# Below the Knee Exoskeleton

Team:
Ryan Oppel (Budget Lead), Alexandra Schell (Team Lead),
Nicolas Watkins (Website and CAD Lead)

NAU NORTHERN ARIZONA UNIVERSITY

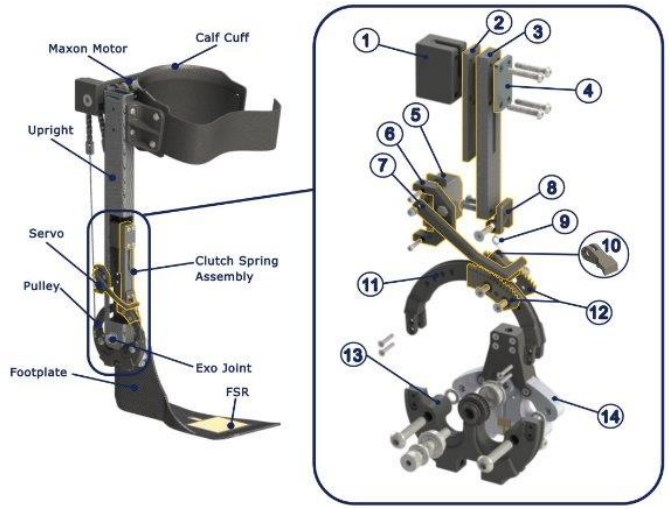
# Project Description

## Goal:

Improve upon the existing Exoskeleton design shifting from holding the battery and motor at the waist, to enclosing all components at the ankle. Our specific focus is:

- Battery selection
- Cover and ingress protection design
- Motor evaluation and mounting hardware design.

The current design has a large belt where the battery and microcontroller Are found, we need to take those components, update them, and put them Into the foot.

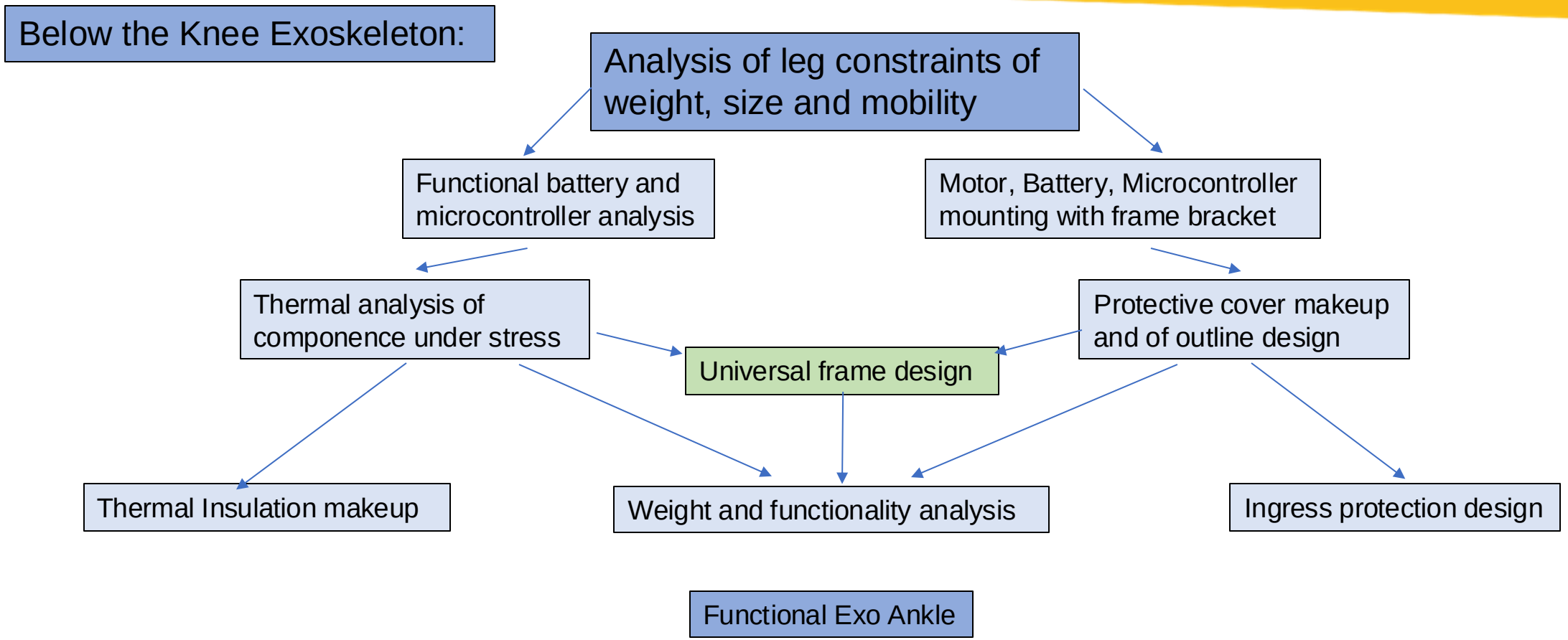



## Our Client:

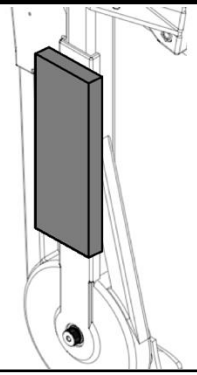
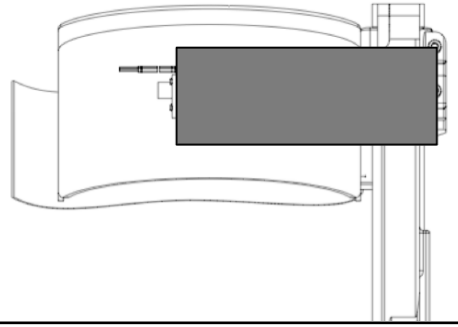
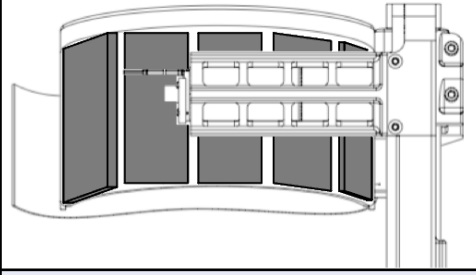
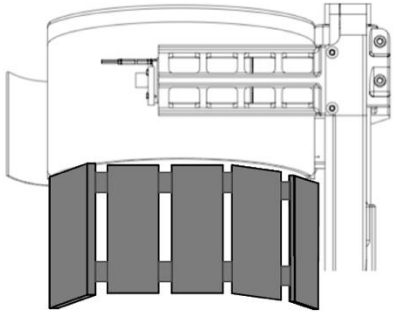
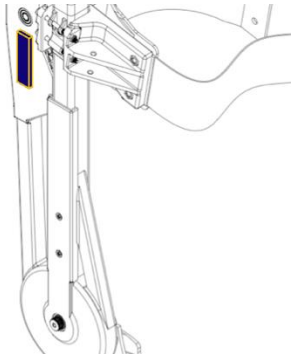
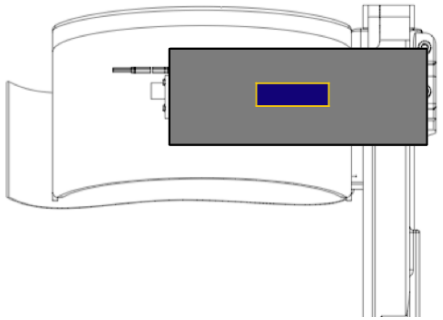
- Prof Zach Lerner, head of Biomechatronic Lab. They develop lightweight wearable robotic exoskeletons to improve the movement of people with walking impairment.
- W.L. Gore

# Project Description: Black Box Model

# Project Description: Physical Decomposition

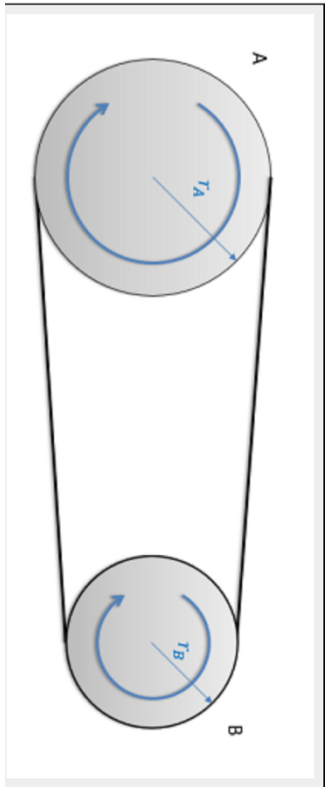


# Concept Generation

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Battery Placement |  |  |  |  |
| Controller Placement |  |  | | |

# Calculations

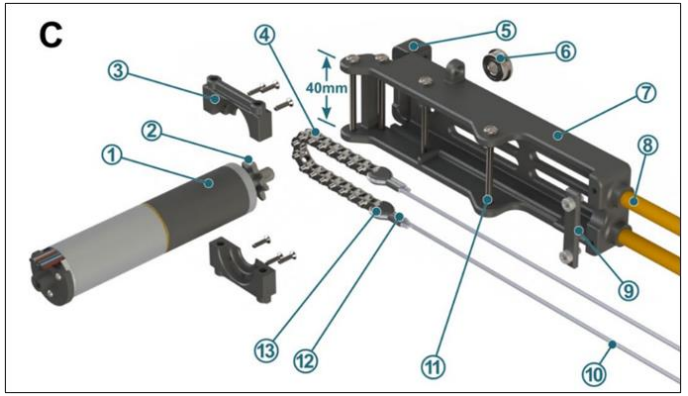
## Gear Ratio and Stress at the Motor




Gear Ratio

$$T_{\text{output}} = T_{\text{input}} \times \text{Gear Ratio}$$

If torque output is labeled as the torque needed at the ankle and torque input is measured at the motor, both calculations were solved in the previous presentation. Input was calculated at 3.7 Nm due to the specs of the motor, and the output is 139 Nm. Due to these numbers, we can assume we need a gear ratio of 38:1.




Stress at the motor

$$\tau = \frac{T*r}{J}$$

$\tau$ = Stress

T = Torque

r = radius of the shaft

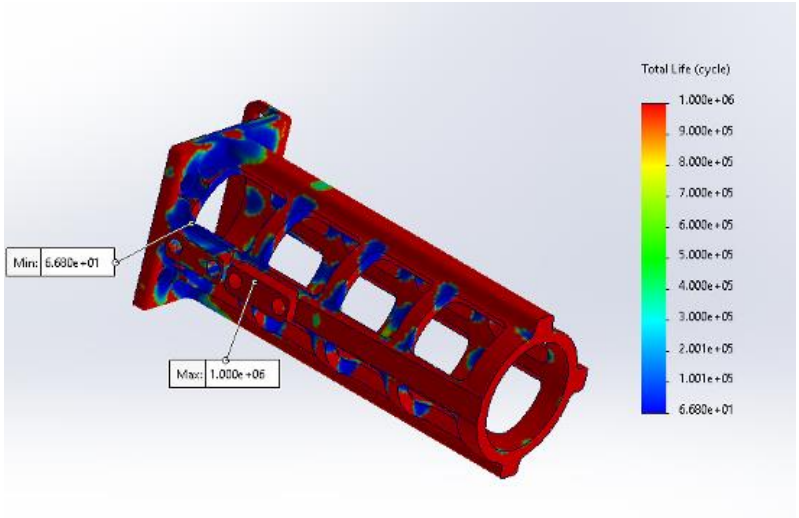
$$J = \frac{\pi r^4}{2}$$

With the above equations and the torque being 3.7 Nm and the radius of the shaft, as designed in Solidworks, being 3 mm, the stress is calculated at 8.74 E7 MPa

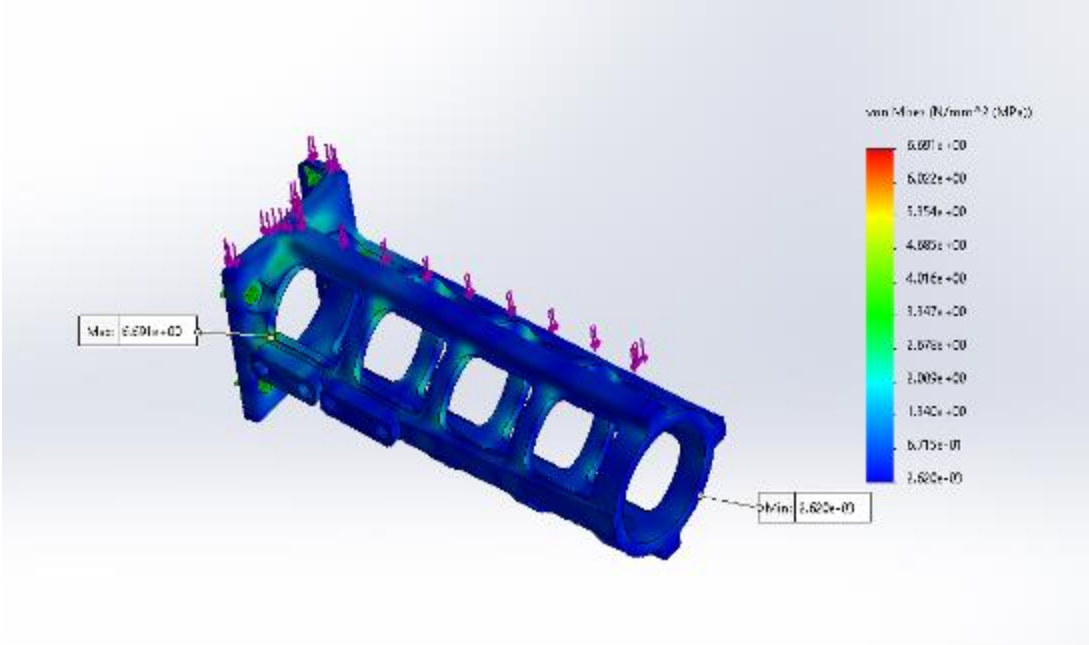
# Solidworks Simulations

Simulation of motor mount:

- High likelihood of bumping into foreign objects.
- No water resistance or protection against debris
- High chance of stress and fracture




Life Cycle based on 15N after 1000000 cycles



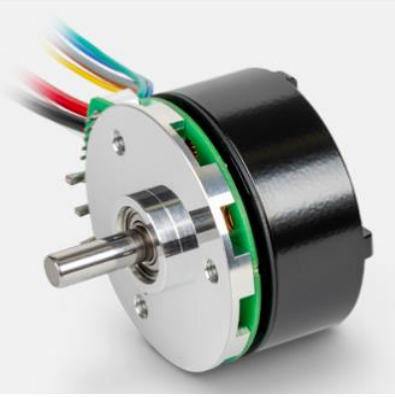
Von Mises stresses based on 15N

# Concept Evaluation

Old: EC-4pole

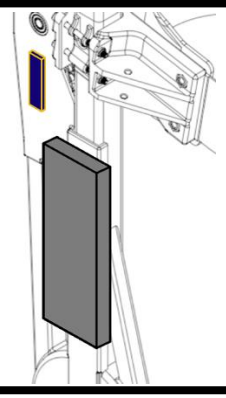
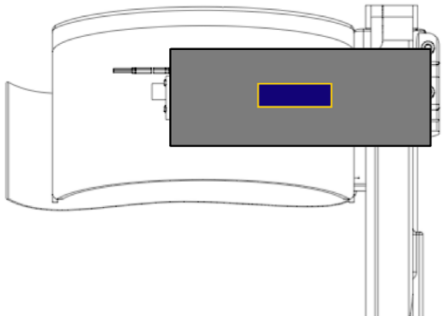
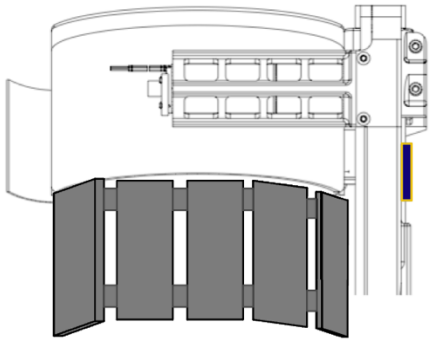
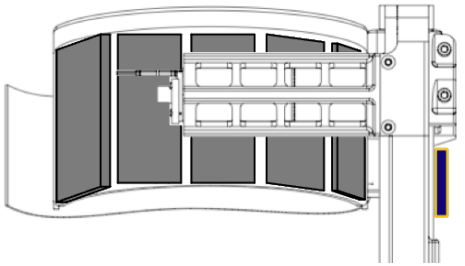

| | |
|---|---|
| Nominal voltage | 36 V |
| No load speed | 16300 rpm |
| No load current | 109 mA |
| Nominal speed | 14900 rpm |
| Nominal torque (max. continuous torque) | 43.7 mNm |
| Nominal current (max. continuous current) | 2.16 A |
| Stall torque | 612 mNm |
| Stall current | 29.1 A |
| Max. efficiency | 88 % |

New: ECX Flat

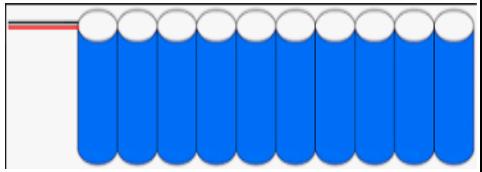


| | |
|---|---|
| Nominal voltage | 24 V |
| No load speed | 10600 rpm |
| No load current | 179 mA |
| Nominal speed | 8100 rpm |
| Nominal torque (max. continuous torque) | 103 mNm |
| Nominal current (max. continuous current) | 4.24 A |
| Stall torque | 438 mNm |
| Stall current | 51.6 A |
| Max. efficiency | 89 % |

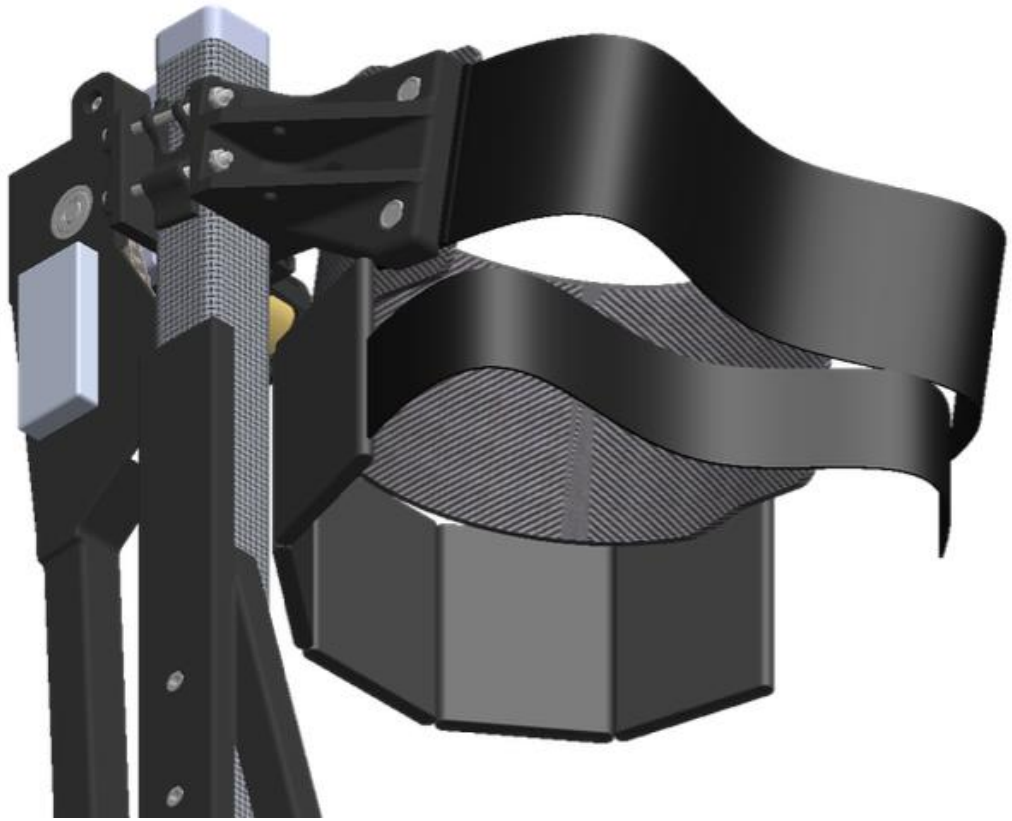
# Concept Evaluation

| | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| | |  |  |  |  |
| High Center of Gravity | 1 | - | + | S | + |
| Heat Transfer to Skin | 3 | + | + | - | S |
| Heat Transfer to Electronics | 4 | + | - | + | - |
| Protection | 5 | - | - | + | + |
| Σ | | 1 | -5 | 6 | 2 |

# Concept Evaluation

| | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| | | 3500mAh 10A Protected Lithium Ion  | Dantona L148A26-4-18-3WA3 Lithium-Ion Battery Pack  | Li-Ion 21700 Battery  | 2p3s 10.8v 6400Mah Lithium Battery Pack  |
| Output power | 2 | S | - | + | + |
| Weight and size | 3 | - | + | - | S |
| Ease of use | 2 | + | + | - | + |
| cost | 2 | + | - | + | - |
| TotalΣ | | 1 | 1 | -1 | 2 |

# CAD

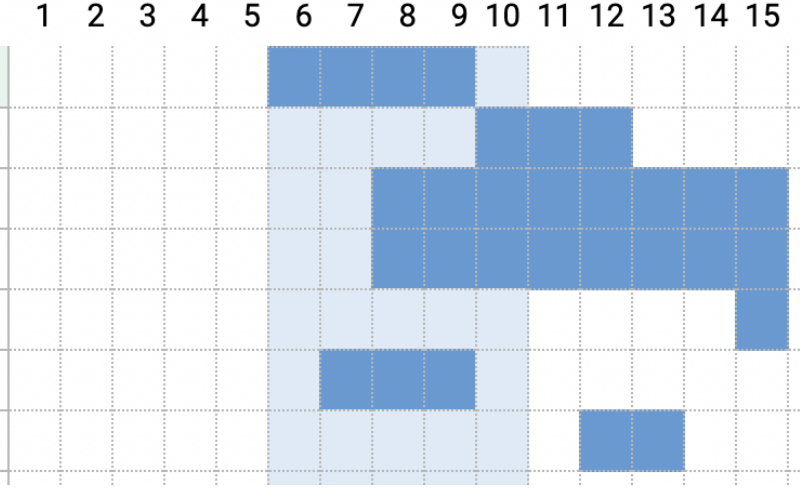


# Schedule

## Overview of the first semester

Below is the tentative schedule of the first semester based on major deadlines.

| 2 | Major Deadlines 1st Semester | | | | | |
|---|---|---|---|---|---|---|
| WBS Number | Task Title | Task Owner | Start Date | End Date | Duration | % Done |
| 2.2 | Initial CAD Design | Nick W | 9/30/24 | 10/28/24 | 28 | 16% |
| 2.1 | 1st Protype Demo | Alex S | 10/28/24 | 11/13/24 | 15 | 0% |
| 2.2 | Final CAD and BOM | Nick W | 10/11/24 | 12/3/24 | 52 | 0% |
| 2.3 | 2nd Protype Demo | Alex S | 10/11/24 | 12/4/24 | 53 | 0% |
| 2.4 | Analysis of Prototype | Team | 12/4/24 | 12/7/24 | 3 | 0% |
| 2.2 | Purchase of Battery | Ryan O | 10/11/24 | 10/26/24 | 15 | 0% |
| 2.3 | Test 1st Prototype | Alex S | 11/13/24 | 11/24/24 | 11 | 0% |



# Budget

## Fundraising

We officially have a GoFundMe account up and running and have advertised it to potential benefactors.

| | |
|---|---|
| Funding From W.L. Gore = | +$4000 |
| NAU Processing Fee = | -$200 |
| Fundraising Contribution = | +$400 |
| Total Budget = | +$4200 |

BoM

| Expenses: | |
|---|---|
| Tools & Prototyping: | |
| 3_d printer Parts | $500 |
| Filament | $50 |
| Testing Material | $400 |
| Parts: | |
| Battery | $1000 |
| Cover | $500 |
| Hardware | $500 |
| Motor | $1000 (maybe) |
| Total Expenses: | $3950 |

# Thank You!

# Project Description

[1] “Compact Drives, Motors, Gears, Sensors | maxon group,” *Maxongroup.us*, 2024. https://www.maxongroup.us/maxon/view/product/motor/ecmotor/ecflat/ECXflat32/ECXA32LZF50E6ILACO1Y330A

[2] “Online shop for high precise drive systems by maxon | maxon group,” *Maxongroup.com*, 2017. https://www.maxongroup.com/maxon/view/product/323217