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SYSTEM OF SYSTEMS DEVELOPMENT FOR THE DoD: TAILORING ACQUISITION REFORM FOR EMERGING NEEDS

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When the Defense Acquisition Performance Assessment (DAPA) panel proposed sweeping reforms to address long-standing problems in defense acquisition, their recommendations did not anticipate critical challenges expected in the development of a System of Systems (SoS). Defense leaders counting on revolutionary SoS capabilities must appreciate that current and proposed acquisition systems insufficiently facilitate SoS development. This article describes the importance of adapting defense acquisition processes to enable effective SoS development and concludes with proposed modifications to the DAPA Report recommendations. Tailoring defense acquisition organization, budgeting, and requirements generation systems to overcome the challenges of SoS acquisition will be essential for tomorrow's military systems to realize their potential.

Decades of efforts to improve defense acquisition processes have made a cliché of the term "acquisition reform." Given this history, few in the acquisition community were surprised when Deputy Secretary of Defense Gordon England ordered a comprehensive assessment of Department of Defense (DoD) acquisition processes (England, 2005). However, the expansive scope Secretary England authorized for this review signaled a desire to examine the problem more holistically. His request for an approach examining "every aspect" of acquisition contrasted with many previous reform efforts that focused primarily on internal defense acquisition community issues.

Authorizing such a comprehensive approach acknowledged a past tendency to underestimate the effects of complex interactions among acquisition personnel and

other stakeholders in requirements generation, oversight, and financial management roles. The panel answering Secretary England's request met his challenge, providing an all-encompassing assessment of defense acquisition and proposing sweeping systemic reforms in its January 2006 *Defense Acquisition Performance Assessment (DAPA) Report*. If implemented, the *DAPA Report*'s key recommendations will fundamentally alter the DoD acquisition framework.

Given many current defense acquisition problems, it was natural for the DAPA assessment panel to focus primarily on observations within today's environment. However, plans for defense transformation portend difficulties that may significantly aggravate the acquisition problems experienced within DoD. In particular, plans to leverage technology to build flexible and integrated "systems of systems" will prove especially challenging.

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This article examines some misconceptions associated with system of systems (SoS) acquisition and proposes refinements to tailor the *DAPA Report* recommendations to better address these challenges. To do this, it briefly describes the defense acquisition framework to place reform efforts in context; and then shows how DoD plans demonstrate the intent to rely on advanced technological solutions, such as system of systems. This approach, while conceptually appealing, presents significant problems to the acquisition community.

One of these hurdles is the need to accept a more realistic viewpoint regarding the maturity of System of Systems Engineering (SoSE). The *Defense Acquisition Guidebook (DAG*, 2006, p. 100) begins a definition of SoSE as "planning, analyzing, organizing, and integrating the capabilities of a mix of existing and new systems into an SoS capability greater than the sum of the capabilities of the constituent parts." The *DAG* description of SoSE goes on to acknowledge the inherent complexities of this emerging discipline.[1] However, because traditional tools such as Systems Engineering (SE) have been monumentally successful in defense acquisition, there is a strong belief that SE is easily adaptable to SoS development. While SE has proven indispensable for development of enormously complex systems, the emerging demands of SoSE will likely outstrip SE's utility.

When the *DAPA Report* and the challenges of SoS development are considered together, it becomes clear that the DAPA panel's recommendations only partially address concerns that complicate SoS development. To facilitate SoS acquisition for defense needs, this article concludes with suggestions to better align the *DAPA Report* recommendations with DoD plans.

THE DEFENSE ACQUISITION FRAMEWORK: UNDERSTANDING THE SCOPE OF REFORM

Determining exactly *what* is being discussed assumes particular importance in defense acquisition because—depending on context and audience—the term "acquisition" is used to describe different constructs. Particularly important for this paper are two distinct perspectives that are commonly distinguished by the terms "little a" and "big A" acquisition.[2]

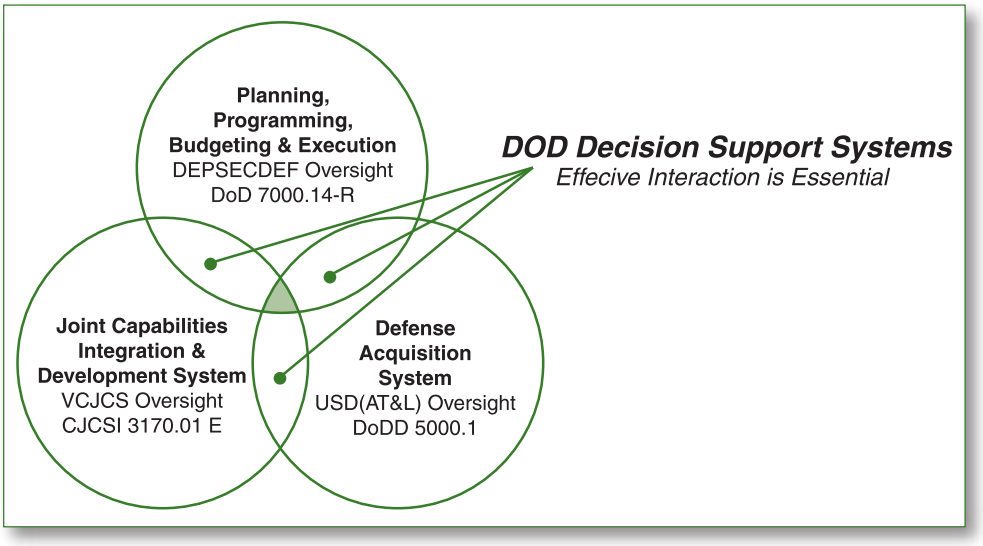
"Little a" vs. "Big A": The Defense Acquisition Framework Through Two Lenses

"Little a" acquisition describes the activities that occur within the Defense Acquisition System (DAS). Typically, factors such as cost, schedule, performance, and risk concern DAS participants as they work to develop actual systems. However, two additional and distinct decision support systems specify warfighter requirements and provide funding.

The Joint Capabilities Integration and Development System (JCIDS) is used to define and generate requirements. Resources are managed through yet another process that coordinates cost estimating and funding activities, known as Planning, Programming, Budgeting and Execution (PPBE). The triumvirate of DAS, JCIDS, and PPBE is intended to establish an integrated defense acquisition, technology, and logistics (AT&L) life cycle management framework (IFC, 2005). The term "big A" usually refers to this larger framework of three interconnected and interlinked acquisition systems (Figure 1).

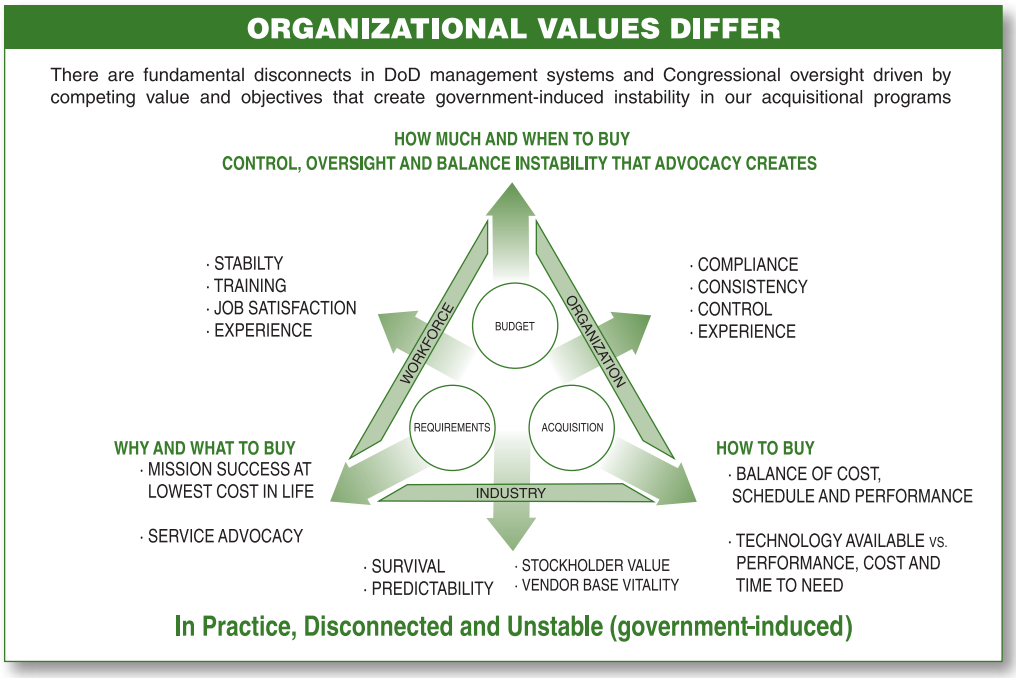
Observers of defense acquisition processes increasingly emphasize the importance of understanding problems that arise from interrelationships, interdependencies, and conflicts among these three systems. The need to harmonize different perspectives, interests, and objectives across the framework presents a fundamental defense

FIGURE 1. THREE INTERACTING SYSTEMS IN "BIG-A" ACQUISITION



acquisition challenge. However, critics sometimes question the effectiveness and feasibility of such cooperation. The *DAPA Report* (2006) focuses on this very point, characterizing current relationships as uncoordinated, fragmented, disconnected, and unstable. Furthermore, the *DAPA Report* paints a picture of even more complex stakeholder interactions, expanding the notion of "big A" to include the acquisition workforce, organizations, and industry (Figure 2).

FIGURE 2. DAPA PANEL VIEW OF ACQUISITION FRAMEWORK



DEFENSE ACQUISITION: A SYSTEM UNDER CONTINUAL REFORM

Previous observers have made similar observations of dysfunction in the "big A" framework. Notably, the landmark "Culture Report" (GAO, 1992) highlighted deep conflicts among the three decision support systems. However, these structural problems were overlooked in subsequent reform efforts in favor of more palatable, incremental changes.

The futility of such small-step acquisition reform has become increasingly apparent. The *DAPA Report* (2006) documents seven successive acquisition reform initiatives attempted since 1992. Most of these focused on process improvement within the DAS, rather than structural changes. Thus, despite well-intentioned goals of reducing costs, accelerating schedules, and better defining requirements, previous reforms have produced limited results.

THE DAPA PANEL: A BROAD MANDATE ENABLES A BOLD APPROACH

The comprehensive assessment that Secretary England requested from the DAPA panel offers an opportunity to break this cycle. Opening the examination to all aspects of acquisition, the three decision support systems were considered as an interacting system. Reporting from this broad perspective, many *DAPA Report* (2006) findings echo similar observations to those found in GAO's Culture Report.

As noted in the Culture Report, the DAPA panel uncovered incompatibilities in behavior that emerged from divergent organizational values. Differences in values stem from inconsistencies among governing instructions, driving factors (i.e., need-based, calendar-based, or event-based), stakeholder interests, and distinctions in organizational cultures. Observing these problems, the DAPA panel's findings criticize the most fundamental elements of acquisition: organization, workforce, budget, requirements, acquisition processes, and industry's role.

Several of the recommendations from the *DAPA Report* (2006) are discussed in a later section of this article. However, a major finding of the DAPA panel sets the stage for a discussion of DoD plans to employ systems of systems in the future: "strategic technology exploitation is a key factor that allows the U.S. to maintain dominant military capabilities" (p. 7). This finding is consistent with overarching guidance for defense transformation as well as multiple roadmaps that establish systems of systems as fundamental building blocks of tomorrow's forces.

ADVANCED TECHNOLOGY FOR DoD TRANSFORMATION: THE RELEVANCE OF SoS DEVELOPMENT

Improved U.S. military capabilities are invariably linked to advanced technology. Planning documents reveal high expectations for concepts such as transformation, network-centric operations, and adaptive systems of systems. However, bringing these concepts to fruition presents daunting challenges to an acquisition system that strains to provide affordable and timely capabilities to warfighters today.

DEFENSE TRANSFORMATION: CONTINUED STRESS ON THE ACQUISITION SYSTEM

Commitment to leveraging advanced technology is signaled throughout the defense establishment. The Secretary of Defense establishes networking as a cornerstone of military transformation in the *National Defense Strategy* by stating, "The foundation of our operations proceeds from a simple proposition: the whole of an integrated and networked force is far more capable than the sum of its parts" (OSD, 2005, p. 14). Uniformed leaders echo this approach. The *National Military Strategy* provides a typical example, describing the desired Joint Force as "fully integrated, networked, decentralized, [and] adaptable" (CJCS, 2004, p. 15).

Furthermore, Service plans flesh out these concepts, attributing robust capabilities to fully networked, interoperable, and adaptive systems of systems. The Air Force's

vision provides a highly optimistic example: "With advanced integrated aerospace capabilities, networked into a system of systems, we'll provide the ability to find, fix, assess, track, target, and engage anything of military significance anywhere" (USAF, 2002, p. 6).

Beyond providing state-of-the-art military capabilities, planners also envision future meta-systems as completely and flawlessly interoperable. One example is found in the USAF *Transformation Flight Plan* (2004, p. 69), which promises "a joint fire control system of systems that enables the Joint Force Commander to seamlessly across the sensor-to-shooter assets of all the Services, put a cursor over a target in a timely manner."

The difficulties experienced to date highlight the need to reconcile substantially differing opinions.

Conceptually, the acquisition community has also embraced SoS development as essential for meeting future military needs. Commitment to this principle is reflected in guidance that links success in defense transformation to "network-centric operations and on individually complex systems linked together in complex systems-of-systems" (DAG, 2006, pp. 170-171). Yet initial systems of systems development efforts suggest the need for new methodologies (Zenishek & Usechak, 2005; Brown & Flowe, 2005; Luman & Scotti, 1996). The difficulties experienced to date highlight the need to reconcile substantially differing opinions regarding the distinctions between an SoS and a highly complex system.

CONFLICTING APPROACHES TO SOS DEVELOPMENT

Capabilities projected for the technologically superior force of the future require interoperability that eclipses the state-of-the-art. Descriptions of future meta-systems imply astonishing utility and flexibility with promises of "multiple autonomous embedded complex systems that can be diverse in technology, context, operation, geography, and conceptual frame" (Keating et al., 2003, p. 41). Most important, transformation proponents envision these interlinked meta-systems providing capabilities far exceeding those of their individual components. This important aspect of an SoS—exponentially complementary capabilities—is the basis of proposals to develop affordable yet tremendously capable military forces centered on adaptive systems of systems.

Many voices in the defense acquisition community assert that the discipline of Systems Engineering is adequate for SoS development. However, findings of re-

searchers who study System of Systems Engineering raise serious questions about this position. These experts believe that the immaturity of SoSE warrants reexamination of basic assumptions regarding the ability of SE to underpin SoS development.

SYSTEMS ENGINEERING: UTILITY AND FUTURE APPLICABILITY TO AN SOS

Because the discipline of Systems Engineering is central to defense acquisition, adherents are enthusiastic about its continued validity for SoSE. Deep commitment to SE principles is reflected in high-level direction that requires all acquisition programs to be "managed through the application of a systems engineering approach" (OSD, 2003, p. 7). The *Defense Acquisition Guidebook (DAG*, 2006) fleshes out this mandate, providing a chapter dedicated entirely to SE.

In its SE chapter, the *DAG* (2006) recommends a "robust systems engineering approach" for all programs "regardless of acquisition category" (p. 21). To facilitate this, the *DAG* details SE's best practices, providing guidance on technical and management processes to be applied throughout a program's life cycle. This wholesale confidence results from decades of successful application of SE principles in developing systems of staggering complexity.

Having demonstrated enormous utility for complex development efforts, SE seems ideally suited for the interconnected systems envisioned for the future. Thus, the *DAG*'s (2006) recommendation of SE for SoS development is unsurprising: "Systems of systems should be treated and managed as a system in their own right, and should therefore be subject to the same systems engineering processes and best practices as applied to individual systems," (p. 100).

The Under Secretary of Defense for Acquisition, Technology and Logistics (USD[AT&L]) underscores this guidance in a policy memo specifically addressing SE's central role for SoSE efforts:

> Application of rigorous systems engineering discipline is paramount…. This is especially true as we strive to integrate increasingly complex systems in a family-of-systems, system-of-systems context. Systems engineering provides the integrating technical processes to define and balance system performance, cost, schedule, and risk (Wynne, 2004).

However, the Defense Department's ability to apply SE to complex systems has come under scrutiny in recent studies (DoD JDCST, 2004; *DAPA Report*, 2006). The DAG (2006) acknowledges some unique SoS development challenges, calling attention to factors such as "greater complexity of integration efforts" and "engineering under the condition of uncertainty" (p. 100). While these viewpoints reveal a budding understanding of the inherent difficulties in SoS development, the challenges associated with SoS implementation may be more daunting than currently appreciated by acquisition professionals.

SYSTEM OF SYSTEMS ENGINEERING: BEYOND ADAPTATION OF TRADITIONAL SE

Stakeholders in government and academia have begun to recognize fundamental differences between the disciplines of SE and SoSE. To develop and apply appropriate SoSE methodologies for the DoD, a System of Systems Engineering Center of Excellence (SoSECE) has been established under the auspices of the USD(AT&L). This organization has coordinated several SoSE conferences as has the Institute of Electrical and Electronics Engineers (IEEE). However, the distinctions between SE and SoSE are not yet widely appreciated. Experts at the National Center for Systems of Systems Engineering describe some of these differences in a seminal paper that characterizes SoSE maturity "in the embryonic stages of development" (Keating et al., 2003, p. 36). To frame a discussion of the dissimilarities between SE and SoSE, these authors consider eight significant areas of distinction: Focus, Objective, Approach, Expectation, Problem, Analysis, Goals, and Boundaries.

Decisions intended to alleviate one problem often carry unintended consequences that aggravate others.

Many of these differences apply directly to SoS acquisition in the DoD. Keating et al. (2003) argue that SoSE requires a fundamental shift in focus from the development of individual systems to the integration of multiple complex systems. Furthermore, Keating et al. describe the importance of methodology-based rather than process-based approaches for SoSE. While DoD has made significant progress in improving interoperability, current organizational structures are optimized for acquisition of single—albeit highly complex—systems through process-based approaches. Shifting cultural norms to reflect a focus and approach compatible with SoS development would suggest significant organizational adaptation.

Similar changes will be required to efficiently budget for SoS development efforts. Keating et al. (2003) demonstrate the importance of flexible system boundaries and pluralistic system goals in SoSE. However, these principles contrast sharply with current practices and standards that segregate acquisition funds by solid boundaries and unitary program goals. Thus, adapting the PPBE system to cope with these SoS characteristics will become increasingly important.

Generating appropriate requirements for an SoS will also require a different approach. The JCIDS operates most effectively when problems are clearly defined, expected capabilities are linked to system characteristics, and overarching objectives can be met by optimizing performance within cost and schedule guidelines. SE provides an ideal analytical framework for this JCIDS construct. In contrast, effective SoS development requires a radically different requirements paradigm that describes

"emergent" rather than defined behaviors, provides "satisfying" rather than optimizing criteria, and defines "initial responses" rather than final solutions (Keating et al., 2003, p. 40). Therefore, requirements generation will require significant cultural and procedural changes to accommodate SoS development.

Although not primarily focused on engineering issues, the DAPA panel expressed pessimism regarding the readiness and competence of DoD systems engineering to support "large-scale integration efforts" (*DAPA Report*, 2006, p. 29). The panel's recommendations address this shortfall and would significantly improve the defense acquisition community's ability to adapt to many future needs. However, tailoring these recommendations to address SoS acquisition could substantially improve DoD's ability to meet its stated goals.

DAPA FINDINGS AND RECOMMENDATIONS: ADAPTING REFORM FOR SOS ACQUISITION

The DAPA Panel returned many recommendations addressing current acquisition shortfalls. However, in three areas—Organization, Budget, and Requirements Generation—the *DAPA Report* (2006) recommendations could be adapted to better prepare the DoD for SoS acquisition.

ORGANIZATION: HEEDING THE DAPA PANEL'S CALL TO BREAK STOVEPIPES AND BARRIERS

In its broad review, the DAPA Panel identifies organizational barriers that hinder efficient program execution. Built around "highly complex" and "fragmented" mechanisms, the acquisition framework produces deeply entrenched and destructive instabilities (*DAPA Report*, 2006, p. 4). Furthermore, organizational problems extend to the highest levels of DoD bureaucracy; the DAPA Panel notes that fragmentation is institutionalized by not connecting "budget, acquisition, and requirements processes … at any level below the Deputy Secretary of Defense" (p. 24). Effectively segregated into discrete communities, stakeholders act without appreciating consequences in a broader organizational context. As a result, decisions intended to alleviate one problem often carry unintended consequences that aggravate others.

DAPA's Recommendation on Organization. The DAPA panel addresses dysfunctional relationships by proposing a fundamental reorganization to the "big A" framework. The *DAPA Report* (2006) recommends that each Service establish a four-star Acquisition Systems Command (ASC) to consolidate and integrate budget, acquisition, requirements personnel, and responsibilities. However, this approach might complicate efforts to coordinate acquisition of SoS programs with joint participation.

Organizational Problems Specific to SoS Acquisition. Consolidation of acquisition efforts within ASCs would represent an important step in overcoming cultural barriers. However, the proposal to vest this power in Service systems commands

would retain—and perhaps raise—barriers that separate individual Services. These barriers could present especially thorny problems for program managers (PMs) attempting to integrate SoS components across Service lines.

Achieving SoS interoperability requirements will require extensive ongoing coordination among developers of each component system. This coordination will only be possible within an organizational structure where a wide spectrum of cost, schedule, risk, and requirements trade-offs between component programs can be resolved. Weighing appropriate tradeoffs will be especially difficult when developers face the tremendously difficult—and poorly understood—challenge of integrating systems in various stages of maturity into a SoS. Current and proposed organizational systems simply lack the mechanisms to effectively and objectively carry out such complex assessments.

To capitalize on the promise of technological superiority offered by an SoS, developers must work within an organizational construct that fosters the emergence of complementary capabilities. The DAPA panel's recommendation to consolidate development, budgeting, and requirements functions could represent an important

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first step toward streamlining acquisition efforts, but inter-Service tensions in joint SoS programs will still exist. While PMs are certainly encouraged to perform this coordination independently, they simply lack the incentives, time, and information to do so effectively.

In some cases, Joint Program Offices (JPOs) could provide oversight for such coordination. However, JPOs incur substantial bureaucratic burdens. As systems of systems proliferate in coming years, more efficient, streamlined, and effective organizational models for joint SoS development will become essential.

The organizational structure proposed by the *DAPA Report* (2006) should be amended to clearly delineate mechanisms to facilitate inter-Service cooperation in programs with extensive joint equities, such as an SoS. One such model would assign SoS sponsorship to a lead Service. Today, acquisition sponsors assume responsibility for "all common documentation, periodic reporting, and funding actions" (CJCS, 2005, A-6). Consolidation (and expansion) of these functions for an SoS could overcome many coordination problems if a Program Executive Officer (PEO) or PM were appropriately empowered. Because this approach might be controversial within the DAPA panel's proposed Service-based ASC organizational structure, provisions

for leadership and sponsorship of joint SoS development efforts should be clearly articulated in acquisition restructuring plans.

BUDGET: EMPOWERING THE SPONSOR OF A SYSTEM OF SYSTEMS

Consolidating SoS development efforts in one organizational structure would offer the potential to perform limited budget trade-offs among component systems as priorities changed. However, implementing budget changes that could support an integrated plan to develop and introduce SoS capabilities would require more disciplined and flexible resource management than is typically demonstrated in DoD acquisition programs.

The *DAPA Report* (2006) reaffirms the existence of fiscal challenges described in many prior defense acquisition studies. However, most previous surveys focused on "little a" acquisition issues. Thus, while many prior criticisms addressed legitimate problems, some of these were symptoms of systemic flaws in the "big A" framework. The *DAPA Report* (2006) employs a wider scope to describe how interactions of the three defense acquisition decision support systems destabilize budgets.

DAPA's Recommendation on Budget Stability. To improve budget stability, the *DAPA Report* (2006) recommends establishing a Stable Program Funding Account (SPFA) for Acquisition Category I (ACAT I) programs. Programs in an SPFA would be protected against the cascade of unintended consequences flowing from budget reprioritizations. However, providing such a buffer would depart dramatically from traditional resource management processes and significantly alter entrenched power relationships.

Acknowledging the political difficulties of instituting such fundamental change in budgeting, the *DAPA Report* nonetheless focuses its SPFA recommendation on programs with the largest capital expenditures. While the *Quadrennial Defense Review Report* offers strong support for the SPFA concept, Congress may be reluctant to forego its traditional oversight of ACAT I programs (OSD, 2006). Instead, selecting a "test-bed" program that would derive great benefits from budget stability might provide a more politically realistic strategy to introduce SPFAs and generate congressional confidence in the concept. An SoS development effort offers great potential for such an initiative because the shifting boundaries and goals in SoS component systems will tend to be especially destabilizing to their budgets.

Budget Problems Specific to SOS Development. The current defense acquisition system typically rewards managers capable of obligating and expending resources that were planned years in advance. Changes in resource requirements, either above or below the appropriated level, are viewed as problems and quickly attract unwelcome scrutiny. PMs of SoS components will face aggressive oversight and burdensome inquiries if their budgets demonstrate instabilities.

However, the inherent characteristics of a SoS will likely produce less stable budgets. Division of programs into individual budget line items tends to emphasize unitary goals, as opposed to the pluralistic goals of an SoS. Even if a single sponsor were empowered to balance limited SoS resources across an array of component systems, this authority would probably be insufficient to compensate "for sudden and potentially dramatic shifts in system boundaries" that require corresponding resource shifts (Keating et al., 2003, p. 41). Furthermore, Keating et al. emphasize that budget-

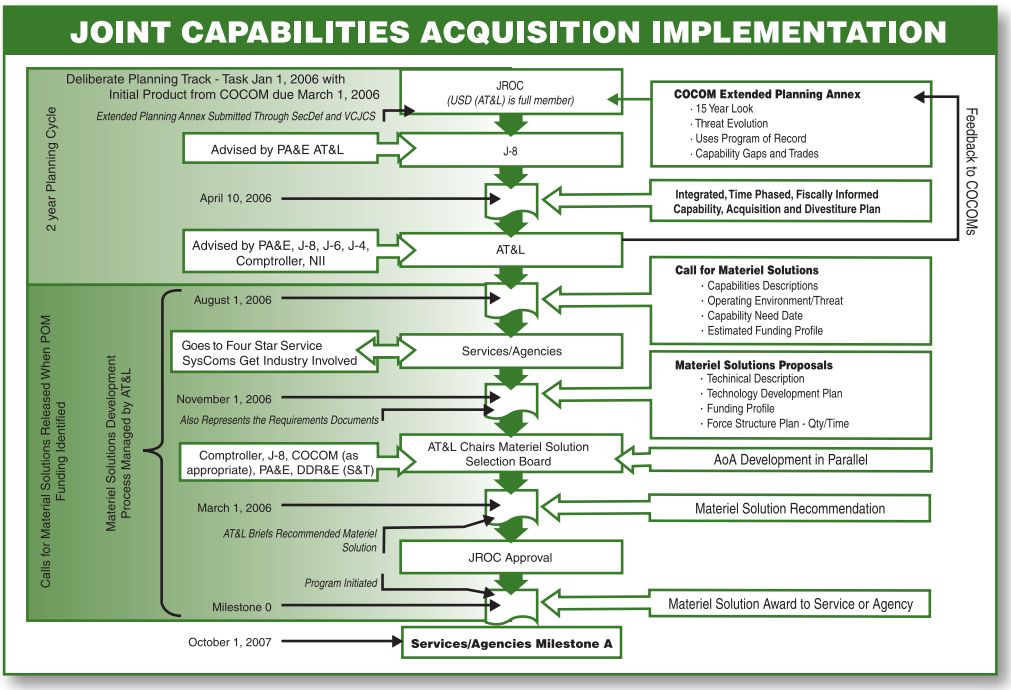
ing methodologies to operate and maintain systems of systems "once they have been fielded are scarce" (p. 43).

Given these destabilizing budget pressures, SoS acquisition will face daunting challenges in the PPBE system. This burden may aggravate resourcing tensions between component systems and jeopardize system-wide development efforts. A reasonable and effective solution for this problem would be to introduce the DAPA Panel's SPFA concept in an SoS, empowering its lead sponsor to manage budget trade-offs across the spectrum of component systems.

REQUIREMENTS: DISCIPLINE AND FLEXIBILITY, STRIKING A BALANCE IN AN SOS

As in resourcing, the DAPA panel also discovered instabilities in requirements generation that were rooted in differing organizational values. Less inclined to scrutinize details of program management and funding, requirements writers mandate "systems that are technologically unrealistic or unable to be delivered [on time]" (*DAPA Report,* 2006, p. 5). Furthermore, the *DAPA Report* describes how extended development timeframes destabilize system requirements due to the need to adapt to evolving operational environments, military priorities, acquisition rules, and overarching policies. Overall, the DAPA panel found little to recommend in the JCIDS, characterizing the system as cumbersome, overly complex, and unsuitable for continued use.

FIGURE 3. DAPA JOINT CAPABILITIES ACQUISITION AND DIVESTMENT PROCESS AND IMPLEMENTATION PLAN



DAPA's Recommendation on Requirements. The DAPA Panel recommended scrapping JCIDS to implement a new system (Figure 3). Its report suggests an alternative Joint Capabilities Acquisition and Divestment (JCAD) planning system that would streamline and simplify processes to "enhance requirements stability" (*DAPA Report*, 2006, p. 44). However, features of the JCAD plan that emphasize a more linear approach and increased inter-Service competition might interfere with effective SoS requirements generation.

The JCAD system would expect the Joint Staff Director for Force Structure, Resources and Assessment (J-8) to develop an "integrated, time-phased, fiscally informed capability, acquisition, and divestiture plan" (*DAPA Report*, 2006, p. 39). The USD(AT&L) would then use the J-8 plan to invite competing proposals for material solutions from the Services. While this procedure could significantly improve requirements generation for many programs, it could introduce counterproductive tensions for integrated SoS development.

REQUIREMENTS PROBLEMS SPECIFIC TO SOS DEVELOPMENT

Developing requirements for a complete SoS will likely require a fresh approach. Most critics of the JCIDS rightly criticize its inability to stabilize requirements. However, proposals to introduce additional discipline in requirements generation fail to address the expected challenges of SoS development. Instead, SoSE experts emphasize the need for increased flexibility to cope with SoS complexities.

Developing requirements for a complete SoS will likely require a fresh approach.

The description of SoS development published by Keating et al. (2003) suggests elements of a new approach. At inception, one must "proceed with the assumption that the initial problem definition or mission is always incorrect or suspect" (p. 43). Additionally, requirements for SoS components will be difficult to articulate as "increasing information intensity, contextual richness, and problem complexity all contribute to the need for evolving systems engineering to address emergent complex systems problems" (p. 40). In essence, SoSE requires adaptation to changing requirements beyond what current acquisition processes allow.

The proposed JCAD system does not provide an effective construct to address these complexities. As described in the *DAPA Report* (2006), JCAD processes are linear and sequential. This process is ideally suited for easily described capability needs, but will not facilitate an appreciation for complex component system interactions that contribute to SoS system capabilities.

SoSE experts envision future requirements generation as a fluid process, capable of coping with shifting environments. Accordingly, SoS requirements must provide for flexibility in parameters and boundaries. Because overall SoS performance results from complex component system interactions, the J-8's ability to produce an "integrated, time-phased, fiscally informed capability, acquisition, and divestiture plan" (*DAPA Report*, 2006, p. 39) that captures SoS capabilities is questionable. Instead, the J-8 should describe SoS requirements more holistically. The proposed JCAD system could accommodate such an approach by emphasizing overarching capabilities and architectures, rather than traditional program proposal elements such as system technical descriptions, delivery profiles, and production quantities.

Furthermore, the JCAD process pits Services against one another to compete for material solutions. This competition would hinder development and integration of SoS components across Service boundaries. As the JCAD process is currently envisioned, Services competing to develop SoS components would lack incentives to prioritize capabilities that enhanced other Services' needs. SoS development in this parochial manner would quickly degenerate into inefficient parallel engineering of systems that might form a loosely interoperable system, but would remain a far cry from the capabilities that integrated SoSE could achieve.

Several modifications to the proposed JCAD could tailor its processes to better support SoS requirements generation. First, because SoS development must be flexible and iterative, the J-8 should describe the incremental value desired for new SoS (or particular component) capabilities rather than attempt to create an integrated, time-phased capability plan prior to program inception. Second, material solutions proposals for SoS components should broadly describe capabilities and integrating architectures instead of specific technical descriptions and force structure proposals. Finally, inter-Service competition should be based on selecting the best leader for SoS integration efforts. This approach would facilitate joint cooperation on proposals, establishing a more collaborative atmosphere for SoS development.

CONCLUSION—RECOMMENDATIONS TO TAILOR REFORM

Decades of unsuccessful reforms have frustrated generations of professionals seeking to fix defense acquisition through incremental improvements. The DAPA panel proposes to break this pattern with a sweeping reform plan, actionable recommendations, and an implementation strategy. While these proposals offer significant promise, they do not anticipate critical challenges presented by SoS development.

While defense leadership is counting on SoS capabilities, the current and proposed acquisition systems are ill equipped to facilitate actual development of these systems. To better facilitate SoS acquisition, the following modifications to the DAPA Report recommendations are suggested:

- ***Organization.*** Plans to restructure defense acquisition must incorporate mechanisms to coordinate joint efforts. Assignment of a lead-sponsor to oversee inter-Service collaboration in SoS development would support this goal.

- ***Budget***. Efforts to stabilize acquisition budgets, such as the SPFA, should be introduced in an SoS development program. This arrangement would empower an SoS lead-sponsor to make trade-offs among component systems.
- ***Requirements Generation.*** The proposed JCAD processes should be tailored to three specific guidelines:
  a) Focus SoS requirements on incremental capability needs and architectures instead of detailed technical descriptions.
  b) Encourage earlier joint cooperation on SoS material solutions.
  c) Use competition to select SoS lead-sponsorship instead of Service-specific material solutions for SoS components.

Incorporating these ideas in today's defense acquisition reforms would help catalyze transformations in the acquisition workforce needed for SoS development and significantly improve the likelihood that tomorrow's systems will realize their potential.

DISCLAIMER

The views expressed in the article are the author's and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

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ENDNOTES

1. SoSE is a top-down, comprehensive, collaborative, multidisciplinary, iterative, and concurrent technical management process for identifying system of systems capabilities; allocating such capabilities to a set of interdependent systems; and coordinating and integrating all the necessary development, production, sustainment, and other activities throughout the life cycle of a system of systems. The overall objective for developing a system of systems is to satisfy capabilities that can only be met with a mix of multiple, autonomous, and interacting systems. The mix of constituent systems may include existing, partially developed, and yet-to-be-designed independent systems (DAG, 2006, p. 100).

2. Many variations of the "little a" vs. "big A" terminology can be found, but nearly all represent the same basic principle discussed here.