NPS-AM-12-C9P02R01-043

EXCERPT FROM THE

PROCEEDINGS

OF THE

NINTH ANNUAL ACQUISITION
RESEARCH SYMPOSIUM
WEDNESDAY SESSIONS
VOLUME I

System Definition-Enabled Acquisition (SDEA)—A Concept for Defining Requirements for Applying Model-Based Systems Engineering (MBSE) to the Acquisition of DoD Complex Systems

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Published April 30, 2012

The research presented at the symposium was supported by the acquisition chair of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

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Preface & Acknowledgements

Welcome to our Ninth Annual Acquisition Research Symposium! This event is the highlight of the year for the Acquisition Research Program (ARP) here at the Naval Postgraduate School (NPS) because it showcases the findings of recently completed research projects—and that research activity has been prolific! Since the ARP's founding in 2003, over 800 original research reports have been added to the acquisition body of knowledge. We continue to add to that library, located online at www.acquisitionresearch.net, at a rate of roughly 140 reports per year. This activity has engaged researchers at over 60 universities and other institutions, greatly enhancing the diversity of thought brought to bear on the business activities of the DoD.

We generate this level of activity in three ways. First, we solicit research topics from academia and other institutions through an annual Broad Agency Announcement, sponsored by the USD(AT&L). Second, we issue an annual internal call for proposals to seek NPS faculty research supporting the interests of our program sponsors. Finally, we serve as a "broker" to market specific research topics identified by our sponsors to NPS graduate students. This three-pronged approach provides for a rich and broad diversity of scholarly rigor mixed with a good blend of practitioner experience in the field of acquisition. We are grateful to those of you who have contributed to our research program in the past and hope this symposium will spark even more participation.

We encourage you to be active participants at the symposium. Indeed, active participation has been the hallmark of previous symposia. We purposely limit attendance to 350 people to encourage just that. In addition, this forum is unique in its effort to bring scholars and practitioners together around acquisition research that is both relevant in application and rigorous in method. Seldom will you get the opportunity to interact with so many top DoD acquisition officials and acquisition researchers. We encourage dialogue both in the formal panel sessions and in the many opportunities we make available at meals, breaks, and the day-ending socials. Many of our researchers use these occasions to establish new teaming arrangements for future research work. In the words of one senior government official, "I would not miss this symposium for the world as it is the best forum I've found for catching up on acquisition issues and learning from the great presenters."

We expect affordability to be a major focus at this year's event. It is a central tenet of the DoD's Better Buying Power initiatives, and budget projections indicate it will continue to be important as the nation works its way out of the recession. This suggests that research with a focus on affordability will be of great interest to the DoD leadership in the year to come. Whether you're a practitioner or scholar, we invite you to participate in that research.

We gratefully acknowledge the ongoing support and leadership of our sponsors, whose foresight and vision have assured the continuing success of the ARP:

- Office of the Under Secretary of Defense (Acquisition, Technology, & Logistics)
- Director, Acquisition Career Management, ASN (RD&A)
- Program Executive Officer, SHIPS
- Commander, Naval Sea Systems Command
- Program Executive Officer, Integrated Warfare Systems
- Army Contracting Command, U.S. Army Materiel Command
- Office of the Assistant Secretary of the Air Force (Acquisition)

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We also thank the Naval Postgraduate School Foundation and acknowledge its generous contributions in support of this symposium.

James B. Greene Jr.
Rear Admiral, U.S. Navy (Ret.)

Keith F. Snider, PhD
Associate Professor

Panel 2. Systems Engineering for Complex Systems Acquisition

Wednesday, May 16, 2012	
11:15 a.m. – 12:45 p.m.	**Chair: Joseph L. Yakovac Jr., LTG, USA, (Ret.),** Naval Postgraduate School; former Military Deputy to the Assistant Secretary of the Army for Acquisition, Logistics and Technology ***System Definition-Enabled Acquisition (SDEA)—A Concept for Defining Requirements for Applying Model-Based Systems Engineering (MBSE) to the Acquisition of DoD Complex Systems*** Paul Montgomery, Ron Carlson, and John Quartuccio *Naval Postgraduate School* ***Development and Extension of a Deterministic System of Systems Performance Prediction Methodology for an Acknowledged System of Systems*** Richard Volkert and Carly Jackson, *SSC-Pacific* Jerrell Stracener and Junfang Yu, *Southern Methodist University* ***Multi-Objective Optimization of System Capability Satisficing in Defense Acquisition*** Brian Sauser and Jose E. Ramirez-Marquez *Stevens Institute of Technology*

Joseph L. Yakovac Jr.—Lt. Gen. Yakovac retired from the United States Army in 2007, concluding 30 years of military service. His last assignment was as director of the Army Acquisition Corps and military deputy to the Assistant Secretary of Defense for Acquisition, Logistics, and Technology. In those roles, Lt. Gen. Yakovac managed a dedicated team of military and civilian acquisition experts to make sure America's soldiers received state-of-the-art critical systems and support across a full spectrum of Army operations. He also provided critical military insight to the Department of Defense senior civilian leadership on acquisition management, technological infrastructure development, and systems management.

Previously, Lt. Gen. Yakovac worked in systems acquisition, U.S. Army Tank-Automotive Command (TACOM), and in systems management and horizontal technology integration for the Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology. He has also served as executive officer and branch chief for the Bradley Fighting Vehicle and as a brigade operations officer and battalion executive officer, U.S. Army Europe and U.S. Army Tank-Automotive Command (TACOM).

Lt. Gen. Yakovac was commissioned in the infantry upon his graduation from the U.S. Military Academy at West Point. He served as a platoon leader, executive officer, and company commander in mechanized infantry units. He earned a Master of Science in mechanical engineering from the University of Colorado at Boulder before returning to West Point as an assistant professor.
Lt. Gen. Yakovac is a graduate of the Armor Officer Advanced Course, the Army Command and General Staff College, the Defense Systems Management College, and the Industrial College of the Armed Forces. He has earned the Expert Infantry Badge, the Ranger Tab, the Parachutist Badge, and for his service has received the Distinguished Service Medal, the Legion of Merit three times and the Army Meritorious Service Medal seven times.

System Definition-Enabled Acquisition (SDEA)—A Concept for Defining Requirements for Applying Model-Based Systems Engineering (MBSE) to the Acquisition of DoD Complex Systems

Paul Montgomery—After retiring in 1990 from a 20-year career in the Navy, Dr. Montgomery served as a senior systems engineer with Raytheon and Northrop Grumman corporations and developed communications, surveillance, and sensor systems for commercial, military (USN, USA, USAF), and intelligence communities (NSA, NRO). He earned his doctorate in systems engineering from George Washington University (DSc ’07), performing research related to cognitive/adaptive sensors, MSEE (1987) from Naval Postgraduate School, and BSEE (1978) from Auburn University. The International Council on System Engineering (INCOSE) certifies him as an expert systems engineering professional (ESEP). Dr. Montgomery is an SE Department–embedded faculty member providing onsite research and instruction support to NAVAIR (Patuxent River, MD), NAVSEA (Dahlgren, VA; Carderock, MD), and NPS SE students in the Nation Capital Region. [prmontgo@nps.edu]

Ron Carlson—Carlson served 26 years in naval aviation as a pilot, seven years of which were at NAVAIR where he led NAVAIR systems engineers through several years of systems engineering revitalization to the NPS SE Department. He is currently in the systems engineering doctoral program at Stevens Institute of Technology and has earned master’s degrees in strategic studies and national policy from the Naval War College and business administration–aviation from Embry Riddle Aeronautical University, and a Bachelor of Science in nuclear engineering from the University of Michigan. Ron Carlson is an SE Department–embedded faculty member providing onsite research and instruction support to NAVAIR (Patuxent River, MD), NAVSEA (Dahlgren, VA; Carderock, MD), and NPS SE students in the Nation Capital Region. [rrcarlso@nps.edu]

John Quartuccio—Quartuccio has more than 27 years of civilian service within the Naval Air Systems Command and the Naval Air Warfare Center. He graduated from The Pennsylvania State University with a Bachelor of Science in mechanical engineering in 1985, and graduated from Lehigh University with a Master of Science in applied mechanics in 1997. He is currently an NPS systems engineering PhD student. Quartuccio is the director of the Systems Engineering Development and Implementation Center (SEDIC) within Air Platform Engineering (AIR-4.1.1) of the Systems Engineering Department. He is also a member of the AIR-1.0 staff as APEO(E) for AIR-1.0 Programs. [john.quartuccio@navy.mil]

Abstract

The complexity of designing and acquiring weapons systems continues to increase due to highly integrated system architectures, rapid technology evolution, and emergence of highly diverse set of missions. The imperatives of system-of-systems integration and interoperability further complicate the system acquisition process. These challenges continue to frustrate completing the acquisition of systems within time and budget goals. The acquisition process is currently aligned to a DoD 5000/WSARA model which tends to be oversight-driven, but this process needs to be underpinned with a robust and dynamic systems engineering enterprise that includes repeatable and quantifiable design-driven processes and metrics in order to cope with complexity and a less experienced workforce.

This paper discusses a concept for an engineering system that is tightly coupled to the acquisition process to (1) reduce acquisition time, (2) reduce risks in achieving system integration and interoperability objectives, (3) controls total ownership costs, (4) informs industry in the development of a system definition-enabled acquisition set of tools, processes, or products that are emerging in the model-based systems engineering community, and (5) supports the emergence of a younger engineering workforce as the seasoned veterans retire.

Background and Problem Definition

Setting the Stage

One of the authors recently attended a vendor presentation of their model-based systems engineering (MBSE) tool. While the tool is useful for straightforward systems, the author challenged the vendor to improve their product to better align to the needs of DoD acquisition of complex systems and asked when such product improvements could be expected. The answer was reasoned and insightful: “When DoD gives us the requirements.” This was not a glib answer and, in fact, despite the ever-increasing number of MBSE tools and products on the market from several vendors, the DoD has yet to provide a set of requirements for an integrated tool set. This paper discusses a way to get started on defining such a set of requirements. We discuss some foundational problems and needs associated with DoD complex systems acquisition and a potential path forward to develop an integrated set of tools (an engineering system). We call this concept *system definition-enabled acquisition* (SDEA).

Complex Systems Acquisition

The current DoD acquisition process (see Figure 1), as specified in DoD 5000, has gone through many adjustments and has a long heritage of acquisition experience based upon the acquisition of stand-alone systems (DoD, 2008). Today’s system acquisitions are more co-dependent on the development of other complex systems in a “systems-of-systems” (SoS) environment. This requires a higher level of coupling between system engineering and the acquisition process to support SoS, as well as the need for higher levels of lead system integrator (LSI) support.

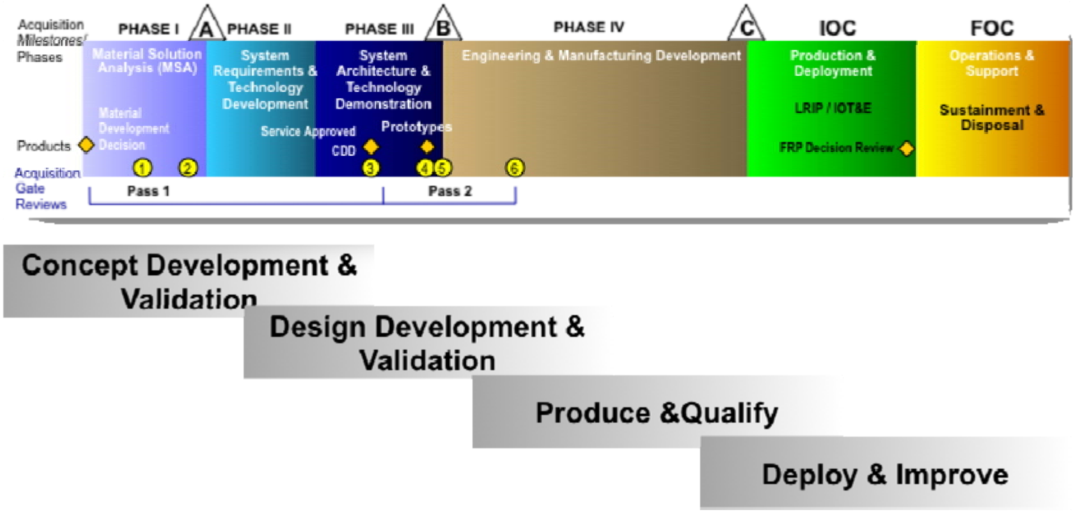


Figure 1. DoD 5000 Acquisition Process
Note. This figure was derived from DoD, 2008.

Figure 1, however, does not actually depict a process nor does it indicate any integrated engineering process. It shows a schedule framework that drives the development of the system from *needs* on the left to a *product* on the right. In the middle are large-scale activity goals that each culminate in major or minor milestones. These milestones provide an opportunity for major elements in DoD or systems command (e.g., NAVAIR, NAVSEA, SPAWAR, etc.) acquisition leadership organizations to observe the status and progress of the system design and overall acquisition performance. In reality, the engineering process is not depicted on this diagram at all. Each organization is allowed to define and describe the process it will follow to design a system, qualify the system, produce the system, and ultimately deploy the system. This paper examines the question, how can we describe a companion engineering system that supports the acquisition system that embraces the higher levels of SoS system complexity, integration challenges, interoperability, and LSI support?

System complexity and system-of-systems interoperability continue to frustrate this acquisition timeline and increase program costs. The rapid pace of technology and the overall system complexity that is being faced and encountered today continues to rise at a level with which many engineers and engineering organizations struggle to cope. Additionally, many systems are the integration of several systems that are being acquired and developed independently and for their own purposes. The systems are integrated to produce a new emergent behavior to satisfy new and emergent warfare doctrine. This SoS method rarely affords the opportunity to affect the design of these co-dependent systems. The functionality, interfaces, operational objectives, and intended system environments all provide a challenge to ensure that the system-of-systems can be integrated successfully while producing new emergent behaviors that are predictable and satisfy the user needs. Couple all of this complexity and SoS realities to the existing system engineering methods, practices, principles, organization old behaviors, and workforce skills, and what emerges is a distinct need for a system that supports a quantifiable and repeatable engineering methodology that also supports a younger and less experienced workforce. Figure 2 depicts the demographics of DoD SE-certified engineers and clearly shows a dearth of experienced engineers “behind” the retiring and very experienced “baby boomer” engineers.

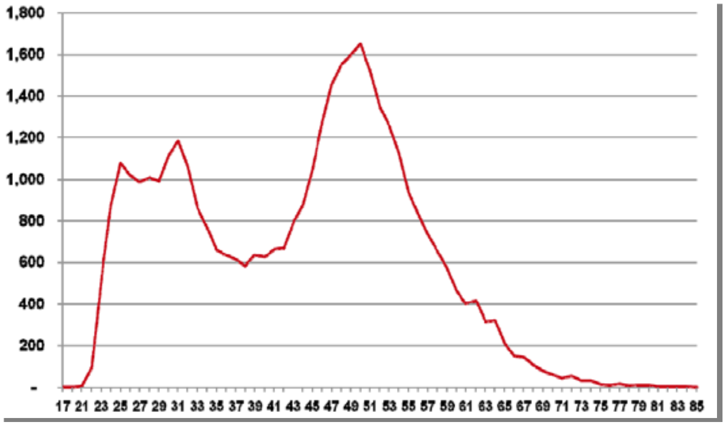


Figure 2. Credentialed DoD Systems Engineers (SPRDE-SE/PSE) Age Demographic Q1 2011
(Welby, 2010)

The above challenges are relatively well known in both the industrial and DoD communities and continue in the discourse in both. The International Council of Systems Engineering (INCOSE), for example, has set a long-range goal of aiding the emerging workforce with greater SE tools (INCOSE, 2007) and processes and methods (INCOSE, 2008). Both communities are actively developing hardware, software, and systems tools to cope with the development of complex systems. In recent years, the systems engineering (SE) community has been developing model-based systems engineering (MBSE) tools and methods to help discipline the design and development of systems (e.g., Vitech, 2011; IBM, 2012). The good news is that many tools are available to assist the engineer to develop solutions across a wide variety of system needs. The bad news is that there is a very large selection of tools, they are not well integrated, and they are often highly tailored for narrow applications. The result is a seemingly endless landscape of un-integrated tools, methods, views, and techniques for system development (see Figure 3). The challenge is to provide the DoD engineering community an “engineering system” based upon many of these existing tools, coupled with tailored tools which will provide a more integrated, repeatable, quantifiable process rather than continuing with the disjointed tool sets and ad-hoc processes.

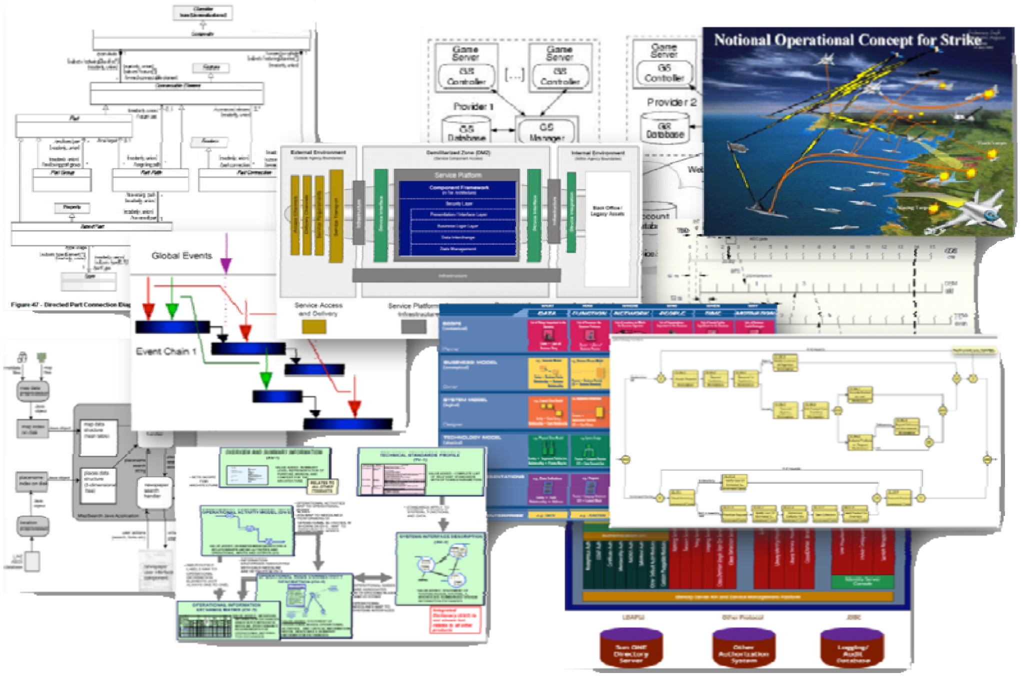


Figure 3. Model-Based Systems Engineering (MBSE) Tools and Practices Are Diverse and Sometimes Inconsistent

Note. This figure was derived from Estefan, 2008.

Problem Definition

The background in the previous sections leads to a discussion of problems with current acquisitions that are diverse, not necessarily new, and can be divided, as shown in Figure 4 and discussed as follows.

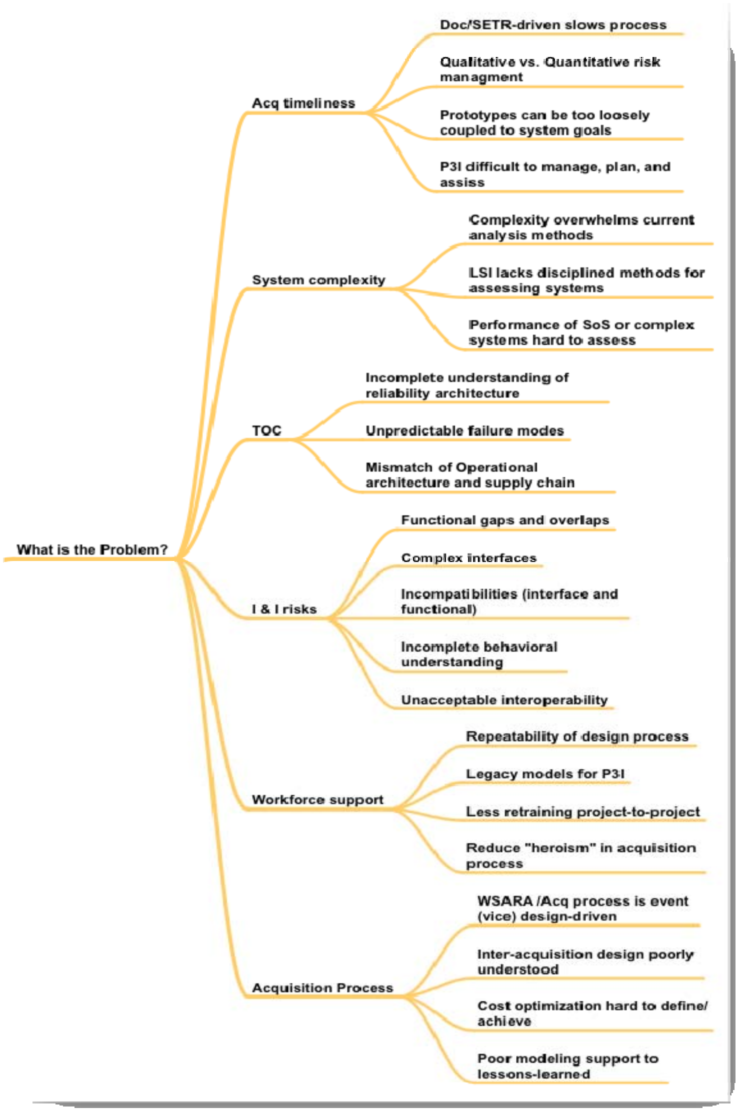


Figure 4. Problem Dimensions of Acquisitions

Acquisition Timeliness

Acquisitions often exceed schedule objectives. The acquisition structure depicted in Figure 1 is, in effect, a document-driven and technical review-driven process; therefore, it tends to be non-adaptive to changing requirements and mission needs. This can result in a slower process that delivers systems that fall short or do not meet user needs despite the pressure on all acquisitions to deliver on schedule and on budget. The systems that are developed by the acquisition process need to have risk-managed processes that are not just qualitative (the dominant method used today) but also quantitative where the risks can be measured with accepted and agreed-upon metrics that can be tightly coupled and integrated into an engineering system. There is an emphasis on prototypes as a key feature of early acquisition activities in DoD 5000 (2008). Without a tightly coupled engineering system, this can lead to prototypes demonstrating technologies alone that are too loosely coupled to engineering goals, objectives, and requirements. Finally the acquisition process and the supporting engineering system often do not have longevity in a quantifiable way such would support such things as pre-planned programmed improvements (P^3I) are qualified in the future.

Acquisition Process

The acquisition process is not design-driven. The DoD 5000 acquisition process is oversight-driven and document-driven. The success of such a process will depend upon the judgments of overseers detecting errors and the quality of the documentation. Currently, the quality of the acquisition process is correlated on those judgments rather than a direct result of quantifiable metrics that emerge from a system engineering system where the status and quality of the design can be assessed repeatedly, with less dependence on the experience and judgment of the overseer. Because each system command and each system engineering organization in each acquisition organization can develop their own engineering processes and methods and practices, the ability to coordinate between agencies in a quantifiable and repeatable fashion is fraught with incompatibilities and risks. This leads to duplicative programs or low levels of interoperability. Cost optimization is very difficult to achieve because system performance is hard to quantifiably measure as the system is being developed and assessments and trade-offs are being made. Finally, there is limited modeling of the system to vet lessons-learned which would enhance one’s ability to make supportability improvements or forge an improvement strategy.

System Complexity

System complexity exceeds engineering system capabilities. Simple systems and complex systems proceed to the acquisition process with essentially the same attentions. It is up to the program’s engineering processes, methods, and systems to cope with the ever-increasing number of complex systems. Current engineering processes reflect the experiences of relatively simple systems but must be adapted to high levels of complexity and interoperability. Given certain failures of large systems in recent years in which the government assigned LSI responsibilities to a contractor, there are initiatives to assign the LSI responsibilities back to the government. This will require a level of engineering processes closely integrated with program management processes. A key need in this area is the ability to assess SoS performance and the emergence system behaviors in a quantifiable manner. The operational test community and the design community need to be working toward the same goals when assembling an SoS which is a key lead system integrator responsibility.

Integration and Interoperability

Systems fail at integration or are not meeting interoperability objectives. The key risks associated with integration of systems, especially system-of-systems, is the existence of functional gaps and overlaps among the systems. Give the number and complexity of the functions; we cannot simply depend on system engineering technical reviews to discover these functional inconsistencies. Generally, these functions and the interfaces should be as simple as possible, modular, and associated with clear performance metrics for ultimate qualification. Incompatibilities or inconsistencies among interfaces and functions are a leading cause of integration failures for systems during their acquisition cycle (Bahill & Henderson, 2005). These discoveries, especially near the end of the acquisition cycle, are extraordinarily expensive and time-consuming. System-of-systems integration also demands the interoperability among these systems as well as the interoperability outside of the system for other systems that are codependent. It is imperative that the behavior of the acquired system and the behavior of the associated external systems be clearly understood, measurable, predictable, and risk-managed throughout the acquisition cycle.

Total Ownership Costs

Total ownership costs (TOC) are difficult to predict and control. The acquisition cost incurred during the development cycle is only a fraction of the total ownership cost of any system. In fact, the development cost is often the minority cost component of the TOC of the system throughout its lifetime. The engineering methods and engineering system that are used during the acquisition of the system needs to have measurable and quantifiable factors that accurately predict total ownership cost of the system. These metrics and vectors also need to be able to aid the support community in controlling the TOC in the long run. If the system is discovered to have unusual failure modes, inconsistent emergent behaviors, incompatible interfaces, and so forth, the system will need improvements or modifications. This can have major TOC impact. These discoveries are often unwanted surprises and/or negative emergent behaviors that should be avoided during the engineering and acquisition phase. The engineering system needs to have very detailed predictable and repeatable behavior modeling of both the acquired system and external systems in order to try to anticipate these negative TOC effects. This is a nontrivial demand on the acquisition engineering system. It requires a high level of probability prediction, failure analysis, operational modeling and analysis, interface performance prediction, and other forward-looking engineering activities that are often not present in the current engineering system. The current system is driven on the need to deploy a system at the end of the acquisition cycle and all focus is on that point. The engineering system, therefore, should be focused on the TOC and total lifecycle engineering goals and system performance and not just the acquisition cycle.

Workforce Support

The veteran engineers are retiring at a dramatic pace and are not being replaced with engineers with commensurate experience. The design process and the attendant system that supports the development of the system during the acquisition cycle needs to provide high levels of repeatability and quantifiability that is less dependent on engineering judgment and more dependent on metrics that provide a highly refined engineering solution. In the past, the development of tools to provide such repeatable and quantifiable design metrics was often far more expensive than assigning experienced engineers to apply their judgment to the solution. Given that many seasoned veteran engineers are retiring and that the state of the art of computer-based tools has been highly enriched in recent years, there is a need to provide system design-driven metrics and artifacts to a younger engineering community. This community is often far more adept at using computer-based tools and computer systems than the retiring engineers. Additionally, the complexity of current systems makes it virtually impossible for the rising workforce to cope without a high level of engineering support system. In fact, even current systems require too much “heroism” of a few extraordinarily experienced engineers to ensure system development success. A system that provides project-to-project consistency and repeatability would be of the most value since the common matrix organization of many engineering organizations often requires an engineer to provide part-time focus on any particular project, and it would be beneficial if the focus method was the same for each project experience using the same metrics, processes, methods, and principles.

Research Questions

Our fundamental thesis is that the DoD needs to describe, in a systematic manner, what is needed in an engineering system that drives the acquisition as much by system-definition details and modeling, as it does by documentation and oversight; thus our term, *system definition-enabled acquisition* (SDEA). As we embark on determining how SDEA could be applied to DoD acquisition, we need to investigate several questions that lead to the solutions of the problems discussed in the previous section. These include the following:

- What is an SDEA concept of operation?
- What are the SDEA requirements?
- What is an SDEA architecture?
- What are the SDEA components, elements, tools, etc.
- What tools are available today?
- Where do these tools fall short in satisfying the needs of the acquisition community?
- How might the SDEA affect organizational roles and responsibilities?
- What are SDEA solicitation strategy key elements?

These research questions result from the perception that a new approach is needed to view the acquisition engine and associated engineering system from a system perspective. Instead of a standalone engineering process in which the primary objective is to produce the necessary engineering documentation and perform well at the associated acquisition reviews that are vetted by highly seasoned and experienced engineers, how can the system be defined and described such that it could actually be designed, viewed by all, and acquired as a system in and of itself? While there are many policies in place at the various systems commands, there is still a great deal of freedom on how to execute these policies from an engineering perspective. What if there was a system that produced repeatable and quantifiable system engineering methods and practices and metrics such that—whether you were at one systems command or another, or developing a system that needed to interoperate with another—an engineer could ensure that the risk associated with the development of the system could be developed in a low-risk fashion?

There are many MBSE tools being advertised from several vendors, and the research questions focus on the fact that these tools are individually inadequate to solve the total engineering problem addressed in this paper. There may be a way to integrate these tools with other associated capabilities to create a system that provides all the features we have outlined so far. The research questions focus on what the capabilities are of these tools, how they map against the needs and requirements of the acquisition community, and finally, what would be needed in addition to integrate these tools. Finally, if an SDEA engineering system were available, how could the organizations that are in place today utilize the system, or in what ways must they make change or adapt in order to provide the higher level of performance which has been enabled by SDEA?

System Definition-Enabled Acquisition (SDEA) System Concept

Top-Level Concept

The top-level SDEA concept is shown in Figure 5. The SDEA system comprises the essential engineering activities today. The SDEA concept, however, is not to view the engineering system as a collection of individual activities but rather a system itself that provides repeatable and quantifiable performance. The SDEA system is synergistic with the program definition, system definition, supportability definition, and system production activities. Note that all of these activities are responsive to the originating stakeholders, program resources and management, TOC, and future improvements to the system. The SDEA system is envisioned to retain all the necessary information that defines and models the system even after all the activities are complete during development. This ensures that there will be a set of engineering artifacts and metrics that allow for a low risk and highly success-oriented opportunity for system improvement in the future. In the diagram, program definition is supported by the SDEA system and the SDEA system is dependent upon program definition for the delineation and definition of a program of record (i.e., at the Pentagon). Program definition leads to system definition and the handoff contract (documents) associated with system capabilities and top-level performance goals. Additionally, program definition leads to documentation and agreements that set in motion long-term supportability strategies and activities such as logistics, training and manpower, and long-term supply chain strategies. The SDEA system supports both system definition in a very repeatable, quantifiable manner as well as provides clear detail and system reliability and supportability metrics to the definition of the support system associated with the acquisition. System production is dependent upon system definition and the objectives of the support community as well as the metrics that come from the supporting SDEA system in order to proceed to production of the system in preparation for deployment. Once again, the SDEA system as depicted in this diagram is not just the encapsulation of disjoint engineering activities or their associated methods and tools, but rather an integrated system that can be employed and deployed in any acquisition activity.

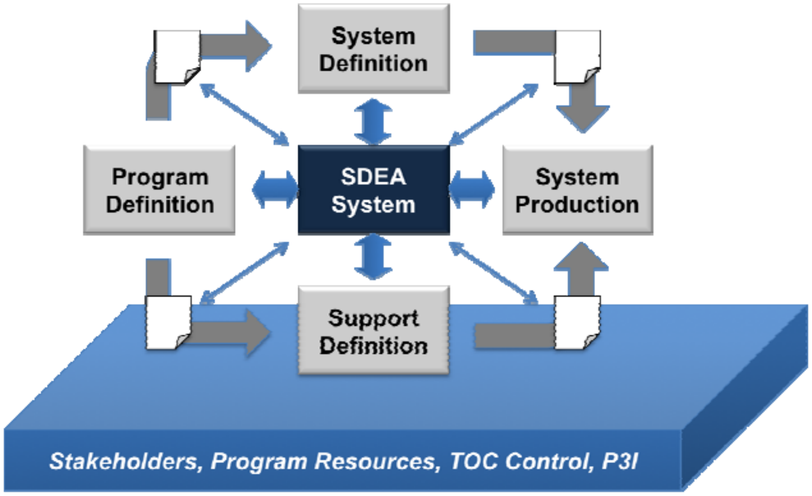


Figure 5. SDEA Provides Central Engineering System Support to Acquisition

Current Acquisition Engineering Approaches

Let us examine a view of today’s acquisition process to explore how SDEA might be employed. Figure 6 depicts current engineering practices as largely document-driven and expert-centric. On the left, needs are originated by operational users which are articulated in operational language such as a concept of operation (CONOP), requirements that are articulated in user terms, and an architecture that is top level in its nature and depicts the constraints, legacy systems, and the external systems that are key elements to provide the capabilities desired. These sets of documents frame the boundaries upon which a program-of-record (PoR) is ultimately built, justified, and defended. The processes that are depicted on the left side of that diagram (often executed at the sponsor’s level) are essentially repeated at the acquisition agency (systems commands). These documents and artifacts that represent either the user needs or the system requirements can produce several solutions that need to be vetted to produce a single path forward. Skilled and experienced engineers assimilate the wide variety of information produced by the documentation and synthesize a preferred alternative. The result is a dedicated set of documents, potentially with a database of requirements, that is forwarded on to the development engineering community, also made up of seasoned veterans who examine the wide variety of engineering issues such as interfaces, architecture, operational analysis, risk management, modeling and simulation, and so forth. This engineering community supports the larger acquisition process by delivering opinion and assessments into the major design reviews, trade studies, and so forth. This process, therefore, proceeds from design documentation to system document analysis to an oversight-oriented acquisition process.

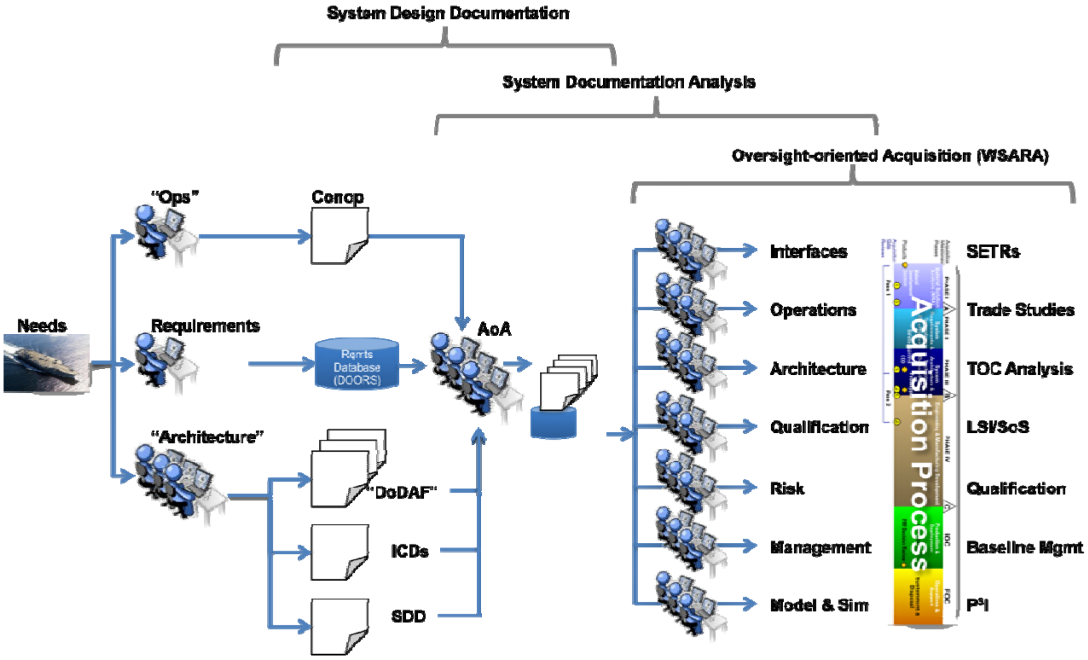


Figure 6. Current Top-Level Engineering Workflow During System Acquisition

SDEA System Approach

How does the SDEA concept differ from today's engineering workflow? As shown in Figure 7, the left side of the SDEA workflow diagram where user needs are articulated, requirements are generated and architectures are developed essentially the same as before. The major difference is that these definitions become part of a system baseline/model that is entered, analyzed, and vetted in a tool-enabled environment. The SDEA system definition environment can semi-automatically generate system alternatives and rank them against a variety of value perspectives. The key at this juncture is that although system experts will still be needed to apply judgment at this juncture in system design, an SDEA system can provide algorithms based upon the data that are in the system definition model that can answer questions in a quantifiable manner, which then enables a higher level of judgment to be applied to a higher level of complex systems. At this juncture, therefore, we are not examining documentation to develop a viable system solution; we are performing system analysis in a way that multiple engineers can ask the same question of the system definition and get the same answer repeatedly, which reduces decision risks along the way. When an alternative is produced, there is a high likelihood that the system design solution that has been derived from a system definition model will satisfy the needs of the user, and the user will have some level of assurance that it will meet integration and interoperability goals when deployed.

This system solution is passed to the right side of the diagram, which provides not only documentation to the teams that must assess the various dimensions of system performance, but also, and more importantly, provides detailed data that enables analysis of system interfaces, architectures, functionality, behaviors, interoperability predictions, quantifiable risk measurements, and so forth. These are the aspects of the system that must pass scrutiny as various design reviews in the acquisition process. By keeping the SDEA system as a system definition oriented system and supported in a software-enabled system, we can aid the engineering community in coping with highly complex and highly interoperable systems in a way that assures success in a dynamic warfare environment.

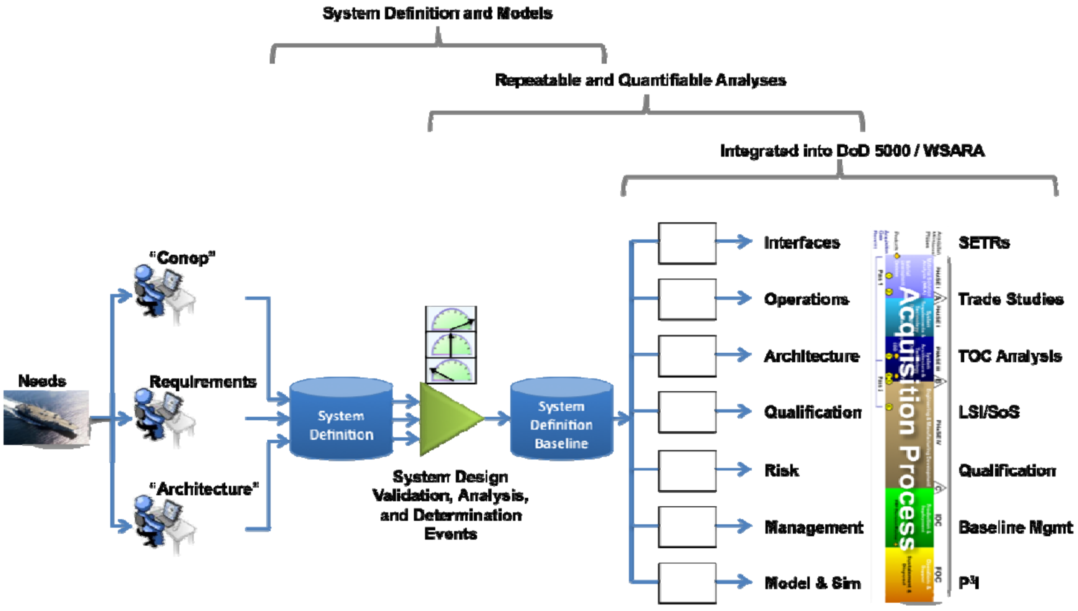


Figure 7. SDEA Engineering Workflow During System Acquisition

SDEA Application Examples

System Interface Design and Analysis

Figure 8 (left) shows an example of the current engineering practices when examining interfaces. When performing interface design and analysis activities for system development, experienced engineers will often use an interface control document (ICD) which details the system interfaces and balances against other architectural documentations such as the DoD Architecture Framework (DoDAF) architectural views (drawings). This process can often be extremely tedious and error-prone. Only the most experienced and seasoned veterans of interface analysis and design have any likelihood of success given a system of any complexity. Most are still likely not to discover errors, gaps, incompleteness, and so forth.

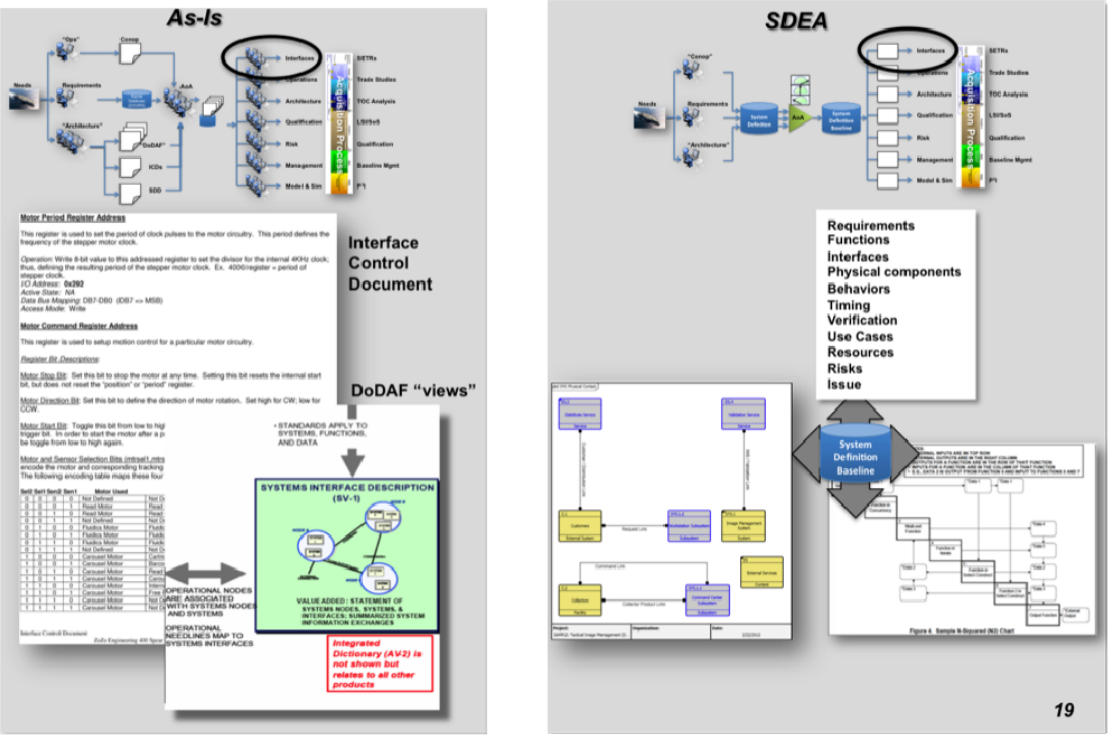


Figure 8. Current and SDEA Interface Design Analysis

In the SDEA approach shown (Figure 8, right), interface analysis can be semi-automated to assist the engineer. The architectural views are not simply drawings but are software models that are carefully built, connected, and defined in several different methods. The parameterized interface descriptions can be compared and contrasted in the SDEA system algorithms to produce a level of measure that indicates the quality of the design for the interfaces. This frees the engineer to not be mired in the minutia of interface bookkeeping but, rather, to apply judgment to whether or not the analysis of the interface is sufficient to support system operations.

System Operational Analysis

Another SDEA comparison is shown in Figure 9. When performing operational analysis, the engineering team is often faced with reconciling an initial capabilities document (ICD), a concept of operation (CONOP), and the attendant architectural views that may or may not have been created by the same creators of the documents themselves. Once again, only a seasoned veteran with many years of experience in reading, analyzing, and reconciling operational documents can have a high likelihood of analyzing whether or not the associated architectural results will support the operational needs of the user.

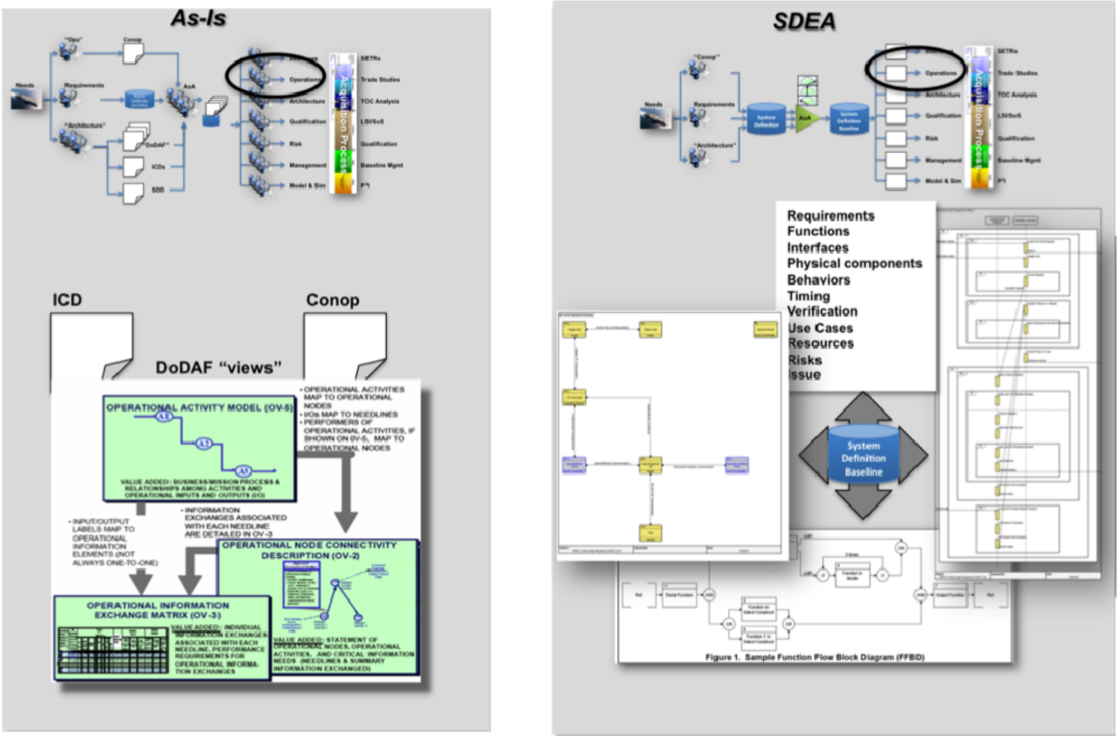


Figure 9. Current and SDEA Operational Analysis

The SDEA example in Figure 9 (right) is a model-driven approach enabling that functionality, physicality, and behaviors are all described with great detail in a system model. This provides a high level of repeatability, such that the SDEA system itself can provide some level of semi-automated metrics of how the system will ultimately operate. This frees the engineering team from reconciling documentation and enables assessing total system performance against the originating user needs for operations.

SDEA Integrated Acquisition Support

The SDEA system will provide a data-driven system definition and model-driven systems engineering approach that supports both the system engineering and design communities as well as the acquisition community with their associated processes (see Figure 10).

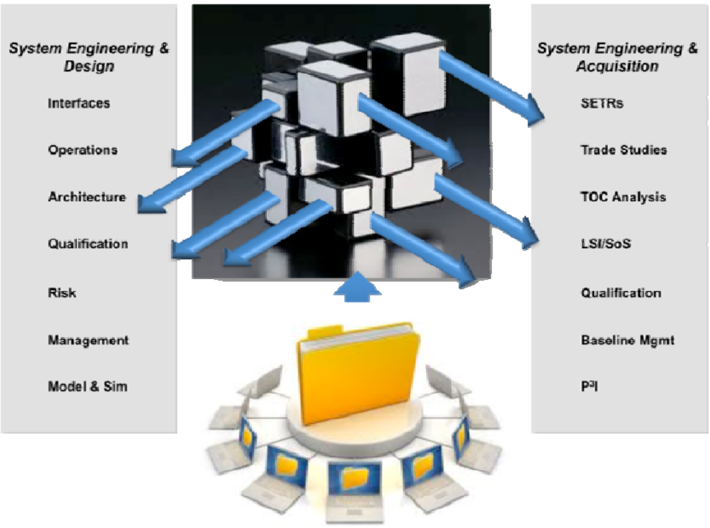


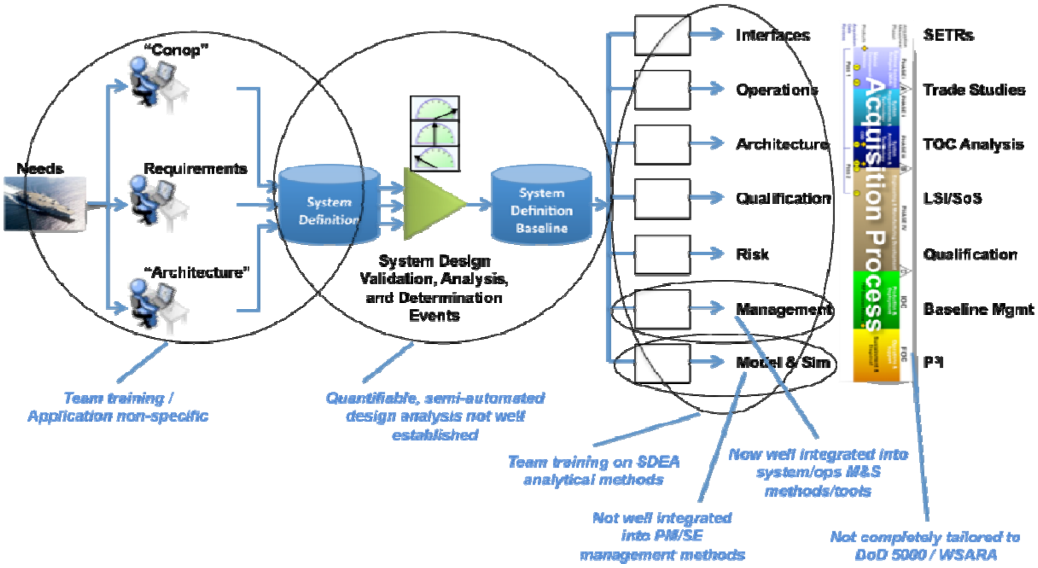
Figure 10. SDEA Provides Quantifiable Analysis in Support of Multiple Perspectives

SDEA System Development and Transition

SDEA Development

Relating back to the opening vignette, has the DoD provided the MBSE vendor community a DoD set of requirements that would start to create SDEA? Not yet, but Dr. Stephen Welby, Assistant Secretary of Defense for System Engineering, casts many MBSE long-range goals for 2020 that start a conversation about many of the SDEA concepts (Welby, 2010).

The development of the SDEA system requires the transformation of engineering practices and methods, but not necessarily principles. Visionary principles essentially remain the same, but there are many factors that need to be transitioned in order for the SDEA system to be a vibrant part of the acquisition cycle. Figure 11 depicts the challenge areas for SDEA transition and each is briefly discussed in the following paragraphs.



Team training / Application non-specific

Quantifiable, semi-automated design analysis not well established

Team training on SDEA analytical methods

Now well integrated into system/ops M&S methods/tools

Not well integrated into PM/SE management methods

Not completely tailored to DoD 5000 / WSARA

Figure 11. Challenges to SDEA Transition

Organizational Processes

The two dominant organizations of program definition (Pentagon) and the acquisition community need to be mutually supported by the SDEA system and need to have a common, error-free handoff between their roles in the acquisition cycle. Both teams need to be trained on how this handoff occurs, and how the SDEA system supports the development of the program and the subsequent development of system top-level design.

Analysis of Alternatives

Using the SDEA system, engineering teams need to understand how to use semi-automated quantification of system analysis that emerges from such a system in order to make higher-level judgments and selections of higher-level system complexities and system-of-systems. This workflow is not necessarily in place today.

Workforce Development

SDEA will provide more refined analysis tools to exploit that system data for engineers to use to develop such analysis as interfaces, architectures, and so forth. The workforce will need to be trained in how to employ those analysis tools and how to interpret the data such that a repeatable level of performance is achieved.

Management Integration

The SDEA system needs to seamlessly support all of the associated processes and tools that are in place in the program management of the system acquisition process with special recognition on cost and schedule and stakeholder support.

Modeling and Simulation

The SDEA system offers new opportunities for the modeling and simulation community to support acquisition. In many cases, the modeling and simulation community is required to develop the model of the system based on documentation and then perform simulation to assess some portion of system performance. Under the SDEA concept, the model is essentially developed in the SDEA system, allowing the modeling and simulation community to focus more on simulation parameters, performance, and analysis against a vetted system model.

The SDEA system will also produce system models that can also execute to produce a measure of whether or not the selected architecture and system solution is viable and will meet essential performance needs. This can obviate the need to expend time and money on modeling and simulation elsewhere. It can help perform concept validation, initial top-level performance assessment, and essential interface analysis that can save a significant amount of time and cost during the early design phases (thus saving acquisition time).

DoD Acquisition Process

The SDEA system will not replace the acquisition system but rather seamlessly integrate and support all of the milestone delineated phases of the acquisition, the design reviews, the gate reviews, as well as the other oversight and documentation of the acquisition system.

SDEA Transition

The SDEA system need not be developed in a vacuum. Most of the engineering communities in the major Navy Systems Commands are currently examining MBSE techniques, as well as examining how to provide more system definition through the use of tools in the engineering community. Our initial plan is to focus on the naval aviation enterprise to develop the needs, goals, objectives, assumptions, constraints, and initial requirements for SDEA. Our strategy is as follows:

- establish advocacy and develop an SDEA champion within the naval aviation systems command;
- select an exemplar program to examine their baseline system processes;
- build a system description of those processes;
- compare and contrast an SDEA system approach to those baseline processes;
- demonstrate and analyze the value of the SDEA system against that comparison;
- begin a campaign of consensus building; and
- develop a solicitation strategy for the development of an SDEA system.

Summary

The following salient issues drive the need for a transformation of a system definition-enabled acquisition (SDEA) engineering system. The DoD needs to turn these issues into needs and requirements, and energize the MBSE vendor community to develop an integrated solution for an SDEA system that supports the design and acquisition of complex systems and SoS.

- Systems continue to grow more complex and are often over stripping region nearing community's ability to manage risk and predict performance.
- System-of-systems acquisition and the government assuming the role of the lead system integrator will become the norm.
- The workforce experience level will be contracting over the next decade as the baby boomers retire and the younger engineers grow into that role.
- Disciplined, repeatable, and quantifiable engineering tools and methods need to be enhanced.
- SDEA system technology is already partially available, however, not yet fully integrated
- Organizational requirements for the SDEA system need to be defined as a total system rather than purchasing individual tools.

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