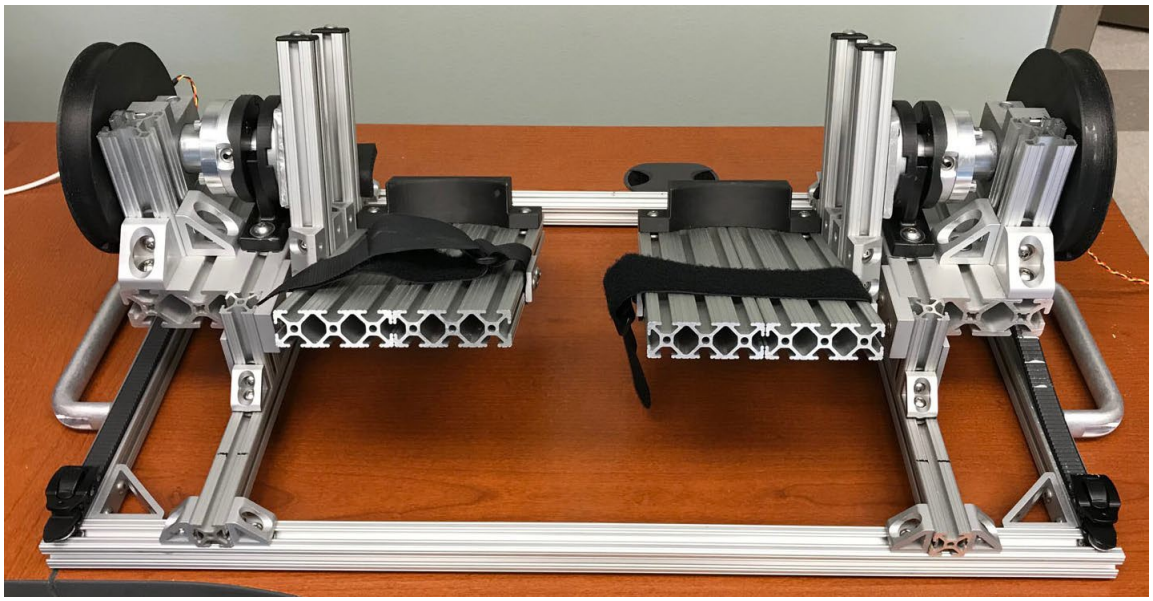
Assembly Instructions



Notes to reader:

These instructions are intended to provide general guidance to constructing the device. Many of the screws and nuts needed for assembly are not shown in the construction images but should be relatively straight forward. If there is confusion, please contact the authors.

Portions of the device (predominantly the mounting hardware) are constructed out of materials that can be attracted to the static magnetic field of the scanner (e.g. various forms of stainless steel). Although we determined that the device was safe to use in our case, it is possible that the device may be more strongly attracted to scanners with a stronger magnetic field, and it is possible for the magnetic attraction to be stronger if you replace some of the pieces with your own alternatives or if the manufacturers alter the material of the parts in the future. Always ensure that all of the screws, nuts, etc. are firmly secured outside the scanner before each use. Even if the apparatus as a whole doesn't have a strong magnetic attraction, a loose screw or nut could become a projectile. Thread locking material may be used to provide additional stability. Along these lines, the hex wrenches with the T-handles that are used to adjust the apparatus outside the scanner are HIGHLY MAGNETIC and should never enter the scanner under any circumstances, ever. For safety, we suggest that you consult an expert when you construct and ultimately introduce the device to the scanner.

Useful tools for construction:

Part #	Part name	#
	80/20 Inc.	
6100	Ball End “L” Hex Wrench – 5/32”	1
6010	Ball End “L” Hex Wrench – 3/16”	1
6110	“T” Handle Ball End Hex Wrench – 5/32”	1
6000	“T” Handle Ball End Hex Wrench – 3/16”	1
6030	“T” Handle Ball End Hex Wrench – 1/4”	1
6105	Ball End Hex Driver – 5/32”	1
6020	Ball End Hex Driver – 3/16”	1

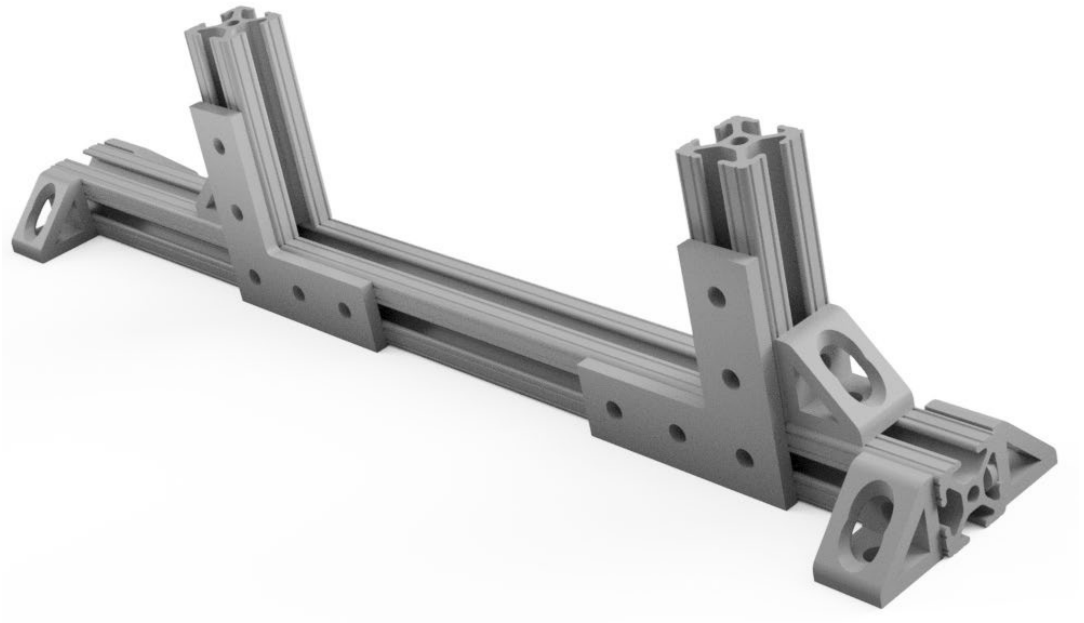
Step 1: Construct the frame

Part #	Part name	#
	80/20 Inc.	
1010-29.5-CL	1.00” X 1.00” T-Slotted Profile - Four Open T-Slots	2
1010-15-CL	1.00” X 1.00” T-Slotted Profile - Four Open T-Slots	2
4136	10 Series 4 Hole - Tall Gusseted Inside Corner Bracket	4
3690	1/4-20 x .500" Button Head Socket Cap Screw (BHSCS)	16
3675	1/4-20 Slide-In Economy T-Nut - Centered Thread	20
2828	10 Series Tread Strip	7’
2820	10 Series Economy T-Slot Cover	1
2887	Aluminum handle	2
	McMaster-Carr	
92185A539	Super-Corrosion-Resistant 316 Stainless Steel Socket Head Screw 1/4"-20 Thread Size, 5/8" Long	4

Step 1: Construct the frame (continued)

- Add aluminum handles to the two short (15”) aluminum T-Slot profiles
    - (2x) 1010-15-CL
    - (2x) 2887
    - (4x) 1/4”-10 x 5/8” screws (92185A539)
    - (4x) 3675 T-nuts
- Add corner brackets to the short (15”) T-Slot profiles
    - (4x) 4136 Corner Brackets
    - (8x) 3690 Screws
    - (8x) 3675 T-nuts
- Add long (29.5”) T-Slot profiles to the short T-Slot profiles
    - (2x) 1010-29.5-CL
    - (8x) 3690 Screws
    - (8x) 3675 T-nuts
- Add rubber tread to long T-Slots
    - 2828 cut to length as needed
    - Note: runs roughly the width of MRI bed and ensures device doesn’t slide relative to participant when in use
- Add plastic tread to short T-Slots
    - 2820 cut to length as needed
    - Note: could be replaced with rubber tread, but it depends on the MR scanner. In our case, the inner section of the bed moves with respect to a permanently fixed part of the bed as the participant is moved into the bore so having plastic here allows the device to move with the participant as needed.

Step 2a: Construct the uprights



Part #	Part name	#
	80/20 Inc.	
1010-3-CL	1.00” X 1.00” T-Slotted Profile - Four Open T-Slots	4
1010-17-CL	1.00” X 1.00” T-Slotted Profile - Four Open T-Slots	2
4132	10 Series 2 Hole - Gusseted Inside Corner Bracket	12
4081	10 Series 5 Hole - “L” Flat Plate	4
3690	1/4-20 x .500" Button Head Socket Cap Screw (BHSCS)	44
3675	1/4-20 Slide-In Economy T-Nut - Centered Thread	44

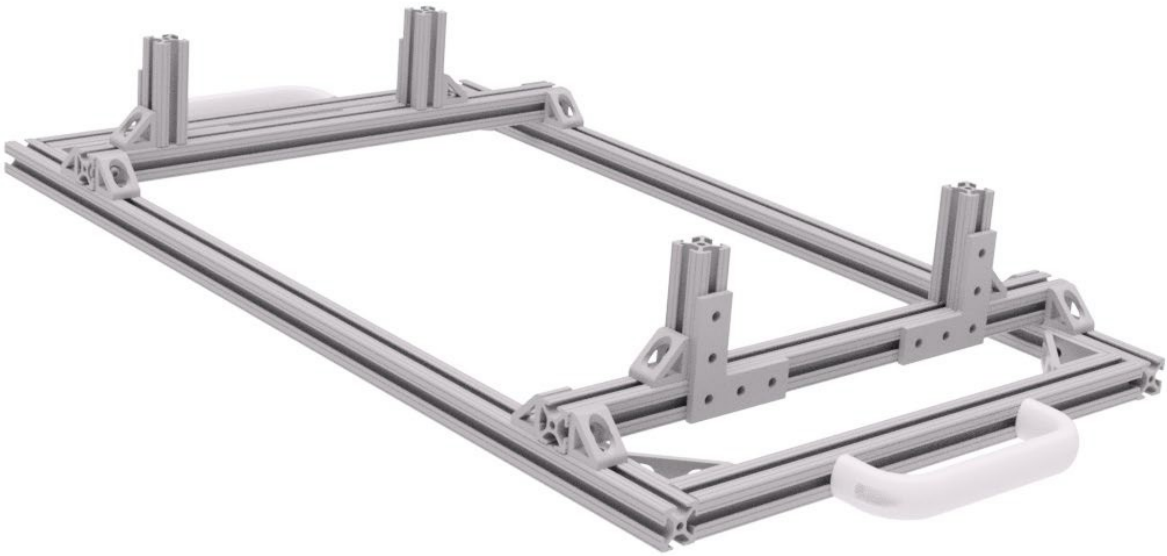
Step 2: Construct the uprights (continued)

Note that the left upright is a mirror image of the right.

Quantities below are for ONE upright. Multiply all parts by 2 to make the total amount of parts needed as listed on previous page

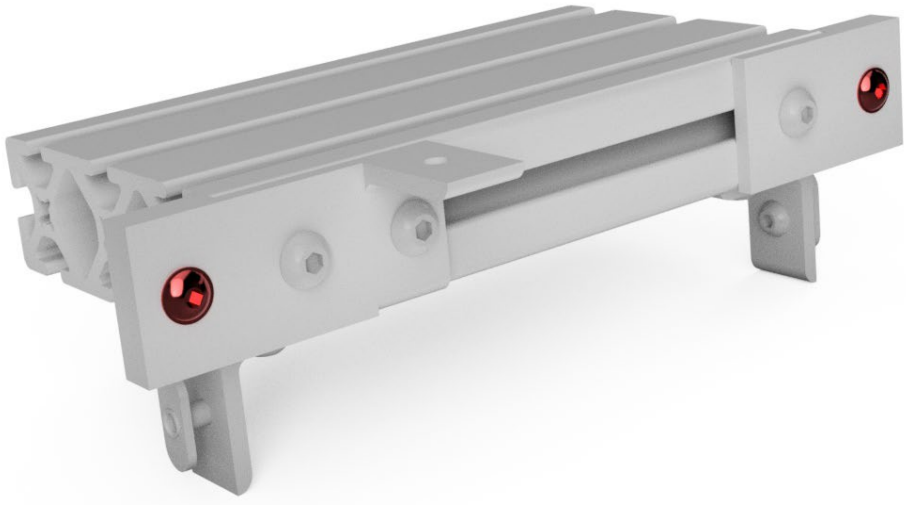
- Attach two short (3”) T-slot profiles to longer (17”) T-slot profile
    - (1x) 1010-17-CL
    - (2x) 1010-3-CL
    - (2x) 4081 L brackets
    - (2x) 4132 corner brackets
    - (14x) 3690 screws
    - (14x) 3675 T-nuts
- Attach corner brackets to ends of long T-slot profile
    - (4x) 4132 corner brackets
    - (4x) 3690 screws
    - (4x) 3675 T-nuts
- Add screws and nuts to corner brackets that will later allow uprights to be secured to bottom frame
    - (4x) 3690 screws
    - (4x) 3675 T-nuts

Step 2b: Attach the uprights to the frame



- Uprights slide into the frame from the side using screws and T-nuts added at the end of the previous step

Step 3: Construct mounting platforms



Part #	Part name	#
	80/20 Inc.	
1545-S-8-CL	1.50” X .4.50" T-Slotted Profile - Eight Open T-Slot, 8" cut to length	2
3678	5/16-18 Slide-in Economy T-Nut - Offset Thread	10
4503	10 to 15 Series 2 Hole - Transition Inside Corner Bracket	6
3675	1/4-20 Slide-In Economy T-Nut - Centered Thread	8
3690	1/4-20 x .500" Button Head Socket Cap Screw (BHSCS)	4
3611	5/16-18 x .625" Button Head Socket Cap Screw (BHSCS)	10
4521	10 to 15 Series 2 Hole - Straight Transition Flat Plate with Flush Offset	4
3604	1/4-20 x .750" Flanged Button Head Socket Cap Screw (FBHSCS)	4

Step 3: Construct mounting platforms (continued)

Note that the left mounting platform is a mirror image of the right.

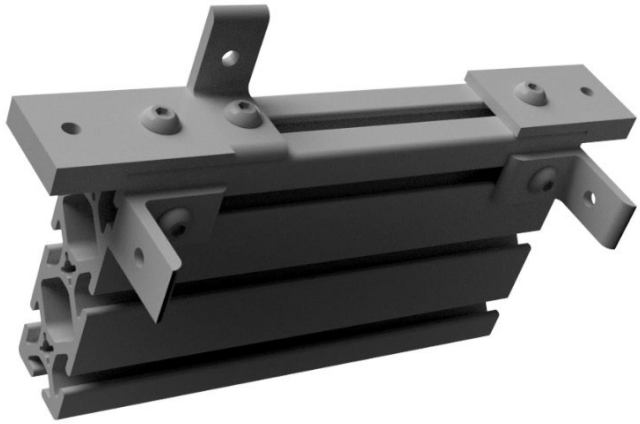
Quantities below are for ONE transducer mount. Multiply all parts by 2 to make the total amount of parts needed as listed on previous page

- Add mechanical stop
    - (1x) 1545-S-8-CL T-slot profile
    - (1x) 4503 transition corner bracket
    - (1x) 3611 screw (mounts through larger hole of transition corner bracket onto the 15 series T-slot profile)
    - (1x) 3678 T-nut
    - You can briefly align the mechanical stop to the center of the T-Slot profile and later make it flush with the straight transition plates

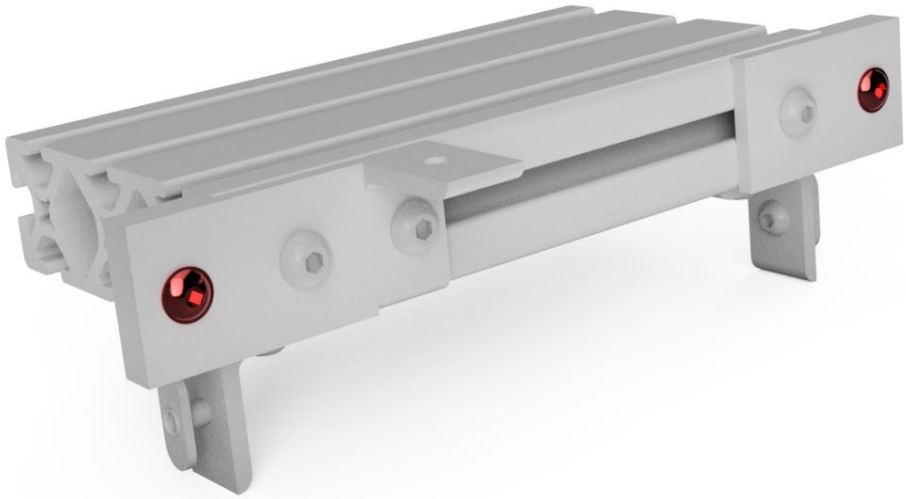
- Add straight transition plates
    - (2x) 4521 straight transition flat plates
        - mount to smallest dimension of the 1545 T-Slot profile (1.5”) via the larger holes in the plates
        - smaller holes (10 series side) used to mount to uprights later and extend off the edges of the 1545 T-slot
    - (2x) 3678 T-nut
    - (2x) 3611 screws

Step 3: Construct mounting platforms (continued)

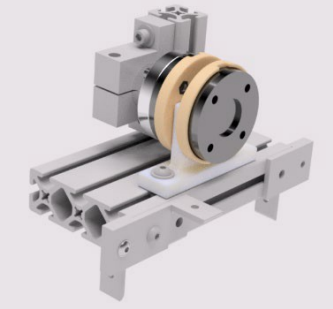
- Add transition corner brackets
    - (2x) 4503 transition corner brackets
        - Bottom side of T-slot profile via larger hole
        - Smaller hole faces outward, flush with edge of T-slot profile to mount to upright later
    - (2x) 3611 screws
    - (2x) 3678 T-nuts

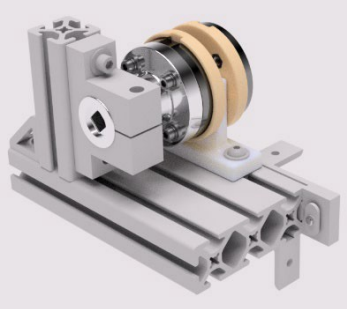


- Add screws and t-nuts that later secure to uprights
    - (2x) 3690 screws
        - Thru smaller holes of 4503 corner brackets
    - (2x) 3604 longer flanged screws (red in image below)
        - Thru smaller holes of 4521 straight transition flat plates
    - (4x) 3675 T-nuts



Step 4: Construct transducer subassemblies



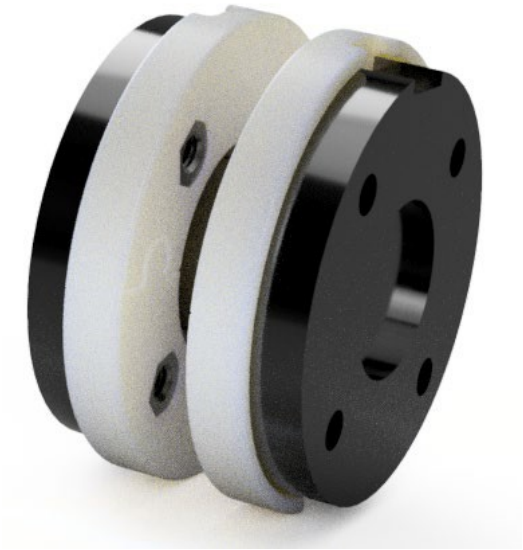


Part #	Part name	#
	80/20 Inc.	
1515-UL-4.25-CL	1.50” X 1.50” Smooth Surface T-Slotted Profile - Four Open T-Slots, 4.25” cut to length	2
4332	15 Series & Ready Tube 2 Hole - Gusseted Inside Corner Bracket	4
5880	15 Series 1.5" Narrow Horizontal Stanchion Base (Note: Remove Clamping Screw)	2
3659	0.345" ID Washer	4
3678	5/16-18 Slide-in Economy T-Nut - Offset Thread	16
3632	Bolt Assembly: SS 5/16-18 x 1.000" BHSCS with Washer and Slide-In Economy T-Nut - Offset Thread	4
3627	5/16-18 x 1.250" Socket Head Cap Screw (SHCS)	4
3607	5/16-18 x .687" Flanged Button Head Socket Cap Screw (FBHSCS)	8
	Transducer Techniques	
TRS-2K	Flanged Reaction Torque Sensor 0-2,000 inch pounds	2
	Custom 3D Printed (Onyx)	
	Lateral Spacer	8
	Transducer Support	2
	Custom Machined 6061 Aluminum (wire EDM for square hole)	
	Coupler	2
	McMcaster-Carr	
91343A100	316 Stainless Steel Serrated Flange Locknut, Super-Corrosion-Resistant, 1/4"-20 Thread Size	16
98201A312	Exact-Grip-Length Flanged Socket Head Screw, 1/4"-20 Thread Size, 1-3/16" Long - 3/16 drive	8
	Other	
	MicroLubrol Silicone Oil (12,500 centistokes, 4 oz)	1
	Aluminum anti-seize lubricant	1

Step 4: Construct transducer subassemblies (continued)

- Prepare lateral spacers
    - Add (16x) nuts (91343A100) to recessed wells of each 3D printed spacer

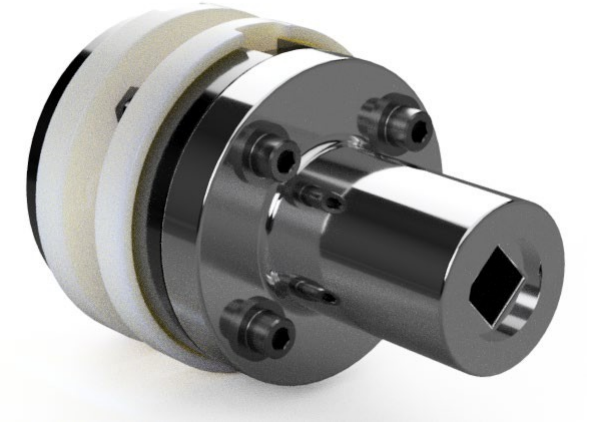
    - Fit spacers over small diameter of the torque transducer, snap pairs together via “puzzle piece” design. Align with mounting holes in torque transducer.



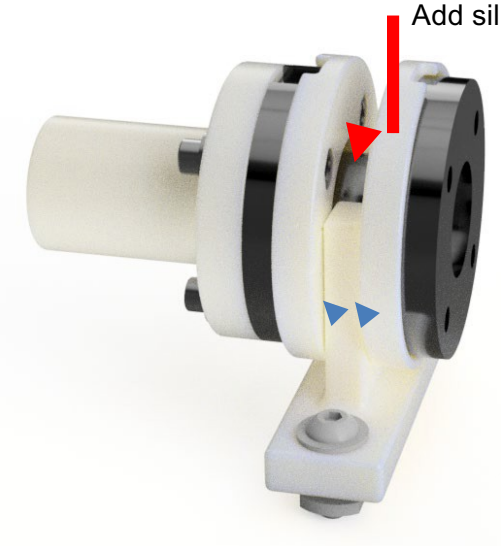
Step 4: Construct transducer subassemblies (continued)

Quantities below are for ONE side. Multiply all parts by 2 to make the total amount of parts needed as listed on previous page.

- Mount torque coupler to torque transducer
  - (4x) 98201A312 Screws
    - Use nuts already fit into lateral spacer on previous page. The spacers will lightly hold the nuts in place until the screws create enough tension to engage the serrated bottom edge of the nuts (i.e. you shouldn't need to use a wrench on the nut when tightening these screws).



- Slide plastic transducer support in between the spacers
  - Fit should be close, but should not have too much friction when rotating.
  - Add lubricant (Silicone Oil)

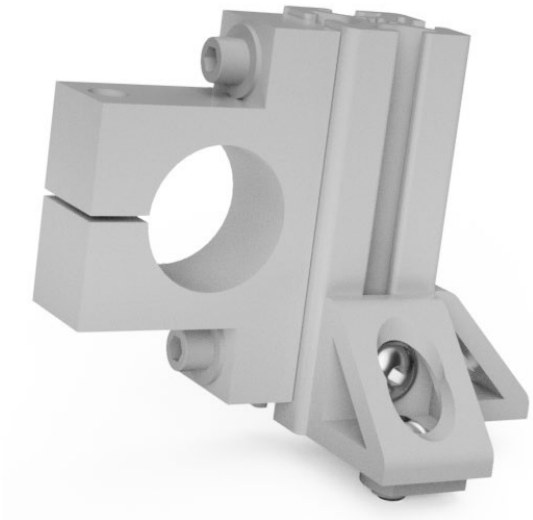


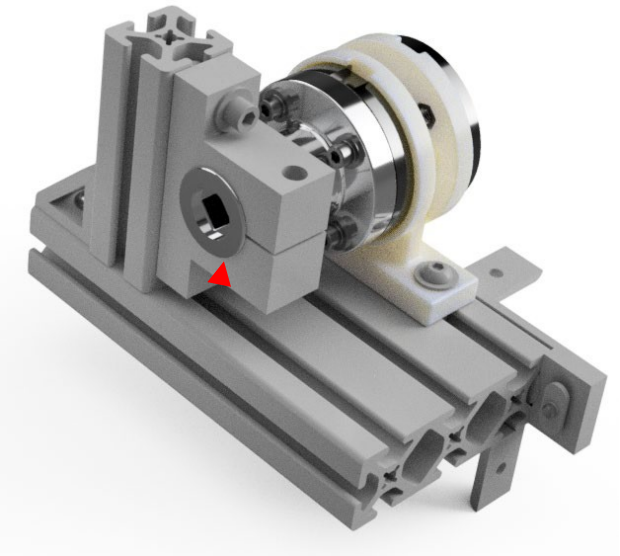
- Add mounting hardware to the plastic transducer support
  - (2x) 3632 bolt assembly (screw and washer)
  - (2x) 3678 T-nut

Step 4: Construct transducer subassemblies (continued)

Quantities below are for ONE side. Multiply all parts by 2 to make the total amount of parts needed as listed on previous page.

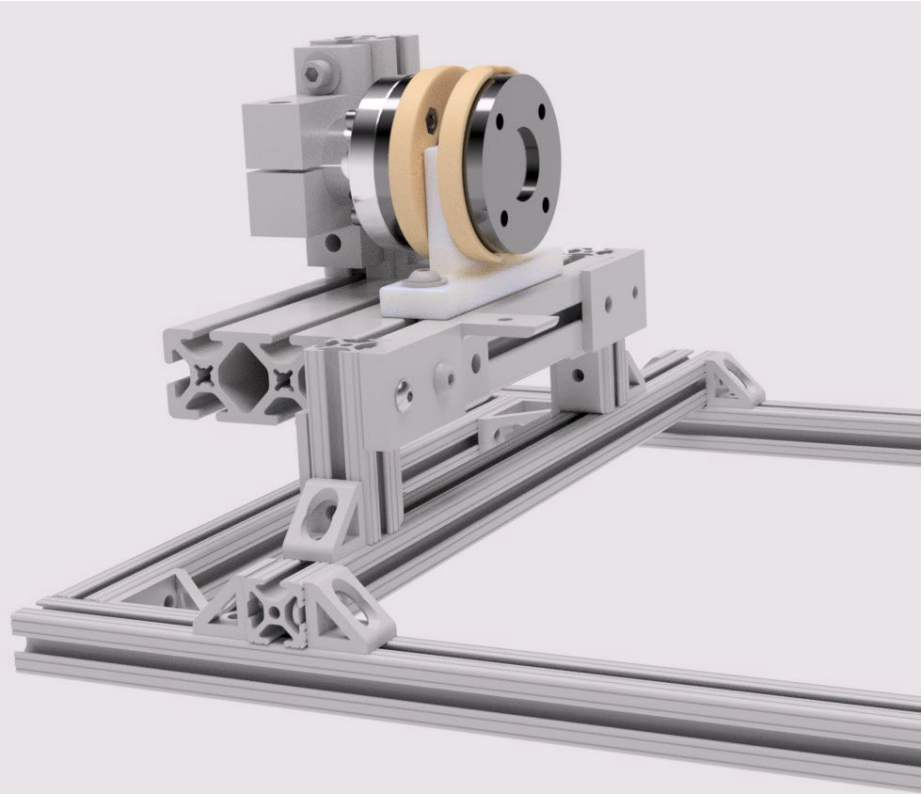
- Attach stanchion to short (4.25”) t-slot profile
  - (1x) 1515-UL-4.25-CL
  - (1x) 5880 stanchion
  - (2x) 3627 screws
  - (2x) 3659 washers
  - (2x) 3678 T-nuts
  - Note: remove handled clamping screw that comes with the stanchion
- Add corner brackets to short (4.25”) t-slot profile
  - (2x) 4332 corner brackets
  - (4x) 3607 screws
  - (4x) 3678 T-nuts
- Slide torque coupler through stanchion, using aluminum anti-seize
- Slide assembly onto mounting platform and secure
- Note: may need to temporarily loosen the two screws keeping the stanchion mounted in order to slide everything together.
- Ensure center of stanchion hole aligns with center of torque transducer as it rests on the transducer support piece. Rotation should be relatively free.





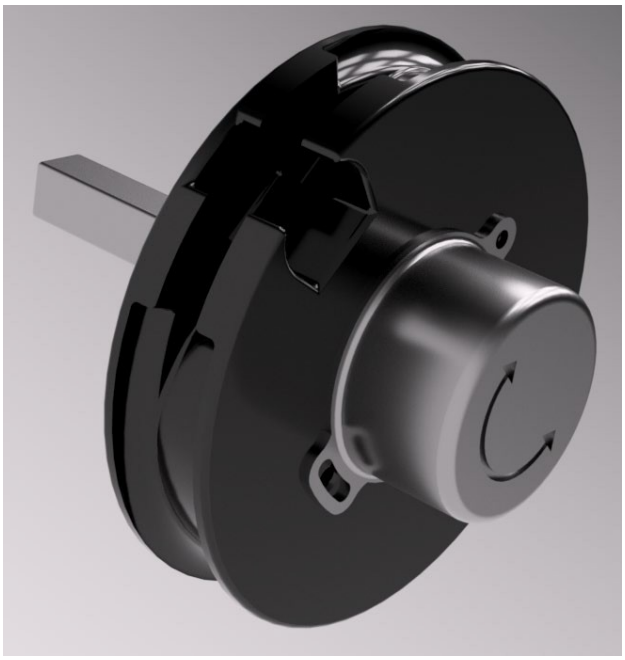
Aluminum anti seize lubricant between stanchion and coupler

Step 5: Mount transducer subassembly onto uprights



- Align and slide into place vertically then secure with screws and T-nuts

Step 6a: Construct drive shaft and mount inclinometer



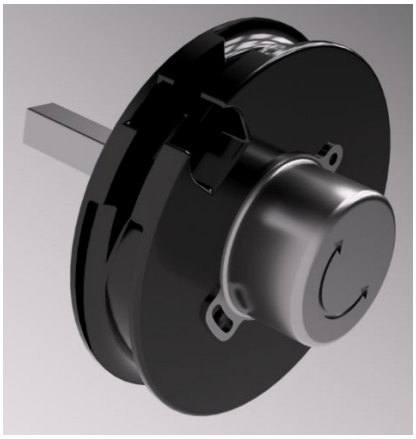
Part #	Part name	#
	McMaster	
98164A119	316 Stainless Steel Button Head Hex Drive Screw Super-Corrosion-Resistant, 6-32 Thread Size, 1" Long	6
90715A007	316 Stainless Steel Nylon-Insert Locknut Super-Corrosion-Resistant, 6-32 Thread Size	4
	Custom 3D Printed (Onyx)	
	6” Pulley with square hole (and notch to hold elastic band)	2
	Spectron Sensors	
SSY0185-67	Ratiometric Electronic Inclinometer	2
	Other	
	6061-T6511 Square Aluminum 0.5" x 0.5" x 3.6"	2

Step 6a: Construct drive shaft and mount inclinometer (continued)

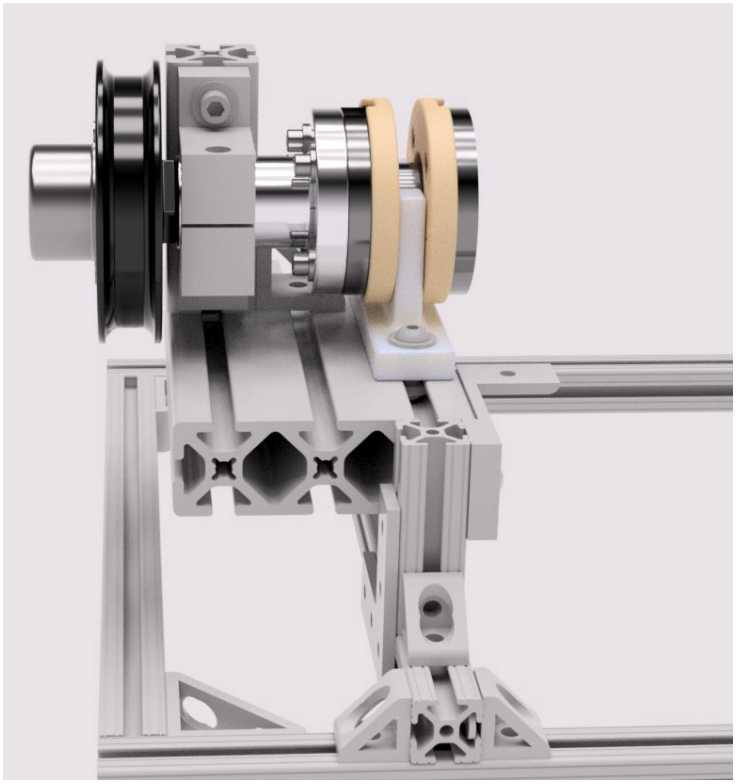
Quantities below are for ONE side. Multiply all parts by 2 to make the total amount of parts needed as listed on previous page.

- Attach drive shaft to pulley
    - (1x) 6061-T6511 Square Aluminum 0.5" x 0.5" x 3.6“
        - Note: due to an iterative design, we had to custom machine the square aluminum down to a slightly smaller size (12.5mm vs. 0.5 inches). Adjust design as needed to your situation
    - (1x) custom printed pulley
    - (1x) 6-32 screw (approximately 1”, custom length as needed)
        - Secures pulley to drive shaft via tapped hole in the drive shaft

- Attach inclinometers (angle sensors)
    - (1x) Tilt sensor
    - (2x) 6-32 screws
    - (2x) 6-32 nuts
    - In later steps, make sure angle sensor is zero’d properly
        - You can use the mechanical stop to hold pedal perfectly parallel to the floor

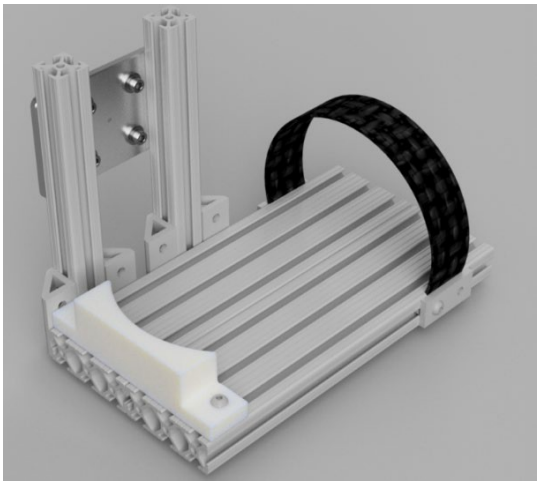


Step 6b: Mount the drive shaft



- Drive shaft slides into square hole of the aluminum torque coupler

Step 7a: Construct the foot pedals

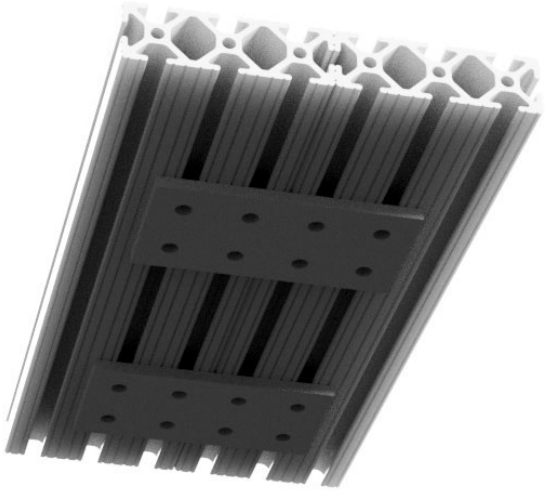


Part #	Part name	#
	80/20 Inc.	
1010-7.25-CL	1.00" x 1.00" T-Slotted Profile - Four Open T-Slots (1/4”-20 tap one end for end cap)	4
1030-11-CL	1.00” X 3.00” T-Slotted Profile - Eight Open T-Slots	4
3692	1/4-20 x .750" Button Head Socket Cap Screw (BHSCS)	4
4107	10 Series 2 Hole - Straight Flat Plate	4
4134	10 Series 4 Hole - Wide Gusseted Inside Corner Bracket	8
4165	10 Series 8 Hole - Rectangular Flat Plate	4
3690	1/4-20 x .500" Button Head Socket Cap Screw (BHSCS)	72
3675	1/4-20 Slide-In Economy T-Nut - Centered Thread	76
	McMaster-Carr	
98201A311	Exact-Grip-Length Flanged Socket Head Screw, 1/4"-20 Thread Size, 15/16" Long - 3/16 drive	8
	Custom Machined Aluminum	
	Pedal side mount	2
	Custom 3D Printed (Onyx)	
	Heel cup	2
	Other	
	2" Wide Hook and Loop Strap	3 ft

Step 7a: Construct the foot pedals (continued)

Quantities below are for ONE side. Multiply all parts by 2 to make the total amount of parts needed as listed on previous page.

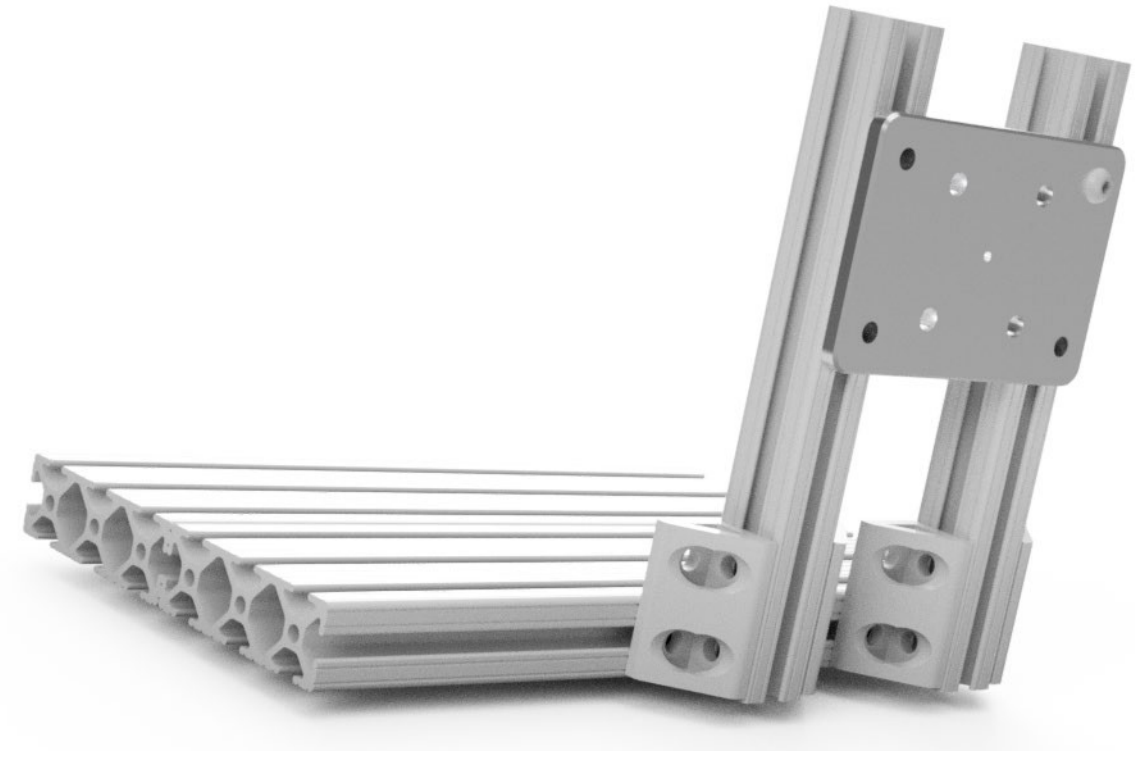
- Combine t-slot profiles to make wide base for foot to rest on
    - (2x) 1030-11-CL
    - (2x) 4107 straight flat plates
    - (16x) 3690 screws
    - (16x) 3675 T-nuts



Step 7a: Construct the foot pedals (continued)

Quantities below are for ONE side. Multiply all parts by 2 to make the total amount of parts needed as listed on previous page.

- Add vertical bars with sliding mount
    - (2x) 1010-7.25-CL t-slot aluminum profile
    - (4x) 4134 corner brackets
    - (1x) custom machined pedal side mount
    - (16x) 3690 screw
        - 12x for corner brackets (one of three holes not used per corner bracket)
        - 4x for custom machined pedal side mount (use widest set of holes)
    - (16x) 3675 T-nut
        - 12x for corner brackets
        - 4x for custom machined pedal side mount
- Ensure pedal side mount can slide freely when screws are loosened (i.e. ensure bars are parallel and correct width apart which is 3.5” on center)



Step 7a: Construct the foot pedals (continued)

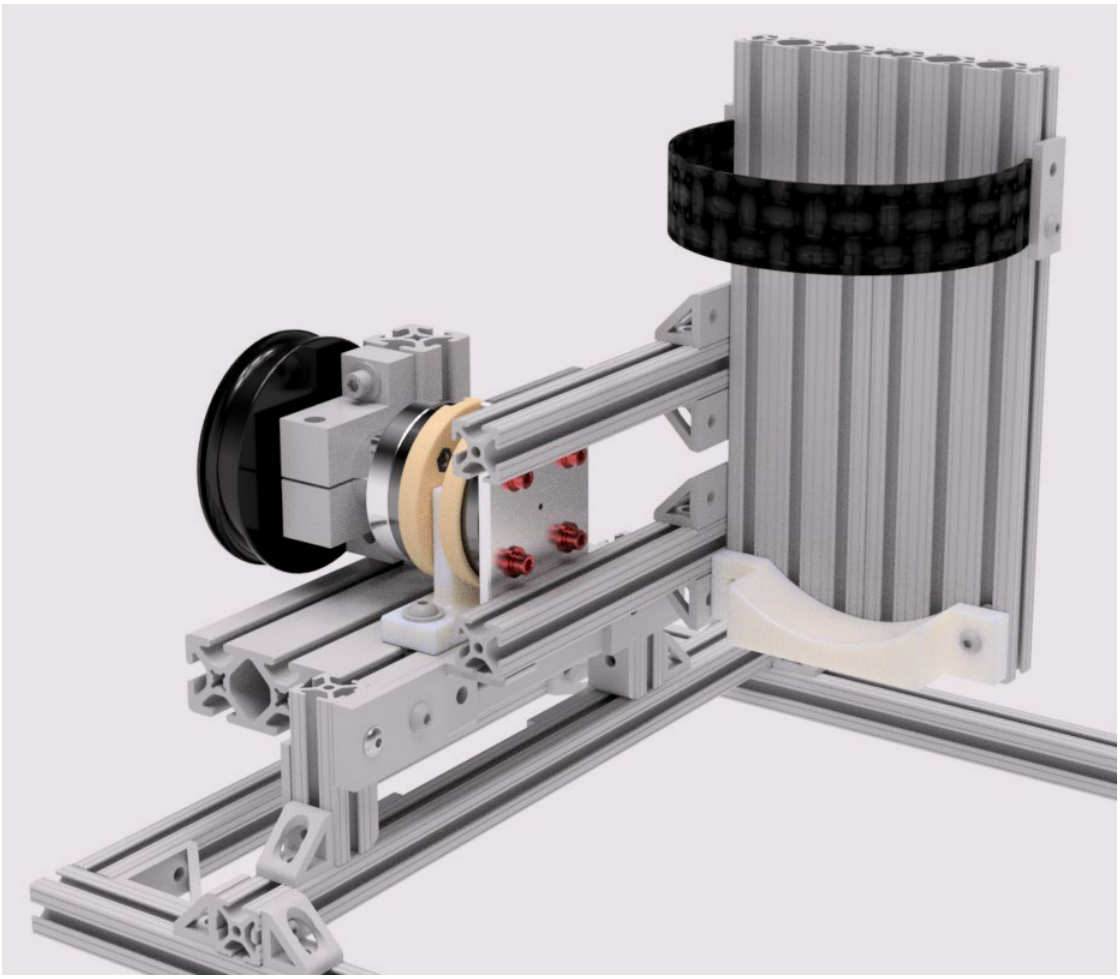
Quantities below are for ONE side. Multiply all parts by 2 to make the total amount of parts needed as listed on previous page.

- Add heel cup
    - (1x) 3D printed heel cup
    - (2x) 3692 screws
    - (2x) 3675 nuts
- Add toe strap
    - Hook and loop strap
        - Cut to length as needed
        - Add holes for screws to pass through
    - (2x) 4165 flat plates
    - (4x) 3690 screws
    - (4x) 3675 nuts

Step 7b: Mount foot pedals to apparatus

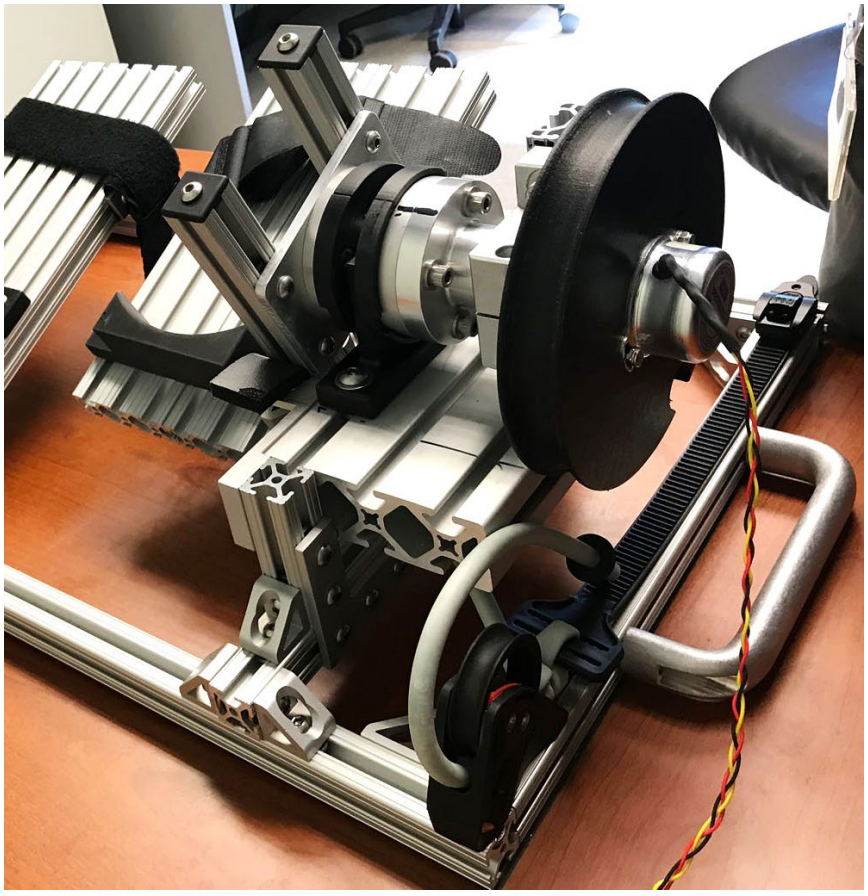
Quantities below are for ONE side. Multiply all parts by 2 to make the total amount of parts needed as listed on previous page.

- (4x) 98201A311 screws (red in image below) go through the torque transducer mounting holes and screw into the serrated flanged nuts built into the 3D printed lateral spacers on the other side



Step 8: Add final remaining components

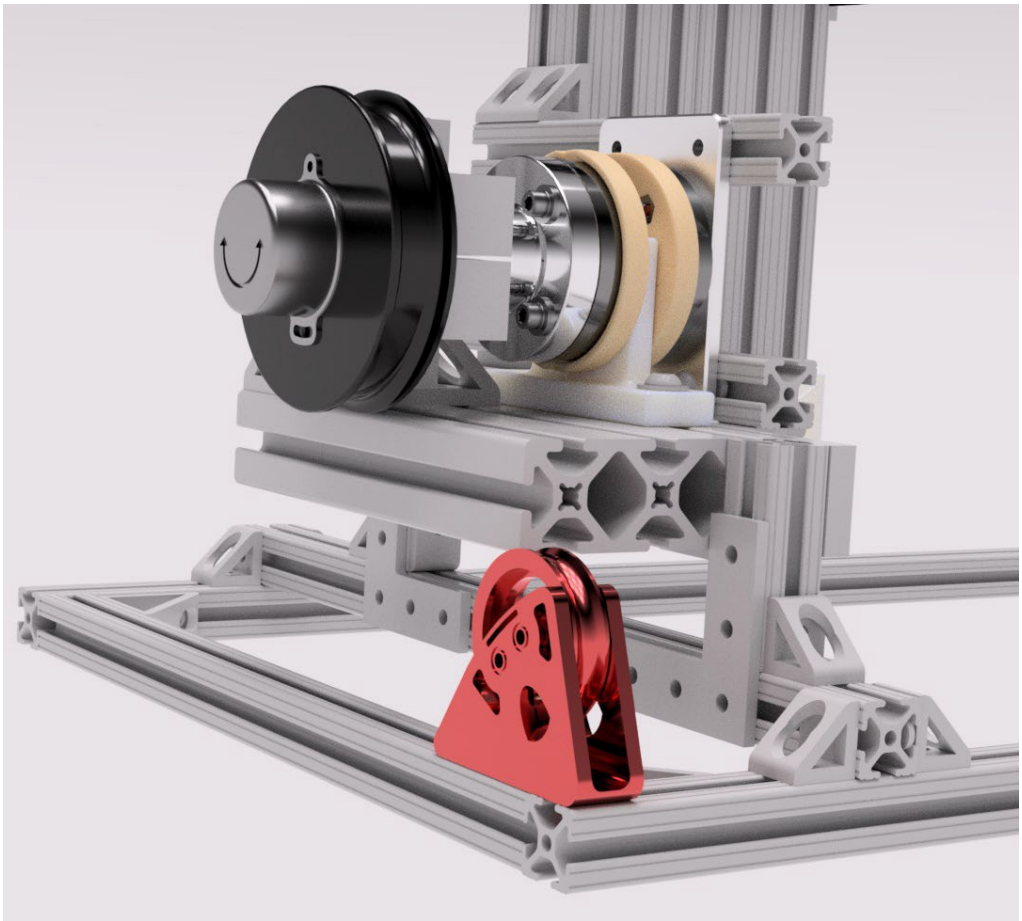
Part #	Part name	#
	80/20 Inc.	
3690	1/4-20 x .500" Button Head Socket Cap Screw (BHSCS)	10
3675	1/4-20 Slide-In Economy T-Nut - Centered Thread	6
2015-plain	10 series end cap	4
	McMaster-Carr	
3211T41	Mounted Pulley for Rope-for Horizontal Pulling with Bearing, for 3/8" Diameter, 1100 lbs. Capacity	2
	M2 Inc.	
RB75-ALU-T	0.75" Aluminum buckle. HIGH Release version	2
	0.75" Ladder Strap with Tab (14")	2
	Other	
	TheraBand Resistance Tubing, Silver (Super Heavy)	50"
	Aluminum washer	2



Step 8: Add final remaining components (continued)

Quantities below are for ONE side. Multiply all parts by 2 to make the total amount of parts needed as listed on previous page.

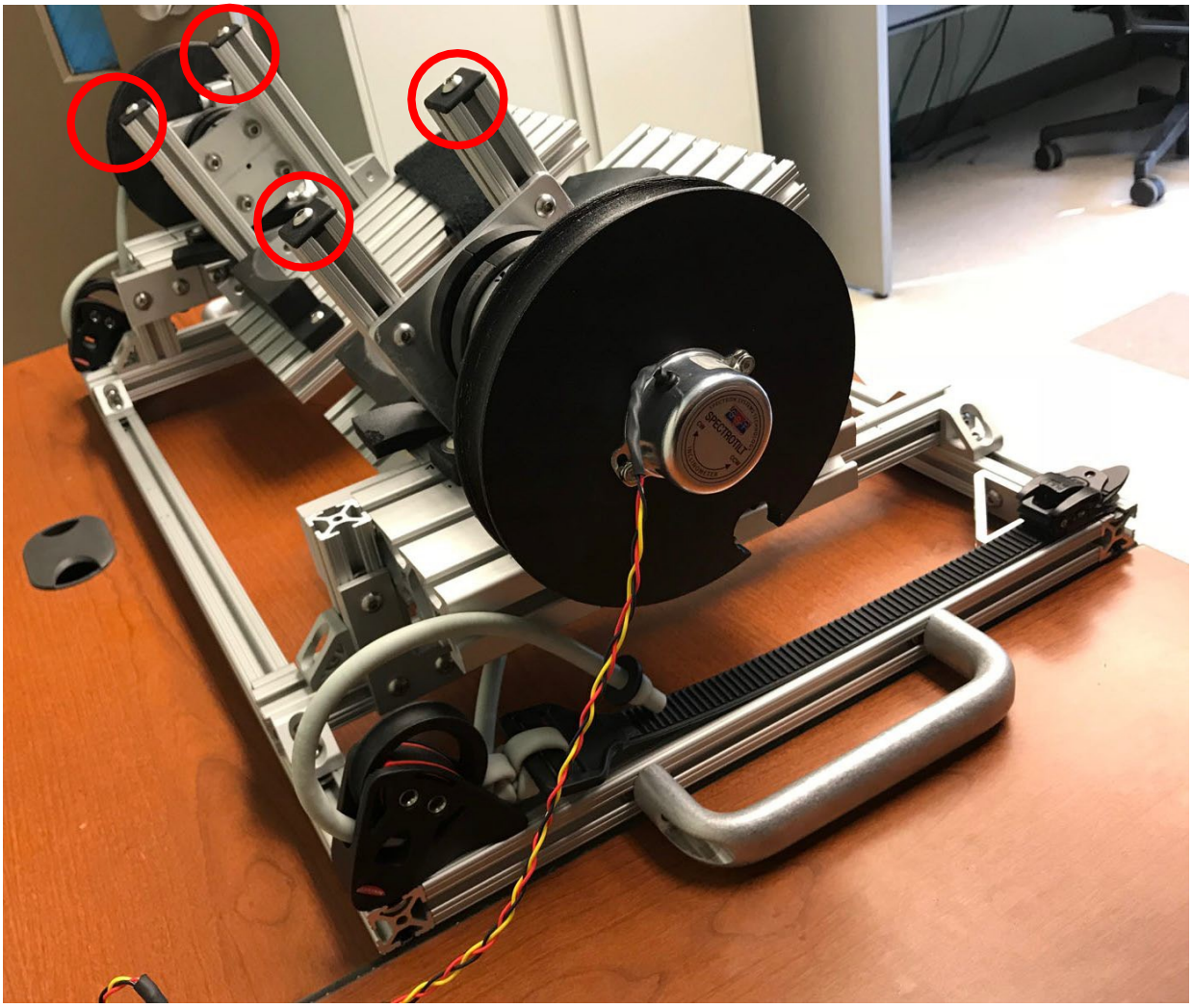
- Mount pulley (red in image below) to frame
    - (1x) 3211T41 pulley
    - (2x) 3690 screws
    - (2x) 3675 T-nuts
    - Note: may need to briefly disassemble part of frame to get one of the screws/t-nuts in to the t-slot profile that has the aluminum handle on it
- Mount ratcheting buckle to frame (see previous page)
    - (1x) ratcheting aluminum buckle, (1x) 3690 screw, (1x) washer, (1x) 3675 T-nut
- Add elastic band and ladder strap (see previous page)
    - Route band through pulley on frame (red in image below) and then over the larger custom printed pulley (black in image below)
    - Tie band to ladder strap
    - Insert ladder strap into buckle



Step 8: Add final remaining components (continued)

Quantities below are for ONE side. Multiply all parts by 2 to make the total amount of parts needed as listed on previous page.

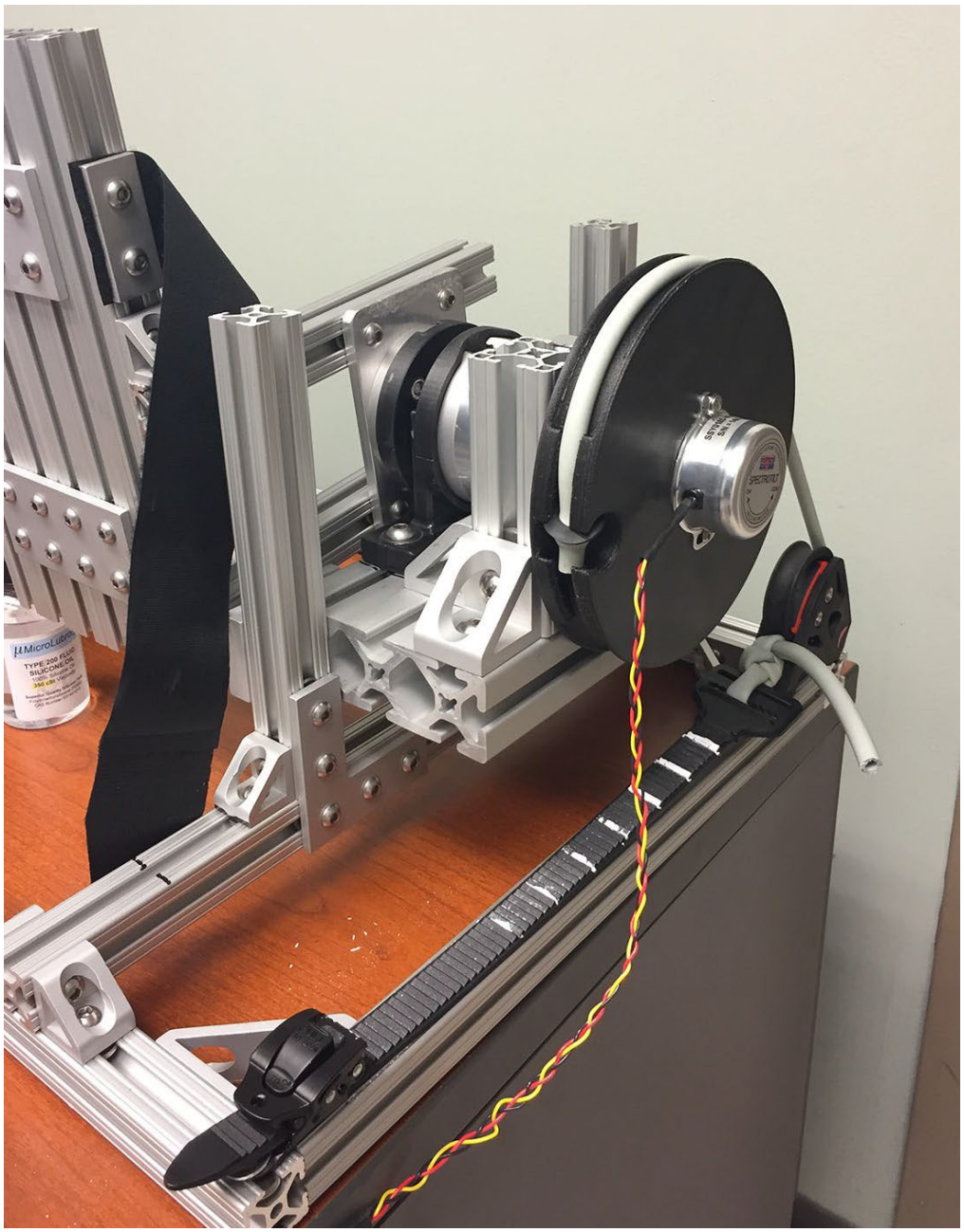
- Add end caps to T-slot profiles as desired
    - We added end caps as circled in image below to prevent participants from accidentally scraping their legs. You can add more as you see fit.
    - (4x) 3690 screws and (4x) 2015-plain end caps



- Make your own custom wiring to connect the sensors to your data acquisition device

Assembly Complete!

Don’t forget to adjust foot pedal for each individual to align ankle joint with center of rotation of the device. You can accomplish this by removing the four screws that secure the foot pedal to the torque transducer. Then, with the foot pedal removed, you can adjust the heel cup’s forward-backward location as well as the vertical location of the pedal side mount, using the pilot hole in the pedal side mount as a reference for the axis of rotation of the device. Then simply re-secure the foot pedal to the rest of the device.



Note: figure above is from a slightly older, non-final version of the device. The primary purpose of this image is to show the elastic band being stretched over the pulleys.