Proposed SoSE Strategy for the Air Force Electronic Systems Center

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Abstract - *This paper describes a proposed System of Systems Engineering strategy for an Air Force Acquisition Organization – the Electronic Systems Center of the Air Force Materiel Command. An acquisition organization is dedicated to building and implementing systems on behalf of using organizations. This proposed SoSE Strategy responds to the requirement to integrate across broad user capability needs. This SoSE Strategy proposal contains four processes: architecture and analysis, testing and evaluation, management, and governance. These processes detail how this organization could improve its approach to SoSE for its many acquisition programs. The focus of this SoSE Strategy includes process methods or steps that require tailoring of already existing systems engineering processes to successfully deliver capabilities that can be shared across the Electronic Systems Center. The paper concludes by discussing implications of the strategy and processes, as well as recommendations for actions, products, key stakeholder decisions and future challenges.*

Keywords: Architecture, Governance, Integration, System of Systems Engineering, and Testing.

1. Introduction

The Electronic Systems Center (ESC) of the United States Air Force Materiel Command (AFMC) is responsible for acquiring most of the Air Force's command and control (C2) and business IT systems. These acquisitions are requirements-driven and structured around acquisition programs – each with their own funding profile and lifecycle. The systems that ESC acquires support a range of operators – airmen, soldiers, sailors, marines and other personnel – performing a range of duties.

Air Force system operators naturally expect their systems to work together, as needed, to support relevant military capabilities.[1] In other words, they expect their systems to be components in relevant Systems of Systems (SoSs)[2] (although it is not always clear exactly what systems belong to what SoSs). A specific capability may require that systems acquired by different programs work together within a given SoS. These programs are more often than not in completely different acquisition organizations and different life-cycle phases, but may be expected to support multiple capabilities across the range of operations.

Typically, the acquirers of individual systems must meet specific requirements within cost and schedule constraints specific to the individual acquisition program. They rarely set out to acquire SoSs (unless so directed as a specific program). ESC does not have an approach for *engineering and acquiring* cross-cutting capabilities outside of the context of an individual program.

ESC does, however, have established program-level systems *engineering* processes (e.g. requirements management, risk management, configuration management, design, verification and validation) that serve to provide a standard of practice across programs. While these processes address the engineering of an individual system within its larger environment, ESC has no standard approach for engineering a SoS as a whole that is greater than the sum of its constituent parts.

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[1] AFI 10-601, Operational Capability Requirements Development[1], defines a capability as "*the ability to execute a specified course of action.*"

[2] The DoD Defense Acquisition Guidebook [2] defines a System of Systems (SoS) as a *"set or arrangement of systems that results from independent systems integrated into a larger system that delivers unique capabilities."*
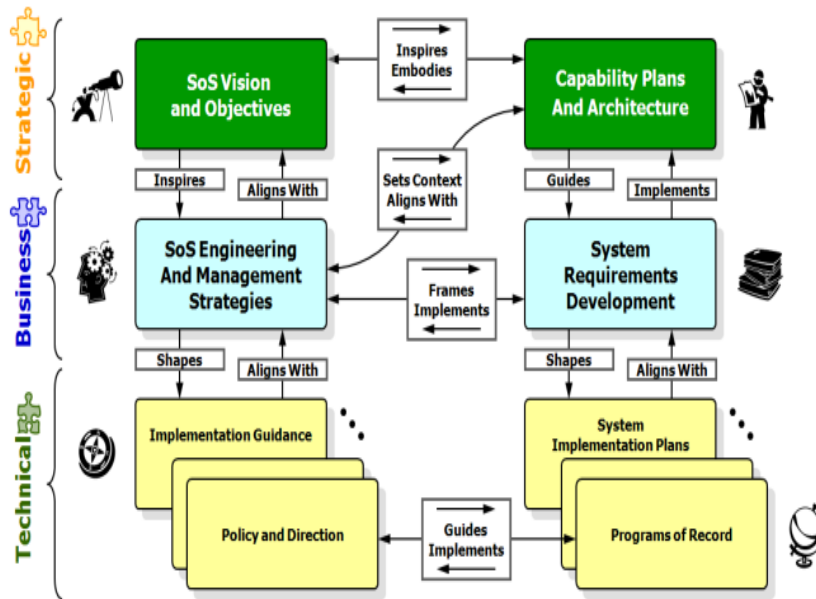
Figure 1 - SoSE Context

2. Proposed ESC System of Systems Engineering (SoSE) Strategy

In lieu of explicitly acquiring SoSs using an intentional top-down methodology[3], ESC is proposing to engineer SoSs by adopting a formal set of SoSE processes and related constructs. The DoD Defense Acquisition Guidebook [2] describes SoS engineering as dealing "*with planning, analyzing, organizing, and integrating the capabilities of a mix of existing and new systems into a SoS capability greater than the sum of the capabilities of the constituent parts.*" There are two basic elements to the proposed ESC SoSE strategy: 1) engineer individual systems so as to allow them to support the SoSs in which they participate and 2) engineer selected SoSs.

To implement this strategy, ESC will need to:

- establish governance mechanisms to identify what SoSs to engineer, to approve SoS engineering artifacts (architecture products, risks, performance measures …), etc
- modify selected existing system-level systems engineering processes to support SoSE
- evolve the acquisition and engineering culture to more readily accept the codependence of

systems in an environment of asynchronous lifecycles and competing stakeholders

- develop or otherwise institute appropriate documentation, training, tools, and socialization of SoSE concepts
- develop and monitor a set of metrics to track SoSE performance and suggest areas of improvement

While not guaranteed to be as efficient or effective as a more top-down approach, the basic goal of this more bottoms-up approach to realizing SoSs is to acquire better overall capability with no additional *overall* expenditure of resources.[4]

3. The SoSE Context

Figure 1 illustrates some of the key elements of the general SoS acquisition environment and the influences and interactions that are necessary to manage a system-of-systems acquisition effort. Functions are divided into strategic, business, and technical (lowest, most detailed level) levels. Each level represents a set of efforts that span the SoS and requires dedicated and directed activities.

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[3] Adoption of a top-down approach to SoS *acquisition* would likely require significant changes in numerous basic requirements, programming, planning, budgeting, and acquisition, processes.

[4] This may entail a reallocation of costs (or even additional cost) to individual programs in the short-term.

CONTROL

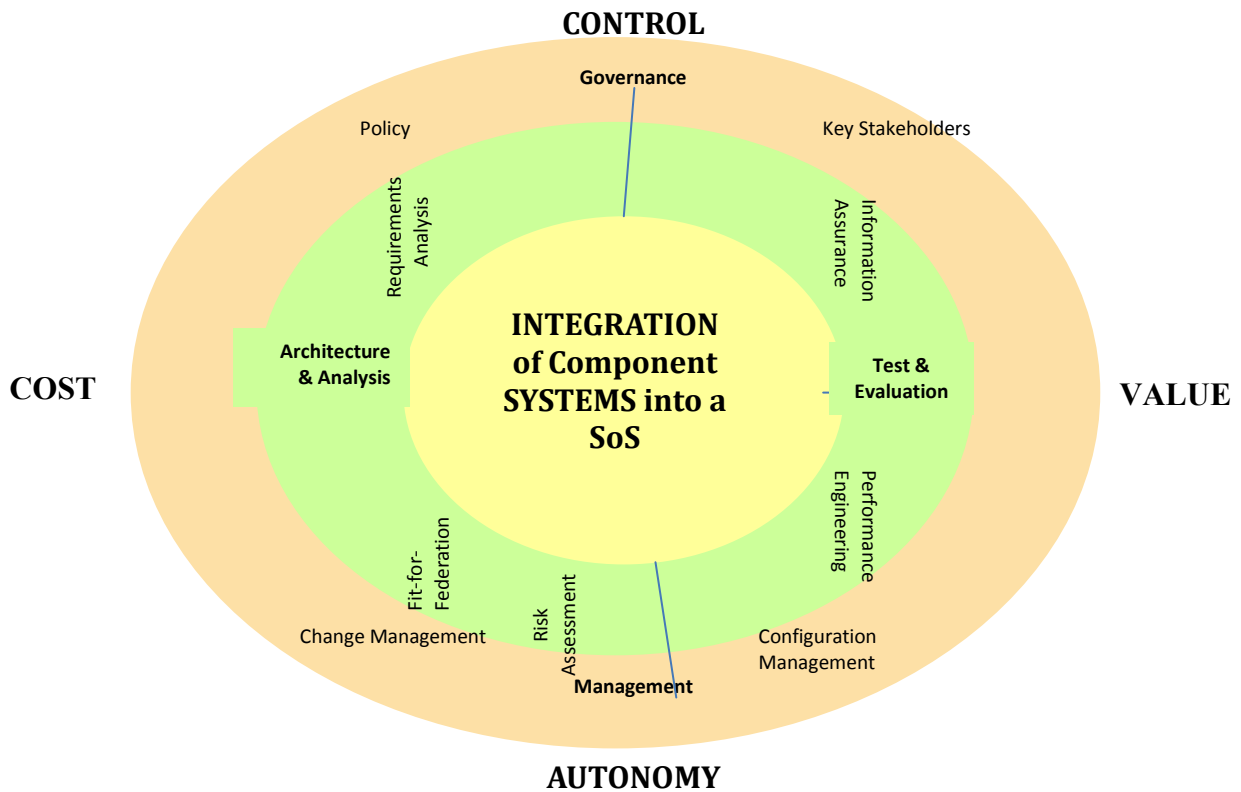Governance

Policy

Key Stakeholders

Requirements Analysis

Information Assurance

Architecture & Analysis

INTEGRATION of Component SYSTEMS into a SoS

Test & Evaluation

COST

VALUE

Performance Engineering

Fit-for-Federation

Risk Assessment

Change Management

Configuration Management

Management

AUTONOMY

At the strategic level, the SoSE vision and objectives are articulated along with a broad architecture that describes the existing state of the SoS and its future evolution. This support the business level decisions (the development of SoS-related strategies and supporting processes). At this highest level, decisions are made that will direct and influence the capabilities deployed, the materiel components of those capabilities, and resources available to support those efforts.

At the business level, specific decisions are made that will ensure implementation of the vision and specific direction is established for system and program implementation. Key strategies and supporting processes are identified and articulated for application at the technical level (as policy, direction, and guidance), where specific programs are targeted and influenced to implement the SoS vision/architecture through the development of system and infrastructure guidance, specific implementation guidance, and implementation plans. Key strategies at this level include acquisition and funding, technology migration and management, continuous evaluation of current systems performance, etc. Each of these strategies is supported by processes aimed at the SoS-level. This paper specifically proposes the following SoSE processes for ESC: Architecture and Analysis, Test and Evaluation, Management and Governance processes.

The lowest level of the context model illustrates how the strategic elements associated with SoSE (and management in general) support the implementation of more focused systems engineering at the system/program level. This direction is necessary to apply the enterprise vision, architecture, strategies and guidance to the building blocks of the SoS via program implementation plans built on a set of requirements extracted from the SoS architecture and capability objectives. Thus, the vision and objectives of the SoS, as articulated in the capability statements and architecture, and expressed in program requirements can be implemented at the system level via a set of engineering process requirements and guidance consistent with the SoS strategies inspired by the vision and objectives.

4. Proposed ESC SoSE Processes

Figure 2 depicts the four primary ESC SoSE processes (Architecture and Analysis, Test and Evaluation, Management, and Governance) within an engineering context that focuses on the integration of component systems into a SoS.

Within the middle concentric circle is the proposed SoSE Architecture and Analysis Process. This process is comprised of the following sub-processes and methods:

- The discovery of system relationships and their inter-dependencies within a SoS. This discovery method has an impact on both the user's experience and the ability to perform a mission.

It is important to understand the underlying component system relationships relative to their general interoperability and to their specialized support for shared global objectives (i.e. net-centricity, cloud computing, service-orientation, cyber-awareness, and efficiency and affordability concerns). More simply stated, there is a need to understand inter-dependencies at a SoS-level, rather than at a system-only-level.

- Assess Fit-for Federation relative to SoS architecture, this method ascertains that the SoS architecture is documented in a way that it is understood as it continues to evolve; and adheres to the rules of related architectures and developing architectures.
- Select Quality Attributes for SoS architectures. This method depends on specific capability objectives and requirements that the component systems of a SoS are designed to meet. Some of the quality attributes for certain systems at ESC pertain to interoperability, performance and information assurance.
- Requirements Analysis. This sub-process provides solutions to improve the understanding of defined system and functional requirements, as well as the relationships between requirements. Examples of areas for SoS requirements analysis at ESC include requirements beyond those of the individual components systems within a SoS and the aggregation of constituent component systems (within a SoS) requirements.
- Risk Assessment. This sub-process provides the ability to evaluate the specified capabilities and assess the viability (and associated risk) of meeting SoS objectives. The following are examples of the ability to assess risk at ESC in regards to SoS engineering context:
  - o Performance risk assessment
  - o Information Assurance risk assessment
  - o Architecture risk assessment

The middle concentric circle also contains the proposed SoSE Test and Evaluation Process. This process is comprised of the following sub-processes and methods:

- Certify and Accredit Information Assurance Controls. This sub-process provides the ability to understand impacts of Certification and Accreditation (C&A) process of component systems of a SoS and their information assurance controls. There is a need to provide a method that shows the ability to understand the vulnerability impact on a SoS via both exposure and threats.

- Performance Engineering. This sub-process provides the ability to establish a performance baseline for the component systems within a SoS. This satisfies SoS user capability needs, while balancing the needs of the component systems within the SoS. This is accomplished by evaluating performance engineering attributes (i.e. availability, response time, throughput and latency). A performance engineering step within this sub-process provides for the ability to establish performance metrics (i.e. Measures of Effectiveness (MOEs) and Measures of Performance (MOPs)). There needs to be a method to establish a testable set of criteria for these performance metrics within the SoS.

Within the outer concentric circle is the proposed SoSE Management Process. This process is comprised of the following sub-processes and methods:

- Change Management. This sub-process provides the ability to address/direct possible changes to SoS component systems and the design of these systems via a flexible process. Examples of these possible changes at ESC include: functionality requirements, capability objectives, performance thresholds, and external interfaces. A critical step within the change management sub-process provides for the ability to address/direct possible changes in SoS architecture.
- Configuration Management. This sub-process provides the ability to identify component systems configurations within a SoS that maintains product information. A step within the configuration management sub-process provides the ability to address specific component dependencies (versioning) and the enumeration of inter-dependencies. Another step in the configuration management sub-process provides for the ability to map high-level requirements and functionality to SoS configuration(s). Configuration management provides a means to link to lifecycle events from concept development through operations and sustainment.

Within the outer concentric circle is the proposed SoSE Governance Process. This process is comprised of the following sub-processes:

- Engage Key Stakeholders. This sub-process provides the ability to mediate differences between stakeholders. Key stakeholders provide the ability to improve communications across authoritative bodies and processes at ESC. Examples of some of these communications at ESC may take the form of SoSE Governance Agreements (i.e. Operational and Service Level

Agreements and Interface Control Agreements). This specifically deals with roles and responsibilities and decisions to be made by key stakeholders with regard to the engineering of a SoS. Key stakeholders have the ability to adapt ESC acquisition culture to accept the co-dependence of systems in an environment of asynchronous lifecycles and competing stakeholders.

- Establish Policy and Direction. This sub-process provides for the ability to create a governance construct to both identify what SoSs to engineer and to approve SoS engineering artifacts. Some ESC-specific examples include:
  - ESC Chief Architect's Office architecture assessment process
  - Link approval of SoS engineering artifacts to enterprise technical guidance (i.e. Engineering Baseline (EB)[5] or to Net-Centric Enterprise Solutions for Interoperability (NESI)[6])

Because the authorities and processes change from time to time and SoS acquisition authority is often unclear, SoSE governance must be both resilient and flexible. A SoS also often spans more than one acquisition organization. All of this makes the SoSE governance process significantly dependent on the SoSE architecture.

There is a need to engage stakeholders within the proposed SoSE governance process. One way is to have forums and working groups that are established based on mutuality of interests, issues, concerns and specific missions to fulfill.

In the white space outside the outer concentric circle, there are opposing factors that apply in a push-pull manner to everything within the three concentric circles. *Cost* and *value* are opposing factors that can be influenced by stakeholders as a means for mitigating cost, schedule and performance risks. A*utonomy* and *control* are opposing factors that represent the natural tension between program managers who want minimal complicating dependencies and other stakeholders who seek control in directing the form of the solution.

5. Actions Needed

The proposed ESC SoSE Strategy and associated processes must be socialized amongst and then approved by key stakeholders.

6. Products Needed

The following ESC-specific products are needed that will affect the desired outcome of the proposed SoSE Strategy:

1. SoSE Strategy and Processes
2. SoSE Policy Statement
3. SoSE Strategy and Processes Training Materials
4. SoSE Strategy and Processes Assessment Mechanisms and Methods
5. SOSE Strategy Implementation Plan

These products should be integrated into and aligned with relevant existing products in areas such as enterprise technical architecture, technology adoption, and systems engineering process assessment.

7. Future Challenges

The proposed ESC SoSE strategy assumes that the bulk of the responsibility for delivering integrated solutions rests on the shoulders of the engineering community – that is, that there is minimal effort to explicitly *acquire* SoSs. Some adaptation of this strategy may be needed should major changes occur that implement a more top-down approach to the acquisition of SoSs.

A different challenge would be determining how to address adaptable architectures, in which systems and SoSs and their components are fitted together like '*Lego blocks*' for expedient purposes that were never the original intent of their individual system design. These SoSs might take advantage of Cloud Computing or Smart Grid infrastructures.

Yet another challenge for the SoSE Strategy to overcome in the future would be how to provide federated architectures at different lifecycle stages, which would follow along with the 'fit-for-federation' thinking. This set of federated architectures could be used to identify capability gaps and identify the '*to-be*' architecture states that will be used by both programs and pre-program initiatives to deliver appropriate capabilities. This could also be addressed from the perspective of how SoS(s) relate to one another

8. Conclusion

SoSE and traditional systems engineering represent aspects of a larger engineering spectrum that spans from component engineering to enterprise engineering. These two domains share a common boundary that must be

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[5] ESC Engineering Baseline (EB) – version 2.1 January 2011 http://herbb.hanscom.af.mil/eb%5CJan2011_ESC_EB_Tech_Guidance_v2_1_1(Public).pdf

[6] Net-Centric Enterprise Solutions for Interoperability (NESI) - version 3.2, Jan 2011 http://nesipublic.spawar.navy.mil/

articulated to ensure that enterprise capability needs are understood and deployed in an integrated and interoperable manner. History has shown the difficulty in achieving this vision via independently developed and deployed "*systems*" built and maintained to a unique set of requirements (rather than a common capability need). Though the design and deployment of systems (in the broader context of delivering a capability) will remain necessary – as will the traditional systems engineering processes that power it – integrated SoS solutions require a set of unifying strategies and supporting processes to ensure the complex capabilities needed by today's War-fighter can be delivered.

There are a variety of different actions and products needed for this SoSE Strategy to be executed and implemented successfully. Also, there are key stakeholder decisions to be made. There are future challenges for the SoSE Strategy. Lastly, the implications that stem from this proposed SoSE Strategy must be considered; that there is a need to work an individual program from the standpoint of knowing that it has to be woven into a larger system, not necessarily that it will be comprised of other constituent parts.

Acknowledgements

References

[1] *AFI 10-601, Operational Capability Requirements Development*, July 2010

[2] Department of Defense, *Systems Engineering Guide for System of Systems,* version 1.0. 2008.

[3] *ESC Engineering Baseline (EB)* - Version 2.1, Jan 2011

[4*] Net-Centric Enterprise Solutions for Interoperability (NESI)* - Version 3.2, Jan 2011

[5] *Net-Centric, Enterprise-Wide System-of-Systems Engineering and the Global Information Grid* – Dr. Jeremy Kaplan – DISA Chair and Professor Industrial College of the Armed Forces – May 4, 2006