SYM-AM-19-054

PROCEEDINGS
OF THE
SIXTEENTH ANNUAL ACQUISITION RESEARCH SYMPOSIUM

WEDNESDAY SESSIONS
VOLUME I

Acquisition Research:
Creating Synergy for Informed Change

May 8–9, 2019

Published: April 30, 2019

Approved for public release; distribution is unlimited.

Prepared for the Naval Postgraduate School, Monterey, CA 93943.

Lead Systems Integration: A Key Enabler for System of Systems Engineering and Integration

Ronald R. 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. He joined the NPS SE department nine years ago. He has a Master of Philosophy from Stevens Institute of Technology, 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. [rrcarlso@nps.edu]

Warren Vaneman—has more than 32 years of leadership and systems engineering experience from various positions within the intelligence community, including as Chief Architect of the Enterprise Ground Architecture at the National Reconnaissance Office. He is also a Retired Navy Reserve Captain. He has a BS from the State University of New York Maritime College, an MS in systems engineering and PhD in industrial and systems engineering from Virginia Tech, and a Joint Professional Military Education Phase 1 Certificate from the Naval War College. The International Council on Systems Engineering (INCOSE) certifies him as a Certified Systems Engineering Professional (CSEP). [wvaneman@nps.edu]

Abstract

Lead Systems Integration (LSI) is an acquisition strategy that employs a series of methods, practices, and principles to increase the span of both management and engineering acquisition authority and control to acquire a System of Systems (SoS) or highly complex systems. LSI is effectively a "marriage" of program management and multiple functional disciplines which must work together cooperatively to assert and execute trade space in the SoS given multiple constituent system acquisitions. To successfully plan, develop, and manage an SoS, a comprehensive development, acquisition, and implementation strategy is required. Our previous research defined the LSI Enterprise Framework as a means to engineer and manage the capabilities and interdependencies of an SoS, that can be executed by the government LSI, across multiple systems, programs, and stakeholder levels. This paper highlights the results from our Fiscal Year 2018 Acquisition Research Program effort. It discusses the integration of the LSI with other processes, used by Navy System Commands (SYSCOMs), to engineer and manage SoS, and provides a blueprint for a more complete governance approach.

Introduction

> *We need … to seek creative solutions to today's and tomorrow's complex problems. … We need to change where it makes sense, adapt as quickly as possible, and constantly innovate to stay ahead of our adversaries. Our ability to adapt more quickly than our enemies will be vital to our future success.* —General R.B. Neller, USMC (2016)

To stay ahead of our adversaries, the military must improve the capability of its systems. These systems are becoming increasingly complex, and so has the effort to develop them. To achieve the improved capabilities, gaps/shortfalls in systems are being filled by integrating them with other systems that possess the required capability. Some of these systems are legacy systems, some are new systems, and some are systems still under development. Furthermore, these systems do not just need to be integrated, they need to be interoperable. They need to speak the same language, use the same units, and if more than one system can sense the same things, they need to determine which data is more accurate.

In the early 2000s, a few high visibility government projects were failing. They were strongly criticized because of cost and schedule overruns, and apparent conflicts of interest. There were multiple contributing factors in these failures: SE practices were not adequate to define and manage these complex programs, they were producing unprecedented System of Systems (SoS) with constituent systems that were in various levels of development, and government procurement policies changed in the 1990s. Additionally, the government did not have the necessary visibility into these projects to foresee impending problems because contractors were performing the design and integration work. These contracted systems integrators often re-allocated resources or funding between disparate programs/program offices or even chose which programs (or contractors) would be used. This led to numerous potential conflicts of interest as well as a loss of control and oversight by the government.

The acquisition and management of mission capabilities across the SoS lifecycle require the complex integration of interdependent new and legacy systems from the lowest component level to the highest enterprise level. The challenge of integrating these disparate constituent systems into an SoS is that they are developed and procured asynchronously, usually by different program offices, and often across different enterprises.

Heretofore, Navy System Commands (SYSCOMs) have been using different approaches to address SoS issues. The two most prevelant approaches are Lead Systems Integration (LSI) and Navy Integration and Interoperability (I&I). LSI is an acquisition strategy that employs a series of methods, practices, and principles to increase the span of both management and engineering acquisition authority and control to acquire an SoS or highly complex systems. The Navy I&I provides an SoS and governance process to identify gaps in Naval missions and to develop and coordinate solutions across system boundaries. Navy I&I provides a more detailed strategy than LSI, but is focused primarily on the early phases of the SoS lifecycle. LSI is more broadly defined, but lacks the details sufficient for an implementation strategy that can be used across the SoS lifecycle. Each of these processes provide clarity to a portion of the challenges faced by government personnel conducting complex SoS integration. However, none stands alone as a prescriptive document to enable the full spectrum of activities required to engineer and manage an SoS.

Both LSI and Navy I&I have a common foundation: the System of Systems Engineering and Integration (SoSE&I) "Vee." The SoSE&I "Vee" provides a model of the high-level activities that need to be performed in engineering and management throughout the SoS lifecycle, but fails to provide implementation guidance, and equally important, it doesn't suggest who performs these activities. Neither LSI or Navy I&I address the full spectrum of the problem. However, LSI provides the broadest framework to address the SoSE&I "Vee." Given that the LSI Enterprise Framework offers the broadest perspective, further defining and enhancing, LSI activities using the SoSE&I "Vee" as the foundation, was used as the premise of this research.

This paper highlights the results from our Fiscal Year 2018 Acquisition Research Program effort. It discusses the integration of the LSI and I&I processes with the SoSE&I "Vee," and establishes the foundation that provides a blueprint for a more complete SoS governance approach. The revised process model includes inputs, outputs, and guiding principles of each phase to yield an implementable solution that can be employed throughout the SoS lifecycle.

Existing System of Systems Processes

This research considered the two previously mentioned strategies in relation to the SoSE&I "Vee" to address the Navy's overall problem with LSI. Systems and SoS are becoming more complex, and emerging threats are proving themselves to be more pressing. As a result, a critical need for integrated and interconnected systems has emerged. The implementation of SoSE&I using LSI techniques must be developed to adequately influence the ever-increasing complexity of the national defense enterprise.

System of Systems Engineering and Integration "Vee"

Essential to the understanding of this research is an understanding of the SoSE&I "Vee." An SoS is "a set or arrangement of systems that results when independent and task-oriented systems are integrated into a larger system that delivers unique capabilities" (Vaneman & Budka, 2013, p. 2). Further defining an SoS is the attribute where the whole is greater than the sum of its parts (Office of the Deputy Under Secretary of Defense (Acquisition and Technology), Systems and Software Engineering [ODUSD(A&T)SSE], 2008). SoSE&I incorporates the basic tenants of SE within the SoS framework and results in "planning, analyzing, organizing, and integrating the capabilities of a mix of existing and new constituent systems into an SoS capability greater than the sum of the capabilities of the constituent systems" (Vaneman, 2016). SoSE&I thus becomes the framework of choice for solving tomorrow's problems as they relate to pressing and emerging threats to the United States. The SoS approach to national defense provides the structure to develop new capabilities through the integration of new and constituent systems. A common foundation for delivering these complex systems is captured in the SoSE&I "Vee," which has built upon the traditional SE "Vee."

The SoSE&I "Vee" is depicted in Figure 1 (Vaneman, 2016). This high-level depiction of the SoSE&I "Vee" provides useful context in using the overall SoS architecture for performing top-down engineering (as in traditional SE) and performing bottom-up verification and validation.

The SoSE&I "Vee" begins at the upper-left side with SoS Architecture & Requirements Development. In this phase, the user needs are defined and transformed into technical requirements that can be executed by the system program office (Vaneman, 2016). The purpose of Architecture and Requirements Development is not only to understand the overall mission needs and establish the boundary of the SoS of interest, but also to uncover the requirements for the individual constituent systems needed to achieve the mission capabilities, their respective interfaces, and to manage and implement SoSE&I processes. It is equally important to develop a comprehensive plan to align systems that are meant to work together for mission success, provide a foundation from which resources can be prioritized to maximize user needs and budget issues, and establish an overarching requirements baseline to improve integration and interoperability across the SoS (Vaneman, 2017).

The bottom of the SoSE&I "Vee" represents the systems engineering activities that are performed by the program offices of the constituent systems. Several individual system SE "Vees" are depicted to illustrate that many constituent systems are developed and managed concurrently, with each system at different maturity levels within its own lifecycle. In this phase, the focus is on the development, sustainment, and management of individual systems (Vaneman, 2016).

The upper-right side of the SoSE&I "Vee" represents the SoS Mission Assurance activities. Mission Assurance is defined as "the part of systems engineering and integration activities which, by means of a combination of design validation, product verification, and systems test, provides the systems engineers, design team, and customer with a high degree of confidence in the successful execution of the required system functions" (Guarro, 2007, p. 14). More plainly, as one moves along the right side of the SoSE&I "Vee," the Mission Assurance process ensures SoS success is documented in the context of mission success from the integration of systems to the operations and sustainment of the SoS. If individual systems meet their individual requirements but SoS interoperability and certification are not achieved, a reassessment of the requirements that were flowed down to the constituent systems is required to be performed in order to ensure individual capabilities combine to provide a more useful SoS capability. Similarly, if the SoS performs adequately but is unsupportable or unsustainable, its requirements will need to be reassessed. Another critical step in this process is the integration of the SoS's constituent systems.

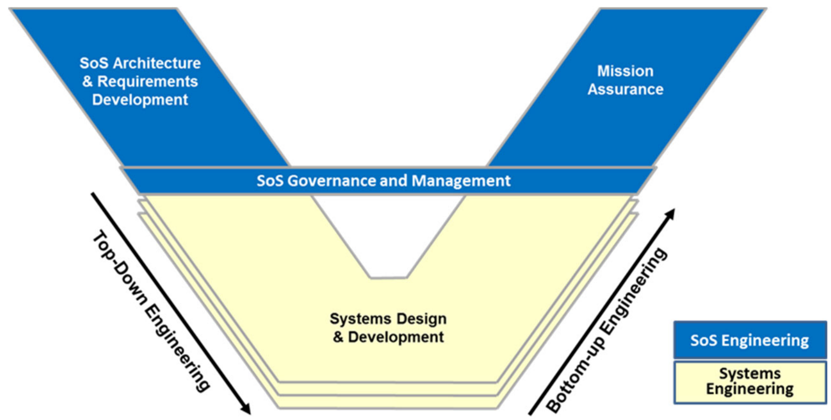

Figure 1. The SoSE&I "Vee"

The final component of the SoSE&I "Vee" is SoS Governance and Management. While not formally described as a process, Governance and Management is a cornerstone of an effective SoS and is comprised of the set of rules, policies, and decision-making criteria that will guide the SoS team to achieve its goals and objectives (Vaneman, 2016). As the complexity of modern SoS increases, the multitude of technical and managerial activities involved become more entangled. As a result, a strong SoS governance and management approach is imperative to address complex emergent issues and those directly related to the triple constraint of cost, schedule, and performance.

The Lead Systems Integration Enterprise Framework

As stated earlier, Lead Systems Integration is an acquisition strategy that employs a series of methods, practices, and principles to increase the span of both management and engineering acquisition authority and control to acquire an SoS or highly complex systems. The LSI function is to assert and execute SoS and stakeholder trade space to affordably optimize integrated mission capabilities across the SoS lifecycle (NPS LSI Cohort #1, 2014). The roles of the LSI are similar to the roles of any systems engineer or system integrator within a program office. The primary difference is the span of LSI design and integration authority that persists throughout the SoS lifecycle (Vaneman & Carlson, 2017).

The LSI Enterprise Framework defines a means to engineer and manage the capabilities and interdependencies of an SoS that can be executed by the government LSI, across multiple systems, programs, and stakeholder levels. The LSI Enterprise Framework (hereafter known as the LSI Framework) captures the complex, interdependent, and mission capability areas through four enterprise levels to characterize the systems from the enterprise to the component level (NPS LSI Cohort #2, 2015; Vaneman & Carlson, 2017). Figure 2 (NPS LSI Cohort #2, 2015) depicts the LSI Enterprise Framework. This framework allows for the alignment of key LSI activities across the enterprise by aligning appropriate touchpoints to the various LSI levels and tasks.

The foundation of the LSI Framework are the four LSI levels. The Enterprise Level is the top layer of the LSI Framework that consists of a variety of stakeholders, from one or many organizations that represent the complex, socio-technical systems that comprises interdependent resources of people, information, and systems that must interact with each other and their environments to achieve mission success (Giachetti, 2010). It is at this level where the capabilities required to achieve enterprise mission success are defined, decomposed into mission capabilities, and allocated to the SoS level to be satisfied as mission capabilities (Vaneman & Carlson, 2018). While the majority of the LSI engineering and management activities occur below the enterprise level, this level is important because this is where organizational, policy, and resource decisions are made for the LSI (Vaneman & Carlson, 2018).

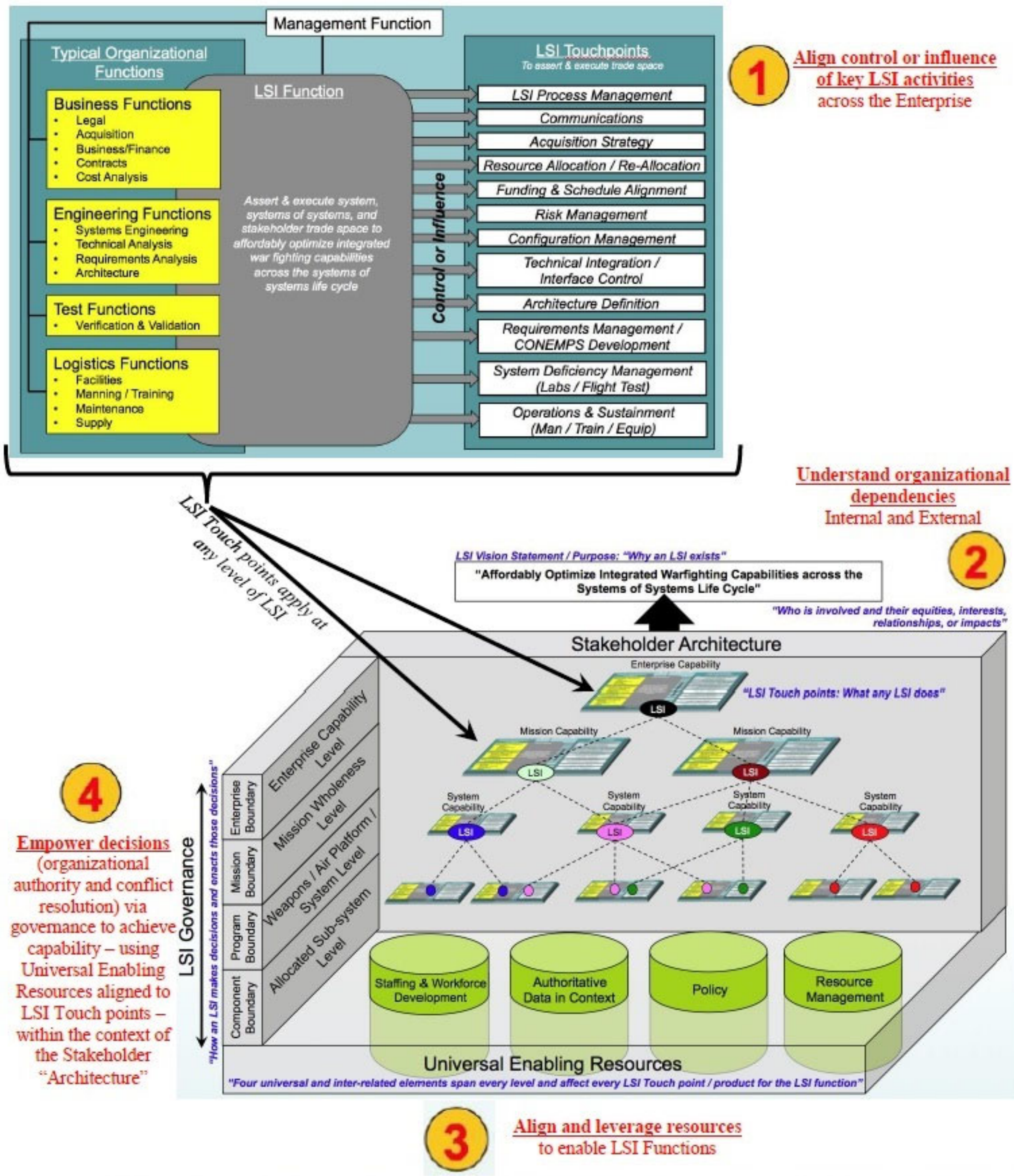

Figure 2. Lead System Integration Enterprise Framework

The Mission Wholeness Level is where a collection of supporting constituent systems and programs are brought together to support end-to-end capability effectiveness for the designated mission areas. Accomplishing a mission that cannot be satisfied by a single system alone has always been an SoS endeavor, but integrating the multiple systems together has frequently been left to small communities consisting of a few systems or the operators themselves (Department of the Navy, 2013). Many LSI governing efforts, at the System of Systems Level, involve a collaborative partnership of multiple program offices, versus a more directive effort that may occur at lower program levels (NPS LSI Cohort #1, 2015). Individual capabilities and functions are allocated to constituent systems for implementation (Vaneman & Carlson, 2018).

The System Level is where a combination of functionally related physical elements are integrated into a usable, system to achieve the system capability. In this level, the emphasis is on traditional systems engineering and development activities. However, two significant roles are important to the LSI. First, the LSI must ensure that the SoS level organization has sufficient insight into the individual programs within the SoS to understand the functionality and interoperability that will result from the engineering and design effort. Second, the LSI must ensure a strong governance model is in place that provides the technical authority to govern system baselines so that the system delivered for integration into an SoS meets the requirements that were allocated to it (Vaneman, 2016). In addition to the LSI's role in ensuring system integration to an SoS, an LSI may be used for the engineering and development of a complex system, where the system is composed of major sub-systems, and a large number of interacting components (Vaneman & Carlson, 2018).

The lowest level of the LSI Framework is the subsystem/component level. This level consists of the allocated sub-systems and components that by themselves may, or may not, provide a usable standalone end product. These are the lowest level building blocks required for any LSI effort and may be managed by a team in a larger program office, or may be managed separately by sub-system program offices (NPS LSI Cohort #2, 2015; Vaneman & Carlson, 2018).

Given the breadth of an SoS acquisition effort and recognizing that an LSI's resources to manage an effort are limited, an LSI must be able to efficiently focus on the highest payoff "touchpoints" of control or influence to assert and execute trade space—aligned across the enterprise—to enable organizational agility. Although previous research has discussed inherently governmental functions for an LSI at a high level, there has been unclear specific applicability to current program processes and organizations—and some definitions also did not fully account for multidisciplinary functions that extend beyond systems engineering (NPS LSI Cohort #2, 2015; Vaneman & Carlson, 2017).

The LSI Framework defines 12 key touchpoints (shown in Figure 2) that apply across all domains as the essential "high payoff" functions and activities. These LSI touchpoints are the functions that assert and execute SoS, complex system, and stakeholder trade space to affordably optimize integrated war fighting capabilities across the system of systems lifecycle. These touchpoints do not necessarily define new processes, but do identify how existing processes can be enhanced and used more efficiently (NPS LSI Cohort #2, 2015). For a detailed discussion of the LSI touchpoint see Vaneman and Carlson (2017).

Universal enabling resources—staffing and workforce development, policies, resource management, and the authoritative data context—are those resources that support LSI-unique execution at any of the touchpoints to assert and execute the trade space. These four enabling resources and inter-related enablers apply at all levels in the LSI Enterprise Framework, and are outside the responsibilities of the typical program offices.

However, the LSI must be aware of these activities, and navigate within them (Carlson & Vaneman, 2018).

Finally, governance empowers decisions across the enterprise by providing a set of decision-making criteria, policies, processes, and actions that guide the stakeholder architecture to achieve the enterprise goals and objectives (Vaneman & Carlson, 2018).

Navy Integration and Interoperability

Navy Integration and Interoperability (I&I) provides SoS and governance processes to identify gaps in naval missions, and to develop and coordinate solutions across system boundaries. To identify the mission gaps, system interaction and behaviors are derived from an enterprise view of naval operational environments and mission objectives (Department of the Navy, 2016). Navy I&I is an important concept to this LSI research because I&I provides detailed processes in the SoS Architecture and Requirements phase of the SoSE&I "Vee" whereas the LSI Framework provides a general overview of the needed processes. These processes together largely focus on the Mission Engineering "Vee," which is very similar to the SoSE&I "Vee," and they can easily be extrapolated to SoSE&I. This Integrated Capability Framework (ICF) is shown in Figure 3 (Vaneman & Carlson, 2018).

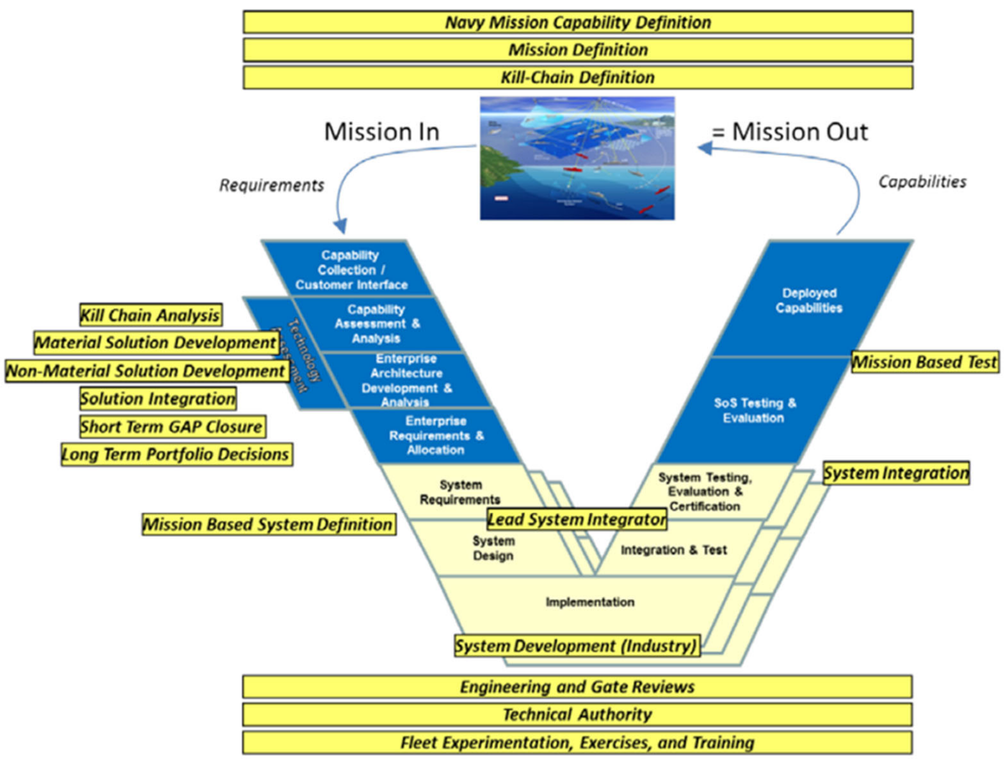

Figure 3. Integrated Capability Framework Use Cases Applied to the SoSE&I "Vee"

The I&I process begins with a Warfare Capability Baseline (WCB) assessment which "uses the concept of a kill chain to organize, or model, the functions performed in the execution of a mission" (Department of the Navy, 2016, p. 12). The goal of the I&I process is to accomplish four distinct tasks: (i) address materiel gaps identified by the WCB; (ii) build mission-based architectures as a basis for system acquisition; (iii) use I&I decisions as a driver to SE reviews and gate processes; and (iv) share mission related information across Systems Commands (SYSCOMs).

As it relates to the SoSE&I "Vee," the first step in the I&I process is the definition of the mission needs and requirements. The significance of this important first step is that it establishes the needs for system development of the constituent systems within the SoS. The mission needs and requirements serve as the primary input to the SoS Architecture and Requirements Development portion of the SoSE&I "Vee," and provide a constant reference for technological progress checks.

Following Mission Definition, I&I establishes the SoS interfaces involved based on the required mission parameters, requirements, and capabilities. This accounts for organizational relationships and helps to define SoS capabilities and needs. The common framework provided by I&I seeks to "facilitate enterprise level engineering across the SYSCOMs and enables efficient system integration and effective force interoperability" (Department of the Navy, 2016, p. 5). This helps lay the ground work needed for individual system design and development.

As can be seen in the ICF, the I&I process is intended to support the warfighter through a mission-based focus on SE, support to the acquisition process by identifying consistent requirements for the SoS early in the process and assisting with analysis efforts through a common I&I repository. Though the I&I process is intended to span the Mission Engineering "Vee" (or SoSE&I "Vee"), it is largely focused on requirements and interface definition and does not provide much SoSE&I detail. As such, the process does not stand on its own.

Use of the ICF enables consistent and more complete definition of Naval warfighter needs, and ensures that all stakeholders from initial concept to test and training understand what the definition of success is for any new or upgraded system. Additionally, training and testing efforts can use the same missions defined in the front end to perform the operational tests and training exercises, ensuring that the systems and sailors are tested and trained in accordance with planned missions. Use of Fleet-defined operational requirements, captured through ICF Mission Models, helps system and platform requirement definition and design, providing a validated and complete mission context including planned operational use during system development. The mission definition also provides system and platform owners with a thorough set of interoperability requirements and ensures existing capabilities are not duplicated. Finally, when completed with operational and system/platform measures tied to mission desired effects, the ICF enables analysis of I&I issues and mission gaps, and the tracking of closure for each one within the SoS (Department of the Navy, 2016).

The Evolution of the LSI Enterprise Framework

Evolving the LSI Enterprise Framework From the SoSE&I "Vee" Model

Lead Systems Integration, and Navy I&I, have emerged as the leading strategies to address SoS issues within the Navy. While each strategy offers insights and partial solutions to the challenges posed by the SoS engineering and acquisition environment, neither addresses the problem that spans the entire SoS lifecycle. One of the goals of this research is to expand the LSI concept by defining an implementation strategy that can be used the across the SoS lifecycle phases and organizational boundaries (Carlson & Vaneman, 2018).

As previoulsy stated, the SoSE&I "Vee" can be used as the common denominator or foundation between LSI and Navy I&I. The LSI Framework represents the process, at a high level, so it can be used to better understand, engineer, and manage the SoS. However, it does not provide the necessary detail for operational use. Navy I&I discusses portions of the SoSE&I "Vee," in more detail than is offered by the LSI Framework, and could be used to better define the SoS. However, Navy I&I is mostly concerned with the SoS Architecture and

Requirements Development Phase of the SoSE&I "Vee." Essentially, LSI provides the breadth across the SoSE&I phases, while Navy I&I captures the depth of one of those phases.

The four top level functions of the SoSE&I "Vee" are shown in Figure 1. These four functions can be decomposed further to provide additional, actionable detail. The SoSE&I "Vee" model does not include the inputs and outputs for each function, the rules and policies governing the activities, or the skills needed to perform those activities. These elements are needed to fully develop an LSI implementation strategy.

To better understand the SoSE&I functions, each were analyzed for inputs, outputs, controls, and position descriptions. Using the Integrated Definition Function Model (IDEF0), the SoSE&I functions can be expanded to incorporate both the LSI and Navy I&I processes. Figure 4 shows a generic depiction of the IDEF0 model. The functional activities (shown in the box) are represented by the SoSE&I functional activities. The inputs (entering from the left) and outputs (exiting from the right) are represented by the inputs to, and outputs from, each SoSE&I functional activity. The controls (entering from the top) are represented by acquisition policies, the LSI touchpoints, and guidance elements defined in the Navy I&I ICF. The mechanisms (entering from the bottom) represent the SoS acquisition position descriptions (knowledge, skills, and abilities) needed to perform the functional activities (Carlson & Vaneman, 2018).

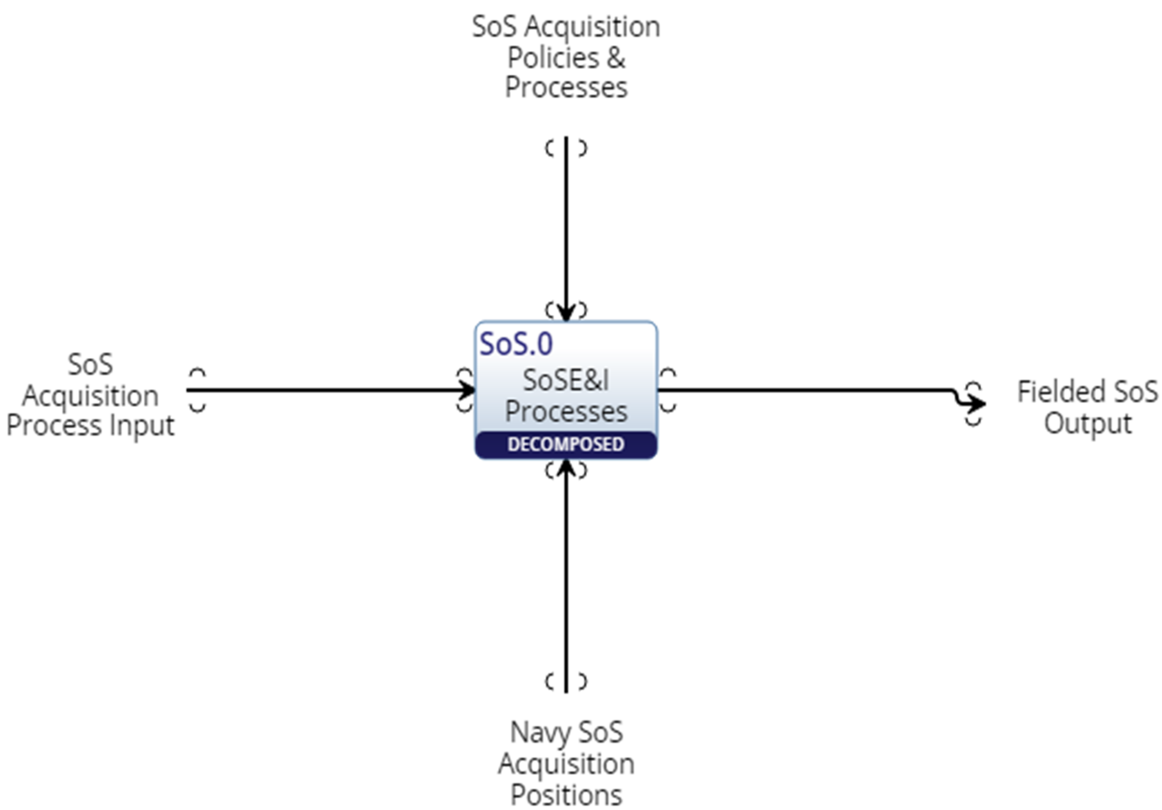

Figure 4. SoSE&I IDEF0 (Level 0) Model

Using the IDEF0 construct, the Navy I&I and LSI processes were analyzed to determine how they may further govern the SoSE&I functions. Figure 5 (Carlson &

Vaneman, 2018) shows the SoSE&I “Vee” as an IDEF0 model. The model illustrates the interdependencies throughout the entire process flow from initial requirements through support of the fielded systems. The correlation between the LSI and I&I processes, embedded on the SoSE&I “Vee,” provides the blueprint for a more complete SoS governance approach with a more executable set of guidelines and should result in an enhanced mission-based SoS development and LSI management effort.

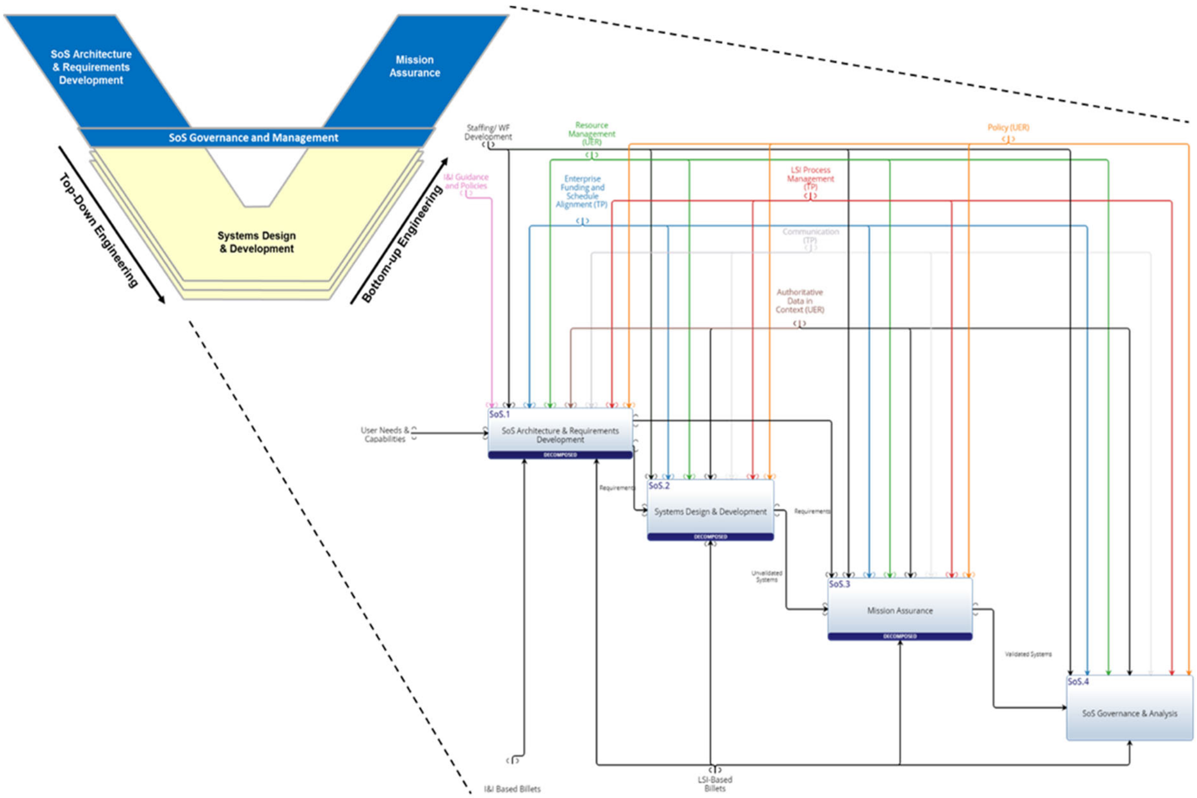

Figure 5. Expanding the SoSE&I “Vee” to an IDEF0 Model

Carlson and Vaneman (2018) further define each of the SoSE&I functions, into subsequent IDEF0 views, to the next level of decomposition. The basis of this further defintion is the decomposed SoSE&I “Vee” model (Vaneman & Budka, 2013; Vaneman, 2016). The entire decomposition of the SoSE&I “Vee,” and subsequesnt development of the corresponding IDEF0 views is beyond the scope of this paper.

For illustration purposes, the decomposition of the SoS Architecture and Requirements Development function is discussed next. (The interested reader can find details of these decomposed SoSE&I functions in Vaneman and Budka, 2013; Vaneman, 2016; and Carlson and Vaneman, 2018.)

SoS Architecture and Requirements Development

The SoSE&I “Vee” begins at the upper-left side with SoS Architecture & Requirements Development. In this phase the user needs are defined, and then transformed into technical requirements that can be executed by the system program office (Vaneman, 2016). The purpose of Architecture and Requirements Development is not only to understand the overall mission needs, and establish the boundary of the SoS of interest, but also to uncover the requirements for the individual constituent systems needed to achieve the mission capabilities, their respective interfaces, and to manage and implement SoSE&I processes. It is equally important to develop a comprehensive plan to align systems that are meant to work together for mission success, provide a foundation from which resources can be prioritized to maximize user needs and budget issues, and establish an overarching requirements baseline to improve integration and interoperability across the SoS (Vaneman, 2017).

The decomposition of the SoS Architecture and Requirements Development stage, as depicted in Figure 6 (Vaneman & Carslon, 2018), relies heavily on existing I&I and LSI processes to provide the guiding principles, or controls. When depicted in this fashion it is clear that neither the existing I&I processes nor LSI Touchpoints covered the entirety of this phase. However, once combined, a more complete process begins to emerge.

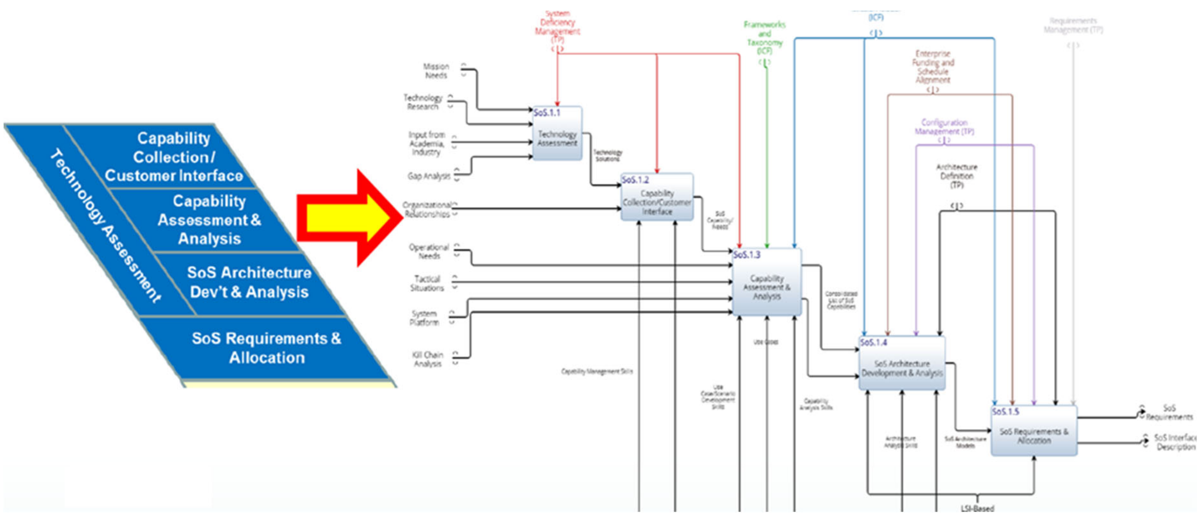

Figure 6. SoS Architecture and Requirements Development Phase

Conclusion

Lead Systems Integration seeks to reduce risk in the affordable optimization of integrated warfighting capability acquisition efforts across the SoS lifecycle, and to increase the speed of capability delivery to the warfighter. It can be executed within existing organizations via enhancements to legacy processes, methods, and practices if the workforce is trained and motivated to think and act differently. The LSI Enterprise Framework provides an effective set of tools, resources, and concepts to help incrementally incentivize this cultural evolution.

To achieve this goal, the Navy should increase systems engineering and SoSE&I technical and management depth and breadth across the workforce by hiring professionals trained in advanced systems engineering concepts. Additionally, the adoption of a directed universal approach to SoS management, such as that presented in this report, should be implemented across the Navy Enterprise in order for LSI to be truly successful. Not only are well-trained personnel required to ensure success, but top-down directed guidance that is common to all Naval Systems Commands for LSI in SoS will enable this approach.

Additionally, a directed universal approach to SoS management, such as that presented in this report, should be implemented and enforced across the Navy Enterprise in order for LSI to be truly successful. Not only are well-trained personnel required to ensure success, but top-down directed guidance that is common to all naval SYSCOMs for LSI in SoS will enable this approach.

References

Carlson, R., & Vaneman, W. K. (2018). Managing complex systems engineering and acquisition through lead systems integration. In *Proceedings of the 15th Annual Acquisition Research Symposium*. Retrieved from http://www.researchsymposium.org

Department of the Navy. (2013). *Naval system of systems engineering guidebook*. Washington, DC: Author.

Department of the Navy. (2016, February 22). *Navy integration and interoperability (I&I) integrated capability framework (ICF) operational concept document (Version 3.2)*. Unpublished document.

Giachetti, R. (2010). *Design of enterprise systems*. Boca Raton, FL: CRC Press.

Guarro, S. (2007, Fall). The mission assurance guide: System validation and verification achieve success. *Crosslink, 8*(2). Retrieved from http://aerospace.wpengine.netdna-cdn.com/wp-content/uploads/crosslink/V8N2.pdf.

Herdlick, B. (2011). *Establishing an operational context for early system-of-systems engineering activities*. Retrieved from https://ndiastorage.blob.core.usgovcloudapi.net/ndia/2011/system/12968_HerdlickThursday.pdf.

Naval Postgraduate School Lead Systems Integrator (NPS LSI) Cohort #1. (2014, September 25). *The roles of the government-led lead system integrator (LSI).* Unpublished report.

Naval Postgraduate School Lead Systems Integrator (NPS LSI) Cohort #2. (2015, October 2). *An enterprise lead systems integration (LSI) framework*. Unpublished report.

Neller, R. B. (2016). *The Marine Corps operating concept*. Washington, DC: U.S. Marine Corps.

Office of the Deputy Under Secretary of Defense for Acquisition and Technology, Systems and Software Engineering (ODUSD[A&T]SSE). (2008). *Systems engineering guide for systems of systems, Version 1.0.* Washington, DC: Author. Retrieved from https://www.acq.osd.mil/se/docs/se-guide-for-sos.pdf

Vaneman, W. K. (2016). The system of system engineering and integration “Vee” model. In *Proceedings of the 10th Annual IEEE Systems Conference*. IEEE.

Vaneman, W. K., & Budka, R. (2013). Defining a system of systems engineering and integration approach to address the Navy’s information technology technical authority. In *Proceedings of the INCOSE International Symposium*. San Diego, CA: INCOSE.

Vaneman, W. K., & Carlson, R. (2017). Defining an enterprise lead system integration (LSI) framework. In *Proceedings of the 12th Annual System of Systems Engineering Conference*. IEEE.

Vaneman, W. K., & Carlson, R. (2018). *Managing complex systems engineering and acquisition through lead systems integration* (NPA-AM-19-008). Monterey, CA: Naval Postgraduate School, Acquisition Research Program.

ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
NAVAL POSTGRADUATE SCHOOL
555 DYER ROAD, INGERSOLL HALL
MONTEREY, CA 93943

www.acquisitionresearch.net