A Simple, Precise, Versatile Component:

Adjustable Strut

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Introduction

The Support Strut:

A creative building technique often utilized is the “Strut”. It consists of two VEX Shaft Collars, which act as mounting points, connected by Coupler Screws and a Standoff. This allows the Collars to be **screwed in or out of the central Standoff, achieving a precise distance** between them.

Struts are far more flexible than VEX C-Channels, **fitting any distance and angle perfectly**. They’re especially useful for creating triangles within the VEX Building System, a system built around squares and right angles.

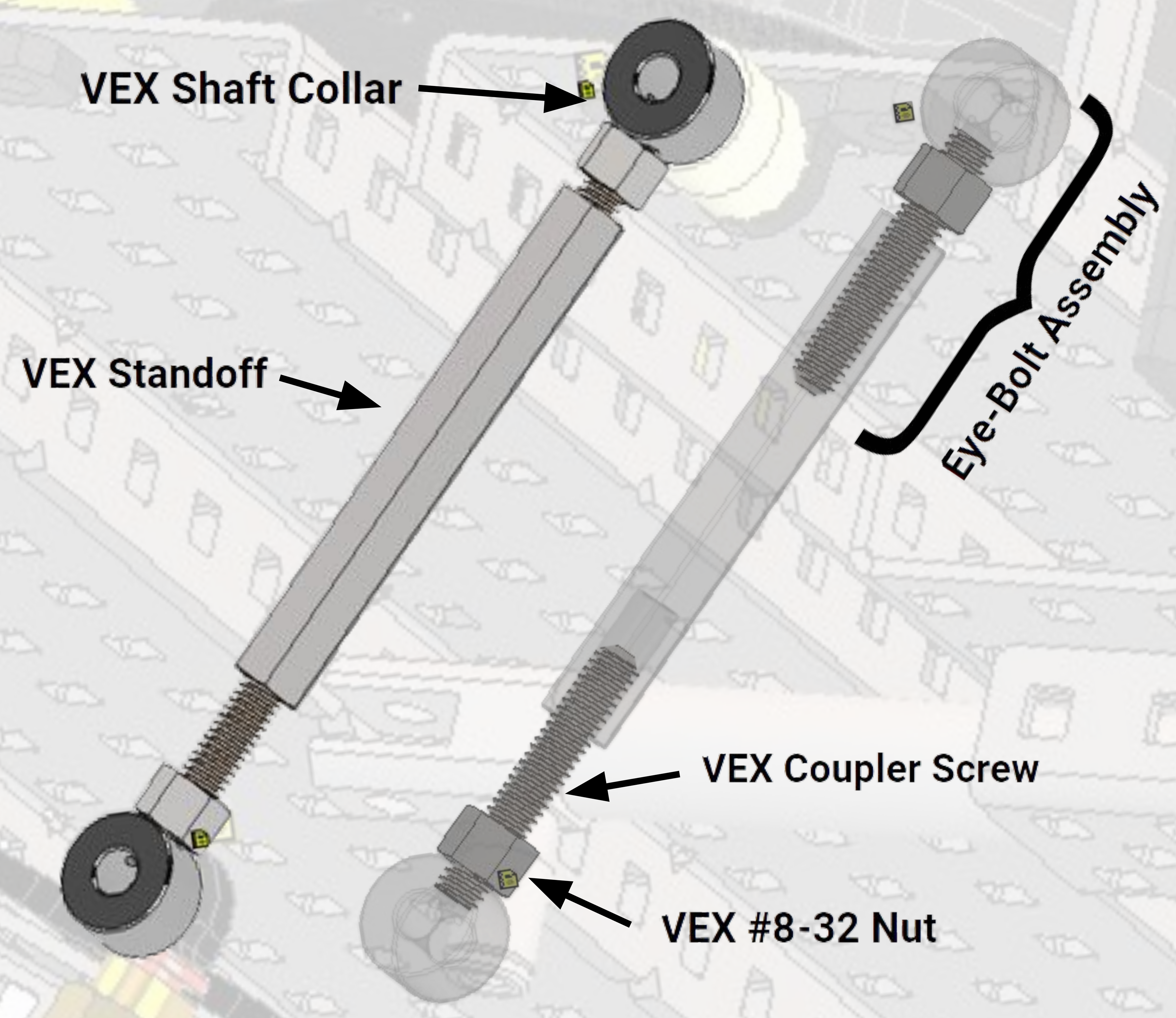


Fig. 1: *The left Strut depicted above is actually* ***part of the robot in the background****. This Strut is part of a Flywheel Mount, and* ***holds our firing mechanism*** *at an exact elevation of 50°.*
However, ***if we changed that angle*** *to 55°, it would be an* ***arduous process*** *of disassembly and reassembly.*

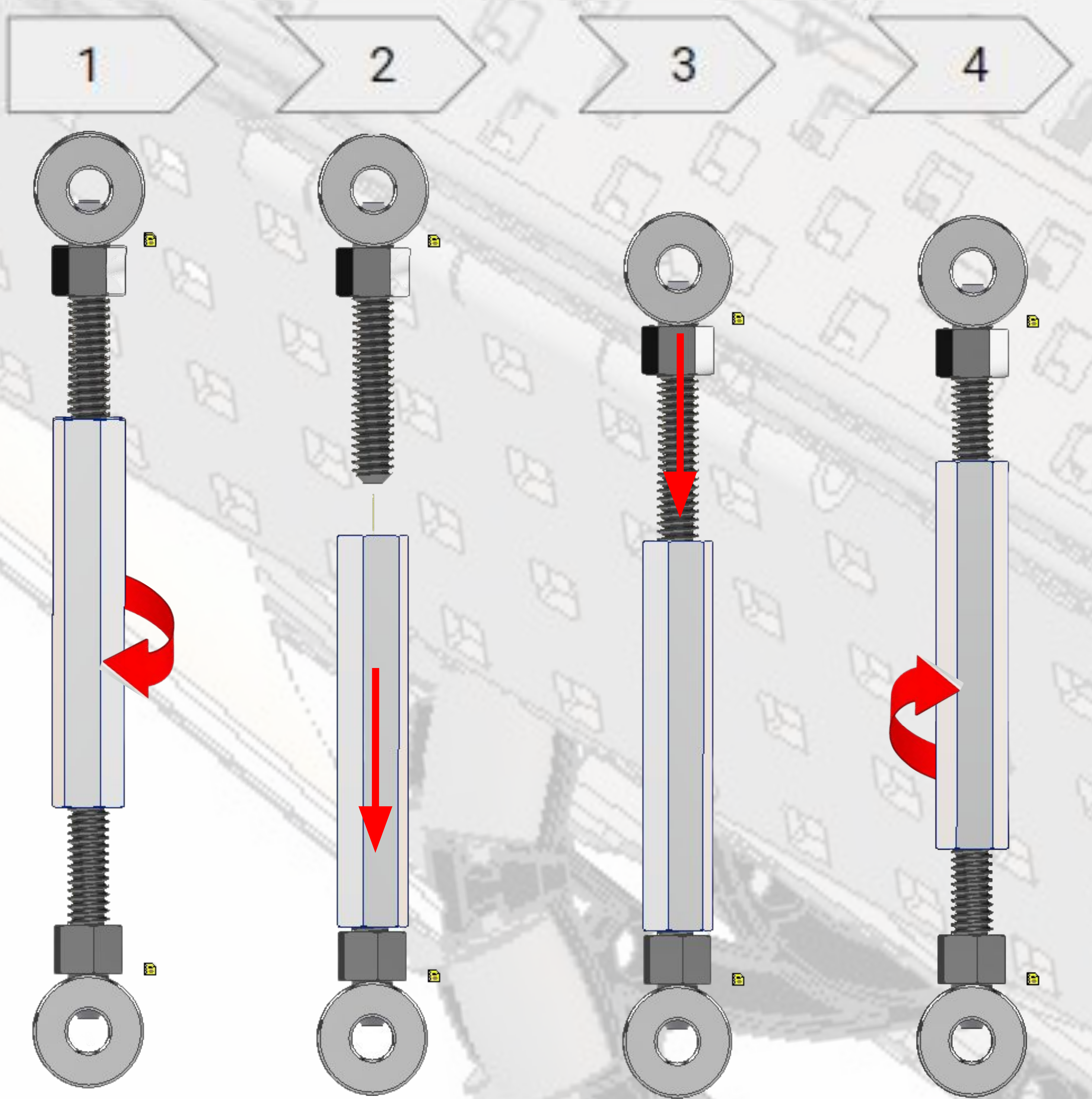


Fig. 2: *To change the length of a Strut, an Eye-Bolt must be* ***completely unscrewed*** *while any above structure is supported. Then the Strut is* ***approximately resized,*** *and finally the Eye-Bolt is re-attached.*

Defining the Problem:

Unfortunately, **it isn’t easy to adjust the length of a Strut** once it’s been built. Since both ends of a VEX Standoff are **threaded in the same direction,** simply turning it **does not extend and contract** the Strut. Instead, the Standoff slides up and down the Coupler Screws.

Adjusting a Strut is a **time consuming and labor-intensive process**, complicating minute changes to structures and making them rarely worthwhile.

Design Brief

DESIGN TEAM:

5069X - Victor C, Carston W, Patrick S, Rodrigo R.

PURPOSE:

Allow structures to be easily and precisely adjusted

PROBLEM STATEMENT:

It is difficult, slow, and imprecise to adjust a Strut, lowering the versatility and usefulness of angled structures in VEX

STATEMENT OF DESIGN:

Design, build and test an Adjustable Strut that can be fit to any distance quickly and without disassembly

CONSTRAINTS:

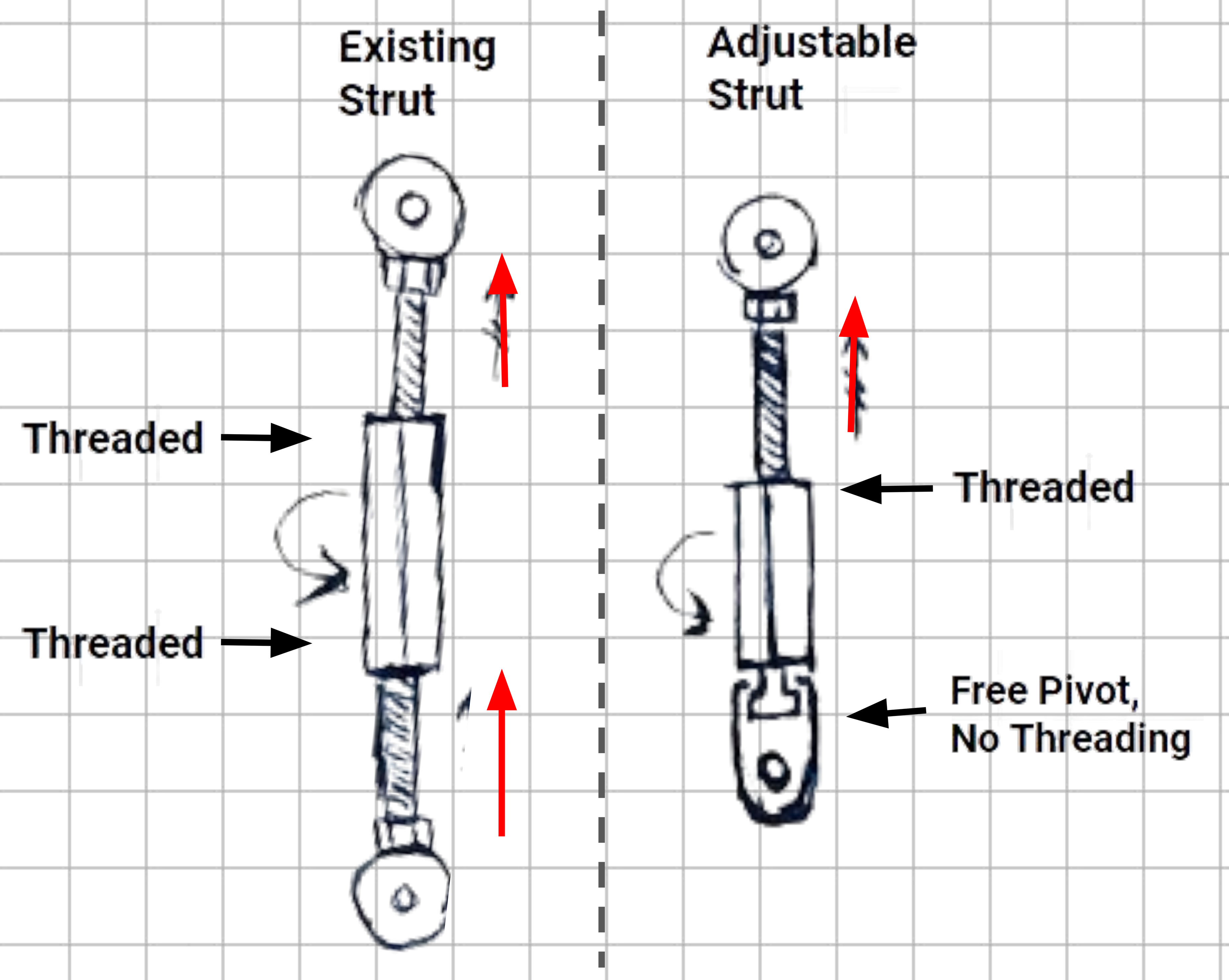
Variable range of length
Substitute for current Struts
No disassembly to change length
3D Printable*
Fits VEX Building System**

DESIGN GOALS:

Adjustable using a standard VEX wrench
Simple, few moving parts
Low tolerances

** On a Dremel 3D40 FDM printer*
*** Units of 0.5" are used, with #8-32 screws being standard for holes*

Working Principle



Standoff to Solution

Struts don't change length as the Standoff is turned because **as one end protrudes from the Standoff, the other retracts** at the same rate.

Fig. 3: *The left sketch illustrates how a standard Strut cancels an extending force by pulling in the opposite side. Think of it as a long nut climbing a single, connected screw. The length of each end changes, but the net length does not.*

The Free Pivot

The simplest solution to this cancellation of forces is **to remove one of the threadings.** Our design consists of a **housing, with threading on one end and a freely rotating pivot on the other.**

This results in an Adjustable Strut, one that **can be easily extended** and contracted simply by turning our new housing part.

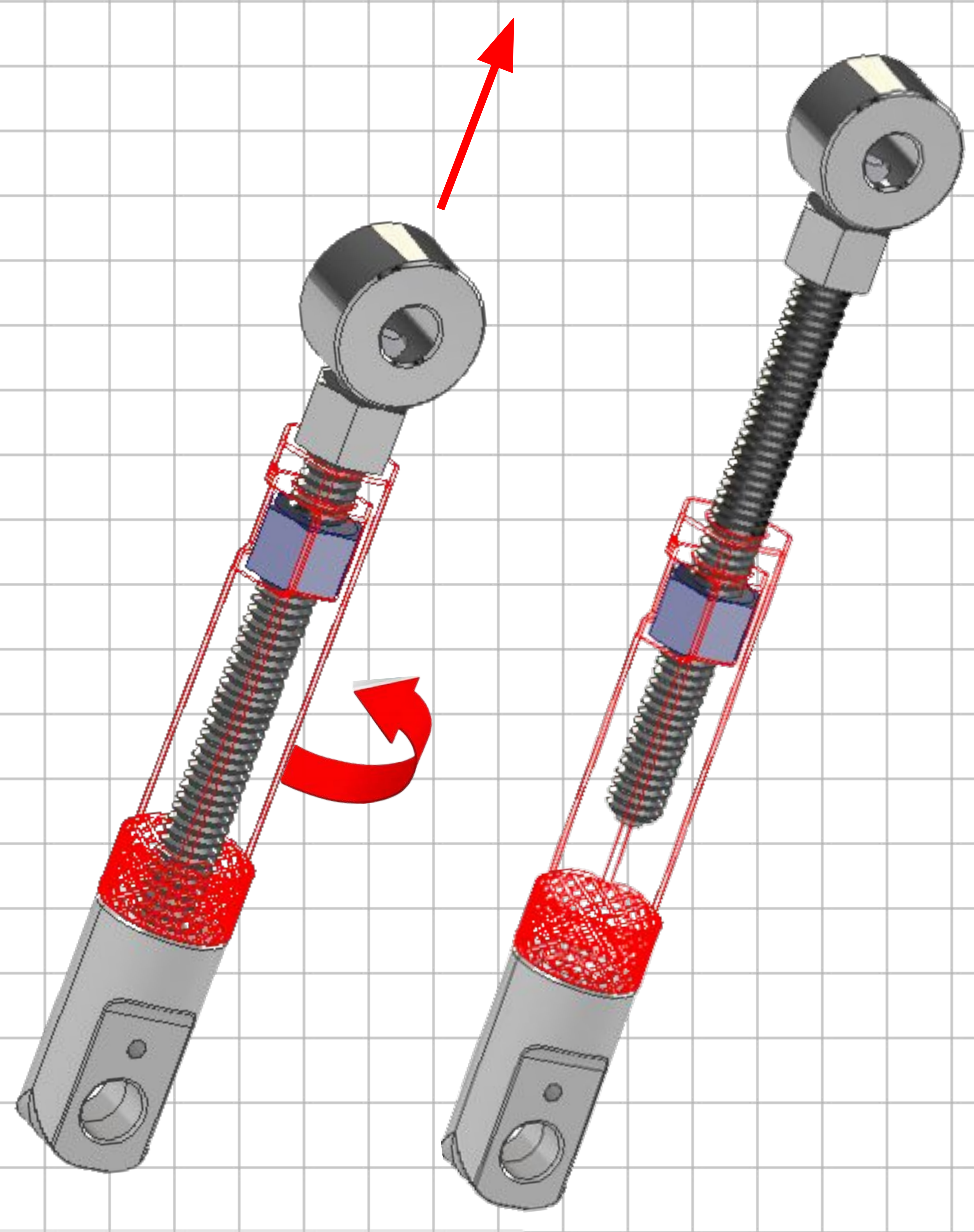
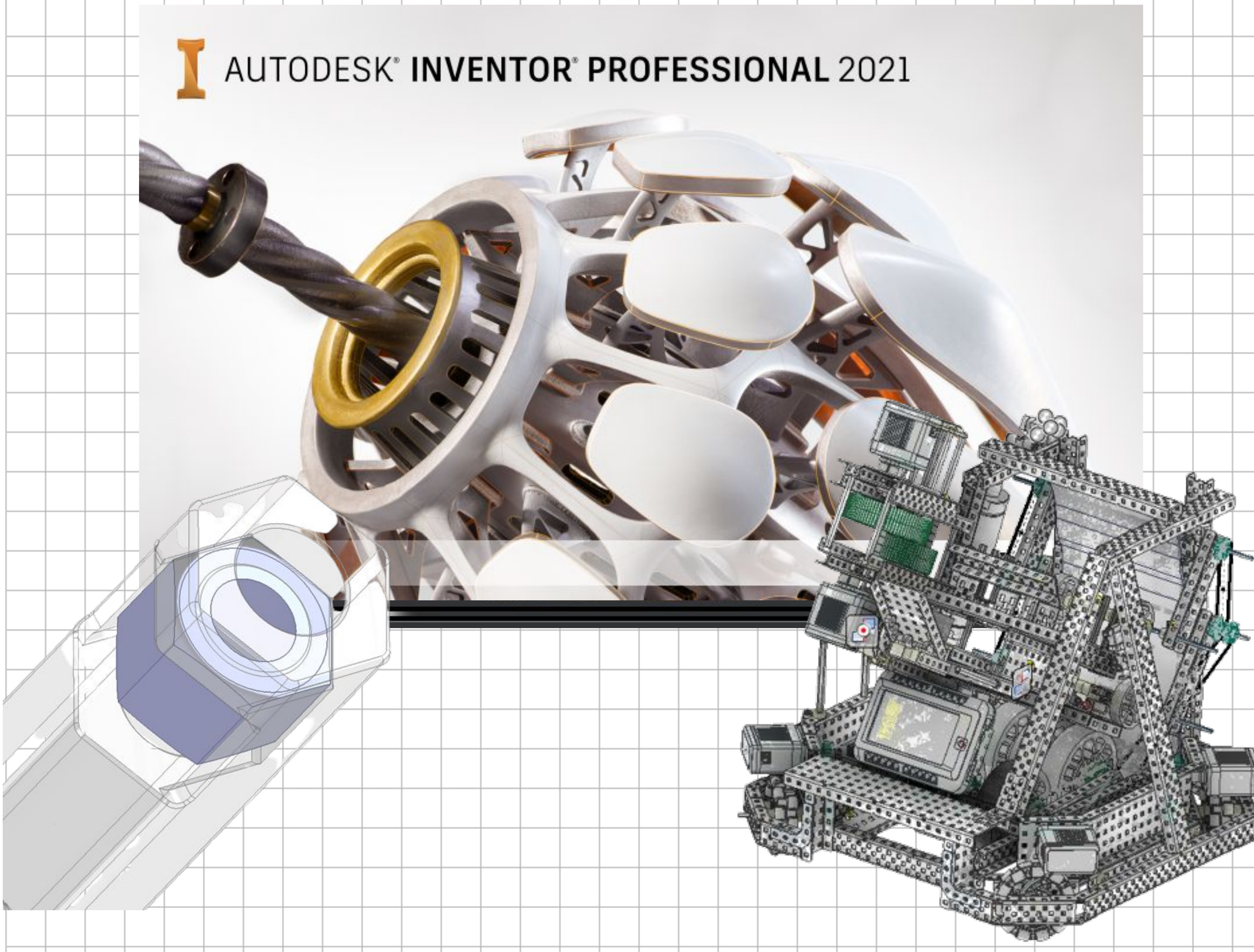


Fig. 4: *When the outer housing is turned, the threaded end pushes the Eye-Bolt in or out, and* ***the freely pivoting end doesn't change length*** *at all.*

Our Software



<u>Autodesk Inventor Professional: Version 2021.4.4</u>

Inventor is the industry standard for CAD modeling, especially for applications involving mechanical, moving, components.

We chose to use Inventor because of its versatility. From Concept Sketching to animating a Presentation, every step of the design process can be completed in one program.

Part Design: VEX Integration

Any new component **must fit into the existing VEX Building System,** so that the same tools, parts, and building techniques can be used.

Since our part will be adjusted by a VEX Wrench, it must **have the same face dimensions as an existing #8-32 Kep Nut.**

In **2D Sketch**, we used **Project Geometry** to capture the dimensions of a Kep Nut's face, which were transferred directly to the design of the Adjustable Strut.

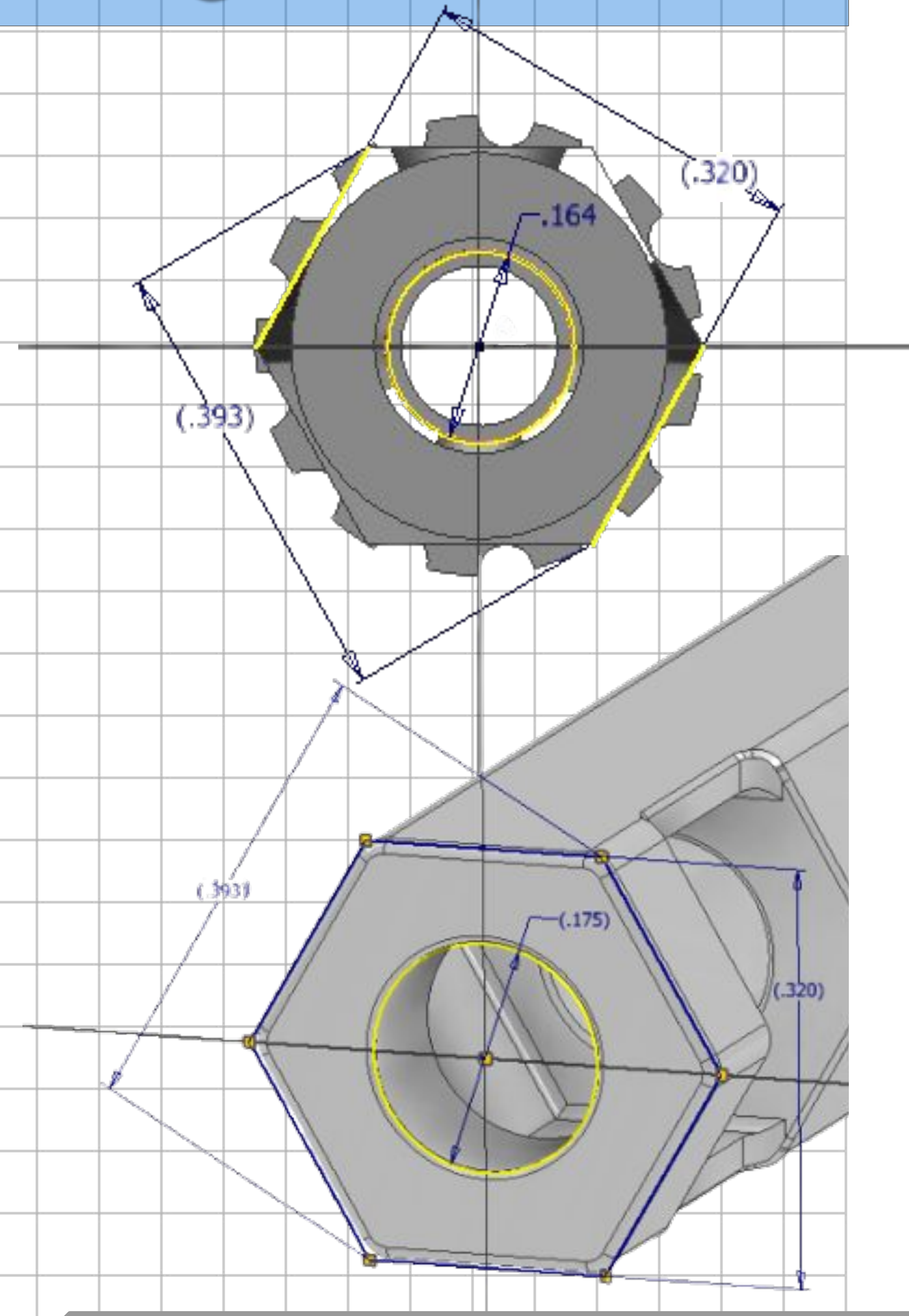
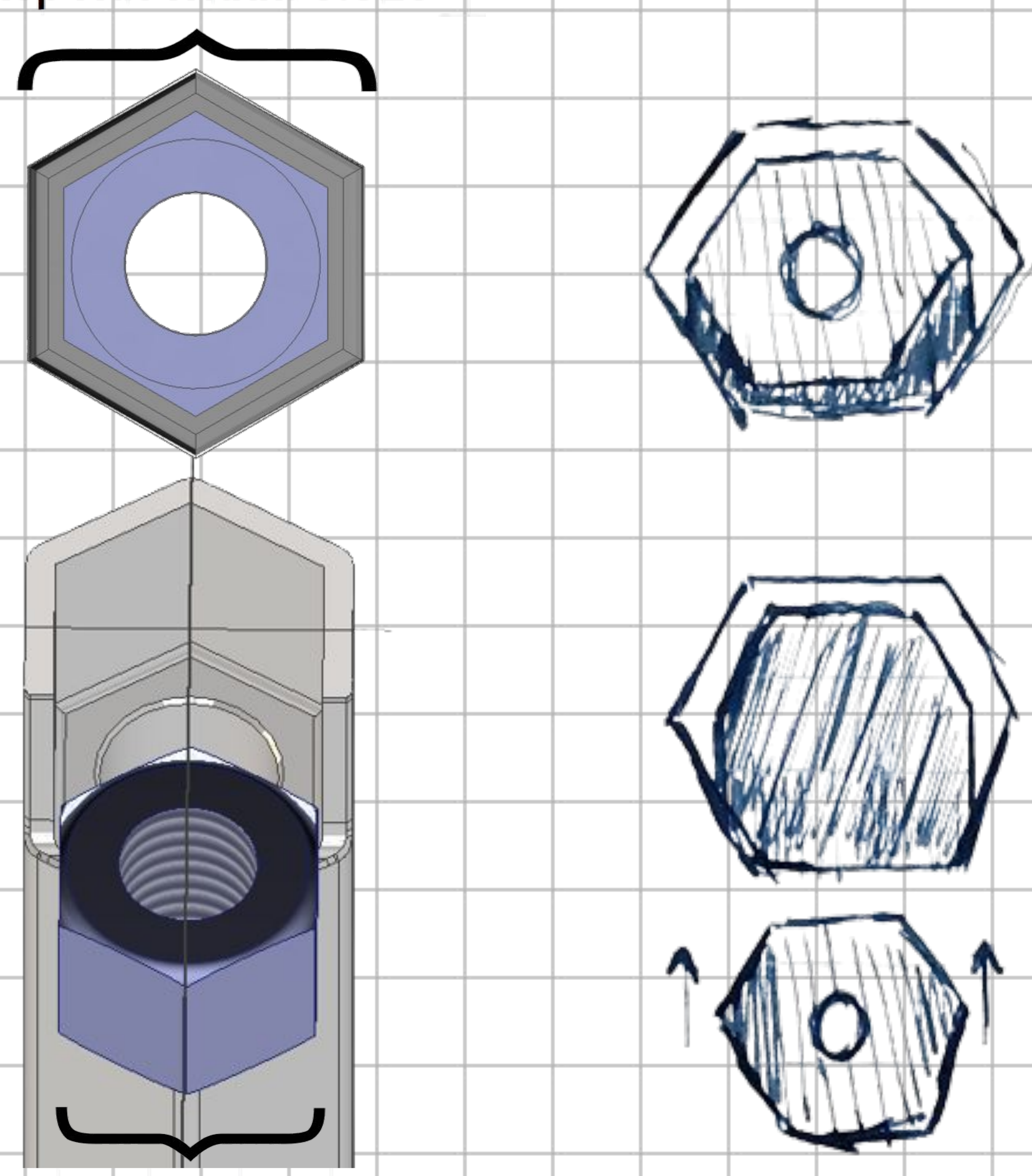


Fig. 5: *For the transverse hole, we decided not to thread our design, as* ***plastic threads are difficult to print and more importantly, weak****. Instead, the hole in our design is slightly larger than the diameter of a #8-32 Screw,* ***allowing for free movement*** *through the design.*

Kep Nut Width: 0.320”



Low Profile Nut Width: 0.250”

Fig. 6: *Since there are two sizes of #8-32 Nut in VEX, we can insert a Low Profile Nut, with a smaller overall size, into the design* ***while still fitting the entire part within*** *the profile of a larger Kep Nut.*

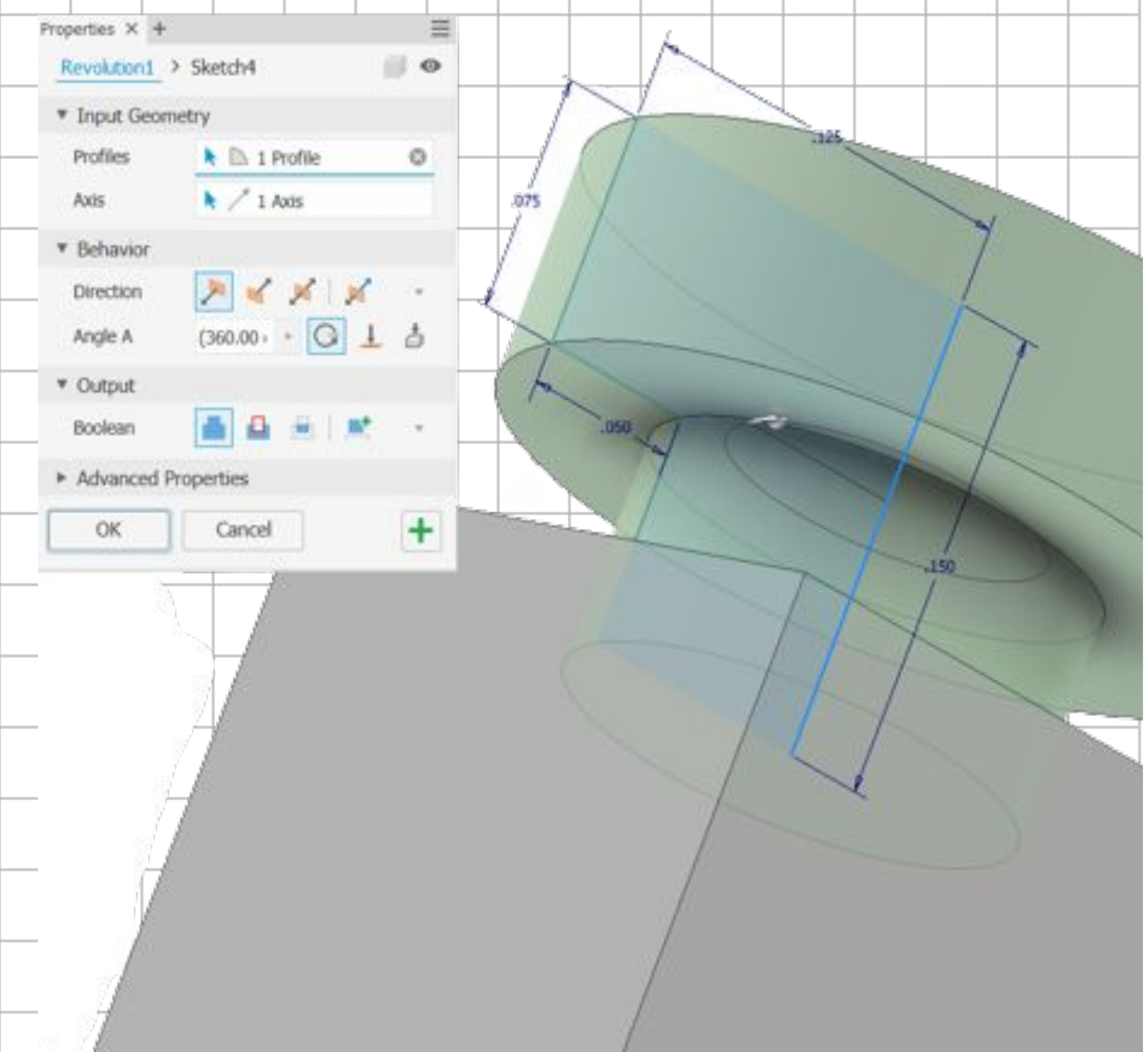
To screw onto an Eye-Bolt, a **Low Profile Nut** fits into the Adjustable Strut housing, **acting as a threaded insert** and eliminating the need for tapping our design.

Part Design: Printing Compatibility

Initially, we intended to **print the entire component as one part.**

To achieve this on our school's Dremel 3D40, we knew that parts that printed inside of another **would require a tolerance of at least 0.01",** between adjacent faces.

To **precisely configure the distances** between the parts of the freely spinning pivot, we **Revolved a cross section sketch**, instead of simply extruding concentric cylinders.



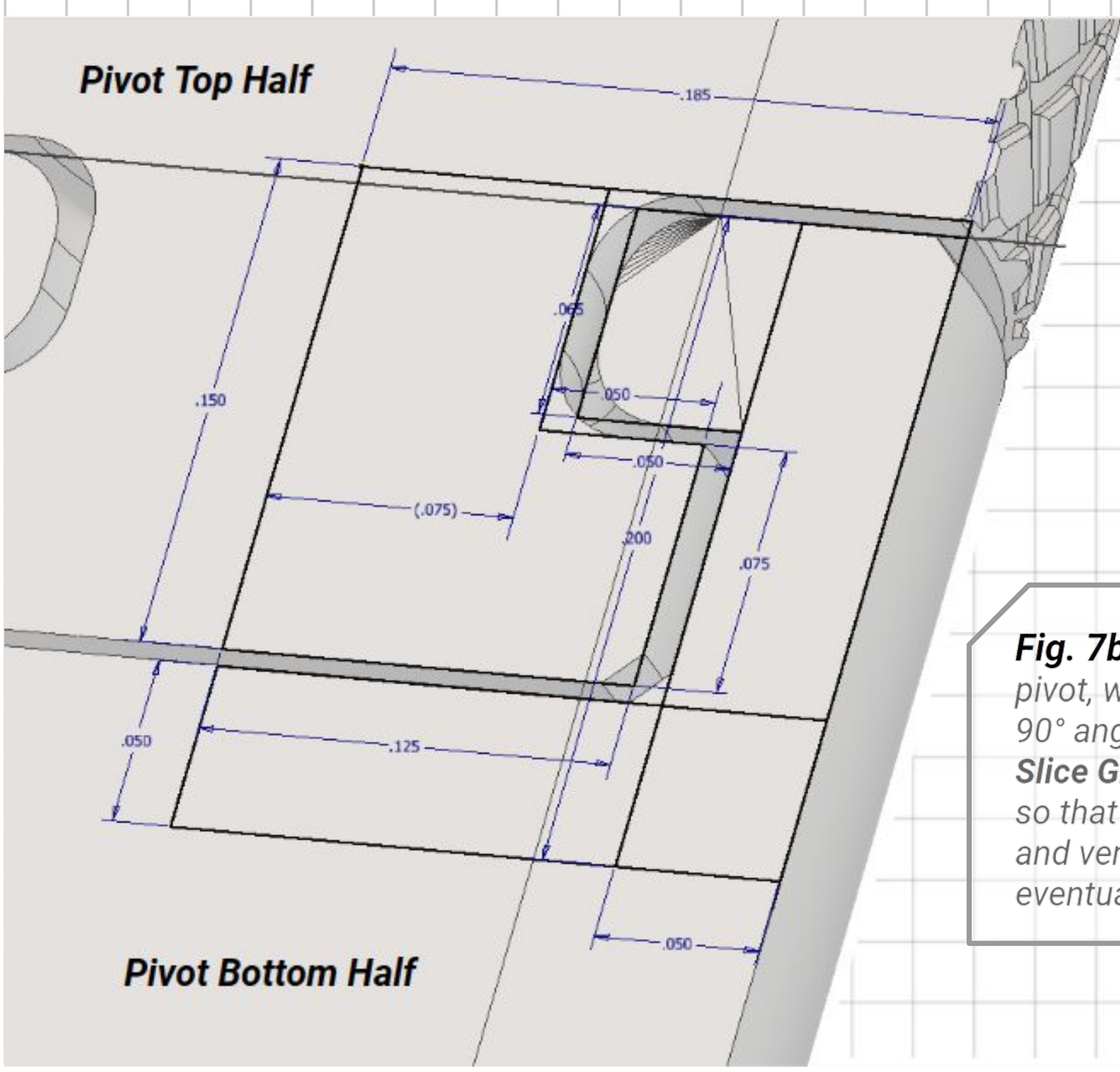


Fig. 7a: *The sketch shown to the left was the source sketch for both parts of the pivot. Being able to **model the cross section** made it easy to **set all of the tolerances** between parts **on a single sketch** instead of having to coordinate dimensions between multiple parts.*

Fig. 7b: *To **resist tension** and shear forces on the pivot, we added **Fillets and Chamfers** to reinforce 90° angles.*
***Slice Graphics** gave us a view of the cross section so that we could complement transitional edges and verify that no faces would touch in the eventual 3D print.*

Part Design: Ergonomics

We realized that **our part would likely be turned by hand** as well as by a wrench.

To improve grip on the design, we **decided to add knurling** at the bottom of the part.

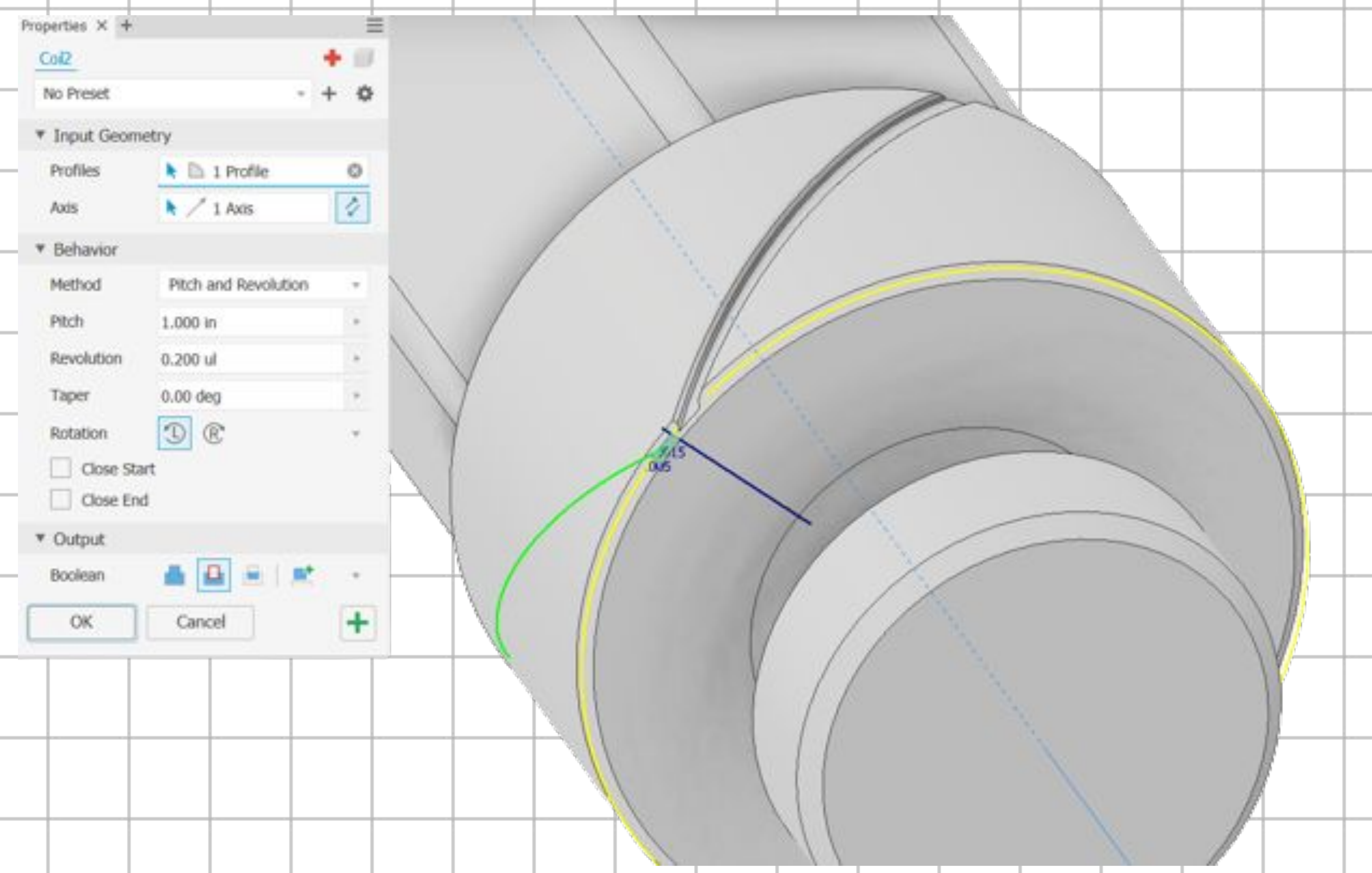


Fig. 8: *Knurling was achieved using the* ***Coil*** *function, which allowed us to* ***cut a groove diagonally*** *across the cylindrical end of the Strut. Then, a* ***Circular Pattern*** *duplicated many instances of the knurling groove around the part.*

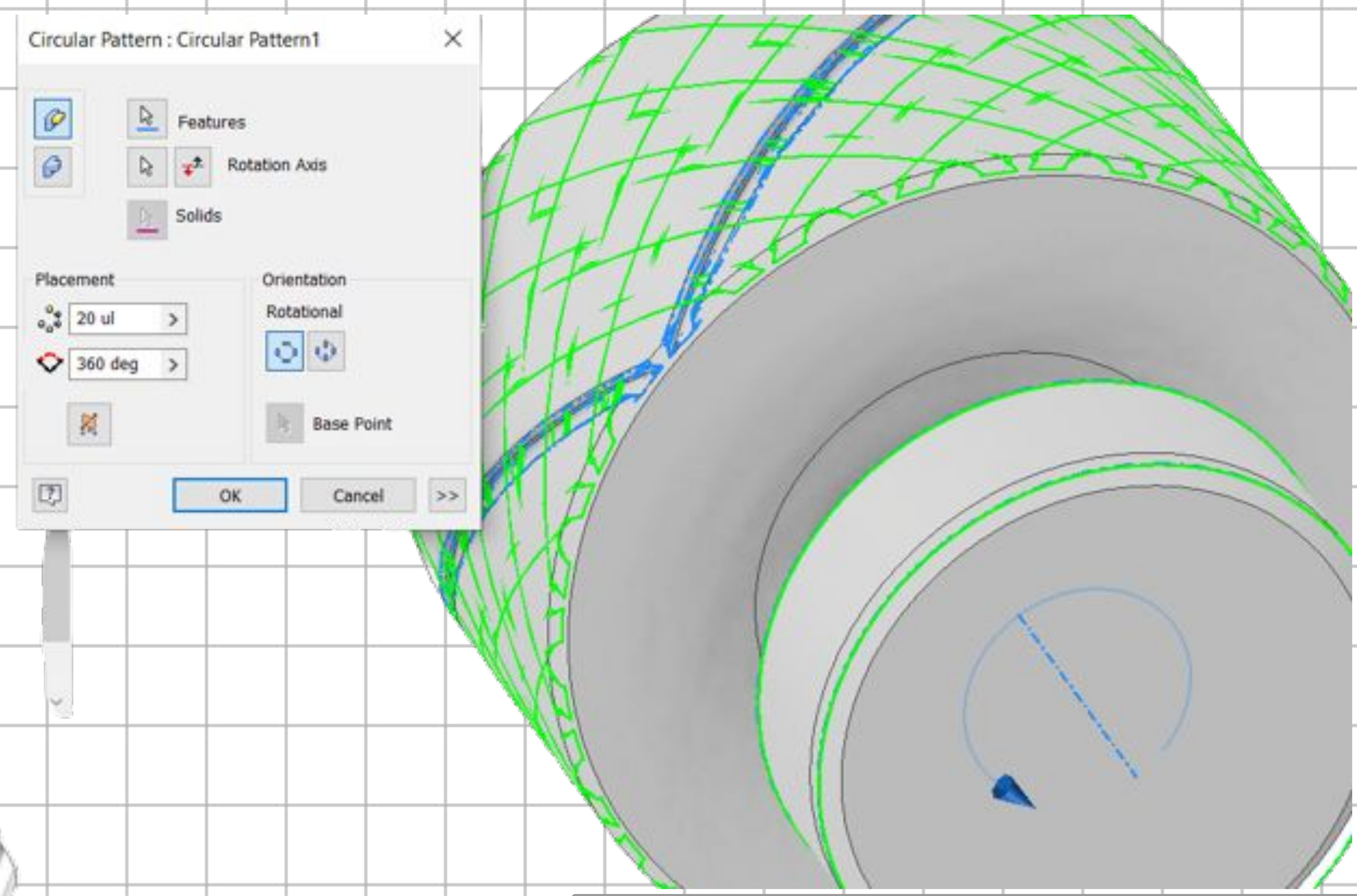


Fig. 9: *A cross-groove was also added with* ***Coil****, to provide grip while turning the Strut in the opposite direction. This was done before the* ***Circular Pattern****, decreasing the number of steps and space needed on the* ***Model Bar****. As a result this entire complex structure is contained entirely within a single Circular Pattern.*

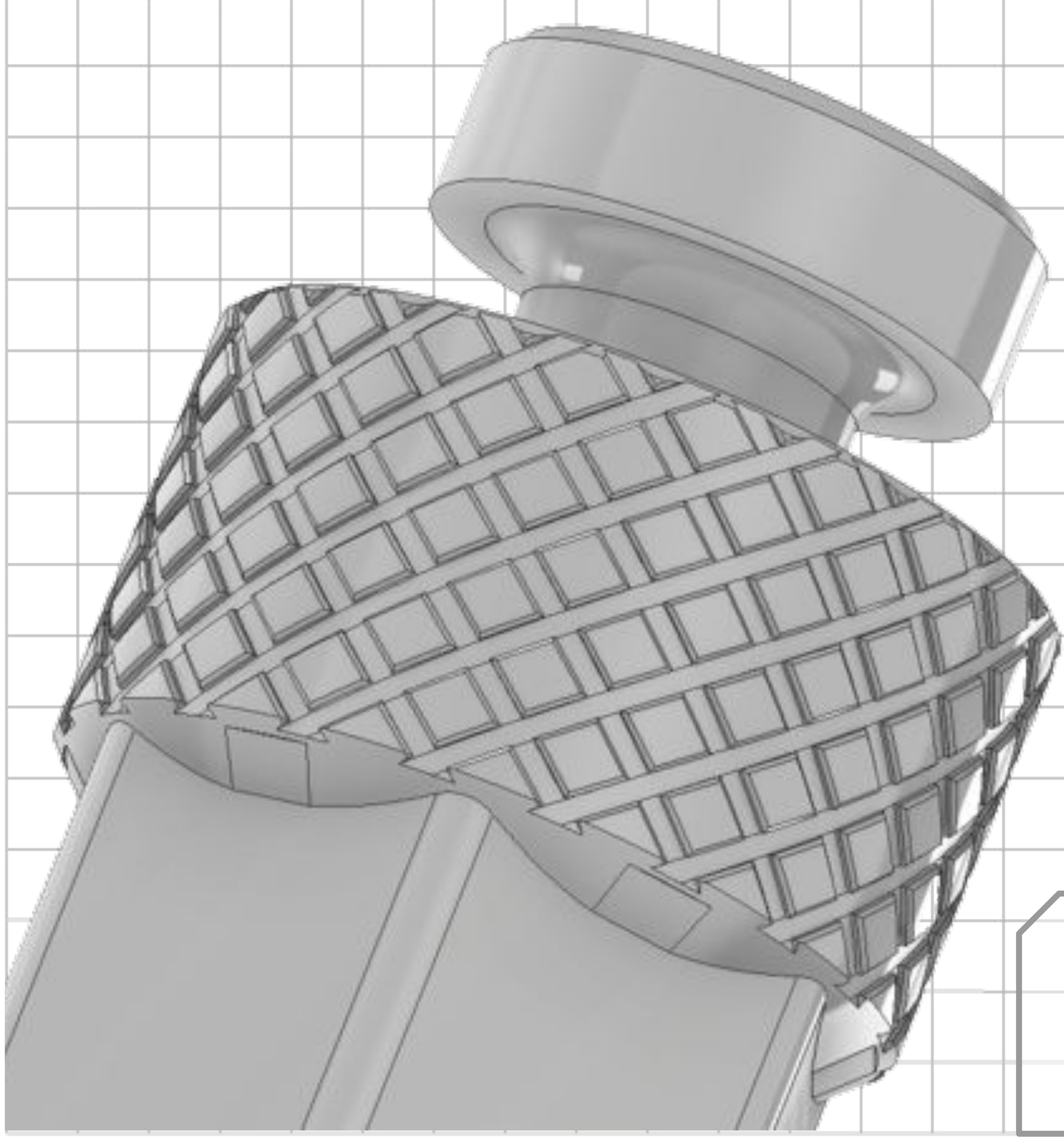
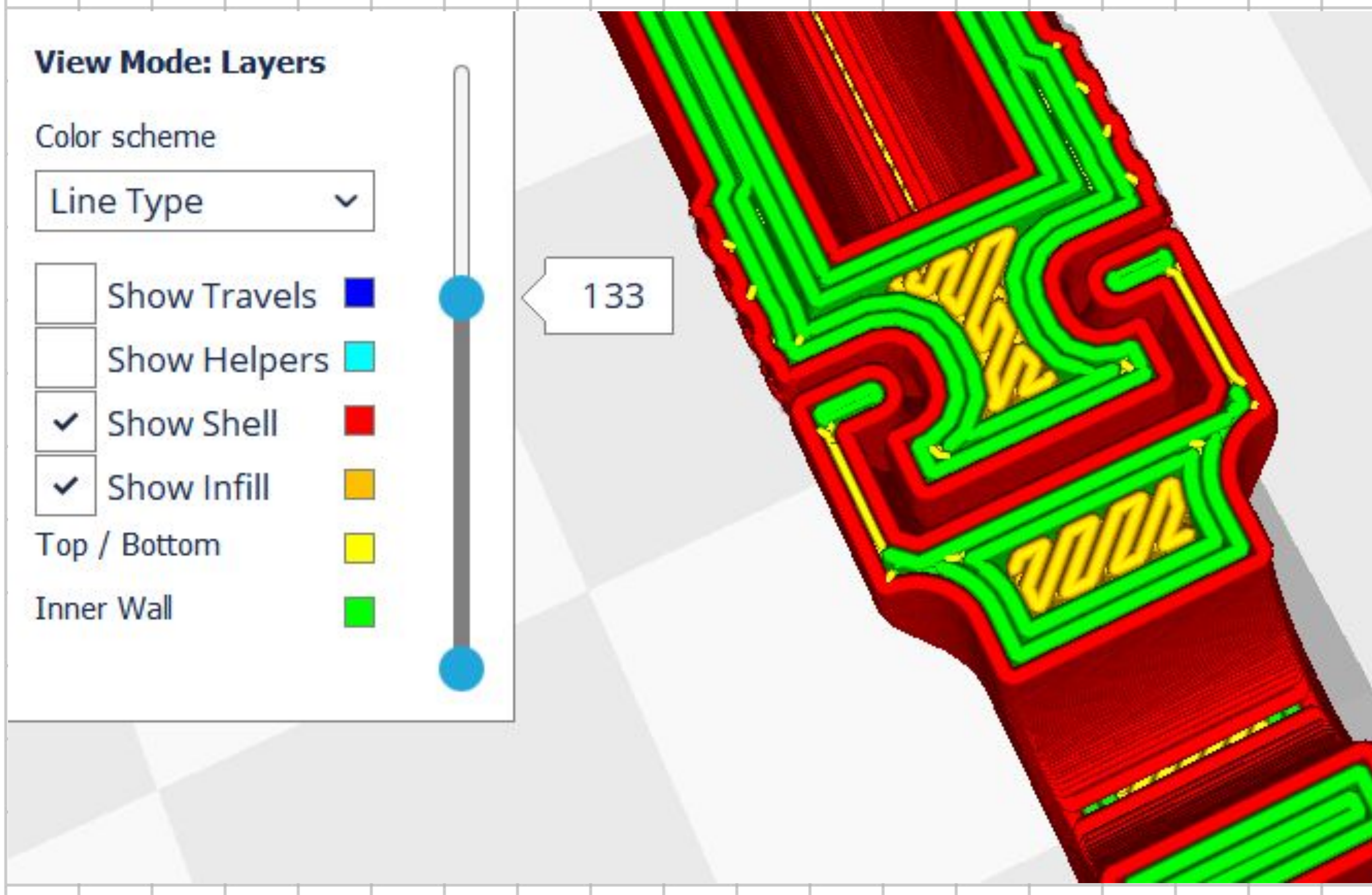


Fig. 10: *To finish the knurling, each of the diamond faces was slightly* ***Chamfer****ed, to smooth over sharp edges. The result was a simple Hill Knurl, providing just enough friction without feeling sharp or abrasive.*

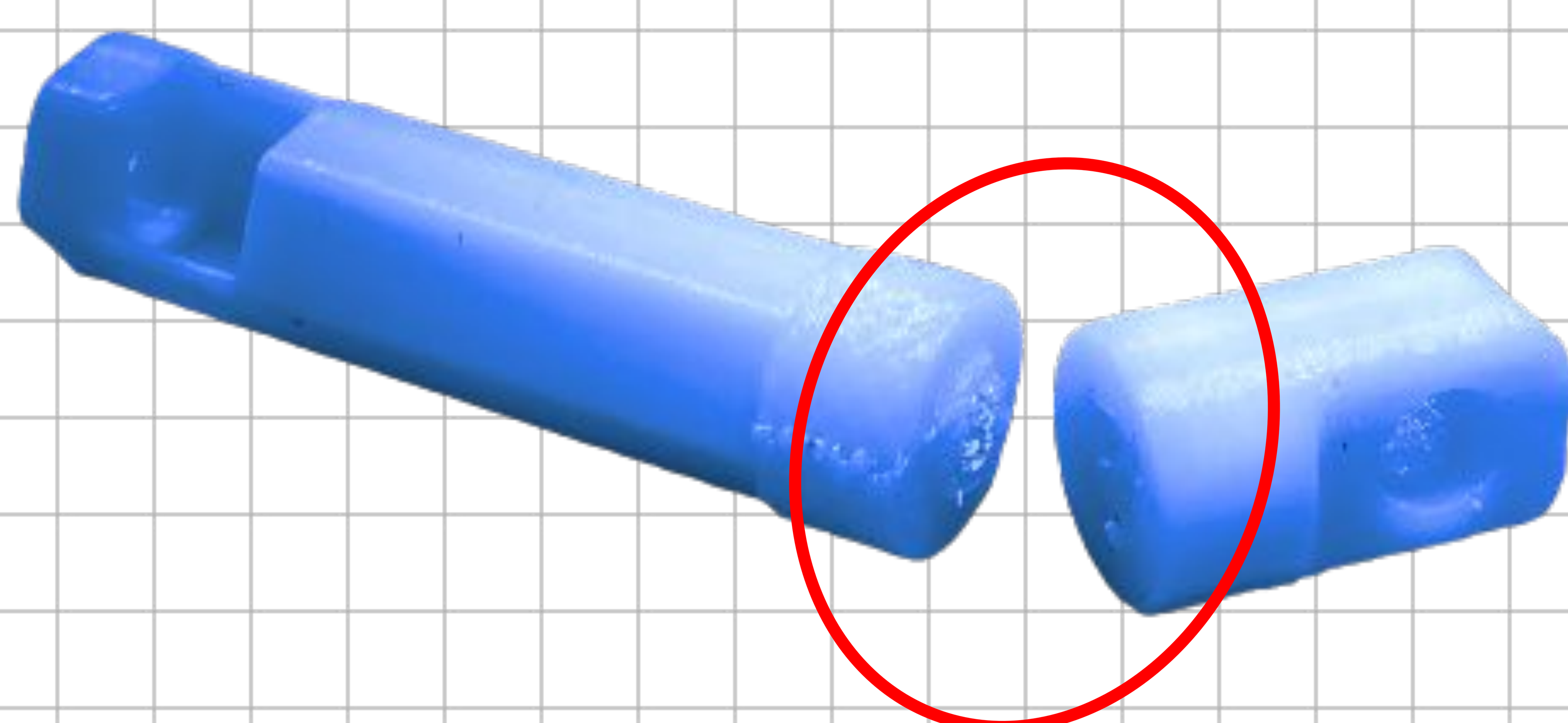
Prototyping

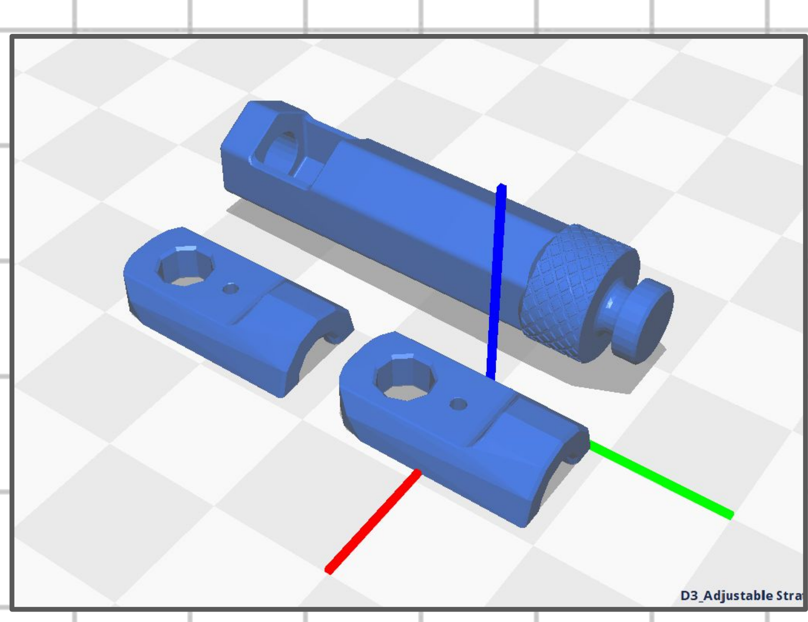


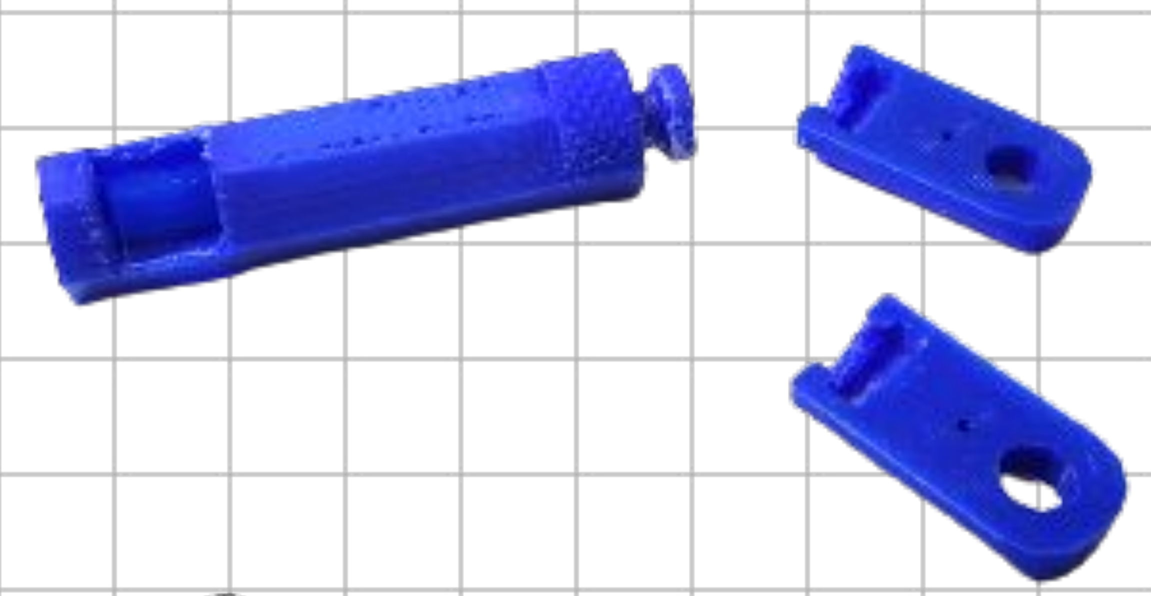
Prototypes were created on a Dremel 3D40 Fused Deposition Modeling Printer. With our design's **small size and tight tolerances,** it was imperative that the **quality of the print was as high** as possible.

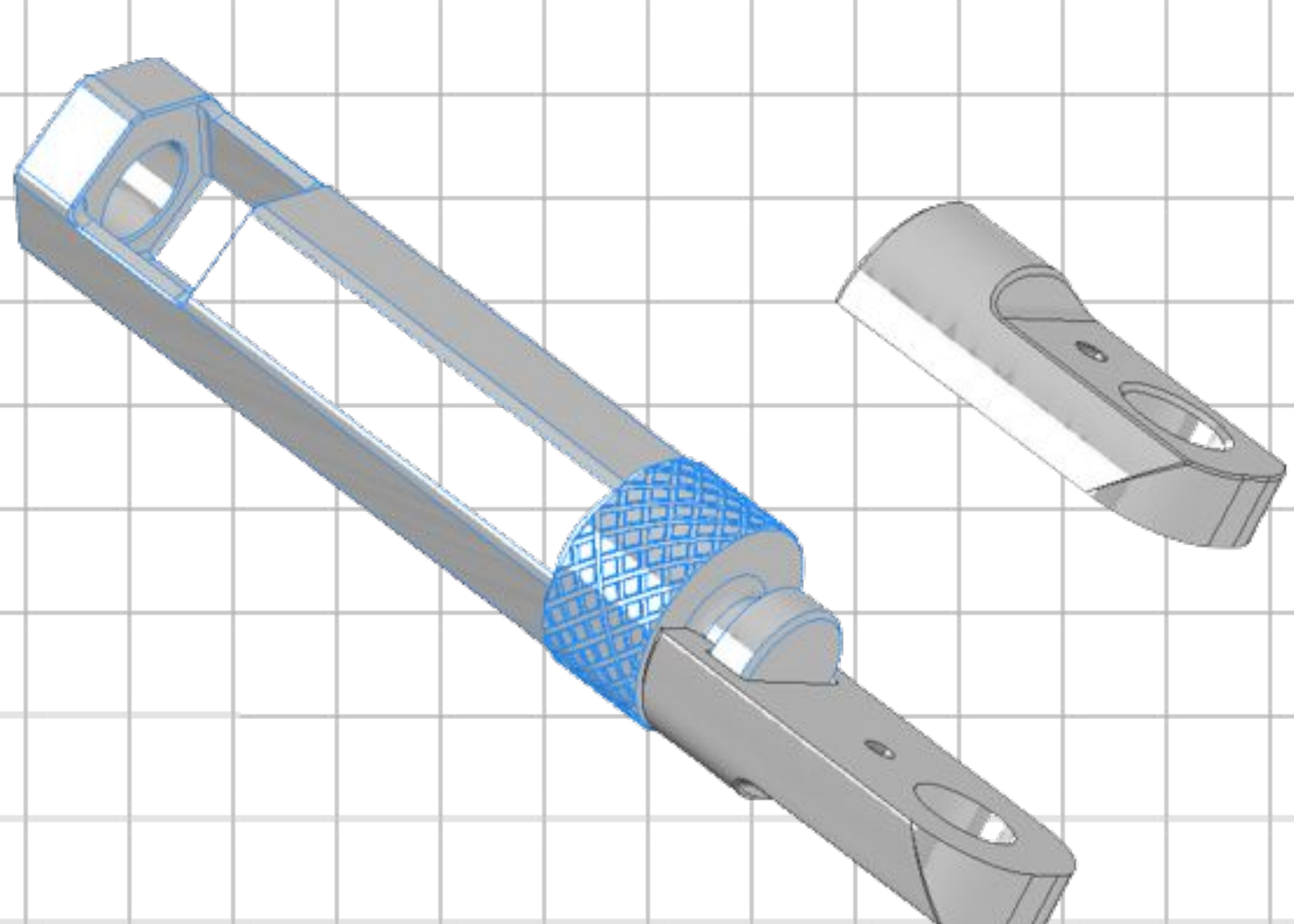
We set the **Layer Height to the minimum,** 0.0015".

Fig. 11: *Unfortunately, the distances between adjacent faces were still too close, and with the long cooling time of PLA filament, the pivot on our first, "one-piece" prototype fused together.*









The second prototype's pivot was **cut in half in Inventor,** printed in two separate parts, and **assembled afterwards,** eliminating any chance of fusing.

This solved the issue with the **only moving part** in our design, and our **tolerances resulted in a smooth-turning** pivot with little play.

Practicality and Usage

As a **direct substitute for any existing Strut,** our Adjustable version can be easily swapped into any application where a regular Strut is applied.

Our design can be implemented in **a mechanism found on nearly every robot** this year: The Launcher.

The goal of this year's game is to **accurately shoot discs** into High Goals, and being able to **make minute adjustments** to the position and elevation of a launching mechanism **simplifies and quickens the fine tuning** of an entire robot.

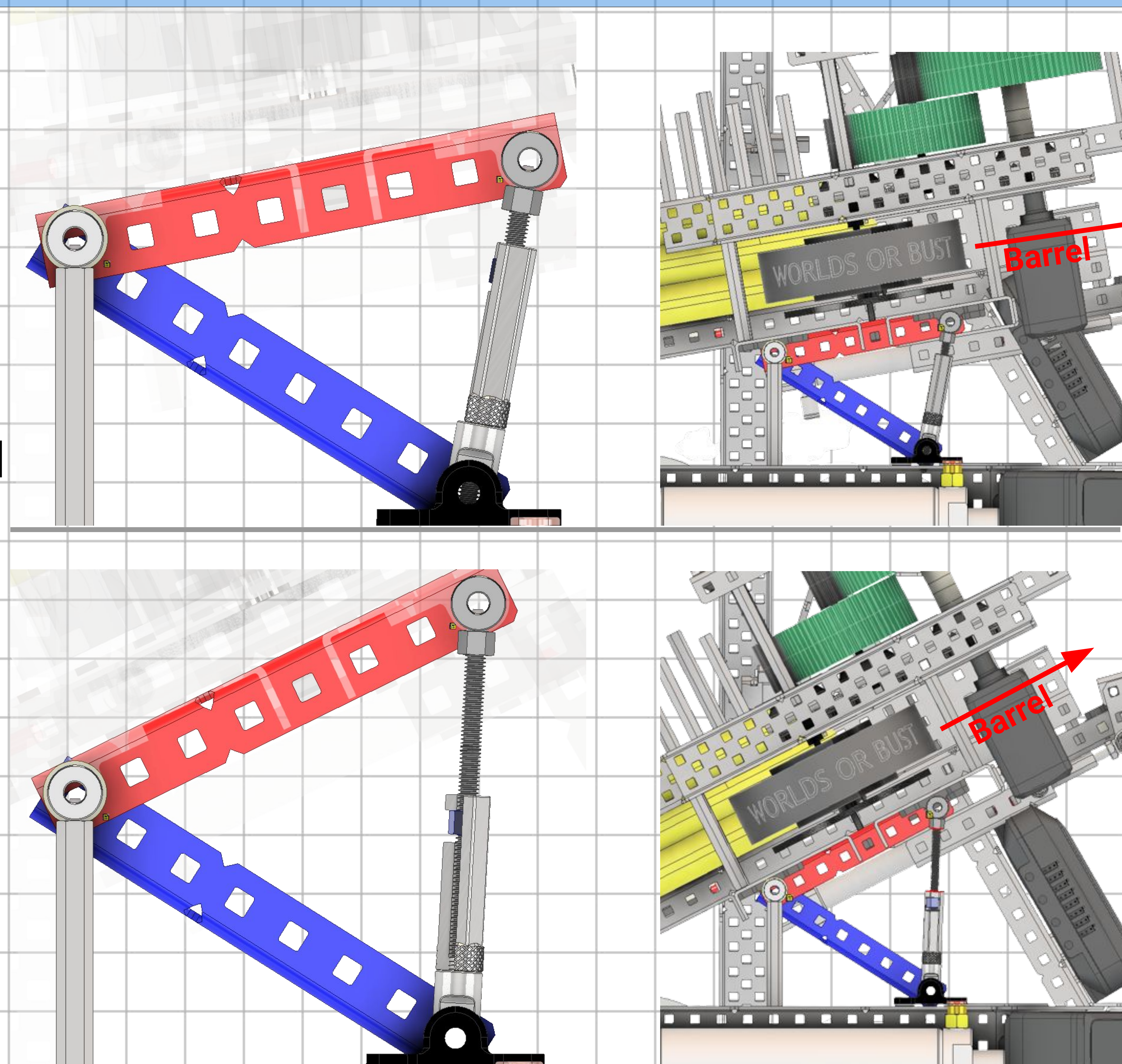
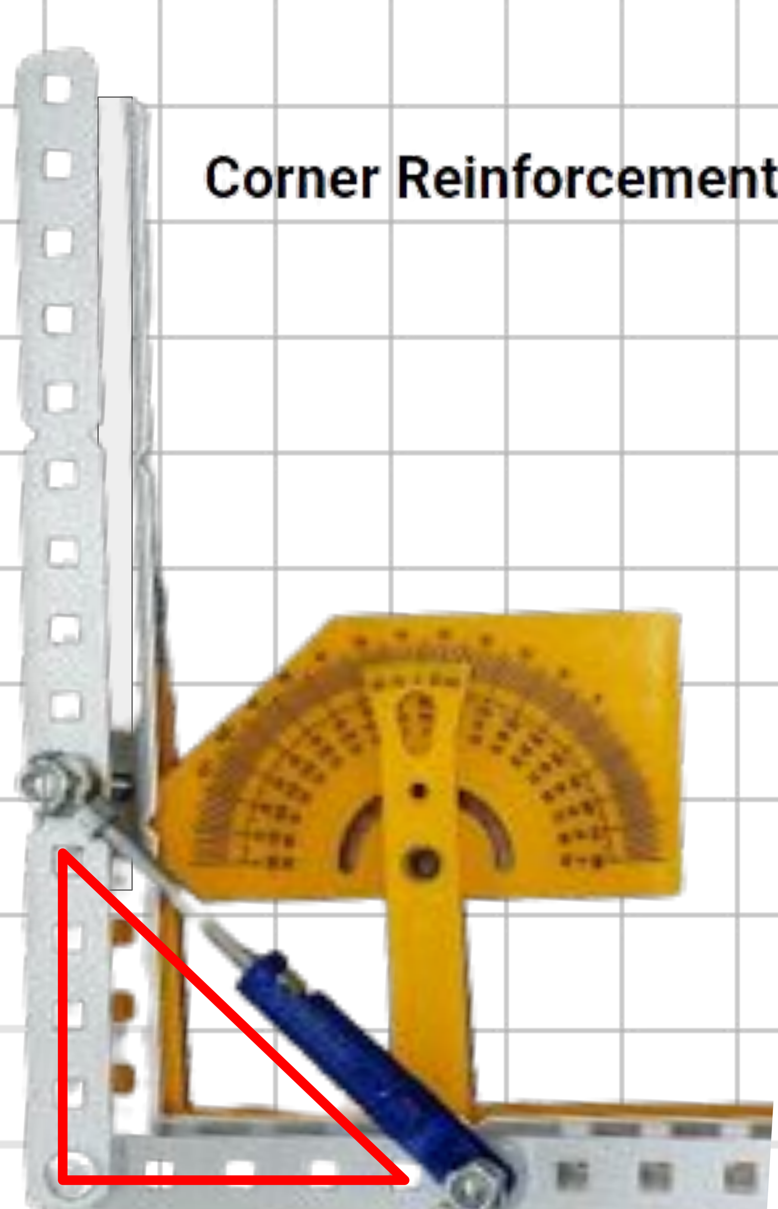
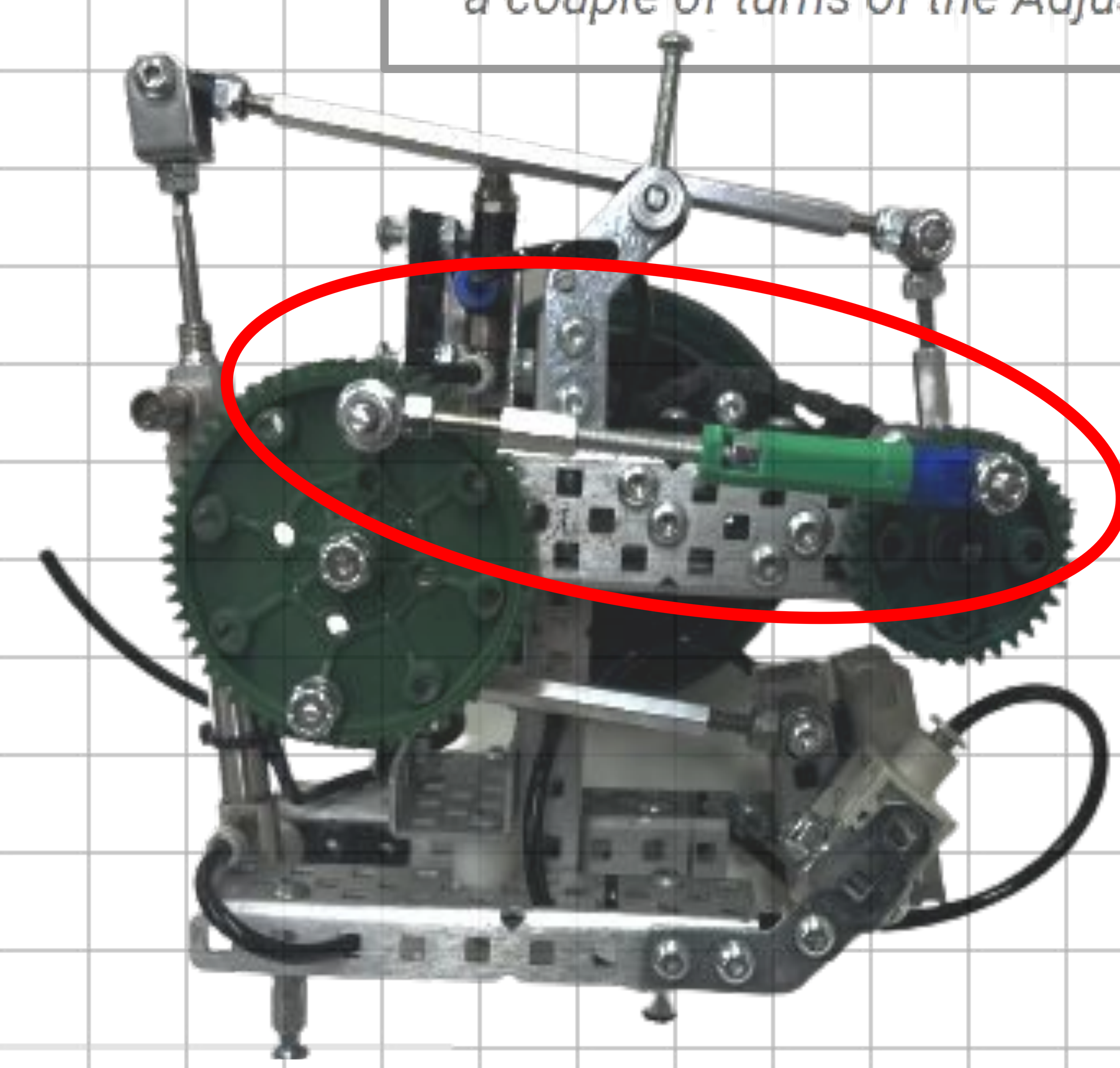


Fig. 12: *The above figures demonstrate the use of an Adjustable Strut as an adaptable replacement for the Flywheel Launcher mount on our robot. As the diagrams on the left indicate, the angle between the blue and red C-Channels can be precisely tuned, and with them, the entire elevation of the Launcher. If our robot was shooting discs too low, it would only take a couple of turns of the Adjustable Strut to sight it in properly*

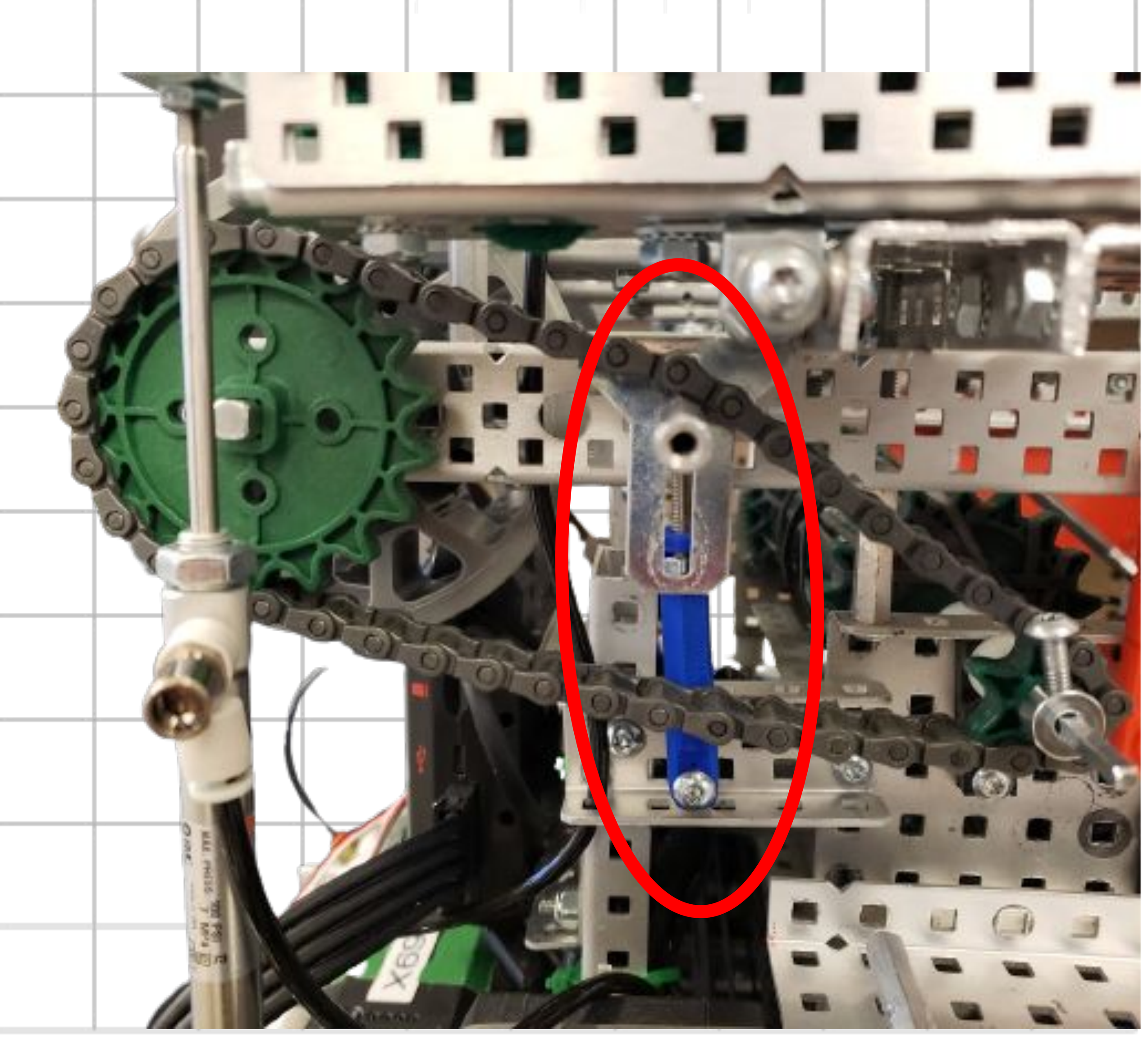


Corner Reinforcement



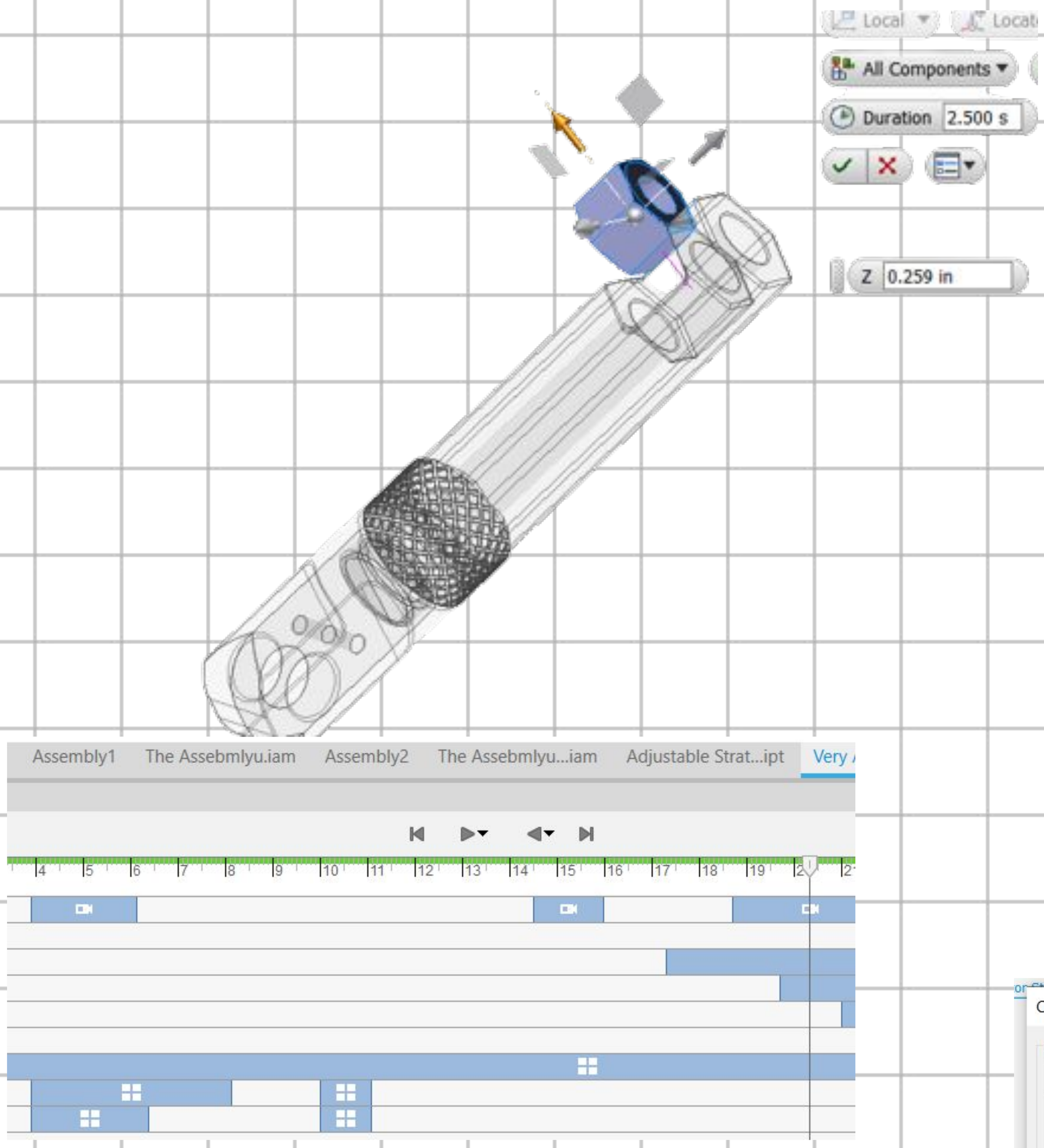
Engine Timing Linkage

Chain Tensioner



Half Scale

Presentation and Studio



To supplement our report, we created an animation showing the construction and utility of our design. Our video was made up of two parts: **Assembly and Demonstration.**

We used **Presentation** initially, which ignored all constraints within our design assembly and allowed us to **Tweak** and **Rotate Components,** illustrating the construction of our design.

Fig. 13: *The* ***Storyboard display was like a second Model Bar,*** *giving us the ability to alter and rearrange certain scenes within the animation.*

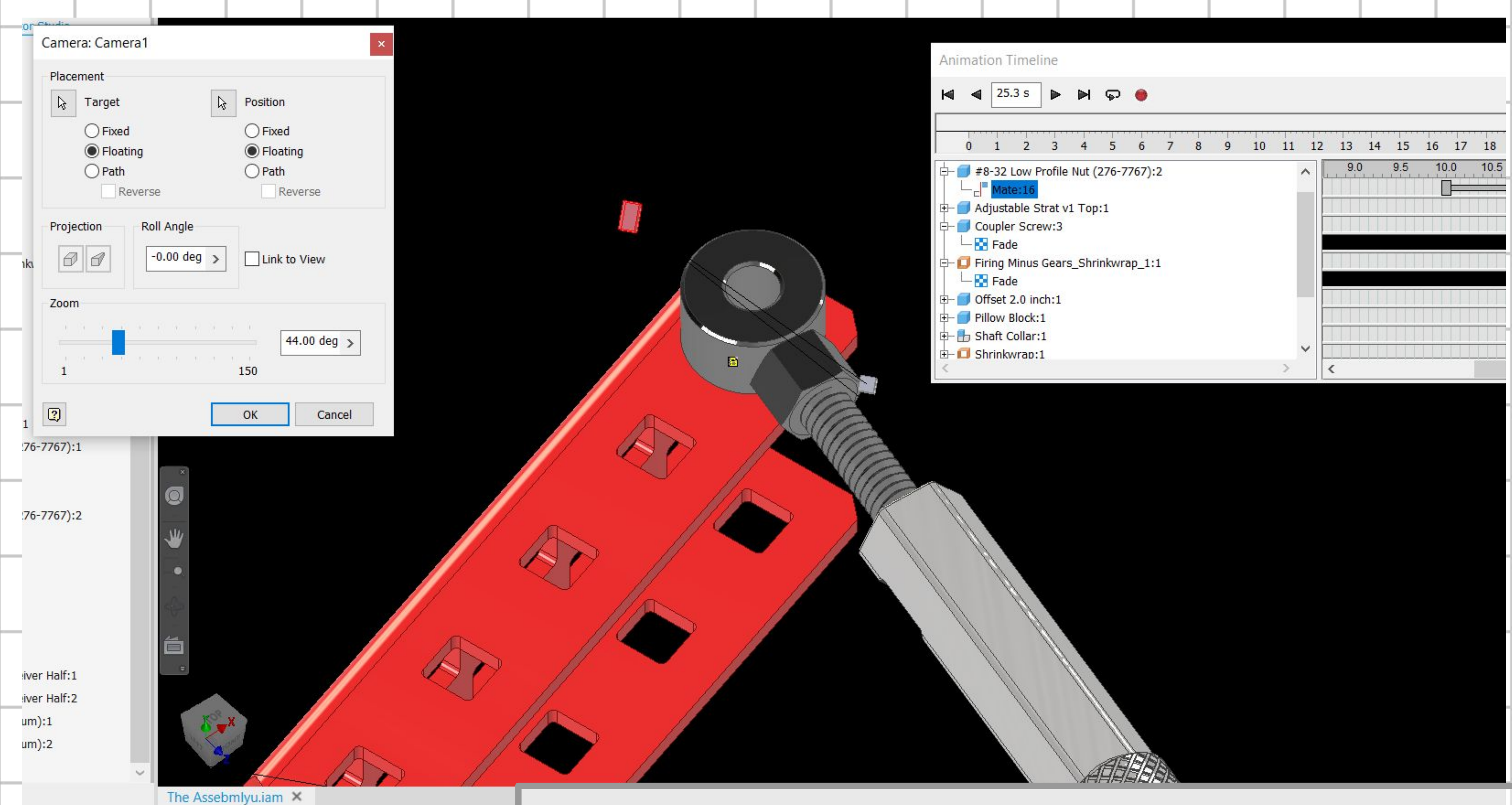
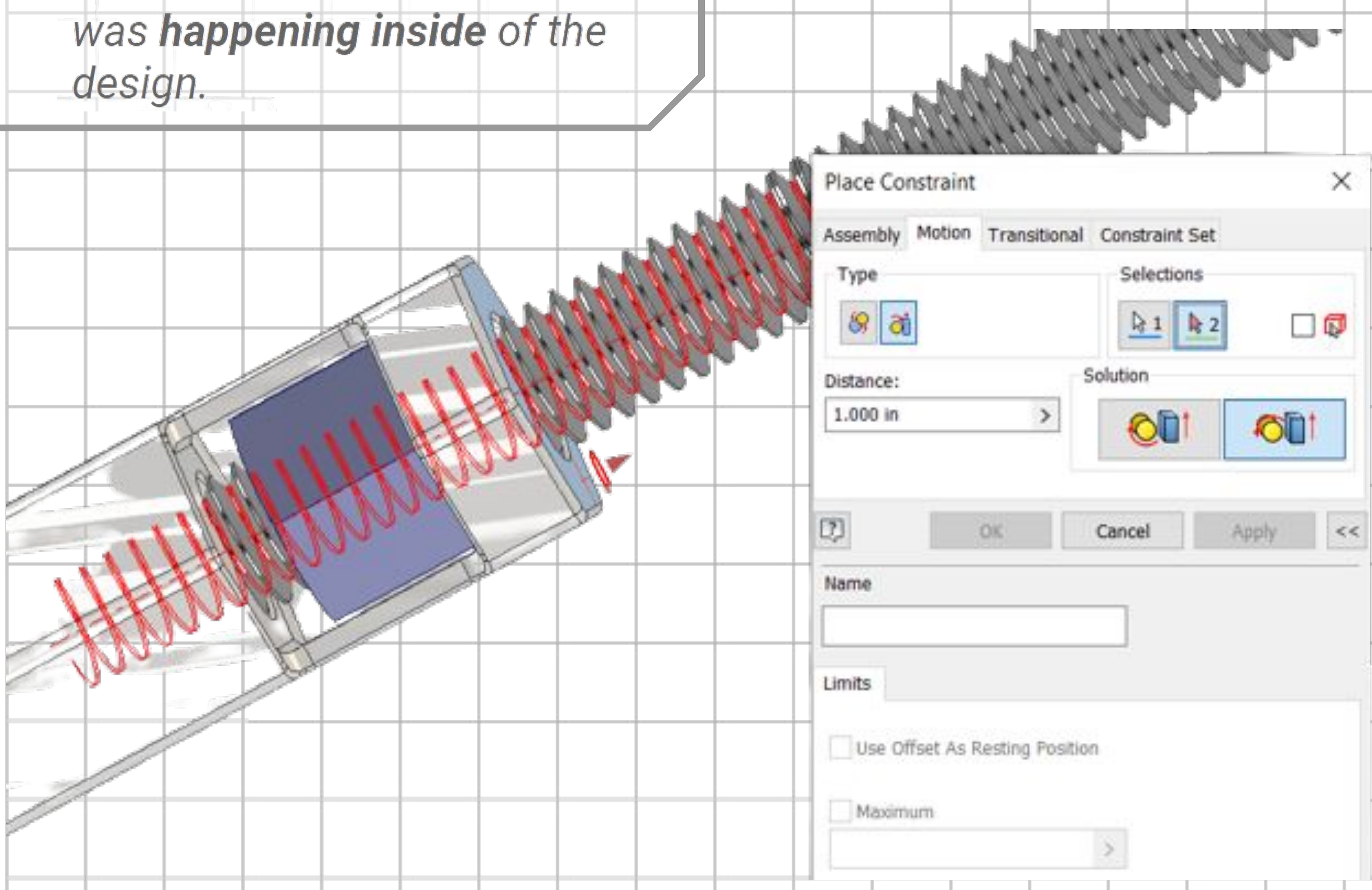


Fig. 14: *We also changed the* ***Opacity of certain parts*** *to give the audience an idea of what was* ***happening inside*** *of the design.*

Fig. 15: *Likely the most difficult challenge that presented itself was learning how to* ***manipulate the Camera in Studio****. Autodesk* ***Forums*** *ultimately taught us how to set the position of, pan, and duplicate Camera Views.*



For demonstrating our design we used **Inventor Studio, a more dynamic and cinematic renderer.**

Fig. 16: *Studio required us to learn to put in* ***Motion Constraints*** *in Assembly, and allowed us to "drive" these to simulate the action of the Adjustable Strut.*

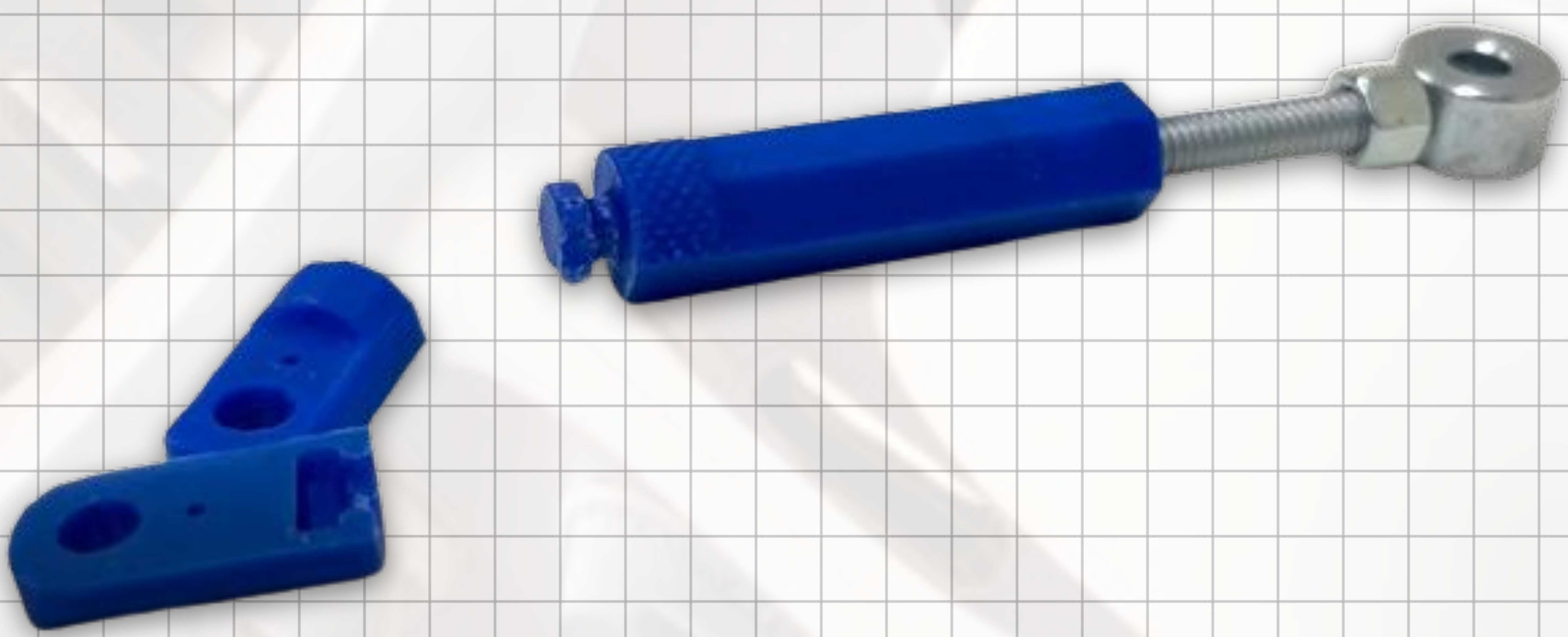
Conclusion

Although we've previously assembled VEX Robots in Inventor, this was the first time we actually got to create a part for one. We learned to utilize Inventor's 2D and 3D tools to bring a design from concept to creation, and added a fourth dimension with animations.

Our goal was to make a useful component even more versatile, and the opportunity to innovate our own part within a preset building system gave us a new perspective on VEX Robotics, and engineering as a whole.

Our team firmly believes in the critical importance of CAD Modeling to the design process, and during this project Inventor has proven its potential as a tool to communicate and present ideas as well.

Moving forward, we'll not only use Inventor as a tool to translate ideas into tangible designs, but also as an indispensable component of our documentation and presentations.



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