



SUTD ORGANIZATION OF
AUTONOMOUS ROBOTICS

Mechanical Design & Fabrication

WEEK 4

Timeline

- 16 September 2021, 7-9pm
- SOAR Projects Showcase

- 27 September 2021, 7-9pm
- Intro To Mechanical Design
- Fusion360 Part I, Basics

- 4 October 2021, 7-9pm
- Fusion360 Part 2, Assemblies

- 30 September 2021, 7-9pm
- Introduction to Arduino

- 7 October 2021, 7-9pm
- Programming & PWM

WEEK 1



WEEK 3



WEEK 4

Timeline

- 11 October 2021, 7-9pm
- Fusion360 Part 3, Simulation
- CAD Speed Challenge

- 14 October 2021, 7-9pm
- Ultrasound & Motor Drivers

• Study Break

- 27 (1030-1800)-28 October (1000-1800) 2021
- SOAR Challenge!

WEEK 5



WEEK 6



WEEK 7

Fabrication Techniques

- Top-Down
 - Machining
 - Milling
 - Lathing
 - Waterjet Cutting
 - Laser Cutting
 - Drilling, Cutting, Bending
- Bottom-Up
 - FDM
 - SLA/DLP
 - SLM/SLS
- PolyJet
- CFF
- Composite Layup
- Casting
- Molding

Overview of FABRICATION Techniques

Milling

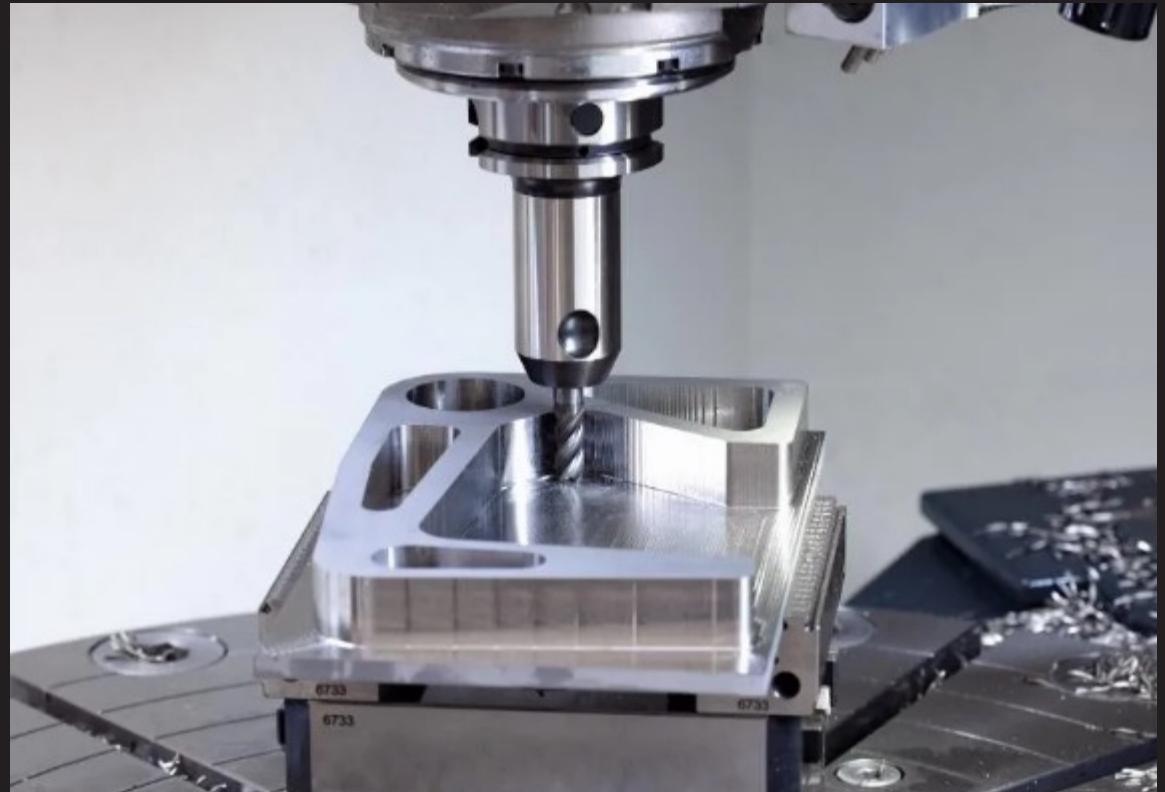
Subtractive Manufacturing

Materials: Aluminum, Steel, Stainless Steel, Titanium, Brass, Copper, PVC, Nylon, Solid Wood/Plywood, Foams

Manual/Computer Numerical Control (CNC)

Typical Use: Milling out parts with good surface finish and high tolerances

Limitations: Cannot mill out "overhangs" (except for high end machines)



The Lathe

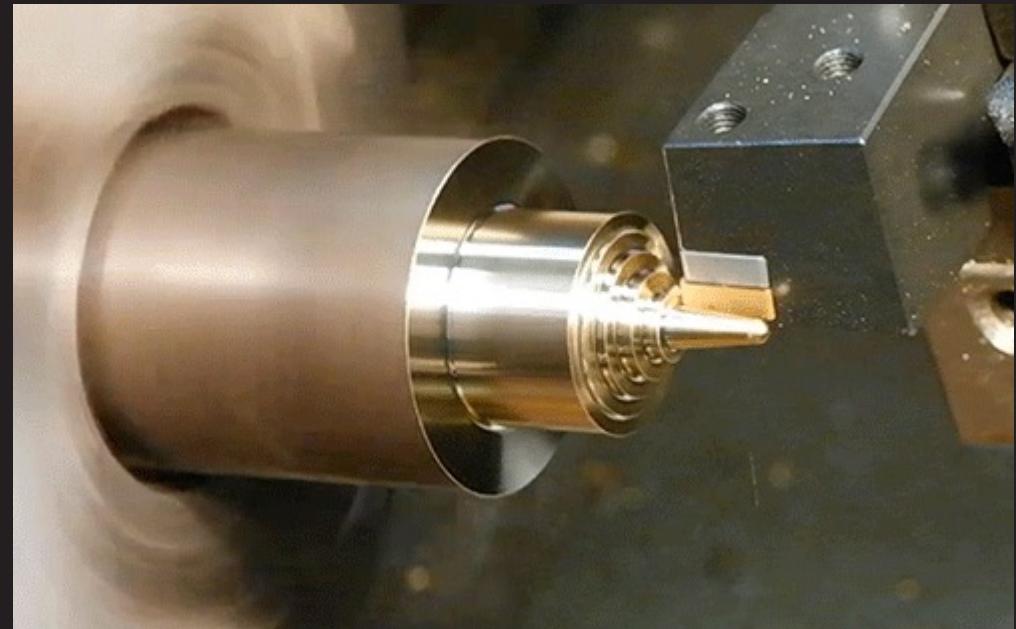
Subtractive Manufacturing

Materials: Aluminum, Steel, Stainless Steel, Titanium, Brass, Copper, PVC, Nylon, Solid Wood/Plywood, Foams

Manual/Computer Numerical Control (CNC)

Typical use: Milling out rotationally symmetrical parts with good surface finish and high tolerance

Limitations: Material must be rigid enough to handle centrifugal/centripetal forces without warping



Waterjet

Subtractive Manufacturing

Materials: Rubber, foam, plastics, leather, composites, stone, tile, glass, metals, food, etc

Not purely a "water" jet, usually includes abrasive like sand/quartz/diamond in the water

Cutting jet usually thicker than laser cutters and less precise and lower resolution



Laser Cutting

Subtractive Manufacturing

Materials: Acrylic, Metals, Wood, Foams,
Cardboard, NOT POLYCARBONATE

Typically more accurate and higher resolution
than waterjet

Cutting beam typically thinner than waterjet

thickness of material to cut usually thinner than
waterjet

Can also do engraving



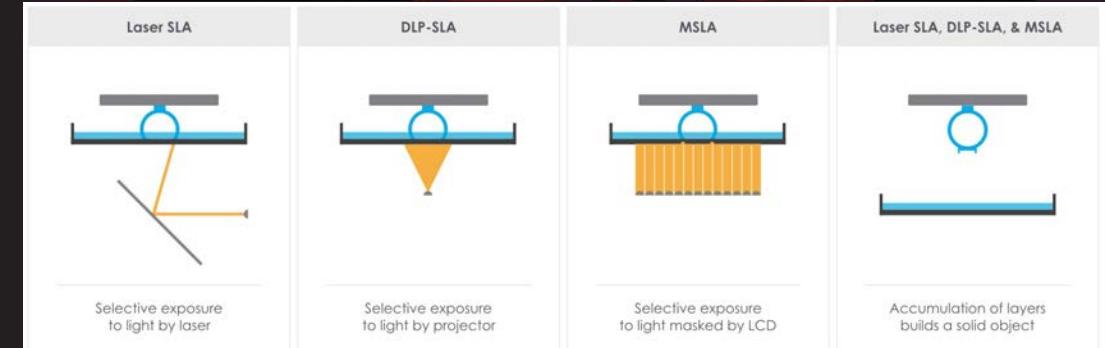
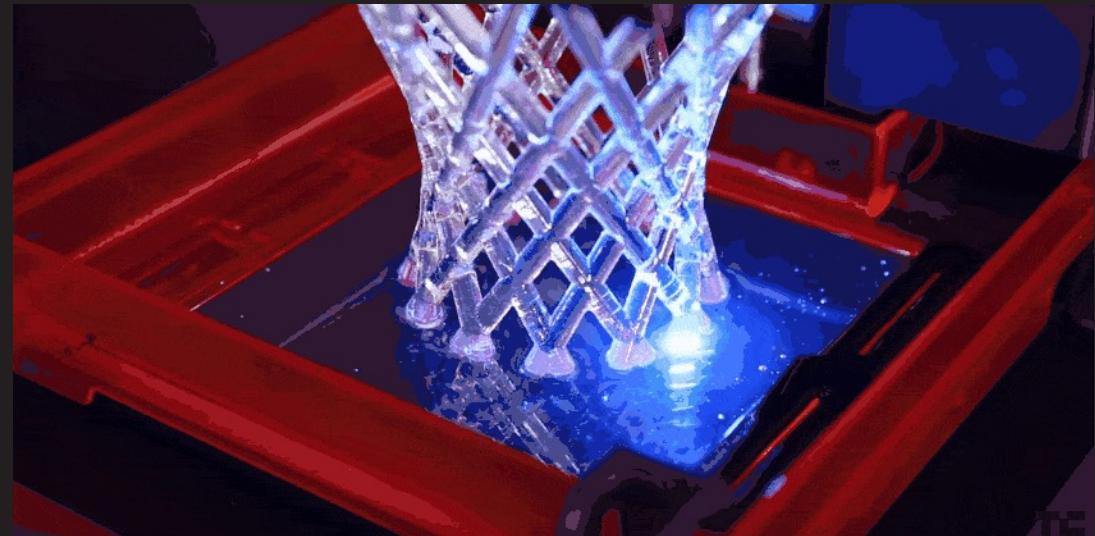
SLA/DLP Printing

Additive Manufacturing

Materials: Assorted UV cured resins with different additives to give different characteristics, eg. engineering resins, dental/medical resins, castable resins

Higher resolution and potentially faster than FDM, though typically smaller maximum print size

Environmental impact: Depending on material, but usually less waste than subtractive manufacturing



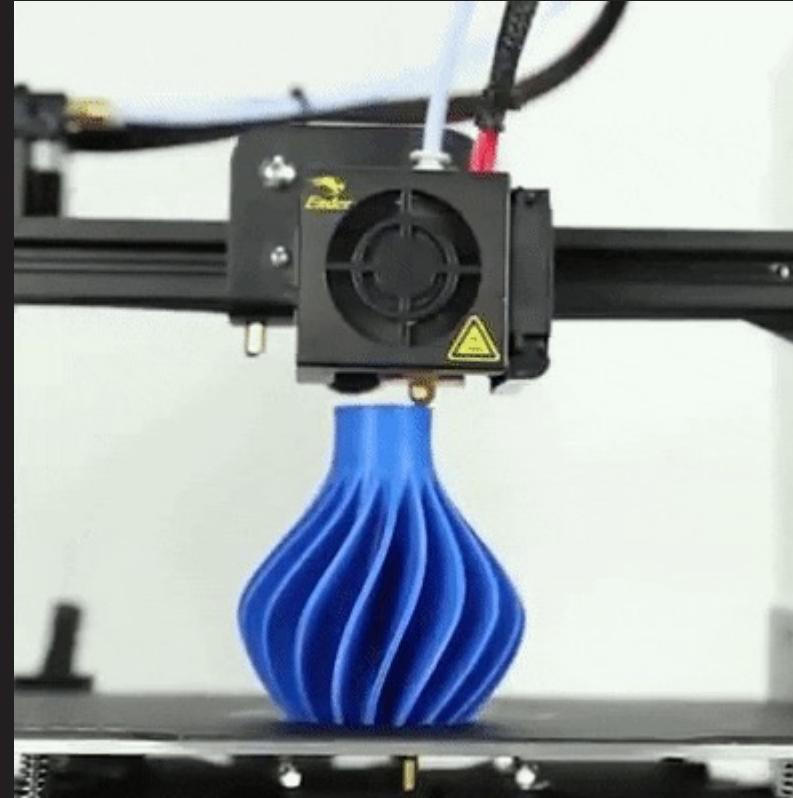
FDM/FFF Printing

Materials: Various thermoplastics, PLA, ABS, PETG, Nylon, TPU, exotic filaments, some with additives

Precision: is dependent on machine but usually 0.1mm layers vertically [z](stepper motor resolution) and 0.3mm [x,y](nozzle diameter)

Cost: ~\$20/kg of PLA

Environmental impact: Depending on material, but usually less waste than subtractive manufacturing



Today's Goal

CAD & Assemble the MG996R



MG996R Live Demo

What You Get:

- Gears
- Axles
- Motor
- Potentiometer
- Bushings
- Screws
- Middle Shell

- To Do:
- Top Shell
- Bottom Shell

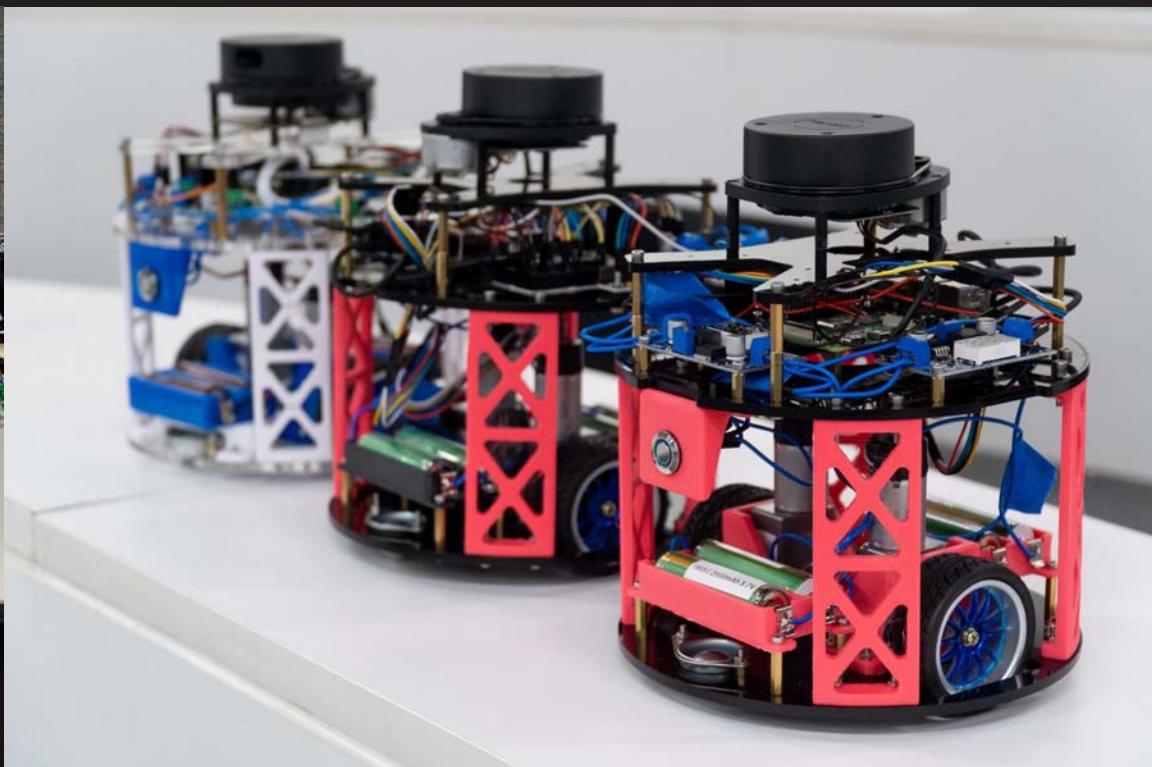
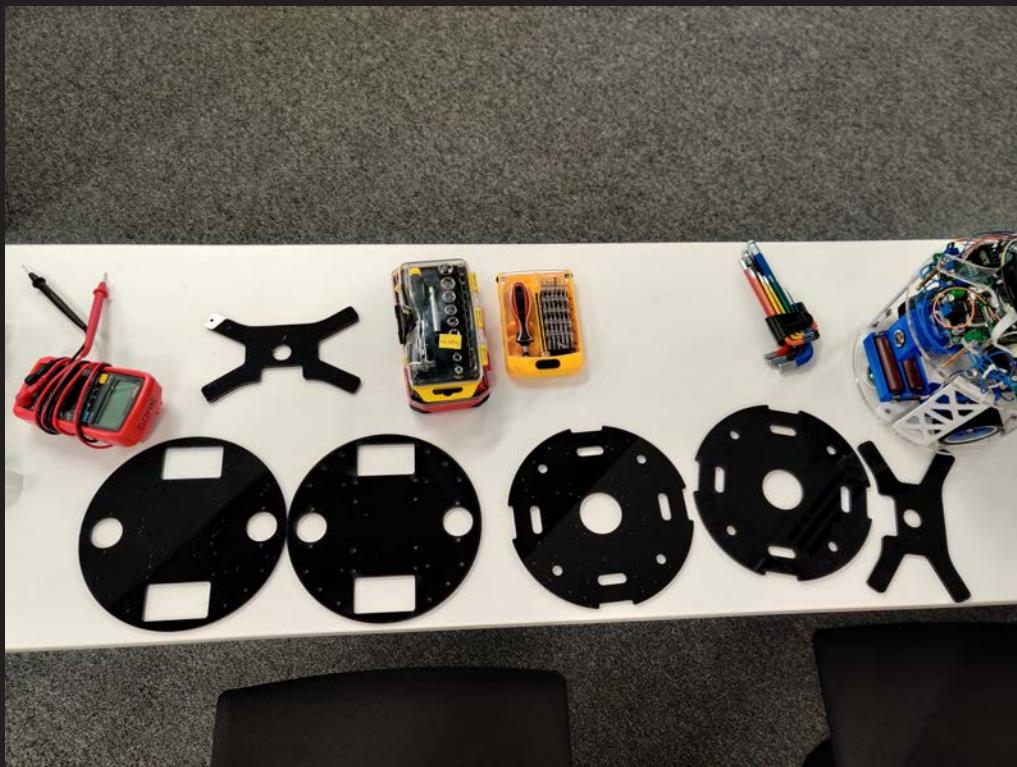
DOWNLOAD Files

https://github.com/sutd-robotics/soar_challenge_2021

WORKFLOW

1. Sketch/imagine the part
2. Use CAD software to build a model
3. Combine with other parts
4. Fabricate
5. Test
6. Repeat (if required)



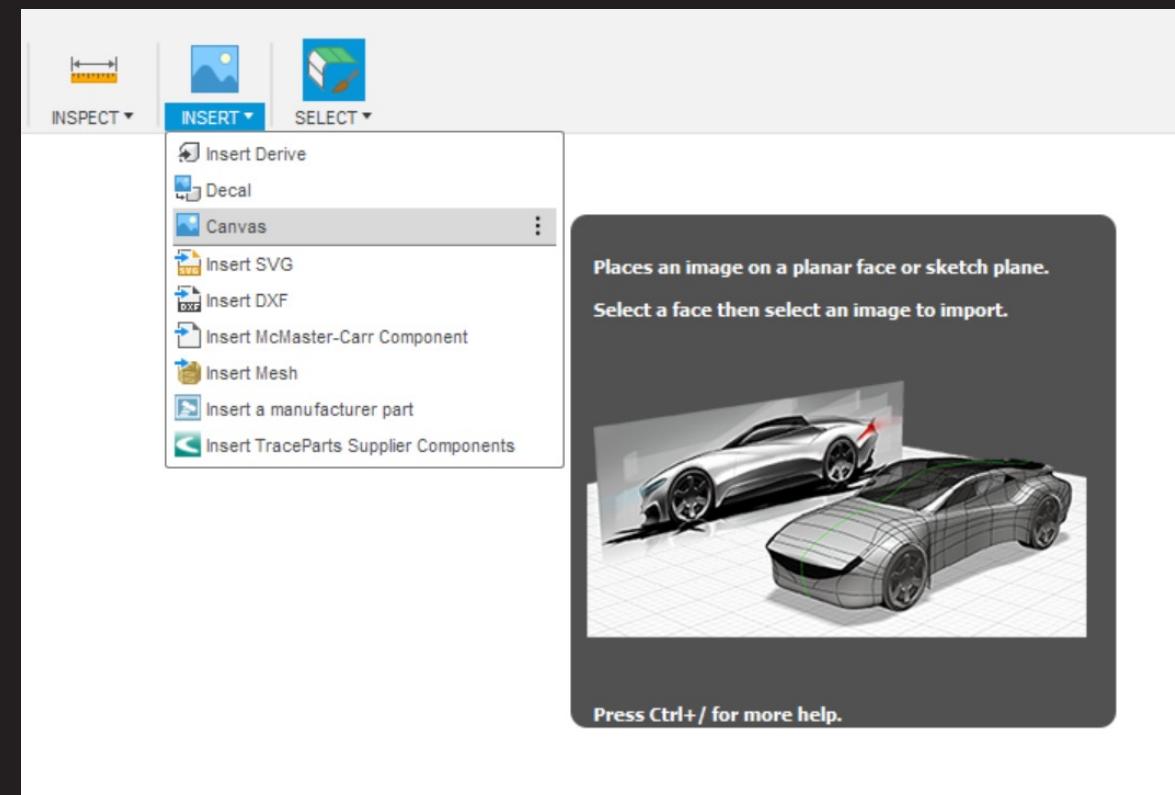


Take Photos of the Top Shell



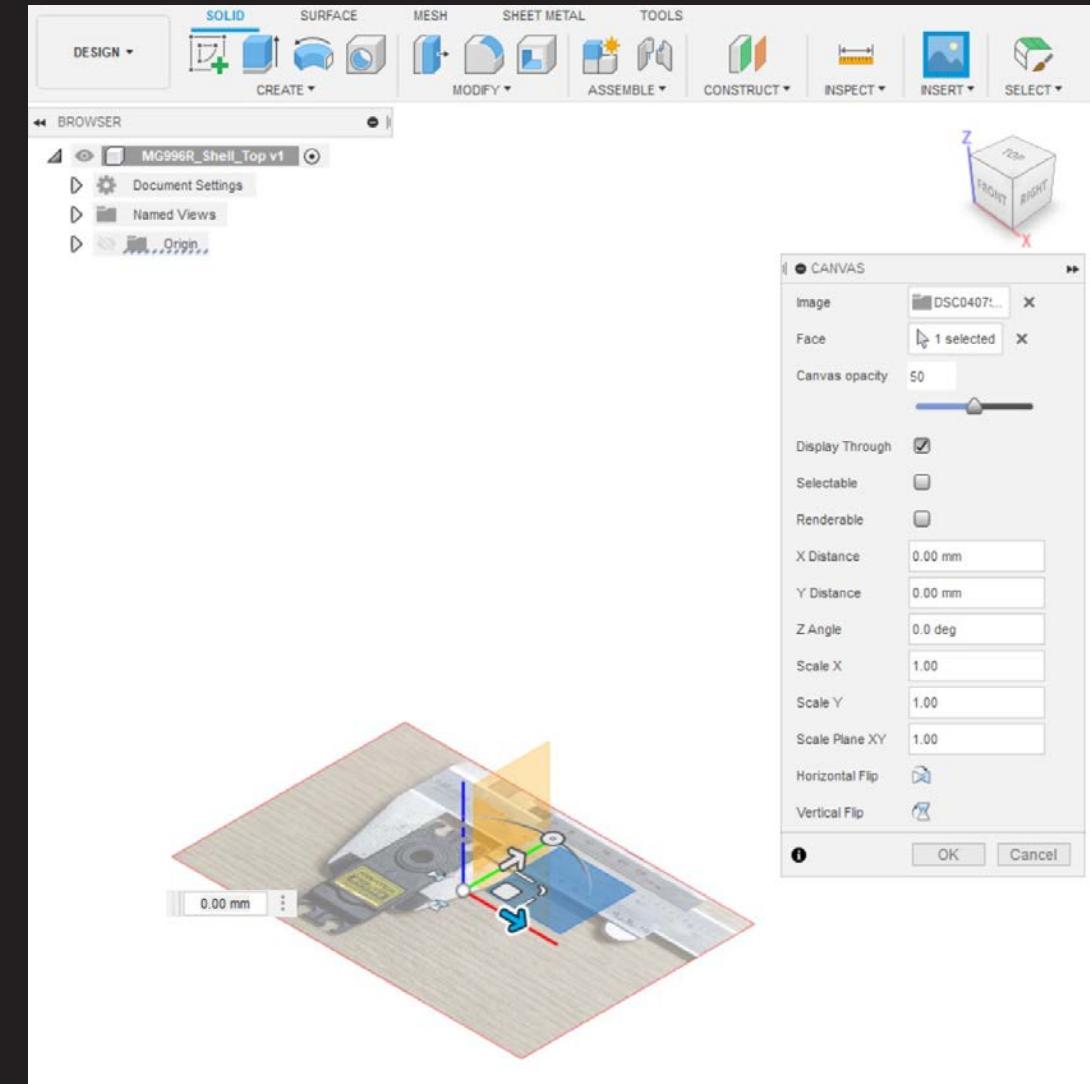
INSERT Canvas

Using images to guide sketching



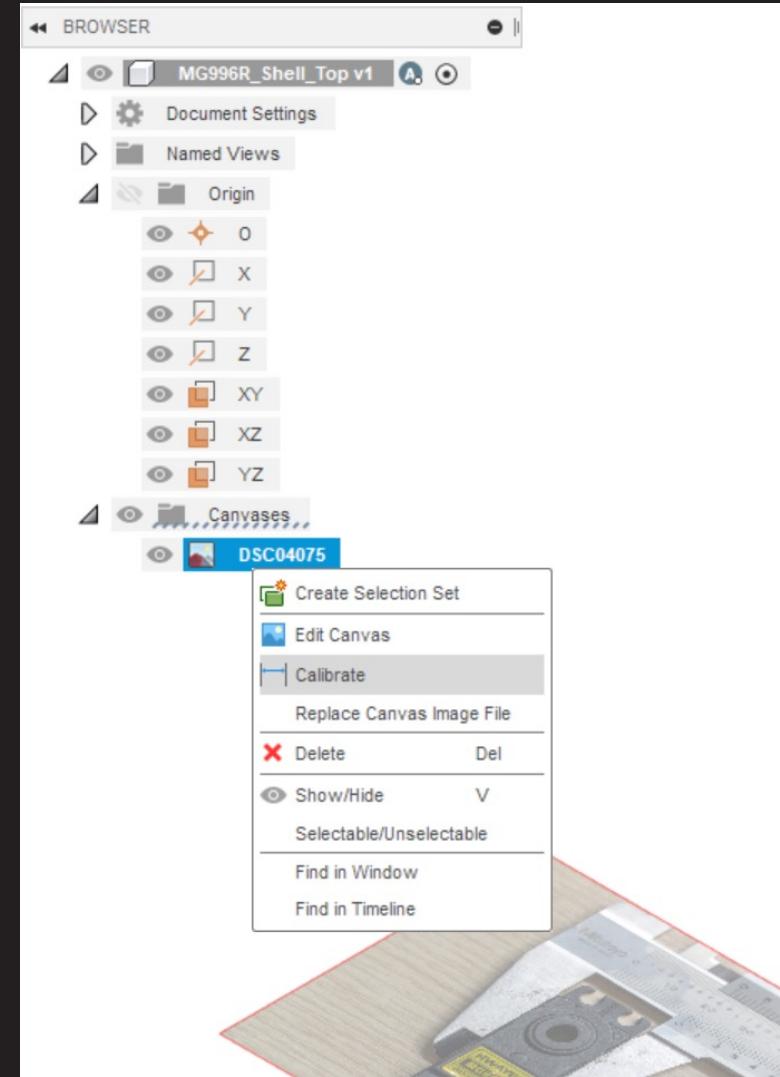
INSERT Canvas

Insert Top View Image onto Top Plane (XY)



CALIBRATE Canvas

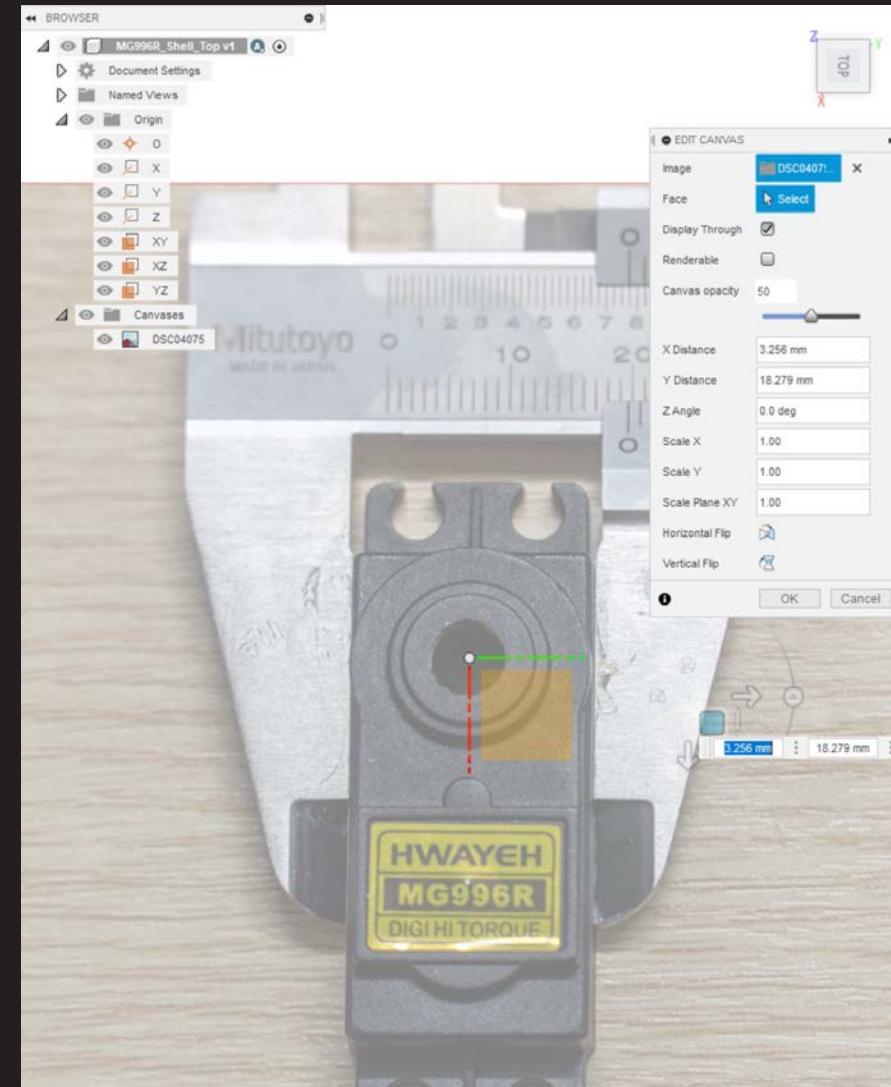
Measure the MG996R using a ruler/vernier caliper



EDIT Canvas

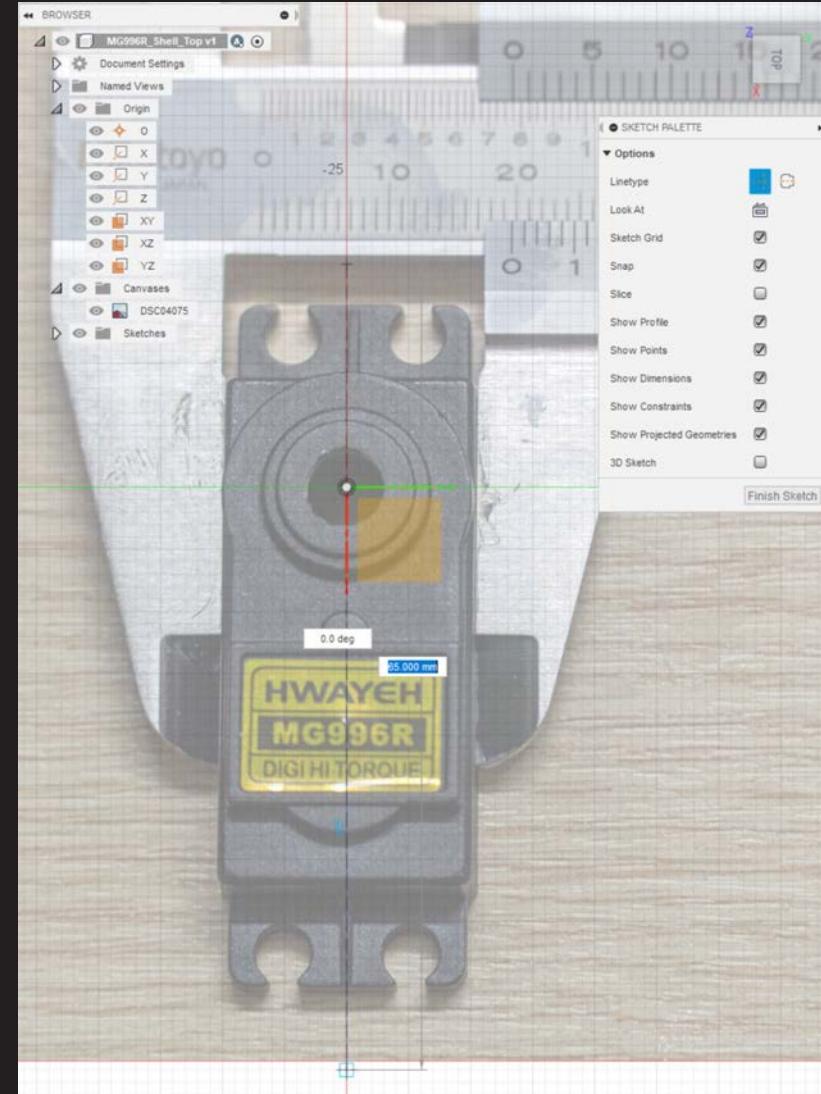
Drag/rotate canvas.

TIP: Position key feature at origin.



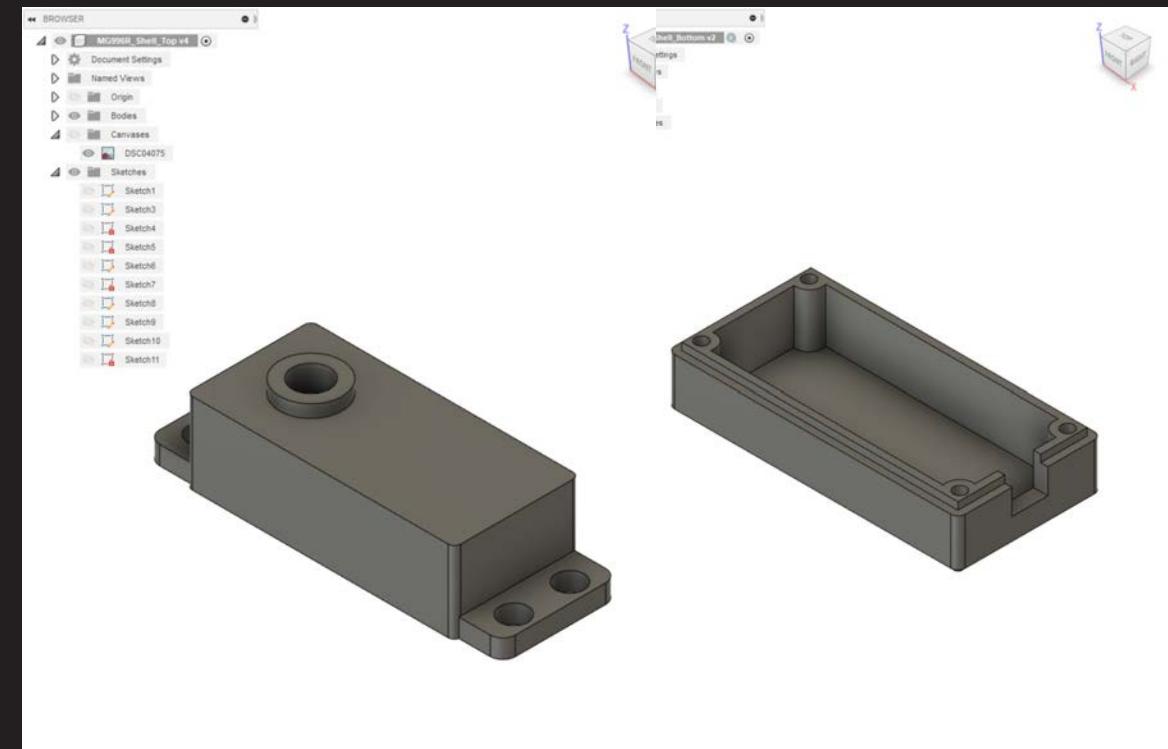
SKETCH & Extrude

Create construction line through origin.



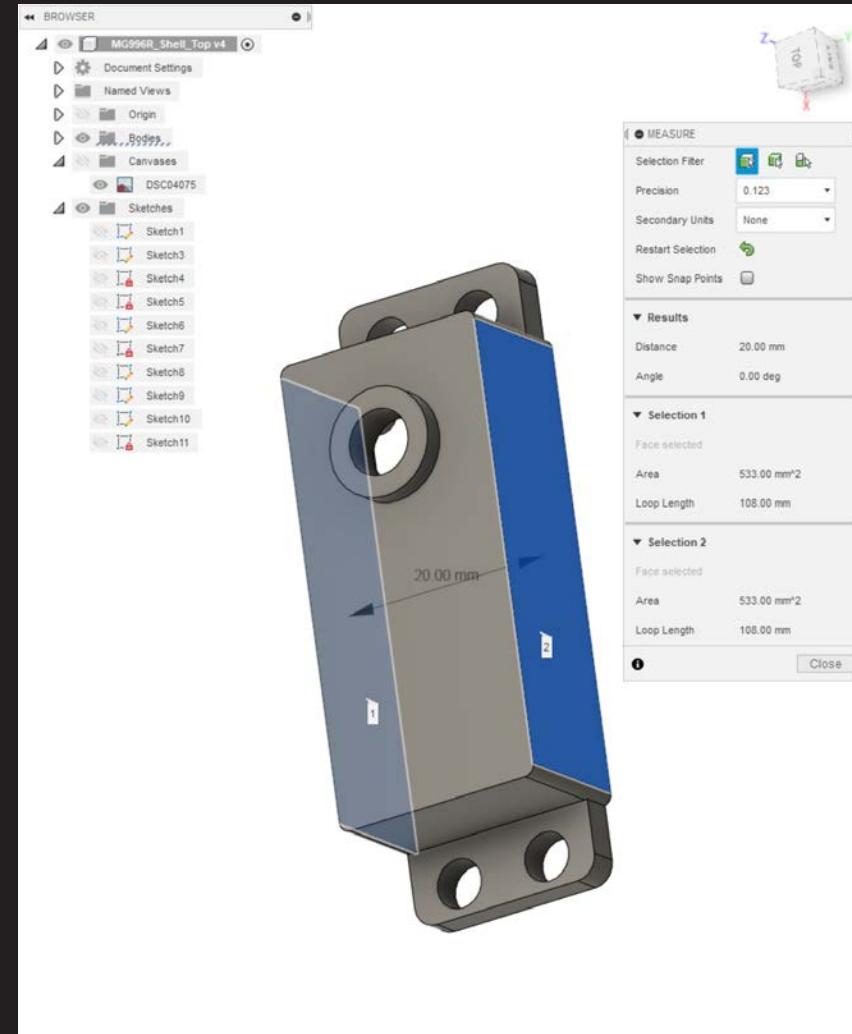
SKETCH & Extrude

Sketch using lines, circles.



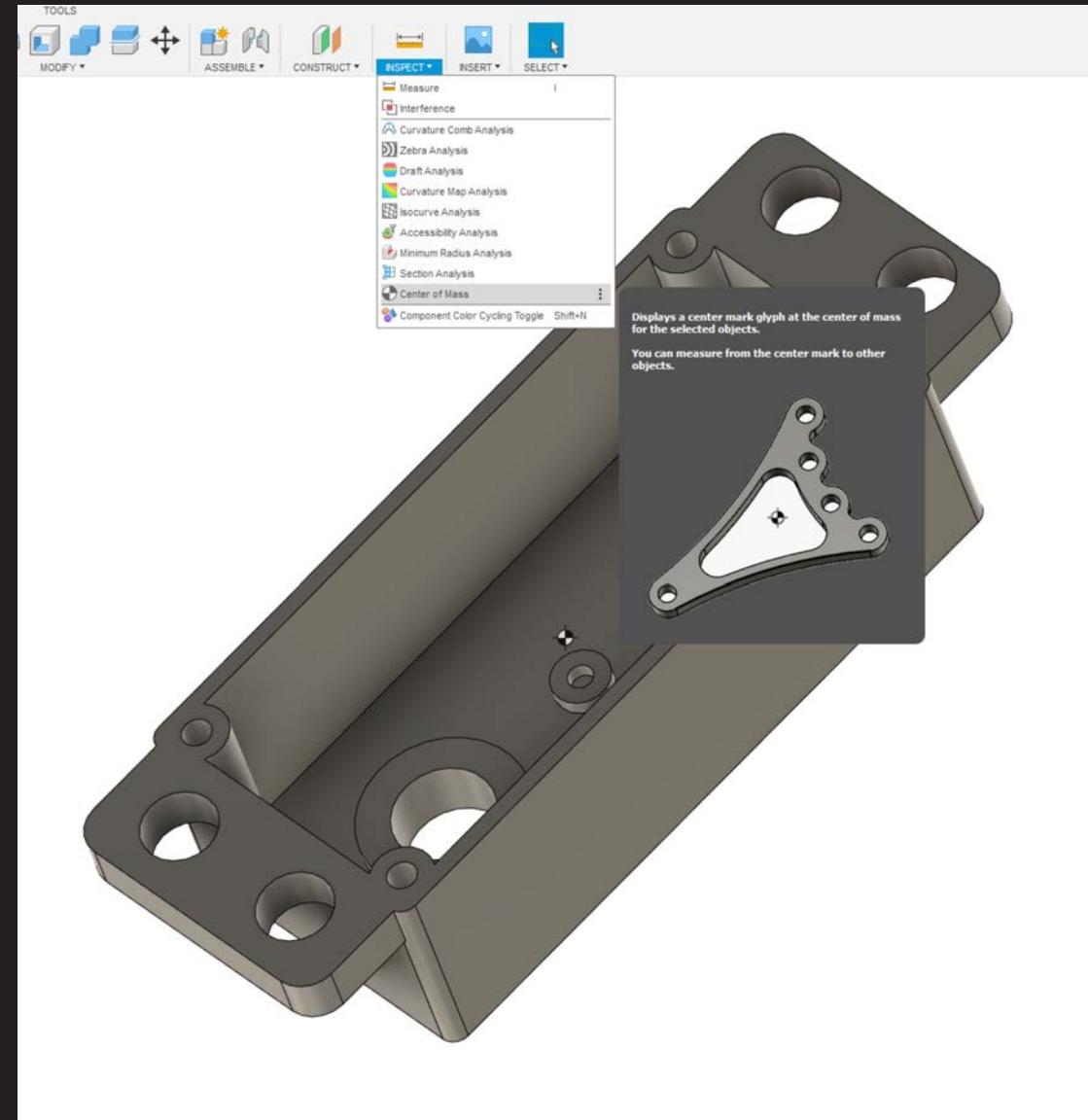
INSPECT - Measure

Good practice: Checking dimensions.
Keyboard Shortcut: 'l' (not L)



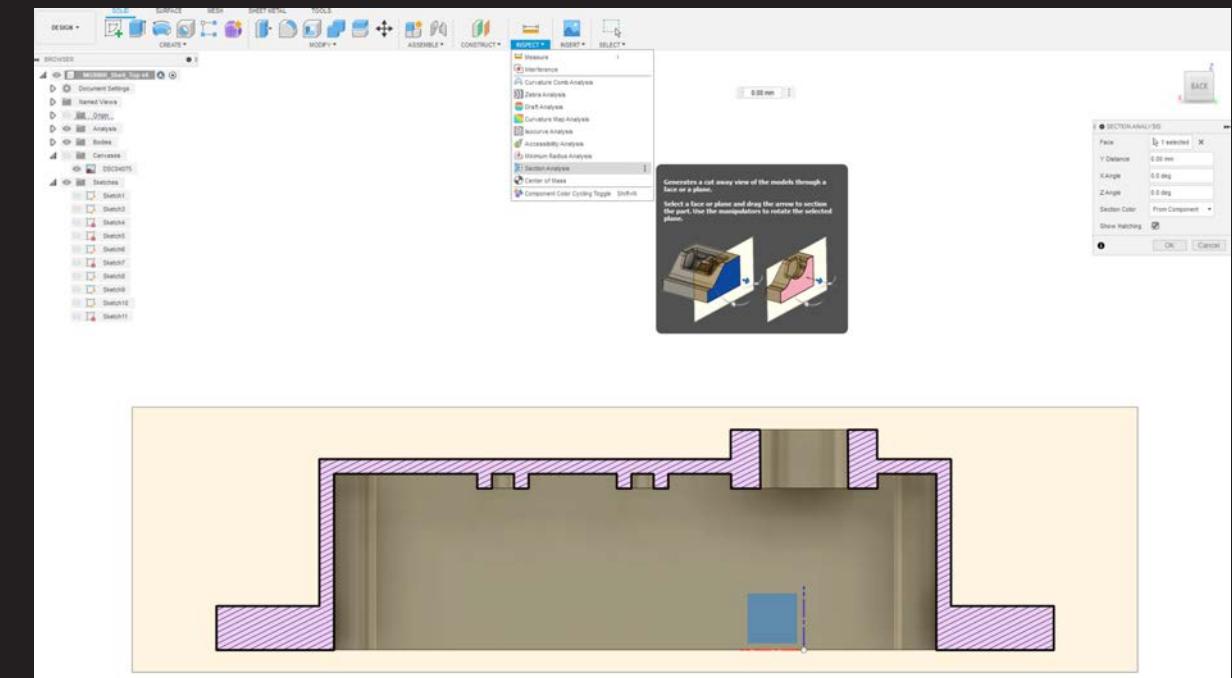
INSPECT - Center of Mass

Checking the Center of Mass.



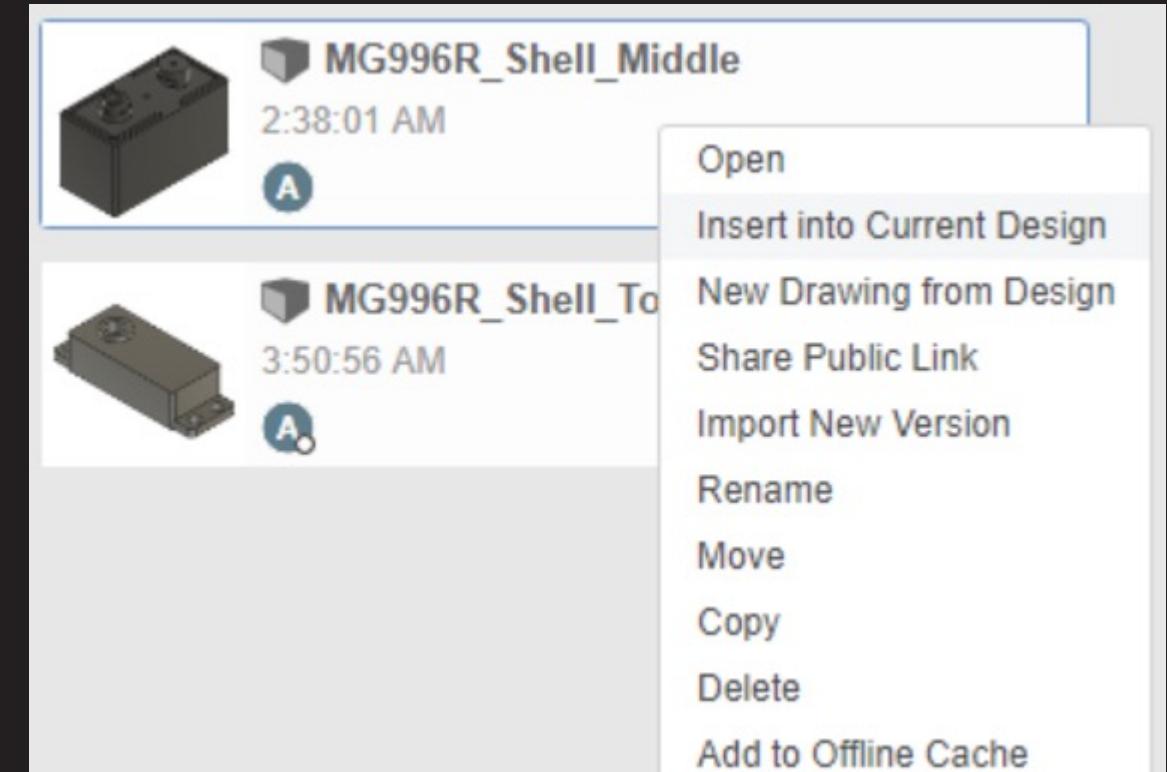
INSPECT - Section Analysis

Check unseen areas.



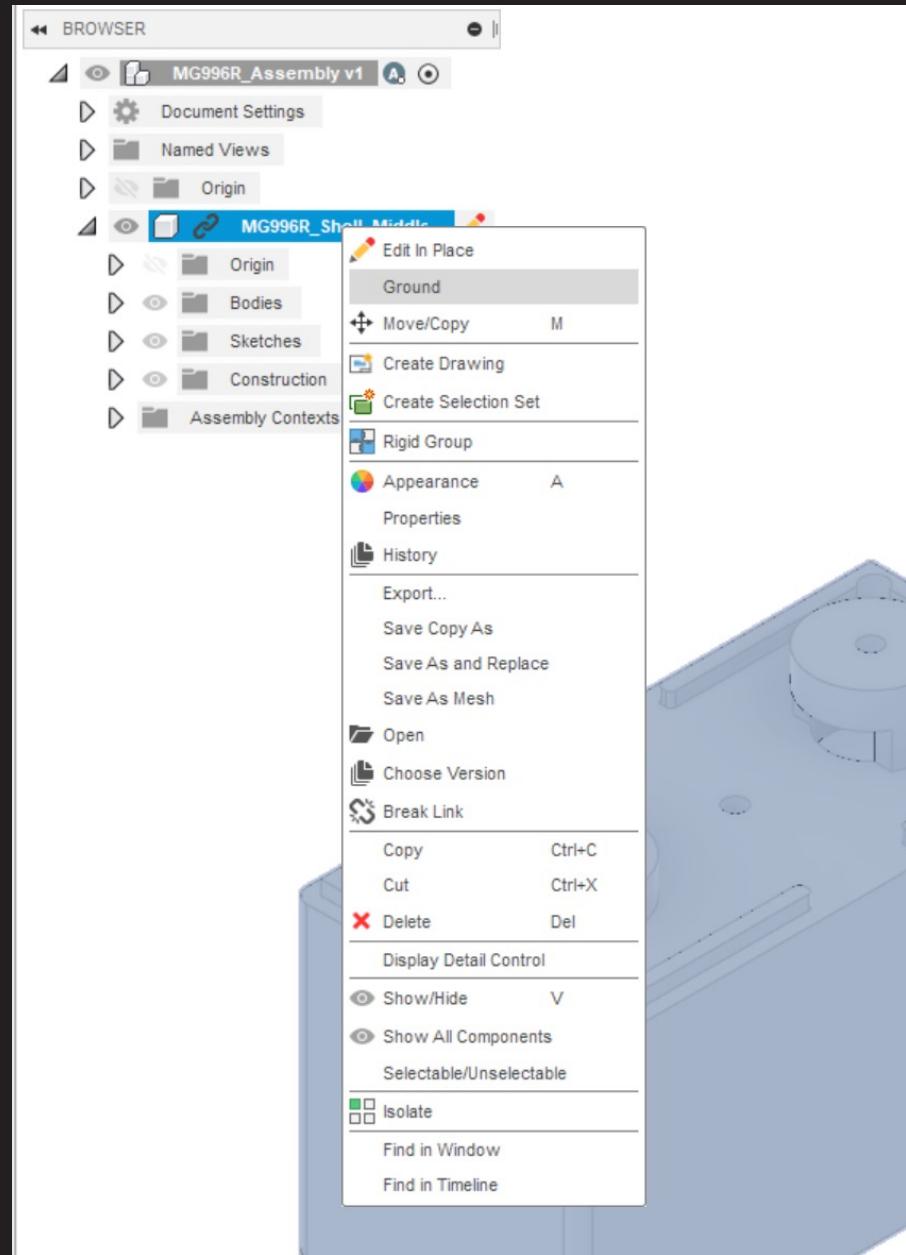
ASSEMBLE – Import Given Components

Insert into Current Drawing.



Ground Middle Shell

Fix the component from moving.



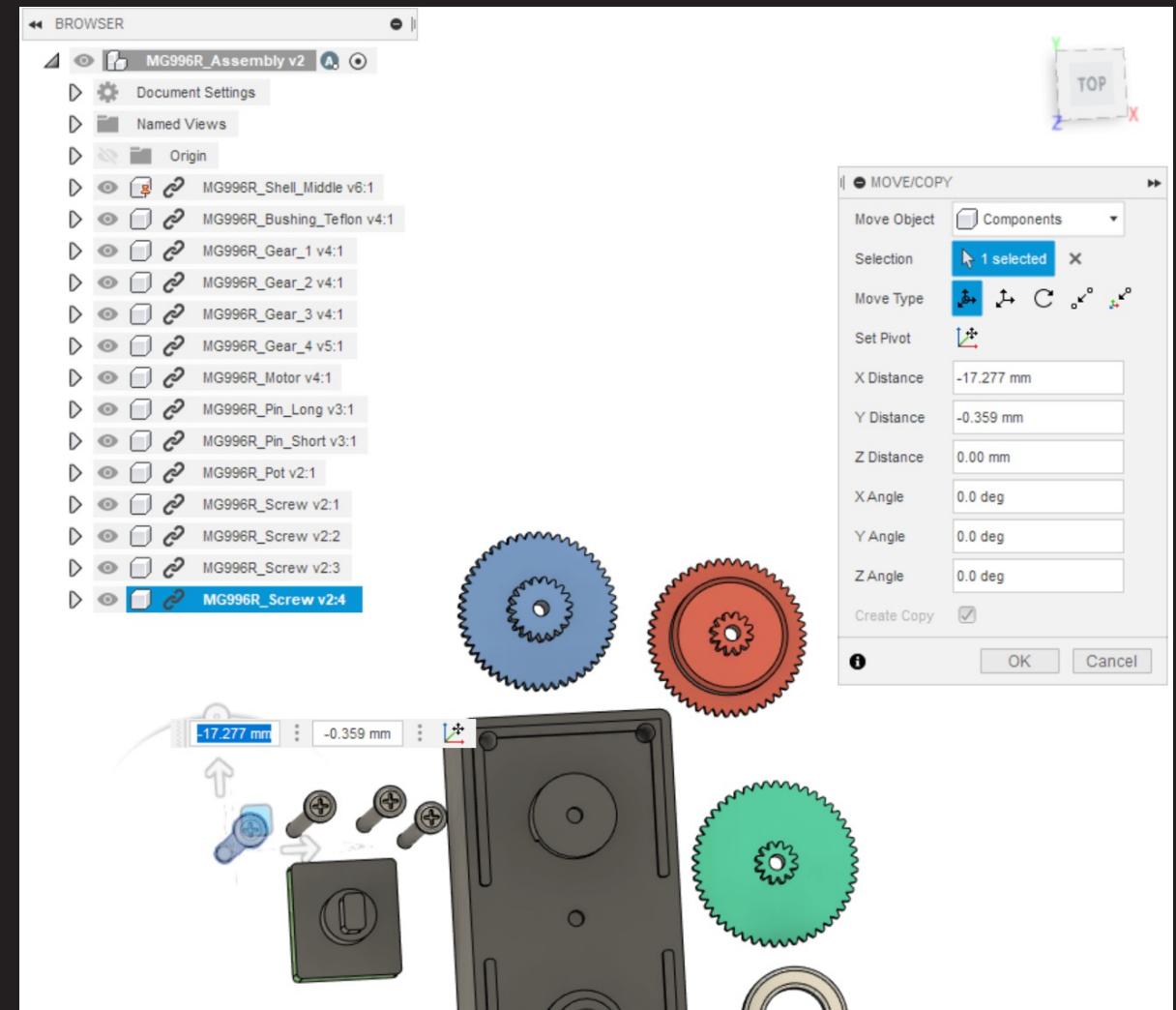
Duplicate Screws

4x Screws using Move/Copy.

Keyboard shortcut: 'M'

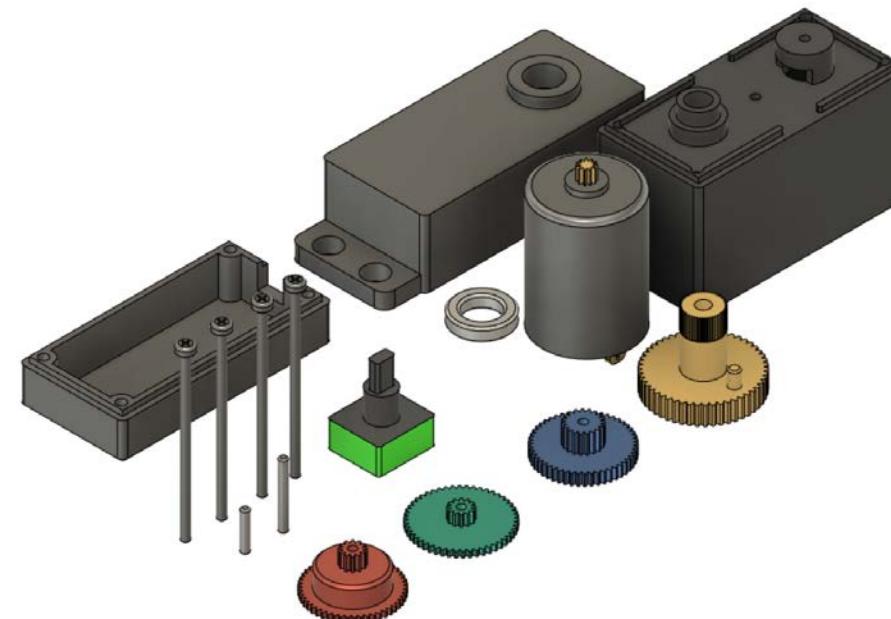
Move object: 'Components'

Create copy: 'Check'



All Components Inserted

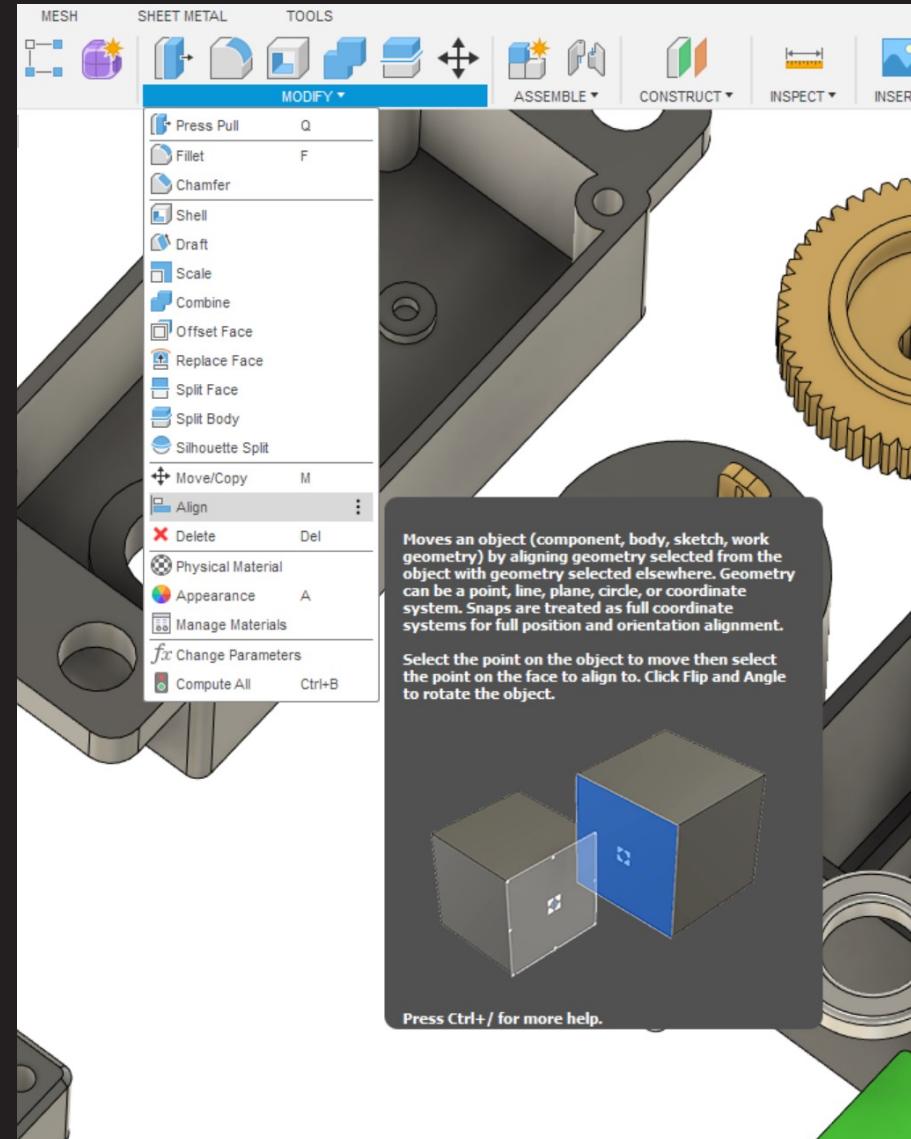
- 4x Screws
- Top Shell
- Bottom Shell
- Middle Shell
- Gears 1-4
- Long & Short Pin
- Potentiometer
- Motor
- Bushing



Align

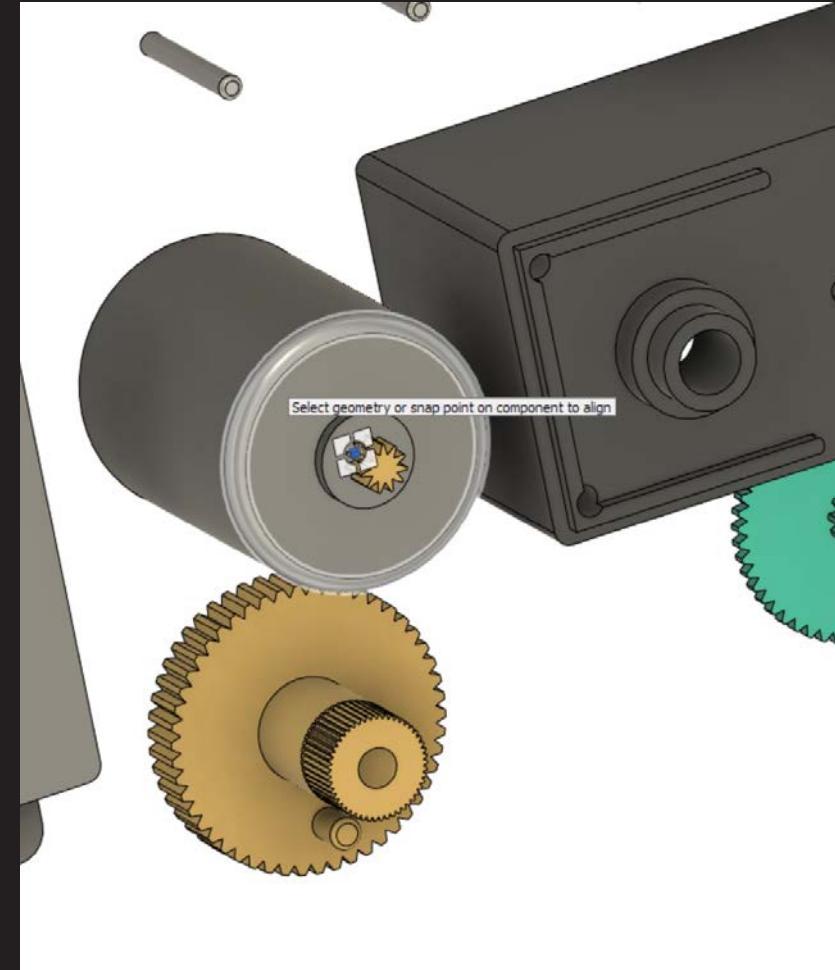
Align components that do not move relative to each other.

Rule 1: Always click on the object that moves first, then the object that stays.



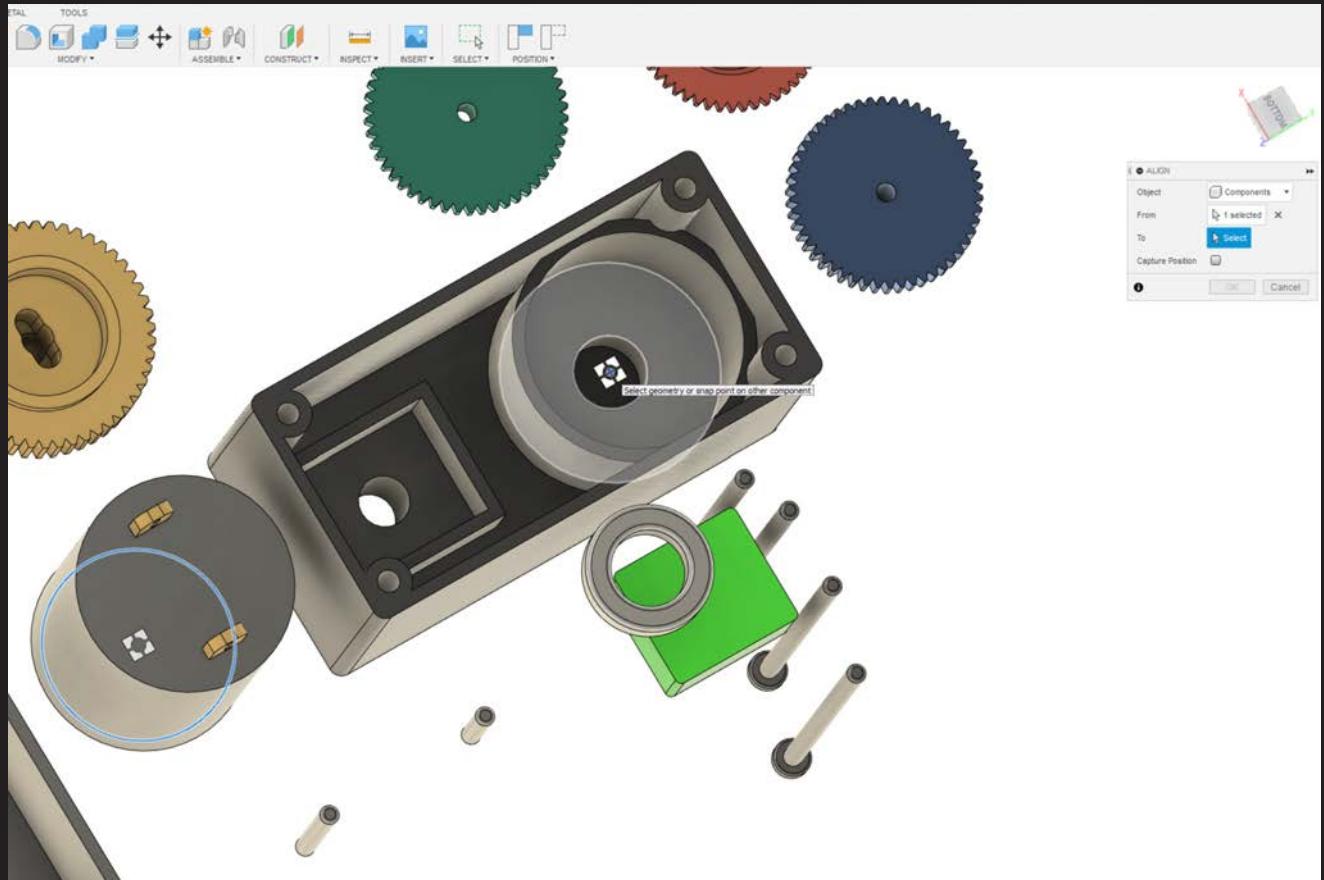
Align Motor

Hold 'Control' to lock on to 'half moons'.



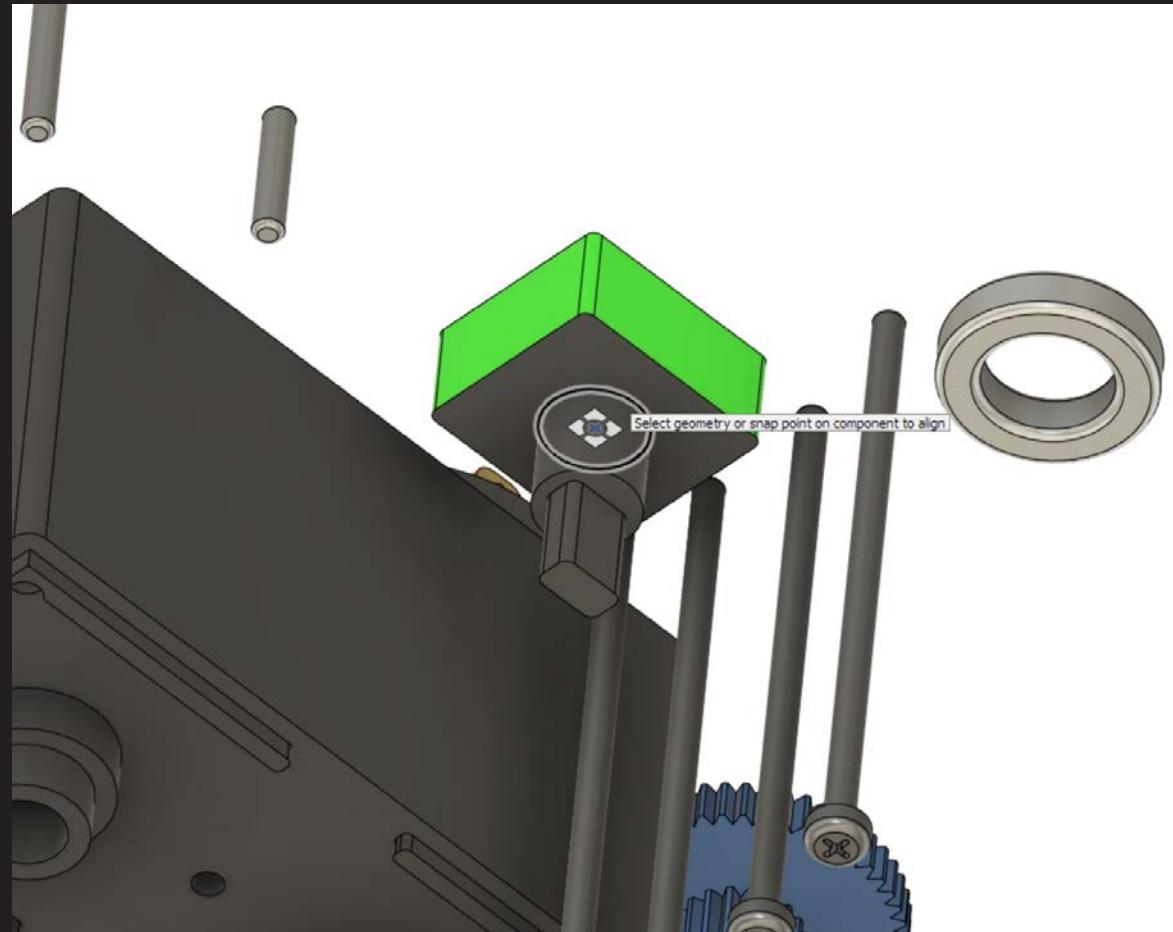
Align Motor

Hold 'Control' to lock on to 'half moons'.



Align Pot

Hold 'Control' to lock on to 'half moons'.



Align Pot

Hold 'Control' to lock on to 'half moons'.



Align Pins

Hold ‘Control’ to lock on to ‘half moons’.

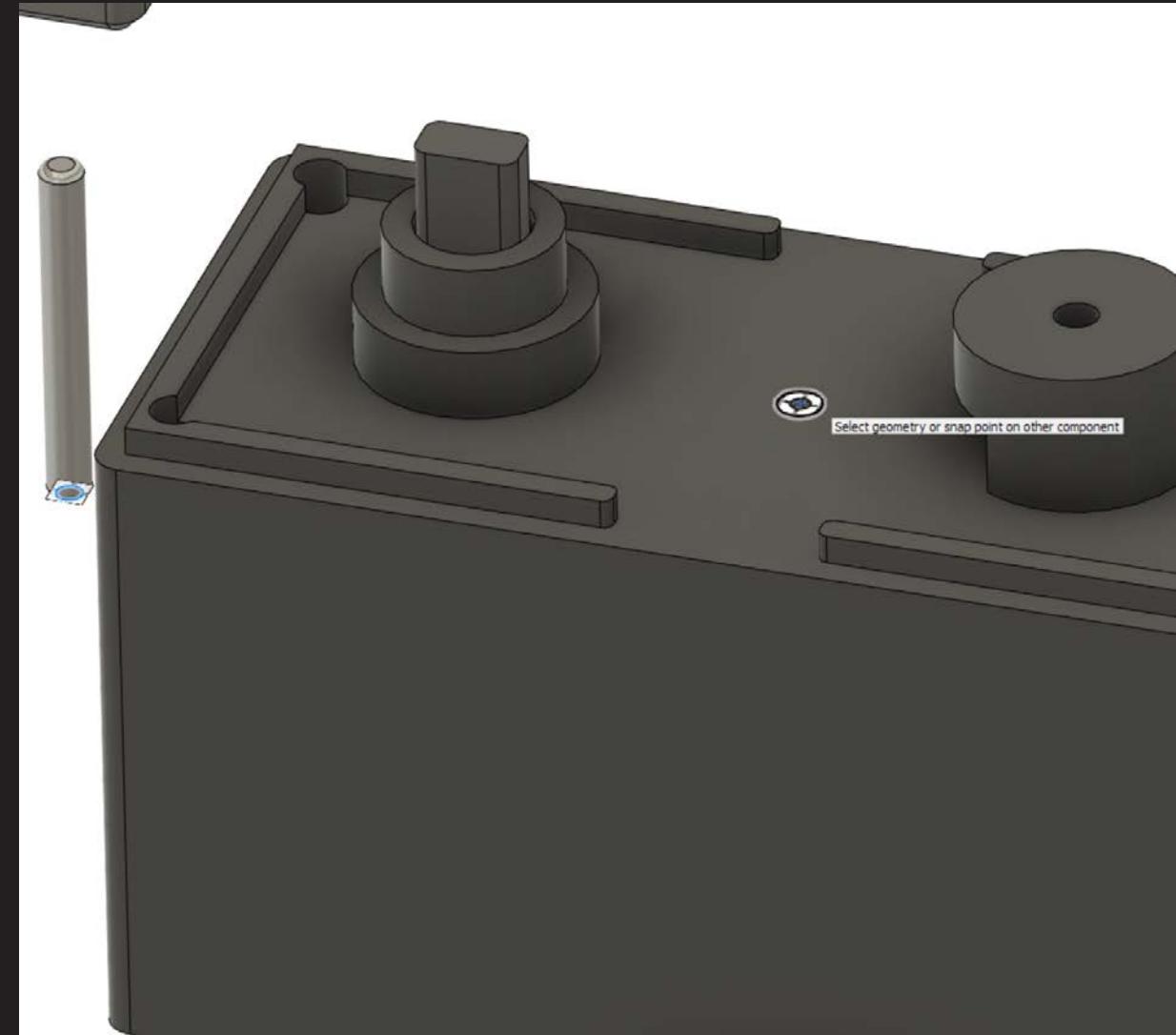
Longer pin in the middle, shorter pin at the side.



Align Pins

Hold 'Control' to lock on to 'half moons'.

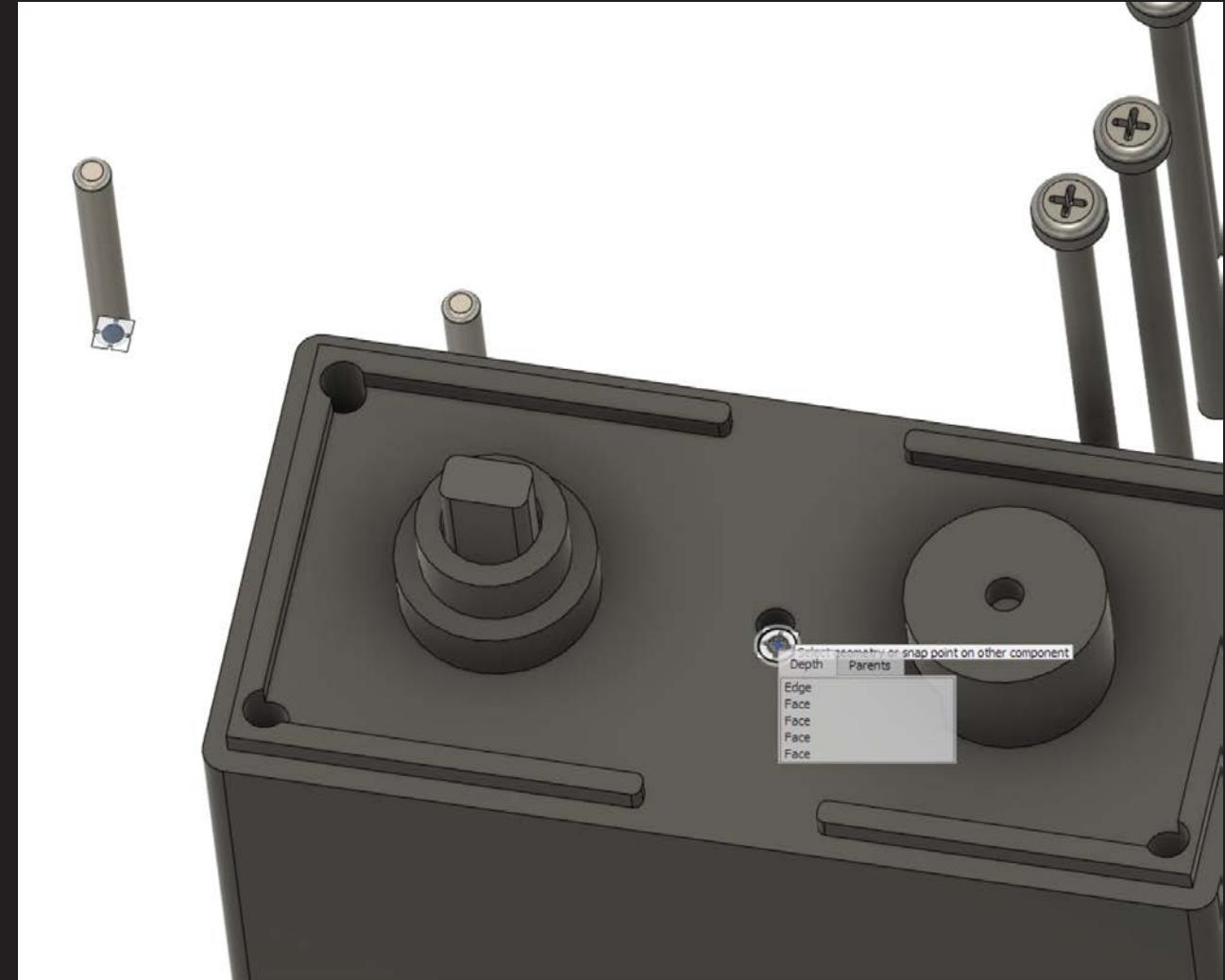
Longer pin in the middle, shorter pin at the side.



Align Pins

Hold 'Control' to lock on to 'half moons'.

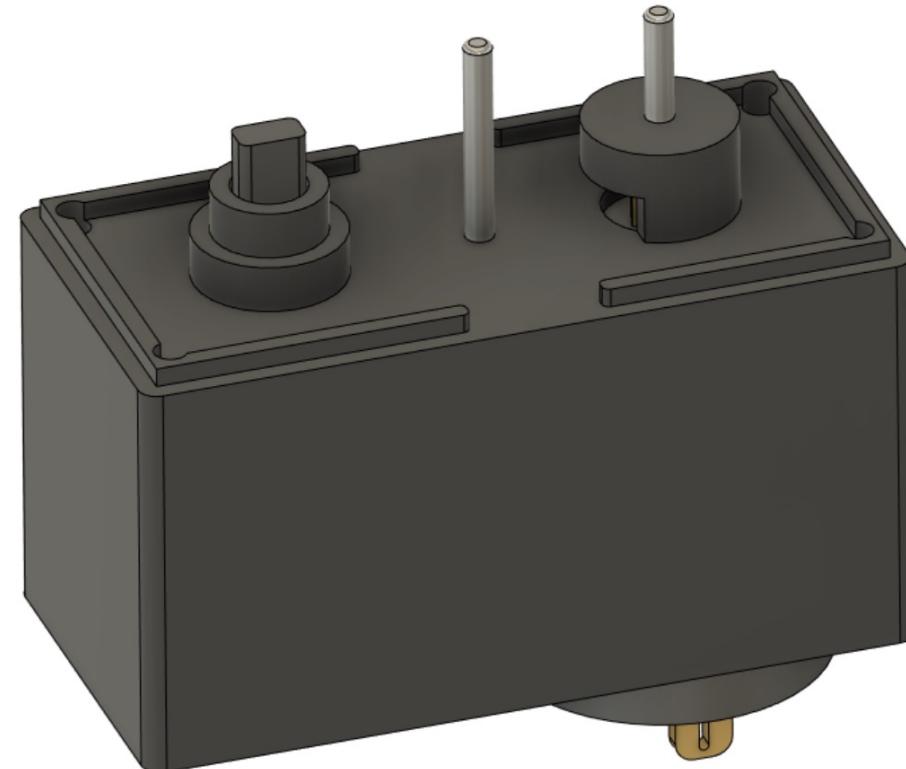
Longer pin in the middle, shorter pin at the side.



Align Pins

Hold 'Control' to lock on to 'half moons'.

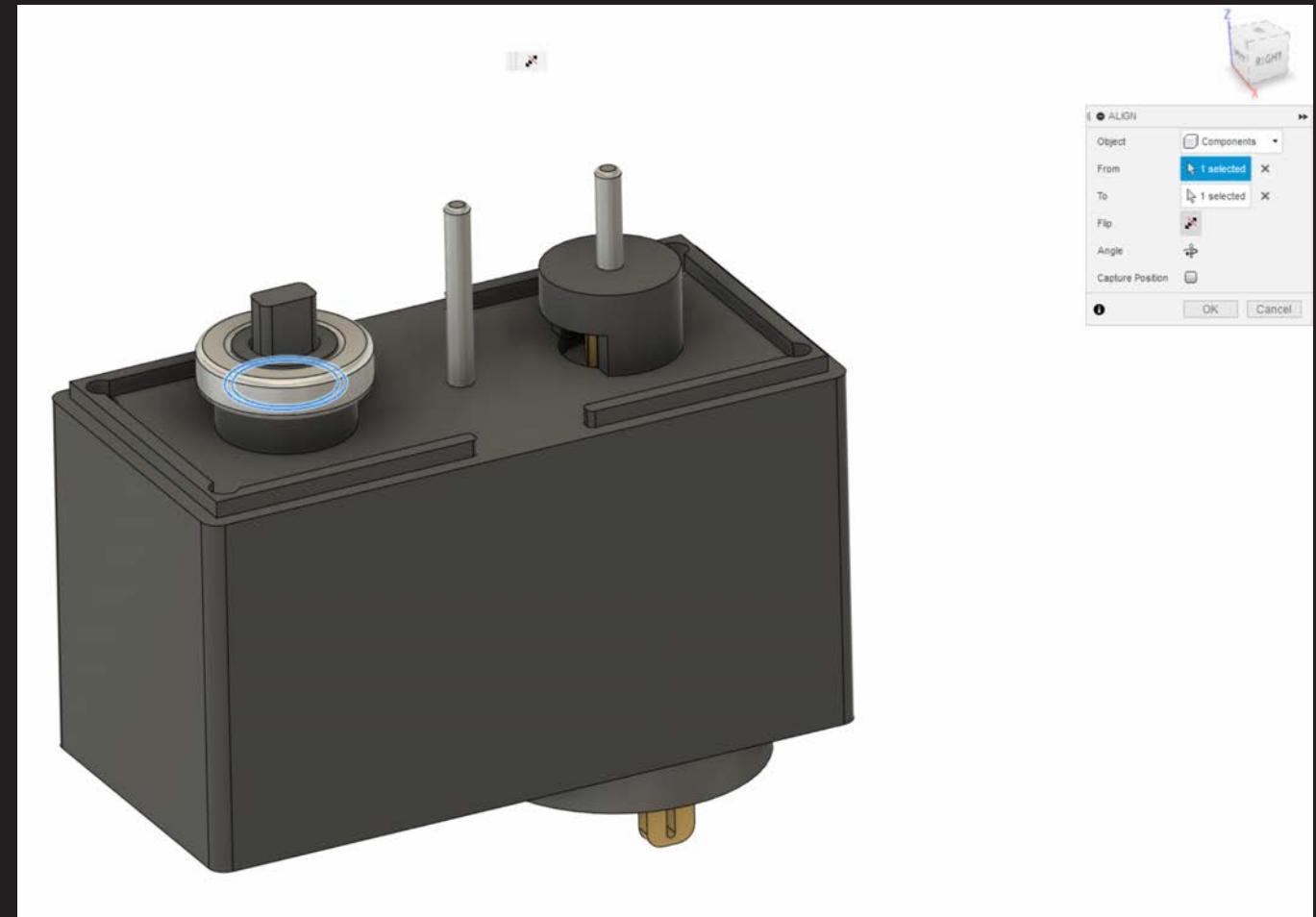
Longer pin in the middle, shorter pin at the side.



Align Bushing

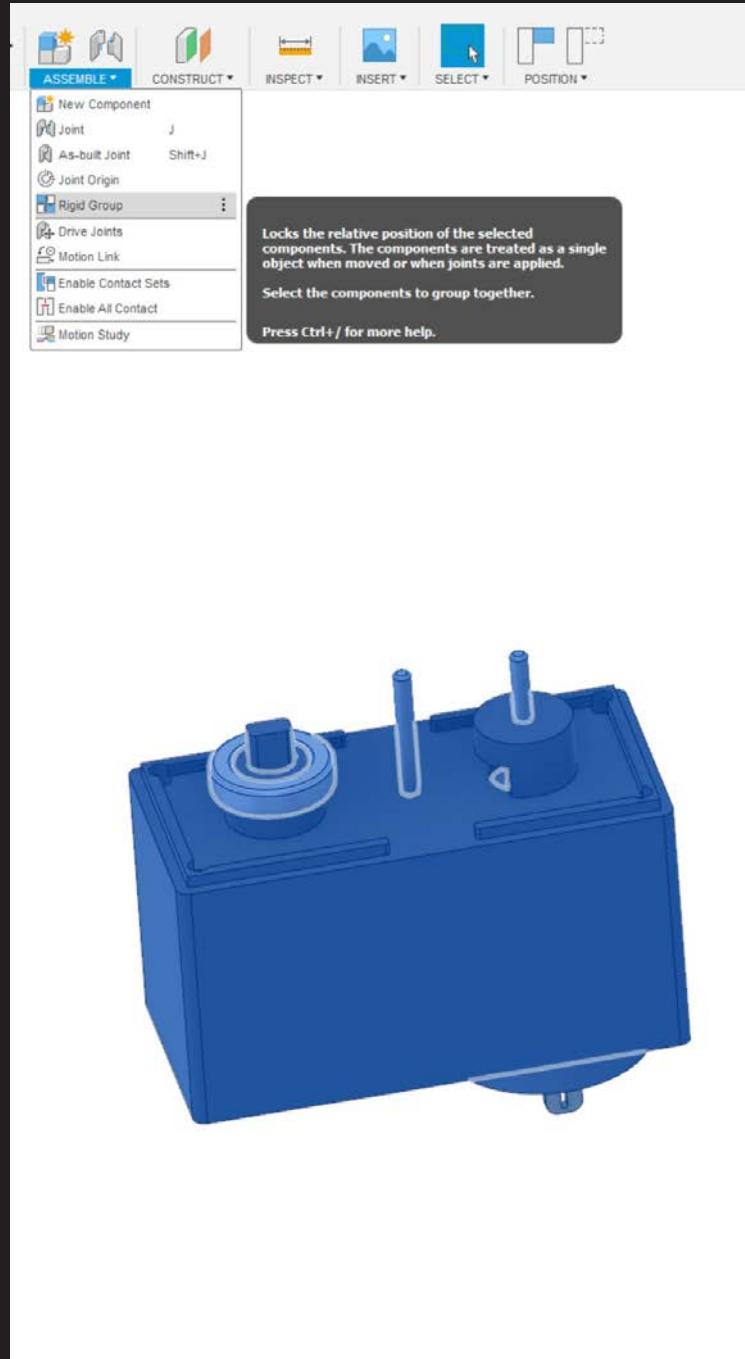
Hold 'Control' to lock on to 'half moons'.

Longer pin in the middle, shorter pin at the side.



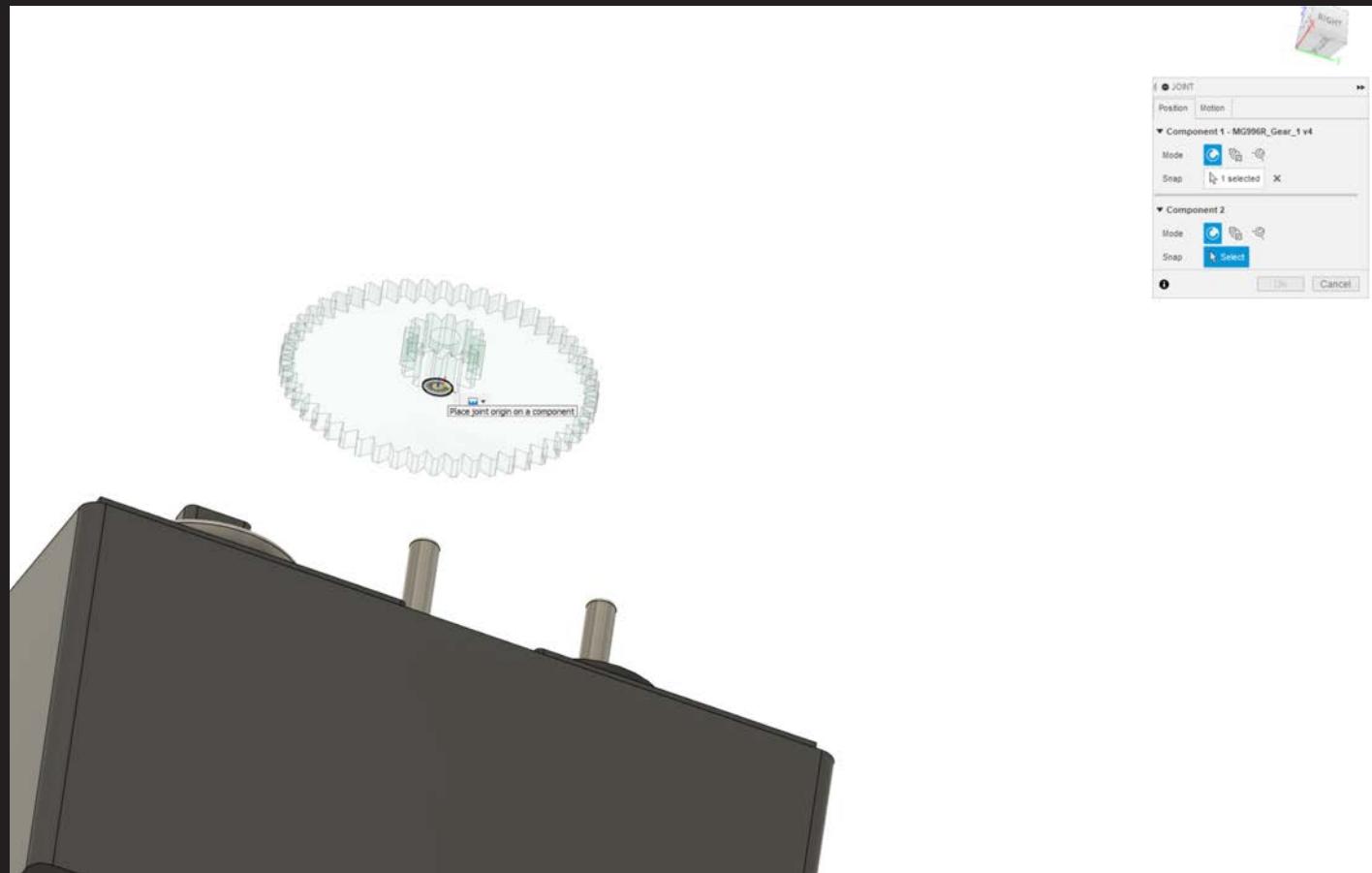
Rigid Groups

Select Middle Shell, Bushing, Pins, Motor, Pot



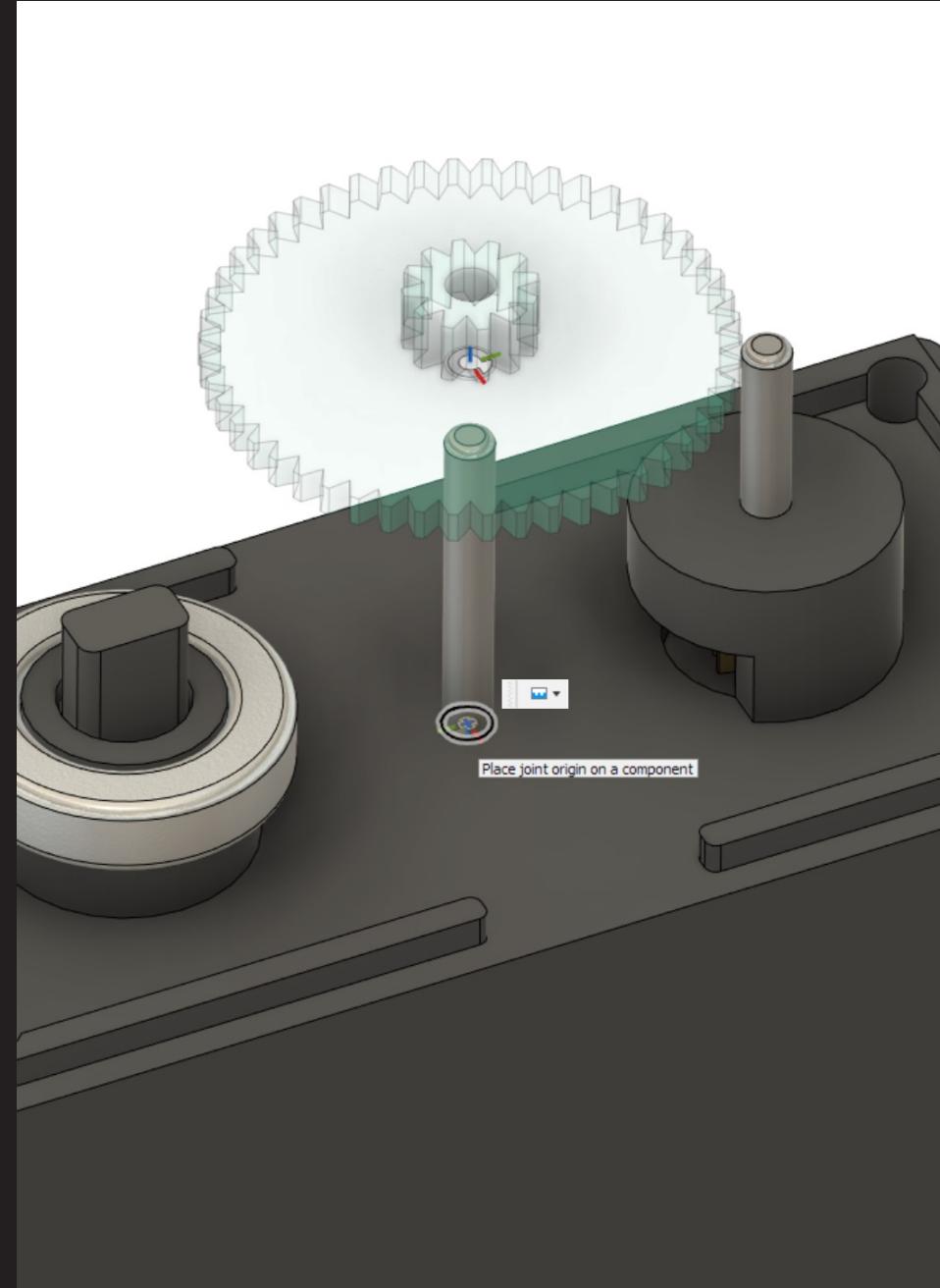
Joints-Gear 1

Join gear 1 to the base of the longer pin.



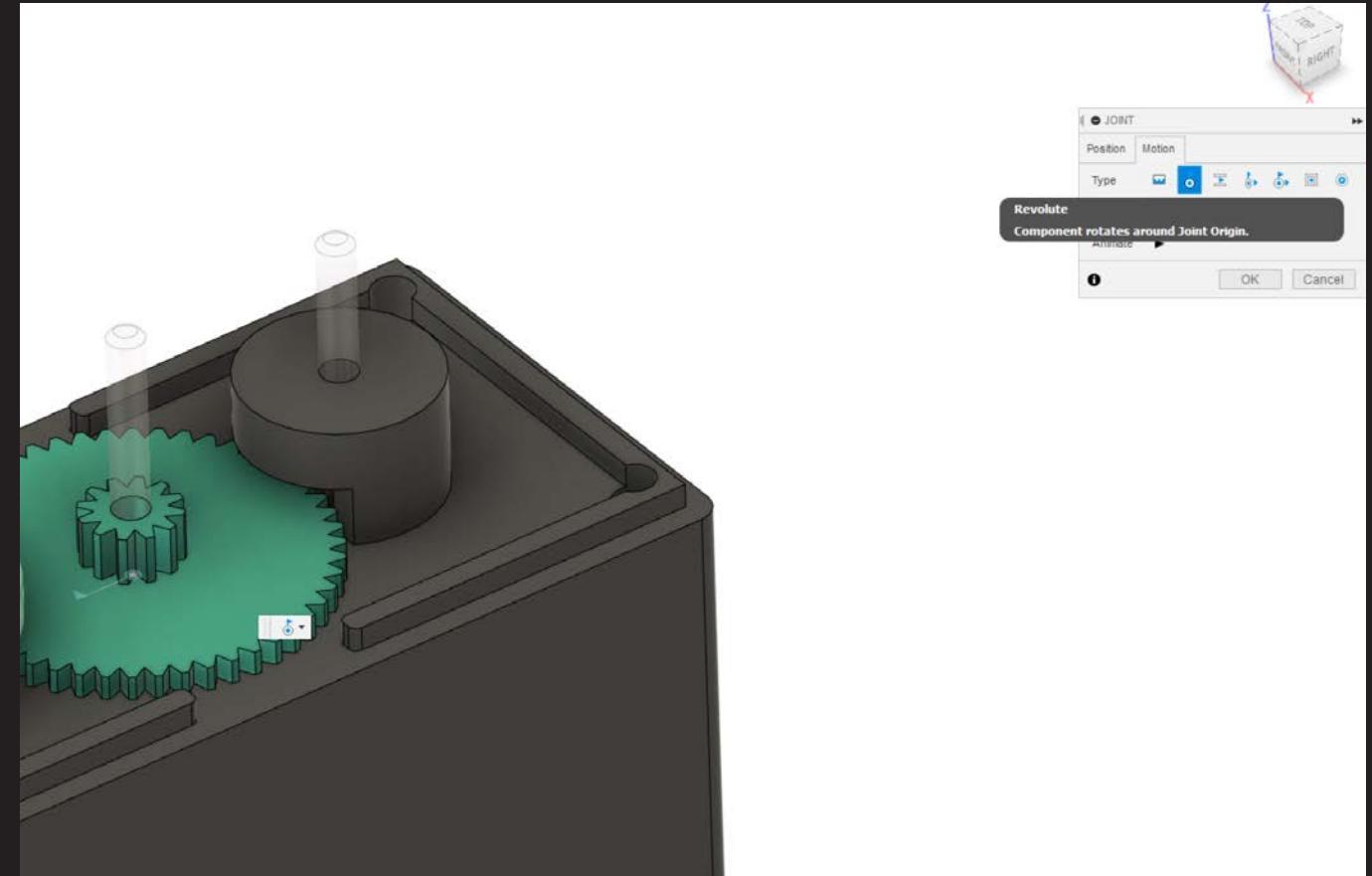
Joints-Gear 1

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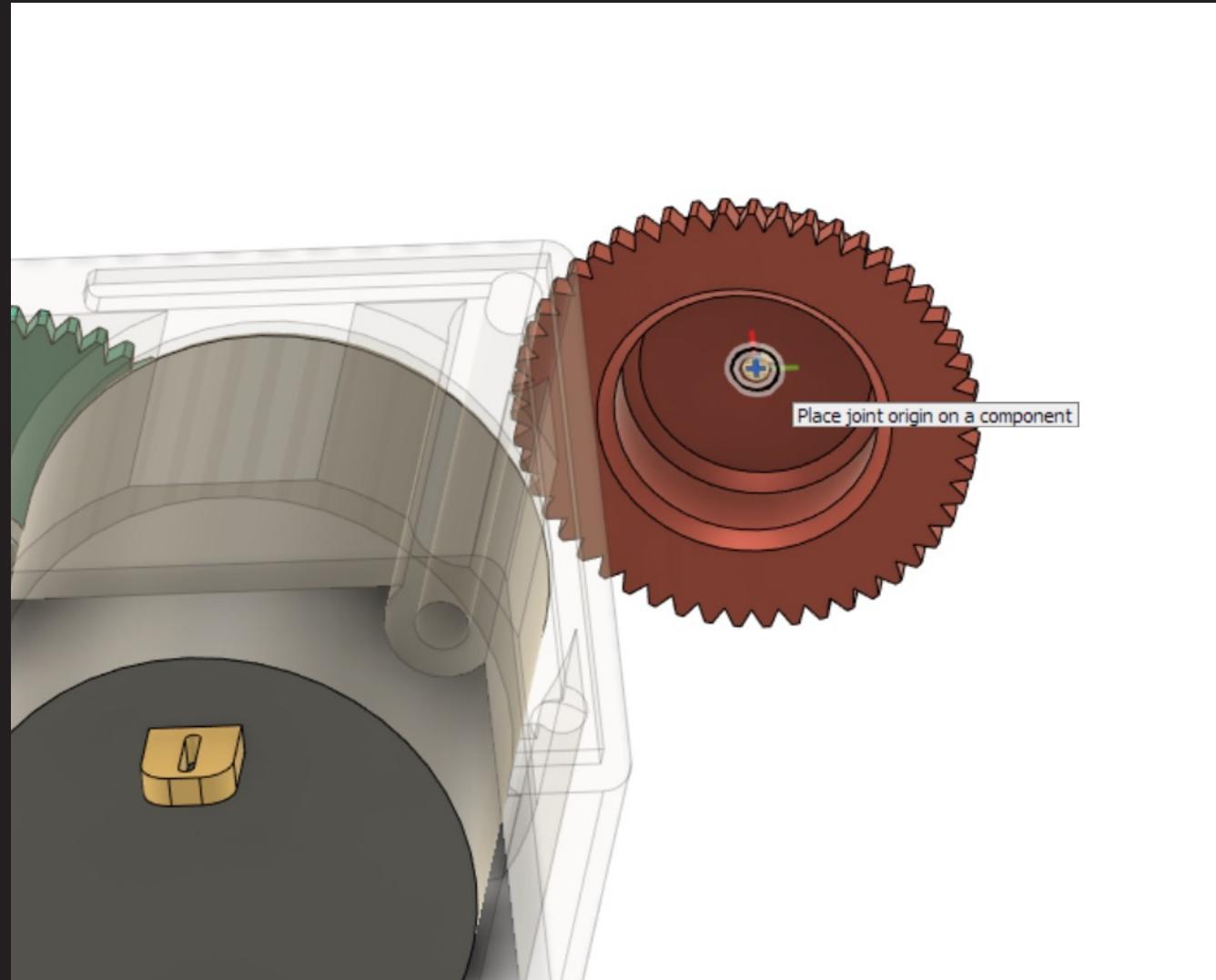
Joints-Gear 1

Under the 'Motion' tab, select 'Revolute'.



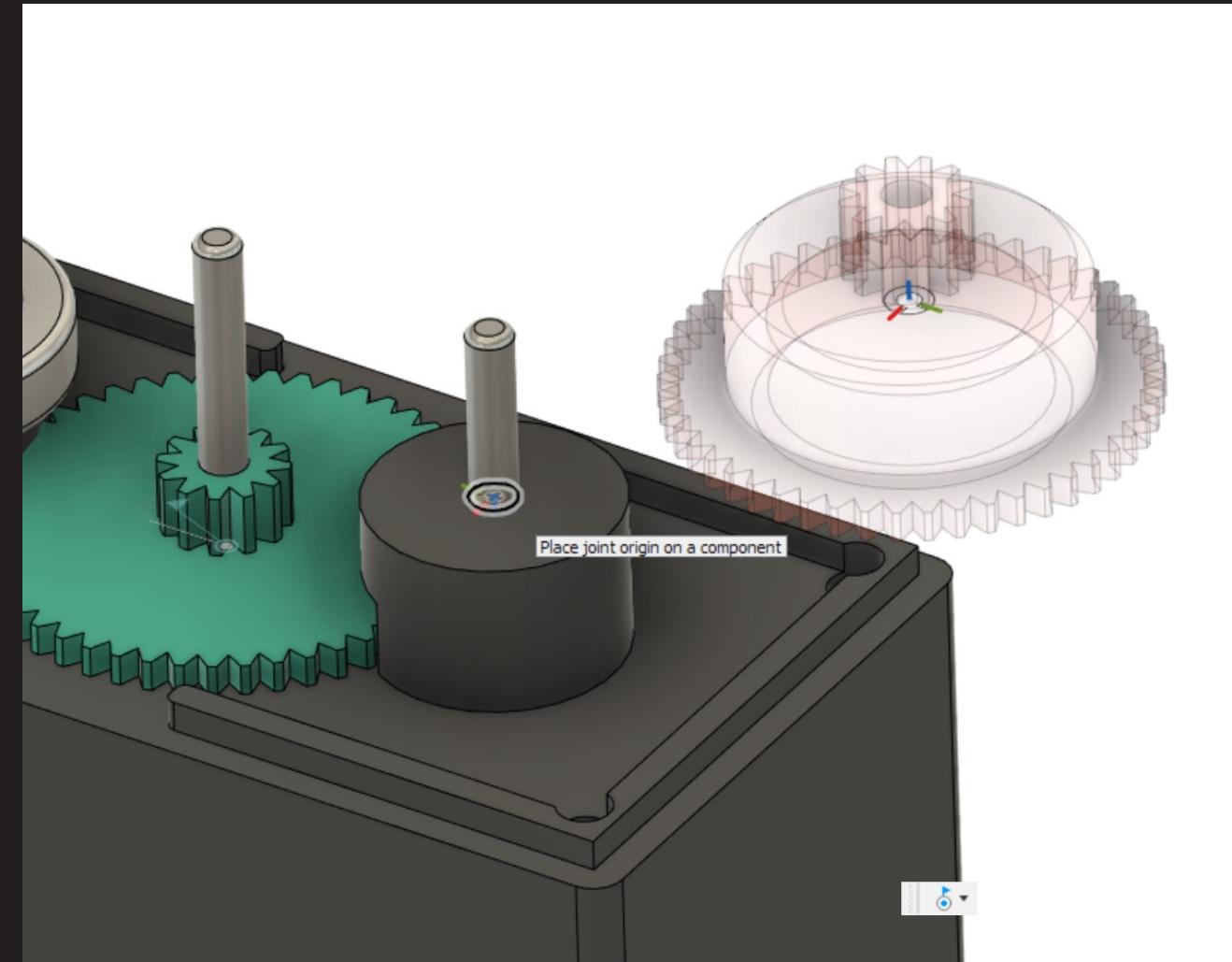
Joints-Gear 2

Similarly, add a joint to gear 2 using ‘revolute’.



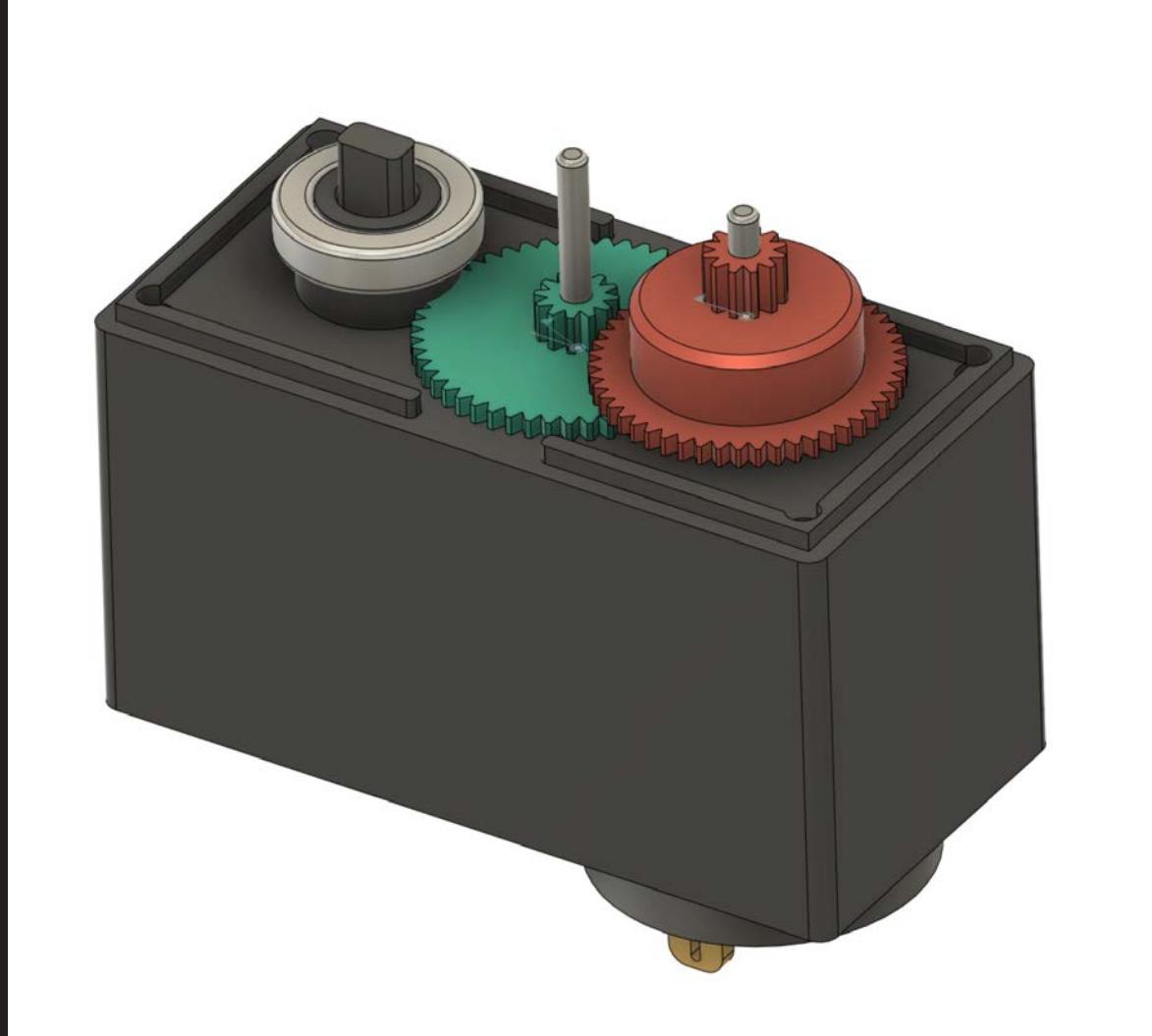
Joints-Gear 2

Similarly, add a joint to gear 2 using ‘revolute’.



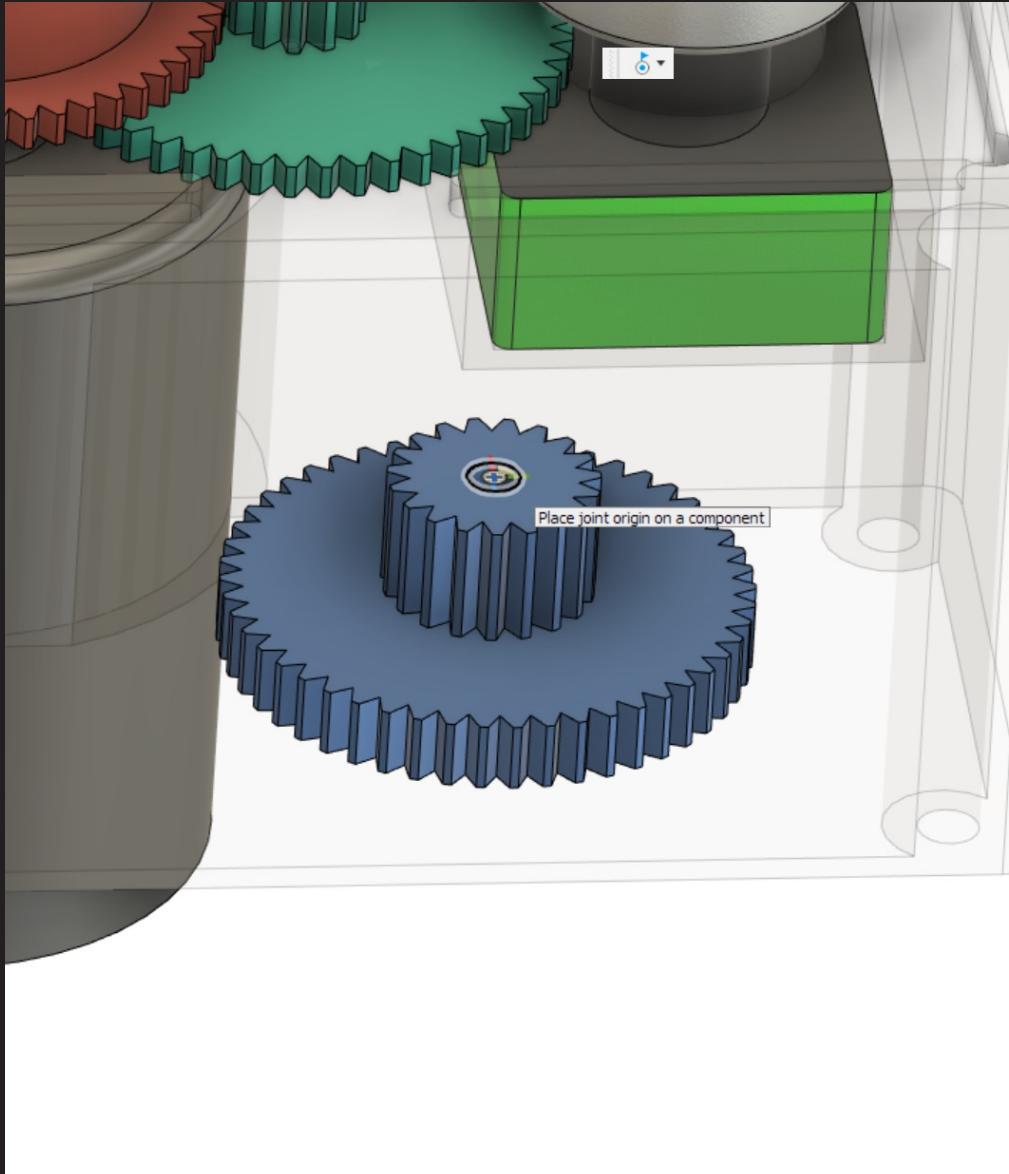
Joints-Gear 2

Similarly, add a joint to gear 2 using ‘revolute’.



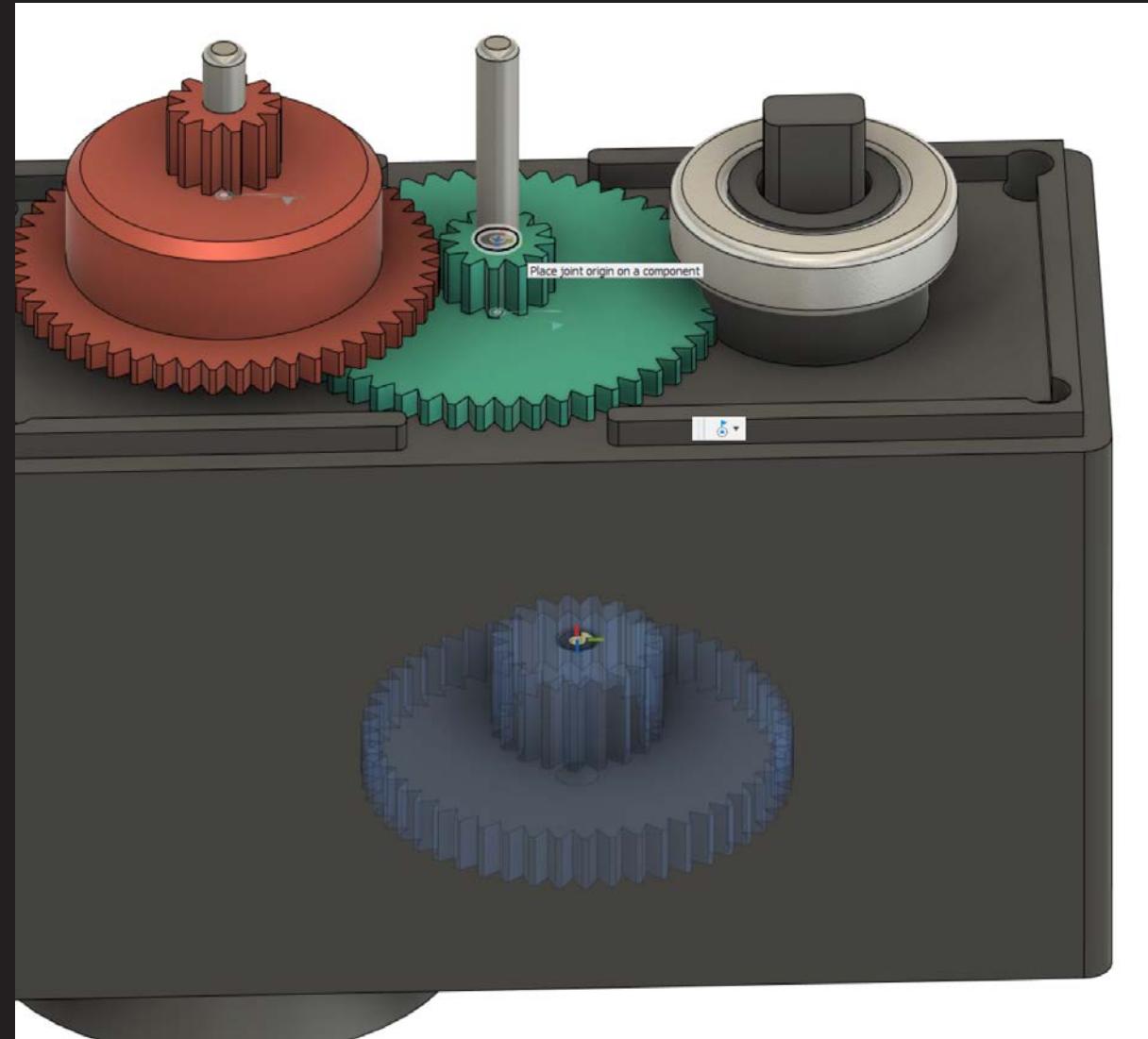
Joints-Gear 3

Similarly, add a joint to gear 3 using ‘revolute’.



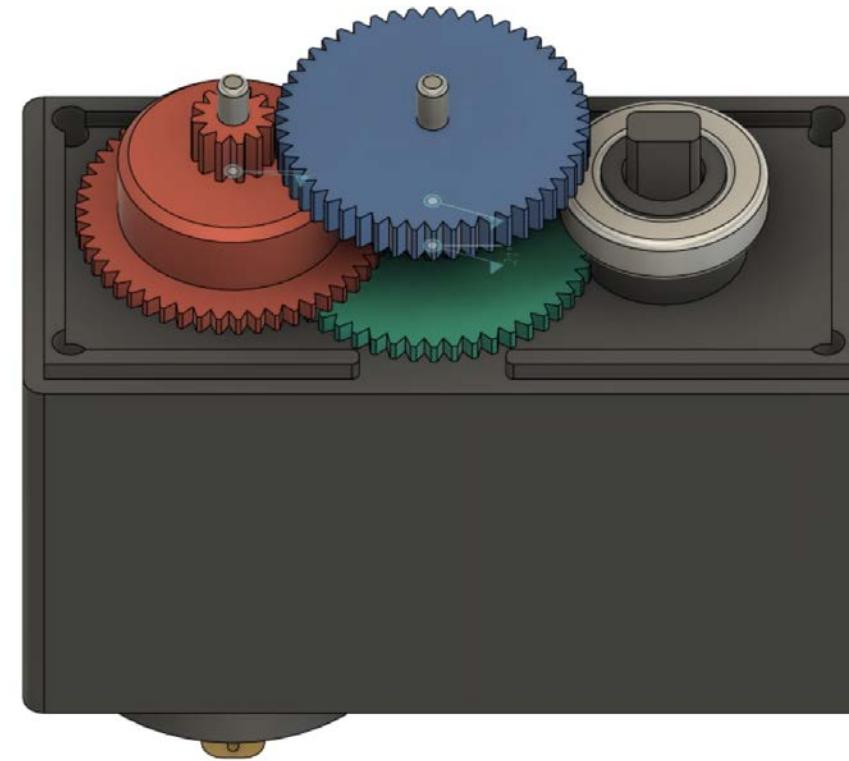
Joints-Gear 3

Similarly, add a joint to gear 3 using ‘revolute’.



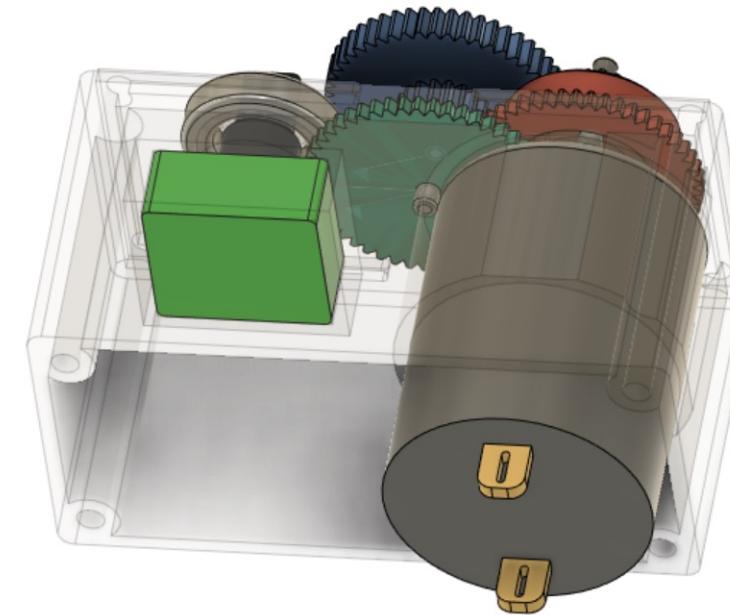
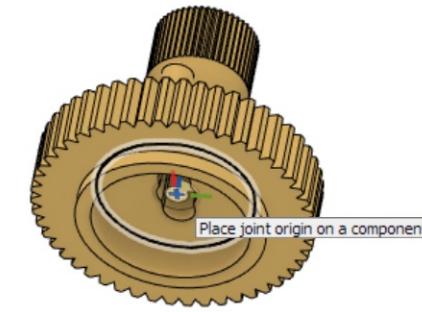
Joints-Gear 3

Similarly, add a joint to gear 3 using ‘revolute’.



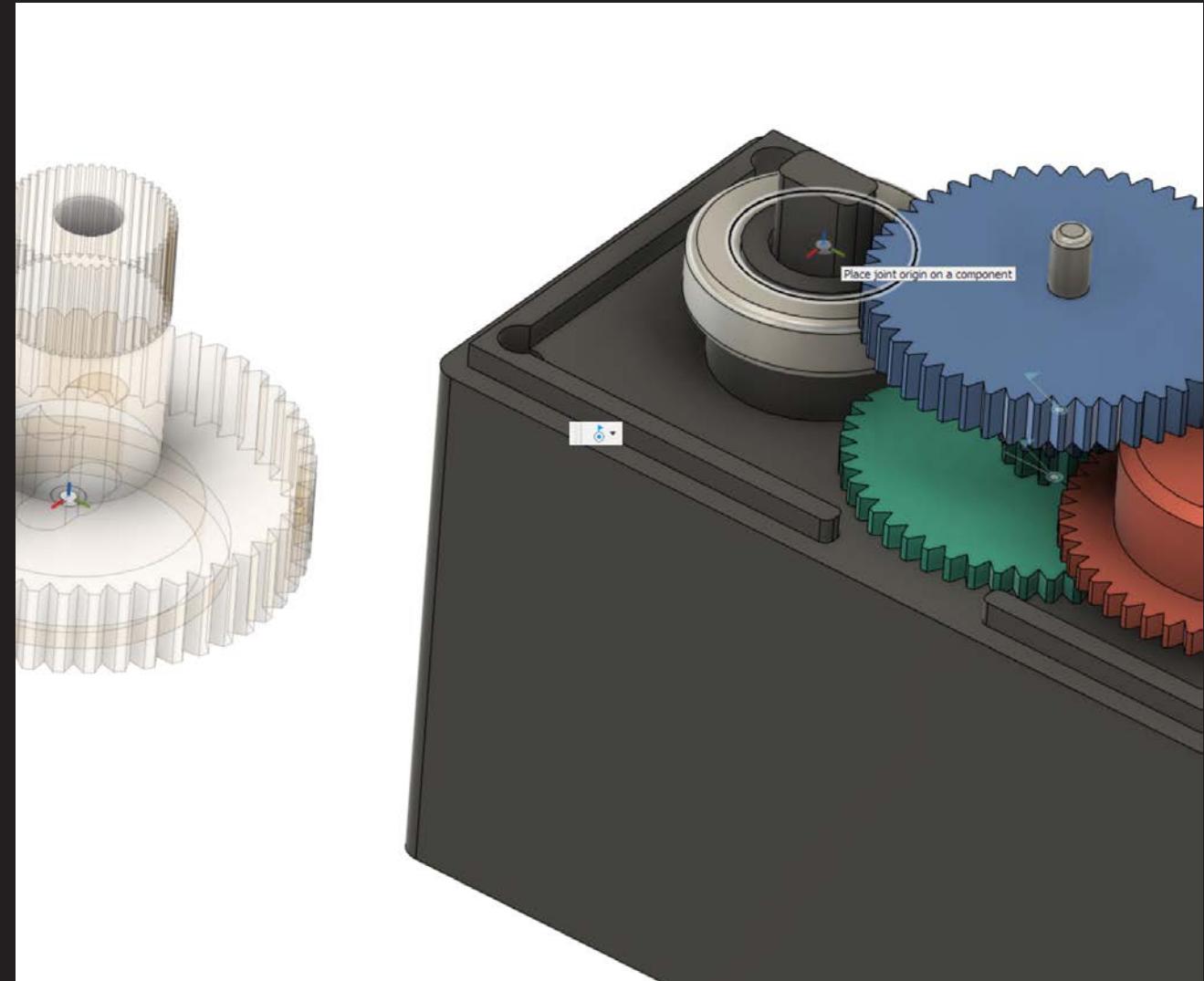
Joints-Gear 4

Similarly, add a joint to gear 4 using ‘revolute’.



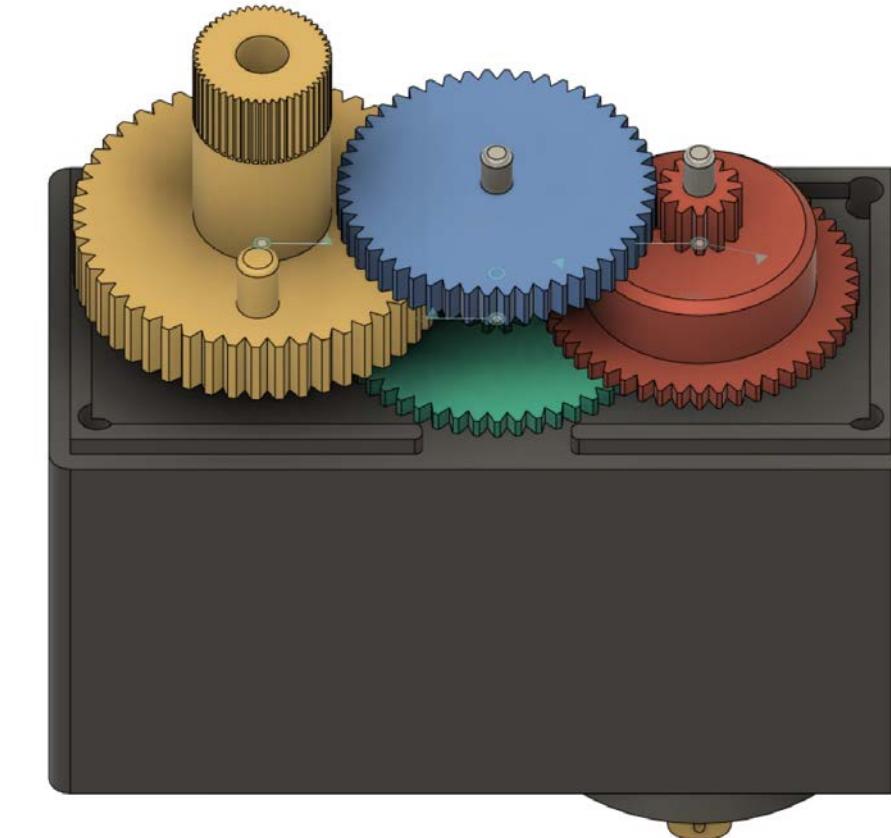
Joints-Gear 4

Similarly, add a joint to gear 4 using ‘revolute’.



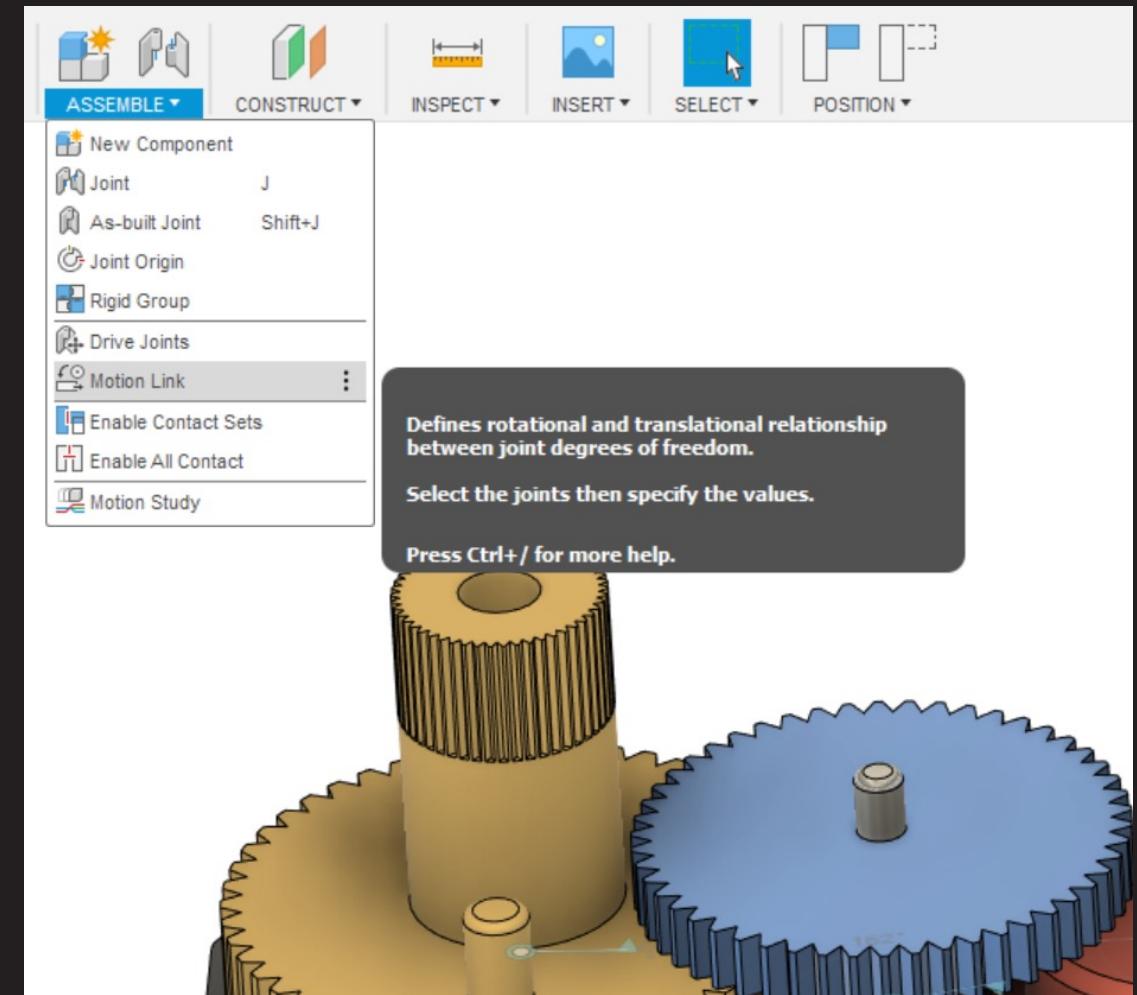
Joints-Gear 4

Similarly, add a joint to gear 4 using ‘revolute’.



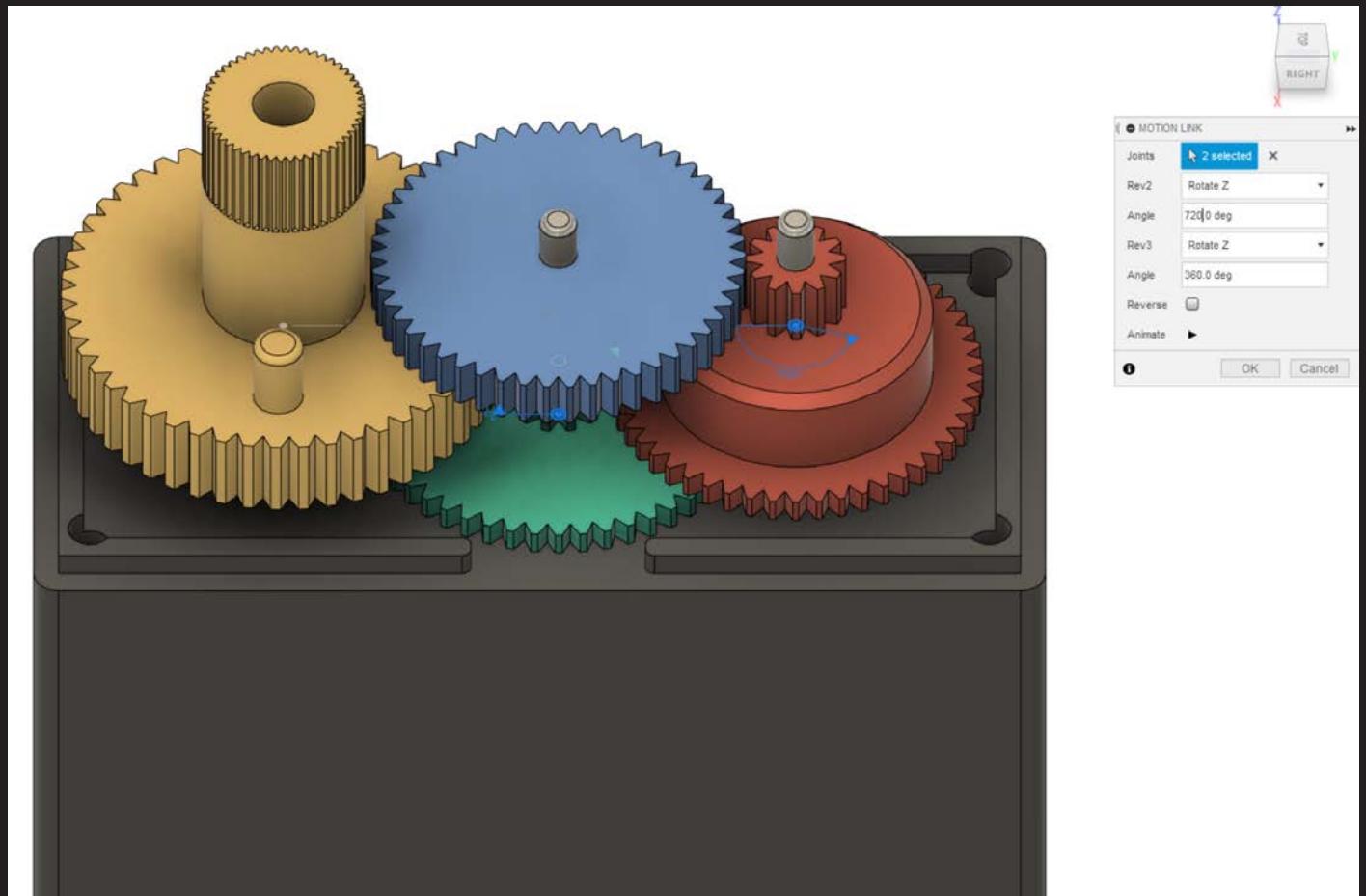
Motion Links

Relating individual joint together.



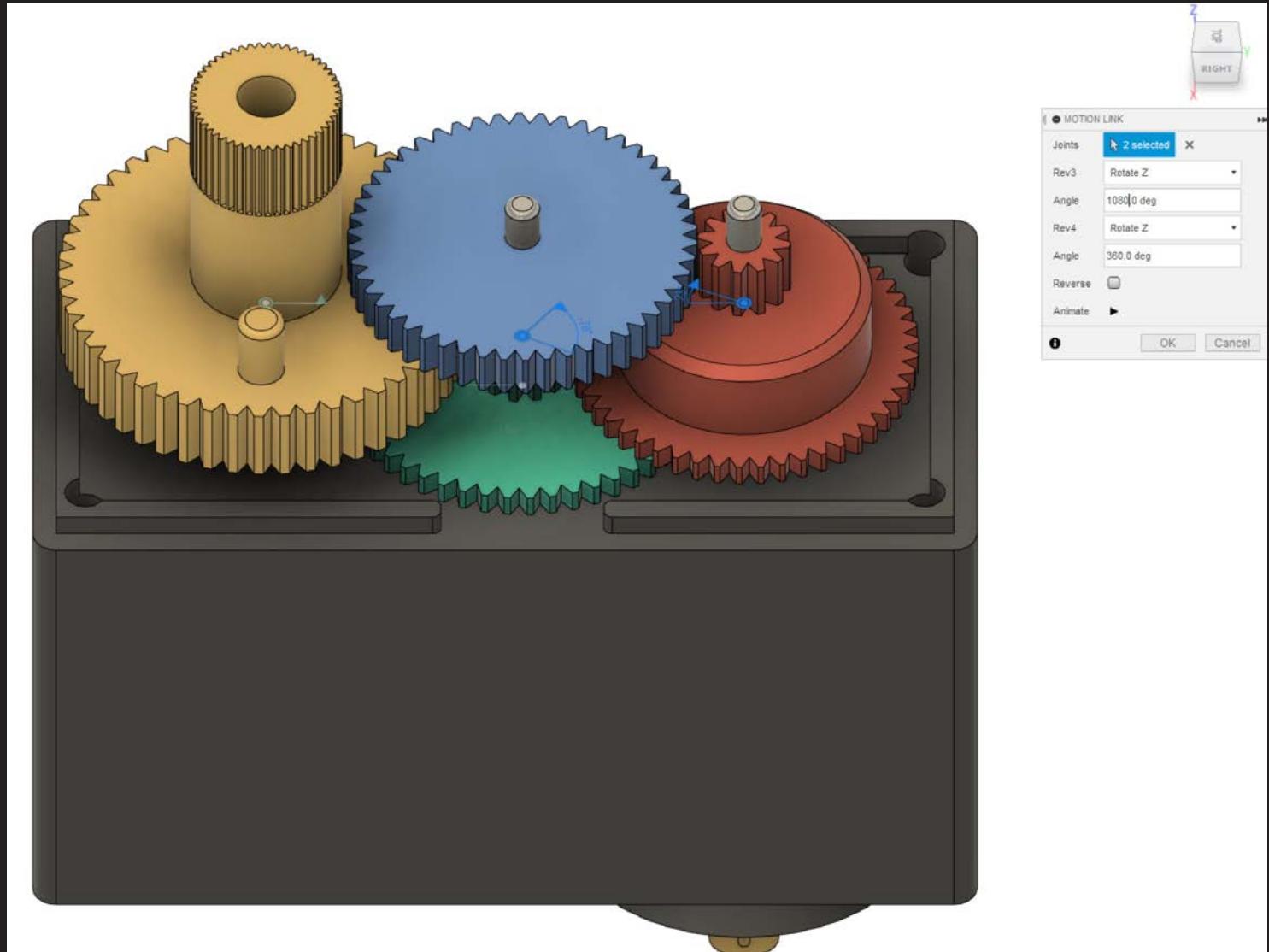
Motion Link Gears 1 & 2

Change the 'gear ratio' by altering the angles option.



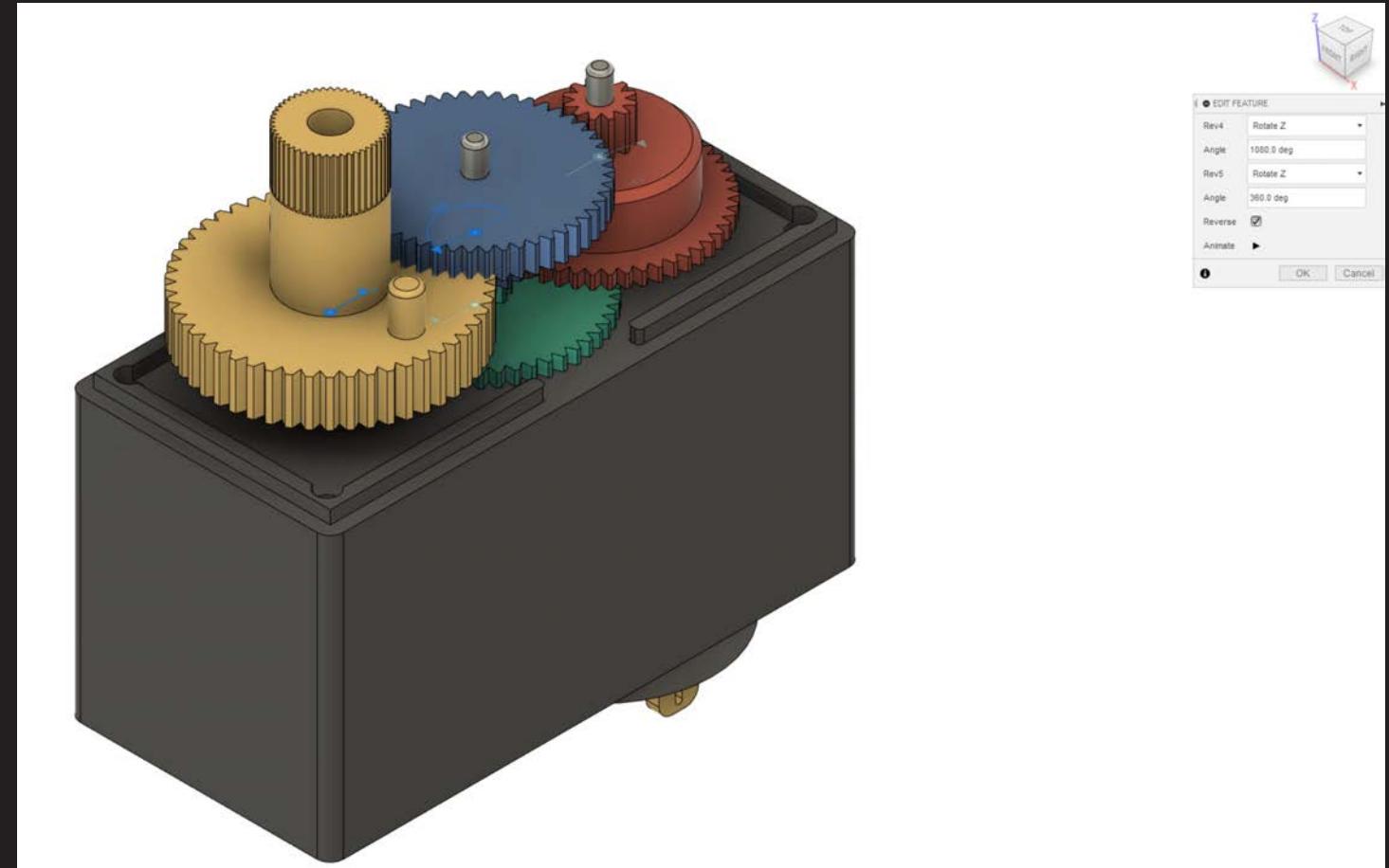
Motion Link Gears 2 & 3

Change the 'gear ratio' by altering the angles option.



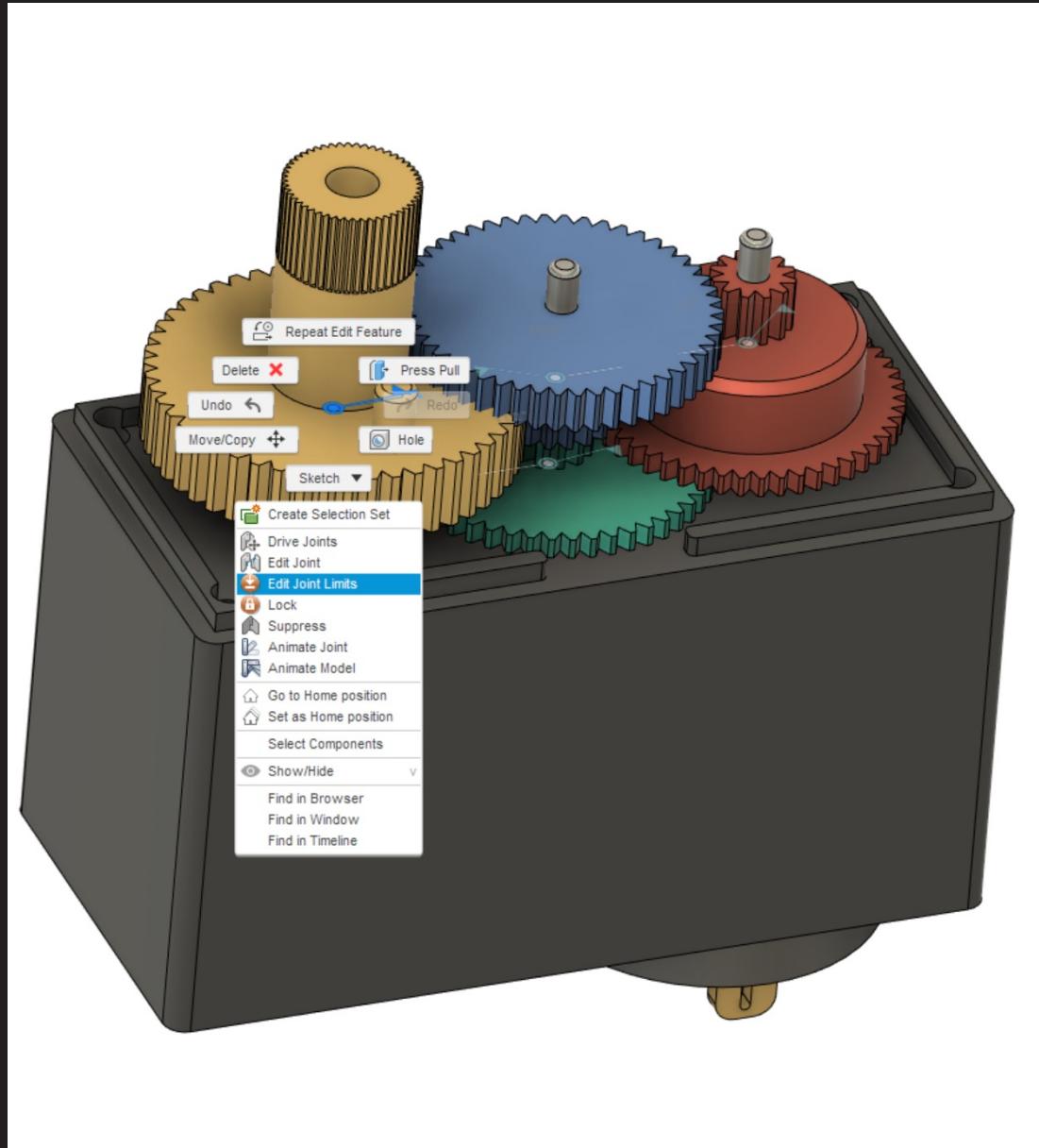
Motion Link Gears 3 & 4

Change the 'gear ratio' by altering the angles option.



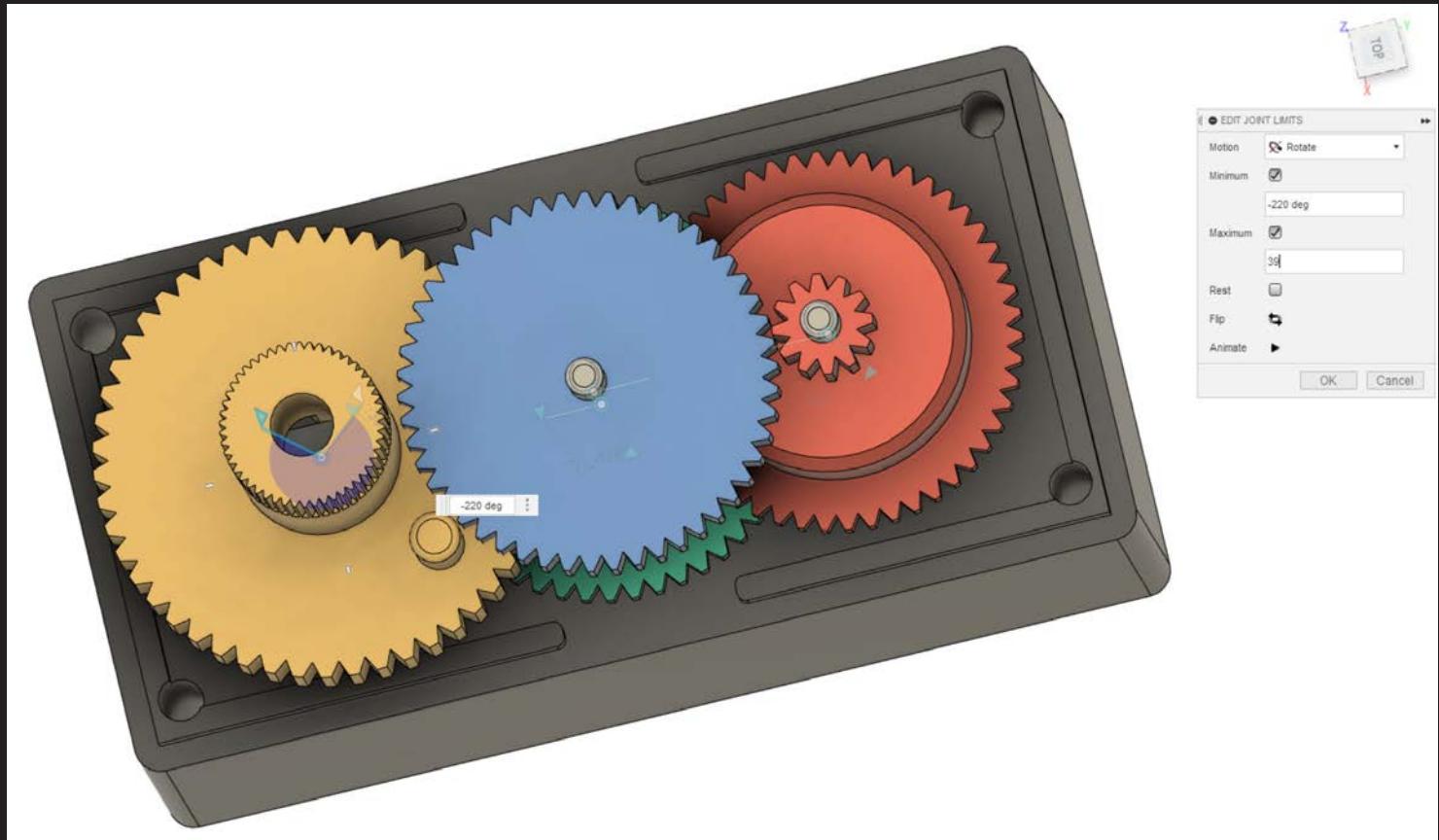
Edit Joint Limits

Limit the ‘sweep’ of the servo.



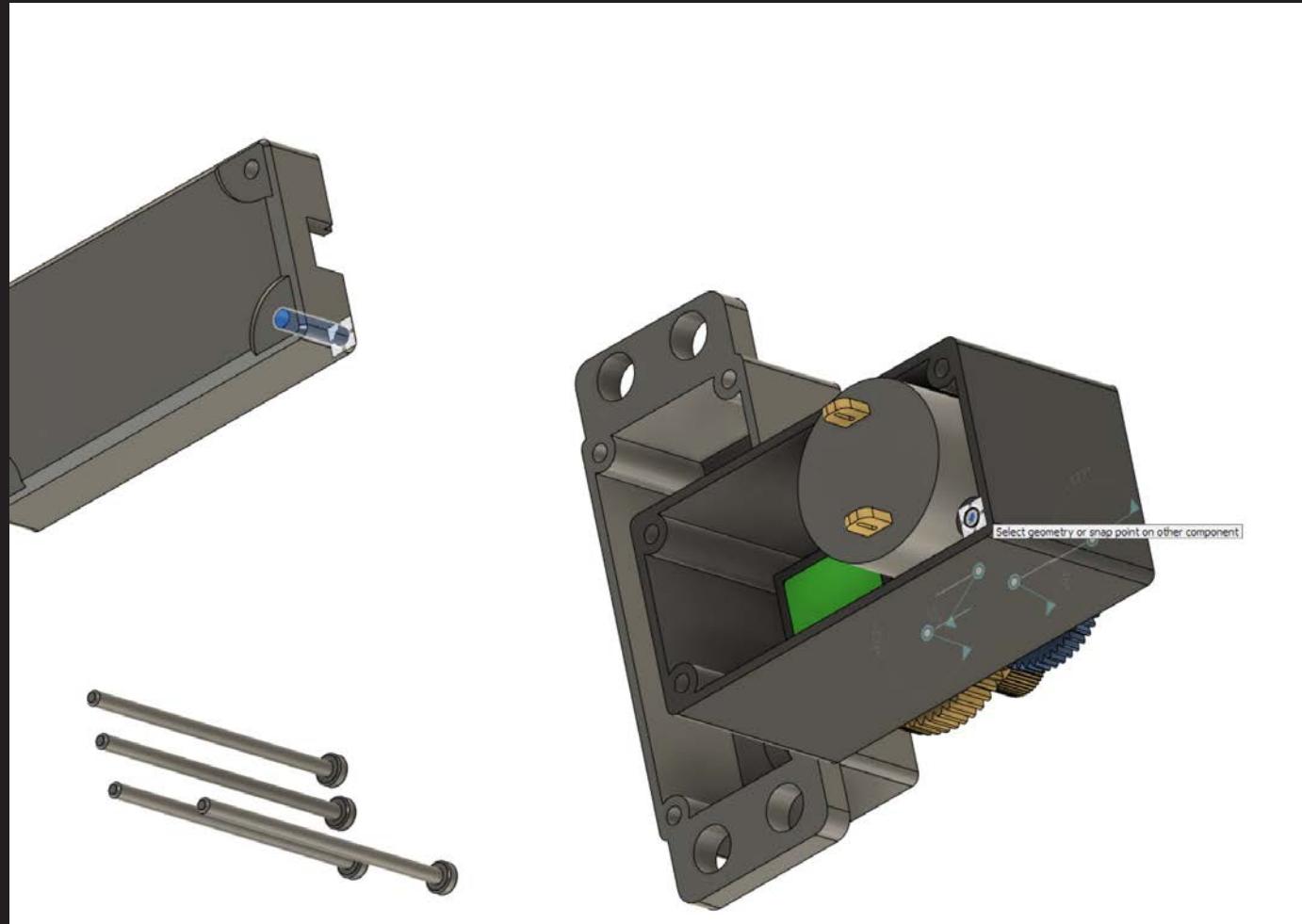
Edit Joint Limits

Limit the ‘sweep’ of the servo.



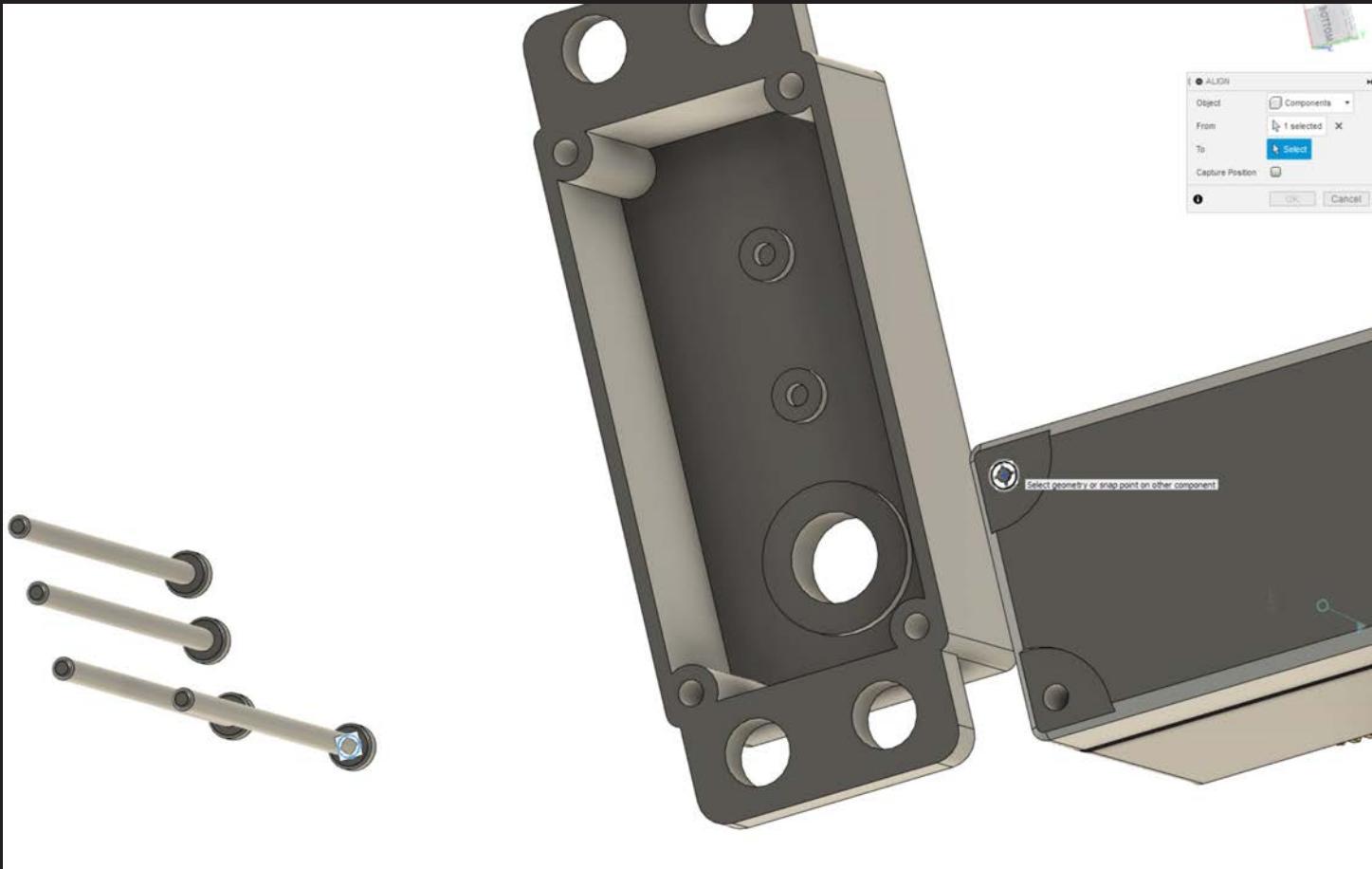
Align Bottom Shell

Assemble the remaining components.



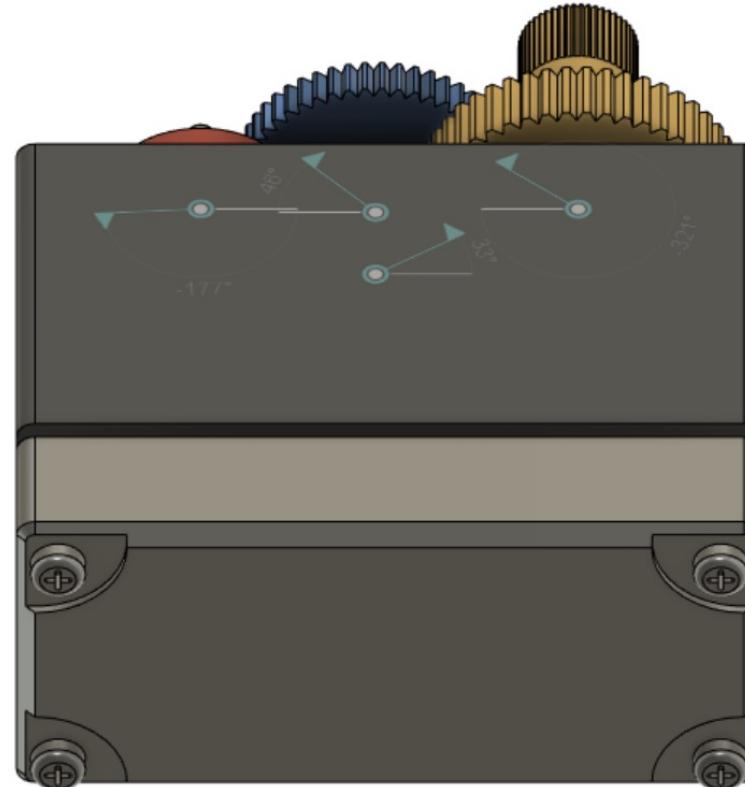
Align Screws

Assemble the remaining components.



Align Screws

Assemble the remaining components.



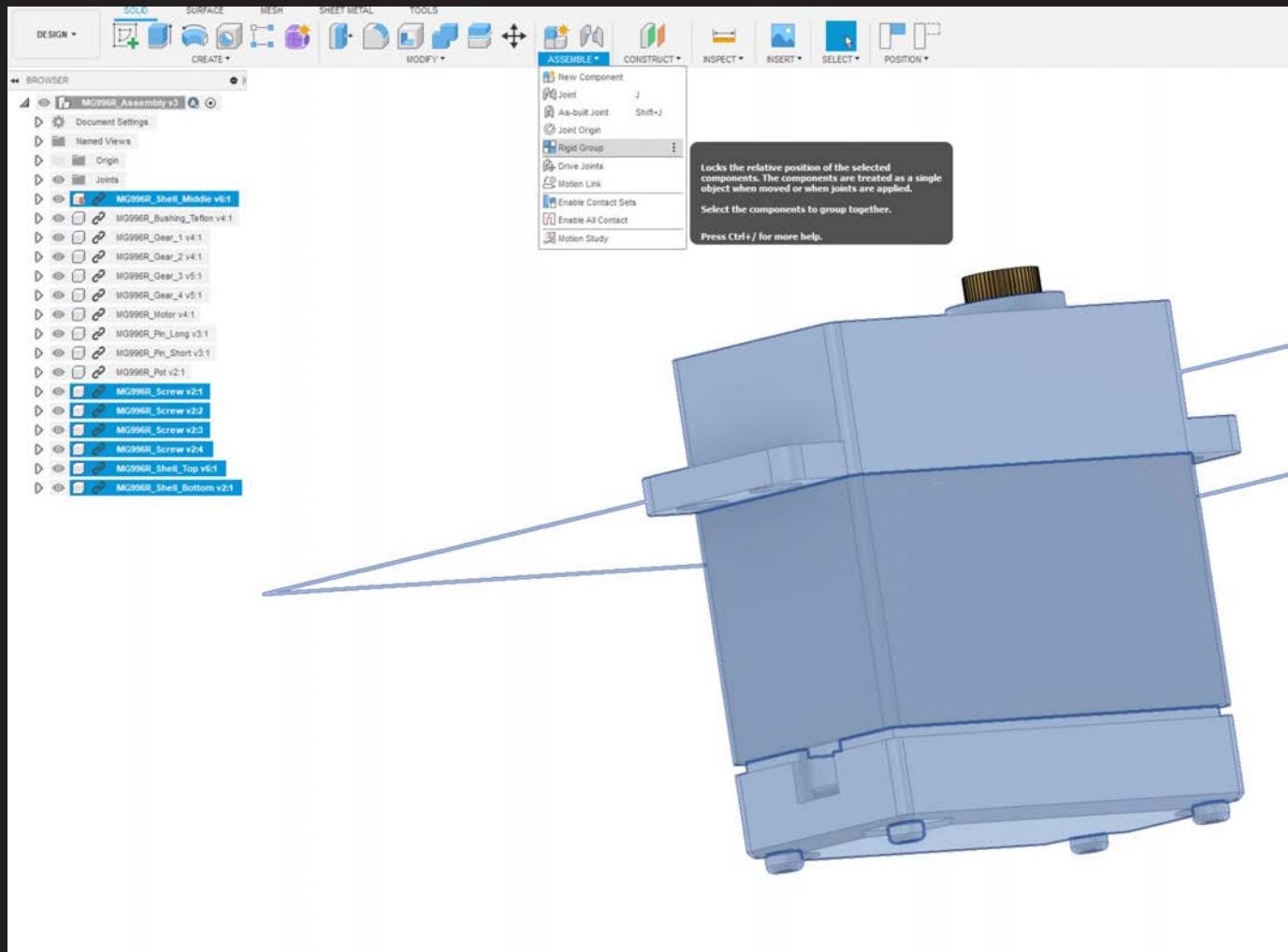
Align Top Shell

Assemble the remaining components.



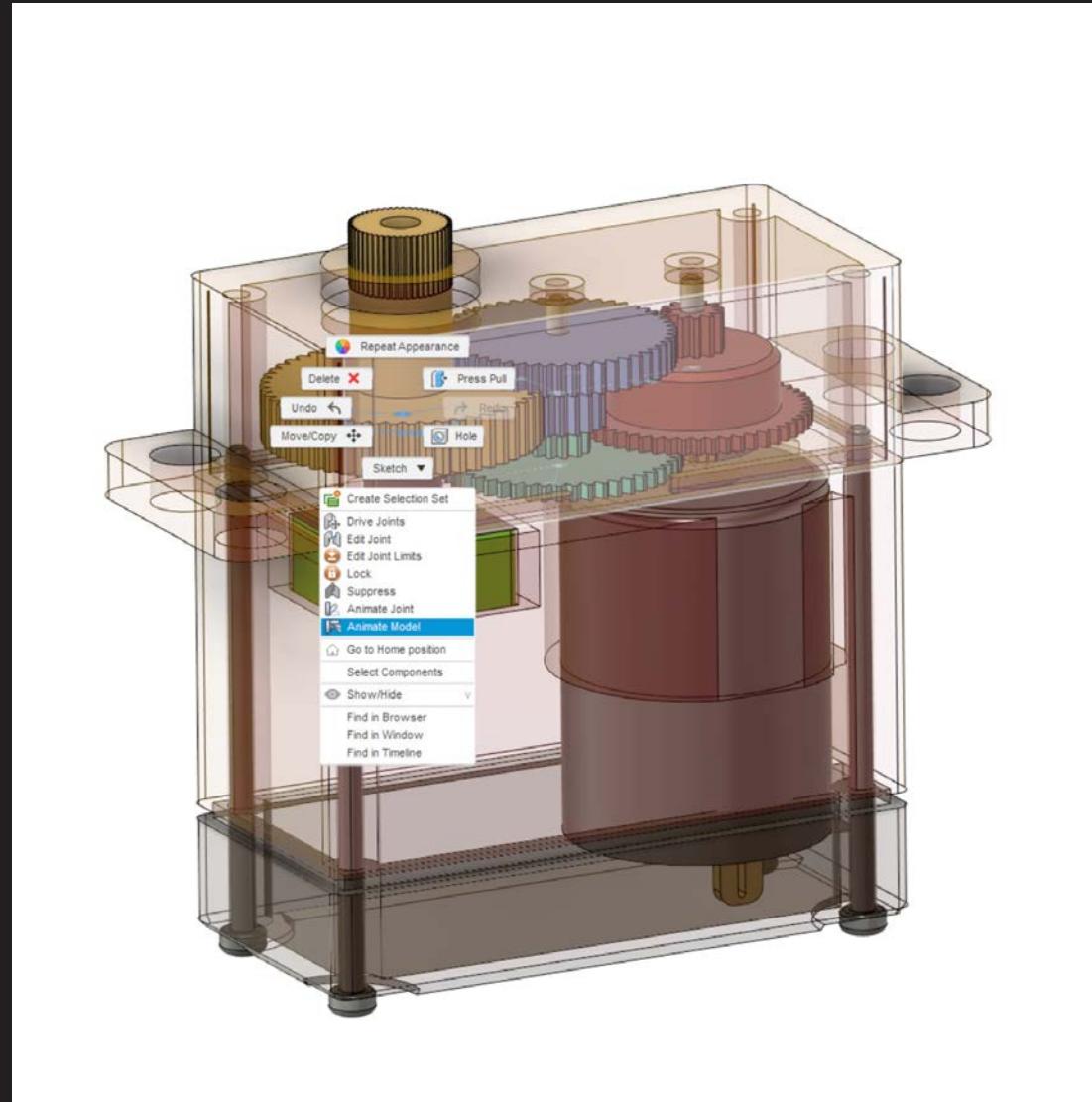
Rigid Group

Fix the top, bottom shells and screws.



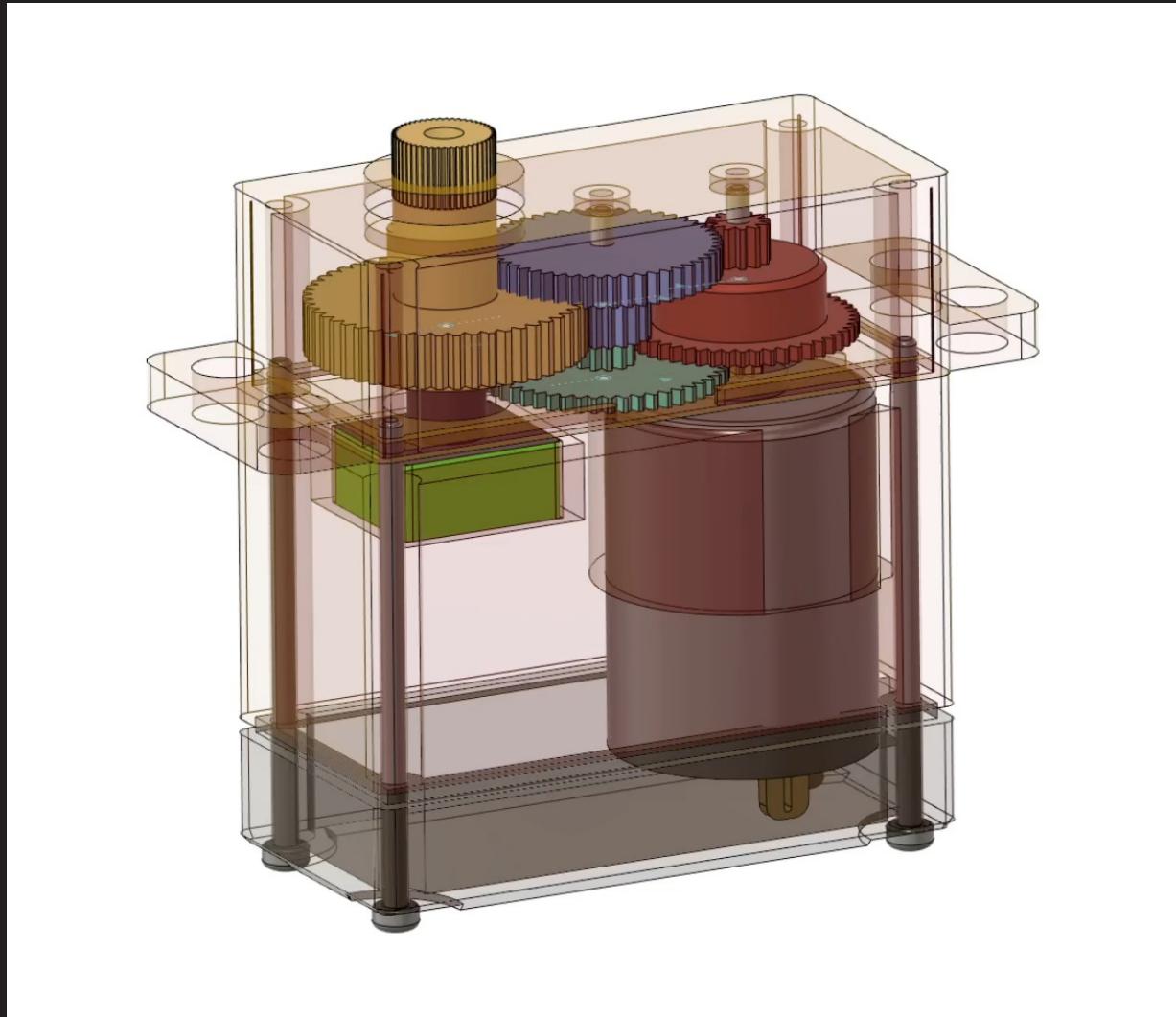
Animate Group

See the servo in action.



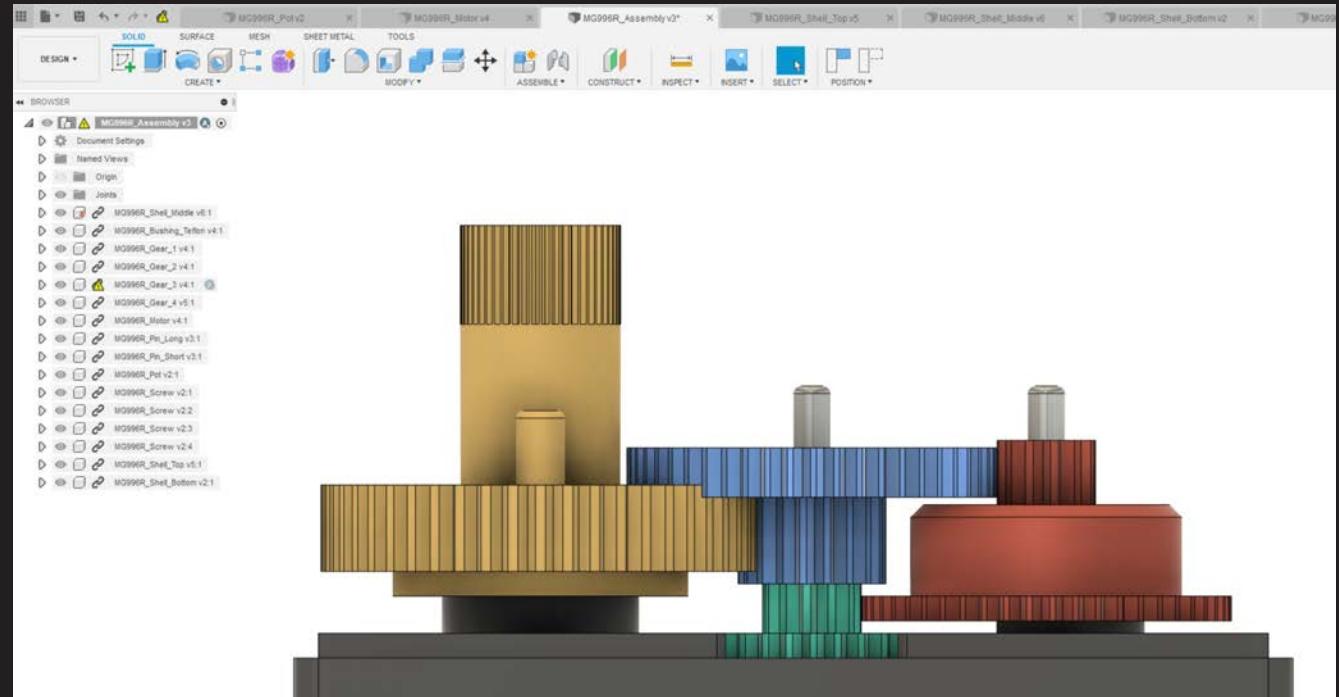
Animate Group

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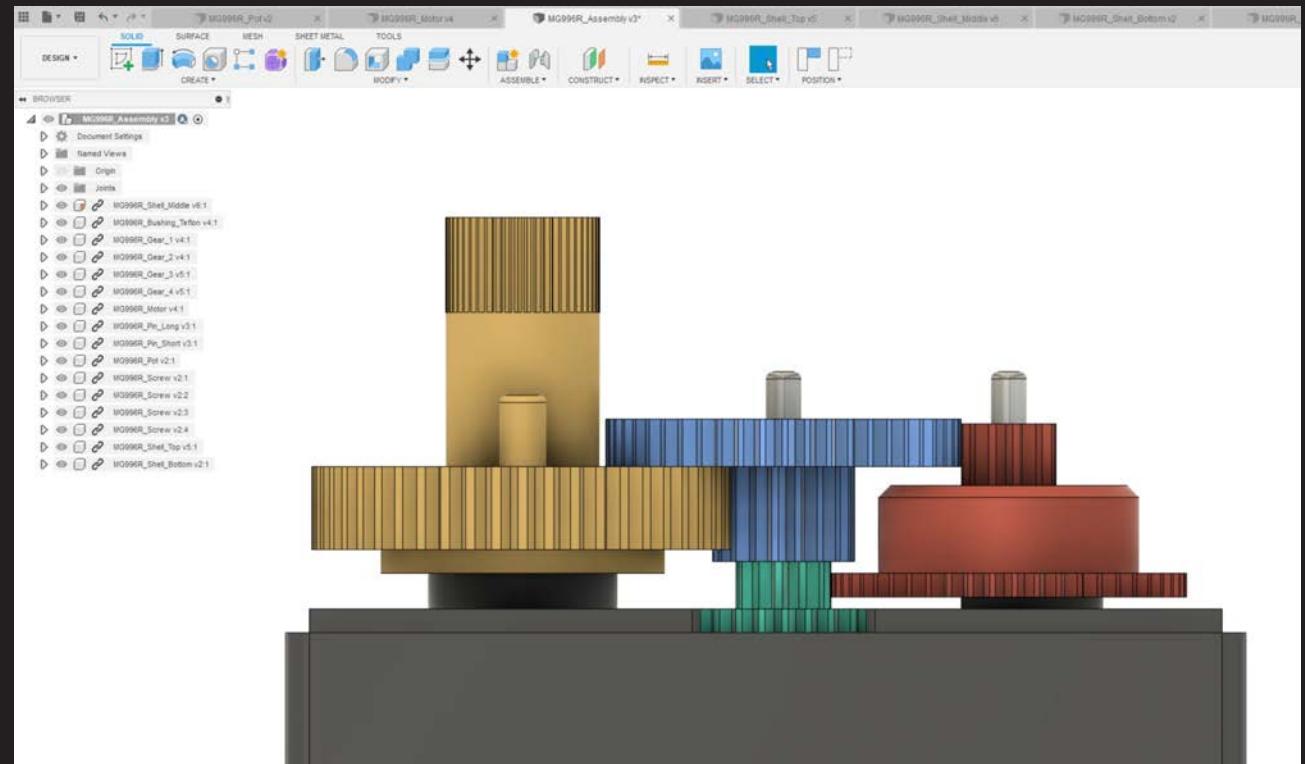
Modify External Component

Click the yellow 'Update' icon in the assembly to update changes.



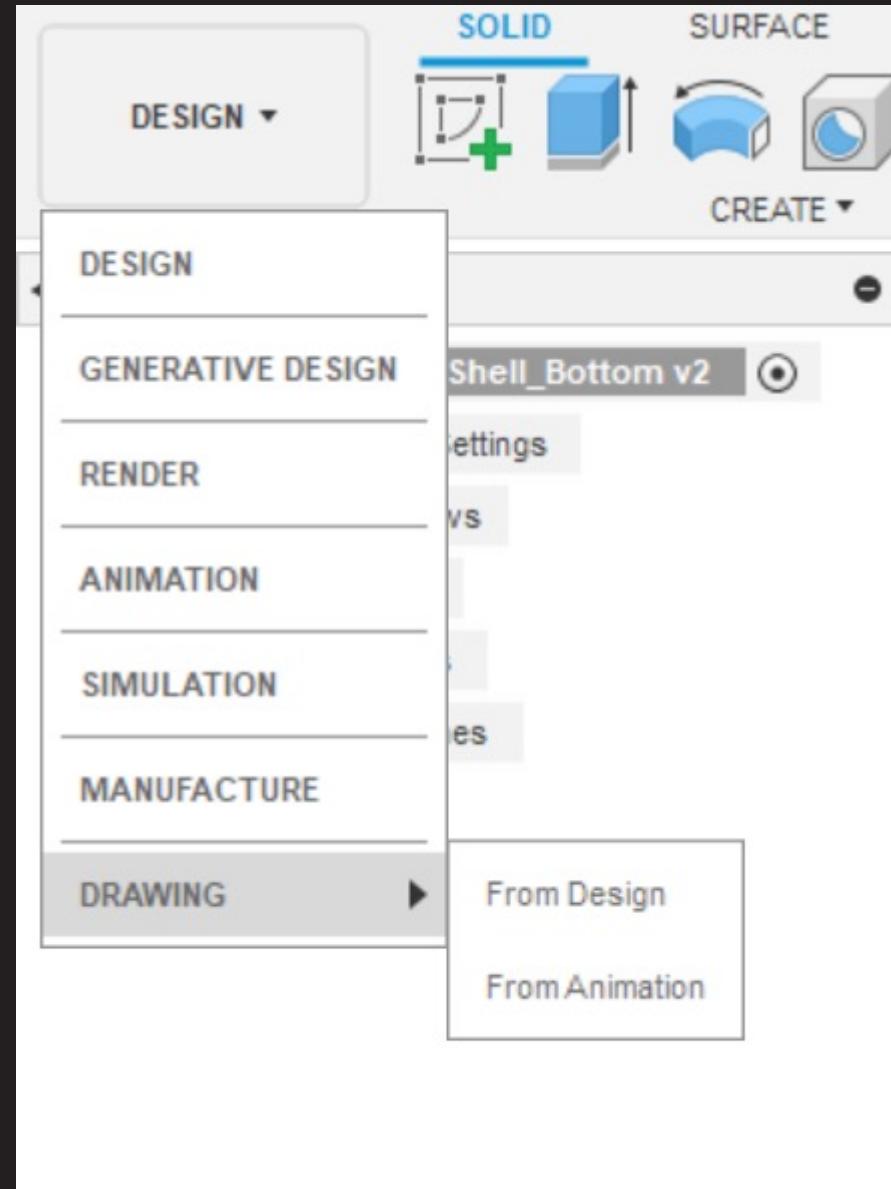
Modify External Component

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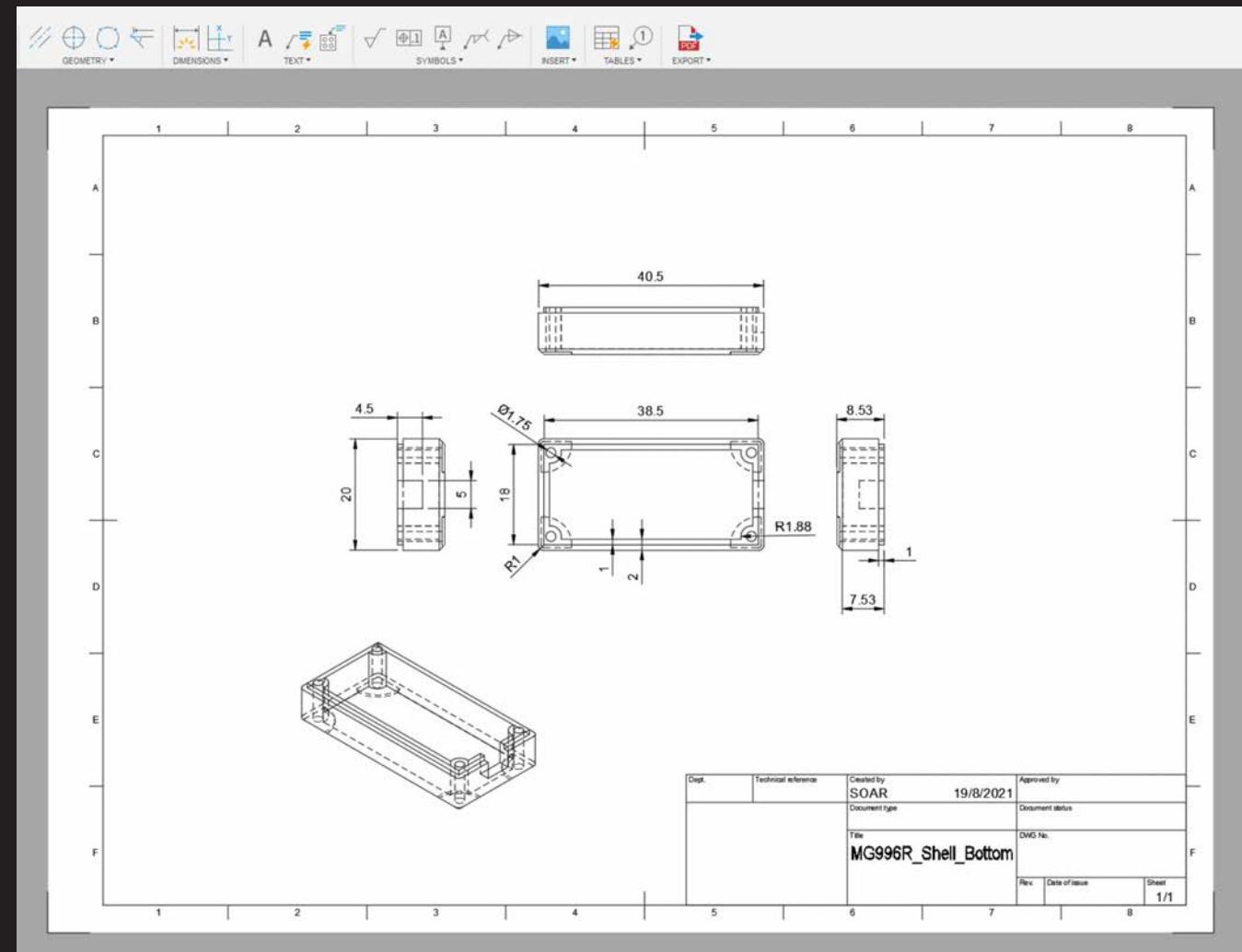
DRAWINGS - Export

Go to drawings from design in
'Workspace' drop down menu.

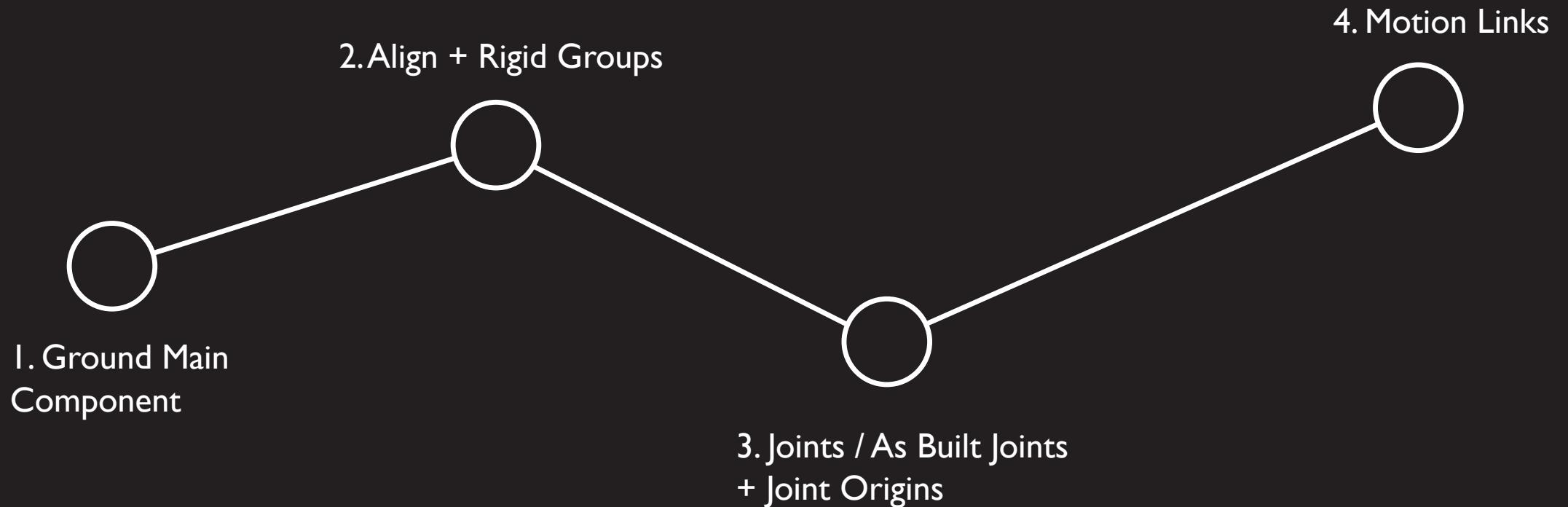


DRAWINGS - Export

Add various views, dimensions.
4 side + 1 isometric

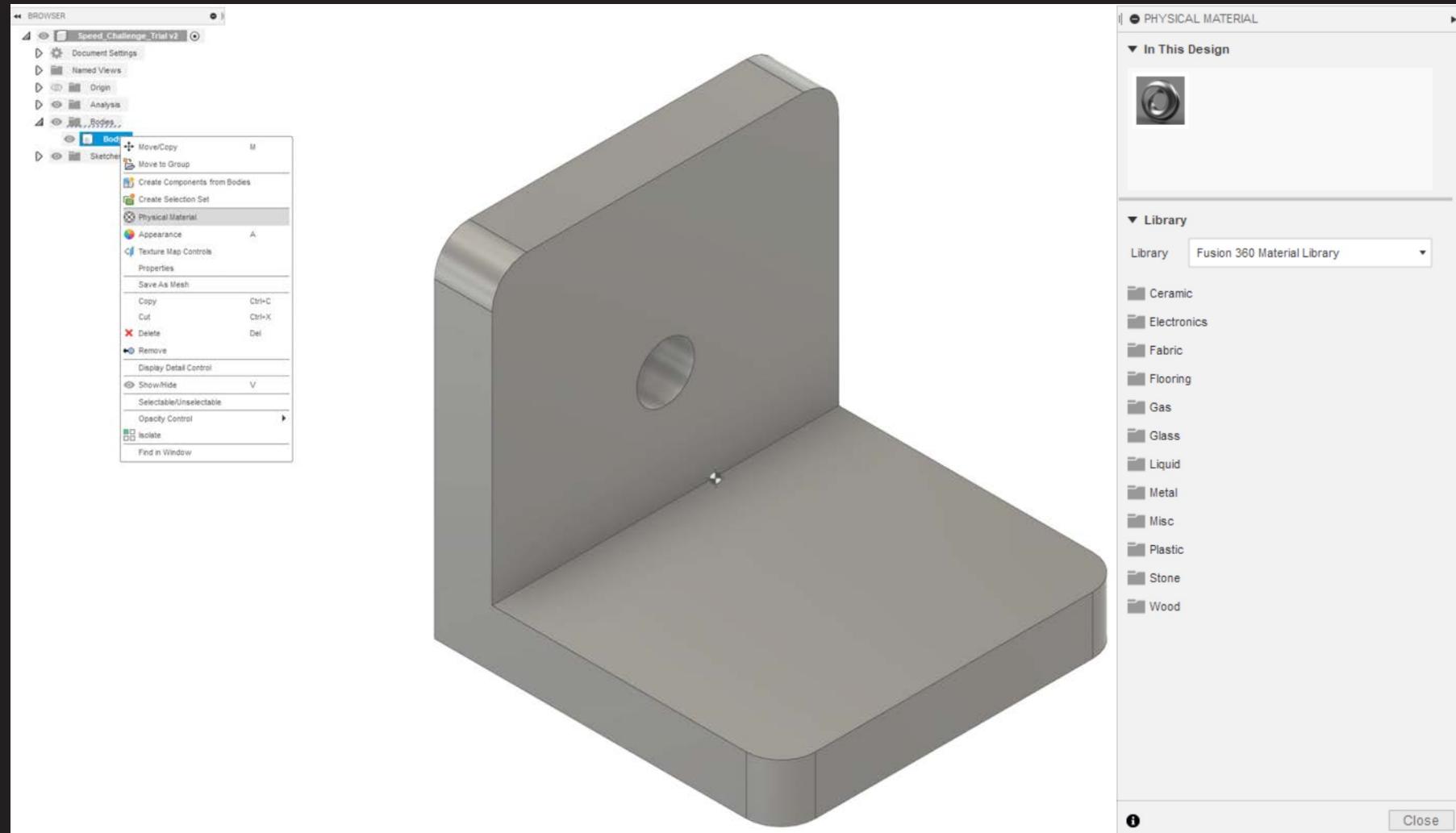


SUMMARY – Assembly Workflow

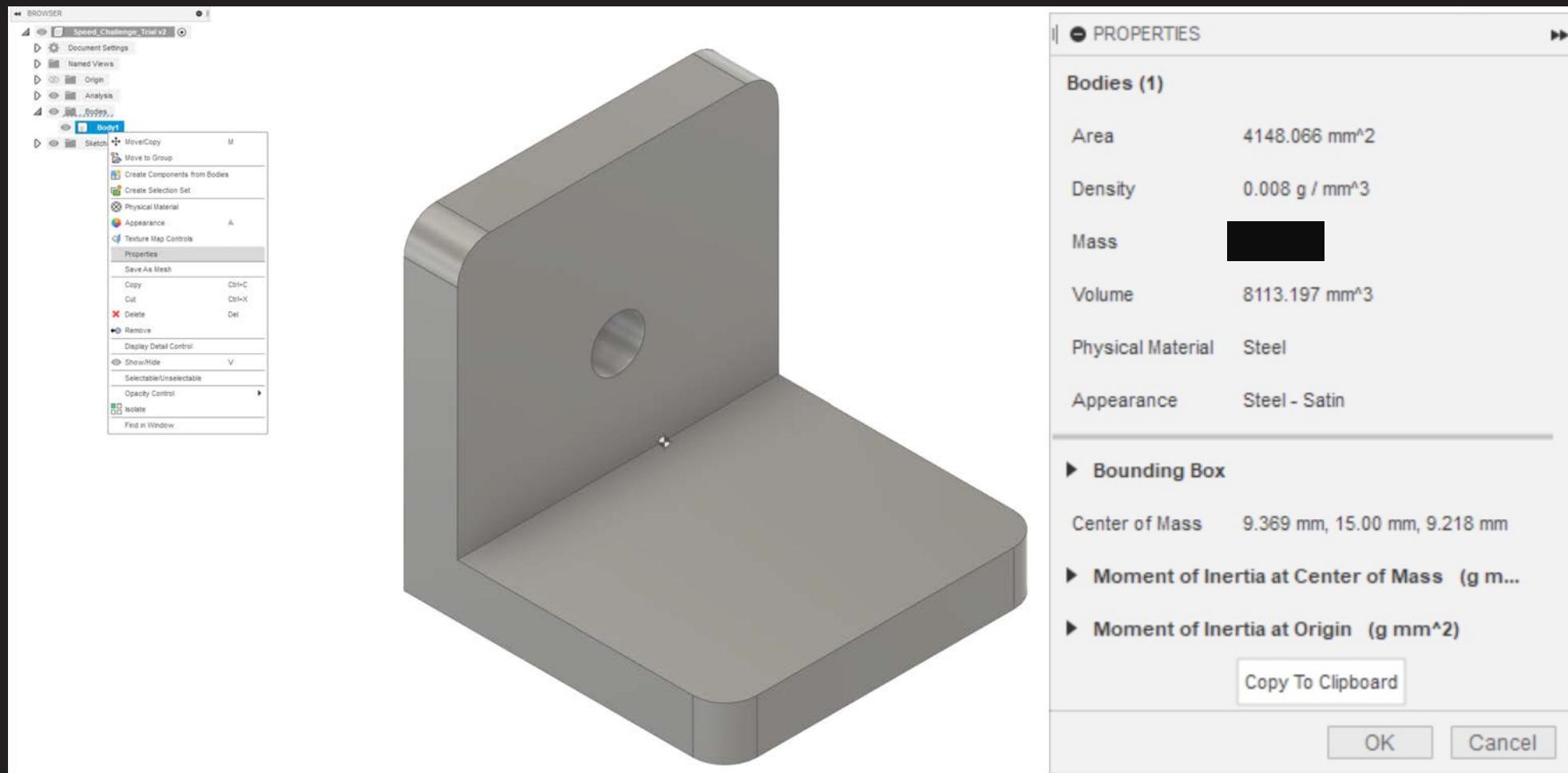


Speed Challenge Trial

Setting a Material

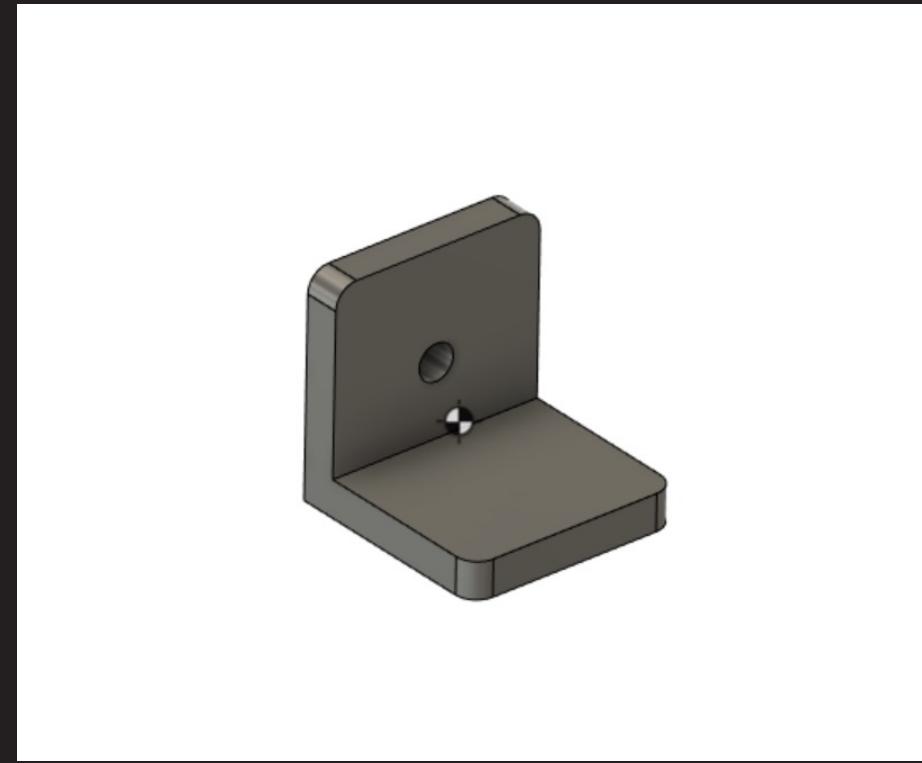


Checking Mass



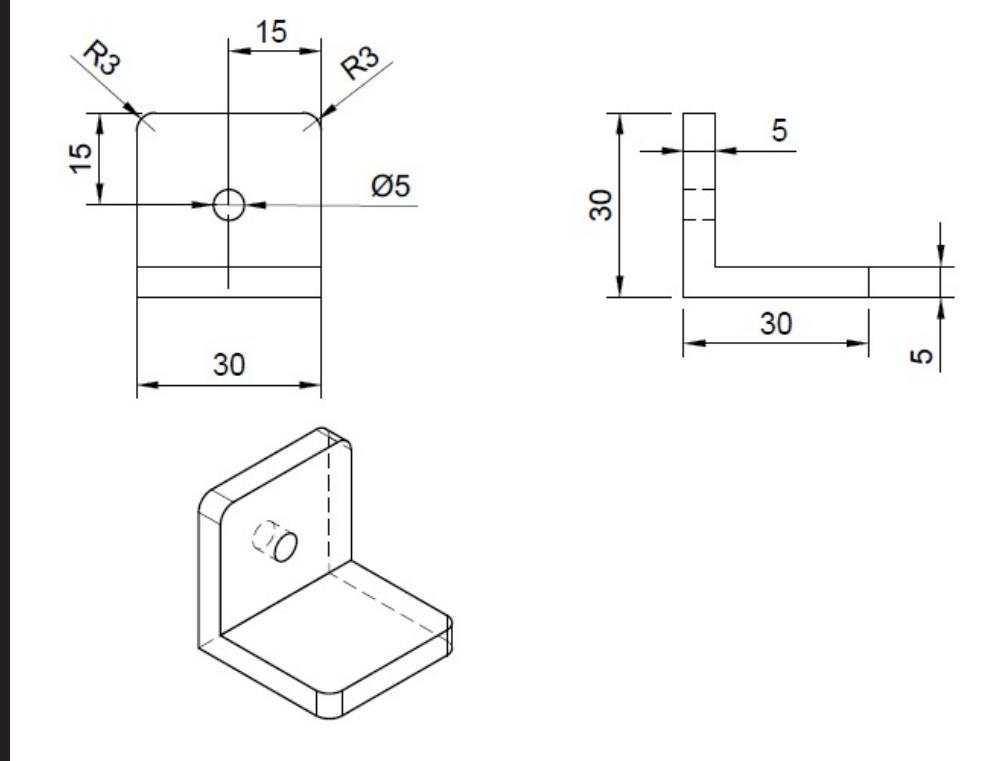
SOAR_Mech_Speed_challenge_Trial.pdf

1. CAD this from the given drawing as quickly as you can but not compromising on accuracy.
2. Under properties, find the mass of the part (with material set to steel)
3. Send the mass of your part in the Discord chat
4. Fastest fingers win!



SOAR_Mech_Speed_challenge_Trial.pdf

1. CAD this from the given drawing as quickly as you can but not compromising on accuracy.
2. Under properties, find the mass of the part (with material set to steel)
3. Send the mass of your part in the Discord chat
4. Fastest fingers win!



See you
next week!