# Development of a Head Impact Telemetry System for mTBI/CTE Research

Alyssa Silberman, Thomas Connelly, Eva Batdorj, and Riley McHale
Arapahoe Community College COSGC Wearables Team 2025-2026

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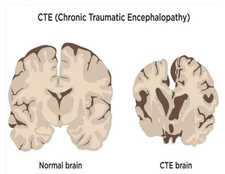
## Abstract

We have been developing a wearable system that records the motion of a user's head during high impact activities such as contact sports. A microcontroller module is worn around the waist and connects to a low-profile head harness containing three accelerometers which may be worn underneath any other headgear that the activity demands (e.g. a football helmet for football). During the activity, the system records hundreds of data samples per second from each accelerometer and persists them to an on-board MicroSD card. After the activity is complete, the microcontroller module can be connected to a PC via USB. The data can then be read by our web application which will provide analysis and graphical visualization of the data, as well as format the data in a comprehensible JSON format for use in other systems. This system, and the data it generates, can be part of a medical research team's arsenal for answering critical questions about mTBIs and CTE: what is the smallest amount of force, torque, and/or kinetic energy one's head can absorb before showing signs of mTBI? We believe progress can be made by correlating this data with other indicators of concussion/mBTI, such as psychological evaluation, blood tests for tau protein, etc. This system can also be expanded in countless ways to accommodate researchers interested in using it; different kinds of data can be collected by adding different sensors, granularity of data can be increased via a higher sample rate, and any number of analytical methods or visualizations can be programmed into our web application.

## Introduction

**Background:**

- Chronic Traumatic Encephalopathy (CTE) is caused by many subconcussive hits over a long period of time.
- Very common in contact sports like football, MMA, boxing, etc.
- The longer a person's history of subconcussive hits to the head, the more likely they are to develop CTE.
- So far, incurable and not directly detectable until after a person's death.
- Different kinds of forces have different impacts - linear, rotational, angular acceleration all affect the brain differently




(Photo Credit: iStock/Getty Images)

**Objectives:**

- Develop a useful tool for researching minor traumatic brain injury (mTBI) and chronic traumatic encephalopathy (CTE)
- Produce data about forces absorbed by the head during high-impact activities that can be used by CTE researchers alongside other methodologies.

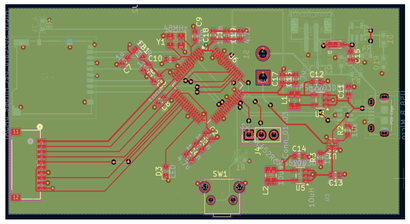
## Materials

- **Electronics:**
  - Custom PCB and Flexi-PCB designs
  - STM32 MCU
  - SD card
  - MicroUSB connectivity
  - Accelerometers to measure head impact data
  - Reflow oven for board assembly
- **Data analysis web application:**
  - React
- **Housing:**
  - 3D Printer
  - Filament

## Methodology

**Electronics:**

The device saves the readings from 3 accelerometers attached to the head to an SD card as a binary file. After use, the device can be plugged into a desktop, and the file can be copied to be analyzed by our web application. The PCB was designed in KiCad and was manufactured through JLCPCB.



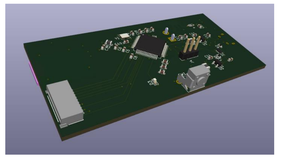
**Housing:**

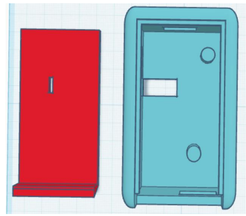
We designed a custom case for our PCB using TinkerCad that has openings for switches and has a functioning lid so the PCB can be removed before uploading to the web platform. The walls are thick for durability during use.

**Website:**

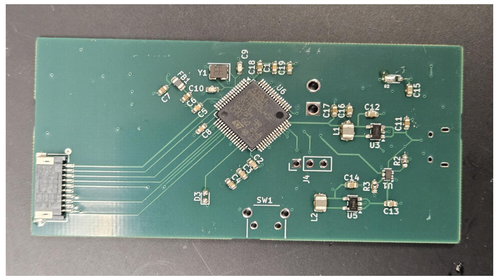
The data from the device is then uploaded to the web platform which was created using React. The data is plotted over time and figures such as peak and average acceleration are generated.

## Results



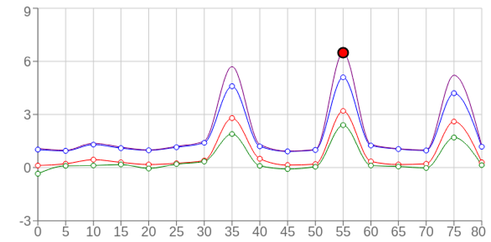


Above are screenshots of our designs for the PCB and iits housing. The housing is 56x97x27mm.



Above is the physical PCB with components soldered to it. Unfortunately, due to technical difficulties, several of the MCU's tiny leads were soldered together, and we were not able to fix it, rendering the device useless.

Below is a plot of mock data that was generated on our web app.




**Biggest Impact**

Time: 55 ms

ax: 3.2

ay: 2.4

az: 5.1

Magnitude: 6.48

Selected file: Sample Data

```
time_ms,ax,ay,az
0,0.12,-0.34,1.02
5,0.22,0.10,0.95
10,0.45,0.12,1.30
15,0.30,0.18,1.10
20,0.18,-0.05,0.98
25,0.25,0.20,1.15
30,0.40,0.35,1.40
35,2.80,1.90,4.60
40,0.50,0.10,1.20
45,0.15,-0.08,0.92
50,0.20,0.05,1.00
55,3.20,2.40,5.10
```

## Conclusion

Through building our device, we learned a lot about the engineering process. We learned it's important to test often before assembling and to talk to stakeholders during the process. We also learned how important it is to shop around for parts when sticking to a budget as some parts were more expensive depending on where they were manufactured/sold.

The PCB design itself was adequate for our needs, but soldering the components proved to be a significant challenge. Even after investing in a reflow oven, we still faced difficulties with component leads soldering together. On very small components with thin leads, this can only be fixed by starting all over, and we did not have time to iterate on the process many times.

We learned how an engineering project can be closely related to many other industries, such as the medical industry. The biggest thing we could've improved upon is reaching out to relevant stakeholders. Having experienced medical researchers guide us on where to narrow our focus in terms of data analysis and visualization would have been immensely helpful.

Just from working together, we learned that when everyone has a specialization, it allows all parts of the project to come together faster than one person having to learn something new at the same time. It's also very important to talk with your team when you're stuck as it often helps you solve the problem.

## Future Work

We hope to improve our wearable device based on testers' feedback before sharing our device with researchers who want to learn more about head impact in specific situations such as football and other sports/ activities, over the course of a year who can modify the device and web application to their needs.

## Acknowledgements

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We want to thank Jennifer Jones for her support throughout the project.