The University of Utah

Bypass Socket

Enabling Researchers to Perform Real-World Tasks with Prosthetic Devices

Michael Paskett

THE UNIVERSITY OF UTAH®

Department of BIOENGINEERING

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Introduction

The University of Utah's bypass socket is a powerful tool enabling non-amputees to perform functional tasks with upper-limb prosthetic devices. Utilizing modular 3D-printed components, the bypass socket can be easily adapted to virtually any prosthetic device. We hope the bypass socket can become a useful resource to researchers, clinicians, educators, and insurers in the upper-limb prosthetics field.

Materials

The bypass socket is comprised of 3D-printed parts and commercially-available components.

3D-Printed Parts

The 3D-printed parts are all available online. With the exception of the Bypass Bearing, all parts are printed with ABS (we used a Fusion3 F400 printer). The Bypass Bearing was printed with dissolvable PVA support on an Ultimaker 3.

The assembly is divided into 3 sections; the 3D-printed parts necessary for each sub-assembly are listed below:

- Humeral Attachment Assembly
    - Humeral Attachment
- Telescoping System Assembly
    - CF Insert – Large – Elbow End
    - 2x - CF Slider – Inner
    - CF Insert – Small – Wrist End
- Wrist Assembly
    - Bypass Bearing Keyfit
    - Bypass Bearing Insert
    - 6x - Wrist Attachments
        - 2x - Small
        - 2x - Medium
        - 2x - Large
    - Wrist Locker
    - 4x - Terminal Device Adapters
        - DEKA Bypass Adapter Nut Side
        - DEKA Bypass Adapter Bolt Side
        - Quick-Disconnect Bolt Side
        - Quick-Disconnect Nut Side
    - Bypass Adapter Proximal Support

Commercial Parts

Please note that most of these parts can be found at a local hardware store, which will reduce costs associated with buying materials in bulk from vendors such as McMaster-Carr.

Item	Quantity	Link	Assembly
3/8”-16 Hex Nut	1	https://www.mcmaster.com/#90473a031/=1d6pd4a	Humeral
Ball Joint	1	https://www.mcmaster.com/#60745k841/=1d6pdhe	Humeral
Thread Adapter	1	https://www.mcmaster.com/#94358a330/=1d6pe53	Humeral
½” Carbon Fiber Rod	1	https://www.rockwestcomposites.com/45240-group	Telescoping
¾” Carbon Fiber Rod	1	https://www.rockwestcomposites.com/45035	Telescoping
3/8”-24 Hex Nut	2	https://www.mcmaster.com/#90473a215/=1d6pj34	Telescoping
M5 Hex Nut	2	https://www.mcmaster.com/#90591a146/=1d6pjki	Telescoping
30 mm M5 Hex Screw	1	https://www.mcmaster.com/#91280a238/=1d6pk30	Wrist
M5 Nylon Insert Locknut	1	https://www.mcmaster.com/#90576a104/=1d6pkot	Wrist
8-32 ½” Phillips Slotted Screw	4	https://www.mcmaster.com/#90604a194/=1d6pkvt	Wrist
8-32 Hex Nut	4	https://www.mcmaster.com/#90480a009/=1d6pldg	Wrist
40 mm M5 Hex Head Screw	1	https://www.mcmaster.com/#91280a242/=1d6plt5	Wrist
18” x 1” Velcro Straps	1	https://www.amazon.com/VELCRO-Brand-90107-Purpose-Straps/dp/B000TGX0HK	Humeral Attachment
2-Part Epoxy	1	https://www.amazon.com/J-B-Weld-8276-KwikWeld-Reinforced/dp/B0006O1ICY	Telescoping
Foam – TRLM-00009 Puf+SRP+Puf	1	https://store.acor.com/products/Multi-Laminated-Materials-by-Acor.html	Wrist
6 mm Airsoft BBs	1	https://www.amazon.com/Soft-Air-Bottle-Ultrasonic-Airsoft/dp/B0013CJKXM	Wrist
Super Glue	1	https://www.amazon.com/Scotch-Super-Liquid-Ounces-AD114/dp/B001PILFVY	Wrist
Wax-Based Chain Lube	1	https://www.amazon.com/Pedros-Ice-Wax-2-0-Bottle/dp/B002VLK15K	Wrist

Tools

- Dremel with diamond cutting blade
- Electric drill
- Phillips screwdriver
- 120-grit sandpaper

Assembly

Humeral Attachment Assembly

Parts:

- 3D Printed
    - Humeral Attachment
- Hardware
    - 3/8”-16 Hex Nut
    - Ball Joint
    - Thread Adapter

Assembly:

1. Insert the 3/8”-16 hex nut into the slot on the Humeral Attachment
2. Attach the thread adapter through the Humeral Attachment hole
3. Attach the ball joint

Video:

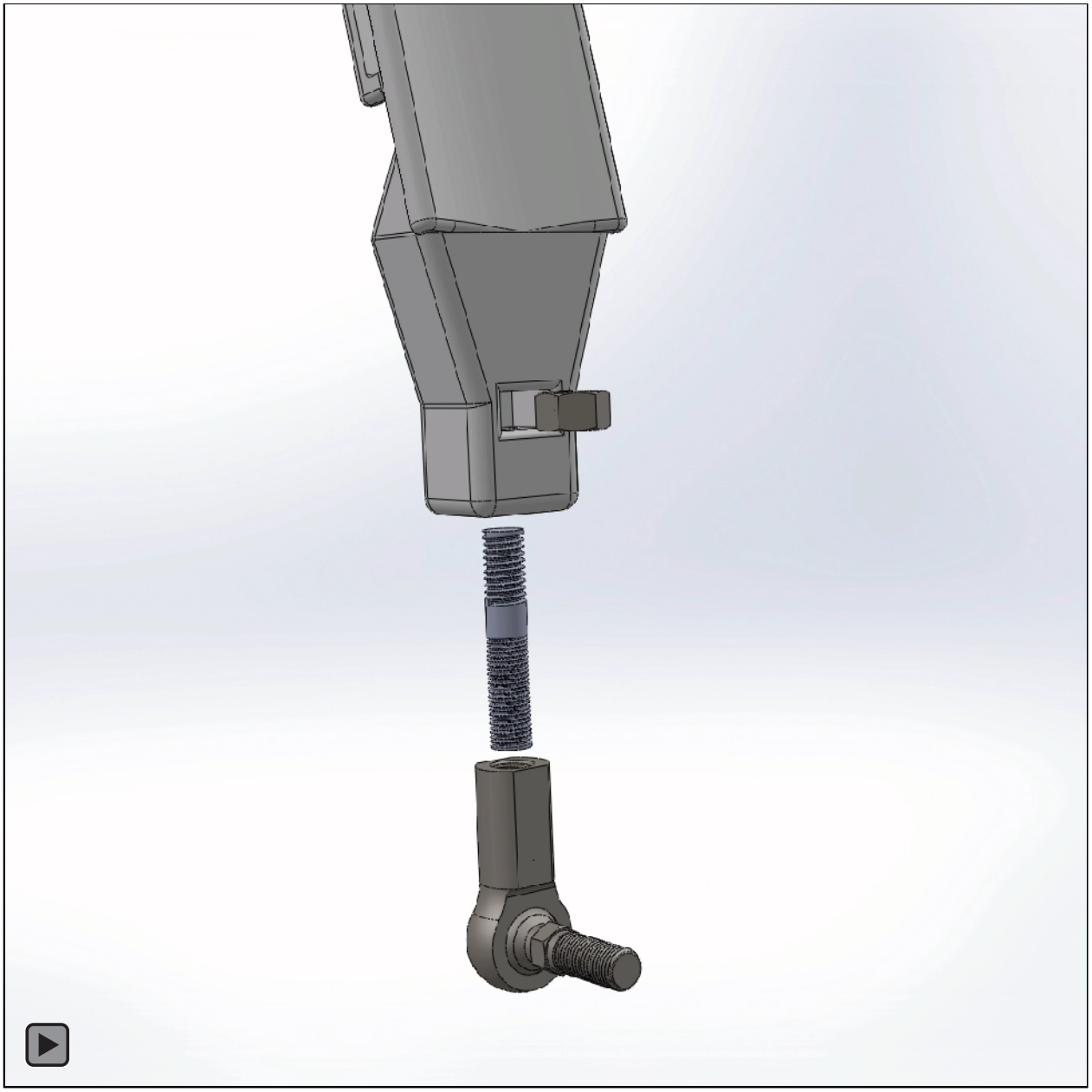

Figure 1 - Humeral Attachment Assembly Video

3D Model:

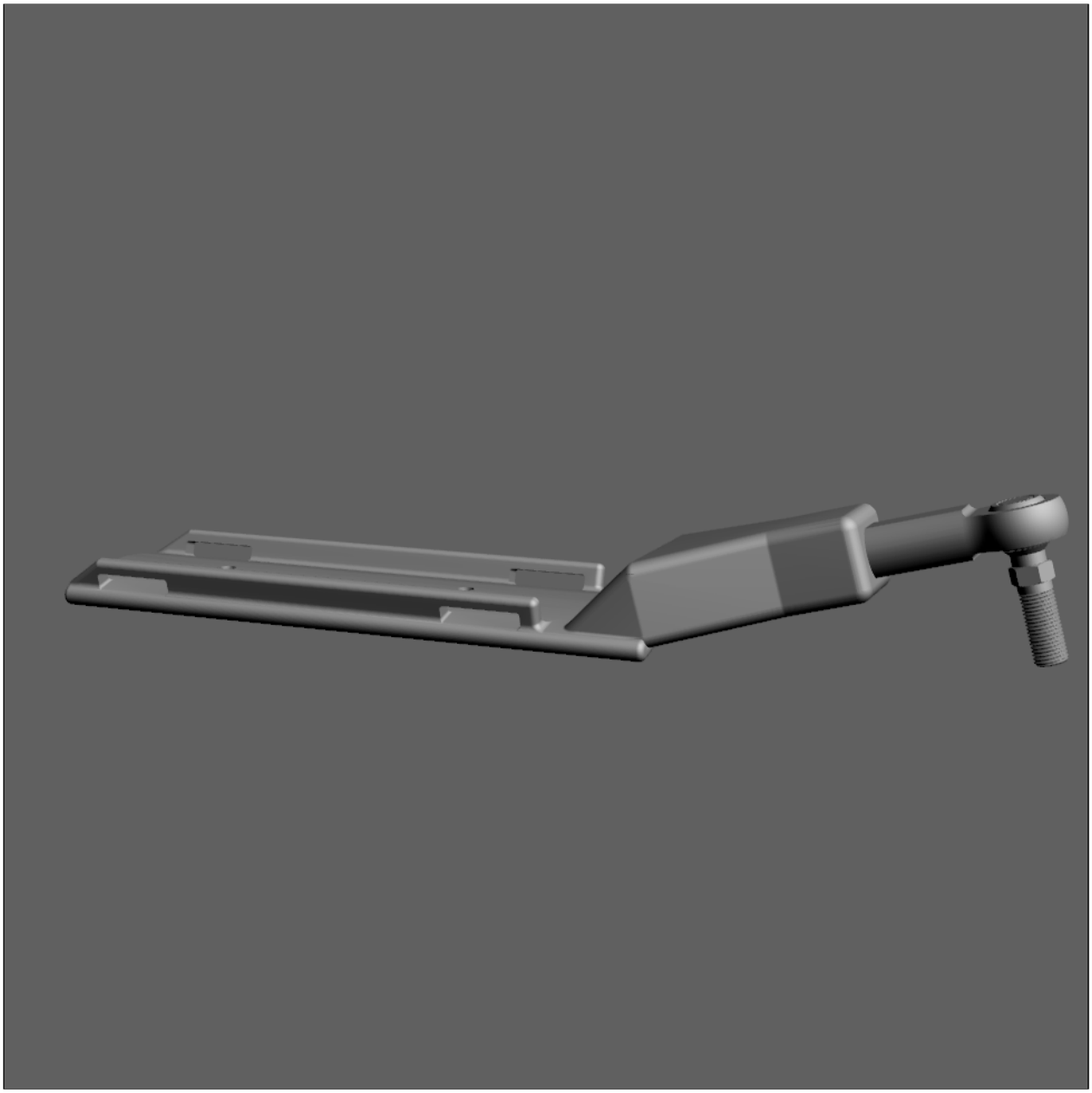

Figure 2 - Humeral Attachment Assembly 3D Model

Exploded view:

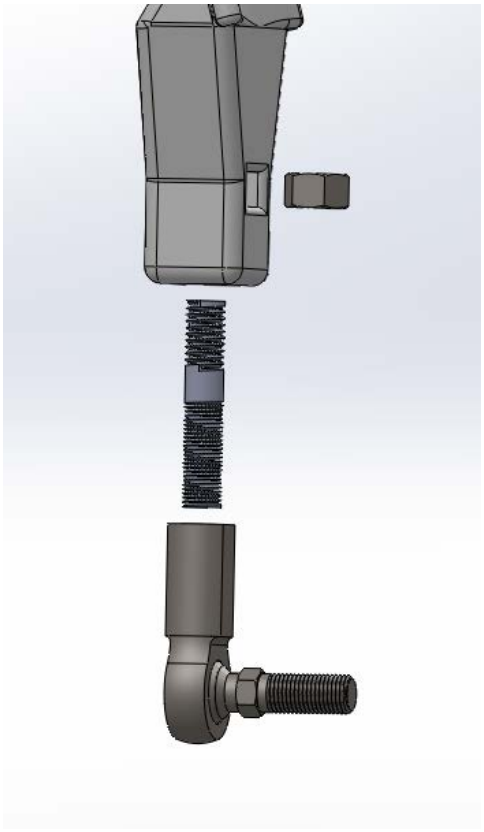

Figure 3 - Humeral Attachment Exploded Assembly

Notes:

- The ball joint will likely still be able to rotate even when flush with the bottom of the Humeral Attachment. This allows greater range of motion when the bypass socket is completely assembled.
- The PTFE liner on the ball joint may require a break-in to move more freely. We attached the joint to a drill and rotated at high velocity while using household oil to reduce heat/damage to the ball joint.

Boa® Enclosure Variation

We contracted with a local prosthetics company (Peak Prosthetics, Salt Lake City, UT) to attach a Boa® enclosure system. This has greatly reduced fatigue experienced when operating the bypass socket with a heavier terminal device (e.g., DEKA LUKE arm - 1.5 kg, 3.3 lbs). A similar product may be found here: https://www.clickmedical.co/store/orthofit/orthofit-lacers/. The inner component of the sleeve is a high-density polyethylene sheet. Feel free to contact Peak Prosthetics if you desire a similar configuration.

The Boa® enclosure system is shown here:

Figure 4 – Boa® Enclosure System on Humeral Attachment

Telescoping System

Parts:

- 3/4” Carbon Fiber Rod
- CF Insert – Large – Elbow End
- 2x 3/8”-24 Hex Nut
- 1/2” Carbon Fiber Rod
- 2x CF Slider – Inner
- CF Insert – Small – Wrist End
- 2x M5 Hex Nut

Preparing the carbon fiber rods:

Cut the ¾” carbon fiber rod to 150 mm, and the ½” carbon fiber rod to 170 mm. We used a Dremel with a diamond blade to cut the carbon fiber. *The dust from carbon fiber is toxic. Work in a well-ventilated area with proper PPE.*

Assembly:

In this assembly, we recommend dry-setting the different components before applying any epoxy, as any errors will likely require the assembly to be redone.

1. Insert the M5 hex nuts into the “CF Insert – Small – Wrist End”
2. Epoxy the “CF Insert – Small – Wrist End” to the inside of the 1/2” carbon fiber rod
    a. Apply a coat of epoxy around the outside of the “CF Insert – Small – Wrist End” and insert it into the carbon fiber rod. Be careful not to epoxy the hex nuts.
    b. Remove excess epoxy
3. Epoxy the “CF Slider – Inner” to the **opposite** end of the 1/2” carbon fiber rod
    a. Apply a coat of epoxy on the outside of the carbon fiber rod and insert it onto the “CF Slider – Inner”
    b. Remove excess epoxy
4. Epoxy another “CF Slider – Inner” to the inside of the large carbon fiber rod
    a. Apply a coat of epoxy on the outside of the “CF Slider – Inner” and insert into the 3/4” carbon fiber rod
    b. Remove excess epoxy
5. Insert the 1/2” carbon fiber rod through the 3/4” carbon fiber rod such that the hex nuts are on the distal end
    a. Note: this must be aligned correctly for the telescoping system to function
6. Insert the 3/8”-24 hex nuts into the “CF Insert – Large – Elbow End”
7. Epoxy the “CF Insert – Large - Elbow End” to the inside of the 3/4” carbon fiber rod
    a. Apply a coat of epoxy around the outside of the “CF Insert – Small – Wrist End” and insert it into the carbon fiber rod. Be careful not to epoxy the hex nuts.
    b. Remove excess epoxy

Video:

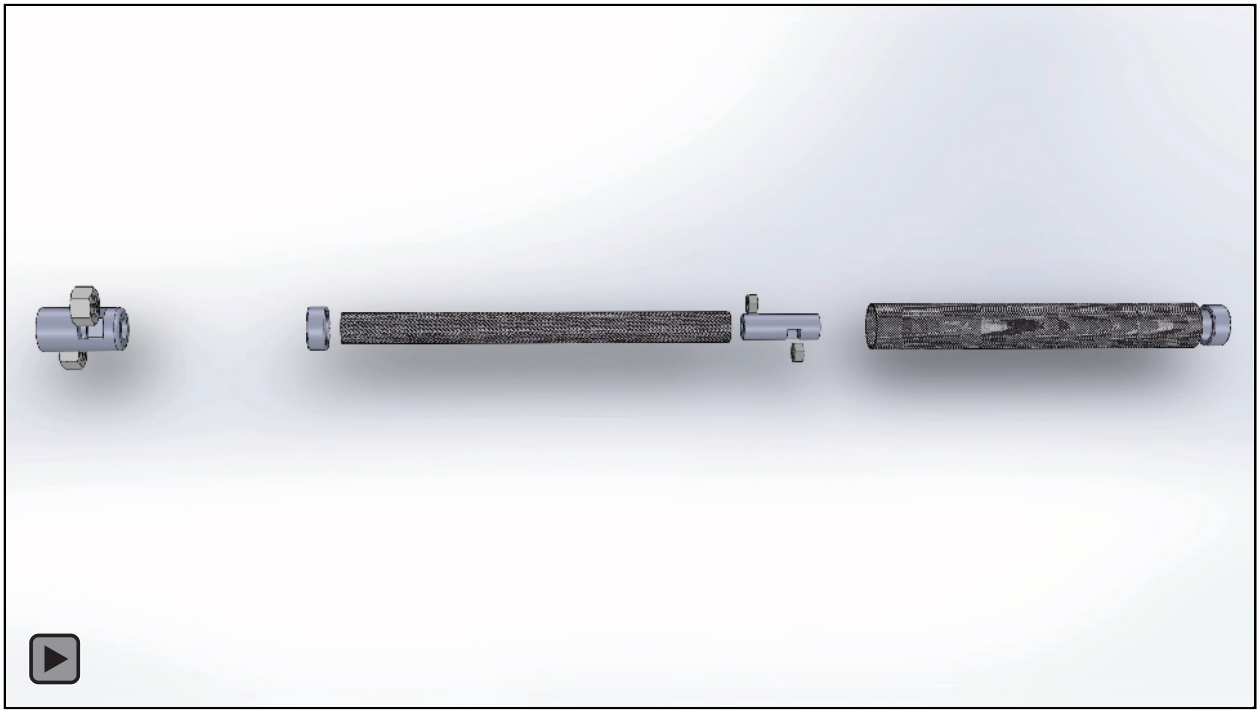

Figure 5 - Telescoping System Assembly Video

3D Model:

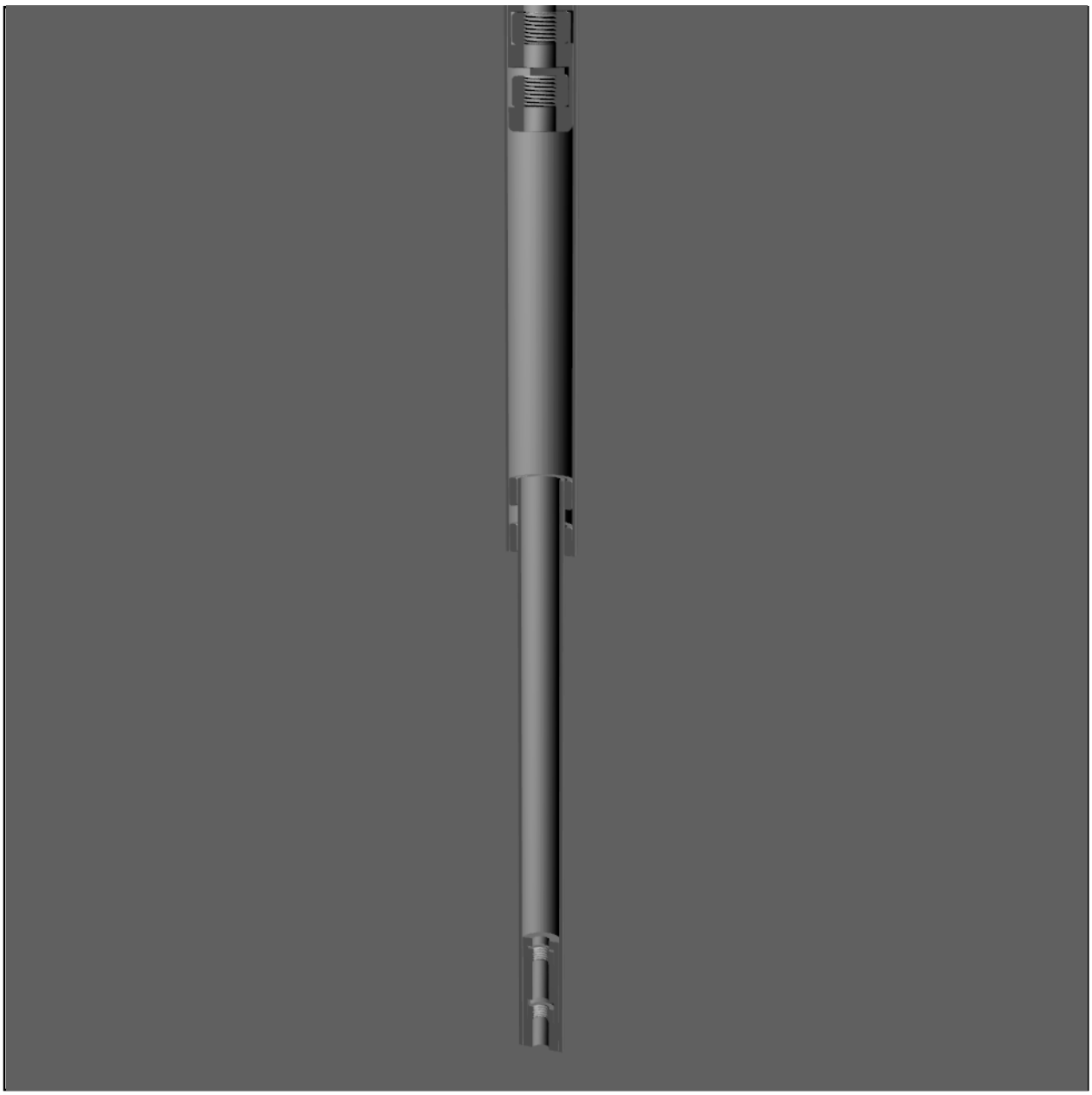

Figure 6 - Telescoping System 3D Model

Exploded view:

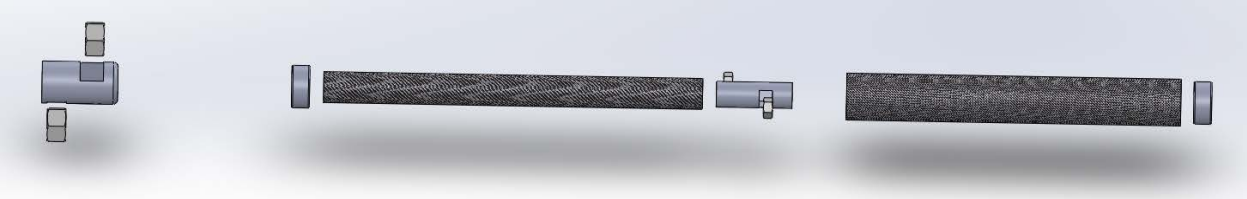

Figure 7 - Exploded View of Telescoping System

Section view:

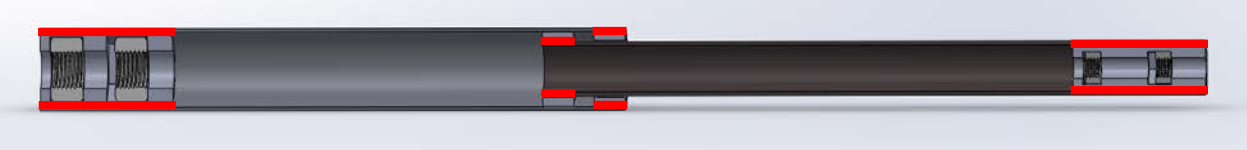

Figure 8 - Section View of Telescoping System. Red indicates epoxied pieces.

Wrist Attachment Assembly

Parts:

- Bypass Bearing Keyfit
- Bypass Bearing Insert
- 2x Wrist Attachment
- Wrist Locker
- 2x Terminal Device Adapter
    - In this example:
        - DEKA Bypass Adapter Nut Side
        - DEKA Bypass Adapter Bolt Side
- M5 Hex Screw Wrist
- Nylon Insert Locknut
- 4x 8-32 Phillips Screw Wrist
- 4x 8-32 Steel Hex Nut Wrist
- Bypass Adapter Proximal Support
- M5 Hex Head Screw Wrist
- Bypass Bearing Drill Attachment
- Tri-density Foam

Bypass Bearing Preparation:

The “Bypass Bearing Keyfit” must be printed with dissolvable support. We printed with an Ultimaker 3, using PLA and PVA (dissolvable in water). We soaked the print overnight and removed what support material we could with small tools. After removing the majority of support material to the extent that the internal part of the bearing can rotate freely, move on to breaking in the bearing.

The bypass bearing requires a break-in to reduce friction. After dissolving the support material in the “Bypass Bearing Keyfit,” insert enough 6 mm airsoft BBs to fill 2/3 of the internal track (~40 BBs). Temporarily tape the hole shut. Liberally apply a wax-based bike chain lube along the rim of the “Bypass

Bearing Keyfit," and using an electric drill, spin the lube into the bearings. After spinning through with chain lube, submerge the "Bypass Bearing Keyfit" in water and spin again to remove any particulate and excess wax in the internal track. Repeat this process until the bearings move with very little friction. We ended up attaching a ½" threaded rod to the underside of the "Bypass Bearing Drill Attachment" which provided much greater torque and stability when using the drill. This break-in process may require several iterations – the bearings need plenty of wiggle room. When the bearings are sufficiently smooth, apply chain lube again and let dry. Finally, remove the tape and epoxy the "Bypass Bearing Insert" into the "Bypass Bearing Keyfit."

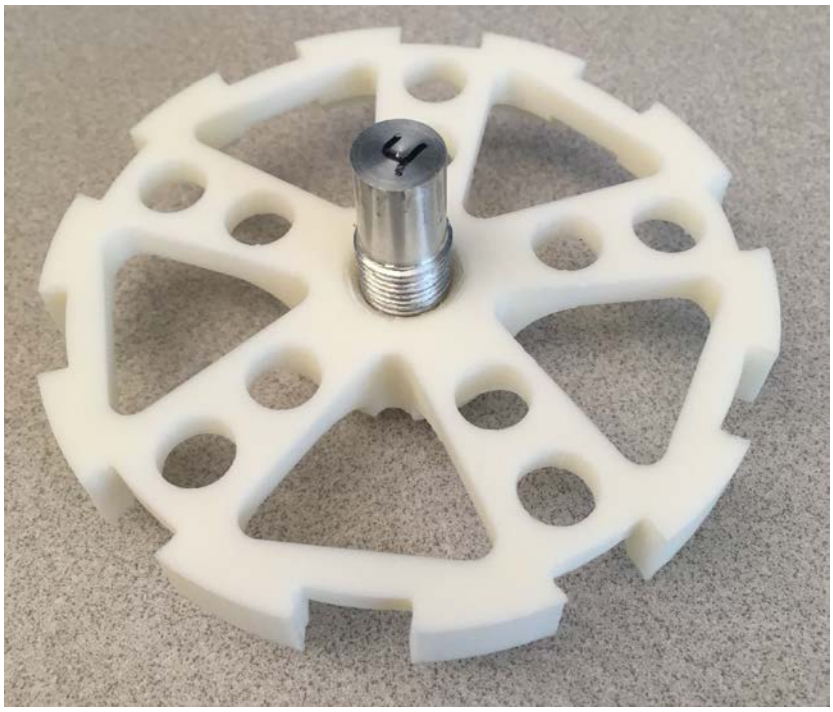

Figure 9 - 1/2" Threaded Rod on "Bypass Bearing Drill Attachment"

Wrist Attachment Preparation:

We applied tri-density foam on the interior of the wrist attachments to increase comfort, especially when using heavier terminal devices. We used superglue to adhere the foam to the plastic.

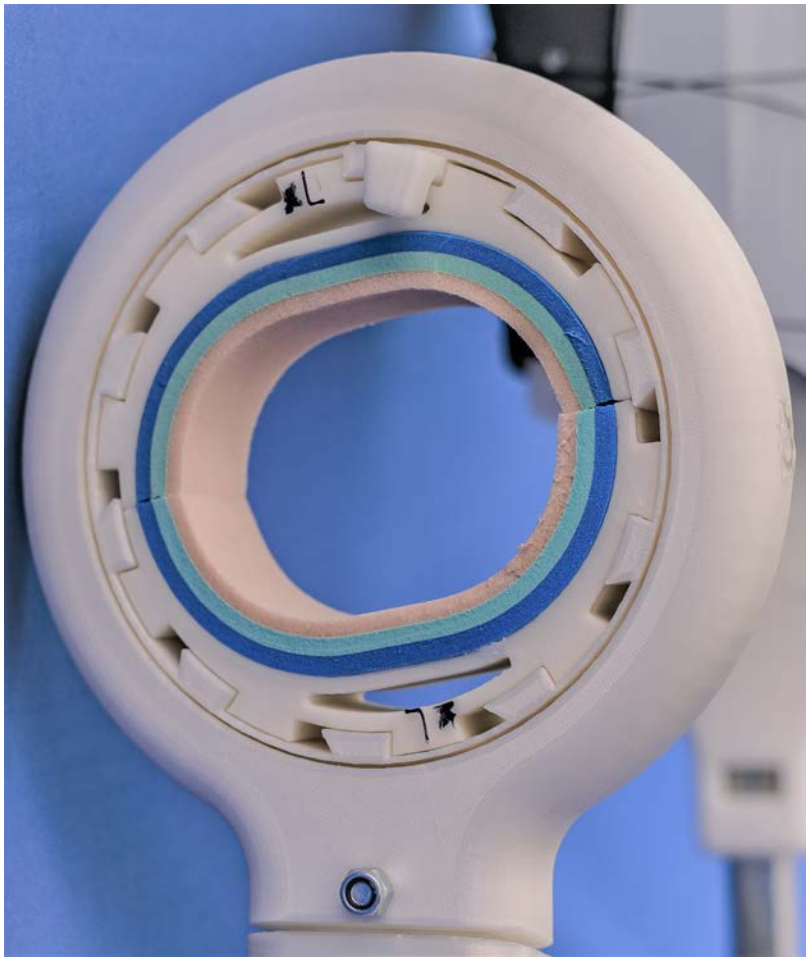

Figure 10 - Tri-Density Foam on Wrist Attachment

Assembly:

1. Epoxy “Bypass Adapter Proximal Support” to “Terminal Device Adapter”
2. Insert M5 Hex Screw Wrist into “DEKA Bypass Adapter Bolt Side” (Terminal Device Adapter)
3. Insert four 8-32 hex nuts into “DEKA Bypass Adapter Nut Side” (Terminal Device Adapter)
    a. These nuts may be epoxied in for ease
4. Insert terminal device
5. Join “DEKA Bypass Adapter Nut Side” with “DEKA Bypass Adapter Bolt Side” around terminal device
6. Fasten four 8-32 Philips screws to secure terminal device
7. Insert “DEKA Bypass Adapter Nut Side” into “Bypass Bearing”
8. Insert M5 hex screw into “Bypass Bearing”
9. Fasten M5 nylon insert locknut onto “Bypass Bearing”
10. Insert “Wrist Attachments” and rotate
11. Insert “Wrist Locker”

Video:

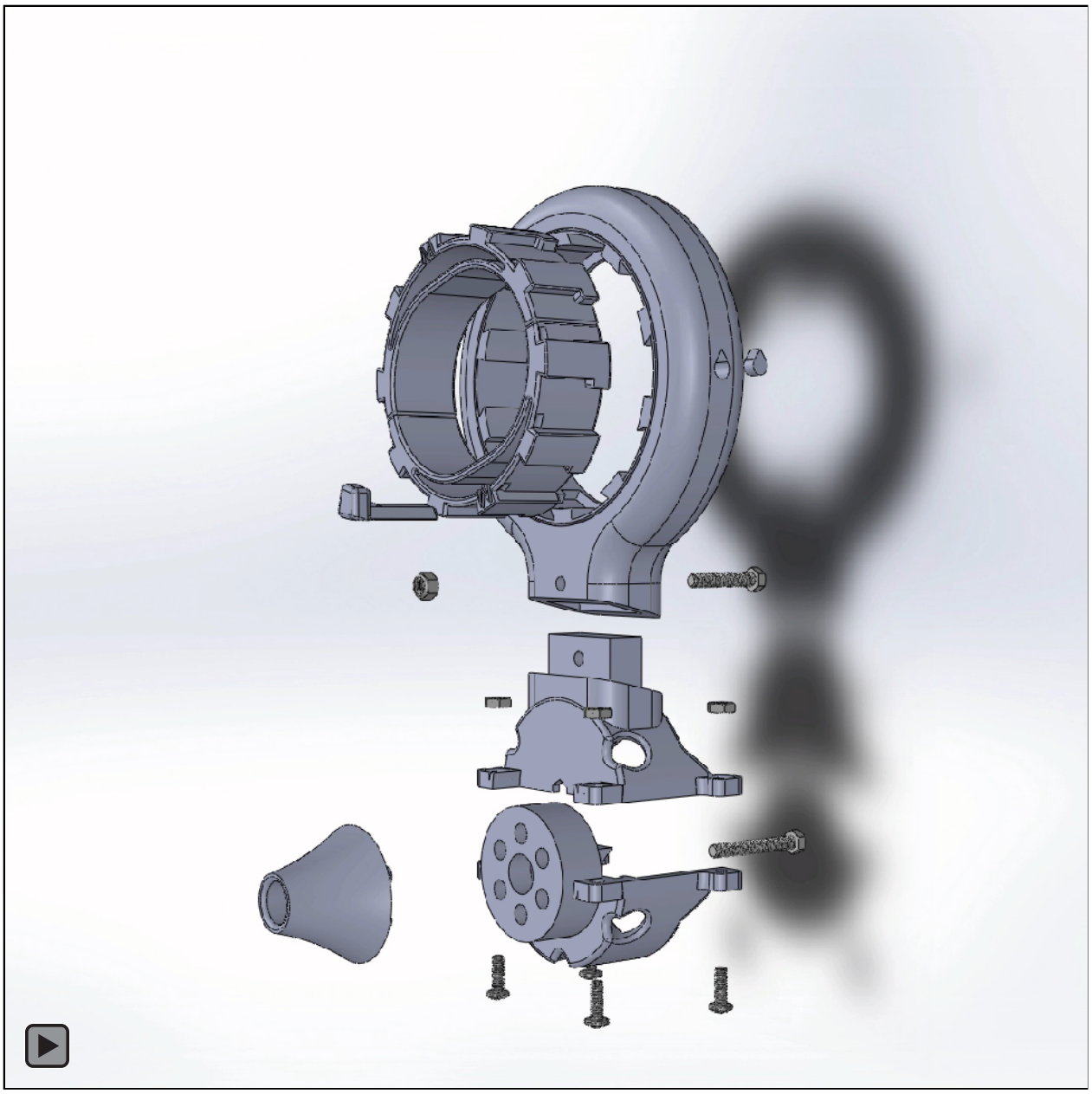

Figure 11 - Wrist Attachment Assembly Video

3D Model:

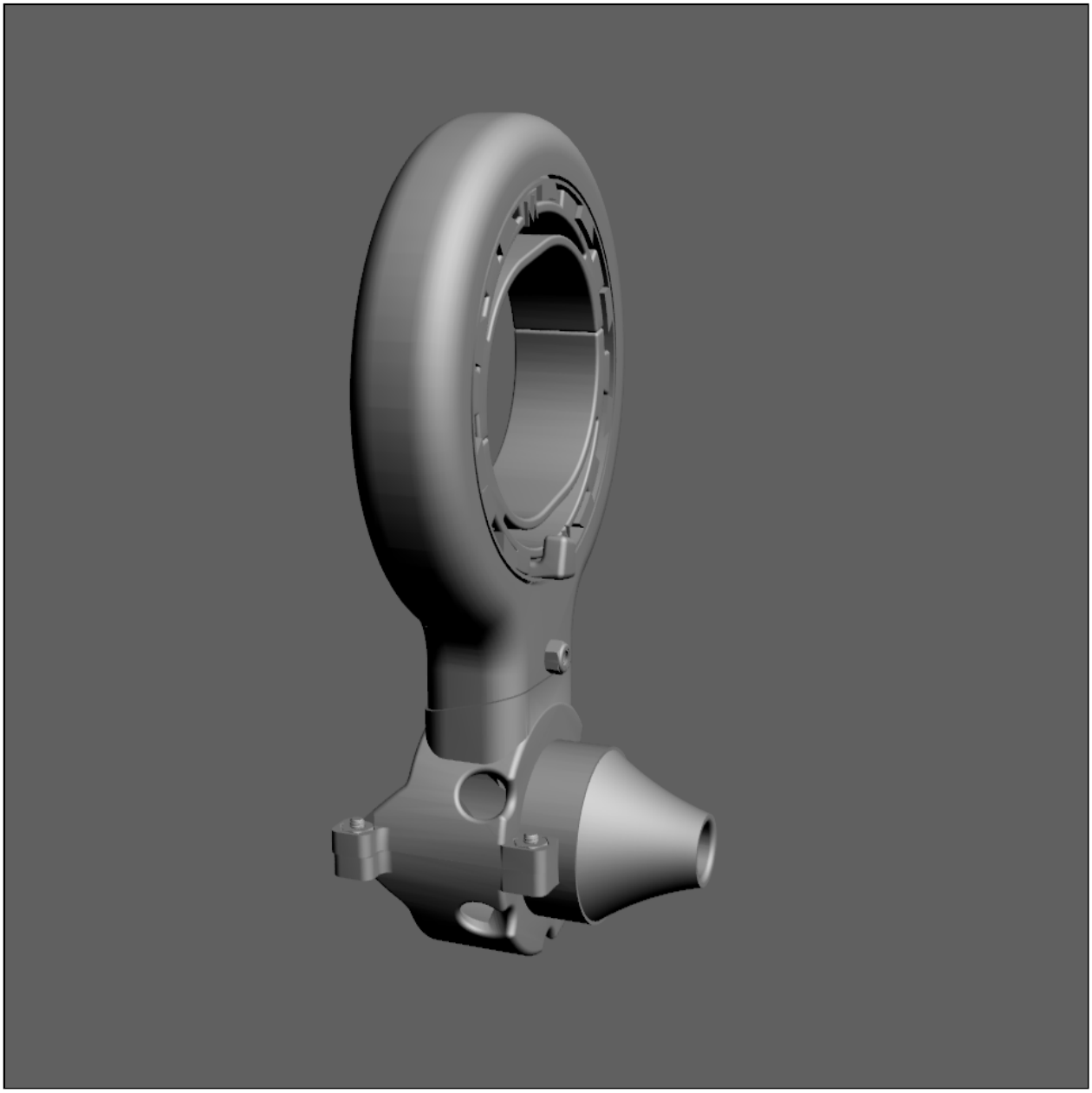

Figure 12 - Wrist Attachment 3D Model

Exploded Views:

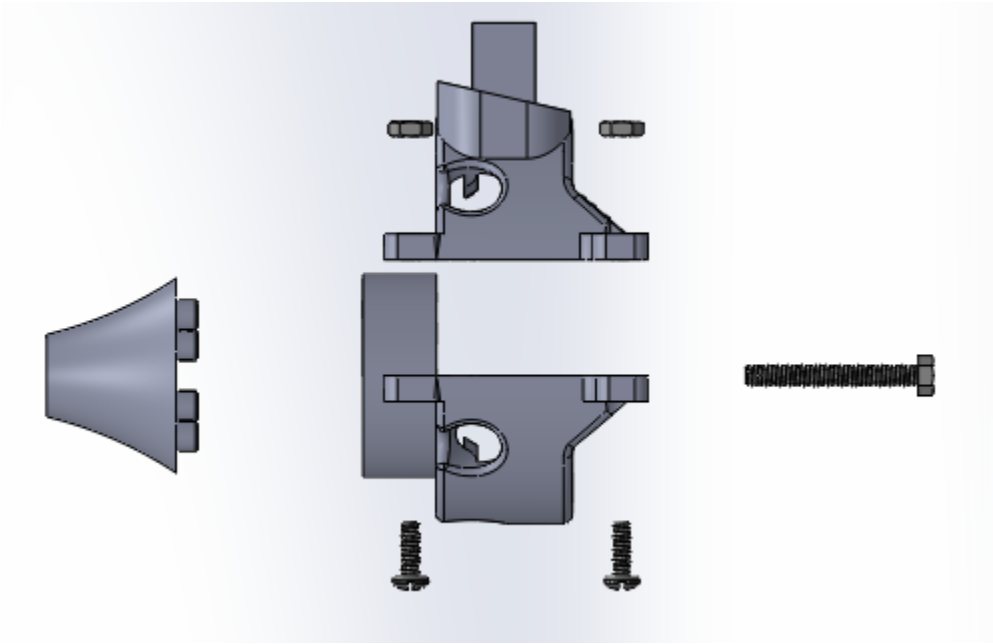

Figure 13 - Terminal Device Attachment Exploded View

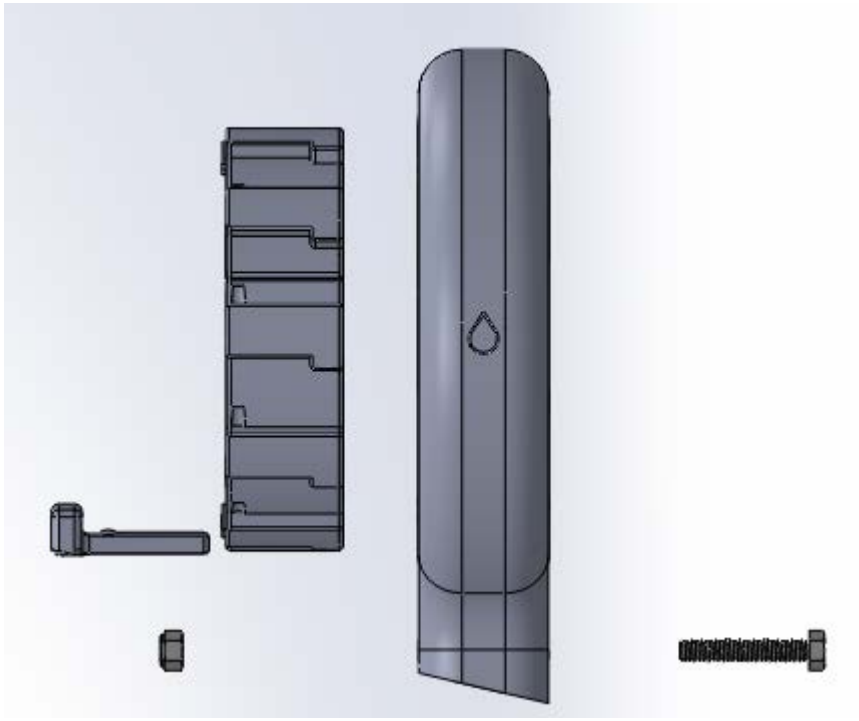

Figure 14 - Wrist Attachment Exploded View

Final Assembly

1. Fasten 3/4” carbon fiber end of telescoping system to ball joint
2. Fasten 1/2” carbon fiber end of telescoping system to wrist attachment

Video:

Figure 15 - Final Assembly Video

3D Model:

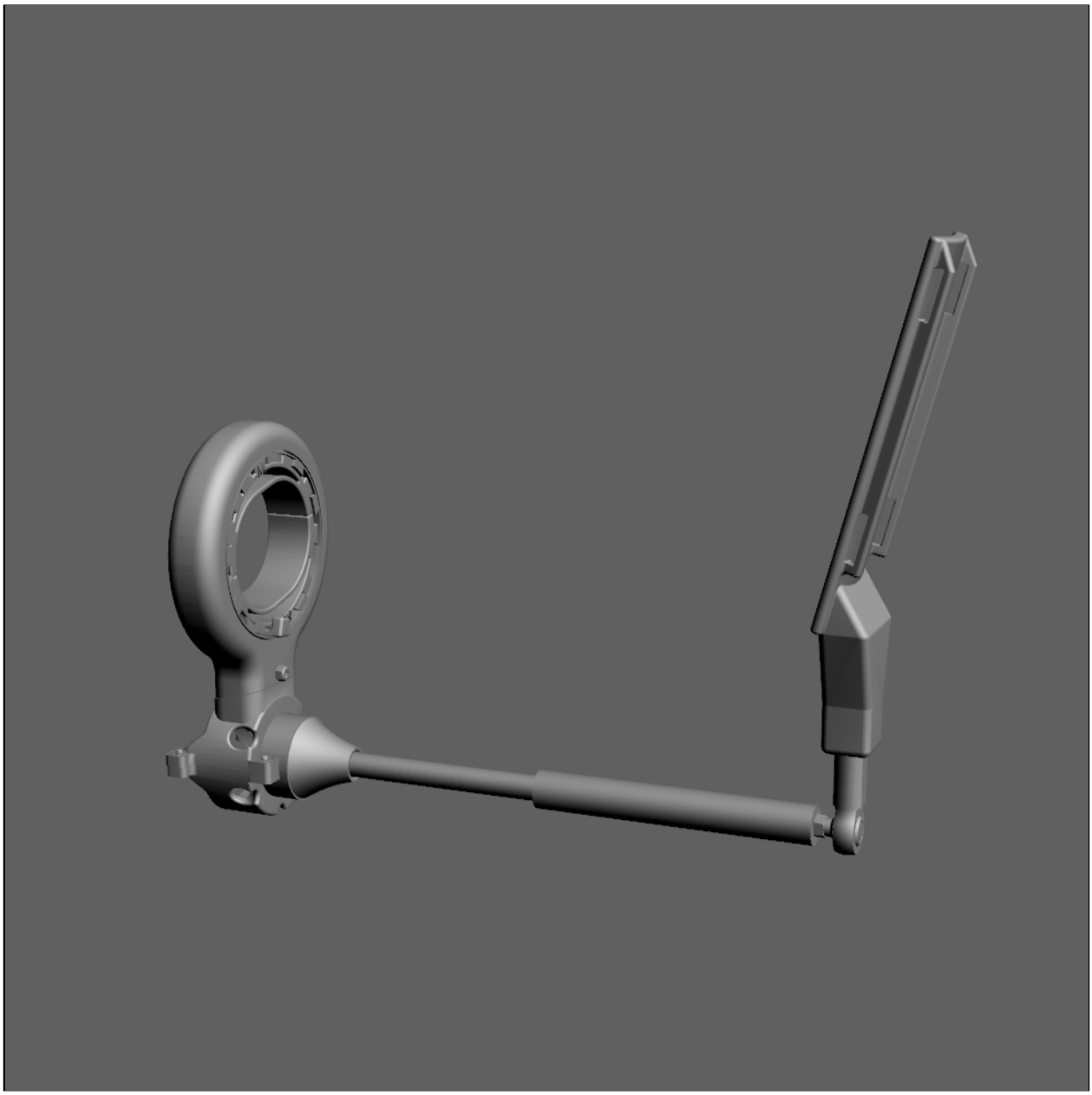

Figure 16 - Final Assembly 3D Model

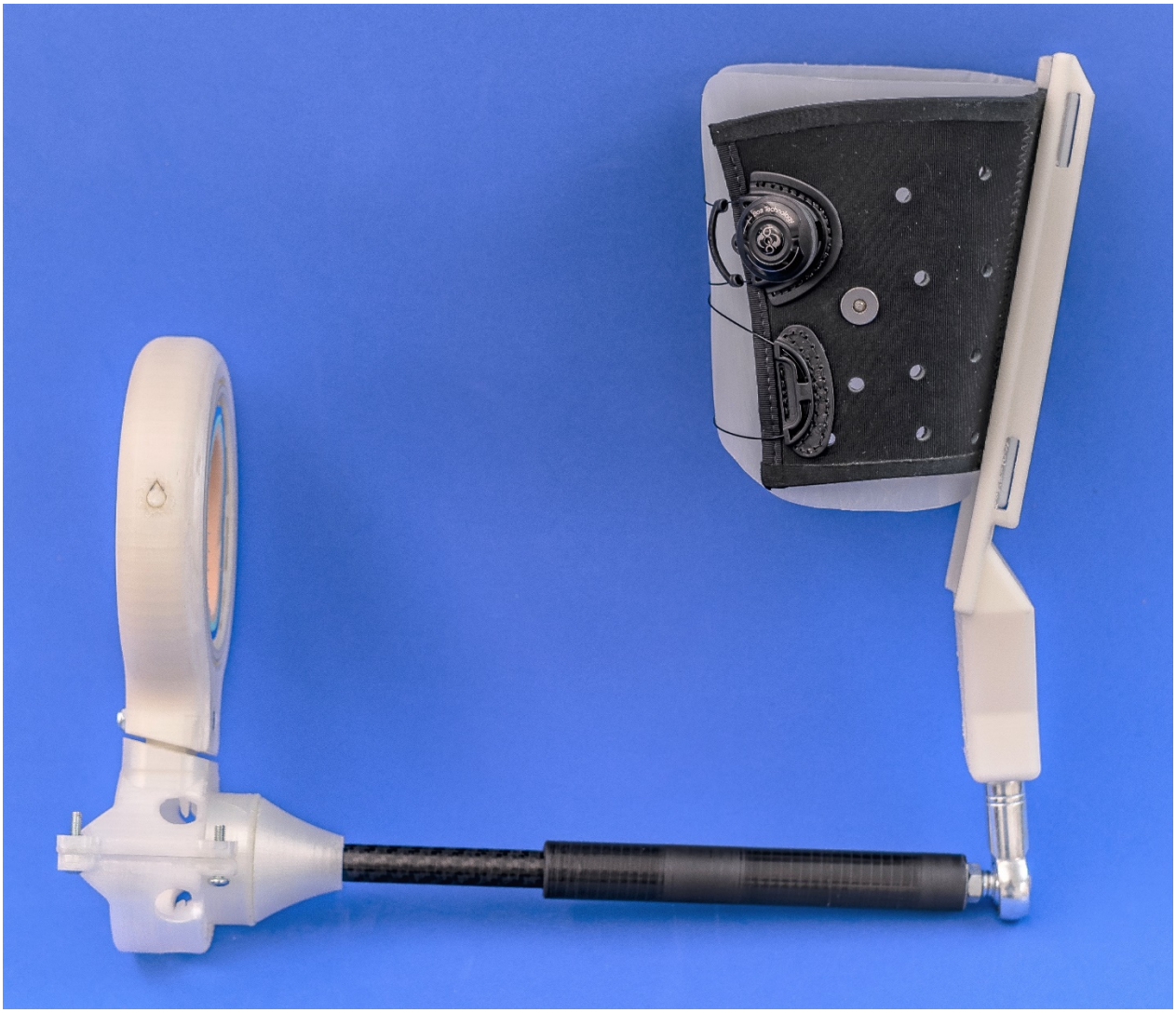

Figure 17 - Completed Bypass Socket

Congratulations! Your bypass socket is complete!