THE DESIGN OF
LASER ALIGNMENT SYSTEM

AS-1 Final Presentation

June 1st , 2020

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Problem Statement

Alignment systems are widely used, from Mars probes to drones. It is especially important to precisely align the interface and related fixtures. My group mainly considers the alignment system to fix a laser pen on the joint surface and point it in any predetermined direction

Mars rover mines rock samples at specified locations

Drones grab designated targets

Scope

DJI Phantom Series
Diagonal Distance 350 mm

DJI Mavic Series
322×242×84 mm (length×width×height)

Design Requirements

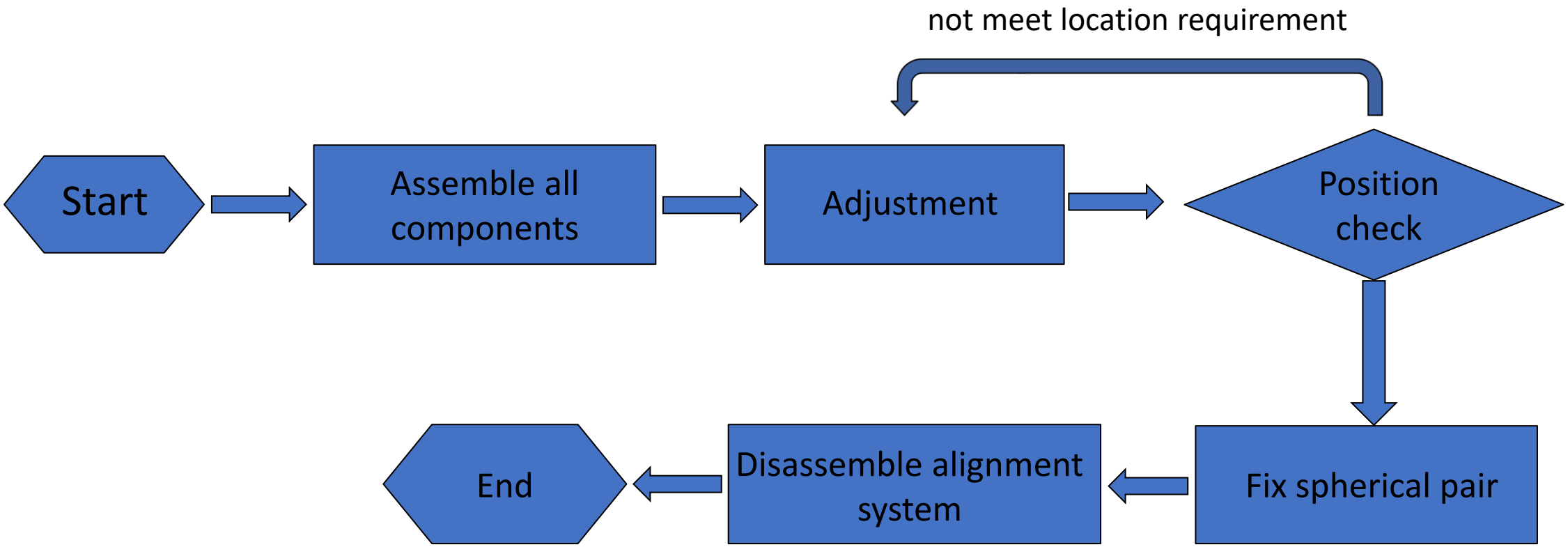
System Requirements

Adjustment range	±10°
Adjustment accuracy	<0.4°
Take off mass	< 500g
System size	≈220mm×220mm×200mm
Working temperature	0℃-40℃
Control dimensions	2-axis(roll pitch)

Other requirements

Easy and safety operation
Simple structure

Functional Decomposition

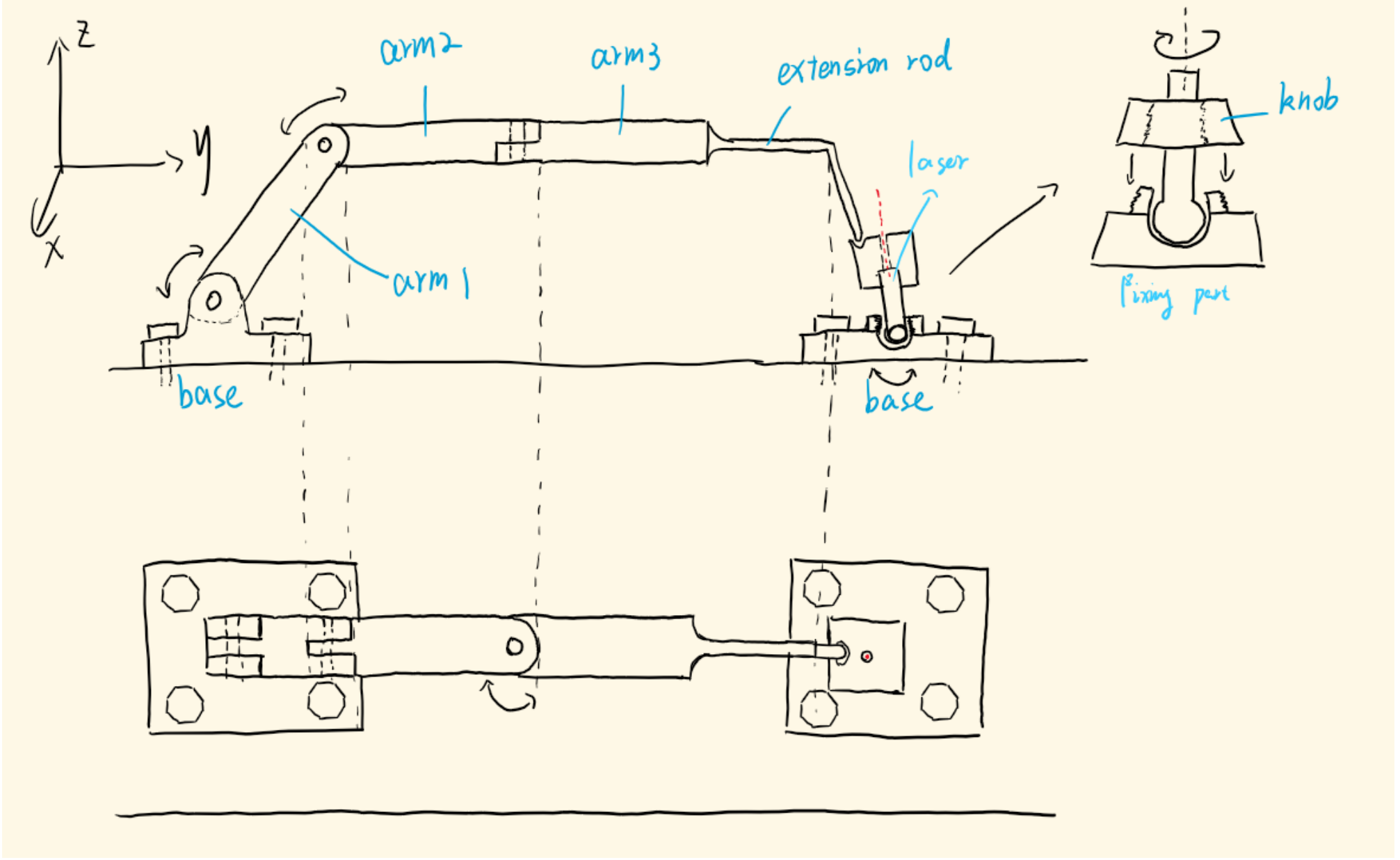


Conceptual Design

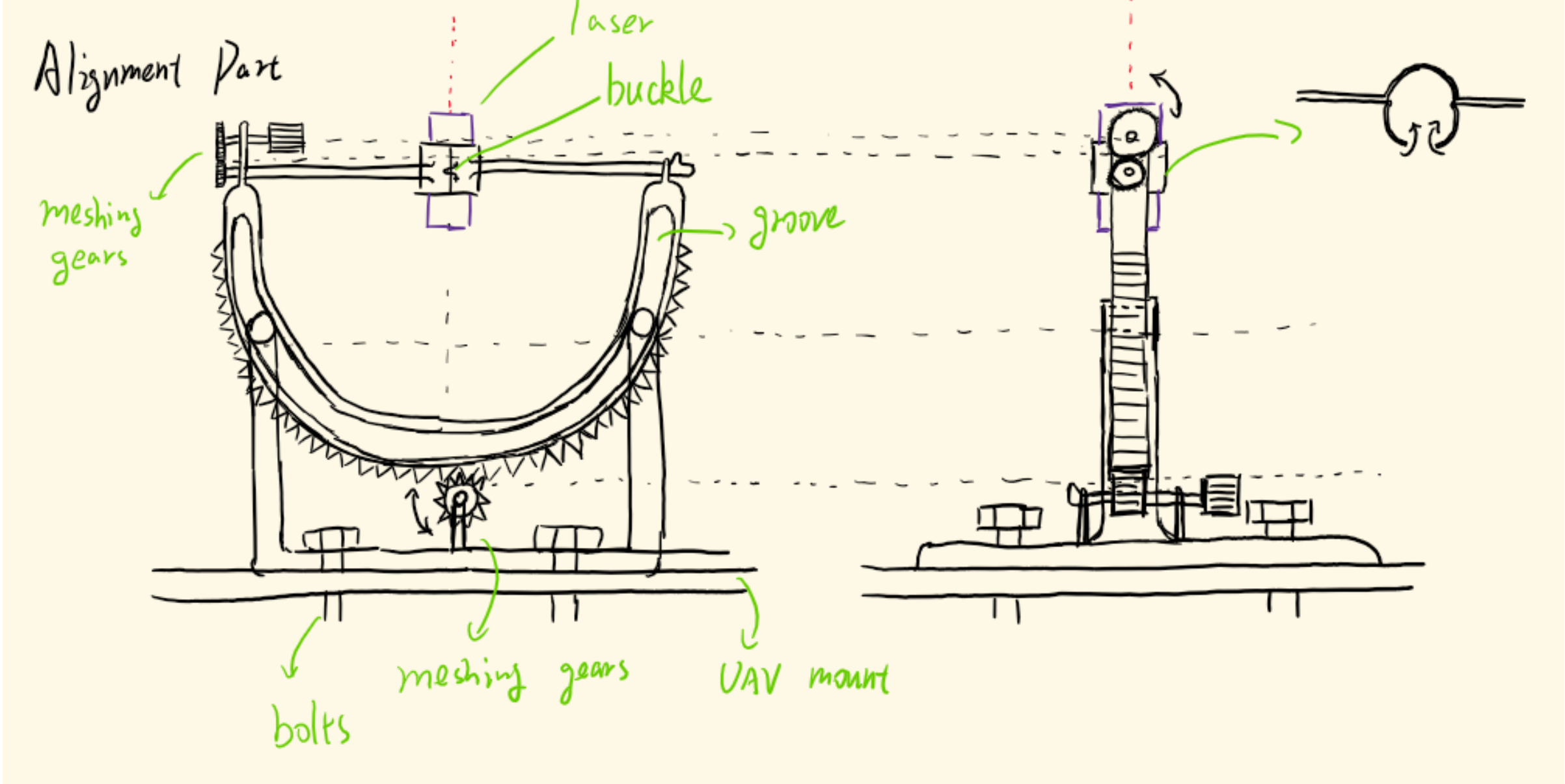
The goal:

to adjust the laser accurately so that it points to a specific location.

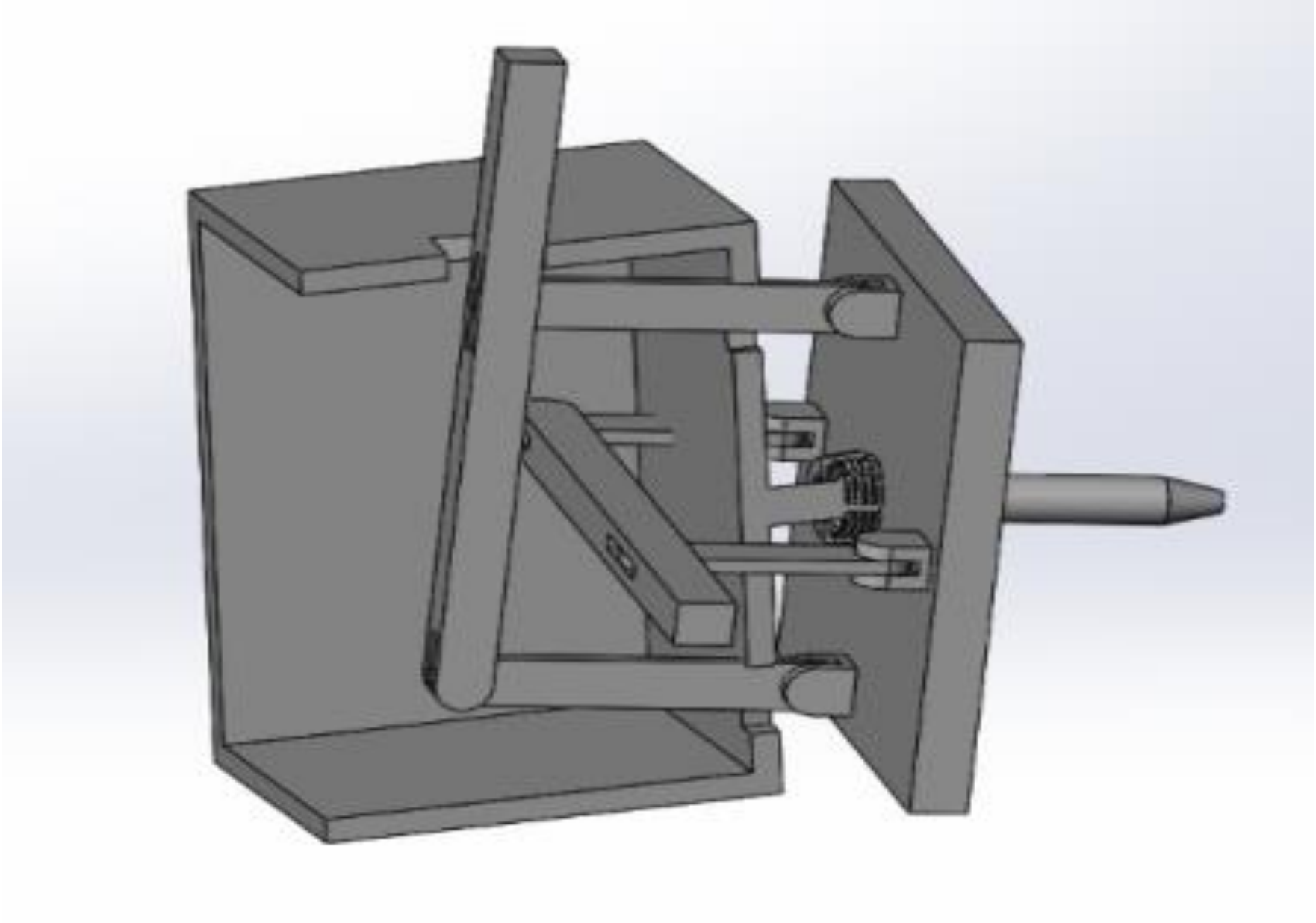
Then, we discuss the solution using the *4-3-5* method and summarized 4 designs.


z
y
x
arm2
arm3
extension rod
laser
knob
arm 1
base
base
fixing part

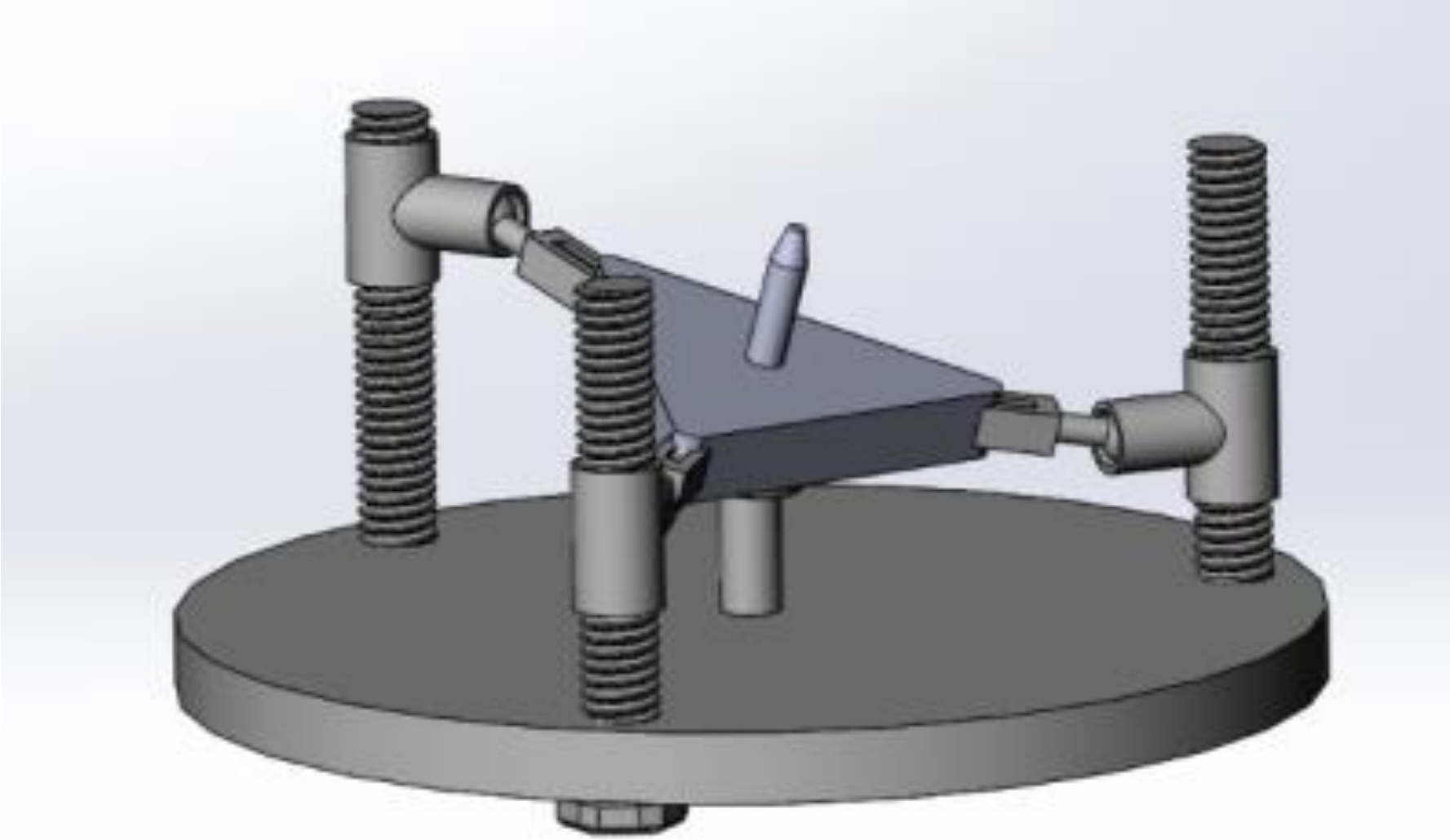
Concept 1


Alignment Part
laser
buckle
meshing gears
groove
bolts
meshing gears
UAV mount

Concept 2



Concept 3



Concept 4

Decision matrices

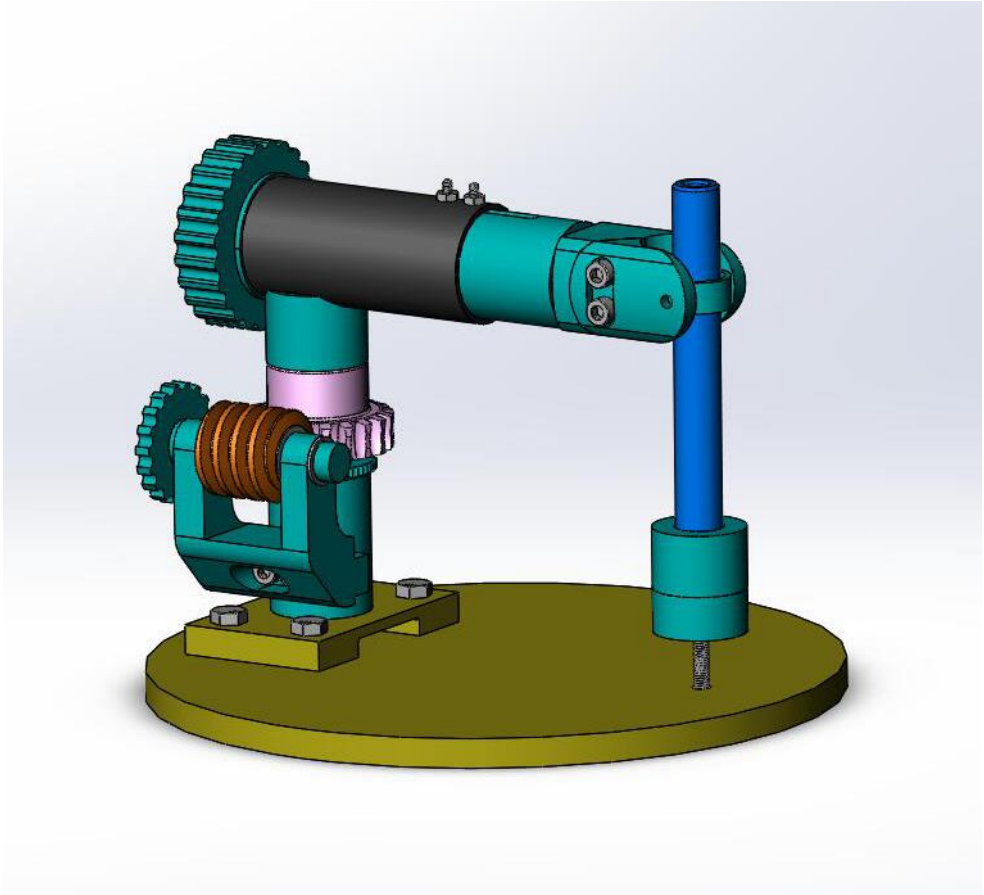
		concept 1		concept 2		concept 3		concept 4	
	Weight	individual score	weight score	individual score	weight score	individual score	weight score	individual score	weight score
light weight	6	6	36	7	42	7	42	10	60
easy to operate	7	9	63	9	63	9	63	9	63
safe	10	10	100	9	90	9	90	9	90
simple structure	8	10	80	8	64	9	72	10	80
high efficiency	6	10	60	10	60	10	60	10	60
reusable	4	8	32	6	24	6	24	6	24
easy to disassemble	7	10	70	6	42	7	49	8	56
low impact	8	10	80	8	64	8	64	7	56
low cost	6	9	54	7	42	8	48	8	48
reliable	8	9	72	9	72	9	72	7	56
high precision	10	8	80	9	90	9	90	9	90
Final score			727		653		674		683

Comparing the advantages and disadvantages of our design.

Final design

Synthesizing everyone's design

- Laser movement controlled by robotic arm fixture
- Fixing laser with ball joint
- Gears can be used to control robotic arm deflection
- We can use the bolt thread to control the elongation and shortening of the robot arm

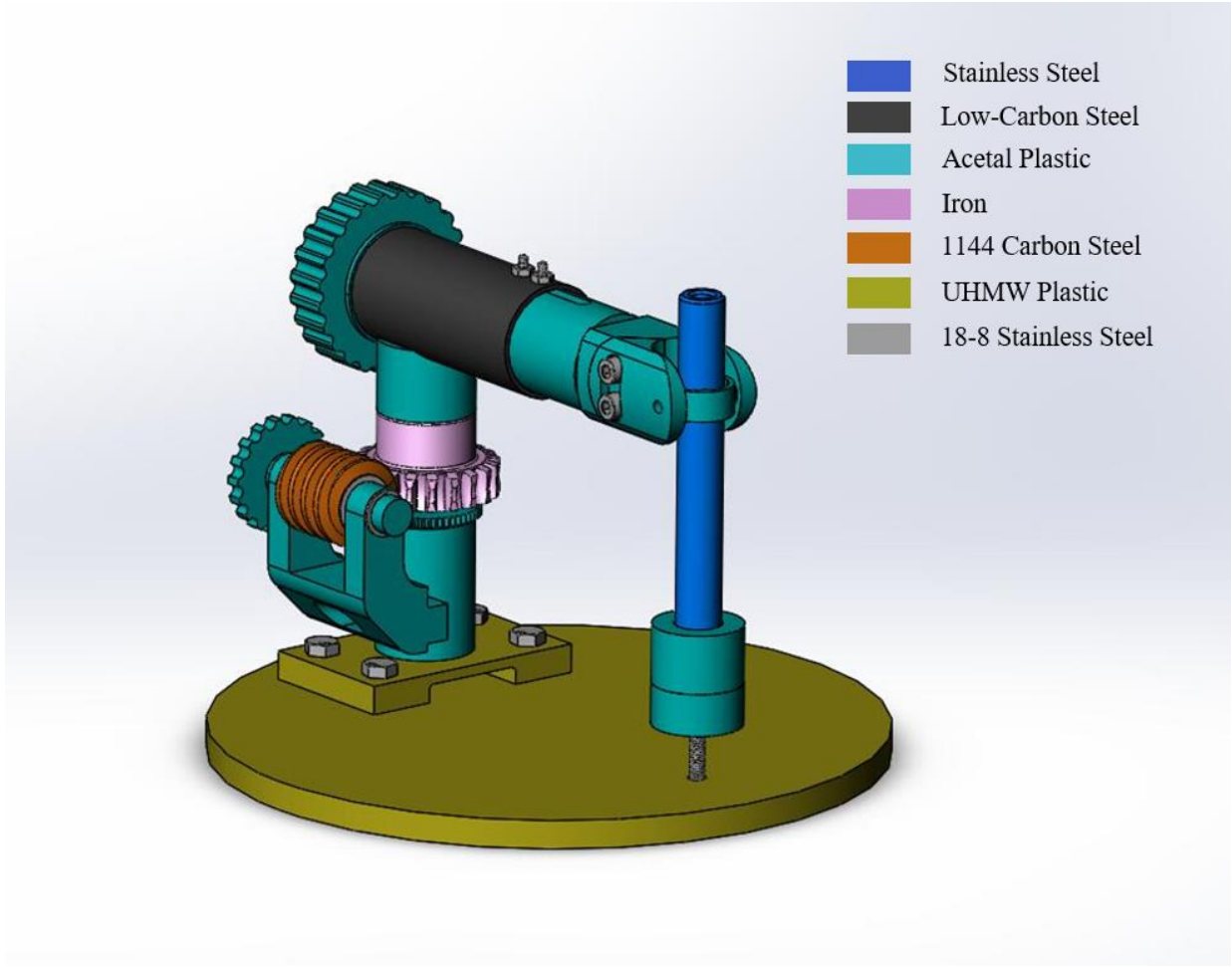


In this system， two adIjustment bolts control two degrees of freedom.

System Requirements		
Adjustment range	±10°	
Adjustment accuracy	<0.4°	
Take off mass	< 500g	
System size	≈220mm×220mm×200mm	
Working temperature	0℃-40℃	
Control dimensions	2-axis(roll pitch)	✓

DFM

This is the design for manufacturability of these two systems. As shown in the figure, different colors represent different materials.



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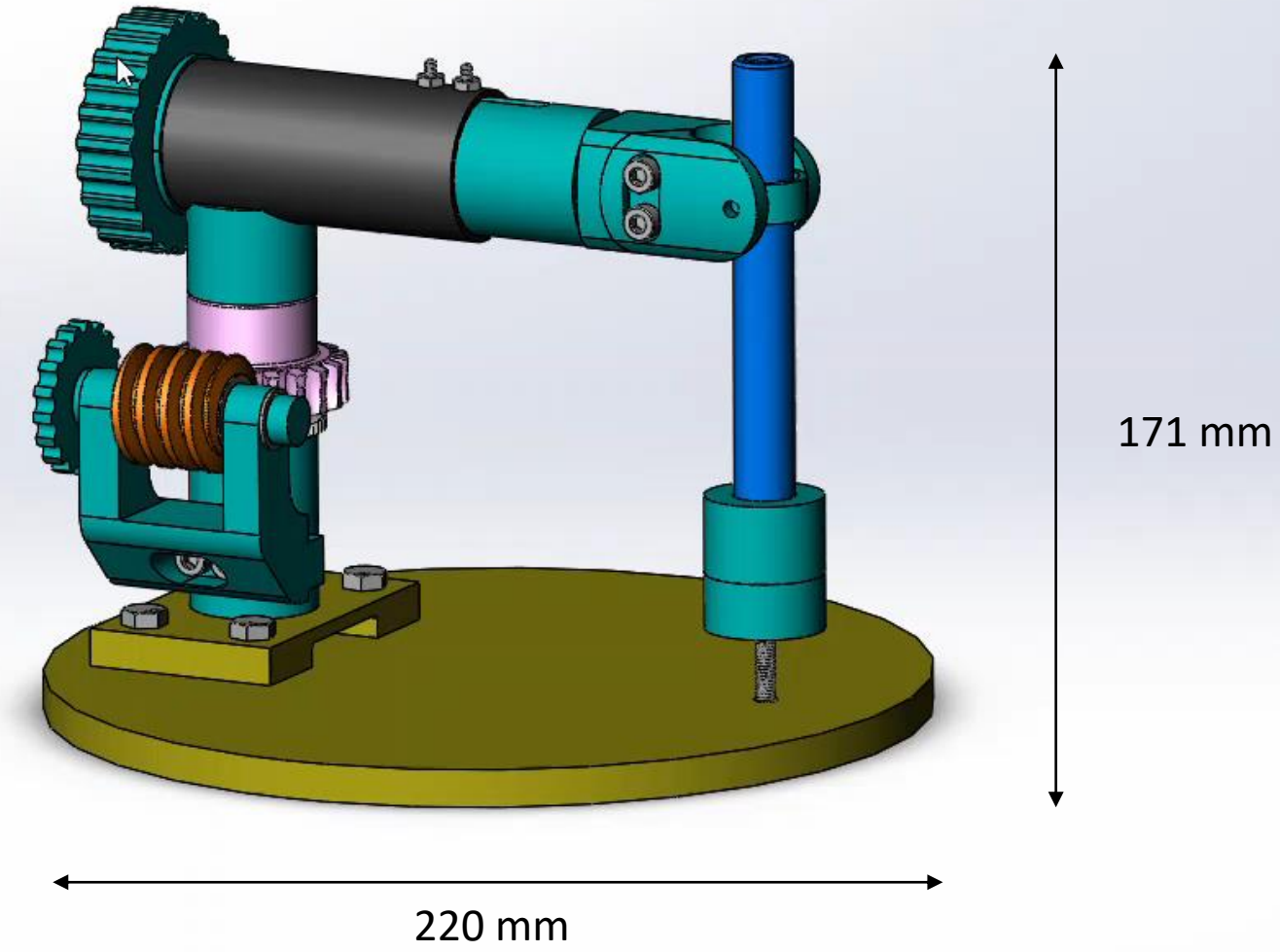
171 mm
220 mm

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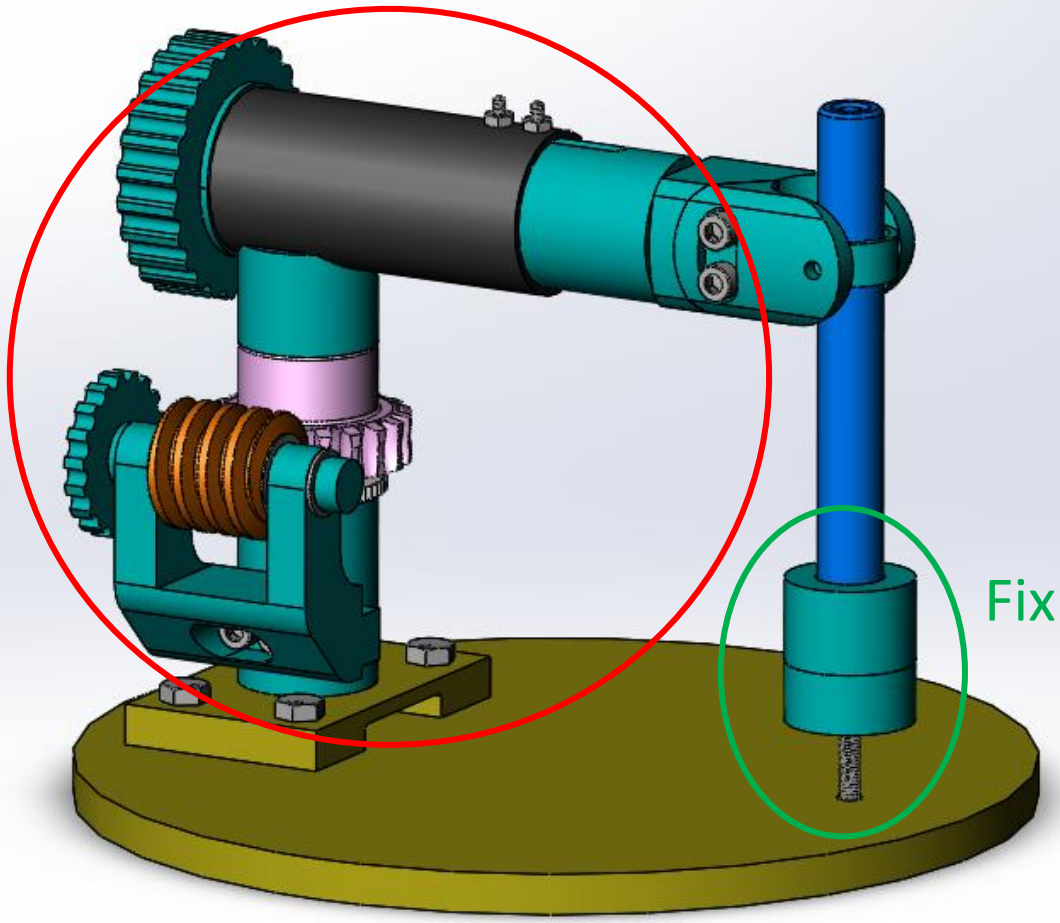
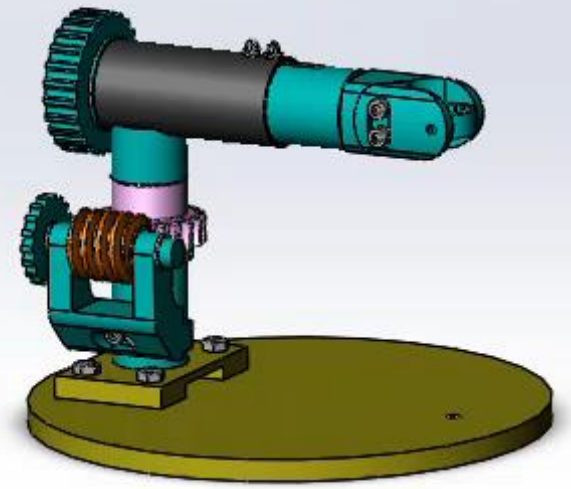
Adjustment Mechanism

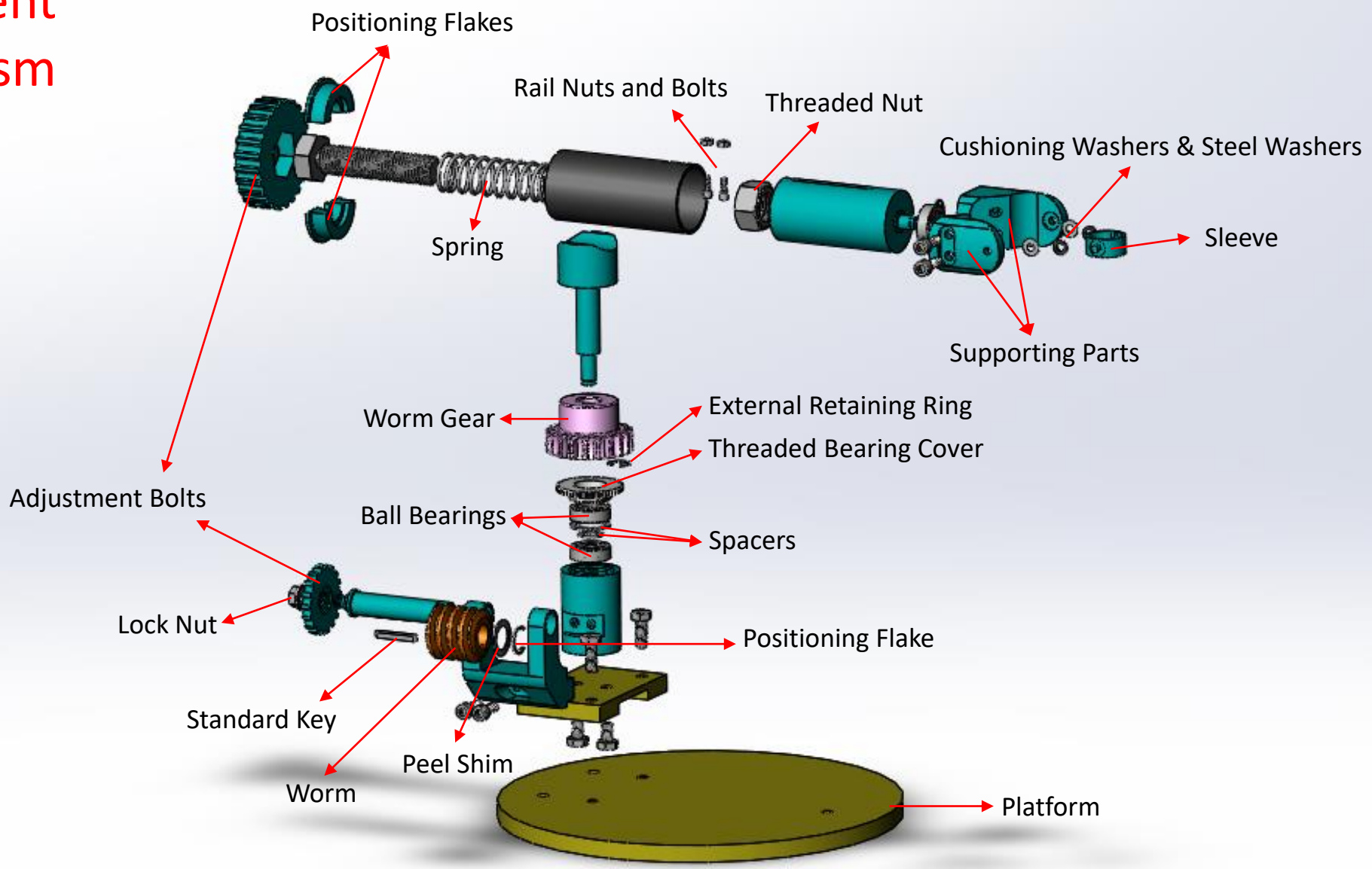


Fixing Mechanism

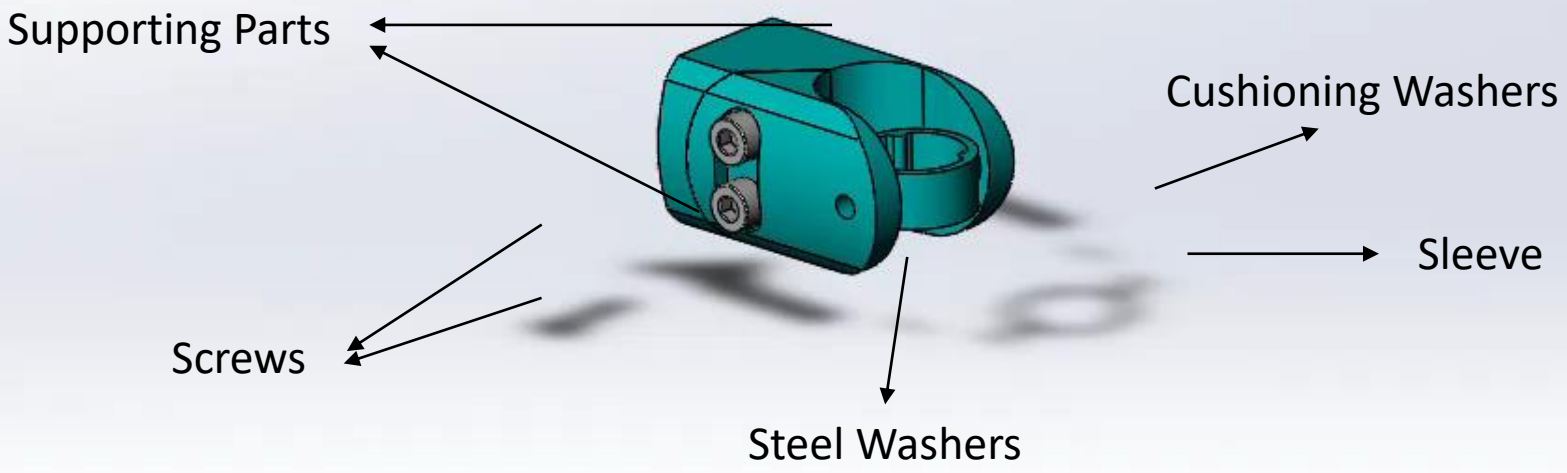
Adjustment Mechanism



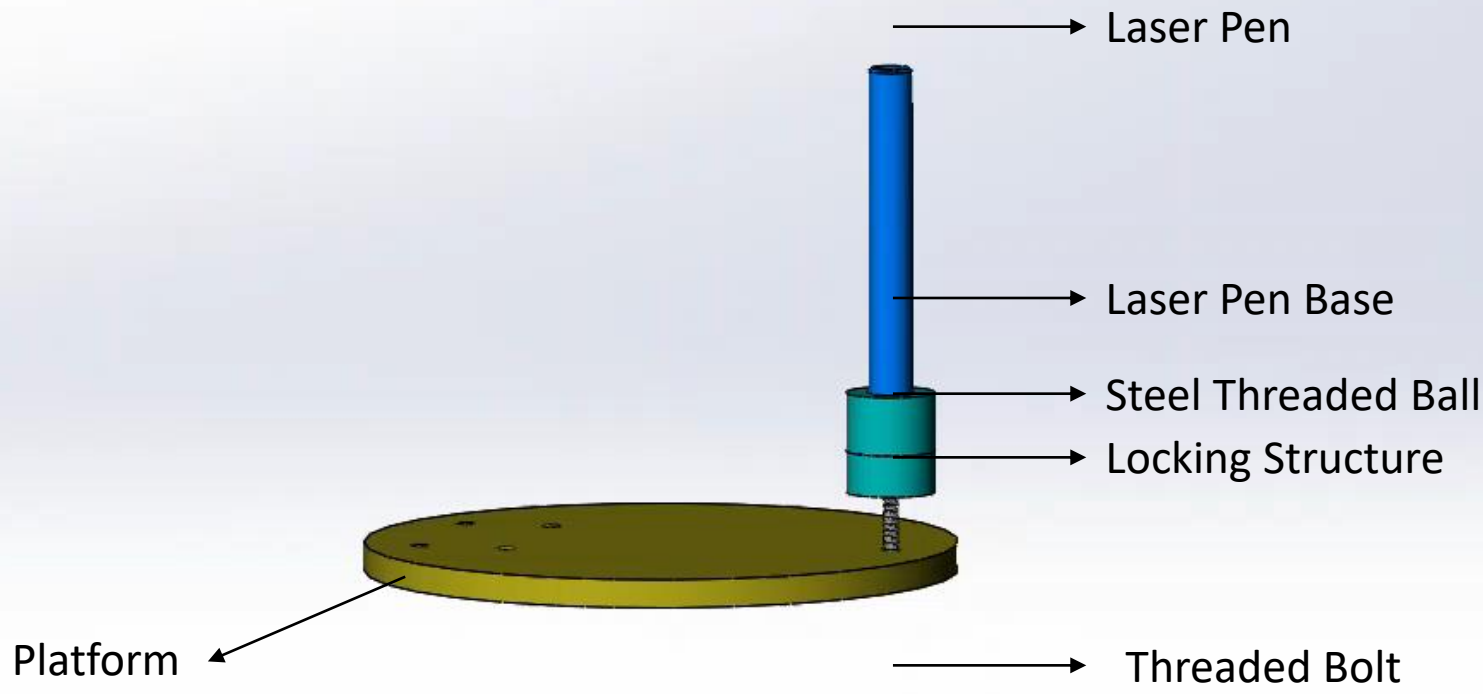
Adjustment Mechanism



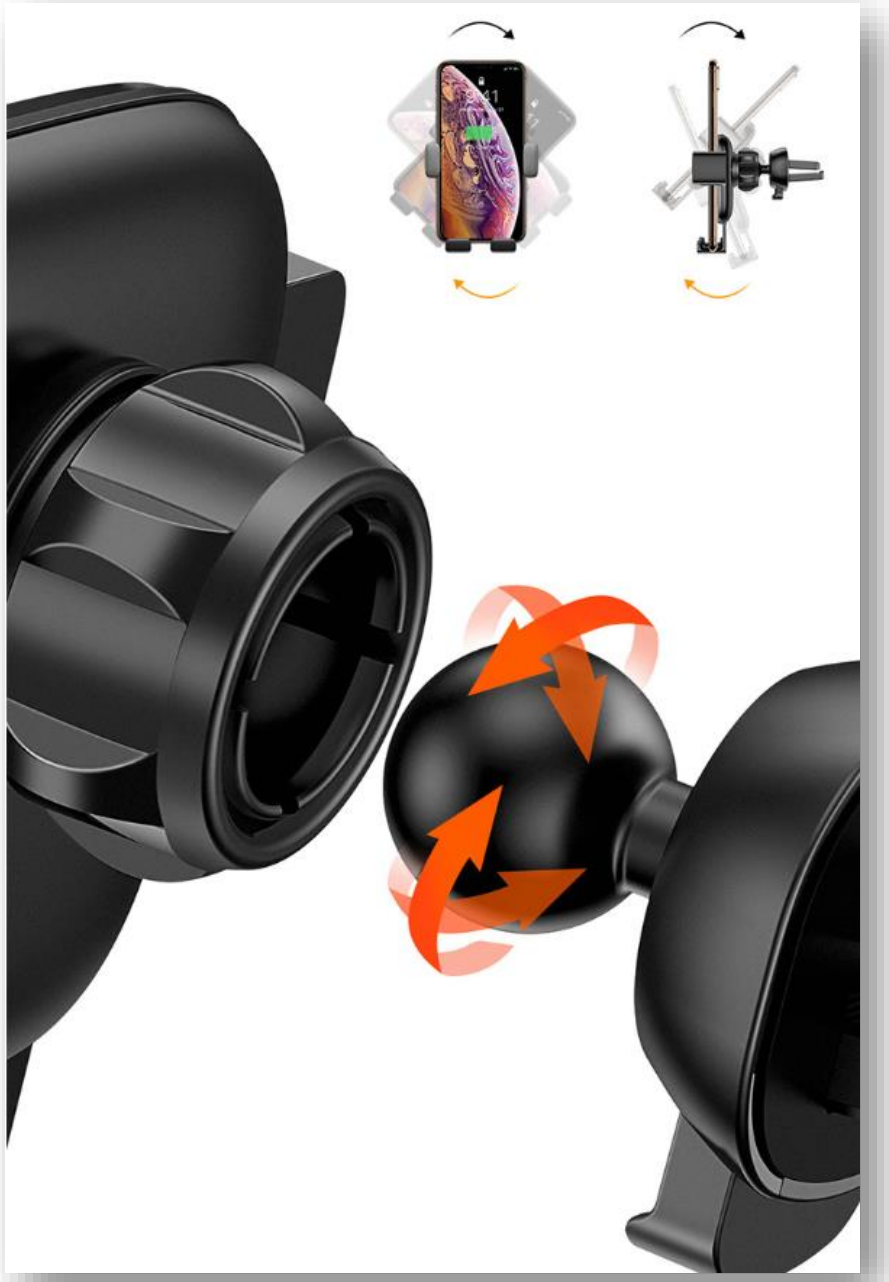
Sleeve Parts



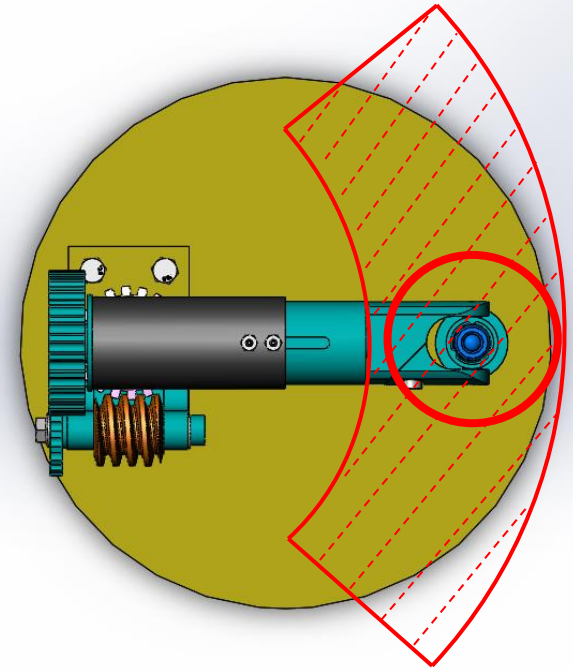
Fixing Mechanism

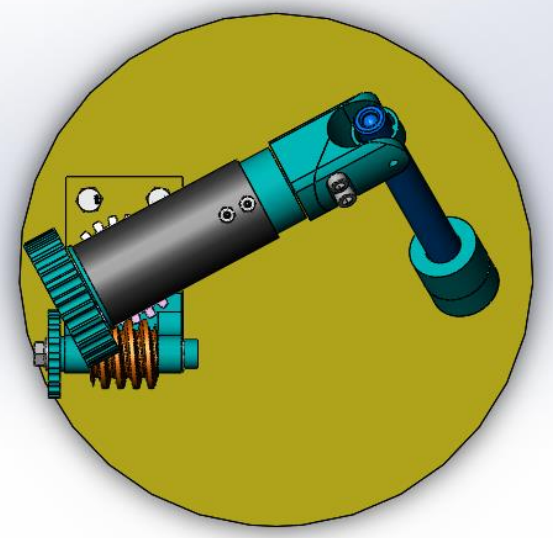


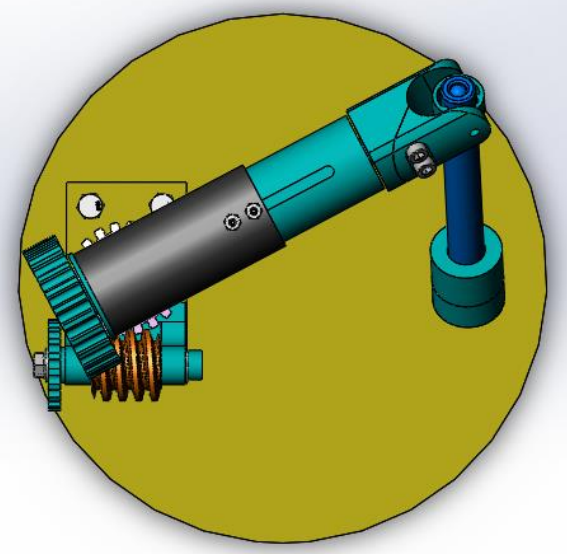
Ball Joint

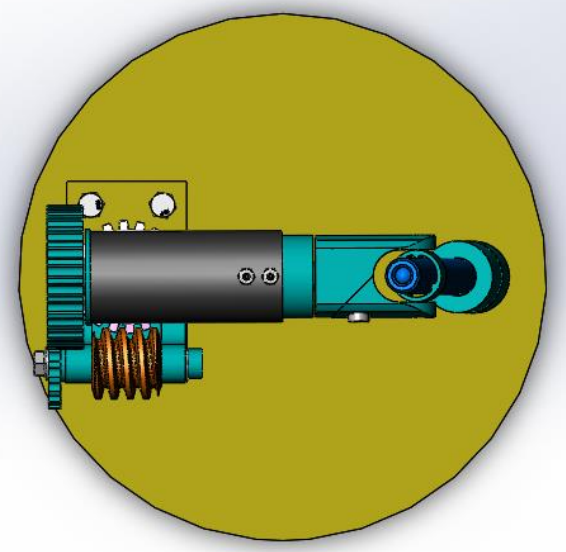


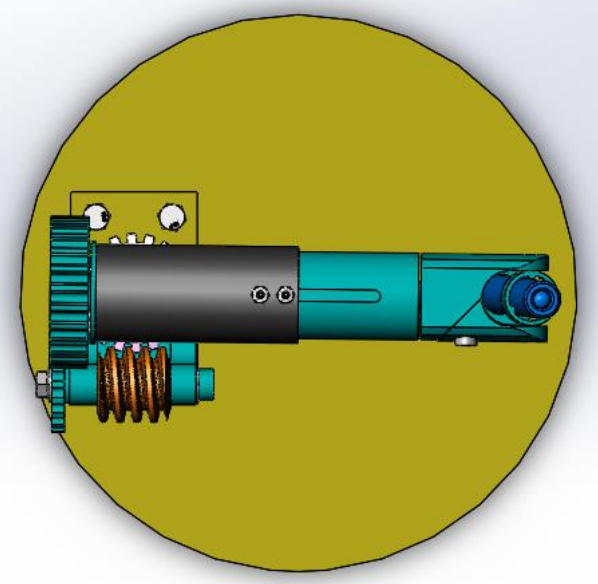
Movement Range

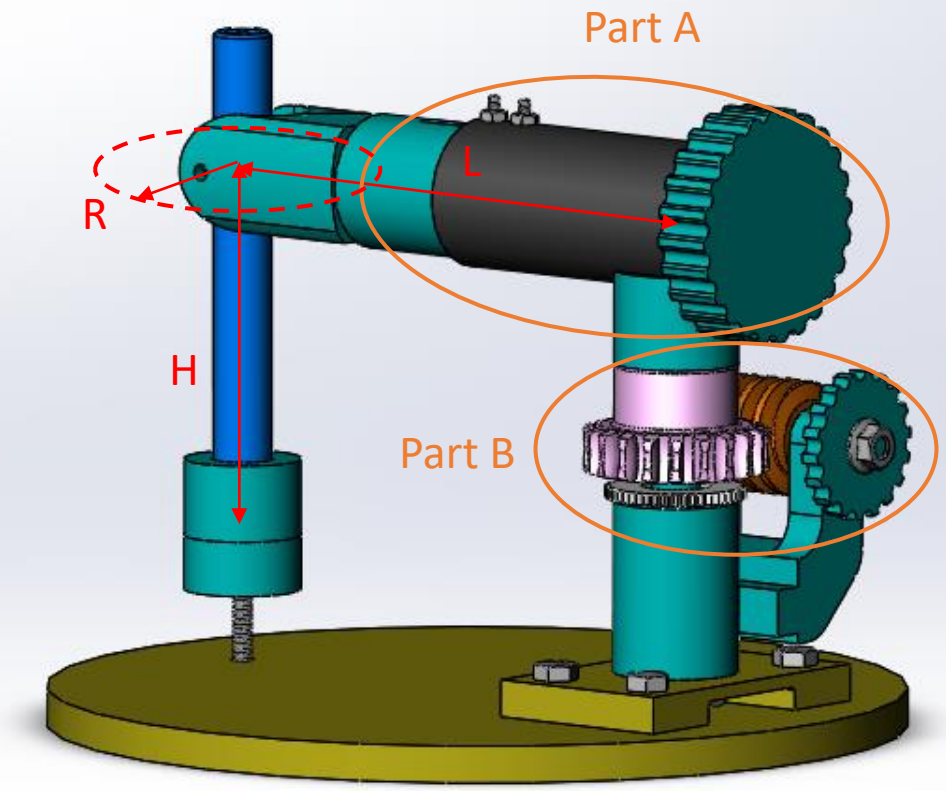












Adjustment Accuracy

Height from the Rod to the Ball Joint (H): 95 mm

Expected adjustment angle of laser pen: 10°

Angle range of the system:30 °

Radius from the base center to the pen (L): 140 mm

Radius of laser pen center (R): 16.75 mm

Radius range of the system: 17.35 mm

Adjustment Accuracy

Because the power of this structure is hand, it's hard to calculate the accuracy of this system. Here we assume the minimum adjustment angle of hand is 4°.

Part A

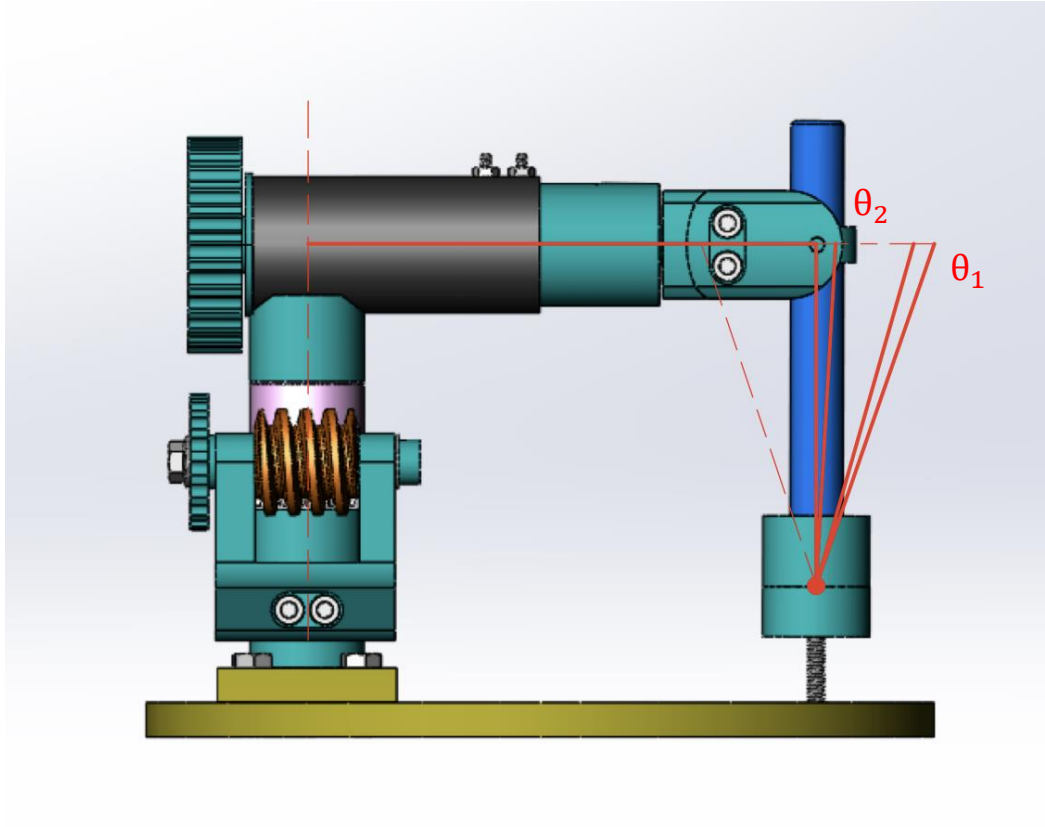
Pitch of the Higher Adjusting Bolt: 2mm

Minimum Adjustment Length of R: 2mm×(4°/360°)=0.0222mm

Minimum Adjustment Angle of Bolt:

$$\theta_1 = 10° - \arctan(\frac{16.75-0.0222}{95}) = 0.0136°$$

$$\theta_2 = \arctan(\frac{0.0222}{95}) = 0.0134°$$



Part B

Speed Ratio: 20:1

Angle per Pitch of the Worm Gear: 360°/20=18°

Worm Gear Minimum Rotation angle: 18°×(4°/360°)=0.2°

Adjustment Angle of the Lower Gear: 0.18°

Minimum Adjustment Angle of Worm Gear:

$$\sqrt{H^2 + R^2} = 96.47mm$$

$$\Delta_1 = \left(\frac{0.2}{360}\right) \times 2\pi(L + R) = 0.547mm$$

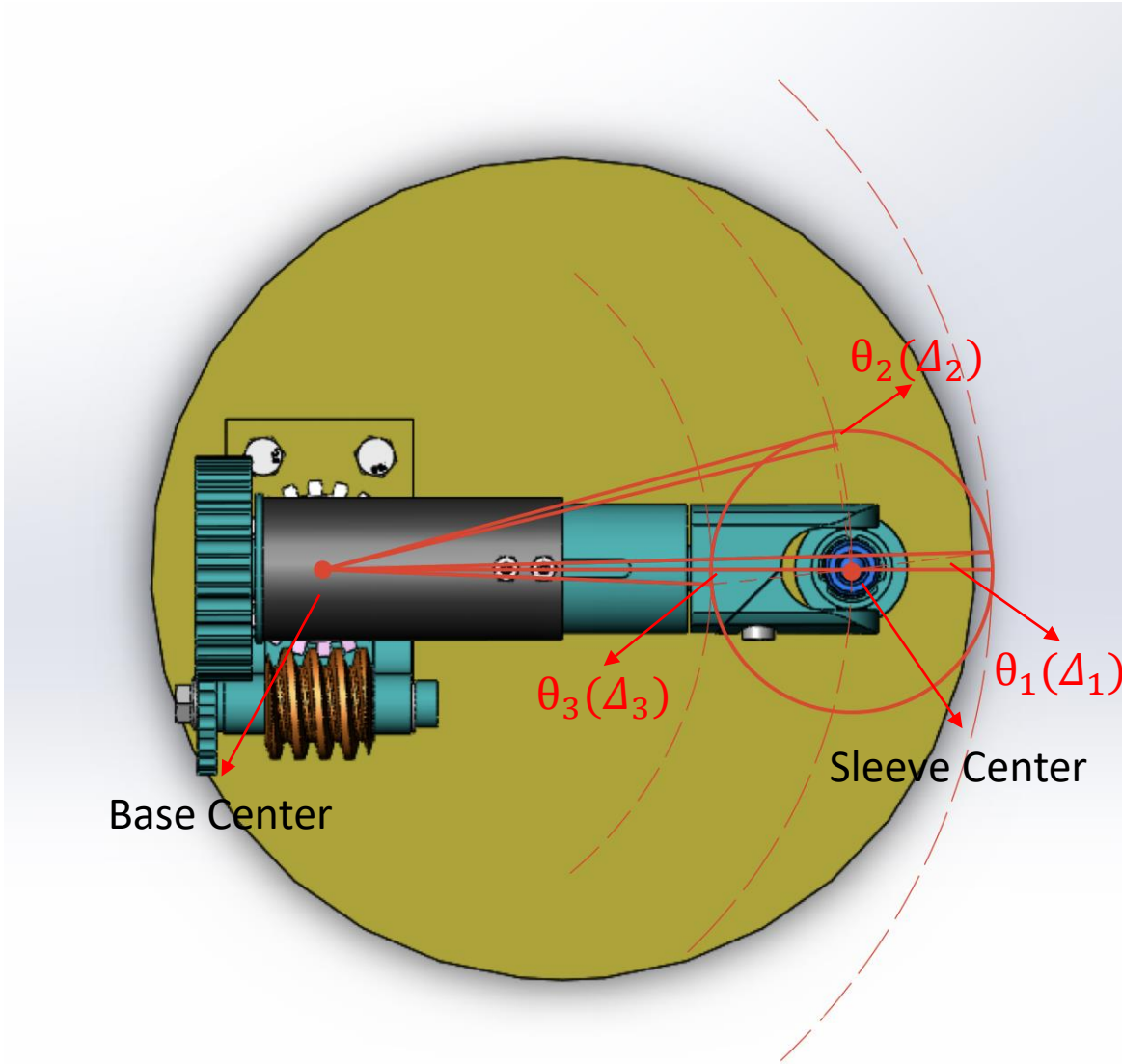
$$\theta_1 = \arcsin\left(\frac{0.547}{96.47}\right) = 0.325°$$

$$\Delta_2 \approx \left(\frac{0.2}{360}\right) \times 2\pi L = 0.489mm$$

$$\theta_2 = 10° - \arctan\left(\frac{16.75-0.489}{95}\right) = 0.287°$$

$$\Delta_3 = \left(\frac{0.2}{360}\right) \times 2\pi(L - R) = 0.430mm$$

$$\theta_3 = \arcsin\left(\frac{0.430}{96.47}\right) = 0.256°$$



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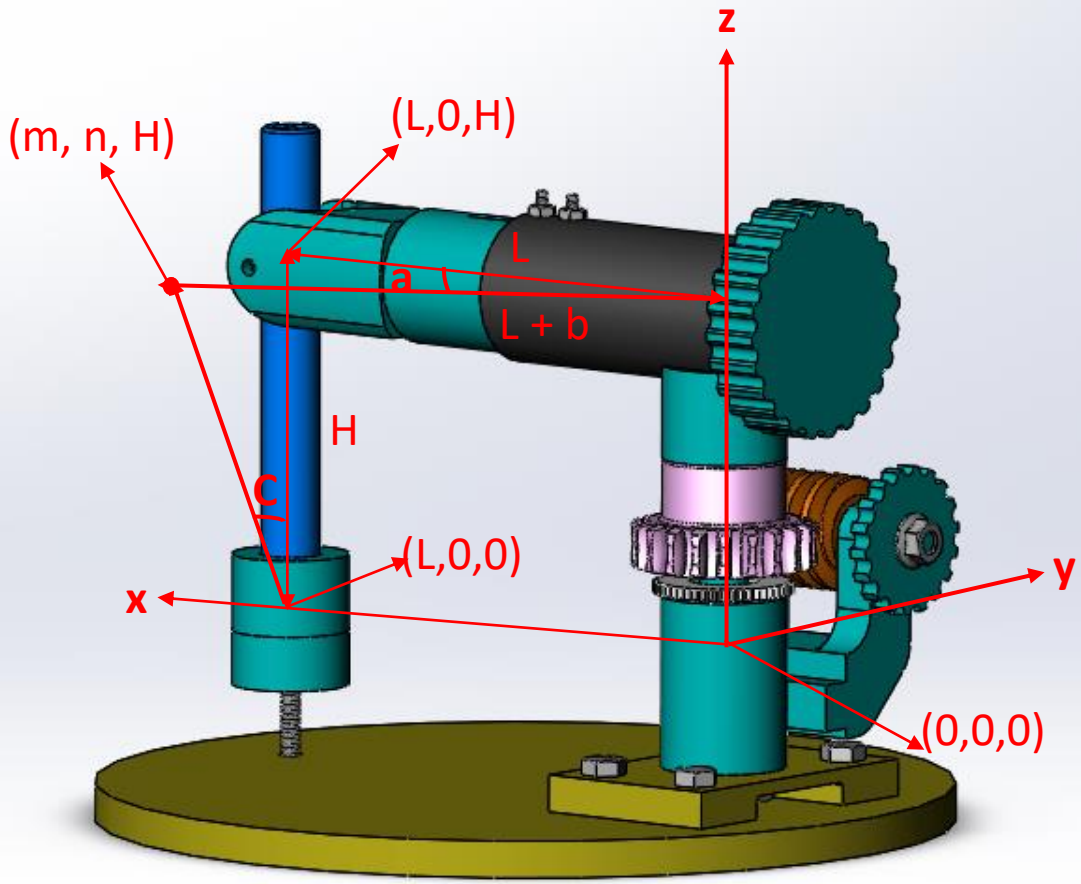


Movement Range

m=(L+b).*cos(a);
n=(L+b).*sin(a);
C=acos(H/((m-L)^2+n^2+H^2)^0.5);
L=140， H=95

Part of the matlab code
m=(140+B).*cos(A/180*pi);
n=(140+B).*sin(A/180*pi);
k=m-140;

C=acos(95./sqrt(k.*k+n.*n+95^2))*180/pi;
C=real(C);

Minimum Adjustment Length of R: 2mm×(4°/360°)=0.0222mm

Worm Gear Minimum Rotation angle: 18°×(4°/360°)=0.2°
Angle range of the system:30 °
Radius range of the system: 17.35 mm

Part of the MATLAB code

```
a=linspace(-30,30,301);
b=linspace(-17.35,17.35,1564);
[A,B] = meshgrid(a,b);
```

1x301 double

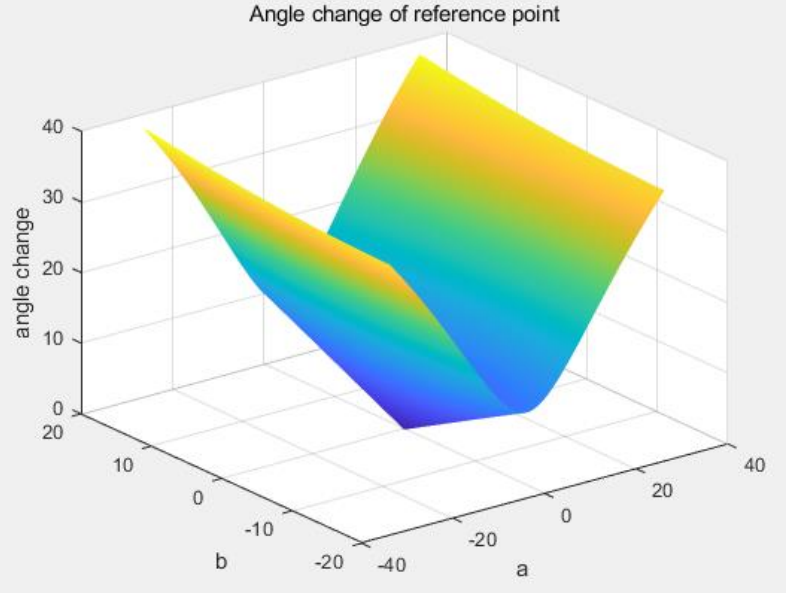
	1	2	3	4	5	6	7	8	9	10	11	12
1	-30	-29.8000	-29.6000	-29.4000	-29.2000	-29	-28.8000	-28.6000	-28.4000	-28.2000	-28	-27.8

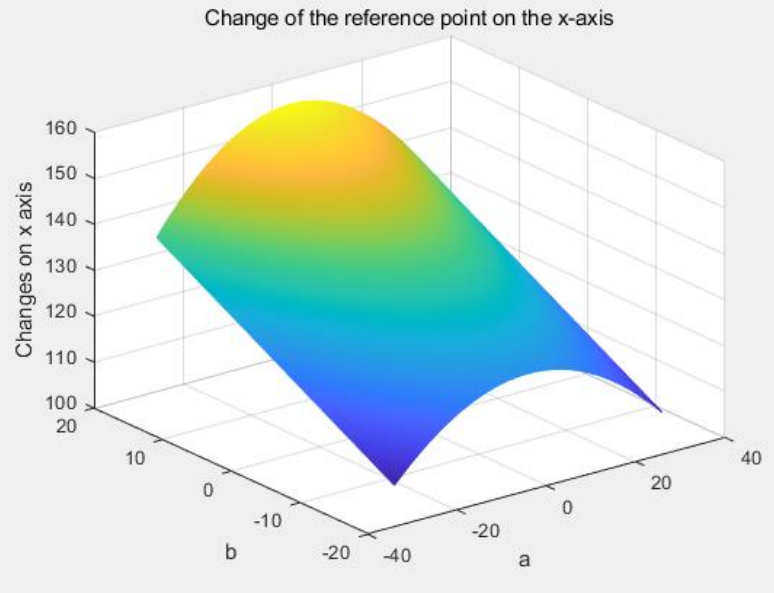
1x1564 double

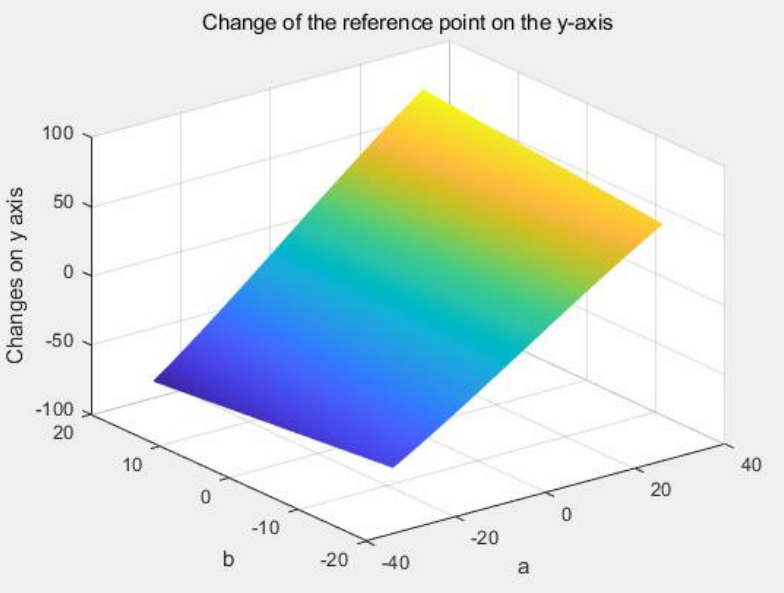
	1	2	3	4	5	6	7	8	9	10	11	12
1	-17.3500	-17.3278	-17.3056	-17.2834	-17.2612	-17.2390	-17.2168	-17.1946	-17.1724	-17.1502	-17.1280	-17.1

Movement Range

Draw the relationship between input a, b and output m, n, c
in the form of image in MATLAB







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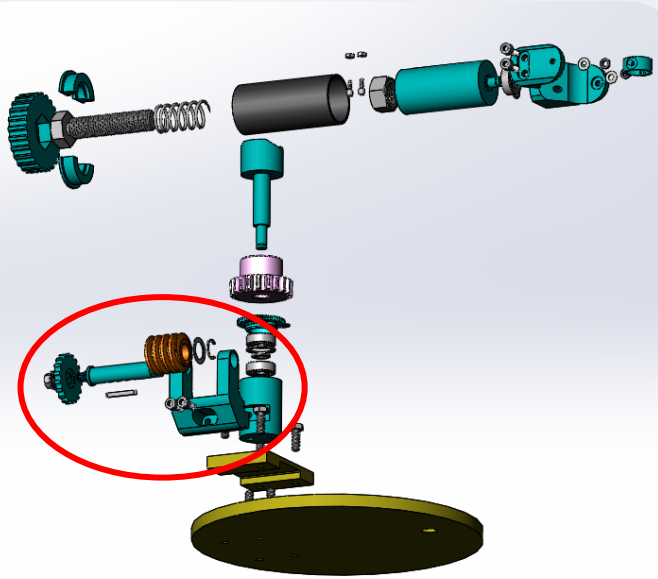
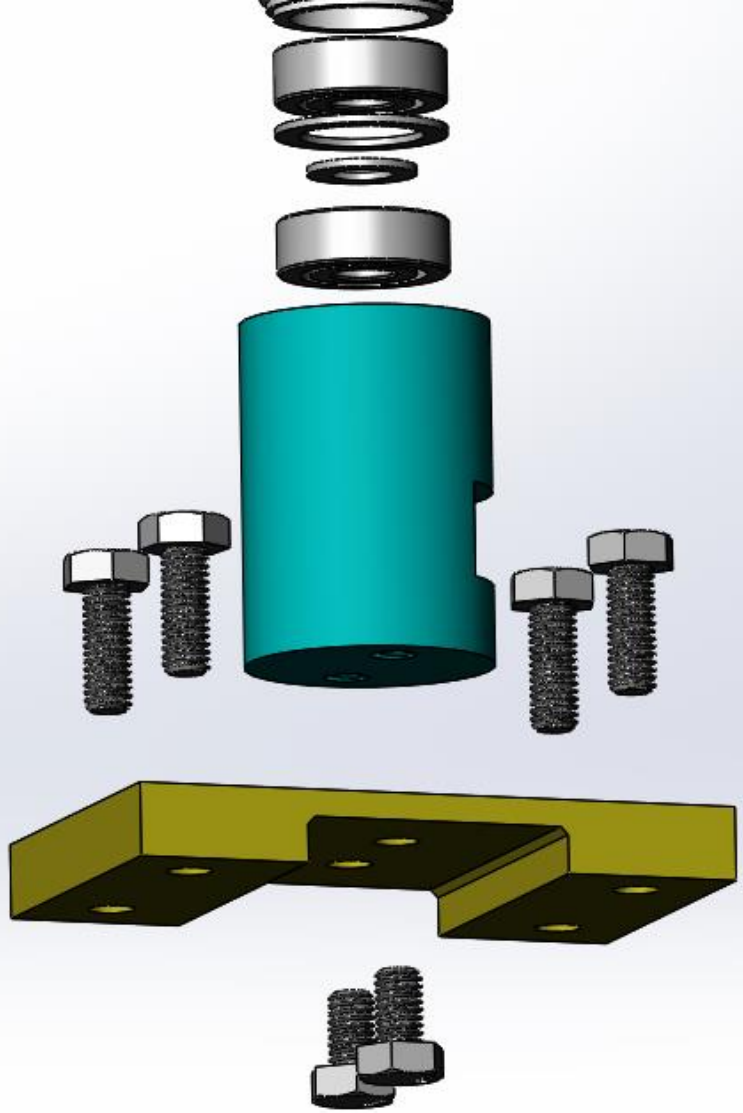
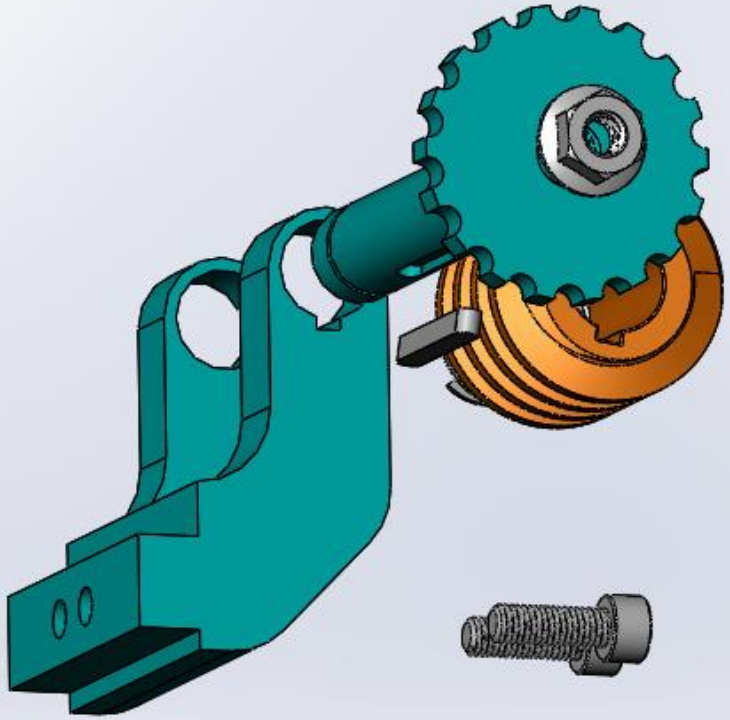
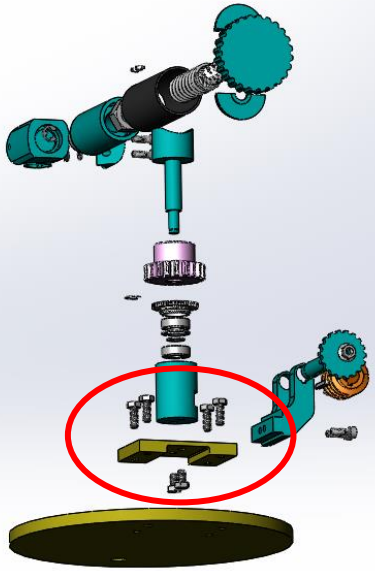
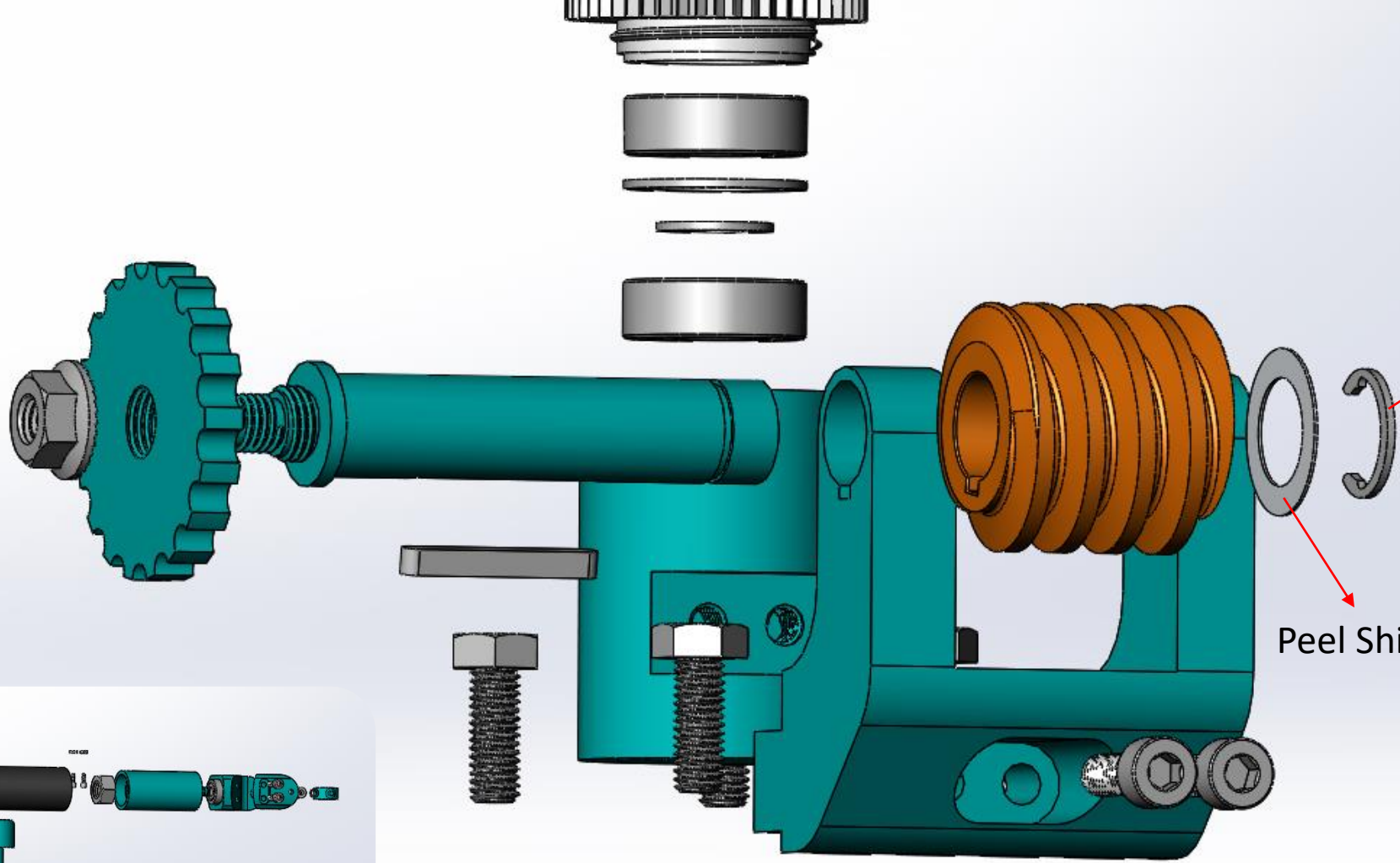
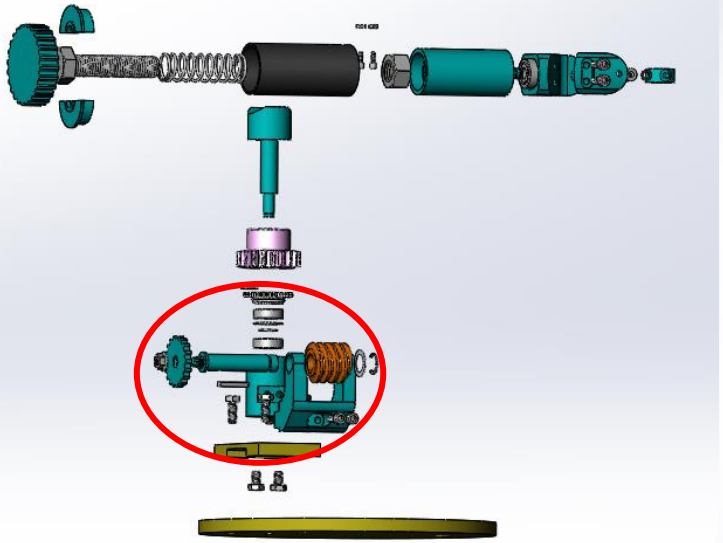


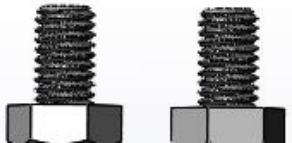


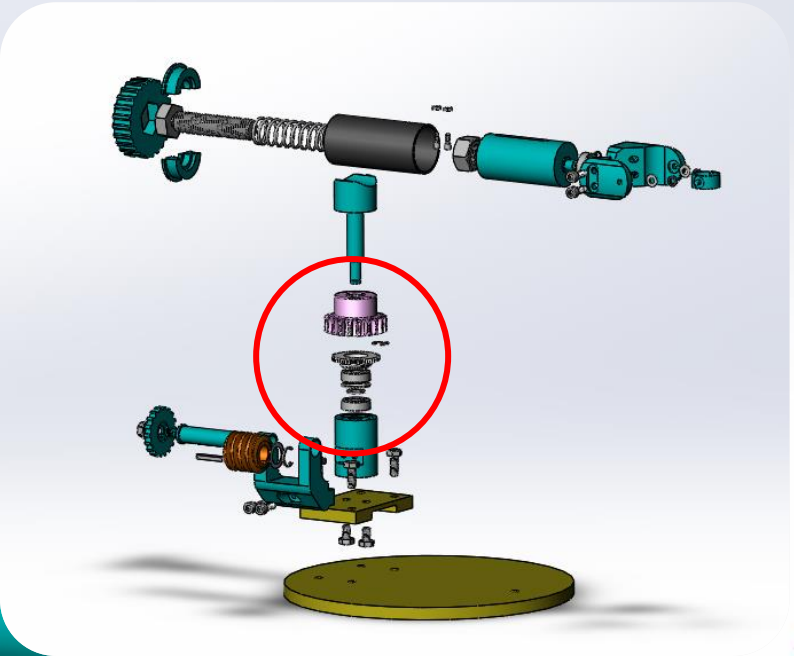


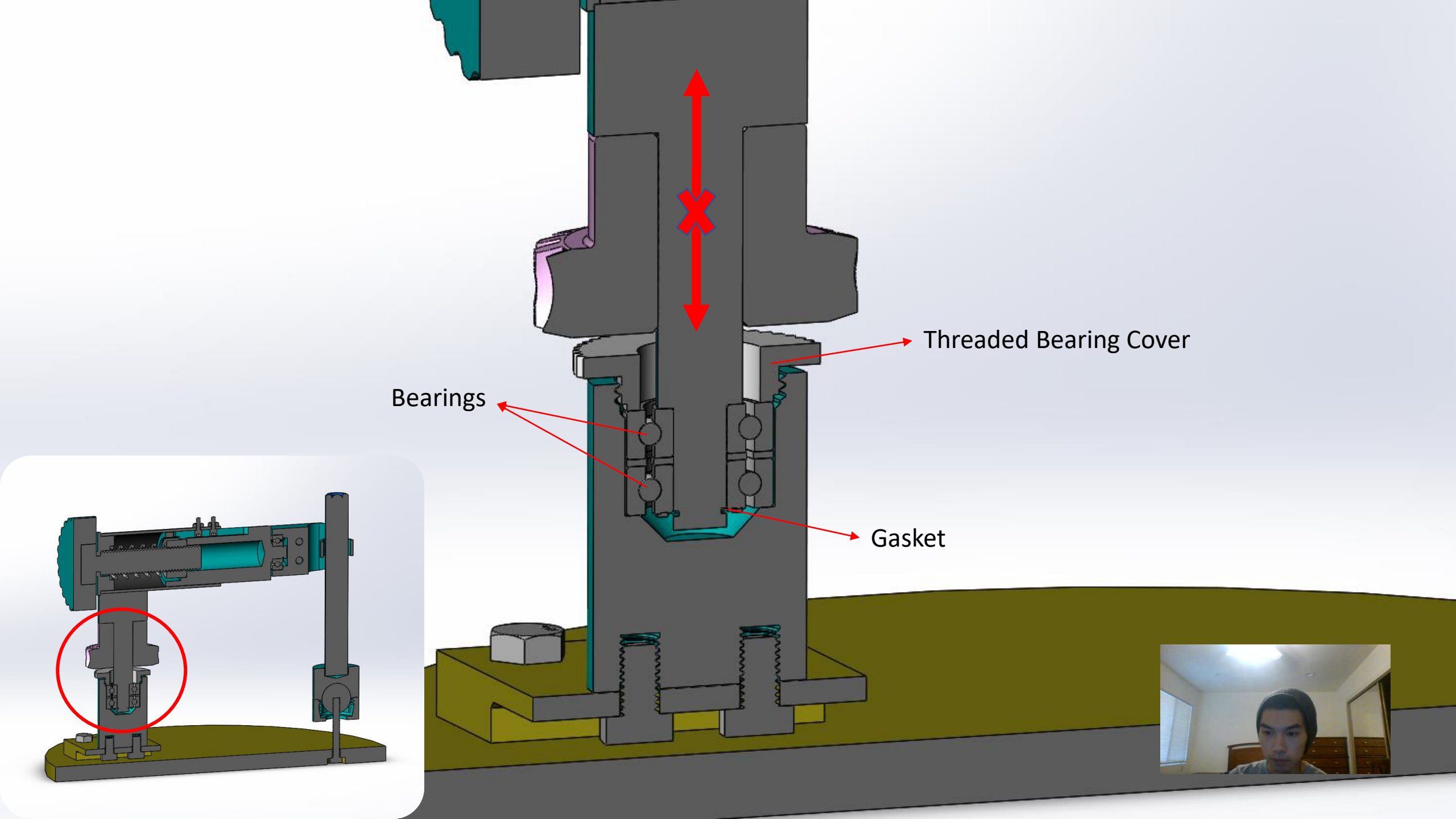


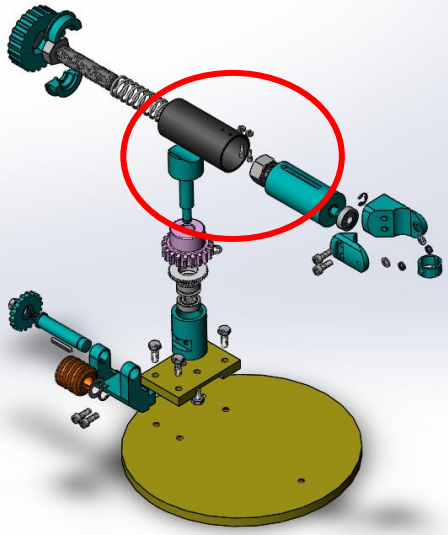

Positioning Flake
Peel Shim

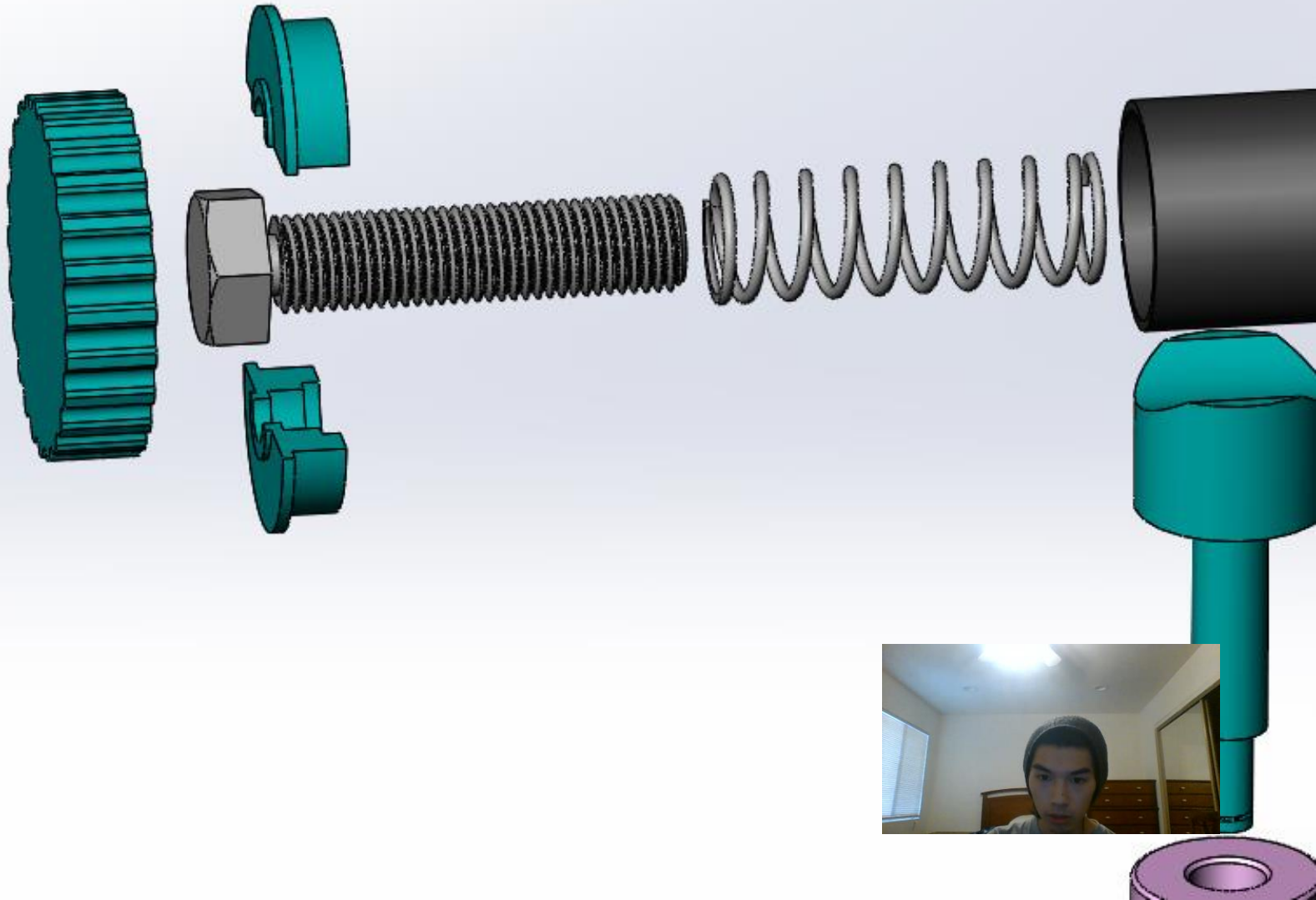


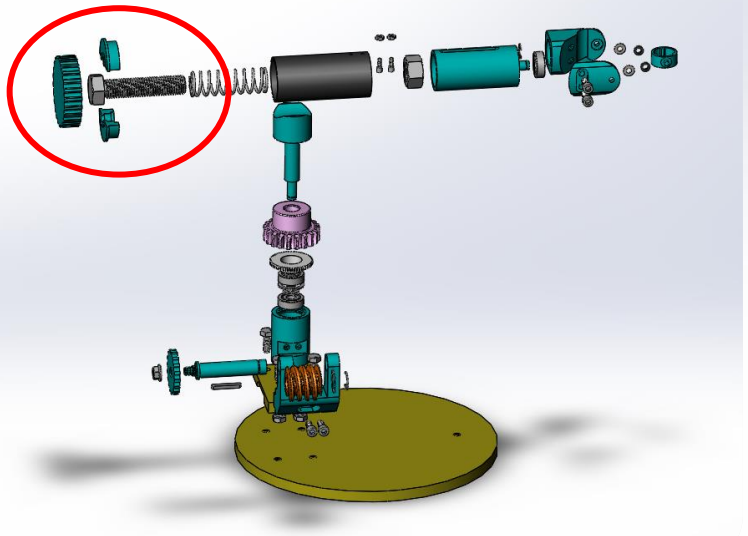


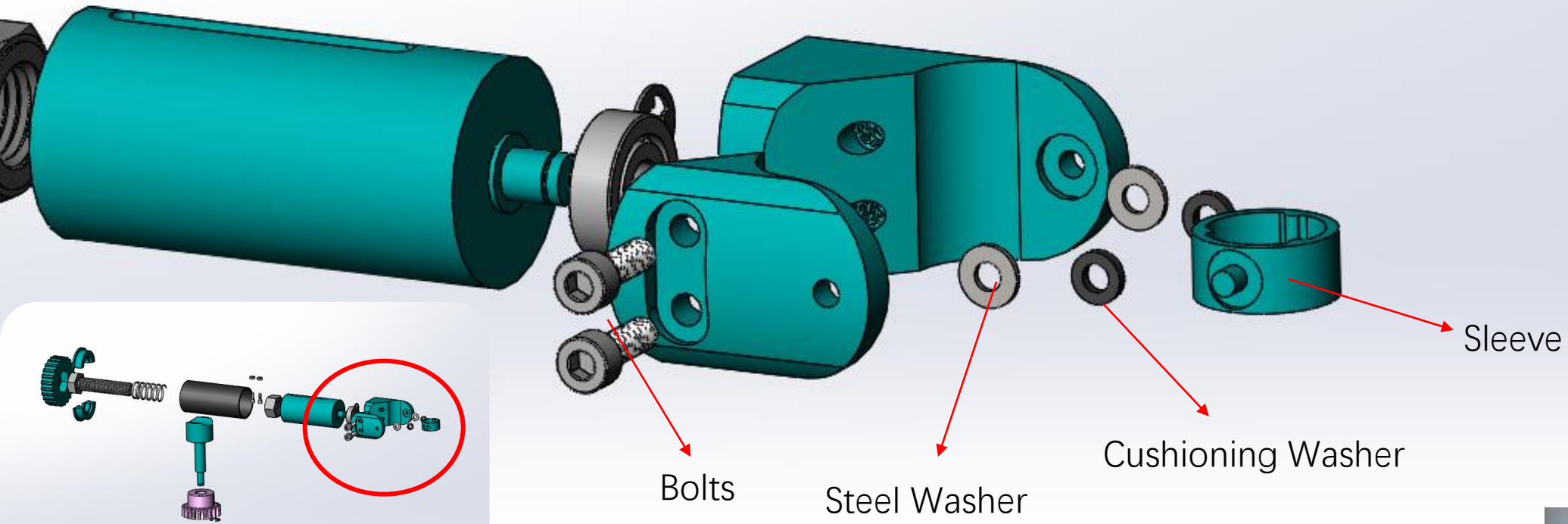



Threaded Bearing Cover
Bearings
Gasket








Sleeve
Bolts
Steel Washer
Cushioning Washer

Q&A

Thanks for watching.