2012 NDIA GROUND VEHICLE SYSTEMS ENGINEERING AND TECHNOLOGY SYMPOSIUM
SYSTEMS ENGINEERING AND INTEGRATION (SE) MINI-SYMPOSIUM
AUGUST 14-16, MICHIGAN

THE TARDEC ADVANCED SYSTEMS ENGINEERING CAPABILITY (ASEC)

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ABSTRACT

Systems Engineering (SE) is a knowledge-based process. Its success depends on timely, efficient and effective knowledge capture, sharing of that knowledge among a diverse set of system stakeholders, and formulation of the system trade space to enable decision makers choose a balanced solution to the problem. As system complexity grows, the challenge for precise capture of SE knowledge compounds, resulting in increased demands on SE practitioners to effectively capture and manage systems information. Technology aids can assist in the capture, sharing and presentation of SE knowledge and enable practitioners to focus on thinking tasks.

The Advanced Systems Engineering Capability (ASEC) developed by the TARDEC Systems Engineering Group (SEG) is an integrated Systems Engineering (SE) knowledge creation and capture framework built on a decision-centric method, high quality data visualizations, intuitive navigation and systems information management that enable continuous data traceability, real-time collaboration and knowledge pattern leverage to support the entire system lifecycle.

The ASEC framework provides a collaborative environment for all stakeholders, practitioners and decision makers to proactively engage in and facilitate the decision-making process throughout the system development process. All facets of SE knowledge (requirements, decisions, risks, opportunities, tests etc) are created, managed and presented in context within a single framework. The framework has been architected to support Model Based Engineering (MBE) and Model Based Systems Engineering (MBSE) information. The ASEC enables decision makers to make informed decisions with confidence based on a mix of qualitative and quantitative inputs and helps assess the ripple effects of multi-decision trade-offs when evaluating competing what-if scenarios. Traceability is maintained to reflect the impact of decisions on requirements, system architectures and project plans.

This paper will provide an overview of the Advanced Systems Engineering Capability (ASEC) framework, its intended application, current and planned capabilities and potential benefits to the Ground Vehicle community.

INTRODUCTION

Research on the Life Cycle Cost (LCC) [1] for diverse systems/products has shown that 75% of the LCC as a percent of baseline LCC is committed during the conceptual phase of the system/product lifecycle. The percentage increases to 85% of LCC committed in the development phase. In contrast, the LCC incurred during the conceptual phase is 1% of baseline LCC rising to 7% of baseline LCC in the development phase. Research has also shown that the cost to identify and resolve a defect and incorporate change rises dramatically in later phases of the system/product's lifecycle.

The Defense Acquisition University (DAU) Systems Engineering Vee model [2] illustrates the technical processes and technical management processes to be performed for the entire system/product lifecycle. The left leg of the Vee model outlines the design processes – Stakeholders Requirements Validation, Requirements Analysis, and Architecture Design. These design processes are followed by the realization processes - implementation to transition which makes up the right leg of the Vee model. The design processes along the left leg of the Vee model are fundamentally the concept and development phases of the system/product lifecycle that are applied recursively at different levels of abstraction and across the different elements (system to sub-systems) of the system/product.

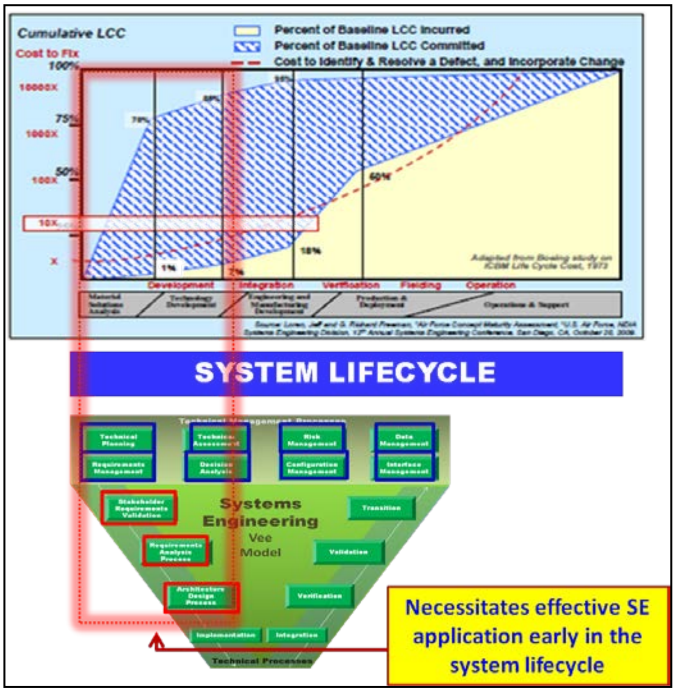

Figure 1: Life Cycle Cost mapped to the SE Vee model

By aligning the DAU Vee model to the LCC illustration by early phases of a system/product lifecycle gives us a mapping between the SE Vee design processes and the percent of baseline LCC committed. The mapping exemplifies the criticality of thorough recursive application of the design processes taking into consideration all aspects of the system/product. It becomes prudent to practice and apply early and effective SE to minimize the number of defects. Early and effective SE application and practice can result in lower defects that positively impact system cost and the realization of higher quality solutions.

CURRENT SYSTEMS ENGINEERING OPERATING ENVIRONMENT

Historically Systems Engineering (SE) practitioners have focused on producing document-based artifacts to relay SE knowledge to stakeholders and developers. More recently a large part of the community has moved towards using view-based artifacts; e.g. DODAF to visually communicate SE knowledge. Documents and views do not carry with them the full system information meta-model. In the current paradigm, information for the system/product is often generated in silos based on pockets of subject matter expertise. It is incumbent of SE practitioners to pull together information from various silos, sew it together and present the information to decision-makers. Every system knowledge change in this operating regime continuously burdens SE practitioners to pull updated information, re-sew and re-present in context. This takes away from the time SE practitioners can apply towards thinking and delivering innovative and effective solution alternatives.

The Engineered Resilient Systems (ERS) [3] briefing from the Director, Advanced Engineering Initiatives, Office of the Deputy Assistant Secretary of Defense (ODASD), Systems Engineering captures the state of the Systems Engineering practice today as slow and sequential with decisions and requirements refinement being made in an ad hoc manner and information lost at every step in the process.

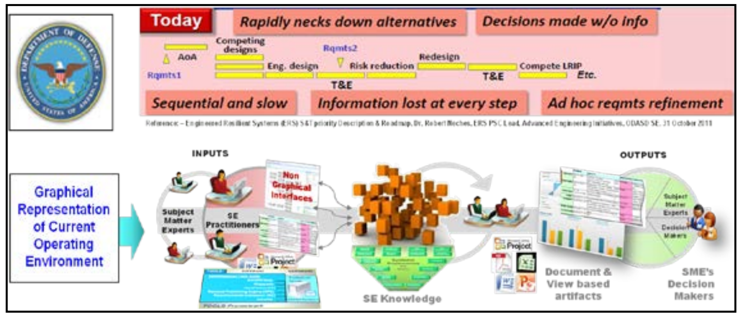

Figure 2: Representation of current operating environment

Outlined below is a list of shortcomings or gaps in the current operating environment that preclude SE practitioners from practicing effective and early SE.

- Silos of Information
- No meta-data transfer
- Two stage process – Think and then link
- Lacks continuous and lifecycle traceability
- Lacks real time collaboration
- Translation loss

DESIRED FUTURE STATE TO ENABLE EFFECTIVE SYSTEMS ENGINEERING

With the ever increasing complexity of weapons systems and systems of systems coupled with diminishing defense budgets, affordability of a system across its entire life cycle becomes a primary consideration. Proactive Systems Engineering that factors performance, affordability and sustainability criteria early in system development trade space provides decision-makers the opportunity to formulate balanced decisions that address the entire system life cycle.

As outlined earlier in the paper the state of Systems Engineering practice today is also echoed by the Decker Wagner Report [4], Final report of the Army Acquisition Review commissioned by the Secretary of the Army, January 2011. Further, the National Industrial Defense Association (NDIA) has published the NDIA 2010 Top 5 SE Issues [5] based on studies conducted by the NDIA.

Collectively these studies baseline the current state of Systems Engineering practice and outlay recommendations to overcome the shortcomings, impediments and gaps.

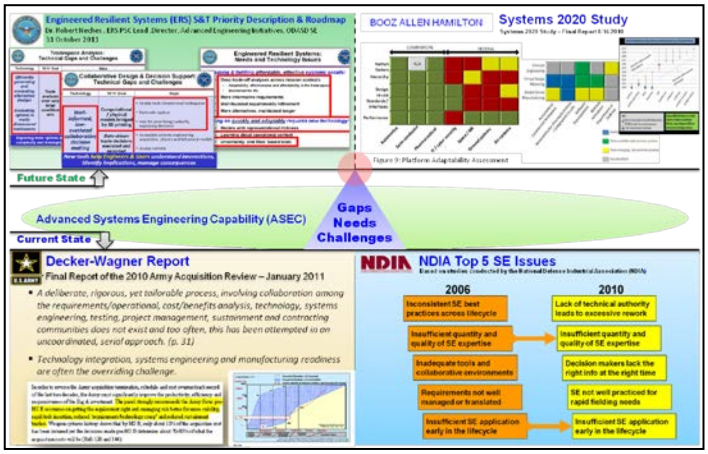

Figure 3: Current State Vs Future State

The 2010 Army Acquisition review [4] calls for the Army to:

• Involve all stakeholders collaboratively in requirements development, development planning and acquisition solicitation, rather than just critiquing others.

• Realistically assess and manage risk, and follow more tailored evolutionary acquisition strategies with associated reductions in steps, time and documentation to provide new systems.

The Engineered Resilient Systems (ERS) [3] briefing from the Director, Advanced Engineering Initiatives, Office of the Deputy Assistant Secretary of Defense (ODASD), Systems Engineering identified the following Technical Gaps and Challenges:

- System Representation and Modeling
- Characterizing Changing Operational Environments
- Cross-Domain Coupling
- Tradespace Analysis
- Collaborative Design and Decision support

To address some of the above recommendations, technical gaps and challenges, the TARDEC SE Infrastructure team within the Systems Engineering Group (SEG) has conceived, designed, and deployed the Advanced Systems Engineering Capability (ASEC). The ASEC is a web-enabled collaborative tool that assists in the capture, sharing and presentation of SE knowledge and enables practitioners to focus on thinking tasks.

TARDEC ADVANCED SYSTEMS ENGINEERING CAPABILITY (ASEC)

The Advanced Systems Engineering Capability (ASEC) developed by the TARDEC Systems Engineering Group (SEG) is an integrated Systems Engineering (SE) knowledge creation and capture framework built on a decision-centric method, high quality data visualizations, intuitive navigation and systems information management that enable continuous data traceability, real-time collaboration and knowledge pattern leverage to support the entire system lifecycle.

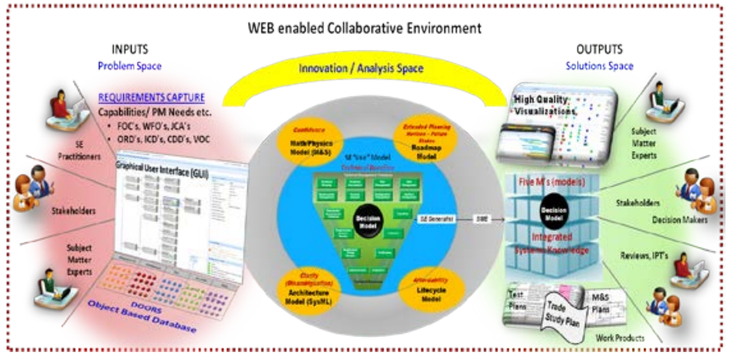

Figure 4: Illustration of the TARDEC Advanced Systems Engineering Capability (ASEC)

The ASEC framework consists of three seamless parts.

1. Problem Space (Inputs)
2. Innovation/ Analysis Space
3. Solutions Space (Outputs)

Problem Space (Inputs):

The framework for the problem space is built for requirements capture. ASEC has the capability at the front end to capture a wide spectrum of needs, synthesize these high-level needs and develop and decompose them into requirements and to manage these requirements over time. The requirements are stored as objects in a DOORS database. A Graphical User Interface (GUI) with intuitive navigation capability connects all stakeholders and serves as the interface for needs capture. Additional GUI canvases support custom applications; Capability Analysis (CA) and Decision Management (DM) within the ASEC framework.

Innovation/Analysis Space (Models):

The core of the Innovation/Analysis space is built on the five model (5M) framework. SE knowledge created from the five models is captured, linked and glued together by a by the decision management engine. The integrated knowledge set for a particular system/product decision is then presented to all stakeholders through high quality visualizations in the collaborative system tradespace.

THE FIVE MODEL (5M) INNOVATION/ANALYSIS FRAMEWORK

The five models from which SE knowledge is created and captured are outlined below.

1) SE 'Vee' Model – This model creates the knowledge that defines the system/product technical baseline. This SE knowledge is created in the SE generalist space by SE practitioners using the built-in ASEC decision management engine. The engine creates a continuous knowledge and solution pull for most of the technical and technical management processes of the SE 'Vee model.

The knowledge created from the other four models is in the Subject Matter Expert (SME) space that is external to the ASEC framework. Knowledge from these models is captured in a manual, semi-automated or fully automated form.

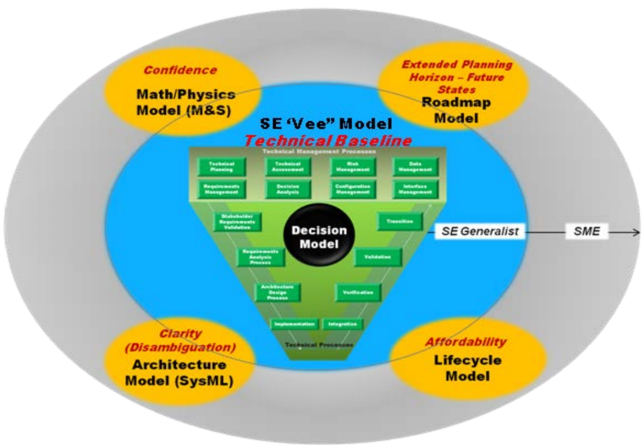

Figure 5: The Five Model (5M) Innovation/Analysis Framework

2) Modeling & Simulation (M&S) Model – These models are math and physics-based and model uncertainty. The knowledge created provides confidence for system/product performance parameters.
3) Architecture Model (SysML) – These models define and simulate the various architecture contexts of the system/product. The knowledge created provides clarity or disambiguation for the system/product architecture.
4) Lifecycle Models – These models create and provide knowledge for the system/product lifecycle. The knowledge created provides affordability, sustainability, reliability and other 'ilities' for the system/product.
5) Roadmap Model – These models provide knowledge for the extended planning horizon. The knowledge created provides the states of various technologies that are mapped to required capabilities and the alignment between the two.

All knowledge created from the five models is captured by the decision model in the context of a system/product decision. The ASEC decision management engine creates a knowledge pull that highlights the relevance of the other system models as inputs to inform a system/product decision.

DECISION MODEL - THE INTEGRATIVE MECHANISM

The Decision model consists of a comprehensive Decision Management methods engine that operates on three levels. The Plan Decisions and Manage Decisions over Time processes are big-picture processes that operate at the system level. Plan Decisions frames a decision model for the entire system, prioritizes open decisions and develops an analysis plan for inform these decisions with appropriate investment, techniques and rigor. The Manage Decisions over Time process views the entire decision model as a roadmap so that future decision states and cross-dependencies may be anticipated.

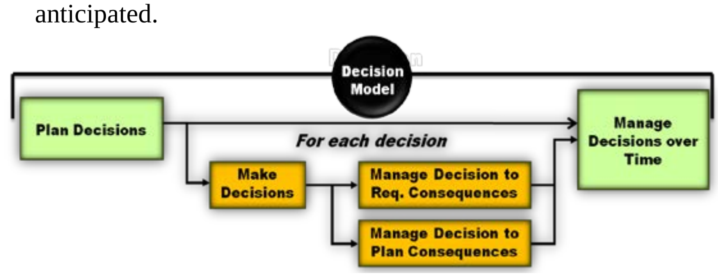

Figure 6: The Decision Methods Engine

The Make Decisions and two Manage Decisions-to-X Consequences processes operate on a per decision basis. They represent a deep-dive into decision analysis to select the best course of action (alternative) for a specific decision and to capture and communicate the implications that this course of action has on system requirements (e.g. derived requirements) and the development plan (e.g. implementation tasks). For a complex system, these processes may be performed 30, 50 or even 100 times depending on the number of decisions that are believed to be of sufficient priority to justify formal decision analysis and traceability.

STAKEHOLDER AND KNOWLEDGE ALIGNMENT THROUGH DECISIONS

SE knowledge for a system/product when presented to stakeholders in the context of a decision has the ability to align active and passive stakeholders with system technical knowledge. Decisions glue various technical knowledge elements of the SE 'Vee' model and present that knowledge as required to stakeholders.

The decision model gives all system stakeholders the ability to comprehend system technical knowledge through system decisions. Stakeholders and decision makers thus have the ability to make better quality decisions with decision-aligned technical system knowledge.

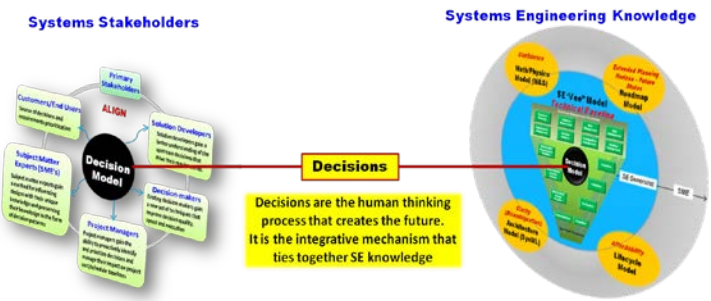

Figure 7: Systems Stakeholders and Systems Knowledge Alignment through Decisions

Outlined below are the benefits for various system stakeholders.

- Decision-makers gain improved ability to visualize and control the high priority choices that will drive their project's success.
- Subject Matter Experts (SME) benefit from a framework that highlights the power of their unique knowledge to influence decisions. SMEs also gain the opportunity to build their knowledge into decision patterns that extend their influence to future systems/product families
- Project managers gain the ability to proactively identify and prioritize decisions and to structure their program plans to maximize decision quality, speed, and parallelism. As decisions are made, project managers are enabled to immediately factor the consequences of these decisions into their project cost/schedule baselines.
- Solution developers gain explicit traceability to the upstream decisions from which their requirements have been derived. This traceability improves understanding of the customer/user intent, highlights requirement gaps/conflicts and facilitates higher-level tradeoffs between the most demanding requirements and constraints.

Solution Space (Outputs):

The solution space consists of presenting and displaying object-based SE knowledge. The SE knowledge is presented in the form of high quality visualizations in the collaborative multi-dimensional system tradespace to stakeholders and decision-makers for fast comprehension and decision making. The system trade space connects SE practitioners and SME's with stakeholders and decision makers to virtually collaborate, evaluate alternatives and scenarios and assess impacts. Further SE knowledge objects can be projected to populate SE artifacts and generate SE work products.

MULTI-DIMENSIONAL SYSTEM TRADESPACE

The ASEC multi-dimensional trade space presents SE knowledge in the form of high quality visualizations. Knowledge from the five models is presented in the context of a decision. For each system/product decision evaluation, alternatives reflecting quantitative and qualitative data are visually stacked between the threshold and objective criteria values. The criteria can be weighted based on the relative importance design margin. Alternatives are discriminated based on total weighted score.

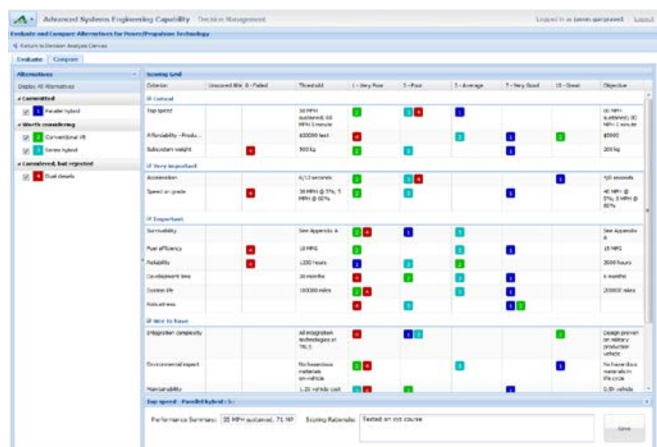

Figure 8: ASEC System Trade Space

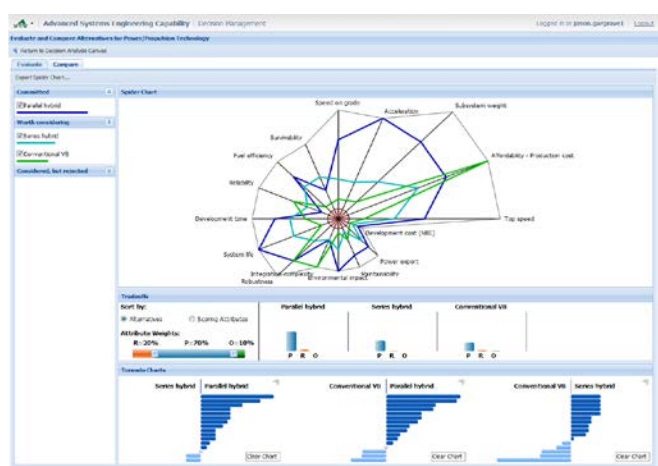

Figure 9: ASEC System Trade Space (Spider Chart)

Other forms of visualization like spider charts and pair wise comparisons are supported in the multi-dimensional system trade space to provide decision-makers the ability to visualize and synthesize complex system knowledge and data sets. The high quality visualization feature in the ASEC solution space enables decision makers to quickly evaluate alternatives in a decision context and make quicker decisions with confidence.

IMPROVED SE EFFECTIVENESS

The ASEC framework is a comprehensive and robust framework built for Systems Engineering success. It has the capability to capture knowledge in a timely, efficient and effective manner and share that knowledge among a diverse set of system stakeholders to formulate the system trade space and enable decision makers to choose a balanced solution to the problem. It is a framework that is scalable to address system complexity and the precise capture of SE knowledge compounds. SE practitioners can use the ASEC as a technology aid to effectively capture, manage and share systems information and in turn enable them to focus on thinking tasks.

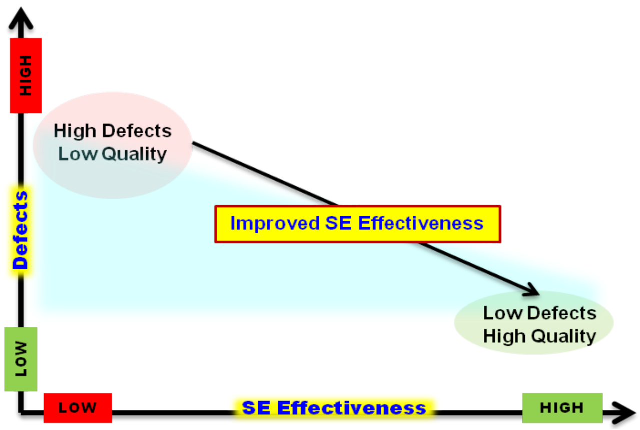

Figure 10: SE Effectiveness Vs Defects

As the capability of the ASEC is enhanced over time it will make possible for early SE application in the system/product lifecycle. Consistent early application of SE in the system/product lifecycle will result in a high degree of SE effectiveness leading to lower defects and higher quality.

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