Protecting American Soldiers: The Development, Testing, and Fielding of the Enhanced Combat Helmet (ECH)

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Abstract

The development, testing, and fielding of combat helmets for United States (U.S.) soldiers offers project management practitioners an opportunity to analyze how programs begin, how they progress through development and testing, and finally how new capability is fielded within the U.S. Defense Acquisition institution. The case study centers on the U.S. Army’s adoption of the Enhanced Combat Helmet (ECH) for soldiers stationed in war zones around the world. The case study is applicable broadly to project managers, business managers, engineers, testers, and logicians involved in project management within the private sector, as well as specifically targeting acquisition professionals within the government defense departments. Emphasis is placed on the development of critical thinking and analysis skills in the areas of project initiation, stakeholder management, and decision making with ambiguous and contradicting testing/field data. The ECH case is in two distinct parts: Part One allows project management practitioners to analyze how to initiate a program with an increased chance of success of meeting desired objectives. Part Two allows project management practitioners to analyze how to determine a procurement and fielding recommendation without stakeholder consensus and with ambiguous data.

KEYWORDS: decision making; critical thinking; stakeholder management; project initiation; product fielding; cost benefit analysis; defense acquisition

Synopsis

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 focuses on the development, testing, and procurement (also referred to as acquisition) of a combat helmet for U. S. Army soldiers. 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 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 intent of the ECH case study was to encourage project management practitioners to analyze a DoD program. The ECH program case study data enables readers to become familiar with the evolution of combat helmets, the basics of combat helmet technologies, and helmet testing. Readers of the case develop alternative strategies in two areas: (1) project initiation decision and (2) procurement and fielding decision.

With respect to the project initiation decision, significant technology advancement enabled the consideration of a new helmet like the ECH. The maturation of a new technology allowed the Army to consider a helmet that offers either similar protection at less weight or increased protection at greater weight than current helmets. However, the setting of requirements in the absence of quantitative analysis to underpin realistic threshold values led to prolonged schedules, especially important 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 was considerable ambiguity in the interpretation of test results and the need for balance between acceptable risk, safety, and protection. Both decisions involve critical thinking, stakeholder management, decision making with uncertainty, and strategic leadership by focusing on the development of recommendations that decision makers can use to make the most informed decision possible.
Intended Audience, Recommended Courses, and Placement

The case is widely applicable to project management practitioners in both the public and private sectors. The case is suited for students concentrating in project management fundamentals or for functional experts in the project management-related fields of systems engineering, testing and evaluation, business and financial management, operations management, and logistics or supply chain management. The case is written at the graduate or executive education level—ideal for MBA courses. The case can be incorporated into the later stages of graduate or executive-level course curricula, used in courses specializing in project/program management, test and evaluation management, operations management, or strategic management—or in an MBA capstone course.

Learning Objectives

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

Relevant Project Management Knowledge Modules

- Project Management Principles
- Project Phases and Processes
- Project Resource Management
- Project Scheduling
- Opportunity and Risk Management
- Business Analysis and Requirements Management
- Project Leadership
- Identifying and Engaging Stakeholders
- Business and Commercial Aspects of Projects
- Governance in Projects

Discussion Questions

Instructors are encouraged to tailor the questions and consider focusing on a few to address in detail.

Part One: Project Initiation Decision

Questions to consider in ECH project initiation include the following:

- Who are the key stakeholders in the ECH program initiation decision and how does the project manager 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 the 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?
- What are some of the key program management fundamental lessons learned from this part of the case?

Part Two: Procurement and Fielding Decision

- Who are the key stakeholders and how does the project manager 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?
- How does the project management address the concerns of the testing and medical communities?
- How do senior leaders and project managers 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 musculoskeletal neck injuries from the weight of helmets?
- What are some of the key program management fundamental lessons learned from this part of the case?

Teaching Strategies

Case Preparation

It is recommended that the case be introduced to the entire class via a lecture with a PowerPoint presentation during face-to-face class time. A sample of the set of introductory slides with notes is included in Appendix 1. Alternatively, students could be assigned the same material in a pre-case preparation reading assignment. The goal of the case study introduction is to familiarize the students with the history of combat helmets, present the basics of helmet testing, and introduce the U.S. Defense Acquisition institutional framework. This same information is built into the case and its appendices.

It is also recommended the students be grouped into teams of about four students each. For each part of the case, we require each student team to write a case study analysis paper (limited to no more than two pages), and prepare brief-
ing slides summarizing their analysis and recommendations (limited to no more than five slides).

The information is presented to allow students to develop alternative strategies in two areas: (1) project initiation decision and (2) procurement and fielding decision. In both areas, students can enhance critical thinking skills by focusing on the development of recommendations in the form of a comparison of options to be used by senior leaders and program decision makers. Understanding the environment and key stakeholders should be emphasized. Alternative strategies or courses of action can be analyzed against decision criteria. Instructors are encouraged to provide the students with the discussion questions to help guide their preparation and analysis.

**Case Study Delivery**

Part One of the case study can be discussed in the class following its introduction. For Part One, instructors can compare student-developed strategies to actual strategy used by the Army as a way to bring out lessons learned or to see ways in which the actual strategy was less than optimal. Instructors can also use the discussion questions to guide the classroom session. Appendix 2 contains a storyboard that can be used facilitate the discussions. The storyboard highlights key points and follows the discussion questions and answers. Also presented in Appendix 2 is a sample decision matrix that can be used to generate discussion and objectively compare alternative strategies.

Part Two of the case study can then be discussed in class as well. Instructors can use the discussion storyboard and sample decision matrix presented in Appendix 3, use the student presentation slides, or present using the discussion questions as a guide.

**Discussion Question Answers**

**Part One: Project Initiation Decision**

- Who are the key stakeholders in the ECH program initiation decision, and how does the project manager manage their expectations?

  **Answers/Discussion Points to Consider:**

  - **Warfighter:** wants an increased capability against rifle threats for current fight as soon as possible. The project manager needs to lay out realistic schedule options for development and testing considering that the new helmet will incorporate new technologies with inherent risks.
  - **Warfighter/User representative (Colonel Billy Johnson):** getting pressured for a helmet to protect against rifle threats but also getting pressured to decrease the weight soldiers wear in combat. Helmet weights average about three pounds—any decrease in weight would have significant benefits by increasing soldier mobility and decreasing battle fatigue, as well as potential long-term health benefits by decreasing neck and back pain for soldiers. Colonel Johnson is a bit antagonistic and skeptical about the defense acquisition system’s ability to deliver. He also has an adversarial relationship with the project manager. The project manager needs to build trust and confidence with the user representative through honest communication and by establishing a collaborative relationship.
  - **Army Leadership/Decision Maker/Army Acquisition Executive (Honorable Cho):** the decision-making authority and the person who approves the acquisition strategy. Hon Cho wants to support the warfighter requirement for a new helmet but must also consider other stakeholders and the big picture with a broader perspective about what’s best for the entire Army. Hon Cho is under pressure to rapidly get a new helmet to soldiers. The project manager needs to provide Hon Cho with the best possible information about technology, cost, schedule, and performance options so that he can make the most informed decision possible. In general, Army leaders face concerns from Congress and the media about not having soldiers adequately protected—resulting in a risk-adverse mentality among Army leaders.
  - **Congress:** supports the Army with resources (funding), concerned about support to the warfighter, and also concerned about the health of the defense industrial base. The project manager needs to ensure Congress gets the information it needs (through required reports, hearings, and testimonies) to properly perform their crucial defense oversight mission.
  - **Testers/Director, Operational Test, and Evaluation (Colonel Crisp):** serves as the independent evaluation of operational effectiveness and suitability of the helmets—concerned about establishing requirements that are operationally realistic and testable. The project manager needs to build trust with the testers through communication and collaboration and serve as a conduit of information between the user representative and the testing community.
  - **Project Manager (Colonel Smith) and Chief Scientist (Dr. Suchez):** ultimately will be responsible for the ECH program cost, schedule, and performance. They must remain neutral—trying not to advocate too strongly for any particular option so that the other stakeholders have ownership of the program. The project manager is charged with delivering a capability as soon as possible within performance and cost constraints, initially acting as the key information source about technology, realistic performance requirements, scheduled options, and cost implications.

- Would the ECH program be considered a “technology push” or “capability pull” program, and what are the implications?

  **Answers/Discussion Points to Consider:**

  - The “capability pull” is the best case, because the folks who will ultimately use the system have identified a need with a capability gap to fill—the customer is defining the requirement. However, sometimes the current technology maturity has not caught up with the identified
need—for example, there are needs for an “invisibility cloak” and a force field at the individual soldier level, but technology, despite Hollywood’s claims, isn’t mature enough to deliver those capabilities.

- The "technology push" is often viewed negatively because of the perception that the developers are searching to find applications for their new invention; that is, the technology is being forced onto the customer.

- In this case, it seems as if the need for a new helmet came almost simultaneously with the maturation of a technology (application of high-molecular-weight poly-ethylene fibers)—a pretty good match between the technology and capability needs.

- How should the ECH requirements be set? Should an increase in protection or weight reduction be emphasized? What is the right balance between reductions of soldier load (combat weight) versus greater soldier protection?

- This is a hard one, because increased protection can be achieved but normally it will add weight to an already heavy helmet. It is related to the acquisition options below because a program of record will allow time for a comprehensive tradeoff analysis and optimization of performance requirements using operational and medical databases as well as modeling and simulation. A rapid acquisition program will require that a directed requirement be written without a complete analysis of performance requirements.

- From the case, new technology supports an ECH that could be 20% lighter (about a ½ pound) while maintaining current protection, or could add limited rifle protection at current helmet weights, or could strive for a really big increase in rifle protection but with added weight.

- There is always extreme pressure to lighten the fighting loads of soldiers in combat. The benefits are obvious: Soldiers with better speed and mobility, with less fatigue and more endurance, and with fewer long-term injuries. At the same time, there is a push for more capability (in this case, better protection), which usually means increased weights. In this case, the warfighters were clear that they desired a new helmet to address the rifle threat. Therefore, the Army struck a reasonable balance of increasing protection while still being constrained by the weight of current helmets.

- How does the Army set testing protocols for the ECH prior to development and manufacturing of a helmet based on a new technology?

- The testing protocols are important because they are placed in the helmet specification in the signed contracts for helmet deliveries. These specifications tell industry the government requirements to be met.

- This is a typical "chicken or egg" question. Helmets with the new technology have never been manufactured. Therefore, the testing protocols can only be established after making helmets and fully characterizing those helmets through design limit testing. However, a full-scale research and development effort requires time and money. The testing protocol for the current helmets was refined as a result of more than a decade of development, testing, and manufacture.

- The new technology in helmets may behave much differently than a para-aramid based helmet after being shot with a bullet. Thus, the testing protocols must be tailored for helmets using different technologies. With nothing else to go on initially, the ECH testing protocols were set the same as current helmet testing protocols. The subsequent schedule slips in the ECH program were partially a result of a refinement of the test protocol learned over time.

- 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?

- Unfortunately, there is no standard formalized decision-making model or process uniformly followed within the Department of Defense. Some projects may be supported by a business case analysis or a cost benefit analysis. But in this case, there is not really enough information to perform these types of analyses. Usually, the decision is made by comparing (listing advantages and disadvantages) alternative options (or courses of action).

- The following are three courses of action or options that are usually considered: a formal ECH program of record, a rapid acquisition of ECH, or not pursuing the ECH (i.e., convince the warfighter that the current helmets provide adequate protection).

- To fairly evaluate these courses of action, discriminating decision criteria must be clearly defined. These criteria need to come from the stakeholder concerns identified above. Clearly, the warfighter is concerned with schedule (how quickly can the ECH be fielded) and performance (address rifle threat protection). The warfighter representative is also concerned about soldier carrying loads and adds to the performance criteria with weight reduction. The Hon Chu concerned with schedule and performance but also adds a cost criterion (the lower the unit cost, the better from an affordability perspective within the Army budget). The testers (in this case, Director, Operational Test and Evaluation) are concerned with operational relevance and testability of the requirements, which could be interpreted as a risk criterion (program executability and relevance). The project manager adds a technology risk criterion.

- The options can then be compared using the decision criteria in a decision matrix. A sensitivity analysis can be done in real time with the students by adjusting the weighting of the criteria.
Sample Decision Matrix:

<table>
<thead>
<tr>
<th>Option</th>
<th>Criteria</th>
<th>Cost</th>
<th>Schedule</th>
<th>Rifle Protection</th>
<th>Risk - Technical</th>
<th>Unweighted</th>
<th>Weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program of Record</td>
<td>Low dependency</td>
<td>2.5</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2.56</td>
<td>32</td>
</tr>
<tr>
<td>Program of Record</td>
<td>High dependency</td>
<td>3.5</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3.51</td>
<td>32</td>
</tr>
<tr>
<td>Field Acquision with Directed Requirements</td>
<td>Low rate</td>
<td>1.5</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1.51</td>
<td>32</td>
</tr>
<tr>
<td>Field Acquision with Directed Requirements</td>
<td>High rate</td>
<td>2.5</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2.51</td>
<td>32</td>
</tr>
<tr>
<td>No Testing</td>
<td>Low rate</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>No Testing</td>
<td>High rate</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>32</td>
</tr>
</tbody>
</table>

Using the criteria of cost, schedule, performance, and risk, the unweighted rankings of the options scored the same (8). Only when schedule was weighted three times as important and performance was weighted twice as important as cost and risk did options become separated in scores. This analysis forces decision makers to really think about why a certain option is favored over other options.

- What are some of the key program management fundamental lessons learned from this part of the case?
  - 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 helmet manufacturers. In this case, an effort that originally planned to field helmets within a year was seeking a production decision almost four years later. The industrial base suffered as the program settled on a sole-source contracting strategy without the benefits of competition to keep costs and schedule 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 had a similar actual schedule timeline.
  - Project managers, 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 Two: Procurement and Fielding Decision**

- Who are the key stakeholders and how does the project manager manage their expectations?

Answers/Discussion Points to Consider:
- Warfighter: wants an increased capability against rifle threats for current fight as soon as possible. The project manager needs to appreciate the urgency of the warfighter requirement.
- Warfighter/User representative (Colonel Billy Johnson): adamantly supports moving forward with production and fielding decision, and dismisses other stakeholder concerns as a risk-adverse and affordability-conscious bureaucracy getting in the way of new capability to soldiers. The project manager needs to support his or her partner but do it in a way that doesn’t dismiss the concerns of the testing and medical communities.
- Army Leadership/Decision Maker/Army Acquisition Executive (Honorable Cho): wants to support the warfighter requirement for a new helmet but must also consider other stakeholders with a broad perspective about what’s best for the entire Army. The project manager needs to provide the best possible information about risk, cost, schedule, and performance options so that the most informed decision possible is made.
- Congress: supports the Army with resources (funding) for a new helmet with greater capability but concerned about soldier safety given the Director, Operational Test and Evaluation opinion that the new helmet may jeopardize soldier safety. The project manager needs to keep Congress informed about the decision and reasoning behind the decision.
- Testers/Director, Operational Test and Evaluation (Colonel Crisp): adamant that the ECH may expose soldiers to unacceptable risk from excessive backface deformations that may cause skull fractures and likely deaths. Also, believes that the ECH was not tested against the most relevant operational threat. Finally, believes that the cost of the ECH (roughly 2½ times that cost of the current helmet) is not worth the capability improvement. The project manager must address the valid concerns raised by the testing community.
- Project Manager (Colonel Smith) and Chief Scientist (Dr. Suchez): want to support the warfighter but also concerned about the soldier safety risks raised by testers. Must present the cost, schedule, performance, and risks of various options so the most informed decision can be made.
- 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?

Answers/Discussion Points to Consider:
- First it is important to simplify the data so leaders and decision makers can understand it. In this case, the test data showed the following:
  - Test Data:
    - Fragmentation protection: ECH 53% > than current helmet
    - 9 mm protection: ECH 10% > than current helmet
    - Rifle protection: ECH 153% > than current helmet
Field Data:
- Complete penetrations resulted in 74% fatality rate
- Partial penetrations resulted in 100% recovery with 100% returned-to-duty and an observed permanent helmet deformation of about 9 mm (compared to pistol requirement of 16 – 25.4 mm)
- It is also important to remind all stakeholders what seems most important to the warfighter: addressing the rifle threat.
- It is not uncommon for different stakeholders to interpret the same raw test data differently. The analysis and evaluation of the data can often lead to different conclusions. In the case, the testers and Surgeon General viewed the backface deformation of tested helmets against rifle threats as extremely negative findings—an indication that soldiers may die from deformations that cause skull fractures. The warfighter representative viewed that same data as a positive finding—an indication that the soldier would likely survive because the bullet didn’t completely penetrate the helmet.
- Development test results and operational field data should both be considered in the decision. The truth is that each stakeholder may place different weighting on the relevance of these sets of data. In the end, the interpretation of the data (the analysis and evaluation) provides information for a well-informed decision. The test data and operational field should be considered complementary because they serve different purposes. The test data help prove that helmets manufactured meet the design and manufacturing requirements; the operational field data provide a combat perspective on the difference between a controlled test environment and the real world, combat environment.

How does the project manager address the concerns of the testing and medical communities?

Answers/Discussion Points to Consider:
- The concerns are warranted, but they must be evaluated with the field data to interpret operational relevance. If you have a picture of a tested helmet with a backface deformation of nearly two inches and then superimpose a human skull on that photo, it is reasonable to assume that a soldier may suffer serious injuries from that type of an event. However, that photo represents a worst-case scenario that is probably not operationally realistic. For example, in combat, the threat round comes from some distance away, slowing down before impact, and hits the helmet at angles. Additionally, there is considerable movement of the helmet and the soldier’s head after impact that is difficult to simulate in testing.
- It is important to understand the inherent safety margin built into resistance to penetration (or \( V_d \)) testing. The testing is done against helmets with muzzle velocity, at point blank range, and 0% obliquity. If the helmets prevent penetration under these conditions, it will provide considerably more protection against a variety of threat rounds at operational relevant distances.
- The field data of battle-damaged helmets is very relevant. The data demonstrate that stopping the bullet is much more important to soldier survival than deformations. In fact, complete penetrations resulted in a 74% fatality rate and partial penetrations resulted in 100% recovery, and an actual observed permanent helmet deformation on only about 9 mm (65% less than the 25.4 mm deformation requirement).
- The details of helmet testing as well as the field data help mitigate the concerns raised by the testers.
- The project manager needs to specifically address the testing, medical, and safety concerns through sharing all the data and alternative interpretations of the data, and its link to operational relevance. Specifically,
  - Not tested against most stressing threat: Testing is performed at the muzzle velocity, 0 meter range, and 0 degree obliquity—this provides an inherent, built-in (albeit not quantifiable) safety margin for the warfighter because threat rounds are fired at considerable ranges and slow down over distances and never come strike at perfect 0 degree obliquity.
  - Excessive backface deformation: Excessive deformations have never been observed in combat and no significant injuries have ever been observed.
- How do senior leaders and the project manager address these concerns with Congress, the media, and the American public?

Answers/Discussion Points to Consider:
- Even before a final decision, stakeholder management is best handled through the development of a comprehensive strategic communications plan that includes top level messages for senior leaders, published questions and answers, and a public affairs and media engagement plan. If you engage these stakeholders early in the process, they are more apt to understand the final decision. You can engage Congress through meetings with the professional staff members, and you can engage the public through media engagements with trusted media organizations. You can also communicate through open source internet announcements and monitor the interest and responses.
- What are the advantages, disadvantages, and second-order implications of various courses of actions for the path forward? What are the decision criteria?

Answers/Discussion Points to Consider:
- The three courses of action are usually considered: procure and field; delay the decision to address concerns...
(more testing, change the requirements); or kill the program (because there is a follow-up program that is in the development stage nearing a production decision in a few years).

- To compare these options, discriminating decision criteria derived from stakeholder concerns can be defined. The warfighter and warfighter representative remain concerned with schedule (how quickly can the ECH be fielded) and performance (address rifle threat protection). The Hon Chu is concerned with schedule and performance but also adds a program's cost criterion. Testers are concerned with operational relevance of testing, cost, and soldier safety. The project manager always has cost, schedule, and performance constraints and interprets soldier safety as a risk criterion.

- In this case, the risk criterion of soldier safety is difficult to use for comparison of options because different stakeholders would list risk as an advantage (pro) or disadvantage (con). For example, the warfighter would list the Risk—Safety criterion as an advantage to procure and field, whereas testers would list it as a disadvantage.

- To overcome this shortfall to a simple comparison listing advantages and disadvantages, the options can then be compared using the decision criteria in a decision matrix. A sensitivity analysis can be done in real time with the students by adjusting the weighting of the criteria.

Sample Decision Matrix:

<table>
<thead>
<tr>
<th>Option</th>
<th>Cost</th>
<th>Schedule</th>
<th>Performance</th>
<th>Risk - Safety</th>
<th>Unweighted Ranking</th>
<th>Weighted Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procure and Field</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>15</td>
<td>5.5</td>
</tr>
<tr>
<td>Delay</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>2.5</td>
</tr>
<tr>
<td>Kill Program</td>
<td>1</td>
<td>6</td>
<td>9</td>
<td>2</td>
<td>37</td>
<td>22</td>
</tr>
</tbody>
</table>

Using the criteria of cost, schedule, performance, and risk, the unweighted rankings of the options indicated that the “procure and field” option was preferred. When the schedule was weighted two times as important, performance was weighted two times as important, and risk was weighted three times as important than cost, the preferred option remained the same. In fact, a sensitivity analysis indicates that with these criteria and qualitative rankings, delaying the program would never be preferred over fielding the helmet. And only when cost is weighted much more heavily than all the other criteria, would the option of kill the program be preferred. Leaders will intuitively support a particular option, and this type of analysis forces a more objective look at the comparison to either support the intuition or really question why a particular option is preferred.

- 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 musculoskeletal neck injuries from the weight of helmets?
  - In this case, the cost criterion is usually dismissed as not as important as other criteria. However, the procurement and fielding decision is a US$35 million decision and the unit cost of the ECH is US$781 compared with the current helmet cost of about US$300. Some, like the testing and medical communities, contend the minimal improvement is not worth the cost.

- This question gets into areas that senior leaders do not like to discuss because it involves making uncomfortable assumptions and acknowledging the lack of data. For example, based on sunk cost investments, pay, and benefits, some estimates put the value of saving a commissioned officer in the US$1 to US$2 million range, and the value of saving an enlisted soldier in the US$200,000 to US$300,000 range. But these are gross estimations.

- In this case, the long-term health impacts of wearing a combat helmet in battle and the effects it has on neck and back injuries remain unknown. The concussive effects of blunt trauma and ballistic events on soldiers wearing helmets, particularly repetitive low-impact events, are not well understood. With this being said, the even longer terms costs to the country in terms of veteran healthcare may be significant.

- Also interesting is the lack of real data that links helmet impacts to injury data in humans. Even if it did exist, using the generalized data for a particular soldier’s injuries would be always questionable.

- In the end, most stakeholders fall back to the “easy button,” basically rationalizing that each soldier life is priceless, and we will spend whatever it takes to protect each soldier. This reasoning is okay, but it avoids the hard decision required concerning balancing program affordability with limited taxpayer resources.

- What are some of the key project management fundamental lessons learned from this part of the case?
  - Test data can be interpreted differently by key stakeholders—leading to ambiguity in the decision-making process. The project manager 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 project manager 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 a controlled test environment to relevance in an operational setting needs to be viewed with caution about its applicability.
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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 project manager is the key to making this happen successfully through effective leadership and communication.

Epilogue

“The rest of the story” or what the Army actually did, can be presented not as the “right answer” but more to provide closure for readers. Many paths often lead to similar end results for acquisition development programs. The case study itself provides the epilogue to the project initiation decision (Part One). For the procurement and fielding decision (Part Two), the Army (and the U.S. Marine Corps for that matter), decided to procure and field the ECH despite the cautions raised by the testing and medical communities. However, it was informally agreed that the Services would not highlight the ECH program with the media, allowing Director, Operational Test and Evaluation to “save face” (considering the “Beyond Low Rate Initial Production Report” to Congress that recommended against fielding). This stakeholder management compromise still allowed the Services to provide the warfighter an increased capability and also set the stage to continually improve helmet testing protocols.

Interestingly, the picture on the right side of Figure 1 in the case study is the only known, acknowledged ECH recovered after being battle damaged. Figure 1 below contains multiple pictures of this ECH. In this case the soldier was shot at close range (less than 100 meters [110 yards]) by an “insider threat” with a rifle. Two rifle rounds struck the ECH. The soldier suffered only a mild concussion and returned to duty after 24 hours rest. The picture of the inside of the helmet clearly shows a deformation exceeding the requirement against 9 mm handgun rounds of 25.4 mm (or 1 inch). This example demonstrates just how many variables can affect the actual head injuries received by soldiers. This example also highlights the limitation of extending test results beyond their intended purpose. The helmet test protocols must be statistically robust and rigorously controlled to ensure the manufactured helmets meet the performance specification requirements—the operational extension of those results to combat is quite complex.

The Army continues to work on improving the performance of combat helmets and improving the testing protocols used to test helmets to ensure they provide maximal protection to soldiers in combat. Further research involves trying to quantify the medical impact (actual human skull and brain affects) of ballistic and blunt trauma impacts to the human skull and brain while wearing these helmets.
Theory Review

Suggested Readings
This review leaned on the fundamental concepts in the following textbooks:


U.S. Defense Acquisition Institutional Framework
To properly analyze the case, students need an appreciation of the environment in which a project manager operates and the processes, which facilitate the development, testing, procurement, and fielding of capability to soldiers. The project manager is at the center of Defense Acquisition, whose purpose is to deliver warfighter capability. The project manager is responsible for cost, schedule, and performance (commonly referred to as the “triple constraint”) of assigned projects—usually combat systems with the DoD (see Figure 2). Project managers are required to have strong leadership skills to effectively guide their assigned programs.

The project manager has a formal chain of command (or authority) through the DoD in the executive branch of federal government. As depicted in Figure 3, the project manager reports directly to a program executive officer, who reports to the component acquisition executive (an Assistant Secretary for that service—either Army, Navy, or Air Force), and 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, a program decision authority is assigned to the appropriate level of the chain of command. For the ECH case study, the decision authority was the Army Acquisition Executive due to the high visibility of the effort with the testers and Congress.

Programs within Defense Acquisition require resources (primarily 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 project manager, through warranted contracting officers governed by the Federal Acquisition Regulations, enters contracts with private companies within the defense industry. Other important stakeholders include actual warfighters, the American public and media, as well as fiscal and regulatory lawyers. Figure 4 highlights the interrelationships between the major stakeholders, with the project manager in the middle balancing the competing interests of many stakeholders.

As a backdrop to this complex acquisition environment for project managers, there are three decision support templates to guide programs (as shown in Figure 5): one for the generation of requirements known as the Joint Capability Integration and Development System, 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. Each of these decision support systems is fundamentally driven by different and often contradictory factors. The requirement generation
system is driven primarily by a combination of capability needs and an adaptive evolving threat—pointing toward the need for a responsive acquisition system. The resource allocation system is calendar driven, with Congress writing an appropriation bill and the President signing the bill every fiscal year—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 and integration and manufacturing challenges occur.

The combination of the project management triple constraint, chain of authority, acquisition environment, and decision support templates provides a framework to view U.S. Defense Acquisition, referred to as the Defense Acquisition Institution and depicted in Figure 6.

An alternate view of the Defense Acquisition Institution is presented Figure 7.

It is important to differentiate the “institution” from the perspective of a project manager. The government project manager leads an organization, generically called a “program management office” with hundreds of acquisition professionals from various disciplines (engineering, testing, logistics, contracting, financial, personnel). Several program offices fall under a program executive office, and each service has between 10 and 20 program executive offices. Each program management office is organized either functionally by disciplines, by products, or as a hybrid structure staffed by matrixed professionals.

Defense Acquisition is the institution within which program offices operate. Defense Acquisition has regulative, normative, and cultural–cognitive elements with activities...
Defense Acquisition is multifaceted and structured, providing mechanisms for applying resources to deliver warfighting capability—a specific need for American society—national security. Defense Acquisition constrains project manager behavior by establishing boundaries like statutory laws from Congress and regulations from the Department of Defense that must be followed, and also controls project manager behavior by establishing cost, schedule, and performance constraints through requirement documents, approved budgets, and milestones. At the same time, Defense Acquisition empowers the project manager by providing the framework within which to apply resources (funding and personnel) to accomplish the mission of designing, developing, testing, procuring, and supporting combat systems for warfighters. Defense Acquisition is both a state of order as well as a process to deliver warfighting capability. Institutions are often resistant to change, and Defense Acquisition is no different. Defense Acquisition has been under constant reform for over three decades as each new executive administration and each new Congress views Defense Acquisition as an easy target for government reform initiatives to increase efficiency and eliminate non-value-added bureaucracy. The end result of continuous reform initiatives is the addition of more oversight and layers of control, thereby strengthening the institutional structure and processes rather than making them more effective.

When we consider Defense Acquisition as an institution, we can examine it through the three pillars of institutions—the regulative, normative, and cultural–cognitive elements. Let us examine which of the three pillars has primacy for various dimensions. Defense Acquisition as an institution rests primarily on the regulative pillar. The system constrains and regularizes project manager behavior through laws, regulations, oversight, and consequences for non-compliance. The Defense Acquisition policies attempt to control and influence future project manager behavior. According to the Department of Defense Directive 5000.01 Defense Acquisition System, the guiding principles of Defense Acquisition are responsiveness, flexibility, innovation, discipline, and streamlined management. Of these principles, discipline—adherence to the laws and regulations—overwhelms the others because Defense Acquisition was formed and molded over decades on the regulatory institutional pillar. The prevalence of laws, rules, and sanctions with Defense Acquisition indicate regulatory pillar foundations. The cost of monitoring a regulative system is bureaucracy and nonvalue-added oversight, which lead to inefficiencies and ineffectiveness. Expedience dominates Defense Acquisition as a basis of compliance. Laws and regulations are crafted and individuals conform to them—all to reinforce the basis of the institution. The mechanism is one of coercion and the effect is fear and guilt rather than honor.

The basis of legitimacy is a distinguishing feature for Defense Acquisition resting on the regulative institutional pillar. All legitimate activities with Defense Acquisition are legally sanctioned rather than being morally governed or culturally supported. This makes sense because it is linked to an expedient basis of compliance and a basis of order with defined rules. The absence of universally accepted and well-defined sets of norms, values, and morals across the nation as well as no formal definition of the American culture make a government institution like Defense Acquisition naturally fall back onto laws and regulations that can be agreed upon and then modified over time when needed. Normative systems rely on individual roles and empowerment. Although Defense Acquisition pays lip service to project manager empowerment, it is overshadowed by a fear of loss of control and accountability. The topic of appropriateness makes sense for normative systems, but within Defense Acquisition, it is too subjective, personal, and non-uniform for each project manager to be guided by the question of “what is the appropriate behavior for me to carry out?” This difference between social norms and laws/regulations often evokes strong feelings in individuals. However, over time, the Defense Acquisition as an institution creates individually accepted roles and responsibilities that are eventually accepted as norms. Thus, dimensions of the normative pillar gain primacy as the institution matures.

The cultural–cognitive pillar of institutions is harder to apply to the Defense Acquisition institution. However, much like normative systems, over time, as the Defense Acquisition institution matures, perceived correctness is established and types of behavior become routine—making other types of behavior not acceptable. An attitude of “It has always been done like this” is prevalent within Defense Acquisition, making reform initiatives and leading change very difficult from a project manager’s perspective, because of the institutional barriers protecting the status quo.

**Organizations Within the Defense Acquisition Institution**

There is a tight connection between institutions and organizations that operate within them. Within Defense Acquisition, there’s the organizational structure associated with the chain of command (presented above), which is different from the program management office organizational structure. The program offices are each organized similarly either as product or functional structures, as depicted in Figure 8.

These diagrams (both the chain of authority shown in Figure 3 and the program management office structures in Figure 8) reflect the military nature of these organizations and how the project manager fits within the Defense Acquisition institution. The project manager is responsible for the cost, schedule, and performance of assigned programs, but is not the program approval authority. Unlike in the private sector where organizations are structured and optimized to
managers in difficult positions with respect to leadership, because project managers are encouraged to be “outside the box,” innovative, critical thinkers, and visionary strategic leaders; however, the Defense Acquisition institution is risk adverse, one of micromanagement and control, with a zero defect mentality. Failures and mistakes are never rewarded within a larger perspective of advancement of the institution. One positive shift over time and spurred by congressional enactment has been the professionalism of the Acquisition workforce. Within the normative pillar of Defense Acquisition, there has been an acceptance of certification and accreditation standards for acquisition professionals within the training, education, and experience realms. The recognition of folks that work within Defense Acquisition as members of a profession—acquisition professionals—goes a long way in building trust and confidence with senior leaders. Ultimately, this would lead to true empowerment of project managers and the elimination of nonvalue-added oversight and bureaucracy without jeopardizing accountability and control.

Strategic Leadership Within the Defense Acquisition Institution and in Defense Acquisition Organizations

Project managers lead organizations within the Defense Acquisition institution. Project managers are first and foremost strategic leaders. To effectively operate within the volatile, uncertain, complex, and ambiguous (VUCA) environment described above, project managers rely on either formal or informal leadership frameworks or models. The term VUCA is often used to describe contemporary military operating environments, but is equally applicable to the Defense Acquisition environment.

A strategic leadership model provides a systematic framework to think, reflect, and interact with individuals and organizations. A strategic leadership model serves as a mental asset
The mission is one of three components of the organizational dimension. The mission is the reason the organization exists, and is the “who,” “what,” “where,” “when,” and “why” of the organization. Within the mission component is vision, strategy, and execution/resources. The vision is a motivating, inspirational statement about the future organizational end-state, providing direction and intent, which guides and focuses an organizational unity of effort.

The strategy is the “how” component of mission/vision. The setting of challenging, realistic goals and objectives is critical to effective strategy development. The alignment of the organizational mission, vision, and strategy facilitates efficient execution. The implementation and execution of the mission, vision, and strategy is resource constrained. The application of resources for mission execution involves prioritization of assets and activities as well as the acceptance of risk in under-resourced areas of the organization.

People. Organizations with reputations for sustained effectiveness have dedicated, hard-working people committed to the organizational vision and mission. The people making up an organization represent the diverse national culture of ingenuity, innovation, dedication, perseverance, and commitment. Empowerment of people within an organization provides ownership of the mission and a sense of purpose, and it ultimately improves organizational effectiveness by promoting involvement and buy-in for goals and objectives. An empowered workforce embraces teamwork and recognizes the synergistic effect of teaming to reach greater levels of organizational effectiveness. Strategic leaders build teams with complimentary competences and negotiating skills while emphasizing ethical behavior. Teamwork encourages openness and diversity of thought, and creates a healthy atmosphere for decision making. Teamwork helps overcome strategic leadership shortfalls and bureaucracy by valuing individual involvement and contribution, which helps leaders make competent decisions. Leaders improve team effectiveness by guiding the decision-making process via consensus, dialectic inquiry, or devil’s advocate techniques. Strategic leaders must recognize team members for hard work, excellence, and innovation. Recognition must be tailored for individuals depending on motivational factors, including greater responsibility, awards, financial incentives, or time.

Culture/Climate. The most challenging organizational dimension component for strategic leaders to address is organizational culture and climate. The climate is the workforce environment that is observed from the outside of an organization. The organizational culture is the core characteristic of how the organization accomplishes its missions and how the workforce acts. The strategic leader can improve the work environment by establishing a positive command climate—focusing equally on people and mission. A good command climate encourages open communication and information sharing, and invests heavily in workforce training and education, which fosters a learning environment. A positive organizational culture continually adapts to challenges, embraces change, but also maintains a focus on core competencies. Within the VUCA environment, adaptive organizations learn and transform to maintain sustained organizational effectiveness. A resilient, learning organization reflects on past mistakes as lessons learned and adapts
to challenges by taking acceptable risks to achieve greater effectiveness while at the same time growing thinking leaders and an agile workforce.

**Personal Dimension**

**Interpersonal Skills.** Interpersonal skills become increasingly important at the strategic leadership level. Strategic leaders must develop a greater reliance on interpersonal skills to lead, influence, motivate, and communicate to the organization. Strategic leaders also consider alternate perceptions and innovative solutions formulated by their staffs, top management teams, and contemporaries. Communication is critical at the strategic level, and strong consistent communication is imperative to a well-functioning team. Leaders must communicate up and down the chain of command, and laterally to other organizations. Communicating to influence or motivate often involves negotiation with senior leaders, other agencies, or staff. Leaders must appreciate the value of negotiation for compromise building at the strategic level within a political landscape. Strong negotiating skills involves the formation of trust, which ties to the strategic leader’s interpersonal skills and values. Motivation of people, teams, and organizations involves determining which factors inspire people to accomplish the organizational mission and vision. Communication and motivation require social competency skills that, along with emotional intelligence, act as multipliers for improved leadership effectiveness. “Soft skills,” such as social awareness and relationship management, play a critical role in motivating, communicating, managing change, and leading diversified organizations. Using effective interpersonal skills, leaders communicate and demonstrate the moral integrity that enables the development of an ethical organizational culture.

**Conceptual Competencies.** The development of strategic leadership conceptual competencies requires the devotion of time for contemplation and reflection. Over time, leaders internalize conceptual models centered on systems, critical and creative thinking, and intellectual standards. The systems approach to problem solving, issue analysis, and decision making fosters an understanding of the interdependent influencing factors as well as second and third order implications. Strategic leaders must balance critical and creative thinking to encourage both divergent and convergent reasoning, necessary for the formation of innovative approaches to complex problems. A leader must acknowledge the limits of his or her perspective and develop top management teams with differing perspectives to accurately assess issues. Addressing an issue from an alternative or opposing perspective allows the leader and organization to understand the weakness of his or her position and enhances the negotiation of a compromise solution.

**Values.** A strategic leader’s values form the moral and ethical foundation upon which interpersonal and conceptual skills rest. An uncompromising adherence to personal values provides an example for the organization and contributes to a positive organizational climate and an organizational culture committed to ethical behavior. Maintaining one’s integrity in words, deeds, and actions builds a culture of trust and openness. Respect for others fosters teamwork and a willingness to consider diverse views, contributing to a climate of team building, professionalism, and excellence. Having the personal courage to maintain the “moral high ground” contributes to the organizational atmosphere of resiliency and commitment. Despite current VUCA challenges, adherence to fundamental core values such as integrity and respect for others remains an imperative for sustained organizational effectiveness.

**External VUCA Environment**

Strategic leaders face complex problems with unintended consequences, multiple implications, and no optimal solutions. The current VUCA environment is a major contributing factor in distinguishing leadership at the strategic level. The political landscape complicates the leader’s ability to focus the organization on the mission and vision. The organization as a whole and the leaders in particular must develop an ability to scan an environment of abundant information and convert information into knowledge through conceptual competencies of critical thinking and systems reasoning. A comprehensive understanding of the VUCA environment allows organizations to minimize threats and capitalize on opportunities. Understanding the political landscape and power relationships allows strategic leaders to promote organizational advocacy amid competing priorities and conflicting goals.

The leadership model shown in Figure 9 is consistent with thoughts about the behavior of organizations from Mahoney in *Economic Foundations of Strategy*. Central to the model is the concept of cooperation among people. Cooperation provides purpose, meaning, and direction, which leads to a willingness to serve the organization through personal choice. The project manager as the leader serves as the executive. Incentives provide motivation, and authority is accepted by participants as legitimate. At the heart of both an organization and the leadership model is decision making. The gathering of information and the processing of information into knowledge in a cooperative team setting leads to the acceptance of executive decisions and ultimately contributes to a more effective organization. The behavior of the organization rests on the behavior of individuals and the leaders. Rational behavior has a stabilizing effect on the organization. Simplicity, unity of command, and decentralization enable more effective decisions and thereby strengthen organizations. Oftentimes, apparently irrational decisions are made because of incomplete information or incorrect assumptions and perceptions. The leadership framework is very consistent.
with the general concepts of organizations providing the ability for cooperation among individuals to make decisions, and a formal structure for authority, procedures, and strategic focus. People are more likely to accept membership to an organization when the organization aligns with their personal goals. Of course, using communication to facilitate cooperation is the central principle of organizational behavior theory. The leadership model discussed above does facilitate the alignment or at least acceptance of both personal rewards with organizational rewards. A key aspect of strategic leadership is ensuring individuals are motivated to participate. The optimization of decision making is what separates really good organizations from the rest—the same can be said for strategic leaders.

**Decision-Making Basics: Introduction to Decision Matrices**

Decision making within the Defense Acquisition institution is complex, and the project manager is at the center of the process. The project manager is uniquely positioned with access to the information needed for the informed, knowledge-based decision to be made by senior leaders. The presentation of the information is important because it often biases the final recommendation or path forward. Sometimes, alternative courses of action or options are developed and then the advantages (pros) and disadvantages (cons) of each option are simply listed. This qualitative comparison is useful but may lead to a suboptimal recommendation, especially when decision stakeholders have preconceived, intuitively based thoughts about what the right option should be. Another complication of listing advantages and disadvantages is that stakeholders have different perspectives—an advantage to one stakeholder may be a disadvantage to another. Finally, if there are three or more options, the best choice may not be obvious.

One method used to avoid these traps in comparing options is to use a decision matrix. In this case, options are defined. Decision criteria are clearly defined. The definition of the decision criteria is an important part of the analysis. The decision criteria should be derived from the stakeholder concerns. Then, each option is ranked qualitatively against each decision criterion for a comparison of the options. This forces the leaders to understand precisely why one option is preferred over another option, avoiding the intuition bias and making the comparison of options more objective.

A basic decision matrix is displayed as follows:

<table>
<thead>
<tr>
<th>Criteria Options</th>
<th>Cost</th>
<th>Schedule</th>
<th>Performance</th>
<th>Risk</th>
<th>Option Scores (Lower is Better)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option #1</td>
<td>1.5</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>6.5</td>
</tr>
<tr>
<td>Option #2</td>
<td>1.5</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>7.5</td>
</tr>
<tr>
<td>Option #3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>

The option scores are totaled in the last column. Option #3 is the preferred option. In this decision matrix, each of the criteria was equally weighted, meaning that neither was more important to the stakeholders than another. Oftentimes, a simple decision matrix with equally weighted criteria leads to options receiving the same total score. That’s the case in the next decision matrix.

<table>
<thead>
<tr>
<th>Criteria Options</th>
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<th>Schedule</th>
<th>Performance</th>
<th>Risk</th>
<th>Option Scores (Lower is Better)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option #1</td>
<td>1.5</td>
<td>1</td>
<td>3</td>
<td>2.5</td>
<td>8</td>
</tr>
<tr>
<td>Option #2</td>
<td>1.5</td>
<td>2</td>
<td>2</td>
<td>2.5</td>
<td>8</td>
</tr>
<tr>
<td>Option #3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>

Against the risk criterion, Option #3 was best, and Options #1 and #2 were equal. Thus, Option #1 and Option #2 each received a 2.5 score [(2 + 3)/2]. Interesting, that in this example situation, the decision matrix would not help get to a preferred or recommended option because all the options scored equally overall.

For most decisions, the criteria used to compare options are not of equal importance. For example, performance may be much more important than schedule, or cost may be the main concern for that particular decision. In these situations, the criteria are weighted accordantly to their importance to the stakeholders. A decision matrix with criteria weighted can help separate the scores of the options for the decision makers. The process of option comparison is the same, but now each option has two scores—one score with unweighted (or equally weighted) criteria and one score with weighted criteria. Note that criteria weighting only serves to...
separate the option scoring; it does change the ranking of the options. Following is an example decision matrix with weighted criterion:

<table>
<thead>
<tr>
<th>Decision Matrix (Qualitative Ranking of Options)</th>
<th></th>
<th>Option Scores (Scores in Brackets)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria</td>
<td>Cost</td>
<td>Schedule</td>
</tr>
<tr>
<td>Option #1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Option #2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Option #3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

To get the weighted scores for each option, the option score is multiplied by the criterion weighting. Then, the total scores are summed for each option. In this situation, the options all scored the same when the criteria were equally weighted. But when the schedule was three times as important as cost and risk, and performance was twice as important as cost and risk, then Option #2 was preferred.

The powerful and useful part of using a decision matrix is that a sensitivity analysis can be used with stakeholders to truly examine why a certain option is preferred and what happens when the weighting of the criteria change. For example, after discussion with the stakeholder, let us assume that weighting of the criteria in the previous matrix was not correct. Really, performance was the most important factor, followed by cost and risk of equal importance, and schedule was the least important factor.

The decision matrix changes accordingly, as shown in this sample:

<table>
<thead>
<tr>
<th>Decision Matrix (Qualitative Ranking of Options)</th>
<th></th>
<th>Option Scores (Scores in Brackets)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria</td>
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<td>1</td>
</tr>
<tr>
<td>Option #2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Option #3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

With performance three times as important as schedule, and cost and risk twice as important as schedule, the preferred option changes to Option #1.

This type of analysis is particularly useful when certain stakeholders are convinced one option should be recommended, but they cannot articulate why. Maybe they just intuitively think that one option is best. The weighting of the criteria can be manipulated until that option comes up favored. Then, the question can be asked if that weighting of the criteria reflects how they feel. For example, if the option is only preferred when one criterion is weighted 10 times as important as other criteria, then maybe the criteria are defined improperly or do not reflect the true importance to the stakeholders.

References


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Appendix 1: Case study introductory slide presentation.

Enhanced Combat Helmet (ECH) Case Study

Why are stakeholders so passionate about helmets?

Force Protection of Soldiers – Army Top Priority!

Speaking Notes:
Folks are passionate about helmets because helmets save lives in combat. Soldiers on active duty as well as the millions of veterans are subject matter experts on combat helmets because they’ve worn them in combat and training. They appreciate that wearing the helmet might be the difference between life and death—dying in combat or returning home safely to their country, family, and loved ones. The American public is passionate because these helmets protect their sons and daughters. The U.S. Congress and senior leaders are passionate because they must prioritize resources to provide soldiers with protective equipment—like helmets. The pictures shown are of combat helmets worn by soldiers in combat and hit by enemy threat bullets. The U.S. Army collects these battle-damaged helmets to study the effect of threat bullets on helmets to better understand the ballistic impacts and the response of the helmet materials in the actual operational environment—all in an effort to improve future helmets for soldiers. After the analysis, the Army returns the helmets to soldiers to allow closure for the soldier. The stories of soldiers being reunited with the helmet that saved their lives is heart-warming.

Transition to next slide:
So, what is the history of Army combat helmets?
Appendix 1: Case study introductory slide presentation.

**Army Combat Helmet Evolution**

*Speaking Notes:*
This slide displays the evolution of Army combat helmets and shows the tradeoff between increased performance and cost over time. The combat helmets show a constant improvement in performance over time. This improvement in performance has been the result of advances in material research and manufacturing techniques, providing the opportunity to significantly increase ballistic protection at a reduced weight. The Personnel Armor System for Ground Troops helmet in the mid-1980s, the Modular Integrated Communication Helmet, and the Advanced Combat Helmet are all based on the para-aramid polymer technology—the most famous of which is DuPont's Kevlar®. In the late 1990s, high-molecular-weight polyethylene was developed. Helmets based on high-molecular-weight polyethylene technology offered the opportunity to consider reduced helmet weight and/or greater ballistic protection. The basis of future Army helmets, both the ECH and its eventual replacement, the Soldier Protection System future helmet, is high-molecular-weight polyethylene technology. This is a common situation in that the maturation of a new technology allows for the consideration for improved capability. Also, take note of the cost of the ECH over its predecessors, which is also typical in that the cost of the new helmet with greater capability would be higher.

*Transition to next slide:*
Now, before we jump into the ECH specifically, let us briefly discuss the basics of helmet testing and requirements.
Appendix 1: Case study introductory slide presentation.

**Ballistic Testing – Penetration**

![Graph showing ballistic testing curve]

**Speaking Notes:**
Helmet requirements must be set so that the requirements can be fairly and accurately tested; that is, the requirements must be testable, measurable, and repeatable. With this in mind, the U.S. Army tests all helmets against testing protocols that are approved by the Director, Operational Test and Evaluation (DOT&E).

Three ballistic properties particularly important for helmets are complete penetration (the bullet goes completely through the helmet), partial penetration (the bullet does not go completely through the helmet), and backface deformation (a measure for the amount the round’s impact indents the helmet material). Depending on the materials selected and manufacturing process, each helmet will demonstrate a ballistic testing curve that this figure represents. The frequency of complete penetration 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% of the rounds completely penetrate and 50% partially penetrate the helmet. 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.
**Speaking Notes:**

$V_0$ 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. $V_{50}$ 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.

**Testing Parameters:**

- $V_0$: “Protection Parameter”
  - Protection requirement set by the warfighter
  - Not a complete material ballistic performance measure
  - Provides “Guaranteed Protection” information
  - Very important parameter for manufacturing and production as well as quality assurance and control

- $V_{50}$: “Material Parameter”
  - Material ballistic performance measure
  - Does not provide “Guaranteed Protection” information
  - There is only one $V_{50}$ for a system
  - Very important parameter for research and development stage to understand material performance
Appendix 1: Case study introductory slide presentation.

Ballistic Testing – Deformation

**Speaking Notes:**
During ballistic testing, if a bullet only partially penetrates the helmet, testers measure the backface deformation using calipers or laser techniques. The lower the backface deformation exhibited by a helmet in testing, the lower the potential for injuries to the wearer’s head. This figure shows a pictorial representation of a sample backface deformation measurement.
Appendix 1: Case study introductory slide presentation.

Deformation Testing – Conclusion

To Increase Testing Success, Keep Deformations this way (less is better)

Data Distribution

Backface Deformation

Average +σ +2σ +3σ

25.4 mm (front/rear helmet requirement)

or

16.0 mm (crown/side helmet requirement)

Speaking Notes:
After a series of tests, testers plot the observed backface deformations for a helmet. This results in a distribution of values around an average value. The lower the average measured backface deformation compared to the required value, the more protection the helmets offer and the greater the testing success rate for the design and manufacturer.

Transition to the next slide:
Now that we have a basic understanding of how the helmet requirements translate into ballistic testing, let’s talk specifically about the ECH.
Appendix 1: Case study introductory slide presentation.

ECH Program

- **Combat helmet system for both U.S. Army and U.S. Marine Corps**
  - Utilizes advancements in technology
    - High-molecular-weight polyethylene

- **Requirements**
  - Improved fragmentation protection requirement
    - 35% increase
  - Improved ballistic protection
    - Increased 9-mm protection
    - Rifle protection
  - Same weight and area of coverage as current helmet

*First helmet designed to protect against a rifle threat*

**Speaking Notes:**

By 2009, both the U.S. Army and U.S. Marine Corps were becoming more concerned about head protection against threat rifle rounds. About the same time, high-molecular-weight polyethylene technology was considered mature enough for application in combat helmets. As a result, the ECH program was approved. Under pressure to procure and field the ECH as quickly as possible, directed requirements were quickly approved. The ECH program was funded with Overseas Contingency Operations funding that included resources to test, procure, and field the ECH. Competitive firm fixed-price contracts for the delivery of helmets to undergo government testing were placed with commercial industry helmet manufacturers. The contracts included firm fixed-price option awards for subsequent production contracts if the helmet passed testing.

The Army essentially pressed the “easy button” by setting the requirements so quickly without optimally balancing the tradeoffs between ballistic protection, weight, and area of coverage. High-molecular-weight polyethylene technology allowed the Army to consider improving the ballistic protection to address rifle threats, but it also allowed the Army to consider significantly reducing the weight of the helmet and maintaining the current protection requirements. The long-term health impact on a soldier’s back, neck, and head of wearing a nearly three-pound helmet cannot be overstated. A polyethylene-based helmet could take a ½ pound off the soldier’s head and neck and still provide the ballistic protection of current helmets.
Appendix 1: Case study introductory slide presentation.

**ECH Timeline**

- **As worn, shot on coronal plane of helmet**
- **Helmet Suspension System**
  - Full Rate Production Decision
  - DOT&E Report sent to Congress
  - ECH Passed Final First Article Test
  - ECH Failed Testing after engineering change proposals
  - ECH Passed next First Article Test
  - DOT&E Test Protocol Updated
- **Improved Helmet Retention System**
  - ECH Failed First Article Testing
  - Army Approved ECH program milestone Low Rate Initial Production
  - ECH Development Test Commenced
  - ECH Contract Award for Developmental Test Articles
  - Army Urgent Statement of Need and Directed Requirement Approved
  - ECH Request for Proposal Released

**Speaking Notes:**

The ECH program began in early 2009 with a request for proposal. Four vendors submitted proposals; however, only one vendor’s design was acceptable. At the end of 2009, this vendor received a contract to produce ECH to undergo government developmental testing. In late 2010, after successful developmental testing, the Army approved the low rate initial production with the selected vendor—now a sole source situation. The 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. In late 2011, the ECH passed the second round of first article testing. To meet an aggressive production schedule, 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 testing for all three production lines. The ECH finally passed testing and achieved its performance requirements.

Despite passing testing, the decision to field was not so easy for Army leaders. In June 2013, DOT&E issued a congressionally mandated Beyond Low Rate Initial Production Report recommending that the ECH not be fielded to soldiers. DOT&E believed that the cost per helmet did not justify the minimal performance increase. Additionally, DOT&E stated 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 supported the DOT&E recommendations.

**Transition to the next slide:**

What should the Army do?
**Speaking Notes:**

This slide presents a useful lens through which to analyze the ECH case. The project manager lies at the center of the framework with responsibility for cost, schedule, and performance. Each program, project, or effort is supported by the decision support templates: the Requirements Generation System provides requirements, the Resource Allocation System provides funding, and the Defense Acquisition Management System provides a schedule framework and milestones.

The stakeholders for projects are many but the critical ones are identified. The project manager’s official chain of command is through the Executive branch, but also reports to Congress (and Congress provides funding and oversight). The project manager works closely with industry partners. Other stakeholders include the warfighters, media, public, and testing community. As you analyze the ECH case, consider looking at the ECH project through this lens—especially important when thinking about decision criteria.
Appendix 2: Discussion storyboard for Part One: Project initiation.

**ECH Case Study Discussion—Initiation**

**Issue:** ECH Program or not and how?

**Root Cause:** Soldiers dying from increasing threats, soldier weight load, new technology

**Path Forward / Recommendation**

- Courses of Action:
  - 1: Program of Record
  - 2: Rapid Acquisition
  - 3: Do Nothing
- Decision Criteria:
  - Performance (rifle threat) - P
  - Schedule (sooner better) - S
  - Cost (lower better) - C
  - Risk – technological - R
- COA1
  - Pros: P, R
  - Cons: C, S
- COA2
  - Pros: P, S
  - Cons: C, R
- COA3
  - Pros: C, R
  - Cons: P, S

**Stakeholders**

- Warfighters: want a new helmet to address rifle threat as soon as possible
- Senior Leaders: want to support the Warfighter but must prioritize resources
- Congress: supports Warfighter; also concerned with industrial base
- Testers: concerned about threat and realistic, testable requirements
- Project management: cost, schedule, performance and technology risk

**Constraints/Considerations**

- Requirements
  - Urgent or formal requirements
  - Balancing protection against weight
  - Testing protocols
- Schedule/Funding
  - Rapid acquisition versus program of record
  - Base budget funding versus contingency funds
  - Technology risk
  - Contracting strategy, industrial base and competition

**Pressures:**

- Performance
- Schedule
- Cost
- Risk

**Lessons Learned:** Don’t underestimate risk or importance of competition; beware of schedule driven-programs

**Speaking Notes:**

The recommended approach traces to the discussion questions and highlights parts of the storyboard in the following sequence:

- Issue: Should the Army pursue a new helmet program and what is the acquisition approach?
- Stakeholders: Discuss the various stakeholders with a particular emphasis on what is important to those stakeholders.
- Constraint/Considerations: Discuss case specifics that would be important in development of options and the comparison of options.
- Defense Acquisition Institution Framework: Discuss using the instructional framework as a lens to address the issue and important pressures put on the project manager. The identification of pressures provides traceability between the stakeholders and decision criteria because the pressures come from the stakeholders and then serve as the most important decision criteria.
- Path Forward/Recommendation: Discuss alternative options, and then use the decision criteria to identify advantages (pros) and disadvantages (cons) with each option. Usually, this qualitative comparison makes it hard to identify the best option. The decision matrix can be used to generate that discussion.
- Lessons Learned: Discuss the bottom line and the most important student lessons learned for project management.
Appendix 2: Discussion storyboard for Part One: Project initiation.

**ECH Case Study Discussion—Initiation**

<table>
<thead>
<tr>
<th>Options</th>
<th>Criteria</th>
<th>Cost</th>
<th>Schedule</th>
<th>Performance</th>
<th>Risk - Technical</th>
<th>Option Scores (Lower is Better)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>unweighted</td>
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<tr>
<td>Program of Record</td>
<td></td>
<td>2.5</td>
<td>2</td>
<td>1.5</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Rapid Acquisition with Directed Requirement</td>
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<td>2.5</td>
<td>1</td>
<td>1.5</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Do Nothing</td>
<td></td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>

**Speaking Notes:**

This is a sample decision matrix, which highlights the advantage of using this approach.

The three alternative strategies compared are:

1. Program of Record: A formal, competitive research and development effort with requirements and test protocols supported with comprehensive analysis effort
2. Rapid acquisition with a directed requirement
3. Do nothing (convince warfighter that a new helmet is not worth the investment)

The decision criteria are:

- Cost (lower helmet unit cost is better)
- Schedule (faster the planned fielding the better)
- Performance (addresses protection from rifle threat)
- Risk—technical (chance of program success or development time dedicated to reduce risk)

Qualitatively ranking the options against these criteria (with 1 the best and 3 the worst option for each criterion) results in all the options scoring equally. But when the schedule is weighted three times as important and the performance is weighted two times as important as cost and risk then options score differently. In this case, a rapid acquisition scored the best because a lower score is best. The sensitivity analysis allows you to change the criteria weighting and examine how different options score.
Appendix 3: Discussion storyboard for Part Two: Project procurement and fielding.

**ECH Case Study Discussion—Procure and Field**

### Stakeholders
- Warfighters: urgent requirement for new helmet to address rifle threat
- Senior Leaders: balance warfighter support with resources and stakeholder concerns
- Congress: supports warfighter; report from DOT&E; funding; industrial base
- Testers: unacceptable risk of injury; wrong threat; and cost
- Project management: cost, schedule, performance and risk (soldier safety)

### Issue: Procure and field or not
**Root Cause:** ambiguous test results and conflicting field results

### Constraints/Considerations
- Cost/Funding: ECH at $781, current helmets around $300; approaching end of fiscal year $30 million decision
- Requirements/Test Data:
  - ECH met requirements
  - ECH offered greater fragmentation, 9-mm, and rifle protection than current helmet
  - Testing done at muzzle velocity, 0 m range, and 0 degrees obliquity worst case and provides an operational safety margin
- Technology: new helmets may be too elastic; deformations from rifle rounds exceeds 9-mm requirements
- Field Data for battle damaged helmets:
  - Partial penetrations results in 100% return-to-duty
  - It’s all about stopping the bullet; deformations irrelevant operationally

### Path Forward
- **COA1**
  - Pros: P, S, R
  - Cons: C, R
- **COA2**
  - Pros: P, R
  - Cons: S, C, R
- **COA3**
  - Pros: C, R
  - Cons: P, S, R

### Pressures:
- Performance
- Schedule
- Cost
- Risk

### Resources
- Schedule
- Cost
- Management

### Lessons Learned: Path forward to address stakeholder concerns; operational perspective on the interpretation of test results is important

**Speaking Notes:**
The recommended approach traces to the discussion questions and highlights parts of the storyboard in the following sequence:

- **Issue:** Should the Army buy and the field the ECH to soldiers?
- **Stakeholders:** Discuss the various stakeholders with a particular emphasis on what is important to those stakeholders.
- **Constraints/Considerations:** Discuss case specifics that would be important in the development and the comparison of options.
- **Defense Acquisition Institution Framework:** Discuss using the instructional framework as a lens to address the issue and important pressures put on the project manager. The identification of pressures provides traceability between the stakeholders and decision criteria because the pressures come from the stakeholders and then serve as the most important decision criteria.
- **Path Forward/Recommendation:** Discuss alternative options, and then use the decision criteria to identify advantages (pros) and disadvantage (cons) with each option. Usually, this qualitative comparison makes it hard to identify the best option. The decision matrix can be used to generate that discussion.
- **Lessons Learned:** Discuss the bottom line, and the most important student takeaways from this part of the case.
Appendix 3: Discussion storyboard for Part Two: Project procurement and fielding.

ECH Case Study Discussion—Procure and Field

Speaking Notes:
This is a sample decision matrix, which highlights the advantage of using this approach.

The three alternative strategies compared are:
• Procure and Field: Spend the US$35 million to buy helmets and field them to soldiers in combat as soon as possible.
• Delay: Delay the decision to buy helmets in order to change the requirements and test more to address concerns.
• Kill Program: An argument to cut losses in this program that is behind schedule and over budget, and shift resources to the next helmet that nearing the end of its development effort.

The decision criteria are:
• Cost (lower program costs is better)
• Schedule (faster the fielding the better)
• Performance (addresses protection from rifle threat)
• Risk-safety (potential safety risks to soldiers compared to the current helmet)

Qualitatively ranking the options against these criteria (with 1 being the best and 3 the worst option for each criterion) results in the Procure and Field option being the most preferred option. When the schedule is weighted two times as important as cost, performance is weighted two times as important as cost, and risk-safety is weighted three times as important as cost, then option scores separate more but the Procure and Field was still preferred. The sensitivity analysis allows you to change the criteria weighting and examine how different options score.