TEXAS
The University of Texas at Austin

EXO MOTION
FINAL PRESENTATION

Novel Improvements to Exoskeletal Systems

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SPRING 2025

Outline

The Problem

- **Current Exos:** Expensive, complex, and uncomfortable, limiting early-stage rehabilitation
- **Market Gap:** Low cost, user-friendly solution with effective gait training modes.

Figure 1: Eksobionics

Background

Strokes

- Stroke occurs when blood flow to the brain is blocked or interrupted, causing issues including movement, speech, and coordination impairment
- Stroke affects **15 million** annually with **80%** of survivors experiencing immediate lower limb mobility loss and **40%** long term

Current Market

- Current exos cost upwards of $100,000, prioritizing power and features over accessibility
  - **5 N-m torque** is sufficient for early rehab
- Market need for data-driven recovery progress tracking

Figure 1: Eksobionics

Problem Statement

Problem Statement

Current market exoskeletons for stroke rehabilitation are often extremely complex and thus expensive, which limits their overall accessibility and usability.

This project aims to improve lower limb exoskeletons by developing an early-stage rehabilitative knee exoskeleton that prioritizes cost-effectiveness, usability, and comfort.

Key Objectives & Core Functions

Key Objectives

1) Achieve 5 N-m torque output
2) Maintain target cost of $1,000 - $2,000
3) Support 70 degree knee flexion
4) Accurate motion tracking at 100-200 Hz and SEA torque sensing at 1000 Hz
5) Reliable torque control with 15% measured error

Core Functionality

- Provide noticeable movement support through a low-torque SEA (5 N-m) with impedance-based and position-based control
- Track movement and user comfortability with incorporated motion sensors (IMUs) and pressure sensors (FSRs)
- Display and store live data to mobile devices/the cloud for clinicians and researchers using Bluetooth

Core Functions

- Provide 5 N-m of resistive and assistive torque through motors/series elastic actuator
- Track comfort through pressure sensors
- Cloud data storage

Design Process

Design Alternatives - Selected Innovation Points

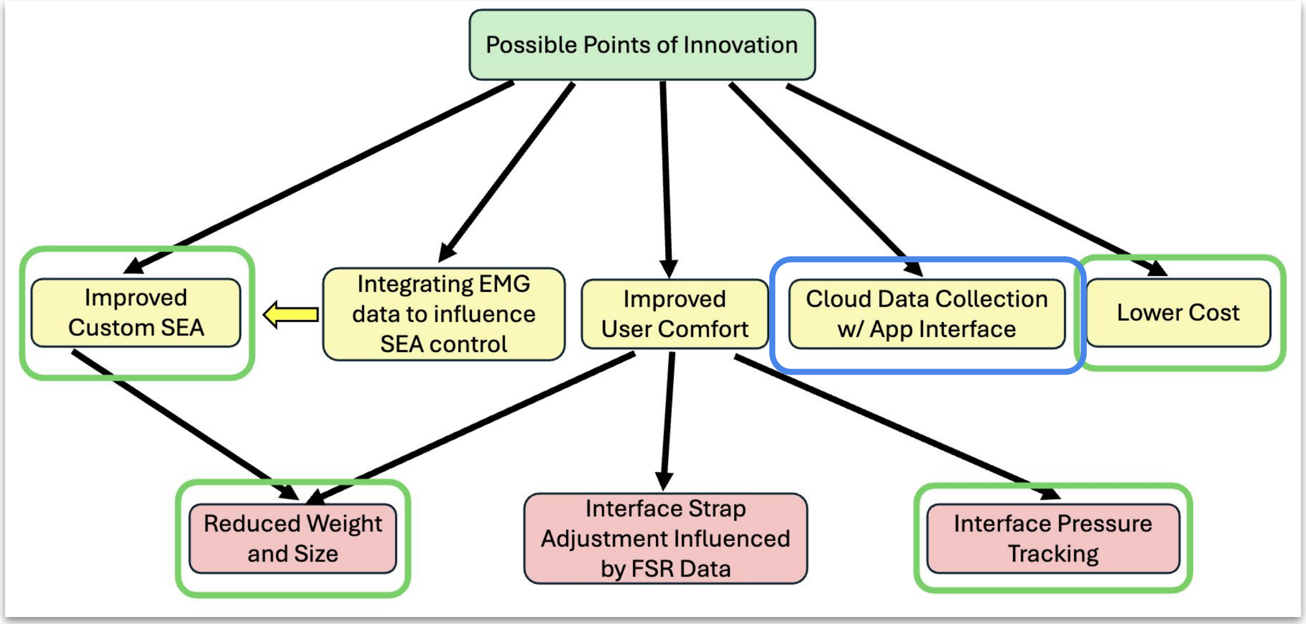


Figure 2: Selected Points of Innovation

Proof-of-Concept

"Pegboard Prototype"

- Test control system
- Identify issues

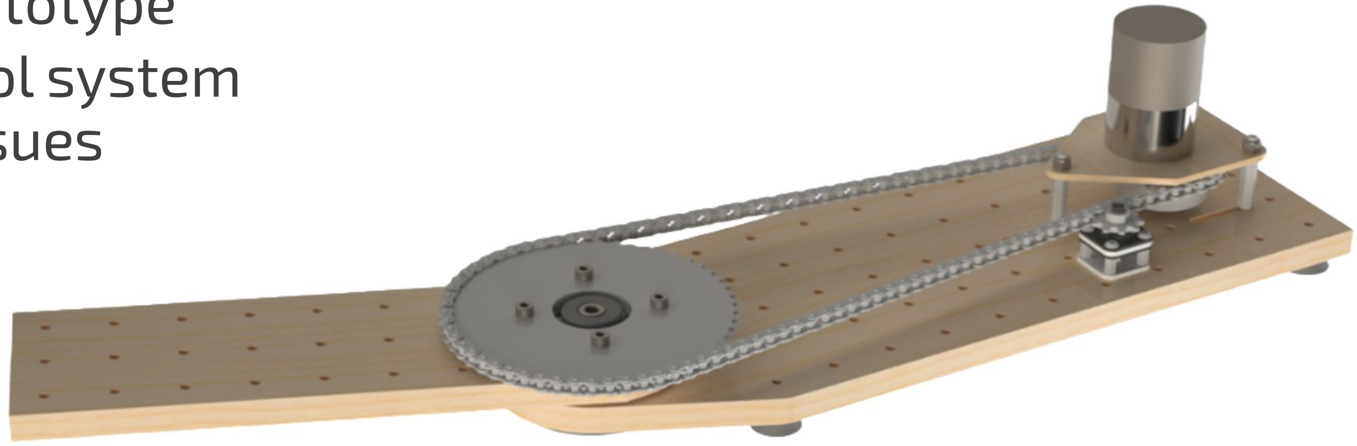


Figure 3: Pegboard Prototype

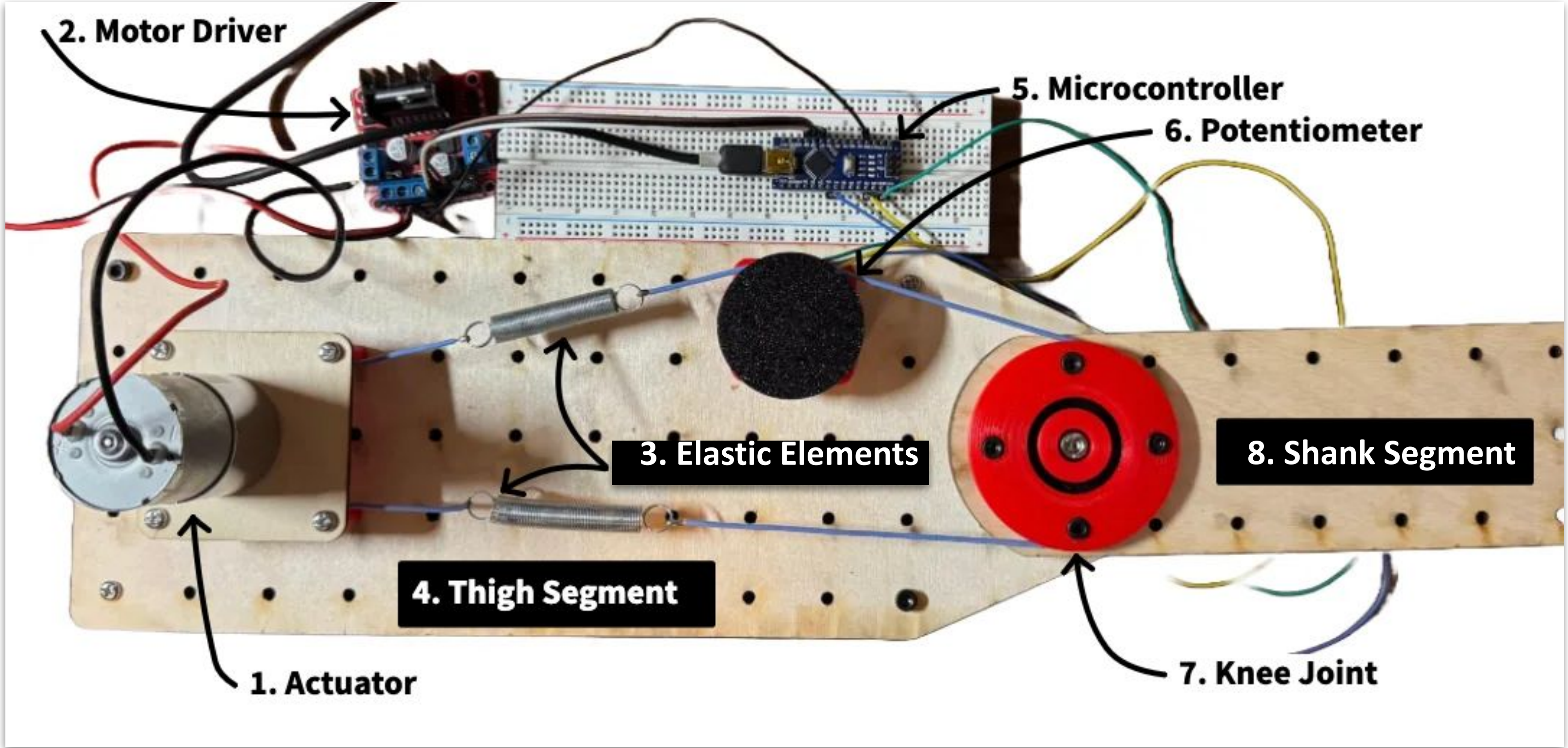


Figure 4: Physical Pegboard Prototype

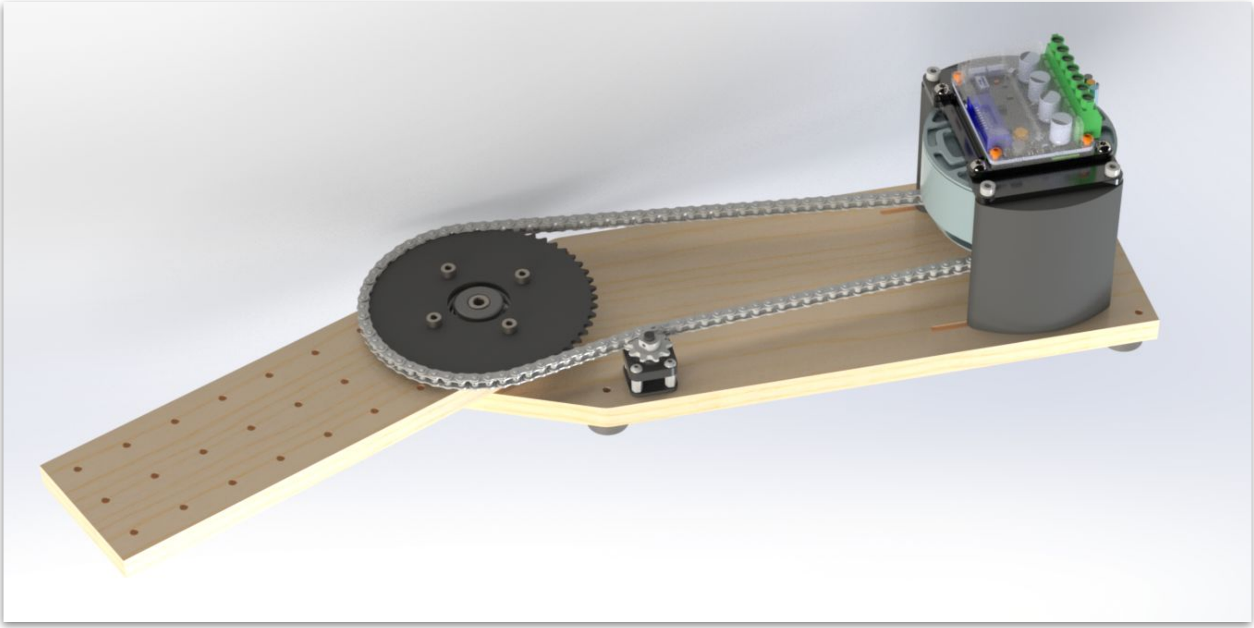


Figure 5: Updated Proof-of-Concept Prototype with new Motor

Final Design Prototype

Final Design Render

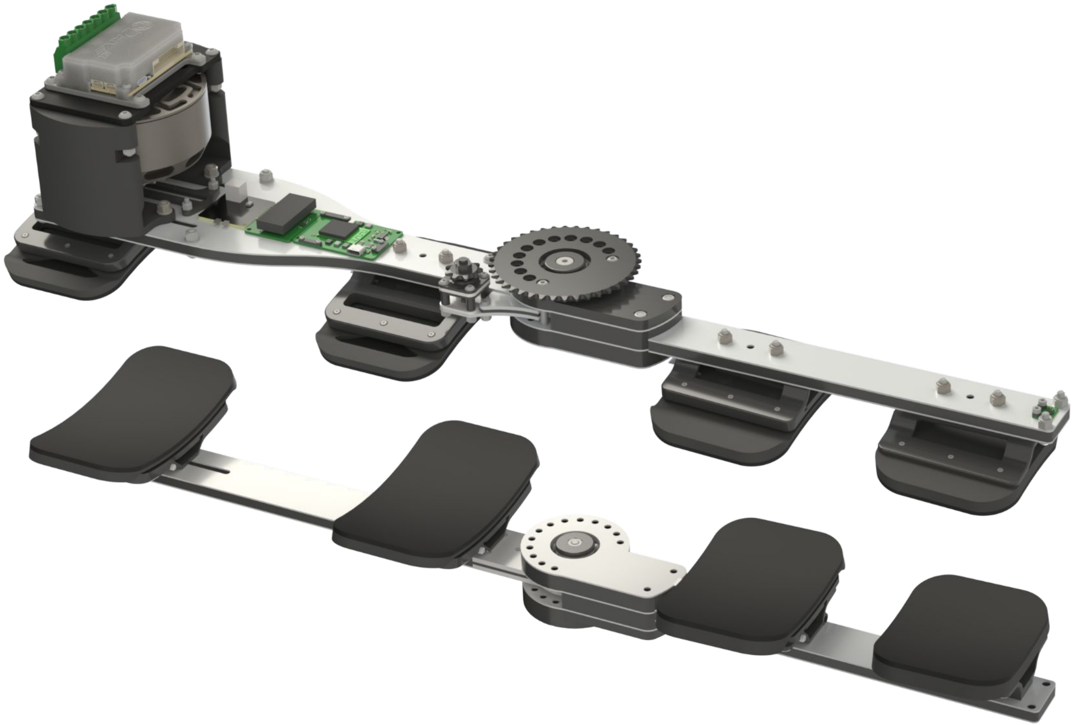


Figure 6: Final Design Render

Components

- Frame: Delrin Core + 6061 Aluminum Plates
- 6S Battery
- Teensy 4.0 (Microcontroller for Control System)
- ESP32 (Data Processing Microcontroller)
- ODrive M8235S Motor (ODrive S1 Driver)
- Magnetic Encoder
- Buck Converter
- Accelerometer (IMU)
- #25 Chain
- Springs
- Carbon-Reinforced PC Sprocket Interface

Components

Electronics

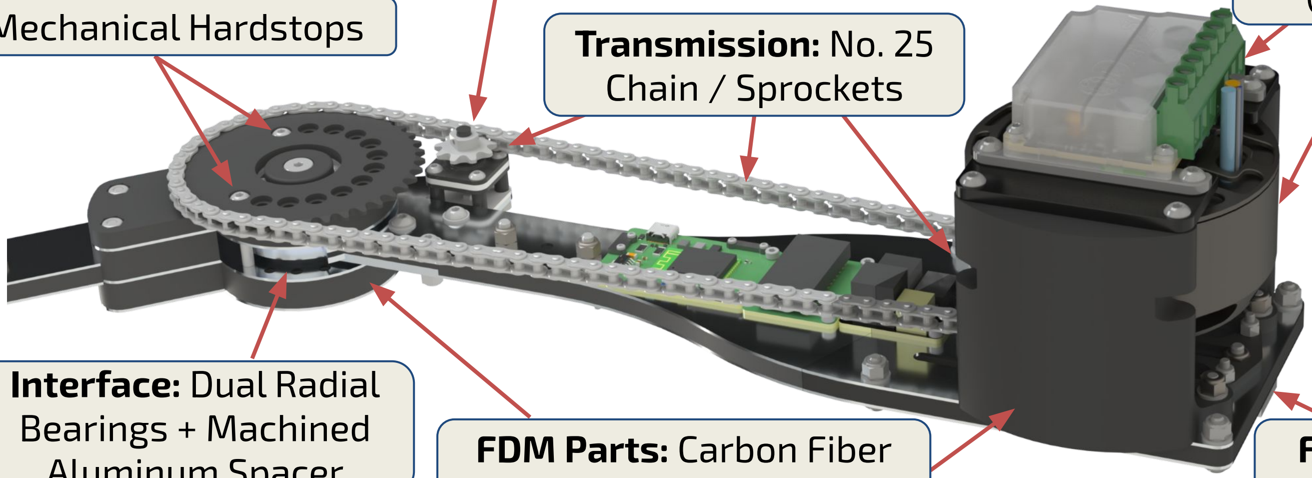
- Teensy 4.0 (Microcontroller for Control System)
- ESP32 (Data Processing Microcontroller)
- Buck Converter

End Effector Torque Monitoring: Magnetic Encoder + Springs

Motor: ODrive M8235S (ODrive S1 Driver)

Safety: Mechanical Hardstops

Transmission: No. 25 Chain / Sprockets



Interface: Dual Radial Bearings + Machined Aluminum Spacer

FDM Parts: Carbon Fiber Reinforced Polycarbonate

Frame: Delrin Core + 6061 Aluminum Plates

- possibly slide with the components we used not clear in the CAD? (eg delrin core in sheet metal frame, chain, spring, teensy, inertial measurement unit) - would be very nice

Final Build

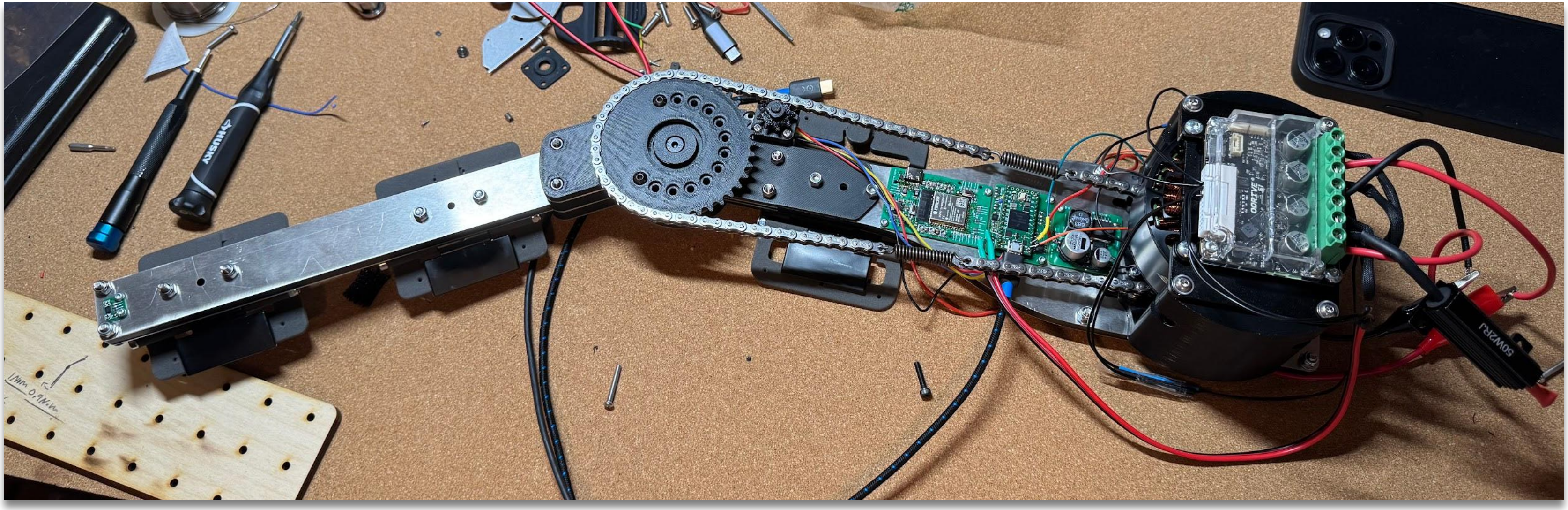


Figure 9: Half of the Exoskeleton

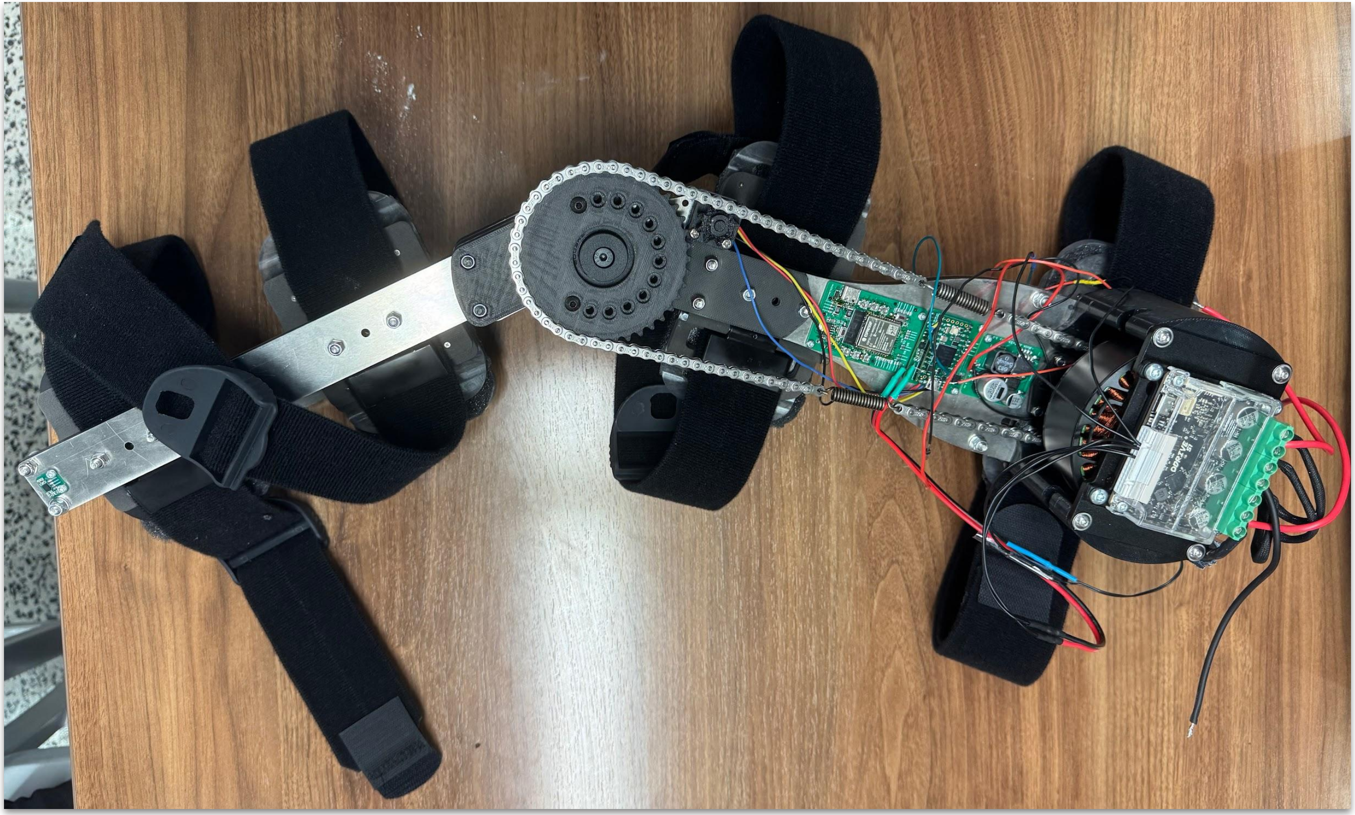


Figure 10: Full Build

Force Sensitive Resistors (FSRs)

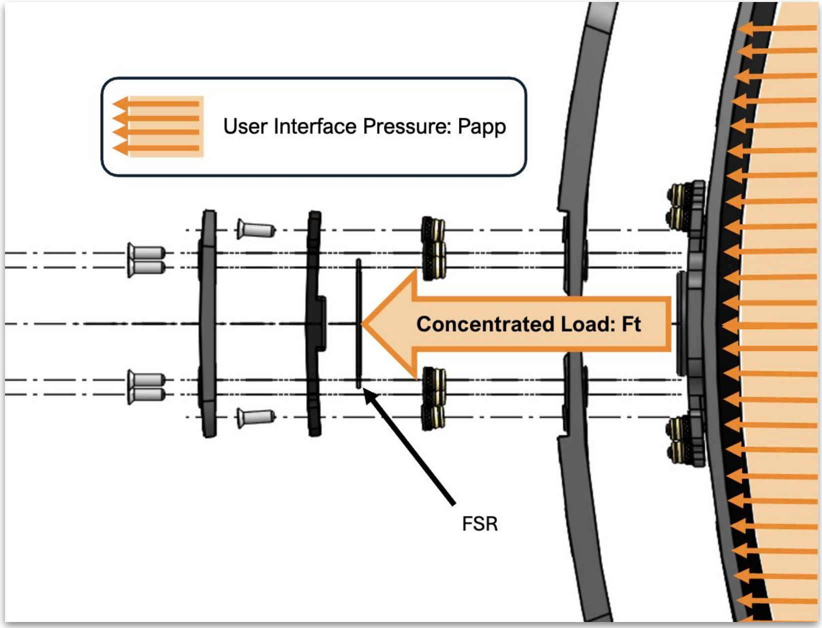


Figure 11: Force Sensitive Resistor Setup

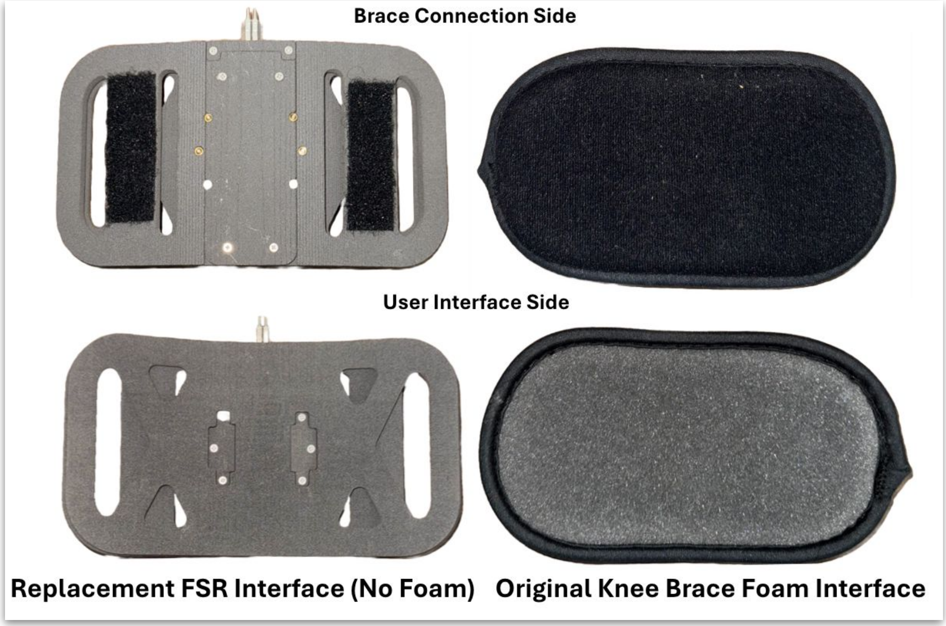


Figure 12: Foam Pads

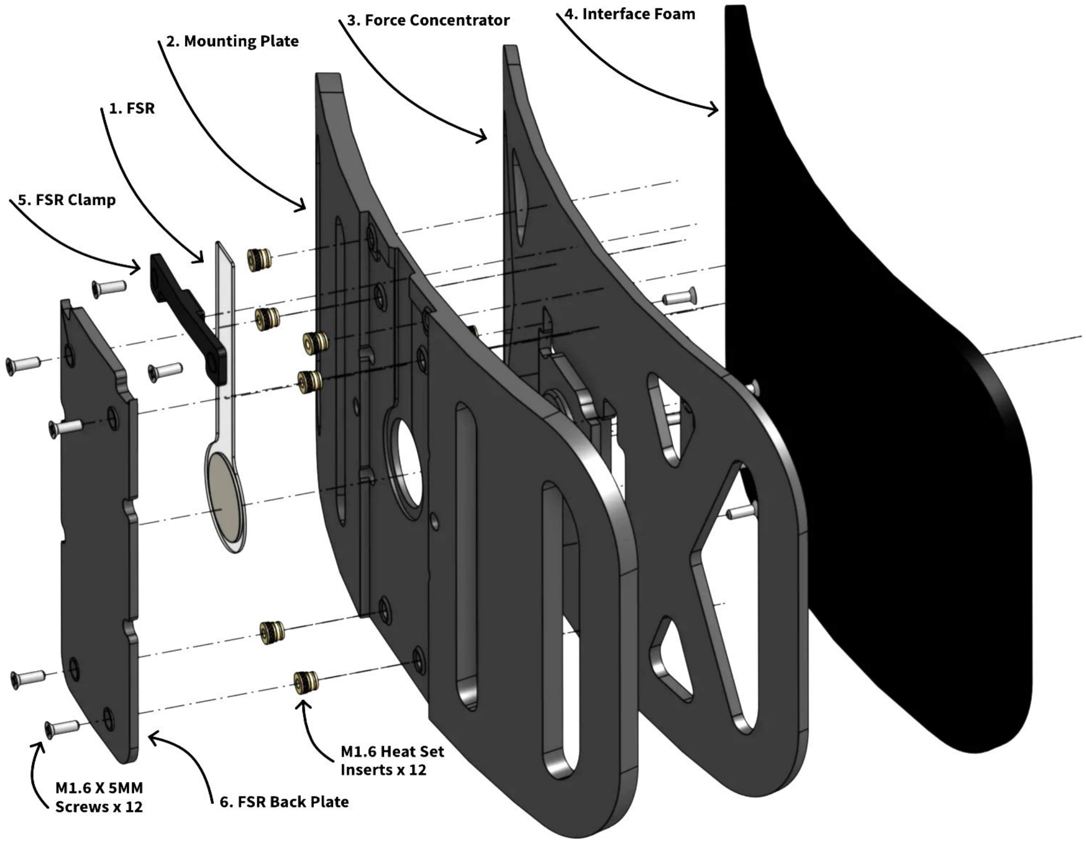


Figure 13: Exploded View of FSR Pads

Finalized Design

- “Explain why the design was chosen”
- “Explain features of the design, highlighting aspects that make it superior to other alternatives and any novel or unique features”
- We kind of did this w/ other slides alr so I’m hiding it

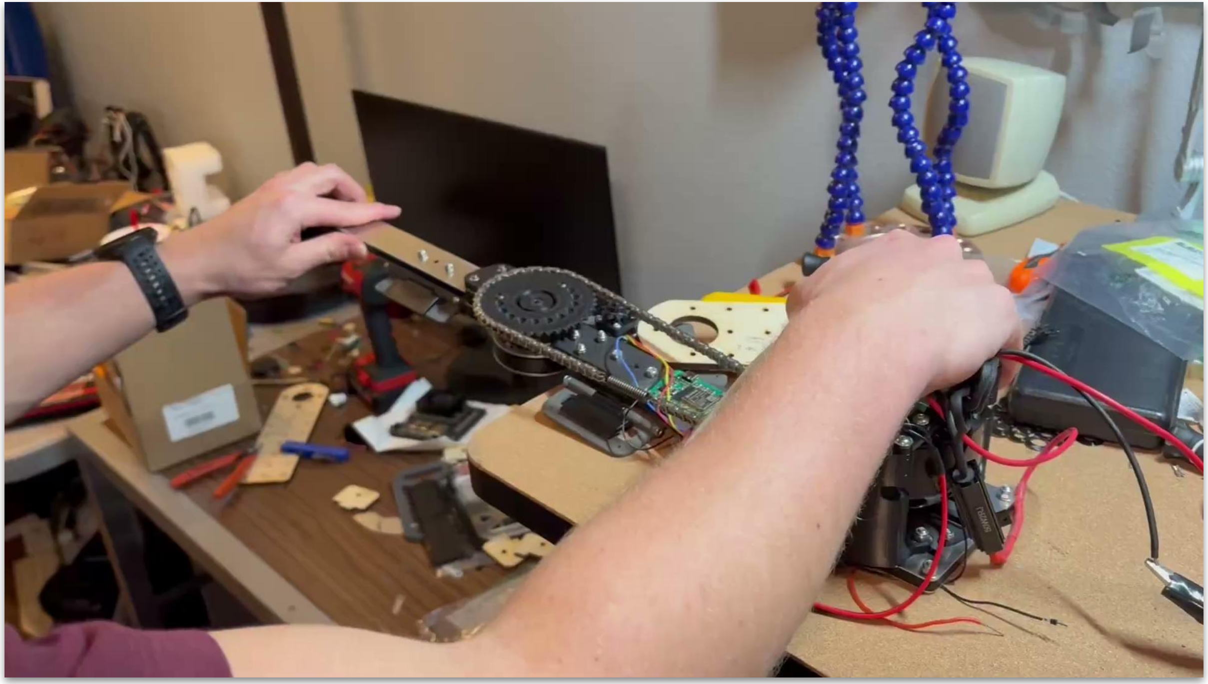
Testing & Demonstration

Testing

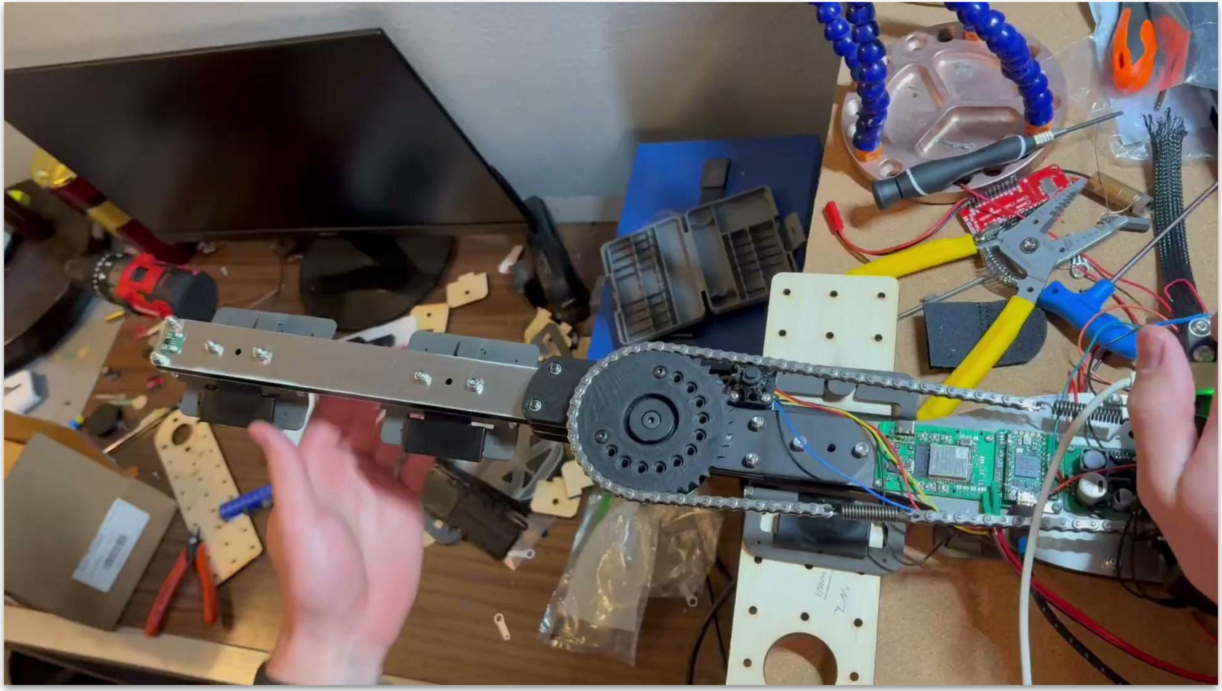
3 Step Plan

1. Test on a table with no wearer, measure 5 N-m of resistive/assistive torque
2. Qualitative sitting test, worn by team members
3. Qualitative walking test

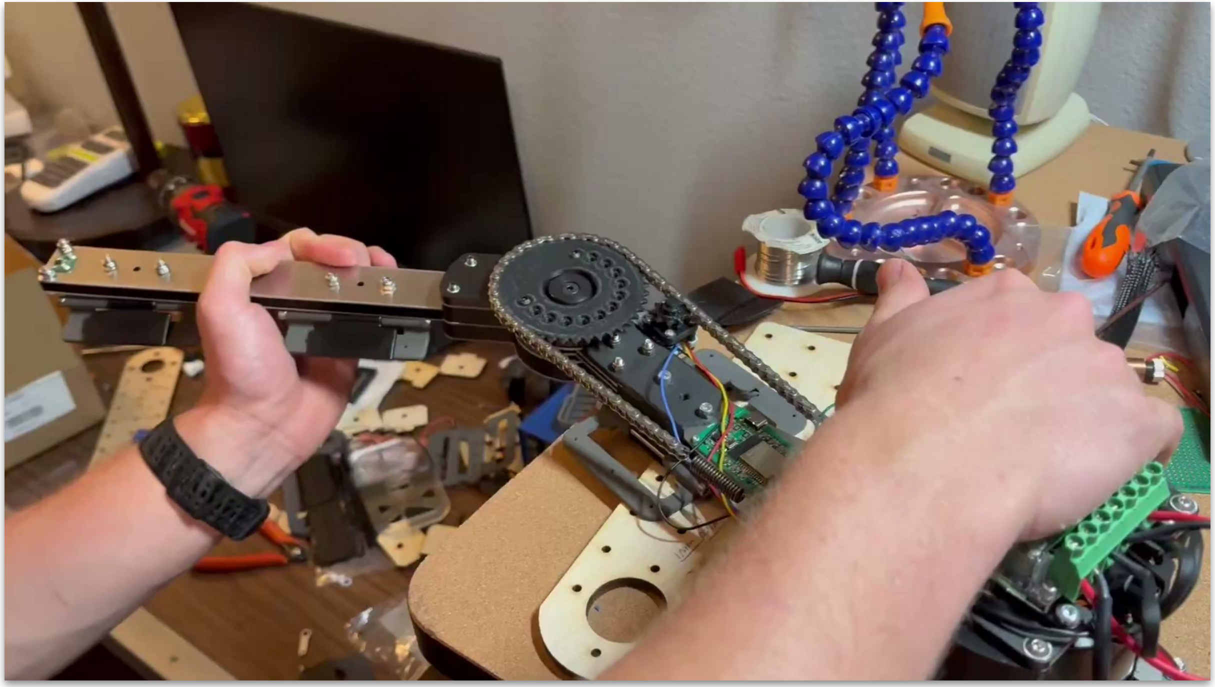
Assistive Mode



Resistive Mode



Variable Stiffness Mode



Compliance Mode

Resistive Mode

Assistive Mode

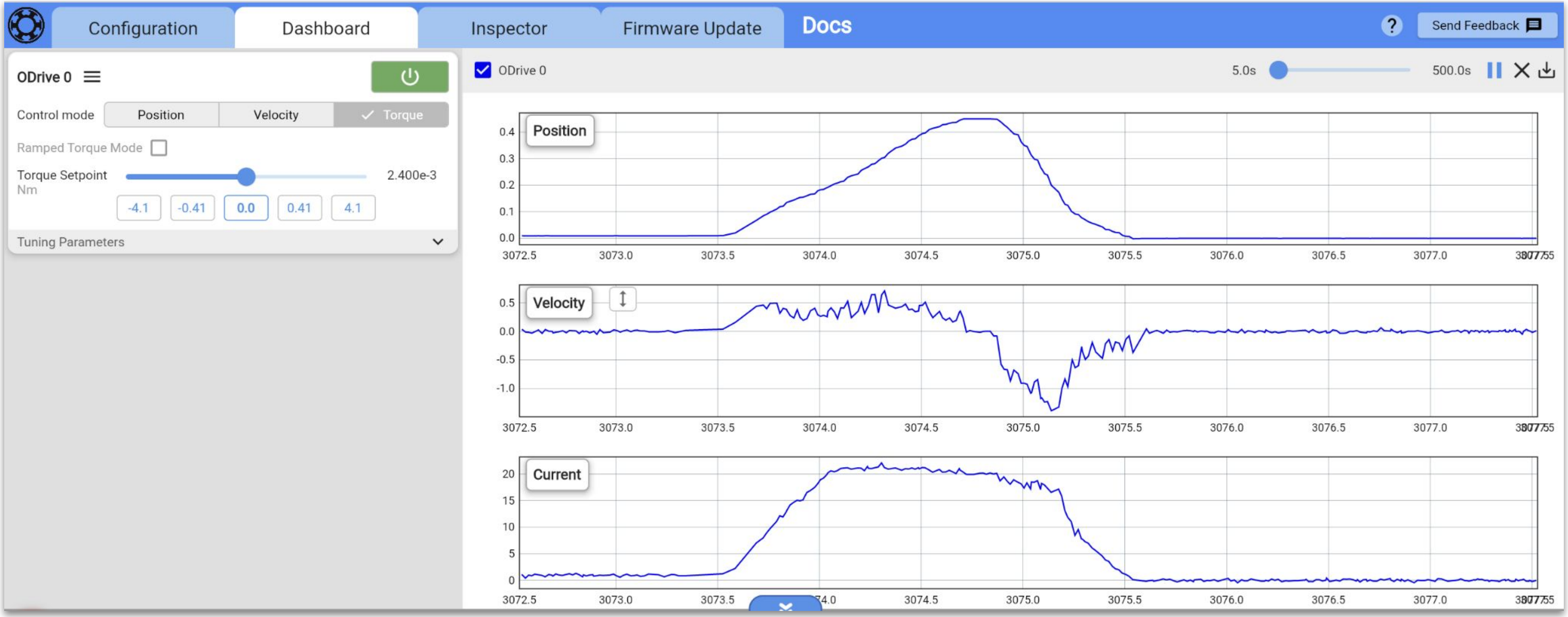


Figure 13: Testing Interface

Data Collection

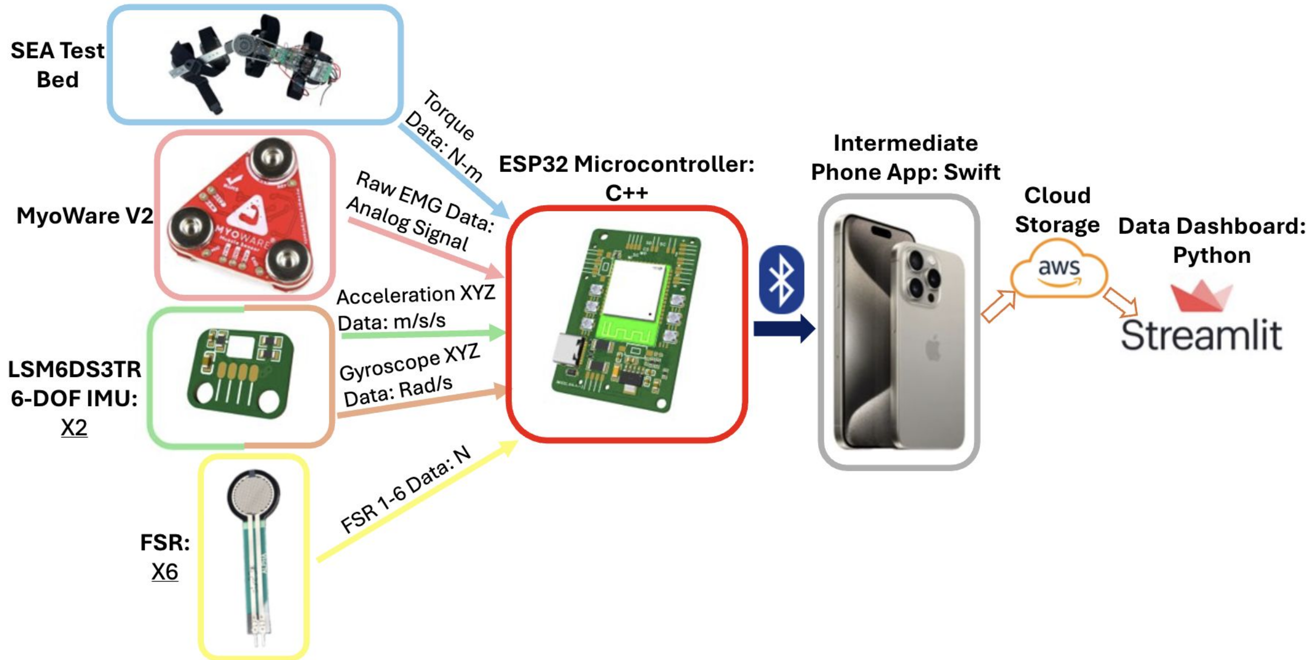


Figure 14: Data Collection Pipeline

Figure 15: Data Collection Dashboard Example

Conclusions

Cost Breakdown

Product Development Costs		
Type	**R&D Cost**	**Production Cost**
Mechanical Hardware	$633.10	< $350
Electrical Hardware	$603.29	< $475
Overhead / Labor / Misc	N/A	~ $150
Total	**$1,236.39**	**< $975**

Mechanical Construction / Hardware

McMASTER

amazon

SendCutSend

~~$633.10~~

< $350

Figure 14: Data Collection Pipeline

Electrical Hardware

MOUSER ELECTRONICS

adafruit

sparkfun ELECTRONICS

amazon

ODrive

~~$603.29~~

< $475

Figure 14: Data Collection Pipeline

Total Cost: $1,284 $\rightarrow$ < $800

Figure 14: Data Collection Pipeline

Goals Achieved

1) Achieved 3.2 N-m torque output
2) Target budget of $1,000 - $2,000 achieved ✔
3) Supported 100 degree knee flexion ✔
4) Accurate motion tracking and torque sensing ✔
5) Reliable torque control with 6% measured error ✔

Next Steps

- Current model supports assistive/resistive torque
  - Position-based variable stiffness mode
- Increased comfort
- Scalable manufacturing
- Potential future revisions:
  - Myoelectric sensors to validate progress

Acknowledgments

- Dr. Scott Evans *(Advisor/Sponsor)*
- Dr. Keena and Dr. Rylander *(Course Instructors)*
- Emily Landgren *(Teaching Assistant)*
- Jason Spivey *(Project Manager)*
- ReNeu Robotics Lab
- Augmenting Human Mechanics Lab
- Central Texas Rehabilitation Center

Thank you!

The University of Texas at Austin

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