Senior Design Team 519: Football Shoulder Pads

Paul Cunningham, Vivi Huynh, Sawyer O'Bryan,

Nicholas Palestrini, Morgan Sefcik

Paul Cunningham

Team Introduction

Morgan Sefcik
Project Manager

Paul Cunningham
Design and Materials Engineer

Vivi Huynh
Design and Manufacturing Engineer

Sawyer O'Bryan
Design and Materials Engineer

Nicholas Palestrini
Product Development and Data Engineer

Paul Cunningham

Sponsor and Advisor

<u>Sponsor</u>
Mike Holloway
Survivor 30th Season Winner

<u>Academic Advisor</u>
Christian Hubicki, Ph.D.
Assistant Professor

Paul Cunningham

Past Work

Project Objective

The objective of this project is to reduce injuries of football players through the improvement of shoulder pads.

Paul Cunningham

Key Goals

Energy Distribution

Lifespan and Durability

Prevent Restrictions of Movement

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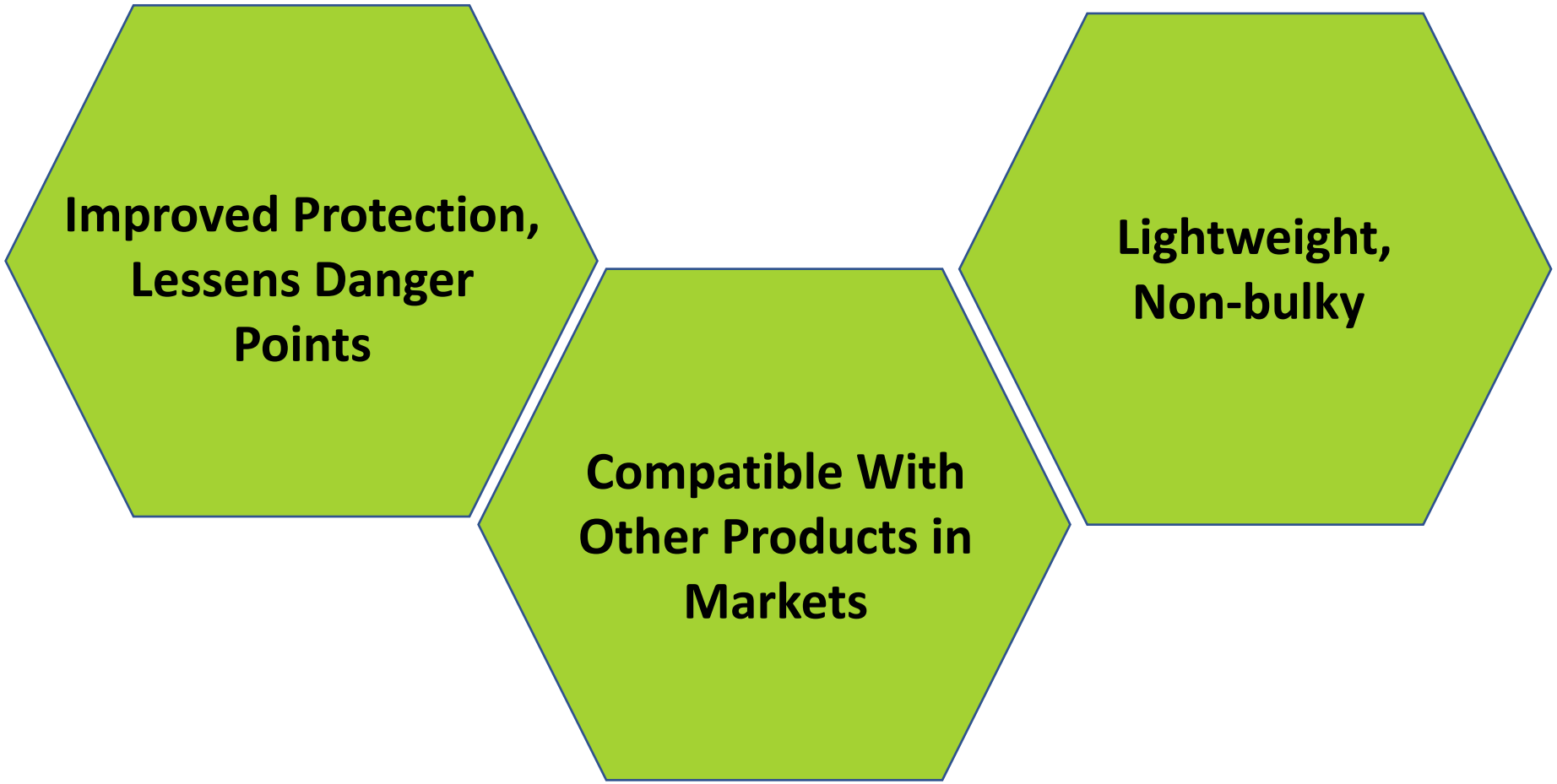
Fundamental Needs



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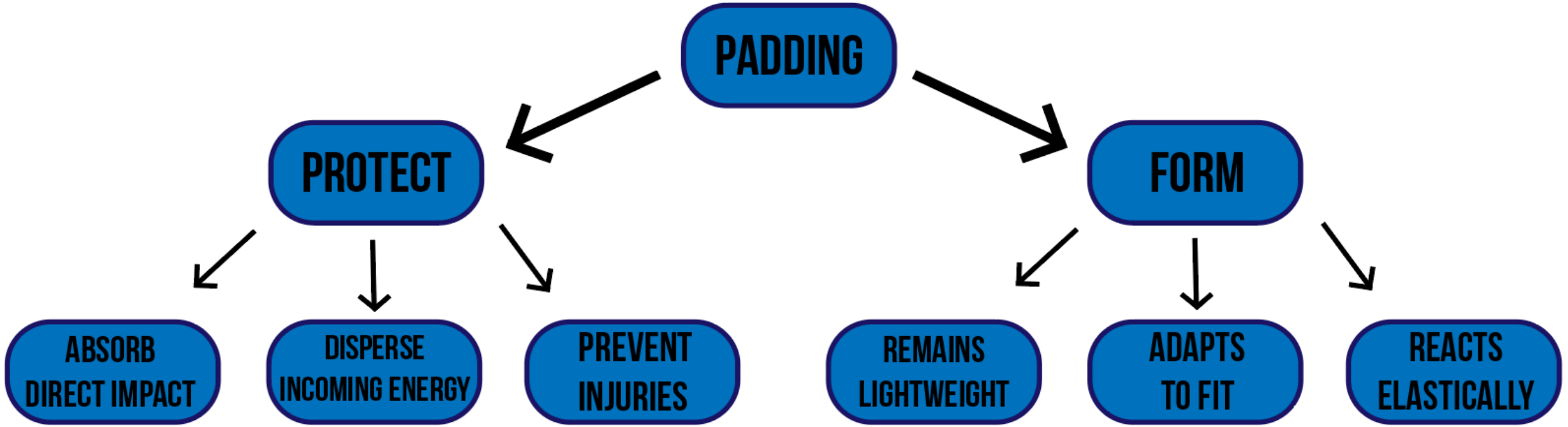
Hierarchy Chart



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Cross-Reference Table

	Protect	Form
Absorb Direct Impact	X	X
Disperse Incoming Energy	X	X
Prevent Injuries	X	
Remains Lightweight		X
Adapts to Fit		X
Reacts Elastically	X	X

Paul Cunningham

Targets & Metrics

Sawyer O'Bryan

Function Table

Function	Metric	Target
Absorb Direct Impact	G-Force (G)	Decelerates impacts by at least 75%
Disperse Incoming Energy	Force (lbf)	Less than 740 lbf
Reacts Elastically	Volume (in^3)	No loss of volume
Remains Lightweight	Weight (lbs)	5 lbs or less
Adapts to Fit	Regulations (in)	½ in gaps
Cost to Produce	US dollars ($)	No more than 10% increase in production cost over current products
Compact Size	Volume (in^3)	Less than 10% bigger than current products
Comfortability	Rating: 1 to 10	At least 7 out of 10

Sawyer O'Bryan

Key Function Targets & Metrics

Function	Metric	Target
Absorb Direct Impact	G-Force (G)	Decelerates impacts by at least 75%
Disperse Incoming Energy	Force (lbf)	Less than 740 lbf
Reacts Elastically	Volume (in3)	No loss of volume

Sawyer O'Bryan

Target – Absorb Direct Impact

Metric: G-Force (Acceleration)

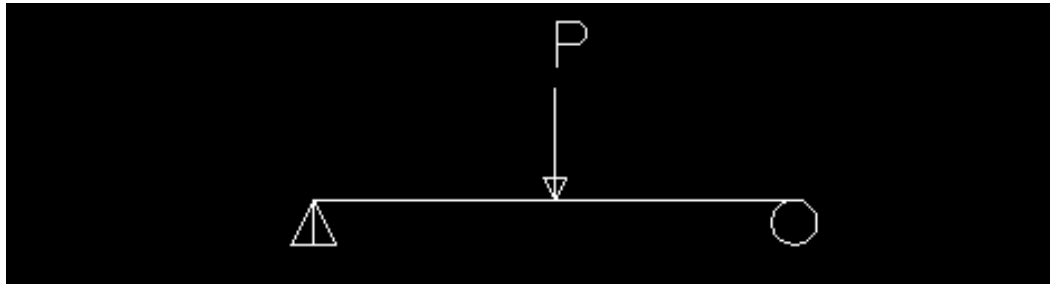
Target: Decelerate Impact Force by 75%

Sawyer O'Bryan

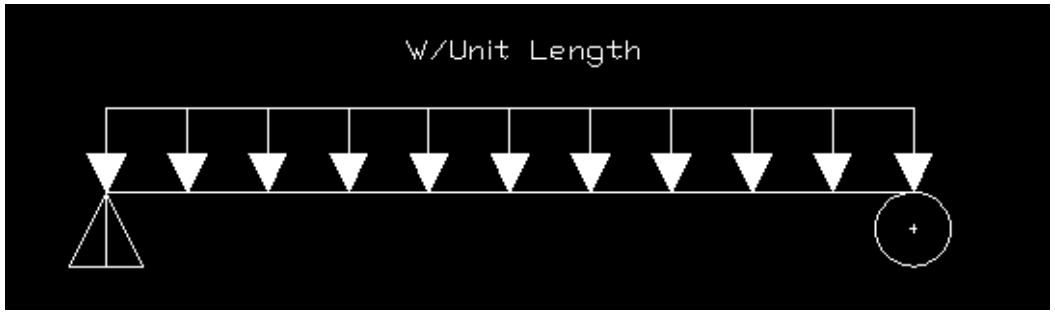
Target – Disperse Incoming Energy

Metric: Force (lbf)

Target: Less than 740 lbf at any specific point



Point Load



Distributed Load

Sawyer O'Bryan

Target – Reacts Elastically

Metric: Volume (in^3)

Target: No change in Volume

Elasticity

- ✓ **An object is considered elastic when it returns to its original size and shape after a load has been removed**
- ✓ **High Elastic Modulus**
- ✓ **Impact must not exceed the material's elastic limit**

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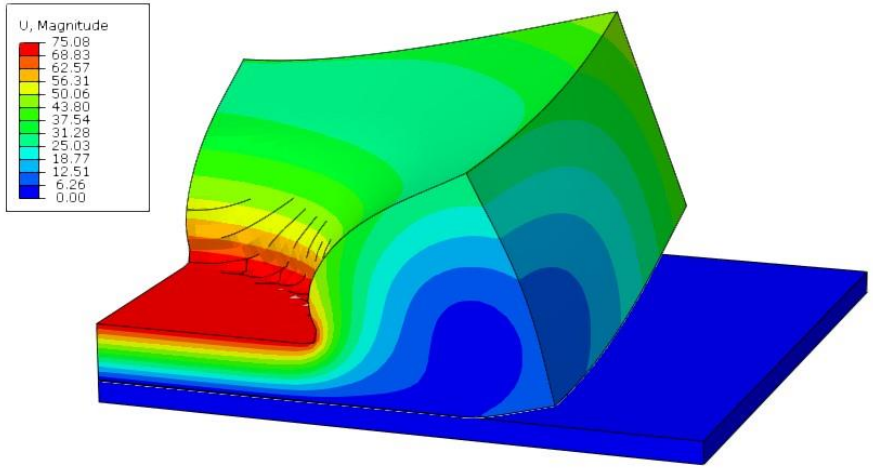
Methods of Validation

ASET Services Drop Test

Finite Element Analysis (FEA)



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Concept Generation

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Concept Generation

Methods

- Biomimicry
- Morphological Chart
- Crapshoot
- Anti-Problem
- Battle of Perspectives
- Brainstorming

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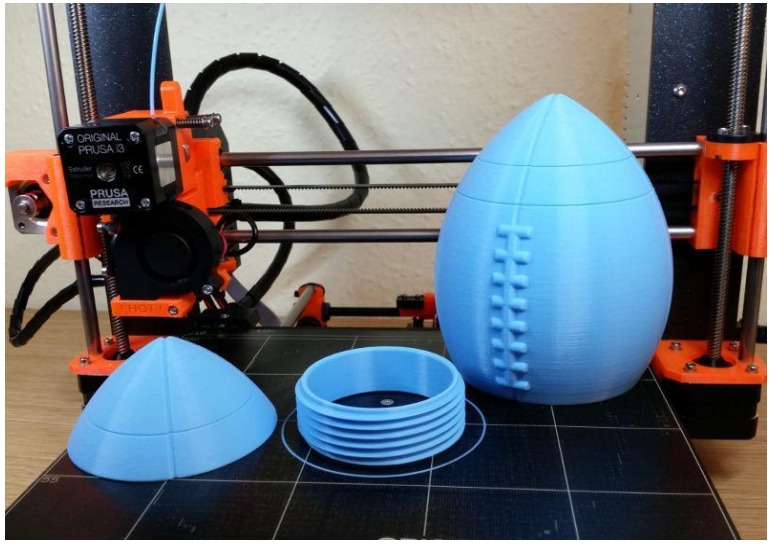
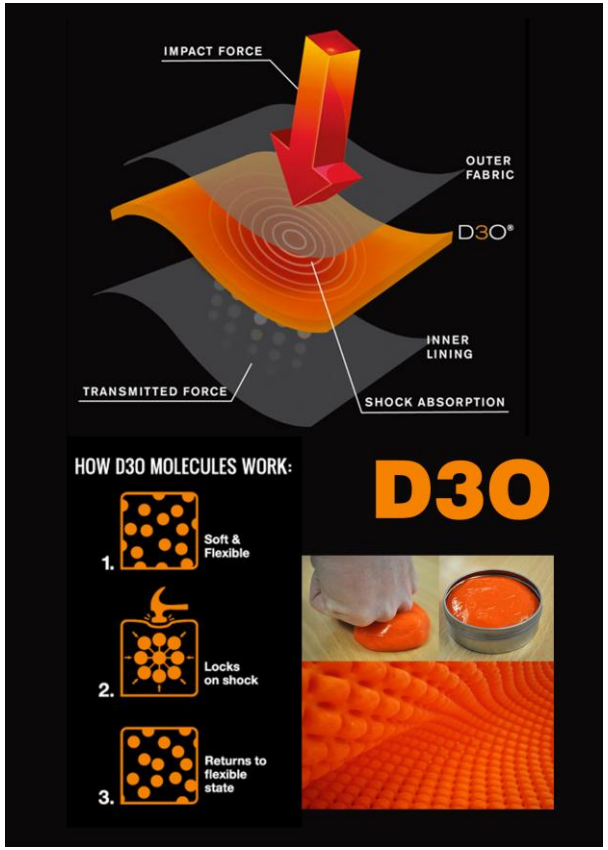
Brainstorming

- Discussion between all group members to produce potential concepts.
- Concepts generated in all categories.
- Many material options were discussed.





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Morphological Chart

- Allows concepts to be generated quickly by listing different design solutions for each component.
- Often similar concepts
- Less creative concepts then other methods

Morphological Chart			
Padding Material	**Shell Material**	**Increase Stability**	**Increase Mobility**
Memory Foam (Current Material)	Plastic (Current Material)	Compression sleeve underneath shoulder	Reduce Shell Volume
Air Pocket Technology	Kevlar	Compression shirt with rib and sternum padding	Reduce Padding Volume
Negative Poisson Ratio material		Casting structure custom fitted to each player	

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Medium Fidelity Concepts

"Non-Newtonian Fluid"

"Padded Compression"

"Open Cell Structure Foam"

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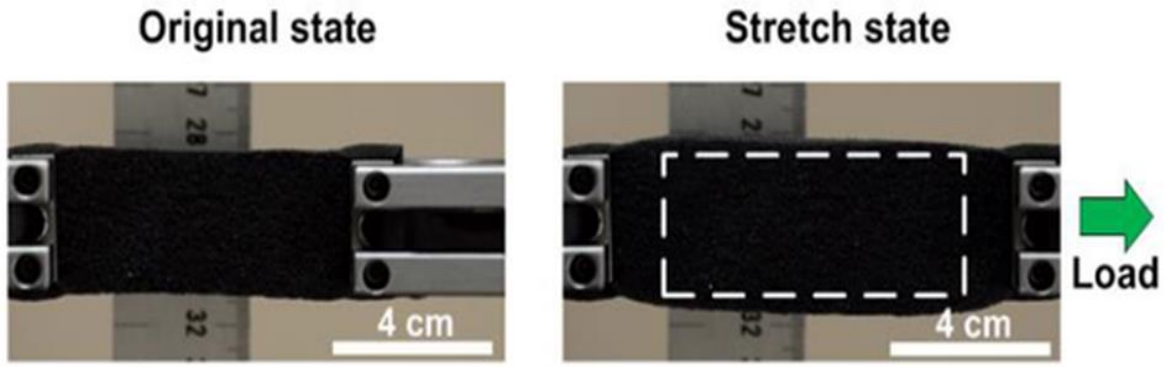
High Fidelity Concepts



"Auxetic Foam"

"Air Pocket Technology"

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Concept Selection

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Pairwise Comparison

Pairwise Comparison						
	1	2	3	4	5	Total
1. Impact absorbent	---------	1	1	1	1	4
2. Lightweight	0	--------	1	1	1	3
3. Flexible	0	0	--------	0	1	1
4. Durable	0	0	1	--------	0	1
5. Easily incorporated into existing products	0	0	0	1	--------	1

Nicholas Palestrini

Pairwise Comparison

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	1	2	3	4	5	Total
1. Impact absorbent	---------	1	1	1	1	4
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3. Flexible	0	0	--------	0	1	1
4. Durable	0	0	1	---------	0	1
5. Easily incorporated into existing products	0	0	0	1	--------	1

Nicholas Palestrini

House of Quality

Key
0 - not at all
1 - slightly
3 - moderately
9 - very much

House of Quality							
	Engineering Characteristics						
IMPROVEMENT DIRECTION		↑	↑	↑	↑	↑	↑
UNITS		Gs	lbf	n/a	lb	in	in^3
Customer Requirements	Importance Weight Factor	Absorbs impact	Disperse energy	Prevent Injury	Lightweight	Adapts to fit	Reacts Elastically
Impact absorbent	4	9	9	3	0	0	1
Lightweight	3	0	0	3	9	0	0
Flexible	1	3	1	1	0	3	3
Durable	1	1	0	3	0	0	3
Easily incorporated into existing products	1	0	0	3	3	3	1
Raw Score	10	40	37	28	30	6	11
Relative Weight %		26.32%	24.34%	18.42%	19.74%	3.95%	7.24%
Rank Order		1	2	4	3	6	5

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Pugh Chart 1

Pugh Chart 1						
SELECTION CRITERIA	Existing Shoulder Pads	Concept 1 Replace interior padding with non-Newtonian fluid	Concept 2 Metal plate insert centered within padding	Concept 3 Non-Newtonian fluid padded compression undershirt	Concept 4 Inflatable undershirt to compensate for ill-fitting shoulder pads	Concept 4 Replace interior padding with Celluelar Urethane
Absorb Impact	Datum	+	+	+	+	+
Disperse Energy		+	+	+	+	+
Prevent Injury		+	+	+	+	+
Lightweight		-	-	-	-	S
Adapts to Fit		+	-	S	+	S
Reacts Elastically		-	S	-	S	S
# of pluses		4	3	3	4	3
# of minuses		2	2	2	2	0

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Pugh Chart 1

Pugh Chart 1						
SELECTION CRITERIA	Existing Shoulder Pads	Concept 1 Replace interior padding with non-Newtonian fluid	Concept 2 Metal plate insert centered within padding	Concept 3 Non-Newtonian fluid padded compression undershirt	Concept 4 Inflatable undershirt to compensate for ill-fitting shoulder pads	Concept 4 Replace interior padding with Celluelar Urethane
Absorb Impact	Datum	+	+	+	+	+
Disperse Energy		+	+	+	+	+
Prevent Injury		+	+	+	+	+
Lightweight		-	-	-	-	S
Adapts to Fit		+	-	S	+	S
Reacts Elastically		-	S	-	S	S
# of pluses		4	3	3	4	3
# of minuses		2	2	2	2	0

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Pugh Chart 2

Pugh Chart 2				
SELECTION CRITERIA	Replace interior padding with Cellular Urethane	Concept 6 Replace interior padding with air pocket technology	Concept 7 Negative Poisson ratio material padded compression undershirt	Concept 8 Replace interior padding with negative Poisson ratio material
Absorb Impact	Datum	-	+	+
Disperse Energy		-	+	+
Prevent Injury		-	+	+
Lightweight		+	-	+
Adapts to Fit		+	+	+
Reacts Elastically		S	+	+
# of pluses		2	5	6
# of minuses		3	1	0

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Pugh Chart 2

Pugh Chart 2				
SELECTION CRITERIA	Replace interior padding with Cellular Urethane	Concept 6 Replace interior padding with air pocket technology	Concept 7 Negative Poisson ratio material padded compression undershirt	Concept 8 Replace interior padding with negative Poisson ratio material
Absorb Impact	Datum	-	+	+
Disperse Energy		-	+	+
Prevent Injury		-	+	+
Lightweight		+	-	+
Adapts to Fit		+	+	+
Reacts Elastically		S	+	+
# of pluses		2	5	6
# of minuses		3	1	0

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Pugh Chart 3

Pugh Chart 3			
SELECTION CRITERIA	Replace interior padding with negative Poisson ratio material	Concept 6 Replace interior padding with air pocket technology	Concept 7 Negative Poisson ratio material padded compression undershirt
Absorb Impact	Datum	-	-
Disperse Energy		-	-
Prevent Injury		-	S
Lightweight		+	+
Adapts to Fit		S	S
Reacts Elastically		+	-
# of pluses		2	1
# of minuses		3	3

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Pugh Chart 3

Pugh Chart 3			
SELECTION CRITERIA	Replace interior padding with negative Poisson ratio material	Concept 6 Replace interior padding with air pocket technology	Concept 7 Negative Poisson ratio material padded compression undershirt
Absorb Impact	Datum	-	-
Disperse Energy		-	-
Prevent Injury		-	S
Lightweight		+	+
Adapts to Fit		S	S
Reacts Elastically		+	-
# of pluses		2	1
# of minuses		3	3

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Criteria Comparison Matrix

Criteria Comparison Matrix						
	Absorbs Impact	Disperses Energy	Prevent Injury	Remains Lightweight	Adapts to Fit	Reacts Elastically
Absorbs Impact	**1.00**	7.00	5.00	7.00	7.00	7.00
Disperses Energy	0.14	**1.00**	1.00	3.00	5.00	5.00
Prevent Injury	0.20	1.00	**1.00**	0.33	3.00	3.00
Remains Lightweight	0.14	0.33	3.00	**1.00**	5.00	3.00
Adapts to Fit	0.14	0.20	0.33	0.20	**1.00**	1.00
Reacts Elastically	0.14	0.20	0.33	0.33	1.00	**1.00**
Sum	**1.77**	**9.73**	**10.67**	**11.87**	**22.00**	**20.00**

Normalized Criteria Comparison Matrix							
	Absorbs Impact	Disperses Energy	Prevent Injury	Remains Lightweight	Adapts to Fit	Reacts Elastically	Critical Weight
Absorbs Impact	0.565	0.719	0.469	0.590	0.318	0.350	**0.502**
Disperses Energy	0.081	0.103	0.094	0.253	0.227	0.250	**0.168**
Prevent Injury	0.113	0.103	0.094	0.028	0.136	0.150	**0.104**
Remains Lightweight	0.081	0.034	0.281	0.084	0.227	0.150	**0.143**
Adapts to Fit	0.081	0.021	0.031	0.017	0.045	0.050	**0.041**
Reacts Elastically	0.081	0.021	0.031	0.028	0.045	0.050	**0.043**
Sum	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

Consistency Comparison	
λ - n	0.67
n - 1	5
Consistency index	0.133
RI Value	1.35
Consistency Ratio	0.099

Consistency Check		
{Ws}	{W}	Cons
3.78	0.502	7.54
1.19	0.168	7.09
0.67	0.104	6.45
0.91	0.143	6.40
0.25	0.041	6.18
0.27	0.043	6.35
Average (λ)		**6.67**

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Concept Comparison Matrix

Disperses Energy Comparison			
	Concept 5 Replace interior padding with Cellular Urethane	Concept 1 Replace interior padding with non-Newtonian fluid	Concept 8 Replace interior padding with negative Poisson ratio material
Concept 5 Replace interior padding with Cellular Urethane	1.00	0.33	0.33
Concept 1 Replace interior padding with non-Newtonian fluid	3.00	1.00	3.00
Concept 8 Replace interior padding with negative Poisson ratio material	3.00	0.33	1.00
Sum	**7.00**	**1.67**	**4.33**

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Final Rating Matrix

Final Rating Matrix			
	Concept 5 Replace interior padding with Cellular Urethane	Concept 1 Replace interior padding with non-Newtonian fluid	Concept 8 Replace interior padding with negative Poisson ratio material
Absorbs Impact	0.15	0.07	0.78
Disperses Energy	0.14	0.57	0.29
Prevent Injury	0.33	0.33	0.33
Remains Lightweight	0.30	0.09	0.61
Adapts to Fit	0.20	0.60	0.20
Reacts Elastically	0.30	0.09	0.61

Alternative Ratings			Concept Final Winner
Concept 5 Replace interior padding with Cellular Urethane	**7.241**	**0.223**	**Concept 8 Replace interior padding with negative Poisson ratio material**
Concept 1 Replace interior padding with non-Newtonian fluid	**10.681**	**0.329**	
Concept 8 Replace interior padding with negative Poisson ratio material	**14.502**	**0.447**	

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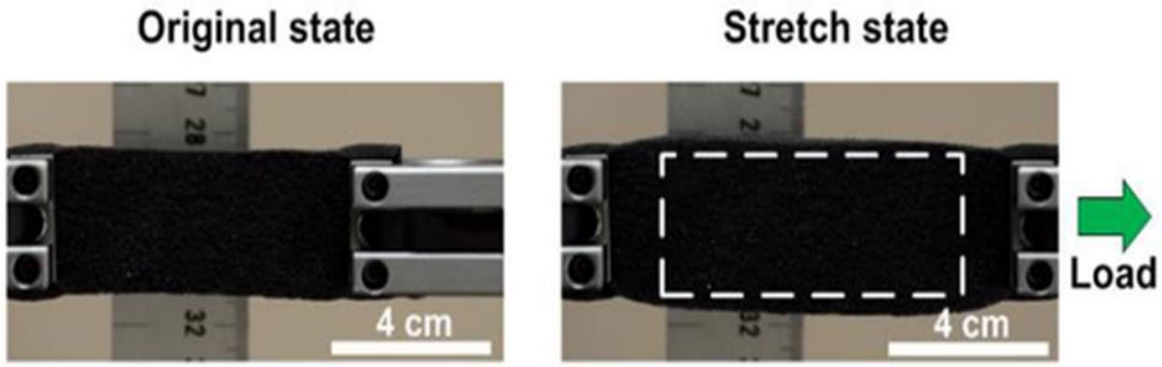
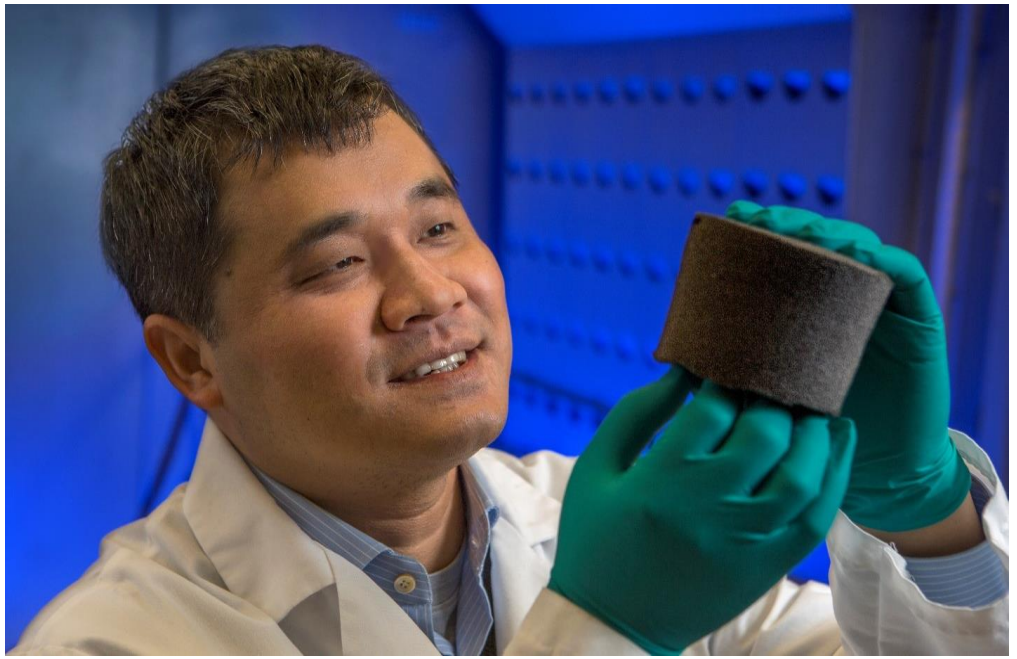
Selected Concept





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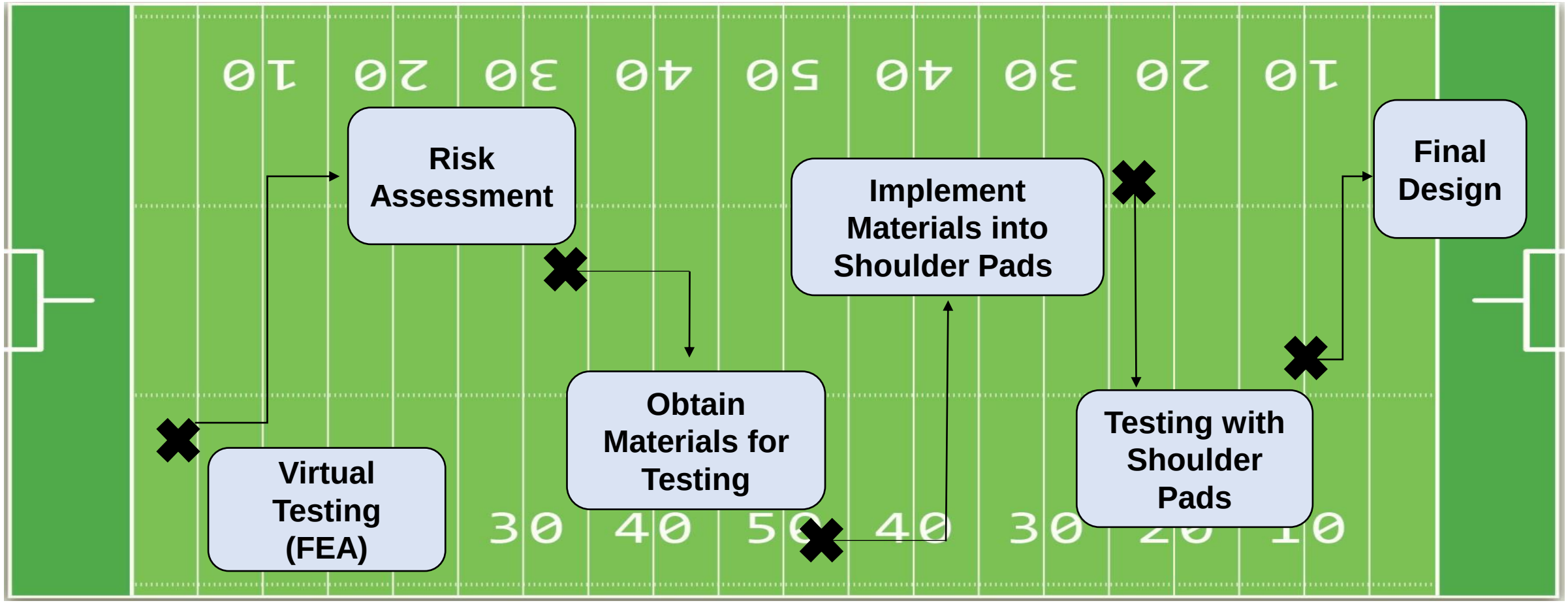
Future Work



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Questions

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