# Individual Analytical Analysis

## Capstone Team
### Flying Squirrel

Ryan Donnellan

**ME - 476C - 001**
**April 25, 2025**

## Introduction:

The purpose of this analysis memo is to calculate torque required to move the flying squirrel and the required battery capacity to operate the flying squirrel for the time specified by the client. While the research and development budget for the team is ample, the total cost of the robot is not so. The team must choose components that meet all the requirements with the total production cost of the robot being less than 1000 dollars. This analysis will give the minimum specifications that meet the client requirements so the team can begin moving forward with construction. The torque calculations that will be discussed in this analysis are only for the robot and anchor points at a single position as the calculations and plots for the robot moving were handled by another member of the team. Results from the torque calculations will be used to determine the motors necessary to make the robot move with the force specified by the client of 10 newtons. The total force exerted by the motors must actually be 20 newtons because the operator is supposed to resist the movement with 10 newtons of force. Then from this calculation, the motors will be determined, and from the motors, the electrical requirements of the battery can be determined as the motors will be drawing the majority of the current from the battery.

## Torque Analysis:

A matlab program was made to evaluate the torque necessary to move the robot with the required force. This code can be found at the end of this document in Appendix A. A breakdown of the code calculations is shown below.

force = the combined force in newtons pulling in any direction.
Radius = the radius of the winch.
R = position vector of robot.
R0 = position vector of robot without z coordinate.
A1-3 = position vectors of anchor points.
rad(i) = current direction of force vector in radians.
x_force and y_force = x and y components of desired force.
V1-3 = vectors from robot to anchor points.
u1-3 = unit vectors from robot to anchor points.
c1-3 = unit vectors from robot to anchor points.
c4 = z component to account for the lifting aspect.
C = matrix of unit vectors.
wireForces = the forces in each individual wire to reach the desired force.
maxT = the maximum force in wireForces.
minT = the minimum force in wireForces.
torque = the maximum force multiplied by the radius of the winch.

| | |
|---|---|
| $d = \begin{matrix} x\_force \\ y\_force \\ 0 \end{matrix}$ | (Eq.1) |
| V = A - R | (Eq.2) |
| u = $\frac{V}{sqrt(x^2+y^2+z^2)}$ | (Eq.3) |
| c = u × (1 + [1;1;0]) | (Eq.4) |
| C = [c1 c2 c3 c4] | (Eq.5) |
| wireForces = lsqnonneg(C,d) | (Eq.6) |
| maxT = max(wireForces) | (Eq.7) |
| minT = min(wireForces) | (Eq.8) |

Table 1: Torque Equations Table

The two position vectors, R and R0, are due to the fact that the cables are connected to both the top and bottom. This code works by taking the position vectors of the robot and anchors and subtracting them to get the vectors from the robot to the anchor. These are then turned into unit vectors and put into a three by four matrix in order along with a vector for the lifting component. This fourth vector is always [0;0;1] which is assuming the robot to always be lifting, but as lifting requires more torque than lowering it is acceptable. This matrix is then combined with the function least square nonnegative to obtain the coefficients necessary to multiply the C matrix by to obtain the desired force. The least square nonnegative function is necessary as cables can only exist in tension and this function will obtain only positive coefficients. The purpose of rad(i) and x and y force is to spin the applied force 360 degrees from the center of the robot. This step is important because as the robot moves closer to the side of the triangle outlined by the anchor points the direction of the force vector is important due to the fact that the closer it gets, the torque required by the motors become exponentially higher. The team had to decide at what point to stop and design for that torque. The movement of the robot is not covered in this report, that function as well as plotting the torque was covered by another member of the team. The results of the combined code are a nominal torque of between 0.1 and 0.2 newton meters.

**Electrical Analysis:**

Using the torque results calculated before, options for motors can be narrowed down significantly. More requirements from the client added to narrow down the selection of motors was, the motors must include a controller and optical encoder. An assumption that was made to determine the battery capacity required for the robot was that the motors and all power drawing accessories would be running at 100 percent output 100 percent of the time. This way there is no doubt that the batteries selected will last the required time of 30 minutes. With these requirements in mind, the motor that will be used for this assignment is the RMD-H-50-15-100-C [1]. Below is a table showing all of the power requirements of the individual components and the total power requirements.

| **Part** | **Quantity** | **Voltage (V)** | **Current (A)** |
|---|---|---|---|
| RMD-H-50-15-100-C Motor [1] | 4 | 24 | 4.9 Rated Phase Current |
| Arduino Uno R3 [2] | 1 | 5 | 0.07 |
| Raspberry Pi [3] | 1 | 5 | 0.8 |
| UMC1BDS32 Motor Controller [4] | 1 | 5 | 0.01 |
| 7 Inch Touchscreen Metal [5] | 1 | 24 | 0.26 |

Table 2: Electronics parts list

| | |
|---|---|
| $Atot = \sum A$ | (Eq.9) |
| $Ah = Atot \times h$ | (Eq.10) |

Table 3 : Battery Capacity Equations Table

The total amount of amps necessary to run the robot is calculated by adding the amperage requirements of each individual power consuming part. The total is calculated to be 20.74 amps delivered continuously. Assuming a worst case 97 percent efficiency in the power cables results in a required amperage of 21.38 amps. Taking the total amount of amps necessary to run the robot and multiplying by the run time of 30 minutes or one half hour gives the result that the total battery capacity of 10.69 Ah or 10690 mAh. To ensure that the battery capacity is adequate, batteries of at least 15000 mAh will be used in the robot as that is the next largest battery size sold. Due to budget restraints, a 6S battery which would be able to provide the required voltage on its own is too expensive as it would cost half of the total production cost at 500 dollars. Two 3S batteries will have to be used in its place and be wired in series to provide the required voltage. Two 3S batteries cost less than one third of a single 6S battery at 125 dollars [6][7].

**Conclusion:**

The results calculated in this analysis will assist the team in the construction of the robot. The calculated values for the torque give the team options in the selection of motors in case it is discovered that the motors currently being used do not fit the needs of the robot. It also ensures that the motor will be able to exert the forces on the hand required by the client. The calculated electrical capacity will ensure that all the motors can output the required force for the time required by the client.

**References**

[1] “H-50-15 details,” MyActuator, https://www.myactuator.com/h-50-details (accessed Apr. 24, 2025).

[2] Raspberrypi, “Documentation/documentation/ASCIIDOC/computers/raspberry-PI/power-supplies.adoc at develop · raspberrypi/documentation,” GitHub, https://github.com/raspberrypi/documentation/blob/develop/documentation/asciidoc/computers/raspberry-pi/power-supplies.adoc (accessed Apr. 24, 2025).

[3] “Arduino Uno REV3,” Arduino Online Shop, https://store-usa.arduino.cc/products/arduino-uno-rev3 (accessed Apr. 24, 2025).

[4] “Motor controller UMC1BDS32 15A, 12-48V w/ can FD & RS485,” RobotShop USA, https://www.robotshop.com/products/motor-controller-umc1bds32-15a-12-48v-w-can-fd-rs485 (accessed Apr. 24, 2025).

[5] “7 inch touchscreen,” Beetronics, https://www.beetronics.com/7-inch-touchscreen (accessed Apr. 24, 2025).

[6] “Tattu 16000mah 22.2V 6s 30c lipo battery pack w/ XT90-S plug,” www.getfpv.com, https://www.getfpv.com/tattu-16000mah-22-2v-6s-30c-lipo-battery-pack-w-xt90-s-plug.html?utm_source=google&utm_medium=cpc&utm_campaign=DM%2B-%2BNB%2B-%2BPMax%2B-%2BShop%2B-%2BUnder-index%2B-%2BSM%2B-%2BALL%2B%7C%2BFull%2BFunnel&utm_content=pmax_x&utm_keyword=&utm_matchtype=&campaign_id=20800417087&network=x&device=c&gc_id=20800417087&gad_source=1&gbraid=0AAAAAD8cN5JNWz0yby4b1P9NcxFqmiKJa&gclid=CjwKCAjwwqfABhBcEiwAZJjC3qUk7mVEYAcJMvvH1bAKXcQhZhC97lXrIluaxIBaMzdx0kAyZB5TRhoC0rcQAvD_BwE (accessed Apr. 24, 2025).

[7] “2 × Ovonic 3s lipo battery 15000mah 130C 11.1V RC lipo battery with EC,” us.ovonicshop, https://us.ovonicshop.com/products/2-ovonic-3s-lipo-battery-15000mah-130c-11-1v-rc-lipo-battery-with-ec5-plug-for-1-8-rc-truck-rc-vehicles-car?srsltid=AfmBOoqOoUz1xiqHnAN_kqDnsoPLDcUCAQjt8EnJkzyNjyjnKcYol09p (accessed Apr. 24, 2025).

**Appendix A: Torque Calculation Code**

```
force = 20; %Newtons, combined force in any direction
radius = 0.005; %meters, radius of pulley
for i=1:201
   R = [0.1;0.2;0.3];
   R0 = R.*[1;1;0];
   A1 = [-0.5;-0.3;0];
   A2 = [0.5;-0.3;0];
   A3 = [0;0.8;0];
   rad(i) = ((i-1)*0.01) * pi()
   x_force(i) = cos(rad(i)) * force
   y_force(i) = sin(rad(i)) * force
   desiredforce(:,i) = [x_force(i);y_force(i);0];
   V1 = A1-R;
   u1 = V1/norm(V1);
   V2 = A2-R;
   u2 = V2/norm(V2);
   V3 = A3-R;
   u3 = V3/norm(V3);
   c1 = u1.*(1+[1;1;0]);
   c2 = u2.*(1+[1;1;0]);
   c3 = u3.*(1+[1;1;0]);
   c4 = [0;0;1];
   C = [c1 c2 c3 c4]
   wireForces(:,i) = lsqnonneg(C,desiredforce(:,i))
   maxT = max(wireForces(:,i))
   minT = min(wireForces(:,i))
   torque = maxT * radius
end
```