

# Overview and assembly of 2<sup>nd</sup> round Trillium prototypes

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These slides give a visual overview of the Trillium robot prototypes, illustrate how the various assembly jigs are meant to be used, and the rough order of operations expected for assembling these prototypes. It is understood that there are multiple ways some of these steps could be accomplished, and we may find better methods as we proceed. Bill of materials is provided. CAD assemblies are embedded in the pptx version.

## Tools needed:

- small hand press
- 0.028" hex driver (flat tip, not ball)
- 0.050" hex driver (any type)
- fine tip tweezers
- fine tip scissors

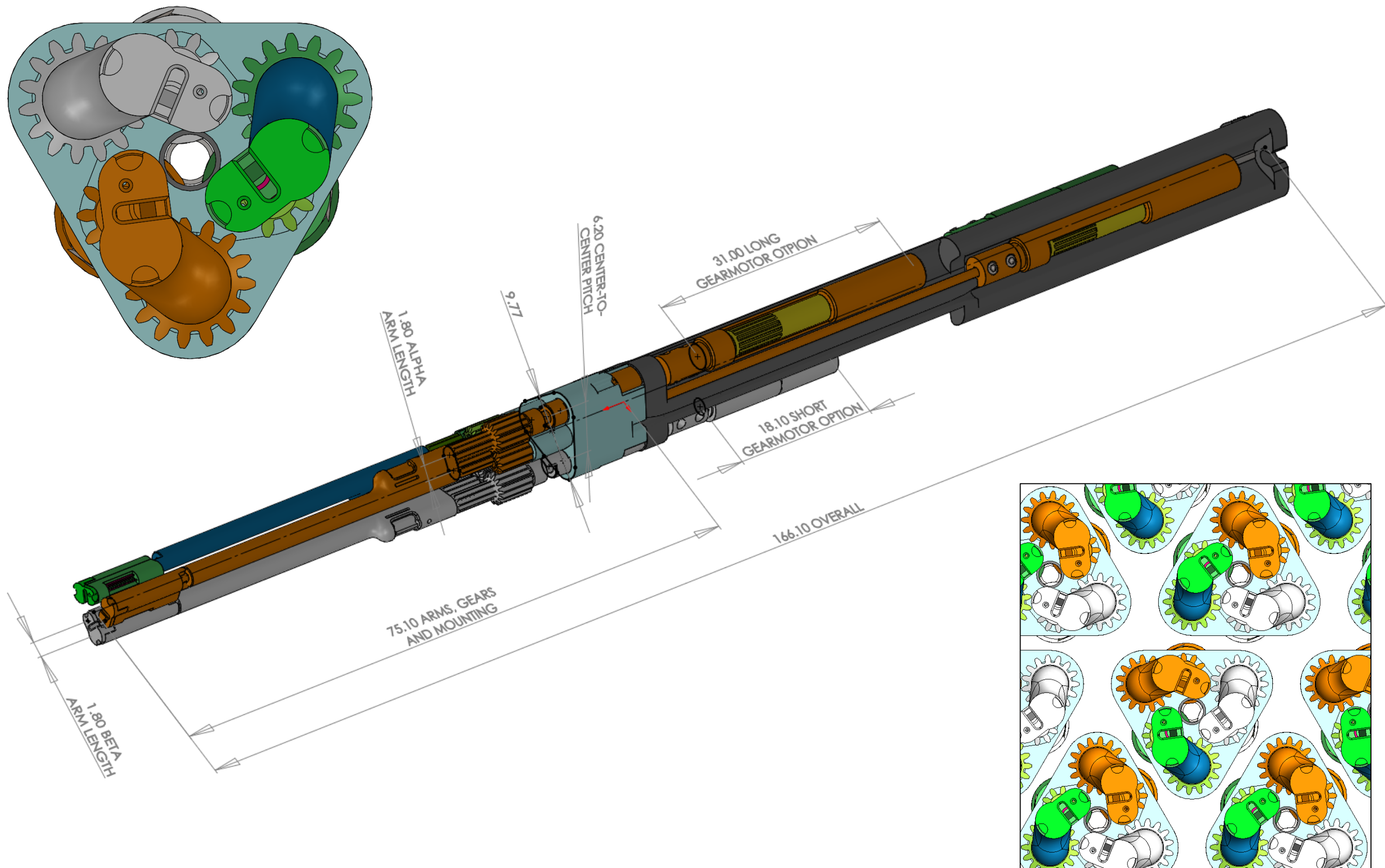
## Useful other tools:

- small vise with rotational freedom
- magnifiers

## Consumables:

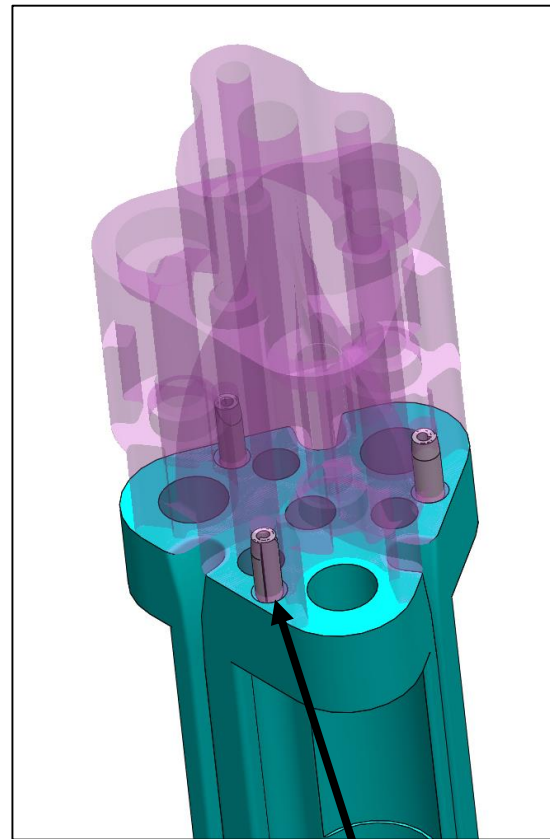
- tape to secure motors, likely polyimide and/or aluminum, widths 1/8" and/or 1/4"

# Trillium "2" prototype



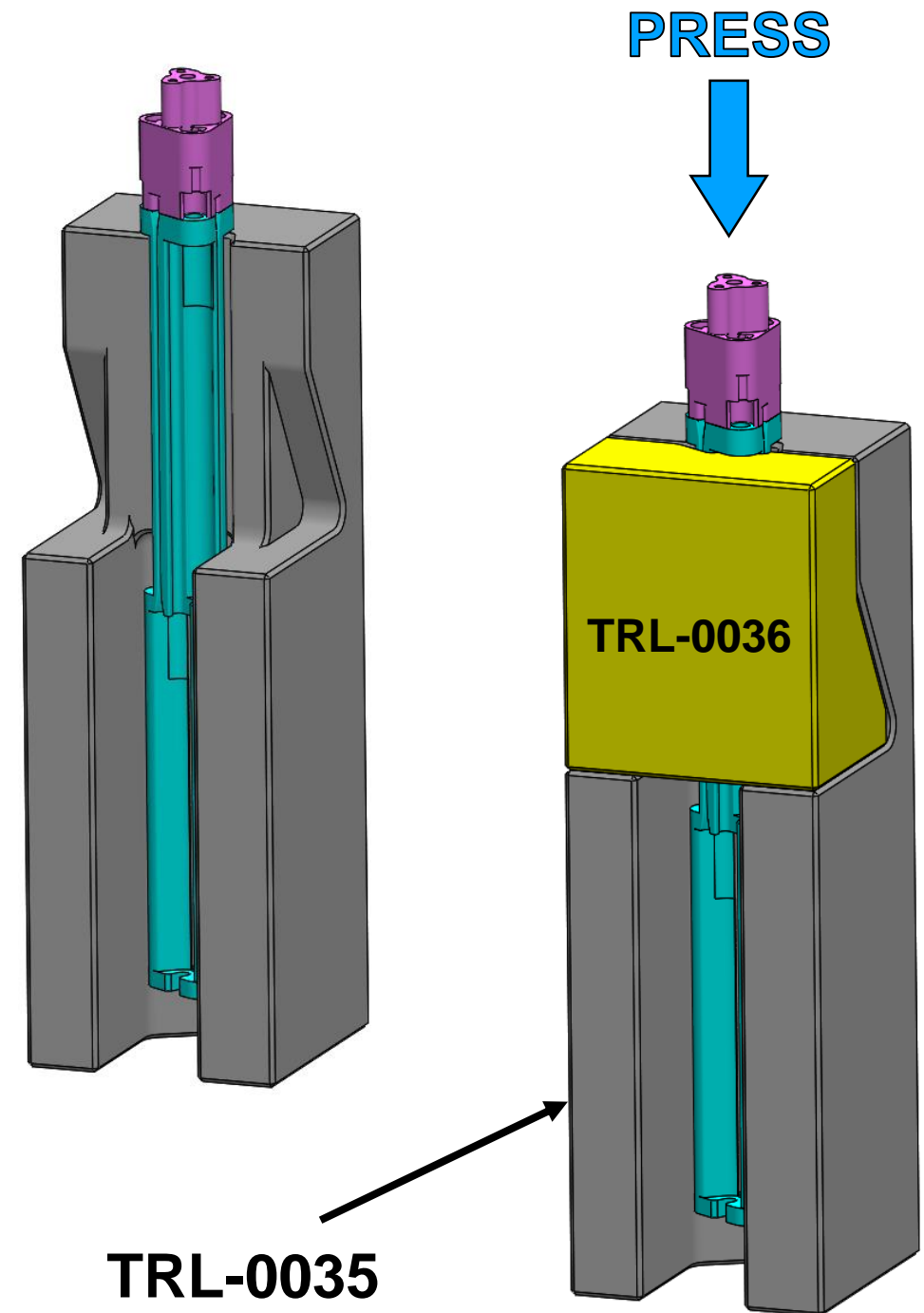
# Aft Structure

Goal: connect with 3x pins



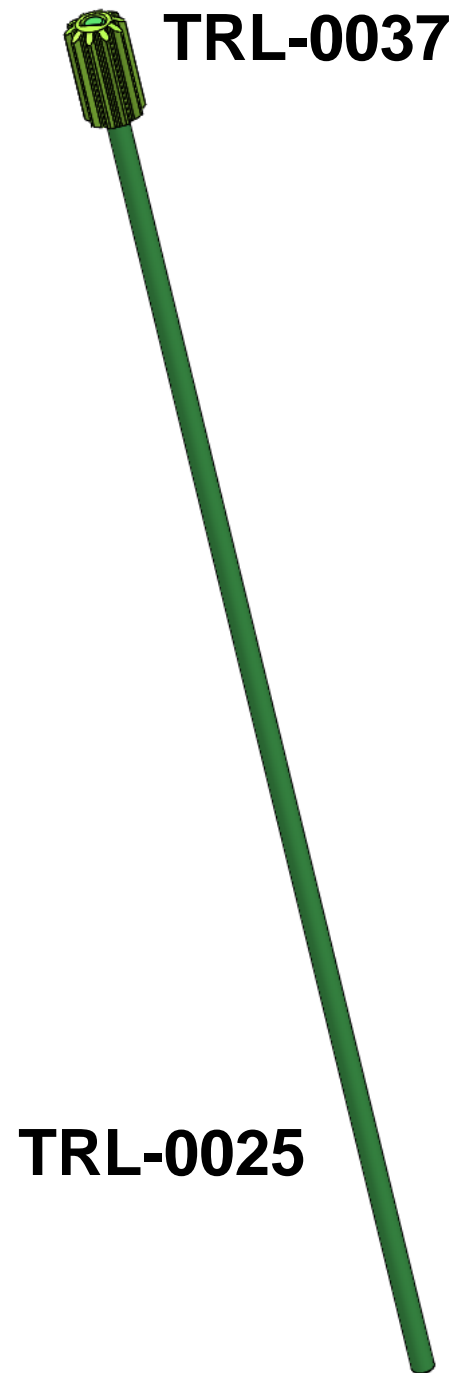
3x  
1/32" x 3/16"  
spring pins

Tooling

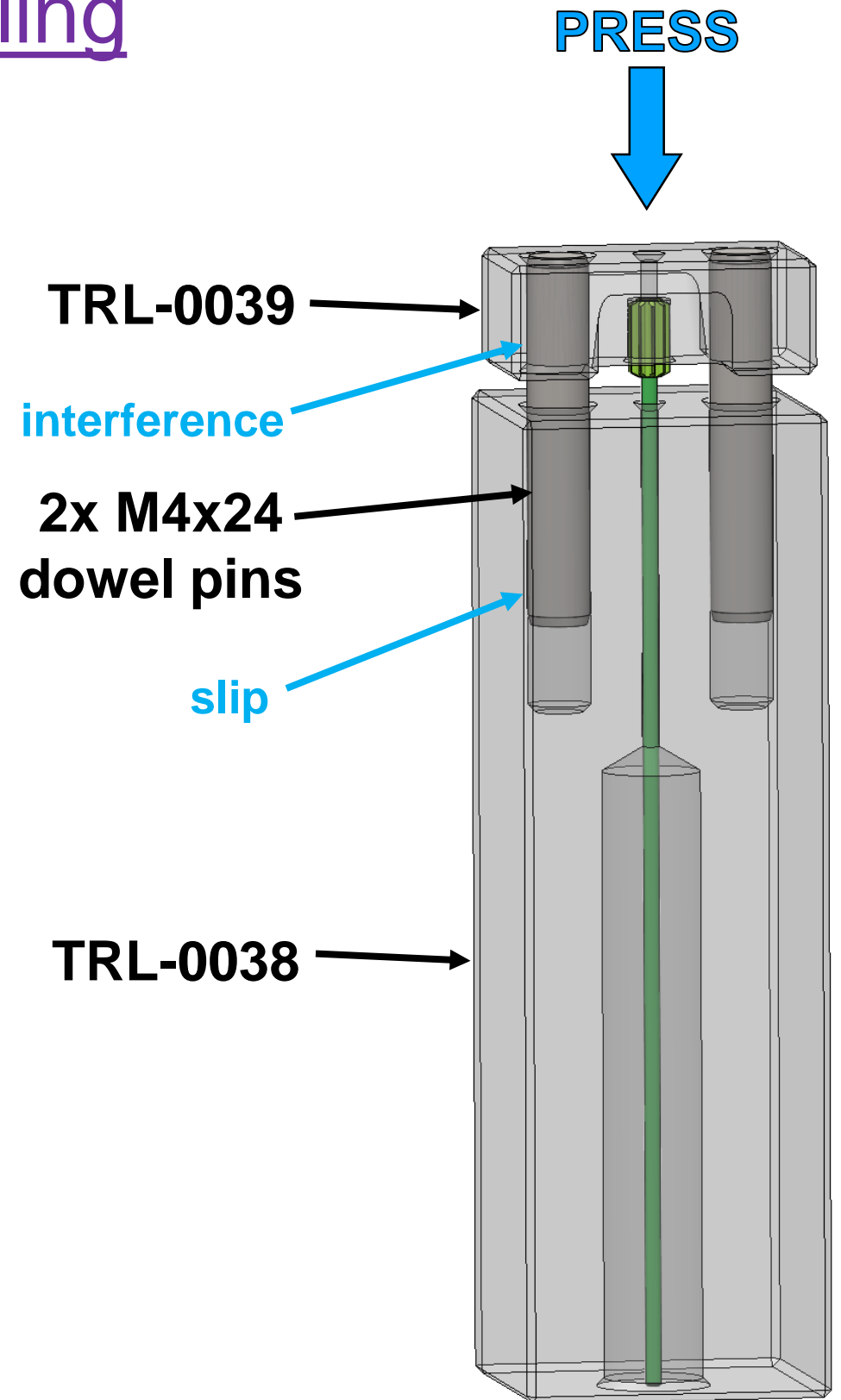


# Beta Motor Shaft Assembly

Goal: press gear on shaft

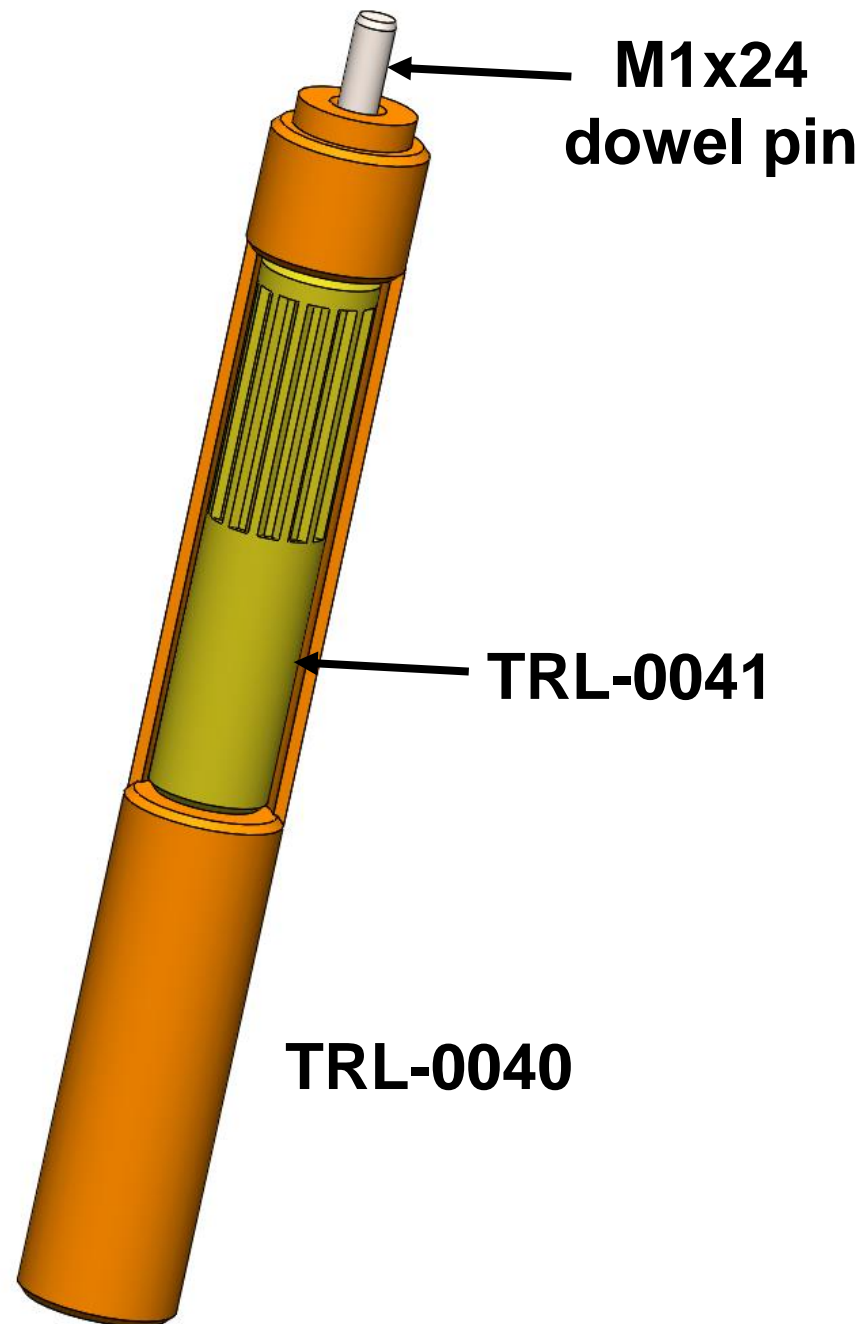


Tooling

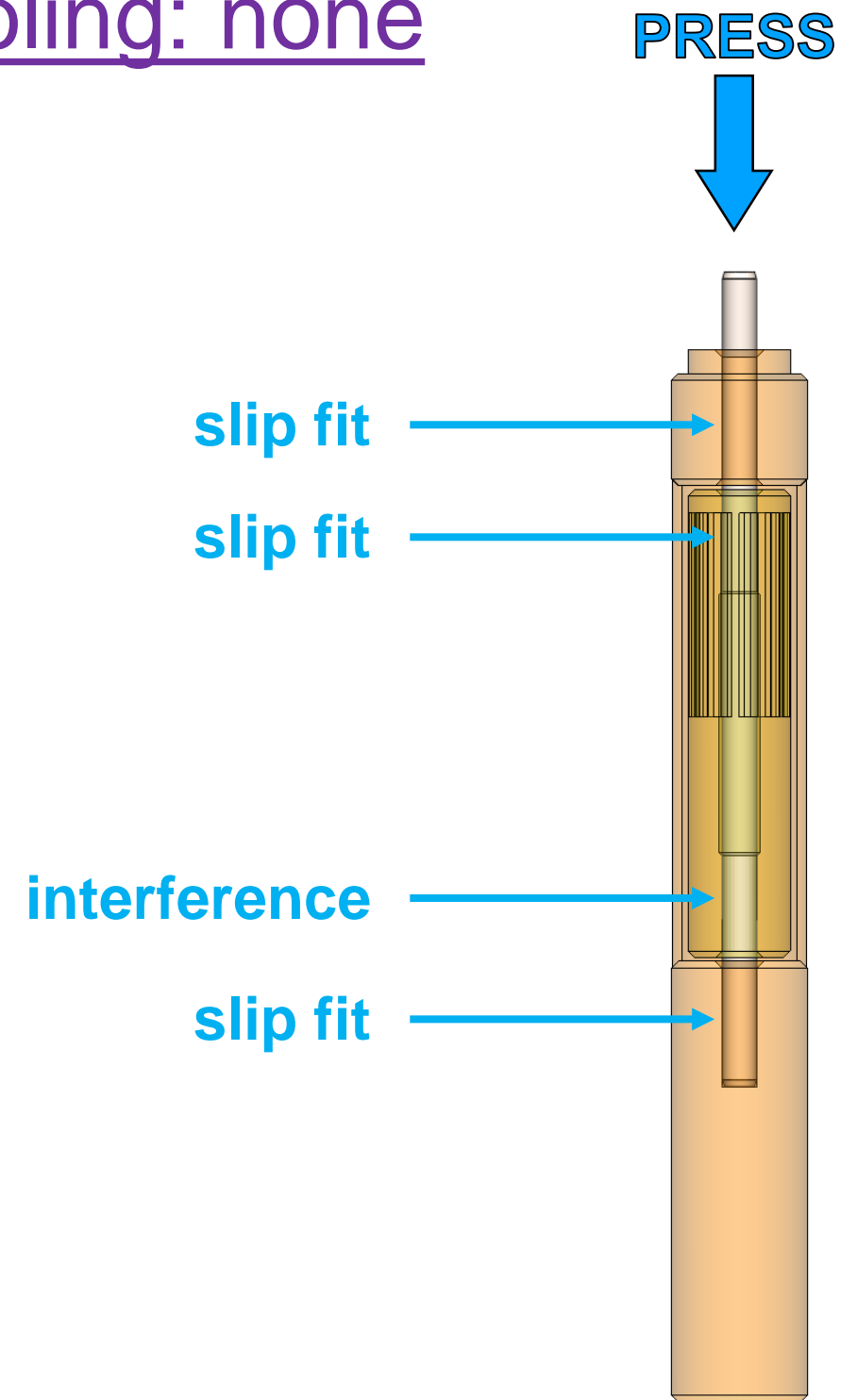


# Manual motor dummy

Goal: press pin into rotator

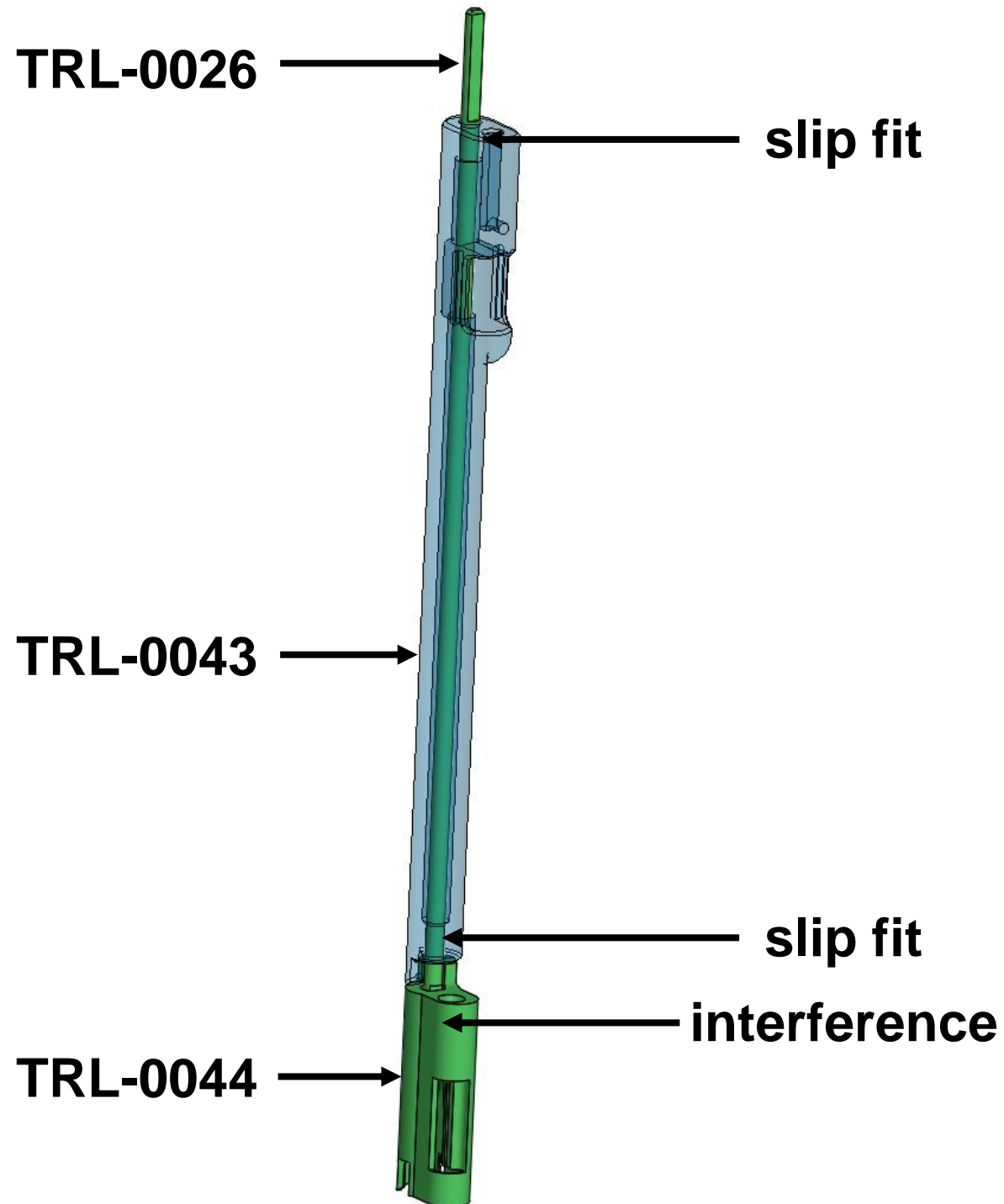


Tooling: none

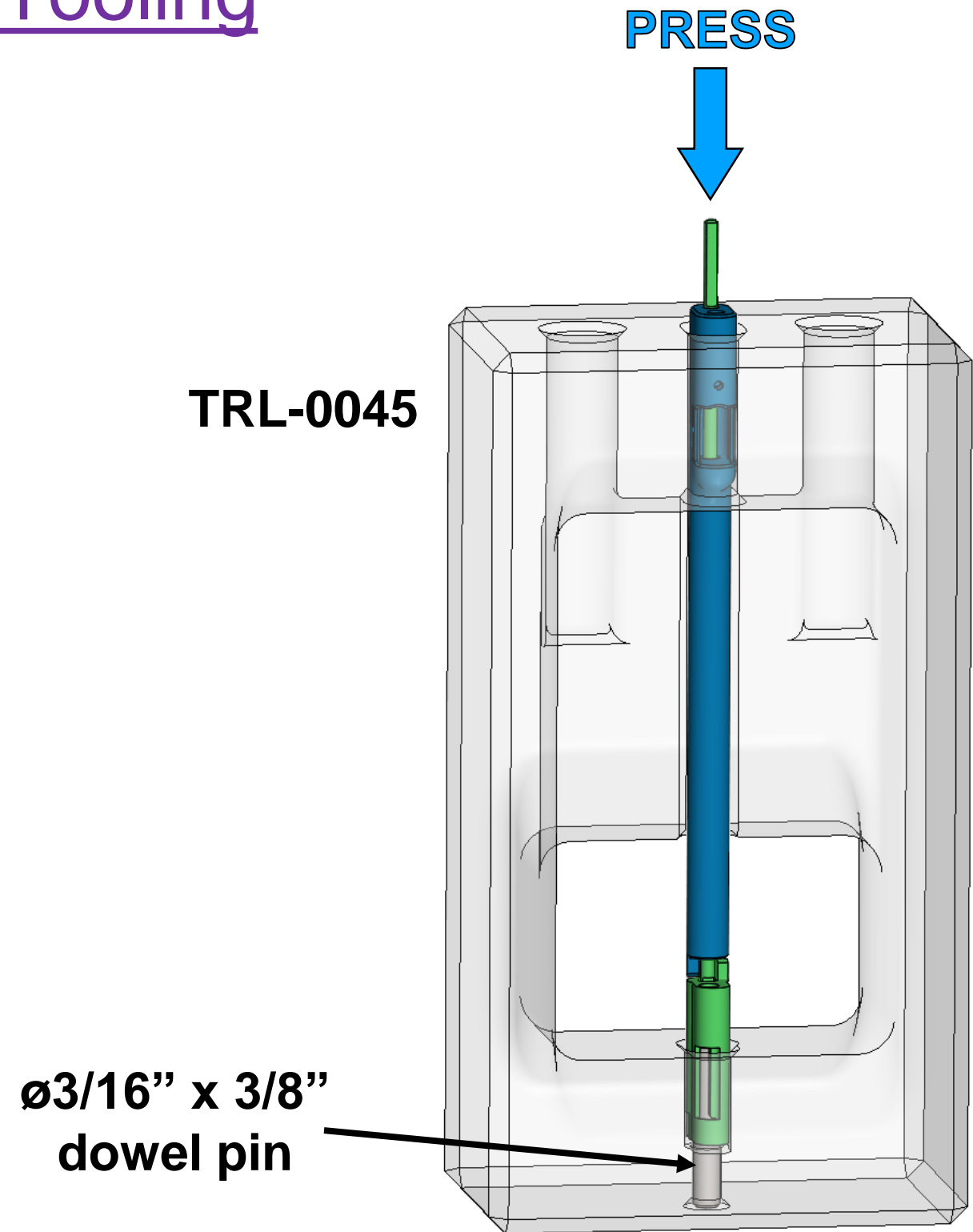


# Beta fiber axis assembly (1 of 3)

Goal: press shaft in fiber arm



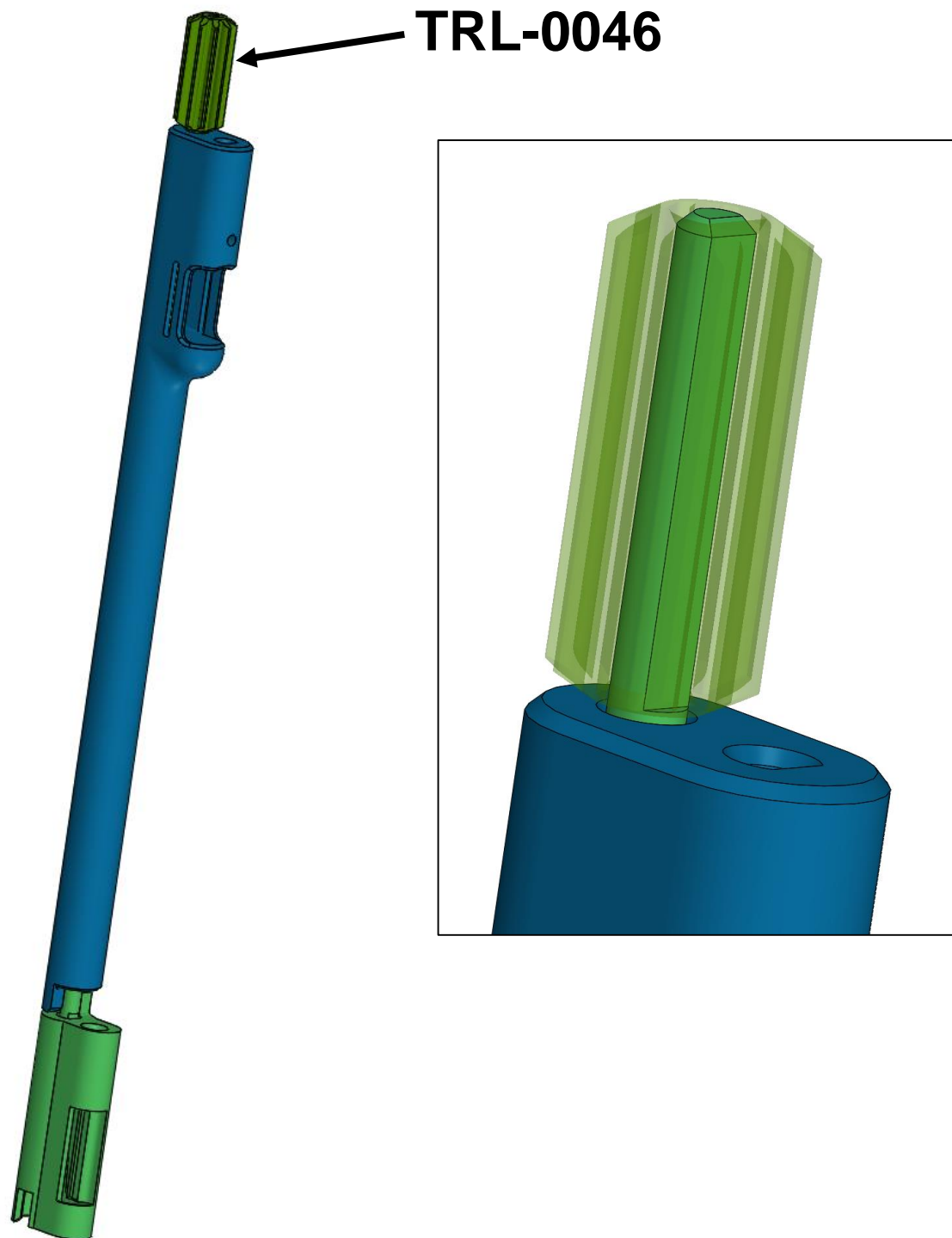
Tooling



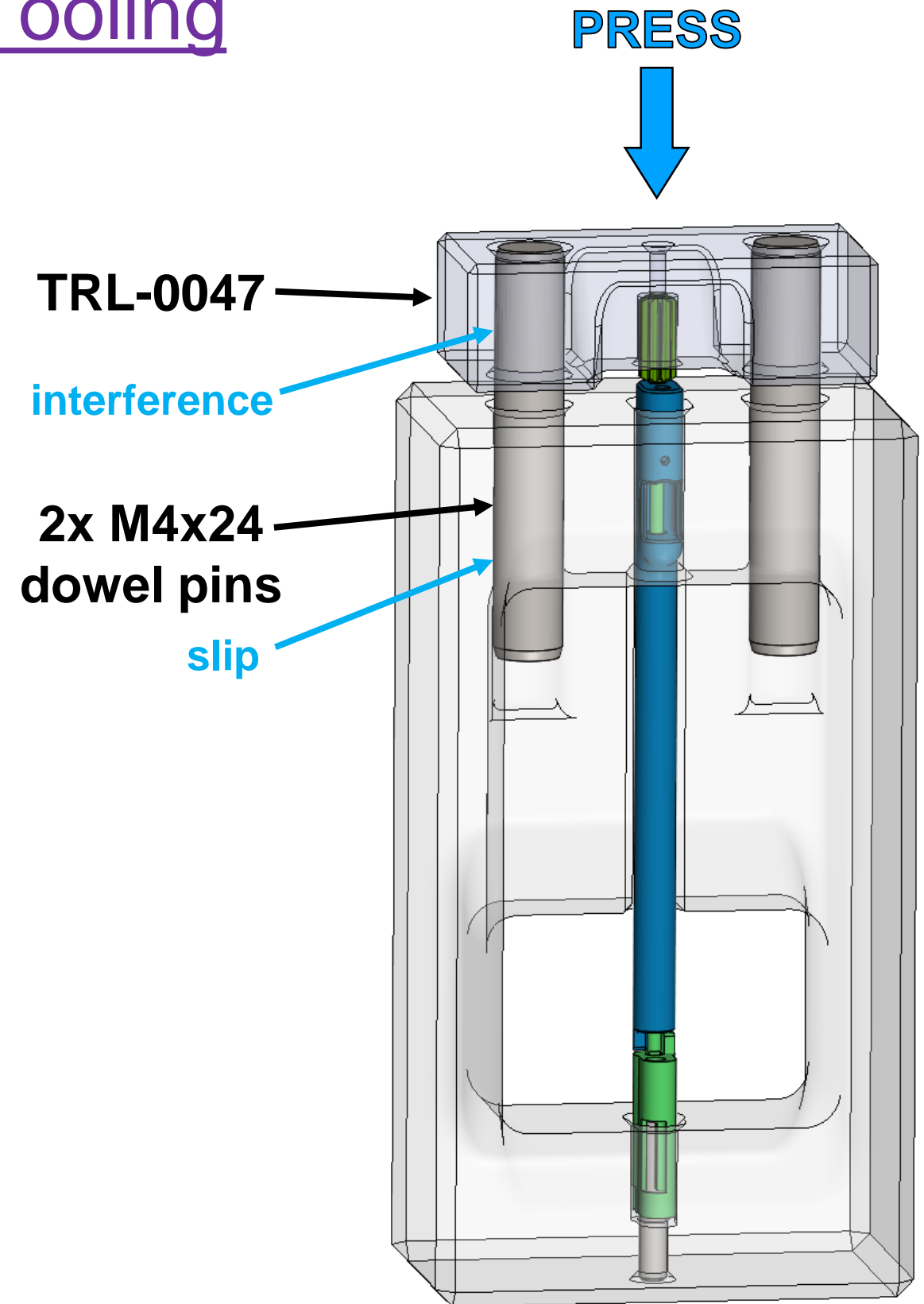


# Beta fiber axis assembly (2 of 3)

Goal: press gear on shaft

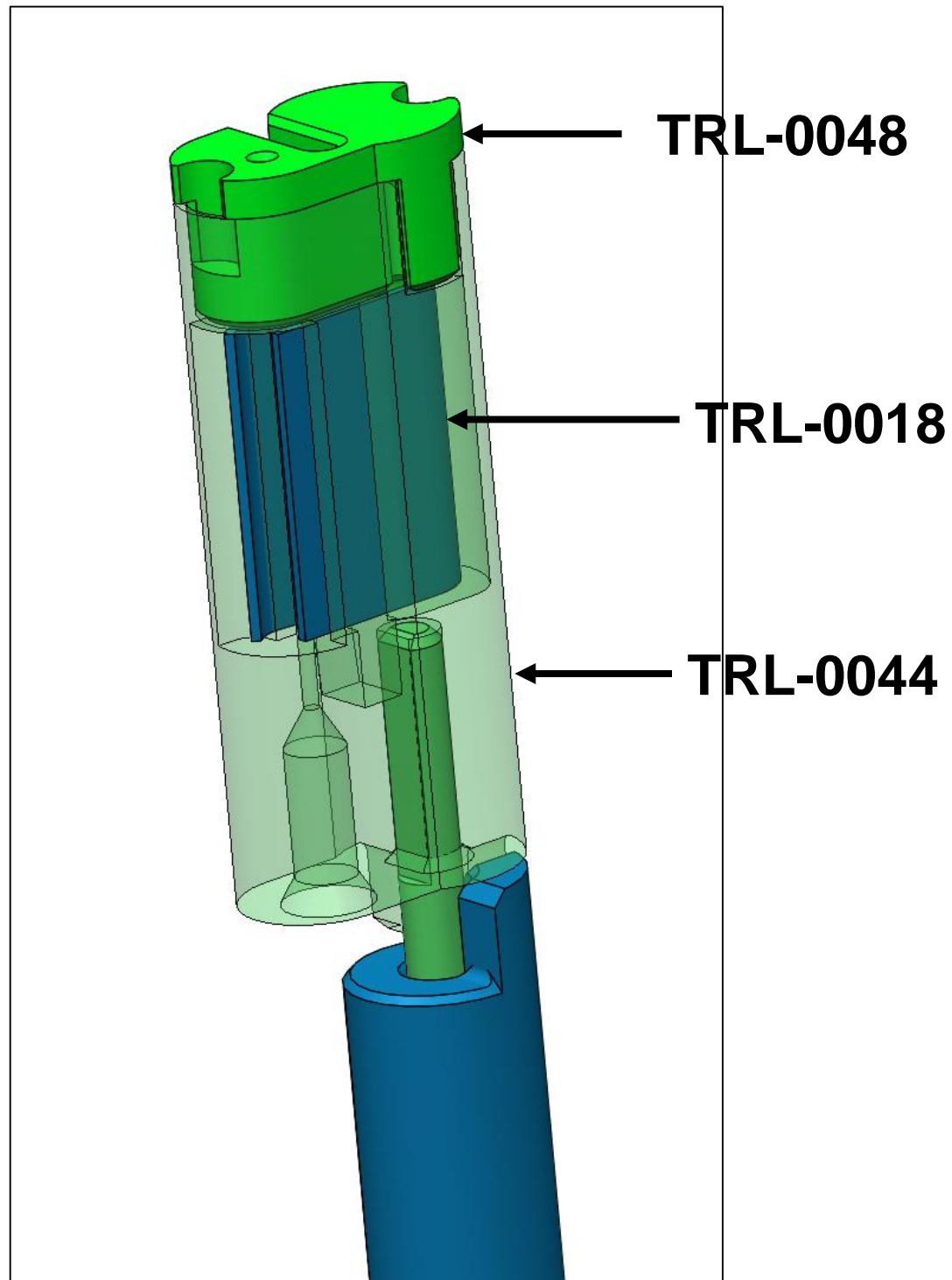


Tooling

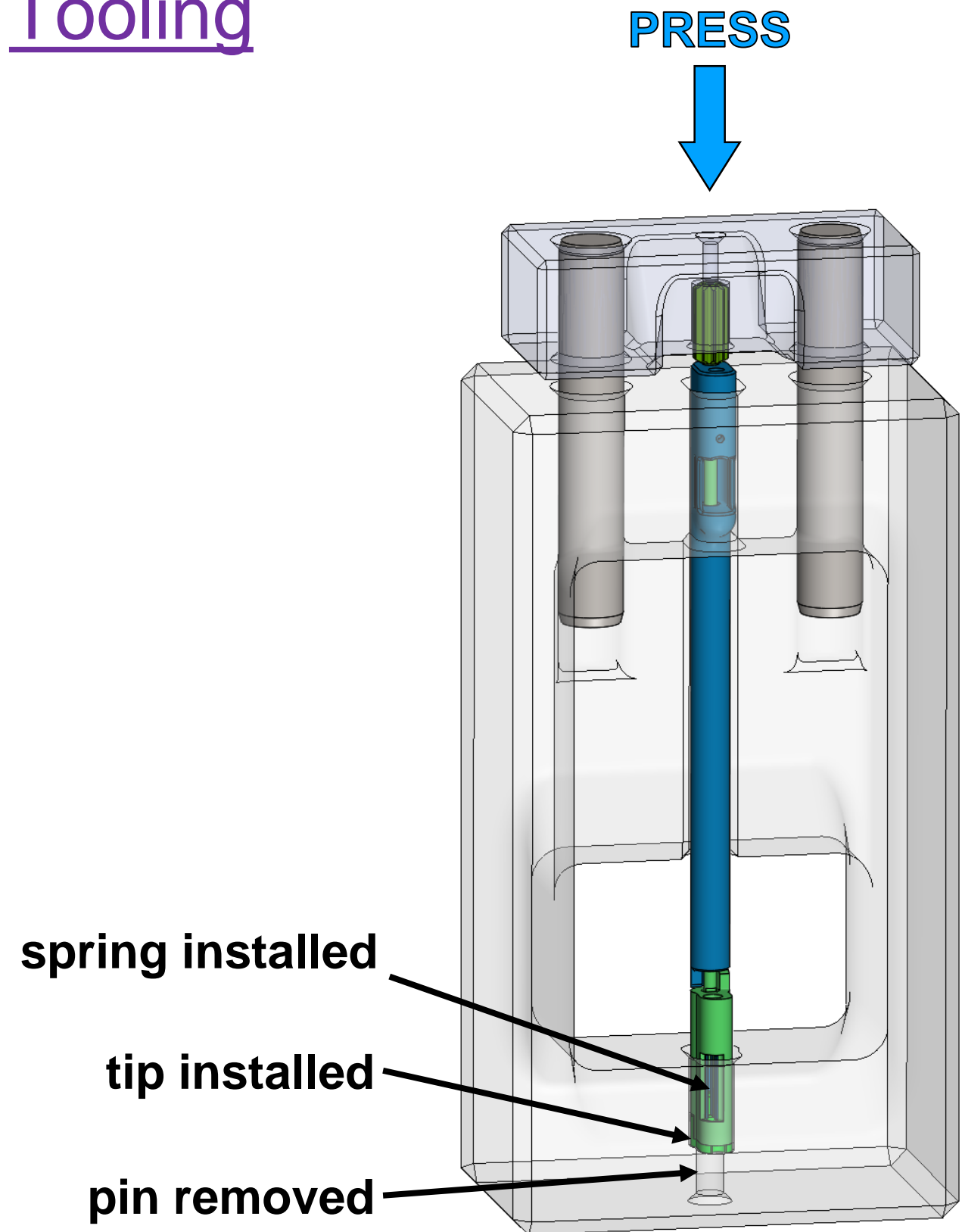


# Beta fiber axis assembly (3 of 3)

Goal: install spring and tip



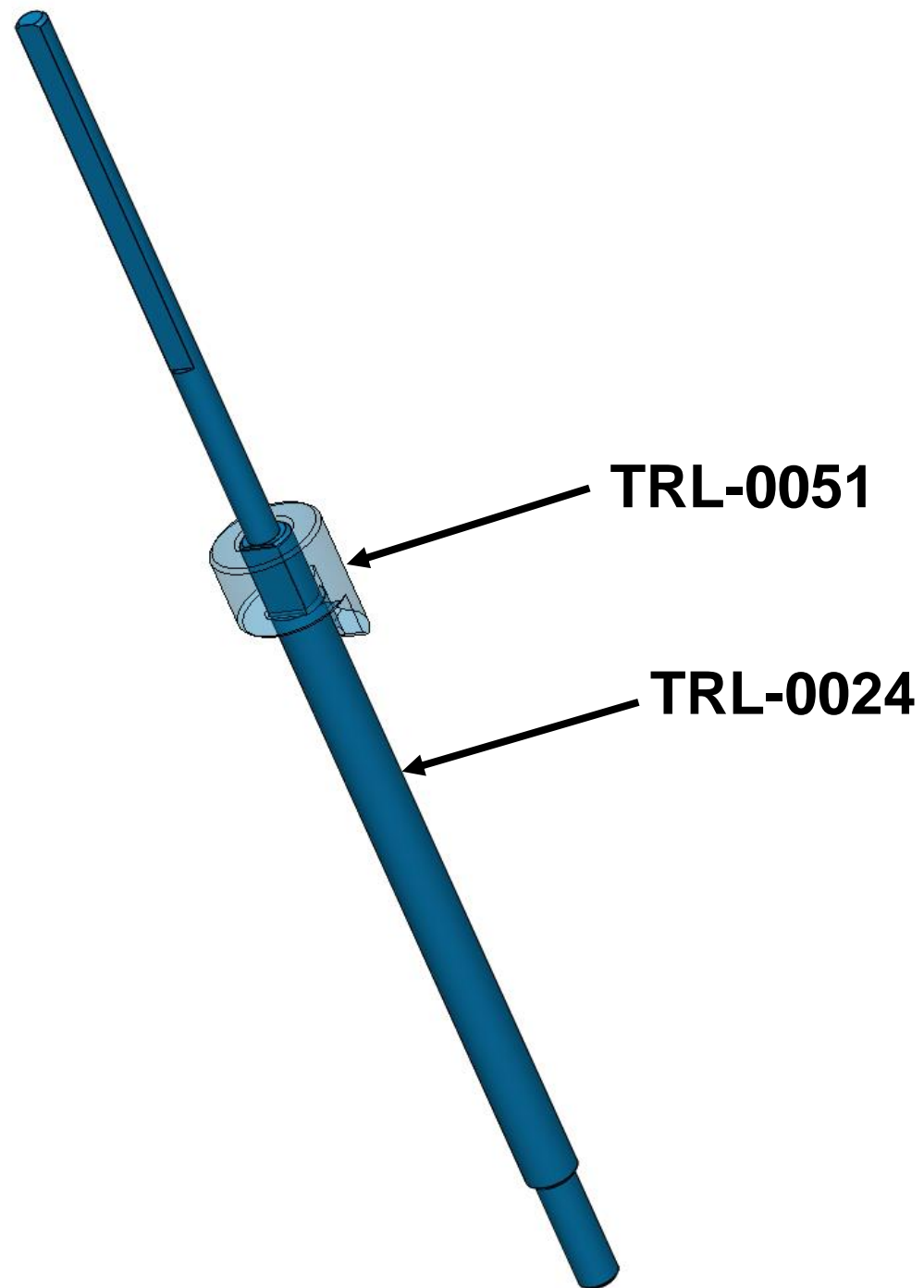
Tooling



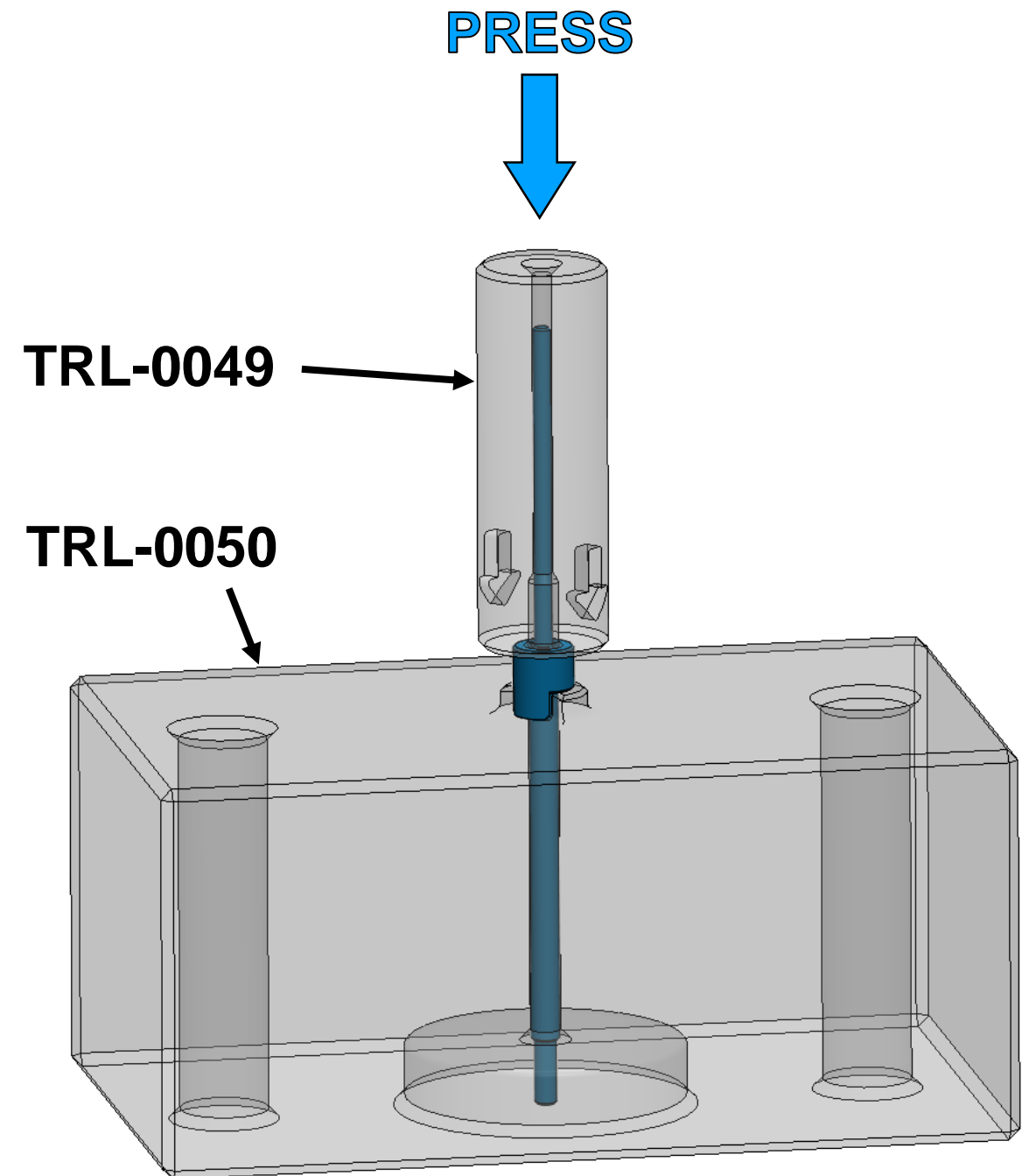


# Alpha stop

Goal: press stop on alpha shaft

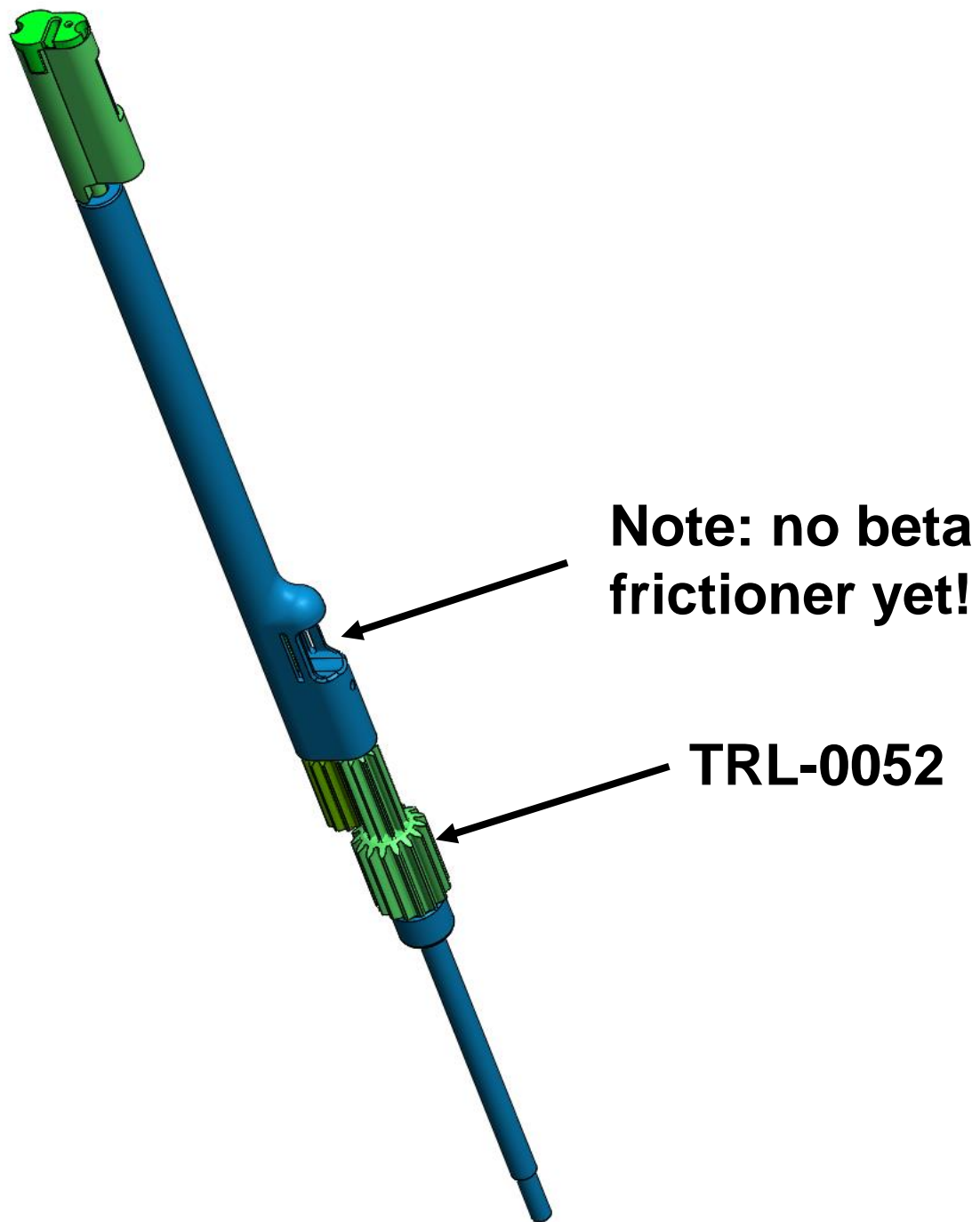


Tooling

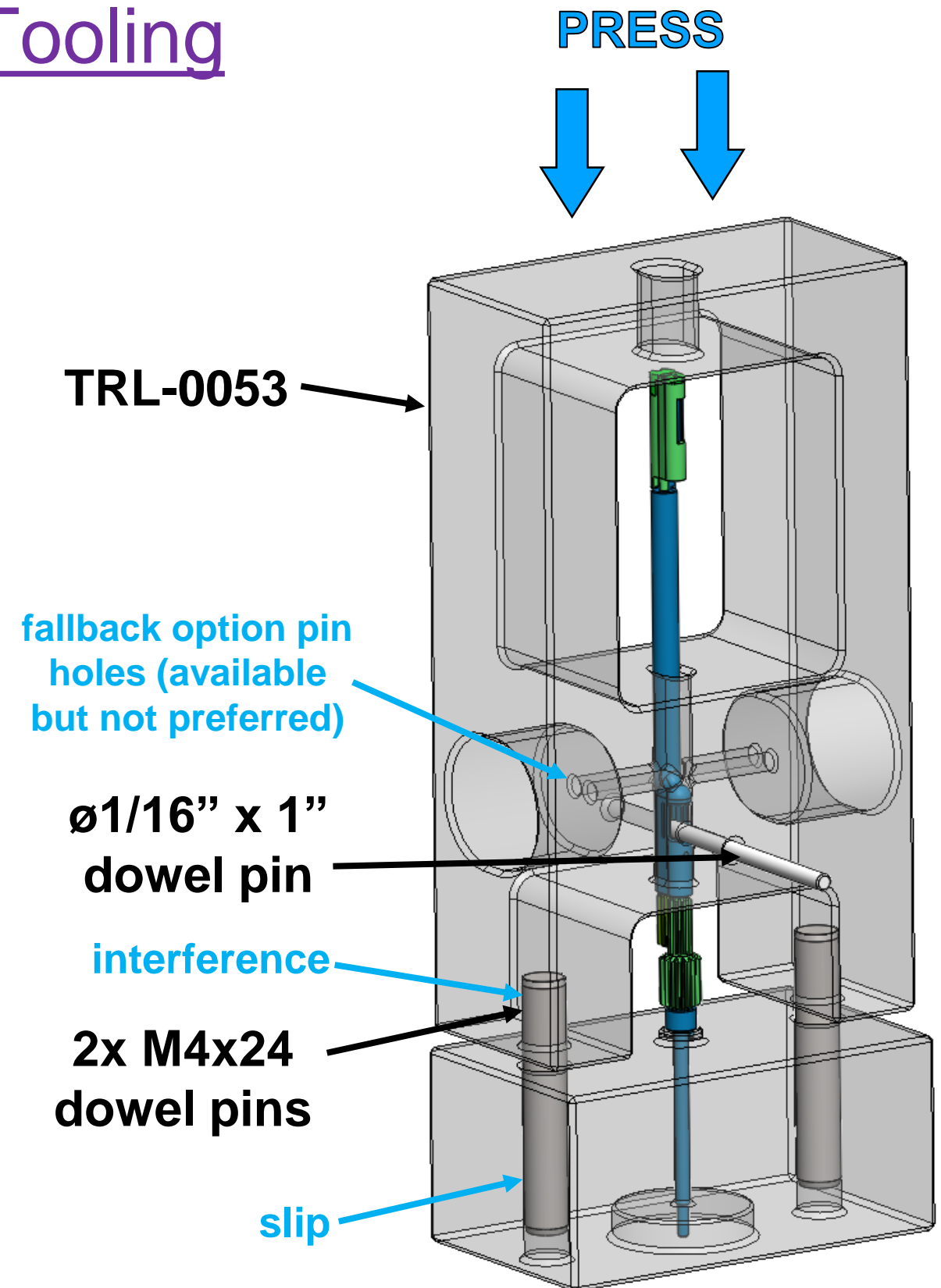


# Alpha shaft + idler + kinematic arms

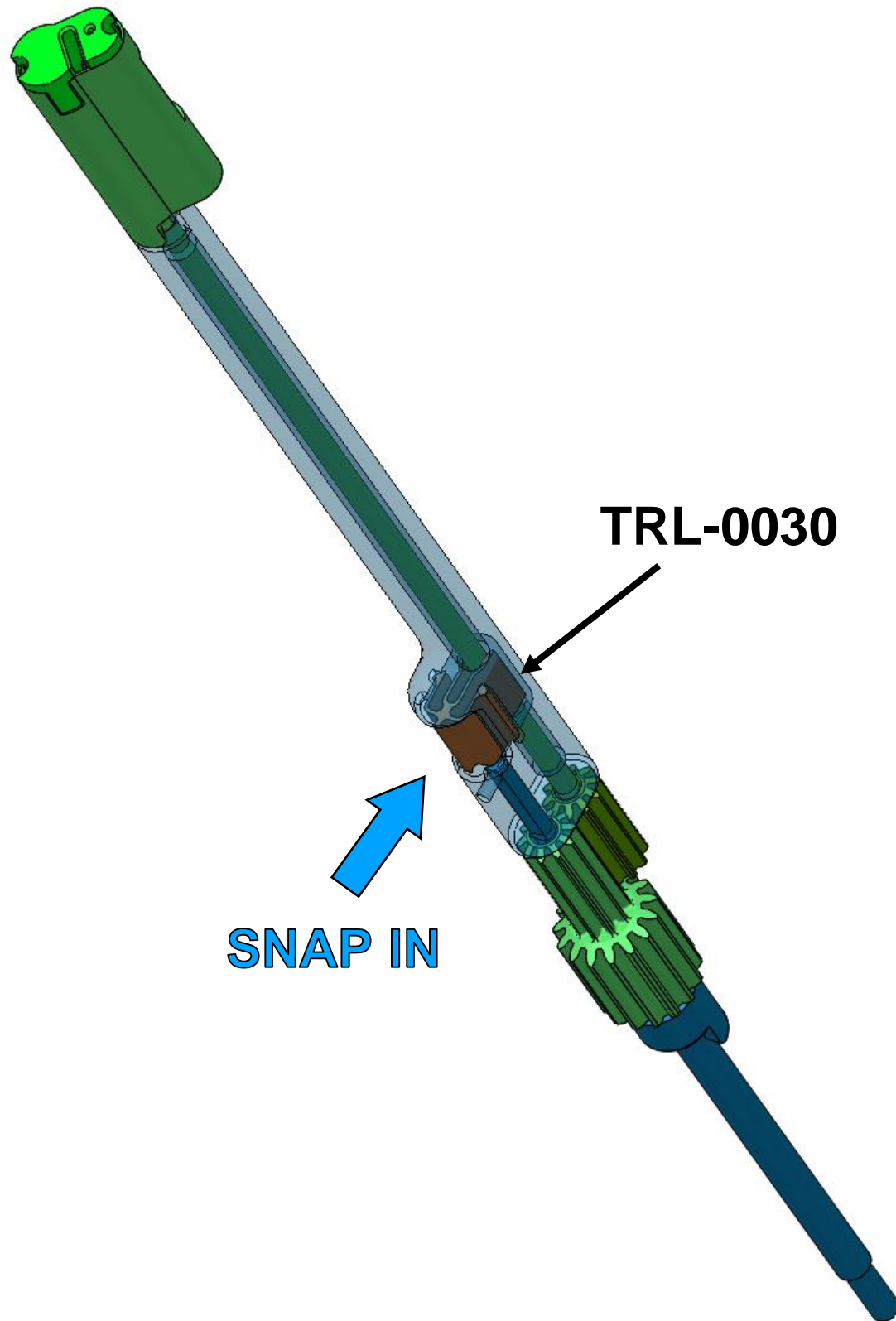
Goal: attach arms + stacked gear to alpha shaft



## Tooling



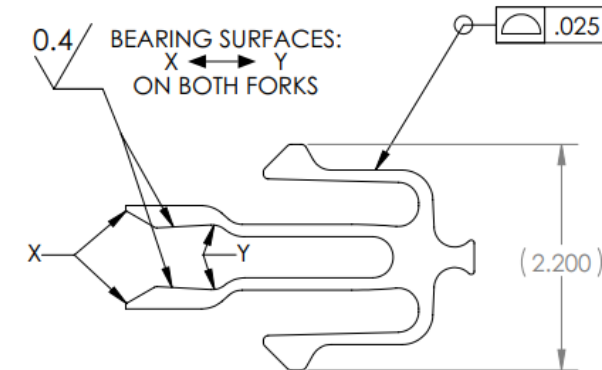
# Install beta frictioner



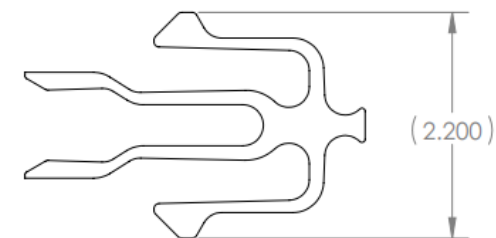
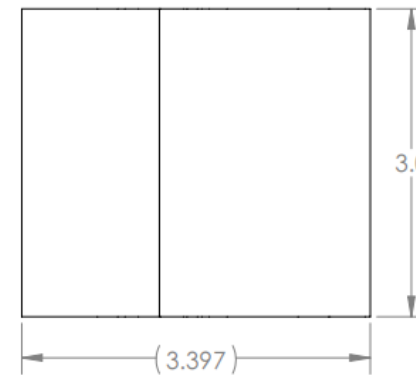
## TWO SIMILAR CONFIGURATIONS:

01 ... 100 um nominal deflection, yield-limited

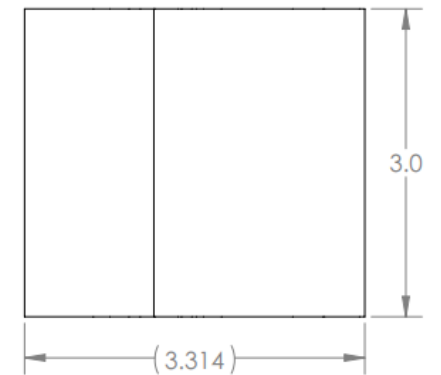
02 ... 50 um nominal deflection, elastic



CONFIG: 01



CONFIG: 02



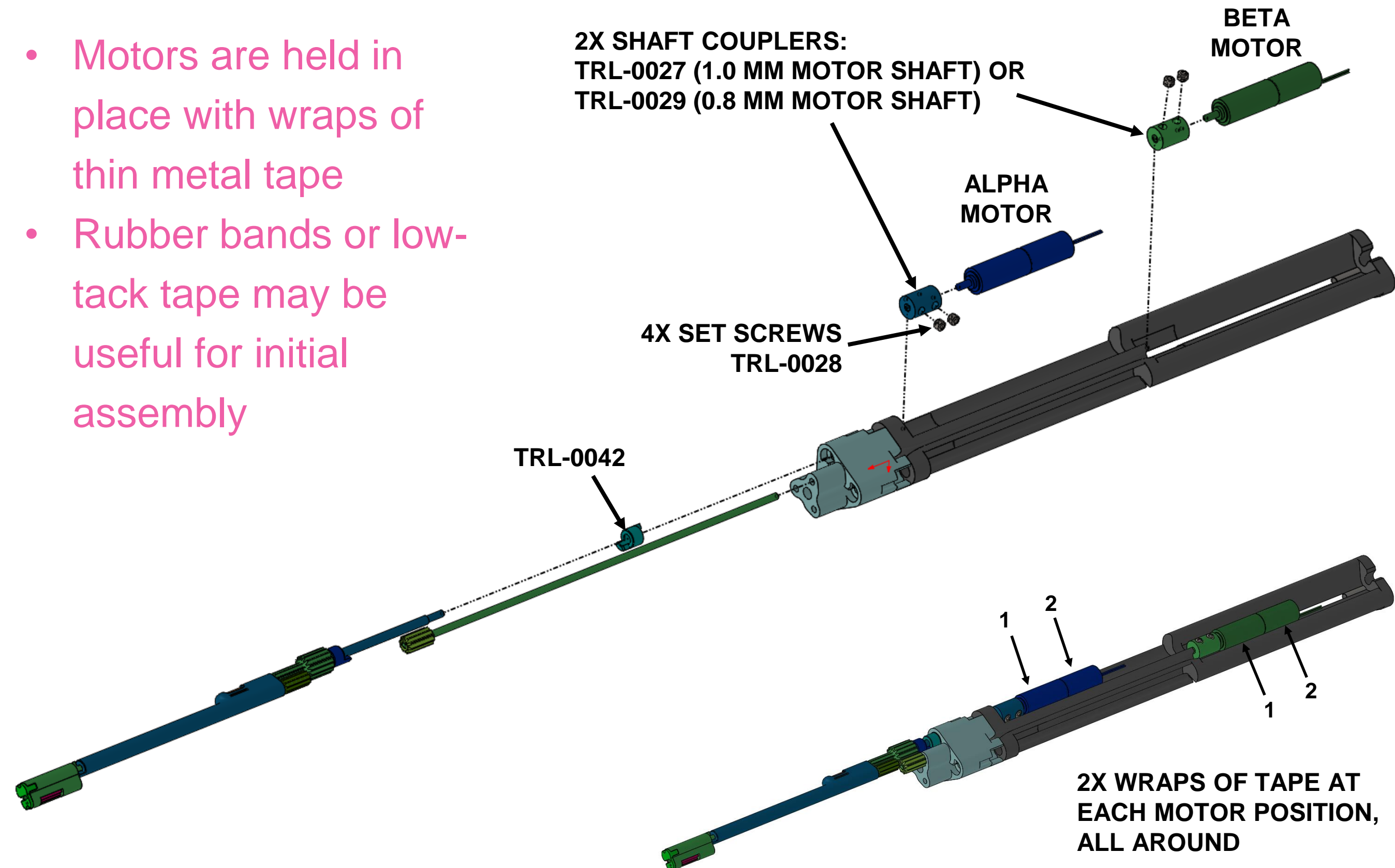
### INFORMATION OF INTEREST TO DESIGN ENGINEER ONLY...

(INCLUDED HERE FOR DOCUMENTATION PURPOSES ONLY):

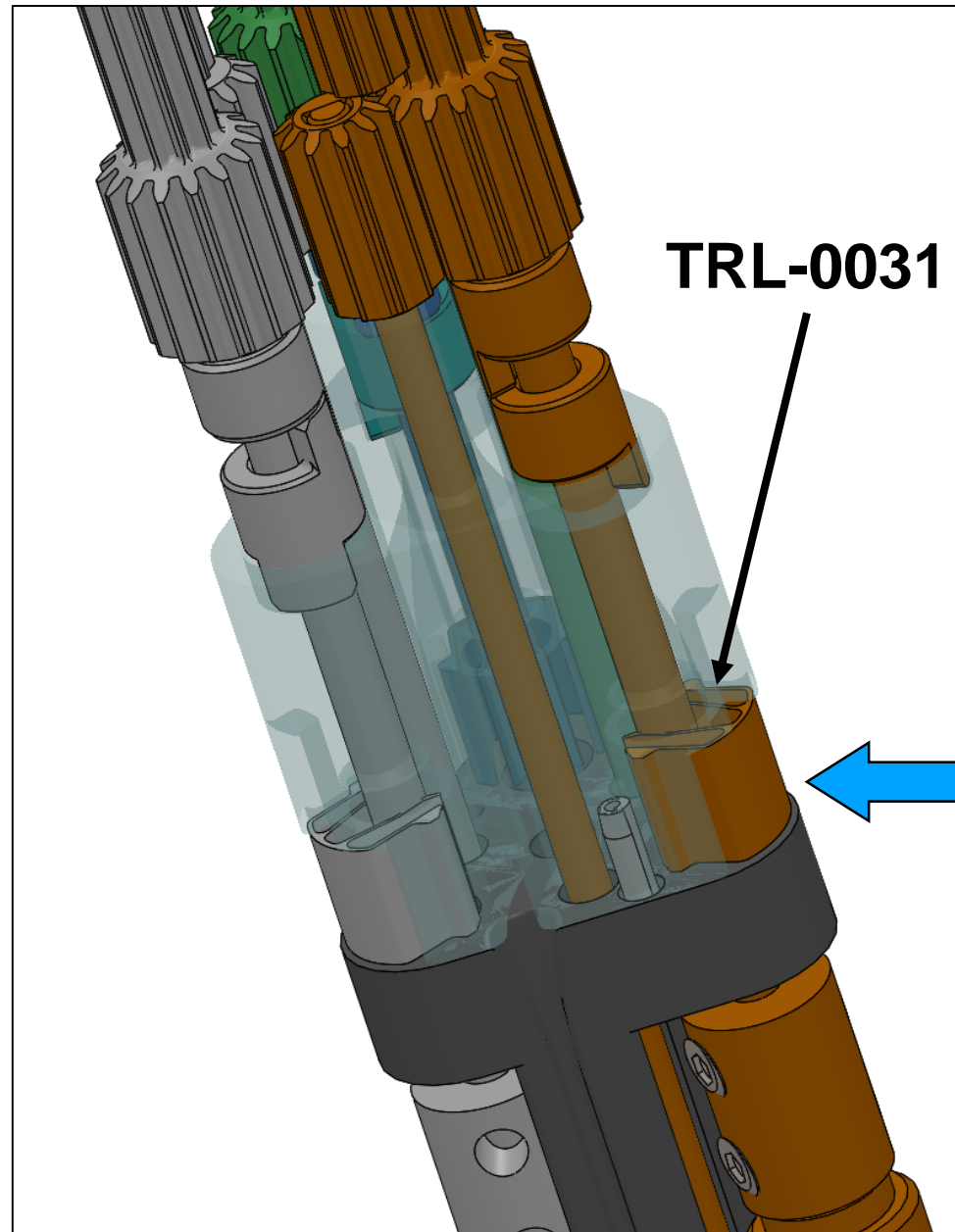
- INTENDED SHAFT DIAMETER = 0.8 MM
- CONFIG 01:
  - 100 UM NOMINAL DEFLECTION EACH FORK.
  - ESTIMATED VALUES: YIELD FOS ~ 1.02 (426 MPA), SPRING CONSTANT ~ 17 N/MM, HOLDING TORQUE ~ 0.12-0.76 N\*MM.
- CONFIG 02:
  - 50 UM NOMINAL DEFLECTION EACH FORK.
  - ESTIMATED VALUES: YIELD FOS ~ 1.84 (237 MPA), SPRING CONSTANT ~ 29 N/MM, HOLDING TORQUE ~ 0.13-0.86 N\*MM.

# Integrate arms and motors to Aft Structure

- Motors are held in place with wraps of thin metal tape
- Rubber bands or low-tack tape may be useful for initial assembly



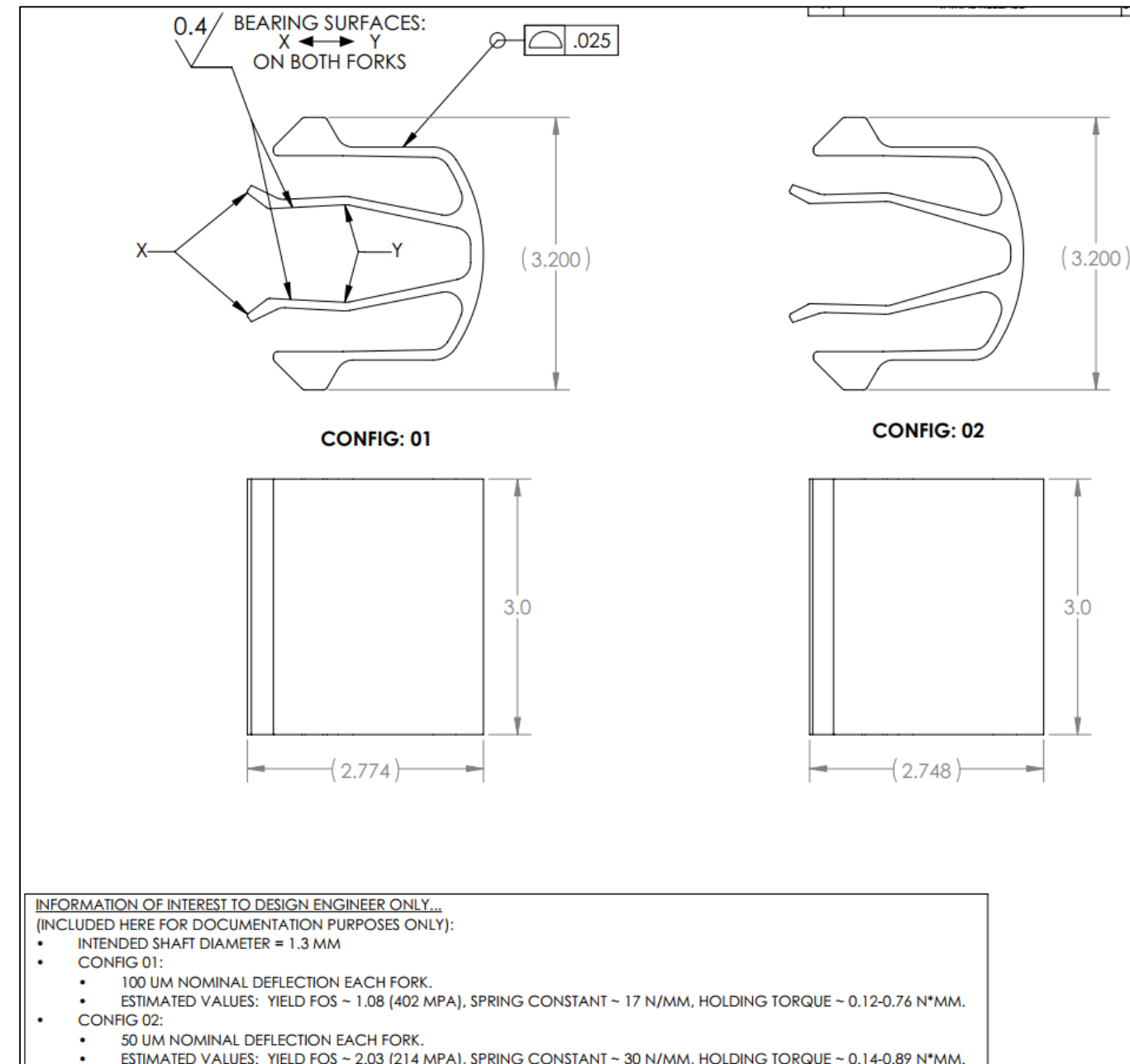
# Install alpha frictioners



## TWO SIMILAR CONFIGURATIONS:

01 ... 100 um nominal deflection, yield-limited

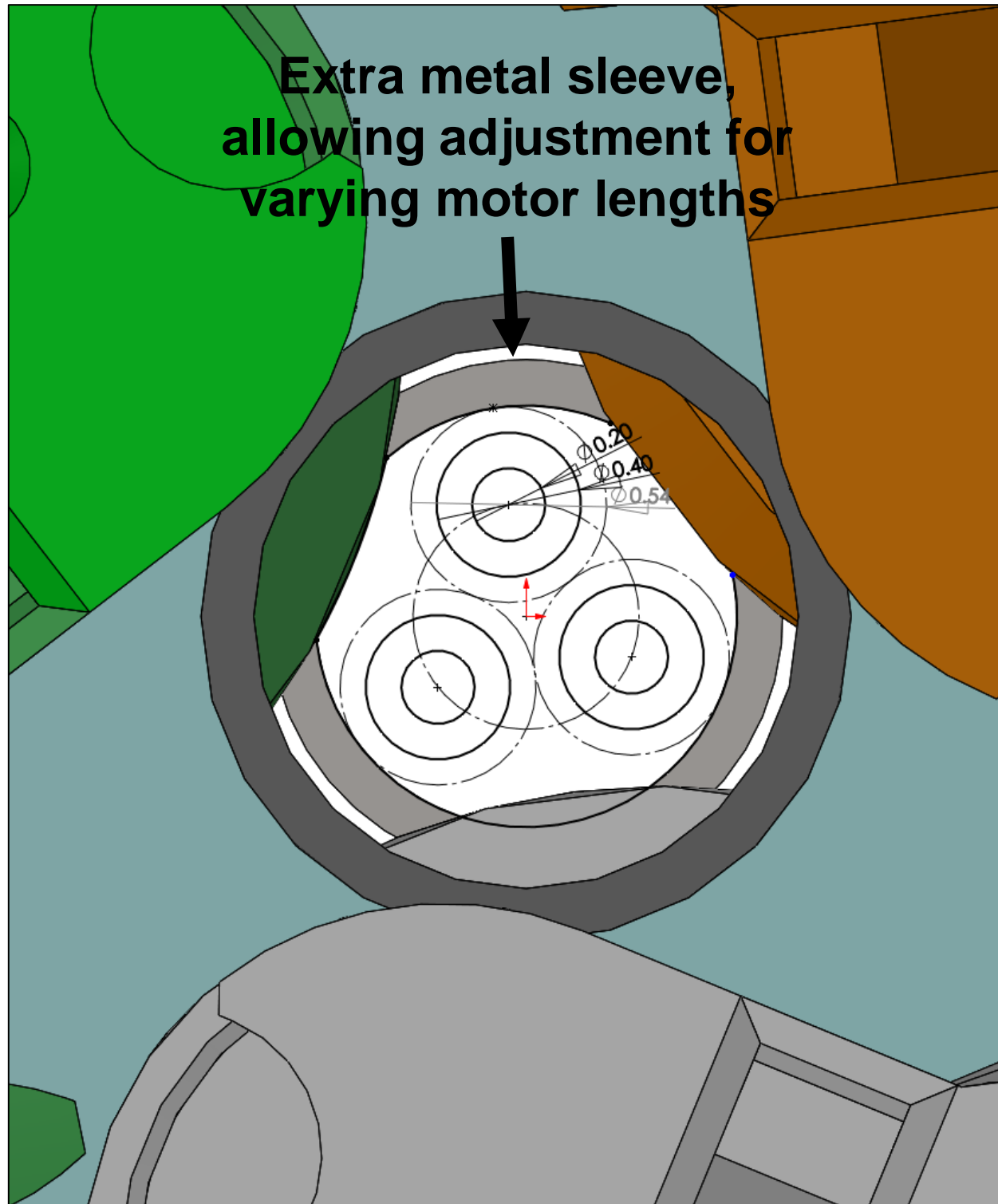
02 ... 50 um nominal deflection, elastic



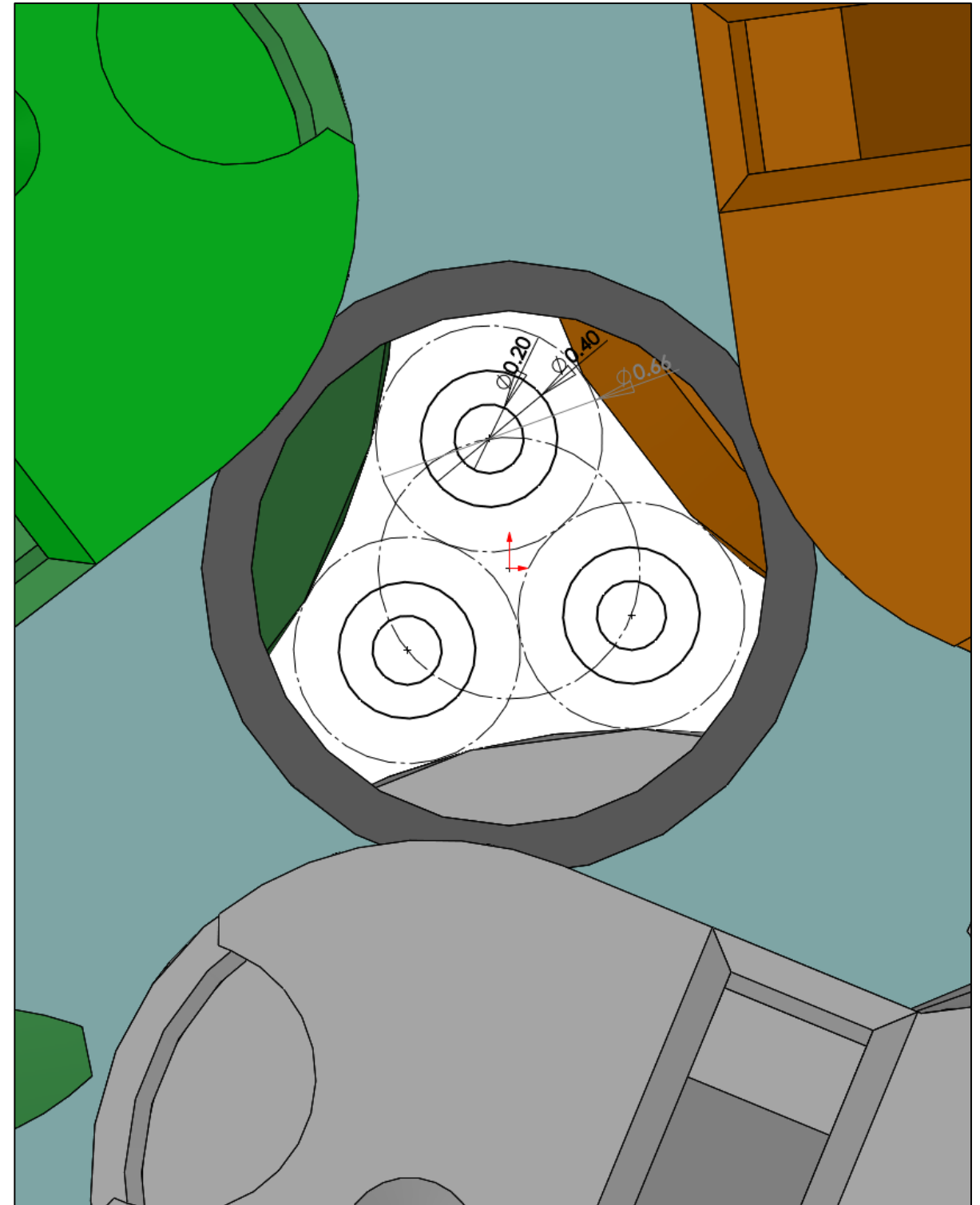


# Fiber route through center hole (preferred)

**Sleeved**, ideal packing =  $\varnothing 0.54\text{mm}$

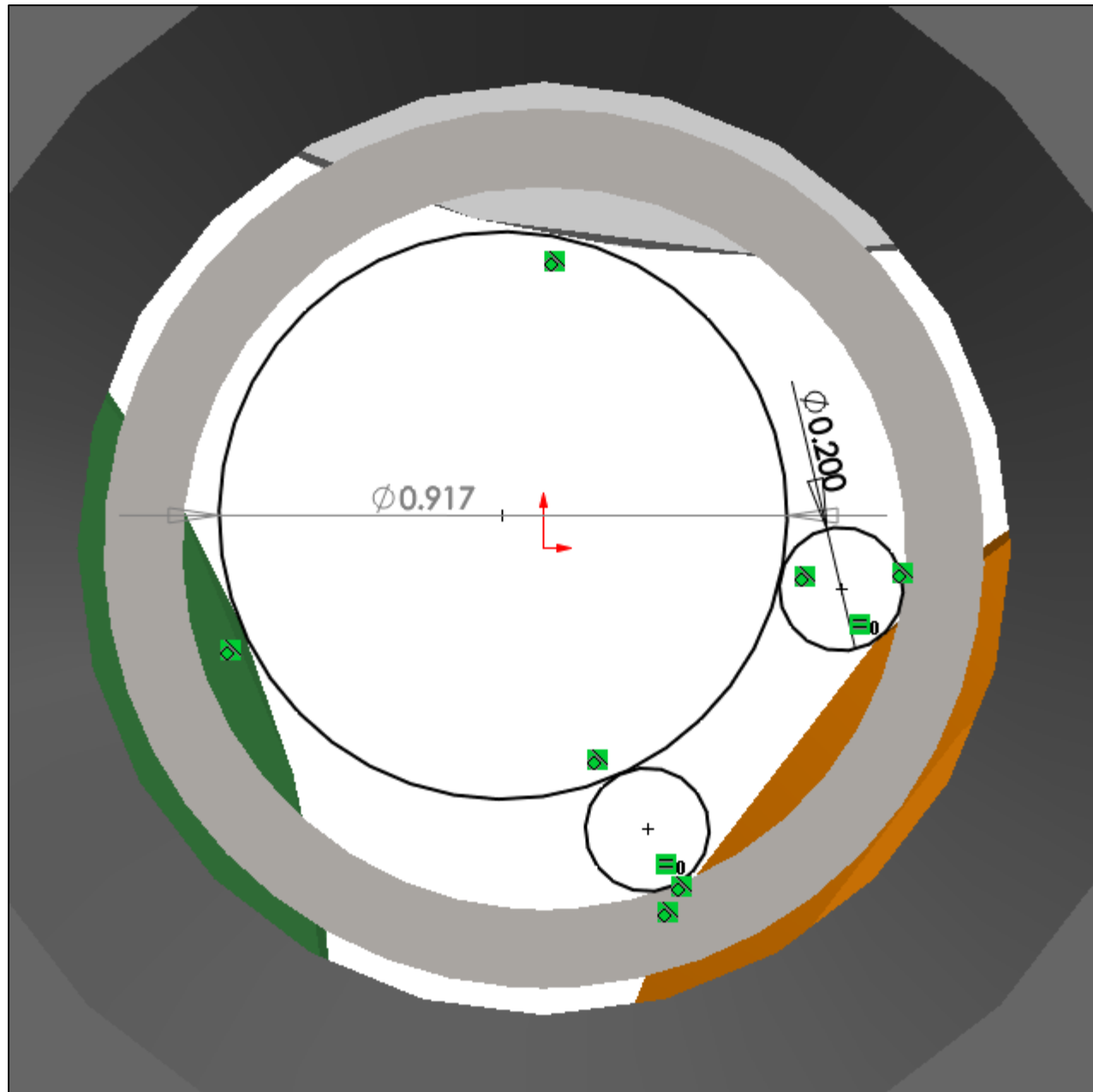


**Unsleeved**, ideal packing =  $\varnothing 0.66\text{mm}$

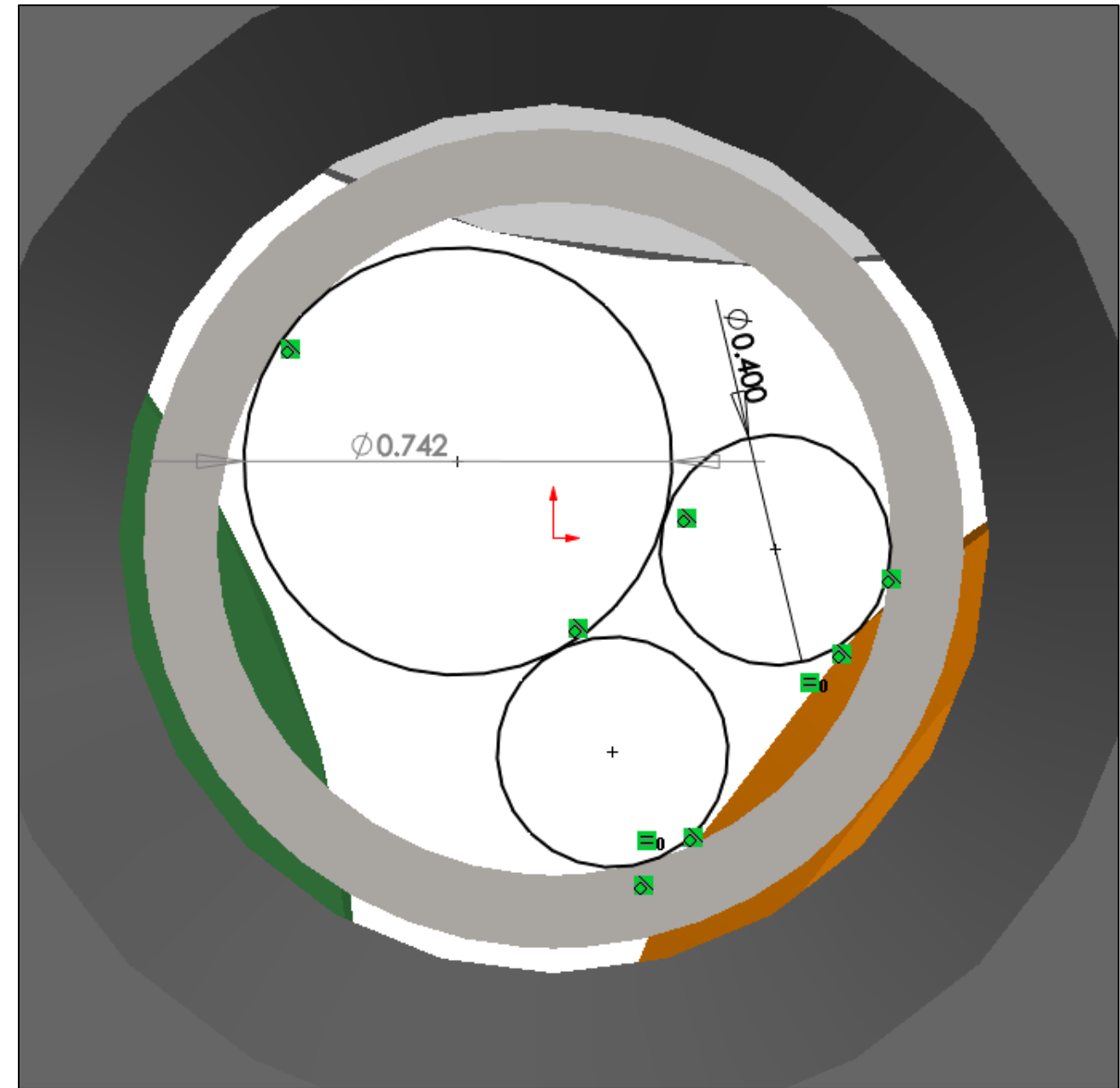


# Center hole route, more packing options / views

**Sleeved,  $\varnothing 0.92$  mm ferrule going past 2x 0.2 mm fibers**

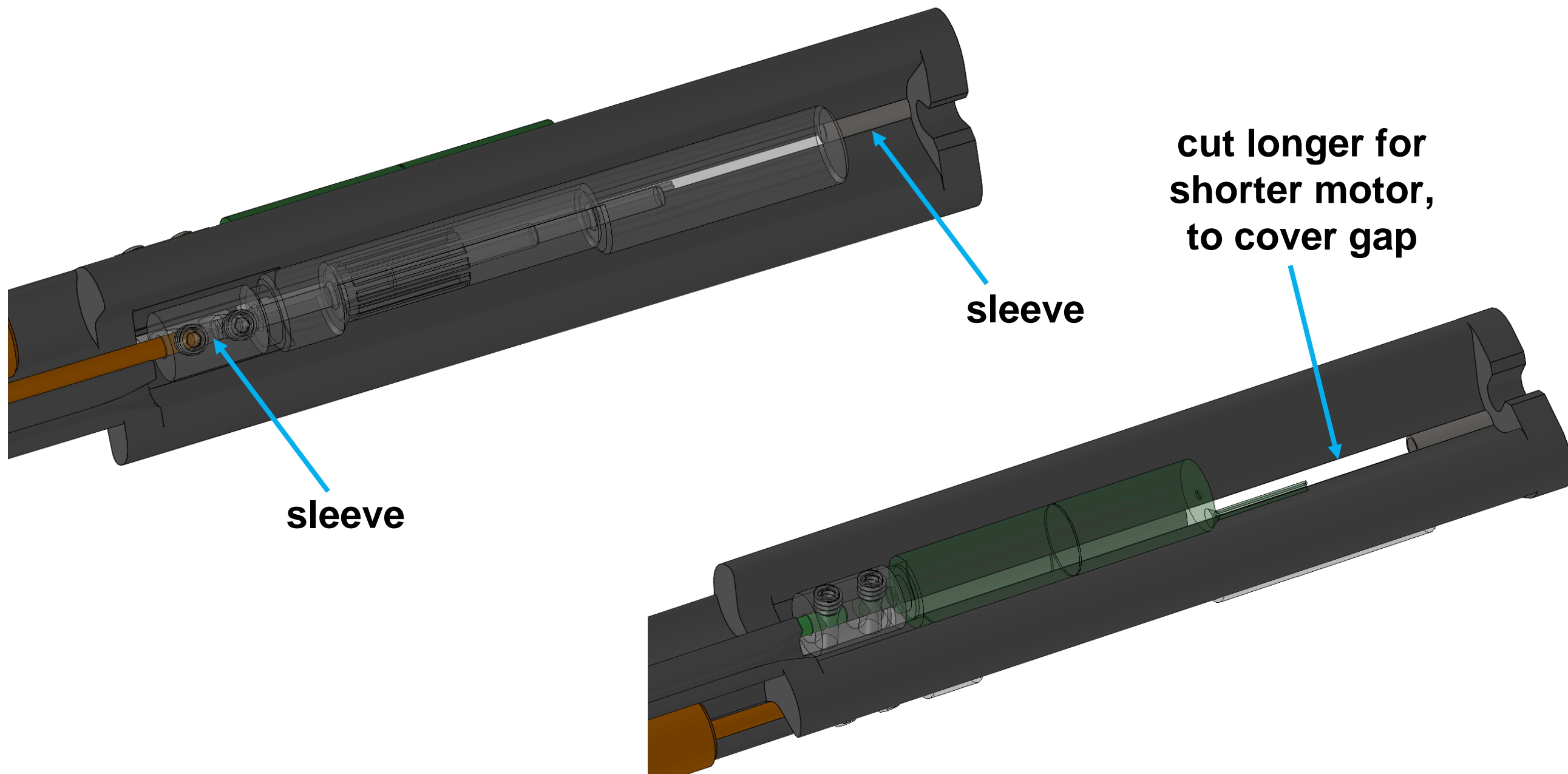


**Sleeved,  $\varnothing 0.74$  mm ferrule going past 2x 0.4 mm tubes**

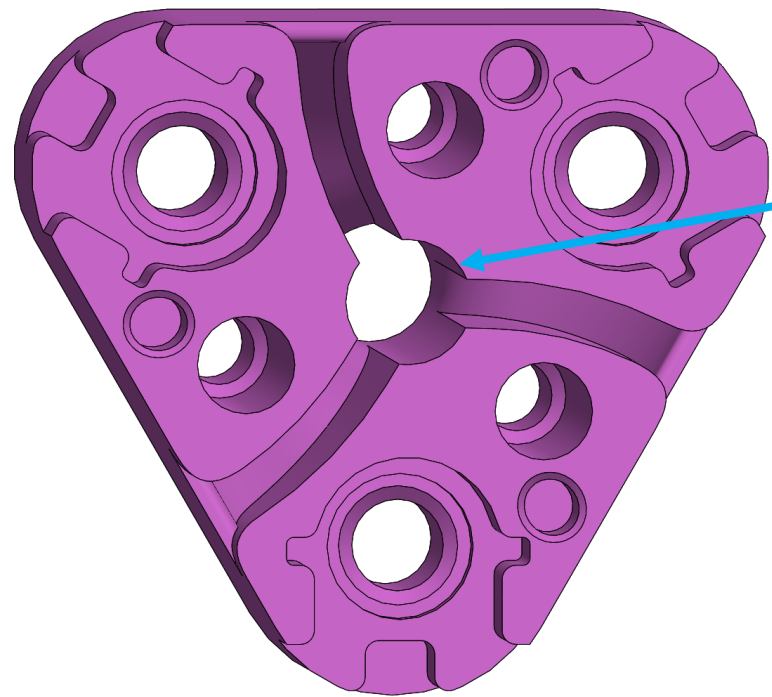


# Fiber route: center hole sleeving

- Prototype (and maybe final version) accommodates significantly different motor lengths
- To easily thread fiber up center hole, can add sleeve at aft end
- Could also sleeve near shaft coupler
- E.g. McMaster 8988K391 (304 Stainless Steel Tubing 0.056" OD, 0.005" Wall Thickness)

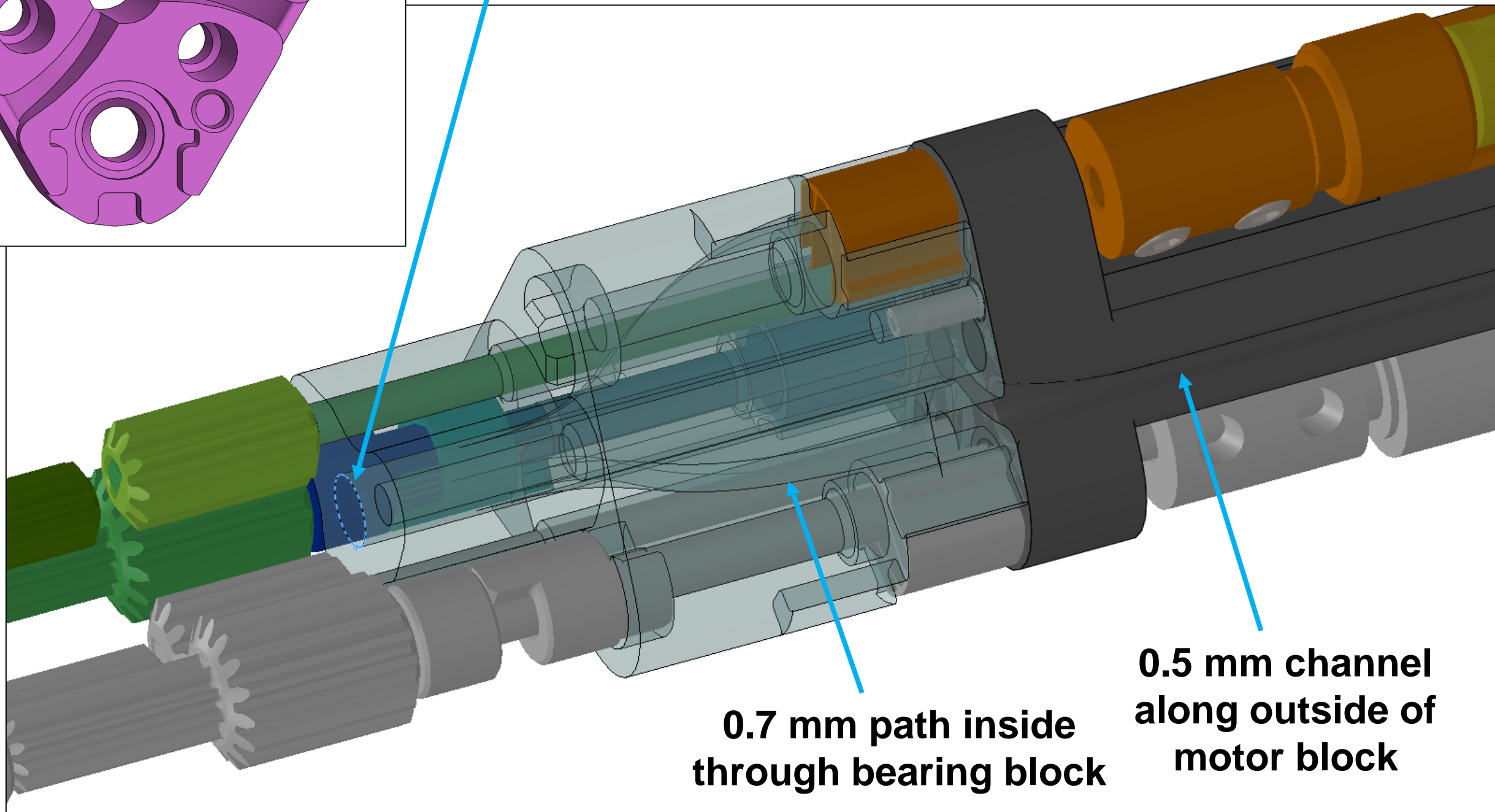


# Outer fiber route



**ø1.8 mm  
center hole**

- ø0.4 mm kapton guide tube in outer channel
- Motor tape shall not directly touch fiber
- Bending of fiber is unavoidable, though bearing block length could be extended to increase ROC



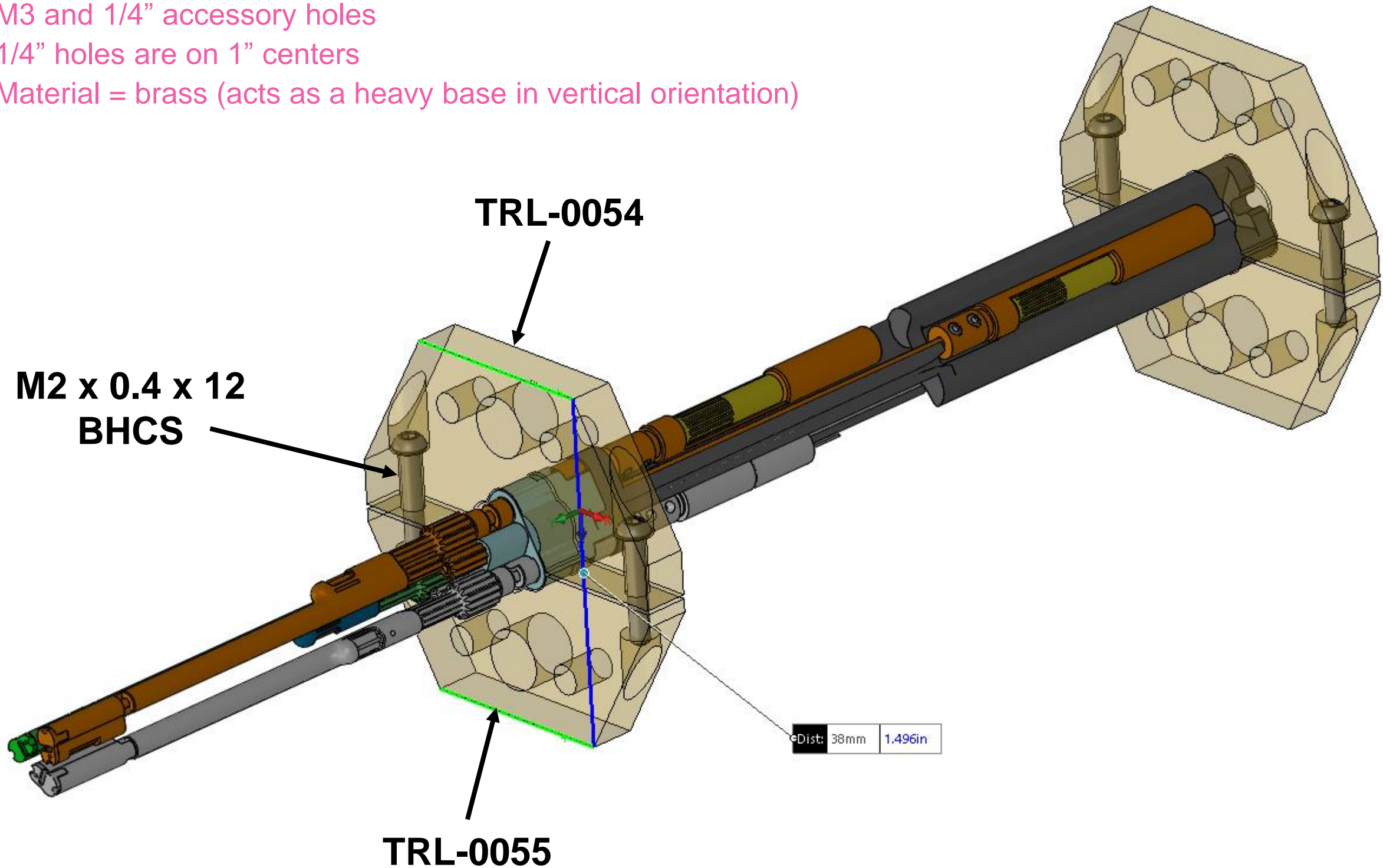
**0.7 mm path inside  
through bearing block**

**0.5 mm channel  
along outside of  
motor block**



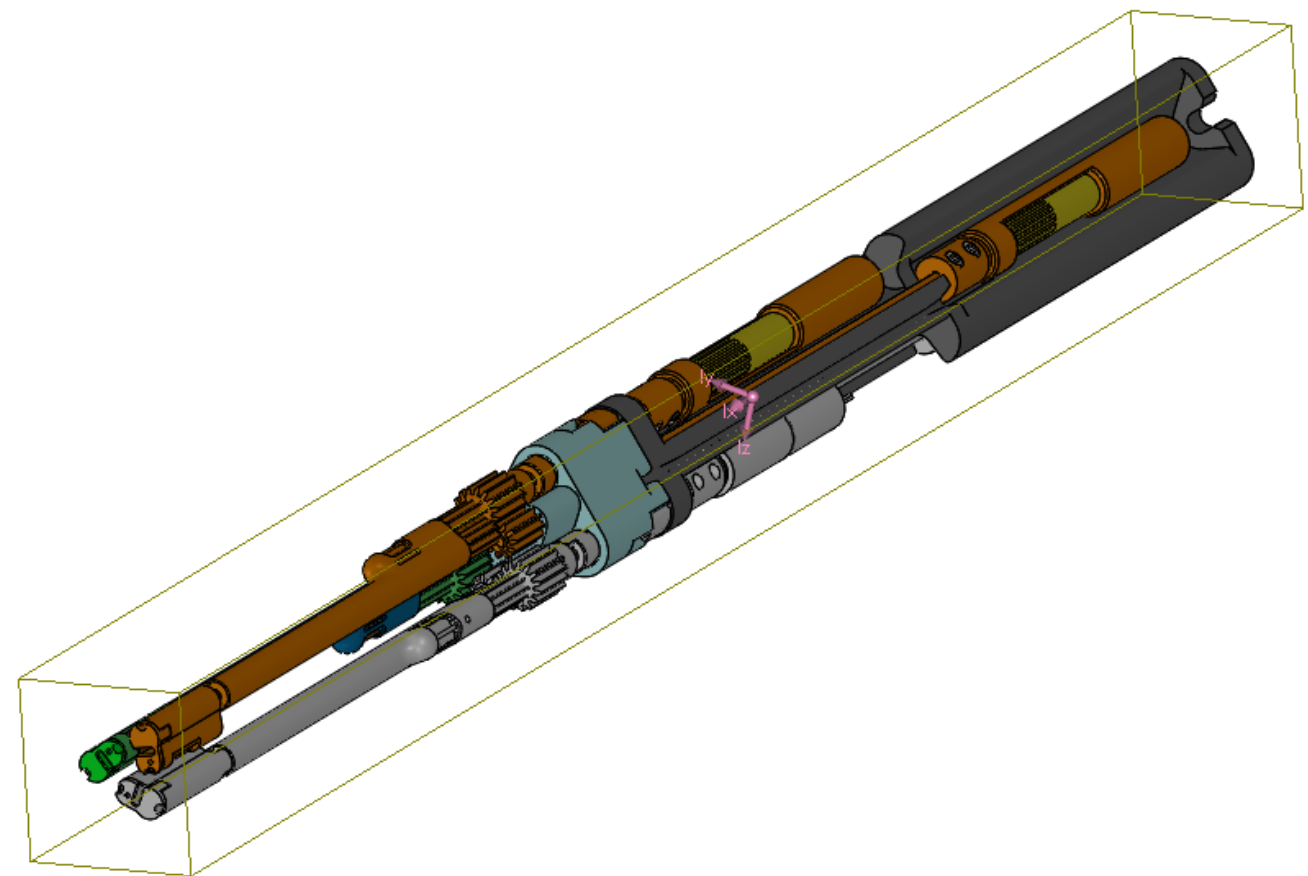
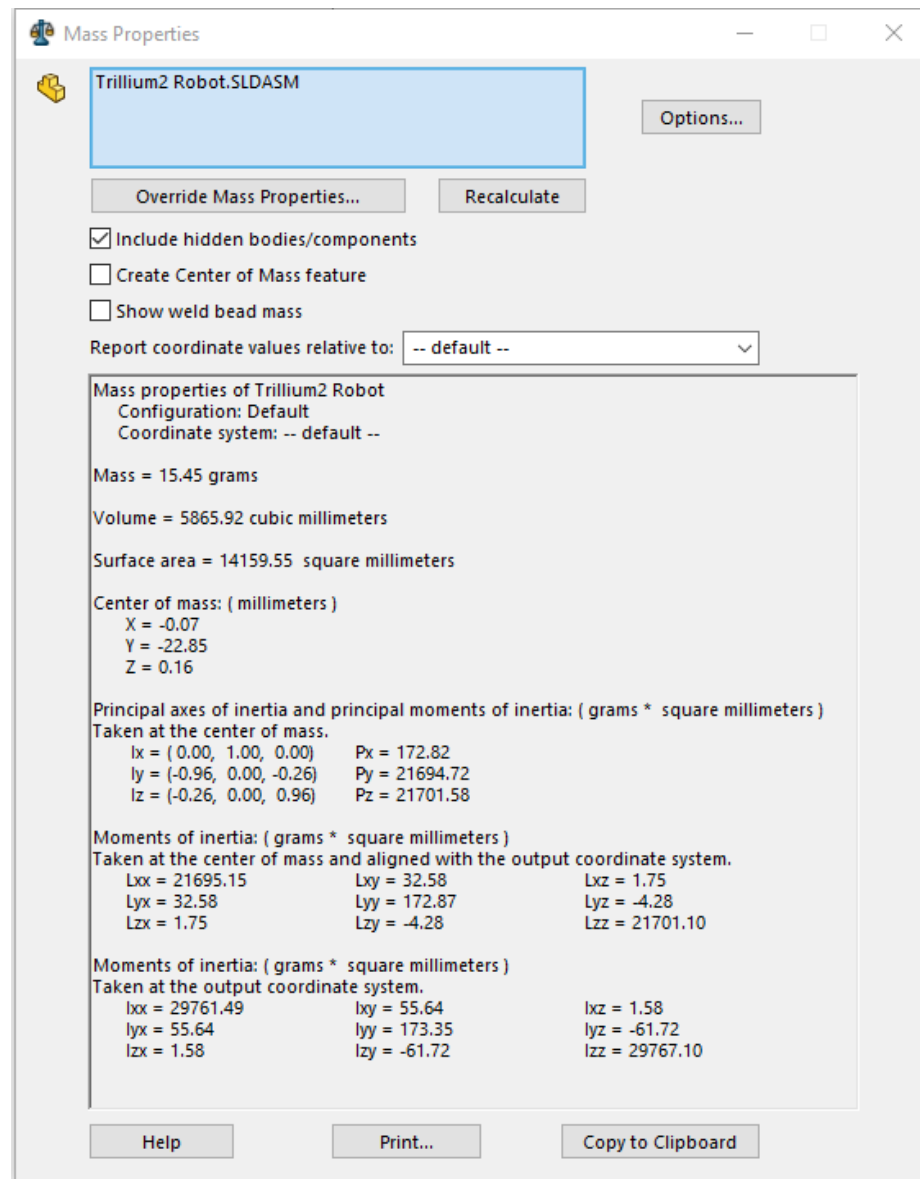
# Hex clamps, for general purpose mounting

- Can install anywhere along length of Aft Structure
- M3 and 1/4" accessory holes
- 1/4" holes are on 1" centers
- Material = brass (acts as a heavy base in vertical orientation)

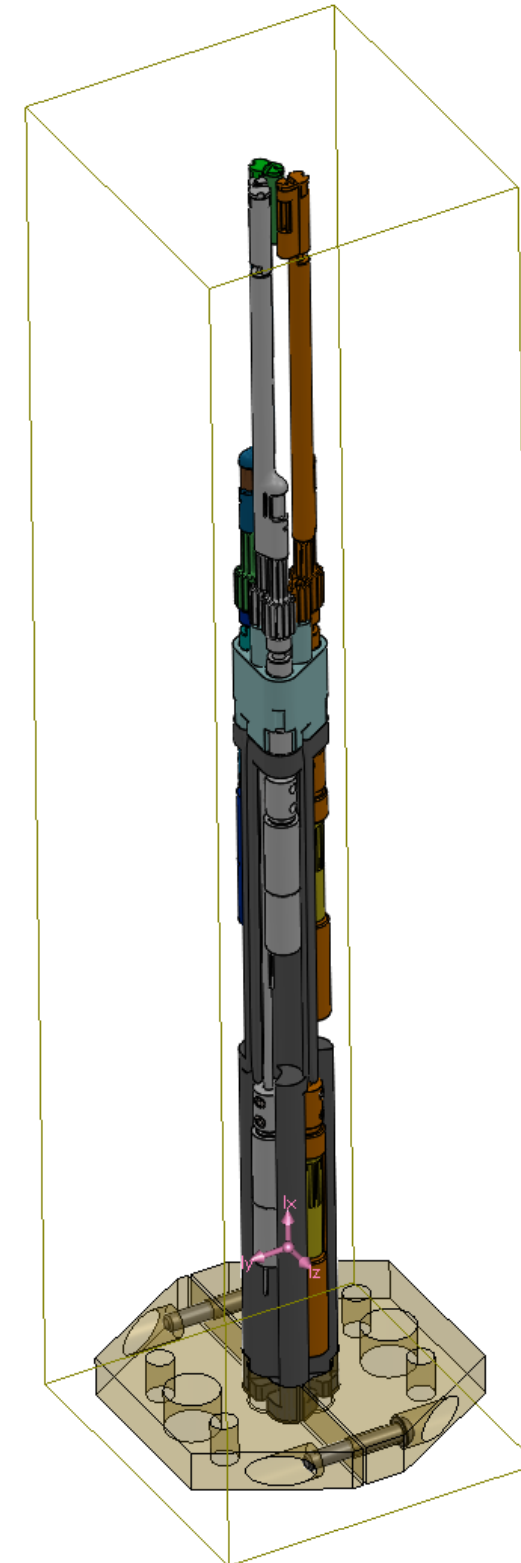
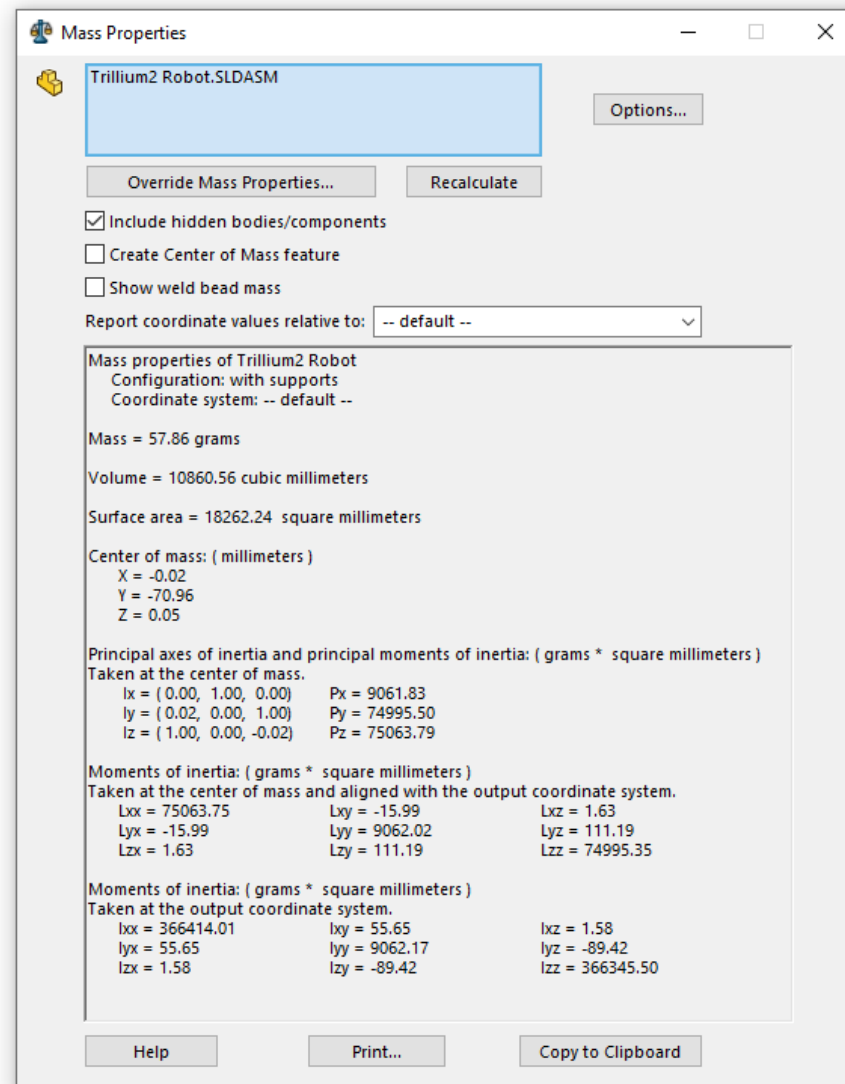




# Mass and C.G.



# Vertical orientation, using brass clamp as a base



# Bill of Materials

Quantities below are sufficient to build 1 unit, actuating 3 fibers.						
Only dummy (manual rotation) "motors" are listed here. For the various vendor parts and options, see this sheet:						
<a href="https://docs.google.com/spreadsheets/d/1GfYmfWz-StRQMiw1Z-BNDIOHAbmoUZN_MIT118-VKsQ/edit?usp=sharing">https://docs.google.com/spreadsheets/d/1GfYmfWz-StRQMiw1Z-BNDIOHAbmoUZN_MIT118-VKsQ/edit?usp=sharing</a>						
All quantities are each, not packages.						
Part #	Description	Quantity	Configs	Category	Note	
TRL-0018	MM Fiber Clip	3	003, 004, 005, 006, 007, 103, 104, 105, 106, 107	Parts	005 is default config as of 2021-06-25	
TRL-0024	Trillium2 Alpha Shaft	3		Parts		
TRL-0025	Trillium2 Beta Shaft	3		Parts		
TRL-0026	Trillium2 Front Shaft	3		Parts		
TRL-0027	Trillium2 Shaft Coupler 10	6		Parts	for motors with 1.0 mm shaft (e.g. Maxon, Namiki, dummy)	
TRL-0028	Trillium2 Shaft Coupler Set Screw	12		Parts	Alternate: TRL-0032	
TRL-0030	Trillium Beta Frictioner	3	01, 02	Parts	01 is yield-limited and 100 um nominal deflection, 02 is elastic and 50 um	
TRL-0031	Trillium Alpha Frictioner	3	01, 02	Parts	01 is yield-limited and 100 um nominal deflection, 02 is elastic and 50 um	
TRL-0033	Trillium Bearing Block	1		Parts		
TRL-0034	Trillium Motor Block	1		Parts		
TRL-0037	Trillium Beta Motor Gear	3		Parts		
TRL-0042	Trillium Alpha Stop Idler	3		Parts		
TRL-0043	Trillium2 Alpha Base	3		Parts		
TRL-0044	Trillium Fiber Arm Chuck	3	OFF1, CTR, OFF1-2L, CTR-2L	Parts	OFF1 is default config as of 2021-06-25	
TRL-0046	Trillium Beta Arm Gear	3		Parts		
TRL-0048	Trillium Fiber Arm Tip	3	OFF1, CTR	Parts	OFF1 is default config as of 2021-06-25	
TRL-0051	Trillium Alpha Stop Shaft Side	3		Parts		
TRL-0052	Trillium Stacked Gear	3		Parts		
McMaster 76925A101	Conductive Aluminum Foil Electrical Tape, 1/4" Wide, 15 Feet Long	1		Parts	4 strips per Trillium	
McMaster 93740A010	420 Stainless Steel Coiled Spring Pin, 1/32" Diameter, 3/16" Long	3		Parts	Alternate: McMaster 91585A703 (M0.7x5 dowel pin)	
TRL-0029	Trillium2 Shaft Coupler 08	6		Optional	for motors with 0.8 mm shaft (e.g. Faulhaber 0308)	
TRL-0040	Trillium Motor Dummy Housing	6		Optional		
TRL-0041	Trillium Motor Dummy Rotator	6		Optional		
McMaster 8988K391	304 Stainless Steel Tubing 0.056" OD, 0.005" Wall Thickness, 1 ft. Long	1		Optional	cut to length and install in Motor Block center hole for fiber protection	
McMaster 93600A134	316 Stainless Steel Dowel Pin, 1 mm Diameter, 24 mm Long	6		Optional		
TRL-0019	MM Fiber Spring Key	1		Tooling		
TRL-0035	Trillium Aft Press Jig A	1		Tooling		
TRL-0036	Trillium Aft Press Jig B	1		Tooling		
TRL-0038	Trillium Beta Motor Shaft Jig	1		Tooling		
TRL-0039	Trillium Arms Beta Motor Gear Cap	1		Tooling		
TRL-0045	Trillium Arms Beta Jig	1		Tooling		
TRL-0047	Trillium Arms Beta Jig Gear Cap	1		Tooling		
TRL-0049	Trillium Alpha Stop Press Collar	1		Tooling		
TRL-0050	Trillium Arms Alpha Jig	1		Tooling		
TRL-0053	Trillium Alpha Arm Press Collar	1		Tooling		
TRL-0054	Trillium Hex Clamp A	2		Tooling		
TRL-0055	Trillium Hex Clamp B	2		Tooling		
McMaster 91585A464	18-8 Stainless Steel Dowel Pin, 4 mm Diameter, 24 mm Long	6		Tooling		
McMaster 92095A455	Button Head Hex Drive Screw, Passivated 18-8 Stainless Steel, M2 x 0.40 mm Thread, 12mm Long	4		Tooling		
McMaster 98105A051	Undersized Dowel Pin, 18-8 Stainless Steel, 1/16" Diameter, 3/8" Long	1		Tooling		
McMaster 98380A423	416 Stainless Steel Dowel Pin, 1/16" Diameter, 1" Long	1		Tooling		

Live google sheet: <https://docs.google.com/spreadsheets/d/1f6k7wWQrdMELiBQAEOWu7vQZDmY4pt3iFM0QOVxfGI/edit?usp=sharing>

# CAD models and drawings

**Packages below are embedded in pptx version of this doc.**



2021-06-29\_Trillium2\_Robot\_Solidworks2016.zip

**Solidworks 2016 top-level assembly**



2021-06-29\_Trillium2\_Robot\_parasolid.x\_t

**Parasolid top-level assembly**



2021-06-29Trillium Drawings.zip

**Fab models and drawings**