Hardware Review

To: Dr. Sarah Oman

From: Prosthetic Hand (18F12)

Date: 3/29/2019

Re: Hardware Review 2

Cuff

Responsibility for the cuff was designated to Felicity. The previous cuff design from Hardware Review 1 (HR1) can be seen in Figure 1A. This design was meant to be thermoformed and have the ability to open and close for adjustability. However, fitting the flat electronic components became impossible, the closing mechanism did not function properly, and the design did not perform well. A new design was brainstormed to be closed and non-thermoformable. This concept can be seen in Figure 1B.

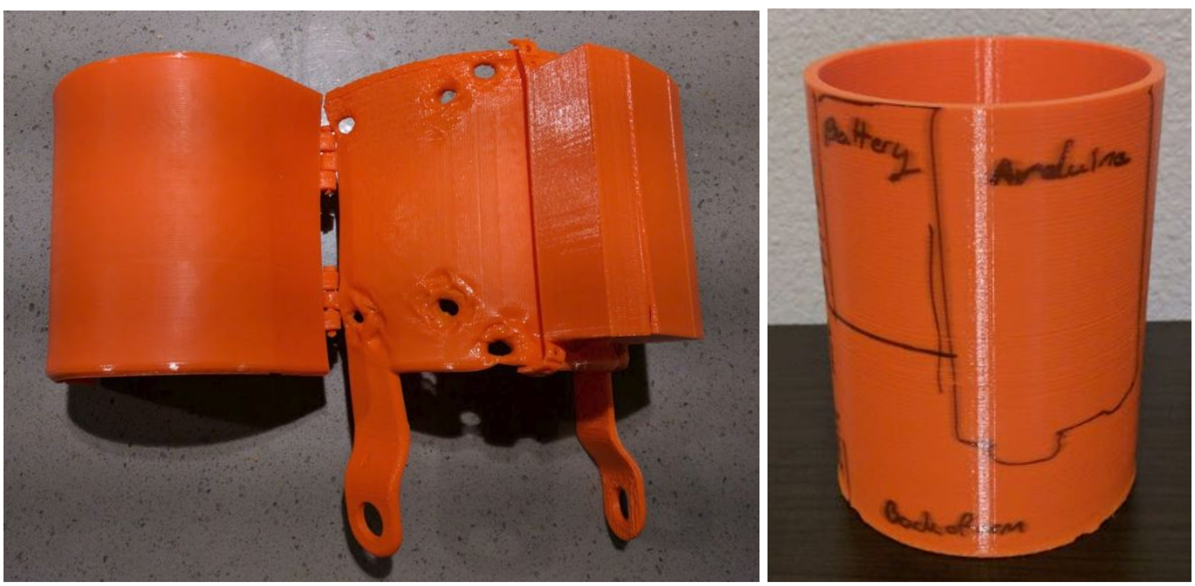

Figure 1: A - Cuff V2.0 (Left), B - Cuff V3 concept (Right)

For HR2, the cuff now incorporates all necessary changes to hold the electronic components, perform and function as needed, and allows for a spring elbow assist. This final cuff design can be seen in Figure 2.

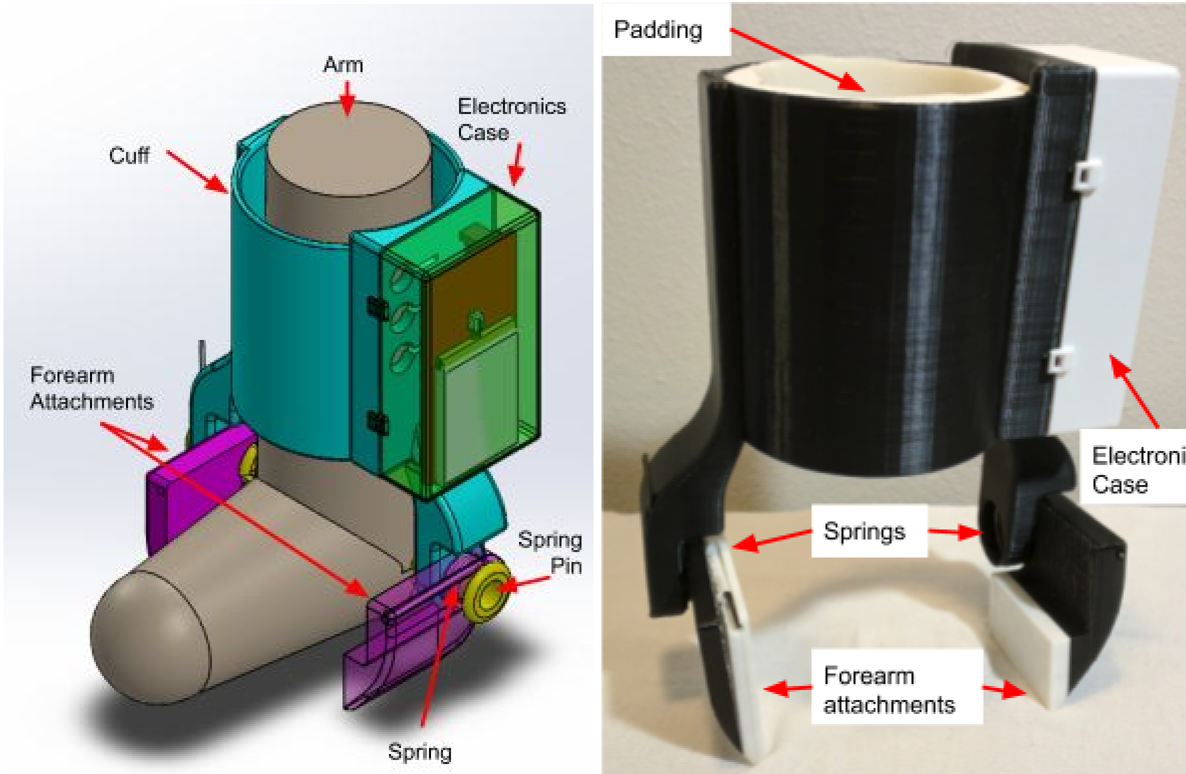

Figure 2: Cuff V3.2 - Final Cuff Design

Cuff V3.2 is scalable for arms as small 1.375 inches in diameter to arms as large as 5.5 inches, with 0.25 inch padding included. The springs of the arm can assist for up to 4lbs of arm load which means that it will require less user force to actuate the elbow. The electronic components all fit inside the 4.25x 2.5x 1 inch casing as shown in Figure 3.

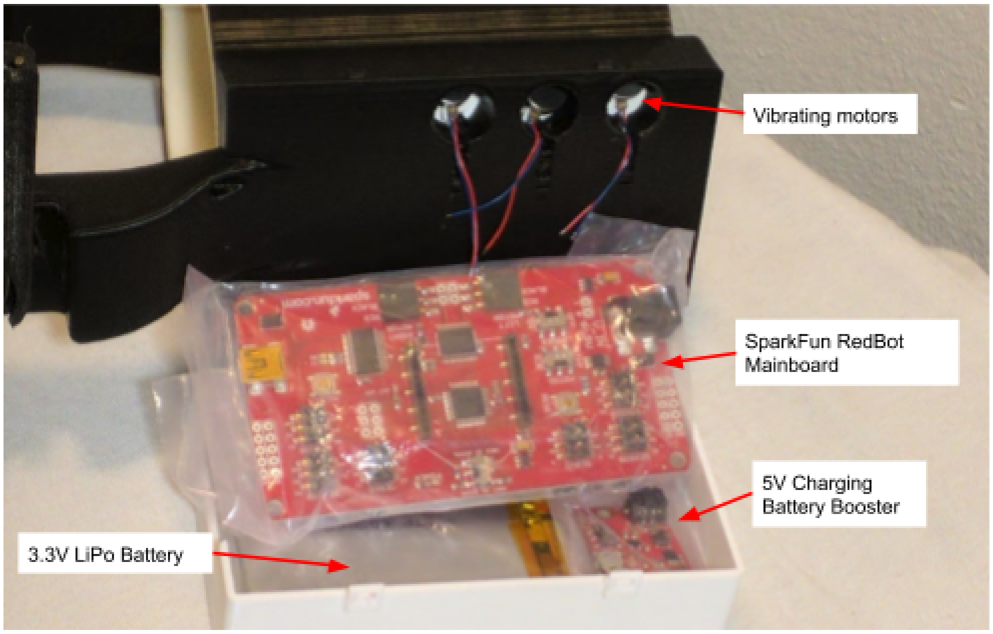

Figure 3: Electronics Case

Inside the electronics casing the vibrating motors are stuck to the sticky side of the padding lining the cuff through three holes. The SparkFun RedBot Mainboard sits above the 3.3V Lithium Ion (LiPo) battery and a 5V charging battery booster. The wiring from the mainboard to the motors in the forearm and the sensors in the fingers will run through the opening at the bottom of the casing, through the holes in the spring pins and to the forearm.

While the cuff design is finished the electronics casing will be modified slightly to screw down the mainboard and battery booster. Screws were not added at this time since there were no online files for the placement of the mainboard and battery booster screw-holes, and modifications could not be made until components came in.

Forearm

The forearm was the responsibility of Allison. The forearm submitted for Hardware Review 1 was two flat halves thermoformed using a mold. The current state of the forearm is two circular halves that connect together with a sliding lock mechanism. The prototype front half is in Figure 4 and the back half is in Figure 5. This printed prototype was presented at the Hardware Review meeting and has been updated since. The prototype was missing attachments to the palm, missing a lid on the front half, and the width of the cuff attachments were too small. These were altered in SolidWorks.

Figure 4: Front Half Printed Prototype

Figure 5: Back Half Printed Prototype

The dimensions of the front connector to the hole on the back half was decreased to allow more of a clearance fit. The diameter of the locking pin was also increased to improve durability. Extruded material at the front was added for attachment to the palm. There is a hole in the middle of the front half for the four servo motors to be screwed into. The front half of the arm is in Figure 6.

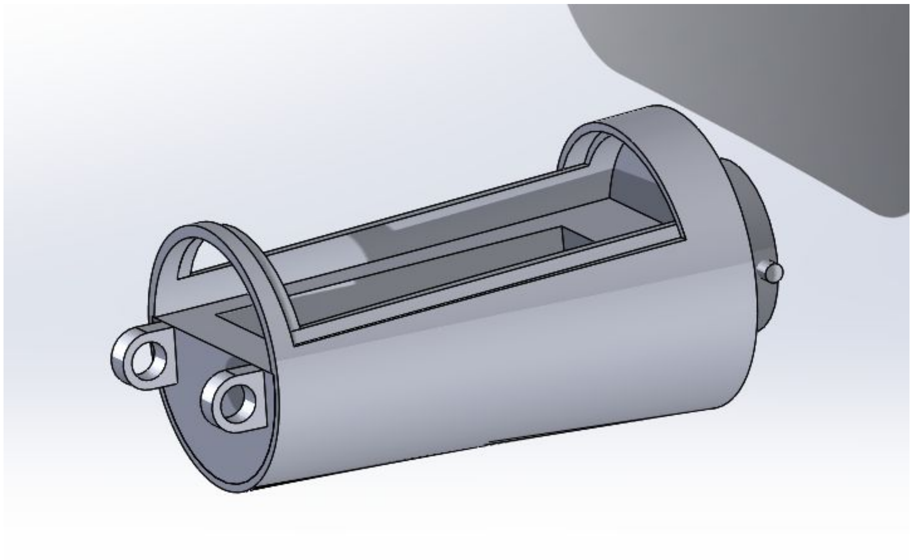

Figure 6: Front Half CAD

The lid that attaches to the front half is in Figure 7. The lid is meant to slide into place with the cut out on the front, and to rest on the material extruded as shown in Figure 8. There is a dent on the lid for ease of removal. The lid is missing a securable attachment, and these might be clips added to the lid and front half that connect at close, or the lid will be screwed on with a screw.

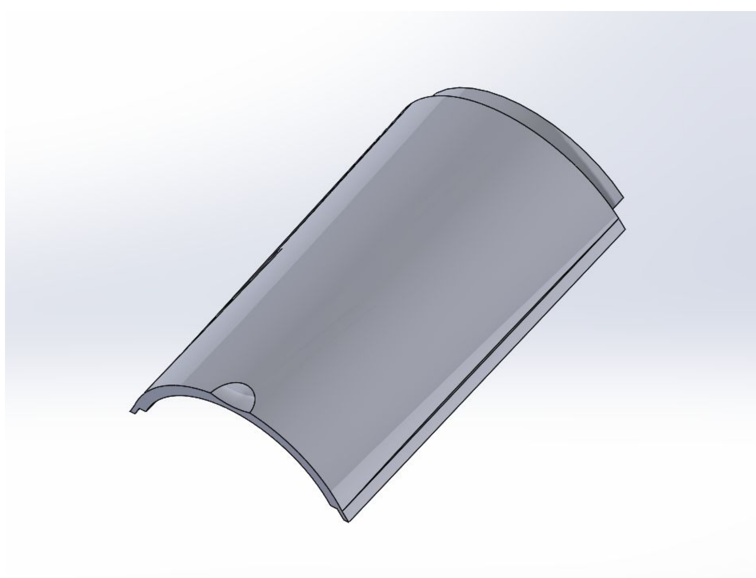

Figure 7: Lid on Front CAD

The back half of the arm (Figure 8) was altered to have an increased diameter cylindrical extrusion at the back, so that the attachments fit the width of the cuff. The sliding-lock cut was also increased in width to account for the diameter increase of the pin-locks.

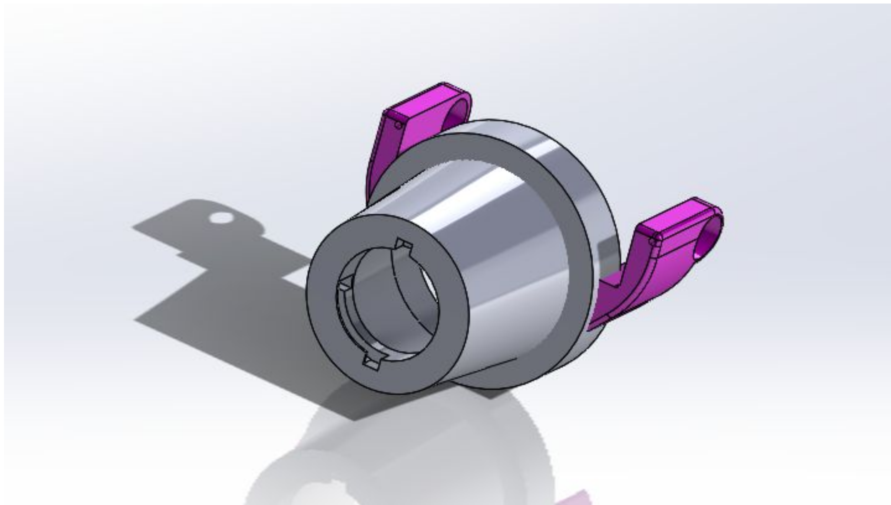

Figure 8: Back Half CAD

A complete assembly of the forearm is shown in Figure 9.

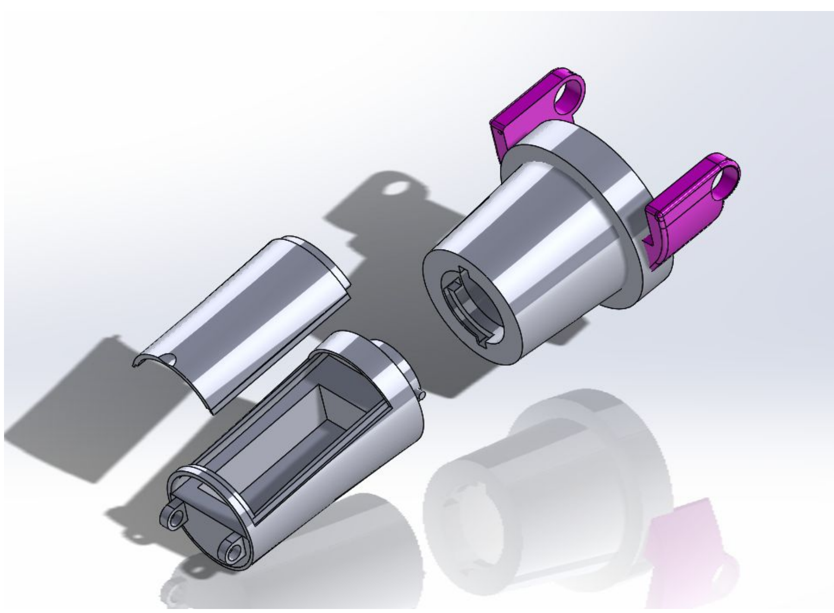

Figure 9: Forearm Assembly

Hand

The palm design was Antoinette's responsibility. This design went through a number of different versions and improvements to find the optimal version. The first palm of the semester can be found in the Figure 10 and Figure 11 below.

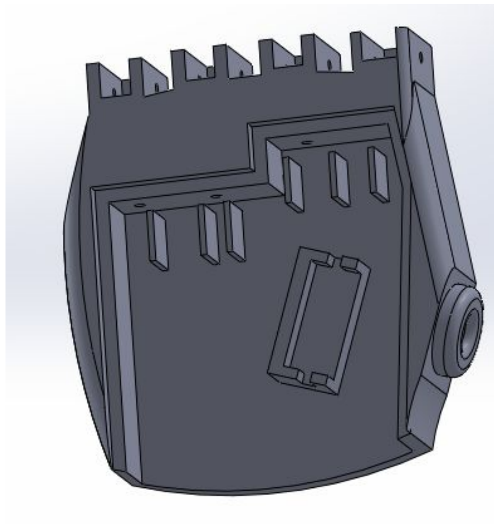

Figure 10: Front Half of First Palm Iteration

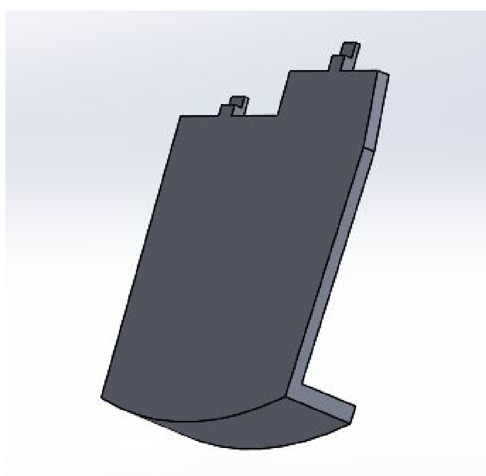

Figure 11: Palmtop of First Iteration

While it had all the components necessary for the palm function, there were a few issues with this iteration. The fingers were spaced in a way that would make it very difficult to manufacture. There was also not a decent way for the pins to be taken out. Based on the pin shape, it would be very difficult to take the pins in or out. Another issue was the thumb connection. Because of the way the wires need to be placed in order for the thumb to move correctly, there needs to be a hole that would allow the wires to rotate without getting tangled. Finally, this palm was missing a connection for the forearm. It was unclear as to how these two components would connect at the time, so it was left out of the first hardware review.

There was also an issue when printing the component. The holes were found to be a bit to small and the back piece came out incorrectly due to its dome shape. The result of the printed part can be found in Figure 12 below.

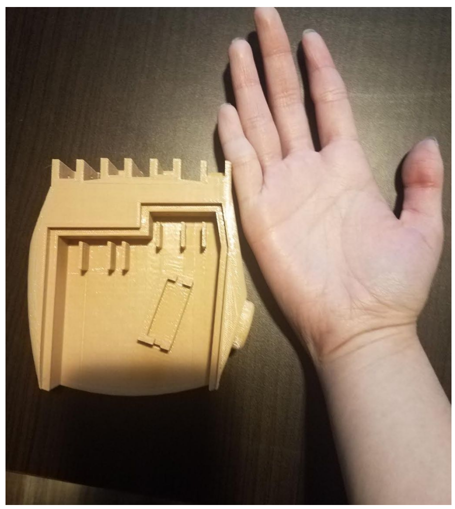

Figure 12: Printed Palm Bottom

Figure 13: Printed Palm Back

The new version of the palm has better attachments for the fingers and the forearm. The new thumb attachment allows the thumb to move horizontally and vertically without the wires getting tangled. This can be seen in the Figure below. For the remaining four fingers, the sizing was adjusted and the overall palm was made to be wider. This made the spacing of the fingers more spread out. These four fingers were also placed on different heights of the palm to make it easier to assemble and disassemble. The left two fingers will be connected using one long pin. While the right two will be separate. This version also includes small holes next to the pin holes. These holes allow for the pin to have a more secure attachment and makes it possible to take disassemble the hand when needed.

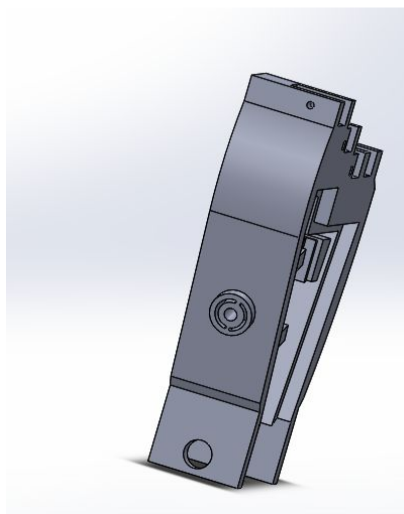

Figure 14: Second Palm Side View

This version also has a connection for the forearm. After much contemplation, it was decided that a simple pin and joint connection would be sufficient. The flat bottom and tight pin fit would prevent the attachment from rotating. The inside of the palm stayed the same with very few adjustments needed. The sizing of the motor placement was changed to fit the motor better during assembly. There are still holes for the wires to go through so this component does not obstruct the wire placement. These holes go underneath the motor.

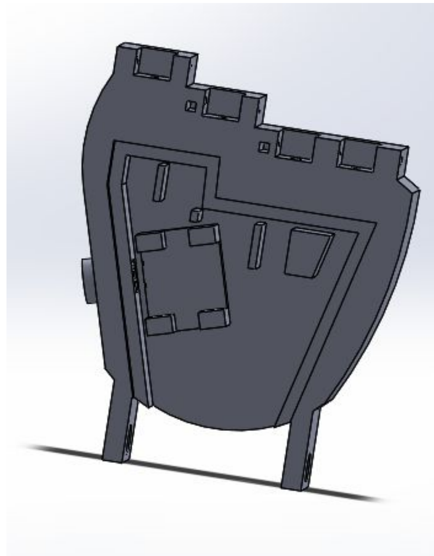

Figure 15: Second Palm Front View

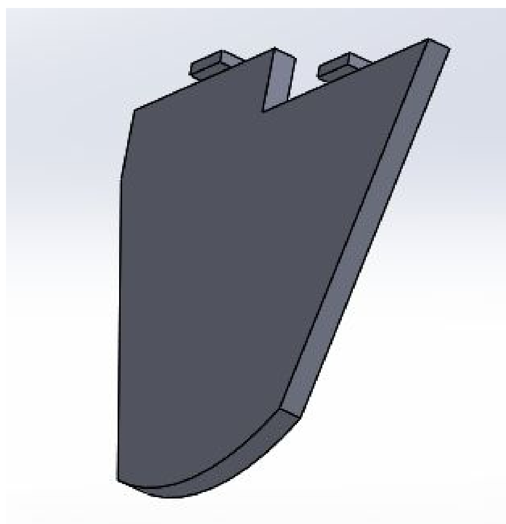

Figure 16: Second Palm Top

A demonstration of how the palm connects to the fingers and the forearm can be seen below.

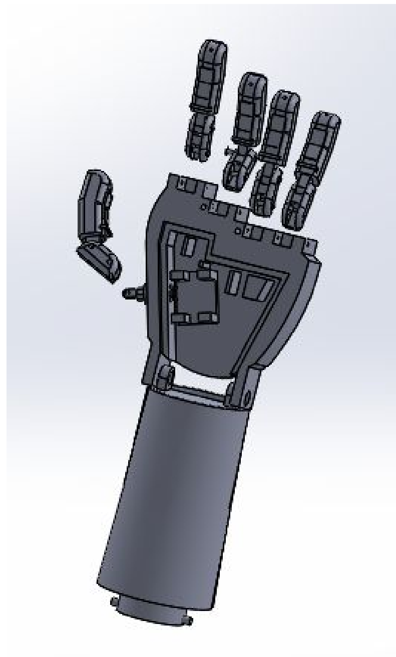

Figure 17: Exploded View of Palm Connections

The maker lab was unable to print the palm attachment in time for the submittal of this hardware review. Even so, the CAD assembly shows an aesthetically pleasing and functional design. It appears that the spacing for the pins and fingers was done correctly. The largest concern with this part is to confirm if the pins will fit in the desired position using the calculated tolerance from the individual analysis.

Fingers

The finger design has had several iterations to improve the success of the fingers. Jannell was responsible for the design of the fingers. The finger design submitted for the first hardware review was composed of proximal and distal segment connected by the a hinge pin that allows the fingers to bend. The segments are curved around the bend to allow it to bend in one direction. These aspects have been kept. However, the design of the segments has changes significantly to improve the finger motions, durability, and senses. The finger motion was improved by altering the fingers to flex and extend. The finger design from hardware review 1 was successful in flexing the fingers but not opening them. There were a few proposed ideas including rubber bands and specialized tendons to unclench the fingers. Unlimitedly, it was decided that specialized tendons would be best because it would allow for more control over the movement. Thus, designs were created to fit the need. There are two current designs for the fingers. They will both be tested and the finger design with the best durability, motion, and sensor placement will be the finger used in the final prosthetic. The two designs differ in tendon and pressure sensor channel shapes and placement. These designs are displayed in Figures 18 and 19.

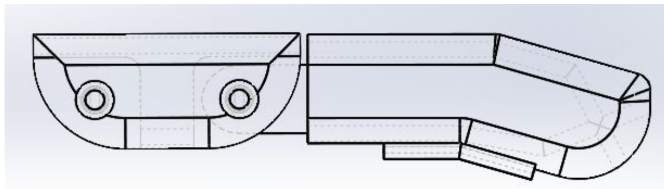

Figure 18: Finger with Crossing Tendon Channels and External Sensor Channels

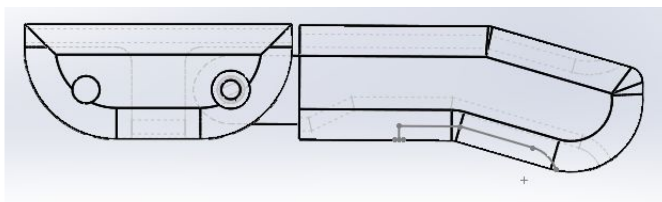

Figure 19: Finger with Parallel Tendon Channels and Internal Sensor Channels

The hinge pin for both of the current designs is the same. It differs from the hinge pin from hardware review 1 because the tolerances and dimensions of the pin and have been altered to fit the updated finger designs. The pin still functions as a link between the segments of each finger. It is designed with a horizontal slit that allows it to be pinched through the holes in the segments. The pin also has caps that hold the pin in place from either side. The pin can be viewed in Figure 20 below.

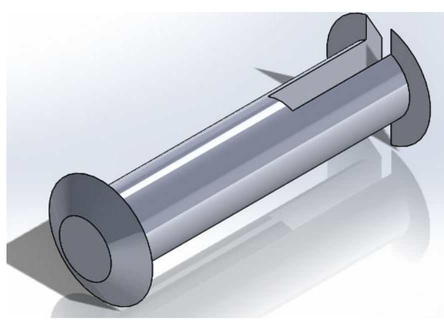

Figure 20: Finger Hinge pin

The major difference between the two current designs is the channels for the tendons and sensors. There are two designs for the tendon channels and two for the pressure sensor channel. The tendon channels can either be crossed and looped around finger tip or the channels can be parallel running across and tying to both the front and back of the fingers. This is visible in the distal finger. See the crossing and parallel channels in the distal digit in Figures 21 and 22 respectively.

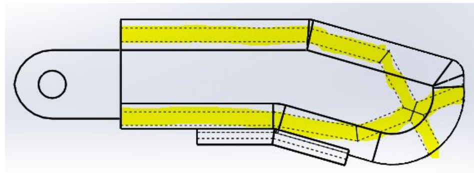

Figure 21: Distal Digit with Crossing Tendon Channels

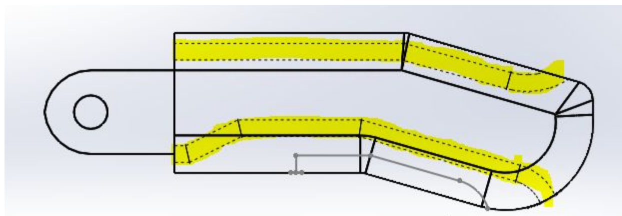

Figure 22: Distal Digit with Parallel Tendon Channels

The two designs for the tendon channels will perform the same task. The crossing channels will allow the artificial tendons (most likely fishing line) to run from its attachment to the motor and through the fingers. This crossing of the channels, as seen in Figure 21, allows the tendon to loop around the finger tip and back to the motor. The two attachments to the motor allow the motor to rotate one direction to flex the fingers and the other direction to open the fingers. A similar effect is achieved by having the parallel channels seen in Figure 22. However, this incorporates two seperate tendons that are attached to the motor. One tendon goes along the back of the finger and the other along the bottom. They are each tied into place and thus will allow the finger to both clench and release like the other design. This idea was proposed because it would be simpler to thread two tendons than to thread through the crossing channels.

The other design difference between the two designs is how the pressure sensor and wires will be incorporated into the fingers. The solution for this was to create a channel for the sensor to run through. This channel could run through the finger externally or internally. This is viewable in Figures 23 and 24 respectively.

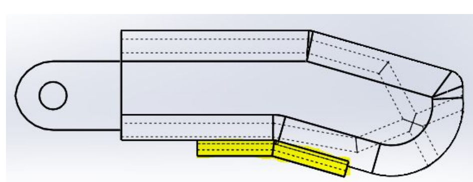

Figure 23: Distal Digit with External Pressure Sensor Channels

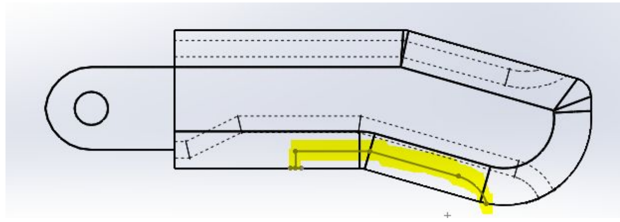

Figure 24: Distal Digit with Internal Pressure Sensor Channels

There are pros and cons for each of these channels. The internal channels are advantageous because the channel will be easy to thread the sensor and wires. However, this design is more bulky and could break off because it protrudes off of the finger. The internal channel make the design more durable and elegant looking. However, inserting the sensor may be more difficult and the finger must be made slightly larger to accommodate the channels and maintain strength. These will both be tested. The final design could result in any of the four combinations of channels. This depends on the effectiveness of each design.

Another deviation from the older design in hardware review 1 is the thumb's rotating base. This part was only briefly mentioned before. It was designed to give the thumb a larger range of motion. While designing the feature, it was realized that rotating the base would cause issues with the other tendons running through the thumb. To keep the tendons from getting twisted during rotation, the base is designed with specialized tendon channels. The current design for the thumb can be viewed in Figure 25.

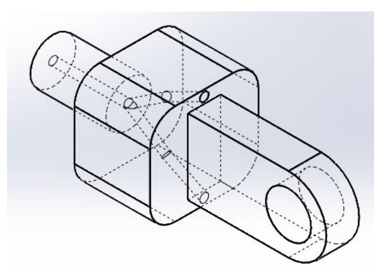

Figure 25: Rotating Thumb Base with Specialized Tendon Channels

These channels start from the front and back of the finger and curve to the center. This keeps them from being caught in the joint. However, this design has been changed because the tendons could get caught in the rotating motor. So, a new design was proposed that the channels should be straight and the palm attachment altered. The new design, Figure 26, will have the tendons go straight through the base and go through the special slits in the palm. The palm can be seen in Figure 27.

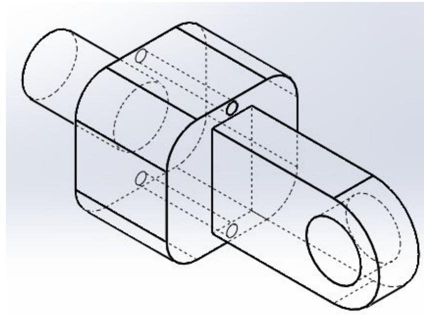

Figure 26: Rotating Thumb Base with Straight Tendon Channels

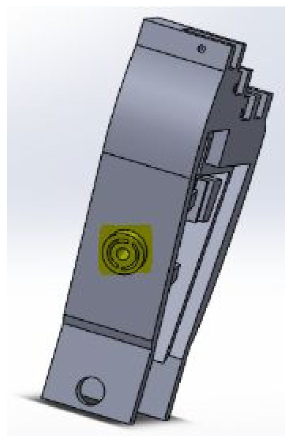

Figure 27: Special Palm Feature with Slits

The rotating base (designed by Jannell) and palm (designed by Antoinette) are connected by the feature highlighted in yellow. The cylinder shaft of the thumb base will slide through the hole in the feature and the tendons will fit through the semicircular slits. This design should keep the tendons from being tangled or twisted at the joint. Once the parts are printed, they can be tested. If there are issues, Toni and Jannell will work together to insure this connection is successful.

There are several features that will be tested to insure that the fingers are strong and incorporate functional tendons and pressure sensors.

Electric Component

While the coding for the wireless communication is being done by the Electrical Engineering team, the code for toe sensors to motor actuation has been finished by Felicity. The components used for the arm are shown in Figure 28. This includes four Tower Pro NG 996R, the SparkFun RedBot Mainboard, a 3.3V LiPo Battery, a 5V booster, and a 1 lb pressure sensor. It was determined during testing the single 3.3V battery and 5V booster is capable of running all four standard servos. At this time, since wireless communication is not complete, testing has been done on a breadboard and no components have been soldered. In the final product, there will be five pressure sensors at the foot that will control the four motors in the forearm and the single micro servo in the palm.

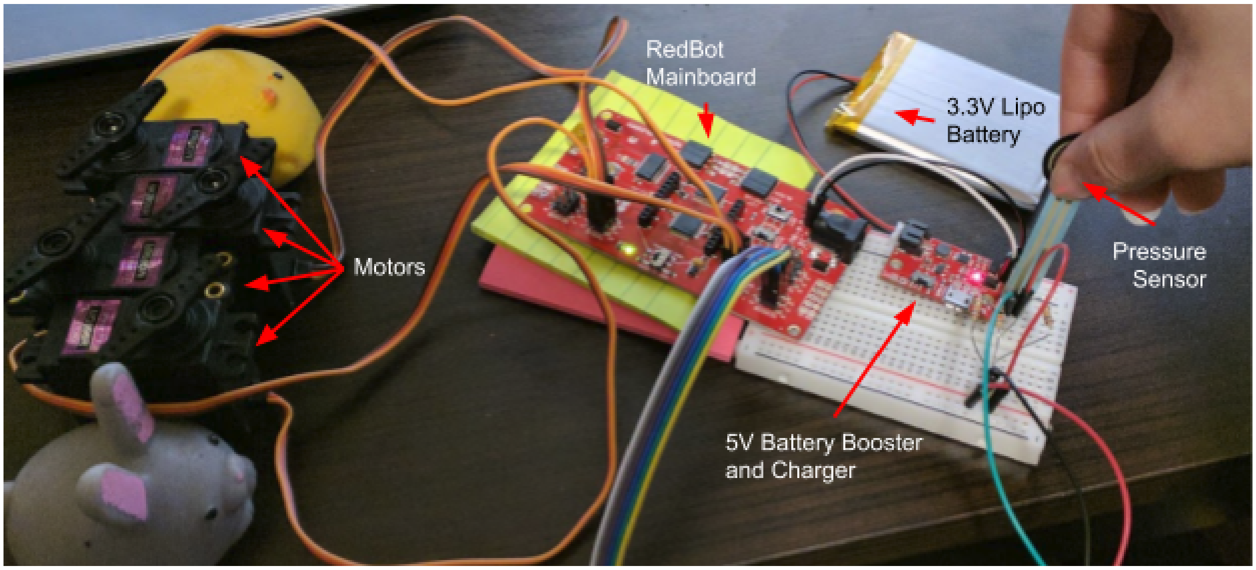

Figure 28: Electronics

Future Work

Future work for the forearm include designing securement for the lid to the motor cavity. Also, while there are holes for the attachment mechanisms, pins still need to be dimensioned and printed so that the arm can be assembled. The hand is mainly complete but printing the part will determine if there are any other changes needed. Most likely, the pins and connections will be the main point of interest.