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Executive Views for System-of-Systems Decision Making

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Authors:
William J. Neal, Ph.D., Hillary L. Richardson

Point of Contact:
William J. Neal, Ph.D.
The MITRE Corporation
7515 Colshire Drive, McLean, VA, 22102
wneal@mitre.org

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William J. Neal, Ph.D., Hillary L. Richardson
The MITRE Corporation

Abstract

Executive Views (EVs) are an emerging framework for command and control (C2) architectures that have shown utility in supporting investment decision making by senior defense leaders. These views provide a novel framework that facilitates collaboration between engineers and decision makers. Engineers traditionally responsible for system and operational views integrate data regarding force structure, platforms, warfighters, transport networks, applications/hardware and manned/unmanned systems in a graphical manner that highlights differences in asset density and distribution for alternative courses of action. Senior decision makers need not have a strong technical background to quickly understand the basis of issue (BOI) and materiel for formations and the impacts on investments, capability gaps, interoperability and portfolio management in today's system-of-systems (SoS). Success has been achieved in EV applications by the U.S. Army and Joint communities, and EVs are becoming a part of institutionalized management processes. Sometimes referred to as "horseblankets", EVs have informed trade studies, and modeling and simulation (M&S) efforts. Experiences by the Army using common data visualization tools and efforts to further automate EV development are discussed.

Traditional Architecture Development

Historians and casual observers of defense information systems will recall many evolutionary paths in design and development approaches. They will remember that over many decades, lessons learned from the multitude of information system developments, were aggregated in efforts by communities of interest. They will remember the consolidation of lessons learned being forged into the formalization and realization of many different methodologies through documented processes and off-the-shelf tools. Primarily, software applications were traditionally the focus of design and development methodologies for information systems. However, information systems also became an integral component of every defense acquisition, from aircraft to armored combat vehicles to small unmanned systems and even to munitions. Additionally, contemporary web-based environments have made the network environment a key consideration in today's information system design and development. Software development and systems engineering methodologies have become common activities for information system developments that are studied and certified academically and professionally. Today, all major information system developments involve the application of some formal methodology and employ a suite of software tools involving notable investment. Department of Defense (DoD) information system developments traditionally employ processes and tools that are similarly used by other federal agencies and commercial entities.

Among the critical processes and tools that have become common in traditional information system developments is architecture. Analogies from home building are often used when discussing the rationale for employing architecture-based approaches in information system developments. However, in the simplest of terms, architecture is principally a means of communication or a basis for common understanding by all parties involved. For building a home, architecture establishes building codes, conveys the home owner's wishes, and documents the contractor's plans. For building a home, architecture is the basis of approval by city planners, architecture provides the plans construction workers use, and architecture is the basis for building inspector approval. Similarly, for traditional building of information systems, architecture establishes technology standards, and architecture conveys both user and designer views for design approval, developments and testing. The DoD Architecture Framework (DoDAF) [see Reference 1] is commonly applied for DoD architecture developments. DoDAF describes specific architecture views and offers processes for constructing architectures as part of overall information system development. DoDAF builds on the successes of commercial and other federal government efforts over the last two decades. DoD 5000 [see Reference 2] and other DoD acquisition policies and guidance directly and indirectly require the development of architectures for acquisition of information systems and all major acquisitions. It is emphasized that traditional DoD architectures were developed for individual information systems. An individual information system is acquired through a single POR having a distinct budget, program manager, and set of formal requirements. Individual information systems almost always interface with other individual information systems, which makes interoperability between loosely coupled or federated information systems a key consideration in design, development and architecture. The resulting architectures are used in the review and approval of design documentation in milestone decisions for programs of record (PORs). Traditional architecture developments for a POR are time consuming and demand substantial resources. They are undertaken as part of the DoD 5000 system, development and demonstration (SDD) phase that is between the B and C milestones. Multiple staff years of work using expensive software toolsets are often required to develop the full set of architecture products for a single POR. Of concern by many is that often times these products are never used beyond Milestone C decisions. Recent activities have been initiated to investigate the value of these architectures and alternatives that might be more beneficial in the long term.

System-of-Systems (SoS) Construct

DoD information system environments have followed commercial trends for several decades. This approach has reduced costs and development times for DoD acquisitions by leveraging commercial technologies, processes, systems and expertise. Commercial trends have led DoD efforts down a path that emphasizes a network based environment. In these environments, coupling between interfaced information systems becomes quite strong. Indeed, new DoD information systems are more interdependent than ever. As a result, systems are often born as members of systems, or a system-of-systems (SoS), rather than as an individual system of a POR. For those who are not familiar with the distinctions of SoS, the concepts may initially seem so subtle as to not deserve significant attention. But, practice has shown that substantial work is needed to work management, technical and operational interfaces, and to refine supporting approaches and methods in a SoS over less complicated individual systems. This trend is epitomized by the mantra “network centric” that was in vogue several years ago. Although DoD terms have changed with leadership, the fundamental technical approach has proven to be successful and enduring.

At roughly the same time as the emergence of DoD pursuits for network based environments, a general shift in DoD acquisition approach arose. A shift towards procuring “capabilities”, rather than “systems”, came about. The Joint Capabilities Integration and Development System (JCIDS) became a DoD policy that emphasized a top-down approach to acquisition, rather than the traditional bottoms-up approach [see Reference 3]. This new capability-based approach actually compliments the acquisition of a SoS. It was found that both require greater hands-on involvement by senior leaders at the department and agency levels than ever before. The technologies and management for DoD information systems was driven away from stovepipes toward a broader centralized view. An unexpected consequence of these reinforcing approaches was the need to explore different management techniques. Management techniques were needed to accommodate a SoS and portfolio of systems. The techniques needed to address problems in cost, schedule and performance for one POR and potential rippling negative impacts on capabilities to be enabled by other PORs.

Tight coupling of technical capabilities in a SoS demands corresponding tight coupling of PORs and their management. Within the DoD as agency budgets grow and shrink, decisions to continue, accelerate and decelerate development and fielding for a POR are made throughout the POR’s lifecycle. DoD decision makers have historically made investment decisions separately for each individual information system, regardless of the interfaces and interoperability among the federation. These DoD decision makers are above the program manager (PM) and program executive officer (PEO) in organization. The decision makers are typically in staffs of the Services (such as Headquarters Department of the Army) or Office of the Secretary of Defense (OSD). The ultimate decision makers depend on POR progress as reported by PMs and PEOs. It is often noted that results of individual decisions for multiple programs are not optimal and it would be better to make decisions on a portfolio of interdependent PORs. This was noted by the Army Science Board in its report on LandWarNet [see Reference 4]. It can be difficult to make the right decisions for a half dozen major acquisitions that are interdependent. The ultimate decision makers are true warfighters who should not be expected to master the technical intricacies of all involved programs. Extreme care must be taken for information system developers to provide the right information and data to the decision makers. Tens of billions of dollars typically hang in the balance to continue, terminate or accelerate a SoS, so decision makers are cautious. It is dependent upon others to provide supporting information with accurate information that is easily consumable. Unfortunately, there is little experience and few lessons learned to prepare senior leaders for SoS decision making. Over the last 3-5 years, attempts by DoD to establish comprehensive portfolio management approaches have not resulted in enduring processes. However, over the last 2-3 years, attempts by DoD to use a novel architecture approach to support portfolio decision making has resulted in enduring processes. The remaining portions of this paper address these experiences.

The obvious question is ‘why can’t traditional management processes support SoS decision making?’ DoD has had in place processes for deliberating the periodic Program of Memorandum (POM) efforts for decades. One might ask why they are not adequate for SoS capabilities. It is found that traditional processes are focused on requirements, cost, schedule and performance of individual PORs. Most importantly, the traditional processes have no mechanisms to factor the relationships, interfaces, interoperability and interdependencies with other PORs or systems. Without such mechanisms, today's processes cannot accommodate the scale and complexity for multiple systems simultaneously. As a result, traditional management processes are unable to determine the relevance, affordability or interoperability for plan capabilities or their alternatives.

The Army recognized the inability of its current processes to extend to meet the scale and complexity of a SoS and the need for a new set of management processes for its SoS environment. The Army, led by the G3 LandWarNet/Battle Command Directorate, embarked on a comprehensive set of formal processes or SoS construct in February 2009 [see Reference 5] that included SoS systems engineering, architecture and 13 others. A Capability Set Management Process was conceived that integrated all of the processes in the SoS construct. In pursuit of a relevant architecture process emerged a specific set of new architecture views known as EVs. EVs were crafted to provide the appropriate information to support decision making for the SoS construct. General officers are found to be able to quickly understand the views and gain an understanding of issues relevant for their participation in information system development. General visualization and office tools have been used to develop the EVs. Efforts have been underway to support EV development with a database infrastructure. Following sections of this paper detail the EV and supporting tools.

Although, other parts of DoD have not adopted this emerging SoS construct, similar approaches are being employed. The Deputy Assistant Secretary of Defense (C3, Space and Spectrum) in the Office of the Assistant Secretary of Defense for Network Information and Integration (ASD(NII)) has been using architecture views for the last several years that have the same form, function and fit as the Army's EVs [see Reference 6]. ASD(NII) has been documenting baseline and planned architecture with this type of architecture. Their products reflect Joint and Service specific SoS and network instantiations. ASD(NII) has imported data from multiple sources, including the Army, to prepare the products. The synergy between the Army and ASD(NII) involving EVs provided the spark for this paper.

SoS Decision Making

The potential significant impact of SoS decision making dictates having them made by senior defense leaders. General and flag officers who are warfighters or have a strong understanding of operational needs and priorities make these decisions. Political appointees with a strong understanding of DoD strategies, policies and business processes make these decisions as well. These leaders do not have mastery over all of the technical nuances of the SoS, and depend on staffs to provide them appropriately distilled information. There are many instances when the ultimate SoS decisions are made by Service Chiefs and Secretaries.

Many different types of decisions are made about the SoS. Decisions include the approval of the configuration of the SoS to be integrated onto types of platforms. Types of platforms include ground combat vehicles, aircraft, spacecraft, soldiers, ships, unmanned systems, and operating centers. Senior leaders may have to decide on the BOI, which is the quantity of platforms in a formation (e.g., expeditionary force, brigade or squad) to be equipped with the SoS. Decision makers must decide on the number of units to be equipped with the SoS in each year. The specific units to be equipped in each year is another decision that must be made. These decisions are structured as investment decisions rather than technical decisions. Until comprehensive SoS processes are put in place, the decisions are formalized as directives for individual PORs. PORs may be continued, accelerated, delayed, restructured or terminated. Senior leaders have come to expect the technical rigor to be documented with architecture. Architecture products are reviewed by staffs before review with decision makers.

Annual POM deliberations and related reviews require SoS decisions. As part of the POM process, specific changes may be made to budgets or directed changes to PORs may come from Congress or the Office of the Secretary of Defense (SECDEF). Similar out of cycle Presidential Budget Reviews occur that demand SoS decisions. A change in defense priorities (e.g., from a Quadrennial Defense Review report) or other SECDEF directive may initiate a SoS decision. For example, an increase in priority for irregular warfare last year increased the need for related capabilities and the SoS supporting Infantry Brigade Combat Teams (IBCTs) received substantially greater quantities of systems at the sacrifice to the SoS supporting Heavy Brigade Combat Teams (HBCTs). SoS decisions have been required to respond to emerging warfighter needs due to theater needs. For example, emerging commercial-off-the-shelf (COTS) and science and technology (S&T) systems have been considered for fielding to Operation Enduring Freedom (OEF) to mitigate SoS shortfalls identified by theater commanders. SoS decisions have been made to mitigate identified cost, schedule and performance problems and risks for one POR that substantially impacts another POR.

Although major SoS decisions are made to support annual processes, such as the POM, minor SoS decisions are also frequently made at ad hoc times as issues and problems arise. For example, SoS decisions are made by senior Army leaders about once a month, although some will argue it averages out to be once a week during times of crisis. Issues requiring SoS decisions are typically raised when officers at the O-6 level cannot resolve them. These officers have the technical expertise in the technologies and systems to offer courses of action and recommendations for escalation to decision makers.

EV Description

Figure 1 is an example EV. Basic information from horseblankets, operational views and system views are combined to create EVs. Horseblankets identify all platforms assigned to formations. As suggested previously, platforms can be many different types of entities including all types of ground vehicles, ships, aircraft, operational centers, dismounted soldiers, unmanned systems, and spacecraft. Formations for a lower echelon unit such as a company may have a hundred or more platforms. Formations for higher echelon units that combine lower echelons such as an expeditionary force will include several thousand platforms. A readable printout of all the platforms in a formation will be large, about the size of a blanket for a horse, hence the name horseblanket. In horseblankets, all platforms are designated by function and role in the formation. Senior leaders are able to quickly scan a horseblanket and easily understand its platforms and relationships to the formation's command and control structure. Information contained in common operational and system views are associated with all platforms. More specifically information normally contained in the Operational Concept (OV-1), Operational Node Connectivity (OV-2), Organization Relationship (OV-4), System Interface Description (SV-1), and System Communications Description (SV-2) is used. The hardware that is integrated into each platform is designated. Designated hardware includes military specific and commercial laptops, servers, and radios; and other major subsystems such as routers and security systems (e.g., High Assurance Internet Protocol Encryptor). Key connections between hardware integrated on a single platform are shown. Major software systems are designated for the hardware on which they run. Waveforms supported by radios are designated. The key difference between traditional horseblankets and EVs is the identification of radio links and networks between platforms. Just as with DoDAF architectures, "as-is" and "to-be" views are developed.

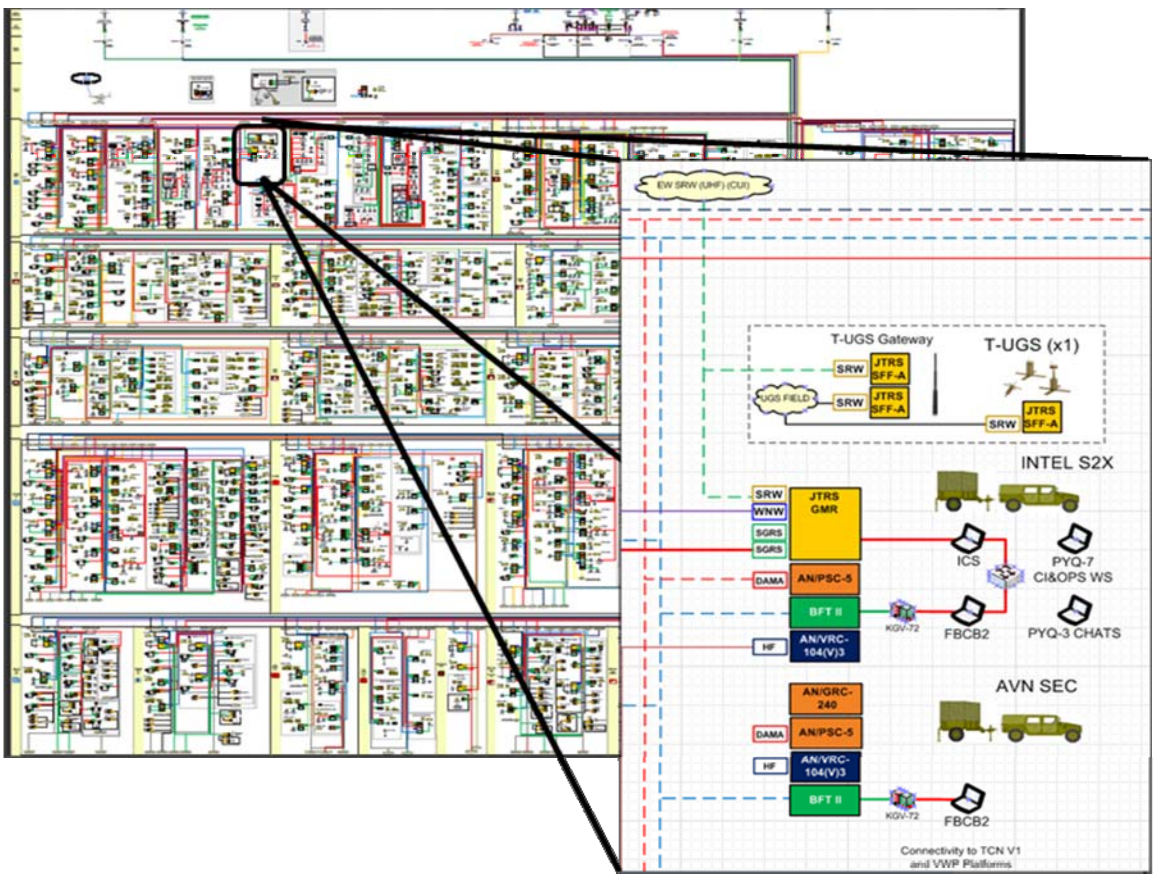

Figure 1: Example EV

The blow-up in Figure 1 shows two ground vehicles of an Army IBCT. The top vehicle includes four computers (i.e., ICS, FBCB2, PYQ-7 and PYQ-3). The FBCB2 and CHATS software are designated for the hardware, and the SRW, WNW, SINCGARS, DAMA, BFT II and HF waveforms are run on the four radios. The dashed lines emanating from the radios identify connections to the formation's networks. A router and an encryption system are also shown to be integrated into this platform. This blow-up provides senior leaders the minimum essential information needed to understand the battle command and networking capabilities for the role (i.e., Intel S2) supported by the platform. Senior leaders have an intuitive feel for the functions conducted with each platform's role. With a basic understanding of the systems, senior leaders can judge the appropriateness of the platform's configuration and connections to the formation's networks. There are over one thousand platforms in the overall EV, which is far too many to inspect without zooming in and out. The overall EV is shown to impress the reader with the scale and complexity of the SoS problem faced by decision makers.

Figure 2 is another EV example. It depicts a possible future Joint aerial transport layer. Just as with the Army IBCT example, air, ground, space and maritime platforms are identified. Radio links between platforms are also seen. Computing hardware and software applications are not identified given the purpose of the EV is to address transport.

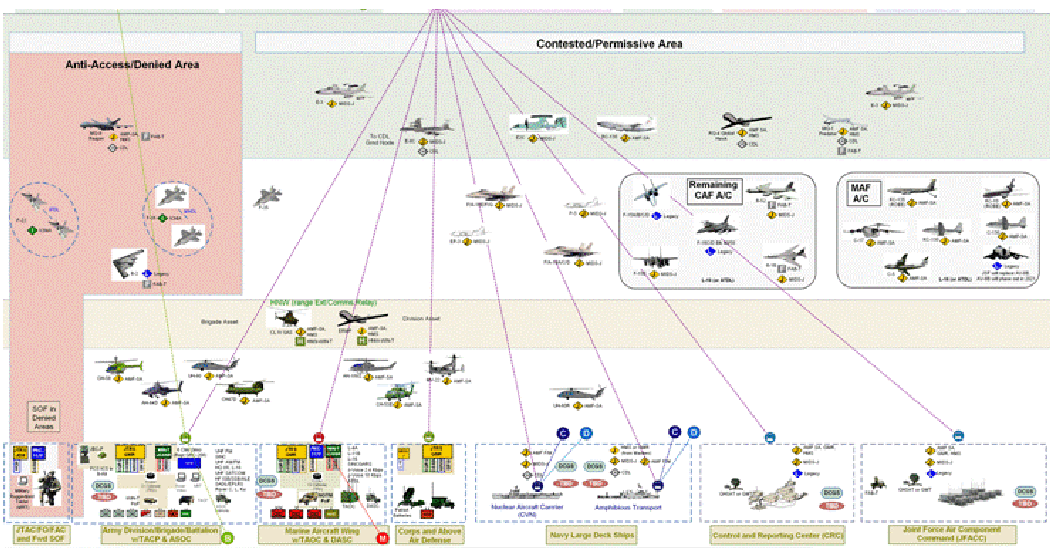

Figure 2: Example EV for a future Joint aerial layer

EVs encompass the complete enterprise and provide views across multiple portfolios. They simply illustrate the BOI which is extremely important for investment decisions for ground forces where the number of platforms equipped with the SoS is quite large. They also simply illustrate network connectivity data where they have informed modeling and simulation (M&S) efforts, trade space analysis, and POM deliberations. Transport capabilities, including voice, data, and video, are depicted with a layered approach, identifying radio types and subnets along with the cross domain classification levels. In essence, the EVs inform and describe fielding density and network connectivity to for future system development, decision support analytics, programmatic reviews, and investment recommendations. Although the figures show static views, with the use of tools, a dynamic aspect of EVs can be utilized. When viewing products, it is possible to filter out specific networks and focus on details needed to support specific budget deliberations and fielded/planned capabilities. The depictions represent a holistic deploying unit and the system, network and operational capability required for mission excitability.

A key element supporting these views is the data. The data format and construct is the basis of the view. The data fields supporting the views are defined to include platform, radio, waveform and network compliment. Platform specific systems are allocated to networks supported by radios and their waveforms. Algorithms can be created to capture the data and render the information on a view graph. These algorithms act like filters and can be created to support any needed view rapidly and quickly. The filters can be applied and changed on the fly to highlight different transport frameworks or view all the information in its entirety.

EV Development

Building EVs can be as complex or as simple as needed. EVs are built in context to a specific outcome desired; i.e. a decision in transport investments, or identification of system density and distribution or both. Platforms and systems necessary to visualize the issue or discussion point are identified and depicted. Relationships of these nodes are vital to identifying characteristics and interactions. They define the context in which EVs are created. Platforms can be gathered from many different resources such as M&S results, authoritative force structures, technology forecasts, system operational guides and DoDAF products. Allocation rules then are developed to allocate systems to platforms based on desired missions and operational capabilities. These allocation rules can be defined as a part of specific courses of action, M&S rules, or practical testing and message network load analysis. The allocation rules are vitally important to the EVs. They provide the foundation of the entity layering and relationship representation in the visual perspectives. After platform and system identification, and allocation rules are finalized, proper information configuration management and storage decisions can be made. Information will need to be collected and captured in a format conducive to display purposes. The information is maintained and updated in a spreadsheet or database type format, facilitating the ease of updating and changing the information. Figure 3 is an example EV spreadsheet. Each row provides information about a platform in a formation. The first set of columns identify the role of the platform. The remaining columns identify the systems, waveforms and network connections. Databases offer the ability to filter the information and allow for the ease of changing the EV content.

3/4	Battalion	TOE Title	Para	Para Desc	Platform	Role	# of TOEs	# per TOE	# Platforms	WIN-T	BFT II / MTS	W/UHF LOS	PRC-148	Iridium	SINCGARS RT	C2 System	BC Tier OTM	Handheld	Uncleared	Long Range	HW Specified	WNW	SRW 1	SRW 2	SRW 3	Call Grp 1	Call Grp 2	Call Grp 3	SINCGARS	SINCGARS	SINCGARS	SINCGARS	SINCGARS	MUOS	HF	WNW	SRW	SINC	MUOS	HF	SFF-C 804	SFF-B 533	MP 191	HH 58	GMR 94	MP 700	SINC 707
5	BDE HQ	HHC	1	Cmd Grp	Stryker	Bde Cdr	1	1	1	POP					4		3						Bde						Bde Cmd	Bde Fire Spt				1	Bde Cmd	0	1	2	1	1	0	0	0	0	0	1	2
6	BDE HQ	HHC	1	Cmd Grp	HMMWV	Bde Cdr	1	1	1						2		2						Bde						Bde Cmd	Bde Fire Spt					Bde Cmd	0	1	2	0	1	0	0	0	0	0	1	2
7	BDE HQ	HHC	1	Cmd Grp	Soldier	Bde Cdr	1	1	1																											0	0	0	0	0	0	0	0	0	0	0	0
8	BDE HQ	HHC	1	Cmd Grp	Soldier	RTO 1	1	1	1											1									Bde Cm Div Cmd					1		0	0	1	1	0	0	0	1	0	0	0	0
9	BDE HQ	HHC	1	Cmd Grp	Soldier	RTO 2	1	1	1											1															Bde Cm	0	0	1	0	1	0	0	1	0	0	0	0
10	BDE HQ	HHC	1	Cmd Grp	HMMWV	Dep Cdr	1	1	1						2		2						Bde						Bde Cmd	Bde Fire Spt					Bde Cmd	0	1	2	0	1	0	0	0	0	0	1	2
11	BDE HQ	HHC	1	Cmd Grp	Soldier	Dep Cdr	1	1	1																											0	0	0	0	0	0	0	0	0	0	0	0
12	BDE HQ	HHC	1	Cmd Grp	Soldier	RTO 1	1	1	1											1									Bde Cm					1		0	0	1	1	0	0	0	1	0	0	0	0
13	BDE HQ	HHC	1	Cmd Grp	HMMWV	FSC	1	1	1						2		1R						Bde						Bde Cmd	Bde Fire Spt	FA Bn Ops Fire			1		0	1	2	1	0	0	0	0	0	0	1	2
14	BDE HQ	HHC	1	Cmd Grp	HMMWV	CSM	1	1	1						1		1R						Bde						Bde Cmd							0	1	1	0	0	0	0	0	0	0	1	0
15	BDE HQ	HHC	1	Cmd Grp	HMMWV	Asst Ops Sgt	1	1	1						1		NA												Bde Cmd							0	0	1	0	0	0	0	0	0	0	0	1
16	BDE HQ	HHC	2	Cur Ops	HMMWV	XO	1	1	1						2		1T						Bde						Bde Cmd	Bde O&I				1		0	1	2	1	0	0	0	0	0	0	1	2
17	BDE HQ	HHC	2	Cur Ops	HMMWV	S1	1	1	1		1				1		1T						Bde						Bde Cmd							0	1	1	0	0	0	0	0	0	0	1	0

Figure 3: Example EV Spreadsheet

Visualization of the information can be accomplished by using any type of COTS products to produce graphics that were shown in Figures 1 and 2. Tools that have been used to display EVs include Visio and NetViz. Other web and service oriented tools are being developed to provide an enhanced capability of connecting active databases to create the view. Once the view is rendered, modifications, are made with this product stand alone or in conjunction with other architecture data and views. The view can be printed and stored in various formats. CADIE is a Database application that is being developed by the Army's Training and Doctrine Command (TRADOC) to automate the preparation and visualization of EV data [see Reference 7]. It may very well represent future architecture tools used in DoD for the development of EVs.

Comparison of Views

EVs bring a different aspect to the decision support environment. They provide a collage of information into one holistic picture. Unlike more traditional DoDAF operational and system views, EVs exemplify the ability to view both the operational, technical, transport, and system integration that DoDAF cannot provide in their traditional perspectives. Issues such as size, weight, power and cooling (SWaP-C) can be highlighted and trades can be examined by viewing individual systems, enabling specific SoS capabilities in one view. DoDAF traditionally has taken on more of a capability or service context, focusing on system functionality. EVs emphasize the SoS context and overlays it in an executable form with integrated systems onto a formation's force structure.

EV Adoption

The Army has made significant use of EVs for decision making over the last several years. The G3 LandWarNet/Battle Command Directorate commonly uses EVs to discuss SoS issues with Headquarters Department of the Army (HQDA) leadership and in informal meetings with the Vice Chief of Staff of the Army (VCSA). These leaders have come to expect to see EVs in discussions about the Army's network and battle command SoS. An architecture group within the G3 LandWarNet/Battle Command Directorate has tasked the development of EVs to other Army organizations, including the Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASA(ALT)) and TRADOC [see Reference 8]. The current portfolio management process for battle command and networks by the Army establishes future states for the SoS in two year increments called "Capability Sets". The baseline Capability Set covers the years 2009 and 2010. Deliberate efforts were required to capture data to construct EVs for this time period. As units rotate in and out of theater, the complement and connectivity of systems for that unit often changes notably. Soldiers in theater are too busy to spend the time necessary to capture baseline architecture data, and make it a low priority upon their return. Additionally, the SoS varies somewhat with each unit. Once reference baseline EVs were established for the Army, EVs were refined for future Capability Sets, i.e., 11/12 and 13/14. EVs have been prepared for many different formation types, by mission area and echelon.

EVs are found to be easily understood by senior leaders without any training in the area of architecture, systems engineering or information system technology. Senior leaders understand the force structure implied by the layout of platforms. They quickly digest the ramifications of integrating a SoS on platforms that have a given role. If only at the level of basic functionality and cost, in the last several years senior leaders have come to commonly call upon EVs to support ad hoc decision making and careful deliberations. By examining EVs, senior leaders have determined platforms that don't need to be allocated capabilities or platforms with low priority for receiving the equipment to save investments. In the case of the Army, a suite of next generation SoS equipment can cost several million dollars for a single ground vehicle. In the grand scheme of things, this is not a large investment worthy of significant deliberation. But when considering the Army has as many as 1,000 ground vehicles in a single brigade the investment is noteworthy. When considering the Army has over 300 brigades, the potential investment can be gargantuan. Eliminating the SoS suite from 10 to 20 vehicles per brigade can reduce investments by tens of millions of dollars. Senior leaders have used EVs to make such decisions. EVs are the only view or format that has and can support such decisions. Traditional operational, system and technical views cannot support decision makers for such purposes. At this time, it can be said that senior Army leaders have adopted EVs as a critical process for decision making.

Within the Army, EVs have been recently used to investigate the allocation of COTS systems into units currently in theater. In some situations, EVs have been used to show that investments in COTS systems for units are so large that they significantly detract funds planned for PORs. As a result, some PORs have been proposed to be accelerated instead of investing in COTS solutions.

Army Program Executive Officers (PEOs) have also employed EVs to support their planning. PEO Command, Control, and Communications Tactical (C3T) and PEO Intelligence, Electronic Warfare and Sensors (IEW&S) have captured detailed baseline EVs for units in Afghanistan. They have incorporated analysis of network capacity into these EVs to determine shortfalls in transport capacity. Augmentation of theater networks were made by these PEOs based on this analysis involving EVs.

The Army use of EVs is unique. The Army has hundreds of thousands of platforms in its force structure that are candidates for allocating SoS equipment. Historically, only maneuver and command and control vehicles were equipped with battle command and network systems. The quantity of systems for these platforms made decision making tractable. In the next several years, combat support vehicles (e.g., HMMWVs), logistic vehicles (e.g., trucks), and even dismounted soldiers will receive systems. The scale of platforms involved and the complexity of the SoS in the portfolio must be addressed with EVs. Although Marine Corp forces have similarities to those of the Army, their near term investments are significantly smaller than those of the Army. The number of ships and aircraft by the Navy and Air Force is relatively small compared to Army platforms. As a result the Army is the Service with the big demand for functionality afforded by EVs. The Joint community that overlooks all defense capabilities has a management problem on a greater scale than the Army. ASD(NII) has been meeting their challenge with EVs. Efforts with EVs by ASD(NII) are indeed on par with those by the Army.

Conclusions

EVs have sufficiently matured over the last several years to proclaim them an enduring method for SoS systems engineering. They have been used to support key critical decisions that impact hundreds of millions of dollars to be invested for tactical networks and battle command. EVs have not replaced traditional operational and system views, but they have augmented them by providing information in a format that is most digestible by senior defense leaders. Table 1 summarizes the difference between traditional and forecasted future views.

	Traditional	Future
Views	**Operational, System, Technical, other DoDAF 2.0**	**Executive**
Construct	**System**	**System-of-Systems**
Purpose	**Design, Development**	**Investment Decision Making**
Users	**PMs, Requirement Developers**	**Senior Leaders**

Table 1: Comparison of Traditional and Future Views

Software tools are developed, maintained and sold for preparation of operational and system views. These tools speed the development of architectures and make the architect's job more efficient and effective. Software tools do not currently exist to support EV developments, but are being developed. EV tools are being developed around databases that contain force structure, SoS information, and allocation rules. EV tools will support the establishment of data elements and the preparation of alternative perspectives. EV tool development is still in its early stages and many lessons learned are needed before common functionality is afforded by different suites. CADIE is an example EV tool that is being matured by TRADOC. Developments for CADIE are expected to produce an EV tool that can be used throughout the Army.

It will likely be several more years before common views are adopted and tools are readily available. With tools, EV development is expected to be less time consuming and error prone. Authoritative operational and system data is crucial for EV development and use. Processes to make authoritative data readily available need to be put in place to further integrate EV developments into normal systems engineering and business practices. EVs can become a part of the arsenal of portfolio management techniques, which have the objectives of improving interoperability, minimizing capability redundancies and gaps, maximizing capability effectiveness, enabling progress to be measured from strategy to outcomes, and delivering needed capabilities more rapidly and efficiently. EVs should ultimately be explicitly reflected in the DoDAF, to provide a common framework and format for all related organizations to use. Incorporation into future versions of DoDAF should also facilitate the development of tools for EV development and integration with developments of operational and system views. Finally, one should look for the DoD SoS SE Guidebook [see Reference 9] to encompass the development of EVs as part of its proposed set of processes.

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