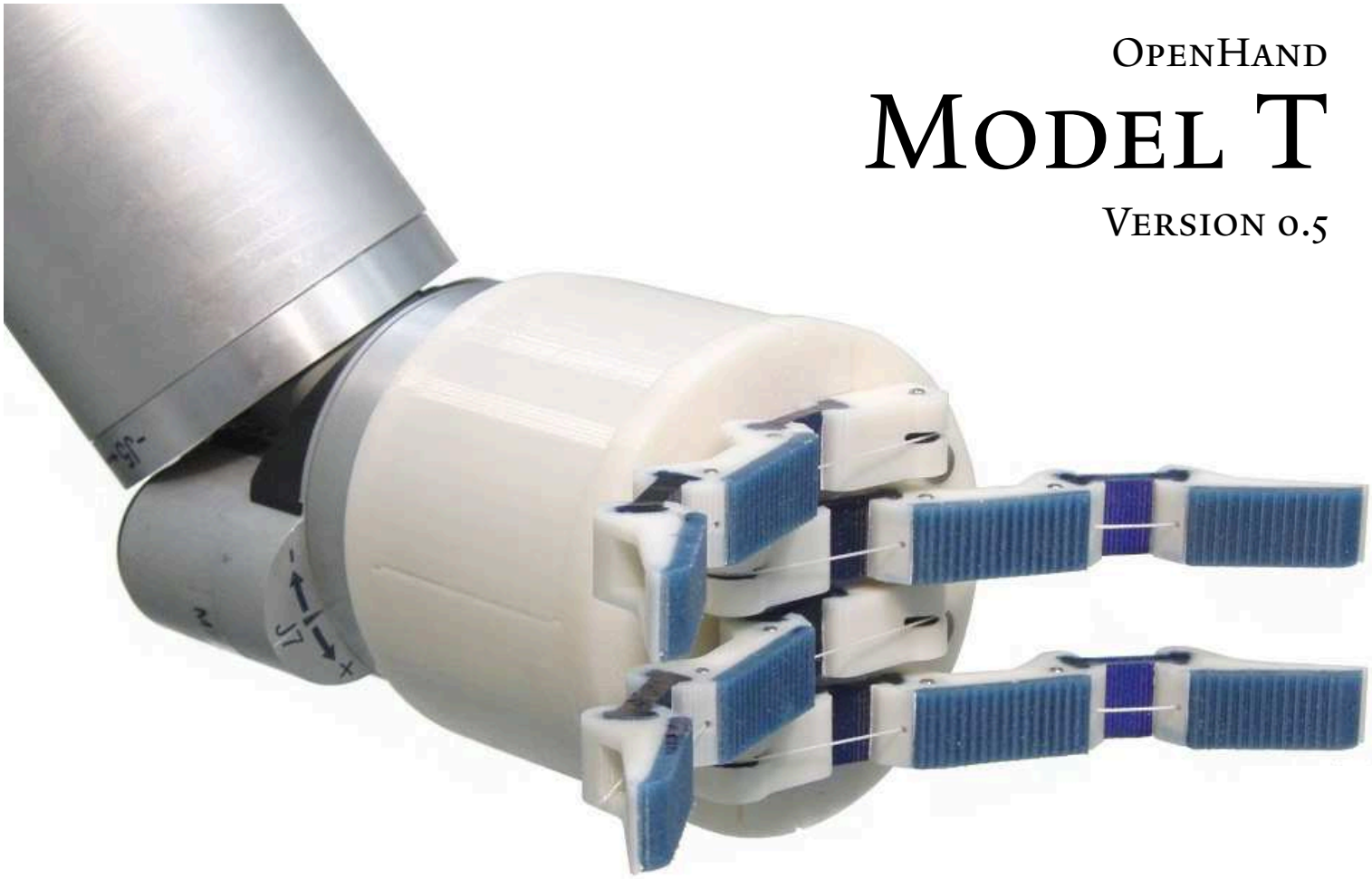
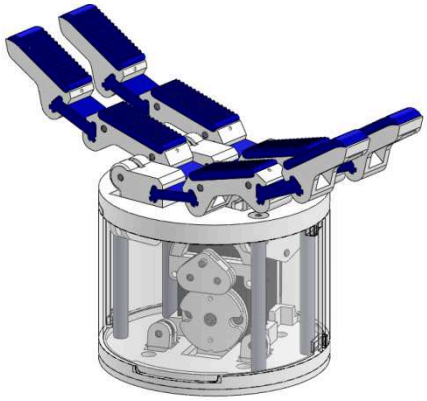
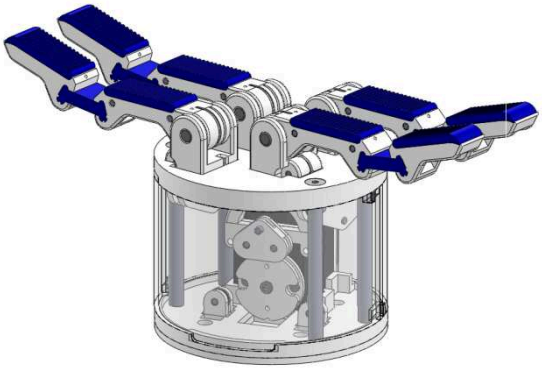


OpenHand

# Model T

Version 0.5





# Assembly Instructions

Last updated: May 23, 2013

the GRAB LAB

# Parts List 1/2 (Flexure Base)

| Part Name | Quantity | Usage | Vendor |
|---|---|---|---|
| a1.stl | 1 | Top Keeper Plate | 3D Print |
| a2.stl | 1 | Top Plate | 3D Print |
| a3.stl | 1 | Bottom Plate | 3D Print |
| a4.stl | 1 | Bottom Keeper Plate | 3D Print |
| b1.stl | 2 | Drive Pulley Block | 3D Print |
| b2.stl | 2 | Routing Base Block | 3D Print |
| b3.stl | 4 | Differential Block | 3D Print |
| b4_a.stl, b4_b.stl | 1 | Servo Block | 3D Print |
| b5.stl | 1 | Servo Pulley | 3D Print |
| d1.stl | 1 | Sunon Fan Clamp* | 3D Print |
| d2_a.stl, d2_b.stl | 1 | Case Shell* | 3D Print |
| finger.stl | 4 | Finger Molds | 3D Print |

* optional

# Parts List 2/2 (Flexure Base)

| Part Name | Quantity | Usage | Vendor |
|---|---|---|---|
| Robotis MX-64 Dynamixel | 1 | Actuator | Robotis [link] |
| Ø1/8", L3/8" steel dowel pin (J1) | 13 | Support Pin | McMaster [98381A470] |
| Ø1/8", L5/8" steel dowel pin (J2) | 12 | Support Pin | McMaster [98381A472] |
| Ø3/8", Wd1/8" nylon pulley (P1) | 12 | Tendon Routing | McMaster [3434T31] |
| Ø1/4", L2-1/2" zinc-plated female standoff (S1) | 4 | Support | McMaster [92474A029] |
| Socket Cap Screw 8-32, L3/4" | 8 | Fastener | McMaster [91253A197] |
| M2.5, L7.5mm bolt | 1 | Fastener | Provided w/ Dynamixel |
| M2, L3mm bolt | 2 | Fastener | McMaster [91292A003] |
| 2-56, L3/4" bolt/nut | 2 | Fastener | McMaster [92196A084] |
| PMC-780 Urethane | 1 | Finger Joint Urethane | Smooth-On [link] |
| Vytaflex 30 Urethane | 1 | Finger Pad Urethane | Smooth-On [link] |
| Sunon 25x10mm 12VDC Fan | 1 | Cooling Fan* | Digikey [link] |
| Power Pro Spectra | 1 | Tendon | Amazon [link] |

* optional

# Parts List 1/2 (Pivot Base)

| Part Name | Quantity | Usage | Vendor |
|---|---|---|---|
| a1.stl | 1 | Top Keeper Plate | 3D Print |
| a2_pivot.stl | 1 | Top Plate | 3D Print |
| a3.stl | 1 | Bottom Plate | 3D Print |
| a4.stl | 1 | Bottom Keeper Plate | 3D Print |
| b1.stl | 2 | Drive Pulley Block | 3D Print |
| b2.stl | 2 | Routing Base Block | 3D Print |
| b3.stl | 4 | Differential Block | 3D Print |
| b4_a.stl, b4_b.stl | 1 | Servo Block | 3D Print |
| b5.stl | 1 | Servo Pulley | 3D Print |
| c1.stl | 4 | Finger Pivot Base | 3D Print |
| d1.stl | 1 | Sunon Fan Clamp* | 3D Print |
| d2_a.stl, d2_b.stl | 1 | Case Shell* | 3D Print |
| finger_pivot.stl | 4 | Finger Molds | 3D Print |

* optional

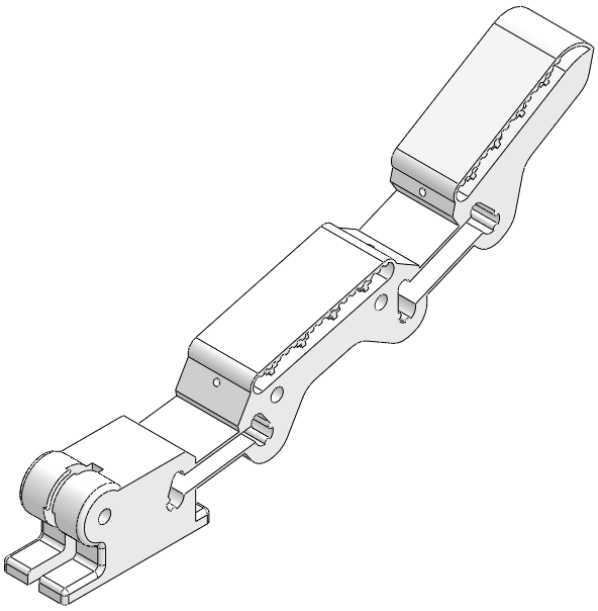
# Parts List 2/2 (Pivot Base)

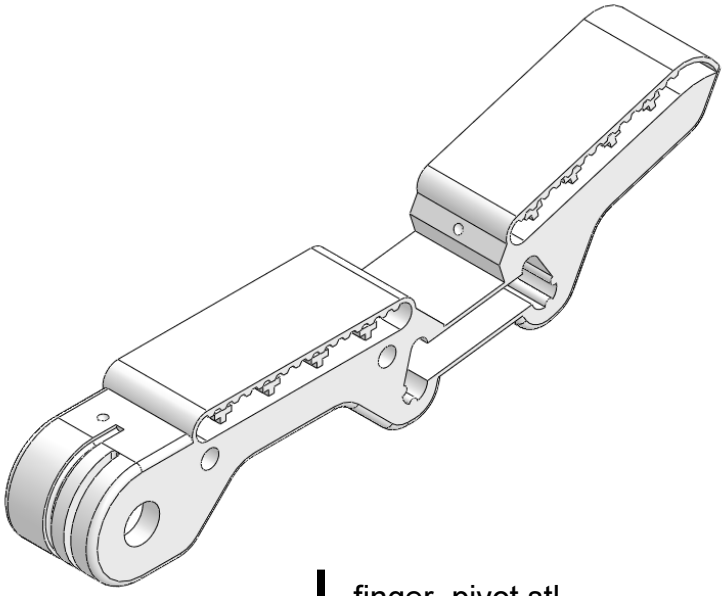
| Part Name | Quantity | Usage | Vendor |
|---|---|---|---|
| Robotis MX-64 Dynamixel | 1 | Actuator | Robotis [link] |
| Ø1/8", L3/8" steel dowel pin (J1) | 13 | Support Pin | McMaster [98381A470] |
| Ø1/8", L5/8" steel dowel pin (J2) | 12 | Support Pin | McMaster [98381A472] |
| Ø1/4", L1" steel dowel pin (J3) | 4 | Joint Pin | McMaster [98381A542] |
| Ø3/8", Wd1/8" nylon pulley (P1) | 12 | Tendon Routing | McMaster [3434T31] |
| Ø1/4", L2-1/2" zinc-plated standoff | 4 | Support | McMaster [92474A029] |
| Socket Cap Screw 8-32, L3/4" | 8 | Fastener | McMaster [91253A197] |
| M2.5, L7.5mm bolt | 1 | Fastener | Provided w/ Dynamixel |
| M2, L3mm bolt | 2 | Fastener | McMaster [91292A003] |
| 2-56, L3/4" bolt/nut | 2 | Fastener | McMaster [92196A084] |
| Torsion Spring, Ø0.34", 0.028" wire diameter, 180˚, left-hand wound | 4 | Joint Return Spring | McMaster [9271K605] |
| PMC-780 Urethane | 1 | Finger Joint Urethane | Smooth-On [link] |
| Vytaflex 30 Urethane | 1 | Finger Pad Urethane | Smooth-On [link] |
| Sunon 25x10mm 12VDC Fan | 1 | Cooling Fan* | Digikey [link] |
| Power Pro Spectra | 1 | Tendon | Amazon [link] |

* optional

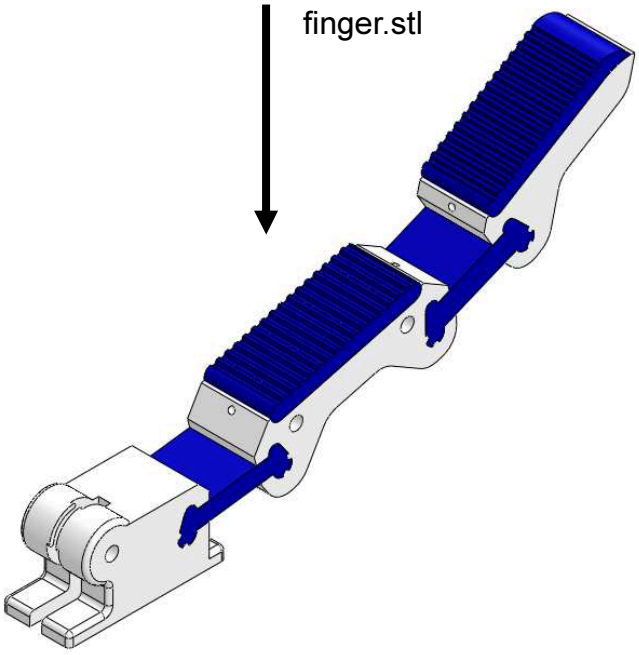
# Part Preparation

## FINGER MOLDING

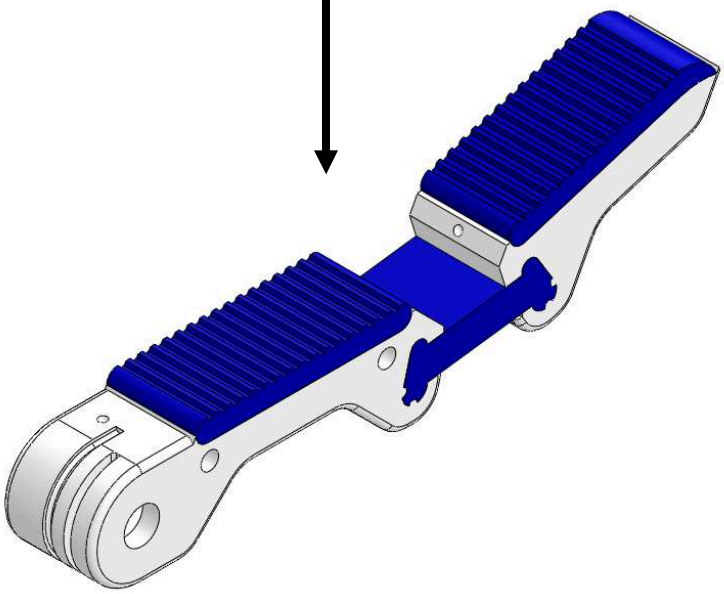


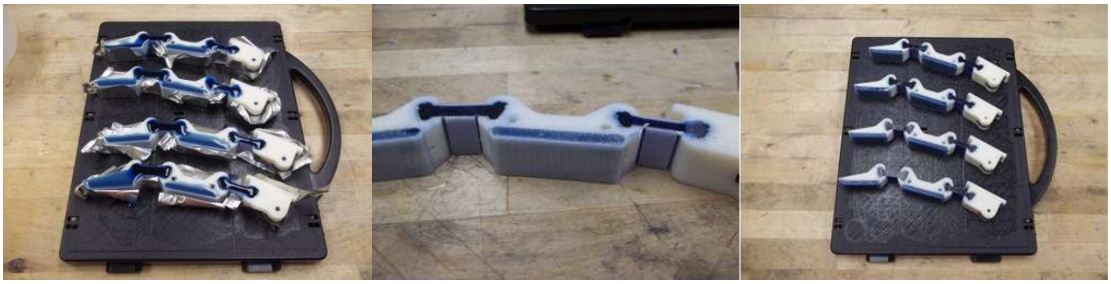


finger.stl



finger_pivot.stl

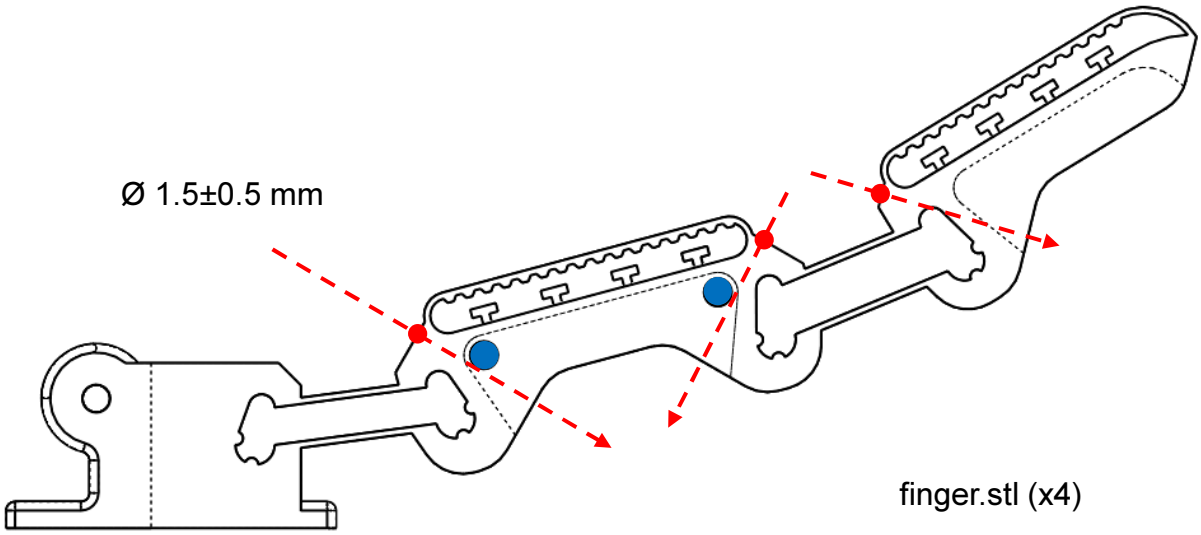


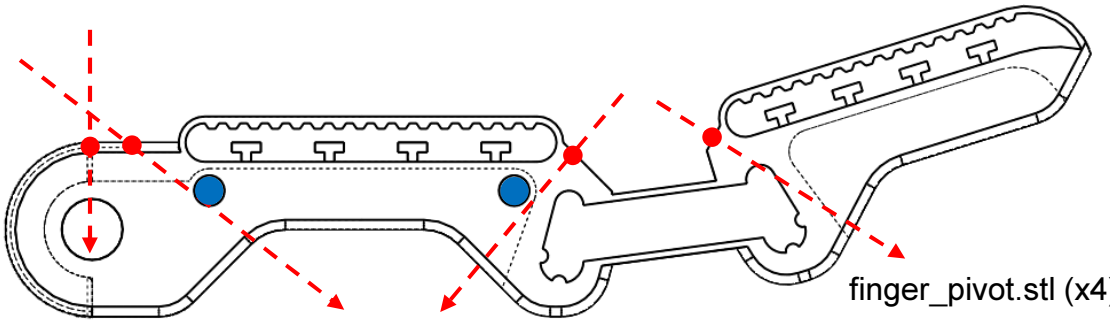


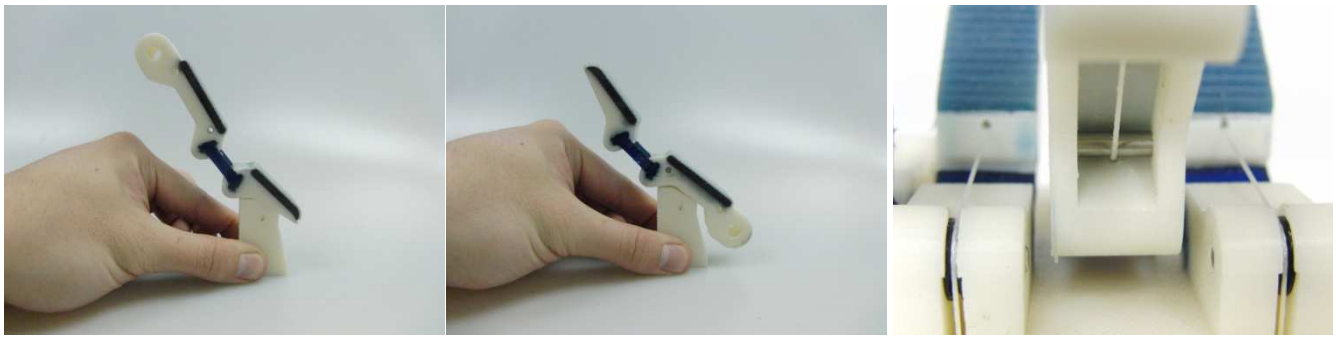
Consult DDM (Dieless Deposition Manufacturing) guide for further details on pouring/preparing the joints and pads for fingers

# Part Preparation

## TENDON ROUTING



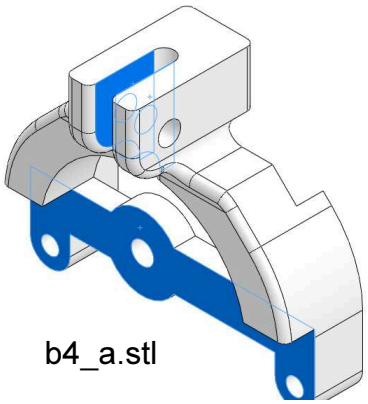



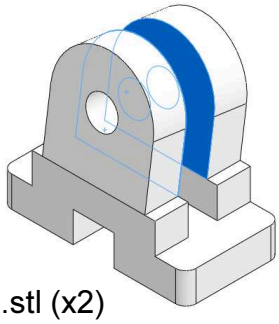
Drill tendon routing holes such that tendon will run tangent to inserted pin. Minimize contact between tendon and ABS but ensure that tendon runs freely. Use *helper_jig.stl* to aid in positioning. Hole should be drilled perpendicular to routing surface.

# Part Preparation

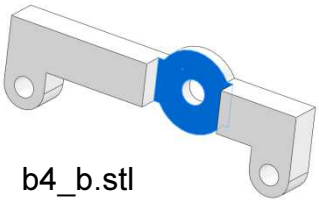
## SURFACE FILING/DEBURRING



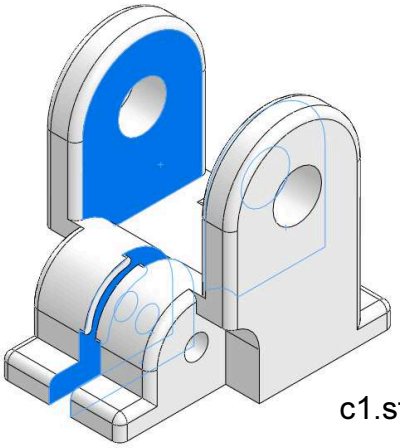
b4_a.stl



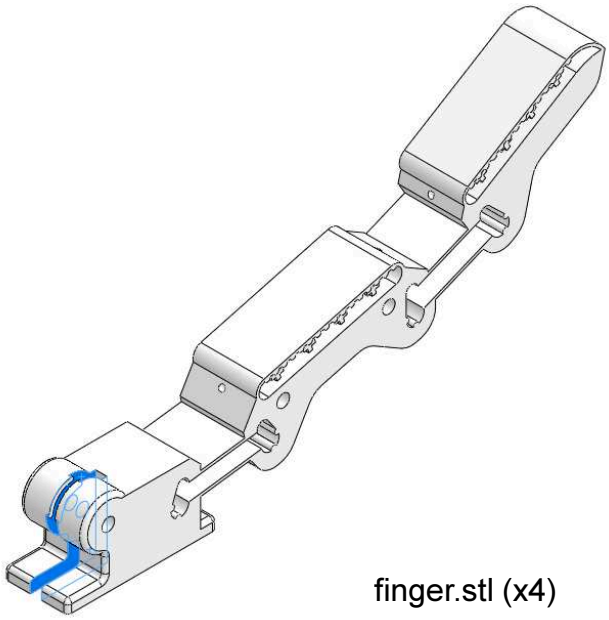
b2.stl (x2)



b4_b.stl



c1.stl (x4)

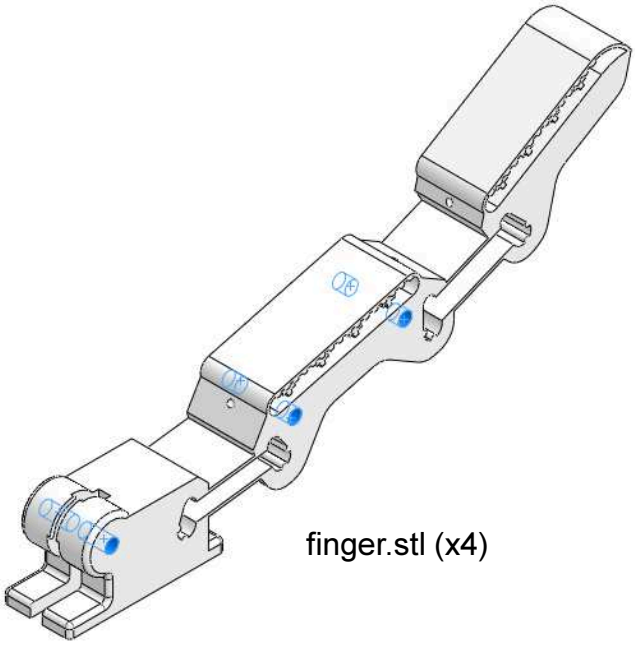


finger.stl (x4)

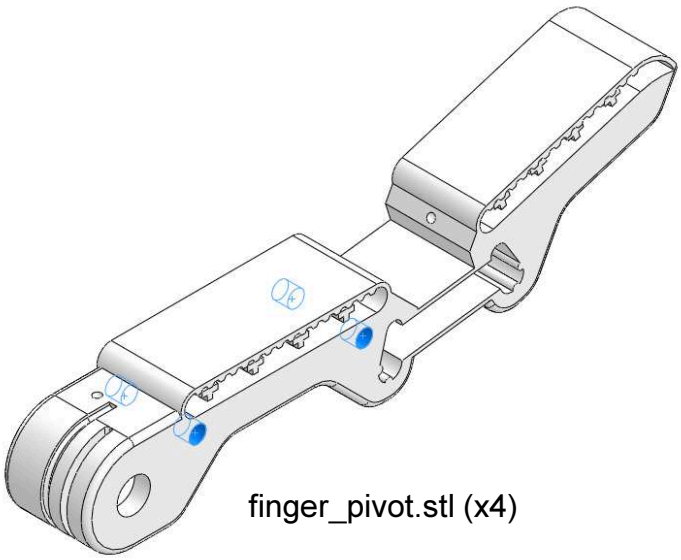
File down and deburr bearing surfaces as indicated above. Ensure that no support material remains, if applicable. Complementary piece (ie. pulley, finger) should slide in freely.

# Part Preparation

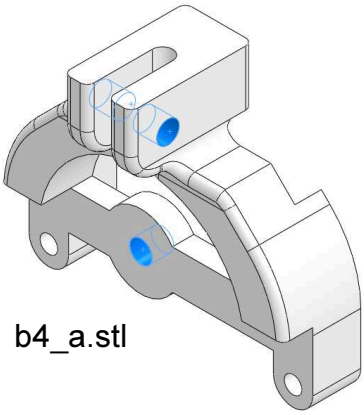
## reaming (1/8" pin holes)



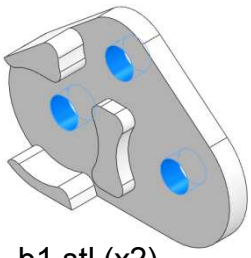
finger.stl (x4)



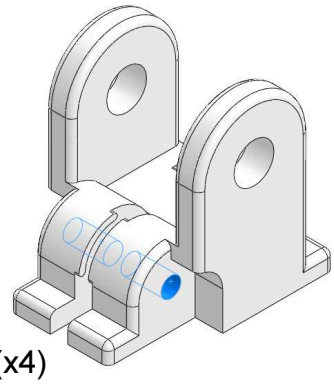
finger_pivot.stl (x4)



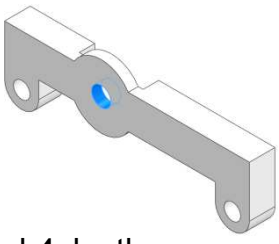
b4_a.stl



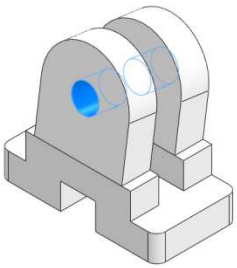
b1.stl (x2)



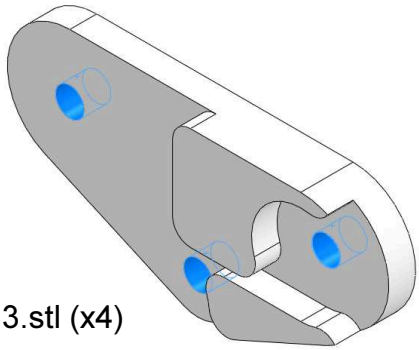
c1.stl (x4)



b4_b.stl



b2.stl (x2)

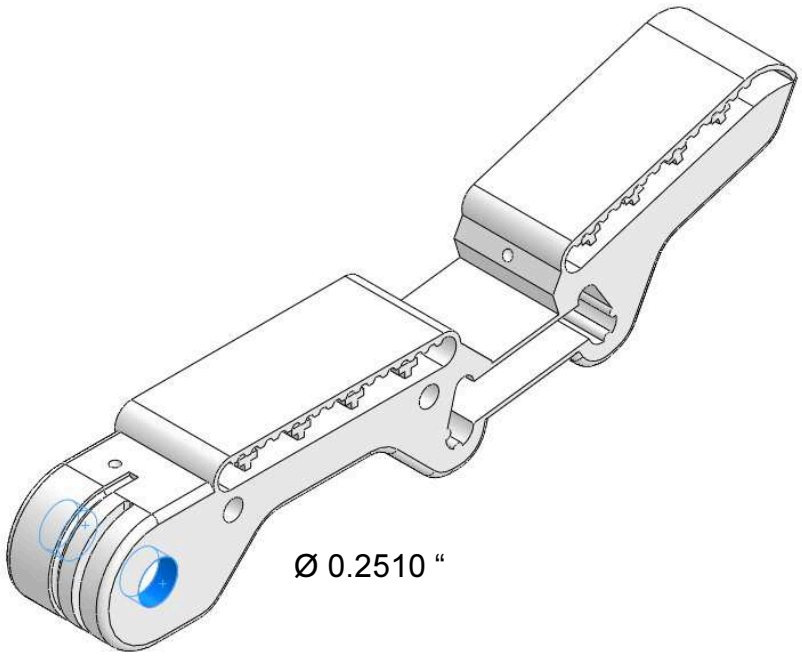


b3.stl (x4)

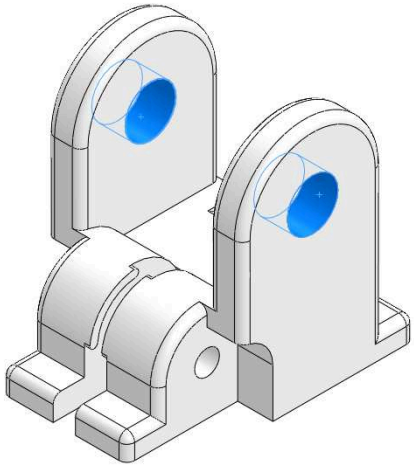
Use Ø0.1240" reamer to prepare pin holes as indicated above. This step can be skipped in lieu of precise 3D printer calibration and parameter selection, but manual reaming is the recommended approach.

# Part Preparation

## reaming (pivot bases)




finger_pivot.stl (x4)

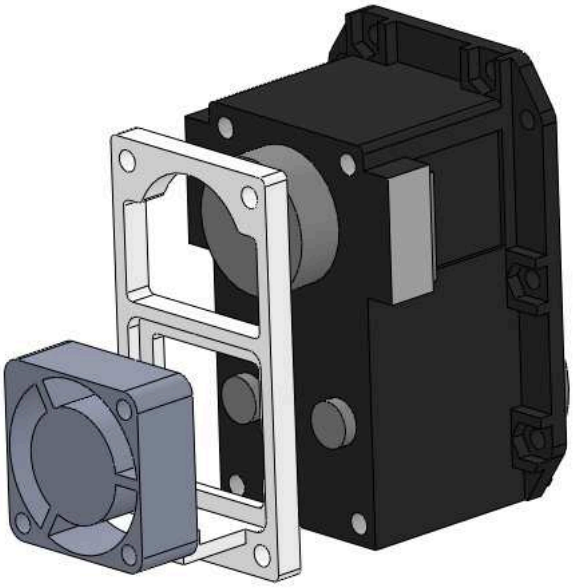



c1.stl (x4)

Use Ø0.2490” reamer to prepare pin holes on pivot bases *c1.stl*, and Ø0.2510” reamer to prepare pin holes on the corresponding fingers *finger_pivot.stl.* Finger should spin freely and loosely on a Ø0.25” steel pin

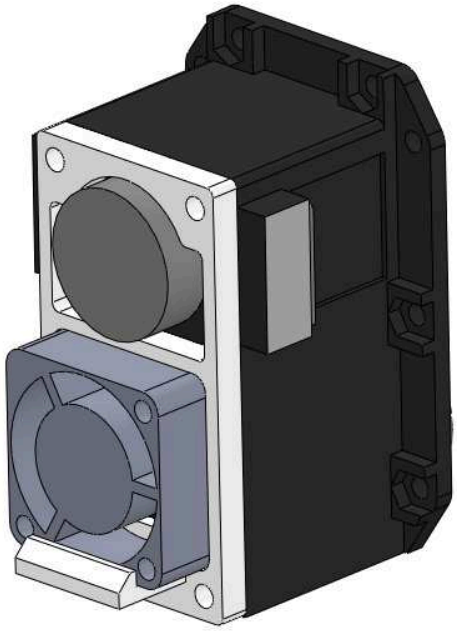
# ASSEMBLY

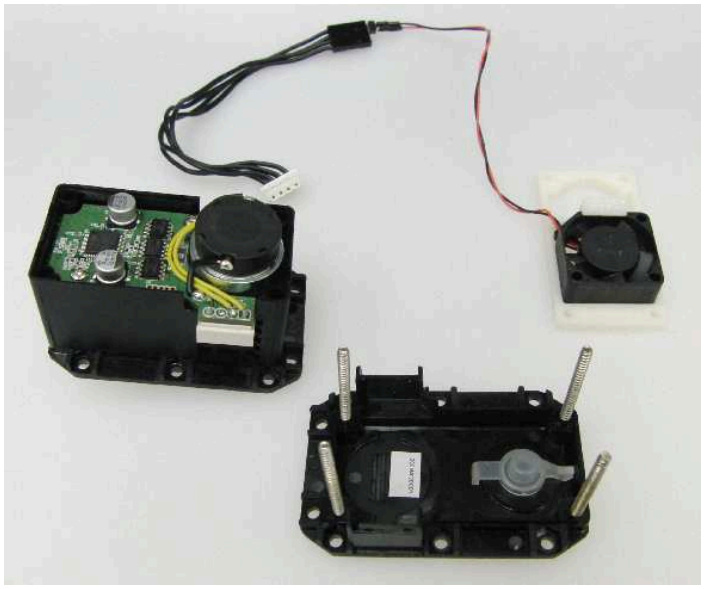
## BLOCK_ACTUATOR



**Parts:**

- Dynamixel MX-64
- d1.stl
- Sunon 12VDC fan

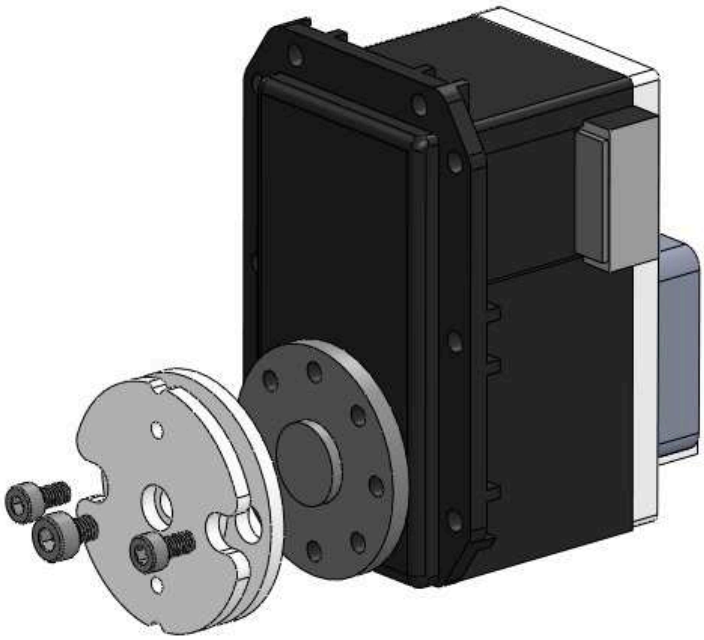




Remove back of Dynamixel MX-64 and replace with fan clamp *d1.stl*. Sunon fan snaps into place. Use same existing screws to attach clamp frame *d1.stl* to servo. Skip this step is fan implementation is not desired.

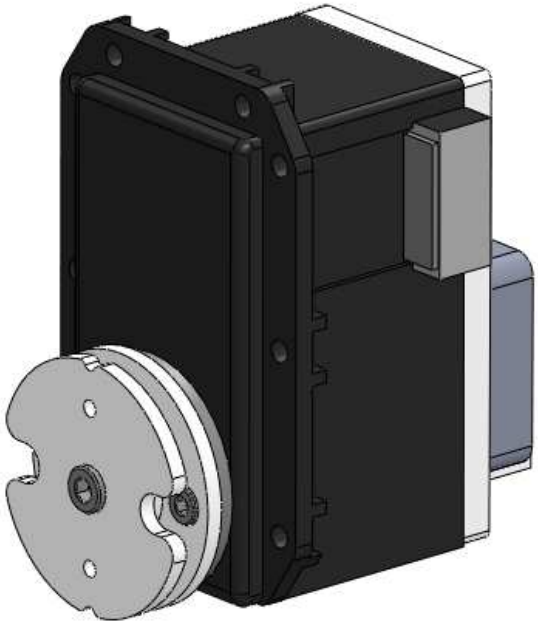
# Assembly

## BLOCK_ACTUATOR



**Parts:**

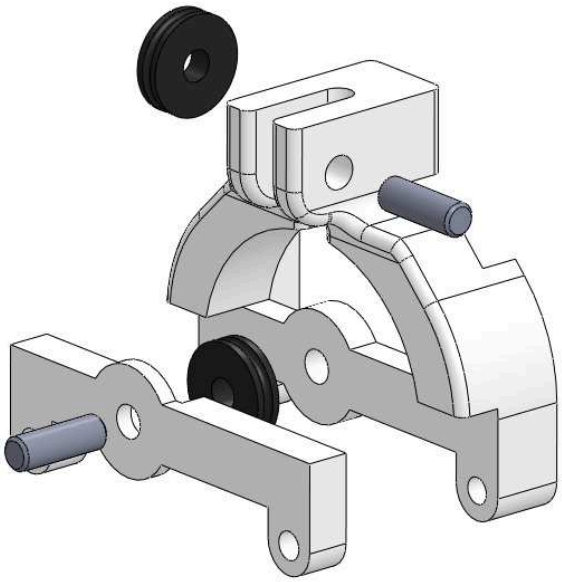
- Sub-assembly from step 6
- b5.stl
- M2.5, L7.5mm bolt
- M2, L3mm bolt



Assemble main drive pulley onto actuator block sub-assembly as shown. M2 bolts should not interfere with servo rotation after assembly.

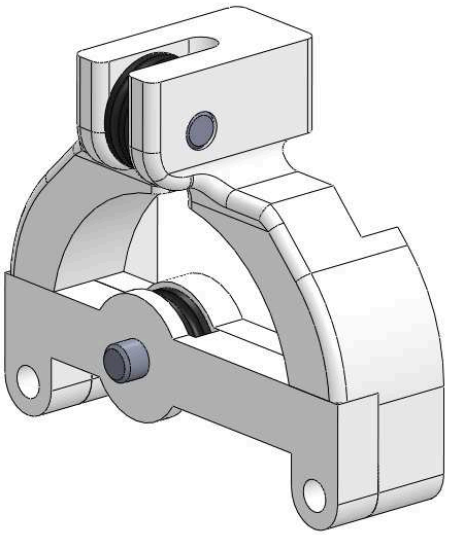
# ASSEMBLY

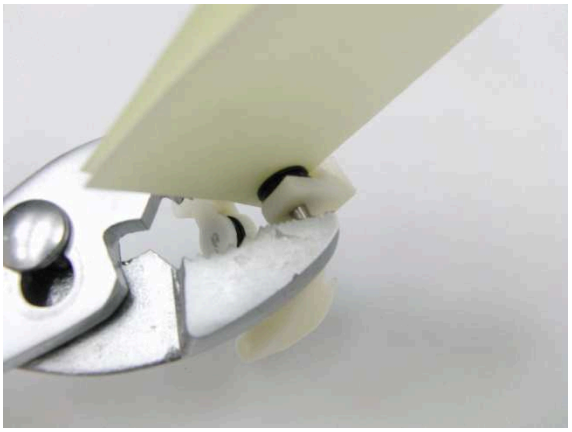
## BLOCK_ACTUATOR



**Parts:**

- Pulley P1 (x2)
- L3/8” pin J1 (x2)
- b4_a.stl
- b4_b.stl

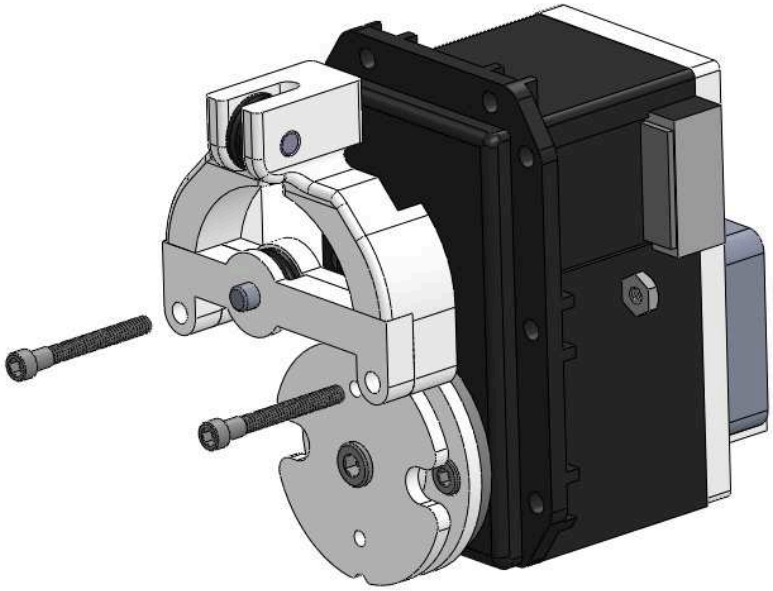




Assemble re-routing sub-assembly as shown above. It is suggested that a paper shim is used when press-fitting the top pin to ensure that the pulley is not pinched.

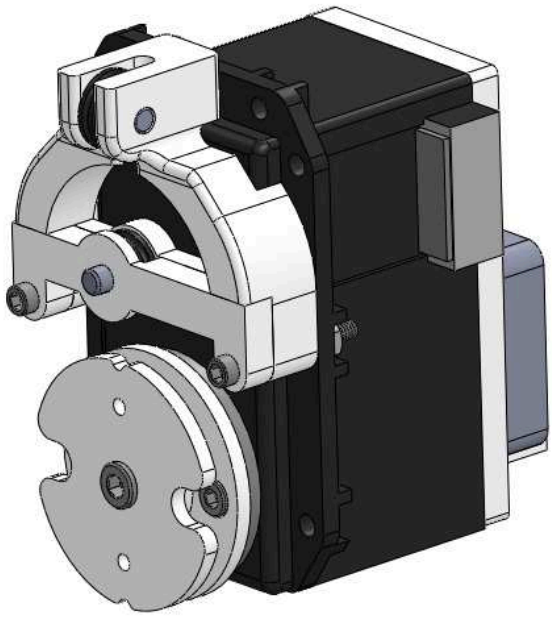
# Assembly

## BLOCK_ACTUATOR



**Parts:**

- Sub-assembly from step 7
- Sub-assembly from step 8
- 2-56 L3/4” machine bolt/nut (x2)



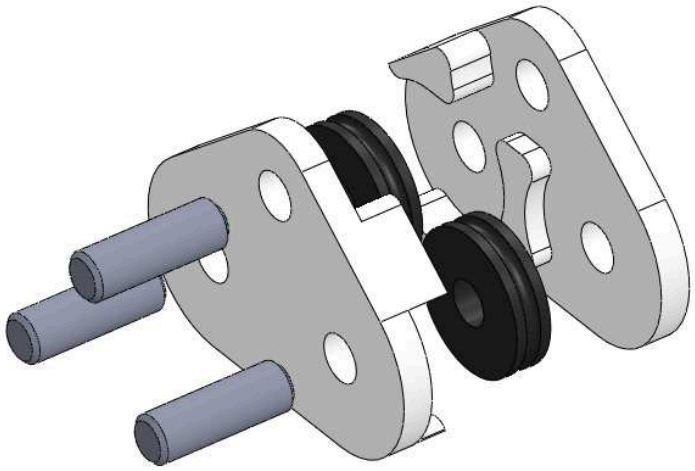
Finish assembly block actuator sub-assembly as shown above. Any bolt/nut pairing of size in close approximation to 2-56 can also be used here. Ensure that both nylon pulleys spin freely.

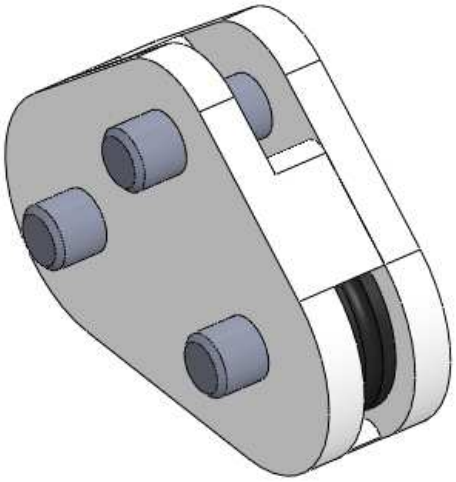
# ASSEMBLY

## PULLEY BLOCKS

**Parts:**

- b1.stl (x2)
- Pulley P1 (x2)
- L3/8” pin J1 (x3)





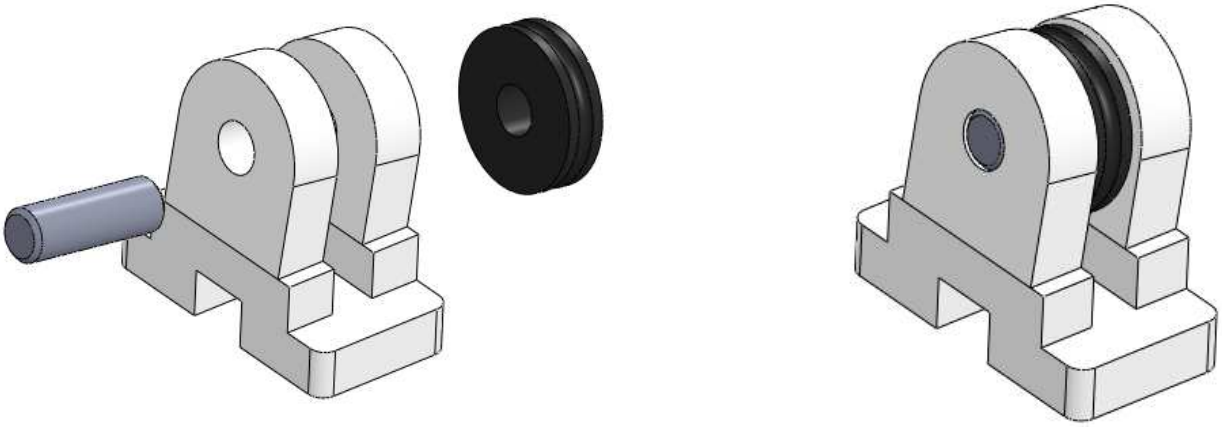
x1

Assemble the drive pulley block as shown above. Shorter steel pins can be used if desired, but pins must be longer than overall thickness of drive pulley sub-assembly

# ASSEMBLY

## PULLEY BLOCKS

**Parts:**
- b2.stl (x2)
- Pulley P1 (x2)
- L3/8” pin J1 (x2)



x2

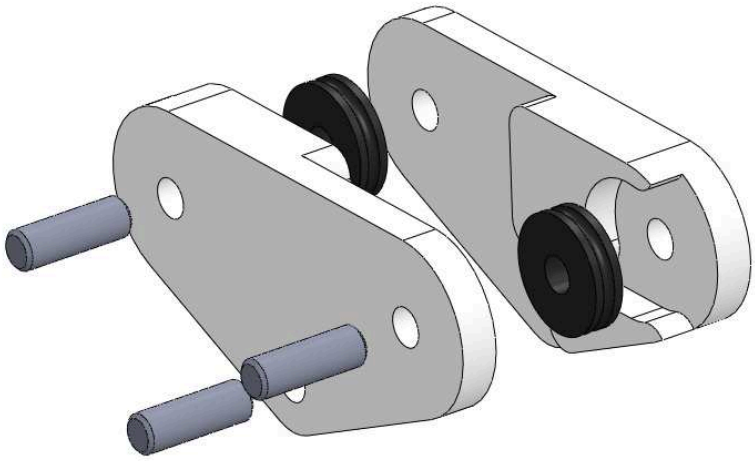
Assemble the sets of pulley blocks as shown above. Ensure that all pulleys can spin freely. Use a paper shim during assembly with *b2.stl* to avoid pinching.

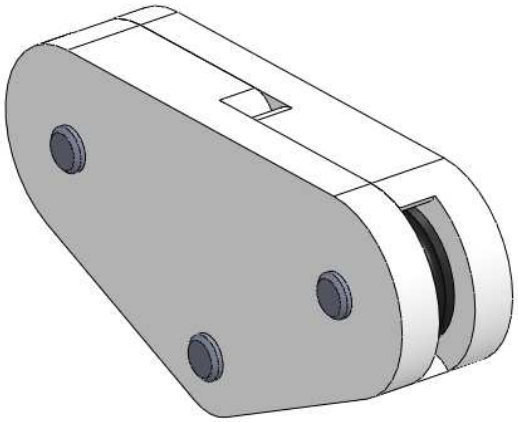
# ASSEMBLY

## PULLEY BLOCKS

**Parts:**

- b3.stl (x4)
- Pulley P1 (x4)
- L3/8” pin J1 (x6)



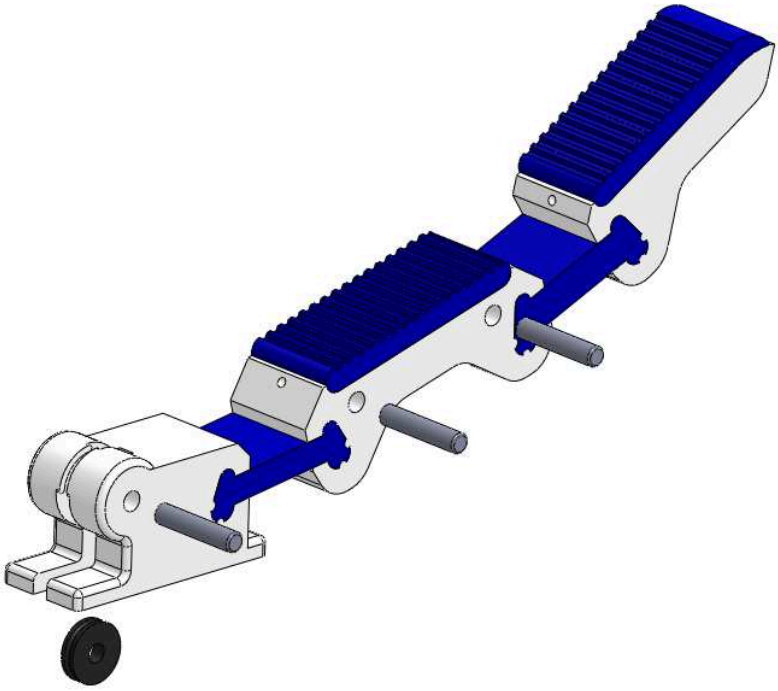


x2

Assemble 2 sets of differential pulley blocks as shown above.

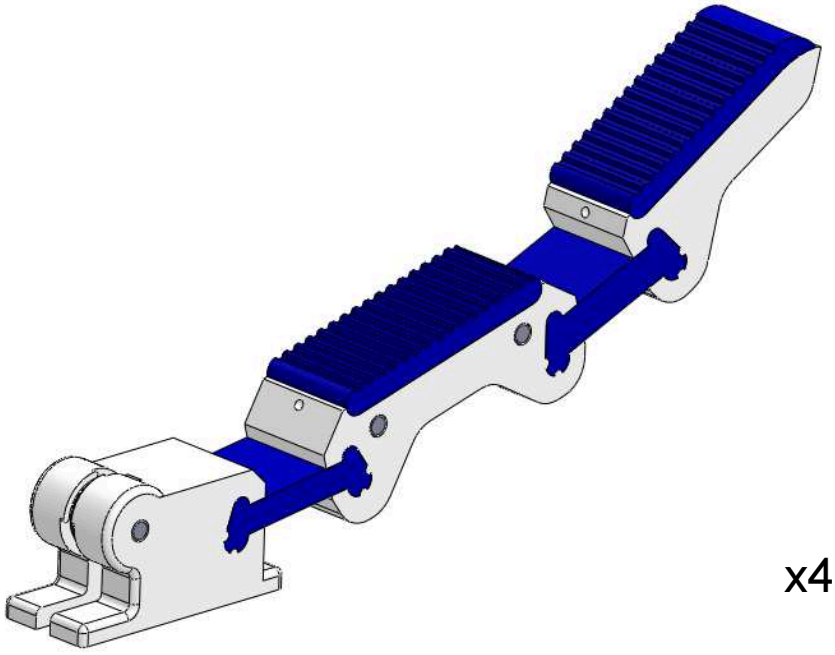
# ASSEMBLY

## FLEXURE-BASE FINGERS



**Parts:**

- finger.stl (x4)
- Pulley P1 (x4)
- L5/8” pin J2 (x12)

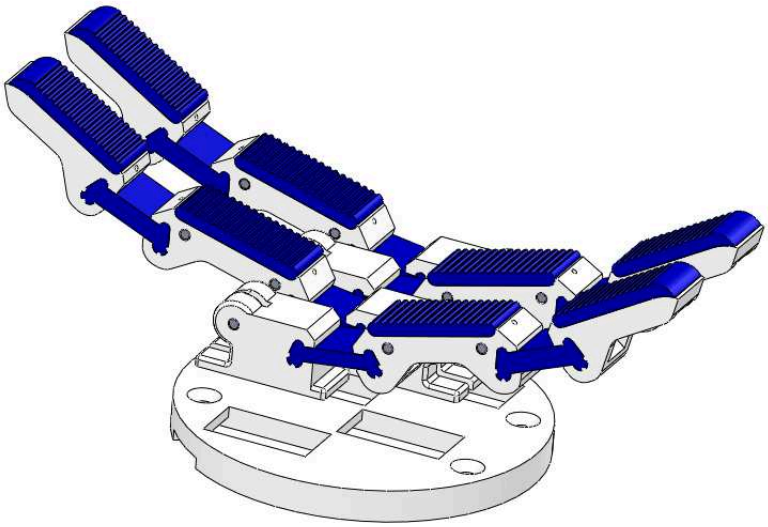


x4

For pivot-base fingers, skip to step 17. Use a shim as done in steps 8 and 11 to ensure that nylon pulley spins freely at finger base

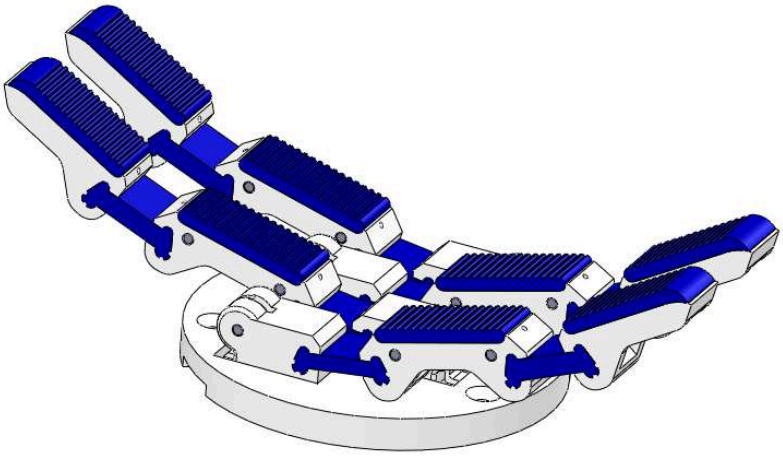
# Assembly

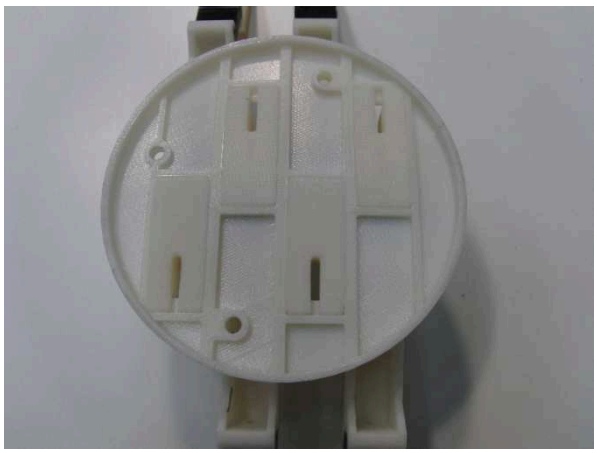
## FLEXURE-BASE FINGERS TOP

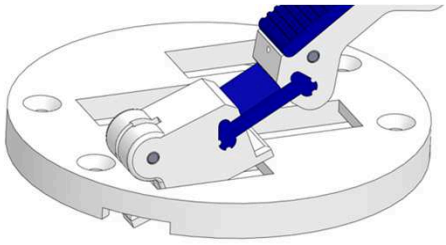


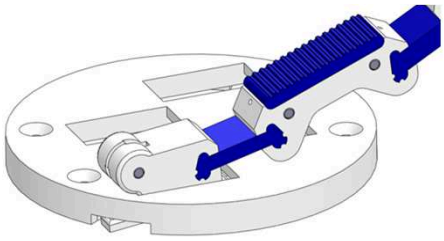
**Parts:**

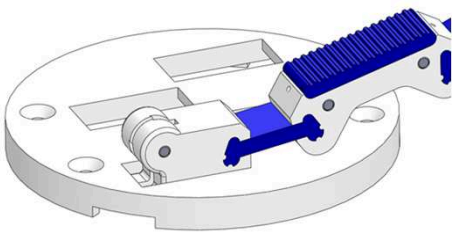
- Finger sub-assembly from step 13 (x4)
- a2.stl







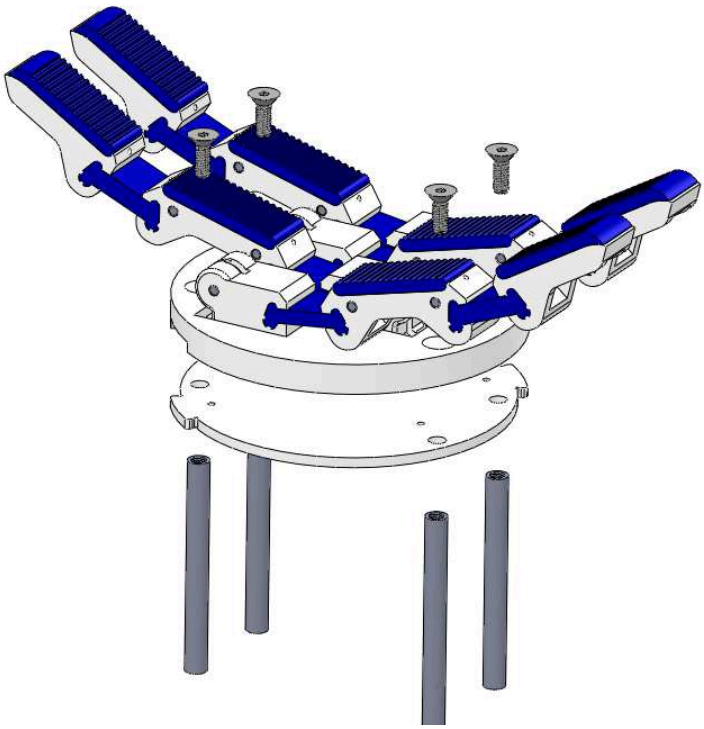




Insert fingers into top plate from above as illustrated in the figures. Finger base should lie flush with plate *a2.stl*

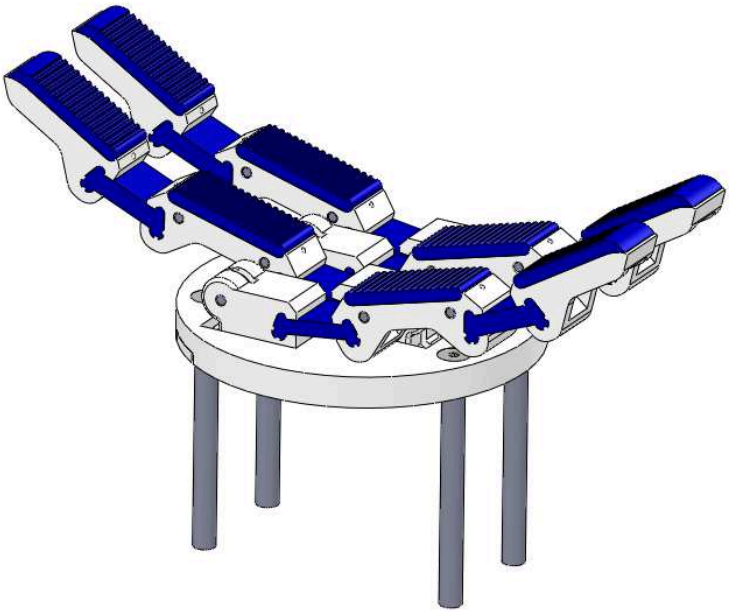
# Assembly

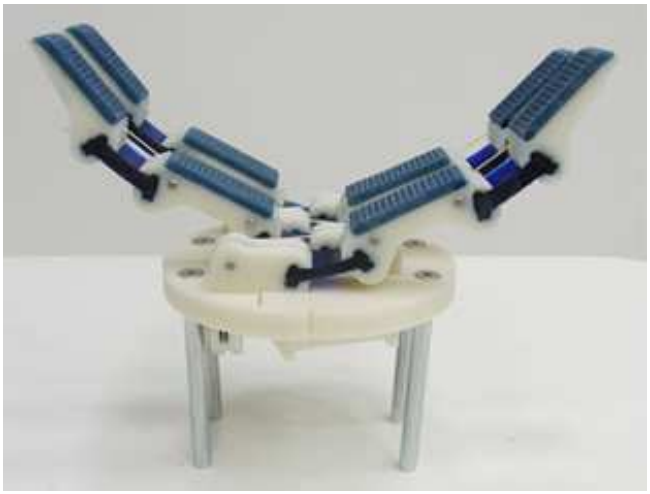
## FLEXURE-BASE FINGERS TOP



**Parts:**

- Sub-assembly from step 14
- a1.stl
- Female standoffs S1 (x4)
- 8-32 Socket Cap Screws (x4)

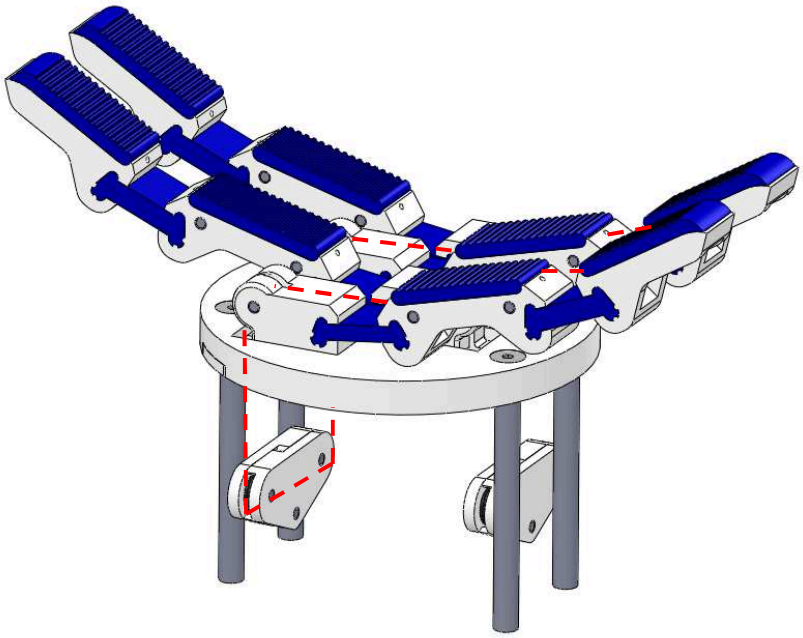




Use socket cap screws and standoffs to fully assemble the top flexure-base sub-assembly. Plates *a1.stl* and *a2.stl* should sandwich and immobilize the finger bases

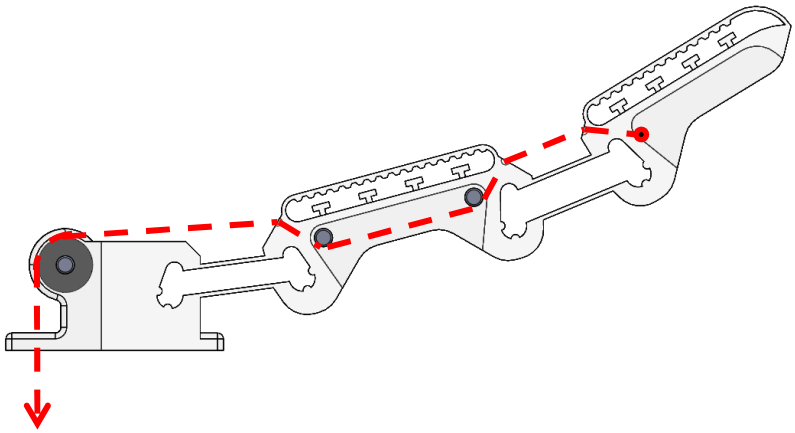
# Assembly

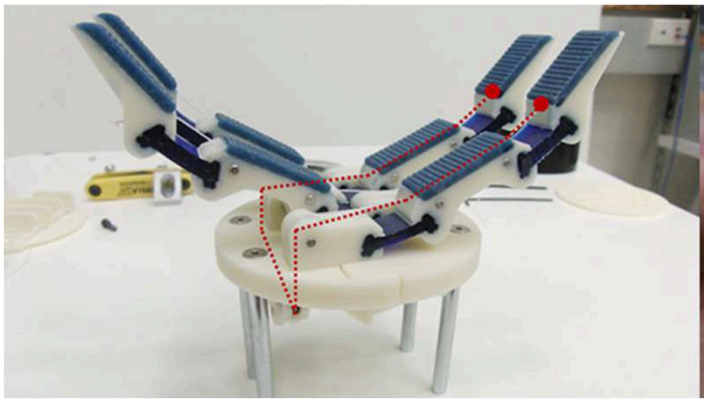
## FLEXURE-BASE FINGERS TOP

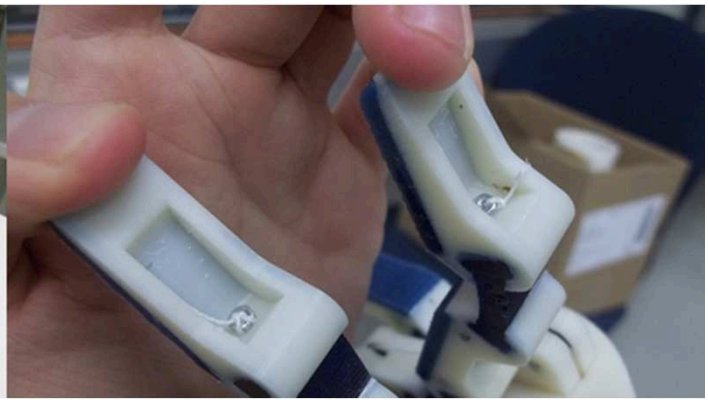


**Parts:**

- Sub-assembly from step 15
- Sub-assemblies from step 12 (x2)
- Spectra Tendon ~8” (x2)



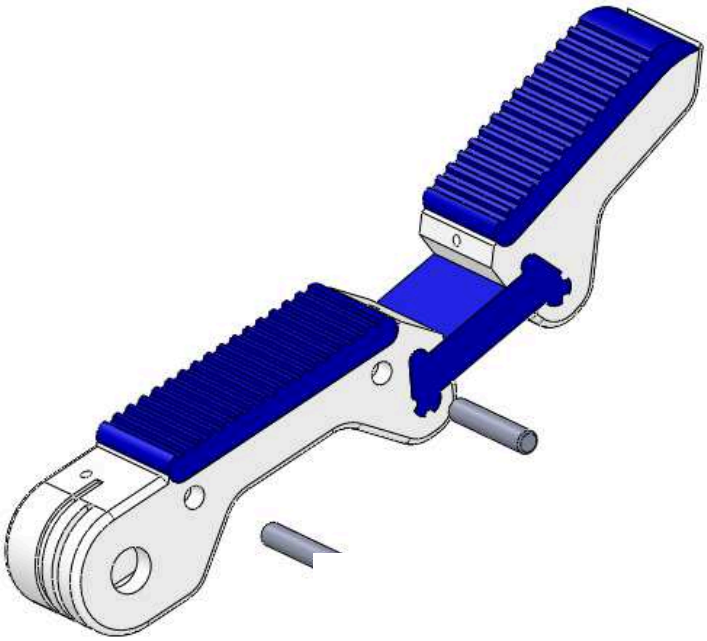


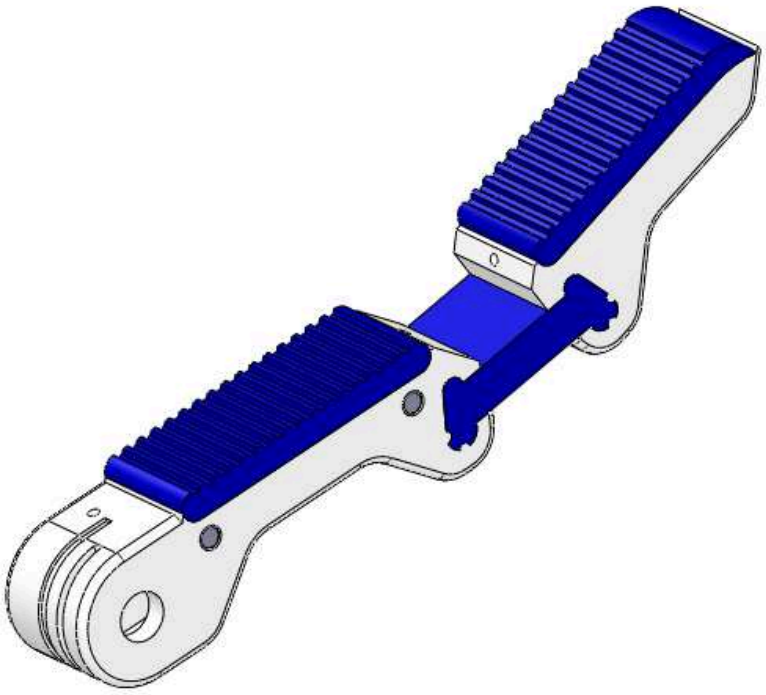


Use tendon to affix differential sub-assembly blocks to the sub-assembly made in the last step. Tendon length should be set such that it is taut when the fingers are at rest. Tendon tied off to small nut at back of finger.

# ASSEMBLY

## PIVOT-BASE FINGERS





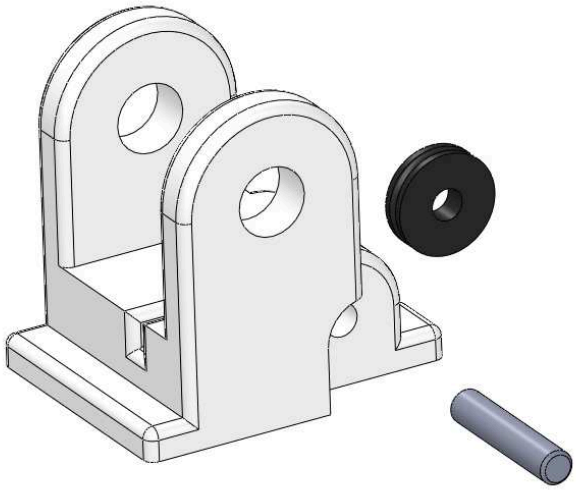
**Parts:**

- finger_pivot.stl (x4)
- L5/8” pin J2 (x8)

Assemble re-routing pins to fingers as shown in figures above.

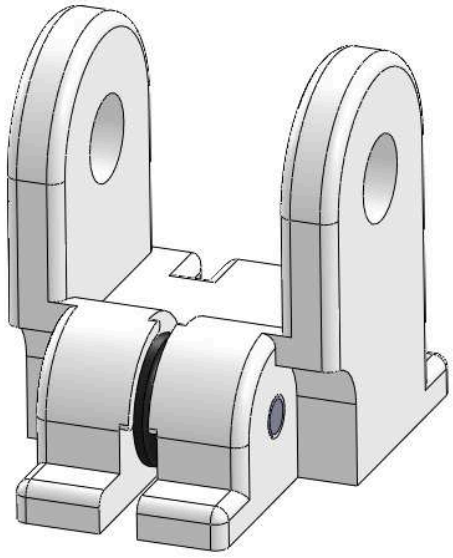
# Assembly

## PIVOT-BASE FINGERS



**Parts:**

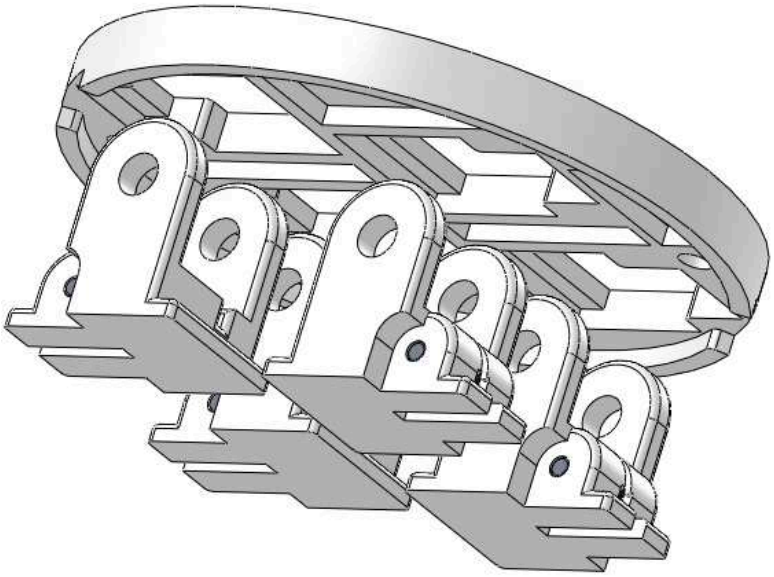
- c1.stl (x2)
- L5/8” pin J2 (x2)
- Pulley P1 (x2)



Assemble pivot base sub-assembly as shown. Use shim when press-fitting the pin and pulley to ensure that the pulley spins freely after assembly.

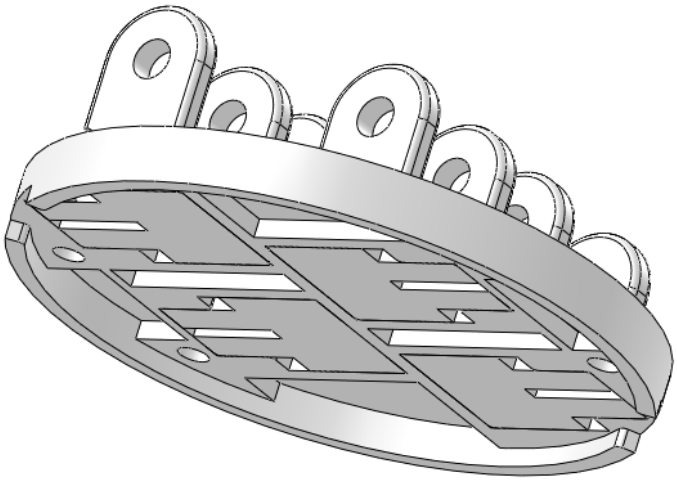
# Assembly

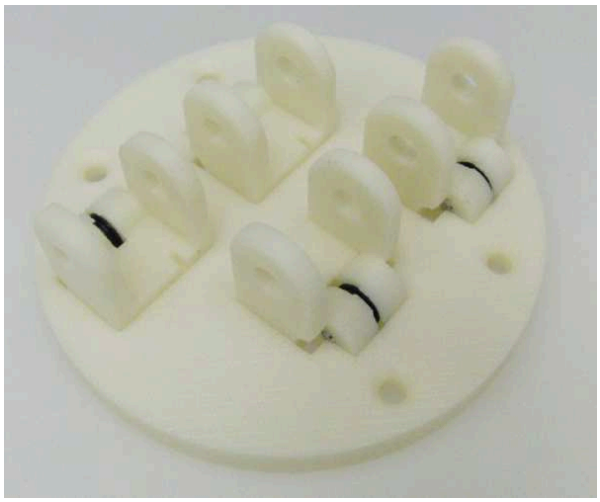
## PIVOT-BASE FINGERS TOP



**Parts:**

- Sub-assemblies from step 18 (x4)
- a2_pivot.stl

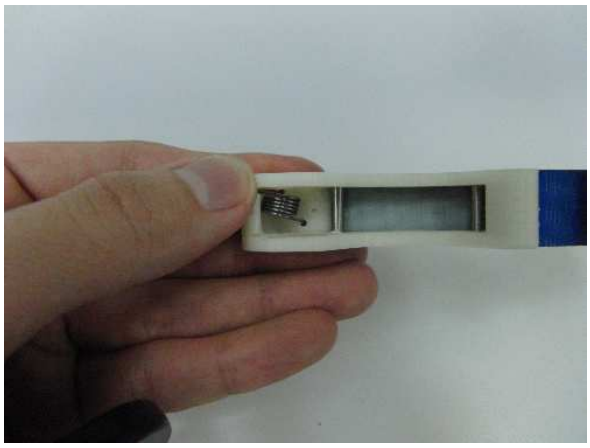


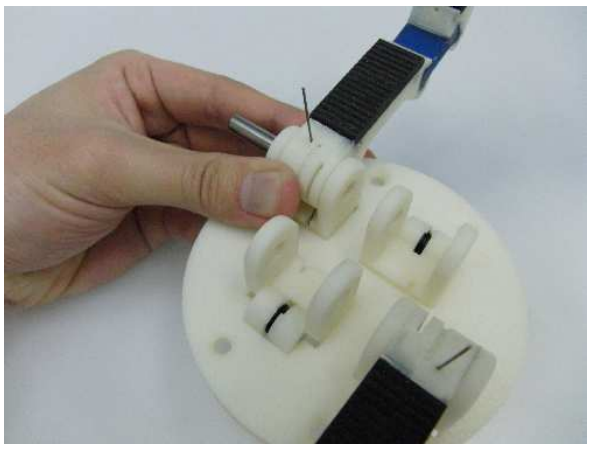


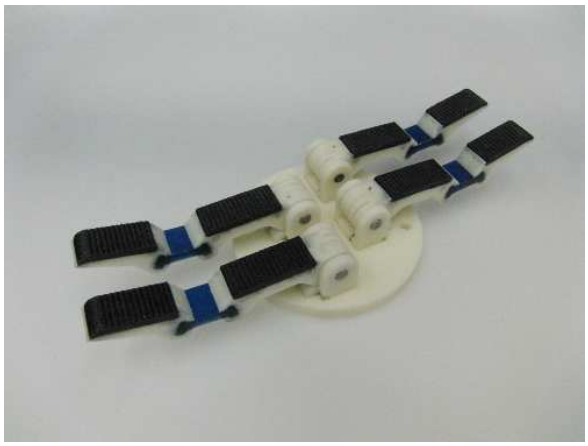
Assemble top pivot base plate as shown above. The finger pivot bases should fit flush with the top plate.

# Assembly

## PIVOT-BASE FINGERS TOP

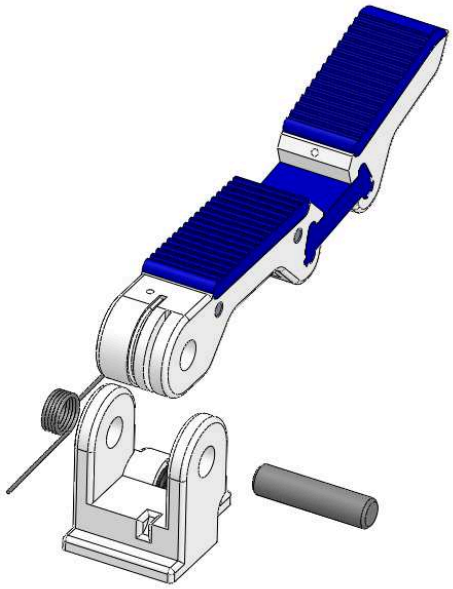






**Parts:**

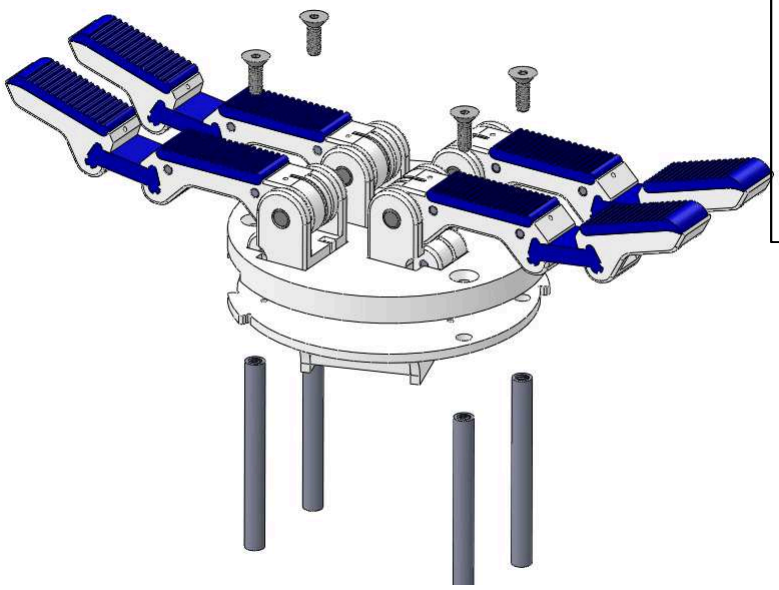
- Sub-assembly from step 19
- Finger sub-assemblies from step 17
- Steel pin J3 (x4)
- Torsion spring (x4)



Assemble fingers onto top plate as shown above. Ends of torsion spring align with opening on finger and slot in finger base. Cut off excess torsion spring ends when done. Ensure that the fingers rotate without friction.

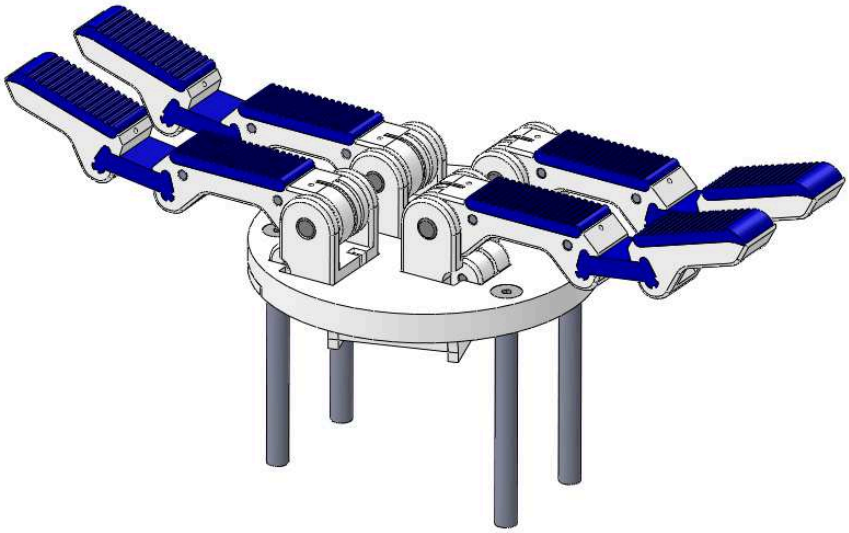
# Assembly

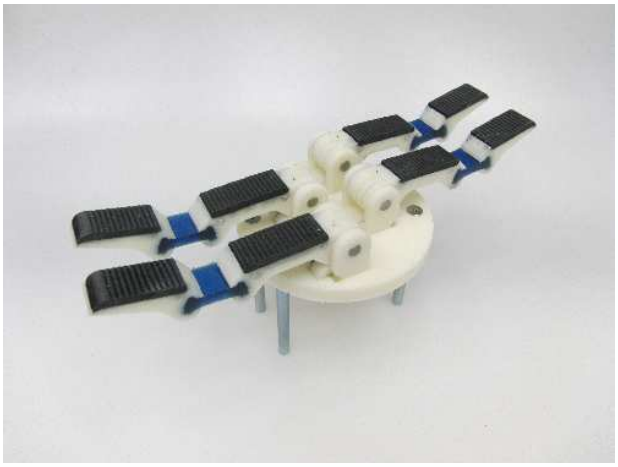
## PIVOT-BASE FINGERS TOP



**Parts:**

- Sub-assembly from step 20
- a1.stl
- Female standoffs S1 (x4)
- 8-32 Socket Cap Screws (x4)



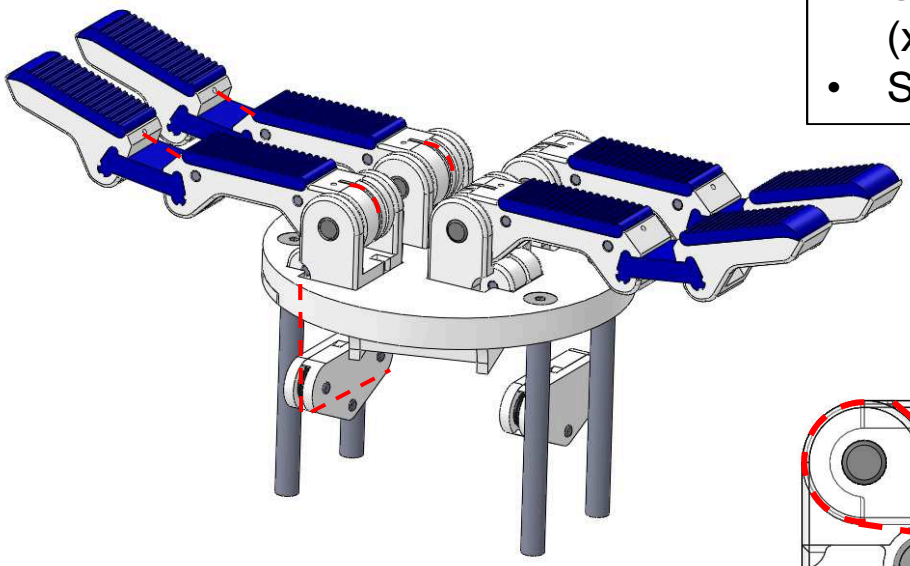


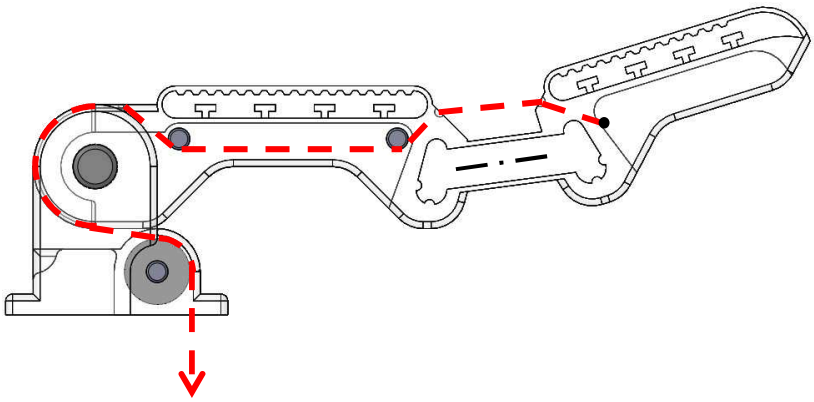
Use socket cap screws and standoffs to fully assemble the top flexure-base sub-assembly. Plates *a1.stl* and *a2_pivot.stl* should sandwich and immobilize the finger bases

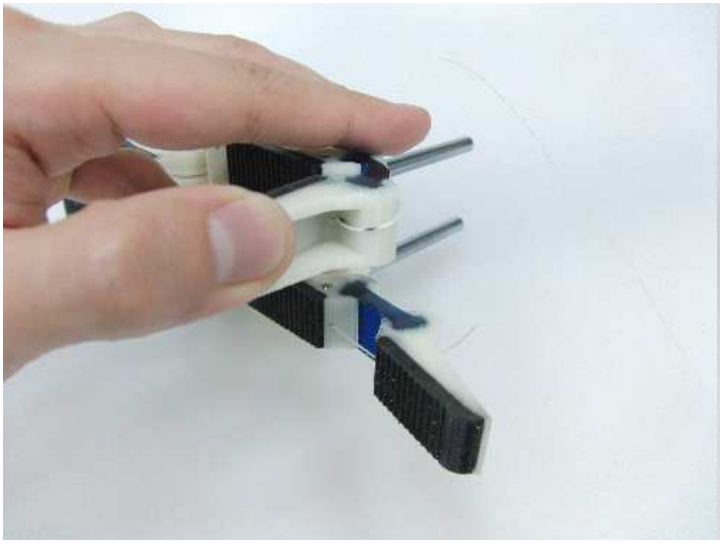
# Assembly

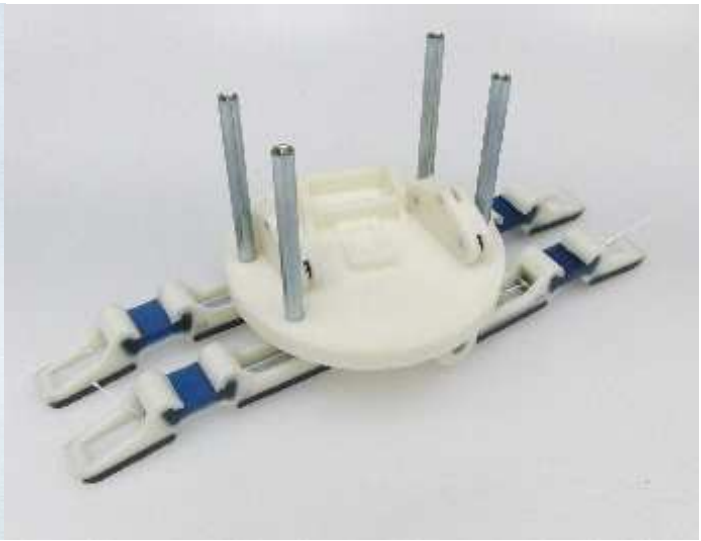
## PIVOT-BASE FINGERS TOP

**Parts:**
- Sub-assembly from step 21
- Sub-assemblies from step 12 (x2)
- Spectra Tendon ~8” (x2)





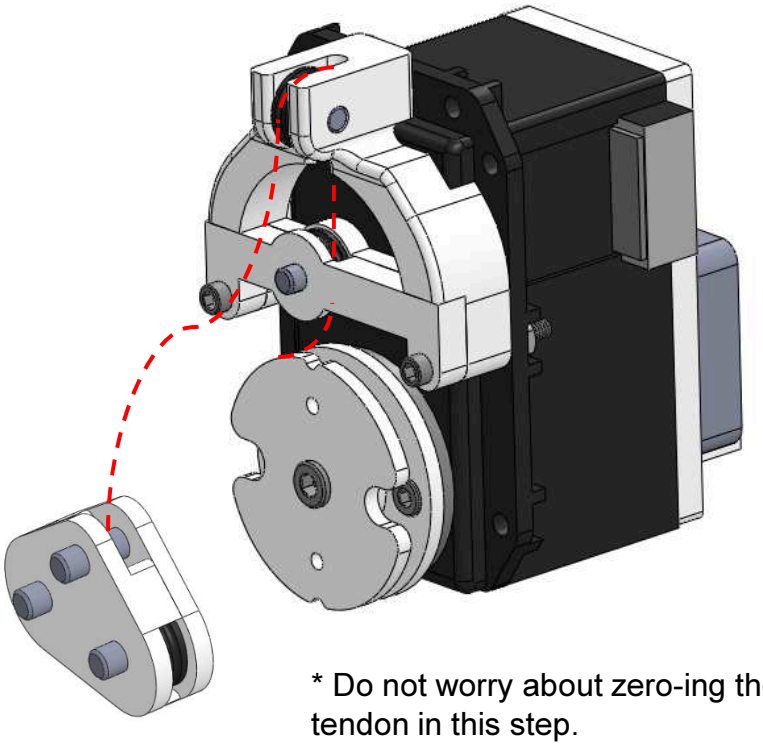




Use tendon to affix differential sub-assembly blocks to the sub-assembly made in the last step. Tendon length should be set such that it is taut when the fingers are at rest. Tendon tied off to small nut at back of finger.

# ASSEMBLY

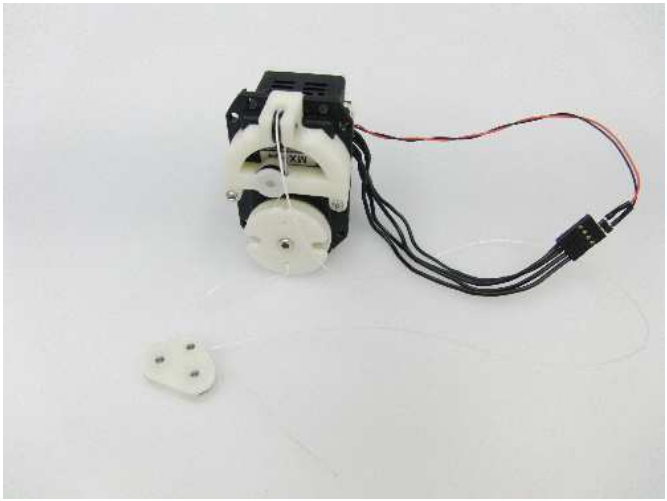
## PIVOT-BASE FINGERS TOP



**Parts:**

- Sub-assembly from step 9
- Sub-assembly from step 10
- Spectra Tendon ~8”

* Do not worry about zero-ing the tendon in this step.



Attach drive pulley block to the actuator block with Spectra tendon. Tendon should tie off on topmost pin in sub-assembly from step 10 and main drive pulley. The improved clinch knot is suggested as a no-slip knot in this situation

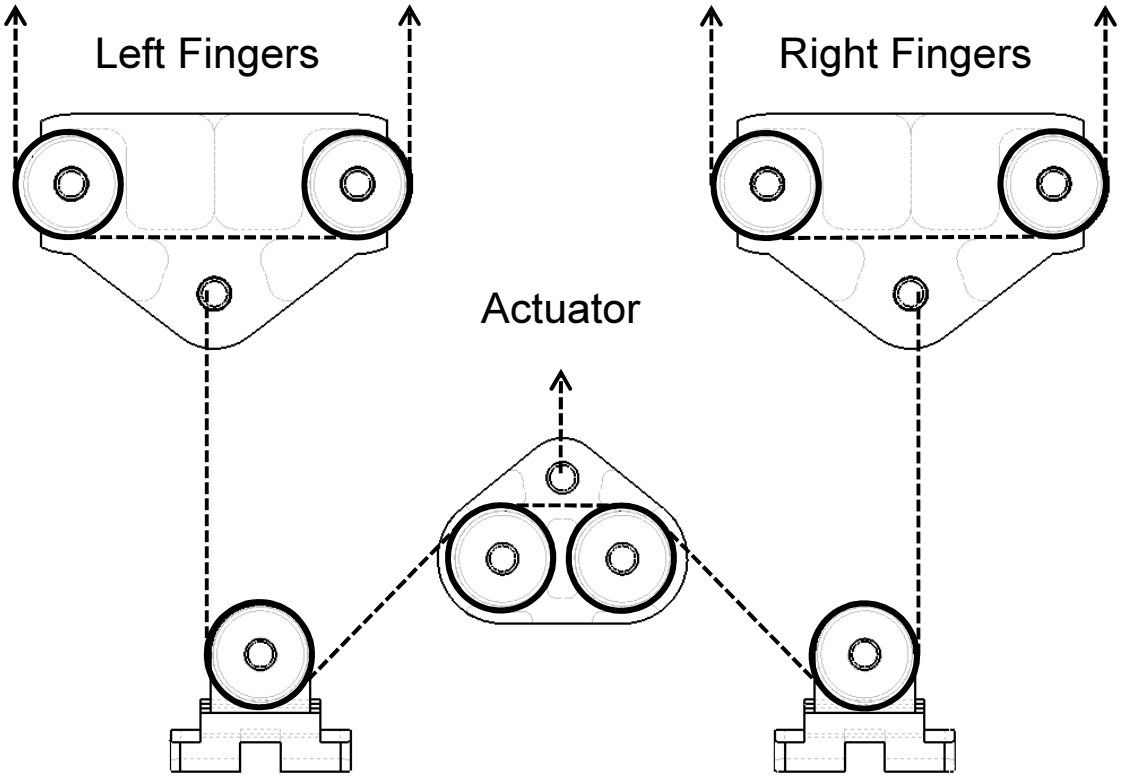
# ASSEMBLY

## FINAL TENDON ROUTING

**Parts:**

- Sub-assembly from step 23
- Sub-assembly from step 22 or step 16
- Spectra Tendon ~8”

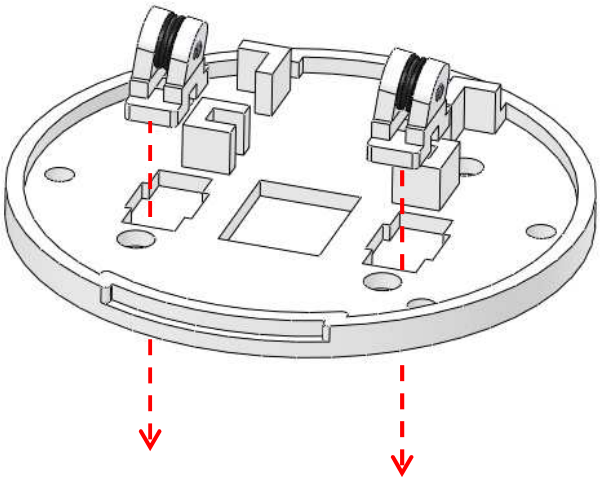
Transmission Diagram

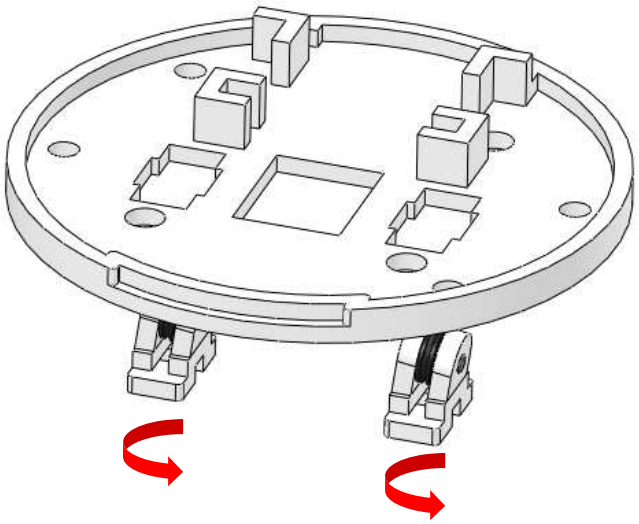


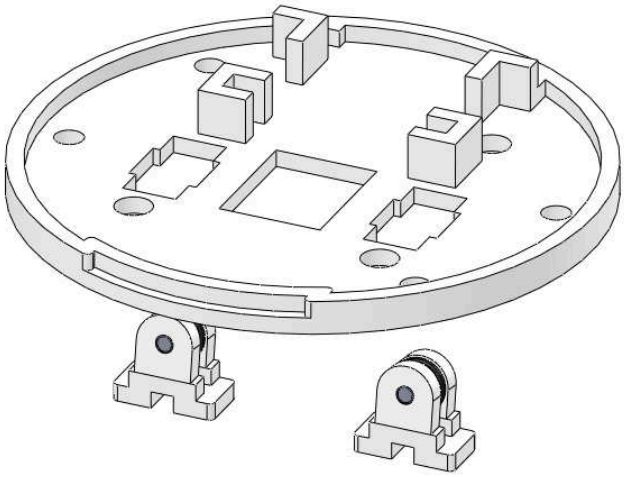

Final tendon runs between the differential blocks from step 12 and through the pulley blocks from step 11 and main drive block from step 10. The tendon length is approximately 14cm (5.5”) and should be taut with the fingers at rest.

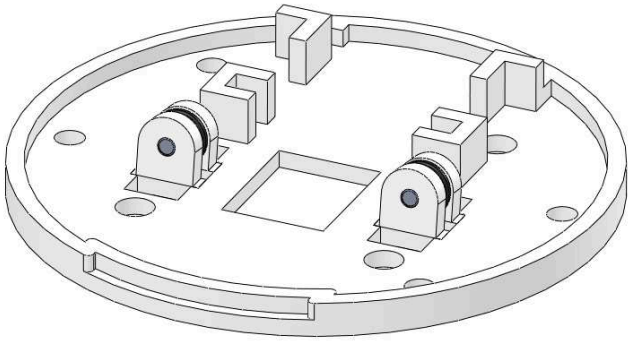
# Assembly

## Final Tendon Routing









Note that the base pulley blocks can be inserted into the bottom base from above, as shown above. This may help in the process of achieving the appropriate tendon length between the differential blocks.

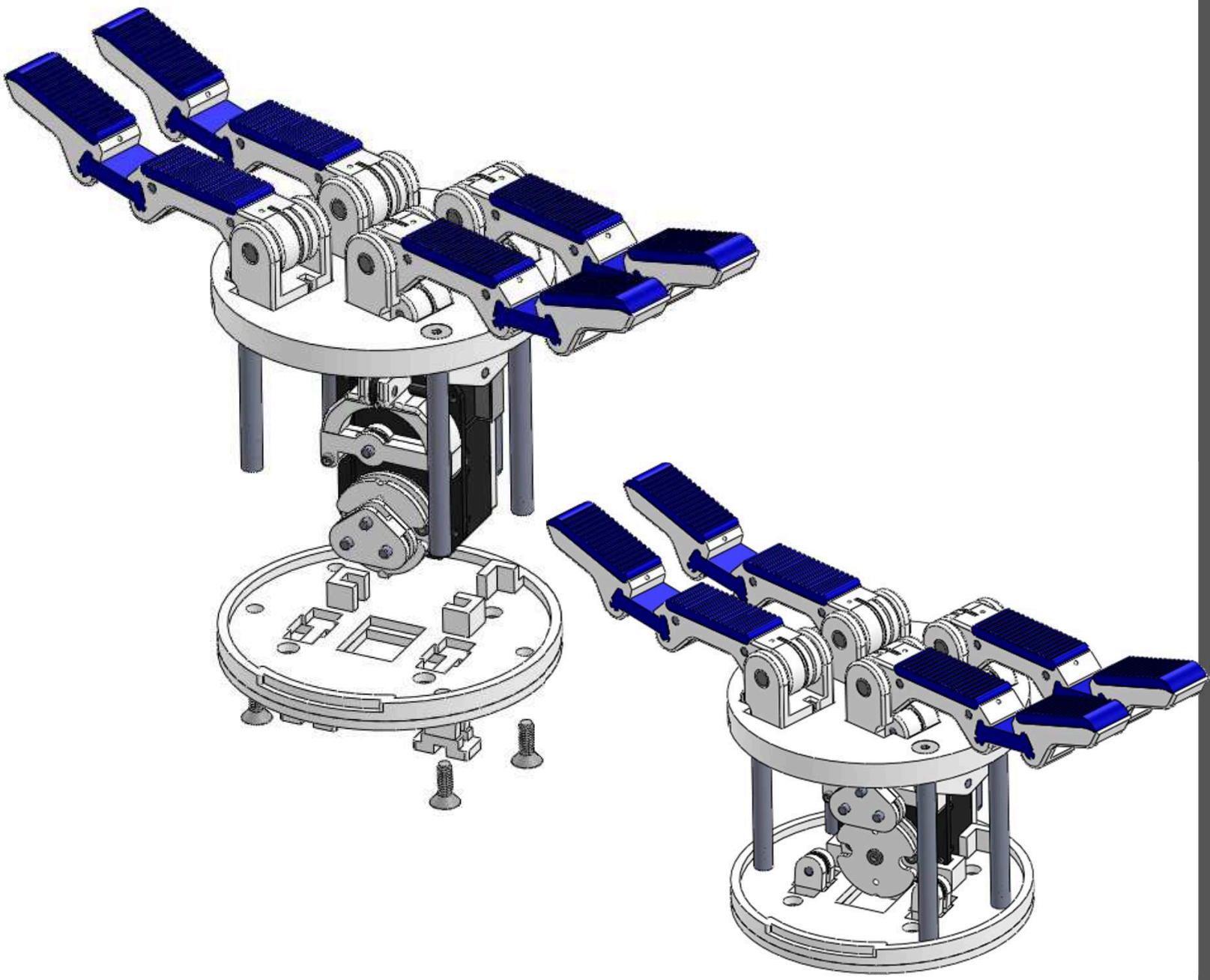
# Assembly

## Final Assembly – Flexure Base

Use remaining socket screws to clamp the entire assembly together in place. The actuator block sub-assembly from step 9 should fit snugly

# Assembly

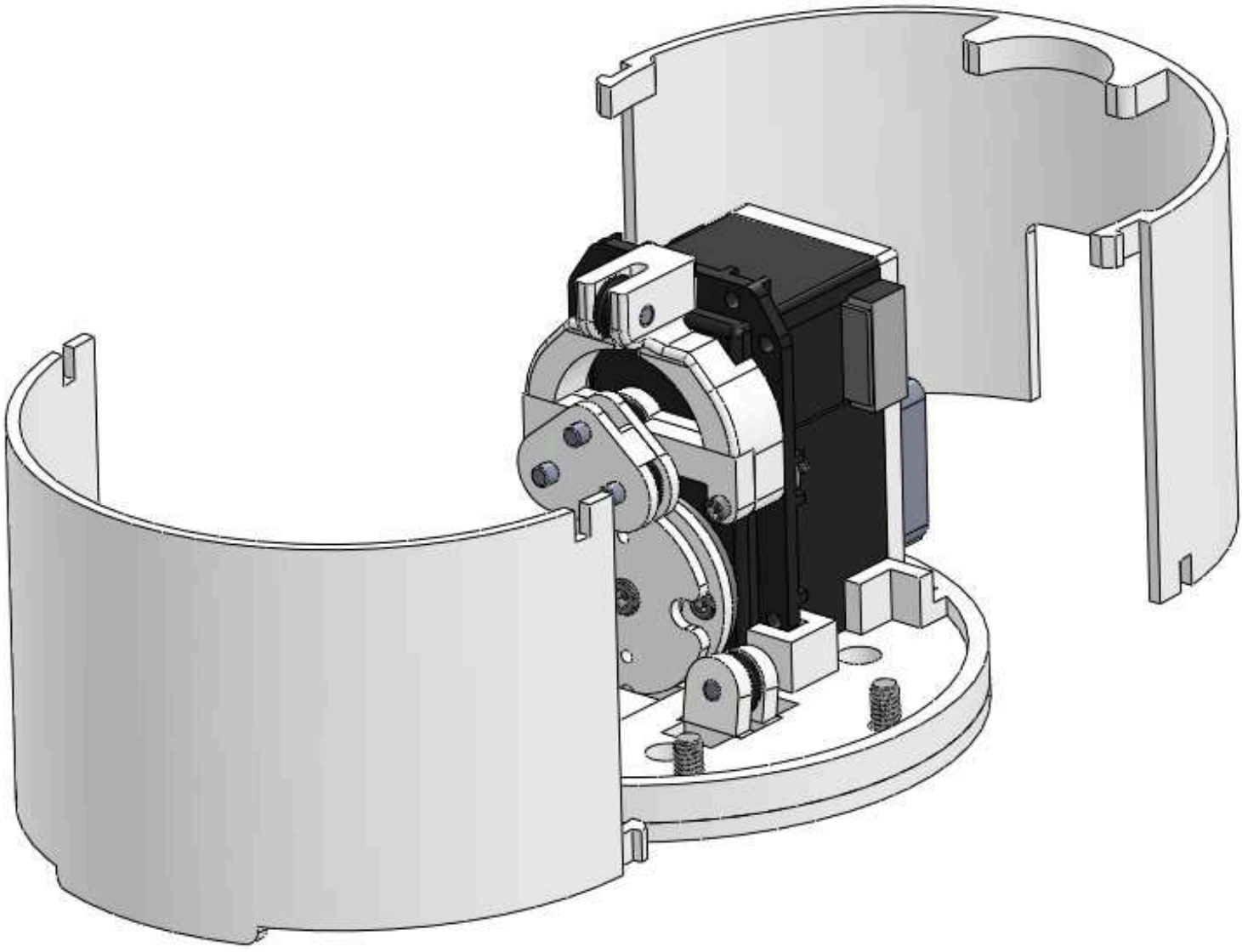
## Final Assembly – Pivot Base



Use remaining socket screws to clamp the entire assembly together in place. The actuator block sub-assembly from step 9 should fit snugly

# Assembly

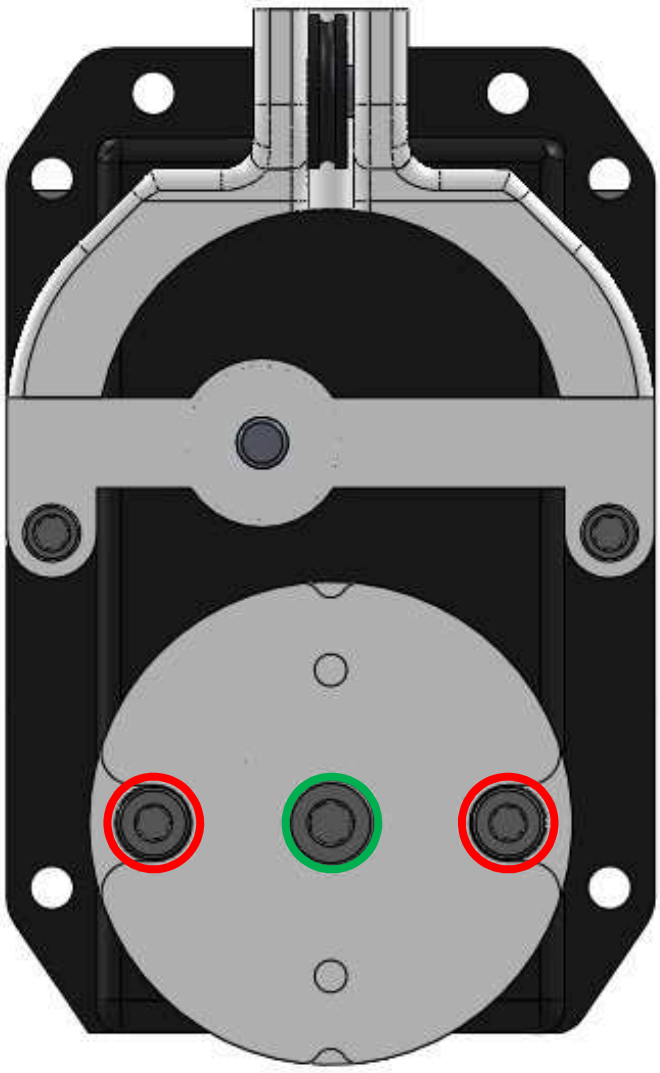
## Final Assembly – Shell



Optional shell snaps together from two sides, as shown above. It may help to pre-loosen either the top or bottom set of socket screws to allow the shells to slide together more easily.

# Post-Assembly

## SERVO ZERO-ING



1. Remove the M2 bolts from the servo pulley
2. Loosen, but do not remove, the central M2.5 bolt, such that the servo pulley can spin freely
3. Connect the Dynamixel and (in position mode) move it to its zero encoder position
4. By hand, turn the servo pulley until the tendon between the pulley and the main drive block is as taut as possible
5. Re-attach the M2 bolts and tighten the servo pulley