FAMU-FSU College of Engineering

ExoFlex

Team 102

January 21, 2025

Introduction

Nikolya Cadavid
Mechanical Engineer

Kyle Giddes
Mechanical Engineer

Arianna Escalona
Biomedical Engineer

Joseph Liberato
Biomedical Engineer

Andrew Baumert
Biomedical Engineer

Aaron Gonzalez
Biomedical Engineer

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Sponsors and Advisors

Academic Advisor
Shayne McConomy
Professor

Academic Advisor
Stephen Hugo Arce
Professor and Sponsor

Engineering Mentor
Taylor Higgins
Point of Contact & Advisor

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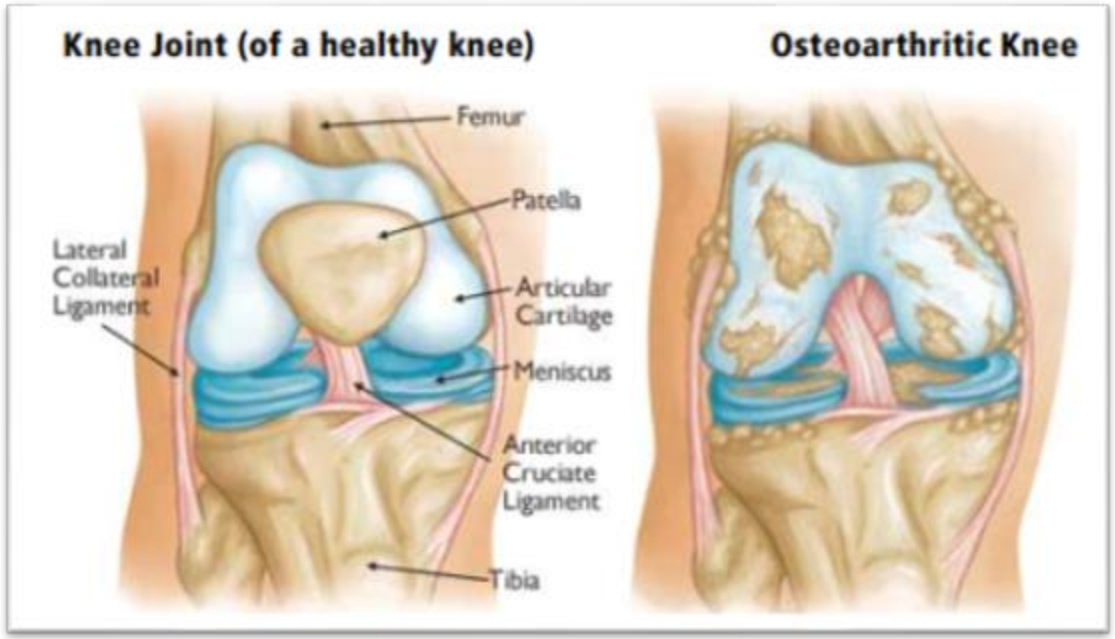
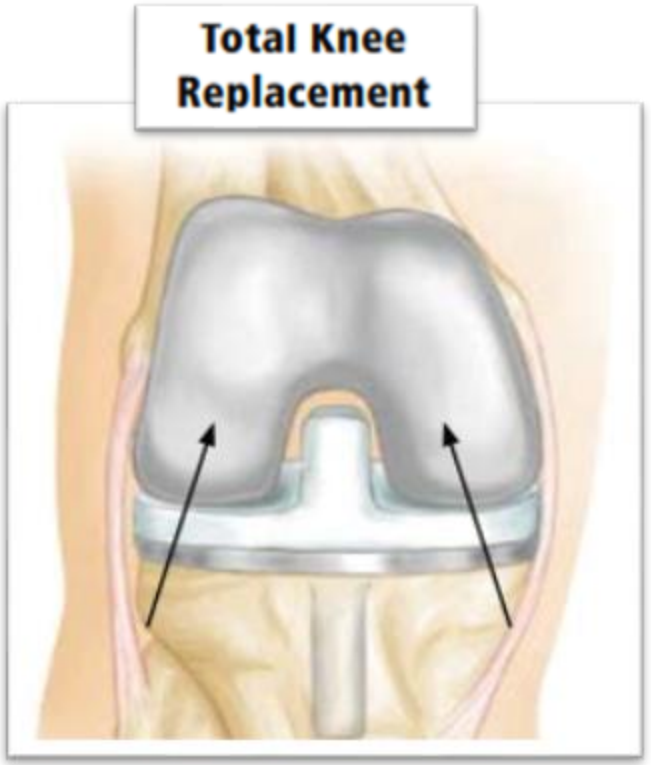
Objective

The objective of this project is to develop a device that enhances the rehabilitation process for patients who have undergone total knee replacement (TKR) by providing mechanical resistance and electrical stimulation, intended for supervised use within established recovery protocols.

Nikolya Cadavid

Total Knee Replacements (TKRs)





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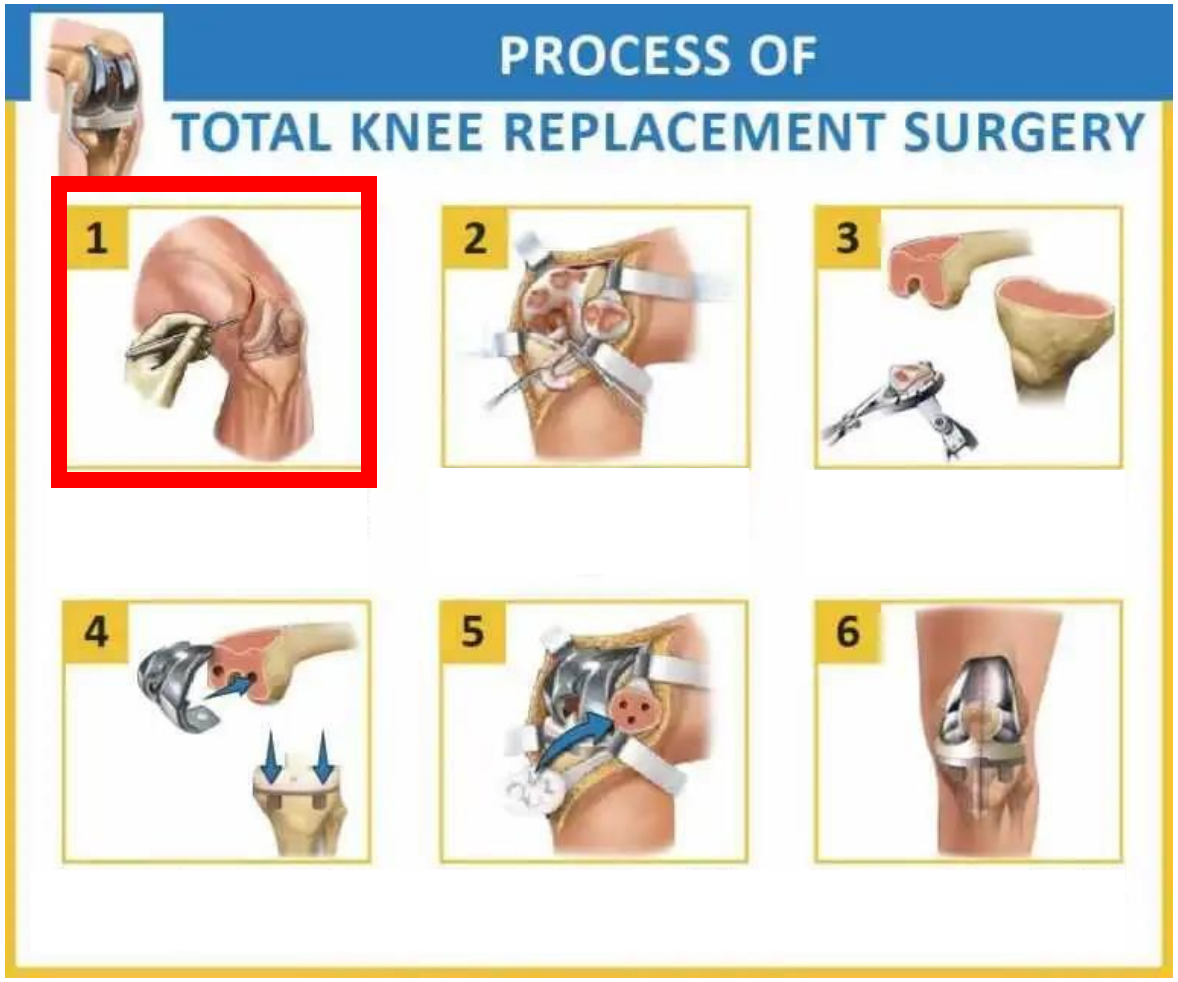
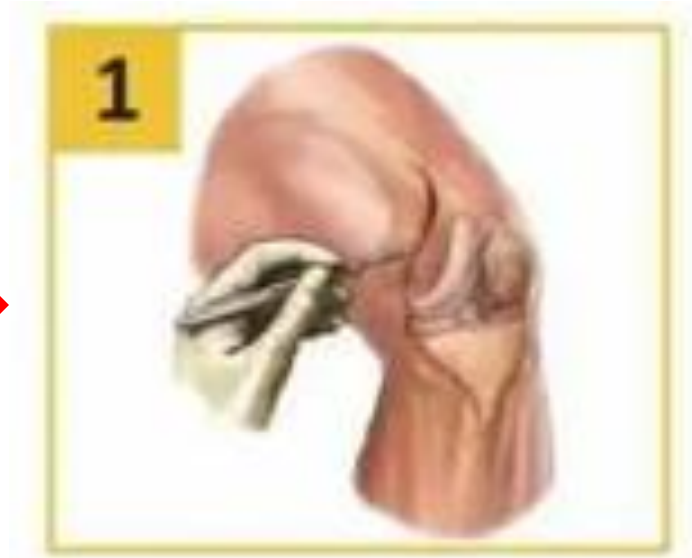
Nikolya Cadavid

Impact of a TKR





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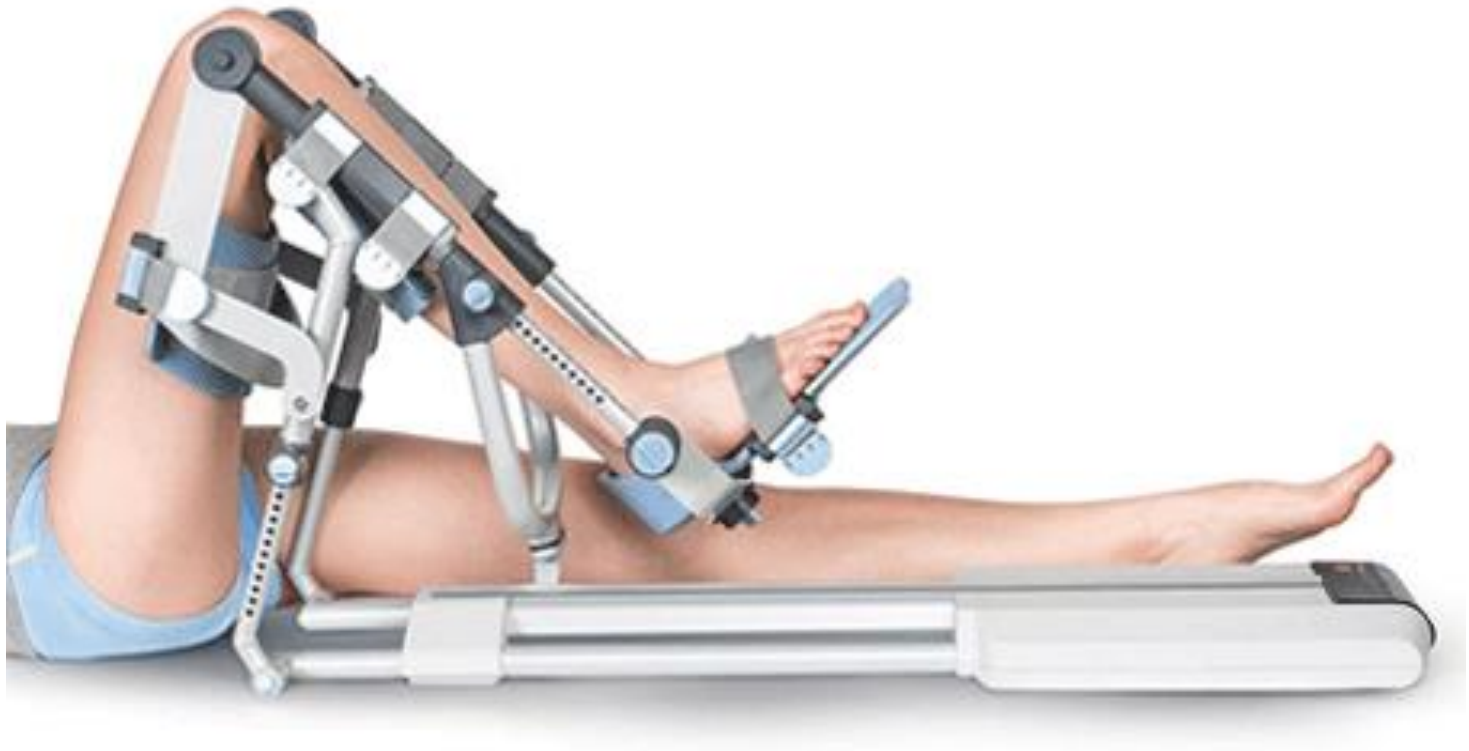
Early Recovery

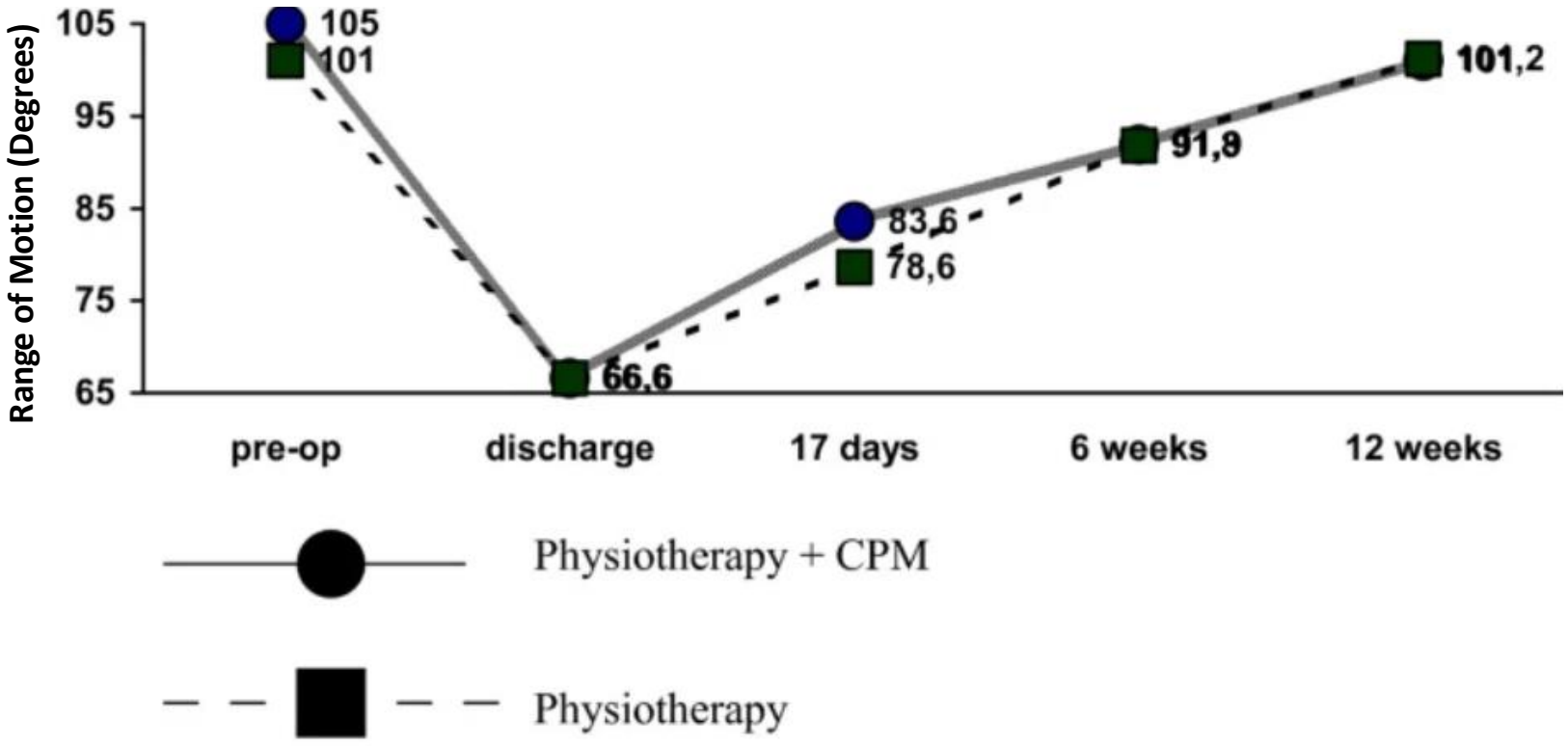


Continuous Passive Motion (CPM) Machine

Limits of Continuous Passive Motion (CPM)

Nikolya Cadavid

Progress of active ROM through the trial period.



T. A. Lenssen, M. J. van Steyn, Y. H. Crijns, et al., "Effectiveness of prolonged use of continuous passive motion (CPM), as an adjunct to physiotherapy, after total knee arthroplasty," BMC Musculoskelet. Disord., vol. 9, no. 60, 2008. Available: https://doi.org/10.1186/1471-2474-9-60

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Rehabilitation Process

Quad Sets

Short Arc Quads

Terminal Knee Extensions

At-Home Recovery Challenges

Straight Leg Raises

Sitting Knee Flexion

Patient getting into a shower post-TKR

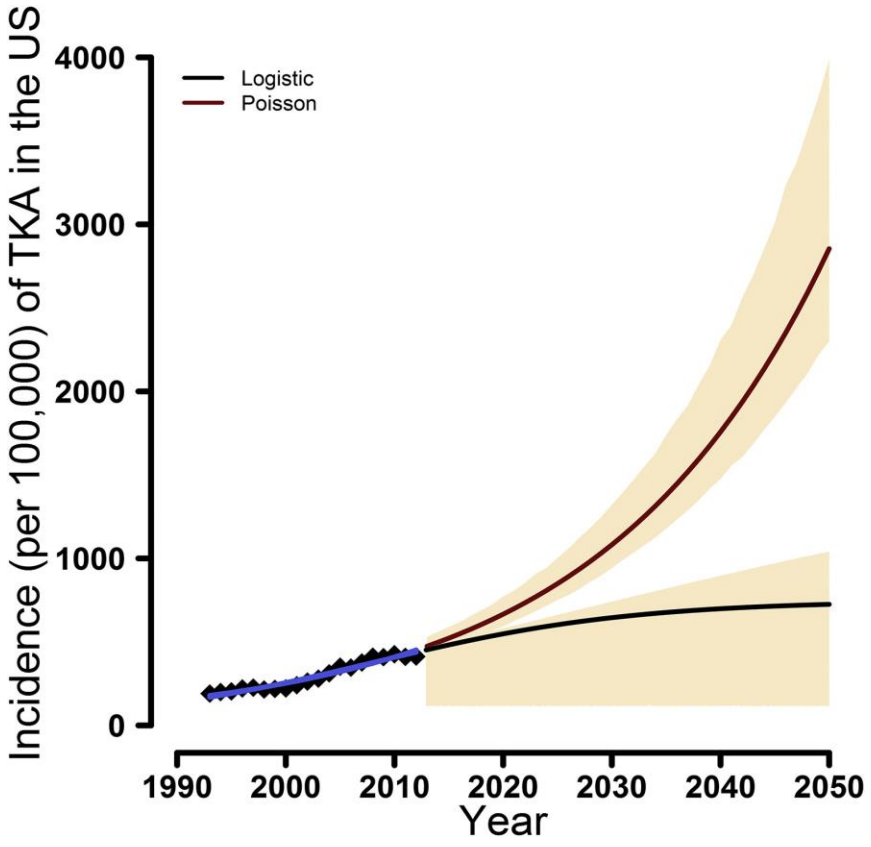
Existing Devices

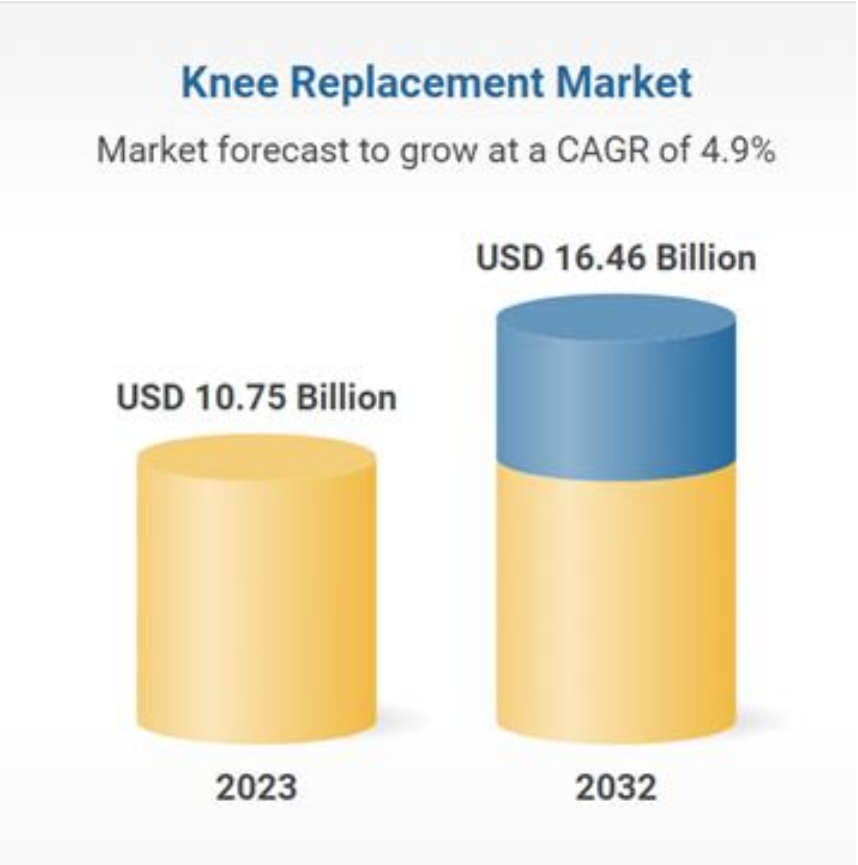
X10 Knee Machine

HAL Single Joint

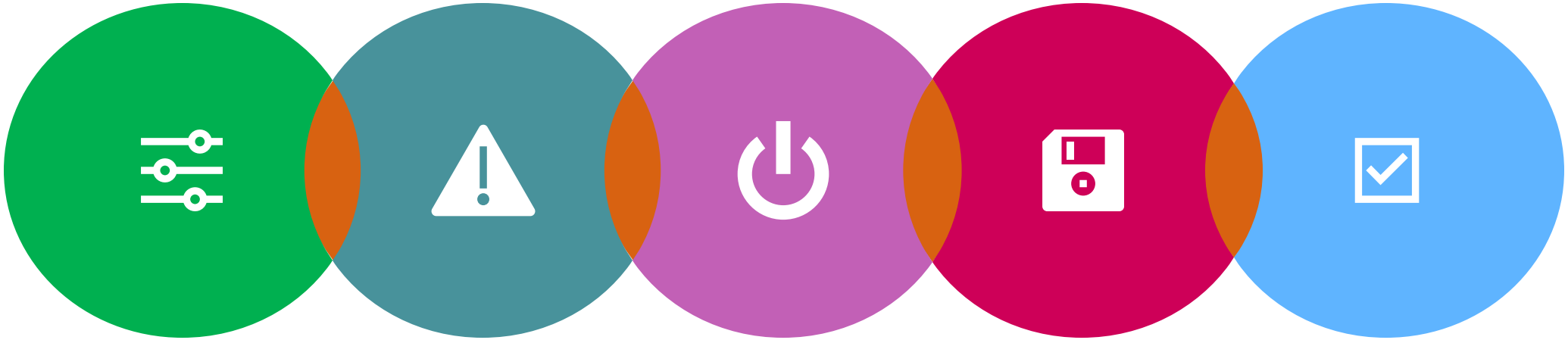
Market Opportunity

- 790k TKRs per year in the US





Key Goals



Adjustable Design

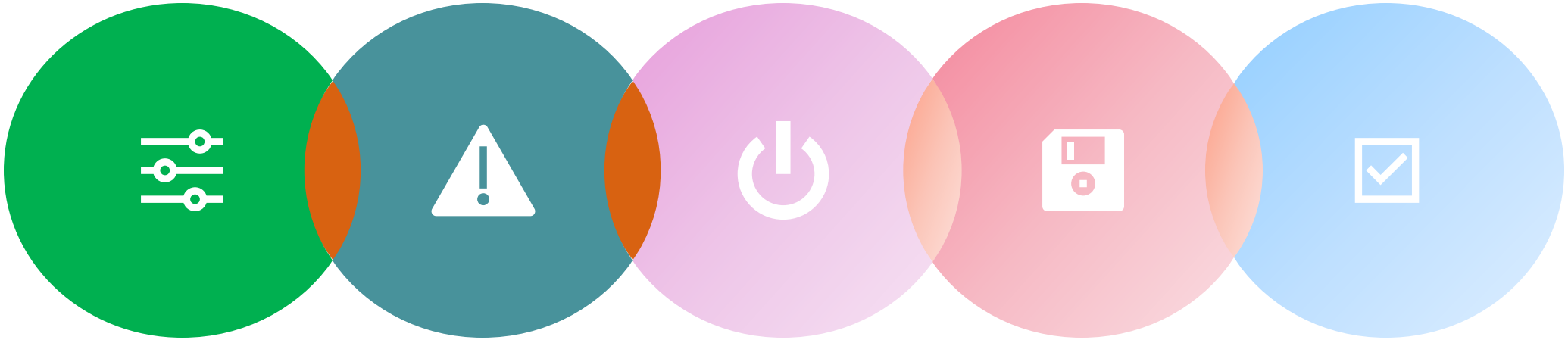
Safety

Electrical Stimulation

Data Aquisition

Convenience

Key Goals



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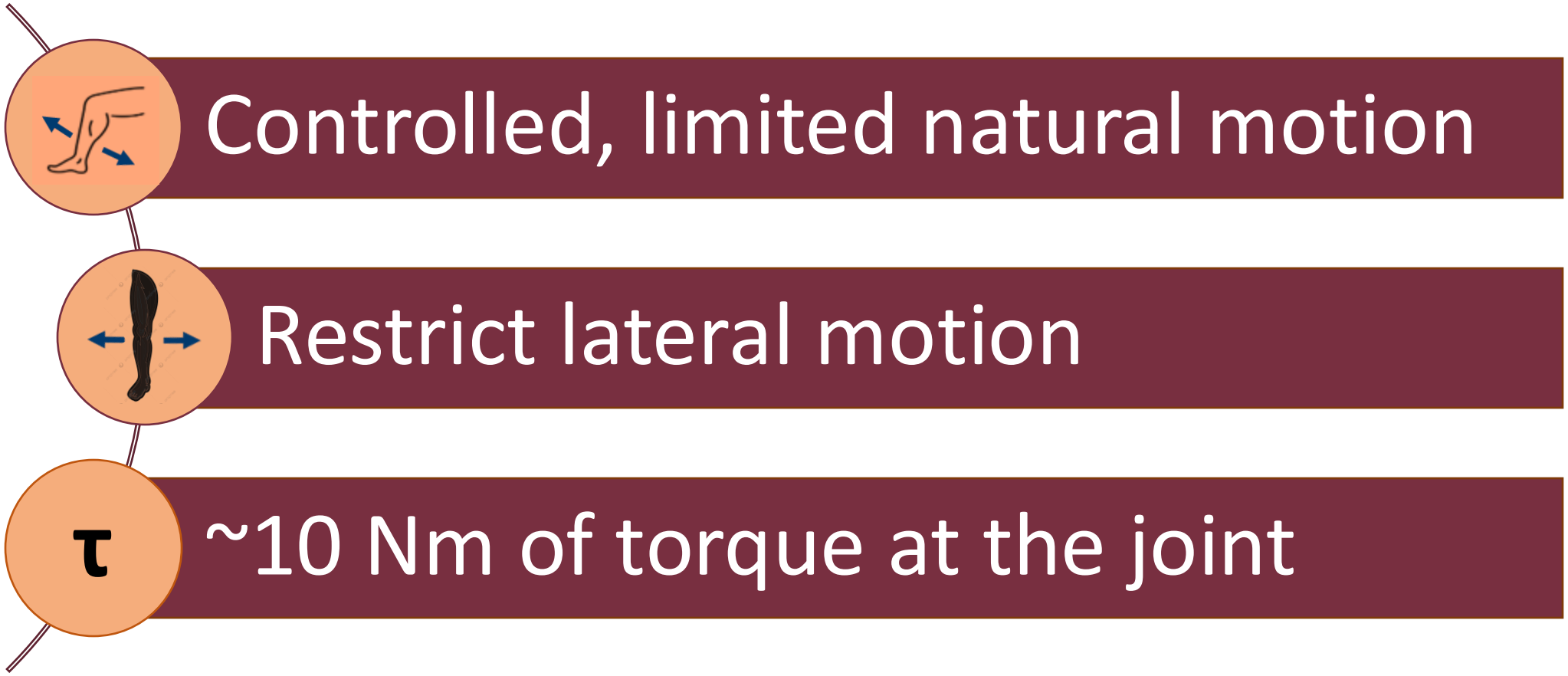
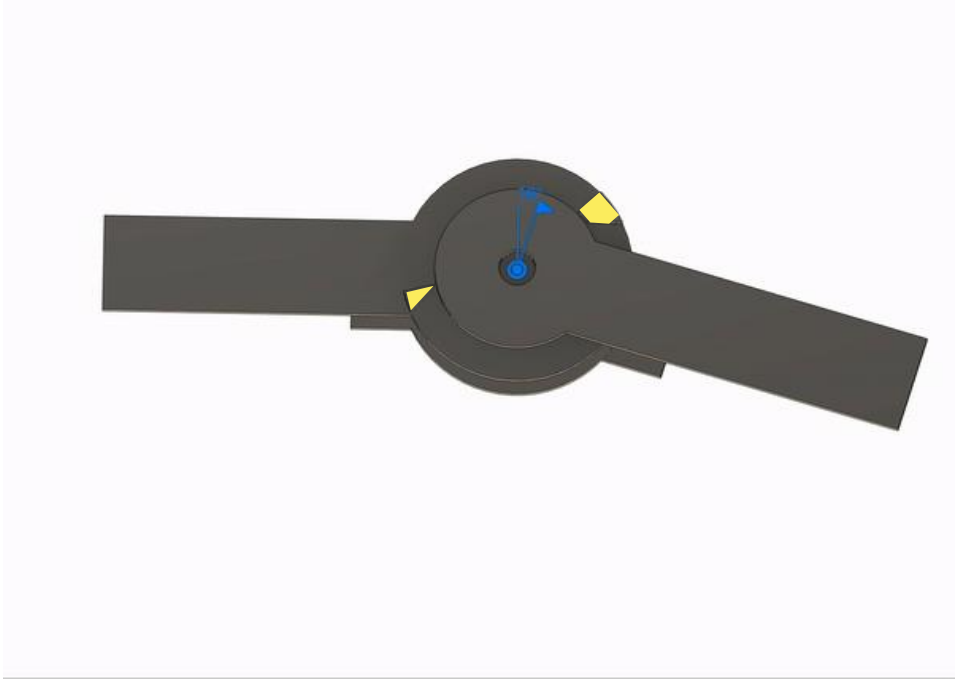
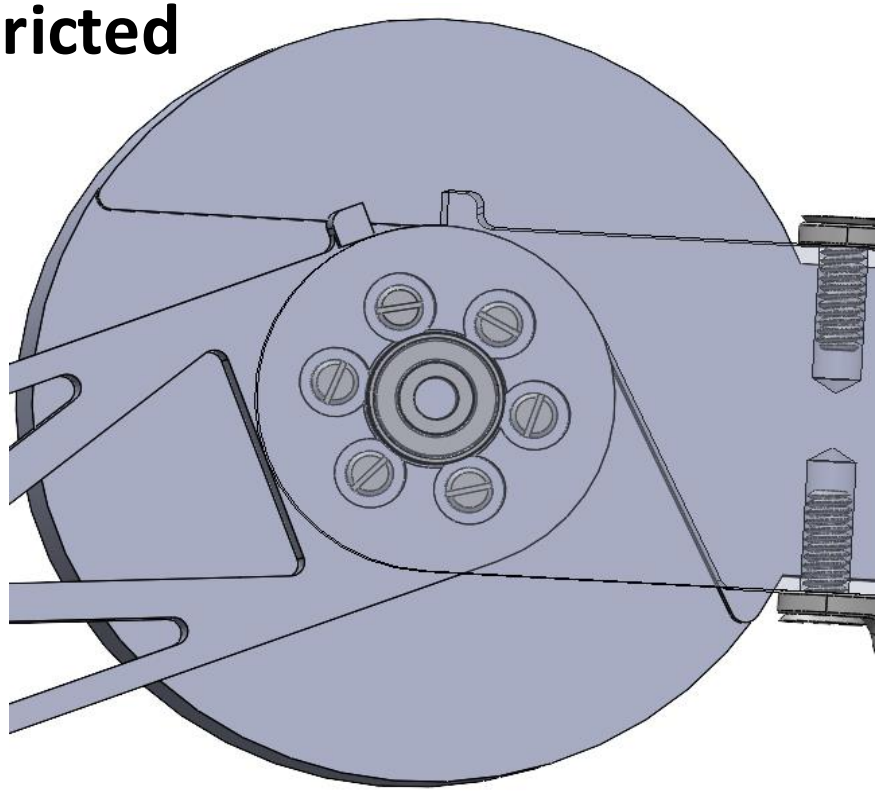
The Targets of Mechanical Design



Motion Constraints

- Natural motion 0° to 120°
- Lateral motion from 0 ± 2° will be restricted



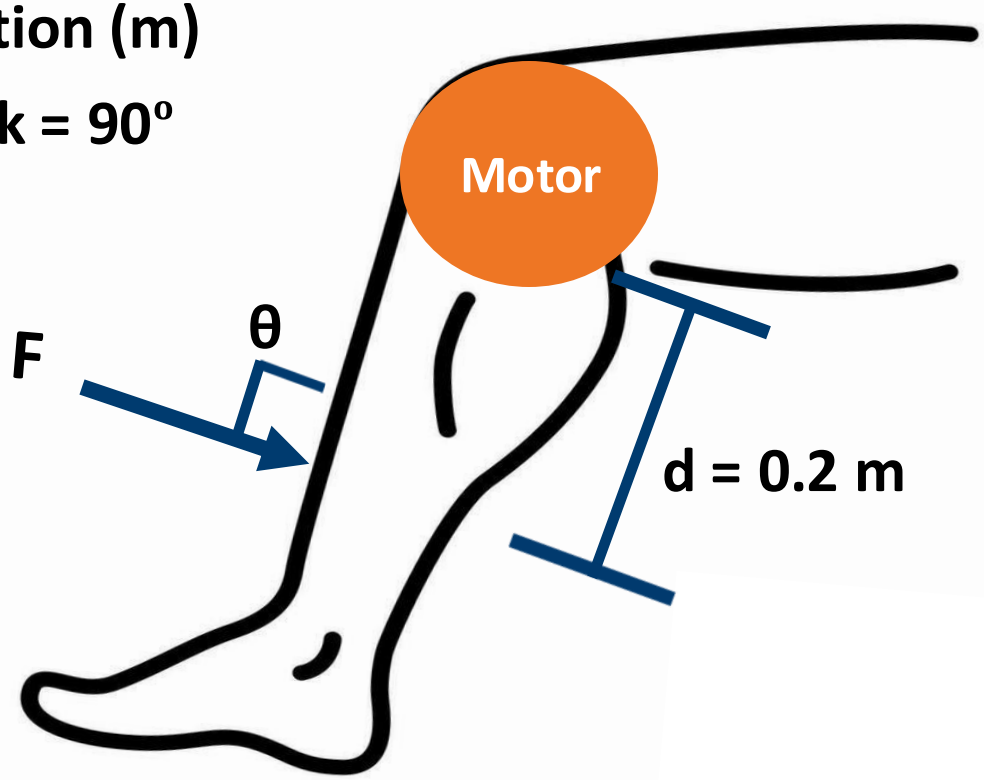


Torque Application

- F = Force applied (N)
- d = distance from the axis of rotation (m)
- θ = angle of force applied to shank = 90°
- τ = torque of the motor (Nm)

$$\tau = F * d * \sin(\theta) \approx 10 \text{ Nm}$$

$$F = \frac{\tau}{d} = 50 \text{ N} \approx 5 \text{ kg}$$



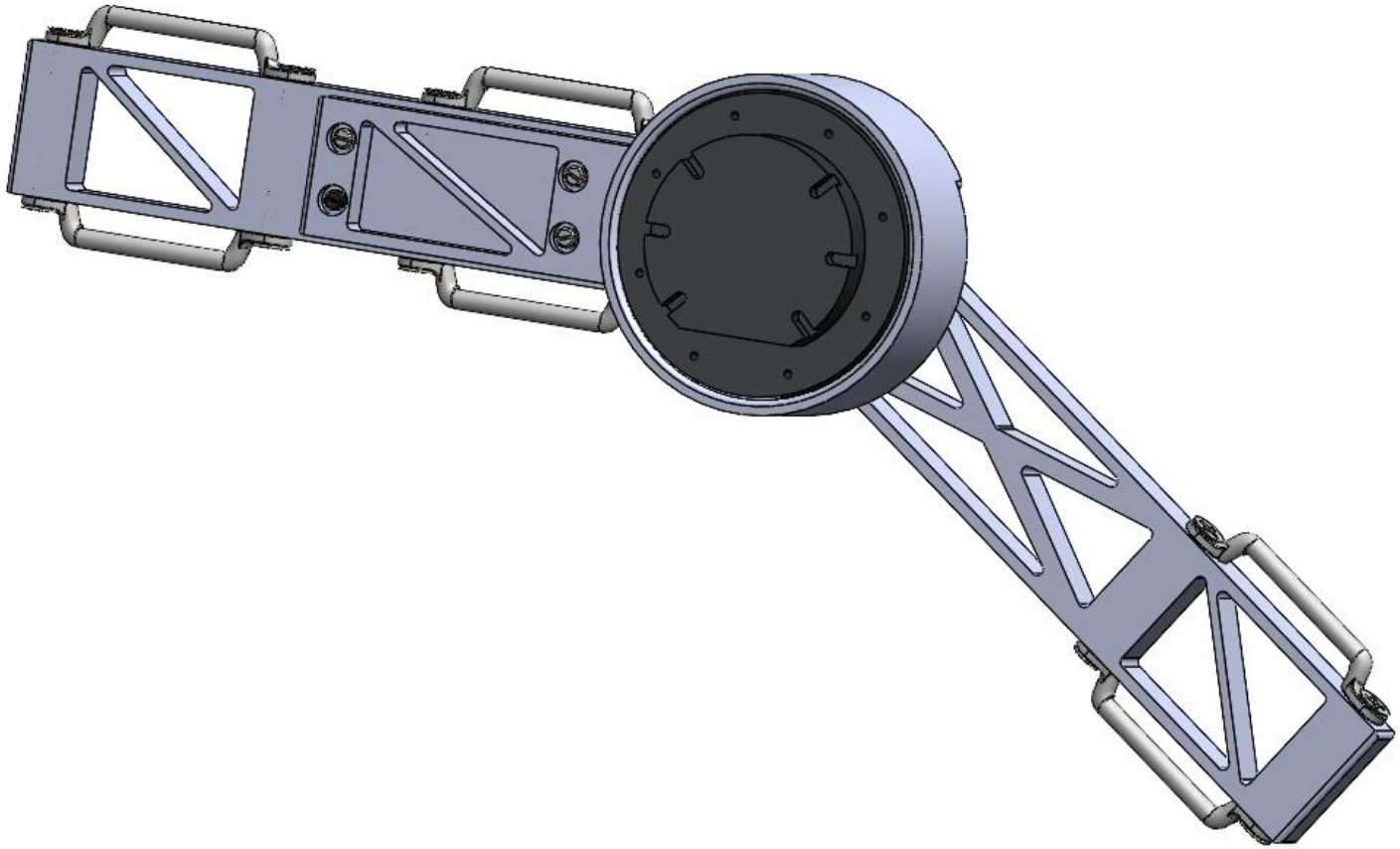
Motor Specifications

- Active actuator system
- Integrated encoder
- Versatile usage
  - Isometric
  - Eccentric
- Rated torque: 10 Nm
- Stall torque: 25 Nm
- Operating voltage: 48V

Material Selection

- 3D print using Nylon 12
- Nontoxic and Biocompatible
- Formlabs Fuse 1+ printer at Innovation Hub
- Batting material/leather for human contact

Assembled Prototype

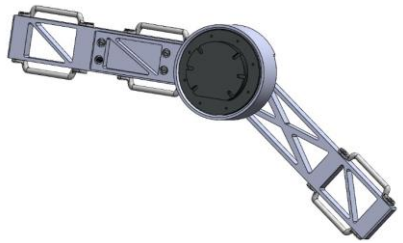


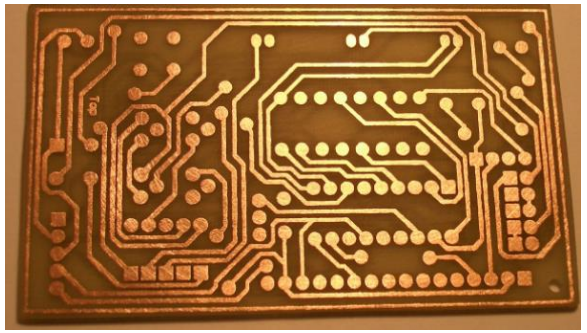
Kyle Giddes

Next Steps for Mechanical Design

Motor Control

Design the motor control system for leg movement and exercise.





Integrate E-Stim

Add physical connections of e-stim components to the device.

Improve Prototype

Include hip component attachment, padding, and adjustable shank.

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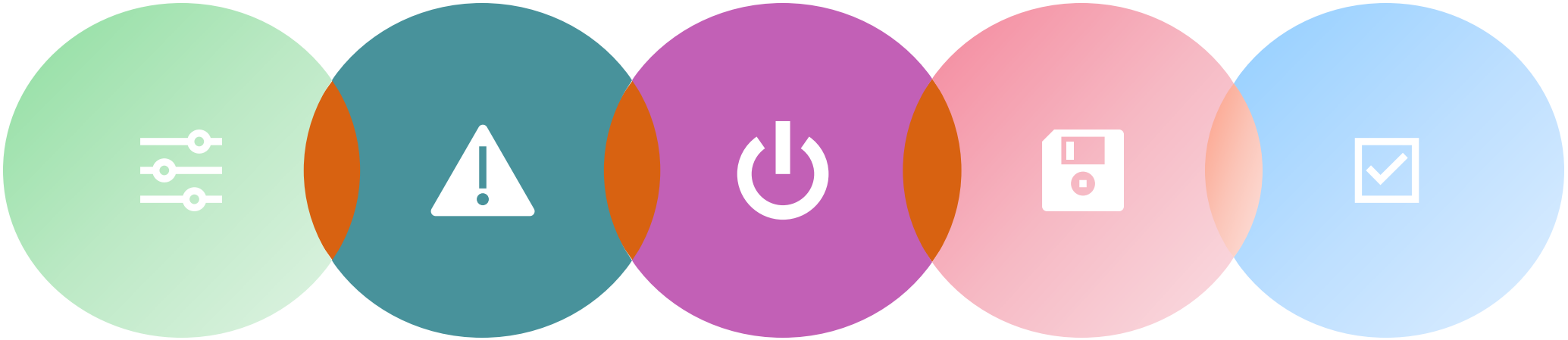
Key Goals



Adjustable Design

Safety

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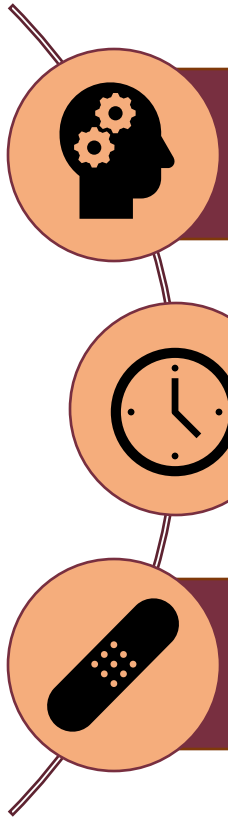
Data Aquisition

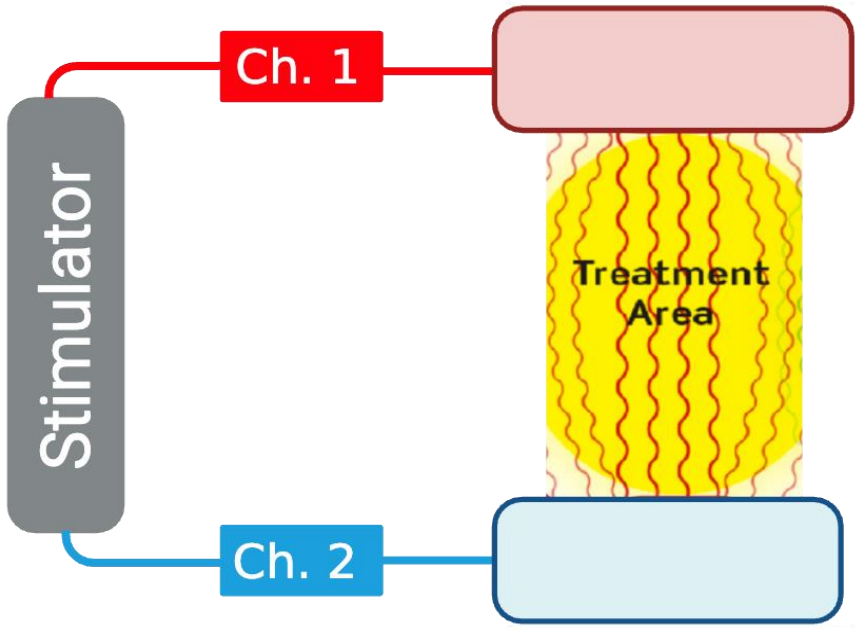
Convenience

The Targets of E-Stim



- Restore quad activation
- Promote early muscle contraction
- Reduce swelling and discomfort

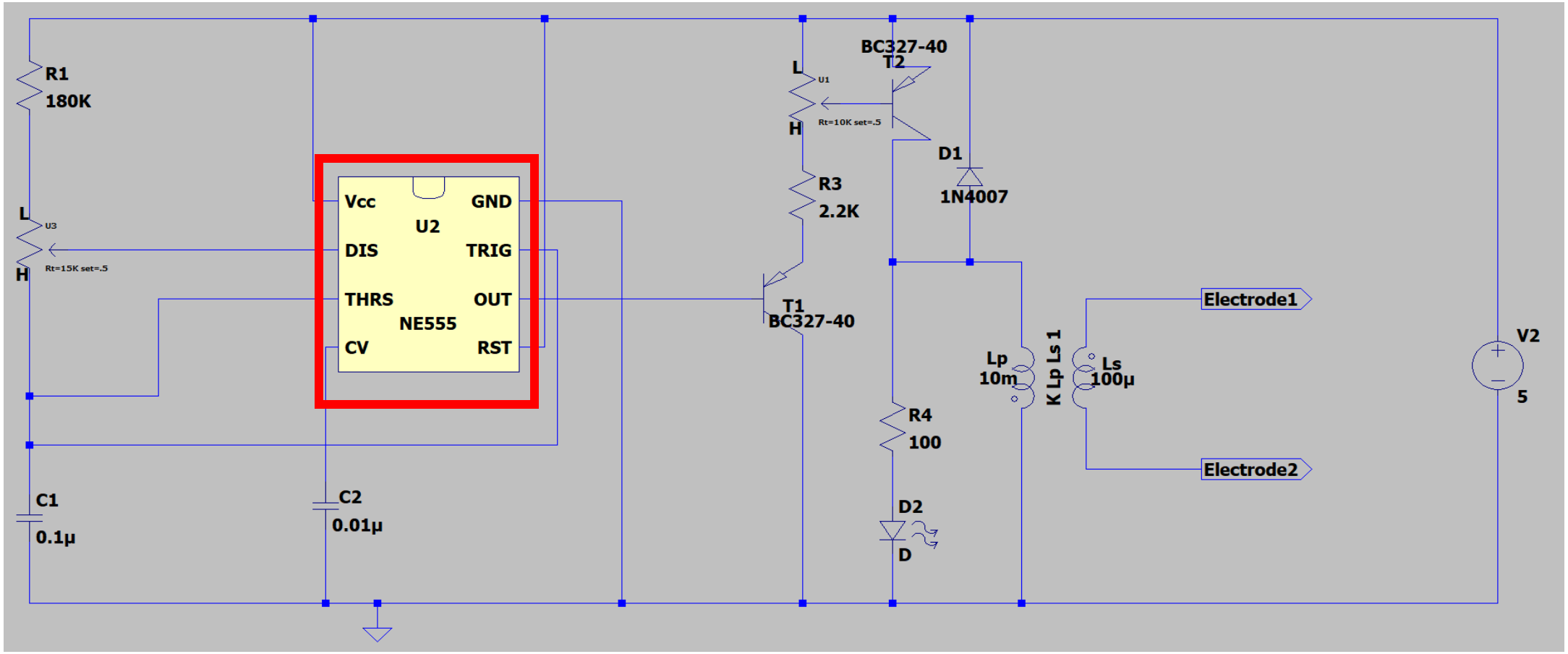
Neuromuscular Electrical Stimulation (NMES)



- Moderate to High Amplitude
- Pulse Frequency: 30 – 80 Hz
- Pulse Duration: 2ms – 4ms

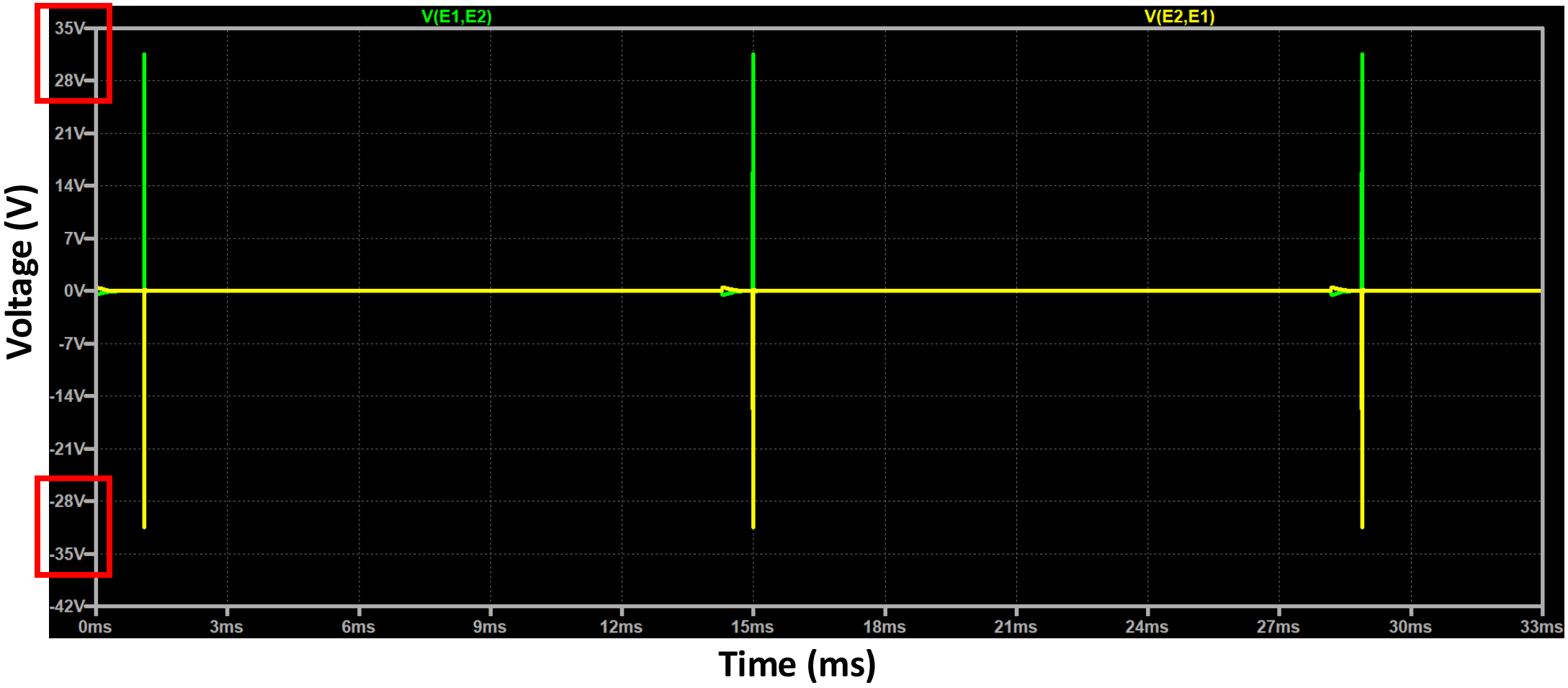
Arianna Escalona

Circuit Diagram



Arianna Escalona

Circuit Simulation Results



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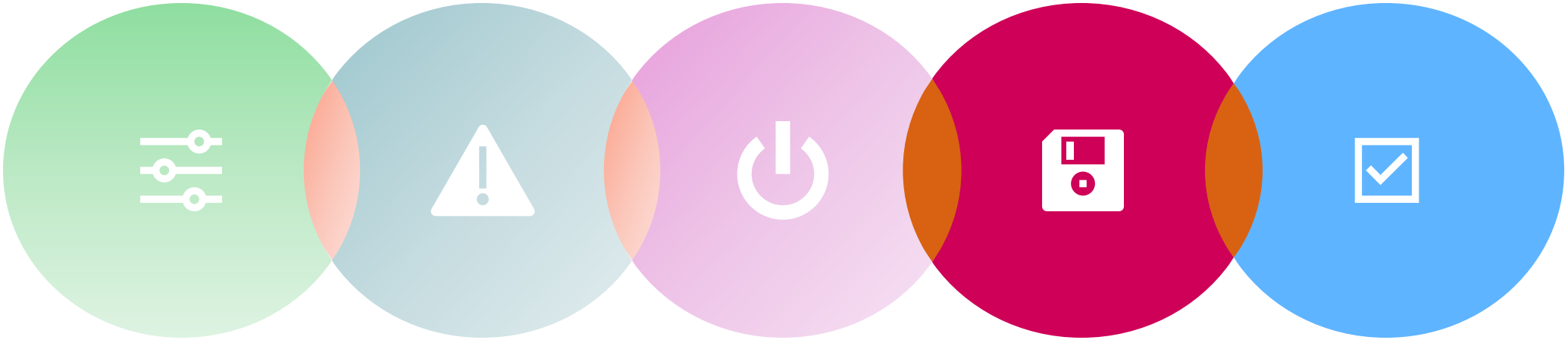

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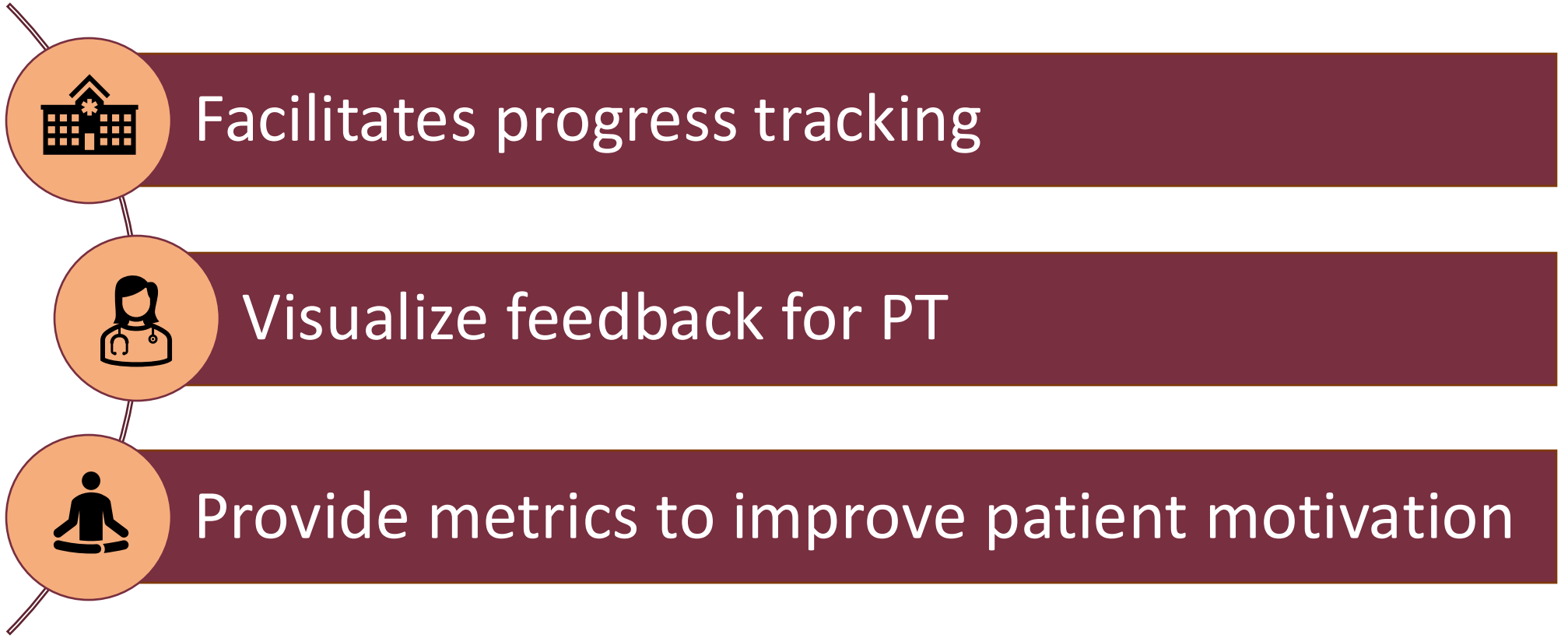
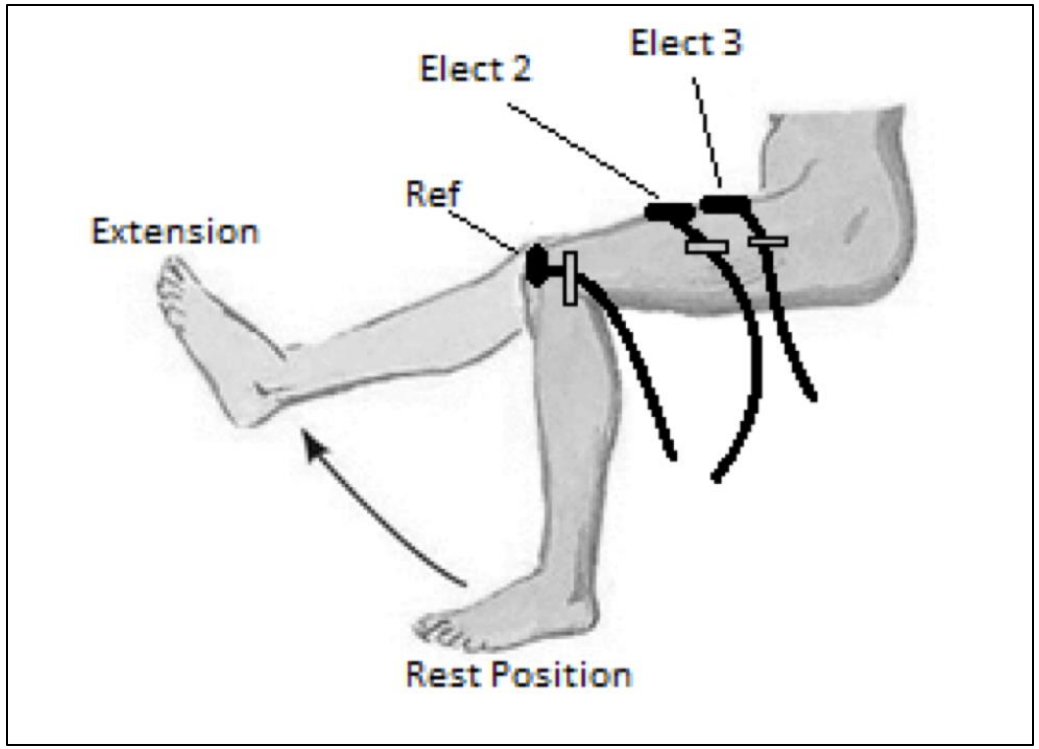
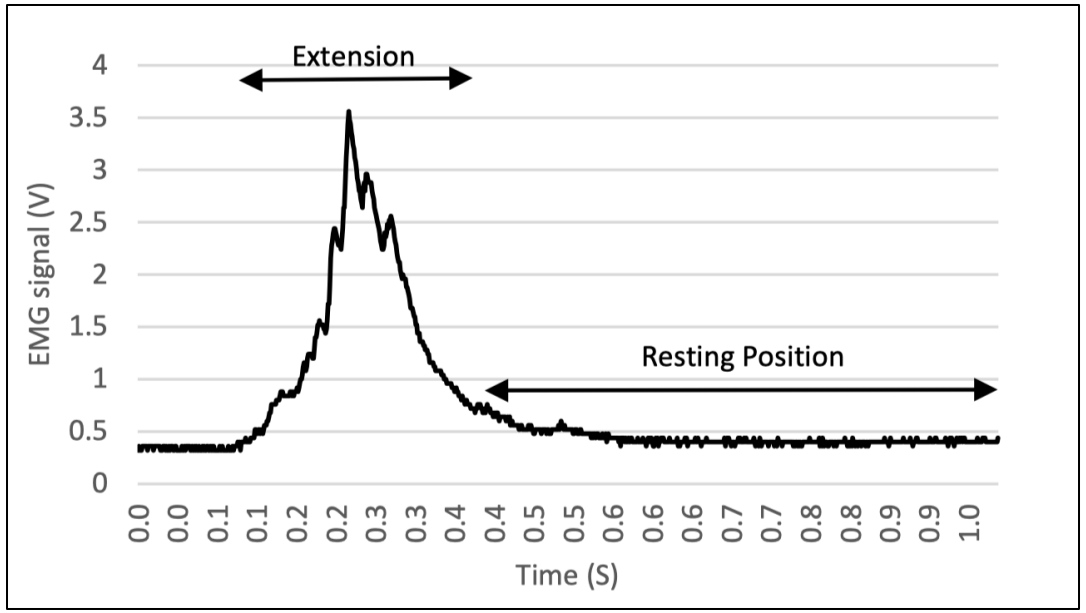
The Targets of Data Acquisition



Data Acquisition - Electromyography (EMG)





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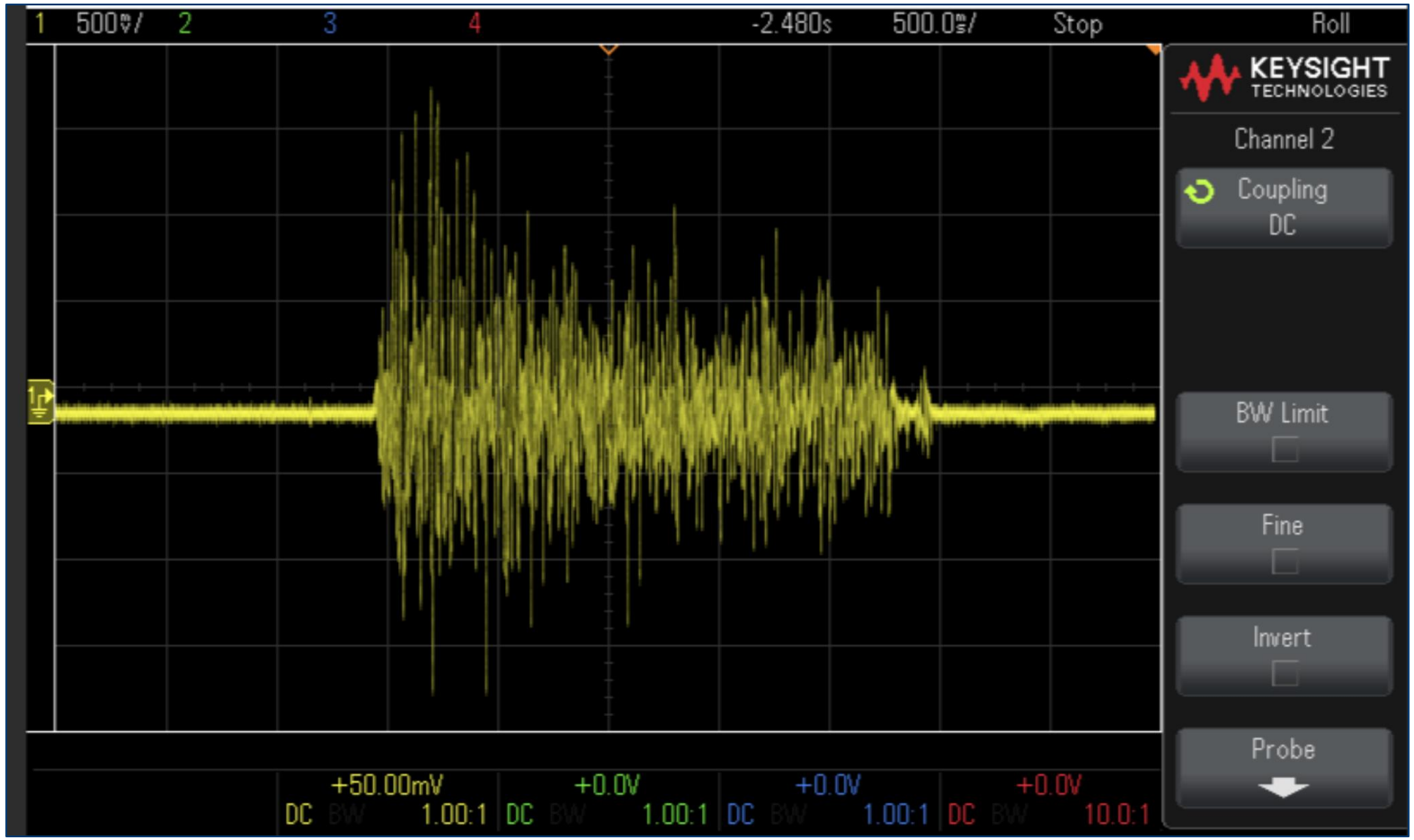
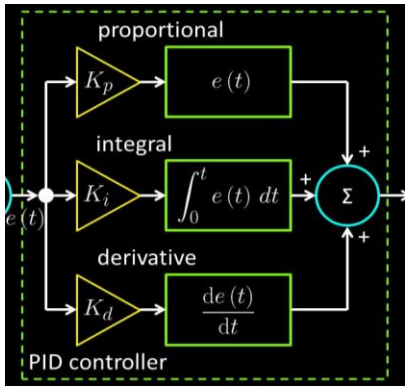


Arianna Escalona

Next Steps for ExoFlex

Systems Integration

Plan for integration of mechanical, electrical, and data acquisition aspects.



Control System

Simulate the system and test control strategies.

Testing

Undergo safety and performance testing testing.

"I have learned all kinds of things from my many mistakes. The one thing I never learn is to stop making them."

- Joe Abercrombie

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