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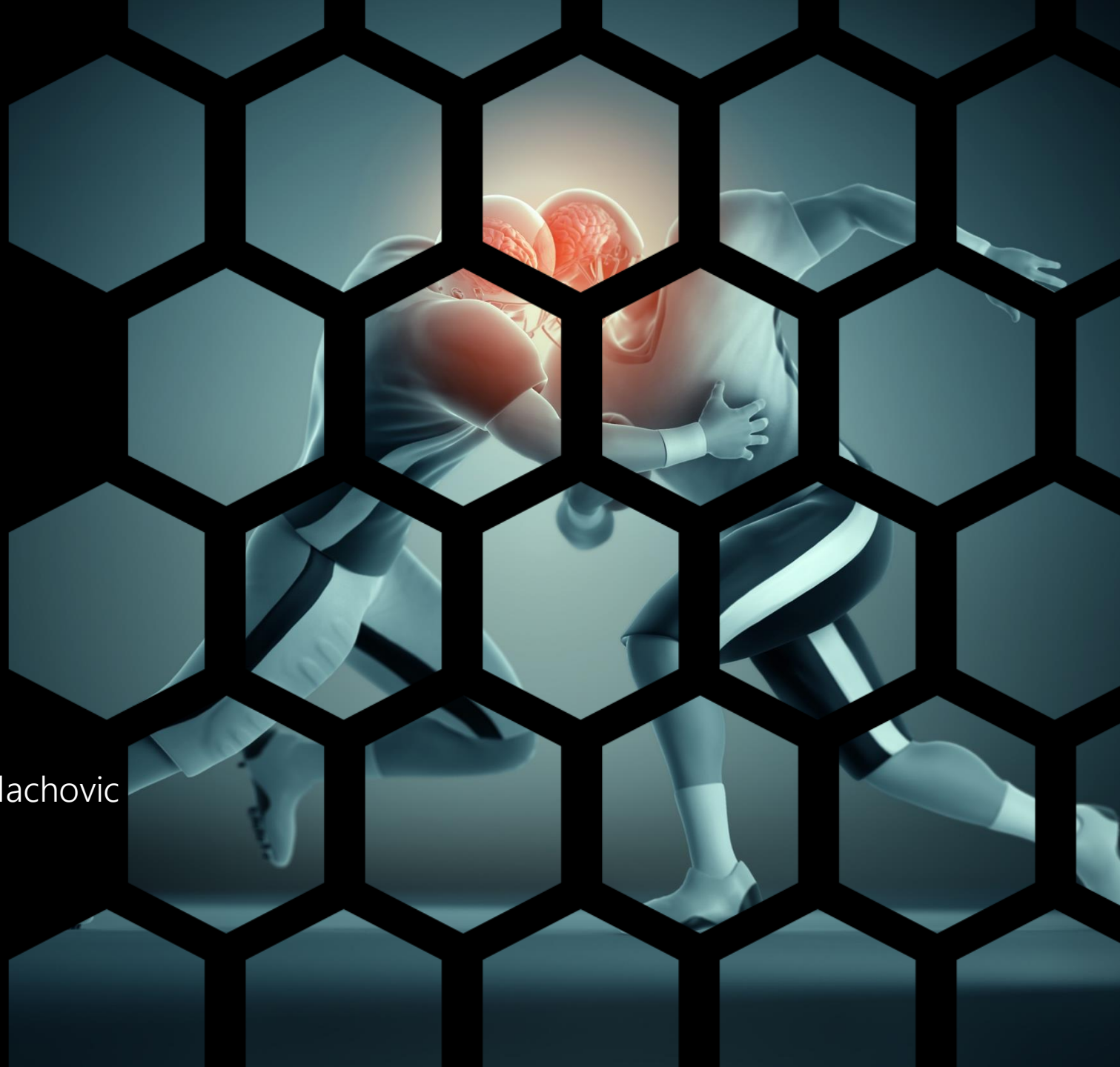
Head Armor Pro
Team 110



S. Devulapalli, A. Dolisca, C. Hollis, R. Stroth, M. Valachovic

Team Introduction

Saiabhinav Devulapalli
Biomedical Engineer

Anghea Dolisca
Biomedical Engineer

Connor Hollis
Mechanical Engineer

Riley Stroth
Mechanical Engineer

Maddie Valachovic
Biomedical Engineer

FAMU-FSU College of Engineering

Sponsor and Advisors

DEPARTMENT OF
CHEMICAL & BIOMEDICAL
ENGINEERING

FAMU-FSU
College of Engineering

Project Supervisor
Dr. Stephen Arce

Project Coordinator
Dr. Shayne McConomy

Academic Advisor
Emily Thiel

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Engineering

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Valachovic

Project Objective

The objective of this project is to design a device that will reduce the risk of concussions for youth football players.

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The Problem to Tackle

Youth Football

5/100 players are diagnosed with a concussion

(UW Medicine, 2018)

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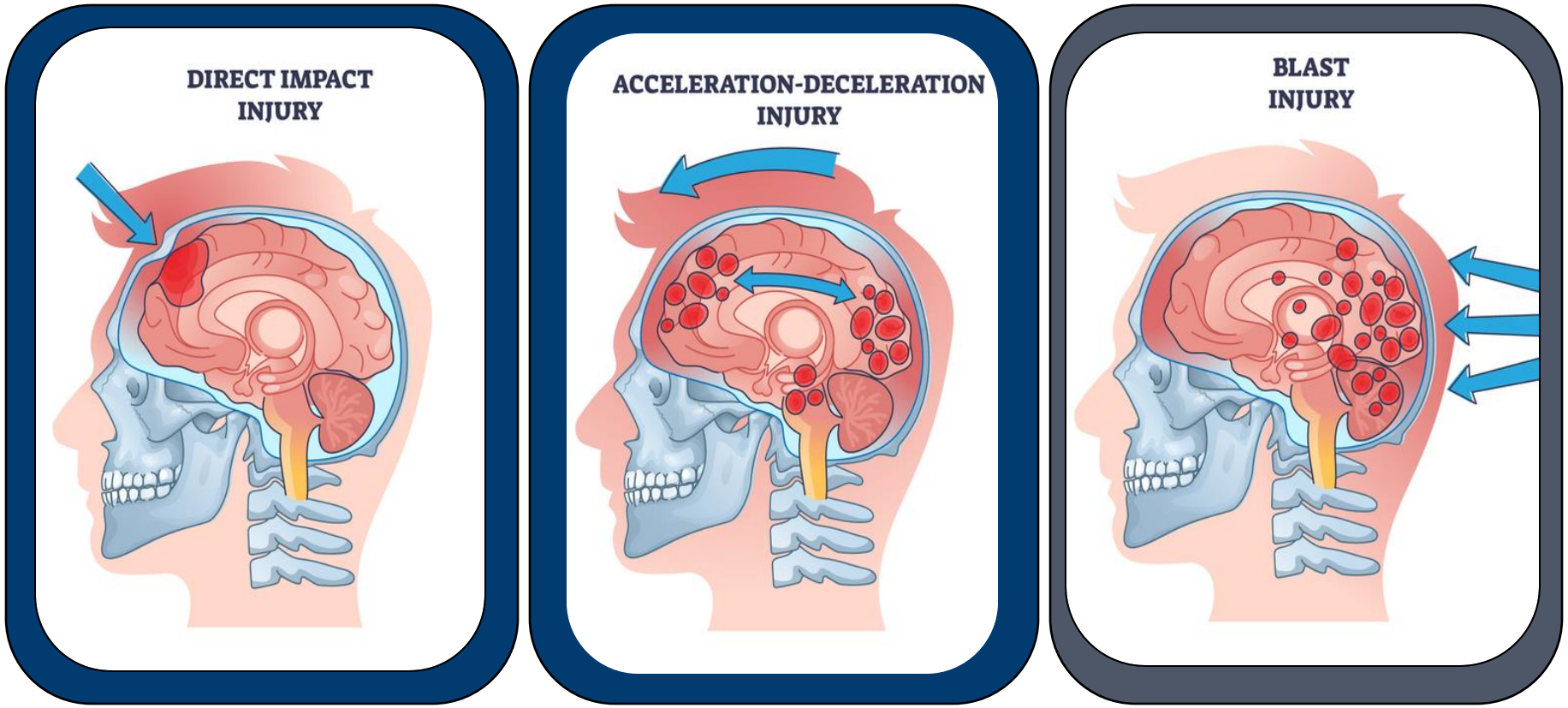
What is a Concussion?



(Mayo Clinic, 2024)

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Current Solutions

Ethylene-vinyl Acetate (EVA) Foam Helmet

Guardian Cap: Closed- Cell Foam

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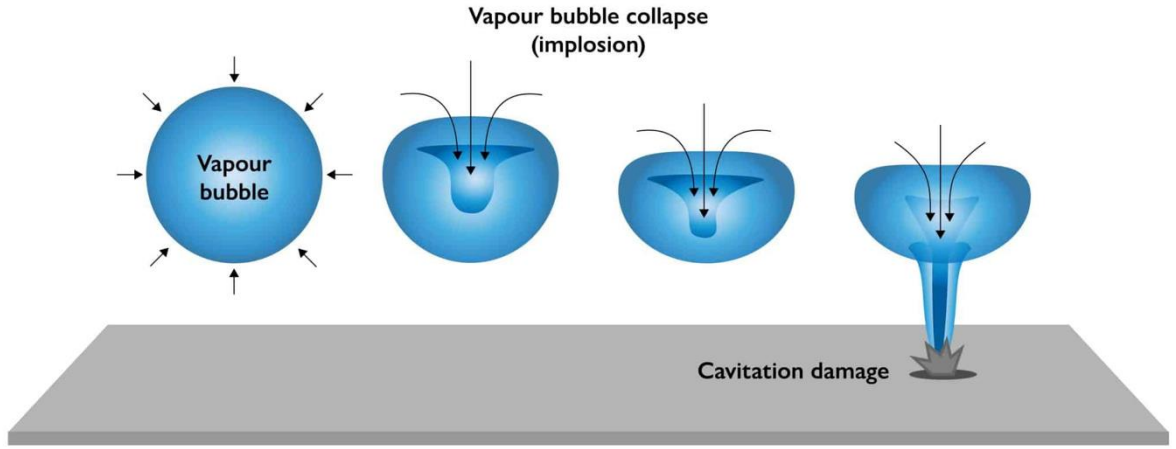
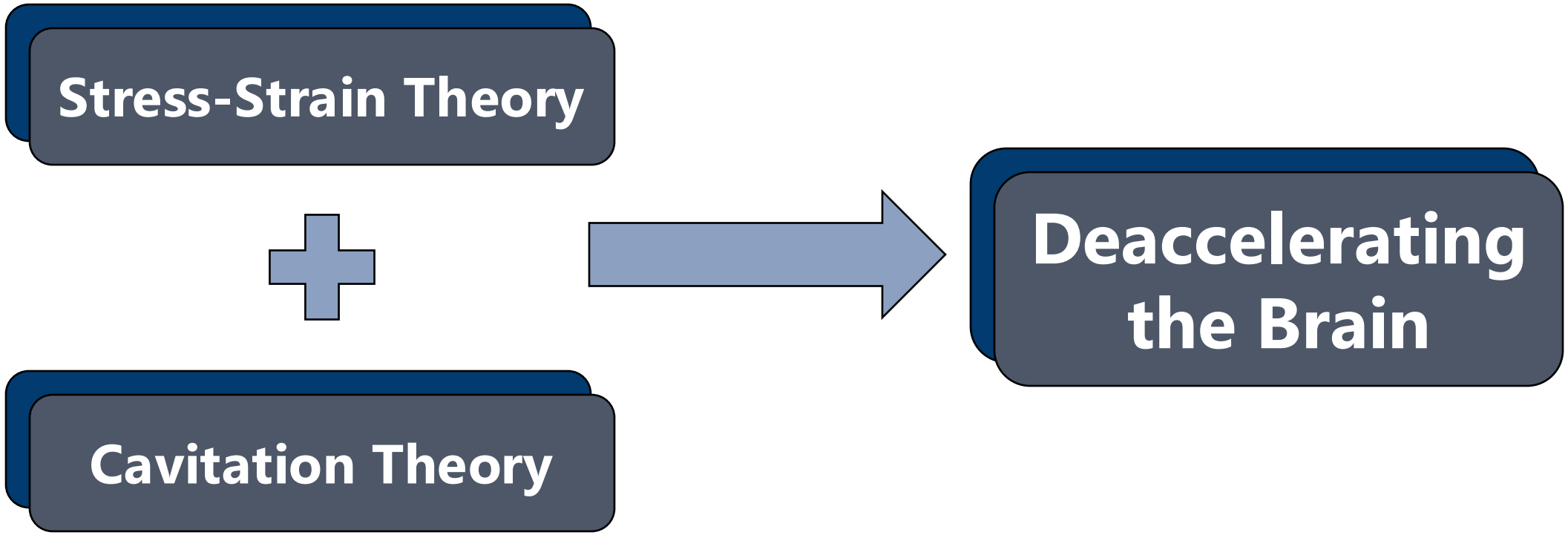
Concussion Theories

Stress-Strain Theory

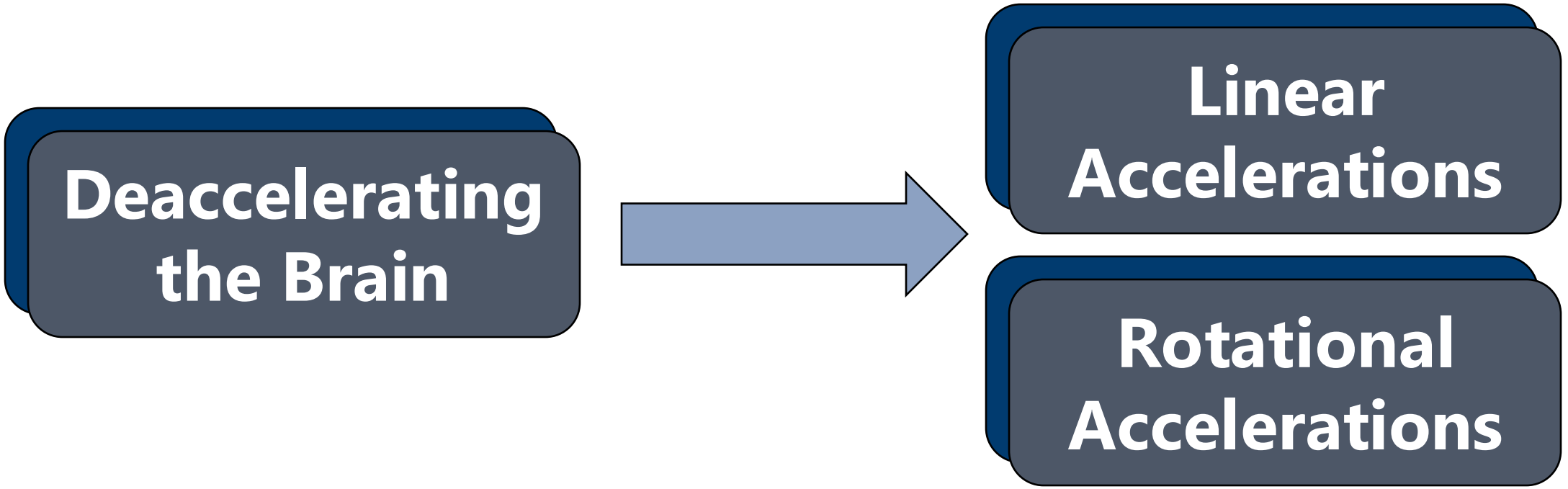
Cavitation Theory



Concussion Theories



Accelerations



Concussive Thresholds

Linear Accelerations

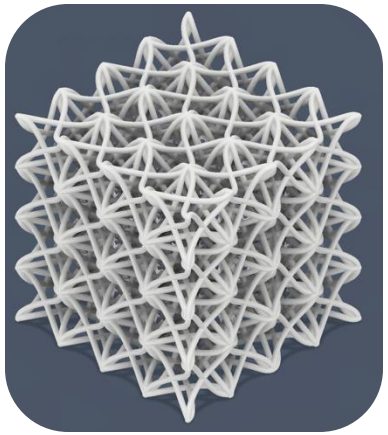
Rotational Accelerations

70 -120 g

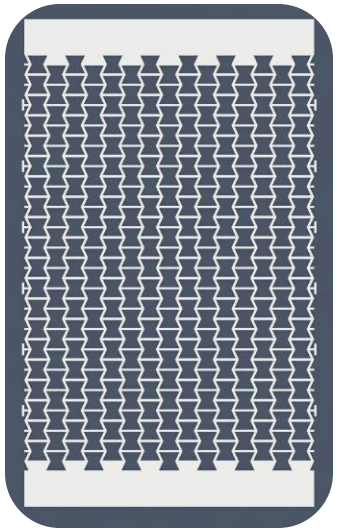
5,600 - 9,500 rad/s^2

Design History

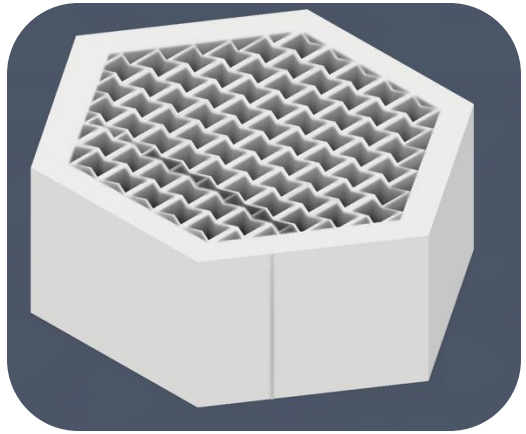
Version 1



Version 2



Version 3

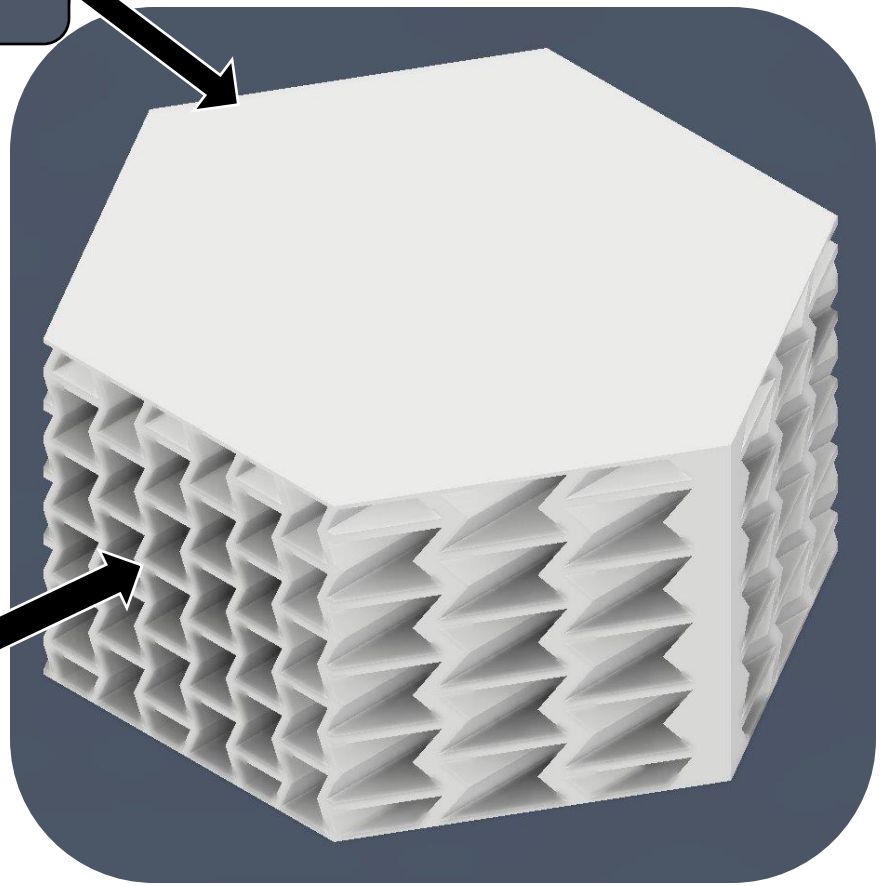


Version 4

Version 5

Final Auxetic Material Design

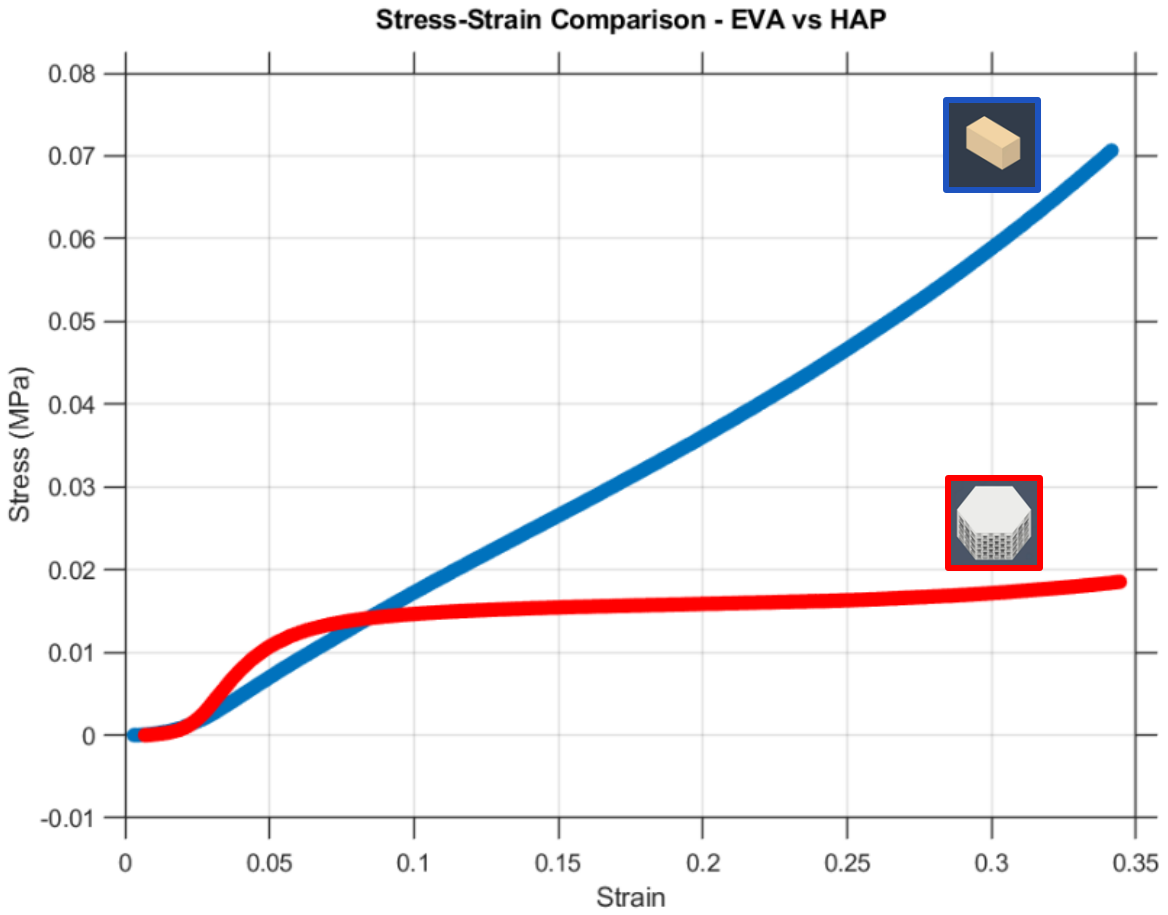
Hexagon Outer Shape



Hourglass Layer

- 3D printing with stereolithography (SLA) technology
- Light weight profile
- Viscoelastic Design
- Negative Poisson's ratio

Compression Testing Results



Material Properties	EVA Foam	HAP Foam
Young's Modulus (MPa)	0.157	0.287
Yield Strength (MPa)	0.009	0.003
Ultimate Strength (MPa)	0.071	0.019
Fracture Strain	0.342	0.567

Head Armor Pro Material Property Reflection

- Greater Fracture Strain = Higher Energy Absorption
  - Allows more deformation before failure
- Higher Young's Modulus = Resists compression early
- Lower Yield & Ultimate Strength = Controlled Stress Plateau
  - Reduces peak force to the head

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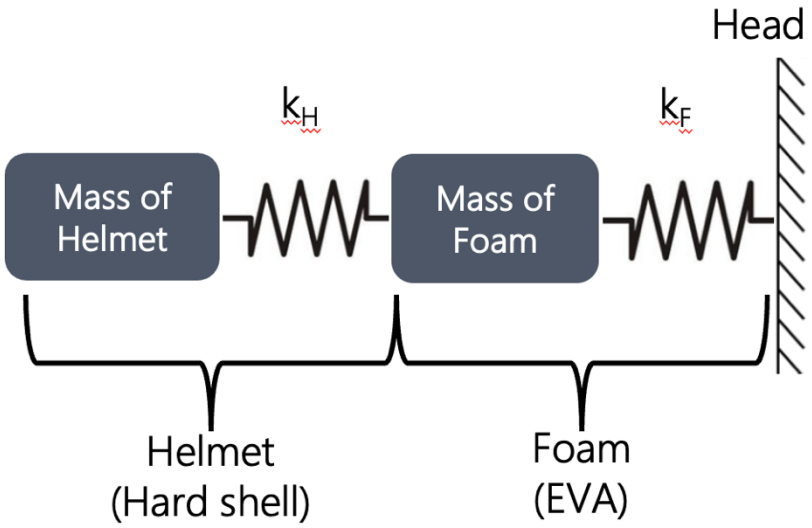
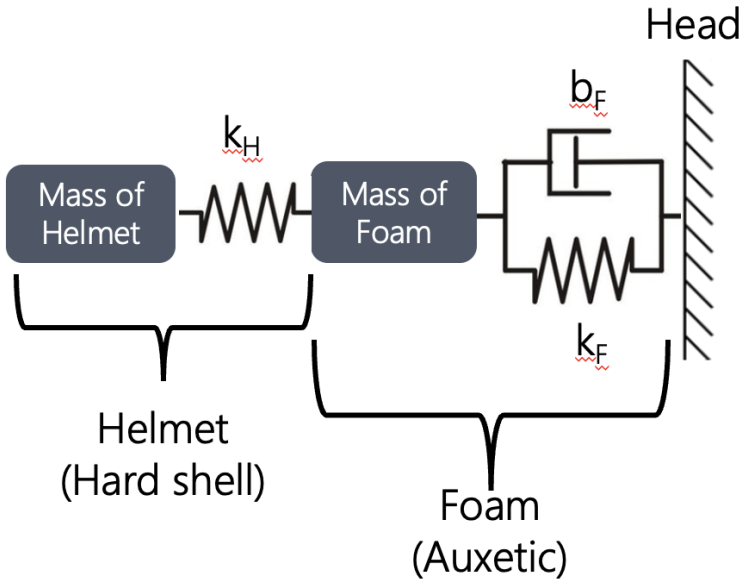
Mechanical Model Comparison



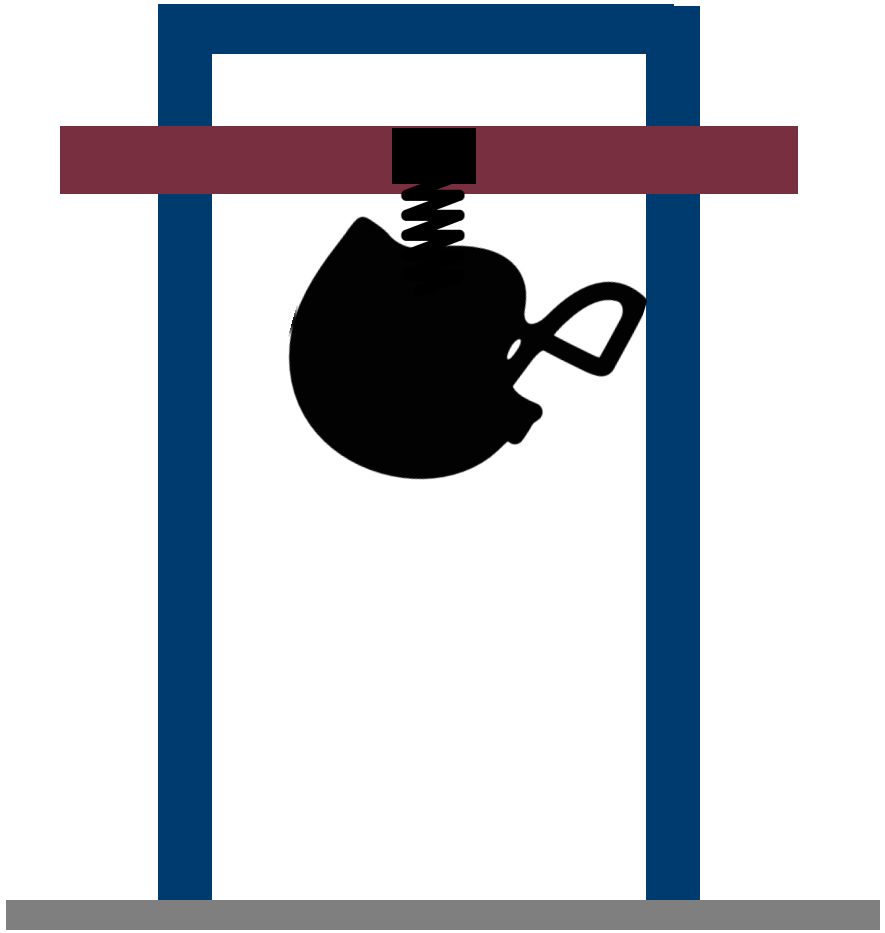


Spring Constants (N/m)	
Helmet	EVA Foam
6000	9728.20

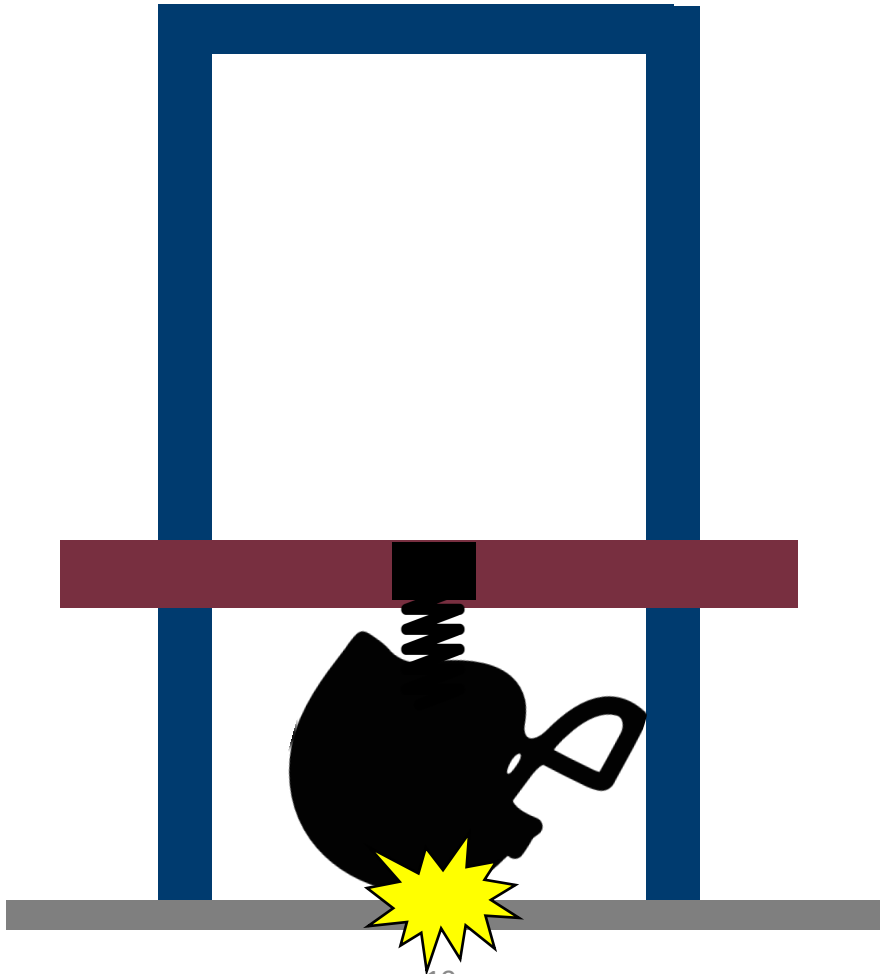
Auxetic Foam (HAP)	
Spring Constant (N/m)	Dampening Coefficient (Ns/m)
1345.21	1.24×10^{10}

Maddie Valachovic

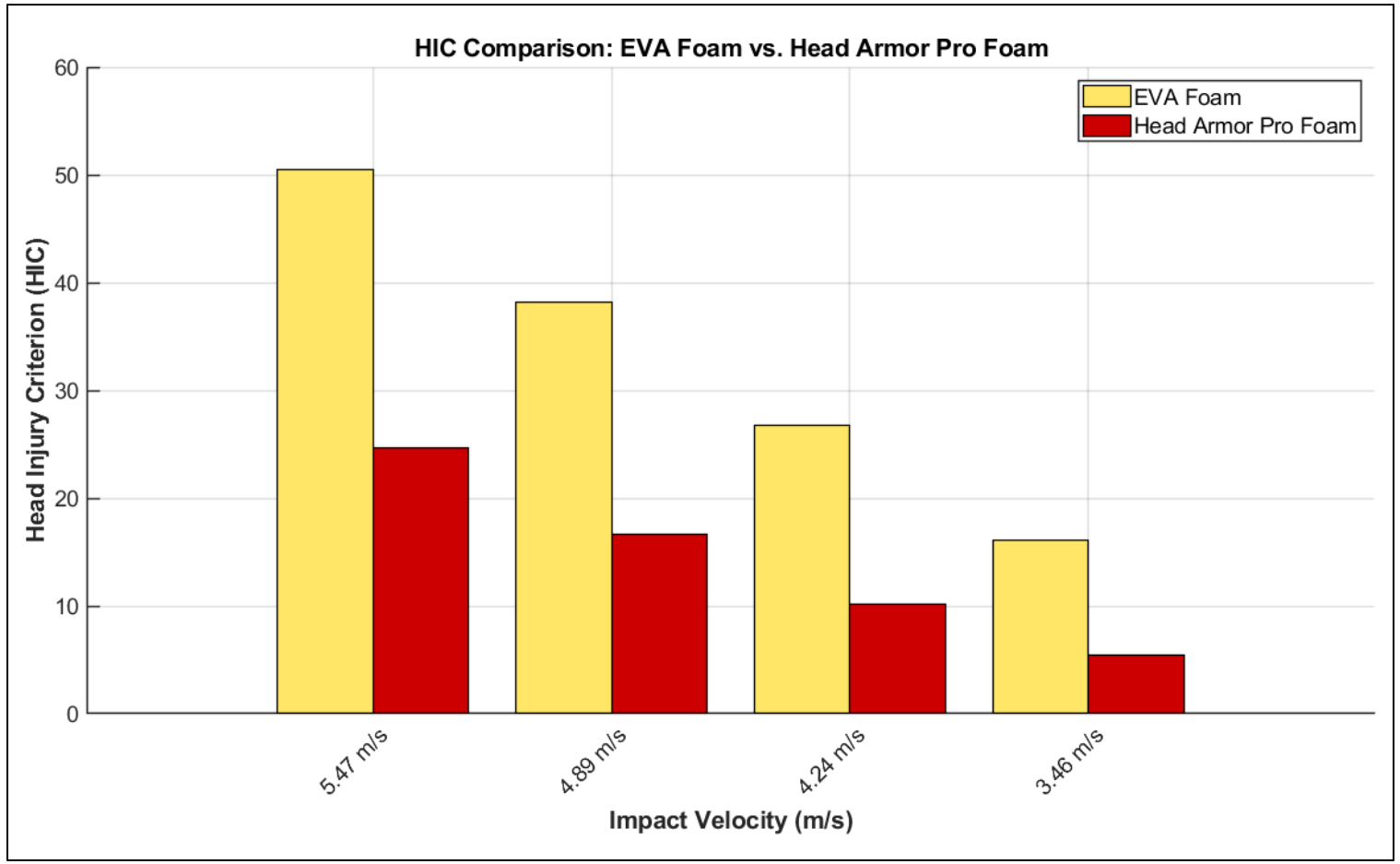
HPMI Drop Test



HPMI Drop Test



HIC Results



Head Armor Pro consistently reduced impact forces by **60%**

Similar results to our Mathematical Model

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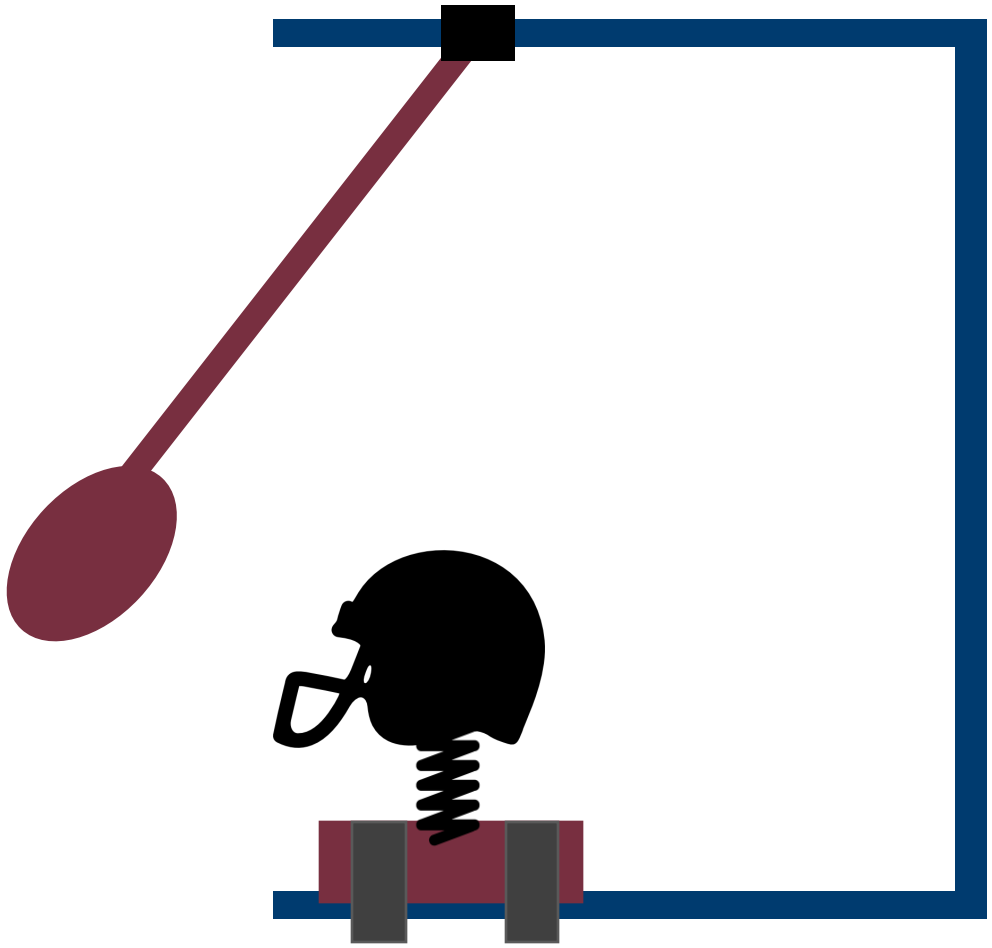
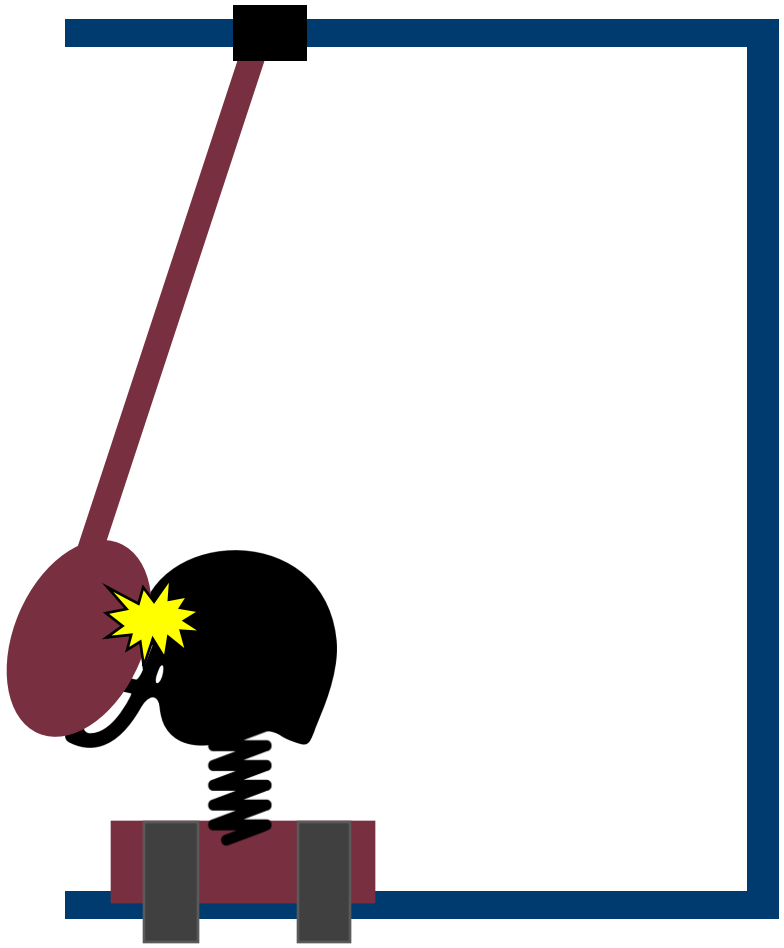
Pendulum Impact Test



Pendulum Impact Test



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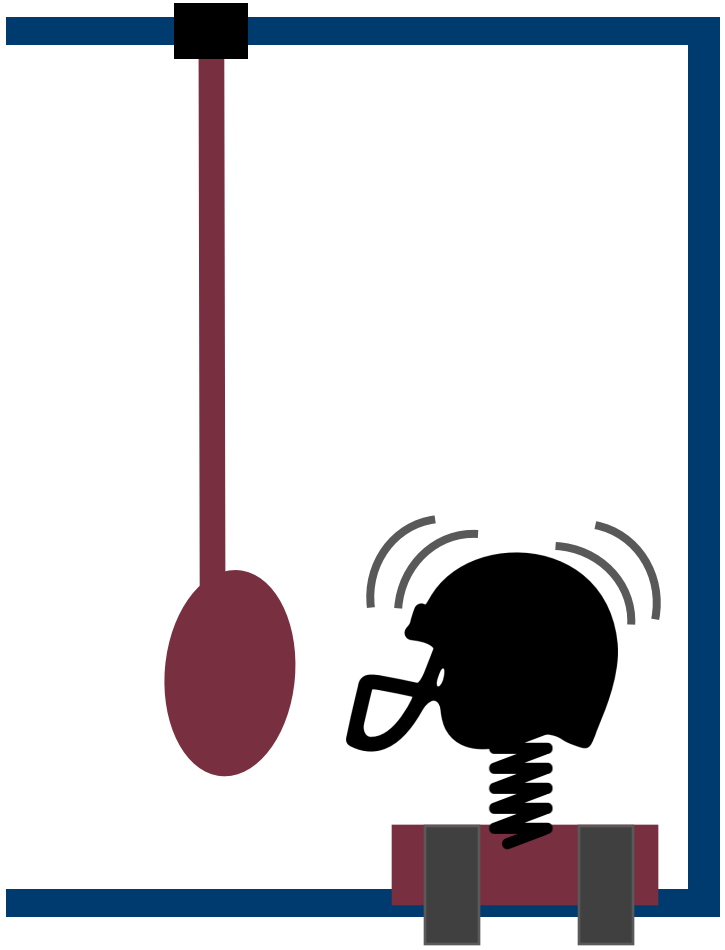
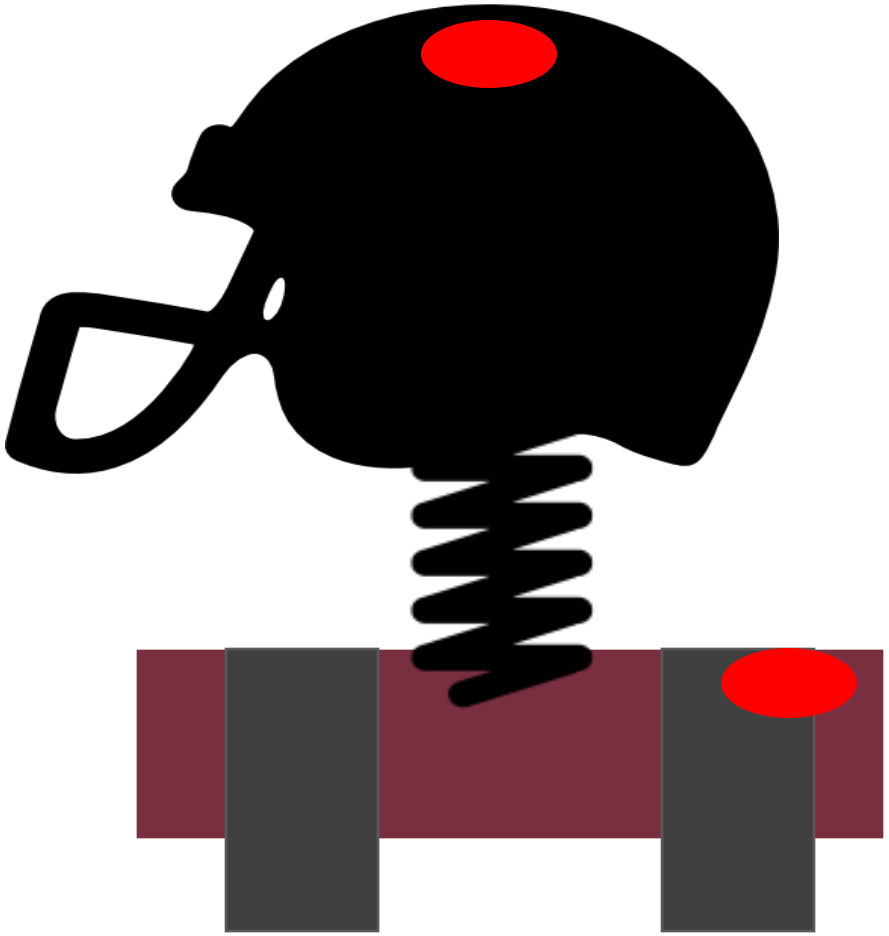


Pendulum Impact Test



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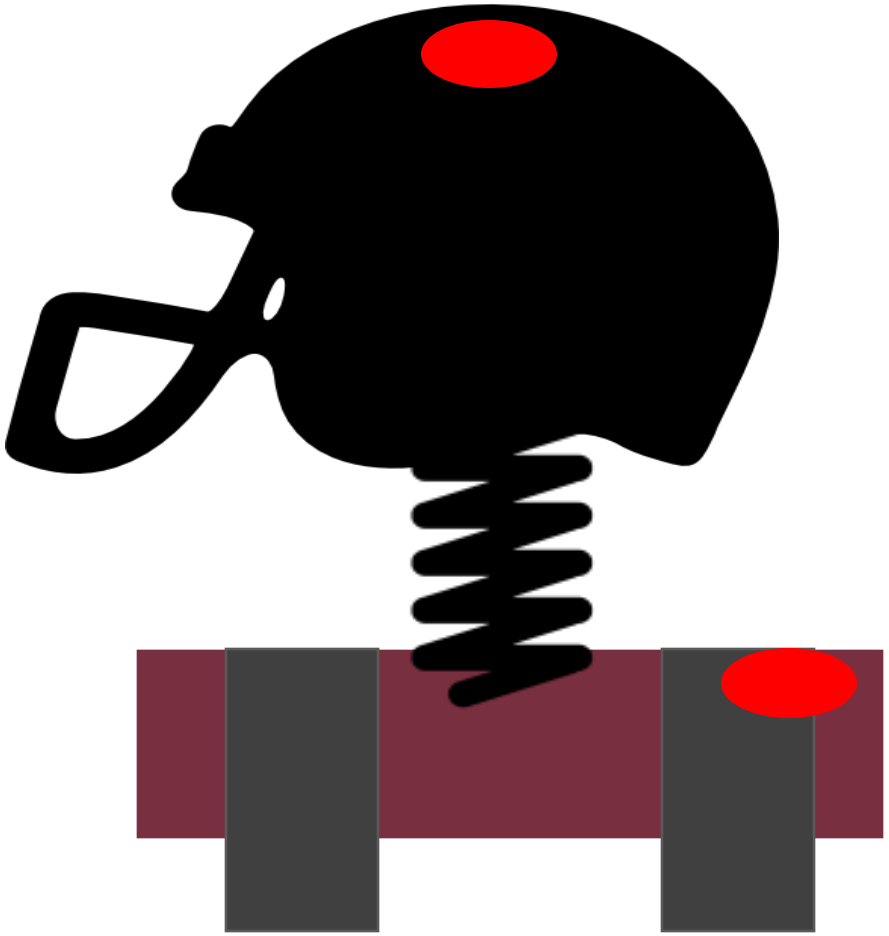
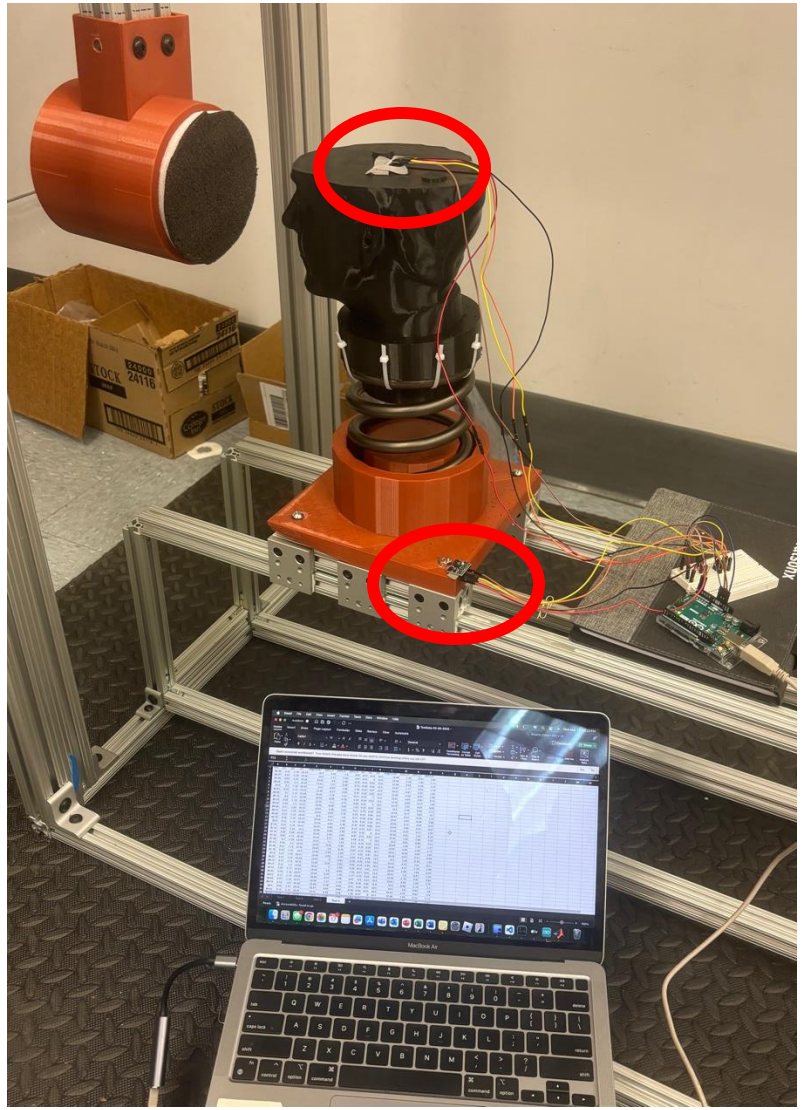
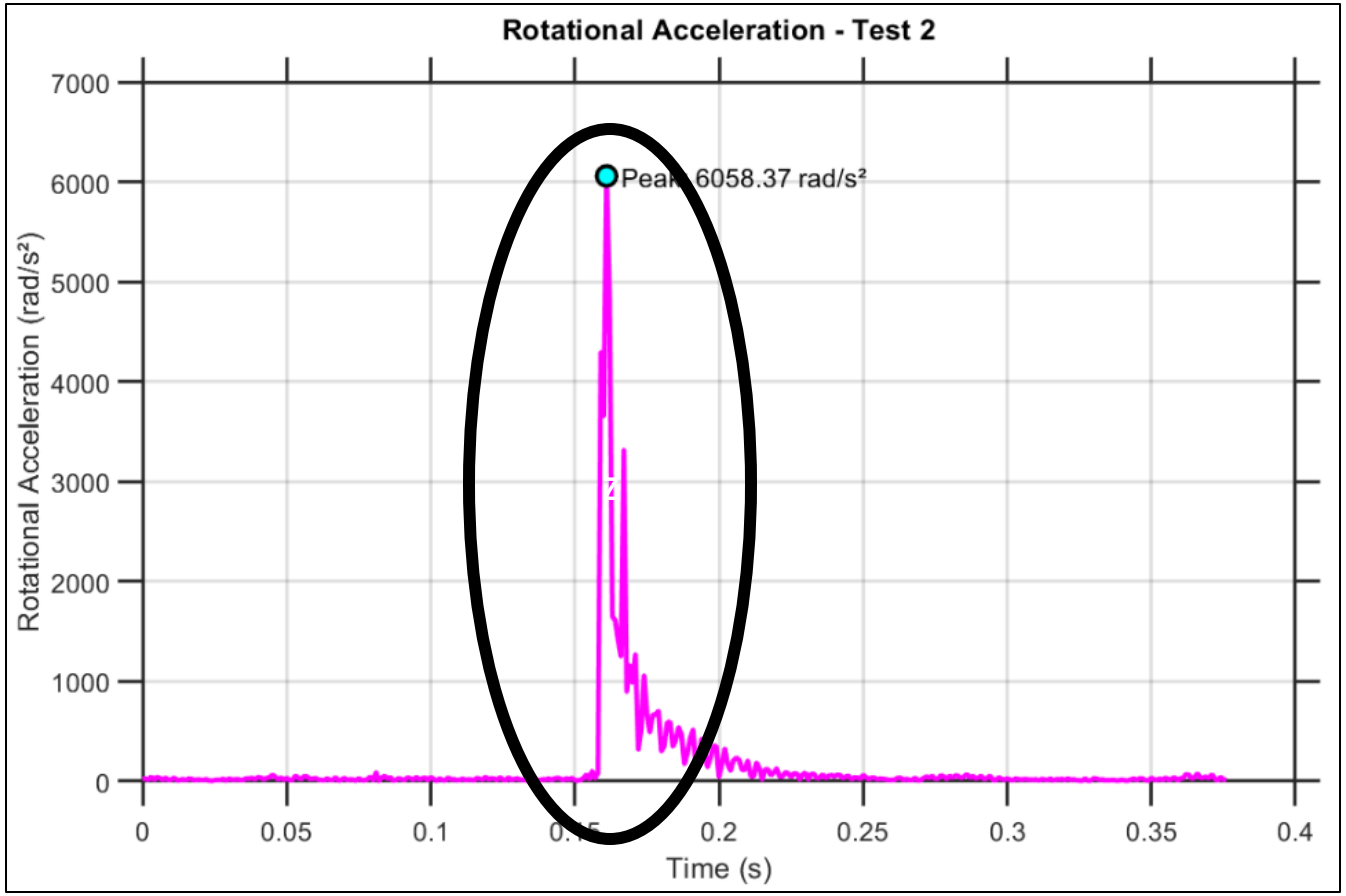
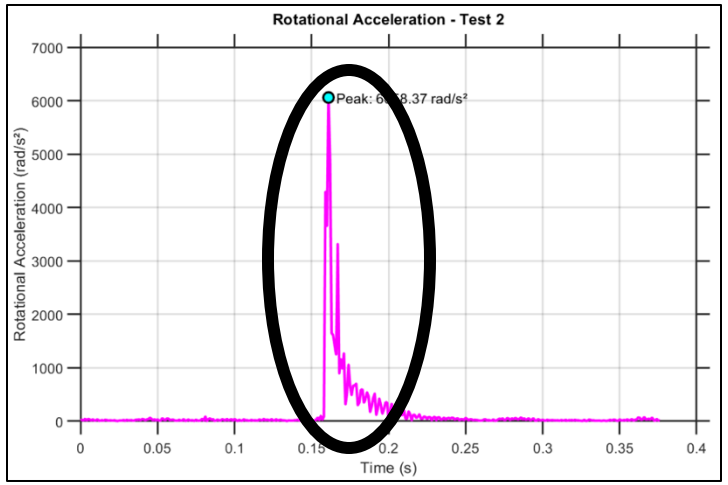


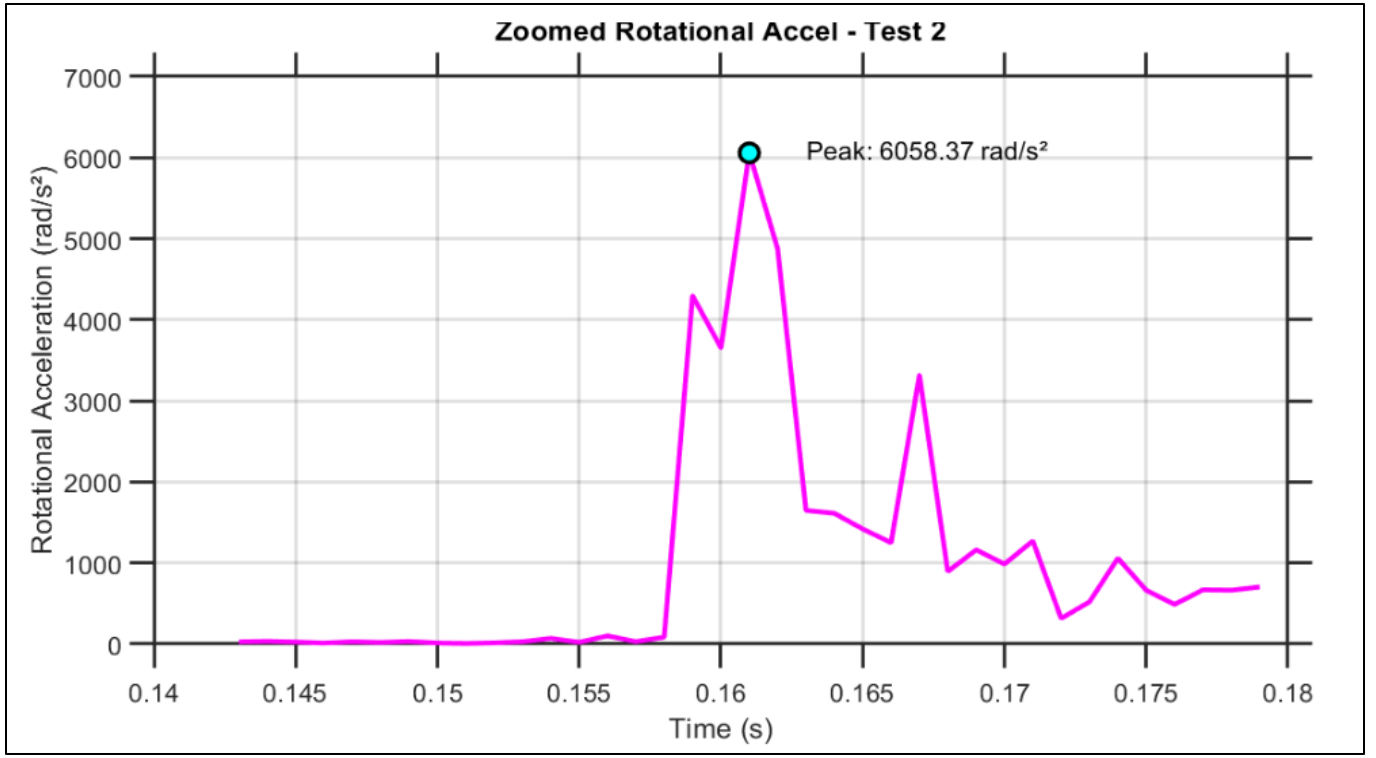


Rotational Acceleration Results



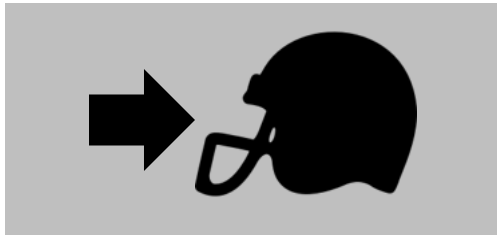
Rotational Acceleration Results

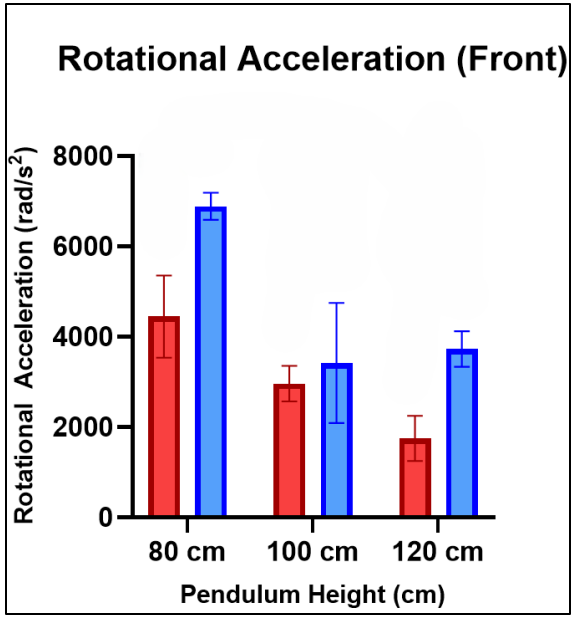


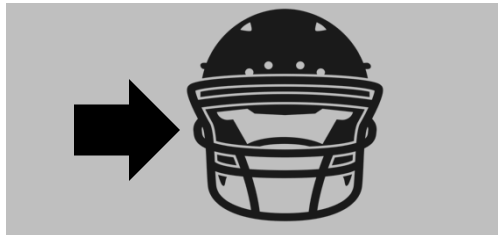


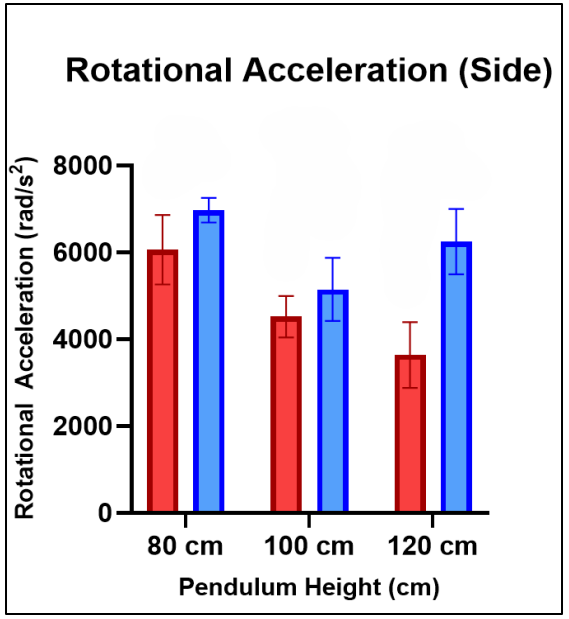
Sai Devulapalli

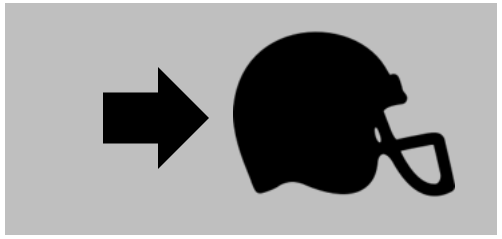
Rotational Acceleration Results

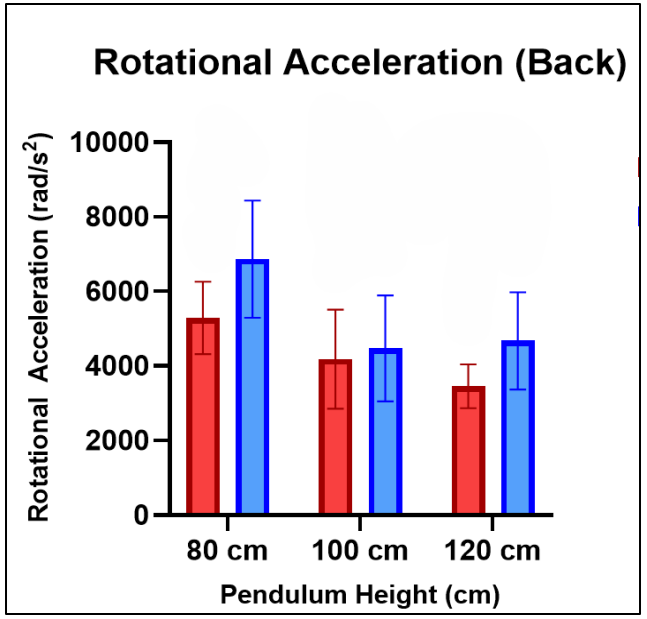












Head Armor Pro
EVA Foam

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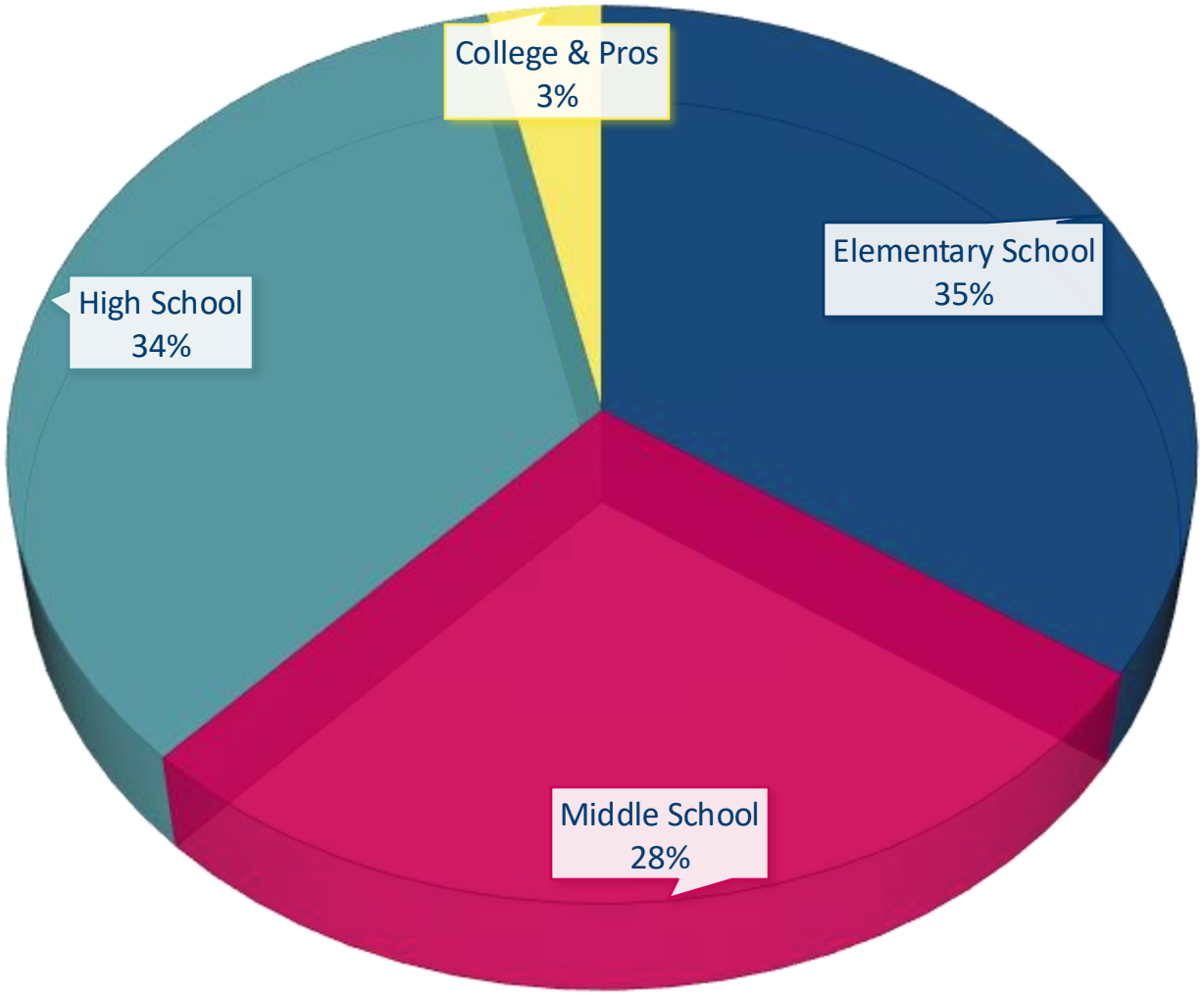
Summary

	Auxetic Foam Design	EVA Foam	Conclusion
Theoretical Acceleration	☑	☒	15% Reduction
Experimental Acceleration	☑	☒	60% Reduction
HIC Value	☑	☒	60% Reduction
Max Rotational Acceleration	☑	☒	33% Reduction
Young Modulus	☑	☒	82% Increase
Fracture Strain	☑	☒	65.8% Increase

Cost, Market, and Opportunity



Elementary School: $52 M

Middle School: $42.4 M

High School: $121 M

College & Pros: $24.9 M

3 Million Players
Market Size: $240.3 M

Future Work

Continue collecting data

Write a publication

Make sure auxetic foam follows ASTM guidelines and NOCSAE

Survey high school football players

Taking a step into other sport protective equipment

Seek out funding

ACCInVenture Prize

- People's Choice Award Voting [3/31 - 4/2]
- Text **FSU** to ACC Number: **415-965-7445**
- Live Broadcast: 4/2 (7PM – 8PM)

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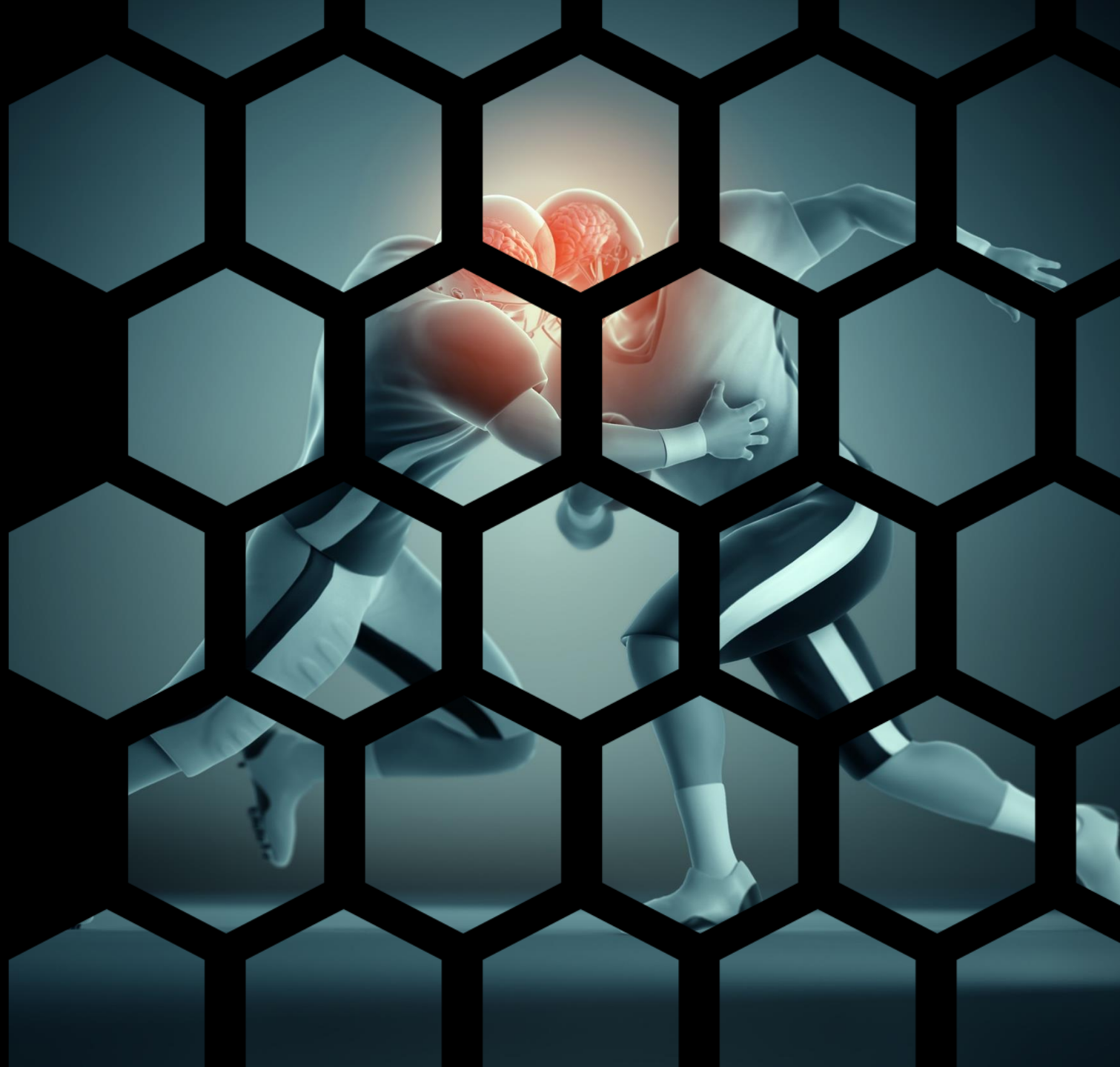
Thank You!



References

Gross, A. G. (1958). A new theory on the dynamics of brain concussion and Brain Injury. *Journal of Neurosurgery*, *15*(5), 548–561. https://doi.org/10.3171/jns.1958.15.5.0548

Wright, R. M., & Ramesh, K. T. (2011). An axonal strain injury criterion for traumatic brain injury. *Biomechanics and Modeling in Mechanobiology*, *11*(1–2), 245–260. https://doi.org/10.1007/s10237-011-0307-1

Östh, J., Bohman, K., & Jakobsson, L. (2022). Head injury criteria assessment using head kinematics from crash tests and accident reconstructions. *Traffic Injury Prevention*, *24*(1), 56–61. https://doi.org/10.1080/15389588.2022.2143238

Deck, C., & Willinger, R. (2008). Improved head injury criteria based on head fe model. *International Journal of Crashworthiness*, *13*(6), 667–678. https://doi.org/10.1080/13588260802411523

Kulkarni, S. G., Gao, X.-L., Horner, S. E., Zheng, J. Q., & David, N. V. (2013). Ballistic helmets – their design, materials, and performance against Traumatic Brain Injury. *Composite Structures*, *101*, 313–331. https://doi.org/10.1016/j.compstruct.2013.02.014

Corona radiata: Radiata, white matter, brain anatomy. Pinterest. (2020, February 11). https://in.pinterest.com/pin/614459942896848304/

Cavitation gifs. WiffleGif. (n.d.). https://wifflegif.com/tags/386612-cavitation-gifs?page=0

Cecchi, N. J., Callan, A. A., Watson, L. P., Liu, Y., Zhan, X., Vegesna, R. V., Pang, C., Le Flao, E., Grant, G. A., Zeineh, M. M., & Camarillo, D. B. (2024, October). *Padded helmet shell covers in American Football: A comprehensive laboratory evaluation with preliminary on-field findings*. Annals of biomedical engineering. https://pmc.ncbi.nlm.nih.gov/articles/PMC10013271/#Sec2

O'Connor, K. L., Rowson, S., Duma, S. M., & Broglio, S. P. (2017, March). *Head-impact-measurement devices: A systematic review*. Journal of athletic training. https://pmc.ncbi.nlm.nih.gov/articles/PMC5384819/

Mayo Clinic. (2024, January 12). *Concussion: Symptoms and causes*. https://www.mayoclinic.org/diseases-conditions/concussion/symptoms-causes/syc-20355594

Shepherd, B. (2017, December 3). *Football and concussions: Information to protect your children*. U.OSU. https://u.osu.edu/groupbetaengr2367/brian-add-stuff-here/#:~:text=According%20to%20a%20study%20done,concussions%20in%20high%20school%20athletes

References

Daneshvar, D. H., Baugh, C. M., Nowinski, C. J., McKee, A. C., Stern, R. A., & Cantu, R. C. (2011). Helmets and mouth guards: The role of personal equipment in preventing sport-related concussions. *Clinics in Sports Medicine*, *30*(1), 145–163. https://doi.org/10.1016/j.csm.2010.09.006

Sinnott, A. M., Chandler, M. C., Van Dyke, C., Mincberg, D. L., Pinapaka, H., Lauck, B. J., & Mihalik, J. P. (2023). Efficacy of Guardian Cap soft-shell padding on head impact kinematics in American football: Pilot findings. *Journal of Sports Science and Medicine*, *22*(4). https://doi.org/10.4085/10650906

Talavage, T. M., Nauman, E. A., Breedlove, E. L., Yoruk, U., Dye, A. E., Morigaki, K. E., Feuer, H., & Leverenz, L. J. (2014). Functionally-detected cognitive impairment in high school football players without clinically-diagnosed concussion. *Journal of Neurotrauma*, *31*(4), 327–338. https://doi.org/10.1089/neu.2010.1512

UW Medicine. (2018, December 12). *Media contact: Brian Donohue, UW Medicine & Lindsay Kurs, Seattle Children's Hospital*.

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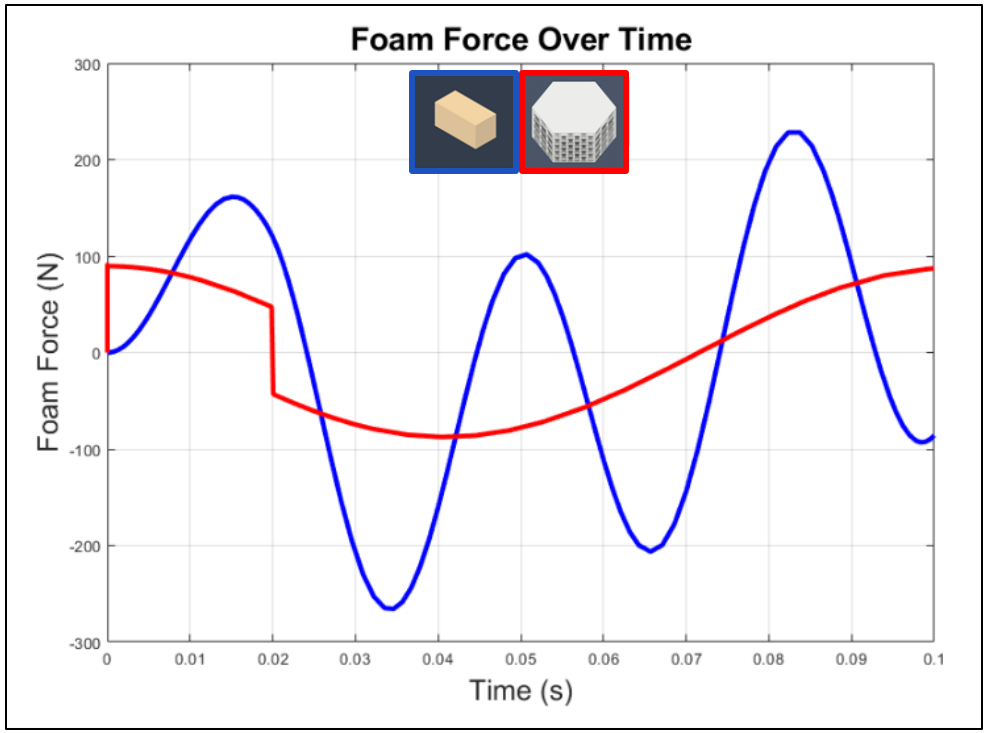
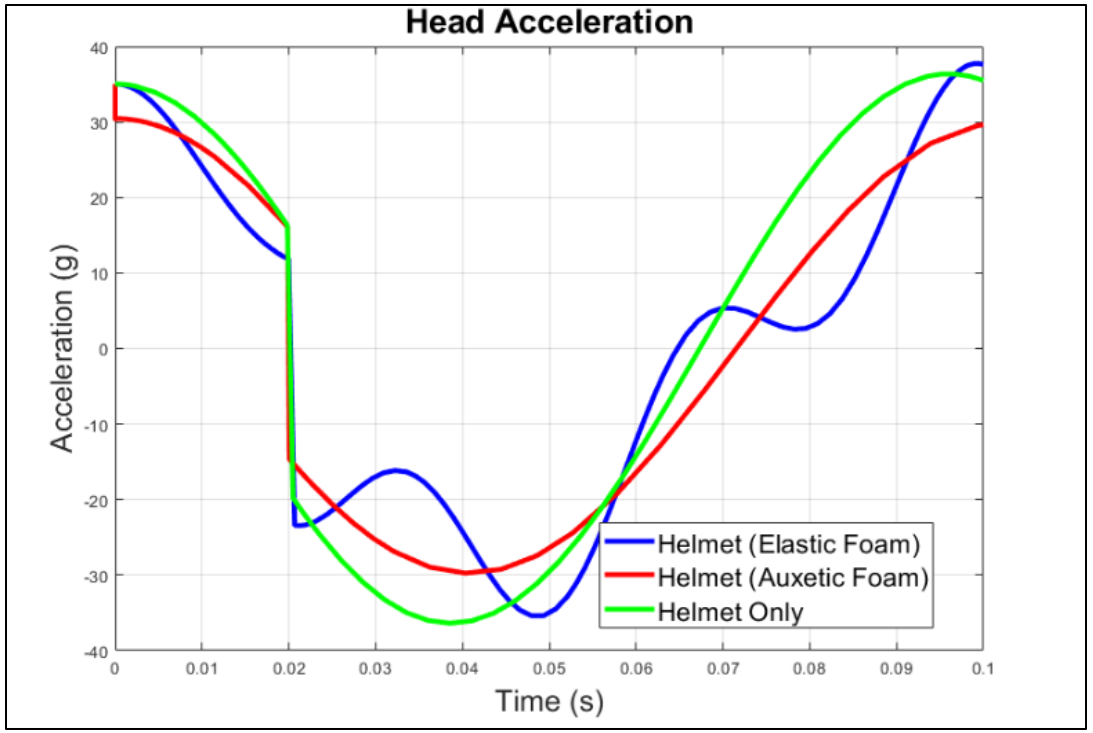
Linear Model – Comparisons





Output Metric	Helmet	Elastic Foam (EVA)	Auxetic Foam (HAP)
Force (N)	687	265.69	91.20
Acceleration (m/s^2)	36.36	37.74	31

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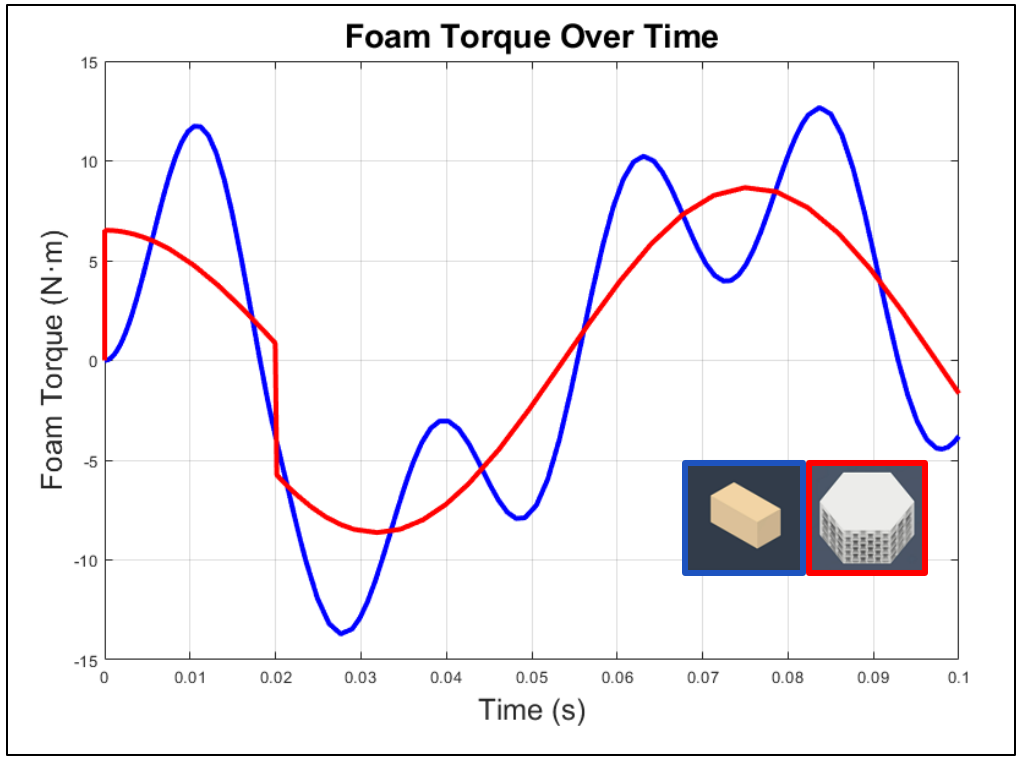
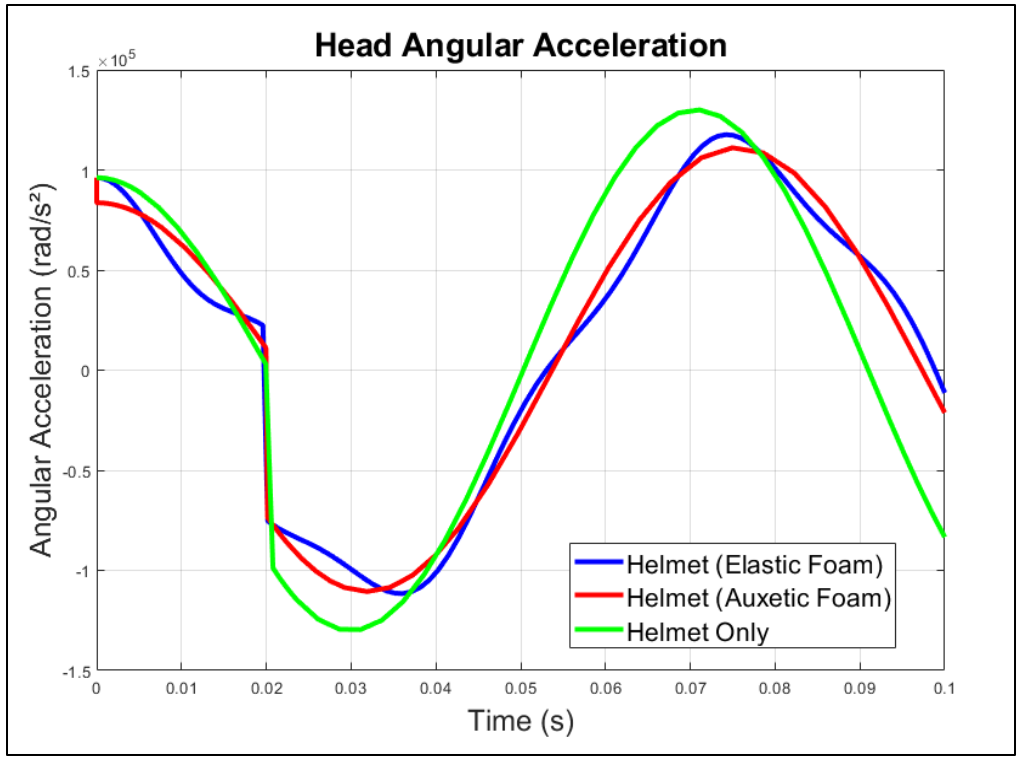
Rotational Model – Comparisons





Output Metric	Helmet	Elastic Foam (EVA)	Auxetic Foam (HAP)
Torque (Nm)	50	13.71	8.66
Rotational Acceleration (rad/s^2)	1.3 x 10^5	1.2 x 10^5	1.1 x 10^5

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