4.2 Design Exploration

4.2.1 Design Decisions

a. Sensor Type and Configuration

Choosing the type and configuration of sensors is critical, as it directly impacts the accuracy and responsiveness of the pressure readings. In this project, load cell arrays have been selected for its ability to detect small changes in pressure across different contact points and have a relevant range weight up to 110 pounds for every load cell. This decision ensures that users receive timely alerts for any potentially harmful pressure levels, making it central to the effectiveness and efficiency of the device.

b. Data Transmission Method

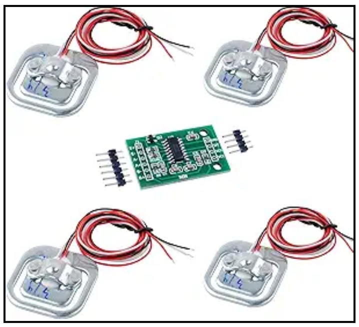
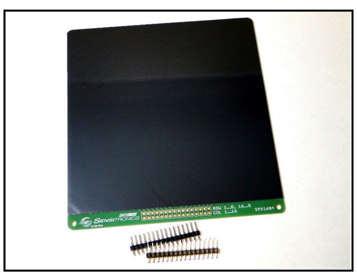
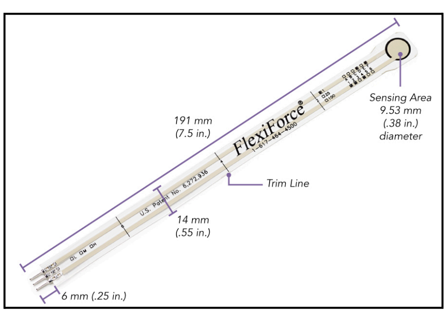
The decision to use Bluetooth for data transmission (instead of WiFi) is based on considerations of energy efficiency, ease of use, and compatibility with mobile devices. Bluetooth's lower energy consumption makes it ideal for wearable devices, extending battery life and reducing maintenance costs for users. Additionally, Bluetooth connectivity offers a simpler user experience for pairing the patch with a mobile app, ensuring the device remains convenient and user-friendly.

c. Mobile App Functionality and Interface

Deciding on an intuitive and accessible interface design for the mobile app is essential. The app's dashboard will display real-time pressure data and send alerts, ensuring that users can quickly interpret data and take corrective action if needed. This focus on user-friendly design helps ensure that the end product meets the needs of adaptive sports athletes and others at risk of pressure sores, increasing the likelihood of adoption and successful use.

4.2.2 Ideation

For the decision on **Sensor Type and Configuration,** we used **experimental prototyping** or hands-on comparative analysis technique to explore potential sensor options. Below are the five options considered:

Potential Sensor Options	Explanation
1. **Load Cells**  *Figure 4.2.2.1*	Selected for their high load capacity of up to 110 pounds, which supports the range of body weights encountered in the application. Each load cell is small (80 g) and compact, making it ideal for a wearable device. Often used in digital bathroom scales, this sensor is a half-bridge strain gauge, providing the precision required for monitoring body pressure effectively.
2. **ShuntMode MatrixArray**  *Figure 4.2.2.2*	A rigid sensor array with 256 force-sensing cells arranged in a 16x16 grid, covering a 4x4 active area. Each cell can measure up to 50 lbs, making it suitable for multi-touch input and pressure mapping. However, its lack of flexibility and limited force range presented challenges for continuous body pressure sensing. This array requires additional soldering to connect to PCBs.
3. **FlexiForce A201 Sensor**  *Figure 4.2.2.3*	This sensor offers various lengths and a thin profile (0.203 mm) but has a small sensing area (9.7 mm diameter) that restricts its ability to cover larger surfaces. It has a standard force range of up to 445 N and operates in a broad temperature range (-40°C to 60°C), which is advantageous in various environmental conditions. However, its limited surface area was less practical for widespread skin contact monitoring, moreover for the adaptive sports athletes.

<table>
<tr><td>4. Thin Film Pressure Sensor

Figure 4.2.2.4</td><td>An affordable option with a maximum force capacity of 10 kg. This ultra-thin and flexible sensor responds rapidly to pressure changes and is both waterproof and sensitive. Although it offers high sensitivity and is well-suited for applications like wearables, its low maximum force limit made it less suitable for the project’s needs.</td></tr>
<tr><td>5. Thin Film Force Sensor (SF15-600)

Figure 4.2.2.5</td><td>This flexible sensor emulates the perception capabilities of human skin, offering high sensitivity, quick response, and durability. It is resistant to bending and temperature fluctuations (-20°C to 60°C) and provides reliable performance. Despite its low price, its 10 kg limit was insufficient for supporting the required pressure ranges in this project.</td></tr>
</table>

4.2.3 Decision-Making and Trade-Off

To evaluate the different sensor options, we used a **weighted decision matrix** that considered key factors relevant to the project, including **force range**, **size and flexibility**, **power efficiency**, **cost**, and **durability**. Each criterion was weighted according to its importance to the project's success. Here is a breakdown of the decision-making process, followed by an explanation of why the load cell was ultimately chosen.

Weighted Decision Matrix

Sensor Option	Force Range (30%)	Size & Flexibility (25%)	Power Efficiency (15%)	Cost (15%)	Durability (15%)	Total Score
Load Cells	9	8	8	8	9	8.45
ShuntMode Matrix Array	6	4	7	5	7	5.85
FlexiForce A201 Sensor	7	5	9	5	8	6.65
Thin Film Force Sensor	4	9	10	9	6	6.80
Thin Film Pressure Sensor	5	9	10	9	6	7.05

Decision Criteria and Weights

1. **Force Range (30%)**: This is a critical criterion, as the sensor must be able to accommodate the pressure exerted by various body parts. Load cells scored highest here due to their wide range of up to 110 pounds, meeting the project's requirements.
2. **Size & Flexibility (25%)**: Flexibility and compactness are essential for user comfort and integration into a wearable device. Thin film sensors performed well in this category due to their ultra-thin design, while load cells also scored reasonably well for their compact dimensions.
3. **Power Efficiency (15%)**: Sensors must consume minimal power to extend the device's battery life. Thin film and FlexiForce sensors scored highly for low power consumption, but load cells also proved efficient enough for this application.
4. **Cost (15%)**: Staying within budget is essential, especially as we tested multiple sensors. Thin film sensors had an advantage here with low prices, while load cells were slightly more expensive but still reasonable.

5. **Durability (15%)**: Sensors need to withstand long-term use under various pressures. Load cells excelled in this category, as they are often used in scales and other applications requiring resilience.

Analysis and Choice

After scoring each option, Load Cells emerged as the highest-scoring sensor due to their broad force range, compact size, adequate power efficiency, and high durability. Although they were slightly more expensive than thin film options, their reliability in accurately measuring the necessary pressure range made them the best fit. The load cells provide stability and consistency, essential for ensuring that the device delivers accurate alerts to users, ultimately supporting the project's goal of effective pressure monitoring.

4.3 Proposed Design

4.3.1 Overview

Our pressure sensor patch is specifically designed to support adaptive sports athletes with nerve damage who may not feel pressure buildup and are unaware when pressure sores begin to develop, particularly on the lower extremities. For these athletes, monitoring pressure points is crucial since they may remain unaware of damaging pressure on certain areas due to impaired nerve function. The patch continuously tracks pressure levels and alerts the user if any area experiences excessive pressure for too long, allowing timely position adjustments to prevent sores.

This device is especially valuable for athletes in wheelchairs or those with limited mobility who frequently sit or place weight on specific parts of their lower body. By proactively alerting users when pressure thresholds are exceeded, the patch helps them prevent pressure sores before they become problematic, supporting a safer, more active lifestyle.

Key Components of the Pressure Sensor Patch

1. **Load Cell Sensors**: These small sensors detect the amount of pressure applied to different areas where the patch is placed. They act like the pressure-measuring technology in digital bathroom scales, allowing us to monitor the force exerted on each sensor. By using multiple load cells, we can cover a larger area and get detailed pressure readings from different body parts.
2. **Microcontroller**: The microcontroller is a small computer chip that processes the information from the load cell sensors. It takes in the pressure readings and checks if any of them exceed a safe threshold. If the pressure becomes too high, the microcontroller triggers a warning to alert the user.
3. **Bluetooth Connectivity**: This feature allows the device to send pressure data wirelessly to a mobile app. With Bluetooth, users can view real-time pressure data on their smartphone, which also alerts them when adjustments are needed.
4. **Mobile App**: The app provides a user-friendly interface that displays pressure readings from the sensors in real time. When excessive pressure is detected, the app sends an alert to the user, prompting them to adjust their position to relieve pressure. The app also logs pressure data over time, helping users and caregivers track patterns and identify areas that may need extra care.

How These Components Work Together

Our pressure sensor patch is specifically designed to support adaptive sports athletes with nerve damage who are unable to feel pressure and may not realize when pressure sores are developing, especially on the lower extremities. The device continuously monitors pressure levels through load cell sensors and sends this data to a microcontroller, which processes the readings and checks for any areas where pressure exceeds a safe threshold.

When excessive pressure is detected, the microcontroller initiates a response: it communicates with the app via Bluetooth to send an alert to the user's phone, and the mat itself produces a vibration or sound, giving an immediate and localized alert. This dual alert system—visual feedback from the app and sensory feedback from the mat—ensures that the user can quickly identify and relieve pressure on vulnerable areas, even without constant app monitoring.

This integrated design promotes user comfort and safety by offering real-time alerts and logging pressure data to track trends over time, helping prevent pressure sores before they develop. Lightweight, portable, and easy to use, the device is a practical tool that fits into an active lifestyle, providing peace of mind for athletes and their caregivers.

4.3.2 Detailed Design and Visuals

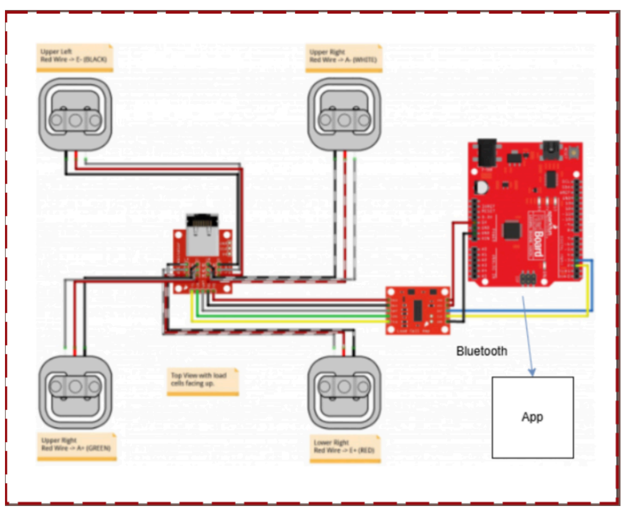


Figure 4.3.2.1
Detailed Design and Visuals of the Project

Our design consists of three major components that interact with each other. The first component is the load cell array, an array of weight sensor bundles that will monitor pressure in different areas. This system is then hooked up to a microcontroller which will process the output from the load cell array and turn this into usable data about the pressure in different regions. The microcontroller will include a Bluetooth module connected to a mobile device.

Figure 4.3.2.2

UI/UX Design of the Application

From here, an application will be reading the Bluetooth output from the microcontroller and display the information visually, pushing out notifications to the user if the pressure exceeds a predefined threshold. These notifications will be sent from the Bluetooth module to the mobile device so the application does not have to constantly run and process large amounts of data in the background.

The wireframes are for the app portion of the solution. These show high-level details about what the sensor is reading. The application will also alert the user when the reading exceeds the safe threshold and let the user know that they need to have their position shifted.

4.3.3 Functionality

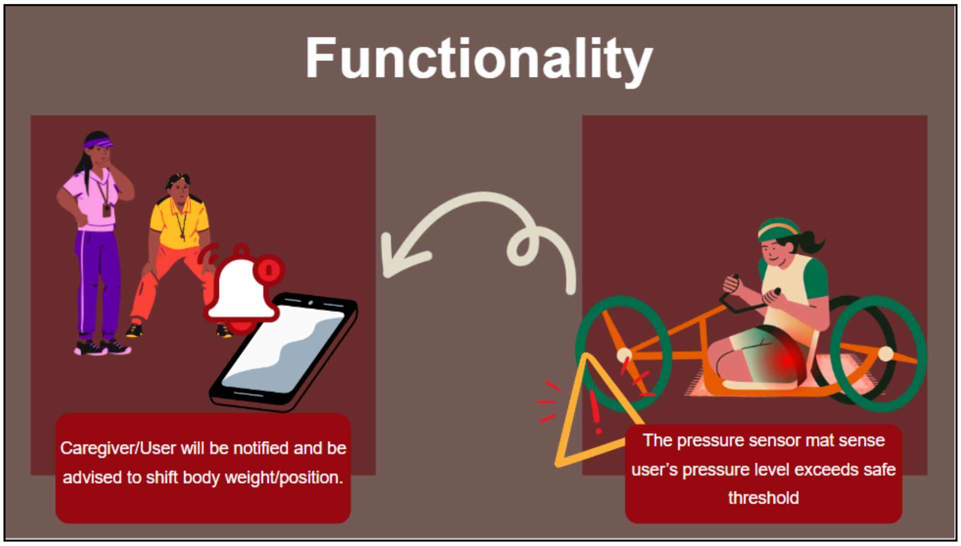


Figure 4.3.3.1
Visual of Functionality

Our pressure sensor patch is designed to operate seamlessly in a real-world context, particularly for adaptive sports athletes with nerve damage who are at risk of pressure sores on their lower extremities. The device is intended to be worn or placed under areas of the body that are prone to prolonged pressure during activities, such as sitting in a wheelchair or engaging in sports training.

User Interaction and Device Response

1. **Setup**: The user would first apply the pressure sensor patch to the targeted area, such as the lower back or thighs, where they are likely to experience prolonged pressure. They would then connect the patch to the mobile app via Bluetooth.
2. **Monitoring**: Once activated, the load cell sensors continuously collect pressure data and transmit this information to the microcontroller. The app displays a real-time visualization of pressure levels, allowing the user to monitor changes as they go about their activities.
3. **Alert Activation**: If pressure on any monitored area exceeds the set threshold for a predefined period, the microcontroller triggers an alert:
    - **In-App Alert**: The app displays a visual alert indicating which area is experiencing excessive pressure. The app also logs this data for trend tracking and future analysis.
    - **Vibration/Sound Feedback**: Simultaneously, the patch emits a vibration or sound to provide a physical alert, allowing users to respond even if they are not actively monitoring the app.

4. **User Response**: Upon receiving the alert, the user can make necessary adjustments to relieve pressure—such as repositioning in their seat, shifting their weight, or taking a brief break. This helps prevent prolonged pressure on a single area, reducing the risk of pressure sores.

5. **Data Logging and Analysis**: The app continually logs pressure data, enabling users and caregivers to review historical trends and adjust their routines or seating arrangements as needed. This data can be used to identify recurring pressure points and refine usage practices, contributing to long-term health benefits.

4.3.4 Areas of Concern and Development

We believe that our design will do very well with satisfying requirements and meeting user needs. We have asked many questions regarding use cases and areas of most concern, and have adjusted our design in accordance.

The biggest point of concern is creating a pad that can fit many of the seats used by the disabled athletes. We need to design a system that can fit on a wheelchair, bike, kayak, etc.

We have requested an example pad that the athletes often use when sitting down. We made contact with the client stating this and they responded stating they don't have a one-size fits all and the design needs to be flexible with multiple seats.

4.4 Technology Considerations

- **Fusion 360** - We are using this software to create the CAD design of the sensor board that holds all of the load cells and other hardware. We also are using it to touch up the design of the cases that hold the individ ual load cells.
- **Artec Scanner** - We are using an Artec Spider 3D scanner to reduce custom component design time and mitigate our lack of 3D modeling ability
- **Bambu** - We are using a Bambu 3D printer to print 3D replicas of brackets for our load cells.
- **Android Studio** - we are using this to design and implement the app-side of the pressure sensor. Android studio provides lots of tools to build a complex UI, and interact with device hardware such as Bluetooth. This complexity can also be seen as a weakness, as you can do a lot with Android Studio and have nearly full control over the device.
- **Figma** - Figma is an excellent design tool for designing the UI portion of the app as well as the general flow of the device. It provides lots of tools for designing complex UIs

4.5 Design Analysis

So far, our team has created a partially functioning prototype of our hardware component of our project. We have designed 4 load cells wired to a raspberry pico W, which all sit in a board that we designed. The four load cells work together to read pressure data and print to a console. We plan to get this hardware component connected to the software side of our project to send received data over WiFi. We also plan to make our product smaller in size in further prototypes.

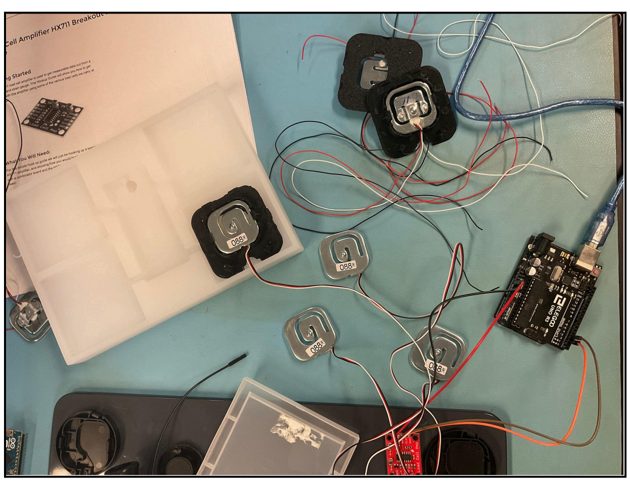


Figure 4.5.1
Current Prototype