Team 6: Final Presentation

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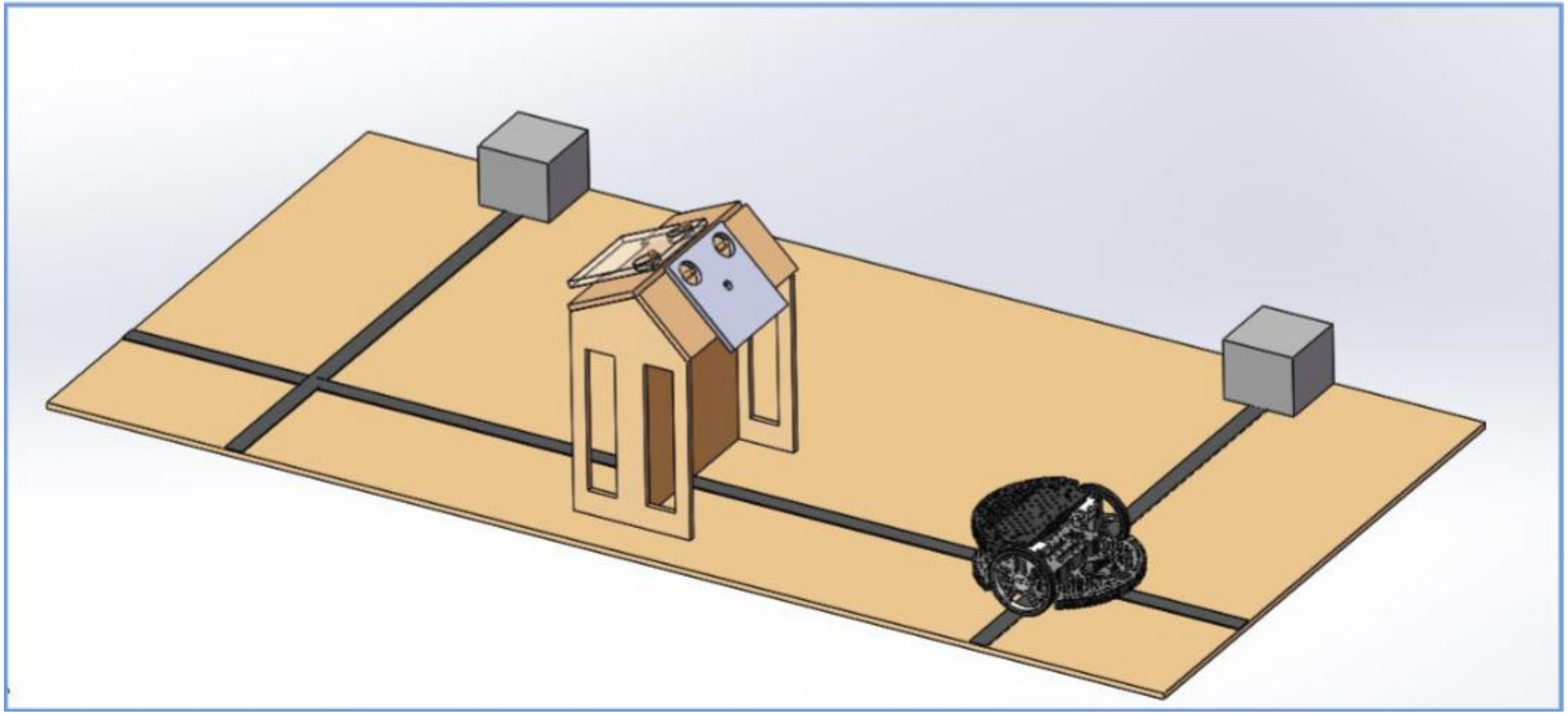
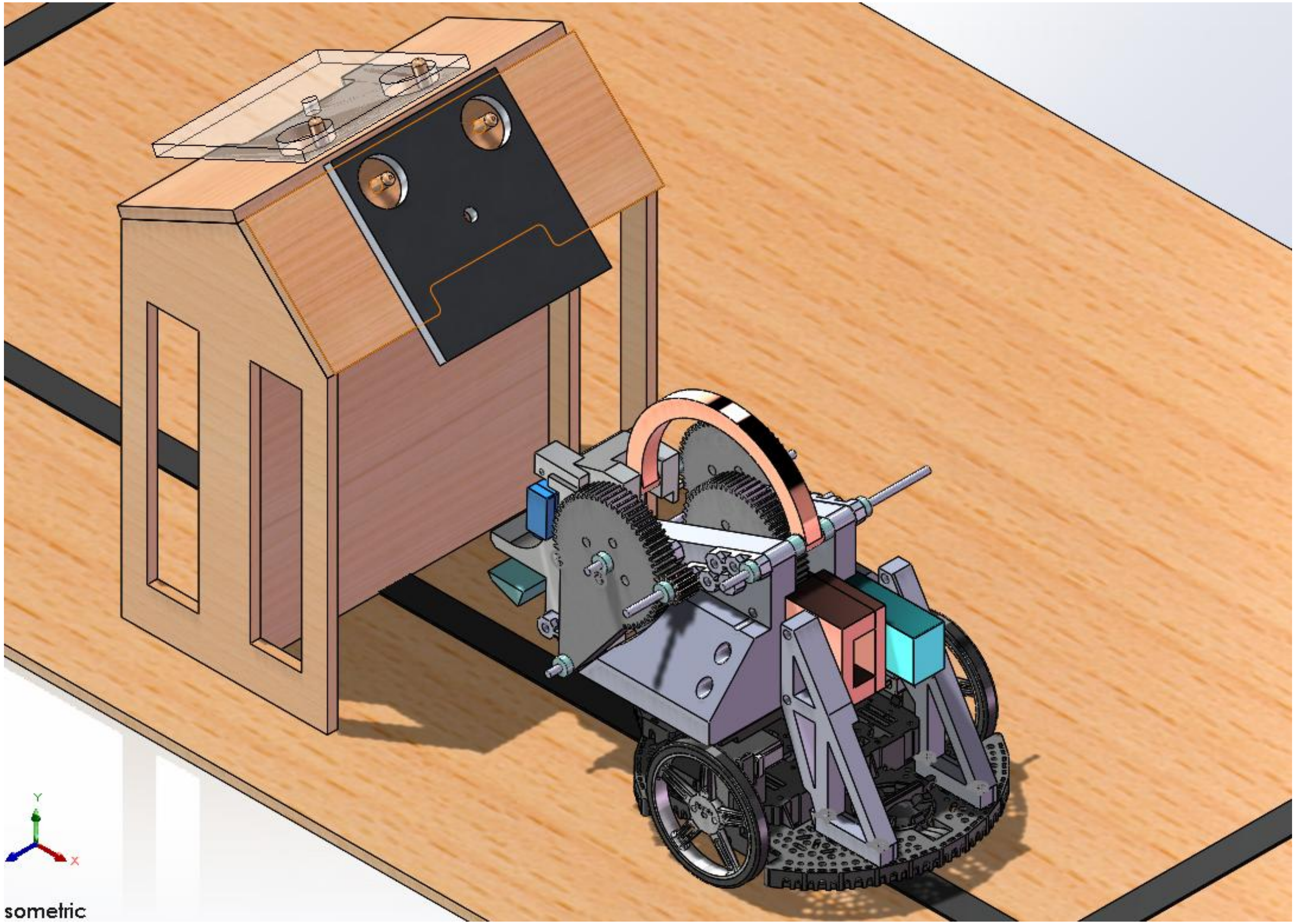
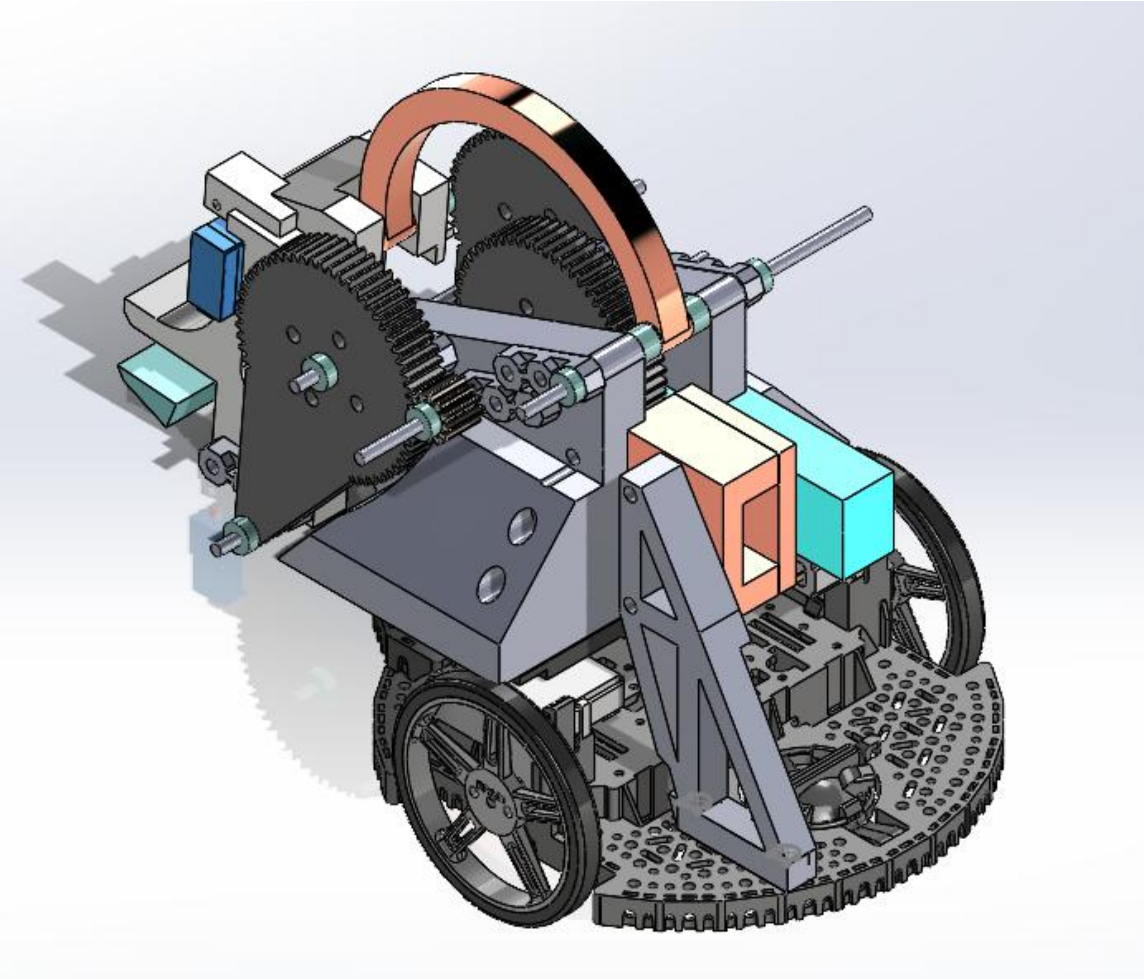
Game Field

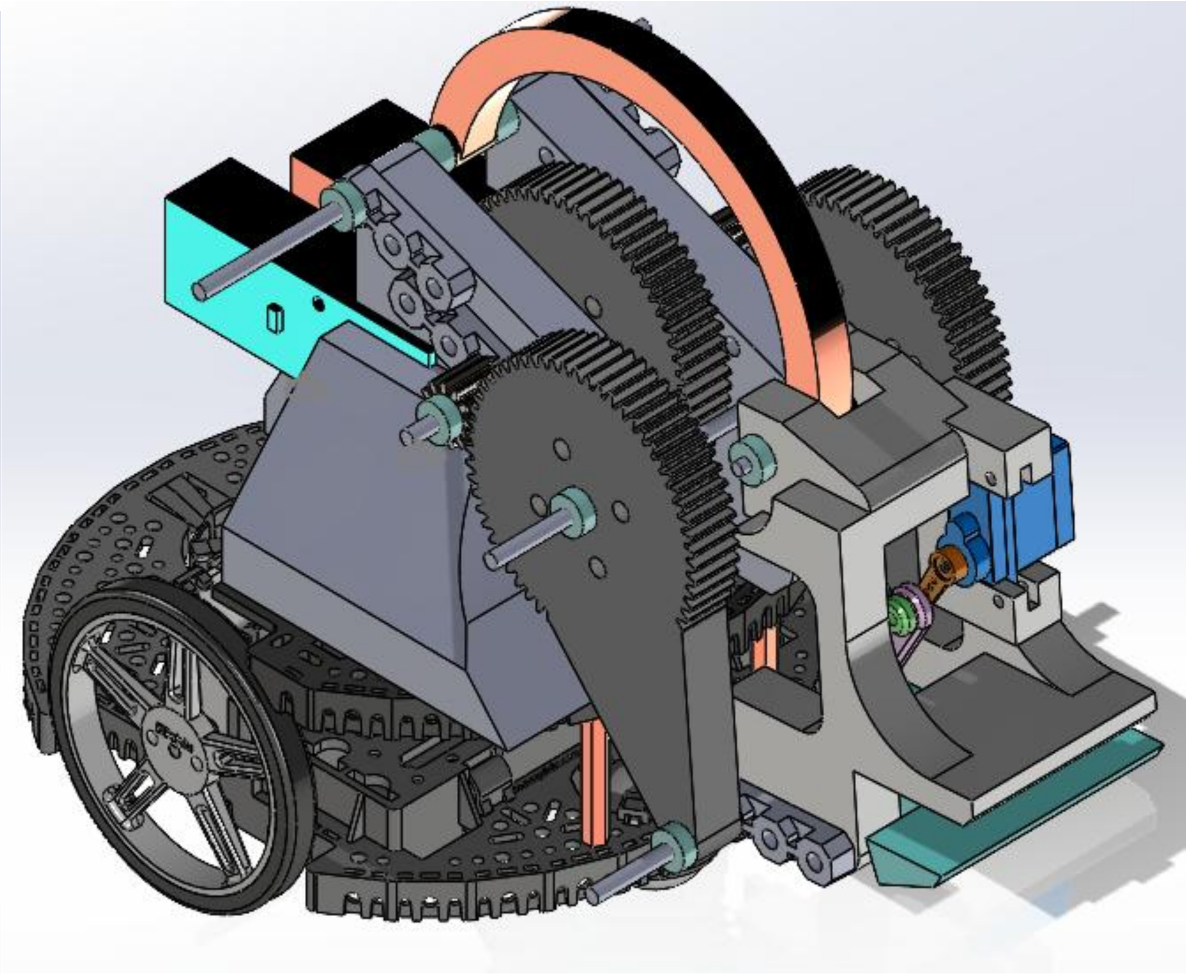


Assembly of Robot on Field

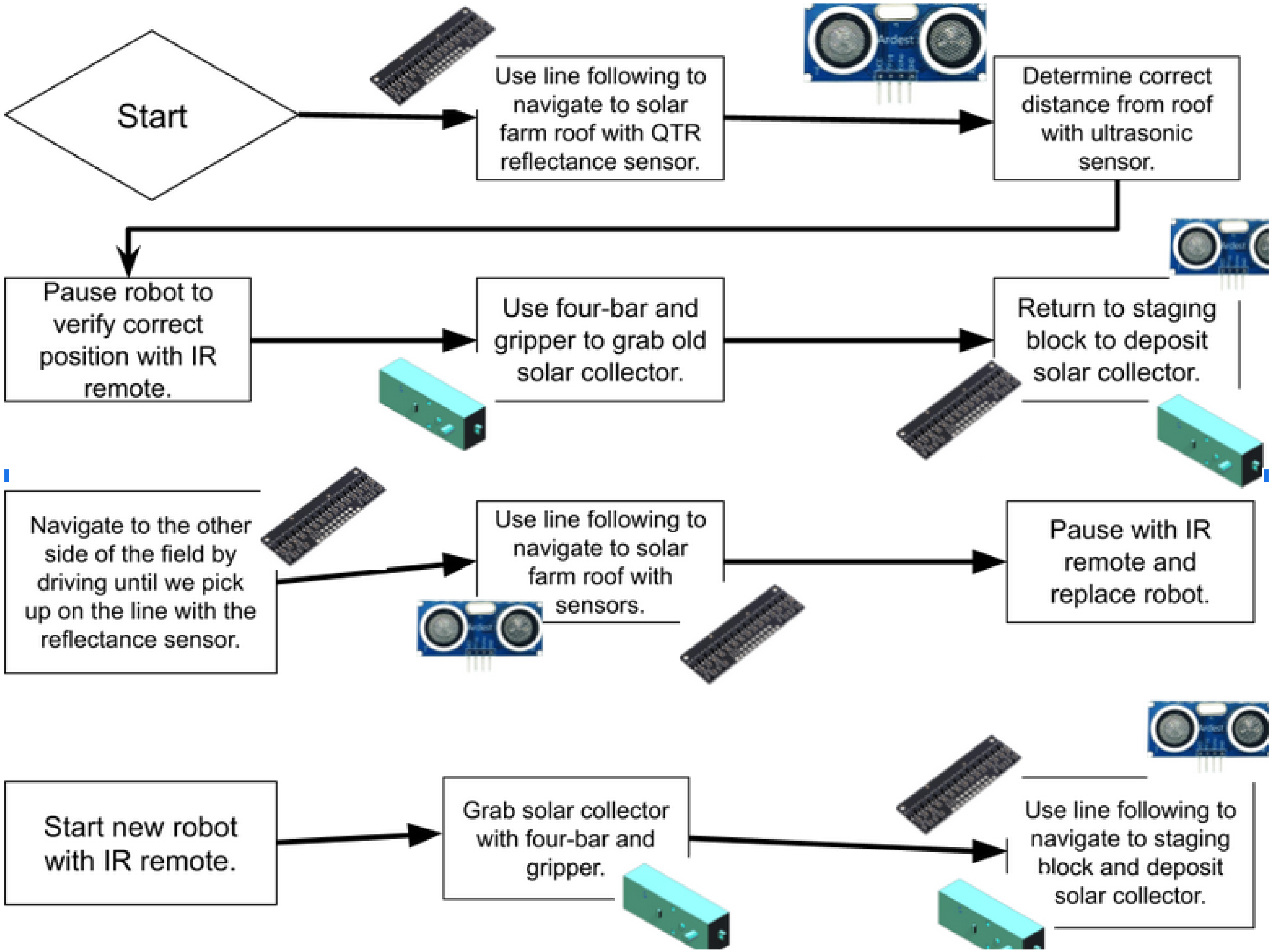


Views of Assembly



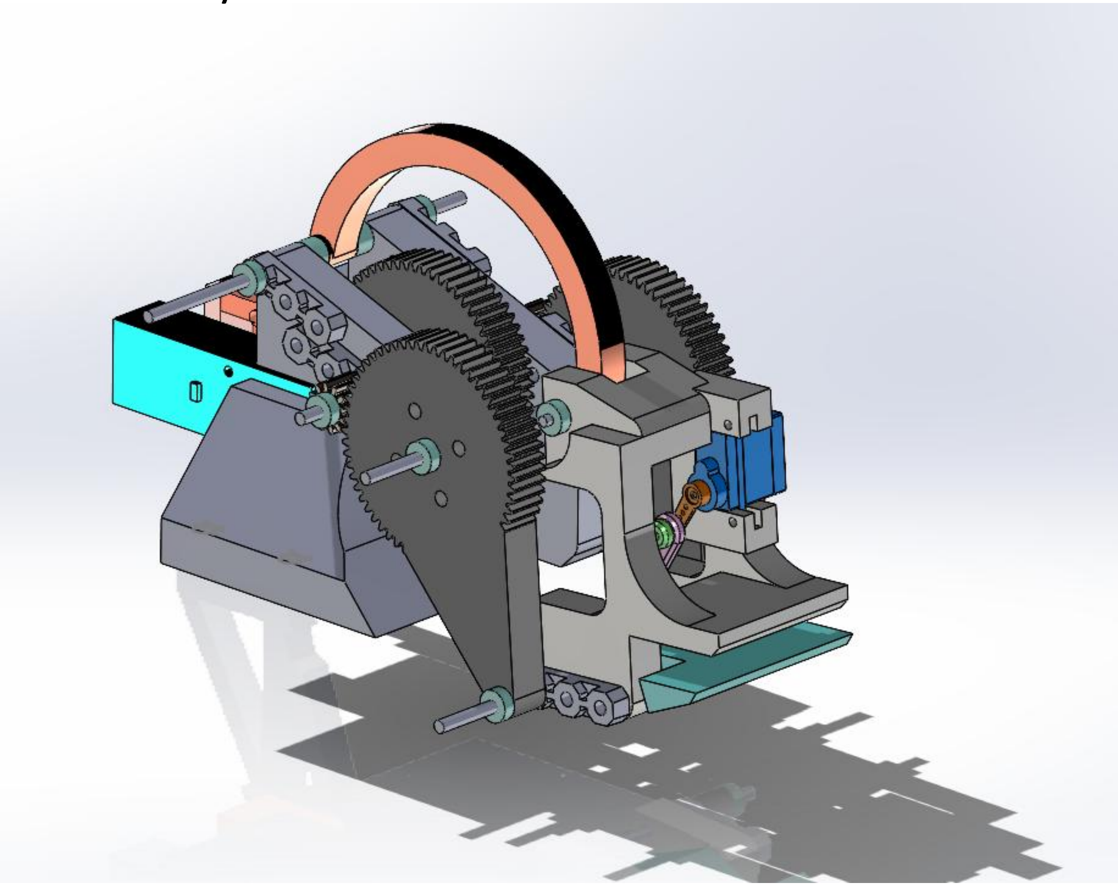


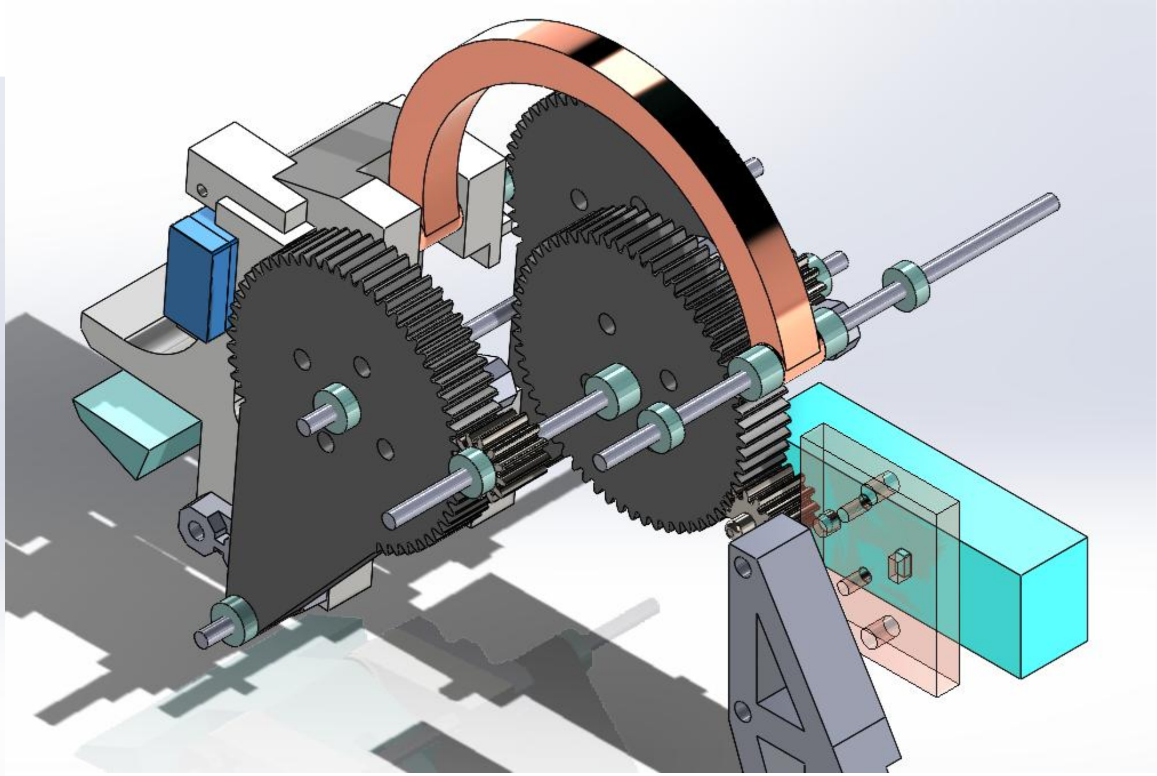
Overview of Strategy



Overview of System

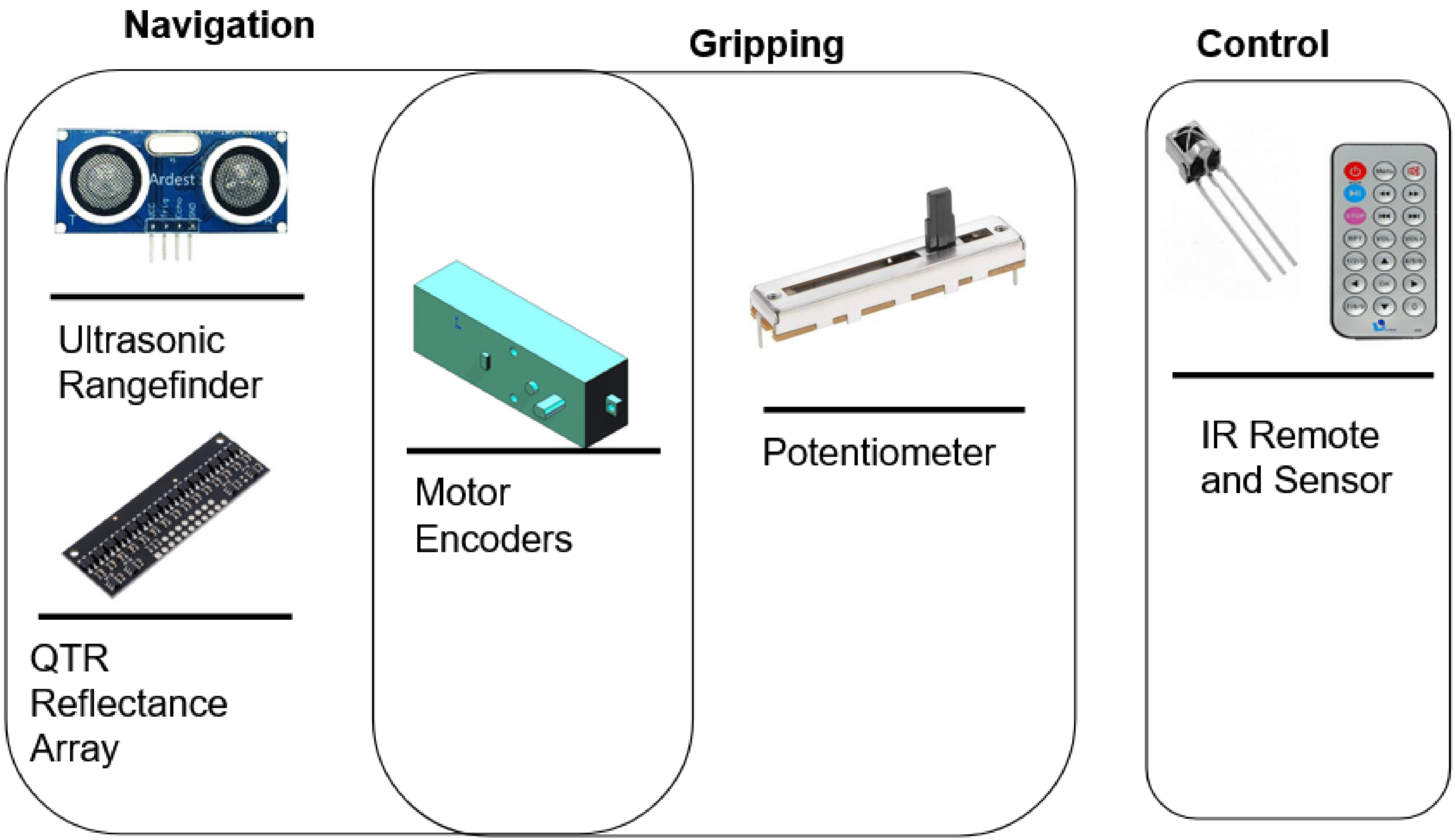
Four-bar system



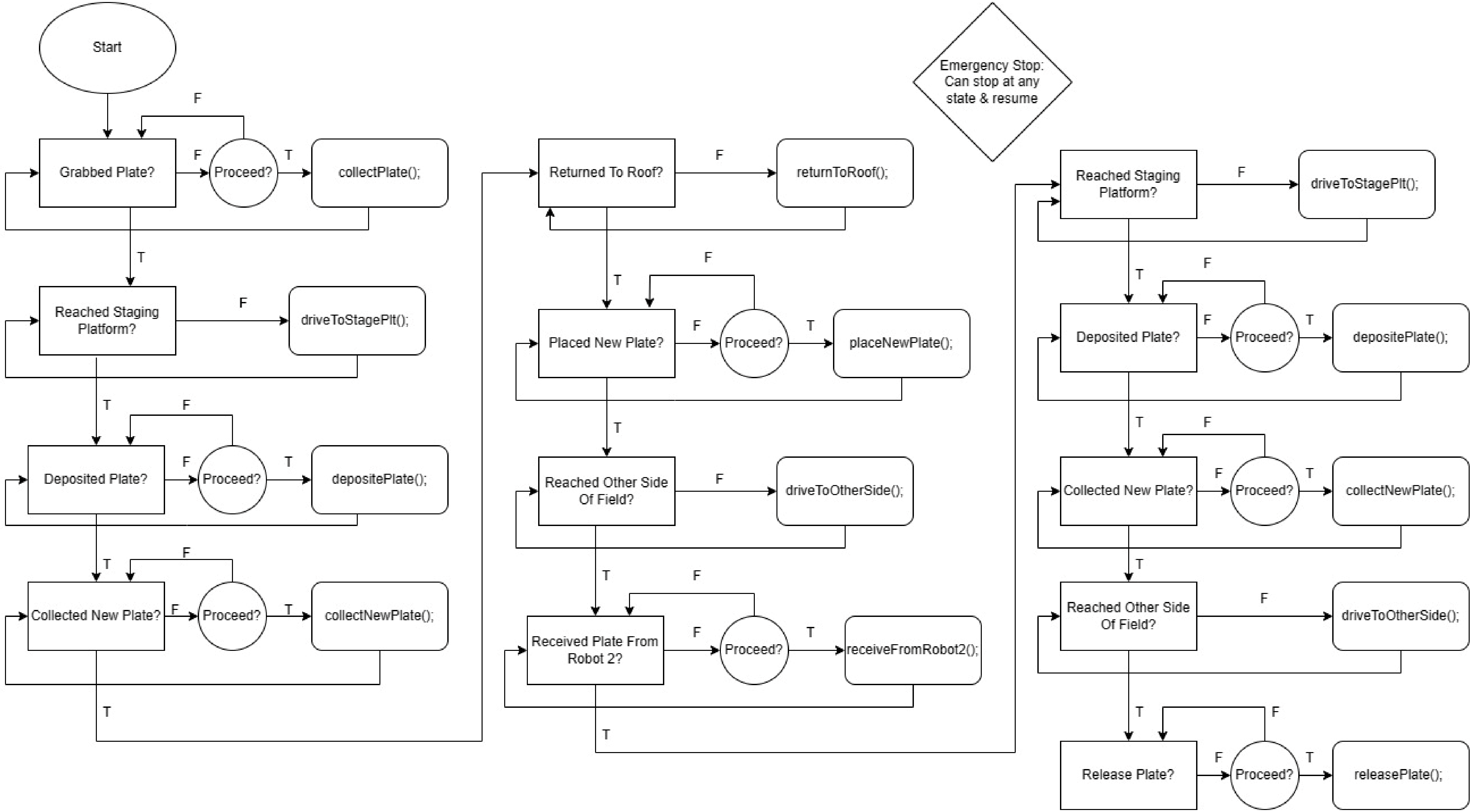


25:1 Gear Ratio

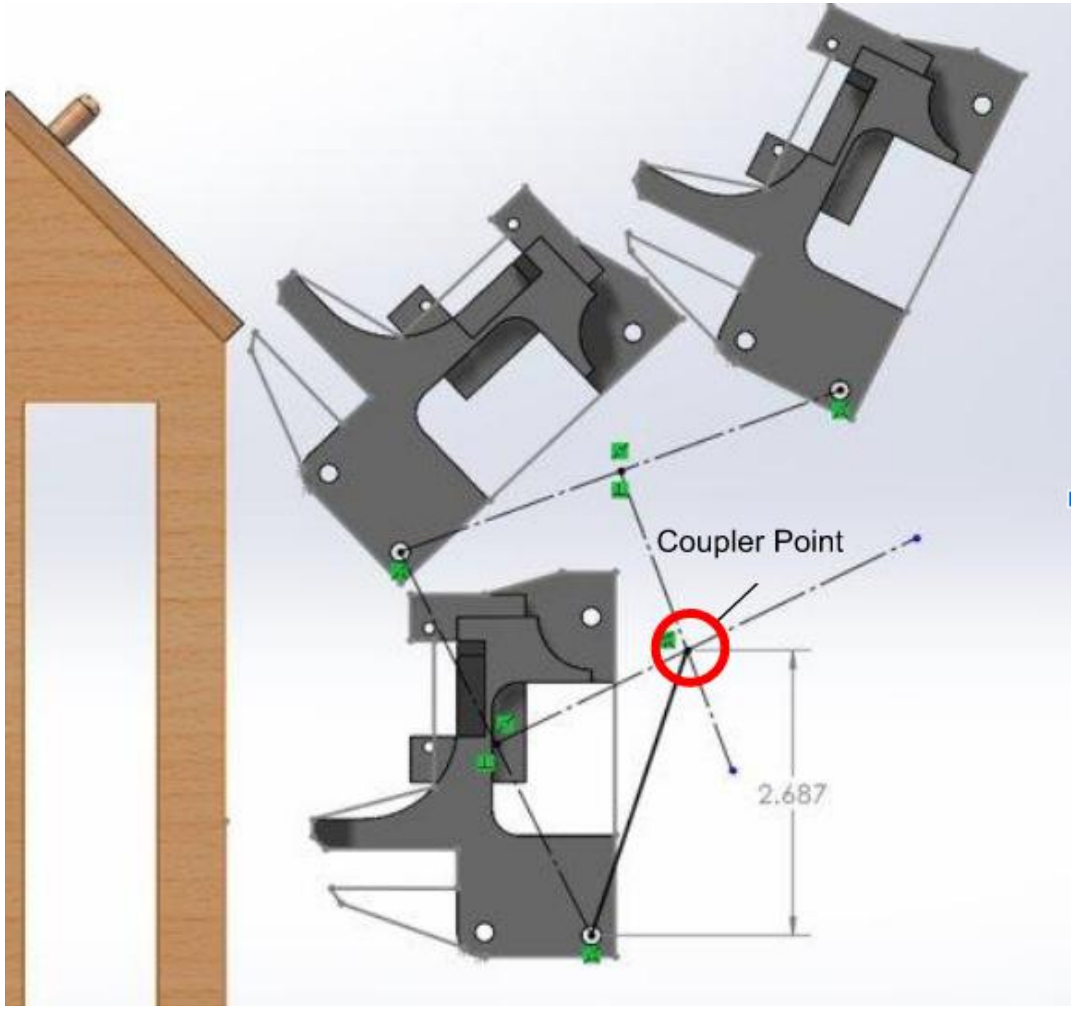
Overview of Sensors



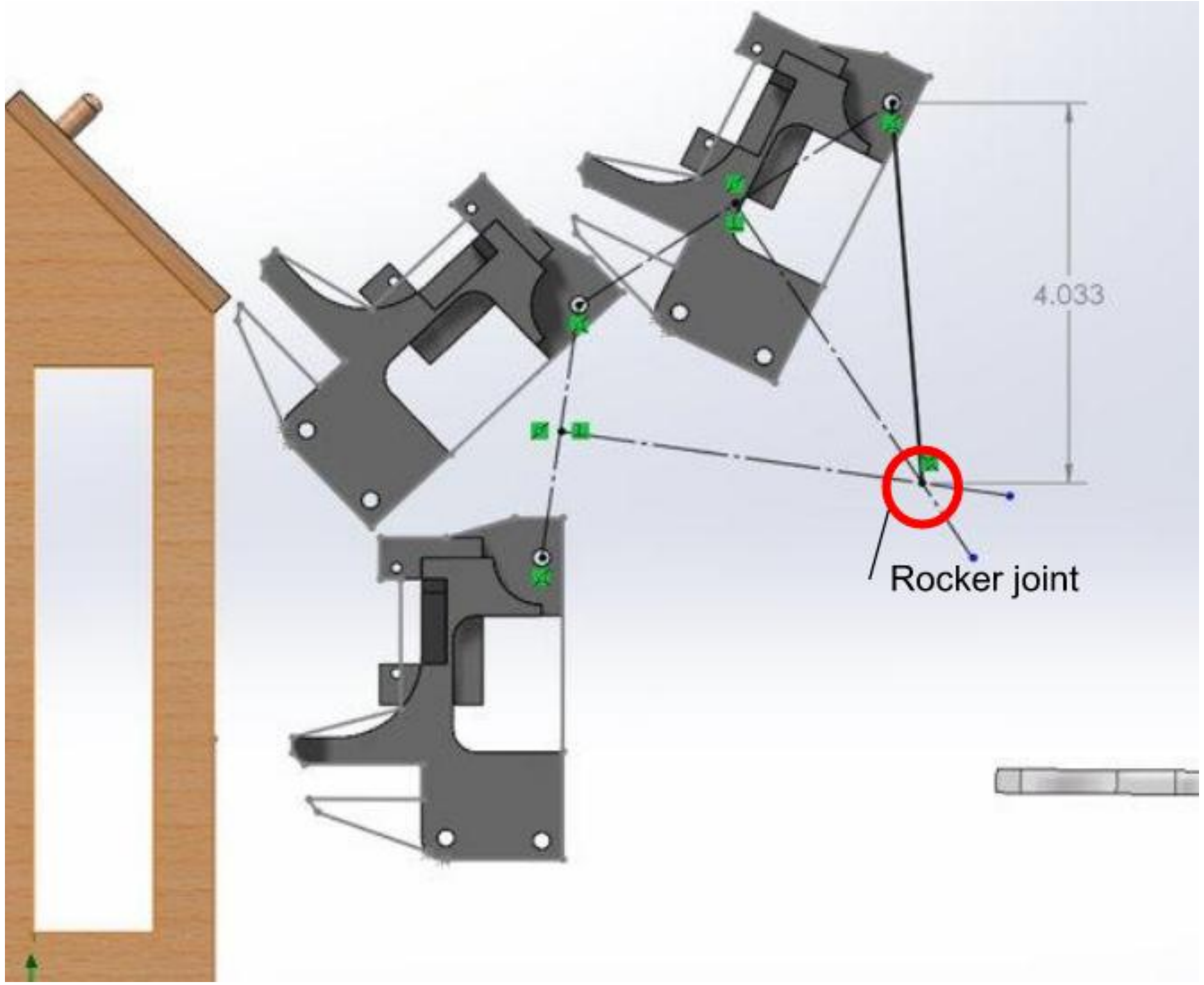
Program Flowchart



Linkage Synthesis Design Process

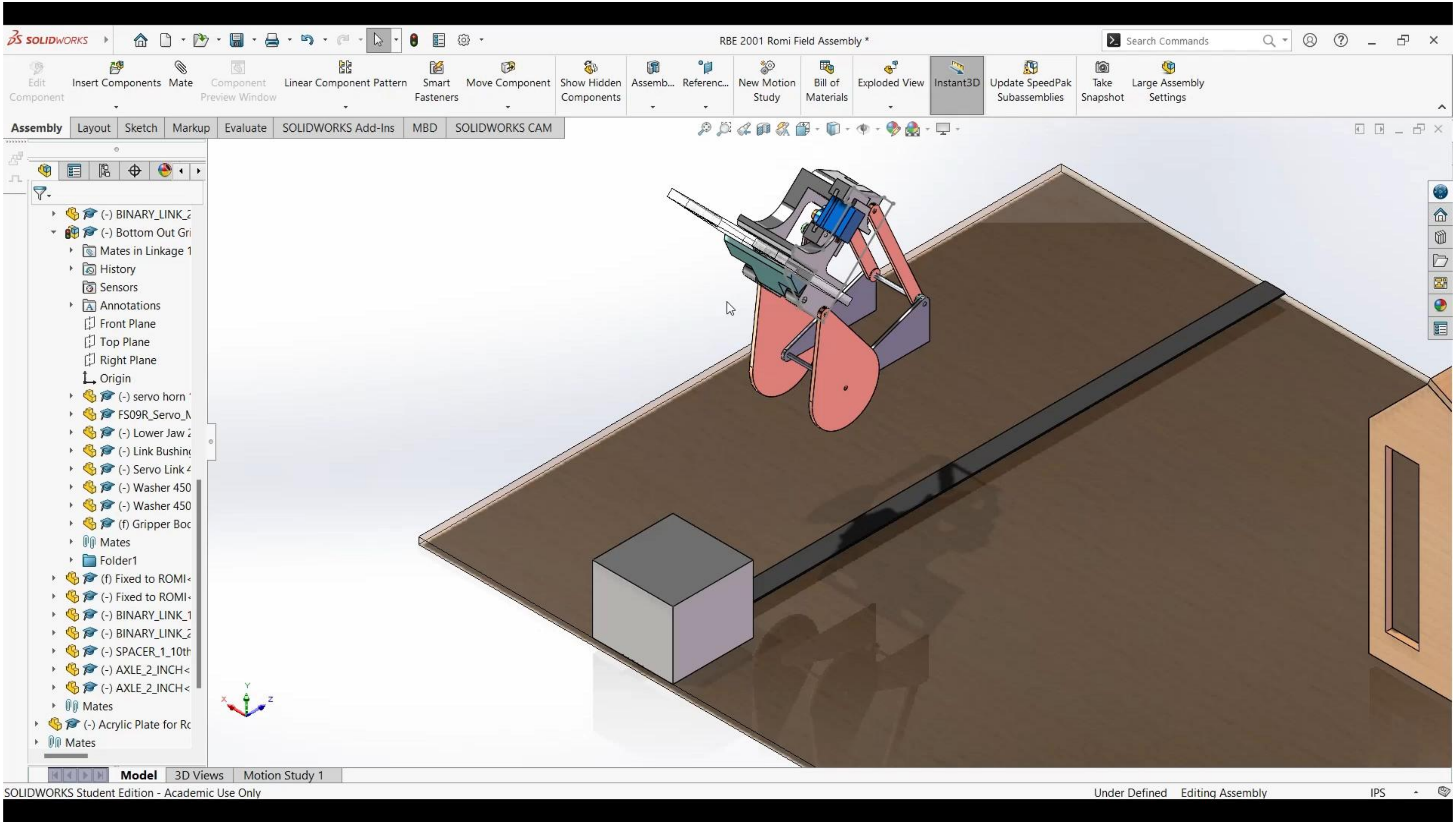


First Joint and Link Length

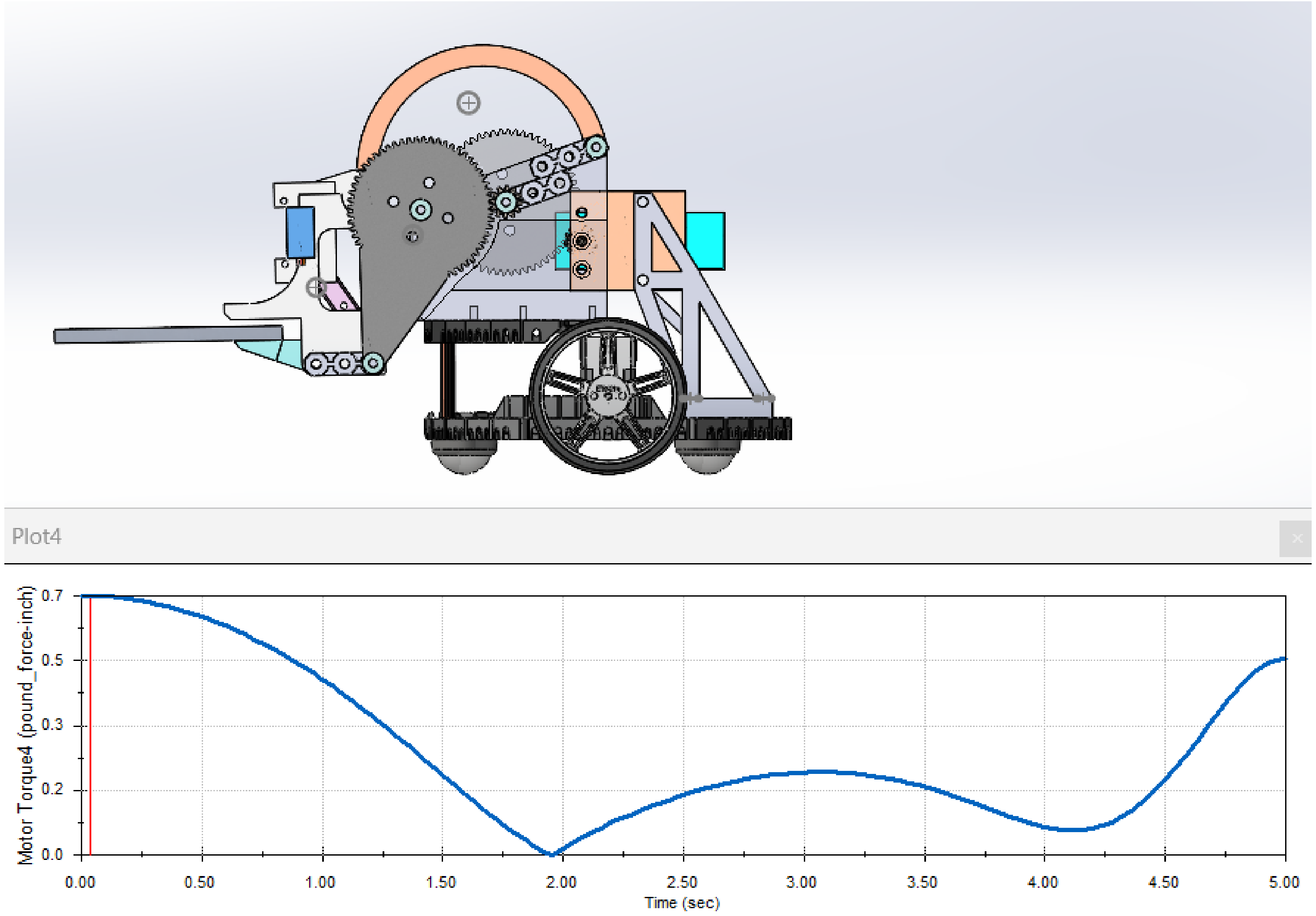


Second Joint and Link Length

Video of Four-bar Achieving Three Necessary Positions



Determining Max Torque Position Through Motion Study



https://vimeo.com/870899861/5f9794d8a0?share=copy

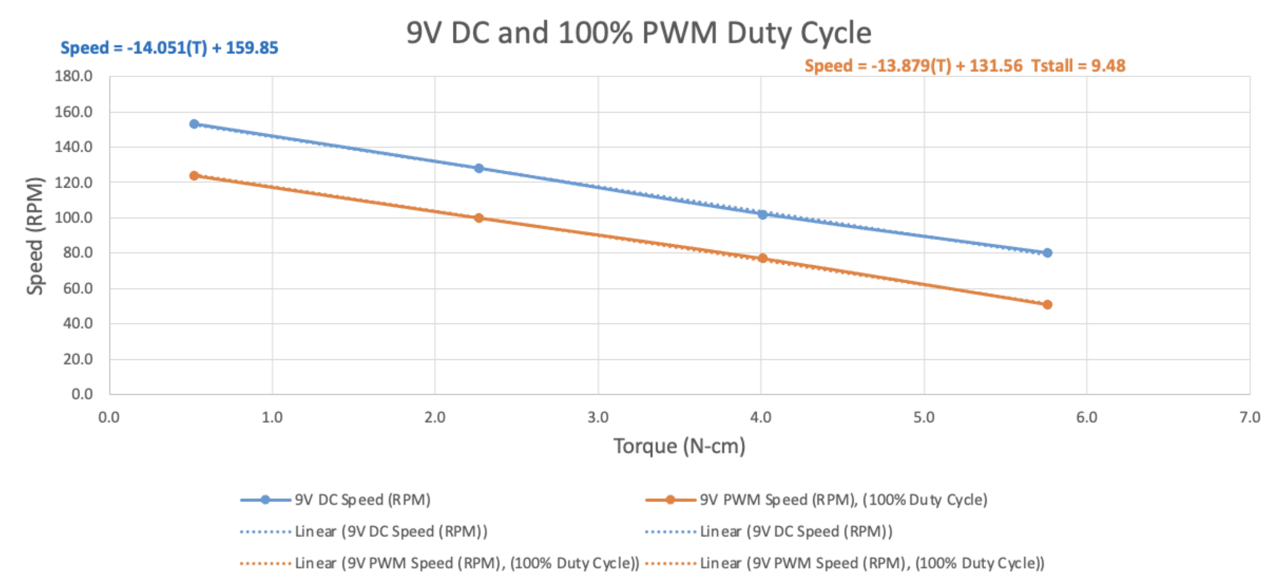
Blue Motor Current Requirement at Max Torque Position

$$I_{stall} := .2425 \cdot A \qquad I_{noload} := 0.09 \cdot A$$

$$T_{stall} := 0.839 \cdot in \cdot lbf \qquad T_{req} := \frac{0.7 \cdot in \cdot lbf}{25}$$

$$I_{req} := \frac{(I_{stall} - I_{noload}) \cdot T_{req}}{T_{stall}} + I_{noload}$$

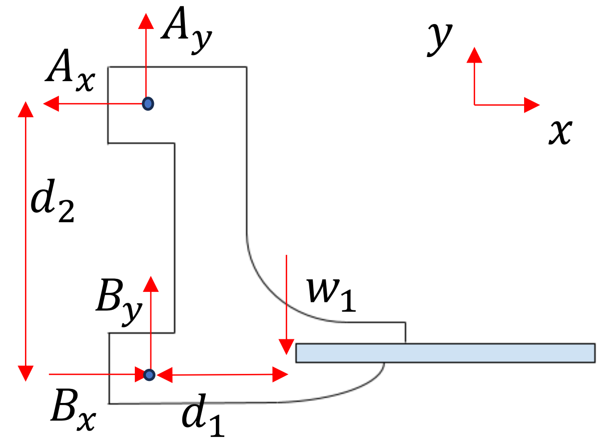
$$\boxed{I_{req} = 0.095\ A}$$



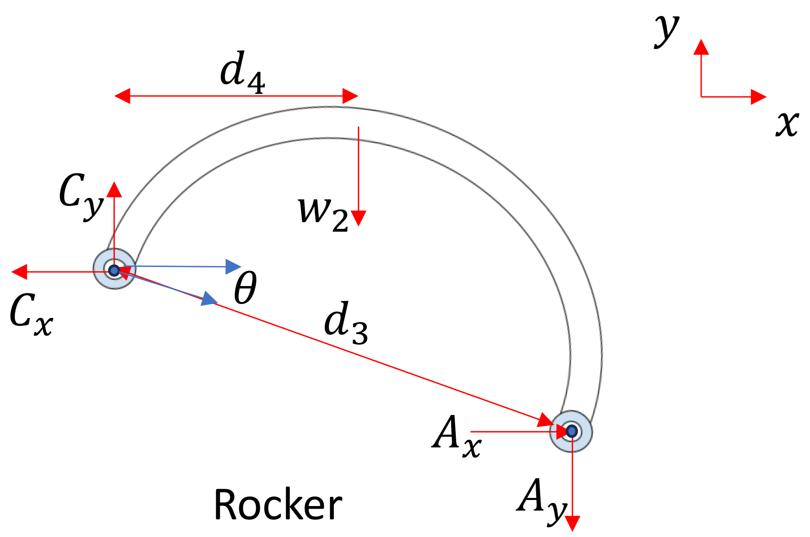
Torque (N-cm)	9V DC Speed (RPM)	9V PWM Speed (RPM), (100% Duty Cycle)	9V DC Current (A)
0.5	153.0	124.0	0.09
2.3	128.0	100.0	0.10
4.0	102.0	77.0	0.14
5.8	80.0	51.0	0.18

$$I_{stall} := I_1 + \frac{(T_{stall} - T_1)}{T_2 - T_1}(I_2 - I_1) := 0.09 + \frac{(T_{stall} - 0.5)}{5.8 - 0.5} \cdot (0.18 - 0.09)$$

Force Analysis on all Joints (Fourbar)



Gripper



Rocker

$$\sum F_x = 0 = B_x - A_x$$

$$\sum F_y = 0 = B_y + A_y - w_1$$

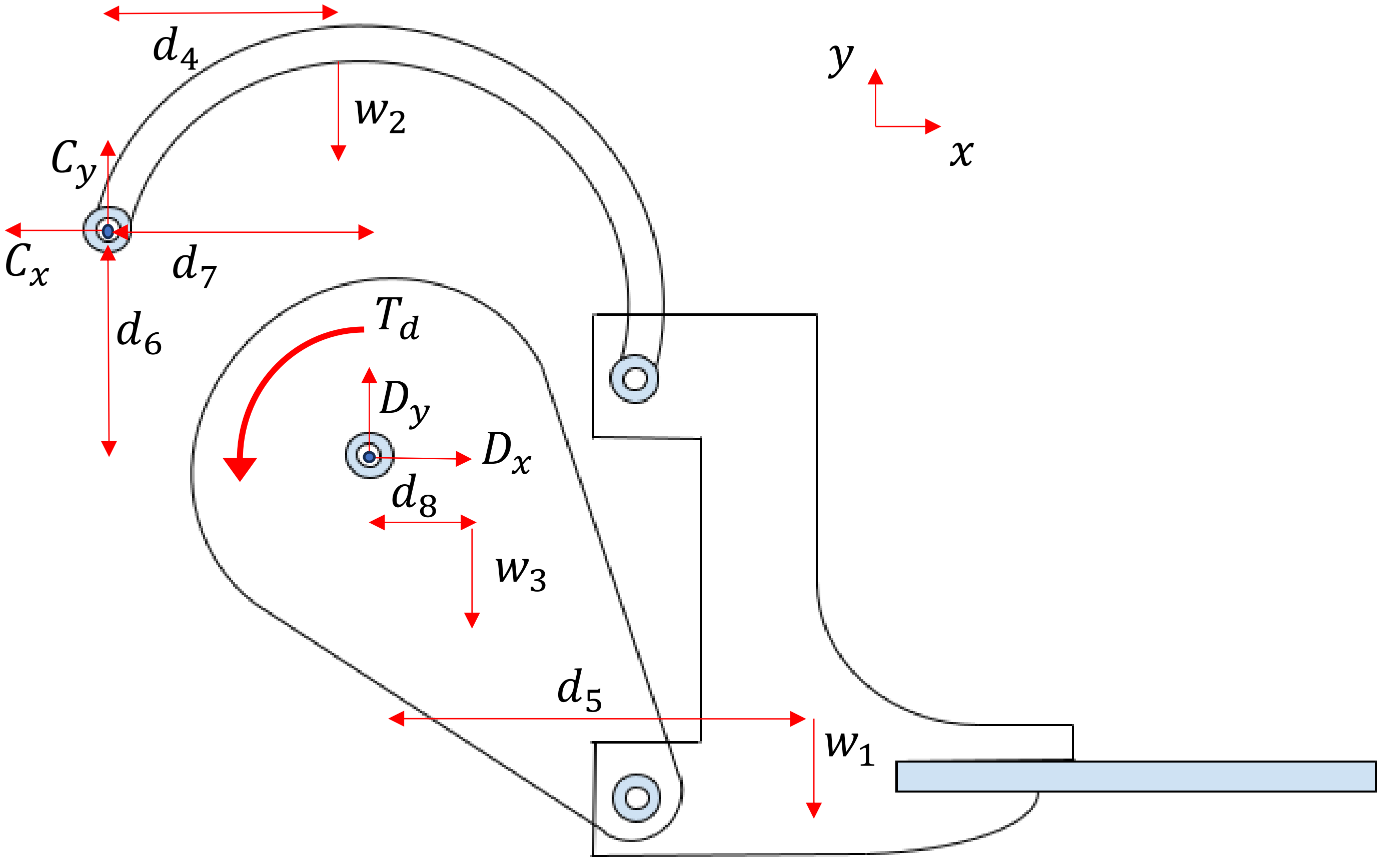
$$\sum M_B = 0 = A_x * d_2 - w_1 * d_1$$

$$\sum F_x = 0 = A_x - C_x$$

$$\sum F_y = 0 = C_y - A_y - w_2$$

$$\sum M_C = 0 = A_x * d_3 \sin(\theta) - A_y * d_3 \cos(\theta) - w_2 * d_4$$

Force Analysis on all Joints (Fourbar cont.)



Full System

$$\sum F_x = 0 = -C_x + D_x$$

$$\sum F_y = 0 = C_y + D_y - w_1 - w_2 - w_3$$

$$\sum M_D = 0 = T_d - w_1 * d_5 + w_2 * (d_7 - d_4) - w_3 * d_8 - C_y * d_7 + C_x * d_6$$

Force Analysis on all Joints (fin.)

Known Parameters:

$w_1 := .48 \cdot lbf$

$w_3 := 0.05293299 \cdot lbf$

$w_2 := 0.021671 \cdot lbf$

$d_1 := 2.773517 \cdot in$

$d_2 := 3 \cdot in$

$d_8 := .147828 \cdot in$

$d_3 := 4.033 \cdot in$

$d_4 := 2.234416 \cdot in$

$d_7 := 3.07317 \cdot in$

$d_5 := 1.881675 \cdot in$

$Theta_1 := 11.23895502 \cdot deg$

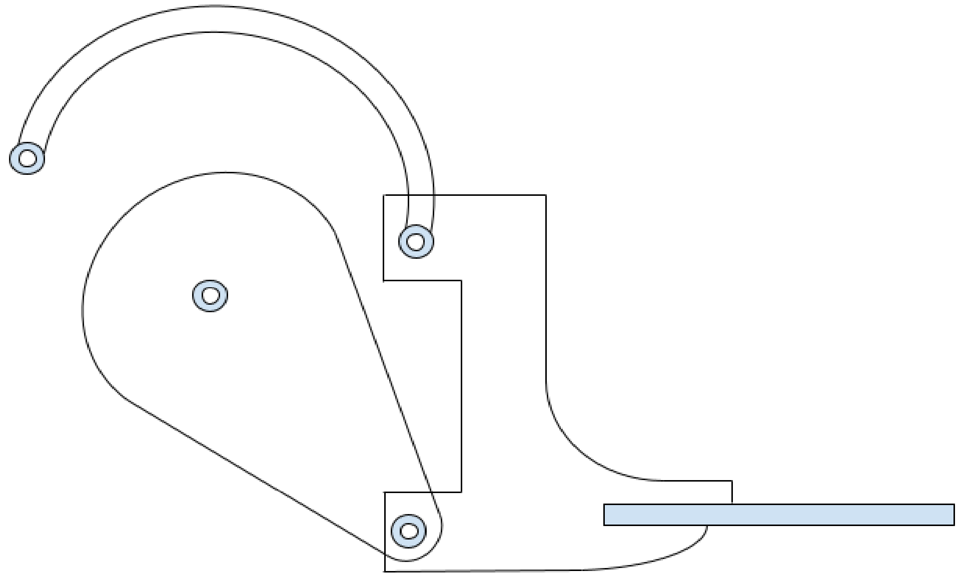
$d_6 := 1.103054 \cdot in$

Supply initial guesses for unknowns:

$B_x := 2 \cdot lbf \quad B_y := 2 \cdot lbf \quad C_x := 2 \cdot lbf \quad C_y := 2 \cdot lbf$

$A_x := 2 \cdot lbf \quad A_y := 2 \cdot lbf \quad D_x := 2 \cdot lbf \quad D_y := 2 \cdot lbf$

$mm := 4 in \cdot lbf$



$$\begin{pmatrix} SA_x \\ SA_y \\ SB_x \\ SB_y \\ SC_x \\ SC_y \\ SD_x \\ SD_y \\ Smm \end{pmatrix} := \text{Find}(A_x, A_y, B_x, B_y, C_x, C_y, D_x, D_y, mm)$$

$SA_x = 0.44\, lbf$

$SA_y = 0.08\, lbf$

$SB_x = 0.44\, lbf$

$SB_y = 0.4\, lbf$

$SC_x = 0.44\, lbf$

$SC_y = 0.1\, lbf$

$SD_x = 0.44\, lbf$

$SD_y = 0.46\, lbf$

$\boxed{Smm = 0.7\, in \cdot lbf}$

Gear Ratio Usage & Efficiency Estimate of Four Bar

$\eta := 0.95$ Gears used: 4 Total Gear Ratio- 1:25 $n_{drivers} := 12 \cdot 12$

$\tau_{out} := 0.7 in \cdot lbf$ $stages := 2$ $r_{gears} := \frac{1}{25}$ $n_{driven} := 60 \cdot 60$

We used 2 stages of gears.
Both stages used a ratio of 12:60

$stage_1 := \frac{12}{60}$ $stage_2 := \frac{12}{60}$

$$\boxed{\tau_{in} := \frac{r_{gears} \cdot \tau_{out}}{\eta^{stages}} = 0.031 \cdot in \cdot lbf}$$

$$ee := \frac{n_{drivers}}{n_{driven}} = 0.04$$

Calculated Stall Torque for 100% Duty Cycle is 9.48 N-cm or 0.839 in-lbs. Our required input torque based on selected gear ratio (1:25) is less than 25% of stall torque (0.210 in-lbs)

Speed of Panel End at Max Torque

$AB := 3 \cdot in$ $\quad DA := 2.84 \cdot in$

$BC := 4.033 \cdot in$ $\quad DC := 3.263 \cdot in$

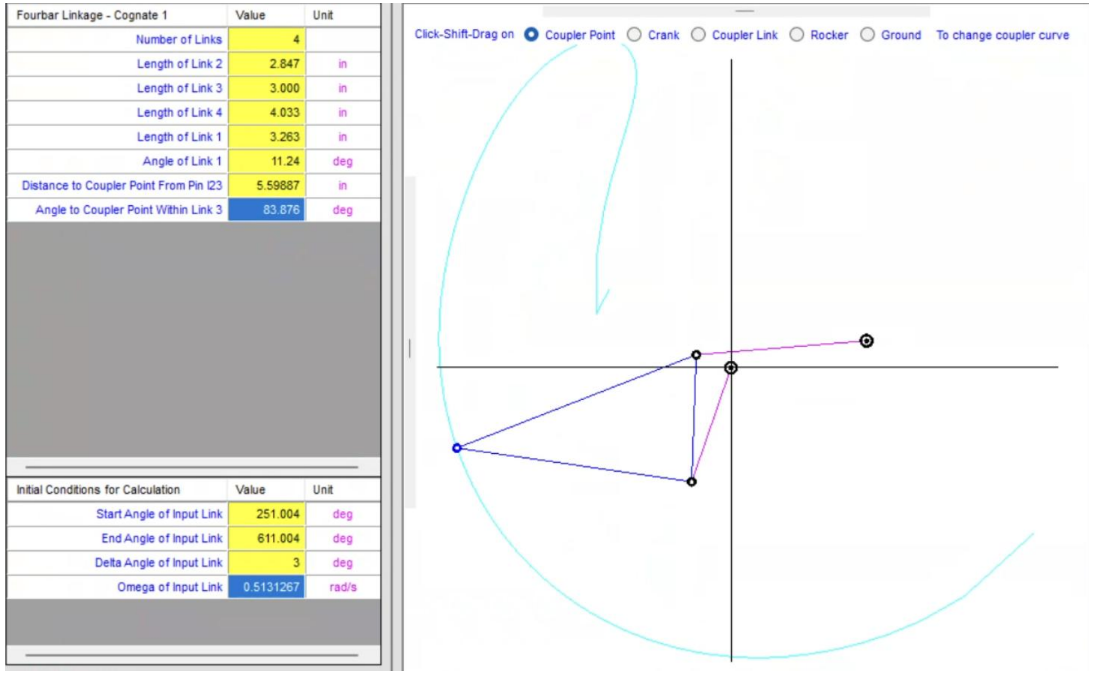
$w_2 := 0.5907 \frac{rad}{sec}$ $\quad I_{cA} := 3.4064 \cdot in$

$I_{cP} := 6.892 \cdot in$

$V_a := DA \cdot w_2$ $\quad V_a = 1.693 \frac{in}{sec}$

$w_3 := \frac{V_a}{I_{cA}}$ $\quad w_3 = 2.95 \frac{rad}{sec}$

$V_p := I_{cP} \cdot w_3$ $\quad \boxed{V_p = 3.386 \frac{in}{sec}}$

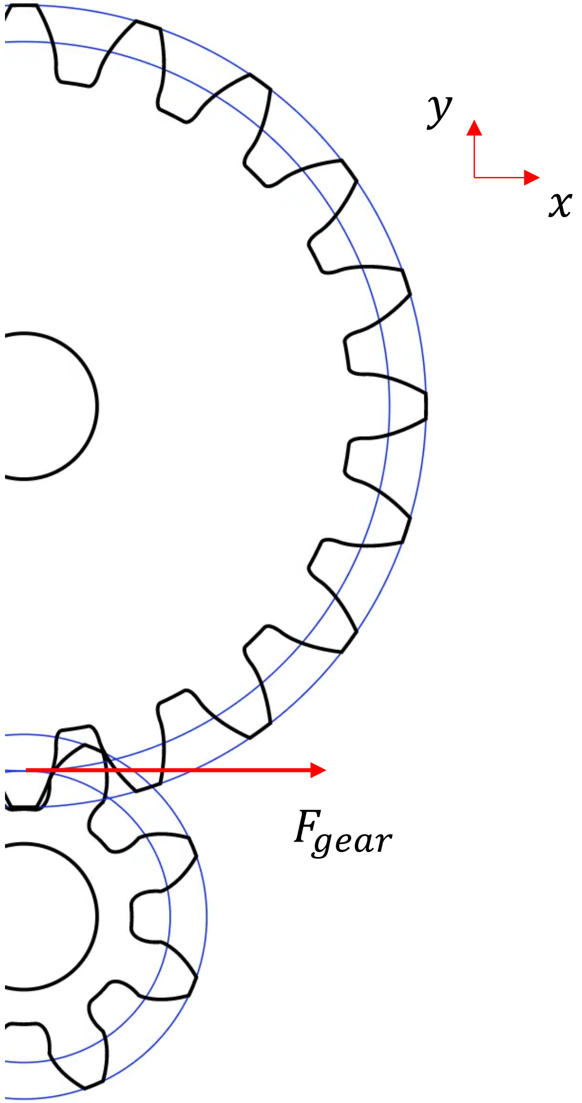


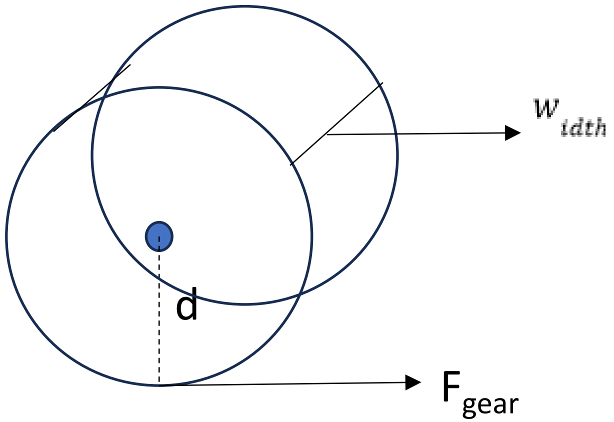
Torque (N-cm)	9V DC Speed (RPM)	9V PWM Speed (RPM), (100% Duty Cycle)	9V DC Current (A)
0.5	153.0	124.0	0.09
2.3	128.0	100.0	0.10
4.0	102.0	77.0	0.14
5.8	80.0	51.0	0.18

$$MOTOR: w = 141.027\ RPM = 14.768 \frac{rad}{sec}$$

$$CRANK: w_2 = \frac{w}{25} = 0.5907 \frac{rad}{sec}$$

FBDs & EOEs, Stresses & Factors of Safety on Gear Teeth





$$\sum M = F_{Gear} * d$$

$P := 24 \cdot \frac{1}{in}$ $\quad d_1 := 1.25 \cdot in$ $\quad T_1 := 0.7 \cdot in \cdot lbf$

$w_{idth} := 0.5 \cdot in$

$y_{ieldSTR} := 8700 \cdot psi$

$F_{Gear} := \frac{T_1}{d_1}$ $\quad F_{Gear} = 0.56 \cdot lbf$

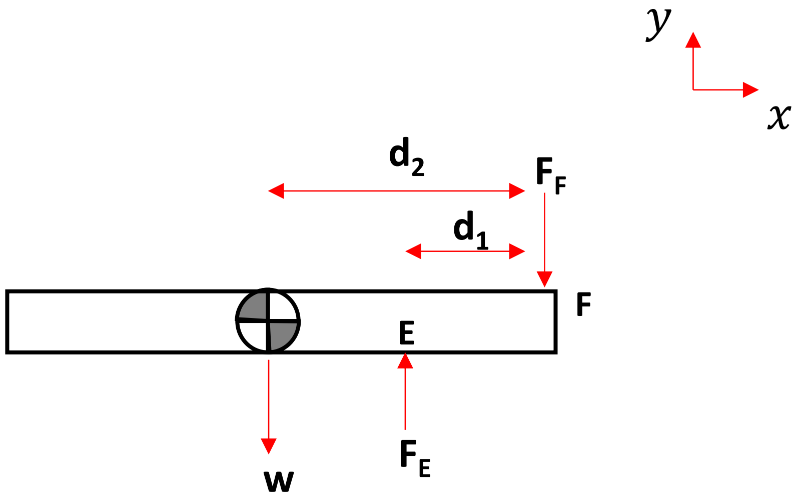
$t_{ao} := \frac{3.14159}{2} \cdot \frac{1}{P}$ $\quad t_{ao} = 0.065 \cdot in$

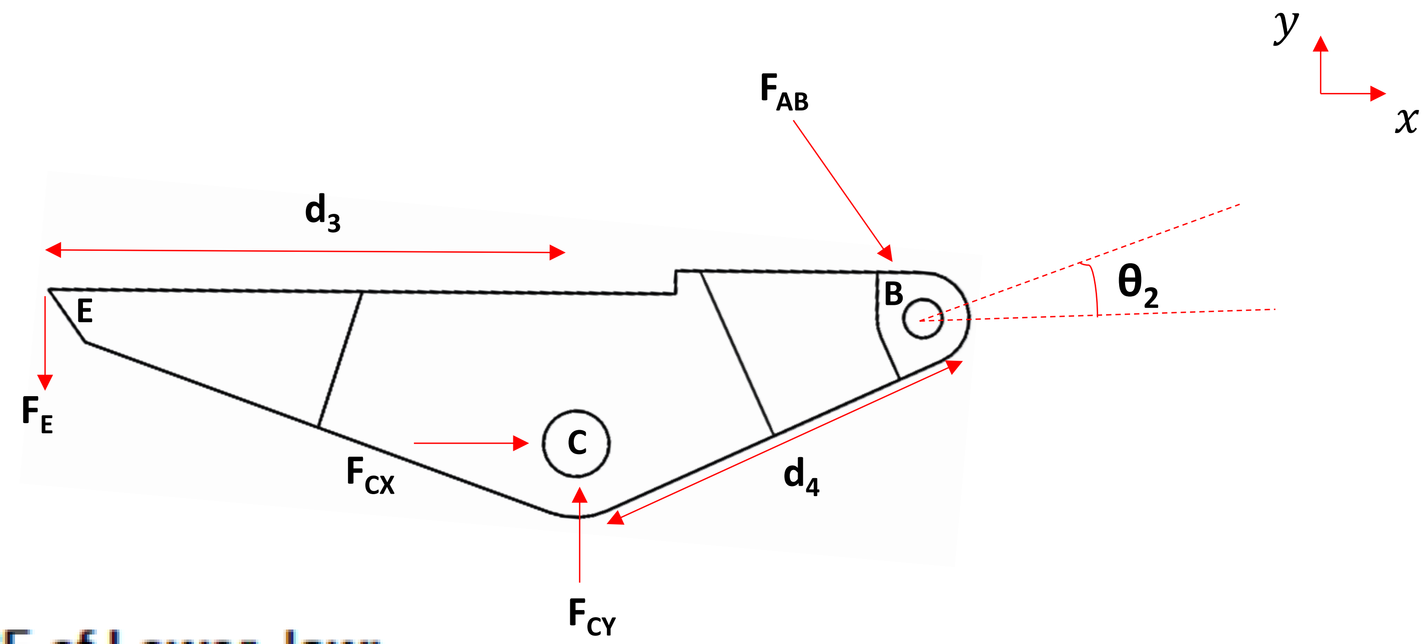
$A_{tooth} := t_{ao} \cdot w_{idth}$ $\quad A_{tooth} = 0.033 in^2$

$S_{igma} := \frac{F_{Gear}}{A_{tooth}}$ $\quad S_{igma} = 17.114\ psi$

$F_{os} := \frac{y_{ieldSTR}}{S_{igma}}$ $\quad F_{os} = 508.405$

Servo Gripper Analysis (Locked Position)





From FBE of Collector:

$$0 = -F_E \cdot d_1 + w \cdot d_2$$

$$0 = -w + F_E - F_F$$

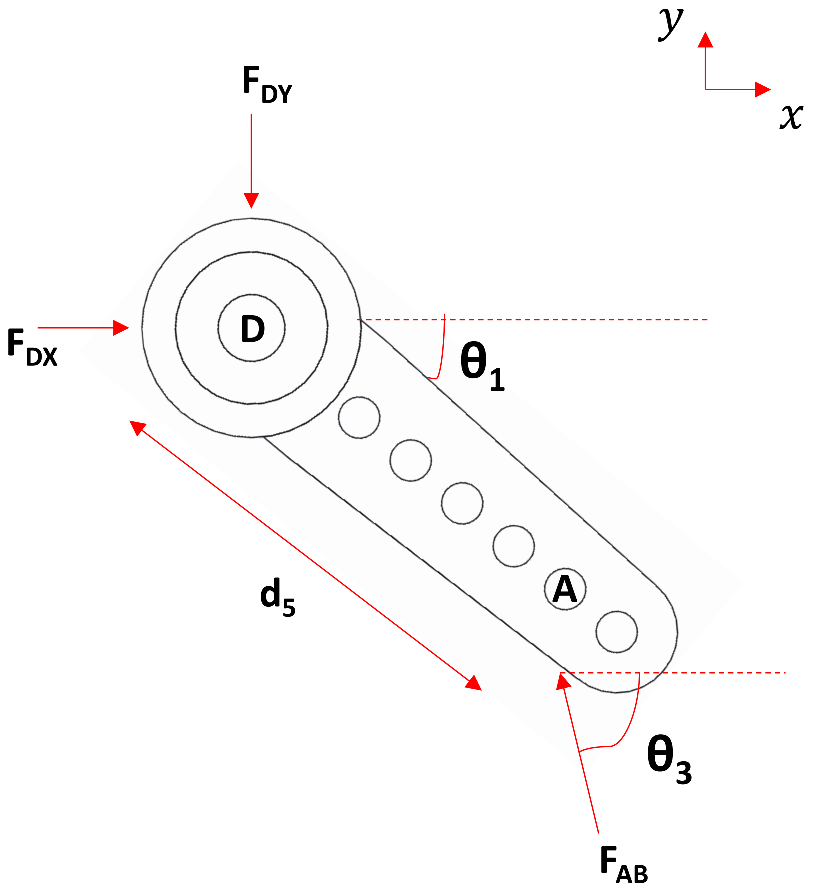
From FBE of Lower Jaw:

$$0 = F_E \cdot d_3 - F_{AB} \cdot \sin(\mathrm{Theta3}) \cdot d_4 \cdot \cos(\mathrm{Theta2}) - F_{AB} \cdot \cos(\mathrm{Theta3}) \cdot d_4 \cdot \sin(\mathrm{Theta2})$$

$$0 = F_{CX} + F_{AB} \cdot \cos(\mathrm{Theta3})$$

$$0 = -F_E + F_{CY} - F_{AB} \cdot \sin(\mathrm{Theta3})$$

Servo Gripper Analysis (Locked Position)



From FBE of Servo Horn:

$$0 = -M_D + F_{AB} \cdot \sin(\text{Theta3}) \cdot d_5 \cdot \cos(\text{Theta1}) - F_{AB} \cdot \cos(\text{Theta3}) \cdot d_5 \cdot \sin(\text{Theta1})$$

$$0 = F_{DX} - F_{AB} \cdot \cos(\text{Theta3})$$

$$0 = F_{AB} \cdot \sin(\text{Theta3}) - F_{DY}$$

Servo Gripper Analysis (Locked Position)

Known Parameters:

$w := 0.3306 lbf$ $d_1 := 1.181 in$ $d_2 := 2.013 in$ $d_3 := 1.496 in$ $d_4 := 1.102 in$

$d_5 := 0.630 in$ $Theta1 := 56.87 deg$ $Theta2 := 13.03 deg$ $Theta3 := 56.87 deg$

Supply initial guesses for unknowns:

$F_E := 0 lbf$ $F_F := 0 lbf$ $F_{AB} := 0 lbf$ $F_{CX} := 0 lbf$

$F_{CY} := 0 lbf$ $F_{DX} := 0 lbf$ $F_{DY} := 0 lbf$ $M_D := 0 in \cdot lbf$

$$\begin{pmatrix} SF_E \\ SF_F \\ SF_{AB} \\ SF_{CX} \\ SF_{CY} \\ SF_{DX} \\ SF_{DY} \\ SM_D \end{pmatrix} := Find(F_E, F_F, F_{AB}, F_{CX}, F_{CY}, F_{DX}, F_{DY}, M_D)$$

$SF_E = 0.56 lbf$

$SF_F = 0.23 lbf$

$SF_{AB} = 0.81 lbf$

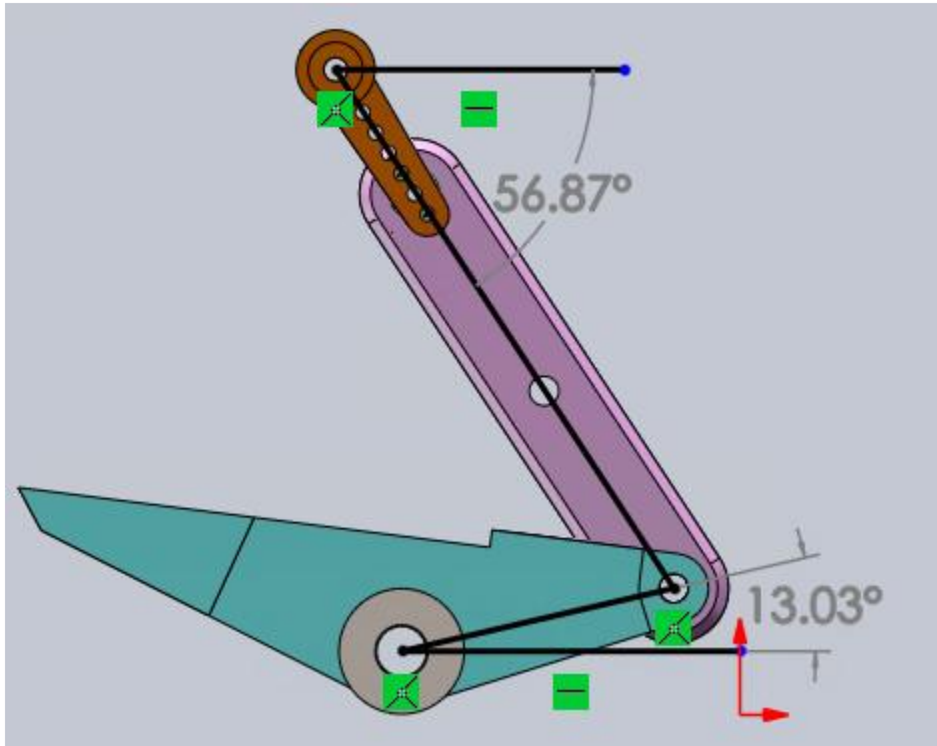
$SF_{CX} = -0.45 lbf$

$SF_{CY} = 1.25 lbf$

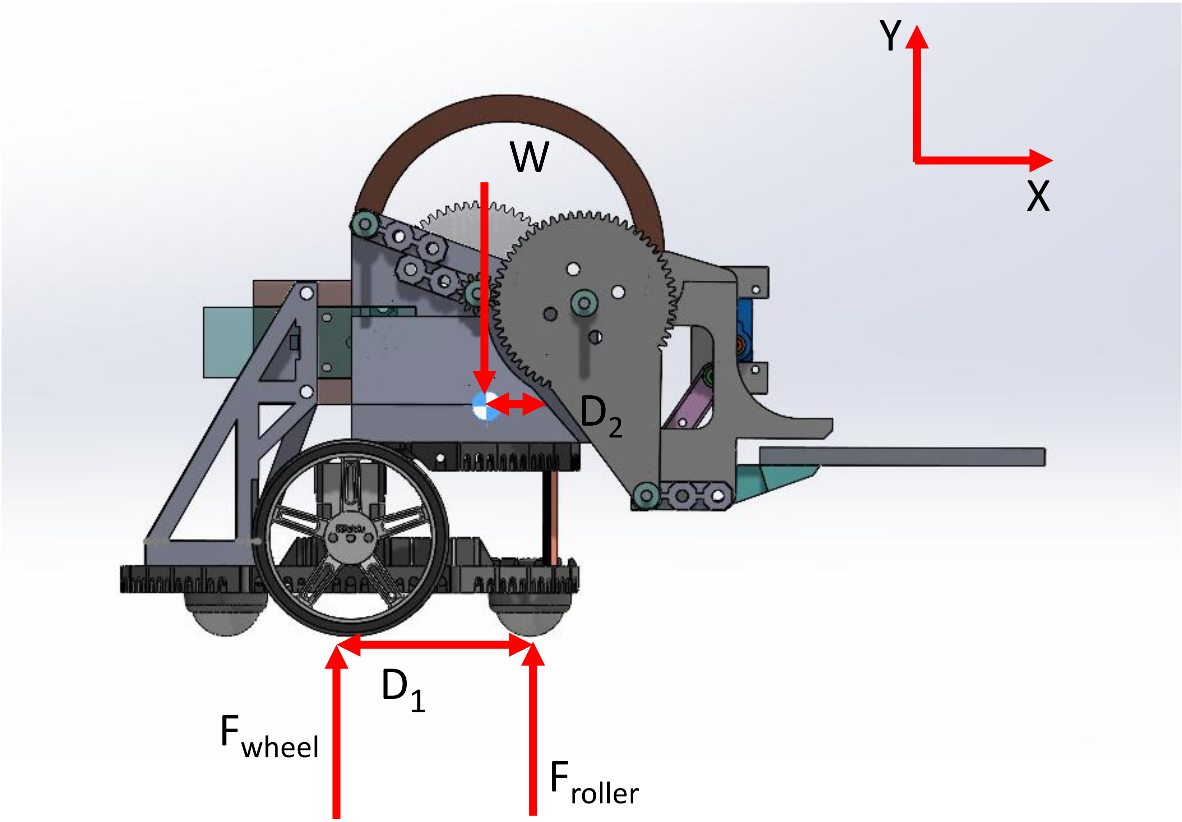
$SF_{DX} = 0.45 lbf$

$SF_{DY} = 0.68 lbf$

$\boxed{SM_D = 0 in \cdot lbf}$



Stability at Max Torque Position w/ Metal Plate



D_1=1.75in

D_2 = 0.549 in

W = 1.94 lbf

$$\sum M_{frontroller} = 0$$

$$0 = -F_{wheel} * D_1 + W * D_2$$

$$F_{wheel} * D_1 = W * D_2$$

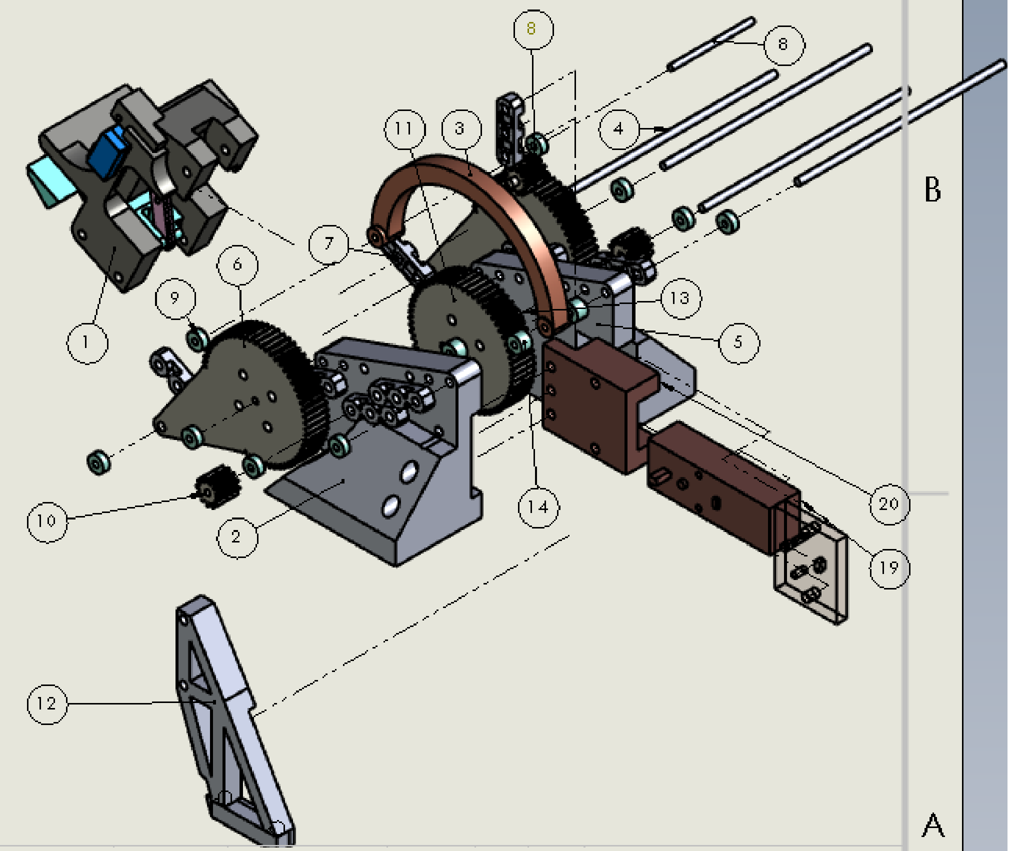
$$F_{wheel} = \frac{W * D_2}{D_1} = \frac{1.94 * 0.549}{1.75} = 0.609lbf$$

$$F_{wheel} = (32\%) \text{ of total weight (W)}$$

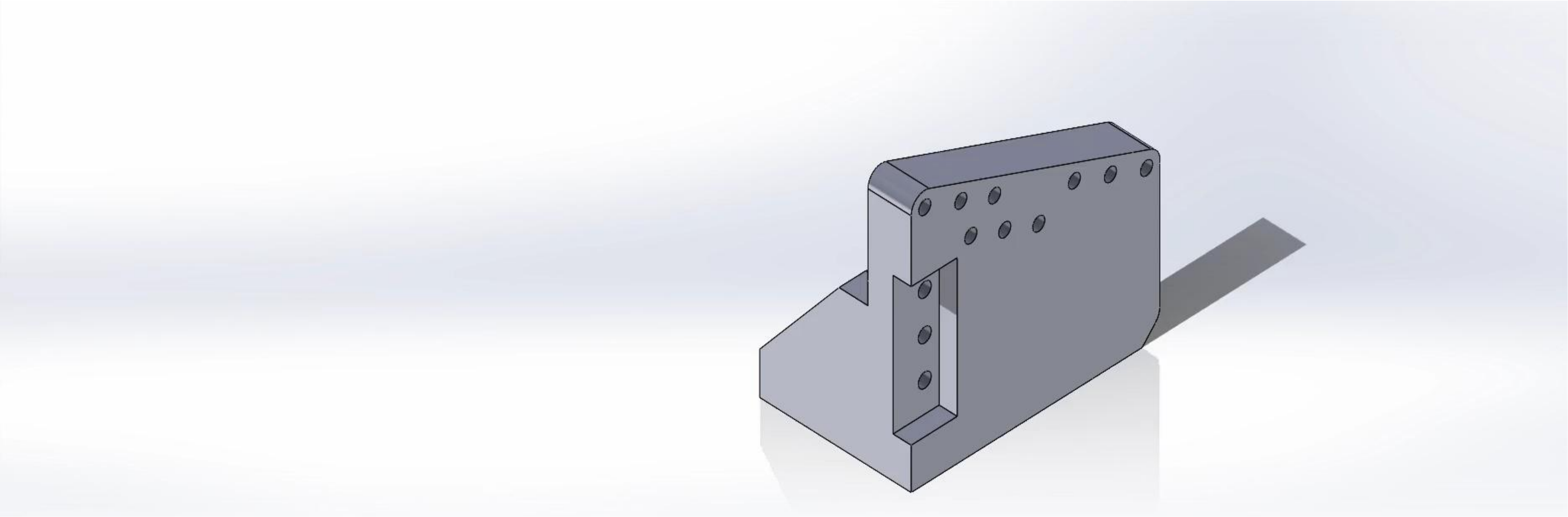
$$\therefore \textit{No worry of slipping/tipping}$$

BOM and Exploded View

ITEM NO.	TITLE	QTY.	MATERIAL	UNIT WEIGHT (lbs)	EXT. WEIGHT (lbs)	UNIT COST ($)	EXT. COST ($)
1	GRIPPER	1	PLA	0.13	0.13	2.40	2.40
2	LEFT_SHAFT_SUPPORT	1	PLA	0.11	0.11	2.07	2.07
3	ROCKER_FOUR_BAR	1	PLA	0.01	0.01	0.39	0.39
4	VEX_SHAFT_5_INCH	4	Steel	0.0	0.00	1.00	4.00
5	RIGHT_SHAFT_SUPPORT	1	PLA	0.11	0.11	1.94	1.94
6	CRANK_FOUR_BAR	2	PLA	0.05293299	0.11	0.48	0.96
7	BEARING_FLAT	9	DELRIN	0.00	0.00	0.55	4.95
8	VEX_SHAFT_2_INCH	1	Steel	0.0	0.00	1.00	1.00
9	VEX_COLLAR	10	DELRIN	0.00	0.00	1.00	10.00
10	12_TOOTH_GEAR	2	PLA	0.00357149	0.01	0.05	0.10
11	60_TOOTH_GEAR	1	PLA	0.04173351	0.04	0.76	0.76
12	BACK_LEFT_FIXED_MOTOR_SUPPORT	1	PLA	0.03	0.03	0.58	0.58
13	.15_INCH_SPACER	1	DELRIN	0.00	0.00	1.00	1.00
14	.25_INCH_SPACER	3	DELRIN	0.00	0.00	1.00	3.00
15	BLUE_MOTOR	1	Plastic, Copper, Steel	0.07	0.07	10.00	10.00
16	MOTOR_SUPPORT_BASE	1	PLA	0.02	0.02	0.49	0.49
17	MOTOR_SUPPORT_LID	1	PLA	0.01	0.01	0.40	0.40
18	12_TOOTH_MOTOR_GEAR	1	PLA	0.00	0.00	0.06	0.06
.	Assembly			ASSEMBLY WEIGHT (lbs)	1.93	ASSEMBLY COST ($)	76.39



Assembly of Robot



Thank you

Any Questions?