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Head Armor Pro

Team 101

Design Review #4

Team Introduction

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Connor Hollis

Project Objective

The objective of this project is to design a device that will reduce the risk of concussions for athletes across all sports, with a specific focus on football players.

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Background Overview

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- Mild, Moderate, and Severe Brain Injury
- TBI: deformation of brain cells due to inertial load
- 5% of youth football players suffer concussions each season
    - Looking to minimize long-term damage for youth players
- Current foam addresses linear forces but not rotational

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Stress-Strain vs. Cavitation

Stress-Strain Theory

- Forces deform brain cells
- After 18% of deformation, becomes plastic and disrupts biochemical process
- Dependent on fiber orientation, location of impact, force amount

Cavitation Theory

- Tensile force exceeds tensile strength of liquid
- Microscopic bubbles form inside homogeneous liquid
- Bubbles implode and release large amounts of energy

Connor Hollis

Stress-Strain vs. Cavitation

Stress-Strain Theory

+

Cavitation Theory

→

Deaccelerating the Brain

Design Goals and Targets

Deaccelerate the brain during an impact **by 5 %**

Must dissipate energy reliably (how much energy are with dissipating)

Energy absorption efficiency is the highest priority, with a target reduction of at least 25% in linear impact forces.

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Design Goals and Targets cont.

Rotational force mitigation, which aims for a minimum of 20% reduction, is also critical for preventing diffuse axonal injury.

Durability- withstanding at least 1,000 impacts

Weight **<** 1.5 kilograms to ensure comfort and practicality

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510(k) Panels

- Identify, explain, and clarify each of the critical decision points in the decision-making process FDA uses to determine substantial equivalence
- Head Armor Pro vs. Riddell SpeedFlex helmet:s

Proposed Device:

Auxetic foam (made of 80A resin) with unique geometric patterns designed to manage linear and rotational forces.

Predicate Devices:

The Riddell SpeedFlex uses expanded polystyrene (EPS) foam for impact absorption. The device does not provide real-time impact monitoring.

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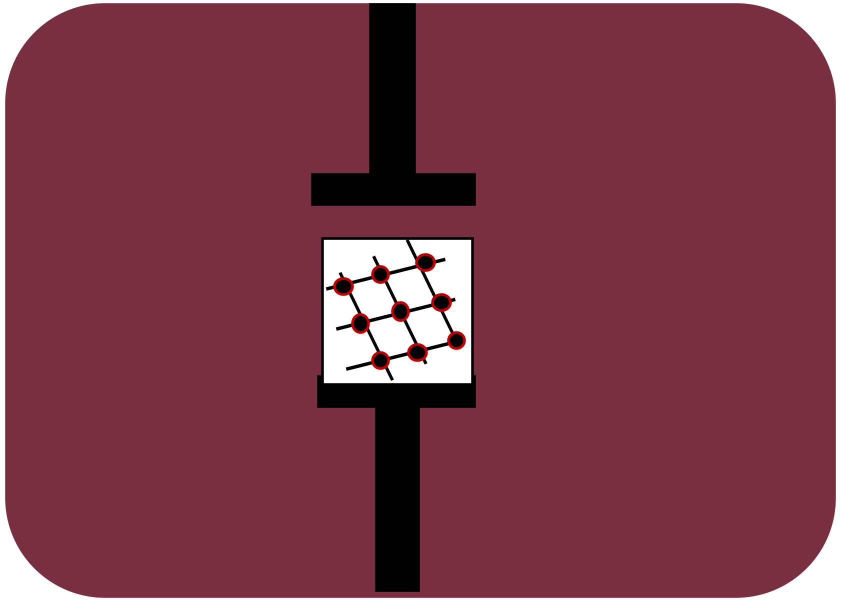
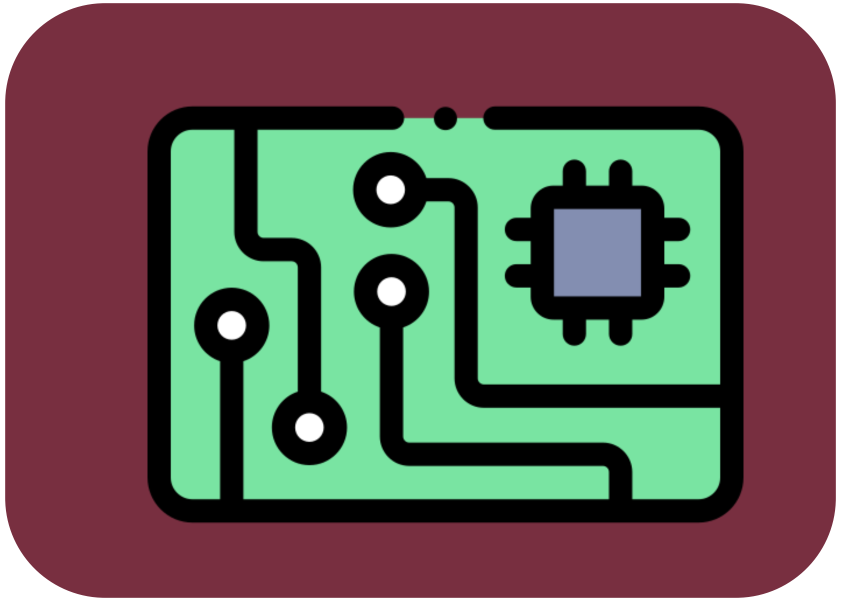
Proposed Solution





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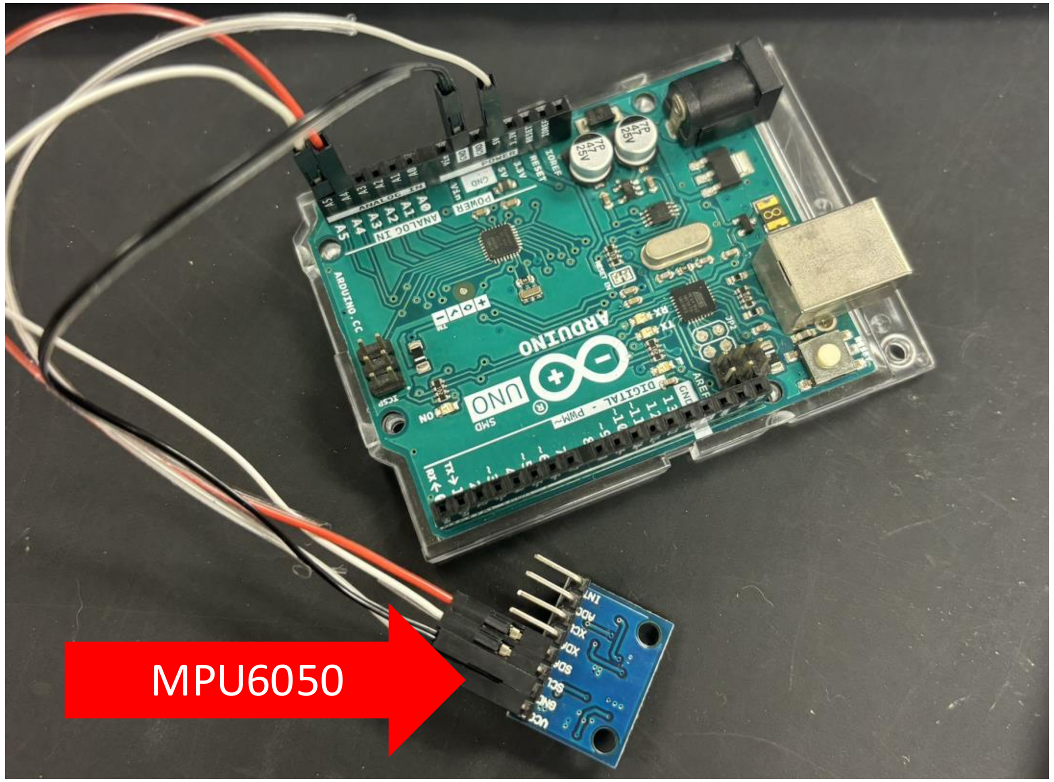
Current Auxetic Foam Design

- Honeycomb hourglass structure
  - 3D printing with stereolithography (SLA) technology
  - Flexible 80A resin
  - Light weight profile
- Hexagonal auxetic foam structure
  - Negative Poisson's ratio
  - Enabling lateral expansion during impact deformation

Riley Stroth

Impact Monitoring Sensor

- Alerts coaches and trainers to high-impact events in real-time, for immediate injury assessments
- Understanding linear and rotational impacts
- <u>Concussive Thresholds:</u>
  - Linear Acceleration- 70 to 120 g
  - Rotational Acceleration- 4500 to 6000 rad/s^2



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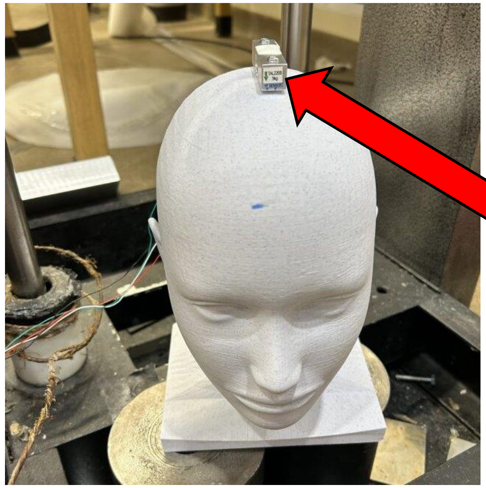
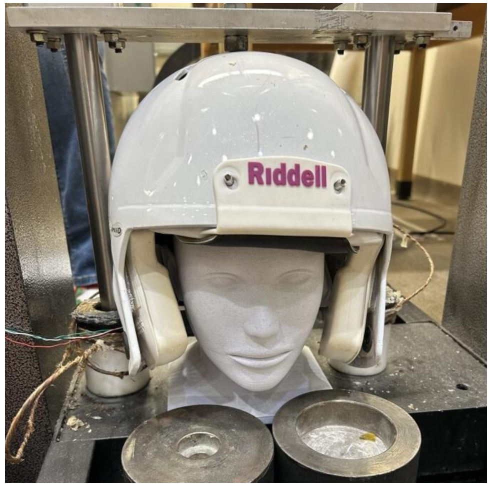
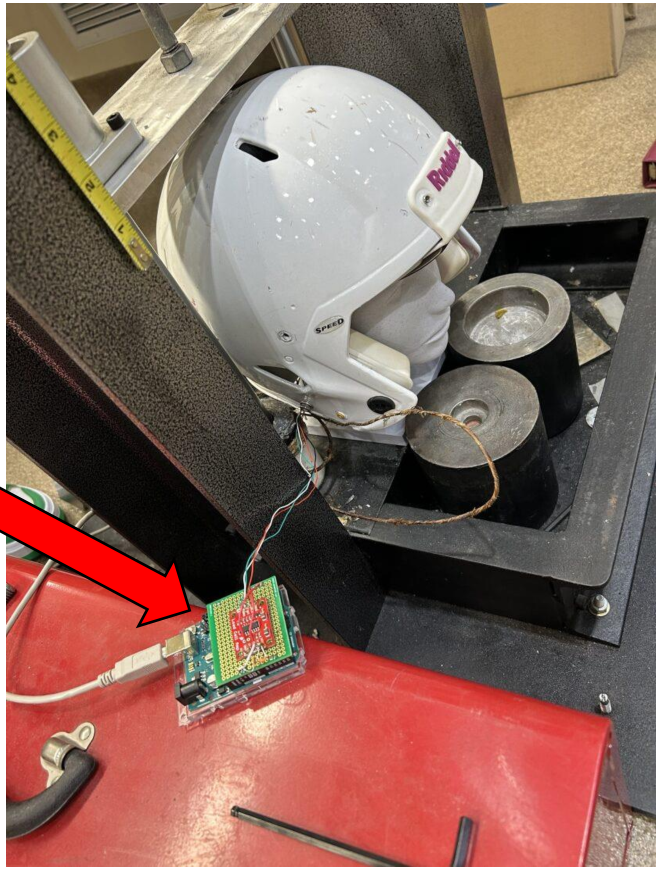
Drop Test – Failures and Successes



Load Cell



Arduino
& Circuit



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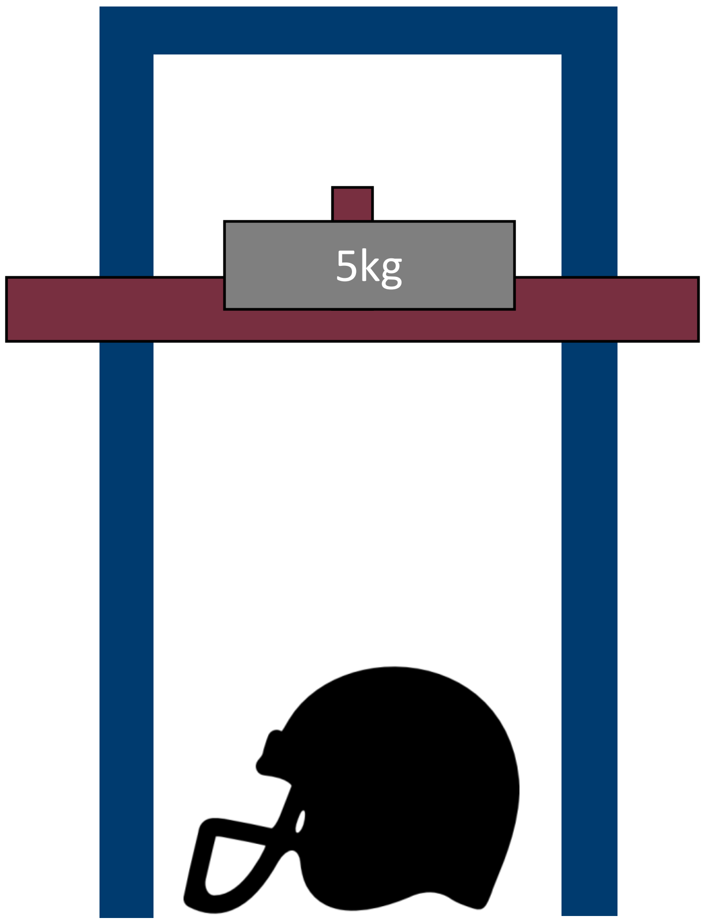
Drop Test – Failures and Successes



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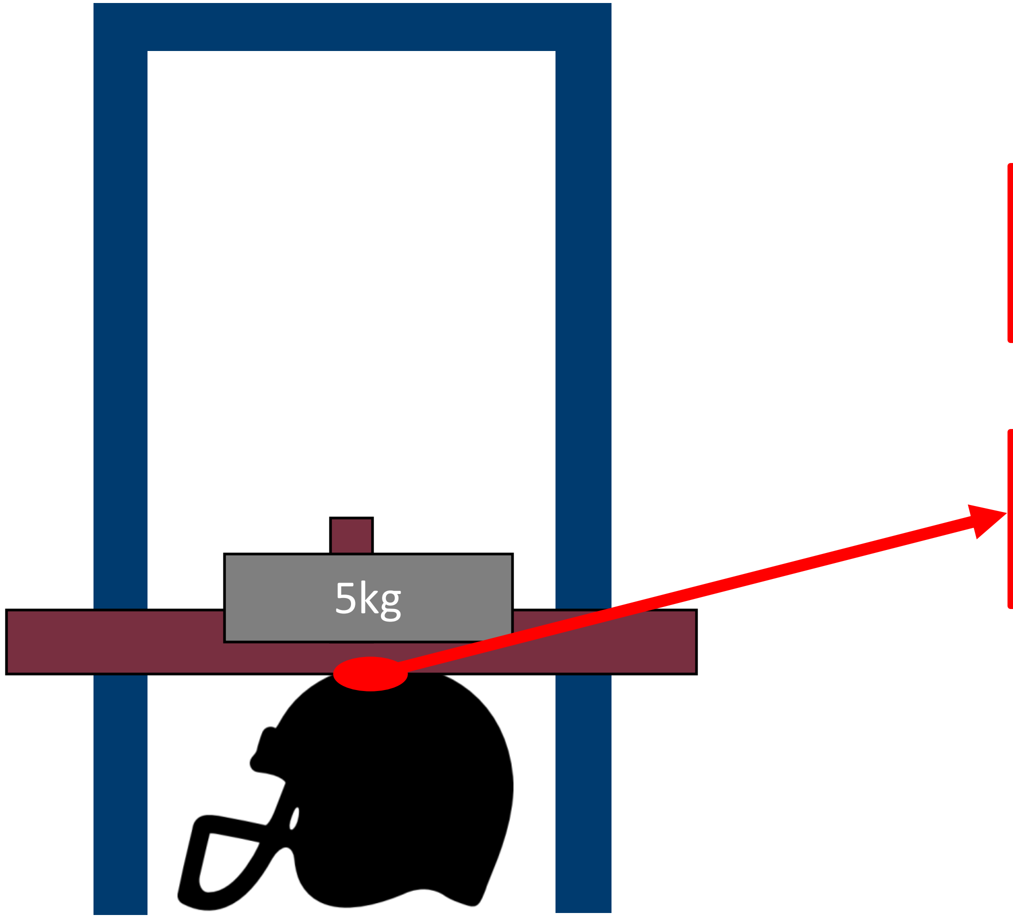
Drop Test – Failures and Successes



Theoretical Value-
Force = Mass • Gravity • Height

Load Cell Reading-
Recorded Pound Force

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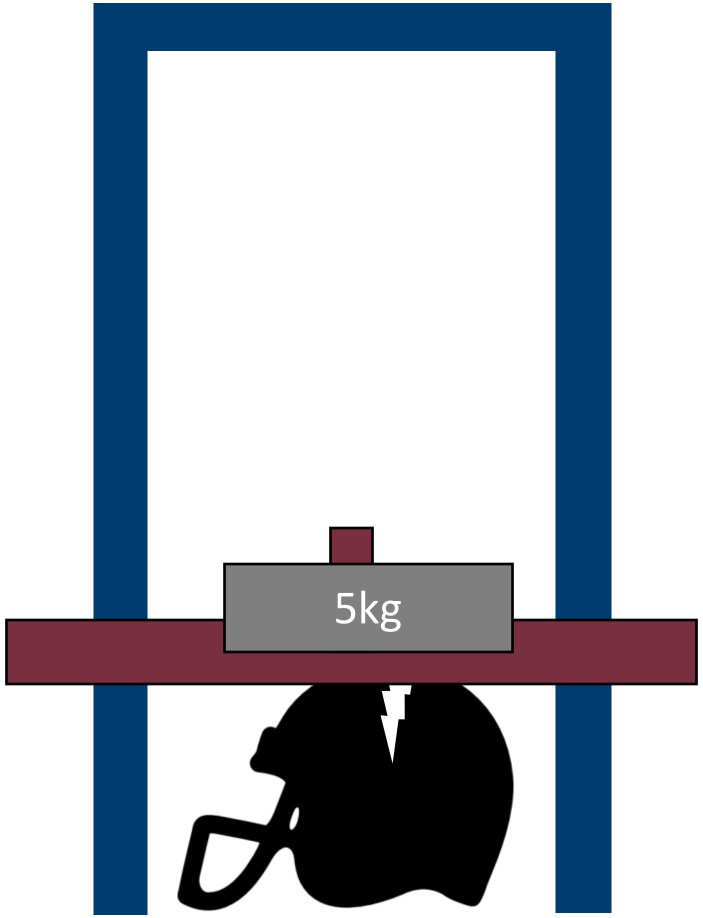
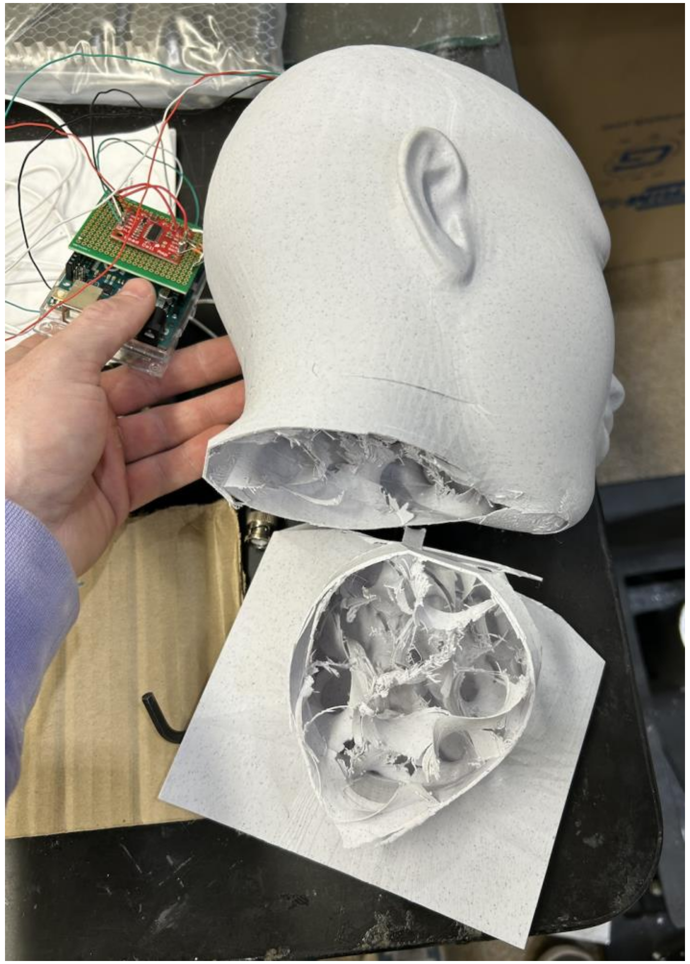
Drop Test – Failures and Successes





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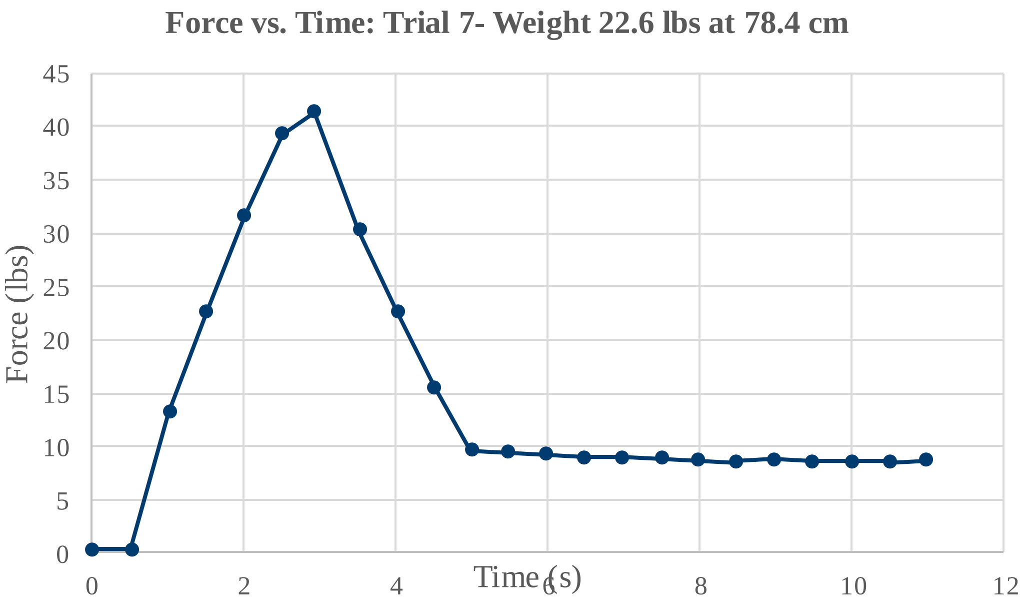
Drop Test – Failures and Successes



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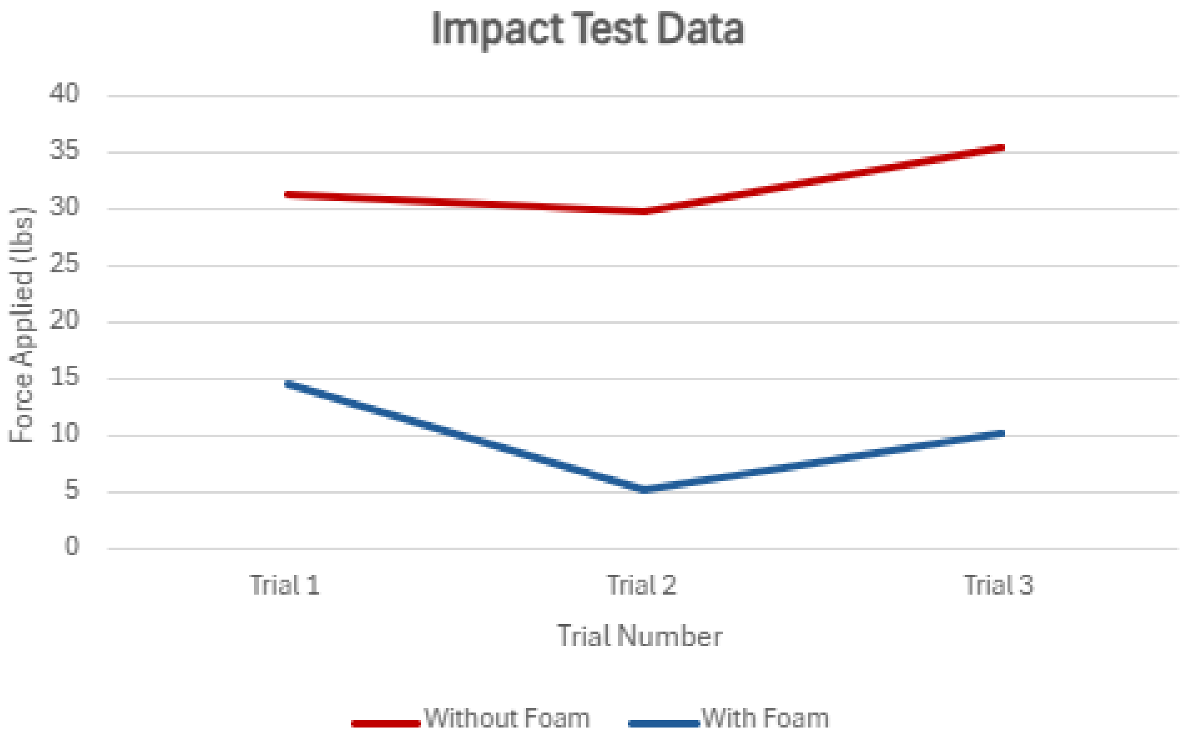
Drop Test – Failures and Successes

The reduction in peak linear forces transmitted to the head

Preliminary data shows **27% reduction** in peak forces



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Redirection-

Taking a step back and breaking the problem down to core components

Treating the Material as a Spring

- Amount of energy stored elastically
- Deformation under certain frequencies
- Energy dissipated during loading
- Stiffness of material

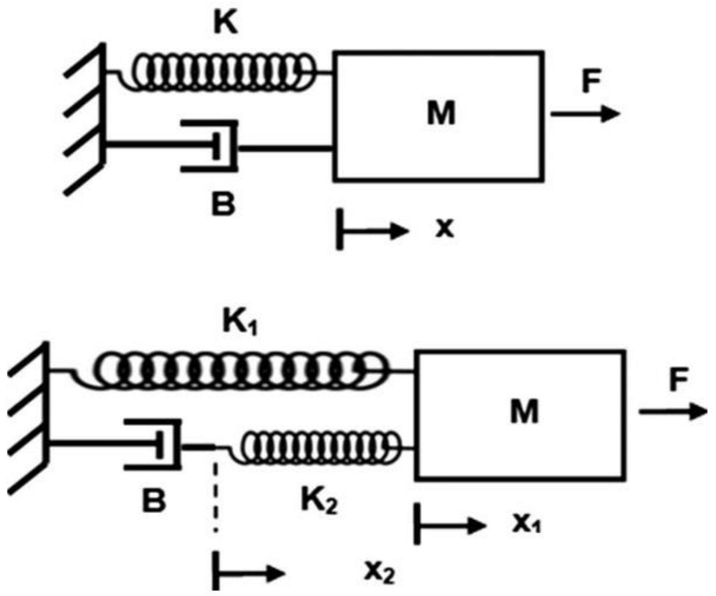

Fig. 6 Schematics of second-order (top) and third-order (bottom) mass-spring-damper models. The head/neck unit (*M*) is connected to a rigid body by springs (K, K_1, K_2) and a damper (*B*).

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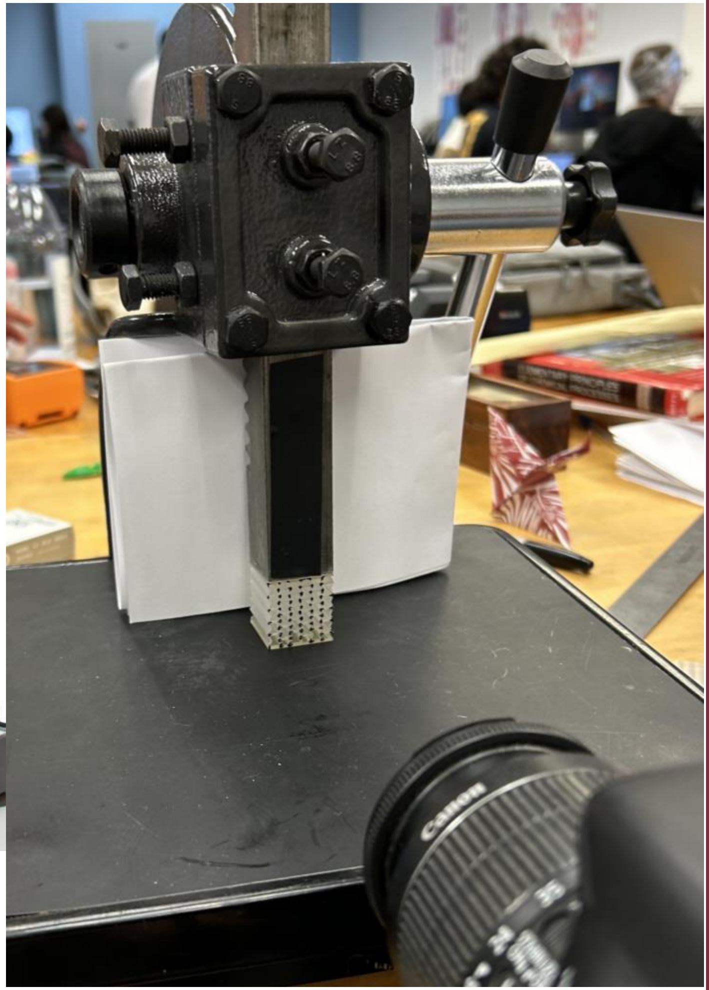
Auxetic Foam vs Current Foam

<u>Instron Machine:</u>

- o Tensile, compressive, and shear testing

- Assess durability, flexibility, and material integrity



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Future Work

Phase 1:

- Spring testing with Instron
- Compression tests vs current foam
- Assure we are hitting linear thresholds
- Understand material properties in environmental conditions

Phase 2:

- Wireless accelerometer
- Testing for rotational impacts
  - Impact tester, pendulum testing, drop testing
- Sizing the foam and implementing into helmet

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