Figure 2. Example Drop Test from ASET Service

The elasticity of the materials can also be examined under the same impact test as previously mentioned. If the material can withstand repeated impacts simulating a hit from a football player then return to shape, then the material will react elastically enough for our design. After each test the material length width and height will be measured with a caliper to determine any changes have been made. While durability over time is an important function, the timeline for this project cannot account for long term experiments. Due to this, associations of long-term durability are connected to multiple and repetitive compression tests of materials for elasticity.

1.5 Concept Generation

1.5.1 Introduction

Now knowing what targets are needed for our project to be successful the next step is to generate concepts that can possibly meet those targets. First group members gathered and brainstormed to come up with possible designs, then each group member was assigned different

concept generation tools to each come up with more ideas. Those tools being biomimicry, anti-problem, crapshoot, morphological chart, battle of perspective, and brainstorming. From using these tools 100 concepts were generated (can be seen in Appendix E).

1.5.2 Concept Generation Tools

Biomimicry

Biomimicry is the design and production of materials, structures, and systems that are modeled on biological entities and processes. It was used for some of the concepts. The majority of these concepts were inspired by the skins and shells of animals and plants. Animals and plants use a variety of ways to protect themselves through their skins and shells. Some obvious examples are an armadillo's shell and the skin around oranges and grapefruit. These skins and shell were researched to determine how their natural protection could be useful for shoulder pads.

Anti-Problem

One of the tools used was the anti-problem where the team asks themselves to solve the opposite problem and the solutions to and attributes that are causing what is happening. From this tool some concepts such as removing shoulder pads altogether so that the players will not hit as hard. This was also suggested by Dr. McConomy early in the semester. Another concept that came from anti-problem was adding pressure points on the inside of the shoulder pads in places on the body where injury risk is low so that the energy is distributed away from high-risk areas.

Crapshoot

Crapshoot tool is a used to generate concepts randomly. This had a very unpredictable outcome. The idea is to select words or phrases that can be selected at random and rearranged to

come up with concepts. The 6 words selected to be used are undershirt, hard plastic, auxetic foam, rib padding, shoulder shocks, density foam. With a roll of the dice, the concepts were then chosen and added to the concept generation table.

Morphological chart

The measure of how successful the selected design is will depend on successfully achieving the maximum amount of the project's key goals. The morphological chart identifies four solution subsystems: Padding Material, Shell Material, Improve Stability, Improve Mobility. Each of these subsystems identifies a component of the design that will contribute to the achievement of the project's key goals. The rows of the chart were filled with potential choices for each subsystem. A concept is generated by combining one component from each subsystem.

Table 4: Morphological Chart

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	

Battle of Perspectives

This tool is used to make decisions with the complex global system in a world of uncertainty. This tool was able to help determine a few concepts with the thought in mind that the world of football players and football as a sport will adapt in a way that will remain uncertain to us.

Brainstorming

After multiple meetings and discussions of our customer needs, functional decomposition, and targets and metrics the group started brainstorming ideas of our concepts. These ideas were all across the board, which was helpful and unhelpful at the same time. These ideas ranged from Orthocast material to water pockets within padding. This gives us many options when looking into concept selection.

1.5.3 5 Medium Fidelity Concepts

Replace interior padding with non-Newtonian fluid

Non-Newtonian fluids are a type of fluid where their viscosity changes based the amount of stress that the fluid is under. Fit was a constant problem that was brought up in the surveys that was given out to athletic trainers, so in replacing the existing padding with a type of non-Newtonian fluid, the padding would always conform to that specific athlete. It would also provide good protection to the athlete since when it is under stress the fluid becomes more viscous and can prevent the user from feeling the impact.

Figure 3: Non-Newtonian Fluid Taking Impact from Punch

Plate insert centered within padding

Nike's Vaporfly shoe utilizes a carbon fiber plate centered within an aerospace insulation padding design to aid in stability, stiffness, and propulsions of each enacting force. The plate's spring is not factored within this design, rather the rigidity aids in proper posture and form. Gathering inspiration from Nike's shoe design, the additional plate within football shoulder pads have the capability to assist in promoting ideal form for football play along with load reduction. Further research is required to find the ideal material for the embedded plate best used for football shoulder pads: carbon fiber, metal, etc.

Non-Newtonian fluid padded compression undershirt

This idea would go in tandem with existing shoulder pads. The non-Newtonian fluid discussed previously would be added to a compression under shirt that would be worn underneath the shoulder pads making the fit of the shoulder pads better while still providing more protection to the athlete. This will allow for the protection already given by the shoulder pad while giving the comfort and better fit that can be attained from having a compression shirt with non-Newtonian fluid. Figure 5 below shows an example of a compression under shirt with

padding. This design will replace the padding in the shoulder, chest, and rib area with the foam used with a non-Newtonian fluid.

Figure 5: Padded Compression Under Shirt

Replace interior padding with Cellular Urethane

Most padding used within football shoulder pads are constructed with closed cells. A closed cell structure is trapped air cells that aid in rebound when pressure is applied. While closed cell structures are sturdier and more durable, the air pockets can dissipate air over time, negating the beneficial air cell property. Open cell structures have a high expansion rate, high elasticity, and allow air to be dissipated along with an air refilling function. Open cell structures are best exemplified with the squeezable portion of a pipette or dropper. The drawback of open celled structured materials is the increase likeliness of breakage or deformity after the elastic region is passed. Most foams utilized are open celled, and cellular urethane is known best for the shock absorption property.

Figure 6: Example of Open Cell Structure Foam

Inflatable undershirt to compensate for ill-fitting shoulder pads

Rather than having air pockets or air cells within the padding material, an undershirt can consist of inflatable air patches that can aid in securing football shoulder pads for an ideal fit. The inflatable air patches are capable of deflating for storage and inflating for fit use. This design is highly reliant on the strength and elasticity of the material that will encase the air patches because any failure from an extreme impact could pop the air patches and result in injury. Due to this, the undershirt is required to have a failsafe of either air dispersion or an increased inflation when dealing with an impact.

Figure 7: Football Helmet with Inflatable Padding

1.5.4 3 High Fidelity Concepts

Replace interior padding with negative Poisson ratio material

Materials with a negative Poisson ratio expands laterally when stretched. So when this material is presented with an impact it will expand, allowing for the energy from the hit to be dispersed over a larger area therefore decreasing the pressure felt by the athlete. Auxetic Foam is example of this type of material that was developed at the High-Performance Materials Institute at FSU by Dr. Chanchung Zeng. If this material is decided to be used Dr. Zeng will be sought after as an advisor to help with research with this specific type of material.

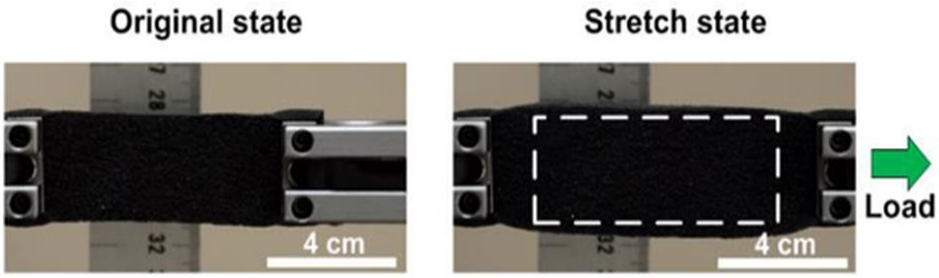

Figure 8: Auxetic Foam Being Stretched

Negative Poisson ratio material padded compression undershirt

The negative Poisson ratio material could also be used in an undershirt as was previously discussed with the non-Newtonian Fluid undershirt. The material will be added in as padding on the shoulders of the compression shirt allowing for the shoulder pads to have a better fit therefore reducing injuries. This will help with the fitting issue that was expressed by the athletic trainers in the survey given while also giving more padding. Figure 8 displays the technology that would be implemented for this design.

Replace interior padding with air pocket technology

Initially when the sponsor of this project, Mike Holloway brought the idea of implementing helmet air technology into shoulder pads. In recent years a lot of research has gone into reducing concussions for football players. From this research helmets companies such as Schutt have implemented air pockets into helmets. To do this the athlete puts on the helmets and then the helmet lining is filled with air, which conforms to the athletes own head. This is the same type of technology would be implemented into shoulder pads. The inner layer of the shoulder pad would be lined with air pockets that will be filled when the athlete is wearing them to conform to that specific person. Figure 7 shows the type of technology that would be implemented for this design.

1.6 Concept Selection

1.6.1 House of Quality

The pairwise comparison is used to determine the importance weight factor of each customer requirement. This is done by comparing each customer requirement head-to-head to determine which is valued above the other receiving a 1 if it is deemed more valuable and a 0 is deemed less valuable.

Table 5: Pairwise Comparison