Individual Analytical Analysis

Capstone Team
Flying Squirrel

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ME476C

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Introduction

This analysis is primarily on the velocity aspects of the Flying squirrel. With respect to the minimum required velocity set by the client, other categories need to be taken into consideration such as motor speed, lift screw pitch, and cable lengths. Each of these components directly impact the motion of the device and need to have set constraints in order to purchase the appropriate items. The team has been asked to consider different table sizes as this will affect cable lengths. Using a smaller table with shorter cables will be used for the analysis as this will require the maximum motor speed to maintain working space for the Flying Squirrel.

Cable Motor RPM

Starting with motor RPM analysis, the size of a table top needs to be assumed as a 48" by 48". The requirements from the client include a velocity of 1 m/s along with forward and backward motion of 6" in both directions and 12" in the left and right directions using three cables. The cables are equal length and 120 degrees apart when the device is at the center of the table. This area is shown in Figure 1.

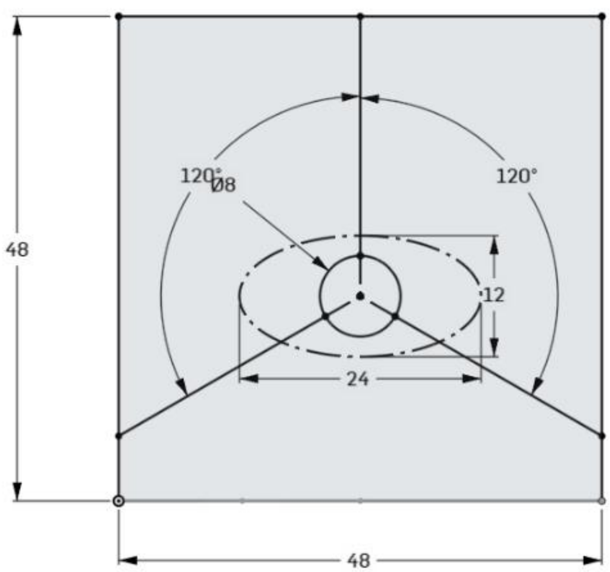

Figure 1. Flying Squirrel at center of 48"x48" table

Figure 2 shows the maximum angle in this workspace when one of the cables becomes tangent to the ellipse. The new angle and cable length can be used with the original cable length to determine the minimum RPM needed to achieve these angles and distances. Another requirement from the client is a 10 mm pulley for the cables. Figures 3 and 4 show an individual triangle from the known values.

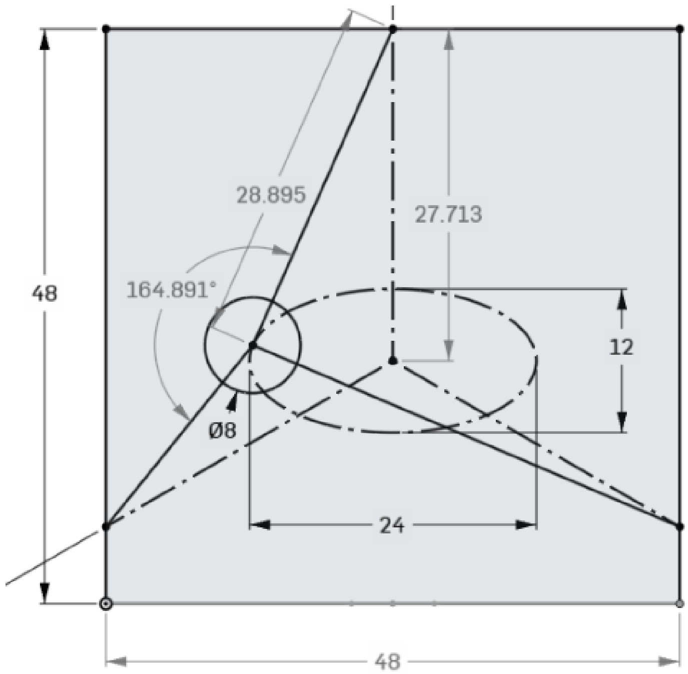

Figure 2. Maximum angle in workspace.

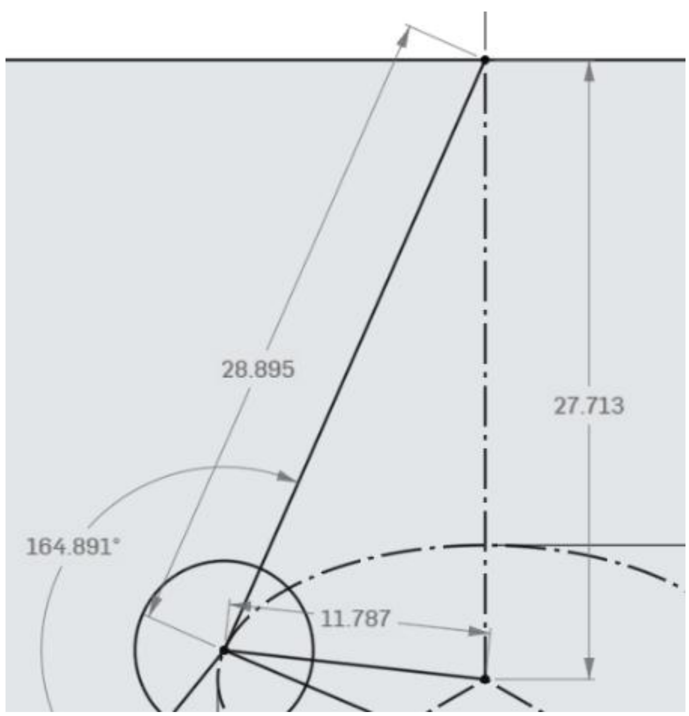

Figure 3. Developed triangle from device reaching maximum angle

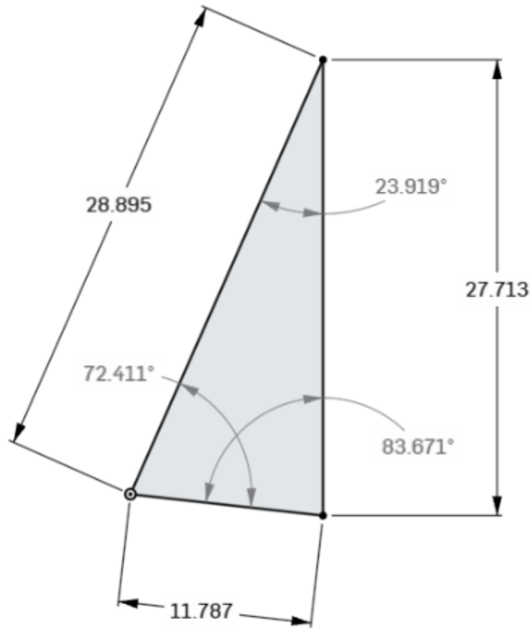

Figure 4. Isolated triangle

These angles and distances were developed using [1] Onshape to eliminate any mathematical errors in calculations. With the known values from the position analysis above and the client requirements, the minimum RPM of the motors can be calculated.

<u>Known Values:</u>

Velocity (v) = 1 m/s

Pulley diameter (d) = 10 mm

Original cable length (a) = 27.713 in

New Cable length (b) = 28.895 in

Distance from original position (c) = 11.787 in

Angle A = 72.441°

Angle B = 83.671°

Angle C = 23.919°

Evaluation:

Starting position at center of table

[2] Velocity to RPM: $\frac{v}{C} * 60$ è $\frac{1}{0.01\pi} * 60 = 1909.86$ RPM

RPM needed to reach maximum angle

RPM_1=RPM_2cos(A) è 1909.86=RPM_2cos(72.441°) è RPM_2= 6330.59 RPM

The minimum motor speed required for this model is 6330.59 RPM. This is strictly based on the assumption that the cables start at equal length and angles. This requirement is decreased as the cable becomes longer. Allowing for the center position to be moved lower and the lower angle to increase also reduces the minimum motor speed. This evaluation can also be worked to determine minimum cable length with known motor speed along with maximum working area with known cable length.

Lift Motor RPM

Similar to the x and y position, the z position shares the same constraints. The difference between the cable motors and the lift motor is that the lift motor is required to turn two screws. The size of the screw is M10x1.5 and the required velocity is 1 m/s. An example of the lift screw from the Flying Squirrel [3] Solidworks model is shown in figure 5 and 6.

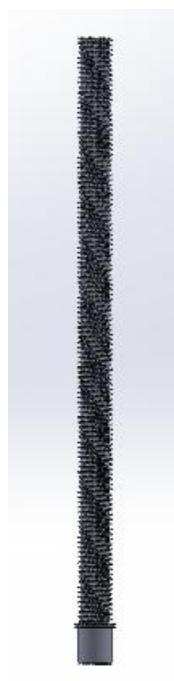

Figure 5. Flying Squirrel lift screw

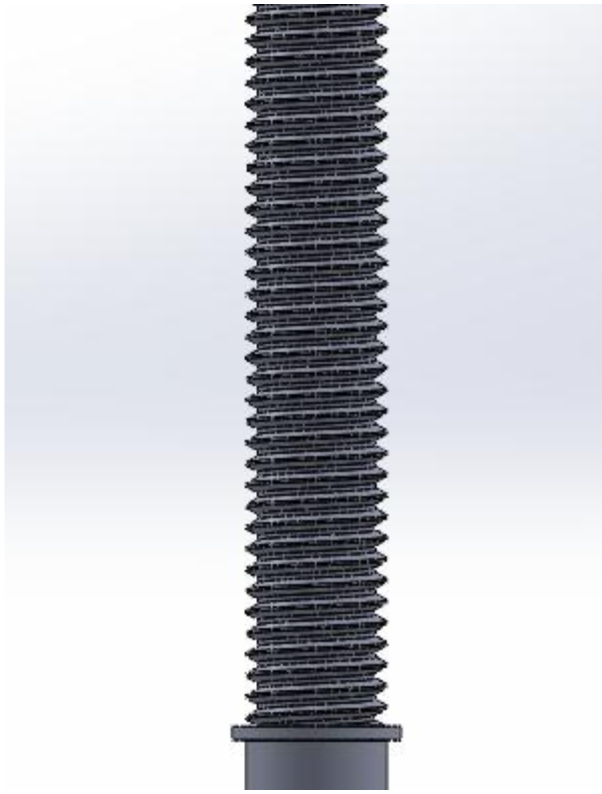

Figure 6. Flying Squirrel thread pitch

In order to determine motor speed, two other variables will be needed: the lead and the linear velocity. The linear velocity is known at 1 m/s. The lead will be assumed using 2 starts on the screw. To get the lead, the pitch needs to be multiplied by the start. In this case, the pitch is 1.5, multiplying the pitch by 2 starts yields 3mm/rev for the lead. The calculation is as follows:

Known Values:

Velocity (v) = 1 m/s

Lead (L) = 3 mm/rev

Evaluation:

[4] v=RPMxL è

$\frac{v}{L} = RPM$ è

$\frac{1*60}{.003} = 20000$ RPM

The minimum required motor speed for the lift screws is 20000 RPM. This number seems dramatically higher than expected. There are a few ways to reduce the RPM needed. The pitch can be increased which will increase the lead. The number of starts can also increase, providing the same results from increasing the pitch. Another way to decrease the necessary RPM would be to use a larger drive belt pulley on the motor compared to the screw. If the drive belt pulley is double the size of the screw size, it would reduce the required RPM by half.

Results

Based on the assumptions above, the cable motors require a minimum of 6330.59 RPM while the lift motor requires 20000 RPM. There are a few ways to decrease the minimum RPM requirements. This analysis shows that the same motor can not be used for both systems in the Flying Squirrel. They need to be selected appropriately to ensure the device is both electrically and thermally efficient.

Bill of Materials

Table 1 shows the bill of materials needed for construction of the device. As mentioned, the motors are different for the cable motors and the lift motors based on velocity requirements

Table 1. Bill of Materials

	Raw Materials, Parts or Components	($) Unit Cost	Quantity	($) Total cost
1	3 Axis force sensor	320.57	1	320.57
2	ODrive S1	59.00	3	177
3	16384 CPR Absolute RS485 Encoder with Cable for ODrive Pro or S1	149	3	447
4	Dual Shaft Motor - D5312s 330KV	59.00	3	177
5	PLA (1Kg)	20.73	1	20.73
6	Trapazoidal Lead Screws,10 x 2, RH steel 15 inches	29.06	1	29.06
7	Trapazoidal Lead Screws,10 x 2, LH steel 15 inches	33.66	1	33.66
8	Trapazoidal Lead nut,10 x 2, LH Bronze	27.82	1	27.82
9	Trapazoidal Lead nut,10 x 2, RH Bronze	25.79	1	25.79
10	2x OVONIC 3S Lipo Battery 15000 mAh 130C 11.1V LIPO battery with EC5 plug for 1/8 RC truck	126	1	126
11	Raspberry Pi 5 2GB	50	1	50
12	ELEGOO UNO Project Super Starter Kit with Tutorial and UNO R3 Board Compatible with Arduino IDE	35.99	1	35.99
13	Strap	6	1	6
14	6.5x3 touch LED screen	74.82	1	74.82
15	Ball bearings	8	1	8
16	DSY Series 750W RS485 DC Servo Motor 24-70VDC 2.39Nm 3000rpm 17-Bit Incremental Encoder IP65	174.86	1	174.86
17	Suction cup	12	3	36
18	Fishing line	25	1	25
19	C-Clamp	5	3	15
20	screws	5	1	5
21	mounts	10	3	30
			Total=	1845.3

Solidworks Model

The CAD model is shown in figures 7 and 8 in its lowered and raised positions and figure 9 shows the Flying Squirrel with transparent shells.

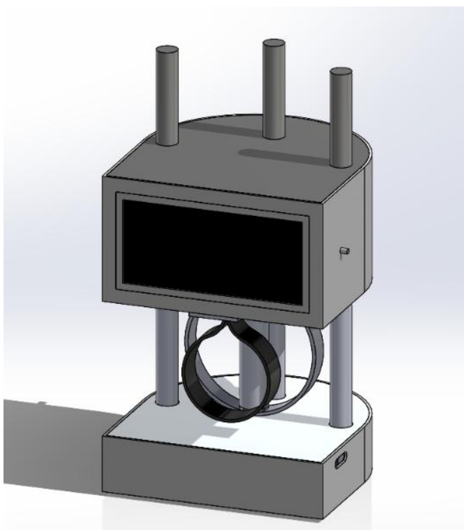

Figure 7. Lowered position

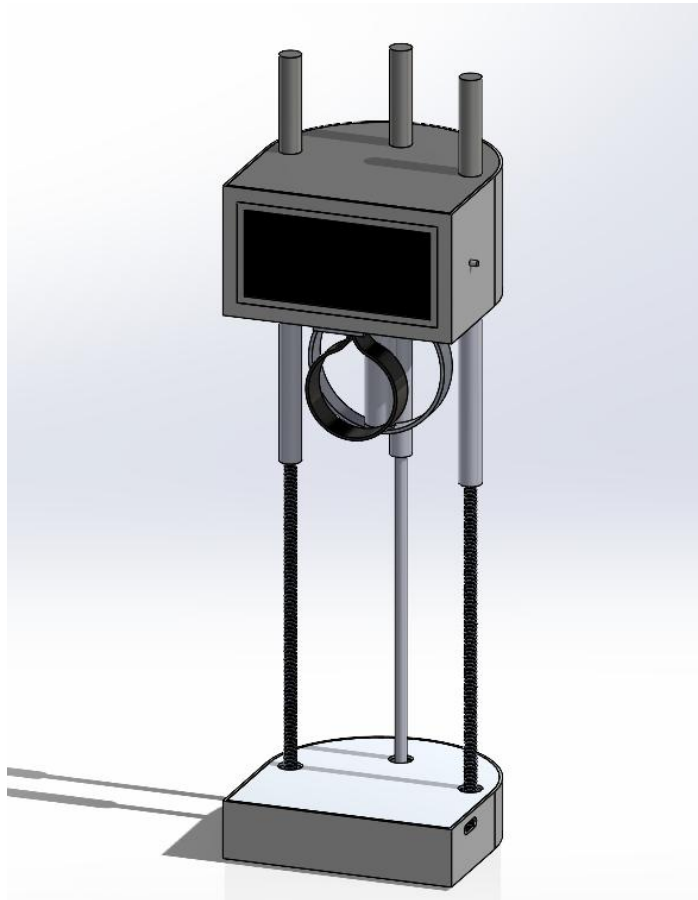

Figure 8. Raised position

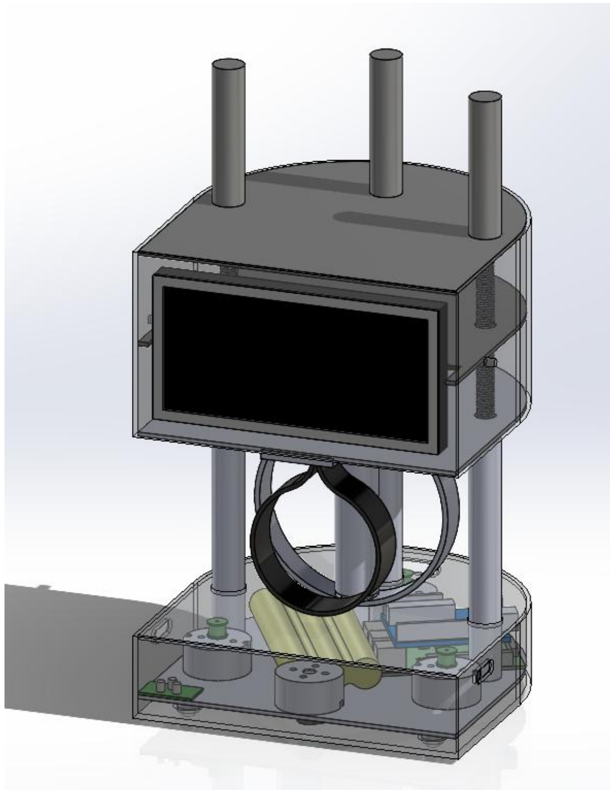

Figure 9. Transparent lower and upper section

The motors and their locations can be seen in figure 9. Figure 10 shows the orientations of the motors and figure 11 shows how the lift screws are driven by the motors.

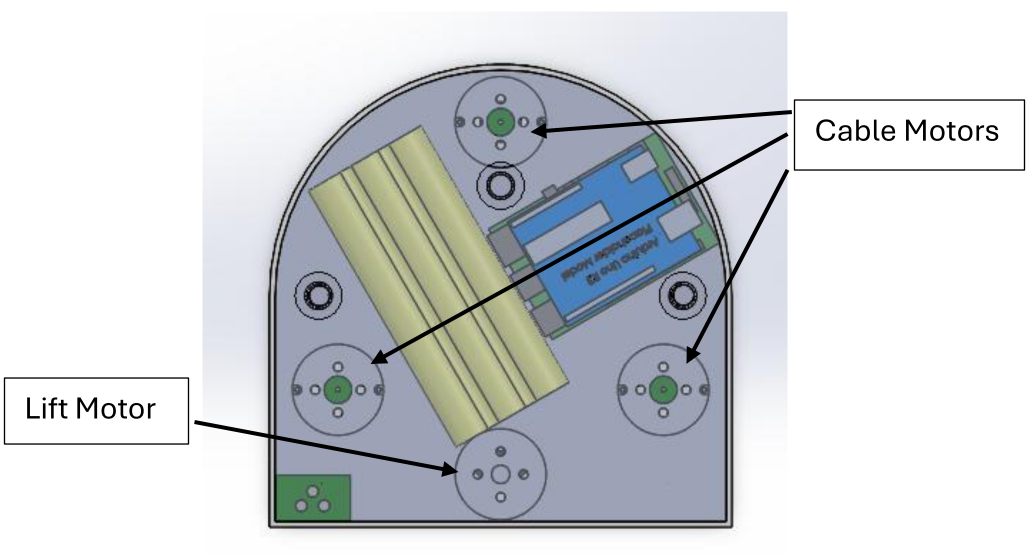

Figure 10. Cable motor and lift motor

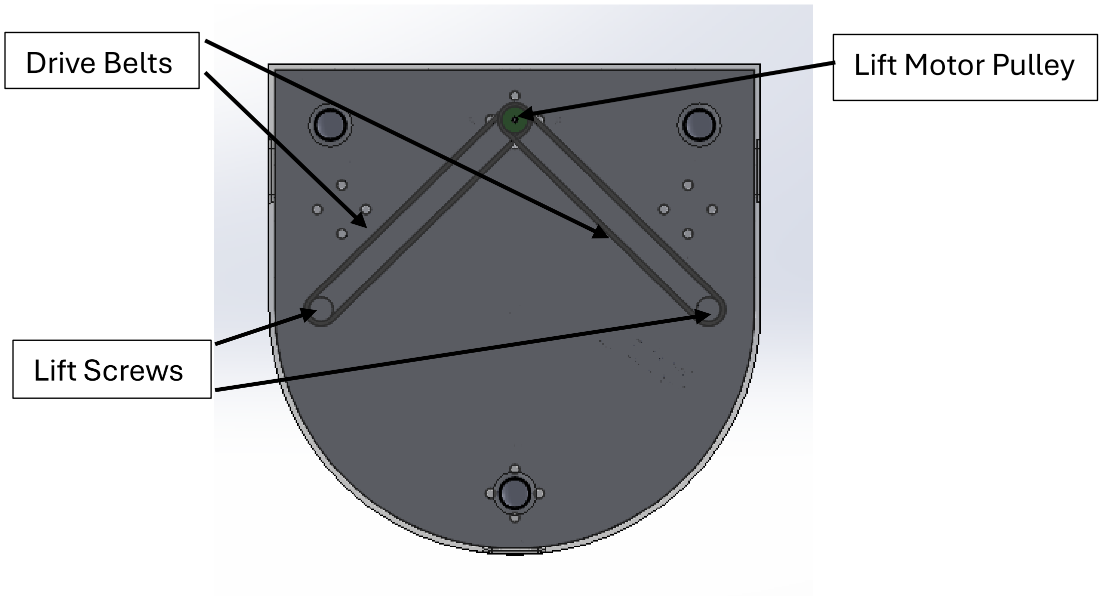

Figure 11. Lift screws, drive belts, lift pulley

Conclusion

The results of this analysis will help with motor selection and proper setup orientation. It will also provide insight into pulley diameters, cable lengths, and lift screw properties. As shown in the CAD model, there is a lot of room for adjustability and relocation if necessary. Other team members' analysis will need to be taken into consideration when making final iterations to this design. These calculations were made based on Dr. Razavian's requirements for the Flying Squirrel and will help with any future changes and requirements.

References

[1] “Onshape,” cad.onshape.com. https://cad.onshape.com/

[2] “eMotors Direct - Canada’s Online Source for Electric Motors, Gearing, and Controls,” www.emotorsdirect.ca. https://www.emotorsdirect.ca/speed-to-rpm

[3] “Flying Squirrel” Solidworks.com, 2024. https://solidworks.com

[4] “Roton Products Inc.,” Roton Products, Inc., Mar. 24, 2020. https://www.roton.com/screw-university/formula-calculators/speed/ (accessed Apr. 27, 2025).