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AoAs: Toward a More Rigorous Determination of Scope

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Panel 20. Enabling Affordable Programs Through Informed Early Decisions

Thursday, May 15, 2014	

3:30 p.m. – 5:00 p.m.	**Chair: Michael McGrath,** Vice President, Systems & Operations Analysis, Analytic Services Inc.
	
	AoAs: Toward a More Rigorous Determination of Scope
	    George Thompson, Analytic Services Inc.
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	    John Yuhas, Analytic Services Inc.
	
	Effectiveness of Competitive Prototyping and Preliminary Design Review Prior to Milestone B
	    William Fast, Naval Postgraduate School
	
	Valuation of Capabilities and System Architecture Options to Meet Affordability Requirement
	    Ronald Giachetti, Naval Postgraduate School

Analyses of Alternatives: Toward a More Rigorous Determination of Scope

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Abstract

Analyses of alternatives (AoAs) play an important part in the acquisition process. The act of selecting a set of alternatives to be compared in an AoA can help decision-makers understand and manage key tradeoffs—or it can prematurely constrict or otherwise distort the solution trade space. It is fairly easy to point to completed AoAs as evidence that many of them have been poorly scoped. But it is much more difficult to spot the problem in real time—or to keep it from occurring at all.

This report identifies four principles designed to help minimize the occurrence of poorly scoped AoAs. These four principles were arrived at by applying formalisms from the disciplines of systems analysis and systems thinking, in combination with a series of semi-structured interviews with members of the AoA stakeholder community (consumers, sponsors, practitioners, and critics).

The principles may be summarized, in systems terminology, as Focus on Outputs and Think Backwards; Start With the Exterior and Work Inwards; Apply Constraints Carefully; and Iterate and Reduce Uncertainty. The report translates these principles into practical terms that can be understood and applied by AoA stakeholders.

Introduction

Background

Within the framework of the Defense Acquisition System (DAS), an analysis of alternatives (AoA) "assess[es] the potential materiel solutions to satisfy the capability need documented in [an] approved" initial capabilities document (ICD; USD[AT&L], 2008, § 4.c.5). Conducted ad hoc during the 1970s and '80s under the label of cost and operational

effectiveness analysis (COEA), this type of assessment has been an important feature of the acquisition landscape ever since a major revision in the Department of Defense (DoD) 5000-series regulations in 1991 (USD[A], 1991; Balut et al., 2004).[1]

Arguably, this emphasis has proved to be a mixed blessing over the years. On the one hand, the "formality and inevitability" of AoAs has helped guard against the potential for premature selection of a preferred alternative (Smith & Thompson, 1995, p. 11). However, the very complexity of the process has also made it prone to start-up delays, which, when combined with the pressure for timely decisions, leads to the seemingly inevitable result that "the time for actual analysis compresses" (Smith & Thompson, 1995, p. 14). Something has to give, and a common practice has been to narrow the AoA scope (for example, by constraining the set of alternatives).

Complicating the problem of AoA scoping has been a steady pressure to make the rigorous comparison of alternative solutions a mandatory step that occurs earlier and earlier in the acquisition timeline. The 1996 revision of the DoD 5000 series formalized the requirement for AoAs to be performed before Milestone B (program initiation; USD[A&T], 1996a; 1996b). And the 2003 revision—which was accompanied by the introduction of the Joint Capabilities Integration and Development System (JCIDS)—included, for the first time, a requirement for AoAs to be conducted during the Materiel Solution Analysis phase, that is, prior to Milestone A (USD[AT&L], 2003a; 2003b).[2] The earlier the AoA, the wider the set of potential alternatives (see Figure 1) and the more disparate they are. As a result, it is more difficult to decide which of them should be considered in the assessment.

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[1] DoD 5000.2-M (USD[A], 199) contains detailed guidance for conducting and documenting these analyses. Balut et al. (2004, p. 19) presented a chronology from a cost-analysis perspective and emphasized the importance of the 1991 revision.

[2] The requirement for functional area, functional need, and functional solution analysis spelled out in the CJCS 3170 series of instructions in 2003 can be interpreted as a desire to push this process even further to the left, so to speak, on the timeline. Interestingly, Smith and Thompson (1995) had eight years earlier argued the case for "put[ting] the initial [AoA] into the time normally reserved for 'requirements analysis'"—or, at the least, "import[ing] some of the attributes of [an AoA] into the requirements analysis process that already takes place" (p. 15).
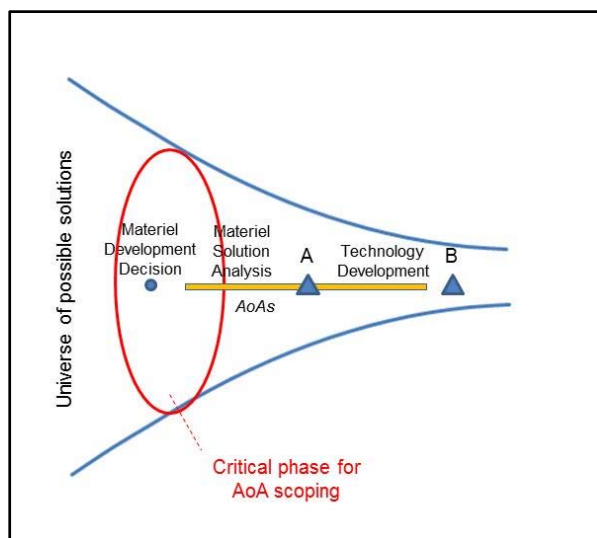
Figure 1. **AoA Scoping in the Context of DAS Phases and Milestones**

Evidence of a Problem

Unfortunately, there is evidence that the AoAs have not always been properly scoped. In 2009, the Government Accountability Office (GAO) reviewed 32 major DoD acquisition programs, 22 of which had included a formal AoA. Of these, 13 AoAs—more than half—were characterized as overly "narrow [in] scope" in the sense that they "focused on a limited number of alternatives" (GAO, 2009, pp. 7, 9). Moreover, there was a strong correlation between AoAs with a narrowly scoped set of alternatives and the occurrence of cost growth in the ensuing programs (GAO, 2009, pp. 10–12).

More anecdotally, it has been common in the authors' experience to hear AoAs described as being scoped around a predetermined solution. ("By the time you reach the Materiel Development Decision [MDD], someone has already decided what the solution is going to be" [see Husband & Kaspersen, 2012, p. 9; Smith & Thompson, 1995, p. 11]). To the extent this is true, the AoA becomes a square-filling exercise or, at best, a process of exploring minor embellishments around a particular type of technology, weapon, platform, or piece of equipment. The potential to conduct a wide-open look at alternative technology solutions is lost.

2009 WSARA and Other Reforms

The Weapon Systems Acquisition Reform Act (WSARA) of 2009 included important changes designed in part to address this problem. A major change in governance was the designation of the director, cost assessment and program evaluation (DCAPE)—a Senate-confirmed position—as responsible not only for formulating AoA guidance but also for the performance of the analysis. This responsibility includes the authority to reject or redirect an AoA.

WSARA (2009) specifies that the AoA study guidance promulgated by the DCAPE should ensure the "full consideration of possible trade-offs among cost, schedule, and performance objectives." By implication, "proper consideration of tradeoffs includes ensuring … that a range of sufficiently different alternatives are examined" (Husband & Kaspersen, 2012, p. 9).

To help discharge these responsibilities during AoA execution, the DCAPE typically establishes a senior advisory group (SAG) that includes the office of the under secretary of

defense for acquisition, technology, and ogistics (AT&L), as well as Joint Staff and Service representatives. In theory, the SAG provides a mechanism for users, analysts, and overseers to adjust AoA scope during execution if necessary.

Implementation of WSARA has been accompanied by a push to shorten AoA timelines. The typical duration of a pre-WSARA AoA has been variously estimated at 16–24 months.[3] In contrast, several stakeholders interviewed for this project cited 6–9 months as the current goal. This shortening of AoA timelines will have significant impacts—both positive and negative—on the problem of AoA scope; these are discussed further in the section titled Why Are Some AoAs Poorly Scoped?

The number of completed AoAs conducted entirely within the post-WSARA timeframe is modest. The consensus within the acquisition community seems to be that it is still too soon to say exactly how the formal realignment of AoA responsibilities, the introduction of the SAG, and the push for dramatically shorter timelines have impacted AoA scoping.

Purpose

This project aimed to identify a set of guiding principles that can be applied by AoA practitioners and sponsors to reduce the incidence of improperly scoped analyses. In particular, we wanted to develop principles that were both (a) grounded in the discipline of systems thinking (see Edson, 2008) and (b) practical, in the sense that they can be readily understood and applied.

In striving for more rigor, the authors are not proposing to remove all subjectivity or sense of "art" from the job of scoping an AoA. Rather, we sought a middle ground in which decisions regarding AoA scope can be influenced by considerations more systematic and rigorous than those arising solely from political, bureaucratic, and/or programmatic pressures.

Limitations

This paper is not intended as a guide to conducting AoAs or related studies. Many such guides do exist, and the findings and recommendations presented here are meant to be understood and applied in the context of those references.[4] Similarly, it is assumed that the reader already has a basic familiarity with the DAS and JCIDS processes.

In this paper, the term scope is associated with the set of alternatives. To be sure, there are other dimensions of scope, such as the set of scenarios, assumptions, or study constraints. We considered these other dimensions only insofar as they shape decisions about the set of alternatives.

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[3] Kowal, in 2009, gave an average of two years with up to six years in some cases. At the other extreme, information obtained from stakeholder interviews cited an average of 16 months. By way of corroboration, Lihani (2011) cited USAF Office of Aerospace Studies data on 27 AoAs conducted from 2000 to 2008; the average length was 20 months. Of the 22 AoAs considered in GAO 09-665 (2009), the majority took between 13 and 30 months.

[4] For example, see USAF Office of Aerospace Studies (2010), *AoA Handbook*; Joint Staff Force Structure (2009), *CBA User's Guide;* and DAU (2013), *Defense Acquisition Guidebook*, section 3.3 (Analysis of Alternatives).

Factors such as organizational roles and responsibilities, institutional culture, and even the predilections of individual decision-makers and executives all contribute to the incidence of improper AoA scoping. While acknowledging the importance of such factors, this paper's recommendations do not address them directly.

A Note on Terminology

The word *system* can have many connotations. (Within the opening pages of this paper, for instance, we have already referred to the "acquisition system," the Joint Capabilities Integration and Development System, and the "weapon systems" that may represent alternative solutions to a capability need.) For clarity, the text indicates the specific type of system that is meant in each case. In particular, the ships, aircraft, vehicles, sensors, communications equipment, computers, and so forth that may be the objects of study in an AoA will be collectively referred to as *combat systems or combat support systems* (C/CSSs).

Approach

The first step in applying a systems thinking approach is to understand the nature of the problem (see the following section). Only then can we explore various system views (see section titled Applying a Systems View) and formulate the resulting insights as a set of recommendations (see Recommendations and Observations section) aimed at improving the practice of determining AoA scope.

This approach entailed two broad methods of inquiry and analysis. The first method was to leverage the existing body of knowledge by reviewing available documents (DoD and Service instructions, guidance, and handbooks; published reports and articles; and other publicly available materials) and conducting interviews with stakeholders representing various roles (that is, identifying the capability needs being addressed in AoAs; overseeing the conduct of AoAs; performing AoAs; and reviewing and critiquing completed AoAs). The second method was to apply formal systems thinking paradigms. These two methods were applied in concert and iteratively: more than once we used systems thinking formalisms to gain insights into an issue identified during interviews, and then used subsequent interviews to test the validity of those insights.

All interviews were conducted on a strict non-attribution basis. Statements derived from interviews are substantiated in this report only to the extent of specifying that a particular view was expressed by one, some, several, most, or all interviewees.

The research and analysis presented herein was conducted from May 2013 through January 2014.

Understanding the Problem

So far, we have not specified exactly what it means to say that an AoA is improperly scoped. The following section addresses this key point, followed by a presentation of some important causes of improper AoA scoping, as identified during stakeholder interviews.

What Is a "Poorly Scoped" AoA?

Establishing consensus on this question proved surprisingly difficult. Almost all interviewees, when asked the question directly, preferred to skip over it and proceed straight to a discussion of causes. In some cases, that discussion made it clear how the interviewee was defining the problem; in other cases, it did not.

Guided as we were by a systems viewpoint—including the notion that alternatives represent a set that has a *boundary* (see Analysis of Selected Conceptagon Triplets section)—we consolidated interviewees' implied constructs in the form of two definitions

based on the properties of boundaries. First, an AoA could be "too narrowly scoped" if its boundary excludes alternatives that should be considered. Second, an AoA could be "too broadly scoped" if it includes alternatives that should not be considered.[5]

These definitions, although helpful, still contain more than a little question begging. On what basis, can we say that an alternative "should" or "should not" be inside the AoA boundary? Here, it is important to remember that the purpose of an AoA is to inform a decision about the materiel solution to a capability need. Thus, poor scoping is that which contributes to a poor decision (for example, by excluding a viable alternative that might have been judged preferable under some reasonable weighing of costs and benefits)[6] or otherwise impairs decision-making (for example, by presenting so much information on so many alternatives that it is difficult to make a good choice).

The two types of improper scoping are further discussed below.

Too Narrowly Scoped

Here, one or more viable alternatives have been excluded, inappropriately limiting the solution trade space. The most obvious way to detect this problem is simply to identify one or more of the missing alternatives. If the AoA has not provided a rationale for exclusion or has simply assumed them out of the picture, we can safely say that the AoA was not well scoped. If a rationale is provided, the test is more difficult: namely, to demonstrate that the alternative might have been preferable under some reasonable weighing of costs and benefits, notwithstanding the stated rationale.

Note that for an AoA in progress—or one that has not yet begun—avoiding an overly narrow scope requires a way of projecting ahead to what the costs and benefits *might* look like at the end of the analysis. This fact argues strongly for taking an iterative approach to defining alternatives, and for explicitly tracking the upper and lower limits of their likely costs and benefits at every step along the way. These practices are reflected in the recommendations contained in section of this report titled Recommendations and Observations.[7]

Too Broadly Scoped

Study teams operating under time and resource constraints rarely make a deliberate choice to include more alternatives than they can adequately analyze within those constraints. However, they can miss opportunities to narrow the set of alternatives, thus

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[5] Note that under these definitions, a particular AoA could be both "too narrow" and "too broad" at the same time! In other words, it could inappropriately exclude some alternatives *and* inappropriately include others.

[6] The use of the word *reasonable* here suggests some parallel with the "reasonable person standard" in tort law. Legal theorists disagree over whether the definition of *reasonableness* should be normative (that is, a reasonable person is one who does what is cost-effective, even if most people would not) or positive (that is, a reasonable person is one who does what most people would do, even if it is not cost-effective; see Miller & Perry, 2012). Fortunately, these distinctions are not so pronounced when it comes to choosing an AoA. The reason is that the choice of a solution path for a DoD acquisition is almost never a completely objective determination because it requires a weighing of costs and non-monetary benefits based on decision-makers' values and perspectives. Hence, the definition in the text boils down to the question of how likely it is that one could find decision-makers whose values and perspectives would have led them to choose the excluded alternative.

[7] They are also consistent with recognized best practices for screening alternatives. See, for example, USAF Office of Aerospace Studies (2008), *AoA Handbook*, section 9.1, which describes not only initial screening for nonviable alternatives, but also "preliminary screening," "later screening," and "final selection."

making less than optimal use of the time and resources available. Another possibility is that AoA guidance may prohibit such narrowing by specifying that certain alternatives *must* be considered in the final presentation of study results. Again, the opportunity cost of carrying these alternatives all the way through the analysis may be so great as to impair the quality of support ultimately provided to the decision-maker.

Testing prospectively (that is, before the AoA is completed) for overly broad scoping is difficult. Because the range of uncertainty around the known costs and benefits of alternatives generally starts out being relatively large, it is easier, early on, to make the argument to leave an alternative in the mix until the uncertainties can be reduced (and thus easier to show that an alternative has been prematurely *ex*cluded). Stated another way, it takes a certain expenditure of analysis effort to show that *no* reasonable decision-maker would be likely to prefer a given alternative.

Why Are Some AoAs Poorly Scoped?

Our interviews with AoA consumers, overseers, practitioners, and critics disclosed several reasons why AoAs may be improperly scoped.

Inappropriate Treatment of Time Constraints

In the section titled Background, we noted the recent trend toward more stringent time constraints on AoAs. Such constraints, *per se*, are not necessarily a problem. In fact, they can contribute to better scoping by avoiding the situation in which a protracted analysis and/or decision-making process fails to keep pace with fact-of-life changes (see section titled Lack of Agility below). However, AoA stakeholders may deal with such constraints by compressing the timeline in inappropriate ways. This may occur before, during, or after the AoA itself.

Some types of compression occur well before AoA initiation, during the JCIDS process. For instance, an advocate of a particular new capability may "save time" by pointing to a prior, approved ICD as inclusive of the unaddressed need for it. The danger is that the new capability in question (for example, hold a particular type of target at risk) may include a constraint (for example, with zero risk of collateral damage) that was not analyzed in the original capabilities-based analysis (CBA). Because the ICD is already approved, further analysis of this constraint is not performed. As a result, alternatives that cause "only a little" collateral damage are guaranteed to be excluded from the trade space. In short, there is no process check on a narrowing of alternatives that has occurred even before the subsequent AoA has begun.

Immediately before or during an AoA, the timeline can be compressed by summarily excluding certain alternatives, without adequately considering their potential effectiveness, cost, risk, and/or feasibility. This action is qualitatively different from accelerating the rate at which screening occurs within the analysis process: It simply restricts the trade space based on what is assumed to be true.[8] In so doing, it greatly increases the risk of an overly narrow AoA.

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[8] A recent example: Starosta (2013) cites a senior Air Force official regarding the upcoming "Ground-Based Strategic Deterrent AoA": "[The] team is starting. We did get re-vectored, though. The department, in this constrained budget environment, would like to do those a little faster with a little less money, and so they have proposed a way to streamline how they're going to perform that study." The article goes on to describe the

Finally, consider the case in which an AoA study team has used a limited amount of time to identify a range of costs and benefits for a set of alternatives. Suppose the resulting uncertainties are such that there is considerable overlap and no clear basis for a decision. If additional analysis could sufficiently narrow the uncertainties, eliminate some of the alternatives, and clarify the decision, then a refusal to extend the analysis timeline may be considered an inappropriate constraint that contributed to an overly broad scope for the prematurely finished AoA.

Inappropriate Focus on Existing C/CSS and/or Operations Concepts

Most interviewees stated a view that can be paraphrased as follows: "Whenever I see something titled '[XYZ] Replacement AoA,' I automatically question whether the scope may be too narrow." The 2009 GAO study mentioned in the Background section made a similar point: an AoA for a helicopter replacement, for instance, could easily be incorporating a premature decision that the underlying capability need is best met by another helicopter of some sort.

The danger can arise not only from an inappropriate focus on existing C/CSS (for example, the notion that a particular platform must be replaced by a similar type of platform), but also a focus on existing concepts of operation (CONOPS). Consider, for example, a sensor that provides input to step 1 of a two-step battlefield decision-making process. An AoA that focuses exclusively on how well the alternatives support step 1 could easily be scoped improperly, as illustrated in Figure 2. Here, instead of a helicopter replacement AoA, we have what might be termed the "Step 1 replacement AoA." In this example, Alternative A would certainly be included in the AoA, since it improves the effectiveness of step 1 relative to the base case. (Granted, it does not change step 2, but overall effectiveness would still be improved.) However, Alternative B might very well be excluded unless the AoA scope was widened to account for the potential improvement it could bring to step 2.

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proposed streamlining: "In effect, the narrower AOA will look into fewer modernization concepts than originally planned." The de-scoping was reportedly performed by a SAG based on "data derived from previous analyses." Note that the authors are not in a position to judge the merits of this particular de-scoping or to declare it "inappropriate." The point is simply that time constraints can potentially exacerbate the problem of AoA scoping.
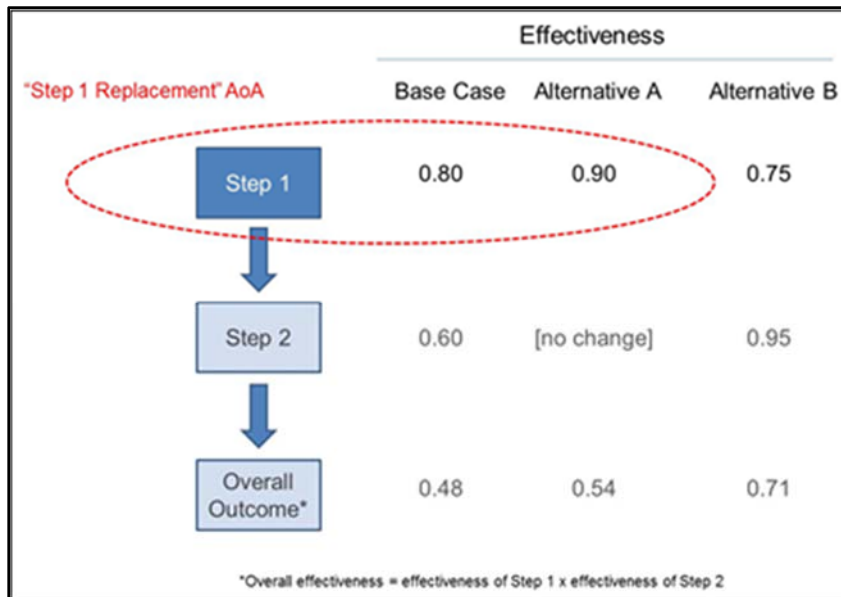
Figure 2. **Example of Inappropriate Focus on Existing CONOPS**

Inappropriate Focus on a Single Warfighting Domain

By the time an AoA begins, a DoD lead component (most often, one of the services) has been designated and has been given responsibility for conducting the analysis. That component will have played a key role in analyzing the capability need and developing the ICD; it will also have had to identify a possible range of feasible alternatives in support of the MDD (USD[AT&L], 2010). There are many reasons behind the designation of a DoD lead component: for example, the availability of technology development expertise, personnel, models and simulations, and budget. Often, the nature of the capability need documented in the ICD makes the choice of a lead service "obvious."[9] To explore this phenomenon further would require a detailed look at the role of the services in the various processes that provide input to the definition of capability gaps and needs (see Frittman et al., 2013)—an assessment well beyond the bounds of this study.

Regardless of the reasons, service proponency of AoAs was identified by several interviewees as a potential contributor to overly narrow scoping. Colloquially speaking, "If the Navy is conducting the AoA, the solution is probably going to live in the water; if the Air Force is conducting the AoA, the solution is likely to have wings; etc." The problem is not necessarily that one service deliberately sets out to exclude solutions that could be developed by another: each particular service simply thinks about capability needs and their solutions in a particular way, corresponding to the warfighting domain it represents. Such viewpoints may not lend themselves well to the full exploration of solutions to joint or coalition warfighting needs.

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[9] The WSARA (2009) stipulates an OSD check on the extent to which requirements approved by the Joint Requirements Oversight Council (JROC) have "engaged in consideration of issues of joint portfolio management" but notes that this was already required by DoD instruction. Cf. Public Law 111-23, §201(c)(3).

Inclusion of Extraneous Issues

The national security landscape is such that new concepts and ideas regularly burst into the universe of discourse: consider, for instance, the history of low-intensity conflict, information operations, or supply chain management. For the purposes of this report, the risk is that a given concept or issue may be so much in vogue that AoA guidance mandates that it be considered—and therefore that an alternative be included—simply because it is a hot topic.

Lack of Agility in Governance and Management Processes

As noted in the Background section, a common complaint is that both AoAs and the JCIDS process take too long. Unfortunately, the result is often a reluctance to make adjustments during AoA execution. For example, even though interim AoA results might suggest that the underlying capability need should be reexamined or articulated differently, this seldom occurs because "too much time has already been expended just to get to this point." One possible result: AoAs that are improperly scoped because they ignore fact-of-life changes that have rendered some alternatives obsolete or made others feasible.

An associated problem is that governance processes may not be able to keep pace with the need for change. Suppose an AoA study team is able to determine, during the course of an AoA, that the costs and benefits of a given alternative, mandated by study guidance, will almost certainly cause it to be dominated by the others. In theory, a SAG could grant a waiver or change of scope. However, if the approval chain leading to the SAG is such that four months' worth of justification is required to avoid three months of wasted effort, the change is unlikely to happen.

Applying a Systems View

Systems Thinking and the Conceptagon

We used a soft systems framework, the Conceptagon (Boardman & Sauser, 2008), to derive comparisons and characterizations that helped us better understand the factors identified in the section titled Why Are Some AoAs Poorly Scoped? The Conceptagon framework is organized around seven triplets (see Figure 3) of system attributes.

We concentrated on four of these triplets:[10]

- *Wholes, Relationships, Parts.* The identification of the system at hand, the constituent pieces, and the relationships that bind those pieces.
- *Structure, Process, Function.* The composition, arrangement, or organization (structures) a system employs to support the key activities (processes) necessary to produce the desired system behavior (function).
- *Inputs, Transformations, Outputs.* The items that enter the system (inputs) and exit it as products or deliverables (outputs) and the changes (transformations) that convert inputs to outputs.
- *Interior, Boundary, Exterior.* The perimeter that separates entities that comprise the system from entities outside its control.

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[10] The remaining triplets (notably, Command, Control, Communication; and Openness, Hierarchy, Emergence) are better suited to identifying organizational or governance solutions, which are not the focus of this paper.

Figure 3. Conceptagon Framework
(Boardman & Sauser, 2008)

Analysis of Selected Conceptagon Triplets

Wholes, Relationships, Parts

What "system" are we analyzing when considering the problem of AoA scope? Figure 4 identifies two very different kinds of systems at work. The upper portion of the diagram depicts what might be termed the "AoA Management and Execution System." That system comprises the organizational entities responsible for planning, conducting, documenting, and applying the AoA. The lower portion of the diagram depicts an entirely different kind of "system." Specifically, the label "AoA Object System" describes the set of C/CSS(s) that are the object(s) of study in the AoA.
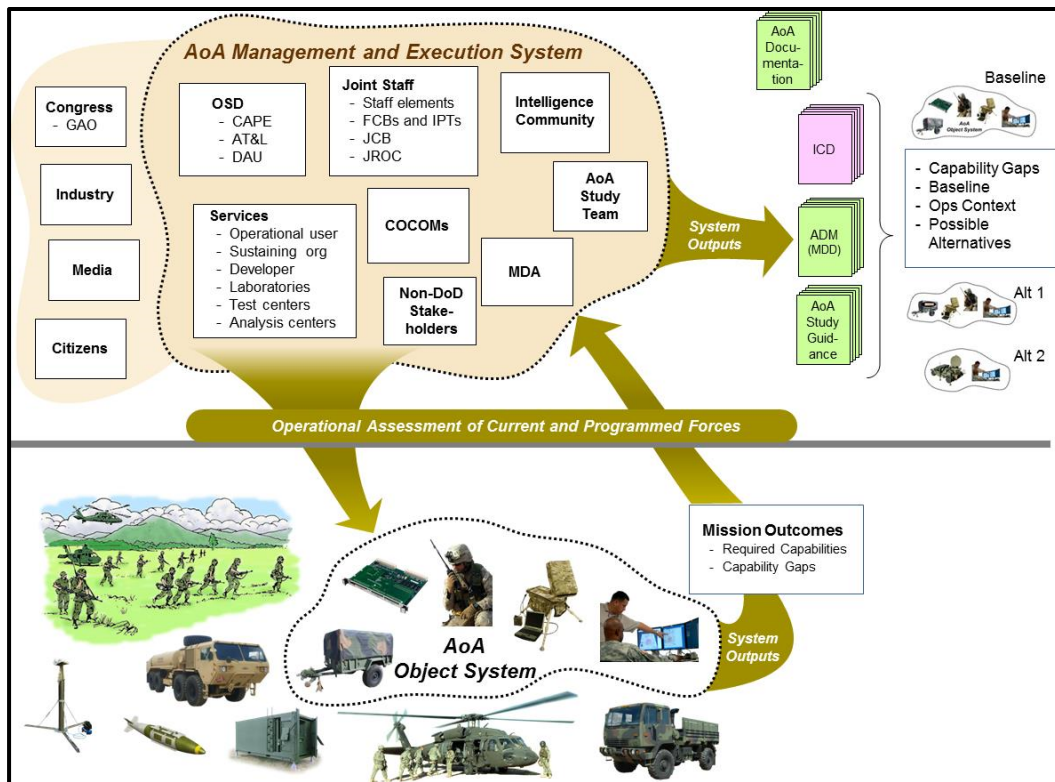
Figure 4.   The Two AoA Systems (Prior to AoA Execution)

In Figure 4, the focus is on the period that precedes the AoA itself. During this timeframe, the Management and Execution System produces several outputs that impact the scope of the ensuing AoA: documentation of the underlying capability need (in the form of an ICD), documentation of the MDD (via an Acquisition Decision Memorandum[11]), and formal AoA Study Guidance. All these outputs are based on the assessment of current and programmed C/CSSs, existing CONOPS (not shown), and the resulting mission outcomes. The capability gap documented in the ICD is associated with the particular set of C/CSSs that "should have been" capable of producing the required capability. This set will become the "baseline" alternative in the AoA. The designation of the baseline establishes a boundary for the Object System.

Figure 5 depicts AoA execution. Here, the output of the Management and Execution System is the completed AoA. Each alternative represents a different possible instantiation of the Object System and is assessed based on its outputs: namely, the predicted mission outcomes it would produce or enable. The assessment may deem some alternatives infeasible on the basis of these outcomes; it may also help identify other alternatives that should be considered. Notice that the reconfigurations that give rise to the alternatives may change the definition of the boundary: a C/CSS that was formerly outside the boundary (for

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[11] MDD documentation can have an important bearing on AoA scope: USD(AT&L; 2010) DTM 10-017 requires that the MDD be based on evidence of a range of "candidate materiel solution approaches [that] have the potential to effectively address the capability gap(s)" and are technically feasible.

example, the helicopter at the bottom right of the collage in Alternatives 1 and 2) may find itself inside the boundary (the same helicopter, dropping a rectangular object in Alternative 3). Thus, the AoA scope is the envelope of the boundaries formed by all the instantiations of the Object System (that is, all the alternatives).
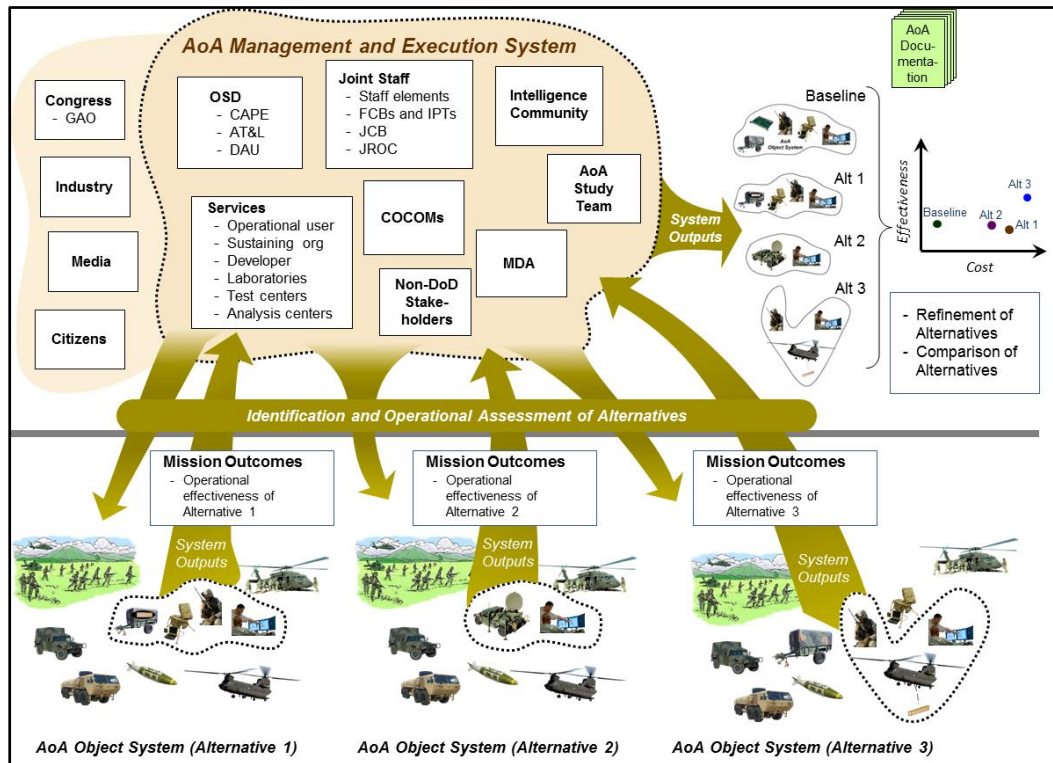

Figure 5.   The Two AoA Systems (During AoA Execution)

In summary, AoA scope is a property of a system output (because an AoA is an output of the AoA Management and Execution System). It results from one system (that is, the Management and Execution System) making decisions about the boundary of another (that is, the Object System) both before and during the analysis. Thinking of scope in this way allows us to introduce several other principles of systems analysis (see section titled Recommendations).

Structure, Process, Function

An AoA lies at the intersection of the three principal DoD decision support systems (JCIDS; the Planning, Programming, Budgeting, and Execution System [PPBES]; and the DAS). Each of the processes that govern those three systems impacts an AoA—and, in particular, the actions taken by the elements of the AoA Management and Execution System to determine its scope. Figure 6 summarizes the key relationships.

In some cases, it is fairly obvious how these functions impact decisions regarding the scope of an AoA. For example, resource availability can limit AoA scope directly (the fewer the resources available for AoA execution, the fewer alternatives can be analyzed to a given level of detail) or indirectly (the fewer the resources available for solutions to capability needs, the fewer alternatives will be deemed affordable). Less obvious are some of the relationships we noted in the Why Are Some AoAs Poorly Scoped? section—for example, the fact that the set of alternatives is profoundly shaped by the *way* in which a capability gap is articulated. This latter point is taken up in more detail in Recommendations.

Process*	Function (relative to AoAs)	Key Structural Elements
JCIDS	Assess current and programmed forces Identify capability gaps and needs	Joint Staff, JROC Combatant commands Component using commands
PPBES	Determine available resources / affordability Enable capability development	OSD CAPE USD(Comptroller) Component HQ
DAS	Acquire future forces Develop future capabilities	USD(AT&L) Component AEs and acquisition commands

*The entries in this column are all termed "systems"; however, the shorthand reference is to the processes that govern the operation of these systems.

AE = Acquisition Executive
DAS = Defense Acquisition System
JCIDS = Joint Capabilities Integration and Development System
JROC = Joint Requirements Oversight Council

OSD CAPE = Office of the Secretary of Defense, Cost and Program Evaluation
PPBES = Planning, Programming, Budgeting, and Execution System
USD(Comptroller) = Under Secretary of Defense (Comptroller)
USD(AT&L) = Under Secretary of Defense (Acquisition Technology & Logistics)

Figure 6.   DoD Decision Support Functions That Impact AoA Scope

Inputs, Transformations, Outputs

Figure 7 depicts the notion that AoAs transform information about forces, capabilities, and C/CSSs into information that aids decision-making by characterizing the trade space of alternative solutions. This view extends the previous triplet by identifying additional factors that impact AoA scope. If data and models are not in place, for example, the resulting inability to analyze certain alternatives within time and resource constraints could act to inappropriately limit scope.
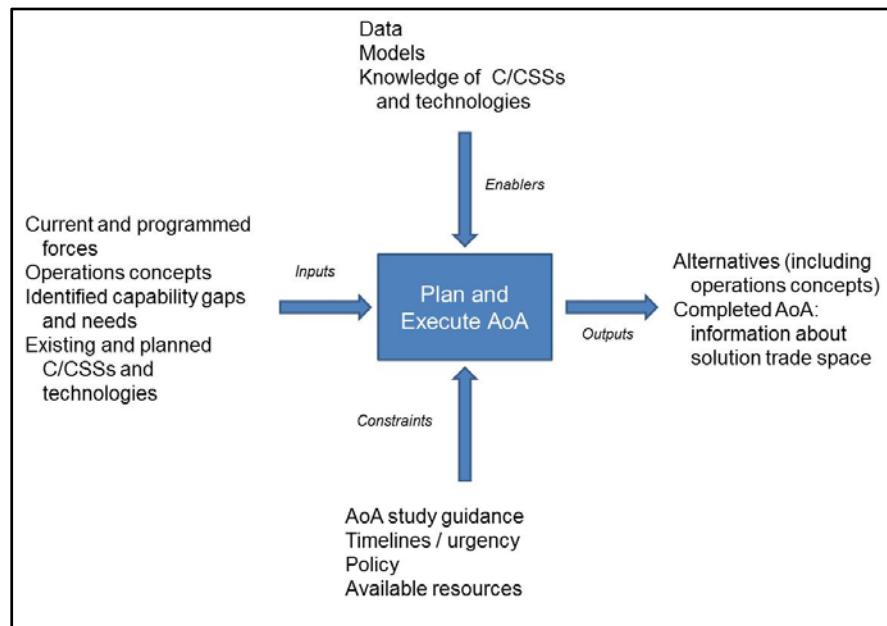

Figure 7.   AoA Inputs, Constraints, Outputs, Enablers

Interior, Boundary, Exterior

The concept of AoA scope as a boundary on the Object System was discussed earlier in this section. The earlier discussion showed the boundary in what might be termed

"C/CSS space." However, this boundary has other dimensions as well—for example, temporal dimensions. Figure 8 shows that some actions taken before AoA initiation (those on the left side of the figure) generally have broad impacts on AoA scope (for example, by excluding whole classes of technologies or solution approaches). Actions taken during AoA execution tend to impact AoA scope more narrowly (for example, making exclusions *within* allowable classes).

Before AoA	During AoA
Identification of capability gaps Gap assessment—CBA Gap documentation—ICD Material Development Decision—ADM AoA Guidance	Study plan development Characterization of alternatives Screening of alternatives Final selection of alternatives

CBA = Capabilities-Based Assessment
ICD = Initial Capabilities Document
ADM = Acquisition Decision Memorandum

Figure 8. **Timeframe of Actions That Impact AoA Scope**

Recommendations and Observations

The study team combined insights based on the system formulation of the problem (see the section titled Applying a Systems View) with insights gained during interviews (see the section titled Understanding the Problem) to arrive at a series of recommendations, which are presented in below, followed by some concluding observations.

Recommendations

The guiding principles that follow are intended to help participants in the AoA Management and Execution System reduce the incidence of improperly scoped AoAs.

Focus on Outputs and Think Backwards

An alternative is any potential configuration of C/CSSs that could produce the required output(s): namely, the military outcomes that would address the documented capability gap to some degree. In formulating alternatives, it is tempting to think forwards— that is, to envision a particular set of C/CSSs and determine whether it produces the required outcome(s) (or could be modified or reconfigured to do so).

To some extent, the JCIDS process *requires* participants to think in terms of particular C/CSSs during the formulation and analysis of capability gaps. Sponsors of capability gaps are directed to consider whether "capability solutions which can satisfy the Sponsor capability requirements exist elsewhere *in the Joint force* [emphasis added]" (CJCS, 2012, para. 5). And CBAs require "the operational assessment *of the current and programmed force* [emphasis added]" (CJCS, 2012, para. 2).

Consideration of C/CSSs during gap formulation is actually inevitable: It may be possible to think about a *capability* without reference to the system that provides that capability; however, it is not possible to think about a *capability gap* without reference to one or more sets of C/CSSs that fails to do so. Thus, by the time an MDD is reached and an ICD generated, the Object System—including its boundaries and interfaces—has already been conceived … with reference to the current and programmed force. The danger is that this process may induce tunnel vision and drive the AoA to an overly narrow scope.

How does one escape this dilemma? At some point *before the formulation of AoA study guidance*, there should be an attempt to work *backward* from a (C/CSS-neutral) statement of the required capability to a set of feasible alternatives that could potentially satisfy it. *Such an attempt should not be bound in any way by the thinking contained in the CBA.*

Formal systems analysis tools and methods can help in drawing the necessary linkages. These methods also show clearly the difference between the "forward" and "backward" thought processes alluded to above. Within version 2.0 of the DoD Architecture Framework (DoDAF), for example, the "forward" progression of thought corresponds to the movement from Operational View (OV) to Capability View (CV).[12] It asks, "What is the CV associated with this particular OV?" This process may be used during the assessment of current and programmed forces to identify capability gaps, resulting in an ICD.

What we have termed the "backward" thought progression can be represented by a subsequent movement from CV-1 (Capability Vision) to CV-6 (Capability to Operational Activities Mapping), as shown in Figure 9. The CV-1 essentially captures the sense of the ICD. Forcing the analyst to carefully translate *capabilities* to *activities*, it becomes possible again to work from a clean sheet of paper by asking questions such as "Are there other kinds of activities or combinations of activities that could produce these capabilities?" "How might such activities be performed or linked to do that?" In the end, one is asking, in DoDAF terms, "What kinds of OVs could correspond to this CV?" Or, in other words, "What kinds of C/CSSs, interacting with each other and with the user in what ways, could potentially meet the stated need?"
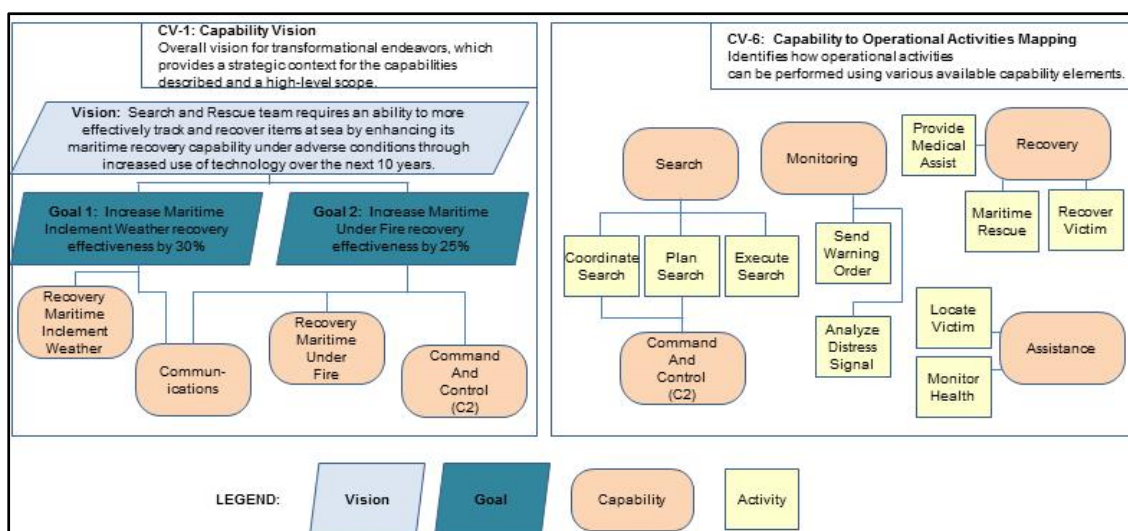

Figure 9. **Translating Capabilities to Activities: Using DoDAF v2.0**
(Wayson, 2010, slides 9 and 14)[13]

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[12] Note that DoDAF itself does not prescribe a progression of thought. In applying DoDAF, one can start almost anywhere, producing only the views required for a particular purpose.
[13] In this example, the CV-6 includes capabilities not shown in the CV-1. The additional capabilities implicit in the CV-1 were formally identified in the Capability Taxonomy (CV-2).

The "backwards" thought transition from CV to OV has an additional benefit. By setting up the question of user interaction with the system, it stimulates additional thinking about the Object System boundary and how that boundary contributes to the definition of alternatives (see the next subsection).

Start With the Exterior and Work Inwards

The usual thought process is to start with a collection of C/CSSs believed to represent an instantiation of the Object System and move conceptually "outwards." Those entities without which the Object System could not exist or function—provided they are within the decision-maker's sphere of influence and authority—are deemed to lie in the interior; all other entities are in the exterior. Although this may be a sound method of *refining* an initial definition, it may not be the best approach to *identifying* alternative instantiations of the Object System.

The suggested approach is to reverse the process—that is, to start by identifying entities that are clearly *not* part of the system and then moving conceptually "inwards." If the stated need is to improve the autonomous navigation capabilities of an existing fleet of aircraft, for example, it may be easy to determine that alternatives involving entirely new airframes are unaffordable. The airframes themselves now lie in the exterior of the Object System and impose a set of compatibility constraints. However, it may not be clear whether alternatives that upgrade both navigation and fire control systems are cost-effective. The "outside-in" approach might allow both types of solutions among the potential alternatives in an AoA.[14]

Outside-in exploration of the boundary also helps identify interfaces that "[participate] in constituting the system" (Cilliers, 2005, p. 611). The eardrum, for example, "forms the boundary between the inner and the outer ear, but at the same time it exists in order to let the sound waves through" (Cilliers, 2005, p. 611). In the same way, the interface constraints identified during an outside-in exploration of the Object System boundary point toward important characteristics of AoA alternatives. They can represent more than simply feasibility constraints. For example, they can uncover important measures of effectiveness.

Apply Constraints Carefully

Every constraint imposed and/or accepted constitutes a decision to exclude some portion of the solution trade space from further consideration. Accordingly, it should be supported by some testable rationale (that is, an explanation of what portion of the trade space is being excluded and why it is not worth considering). An important question to ask: What would it take to change this constraint? To see the importance of asking this question, consider several examples.

The first example considers the well-known constraint termed *affordability*. For many years, decision-makers relied on AoAs to identify cost-effective solution approaches only to discover that the resulting programs could not be executed with available resources—that is, they were unaffordable. In response, the USD(AT&L) has mandated that affordability be considered at Milestone A (Husband & Kaspersen, 2012, p. 9). An overly restrictive approach would be to define affordability as the difference between expected out-year

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[14] An interesting parallel in the world of object-oriented software design is the recent interest in "Outside-In Development."   For a practical illustration, see Bache (2013).

obligational authority and the expected out-year costs of current and programmed C/CSSs. That approach, however, fails to consider the possibility that the benefits of meeting the capability need at hand may be so great as to be worth terminating or forgoing some current or programmed C/CSSs. Rather than unduly constrict the trade space with this narrow definition, decision-makers would be better served by asking, "What other capabilities would we be willing to forgo to achieve this one?"[15]

Another example was mentioned earlier: The Object System is usually constrained to exclude elements that are outside the decision-maker's sphere of influence or authority (see Oliveira, 1973, p. 3). Suppose the decision-making authority is organization X and all materiel alternatives are believed to be related to technology A, for which that organization is responsible. Further, suppose that the AoA study team discovers, while developing its study plan, a set of potential alternatives based on technology B, for which the responsible organization is Y (a parallel organization in the hierarchy). The argument that "those aren't our technologies and we can't make decisions about them" should not be considered sufficient grounds for dismissing the newly discovered set of alternatives—even though the consequences, in terms of process, may be painful (for example, moving the decision-making authority to a higher level).

Even the capability gap itself can be articulated in such a way as to over-constrain the solution trade space—as, for example, might occur if alternatives that fail to close the gap *completely* are dropped. During the interviews the study team conducted, we learned that new JCIDS guidance under development will address this point by stating clearly that ICDs should *not* include threshold values for key performance parameters.

Iterate and Reduce Uncertainty

Because the environment can change over time, the boundary of the Object System should be allowed to change as well. Standard AoA practice accounts for such change through the normal screening process. Less common, but equally important, is the occasional need to add alternatives or fundamentally change the nature of the alternative set. Such changes can arise for a number of reasons: for example, during the interval between the CBA and the AoA, the state of technology may have evolved such that alternatives once thought to be infeasible are now feasible.

The recommendation is to take an iterative approach: specifically, to check and recheck the validity of assumptions and constraints throughout AoA preparation and execution. Note that this concept extends to the period before the AoA has actually begun. In the earlier example of the aircraft navigation system (see the above subsection Start With the Exterior), we remarked that a certain decision might be "easy to determine" and that another decision "might" result in a certain outcome. Ideally, these decisions are informed by quick analysis at a low level of detail. Although the analysis results may come with a wide range of uncertainty, they may still be sufficient to allow for the right decision regarding the Object System boundary. If not, the analysis is refined to the point that it does support the decision.

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[15] Based on the interviews the study team conducted, there is evidence that this question is now being posed as a way of attaching resource priority levels to DoD capability needs.

The associated need is for CBA and AoA governance processes that can respond quickly to the need for such adjustments. The establishment of the SAG (supported by Joint Staff Functional Control Boards) as an ongoing governance mechanism is undoubtedly a step in the right direction—although there is evidence from the study team interviews that the process is not yet as agile as it needs to be. For example, it is not clear to what extent the SAG can, on its own authority, redirect the execution of an AoA along lines that deviate from the boundaries established by a validated ICD. If the impacts of real-world change can be accommodated only by restarting the JCIDS process from scratch, they are unlikely to be considered at all.

Summary and Conclusions

A scheme for applying these recommendations is summarized in Figure 10, which shows the alignment of key principles according to stakeholder roles and process timelines. The absence of an entry does not mean that participant is exempt from that particular principle—merely that it is not necessarily key to AoA scoping at that particular point in the AoA process.

Figure 10.   Summary of Key Principles for Improving AoA Scoping

One important implication of Figure 10 is that systems thinking should not be considered an exercise solely for AoA study team analysts. Senior executives, warfighters, and DoD business process owners can all benefit from applying a systems view to the practice of AoAs. That practice continues to evolve within the DoD, and the challenges of the future will doubtless be different from those of the past. Cultural, organizational, and individual behaviors will continue to frustrate the best process designs. Nevertheless, the study team is confident that the above principles can improve the DAS by reducing the incidence of poorly scoped AoAs and thus enable better acquisition outcomes.

References

Bache, E. (2013, April 19). Outside-in development with double loop TDD [Web log post]. Retrieved from http://coding-is-like-cooking.info/2013/04/outside-in-development-with-double-loop-tdd/

Balut, S. J., et al. (2004, September). *IDA 2004 Cost Research Symposium: Investments in, use of, and management of cost research* (Document D-3018). Alexandria, VA: Institute for Defense Analyses.

Boardman, J., & Sauser, B. (2008). *Systems thinking: Coping with 21st century problems*. Boca Raton, FL: CRC Press.

CJCS. (2003, June 24). *Operation of the Joint Capabilities Integration and Development System* (CJCS 3170.01). Washington, DC: Author.

CJCS. (2012, January 19). *Manual for the operation of the Joint Capabilities Integration and Development System* (JCIDS manual). Washington, DC: Author.

Cilliers, P. (2005). Knowledge, limits, and boundaries. *Futures*, 37, 605–613. Retrieved from http://www.complexityforum.com/members/cilliers%202005%20knowledge%20limits.pdf

Defense Acquisition University (DAU). (2003, September 16*). Defense acquisition guidebook*. Retrieved from https://acc.dau.mil/docs/dag_pdf/dag_complete.pdf

Edson, R. (2008). *Systems thinking. Applied. A primer* (Version 1.1). Retrieved from https://www.anser.org/docs/systems_thinking_applied.pdf

Frittman, J., et al. (2013). A comparative assessment of the Navy's future naval capabilities (FNC) process and Joint Staff capability gap assessment process as related to Pacific Command's (PACOM) integrated priority list submission. In *Proceedings of the 10th Acquisition Research Symposium* (pp. 240–261). Monterey, CA: Naval Postgraduate School.

GAO. (2009, September). *Defense acquisitions: Many analyses of alternatives have not provided a robust assessment of weapon system options* (09-665). Washington, DC: Author.

Husband, M., & Kaspersen, K. (2012). The AoA: An early filter to create an affordable program. *Defense AT&L,* 7–10. Retrieved from http://www.dau.mil/pubscats/ATL%20Docs/May_Jun_2012/Husband_Kaspersen.pdf

Joint Staff Force Structure, Resources, and Assessments Directorate (JCS J-8). (2009, March). *Capabilities-based assessment users' guide* (Version 3). Washington, DC: Author.

Kowal, B. W. (2009, October 28). Air Force materiel command early systems engineering initiative. In *Proceedings of the 12th Annual NDIA Systems Engineering Conference.* Retrieved from http://www.dtic.mil/ndia/2009systemengr/2009systemengr.html

Lihani, B. (2011, May 11). *Analysis of alternatives (AoA): HQ NORAD/J35W*. Retrieved from http://www.ofcm.noaa.gov/wg-mpar/meetings/2011-02/2b%20DOD.pdf

Miller, A.D., & Perry, R. (2012, May). The reasonable person. *New York University Law Review*, 87(2), 323–392. Retrieved from http://www.nyulawreview.org/sites/default/files/pdf/NYULawReview-87-2-Miller-Perry.pdf

Oliveira, R. F. (1973). *Systems analysis in land-use planning: A conceptual development* (General Technical Report PSW-5). Berkeley, CA: USDA Forest Service, Pacific Southwest Forest and Range Experiment Station.

Smith, M., & Thompson, F. (1995). *Information and frustration: Observations on cost and operational effectiveness analyses*. Alexandria, VA: Center for Naval Analyses.

Starosta, G. (2013, October 4). OSD approves start of analysis of alternatives on minuteman III's future. *Inside the Air Force.*

USAF Office of Aerospace Studies (AFMC OAS/A9). (2008, July*). Analysis of alternatives (AoA) handbook: A practical guide to analyses of alternatives.* Kirtland AFB, NM: Author.

USD(A). (1991, February 23). *Defense acquisition management documentation and reports* (DoD 5000.2-M). Washington, DC: Author.

USD(A&T). (1996a, March 15). *Defense acquisition system* (DoD Directive 5000.1). Washington, DC: Author.

USD(A&T). (1996b, March 15). *Mandatory procedures for major defense acquisition programs* (DoD 5000.2-R). Washington, DC: Author.

USD(AT&L). (2003a, May 12). *The defense acquisition system* (DoD Directive 5000.01). Washington, DC: Author.

USD(AT&L). (2003b, May 12). *Operation of the defense acquisition system* (DoD Instruction 5000.2). Washington, DC: Author.

USD(AT&L). (2008, December 8). *Operation of the defense acquisition system* (DoD Instruction 5000.02). Washington, DC: Author.

USD(AT&L). (2010, September 13). *Development planning to inform materiel development decision (MDD) reviews and support analyses of alternatives (AoA)* (Directive-Type Memorandum DTM 10-017). Washington, DC: Author. Retrieved from http://www.hsdl.org/?view&did=728880

Wayson, M. (2010, May 11). DoDAF V2.0 Update. *DoD Enterprise Architecture Conference.* Retrieved from http://dodcio.defense.gov/Portals/0/Documents/DODAF/DoDAF2-0_update.ppt

Weapon Systems Acquisition Reform Act (WSARA) of 2009, Pub. L. No. 111-23 (1990).Washington, DC: U.S. Government Printing Office.

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