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A Rationale and Framework for Establishing a Systems Engineering Community within the Department of the Army

8 March 2011

by

Alan Clayton,

Anders Wiborg, and

Amie Riva

Advisors: Gregory A. Miller, Senior Lecturer,

Gary O. Langford, Senior Lecturer, and

Lisa Heidelberg

Graduate School of Engineering & Applied Sciences

Naval Postgraduate School

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A RATIONALE AND FRAMEWORK FOR ESTABLISHING A SYSTEMS ENGINEERING COMMUNITY WITHIN THE DEPARTMENT OF THE ARMY

ABSTRACT

Army acquisition programs are faced with increasing technical complexity and interdependence as most program products must integrate into a system of systems. The low quantity of systems engineers and the poor quality of systems engineering are credited as central to program failures. In an Army Systems Engineering Forum, the Army System of Systems Engineer (SoSE) asked what could be done to recruit, train, certify, and retain systems engineers. In this paper, we answer that question and identify that it cannot be "fixed" in isolation by addressing an Army culture that does not focus its efforts on training the personnel it already has. Quantity issues are not being addressed at the Service level with recruiting efforts. Organizations do not have formal collateral personnel exchange programs, yet many perform systems engineering functions. Training and certification gaps exist despite availability of training because personnel are not mandated to be certified to accept positions, in many cases. Systems engineering, although not blameless, is not the only issue. We also explore how the technical background of those who blame or want to fix systems engineering is an unbalanced perspective and omits the organizational issues and individual contributions of systems engineers and the other members of the program manager's (PM) team.

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About the Authors

Alan Clayton, Defense Contractor, retired U.S. Army, LTC, Signal Corps. Mr Clayton earned a BS in engineering science in 1990 from the University of Florida and an MS from the Naval War College in 2002. He retired after more than 26 years of combined active, reserve, and National Guard service in 2007. Mr Clayton is a principal systems engineer currently employed by Science Applications International Corporation in support of the Joint Program Executive Office of the Joint Tactical Radio Program.

Anders Wiborg, United States Army Civilian, Army Test and Evaluation Command, Dugway Proving Ground, West Desert Test Center. Mr. Wiborg earned a BS in computer science in 2002 from Gonzaga University. Mr. Wiborg is certified through Defense Acquisition University at Level III in Test and Evaluation and Program Management. Mr. Wiborg is currently serving on a developmental assignment to the Joint Project Manager for Nuclear Biological and Chemical Contamination Avoidance, Product Director—Combating Advanced Threats as the Test and Evaluation Lead, having served in a wide range of assignments in seven years of federal civil service.

Amie Riva, United States Army Civilian, CECOM Life Cycle Management Command, Software Engineering Center, Command and Control Solutions Directorate. Mrs. Riva earned a BA in Sociology in 1977 from Douglass College, Rutgers the State University of New Jersey. Mrs. Riva is a certified defense financial manager with acquisition specialty, as well as Level III certified in Business Cost Estimating and Financial Management, and Level III certified in Program Management through the Defense Acquisition University. Mrs. Riva is a program analyst, having served in a wide range of assignments in 29 years of federal civil service.

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LIST OF ACRONYMS AND ABBREVIATIONS

AF	Air Force
AFSB	Air Force Study Board
AIAA	American Institute of Aeronautics and Astronautics
ALT	Acquisition, Logistics, and Technology
ASA(ALT)	Assistant Secretary of the Army (Acquisition, Logistics, and Technology)
ATEC	Army Test and Evaluation Command
CSTF	Central Technical Support Facility
DA	Department of the Army
DAU	Defense Acquisition University
DDRE	Director, Defense Research and Engineering
DoD	Department of Defense
FCS	Future Combat Systems
GAO	Government Accountability Office
INCOSE	International Council on Systems Engineering
IT	Information Technology
JAP	Joint Applied Project
JPO	Joint Program Office
JTRS	Joint Tactical Radio Systems
MDAP	Major Defense Acquisition Program
MRAP	Mine Resistant Ambush Protected
MSPM	Master of Science in Program Management
NASA	National Aeronautics and Space Administration
OJT	On-the-job-training
OPM	Office of Personnel Management
OUSD(AT&L)	Office of the Under Secretary of Defense (Acquisition, Technology, and Logistics)
NATO	North Atlantic Treaty Organization
NDIA	National Defense Industrial Association
PM	Program Manager

PEO	Program Executive Office
POV	Point of View
R&D	Research and Development
RDECOM	Research, Development, and Test Command
RTR	Recruiting, Training, and Retention
SCEP	Student Career Experience Program
SE	Systems Engineering
SEIT	Systems Engineering Integration Team
SoS	System of Systems
SoSCOE	System of Systems Common Operating Environment
SoSE	System of Systems Engineering
SPRDE	Systems Planning, Research, Development, and Engineering
SPRDE–SE	Systems Planning, Research, Development, and Engineering–Systems Engineering
SPRDE–PSE	Systems Planning, Research, Development, and Engineering–Program Systems Engineering
SPRDE–S&TM	Systems Planning, Research, Development, and Engineering–Science and Technology Management
STEP	Student Temporary Employment Program
T&E	Test and Evaluation
TOP	Technical, Organizational, and Personal
TRADOC	Training and Doctrine Command
USD(AT&L)	Under Secretary of Defense (Acquisition, Technology, and Logistics)
U.S.	United States
USAF	United States Air Force
USN	United States Navy
VCSA	Vice Chief of Staff of the Army
WSARA	Weapon Systems Acquisition Reform Act

I. INTRODUCTION

A. BACKGROUND

Arguably, the United States (U.S.) fields the most operationally effective military force in the world. However, fielding such a force has been challenging, as seen by the multiple Government Accountability Office (GAO) reports of cost and schedule overruns. According to the GAO, development costs for Major Defense Acquisition Programs (MDAP) are often underestimated at program initiation, sometimes by 30–40% (GAO, 2008c). Additionally, weapons systems programs are initiated without sufficient knowledge about system requirements, technology, or design maturity. This lack of knowledge leads managers to rely on assumptions that are consistently too optimistic, exposing programs to unnecessary risks, and, ultimately, to cost growth and schedule delays (GAO, 2008b). The GAO has also reported that within the Department of Defense (DoD), there was an average delay of 22 months in delivering initial capabilities for MDAPs (GAO, 2010).

The acquisition community within the DoD has come under intense scrutiny from Congress for cost overruns and schedule delays and has caused extreme frustration for the warfighters because of the late-to-need delivery of reduced capabilities (GAO, 2009). The increasing complexity of acquisitions within the DoD is part of the reason. Weapons systems acquisitions, the totality of effort to bring a product to fielding, are no longer complete, stand-alone fielded entities; instead, they are systems within systems with interdependencies on a scale never before attempted.

The U.S.—and specifically the DoD acquisition process—faces a complex and uncertain security landscape in which the pace of change continues to accelerate. Changes include new foreign powers, non-state actors, and the availability of destruction-enabling technologies (DoD, 2010).

The difficult task of a systems engineer includes translating the warfighter's request for capability into a solution that properly addresses the tradeoffs between multiple factors (e.g., cost, schedule, performance, and quality). This includes the interconnectedness of subcomponents and their impact on the system within other systems. Internal reviews and external studies have postulated that the quantity and verifiable quality of systems engineers present in the government workforce are not equal to this task (Gates, et al., 2009). The quality of a systems engineer, for the context of this paper, is defined as the measure of a person's ability to apply the tools and best practices of systems engineering consistently and with success in the execution of their duties.

The lack of quality and proper systems engineering early[1] in system design results in waste. At best, it causes cost growth and time delays. At worst, it results in unusable products and/or cancelled programs (Defense Acquisition University [DAU], 2011).

This complex and uncertain security landscape was identified as a significant problem by a 2009 GAO report, which identified knowledge gaps that are largely the result of a lack of early and disciplined systems engineering analysis of a weapon system's requirements prior to beginning system development (GAO, 2009). The 2009 GAO report also stated that the government often does not perform the proper up-front requirements analysis to determine whether the program will meet its needs; significant contract cost increases can and do occur as the scope of the requirements changes or becomes better understood by the government and contractor (GAO, 2009).

Since the early 2000s, the DoD and the Department of the Army (DA) have seen a dramatic deterioration in the capability to field weapons systems on the planned budget, cost, and schedule (GAO, 2009). Current military acquisition programs take two to three times longer to move from program initiation to system deployment than they did 30 years ago (Air Force Studies Board [AFSB], 2008). This systematic delay has occurred during a period in which traditional threats have been increasing in frequency and emergent threats in cyber, electromagnetic, and chemical/biological warfare are being implemented at a more rapid pace. Many causes for this trend have been suggested, including the increased complexity of the tasks and the systems involved from both technological and human/organizational perspectives; funding instability; loss of "mission urgency" after the end of the Cold War; bureaucracy—which increases cost and

[1] Early is defined as starting at the formulation of the initial concept for a program.

schedule but not value—and the need to satisfy the demands on an increasingly diverse user community (AFSB, 2008, p. 1)

Figure 1 provides a visual perspective of how the acquisition landscape has evolved and what we can expect for the next decade (Torelli, 2010b).

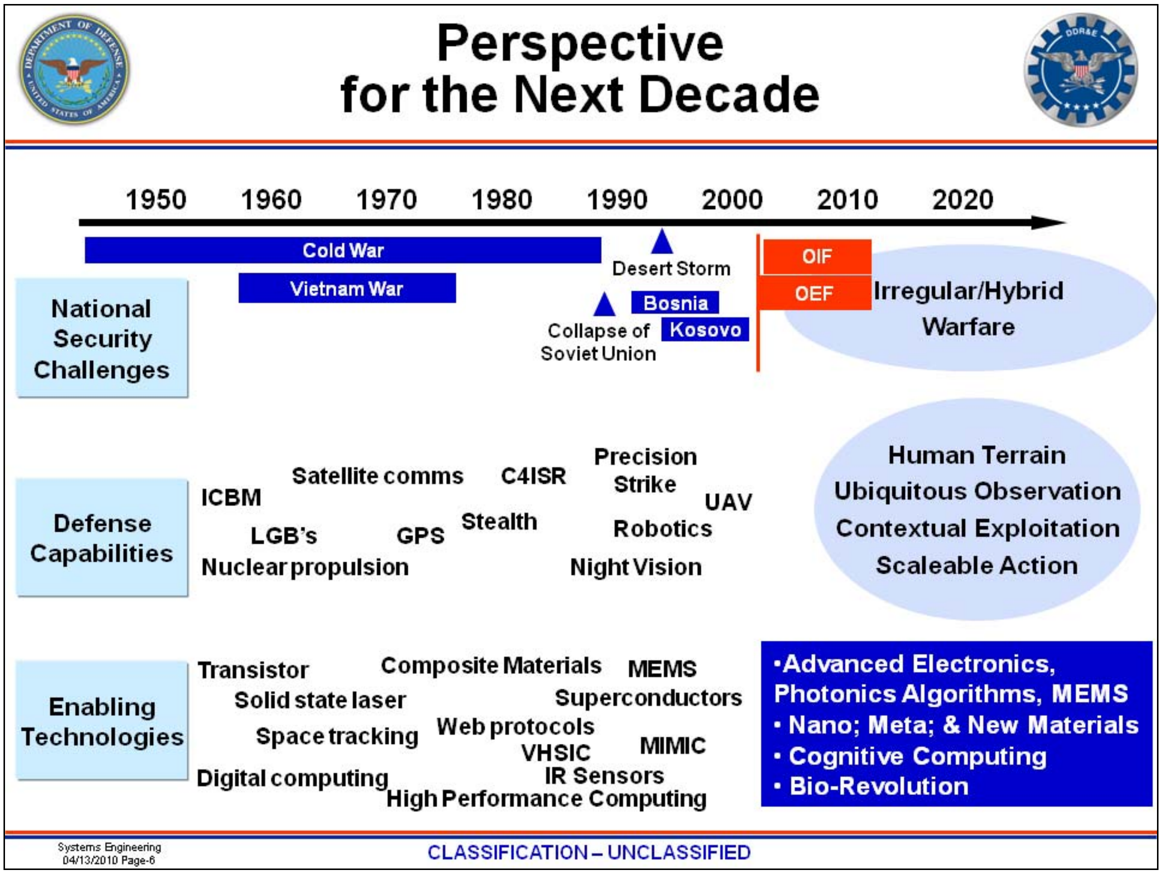

Figure 1. Perspective for the Next Decade
(Torelli, 2010b)

The Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA[ALT]) considers the systems engineering expertise within the Army workforce fundamental to delivering on-time, on-budget, and on-performance products. This assessment is supported by the 2010 GAO annual report on defense acquisition, which stated that the GAO analysis allows them to make observations about the DoD's management of technology, design, and manufacturing risks and its use of early systems engineering to reduce these risks (GAO, 2010). Because the scope of projects has grown from single-use systems to a federated systems of systems, the ASA(ALT) believes that an increase in the amount of systems engineering capability within the Army would dramatically increase the percentage of projects that would be delivered on time and on budget and would also meet original key performance parameters. In a 2009 RAND Corporation study performed for the ASA(ALT), researchers observed that the underlying problem in major acquisition programs is a lack of systems engineering expertise overall and a lack of effective systems engineering in system development started as early as the requirements development phase (Gates et al., 2009).

Our focus in this paper is on systems engineering within the context of Army acquisition. More specifically, we explore systems engineering staffing practices (recruit, train, and retain) within the Army Acquisition Corps, and the perception that the systems engineering workforce is either a source of, or solution for, program failures attributed to acquisition complexity. Development of a useable, viable framework for systems engineering usage across the complete DoD acquisition process will be a significant challenge for the Army due to the complex nature of Army acquisition programs. Our purpose in this project was to identify weaknesses in the DA's systems engineering staffing and personnel approaches in order to determine methods for identifying and addressing shortfalls, to assess temporary and long-term needs, and to determine potential policy changes necessary to maintain a quality systems engineering capability.

B. MOTIVATION FOR THIS PROJECT

The ASA(ALT) System of Systems Engineering (SoSE) staff believes that

- the Army needs to increase the overall strength of its systems engineering capabilities;
- the SoSE needs to make a recommendation to leadership for supporting this increase; and
- the recommendation must articulate recruitment, training, certification, retention, and cross-program utilization, and it should contrast where and how systems engineers are used currently for background. (M. Kwinn, personal communication, July 13, 2010)

These capabilities will be used in

- acquisition,
- requirements development,
- test and evaluation,
- system of systems integration, and
- personnel recruiting, training, and retention.

The ASA(ALT) is committed to determining the best way to recruit, train, and retain systems engineers to address this issue, but he also wants to know if the lack of systems engineers is the only problem.

The central question is, what recommendations should the ASA(ALT) SoSE make to the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]) to ensure that the proper personnel are recruited, trained, certified, and retained to increase the U.S. Army systems engineering capability that is needed to meet the increasingly complex requirements of the Army's system of systems strategy? For example, how does the DoD systems engineering community ensure that the proper skill sets are being identified and being implemented correctly within the systems engineering community to ensure a qualified and retainable acquisition, logistics, and technology (ALT) workforce?

C. RESEARCH QUESTIONS

The questions we extrapolated from the focus of the ASA(ALT) include the following:

- Can systems engineering help the Army acquire products that meet requirements on cost and on schedule?
- What are the barriers for the Army in acquiring products that meet requirements and satisfy constraints of cost, schedule, and policy?
- Are programmatic errors that are not the sole responsibility of systems engineering being attributed to systems engineering rather than to poor program management?
- Is the lack of a formalized systems engineering approach within the Army causing Army acquisition programs to fail? If so, what can be done to resolve this?

- How does the Army formalize its systems engineering approach in acquisition programming to ensure that Army acquisition programs are positively affected by systems engineering personnel?
- How does the Army set up a systems engineering career path that allows both traditional engineers and systems integrators to succeed?
- Are there additional skill sets that should be incorporated into the current systems engineering path that would allow for less technical (but still very capable) individuals with a management focus to function in the systems engineering career field?
- How can the DA benefit from what other DoD organizations are doing to implement systems engineering?

D. ORGANIZATION OF THE REPORT

Chapter I provides a background, explains our motivations, and creates the starting point for the questions that are core to our research.

Chapter II provides our analysis approach.

Chapter III analyzes whether systems engineering is the central issue that external studies postulate, or if there are other contributing factors.

Chapter IV provides a review of the current state of systems engineering with additional focus on the Army's needs.

Chapter V assesses our research and details our findings and results.

Chapter VI provides our conclusions and makes recommendations for changing the structure and processes for building a systems engineering community to meet the needs and expectations of 21st century Army acquisition programs and stakeholders.

II. ANALYSIS APPROACH

A. ANALYSIS STRUCTURE

The starting point of view for our case was from the position of the most senior engineering advisor (the SoSE) to the Army director of acquisition. The SoSE has previous work experience that includes serving as the Army's chief architect in the Army's Deputy Chief of Staff for Command, Control, Communications, Computers, and Intelligence and as director of the Army's Central Technical Support Facility (CTSF) at Fort Hood, TX. The context of this perception is where this question of "best method" for recruiting, training, and retaining systems engineers originated. In parallel, we asked, why is recruiting, training, and retaining the perceived solution, and what problem(s) will this solve? This point of view from the SoSE is greatly influenced by his personal experiences. A future SoSE might have a different point of view due to personal experiences, but this point of view is critical because it comes from the peak of the Army's engineering expertise.

To understand the intention and subtext of the question, we have extrapolated additional questions, as shown in Figure 2. The majority of these subquestions can be reached by asking why or what makes this so. Using questions of this type as a tool, we focused our research on the perceived positive impact that greater numbers of highly qualified systems engineers would have on acquisition programs, rather than on the quality of the currently trained DoD systems engineers.

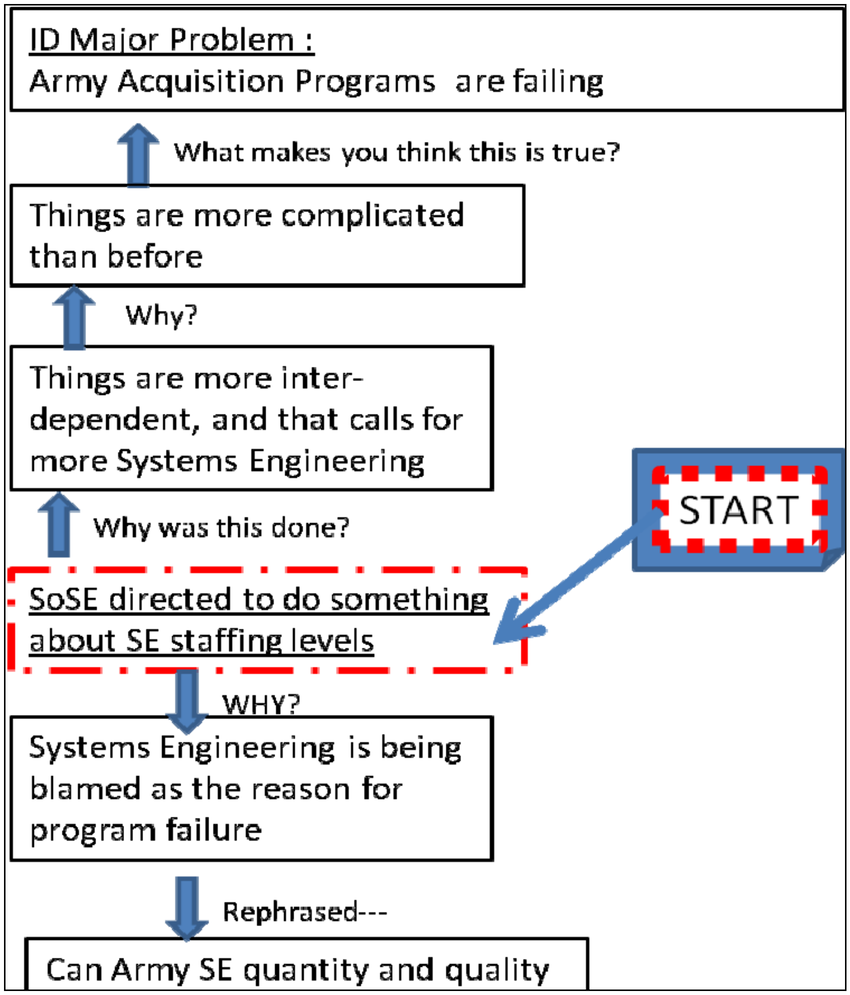

Figure 2. Problem Deconstruction

The desired end state is a successful integration of systems engineering processes on individual programs that results in a quality and cost-effective system of systems. This integration has several components, some less obvious than others:

- Successful programs need effective systems engineering to integrate their components into a functional system. Early initiation of systems engineering into the acquisition process helps to assure efficiency, reduce overall cost, and increase the chances of staying on schedule. However, this can prove to be costly, both in terms of funding and time. Early in the acquisition process, PMs may be more concerned with more tangible results (boots on the ground) in order to maintain the funding stream for their program.
- Successful integration of products from multiple PMs requires effective systems engineering in the beginning and the middle of programs to

increase the likelihood that PMs will buy into and work toward a shared goal. It often requires creativity in adapting systems to achieve more than the sum of the individual components. It can also require some shifting of responsibilities and costs between programs to achieve the best effect. Process standards clearly fall within the realm of effective systems engineering. The shifting of any responsibility or cost between PMs requires management skills more than engineering skills.

- Successful integration also requires a working level of interoperability between supporting organizations. Without interoperability between organizations, test and evaluation of the interdependent products to assess interface standards for compliance, or possibly for modification, is problematic at best. This ability is often described as "herding cats," (2011) and has more of a political or financial emphasis than pure engineering.

As indicated by the above list, it is apparent how skills move from classical engineering to adaptive expertise with an engineering focus and on to leadership or governance functions with an overall acquisition focus.

One of the difficulties in presenting a definition of systems engineering in concise terms can be found in the relational differences that a single systems engineering definition can have from different points of view. In other words, systems engineering can mean different things to different organizations, and it can have divergent meanings to the people within those organizations.

The analysis then moved outside of the frame of reference of the senior advisor, or SoSE, to encompass alternate points of view from successively different organizations and institutions in order to draw comparisons. We reviewed documents, briefings, white papers, and training materials from the Army, Air Force, Navy, National Aeronautics and Space Administration (NASA), and several DoD industrial partners on systems engineering practices within their respective organizations. We examined and reviewed these documents with curricula from several educational institutions. A significant correlation was found in the certification, experience, duties, expectations, and education of systems engineers. Consistency would have been a strong indicator for a "shared" vision or understanding of what the systems engineer would be doing in each organization.

Chapter III will analyze how the central question asked by the SoSE could have been formulated in error due to the requestor's position, organization, and background. A comparison is provided between the technical, organizational, and personal perspectives.

B. LITERATURE REVIEW

Our review of the literature encompassed the areas of interest that we identified as our research questions and those areas that we further detailed and highlighted in our research matrix (Appendix A). Research for the thesis project focused on reviews of Army and other Service policy statements on systems engineering, Army and other DoD systems engineering organizational websites, and a variety of curricula from universities, the International Council on Systems Engineering (INCOSE), and other systems engineering certification organizations. Additionally, in the area of human capital, recruitment, and retention, we reviewed workforce surveys and programs from NASA, a large-scale organization similar to the DoD, and resources from the Office of Personnel Management (OPM) Human Capital Assessment and Accountability Framework, which provided information on recruitment and retention. We also reviewed information gleaned from our coursework during the Naval Postgraduate School Master of Science in Program Management (MSPM) program.

III. IS SYSTEMS ENGINEERING THE CENTRAL ISSUE?

A. PRIMARY AND CONTRIBUTING QUESTIONS

1. Primary Question

- How does the Army recruit, train, certify, and retain qualified systems engineers?

The ASA(ALT) directly experiences the combined effects of the outcome rather than a lack of systems engineering in isolation. The question of how to recruit, train, and retain systems engineering personnel is deceptively straightforward, or would seem so until the answer becomes "it depends." How this question is answered, it turns out, depends a great deal on how these systems engineers are expected to perform after they have been recruited and trained.

2. Contributing Questions

The answer to the primary question leads immediately to the following contributing questions:

- What makes a systems engineer qualified?
- Why are systems engineers perceived to be in short supply?
- Is a lack of systems engineers the only problem, or is that lack part of a more complex issue?

To provide the answers that have the greatest possible impact, a context surrounding the reason for why a lack of qualified systems engineers is believed to matter must be explored. The primary question, therefore, is too broad reaching to be met with a succinct answer that will satisfy all of the challenges facing the Army acquisition community. Each of the subsets of the primary question is narrow enough when asked individually to provide a slightly more succinct answer.

B. WHAT IS A SYSTEMS ENGINEER?

The DoD defines systems engineering as an interdisciplinary approach or a structured, disciplined, and documented technical effort to simultaneously design and develop systems products and processes to satisfy the needs of the customer. Systems engineering transforms needed operational capabilities into an integrated system design through concurrent consideration of all life cycle needs (DAU, 2010b). The GAO defines systems engineering as the translation of customer needs into specific product requirements for which requisite technological, software, engineering, and production capabilities can be identified through requirements analysis, design, and testing (GAO, 2009).

To begin to understand the problem, we first had to understand the current area(s) of operation under which systems engineering were expected to perform. Before beginning to answer a question, that question must be understood. Context is critical here. Before we gathered data exclusively in support of recruitment, training, and certification programs, we needed to inquire why this question was being asked. As stated earlier in this paper, a deconstruction of the problem(s) was used to make sure that we were researching the right questions in the right context. This approach may seem obvious, but, unfortunately, making sure the right question is being asked can lead to the discovery of underlying context—the intent of the question should not be lost in the wording. A child asking "why does my stomach hurt?" could prompt one of several reasons: illness, hunger, overeating, or roughhousing with a sibling. Too many words have multiple meanings, and sometimes the question needs a bit of research.

Despite today's bleak economic outlook, there are glimmers of opportunity and growth in the technology and engineering industries—and systems engineering is emerging as a must-have career field. According to a ranking of the best jobs in America by CNN Money, "there will be a high demand for systems engineers over the next decade" (Amaba, 2010). In his article, Ben Amaba (2010) stated that

> the role of today's systems engineer combines the best attributes of electrical engineers, mechanical engineers, and software developers to take on the world's most challenging problems. These types of challenges also come with a high level of uncertainty and risk, which adds another unique layer of skill requirements to the job. (p. 1)

He went on to state that to help meet the growing demand for systems engineers, a new generation of specialists will be needed. And with the retirement of the "Moonshot

Generation," the engineering experts who were the driving force in successfully landing man on the moon, the push to replenish these ranks is all the more urgent. Thankfully, an increasing number of colleges and universities are evolving their engineering curriculum to address this need.

Systems engineering is a discipline that emphasizes best practices across multiple disciplines. The systems engineering process is considered reusable; however, it is dependent on having the necessary expertise with the pertinent historical knowledge to recognize the good and bad from previous systems engineering process efforts. In an ideal situation, the personnel undertaking the systems engineering process would have requisite knowledge through previous practical experience. During an April 7, 2010, keynote speech, Dr. Art Pyster (2010) of the Stevens Institute of Technology posited that previous practical experience is rarely available at the level necessary to provide adequate systems engineering guidance. When practical experience is not readily available, the systems engineering process must normally default to the academic training realm, in which theoretical knowledge is imparted on the systems engineering students with the expectation that an extraction to the practical systems engineering process arena will occur. This background of practical experience is referred to as the difference between classical engineering and adaptive engineering.[2] Some of this theoretical knowledge is imparted in the form of education in critical thinking and problem solving, which comes with the process of learning to become an engineer. This foundation is built upon in order to gain the experimental knowledge and understanding of the systems engineering concept in the context of an entire system.

C. MULTIPLE PERSPECTIVES

1. A Multiple Perspective Approach on Why the Army May Have Asked the Wrong Questions

By identifying the lack of systems engineering as the cause and programmatic failure as the effect, the ASA(ALT) leadership may have been using an overly technical

[2] Adaptive engineering is defined as the process whereby an item is modified to meet the requirements of a user for whom the item was not originally designed.

perspective. An organizational/institutional perspective would ask what must be done and who must do it. Further contrast is provided by the personal/individual perspective, which would instead seek to identify factors that drive the individual to do something about the situation. What empowers the individual rather than the organization?

In his article, Harold A. Linstone (1984) stated that a multiple perspective approach links the technical/analytic perspective (T) with organizational/institutional (O) and personal/individual (P) perspectives. The approach is to use T, O, and P together. It also helps to explain why decision-makers cannot rely on a single perspective alone. Linstone (1984) wrote,

> The T perspective: Problems are simplified by abstraction, idealization, and isolation from the real world. The implicit assumptions and characteristics include reductionism, reliance on scientific logic and rationality, problem-solution focus, quantification, use of data and models, optimization, and objectivity of the analyst. Jay Forrester's systems dynamics modeling of companies, cities, and the world is an example. The power and success of this technical world view and its value in yielding remarkable insights and excellent predictions in science and engineering remains unchallenged. But, as the recent work in complexity science has underscored, it has serious limitations in dealing with complex, nonlinear, adaptive systems. Unfortunately, most real world socio-technical systems are of this kind. (p. 1)

The primary question taken alone appears to assume that addressing the vacancies in systems engineering personnel and the requisite systems engineering skills—meaning certification—will resolve the problems facing the Army acquisition community.

In a systems engineering forum, where the ASA(ALT) gathered subject-matter experts in order to gain an acknowledged consensus, a concern was raised regarding the methods that have been used for decades in developing weapons, platforms (trucks or tanks), communications, and other tools of war and peace, and whether they were adequate enough to ensure a fully functional, integrated capability in the hands of the warfighter.

Systems are now both interdependent and, at times, in competition for resources like power, space, and weight on their respective platforms. Among many examples for how the big picture was lost by developers of individual components was the following example given at the former Future Combat System (FCS) synchronization summit. The platform (in this case, an armored troop carrier) was slated for the installation of more computer equipment, communications gear, and electronic warfare defense ability than it was able to physically fit or electrically power (Joint Program Executive Office Joint Tactical Radio System [JPEO JTRS], 2010). Based on researcher Alan Clayton's experience with the JTRS program, we were able to determine that the platform was a system of systems. The systems were developed in isolation, with each PM assuming resource availability. The first equipment fielding into that vehicle depleted most of the resources, leaving less than adequate space or power for the remaining components of the system of systems.

2. Multi-Organizational Interaction Point of View

When challenged with hardware and software conflicts, a Program Executive Office (PEO) must decide whether to rewrite the software or fix the problem in hardware. The PM responsible for the software may have a strong opinion of the relative merits in the comparison that would not be shared with the hardware PM. Each PM may wish for the other to sacrifice funding, timeline, and program credibility rather than volunteer to take on the task. For programs within the Army or under a single PEO that were intended to operate together as a system of systems at program inception, there should be performance specifications that mandate one or the other PM to comply with the interface standards when known and risk management strategies implemented for unknown situations.

This matters significantly because from the point of view of a PM, success is usually specified internally as being within defined performance parameters—being on cost and on schedule. External factors, such as the change of an external interface, are considered risks to be managed. An organization considers external interoperability in terms of risk to program execution.

3. Why the Organizational Perspective Matters

Each organization and its respective PM have to interpret tasks within the context in which they are assigned and resourced. This means that their development is supposed to include knowledge of everything that will need to be done both within and on the periphery of their acquisition effort. For example, the developer of a software application would need to understand the hardware and operating environment in which he will implement his program. There is at present no common software operating environment in use on all Army systems, so each application tends to be uniquely tailored and somewhat non-portable. If a change to an operating environment renders a second organization's software application inoperative, the second organization's perspective is not going to be in agreement with the organization that changed the operating environment.

For programs allowed to gestate in the absence of a larger interface context or end state, connecting the dots once they mature will not only be difficult and expensive but also will require the use of management reserves to make necessary product changes. Worse yet, it may be open to interpretation as to whether the work is within scope, and it may be hard to figure out how to legally expend funds. This interpretation is both a systems engineering issue and a contracts issue. The systems engineers from both parts of the future system (in the case of a two-part system) together with architects work out the engineering issues, which are resolvable in trade-space. Decision-makers work through the trade-space analysis and make the "big picture" political decision. The contracting person(s) carries out the consensus view. This is something NASA does routinely. Systems engineers also do this regularly in the commercial world.

Organizations need to ensure that they do both the engineering for their product and manage the systems engineering for the product's placement in the big picture. But who is in charge of the bigger picture? For example, the Army's tactical network is a federated system of systems at best, which was designed using a systems engineering architectural process. Control, as such a term makes sense in the context of standards, is shared by multiple Army and Joint PMs and strongly influenced by commercial, federal, and DoD standards bodies—all while being directed by Army Staff elements that have the ability to influence decisions directly or by control of personnel or funds. The design elements under the purview of an engineer or systems engineer need to be handled more effectively and qualified recruitment and qualified training can address those. However, engineering practices are not adequate to control all aspects of making programs successful. The engineers in the PM shops need to follow requirements set forth by leadership in external organizations, but this requires an O perspective and engineers are very T perspective focused. Just as the T is the realm of the engineer, the PM must take responsibility for the O.

D. REPEATED ATTEMPTS TO "FIX" ACQUISITION AND SYSTEMS ENGINEERING

There have been countless new and revised processes implemented through the DoD acquisition community over the past 10 years, yet there is almost no noticeable sign that systems development is becoming more efficient (GAO, 2009). The government trend in systems acquisition of over-budget and over-schedule programs is one of diminishing returns as the procurement of a system matures and the processes within the system become more complex. In a May 2010 *Defense News* article summarizing a recent GAO report to the House Oversight and Government Reform Subcommittee on National Security, Rep. John Tierney (D-Mass.) said the Pentagon is still not taking "some common-sense steps" (Matthews, 2010) that would almost certainly save money, such as testing prototypes to make sure they meet military needs before beginning production. Delays and cost increases have been persistent for decades and have been "implicitly accepted as the cost of doing business. It will take considerable and sustained effort [to change that status quo]" (Matthews, 2010).

Numerous efforts to reform the acquisition system have been undertaken by the DoD, such as the many changes made to acquisition policies, and recommendations have been made for improving the DoD's acquisitions by various commissions, think tanks, and government organizations—all of which culminated in various legislation passed by Congress. In 1986, the Packard Commission, named for its chair, Mr. David Packard, was appointed by President Ronald Reagan to study government procurement within the DoD. The culmination of this commission's study resulted in the passage of the Goldwater–Nichols Act of 1986. Additionally, the Defense Acquisition Workforce

Improvement Act (DAWIA) of 1990[3], the Acquisition Streamline Act of 1994, the Clinger–Cohen Act of 1996, the Intelligence Reform and Terrorism Prevention Act of 2004, and the Weapons Systems Acquisition Reform Act of 2009 were all passed by Congress to address improvements to the DoD acquisition process.

In an effort to address cost and schedule overruns, the DoD has published numerous policies, undertaken many studies, and developed several guides and pamphlets, such as the DoD Instruction 5000.02 (USD[AT&L], 2008), the *Systems Engineering Guide for Systems of Systems* (Director, Systems and Software Engineering, 2008), and a DAU Acquisition Encyclopedia entry, *Systems Engineering Plan* (DAU, 2009). The *Naval Systems Engineering Technical Review Handbook* (Department of the Navy [DoN], 2009), and the Air Force Systems Engineering Model (Air Force Center for Systems Engineering, 2010) are examples of what the other Services have published to augment the DoD's policies and to develop Service-specific processes. There is no equivalent document that currently exists within the DA.

On December 8, 2008, the DoD issued an updated DoD Instruction 5000.02 (USD[AT&L], 2008) that included a number of major systemic changes, such as an entire section on systems engineering, a requirement for a lead systems engineer to be placed on every PEO staff, a mandatory requirement for competitive prototyping, an increased emphasis on scheduling and executing timely systems engineering and technical reviews, and a requirement that all programs go through a Materiel Development Decision process prior to entering the acquisition system.

Programs may fail or exhibit cost and schedule overruns for many reasons. Some of these are external to the program, such as funding instability, and others are internal to the program and, thus, under the control of DoD managers. Two critical factors that fall in the latter category and that relate to the success or failure of programs are the need for high-quality systems engineering and the related issue of the need for a high-quality systems engineering workforce.

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[3] Extensive changes were made to the DAWIA in 2003, and the changes have been informally called DAWIA II, even though its public law number was never changed from the original numbering from 1990.

With budgets becoming tighter and public scrutiny becoming stronger, as well as with an increased focus being placed on advanced technology and with demands arising from the shift toward network-centric warfare, there has been a major emphasis placed on systems engineering within the DoD (Wynne & Schaeffer, 2005). In addition to the previously referenced policies, the creation of the Systems and Software Engineering Office within the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD[AT&L]) points to an understanding of the contributions that systems engineering can make to modern acquisition. Multiple GAO reports have identified the potential value that systems engineering can provide to the technical stability, cost stability, and positive schedule performance of a DoD acquisition program (GAO, 2010).

E. THE BLAME GAME

1. Issues Often Blamed on Systems Engineering

There can be cultural, financial, educational, structural, and political barriers to understanding the problems and implementation of possible solutions. People are comfortable in their own skill set and operate within that ability, sometimes to the detriment of what is actually required. PMs function in their acquisition role, just as engineers function more comfortably in their technical arena. To force a PM to function as an engineer, and vice versa, provides great personal learning opportunities, but can also expose a program to greater risk as a function of the learning process that occurs when a person is placed into a new position.

The underlying trigger that creates the complex interdependencies in technology and systems engineering was incorrectly identified by the SoSE, RAND, the director of Defense Research and Engineering (DDR&E), and by other engineering organizations as a catch-all fix.

Differences in perception of systems engineering vary considerably from organization to organization—a problem that is exacerbated by the Army's stovepipe organizational structure. Some structural and political barriers exist with good intention—that intention being the sheltering of ways that work well for the uniqueness of the Army. There may be resistance to good ideas that work elsewhere but that are not viewed as adaptable to "the Army way." These and other types of good intentions, such as Service loyalties and pride of ownership, can have second- and third-order effects, including lack of jointness among systems, competing initiatives, and support issues that are counterproductive. In this thesis, we seek to expose these counterproductive issues.

2. Determining the Root Cause of Failure

Based on conversations with the SoSE, it is believed that the Army needs senior systems engineers to do adaptive engineering and programmatic system of systems integration. As a starting point, systems engineering in NASA was heavily and classically engineering-centered. NASA is risk-adverse, methodical, and prone to relying heavily on modeling and simulation before execution. The U.S. Navy is classically trained, with emphasis on ensuring successful programs through rigorous academic instruction. In contrast to these organizations, the Army takes risks in program execution, as evidenced by programs such as FCS, Crusader, and System of Systems Common Operating Environment (SOSCOE).[4] Educational institutions, although able to teach engineering, have limited ability to impart the tactical experience that may be necessary to build into the end state system/weapon/unit capability the flexibility that the Army and all Services need.

The SoSE perspective must still acknowledge that stakeholders with different points of view will evaluate priorities differently.

- Who are these stakeholders?
- What is their point of view, and how does that influence their opinion of the value/role of systems engineering?
- Who has the ability to operate cross-PM and cross-PEO (if not the systems engineers)?

[4] It should be noted that these programs were not high risk due to technology-related issues. Instead, these programs were deemed high risk due to poor architecting design, poor integration, and poor execution of a poor architecture design.

To expect all capabilities to be resident in a single individual is unrealistic and unproductive because a single person cannot be expected to be a certified expert in all of the above-mentioned areas and still be a functionally productive employee.

Considering the importance that the ASA(ALT) SoSE has placed on recruiting systems engineers, it is worthy to note that there is no OPM general schedule job classification for a systems engineer. At the start of this research project, we considered this to be potentially an error. But a solid training and certification structure exists within the DoD to enable the correct placement of applicants into systems engineering positions. What remains to be done is to implement hiring guidelines to encourage use of these credentials as discriminators.

Figure 3 shows in simplistic form the career path progression of an engineer or acquisition professional along the x and y axis. "Pure" engineering would progress from left to right along the bottom. PMs rise along a path on the left side of the figure. For systems engineers to fulfill every expectation within both the engineering and acquisition communities, it is necessary to have all of the underlying requirements of both professions. However desirable, this is unrealistic and identifies why solutions within the PM's program are best generated by teams. Without disagreeing with the analysis that the DoD needs more engineers and, in particular, systems engineers, does the Army need *only* systems engineers? Or, is something else needed to augment systems engineering?

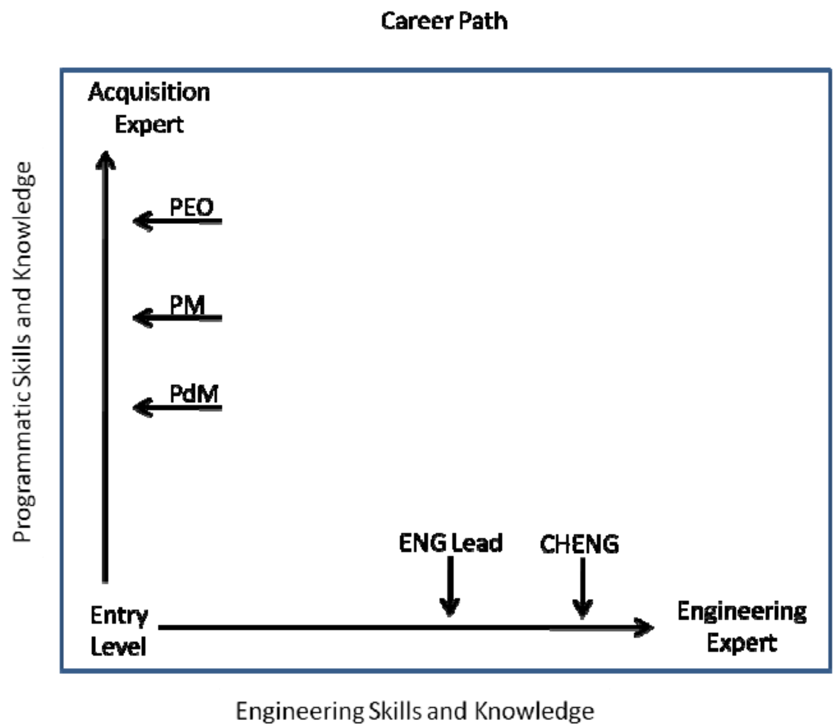

Figure 3. Career Path Progression of Engineer or Acquisition Professional

Systems engineering at the undergraduate level can be found at selected schools, but systems engineering courses are more readily available at the graduate level of study. One factor that continues to drive academics toward graduate rather than undergraduate teaching of systems engineering is that, fundamentally, systems engineering is the integration of multiple[5] disciplines with the goals of meeting the user's needs. Understanding and implementing best practices can more easily be accomplished by engineers with more experience. Using Figure 3 as a guide, increasing engineering knowledge, and systems engineering expertise in particular, leaves voids of knowledge between engineering and acquisition. Cross-training between systems engineering and acquisition career fields would address this as a two-dimensional solution. Adding requirements analysis and generation that is accomplished by the Training and Doctrine Command (TRADOC), an activity that precedes development, creates a third dimension of depth not shown in this diagram. Although the 2-D model shown in Figure 3 is

[5] Some of which include Operations, Cost and Schedule, Performance, Training and Support, Test and Evaluation, Disposal and Manufacturing.

adequate to represent expertise internal to the program, the third dimension is useful in visualizing the program's relationship to the Army's requirements generation located within TRADOC. Although this graphical analysis is far from all-encompassing, systems engineering alone is unlikely to be the sole cause of acquisition failures.

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IV. CURRENT STATE OF SYSTEMS ENGINEERING

A. WHY SYSTEMS ENGINEERING IS IMPORTANT

Systems engineering is a specialty that has been gaining ground since the late 1940s; however, the DoD did not officially begin applying systems engineering practices until 2009. The actual ground gained is still minimal compared to the overall field of engineering. According to the National Science Board's (2010) "Science and Engineering Indicators" report, a total of 68,227 undergraduate engineering degrees were awarded in 2006. By comparison, only 723[6] engineering degrees were awarded in the field of systems engineering during the 2006 calendar year (Engineering Manpower Commission & American Association of Engineering Societies, 2006). Training in the field of systems engineering has been incorporated into the Systems Planning, Research, Development, and Engineering (SPRDE) career field by the DAU. However, the implementation of systems engineering practices by non-systems engineers is still widely prevalent in the DoD due to the inconsistent utilization of trained systems engineers. Anecdotal evidence based on multiple conversations within DoD acquisition communities have led us to infer that many systems engineering positions are filled by non-engineer managers who do not hold engineering degrees. While managers are capable of systems thinking,[7] this is usually applied to non-engineering work, which does not require the same level of rigor applied to a systems thought process as systems engineering requires (Franks & Waks, 2004). This creates a disparate level of understanding and functional capability between junior personnel who are expected to understand and perform systems engineering functions, senior staff members who may be classically trained in systems engineering, and those who have "become" systems engineers simply because the signs on their office doors label them as such.

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[6] Included in the total 68,227 as identified by the National Science Board's 2010 report. This number does not include any graduates from DoD-sponsored educational facilities.

[7] Systems thinking allows people to apply their understanding of social-based systems explicit and improve them in a similar way that engineers use engineering principles to make explicit their understanding of engineering systems.

The European Space Agency (2009) described systems engineering as what turns "an initial idea into a full system description, with all necessary elements integrated into a complete whole." They further stated that

> systems engineers maintain the focus on the space system as a whole rather than a collection of functional elements through regular project reviews occurring during subsequent "Phase C/D" development, production and testing. These serve to ensure the mission remains on track. Systems engineering also guides technology development and assesses the impact of new technologies. (ESA, 2009)

Many organizations have postulated that good systems engineering efforts early in the life of a program will result in improved schedules, lower cost, and better product. NASA conducted a study to analyze it. In the late 1980s, Werner Gruhl (2003) of the NASA Comptroller's office set out to improve cost estimation on NASA projects. As part of his effort, he mandated that NASA projects track costs to a common Work Breakdown Structure (WBS) that would allow gathering data across projects. This additional tracking was funded as part of each project. Over several years of live and historic projects, he developed the chart shown in Figure 4 that shows the impact of "front-end" investment (i.e., system definition and analysis) on the accuracy of cost estimation (Gruhl, 2003).

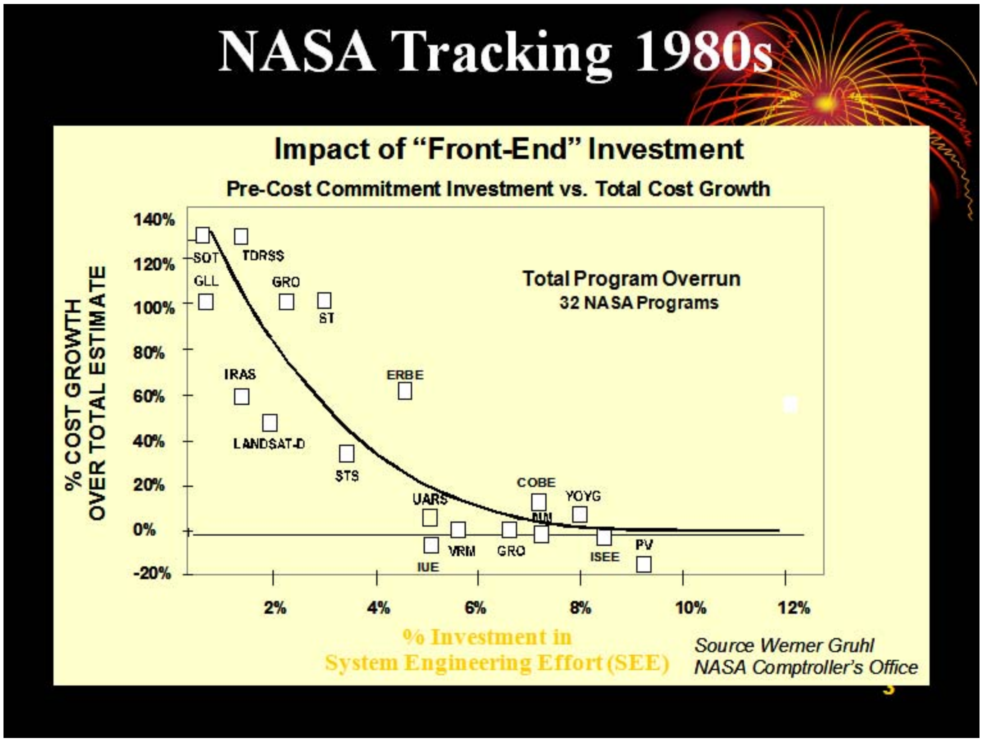

Figure 4. Impact of Front-End Investment
(Gruhl, 2003)

Despite the noted wide dispersion of data, NASA contended that this provided ample evidence for systems engineering investment. In this particular study, the findings were used to recommend a 10–15% investment of program funds to the effort. However, the study did caution that poor quality systems engineering reduces the effectiveness of any potential gain.

This assessment was reinforced during a 2004 presentation to the 14th Annual International INCOSE Symposium in Toulouse, France, where Mr. Eric Honour presented a statistically relevant study, which concluded that increasing the level and quality of systems engineering has a positive effect on cost compliance, schedule compliance, and the subjective quality of the projects (Honour, 2004).

There have been multiple studies performed since 2000 that have described the need for a robust systems engineering capability, but none make a more compelling argument than a 2008 report published by the Air Force Studies Board that studied multiple USAF acquisition programs and came to some common findings. This report made the following statements:

- There is a need for an appropriate level of systems engineering talent and leadership early in the program, with clear lines of accountability and authority. Senior systems engineering personnel should be experienced in the product(s) domain, with strong skills in architecture development, requirement management, analysis, modeling and simulation, affordability analysis, and specialty engineering disciplines (e.g., reliability, maintainability, survivability, system security, and technology maturity management). (AFSB, 2008, p. 49)
- There is a need to establish and nurture a collaborative user/acquirer/ industry team pre-Milestone A to perform system trade-offs and manage overall system complexity. Today, there are often significant disconnects in the hand-offs between users, acquirers, requirements developers, industry, and others. Some of the "best practices" include structured collaboration among these members. (AFSB, 2008, p. 50)
- One must clearly establish a complete and stable set of system-level requirements and products at Milestone A. While requirements creep is a real problem that must be addressed, some degree of requirements flexibility is also necessary as lessons involving feasibility and practicality are learned, insights are gained, technology is matured, and the development subsequently proceeds. Certainly control is necessary, but not an absolute freeze. Also, planning ahead for most likely change possibilities through architectural choices should be encouraged, but deliberately managed, which is a concept encouraged herein. A typical program execution team has a program manager (PM)-level systems engineering integration team (SEIT), with responsibility, authority, and accountability to perform the systems engineering functions (including analysis, modeling and simulation, architecture development, requirements management, and so on). Some of the "program discipline" needs to be in pre-Milestone A management. (AFSB, 2008, p. 50)
- It is necessary to manage the maturity of technologies prior to Milestone B and to avoid reliance on immature technologies. Technology maturity and risk mitigation plans should be carefully managed as an integral part of program plans. (AFSB, 2008, p. 51)

The above statements represent findings from the USAF study as a result of successes and failures that were achieved during USAF acquisition programs. These results serve as guideposts to successful product and program development and are applicable to DoD and U.S. government acquisition programs in general. While this report did not directly result in any new policies being enacted, it is our belief that the commissioning of this report by the AFSB is indicative of the importance that the USAF places in systems engineering.

Although the SoSE is reading reports obtained from the office of the DDR&E (Welby, 2010) and having discussions with the Army Acquisition Executive, both of which identify systems engineering as the root cause of program failure, the list of must-have improvements identified engineering as only one component of the needed fix.

Program failure is a combination of interrelated problems. We identified one problem causing failures of programs to be personnel in systems engineering positions with training less than 100% complete. This is linked with the complexity of the technological aspect of the program as a system and its place in the system of systems. In a sense, people in these positions were in over their heads. Another portion of the problem falls within the realm of an acquisition professional rather than in systems engineering. The final portion is the organizational lack of commitment that PMs and PEOs have to train their staffs.

B. WORKFORCE STATUS

According to the DDR&E, the DoD is lacking in DAU-certified systems engineers (Welby, 2010). Because the Army is subordinate to the DoD, and because their certification numbers are included in the report from the office of the DDR&E, one can infer that the Army is similarly lacking DAU-certified systems engineers.

Clearly, training and certification are available to the DoD with a recognized level of standardization from a variety of sources. But this has not "fixed" the Army's dearth of systems engineering expertise. The problem may be structural inhibitors that prevent student attendance and/or a perception of too narrow of an acquisition focus for the research and development (R&D) or test and evaluation (T&E) communities. INCOSE described certification in this way: "Certification is a formal process whereby a community of knowledgeable, experienced, and skilled representatives within an organization, such as INCOSE, provides formal recognition that a person has achieved competency in specific areas (demonstrated by education, experience, and knowledge)"

(INCOSE, 2010b, para 2). No current certification numbers for the Army or the DoD in general are publicly available for INCOSE certifications.

In a January 19, 2010, briefing to the 6th North Atlantic Treaty Organization (NATO) Life Cycle Management Conference in Brussels, Belgium, Mr. Nicholas Torelli (2010a), Director of Mission Assurance, Systems Engineering Directorate, Office of the Director of Defense Research and Engineering, United States DoD, provided data that showed definitively that the U.S. DoD acquisition workforce is largely comprised of personnel with more than 25 years of service. During this same briefing, Mr. Torelli concluded that the majority of the current DoD acquisition workforce has entered the portion of their career during which they should be mentoring and training the incoming workforce. Mr. Torelli noted that the incoming workforce is sorely lacking in practical experience in the field of systems engineering and explained that one of his organizational challenges is to ensure that the USD(AT&L) is able to accomplish the following:

- Better manage workforce development requirements and certification standards,
- Make better decisions about human capital strategy and initiatives for the systems engineering workforce,
- Provide acquisition programs with the quantity and quality of systems engineers that they need to be successful, and
- Enable the USD(AT&L) to better determine shortfalls at all levels in both competencies and workforce size. (Torelli, 2010a)

Briefings held since late 2008 in the systems engineering arena (Jaggers, 2010; Sharper, 2008; Torelli, 2008; Vannucci, 2008, 2009; Vannucci & Barnabe, 2008; Welby, 2009, 2010) have echoed one common DoD overarching goal: "[to] develop future technical leaders across the acquisition enterprise" (Welby, 2010). Each of the presentations that echoed this goal has noted that the actual execution of the goal is extremely difficult.

A conspicuous example of improper personnel placement is the finding that, in some instances, the systems engineer is a systems engineer in name only. On projects personally familiar to the authors were systems engineering billets filled by persons with no systems engineering training and, in some cases, no engineering training at all. Blame in a situation like this would fall on the systems engineering community if the program failed, but it is actually a failure of the personnel selection process.

In contrast, an excellent example of why effective systems engineering is a valuable goal is the recent success that the Mine Resistant Ambush Protected (MRAP) program has experienced using systems engineering best practices during budget drills for life cycle management. Kevin Fahey, Program Executive Officer Combat Support and Combat Service Support, is quoted as saying "applying systems engineering best practices and Lean Six Sigma (LSS) principles to the MRAP requirements management process enabled the JPO (Joint Program Office) MRAP to reduce process inefficiencies, providing an unprecedented cost avoidance to DoD" (Osborn, 2010).

C. TRADITIONAL SYSTEMS ENGINEERING FUNCTIONS DONE OUTSIDE THE ACQUISITION ARENA

TRADOC serves as the user's representative to establish what the product must do or performance specifications, commonly referred to as *requirements*. Requirements would also include the condition under which the performance should be expected. For example, the performance expected of a battery in desert versus arctic climates might be different. Some engineering skills are needed to ensure that the specification handed to PMs is either within the realm of the possible (and affordable) or at least worthy of research and development to make it so. TRADOC follows guidance from the acquisition community and defines performance specifications rather than identifies the material solutions. Does it matter that the requirements managers, specifying the performance of the product and identifying the context of that system within the system of systems, are not systems engineers or engineers at all? The overlap between TRADOC's efforts and the formal analysis of alternatives that systems engineers should actively participate in is significant.

In Figure 5, the relationship between warfighters, TRADOC, and the material developers is a two-way flow with needs—specifications—and product in the outer circle and feedback to improve product in the inner circle. The mere fact that this classic model is used more often than any other is indicative of the omission of other important organizational perspectives.

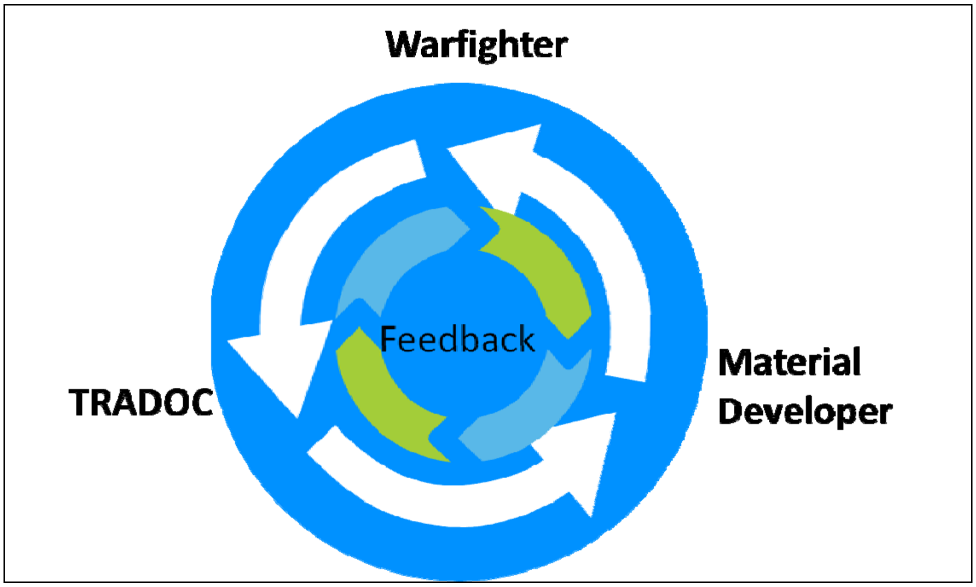

Figure 5. Classic Development Cycle

Missing from Figure 5 is the Army's Test and Evaluation Command (ATEC) and all of the elements of the U.S. Army Research, Development, and Engineering Command (RDECOM). Inclusion of these entities is shown in Figure 6. ATEC is needed because ATEC's evaluators determine product maturity or suitability. Consultation on testable metrics would be advisable. RDECOM often is on the cutting edge of the dividing line between achievable and not feasible. There may be workload, interdisciplinary systems inexperience, or other limitations that make this less than ideal. However, personnel transfers between TRADOC, RDECOM, ATEC, and the material developer are not fluid and this limits potential cross-pollination benefits. The benefit of transferring systems engineering personnel among these organizations includes, but is not limited to, a shared outlook that creates a greater holistic universal perspective for analysis of alternatives, requirements generation, and selection of evaluation criterion.

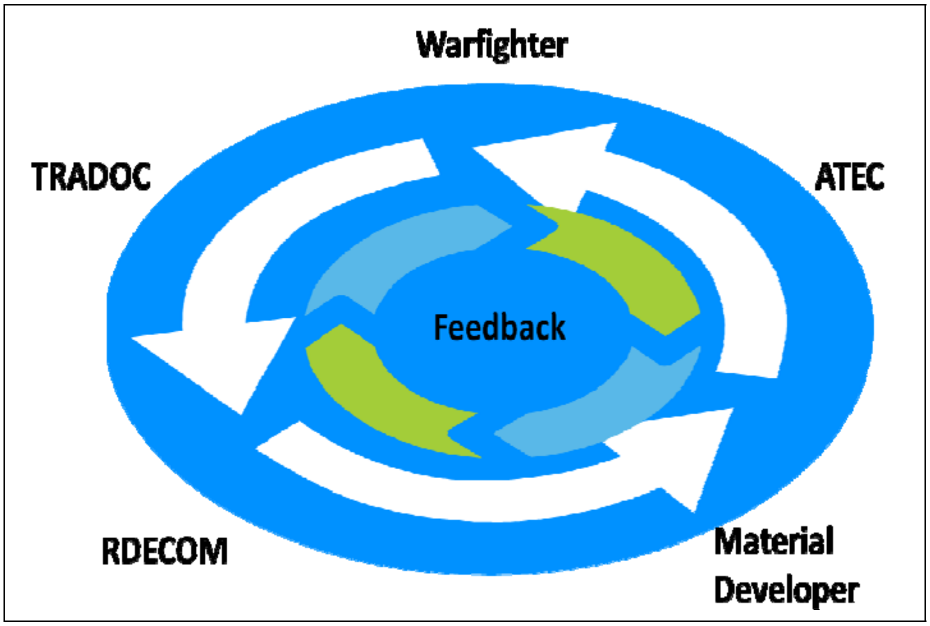

Figure 6. Modified Development Cycle

D. ORGANIZATIONAL AND CULTURAL ISSUES

In the life of a program, systems engineering is critical in the early stages. It is inconceivable that a PM would hire or promote his systems engineer into the program's staff just in time to send him off to training. It is natural for leadership to want to hold on to their critical personnel and release non-essential personnel for school. What happens when that key individual cannot or will not go? In effect, training may be offered to those less likely to be the best. Competition for PEO-managed training dollars may also be an inhibitor to employee access to training. Depending on the fiscal health of a PEO, training opportunities may be limited. These structural barriers exist because of the environment in which PMs operate. Most PMs will want their systems engineers trained and certified, but will expect it to be done on someone else's time and budget.

Only senior management at PEO and above can institute a change in the culture that rewards not only those who manage to take training but also those who sacrifice so that training can be done. We postulate that lack of familiarity with what the DAU, NPS, and other dedicated systems engineering postgraduate institutions can offer is attributable in part to apathy. Many personnel do not seek training if it is not required. Leadership does not require it because they do not want to pay for it or excuse personnel to attend training.

Transforming the workforce will require a different mentality, a new paradigm that rewards individuals for their initiative in seeking and taking training, encourages a leader to let subordinates get the certification, and possibly requires completion within a set time to earn credentials from initial entry into a systems engineering position. Perhaps linking the pay increase of promotions to successful credentials would provide enough incentive.

It is also useful to note that in larger systems engineering organizations like ATEC and RDECOM, senior personnel would also be working toward their own certification and may be somewhat more sympathetic to subordinate requests for training. This cooperative attitude may be further incentivized by encouraging cross-organizational transfers from acquisition organizations, such as PMs or PEOs, or TRADOC locations to ATEC and RDECOM to enable training and to further increase interdepartmental coordination. By making budgetary allowances to organizations that are better able to facilitate this type of training, personnel can rotate through those commands and then return to their sponsor organizations.

V. FINDINGS

A. RECRUITMENT

The Office of Personnel Management (OPM, 2008) estimated that as of October 1, 2006, 57% of full-time, permanent federal employees would be eligible to retire by 2015. This may place some departments at risk of a "brain drain" if too many experienced workers and managers leave at once. At the same time, however, it also presents an opportunity to bring new talent into the workforce to build a solid foundation for the future.

It would be a misperception for the Army to believe that merely increasing the number of systems engineers in the acquisition community would satisfy systems engineering recruitment objectives. Quantity must be balanced with quality. Although quantity goals can be determined for open position numbers and attrition rates, quality goals will be more subjective. These goals could include degree type (since few will have an undergraduate degree in systems engineering), grade point average (GPA), the ranking of the school attended, prior certifications, and prior work or experience factors. Prior certifications include, but are not limited to, certification as a Certified Systems Engineering Professional under INCOSE's certification process, or one of the certification levels within the DAU that are associated with the Systems Planning, Research, Development, and Engineering–Systems Engineering (SPRDE–SE), SPRDE–Program Systems Engineering (SPRDE–PSE), or SPRDE–Science and Technology Management (SPRDE–S&TM) fields. Desired quantity and quality can then lead to successful recruiting that refills the ranks of the Army's aging engineering workforce.

Recruitment is not an event; it is a process. Moira Hanna (2010) explained recruitment as being comprised of several steps: "applicant generation, maintaining applicant status, and applicant job choice/decision." After determining which skills to add to the workforce, and which is a preparation phase preceding recruitment, the government must determine both a method of reaching out to potential applicants and where to direct efforts (Hanna, 2010, p. 1).

The challenges in recruiting are great when an agency is working against the thought processes of current undergraduate students, as found in a recently published 2009 survey by the Partnership and Universum USA group (2009). This survey resulted in the following findings, as shown in Figures 7 and 8:

- Interest in government service is lower among individuals in groups that the government needs most. For example, students with technical/scientific majors are less interested in government and public service than non-technical majors from similar universities.
- Salary expectations are high. Respondents[8] expected to earn an annual salary of more than $49,000 in their first job after graduation. In contrast, starting salaries for entry-level federal government employees with undergraduate degrees typically range from about $30,000 to $38,000, adjusted by locality.

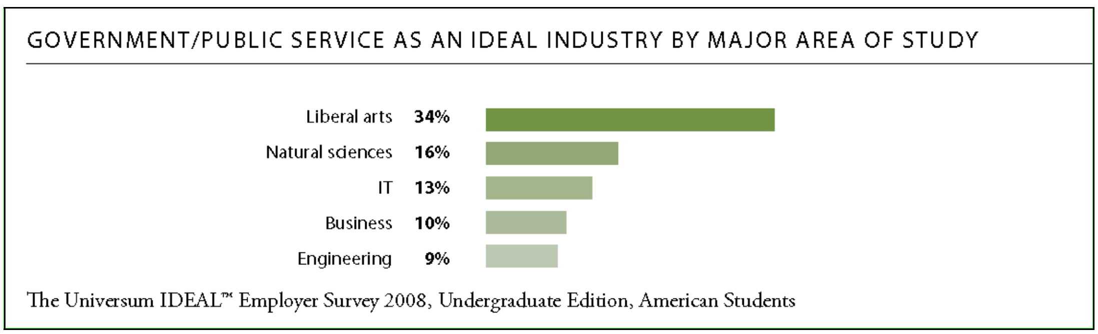

Figure 7. Government/Public Service as an Ideal Industry by Major Area of Study
(Partnership and Universum USA, 2009)

[8] Respondents were from a pool of 31,876 undergraduate students at U.S. universities who participated in the Universum USA's 2008 annual survey.

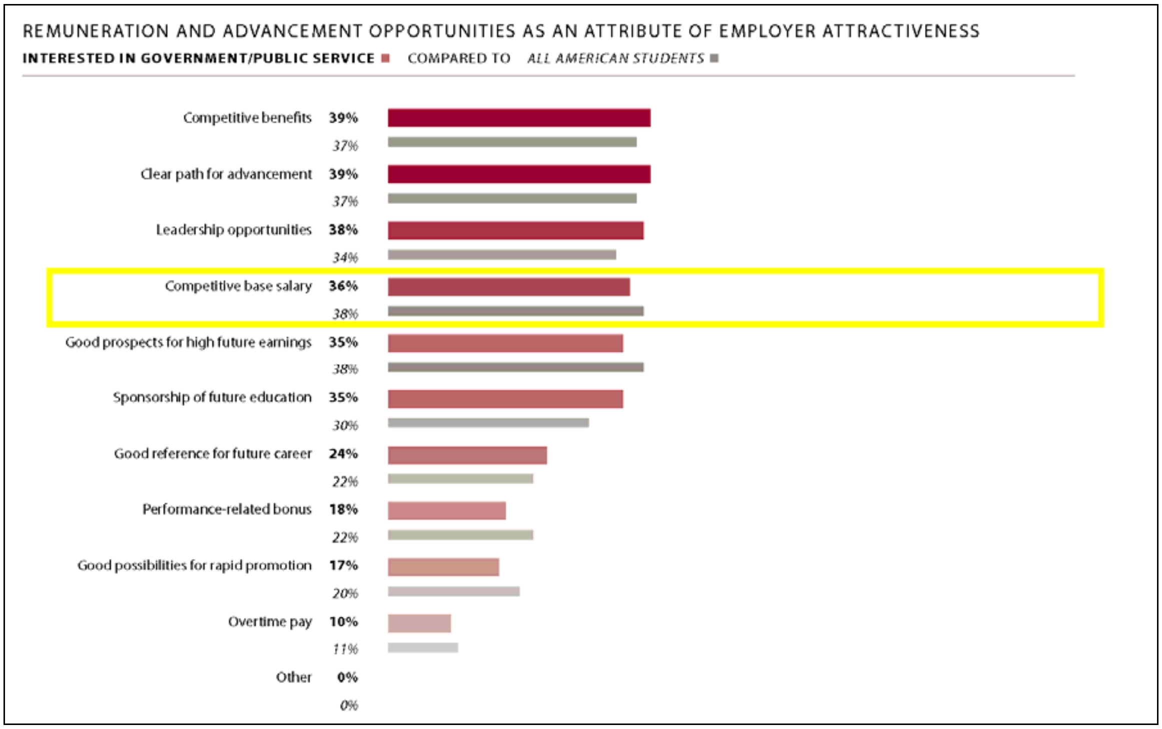

Figure 8. Remuneration and Advancement Opportunities as an Attribute of Employer Attractiveness
(Partnership and Universum USA, 2009)

1. Applicant Generation

The military arm of the DoD is more rooted in methods and in the infrastructure to recruit than its civilian counterpart. The Reserve Officer Training Corps (ROTC) on college campuses is conducted with awareness of, and in cooperation with, local recruiting offices. Although it is a separate chain of command and operates under different quota systems, the ROTC has an established presence that is immediately recognizable and updated and that operates within the digital vernacular of web pages and social media used by the men and women they want to meet. It is beyond the scope of this paper to determine whether the ROTC and Army Recruiting Command infrastructure can be leveraged for Army engineering recruitment, but it is not unrealistic to consider reserve commissioning paired with civilian government service after graduation. Currently, there is a program offered by the Naval Surface Warfare Center, Panama City, FL, that could be leveraged by the Army, but further analysis is necessary to determine if this program would support the needs of the Army. Some defense industry partners are using similar recruiting tactics.

Boeing Aerospace has been using social media such as Facebook as early as 2007 for advertising, contests, and giveaways (Chang, 2007). With nationwide access via the Internet, the Army can target interns as well as future workforce. Internships often lead to new hires that have a better base understanding of the job they are hired to do. One benefit of internships is the recruitment effort conducted by the intern after he returns to campus to complete his schooling. These are the types of social media tools the Army needs to use in order to promote hiring.

2. Combating Financial Misperception

Economic forces have made government careers more desirable during the economic downturn of 2009–2010. Salary expectations are traded for job security. That incentive will not be as dominant of a factor after the economy recovers. What can the government offer instead? The government's ability to bring engineers onboard who lack experience and to offer follow-on engineering or acquisition training gives prospective newcomers more to consider. Certification or educational assistance outside of core engineering could also be offered. Army recruiters often use educational opportunities to entice people to join the Service. Why not apply the same logic to postgraduate education for those who merit the benefit? The Army also offers student loan forgiveness to soldiers with undergraduate degrees. For select specialty skills, loan forgiveness would be worthwhile for the Army in order to fill key positions. Less desirable jobs, hard-to-fill vacancies, or assignments to hardship locations can be tied to greater benefit packages.

It is a commonly held misperception that defense contractors are typically paid more than their government counterparts. This perception appears to be misplaced. Figure 9 shows a snapshot taken from the salary review website Glassdoor (www.glassdoor.com), which shows that the average[9] salary of a systems engineer is around $82,000 per year (Glassdoor, 2011a). Finding a government salary comparison is difficult because of the lack of specific salary reporting. Glassdoor has a smaller data set of salaries that average[10] out to $77,600 per year (Glassdoor, 2011b). This snapshot of government salaries for all engineering position data available is reflected in Figure 10. Even with this data showing a 5% difference in salaries, recruiters trying to fill positions that offer lower pay have to use other incentives to combat the commonly held misperception in order to attract applicants.

[9] Salary data was taken from a random sample of 702 salaries based on the job title *systems engineer* from the salary information website Glassdoor (www.glassdoor.com).

[10] Salary data was taken from a random sample of 21 salaries based on the job title *engineer* from the salary information website Glassdoor (www.glassdoor.com).

Figure 9. Snapshot of Randomly Selected Data on Available Salaries for Systems Engineering Jobs Within the Private Sector
(Glassdoor, 2011a)

Figure 10. Snapshot of All Available Engineering Salary Data
(Glassdoor, 2011b)

3. Applicant Quantity and Quality

A larger pool of interested potential hires is one method of ensuring that enough applicants are able to meet the needed qualifications. Too many organizations claim to be hiring "the best and the brightest" without qualifying their use of that phrase. David Halberstam (1972) coined that phase for the title of his book, which describes the John F. Kennedy presidential team mired in Vietnam, in order to capture a sardonic rather than flattering tone (Rich, 2008). But the *real* need for systems engineers is unlikely to be met by only new graduates, however academically ranked. This is because, as we noted earlier, experience is essential for adaptive engineering within the context of what the Army wants to accomplish with system of systems engineering and integration. However, even advocates of the "grow your own" engineering force will admit that a substantial base is necessary as a starting point.

Recruiting is important, but as The Honorable Mr. Ashton B. Carter, USD(AT&L), stated in his 2010 interview with *Defense AT&L* magazine, "workforce size is important, but quality is paramount" (Anderson, 2010, p. 7). The key to ensuring that quality recruits are found across all levels of the acquisition field is to ensure that the recruitment begins before the current senior level of government employees start retiring.

It may take time to find quality, and it may even be necessary to grow more experienced quality from within if it cannot be found elsewhere.

The easiest way to ensure that recruiting begins quickly is to leverage internships and other entry-level intern programs, which will allow the government to flexibly recruit personnel and provide on-the-job training (OJT). In this manner, classroom learning is supplemented, and candidates experience OJT in real-world scenarios in order to determine if each candidate is correct for the position or if the candidate can be helped to grow into it.

4. Recruiting Practices

Employers must seek access to new ideas and viewpoints by expanding the current search for new middle-level talent from outside the profession—that is, to search for more than traditional engineering graduates. They must recruit from other technical fields such as information technology (IT), physics, chemistry, and biology. This can be summarized by simply stating that they must consider resumes that do not look like the resume of the hiring official.

A mistake made in current student recruitment is to underestimate students' knowledge and abilities—that is, to "pitch" too low. Students today are often better educated in specific technical subjects than their teachers (Partnership for Public Service, 2010). There has been much progress in school curricula in recent years, but because education systems tend to sustain and replicate themselves, major changes are often rejected, regardless of their merit.

The following guidelines will enhance the motivation, education, and training of young people:

- Establish and maintain contact with young people throughout their education and their transition into the ranks of employees.
- Make contact not solely with students but also with all those who impact their decision-making, such as parents, teachers, student advisers, career guidance counselors, school administrations, among others.

- Establish and encourage partnerships among professional engineering associations, colleges, industry, and federal, state, and local government agencies.
- Support scholarships and internships.
- Provide hands-on student research opportunities such as access to government acquisition programs.

Other government agencies are already participating in these sorts of internship recruitment efforts. For example, many of NASA's external hires for entry-level positions have been through the Cooperative Education Program, which provides NASA centers with the opportunity to develop and train future employees and to assess the abilities of potential employees before making them permanent job offers (GAO, 2008a).

Fortunately, mechanisms are already in place for agencies to capitalize on successful internships by hiring students. The federal Student Temporary Employment Program (STEP) and the Student Career Experience Program (SCEP) not only provide work experience that directly relates to a student's academic program and career goals, but also SCEP allows for noncompetitive conversion to term, career, or career-conditional appointments.

B. TRAINING AND CERTIFICATION

Figure 11 serves as a guide for understanding the education progression for Army engineers and acquisition experts. The engineer in an acquisition support role learns more about aspects beyond their initial specialty and ideally would follow a path to systems engineering. This is different from continuing in a specialized engineering education that would maintain movement on the horizontal line. Learning DoD acquisition and systems engineering is not likened to a master's degree in mechanical engineering. This is because the systems engineering taught at the DAU would be focused on the way the engineer supports the PM. The hypothetical jack-of-all-trades resides at the pinnacle in the upper-right corner, which we have labeled Inter-PEO Systems Integrator because the skills are neither solely engineering nor programmatic.

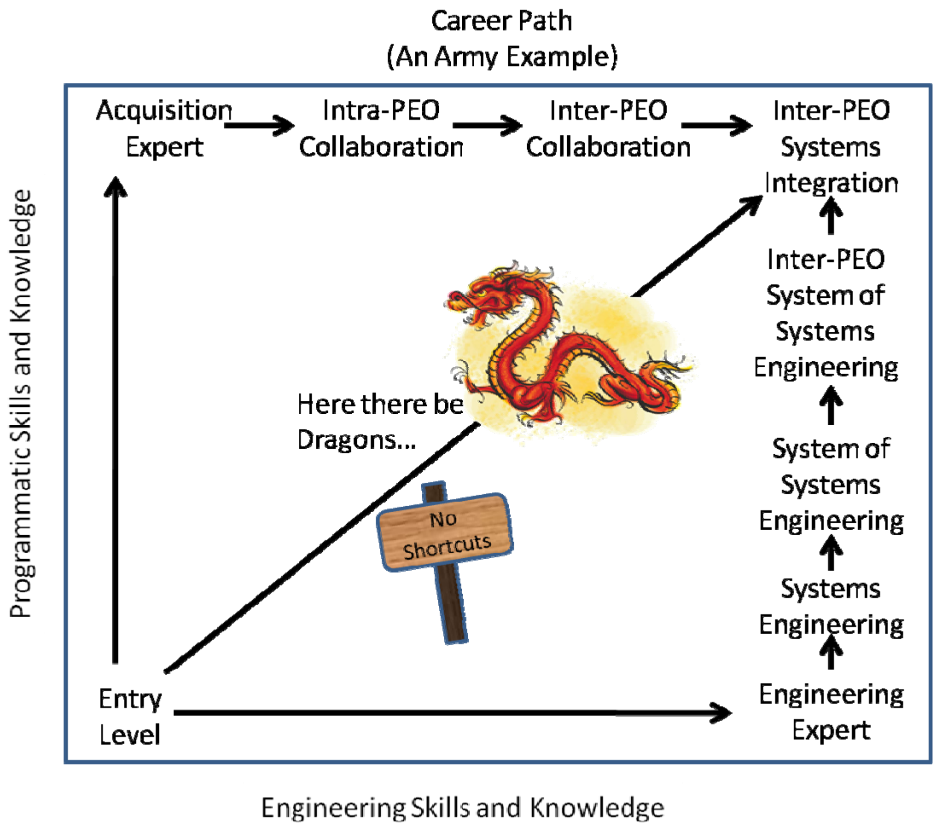

Figure 11. Career Path Progression for Systems Integrator

Systems engineering for a typical PM in this circumstance is subordinate to system of systems engineering or systems integration. The systems engineer looks inward over the domain of the PM or PEO. The system of systems engineer looks up/outward at the next levels in the hierarchy and laterally among peer programs to determine how their respective efforts can combine to fit together as a whole.

At the lowest levels, exceedingly specialized knowledge in a particular area is needed. Development expertise overshadows integration expertise. But at each successive step, the realm of an integrator involves increasingly broader skills over multiple areas.

Referring again to Figure 11, as an acquisition professional increases his scope, he becomes an inter-disciplinary integration expert who is able to keep contributing PMs and their programs aligned. Engineering is only one of those disciplines. As stated before, the chart has "Integrator" in the upper-right corner rather than "Engineer" for a reason. The Master Integrator may or may not have the title of engineer, but she will have engineering training. Likewise, the Master Integrator may not have held an acquisition position as a PM, but she will have taken the training. ASA(ALT) expert Jon Englebrektson (personal communication, December 13, 2010) coined the position as a "Program of Programs Manager" and a partner to the system of systems engineer.

INCOSE has also created a multilevel certification program (INCOSE, 2010b). This program recognizes the skills of a variety of enrollees and certifies them at various stages in their career. While this may be a clearly recognized and very portable certification, it may not be easily worked into the busy schedule of the Army civilian. INCOSE certification levels are depicted in Figure 12. The ability to add extensions to the certifications, such as a specialty in acquisition, is illustrated in the right-hand side of the figure.

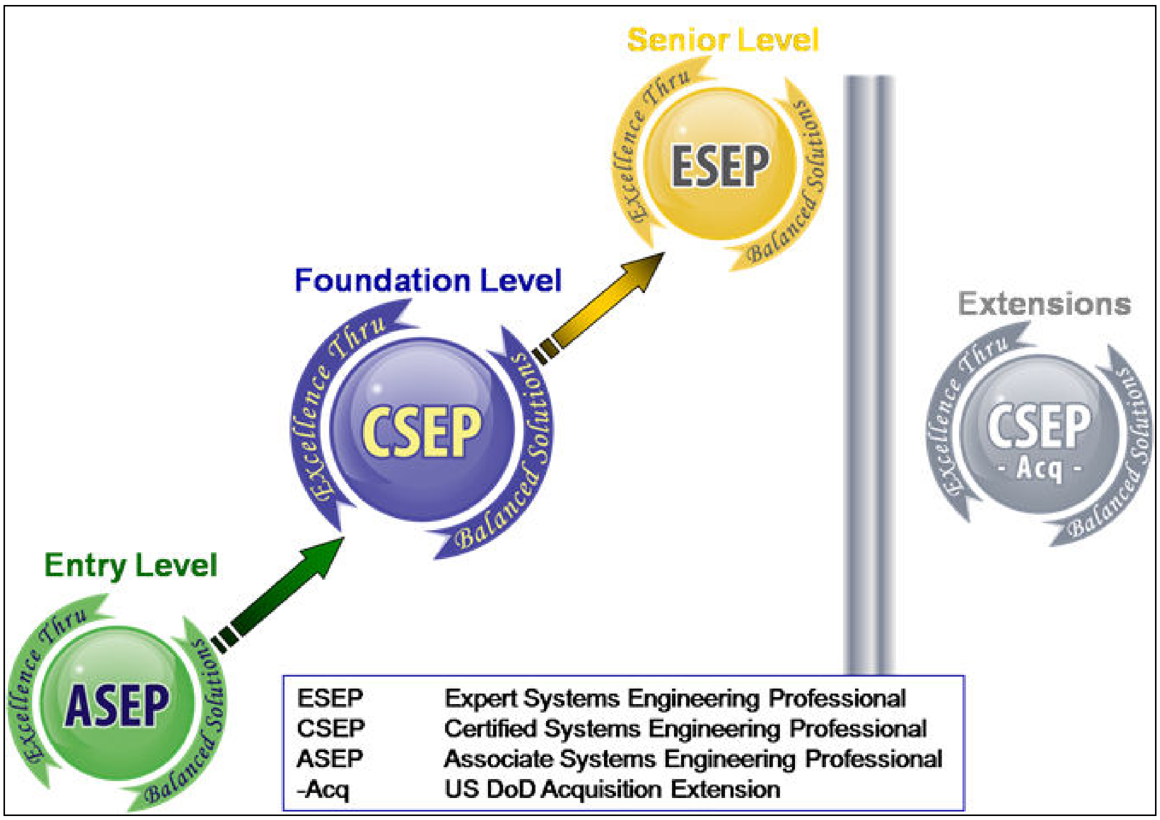

Figure 12. INCOSE Certification Program Progression
(INCOSE, 2010b)

NASA has developed a similar approach, as shown in Figure 13. Core competencies overlap between project management and systems engineering. However, the NASA structure and approach, as noted before, does not "fit" perfectly in the Army (NASA, 2010).

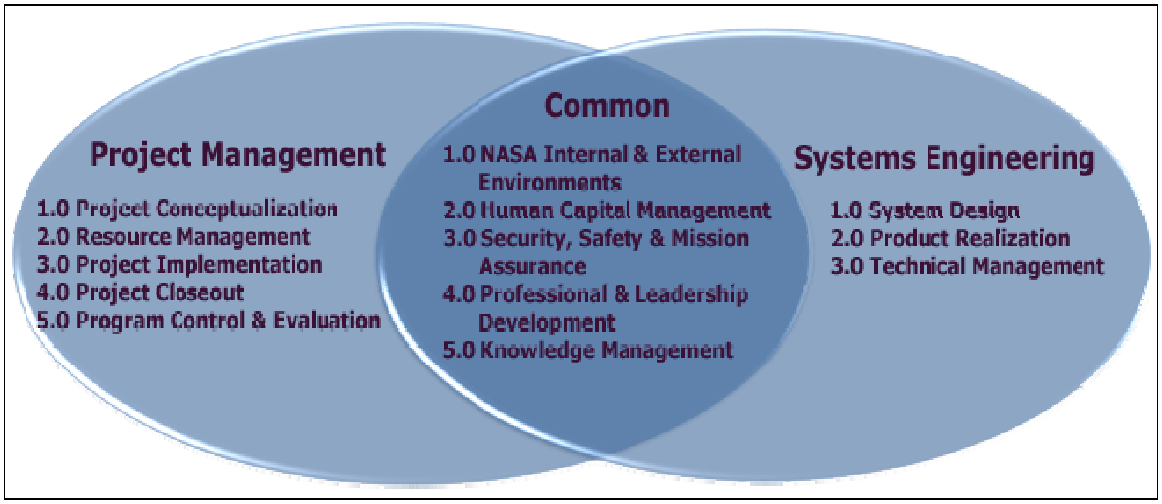

Figure 13. NASA Project Management and Systems Engineering Competency Framework

The key variable, however, is building greater awareness for the field of systems engineering and ensuring that the right kinds of skills are being applied toward these positions. Solving that important challenge could go a long way in helping overcome society's technology challenges and creating a skilled workforce that can more readily find valuable employment opportunities (Amaba, 2010).

The number of college and universities offering programs in systems engineering is increasing as students recognize the employment opportunities available in both government and industry. Schools with smaller systems engineering programs are expanding them as the rate of interest increases (Amaba, 2010). With academia course material currently in an evolutionary stage, how can the Army ensure standardization of the education levels of the systems engineering applicants that it receives who have degrees in systems engineering? The DAU, available to all DoD employees to train in a variety of career fields, is a source for possible standardization.

In response to the perceived need for systems engineers and systems engineering training, the DAU has developed a three-level training and certification program for systems engineers and program systems engineers (see Appendices B and C). These programs allow for a wide range of participants and skill levels, from the newly hired to the more experienced personnel. Experienced personnel are described by the DAU (2010a) as individuals who have four years of technical experience in an acquisition position. Of that experience, at least three years must come from positions in SPRDE–SE, SPRDE–PSE, or SPRDE–S&TM. The remaining year of experience may come from positions in IT, Test and Evaluation, Production Quality Management, PM, or Life Cycle Logistics.

Similar experience gained from other government positions or industry is acceptable as long as it meets similar standards. Experience is further broken down into type of assignment. These are categorized as follows:

- functional specialist,
- software/IT engineer,
- developmental engineer, and
- science and technology research engineer or scientist.

Relatively clear definitions of associated duties can be found in the DAU Certification Guide for each of these assignments at each of the three levels (DAU, 2010a). Completion of course modules for each level of DAU SE certification, per the DAU SE Certification Guide, ensures some standardization of quality and competency.

Core Certification Standards are published as guidelines for acquisition, functional training, education, and experience. DAU courses available in the "Core Plus Development Guide" (DAU, 2010a) are clearly listed and broken down for each assignment type. As a side benefit, this certification structure addresses training for systems engineers operating in traditional engineering roles and the positions of Integrator or Program of Programs Manager (J. Engelbrektson, personal communication, December 13, 2010). Clearly, the perceived need for training from the context of an acquisition professional can be readily fulfilled.

On larger programs, with program elements co-located, an alternative training option is to bring the trainers to the program area and have the training conducted on-site with the project. The trainers come to the project and "educate" the systems engineers on exactly what they need to do and the next steps to take. The FCS, as an Army example, was spread across multiple states and is a program that would not have lent itself to this training solution.

C. RETENTION

The loss of experienced employees, due to retirement or to more promising opportunities, can deal a serious blow to an agency's operational capacity and performance, if the departing workers leave with institutional knowledge and organizational savvy that up-and-coming staffers do not yet have. Attrition and retention are important indicators about the state of the workplace environment.

Any job (even within the government) must offer a rewarding lifestyle. Managers and supervisors of government civilians should seek employees' guidance on their work environment and recognize that especially with today's young people, flexibility and the use of the most current electronic tools are of importance. Retention can be as simple as ensuring that employees are being used to their fullest possible capabilities. The 2008 report by the Merit Systems Protection Board to the President of the United States found that employees overwhelmingly agreed (91%) that their work was important, while one third (32%) indicated that their job did not make good use of their skills and abilities (U.S. Merit Systems Protection Board, 2008).

Another key element in retention is creating a revised attitude toward failures: instead of chastising those whose ideas or projects do not succeed, employers must now recognize the value of failures as a way to learn not only how to prevent future failures but also how to open new pathways to successful results. More and more employers have begun to tolerate failures by their youngest engineers and provide them with the resources needed to assure greater successes later (American Institute of Aeronautics and Astronautics [AIAA], 2009).

Employees should be encouraged to develop project management skills and be given the opportunity to learn a broad spectrum of jobs rather than be expected to focus on a single one. They should receive recognition of their ability and their contributions to society and the profession. As stated earlier in this chapter, training is available and employees who are allowed access to that training are more likely to stay with their organizations. It is up to employers to make it happen.

Employers should not foster "workaholics" by setting the example of 24/7 work; instead, they should encourage a life outside the work place, and they should strive to work a 40-hour week. All workers, regardless of position, should be given at least a summary of the key points of the company strategy. Typically, about two thirds of employees do not involve themselves in their company's goals and nearly half are totally disconnected from their employer (AIAA, 2009). Employers should also ensure that employees understand their role in the greater good and that the employees make a difference in the lives of other people (AIAA, 2009). These two ideas are reinforced by the survey data summarized in Figure 14.

CAREER GOALS OF AMERICAN STUDENTS INTERESTED IN SELECTED INDUSTRIES FOR EMPLOYMENT AFTER GRADUATION

Career Goals	All American Students	Students Interested in Government/Public service	Students Interested in Nonprofit/Not-for-Profit Industry
To be a leader or manager of people	32%	26%	19%
To be a technical or functional expert	15%	12%	5%
To be autonomous or independent	14%	13%	13%
To be competitively or intellectually challenged	40%	40%	39%
To be dedicated to a cause or to feel that I am serving a greater good	46%	63%	80%
To be entrepreneurial or creative/innovative	24%	15%	20%
To be secure or stable in my job	46%	44%	32%
To have an international career	17%	25%	28%
To have work/life balance	66%	60%	63%

The Universum IDEAL™ Employer Survey 2008, Undergraduate Edition, American Students

Figure 14. Career Goals of American Students Interested in Selected Industries for Employment After Graduation
(AIAA, 2009)

According to a 2010 report published by the Partnership for Public Service and Booz Allen Hamilton (2010), retention can be best summarized, as depicted in Figure 15, by ensuring that a balance is met between the four major areas that describe needs that all employees have in order to feel valued and happy:

- teamwork, supervision, and leadership;
- performance management, compensation, benefits, and work/life;
- agency mission and employee skills match; and
- employee development and support.

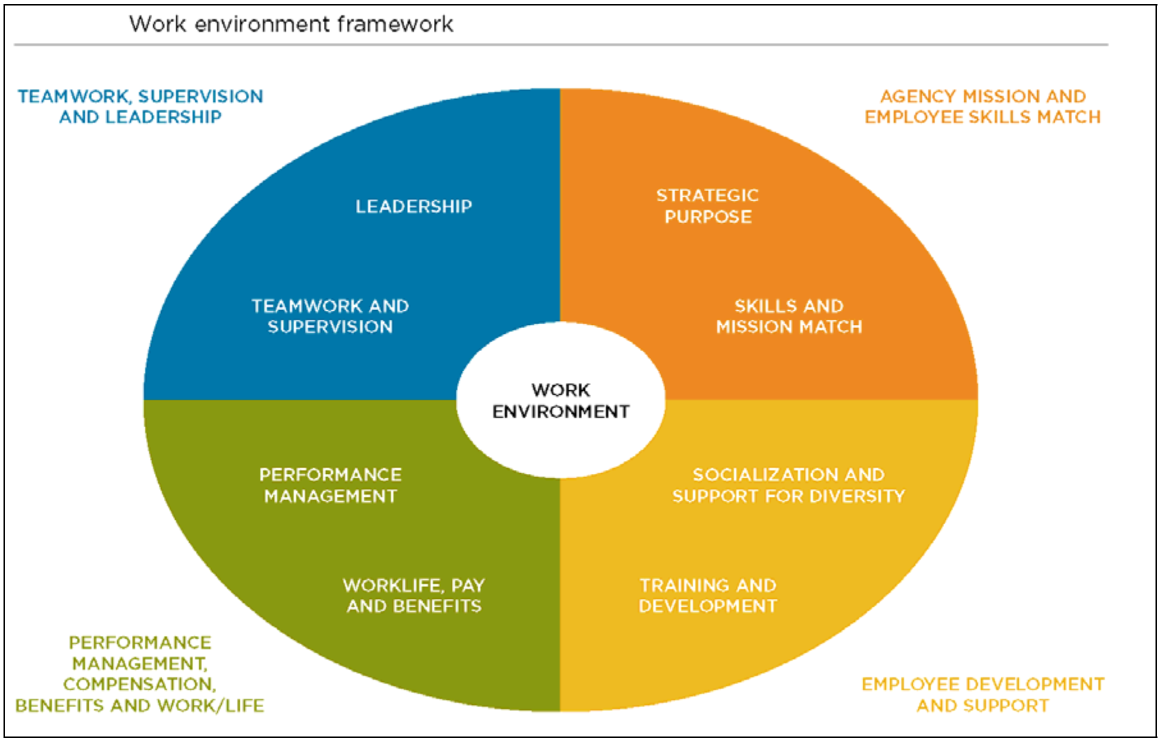

Figure 15. Work Environment Framework
(Partnership for Public Service & Booz Allen Hamilton, 2010)

VI. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

This joint applied project was created to answer the primary question, what recommendations does the ASA(ALT) SoSE need to make to the USD(AT&L) to ensure that the proper personnel are recruited, trained, certified, and retained in order to increase the U.S. Army systems engineering capabilities needed to meet the increasingly complex requirements of the Army's system of systems strategy?

Over the course of researching and writing this joint applied project, we have come to conclusions that we did not originally expect. The technical aspects of training available to the systems engineering community within the DoD appears robust enough to provide value, but staffing the systems engineering community has been problematic at best. It is the implementation of proper recruiting, the use of training, and retention (RTR) that have been the problem. A common theme across the U.S. government is that one rarely ever thinks that RTR is important until we hit a major crisis point, and then when things are slower, no one is thinking about RTR because they are in the process of regrouping.

RTR is a matter of leadership making RTR a priority for their people. It is a matter of supervisors and key management staff acknowledging that education and certification are important—more important than just getting the job done.

If the Army acquisition community wants its people to augment and enhance their current ways of looking at problems and solutions, to stay interested and focused, and to retain its people and provide the necessary continuity that is required to support MDAPs, then it needs to create the proper work environment that allows the RTR actions to occur, without sacrificing the overall mission requirements. This appears to be applicable beyond the Army acquisition community; however, more follow-up study is necessary to determine true applicability.

To phrase it differently, a supervisor might say, “I can do without you for a couple of weeks, if it means you're coming back better and stronger than before.” What a supervisor saying that does to an employee is leave the impression, “I'm valued by this organization and they're interested in my future.”

Additionally, making certification one of the requirements for promotion and for greater responsibility helps to solidly convey the commitment by an organization’s leadership to their people. This way, the promotion requirements are codified in a manner in which people can readily understand where they are within the organizational structure.

The key to a great organization has never solely been its ability to execute its technical mission as efficiently as possible. Leadership guru Warren Bennis best summed up this idea in the following quote:

> Good organizations make people feel that they're at the very heart of things, not at the periphery. Everyone feels that he or she makes a difference to the success of the organization. When that happens, people feel centered and that gives their work meaning. An organization is only as a good as its people. (Heathfield, 2011)

B. RECOMMENDATIONS

As a result of the data and analysis from this paper, we are providing the following recommendations for the ASA(ALT) in four categories: Overarching, Recruitment, Training & Certification, and Retention. These recommendations consist of both recommendations and additional areas of focus that we believe the SoSE needs to consider as part of the process to fix their problem.

The following are our recommendations for the SoSE.

1. Overarching

- Realize that changes to the systems engineering RTR process will not be a panacea for the problems that plague systems engineering for the ASA(ALT).
- Create an ability to articulate exactly what the Army is looking for from systems engineering personnel, to include

- defining what activities a systems engineer is expected to perform in support of an acquisition program,
- listing the artifacts of those performed activities, and
- creating metrics to measure success.

- Ensure that recruiting, training, and retaining employees are not short-term goals and that short-term fixes are not something that should be expected.
- Create incentives for systems engineering employees who want to stay in these positions.
- Develop a metric (or series of metrics) to ensure that the proper workforce size and quality are met.
- Develop a process that ensures that organic workforce growth is adequately met.
- Develop a system to ensure that proper retirement knowledge transfer occurs given the fact that 57% of the DoD acquisition workforce is expected to retire by 2015.

2. Recruitment

- Establish an Army systems engineering recruitment strategy.
- Focus on creating a work environment that attracts personnel who would not normally be interested in government service.
- Increase focus on out-of-the-box candidates as the best candidates for the job, even if they might not appear to be the best ones on paper.
- Improve the advertising to potential recruits in areas in which government service provides more value than the private sector (e.g., the ability to make a difference in real-world situations).
- Improve the ability of the recruitment process to include current DoD non-Army personnel into the overall recruitment process.

3. Training and Certification

- Develop a rapport with education providers to present recommendations to influence the kind of curricula that are out there for systems engineering (e.g., more broad-based program management skills).
- Develop a cross-training capability for new systems engineers coming into the government, such as a specialized systems engineer intern-type program so that these new graduates get a feel for the total acquisition process from the perspectives of different people, levels of responsibility, subject-matter experts, program offices, PEOs, etc.

- Focus on education and specialized experience to ensure that the right people are being selected for key positions.

4. Retention

- Ensure that the retention of good people is a focus for the leadership in the Army—cross-training opportunities, opportunities with industry, long-term training opportunities, and perhaps even a separate pay scale like there is for scientists need to be an initiative that is a high priority for Army leadership.
- Develop a process that allows people who have the capability to be systems integrators to be recognized by management as able to take on systems engineering types of positions, even if they are not necessarily schooled engineers. Provide opportunities to attend conferences and symposia to allow for community recognition and involvement.
- Recognize personnel for their achievements in continuous learning.

APPENDIX A. RESEARCH MATRIX

Table A1. Research Matrix Developed to Focus Research, Questions 1–9

	RESEARCH QUESTION	ANALYSIS NEEDED	DATA REQUIRED
1	What is a Systems Engineer	Assessment of posititions currently identified as SE but NOT associated with traditional engineering backgrounds and prerequisites	Current Army definition of Systems Engineer
		Review of SE literature from course	Incose definition
		What systems engineers need to know (handout)	DoD definition (Def Acq Guidebook)
		Review of DDRE briefings	Mis-identification instances
1a	How are Systems Engineers currently utilized	Review of current SE policies	Army SE overview NDIA SE conference
		Review of New Acq Initiatives and implementation for SE, OSD	OSD policy on Army SE policy for PEOs
			RDECOM SE policy for PEOs
2	How does the Army recruit, train, certify and retain a core competency of Systems Engineers	Review of current Army policy for hiring Sys Engrs	Definition of policies
		Motivation theories	Review of current literature
		Retention theories	Review of current literature
3	Why are Army acquisition programs failing	Leadership?/Budget/Stovepipe programs that lack required interoperability	Look at programs that have recently failed, been restructured, or cancelled to find out what were the factors driving the decisions -- could they have been attributed to the lack of systems engineering?
		What is the cultural resistance to Ses?	Rand Study
3a	Why are recently fielded and currently fielding Army systems not compatible/interoperable	Review of ASAALT briefings	PEO-I and FFID direction from VCSA.
		DoD SE Briefings	
4	What has changed that makes the need for Systems Engineering greater	Review of top 5 SE issues in Defense Industry - NDIA task force	Pull information from handout, RAND STUDY, RDECOM information, C3T information
5	What is being done by other parts of the Government, DoD, Industry and Academia in the field of SE and the context of their efforts	What is diferent about the way NASA or Navy solves a problem and the way the Army does it?	Comparison of courses offered; where is there a gap. Need Raytheon SE plan, NASA SE plan, Navy SE plan, Rand corp report, REDECOM SE plan, C3T teaming arrangement. DAU Curriculum, NPS, INCOSE, NASA, Academia, Also reference Achitecture training for Capability Managers in TRADOC.
		Army reconfigures unit structure and mission "on the fly" - what impact does this have on SE or on routine vs adaptive expertise?	
		Is SE focus too narrow?	
6	Does the Army need only Systems engineering or is something else needed to agument systems engineering	Review of WSARA?	WSARA and "trends" of civilianizing positions. Gates direction to reduce contractor spaces.
7	How do the challenges faced by ASAALT qualify as wicked problems and how are these wicked problems solved	What are wicked problems; definition; examples	Definition of wicked problems, Case study, restructuring to make problems go away, taming wicked problems.
8	Is it enough to have "engineering analysis" levy engineering requirements on PMs to adjust product when that will have programmatic cost and schedule impacts	TRL migration to SRL, Points awarded for solving problems traditionally outside the PM's lane.	NASA analysis - SRL research, Systems view
9	Are systems engineers to be empowered over the PMs	Systems engineering needed up front - poor articulation of benefits causes PM's to not invest.	DAU training for SE, Requirements tracability impact on SE, post-production SE perspective,

Table A2. Research Matrix Developed to Focus Research, Questions 10–15

	RESEARCH QUESTION	ANALYSIS NEEDED	DATA REQUIRED
10	How do we acquire adaptive experts rather than the routine experts that formal engineering education produces	How do we apply systems thinking in an approach that leverages SE, operates within the contractual/legal language of Acquisition and understands the reality of human behavior impacts on the DoD procurement process	Find examples of successful programs that think outside the box.
		Can we develop courseware that challenges people to think outside the box?	Find classes like NPS, DAU, and UCSD. Focus on critical thinking, non-traditional problem solving.
11	How are organizations structured to allow for the adaptive expertise/paradigm shifing to allow for out of the box solutions	Are these examples applicable to ARMY?	Find examples of successful programs that think outside the box. Manhattan Project, the Wiz Kids, other examples? We need published information that SHOWS how Army re-invents itself every year/every war/ every change in leadership.
12	What kind of training curriculum do we build for the systems integrator/adaptive expert	Review of career path Alan developed	TRADOC core competencies
		Leadership	Look at NASA SE leadership development program
		How do we build from the various SE and Acquisition courses currently in the marketplace (both gov't and industry) -- what is the "best of breed" in each of these areas that would establish a cohesive coursewarefor Systems Integration	DAU Curriculum, NPS, INCOSE, NASA, Academia
13	What is required to retain and motivate the adaptive experts/systems integrators	How does industry retain and motivate, what works and how much does it cost?	OPM Materials
		What are current government practices and policies	Positioning the agency, designing and implementing a diversity program, sustaining commitment
		Building and maintaining a diverse workforce	Look at industry
		National Grid website	Building a world-class workforce
		Nat'l Assoc of State Workforce Board Chairs	Building and retaining the aerospace workforce
		Will Examples from NASA be applicable to Army	NASA briefs - show narrow focus does NOT matter in regards to rewards.
14	What are the tools of the of the SE trade and how can they be maximized to ensure maximum utility	Cross walk these tools between acquisition, ARCIC, ASA(ALT) and industry.	DAU SE training (tools) INCOSE "tools" - SAIC "tools" (release required)
15	Cultural and policy impediments	Corporate resitance to change	Rice bowls….. Library book

APPENDIX B. DAU SPRDE–SE CERTIFICATION PROGRAM

Table B1. DAU SPRDE–SE Certification Guide Level I
(DAU, 2011)

Feature - Systems Engineering Certification Guide Level I

Level I | Level II | Level III

Level I Certification Guide

Type of Assignment	Representative Activities
Functional Specialist	▸ Plans, organizes, and conducts engineering activities relating to the design, development, fabrication, installation, modification, sustainment, and/or analysis of systems or systems components for a functional specialty (i.e., reliability and maintainability, systems safety, materials, avionics, structures, propulsion, chemical/biological, human systems interfaces, weapons, etc.). ▸ Demonstrates how systems engineering technical processes and technical management processes guide engineering activities for a functional specialty.
Software/IT Engineer	▸ Plans, organizes, and conducts engineering activities relating to the design, development, and/or analysis of software and information technology systems or systems components. ▸ Demonstrates how systems engineering technical processes and technical management processes guide software development and/or IT integration activities.
Developmental Engineer	▸ Plans, organizes, and conducts engineering design and development activities for systems or systems components. ▸ Demonstrates how systems engineering technical processes and technical management processes guide design and development activities.
Science and Technology (Research Eng or Scientist)	▸ Plans, organizes, and conducts science and technology research and engineering activities supporting acquisition programs, projects, or activities. ▸ Demonstrates how systems engineering technical processes and technical management processes guide science and technology research and engineering activities.

Core Certification Standards (Required for DAWIA certification.)	
Acquisition Training	▸ **ACQ 101** Fundamentals of Systems Acquisition Management
Functional Training	▸ **SYS 101** Fundamentals of Systems Planning, Research, Development, and Engineering
Education	▸ Baccalaureate or graduate degree in a technical or scientific field such as engineering, physics, chemistry, biology, mathematics, operations research, engineering management, or computer science
Experience	▸ 1 year of technical experience in an acquisition position from among the following career fields/paths: SPRDE-SE, SPRDE-S&T, IT, T&E, PQM, FE, PM, or LCL ▸ Similar experience gained from other government positions or industry is acceptable as long as it meets the above standards

Table B2. DAU SPRDE–SE Core Plus Development Guide Level I (DAU, 2011)

Core Plus Development Guide (Desired training, education, and experience.)	Type of Assignment			
Training	Func Spc	Soft/IT Eng	Dev Eng	S&T (Res Eng/Sci)
BCF 102 Fundamentals of Earned Value Management	✓	✓		
BCF 106 Fundamentals of Cost Analysis	✓			
BCF 107 Applied Cost Analysis **(R)**	✓			
CLE 001 Value Engineering	✓			
CLE 004 Introduction to Lean Enterprise Concepts	✓	✓	✓	✓
CLE 009 System Safety in Systems Engineering	✓		✓	
CLE 011 Modeling and Simulation for Systems Engineering	✓	✓	✓	✓
CLE 015 Continuous Process Improvement Familiarization	✓	✓	✓	✓
CLE 036 Engineering Change Proposals for Engineers	✓	✓	✓	✓
CLL 011 Performance-Based Logistics	✓			
CLM 013 Work-Breakdown Structure	✓	✓	✓	✓
CLM 016 Cost Estimating	✓	✓	✓	✓
CLM 017 Risk Management	✓	✓	✓	✓
IRM 101 Basic Information Systems Acquisition		✓		
LOG 101 Acquisition Logistics Fundamentals	✓		✓	
LOG 102 Systems Sustainment Management Fundamentals	✓			
PQM 101 Production, Quality, and Manufacturing Fundamentals	✓		✓	
SAM 101 Basic Software Acquisition Management		✓		
TST 102 Fundamentals of Test and Evaluation	✓	✓	✓	✓
Education				
▸ None specified				
Experience				
▸ One (1) year of technical experience (in addition to core certification experience)				

Notes:

1 The Core Certification Standards section lists the training, education, and experience REQUIRED for certification at this level.

2 "(R)" following a course title indicates the course is delivered as resident based instruction.

3 When preparing your IDP, you and your supervisor should consider the training, education, and experience listed in this Core Plus Development Guide if not already completed.

Table B3. DAU SPRDE–SE Certification Guide Level II
(DAU, 2011)

Feature - Systems Engineering
Certification Guide Level II

Level I | **Level II** | Level III

Level II Certification Guide

Type of Assignment	Representative Activities
Functional Specialist	Organizes, conducts, and/or monitors engineering activities in a functional specialty relating to the design, development, fabrication, installation, modification, sustainment, and/or analysis of systems or systems components. Analyzes, conducts, and/or monitors engineering activities in a functional specialty relating to the design, development, fabrication, installation, modification, sustainment, and/or analysis of systems or systems components. Applies systems engineering technical and technical management processes to a functional specialty in IPT environments.
Software/IT Engineer	Organizes, conducts, and/or monitors engineering activities relating to the design, development, and/or analysis of software and information technology systems or systems components. Applies systems engineering technical and technical management processes to software and IT development.
Developmental Engineer	Organizes, conducts, and/or monitors engineering design and development activities for systems or systems component. Applies systems engineering technical and technical management processes during systems development.
Science and Technology (Research Eng or Scientist)	Organizes, conducts, and/or monitors science and technology research and engineering activities supporting acquisition programs, projects, or activities. Applies systems engineering technical and technical management processes to managing or conducting science and technology research and engineering activities.

Core Certification Standards (Required for DAWIA certification.)	
Acquisition Training	**ACQ 201A** Intermediate Systems Acquisition, Part A **ACQ 201B** Intermediate Systems Acquisition, Part B **(R)**
Functional Training	**SYS 202** Intermediate Systems Planning, Research, Development, and Engineering, Part I **SYS 203** Intermediate Systems Planning, Research, Development, and Engineering, Part II **(R)** **CLE 003** Technical Reviews
Education	Baccalaureate or graduate degree in a technical or scientific field such as engineering, physics, chemistry, biology, mathematics, operations research, engineering management, or computer science
Experience	2 years of technical experience in an acquisition position. Of that: - At least 1 year in a SPRDE-SE, SPRDE-PSE, or SPRDE-S&TM position - Remainder may come from IT, T&E, PQM, PM, or LCL Similar experience gained from other government positions or industry is acceptable as long as it meets the above standards

Table B4. DAU SPRDE–SE Core Plus Development Guide Level II (DAU, 2011)

Core Plus Development Guide (Desired training, education, and experience.)	Type of Assignment			
Training	Func Spc	Soft/IT Eng	Dev Eng	S&T (Res Eng/Sci)
CLB 016 Introduction to Earned Value Management	✓	✓		
CLB 017 Performance Measurement Baseline	✓	✓		
CLC 041 Predictive Analysis and Systems Engineering	✓	✓		
CLE 007 Lean Six Sigma for Manufacturing	✓	✓	✓	
CLE 016 Outcome-Based Performance Measures	✓	✓		
CLE 017 Technical Planning	✓	✓	✓	✓
CLE 026 Trade Studies	✓	✓	✓	✓
CLM 029 Net-Ready Key Performance Parameter (NR-KPP)	✓	✓	✓	✓
CLM 031 Improved Statement of Work	✓	✓	✓	✓
CLM 032 Evolutionary Acquisition	✓	✓	✓	
CLM 101 Analysis of Alternatives (AoA) (USAF Process)	✓	✓		✓
IRM 202 Intermediate Information Systems Acquisition **(R)**		✓		
LOG 103 Reliability, Availability, and Maintainability (RAM)	✓		✓	
LOG 200 Intermediate Acquisition Logistics, Part A	✓		✓	
LOG 204 Configuration Management	✓	✓	✓	✓
PQM 201A Intermediate Production, Quality, and Manufacturing, Part A		✓		
STM 202 Intermediate S&T Management **(R)**				✓
TST 203 Intermediate Test and Evaluation **(R)**				✓

Education

- Graduate degree in a discipline such as engineering, physics, chemistry, biology, mathematics, operations research, engineering management, or computer science

Experience

- Two (2) years of technical experience (in addition to core certification experience)

Notes:

1 The Core Certification Standards section lists the training, education, and experience REQUIRED for certification at this level.

2 "(R)" following a course title indicates the course is delivered as resident based instruction.

5 When preparing your IDP, you and your supervisor should consider the training, education, and experience listed in the Core Plus Development Guide at this and the lower level(s) if not already completed.

13 Some continuous learning (CL) modules have been created by extracting lessons in their entirety from a training course. If this is the case for the CL module(s) identified in the above core certification standards, the course from which the CL module was extracted is identified in the "Notes" section of the CL course description and the course can be substituted to meet the certification standard.

Table B5. DAU SPRDE–SE Certification Guide Level III
(DAU, 2011)

Feature - Systems Engineering
Certification Guide Level III

Level I | Level II | **Level III**

Level III Certification Guide

Type of Assignment	Representative Activities
Functional Specialist	▸ Leads and/or manages engineering activities in a functional specialty relating to the design, development, fabrication, installation, modification, sustainment, and/or analysis of systems or systems components. ▸ Ensures appropriate systems engineering technical and technical management processes are properly applied to functional specialty activities that support IPT environments.
Software/IT Engineer	▸ Leads and/or manages engineering activities relating to the design, development, and/or analysis of software and information technology systems or systems components. ▸ Ensures appropriate systems engineering processes are properly applied to software development and/or IT integration activities.
Developmental Engineer	▸ Leads and/or manages design and development activities for systems or systems components. ▸ Ensures appropriate systems engineering processes are properly applied during systems development.
Science and Technology (Research Eng or Scientist)	▸ Leads and/or manages science and technology research and engineering activities supporting acquisition programs, projects, or activities. ▸ Ensures appropriate systems engineering processes are properly applied during science and technology activities.

Core Certification Standards (Required for DAWIA certification.)	
Acquisition Training	▸ Acquisition Training identified at Level II must have been completed
Functional Training	▸ **SYS 302** Technical Leadership in Systems Engineering **(R)** ▸ **CLL 008** Designing for Supportability in DoD Systems
Education	▸ Baccalaureate or graduate degree in a technical or scientific field such as engineering, physics, chemistry, biology, mathematics, operations research, engineering management, or computer science
Experience	▸ 4 years of technical experience in an acquisition position. Of that: ▸ - At least 3 year in a SPRDE-SE, SPRDE-PSE, or SPRDE-S&TM position ▸ - Remainder may come from IT, T&E, PQM, PM, or LCL ▸ Similar experience gained from other government positions or industry is acceptable as long as it meets the above standards

Table B6. DAU SPRDE–SE Core Plus Development Guide Level III
(DAU, 2011)

Core Plus Development Guide (Desired training, education, and experience.)	Type of Assignment			
Training	Func Spc	Soft/IT Eng	Dev Eng	S&T (Res Eng/Sci)
CLE 008 Six Sigma: Concepts and Processes	✓	✓	✓	✓
CLE 021 Technology Readiness Assessments	✓	✓	✓	✓
CLE 301 Reliability and Maintainability	✓	✓	✓	✓
CLL 022 Title 10 Depot Maintenance Statute Overview	✓		✓	
CLL 023 Title 10 U.S.C. 2464 Core Statute Implementation	✓			
CLL 024 Title 10 Limitations on the Performance of Depot-Level Maintenance (50/50)	✓			
CLL 025 Depot Maintenance Interservice Support Agreements (DMISA)	✓			
CLM 014 IPT Management and Leadership	✓	✓	✓	✓
CLM 034 Science and Technology—Lesson from PMT 352A				✓
LOG 201 Intermediate Acquisition Logistics, Part B **(R)**	✓		✓	
LOG 235 Performance-Based Logistics, Part A	✓			
LOG 236 Performance-Based Logistics, Part B **(R)**	✓			
PMT 251 Program Management Tools Course, Part I	✓		✓	✓
PMT 256 Program Management Tools Course, Part II	✓		✓	✓
PMT 352A Program Management Office Course, Part A	✓		✓	✓
PQM 203 Preparation of Commercial Item Description for Engineering and Technical Personnel			✓	
SAM 301 Advanced Software Acquisition Management **(R)**		✓		
STM 303 Advanced S&T Management **(R)**				✓
TST 303 Advanced Test and Evaluation **(R)**	✓	✓	✓	✓
Education				
‣ Graduate degree in a discipline such as engineering, physics, chemistry, biology, mathematics, operations research, engineering management, or computer science				
Experience				
‣ Four (4) years of technical experience (in addition to core certification experience)				

Notes:

1 The Core Certification Standards section lists the training, education, and experience REQUIRED for certification at this level.

2 "(R)" following a course title indicates the course is delivered as resident based instruction.

5 When preparing your IDP, you and your supervisor should consider the training, education, and experience listed in the Core Plus Development Guide at this and the lower level(s) if not already completed.

13 Some continuous learning (CL) modules have been created by extracting lessons in their entirety from a training course. If this is the case for the CL module(s) identified in the above core certification standards, the course from which the CL module was extracted is identified in the "Notes" section of the CL course description and the course can be substituted to meet the certification standard.

APPENDIX C. DAU SPRDE–PSE CERTIFICATION PROGRAM

Table C1. DAU SPRDE–PSE Certification Guide Level I
(DAU, 2011)

CERTIFICATION STANDARDS & CORE PLUS DEVELOPMENT GUIDE
SPRDE – PROGRAM SYSTEMS ENGINEER LEVEL I

Type of Assignment	Representative Activities
Acquisition Program Systems Engineer	● Demonstrates how systems engineering technical and technical management processes apply to acquisition programs. ● Interacts with program IPTs regarding the proper application of systems engineering processes. ● Develops systems models and work breakdown structures; uses top-down design and bottom-up product realization.
Sustainment Program Systems Engineer	● Demonstrates how systems engineering processes apply while working in a program office or user support team supporting in-service, out-of-production systems. ● Interacts with user support teams regarding sustainability and reliability/maintainability improvements on fielded systems.

Core Certification Standards (required for DAWIA certification)	
Acquisition Training	ACQ 101 Fundamentals of Systems Acquisition Management
Functional Training	● SYS 101 Fundamentals of Systems Planning, Research, Development, and Engineering ● Two 100-level courses must come from the following list: ● BCF 102 Fundamentals of Earned Value Management ● IRM 101 Basic Information Systems Acquisition ● LOG 101 Acquisition Logistics Fundamentals ● LOG 102 Systems Sustainment Management Fundamentals ● PQM 101 Production, Quality, and Manufacturing Fundamentals ● TST 102 Fundamentals of Test and Evaluation
Education	Baccalaureate or graduate degree in a technical or scientific field such as engineering, physics, chemistry, biology, mathematics, operations research, engineering management, or computer science
Experience	● 2 years of experience in an SPRDE-SE, SPRDE-PSE, or SPRDE-S&TM acquisition position ● Similar experience gained from other government positions or industry is acceptable as long as it meets the above standards

Table C2. DAU SPRDE–PSE Core Plus Development Guide Level I (DAU, 2011)

Core Plus Development Guide (desired training, education, and experience)	Type of Assignment	
Training	**Acq Prg Sys Eng**	**Sus Prg Sys Eng**
BCF 102 Fundamentals of Earned Value Management	✔	
BCF 106 Fundamentals of Cost Analysis	✔	
BCF 107 Applied Cost Analysis (R)	✔	
CLB 009 Planning, Programming, Budgeting, and Execution and Budget Exhibits	✔	✔
CLB 016 Introduction to Earned Value Management	✔	✔
CLC 108 Strategic Sourcing Overview		✔
CLC 112 Contractors Accompanying the Force		✔
CLE 001 Value Engineering	✔	✔
CLE 004 Introduction to Lean Enterprise Concepts	✔	✔
CLE 009 System Safety in Systems Engineering	✔	
CLE 011 Modeling and Simulation for Systems Engineering	✔	
CLE 015 Continuous Process Improvement Familiarization	✔	✔
CLE 036 Engineering Change Proposals for Engineers	✔	✔
CLL 002 Defense Logistics Agency Support to the PM	✔	✔
CLL 006 Depot Maintenance Partnering		✔
CLL 011 Performance-Based Logistics	✔	✔
CLL 017 Introduction to Defense Distribution		✔
CLM 013 Work-Breakdown Structure	✔	
CLM 016 Cost Estimating	✔	✔
CLM 017 Risk Management	✔	✔
CLM 021 Introduction to Reducing Total Ownership Costs (R-TOC)	✔	
CLM 032 Evolutionary Acquisition	✔	✔
IRM 101 Basic Information Systems Acquisition	✔	✔
LOG 101 Acquisition Logistics Fundamentals	✔	
LOG 102 Systems Sustainment Management Fundamentals		✔
PQM 101 Production, Quality, and Manufacturing Fundamentals	✔	
TST 102 Fundamentals of Test and Evaluation	✔	✔
Education		
None specified		
Experience		
None specified		

Notes:

- The Core Certification Standards section lists the training, education, and experience REQUIRED for certification at this level.
- "(R)" following a course title indicates the course is delivered as resident based instruction.
- When preparing your IDP, you and your supervisor should consider the training, education, and experience listed in this Core Plus Development Guide if not already

Table C3. DAU SPRDE–PSE Certification Guide Level II
(DAU, 2011)

CERTIFICATION STANDARDS & CORE PLUS DEVELOPMENT GUIDE
SPRDE – PROGRAM SYSTEMS ENGINEER LEVEL II

Type of Assignment	Representative Activities
Acquisition Program Systems Engineer	• Applies systems engineering technical and technical management processes in IPTs. • Develops program/project systems engineering plans, etc.
Sustainment Program Systems Engineer	• Applies systems engineering processes in program offices and/or user support teams for in-service, out-of-production systems. • Develops system upgrade/modification plans to support new or interoperability requirements. • Develops obsolescence mitigation, technology insertion/modernization, reliability/maintainability improvement, etc., plans, as appropriate.

Core Certification Standards (required for DAWIA certification)	
Acquisition Training	• ACQ 201A Intermediate Systems Acquisition, Part A • ACQ 201B Intermediate Systems Acquisition, Part B (R)
Functional Training	• LOG 204 Configuration Management • SYS 202 Intermediate Systems Planning, Research, Development, and Engineering, Part I • SYS 203 Intermediate Systems Planning, Research, Development, and Engineering, Part II (R) • CLE 003 Technical Reviews • One 100 or 200 level course must come from the following list: • BCF 106 Fundamentals of Cost Analysis • BCF 208 Software Cost Estimating (R) • IRM 202 Intermediate Information Systems Acquisition (R) • LOG 103 Reliability, Availability, and Maintainability (RAM) • PMT 251 Program Management Tools Course, Part I • PQM 201A Intermediate Production, Quality, and Manufacturing, Part A • STM 202 Intermediate S&T Management (R) • TST 203 Intermediate Test and Evaluation (R)
Education	Baccalaureate or graduate degree in a technical or scientific field such as engineering, physics, chemistry, biology, mathematics, operations research, engineering management, or computer science
Experience	• 4 years of experience in an acquisition position. Of that: • - At least 3 years of experience in an SPRDE-SE, SPRDE-PSE, or SPRDE-S&TM acquisition position • - Remainder may come from IT, T&E, PQM, PM, or LCL • Similar experience gained from other government positions or industry is acceptable as long as it meets the above standards

Table C4. DAU SPRDE–PSE Core Plus Development Guide Level II
(DAU, 2011)

Core Plus Development Guide (desired training, education, and experience)	Type of Assignment	
Training	**Acq Prg Sys Eng**	**Sus Prg Sys Eng**
CLE 007 Lean Six Sigma for Manufacturing	✔	✔
CLE 008 Six Sigma: Concepts and Processes	✔	✔
CLE 017 Technical Planning	✔	✔
CLE 021 Technology Readiness Assessments	✔	
CLE 026 Trade Studies	✔	✔
CLL 022 Title 10 Depot Maintenance Statute Overview	✔	
CLL 023 Title 10 U.S.C. 2464 Core Statute Implementation		✔
CLL 024 Title 10 Limitations on the Performance of Depot-Level Maintenance (50/50)		✔
CLL 025 Depot Maintenance Interservice Support Agreements (DMISA)		✔
CLM 029 Net-Ready Key Performance Parameter (NR-KPP)	✔	
CLM 101 Analysis of Alternatives (AoA) (USAF Process)	✔	
LOG 103 Reliability, Availability, and Maintainability (RAM)		✔
LOG 200 Intermediate Acquisition Logistics, Part A	✔	
LOG 201 Intermediate Acquisition Logistics, Part B **(R)**	✔	
LOG 235 Performance-Based Logistics, Part A	✔	
LOG 236 Performance-Based Logistics, Part B **(R)**	✔	
PMT 251 Program Management Tools Course, Part I	✔	✔
PMT 256 Program Management Tools Course, Part II	✔	✔
PQM 201A Intermediate Production, Quality, and Manufacturing, Part A		✔
PQM 201B Intermediate Production, Quality, and Manufacturing, Part B **(R)**		✔
TST 203 Intermediate Test and Evaluation **(R)**		✔

Education
Advanced degree or graduate studies in engineering, physics, chemistry, biology, mathematics, operations research, engineering management, computer science or a related field.

Experience
None specified

Notes:

- The Core Certification Standards section lists the training, education, and experience REQUIRED for certification at this level.
- "(R)" following a course title indicates the course is delivered as resident based instruction.
- When preparing your IDP, you and your supervisor should consider the training, education, and experience listed in the Core Plus Development Guide at this and the lower level(s) if not already completed.
- Some continuous learning (CL) modules have been created by extracting lessons in their entirety from a training course. If this is the case for the CL module(s) identified in the above core certification standards, the course from which the CL module was extracted is identified in the "Notes" section of the CL course description and the course can be substituted to meet the certification standard.

Table C5. DAU SPRDE–PSE Certification Guide Level III
(DAU, 2011)

CERTIFICATION STANDARDS & CORE PLUS DEVELOPMENT GUIDE SPRDE – PROGRAM SYSTEMS ENGINEER LEVEL III	
Type of Assignment	**Representative Activities**
Acquisition Program Systems Engineer	● Analyzes and applies processes while integrating multiple domains (analytic or engineering specialties) at a system or systems-of-systems level. ● Leads and/or manages systems engineering activities, develops systems engineering plans, and leads and facilitates IPTs. ● Demonstrates excellence in management, leadership, communications, and briefing skills.
Sustainment Program Systems Engineer	● Leads and/or manages systems engineering activities for programs supporting in-service, out-of-production systems. ● Analyzes and applies systems engineering processes in planning and execution of obsolescence mitigation, system upgrades and modifications, technology insertion, modernization, sustainability, reliability/maintainability improvements, etc., as appropriate. ● Demonstrates excellence in management, leadership, communications, and briefing skills.

Core Certification Standards (required for DAWIA certification)	
Acquisition Training	Acquisition Training identified at Level II must have been completed
Functional Training	● SYS 302 Technical Leadership in Systems Engineering (R) ● CLL 008 Designing for Supportability in DoD Systems ● Two 200 or 300 level course must come from the following list: ● BCF 211 Acquisition Business Management (R) ● IRM 304 Advanced Information Systems Acquisition (R) ● LOG 200 Intermediate Acquisition Logistics, Part A ● LOG 201 Intermediate Acquisition Logistics, Part B (R) ● PMT 256 Program Management Tools Course, Part II ● PQM 201B Intermediate Production, Quality, and Manufacturing, Part B (R) ● PQM 301 Advanced Production, Quality, and Manufacturing (R) ● STM 303 Advanced S&T Management (R) ● TST 303 Advanced Test and Evaluation (R)
Education	Baccalaureate or graduate degree in a technical or scientific field such as engineering, physics, chemistry, biology, mathematics, operations research, engineering management, or computer science
Experience	● 8 years of experience in an acquisition position. Of that: ● - At least 5 years of experience in an SPRDE-SE, SPRDE-PSE, or SPRDE-S&TM acquisition position ● - Remainder may come from IT, T&E, PQM, PM, or LCL ● Similar experience gained from other government positions or industry is acceptable as long as it meets the above standards

Table C6. DAU SPRDE–PSE Core Plus Development Guide Level III
(DAU, 2011)

Core Plus Development Guide (desired training, education, and experience)	Type of Assignment	
Training	Acq Prg Sys Eng	Sus Prg Sys Eng2
ACQ 450 Leading in the Acquisition Environment (R)	✔	✔
ACQ 451 Integrated Acquisition for Decision Makers (R)	✔	✔
ACQ 452 Forging Stakeholder Relationships (R)	✔	✔
CLL 014 Joint Systems Integrated Support Strategies (JSISS)	✔	
CLL 015 Business Case Analysis	✔	
CLL 203 Diminishing Manufacturing Sources and Material Shortages (DMSMS) Essentials		✔
CLL 204 Diminishing Manufacturing Sources and Material Shortages (DMSMS) Case Studies		✔
CLM 014 IPT Management and Leadership	✔	✔
CLM 031 Improved Statement of Work	✔	✔
CLM 035 Environmental Safety and Occupational Health—Lesson from PMT 352A	✔	✔
CLM 200 Item-Unique Identification		✔
FE 201 Intermediate Facilities Engineering		✔
LOG 350 Enterprise Life Cycle Logistics Management (R)		✔
PMT 352A Program Management Office Course, Part A	✔	✔
PMT 352B Program Management Office Course, Part B (R)	✔	✔
PQM 301 Advanced Production, Quality, and Manufacturing (R)		✔
TST 303 Advanced Test and Evaluation (R)	✔	✔
Education		
Advanced degree or graduate studies in engineering, physics, chemistry, biology, mathematics, operations research, engineering management, computer science, or a related field.		
Experience		
None specified		

Notes:

- The Core Certification Standards section lists the training, education, and experience REQUIRED for certification at this level.
- "(R)" following a course title indicates the course is delivered as resident based instruction.
- When preparing your IDP, you and your supervisor should consider the training, education, and experience listed in the Core Plus Development Guide at this and the lower level(s) if not already completed.
- Some continuous learning (CL) modules have been created by extracting lessons in their entirety from a training course. If this is the case for the CL module(s) identified in the above core certification standards, the course from which the CL module was extracted is identified in the "Notes" section of the CL course description and the course can be substituted to meet the certification standard.

APPENDIX D. ITEMS OF INTEREST THAT EXCEED THE SCOPE OF THIS PROJECT

We have not done any research into the overall cost factor that would be applied to any additional training requirements. This would need to be researched in further detail prior to implementation of any of the recommendations made in this chapter.

There has been no analysis done as to the current value of the DAU certification offerings as they relate to the Army's acquisition needs. There has also been no analysis as to the value of the traditional educational formats found in colleges and universities in that same context. There would need to be additional analysis done prior to any adjustments being made to the above-mentioned items.

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- EU-US Defense Industrial Relationships
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- Managing the Services Supply Chain
- MOSA Contracting Implications
- Portfolio Optimization via KVA + RO
- Private Military Sector
- Software Requirements for OA
- Spiral Development
- Strategy for Defense Acquisition Research
- The Software, Hardware Asset Reuse Enterprise (SHARE) repository

Contract Management

- Commodity Sourcing Strategies
- Contracting Government Procurement Functions
- Contractors in 21st-century Combat Zone
- Joint Contingency Contracting
- Model for Optimizing Contingency Contracting, Planning and Execution
- Navy Contract Writing Guide
- Past Performance in Source Selection
- Strategic Contingency Contracting
- Transforming DoD Contract Closeout
- USAF Energy Savings Performance Contracts
- USAF IT Commodity Council
- USMC Contingency Contracting

Financial Management

- Acquisitions via Leasing: MPS case
- Budget Scoring
- Budgeting for Capabilities-based Planning
- Capital Budgeting for the DoD
- Energy Saving Contracts/DoD Mobile Assets
- Financing DoD Budget via PPPs
- Lessons from Private Sector Capital Budgeting for DoD Acquisition Budgeting Reform
- PPPs and Government Financing
- ROI of Information Warfare Systems
- Special Termination Liability in MDAPs
- Strategic Sourcing
- Transaction Cost Economics (TCE) to Improve Cost Estimates

Human Resources

- Indefinite Reenlistment
- Individual Augmentation
- Learning Management Systems
- Moral Conduct Waivers and First-term Attrition
- Retention
- The Navy's Selective Reenlistment Bonus (SRB) Management System
- Tuition Assistance

Logistics Management

- Analysis of LAV Depot Maintenance
- Army LOG MOD
- ASDS Product Support Analysis
- Cold-chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition
- Lean Six Sigma to Reduce Costs and Improve Readiness

- Naval Aviation Maintenance and Process Improvement (2)
- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)
- Risk Analysis for Performance-based Logistics
- R-TOC AEGIS Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to AEGIS and SSDS
- Managing the Service Supply Chain
- Measuring Uncertainty in Earned Value
- Organizational Modeling and Simulation
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