Project Statement & Specifications

Military Helmet

TEAM #6

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Statement of Need

The Advanced Combat Helmet currently used by the United States Army was designed mainly for ballistic performance, to protect the head from projectiles. However, many of the injuries experienced by soldiers in the current wars in Iraq and Afghanistan are due to traumatic brain injuries, not blunt trauma. Warfare practices have evolved from the projectile fire commonly used in previous wars to currently used improvised explosive devices. The helmets presently used do not adequately protect soldiers against closed brain injuries sustained from improvised explosive device detonations.

Traumatic brain injury is also common among motorcyclists. Many motorcycle helmets in use are an excellent protection from these types of injuries. The proposed project aims to incorporate the design of the much safer motorcycle helmets into the Advanced Combat Helmet. The goal is to improve upon the current design to produce a helmet that will reduce the risk of traumatic brain injury caused by improvised explosive device explosions (IEDs).

Introduction and Overview

This project was brought to the Biomedical Engineering program by the School of Nursing. During a lecture on traumatic brain injuries, a nursing student who was a former soldier in the US Army inquired upon the helmets he used in Iraq. An avid motocross rider, the nursing student was curious as to why the helmets used in motocross provided better protection from traumatic brain injury (TBI) than those used in combat in Iraq. It is estimated that almost 90% of military personnel treated for injuries in Iraq were injured by IED explosions. Almost half of those injuries were incurred on the head.
In a recent article issued in *The New England Journal of Medicine*, 2525 U.S. Army infantry soldiers were surveyed after a year-long deployment in Iraq on mild traumatic brain injury (Hoge et al.). Mild traumatic brain injury was defined as an injury with loss of consciousness or altered mental status. The results of the study indicated that of the 2525 soldiers, 4.9% reported injuries with loss of consciousness, 10.3% reported injuries with altered mental status, and 17.2% reported other injuries during deployment. Of the soldiers reporting loss of consciousness, 43.9% experienced post-traumatic stress disorder (PTSD). Other reported injuries and soldiers with no injuries reported lower percentages of PTSD. After further investigation, it is believed that TBI is associated with PTSD and many other mental or health related issues for returning soldiers.

Indicated in Table 1 of the study, the greatest cause for traumatic brain injuries were due to blasts or explosions, such as from IEDs, vehicle accidents, and falls. Less TBIs were caused by bullets, fragments, or shrapnel. The effect of IED blasts is of growing concern for the military. IEDs alter atmospheric pressure rapidly, producing waves of shear and stress forces on the body. Organs of different densities accelerate at different rates with these energy waves and ultimately result in displacement, stretching, and shearing forces. The brain is very susceptible to these atmospheric changes, which is why TBI commonly results from an IED blast.

The current military design for helmets are most effective at protecting a soldier’s head from bullets, fragments, or shrapnel penetration; however, as indicated in the data, the risk of TBI is still present. To account for TBIs, the new helmet design will incorporate the protective features of the current Advanced Combat Helmet, but also will include ideas from the common protective motorcyclist helmet which is more successful at preventing head injuries from impact
forces. The new helmet will provide better protection against TBIs from explosions, vehicle accidents, and falls.

**Realistic Constraints:**

The helmet must be reproducible on a large-scale basis. In addition, the revised helmet should be relatively cost-efficient compared to the original design. Based on these constraints, the choice of material must fall into the realm of both affordability and ease of acquiring it. In addition, the material must withstand any temperature or altitude among other environmental factors, whether that is the hot dry climate of the Middle East or the moist weather of a rainforest in Africa or the South Pacific. Resistance to water is therefore a large priority. This includes resistance to the growth of any fungus or bacteria that may be harmful to the user. The design must be flame resistant and must not be damaged when subjected to vibration. The material must also function for a comparable time frame compared to the original design. Any color additives available for the material must also be considered for optimal camouflage.

It is also economically valuable for the helmet to be backwards-compatible with all attachments of the previous helmet design, including any radio and goggle packages currently available by the current Advanced Combat Helmet manufacturer, Gentex. Similarly, any new additions to the helmet redesign must not obstruct the user’s field of view or range of movement any more than the original because any decrease in these characteristics may put unnecessary fatigue on the individual and may result in serious injury or death if in conflict. The helmet’s weight must also factor into this. The current helmet weights vary depending on size and are recorded in Table A of the Technical Specifications section that follows. The published weights include any possible attachments and thus those should also be put into consideration.
Other Data:

The School of Nursing will be assisting in the design of this helmet. The nursing student will provide access to Army supplies and helpful information. Current and former soldiers will also offer input to many issues they faced while wearing the helmets. They will also make suggestions to improve upon the design based on their experiences in the field.

A considerable amount of scrutiny must be placed into the question of comfort versus function. Both areas are large priorities but are in many cases diametrically opposed to one-another. It should also be noted that a lapse in either of these fields will have large negative consequences on the user, with the worst case scenario being the death of him/her in combat due to the failure of the helmet. It should also be noted that the definition of a helmet is the protection of the head, so even if a balance must be struck, it must protect the head and brain of any potential threats, including common battlefield dangers such as gunfire and shrapnel. Unfortunately, due to the nature of certain dangers, the chance of properly stopping them is slim. These threats include large-caliber ammunition or explosions that will injure the user simply due to the kinetics and the forces at work. Thus, although these dangers should be considered, a more productive focus would be to prevent threats that are in the realm of stoppable, such as lower-caliber weapons fire or physical contact.

The full testing apparatus of Gentex, the designers of the original helmet, is unavailable for the testing of the redesign. The client is providing a sample of the original helmet for any needed testing, but not all sizes or attachments are available. In addition, the model given will probably not be a perfect specimen and may be worn with age, thus changing any data acquired through testing. However, with the focus on the project on preventing brain injuries, the additional data provided by the nursing student and Army soldiers may provide a key element
not available by Gentex, which in turn may provide some insight into some redesign specifications that could lead to noticeable increases in safety with respect to the goal.

One final note of consideration should be the differences in helmets designed for different tasks. For example, the design of a helmet created for a driver of a motorcycle may show insight into how to prevent brain damage due to any concussive forces because of the high velocities a helmet must protect against in the case of an accident.

**Questions:**

Although there are multiple sizes of the original helmet design, the question arises if multiple prototypes of the redesign should be made to accommodate. Also, since not all of the optional equipment can be acquired for testing, any possible extenuating circumstances involving their weights or moments they enact on the heads may not be fully comprehended. Thus, it may follow that the redesigned helmet may not be compatible with every attachment even though it would be economically sound to do so.

Although the purpose of the redesigned helmet is to decrease the amount of head and brain injuries compared to the original model, no amount of change is specified. Therefore, the large question arises of how much of an increase in safety is enough? Although the reactionary answer to this may be the maximum possible gain, too many factors are at play to accurately answer this. For example, the balance between comfort versus function creates a situation where any focus on one will actually cause a decrease in safety due to the neglect of the other. In addition, factors such as weight, color, reliability, size, and cost all require attention.
Other Activities

As this project will be designed and experimented on in the Senior Design lab, some contrasts must be made to how implementation would occur in industry. There is a long list of US Army standards that must be followed by manufacturers interested in contracting with the Army. There are many inspections and compliance issues that must be verified prior to production, which the project will not have to undergo as long as it remains a senior design project.

The testing conditions may also vary from what is available in industry. It may be difficult to reproduce the standard ambient atmosphere required for all testing of a US Army helmet. Testing ballistic and projectile effects on the helmet may also not be what is experienced in industrial settings, due to laboratory and safety restraints and restrictions.

Technical Specifications:

Environmental:

Temperature: -60°F - 160°F
Altitude: sea level to 15,000 ft and 40,000 ft equivalent pressure

Physical:

Shell thickness: 0.400 in maximum
Shell color: Foliage Green 504
Weight: see Table A below
<table>
<thead>
<tr>
<th>Size</th>
<th>Maximum Weight (ounces)</th>
</tr>
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<tbody>
<tr>
<td>Small (S)</td>
<td>47</td>
</tr>
<tr>
<td>Medium (M)</td>
<td>49</td>
</tr>
<tr>
<td>Large (L)</td>
<td>53</td>
</tr>
<tr>
<td>Extra-Large (XL)</td>
<td>62</td>
</tr>
</tbody>
</table>

Table A. Weights of Advanced Combat Helmets with Respect to Size. (Sutter, 11)

**Mechanical:**

- Tensional strength: 150 lbs minimum
- Dynamic strength: withstand 25 ft/sec drop

**Ballistic:**

- Transient Deformation:
  - 9mm projectile at 1400 ft/s to:
    - Right side, left side, and crown 0.63 in maximum
    - Front, back 1.0 in maximum

Ballistic limit: Must be able to withstand projectiles at minimum velocities in accordance with Table B at the following conditions:

a. ambient (70°F)
b. extreme hot (160°F)
c. extreme cold (-60°F)
d. after immersion in seawater, tested at ambient temperature (70°F)
e. after exposure in weatherometer, tested at ambient temperature (70°F)
<table>
<thead>
<tr>
<th>Projectile</th>
<th>$V_{50}^{ballistic}$ Limit at 0° Obliquity (ft/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-grain RCC$^1$</td>
<td>4075</td>
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<tr>
<td>4-grain RCC</td>
<td>3450</td>
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<tr>
<td>16-grain RCC</td>
<td>2425</td>
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<tr>
<td>64-grain RCC</td>
<td>1700</td>
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<tr>
<td>17-grain FSP$^2$</td>
<td>2200</td>
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</table>

Table B. Minimum $V_{50}^{ballistic}$ Limit at 0° Obliquity (Sutter, 11)

Note: 1/RCC = Right Circular Cylinders, 2/FSP= Fragment Simulating Projectile – MIL-P-46593A, Type 2.

Safety:

Chinstrap must be worn properly for best helmet performance.

Maintenance:

Helmet must be washable.

References Cited:
