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Identifying Governance Best Practices in Systems-of-Systems Acquisition

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Panel 5. Beyond Better Buying Power: Assessing Progress and Institutionalizing Success

Wednesday, May 14, 2014	
1:45 p.m. – 3:15 p.m.	**Chair: James E. Thomsen,** Principal Civilian Deputy, Assistant Secretary of the Navy (Research, Development, & Acquisition) ***Identifying Governance Best Practices in Systems-of-Systems Acquisition*** Joshua Archer, Center for Strategic & International Studies David Berteau, Center for Strategic & International Studies ***Beyond Business as Usual? Better Buying Power and the Prospects for Change in Defense Acquisition*** Zach Huitink, Syracuse University ***Creating a Cost-Conscious Culture: From RFP Through Execution*** Kathlyn Hopkins, Marine Corps Systems Command

Identifying Governance Best Practices in Systems-of-Systems Acquisition

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Abstract

Increasing budgetary constraints and the rapid growth of threats to global security have made the need for a new model of acquisition governance ever more obvious. In order to make better use of its defense dollars while contracting to acquire more advanced defense capabilities, the defense acquisition community in the United States needs to improve governance processes for complex acquisitions.

Over the last decade, researchers at the Center for Strategic and International Studies (CSIS) have studied and analyzed the increased challenges of complexity in defense acquisitions. Through workshops, conferences, and publications, CSIS has examined how the government purchases complex systems, what challenges it encounters in doing so, and what key attributes of governance can be modulated to provide more effective acquisition.

The study underlying this report explored one simple question: In complex systems of systems, what best practices contribute to better, more efficient acquisitions? To answer this question, the CSIS project team reviewed its past work on complexity in acquisitions, analyzed new scholarship on the subject, and conducted detailed interviews with executives from across the defense acquisition community. This 12-month effort culminated with the production of a new model of acquisition governance model presented in this abridged version of a longer technical report on the research.

The governance framework starts with eight attributes of program management, which CSIS developed under its past research on the subject. The study applied this framework to seven acquisition case examples of various sizes and complexity which have shown differing degrees of program success. CSIS also conducted 11 interviews with 17 acquisition executives and stakeholders covering each of the case examples to help identify success drivers and good governance themes. Finally, CSIS used the case studies and interviews to develop a model of acquisition governance that could help strengthen the ability of acquisition leaders to more effectively and efficiently acquire complex systems of systems (SoS).

The research illustrates how best practices in the three most critical attributes—level of organizational focus, decision-making authority, and enforcement—can make the difference

between success and failure of an acquisition effort. Best practices in the remaining attributes also enable the efficient production and procurement of effective systems of systems and assist mission success in large, complex acquisitions.

Readers should refer to the full report for supporting evidence in the form of case studies and interview summaries.

Introduction

Complexity: The Problem Defined

As the defense needs of the nation’s warfighters have evolved, acquisition preferences within the Department of Defense (DoD) have also transformed in a way that pushes human capital, technical knowledge, and production assets away from the government and toward industry. However, existing models seem to fall short of providing an effective governance approach when faced with the evolving challenges of complexity.

Within complexity theory, complex systems are defined as those systems in which multiple components interact with and exert influence on one another and the various factors in their external environments over time. This research focuses on complexity within SoS acquisition specifically. As a result, this paper uses complexity to describe systems consisting of multiple sub-systems and components that are typically developed and managed by more than one organizational element. The existing literature has applied the principles of complexity theory extensively to such fields as economics and business management. This research aims to contribute to the literature by identifying best practices specific to the challenges defense and federal-civil acquisition managers confront in their SoS acquisition efforts. This focus is narrow, but as with other work that has been undertaken on complexity, its implications are applicable to other disciplines.

Complex systems present four related problems for defense acquisition planners and decision-makers. First, the conceptual size of a complex system is larger than a traditional system. For example, ground vehicles used in the early- to mid-20th century were treated as one product; their interactions with other materiel were not negligible, but those interactions could be managed on a tactical level post-deployment. Conversely, today’s ground vehicles contain their own sub-systems. A personnel carrier might have dozens of its own active and passive protection systems interacting with the vehicle and the external environment, a number of different communications devices, and various on-board weapons platforms, to name a few. Each of these systems has its own acquisition demands above and beyond the base requirements of the vehicle itself.

Second, each of the sub-systems within a system, as well as the systems external to it, interacts with others. Some of those interactions can be forecast to some degree, but forecasts will have limited accuracy. Furthermore, interactions can produce cascading interactions and change the behavior of other sub-systems or the system as a whole. This contributes to a third problem presented by complexity, namely that the output of a system is not equal to the sum of its inputs. The interactions can create amplified or diminished outcomes. This is a driver of complexity in defense platforms, as the multiplying effects of complementary systems can create new and more advanced defense technologies. However, as with the interactions themselves, it is difficult to forecast the individual and aggregate results of the system and sub-system interactions, much less to harness them for a desired outcome.

Finally, complexity is a management problem because it operates outside the boundaries of traditional linear approaches to acquisition governance. This is central to the objective of this report. Traditional, risk-averse governance approaches to designing, engineering, developing, and procuring defense weapons and platforms are not adequately flexible to manage the unpredictable interactions of systems, sub-systems, and the external environment. They are based on static program objectives to acquire dynamic technologies. Those technologies then often evolve at widely different rates of development, and upgrading platforms with long life cycles can be difficult.

Models of SoS Governance

In order to understand the problem presented by complexity, it is important to have a framework with which to conceptualize complex acquisition. Broadly speaking, there are two ways to conceptualize efforts to acquire systems of systems: the traditional model and the enterprise model.

In the traditional model of acquisition governance, a program office or a similar central authority mandates and governs the capabilities comprising a systems of systems. Linear acquisition activities follow defined user needs, typically in the form of broad tactical requirements. The acquisition activities begin with overarching technical requirements, which inform offers or bids from government and industry suppliers. Program offices analyze bids for their closeness-of-fit to certain criteria and select a winning solution. The winning contractor then develops, produces, and deploys the systems of systems (see Figure 1).

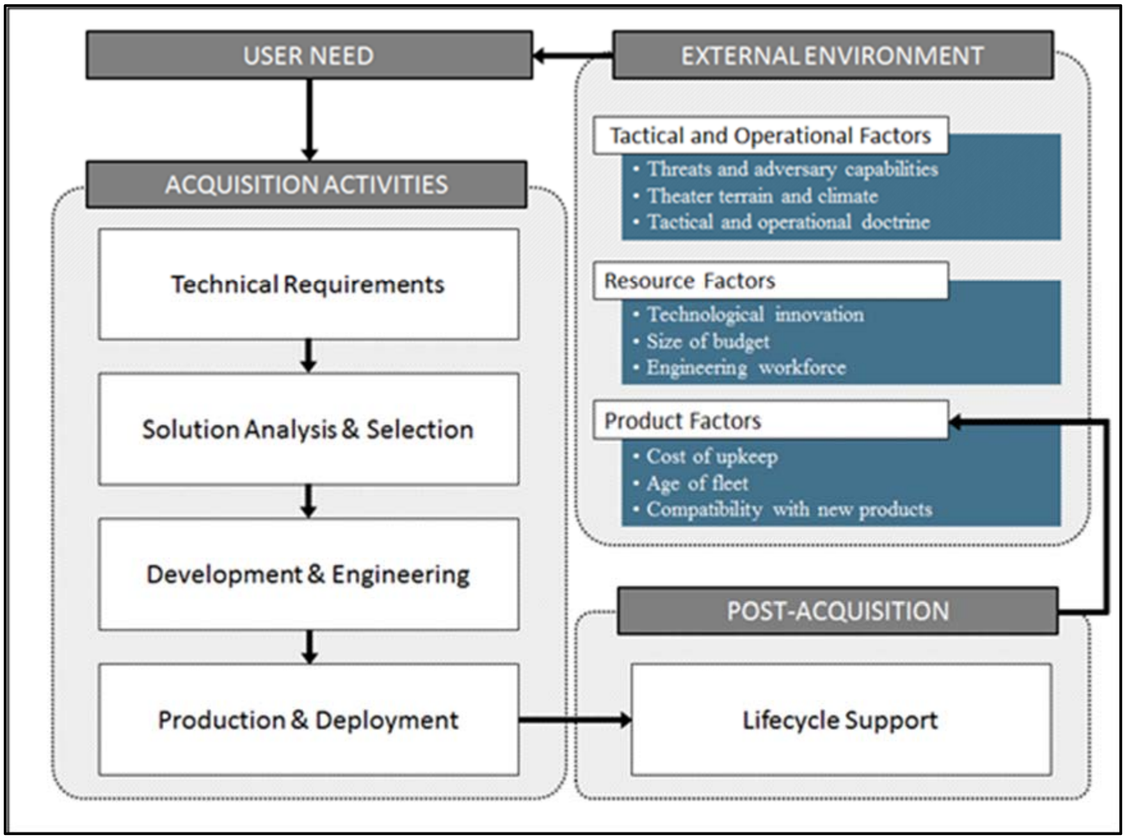

Figure 1. Traditional Acquisition Governance

Note. This figure comes from CSIS analysis. “Acquisition Activities” was adapted from standard defense acquisition protocols, as outlined in DoD guidance documents (2008, p. 12).

Challenges pursuant to this model emerge from its linearity. The case studies identify three interrelated ways in which the linearity of the traditional model challenges the ability of the DoD to execute complex SoS efforts and to deliver capabilities on-cost and on-schedule. First, individual stages of the acquisition process have difficulty responding to changes in user needs and the external environment once these inputs have set the technical requirements. Second, efforts to preempt changes in those inputs often result in acquisitions of immature technologies with high levels of risk. Finally, as delays occur in the development of components of the systems, parent systems cannot adapt, which in turn can create setbacks. This effect can occur in any complex effort regardless of the model, but the structure of the traditional model of governance exaggerates this effect.

In contrast with the traditional model, the enterprise model of acquisition governance breaks SoS acquisition into different layers of authority. This characteristic is a key difference between the enterprise model and the traditional model, which employs a top-down unified approach to governance. The division of authority allows different stages of an SoS acquisition effort to influence one another in separate bilateral relationships. It also enables individual stages of acquisition to adapt to changes in the external environment. These characteristics comprise a more agile approach to acquisition (see Figure 2).

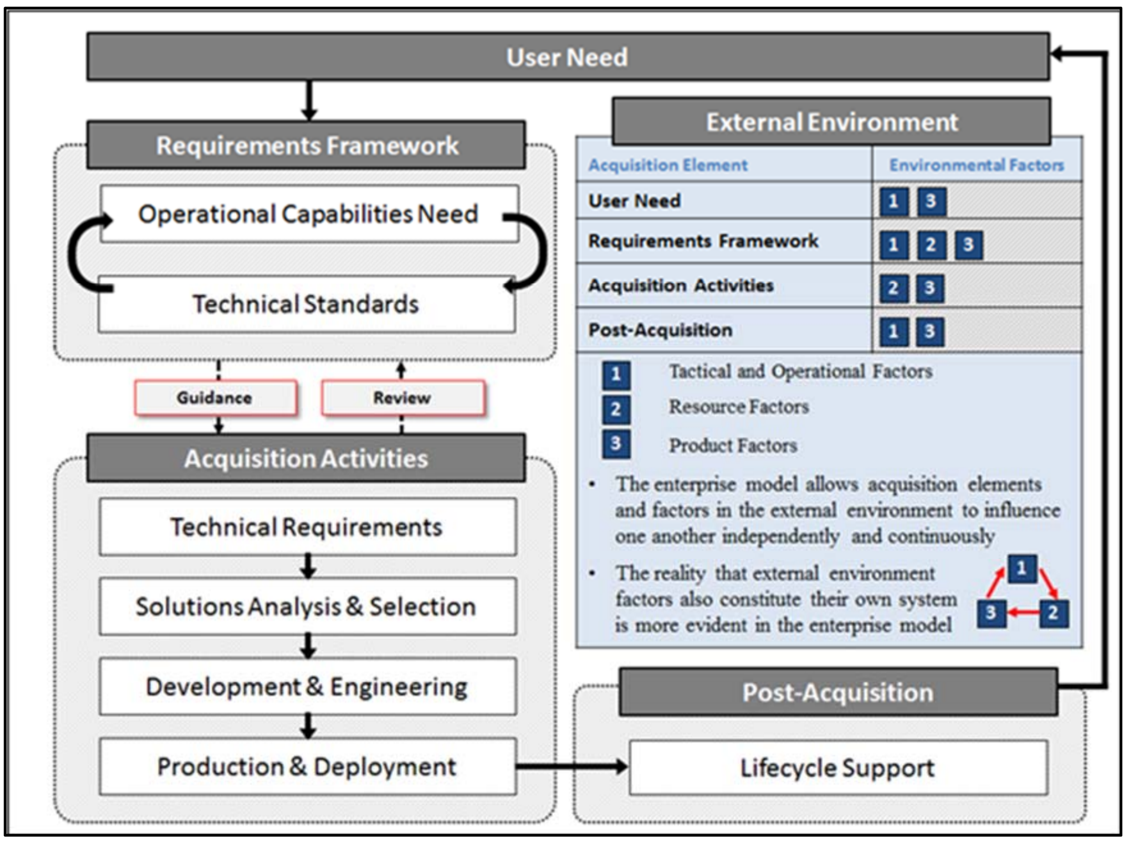

Figure 2. Enterprise Acquisition Governance
Note. This figure comes from CSIS Analysis.

As illustrated by Figure 1 in the previous section, the traditional model treats the external environment as its own unit. This allows environmental factors to inform user needs but makes it more difficult for them to influence other stages of the acquisition effort. For example, resource factors are critical to solutions analysis and selection; however, aside from the influence of resource factors in the initial stages of solutions analysis, top-down governance in the traditional model complicates real-time adjustment to changes in those factors.

Analysis of these models indicates that layered authority is the key differentiator between the enterprise and traditional approaches to acquisition. However, CSIS case study analysis suggests that the acquisition community has been selective about how it divides authority, even in those efforts most representative of the enterprise model. This research uses the eight-attribute governance framework to observe how individual attributes relate to each case's ability to manage complexity internally and externally. The cases show that *the ability to manage complexity directly correlates with the degree to which the responsible stakeholders have independent authority in each attribute for which they are accountable.*

The seven cases included in this study include two cases with more traditional governance models and five with governance models that were closer to the enterprise model. Here are the seven cases.

Traditional Governance Cases:

1. Future Combat System (FCS)
2. Integrated Deepwater System (Deepwater)

Enterprise-Wide Governance Cases:

3. Counter Rocket, Artillery, and Mortar (C-RAM)
4. Distributed Common Ground System (DCGS)
5. Global Nuclear Detection System (GNDS)
6. Harvest Hawk
7. Maritime Domain Awareness (MDA)

Attributes of SoS Governance

CSIS developed its framework for analysis of governance in complex acquisitions to help understand the drivers of success in SoS acquisition. The framework is the product of research on SoS governance models, interviews with program stakeholders and industry leaders, and a findings refinement process involving input from SoS experts. It consists of eight attributes that collectively represent concerns, questions, and issues that must be addressed for an organization to succeed in acquiring a complex systems of systems. The importance and significance of these attributes varies depending on the system to which the framework is being applied.

The eight governance attributes are as follows:

- Level of organizational focus: the level at which SoS governance occurs within the organization. This is not the same as systems/capabilities focus or technical focus, both of which are outside the scope of the CSIS SoS governance analysis.
- Integration of functional end-user needs: the mechanisms and frequency with which the functional needs of end-users are built into the systems of systems and at which points in the process this incorporation occurs.
- Decision-making authority: the governance mechanisms for SoS delivery, including how budget is allocated, standards set, tradeoffs managed, and inconsistencies adjudicated.
- Enforcement: the mechanisms and level of oversight by which the objectives of the SoS capability to be delivered are ensured.

- Workforce: the examination of SoS workforce structures, unity of mission, and capability development through use of contracting.
- Incentive structure: the alignment between the enterprise's goals and the incentive and reward structures of the stakeholders and organizations that implement them.
- Knowledge ownership/access to knowledge: the accessibility of information regarding the operating environment, technical standards, and the other parts of the systems of systems.
- Risk assessment/risk management: risk assessments and management strategies tailored to the mission accomplishment and the flexibility and resilience required for delivering systems of systems in the face of unforeseen developments.

This research examined seven case studies to profile their characteristics in each of these attribute areas. It then conducted interviews with acquisition executives and other program stakeholders to understand which attributes were most important in producing the successes of each effort, as well as those areas in which each effort did not perform optimally. A detailed analysis of each case study is available in the full report associated with this proceedings paper.

Results of CSIS Interviews With SoS Program Stakeholders

Case studies on seven example SoS acquisition efforts comprised the core of this CSIS research effort. These case studies facilitated analysis of the specific governance attributes for each case and provided important qualitative gauges on their importance. The results of these interviews suggest that an agile and multi-layered governance process can lessen the operational burden of managing and delivering complex systems of systems. Furthermore, strong enforcement mechanisms are necessary to ensure outcomes are in line with expectations.

The CSIS research team conducted 11 interviews in total with the participation of 17 acquisition executives. Each interview lasted about 1–2 hours and was semi-structured to allow interviewees to stray from the explicit governance attributes and provide more general commentary on acquisition challenges.

The interviews suggested that five themes are critical to understanding governance of complex acquisition. These themes are presented here in order of importance to governance.

Theme #1: Stakeholders must maintain focus on the end-result of an acquisition effort at the enterprise level.

First, complex acquisition governance requires that all stakeholders maintain focus on the end-result at the enterprise level. This structural issue is central to a system's ability to operate in an environment consisting of multiple other systems. Interviewees suggest that a narrow focus—focus on a specific product or capability set, for example—compromises the value of a single system's acquisition to the overall objectives of the systems of systems and its user communities. This narrow focus also contributes to demand uncertainty in instances where stakeholders simultaneously develop multiple competing capabilities to accomplish the same end goal.

One case that CSIS examined, Future Combat Systems (FCS), offers several insights about the impact of a product- or program-level focus on the success of an acquisition effort. A former DoD acquisition official involved in overseeing FCS said that many in the acquisition community charged with approving the program at its various decision milestones were concerned that FCS network components seemed to duplicate functions available with existing technologies. Furthermore, the source continues, FCS had no roadmap for integration with interacting systems, particularly the Warfighter Information Network-Tactical (WIN-T), an all-encompassing Army tactical network program, and Joint Network Node (JNN), a SatCom system. One interviewee criticized the program for attempting to build its own operating systems from scratch rather than use existing operating systems able to interface with WIN-T and JNN. The engineers had no plan for bringing those pieces together, and testing their interactions required that the entire system first be fielded, the interviewee reports.

Interviews with several program executives and stakeholders emphasized the importance of enterprise-level focus. In cases such as FCS where focus is narrow, problems emerge where the feasibility of end-state integration is unclear. Integration problems also surface in cases where enterprise-focus is present, however. For example, in another CSIS case study, Maritime Domain Awareness (MDA), acquisition executives maintained a focus on the objectives of the entire enterprise but were presented with challenges to enterprise-wide integration all the same.

Theme #2: A layered decision-making structure with distinct, delegated authority must be clearly established at the outset of complex acquisition efforts.

The reason for integration problems, even in those programs in which organizational focus is held at the enterprise level, underscores a second theme about complex acquisition governance. It suggests that a layered decision-making structure with distinct, delegated authority must be clearly established at the outset of complex acquisition efforts in order for their level of organizational focus to matter.

Interview results show that the various process constraints faced by each of the acquisition case studies—for example, clarity and consistency of scope, availability of personnel, inventory of resources, and so forth—are due in part to their decision-making structures. Process constraints also translate to poor outcomes in cases where decision-making structures were not designed to meet the specific needs of an acquisition effort, or where decision-making authority was weak or non-existent.

The MDA effort demonstrates the challenges created by weak and heavily centralized decision-making authority. In that case, interviewees report that the Executive Agent for MDA (EAMDA) has notional leadership over stakeholder agencies but no real decision-making authority. Instead, it serves in the role of what one interviewee calls a “broker and a cheerleader.” Formally, EAMDA issued an Initial Capabilities Document (ICD) to allow material solutions development under the standard defense acquisition process. However, there is no formal lead for requirements generation or subsequent acquisition decisions. As a result, stakeholder agencies have different perceptions of the MDA charter and what technologies satisfy its core mission objectives. These definitional issues emerge in the absence of strong central leadership. Interviewees support this observation and report similar challenges in the Global Nuclear Detectiong System (GNDS) case study, which is also examined in the full technical report.

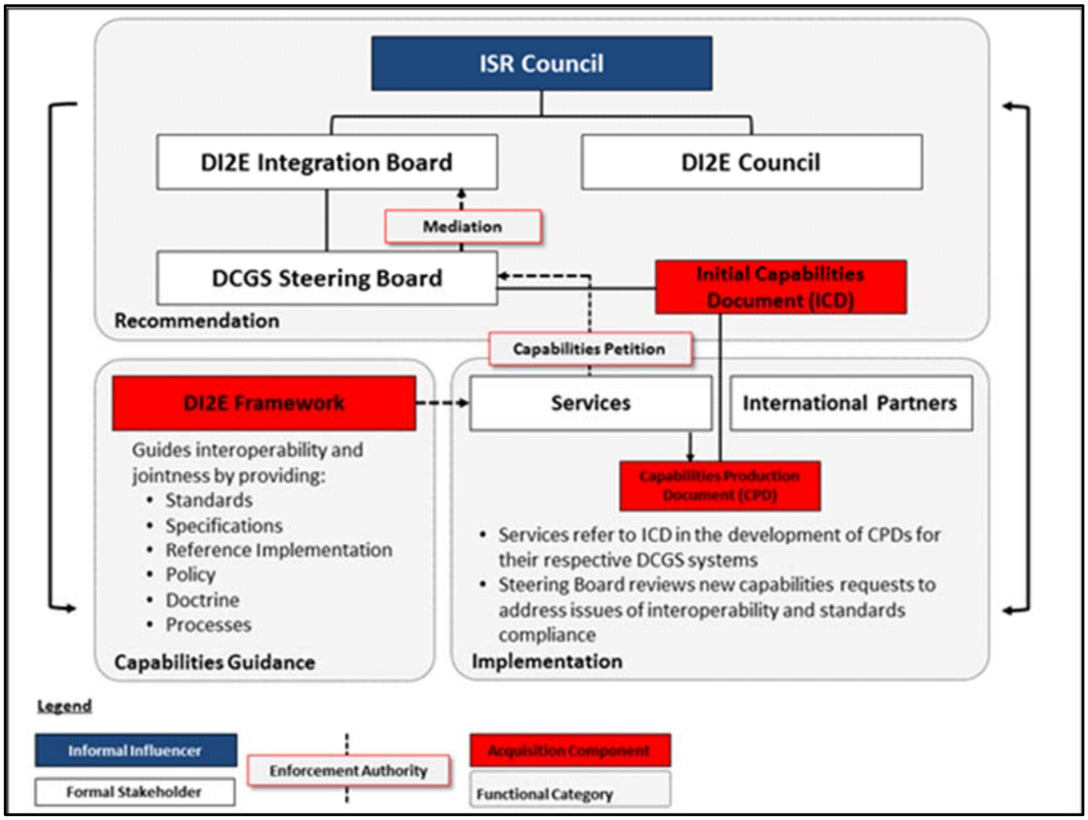

Figure 3. Distributed Common Ground System Conceptual Governance Structure and Key Acquisition Processes

Note. This figure comes from CSIS analysis.

CSIS analysis of the Distributed Common Ground System (DCGS) contrasted with the MDA case in important ways. The DCGS decision-making structure is relatively well-suited to the mission objectives of that acquisition, particularly in its decentralization. One DCGS executive reports that DCGS decision-making is conceptually separated into recommendation and implementation functions. Figure 3 illustrates this concept in the DCGS organizational structure and the key acquisition processes.

The DCGS Steering Board serves as a strong, central leadership entity to provide capabilities guidance and keep development and procurement efforts aligned with core mission requirements. The Army, Air Force, Navy, and Marine Corps each have their own lead entities for the implementation functions. Each of the service components refers to the ICD to draft Capabilities Production Documents (CPDs) for each of their respective systems. The DCGS Steering Board then reviews the new capabilities to determine their fit with the standards and specifications established in the ICD and governed by a central interoperability framework, the Defense Intelligence Information Enterprise (DI2E). Similar to MDA and GNDS, this workflow represents an agile approach to decision-making that empowers end-user communities with substantially different requirements to make their own procurement decisions. However, it is supplemented by strong, formalized central leadership.

Theme #3: Decision-makers must design effective management and enforcement mechanisms and integrate them into the acquisition process.

Interviewees suggest that enforcement mechanisms are the critical component tying together the enterprise focus with product-level decision-making. In order to maintain short chains of authority between the technical communities in the production chain with the enterprise-level planners at the top, decision-makers must design effective management and enforcement mechanisms and integrate them into the acquisition process. Formalized program management mechanisms consisting of a well-defined set of performance criteria have the advantage of lessening the process burden of complex acquisition. With complementary incentives and metrics for monitoring performance, enhanced program management can also contribute to improved cost and schedule outcomes.

The process advantages of effective program management are apparent in the DCGS case. The DCGS effort runs an overarching recommendations and review process through the DCGS Steering Board, but delegates acquisition implementation to individual end-user communities based on a common set of standards established in the DI2E Framework. At the systems level, the acquiring service can approach risk in technology acquisition on a case-by-case basis. The acquiring armed forces component can also design its contract or contracts based on the scale of a particular acquisition item, or whether the acquisition is developmental or non-developmental. At the enterprise level, the DCGS Steering Board has a mediation process through which it can deny efforts that it determines to be too risky or that do not contribute to the DCGS mission objectives.

The effectiveness of the DCGS program management structure is particularly apparent when compared with the management systems used in other large complex acquisition cases, such as FCS and Integrated Deepwater System (Deepwater). In these cases, acquisition was directed through single, service-centric programs of record. An overarching rule-set was applied to all subordinate efforts. Sources interviewed suggest DCGS has avoided the process rigidity that plagued FCS and Deepwater in part because of its separation of top-down program recommendations and bottom-up program implementation.

Theme #4: Program leadership must prevent vested interests and cost concerns from becoming barriers to knowledge ownership.

Organizational focus at the enterprise level, driven by clearly delegated decision-making authority and supported by effective enforcement mechanisms, creates the necessary underpinnings of a complex governance structure. However, any one of these structural elements can be compromised when stakeholders are unable or unwilling to share information. This points at a fourth theme in complex acquisition governance: In order to execute a complex acquisition effort effectively and efficiently, agencies and offices partnered in the technical development of systems as well as the duties of program management must be able to access and share information among themselves. Oftentimes, barriers to knowledge access can inhibit the success of a complex project. Conversations with interviewees suggest that knowledge access also depends on strong incentives for active sharing of information about technologies, program goals, and progress toward established milestones.

Interviewees indicate that there are two types of barriers to effective information sharing and knowledge access. The first barrier is knowledge protectionism. Especially in instances of collaboration between private sector stakeholders, conversations with interviewees suggest that companies are more likely to withhold information from partner entities due to competition for other government contracts. This concern was especially strong in early efforts to make the DCGS Integration Backbone (DIB) software package open-source. In an effort to facilitate software revisions to help meet the needs of individual end-user communities, the DCGS Steering Board and DI2E Integration Council were strongly supportive of revealing the DIB source code to the development community. However, according to one program source, the DIB parent developer resisted efforts to make the software open-source. In the end, DCGS customer offices were able to compel the contractor to share its knowledge.

Program challenges resulted from early resistance to revealing the DIB software code. By compelling its primary software contractor to open its code for other users to access and develop, the DCGS program office demonstrated how a large organization can work to reduce the impact of knowledge protectionism. Using the code, DIB challenger MarkLogic successfully developed a version of the DIB based on Extensible Markup Language (XML, an open-standards software encoding format) to help meet the needs of a sub-segment of the broader end-user community, the U. S. Special Operations Command (USSOCOM), which had a need for a high-performance reconnected-ops DI2E.

A second barrier to information sharing is created by differing levels of information management capabilities. Levels of technical astuteness can be widely different between government customers and industry suppliers. This problem is compounded by varied clearance privileges required for access to, and use of, compartmentalized information. Sources interviewed indicate this problem has complicated several systems-of-systems acquisitions. Interviewees suggest that information needs among stakeholders in MDA are challenged both by the breadth of information collected and the need to filter it to lower levels of clearance, especially unclassified civil users in the Coast Guard. For participants in the Hercules Airborne Weapons Kit effort—known more commonly as Harvest HAWK—data relevant to that program were only accessible through a single computer network, requiring physical ownership of the data for effective information sharing. Sources point to these barriers as real and addressable challenges to acquiring and integrating systems of systems.

Theme #5: Leaders at each level of the systems of systems must be adaptable to changes that result from human behavior.

A fifth and final theme of complex governance reported by interviewees observes that leaders at each level of the systems of systems must be adaptable to changes resulting from human behavior. This theme is applicable not just to the acquisition of complex systems of systems involving many components and stakeholders but also to other systems in the natural world. Human behavior is the ultimate uncertainty, and agility is critical to absorbing the impact of its changes.

Within SoS acquisition efforts specifically, effective governance will recognize changes in the needs of a system's end-users early and, based on that recognition, reevaluate the approaches to a planned acquisition. This feedback loop can be formalized through component-level proposals for new capabilities (MDA). It can also be more ad hoc, incorporating standards-based innovations developed by end-users into the completed systems of systems (DCGS). In either case, the traditional approach to acquisition appears to limit responsiveness to end-user needs.

In general, effectiveness appears to share a strong correlation with cases that were initiated with a clear end-user in mind. For example, the Harvest HAWK acquisition was born out of the necessity to provide air support for Marines in Afghanistan. Marines deployed to train Afghan security forces developed an urgent need for air support when their training unit encountered persistent attacks from adversary forces. Information obtained from the

Marines provided an impetus for the Harvest HAWK acquisition effort, making this case particularly representative of the effective use of human information inputs to produce and procure capabilities specifically answering the needs of the end-user.

An additional aspect of human input is the workforce that a systems-of-systems effort has at its disposal. A good technical and program management workforce can make the difference between an effort's success and failure. Recruiting a truly great workforce can dramatically improve both the magnitude of a system's success as well as the process required to develop and procure it. Harvest HAWK provides an example of the importance of skilled technical personnel supplemented by experienced program managers. One source indicated that Harvest HAWK's success in delivering a complex capability in a small period of time is attributable in part to the ability of the program management to take advantage of the technical workforce available through Naval Air Systems Command (NAVAIR).

Several other cases illustrate that a strong program management workforce is not as effective in delivering a system-of-systems capability when it has a weak technical workforce at its disposal. Sources suggested that workforce strength is not measured by technical skillsets alone. Rather, complex acquisition efforts benefit when their workforce is empowered to use its technical know-how to innovate new approaches to solving problems.

Although technical astuteness tends to reside with human capital in engineering functions, program managers often mistake general capabilities needs with prescriptive technical requirements under the existing framework for acquisition. Sources interviewed suggest that there is structural resistance to bottom-up innovation of new approaches to meeting capabilities demands, but several cases included examples where changing both personnel and their empowerment led to breakthroughs on problems.

Analysis of Best Practices

CSIS independently assessed success factors in the attributes and supplemented analysis with primary input from sources interviewed. This analysis extracted the best practices presented here. This approach facilitated analysis by incorporating the existing literature on complex systems with the expertise of acquisition executives involved in individual or multiple cases.

Critical Best Practices

An assessment of the case studies shows that success in three attributes in particular is critical to SoS acquisition. Those attributes are level of organizational focus, decision-making authority, and enforcement. The attributes are closely related, and strong performance in any one is dependent upon performance in the other two.

Organizational focus at the enterprise level is critical to enabling SoS integration and facilitating flexibility for quick and substantive response to changes in the external environment. Although critical, enterprise-level focus is limited when it is not supplemented with some program-level focus on individual capabilities. The DCGS case, for example, shows the value of allowing programs and sub-system acquisition efforts to govern themselves to a certain point.

The key to differentiating these two levels of focus and ensuring that they interact with and respond to one another is in part related to the decision-making authority attribute. At the program level, stakeholders should be delegated the authority to make decisions about systems and technologies with a low burden of approval from the enterprise level. This is especially important in complex systems of systems. The organizational legwork a program has to perform in order to approve a new sub-system that has newly developed or emerged as an end-user need can prevent the program from timely and effective integration of that technology or capability.

One way to achieve the right level of agility in decision-making delegation is to establish open-source standards for new technologies and systems as a replacement for traditional, formal oversight mechanisms. In interviews with CSIS, several Coast Guard executives indicated that it is already implementing this best practice post-Deepwater to ensure interoperability among C4ISR systems across its fleet of surface vessels and aircraft. Interviews also indicate DCGS revealed its DCGS Integration Backbone (DIB) for open source use, allowing industry to create a new and specialized XML-based search engine in order to meet a very specific end-user need. Therefore, this best practice assists decision-makers at the enterprise level by lessening their programmatic requirements, and empowers decision-makers at the program level, as well as end-users themselves, to reflect SoS ecosystem changes in their planned acquisition activities.

The enforcement attribute links decision-making authority with level of organizational focus. Effective enforcement mechanisms enable enterprise governance authorities to keep program managers on-cost and on-schedule while easing the operational burdens associated with delivering large, complex systems of systems. Although statutory mechanisms for enforcement are established in the DoD's standard acquisition process, case study analysis finds those mechanisms custom-tailored to the specific demands of the individual systems of systems to be most successful. For example, the DCGS effort created a central authority to review petitions for capabilities from an enterprise perspective, and reserves the right to deny a sub-system acquisition effort in the event that it is determined to be incompatible with the SoS objectives. This exists outside of the standard DoD acquisition enforcement mechanisms. Furthermore, the case of FCS illustrates how existing mechanisms can in fact be counterproductive and conceal underlying problems in a complex SoS acquisition effort.

Enabling Best Practices

In addition to the critical best practices, performance in the remaining attributes enables SoS acquisition efforts to reach end capabilities with fewer cost and schedule problems. These enabling best practices also contribute to greater alignment between a systems of systems and the needs of its end-users. Finally, best practices in the remaining attributes help to mitigate problems of technology obsolescence and help ease the tendency for innovation in modern defense platforms to lag behind commercial industry.

Successful SoS acquisition efforts accomplish greater integration of functional end-user needs in part through the encouragement of innovation at the sub-systems level. One best practice in this regard involves the establishment and publication of open standards for software and systems. The DCGS offers one example. In that case study, DCGS program management responded to a SOCOM need for high-performance reconnected ops DI2E by pressuring the DCGS prime contractor to release the DIB source kernel for open-source collaboration. Using the DIB package, MarkLogic, a supplier of enterprise database software, created an XML database. In the end, the software proved valuable to SOCOM, a specific end-user community with unique, niche requirements.

In addition to revealing systems for open-source innovation, case study analysis also indicates that kit-based and modular approaches to materiel development can contribute to greater integration of end-user needs. The reverse of this is the more traditional platform-based development. Harvest HAWK provides one example of this best practice. In that program, users found the original kit to be inconvenient because of its weapons release mechanism. Namely, in order to deploy missiles, the system had to first depressurize. The installation of a derringer door into the kit corrected the issue, and was made possible by the fact that the kits are not permanently installed on the C-130J platforms. The roll-on/roll-off nature of the Harvest HAWK capability allows for refinements not requiring significant SoS-level changes. In contrast with this best practice, systems acquired under a traditional model show a heavily diminished ability to integrate changing end-user needs. Future Combat Systems (FCS), for example, folded all capabilities into a slow-moving platform acquisition effort in a way that precluded changes to sub-systems based on new end-user needs.

In either of the two best practices in user needs integration (i.e., open source standards and kit-based development), performance in knowledge ownership and access to knowledge is an important enabler. For this reason, case studies illustrate that open-source publication of standards and basic software is a best practice in the information access attribute. However, revealing the foundation for a systems of systems alone is not enough to enable stakeholders to develop and refresh sub-systems. This information is only meaningful insofar as leadership in any SoS acquisition effort recognizes that stakeholders across systems of systems vary widely in their ability to access, understand, and use information that is available to them.

Systematic and institutional stovepipes are one obstacle to information ownership. Other, less tangible obstacles include lower technical expertise among information consumers, lack of sufficient resources to handle the financial and technical costs of information, and compatibility issues in the recipients' systems with the format or type of information. Therefore, one best practice to facilitate knowledge ownership and access to information is to campaign for—or in the event that the provider of information is also the lead stakeholder for a systems of systems, to approve and make available—the budgetary and technical resources necessary for information management.

Workforce best practices comprise a third enabling factor in SoS acquisition. Identifying, recruiting, and retaining the most appropriate personnel for any SoS acquisition effort can substantially impact the effort's process and outcomes. However, identifying best practices in this attribute is particularly difficult for two reasons. First, human inputs are unpredictable. In the case of Harvest HAWK, replacing a single engineer rescued the program from a months-long logjam when the new engineer identified an error in a sub-system's code that had been inhibiting the proper function of the systems of systems. Second, workforce is a complex system in itself; technical and programmatic personnel interact with one another at different levels with unpredictable impacts.

Analysis of the case studies indicates that one best practice in the workforce attribute is to balance programmatic and technical personnel based on the specific needs of a program. At the enterprise level, the ideal workforce is weighted toward programmatic workers with some technical personnel available to provide overarching direction. At the systems level, technical personnel are more prevalent in the ideal workforce. Weighting toward technical personnel rather than programmatic personnel allows the workforce to avoid parochial interests and provide metrics-based assessments of progress toward a sub-system's development.

Incorporating recent and one-time end-users into the workforce is an additional best practice that enhances the alignment of outputs with the need they are expected to satisfy. The Deepwater family of vessels has been incorporating this best practice into its efforts to acquire the vessels formerly comprising that systems of systems. The presence of decision-makers with recent field experience in the Harvest HAWK initiative also contributed to that program's success in producing an effective systems of systems to meet an urgent operational need on the part of the Marine Corps for close air support.

Regarding the incentive structure of an acquisition effort, analysis indicates fostering and satisfying greater mission commitment among stakeholders is an ideal motivator. Although mission commitment seems intangible and difficult to effect, the case studies highlight different ways to enhance the commitment of personnel throughout an acquisition effort's hierarchy to the effort's values and desired end-state. For example, having strong budgetary advocates at the executive level communicates to stakeholders that their work in the acquisition of a systems of systems is valuable to the end-user and to the organization as a whole. Analysis indicates that personnel management tools can provide additional incentives. For example, as shown in the Deepwater case, the strategic appointment of accomplished personnel to leadership positions can inspire confidence throughout a program. Similarly, accountability at each level of the personnel hierarchy provides a disincentive to poor performance.

Case study analysis also illustrates that acquisition managers can influence an effort's success through incentives aimed at other systems and organizations. Most notably, high barriers to the entry of new technologies into an acquisition effort act as a disincentive to mid-stream innovation and damage the long-term effectiveness of a systems of systems. The Harvest HAWK case offers several examples of barriers to entry and their impact on an effort's process and outcomes. At the front end, the Marine Corps did not conduct a competition for source selection on the Harvest HAWK contract. Challenges that emerged later in the development process may have surfaced sooner if competitive offerings had been evaluated. In contrast with this situation, lower barriers to entry of competitive and more recent technologies in DCGS facilitated the emergence of a competitive database solution that ultimately improved the operability of the entire systems of systems.

These best practices above represent ways to structure a complex acquisition effort to improve effectiveness and efficiency based on seven of the eight attributes analyzed. Identifying best practices in risk assessment, the final attribute, presents two significant challenges. First, risk is an inherent and unavoidable aspect of complexity. In addition to uncertainties originating in the development and procurement of individual systems, the interactions between and among those systems also creates potential areas of risk. Second, risks emerge in different stages of any given project in ways that cannot be predicted, complicating the universal application of best practices. For example, the Army's approach to FCS exhibited greater risks in the early stages of system development. The effort was particularly risky in its requirements generation processes, which led to the selection of immature and untested technologies. Conversely, Harvest HAWK was non-developmental by default, and requirements in the early stages of that acquisition were less risky. It would appear that Harvest HAWK has adopted this as a best practice to reduce and manage risk. In fact, risks were just displaced elsewhere. They emerged when the Marine Corps began piecing existing systems together and creating new interactions for which the sub-systems had not been designed.

Difficulties aside, analysis indicates best practices for the management and assessment of risk exist, but they should be evaluated for their fit with the specific objectives and challenges of an SoS acquisition effort and its unique sub-systems and interactions.

A New Model of Systems-of-Systems Acquisitions

By combining the results of its case study analysis with the themes gathered through the primary research interviews, CSIS developed the acquisition model presented in Table 1. This model reflects the best practices described earlier in this report.

Table 1. Best Practices in Systems-of-Systems Acquisition

Governance Attributes	Program Characteristics
Level of organizational focus	• Program-level focus supplemented by overarching enterprise-level governance and short authority chains
Decision-making authority	• Stakeholders are given relative autonomy to make systems-level decisions based on standards and common operating environments installed at the enterprise level • A central governance oversight body holds auditing and enforcement powers in order to maintain commitment to systems-of-systems core objectives
Enforcement	• Enterprise-level authorities maintain ability to review and revise gate decisions as sub-systems evolve and needs change • Clear, systems-specific reporting requirements are established based on technological maturity and projected development schedules to support enforcement authority
Integration of functional end-user needs	• Kit-based, modular systems allow timely integration of end-user needs and changes in the external environment • End-users are encouraged and empowered to develop their own sub-systems solutions in compliance with established SoS standards
Workforce	• Systems-level technical workforce includes recent or one-time end-users in order to create greater symmetry between end capability and changing user needs • SoS-level technical workforce is small and agile to avoid parochial interests • Lean but dedicated programmatic workforce to create and support technical expertise
Incentive structure	• Uses budgetary and personnel levers to foster mission commitment and compliance with established standards • Low barriers to the entry of new technologies and the innovation of existing solutions
Knowledge ownership/ access to knowledge	• Leadership shows sensitivity to the wide range of information-handling capacity and ability of different stakeholders throughout an organization to manage and understand information • Leadership also campaigns to accommodate those stakeholder entities with lower information-handling capacity and ensure their interests are also incorporated into the information feedback loop • Standards and network backbones are freely shared amongst stakeholders to encourage user-level innovation and collaboration
Risk assessment/risk management	• Critical technologies are highly mature and commercial off-the-shelf (COTS) where possible • Clear, measurable metrics are established to monitor less mature technologies and changes in the external environment

Concluding Thoughts and Topics for Further Research

The research and analysis presented in this abridged version and explored in the associated CSIS technical report represent an important contribution to DoD efforts to improve its performance in delivering large, capable defense systems. This is a critical need for the nation’s defense planners and acquisition leaders. Downward budget pressure is likely to continue into the foreseeable future, and the threats are becoming more complex due to the increasing pace of global technological change and democratization of the means to inflict harm. Both of these pressures demand more robust governance for SoS acquisition.

Additional research is necessary to refine the proposed governance model, test its theoretical impact on acquisition efforts through desktop systems modeling and simulation exercises, and observe its applicability to other challenges related to complexity. Subsequent research might attempt to answer the following pressing topics:

- Can exceptional performance in enabling attributes make up for poor performance in the three critical attributes?
- What human capital planning helps ensure success in the three critical attributes, especially decision-making authority?
- How can the governance framework be applied to other complex problems, such as battlefield command and corporate governance?
- What quantitative modeling methods can be used to predict attribute shortfalls and simulate acquisition success and failure scenarios?

These topics represent only a few areas of interest for further research. Additional research would apply successes in complexity research from other disciplines to the challenge of mapping complex acquisition efforts and forecasting mission success.

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