National Defense Industrial Association
Systems Engineering Division
Working Group Report

Top Systems Engineering Issues
In
US Defense Industry
2016

V7c

Background

The NDIA Systems Engineering Division determined that an update to the Top Issues in Systems Engineering (SE) report that was issued initially in 2003, updated in 2006 and again in 2010 was needed. The issues related to our defense industry are complex, affecting both the industry organizations as well as the government and military organizations.

A Working Group was formed, inputs were solicited in advance, and a reconciliation meeting with 18 members was held on August 17th and 18th, 2016. Although numerous separate issues were identified, the group found that the bulk of these actually fell into several major issue categories. The detailed results, including the status of the previous 2006 and 2010 SE issues, are described below.

Status of Activities against the Top Systems Engineering Issues for 2006 and 2010

#		2010 Status	2006 Issue
1	**Key systems engineering practices known to be effective are not consistently applied across all phases of the program life cycle**	***Institutionalization of practices has shown value when adopted but adoption tends to be spotty. *Determination of proficiency in applying practices appears to be problematic**	***Institutionalization of systems engineering practices has increased and practices are effective when followed. However, improvements in modeling of life-cycle data is critical.**
2	**Insufficient systems engineering is applied early in the program life cycle, compromising the foundation for initial requirements and architecture development.**	***Improving by necessity in complex systems. * Policy updates (5000.2, competitive prototyping and earlier decisions) imply SE engagement, but are not explicit (subsequent revisions may have already addressed this or are in work)**	**This area continues to improve but is hampered by a lack of sufficient systems engineering experience, skills and critical tools to define and engage programs, especially on the government side**

3	**Requirements are not always well-managed, including the effective translation from capability statements into executable requirements to achieve successful acquisition programs.**	*** WSARA requirements for development planning are believed to be an improvement. * Variability in approaches to requirements definition, validation and consolidation continue**	*** Tool solutions for requirements decomposition and tracking exist within the marketplace, but adoption is only limited due to business leader's low perceived value of implementation. * Tempo of threat emergence continues to increase thus creating an environment of continuously evolving requirements and associated architectures for many systems.**
4	**The quantity and quality of systems engineering expertise is insufficient to meet the demands of the government and the defense industry.**	*** Resource issues persist, in government and industry. * Shortages: leadership, domain, architects, systems engineers. * Initiatives: acquisition workforce, STEM, cross-training. * Value of having experience to enhance educated workforce is better understood**	*** This remains a serious hindrance to achieving success as noted in item 2 above. One factor is that the Defense industry is seen as a less desirable career path for college graduates. Another factor is the loss of industry experience from a retiring workforce. * Ability to determine systems engineering proficiency has improved but still needs increased focus**
5	**Collaborative environments, including SE tools, are inadequate to effectively execute SE at the joint capability, system of systems (SoS), and system levels.**	*** State of the practice techniques not widely utilized. * Multiple tools are available but little guidance on preferences exists. * Emphasis on SoS seems to have diminished**	*** New tools are still slow in adoption due to cost (training, licenses) and interoperability issues. * Major shortfall still exists in effective Life Cycle Cost models * SoS and complex systems focus has improved, driven partly by CyberSecurity aspects. * An open-source tool usable in a government-industry collaborative environment is an essential element.**

Identification of the Top Systems Engineering Issues for 2016

The workshop participants reviewed the top Systems Engineering Issues from the previous two versions (2006 and 2010) and identified additional issues during the workshop. The issues were discussed, reviewed and prioritized into the top issues by voting and consensus. For each of the top issues, additional details and explanations were developed, and recommendations were

gathered to address their correction or to drive improvement. Special attention was given to making the recommendations actionable and specific. Several issues from 2006 and 2010 remain almost unchanged from the previous lists but the recommended actions herein are believed to be more focused and actionable.

The top Systems Engineering issues as of 2016 were deemed to be the following. Please note that the issues are listed in a priority order based on our judgment of their importance.

- Professional Development/Human Capital
  The large number of existing and new and upgrade programs within the defense system requires substantial numbers of experienced systems engineers for both the government side as well as industry side.
- Cyber Resilient and Secure Systems
- Architecting for cyber resiliency and the system security specialties working together provide a security perspective and focus throughout the SE "V". Program Protection is the integrating process for mitigating and managing risks to advanced technology and mission-critical system functionality from foreign collection, design vulnerability or supply chain exploit/insertion, battlefield loss, and unauthorized or inadvertent disclosure throughout the acquisition lifecycle.
- Systems Engineering for Rapid and Flexible Acquisition
  The tempo and varying threat from adversaries remains unabated, which requires a flexible and rapid acquisition process to allow our warfighters to effectively meet and counteract the threats.
- Systems Engineering for Resilient Systems
  Resilient systems are a relatively new thrust within the DoD and will require unique systems engineering knowledge and experience, including but not limited to cyber security aspects, as well as fundamental, cultural changes to organizational structures and management approaches to facilitate the technology advances
- Mission Engineering and Mission Assurance Focus within Systems Engineering.
  The systems engineering organizations within government and industry need to add focus on mission engineering/mission capability, especially considering the cost and complexity of today's weapon systems and associated pace of change in technological capabilities
- Early Systems Engineering Engagement
  It is well established that competent early systems engineering effort on programs is essential to program success, in order to assure that a thorough needs analysis and requirements development process is followed prior to actual design activity, and this is even more critical in today's complex systems and systems-of-systems. This is especially true in the Development Planning process.

Top SE Issues and Discussion Points

Issue 1: Human Capital/Professional Development

We have inadequate systems engineering capital available to the defense complex to adequately meet the demands of both government and industry

The following main points, many of which carry over from 2010, provide amplification of this issue:

- Experienced, trained systems engineering personnel are in short supply, in both industry and government. This situation is exacerbated in government by the migration of systems engineers in mid-career due to inequities in compensation and incentives vs. industry.
- The defense complex (industry and government) is no longer an "employer of choice."
- Millennials are generally not enamored with defense as a whole as they typically consider it "boring".
- There is inadequate recognition within government program management offices of the value of systems engineering which we believe is caused by a continuing gap in the understanding of systems engineering functions and benefits.
- The difference between performed systems engineering work between government and industry systems engineers may be a factor in that the industry side is more "hands on" which is highly preferred and similar to colligate training.
- There is a recognized definition of systems engineering processes but a mature definition of systems engineering competencies and competency assurance are lacking.
- Recent decades have seen the government transition execution work to industry, an expansion of industry's value chains, and increased focus on Systems Engineering. These trends present a challenge to the development of Systems Engineering human capital, a significant factor for Systems Engineering success is a deep expertise in multiple engineering disciplines that has been developed through hands-on engineering execution over years of experience.

Issue 1 Recommendation:
NDIA Systems Engineering Division to convene a joint government/industry short-term study, to develop workable approaches to begin fostering additional interest in systems engineering as an important discipline and provide motivation to join the defense/industrial complex.

- The use of mentoring should be strongly encouraged and used to support the next generation of systems engineers. Consider use of the term "Apprentice" in some circumstances.
- Engage with NDIA and others to develop a workable "branding" strategy for systems engineering that would clearly depict systems engineering as an essential, overarching "umbrella" aspect of engineering that is critical to program/project success.

- Encourage more universities and colleges to develop an advanced degree systems engineering curricula, possibly in cooperation with the Defense Acquisition University, using actual practitioners to not only develop the curricula but also assist in teaching same.
- Work with such groups as the NDIA SED Education and Training Committee, INCOSE, and the Systems Engineering Research Center (SERC)to investigate and recommend specific methods and techniques to accelerate the training and development of Systems Engineers to include purposeful OJT rotation programs to complement course work.

Issue 2: Cyber Resilient and Secure Systems

System survivability in a cyber contested operational mission environment is critical. We need to elevate the system security risk to the program risk register to ensure a security focus. We need well defined methods, processes, standards, metrics and measures, along with skilled professionals to integrate system security into our product development lifecycle.

Due to the evolving and persistent cyber system security threat that impacts our interconnected systems, focused attention is required. The following main points also include tenants of engineered resilient systems and mission assurance:

- System Security risks must be added to the program risk register to ensure that security doesn't get traded away to system technical capabilities and cost reduction efforts.
- Well defined metrics and measures are needed to conduct trades: cost, risk, and performance.
- Operational CONOPS and SoS along with System critical mission threads are essential to initiate and focus the system mission functional criticality analysis.
- Integration of the security specialties into the system security architecture view needs to be defined and methods developed.
- NIST SP 800-160 establishes a foundation for System Security Engineering best practices. We need to develop education and awareness training to include a range of proficiencies for different security specialties with experience in mission system platforms and embedded systems, along with a range of acquisition professionals.

Issue 2 Recommendation:

NDIA System Security Engineering Committee with support from the NDIA Systems Engineering Division to convene a joint government/industry activity such as a workshop or summit, to dialog the relevant issues.

- A Summit is recommended to bring Government, Industry, and FFRDC working groups together to share developments, strengths, gaps, opportunities, and recommendations.

The NDIA System Security Engineering Committee hosted a 3 day NDIA Program Protection Summit in May 2014 and is preparing for a Spring 2017 follow-up.

- The new System Survivability KPP values are intended to define objective values for a capability solution and derived from operational requirements of the system. Connecting the SS KPP, Cyber Resiliency metrics, and System Security Specialty Risk Mitigations offers a compelling means to conduct risk, performance, cost trades and compare one solution to another.
- Verification and validation criteria need to be identified and methodologies established to achieve same.
- Cyber Resilient and Secure System requirements SOW & RFP along with Sections L&M evaluation criteria guidance needs to be matured with metrics and measures to ensure a holistic approach for managing system security risks.

Issue 3: Systems Engineering for Rapid and Flexible Acquisition.

Increasingly urgent demands of the warfighter require effective capabilities be fielded more rapidly than the conventional acquisition processes and development methodologies allow.

The following main points, many of which carry over from 2010, provide amplification of this issue:

- The warfighter needs rapid deployment of systems to meet the ever-changing threats and requirements of current military actions, since the threat is adapting and evolving more quickly that the acquisition cycle can accommodate.
- The ultimate objective is to do as good a job in meeting requirements as quickly as possible..
- The incorporation of an “optional” Milestone A does not appear to have significantly improved development speed.
- Measurement of the impact of Agile methodology has been difficult, and some users have assessed no demonstrable improvement in acquisition cycle times. However, agile techniques have proved useful in certain applications, warranting further investigations and success story capture via venues such as the SERC.
- In a rapid response environment, a strong SE capability along with appropriate Subject Matter Experts is crucial to set up and make effective trades on technical approaches and processes according to the urgency of the need and characteristics of the effort. This will facilitate an explicit determination and assessment of the consequences (e.g., impact to technical, sustainment, production, interoperability) and the level of risk acceptable to support a decision to field the capability.

- Rapid response to prioritized needs depends heavily on a tightly integrated and capable acquisition team along with a committed and available supply chain. Preservation of these participants has been extremely challenging in the past decade.
- Critical success factors for responding rapidly to urgent needs (e.g., stable requirements, robust architecture, capability reuse, clear understanding of the capability gap, domain expertise, reliable technology, highly capable team, etc.) are generally understood, but are not yet well-documented and used in decision-making.

Issue 3 Recommendation:

NDIA Systems Engineering Division to convene a joint government/industry study, with cross-functional representation including T&E, to develop risk-driven guidance on tailoring SE processes and activities and DoD acquisition requirements from the Defense Acquisition System to achieve rapid acquisition and deployment.

Details of this recommendation include the following points to be addressed:

- Industry experience in accelerated acquisition for different program types and constraints can be leveraged to provide input on characterizing the tradeoffs, critical success factors, and measures of effectiveness that may be applicable to specific program situations and associated potential life cycle impacts.
- While changing requirements in a dynamic environment must be recognized by the acquisition system as a "way of life", attendant provisions are needed to accommodate such without having a cumbersome and time-consuming contract process that introduces additional delays and unnecessary costs to the development process.
- There are inevitable SE tradeoffs required to balance all constraints (cost, schedule, technical maturity, process rigor, and sustainment) to make informed program decisions for a rapid response to urgent mission needs. Successful materiel solutions are often a function of well documented architectural and design baselines of existing systems and components, thus allowing effective reuse, integration, and verification in the extension of system functionality.
- Key government stakeholders, such as the Rapid Fielding Office and Defense Portfolio Managers, should be engaged in developing these recommendations and ensuring their relevance and viability in a rapid acquisition environment.

Issue 4: Systems Engineering for Resilient Systems

Implementation of Resilient Systems requires unique systems engineering expertise which typically does not exist within the current community.

The following main points of this new item provide amplification of this issue:

- The definition of a Resilient System as "effective in a wide range of situations, readily adaptable to others through reconfiguration or replacement, with graceful and detectable degradation of function" remains valid and appropriate and is considered an essential capability in a modern weapon system.
- Cyber Security or Cyber Resiliency is perceived to be the most pressing element of system resiliency and thus is addressed separately as Issue 2 above.
- Resiliency in this context requires a substantial shift in the planning and systems engineering process. The fundamental change in the ERS environment is that design options are left open for as long as possible, changing from requirements-based design to mission or capability-based design. Mission engineering is of interest to the ERS community to further explore this shift. Methods to specify the types of rapidly-adaptable and robust designs is needed, including Section L and M language

Issue 4 Recommendation:

NDIA Systems Engineering Division to convene a joint government/industry activity such as a workshop, possibly at the classified level, to dialog the relevant issues and attempt to reach consensus on effective approaches.

Details of this recommendation include the following points to be addressed:

- NDIA did initiate such a workshop series in late 2012 shortly after the transition of ERS from the DoD (DASD/SE) to the US Army (ERDC/RDECOM), but this was at the same time as the DoD "no-conference" policy was initiated and the effort was unfortunately canceled since government personnel would not be allowed to participate. A revised push to initiate such a workshop series, and a formal User Group, is essential and appropriate.
- Critical elements of design needed to accommodate ERS concepts must be identified and vetted, including architecture, standardization, and validation/proof-of-concept approaches.
- Modeling & simulation tools to support ERS concepts should be explored.

Issue 5: Mission Engineering and Mission Assurance Focus within Systems Engineering

Systems Engineering within the government and industry need to provide more focus on mission engineering/mission capability in order to field and project a more effective military presence and capability

The following main points provide amplification of this issue:

- Mission Engineering is essential in this day of high-tempo operations dealing with a variety of threats involving multi-service, interoperability response.
- There is little if any focus on mission engineering or mission capability at the PEO or cross-service, cross-agency level.
- The JCIDS process (Joint Capability Integrated Development System) was intended to address this issue but seems to have fallen short. Identification of any capability gaps across a time-line continuum via Mission Engineering will allow the acquisition community to identify specific, needed materiel and non-materiel solutions to benefit JCIDS.
- The capability to perform mission engineering or related use cases exists in many quarters (e.g., industrial base, defense research labs, and academia) but is not utilized effectively
- Insufficient focus of systems engineering at the system-of-systems level is compounding the issue
  Inadequate focus of the tradeoff process at the true mission level is also an issue as the primary tradeoffs still occur at the individual program level.

Issue 5 Recommendation:
Provide a small but persistent mission engineering-focused subset of DoD systems engineers to facilitate the institutionalization of mission engineering at the enterprise level within the Department.

Details of this recommendation include the following points to be addressed:

- DASD(SE) should consider hosting a series of roundtables to share experiences of each Service and Agency on their activities within the mission engineering environment.
  - The roundtables would identify policy, organizations, methods, tools, challenges and opportunities for Mission Engineering improvements at the enterprise level.
  - Some of the roundtable sessions should include industry partners as they can share their experiences
- Policy should be developed that would assist in synthesizing common approaches, challenges, and specific actions for the acquisition community
- Identification of the most pressing mission areas needs to occur to help provide immediate focus.
- Identification of impediments to achieving Mission Engineering is essential; such as people, organizational structure, funding, and process.
- Revisit the JCIDS process to assure that it is being implemented properly and effectively.
- Consider updating the JCIDS process to allow for inputs from a Mission Engineering process to influence JCIDS decisions.

Issue 6: Early Systems Engineering Engagement

The increasing complexity of defense systems requires more and more early systems engineering especially in the Development Planning process to help assure effective systems

The following main points provide amplification of this issue:

- The Weapon Systems Acquisition Reform Act (WSARA) of 2009 mandated an increased focus on systems engineering and also a formal Development Planning process which would provide more focus on systems engineering "up-front".
    - While each service has indeed created a Development Planning process, our observation is that we still do not have adequate systems engineering up front in many cases and programs are handicapped or unnecessarily burdened as a result
- Lack of adequate and experienced systems engineering talent, per Issue 1, is having a detrimental effect on the Development Planning process.
    - This tends to lead to unrealistic technical expectations, cost and/or schedule assumptions in the early project phases
- Technical decision makers tend to not have the right information & insight at the right time to support informed & proactive decision making; or they may not be aware of and act on all the technical information available to ensure effective & efficient program planning, management & execution.
- Without proper and comprehensive SE, PMs and other decision makers (i.e., Milestone Decision Authorities [MDAs]) do not know what information they lack in terms of technical issues and risks
    - PMs and MDAs do not always have the information they need to make informed decisions
    - Programs do not always start with good requirements/capabilities
    - Programs do not always capture evolving requirements adequately and determine the impacts of the evolving requirements changes
    - Programs do not always present information to decision makers in a manner that fully conveys potential impacts the program under review, particularly regarding the effects on other programs and their systems' capabilities. (e.g., Systems-of-Systems environment)
- There are no consistently applied methods for presenting key SE information to decision makers. This constraint is compounded by a high turnover rate of PMs and others in the acquisition decision chain with their differing styles.
- It is difficult to use currently available standard SE tools early in life cycle (MDD/MS-A timeframe). In addition, many of the tools are not readily available and the engineers have not been trained in their use.
- Systems engineering practices known to be effective are not consistently applied or properly resourced to enable early system definition.

Issue 6 Recommendation:

Services should initiate a focused systems engineering approach to Development Planning using the most experienced personnel available on all programs of significance.

Details of this recommendation include the following points to be addressed:

- Goals and objectives of WSARA should be re-examined to assure that each Service has implemented an effective and properly staffed Development Planning methodology
- Maximum involvement of defense industry should be planned to assure that the latest technologies, methodologies, and practices developed by defense industry relative to the system under consideration are brought to the forefront and understood as potential enablers of an effective solution.
- Identify specific areas, activities and knowledge in the pre-milestone "A" timeframe where Industry engagement could inform early technical analysis and engineering for DoD Acquisition Programs.
    - Understand the available and potential mechanisms necessary to facilitate Industry involvement in that early technical analysis and engineering.
- Identify shortfalls in SE tools and methodologies for potential action by M&S vendors.

Observations

In addition to the items identified in the above, the work group felt that several additional observations were pertinent to the Top Systems Issues discussion.

Observation 1:

The work group believes that the rigorous implementation of 3rd party evaluations is not adding the anticipated or expected value.

Recommendation:

Look at case studies to determine if the 3rd party evaluations are providing any value added and specifically what that value is.

Observation 2:

Interoperability between the various model-based systems engineering tools is still not mature or effective.

Recommendation:

Request that the Systems Engineering Research Center (SERC) initiate an interface standard recommendation activity for architecting as well as modeling and simulation tools.

Observation 3

Life Cycle Cost models still do not have the accuracy, fidelity or maturity to support programmatic decision making.

Recommendation:

Initiate a concerted effort among the tool vendors and universities, perhaps involving the SERC, to further mature existing models and develop potential new models where sufficient applicability is present.

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For additional information, contact the NDIA Systems Engineering Division:

Top SE Issues Work Group Chairs:

- Bob Rassa, Chair, Raytheon Co; RCRassa@Raytheon.com
- Tim White, co-chair, Raytheon Co: Timothy_White@Raytheon.com

SE Division Chair: Frank Serna, Draper Lab, fserna@draper.com

NDIA Committee Executive: Britt Sullivan, BSullivan@ndia.org

Appendix A

Task Group Participant Organizations

The Boeing Company
Booz Allen Hamilton
Draper Lab
Harris Corp
Lockheed Martin Corporation
MITRE
Raytheon Company
Rolls Royce
Stevens Institute of Technology
Software Engineering Institute
USAF – SAF/AQR
Worcester Polytechnic Institute