

# ACTIVE POSTURAL CORRECTION VEST PROJECT PROPOSAL

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# 1. Introduction

## 1.1 Problem

Poor posture is an extremely common issue in modern society, especially in the workplace, where employees sit and slouch for hours on end while sitting at a desk. Slouching every day can lead to long-term health complications like musculoskeletal imbalances, chronic back pain, and reduced respiratory efficiency. These issues can be debilitating as people get older, so it is important to reinforce good posture as often and as early as possible.

Existing solutions are mainly temporary solutions for a long-standing problem. Regular braces do not require any muscular effort from the person, so the reinforcement of good posture by the person themselves is not necessary, and the problem is not actively addressed. Devices that send notifications but do not actually enforce corrections do not exactly tell the user how their posture is improving, and the problem may not truly be fixed using this method either. There is a lack of active solutions that physically assist the user in regaining proper posture without requiring constant conscious effort or just doing all the work for them with no effort at all.

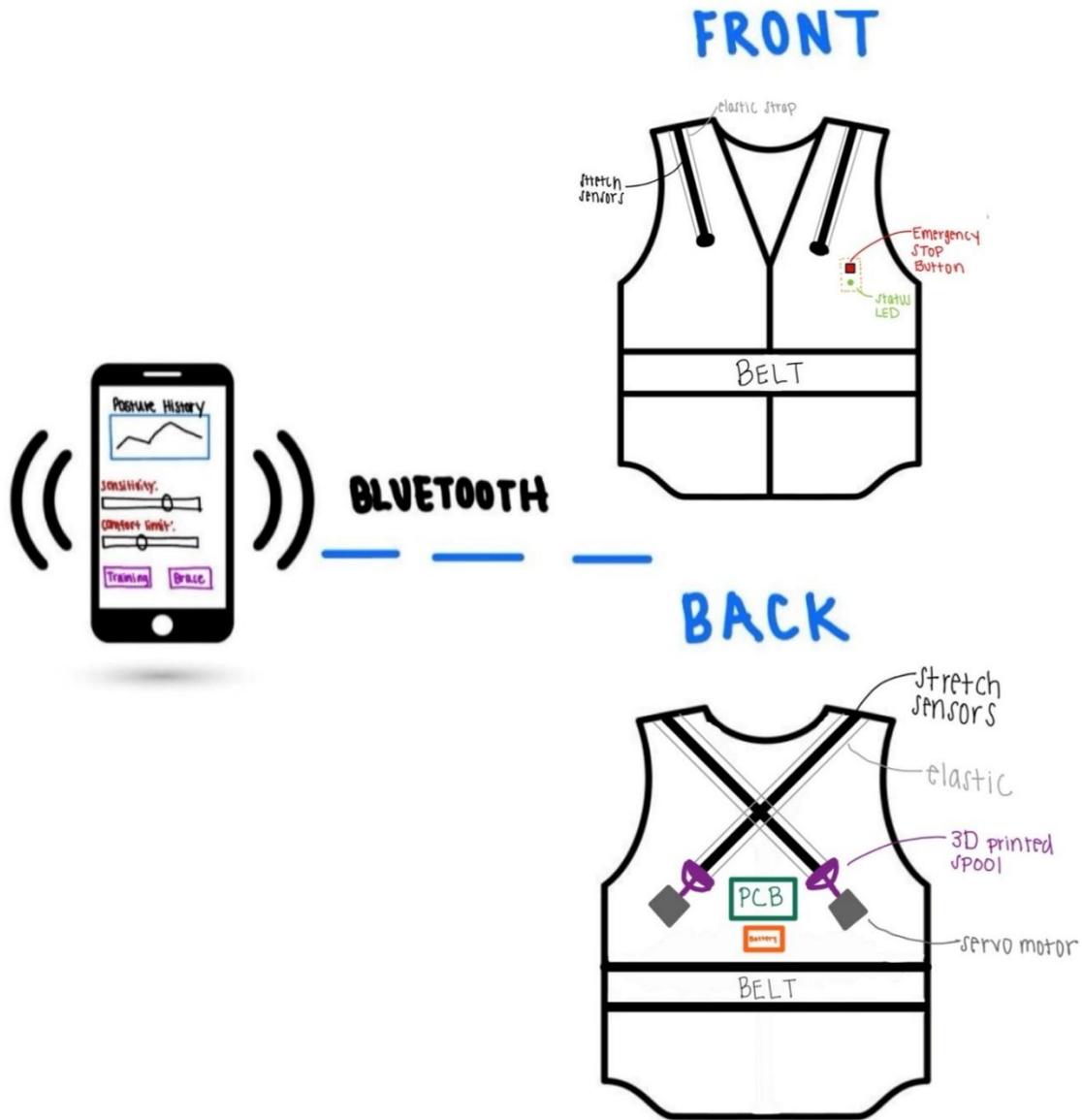
## 1.2 Solution

We propose an Active Postural Correction Vest. Unlike passive braces, this system uses an active electromechanical feedback loop to physically retrain the user's posture, then letting go of the tension so that good posture is maintained by the user, not just the device itself.

The device itself consists of a wearable vest equipped with stretch sensors which attach to elastics. These sensors continuously monitor how much the elastics are extended. When the system detects a "slouch" state (shown by the stretch sensor reading shifting away from the calibrated threshold), the central PCB triggers a high-torque servo motor mounted on the back plate. The servo reels in a cabling system made of elastic connected to the shoulder straps, physically pulling the user's shoulders back into a proper position. Once the sensors detect that the user has returned to the correct posture, the servo releases tension, allowing for natural movement and self-maintained posture until the next slouch event. In terms of safety precautions, we plan to create an assistive device that does not use a lot of force, so it cannot cause any damage. We also are going to have an emergency stop button as well as an auto shut off when the resistance level reaches a level that is too high. We also will filter out noise by adding a timer that only activates the motors if the person is sitting in a slouched position for a prolonged time

The Bluetooth app will consist of a calibration setting, a posture log, and a mode toggling capability. For the calibration setting, each user can calibrate the sensors on the vest to their own posture and slouch positioning to start. In the posture log, users can see what their posture activity looks like each day, and they can see how the device is helping them improve their posture. The mode toggling capability of the app will be between the active mode, where the device will release the tension after correcting the user's posture, and brace mode, where the device will keep its tension after correcting the user's posture.

### 1.3 Visual Aid



**Figure 1:** Simple sketch of the physical design of Posture Correction Vest

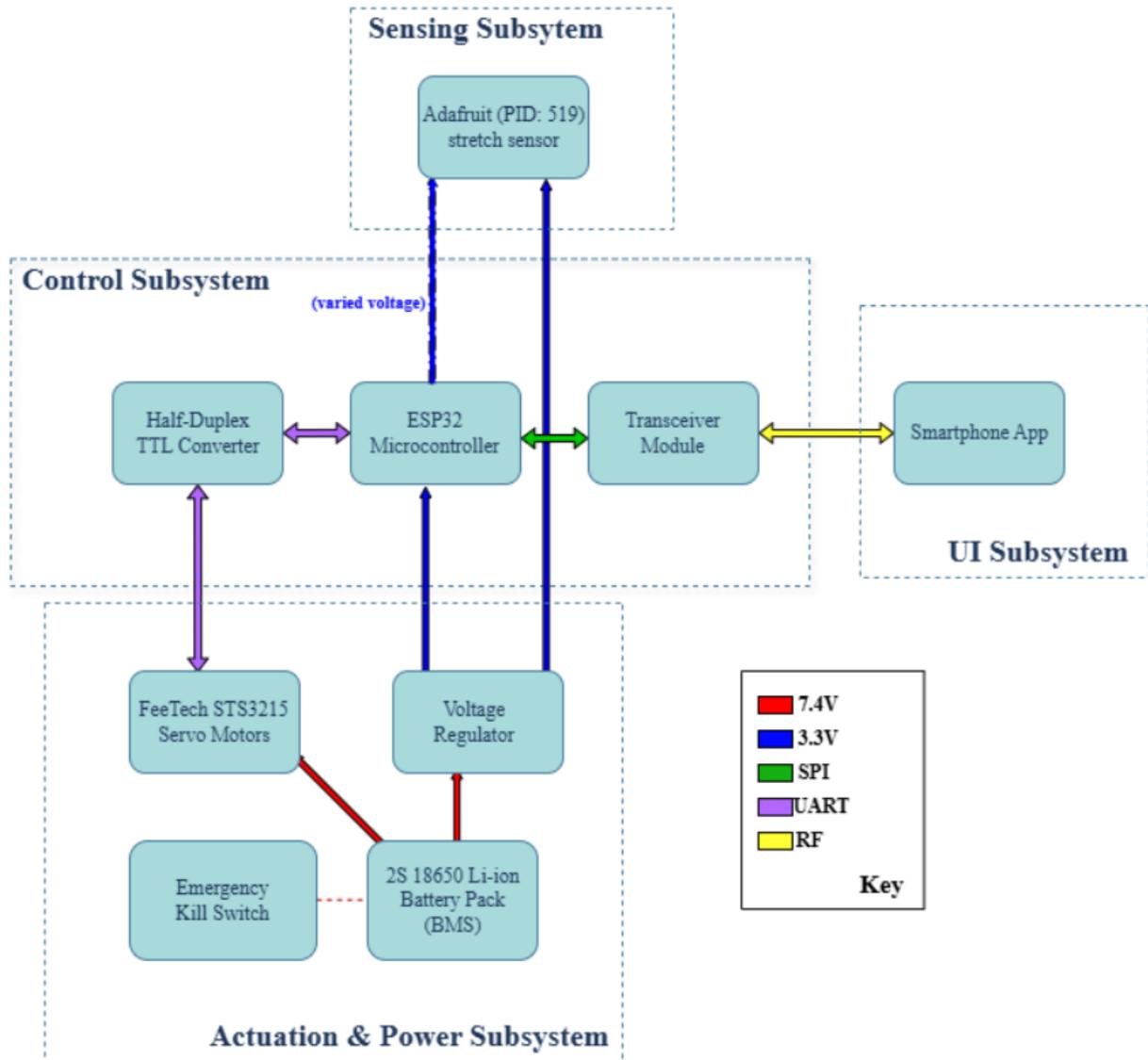
### 1.4 High-Level Requirements

- The system must provide active postural restraining by detecting a slouch automatically (after a 30 second delay) and applying corrective tension for 10 seconds until the user returns to a calibrated upright position, where the tension will be released after 10 seconds of consistent proper posture.
- The system must be able to distinguish between poor posture and natural movement by utilizing a time delay of 30 seconds after sensing a slouch event so that it is only triggered by a prolonged period of slouching.

- The vest must support daily tracking of user behavior with a wireless interface and a mobile app which will be calibrated for the user and allow them to visualize their postural habits and to adjust their preferred mode (brace or active).

## 2 Design

### 2.1 Block Diagram



**Figure 2:** Block Diagram for Hardware/Electrical Design

### 2.2 Subsystem Overview

#### 1. Actuation and Power Subsystem

The actuation and power subsystem provides all the electrical power and drives the physical correction capabilities of the vest. This subsystem consists of the motors and kill switch along with the battery pack and voltage regulator. The battery pack provides the main DC source. The hardware emergency kill switch is placed on the motor power path, so that motor power can be cut instantly if needed. The voltage regulator generates a stable 3.3V for the ESP32. This subsystem connects “upward” to the Control and Sensing subsystems via the 3.3V rail.

## 2. Control Subsystem

The control subsystem executes posture detection as well as safety decisions. The ESP32 reads stretch sensor voltages, applies logic to confirm sustained slouching, and issues motor commands when correction is needed. It also utilizes the smart serial servos for torque feedback and enforces limits by stopping or reversing motion when the load exceeds a comfort threshold. This subsystem connects to the Sensing subsystem via ADC inputs from the stretch sensors. It connects to the Actuation subsystem via a half-duplex UART servo bus. Lastly, it connects to the Wireless/UI subsystem via Bluetooth.

## 3. Sensing Subsystem

The sensing subsystem provides posture measurement signals. Conductive rubber stretch cords are mounted in the strap path so that strap extension changes their resistance. Each sensor is conditioned into an analog voltage through a voltage-divider circuit and read by the ESP32. In addition, servo load is treated as a safety measurement that can replace pressure sensors. This subsystem connects to the Control Subsystem through ADC (stretch).

## 4. Wireless/UI Subsystem

The Wireless/UI Subsystem provides user interaction, calibration, and logging. A smartphone app exchanges BLE packets with the ESP32 to run calibration, set detection sensitivity and comfort limits, and display posture history and events. This subsystem connects only to the Control subsystem (wireless data) and applies those parameters to sensor interpretation and actuation behavior.

## 2.3 Subsystem Requirements

### 1. Actuation and Power Subsystem

The Actuation and Power Subsystem overall enable the active postural restraining with the motor and battery system to apply the corrective tension for 10 seconds, then release after another 10 seconds, and ensures user safety with the emergency kill-switch. This block consists of a 2S 18650 Li-ion Battery Pack which provides 7.4V to the rest of the physical system. This battery pack is connected to the two FeeTech STS3215 Servo Motors which each require 7.4V, which are also connected to the control subsystem. The Battery Pack is also connected to the voltage regulator which is used to step down the 7.4V supply from the battery to 3.3V to connect to the ESP32 Microcontroller in the Control Subsystem and the Adafruit stretch sensors in the Sensing Subsystem. For safety purposes, we have a connection between an Emergency Kill Switch which will shut down all the subsystems in case of emergency.

### **Subsystem Requirements:**

1. E-Stop: If this component fails, we will lose wearable safety for the vest.
2. Servo-battery connection: If this component failed, the servos could not generate the necessary tension to correct posture.
3. Voltage Regulation: If this component failed, the microcontroller and sensors could not run, as they expect the voltage to be stepped down to 3.3V.

## 2. Control Subsystem

The Control Subsystem implements logic for the 30 second delay time when detecting a slouch event, interprets sensor data, commands motor actuation, and enforces the limits on safety for the vest. The Control Subsystem includes the ESP32 Microcontroller, which requires 3.3V from the voltage regulator in the Actuation and Power Subsystem. This microcontroller has a built-in Transceiver module which will communicate with the microcontroller via SPI. This Transceiver Module will interface with the UI subsystem via RF, which will allow for Bluetooth connection to the mobile app. The microcontroller also must interface with a Half-Duplex TTL converter in order to communicate with the Servo motors. This TTL converter is necessary because the ESP32 uses a standard 2-wire UART protocol with TX and RX buffers, while the STS3215 servo motors that we are using require a 1-wire half-duplex data line. Essentially, the UART communication between the ESP32 and the TTL converter is full-duplex, while the UART communication between the STS3215 servo motors and the TTL converters is half-duplex, which is why conversion is necessary here. Lastly, the ESP32 interfaces with the Adafruit stretch sensors in the Sensing Subsystem via a varying voltage (which will be further explained in the Sensing Subsystem).

### **Subsystem Requirements:**

1. 30 Second Delay Logic: If this fails, there is no accuracy to slouch event detection, and the vest will correct for small movements where it should not.
2. TTL Converter: If this fails, the microcontroller cannot communicate with the servo motors.
3. ESP32 Microcontroller: If this fails, no data can be processed from the stretch sensors, safety will be violated, and overall actuation will not happen.

## 3. Sensing Subsystem

The Sensing Subsystem will distinguish a slouch event versus normal movement and will provide the signal that is measured for the delay of 30 seconds before a slouch event is acted upon. This subsystem will use a conductive rubber cord (Adafruit PID:519) which is supplied with 3.3V from the voltage regulator in the Actuation and Power Subsystem. The circuit for these stretch sensors is formed as a voltage divider using a fixed pull-down resistor. These stretch sensors communicate with the ESP32 by outputting a varying analog voltage between 0V to 3.3V directly to the microcontroller's ADC pins.

### **Subsystem Requirements:**

1. Connection with ESP32: If this fails, we will not get data from the stretch sensors

2. Cord in good condition: If this fails, we will not be able to retrieve accurate data from the conductive cord

#### 4. Wireless/UI Subsystem

The User Interface Subsystem overall makes long-term tracking and user-adjustable utilities available. The smartphone app will communicate with the Transceiver Module in the ESP32 in the Control Subsystem via RF, or Bluetooth. It will get data from the microcontroller for long-term posture tracking and will also allow for a brace setting to be set, which will be communicated from the application to the microcontroller. The app will also provide calibration upon first use of the vest in order to allow it to be customizable to the user's exact posture habits.

#### Subsystem Requirements:

1. Connection with ESP32: If this fails, we will not be able to get the necessary data about sensors/motors, nor will we be able to calibrate the vest to each unique user
2. User-Friendly Interface: If this fails, users will not be able to set any parameters for their brace and may have a hard time calibrating their vest.

#### 2.4 Tolerance Analysis

A key project risk is the servo-driven spool mechanism exerting too much force and applying excessive strap tension. This could cause discomfort or potentially unsafe pressure on the user's shoulders/chest. Since the servo can generate large torque, small changes in spool radius or friction can amplify strap force. If the strap force is too high, the design would fail the requirement that the device remain safe/comfortable and stop actuation when resistance becomes too high.

The linear pulling force exerted on the user's straps is approximately:

$$F = \frac{\tau}{r}$$

where:

- $F$  = strap force (N)
- $\tau$  = servo output torque (Nm)
- $r$  = spool radius (m)

Since the STS3215 servo is extremely powerful, at a 7.4V battery supply, its stall torque is approximately 19 *kgcm*

If we designed a 3D-printed spool with a radius of 2 cm:

$$F = \frac{\tau}{r} = \frac{19kgcm}{2cm} = 9.5 kg$$

A linear pull of 9.5 kg (roughly 21 lbs) could be too much force for a posture brace and could cause extreme discomfort or strap failure. A standard posture brace relies only on gentle resistance typically only needing 2-5kg of force to prompt the user to engage their own muscles. To address this issue, our tolerance limit must be defined in our software. The system must be constrained to operate between 2kg and 4kg of linear force. To do so, the ESP32 must read the UART load data and trigger an auto-shutoff if the load exceeds 5kg (which is 1/3 of the motor's full capacity). In essence, our analysis proves that the STS3215 is more than feasible for physical requirements, but the risk lies entirely in limiting the motor's torque through software to maintain a 5kg maximum tolerance.

## 3. Ethics, Safety, and Societal Impact

### 3.1 Ethics

As engineers with a goal to produce a positive impact, we want to approach this from a professional standpoint as this can affect everyday lives. Under the **IEEE Code of Ethics**, our first obligation is to protect and uphold public health and safety (IEEE 1.1). In terms of our posture vest, this involves acknowledging that we are placing a motorized system onto a human body. In order to avoid ethical breaches, we are prioritizing a human-centered design, as this device is meant to aid, and is not a replacement for muscular effort. It is not meant to be a device used by workers whose job requires an unrestricted range-of-motion, or by those that have serious musculoskeletal injuries that require the intervention of medical help. We have a professional duty to be honest and realistic in the claims we make, which is why we will specify the audience that should and should not use this device (IEEE 1.5). It would be unethical to market this product as a medical solution for scoliosis or chronic injury, and instead, we will clearly define it as a training tool for behavioral correction. Additionally, since the vest utilizes a microcontroller for data logging, we are bound to handle user data with integrity (IEEE 1.1), and ensure that sensitive information about an individual's physical health remains private and secure by locking that information to the user only (AKA moderators have no access).

### 3.1 Safety

Regarding safety and regulations, the project sits at the intersection of wearable technology and assistive devices. While the **FDA's General Wellness Policy** provides a pathway for low-risk devices like ours to bypass the rigorous 510(k) clearance required for Class II medical devices, we still aim to align with **IEC 60601-1** standards for basic safety and essential performance. This includes rigorous testing for electromagnetic compatibility to ensure we don't interfere with other vital electronics. On a local level, we are adhering to the **University of Illinois Division of Research Safety (DRS)** protocols, specifically concerning the thermal management of Li-Ion batteries and the structural integrity of our vest and other components. To mitigate the risk of mechanical over-extension, we are integrating physical limiters that prevent the servo motor from ever pulling beyond a safe anatomical range, regardless of what the software instructs.

### 3.1 Societal Impact

The impact of this vest extends beyond the individual user. Socially and globally, it addresses the problems that many white-collar and office workers have with posture and "Tech Neck", potentially lowering the long-term economic burden of musculoskeletal injury and strain. By choosing materials like breathable mesh and natural fibers, we aim to both fulfill our environmental responsibility to minimize e-waste and provide a comfortable solution for all users.

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