Mechanical Hip Prosthetic – Horizon Hip

AIDEN CAMISA, VICTORIA LYON,

MATT MARTINEZ, QUINN O'NEILL

HORIZON HIP

EMPOWERING EVERY STEP

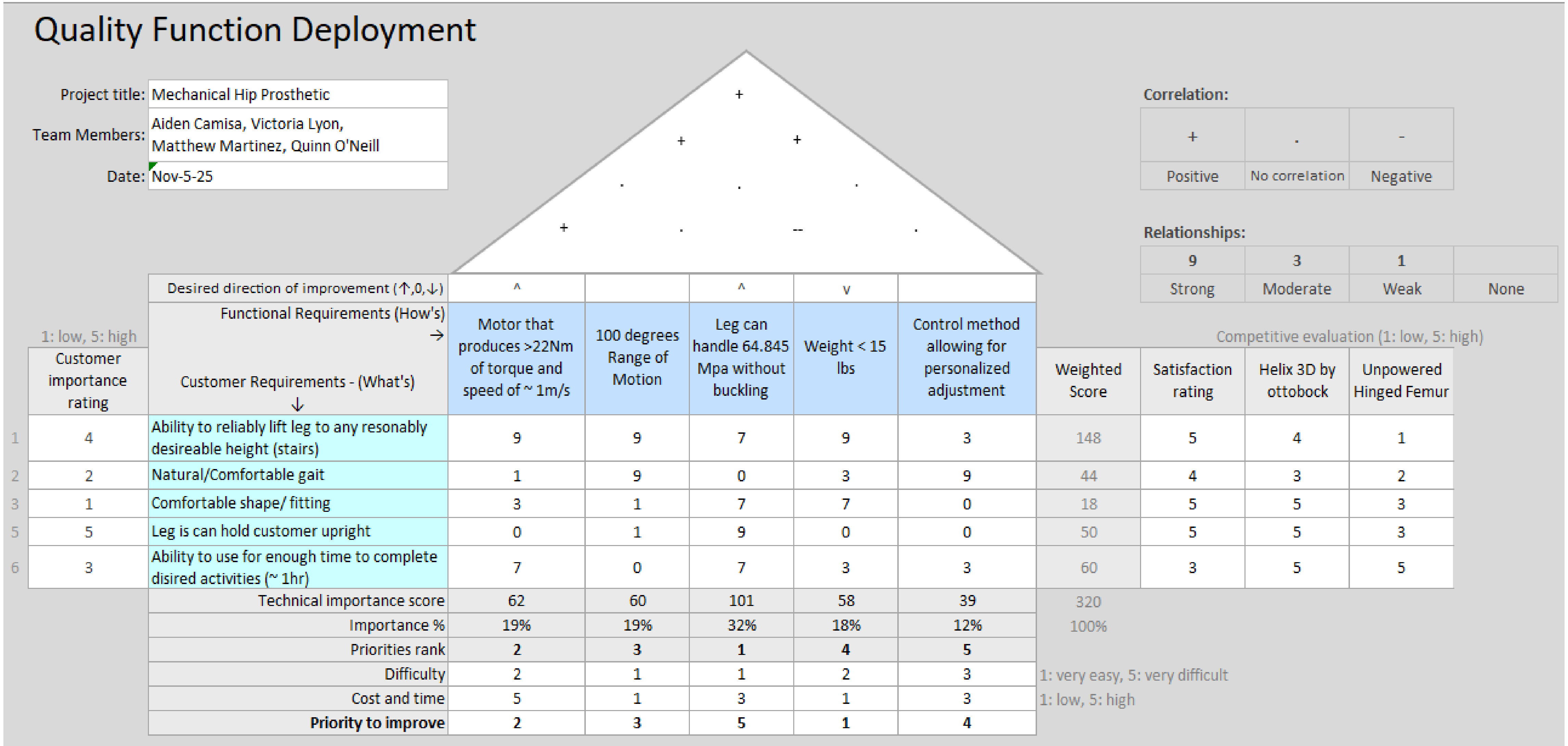
Project Description

- Design and build a fully powered hip prosthesis
- Enable controlled motion for patients with total hip disarticulation
- Use a high-performance motor to replicate natural hip torque and ROM
- Maintain lightweight construction for improved comfort and usability

Clients: Dr. Dante Archangeli and Dr. Reza Razavian, NAU Mechanical Engineering Faculty

Otto bock Helix 3D – Industry Standard

Design Requirements



Quality Function Deployment

Project title: Mechanical Hip Prosthetic
Team Members: Aiden Camisa, Victoria Lyon, Matthew Martinez, Quinn O'Neill
Date: Nov-5-25

Correlation:

+	.	-
Positive	No correlation	Negative

Relationships:

9	3	1	
Strong	Moderate	Weak	None

Competitive evaluation (1: low, 5: high)

	1: low, 5: high Customer importance rating	Functional Requirements (How's) → Customer Requirements - (What's) ↓	Motor that produces >22Nm of torque and speed of ~ 1m/s	100 degrees Range of Motion	Leg can handle 64.845 Mpa without buckling	Weight < 15 lbs	Control method allowing for personalized adjustment	Weighted Score	Satisfaction rating	Helix 3D by ottobock	Unpowered Hinged Femur
		Desired direction of improvement (↑,0,↓)	^		^	v					
1	4	Ability to reliably lift leg to any resonably desireable height (stairs)	9	9	7	9	3	148	5	4	1
2	2	Natural/Comfortable gait	1	9	0	3	9	44	4	3	2
3	1	Comfortable shape/ fitting	3	1	7	7	0	18	5	5	3
5	5	Leg is can hold customer upright	0	1	9	0	0	50	5	5	3
6	3	Ability to use for enough time to complete disired activities (~ 1hr)	7	0	7	3	3	60	3	5	5
		Technical importance score	62	60	101	58	39	320			
		Importance %	19%	19%	32%	18%	12%	100%			
		Priorities rank	**2**	**3**	**1**	**4**	**5**				
		Difficulty	2	1	1	2	3	1: very easy, 5: very difficult			
		Cost and time	5	1	3	1	3	1: low, 5: high			
		Priority to improve	**2**	**3**	**5**	**1**	**4**				

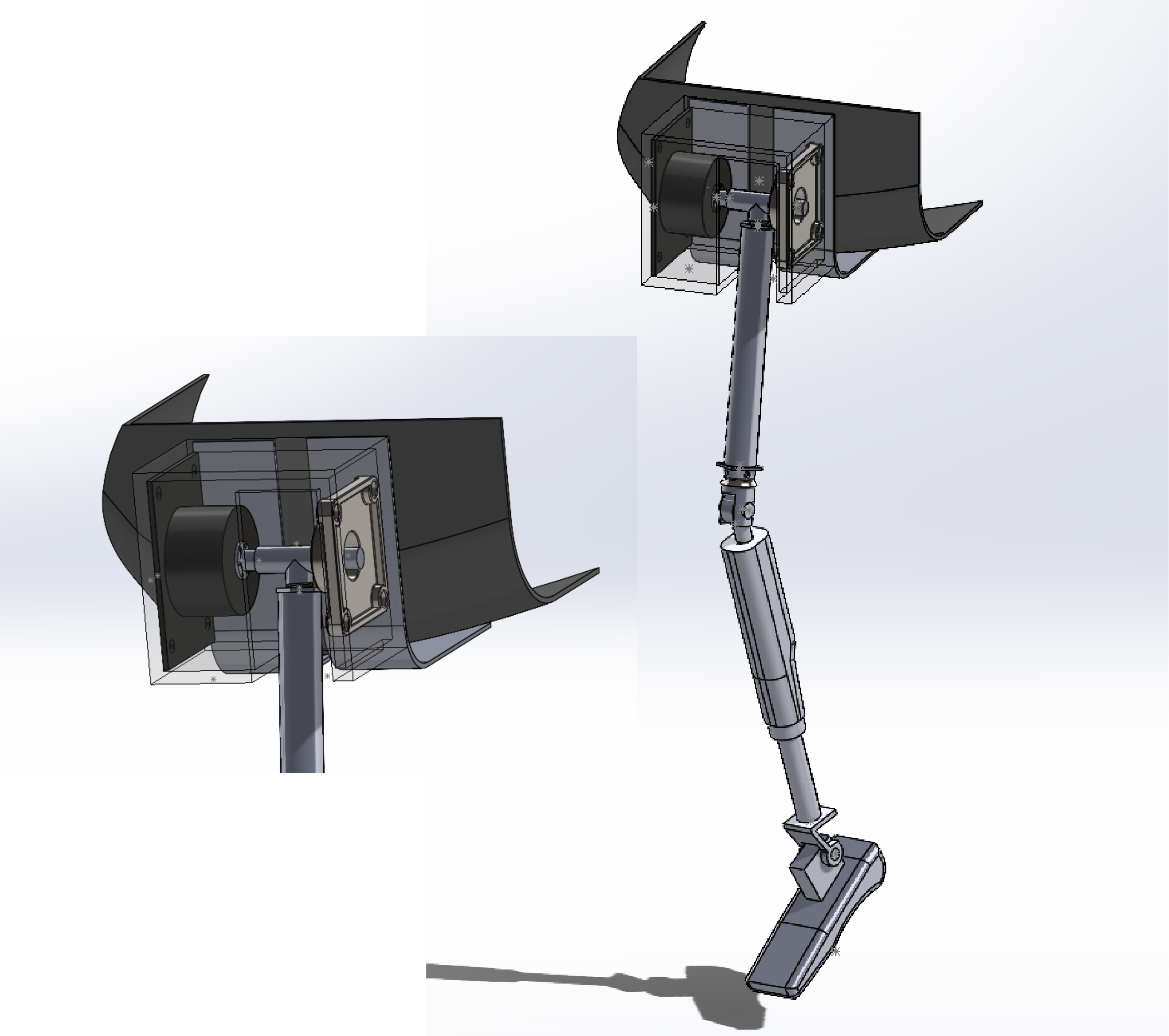
Design Description

Function:

- Motor receives signal [Raspberry Pi]
- Motor drives shaft necessary amount of torque to goal rotation
- Shaft rotates, handles load with bearing, and creates motion in sagittal plane
- Motor is back-driven in gait, system restarts

Sub-Assemblies:

- Motor Shaft – Shaft adapter – Bearing
- Shaft adapter – Reducer bushing – Pylon

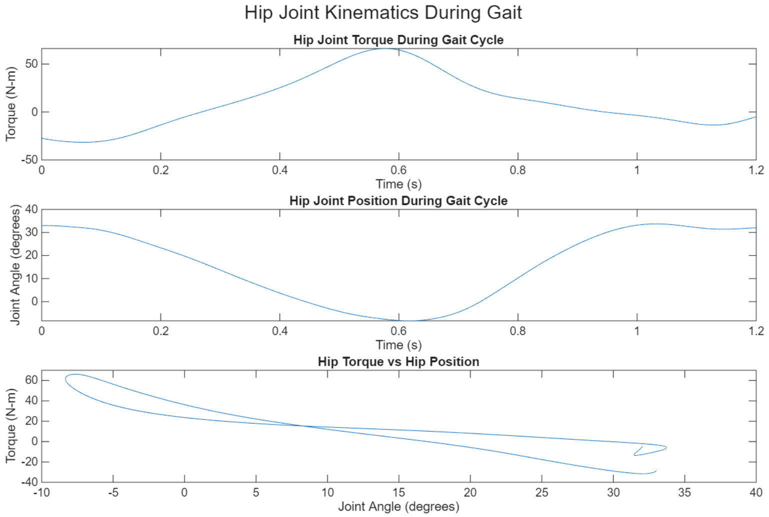


Motor Analysis

What We Know

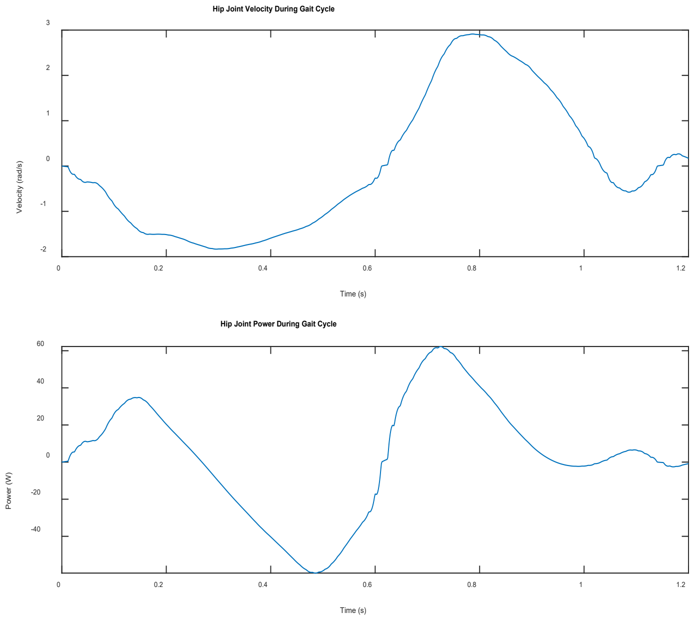
$$\tau_{hip} = -BW \cdot \tau$$

$$t = 1.2\ seconds$$



$$\omega_{hip} = \frac{d\theta}{dt}$$

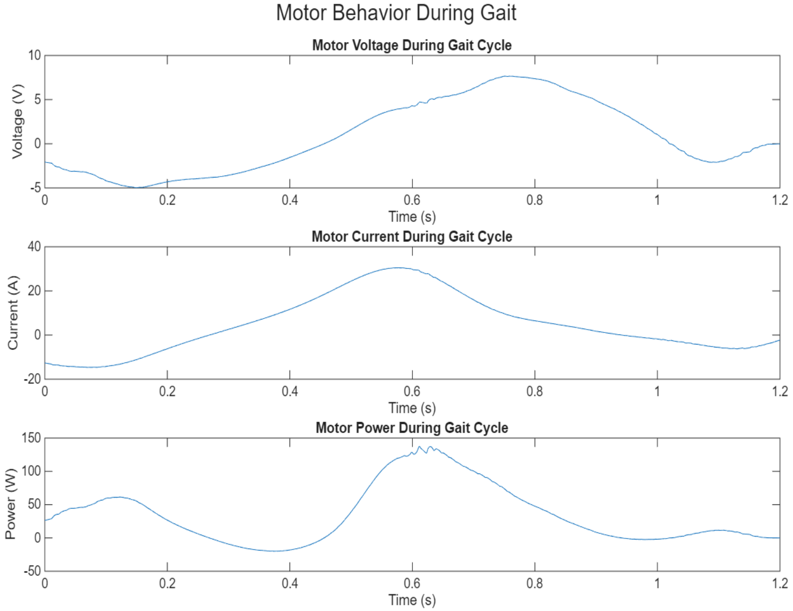
$$P_{hip} = \tau_{hip} \cdot \omega_{hip}$$



$$I = \frac{\tau_m}{k_t}$$

$$V = IR + k_t \omega_m$$

$$P = V \cdot I$$



Other Activities Analyzed

- Ramp Ascent/Descent
- Stair Ascent/Descent
- Sit-to-Stand

Motor Analysis

- Specifications from CubeMars
- Plugged into previous equation
- Analyzed in MATLAB

Metric / Spec	AK80-64 (KV80)	AKE90-8 (KV35)
Torque constant k_t(N·m/A)	0.136	0.272
Resistance R(Ω)	0.220	0.164
Motor inertia J_m(kg·m²)	5.645×10^{-5}	3.377×10^{-4}
Internal gear ratio	64:1	8:1
KV (rpm/V)	80	35
Voltage limit (system)	48 V	48 V
Peak current limit (motor)	19 A	72 A
Continuous current limit (RMS)	7 A	21 A
Weight (g)	850	1400

Motor Analysis

Motor	Gear Ratio	Peak Current (A)	RMS Current (A)	Max Voltage (V)	Max Power (W)
AK80-64 KV80	1	8.44	3.63	25.75	81.28
AKE908 KV35	1	30.47	13.84	7.66	137.56

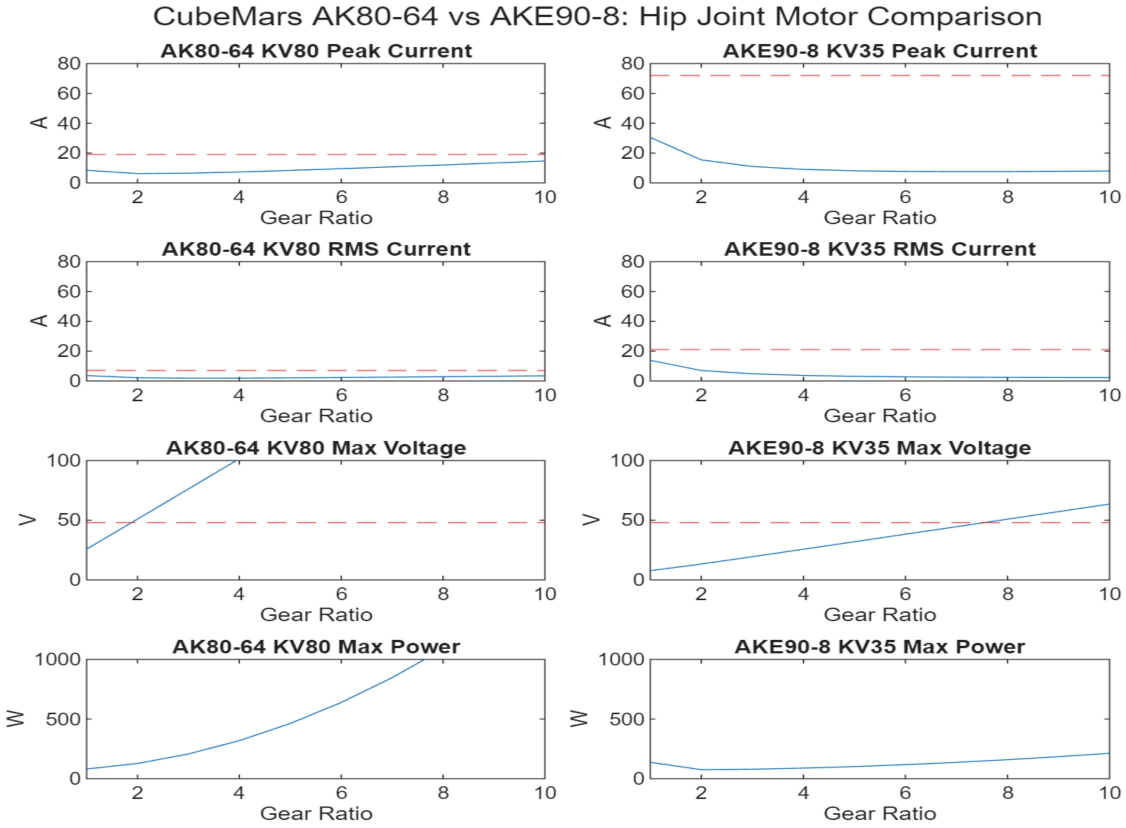
Motor Selection

AK80-64 (KV80)

- Provides required hip torque with lower electrical demand
- Stays within limits
- More efficient – smaller battery use
- Lighter weight

What's Next

- Real-life motor testing
- Thermal Analysis
- Control



CubeMars AK80-64 vs AKE90-8: Hip Joint Motor Comparison

AK80-64 KV80 Peak Current

AKE90-8 KV35 Peak Current

AK80-64 KV80 RMS Current

AKE90-8 KV35 RMS Current

AK80-64 KV80 Max Voltage

AKE90-8 KV35 Max Voltage

AK80-64 KV80 Max Power

AKE90-8 KV35 Max Power

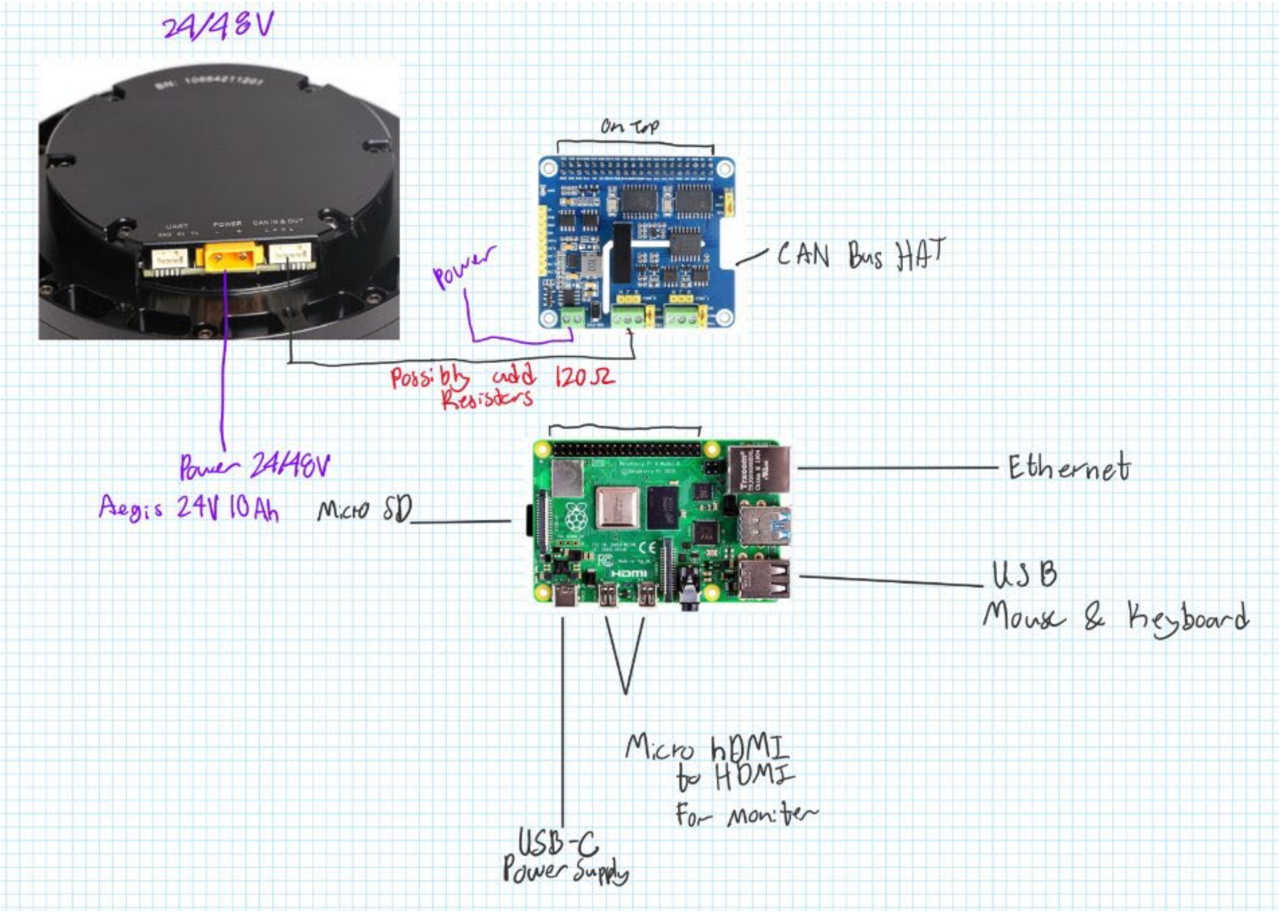
Electrical Sub Assembly

Main Parts

- Motor AK80-64
- Raspberry Pi 4b
- CAN bus hat
- Aegis Lithium Ion Battery
- LabVIEW interface

Function

- CAN bus works to connect to motor and Pi
- Pi works as brain for the device.
- Motor moves the shaft in desired direction.



Engineering Calculations – Shaft Design

What shaft material will best support the necessary load of walking?

Parameters:

- $d = 20mm$
- $T_m = 48\ N * m$
- $M_a = 176\ kN * m$
- $S_e(AL) = 270\ MPa \mid S_{ut}(AL) = 110\ MPa$
- $S_e(Ti) = 480\ MPa \mid S_{ut}(Ti) = 550\ MPa$
- $T_a = M_m = 0$

Von Mises Stress:

$$\sigma'_a = \sqrt{(\frac{\mathbf{32}K_f M_a}{\pi d^3})^2 + 3(\frac{\mathbf{32}K_{fs} T_a}{\pi d^3})^2}$$

$$\sigma'_m = \sqrt{(\frac{\mathbf{32}K_f M_m}{\pi d^3})^2 + 3(\frac{\mathbf{32}K_{fs} T_m}{\pi d^3})^2}$$

Results	Aluminum (6061)	Titanium (Grade 4)
σ'_a	336.25 MPa	340.71 MPa
σ'_m	.0382 MPa	.0425 MPa
σ'_{max}	336.29 MPa	340.75 MPa

Based on these results, **Grade 4 Titanium would be the best material solution**.

Further adjustments could include shoulder design / filet grooves on shaft to improve stress distribution.

Engineering Calculations – Battery

Assumptions (From the motor analysis)

Maxes

- Voltage = 30.5 V
- Peak Motor Current = 8.44 A
- RMS Motor current = 3.6A
- Implied electrical power = 102.75 W
- η = 0.90
- Depth of Discharge = 80% (Lithium-ion Battery)

Equations:

$$E_{bat,needed} = \frac{P \cdot t}{\eta} \quad (\mathrm{Wh}) \qquad \mathrm{Ah}_{nom} = \frac{E_{bat,needed}}{V} \qquad \mathrm{Ah}_{pack} = \frac{\mathrm{Ah}_{nom}}{\mathrm{DoD}}$$

1) Energy of the battery: Energy in W-h needed to run for time
2) Nominal pack capacity: Amp hours of capacity needed by the battery.
3) Pack Capacity accounting for DoD: Takes in account of the depth of discharge

Run time	Energy of Battery	Ah (nominal)	Ah (DoD)
30 min	57.08	1.87	2.34
1 hour	114.17	3.74	4.68
4 hours	456.67	14.97	18

Choice

We decided on the Aegis 24V 10Ah Lithium-Ion battery pack.

DoD of 100% and η of 90%

We expect to get 1.5 Hours to 2 Hours

Engineering Calculations - Bearing

Assumptions:

S_f = 2
F_r=1324N
D_i= 20mm
The bearing loaded at the end of shaft, reaction force located ¾ along the shaft

Reaction Force:

$$\sum M = 0 \sum F = 0$$

$$F_D = 1986\ N$$

Allowed force of 6550N via online research

Bearing Life:

Bearing listings give all the information we need to test if our bearing is suitable.

$$L_R = 10^6 \qquad C_{10} = 6550N$$

To find bearing life we use 2 formulas:

$$C_{10} = F_D(\frac{L_D}{L_R})^{\frac{1}{3}} \quad \text{and} \quad L_D = l_D n_D 60$$

Combined to get

$$l_D = \frac{1}{60n_D} L_R(\frac{C_{10}}{F_D})^3$$

Giving us a lifetime rating of **9965 hours** of operation.

Design Validation - FMEA

1. Identify				2. Classify									3. Take action	4. Action results			
Item (component, part, assembly)	Function	Requirements	Failure mode	Effect(s) of potential failure	Severity	Classification	Potential causes of failure	Current design controls (prevention)	Occurrence likelihood	Current design controls (detection)	Effectiveness of best method of detection control	RPN (Risk priority no.)	Recommended action(s)	Severity	Occurrence	Detection	RPN (Risk priority no.)
Motor	Providing torque to the shaft	Motor must provide enough torque, smooth, accurate torque/positioning	Control instability or sustained vibration during gait	User discomfort, reduced balance, risk of fall, joint wear	9	Safety	Poor control tuning, insufficient damping	Torque limits, firmware control	3	Manual Testing, Encoder	3	81	Implement rate limits, use high-rate inner current/torque loop	9	2	2	36
Motor	Providing torque to the shaft	Motor must provide enough torque	Motor can not meet required torque to lift leg	Leg stops moving	4	Product failure	Motor is defunct	Product testing, inspection	1	Torque monitor, current sensing	1	4	Maintenance schedule	5	4	3	60
Motor Shaft	Power Transmission	Transmit movement	Detaches from motor	Hinders rotation	10	Safety	Fastener failure, vibration	Motor casing, using standard bolts	3	Gait stability	4	120	Include repair kit, include fasteners or clamps with design.	10	2	2	40
Motor Shaft	Power Transmission	Handles load	Shaft breaks	Joint & leg detaches	10	Safety	Material failure	Material Selection, mathematical modeling	2	Gait stability	4	80	Replace shaft, bring to prosthetist	5	3	3	45

Design Validation - FMEA

1. Identify				2. Classify									3. Take Action	4. Action Results			
Item (component, part, assembly)	Function	Requirements	Failure mode	Effect(s) of potential failure	Severity	Classification	Potential causes of failure	Current design controls (prevention)	Occurrence likelihood	Current design controls (detection)	Effectiveness of best method of detection control	RPN (Risk priority no.)	Recommended action(s)	Severity	Occurrence	Detection	RPN (Risk priority no.)
Battery	Provide Power to the motor	Provides enough power for the motor to allow it to produce the required torque	Does not reach required power	The motor doesn't power the leg, and the leg is not able to reach the required gate	4	Product failure	Dysfunctional battery. Low power battery.	Mathematically determines the amout of power required for the motor	1	Low voltage alarm in testing	1	4	Use battery with 20-30% capacity margin	5	4	3	60
Battery	Provide Power to the motor	Provides enough power for the motor to allow it to produce the required torque	Wires break / detatch from motor	Leg stops moving with power. potential danger with loose wires	6	Safety	wires not secured tightly	Clips built into motor, and no major movement of motor or battery, and sealing of the wires to the mold	3	Motor stops working, look at wire	2	36	secure wires closely to the mold to prevent damage and movement	7	3	2	36
Rasberry Pi Controllor (Electrical system)	Acts as a computer to provide control	Simple and easy Interface	No Control of leg	Locks in place or becomes frozen in place. Possible triping and injury	4	Product failure	Code is wrong or something is unplugedx	Rasberry pie with a CANbus attachment to the motor.	4	Testing the code and wiring before using it on a individual	5	80	Implement a test sequence to make sure everything works.	4	4	1	16
Attachment Plate	Suspend system on socket	Securely hold system without movement	Detaches from socket	System detaches	10	Safety	Extreme wear, unforseen force	Secure standard fasteners	2	Stability, inspection	3	60	Safety test, user manual	5	4	3	60

Testing Procedures

Engineering Requirements Used

- Range of Motion
- Actuation Torque
- Power Efficiency of the System.

University of Utah Biomechanics Lab

Kinematic Positioning Testing

- Validate ROM by using a motion capture setup to record the position of the hip

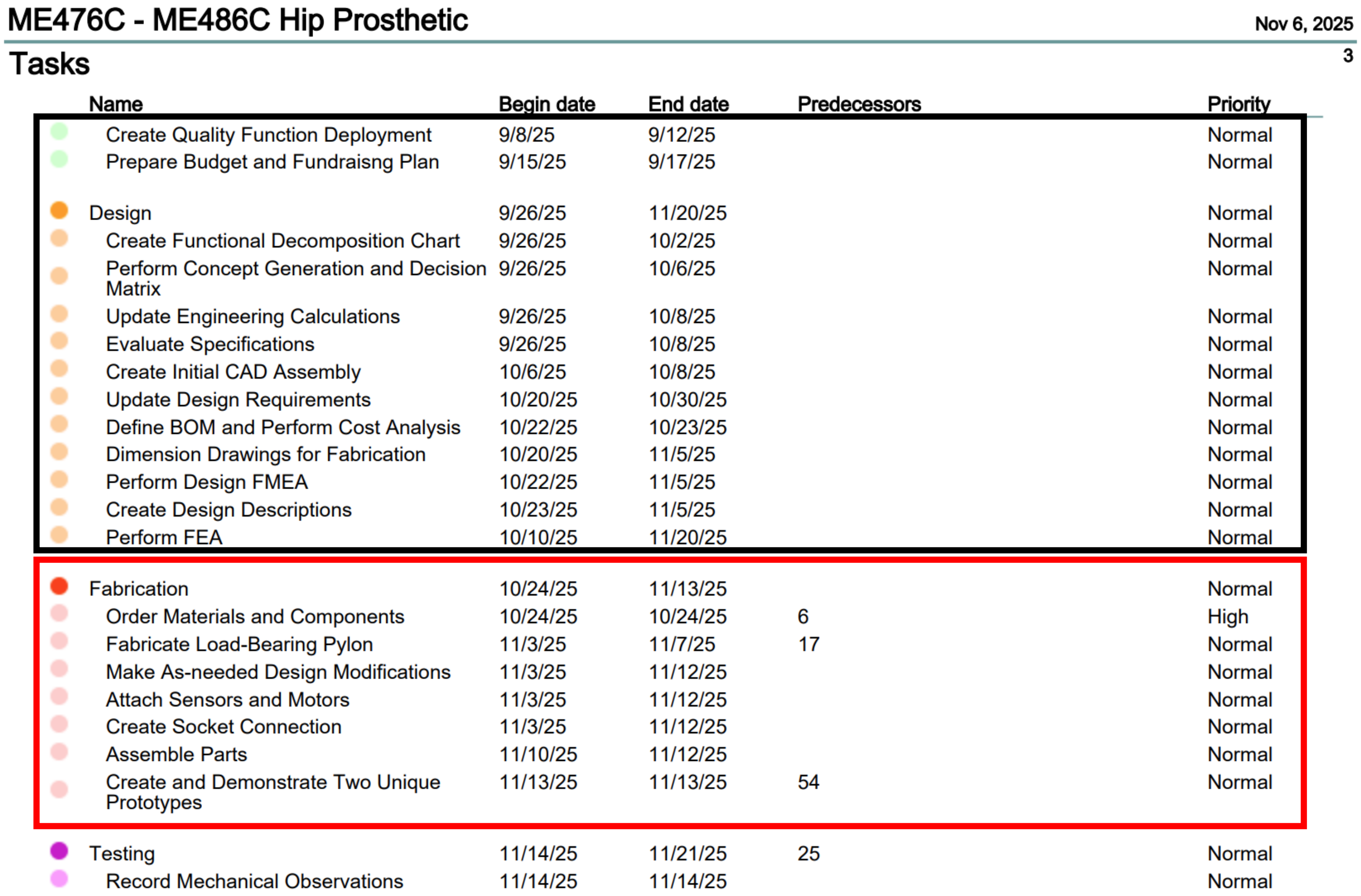
Static Load Testing

- Adding additional load to the device to verify the structural safety

Battery Endurance Testing

- Assess battery life and effects of loss of power

Schedule



ME476C - ME486C Hip Prosthetic

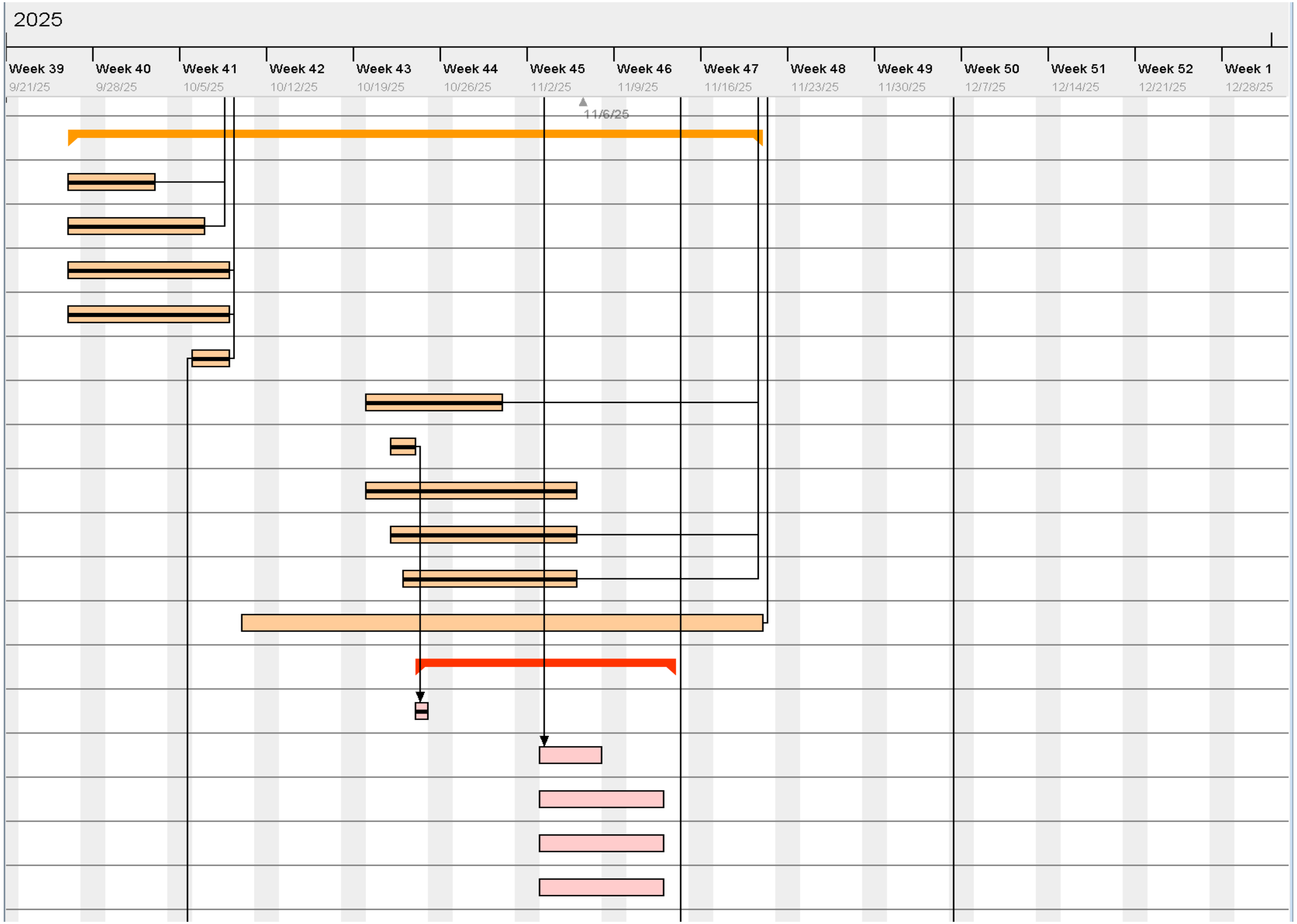
Nov 6, 2025

Tasks

3

	Name	Begin date	End date	Predecessors	Priority
●	Create Quality Function Deployment	9/8/25	9/12/25		Normal
●	Prepare Budget and Fundraisng Plan	9/15/25	9/17/25		Normal
●	Design	9/26/25	11/20/25		Normal
●	Create Functional Decomposition Chart	9/26/25	10/2/25		Normal
●	Perform Concept Generation and Decision Matrix	9/26/25	10/6/25		Normal
●	Update Engineering Calculations	9/26/25	10/8/25		Normal
●	Evaluate Specifications	9/26/25	10/8/25		Normal
●	Create Initial CAD Assembly	10/6/25	10/8/25		Normal
●	Update Design Requirements	10/20/25	10/30/25		Normal
●	Define BOM and Perform Cost Analysis	10/22/25	10/23/25		Normal
●	Dimension Drawings for Fabrication	10/20/25	11/5/25		Normal
●	Perform Design FMEA	10/22/25	11/5/25		Normal
●	Create Design Descriptions	10/23/25	11/5/25		Normal
●	Perform FEA	10/10/25	11/20/25		Normal
●	Fabrication	10/24/25	11/13/25		Normal
●	Order Materials and Components	10/24/25	10/24/25	6	High
●	Fabricate Load-Bearing Pylon	11/3/25	11/7/25	17	Normal
●	Make As-needed Design Modifications	11/3/25	11/12/25		Normal
●	Attach Sensors and Motors	11/3/25	11/12/25		Normal
●	Create Socket Connection	11/3/25	11/12/25		Normal
●	Assemble Parts	11/10/25	11/12/25		Normal
●	Create and Demonstrate Two Unique Prototypes	11/13/25	11/13/25	54	Normal
●	Testing	11/14/25	11/21/25	25	Normal
●	Record Mechanical Observations	11/14/25	11/14/25		Normal

Schedule


2025
Week 39
9/21/25
Week 40
9/28/25
Week 41
10/5/25
Week 42
10/12/25
Week 43
10/19/25
Week 44
10/26/25
Week 45
11/2/25
Week 46
11/9/25
Week 47
11/16/25
Week 48
11/23/25
Week 49
11/30/25
Week 50
12/7/25
Week 51
12/14/25
Week 52
12/21/25
Week 1
12/28/25
11/6/25

Budget Overview

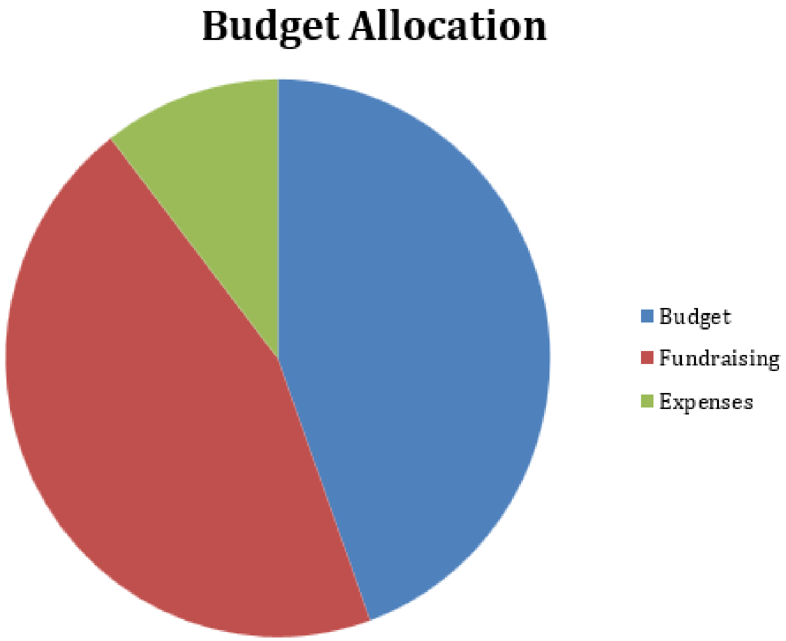
Budget		4500		
Fundraising		4550		
Expenses		1064.82		
Available Balance		7985.18		

FUNDRAISING LOG

Date	Source	Amount ($)	Type	Notes
Pending	i-Corp Aspire Course	$3,000	Monetary	On hold
10/29/2025	NextStep Prosthetics	$1,500	In-Kind	Physical Lower Leg
11/5/2025	NextStep Prosthetics	$50	In-Kind	3D Printing

EXPENSE LOG

Date	Item/Purpose	Amount ($)	Location	Notes
10/27/2025	Adapter	3.21	NAU Surplus	
10/27/2025	Micro HDMI cable	31.81	BestBuy	
Pending	AK80-64 Kv80 Motor	989.9	CubeMars	With driver board
Pending	RUBIK Link V2.0	39.9	CubeMars	



Thank you

References

- https://www.cubemars.com/product/ake90-8-kv35-quasi-direct-drive-actuator.html
- https://www.cubemars.com/product/ak80-64-kv80-robotic-actuator.html