NORTHERN ARIZONA UNIVERSITY

BIOMECHATRONIC HIP EXOSKELETON TEAM (BHET)

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INTRODUCTION (KEEGAN)

Project Overview

Project Clients

- Leah Liebelt
- Biomechatronics Lab at NAU

Project Goal

- Design the mechanical portion of a hip exoskeleton that assists walking for children with cerebral palsy
- Will compliment other exoskeletons already in use (knee and ankle)

Project Sponsors

- W.L. Gore and Associates

What Will the Exoskeleton Do?

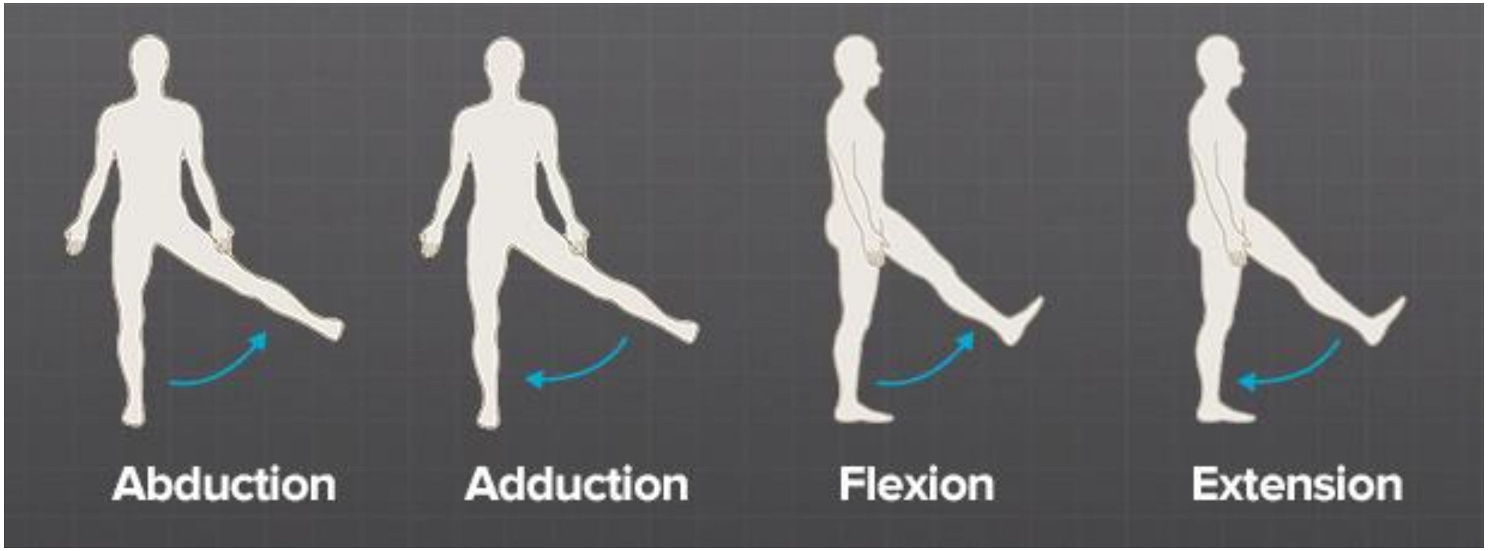


Figure 1: Hip Movement [1]

The Hip Exoskeleton Must Assist Movement in Flexion and Extension

It Must also Allow for Full Freedom of Motion in Abduction and Adduction

[1] Brainlab.org, "How Does a Hip Joint Move?," Brainlab.org, [Online]. Available: https://www.brainlab.org/get-educated/hip/hip-anatomy/how-does-your-hip-joint-move/. [Accessed 22 April 2020].

REQUIREMENTS AND SPECIFICATIONS (KEEGAN)

Customer and Engineering Requirements

Table 1: Customer Requirements

Customer Requirements	Weights
Hip Actuation	5
Full Range of Motion	5
Sense Torque	5
Minimize Metabolic Cost	4
Safe to Operate	4
Untethered	4
Durable	3
Easy to don and doff	2
Comfortable	2
Reliable	2
Within Budget	1
Fit small to medium build	1

Table 2: Engineering Requirements

Engineering Requirements	RTI	Units
Extension/Flexion ↑	11.3%	Degrees
Operation time/cycle (time per test) ↑	11.0%	Minutes
User comfort rating (0 - 10)	9.4%	
Power Required	7.5%	Watts
Torque applied ↑	7.3%	N-m
Cost to manufacture ↓	7.3%	$
Abduction/Aduction	7.2%	Degrees
Rotation	7.2%	Degrees
Torque to operate (unasissted) ↓	6.6%	N-m
Weight ↓	6.6%	N
Cycles to failure	6.5%	
Compliance/conformability	4.8%	
Noise ↓	3.8%	Db
Time to don/doff	3.4%	Minutes

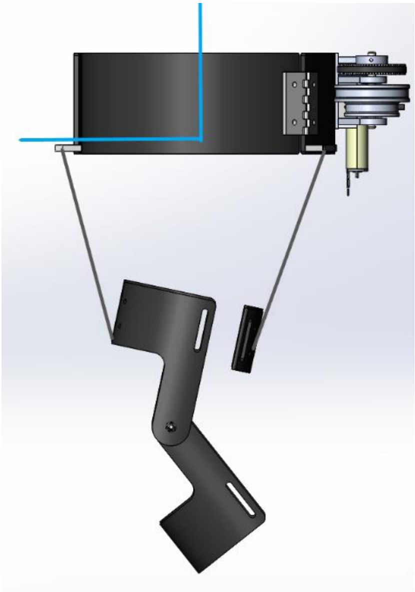
Summary of Requirements

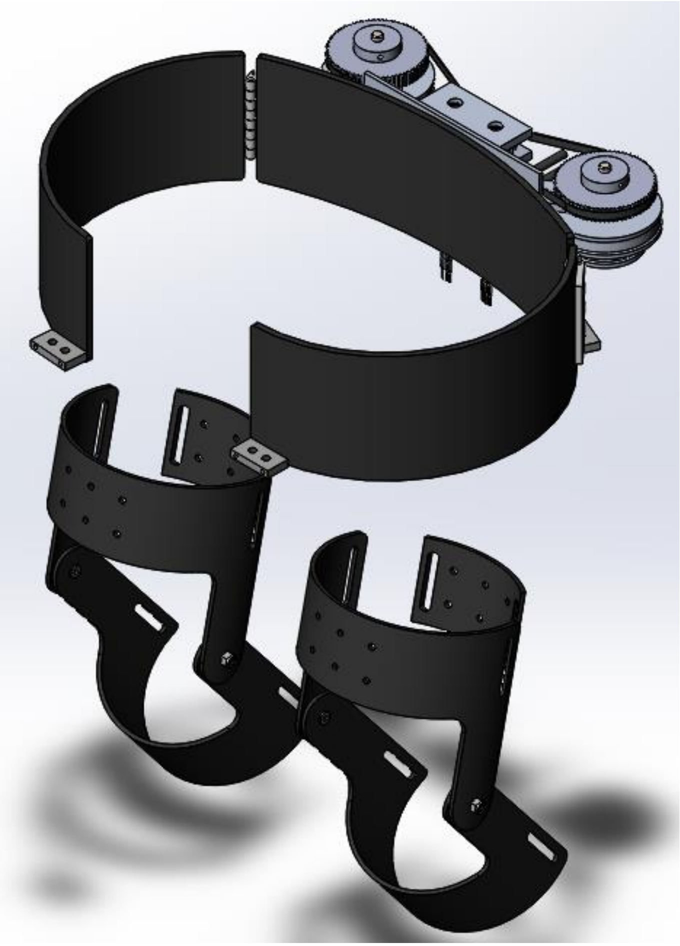
- Applies Torque in Extension/Flexion
- Allows for Full Range of Motion
- Lightweight and Comfortable
- Easy to take on/off
- Within Budget

SOLUTION TO THE PROBLEM (SEAN)

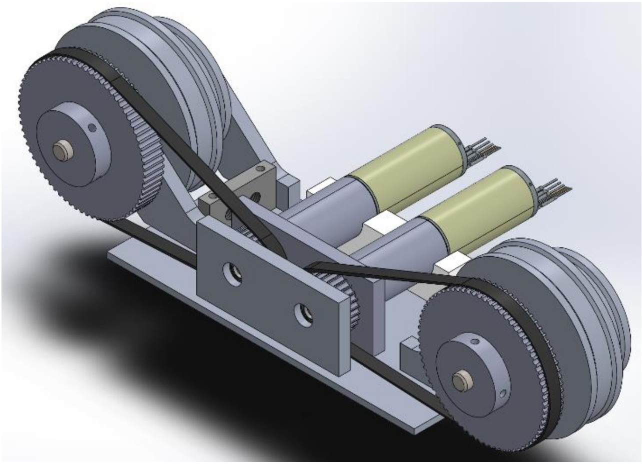
HIP EXO DESIGN OVERVIEW

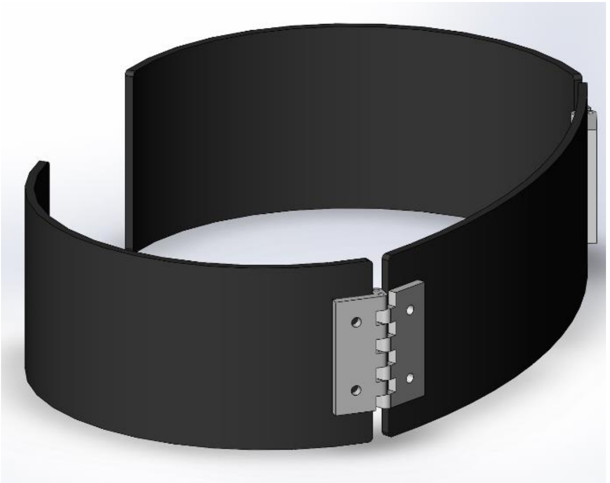
- Assistive torque generated by BLDC motors
- Torque is transmitted to the wearer through cables
- Bowden tube guides cables to be aligned with extension/flexion plane of hips





HIP EXO SUBSYTEMS





Motor Mount

- Secures drivetrain components
- Multiplies torque

Hip Belt

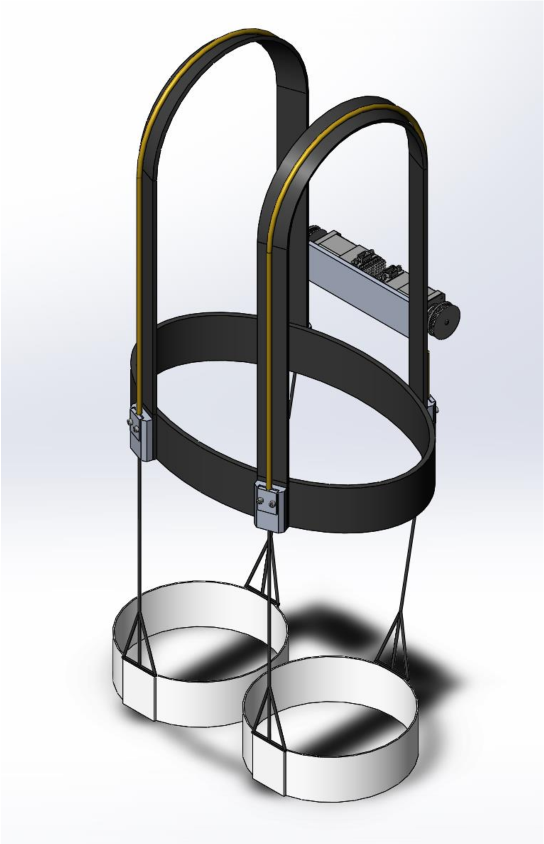
- Secures Exo to wearer
- Positions cable blocks

Knee Brace

- Transmits Torque to legs

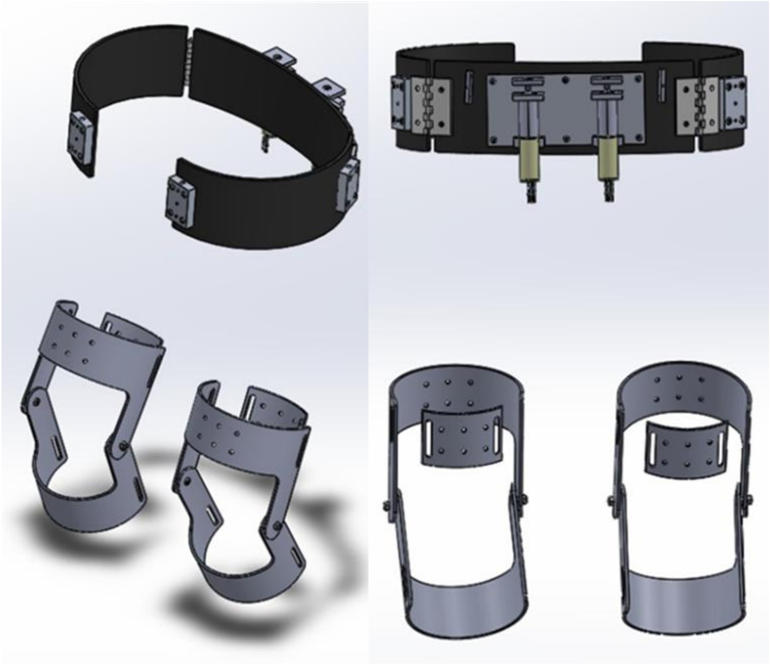
DESIGN ITERATIONS (SEAN)

HIP EXO DESIGN ITERATIONS



- Semi-Rigid Frame
- Cables directly driven by motors
- Soft straps secure legs

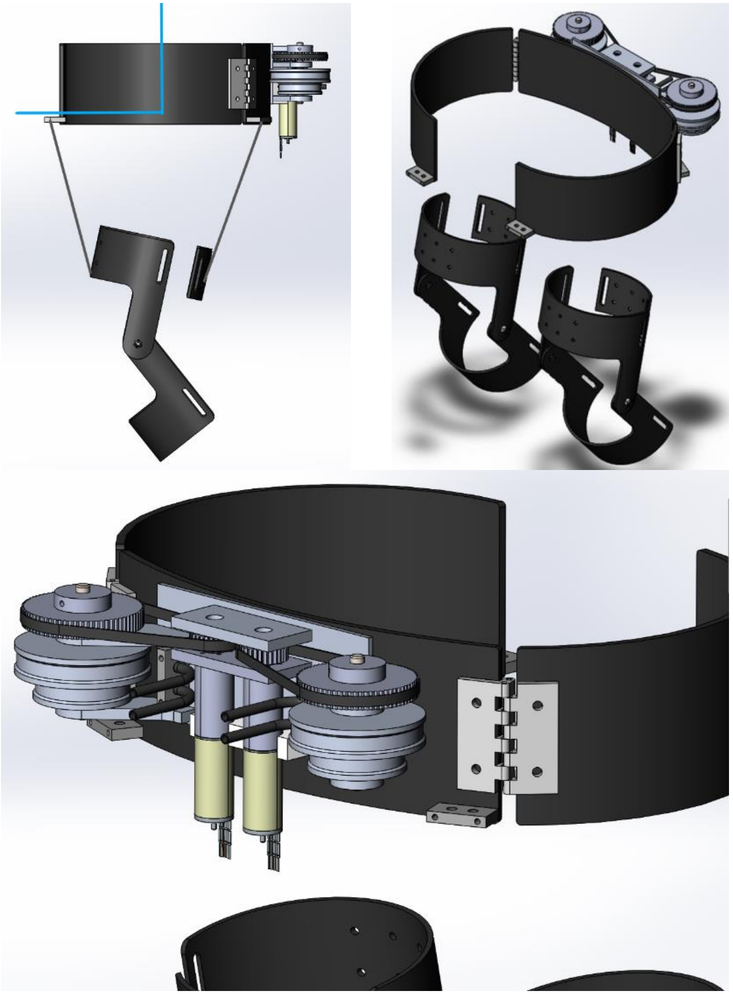
HIP EXO DESIGN ITERATIONS



- Rigid Knee Brace
- Vertical motor orientation
- Simplified harness

FINAL DESIGN

- Refined motor mount and drivetrain



MANUFACTURING (KEEGAN)

MANUFACTURING PROCESSES

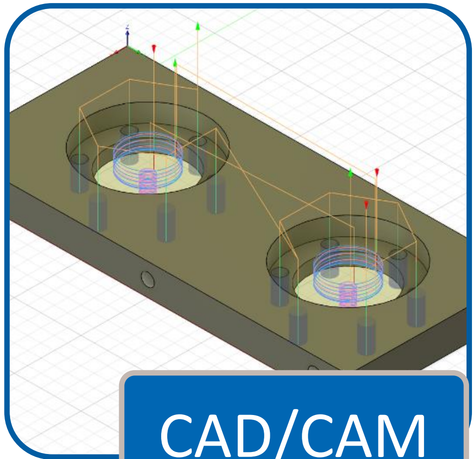
Machining

- All 6061 T6 Aluminum Parts
- Motor Mount Assembly

Forming

- All Kydex Parts
- Hip Belt and Knee Braces

MACHINING

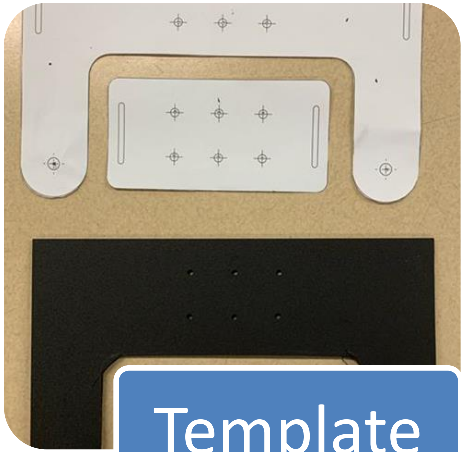


CAD/CAM

Machining

Finished Part

FORMING



Template

Forming

Finished Part

TESTING (INNA)

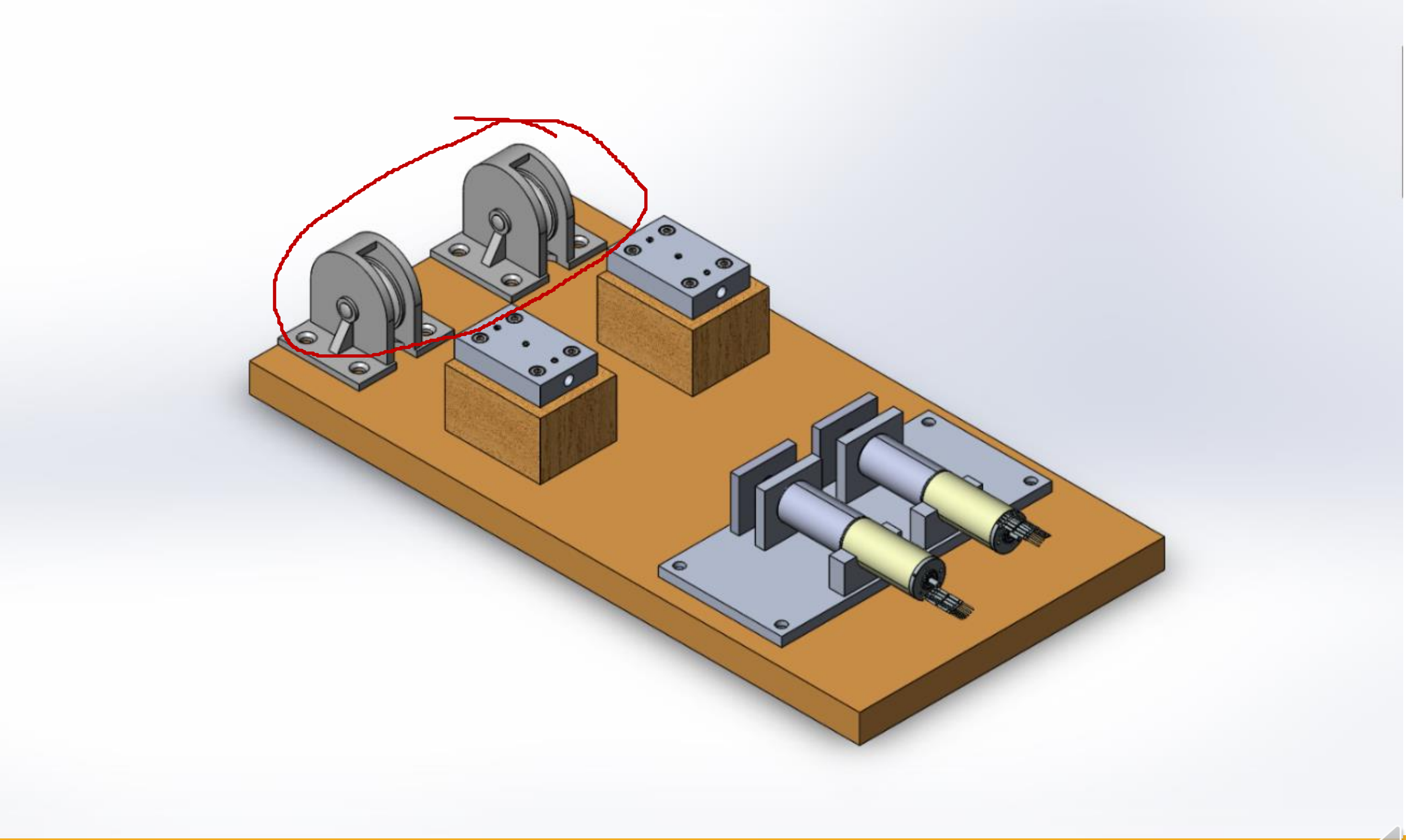
Testing Procedures

- Torque/Power Output
- User Comfort Rating/Survey
- Fitment Tests
- Fatigue Failure Modes

TORQUE/POWER OUTPUT

- Objective: Verify torque applied to the system and the power delivery of the design
- Procedure: Test will be performed using the motor mount assembly attached to a test fixture which will be shown in the following figure.
  - Torque Test: Actuation cables applied to load cells; output will be recorded by an Arduino microcontroller. Different power levels will be tested.
  - Power Test: Use of the same test fixture, actuation cables would be routed through pulleys and then attached to weights. Motors will be programmed to run and lift the weights. Time to lift weights will be recorded.

TORQUE/POWER OUTPUT



USER COMFORT RATING/SURVEY

- Objective: Receive feedback on the hip exoskeleton design from a variety of people to check for any changes that need to be completed.
- Procedure: The test would be conducted at the Biomechatronics Lab, and 10 people would be chosen to try the hip exoskeleton and answer a survey rating the experience on a 1-5 scale and comment on the experience.

Survey Qusetion	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8	User 9	User 10	Total
User comfort(Hip Belt)											
User comfort(Knee Brace)											
Time to don/doff											

FITMENT TESTS

- Objective: Test will be run by the BHET team and conducted by each team member. The tests will record weight, conformability, and range of motion.
- Procedure: The tests record the overall fit of the system
  - Weight: A high-accuracy scale would be used
  - Conformability: A tape measure will be used to record the min/max waist the belt can fit on.
  - Range of motion: each team member will move their leg in each range of motion, the angle will be measured with a goniometer.

Fatigue failure modes

- Objective: Identify points of failure in the completed device. The tested points of failure will focus on creep deformation in the motor mounts and high cycle fatigue in the Bowden cable housing.
- Procedure: The device will be mounted on the test fixture from the Torque/Power output test. Then it will be run as if it is actuating motion. Test will run until there is wear on either the Bowden cable or the motor mount. Once wear is present, the amount of cycles will be recorded.

Budget

PART (SOLIDWORKS PART NAME)	MATERIAL	DIMENSIONS (in.)	SUPPLIER	QTY.	COST/UNIT	COST
Base_Plate_V1	6061 T6 AL	0.25 x 3 x 12	OnlineMetals	1	$6.30	$6.30
Bearing_Block_V1	6061 T6 AL	0.25 x 1.5 x 48	OnlineMetals	1	$10.05	$10.05
Housing Clamps (At motor assembly)						
Housing Clamps (At cable termination)						
Face_Plate_V2						
Mounting_Bracket_V5	6061 T6 AL	0.5 x 1.5 x 24	OnlineMetals	1	$12.06	$12.06
KneeBraceTop_V2	Kydex	0.125 x 12 x 12	McMaster-Carr	2	$10.16	$20.32
KneeBraceTop-Back_V2						
KneeBraceBottom_V2						
Motors	N/A	N/A	Maxxon	2	$815.73	$1,631.46
					Total	$1,680.19

HARDWARE	MATERIAL	DIMENSIONS (in.)	SUPPLIER	QTY.	COST/UNIT	COST
M4 x 20mm (100 pack)	SS A2-70	N/A	Copper State	1	$8.76	$8.76
M4 x 10mm (100 pack)	SS A2-70	N/A	Copper State	1	$6.20	$6.20
M3 x 10mm (100 pack)	SS A2-70	N/A	Copper State	1	$4.09	$4.09
M3 x 20mm (100 pack)	SS A2-70	N/A	Copper State	1	$5.77	$5.77
Shoulder screw	316 SS	0.25 Shoulder, 10-32	McMaster-Carr	2	$5.32	$10.64
Nylon Insert Locknut (50 Pack)	316 SS	10-32 Thread Size	McMaster-Carr	1	$4.71	$4.71
Bearings for Bearing_Block_V1	Steel	3mm W, ID 6mm, OD 10mm	McMaster-Carr	2	$12.06	$24.12
					Total	$64.29

Alternative Part Materials	MATERIAL	DIMENSIONS (in.)	SUPPLIER	QTY.	COST/UNIT	COST
Bearing_Block_V1	7075 T6	0.25 x 1.5 x 48	OnlineMetals	1	$40.24	$40.24
Housing Clamps (At motor assembly)						
Housing Clamps (At cable termination)						
Face_Plate_V2						
					Total	$40.24

Legend
Already Purchased
Aquired w/out Purchase
No longer needed

Shipping - Online Metals	$21.92
Amount Purchased	$1,681.79
Amount to Purchase	$64.29
Budget	$2,250.00
Funds Available	$568.21

Future Work

finalizing the manufacturing and testing of the finished design.

The other knee brace and remaining components of the motor mount assembly will have to be completed by future parties.

The goal of this capstone project for the remainder of this semester is to lay the groundwork for future iterations of the hip exoskeleton design.

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THANK YOU