

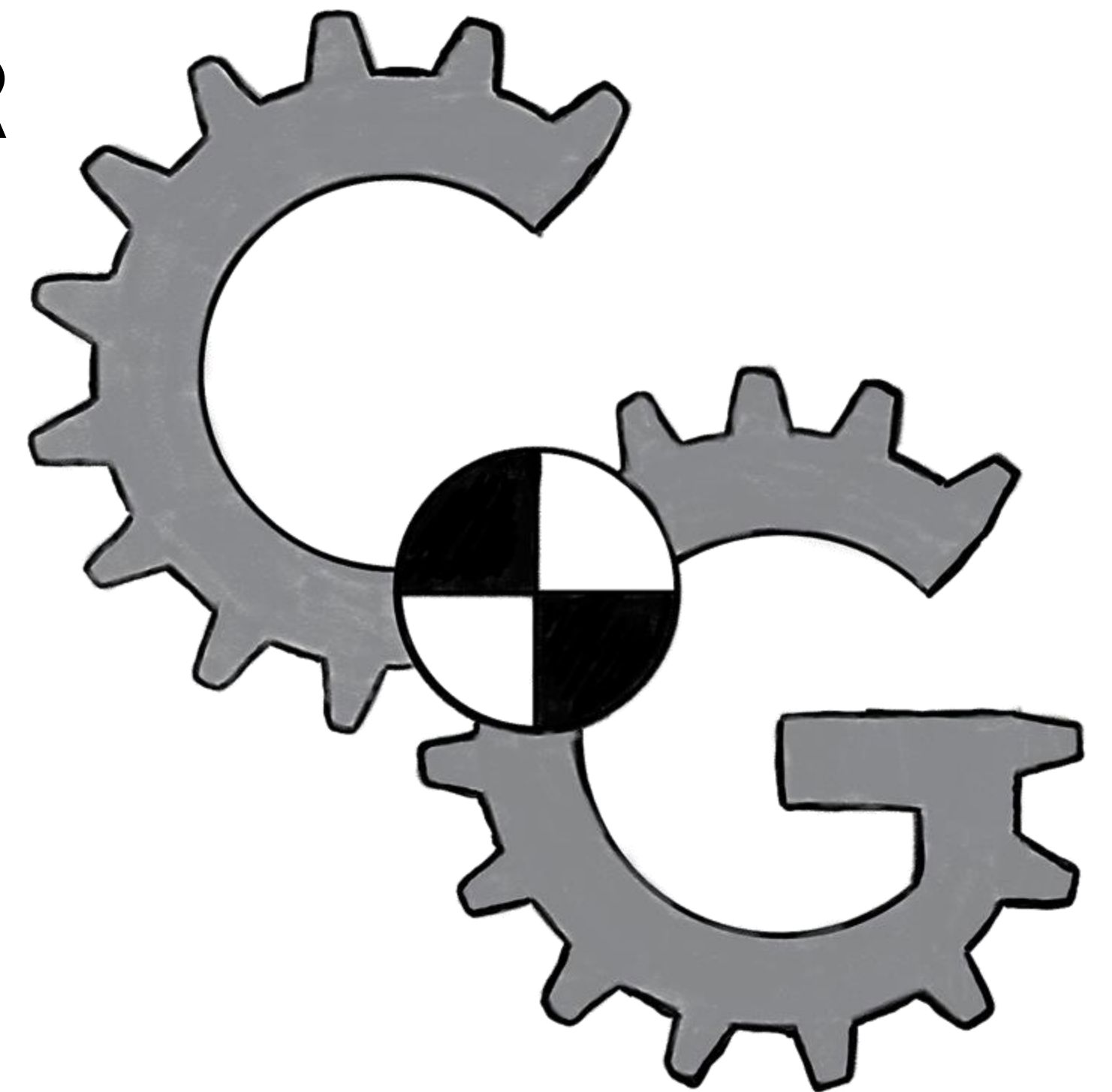


University of Idaho

College of Engineering

3-AXIS CENTER OF GRAVITY INSTRUMENT

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KENDALL GRAY
ERIC SMEAD**



INTRODUCTION



I Center of Gravity

I Natural Frequency of Entire Device

I Strain on Server Rack Mount Ears

PROJECT REQUIREMENTS

MECHANICAL

- I Automatic
- I Vibration Test
- I 50 lbs
- I 24" x 12" x 20"
- I Rack Mount Capabilities
- I Re-creatable

ELECTRICAL

- I 1.0% Accuracy
- I 120 VAC

SOFTWARE

- I Average Cartesian CG

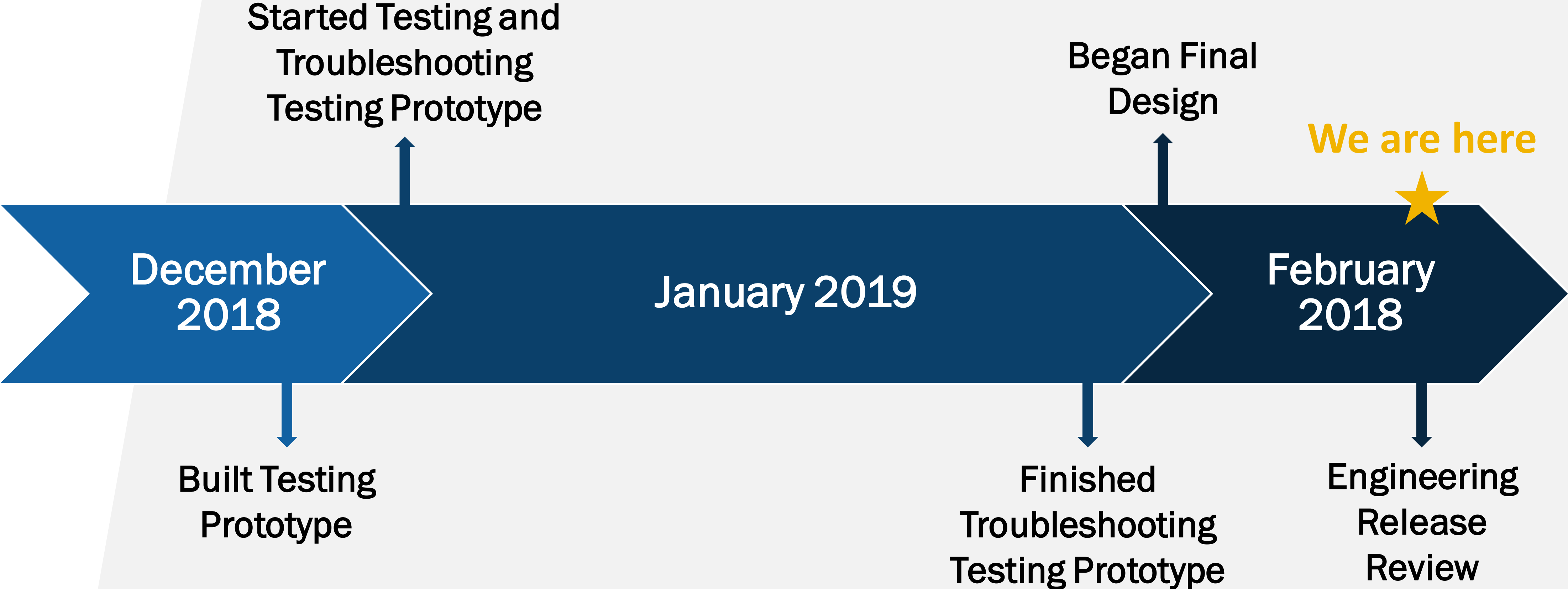
ENVIRONMENTAL

- I 60 to 85 °F

COST

- I \$1661

PROGRESS SINCE SNAPSHOT 2



TESTING PROTOTYPE PROGRESSION



First Design Iteration

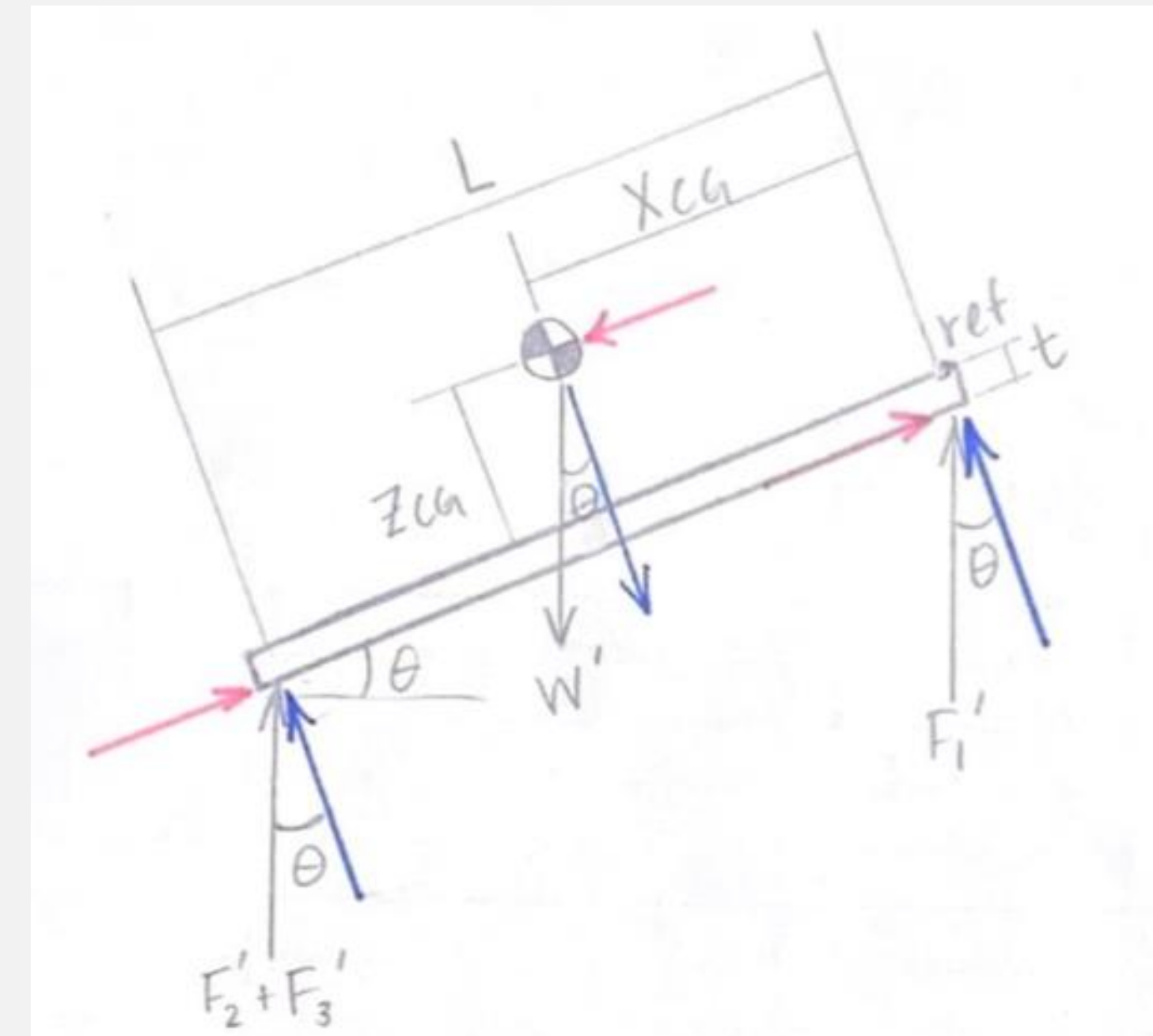
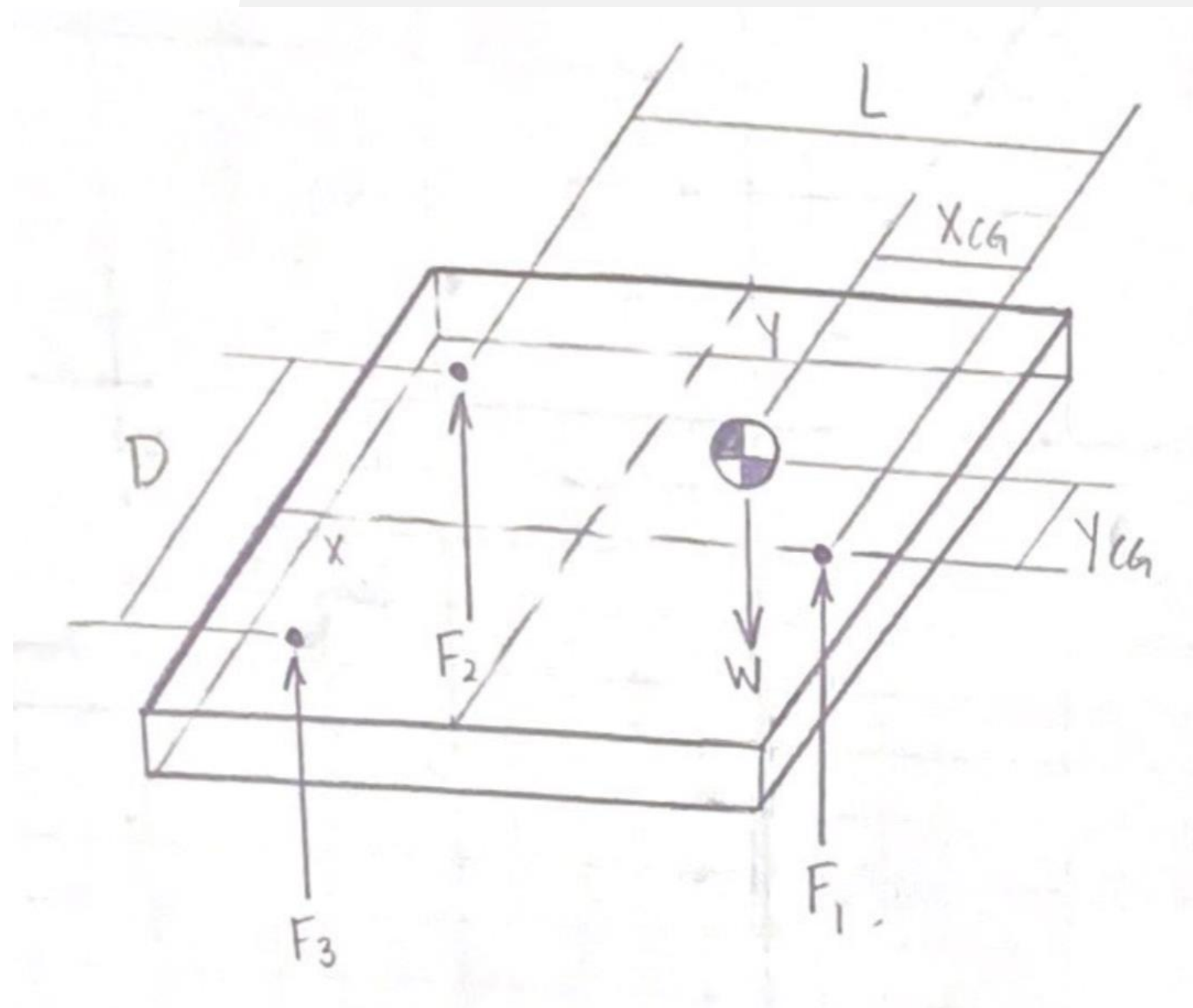


Second Design Iteration



Final Design Iteration

EQUATIONS



$$X_{CG} = \frac{(F_2 + F_3)L}{W}$$

$$Y_{CG} = \frac{(F_2 + F_3)D}{2W}$$

$$Z_{CG} = \frac{(F'_2 + F'_3) \cos \theta * L - W' (\sin \theta * t + \cos \theta * x_{CG})}{W' \sin \theta}$$

CG TESTING DATA

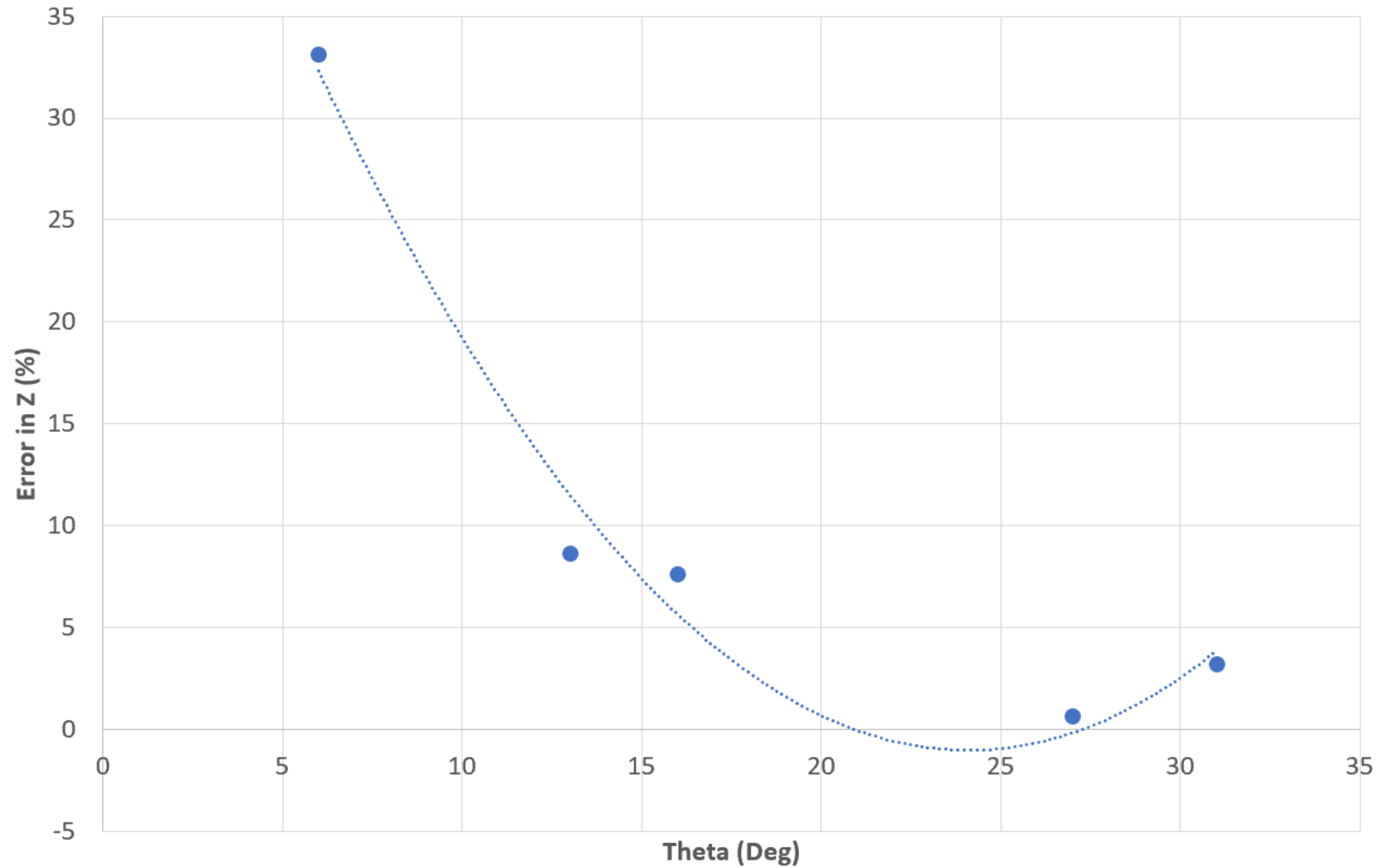
	Measured	Actual	Percent Error
X	2.7"	2.75"	2.1%
Y	2.6"	2.6"	2.9%
Z	1.8"	1.9"	3.6%



ANGLE STUDY

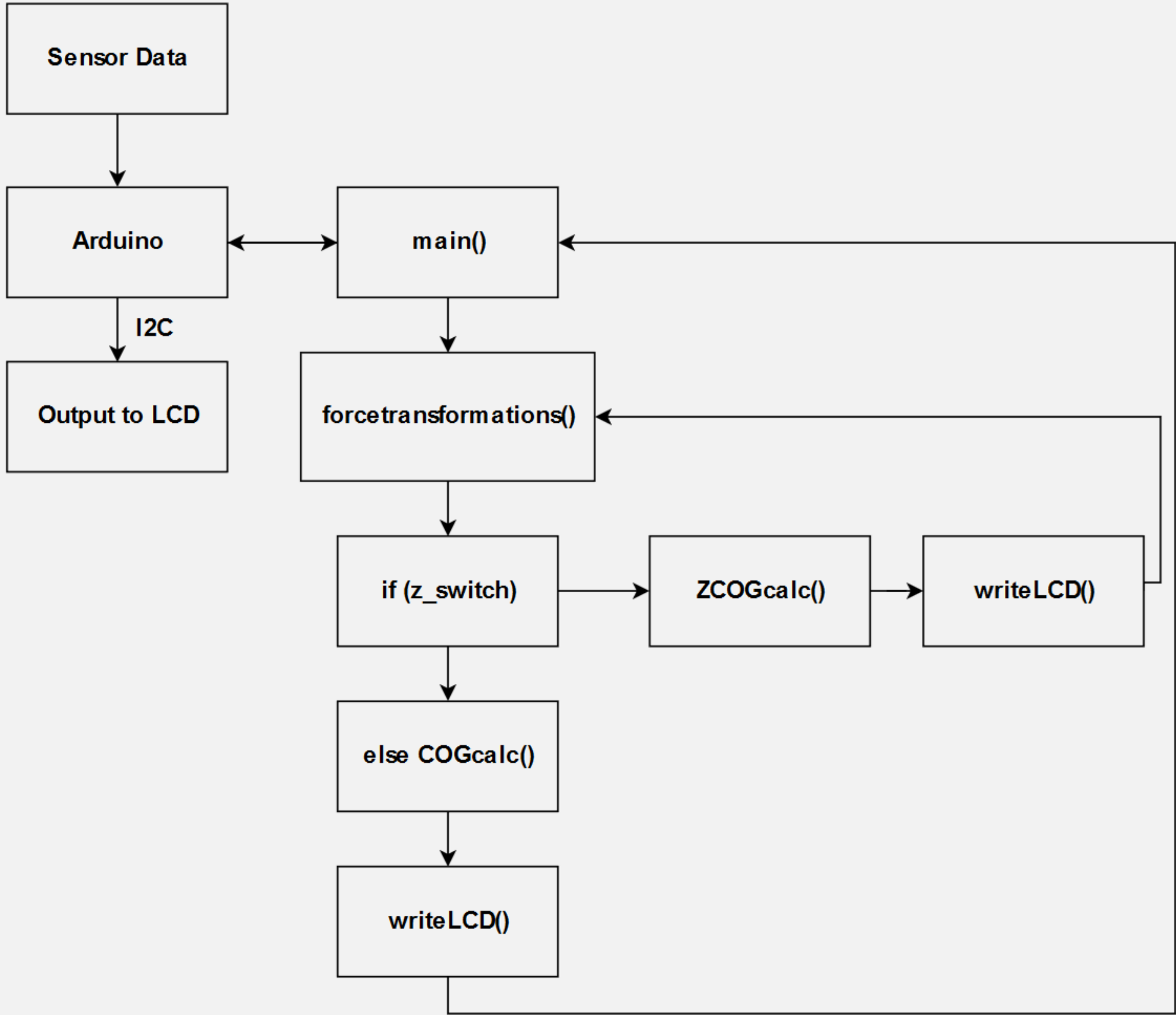


Error in Z vs. Theta

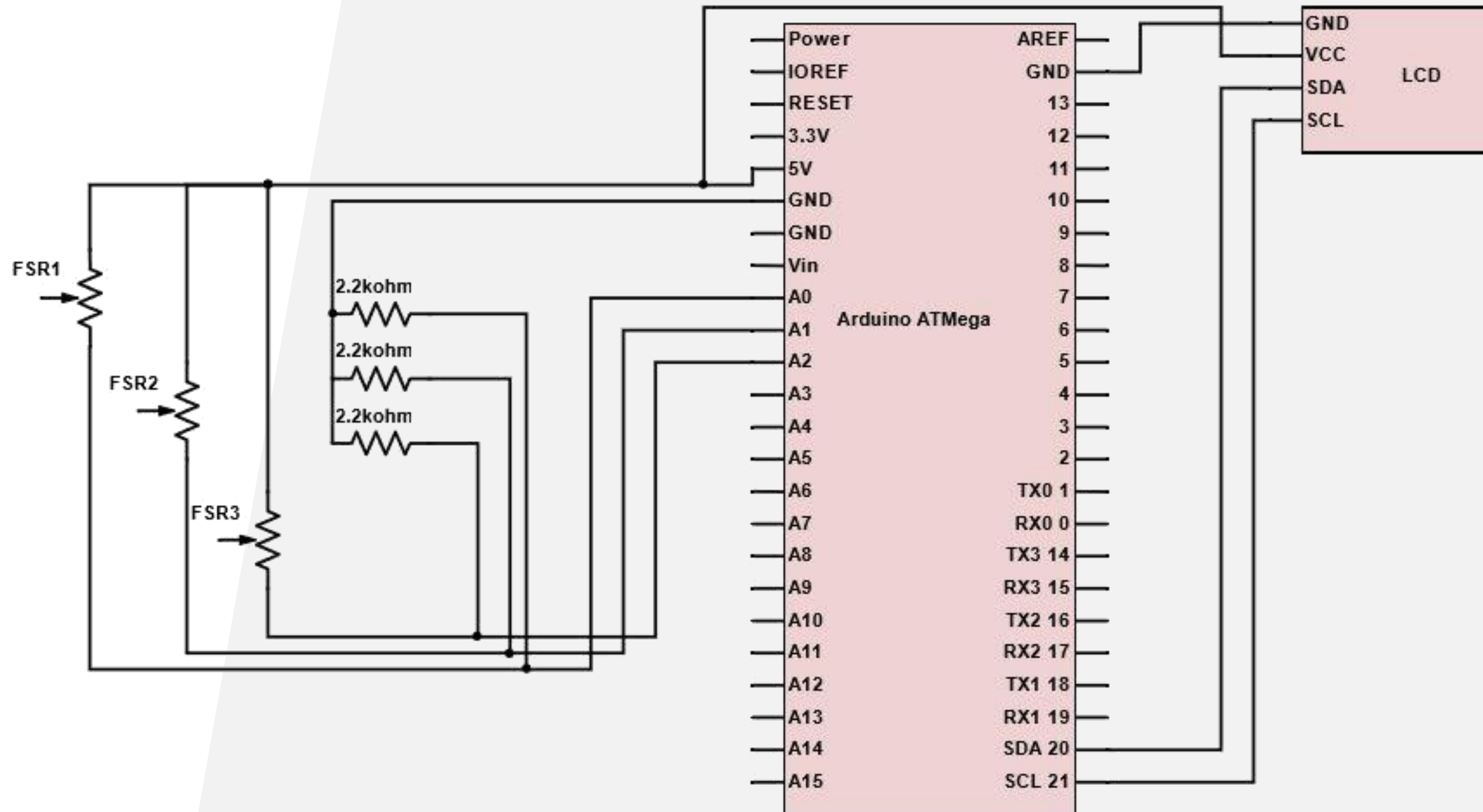


Theta	Error in Z
6°	33%
13°	9%
16°	8%
27°	0.6%
31°	3%

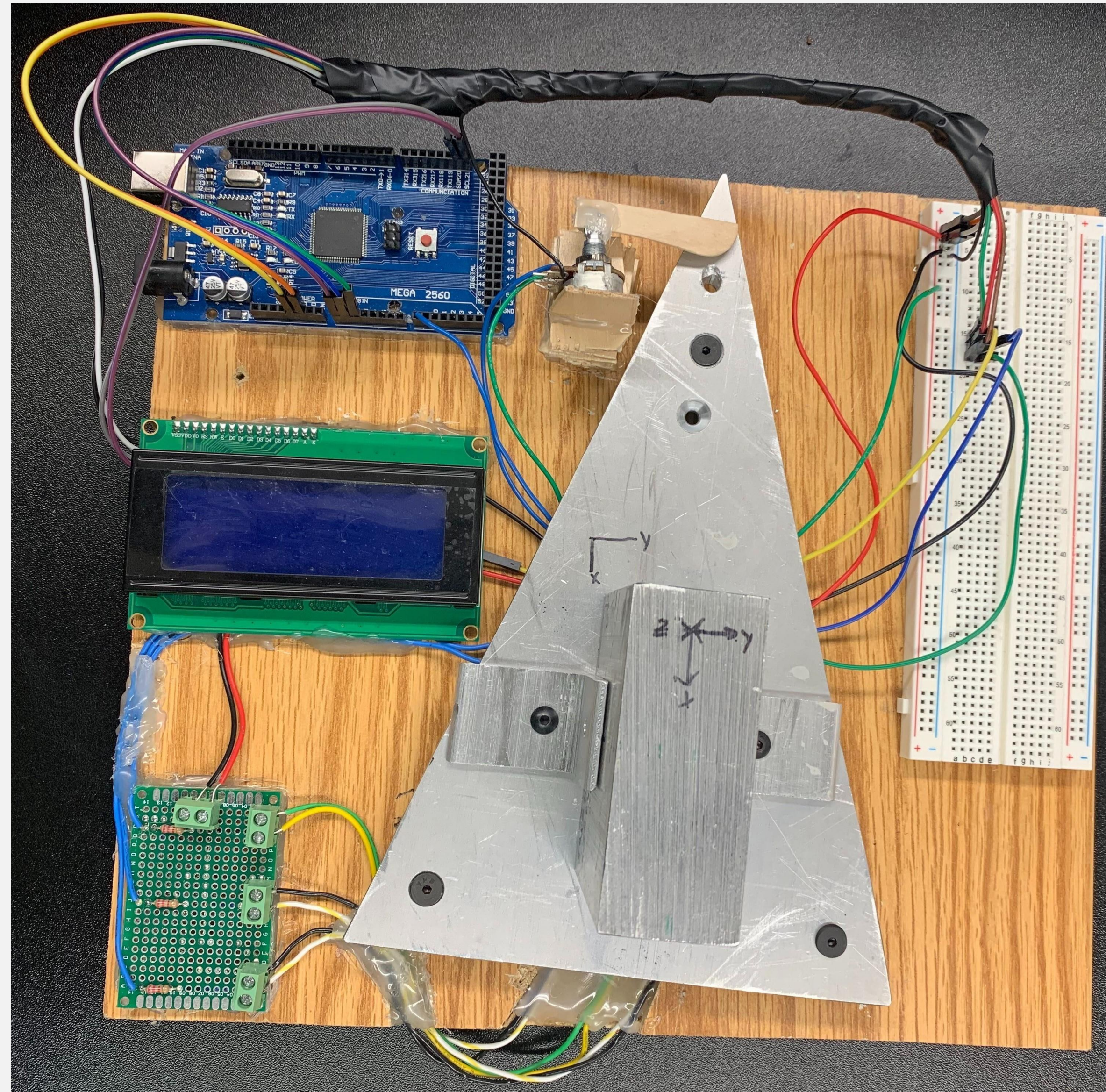
ELECTRICAL PROTOTYPE BLOCK DIAGRAM



ELECTRICAL PROTOTYPE SCHEMATIC



ELECTRICAL PROTOTYPE



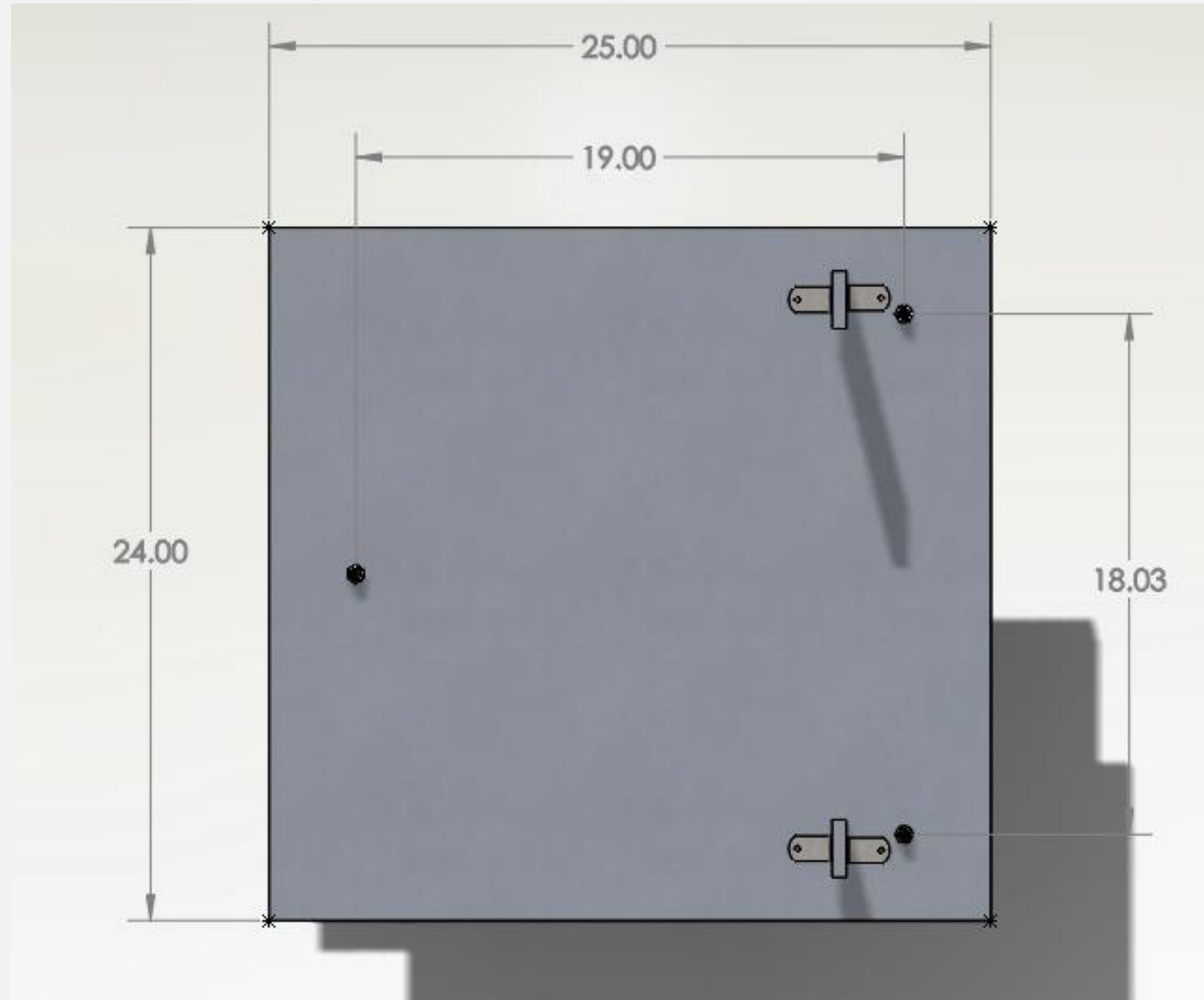
FINAL DESIGN



FINAL DESIGN

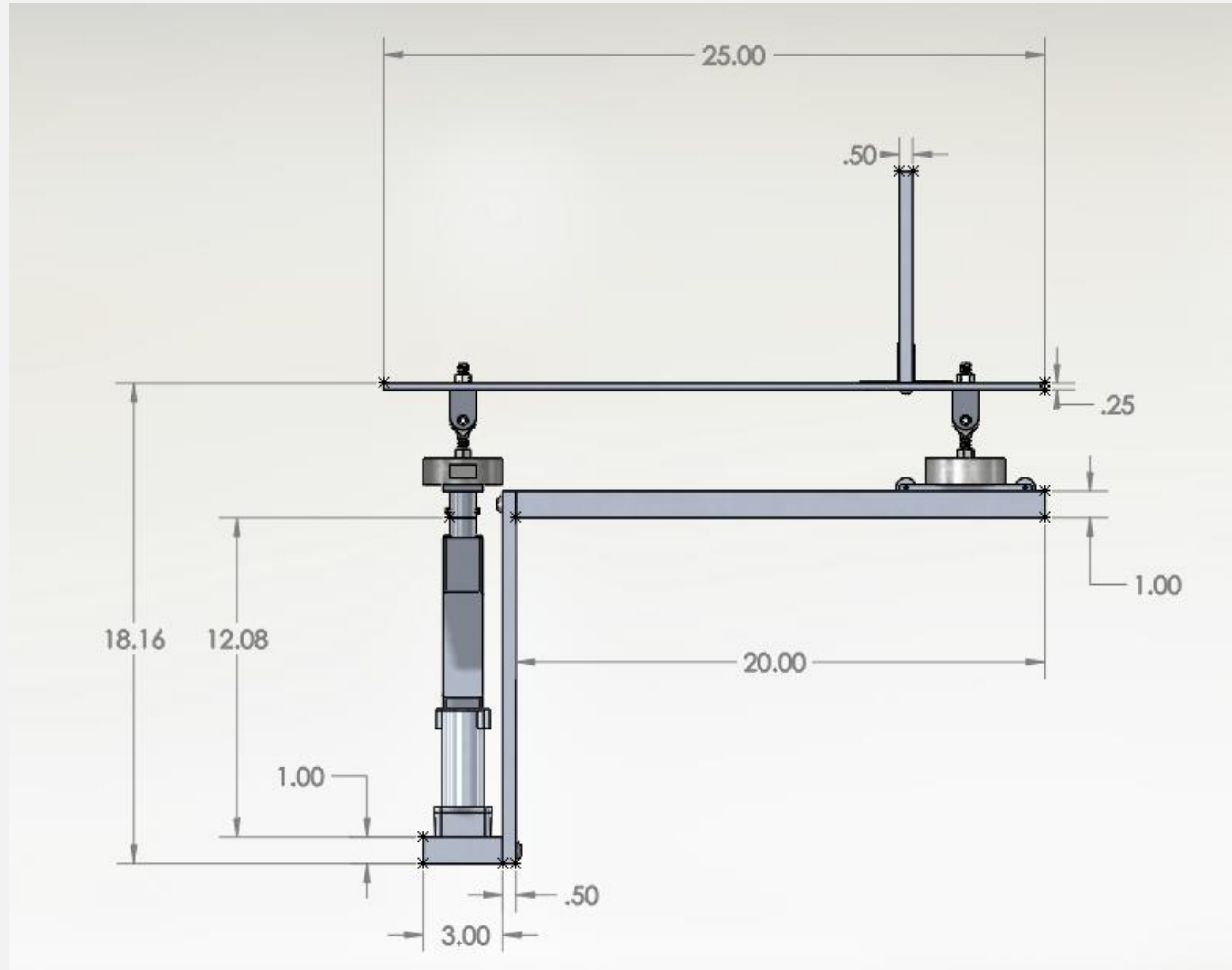


TOP VIEW



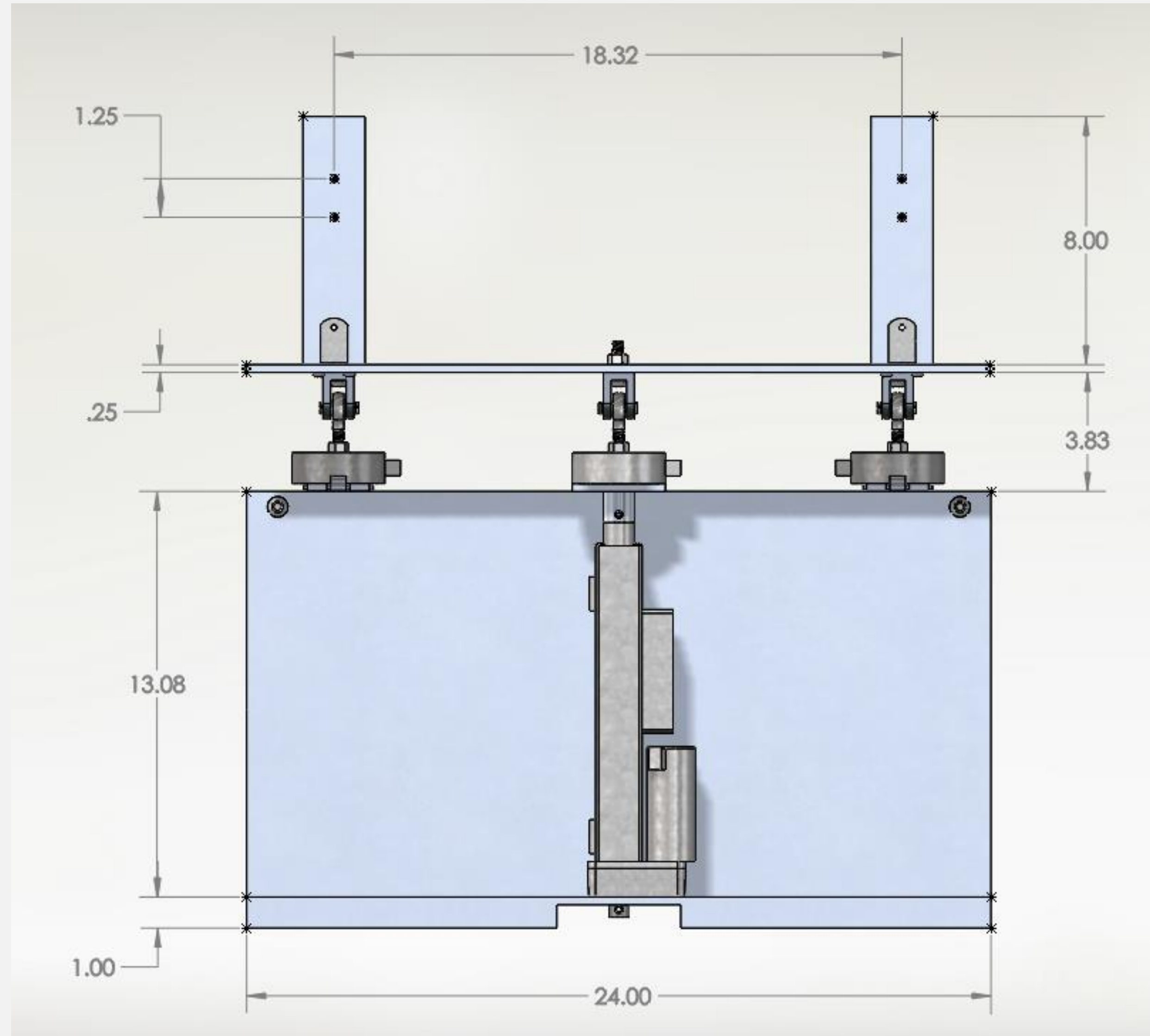
Dimensions are in inches

SIDE VIEW



Dimensions are in inches

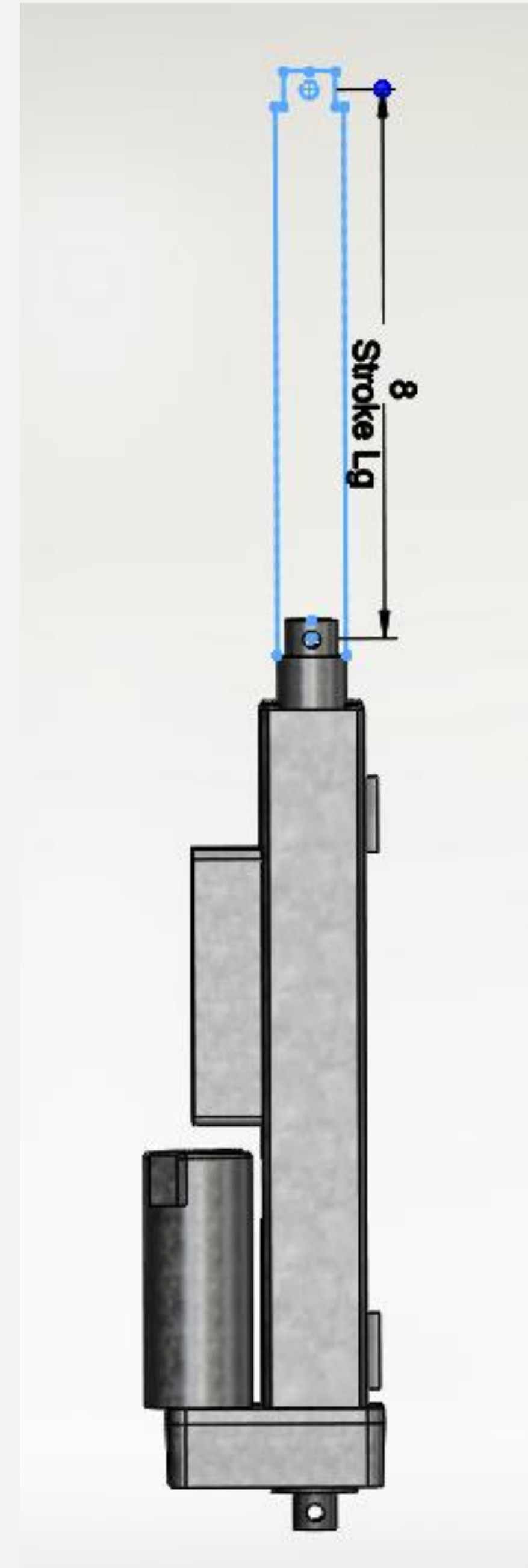
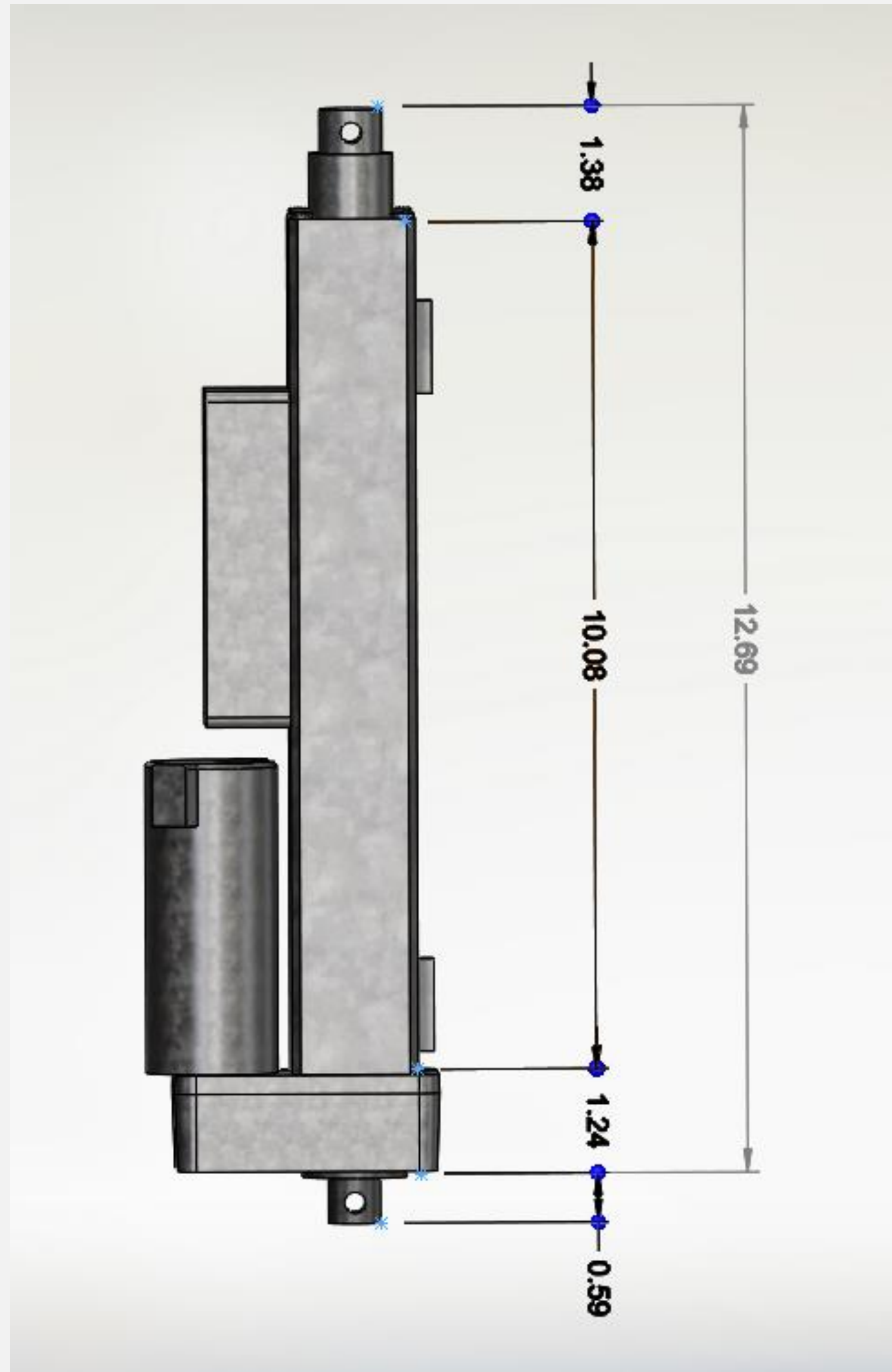
FRONT VIEW



Dimensions are in inches

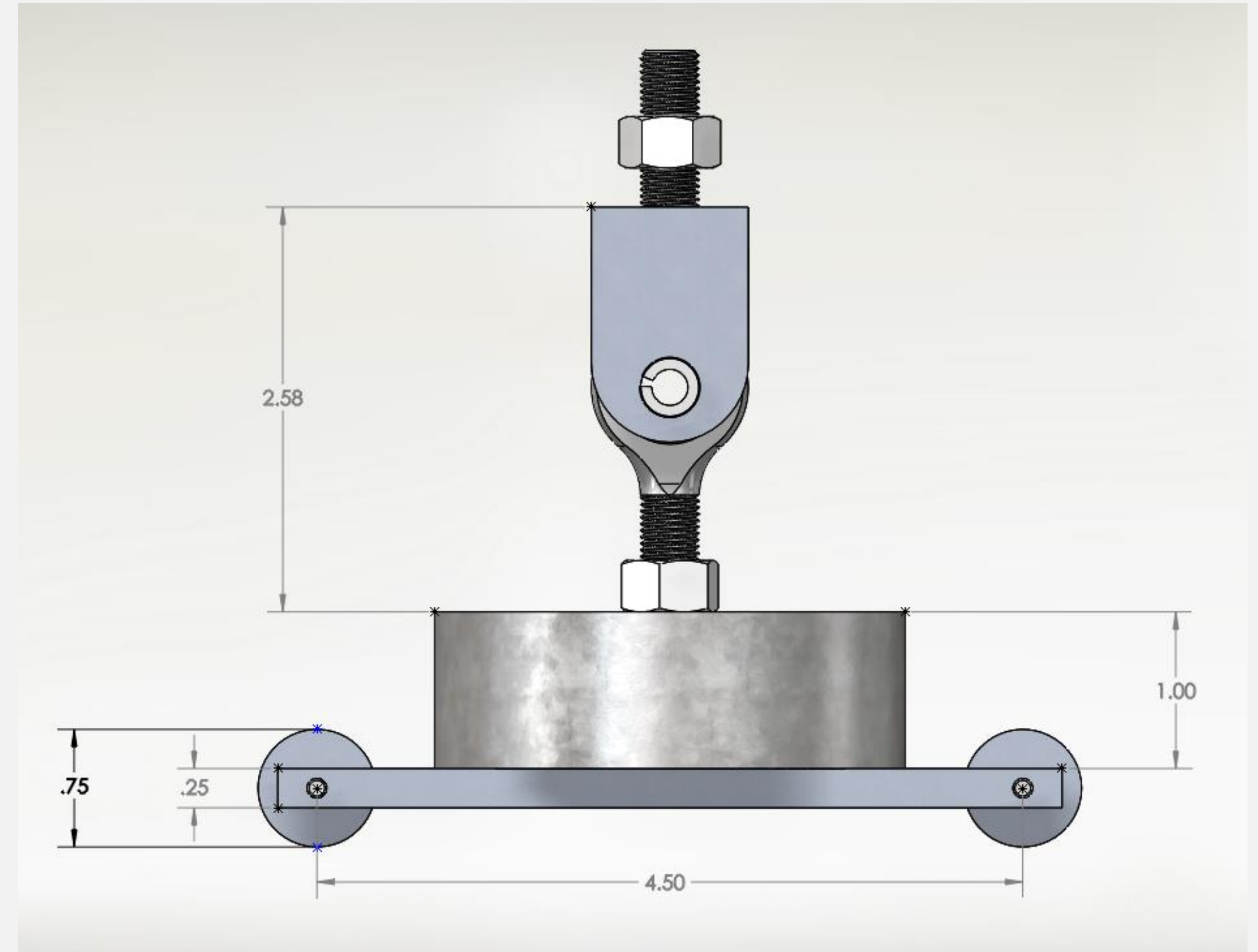
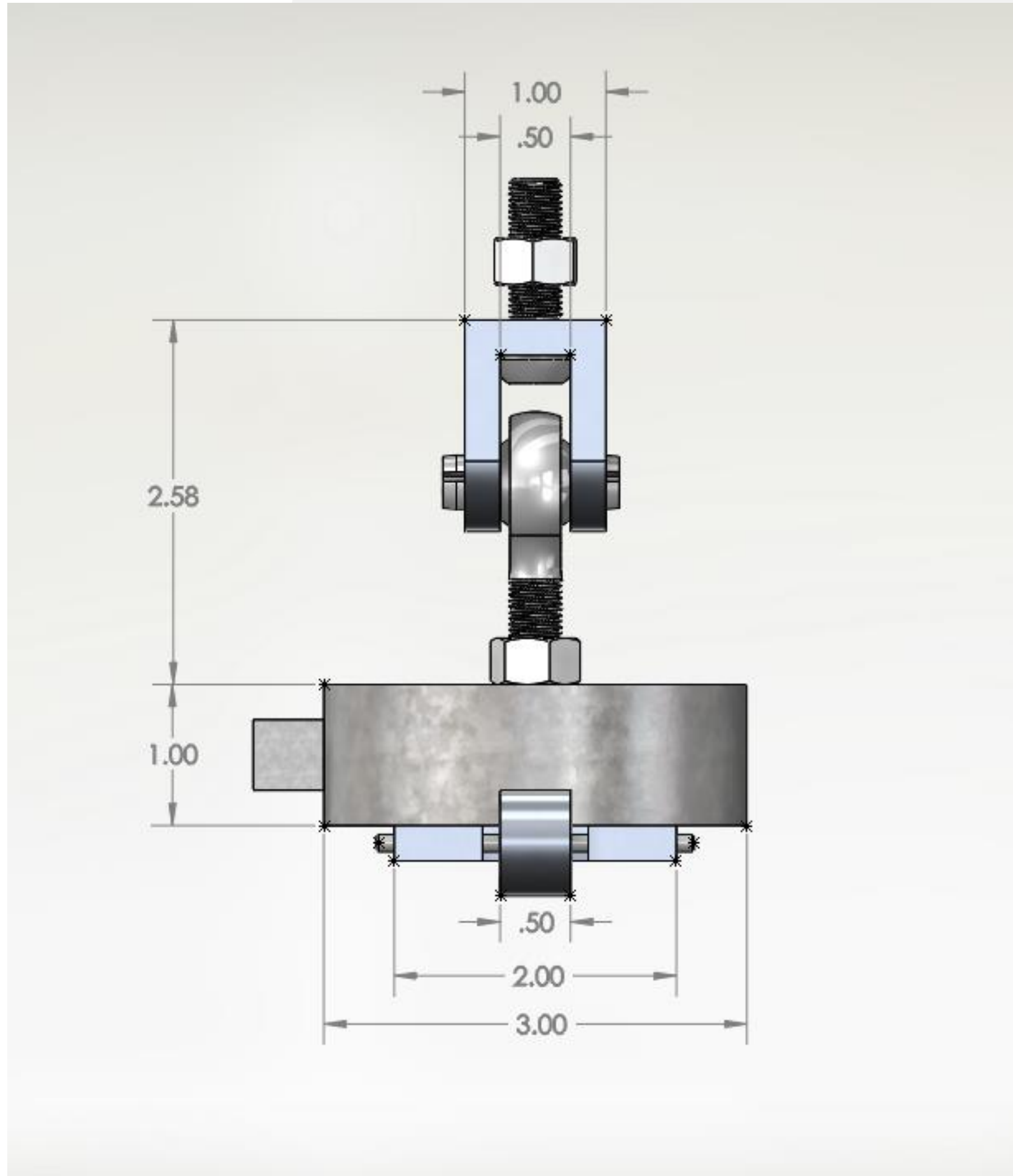
LINEAR ACTUATOR

Rated to 100 lb.



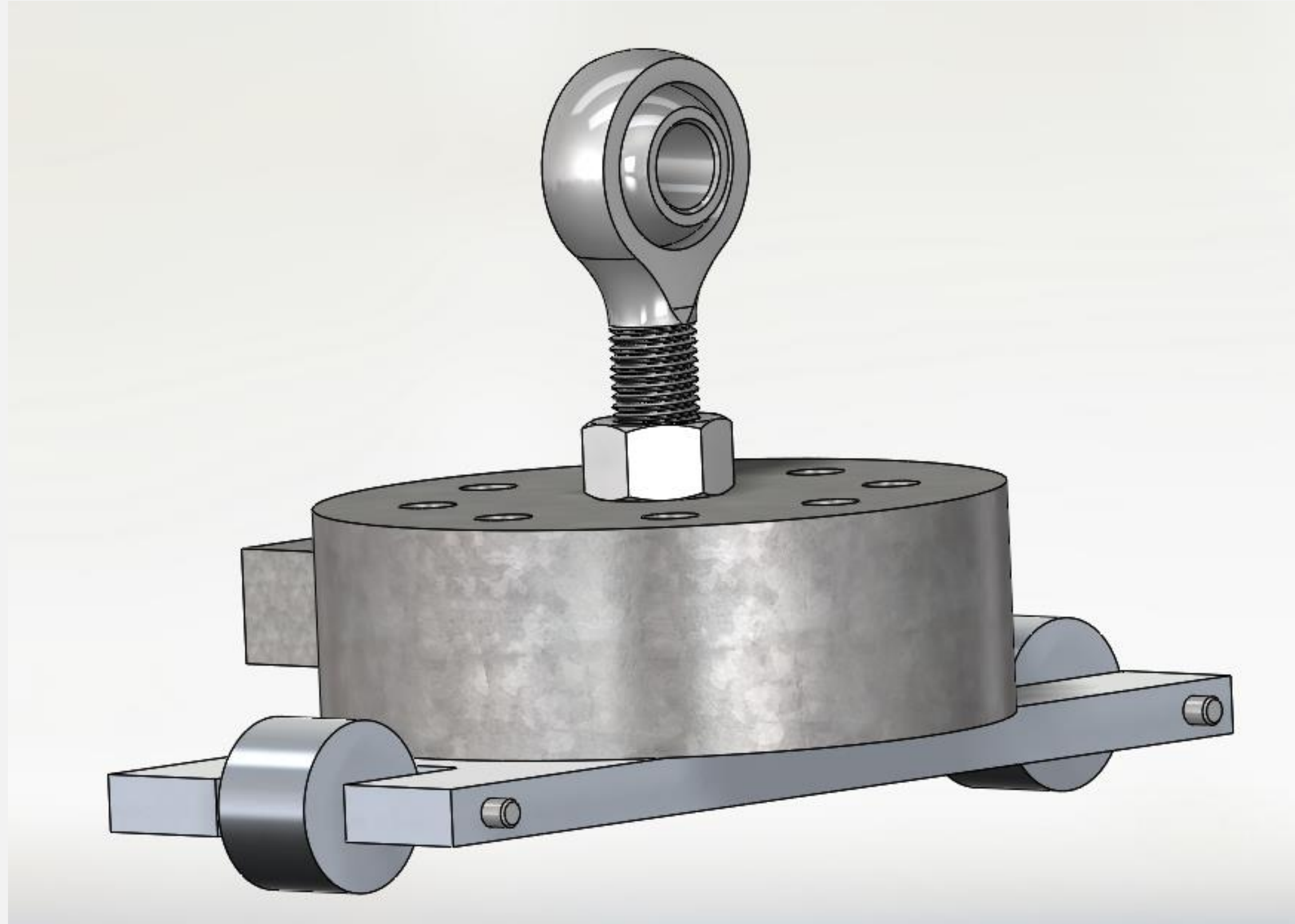
Dimensions are in inches

SENSOR ROLLERS

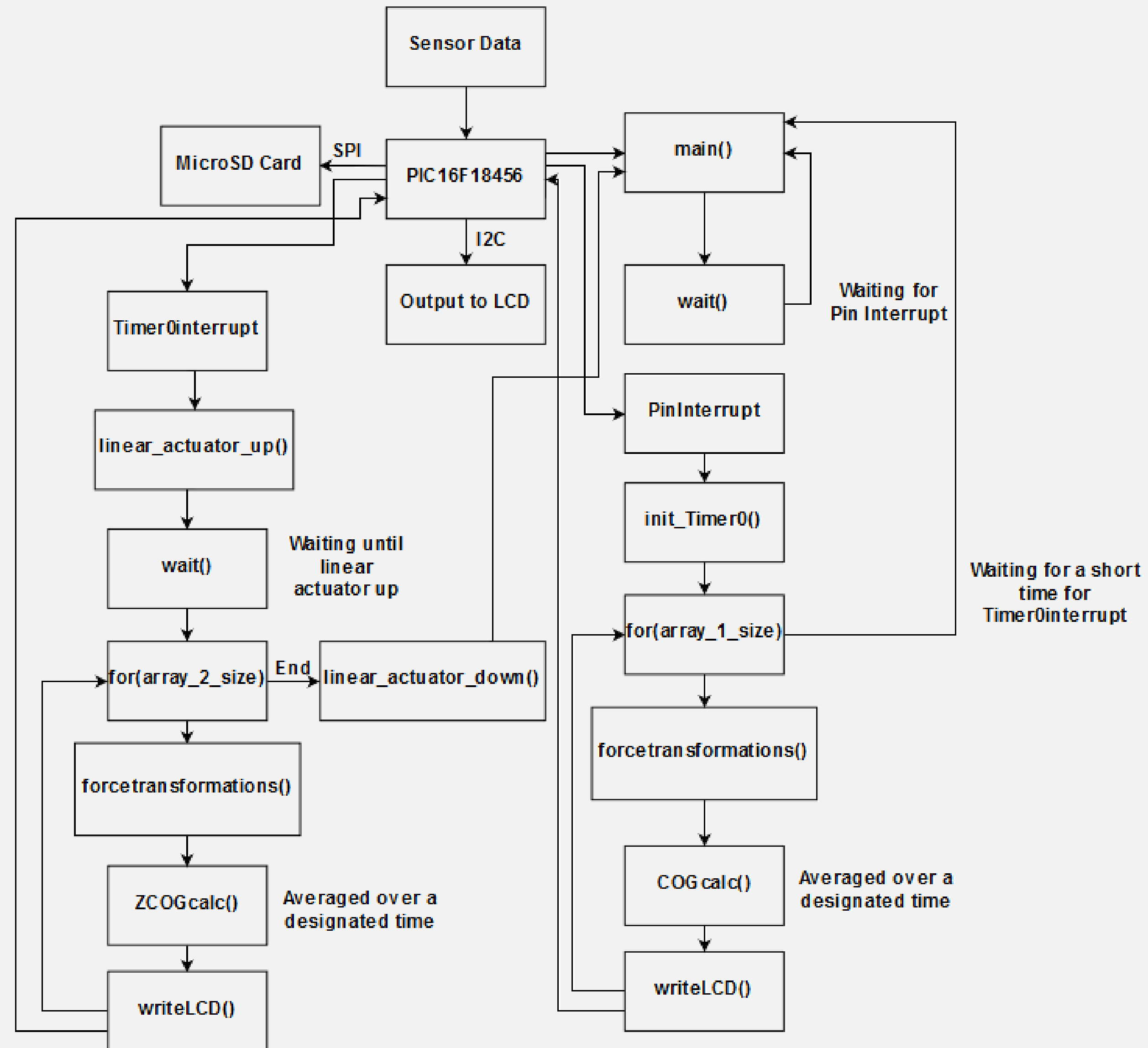


Dimensions are in inches

BALL JOINT



ELECTRICAL FINAL DESIGN



SENSOR SPENDING



Sensor Accuracy	Company	Model	Total Cost
0.1%	Lord Sensing	PNC710	\$2745
0.5%	Omega	LCFL	\$2118
0.7%	Honeywell	Model 13	\$2026.23
1%	Omega	LCM201	\$1792

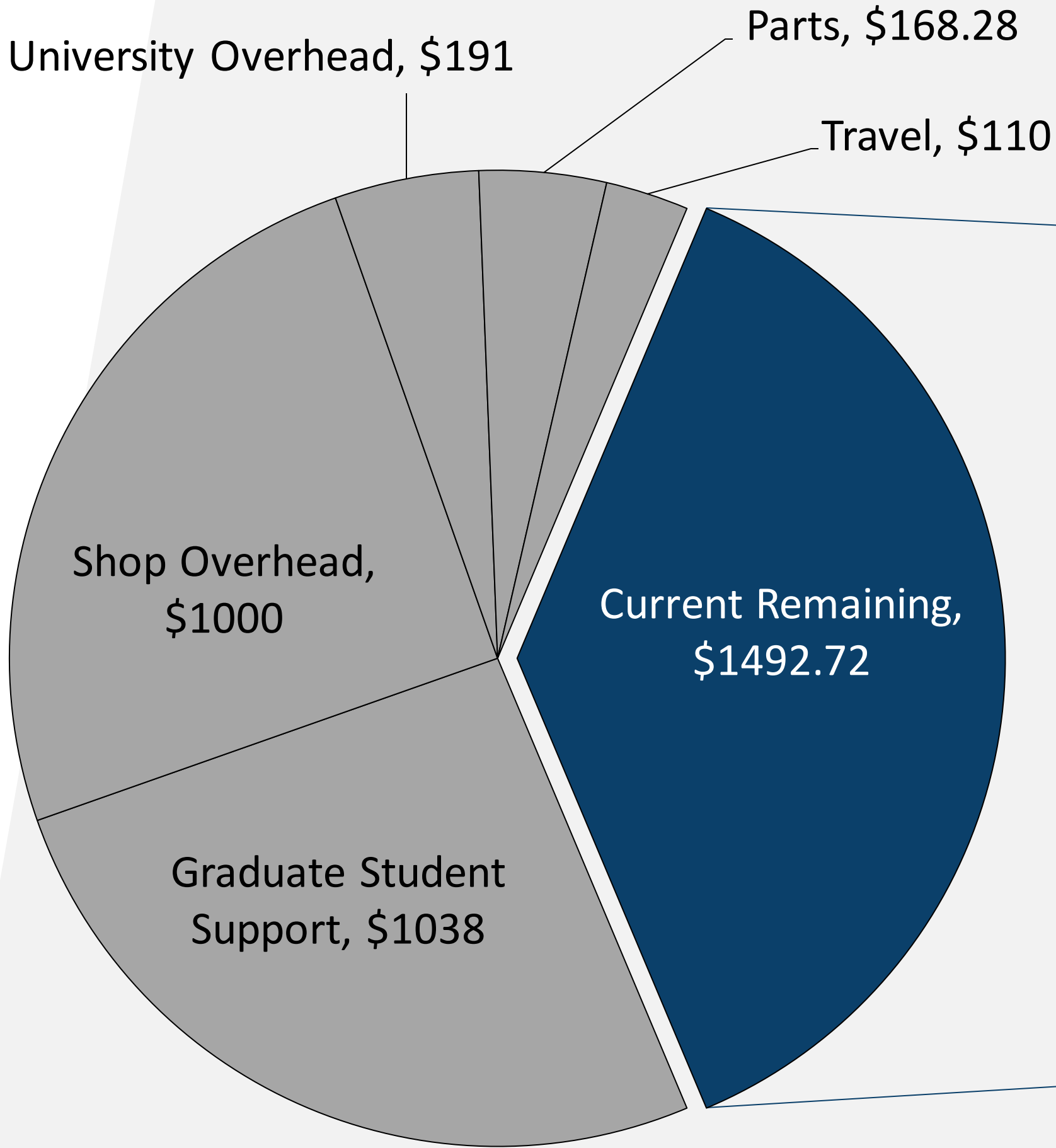
UNCERTAINTY ANALYSIS



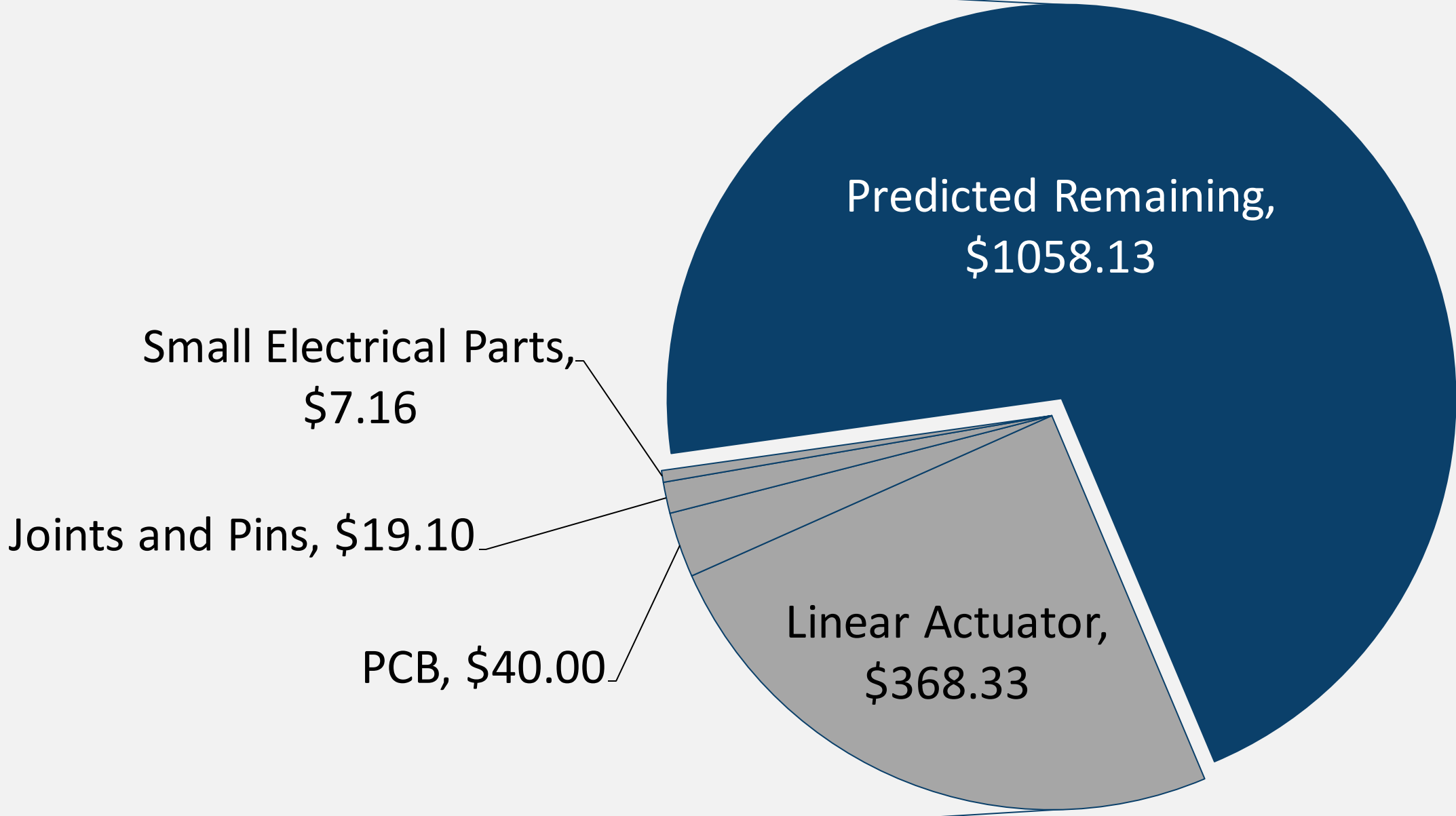
Sensor Accuracy	Total Cost	X Accuracy	Y Accuracy	Z Accuracy
0.1%	\$2745	0.05%	0.12%	0.97%
0.5%	\$2118	0.24%	0.59%	3.67%
0.7%	\$2026.23	0.34%	0.83%	5.10%
1%	\$1792	0.49%	1.18%	7.26%

BUDGET DISTRIBUTION

CURRENT SPENDINGS



PREDICTED SPENDINGS

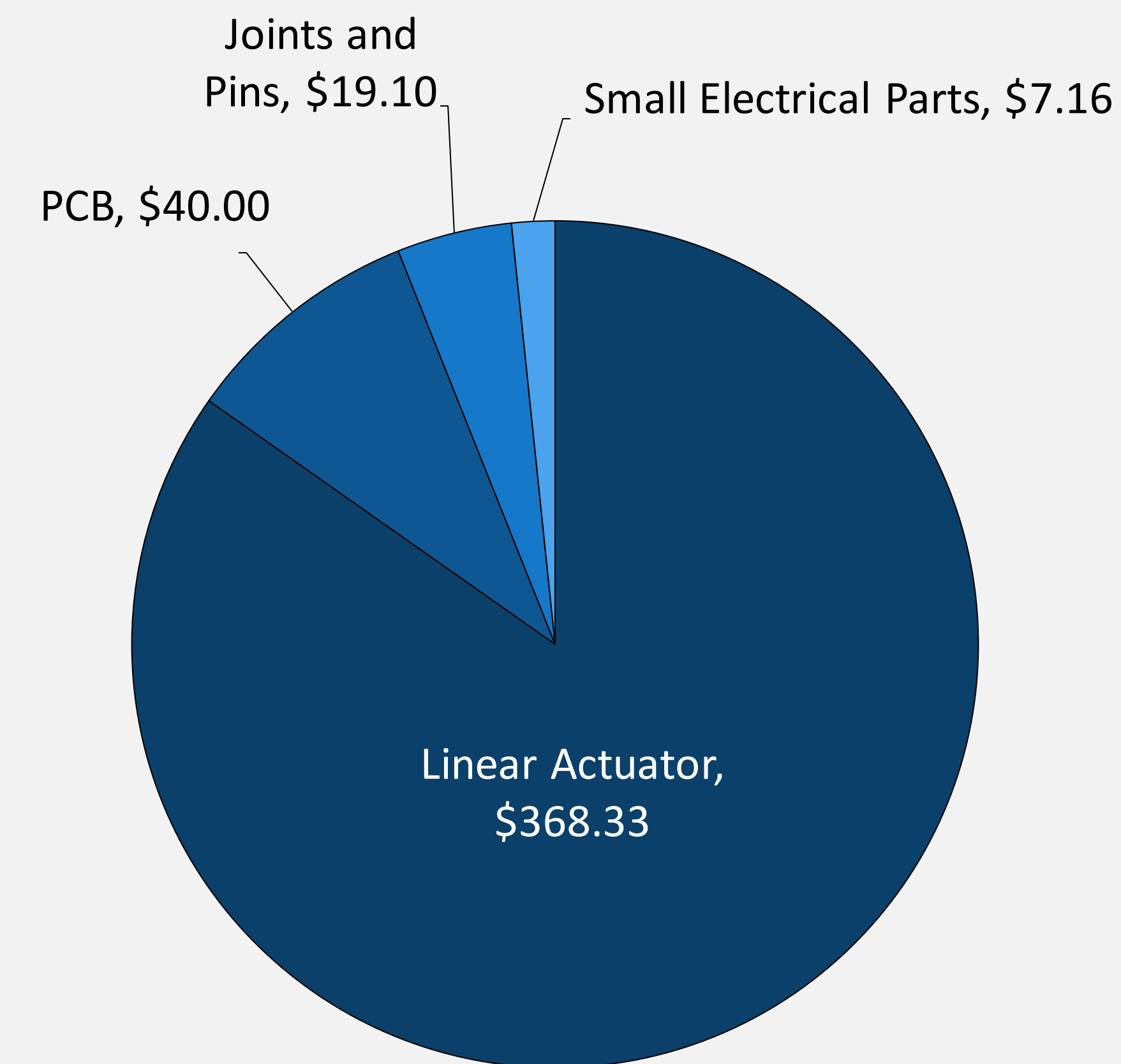




PREDICTED COST OF FINAL DESIGN

Sensor Accuracy	Cost of 3 Sensors	Other Parts	Total Cost
0.1%	\$2745	\$401.73	\$3239.01
0.5%	\$2118	\$401.73	\$2612.01
0.7%	\$2026.23	\$401.73	\$2520.24
1.0%	\$1792	\$401.73	\$2286.01

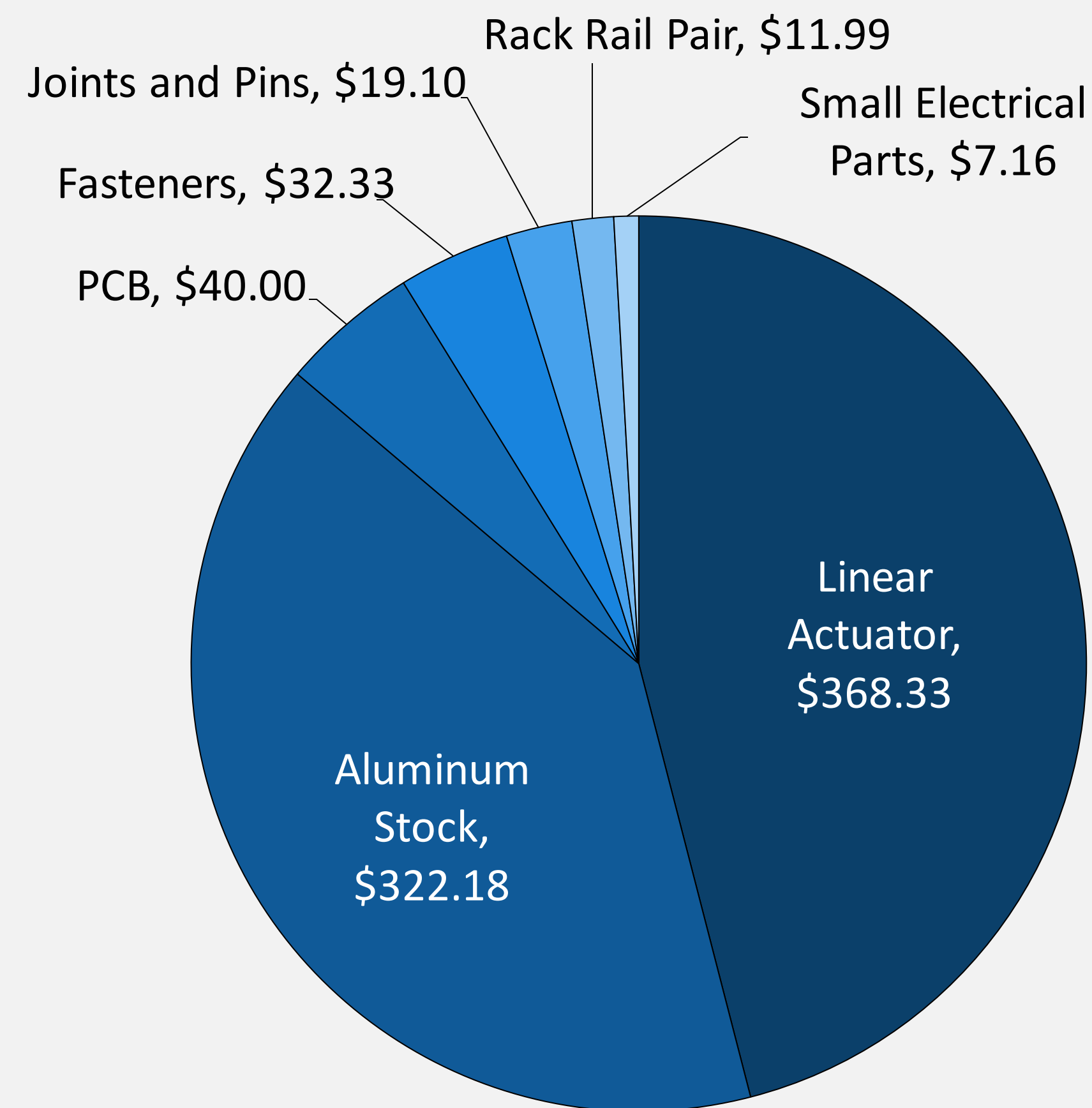
“Other Parts” Cost Distribution



ESTIMATED COST TO RECREATE

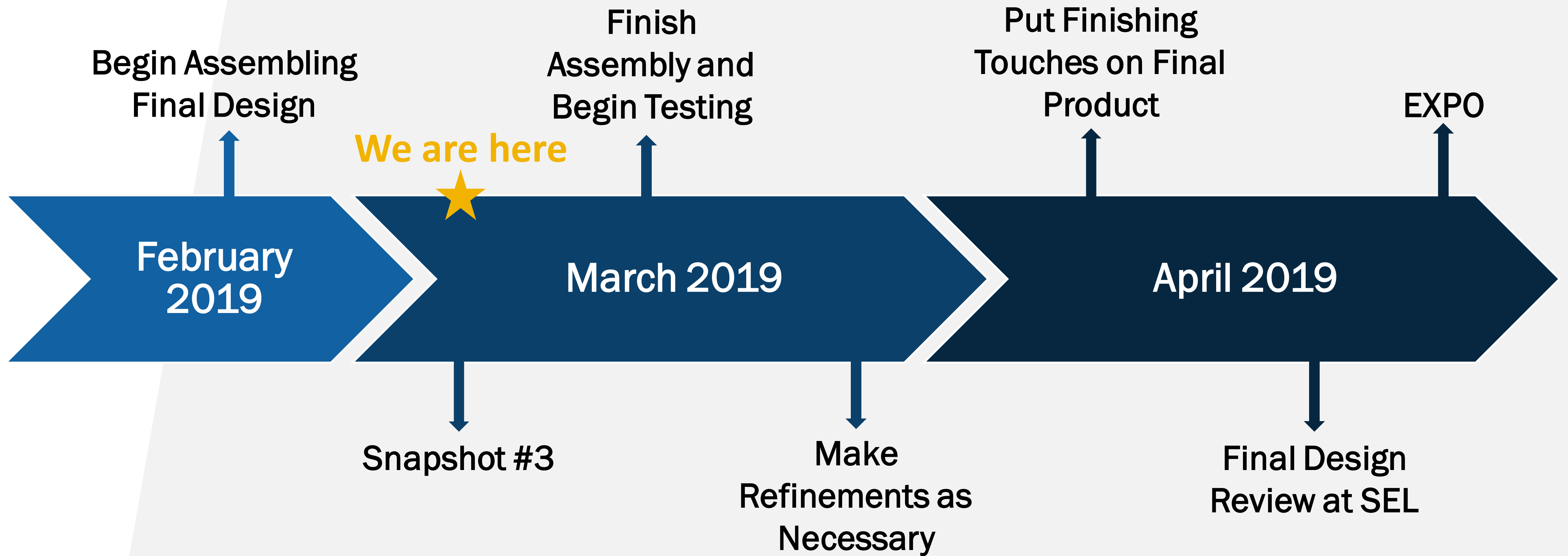
Sensor Accuracy	Cost of 3 Sensors	Other Parts	Total Cost
0.1%	\$2745	\$801.09	\$3546.09
0.5%	\$2118	\$801.09	\$2919.09
0.7%	\$2026.23	\$801.09	\$2827.32
1.0%	\$1792	\$801.09	\$2593.09

“Other Parts” Cost Distribution



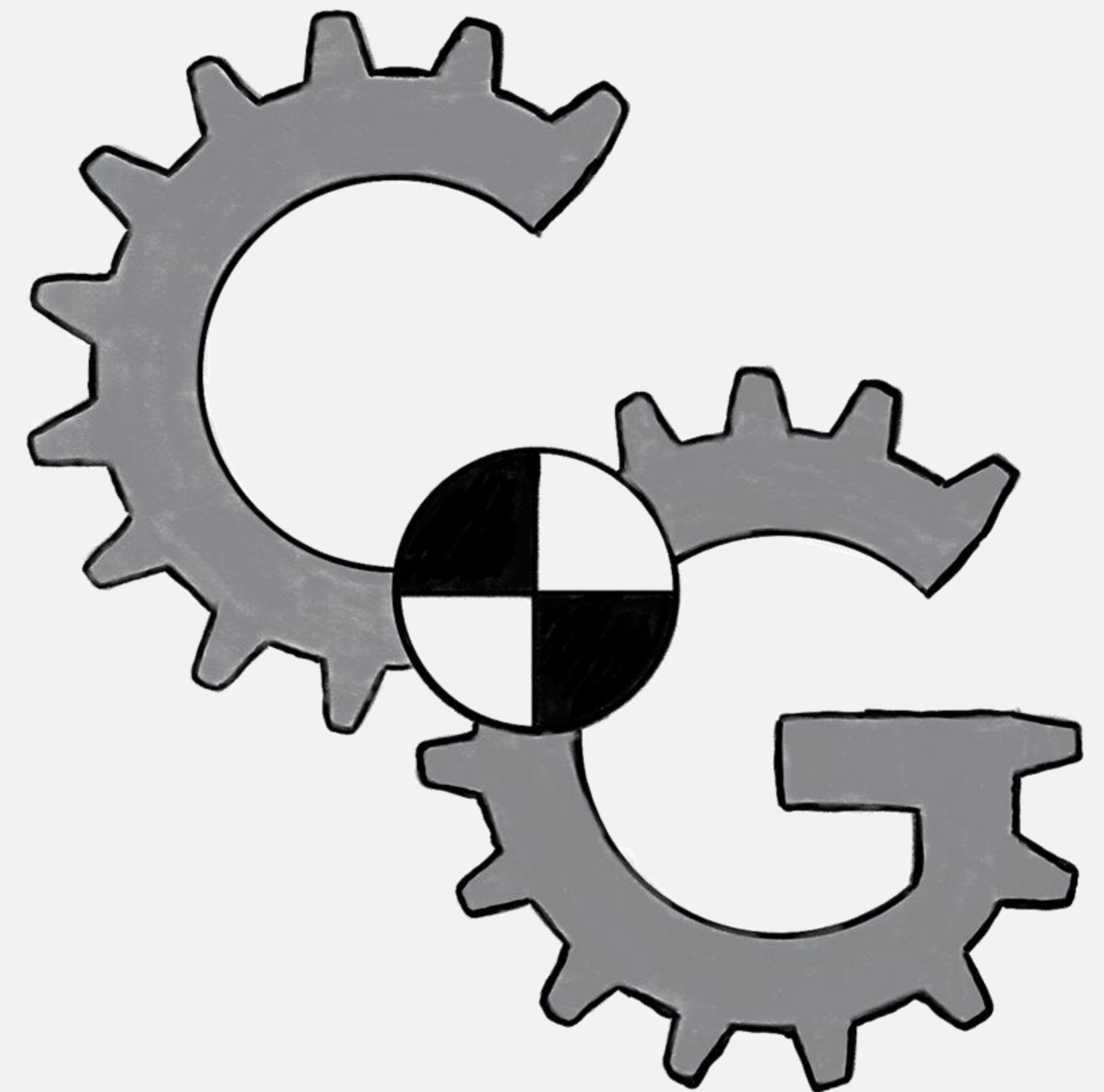


WHAT WE PLAN TO ACCOMPLISH



POTENTIAL PROBLEMS/SOLUTIONS

- I Deflection of plate under linear actuator
- I Ball joints instead of pins
- I Accuracy vs. cost tradeoffs
- I Shop schedule



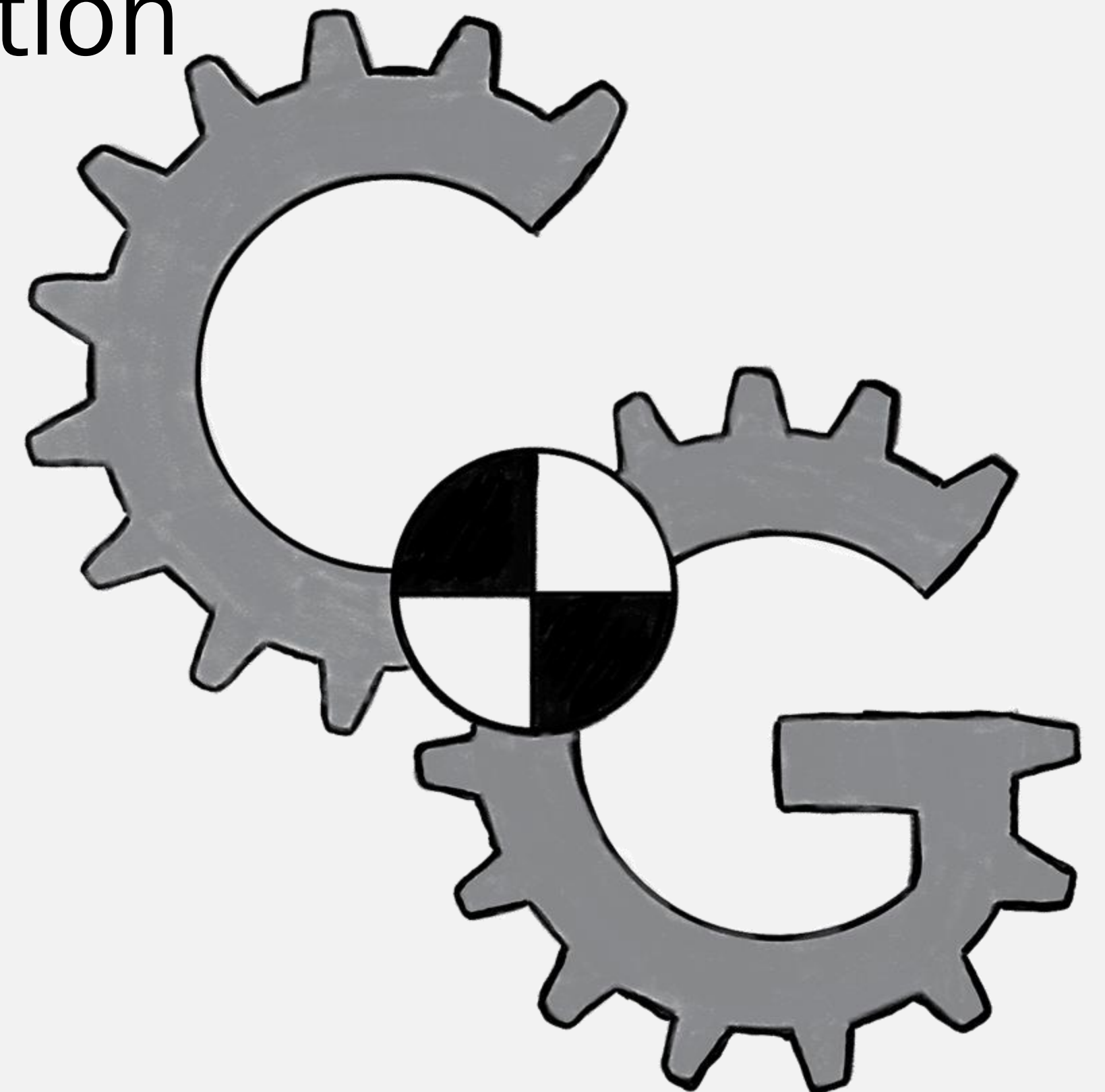
POTENTIAL PROBLEMS/SOLUTIONS CONT.



I Incorrect PCB design/printing

I Incorrect thermal effects/weight calibration

I Sensor Noise





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DECISION MATRIX

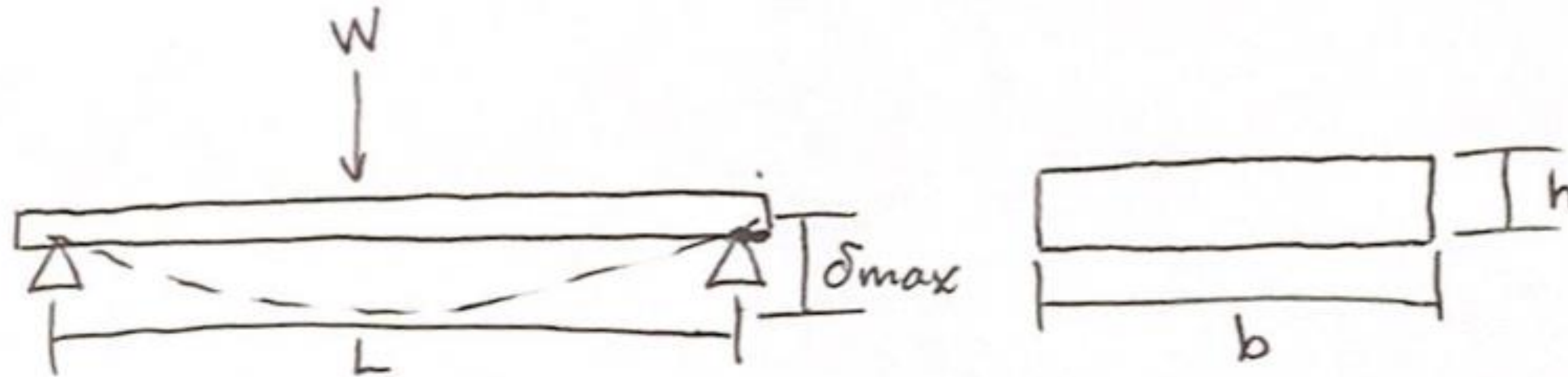
		Criteria (0-100)									
		X and Y Axis	Z Axis	Size	Accuracy (X-Y)	Accuracy (Z)	Ease of Use	Time	Rack Mount Capable		
Importance Rating (0-100)		100	95	50	95	95	85	10	100		
Design Idea	Comment									Totals	Percentage
Design 1	Cantilever Beam	100	100	100	92	50	90	100	100	56640	89.90%
Design 2	Automatic Rotation	100	100	100	100	100	90	80	10	52950	84.05%
Design 3	4 Transducer tilt table	100	100	100	100	100	100	100	50	58000	92.06%
Design 4	JPL tilt table	100	100	100	100	100	100	100	50	58000	92.06%
Design 5	Rack Mounted	100	0	100	92	0	90	0	100	41390	65.70%
Design 6	Cantilevered Beam with Box	100	100	90	92	100	90	100	100	60890	96.65%
Design 7	Prototype 1 - AT-AT	0	0	100	0	0	90	100	50	18650	29.60%
Design 8	Prototype 2 - Triangle	100	100	100	80	50	100	100	100	56350	89.44%
Design 9	Prototype 3 - Testing Prototype	100	100	100	95	85	100	100	100	61100	96.98%

CG TESTING DATA



L - Shaped Piece							
	Force Readings in Pounds	1	2	3	4	5	AVERAGES
Horizontal	F1	0.61875	0.81875	0.43125	1.00625	0.81875	
	F2	0.2375	0.39375	1.14375	0.55	0.0125	
	F3	0.75625	0.39375	0.03125	0.05	0.78125	
Vertical	F1'	0.5	0.69375	0.31875	0.8875	0.69375	
	F2'	0.29375	0.4875	1.20625	0.6125	0.075	
	F3'	0.81875	0.41875	0.08125	0.10625	0.84375	
	W_horizontal	1.6125	1.60625	1.60625	1.60625	1.6125	
	W_vertical	1.6125	1.6	1.60625	1.60625	1.6125	
	X	13.55814	10.78599	16.09339	8.217899	10.82946	
	Y	2.573643	0	-5.54086	-2.49027	3.813953	
	Z	1.797069	1.900114	1.647929	1.808925	1.957441	1.822295329
					ERROR	3.582258%	

DEFLECTION OF TOP PLATE



Max. displacement when W acts
in the center.

$$\delta_{\max} = \frac{-WL^3}{48EI}$$

$$E = 10 \times 10^6 \text{ psi}$$

$$W = -50 \text{ lb}$$

$$L = 19 \text{ in}$$

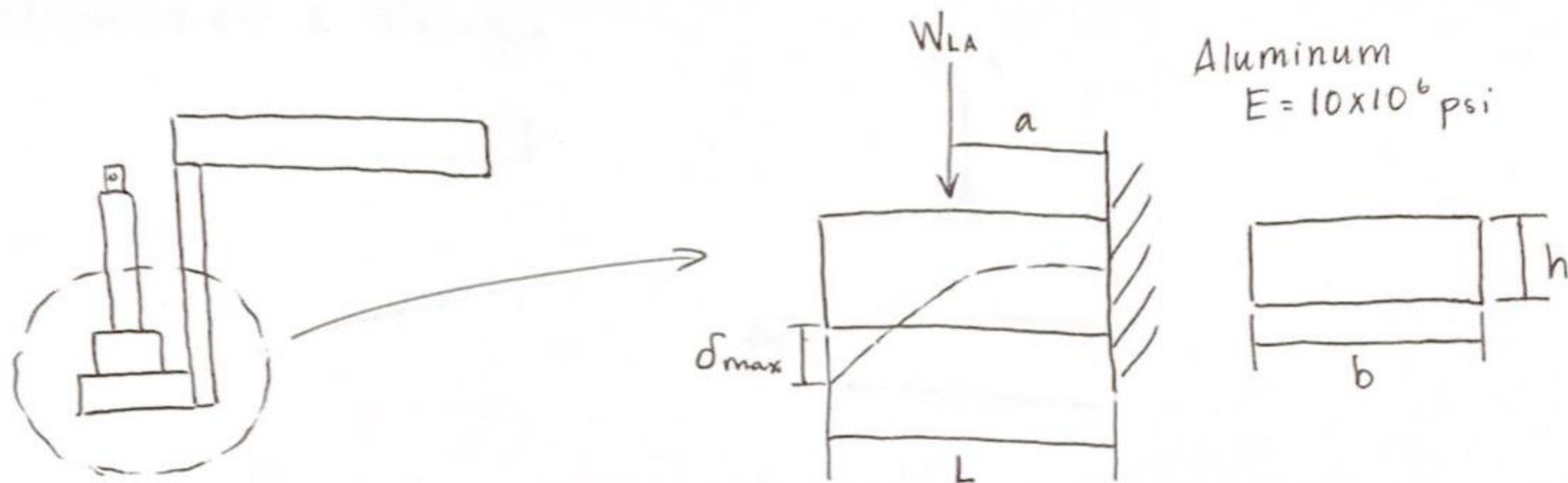
$$b = 18 \text{ in}$$

$$h = .25 \text{ in}$$

$$I = \frac{bh^3}{12} = \frac{(18 \text{ in})(.25 \text{ in})^3}{12} = .0234375 \text{ in}^4$$

$$\delta_{\max} = \frac{-50 \text{ lb} (19 \text{ in})^3}{48(10 \times 10^6 \text{ psi})(.0234 \text{ in}^4)} = \boxed{-.0305 \text{ in}} \rightarrow \text{negligible} \checkmark$$

DEFLECTION OF L



$$\delta_{max} = -\frac{W_{LA} a^2}{6EI} (3L - a)$$

$$I = \frac{bh^3}{12} = \frac{(24 \text{ in})(1 \text{ in})^3}{12} = 2 \text{ in}^4$$

$W_{LA} = 50 \text{ lb}$ (Maximum)
 $a = 2 \text{ in}$ (Maximum)
 $L = 3 \text{ in}$
 $b = 24 \text{ in}$
 $h = 1 \text{ in}$

$$\delta_{max} = \frac{-50 \text{ lb} (2 \text{ in})^2}{6(10 \times 10^6 \text{ psi})(2 \text{ in}^4)} (3(3 \text{ in}) - 2 \text{ in}) = \boxed{-0.0000117 \text{ in}} \rightarrow \text{negligible} \checkmark$$

FULL BREAKDOWN OF PART COSTS

Aluminum Stock

.25 x 24 x 24 Sheet	\$ 52.32
1 x 24 x 24 Sheet	\$ 207.06
.5 x 14.125 x 24 Sheet	\$ 61.35
.75"D x 1.5" Rod	\$ 1.45

Other Fasteners

Hex Nut (3x)	\$ 0.25
3/8"D x 1.25" Threaded Screw (10x)	\$ 5.40
3/16"D x Threaded Screw (4x)	\$ 0.15
L Bracket (4x)	\$ 4.00
Clevice (3x)	\$ 22.53

Joints and Pins

Long Pins (4x)	\$ 7.34
Ball Joint (1x)	\$ 11.34
1/4 "Spring Pin	\$ 0.05
1" Spring Pin	\$ 0.04
3/8" Spring Pin (3x)	\$ 0.33

Small Electrical Parts

MicroSD Port	\$ 0.98
Microcontroller	\$ 0.96
8GB MicroSD Card	\$ 4.99
MicroUSB Port	\$ 0.23