

ME 476C – Smart Helmet

Preliminary Report

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DISCLAIMER

This report was prepared by students as part of a university course requirement. While considerable effort has been put into the project, it is not the work of licensed engineers and has not undergone the extensive verification that is common in the profession. The information, data, conclusions, and content of this report should not be relied on or utilized without thorough, independent testing and verification. University faculty members may have been associated with this project as advisors, sponsors, or course instructors, but as such they are not responsible for the accuracy of results or conclusions.

EXECUTIVE SUMMARY

The purpose of the project is to create a Smart Helmet device that prevent head injuries and collect any type of data such as speeds, distance, velocity, force of impacts, and anything that can be measured. The specified sport that the team will do further research in is Football, simply because the amount of brain injuries that occur in the sport. To come up with a design for the project, the team utilized various methods to come up with the most viable design that corresponds to the client's needs. Multiple designs were generated and put into a Pugh Chart and then were scored based on feasibility as well as meeting with customer requirements. A final design that was selected from the Decision Matrix, a design that involves Magnetorheological Fluid along with D30 material with the implementation of laser sensors to record any data that is necessary for the project. The process of how the team will work is provided and how the team plans to test the helmet in the future.

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1 BACKGROUND

1.1 Introduction

Injuries occur every day and especially when one plays in any physical contact sports, whether that is from hockey to simply as riding a bicycle. Traumatic brain injuries occur when an impact against the head is taken or rapid movements of the head. These brain injuries can have long-term effects on people. A smart helmet will be able to protect the user as they are playing their respective sport by analyzing the environment and make any preparations to ensure the safety of the person. This task will be done by using sensors to see the oncoming impact and have a sensor harden a specific material as the helmet reads the current situation. At the same time, the smart helmet will be able to collect data of the impact and will be able to be accessed to any personnel of the respective sport. As of now, the team will focus on the American sport, football. This will allow the team to focus on one sport and create a system that will be able to withstand constant impacts and be able to monitor players as they play so any staff can determine the player's eligibility. Once testing is completed, the team will be able to create a smart helmet for any sports.

1.2 Project Description

Following is the original project description provided by the sponsor.

“Falls, accidents are major causes of traumatic brain injury. Traumatic brain injury occurs due to the impact of the head against objects or rapid movement of the head and can have long-term effects on people. While the major task of a helmet is to protect the head against impacts and constrain its motion to prevent very rapid motions, it should also be able to provide data on performance of the helmet as well as health of the person. A smart helmet should first protect the head against impacts/rapid motion to the best possible, and second can monitor and record the acceleration of the head and the impact forces (upon accident or fall) and based on those data make suggestions to the user. It should also optimize the user’s performance in terms of speed, safety and other important criteria. You will design a smart helmet with great protection capability against impacts which will be able to recognize the risk of brain injury by monitoring and recording head kinematics as well as optimize the user’s performance. Teams may be tasked with a specific sport in mind or make the project applicable to all sports.” [1]

1.3 Original System

This project involved the design of a completely new smart helmet system. There was no original system when this project began.

2 REQUIREMENTS

Section 2 contains the customer requirements obtained from the client and the engineering requirements that specify the measurable parameters or conditions of the customer needs. The testing procedures will determine how the team will test the design. Lastly is the house of quality that is based from the customer requirements and engineering requirements.

2.1 Customer Requirements (CRs)

The CRs of the project are listed as follows along with their weights:

Table 2: Customer Requirements for Smart Helmet

Factors	Rating Weight	Description
High Protection	5	High protection is listed as the highest weight because safety is the priority of the client.
Similar size of helmet	4	The size of the helmet is a four because the client wants the smart helmet to be similar to those helmets in the current market. No company wants a helmet that is too large and heavy, this does not make sense, so the size of helmet does matter.
Life Expectancy	4	The smart helmet should be able to function as a helmet and last as long as a regular helmet.
More Comfortable	3.5	The smart helmet needs to be comfortable to the user to ensure the safety of their well-being.
Transmit Data	4.5	The client wants the team to be able to collect data of the user and impacts occur during their respective sport.
Small Sensor	3	The size of the sensor matters because the sensor must be able to fit within the interior of helmet and still function
Strong battery	2	A battery will ensure the life expectancy of the helmet.

2.2 Engineering Requirements (ERs)

The ERs of the project are based of the CRs in the previous section. The requirements are listed as follows:

Table 3: Engineering Requirements for Smart Helmet

Requirements	Description
Decrease Impulse	During a sudden break during driving, a shock or impulse arises which can potentially cause accidents due to imbalance. The smart helmet will be designed to decrease impulse and control the situation.
Maintain Volume	As stated above “in similar size of helmet” section of customer requirements, users need helmets of normal size and hence maintain the volume of other manufactured helmets.
Increase factor of safety	The smart helmets should be scientifically designed in a way that improves the damage reduction in case of an accident.
Ductility	Ductility is a stretch by a material when a tensile stress is applied to it. The smart helmet should be engineered in a way that does not break or take damage and should show some stretch ability.
Increase power	The customer requirements a strong battery, small sensor, and data transmission (given in Table 2) will increase the helmet’s power.
Decrease Diameter	The smart helmet should be engineered in a way that sensors/wires of any electronic device is less in diameter. These accessories may collide with CR of “more comfortable” but it’s needed for a manageable helmet.
Increase voltage	The Smart Helmet should be designed in a way that the helmet has a “Strong battery” and has the option of amending the voltage for better performance.

2.3 Testing Procedures (TPs)

Testing procedure is a way or method of evaluating the working and functionality of a certain entity. For our Smart Helmet project, the team intends to analyze and specify testing procedures for each of the Engineering Requirements developed by the team in the previous section. Later, use the same sequence of Engineering Requirements in the House of Quality.

The testing procedures for Engineering Requirements are explained below:

1. Decrease Impulse

Conduct experiments to ensure that impulse is decreased in Smart Helmets. For this purpose, put the helmet on a motorcycle-driver dummy and let an accident happen. After this, calculate the impulse values using smart helmet and test the results.

2. Maintain Volume

Test the volume of Smart Helmets by comparing the dimension with an ideal helmet.

3. Increase factor of safety

After analyzing the results achieved in point 1, increase factors of safety by optimizing and remodeling the helmet.

4. Ductility

Test the stretch ability of helmets by going through different concepts and experiments related to Physics.

5. Increase power

Test and compare different batteries for the smart helmet. In this way, choosing a battery with the highest performance.

6. Decrease Diameter

By going through different design considerations, decrease the diameter of smart helmet technology without compromising the equipment inside.

7. Increase voltage

Conduct different tests so that a solution for highest and accurate voltage required by Smart Helmets.

2.4 House of Quality (HoQ)

House of Quality or HoQ is a device that makes an interpretation of the client requirements into specialized descriptors. The HoQ is the most helpful and straightforward apparatus used to change over the client needs into specialized descriptors. House of Quality is a network additionally called Quality Matrix. The matrix gives us subtle elements like client prerequisites, specialized descriptors, need of the different descriptors, connection between the descriptors, target esteems for every descriptor, and so forth. It likewise indicates aggressive assessment between different items with the present item. For the project, the team developed a detailed HoQ, which can be seen in Appendix A,

In the Appendix A, it can be observed that the added engineering requirements (Decrease Impulse, Maintain Volume, Increase factor of safety, Ductility, Increase power, Decrease Diameter, Increase voltage) based on their importance. Similarly, with the customer requirements (High Protection, Similar size of helmet, Life Expectancy, More Comfortable, Transmit Data, Small Sensor, Strong battery) based on their weights and rating by the customers. In the end, the team plotted them and ranked the modules based on their rankings.

House of Quality aided in the project in multiple ways. First, HoQ helped in the team's decision as the coming up with design solutions which can be seen in chapters three and four. The HoQ enabled the team to choose what is the most important part the team should focus on and how to improve the design to create a new design. The requirements are based from the previous two sections of this chapter. These requirements tell how the team will implement a new system into the smart helmet while remaining to the team's intention of the client.

3 EXISTING DESIGNS

Defining the project is important to understand the goal, and the requirements for the project. The next step after understanding the project is to learn about existing designs. One approach to designing a new, re-engineered system is to learn about the technology that is currently available before coming up with designs. Information on existing products are found from the internet and through engineering literature. This section contains research on existing designs at the system level, functional decomposition, and subsystem level designs. The system level designs are designs relating to the entire project and help with understanding what technology is available that relates to the project. Functional decomposition consists of understanding the necessary inputs and outputs of the system and the various functions of the project. The subsystem level research helps in gaining a better understanding of various applications of the subsystems of the project.

3.1 Design Research

The process for design research consist of research through the internet and gaining information from faculty that has experience in topics related to the project. The internet was able to provide information of the smart helmet technology that is currently available. Effective keywords such as smart, sensing, and football helmet were used in the internet research process to help find technology that closely relates to the project. Faculty with a background related to the project were also pursued for the design research of the project. Dr. Hesam Moghaddam who is also the client of the project shared about brain injury threshold information and the importance of knowing threshold values for the project. Also Dr. Ciocanel shared his understanding of magnetorheological (MR) fluid and its application to the project.

3.2 System Level

An existing system level design is one that accomplishes requirements similar to the smart helmet project. The system level design research in the project helps with understanding products that have similar requirements as the project. Understanding similar systems will be useful for coming up with design ideas for the project. Understanding systems related to the project assures that the design is new, and also helps with coming up with creative ideas by building from existing systems. The faults in system level designs is important to know so this project can improve on those faults and avoid them.

3.2.1 Existing Design #1: Vicis Morphing Helmet with Innovative Padding Design

The Vicis company smart helmet took the approach of creating a new padding design for their smart helmet. Their design includes columns of padding instead of the conventional block shape padding that normal helmets have. The columns allow the helmet to flex more than other helmets and absorb more of the impact than typical helmets. Figure 1 shows the section of the helmet that Vicis implemented their smart design of column shaped padding. This is useful to the project because one requirement of the smart helmet project is to increase the protection and this design satisfies this requirement by doing a simple change to the padding of the helmet.



Figure 1: Viscis Helmet

3.2.2 Existing Design #2: Riddell Sideline Response System and Insite Impact Response System

The Riddell Insite Response system is an impact monitoring system for football helmets that uses sensors that go in the helmet to collect data and report the data to the sideline. This system shown in figure 2 allows the player to be monitored during a game or practice session for serious head injuries that exceed a calculated threshold. This system-level existing design collects data from impacts with sensors and shares that data which is directly related the customer requirement for the smart helmet project of implementing sensors to collect and share data from impacts. This design is helpful for the project because the system can be used to help guide the design of the sensors in the smart helmet and the data collection and sharing system.



Figure 2: Riddell Insite Sensor

3.2.3 Existing Design #3: Xenith helmets

The Xenith helmets include a reengineered padding system that moves with the head instead of with the hit. The padding reduces linear and angular forces which is one of the customer requirements for the smart helmet project. They also changed the adjustment system that is more variable and allows players to get a more custom fit that increases the comfort. The Xenith helmet padding design is shown in figure 3.



Figure 3: Xenith Helmet

3.3 Functional Decomposition

3.3.1 Black Box Model

Black Box model is one of the most important technique for the engineering project. Figure 4 shows the inputs and outputs for the smart helmet project. The inputs are based on three main categories such as energy, material, and signal. However, both inputs and outputs should satisfy the customer needs toward the smart helmet project. This project should accomplish many important functions such as comfort materials, lightweight, safety, and smart technology. The team decided to include the elasticity material in the helmet for the comfort purpose. Figure 4 shows the elasticity material as input and hardened as output in the black box model. Safety is another important function in customer needs. As a result, the team created the kinetic energy as input and injury as output as discussed in Figure 4. Another important function of the customer needs is lightweight. The team is trying to reach the lightest weight as possible in this design. One way of that is to decrease the weight of the helmet by decreasing the elasticity material. Finally, smart technology is one of the customer needs in this project. As discussed in the Figure 4, the team will create a sensor with a smart technology in this project. This customer need will help the team to improve the features of the helmet.

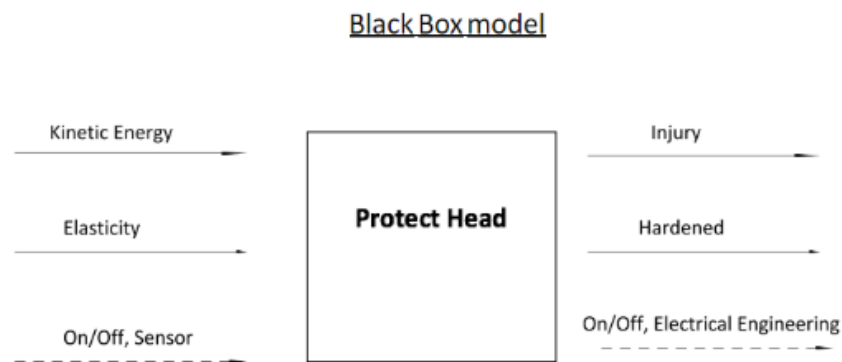


Figure 4: Black Box Model

3.3.2 Functional Model/Work-Process Diagram/Hierarchical Task Analysis

Hypothesized Functional model (HFM) is a very useful technique in this project. The main purpose of the hypothesized functional model is to understand the inputs and outputs of the smart helmet project. It also gives a detailed information about the design project. The HFM is more developed process than the black

box model because it breaks the component of the inputs and outputs in detail. Appendix B shows how the components of the customer needs broke down through this project. Appendix B gives the team a brief and detailed ideas about the working process. It helps the team to fully understand how the project works, and what are the main results of this working process. The HFM is a very helpful process for the smart helmet project because it improves the performance of the project. For example, when the team decides to create something, then the team should focus on the results, and the input situation through this design. However, the HFM will help through this situation because it helps the team to know the advantages and disadvantages of the inputs and outputs situation through this project.

3.4 Subsystem Level

After decomposing the project and understanding the inputs and outputs for the system and the various subsystems involved with the project it is important to look at different existing designs that relate to the project. Sensing is a subsystem that is important for the project and was defined in the functional model to be necessary and have a kinetic energy input and a signal output. The next subsystem that is researched is the controllable padding subsystem that relates to the elastic section in the functional model that takes in kinetic energy and a signal and distributes the kinetic energy to the head in a safe way. The last subsystem researched is the data transmission subsystem because from the functional decomposition, the sensor is collecting information and there needs to be a way to transmit the information.

3.4.1 Subsystem #1: Sensing

Sensing is a subsystem defined in the functional decomposition for the smart helmet project that takes kinetic energy input and outputs a signal. To gain a better understanding of this subsystem it is important to investigate existing products that involve this subsystem and see how it is applied. Once knowing how other products apply sensing into their design it will be easier to implement this subsystem into the smart helmet design. Sensing is important to the overall project because it is a requirement from the client to include sensors that can measure linear and angular forces the head can experience in an impact.

3.4.1.1 Existing Design #1: Accelerometers in Phones and Laptops

Phones accelerometers sense acceleration forces and applications use it to determine the devices orientation. Some phones have features of going to sleep when faced down, the accelerometer in the phone is used to sense if the phone is facing down. Laptops also use accelerometers to protect itself, there are accelerometers in laptops that can detect a freefall and stop the hard drive in order to prevent it from becoming damaged during the drop. This relates the sensing subsystem of the smart helmet project because accelerometers like the ones used in phones and laptops can be used for the project to collect the data required by the client. The data that the client wants the project to collect are linear and angular forces and this device does both.



Figure 5: Phone Accelerometer

3.4.1.2 Existing Design #2: Motion Laser Sensor Detectors

Laser sensors are essential in buildings that requires security. Nowadays, most security sensors use the

motion laser detector. The team decided to include this type of sensor in the smart helmet project. The main purpose of this sensor is detecting the motion of any movement in a particular range. The motion laser sensor works using programmed codes. One of the most common programming code kit is Arduino and using Arduino, the team will be able to detect any type of motion in the football game. Ultrasonic included in the Arduino is very useful device for detecting the distance of the players. The team will use this device to help the laser performance in the smart helmet project. Safety is one of the most important customer needs in this project. As a result, the team will be able to increase the safety with this specific type of system. The laser sensor will be programmed based on the Ultrasonic device that detect motion. Thus, the motion laser sensor will sense any kind of motion in a specified distance. In addition, the team can use the PIR motion detector which is included in the Arduino kit as well. The purpose of this advance device is to detect any motion for a specified range. This device can be alternative for the Ultrasonic device. The team can use either one of those devices. Moreover, most of the cars use this motion laser sensor that detect any movement. The team can also use this device for the smart helmet project by maximizing and minimizing the ranges of the programmed codes. Overall, a motion detector sensor is an improved device that can assist the smart helmet project.

3.4.1.3 Existing Design #3: XOnano Smart Foam Sensor

The XOnano smart foam sensor is a sensor imbedded in foam to be used in applications similar to the smart helmet project. The company's initial product was a smart foam football helmet that transmits data in real-time. The way the foam works is by placing the sensor anywhere on the player such as the helmet, and the sensors senses any excessive motion (such as a tackle) and records the data. The smart foam measures the impacts and pressure while not sacrificing the comfortability aspect of the application. This product relates to the project because comfortability and sensing is a customer requirement for the smart helmet project and this design accomplishes both requirements.

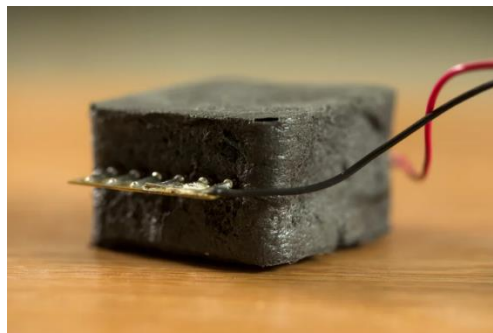


Figure 6: XOnano Foam Sensor

3.4.2 Subsystem #2: Variable Padding

The variable padding subsystem is the part of the smart helmet that allows for controllability of the protection in the helmet. An example of padding that allows for variability is ferrofluids that have a stiffness that can change and sometimes be controlled. The controllable padding subsystem satisfies the customer need of implementing a smart and innovative technology into the project while increasing the protection of the product. After analyzing system level designs that collect data from a collision and transmit the data, it is important to keep the project unique by being innovative and this subsystem keeps the project innovative.

3.4.2.1 Existing Design #1: Audi Magnetic Shock Absorber

A shock absorber is used to dampen the forces felt on the car from the uneven ground and Audi was able to implement a controllable fluid called magnetorheological (MR) fluid into the system. The MR fluid works by having iron particles inside the fluid and to enable the fluid to become stiff, a magnetic field is applied to the fluid, thus making the fluid stiff. Figure 7 shows a diagram of the shock absorber and how it implements the MR fluid into the system. This existing design relates to the subsystem of the project for a variable padding because this fluid is used as a variable padding for the shock absorber. A shock absorber is constantly moving up and down while a car is moving, and this relates to the smart helmet project due to football players constantly experiencing impacts to the helmet.

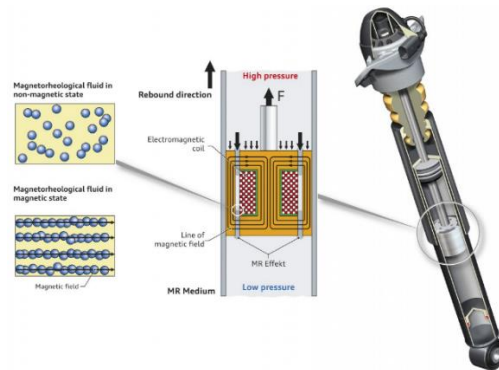


Figure 7: Audi

3.4.2.2 Existing Design #2: Automotive Airbag

Cars are equipped with airbag systems that manipulate the impulse equation by increasing the time an impact occurs so that the forces the driver or passengers experience will be decreased. This system effectively increases the safety in cars and has a similar functional decomposition as the smart helmet project. The airbags inflate rapidly on impact as shown in figure 8 and absorbs the forces of the person being accelerated. This relates to the smart helmet project because in both cases there are forces exerted on the user that can be lethal and an airbag can potentially reduce the force. Airbags could possibly be implemented into the smart helmet project because the system works but needs to be manipulated to work in the application of a smart helmet. One way to manipulate the application is by using the impulse equation and decreasing the time. When the time is decreased, the force of the impact will be reduced, which is what the team is striving for.



Figure 8: Deployed Airbags

3.4.2.3 Existing Design #3: D30 Armor

D30 is a polymer that provides protection when quick high forces are being applied to it as shown in figure 9 and is soft when there is a force being applied for a long time. This relates to the smart helmet project because it can be used as a padding for the helmet and provides variability compared to conventional foam helmets. This armor is currently used in padding for sports and is effective in protecting players during collisions. The D30 material isn't controllable but based on the process of making this polymer, the variability can be set based on the needs of the application.



Figure 9: D30 Material Protecting Hand from Hammer

3.4.3 Subsystem #3: Transmit Data

Transmitting data is related to the customer requirement of making the data collected from the sensors available to be analyzed. The functional decomposition of the project also shows that after the sensor collects the data, the next function of the device is to transmit the signal from the sensor to another device that will process the signal. Transmitting information is an important subsystem of the project because the data collected would be useless in the case that it can't be moved.

3.4.3.1 Existing Design #1: Phone Applications

Most people nowadays have phones on them that have numerous apps that transmits data. For example, there are phone applications that have maps and shows the data relating to the location of the phone. Phones are easily accessible and there are many apps made for them to transmit data. This relates to the subsystem of the smart helmet project of transmitting information because this design is commonly used and is readily available for most people. Figure 10 shows a phone with apps that transmit data.



Figure 10: Phone Applications to Transmit Data

3.4.3.2 Existing Design #2: Car Bluetooth connection with Phones

Bluetooth is used in many applications and are commonly used in newer automobiles allowing the driver to listen to their music and make calls with the car from their phone through a Bluetooth transmission as

shown in figure 11. Newer car models also display the information from the phone about what song is playing or who is calling. This relates to the subsystem of the project relating to transmitting the data from the sensor because Bluetooth in cars effectively transmit data from a phone to the car without wires connecting the two which is what is wanted in the smart helmet project. The functional model does not display an input of wires for the transmission which means it is necessary to have a form of wireless transfer of data and Bluetooth does this effectively.



Figure 11: Car Bluetooth Transmission Example

3.4.3.3 Existing Design #3: Live Streaming from Websites

The last existing design for transmitting data is website streaming. There are many websites that transmit data such as Twitch, which streams live video of people playing video games. These websites are effective at allowing people to follow and watch their favorite gamer live. This relates to the project because the data collected from the sensors of the smart helmet could be projected live onto a website where people can stream in and keep updated on the players condition. Figure 12 shows the Twitch streaming website.



Figure 12: Video Game Streaming Website

4 DESIGNS CONSIDERED

After understanding, asking and researching, it was time to work as team to create concepts that would help the team reach the goal. Each team member came up with two ideas, with a total of ten concepts to help expand ideas to work for the current goal. All the ideas have been put in a Pugh Chart that can be found in Appendix C. After putting in all the ideas in the Pugh Chart and discussing relationship between the designs with the customer needs, the team selected the most optimal design that corresponds with the customer needs.

4.1 Design #1: MR Fluid Two

Magnetorheological Fluid two is helmet that comes with sensor contacting with Arduino, and MR fluid which can help to control the viscoelastic. The way that the helmet works is using sensor to know the motion and distance. By defining the distance, Arduino will save data and active MR fluid and viscoelastic to be formed correctly by becoming solid or flexible depending on the collision. MR Fluid two design has two negative relationships with customer needs which are lightweight, and affordable. The reasons why these negative relations exist for this project is MR fluid which is heavy and expensive. The design has three positive relationships which are controllability, safety, data collection. By having MR fluid, the controllability of helmet will be easy by control the viscoelastic after getting the distance between the players, so that will increase the safety of the players from injuries. The design can find in figure 13.

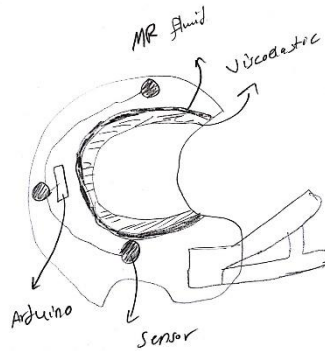


Figure 13: MR Fluid Two Concept

4.2 Design #2: Transferring

Transferring is helmet that comes with sensor, transferring data, and viscoelastic. The work for this helmet is starting with the sensor that contacting with the part of transfer data, so the coach will know players' movement and cases of injury. Also, this helmet comes with viscoelastic that can protect the brain during collision. Transferring helmet has three positive relationships with customer needs. First, this design has lightweight because it is coming without any kind of heavy solid or liquid as MR Fluid two design comes. The cost of the design is not expensive as some of other designs, so that makes the relationship with affordable be positive. Because the transferring helmet does not come with kind of smart ways, the helmet will look better which make the relationship with appearance be positive. In other hand, transferring design has difficulty of controlling the viscoelastic and transferring data which makes negative relationship with controllability. Without having the control of viscoelastic and transferring data in a large percent, the team will not have secure safety, so the team will not hit targets. The design can find in figure 14.

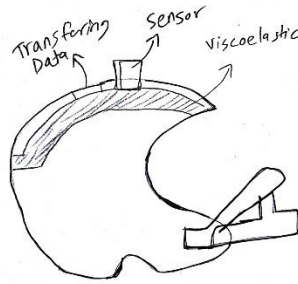


Figure 14: Transferring Design

4.3 Design #3: Airbag

Airbag is the design that has sonar, data collection, and airbag behind section of shell. When the players will start the game, the sonar will feel the body that around each player with determine how strong collision is, so the airbag can dilate correctly depending with collision' cases. The expansion of airbag will be outside of the helmet which reduce the severity of the collision and come back to the helmet normally after protecting the brain. Airbag design has four positive relationships with customer needs. Because it will come with airbag which means it is using gas without having solid or liquid, the helmet is not be heavy. In addition, it is simple design which will help to not pay as other designs, so the relationship with affordable be positive. Airbag is the design that has a large percentage of protection that the team is looking for, the design gets positive rapport with the safety. The design is easy to control and save injury information when it is using the sonar, it ended with positive with controllability as well. However, when the design is protecting the players by using the airbag, the design will not look normally which makes negative relationship with appearance. The Airbag design can be found in figure 15.

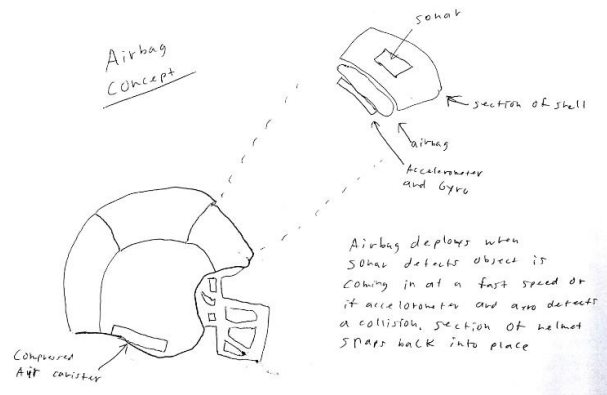


Figure 15: Airbag design

4.4 Design #4: Suba Diving

The main idea for this design is mixing up the scuba diving's stretched suite with the football helmet. The scuba diving suite is a very starched material because for the movement of the diver in the ocean. Scuba diving suite can also absorb the sweat from the diver's body. As a result, this design is talking about attaching the scuba diving suite to the football's player head. Moreover, scuba diving suite observes the strong movement in the body. Thus, this stretched material can absorb the strong movement in the player's head. The advantages of the scuba diving helmet are comfortable material, light weight, less expensive, strong movements absorb, and sweats absorb. On the other hand, the disadvantages of this design are skin sensitivity and having an allergic to this specific material. Thus, the scuba diving has three positive relationship with the customer needs which are lightweight, appearance, and safety. The affordable, controllability, sensing are the three-negative relationship with the customer needs. The design

can find in figure 16.

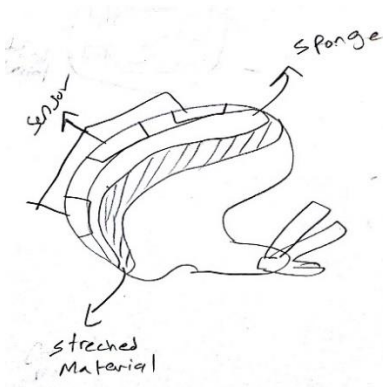


Figure 16: Scuba Diving

4.5 Design #5: Boxing Helmet

The main idea of this design is mixing up the boxing helmet with the football helmet. The shape of boxing helmet is square, and it's attached with a very comfortable material. This comfortable material can absorb the hit from other players. However, the idea of this design is creating a smart helmet for a football player's that has this comfortable material. The football game has a lot of hits and strong movement during the game. As a result, the team decided to create a movement detector that can absorb the motion of the players without any sound. This sensor will absorb the hit before it comes to the smart helmet without knowing the players. The advantages of this design are comfortable material, movement detector, and strong hits absorber. The disadvantages of this design are heavy materials, expensive materials, and long materials that might not be able to fits the helmet. Thus, the boxing helmet has two positive relationship with the customer needs which are safety and appearance. In other hand, the design ends with four negative relationship with the customer needs which are lightweight, controllability, sensing, and data collection. The design can be found in figure 17.

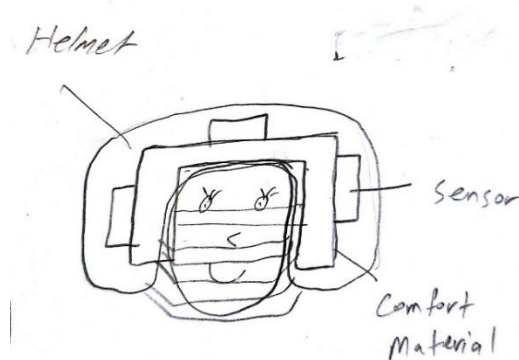


Figure 17: Boxing Design

4.6 Design #6: Transforming

This idea designed based on Transformers movie. In the film, the cars transform into robots or machines. Hence, this smart helmet is a transforming helmet which decrease the hit of the players. In football helmet, many players get a vibration effects because of the strong hits. In this design (which can be seen in figure 18 below) the hit will almost be neglected because of the transforming feature. In more details, when a player hit this helmet strongly, then the transformation feature in the helmet will occur fast if the hit was strong enough. On the other hand, the hit of the players will occur really slow if the hit is not

strong enough. The objective of this smart helmet is to decrease the hits of the players and transforming the hits of the players. The process of transforming the hit is to absorb the shock force from the players and transform it from one state to another state. For example, if the car hits another car, then the damage of the car should be fixed. However, in this design the damage of the helmet will be fixed by transforming the helmet into new state. In this new state, the damage of the helmet will be almost neglected. Therefore, the transformation feature will improve the performance of the helmet because of observing more and more hits.

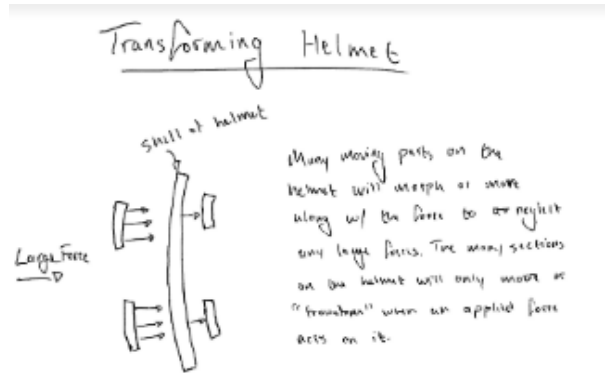


Figure 18: Transforming Design

4.7 Design #7: Columns of fluids

This design consists of sensors and MR fluids. The sensors have many objectives such as detect the incoming impact speed, and another sensor is to detect the helmet speed. With the linear acceleration data from the accelerometer, the team will be able to record the data of the upcoming hit. Furthermore, the ultrasonic sensor will detect the distance between the smart helmet and the other players. However, with this design the padding attached in the helmet will provide fluid to the players. The MR fluids column will help in increasing the safety of this project because the coach and the player will identify any major injuries in the football game.

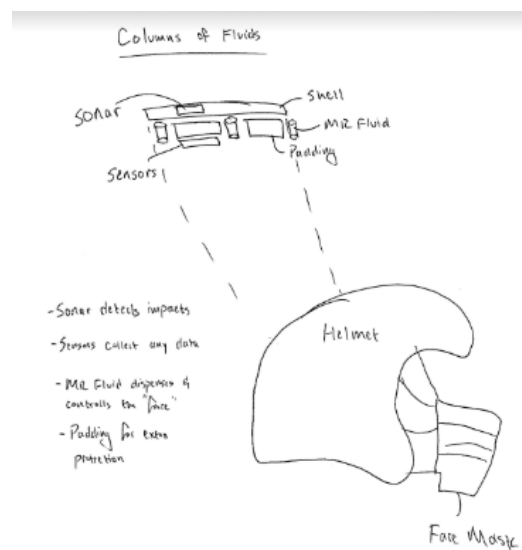


Figure 19: Column of fluids design

4.8 Design #8: D3O Helmet

Some companies are using D3O material with motorcycle gear such as the jacket. Hence, this D3O helmet designed based on that idea. The main idea of this design is to absorb the shock force with using comfortable materials such as D3O material. The main objective of this design is to convert the hit of other players into comfort situation by absorbing the shock of the hit. In more details, the D3O will expand with no hit situation. However, the D3O material will compress into rigid body with strong hit. This strong rigid body will save the head from getting a serious injury in football field. The upper side of the material is rigid, but the internal part of the D3O material is soft for the players head.

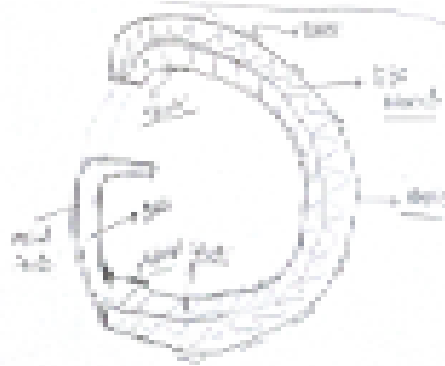


Figure 20: D3O Helmet

4.9 Design #9: Vibration Helmet

The team generated this idea from the vibration movement. In the football field, many vibrations occur due to the strong hits between the players. However, the main idea of this design is to convert and absorb the strong hit into a comfort situation. This design is basically consisting of light, sensor, D3O material, sponges, and metal fence. The light is attached to the upper part of the helmet. The main objective of this component is to decrease the process of saving players on the football field. The light will notify the coach and the other players of the serious injury. Hence, the player will be secured quickly. Another objective of this design is to have more than one comfort material to increase the comfort of the player. The only disadvantage of this design is the weight, which is far more than expected because of adding more than one material into it. The two materials are sponge and D3O materials.

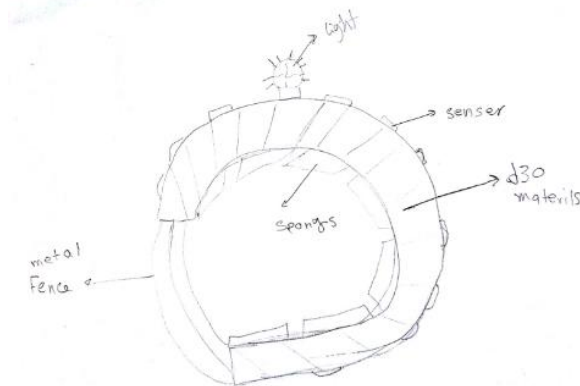


Figure 21: Vibration helmet

4.10 Design #10: Padding of Helmet

This design looks more into the inside of the helmet and explores one variation of how the padding can be displayed to provide protection and comfort at the same time. As seen below in figure 22, the padding design will decrease the amount of force as the force reaches closer to the head. The padding will implement the MR fluid in the middle to absorb most of the force impact, the viscoelastic material will be part of the padding to assist with the MR fluid. The viscoelastic material is added because the fluid is too dense, thus making the fluid heavy, so the viscoelastic will act along the fluid to absorb any forces. The foam is essentially part of the padding, the viscoelastic will be integrated with the foam.

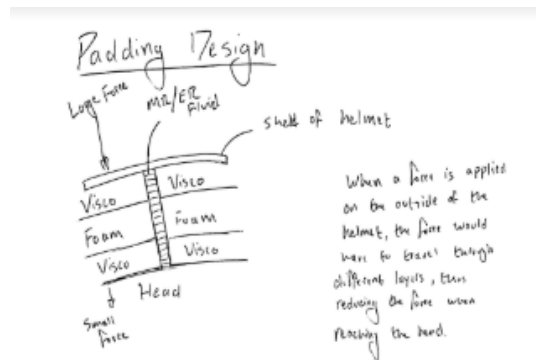


Figure 22: Padding of Helmet Design

5 DESIGN SELECTED

Section 5 contains the rationale for design selection below that will describe the reasons for choosing one of the possible solutions to the project. The rationale for design entails the selection of possible solutions from the generated Pugh Chart and Decision Matrix. Details of the advantages and disadvantages will be given to justify the one possible solution. The design description details the proposed design and justifies the design.

5.1 Rationale for Design Selection

The selected design solution will be the utilization of the MR fluid while incorporating the D30 material from design eight and laser sensors, which is part of design seven. The process of choosing the final solution derived from the Pugh Chart, which can be seen in Appendix C, and the design was set as the datum. While the other concepts from Chapter 4 were compared to the MR fluid, the top four designs were then selected and compared in a Decision Matrix as seen in Appendix D. The MR fluid design scored the highest (design one) out of all because the designs and will enable the team to do two main functions. The first main function allows the team to meet the client's needs as their main objective is to have data collection of impact forces of the user. The second function is making the smart helmet "smart" by implementing a system that will enable the helmet to detect oncoming impacts and make any preparations for the impact, i.e., the MR fluid being activated with a magnetic field and allowing the helmet to change the stiffness of the padding.

5.2 Design Description

The design selected involves a viscoelastic material implemented into the foam. Laser sensors are mounted on the front and back of the helmet to detect incoming players. An accelerometer is used to measure the forces exerted on the head. The laser sensor will start by collecting data of incoming players, and when the impact occurs the accelerometer will collect more information. The data collected will be used to calculate if the player has experienced a hit that was severe enough to pass a threshold of doing damage to the head. Currently the data will be recorded onto a SD card to later be evaluated but after testing is performed, and accurate values are able to be recorded, the team will work on transmitting the data live to a smart device.

The exploded view of the smart helmet design is shown in figure 23. There will be more sections of padding throughout the entire helmet, the single section of padding is shown to portray an exploded view of what is going to be inside the helmet.

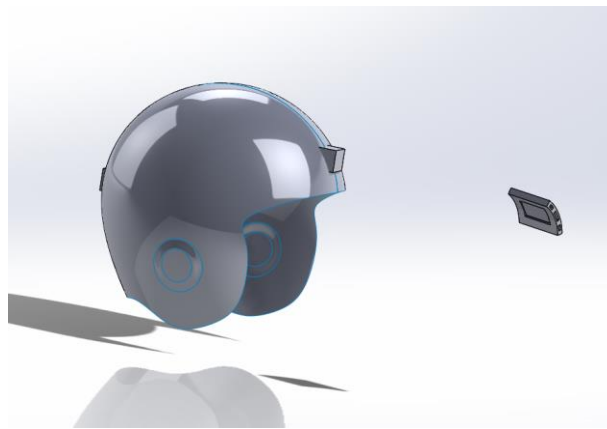


Figure 23: Exploded View of Shell and Section of Padding

6 Proposed Design

The team will implement the design by making a physical change in a current system as well as writing code to helmet to make the helmet “smart”. In Appendix E, the figure shows how the team will manipulate the shell of current football helmets to mount the laser sensors. More research is necessary to find more specs on laser sensors that will fit this application and once the sensor is chosen the dimensions for the sensor will be adjusted in the design. Appendix F shows a drawing of the padding design for the smart helmet. Slots through the foam are going to be cut out to apply the viscoelastic material to improve the absorption of impacts. Another section will be cut out to fit the accelerometer, and it is placed on the inner side of the padding closest to the head to record accurate data.

Bill of Materials

The team has conducted the economic analysis that can find in table 4. The total cost of smart helmet is known. The parts that the team needs to build the smart helmet are listed in table 4. The bill of materials displays the part numbers, component description, how many pieces needed to have for each component, what is the cost with the reference that the team used to know how much each part cost. The material that would go into the smart helmet are battery, MR fluid, Viscoelastic, laser sensor, Arduino, data memory, and RTCSD-01. By having the Economic analysis, the team found the total cost of smart helmet design that would be \$1068.33.

Table 4: Bill of Materials of our design (Smart Helmet)

Part #	Component Description	Quantity	Cost (\$)	Ref.
1	Football Helmet	1	107.95	[6]
2	Battery	1	3.91	[7]
3	Viscoelastic	1	30	[8]
4	Laser Sensor	2	28.54	[9]
5	Arduino	1	60	[10]
6	Data Memory	1	19.99	[11]
7	RTCSD-01	1	17.95	[12]
8	MR Fluid	1	799.99	[13]
	Total		1068.33	

Schedule

The Gantt chart helps to divide the work among the team equally. It helps the team to know when the deadline of assignments is, so the team can finish each assignment before the due date. As seen Appendix G, the chart comes with task name, start date, the due of the assignments, assigned to, what percentage done, time spent for each part of the assignments. All that comes from the Gantt chart which can find in Appendix G and H. Also, the schedule for upcoming semester spring 2019, ME 486C course plan can find in Gantt chart in purple bars.

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8 APPENDICES

8.1 Appendix A: House of Quality

Table A: House of Quality

		Project: Smart Helmet													
		Date: 09/23/2018													
		Input areas are in yellow													
		Legend													
		A Vicis													
		B Ridell													
		C xonano													
Decrease Impulse															
Maintain volume															
Increase factor of safety															
Ductility			(+)	(++)											
Increase power				(++)											
Decrease diameter			(++)												
Increase voltage				(+)		(++)									
		Technical Requirements							Customer Opinion Survey						
Customer Needs		Customer Weights	Decrease Impulse	Maintain volume	Increase factor of safety	Ductility	Increase power	Decrease diameter	Increase voltage	1 Poor	2	3 Acceptable		4	5 Excellent
High protection	5	9	9	9	3	9						C	A	A	
Similar size of helmet	4	3	9		3		9						B	AB	
Life expectancy	4	9		9		9		3					C	A	
More comfortable	3.5	9	3		9		3					A	A		
Transmit data	4.5	9	3			9									
Small sensor	3	9	3				9					BC	A	C	
Strong battery	2						9	9				B		A	
Technical Requirement Units		N.S	m^3	N/A	N/A	W	m	v							
Technical Requirement Targets		192	114	81	59	140	74	30							
Relative Weight %		27.9	17	12	8.5	20	11	4.4							
Rank order		1	3	4	6	2	5	7							

8.2 Appendix B: Functional Model

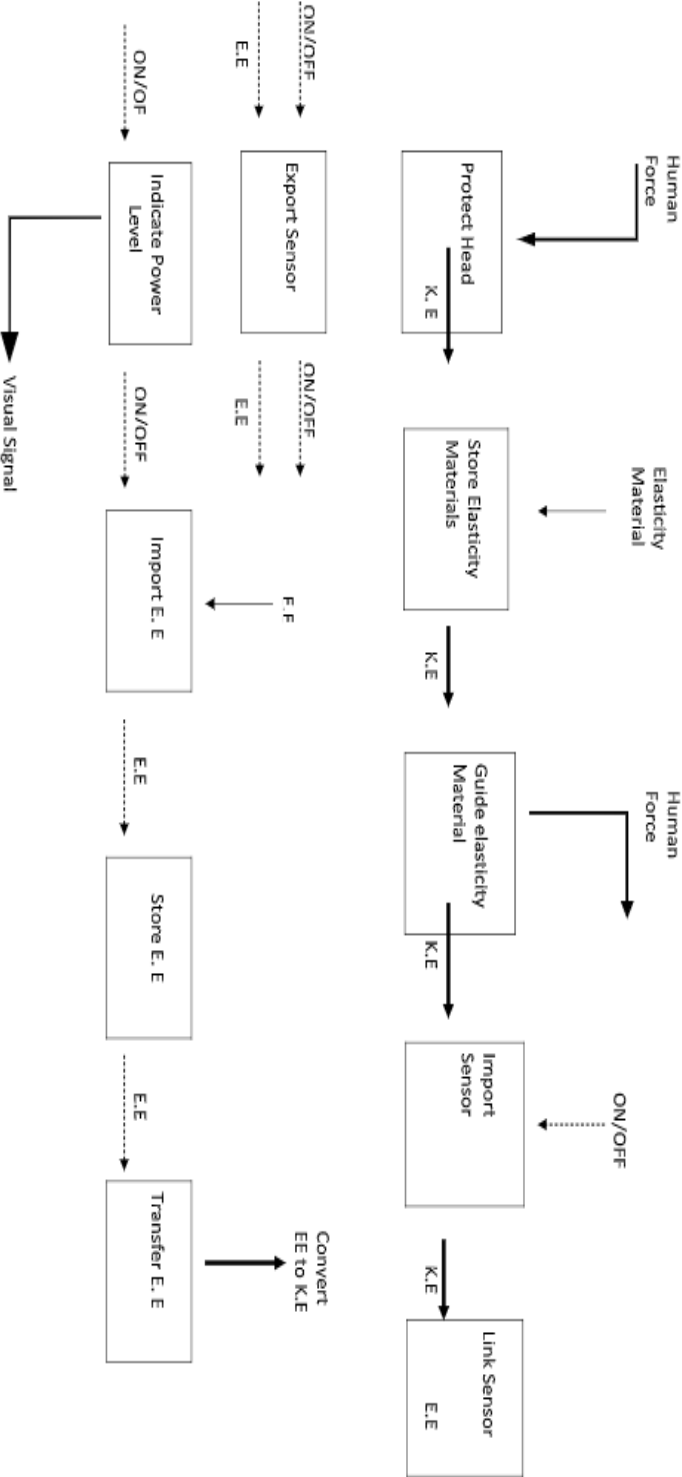







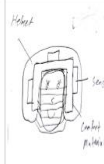
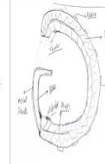



Figure B: Functional Model

8.3 Appendix C: Pugh Chart

Table C: Pugh Chart

										
Criteria	MR Fluid	Airbag	Transforming	Padding	MR Fluid #2	Transferring	Scuba Diving	Boxing helmet	D3O Helmet	Vibration
Light Weight	D	+	+	+	-	+	+	-	-	S
Affordable		+	S	S	-	+	-	S	+	-
Appearance	A	-	+	+	S	+	+	+	+	+
Safety		+	S	+	+	-	+	+	+	+
Controllability	T	+	-	S	+	-	-	-	-	-
Sensing		S	-	-	S	S	-	-	-	-
Data Collection	U	S	-	-	+	S	S	-	S	-
Sum (+)		4	2	3	3	3	3	2	3	2
Sum (-)	M	1	3	2	2	2	3	4	3	4
Sum (s)		2	2	2	3	2	1	1	1	1



8.4 Appendix D: Decision Matrix

Table D: Decision Matrix

Criteria	Weight %	Design Options							
		Magnetorheological		Electrorheological		Viscoelastic		Airbag	
		Score (1-100)	Weighted Score	Score (1-100)	Weighted Score	Score (1-100)	Weighted Score	Score (1-100)	Weighted Score
Light Weight	20	20	400	30	600	40	800	50	1000
Affordable	6	40	240	50	300	60	360	50	300
Appearance	5	80	400	80	400	90	450	75	375
Safety	30	90	2700	70	2100	60	1800	60	1800
Controllability	12	90	1080	70	840	10	120	60	720
Sensing	15	80	1200	75	1125	85	1275	80	1200
Data Collection	12	70	840	65	780	80	960	80	960
	100	Total	6860	Total	6145	Total	5765	Total	6355

8.5 Appendix E: Helmet CAD View

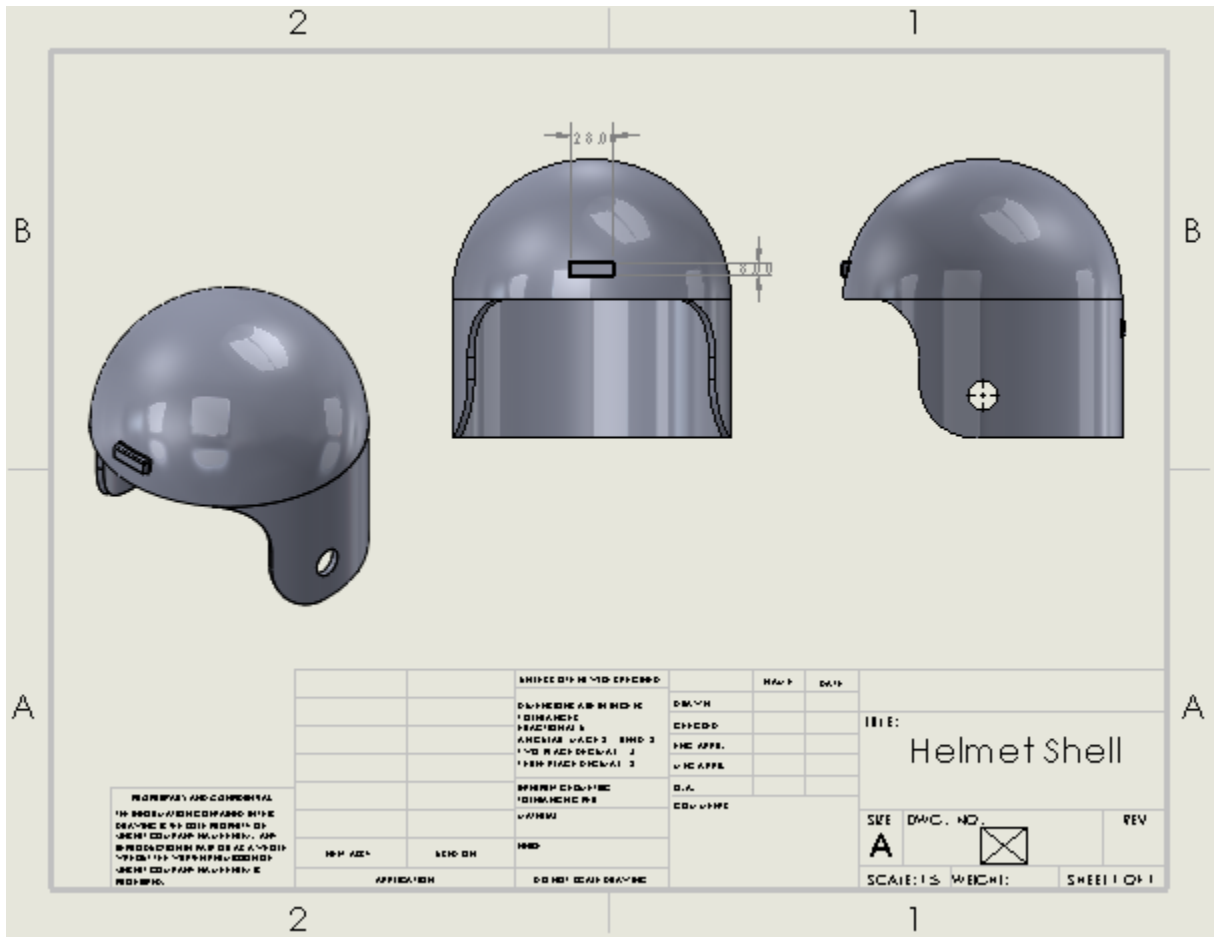


Figure E: Draft of Exploded View of Helmet

8.6 Appendix F: Inside of Helmet Padding CAD View

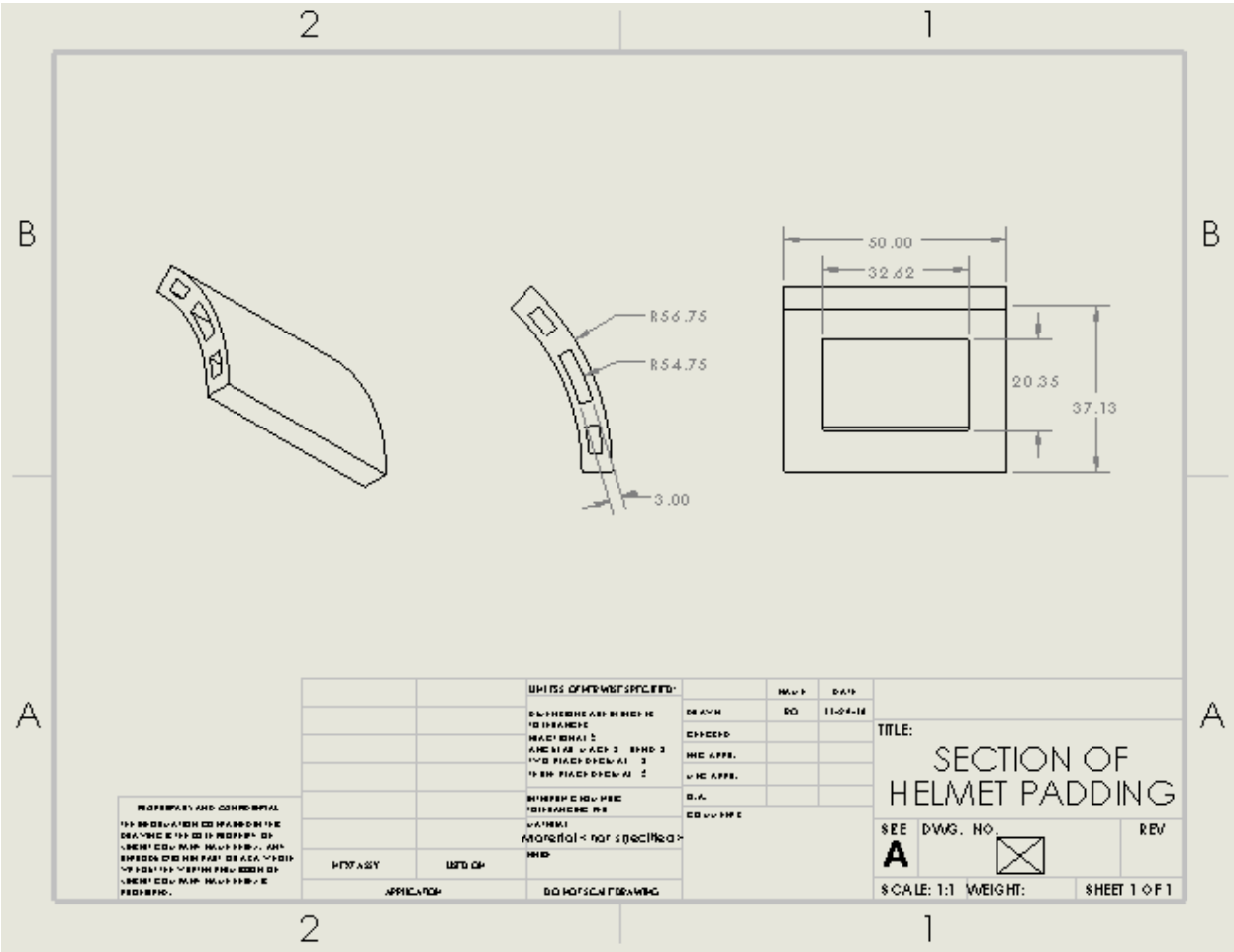


Figure F: Draft of Exploded View of Helmet Padding

8.7 Appendix G: Schedule of ME 476C

Table G: Fall Gantt Chart

	Task Name	Start	Finish	Assigned To	Duration	Sep				Oct				
						Sep 9	Sep 16	Sep 23	Sep 30	Oct 7	Oct 14			
1	- Meeting 1	09/11/18	09/12/18		1.146d									
2	Client Meeting	09/11/18	09/11/18	M and R	40m	M and R								
3	Team Chart	09/12/18	09/12/18		1h 10m									
4	- Meeting 2	09/17/18	09/19/18		2.281d									
5	Shearing ideas	09/17/18	09/17/18		1h 15m									
6	Staff meeting	09/17/18	09/17/18		1h									
7	- Meeting 3	09/19/18	09/19/18		0.281d									
8	pre-presentaion	09/19/18	09/19/18	All	2h 15m	All								
9	- Meeting 4	09/23/18	09/24/18		2d									
10	review presentation	09/23/18	09/23/18		1h									
11	- Presentation	09/24/18	09/24/18		1d									
12	Project Description	09/24/18	09/24/18	Mana	1d			Mana						
13	Background and Benchmarking	09/24/18	09/24/18	Race	1d			Race						
14	Design Requirement	09/24/18	09/24/18	Titus	1d			Titus						
15	Customer needs	09/24/18	09/24/18	Omar	1d			Omar						
16	Engineering Requirements	09/24/18	09/24/18	Omar	1d			Omar						
17	Schedule and Budget	09/24/18	09/24/18	Fares	1d			Fares						
18	Conclusion	09/24/18	09/24/18	Titus	1d			Titus						
19	References	09/24/18	09/24/18	Titus	1d			Titus						
20	- Meeting 5	10/03/18	10/03/18		0.375d									
21	Website check	10/03/18	10/03/18		3h									
22	- Meeting TA	10/08/18	10/08/18		0.125d									
23	Report	10/08/18	10/08/18		1h									
	Task Name	Start	Finish	Assigned To	Duration	Oct			Nov					
						Oct 7	Oct 14	Oct 21	Oct 28	Nov 4	Nov 11	Nov 18	Nov 25	Dec 2
24	- Staff Meeting 2	10/08/18	10/08/18		0.125d									
25	Giving the team parts to work on.	10/08/18	10/08/18		1h									
26	- Staff Meeting 3	10/15/18	10/15/18		0.125d									
27	Shearing the information of that parts with PhD	10/15/18	10/15/18		1h									
28	- Meeting 6	10/21/18	10/21/18		0.125d									
29	pre-presentaion	10/21/18	10/21/18	all	1h			all						
30	- Presentation 2	10/22/18	10/22/18		1d									
31	Project Description	10/22/18	10/22/18		1d									
32	Designs Considered (Product)	10/22/18	10/22/18		1d									
33	Design Selected	10/22/18	10/22/18		1d									
34	Schedule & Budget	10/22/18	10/22/18		1d									
35	- Staff team meeting 4	10/29/18	10/29/18		1d									
36	Meeting with professor/ Website check 2	10/29/18	10/29/18	All	1d			All						
37	- Meeting 7	10/31/18	10/31/18		0.125d									
38	Website check 2	10/31/18	10/31/18	All	1h			All						
39	- Staff team meeting 5	11/05/18	11/09/18		5d									
40	Analytical Reports due	11/05/18	11/09/18	All	5d					All				
41	- Meeting 8	11/14/18	11/14/18		0.125d									
42	Discussing next assignments	11/14/18	11/14/18	All	1h						All			
43	- Staff team meeting 5	11/19/18	11/19/18		0.042d									
44	Discussing the update of the team' parts	11/19/18	11/19/18	All	20m							All		
45	- Meeting 9	11/20/18	11/20/18		0.125d									
46	review presentation	11/20/18	11/20/18	All	1h								All	

	Task Name	Start	Finish	Assigned To	Duration	Nov			
						Nov 11	Nov 18	Nov 25	Dec 2
47	- Presentation 3 final	11/26/18	11/26/18		1d				
48	Project Description	11/26/18	11/26/18		1d				
49	Designs Considered (Product)	11/26/18	11/26/18		1d				
50	Design Selected	11/26/18	11/26/18		1d				
51	Schedule & Budget	11/26/18	11/26/18		1d				
52	- Meeting 10	11/28/18	11/28/18		0.125d				
53	Discussing the final report and dividing the work	11/28/18	11/28/18	All	1h				
54	- Staff team meeting 6	12/03/18	12/07/18		5d				
55	Discussing Full prototype	12/03/18	12/03/18		1d				
56	BOM, & CAD package, Full prototype	12/03/18	12/07/18		5d				
57	Website check 3	12/03/18	12/07/18		5d				

8.8 Appendix H: Schedule of ME 486C

Table H: Spring's Pending Schedule

	Task Name	Start	Finish	Assigned To	Duration	Jan							Feb			Me			
						Jan 13	Jan 20	Jan 27	Feb 3	Feb 10	Feb 17	Feb 24	Mar 3	Mar 10					
58	Plan Spring 19	01/13/19	03/01/19		36d														
59	Website check 1	01/20/19	01/20/19		1d														
60	Hardware review 1	01/13/19	01/15/19		3d														
61	Indv. Analysis	02/26/19	03/01/19		4d														
62	Midpoint Presentation	03/11/19	03/14/19		4d														
63	Hardware review 2	03/12/19	03/14/19		3d														
64	Midpoint report	03/11/19	03/15/19		5d														
65	Website check 2	03/25/19	03/29/19		5d														
66	Final product testing proof	04/08/19	04/12/19		5d														
67	UGRADS practice	04/16/19	04/16/19		1d														
68	Operation Manual and Assembly	04/17/19	04/19/19		3d														
69	UGRADS	04/23/19	04/23/19		1d														
70	CAD Package	04/30/19	05/01/19		2d														
71	Final Report	05/01/19	05/03/19		3d														
72	Website Final Check	05/10/19	05/10/19		1d														