Standard Operating Procedure: Automated Reach-to-Grasp Task (AutoRG) System Assembly

1. Purpose

1.1. This SOP describes the procedures necessary to properly assemble the hardware of the AutoRG system.

1.2. This SOP assumes that the following processes are already completed:
1.2.1. The software has been downloaded/initialized with a Windows computer (see: AutoRG_SoftwareInitialization_SOP)

2. Equipment and Terminology

2.1. Cage – Refers to acrylic cage in which the rat is placed for the duration of the session

2.2. Stage – Refers collectively to the 4 stage blocks that are pre-assembled into one single stage, of which the cage is placed on top (Extrusion-PLA 3D print)

2.3. Handle Base – Refers to the base to which the linear motion rail is affixed (Extrusion-PLA 3D print)

2.4. CPX – Refers to the Circuit Playground Express

2.5. CRICKIT – Refers to CRICKIT board that is attached to the CPX

2.6. Pellet Dispenser – Refers collectively to the Pellet Dispense Base and Food Silo that compose the pellet dispense apparatus (SLA-resin 3D print)

2.7. Pellet Dispense Base – Refers to base of Pellet Dispenser that has the 4 legs and includes an insertion point for the Pellet Servo (SLA-resin 3D print)

2.8. Pellet Servo Actuator – Refers to circular piece of Pellet Dispenser that connects to Pellet Servo and rotates within the Pellet Dispenser to allow pellets to be delivered (SLA-resin 3D print)

2.9. Food Silo – Refers to top of Pellet Dispenser that holds the reservoir of pellets (SLA-resin 3D print)

2.10. Pellet Dispense Tower – Refers to the tower block on which the pellet dispenser sits (Extrusion-PLA 3D print)

2.11. Pellet Receptacle – Refers to the receptacle that receives the pellet tubing from the pellet dispenser and re-directs the pellet into the slit of the cage (Extrusion-PLA 3D print)

2.12. Pellet Tubing – Refers to the rubber tubing that connects the pellet dispenser to the pellet receptacle (Saint-Gobain Tygon S3 E-3603 Food Tubing)

2.13. Pellet Servo – Refers to the continuous servo that actuates the pellet dispenser

2.14. Calibration Knob – Refers to knob that is used to calibrate the continuous servo (SLA-resin 3D print)

2.15. Load Cell – Refers to mini load attached to handle

2.16. Load Cell Carriage – Refers to bottom half of load cell casing that connects load cell to linear motion rail (SLA-resin 3D print)

2.17. Load Cell Handle Adapter – Refers to top half of load cell casing that connects load cell to handle (SLA-resin 3D print)

2.18. Proximal Servo Arm Adapter – Refers to servo arm adapter that connects directly to positional servo arm (SLA-resin 3D print)

2.19. Distal Servo Arm Adapter – Refers to servo arm adapter that connects the proximal servo arm to the high cube intermediate joint (SLA-resin 3D print)

2.20. High Cube Intermediate Joint – Refers to joint connecting the distal servo arm adapter to the load cell rail adapter (SLA-resin 3D print)

2.21. Handle – Refers to 1.5mm AF hex key that is affixed to the load cell apparatus

2.22. Load Cell Apparatus – Refers to load cell, load cell casing components, and rail attachment component

2.23. Rail – Refers to the 100mm-long linear motion rail on which the load cell apparatus sits

2.24. Positional Servo – Refers to the positional servo that actuates the movement of the load cell apparatus to modulate the handle distance

2.25. Positional Servo Casing – Refers to SLA-printed casing that encloses the Positional Servo and sits at the back of the Handle Base (SLA-resin 3D print)

2.26. Qwiic Scale – Refers to red analog-to-digital converter that connects the load cell to the Qwiic Adapter.

2.27. Qwiic Adapter – Refers to the component that receives a plug from the Qwiic Scale and projects wires to the CRICKIT and CPX boards.

2.28. CPX Holder – Refers to component where CPX rests; snaps into back of Pellet Dispense Tower.

2.29. Power Cord – Refers to the cord connecting the CRICKIT board to power

2.30. USB Cord – Refers to the cord connecting the CPX (micro-USB) to the computer (USB)

2.31. Other assembly materials:
- 2.31.1. All-Purpose Krazy Glue
- 2.31.2. 1.5, 2, 2.5mm AF Hex Keys
- 2.31.3. Parafilm M
- 2.31.4. Fasteners:
  - 2.31.4.1. M3-0.5 x 6mm Sock Cap Screw (High Cube Intermediate Joint to Load Cell Carriage)
  - 2.31.4.2. M3-0.5 x 12mm Socket Cap Screws (Rail to Handle Base)
  - 2.31.4.3. M3-0.5 x 16mm Socket Cap Screws (Load Cell Carriage to Rail)
  - 2.31.4.4. M2.5-0.45 x 25mm (total length) / 20mm (threaded length) screw (Distal Servo Arm Adapter to High Cube Intermediate Joint) (Proximal Servo Arm Adapter to Distal Servo Arm Adapter) (Load Cell to Load Cell Handle Adapter and Load Cell Carriage)
  - 2.31.4.5. M2.5-0.45 x 6-8mm Socket Cap Screws (CPX to CPX Holder and Qwiic Scale to Handle Base)
  - 2.31.4.6. M3-0.5 mm hex nuts

3. Assembly Procedure

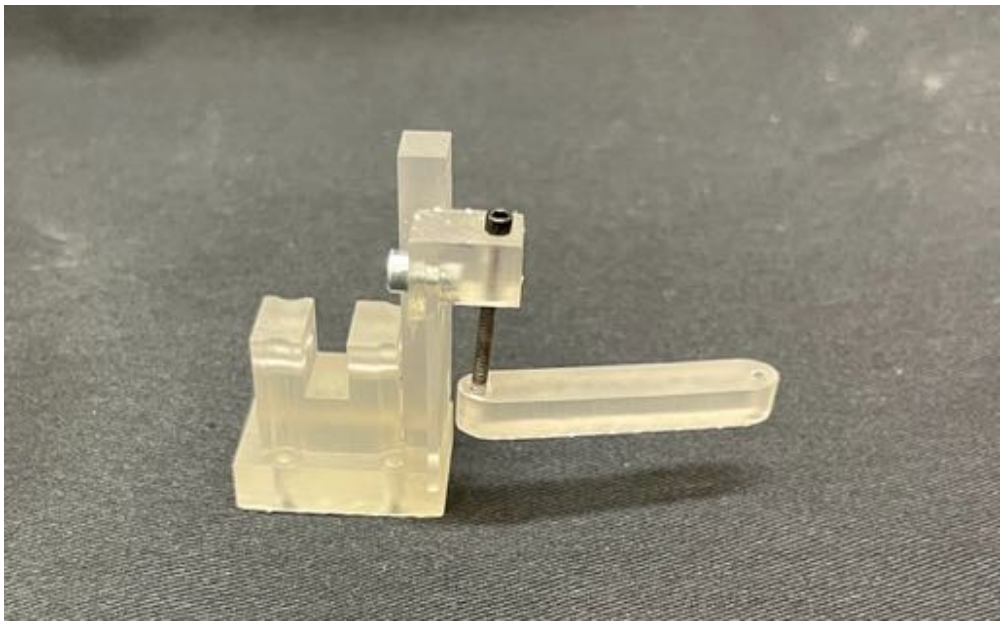
3.1. Download all STL files from Github. Print as specified (SLA or extrusion) in “Equipment and Terminology”

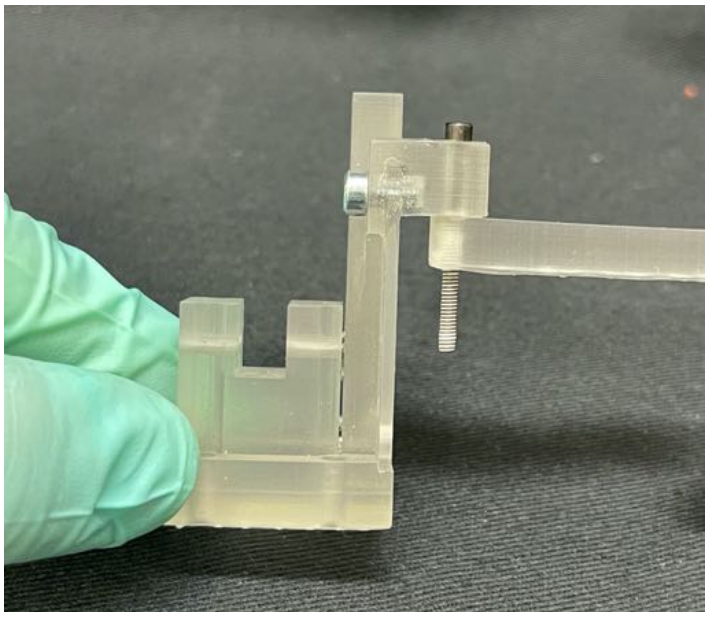
Load Cell Apparatus Assembly

3.2. Align hole of High Cube Intermediate Joint with top left hole (as viewed from back) of Load Cell Carriage (see pictures below).

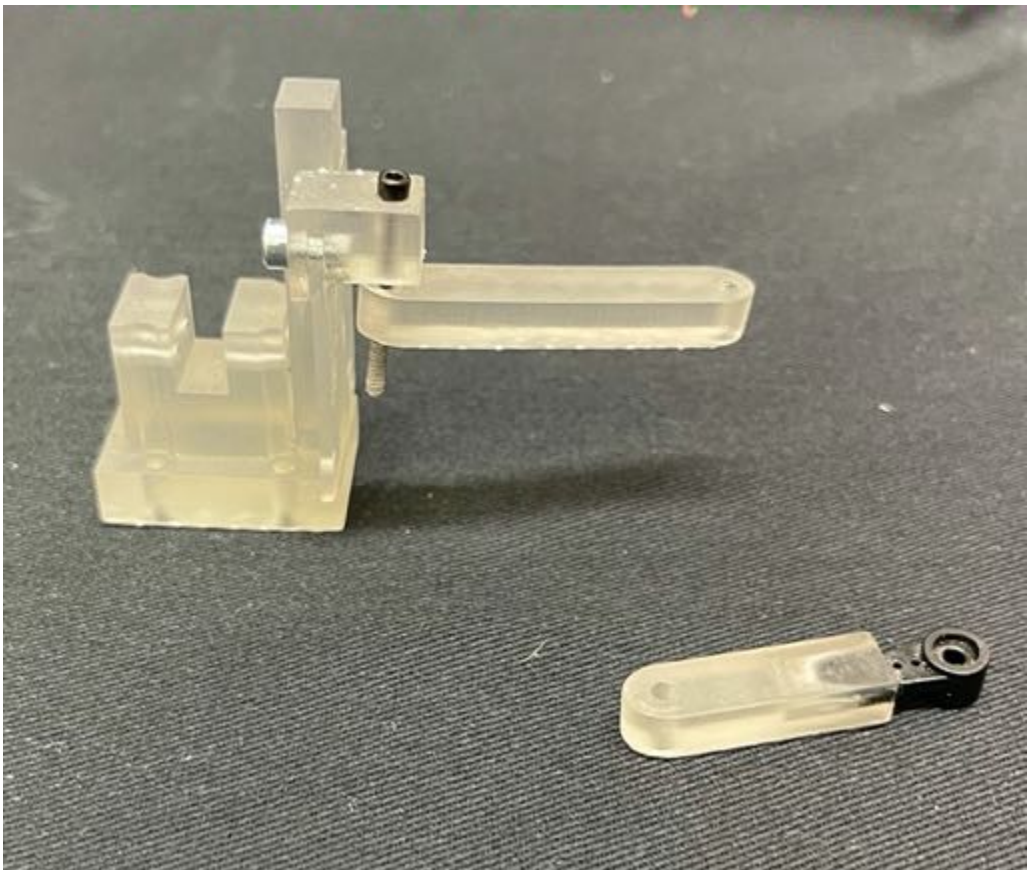
3.3. Apply Krazy Glue on tip of M3-0.5 x 6mm screw. Insert screw into hole to connect High Cube Intermediate Joint and Load Cell Carriage. Press screw in firmly and put glue along edges of cube/carriage interface to reinforce hold. Allow glue to dry.

3.4. Use M2.5-0.45 x 25mm (total length) / 20mm (threaded length) screw to affix Distal Servo Arm Adapter to High Cube Intermediate Joint. Screw in until surfaces of each piece are touching, but *do not* tighten the two components together. Ensure that Distal Servo Arm Adapter can rotate freely. *Tightening completely will cause the Load Cell Carriage to fracture when rotating Distal Servo Arm Adapter.*

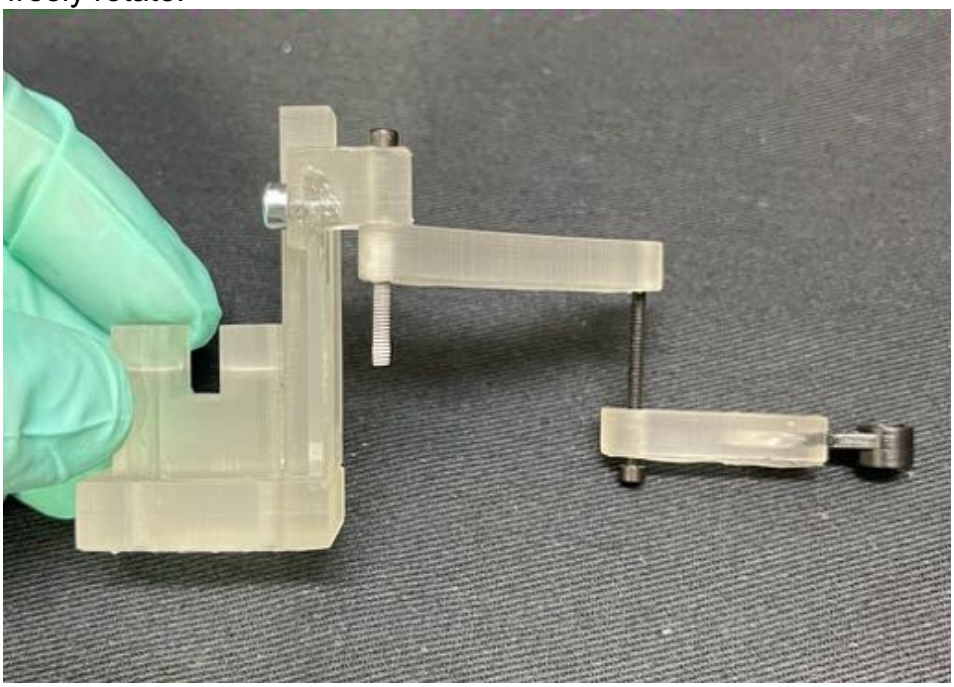


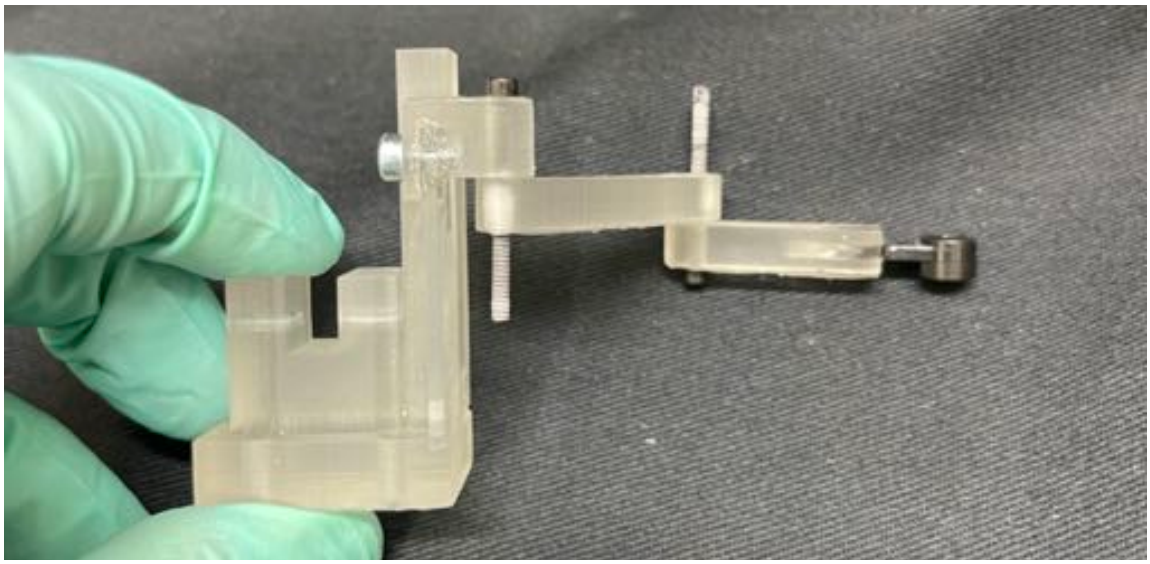


3.5. Using black plastic arms that come with the Positional Servo: Glue straight plastic servo arm into Proximal Servo Arm Adapter, as shown. Allow glue to dry.

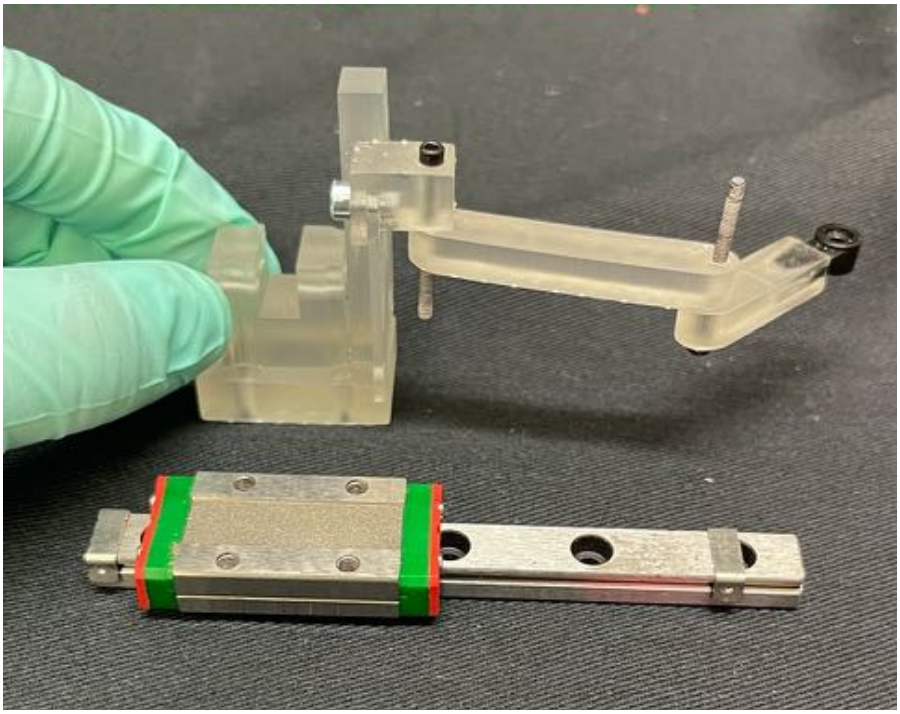


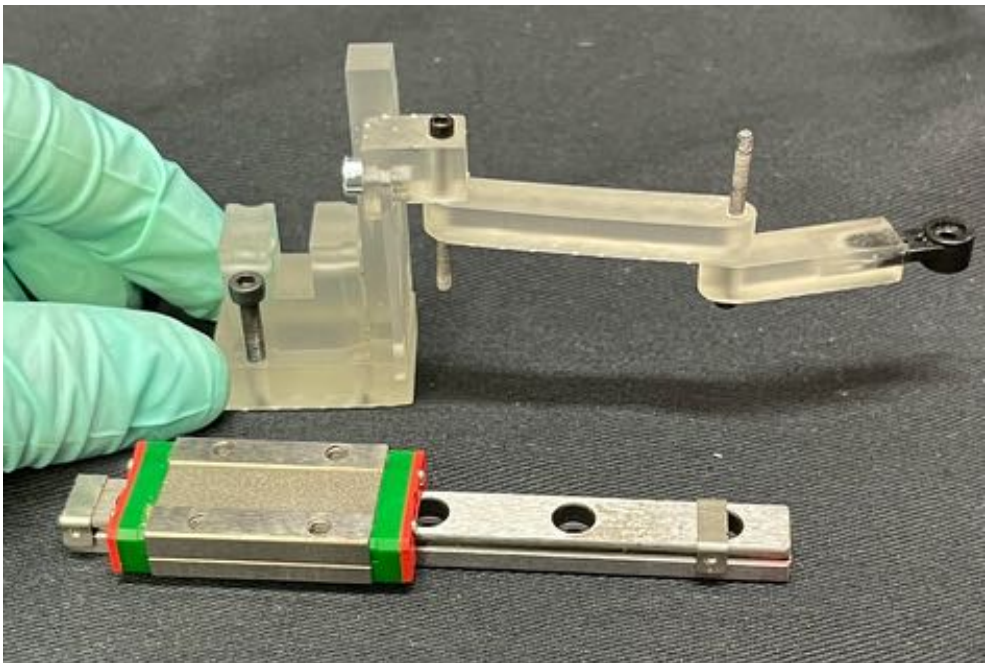
3.6. Connect Proximal Servo Arm Adapter to Distal Servo Arm Adapter with M2.5-0.45 x 25mm (total length) / 20mm (threaded length) screw, with the screw oriented upside-down as shown. Ensure that Proximal Servo Arm Adapter is oriented such that the hole with the notches on the black plastic servo arm is facing down (so that piece can later be plugged into servo). Screw in until the servo arm adapter surfaces are touching, but do not tighten. Ensure each piece can freely rotate.

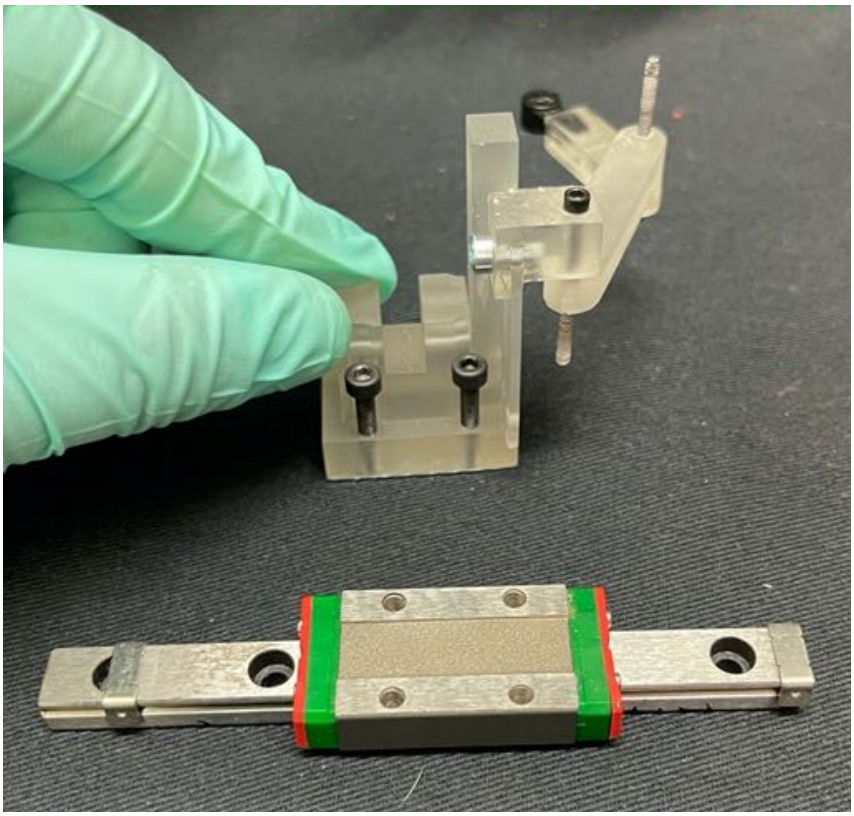


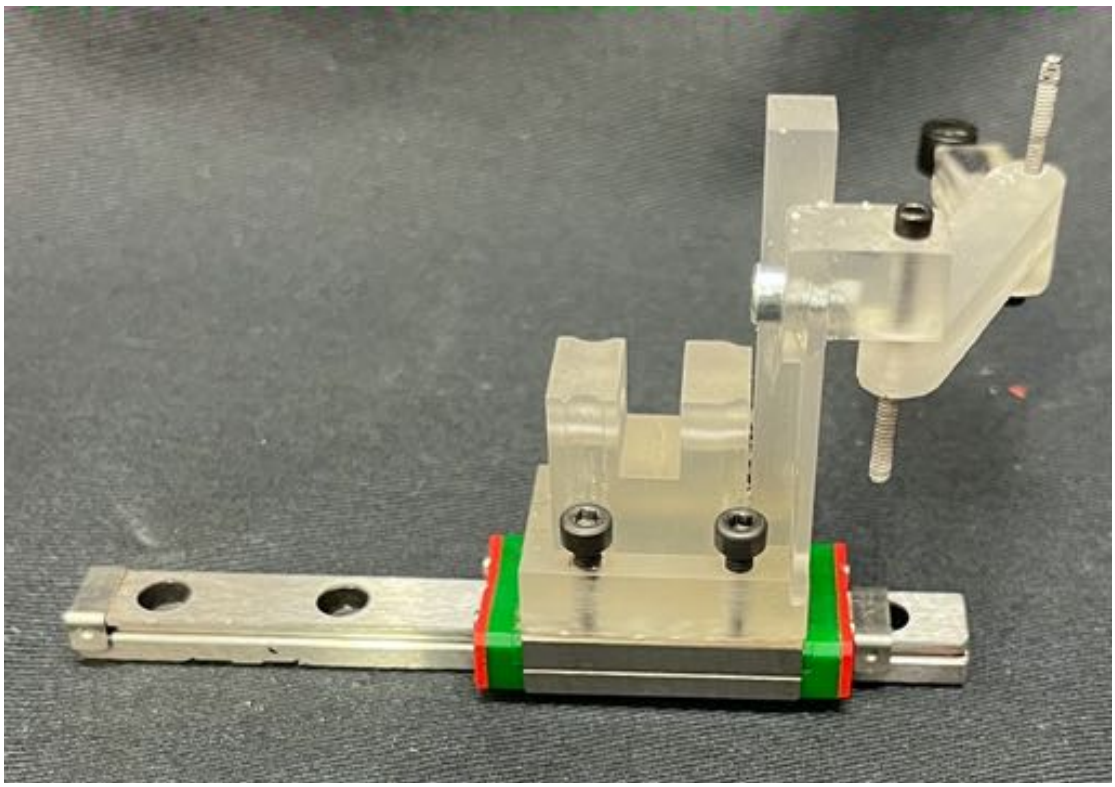


3.7. Screw Load Cell Carriage into Rail with 4 M3-0.5 x 16mm screws.

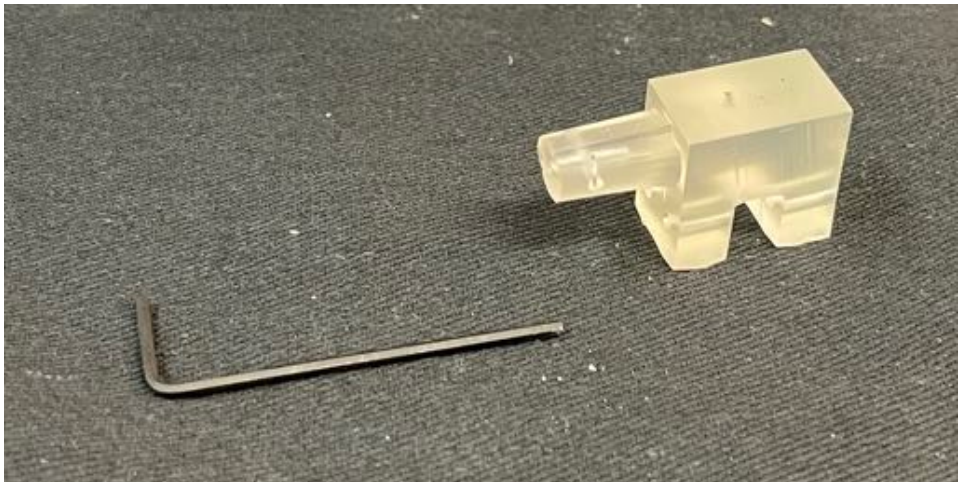


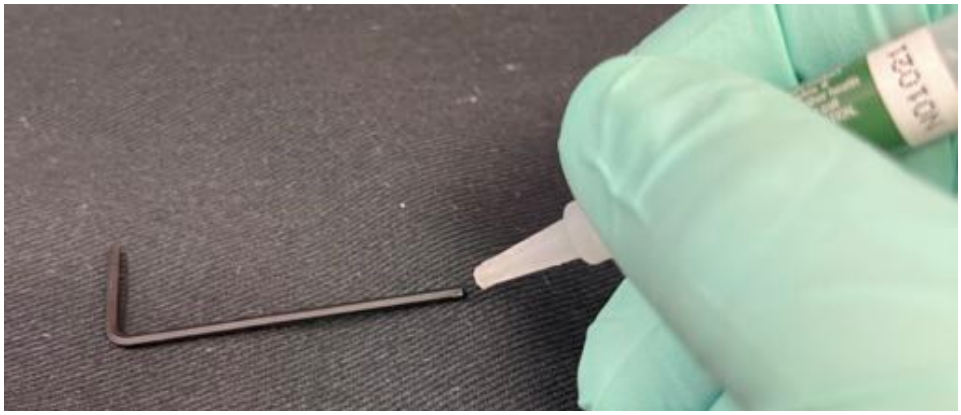


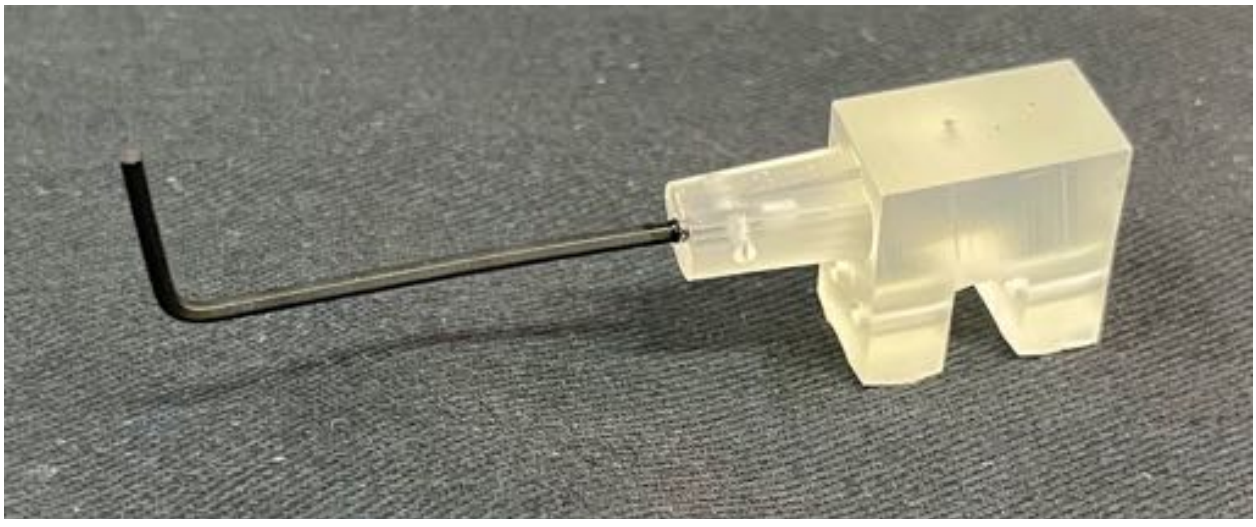




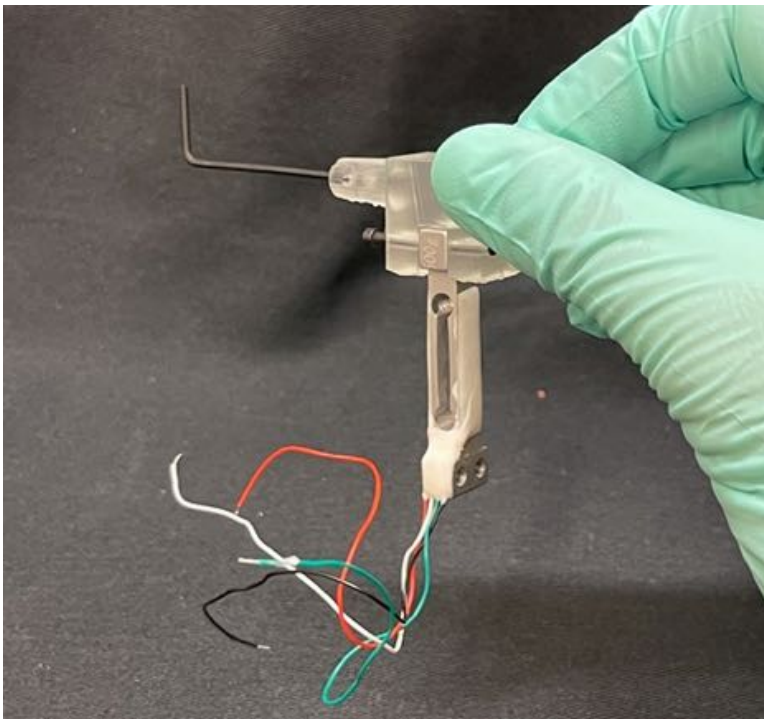
3.8. Apply glue to end of 1.5mm AF hex key and insert into main hole of Load Cell Handle Adapter. Press hex key into hole firmly and ensure that the bend of the hex key is facing up while glue is still wet. Once hex key is securely in the hole and oriented correctly, allow glue to dry.

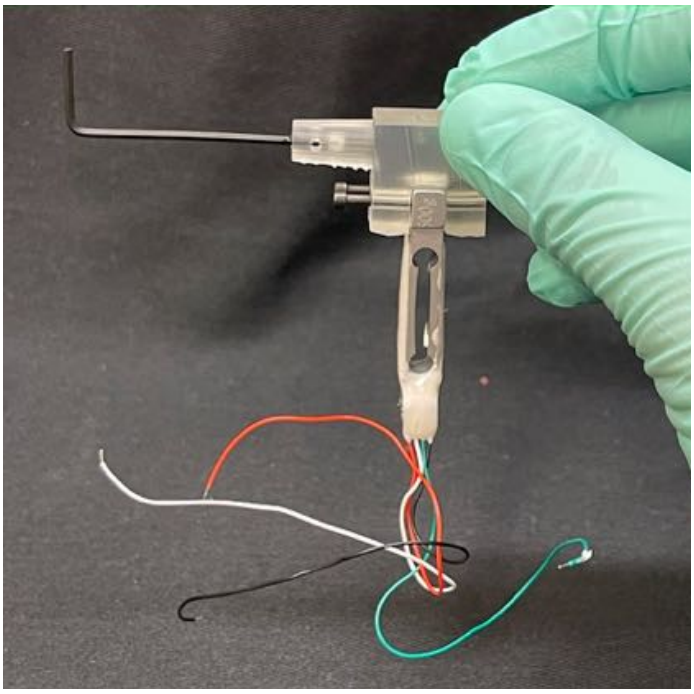


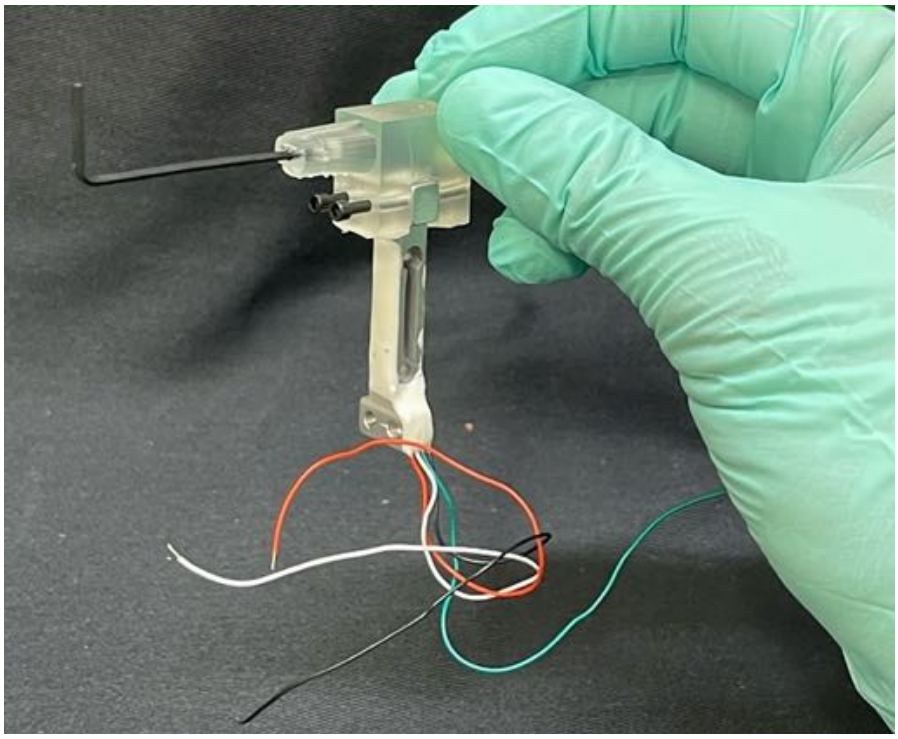




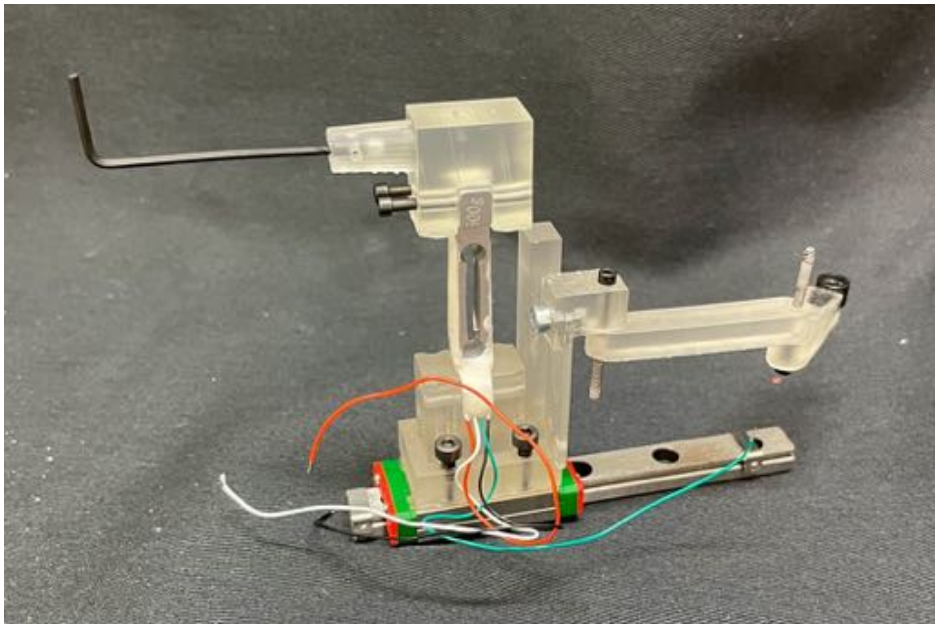
3.9. Screw top of Load Cell into Load Cell Handle Adapter with M2.5-0.45 x 25mm (total length) / 20mm (threaded length) screws. Recommended to wrap end of screw with Parafilm M to create a tighter fit.

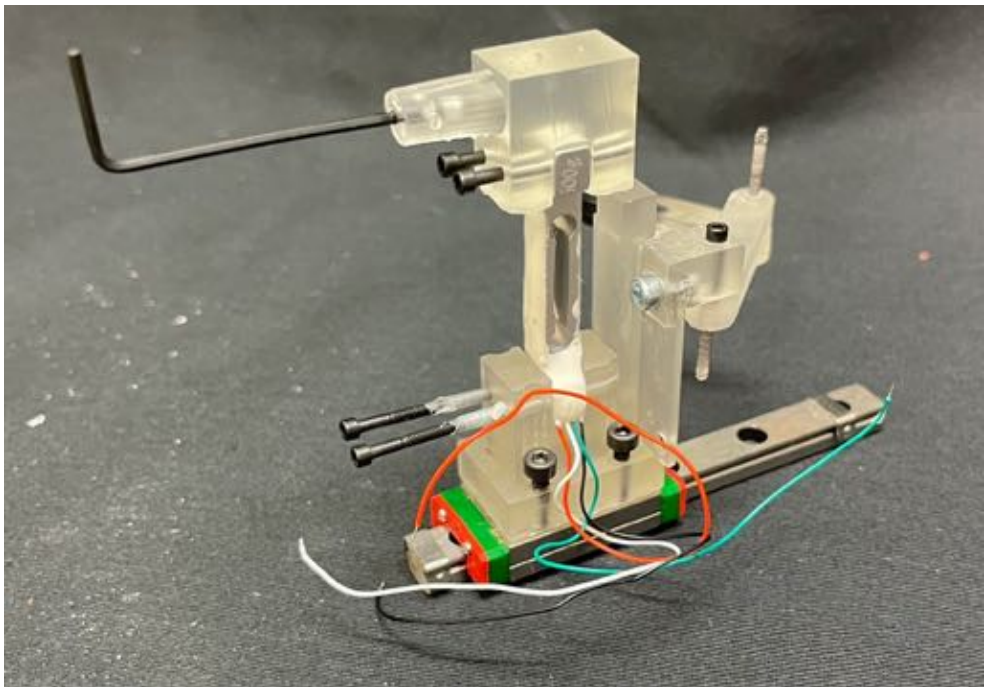


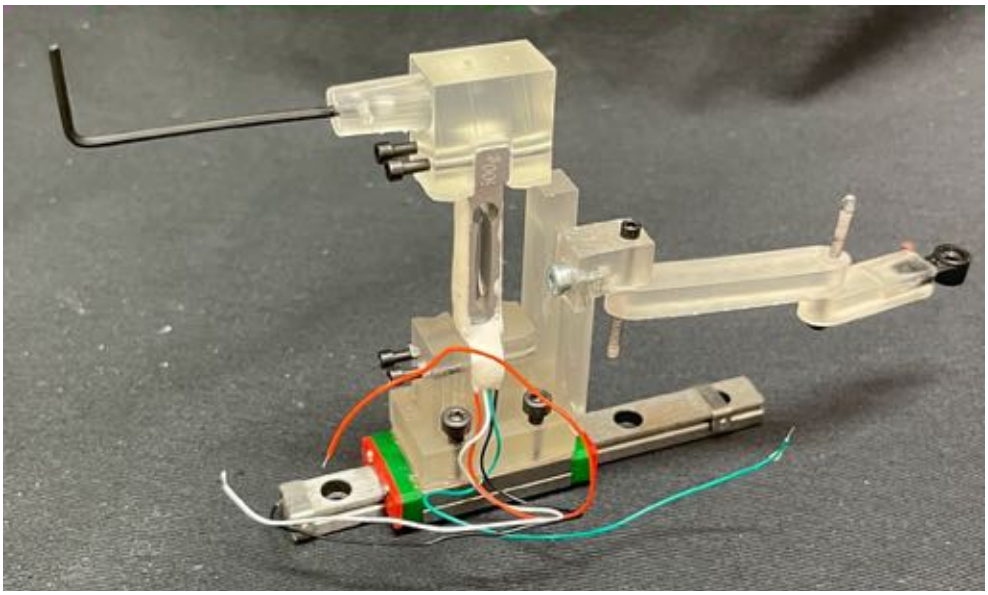




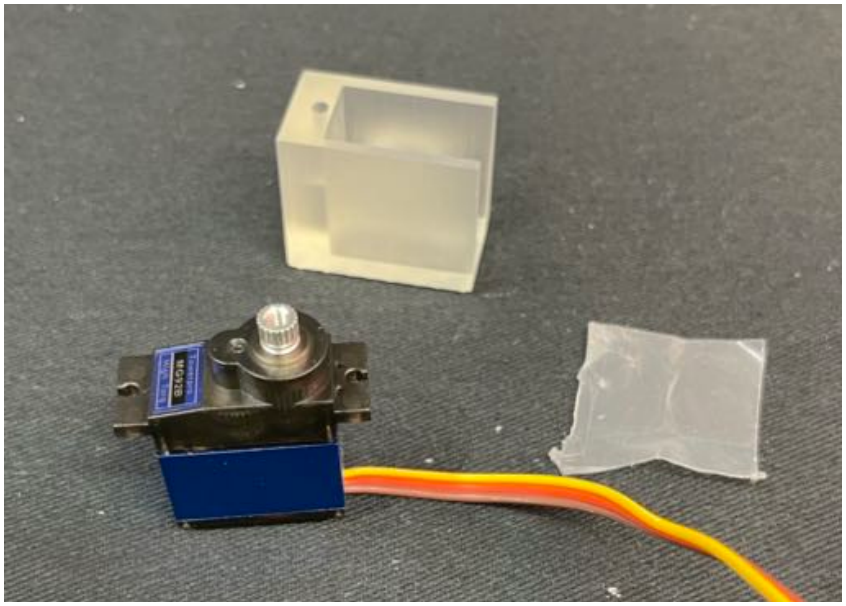
3.10.Screw Load Cell into Load Cell Carriage with M3-0.5 x 16mm screws.
Recommended to wrap end of screw with Parafilm M to create a tighter fit.

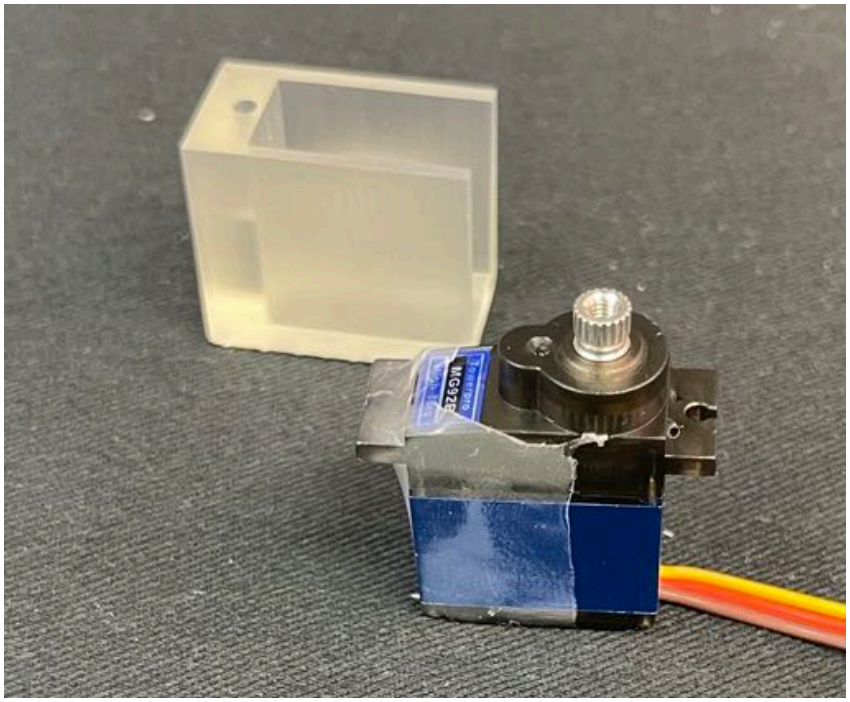






3.11. Wrap Parafilm M around Positional Servo, as shown.



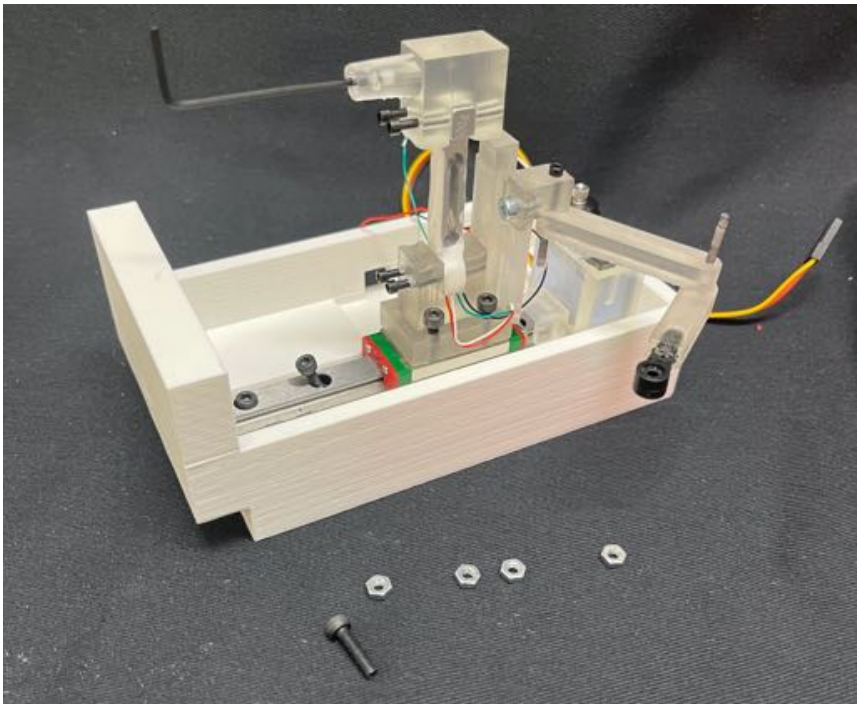


3.12. Insert Parafilm M-wrapped Positional Servo into Positional Servo Casing.

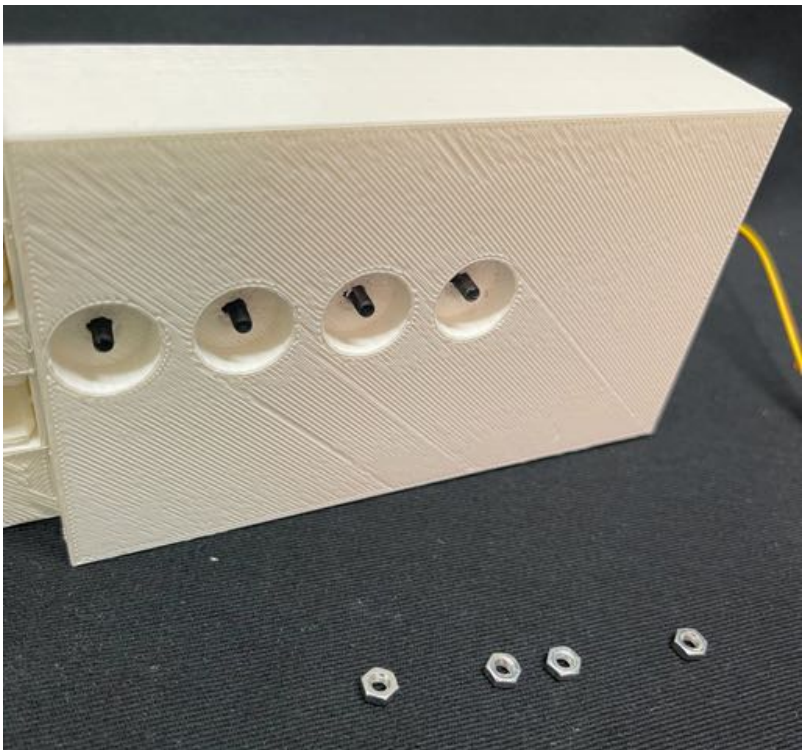
3.13. Fasten the Positional Servo into the Positional Servo Casing with the 7.5mm-long screw that comes with the commercial Positional Servo.

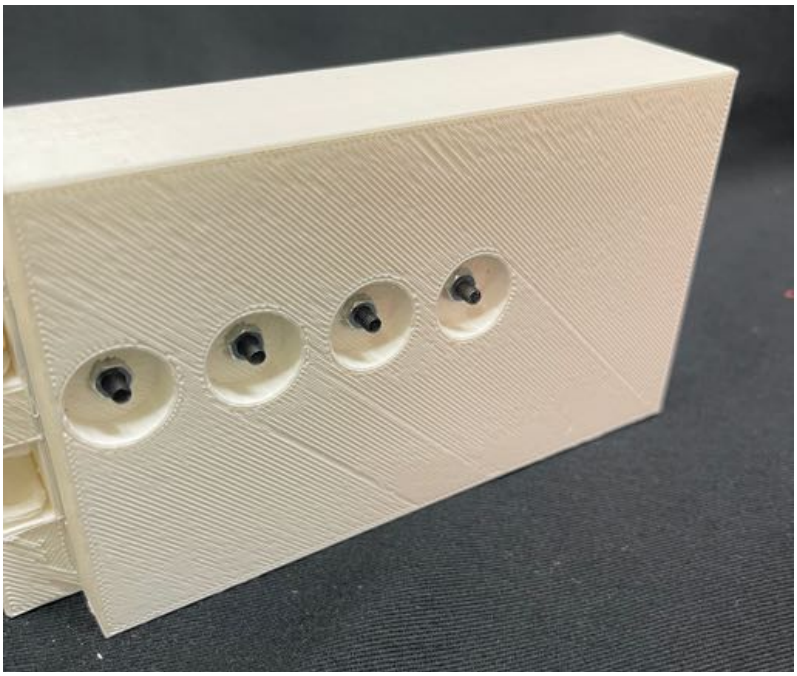
3.14. Align holes of Rail (which should now be connected to the Load Cell Apparatus) with the holes of the Handle Base. Place Positional Servo Casing (and enclosed Positional Servo) on the back insertion point on the Handle Base, with the front portion of the casing slightly covering part of the Rail.

3.15. Insert M3-0.5 x 12mm screws into holes of Rail and through the holes of the Handle Base. *You will have to move Load Cell Carriage along rail to access all the screw holes.*

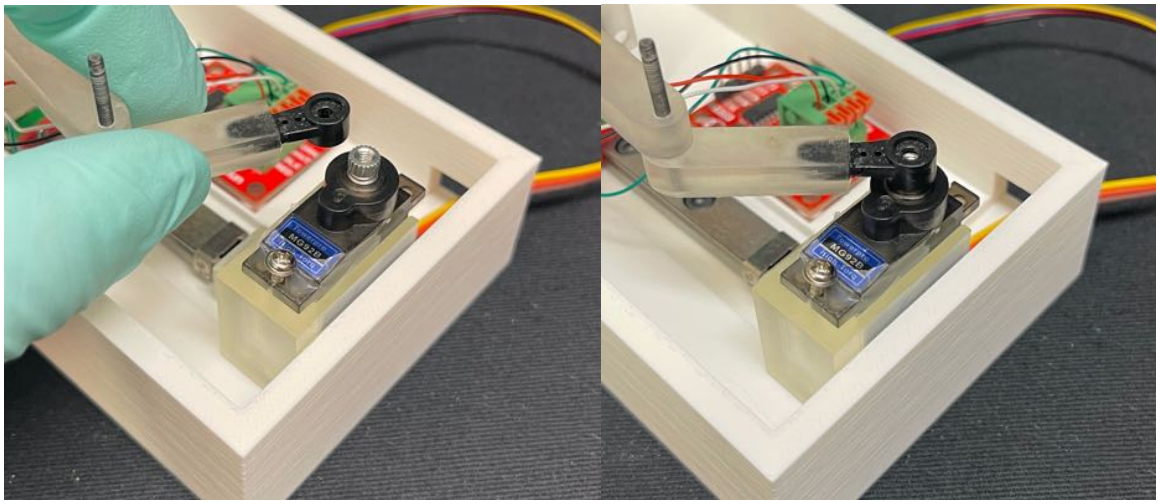


3.16. Screw in M3-0.5 mm hex nuts to the M3-0.5 x 12mm screws on the bottom of Handle Base to affix the Rail to the Handle Base. *Recommended strategy for this: Tighten nut onto screw by hand until nut is securely on screw. Then, hold nut in place with tweezers, push nut flush against bottom of Handle Base, and tighten screw onto nut until screw is flush against bottom of bore hole of Rail.*

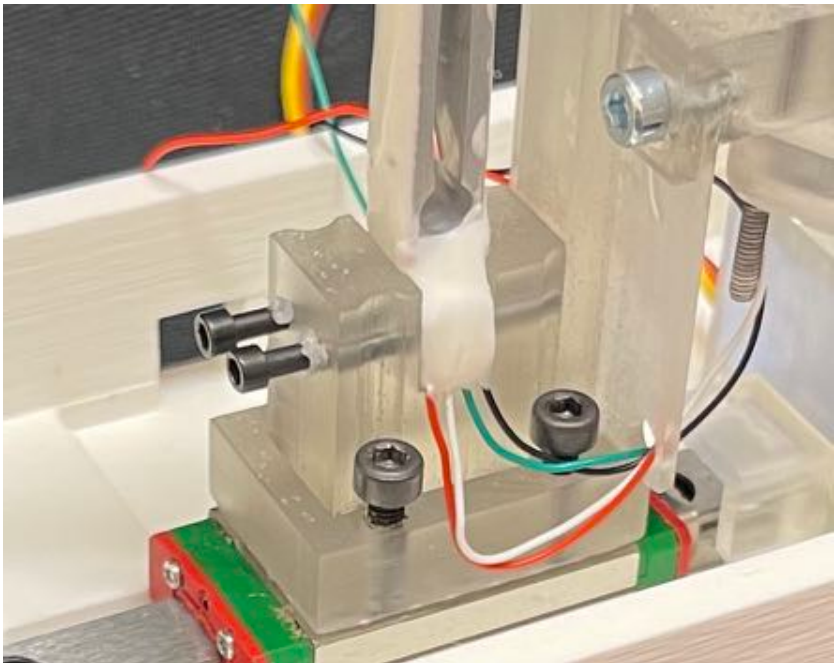




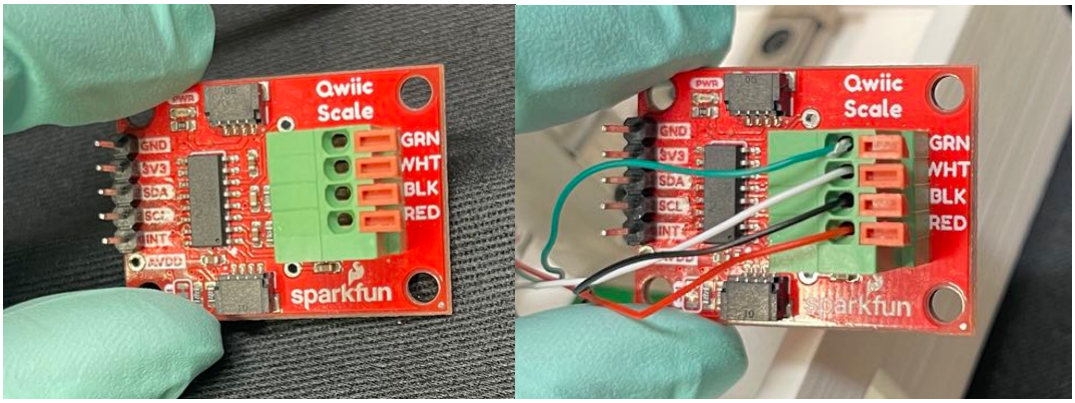
3.17. Move Load Cell Carriage to front of Rail and attach black servo arm to rotating piece of Positional Servo. *You will likely need to re-attach this arm during first calibration so that the Load Cell Carriage is positioned at the front of the Rail when the Positional Servo is set to 0º (see AutoRG_Calibration_SOP)*.



3.18. Run 4 wires from Load Cell (red, white, green, black) through hole on bottom left (as viewed from back) of Load Cell Carriage.



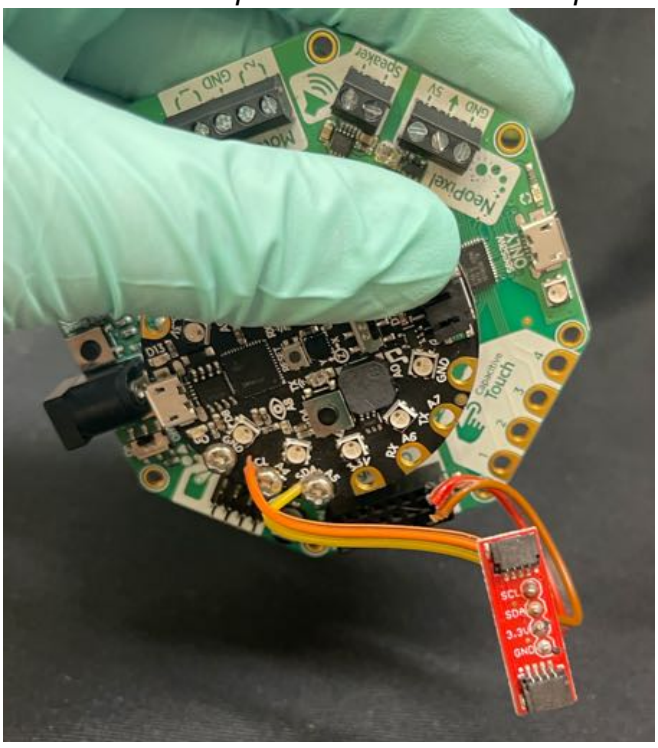
3.19. Plug in Load Cell wires into corresponding port of Qwiic Scale (labeled on Qwiic Scale by color). *Press orange lever down for corresponding plug hole, insert wire fully, and release lever. Tug on wire lightly to ensure that it is fully plugged into Qwiic Scale port.*

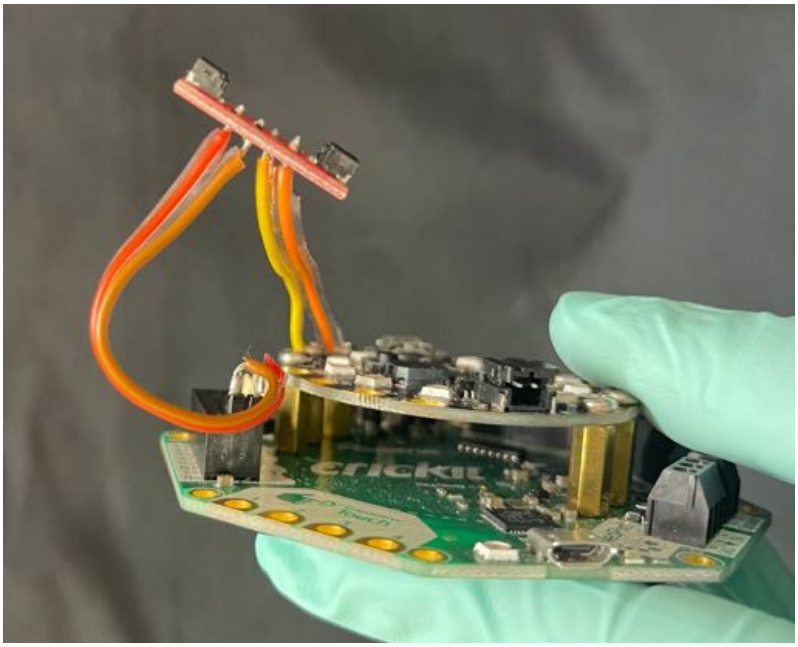


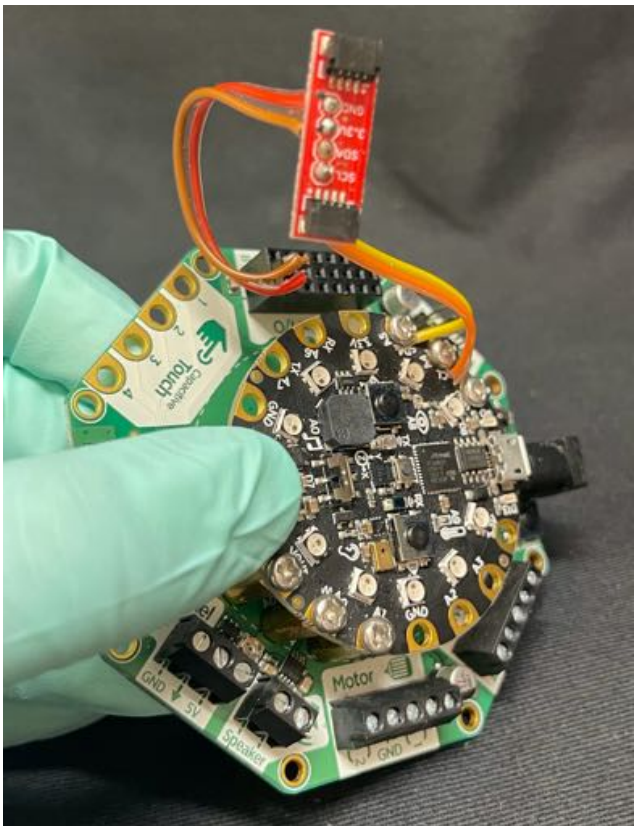
3.20. With ~75mm long insulated wires, solder 4 wires into SCL, SDA, 3.3V, and GND pins of Qwiic Adapter.

3.21. Connect 3.3V and GND wire from Qwiic Scale into 2 male pins. Plug male pins into corresponding 3.3V and GND female pin connector of CRICKIT board.

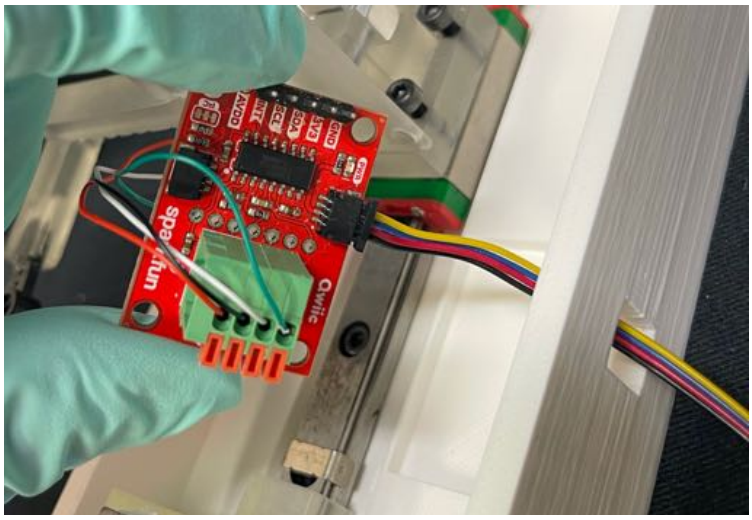
3.22. Loosen screws on SCL and SDA locations of CPX. Wrap corresponding SCL and SDA wires from Qwiic Scale underneath screw head and tighten screw onto wire so that a firm connection is established. *Alternatively, solder each wire to a metal plate and screw each metal plate underneath corresponding screw.*

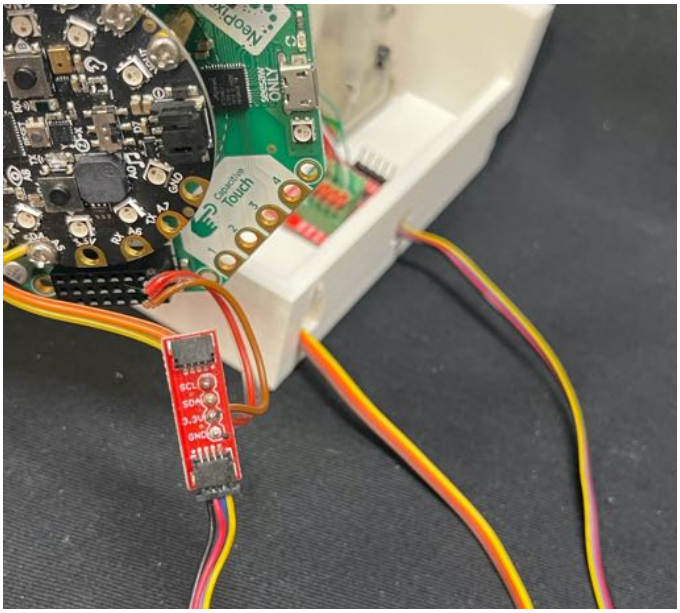


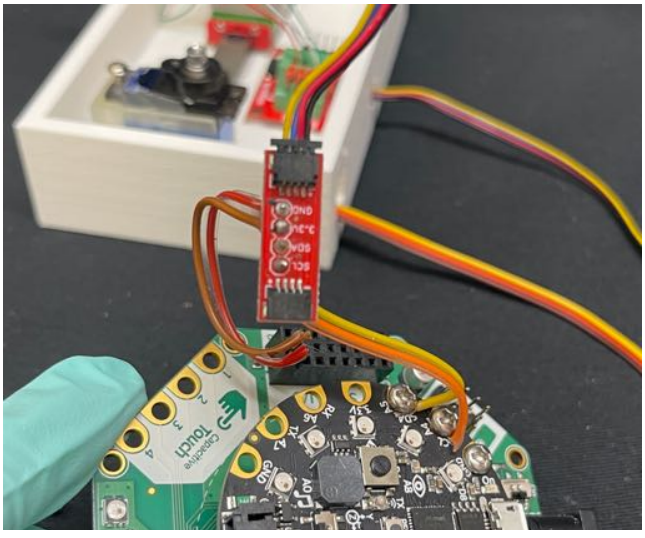




3.23. Place Qwiic Scale in its Handle Base indentation. Run STEMMA QT / Qwiic Cable through hole next to Qwiic Scale and connect cable to Qwiic Scale. Plug other end of STEMMA QT / Qwiic Cable into Qwiic scale, as shown.


sparkfun



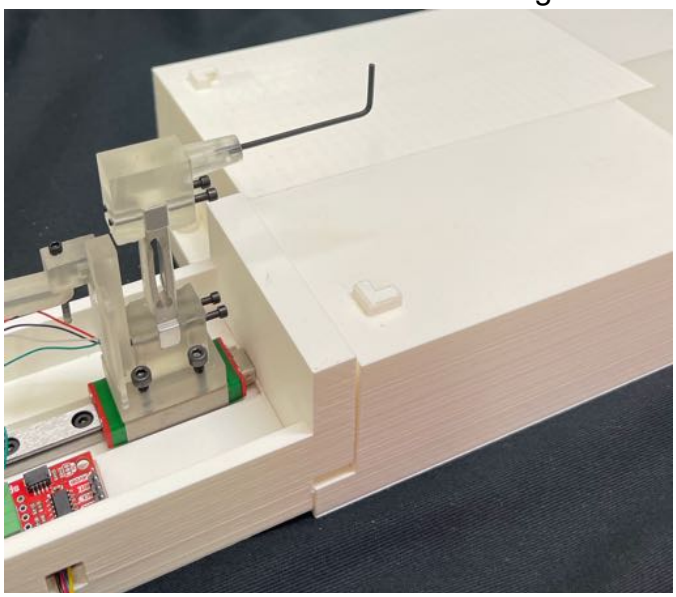


3.24. Screw in Qwiic scale to Handle Base holes with M2.5-0.45 x 6-8mm screws.

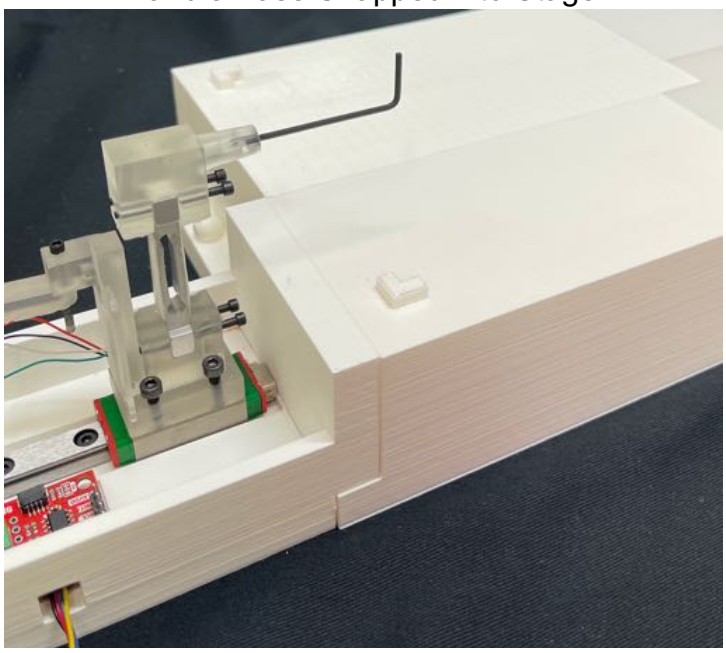
3.25. Snap 4 quadrants of Stage together.

3.26. Snap Handle Base to front right quadrant of Stage.

Handle Base Positioned on Stage:

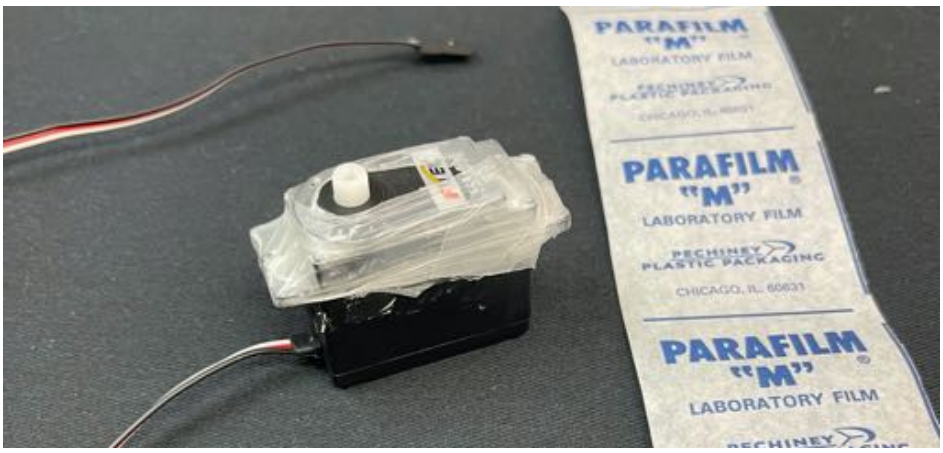


Handle Base Snapped into Stage

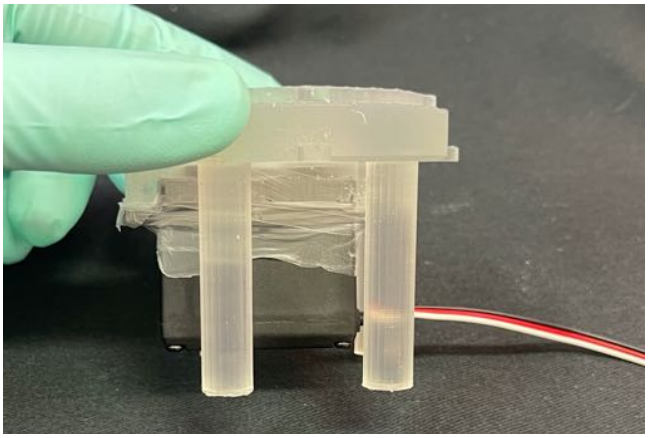


Pellet Dispenser Assembly

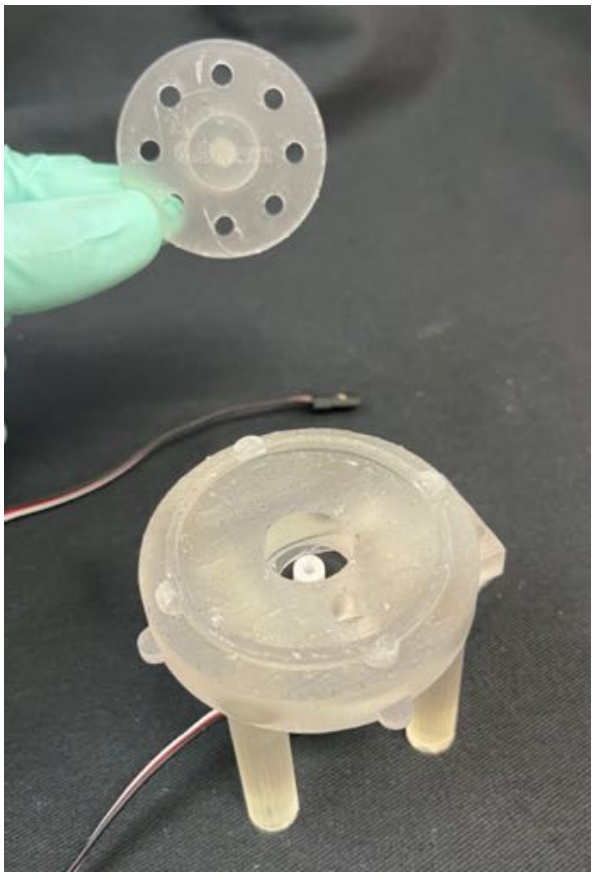
3.27. Wrap Parafilm M around top of Pellet Servo (continuous servo) as shown.

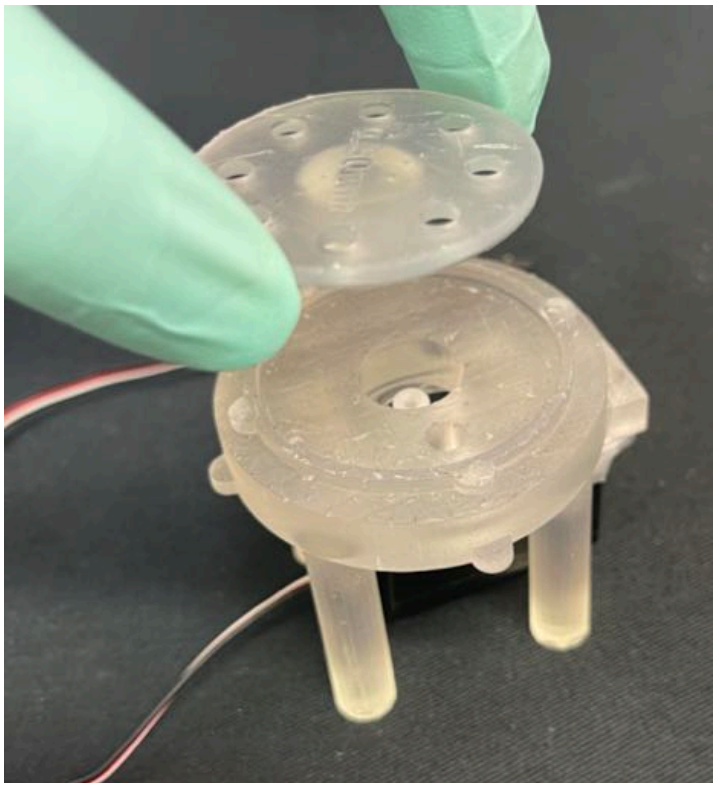


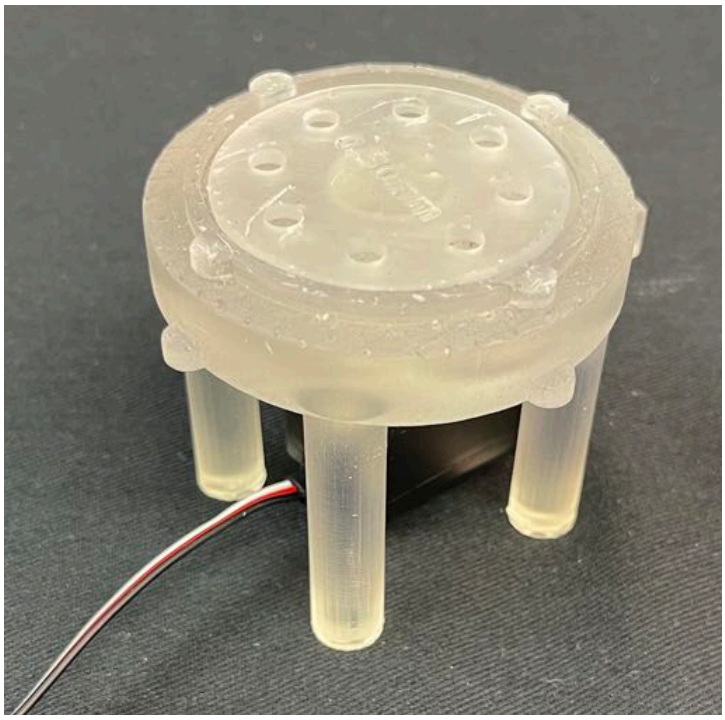
3.28. Insert Pellet Servo into Pellet Dispense Base.



3.29. Place notched Pellet Servo Actuator onto rotating component of Pellet Servo. Ensure notches are aligned and Pellet Servo Actuator is securely attached to rotating component of Pellet Servo.







3.29.1. Before proceeding: Ensure that servo will rotate properly (assuming software has been downloaded and initialized).

3.29.1.1. Plug Pellet Servo into “Servo” Row 2 spot on CRICKIT (black wire faces inward, white wire faces outward, as pictured below.

3.29.1.2. Turn on CPX, plug into power, and plug USB connection into computer

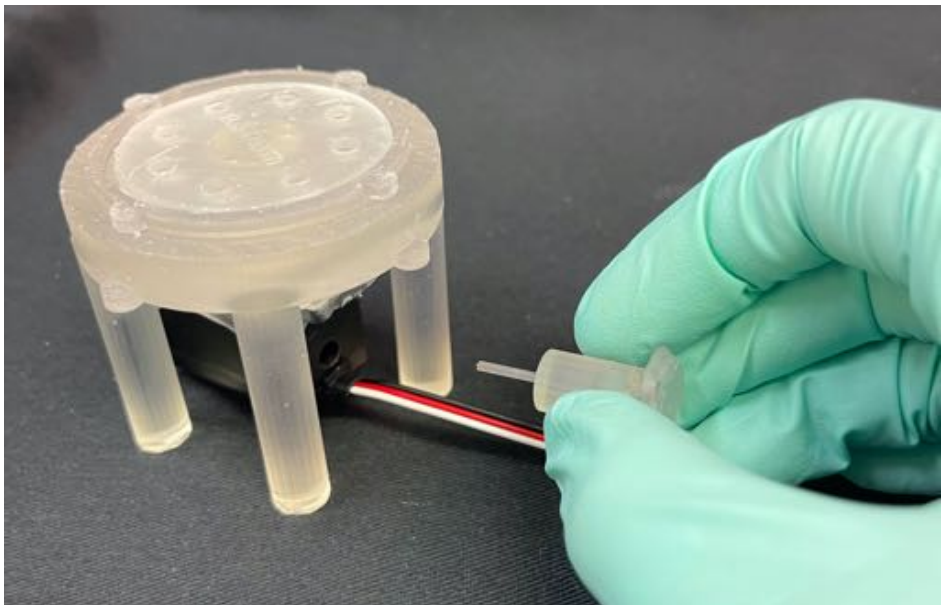
3.29.1.3. Boot up Calibration_GUI, and click “Run” on Editor tab of MatLab to open GUI.

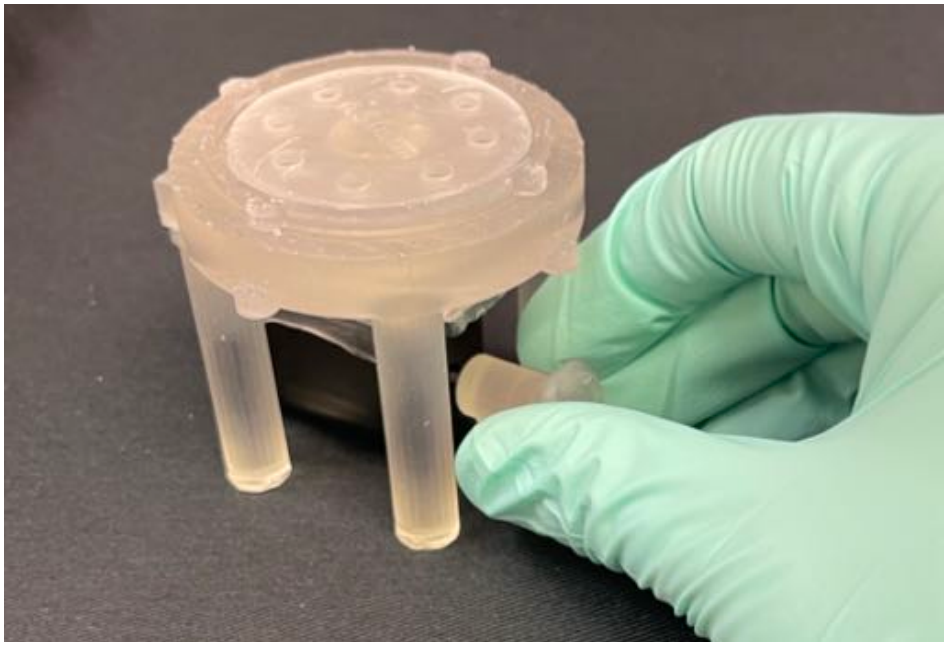
3.29.1.4. Check COM port for CPX in computer’s “device manager” section. Enter corresponding COM code (e.g., COM5) and click “Connect” (see AutoRG_Calibration_SOP for more detailed instructions).

3.29.1.5. Click “Start Read”, and check that GUI is receiving load information from Load Cell in upper graph.

3.29.1.6. Click “Dispense Pellet”. Servo should rotate at least once; check that it rotates smoothly. If rotation continues rapidly, must calibrate Pellet Servo:

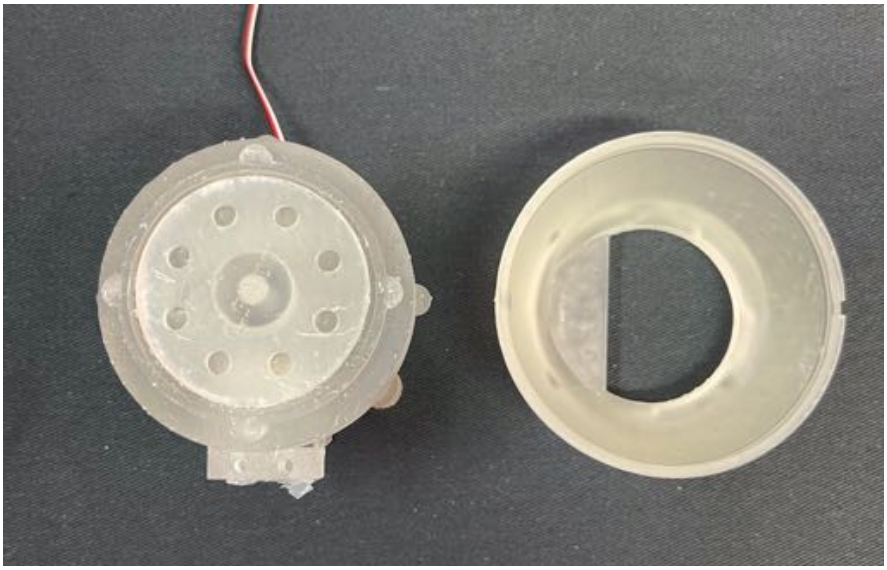
3.29.1.6.1. Insert Calibration Knob into hole of Pellet Servo (can be difficult to find exact hole). Rotate Calibration Knob and observe the spinning of the Pellet Servo to either increase in speed or decrease in speed. *If speed does not change when knob is turned, readjust position of Calibration Knob in hole until it affects the spinning speed.* Turn knob in direction that decreases speed of rotation and modulate turning of knob until Pellet Servo is not moving.

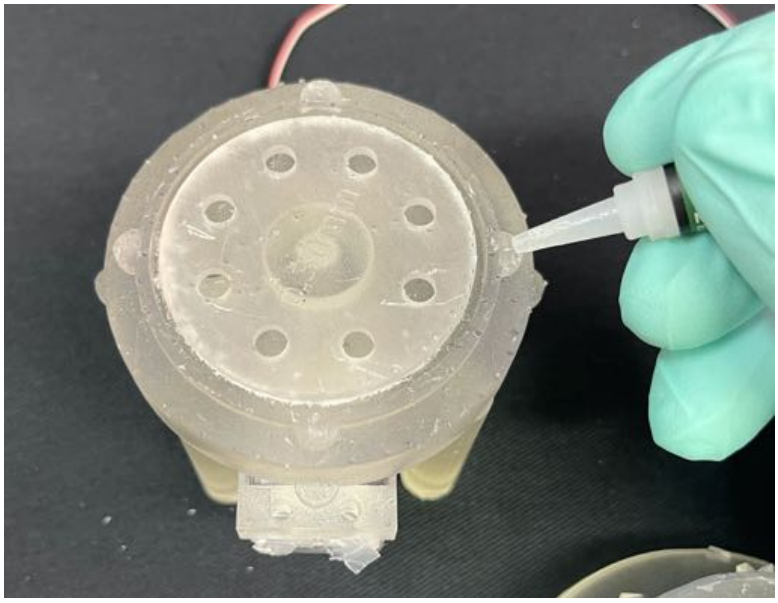


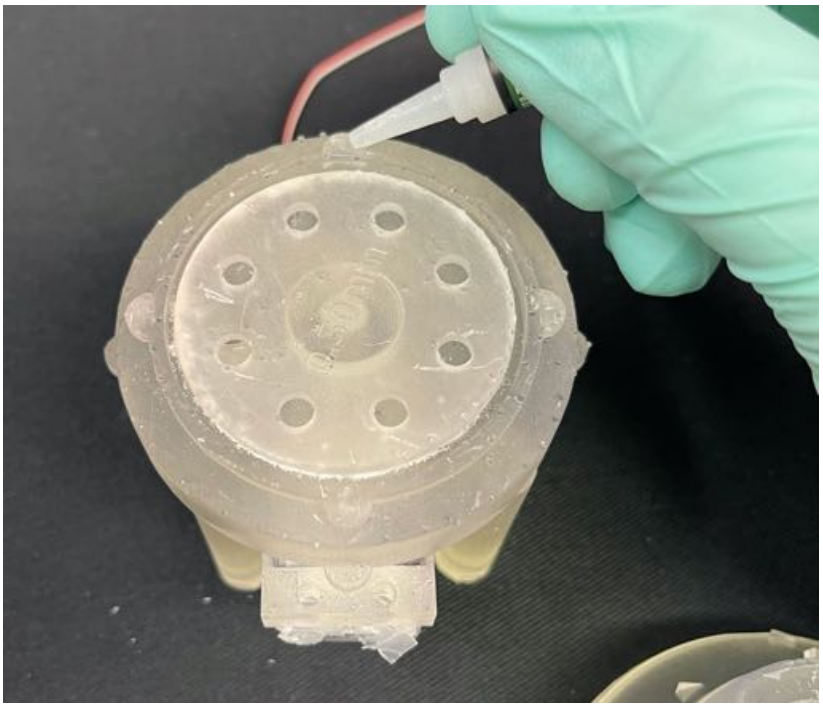


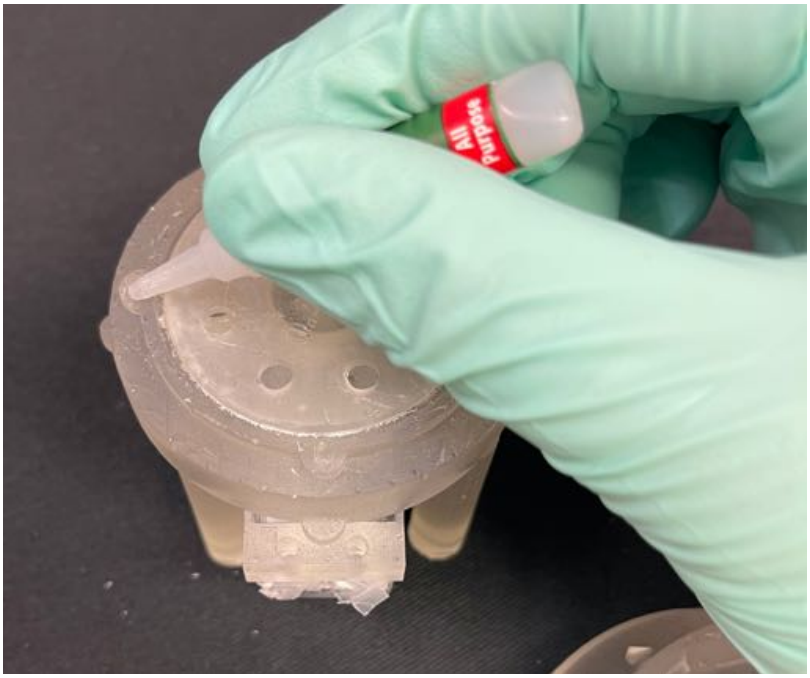
3.29.1.6.2. To check that calibration is complete: Click “Dispense Pellet” again. Pellet Servo should rotate once and stop after.

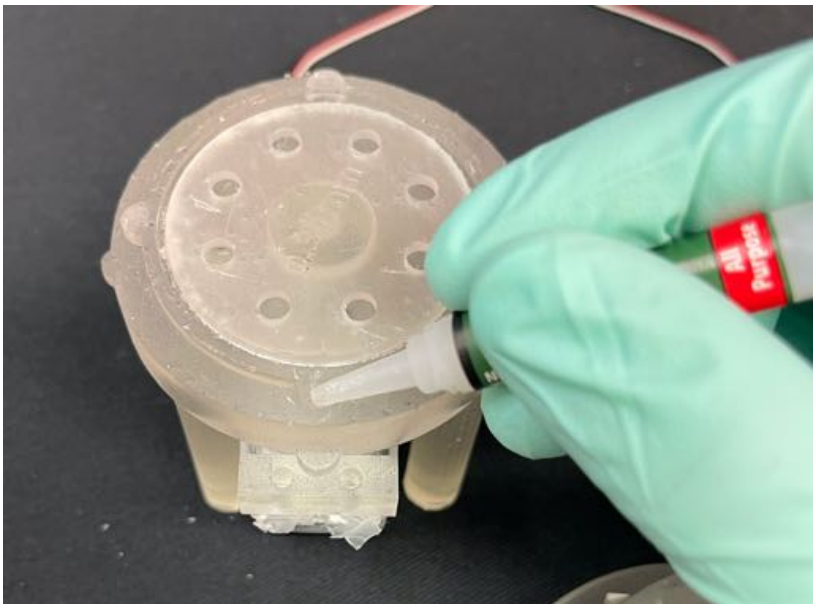
3.30. Place glue on bottom edges of Food Silo and top edges of Pellet Dispense Base and adhere Food Silo to this Pellet Dispense Base. Take care to ensure glue does not spill onto Pellet Servo Actuator component, or rotation will be impaired. Ensure that Food Silo is oriented correctly on the Pellet Dispense Base (the dispense hole on base should be covered by the semicircle of the Food Silo). Turn upside down (top of Food Silo facing down) and allow glue to dry.








All Purpose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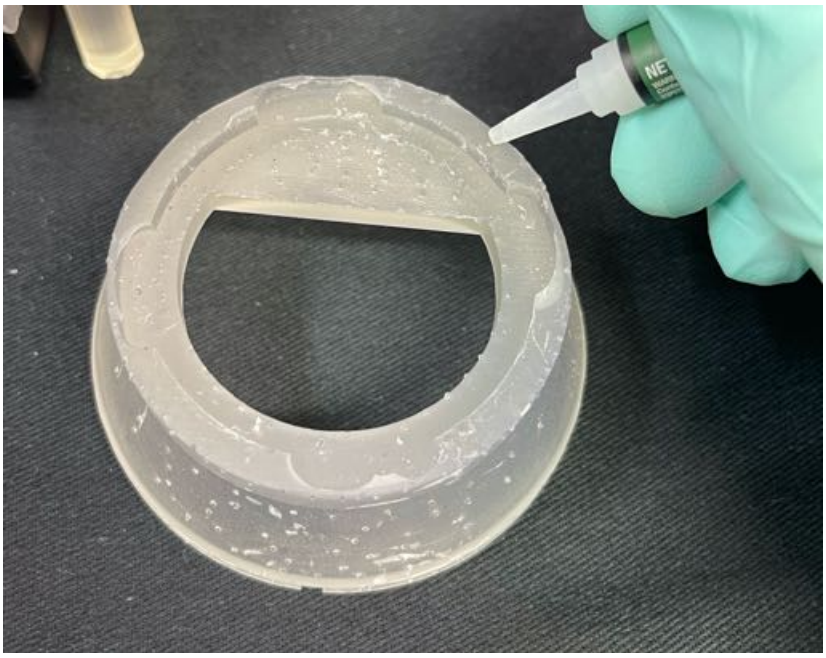
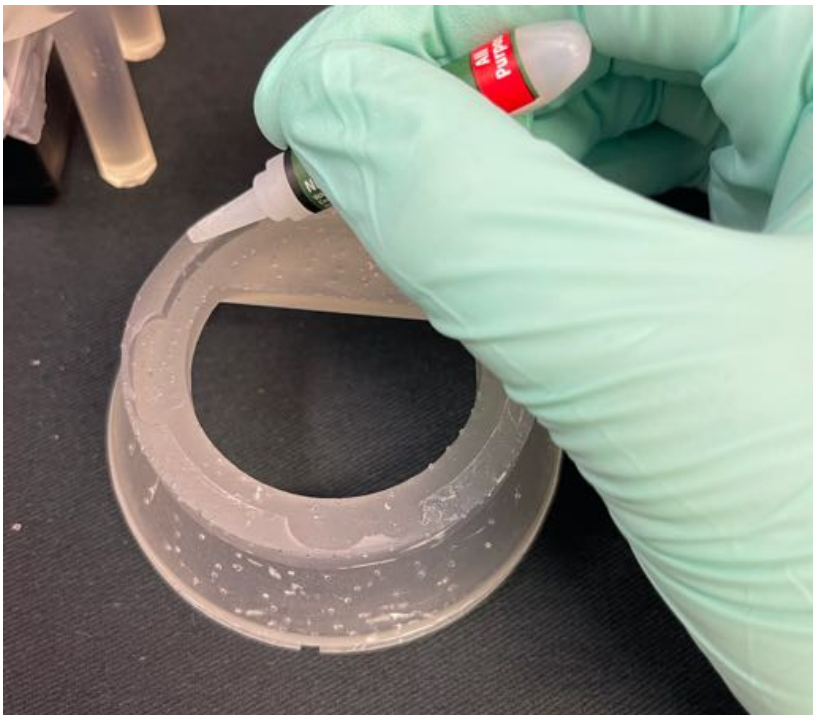
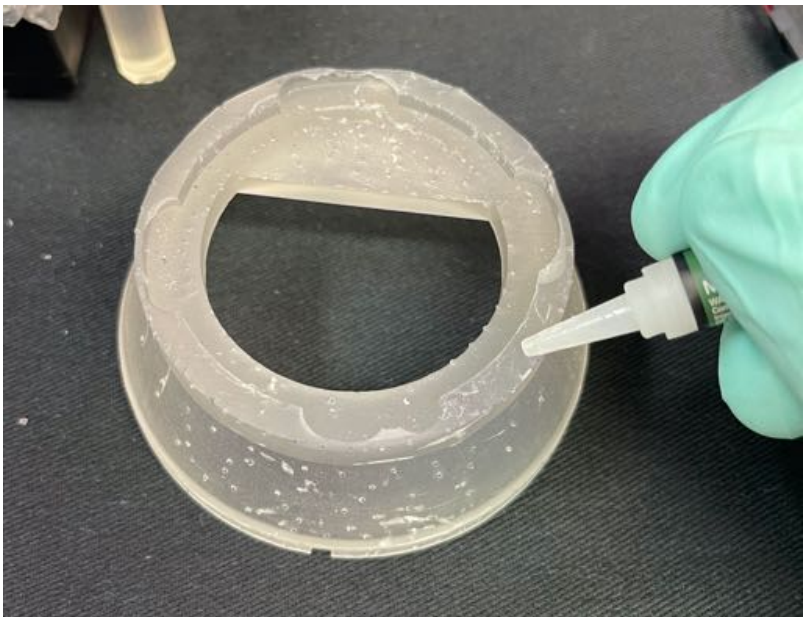
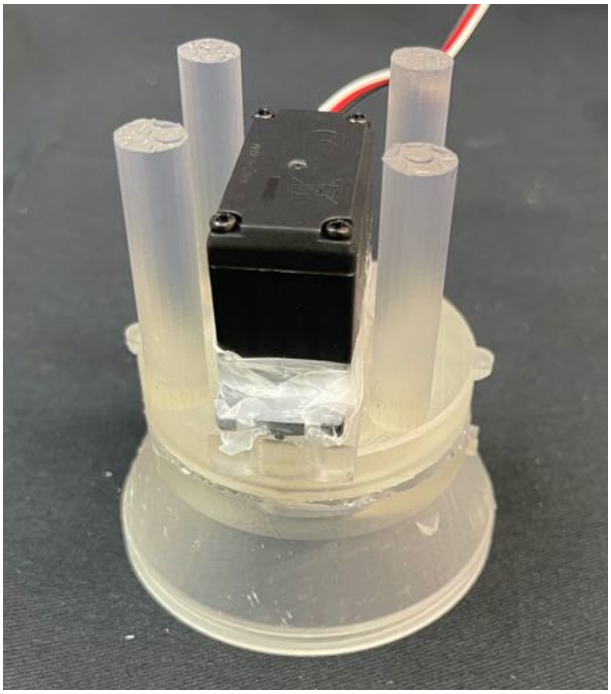


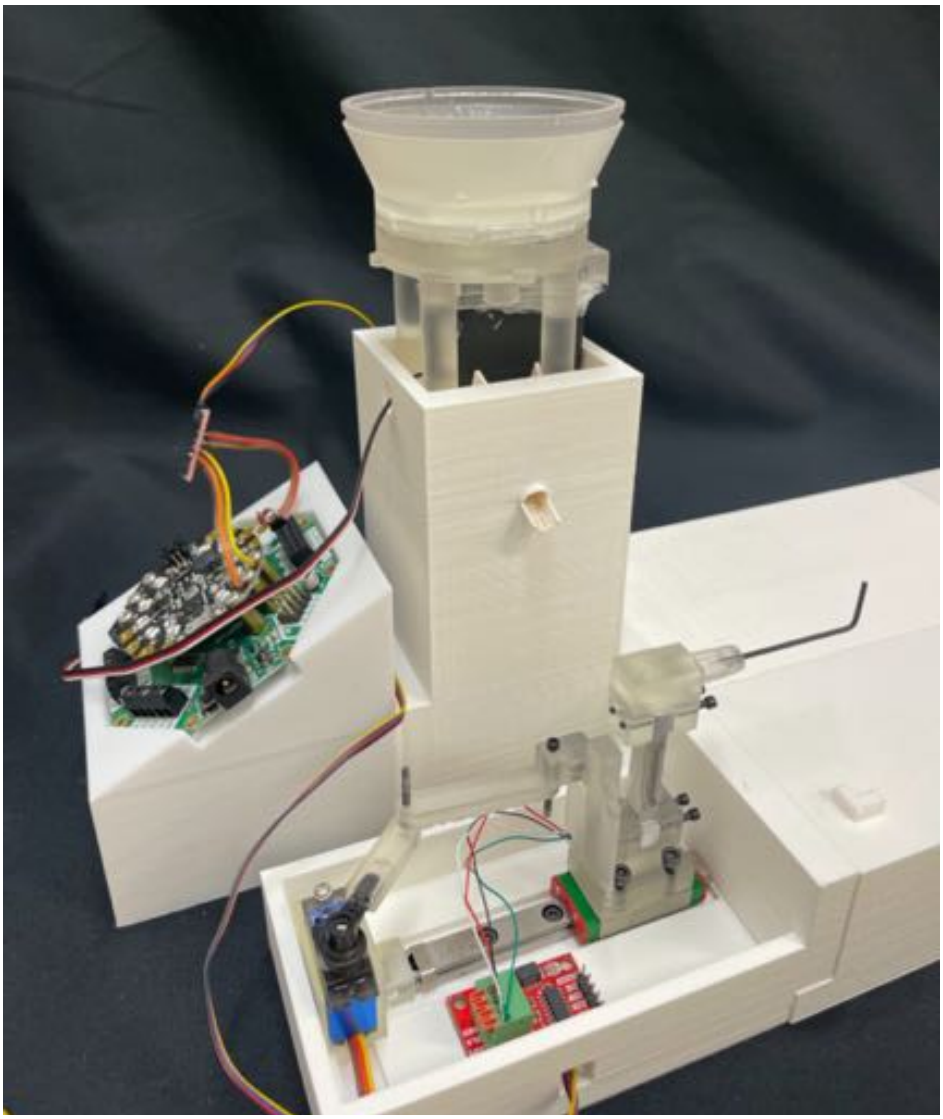






3.31. Snap Pellet Dispense Tower into the front left quadrant of the Stage.

3.32. Place Pellet Dispenser on top of Pellet Dispense Tower. Run wire of Pellet Servo out of hole on top of tower.

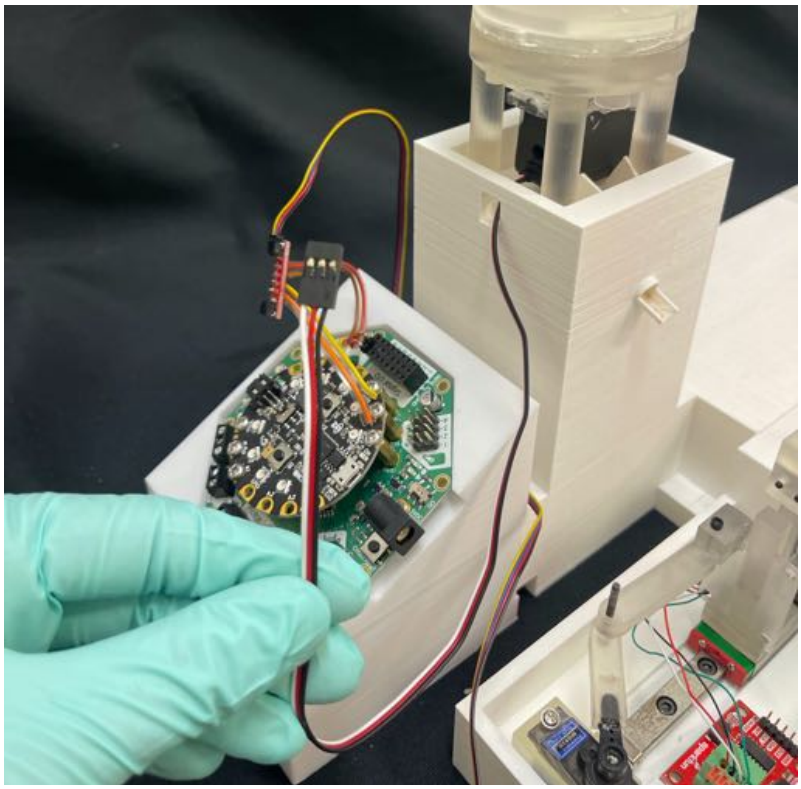


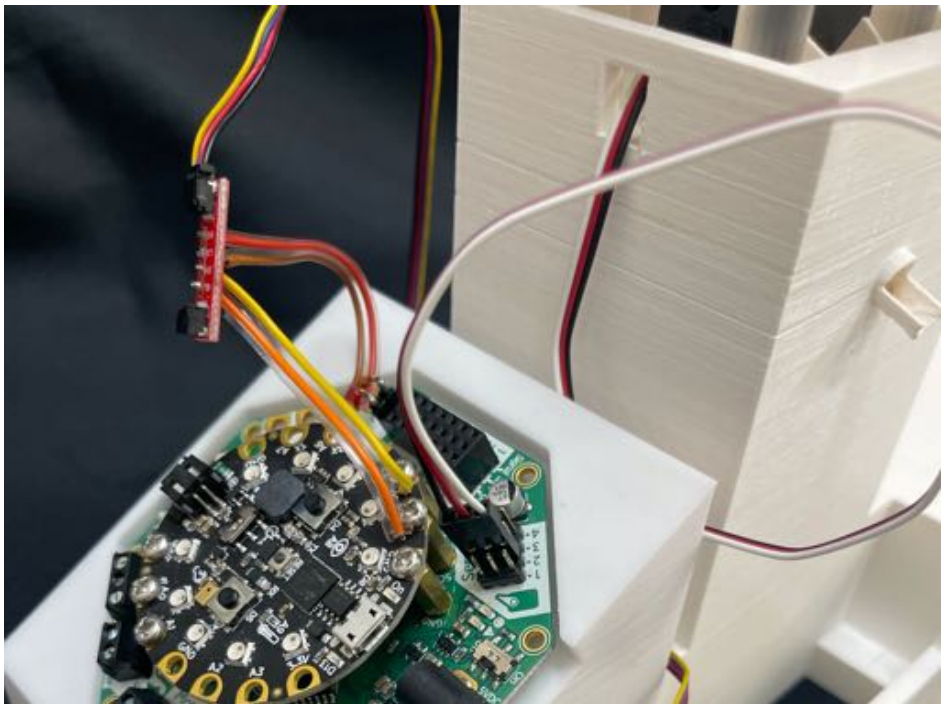
Final Assembly Steps

3.33. Snap CPX Holder into back of Pellet Dispenser Tower.

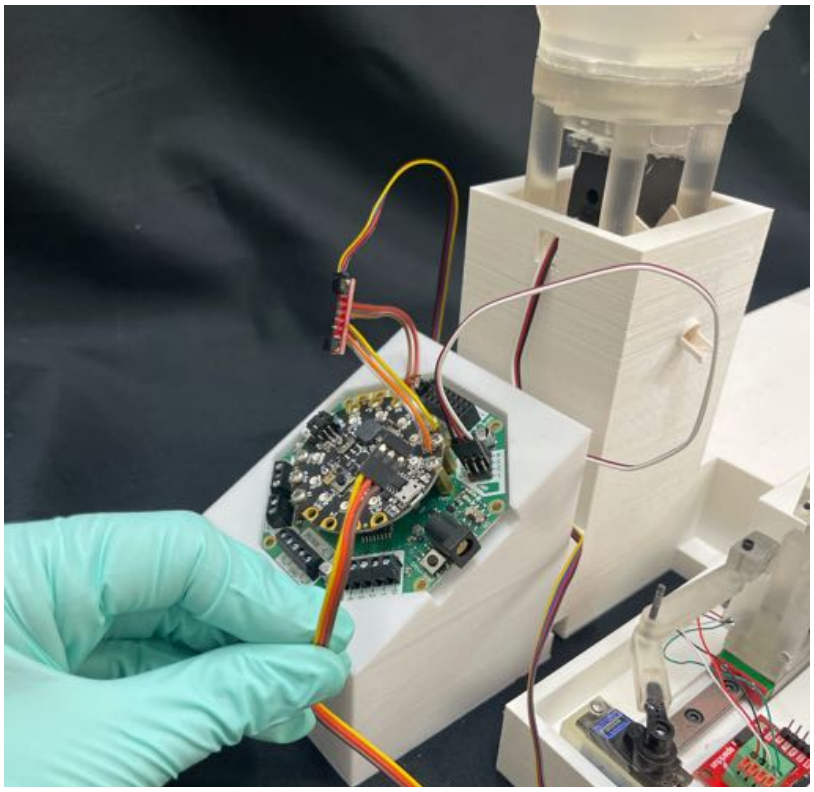
3.34. Place CPX/CRICKIT into position on CPX Holder. Screw CRICKIT into holes with M2.5-0.45 x 6-8mm screws.

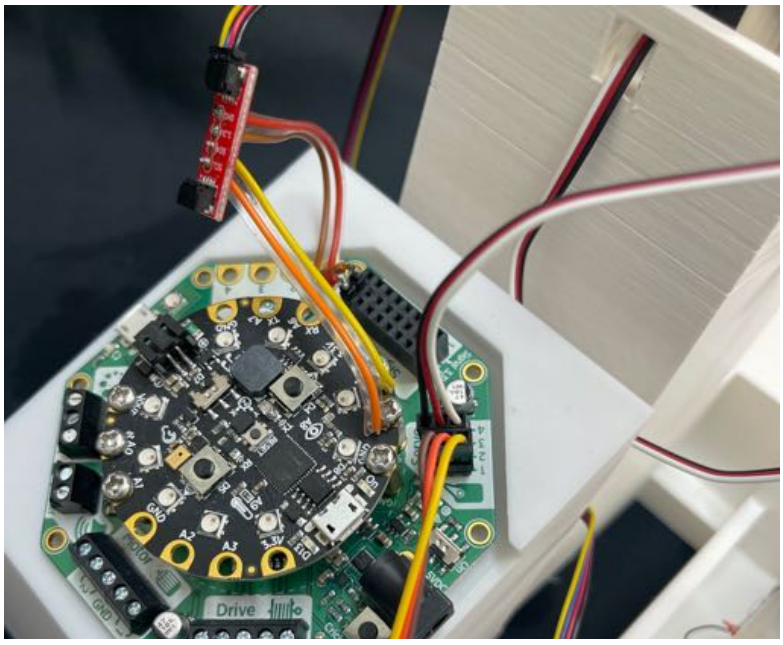
3.35.Plug in Pellet Servo into Row 2 of “Servo” section on CRICKIT (black wire on inner pin, white wire on outer pin).





3.36. Run wire of Positional Servo through nearby hole on Handle Base, and plug into Row 1 of “Servo” section on CRICKIT (brown wire on inner pin, yellow wire on outer pin).





3.37. Place Cage on top of Stage. *Glue in PLA block on inner wall as shown if desired. This block helps to force the rat to only reach with the left forelimb.*

3.38. Place Pellet Receptacle in front right slit of Cage.

3.39. Cut Pellet Tubing (outer diameter: 12.5mm, inner diameter: 9.5mm) to ~94mm in length. Run piping from opening of Pellet Receptacle to opening of Pellet Dispense Tower.