Coupler Design

*** The DREAM Team ***

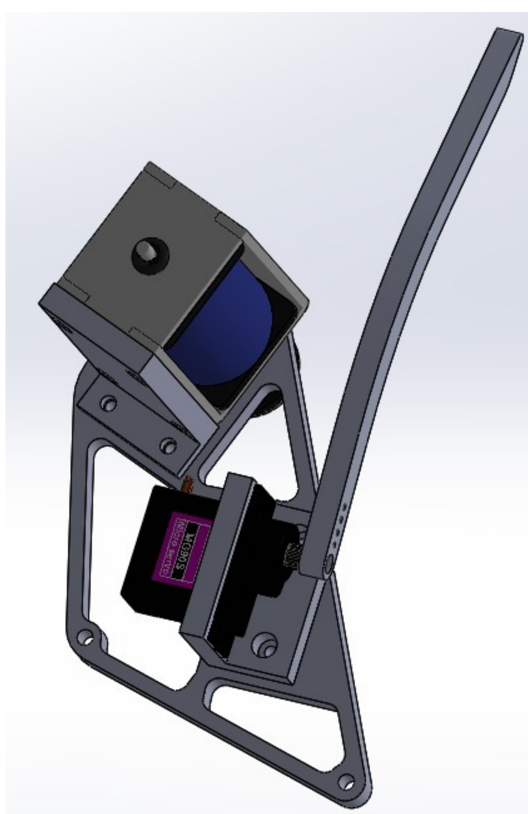
Miles Huntley-Fenner

Leon Aharonian

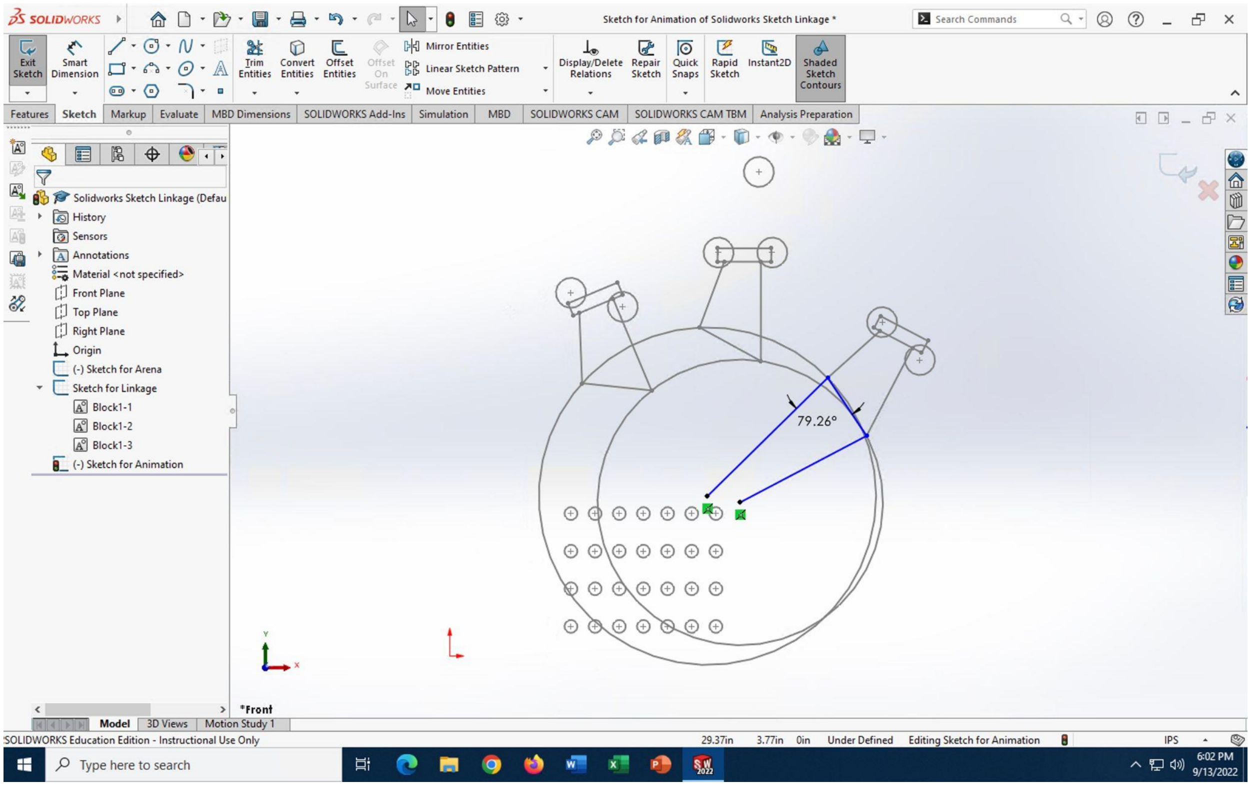
Phillipe Dumeny

Christina Wright

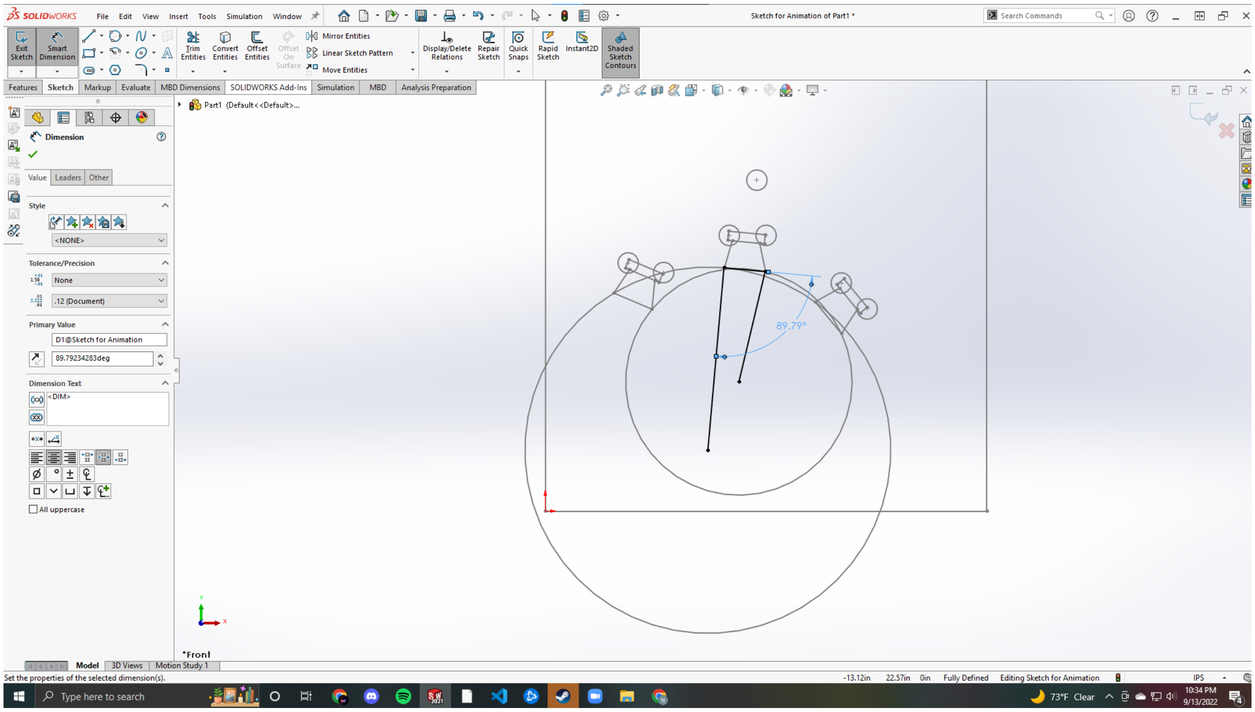
Nico Aldana



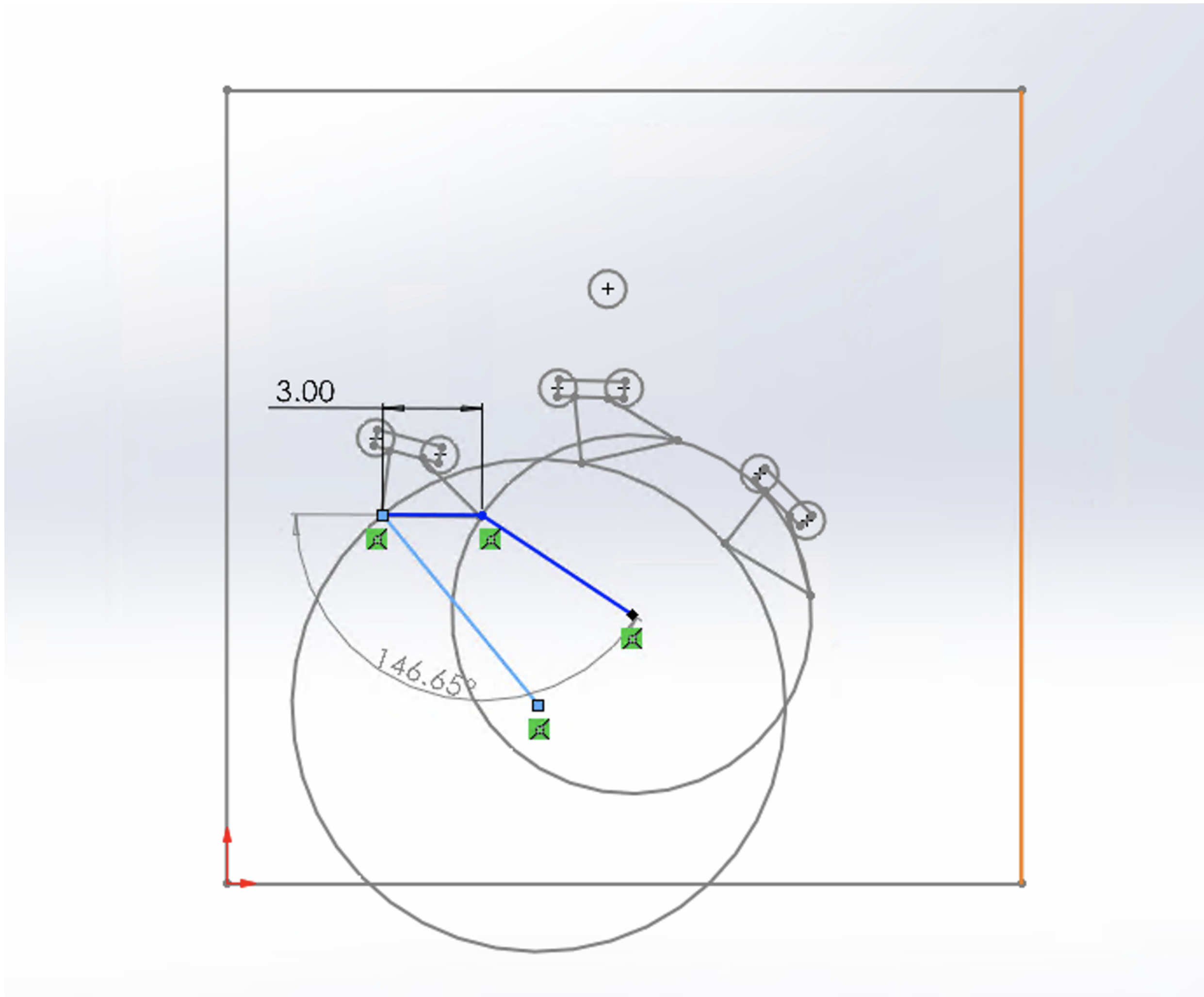
Rejected Linkages



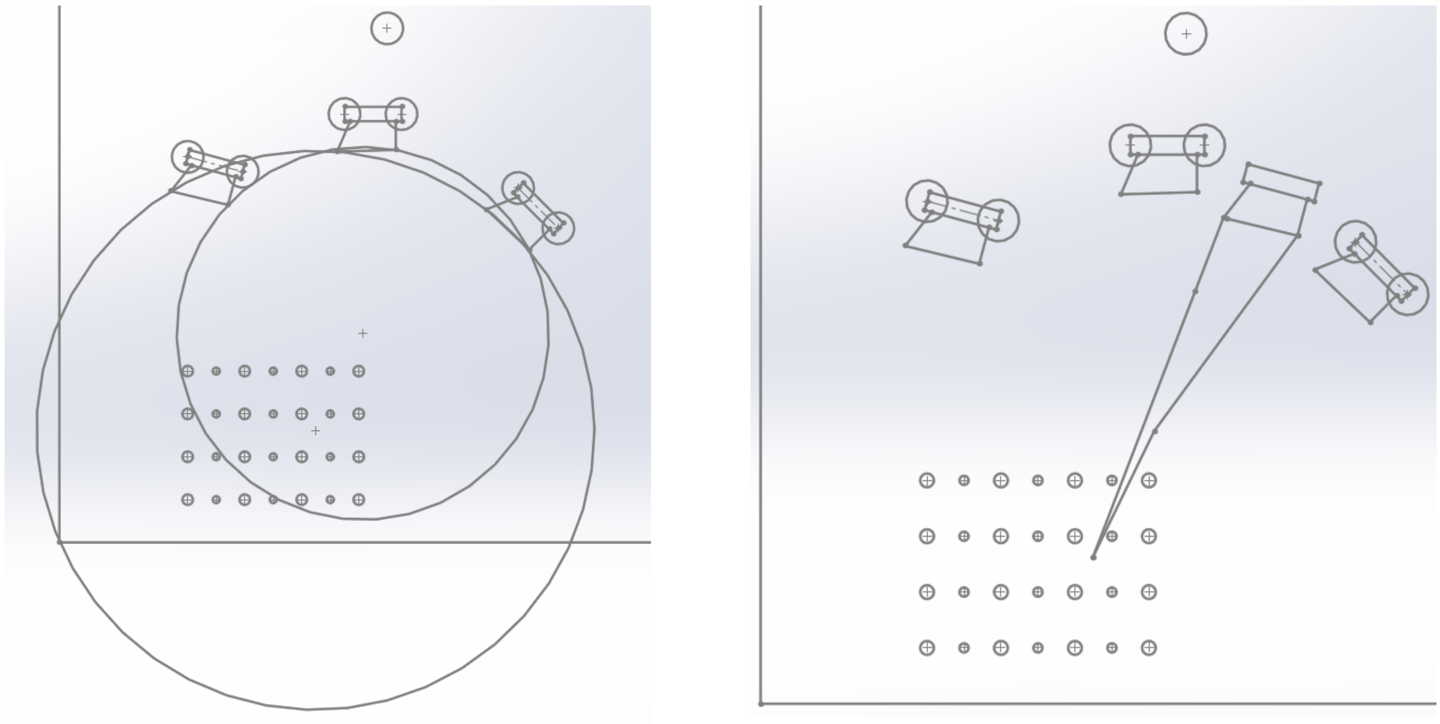
This linkage was made on a remote desktop, and the original file was lost. Furthermore, the acrylic bar does not press the buttons straight, and there is a risk that the buttons may be missed entirely in practice.



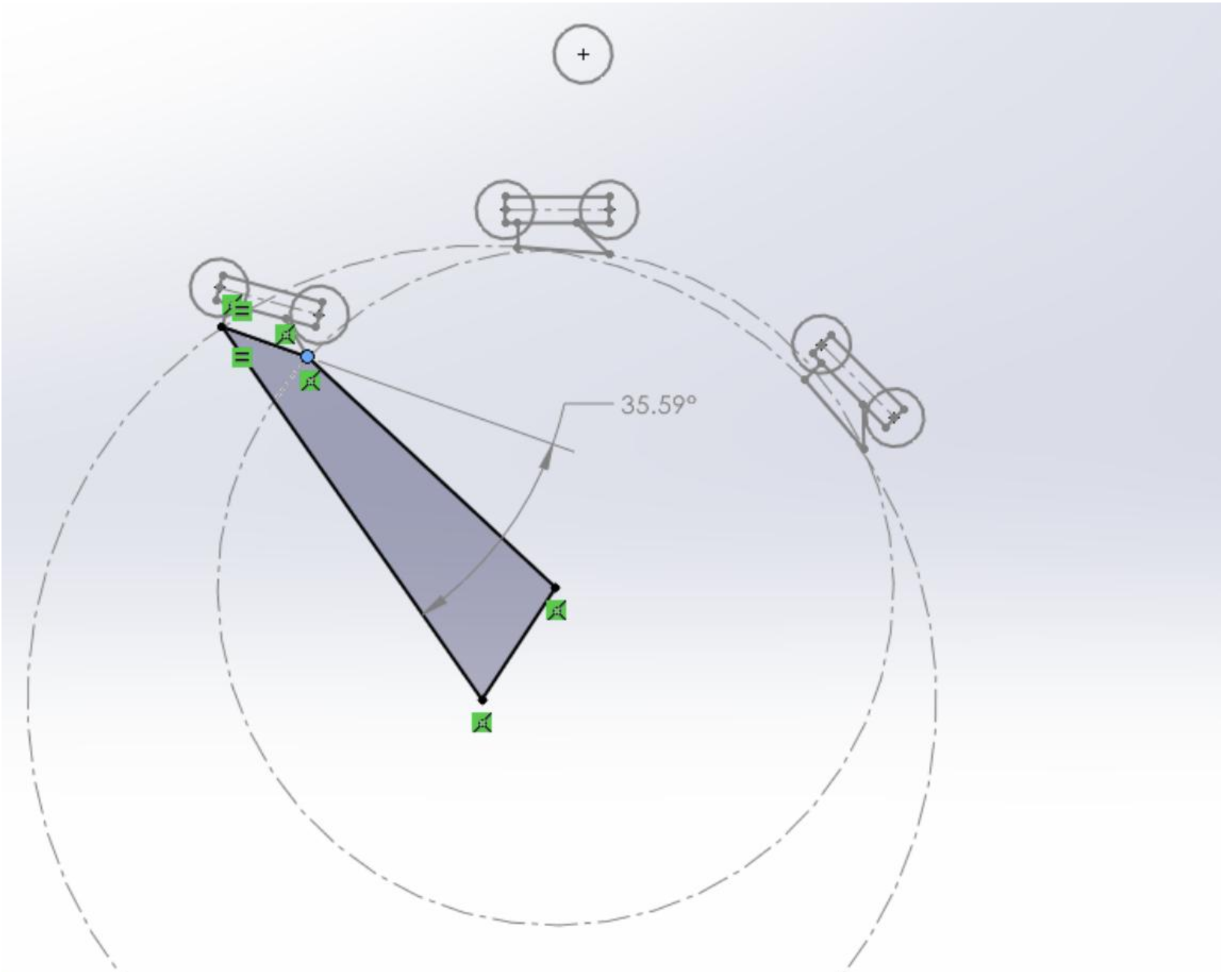
This linkage was rejected due to the long linkage lengths. Longer linkages have higher moments of inertia, requiring higher torque from the motors. We are trying to avoid straining the motors and transmission too much because we are prioritizing speed. Also, from a budgeting standpoint, using less material is generally a better idea.



This linkage was rejected because of the less than ideal transmission angles which range from 145° to 35°. This would make the mechanism inefficient in ⅔ necessary positions. The arms are also rather long which the shortest arms were a main focus for our team.



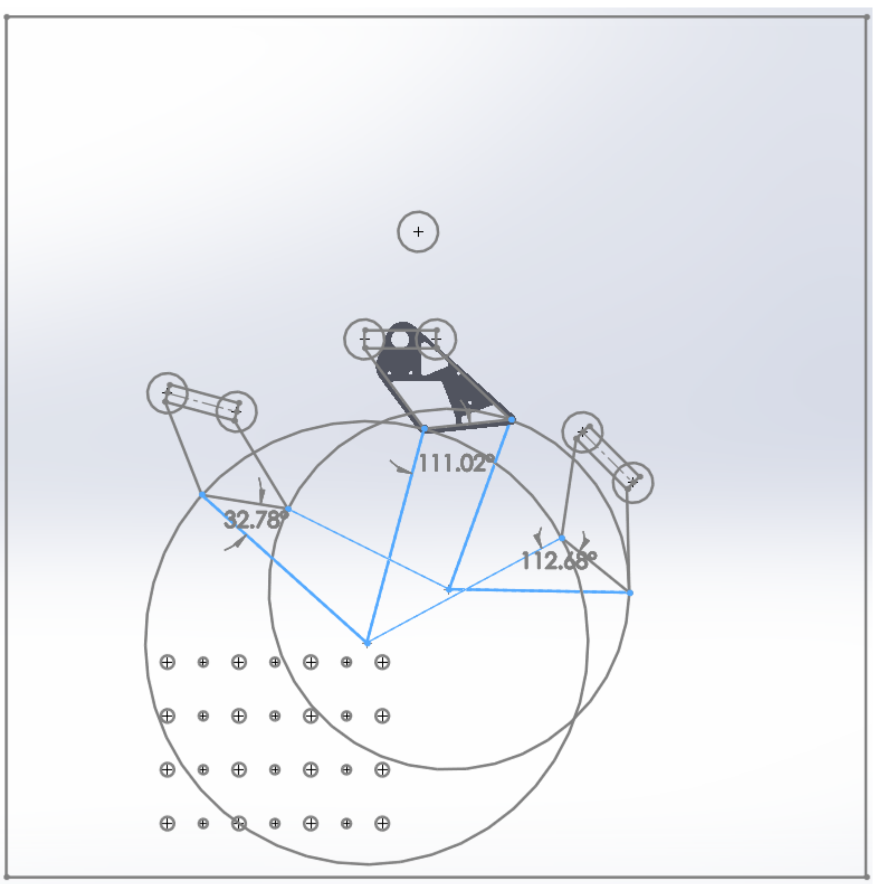
This linkage was rejected because the like are way too long / we were able to find a coupler that allowed the linkage to be smaller. As stated previously, Longer linkages means a greater moment of inertia which makes it harder to accelerate in the first place but also harder to stop in the right position. This makes it slower and less accurate. For this reason we want linkages that are as short as possible.



This linkage was also rejected due to the length of its' links, as well as the fact that the overall angles could be much more optimized, as was done in our final design choice.

The Chosen One

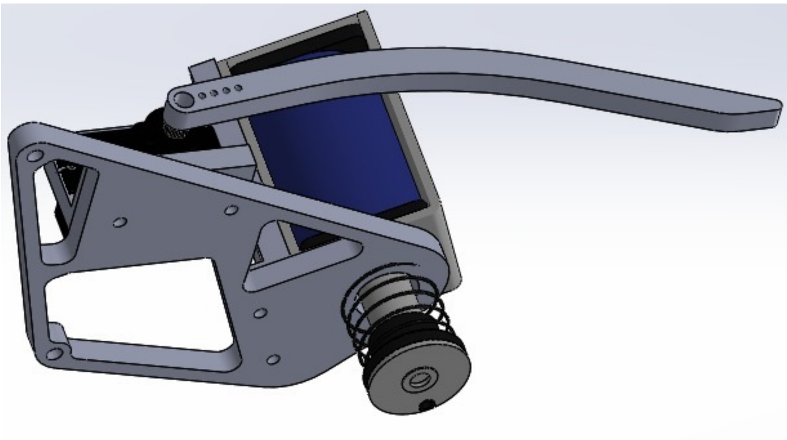
An image of the chosen linkage in 3 position:



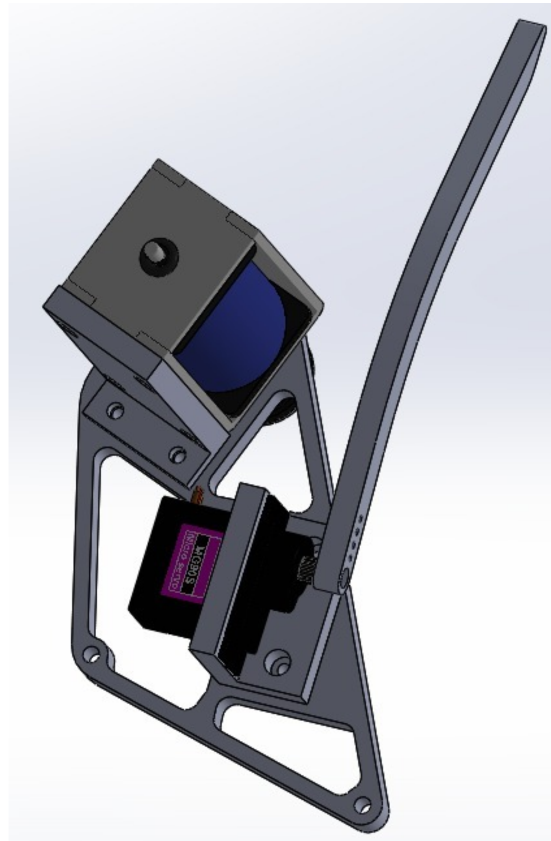
The image to the left depicts our chosen linkage in all three positions. The blue linkage pairs are superimposed on each other to show all three positions in one image. The coupler plate design, which will be detailed later can be seen lined up in the middle position.

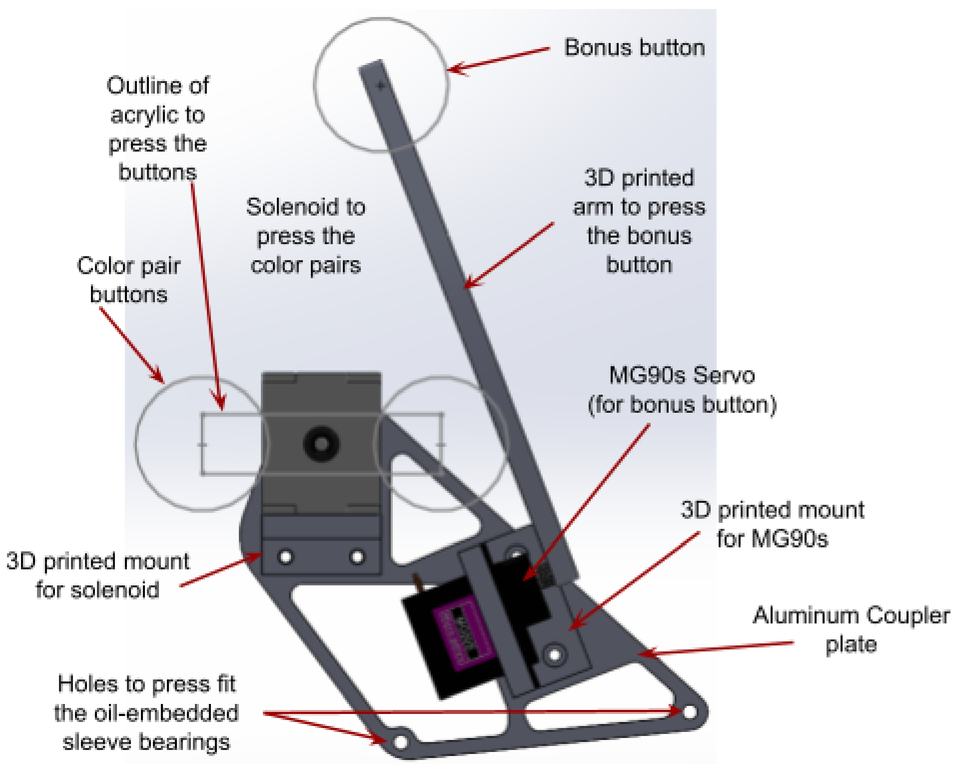
We ultimately decided that speed is the most important criteria for us. While having our ground links outside the mounting area will inevitably increase the size of our mechanism, it allows us to make the linkages a lot shorter and we feel like this is a valuable trade off to maximize our score. Furthermore, the transmission angle isn't the most optimal but it is within 30° to 150° – which was our goal. The 111° and 112° are very acceptable to us. While the 33° is a bit low this is also a compromise we are willing to make for the sake of having shorter linkages.

The Actual Coupler Assembly

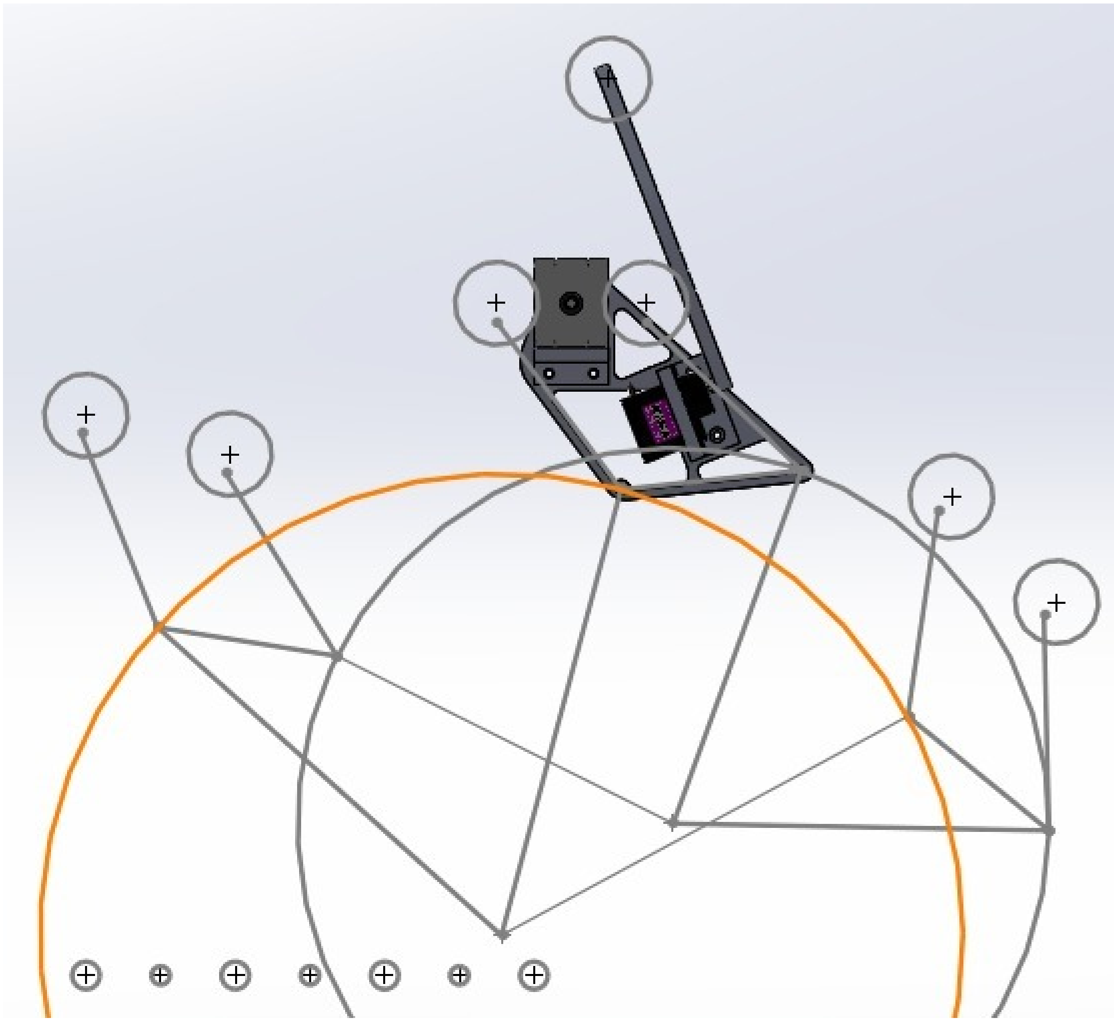


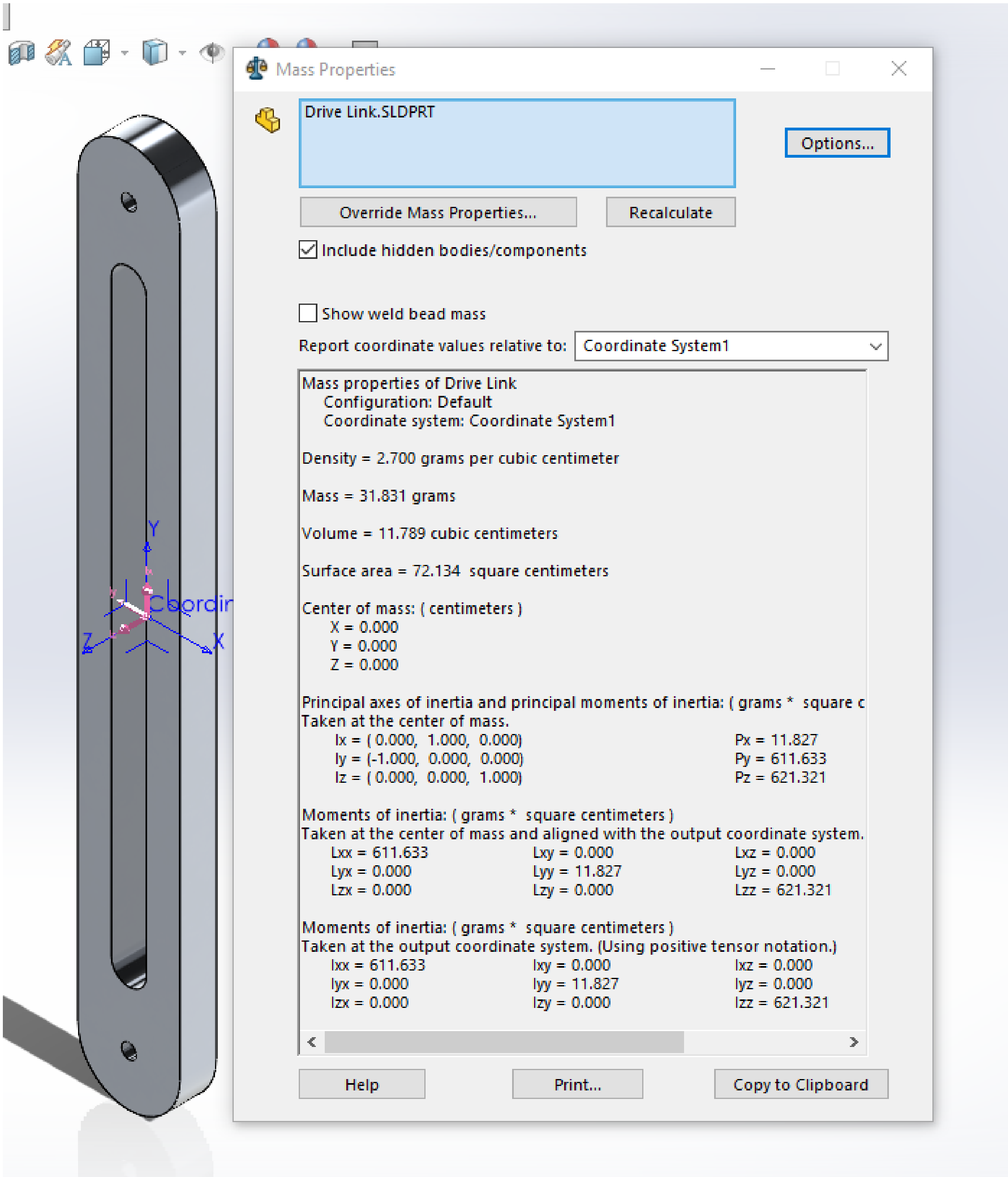
The plan is to press the button pairs with a solenoid and the bonus button with a servo motor. The coupler plate will be made out of a sheet of Al which we will cut on the water jet. It will attach to the rest of the linkages using the oil-embeded sleeve bearing. Both the Solenoid and the servo will be attached to the plate using 3D prointed brackets. We will use small screws and threaded inserts to attach the actuators to the the brackets and the brakets to the coupler plate (the whole zizes will be adjusted once we actually have the actuators and can measure the holes).

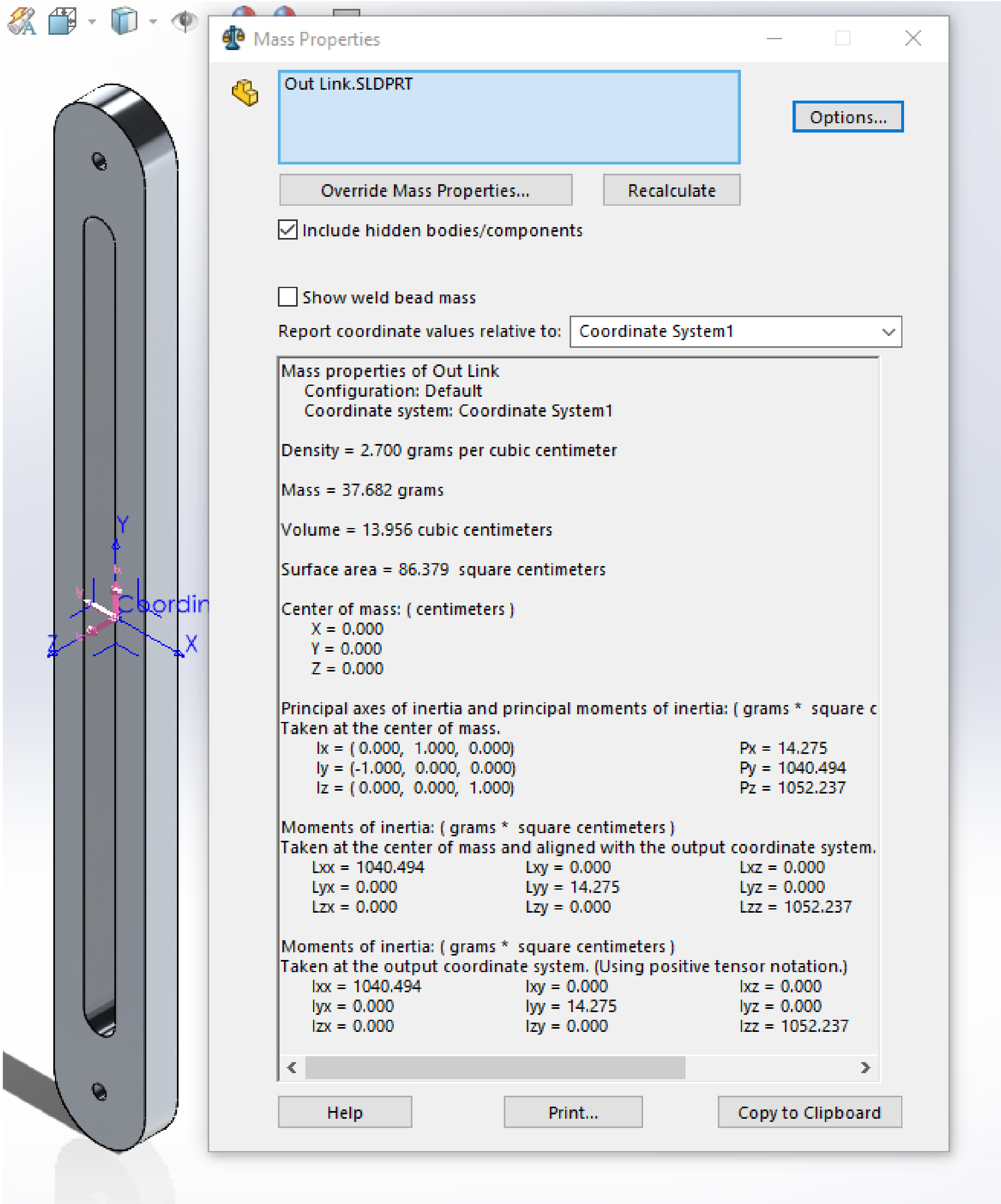


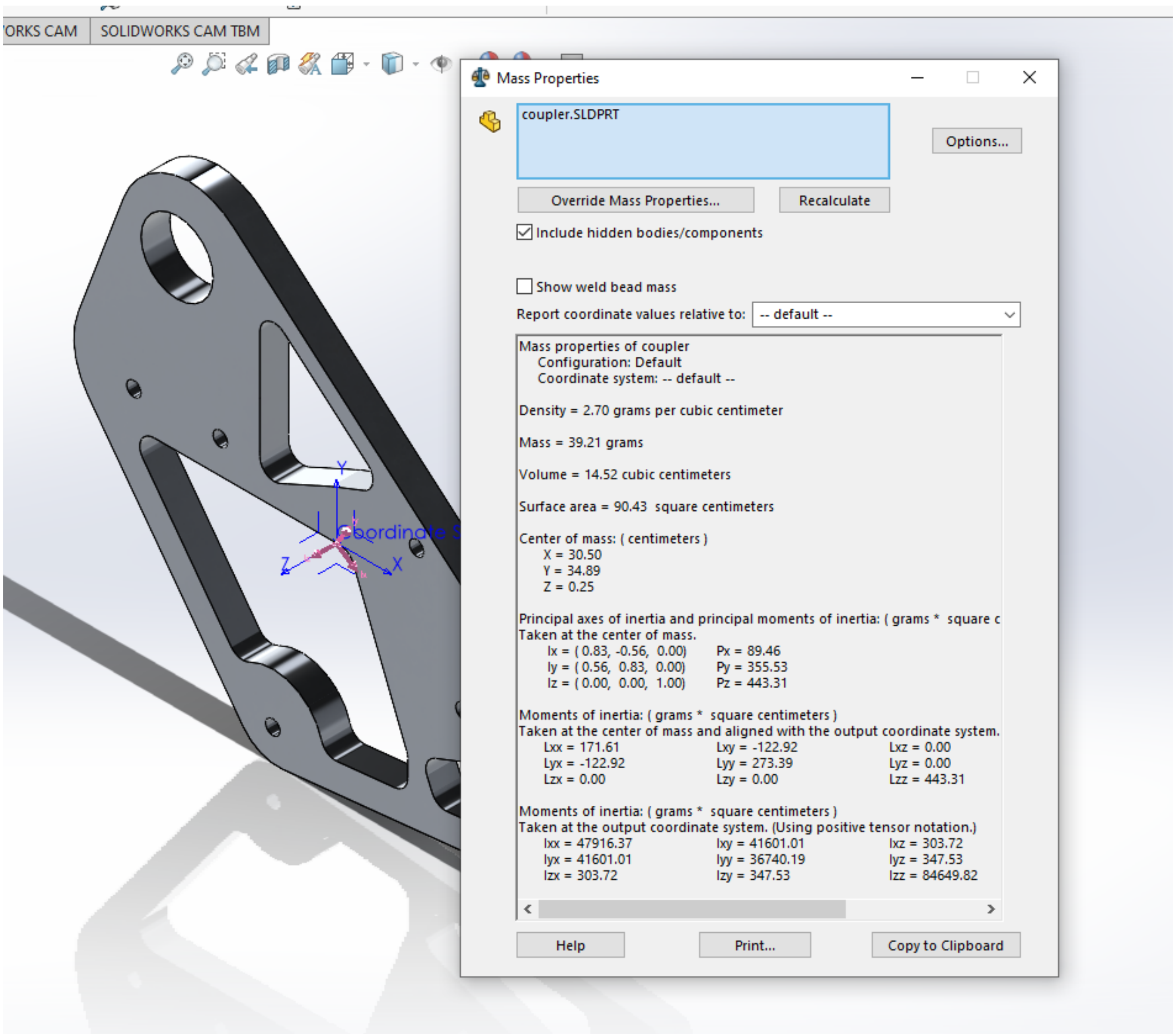


It is important to note that the bonus button can be hit when the linkage is in the middle position, hovering over the center button pair. This greatly simplifies our code and calculations because we only need to move the four bar linkage into three distinct positions as opposed to adding a fourth for the bonus button. Additionally, using a servo allows us to have a actuator closer to the acces of rotation, thus reducing the inertia, and allows us to fold the attached arm down to minimize our initial start dimensions.

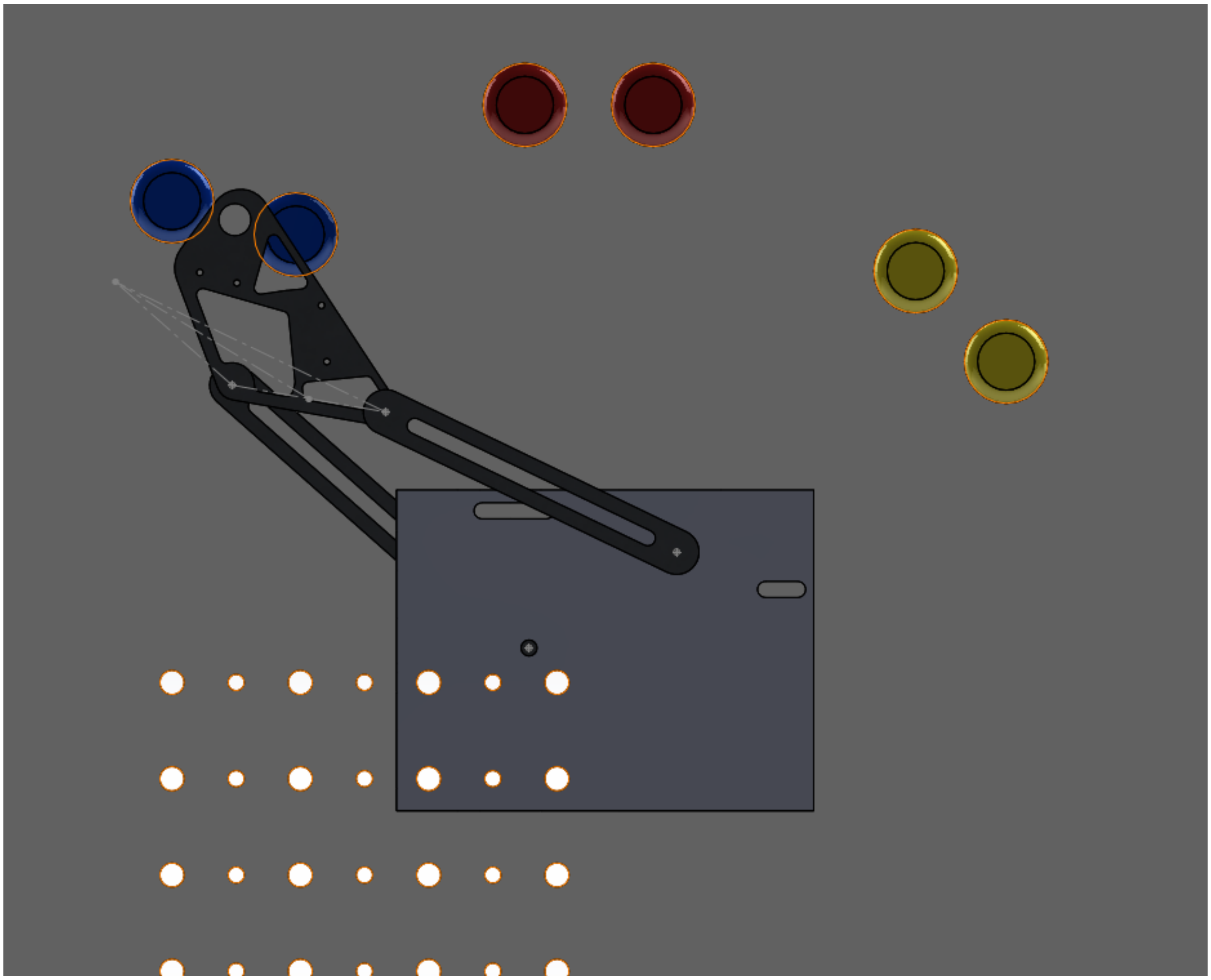


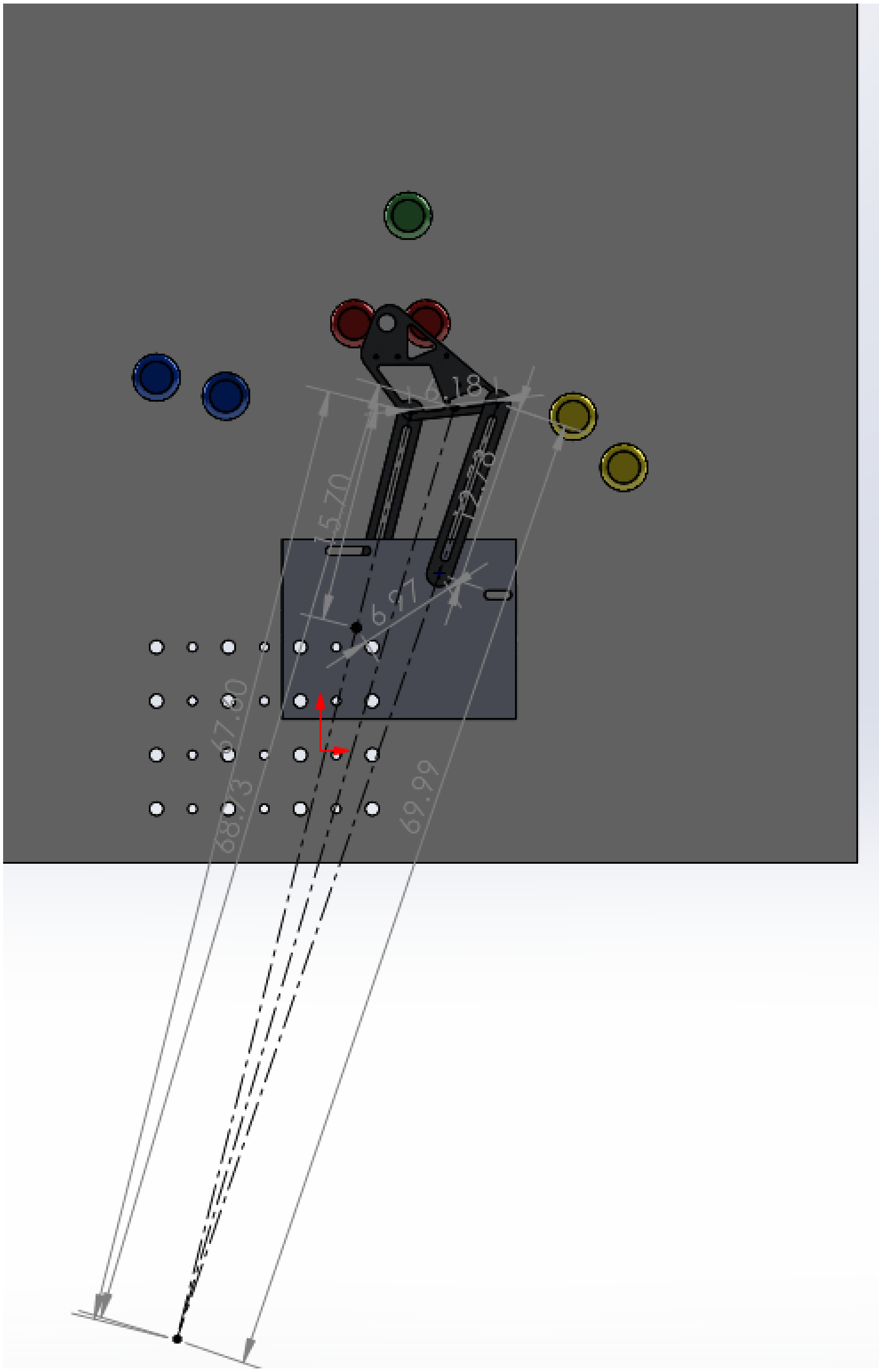

Mass Properties
Drive Link.SLDPRT
Options...
Override Mass Properties...
Recalculate
Include hidden bodies/components
Show weld bead mass
Report coordinate values relative to: Coordinate System1
Mass properties of Drive Link
Configuration: Default
Coordinate system: Coordinate System1
Density = 2.700 grams per cubic centimeter
Mass = 31.831 grams
Volume = 11.789 cubic centimeters
Surface area = 72.134 square centimeters
Center of mass: (centimeters)
X = 0.000
Y = 0.000
Z = 0.000
Principal axes of inertia and principal moments of inertia: (grams * square c
Taken at the center of mass.
Ix = (0.000, 1.000, 0.000) Px = 11.827
Iy = (-1.000, 0.000, 0.000) Py = 611.633
Iz = (0.000, 0.000, 1.000) Pz = 621.321
Moments of inertia: (grams * square centimeters)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 611.633 Lxy = 0.000 Lxz = 0.000
Lyx = 0.000 Lyy = 11.827 Lyz = 0.000
Lzx = 0.000 Lzy = 0.000 Lzz = 621.321
Moments of inertia: (grams * square centimeters)
Taken at the output coordinate system. (Using positive tensor notation.)
Ixx = 611.633 Ixy = 0.000 Ixz = 0.000
Iyx = 0.000 Iyy = 11.827 Iyz = 0.000
Izx = 0.000 Izy = 0.000 Izz = 621.321
Help
Print...
Copy to Clipboard
Y
X
Z


Mass Properties
Out Link.SLDPRT
Options...
Override Mass Properties...
Recalculate
Include hidden bodies/components
Show weld bead mass
Report coordinate values relative to:
Coordinate System1
Mass properties of Out Link
Configuration: Default
Coordinate system: Coordinate System1
Density = 2.700 grams per cubic centimeter
Mass = 37.682 grams
Volume = 13.956 cubic centimeters
Surface area = 86.379 square centimeters
Center of mass: (centimeters)
X = 0.000
Y = 0.000
Z = 0.000
Principal axes of inertia and principal moments of inertia: (grams * square c
Taken at the center of mass.
Ix = (0.000, 1.000, 0.000) Px = 14.275
Iy = (-1.000, 0.000, 0.000) Py = 1040.494
Iz = (0.000, 0.000, 1.000) Pz = 1052.237
Moments of inertia: (grams * square centimeters)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 1040.494 Lxy = 0.000 Lxz = 0.000
Lyx = 0.000 Lyy = 14.275 Lyz = 0.000
Lzx = 0.000 Lzy = 0.000 Lzz = 1052.237
Moments of inertia: (grams * square centimeters)
Taken at the output coordinate system. (Using positive tensor notation.)
Ixx = 1040.494 Ixy = 0.000 Ixz = 0.000
Iyx = 0.000 Iyy = 14.275 Iyz = 0.000
Izx = 0.000 Izy = 0.000 Izz = 1052.237
Help
Print...
Copy to Clipboard
Y
X
Z
Coordin

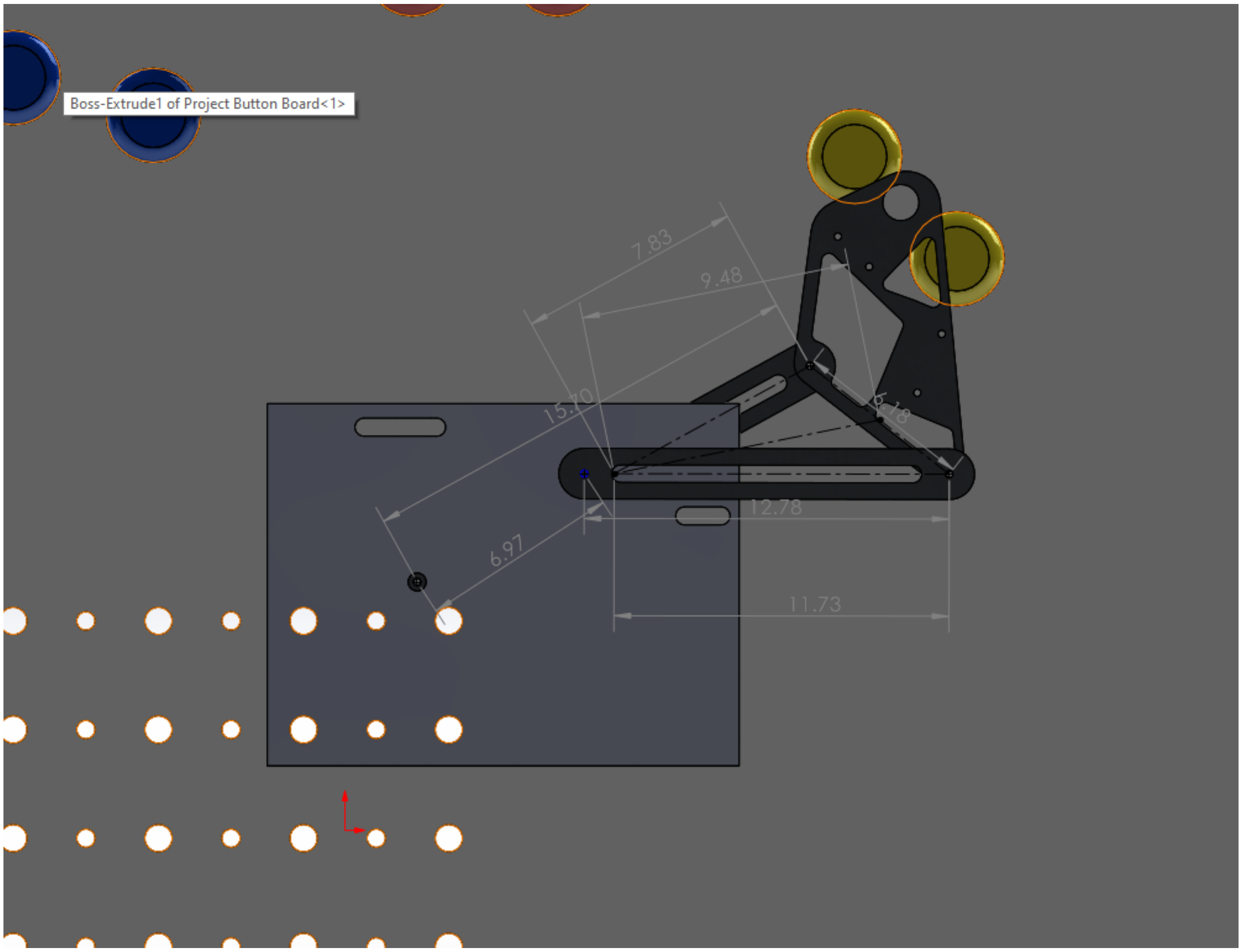


ORKS CAM
SOLIDWORKS CAM TBM
Mass Properties
coupler.SLDPRT
Options...
Override Mass Properties...
Recalculate
Include hidden bodies/components
Show weld bead mass
Report coordinate values relative to:
-- default --
Mass properties of coupler
Configuration: Default
Coordinate system: -- default --
Density = 2.70 grams per cubic centimeter
Mass = 39.21 grams
Volume = 14.52 cubic centimeters
Surface area = 90.43 square centimeters
Center of mass: (centimeters)
X = 30.50
Y = 34.89
Z = 0.25
Principal axes of inertia and principal moments of inertia: (grams * square c
Taken at the center of mass.
Ix = (0.83, -0.56, 0.00) Px = 89.46
Iy = (0.56, 0.83, 0.00) Py = 355.53
Iz = (0.00, 0.00, 1.00) Pz = 443.31
Moments of inertia: (grams * square centimeters)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 171.61 Lxy = -122.92 Lxz = 0.00
Lyx = -122.92 Lyy = 273.39 Lyz = 0.00
Lzx = 0.00 Lzy = 0.00 Lzz = 443.31
Moments of inertia: (grams * square centimeters)
Taken at the output coordinate system. (Using positive tensor notation.)
Ixx = 47916.37 Ixy = 41601.01 Ixz = 303.72
Iyx = 41601.01 Iyy = 36740.19 Iyz = 347.53
Izx = 303.72 Izy = 347.53 Izz = 84649.82
Help
Print...
Copy to Clipboard





6.18
15.70
17.78
6.97
67.80
68.73
69.99



Boss-Extrude1 of Project Button Board<1>
7.83
9.48
15.70
6.97
12.78
11.73

Fixed Variables		
Variable	Value	Units
minput	31.831	(gram)
moutput	37.682	(gram)
mcoupler	39.21	(gram)
Iinput_CG	621.321	(gram*cm^2)
Ioutput_CG	1052.237	(gram*cm^2)
Icoupler_CG	84649.82	(gram*cm^2)

To use this spreadsheet refer to the Transmission Selection lab tutorial. Cells highlighted orange are the only cells that need an input. All of the light gray cells are automatically calculated based on the orange cells.

Your Input
Calculated Cells
Calculated Transmission Ratio

Position 1 - Starting Configuration		
Geometric Variables		
Variable	Value	Units
R1 (input link)	12.78	cm
R2	1000	cm
R3	1000	cm
R4 (output link)	15.7	cm
R5	1000	cm
Total Inertias of a Link (via Parallel Axis)		
Variable	Value	Units
Iinput	1921.047575	(gram*cm^2)
Ioutput	3374.296045	(gram*cm^2)
Icoupler	39294649.82	(gram*cm^2)
Scale Factors		
R1/R2	0.01278	(unitless)
(R1*R3)/(R2*R4)	0.8140127389	(unitless)
Total Inertia		
Itotal	10574.8449	(gram*cm^2)

Position 2		
Geometric Variables		
Variable	Value	Units
R1	12.78	cm
R2	69.99	cm
R3	67.6	cm
R4	15.7	cm
R5	68.73	cm
Total Inertias of a Link (via Parallel Axis)		
Variable	Value	Units
Iinput	1921.047575	(gram*cm^2)
Ioutput	3374.296045	(gram*cm^2)
Icoupler	269870.5238	(gram*cm^2)
Scale Factors		
R1/R2	0.1825975139	(unitless)
(R1*R3)/(R2*R4)	0.7862160472	(unitless)
Total Inertia		
Itotal	13004.80342	(gram*cm^2)

Position 3 - Final Configuration		
Geometric Variables		
Variable	Value	Units
R1	12.78	cm
R2	11.73	cm
R3	7.83	cm
R4	15.7	cm
R5	9.48	cm
Total Inertias of a Link (via Parallel Axis)		
Variable	Value	Units
Iinput	1921.047575	(gram*cm^2)
Ioutput	3374.296045	(gram*cm^2)
Icoupler	88173.63838	(gram*cm^2)
Scale Factors		
R1/R2	1.089514066	(unitless)
(R1*R3)/(R2*R4)	0.5433691172	(unitless)
Total Inertia		
Itotal	107583.0236	(gram*cm^2)

Transmission Calculations		
Variable	**Value**	**Units**
Maximum Linkage Inertia (IL)	107583.0236	(gram*cm^2)
Imotor	25000	(gram*cm^2)
Transmission Ratio (N)	2.074444732	**(unitless)**

1

$$N_{encoder} = 0.1875 \cdot \frac{\pi}{180} \cdot r_1 \cdot \frac{1}{0.5}$$

$N_{encoder} = 0.836449044018$

2

$$d_x = 0.1875 \cdot \frac{\pi}{180} \cdot r_1 \cdot \frac{1}{N}$$

$d_x = 0.201651167796$

3

$$r_1 = 127.8$$

−10 127.8

4

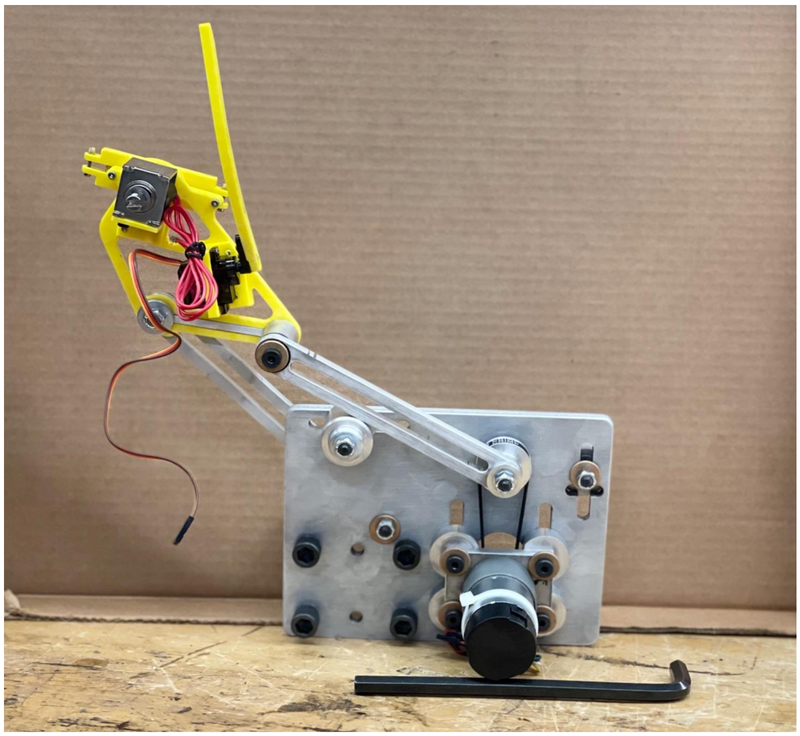
$$N = 2.074$$

−10 10

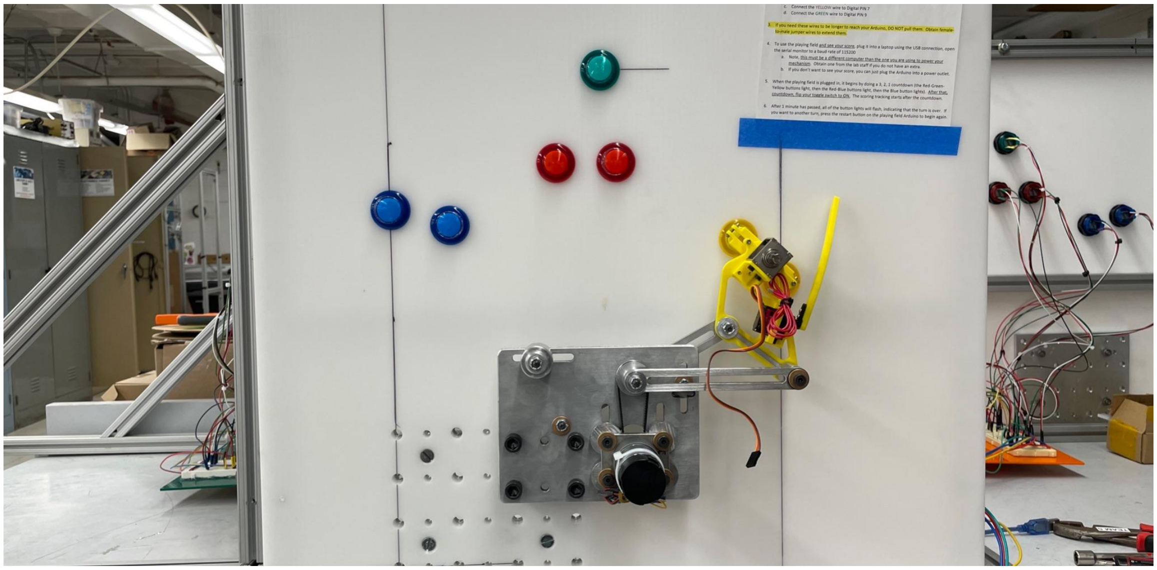
Part 5: Machining

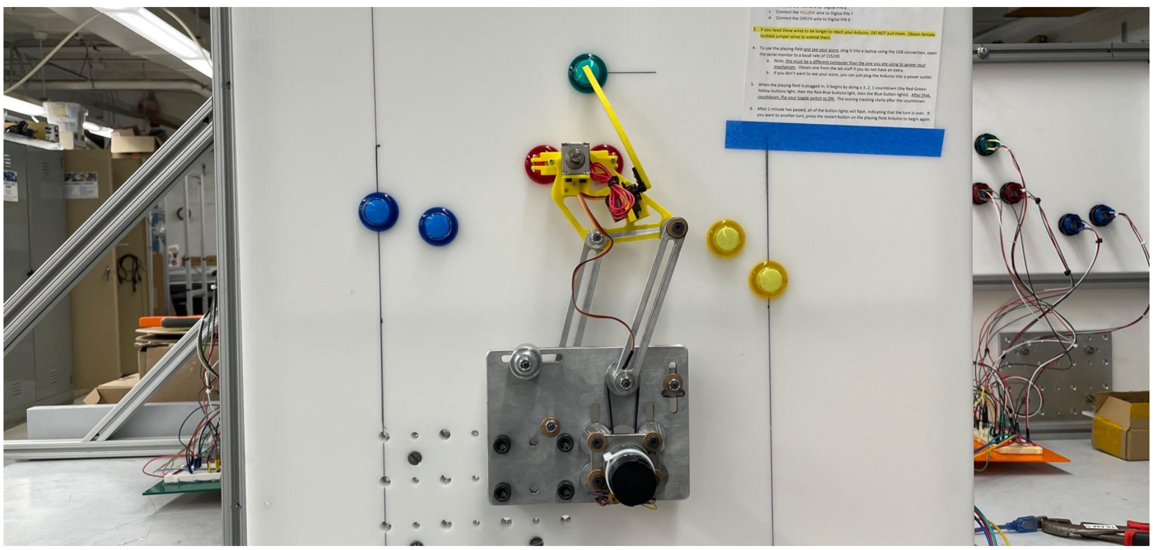
Completed Assembly:

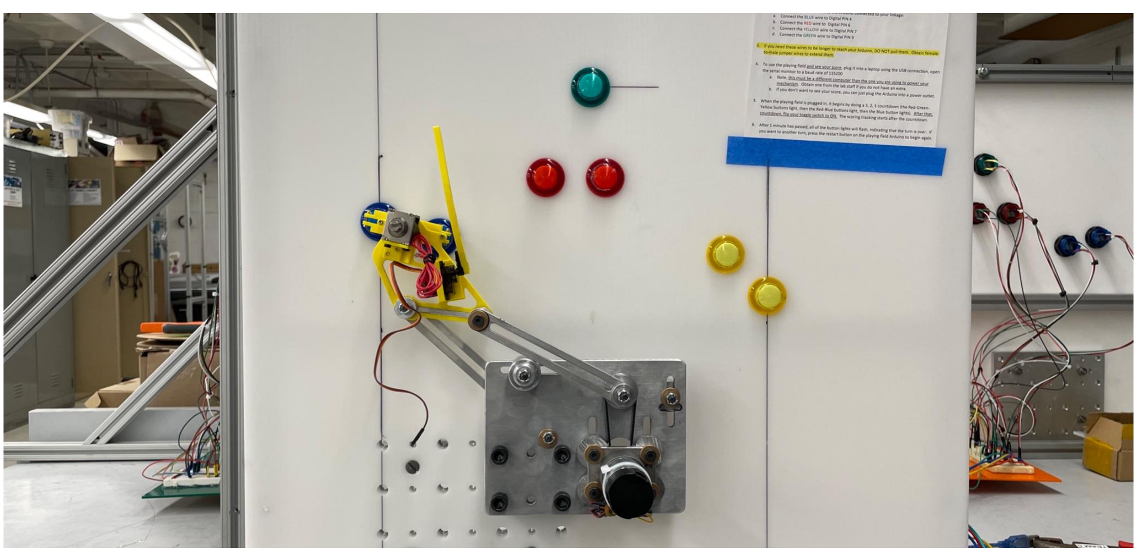
Completed Assembly



Assembly Attached to Playing Field



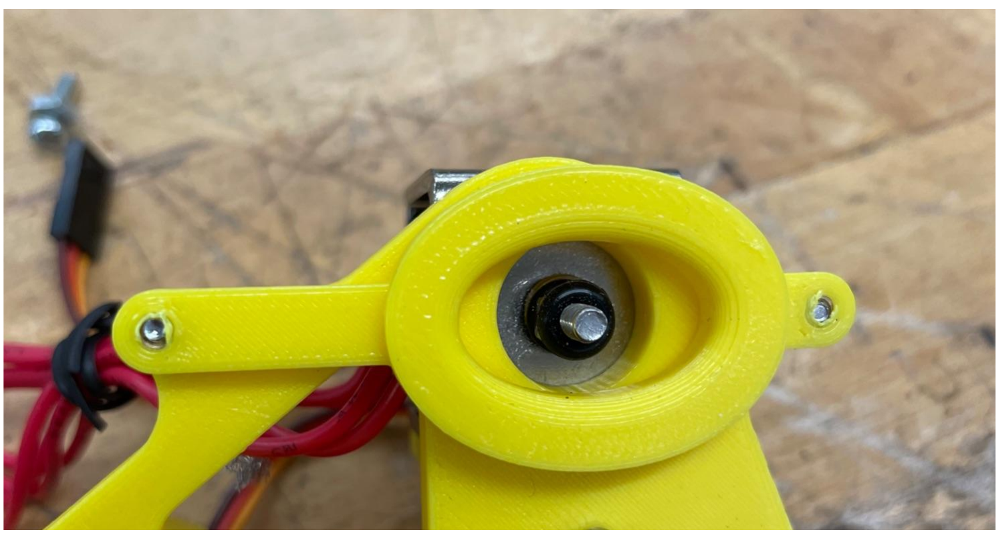




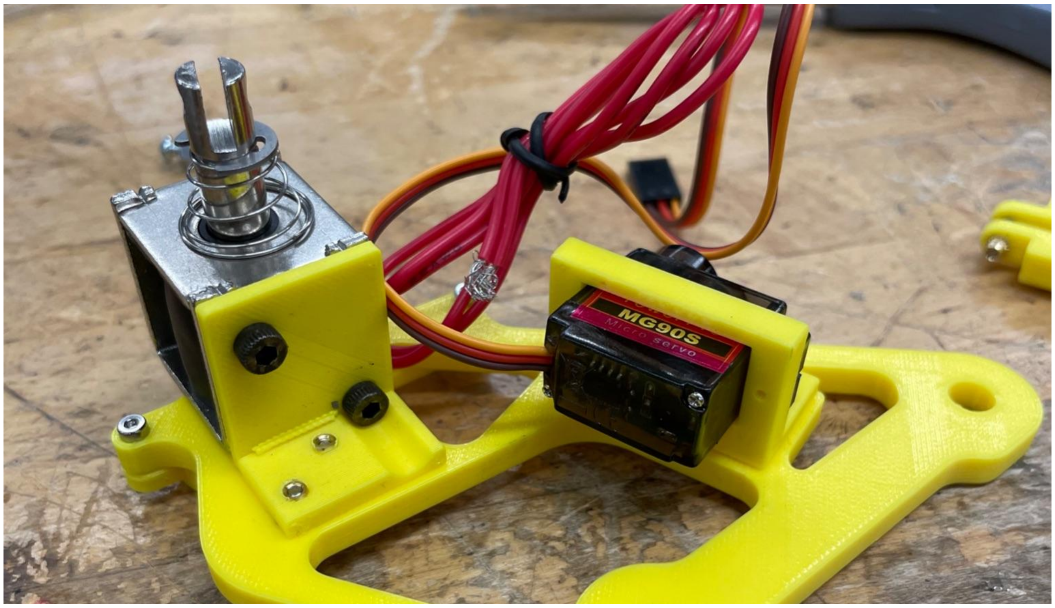
Individual Parts:

Acrylic Holding Piece

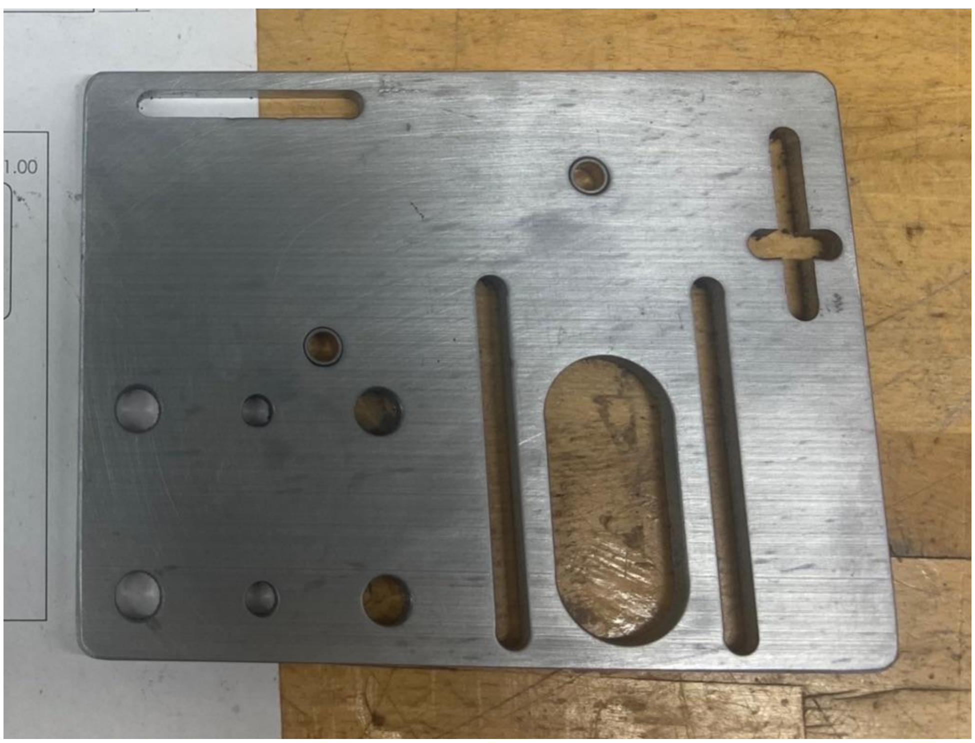
Acrylic Homing Piece



Solenoid and Servo Mounts

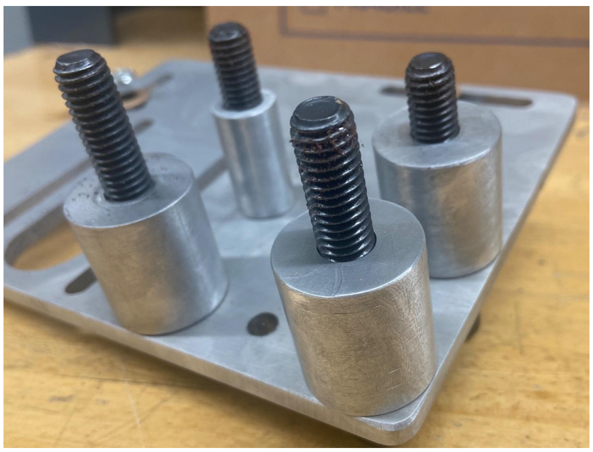


Ground Plate

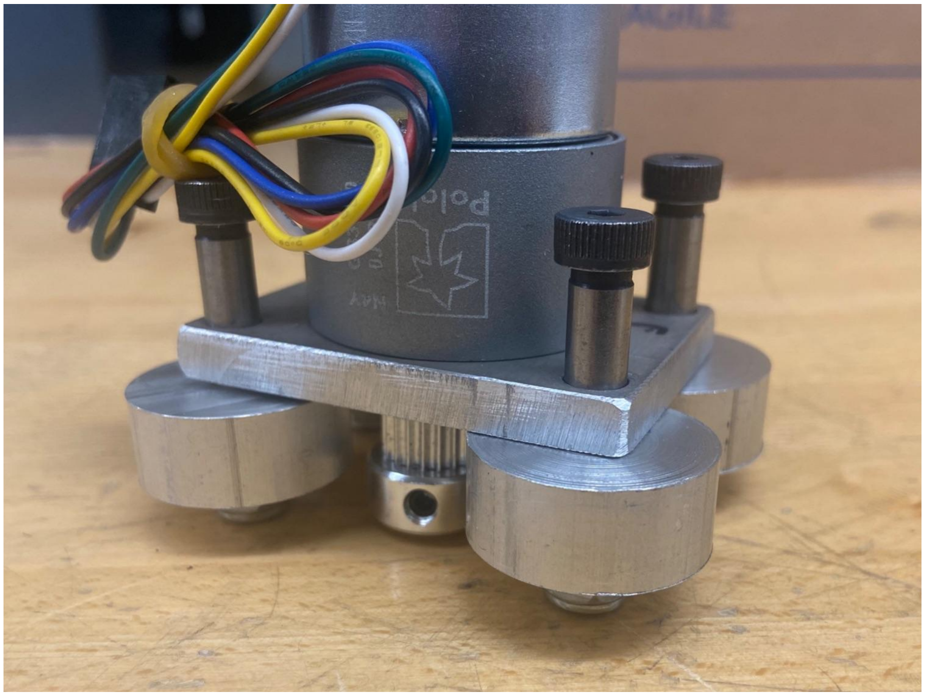


Linkage Spacers

Spacers Between Ground Plate and Game Board

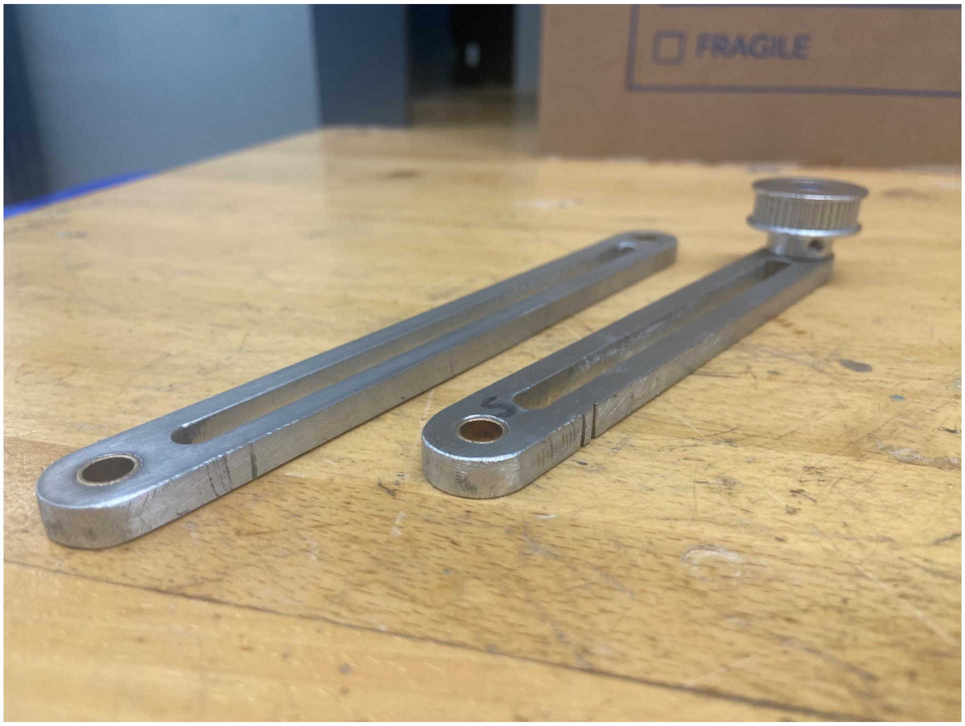


Spacers Between Motor and Ground Plate

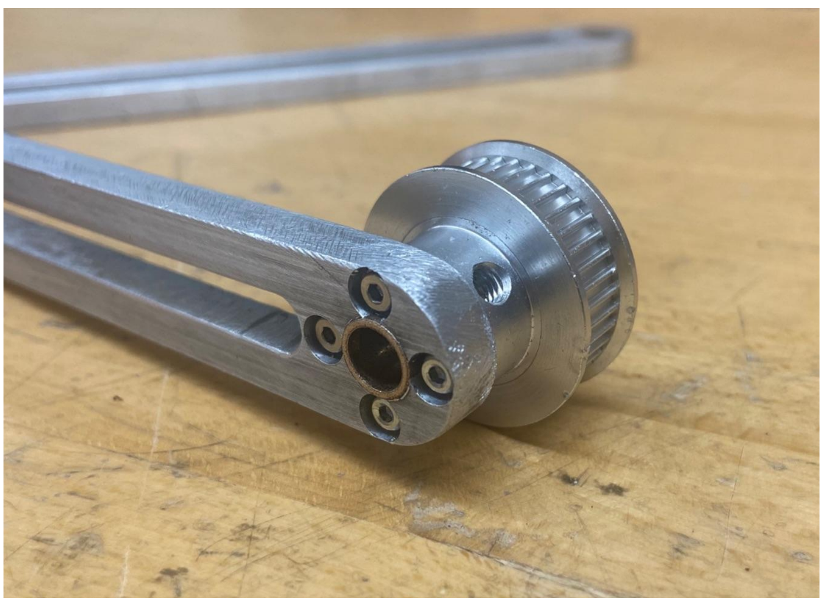


Hard Stops

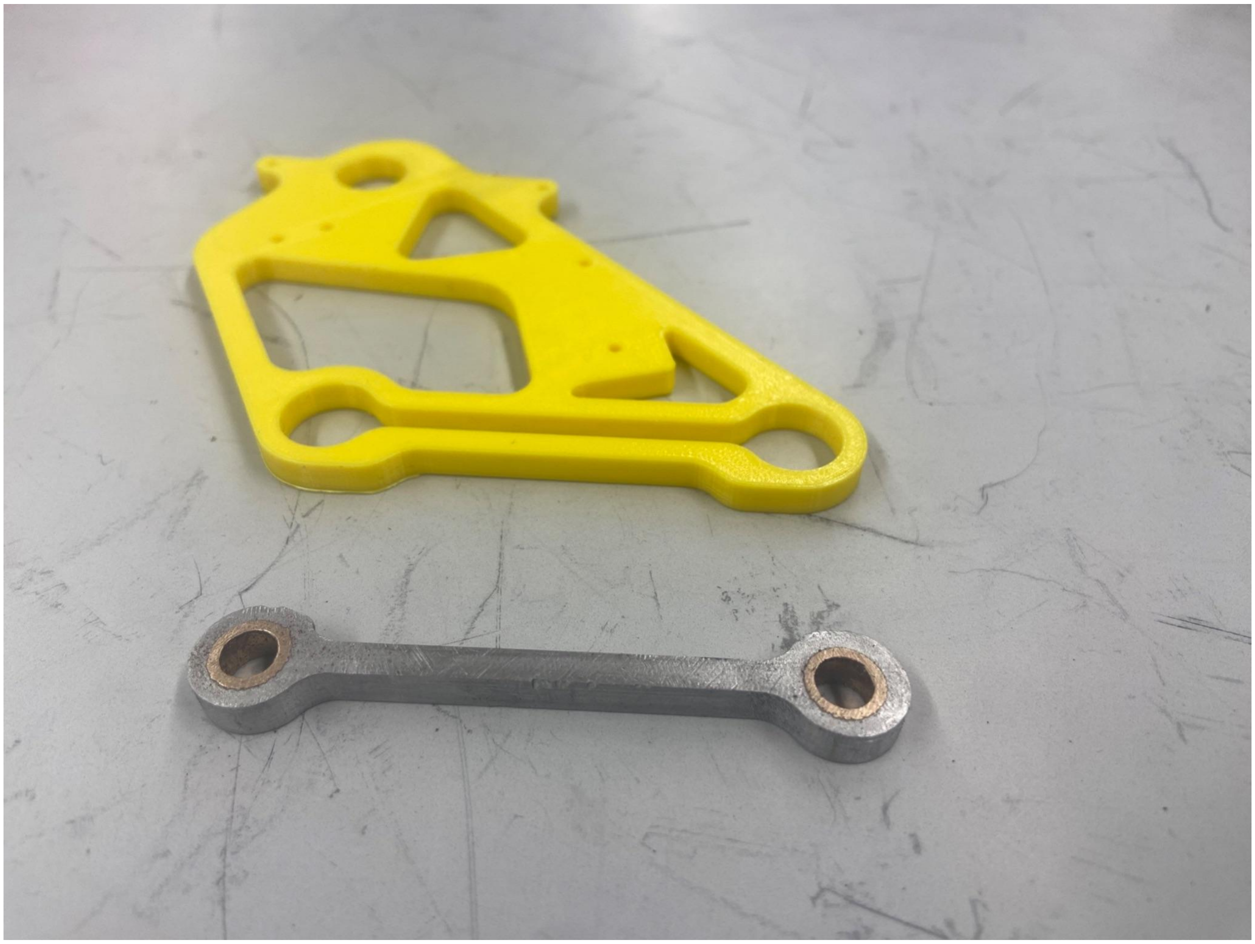
Input and Output Links



[Highlight] Countersinks and M2 Taps for Driving Transmission



3D Printed Coupler with Aluminum Inlay for Strength

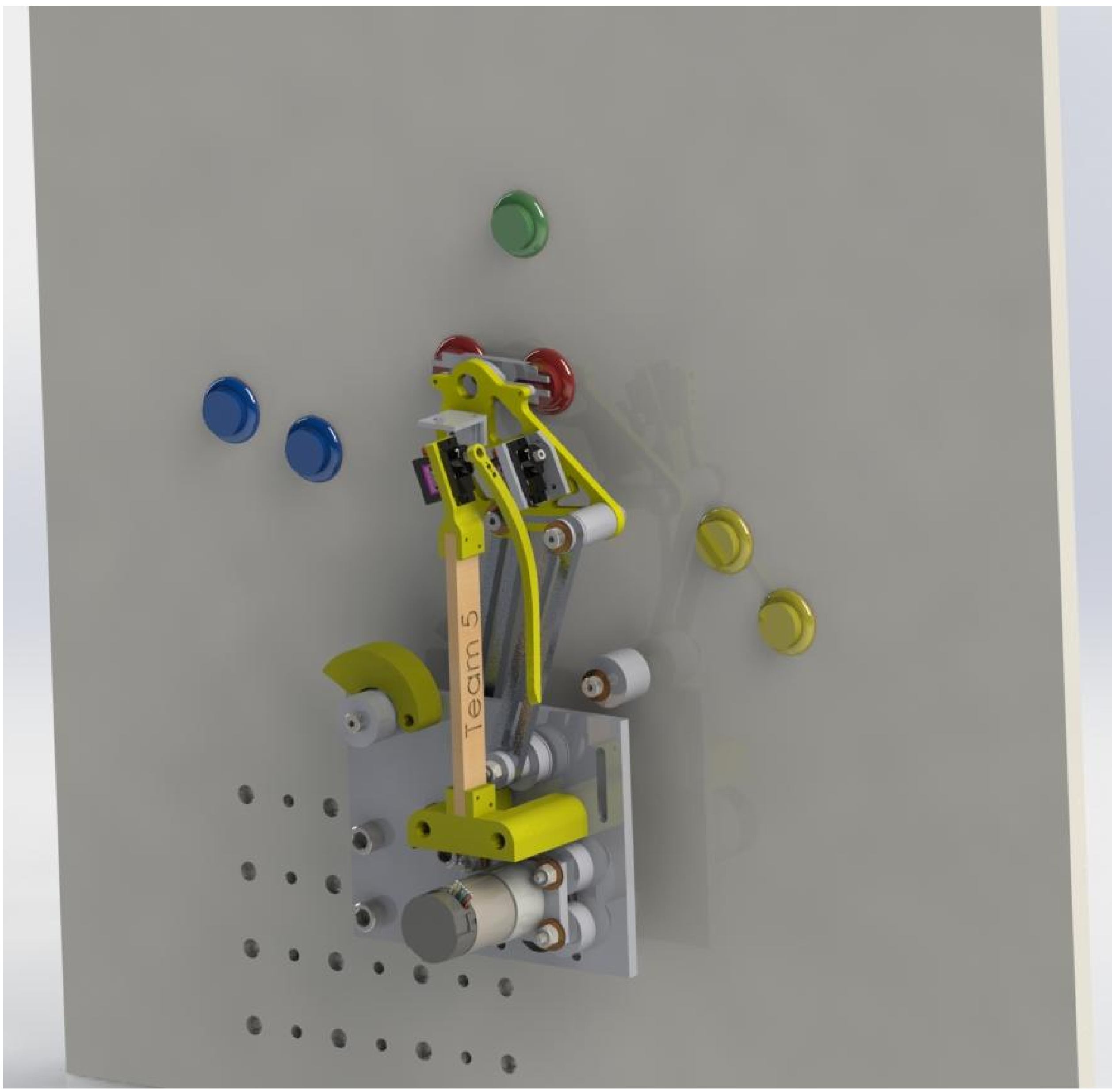


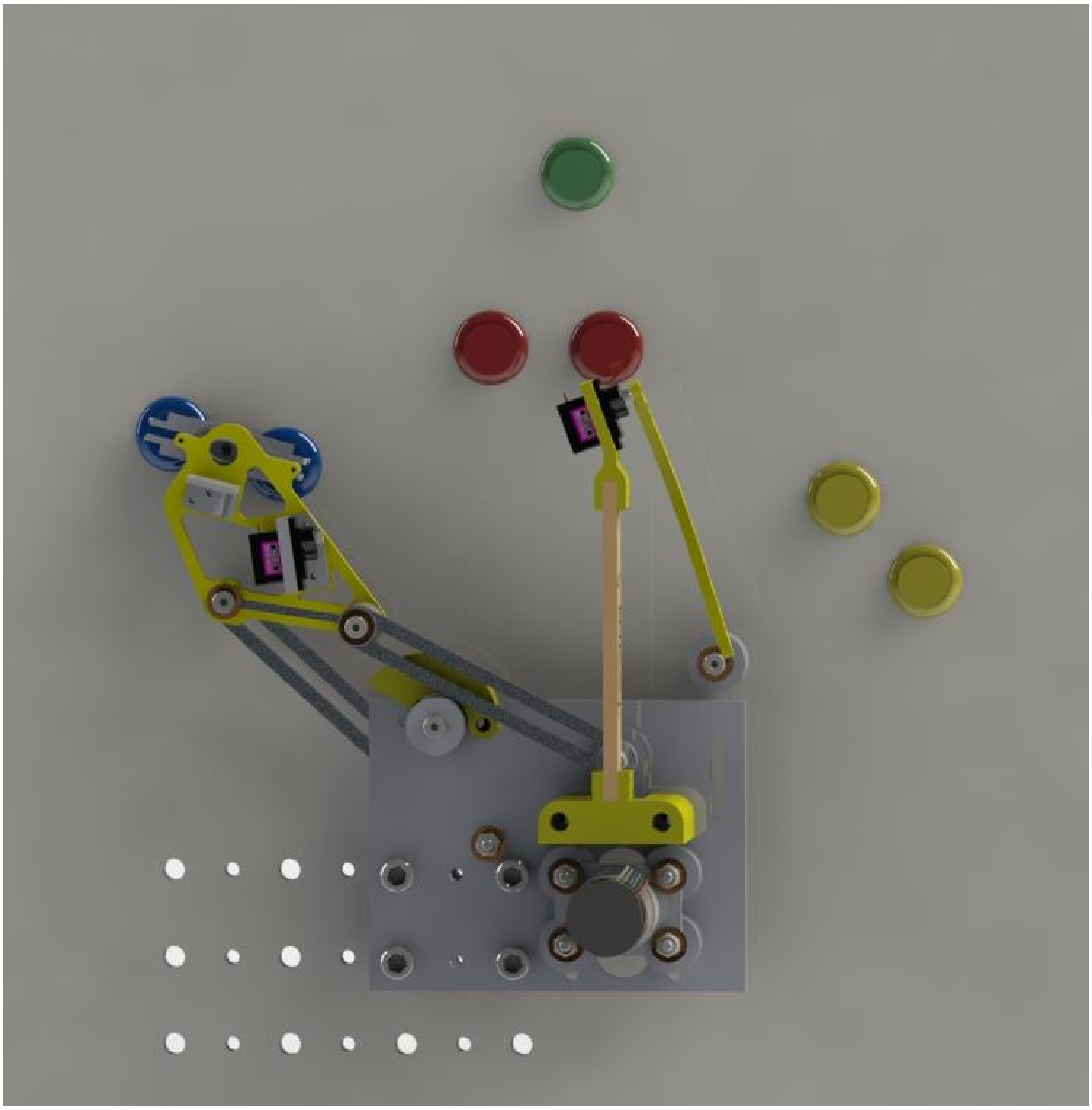
Final Assignment

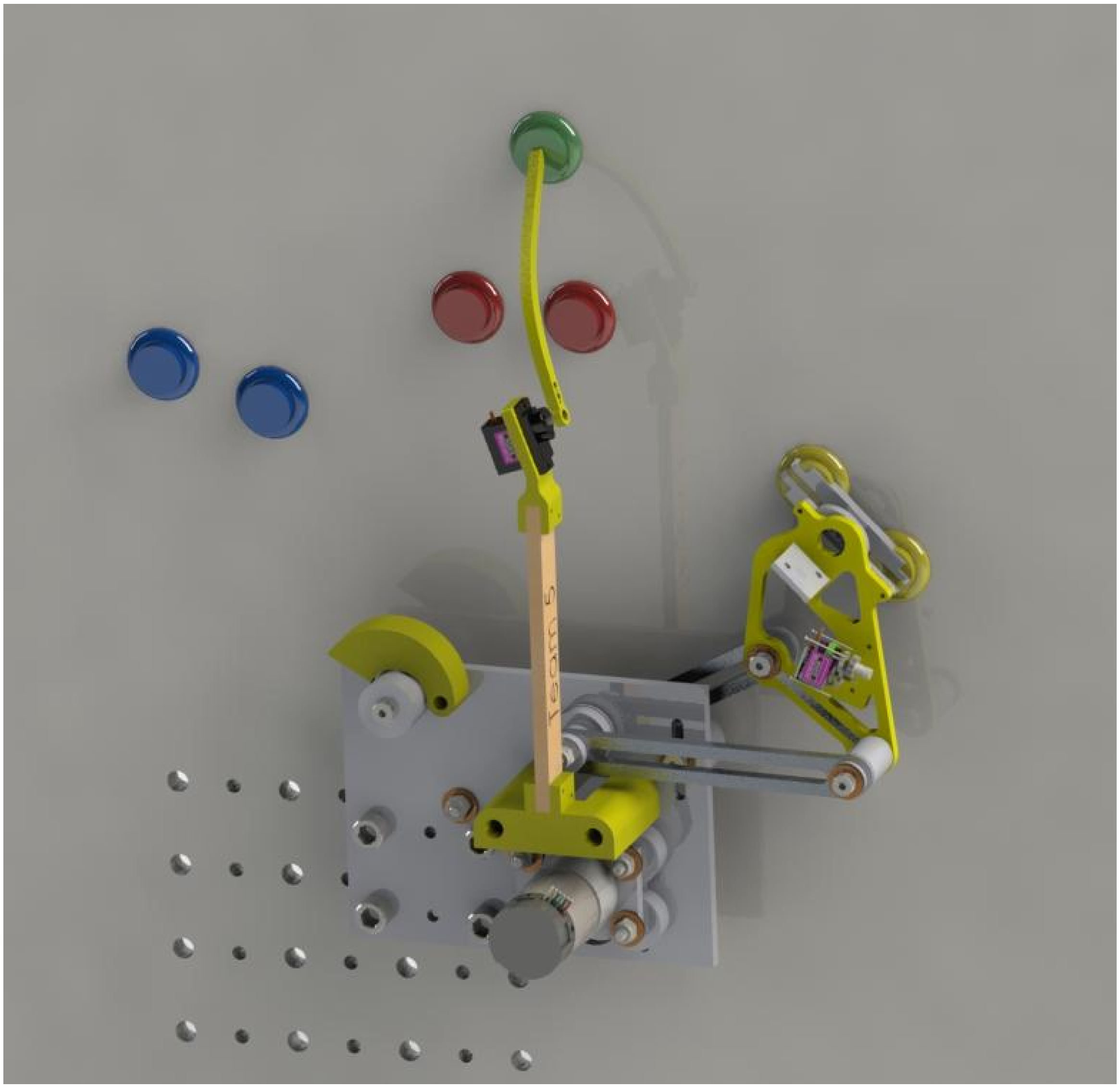
Machine Design 12/17/2022

Miles Huntley-Fenner
Nico Aldana
Phillipe Dumeny
Christina Wright
Leon Aharonian

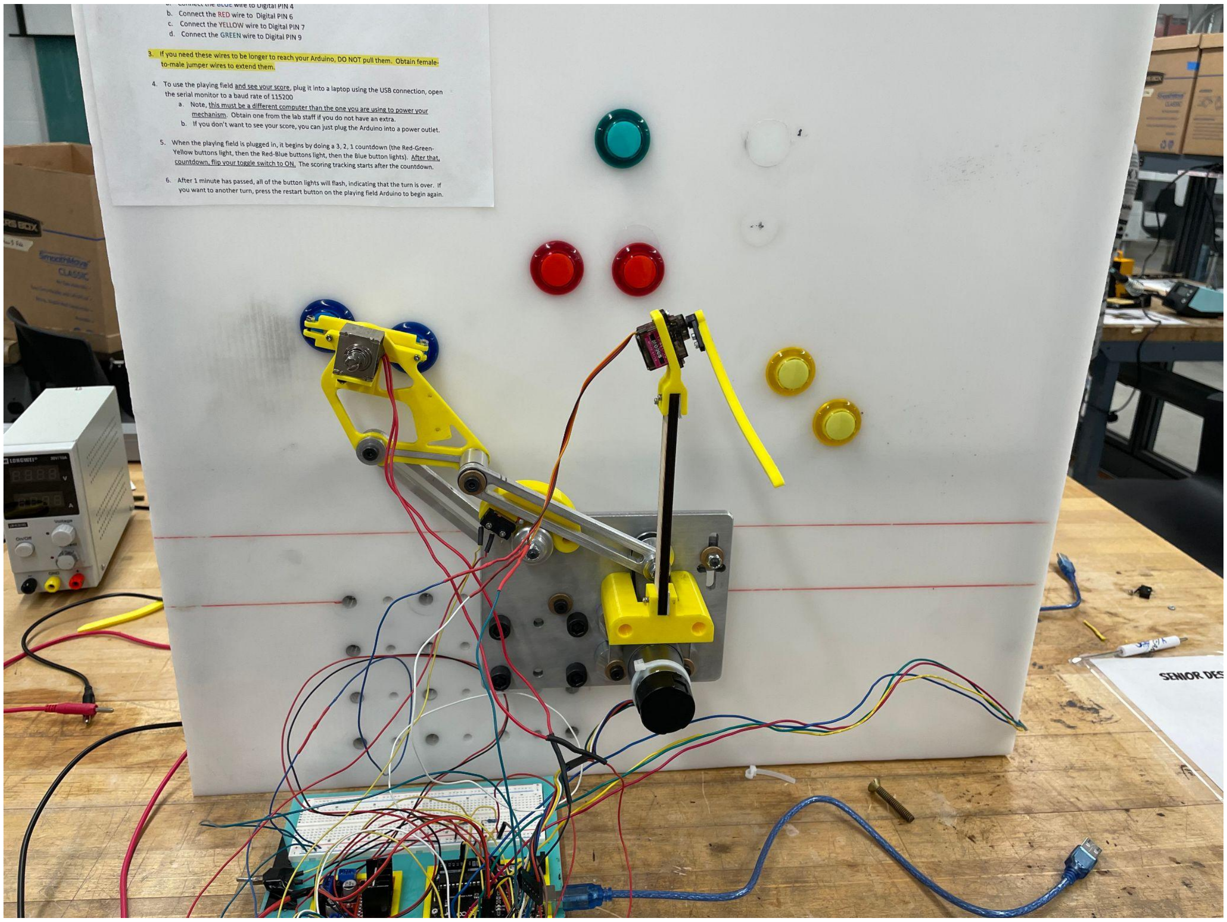
Fully Rendered CAD of final design in all three positions:

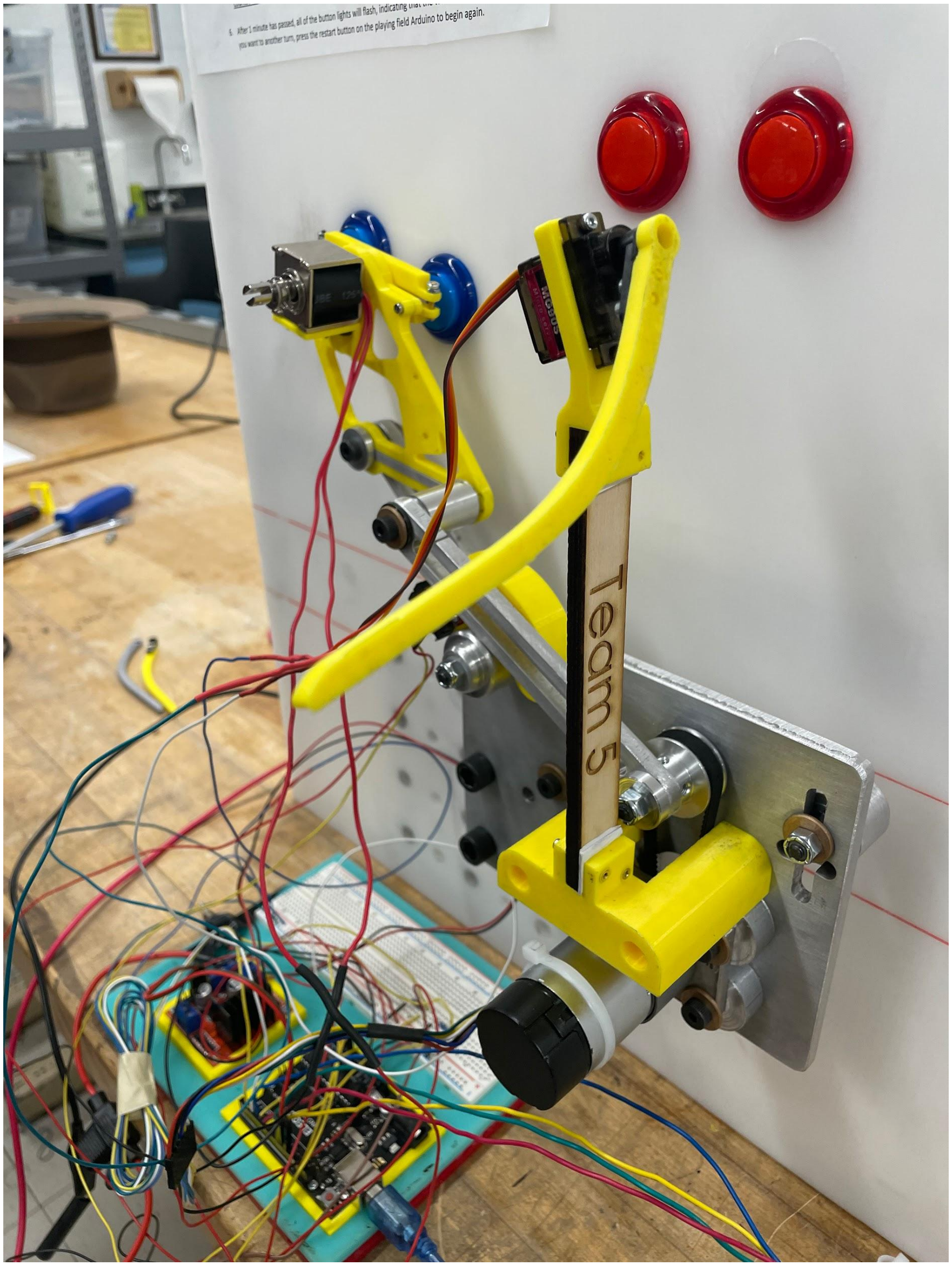





Team 5

Final setup:


b. Connect the RED wire to Digital PIN 6
c. Connect the YELLOW wire to Digital PIN 7
d. Connect the GREEN wire to Digital PIN 9
3. If you need these wires to be longer to reach your Arduino, DO NOT pull them. Obtain female-to-male jumper wires to extend them.
4. To use the playing field and see your score, plug it into a laptop using the USB connection, open the serial monitor to a baud rate of 115200
a. Note, this must be a different computer than the one you are using to power your mechanism. Obtain one from the lab staff if you do not have an extra.
b. If you don't want to see your score, you can just plug the Arduino into a power outlet.
5. When the playing field is plugged in, it begins by doing a 3, 2, 1 countdown (the Red-Green-Yellow buttons light, then the Red-Blue buttons light, then the Blue button lights). After that, countdown, flip your toggle switch to ON. The scoring tracking starts after the countdown.
6. After 1 minute has passed, all of the button lights will flash, indicating that the turn is over. If you want to another turn, press the restart button on the playing field Arduino to begin again.


6. After 1 minute has passed, all of the button lights will flash, indicating
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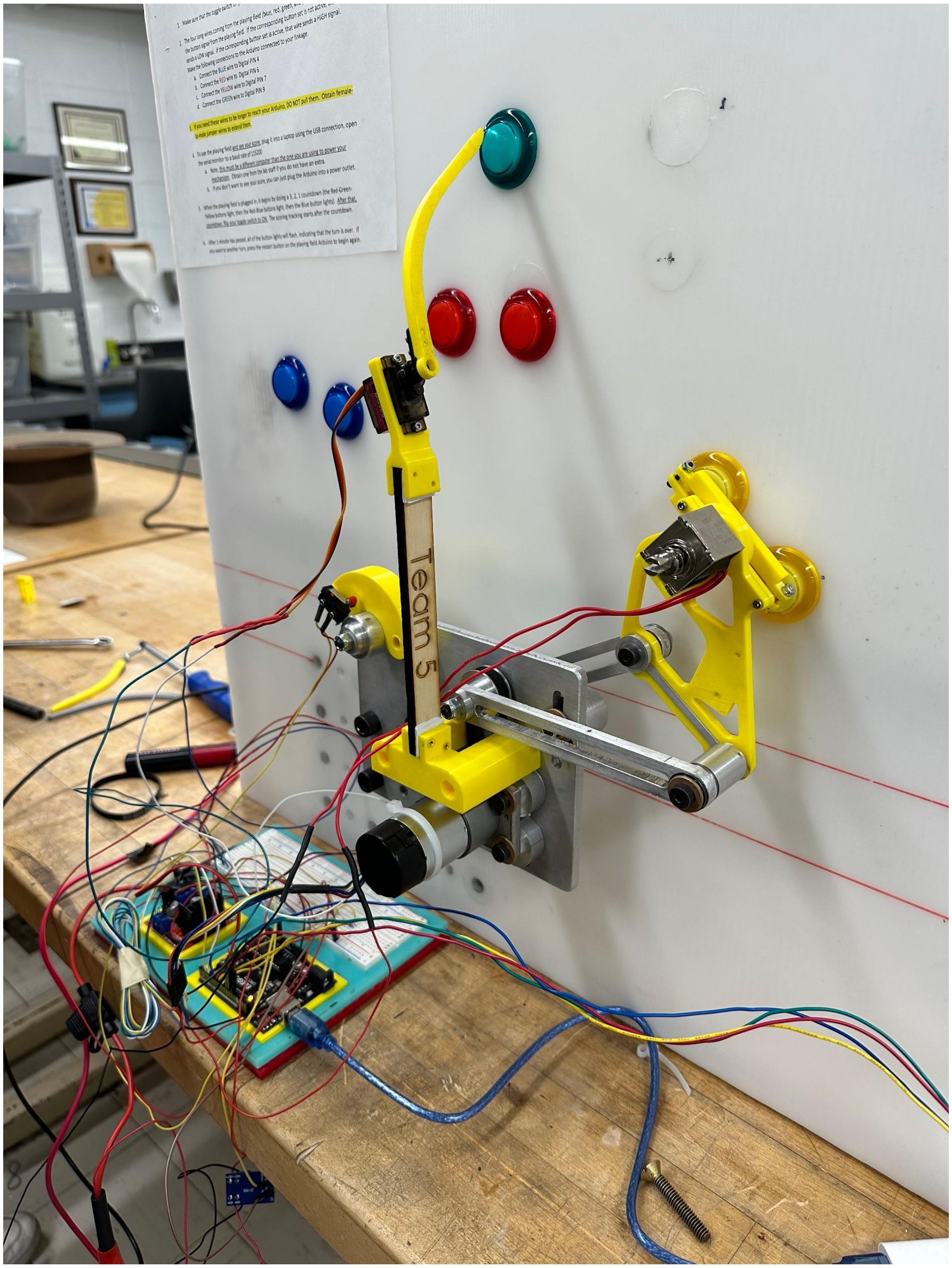
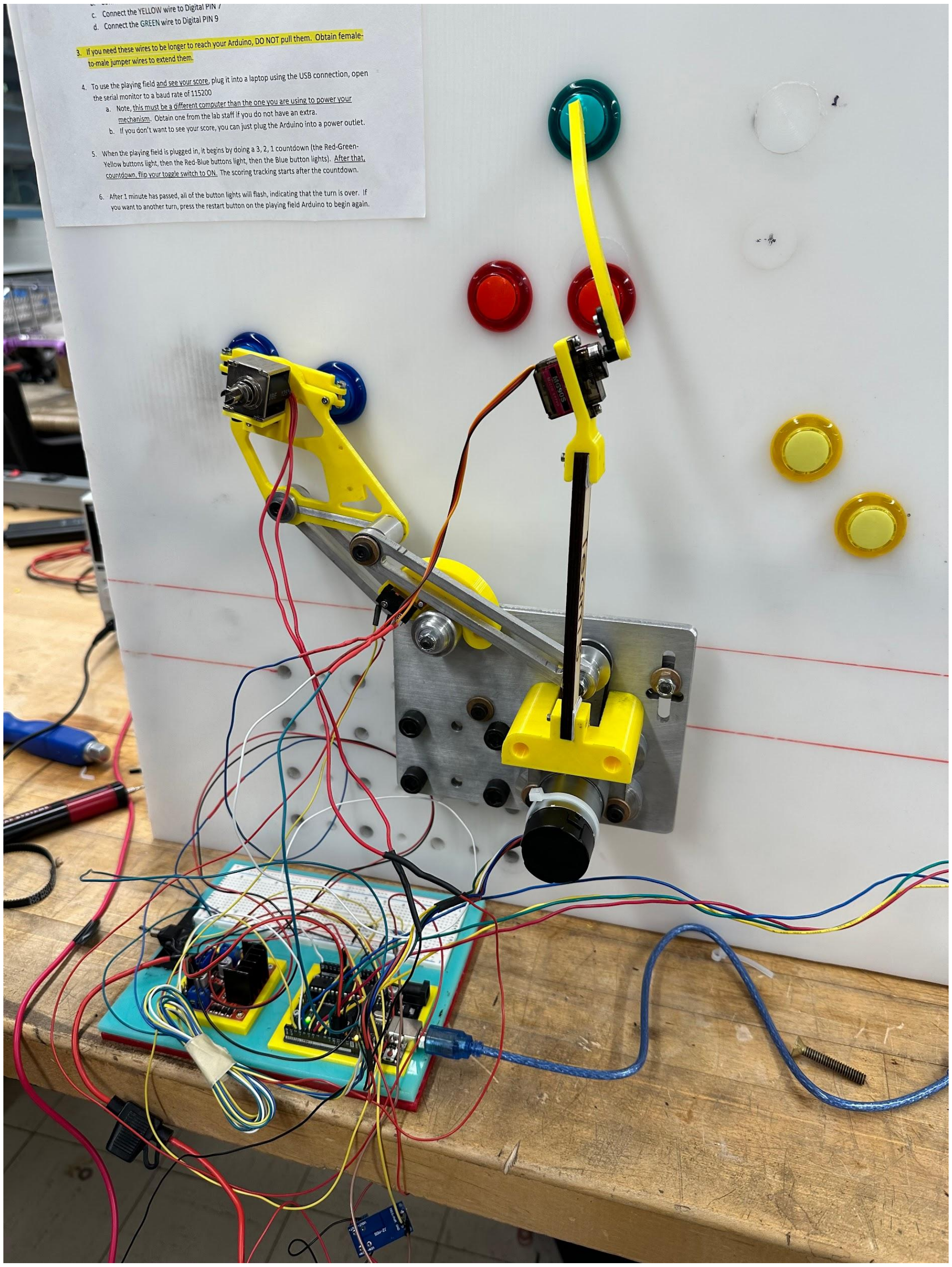
Team 5


Team 5


c. Connect the YELLOW wire to Digital PIN 7
d. Connect the GREEN wire to Digital PIN 9
3. If you need these wires to be longer to reach your Arduino, DO NOT pull them. Obtain female-to-male jumper wires to extend them.
4. To use the playing field and see your score, plug it into a laptop using the USB connection, open the serial monitor to a baud rate of 115200
a. Note, this must be a different computer than the one you are using to power your mechanism. Obtain one from the lab staff if you do not have an extra.
b. If you don't want to see your score, you can just plug the Arduino into a power outlet.
5. When the playing field is plugged in, it begins by doing a 3, 2, 1 countdown (the Red-Green-Yellow buttons light, then the Red-Blue buttons light, then the Blue button lights). After that, countdown, flip your toggle switch to ON. The scoring tracking starts after the countdown.
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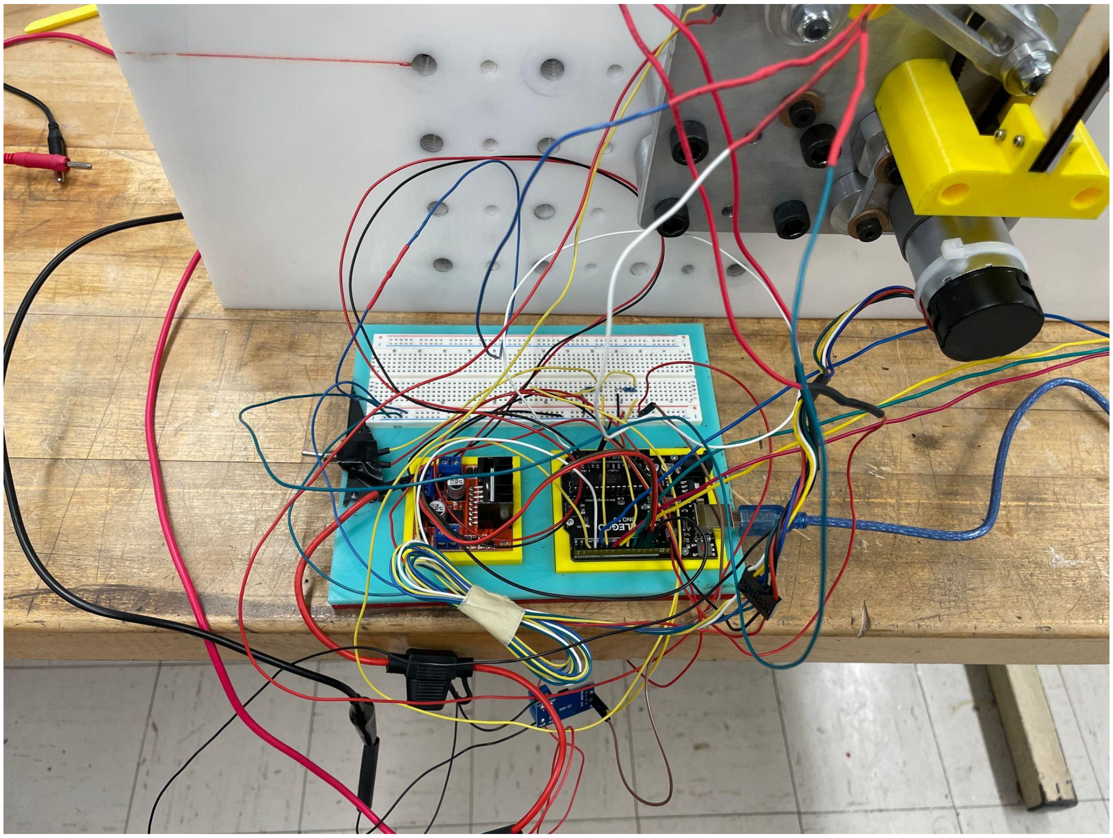
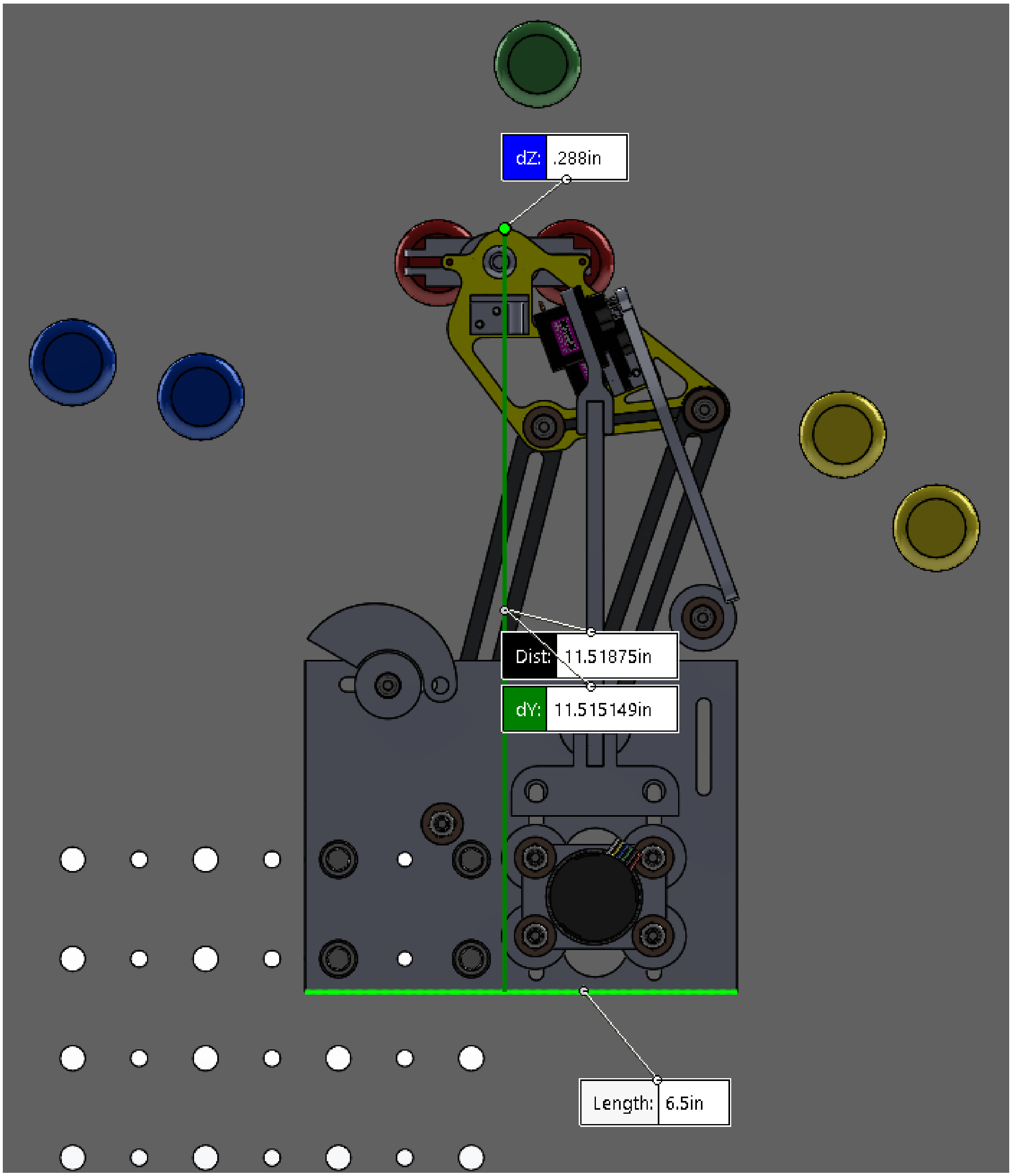
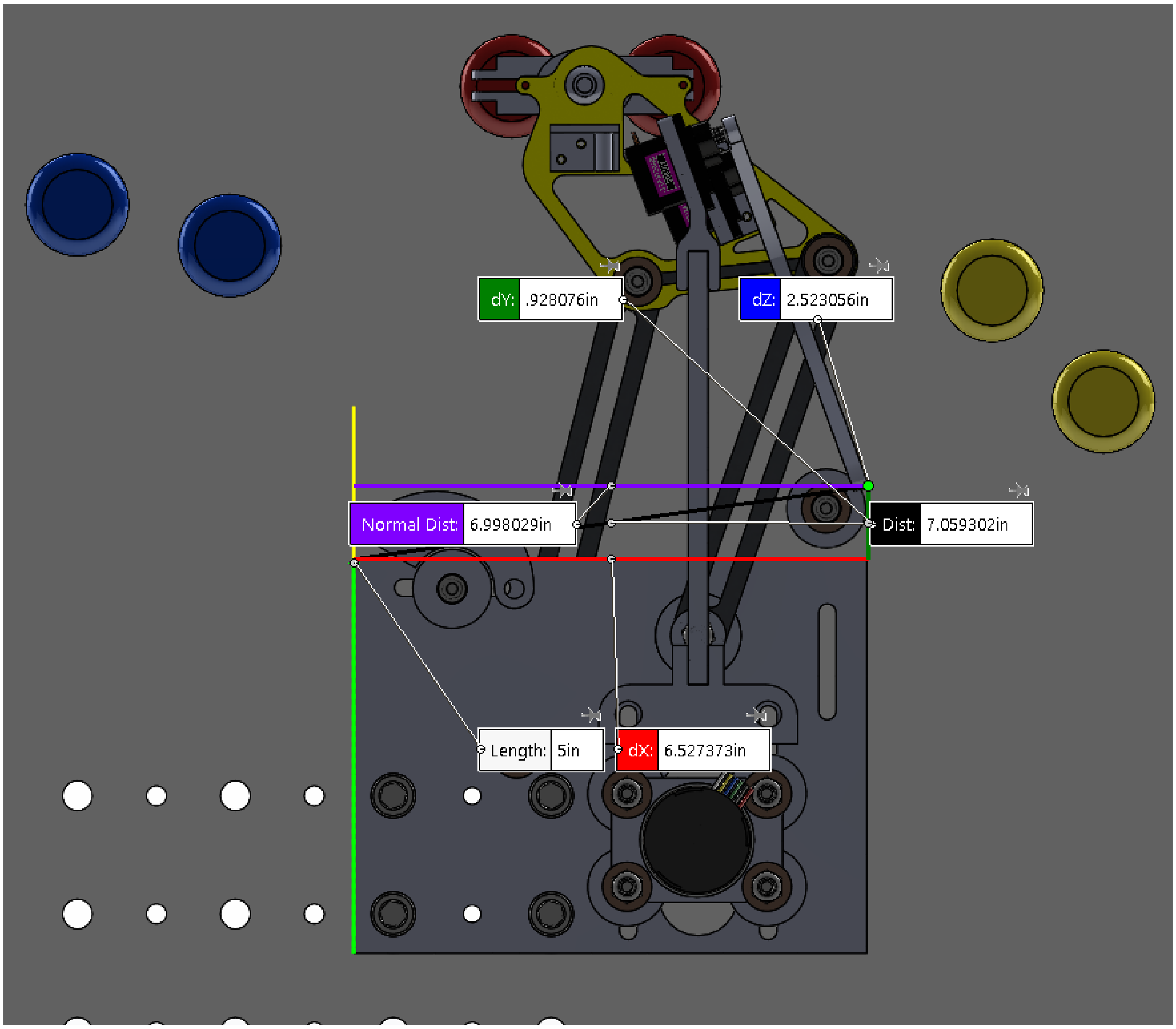
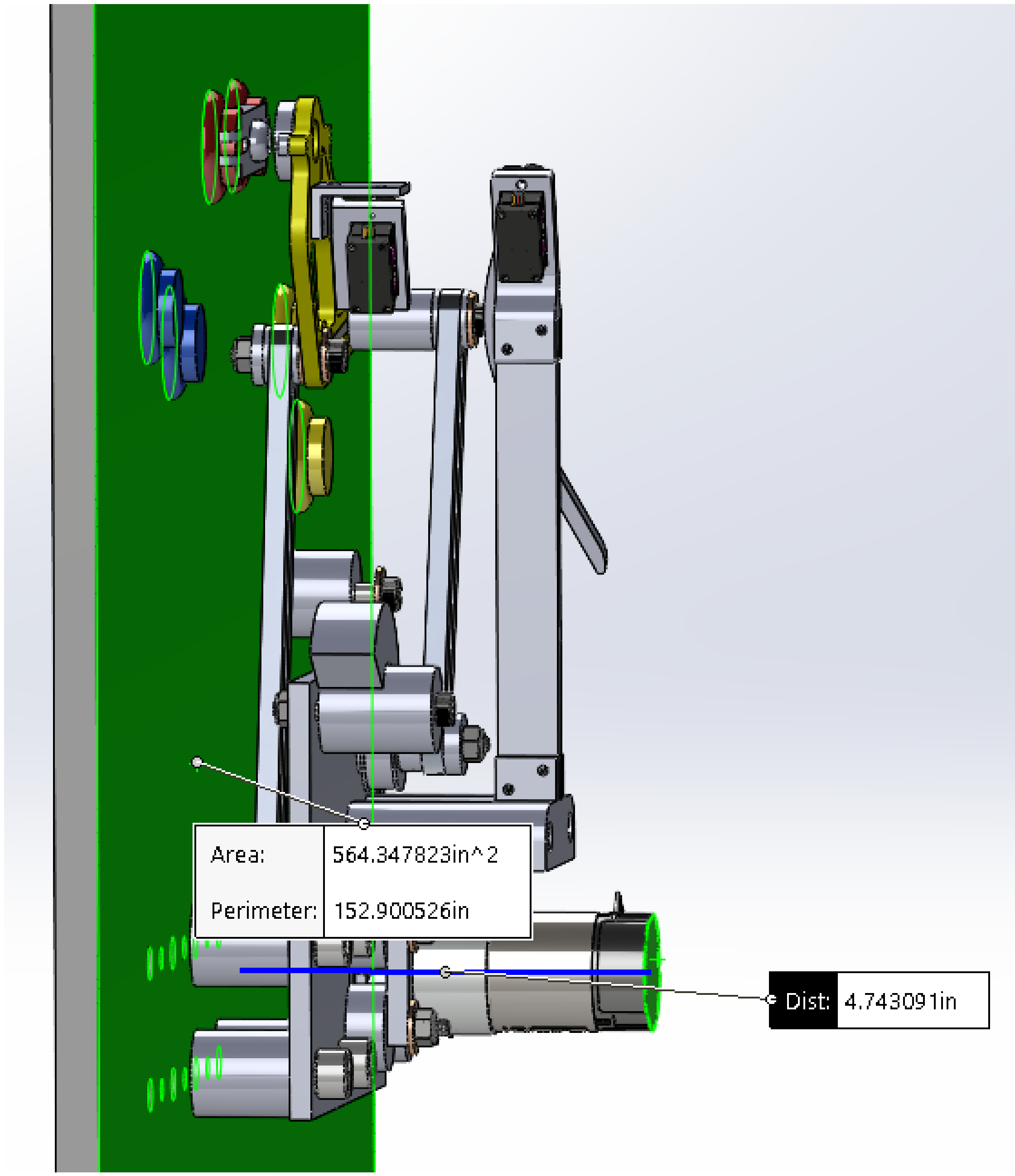


Volume of our mechanism:

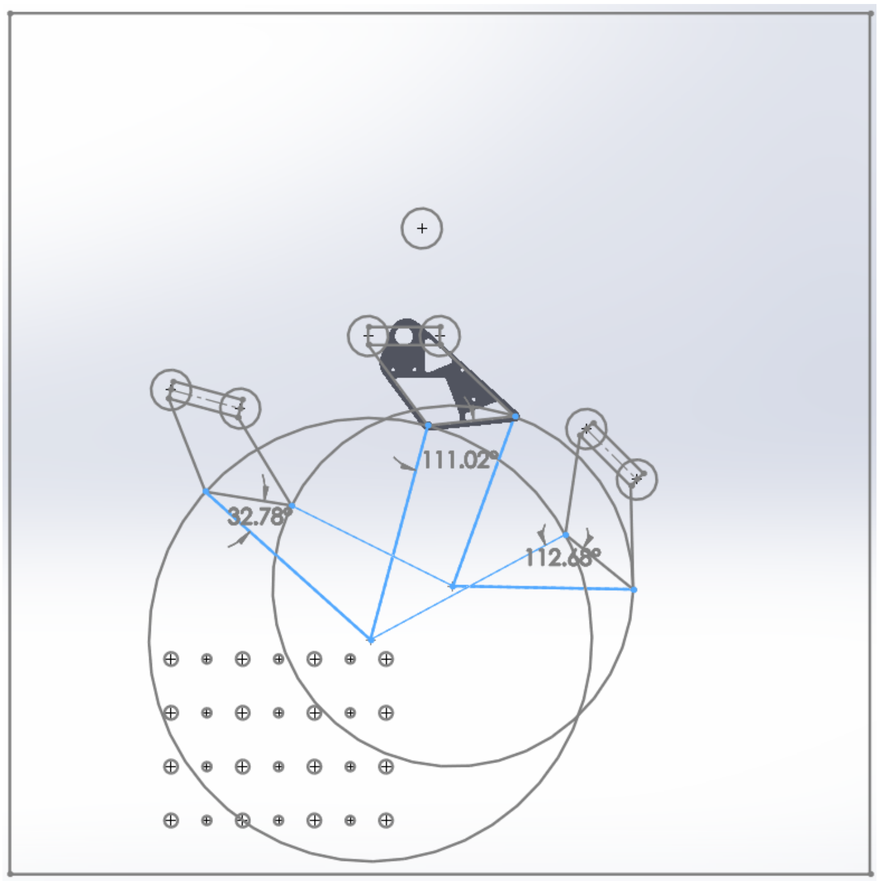



dY: .928076in
dZ: 2.523056in
Normal Dist: 6.998029in
Dist: 7.059302in
Length: 5in
dX: 6.527373in



Volume: dz*dx*dy = (4.743”)(6.52737”)(11.51515”) = **301.88481 in^3**

Transmission Angle Deviation



Largest Transmission Angle Deviation: 90 - 32.78 = 57.22
Transmission Angle Deviation Left: 90 - 32.78 = 57.22
Transmission Angle Deviation Right: 180 - 112.68 = 67.32

Left and Right Button Locations are Worst Transmission Angles

Cost Analysis:

All 3D printed parts: $2.41

20 N Solenoid: $9.99

Servo: $3.33

Timing Belt and Pulley: $11.89

Total: $27.62