	Part Drawings	77
7	Suggestions for Design Revision	78
7.1	Arm	78
7.2	Leg	78
7.3	Shoulder	78
7.4	Head	78
7.5	Hip	79
7.6	Full Assembly	79
8	Team Member Contributions	80

List of Figures

1	Lower casing and shaft with hole highlighted.	7
2	Assembled lower casing, shaft, and bushing.	8
3	Threaded inserts with holes in forearm highlighted.	8
4	Threaded inserts pressed into holes in forearm.	9
5	Close-up of threaded inserts in forearm.	9
6	Large gear bolted onto forearm.	10
7	Forearm assembled onto lower casing.	10
8	M2 threaded inserts above holes in lower casing.	11
9	M2 threaded inserts pressed into holes in lower casing.	11
10	Close-up of motor bolted onto lower casing.	12
11	Motor and forearm assembled onto lower casing.	12
12	Threaded inserts above highlighted holes in upper casing.	13
13	Threaded inserts pressed into holes in upper casing.	13
14	Close-up of bolts holding casings together.	14

15	Final arm assembly.	14
16	Threaded inserts in leg shell.	15
17	Knee and ankle motors.	16
18	Spring pin in gears.	17
19	Bolt holes in knee and ankle motors.	18
20	Route wires through holes.	19
21	Bolt motor to casing.	20
22	Assemble calf.	21
23	Insert bearings into calf.	22
24	Align ankle gear.	22
25	Assemble calf with ankle block.	23
26	Put shaft through ankle block.	23
27	Put spring pins in large gear.	24
28	Retaining rings on ankle shaft.	24
29	Bolt clam shell parts.	25
30	Bearings in thigh.	26
31	Align large gear.	27
32	Knee shaft in gear.	27
33	Thigh assembled onto calf.	28
34	Secured gears.	29
35	Retained shaft on knee.	29
36	Final shaft in thigh.	30
37	Final ankle assembly.	31
38	AX-12A motor assembly.	32
39	Rear motor plate assembly exploded.	33
40	Rear motor plate assembly.	34
41	Front motor plate assembly exploded.	35
42	Front motor plate assembly.	35
43	Front torso press fits.	36
44	Back torso press fits.	37
45	Bicep motor casing press fits.	38
46	Bicep motor casing assembly exploded.	39
47	Bicep motor casing assembly.	40
48	Shoulder crossway assembly exploded.	41
49	Shoulder crossway assembly exploded.	41
50	Shoulder small shaft subassembly exploded.	42
51	Shoulder small shaft subassembly.	43
52	Shoulder subassembly large shaft exploded.	44
53	Cut end off of shaft.	44
54	1/8 inch hole in shaft.	45
55	D-shaft with grooves.	45
56	Bearings in chin.	45
57	Bearings on both sides of chin.	46
58	Gear before hole is drilled.	46
59	Gear with 1/8 inch hole.	47
60	D-shaft though neck, chin, and gear.	48

61	Gear assembled.	48
62	Clamp casing around motor.	49
63	Attach shaft coupler to motor.	50
64	Spring pin in gear.	51
65	Press threaded inserts into holes in top of chin.	52
66	Mount motor onto chin.	52
67	Press threaded inserts into base of head.	53
68	Place two halves of head together.	54
69	Screw head piece to chin piece.	54
70	Exploded view of hip.	55
71	Exploded view of inner gimbal subassembly.	56
72	3D printed inner gimbal shell.	57
73	Motor and bushing placed in the shell.	58
74	Gears placed in inner gimbal shell.	59
75	Other half of inner gimbal shell.	60
76	Motor and motor cover.	61
77	Second motor in inner gimbal subassembly.	62
78	Finished inner gimbal subassembly.	63
79	Exploded view of middle gimbal subassembly.	64
80	Inner gimbal sitting in middle gimbal.	65
81	Red shaft enables Jimmy to swing his leg sideways.	66
82	Bottom part of outer gimbal.	67
83	Motor in outer gimbal shell.	68
84	Linkage system that enables Jimmy to turn.	69
85	Hip subassemblies in bottom outer gimbal shell.	70
86	Fully assembled hip.	71
87	Attaching the torsos.	72
88	Securing the torsos.	72
89	Front motor plate assembly.	73
90	Front motor plate assembly.	74

1 Executive Summary

Jimmy X is designed to be built by any individual or organization, such as a high school, with a 3D printer. He is around 30 inches tall. We anticipate him to cost around \$4000, depending on the cost of plastic for different 3D printers.

We designed Jimmy X with two important features in mind. First, he needed to be able to walk. Second, he needed to be expressive and have character so that the user could interact with him.

We expect that users will modify everything about him from the mechanical design to the software that controls him. Our design decisions should be viewed as suggestions, not requirements. We hope that the user will gain engineering experience by using our design as a platform to create the Jimmy that they want to interact and experiment with.

This document is a full guide to building the Jimmy X that we have designed. It includes a full list of parts to buy and print, our part numbering guide, full detailed assembly instructions, and technical part and assembly drawings. We also include suggestions for revisions to our design that can be explored. Users can download all of our Solidworks files and modify them, either according to our suggestions or based on new ideas.

Jimmy X's current design allows for the following number of degrees of freedom at each joint: one in the neck, two in the shoulders, one in the elbow, three in the hip, one in the knee, and two in the ankle. These degrees of freedom should allow Jimmy to walk. He is statically determinate at all times, meaning that if his motors are shut off at any time he can stand in his current position. He is able to keep his center of gravity over one foot at all times by rotating his hip and ankle to shift his upper body.

With some creativity, degrees of freedom could be added in any of the joints. Alternatively, Jimmy could shrink if some degrees of freedom were removed. We chose the degrees of freedom represented here because we found it to be a good compromise between Jimmy being able to walk and express character and keeping him relatively affordable.

2 Bill of Materials

See attached sheets.

3 Assembly Instructions

Follow these instructions to assemble our version of Jimmy X.

3.1 Arm Assembly

Instructions are for assembly of the right arm. Follow the same steps to assemble the left arm.

Begin with the lower casing (16003). Press the shaft (16004) into the supported hole in the casing.

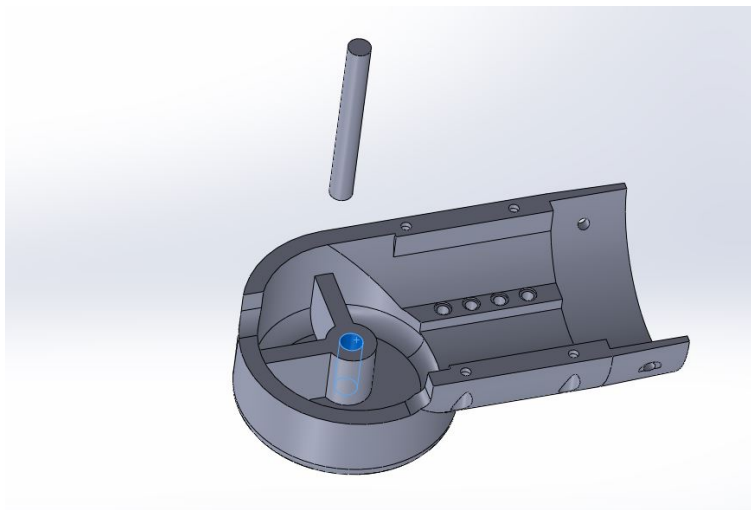


Figure 1: Lower casing and shaft with hole highlighted.

Slide one of the bushings (16005) over the shaft.

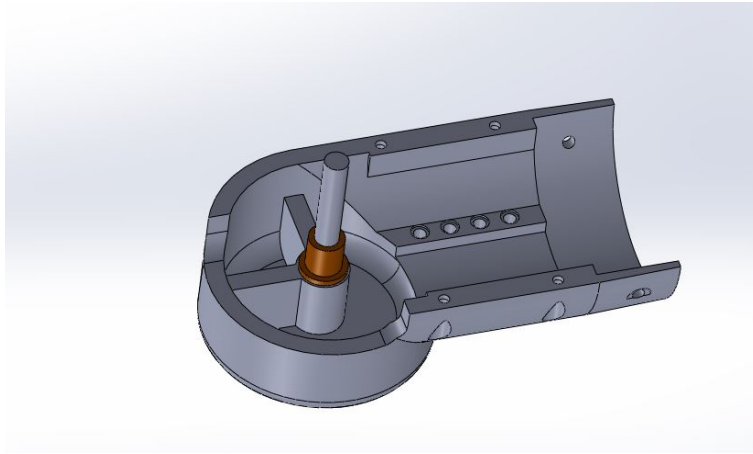


Figure 2: Assembled lower casing, shaft, and bushing.

Next, take the forearm (16001) and press six of the 4-40 threaded inserts (16006) into its six holes. Be sure that the inserts are facing up.

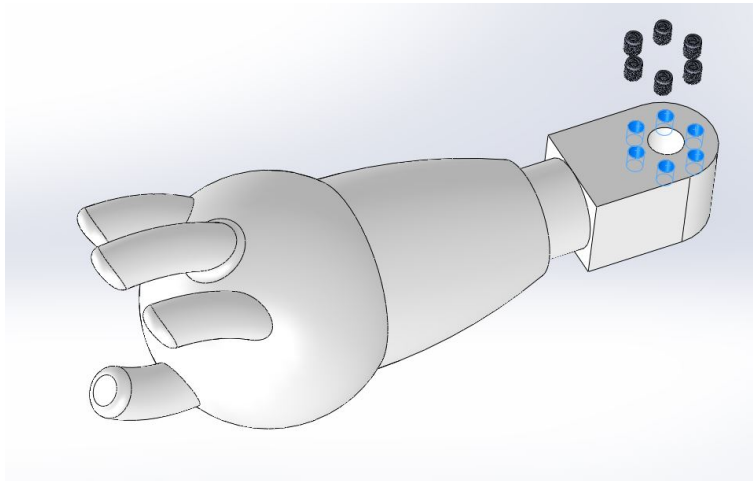


Figure 3: Threaded inserts with holes in forearm highlighted.

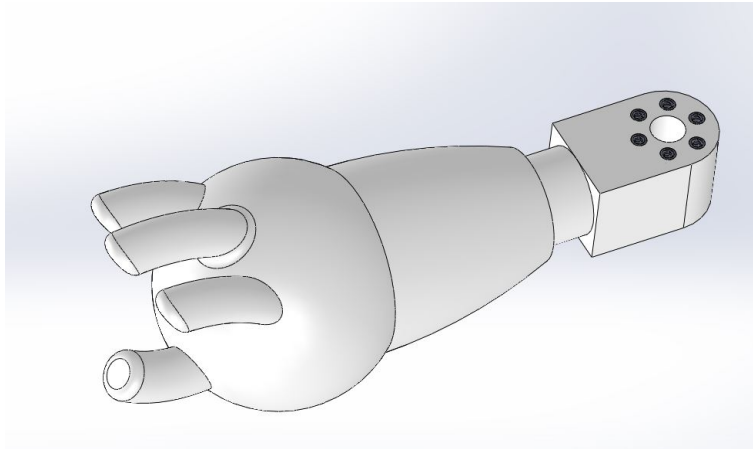


Figure 4: Threaded inserts pressed into holes in forearm.

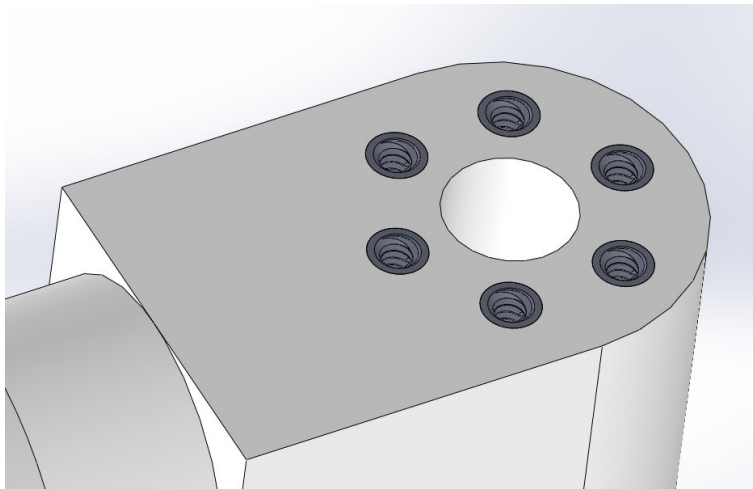


Figure 5: Close-up of threaded inserts in forearm.

Bolt larger gear (16009) onto forearm with six of the 4-40 bolts (16012) screwed into the threaded inserts.

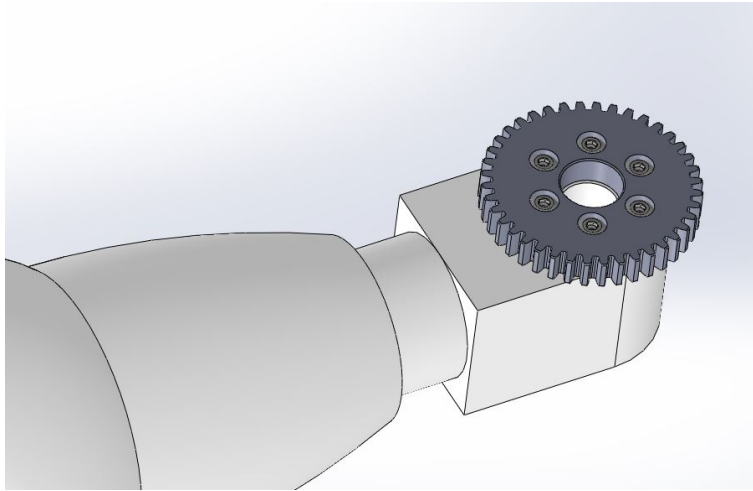


Figure 6: Large gear bolted onto forearm.

Ensuring that the thumb is down, slide the assembled forearm over the shaft and the lower bushing. Slide the upper bushing over the shaft so that the flange of the bushing is flush with the face of the large gear.

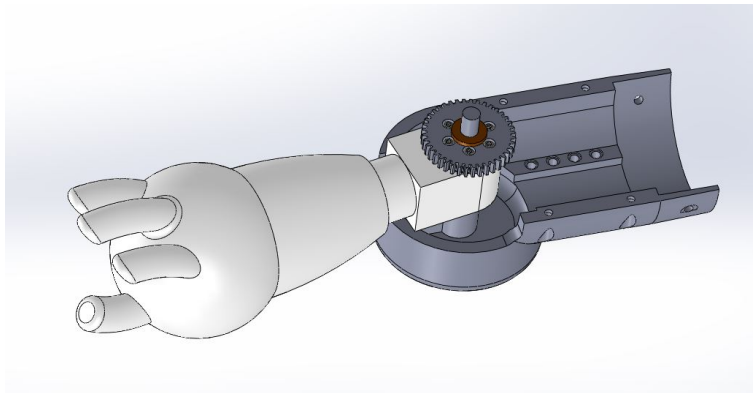


Figure 7: Forearm assembled onto lower casing.

Place the M2 threaded inserts (16010) into the eight holes in the lower casing.

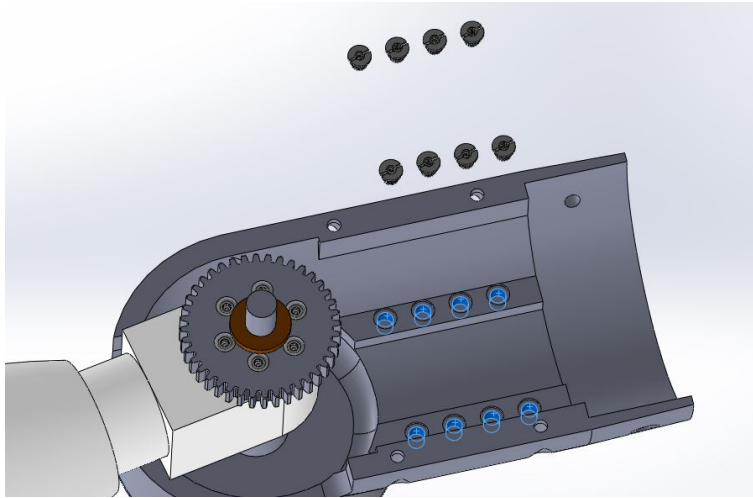


Figure 8: M2 threaded inserts above holes in lower casing.

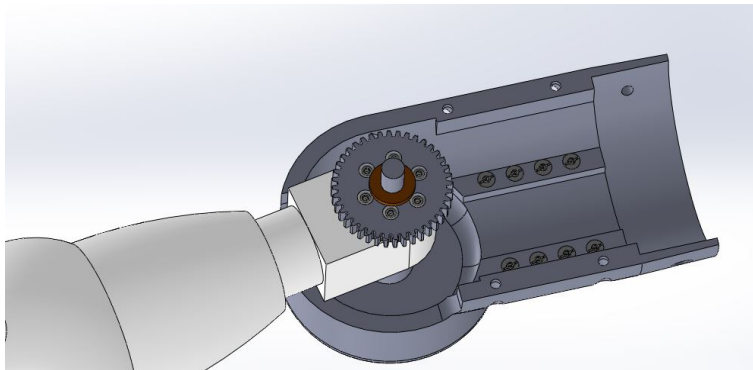


Figure 9: M2 threaded inserts pressed into holes in lower casing.

Remove the servo horn that comes with the motor. Replace it with the smaller gear (16008). Use an adhesive if necessary to secure the gear to the motor shaft. Fix the motor (16002) in place using the M2 bolts (16011). Ensure that the gears mesh.

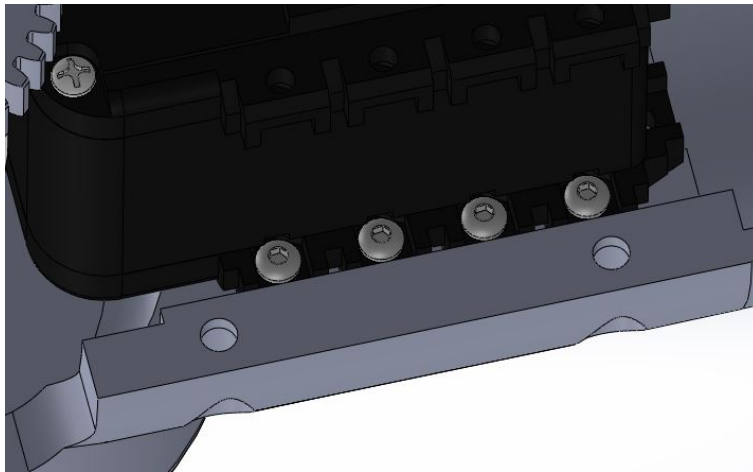


Figure 10: Close-up of motor bolted onto lower casing.

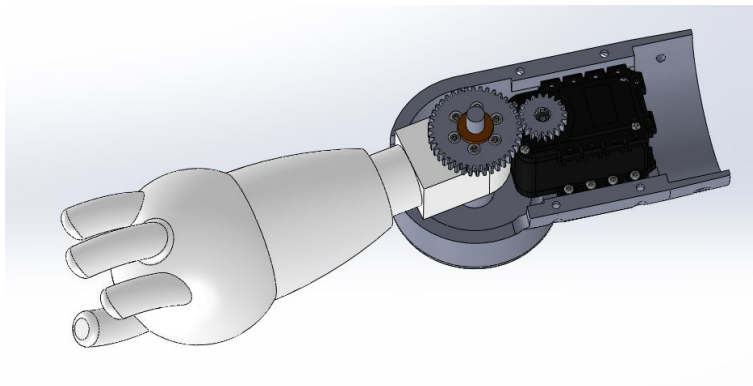


Figure 11: Motor and forearm assembled onto lower casing.

Press four of the 4-40 threaded inserts (16006) into the four holes of the upper casing (16007).

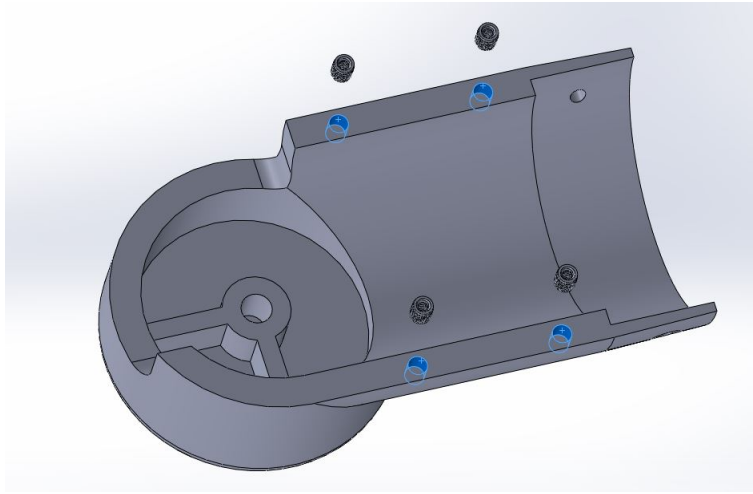


Figure 12: Threaded inserts above highlighted holes in upper casing.

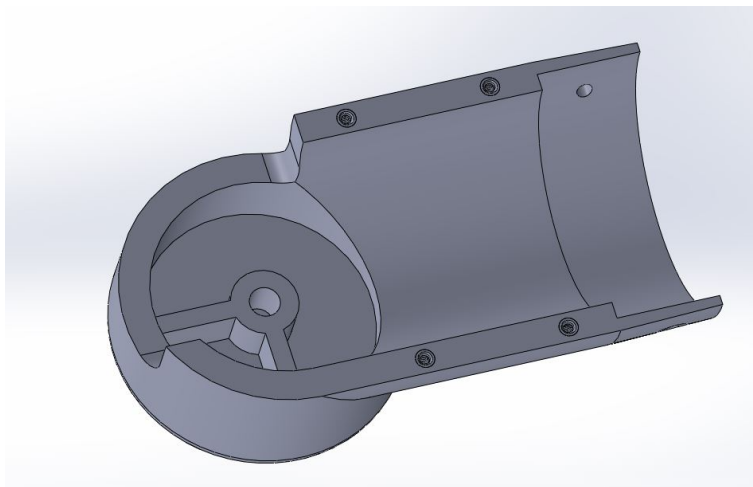


Figure 13: Threaded inserts pressed into holes in upper casing.

Place the upper casing on the rest of the assembly, positioning it by pressing the shaft into the support hole of the upper casing. Fix the two casings together with the 4-40 bolts (16012).

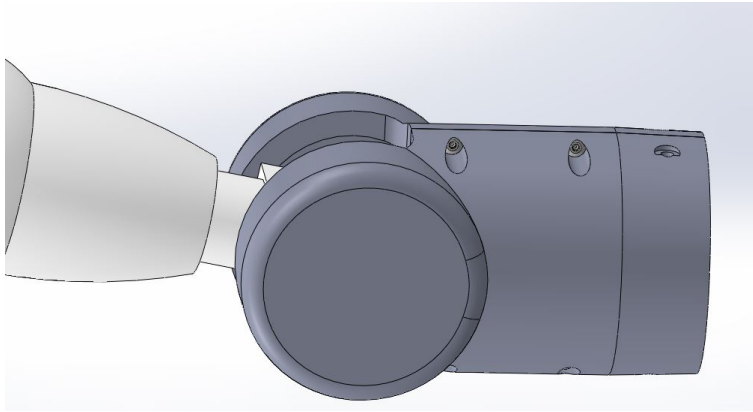


Figure 14: Close-up of bolts holding casings together.

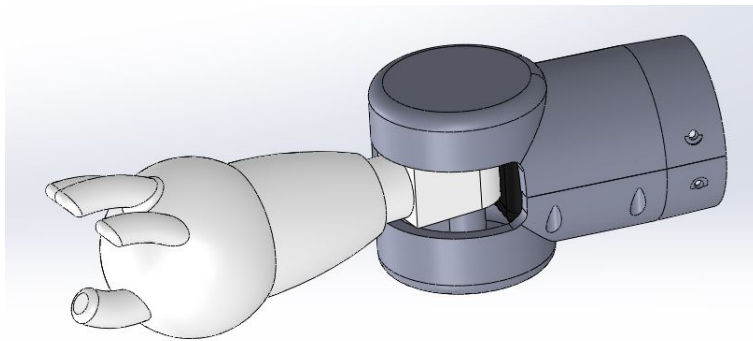


Figure 15: Final arm assembly.

Follow the same steps for the left arm. When making the left arm, substitute the following parts: 16013 for 16001, 16014 for 16007, and 16015 for 16003. Set the arms aside. Wires will route through the shoulder.

3.2 Leg Assembly

Put threaded inserts (12110 12111) into the shell for motors and the left clam shell half (12001).

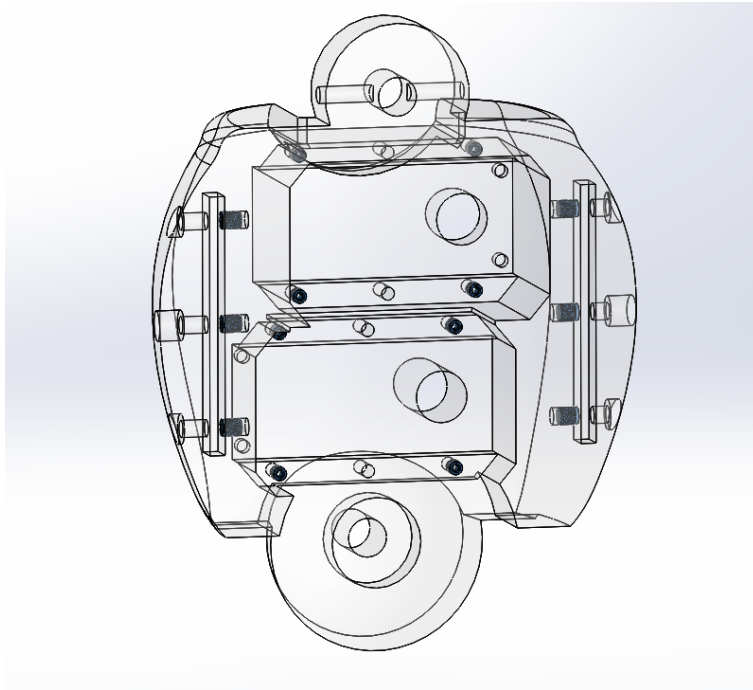


Figure 16: Threaded inserts in leg shell.

Attach the smaller gears (12103) to the knee and ankle motor (12101).

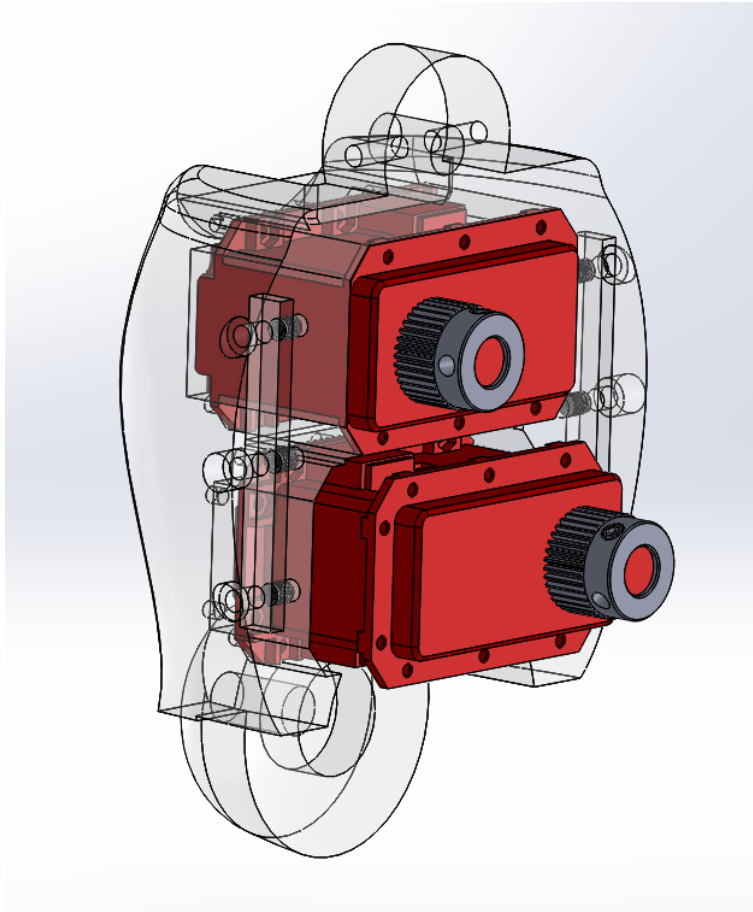


Figure 17: Knee and ankle motors.

Insert spring pin (12107) into hole in smaller gears (12103).

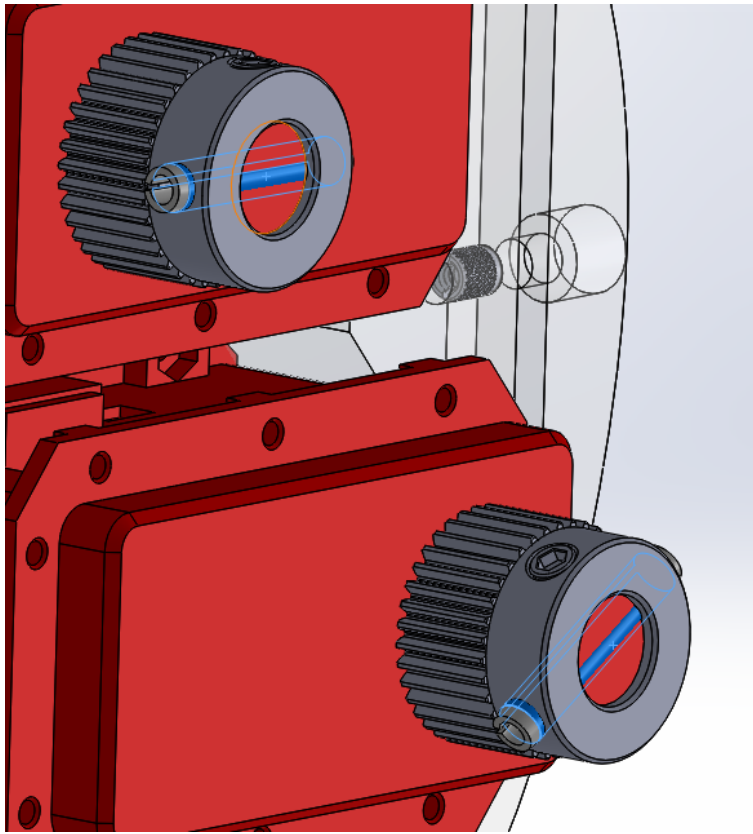


Figure 18: Spring pin in gears.

Align the bolt holes of the knee and ankle motor (12101) to the threaded inserts (12111)

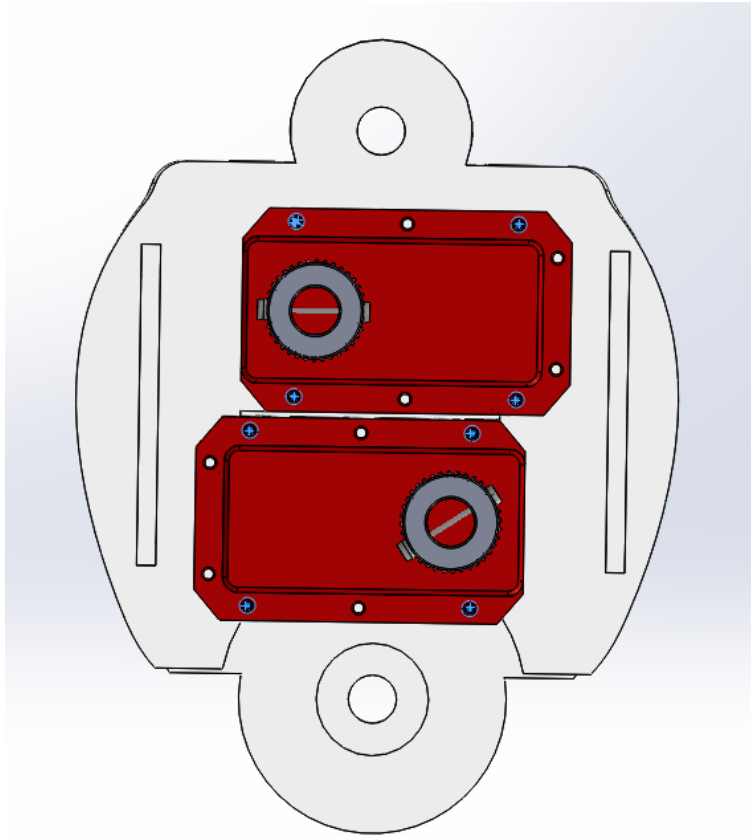


Figure 19: Bolt holes in knee and ankle motors.

Pull knee motor (12101) wires through top hole.

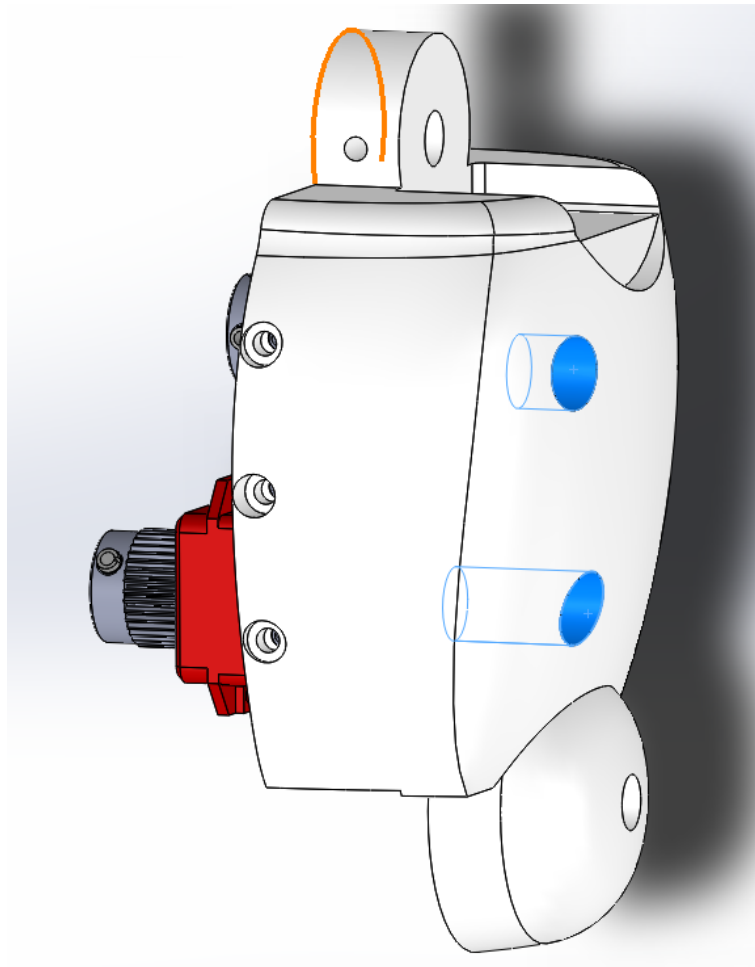


Figure 20: Route wires through holes.

Insert bolts (12113) to secure motor to left clam shell (12001).

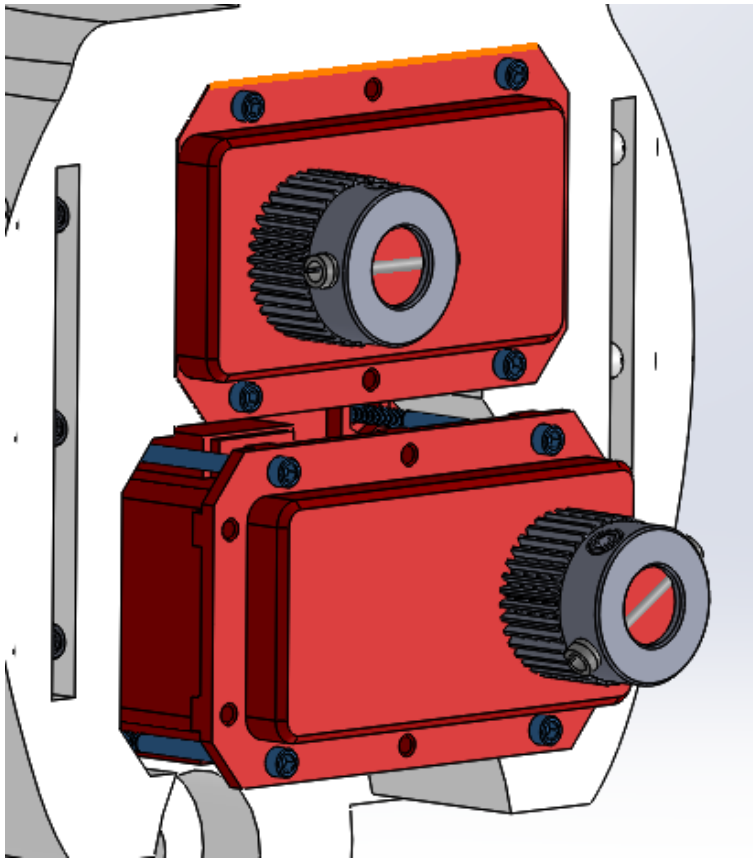


Figure 21: Bolt motor to casing.

Put on right shell half (12001).

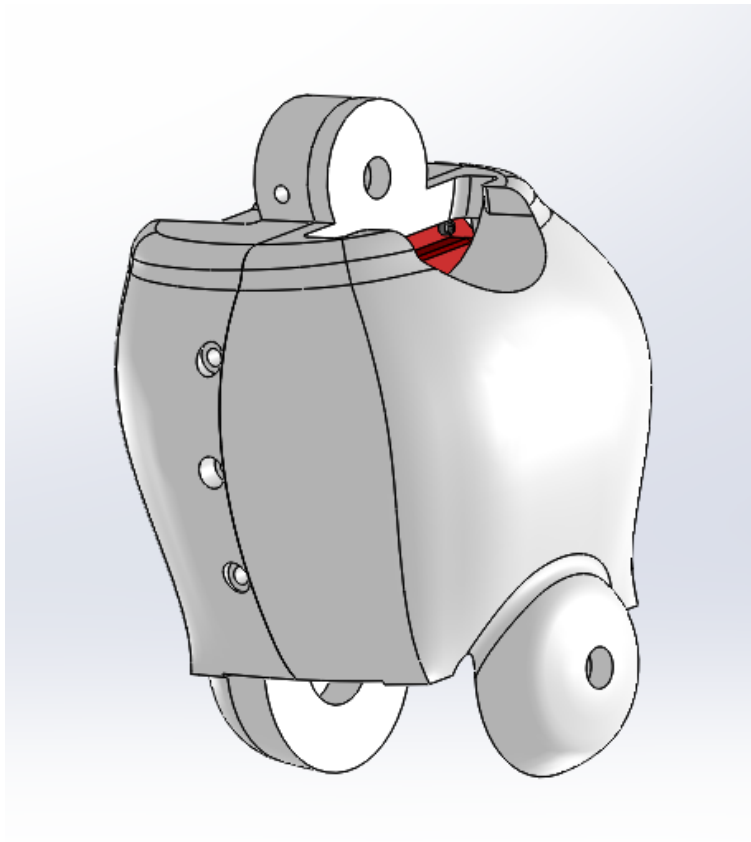


Figure 22: Assemble calf.

Insert bearings (12114) to lower part.

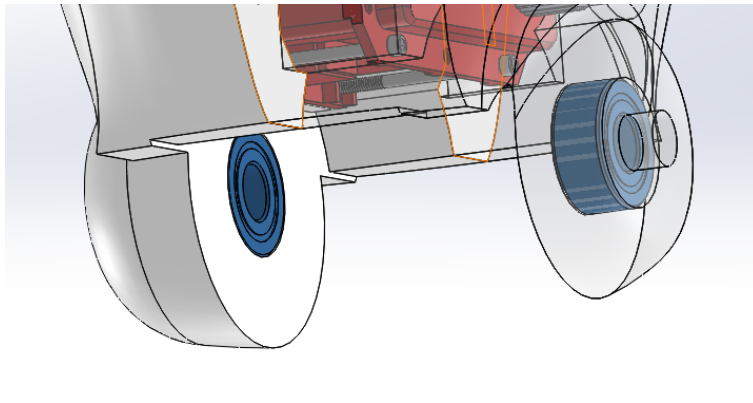


Figure 23: Insert bearings into calf.

Line up larger gear (12105) for the ankle portion.

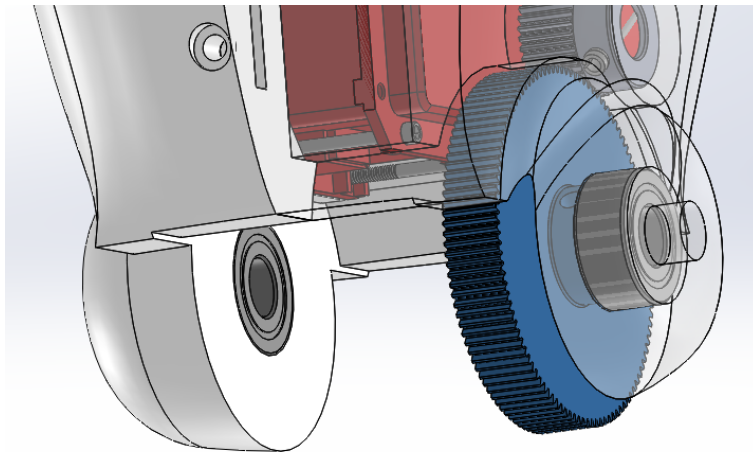


Figure 24: Align ankle gear.

Line up current assembly with the ankle block (11001).

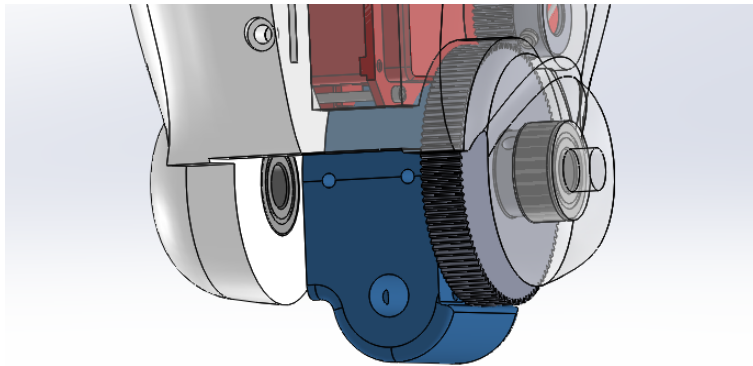


Figure 25: Assemble calf with ankle block.

Put roll shaft (11005/12104) through the ankle block and shell (12001).

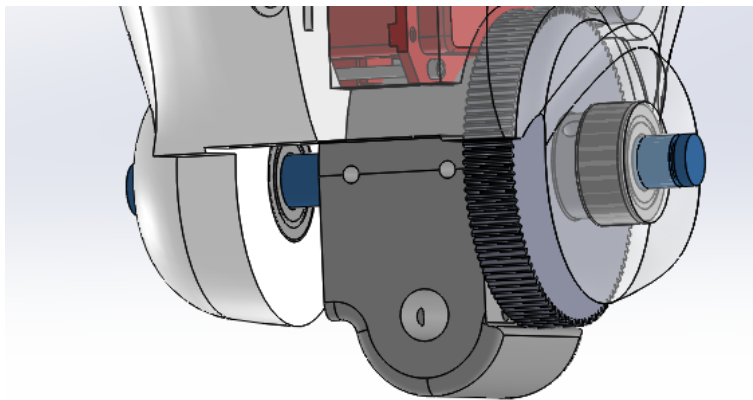


Figure 26: Put shaft through ankle block.

Put spring pins (12107) through the larger gear (12105).

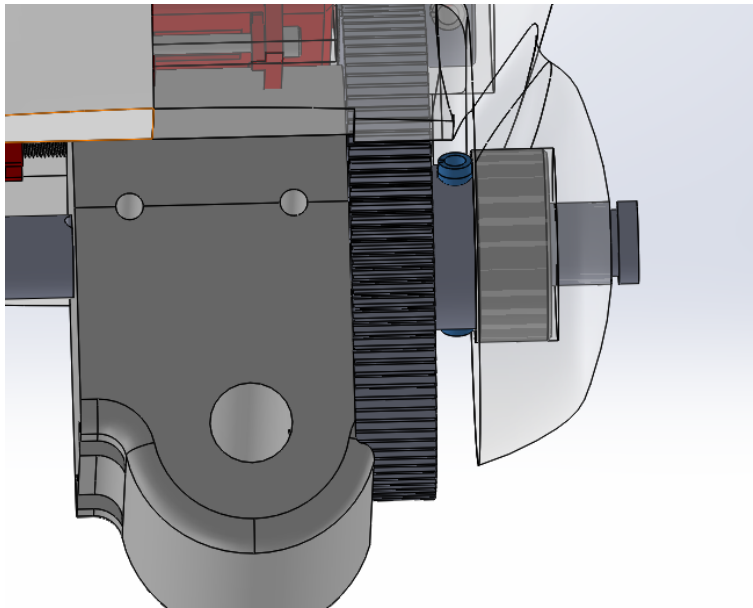


Figure 27: Put spring pins in large gear.

Put retaining rings (12102) on the ankle shaft (11005/12104).

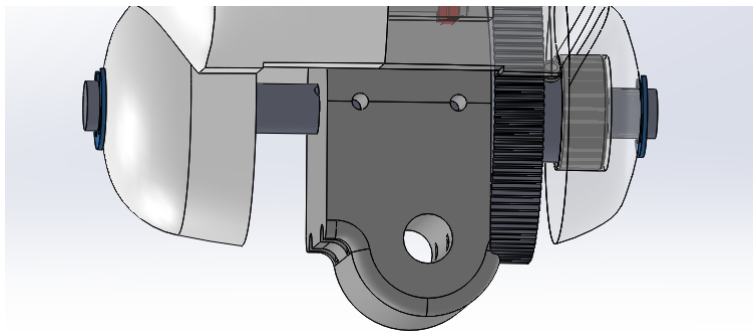


Figure 28: Retaining rings on ankle shaft.

Put bolts (12112) through the clam shell parts.

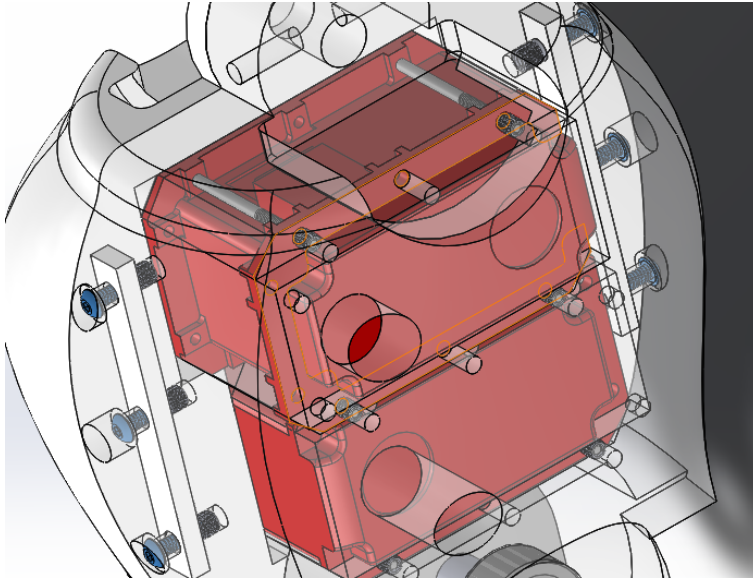


Figure 29: Bolt clam shell parts.

Add bearings (12114) in the thigh piece (12108).

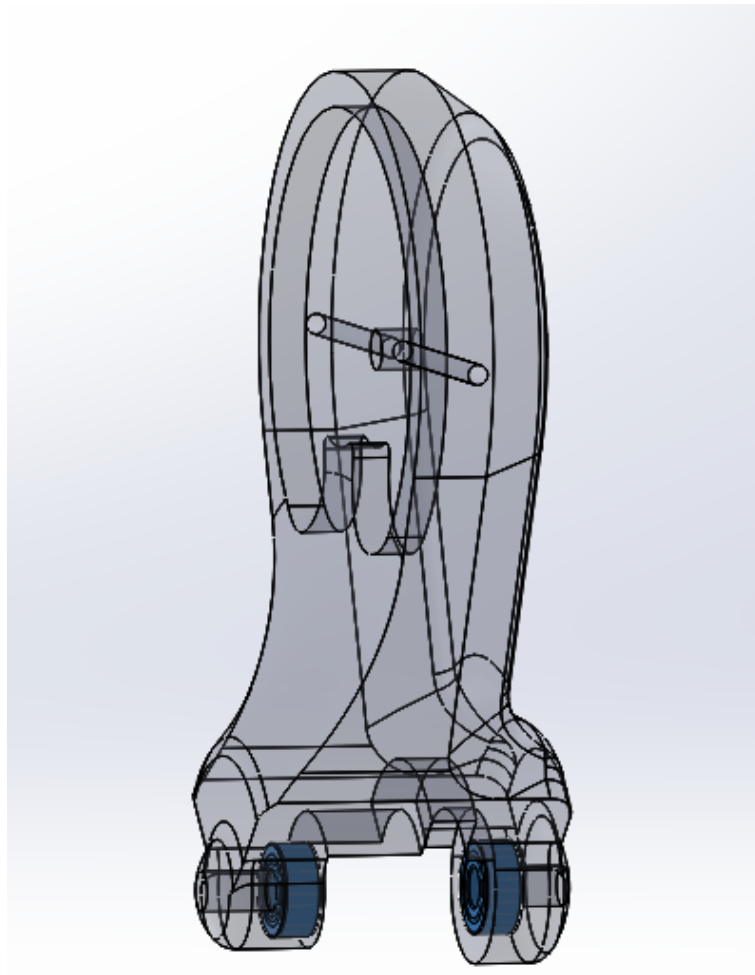


Figure 30: Bearings in thigh.

Add larger gear (12105) to the top and line it up.

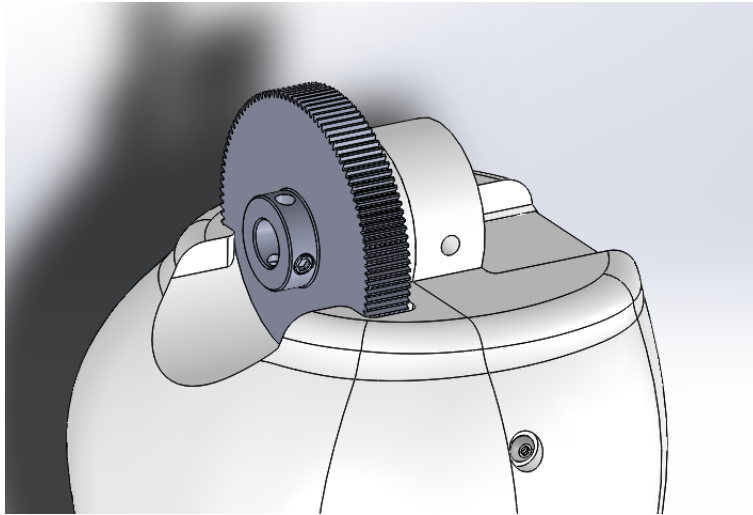


Figure 31: Align large gear.

Add knee shaft (12109).

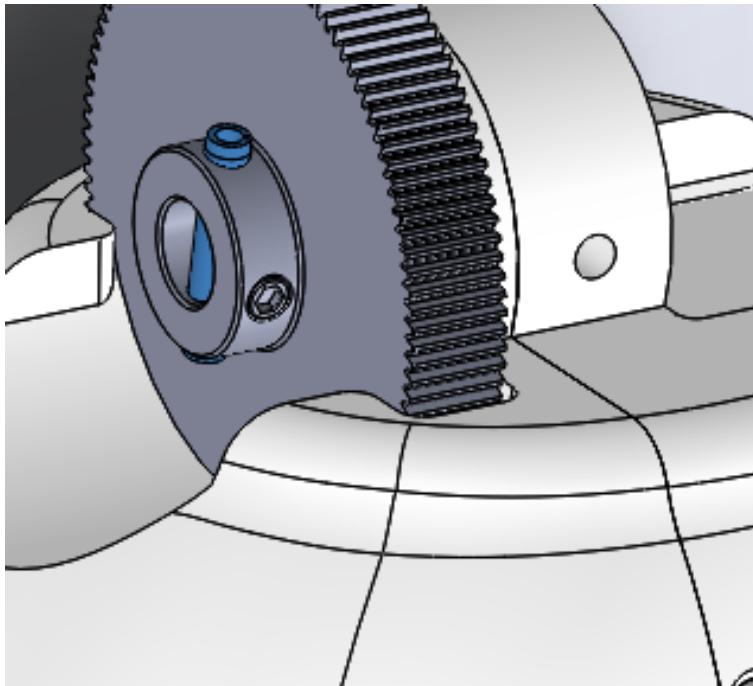


Figure 32: Knee shaft in gear.

Add thigh piece (12108).

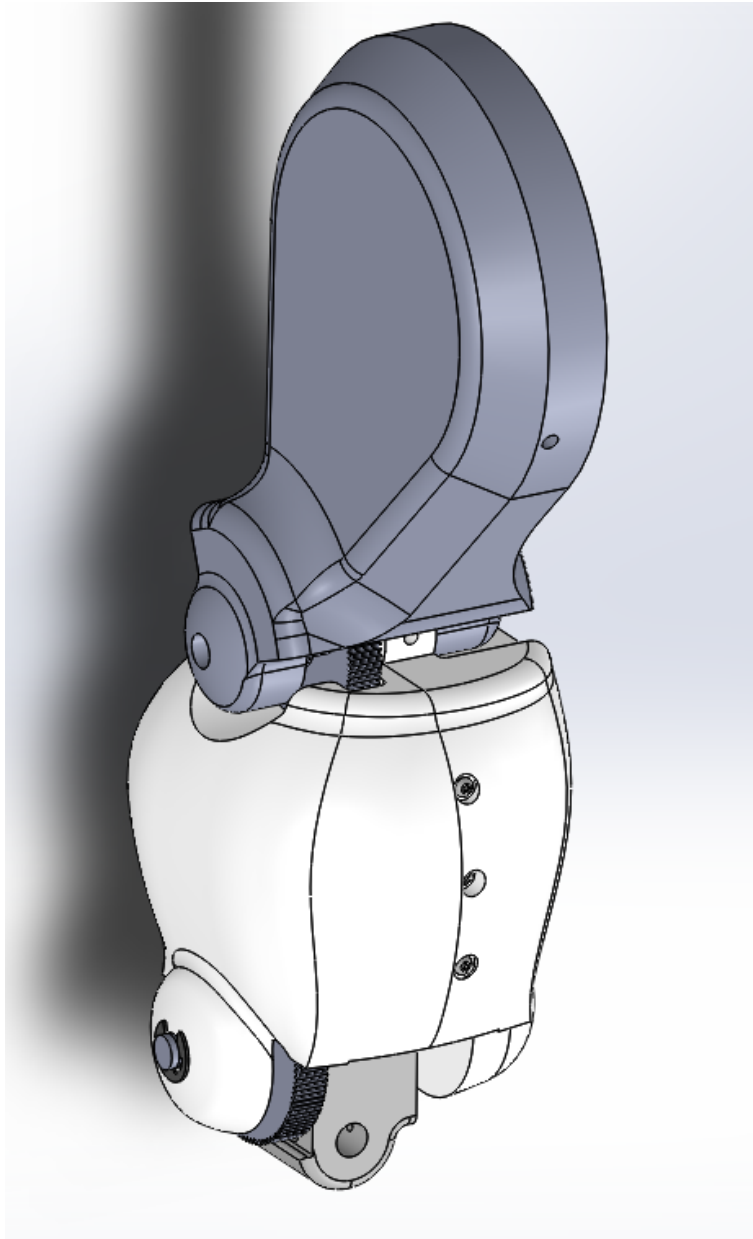


Figure 33: Thigh assembled onto calf.

Add pin (12107) for gears (12103 12105).

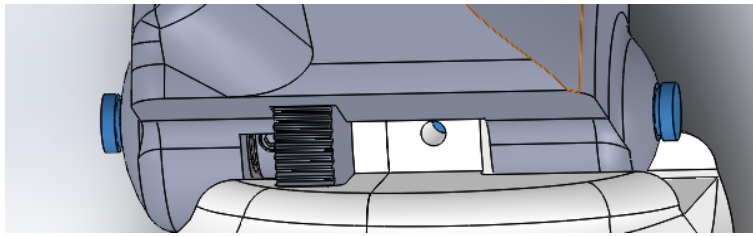


Figure 34: Secured gears.

Add retaining rings (12102) for knee shaft (12109).

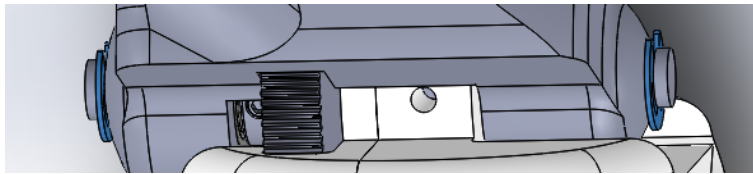


Figure 35: Retained shaft on knee.

Add shaft pin (12115) through clam shell and rotation shaft (12116) to thigh piece.

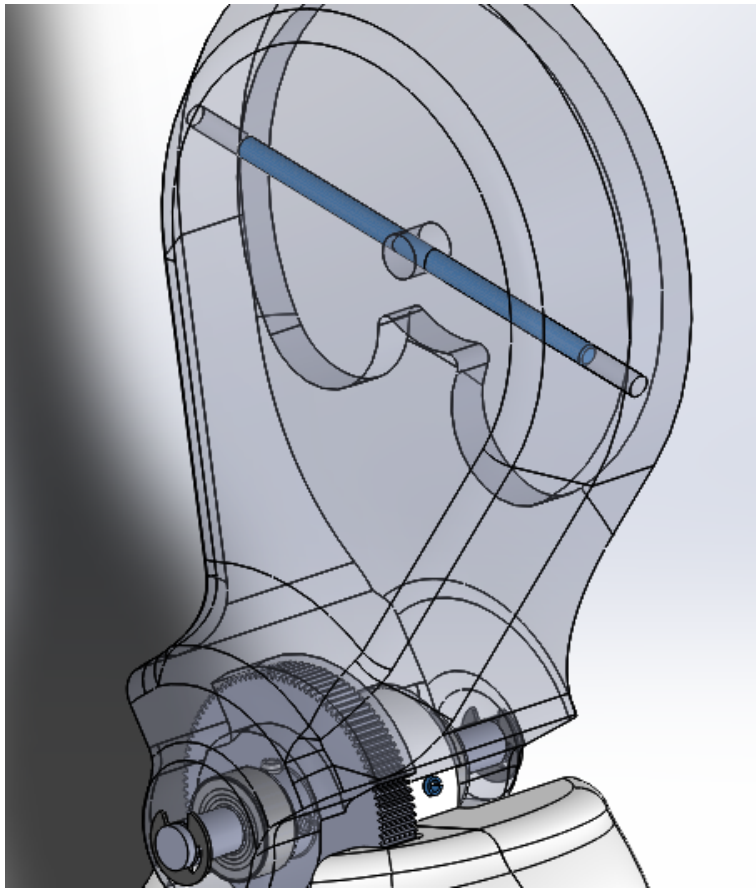


Figure 36: Final shaft in thigh.

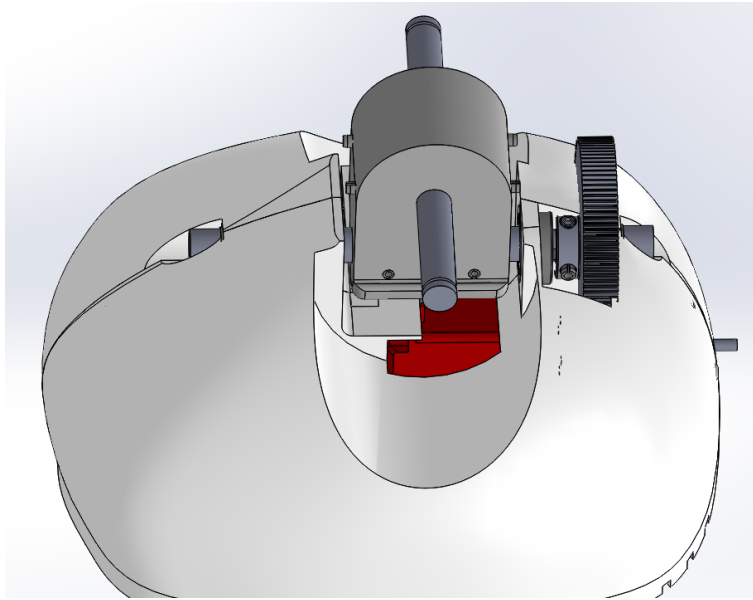


Figure 37: Final ankle assembly.

3.3 Shoulder Assembly

Before assembling the shoulder joint, assemble four Dynamixel AX-12A motors (14004). To assemble the motors, remove only the motor horn (14004) from the AX-12A by removing the machine screw fixing it in place. Alter the motor horn according to the attached part drawing (JIMMYX-14004). Reference Figure 38 for further assembly of the motor. Using the $\frac{3}{16}$ " diameter $\frac{1}{4}$ " length spring pins (15008), press fit the altered 12 tooth gear (15004) to the motor horn. Pass the M2.6 lock washer (15005), followed by the M2.6 washer (15006), followed by the 12 tooth spur gear and motor horn onto the M2.6 x 12mm machine screw (15007). Finally, put the horn in place on the motor and screw the M2.6 x 8mm machine screw in place.

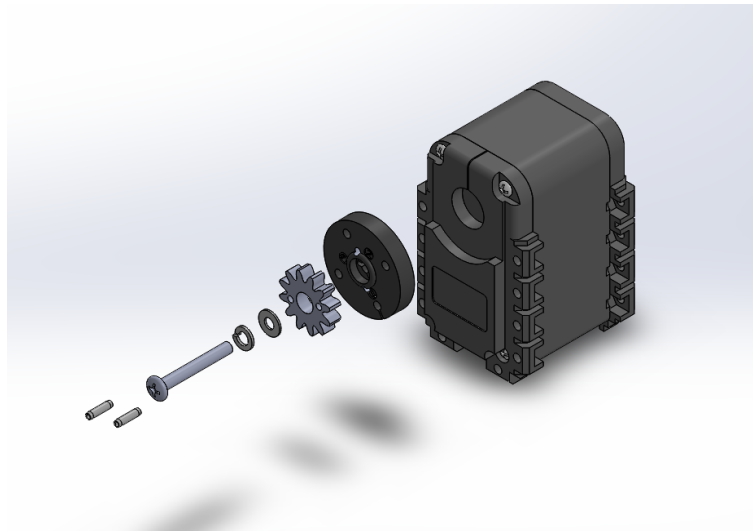


Figure 38: AX-12A motor assembly.

Use one of the assembled AX-12As in the following assembly of the rear motor plate as seen in Figure 39. Place seven of the M2 hex nuts (15013) in the nut housing locations inside of the mounting flanges of the AX-12A. Three will be located on the side with the horn and four will be located on the back of the motor opposite the horn. Place the motor with nuts in place inside the flanges of the rear motor plate (15001 configuration: back motor plate). Use seven M2 x 6mm machine screws (15014) to bolt the motor in place inside the plate flanges. At the end of these assembly instructions, five 4-40 3/8" machine screws will be used to fix the rear motor assembly seen in Figure 40 to the torso.

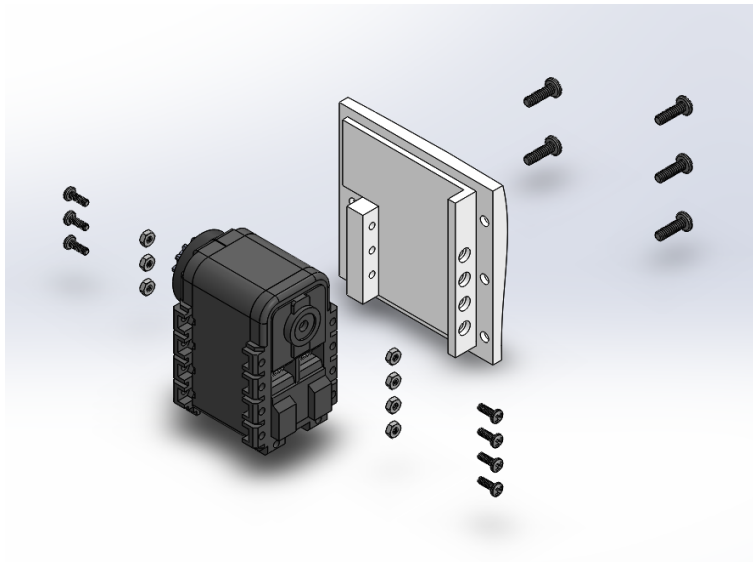


Figure 39: Rear motor plate assembly exploded.

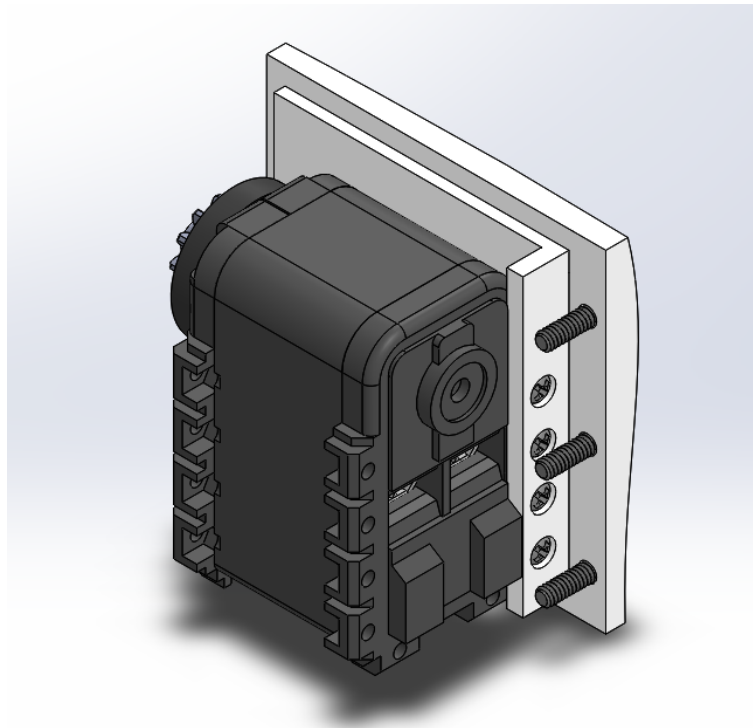


Figure 40: Rear motor plate assembly.

In a similar fashion, assemble a second AX-12A to the front motor plate (15001 configuration: Front Motor Plate) as in Figure 41. Place seven more M2 hex nuts in the nut housings inside the motor mounting flanges. Place the motor between the front motor plate flanges and use seven M2 x 8mm machine screws (15012) to mount it in place. At the end of these assembly instructions, five 4-40 3/8" machine screws will be used to fix the front motor assembly seen in Figure 42 to the torso.

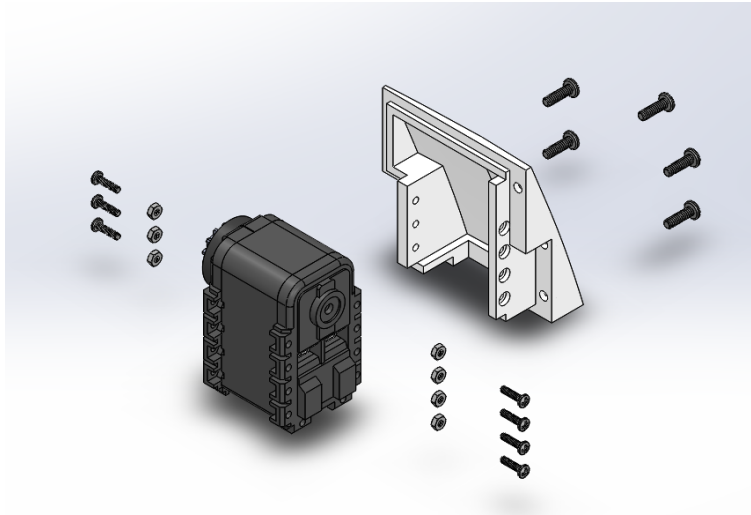


Figure 41: Front motor plate assembly exploded.

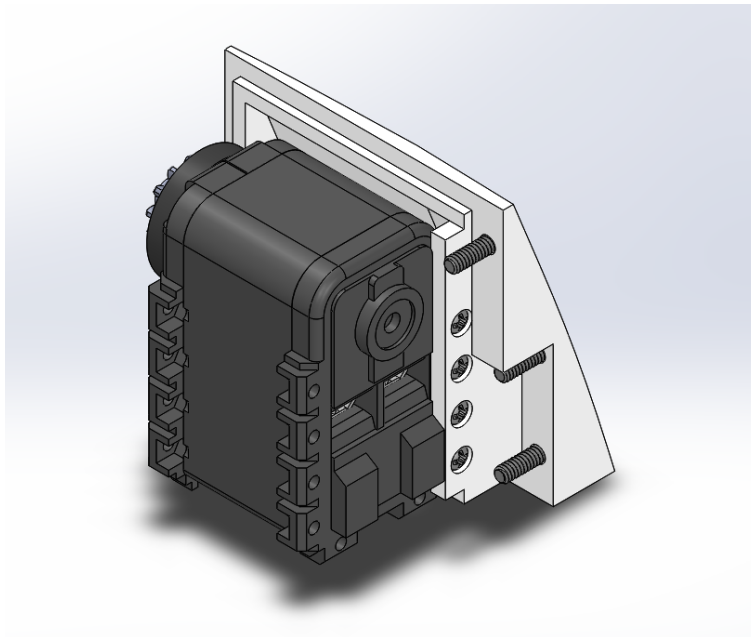


Figure 42: Front motor plate assembly.

Before assembling the shoulder further, press fit the appropriate threaded inserts into the front and back torso as follows. According to Figure 43, press fit eight 4-40 un-flanged threaded inserts (15018) into the holes in the center

face of the front torso (15001 configuration: torso front). Each insert is pictured in front of its press fit hole. The back torso (15001 configuration: back torso) contains three 4-40 un-flanged threaded inserts. According to Figure 44, press fit the inserts into the holes in the middle of the center face. Once again, the inserts are pictured in front of their press fit holes.

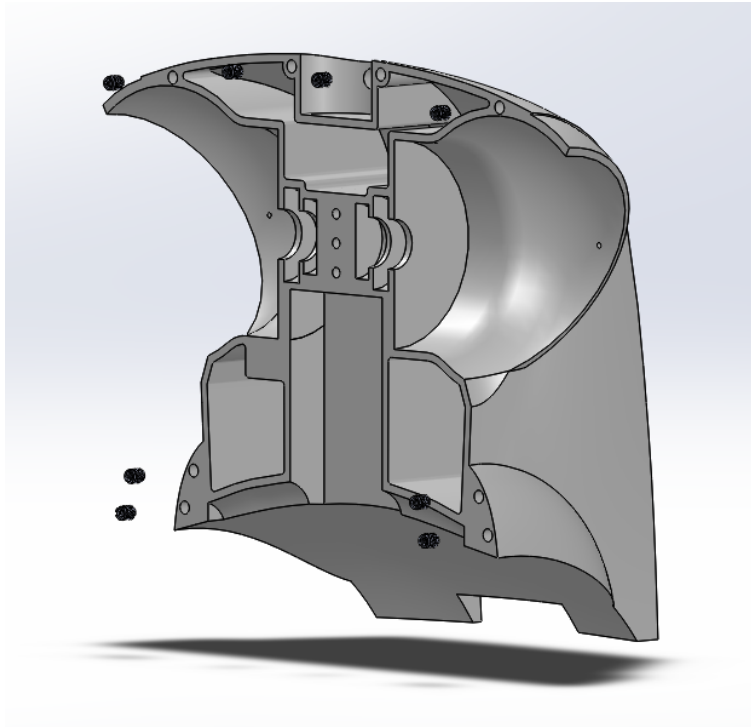


Figure 43: Front torso press fits.

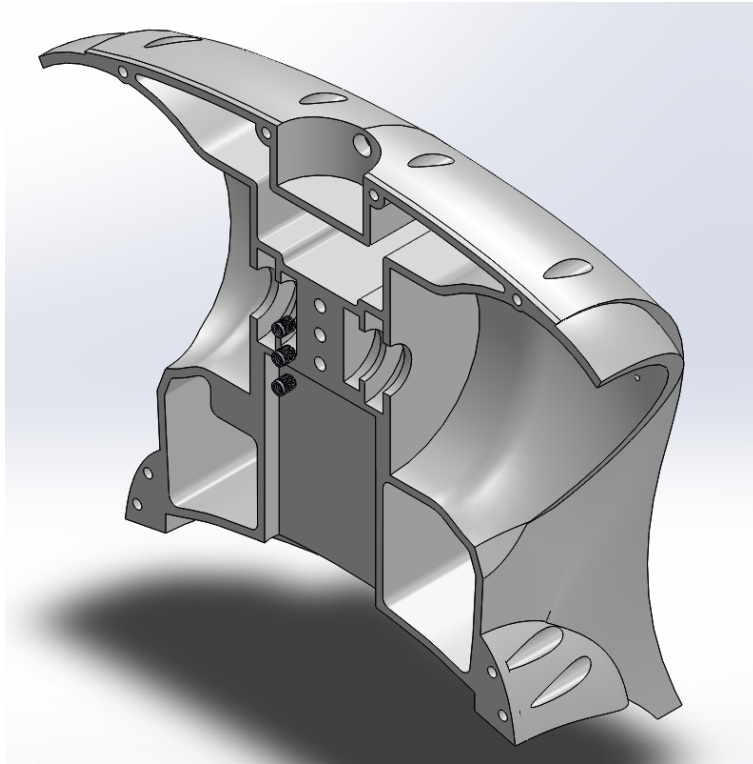


Figure 44: Back torso press fits.

In the following instructions, along with the supplied images, feel free to reference the shoulder assembly drawing (JIMMYX-15100). Using the remaining sixteen 4-40 un-flanged threaded inserts, press fit four into each of the bicep motor casings (15104). Reference Figure 45 for the location of the inserts which are pictured just above their press fit holes.

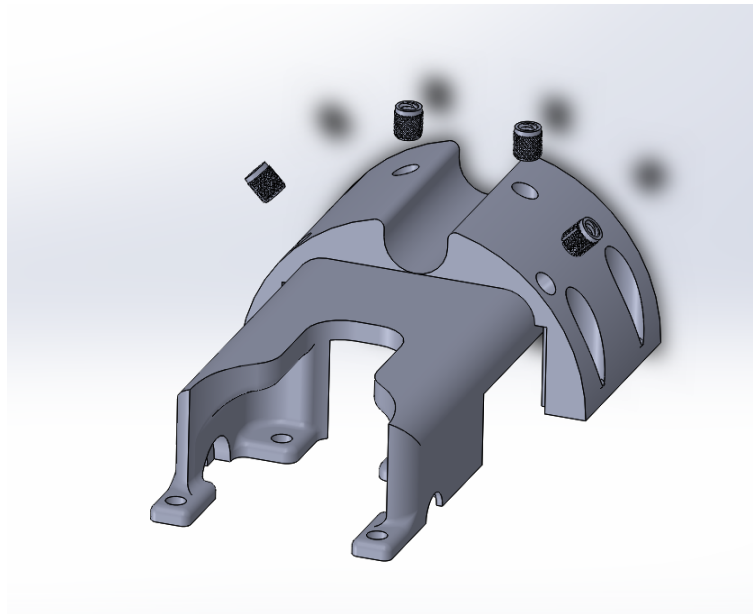


Figure 45: Bicep motor casing press fits.

Next, use Figure 46 to assemble the bicep motor casings around the remaining two AX-12A motors. The inserts pictured in Figure 46 should have just been press fit in place. Close two of the bicep motor casings around one AX-12A. Using eight 4-40 hex nuts (15020) and eight 4-40 3/8" machine screws (15017) bolt the bicep motor casings together around the motor. The nuts and bolts are pictured in Figure 46 in concentric with their respective bolt holes. Assemble the remaining motor casings and AX-12A in this fashion. The final assembled motors and casings should resemble Figure 47. Note the semicircular cutouts in the top of the bicep motor casing. This hole will be used to pass wires to the elbow motors.

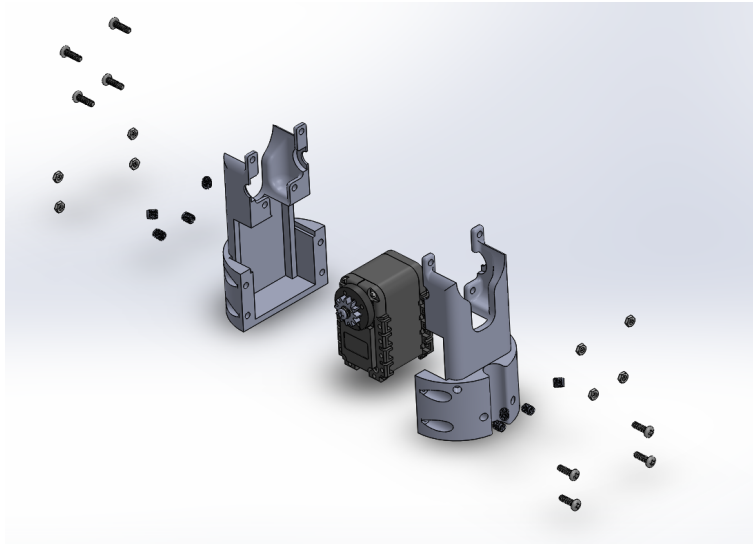


Figure 46: Bicep motor casing assembly exploded.

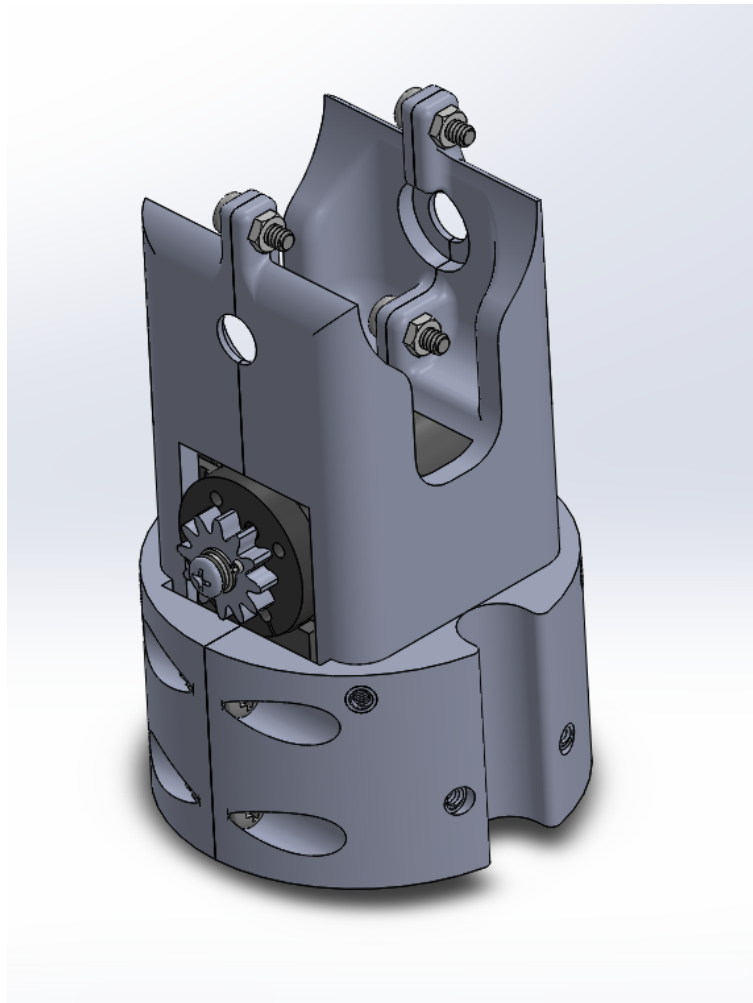


Figure 47: Bicep motor casing assembly.

Now, assemble the shoulder crossway assembly according to Figure 48. Press fit four 4-40 flanged threaded inserts (15009) into the four holes in each shoulder crossways (15105) as seen in the figure. Screw the two 1/4" cam followers (15106) into the outer two inserts of each shoulder crossways. Place a 48T altered hubless spur gear (15015) around the large 1/2" shaft of each crossways and use two 4-40 3/8" machine screws (15017) to screw the gear into the inner inserts and fix it in place. The assembled crossways assembly should appear as in Figure 49.

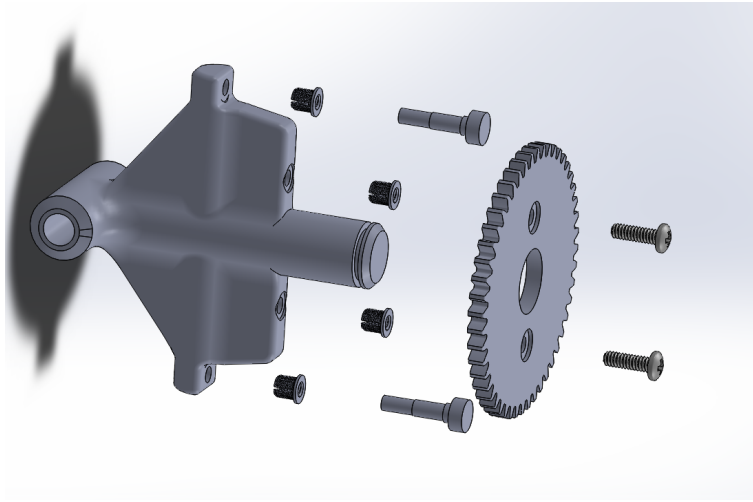


Figure 48: Shoulder crossway assembly exploded.

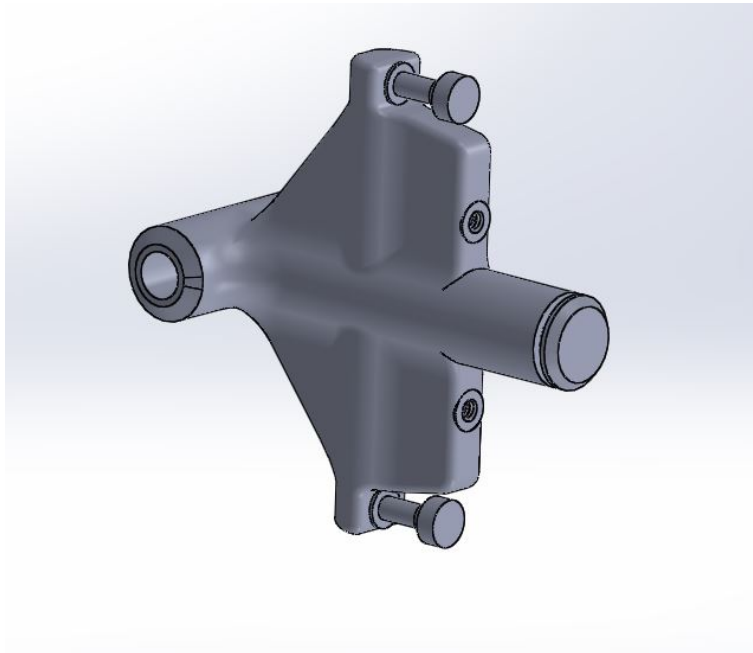


Figure 49: Shoulder crossway assembly exploded.

Next, use Figure 50 to attach the shoulder crossways assembly to the bicep motor casing assembly. Attach a 1/4" side mount retaining ring (15112) onto one end of the 1/4" machined aluminum shaft (15111). Press the 1/4" shaft ball

bearings (15113) into the inside of the motor casing mounting flanges into the respective bearing pockets. Next, pass the back side of the bicep motor casing assembly (opposite the motor horn) onto the shaft. The shaft should pass through the bearings as well. Pass the shaft through the hole in the shoulder crossways before passing through the opposite side of the bicep motor casing and bearing. Next, pass the 1/4" shaft thrust bearing (15127) onto the shaft followed by the 48 tooth clamp style hub spur gear (15103). Clamp the gear in place against the thrust bearing using the 5/16" shaft collar (15114) and finally fix the other 1/4" retaining ring on the end of the shaft. The completed subassembly should appear as in Figure 51.

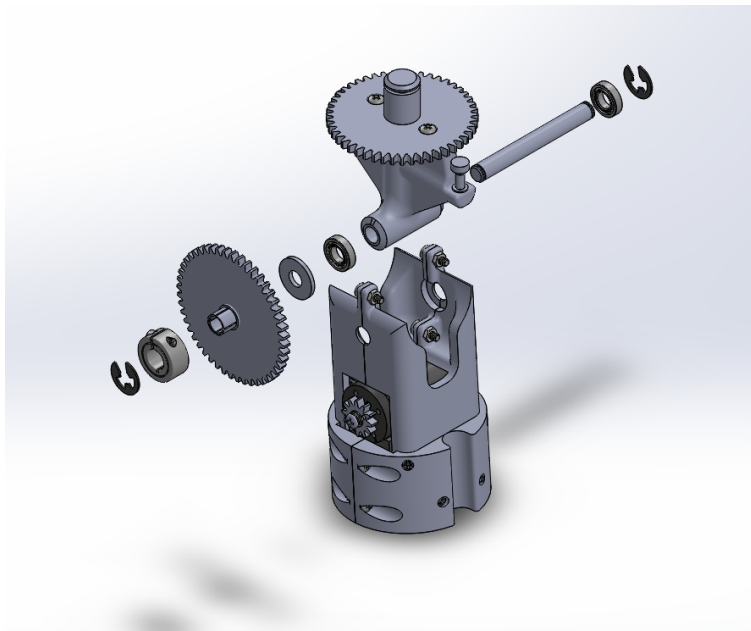


Figure 50: Shoulder small shaft subassembly exploded.

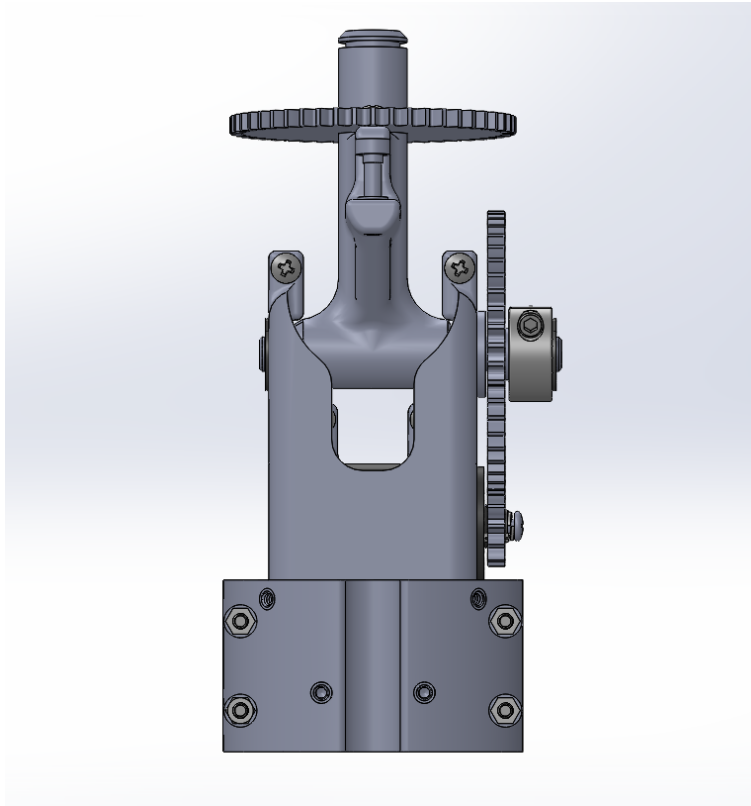


Figure 51: Shoulder small shaft subassembly.

Now complete the subassembly by placing the 1/2" shaft thrust bearing (15016), followed by the 1/2" shaft ball bearing (15010) on the 1/2" shaft of the shoulder crossways. Please reference Figure 52 for help. Finally, mount the 1/2" side mount retaining ring (15011) at the end of the shoulder crossways 1/2" shaft. The ball bearing and thrust bearing are free to move for the moment.

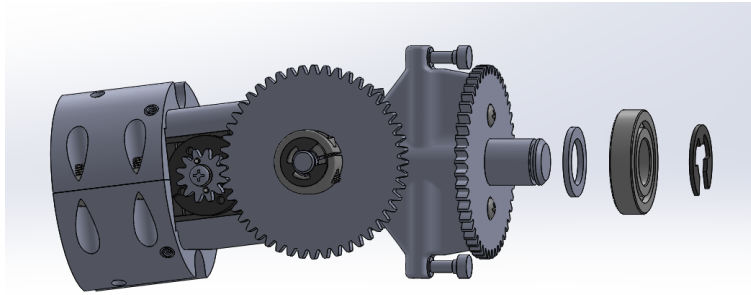


Figure 52: Shoulder subassembly large shaft exploded.

Now, mount the aesthetic shoulder ball shells (15002) onto the subassemblies using Figure ???. Before doing so, however, pass any necessary wires through the cutouts in the bicep motor casing. Place the ball shells around the bicep casings and screw two 4/40 1/4" machine screws (15019) into the inserts in each bicep to fix each shell in place. The subassembly should appear now as those in Figure ???. Place each of the subassemblies with the shells into the back torso so that the 1/2" shaft ball bearing fits into the round cut in the torso as in Figure ???. The retaining ring should be on the inside of the flange constraining the 1/2" bearing. For now, the shoulder assembly is complete. We will add in the final shoulder motors after closing the torso later.

3.4 Head Assembly

Begin by preparing the D-shaft (14013). First remove 1 inch from the length so that the remaining piece is 5 inches long.



Figure 53: Cut end off of shaft.

Next, drill a 1/8" hole centered in the flat face of the shaft (see drawing for dimensions).



Figure 54: 1/8 inch hole in shaft.

Finally, use a lathe to create a 0.21" diameter, 0.29" wide groove on each end of the D-shaft (see drawing for dimensions), as shown in Figure 55.

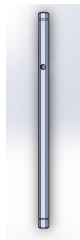


Figure 55: D-shaft with grooves.

Insert a bearing on each side of the hole in the chin. Make sure that the bearing is pushed in until it reaches the rests along the ridge inside of the chin.

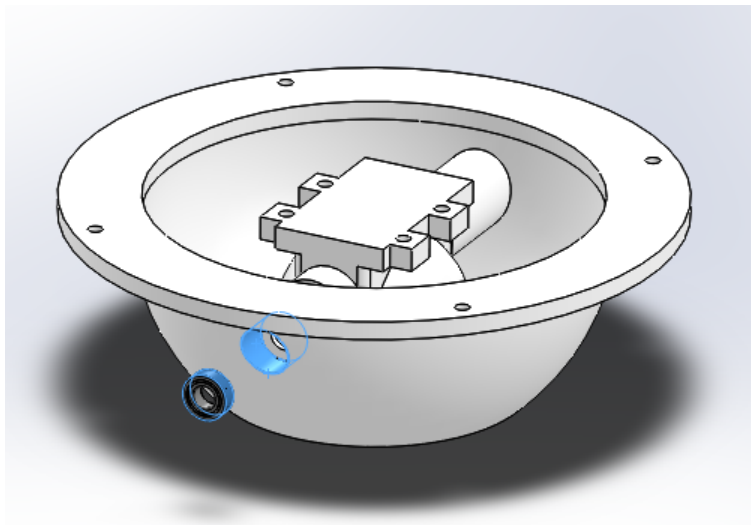


Figure 56: Bearings in chin.

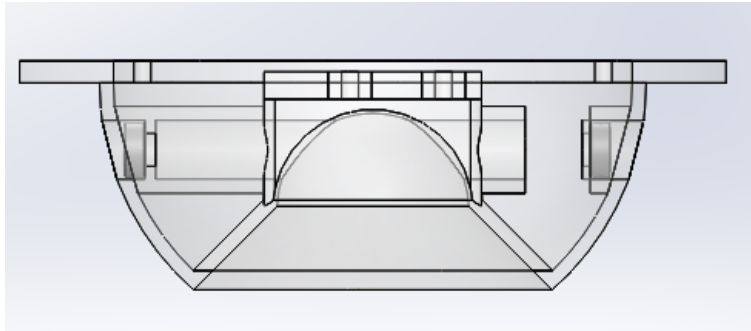


Figure 57: Bearings on both sides of chin.

Drill $1/8$ " holes into each of the gear hubs, making sure that the holes are centered on the hubs.

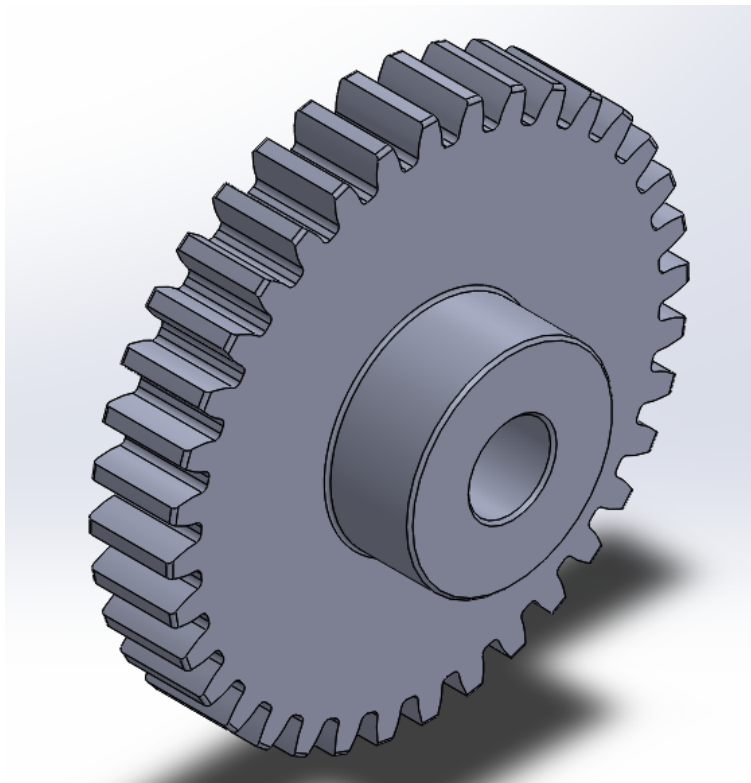


Figure 58: Gear before hole is drilled.

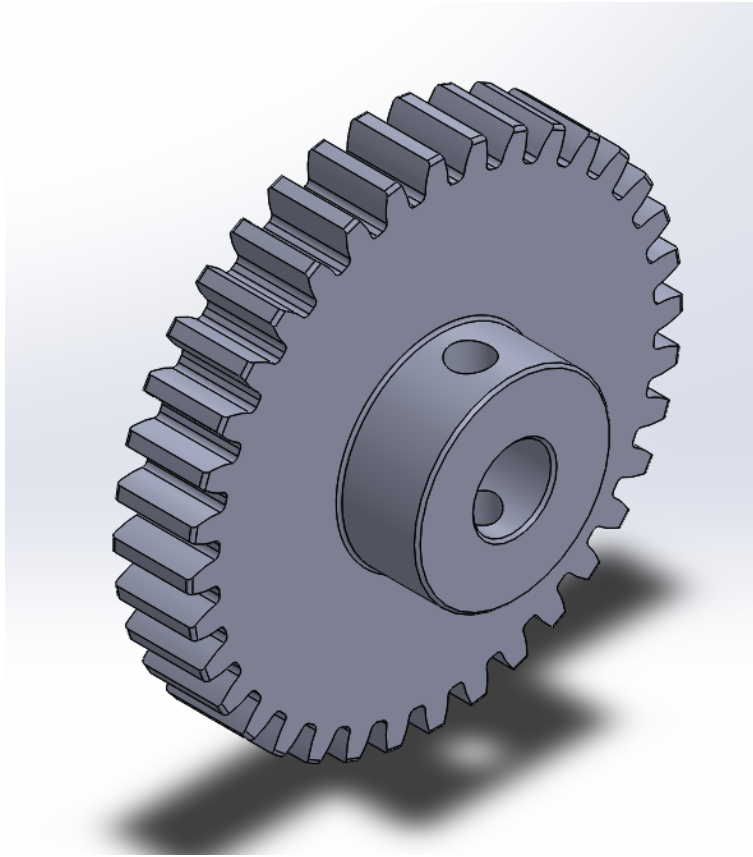


Figure 59: Gear with 1/8 inch hole.

Place the neck (14003) inside of the chin and hold the 1" gear in the cutout of the chin. Insert the D-shaft with the flat face up so that the gear is held in place. Line up the hole that was drilled in the D-shaft with the hole in the hub of the gear. Insert spring pin into the hole in the hub and shaft to secure the gear in place.

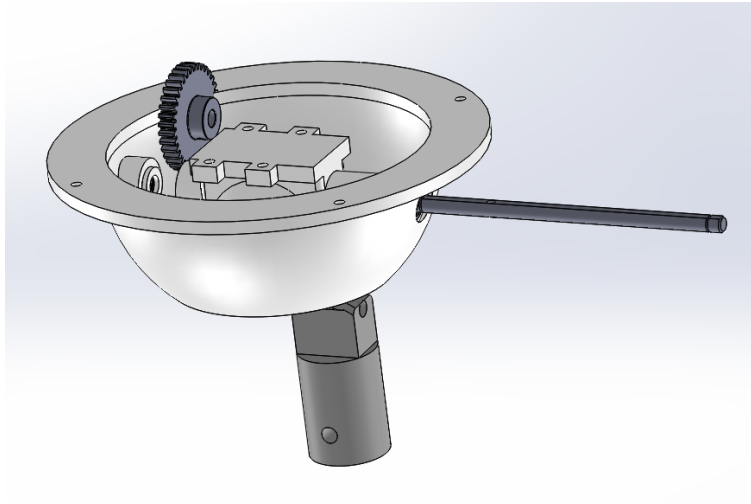


Figure 60: D-shaft though neck, chin, and gear.

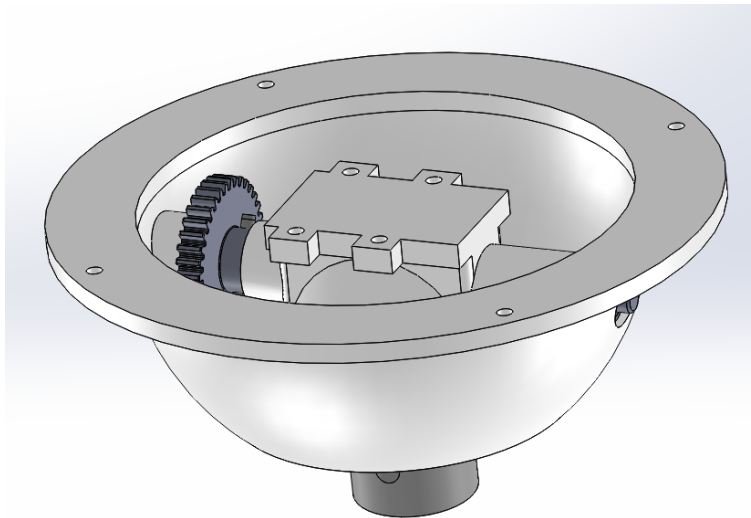


Figure 61: Gear assembled.

Take the two halves of the motor mount (14011) and clamp them around the AX-12 motor (14004). Secure the motor mount as shown in Figure 62 with the M2 screws (14013) and nuts (14012).

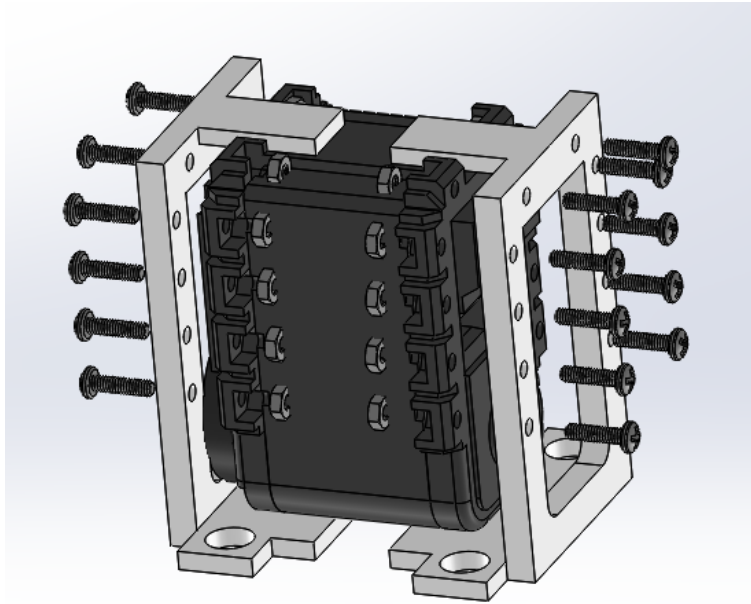


Figure 62: Clamp casing around motor.

Attach the shaft coupler to the servo horn with four M2 (14027) screws as shown in Figure 63.

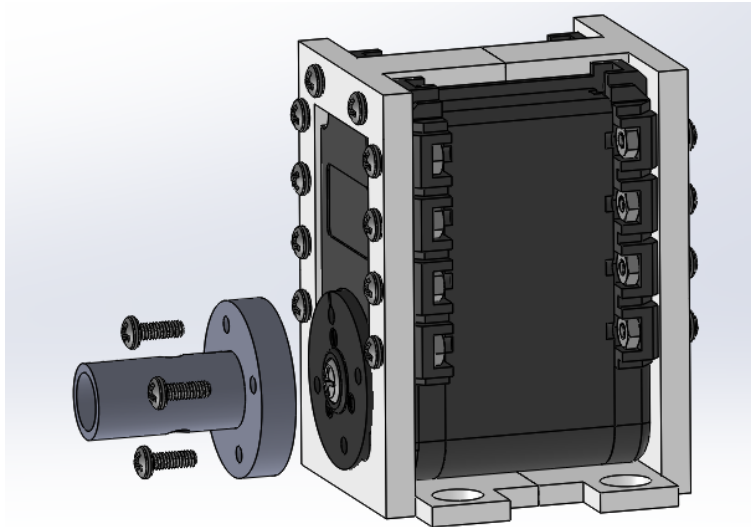


Figure 63: Attach shaft coupler to motor.

Slide the 0.5" gear (14017) onto the coupler. Line up the hole in the coupler with the hole in the gear and insert a spring pin.

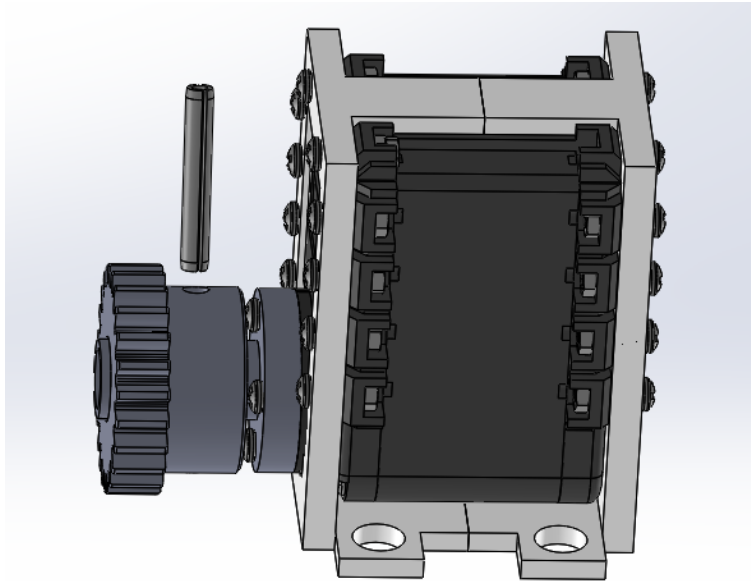


Figure 64: Spring pin in gear.

Now that the motor and gear have been assembled, the motor must be attached to the chin. Insert 4-40 expansion inserts (14023) into each of the four holes in the middle of the chin as shown.

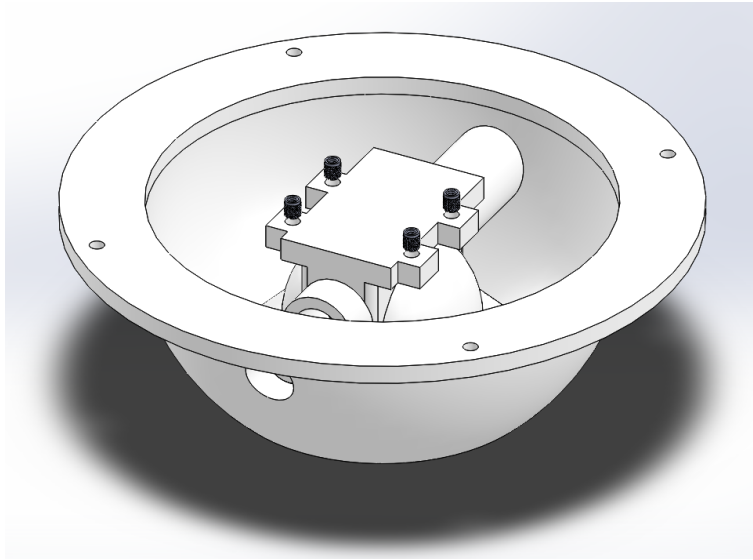


Figure 65: Press threaded inserts into holes in top of chin.

Once the inserts are in, the motor and gear assembly can be screwed into the chin with 4-40 3/8" screws (14024).

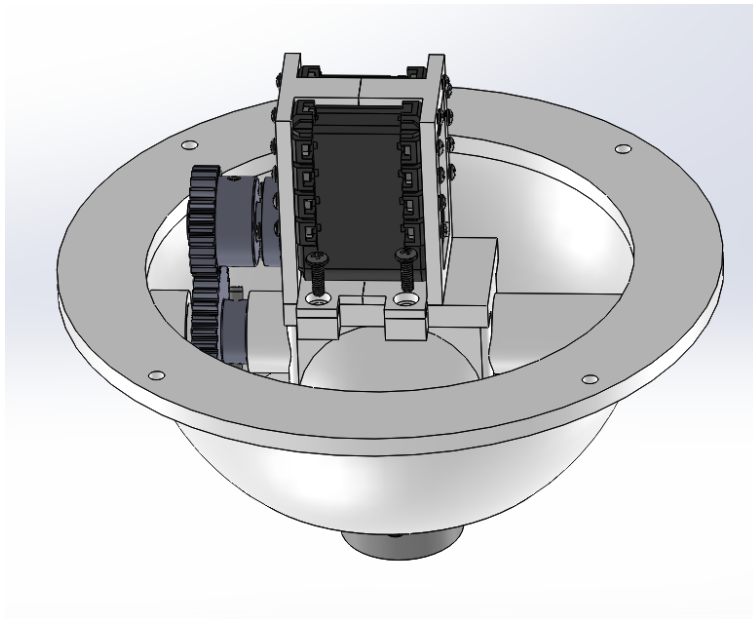


Figure 66: Mount motor onto chin.

Next, the head must be assembled and attached to the chin. Begin by inserting a 4-40 3/8" screw into each of the four holes at the base of the head.

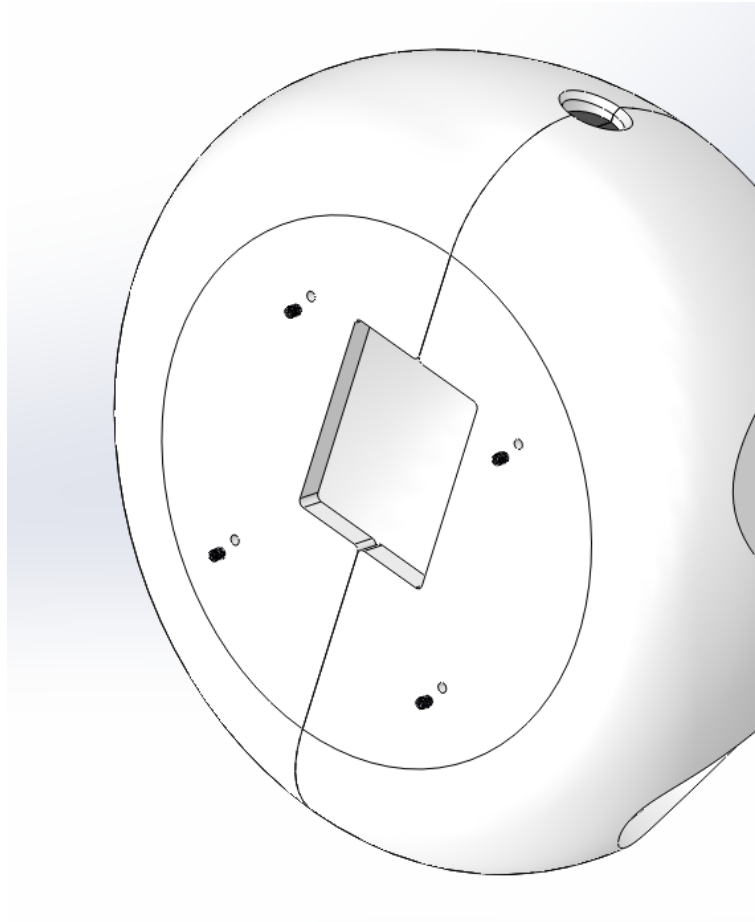


Figure 67: Press threaded inserts into base of head.

Place the necessary electronics into the head. The head can then be put together, making sure to line up the pegs and holes on the inner face of the head.

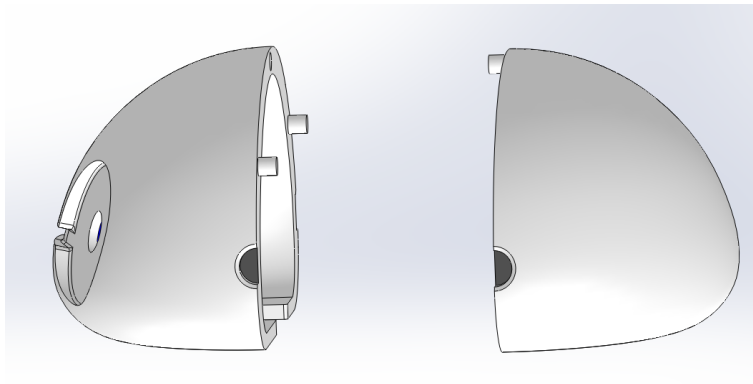


Figure 68: Place two halves of head together.

Line up the four holes in the head with the four holes in the chin and insert s4-40 3/8" screws up through the chin into the head.

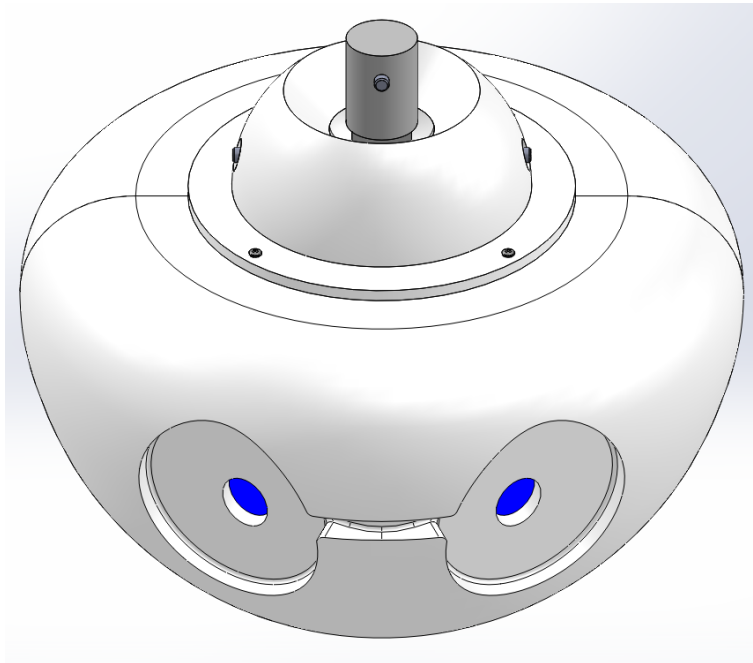


Figure 69: Screw head piece to chin piece.

3.5 Hip Assembly

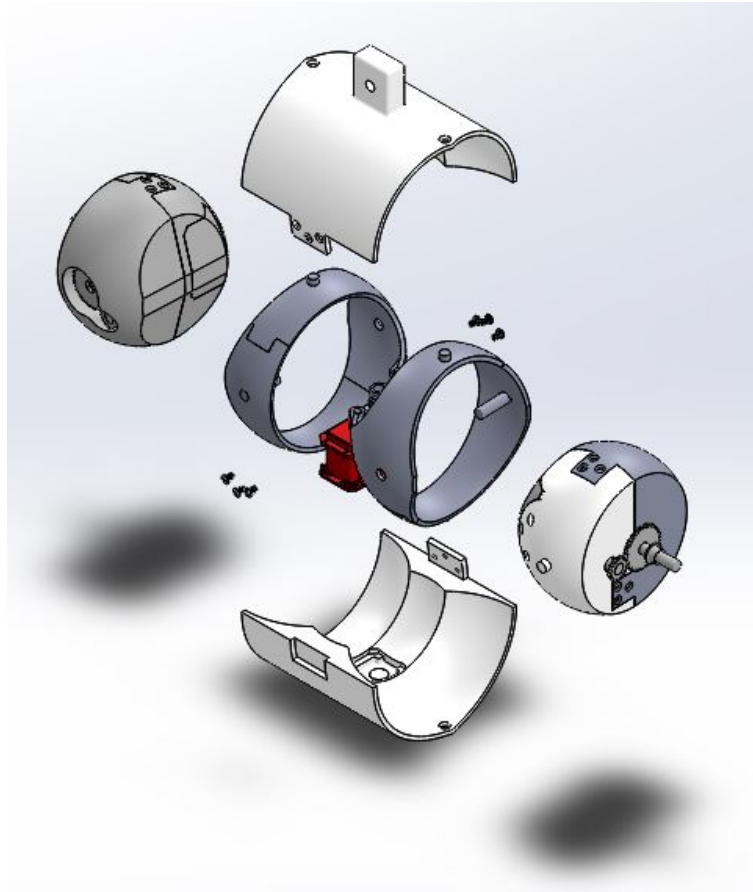


Figure 70: Exploded view of hip.

The hip of Jimmy contains three main parts, each conveniently encased within their own shells. We will refer to these shelled assemblies as the Outer Gimbal (13001), Middle Gimbal (13203), and Inner Gimbal (13101). To assemble, we first start with the Inner Gimbal and work our way out to the Outer Gimbal.

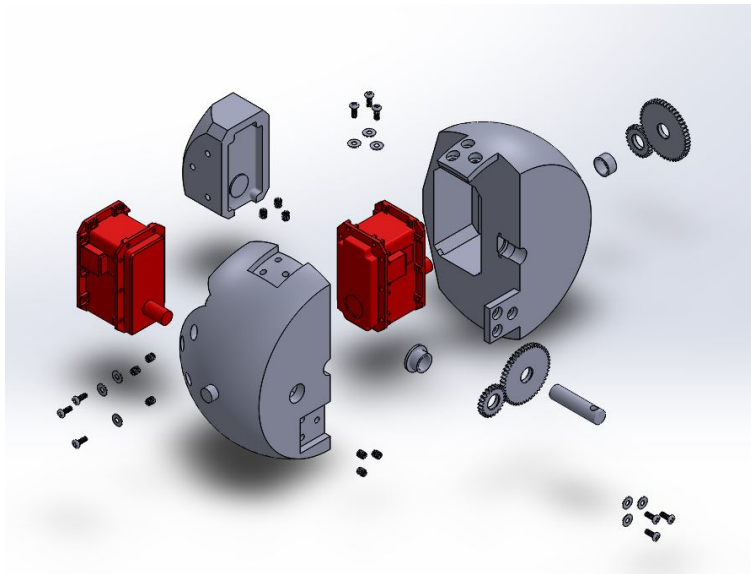


Figure 71: Exploded view of inner gimbal subassembly.

The Inner Gimbal subassembly contains the parts that enable Jimmy to swing his legs forward and out. This allows him to balance and walk forward.

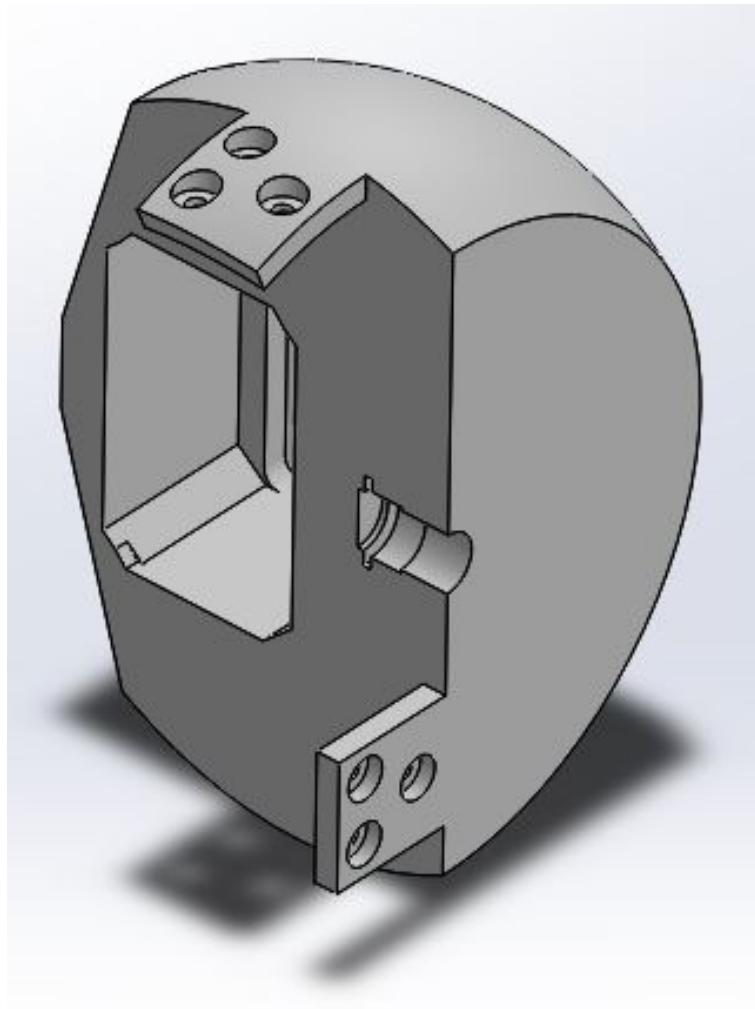


Figure 72: 3D printed inner gimbal shell.

First start with half of the Inner Gimbal shell (13101). This shell contains pockets for most of the parts. Simple place one of the MX-106 motors (13102) and the flanged bushing (13105) into their pockets.

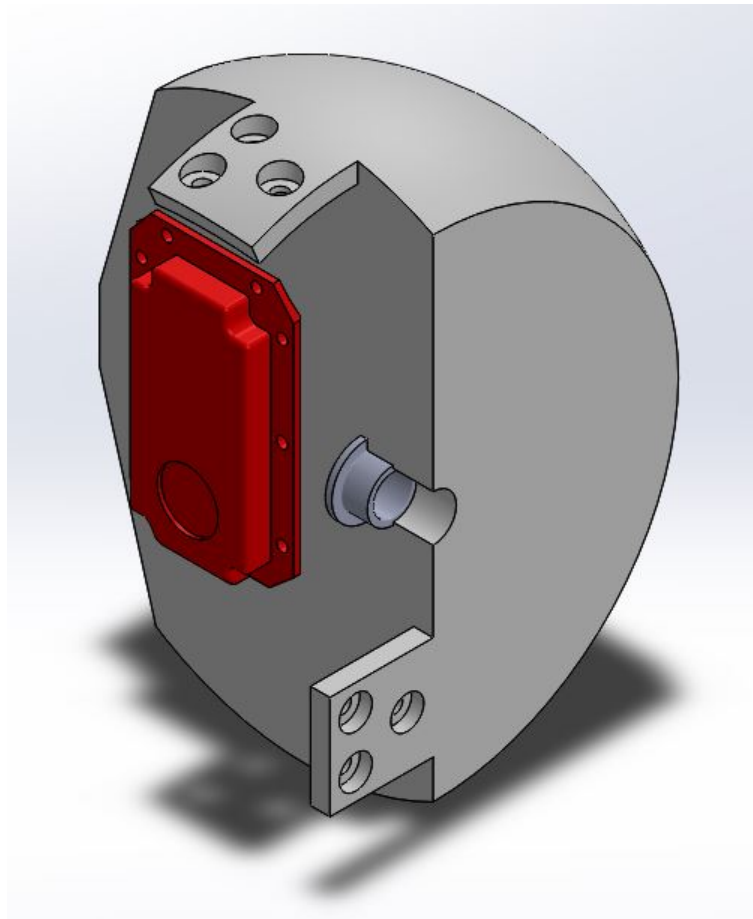


Figure 73: Motor and bushing placed in the shell.

Then turn around the part and put in the gears (13103 13104) in their assigned pockets. The smaller gear will fit directly onto the motor shaft and is held in place with a key. The larger gear will be restrained in later steps.

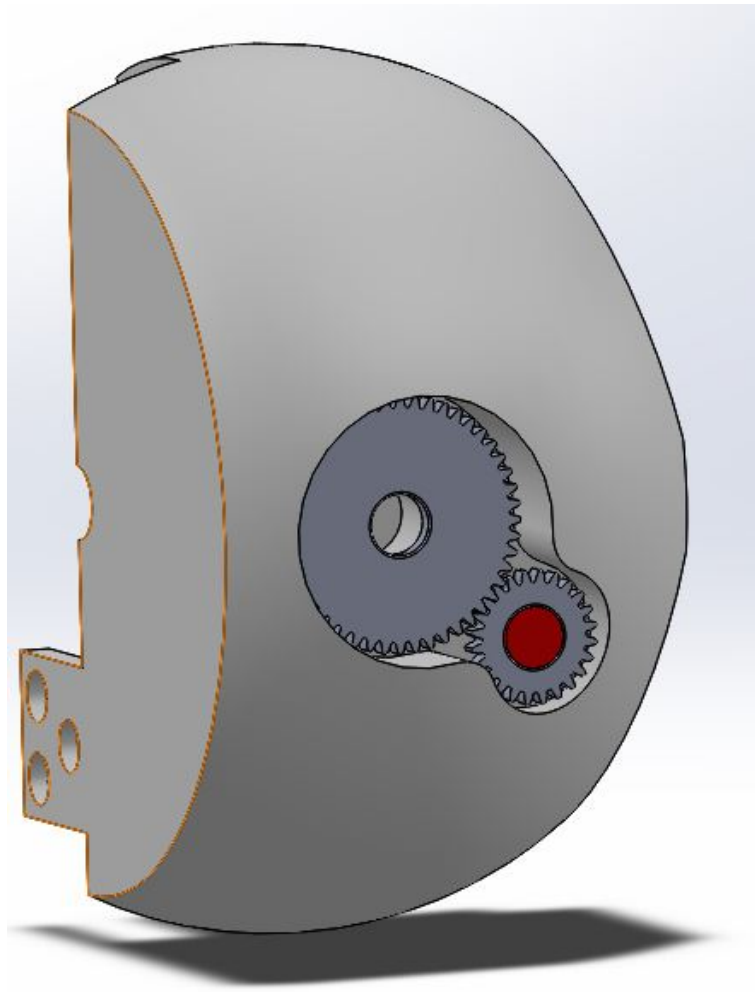


Figure 74: Gears placed in inner gimbal shell.

Now take the other half of the Inner Gimbal shell and place the other motor and the motor cover (13107) together. The motor will be placed, once again in the pocket, and the motor cover will constrain the motor's movements.

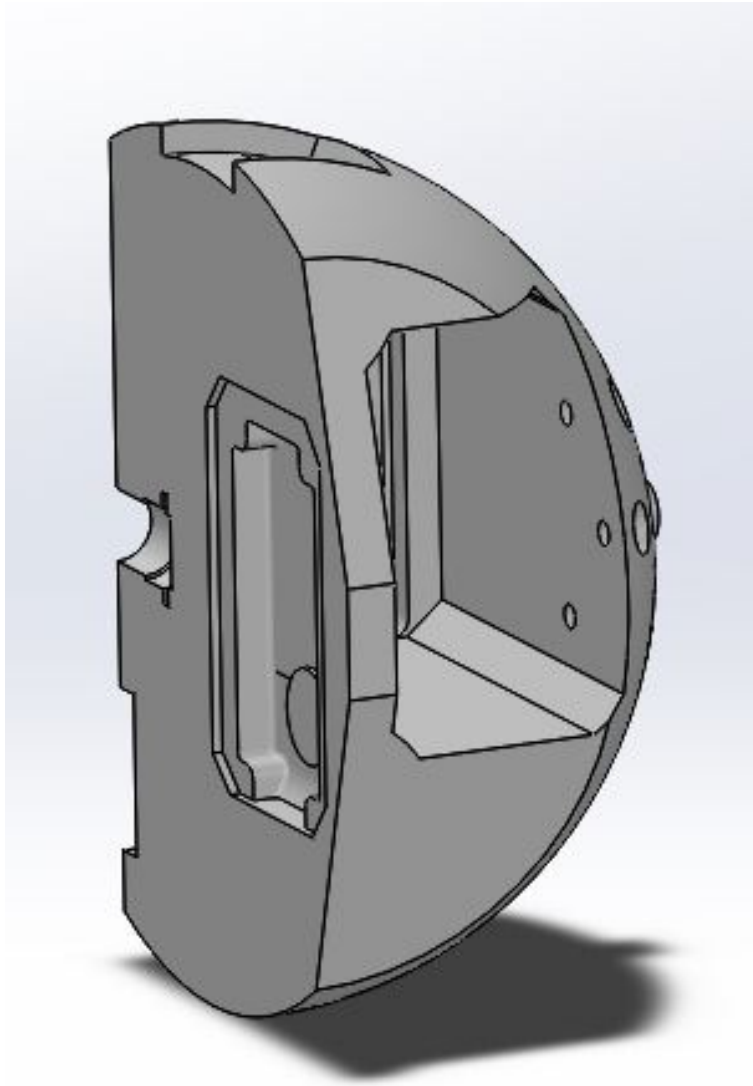


Figure 75: Other half of inner gimbal shell.

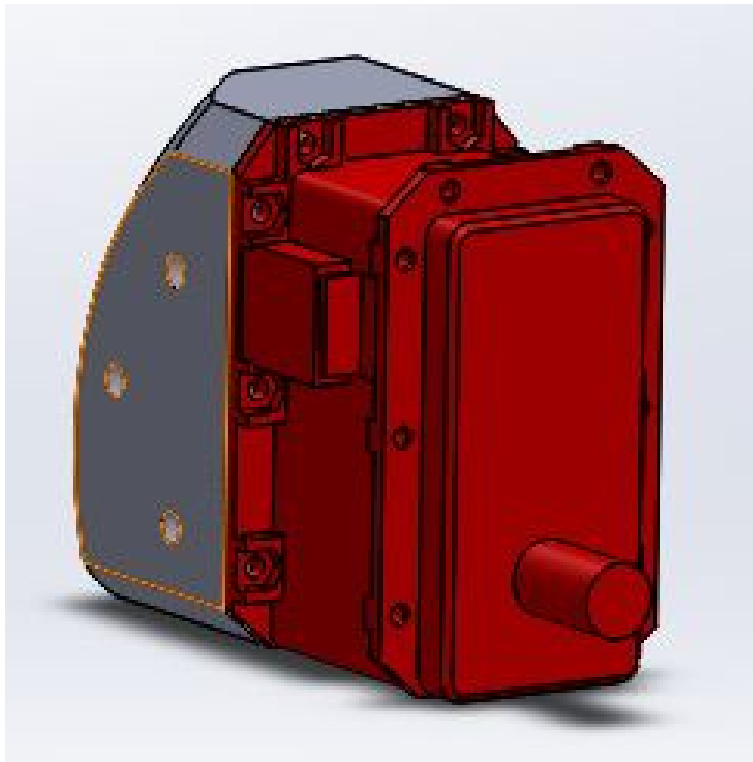


Figure 76: Motor and motor cover.

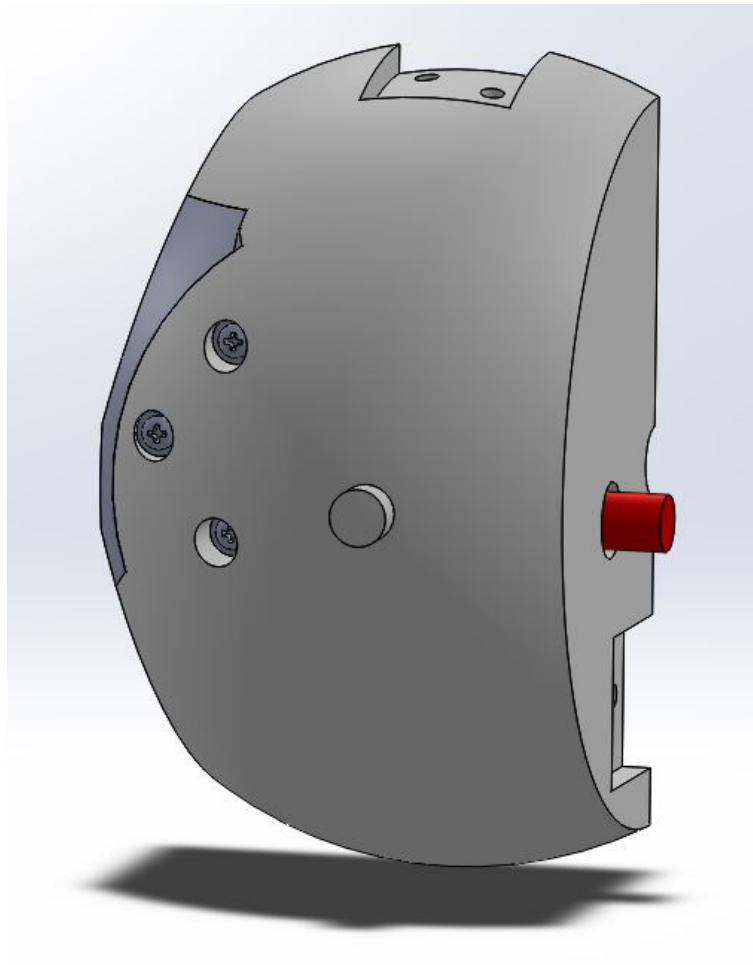


Figure 77: Second motor in inner gimbal subassembly.

Remember to install the 4-40 threaded expansion inserts (13303) into the side of the motor cover. Once the cover is in the shell, use the 4-40 screws (13301) and washers (13302) to secure it. Now that the appropriate components are in their pockets, we can seal the shell. Align the flanges and sockets of the two halves and screw them together with the same machine screws.

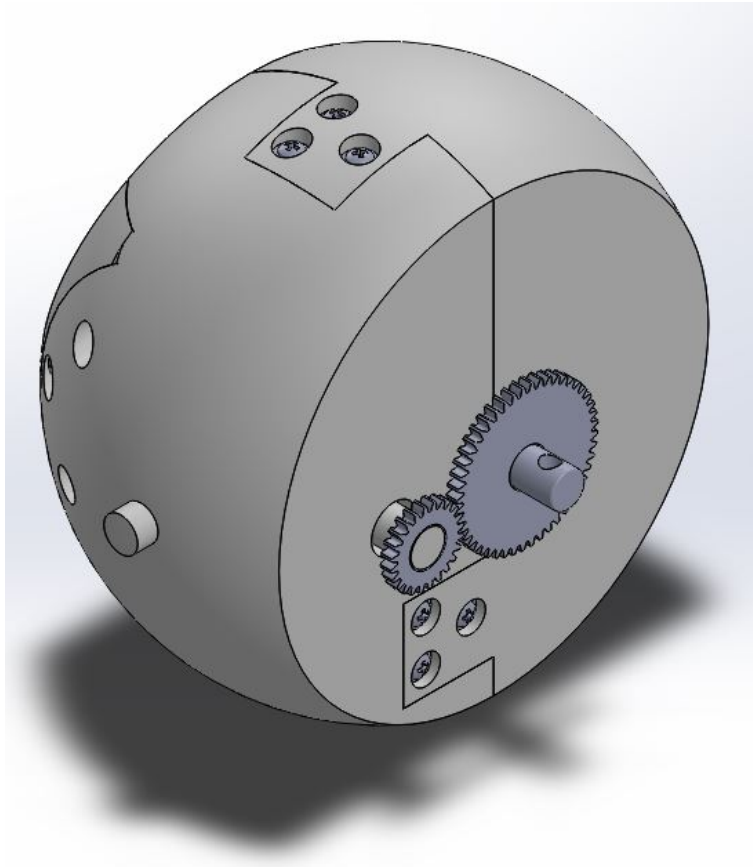


Figure 78: Finished inner gimbal subassembly.

Add the shaft (13108) that connects to the thigh into the running hole, through the flanged bushing. Finally, add the next pair of gears. One goes directly on the motor shaft with the key, and the larger one goes on the shaft. Next, we move onto the Middle Gimbal subassembly.

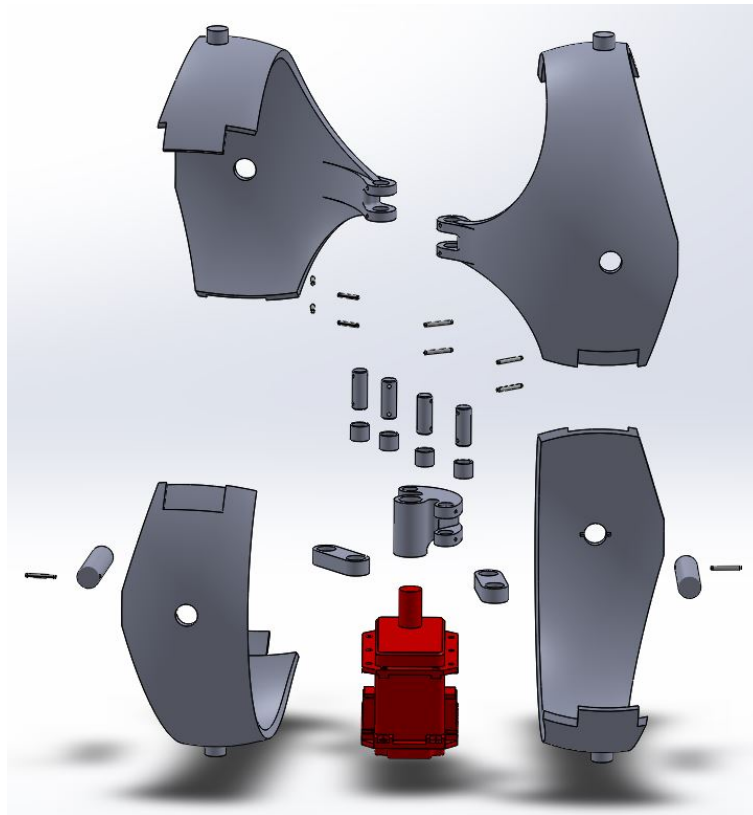


Figure 79: Exploded view of middle gimbal subassembly.

This subassembly requires two Inner Gimbal subassemblies. Each Inner Gimbal subassemblies will be encased by the Middle Gimbal shell (13202). Like the Inner Gimbal, the Middle Gimbal splits in two to conveniently enclose the Inner Gimbal subassemblies.

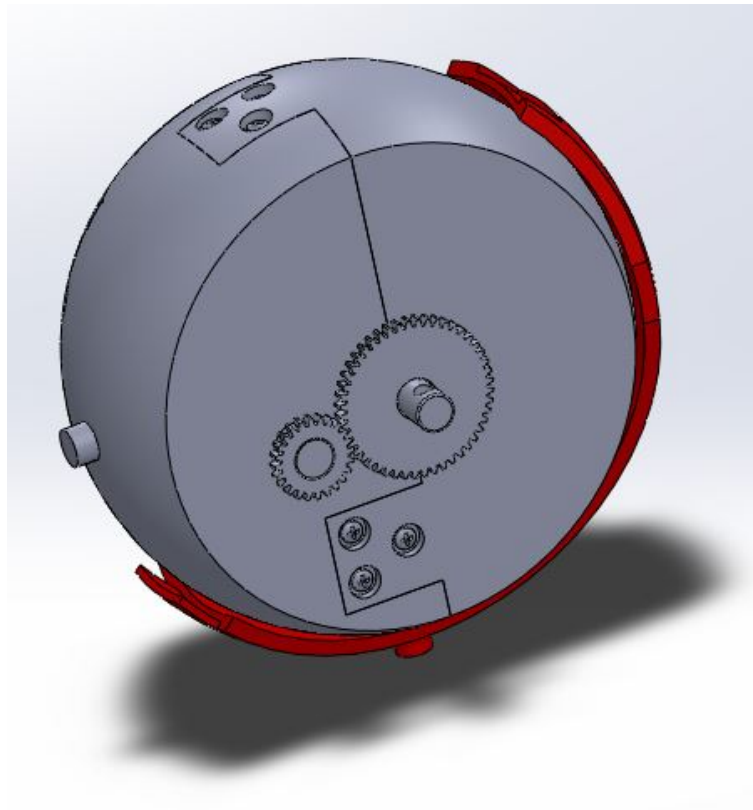


Figure 80: Inner gimbal sitting in middle gimbal.

Align the flanges of the Middle Gimbal and secure them with spring pins of at most, 0.15" in length.

To constrain the Inner Gimbal, the shaft (13108) that goes through the larger gear must be attached using another spring pin (13205). In order to install the shaft, place the shaft through the larger gear first, securing it with a key, and then aligning the spring pin so that it sits in the small pocket of the Middle Gimbal shell.

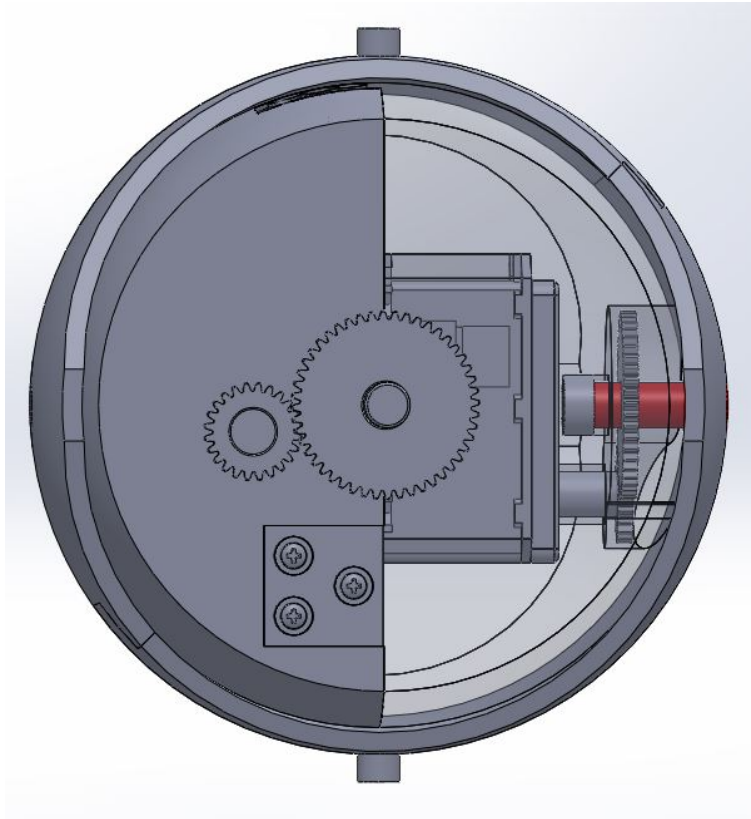


Figure 81: Red shaft enables Jimmy to swing his leg sideways.

Lastly, the Outer Gimbal is simply the hip's outer shell. Observe the spherical sweeps in the shell that enables the rotation of the other gimbals. Like the other shells, the Outer Gimbal is cut in half.

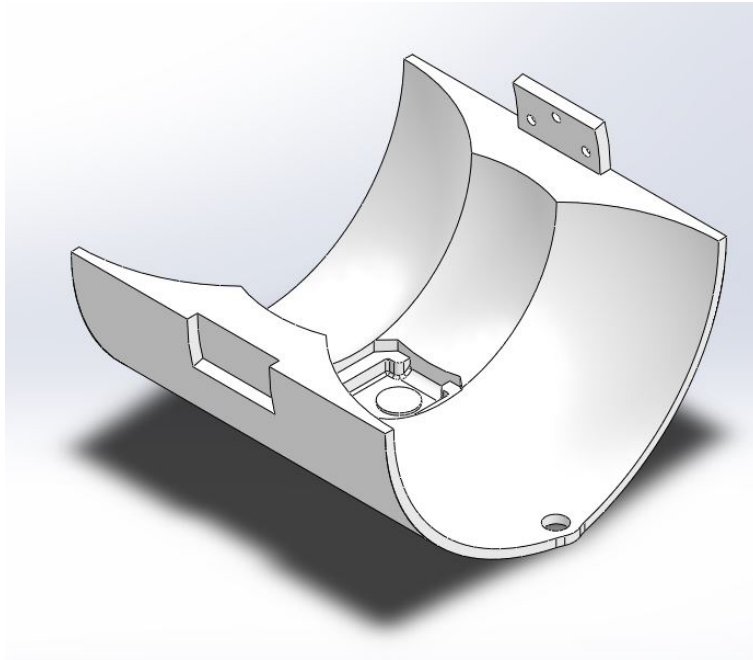


Figure 82: Bottom part of outer gimbal.

Place the last of the five motors in the pocket and secure it using the same set of screws used to secure the shells.

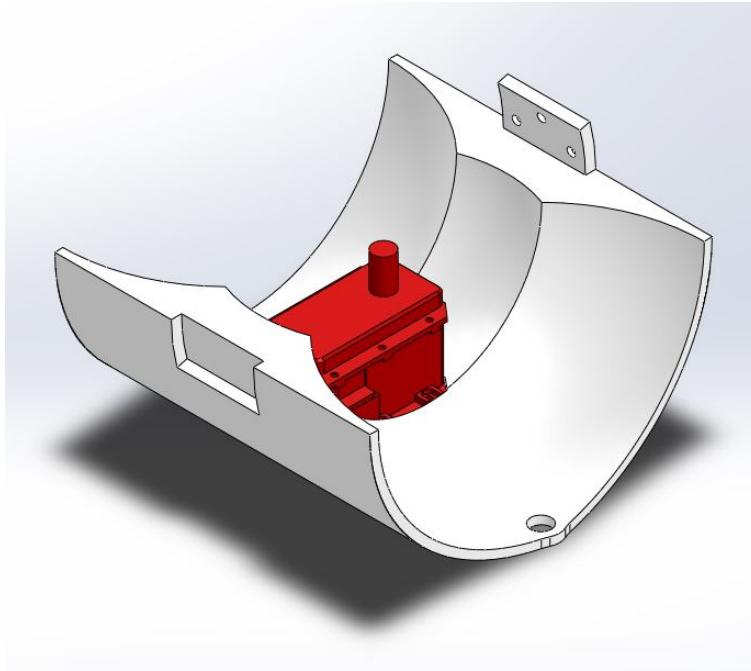


Figure 83: Motor in outer gimbal shell.

Now we integrate the subassemblies to this motor. First and foremost, attach the motor drive arm (13204) to the motor shaft using a key. Place sleeve bearings through the holes of the linkages (13206) to enable smooth motions. Then, run shafts (13202) through the other two holes of the drive arm and through the linkages. Secure the shafts with spring pins (13205).

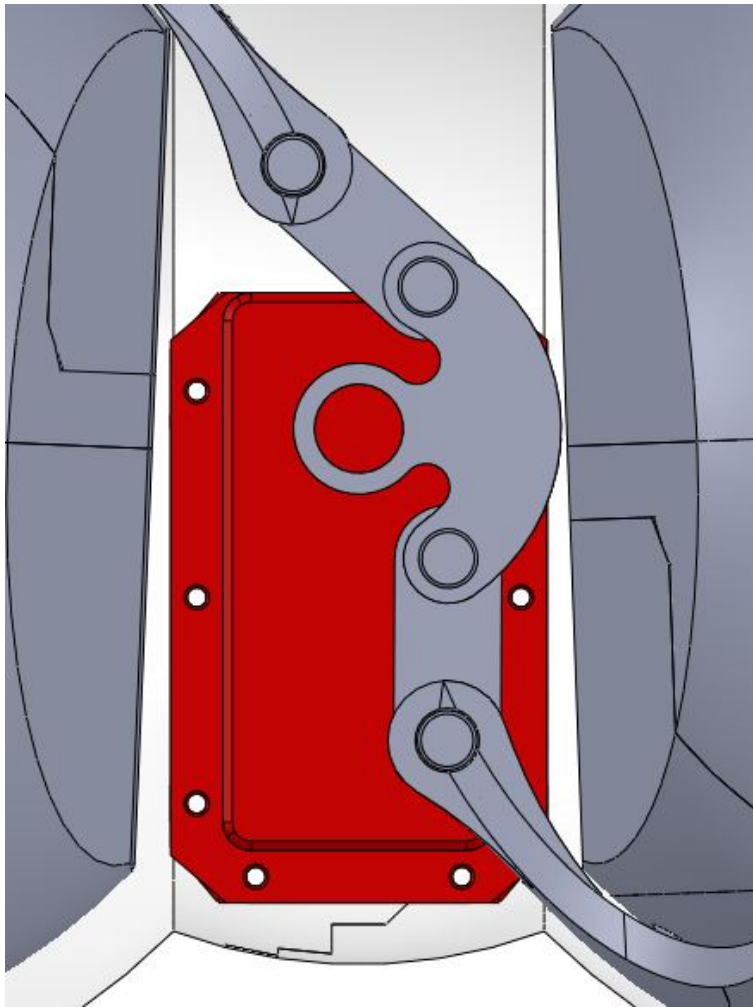


Figure 84: Linkage system that enables Jimmy to turn.

The same steps must be done to attach the arms from the Middle Gimbal.

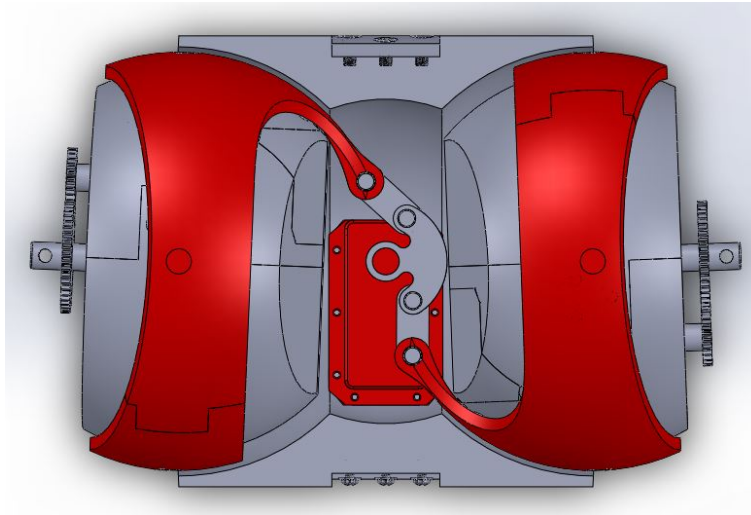


Figure 85: Hip subassemblies in bottom outer gimbal shell.

To further constrain the subassemblies, align the extruded posts from the Middle Gimbal into the holes of the Outer Gimbal, which allows Jimmy to turn his legs towards or away each other. Lastly, add the top half of the Outer Gimbal shell and secure it with the 4-40 screws.

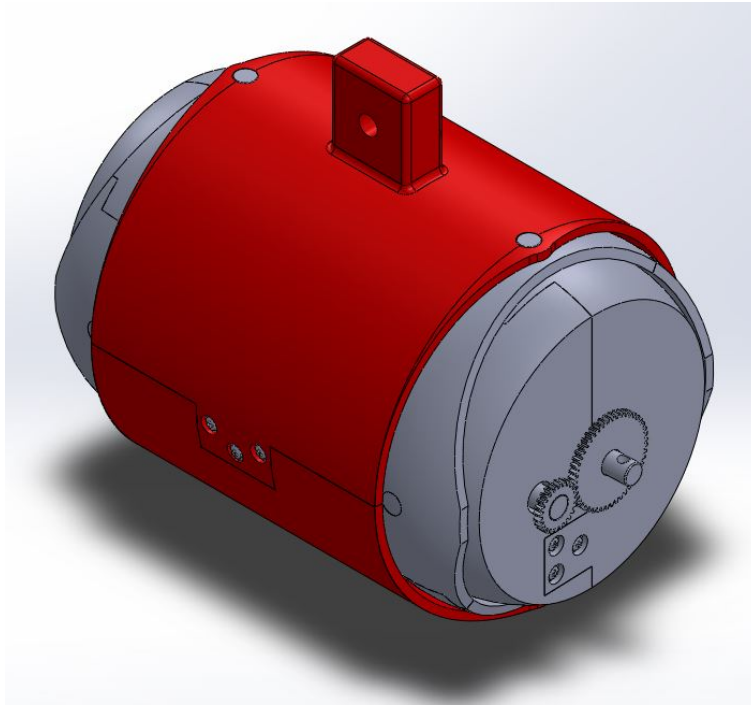


Figure 86: Fully assembled hip.

3.6 Final Assembly

Now that the head and shoulders are in place within the back torso, we'll place on the front torso. Put the front torso onto the back torso so that shoulder assemblies and head assemblies stay in place. Be careful not to disturb them. Make sure the pin attaching the neck to the torso passes through the hole in the front torso as well. When the front torso is in place on the back torso, screw three 4-40 1/2" machine screws through the front torso motor cutout into the inserts in the back torso as in Figure 87. After these three screws are in place, flip the torso over to access screw holes on the back torso. Screw eight 4-40 1/4" machine screws through the screw holes on the back torso into the inserts in the front torso as in Figure 88 to further secure the torsos.

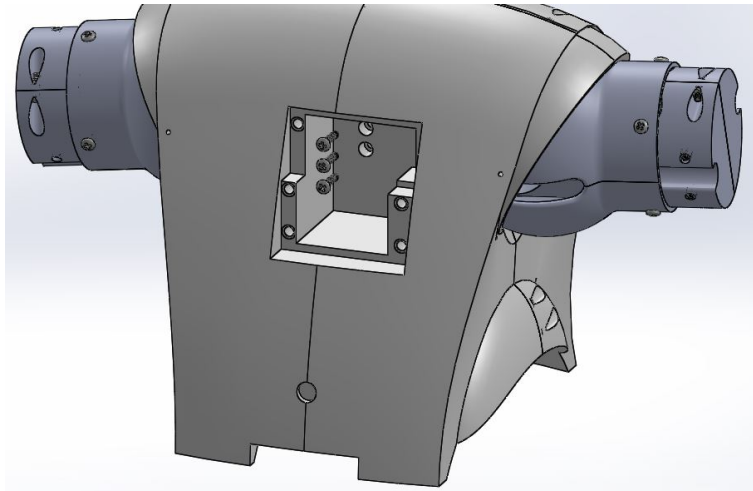


Figure 87: Attaching the torsos.

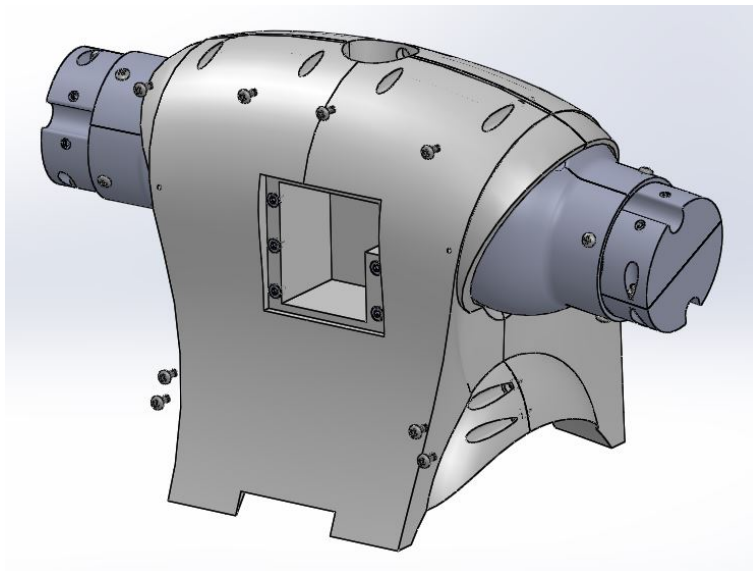


Figure 88: Securing the torsos.

Now, attach the front and rear motor plates using Figures 89 and 90 respectively. The front motor plate assembly should fit into the cavity in the front of the torso and bolt in place into the previously press fit threaded inserts with five 4-40 3/8" machine screws (15017). The rear motor plate should mount similarly in place with five more 4-40 3/8" machine screws bolted into the threaded inserts in the back torso.

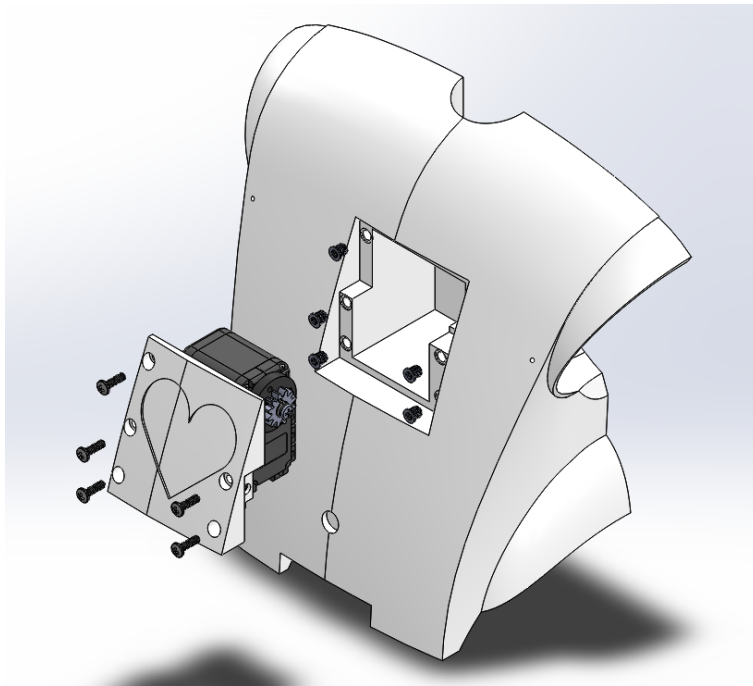


Figure 89: Front motor plate assembly.

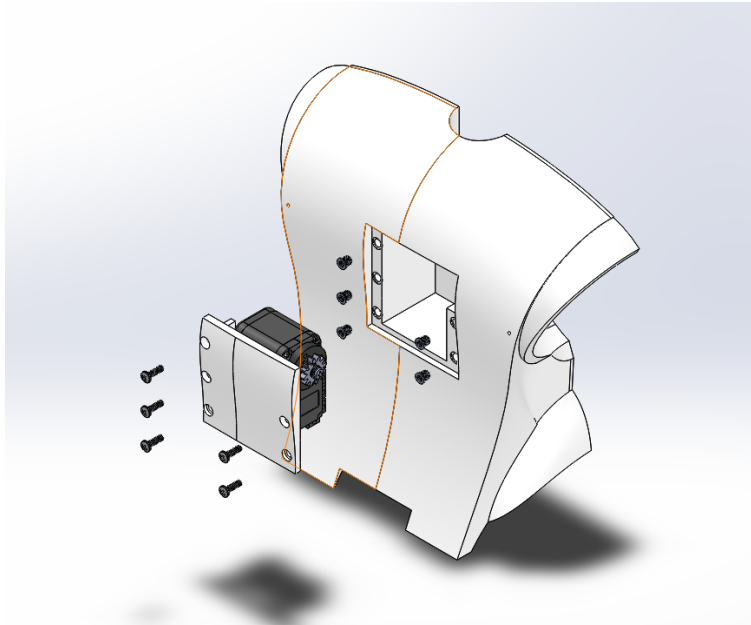


Figure 90: Front motor plate assembly.

In order to attach the legs to the hip, we utilize the walking forward rotation shaft. This shaft has a hole for a four inch long dowel pin (12116) to go through the thigh. This allows Jimmy's entire leg to rotate with the rotation of the large gear.

4 Printing Instructions

Parts to print and printing instructions.

5 Assembly Drawings

This section includes five assembly drawings, one from each team member.

6 Part Drawings

This section includes part drawings of anything that requires post-machining.

7 Suggestions for Design Revision

Given time to revise our design, there are some changes we know we would make. We encourage anyone building our Jimmy X to consider exploring these changes on their own. We also recommend approaching our designs with a critical eye in order to find other areas of improvement. We have broken down our revisions into Jimmy's individual sections.

7.1 Arm

Jimmy's arms could be shrunk in diameter so that his biceps are closer in size to the original Jimmy character. They could also be shortened. This would require shrinking the casings and possibly moving some internal components. We would also like to explore 3D printed gears versus post-machining gears. We currently have one printed gear replacing the servo head which is convenient. If that did not work well, although we expect it to given the resolution of a MakerBot, a stock gear could be bolted onto the servo head or attached with an adhesive. If 3D printing was a good option for creating gears, we could possibly eliminate the need to bolt a gear onto the forearm and could instead print a gear directly into it. We could also explore driving the forearm directly from the motor which would eliminate the gears, the shaft, and the bushings.

7.2 Leg

Because the leg is such a large section, we would like to give more consideration to routing wires from the lowest motors to the torso. This would mean, in part, redesigning the shells for the legs which would also allow us to make them look more like the original Jimmy character. Finally, we would like to make our gear attachments more robust. We are currently worried about them being cantilevered.

7.3 Shoulder

The motors that drive Jimmy's shoulders are currently difficult to place into the assembly. We would like to find an easier way to fix the motors to the front and rear casings to fix this. We would also make some changes to the gears used. First, we would eliminate post-machining if at all possible. Second, we would create a method of attachment for the 12T gear to the servo horn that doesn't involve altering or removing the servo horn that the motor comes with.

7.4 Head

The biggest area we would like to improve in the head is the electronics mount. Because we are mounting so much in the head we want to be sure that they are secure. We would also like to cut weight from the shell of the head, as it does

not need to be very thick or strong. For a slightly larger and more expensive Jimmy, we would also add a second degree of freedom to the head.

7.5 Hip

We would like to make the whole hip smaller by shrinking the structures around the motors. Doing this would cut weight from the shell which is desirable. We would also like to make it more robust and avoid using 3D printed parts as structural components.

7.6 Full Assembly

The biggest thing we would like to change in the full assembly is the standardization of hardware. For example, all casings require 4-40 bolts but some are different lengths. In a final revision, we would be sure to make all hardware standardized to reduce cost and complexity. Anyone building Jimmy X could do this on their own. We would also have taken more time to plan where each individual electronics component would go. With more planning we could possibly have more free space in the torso and head.

8 Team Member Contributions

We split the mechanical design up so that each team member was responsible for one of Jimmy's subassemblies. This included making relevant part drawings, assembly drawings, and assembly instructions.

- Arm: Kate Maschan
- Leg: Maggie Su
- Shoulder: Kari Bender
- Head: Maddie Perry
- Hip: Jess Sutantio

Everyone integrated their own designs into the final assembly. Kate also assembled this report. We feel that everyone on the team pulled their weight and contributed to our final product.