



**Research Report 1981**

**An Alternative Front End Analysis  
Strategy for Complex Systems**

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# AN ALTERNATIVE FRONT END ANALYSIS STRATEGY FOR COMPLEX SYSTEMS

## EXECUTIVE SUMMARY

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### Research Requirement

This research is being conducted in response to requests by the U.S. Army Air Defense School Commandant, Ft. Sill, Oklahoma, and Director for Manpower and Personnel Integration (MANPRINT), Headquarters, Department of the Army (HQDA) G-1. The purpose of this phased research is to develop an alternative front end analysis (FEA) strategy for new and evolving, highly automated, complex systems that rely upon multilevel command and control integration. This research is in response to growing concerns that current training and strategies to identify that training are insufficient to address the growing complexities of automated systems. Primary concerns are oriented on issues related to supervisory control, problem solving, and decision-making within integrated crew-based automated systems. The intent of this initial phase of the research is to identify an alternative FEA process that will address these specific training requirements and make training recommendations. Pragmatically, this phase defines an alternative FEA strategy for complex systems that will next be applied to Patriot air battle management training as a use case to validate and refine one of two FEA alternative strategies.

### Procedure

Two alternative FEA strategies to the traditional task-based approach, underlying much of current military training, were identified by examining existing literature pertaining to air defense training and performance, FEA approaches, and performance and training issues and recommendations for training complex tasks in individual and collective settings. Literature was evaluated for relevance and applicability to complex programs of interest. Relevant research findings and recommendations were used to identify ways the U.S. Army's current Systems Approach to Training (SAT) analysis could be adapted or replaced to address specific training and performance issues identified in the literature. Proposed alternative strategies were reviewed in terms of their applicability for two U.S. Army Air Defense School programs of interest, Patriot and the emerging Army Integrated Air and Missile Defense (AIAMD) architecture. Thus, our findings during this initial phase are based on viewing Patriot operations as a complex system, research on multiple FEA approaches, relevant research on individual and team/collective training, and research examining decision-making in complex situations.

### Findings

Patriot research over the past nine years has identified a number of operational performance issues and associated training concerns. These concerns can be broadly categorized into three areas: (a) operator expertise using automated systems; (b) skill decay; and (c) crew communication and coordination within the context of highly automated systems. We found that training research directly and indirectly addresses these areas, particularly in regard to collective training, expertise, decision-making and problem solving, and situational awareness within the

context of highly automated systems. Two alternative FEA approaches were developed to match analytic capabilities to known air defense training concerns. The first proposed approach combines an event-based analysis with collective team-based analyses. This approach provides the benefit of incorporating collective performance requirements directly within an operational mission event context. The second approach combines collective team-based analyses with an expertise-based analysis. This approach retains the benefit of incorporating collective performance requirements within traditional task-based strategies, as well as adding assessments of individual performance skill level requirements for completing complex tasks in ambiguous situations. Based on the results of this research, an alternative strategy combining collective team and expertise-based analyses was recommended for the next phase of this research.

#### Utilization and Dissemination of Findings

The results from this initial phase were presented to senior leaders and staff from the U.S. Army Air Defense School during a briefing at Ft. Sill, OK, on 13 March 2014. The recommended FEA approach was approved by the Air Defense School for the next phase of this research, i.e. applying the strategy to current Patriot missile training. Given the scope and depth of Patriot missile training, this assessment will be limited to air battle management training. The results from this case use application will be presented in a separate report following completion of the second phase of this research.

# AN ALTERNATIVE FRONT END ANALYSIS STRATEGY FOR COMPLEX SYSTEMS

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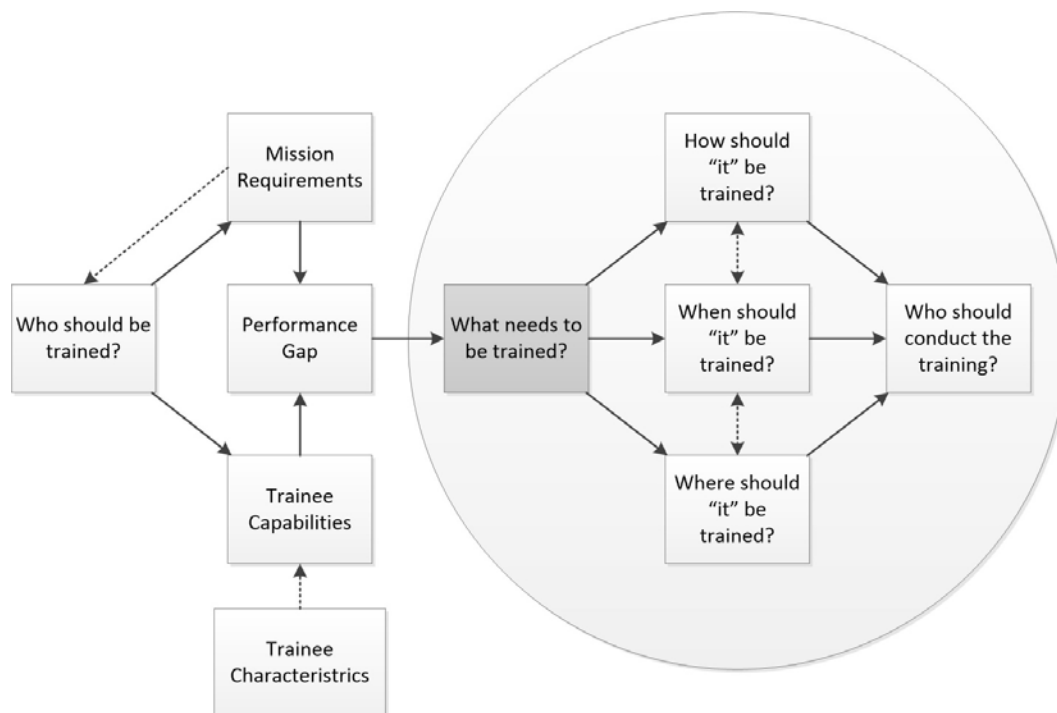
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# An Alternative Front End Analysis Strategy for Complex Systems

## Introduction

Historically, front-end analyses (Harless, 1968) have been used to identify and analyze performance requirements and issues at the beginning of the instructional design process. A front end analysis (FEA) not only acts as a training needs assessment, but also identifies when training is not required or the best option for addressing a system requirement (Romiszowski, 1981; U.S. Department of the Army, 2004). Although the scope of an FEA varies with the context in which it is applied, organizations have routinely relied upon systematic, iterative strategies to define training needs and programs.

As a collection of analyses conducted prior to implementation of a project, an FEA should define, especially in military training environments, the context of the training needs and answer a series of questions that inform subsequent training design, development, and delivery. Figure 1 illustrates a generic FEA process and the questions typically addressed through an FEA. “What needs to be trained?” is the central question of any training FEA. Performance gaps (e.g., the difference between trainee capabilities and mission requirements) provide the input to what needs to be trained, while the answers to that question lead to more specific questions about when, where, how, and by whom training should be delivered. Regardless of the types of analyses used, or the specific questions asked, a consistent feature of an FEA is that the results are entirely dependent on what is included and the types of questions asked. Consequently, the FEA should be oriented to address known training shortcomings regardless of the source. Furthermore, the FEA should be designed to collect and analyze data specifically associated with those shortcomings.



**Figure 1.** FEA core constructs.

Traditionally, instructional developers, especially within military organizations, in general, and the Army, specifically, have taken a task- or topic-centered approach to identifying and defining the knowledge, skills, and abilities (KSAs) required to employ developing systems. The Army's ADDIE process (Analysis, Design, Development, Implementation, and Evaluation), originally embedded within the Army's larger ISD (Instructional Systems Design) and SAT (Systems Approach to Training) strategies, provides an excellent example of a largely task-based approach to defining training requirements (see U.S. Department of the Army, 2004; U.S. Department of the Army, 2013). Key outcomes of this process establish criteria for successful performance outcomes and set specific job performance requirements, expectations, and training needs and standards. In many cases, the overall challenge addressed in traditional FEAs has been one of defining an organization's problems or needs and then revising or modifying existing training requirements, programs, and products to fit them. Thus, traditional FEAs often focus on individual tasks and roles with little regard for critical decision and coordination points, interpersonal interactive skills and requirements, or the full range of collective, interdependent activities inherent in operating complex, networked systems.

This report summarizes our attempt to identify or develop alternative FEA approaches better framed to address the complex challenges and issues emerging from the deployment of highly complex, increasingly automated systems. Our approach will examine key components of operations within an exemplar complex system, the Patriot<sup>1</sup> ADA system, as well as research on decision-making in uncertain circumstances, crew coordination, team decision-making, cognitive task management, and the interaction of individuals within complex systems. The Patriot system, as a use case, provides an operational context for identifying and understanding the elements of complex systems that require different approaches to learning and training than defined by traditional FEAs. This research is being conducted in response to requests by the U.S. Army Air Defense School Commandant, Ft. Sill, Oklahoma, and the Director for Manpower and Personnel Integration (MANPRINT), Headquarters, Department of the Army (HQDA) G-1.

## **Patriot Air and Missile Defense Training**

The Patriot is a surface-to-air missile defense system that is routinely deployed worldwide. Patriot has a long history of successful employment by the U.S. Army. Since 1969, the system has undergone several modifications, which have expanded its capability and added to its complexity. Originally designed to counter medium altitude air threats, it is now the Army's primary antiballistic missile (ABM) system. Patriot is employed in the field through a battalion echelon organizational structure. The line battery is the basic building block of a Patriot unit, and includes up to six missile launchers, a radar, an Engagement Control Station (ECS), an Antenna Mast Group (AMG), and a Battery Command Post (BCP). At the battalion level, the Information and Coordination Center (ICC) identifies, prioritizes, and coordinates threat tracks within its assigned area by integrating input from multiple ECSs. Together, the ECS and ICC are tasked with monitoring readiness, ordering threats, and giving priorities to

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<sup>1</sup> The authors recognize that PATRIOT is an acronym for "Phased Array Tracking Radar to Intercept on Target"; however, the more commonly found colloquial short reference, "Patriot," will be used throughout this report to refer to the PATRIOT missile system and its components just as it appears in numerous published articles, reports, directives, and doctrinal manuals.

radar, among other responsibilities. The ICC is the link between the Patriot ECS and higher command structures.

Although a detailed evaluation of current Patriot training is beyond the scope of this research effort, observations of current U.S. Army ADA School (USAADASCH) training methods suggest current training methods are based on traditional task-based principles incorporated into the Army's SAT analysis process. Potential training limitations can be gleaned from sources that attempt to link training issues with mission performance problems. Overall, researchers familiar with Patriot training and operations have concluded that poor operational performance and errors may be due to disconnects between institutional training, unit training, and current operational responsibilities (Hawley, 2011). They also insist that Patriot training and assessment should be more rigorous in order to minimize the frequency of critical decision errors (Hawley, 2007; Brooks et al., 2012).

Judgment errors regarding decisions on the potential engagement of an identified threat, if left unchecked and unresolved, may ultimately lead to one of two final outcomes: (a) allowing a hostile weapon, mistakenly identified as a friendly asset, to penetrate the defenses and damage or destroy a protected asset; or (b) attacking a friendly asset, mistakenly identified as a hostile target (i.e., fratricide). Patriot training research during the last nine years has largely focused on the latter of these outcomes (i.e., fratricide incidents) to determine the contributing factors to these mission failures. The factors identified through this research can be organized as:

- lack of operator expertise using highly sophisticated systems;
- skill decay; and/or
- poor crew communication and coordination within the context of highly automated systems.

These judgment errors may be minimized with frequent mission performance in a wartime environment. In “peacetime” training, however, practice at this high level of tasking is often not achieved. As such, traditional peacetime training models are being questioned across the military services, with a growing call to decrease initial institutional training time and move personnel into the field more quickly. This pressure is often associated with cost reduction, but there is also a higher demand for trained mission-ready Soldiers due to current and projected mission requirements.

**Operator Expertise.** Research examining the link between mission performance and training concluded that generalized training failed to develop the necessary levels of operator expertise, focusing instead on individual task proficiencies (Hawley, 2009; Hawley, Mares, & Giammanco, 2006; Hawley & Mares, 2006). Expertise can be described as consistently superior performance on a specified set of tasks in a domain (Ericsson & Charness, 1994, cited in Hawley, 2009). Concentrating training on individual task performance, however, rather than whole-job proficiency, does not necessarily result in expertise (Schneider, 1985, cited in Hawley, 2009). The use of rote practice and routine drills of system processes, such as typical in Patriot training, reinforces automation bias, which is the bias towards accepting outcomes from automation (Hawley, 2007). Automation bias can result in failures of monitoring (vigilance problems) and decision biases, whereby the operator automatically defers to the machine output.

Over-reliance on the machine may be directly attributed to a lack of expertise in understanding how the system actually operates and when circumstances deviate from standard procedures and training. The disconnect between task-based training and expert performance can be traced back to how training requirements are determined, as well as how training outcomes are measured.

Related to automation bias and individual task proficiency training, Hawley (2007) concluded that operators lack an adequate comprehension of the tactical situation. He attributed this to Patriot system operators being trained to successfully repeat and complete routine drills rather than actively construct a mental model of the tactical situation and its relevant components. The failure to frame an accurate mental model and understanding of the operational and tactical environment constrains operator responses in novel situations and scenarios. If whole-job proficiency is an aspect of expertise, then training to a more advanced understanding of the tactical situation and effective adaptation to change needs to build on a comprehension of system operation and individual task proficiencies. Hawley and Mares (2007) and Brooks et al. (2012) concluded that adaptive decision-making is not enabled among Patriot operators (nor trainees), and that training should focus less on routine drills and more on the application of varied scenario-based simulations to encourage decision-making in complex situations.

**Skill decay.** Hawley and Mares (2006) assert that high levels of technological automation will contribute to skill decay (i.e., forgetting) in Soldiers, as well as other performance issues, as they increase their reliance on automated processes and decrease their reliance on their own knowledge and expertise. Citing Klein (2003), Hawley and Mares caution that increasing automation can impair individual skills in three ways beyond basic skill decay: (a) disabling the expertise of skilled operators; (b) slowing the rate of learning enough to block the development of systematic expertise; and (c) reinforcing dysfunctional skills that interfere with subsequent expertise attainment.

According to Brooks et al. (2012), the Institute of Defense Analyses (IDA) concurred with Hawley and Mares' conclusions, predicting that "based on the task description for the original Patriot air battle engagement, the performance of operators will diminish quickly after a period of nonuse as predicted by the Hagman-Rose [see Hagman and Rose, 1983] skill retention model" (Brooks et al., 2012, p. 11). Left unchecked, these effects will eventually result in a small percentage of operators sufficiently skilled to perform the task following a retention interval or a period of nonuse. Brooks and colleagues further point out that successfully retained skills may be limited and may not improve with practice unless the training adds novelty and challenge to the scenarios. Skill decay and the over-reliance on automation features will negatively affect mission performance and training progress unless such effects are addressed directly through training and training designs.

**System technology.** The appropriate level of automation and human interaction within technologically advanced operational systems is a common topic in the field of human factors, and automation in Patriot is no exception (Endsley, 1997a; Hawley, 2011). Fratricide incidents during Operation Iraqi Freedom pushed this issue to the forefront of Patriot design and training. The Defense Science Board (DSB) created a task force to examine the lessons from the Operation Iraqi Freedom Patriot systems' performance and determine how future development of the Patriot or follow-on systems could avoid future incidents (Brooks et al., 2012). The DSB

summary report declared that the operating protocol was largely automatic, and operators were trained to trust the information generated by the system's software. The solution proposed to address deficiencies noted in the fratricide incidents was "more operator involvement and control in the functioning of the Patriot battery, which will necessitate changes in software, displays, and training" (Defense Science Board, 2005, p. 2, as cited in Brooks et al., 2012, p. 17). This recommendation focused on Patriot system designs rather than significantly altering Patriot training. The technology, however, received similar examination in terms of how to train to the current automation-human balance.

Concurrent to the DSB inquiry, Hawley and associates examined the impact of automation on air defense command and control operators and the consequences of changing their roles from traditional operators to supervisors of automated processes (Hawley, Mares, & Giammanco, 2005). As explained by Hew and colleagues, "supervisory control is where a machine closes a control loop, and a supervisor intermittently programs the machine" (Hew, Lewis, Radunz, & Rendell, 2010, p. 1). At issue is how two decades of technical enhancements through system evolutions have changed operator roles from being traditional duties to supervisors of automated processes (Hawley, Mares, & Giammanco, 2005). Training, however, did not keep up. "Operators lacked the rigorous training to deal with this different role — a role as supervisor of automated functions and services subordinate to the operator" (Brooks et al., 2012, p. 5). Brooks and his associates concluded that training shortcomings are the result of a lack of proper job task analysis (focusing on system operation tasks rather than supervisory controls tasks), the lack of training requirements reanalysis during or after significant upgrades, and a reliance on training devices that focused on narrow training scenarios or rote training methods. These issues are a direct consequence of the continual evolution and technological automation advances of the Patriot system. Unless addressed by new training designs, these issues are likely to be compounded with the air defense community's pending transformation to the Army Integrated Air and Missile Defense (AIAMD) architecture.

In moving forward with the AIAMD architecture, the Army is developing and testing new air and missile defense (AMD) systems integrating air defense artillery (ADA) sensors and shooters under a common, networked battle command architecture. A critical component of this architecture is the AIAMD Battle Command System (IBCS)<sup>2</sup>. The IBCS comprises hardware and software permitting AIAMD enabled sensors and weapons platforms to be engaged remotely via an integrated fire control network (IFCN) operated from IBCS Engagement Operations Centers. Each sensor and weapons platform will have a plug and fight interface module providing distributed battle management functionality enabling network-centric operations through the IBCS. Although originally designed to integrate a wide range of established and evolving systems, recent decisions regarding developing and fielding a number of these systems have focused resources on the integration of the Patriot missile system into the AIAMD and its supporting IBCS. Thus, this architecture employs an overarching system-of-systems capability with participating AMD components functioning interdependently to provide a level of operational capability not achievable by the individual systems acting alone. Many leaders and

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<sup>2</sup> Although "IBCS" technically refers to the Army's Integrated Air and Missile Defense (AIAMD) Battle Command System, it most often is referred to by its shorter acronym, Integrated Battle Command System (IBCS), to limit confusion when discussed in tandem with the overarching system architecture, AIAMD. The shorter referent will be used throughout the remainder of this report for the same reasons.

training experts are concerned that current training practices and standards will not meet the challenge of developing expertise in these types of complex, technology-intensive systems and architectures (see Hawley, 2011).

While examining the Patriot missile system can enhance our practical understanding of the types of tasks and decision-making required for complex systems, the soon to be deployed AIAMD architecture adds a greater level of complexity to these requirements. The AIAMD architecture will integrate various AMD sensors and weapons into a single, integrated fire control and battle command network. This integration within a system-of-systems design will provide a level of operational capability not readily achievable by these individual systems operating independently within a theater of operations. It is anticipated that the integration of these systems will significantly increase the challenges Soldiers face in monitoring and defending an increasingly dynamic and expanded battlespace, particularly in the areas of sensor operations and communication, command, and control functions. An additional challenge will be a lengthy transition period, during which Soldiers will be required to manage and work in a mixed environment of transitioning IBCS enabled and legacy systems.

Based on many of the issues highlighted by Hawley and his colleagues (see Hawley, 2011; Hawley & Mares, 2006; Hawley, Mares, & Giammanco, 2006), the impact of combining multiple air defense operations, sensors, and weapon systems in an IAMD environment could potentially overwhelm decision makers at each level of the engagement process. Not only will it be critical to ensure the software and systems perform as designed, but careful consideration must also be paid to the projected workload demands and training required in both institutional and unit training environments to prepare Soldiers, and their instructors, to effectively carry out their responsibilities in such a complex, overlapping battlespace. Since traditional FEA strategies have largely been task focused processes designed for fairly well-defined or bounded operational environments, they seem increasingly ill-suited for progressively more complex, multisystem environments that significantly alter the roles of human decision makers and operators within highly automated command and control environments.

## **Method**

As described earlier, the overall goal of this research is to develop new FEA strategies for new/evolving, highly automated, complex systems relying on multilevel command and control integration. In order to establish an operational context for this multiphase research effort, it will focus on current Patriot system training and its evolving transition to the AIAMD architecture. This initial phase of the research will identify, propose, and justify alternative FEA strategies for complex, highly automated systems, in general, and the Patriot missile system, specifically. Subsequent phases of this research will apply the strategy recommended at the end of this report to identify potential gaps in current Patriot training and certification requirements and, later, to Patriot's transition into the AIAMD architecture.

In order to reach the goals of this research, the research team reviewed published literature on FEA strategies, processes, and applications. The team also conducted an extensive review of research on the challenges and issues associated with complex, highly automated systems, with a specific focus on issues impacting their design and application to various training courses or programs of learning. Finally, detailed information was collected and examined from

training units and weapon system subject matter experts (SMEs) regarding current Patriot system components and processes, training systems, and performance requirements.

### **Literature Findings**

Building upon initial literature sources and published reports provided by ARI researchers, the team identified additional relevant literature through an examination of references cited in these initial sources and through online searches of library research catalogues. This resulted in a compilation of peer-reviewed articles, industry association publications, government documents, books, and conference proceedings focusing on FEA, training design and development, as well as identified Patriot training issues and challenges.

This literature was examined to determine the applicability and appropriateness of the reported FEA research to this specific research. The criteria used by the team to evaluate the merits of these works included the publication's discussion of complex, integrated command and control systems; balance of human operator and command automation roles and requirements within complex, highly automated systems; and ADA training requirements, issues, and strategies. The extent to which the information could be generalized to the ADA community was also considered. Specifically, the team determined if and how the literature addressed the following domain areas:

- existing and emerging FEA models and processes;
- human-machine interactions;
- situational awareness;
- individual and collective tasks;
- multiple levels of performance;
- decision points;
- routine and adaptive decision-making;
- cognitive tasks;
- the operating environment; and
- other issues identified by publications that emerged as recurring themes.

The team initially intended to analyze existing FEA models and potential new models that could address the complexities of the identified training systems and issues identified in the literature. During the course of the literature review, however, it became evident that this body of literature did not include specific, well-defined FEA models that could be considered as alternatives to the established, traditionally task-based approaches at the core of military training designs. Consequently, the team focused on analytic models and alternatives that addressed, or potentially could address, the entire instructional design process from beginning to end. The goal of this review was to identify components that could be adapted in whole or in part to meet our project goals.

The following discussion summarizes the team's evaluation of a number of model components and characteristics based on multiple sets of criteria, including the extent to which they addressed issues of interest to the ADA community, e.g., human-machine interactions, situational awareness, adaptive decision-making, collective tasks, critical decision points, and a



military operating environment. FEA process issues, such as data requirements, time, and expertise required for applying the strategy, are also considered in this discussion.

## FEA Approaches and Design

**U.S. Army System Approach to Training Analysis.** The Department of Defense (DOD) provides guidance for the development of instructional systems through the DOD military handbook five-part series, MIL-HDBK 29612-1A, -2A, -3A, -4A, and -5, published 31 Aug 01, where each volume focuses on a unique aspect of training acquisition and Instructional Systems Design (ISD). MIL-HDBK-29612-2A, Instructional Systems Development/Systems Approach to Training and Education (Part 2 of 5 Parts), addresses DOD’s system approach to training and education (i.e. SAT) (U.S. Department of Defense, 2001). The DOD ISD process follows the cyclical “PADDIE” model. “PADDIE” is an acronym for planning, analysis, design, development, implementation, evaluation. The complete DOD ISD/SAT model is shown in Figure 2, as adapted from MIL-HDBK 29612-2A guidance (U.S. Department of Defense, 2001, p. 10).

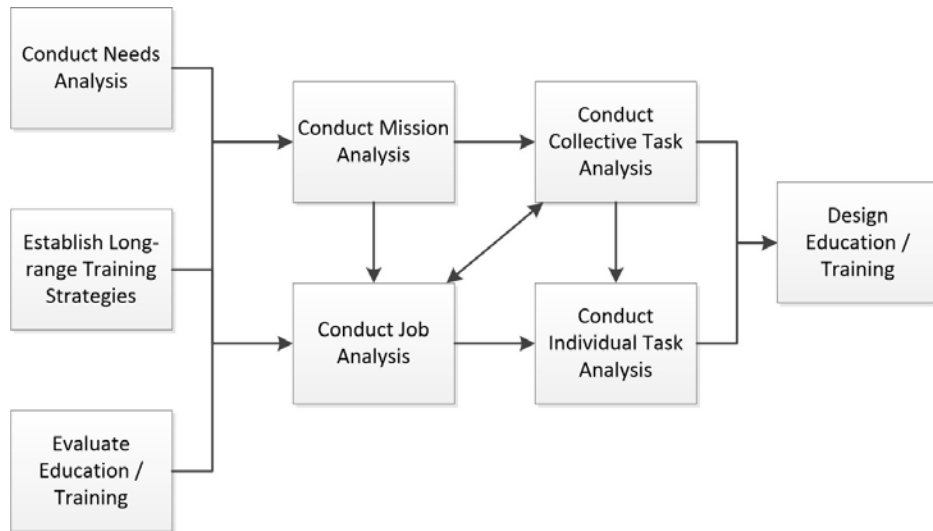


**Figure 2.** DOD ISD/SAT model.

Each branch of the U.S. military adapts DOD guidance to some degree in order to match their specific requirements, doctrine, and language. The Army’s approach to SAT is documented in a series of Training and Doctrine Command (TRADOC) pamphlets; TRADOC Pamphlet 350-70-6 (U.S. Department of the Army, 2004) presents the analysis phase of SAT.

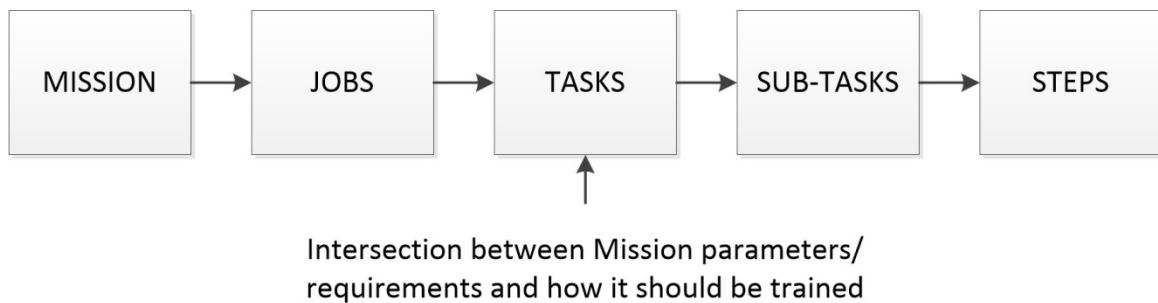
The FEA portion of the Army’s SAT includes five types of training analyses: needs, mission, collective task, job, and individual task analyses. The analysis process flow and relationships are shown in Figure 3. Like other DOD Services, the Army’s SAT process utilizes a variety of analyses, which may or not be directly applicable to any specific project. For example, a training system evaluation may trigger the need for a requirements analysis beginning

with a mission or job analysis, without being part of or included in an actual FEA. Similarly, the project's scope can determine whether collective or just individual task analyses will be conducted.



**Figure 3.** U.S. Army SAT analysis process (U.S. Army, 2004, p. 10).

As briefly described earlier in this report, the Army's SAT analysis is primarily a task-based analysis process. In other words, tasks are the primary unit of analysis, regardless if those tasks are cognitive or psychomotor in nature. As shown in Figure 4, the mission is deconstructed into jobs, which, in turn, are deconstructed into tasks. Tasks, in turn, are deconstructed into sub-tasks and steps. Tasks, however, are the basis for determining learning objectives and training strategies in subsequent analyses. Task attributes, such as performance difficulty and required knowledge or skill learning levels, inform decisions about training methods and delivery options. Tasks in a task-based analysis represent the intersection between what to train (deconstructed from mission performance) and how to train (based on specific task attributes).



**Figure 4.** Mission-task deconstruction.

This process provides for a step-wise standardized procedure that may be applied regardless of specific missions or jobs. While the task-based process provides a logical linkage between mission requirements and training tasks, the deconstructive nature of the analysis also results in some weaknesses. Task deconstruction usually results in the tasks being analyzed out of context. One consequence is that crew and/or system coordination is insufficiently analyzed.

The standard process identifies collective tasks, but orients analysis on individual performance rather than a systems understanding. This yields an identification of tasks that must be coordinated but fails to identify or analyze the coordination processes necessary for successful mission performance. A second consequence is that higher level cognitive requirements that reflect task context, such as situational awareness or crew resource management (CRM), are often ill-defined, which results in ill-defined training requirements and training recommendations.

A review of Patriot training documentation, research, and training observations supported our earlier assertion that current Patriot training was based on the Army's SAT task-based analysis to determine training requirements. While this approach provided a comprehensive framework for determining and structuring Patriot training tasks, it also contains a focus on individual task performance with a minimal understanding of how the automated system may affect Soldiers' cognitive interpretation of mission events or communication and coordination among crew members.

Given the limitations of the current SAT approach, it was determined that alternative analytic approaches should be considered. The current approach does not seem to adequately address interactions within complex systems. Secondly, the current approach, while task-based, focused more on the physical tasks required to operate a system rather than the complex cognitive tasks required to successfully complete a mission. Last, the current approach focuses on individual performance, while the performance of more complex missions such as required for Patriot operations require integrated performance as a member of a crew/team.

**Alternative FEA Considerations.** The DOD ISD process, in general, and the U.S. Army's SAT analysis process, specifically, focus on tasks required for successful operation of systems and missions. Army organizations conduct FEAs to support course design, development, implementation, and evaluation. While specific analytic models and processes may vary across projects and organizations, the ISD guidelines established by the DOD and U.S. Army set standards that must be adhered to when designing and structuring training programs. This research provides an opportunity to identify, explore, and test alternate methods for conducting FEAs. It is our opinion that a complementary FEA approach (i.e., one that leverages existing Army task-based processes and terminology) is most desirable for framing FEA applications to future training situations.

Variation in how or what analyses are conducted, depending on project characteristics, needs, or goals, is routine and within the bounds of established ISD guidelines and standards. For example, in the conduct of a large-scale complex U.S. Navy aviation FEA, Weeks, LeVita, and Hadley (2008) incorporated a bottom-up analysis (i.e., categorizing tasks, duties, and tasks based on task performance) to supplement the usual top-down analysis (i.e., mission-duty-tasks) employed by the Navy. Likewise, Buehner, Drzymala, and Brent (2010) incorporated a multilevel analysis to support the identification and delineation of complex tasks associated with large crew mission performance.

The literature on alternative FEAs is limited. There appears to be little impetus and opportunity for practitioners (Government or otherwise) to aggressively seek or develop new approaches due to the requirements of established DOD standards and processes. Despite the

historical success of the current DOD FEA processes, there is growing concern that these processes are insufficient to address emerging analytical needs for complex tasks and the way modern warfare is conducted (see Hawley, 2011; Hawley & Mares, 2006; Hawley, Mares, & Giammanco, 2006). Task complexity is increasing as the technology of tools used by Soldiers advances. Individual Soldiers can accomplish more with advanced tools; but doing more translates into increased information processing demands, situational awareness requirements, decision-making, communication, and coordination. Complex tasks that are difficult to deconstruct and analyze using standard FEA processes can be roughly categorized as individual information-processing, situational awareness, and adaptive decision-making; and collective (team) communication and crew management.

In a study of best training design practices, Visscher-Voerman and Gustafson (2004) examined how expert designers, as identified by their peers, implemented the ADDIE model.<sup>3</sup> The strategies of 24 expert professional designers were examined, including the types of analytic models incorporated into their front end analyses. While this study did not focus on DOD practices, the most common type of analysis utilized by these experts was task analysis (see Table 1). This study illustrated that FEAs are not fixed processes, but employ a variety of analyses dependent, presumably, on project needs.

Table 1.  
*Types of “ADDIE” Analyses*

Analysis Type	Number of Designers Using (N=24)
Problem analysis	3
User needs assessment	6
Reuse or repurpose analysis	5
Prototype design and analysis	4
Solution analysis	6
Content analysis	6
Task analysis	8
Feasibility study	5

Cognitive task analysis (CTA) is a specialized approach that attempts to capture and understand cognitive processes that underlie behavior that may be used to supplement or replace “normal” task analysis (see Chipman, Schraagen, & Shalin, 2000; Clark & Estes, 1996). Like other types of analyses, CTA can be integrated within a FEA approach. CTA is not a single approach, but represents a collection of more than 100 methods and processes (Yates, 2007). Although specific processes vary, all assume that understanding comes from information provided by experienced, proficient experts in the domain under study (Munro & Clark, 2013). While CTA exists as a separate field of study, its principles and practices are often incorporated into task analysis procedures in common practice. For example, the term “behavioral” task has been generally replaced with “psychomotor” task, an acknowledgement that most tasks are a combination of cognitive process and behavioral actions. However, CTA offers a more cognitively focused data framework that can be incorporated into an alternative FEA process.

<sup>3</sup> This model assumes that planning is an interactive and continuous component of the core ADDIE, thus planning is not identified as a separate process.

An alternative FEA model presented by Gordon (1991) provides a framework loosely based on three levels of human cognition: implicit processing, rule-based, and analytic. Gordon's proposed approach is oriented to the development of artificial intelligence systems and is subsequently strictly cognitive in nature. The lesson of Gordon's research is that an FEA must gather information relevant to certain factors, such as cognitive characteristics, and use that information to guide subsequent development. This approach is, of course, common to most FEA strategies and offers little guidance for military training system designs.

Van Merriënboer and colleagues (2003) detailed an instructional design approach oriented toward complex learning according to Cognitive Load Theory. This Four-Component Instructional Design model (4C/ID) (see also van Merriënboer, Clark, & de Croock, 2002) couples complex problem solving with completing procedures matching an authentic set of tasks. It incorporates common training principles such as scaffolding, whole task practice, and just-in-time learning to allow learners to navigate an increasingly complex learning environment through their own increasing skill-sets and just-in-time external support that provides information on performance and knowledge requirements. One of the key discriminating elements of van Merriënboer et al.'s model was the identification of appropriate part-tasks that supports very complex, whole-task learning. This approach required that sufficient information be gathered to inform the four principle components of the model:

1. learning tasks (i.e., the learning tasks need to be identified);
2. supportive information (i.e., the knowledge or information needed to perform each task);
3. procedural information (i.e., the steps and processes necessary to performance each task);  
and
4. part-task practice (i.e. the constituent elements of each task).

The authors also differentiate between variable (e.g., reasoning and decision-making) and recurrent (e.g., routine) tasks, which each suggest different types of training approaches.

In a recent review of training efficacy, Vogel-Walcutt and colleagues (2013) concluded that technology-based experiential learning approaches are the best ways, to date, to train military adaptation, decision-making, and problem solving. The authors argued, however, that most training systems are best described as “practice platforms” rather than training devices, due to insufficient use of instructional design principles in the original design of the systems. The appropriate use of instructional design principles that match design considerations to appropriate instructional methods and media must be supported by sufficient and appropriate data collected during an FEA. Platforms intended to train adaption, decision-making, and problem solving must provide trainees with opportunities to try, fail, and learn, rather than simply practicing routine or predictable tasks. The FEA, then, must identify and analyze real world situations and environments that require more complex behaviors and skills.

Despite interest in altering FEA models to better address more cognitive, advanced, and crew-based training tasks, alternative FEA models and processes and processes have not gained a significant foothold in the training community. Contrary to the well defined precedence (and requirements) of the standardized DOD model, alternative approaches are typically steeped in

theory and lack pragmatic instruction for non-expert practitioners. A challenge, therefore, is to identify alternative approaches that can be framed for practical application.

## **Collective Training**

One basic FEA question is “Who needs to be trained?” This question is often answered before the analysis is begun. The scope of an FEA is typically defined by a personnel designation, which is then used to further define associated mission, jobs, and duties. A potential shortcoming of this standard approach is that it frequently removes the individual Soldier from the context of what needs to be trained. In other words, a Soldier's individual mission, jobs, duties, and tasks are prioritized above the unit's mission, and collective tasks are conceptualized as an off-shoot of an individual's task performance. The mission, not specific personnel or task defined positions, should be the determining factor in deciding “who” should be included in the FEA. In the case of Patriot, it is quite clear that demands placed upon the entire Patriot crew should be carefully considered.

Teamwork and teamwork skills are closely related to expertise. Kozlowski (1998) found that expertise is best developed within intact teams operating in realistic performance settings. Intact teams are those teams that remain together to work as a crew, rather than the team membership changing for each mission. Following this teamwork orientation, Hawley and Mares (2007) suggest borrowing from crew resource management (CRM) research and strategies. As described by Helmreich and Foushee (1993), CRM focuses on crew-level, rather than individual level training and performance processes and outcomes. CRM seeks to optimize “...not only the person-machine interface and the acquisition of timely, appropriate information, but also interpersonal activities including leadership, effective team formation and maintenance, problem-solving, decision-making, and maintaining situation awareness” (Helmreich and Foushee, 1993, p. 4). While the term has been most commonly applied to aviation disciplines, CRM provides a proven framework for identifying, managing, and developing crew-based processes and proficiencies. Hawley and Mares (2007) identified a number of common CRM training elements that aligned to behavior categories directly relevant to Patriot crew performance:

- mission planning and evaluation;
- task management;
- enhancing situational awareness;
- crew coordination;
- communications;
- risk management; and
- tactics employment.

What is important to consider is that each of these CRM proficiencies reflects well-defined collective or team behaviors and outcomes, and related performance areas for individuals operating complex systems. Although each member of the crew has unique individual responsibilities that contribute to the whole, the crew's performance is a collective outcome that requires more than the simple aggregation of isolated individual outcomes within a standardized performance sequence. For example, if communication and coordination between crew

members breaks down and hinders the transfer of critical information within the crew, it is difficult to see how the crew, or the appropriate command positions, can arrive at a correct decision or expediently resolve an issue. This communication transfer, often critical in aviation circumstances, is also relevant to situations such as the Patriot. Communication among the crew and to higher authorities is critical to successful mission performance. Through observation, this communication appears most successful when common team terminology is established within the intact team.

Kozlowski and Klein (2000) provide a useful framework for differentiating between individual, collective, and other team based requirements. Team members engage in task work and teamwork processes. Individual task work elements are the performance components that do not require interaction with other team members. Teamwork, on the other hand, encompasses both the interdependent components that must be performed by multiple individuals (i.e., collective tasks), as well as the behaviors within the team that promote high performance (e.g., good communication and coordination). Team performance is thus the result of individual task work, collective tasks, and the interaction of the team itself that must be managed and coordinated to achieve successful outcomes. Thus, teamwork can be defined as “the interdependent components of performance required to effectively coordinate the performance of multiple individuals” (Salas, Cooke, & Rosen, 2008, p. 541). Van Berlo, Lowyck, and Schaafstal (2007) also concluded team training must consider both task work (primarily the cognitive and technical skills necessary to perform tasks) and teamwork (primarily the social and communicative skills required to function within a team).

Cooke, Salas, and Cannon-Bowers (2000) summarized team-based competencies into three primary dimensions: cognitions, skills, and attitudes. These competencies, while similar to traditional task categorizations for individual performance, refer specifically to the team-based dimensions of cognitions, skills, and attitudes. For example, team or collective cognitions refer to those cognitive tasks performed as a member of team, rather than as an individual. The same is true of skills and attitudes. These competencies reflect those of the team interactions, rather than focusing only on individual performance. Weaver, Rosen, Salas, Baum, and King (2010) have taken further steps to define these competencies as reflected in Table 2. Most competencies are unique to team performance environments, and all reflect a team orientation. For example, “accurate/shared mental models,” a competency within cognition, reflects the mental organizational structure or model that an individual has relative to the role in and interaction with the team. Thus, this competency includes an individual level requirement (i.e., accuracy) and a collective requirement (i.e., shared). Other competencies, such as mutual trust, backup behavior, and conflict management, are relevant only in a collective or team environment. Team-based competencies can inform collective training requirements that may not be identified from a solely task-based analytic model.

Table 2  
*Team Training Competencies*

<b>Competency Category</b>	<b>Competency</b>	<b>Descriptor</b>
Attitude	Mutual trust	Trust across and between team members
	Team/collective efficacy	How well the team works together effectively
	Team/collective orientation	Common focus of the team
	Psychology safety	Feeling of security in team and decision
Cognition	Accurate/shared mental models	Common cognitive model for mission activities
	Cue-strategy associations	“Triggers” that provide cues to associate action
Behavior	Closed-loop communication	Communications within the team
	Team leadership	Leadership roles for each crew member
	Mutual performance monitoring	Individual monitoring of team performance
	Backup/supportive behavior	Performance of the individual that benefits the team
	Conflict management	Management of disputes within team
	Mission analysis	Individual, collective analysis of desired outcomes
	Team adaptation	Ability of team unit to adapt to any change

Adapted from Weaver, Rosen, Salas, Baum, and King (2010)

Conceptualizing mission performance as composed of individual tasks and team competencies leads also to an alternative view of performance assessment. In this instance, individual performance metrics should be supplemented by team-based metrics in order to clearly integrate team performance outcomes as a part of mission performance assessments. In their research measuring teamwork within an antiaircraft team, Smith-Jentsch, Johnston, and Payne (1998) concluded that there are differences between team dimensions for training and team dimensions for assessment. Based on their research, assessment measures of team competencies need to be discrete and observable, even though that is not necessarily always the case for other training tasks, skills, or other requirements. Thus, Smith-Jentsch et al. (1998) refined the the team competencies they identified to eliminate redundancies and nonobservable behavior. They also expanded the number of training dimensions that their research indicated were directly relevant to desired team performance outcomes. Applying the same approach to our findings, we refined the basic dimensions summarized in Table 2 to incorporate assessment parameters supported by our research review and documented crew/team training requirements. While the “original” dimensions may still facilitate the identification of general team training requirements, the refined dimensions summarized in Table 3 provide a more detailed foundation for informing what will be needed in an FEA strategy.



Table 3  
*Teamwork Dimensions*

<b>Training Dimension</b>	<b>Assessment Dimensions</b>	<b>Descriptor</b>
Communication	Communication	Ability of the team to connect in speech and writing
Feedback	Information exchange	The way in which communication occurs resulting in understanding by the recipient
Backup behavior	Supportive behavior	Demonstration of the way in which an individual's behavior is supportive of team outcomes
Team initiative / leadership	Team initiative / leadership	The way in which the individual crew members and the team take charge to achieve the goals of the team
Monitoring		Tracking of team performance and outcomes
Coordination		Organization and synchronization of effort within them
Situational awareness		Ability of individual crew members to know what is going on around them

Adapted from Smith-Jentsch, Johnston, and Payne (1998)

Huddlestone and Pike (2008) recommended supplementing task-based analysis with analyses that focus on collective training requirements. They pointed out that collective tasks typically fall into processes in the realms of command and control, communication, and teamwork. Based on this research, they developed a training needs analysis (TNA) Triangle Model that supplements traditional task analyses with two additional domains: training environment analysis and training overlay analysis (Huddlestone & Pike, 2009). Training environment analysis examines real, synthetic, and communications environments that surround an operational setting. Training overlay analysis focuses on instructor roles and other instructional design elements. The training environment analysis is particularly relevant to the current research as it emphasizes the need to identify the parties and processes associated with each training task. An examination of the training environment places the subject area into a mission context and brings other individuals and organizations, with their associated interdependent procedures and processes, into the analytic framework.

Collective training within a team context is not a simple matter of joining individual tasks at the proper time and place. Team researchers agree that collective and team training are subject to different processes, attributes, requirements, and goals than individual training. Lum, Fiore, Rosen, and Salas (2008) suggested that collective training for team problem solving needs to undergo four collaborative stages: (a) knowledge construction, (b) collaborative team problem solving, (c) team consensus, and (d) outcome evaluation and revision. Knowledge construction is tied to team performance, in general, with multiple researchers pointing to the importance of shared cognition (Salas, Cooke, & Rosen, 2008) or shared mental models as precursors to successful team performance. Shared cognition is the collective cognitive activity from individual group members where the collective activity impacts group goals. Shared cognition is

linked to knowledge. Thus, knowledge possessed by effective teams has been referred to as shared knowledge, or shared mental models (Klimoski & Mohammed, 1994). In their review of 50 years of team performance research, Salas and his associates concluded that shared cognition is a critical driver of team performance (Salas & Fiore, 2004, as cited in Salas, Cook, & Rosen, 2008). Shared cognition is particularly important in developing shared mental models, team situation awareness, effective team communication, and team decision-making.

## **Decision-making**

Decision-making and problem solving are usually distinguished as separate processes. However, as Jonassen (2012) pointed out, decision-making is really a core component of problem solving. Problems can be categorized along a continuum from well-structured to ill-structured (Jonassen, 2000). As problems become more ill-defined or complex, the decision-making process, in turn, becomes more complex, encompassing multiple types of decisions and an iterative rather than linear process. According to Yates and Tschirhart (2006), there are many different kinds of decisions, including:

- choices, a selection is made from a subset from larger set of alternatives;
- acceptances/rejections, a binary choice (i.e., yes or no) in which only one specific option is accepted or not;
- evaluations, statements of worth backed up with a commitment to act; and
- constructions, attempts to create ideal solutions given available circumstances and resources.

Planning for and executing military operations clearly require all four types of decision-making, with the decisions often made under great stress and/or time pressures. As the decision type becomes more complex, so, too, should its associated training. Standard FEA and task analysis procedures have proven adept at determining training requirements for choices and acceptances/rejections, as these decisions often follow rule-based procedures or steps. However, determining the proper training requirements for evaluation and construction decisions have proven a great deal more elusive.

Decision-making during the planning and executing of military operations can be viewed as a fairly unique form of decision-making. While one hopes that operational decision-makers rationally consider an extensive array of potential options and variables, it is understood that Soldiers typically do not have the time to methodically complete a decision-matrix or extensive risk assessment in the middle of an operation or, as with Patriot fire control officers, to arrive at a decision to engage an unidentified threat. Thus, the process is more along the lines described by Gigerenzer and Goldstein (1996), who argued individuals' inferences during decision-making are frugal and do not rely on much deliberation. Mission planning intends to limit major decisions during operations, yet there are limits to what can be reasonably known, predicted, and planned in any situation or environment. The greatest challenge for military decision-makers is not what to do when events unfold as planned or anticipated, but what to do when the unexpected (and unplanned) occurs and more adaptive decision-making that can adjust to an evolving, fluid operational environment is needed.

Klein, Calderwood, and Clinton-Cirocco (1986) examined decision-making by proficient personnel under conditions of time pressure where life and property were at stake, similar to what is the norm in military operations. The authors found evidence of simultaneous comparisons and relative evaluation of two or more options in less than 12% of the decision points. Using experience and a pre-established mental model were found to be the most common processes to assess the situation as typical and to identify a course of action. Based on this research, the authors proposed a Recognition Primed Decision (RPD) model that emphasized the use of recognition rather than analysis for rapid decision-making.

Fadde (2009) has since applied the RPD model to training environments, proposing the training of recognition skills to hasten the development of expertise. RPD has been assumed to require years of applicable experience. Fadde, however, suggests expert recognition performance, which requires a rapid sequence of recognition, decision, and action, can be accelerated by training recognition skills. Fadde points out, "Recognition training does not replace direct instruction in rules, concepts, and procedures but rather enhances it...at the appropriate time in the learner's development" (p. 360). Given the demand for proficient Patriot crew members, it seems worth exploring the possibility of integrating Patriot specific "expertise" training into the training continuum.

Satisficing, another decision-making strategy, may also have relevance to this discussion. Satisficing is a decision-making strategy or cognitive heuristic that entails searching through the available alternatives until an acceptability threshold is met (Coleman, 2006). In a team environment, the team members search through available choices to come to consensus on the best strategy. While the strategy itself may apply to decision-making in complex situations, it also is dependent upon the types of decisions to be made, and the timing of the decisions. Satisficing is a strategy to be considered when there is an unlimited amount of information available and it is necessary to eliminate options (Sternberg, 2009). In the use cases to be considered for Patriot training, the application of this model may be relevant.

## **Expertise**

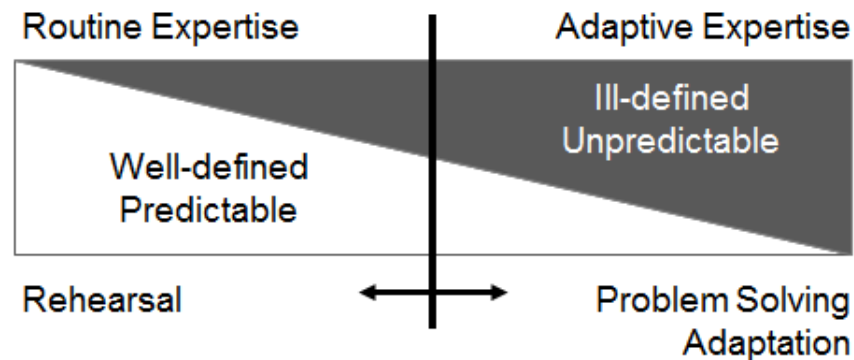
Training to expert performance is not typically addressed in military training FEAs. This may be due to the expectation that expertise is achieved through field experience and on-the-job training, two things that do not often fall within the realm of an FEA training requirements analysis. It has been pointed out that expertise can be viewed as a learning process characterized as an active problem solving process in a specific context (Valkeavaara, 1999). Furthermore, van Gog, Erikson, Rikers, and Paas (2005) pointed out that expertise is not related to the amount of experience in the domain, but rather the amount of deliberate effort and practice that has been applied to improve performance. According to Valkeavaara (1999), a better understanding of expertise in the field can be achieved by taking a closer look at problematic situations encountered by experts in the field, yielding information about the types of situations, the types of solutions sought or attempted, and the type of knowledge gained from experience. Important to an FEA is the type of knowledge gained from problematic encounters, and what knowledge base is needed to place operators in a position to resolve and learn from those situations. A related question is whether problematic situations (and accompanying solutions or knowledge gained) can be categorized in a way to inform FEA data requirements and specific training recommendations.

Chi (2006) identified a number of expertise-related concepts relevant to military settings, including a proficiency scale of six expertise related categories: novice, initiate, apprentice, journeyman, expert, and master. These categories may be helpful in constructing a performance continuum that aligns with training requirements, although the categories do not align directly to commonly used military categories. Of greater interest in determining what defines an “expert,” Chi also described manifestations of experts' skills. According to Chi, experts excel in the following ways (note that all references are cited in Chi, 2006, pp. 23-24):

- experts generate the best solutions in solving problems, typically faster and more accurately than non-experts (Klein, 1993);
  - experts can detect and recognize cue stimuli faster than novices, as well as underlying structures of problems or situations (Chi, Feltovich, & Glaser, 1981);
  - experts analyze problems, particularly qualitatively, compared to novices (Simon & Simon, 1978; Voss, Greene, Post, & Penner, 1983);
  - experts have more accurate self-monitoring skills in terms of their ability to detect errors and the status of their own comprehension compared to non-experts;
  - experts are better at choosing the most appropriate strategies compared to non-experts;
  - experts are more opportunistic than novices, better at utilizing available resources (Gilhooly et al., 1997); and
  - experts easily retrieve relevant knowledge and strategies (Alexander, 2003, p. 3) and perform skills more automatically (Schneider, 1985) than novices.
- On the other hand, experts also have shortcomings, also identified by Chi (2006):
- expertise is domain-limited, and not usually transferable to other domain areas;
  - experts may be overconfident and overestimate their understanding of a situation (Chi, 1978, cited by Chi, 2006);
  - experts may gloss over a problem or situation and fail to perceive or recognize details attended to by novices;
  - expertise is context dependent (i.e., domain knowledge may not be accessed by experts if contextual cues of a problem or situation are not recognized);
  - experts are often inflexible, and not as ready as novices to adapt to new rules or procedures;
  - experts are often inaccurate in predicting performance of others (particularly novices) and are less likely than novices to incorporate peer feedback into their behavior; and
  - experts are often biased in their assessment, with the bias reflecting their knowledge and experience domain.

The above expert characteristics should be considered during the course of an FEA, particularly when collecting and analyzing data from subject matter experts. While experts can provide the most detailed and “tested” information, they may also misjudge the relevance, difficulty, or training implications of operational tasks and skills. Furthermore, while experts may be more proficient and capable of rapid decision-making, other qualities (e.g., perception biases, overconfidence, or inflexibility) may negatively influence their demonstrated expertise over mission events in the operational setting.

Kozlowski (1998) differentiated routine expertise from adaptive expertise. Kozlowski's relationships between expertise, situation predictability, and task requirements can be depicted visually as illustrated in Figure 5. According to Kozlowski's research, routine expertise is effective in well-defined predictable situations, and can be achieved through the learning and rehearsal of routine tasks. Adaptive expertise, on the other hand, is needed for success in ill-defined, unpredictable situations. Adaptive expertise requires problem solving and adaptation of previously learned skills, knowledge, and experiences to achieve successful task outcomes. Routine and adaptive expertise lies on a continuum where the less defined or predictable a situation becomes, the more adaptive expertise is needed to be successful. Conversely, the more defined or predictable a situation is, the more likely routine expertise is sufficient for success. Expertise requirements (i.e., routine versus adaptive) can be determined by understanding the situation and operating environment. If, for example, the heavy horizontal bar in Figure 5 represents the predictable (left end of the scale) versus unpredictable (right end of the scale) nature of the Patriot mission environment, then the white portion left of the vertical bar represents the realm of tasks and skills that can be trained using routine task rehearsal while the gray portion left of the bar represents more complex tasks and skills that require more adaptive expertise.



**Figure 5.** Expertise Continuum.

Following our illustration in Figure 5, it can be theorized that some Patriot training and operations concerns are associated with tasks and skills that lie in the adaptive expertise (gray portion left of the bar). While there is heavy reliance on checklists for task performance, the areas in adaptive expertise may be required is in those situations where decision-making in uncertain circumstances occurs. If this is confirmed through an adequate FEA, then new or revised Patriot training should emphasize the acceleration of adaptive expertise required for those complex tasks.

According to Kozlowski (1998):

Adaptive expertise entails a deep comprehension of the conceptual structure of the problem domain. Knowledge must be organized, but the structure must be flexible. The process goes beyond procedural knowledge of an automatic sort. Adaptive experts understand when and why particular procedures are appropriate as well as when they are not. A key factor for the development of adaptive expertise is the encouragement of active learning strategies during training. (p. 119)

Hawley (2009) recommended three strategies that apply Kozlowski's principles to Patriot training: (a) extensive deliberate practice with expert feedback; (b) scenarios characterized by increasing variability and novelty that challenge routine skills; and (c) a focus on developing sense making skills that facilitate an operator's ability to recognize when to shift from automatic processing to critical thinking and problem solving (see also Kozlowski, 1998).

Other researchers offer additional recommendations for training expertise. Fadde (2013) proposed an instructional design theory of Expertise-Based Training (XBT) as a way to train expertise by decreasing decision-making time. This approach is based on the recognition component of the previously described RPD model, with a focus on how to accelerate the decision-making training. Fadde's strategy was designed to be introduced early in the training continuum, and can be delivered using laptops or mobile technologies to supplement and not replace current training. Bills (2009) concluded that a "total training approach" to complex training, including simulation and gaming, will advance metaskill development associated with expertise. Adams and Ericsson (2000) demonstrated the effectiveness of problem focused training for aviation, but point out training effectiveness varies between novices and experts. Finally, it has been shown that one effect of expertise is the development of applicable schemas, which, in turn, reduce the working memory load (Van Gog, Ericsson, Rikers, & Paas, 2005). While schemas are likely developed during Patriot training, it is unknown whether this schema development is a targeted training objective or an unintended consequence of incoming Soldiers' implicit prior knowledge and experiences.

### **Situational Awareness and Automated Systems**

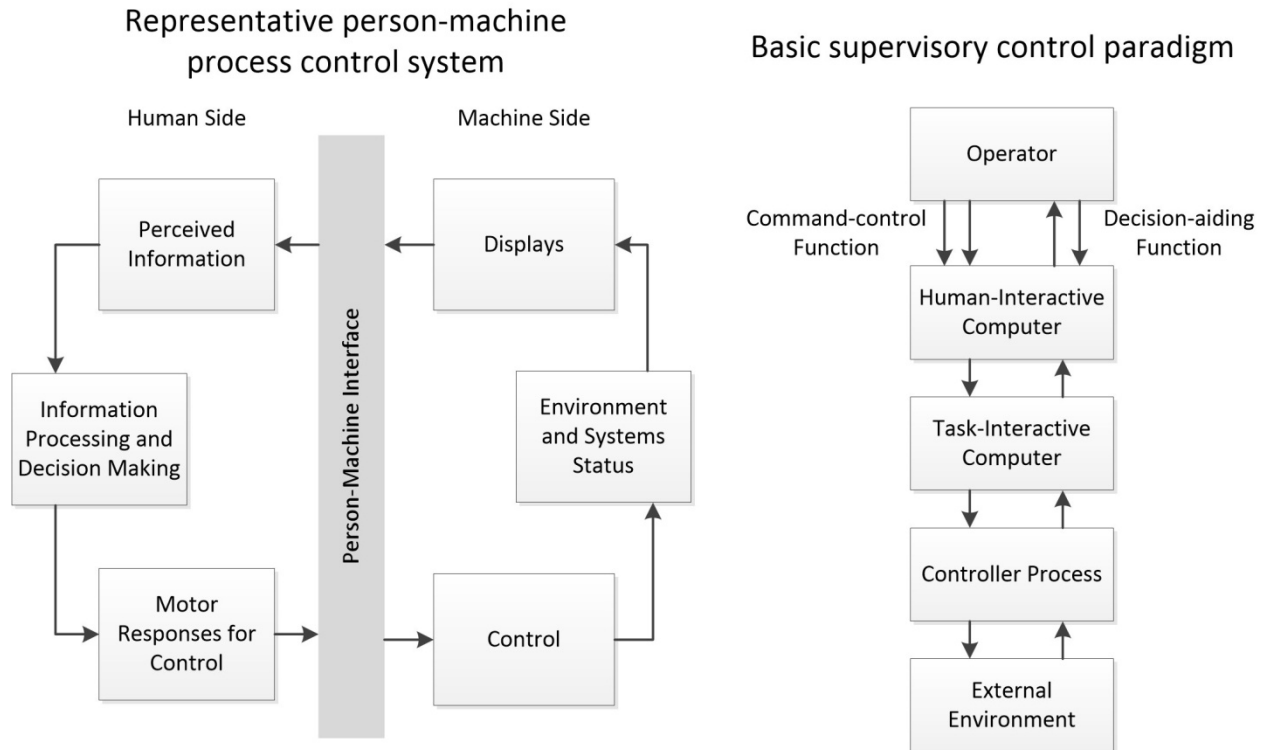
Situational awareness is a construct common to military operation environments and is closely tied to Patriot operational concerns, including decision-making (Endsley, 1997b; Guitouni, Bélanger, & Wood, 2011), supervisory control (Hew, Lewis, Radunz, & Rendell, 2010), and vigilance (Warm, Parasuraman, & Matthews, 2008). Situational awareness is a critical input for, but is separate from, mission and operational decision-making. Situational awareness skills enable decision makers to process the context for evaluating events, identifying potential courses of action, and determining appropriate interventions. Thus, situational awareness can be conceptualized from multiple perspectives. Perhaps the most common framework considers it in terms of differing levels of awareness. Endsley (1997b) described three levels of situational awareness: (a) Level 1, perception of the elements in the environment, (b) Level 2, comprehension of the current situation, and (c) Level 3, projection of future status. Guitouni, Belander, and Wood (2011) on the other hand conceptualized situational awareness as one of three types: (a) Baseline or Routine, to provide monitoring or warning services; (b) Targeted, focused on a specific operation or event; and (c) Decision Support, which integrates information from baseline and target situational awareness necessary to decide on an intervention.

Nofi (2000) pointed out that situational awareness is not just an individual construct, but that it applies to teams and collective environments, as well. Harknett (1996, as cited in Nofi, 2000) first advanced the idea of shared situational awareness as a key manifestation of organizational change through electronic networking technologies. According to Nofi, shared situational awareness implies all team members interpret a given situation in the same way. Stanton et al. (2006) built upon this position by insisting each team member's unique, but

compatible, situational awareness contributes to the shared situational awareness of the team. Stanton's model of distributed situational awareness seems more reflective of common military operational environments such as Patriot, where each crew member is receiving varying, distinct types and amounts of information. Achieving and maintaining effective collective or team situational awareness is a significant challenge in complex command and control operations. Over time, operators and designers have often turned to technology to enhance Soldiers' situational awareness or, at least, their ability to quickly discern critical aspects of the situation that require direct action or interventions. With a greater capacity than their human counterparts to near simultaneously monitor and interpret an increasingly broader range of varied inputs from multiple systems and to quickly act on the calculative outcomes of preset conditions, automated processes and systems have grown in scope and presence throughout the military.

While the proliferation of automated systems may be intended to reduce operator workload, they also typically decrease operator situational awareness by lessening operators' interaction with the system (Endsley, 1997b). A key aspect of situational awareness, vigilance, is affected, perhaps to new levels of complacency due to increasing over-reliance on automation. Vigilance failures significantly reduce situational awareness as operators may neglect monitoring tasks, attempt to monitor but do so casually or poorly, or are aware of indicated problems but falsely attribute any alarms to system errors (Endsley, 1997b). Hew and associates (2010) attribute poor situational awareness in automated systems to the fact that these systems require a different form of situational awareness that may be neglected during training, related to the interaction of vigilance in situations with automated systems.

Hawley, Mares, and Giammanco (2005; 2006), Hew (2010), and their respective associates also agreed that automated systems present unique, unexpected challenges to situational awareness. Based on their research, these challenges are directly tied to supervisory control. Supervisory control is where a machine closes a control-loop, i.e. decides what action is required and executes it, and a human supervisor intermittently adjusts the machine. The differences between traditional human control and supervisory control paradigms are summarized in the diagrams in Figure 6, as adapted from Hawley, Mares, and Giammanco (2005).



**Figure 6.** Comparison of supervisory control versus person-machine control processes. Adapted from Hawley, Mares, and Giammanco (2005)

As Figure 6 illustrates, in the supervisory control paradigm, the operator is further removed from controlling and making decisions within the environment. Furthermore, in the supervisory control paradigm, the system provides a more advanced decision aiding function through which the system assumes control of the actions and processes that results in that decision aid. Hawley and his colleagues (2005, pp. 19-21) raise a number of concerns resulting from this transition of controls, interactions, and processes to an automated system:

- Newly automated systems seldom provide all anticipated benefits. There are often discrepancies between what operators expect, what designers require, and actual system performance.
- While monitoring is usually increased, automation does not decrease nor necessarily simplify work requirements, but changes them.
- A belief in a system's infallibility can lull operators into a false sense of security. Consequently, operators may not perform necessary checks. Conversely, in systems that frequently fail, operators may lose trust in the information they receive from the system.
- Automation transforms operators into system monitors rather than active controllers. This is a particular design problem in balancing control between the operator and the system.
- As more operator control functions are replaced by the system, the operator becomes less familiar with how things should function, potentially delaying response time to abnormal situations or events.



- Automation does not eliminate the possibility for human error, but relocates human errors to a different, often higher, level. These higher level errors can be more significant than human errors in a less automated system.
- Highly automated systems tend to reduce the frequency of crew member interactions, resulting in a need to intentionally maintain crew communication and coordination.
- The operation of automated systems often requires more training, particularly at a higher conceptual level.

Hawley, Mares, and Giammanco (2005) reported that these issues can and must be addressed in the designs for Patriot training. Using a proven framework from similar performance domains, Hawley and colleagues cited a training model for complex decision-making (see McPherson & Kernodle, 2003) that outlines three training areas necessary for effective performance: (a) declarative knowledge, facts and rules governing the problem situation; (b) tactical knowledge, analysis, planning, self-monitoring, anticipation, etc., what to do; and (c) procedural knowledge, how to execute the intent decided in step two.

Hawley and his colleagues concluded that Patriot training emphasizes areas (a) and (c), but does not adequately address area (b). They observed that the missing pieces involve translating background knowledge and the current tactical situation into an appropriate course of action. They further argued that Patriot training must change to include the conditions for deliberate practice, including valid training scenarios, effective after action reviews, and time to develop the necessary levels of expertise (Hawley, Mares, & Giammanco, 2005, pp. 25-26).

As discussed earlier in this report, an FEA should provide an analytic framework that lays the foundation for training designs and programs. The standardized DOD task-based FEA, in general, and the Army's corresponding SAT process, specifically, is usually a sufficient and effective means to determine most individual, procedurally defined training requirements. Advantages of using a task-based analysis include the fact that it:

- breaks down mission requirements into discrete, easy-to-manage parts;
- usually provides clear start and stop indications;
- provides a relatively easy translation of tasks into learning objectives;
- includes performance tasks that are relatively easy to measure; and
- relies upon standard and common practices.

Task-based analysis alone, however, is less effective in analyzing complex and/or cognitively defined tasks. It is especially insufficient for analyzing tasks that require adaptation or variation from established standards, procedures, or routine practices. Thus, key limitations of task-based training analysis include:

- an insufficient capability to address cognitive tasks that are difficult to deconstruct and analyze;
- the difficulty, and often insufficiency, of translating individual tasks into team (or collective) tasks; and
- typical conceptualizations of collective tasks as an aggregation and/or alignment of discrete individual tasks.

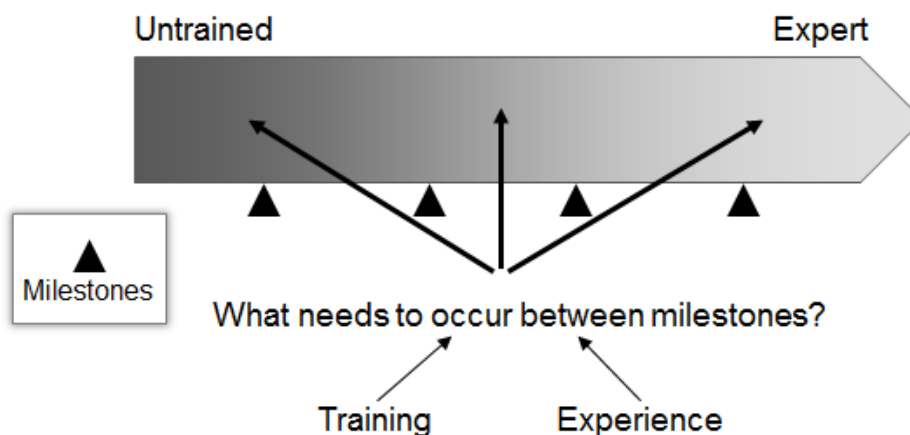
Supplementing, rather than replacing, the Army’s SAT process with targeted analyses should maintain the advantages of the current process, while addressing its disadvantages and weaknesses in regards to more complex contexts.

### Other FEA Approaches

The scope of training contexts and issues drive the design of any FEA approach. Thus, the scope of an FEA must be sufficient to ensure the questions, issues, or deficiencies behind the triggering event(s) will be addressed sufficiently. Two questions essentially determine an FEA’s scope: (a) who to include (i.e., training for what personnel category(s)); and (b) what aspects of training should be included in the analysis?

In the case of Patriot training, the question, “Who should be included in the FEA?” can be derived directly from existing mission requirements. This is due to the crew orientation of mission performance as well as the questions driving the FEA request. For example, questions regarding the Patriot’s mission are not confined to individual crew positions, but include system failures where the system is conceptualized as both human and technology systems. Focusing on one or two individual crew positions would not include the level of system analysis required to comprehensively address mission processes and outcomes. Including all crew positions in the FEA will provide a system framework for understanding mission requirements that can then be translated into training requirements for the team, as well as for individual crew members.

Answers to the question, “What aspects of training should be included?” can be derived directly from the issues driving the FEA requirement. Based on published reports of Patriot mission performance and training, or apparent shortfalls in these areas (see Hawley, 2007 & 2011), an FEA should include a careful consideration of the various levels of expertise required during operational missions. Furthermore, concerns expressed in these reports about individual and team adaptability, interpretation of information, and decision-making effectiveness during mission events suggest that team training requirements need to be included in the FEA process. Thus, the entire training continuum needs to be considered, from initial Patriot training through expert performance (see Figure 7).



**Figure 7.** Training continuum.

Critically applying this training continuum in the FEA will emphasize the need to identify a wide range of training tasks and requirements from untrained to expert operators. This information can then be used to identify appropriate training milestones and the type of training required to achieve these milestones. Training recommendations, such as how to train, where to train, when to train, and who to provide the training to, can then be overlaid onto the training continuum. This comprehensive approach will minimize assumptions about when, how, and who is responsible for training across the continuum. It should also provide a more holistic approach to understanding individual and collective team training progression.

### **Collective/Team FEA**

The team-based nature of Patriot batteries and crews dictates that training should include a strong collective emphasis. This training must focus on team competencies, collective tasks and team processes to enhance team performance and develop needed expertise throughout the team (see Salas, Cooke, & Rosen, 2008). Training strategies to improve team members' understanding of each other's roles, CRM and team processes, adaptation, and decision-making should be incorporated into crew members' training cycles. Thus, the how, when, and by whom questions that drive training designs must be addressed through an FEA process that intentionally accounts for and analyzes team training requirements. This is important for several reasons:

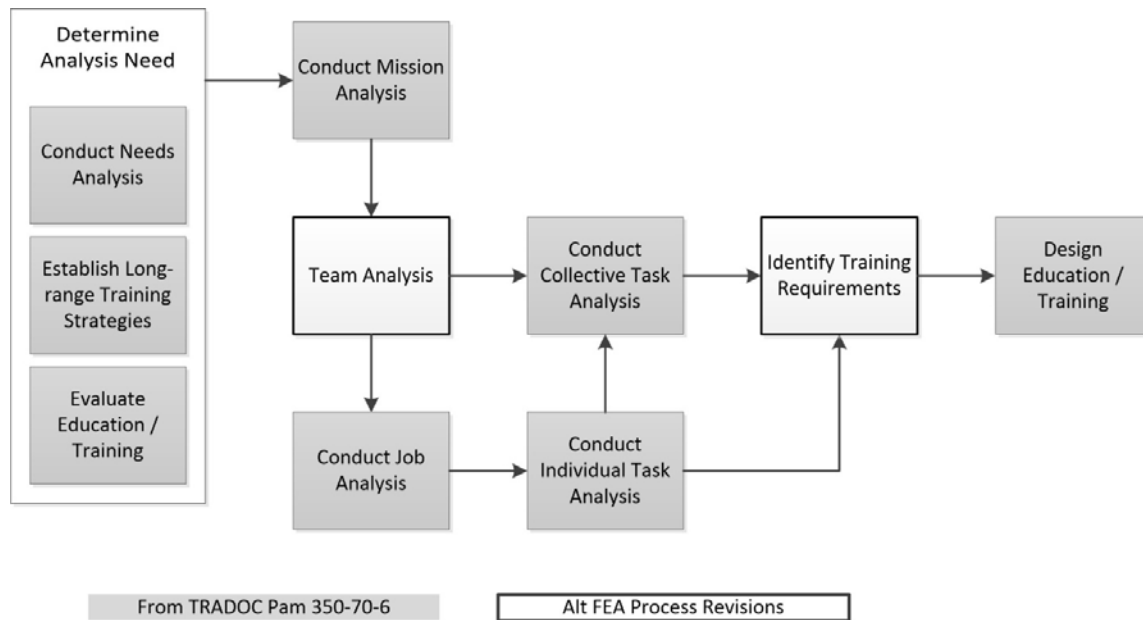
- “team” training requirements may be different than individual or collective task training requirements;
- team-based competencies need to be integrated into mission and context specific training; and
- performance should be assessed at the team level, as well as individual levels, as part of any evaluation process.

Anticipated benefits and risks of supplementing the standard FEA process with a focused collective/team analysis are summarized in Table 4.

Table 4  
*Collective/Team Analysis Benefits and Risks*

<b>Benefits</b>	<b>Risks</b>
Team training and performance requirements will be identified	Could de-emphasize consistent focus on tracking individual progress within a collective setting; must ensure that individual requirements and metrics are maintained and augmented by collective/team based metrics
Individual and collective tasks will be analyzed within a mission context	Appropriate collective/team metrics may not exist and may be difficult to develop within existing weapon systems and doctrines
Integrity of the Army task-based FEA strategy (i.e., SAT) is maintained	Results may require adjustment of training responsibilities
Analysis will complement current individually focused analyses	Results may require additional training resources

Team analyses should be integrated into the Army’s established SAT analysis process as illustrated in Figure 8. These analyses should be conducted immediately following the mission analysis, feeding directly into collective tasks analyses (to determine team task and performance requirements) and individual job analyses (to determine individual training requirements). Individual and collective task analyses, in turn, highlight aggregated training requirements for the team, as well as those for individual crew members. The difference between this approach and the standard Army SAT approach is the intentional focus and inclusion of collective and team training requirements as the main analytic framework, rather than identifying team requirements by simply combining individual tasks and requirements into collective requirements.



**Figure 8.** Integrating team analysis into the U.S. Army’s SAT analysis process.

### Expert-based FEA

Determining training requirements beyond rote performance of routine or clearly defined procedures requires an analysis of expert performance, or expertise. Expertise analysis will reorient the scope of training analysis by identifying the tasks, processes, and responsibilities that are necessary to respond effectively to unpredicted or novel situations and events characteristic of complex systems and ambiguous operating environments. Expertise analysis, by definition, provides insight to advanced mission performance skills, such as situational awareness and adaptive decision-making, that could be de-emphasized in a traditional task-based FEA. An expertise analysis must:

- focus on tasks necessary to address novel situations and events;
- extend beyond predictable performance tasks to identify what happens when the unknown is encountered; and
- consider the training continuum of all crew positions.

Anticipated benefits and risks of supplementing the standard, task based FEA process with a focused expertise-based analysis are presented in Table 5.

Table 5

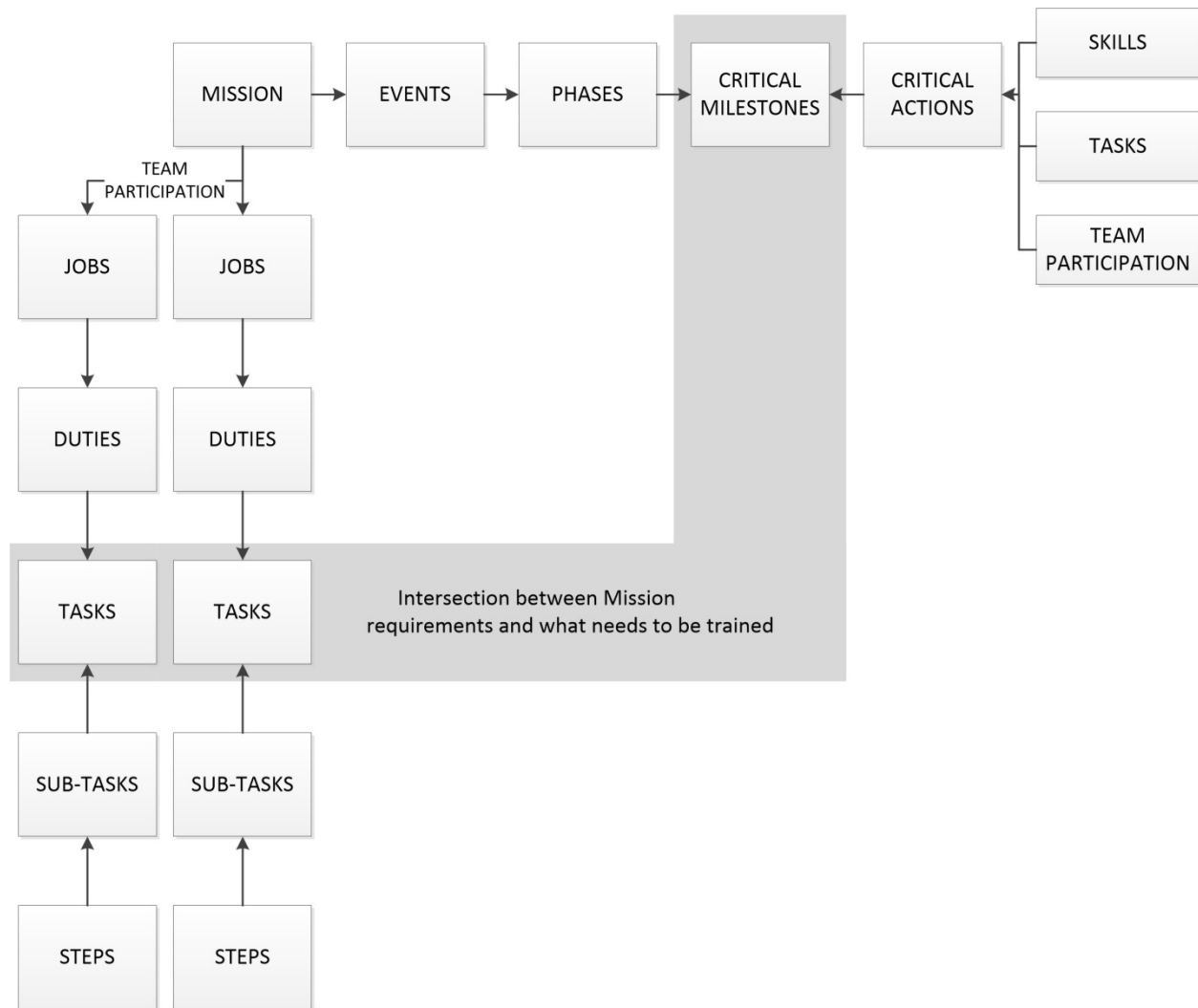
***Expertise Analysis Benefits and Risks***

<b>Benefits</b>	<b>Risks</b>
Increased likelihood that complex tasks can be deconstructed to inform training recommendations	Recommendations may require a redistribution of training responsibilities across the training continuum of all crew members
In-depth examination of distinguishing characteristics of and progression from novice to expert operator	Results may require additional training resources
Integrity of the Army task-based FEA is maintained	
Analysis will complement standard task-based analyses	
Mission environment and performance is primary analytic context	

Generally, the expertise analysis process would be the same as the standard SAT analysis process (see Figure 3). The difference between the standard SAT process and this analysis is in the scope of tasks and skill levels identified and analyzed.

**Event-based FEA: Mission Deconstruction**

Task-based analysis following the Army’s SAT analysis process may be insufficient to analyze all of the collective and individual tasks associated with increasingly complex, highly automated weapon systems (e.g., Patriot and AIAMD mission performance). Task-based analysis deconstructs mission requirements into associated duties and tasks. Thus, specific tasks are the primary unit of analysis following this process. An alternative approach deconstructs these mission requirements into other units of analysis, such as the sequence of events that are required to fulfill mission requirements (see Figure 9). Event-based deconstruction would drive the identification of mission events, phases, critical milestones, and critical actions.



**Figure 9.** Event-based mission deconstruction.

Event-based deconstruction would still follow mission requirements; the difference is in the type of analytic framework underlying the analyses. Event analysis is based on a systems analytic approach that would consider the interdependencies among crew responsibilities within a required sequence of tasks, as well as discrete individual requirements during mission performance. As illustrated in Figure 9, a mission-event deconstruction would capture collective task requirements within the primary analytic framework at the beginning of the analysis, rather than toward its end, which is a common consequence of deriving collective requirements by combining individually defined requirements. This approach could also potentially capture complex performance requirements and sequences that are difficult to capture when relying on individual task analysis results alone. Event analysis potentially addresses several task-based analysis shortcomings:

- task and skill performance would be analyzed within the context of mission performance and requirements;
- crew member participation would be analyzed within the mission’s context; and

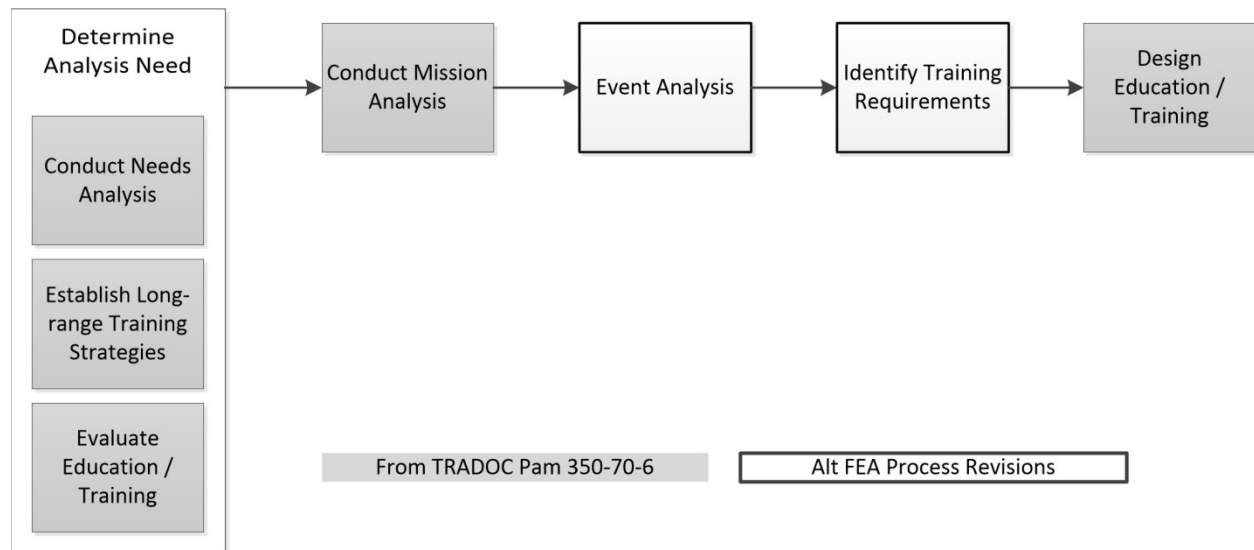
- task complexity would not necessarily be over simplified during the deconstruction process.

Table 6 summarizes the anticipated benefits and risks of employing an event-based approach within an FEA.

Table 6  
***Event Analysis Benefits and Risks***

<b>Benefits</b>	<b>Risks</b>
Event-based team performance measurement would minimize complex task analysis weaknesses	Task delineation may be lost
Incorporates team/collective requirements identification as an integral part of the process	Data and analysis complexity may not be repeatable
Team performance standards more readily identified	
Mission environment and performance is primary analytic context	

Event analysis would not necessarily complement the Army’s standard SAT approach. Mission deconstruction using events rather than jobs and duties would, in fact, replace a foundational element of the SAT process - task analysis. As Figure 10 illustrates, training requirements are identified directly from event analysis findings. This approach, then, would lose the task delineation that is the basis of current Army training designs such as Patriot.



**Figure 10.** Event analysis process.

## Conclusions

Each of the proposed FEA strategies reviewed in this report have distinct attributes that would frame how they might be adapted to augment the Army’s current SAT FEA process to address the demands and challenges found in complex, highly automated systems and architectures, such as Patriot and AIAMD. Each strategy promises benefits as well as risks compared to the current SAT analysis process. Table 7 compares the benefits and risks of each alternative with those associated with the Army’s established SAT process.

Table 7

***Alternative Comparison: Benefits and Risks***

<b>Benefits</b>	<b>Army SAT</b>	<b>Event Analysis</b>	<b>Team Analysis</b>	<b>Expertise Analysis</b>
Compatible with the Army’s SAT analysis process	X		X	X
Utilizes Army’s SAT task-based approach	X			X
Team training requirements are a unit of analysis, emphasizing team performance requirements as complement to individual performance requirements		X	X	
Increases the likelihood that complex tasks will be deconstructed appropriately		X		X
Identifies distinguishing characteristics of novice to expert progression				X
Team performance standards more readily identified		X		
Mission environment and performance is primary analytic context		X	X	X
<b>Risks</b>				
Results may require adjustment of training responsibilities			X	X
Results may require additional training resources	X	X	X	X
May de-emphasize individual performance and progress		X	X	
Appropriate team metrics may not exist or be readily defined	X		X	
Process complexity may not be repeatable with available FEA resources		X		

The overriding conclusion that emerges from these comparisons and our review of relevant literature and training reports is that existing FEA approaches have some fairly well recognized limitations. It is apparent that new FEA strategies and approaches that build upon the strengths of multiple approaches are needed to address the emerging issues, requirements, and roles demanded by new and evolving increasingly complex, highly automated systems and architectures. Thus, FEA strategies and designs that are hybrids of multiple approaches, integrating FEA-related processes, concepts, and analyses, appear to be the most effective way to address command dependencies within and between echelons, critical decision points, and training requirements for complex, highly automated multisystem architectures (e.g., the emerging AIAMD environment), yet remain flexible enough to be applied to current systems (e.g., Patriot).

**Two Alternative FEA Approaches**

Based upon our theoretical review and consideration of the Patriot weapon system and its pending transition to the AIAMD/IBCS operational architecture as an exemplar of evolving complex, highly automated systems, we offer two alternative FEA approaches that incorporate previously discussed aspects of event, expertise, and collective/team analyses. Both alternatives include team analyses due to: (a) identified concerns about increased demands on crew and team integration, performance, adaptability, and decision-making during mission performance; and (b) the fact that complex weapons systems and multisystem architectures require collective, as well as individual, participation from multiple team members and crews/teams to accomplish the mission. The two recommended alternatives are:



1. Alternative 1: Replace the standard SAT analysis with a combination of team and event analyses.
2. Alternative 2: Supplement the standard SAT analysis with a combination of team and expertise analyses.

Alternative 1 reflects a departure from the established task-based analyses underlying the Army's SAT FEA approach. Rather than deconstructing mission requirements into discrete duties and tasks, this approach focuses on the sequence of events required to fulfill mission requirements. A key aspect of this focus is that it considers not only broad mission requirements, but also the sequences of individual and collective actions and events that must be accomplished to achieve defined mission milestones and critical actions.

One advantage of this alternative is that event and team analyses complement each other, especially in more complex and/or multisystem architectures that often demand an in-depth understanding of the sequence of events and combination of individual and collective actions that frame critical mission requirements, actions, and milestones. Another advantage of this approach is that, being significantly different from traditional task-based analyses, it should lead to a complete reconsideration of mission requirements and performance standards in terms of supporting events, sequences, and roles rather than relying on a simple or subjective amalgamation of related tasks to define mission requirements and critical training areas.

However, the uniqueness of an event-based approach may result in data and findings that are unfamiliar to personnel used to interpreting the results from traditional task-based FEAs. Another disadvantage is that the similarity of event and team data and analyses may result in redundant considerations and an inefficient process. There is also the disadvantage that incompatibility of event-analysis with task-based analysis requires this approach to replace, rather than supplement the standard SAT analysis. This effect may yield results that are difficult to translate into familiar training design language and recommendations.

Unlike the first alternative, Alternative 2 centers on an expertise analysis that aligns directly with the standard task-based analysis approach. Alternative 2 combines the outcomes from the traditional task-based analyses with a critical examination of corresponding expertise progression and requirements and collective/team responsibilities. Thus, this alternative expands, rather than replaces, the Army's established SAT approach.

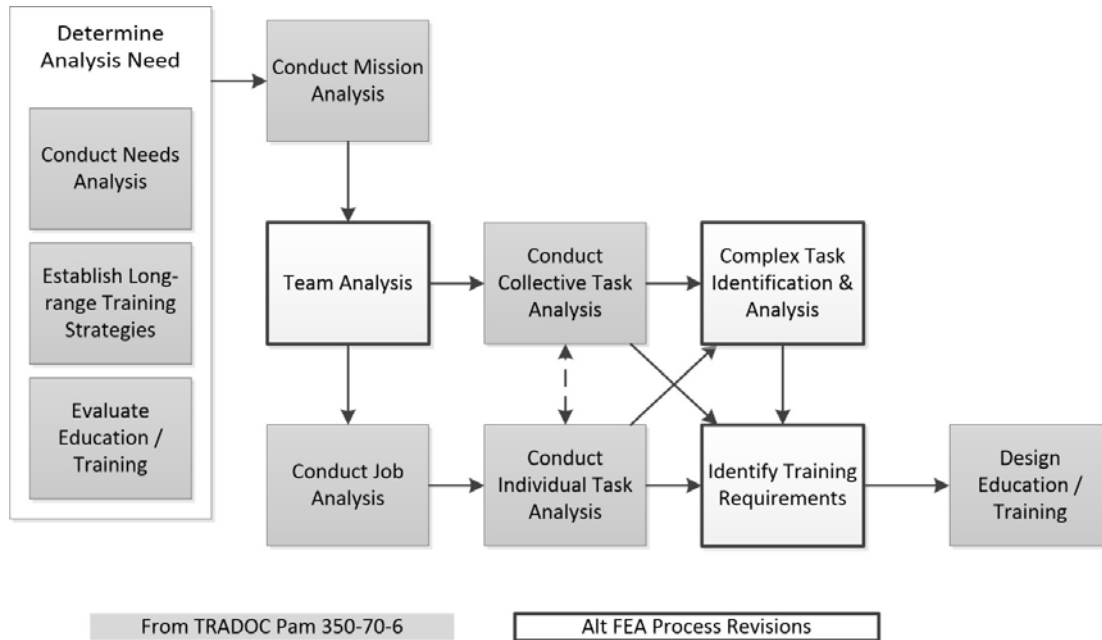
Since Alternative 2 represents an expansion of current practices, it is expected that the associated FEA procedures, data, and findings will be more familiar to and easily interpreted by potential users. Much like combining events and team analysis strategies in the first alternative, this alternative also has the advantage that collective/team and expertise analyses data and findings will complement each other. Expertise analyses will extend what is known or determined about individual and collective/team training tasks, while collective/team analyses will highlight broader system and crew requirements. Of course, this approach assumes that team analyses are conducted in terms of defined mission performance requirements.

## Recommended FEA Approach

Given the challenges of coordinating and integrating inputs and actions from multiple systems and increasing levels of automated controls and decision processes associated with evolving systems, as well as recent related concerns and issues identified within Patriot testing, training, and operations, Alternative 2 seems to offer greater potential at this time by integrating collective/team and expertise analyses into the standard SAT analysis process. This alternative is recommended for additional testing and refinement due to (a) its compatibility with the standard SAT analysis process, and (b) the complementary nature of the two analyses. Additionally, including analyses targeting collective communication and coordination requirements, as well as individual and collective task performance with an examination of related expertise levels and progression, should provide a sound foundation for identifying potential options that address the emerging issues within Patriot training and accelerate the development of expertise needed to meet the challenges of more complex, highly automated systems operating in frequently ambiguous situations. Given the limitation of time and resources for testing and validating this recommended FEA strategy, it is also recommended that air battle management tasks and processes be the focus of the next phase of this research and include an examination of:

- collective training requirements determined through the team analysis portion, focusing on team processes, interdependencies, management, and coordination;
- complex individual tasks, particularly tasks related to adaptability, decision-making, and problem solving determined through an expertise analysis; and
- the entire training continuum, by identifying training and assessment milestones, requirements, and crew/system responsibilities, including determining collective and expertise task requirements from basic to expert.

The recommended approach will be designed to align and integrate with the U.S. Army's standard SAT analysis process as shown in Figure 11. Note that the team analysis flows directly from the mission analysis, and preliminary team analysis findings are then used to examine both collective and individual tasks. It is anticipated that the expertise and team analyses will inform each other, and that data collection procedures will leverage SME participation by integrating interview and discussion topics. Consequently, while the process illustrated in Figure 11 is shown to be linear in nature, in practice it is likely to be reiterative wherein each analysis informs and validates the other. The process flow highlights the analytic priorities within the strategy, in that collective/team processes and requirements will be used to frame the context of subsequent analyses.



**Figure 11.** Recommended FEA approach process.

The team analysis is process and function oriented. This analysis examines the functions, inputs, and outputs of each crew position to identify roles and interdependencies within the crew-based system. Interdependencies are examined to identify the communication and coordination processes and requirements within the crew as well as between the crew and higher command echelons. Data to support these analyses is collected through both crew and individual interviews from experienced operators, team leaders, and unit leaders. Interviews should begin by framing the mission parameters then spiraling down into specific actions and processes.

Questions guiding the team analysis are oriented around teamwork and team performance during mission performance, including the context, environment, team composition and processes, and individual and collective task requirements, management, and coordination. The following sample questions and topics form the basis of individual and crew-based interviews:

1. Identify and describe the crew composition.
2. Describe the mission requirements and processes.
3. Identify and describe key events/moments (e.g., milestones) during each phase.
4. Using the defined mission requirements, identify crew member tasks and responsibilities.
5. Describe each crew member's responsibilities during each mission phase.
6. Describe what each crew member does to accomplish/reach each milestone.
7. What are the knowledge, skills, and abilities each crew member needs to accomplish their job?
8. What are the crew leaders' responsibilities during each mission phase?
9. Describe what the crew does to reach/accomplish each milestone.
10. Describe how the crew interacts during each phase.

11. Who coordinates crew interactions? Always? Does anyone else ever step in to assist or correct what is happening?
12. What are the risks during each mission phase?
13. How are risks mitigated?
14. Describe the mission planning / preparation process.
15. How are errors detected?
16. How are errors corrected?

The expertise portion of our proposed FEA begins with the identification of the complex tasks that will drive the analysis. Complex task identification is accomplished using two methods. One method analyzes existing task lists and archival performance data. An examination of past performance data will identify difficult tasks as evidenced by lower than average scores during trainee and operator evaluations. Existing tasks are assessed for task complexity as they emerge through individual and crew-based interviews. Interviews and examinations of standard operating procedures provide an opportunity to identify critical decision and coordination points, and inform predictable and unpredictable situations. The second method seeks to identify “new” tasks and situations through SME interviews. These interviews should explore past situations encountered by SMEs that were novel or unexpected based on their training experience. These situations, actions, processes, and outcomes are documented, categorized, and analyzed to identify common and uncommon situations and tasks encountered by expert operators. The following sample questions and topics should guide the identification of “new” tasks not accounted for in existing task lists:

1. Identify and describe unpredictable events you have encountered during operations.
2. How were those events initially identified?
3. How were those events handled/resolved?
4. What critical knowledge and/or skill did you require to handle/resolve the event?
5. What tasks and performance qualities/characteristics distinguish expert performance from non-expert performance?

Next, the information gained from SME interviews will be analyzed to translate broad mission events into specific cognitive and performance tasks. This requires that:

1. mission events be categorized and analyzed;
2. responsive behaviors be identified, analyzed, and categorized; and
3. training tasks be identified or developed from these findings, then validated by SMEs.
4. An appropriate sequence for individual and collective training events will be determined with the assistance of system experts and validated by SMEs.

Expert operators and experienced team leaders will be critical data sources for this research since the experience of resolving unpredictable situations is key to identifying the successful application and resolution of complex tasks, such as problem solving and decision-making, in operational settings.

Our proposed FEA is designed to also address the current and proposed training continuum across crew positions, including the timeline of current training progression and

milestones, training requirements and recommendations between those milestones, anticipated resource requirements, and recommendations of where training should occur and who (i.e., the institution or unit) should provide the training. Additional data will focus on defining the current training situation, identifying training gaps, and providing a framework for later FEA recommendations. Guiding questions and topics for the training situation should be oriented on what is trained and how it is trained, as well as gaining organizational input about known training issues. Preferred data sources for these topics include command-level SMEs, training directors, and training documentation such as course materials, training guidance, and incident reports.

The following sample questions are typical of those used to define the FEA's framework and inform the current training situation:

1. What are known gaps between the current training system and mission requirements?
2. What are known problems with current training system?
3. What are the causes of those problems?
4. What are the impacts of those problems?
5. What are the organizational objectives of the FEA?
6. What constraints should be accounted for during the FEA?
7. What individual KSAs (Knowledge, Skills, and Abilities) are currently trained?
8. How are individual KSAs currently trained?
9. What crew competencies are currently trained?
10. How are crew competencies currently trained?
11. What crew-specific leader KSAs are currently trained?
12. How is crew-specific leadership currently trained?
13. What is the training progression?
14. What are the training resources?

The recommended FEA approach includes analyses and data to examine and define complex tasks and collective communication and coordination requirements. It integrates collective/team analysis and expertise analyses to supplement current task-based, individually focused training requirements. The proposed approach complements the Army's established SAT analysis process, which should enhance the ability of findings and recommendations to be successfully integrated within future training designs, development approaches, and implementation strategies.

During the next phase of this research, the proposed FEA strategy will be applied to the use-case of the Patriot missile system. These results will inform any revisions necessary to ensure that the selected FEA approach addresses the key complexities of the mission operations in this circumstance. In the final phase of this research, the subsequently revised approach will then be applied to a second use case, i.e. the transition of Patriot operations into the AIAMD architecture. The ultimate objective of this research is to provide an FEA strategy uniquely attuned for defining the training requirements for complex, highly automated systems.

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## Acronyms

4C/ID	Four-Component Instructional Design
ABM	Antiballistic Missile
ADA	Air Defense Artillery
ADDIE	Analyze, Design, Develop, Implement, and Evaluate
AIAMD	Army Integrated Air and Missile Defense
AMD	Air and Missile Defense
AMG	Antenna Mast Group
ARI	U.S. Army Research Institute for the Behavioral and Social Sciences
BCP	Battery Command Post
CRM	Crew Resource Management
CTA	Cognitive Task Analysis
DOD	Department of Defense
DSB	Defense Science Board
ECS	Engagement Control Station
FCOE	Fires Center of Excellence
FEA	Front End Analysis
HQDA	Headquarters, Department of the Army
IBCS	Integrated Battle Command System
ICC	Information and Coordination Center
IDA	Institute of Defense Analyses
IFCN	Integrated Fire Control Network
ISD	Instructional Systems Design
KSAs	Knowledge, Skills, and Abilities
MANPRINT	Manpower & Personnel Integration
MIL-HDBK	Military Handbook
PADDIE	Planning, Analysis, Design, Development, Implementation, and Evaluation
PATRIOT	Phased Array Tracking Radar to Intercept on Target
RPD	Recognition Primed Decision
SAT	Systems Approach to Training

SME	Subject Matter Expert
TNA	Training Needs Analysis
TRADOC	U.S. Army Training and Doctrine Command
USAADASCH	U.S. Army Air Defense Artillery School
XBT	Expertise-Based Training