2017-07

Enhanced Combat Helmet (ECH) Case Study

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NPS-AM-17-211

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26 July 2017

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The research presented in this report was supported by the Acquisition Research Program of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

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Table of Contents

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Executive Summary

This Enhanced Combat Helmet (ECH) case study encourages critical analysis of a U.S. Defense Department project at two key decision points: project start and production. The case centers on the development, testing, and procurement (also referred to as acquisition) of the ECH for U.S. Army Soldiers and U.S. Marines. Two things make this case study particularly interesting. First is that key project stakeholders are passionate about helmets because they save lives in combat and all Soldiers and Marines consider themselves subject matter experts on helmets—resulting in wide applicability. Second is the fact that the key decisions involved with the ECH effort involved ambiguous data within a complex acquisition environment—requiring decision making under uncertainty. The ECH case study reinforces critical thinking in uncertain environments, documents lessons learned for sound project management for future application, and provides wide private sector exposure to the complexities of public sector acquisition and helmet manufacture in particular.

The following are the learning objectives for this case study:

- Develop the ability to critically analyze a project at key decision points—**critical thinking**.
- Identify key stakeholders and outline their contribution to the pending decision—**stakeholder management**.
- Develop alternative recommended strategies or courses of action for the decision maker—**decision making with uncertainly or ambiguous data**.
- Compare alternative strategies and identify decision criteria used for the comparison—**decision making with uncertainly or ambiguous data**.
- Identify second-order considerations or consequences of the recommended strategies—**strategic management/leadership**.

The efforts to modernize helmets face the same defense acquisition challenges that all programs within the Department of Defense (DOD) face: a complex, bureaucratic defense acquisition institution, accelerated pace of technology innovation, technology immaturity, rapidly evolving threats, unstable requirements, and declining defense budgets leading to unstable funding. However,

the protection of Soldiers and Marines in combat remains a top priority for senior leaders in the Services, DOD, and Congress. The DOD has committed considerable resources and funding over the years in research and development, resulting in advanced materials and manufacturing processes. The American Soldier and Marine going into battle today has technologically advanced, rigorously tested combat equipment. This case study centers on combat helmets, which provide Soldiers skull and brain protection against both ballistic threats (i.e., bullets) and blunt impact forces, and prevent mild traumatic brain injury and concussions. The combat helmets that Soldiers and Marines wear into battle show a constant improvement in performance over time. This improvement in performance has been the result of advances in material research and manufacturing techniques. Advances in material research provided the opportunity to increase ballistic protection at a reduced weight. The ballistic aramid technology allowed helmets to provide not only fragmentation protection from explosions but also small caliber hand gun protection at a reasonable weight. In the late 1990s and early 2000s, the U.S. Army Research Lab, the U.S. Army Research Development and Engineering Command, and commercial industry teamed to mature the next generation of ballistics materials, resulting in the development of high molecular weight polyethylene (HMWPE) ballistics fibers that could be weaved into fabrics with application to combat helmets—resulting in reduced weight and greater ballistic capability. The application of HMWPE to helmets allowed the Army to consider the following basic options for the new helmet requirements: (1) maintain the protection levels of the current helmets with a reduced weight of up to 20% or (2) increase the protection levels but maintain (or increase) the weight of the helmet.

Part 1 of the case focuses on the decision to initiate the ECH program. Guidance from the warfighting community and senior leaders was clear: the top priorities were maximum protection and weight reduction. Specifically, the ECH had to address the rifle threat, be fielded as quickly as possible, and reduce the weight on Soldiers and Marines in combat. In this part of the case, program management professionals can compare the various courses of actions developed for the initiation of an ECH effort with the actual ECH program. Valuable insights can be gleaned as lessons learned. It may be possible to avoid strategy pitfalls, and project management teams may be better able to manage cost, schedule and performance trade-offs—and ultimately deliver capability more successfully. Questions to consider include the following:

- Who are the key stakeholders in the ECH program initiation decision and how should their expectations be managed?
- Would the ECH program be considered a "technology push" or "capability pull" program, and what are the implications?
- How should the ECH requirements be set? Should increased protection or weight reduction be emphasized? What is the right balance between reductions of Soldier load (combat weight) versus greater Soldier protection?
- How does the Army set testing protocols for the ECH prior to development and manufacturing of a helmet based on a new technology?
- What are the advantages and disadvantages of various acquisition approaches for the development, testing, procurement, and fielding of the ECH? What are the criteria used to compare the alternative approaches?

Part 1 of the case offers key fundamental defense acquisition and program management lessons, which include the following:

- All programs are held to the constraints of cost, schedule, and performance. However, programs that involve the application of a new technology inherently include high levels of integration, manufacturability, producibility, and quality risk. These programs should guard against being primarily schedule-driven. Time is required to optimize the requirements and testing protocols and allow the widest possible participation in the program by interested and innovative manufacturers. In this case, an effort that originally planned to field helmets within a year was seeking a production decision almost fours year later. The industrial base suffered as the program settled on a sole-source contracting strategy without the benefits of competition to keep costs and schedules in check. A program that is knowledge-driven from a research and development effort that includes many competitors from the industrial base may have proven more beneficial, and may have had a similar actual schedule timeline.
- Project managers (PMs), decision makers, and senior leaders should be realistic about the risks associated with development efforts that are primarily schedule-driven rather than knowledge-driven.

Part 2 of the ECH case study focuses on the decision to actually procure and field the helmets to Soldiers and Marines despite the objections of the testing and medical communities. The ECH program began in early 2009. The Army and the Marine Corps approved urgent requirements based on combat operations and the need for increased protection against enemy rifle threats. The Army and USMC set broad requirements to include a 35 percent increase in fragmentation protection, increased 9mm pistol protection, and rifle threat protection—all at the same weight of the current helmet. After passing testing and four years after program initiation, in the summer of 2013, the ECH was ready for a full rate production decision. The decision would involve significant procurement money to buy and field the ECH. Despite passing testing against the requirements, senior leaders faced a difficult decision because not all key stakeholders interpreted the test results similarly, raising significant safety concerns. Specifically, the testing and medical communities believed that the ECH was not operationally effective or operationally suitable for fielding and that the risk of injury to Soldiers and Marines was unacceptable—Soldiers and Marines wearing the ECH could suffer life-threatening skull fractures. Questions to consider include the following:

- Who were the key stakeholders and how should their expectations be managed?
- How does the Army balance the importance of development test data versus field data from helmets that were battle damaged? Should developmental test results or field data carry more weight in decision-making? How can the same development test data be interpreted differently by stakeholders?
- Are the concerns of the testing and medical communities warranted?
- How does the Army address these concerns with Congress, the media, and the American public?
- What are the advantages, disadvantages, and second order implications of various courses of actions for the path forward? What are the decision criteria?
- How do you quantify benefits, such as saving a Soldier’s life, and compare these benefits with long-term, potential health problems like concussions or muscular-skeletal neck injuries from the weight of helmets?

Part 2 of the case offers key fundamental defense acquisition and program management lessons, which include the following:

- Test data can be interpreted differently by key stakeholders—leading to ambiguity in the decision making process. The PM is in a position to understand not only the business side of the project (cost and schedule) but also the engineering side of the project (technology, testing, and risks). With this knowledge, the PM needs to try to reduce the uncertainty associated with the test data and present an interpretation in an unbiased, rational manner.
- The extension of test data obtained in controlled test environment to relevance in an operational setting needs to be viewed with caution as to its applicability and viewed from the proper perspective—from the perspective of the ultimate customer, in this case the warfighter.
- The cost constraints of projects should not be minimalized, which is particularly hard to do in schedule-driven projects with urgent requirements.
- The recommendation is easier for the decision maker if all the stakeholders are engaged early and often in the process, if their concerns are addressed, and if they have some ownership and buy-in in the path forward; the PM is key to making this happen successfully through effective leadership and communication.

The intent of the ECH case study is to encourage project management professionals to analyze a DOD program. Readers become familiar with the evolution of combat helmets, the basics of combat helmet technologies, and helmet testing. Readers then can develop alternative strategies in two areas: (1) project initiation decision and (2) procurement and fielding decision. In both areas, the objective is to enhance critical thinking skills by focusing on the development of recommendations that senior leaders and program decision makers can use. Understanding the environment and key stakeholder management are critical considerations. Leaders can analyze alternative strategies or courses of action against decision criteria.

With respect to the project initiation decision, the setting of requirements in the absence of quantitative analysis to underpin realistic values often leads to failed defense acquisition efforts, especially important in the current environment with limited funding, an emphasis on cost consciousness, intense scrutiny on program cost and schedule overruns, and pressures to field new capabilities to the warfighters quickly. Complicating the procurement and fielding decision is considerable ambiguity in the interpretation of test results and the need for balance between acceptable risk, safety, and protection.

Introduction

Coverage of the return of battle-damaged helmets (as shown in Figure 1) to Soldiers is a good news story. It underscores the importance of Soldier protective equipment for combat effectiveness and Soldier force protection. Soldiers are wearing the very best combat helmets that industry can produce. However, the efforts to modernize helmets, and all protective combat gear for that matter, face the same defense acquisition challenges that all programs within the Department of Defense (DOD) face: a complex, bureaucratic Defense Acquisition institution.[1]

The accelerated pace of technology innovation, rapidly evolving threats, and declining defense budgets make program management within the DOD challenging but even more critical than ever. Defense acquisition operates in an uncertain, complex, and ambiguous environment, but maintains a simple focus: develop, procure, and field advanced warfighting capability to Soldiers to enable technological superiority on the modern battlefield.

In Figure 1, the photo on the right is a photo taken by U.S. Army Program Executive Office (PEO) Soldier of a battle-damaged helmet returned to a Soldier in a ceremony at Fort Belvoir in 2016. In news coverage entitled "U.S. Army Soldier Reunited with Equipment that Saved His Life in Afghanistan," the reporter covers the Soldier's description of how his helmet saved his life. The photo on the left is another photo taken by PEO Soldier of a recovered helmet damaged by enemy fire in Afghanistan.

[1] Refer to Appendix 1 for a description of the U.S. Defense Department acquisition institution.

Figure 1. Why Are Stakeholders So Passionate About Helmets?

Current Situation, Summer 2013

Monday Morning Project Management Office Staff Meeting:

Chief Engineer, Project Office for Soldier Protection and Individual Equipment (PM SPIE): "Sir, we have an Enhanced Combat Helmet (ECH) update. We just learned that director, Operational Test & Evaluation (DOT&E) sent Congress the ECH Beyond Low Rate Initial Production (BLRIP) Report, and recommended that the Army not buy or field the ECH. The report says the unit cost is too high and that Soldiers wearing the ECH would have an unacceptably high risk of dying from excessive backface transient deformation from threat bullets."

Project Manager, Soldier Protection and Individual Equipment (PM SPIE)[2]: "Hmm, that puts us right in the middle between the warfighters and the operational testers. Both Army senior leaders and Congress rely on the independent assessment of DOT&E for good reasons. DOT&E has a lot of influence."

Chief Engineer: "Yes sir. Also, DOT&E received concurrence from the Army surgeon general with their assessments and recommendations."

PM SPIE: "So, after a four-year joint development and testing effort with the USMC in which the ECH finally passed its requirements, now we have to get an Army decision on whether to buy and field the ECH against the recommendations of the testing and medical communities, who have legitimate safety concerns?"

Chief Engineer: "Yes sir. However, the warfighters and Army combat developers have been very involved in this effort, and they remain adamant that the ECH should be fielded to deploying Soldiers. The requirement remains over 35,000 helmets. The USMC is strongly in favor of buying and fielding the ECH as well."

PM SPIE: "What's the funding situation?"

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[2] Within the U.S. Defense Acquisition, a program manager (usually a U.S. Army officer in the rank of colonel) reports to a politically-appointed civilian called the Army acquisition executive—the ultimate program decision authority. The director, Operational Test & Evaluation (DOT&E) is an independent, politically appointed, senior executive charged with overseeing operational live fire testing and reporting directly to the secretary of defense and Congress on program testing.

Chief Engineer: "We have over $35 million in operations and maintenance (O&M) Overseas Contingency Operations (OCO) funding reserved for the buy that must be obligated by the end of the fiscal year (FY)."

PM SPIE: "Okay. Well, you know the drill. DOT&E probably already has the ear of the Army acquisition executive (AAE). Because the ECH was a wartime directed requirement with high visibility, the AAE is the Milestone Decision Authority (MDA). Let's get together a solid briefing to review, and let's start scheduling the pre-briefs to the AAE staff. Also, we need to be prepared to provide the congressional committees an update with the Army's decision. There are many stakeholders involved with the ECH, and some will not be happy. So, we need to think about how this will play out with the media and senior leaders from all the stakeholders with a solid strategic communications plan."

Background

The protection of American Soldiers in combat remains a top priority for senior leaders in the U.S. Army, DOD, and Congress. The DOD has committed considerable resources and funding over the years in research and development, resulting in advanced materials and manufacturing processes. These investments have paid off. The American Soldier going into battle today has technologically advanced, rigorously tested combat equipment. Soldiers know that their combat equipment works as intended. In the end, this increases the combat effectiveness of the Soldiers and their units. One can consider the force protection of Soldiers as a layered approach. The outer force protection layer for Soldiers is situational awareness. The middle force protection layer is concealment. The inner force protection layer is personal protective equipment, like helmets, eyewear, and ballistic vests with ceramic plate inserts. This case study centers on combat helmets, which provide Soldiers skull and brain protection against both ballistic threats (i.e., bullets) and blunt impact forces, and prevent mild traumatic brain injury and concussions.

Army Combat Helmet Evolution

Figure 2 graphically displays the evolution of Army combat helmets and shows the tradeoff between increased performance and cost over time. The combat helmets that Soldiers wear into battle show a constant improvement in performance over time. This improvement in performance has been the result of advances in material research and manufacturing techniques. Soldiers wore the M1 helmet, nicknamed the “steel pot,” from the 1940s through the late 1970s. The M1 provided ballistic protection largely because steel is hard. The M1 helmet consisted of a pressed manganese steel shell with a webbing suspension that Soldiers fitted to their heads. However, the M1 helmet was heavy and uncomfortable, and it provided little blunt trauma protection.

Advances in material research provided the opportunity to increase ballistic protection at a reduced weight. The maturation of ballistic fabrics based on para-aramid polymer technology enabled the Army to replace the M1 with the Personnel

Armor System for Ground Troops (PASGT) helmet in the mid-1980s. The PASGT helmets were in the 3- to 4-pound range (lighter than the M1) and provided increased ballistic protection. The shell of the helmet consisted of layers of ballistic aramid fabric, the most famous of which is DuPont’s Kevlar®. Thus, the PASGT was nicknamed simply “Kevlar” or “K-pot.” The ballistic aramid technology allowed helmets to provide not only fragmentation protection from explosions but also small caliber hand gun protection at a reasonable weight. Eventually, the Modular Integrated Communication Helmet (MICH) replaced the PASGT helmet on a limited basis. By the mid-2000s, the Advanced Combat Helmet (ACH) was the Army’s primary helmet. The basis for both the MICH and ACH is para-aramid polymer technology. These helmets provided Soldiers important performance improvements like reduced weight and better blunt impact protection through an interior suspension system using foam pads versus webbing.

In the late 1990s and early 2000s, the U.S. Army Research Lab, the U.S. Army Research Development and Engineering Command, and commercial industry teamed up to mature the next generation of ballistics materials, resulting in the development of high molecular weight polyethylene (HMWPE) ballistics fibers that could be woven into fabrics with application to combat helmets. HMWPE are polymer materials with different performance characteristics than para-aramid polymer materials. Para-aramids are a thermoset polymer, which means that above certain temperatures the polymer breaks down, loses its properties and cannot be remolded back into its original state when cooled. On the other hand, HMWPE are thermoplastics, which means that above a certain temperature the polymer breaks down but it can be remolded into its original state when cooled. The application of HMWPE fiber material in helmets created the misperception that helmets made with HMWPE materials might easily lose their form under ballistic events and potentially jeopardize Soldiers’ safety. Ultimately, the advantages of HMWPE helmets for reduced weight and greater ballistic capability outweighed this concern. The basis of future Army helmets, both the ECH and its eventual replacement, the Soldier Protection System (SPS) Integrated Head Protection System (IHPS), is HMWPE technology.

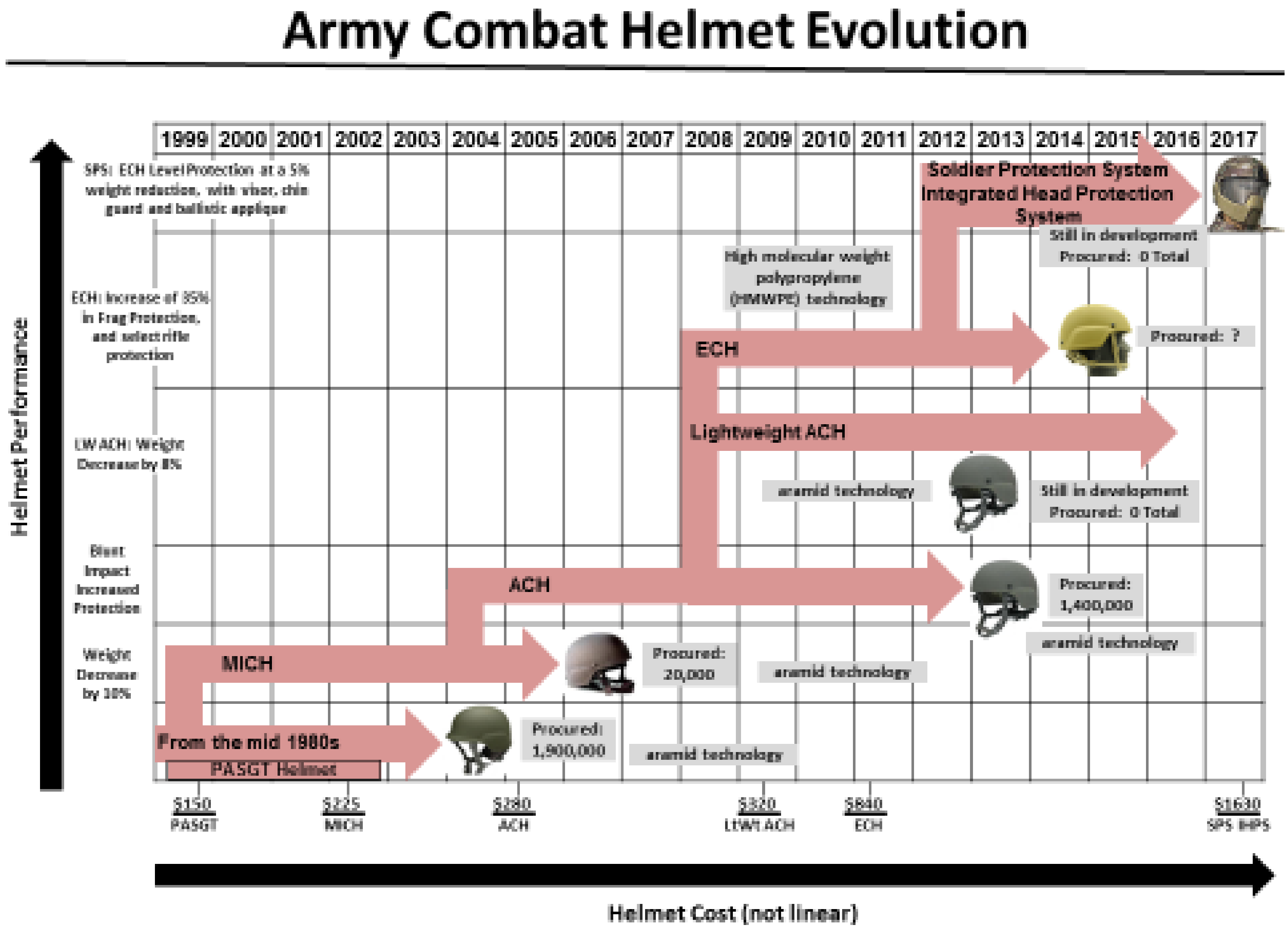

Figure 2. Evolution of Combat Helmets

Helmet Testing Basics[3]

The Army rigorously tests combat helmets worn by Soldiers against protocols to ensure they conform to stringent requirements to protect Soldiers against both blunt trauma and ballistic threats. Three ballistic properties particularly important for describing impacts to helmets are complete penetration (the bullets goes completely through the helmet), partial penetration (the bullet does not go completely through the helmet) and backface transient deformation (BTD, a measure for the amount the round's impact indents the helmet material). The final performance of the helmet in testing and in combat depends both on the inherent properties of the materials used to develop the helmet and the processing techniques used to manufacture the helmet. Helmet requirements are performance-based requirements. Each helmet manufacturer optimizes its design over time using a combination of materials (layers of polymer fibers woven into sheets with chemical binders) and different processes based on temperature, pressure, and time. The use of statistics is important in testing because testing simulates live combat, and the warfighter requires a high confidence that the helmets will perform as advertised. The testing must balance the need for statistical confidence with the costly and destructive nature of the testing.

Operational Field Data

As was presented previously, the Army collects battle-damaged helmets from Soldiers. Before returning them, the Army conducts forensic studies to better understand enemy threats and analyze the performance of the helmets to improve future designs. Figure 3 presents the data collected from combat operations in Iraq and Afghanistan from 77 helmets hit by small arms bullets. When the bullet completely penetrated the helmet, the Soldiers died nearly 75 percent of the time. When the bullets did not completely penetrate the helmet (partial penetration), the average permanent helmet deformation was about 9mm and the Soldiers all survived with relatively minor head/neck injuries and eventually returned to duty.

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[3] Appendix 2 presents a tutorial on helmet testing.

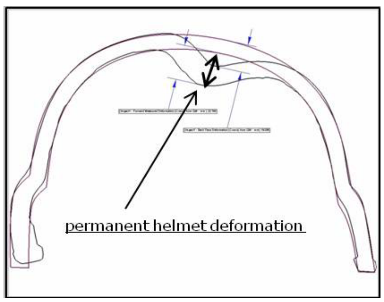
Recovered Protective Equipment Data

- 77 useable Helmet engagements collected
  - Resulting from Small Arms Fire
  - 31 WIA engagements
  - 45 KIA engagements

Ballistic Results	Total #	WIA	KIA	Fatality %
Partial Penetration	16	16	0	0%
Complete Penetration	61	15	45	73.7%

- Analysis:
  - **If a helmet stops the bullets, the Soldier has a very high probability for survival**
  - 0% fatality rate for partial penetrations
  - For partial penetrations, no serious behind helmet blunt trauma reported and no serious neck injuries reported
  - 73.7% fatality rate for complete penetrations

AVG PHD Depth 9.02mm



PHD (mm)	Main Injury	Ballistic Result
4.29		PP
1.52		PP
15.61		PP
15.25		CP
2.07		PP
0.48		PP
10.34		CP
1.42		PP
23.98		CP
5.32		PP
14.99		CP
13.68		CP
7.41		CP
9.66	Injuries range from no injuries to minor injuries with full recovery and return to duty	CP
3.02		PP
15.99		CP
2.41		PP
3.53		PP
9.53		PP
15.78		CP
6.49		PP
11.04		CP
9.22		PP
10.12		PP
6.64		PP
17.22		CP
9.79		CP
13.93		CP
0.88		PP

2 WIA instances had complete penetrations with no head injuries (not included)

Acronyms

- **PHD**: Permanent Helmet Deformation
- **PP**: Partial Penetration
- **CP**: Complete Penetration
- **WIA**: Wounded in Action
- **KIA**: Killed in Action

Figure 3. Recovered Protective Helmet Data

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Part I: Project Initiation Decision, Early 2009 Timeframe

Colonel Bob Smith[4] was recently assigned as the project manager (PM), Soldier Protection and Individual Equipment—the office responsible for developing, testing, procuring, and fielding helmets to Soldiers. Colonel Smith was a seasoned defense acquisition veteran with more than 15 years of project management experience. During his preparation for this position, the guidance from the warfighting community and senior leaders was clear: The top priorities are maximum protection and weight reduction.

Colonel Smith was preparing for a key decision in the Pentagon regarding the start of a new helmet program, named the Enhanced Combat Helmet (ECH). Luckily, Colonel Smith's chief engineer for the program office, Dr. James Suchez, was an armor expert. Dr. Suchez led the efforts to mature HMWPE technologies across the DOD and with the commercial industry for the last decade. Dr. Suchez explained that the application of HMWPE to helmets allowed the Army to consider the following basic options for the new helmet requirements: (1) Maintain the protection levels of the current helmets with a reduced weight of up to 20 percent, or (2) increase the protection levels but maintain (or increase) the weight of the helmet.

Colonel Smith knew that the Army senior leaders would rely on the advice and recommendations of the PM during the meeting. The final decision would be made by the Army Acquisition Executive (AAE). However, the AAE would likely turn to key stakeholders before making the final decision. The first stakeholder was the PM, and Colonel Smith was well prepared to discuss key considerations from a cost, schedule, performance, and technology perspective.

The second stakeholder was the warfighter representative, also called the "user" representative. The warfighter representative was a crusty old officer named Colonel Billy Johnson from Fort Benning, home of the U.S. Army Maneuver Center

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[4] The names in this case are fictitious.

of Excellence. Colonel Johnson spent most of his time in the Army leading Soldiers in combat. Colonel Johnson took his job seriously as the approver of the requirements. He was passionate about the possibility for a new helmet because he believed that the current helmets were too heavy and uncomfortable. He also represented the warfighters currently downrange in combat, and was under extreme pressure to approve requirements for a new helmet to protect Soldiers not only against fragmentation and handgun rounds, but also against enemy rifle threats.

Another key stakeholder was Colonel Harry Crisp, the representative from DOT&E. Any new helmet development program would fall under DOT&E oversight to approve the testing protocols used to ensure the requirements were met. DOT&E would also provide an independent assessment of the helmet's operational effectiveness and suitability for Soldiers to Army senior leaders and document that assessment in reports to Congress. Colonel Harry Crisp had years of experience as a tester and evaluator of Army systems. The importance, influence, and visibility of DOT&E's independent assessment were increased by the recent congressional and public concerns calling into question the adequacy of Soldiers' protective equipment.

Colonel Smith knew that each of the stakeholders was passionate about a new helmet program. He realized that his role as the PM was not to advocate for a new program but to give advice about the underpinning technological possibilities; additionally, he needed to lay out the cost, schedule, and performance implications of various strategies for the development, testing, and procurement of the new helmet.

Two important determinants of program success are requirements definition and alignment of those requirements against capability gaps. Simply put, poorly defined requirements will set a project's initial trajectory that will be difficult to fix later in the development cycle. Project initiation can be the result of a need from the warfighters generically called *capability pull*. Alternatively, the project might be the result of an innovative new technology without a specific identified warfighting application generically called *technology push*. The question of technology push or capability pull at program initiation often delays efforts and creates perception challenges among key stakeholders. The ECH effort was driven by the urgent need for a new helmet to address protection for Soldiers against rifle threats in combat, and was enabled by the maturation of HMWPE technologies. The ECH requirements must balance acceptable minimum risk versus maximum safety for protective equipment, and weight reduction (Soldier load) versus protection (ballistic and blunt force). Colonel Smith knew that this balance would not be an easy compromise for any of the stakeholders.

During the meeting hosted by the AAE, Colonel Johnson was adamant that the ECH had to address the rifle threat, be fielded as quickly as possible, and reduce the weight on Soldiers in combat. Colonel Smith laid out the basic options that he had discussed with Dr. Suchez; the ECH would not be able the address the rifle threat and also reduce the helmet weight. Colonel Johnson was not happy, and doubted the validity of the technology assessment. He stated that, just a week prior, he received an industry brief from a company that claimed they could develop a helmet at reduced weights that also addressed increased threats. Dr. Suchez, also in attendance, spoke up and said that it was not unusual for industry to make claims that they could not back up, and that the application of a new technology into helmets is technically challenging from a manufacturing perspective. “It’s one thing to produce a prototype helmet in a controlled laboratory,” he said, “but completely different to produce many helmets from a manufacturing line that consistently perform against rigorous testing requirements.”

To address the schedule aspect of the program, Colonel Smith next laid out the options of pursuing a program of record (PoR) through the deliberate acquisition process versus pursuing a rapid acquisition process supported by a directed or urgent requirement. Establishing formal ECH PoR would involve a four-year time period. Year 1 would allow refinement, analysis, and approval of formal requirement documents and the development of testing protocols. Year 1 would also allow the Army to request development and procurement funding from Congress in the Army’s base budget for the program. Years 2 and 3 would involve development and testing of ECH prototypes resulting from competitively awarded contracts (probably cost-plus type contracts) to be awarded to industry companies. Year 4 would allow the

Army to award procurement contracts to the successful companies for the manufacture and production of ECHs. Again, Colonel Johnson was not happy that it would take four years to get the ECH to Soldiers.

The alternative to a PoR was to use the rapid acquisition process. In rapid acquisition, the Army could write a directed requirement (probably within a month) for the ECH, and the Army could award competitive contracts (probably fixed-price contracts for certain quantities with production options) to industry within six months. A rapid acquisition effort could be funded with Overseas Contingency Operations (OCO) money, which was limited to procurement money and no development money. Another six months would be required to test the helmets. So, ECHs could be on Soldiers in just over a year. Colonel Johnson was much happier with the second strategy. But, Colonel Crisp was quick to point out that for the rapid acquisition options, the ECH requirements would not be underpinned by analysis, and the test protocols would have to rely on the protocols for current helmets because there would be no time to develop test protocols specifically for the ECH. Colonel Crisp noted this was particularly important for the ECH, which would rely on thermoplastic polymers. The ECH based on HMWPE might perform much differently than the current para-aramid based helmets. For example, ECHs might lose their rigidity after being shot once and offer much less protection from multiple shots. Also, the ECH may deform excessively, leading to head trauma and skull fractures. There were legitimate testing and safety concerns that would have to be addressed.

Colonel Smith tried to remain neutral. Both strategies had advantages and disadvantages. Decision-making involves defining and analyzing alternative approaches. It came down to the level of risk the Army was willing to accept. The ECH project initiation decision also encompassed setting future funding levels and procurement quantities, as well as addressing industrial base concerns, competition, and testing implications. From past experience, Colonel Smith understood that stakeholder management would be key to the success of the ECH program and that proper communication and collaboration would increase the chances of program success.

The AAE was pleased with the frank dialogue between the key stakeholders and stated that enough information was presented for an informed decision on whether or not to initiate the ECH program. Before prioritizing resources for the ECH program, the ECH would need to be considered through the lens of the defense acquisition institutional framework presented in Figure 4. The PM has cost, schedule, and performance responsibilities, and manages the effort with the Defense Acquisition Management System. The PM's official chain of command is in the executive branch, but the PM also reports to Congress with program status updates and works through contracts with industry. The requirements generation system provides requirements and the resource allocation system provides funding. Depending on the program, the public and media perceptions may be important considerations.

In this part of the case, program management professionals can compare the various courses of actions developed for the initiation of an ECH effort with the actual ECH program described below. Valuable insights can be gleaned as lessons learned. It may be possible to avoid strategy pitfalls, and project management teams may be better able to manage cost, schedule, and performance trade-offs—and ultimately deliver capability more successfully. Questions to consider include the following:

- Who are the key stakeholders in the ECH program initiation decision, and how does the PM manage their expectations?
- Would the ECH program be considered a "technology push" or "capability pull" program, and what are the implications?
- How should the ECH requirements be set? Should increased protection or weight reduction be emphasized? What is the right balance between reductions of Soldier load (combat weight) versus greater Soldier protection?
- How does the Army set testing protocols for the ECH prior to development and manufacturing of a helmet based on a new technology?
- What are the advantages and disadvantages of various acquisition approaches for the development, testing, procurement, and fielding of the ECH? What are the criteria used to compare the alternative approaches?

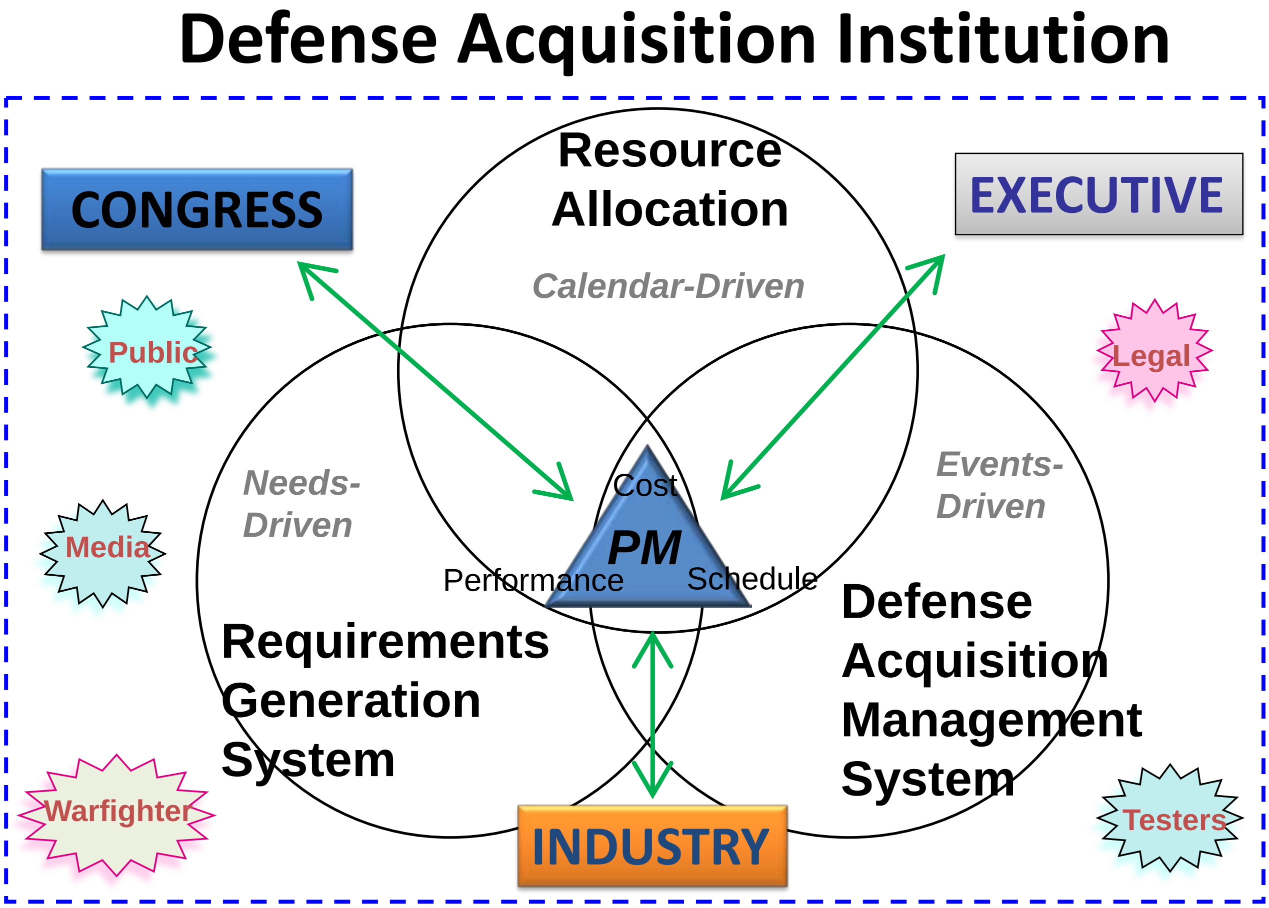

Figure 4. U.S. Defense Acquisition Institution

The ECH Program

The ECH program began in early 2009. Figure 5 depicts the ECH program timeline. The Army and the U.S. Marine Corps (USMC) approved urgent requirements based on combat operations and the need for increased protection against enemy rifle threats. The Overseas Contingency Operations (OCO) account funded the ECH program. The acquisition procurement objectives were set based on the predicted numbers of deploying Soldiers. The Army and USMC set broad requirements, including a 35 percent increase in fragmentation protection, increased 9mm pistol protection, and rifle threat protection—all at the same weight of the ACH. The acquisition strategy was a single step development in which competition was encouraged among industry manufacturers. The original request for proposal asked for each ECH vendor to deliver test data validating their claim that their ECH design met the combat helmet test protocols used at the time for the ACH and the new ECH requirements for rifle protection. Four vendors submitted proposals. However, only one vender's design was acceptable. At the end of 2009, this vendor received a contract to produce ECHs to undergo government developmental testing with contract options for production deliveries after successful first article tests (FATs). In late 2010, after successful developmental testing, the Army and USMC approved the Milestone C to enter into low rate initial production (LRIP) with the selected vendor. The LRIP decision permitted the production of a small number of helmets to undergo testing in order to validate that the contractor could successfully produce the helmets to performance requirements.

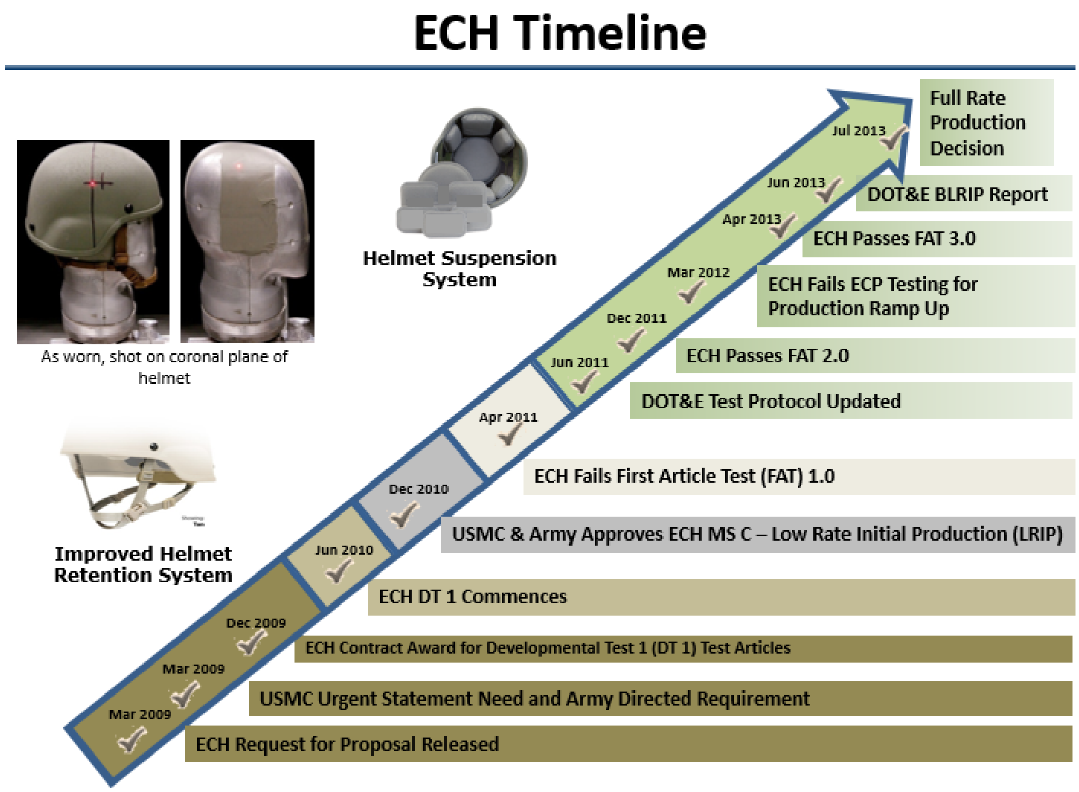

Figure 5. ECH Program Timeline

In late 2011, the ECH passed the second round of FAT. To meet an aggressive production schedule for the Army and USMC, the ECH vendor submitted an engineering change proposal for a second and third production line. It would take all of 2012 for the vendor to successfully pass the third round of FAT for all three production lines after working through issues between test sites (U.S. Army Test Center and National Institute Justice laboratories), as well as issues with the source of rifle rounds (Winchester versus Hornady versus Remington).

The ECH FAT results demonstrated that the ECH met its requirements and offered Soldiers the potential for greater protection compared to the ACH. Against a requirement for a 35 percent increase in fragmentation protection compared to the ACH, the ECH demonstrated an average increase of 53 percent. For the 9mm BTD requirements, the ECH demonstrated an average increase in performance of 10 percent over the ACH performance. Finally, against the chosen test rifle threat, the ECH demonstrated an over 153 percent increase in protection over the ACH for resistance to penetration. Of note is the fact that there was no BTD requirement against rifle threats for the ECH. The legacy ACH 9mm BTD requirements were too restrictive for rifle threats, and there was no basis to assign 9mm BTD requirements to rifle threats without injury data, which does not exist. To avoid jeopardizing the program due to unachievable or unrealistic requirements, rifle BTD testing occurred for government reference purposes only.

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Part II: ECH Procurement and Fielding Decision, Summer of 2013

After passing FAT and four years after program initiation, in the summer of 2013, the ECH was ready for a full rate production (FRP) decision, after which the ECH would be produced as quickly as possible to the approved acquisition objective quantity. Each production lot of helmets would undergo lot acceptance testing (LAT) to verify continued compliance to specification requirements. Finally, after passing LAT, the Army could field helmets to Soldiers deploying into combat. But, should they?

The FRP decision would involve significant procurement money to buy and field the ECH. Despite FAT results in which the ECH demonstrated superior performance against the requirements over current helmets, Army leaders, specifically the AAE, faced a difficult decision. Not all key stakeholders interpreted the test results similarly, raising significant safety concerns for Soldiers. The DOT&E issued a congressionally mandated Beyond LRIP Report recommending that the ECH not be fielded to Soldiers. DOT&E believed that the cost per helmet (roughly two and half times the current helmet) did not justify the minimal performance increase. DOT&E was also concerned that the Army did not test the ECH against the most stressing or most prevalent enemy rifle threats. Additionally, and more importantly, DOT&E stated that Soldiers wearing the ECH in combat would face an unacceptable risk of head injuries due to excessive backface deformation caused by rifle rounds. The medical community, through the Army Surgeon General, supported the DOT&E recommendations. These concerns put the AAE in a difficult position. To further complicate matters, the AAE had spoken to DOT&E, who emphatically stood behind their recommendation.

Again, the AAE convened the same Council of Colonels that met four years earlier to discuss the decision to initiate the ECH program. Colonel Smith admitted the ECH program had not met the original timelines, but emphasized that the ECH had finally successfully passed testing and met its performance requirements. Colonel Smith also stressed that $35 million was at risk if the procurement decision passed the end of the fiscal year, which was nearing. Colonel Crisp noted that he understood the program history well and understood the challenges. However, in DOT&E's opinion, the ECH was not operationally effective or operationally suitable for fielding to Soldiers. The risk of injury to Soldiers was unacceptable; in DOT&E's and the Army Surgeon General's opinion, Soldiers wearing the ECH could suffer life threatening skull fractures from excessive BTD from threat rifle rounds. Additionally, Colonel Crisp noted that the ECH was not tested against the most stressing threats, bringing in question the validity of the requirements. Colonel Johnson was livid that there was even a question about the requirements. The entire community and all stakeholders had agreed to the original requirements more than four years ago. Everyone had accepted the program risks. Now, three years later than planned, when the ECH finally passed testing, concerns were raised. Colonel Johnson stated that the warfighter community strongly recommended getting the ECH to Soldiers as quickly as possible.

Colonel Smith again tried to remain neutral to avoid the appearance that the PM was biased toward buying the ECH. However, he was compelled to provide the complete picture to the AAE for the most informed decision. His program office was also charged with the collection and analysis of battle-damaged helmets from Soldiers who had been shot in the head while wearing their helmets. Analysis of those helmets indicated that no Soldiers had died or suffered major injuries as a result of excessive backface deformation of the helmet. The average deformation observed was 35 percent of the 9mm BTD requirement of 25.4mm (or coincidentally, exactly 1 inch). Colonel Crisp interrupted and stated that DOT&E placed no value on the results because they were not statistically robust and were not done under strict testing conditions where the variables were controlled. Colonel Crisp also pointed out that the government's own reference testing indicated that the BTD observed from the test rifle threat was 18 percent to 89 percent higher than the 9mm BTD requirement. Colonel Smith concurred with those numbers but indicated that he was not finished presenting the rest of the field data results, which indicated that nearly 74 percent of Soldiers died if the threat round completely penetrated the helmet. Again, Colonel Crisp dismissed that data, and again brought up the rifle threat round used in testing. Colonel Johnson asked a question about the operational safety margin built into the testing. Colonel Smith replied in the affirmative that the chosen rifle round was fired at the ECH at muzzle velocity and at 0 percent obliquity, operationally providing Soldiers a safety margin, because in combat, rounds are fired at considerable distance, slowing down in flight and striking at non-direct angles. Therefore, even though the chosen test round was not the most stressing rifle threat round, the ECH still provided considerable protection and 153 percent more protection from penetration than the current helmet against the rifle threat.

The AAE realized that the meeting of the Council of Colonels was probably at a point of agreeing to disagree. The AAE understood each of the positions clearly and thanked everyone for their candid and articulate input. In light of the data presented, should the Army buy and field the ECH? Specifically, the following questions should be addressed:

- Who were the key stakeholders and how would the PM manage their expectations?
- How does the Army balance the importance of development test data versus field data from helmets that were battle damaged? Should developmental test results or field data carry more weight in decision-making? How can the same development test data be interpreted differently by stakeholders?
- Are the concerns of the testing and medical communities warranted?
- How should the Army address these concerns with Congress, the media and the American public?
- What are the advantages, disadvantages, and second order implications of various courses of actions for the path forward? What are the decision criteria?
- How do you quantify benefits (such as saving a Soldier’s life) and compare these benefits with long-term, potential health problems like concussions or muscular-skeletal neck injuries from the weight of helmets?

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Conclusion

The intent of the ECH case study is to encourage project management professionals to analyze a DOD program. After reading and studying the ECH program case study data to become familiar with the evolution of combat helmets, the basics of combat helmet technologies, and helmet testing, participants can develop alternative strategies in two areas: (1) project initiation decision and (2) procurement and fielding decision. In both areas, the objective is to enhance critical thinking skills by focusing on the development of recommendations that senior leaders and program decision makers can use. Understanding the environment and key stakeholder management are critical considerations. Leaders can analyze alternative strategies or courses of action against decision criteria.

With respect to the project initiation decision, significant technology advancement enabled the consideration of a new helmet like the ECH. The maturation of HMWPE technology allowed the Army to consider a helmet that offers either similar protection at less weight or increased protection at the same or greater weight than current helmets. However, the setting of requirements in the absence of quantitative analysis to underpin realistic threshold values often leads to failed Defense Acquisition efforts, especially important in the current environment with limited funding, an emphasis on cost consciousness, intense scrutiny on program cost and schedule overruns, and pressures to field new capabilities to the warfighters quickly. Complicating the procurement and fielding decision is considerable ambiguity in the interpretation of test results and the need for balance between acceptable risk, safety, and protection.

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Appendix 1. U.S. Defense Acquisition Institution—Decision Framework

Within the U.S. Defense Department, the development, testing, procurement, and fielding of capability for the warfighter operates within a decision-making framework that is complex. Within the private sector, similar frameworks exist. The U.S. defense acquisition institution has three fundamental support templates that provide requirements, funding, and management constraints. The executive branch, Congress, and industry work together to deliver capability, with the PM as the central person responsible for cost, schedule, and performance. Figure 6 depicts this framework.

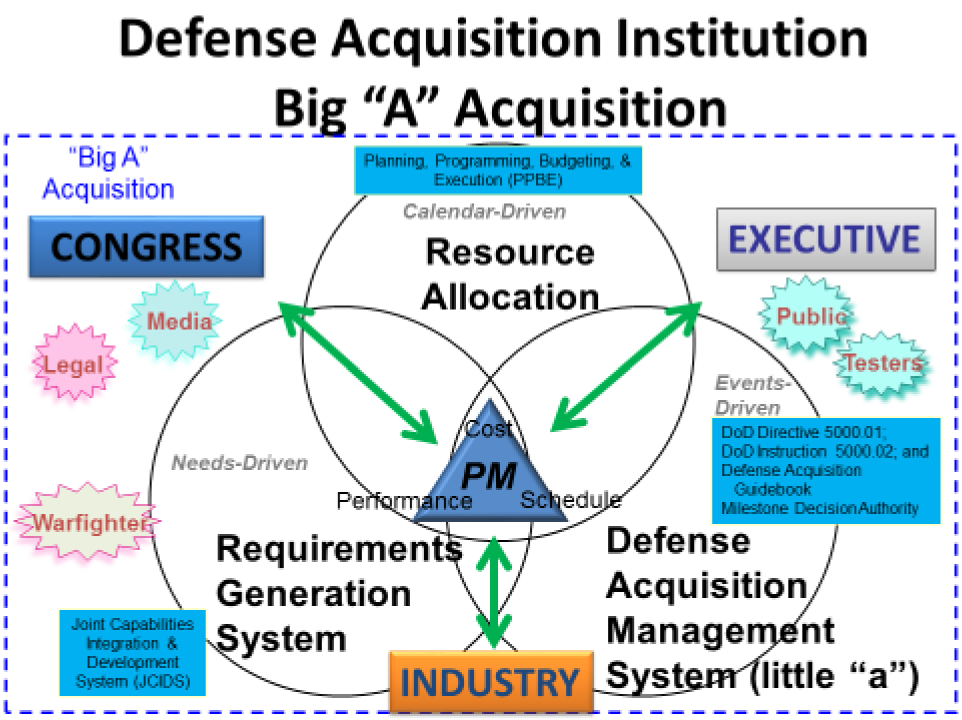

Figure 6. Defense Acquisition Institution—Big "A" Acquisition

The government program manager (PM) is at the center of defense acquisition, which aims to deliver warfighter capability. The PM is responsible for cost, schedule, and performance (commonly referred to as the "triple constraint") of assigned projects—usually combat systems within the DOD. The PM has a formal chain of command in the DOD through the executive branch of government. The PM typically reports directly to a program executive officer (PEO), who reports to the service acquisition executive (an assistant secretary for that service—either Army, Navy, or Air Force), who reports to the defense acquisition executive (the under secretary of defense for acquisition, technology, and logistics). Depending on the program's visibility, importance, and/or funding levels, the milestone decision authority (MDA) is assigned to the appropriate level of the chain of command.

Programs within defense acquisition require resources (for funding) and contracts (for execution of work) with industry. Congress provides the resources for the defense programs through the annual enactment of the Defense Authorization and Appropriation Acts, which become law and statutory requirements. The PM, through warranted contracting officers governed by the Federal Acquisition Regulation (FAR), enters contracts with private companies within the defense industry. Other important stakeholders include actual warfighters, the American public, the media, and functional experts (i.e., engineers, testers, logisticians, cost estimators, etc.), as well as fiscal and regulatory lawyers.

As a backdrop to this complicated organizational structure for defense PMs, there are three decision support templates: one for the generation of requirements known as the Joint Capability Integration and Development Systems (JCIDS), a second for the management of program milestones and knowledge points known as the Defense Acquisition Management System, and a third for the allocation of resources known as the Planning, Programming, Budgeting, and Execution System (PPBES). Each of these decision support systems is fundamentally driven by different and often contradictory factors. The requirement generation system (JCIDS) is driven primarily by a combination of capability needs and an adaptive, evolving threat. The resource allocation system (PPBES) is calendar-driven by Congress writing an appropriation bill—providing control of funding to the Congress and transparency to the American public and media for taxpayer money. The Defense Acquisition Management System is event-driven by milestones based on commercial industry best practices of knowledge points and off-ramps supported by the design, development, and testing of the systems as technology matures. Often integration and manufacturing challenges occur.

Appendix 2. Helmet Testing Basics

The Army rigorously tests combat helmets worn by Soldiers against protocols to ensure they conform to stringent requirements to protect Soldiers against both blunt trauma and ballistic threats. Typical battlefield ballistic threats include fragments from explosive devices and bullets from handguns and rifles. Within the DOD, System Threat Assessment Reports document relevant and existing helmet threats, and these threats are validated by the National Ground Intelligence Center (NGIC). With respect to fragmentation, the ARL has proven that five fragment simulators represent 95 percent of the range of threat fragments Soldiers expect to face from exploding munitions. Fragment threats used in testing include the 2 grain right circular cylinder (RCC), 4 grain RCC, 16 grain RCC, 64 grain RCC, and 17 grain fragment simulating projectile (FSP). Hand gun threats include the 9mm full metal jacket (FMJ) 124 grain, 0.357 Sig FMJ 125 grain, and the 44 Mag 240 grain. These threats are defined by the National Institute of Justice (NIJ). Rifle threats include eight different rounds to include 5.45mm, 5.56mm and 7.62mm rounds (both armor-piercing and non-armor-piercing varieties).

Helmet testing is a form of destructive testing because the helmets are non-recoverable after the testing. Generally, testing can focus on physical properties (like density or melting point), mechanical properties (like tensile strength or impact strength), and ballistic properties. Three ballistic properties particularly important for helmets are complete penetration (the bullets goes completely through the helmet), partial penetration (the bullet does not go completely through the helmet), and backface transient deformation (a measure for the amount the round's impact indents the helmet material).

Depending on the materials selected and the manufacturing process, each helmet will demonstrate a ballistic testing curve, represented in Figure 7. The frequency of complete penetration (CP) can be plotted against the striking velocity of the round. A striking velocity of V_0 is the highest velocity at which no rounds completely penetrate the helmet shell. A striking velocity of V_{100} is the velocity at which all rounds completely penetrate the helmet shell. The V_{50} striking velocity represents the velocity at which 50 percent of the rounds completely penetrate and 50 percent partially penetrate the helmet. Figure 7 labels the zones of variation and non-variation. The variation zone represents a performance area for the helmet in which the helmet may provide the different levels of protection but demonstrate the same V_0 and V_{100} characteristics.

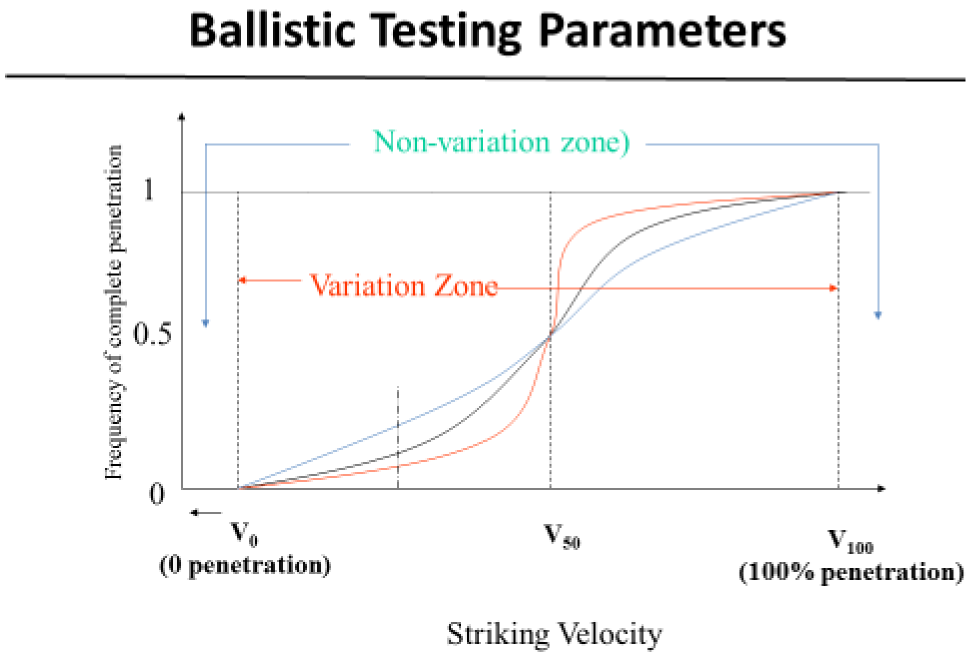

Figure 7. Ballistic Helmet Testing—Penetration

V_0 is the "protection parameter" because it identifies the warfighter's guaranteed protection level. It is an important parameter in production quality and control. However, it does not completely measure material performance and depends greatly on the production process. Generally, helmet manufacturers want to make the actual V_0 demonstrated by a helmet higher than the V_0 required to ensure a helmet passes testing (see Figure 8). V_{50} is the "material parameter" because it does not represent a guaranteed level of protection but is important in the optimization of the helmet design. There is a unique V_{50} for each helmet design. Generally, the design goal is to make V_{50} as high as possible and as close to V_{100} as possible.

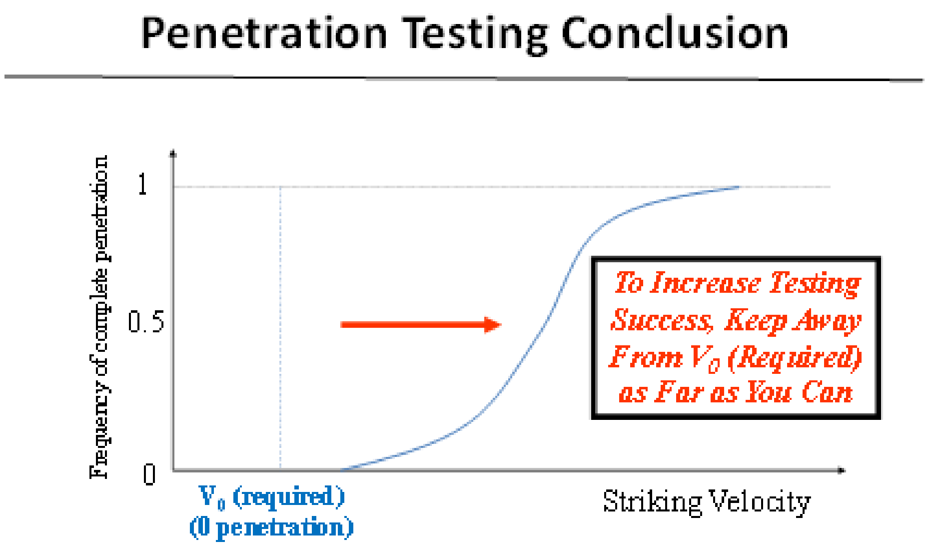

Figure 8. Penetration Testing Conclusion

During ballistic testing, if a bullet only partially penetrates (PP) the helmet, testers measure the backface transient deformation (BTD) using calipers or laser techniques. The lower the BTD exhibited by a helmet in testing, the lower the potential for injuries to the wearer's head. Figure 9 is a pictorial representation of a sample BTD measurement. After a series of tests, testers plot the observed BTDs for a helmet. This results in a distribution of values around an average BTD value (Figure 10). The lower the average measured BTD compared to the required value, the more protection the helmets offer and the greater the testing success rate for the design and manufacturer (Figure 10).

There is an additional important point to understand about helmet testing with respect to battlefield operational relevance. In testing, the Army performs V_0 resistance to penetration and BTD testing with the threat rounds fired at the helmet at speeds representing threat weapon muzzle velocity and at angles of 0 percent obliquity. This represents a worst-case condition that is representative of extremely close combat scenarios. Under these conditions, the round strikes the helmet with the maximum force and the highest chance for penetration. During combat, however, the enemy fires at various distances from their targets. Over these distances, bullets slow down and strike their intended targets at various angles.

Therefore, in combat, bullets strike Soldier helmets at speeds significantly lower than muzzle velocity speeds and from non-perpendicular angles.

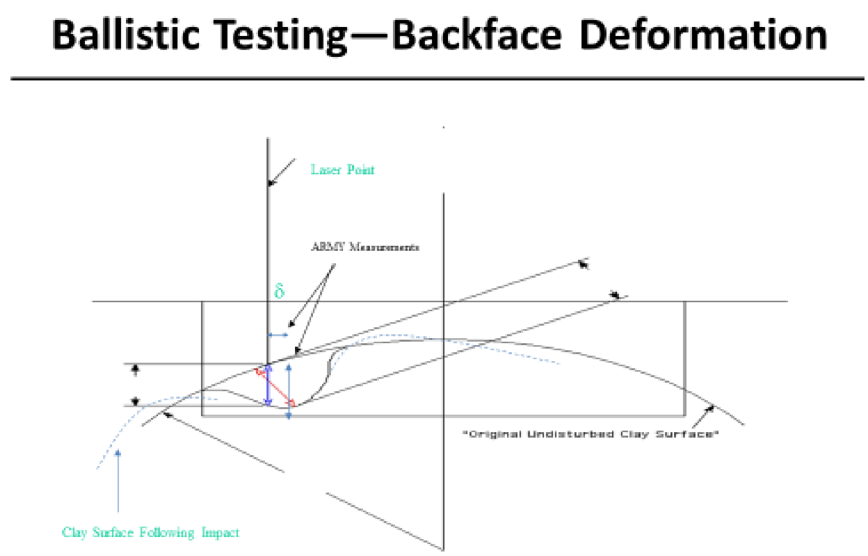

Figure 9. Ballistic Testing—Backface Deformation

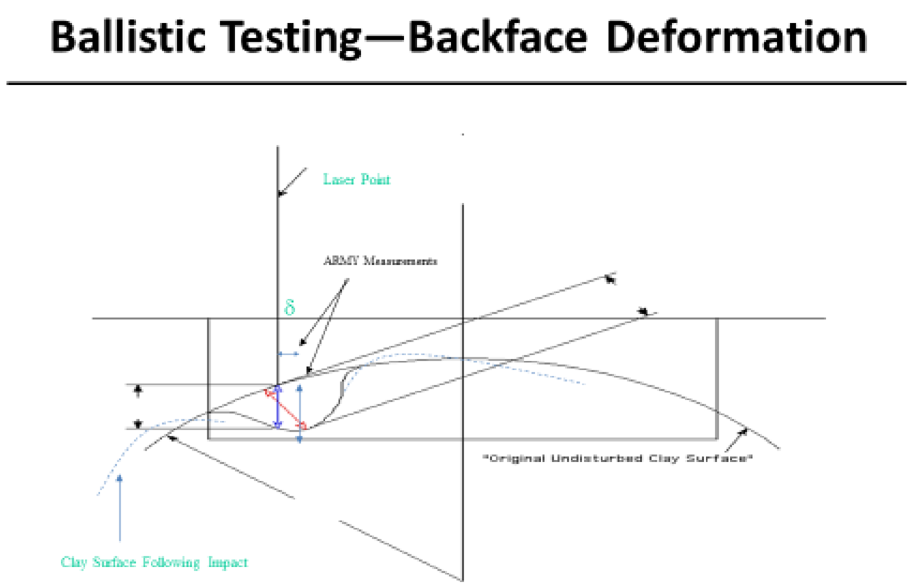

Figure 10. Deformation Testing—Conclusion

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