

The slide features decorative circuit board patterns in the corners. The top-left and bottom-right corners have black and orange lines forming various shapes, including circles and squares. The bottom-left corner has a cluster of small orange dots and black lines. The bottom-right corner has a series of orange dots and black lines forming a zig-zag pattern.

# TEAM C1: CLIMB

# Final Presentation

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Alexander Nguyen, Jubahed Qayum, Joshua Ramos

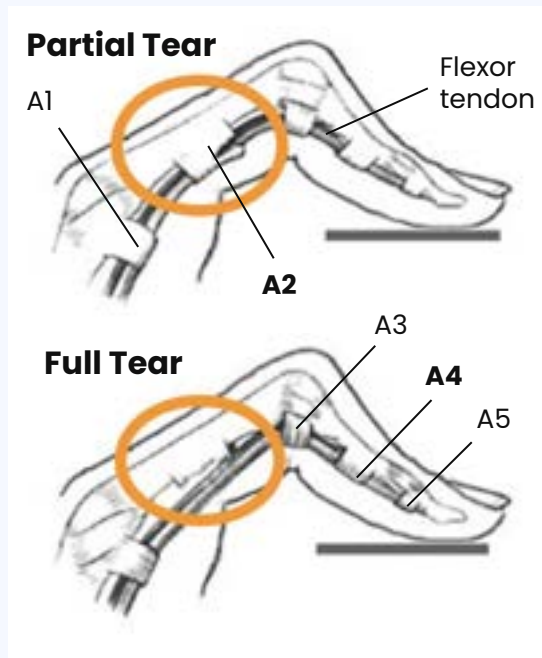
# The Problem & Our Solution

## Rock Climbers & Pulley Injuries

- 44.5 million climbers around the world
- Most common injury
  - Pulley rupture
- 3-12 month recovery

## Our Solution

- Comfortable wearable device
- Minimal restrictive effect on climber
- Prevent injury before it happens through alarms
- Provide weight distribution data



# Use Case & Design Requirements

Use Case Requirement	Technical Requirement
<b>Comfortable &amp; Unobtrusive</b>	The sensors shall be placed such that <b>less than 30%</b> of per-finger surface area is covered.
<b>Prevent Pulley Injuries</b>	The device shall be sensitive <b>up to 70 lbs</b> of force per sensor.
→	On-device haptic alarm shall fire <b>within 200ms</b> from when user's breach the safety threshold.
<b>Provide Useful Feedback</b>	Analytics and suggestive feedback shall display <b>within 10s</b> of workout completion.

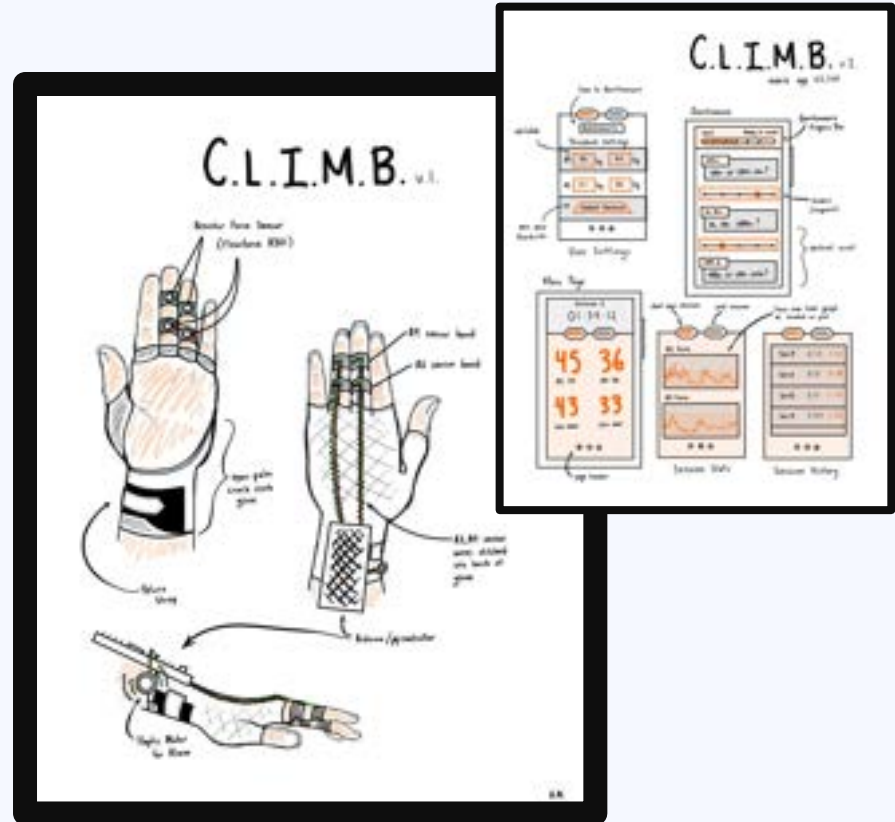
# Solution Approach

## Wearable Glove

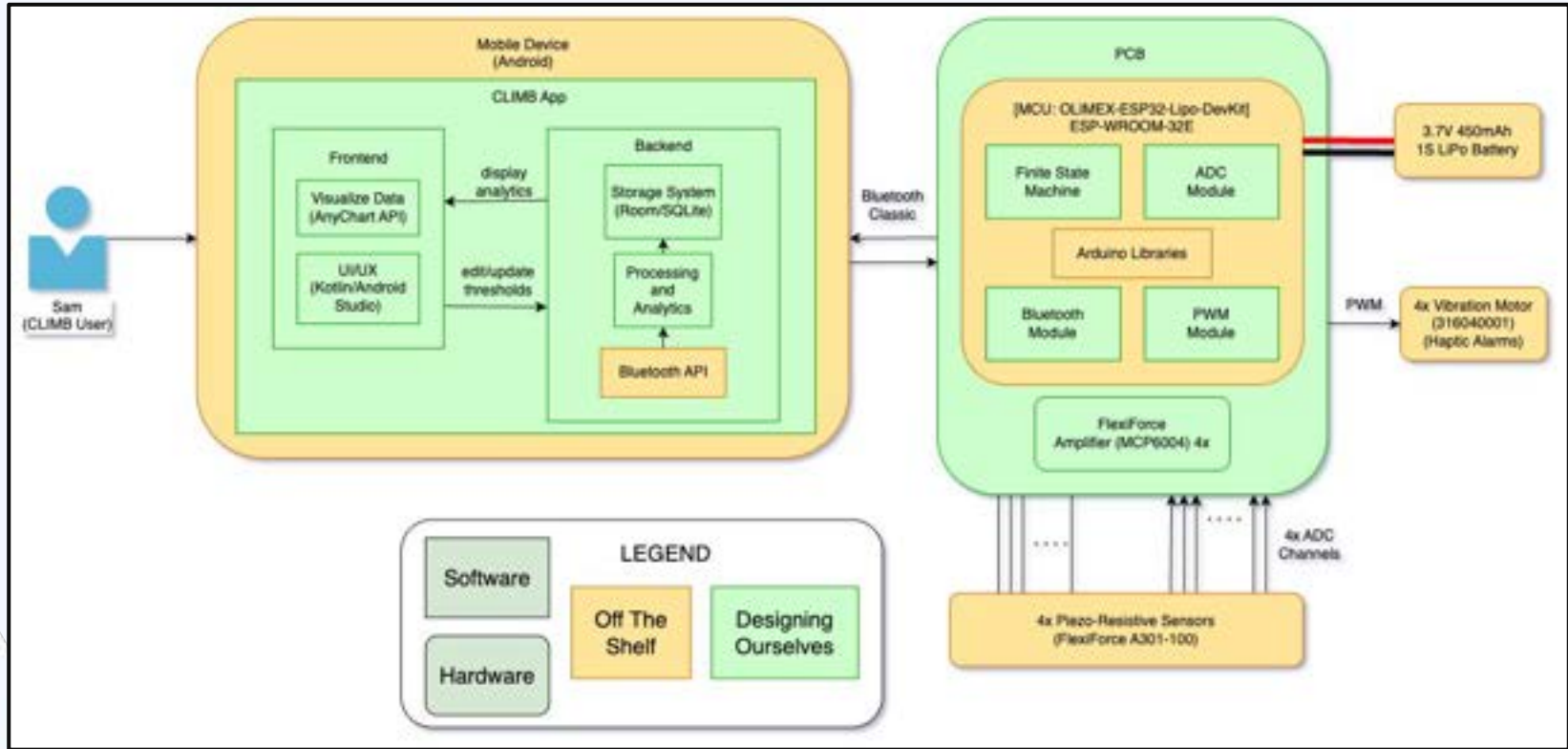
- Track force distribution data
  - Piezoresistive sensors
- Pulley Alarms
  - Haptic Motors

## Mobile App

- Determine and set safety thresholds
- Start and end climbing sessions
- Display and analyze session data



# Complete Solution



# Glove (Hardware Solution)

## Continuous Force Reading

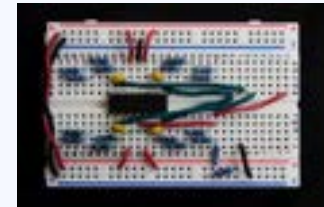
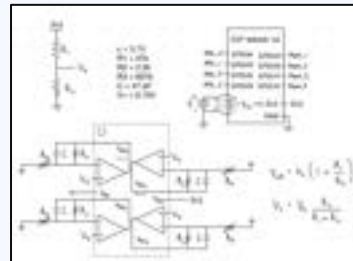
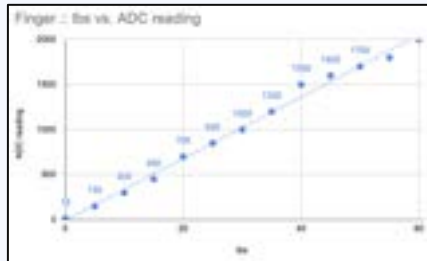
- Sampling rate  
 $T = 0.1s$  (100ms)

## Maintain Distinct Thresholds

- Four sensors & pulleys per hand
- Target A2, A4, pulleys:  
middle and ring fingers

## Fire Haptic Motor Alarms

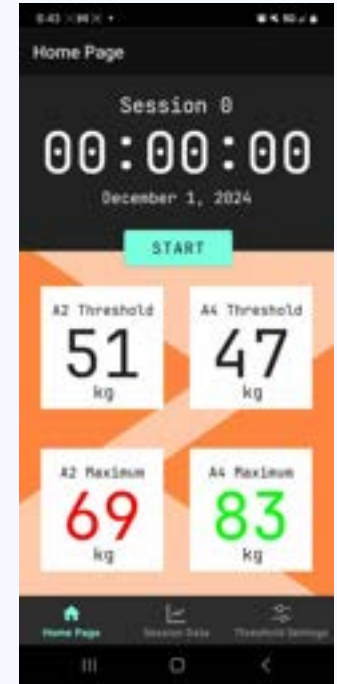
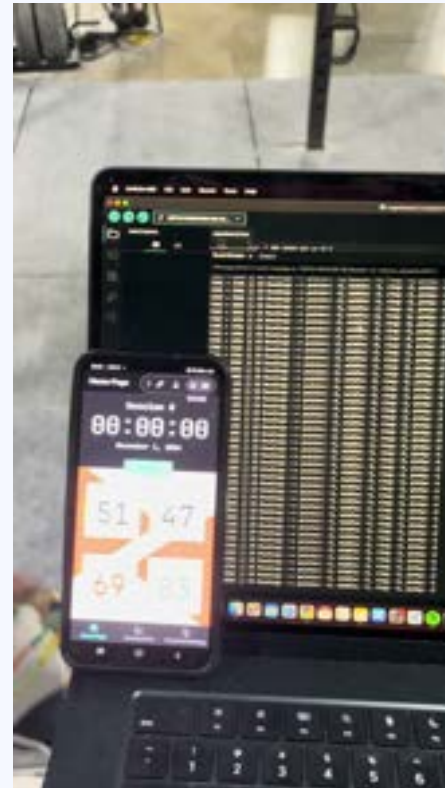
- Increased risk  $\rightarrow$  stronger alarms





# Mobile App (Software Solution)

```
Serial Monitor x Output
Message (Enter to send message to 'ESP32-WROOM-0A Module' on '/dev/ttyUSB0serial-0001')
TIME = 9198 || CR Readings -> pointer: 3, middle: 1, ring: 0, pinky: 0
TIME = 9308 || CR Readings -> pointer: 4, middle: 0, ring: 0, pinky: 1
TIME = 9398 || CR Readings -> pointer: 4, middle: 0, ring: 0, pinky: 0
TIME = 9498 || CR Readings -> pointer: 4, middle: 0, ring: 7, pinky: 0
TIME = 9598 || CR Readings -> pointer: 4, middle: 0, ring: 8, pinky: 0
TIME = 9698 || CR Readings -> pointer: 4, middle: 0, ring: 7, pinky: 1
TIME = 9798 || CR Readings -> pointer: 4, middle: 0, ring: 7, pinky: 0
TIME = 9898 || CR Readings -> pointer: 2, middle: 0, ring: 6, pinky: 0
TIME = 9998 || CR Readings -> pointer: 4, middle: 1, ring: 7, pinky: 0
TIME = 10098 || CR CALIBRATION COMPLETE - pointerCR: 4, middleCR: 1, ringCR: 6, pinkyCR: 1
pointer: 4 lbs, middle: 1 lbs, ring: 6 lbs, pinky: 0 lbs
TIME = 10158 || pointer: 4 lbs, middle: 1 lbs, ring: 6 lbs, pinky: 0 lbs
TIME = 10258 || pointer: 3 lbs, middle: 1 lbs, ring: 5 lbs, pinky: 0 lbs
TIME = 10358 || pointer: 3 lbs, middle: 2 lbs, ring: 5 lbs, pinky: 0 lbs
TIME = 10458 || pointer: 4 lbs, middle: 1 lbs, ring: 6 lbs, pinky: 0 lbs
TIME = 10558 || pointer: 3 lbs, middle: 0 lbs, ring: 6 lbs, pinky: 0 lbs
TIME = 10658 || pointer: 4 lbs, middle: 1 lbs, ring: 7 lbs, pinky: 0 lbs
TIME = 10758 || pointer: 3 lbs, middle: 0 lbs, ring: 6 lbs, pinky: 0 lbs
TIME = 10858 || pointer: 3 lbs, middle: 1 lbs, ring: 6 lbs, pinky: 0 lbs
TIME = 10958 || pointer: 3 lbs, middle: 0 lbs, ring: 6 lbs, pinky: 0 lbs
TIME = 11058 || pointer: 3 lbs, middle: 0 lbs, ring: 6 lbs, pinky: 0 lbs
TIME = 59111 || pointer: 13 lbs, middle: 11 lbs, ring: 0 lbs, pinky: 18 lbs
TIME = 59211 || pointer: 32 lbs, middle: 56 lbs, ring: 51 lbs, pinky: 44 lbs
TIME = 59311 || pointer: 0 lbs, middle: 7 lbs, ring: 3 lbs, pinky: -1 lbs
TIME = 59411 || pointer: -1 lbs, middle: 2 lbs, ring: 0 lbs, pinky: -2 lbs
TIME = 59511 || pointer: -1 lbs, middle: 1 lbs, ring: 1 lbs, pinky: -1 lbs
TIME = 59611 || pointer: 0 lbs, middle: 4 lbs, ring: 5 lbs, pinky: -2 lbs
TIME = 59711 || pointer: 0 lbs, middle: 10 lbs, ring: 0 lbs, pinky: -1 lbs
TIME = 59811 || pointer: 30 lbs, middle: 13 lbs, ring: 12 lbs, pinky: 24 lbs
TIME = 59911 || pointer: 39 lbs, middle: 15 lbs, ring: 14 lbs, pinky: 32 lbs
TIME = 60011 || pointer: 47 lbs, middle: 15 lbs, ring: 16 lbs, pinky: 35 lbs
TIME = 60111 || pointer: 40 lbs, middle: 17 lbs, ring: 19 lbs, pinky: 31 lbs
TIME = 60211 || pointer: 48 lbs, middle: 18 lbs, ring: 23 lbs, pinky: 41 lbs
TIME = 60311 || pointer: 44 lbs, middle: 15 lbs, ring: 36 lbs, pinky: 39 lbs
TIME = 60411 || pointer: 0 lbs, middle: 11 lbs, ring: 10 lbs, pinky: -2 lbs
```



# Testing Requirements

Testing (Goal)	Specification
<b>Ergonomic Validation</b>	Survey 20 random climbers to determine usability (yes/no), WTP (\$), and obtrusiveness (%)
<b>Durability Verification &amp; Validation</b>	Sensitivity drift and wear/tear is measured after each of 20 static & dynamic uses (2 minutes /) with 80kg applied (drift to be within 2.5%)
<b>Safety Verification</b>	<ul style="list-style-type: none"><li>(1) Verify that a constant 0 – 60 lbs is consistent (within 5%) at each 5lb increment reading over 20 trials</li><li>(2) Verify that at least one alarm is triggered within 100ms when force reading is within 20% of threshold at a 99% success rate</li><li>(3) Verify that second alarm fires within 200ms of threshold excession with a 99% success rate</li></ul>
<b>Feedback Verification</b>	Verify that 20 (~96kb) batches (batch/use) ship to the mobile device within 10s at a 95% success rate



# Hardware Testing Results

Specification	Requirement	Result
Sensitivity drift	< 2.5%	~ 2%
Reading Consistency	< 5%	~ 3%
Alarm Fire	> 99%	100%
Battery Life	> 3 Hours	Ongoing
CLIMB Survey	20 Climbers	Ongoing (5)

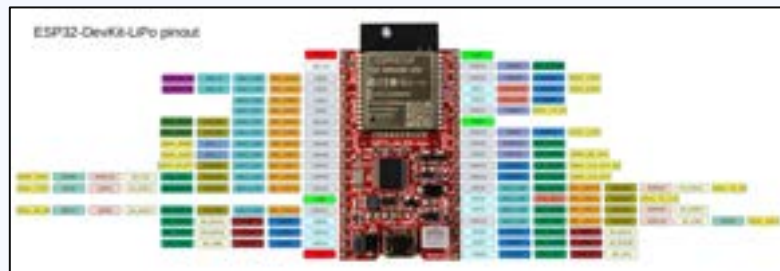
“Yeah I’d use that as long as my fingertips and palm are free, it’d definitely save people from getting pulleys.” ~ fellow climber at ICB

# Software Testing Results

Specification	Requirement	Result
Bluetooth Pairing Time	< 5s	~ 1s
Bluetooth Distance	> 10ft	30ft
Bluetooth Shipment Time	< 5s	~ 3s
Time to load 3kB from database	< 3s	~ 2s
Data visualization Time (Charts)	< 2s	Ongoing

# Design Tradeoffs

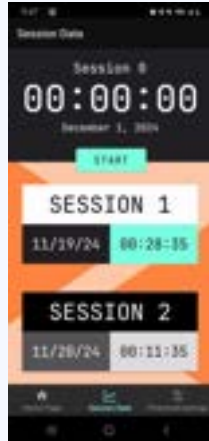
- MCU
  - ESP32 →  $\sim(25 \times 18 \times 3)$ mm, clk: 240MHz, built-in BT Classic/LE support,  $\sim 0.6$ W, 15 ADCs
    - Olimex →  **$\sim 15$** \$, **smaller**, has **on-board power jack**, reduces the need to design/purchase LDO and add complexity to PCB
    - Adafruit →  **$\sim 8$** \$, **larger size, no LDO (& power-jack)**
  - STM32FRE →  $(68 \times 53 \times 13)$ mm, clk: 160MHz,  $\sim 0.3$ W, no built-in BT support, 9 ADCs
- Sensor attachment
  - Tape → more grip flexibility, modularity, greater placement accuracy
  - **Nylon Rings** → greater placement consistency, less grip



# Looking Ahead & Proj Management

## Next Steps

- Add second glove
- PCB & Capsule
- Display data retrieved from database
  - Analytics
  - Session history



## Schedule

