RBE 2001 FINAL PROJECT PRESENTATION

EMILY AUSTIN, MICHAEL BESKID, JONATHAN GONG

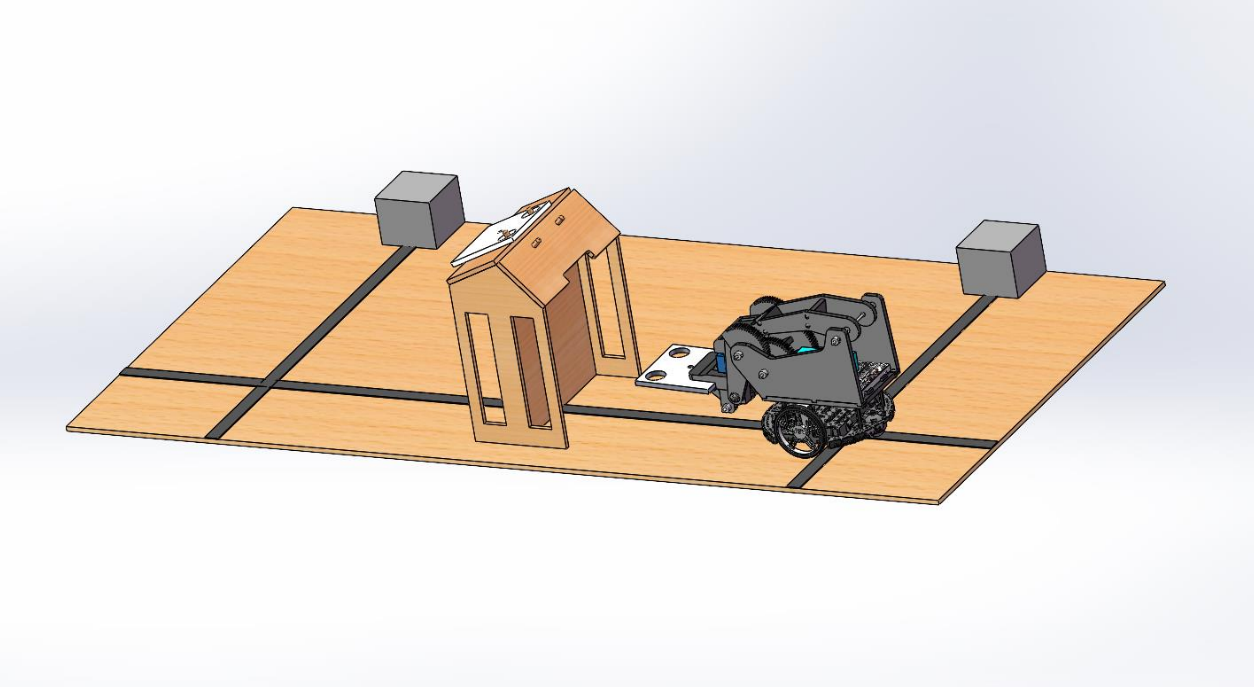
STRATEGY AND SYSTEMS

Strategy:

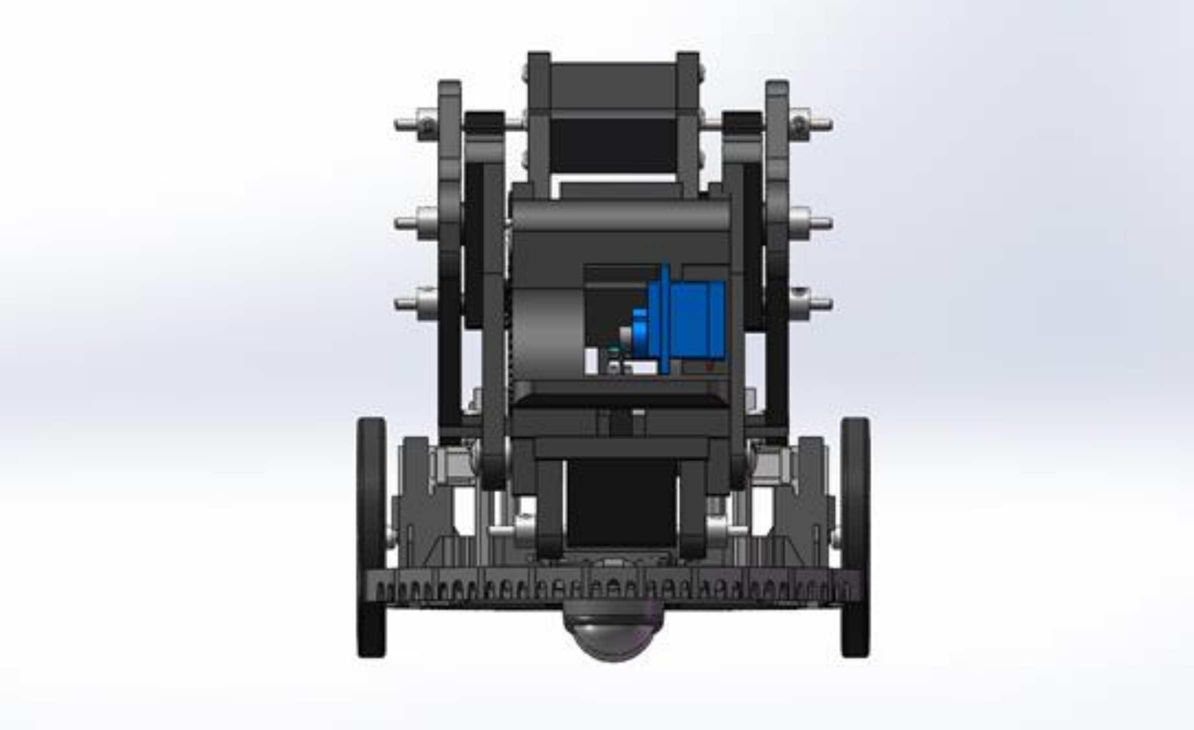
- Start on the 45-degree roof side
- Grab collector from roof and place on staging block
- Pick up new collector and place back onto roof
- Autonomously move to the other side of the field
- Repeat process for 25-degree roof
- Stop after new collector is placed

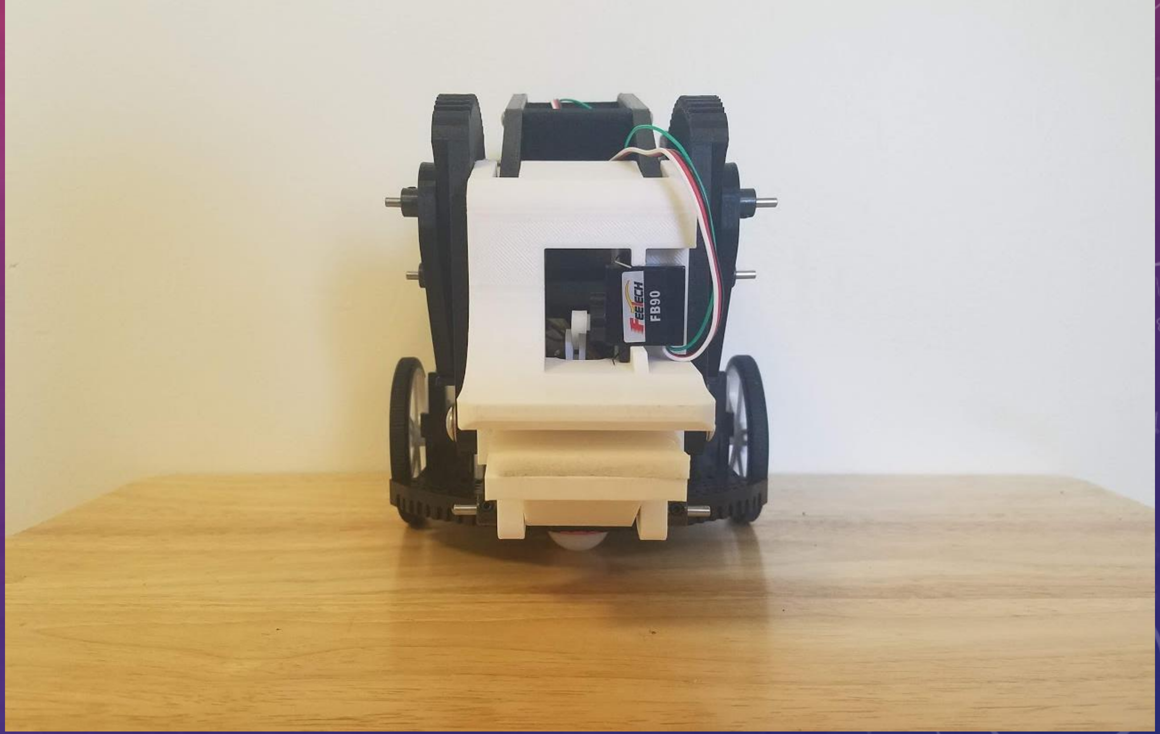
System:

- Designed a gripper to grab the collector
- Use a four-bar mechanism to lift the collector to/from the roof
- Have a two stage 1:25 transmission to power the four-bar mechanism

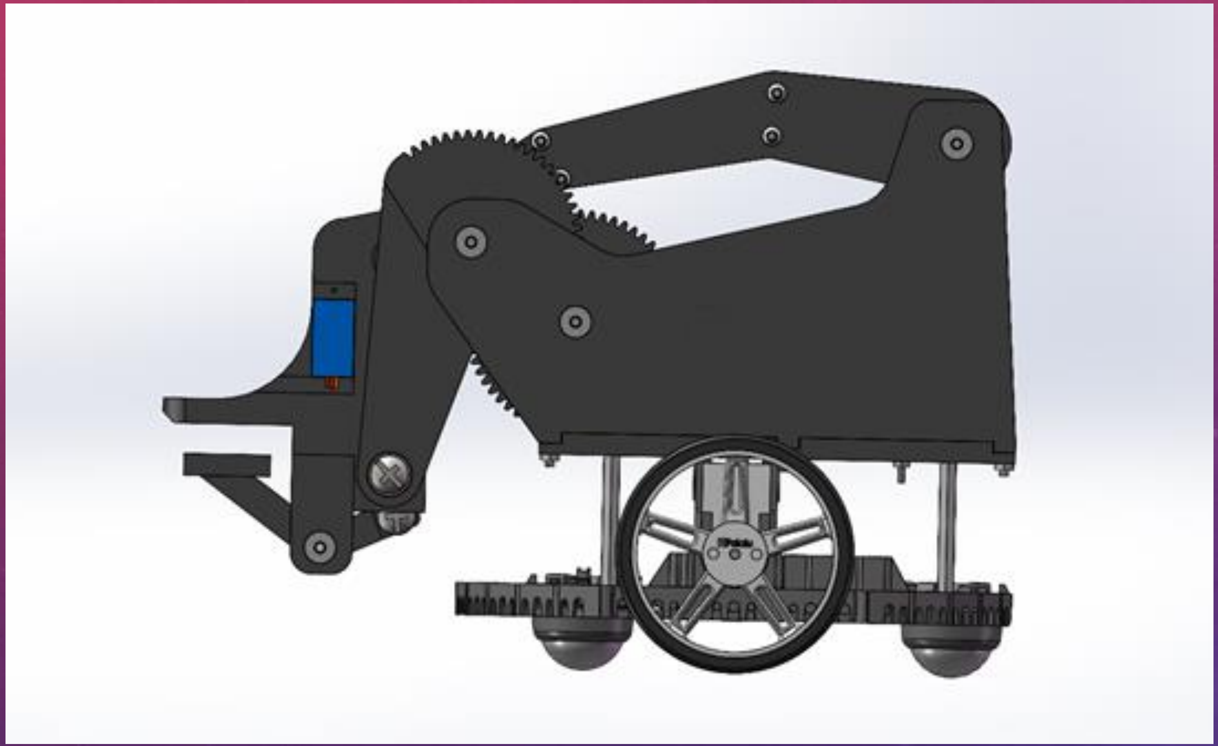


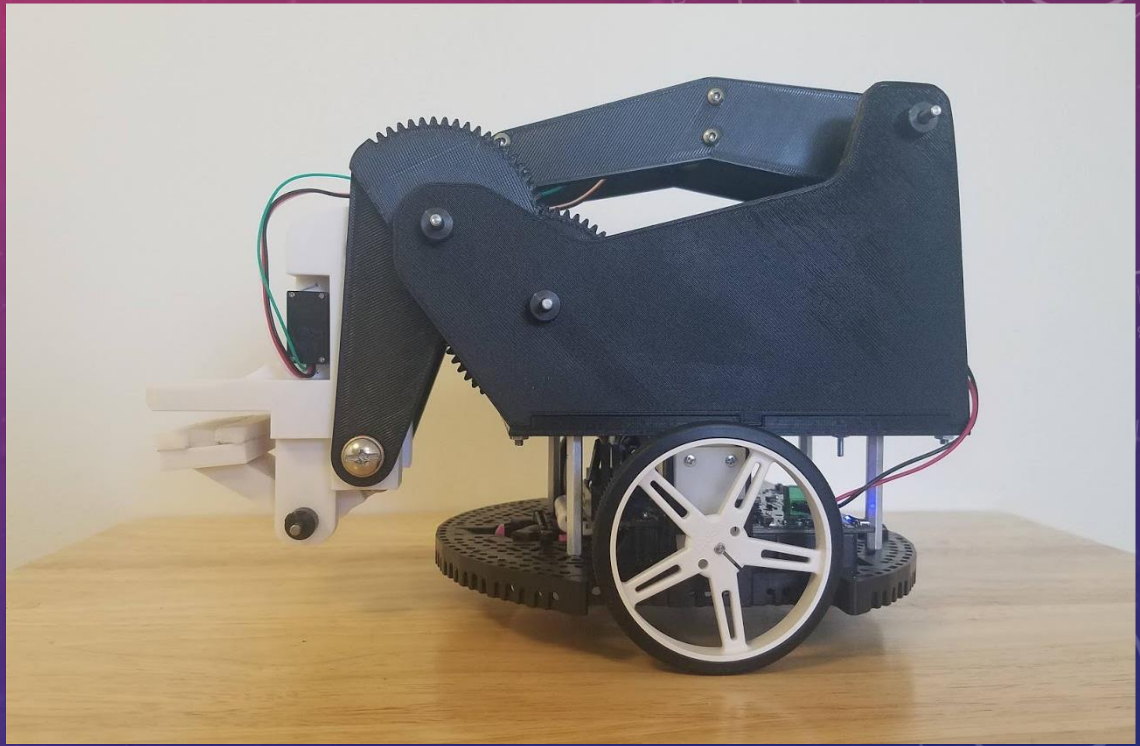
DESIGN OVERVIEW



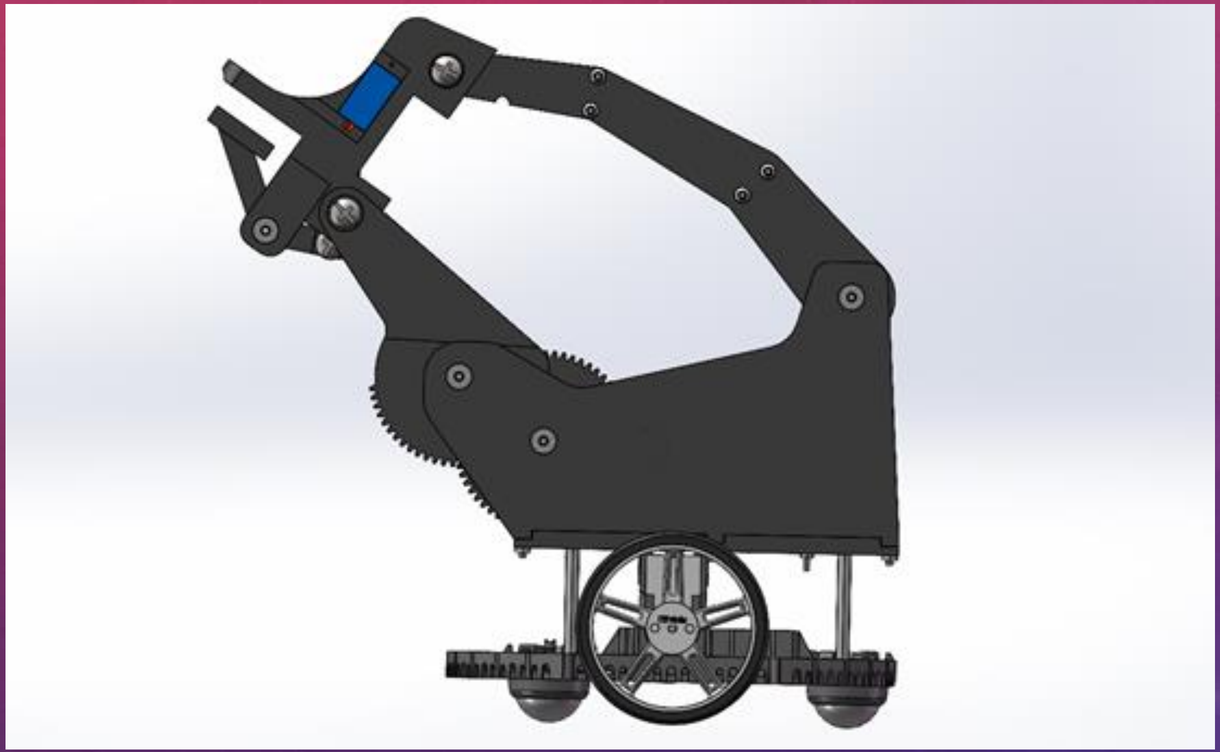


Front View

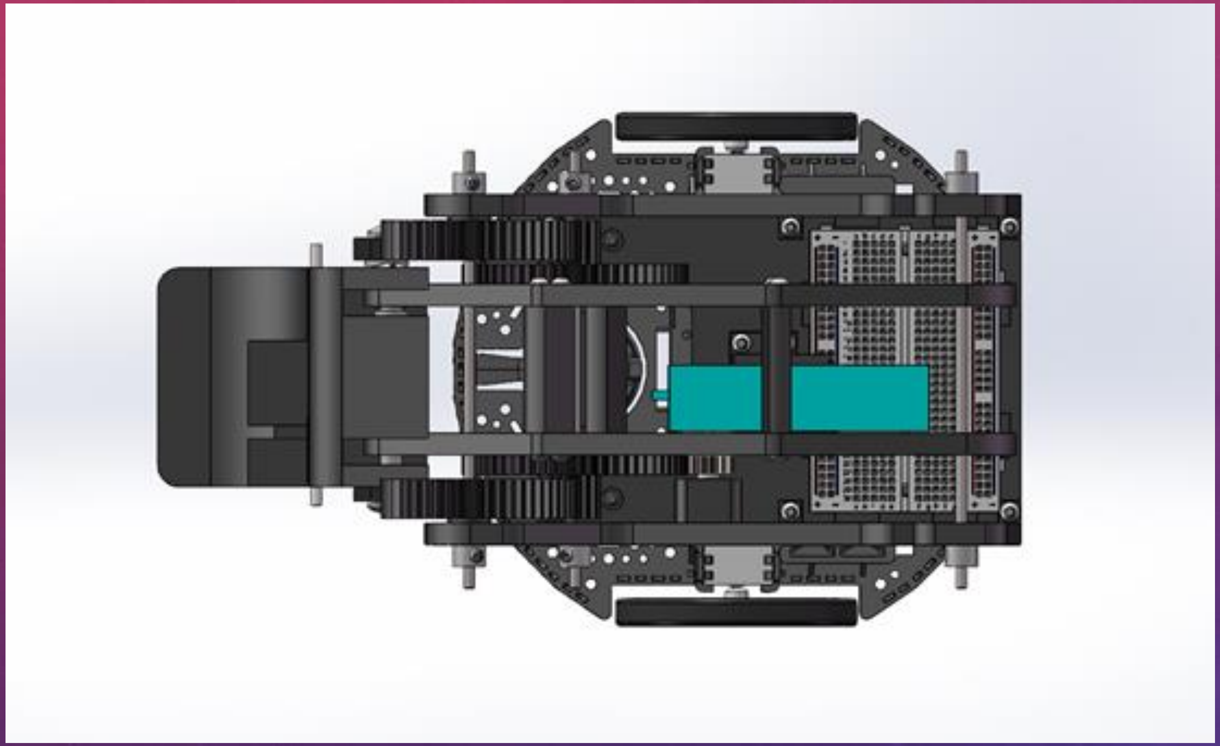


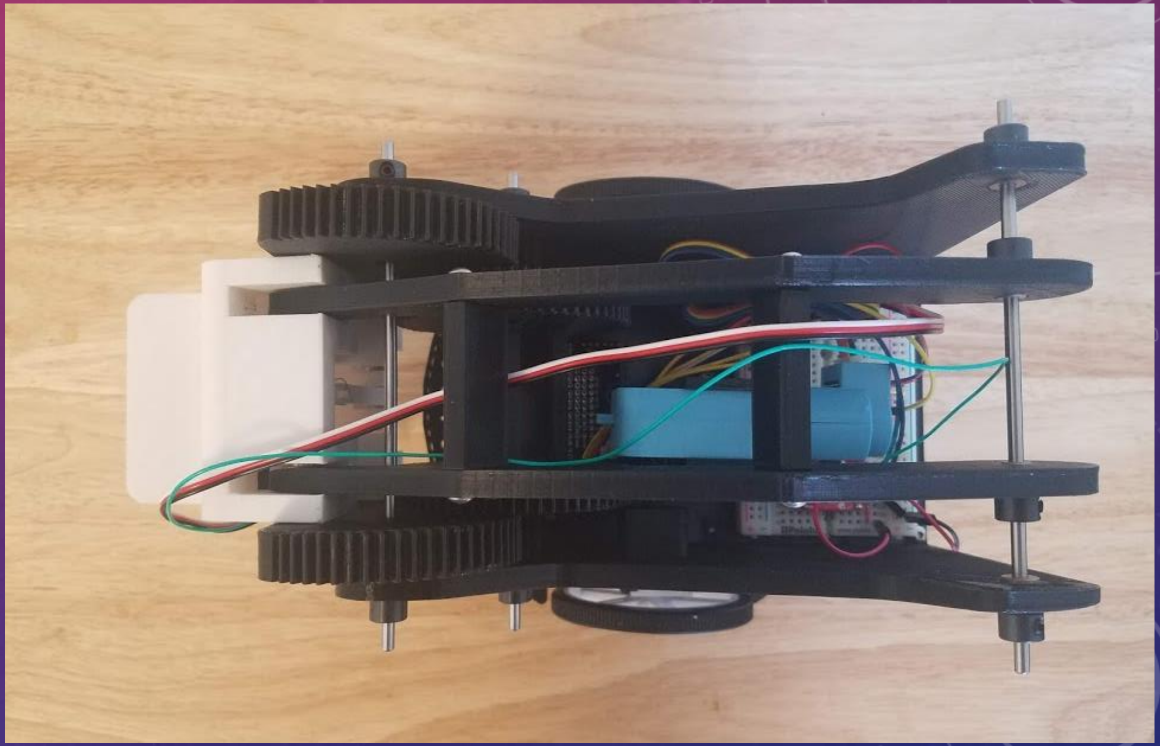


Side View, Arm Lowered

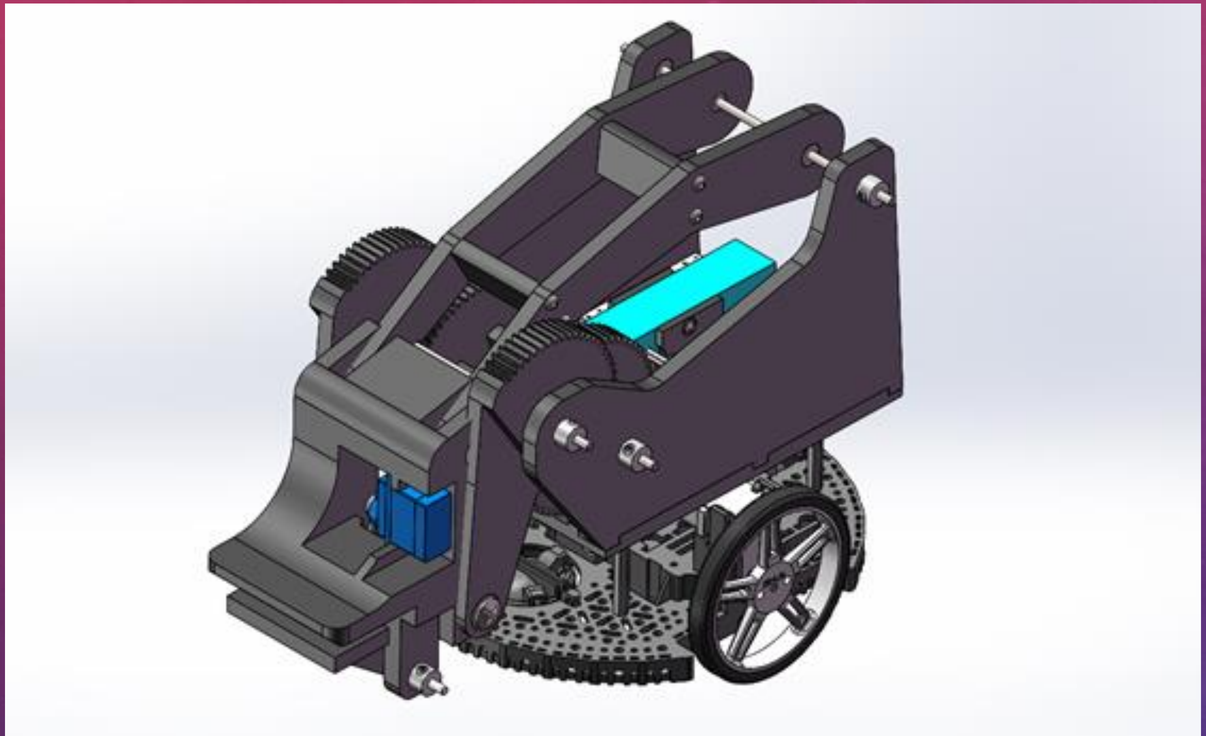


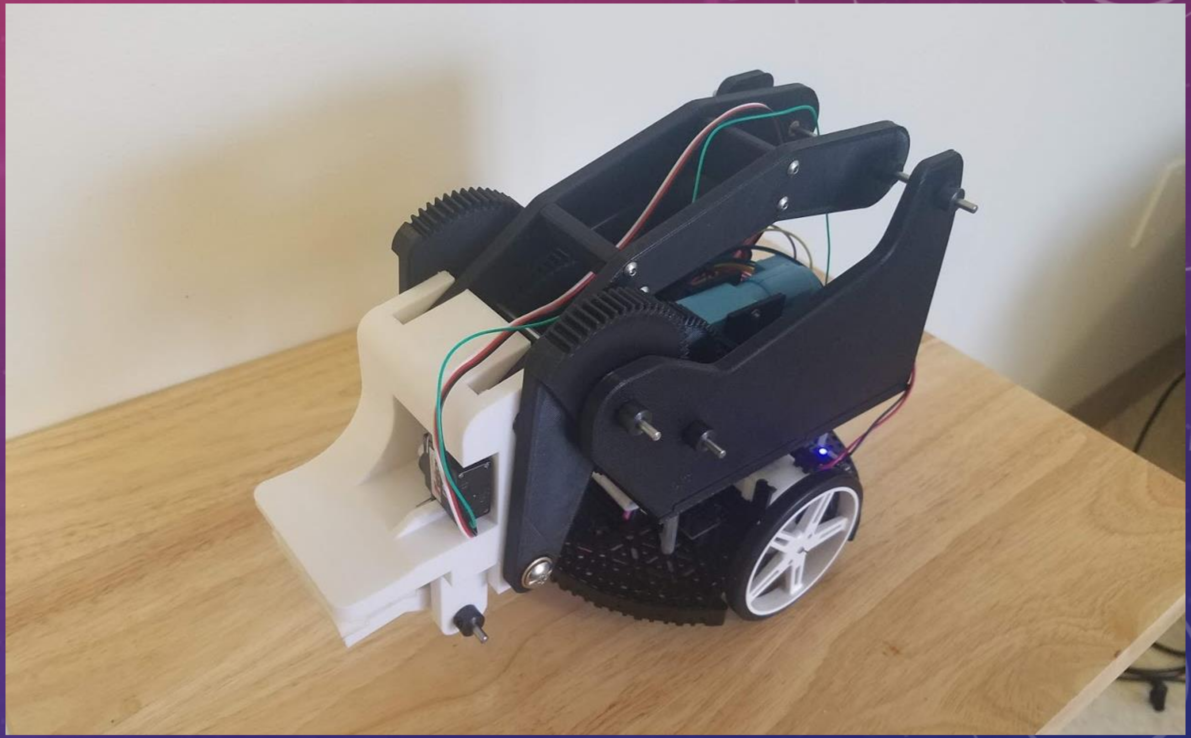
Side View, Arm Raised



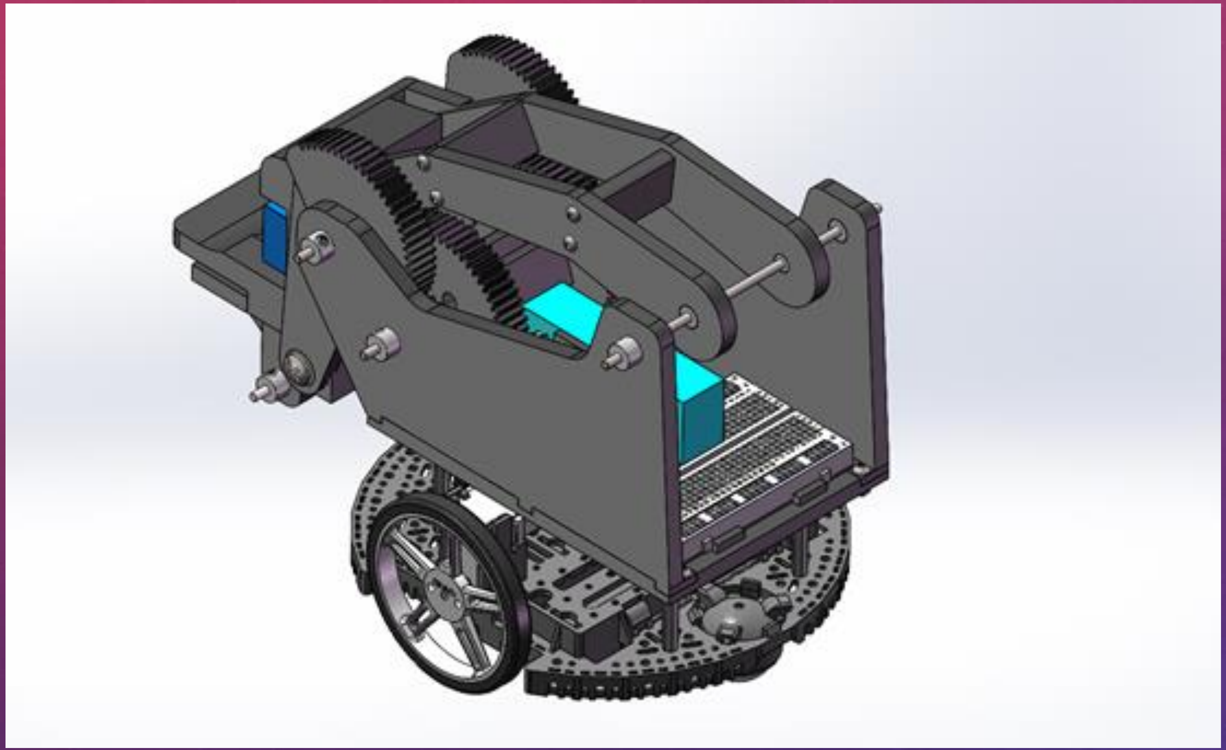


Top View

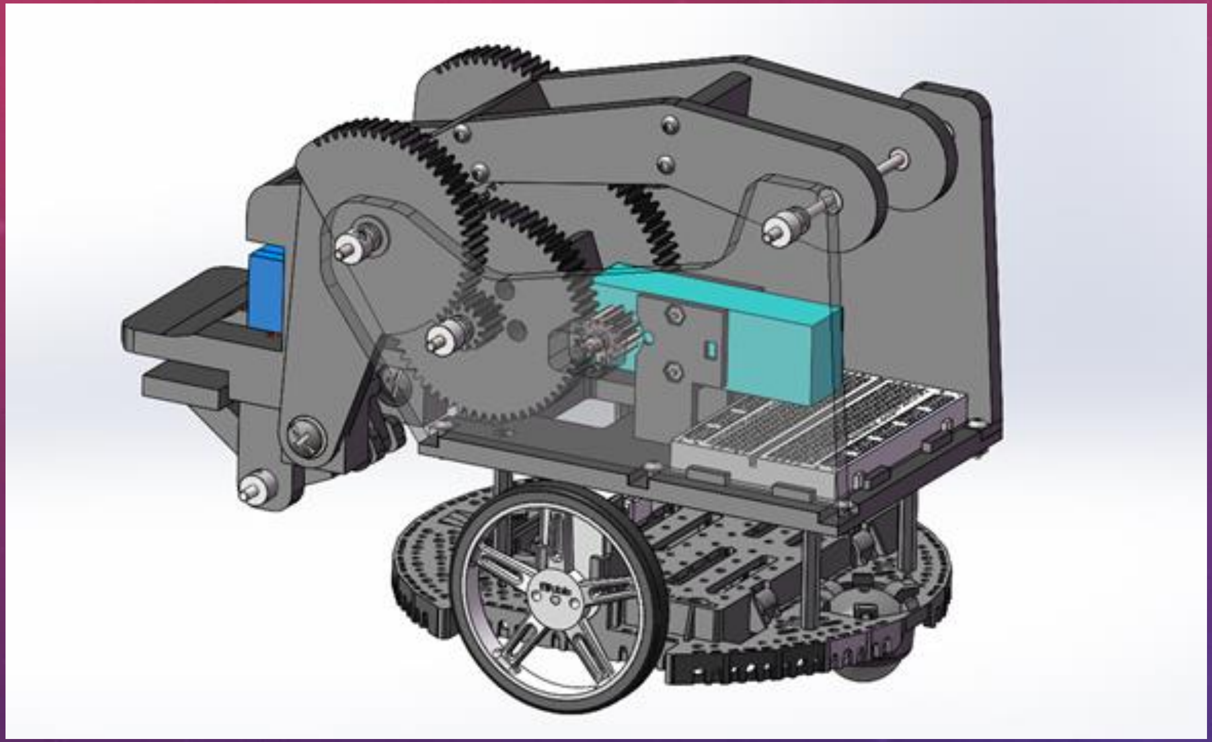


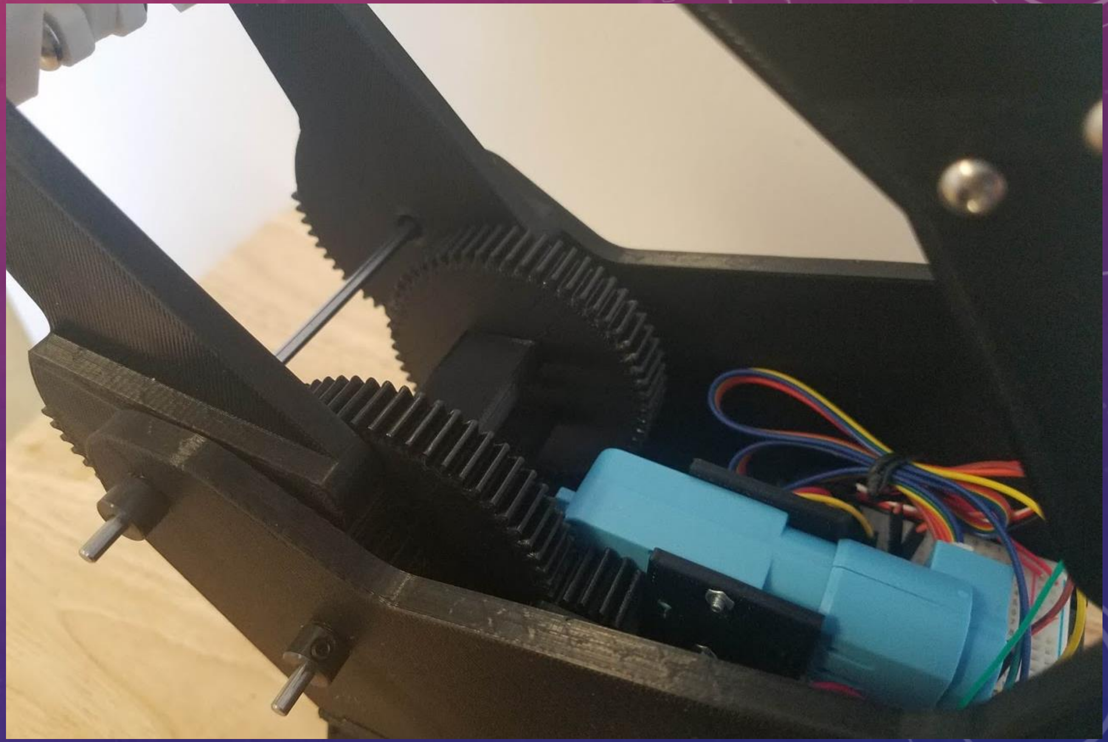


Front Isometric View



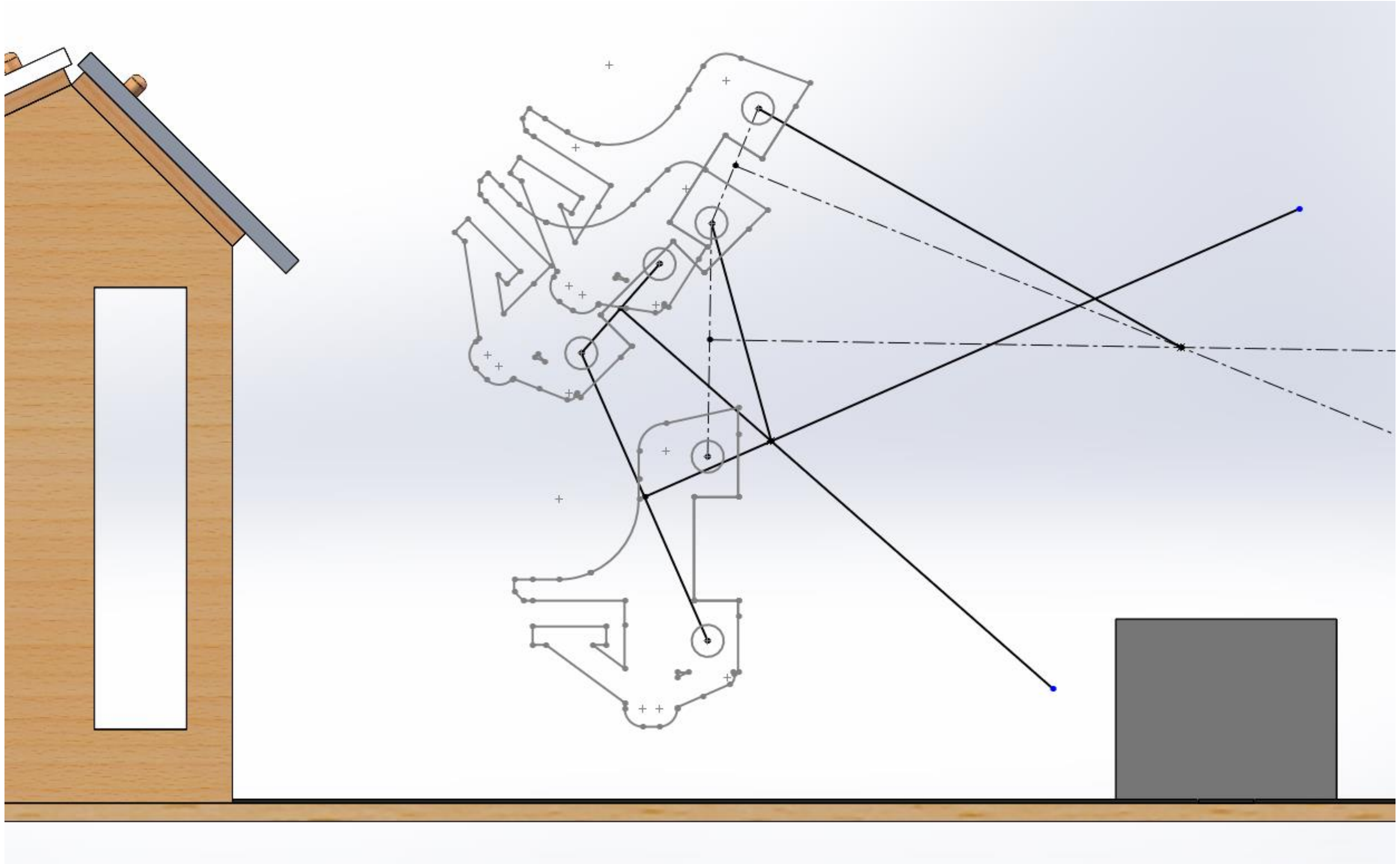
Back Isometric View



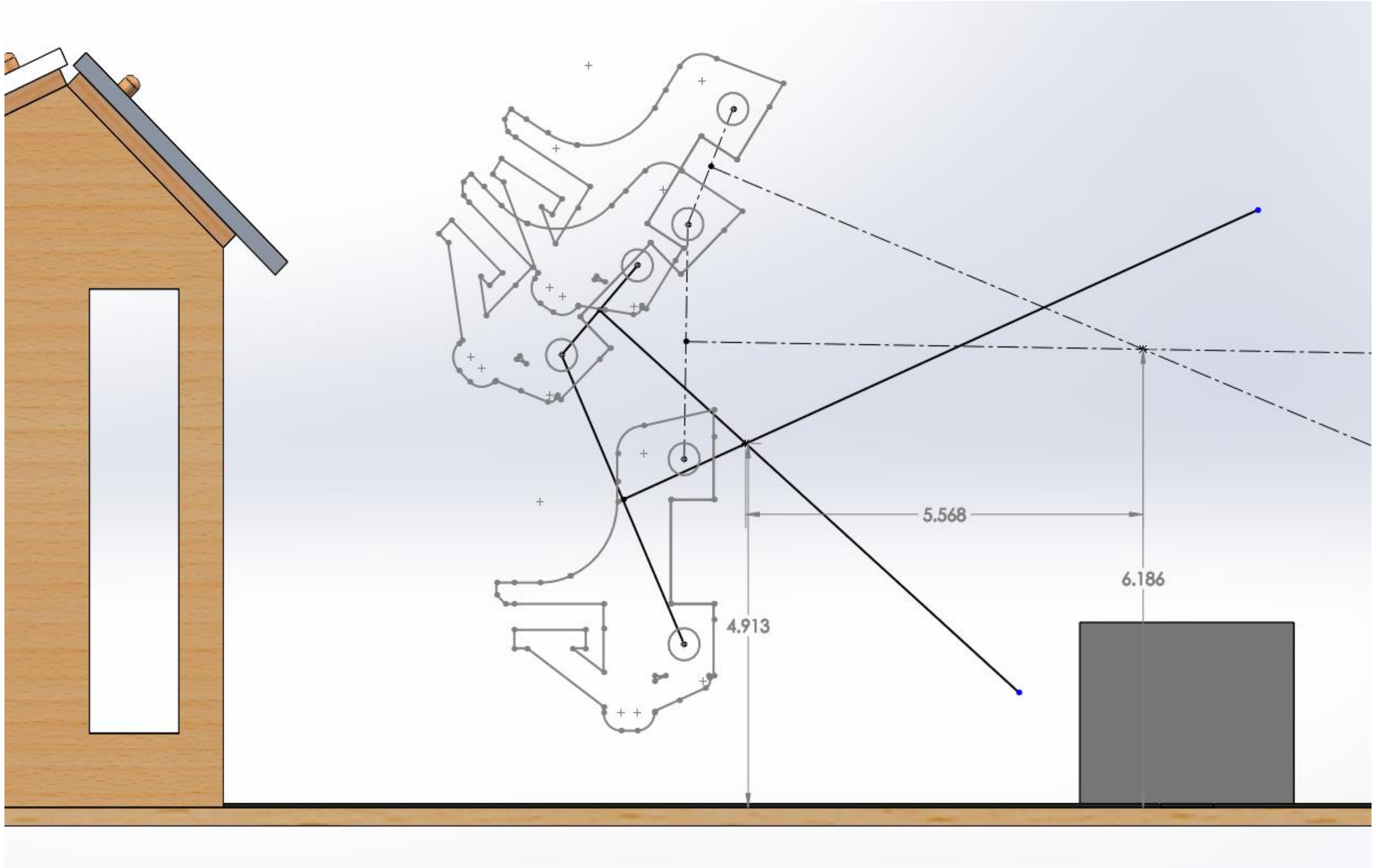


Transmission Detail View

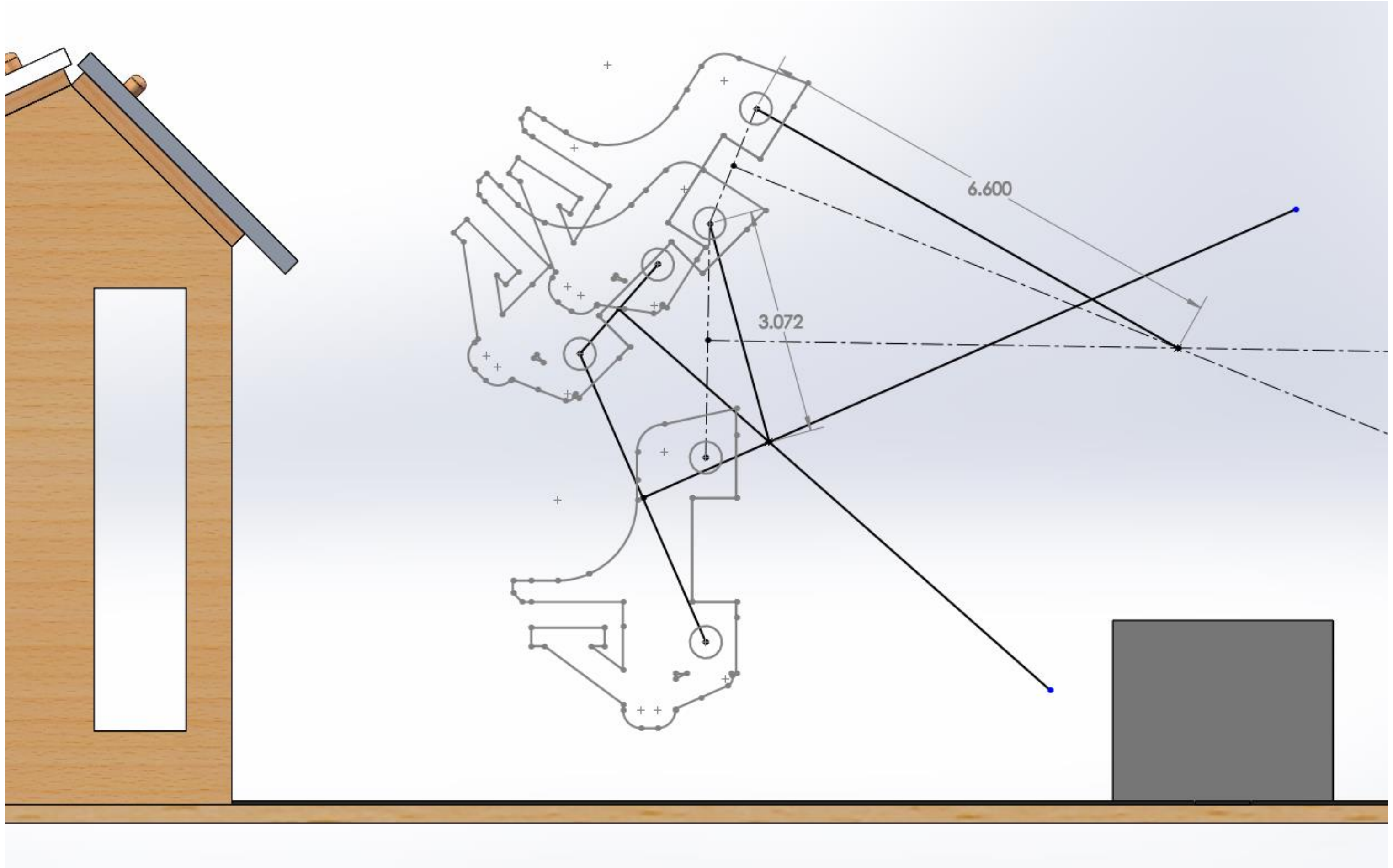
LINKAGE SYNTHESIS DESIGN PROCESS



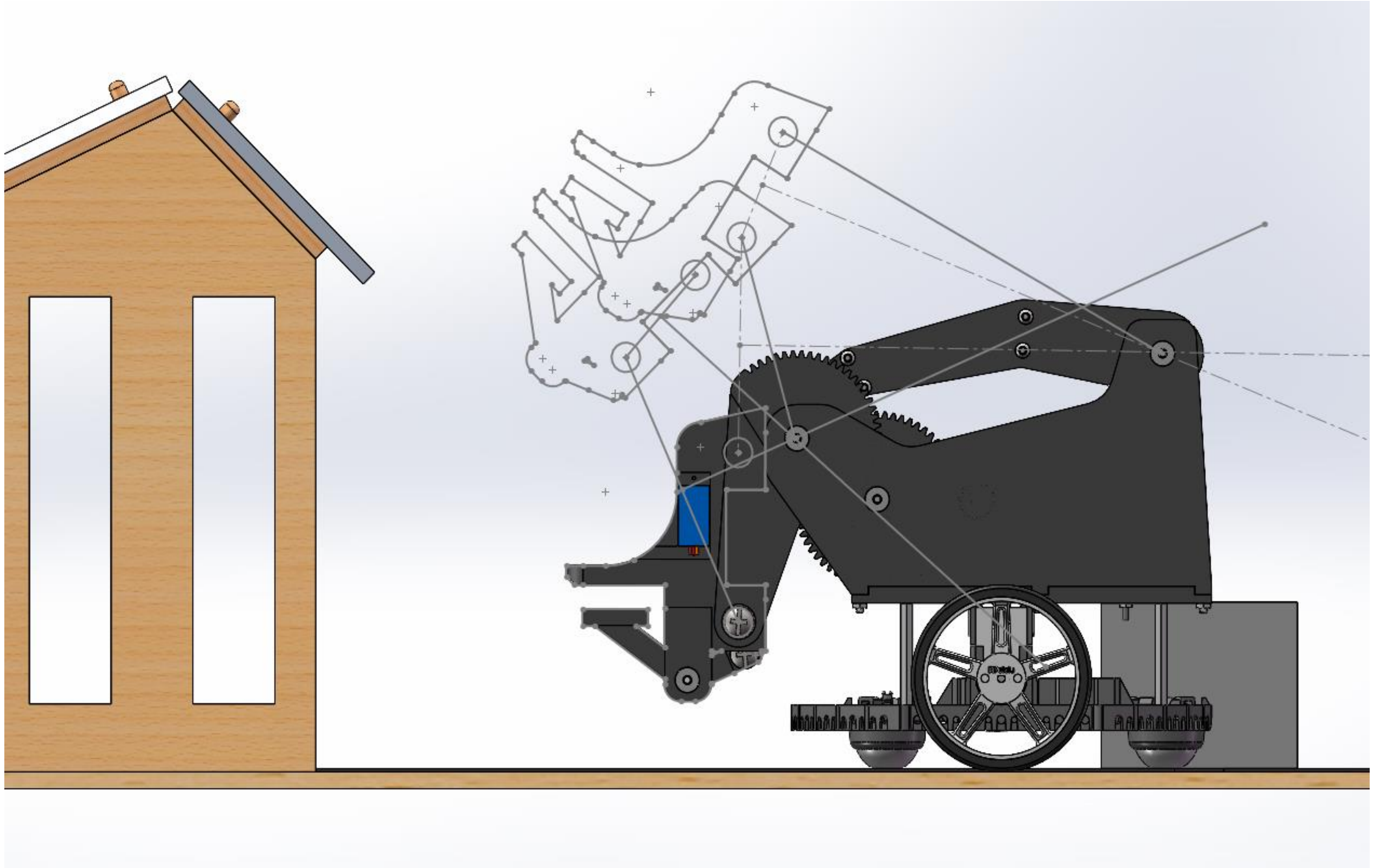
Linkage Synthesis Design Sketch



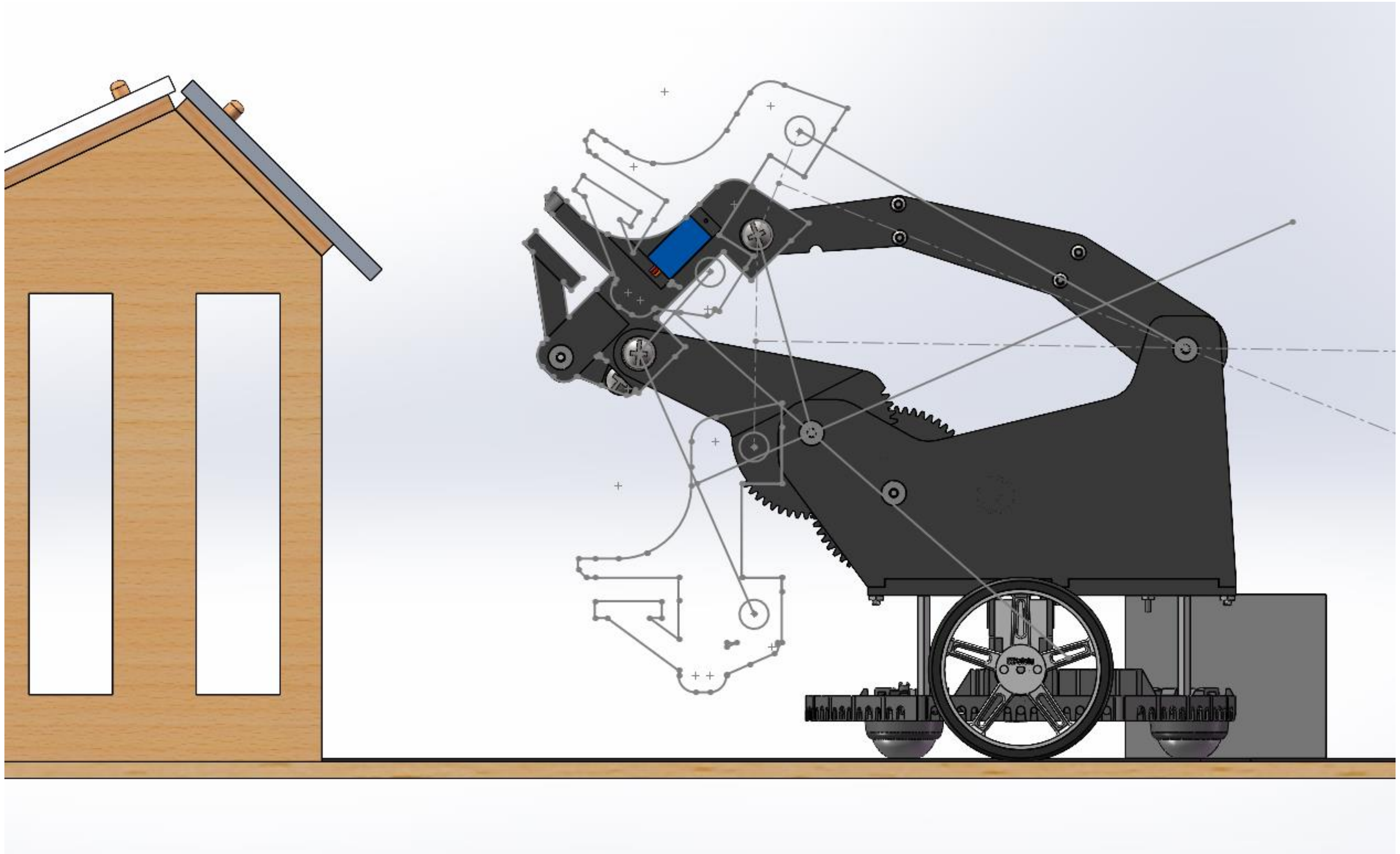
Fourbar Lift Mechanism Joint Locations



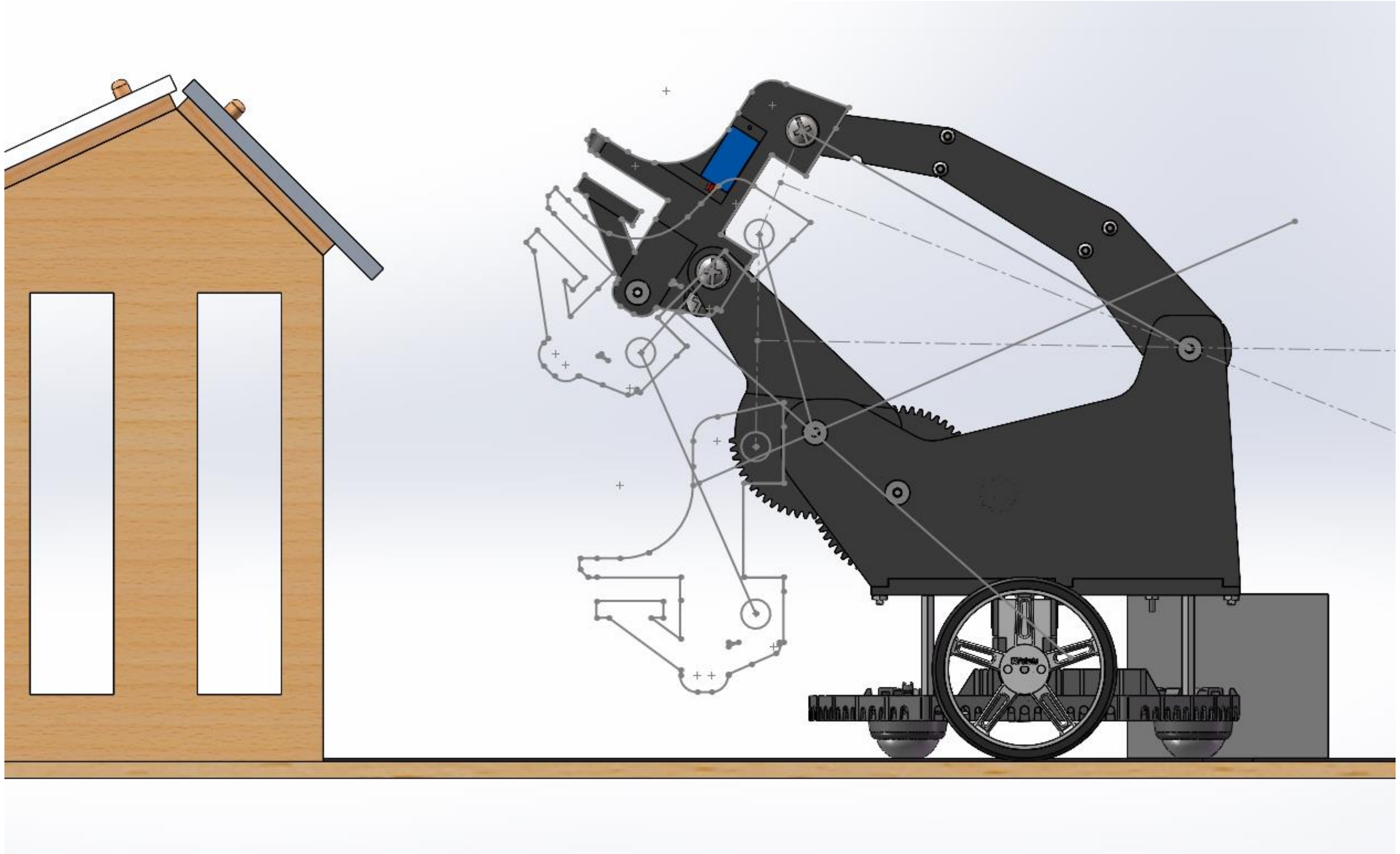
Fourbar Lift Mechanism Link Lengths



Lift Mechanism Gripper Position 1 (0-deg)



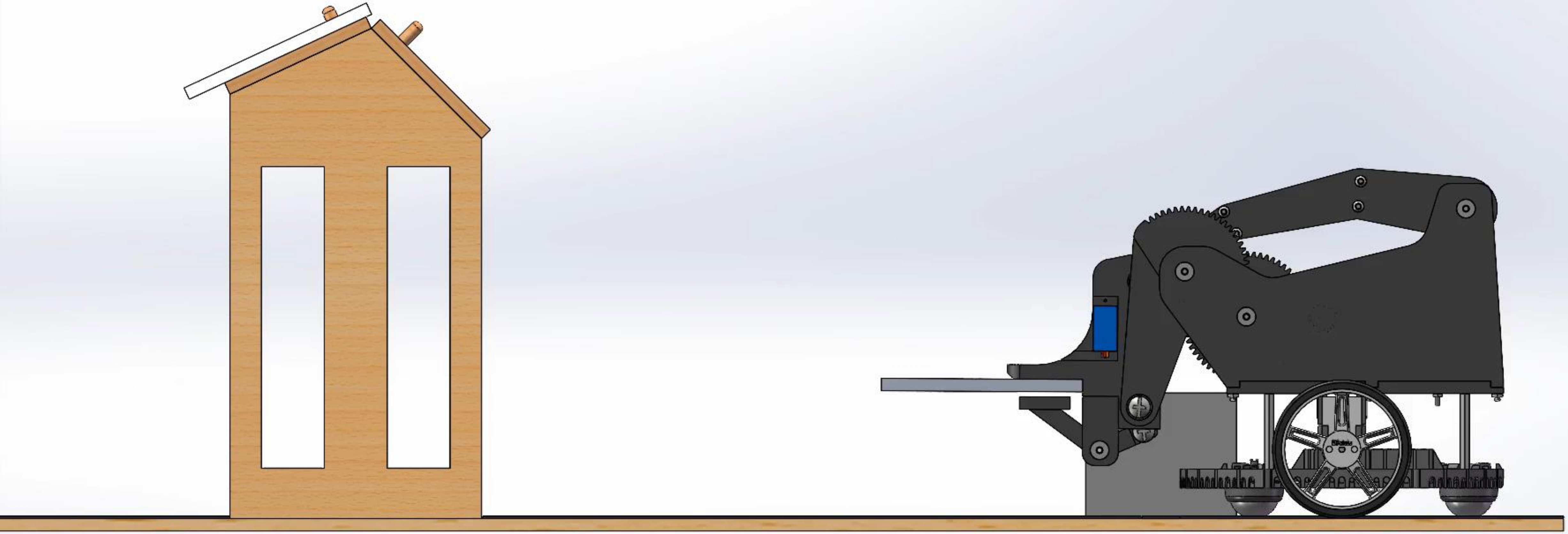
Lift Mechanism Gripper Position 2 (45-deg)



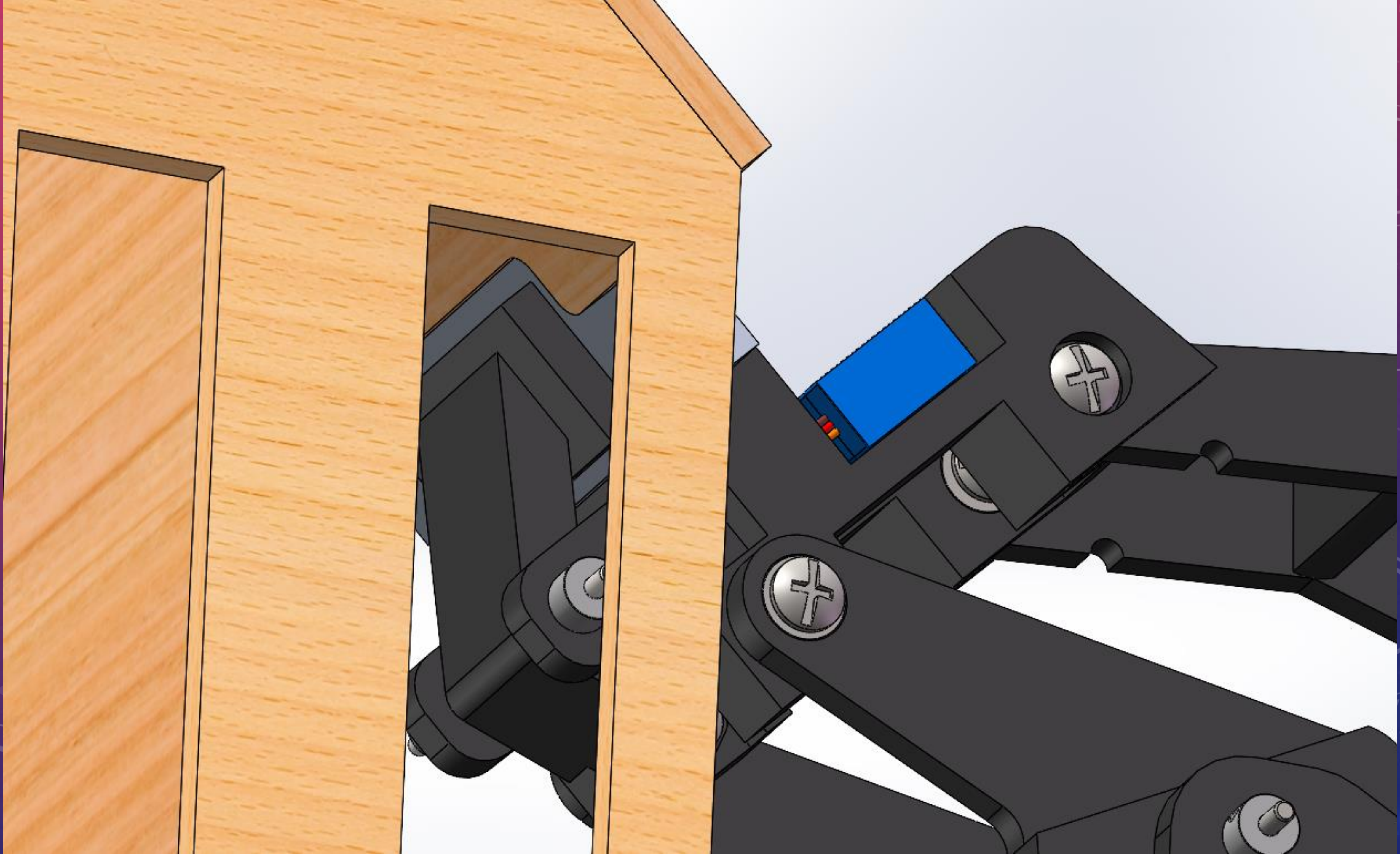
Lift Mechanism Gripper Position 3 (25-deg)

PICK-UP AND DEPOSIT OF SOLAR PANELS

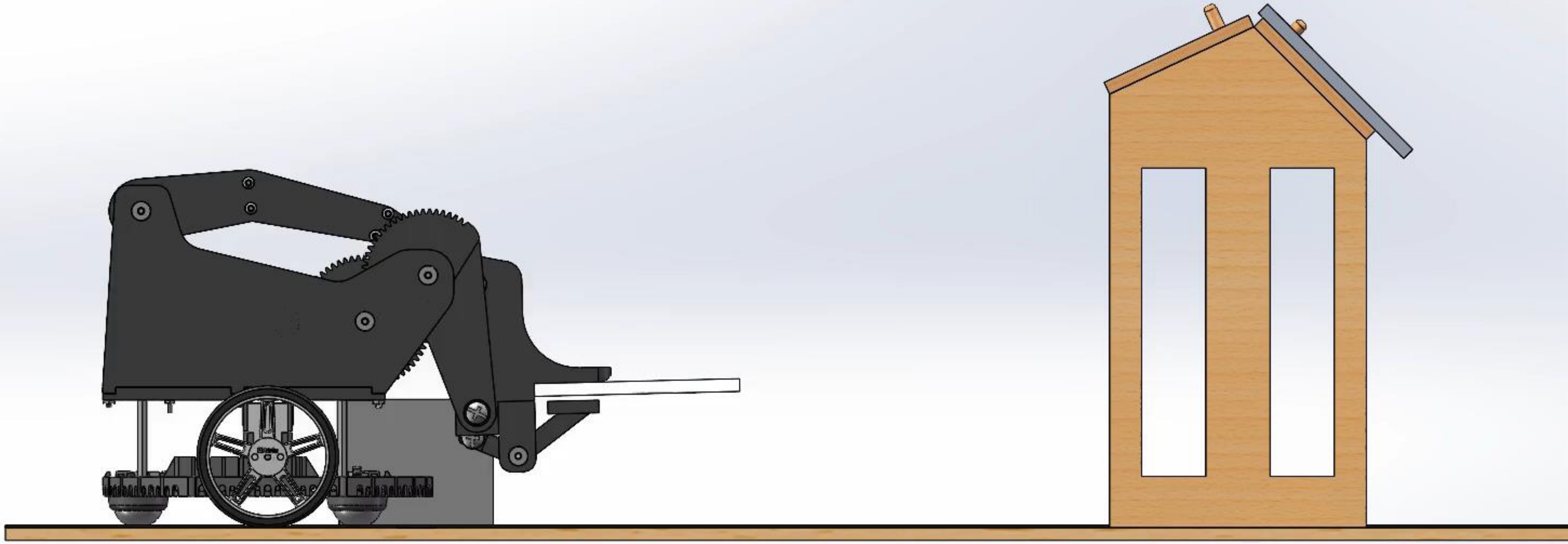
45-Degree Roof Pickup Collector



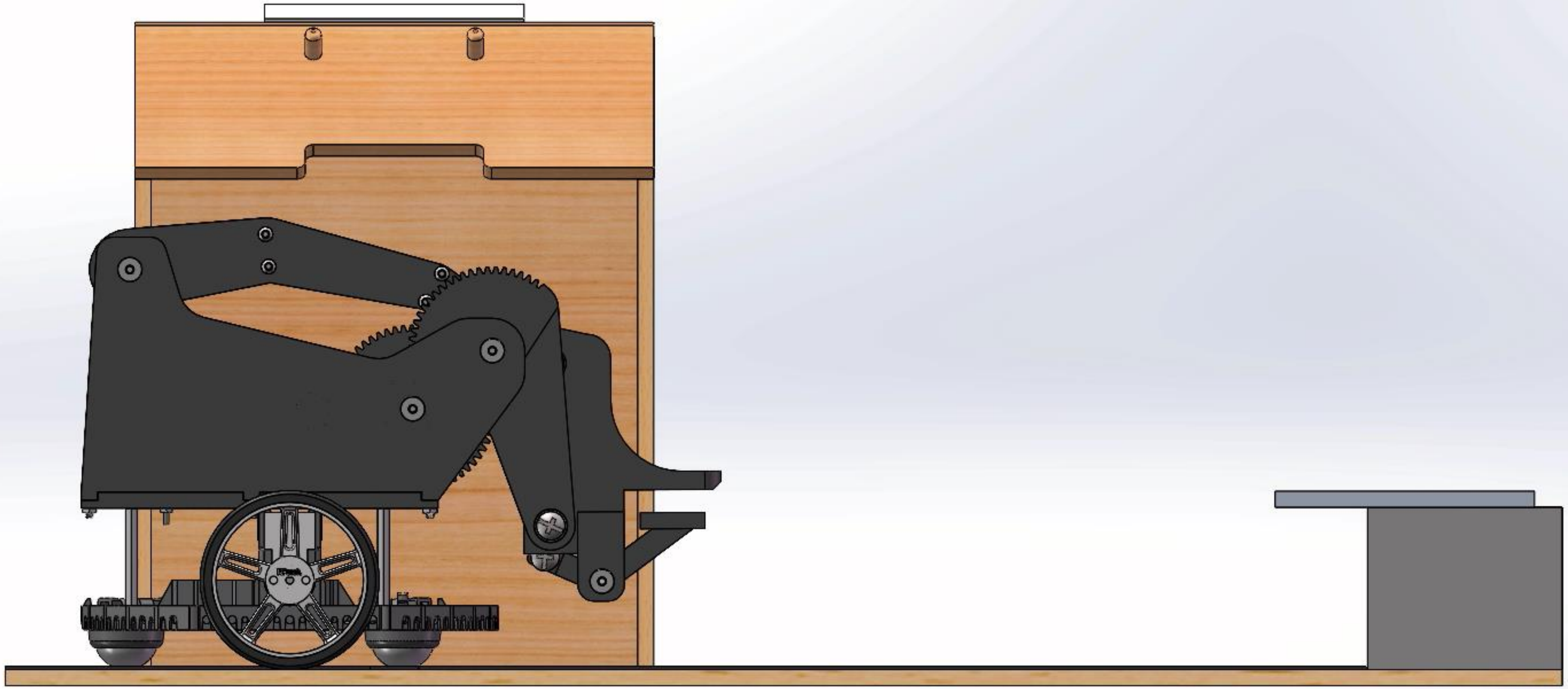
45-Degree Roof Place Collector



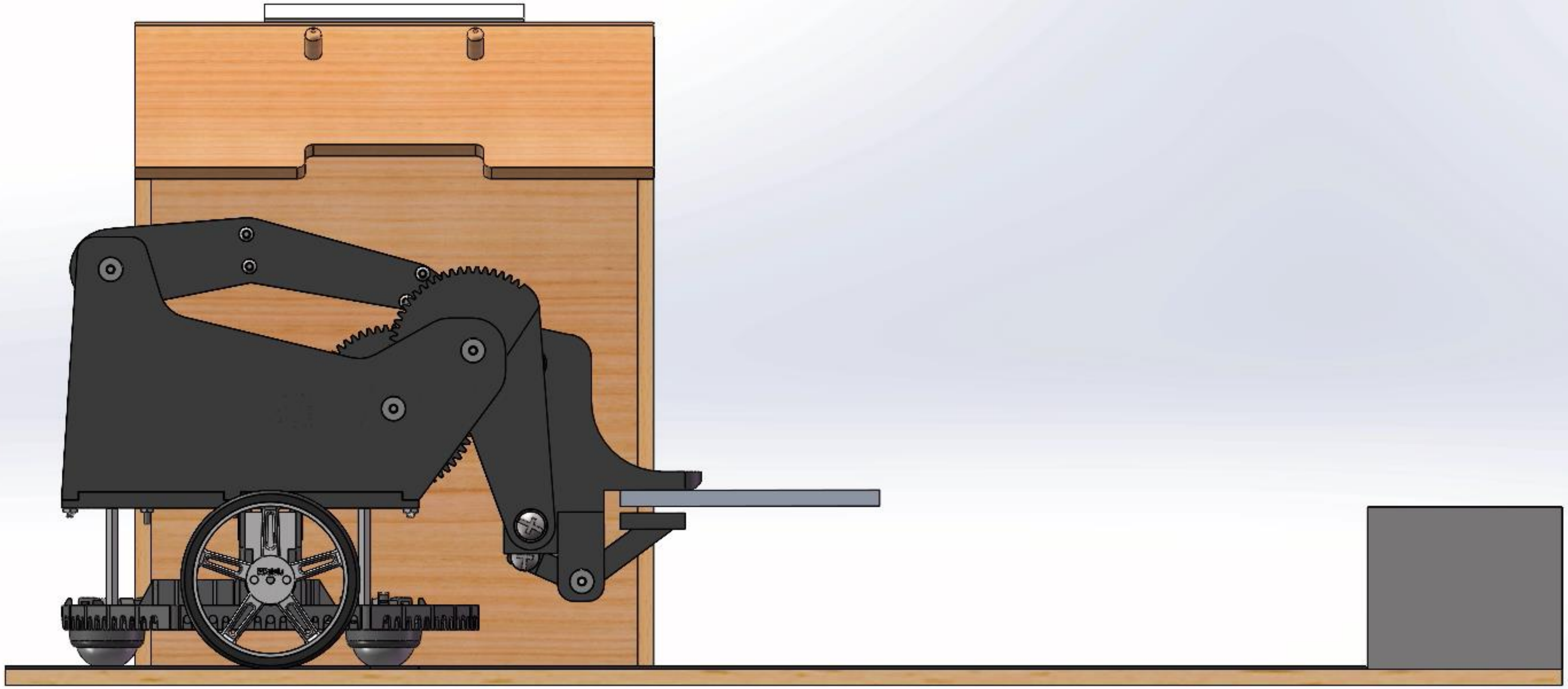
25-Degree Roof Pickup Collector



25-Degree Roof Place Collector

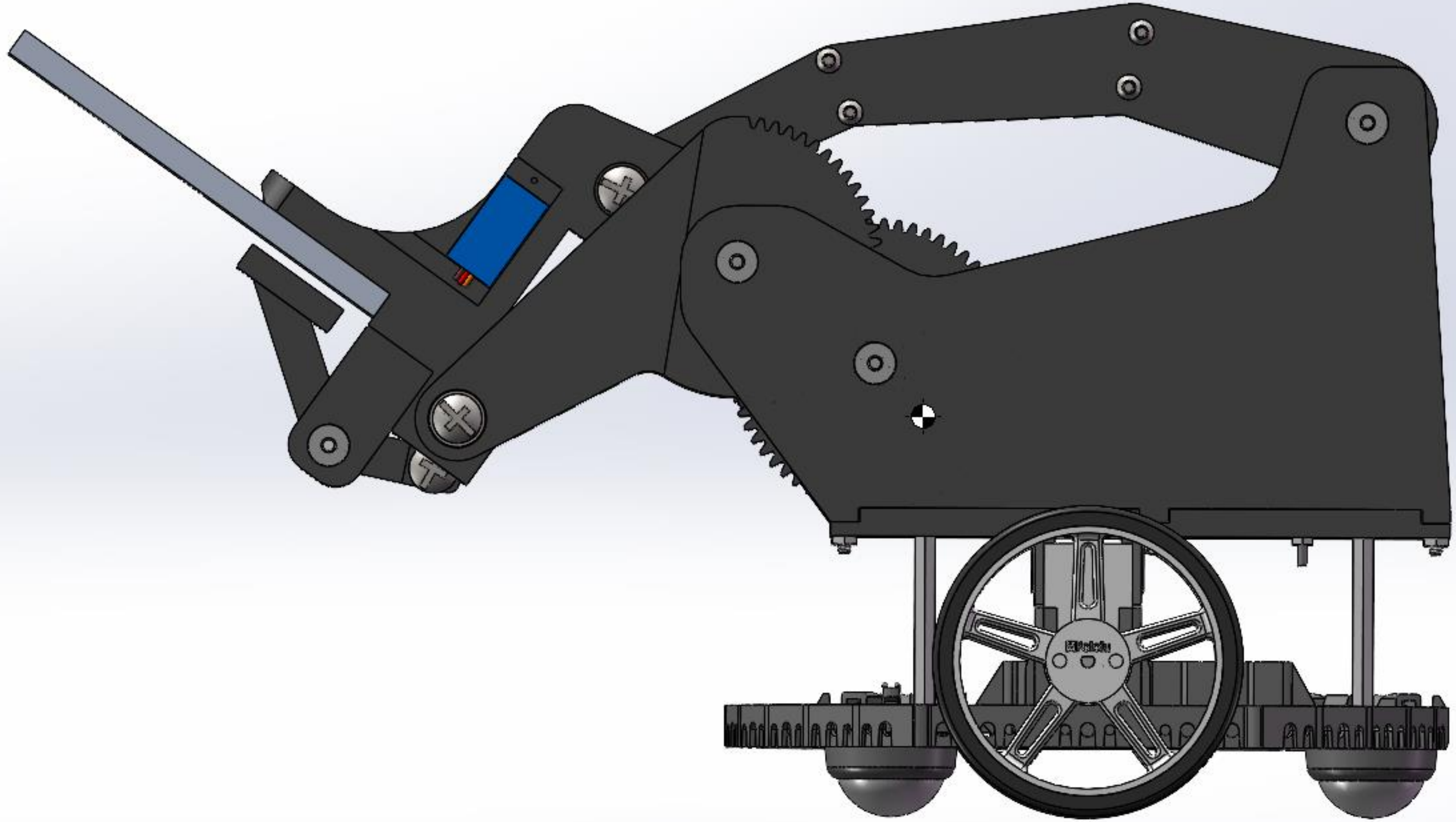


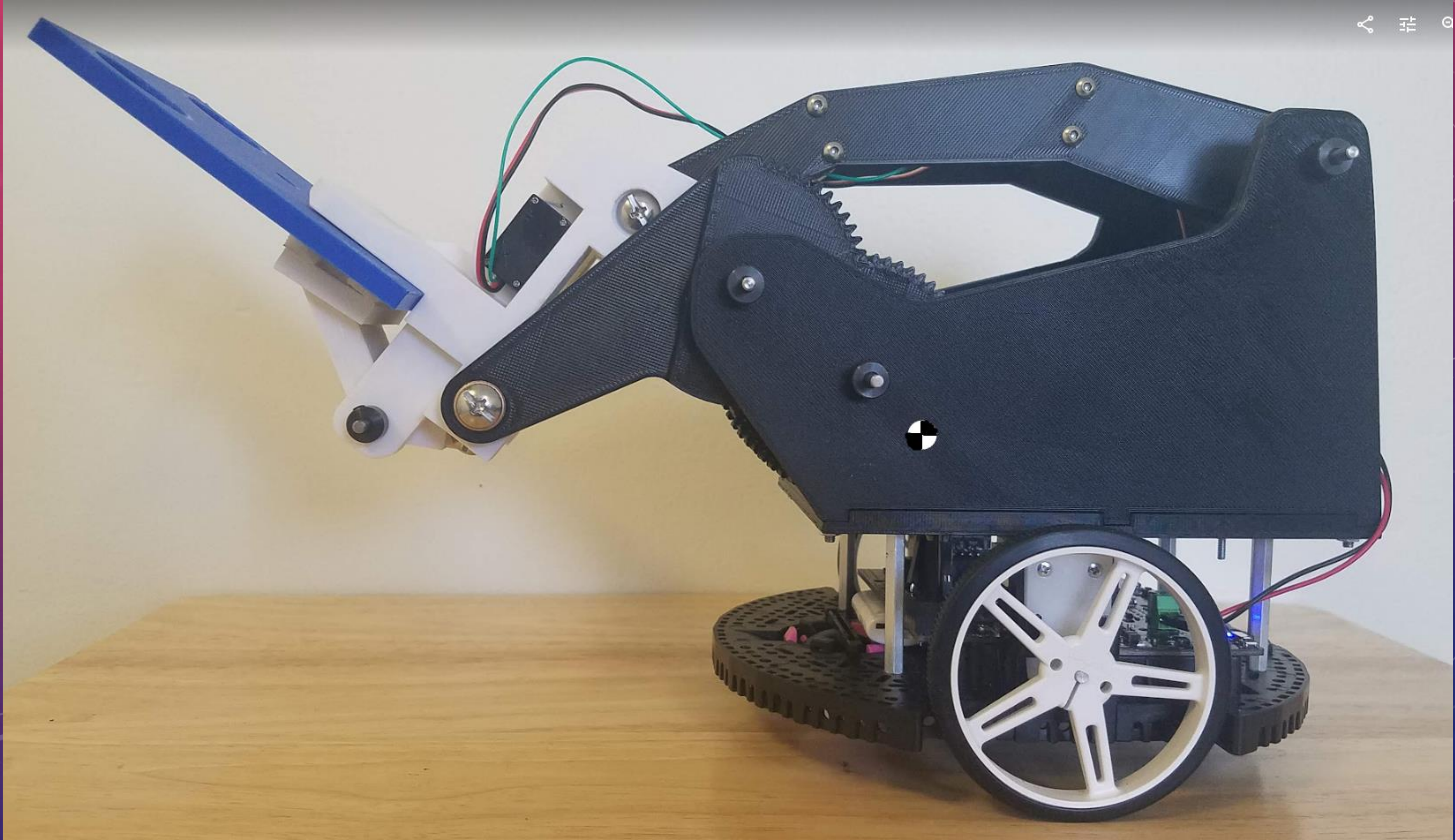
Staging Area Pickup Collector



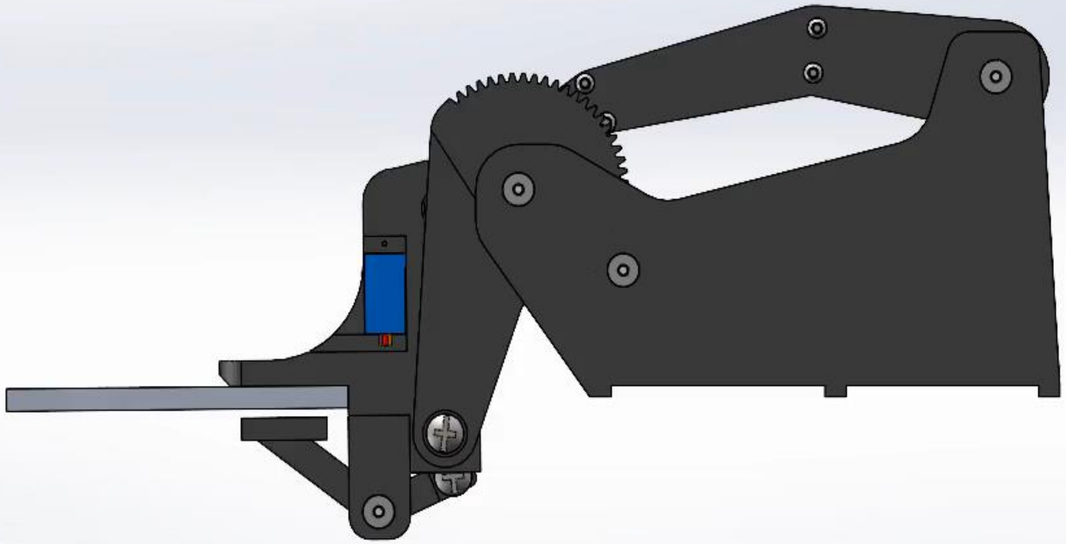
Staging Area Place Collector

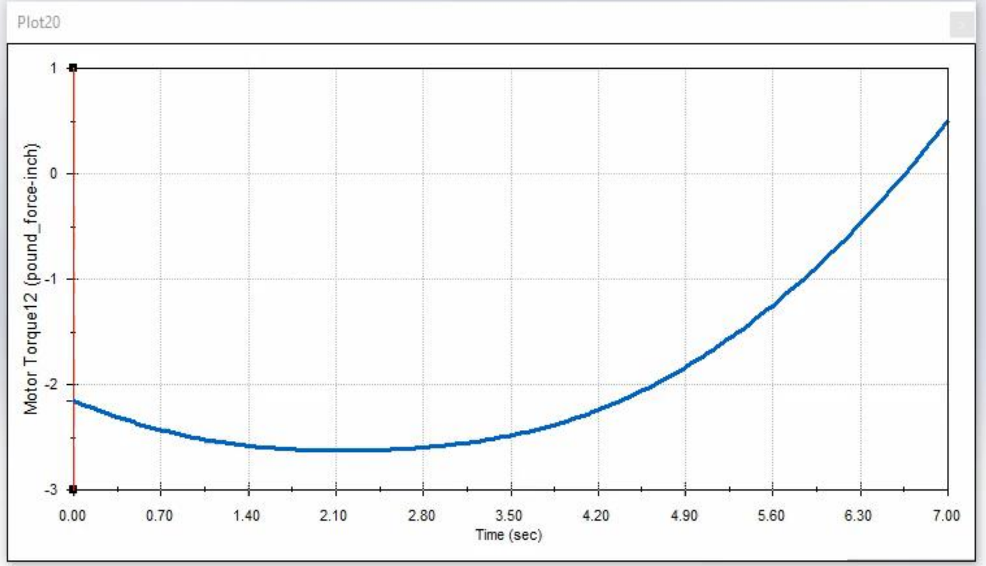
MAXIMUM REACH ORIENTATION/CENTER OF MASS



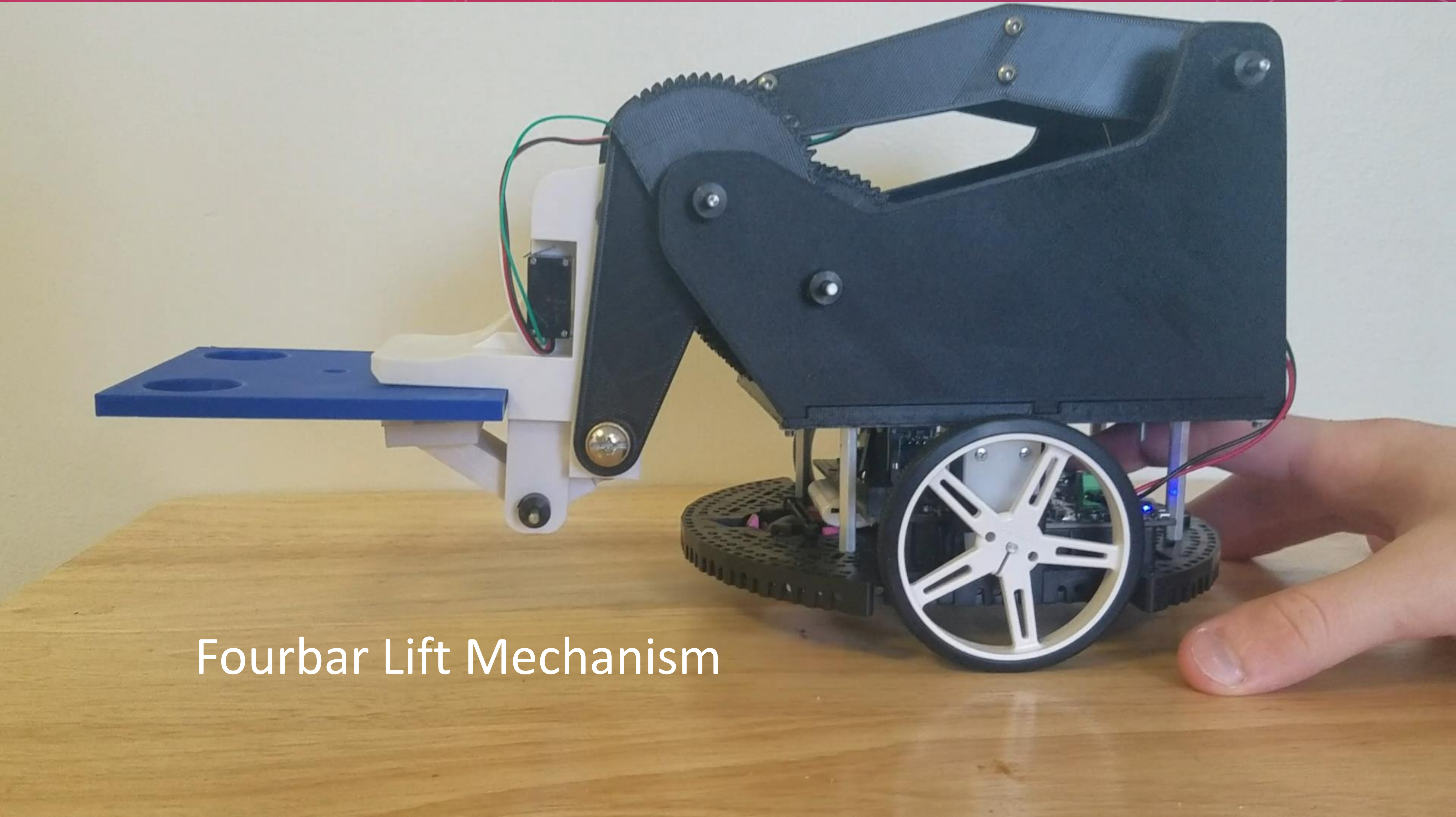


MOTION STUDY

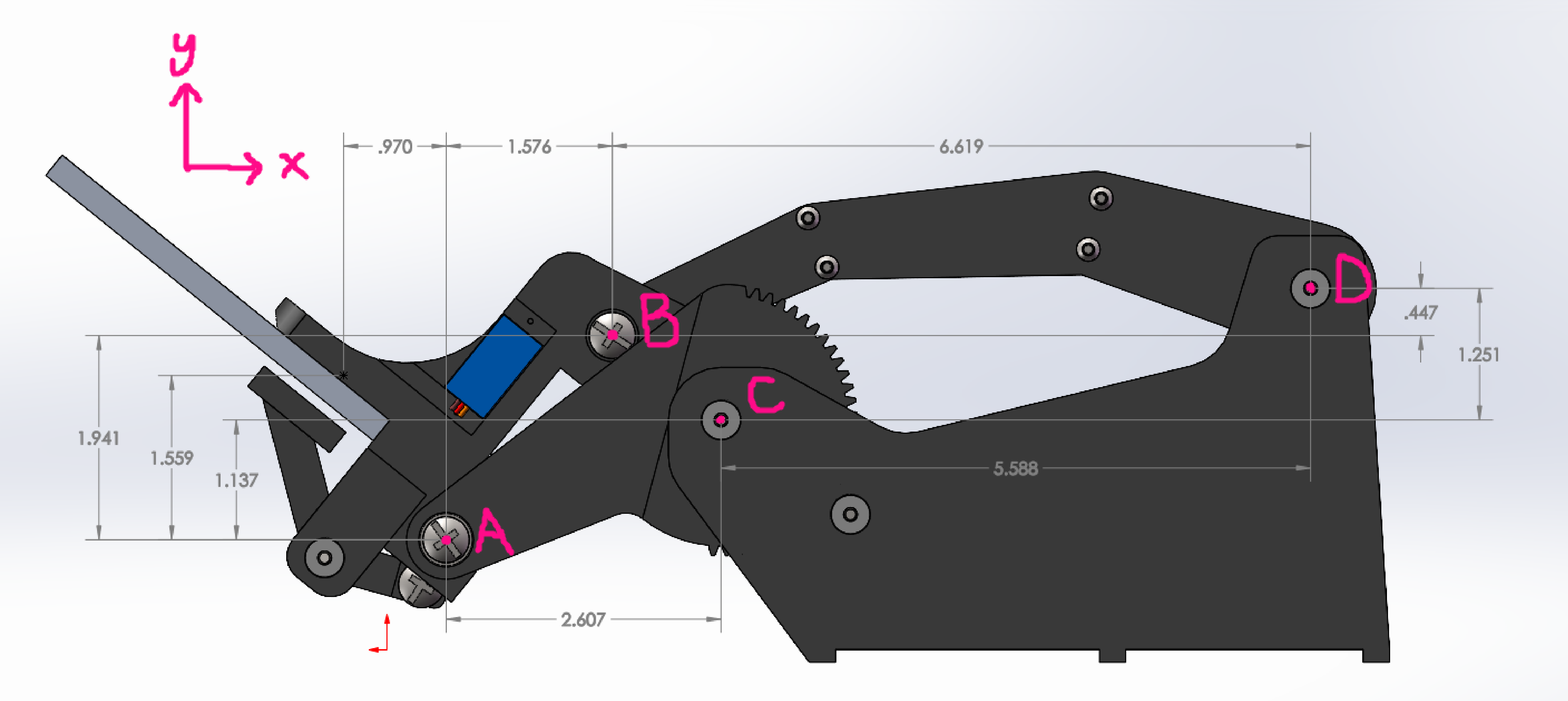




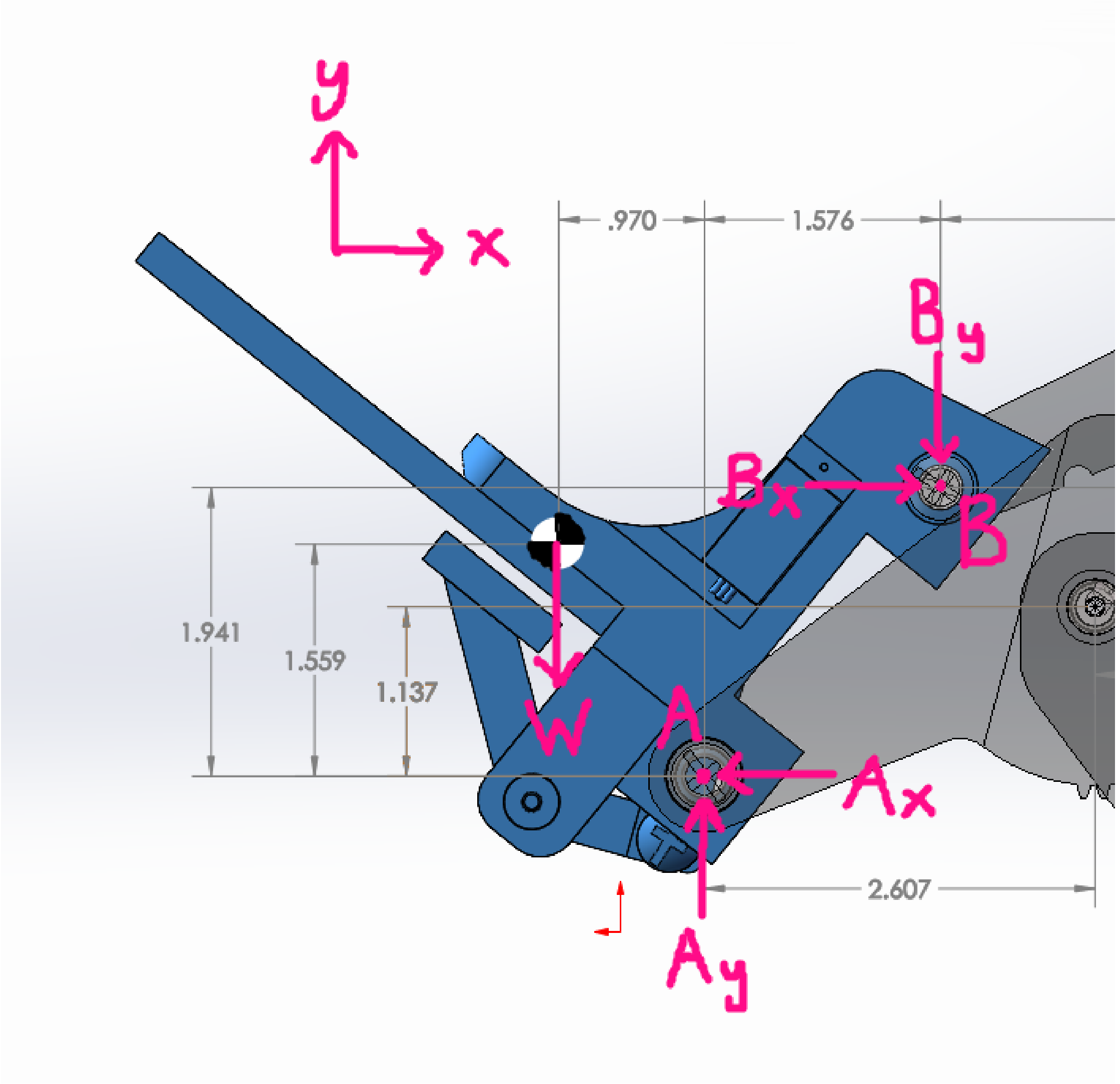
Maximum Torque: 2.63353 in-lbf @ 2.16 seconds


Fourbar Lift Mechanism

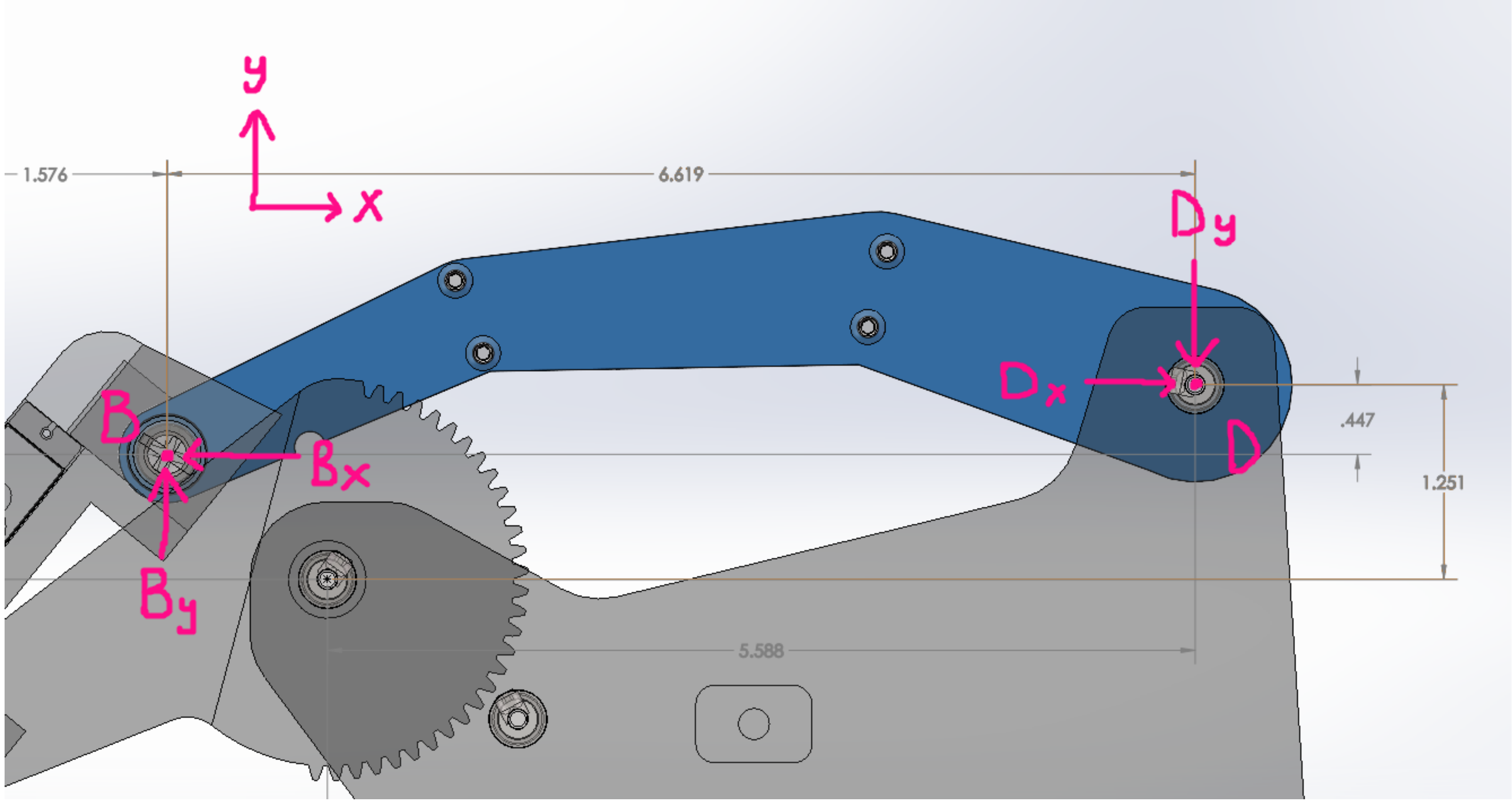
FORCE ANALYSIS OF FOURBAR LIFTING MECHANISM



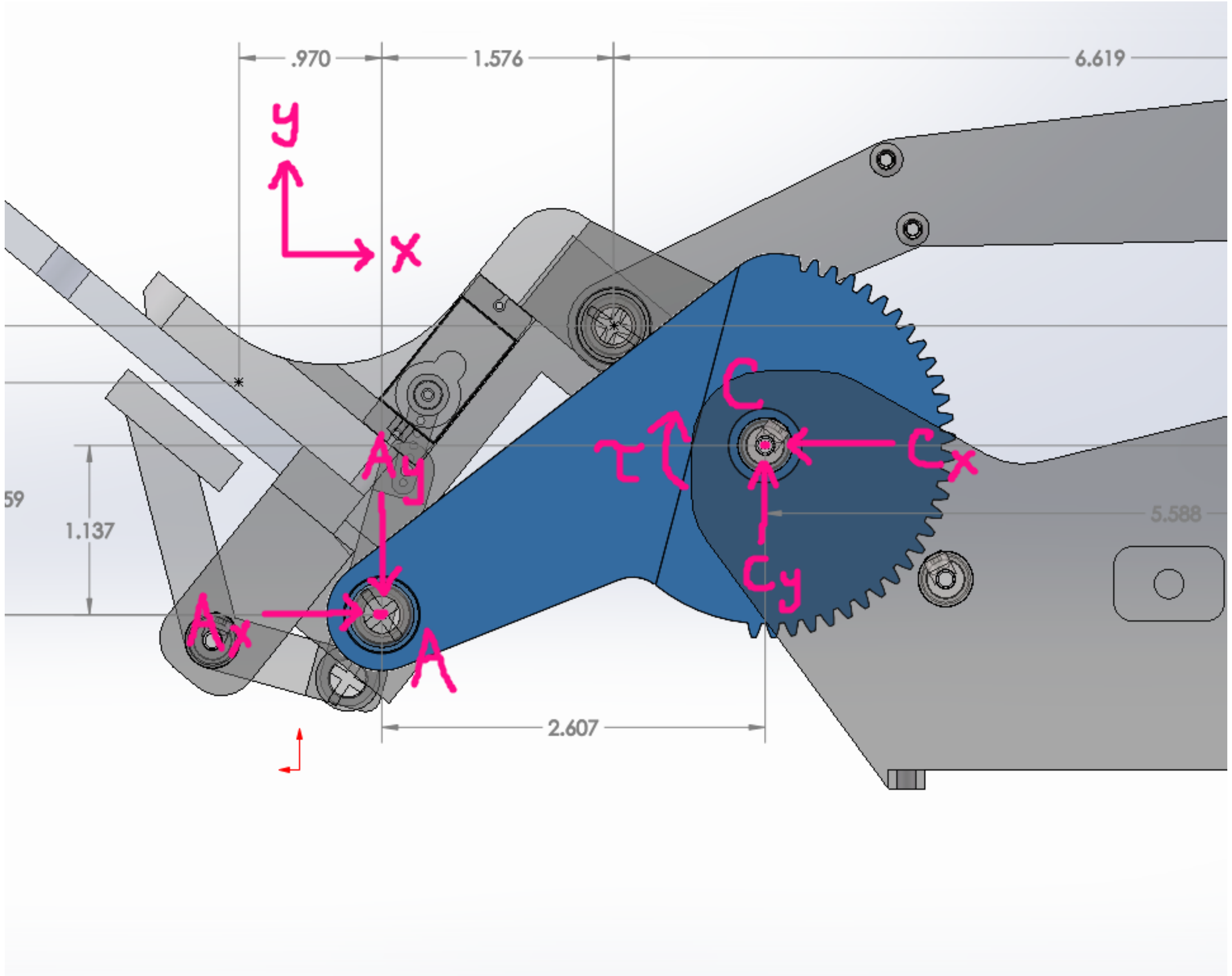
Four Bar Lift Mechanism



FBD of Coupler



FBD of Rocker



FBD of Crank

Known Parameters:

$W_1 := 0.79483\,lbf$ $r_1 := 1.941\,in$ $r_2 := 1.576\,in$ $r_3 := .970\,in$ $r_4 := .4$

$r_5 := 6.619\,in$ $r_6 := 1.137\,in$ $r_7 := 2.607\,in$

Supply initial guesses for unknowns:

$A_x := 2\,lbf$ $A_y := 2\,lbf$ $B_x := 2\,lbf$ $B_y := 2\,lbf$ $C_y := 2\,lbf$

$D_x := 2\,lbf$ $D_y := 2\,lbf$ $T_1 := 2\,in \cdot lbf$ $C_x := 2\,lbf$

From equations of equilibrium we have nine equations with nine unknow

Given

From FBD of Coupler

$$0 = -B_x \cdot r_1 - B_y \cdot r_2 + W_1 \cdot r_3$$

$$0 = B_x - A_x$$

$$0 = A_y - B_y - W_1$$

From FBD of Rocker:

$$0 = -B_x \cdot r_4 - B_y \cdot r_5$$

$$0 = D_x - B_x$$

$$0 = B_y - D_y$$

From FBD of Crank:

$$0 = -T_1 + A_x \cdot r_6 + A_y \cdot r_7$$

$$0 = A_x - C_x$$

$$0 = C_y - A_y$$

Mathcad Calculations

$$\begin{pmatrix} SA_x \\ SA_y \\ SB_x \\ SB_y \\ SC_x \\ SC_y \\ SD_x \\ SD_y \\ ST_1 \end{pmatrix} := \mathrm{Find}(A_x, A_y, B_x, B_y, C_x, C_y, D_x, D_y, T_1)$$

$$SA_x = 0.42\,\mathrm{lbf}$$

$$SA_y = 0.77\,\mathrm{lbf}$$

$$SB_x = 0.42\,\mathrm{lbf}$$

$$SB_y = -0.03\,\mathrm{lbf}$$

$$SC_x = 0.42\,\mathrm{lbf}$$

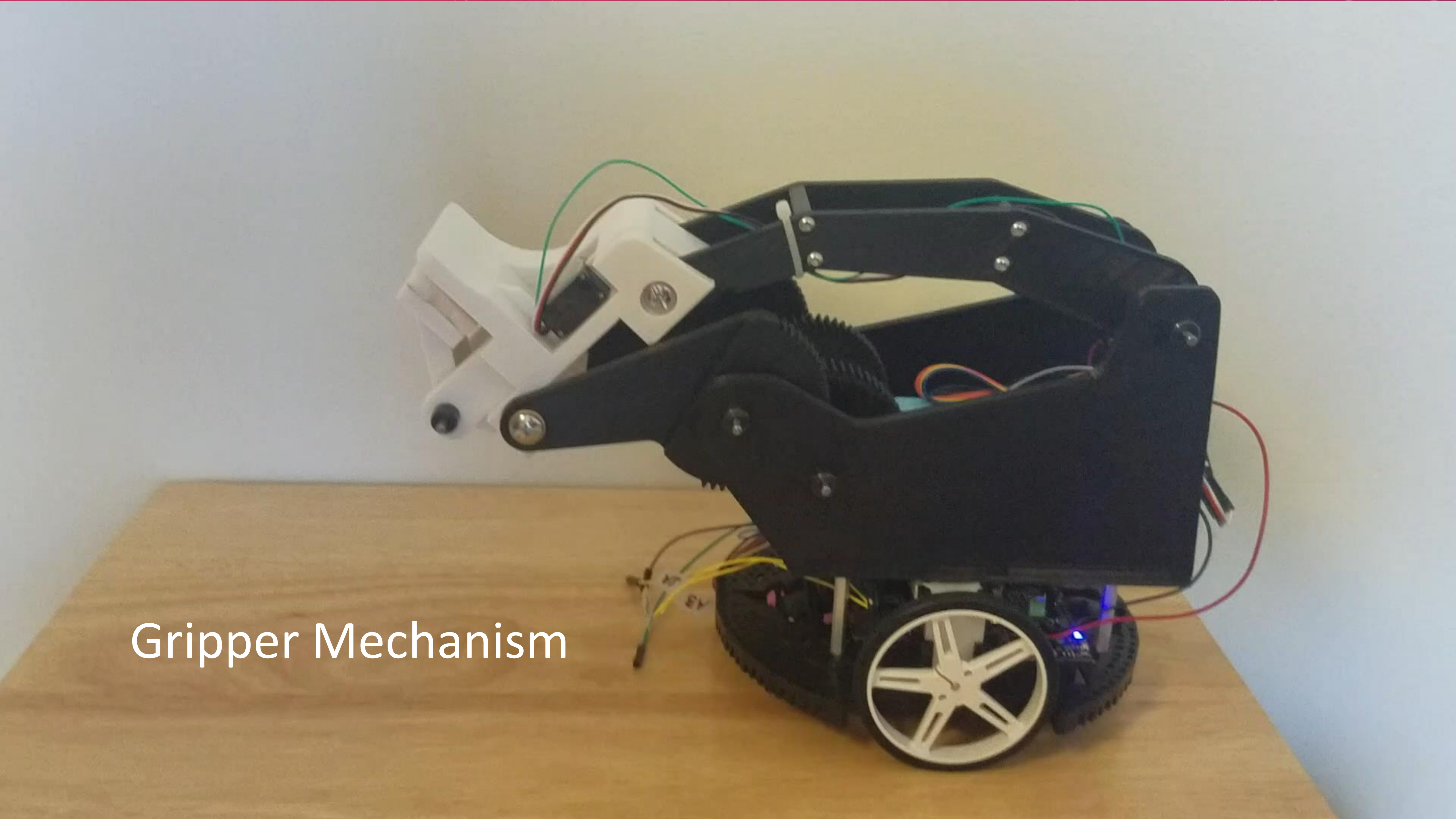
$$SC_y = 0.77\,\mathrm{lbf}$$

$$SD_x = 0.42\,\mathrm{lbf}$$

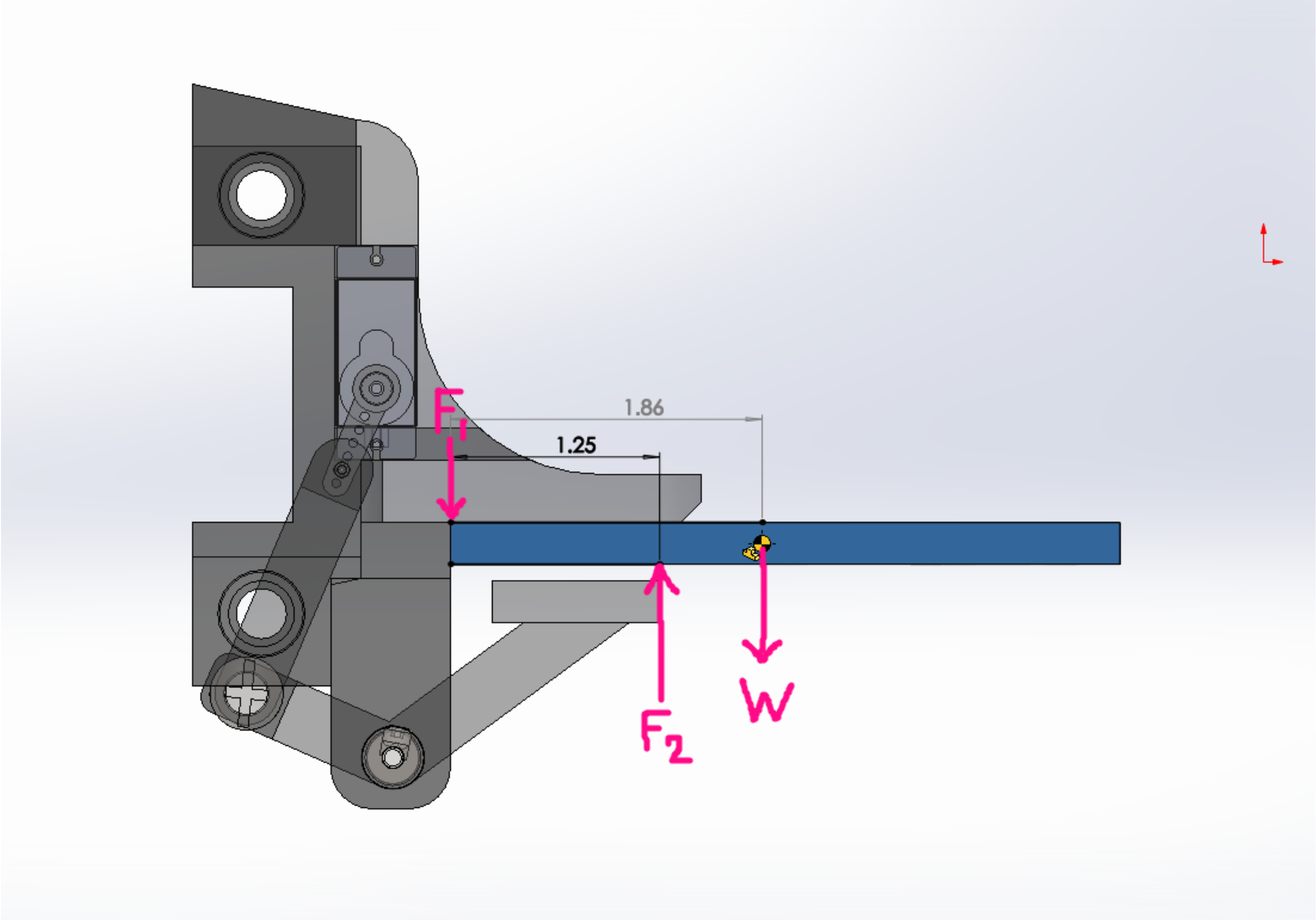
$$SD_y = -0.03\,\mathrm{lbf}$$

$$ST_1 = 2.48\,\mathrm{in}\cdot\mathrm{lbf}$$

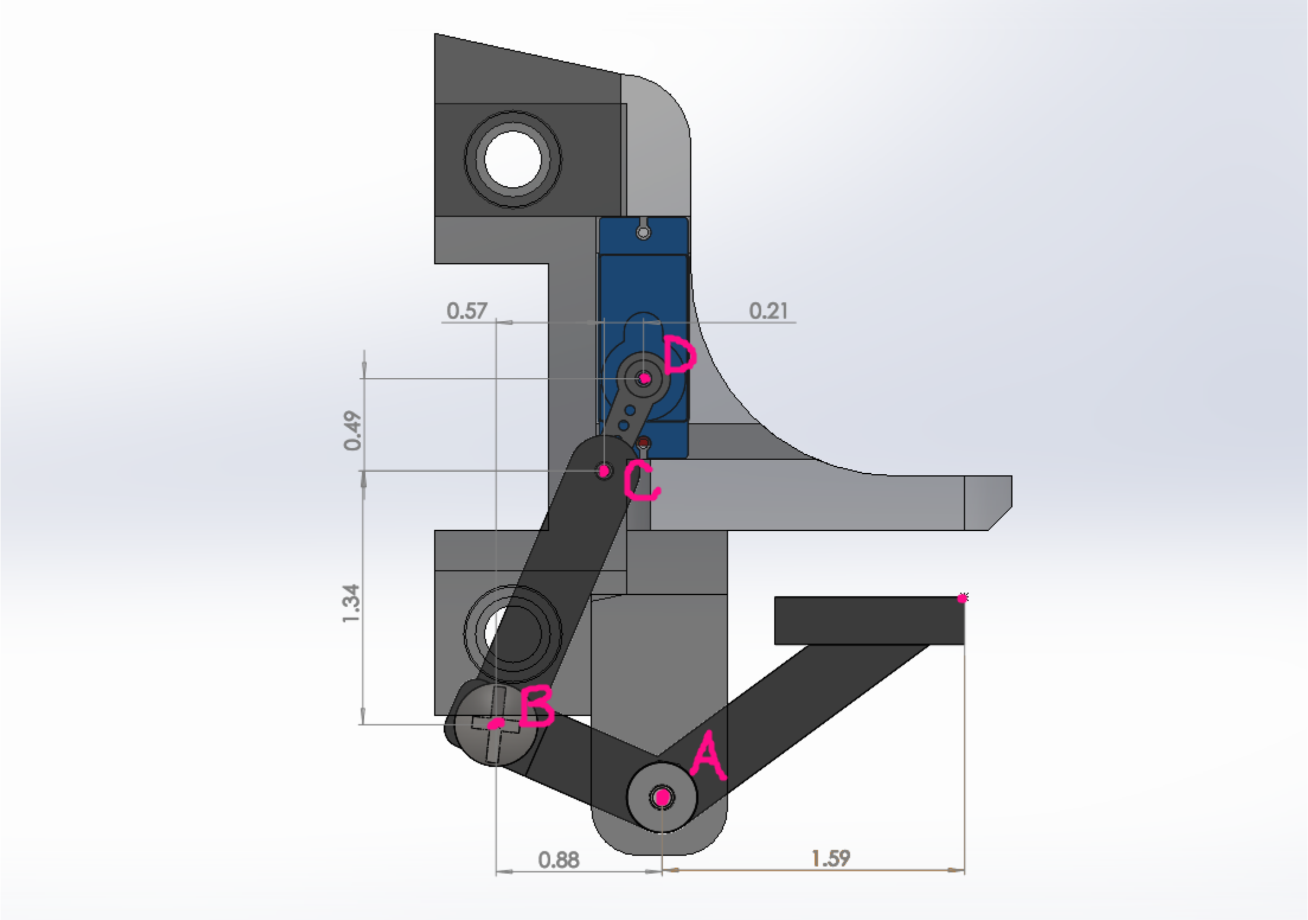
Mathcad Calculations


Gripper Mechanism

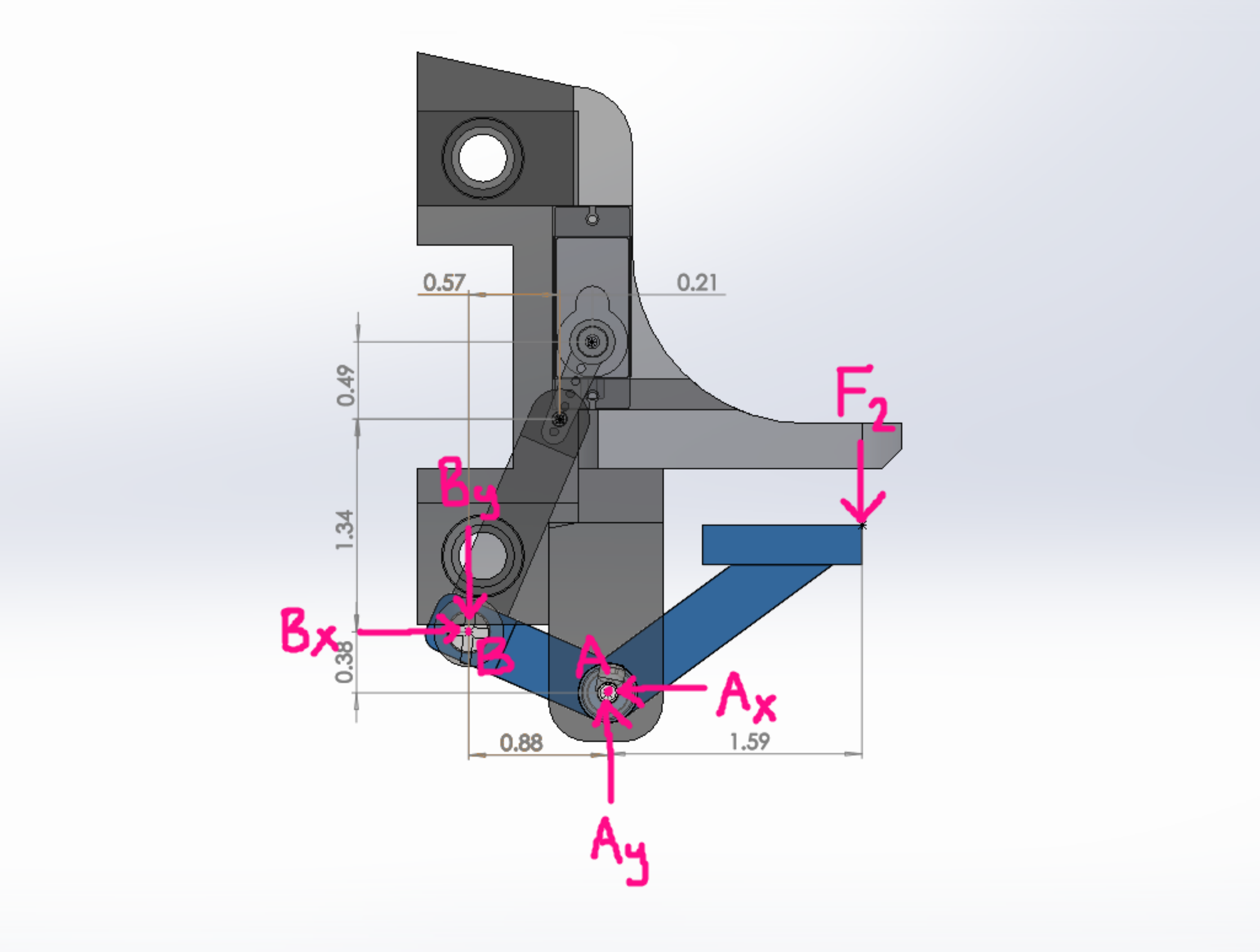
FORCE ANALYSIS OF GRIPPER MECHANISM



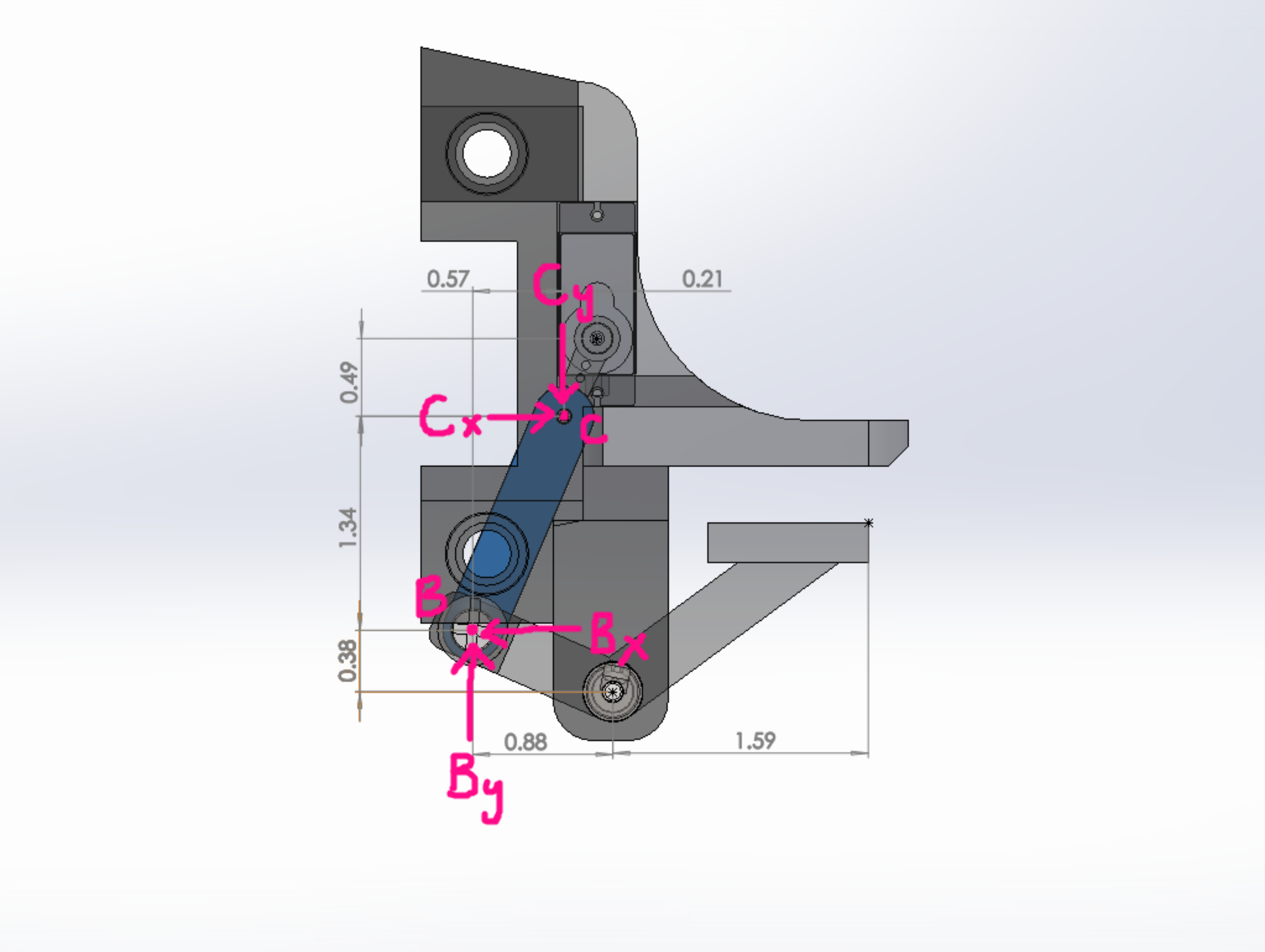
FBD of Solar Collector



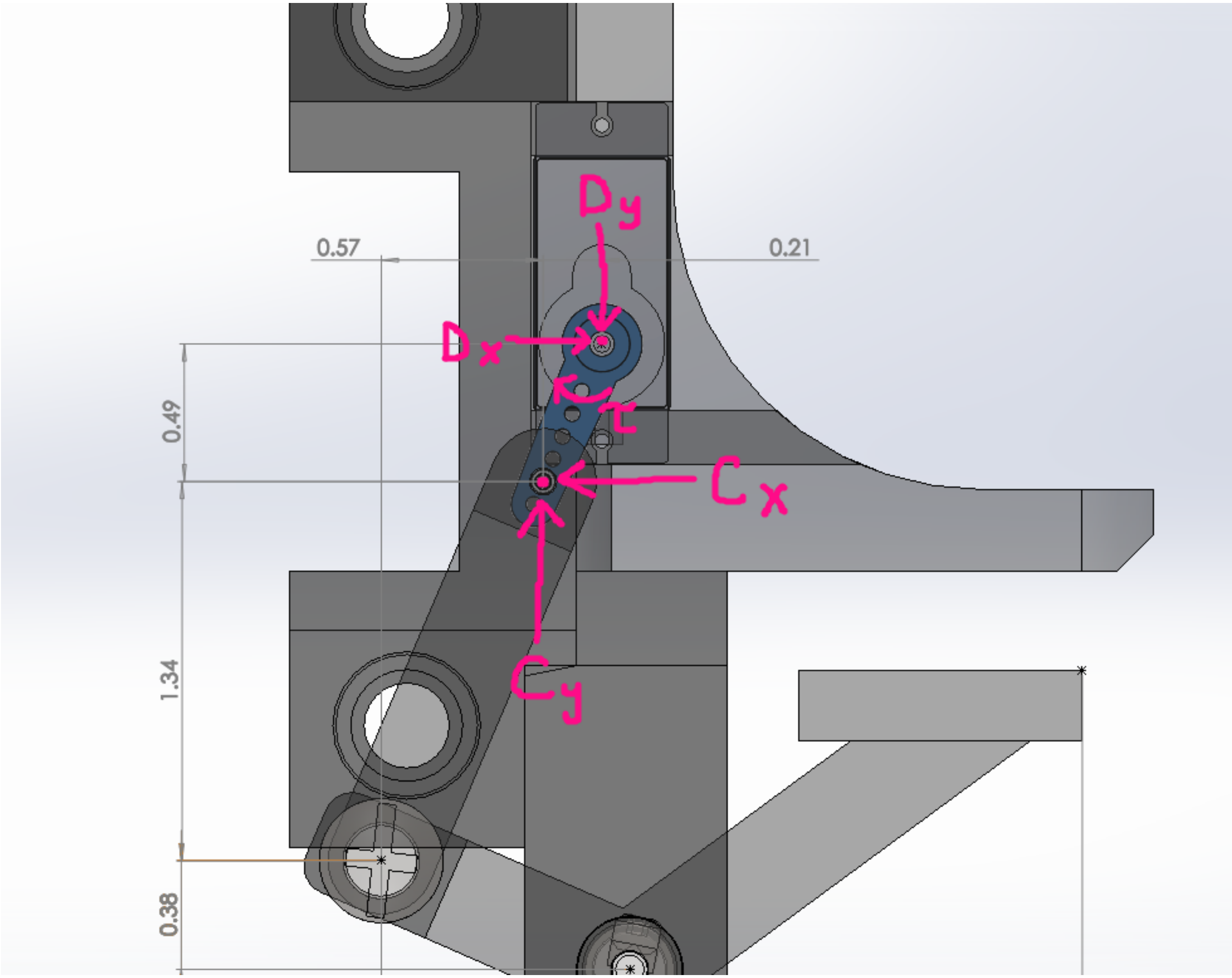
Gripper Mechanism



FBD of Lower Jaw



FBD of Link



FBD of Servo Horn

Known Parameters:

$W_1 := .35 lbf$ $r_1 := 1.25 in$ $r_2 := 1.86 in$ $r_3 := .88 in$ $r_4 := .$

$r_5 := 2.47 in$ $r_6 := 1.34 in$ $r_7 := .57 in$ $r_8 := .49 in$ $r_9 := .$

Supply initial guesses for unknowns:

$A_x := 2 lbf$ $A_y := 2 lbf$ $B_x := 2 lbf$ $B_y := 2 lbf$ $C_y := 2 lbf$

$D_x := 2 lbf$ $D_y := 2 lbf$ $C_x := 2 lbf$ $T_1 := 2 in \cdot lbf$ $F_1 := 2$

From equations of equilibrium we have nine equations with nine unknow

Given

From FBD of Plate

$$0 = F_2 \cdot r_1 - W_1 \cdot r_2$$

$$0 = F_2 - F_1 - W_1$$

From FBD of Lower Jaw:

$$0 = A_y \cdot r_3 - A_x \cdot r_4 - F_2 \cdot r_5$$

$$0 = B_x - A_x$$

$$0 = A_y - B_y - F_2$$

From FBD of Link

$$0 = -B_x \cdot r_6 - B_y \cdot r_7$$

$$0 = C_x - B_x$$

$$0 = B_y - C_y$$

Mathcad Calculations

From FBD of Servo Horn

$0 = -T_1 - C_x \cdot r_8 - C_y \cdot r_9$ $\Sigma M_D := 0$

$0 = D_x - C_x$ $\Sigma F_x := 0$

$0 = C_y - D_y$ $\Sigma F_y := 0$

$$\begin{pmatrix} SF_1 \\ SF_2 \\ SA_x \\ SA_y \\ SB_x \\ SB_y \\ SC_x \\ SC_y \\ SD_x \\ SD_y \\ ST_1 \end{pmatrix} := \mathrm{Find}(F_1, F_2, A_x, A_y, B_x, B_y, C_x, C_y, D_x, D_y, T_1)$$

$SF_1 = 0.17\,\mathrm{lbf}$

$SF_2 = 0.52\,\mathrm{lbf}$

$SA_x = -0.34\,\mathrm{lbf}$

$SA_y = 1.32\,\mathrm{lbf}$

$SB_x = -0.34\,\mathrm{lbf}$

$SB_y = 0.79\,\mathrm{lbf}$

$SC_x = -0.34\,\mathrm{lbf}$

$SC_y = 0.79\,\mathrm{lbf}$

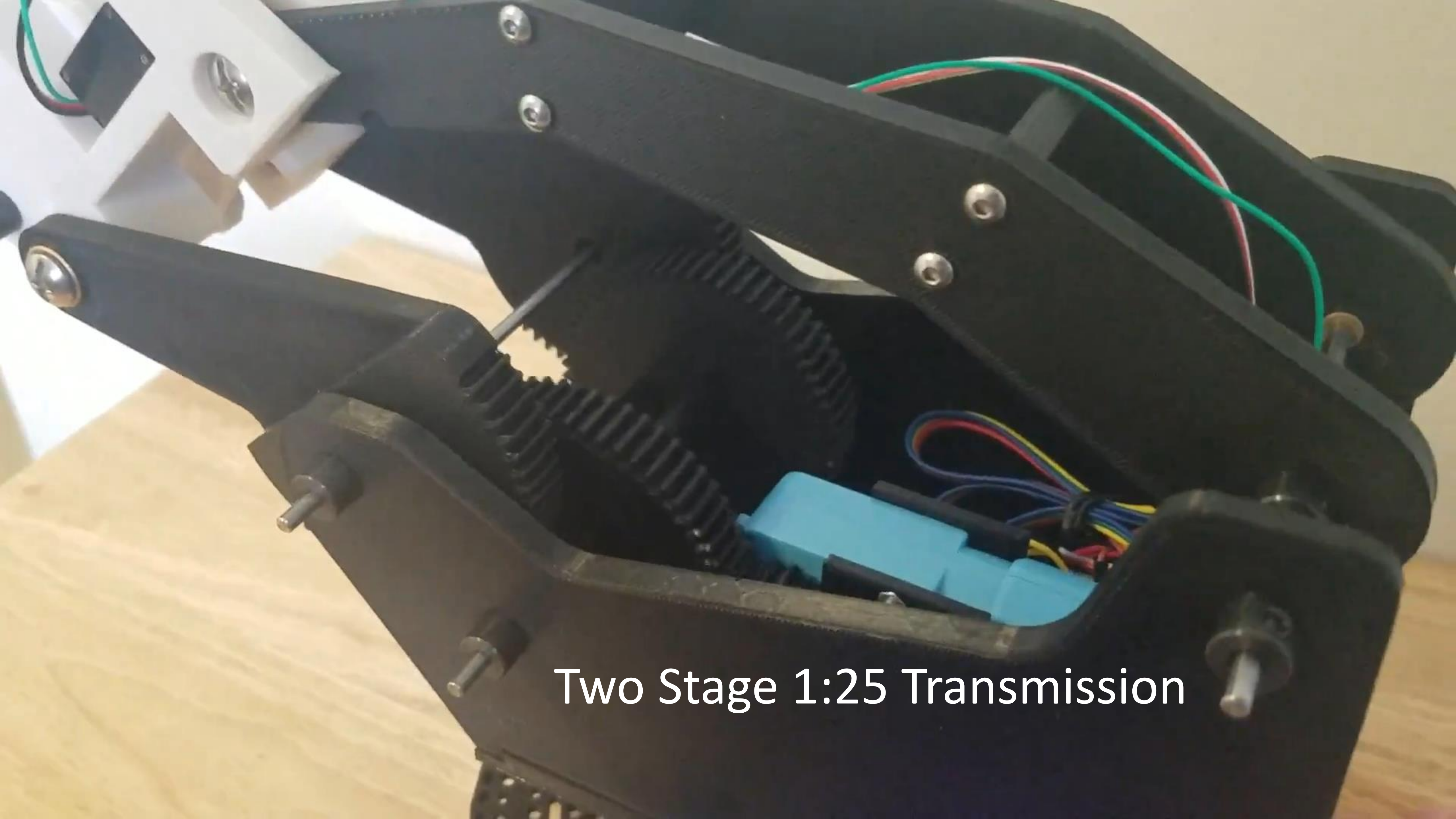
$SD_x = -0.34\,\mathrm{lbf}$

$SD_y = 0.79\,\mathrm{lbf}$

$ST_1 = -1.25 \times 10^{-3}\,\mathrm{in \cdot lbf}$

Mathcad Calculations

FORCE ANALYSIS OF GEAR TEETH


Two Stage 1:25 Transmission

Calculating the Force on the gear tooth:

$$\tau_{crank} = r \times F$$
$$F = \frac{\tau_{crank}}{r\cos\theta}$$

$$F = \frac{2.63353\ in \cdot lbf}{(1.25in)\cos(14.09°)}$$

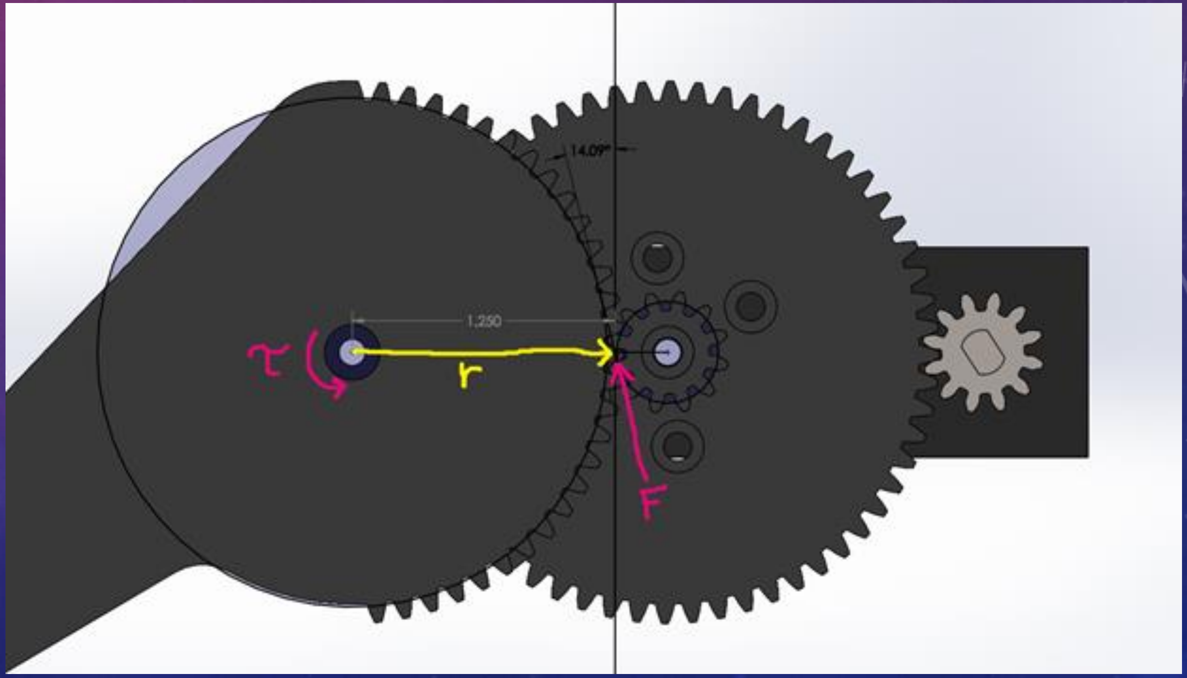
$$F = 2.172\ lbf$$

Calculating Torque on Intermediate Shaft :

$$\tau_{int} = \tau_{crank}\left(\frac{driver}{driven}\right)\left(\frac{1}{efficiency}\right)$$
$$\tau_{int} = (2.63353in \cdot lbf)\left(\frac{12}{60}\right)\left(\frac{1}{0.90}\right)$$

$$\tau_{int} = 0.5852\ in \cdot lbf$$

Second Stage



First Stage

Calculating Force on the gear tooth:

$$\tau_{int} = r \times F$$

$$F = \frac{\tau_{int}}{rcos\theta}$$

$$F = \frac{0.5852\ in \cdot lbf}{(1.25in)\cos(14.09°)}$$

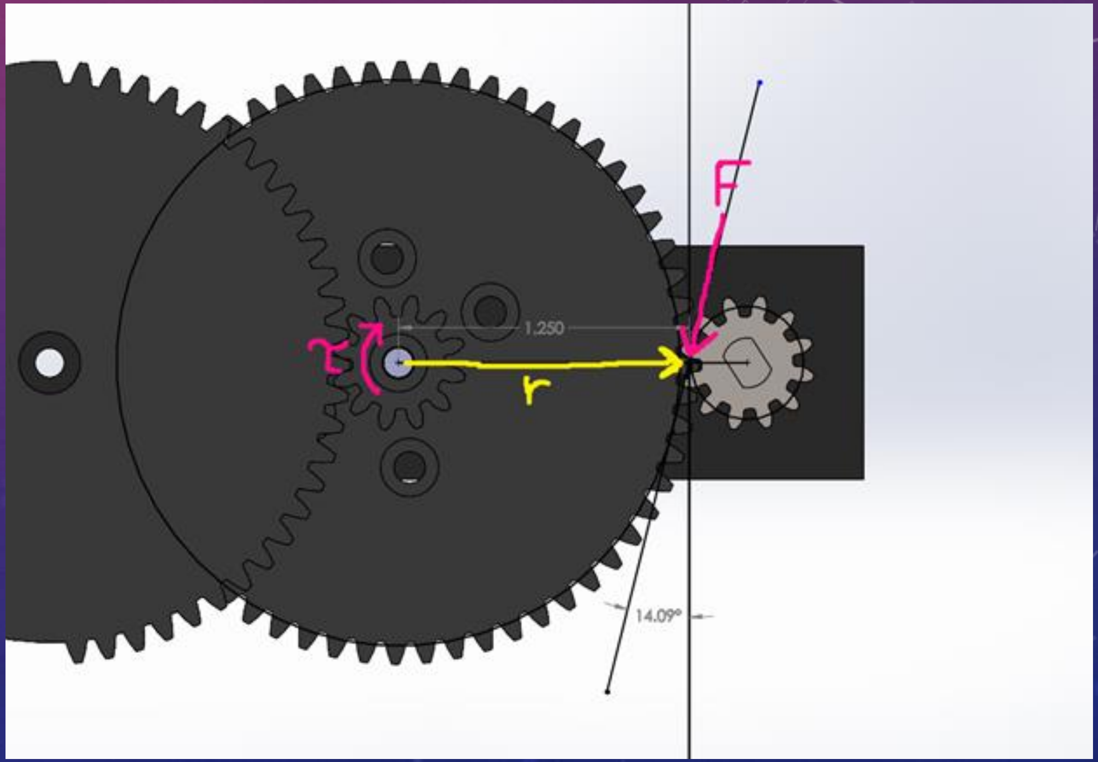
$$F = 0.483\ lbf$$

Calculating the output torque of the blue motor:

$$\tau_{motor} = \tau_{crank}\left(\frac{drivers}{driven}\right)\left(\frac{1}{efficiency}\right)^{n}$$

$$\tau_{motor} = (2.63353in \cdot lbf)\left(\frac{12}{60}\right)\left(\frac{12}{60}\right)\left(\frac{1}{0.90}\right)^{2}$$

$$\tau_{motor} = 0.13005\ in \cdot lbf$$



FACTOR OF SAFETY OF GEAR (2^{ND} STAGE)

$$t = \frac{\pi}{2P}$$

$$t = \frac{\pi}{2 \cdot 24} = .06545\ in$$

$$A = t * b$$

$$A = .06545\ in \cdot .45\ in = .02945\ in^2$$

$$\sigma_{max} = \frac{F}{A}$$

$$\sigma_{max} = \frac{2.172\ lbf}{.02945\ in^2} = 73.75212\ psi$$

$$FoS = \frac{\sigma_y}{\sigma_{max}}$$

$$FoS = \frac{2500\ psi}{73.75212\ psi} = 33.90013$$

* t = tooth thickness, b = face width

FACTOR OF SAFETY OF GEAR (1^{ST} STAGE)

$$t = \frac{\pi}{2P}$$

$$t = \frac{\pi}{2 \cdot 24} = .06545\ in$$

$$A = t * b$$

$$A = .06545\ in \cdot .45\ in = .02945\ in^2$$

$$\sigma_{max} = \frac{F}{A}$$

$$\sigma_{max} = \frac{.483\ lbf}{.02945\ in^2} = 16.40068\ psi$$

$$FoS = \frac{\sigma_y}{\sigma_{max}}$$

$$FoS = \frac{2500\ psi}{16.40068\ psi} = 152.4327$$

* t = tooth thickness, b = face width

FOURBAR COMPONENT SPEEDS

Linkages - Student Edition - by R. L. Norton - Copyright 2017 Release 10.0 Rev 2.0.7 8/13/2017 Input Screen

Help | Constant Velocity | Recalc | Show | Zoom Out | Normal | Zoom In | Redraw | Step | Run | Copy | Print | <Back | Next>

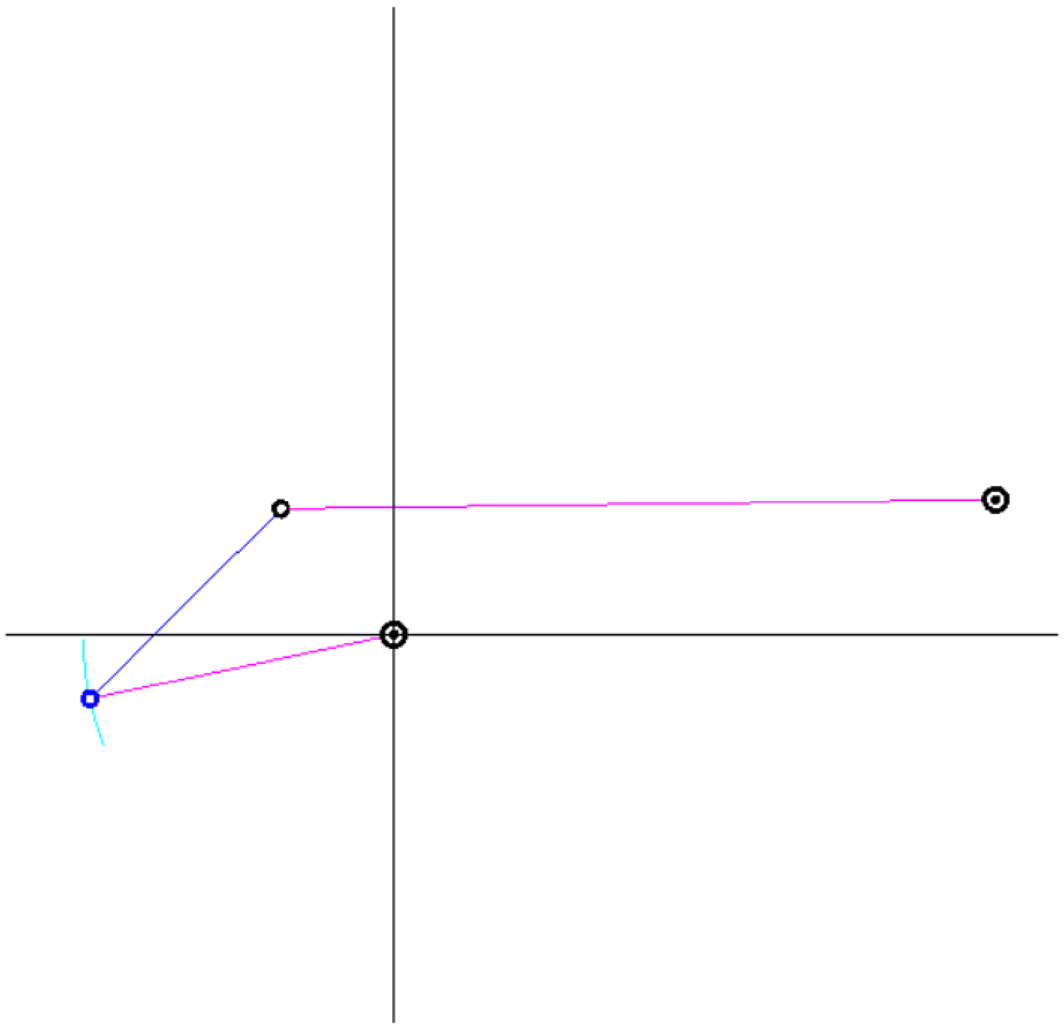
Autocalc: On
Loop 1 Mode: Open / Xed
Ground Coord.: Cart / Polar
Calculating For: Constant Velocity
Angle Step: 191.9 deg
Grashof Condition: Non-Grashof
Toggles @+/-: 43.4 deg

Fourbar Linkage - Cognate 1	Value	Unit
Number of Links	4	
Length of Link 2	2.884	in
Length of Link 3	2.5	in
Length of Link 4	6.635	in
Length of Link 1	5.726	in
Angle of Link 1	12.62	deg
Distance to Coupler Point From Pin I23	0	in
Angle to Coupler Point Within Link 3	0	deg

Initial Conditions for Calculation	Value	Unit
Start Angle of Input Link	180.95	deg
End Angle of Input Link	200.95	deg
Delta Angle of Input Link	1	deg
Omega of Input Link	0.377	rad/s

Animation Control
Cycles 1 Range 1000

Click-Shift-Drag on: Coupler Point / Crank / Coupler Link / Rocker / Ground — To change coupler curve



<-- Start Time ----> End -->

Linkages - Student Edition - by R. L. Norton - Copyright 2017 Release 10.0 Rev 2.0.7 8/13/2017 Print Screen

Print To Screen | Omega2 | Mag | 3 | Omega3 | Mag | 3 | Omega4 | Mag | 3 | w4 / w2 | Mag | 3 | Next >

Print Every: 1 | Set Angle Dec Plcs: 3 | Set Data Dec Plcs: 3 | Functions: 1, 2, 4 | Coordinate System: Global, Local | Omega magnitudes for all links | Refresh

Current Model Parameters

Fourbar Linkage	Value	Unit
Links	4	
Link 2	2.884	in
Link 3	2.500	in
Link 4	6.635	in
Pivot O4x	5.59	in
Pivot O4y	1.25	in
I23-CplrPt	0.000	in
CplrPtAng3	0.00	deg

Initial Conditions	Value	Unit
Start	181.0	deg
End	201.0	deg
Delta	1.0	deg
Omega2	0.4	rad/s

Input Angle (deg)	Omega2 Mag (rad/sec)	Omega3 Mag (rad/sec)	Omega4 Mag (rad/sec)	w4 / w2 Mag (ratio)
180.950	0.377	0.045	0.151	0.402
181.950	0.377	0.052	0.150	0.397
182.950	0.377	0.059	0.148	0.391
183.950	0.377	0.065	0.145	0.386
184.950	0.377	0.072	0.143	0.380
185.950	0.377	0.079	0.141	0.375
186.950	0.377	0.086	0.139	0.369
187.950	0.377	0.093	0.137	0.363
188.950	0.377	0.100	0.135	0.357
189.950	0.377	0.107	0.132	0.351
190.950	0.377	0.114	0.130	0.345
191.950	0.377	0.122	0.128	0.339
192.950	0.377	0.129	0.126	0.333
193.950	0.377	0.136	0.123	0.327
194.950	0.377	0.143	0.121	0.321
195.950	0.377	0.150	0.119	0.314
196.950	0.377	0.157	0.116	0.308
197.950	0.377	0.164	0.114	0.302
198.950	0.377	0.171	0.112	0.296
199.950	0.377	0.178	0.109	0.290
200.950	0.377	0.184	0.107	0.284

Omega2 Mag		
Max	0.377	rad/sec
Min	0.377	rad/sec
P - P	0.000	rad/sec

Omega3 Mag		
Max	0.184	rad/sec
Min	0.045	rad/sec
P - P	0.139	rad/sec

Omega4 Mag		
Max	0.151	rad/sec
Min	0.107	rad/sec
P - P	0.044	rad/sec

w4 / w2 Mag		
Max	0.402	ratio
Min	0.284	ratio
P - P	0.117	ratio

Michael Beskid

Design No. 1

03-11-2021
at 19:05:07

File: Model_1

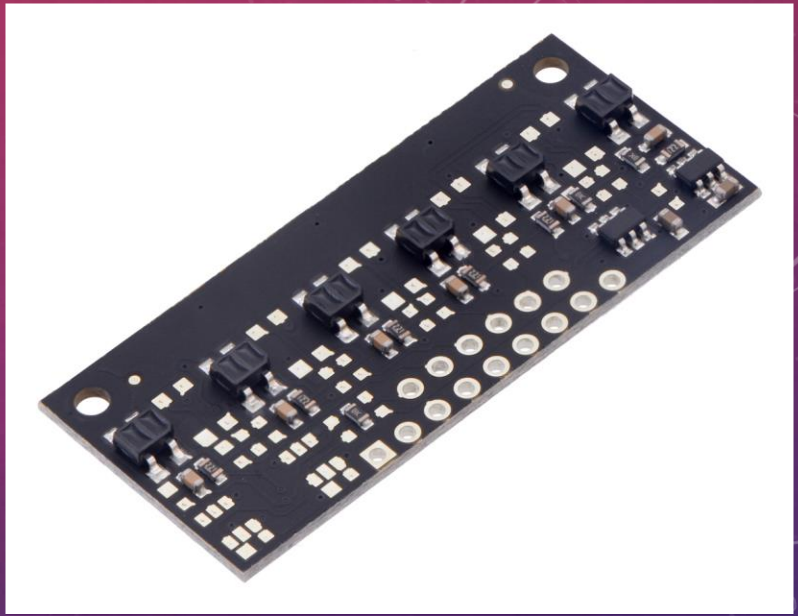
Fourbar Component Speed Results

Angular Speed of Crank: 0.377 rad/s
Angular Speed of Coupler: 0.144 rad/s
Angular Speed of Rocker: 0.130 rad/s

SUMMARY OF SENSORS

Reflective Sensor Array:

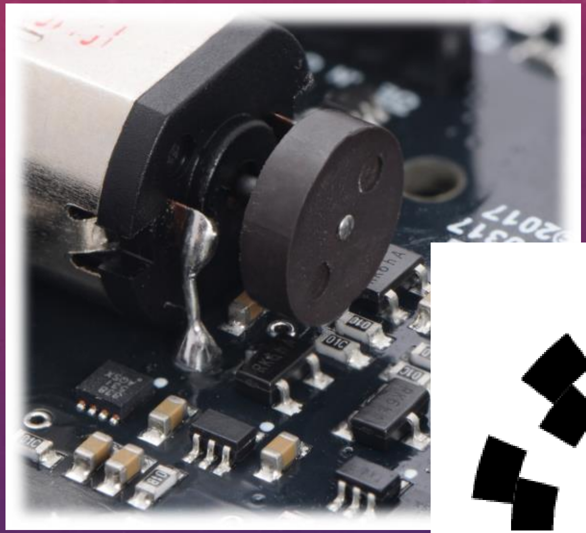
- Detect light levels to follow the black lines on the field
- Keep robot on straight course to target with proportional control
- 8 IR LED/phototransistor pairs (using 2 for robot)
- Optimal sensing distance: 0.125”

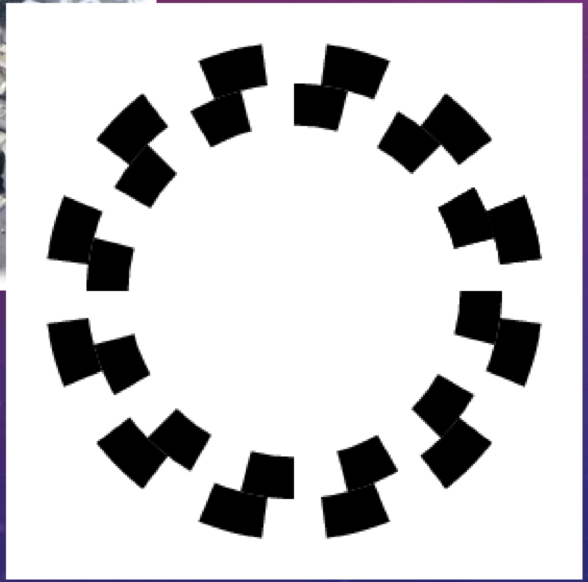


Ultrasonic Sensor:

- Detect the distance the robot is away from the roof and the staging block
- Position the robot optimally for grabbing and placing the solar collectors
- Range: 2cm – 4m
- Accuracy: ~0.5cm

IR Sensor:
- Detect input signals from the IR remote
- Receive user commands to proceed
- Respond to emergency stop signal





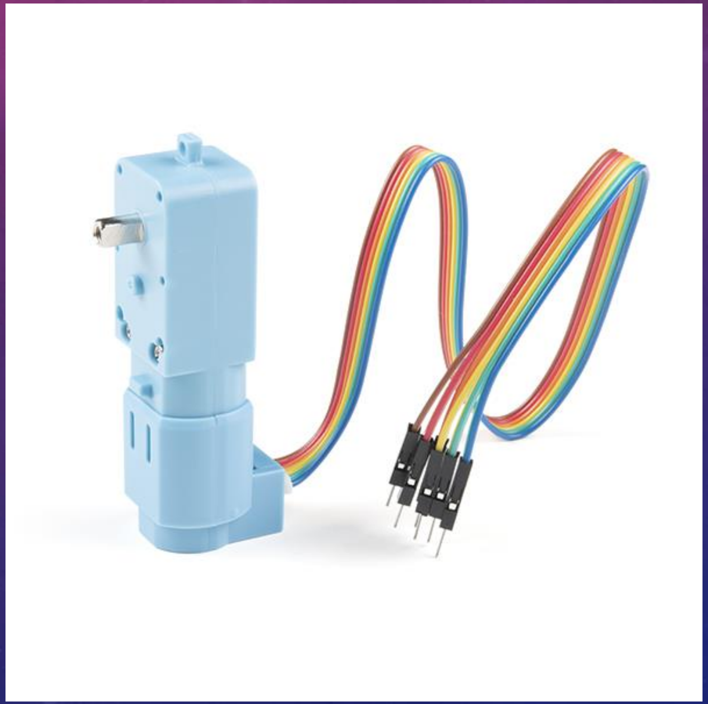
Optical Quadrature Encoders:
- Keep count of the motor rotations
- Control drive motors to drive for target distance
- Measure arm position for PID control algorithm
- Drive motors: 1440 counts/revolution
- Blue motor: 540 counts/revolution

BLUE MOTOR CURRENT REQUIREMENT

$$I = \left(\frac{I_{stall} - I_{noload}}{T_{stall}}\right) \cdot T + I_{noload}$$

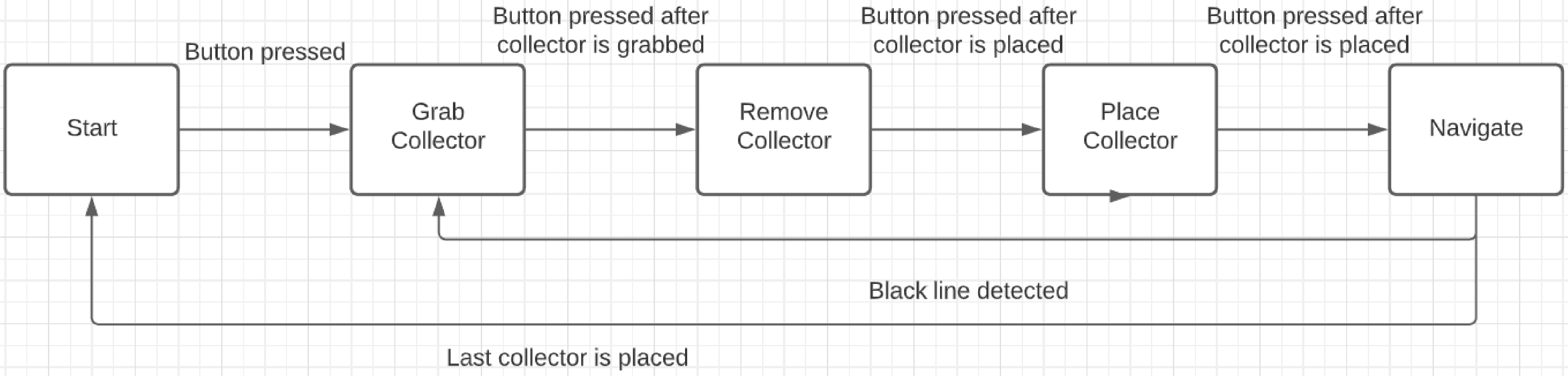
$$I = \left(\frac{0.32\ A - 0.04\ A}{.092\ N \cdot m\ \cdot \left(\frac{3.281 ft}{1m}\right) \cdot \left(\frac{12\ in}{1 ft}\right) \cdot \left(\frac{1\ lbf}{4.448\ N}\right)}\right) \cdot (0.13005\ in \cdot lbf) + 0.04\ A$$

$$I = .08471A$$



PROGRAM OVERVIEW

PROGRAM FLOWCHART



Start:
- Initialize sensors and systems
- Pressing IR remote button switches to Grab Collector

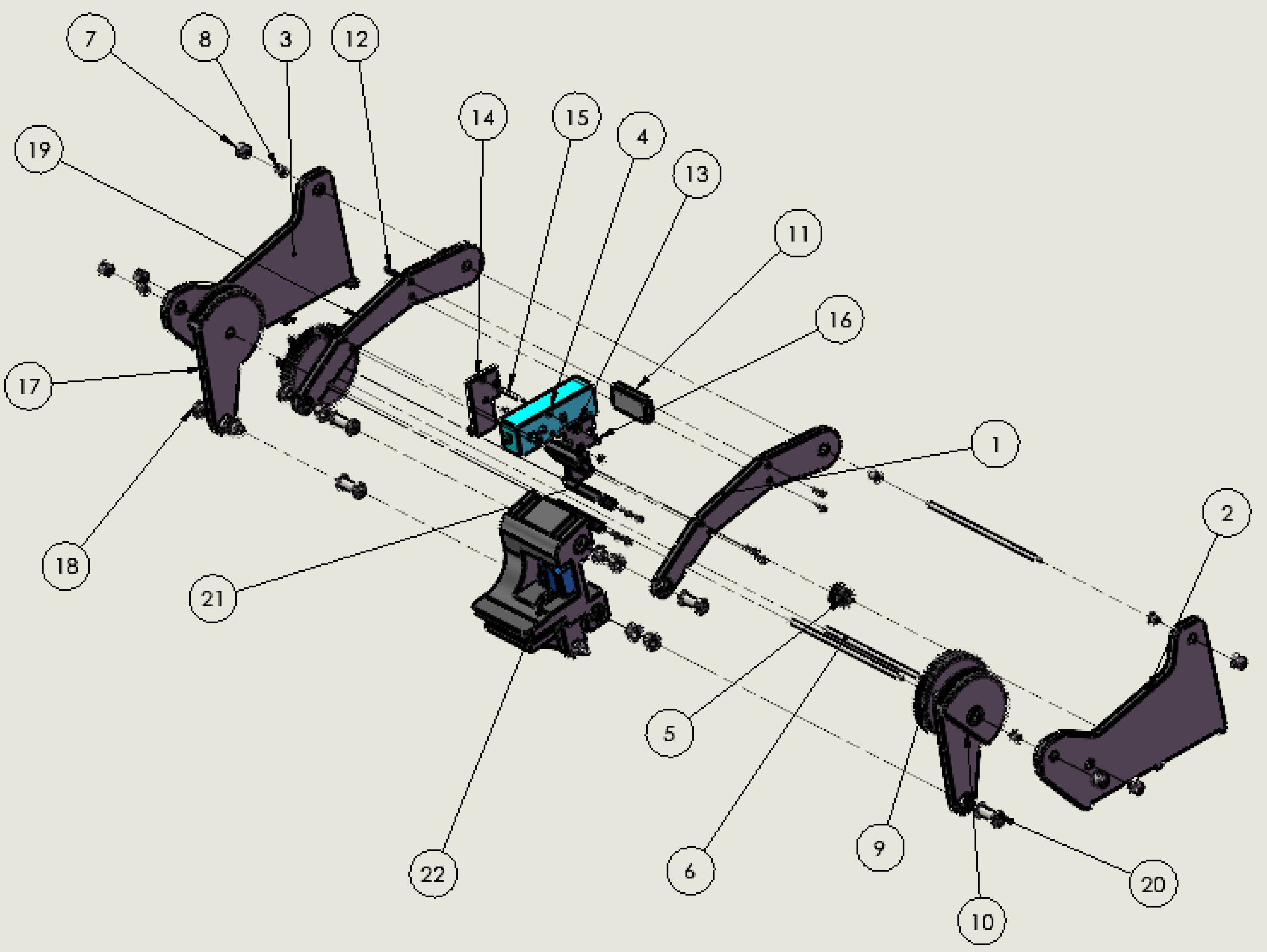
Grab Collector:
- Drive up to the roof while line following and using ultrasonic sensor for distance
- Check boolean to know which position to lift arm to
- Lifts arm to that position
- Grab the collector
- Switch to Remove Collector when IR remote is pressed

Remove Collector:
- Remove the collector from the roof
- 180 degree turn and drive to black line intersection
- Check boolean to know which way to turn
- Drive to staging block while line following and using ultrasonic sensor for distance
- Place collector on staging block
- Switch to Place Collector when IR remote is pressed

Place Collector:
- Picks up new collector when IR remote is pressed
- 180 turn and drive to black line intersection
- Check boolean to know which way to turn
- Drive up to roof while line following and using ultrasonic sensor for distance
- Lift arm to the roof position
- Place collector
- Toggle Boolean value to indicate task completed
- Switch to Navigate when IR remote is pressed

Navigate:
- Open gripper mouth
- Drive back a certain distance
- Check boolean value to see if both collectors have been placed
- If true, switch to Start
- If false, drive to the other side of the field by making a series of turns using the drive motor encoders, and find black line
- Switch to Grab collector once on the other side of the field

ASSEMBLY DRAWING/BOM



TEAM 3	SCALE: 1:1	FOURBAR LIFT MECHANISM	MARCH 12 2021

ITEM NO.	PART NUMBER	QTY.	UNIT COST	EXT. COST	MATERIAL	UNIT WEIGHT (LBS)	EXT. WEIGHT (LBS)
1	LONG_LINK_L	1	$0.79	$0.79	PLA	0.075	0.07
2	CHASSIS_WALL_L	1	$2.27	$2.27	PLA	0.202	0.20
3	CHASSIS_WALL_R	1	$2.16	$2.16	PLA	0.195	0.20
4	BLUE_MOTOR	1	$5.95	$5.95	Copper	0.707	0.71
5	PINION	1	$0.44	$0.44	PLA	0.00386867	0.00
6	DRIVE STEEL SHAFT	3	$4.32	$12.96	Cast Carbon Steel	0.017	0.05
7	SET SCREW SHAFT COLLAR	6	$1.23	$7.38	Plain Carbon Steel	0.01	0.06
8	FLANGED SLEEVE BEARING	10	$0.79	$7.90	Cast Carbon Steel	0.003	0.03
9	12T 60T GEAR	2	$1.13	$2.26	PLA	0.100	0.20
10	SHORT_LINK_L	1	$1.18	$1.18	PLA	0.10403132	0.10
11	ARM_BRACE_2	2	$0.11	$0.22	PLA	0.011	0.02
12	HEX DRIVE SCREW	16	$.08	$1.28	18-8 Stainless Steel	0.0014	0.02
13	MOTOR_BRACKET_L	1	$0.11	$0.11	PLA	0.013	0.01
14	MOTOR_BRACKET_R	1	$0.11	$0.11	PLA	0.010	0.01
15	LONG_SCREW	2	$0.10	$0.20	Cast Carbon Steel	0.002	0.00
16	HEX_NUT	2	$0.04	$0.08	Cast Carbon Steel	0.000	0.00
17	SHORT_LINK_R	1	$1.18	$1.18	PLA	0.10403064	0.10
18	QUARTER INCH FLANGED BEARING	8	$0.81	$6.48	Cast Carbon Steel	0.006	0.05
19	LONG_LINK_R	1	$0.79	$0.79	PLA	0.075	0.07
20	BINDING_BARREL	4	$2.52	$10.08	Cast Carbon Steel	0.017	0.07
21	GEAR_BRACE	2	$0.11	$0.22	PLA	0.012	0.02
22	GRIPPER	1	$25.00	$25.00	PLA, Cast Carbon Steel	0.44	0.44
				ASSEMBLY COST $89.04			ASSEMBLY WEIGHT 2.43 (LBS)

TEAM 3	SCALE: 1:1	FOURBAR LIFT BOM	MARCH 12 2021

THE END ☺