Analysis of Alternatives (AoA) Methodologies: Considerations for DHS Acquisition Analysis

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The Homeland Security Act of 2002 (Section 305 of PL 107-296, as codified in 6 U.S.C. § 185) authorizes the Secretary of the Department of Homeland Security (DHS), acting through the Under Secretary for Science and Technology, to establish one or more federally funded research and development centers (FFRDCs) to provide independent analysis of homeland security issues. Analytic Services Inc. operates the Homeland Security Studies and Analysis Institute (HSSAI) as an FFRDC for DHS under contract HSHQDC-09-D-00003.

HSSAI provides the government with the necessary expertise to conduct: crosscutting mission analysis, strategic studies and assessments, development of models that baseline current capabilities, development of simulations and technical evaluations to evaluate mission trade-offs, creation and evolution of high-level operational and system concepts, development of top-level system and operational requirements and performance metrics, operational analysis across the homeland security enterprise, and analytic support for operational testing evaluation in tandem with the government’s acquisition process. HSSAI also works with and supports other federal, state, local, tribal, public and private sector organizations that make up the homeland security enterprise.

HSSAI’s research is undertaken by mutual consent with DHS and is organized as a set of discrete tasks. This report presents the results of research and analysis conducted under

**Task 13-01.04.05**

AoA Methodologies: Cost Estimation and Analysis Revisions

The purpose of this task was to finalize development of a useful but nonprescriptive reference document to improve the organization and conduct of analysis of alternatives (AoA) studies for DHS. This document is a revised version of one published under task 12-01.02.10 in May 2013.

The results presented in this report do not necessarily reflect official DHS opinion or policy.
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INTRODUCTION

The purpose of this document is to describe the role of an analysis of alternatives (AoA) and alternatives analysis (AA) in the broader Department of Homeland Security (DHS) acquisition process and to discuss the major steps and key methodological considerations inherent in the AoA process. It is intended to assist the government decision makers who use the AoA outputs and the analysts who develop AoA reports. It endeavors to provide a common understanding and set of expectations regarding how to interpret DHS guidance for AoAs. It also identifies and frames key issues that decision makers and analysts ought to address when planning and scoping the AoA effort. Finally, this document highlights lessons learned from the Homeland Security Studies and Analysis Institute’s (HSSAI) experience performing AoAs for DHS.

The document assumes that the reader is familiar with formal DHS guidance describing the acquisition process and the process for developing AoAs. This DHS guidance is prescriptive for all major acquisition programs (i.e., level 1 or 2), when annual expenditures are expected to exceed $100M, and it includes the following:

- DHS Acquisition Management Directive Number 102-01, Revision Number 01, issued 20 January 2010
- DHS Acquisition Management Instruction/Guidebook Number 102-01-001, issued 1 October 2011. Of particular relevance is “Appendix G: Analysis of Alternatives (AoA)/Alternatives Analysis (AA)”
- DHS Intermediate Systems Acquisition Module 2: Analyze/Select Phase, Analysis of Alternatives (online course)

Note that DHS also offers a two-day Capital Planning and Investment Control (CPIC) course that covers both cost-benefit Analyses (CBAs) and AoAs.

The first three sections of this document address the purpose of an AoA, the AoA study team and organization, and the scope of an AoA. The remaining sections focus on a particular phase of the analytic process. In terms of section organization, with a few
exceptions, each of these remaining sections will include (1) a brief description of any relevant DHS guidance, (2) key analytic considerations, and (3) a summary of key issues. This document is intended to supplement the formal directives and instructions in the above mentioned resources by providing practical suggestions for implementing the AoA process.
PURPOSE OF AN ANALYSIS OF ALTERNATIVES

Overview of DHS Guidance on the Purpose of an AoA

An AoA is a study to evaluate and compare operational effectiveness, suitability, cost, and risk associated with multiple alternative solutions to an identified gap in meeting homeland security mission requirements. The purpose of an AoA is to provide decision makers with a systematic, objective evaluation of the alternatives in the relevant trade space. The result of this analysis is an objective, analytically defensible, data-driven set of findings that identify and document the relative benefits, costs and risks associated with the solutions considered.

Decision makers use the AoA results to inform their down-selection process (i.e., making choices among alternatives). The AoA is also part of the government’s submission at the solution engineering review (SER). This review is conducted by the lead DHS component or activity and is intended to lead to selection of the preferred solution or set of solutions that the government will implement. Once the government has made this decision, the data and analysis in the AoA report will also serve as key inputs to the final operational requirements document (ORD), concept of operations (CONOPS), life cycle cost estimate (LCCE), and integrated logistics support plan (ILSP).

Key Considerations in Approaching an AoA Study

To fulfill this purpose, both the government sponsors and AoA analyst team should approach and execute the study with the following points in mind:

- **The independence of the AoA team is vital to the defensibility of the AoA results.** Stakeholders who are familiar with the capability gaps and some, if not all, of the potential solutions will have opinions as to which alternative constitutes the best solution. DHS guidance therefore calls for the government to select an organization to conduct the AoA that is independent of both the organization that will acquire and use the solution, and the organization sponsoring the acquisition. Further, when commissioning an AoA, the government should intend that the analytic results inform the decision-making process rather than the

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8. Ibid., G-5.
validation of a preferred alternative. This ensures that the AoA functions as an unbiased assessment rather than a box-checking exercise.

Independence should be an inherent attribute of the study team. In other words, the team is chosen because it is capable of performing the AoA and has no motivation to support one alternative over another, apart from the results of the analysis. Transparency in the team’s work—its assumptions, analyses, and conclusions—further guarantees independence by exposing biases (conscious or otherwise) so that they do not persist and influence the results. Finally, nondisclosure agreements (NDAs) and financial disclosure statements can reinforce such independence.

Study independence

Independence for the study team is most critical when departmental politics require a fresh look at systems prospectively under development within a program. The desired degree of independence for the AoA study team should be reflected in the study organization and governance (see figure 3 in the next section). Since an AoA relies upon a great deal of program documentation, data, and expertise, independence cannot mean entirely independent development of data and documentation. Critical elements of the analytic process (i.e., scope, methodology, interpretation of analytic results, and report language used to describe the results) determine the degree of independence of the study team. However, the narrow view of an AoA may overlook critical impacts on other government considerations. Therefore, it is valuable to solicit stakeholder input to the study team’s efforts; however, independence is preserved by careful consideration and inclusion of those inputs.11

Based on HSSAI experience, AoAs and AAs can take 10 months or more to complete. For major acquisition programs in the Department of Defense environment, AoA timelines typically range from 12 months to 2½ years.12 That said, timelines can always be shortened;13 it is a question of study scope.

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11 Federally funded research and development centers (FFRDCs), such as HSSAI, are frequently selected to perform AoAs because of their inherent independence and freedom from commercial conflicts of interest.


13 In fact, there has been some recent high-level discussion within the Department of Defense about AoA timelines with an emphasis on shortening them. This is highlighted in a recent Inside the Air Force story [see Inside the Air Force, “OSD Approves Start of Analysis of Alternatives on Minuteman III's Future”],
Resources, including time, usually dictate scope. That is, when the time allotted to perform a study is shortened, that will generally translate into a decrease in the amount of data that can be collected and research and analysis that can be done. That in turn will decrease the size and detail of the product and the information provided by the study. In combination, these factors can lead to a decreased understanding of risk (or increased uncertainty). Accommodations can be made when time or resources are limited, but not without a reduction in scope.

- **The AoA results inform the decision-making process but may not identify one definitive solution.** As a systematic and objective evaluation of the alternatives, the AoA serves as a primary source of information for use by decision makers for selecting one or more alternatives to employ. However, the AoA may (and usually will) identify multiple alternatives that are expected to provide a cost-effective solution, each with its own accompanying set of pros and cons. The AoA, therefore, informs decision makers’ down-selection process, but it does not make the decision for them.

**Role of the AoA in the DHS Acquisition Cycle**

The DHS acquisition life cycle framework (ALF) is depicted in Figure 1 below. It consists of four major phases: an assessment of the need or problem that a solution (material and/or non-material) will address; an analysis of the alternative solutions and down-selection to the optimal solution or solutions; the process of developing or obtaining a chosen material solution; and the process of producing, deploying, and supporting the solution in the field. Each phase of this cycle involves a defined set of activities\(^\text{14}\) that culminate in an acquisition decision event (ADE). The acquisition decision authority (ADA)\(^\text{15}\) then reviews the acquisition effort’s level of maturity and risk and determines whether to approve transition to the next phase in the cycle.\(^\text{16}\)

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\(^\text{15}\) The decision as to who serves as the acquisition decision authority is determined by the life cycle cost of the acquisition. See Department of Homeland Security, *DHS Acquisition Management Instruction/Guidebook Number 102-01-001*, 16-18.

\(^\text{16}\) Ibid., 21-22.
The government conducts an AoA early in the acquisition cycle as a method of studying the trade-offs between alternatives to identify the best solution to pursue. Specifically, the AoA process generally occurs in the second (“analyze/select”) phase of the cycle. The AoA is therefore able to use products from the first (“need”) phase as inputs to the analytic process. During the first phase, the government will have identified and described the capability gaps that result in the need to acquire a new solution. The government component describes these in a mission needs statement (MNS). The acquisition decision authority’s formal approval of the MNS and the capability development plan (CDP) is part of the requirements for achieving milestone ADE-1. The CDP includes an analysis approach section that establishes the acquisition decision authority’s high-level guidance for the conduct of the AoA or AA. (Note that the government program manager and the study lead should scrutinize the approved MNS and CDP, because they will guide the direction of the AoA from this point forward.)

As a key component of the “analyze/select” phase, the AoA’s purpose is to provide an objective and systematic analysis of alternatives that address the capability gaps and mission needs identified in the “need” phase, and document the results to support the government’s selection of the optimal solution. The output of the AoA provides the government decision maker with an objective assessment of the alternatives and a recommendation as to the solution or solutions that best address the capability gap and mission needs. The government sponsor is ultimately responsible for making the final decision.
selection as to which solution or solutions to implement; the AoA report marks the beginning of this final down selection and significantly informs the process.

The AoA, however, does not serve as the only input to this process. Within DHS, other considerations might include urgency or priority for meeting the defined mission need; the budget; other related efforts and programs inside or outside the department; the impact on state and local entities; technical maturity; and other factors. Furthermore, an AoA does not typically identify a single alternative to be the clear, optimal choice across all scenarios or implementations. Instead, the AoA describes the effectiveness, cost, suitability, and risk trade-offs between alternatives. The government may then choose to conduct further testing, modeling, or other information gathering processes to finalize and validate the final alternative selection. During this process, the government may find it beneficial to occasionally consult the AoA team to draw upon the members’ expertise and knowledge gained during the AoA.

The government component’s selection of a preferred solution marks the conclusion of the analysis and down-selection process. The ADA’s approval of the component’s selection is represented as milestone ADE-2A in Figure 1. For material solutions, this triggers the “obtain” phase. In this phase, the government acquires and implements the selected alternative. While the level of detail provided in the AoA need only be sufficient to support a relative comparison between alternatives and/or a comparison against baseline or threshold requirements, the draft CONOPS, requirements, and costs contained in the AoA report will continue to inform the government during the “obtain” phase. During this phase the government develops the final ORD, CONOPS, and LCCE for the chosen solution.  

### Difference between an AoA and an AA

The DHS component pursuing the acquisition may request that the ADA approve an AA rather than an AoA. An AA is a more constrained version of an AoA that evaluates only a set of specific material solutions. It is conducted within a set of requirements, measures of effectiveness, and measures of performance that the DHS component largely (or even wholly) determines in advance. The decision to conduct an AA rather than an AoA is

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20 Department of Homeland Security, *DHS Acquisition Instruction/Guidebook Number 102-01-001*, “Appendix G,” G-3; Ibid., 25; also, as discussed in the *DHS Acquisition Instruction/Guidebook*, to justify conducting an AA rather than an AoA, the component must demonstrate both that a material solution is required to address the capability gaps, and that there are at least three material alternatives that appear viable. Meeting these criteria requires the component to conduct an initial analysis of the potential alternatives that is of sufficient scope and depth to conclusively eliminate nonmaterial solutions (i.e., solutions involving changes to doctrine, organizations, training, leadership, personnel, facilities, or regulations, grants, and standards). This requires the component to accomplish several of the key methodological and analytical tasks that an AoA team would need to undertake if it were tasked to analyze such alternatives. As a result of the component’s work to down-select the list of alternatives to a set of material solutions, then the AA team begins its analysis with both a bounded set of alternatives and
made at the initiation of the “analyze/select” phase, or milestone ADE-1 in Figure 1. For purposes of this document, we use the term AoA, but the analytic requirements and lessons learned apply to both AoAs and AAs unless otherwise stated.

**Major Sections of Analysis in an AoA**

In broad terms, an AoA generally includes the following phases of analysis:

- **Characterize the challenges (or threats)** that triggered the need for the new capabilities described in the MNS. This phase may be most easily understood when characterizing the challenges posed by adversarial threats that commonly spark the need for the development of new capabilities. However, threats in the traditional sense are not the only source of challenges to our missions, goals, or business plans. For example, a “challenge” to DHS could be a physical terrorist threat, a category 5 hurricane, a congressionally mandated change in immigration policy, or a boom in the flow of commerce through U.S. seaports. Regardless of the specifics, challenges are things imposed on DHS (i.e., important factors DHS cannot control). Characterizing these challenges provides the detail necessary for identifying alternatives that may effectively fill current gaps in capability. Despite its overly narrow implication, in the interest of simplicity, we will use the term “threat” in this document when referring to the source of the challenge to our homeland security missions, goals, or business plans. We leave it to the reader to extrapolate this concept to the broader set of sources whose challenges may demand the development of new capabilities.

- **Identifying alternatives**, including both material and nonmaterial solutions, which will be the subject of analysis in all other phases of the AoA.

- **Developing operational scenarios and CONOPS** to describe how the alternatives will be used in the field and to identify the characteristics and constraints of the operating environment. This results in a description of the operating environment and a specific viable CONOPS for each alternative, which shapes the development of the analytic framework for analyzing each alternative’s operational effectiveness and suitability. As opposed to the “threat” above, this area focuses primarily on what DHS can control. Although suitability issues for

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21 “Intermediate Systems Acquisition Course, Analysis of Alternatives, What Is an Alternatives Analysis (AA)?” Department of Homeland Security, accessed 18 October 2012, [https://learn.test.dau.mil/CourseWare/803897_3/Module2/M2_Lesson01/2_1_5body.html](https://learn.test.dau.mil/CourseWare/803897_3/Module2/M2_Lesson01/2_1_5body.html); and “When Should you Perform an AoA/AA?” accessed 18 October 2012, [https://learn.test.dau.mil/CourseWare/803897_3/Module2/M2_Lesson01/2_1_7body.html](https://learn.test.dau.mil/CourseWare/803897_3/Module2/M2_Lesson01/2_1_7body.html).

22 “Intermediate Systems Acquisition Course, Analysis of Alternatives, What Is an AoA?” accessed 18 October 2012, [https://learn.test.dau.mil/CourseWare/803897_3/Module2/M2_Lesson01/2_1_3body.html](https://learn.test.dau.mil/CourseWare/803897_3/Module2/M2_Lesson01/2_1_3body.html); “Who Conducts the AoA?” accessed 18 October 2012, [https://learn.test.dau.mil/CourseWare/803897_3/Module2/M2_Lesson01/2_1_8body.html](https://learn.test.dau.mil/CourseWare/803897_3/Module2/M2_Lesson01/2_1_8body.html); and “AoA: Cost Analysis,” accessed 18 October 2012, [https://learn.test.dau.mil/CourseWare/803897_3/Module2/M2_Lesson01/2_1_32body.html](https://learn.test.dau.mil/CourseWare/803897_3/Module2/M2_Lesson01/2_1_32body.html).
the alternatives may be identified during the effectiveness or cost analysis, we will represent the process of considering suitability within the section labeled “Defining Operational Scenarios and CONOPS”.

- **Evaluating operational effectiveness**, which involves developing a set of measures and metrics that reflect viable CONOPS for each alternative, and then assessing the performance of each alternative within this framework. Given the likely uncertainties involved, risk considerations should also accompany estimates of effectiveness.

- **Estimating life cycle costs** associated with each alternative. For an AoA, this analysis involves estimating costs for research and development, testing and production, operations and support, and disposal. Given the likely uncertainties involved, risk considerations should also accompany estimates of cost.

- **Conducting a cost-effectiveness comparison** between the alternatives by considering the results of the operational effectiveness analysis and the cost analysis. This comparison should combine the risk considerations that were identified separately during the effectiveness and cost analyses.

Figure 2 provides a flow diagram that roughly illustrates the relationships between these phases of analysis. Much of the remainder of this document focuses on the typical challenges that arise during each phase of analysis and the methodological questions that should be considered in the planning phase of the AoA to prepare to meet these challenges.

![Figure 2. Typical phases of an AoA](image-url)
STUDY AND PROJECT GOVERNANCE

To establish a strong foundation for the AoA, it is critically important that the AoA be framed properly from the beginning. This means that the (ADE-1) approved mission need statement and the CDP’s analysis approach must be correct, complete, and articulated clearly. They should be mutually understood, vetted, and confirmed by all of the responsible stakeholders before the AoA starts. If the scope is narrowed prematurely or the range of alternatives is constrained inappropriately, it will not matter how well the AoA is executed. The observations and insights could be rendered meaningless.

One way to ensure that an AoA has a sound foundation is to establish an effective mechanism for governance at the outset. This will also keep the AoA on track during its course. Since it is impossible to prescribe all the study details in advance, it follows that many decisions must be made throughout the course of the analysis. Therefore, the fundamental question when establishing study governance is: Who will be empowered to make which decisions?  

Overview of DHS Guidance on Governance

DHS guidance is largely silent regarding governance of an AoA. This undoubtedly reflects the fact that every situation is different. Therefore, it does not make sense to prescribe a specific oversight and support structure. The best structure depends on the agency or component sponsor, the user and operator organizations, the scope of the study, the study performer, and other factors. As a result, DHS guidance simply points out that the study plan (to be discussed later in this section) should include a section that “describes the planned oversight and review process” and identifies organizational roles and responsibilities.

Key Analytic Considerations on Governance

There are several key, interrelated aspects of project governance that should be considered prior to the AoA kickoff. These aspects are outlined in the questions below and described in more detail in the following subsections:

- Who should conduct the AoA (i.e., study team lead and composition of the study team)?
- How will the study team be organized?
- Who has oversight of the study team?
- Who will assure coordination and access to data?

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Who will approve the study plan and the final report?

**AoA Study Team Lead and Organization**

The question of who should lead the study is one of the most important decisions the government makes in the lead-up to an AoA, because it affects the answer to the third question about who should have oversight. As previously discussed, study independence is an important factor in these decisions. Since the CDP specifically identifies the study lead or provides guidance for his or her selection, the considerations below are most relevant to those who draft the CDP for ADE-1 approval.

With respect to the day-to-day activities of the analysis team, the question translates into: Who should actually perform the analysis? As Figure 3 below suggests, there are several options. Each option has certain advantages and disadvantages.

**Figure 3. Study team options**

In one case, the government may be reluctant to adopt the model shown on the left because if the government does not lead the study, it risks a loss of control. On the other hand, that loss of control could be beneficial in some situations. If the analysis must deal with issues that are politically or otherwise contentious, the government may prefer this model because it emphasizes the independence of the study team. A third possibility is that the government may decide to function as the lead and also to constitute the team with others (e.g., FFRDCs or other contractors) performing designated roles within the government-led, integrated study team structure.²⁵

It is possible that, because of classification issues or the possibility that specific and critical analytic expertise only resides within DHS, government and nongovernment personnel may be integrated into a single team. Since the team leader needs authority to direct the team, an integrated study team generally dictates a government study lead.

Within the study team, responsibilities are most often assigned according to the expertise required for a particular phase of the analysis. Without going into detail for each phase, one can make some general observations, including:

- Operational expertise in the mission area (e.g., border protection, immigration, and disaster relief) is important. It is not critical, but it is helpful if the study lead has this expertise.

Scientific expertise will also be required for the specific technologies being considered as alternatives (e.g., physicists for radiation scanning).

Operational analysts will be required to analyze operational processes for more effective or efficient ways of accomplishing tasks and missions. They must consider the context and environment in which the technologies will be deployed, and understand and incorporate the operator’s priorities, constraints, and concerns.

Cost and risk analysis expertise will be required.

Depending on the complexity of the study, small subteams of analysts may be required to handle specific phases of the AoA.

AoA Coordination and Oversight

This subsection will deal with four areas involving coordination and oversight of the AoA effort. These four areas are (1) the oversight and review process, (2) the coordination between the study team and government participants and stakeholders, (3) the schedule, and (4) risk management.

Oversight and Review Process

The entire acquisition process, including the AoA, is ultimately overseen by an acquisition decision authority. Normally, the ADA is at the senior executive service (SES) level.\(^{26}\) The ADA responsibility can be delegated lower, but the level of the ADA (i.e., at the component level or above) typically depends on the size or level (1, 2, or 3) of the program. The ADA may also be the component acquisition executive (CAE), but that is not always the case. Regardless, the ADA approves and launches a new AoA effort, explicitly or implicitly, when he or she allows the proposed acquisition to move into the “analyze/select” phase at ADE-1.\(^{27}\) The CAE also eventually approves the final report.\(^{28}\)

Following the ADE-1 decision, a program manager is assigned. The program manager is responsible for producing an AoA during the “analyze/select” phase of the acquisition process and in preparation for an ADE-2A decision. It is the program manager who must decide how to organize, resource, and execute the AoA, as described earlier in this section.

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\(^{26}\) Department of Homeland Security, *DHS Acquisition Management Instruction and Guidebook Number 102-01-001*, 16.


Coordination between AoA Team, Working Groups, and Stakeholders

In Figure 3 above, the “agency” is shown as a monolith. However, it is rarely the case that all decision makers and stakeholders reside within the same organizational unit. Even when an FFRDC independently leads the study, some guidance and direction is provided (e.g., to determine whether the products are formally acceptable). Therefore, the next question is: How will the agency or component organize itself for the purpose of providing study guidance? Again, there are several possibilities, some of which are represented schematically in Figure 4 below. (For convenience, the figure shows the study lead as half government and half nongovernment. In reality, the study lead would be one or the other. This is meant to show that there is an option.)

![Figure 4. Possible nexus for AoA guidance and direction](image)

In model A, the decision makers collaborate directly with one another but designate one of them to be “first among equals” for the purposes of providing direction to the study lead. This model may work well in situations where the scale of the analysis is modest and there are well-established working relationships among the principals.

Model B is similar, except that the decision makers function by consensus and communicate general guidance through a designated agency lead. The designated agency lead provides more detailed guidance as appropriate. Note that the responsibility for engendering collaboration rests at the principal level. As a result, there is a risk that the stakeholder organizations may become “disconnected” if too much time elapses between major decision points.

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To avoid this possibility, model C shows explicit collaboration and communication occurring at a level below the principals. Note, however, that a single government entity is always designated as either the study lead or the agency’s lead to communicate the government’s guidance to the FFRDC and/or contractor study lead. The FFRDC or contractor is never responsible for directly coordinating and/or articulating the government’s position.

The working-level collaboration is further formalized in model D, which shows the use of an agency steering group that operates at a level below the principals. (The figure shows a single principal decision maker, but there could be more than one.) Model D can be viewed as a more formal version of model C. Also note that it is essentially the same as model A, except that the study team interface is one level removed from the decision makers themselves.

Figure 4 shows four representative models, but in reality there are innumerable possibilities. The appropriate choice will depend on the scale and complexity of the problem, the organizational structure, and decision-making procedures of the agency. It will also be affected by the working relationships among the principal stakeholders. In some cases, the governance model may be dictated by established processes and procedures within the agency. In all cases, it is essential that the governance model be well articulated and understood at the outset.

For large studies, the governance model may be formally set down in terms of reference (TOR) or a similar document. Note that such a document is an agreement between and among government decision makers, agency representatives, and other stakeholders. The prospective study team is not normally a signatory, although team members may be consulted during the drafting of the document (particularly on those sections of the TOR that describe the nature of the problem to be solved).

Again, whether formally documented or not, the governance model should be explicitly agreed upon at the outset. It is good practice to be as specific as possible by (1) drawing the governance diagram (per Figure 4 above), (2) describing who is empowered to make decisions and the nature of those decisions, and (3) clearly identifying responsibilities for providing information, data, analyses, products, etc. For example, this document should specify who will:

- approve changes to the study questions, should they become necessary.
- approve the study team composition.
- approve the study schedule.
- approve major assumptions.
- approve representative environments and/or scenarios.
- approve the set of alternatives that will be considered.
- approve models, methods, and tools.
- approve and provide data.
- approve or provide external contacts and access to subject matter experts.
- approve analysis findings and conclusions.
- approve recommendations.
- approve interim and final products.

Based on HSSAI experience, the government normally makes use of focused working groups to support the program manager and to support an executive oversight and steering group or committee composed of mid-level, agency, and user-component representatives. Within DHS, typical working groups might include:

- multi-functional teams (e.g., systems engineering and requirements management working group): established by the user, operator, or component to produce the MNS, CDP, and P-CONOPS. These documents provide requirements that frame the AoA and describe mission needs and capability gaps, any viable alternatives already identified, and information on operational concepts and constraints.

- test planning: plans and conducts formal testing of alternative technologies.

- modeling and simulation: conducts any modeling or simulation required to generate performance data for the alternatives.

- stakeholders: provides a voice for stakeholders and a source for operational data.

- threat working group: provides the DHS-approved threats and scenarios.

Figure 5 below depicts a notional example.
Figure 5. Notional AoA organizational oversight and support structure

Through the program manager or his or her AoA project manager, these working groups receive modeling, simulation, and data requirements from the AoA study team. They, in turn, are responsible for sourcing the requirements and providing them back to the study team through the program or project manager.

**Schedule and Major Products**

**Review Process**

The frequency of meetings, briefing, and teleconferences as part of the government’s oversight and review process will depend, in large part, on the governance structure adopted. Regardless, to ensure the study team is heading in the right direction and at the right pace, it is important to have regular and frequent meetings early in the effort. This also provides the study team with opportunities to voice process concerns or to discuss problems with data collection.
**Major Deliverables**

- **Study plan.**\(^{30}\) The study plan is a key acquisition deliverable that describes how the AoA will be conducted. The study plan is reviewed and approved by the CAE before beginning the AoA. This deliverable is a more detailed, fleshed-out version of the skeletal government *analysis approach* section of the CDP produced earlier. It includes and/or builds upon the ground rules and assumptions described in the CDP;\(^{31}\) describes the composition, roles, and responsibilities of the AoA team, working groups, and stakeholders; describes the oversight and review process for the AoA; outlines an initial set of alternatives; and describes the methodology that the AoA team intends to use for each phase of analysis and for consolidating and presenting its analytical results. The description of methodology should include a preliminary framework for analyzing operational effectiveness with draft measures of effectiveness and measures of performance. The study plan should also identify the data and other resources the AoA team will need to complete the study\(^{32}\) and/or describe the governance and project management processes through which data will be requested and provided.

Unless the study team produces a more detailed “analysis plan” later, the study plan will ordinarily be used as the skeleton for the AoA final report. As a result, the study plan is a critical process milestone and an important potential oversight tool.

- **Preliminary results review (PRR).** This takes the form of a briefing and is not required by DHS guidance for AoAs. However, it is beneficial to both the AoA team and the government component sponsoring the AoA. At the PRR, the AoA team provides the decision maker an early look at the AoA results as well as the format and level of detail with which they will be presented in the AoA final report. This gives the government an opportunity to provide feedback to shape the presentation of final results in the AoA report and to improve its usefulness. The schedule for the PRR briefing should be driven by the anticipated availability of preliminary results (i.e., analytical results in enough detail to examine the trade space in a briefing or discussion, but prior to full examination and written reporting).

- **AoA final report.** The results of the AoA are documented in a final report and generally presented at preliminary solutions engineering review (PSER) briefings to the ADA or to an executive steering committee appointed by him or her to provide oversight. DHS guidance provides a template detailing the preferred format for the AoA report.\(^{33}\) The study plan typically follows this same format or

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\(^{30}\) Department of Homeland Security, *DHS Acquisition Instruction/Guidebook Number 102-01-001*, “Appendix G,” G-3 describes the study plan and says “The Sponsor/PM, in conjunction with the organization/entity that will lead the analysis shall prepare a Study Plan . . . and provide it to the Component Acquisition Executive (CAE) prior to initiating the AoA/AA effort.”

\(^{31}\) Ibid., G-3.

\(^{32}\) Ibid., G-3 – G-4.

\(^{33}\) Ibid., G-6 – G-16.
template; the AoA team can therefore “recycle” parts of the study plan in the final report (primarily sections 1 and 2, as well as large portions of sections 3 to 5).

To save time and effort, the program manager may be tempted to forgo a final report and instead ask for a final briefing. This would be unwise. If the study is worth doing, it is worth documenting well. In fact, the Air Force AoA experts say “a study not documented is just as good as a study not done.” This is particularly true when the program is delayed for budget reasons and the study is put on the shelf. The hard questions may come a year or two later, when the study team is disbanded and the ADE-2A acquisition decision has to be made.

Risk Management

Risk can be a confusing term in the AoA arena because widely different concerns share that same label. There are at least three types of risk that the government and the AoA team will confront and must manage during the AoA process or account for within the analysis process itself.

- **Programmatic risks** describe uncertainties (often funding issues) that could have a negative impact on the overall acquisition program under which the AoA provides support. Naturally, program risk could also undermine or preclude successful execution of the AoA. These risks are most appropriately tracked and managed by the government agency or component. Unless these risks reduce the resources devoted to the AoA or shorten the timeline for completion of the AoA, most often program risk will be transparent to the study. Sometimes, though, program risk can affect the viability of certain alternatives due to cost and affordability.

- **AoA project risks** describe uncertainties that could negatively affect the quality of one or more components of the AoA analysis. Unavailable data are among of the most common project risks. For example, a serious project risk might be a lack of quantitative data describing the performance of one or more alternatives on a key metric. These risks are most appropriately tracked and managed by the AoA team and regularly communicated to the government.

- **Alternative risks** describe uncertainties that could have a negative impact on a particular alternative’s operational performance or cost. This might include programmatic risk for the alternatives themselves, but this should not be confused with the program risk described above. For that reason, these risks will not be addressed any further here because they are not relevant to this discussion about governance and oversight. They will be handled in the analysis discussion later in this document.

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35 The government, however, should be involved in any discussions about “workarounds” when unavailable data will significantly alter the analysis approach laid out in the study plan.
SCOPING THE STUDY

The scope of the AoA significantly frames the study. It defines the breadth and depth of the AoA, including the number and diversity of threats, scenarios, alternatives, and CONOPS considered. It also includes the level of detail for the analysis. Starting from governance and known study constraints through analytic data requirements, the scope is typically expected to evolve over the course of the study. However, the scope should also note that development or delivery of critical analytic data may be outside the control of the AoA team. The time frame of the program and resulting AoA schedule imposes one constraint or pressure on the scope; analytic needs often apply pressure on the scope in the opposite direction.

Overview of DHS Guidance on Scoping an AoA

DHS guidance on scoping an AoA is minimal. The AoA report template implies that scoping guidance should address the following: “Describe, in broad terms, the nature of the possible alternative solutions to be considered. Identify any constraints on alternatives identified by the MNS, CDP, and/or CONOPS.”36

At a high level, the CDP should contain additional scoping guidance. First, the CDP scopes the analysis by directing an AoA or an AA. Beyond that, the CDP may prescribe the alternatives required for the analysis, ground rules and assumptions, and the level of study detail.37 This guidance leaves many aspects of the scoping effort unsaid and up to the analytic and governing team to define. The driving force of the scoping effort should be to define what questions the decision maker needs the AoA to answer. The scoping effort should also limit the analytic effort to answer those questions. This scope will set the boundaries of the effort and may need to be updated through the course of the study.

Key Analytic Considerations in Scoping an AoA

In consideration of these realities affecting the AoA, this document recommends adoption of an iterative development process with explicit reconsideration of study scope at critical junctures. The study phases and key considerations or constraints are listed below:

- **AoA context**: program deadlines, contractual arrangements for the various participants, and government oversight expectations
- **Analytic starting point**: AoA governance, especially the AoA study team in relation to other program activities; key reference and background documents, anticipated scope, and scale of the alternatives
- **Analytic study plan and execution**: identification of alternatives; degree and depth of analysis; specification of analytic methodology, especially determination

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of the threat or mission scenarios for the analysis and the measures of effectiveness; data requirements for comparable basis; and preliminary results

- **Finalizing results**: execution of analysis, exploration of the trade space, and representation of final results

Figure 6 provides a diagram of the relationship among these various study phases. In particular, realities introduced during the analytic study plan and execution may affect the scope of the study, typically evolving in the face of inadequate or biased data for at least one alternative within the analytic methodology planned. In this case, scope of the study must be explicitly reconsidered, either by (1) modifying the study context (e.g., program deadlines); (2) adjusting analytic starting point (e.g., revising alternatives selected, aligning program reference documents); or (3) resetting the study plan. Finally, the scope of the study is typically broader than what can be manageably presented in an oversight briefing. Therefore, it is important to get agreement between the study team and program staff about which results are most important to present and how best to present them. Occasionally, this requires modest modifications of the analytic calculations to generate the appropriate representations.

![Figure 6. Diagram of study phases with iterative consideration of study scope](image)

These are the key program reference documents that will usually influence the direction of the AoA:

- mission needs statement (MNS)
- preliminary concept of operations (P-CONOPS)
- capability development plan (CDP)
- preliminary operational requirements document (P-ORD)

DHS acquisition guidance provides a description of each.38

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38 Ibid., “Appendices C, D, F, and H.”
**Pragmatic Issues in Scoping an AoA**

**Controlling Changes in Scope**

Critical elements of study scope should be revisited frequently. One of the strongest pragmatic considerations for study execution is establishing processes to document mismatches of AoA constraints, scope, and reasonable study execution. Once these mismatches are identified, then the choices are to refine the AoA context, constraints, and assumptions or adjust the expectations of the study results.

Formal requests for data from the AoA study team are an excellent means of establishing data requirements. These data requests can be sent to the program manager through pre-established governance channels. The request should also contain deadlines for return of reasonable descriptions of the types of data available and a schedule for data delivery. Formal data requests also introduce natural points to review the relationship between analytic direction (via available data) and study scope. The challenges of gathering objective data should not be underestimated; they can become a major determinant of AoA performance and success.

Other typical program elements such as processes to manage the integrated master schedule (IMS) and program risks present similar opportunities to pose concerns about study scope. Lastly, the AoA study team should ensure that all critical elements affecting the scope of the study be reviewed and approved in accordance with the established AoA oversight or governance construct.

**AoA Alignment with Program Documents**

The quality and stage of development of the foundational program documents will vary from one AoA to another. Realignment or modification of these documents may pose a particular challenge to the AoA team. In general, the development of these documents will be managed within a different part of the program, often with different governance and contract considerations. If the choice of alternatives or direction of the analysis is running contrary to these fundamental documents, the AoA study team should engage the program manager and the document development teams early in the process. This will help the AoA study team to understand the inputs and constraints guiding their development and potentially to influence document updates to align better with the emerging AoA study direction and results.

When all is said and done, there must be a complimentary and supporting relationship among the AoA analysis findings, the ORD, the approved CONOPS, and the MNS. Accordingly, the selected alternative must be capable of the operational performance specified in the refined ORD that closes or mitigates the capability gaps identified in the MNS, when used in accordance with the refined CONOPS.

**Consider Scope When Forming the Study Team**

The AoA’s scope will influence the expertise, competencies, and size of the study team required to perform the analysis. The program manager should have this in mind when
deciding how to source the study team. Whether obtaining government, FFRDC, or private contractor support, communicating the AoA’s scope to prospective performers is an important prerequisite for forming and resourcing an effective study team. First, understanding the study’s scope will help the technical leads of prospective performers to advise the program manager regarding the necessary team composition. Second, if contracting for analytic services, scope provides information critical for estimating costs appropriate to the analytic requirement. Without an adequate description of the study’s scope, there is a good chance that the analysis team will be improperly sized or include the wrong competencies for the task.

Further scope considerations are described in relevant sections in the remainder of this document.
CHARACTERIZING CHALLENGES (THREATS)

As previously discussed, within DHS, a “challenge” might be a physical terrorist threat, a category 5 hurricane, a congressionally mandated change in immigration policy, or an increase in the flow of commerce through U.S. seaports. Regardless of the specifics, “challenges” for the purposes of an AoA are elements of the operating environment imposed on DHS (i.e., important factors DHS cannot control). Understanding these challenges informs the scope and identification of alternatives that may be effective within that environment. It is important that the challenges be described fully so that any factors relevant to the AoA are known. If some of the elements necessary to properly characterize the challenges are not known, assumptions should be made and documented. For simplicity, in this document, we will use the term “threat” as a substitute for the broader set of factors that challenge our homeland security missions, goals, and business plans.

Overview of DHS Guidance on Describing the Threat

DHS guidance on description of the threat or threat scenarios is minimal, but a short discussion is included in the DHS Acquisition Instruction/Guidebook, Number 102-01-001, “Appendix G: Analysis of Alternatives (AoA)/Alternatives Analysis (AA)” (section 2) under “conditions and assumptions.” This section of the guidance considers both the threat and the DHS operational scenarios in a single discussion. In this document, they are treated separately.

Key Analytic Considerations in Describing the Threat

The key analytic consideration in describing the threat is to characterize it in sufficient detail to enable evaluation of the effectiveness of the alternatives in detecting, preventing, interdicting, or mitigating its consequences. Depending on the threat and mission being evaluated, threat detail provides the effectiveness analysis team with the means to develop useful measures of effectiveness. It also provides the cost team with the means to understand the critical elements of the CONOPS to inform cost analysis decisions.

Since DHS has little or no control over the threat, it is critical that the proper description of the potential threats be explicitly stated and understood by the study team. This understanding may involve collaboration with other elements of the government to describe the threats and potential consequences if those threats are not countered. One example of a threat is an adversary who tunnels across an international border to transport drugs, money, people, or weapons without detection or inspection by proper authorities. Further details in describing this threat, such as specifics about the objects themselves and about the adversary’s capabilities and knowledge, allow the analysts to understand how to organize their effectiveness measures and conduct the effectiveness evaluation.

DHS or the program manager may be unable (or unwilling) to state specific threat characteristics. Regardless, there is likely a range of possibilities. Further, a strong threat analysis does not require, and often should not include, a prescriptive determination about the threat. It does not require anyone to make a statement about what the adversary will
do. Predictions of adversary actions are not useful, since the actions will not be known with certainty until after the fact. That said, a thorough threat analysis would consider ranges of possibilities, across the relevant dimensions, and provide relative, logical probability weightings within this resulting matrix to ensure that a representative cross section of potential conditions is considered.

An AoA team should bear in mind the following considerations about threat when conducting an analysis:

- Threat is defined in consultation with appropriate intelligence or scientific communities and based on characteristics of potential sources, vulnerabilities, and potential consequences of an incident. For natural threats such as hurricanes and earthquakes, the study team should consult with the scientific community, which best understands the characteristics of the threat, and the recovery community, which best understands the consequences.

- Some threat characteristics or consequences may require consideration of classified materials to describe them accurately.

- The AoA team may need to make a decision about how to characterize the threat in an unclassified version of the AoA or AA report.

- For security classification reasons, or for other reasons, the threat may be characterized in the AoA as a defined set of threat characteristics (e.g., specific means of attack, specific tactics, specific locations, etc.), without identifying the threat sources, as long as this does not adversely affect the results of the AoA. For instance, in the tunnel example described previously, the set of threat characteristics may be the different types of known tunneling techniques and not the specific items that are being smuggled through the tunnels (e.g., drugs, money, people, or nuclear materials) or the groups digging the tunnels. In some cases it may not be important to know what is being smuggled or who is doing the smuggling, but only to know how to detect and interdict the tunnels themselves.

- The threat description usually has a direct impact on how the scenarios and CONOPS should be developed. The CONOPS can be developed to combat a generic threat, but usually must be distilled down to how the capabilities will be used against a specific threat, under specified conditions, to enable effectiveness evaluation.

- The threat analysis or description may be provided to the AoA team with limited opportunity to alter it. If this is the case, and if the provided threat is complete, the AoA need not spend resources to further develop the threat other than to verify its completeness. If the threat description is not considered complete for purposes of the AoA, but a fuller threat analysis is not part of the scope of the AoA, the AoA

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39 This assumes that an AoA will be conducted in the face of threats that rarely happen. By contrast, for any threat that may have occurred with any frequency, the threat analysis may rely on historical data describing instances of the threat (e.g., occurrences of natural disasters).
team will need to isolate missing aspects of the threat description, make and document necessary assumptions, and perform sensitivity analyses around the assumptions to include in the final report. If any of the sensitivity analyses show that the final results are sensitive to the assumptions made about threat, then the final report should most likely include a recommendation that a more complete threat analysis be undertaken.

- As part of the iterative approach to managing the scope of the study, threat analysis should be dynamic and considered in conjunction with the alternatives. Particularly in the case of an intelligent adversary, the study team should explore how the threat may adjust if a particular alternative is implemented. In other words, the analysis needs to consider the robustness of potential measures (i.e., alternatives) that could be implemented and the likely threat countermeasures. The AoA should also consider the counter-countermeasures DHS might implement after the threat has adapted. If an expensive alternative is easily and cheaply circumvented, it is probably not a good investment. In fact, implementing poorly thought out measures, in some cases, can even result in a situation that is more dangerous than if DHS had done nothing.
IDENTIFYING ALTERNATIVES

Identifying alternatives is one of the most difficult challenges for any AoA. The choice of alternatives strongly affects the scope of the study, the measurement and analytic methodologies, and the degree of difficulty in estimating alternatives’ cost.

Overview of DHS Guidance on Identifying Alternatives

The DHS Acquisition Instruction/Guidebook specifies that an AoA or AA must consider a minimum of three viable alternatives and the government may identify some or all of the alternatives for consideration prior to initiating the AoA or AA. Beforehand, as a standard business practice, the government may issue a request for information (RFI) to ensure it has captured the full range of viable alternatives. In general, all of the alternatives identified for consideration in the AoA must meet two basic criteria: they must address the capability gaps identified in the MNS and CDP, and they must present a viable or realistic CONOPS. Regardless of how the list of alternatives is constructed, the AoA or AA team should consider each in the context of the current or possibly modified MNS, CDP, P-ORD and P-CONOPS.

The DHS guidance recommends that an AoA first consider solutions that are nonmaterial in whole or in part because they often require fewer resources to implement. However, in the case of an AA, all alternatives under consideration will be material solutions.

Sometimes the government approaches the AoA with a clean slate (i.e., no written, predefined alternatives), and the study team must identify all of the alternatives. Whether or not some alternatives are mandated for inclusion in the study, part of the team’s job is to discover stakeholder views about potential alternatives. For example, the team should ask the stakeholders what might reasonably be considered as a cost-effective way of solving the problem. This step is essential for the credibility of the AoA.

Beyond the guidelines highlighted above, DHS documentation offers little detail about actual selection of alternatives for an AoA. However, the documentation does give a few general principles:

- **Viability of alternatives**: “The AoA explores these alternatives with the goal of identifying the most promising approach to achieve user-required capabilities within practical performance, cost, schedule, and risk boundaries.”

- **Feasibility of comparison**:

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40 Note that there is frequently no requirement for an AA to determine alternatives since they are typically assigned in the contractual and governance documents establishing the AA.
42 Ibid.
43 Ibid., G-1-G-3.
45 Department of Homeland Security, DHS Acquisition Management Instruction/Guidebook Number 102-01-001, 34.
AoA Methodologies: Considerations for DHS Acquisition Analyses

- "To the extent possible, benefits [of an alternative solution] should be expressed in terms that enable a comparison between effectiveness and costs."46

- "There must be consistency and traceability among the MNS, the CONOPS, the business, operational, and technical requirements, the financials and various alternatives’ evaluation."47

- Reasonable range of alternatives (constrained by resources and defined scope):
  
  - "The study team should initially identify and analyze high level capability concepts and options derived from the Study Plan, CONOPS, or other sources to eliminate less desirable alternatives and narrow the field to more desirable options."48
  
  - "Only the top three to five most effective, viable, and affordable alternatives should be fully examined in the AoA/AA."49

- Explanations for eliminating alternatives: "A rationale should be included for any candidate alternative not included in the analysis."50

Key Analytic Considerations in Identifying Alternatives

In addition to the general principles outlined above for guiding the identification of alternatives, in HSSAI’s experience, there are a number of other critical considerations. They are discussed in the following subsections.

Establish or Define System Scope

The mission tasks and their desired outcomes and the trade space of doctrine, organization, training, materiel, leadership, personnel, facilities, and regulations, grants and standards (DOTMLPF-RGS) effectively define the scope of the system within which alternatives are identified and analyzed. The study scope and system scope must be aligned so that the AoA is feasible.

In the course of the AoA, analysis of the mission tasks and development of effectiveness measures may lead to reconsideration of the effective trade space to explore. For example, nonmaterial solutions may not be viable if there are no data corresponding to the effectiveness measures chosen. As the analysis evolves, then, it may be critical to reconsider the system and study scope accordingly.

46 Ibid., 35.
48 Ibid., 41.
49 Ibid.
50 Ibid.
If the study scope restricts the trade space of DOTMLPF-RGS to material solutions, then the AoA transforms into an AA. Still, it is important to have documentation of the complete DOTMLPF-RGS process as a foundation for the AA.

**Describe the Baseline System**

Ordinarily, the AoA team must consider the current baseline system as an alternative, at least in the earliest phases of the AoA. In fact, the baseline is normally pre-identified for the AoA or AA and used for explicit comparison later in the study, assuming the baseline actually addresses the associated required mission tasks. Even when comparison to the baseline is not an explicit criterion, it is often useful for presentation purposes in the final report since it can illustrate the potential performance gain of the assessed alternatives or inform the decision as to whether or not any of the alternatives provide sufficient performance improvement to justify the investment of resources. As such, a full description of the baseline, focusing on CONOPS, measures of effectiveness, measures of performance, and life cycle cost are important data for the AoA.

**Identify Objective Criteria for Including Alternatives**

Perhaps the most important step in identifying alternatives is to fully describe the objective criteria for selecting them. The reason for this is that the identification of alternatives may be politically charged. In that case, both stakeholders and operators often have strong opinions about a preferred solution well before the AoA starts. In addition, vendors frequently campaign for their systems through DHS and its components and occasionally involve members of Congress. Thus, if a reasonable alternative is not included in the AoA at the beginning (or injected later) or it is excluded prematurely without apparent good cause, the entire AoA could be dismissed as invalid.

Therefore, as early as possible, the program or project manager and the study team should begin developing the selection criteria for alternatives to be considered viable candidates for satisfying the approved mission needs. Because of the potential negative impact on the credibility of the AoA, early in the process, the oversight committee should vet the selection criteria. As part of that process, the study team should share the implications of the selection criteria so it is clear which alternatives were selected and which were not.

Perhaps the first factor to consider is a required maturity level for the potential material solutions. The term for this technological maturity in the acquisition business is technology readiness level (TRL). It can vary from TRL-1 for a paper concept to TRL-9 for a fielded system. Therefore, a TRL-9 alternative could be available today, whereas a TRL-1 alternative may never be available.

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As a result, the program timeline (not the AoA timeline) becomes critical. Depending on the mission need and the anticipated time for deployment of the system to meet that need, some alternatives simply cannot be ready in time. Figure 7 below depicts a range of timelines.

![Figure 7. Typical TRL timelines](image)

In most circumstances, if DHS needs a deployed solution next year, it is probably safe to rule out TRL-1 to TRL-5 alternatives. Since TRL-7 is associated with a physical system prototype demonstration in an operational environment, this is sometimes used as a threshold.

Beyond this initial TRL cut, it is important to consider whether other alternatives should be rejected for cost or suitability reasons (e.g., physical size of the deployed system) or due to serious concerns about data availability. If test or modeling data are required, for example, the time to plan and execute the test or build the models and generate the data may not be consistent with the timeline for the AoA. Such a situation would require reconsideration of the AoA scope or the defined constraints, or both.

**Set a Common “Definitional Scale” for Alternatives**

Whether the study is an AA or an AoA, for the purposes of the analysis, it is important to ensure that all of the alternatives are defined with the same level of specificity. The specificity will typically track with the developmental stage of the alternatives. In other words, a more conceptual system will have fewer detailed characteristics associated with it than a more mature alternative. Thus, when a short deployment timeline is anticipated that requires more specific alternative definition, a more conceptual system may not have the specific data necessary to put it on equal analytic footing with other alternatives.

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As a result, this definition of scale often leads to a decision about whether to characterize alternatives as specific, vendor-available systems or models (e.g., a 2012 Ford F-150 equipped with a towing package) or as more general classes (e.g., late-model domestic pickup trucks). When considering classes, the study team must still describe how the representative systems are defined (i.e., performance specifications and cost). As part of this, the team will invariably have to relax vendor specificity to properly portray the wider class of systems.

**Develop Lists of Prospective Alternatives**

To ensure that the alternatives chosen for the AoA represent the best set, it is important to start with a reasonably comprehensive consideration of possible elements of the system alternatives. Beyond guidance provided in the CDP, several approaches may be used to generate the list of prospective system alternatives:

- review existing program documents
- mine research literature
- interview program personnel
- perform market research
- consult with DHS Science and Technology subject matter experts
- review or conduct governmental requests for information or “industry days”
- conduct a workshop of subject matter experts

The overall timeline for the AoA study will determine how much time and research can be devoted to this effort. One caution for this phase of identifying alternatives is that the AoA study team should take care not to inject or attribute too much technical innovation to specific alternatives. Introduction of technical enhancements, unless well justified, may appear to bias the AoA toward a particular alternative, thus undermining the study’s credibility.

**Identify Measures for Evaluating Prospective Alternatives**

As referred to above, a critical limiting factor for prospective alternatives is whether data are available to actually compare the alternatives according to measures selected for the AoA comparisons. The resolution to this potential concern is to iterate through a spiral assessment process: (1) defining measures (see later section in this document), (2) considering prospective data for alternatives, (3) evaluating feasibility of obtaining data within the study timeline (possibly through tests or modeling), and (4) reconsidering scope of analysis or measures and preliminary alternatives. This iterative process should lead to a feasible set of alternatives.
Develop Consistent CONOPS for System Alternatives

For all system alternatives, a CONOPS should be developed with similar degrees of specificity within the overall study constraints. CONOPS should not be vague for some alternatives and more detailed for others. This will ensure that any CONOPS dependence implicit in the analysis will have comparable precision across all alternatives. Once this specificity is defined, these CONOPS should consistently align with any analytic assumptions and data inputs used to conduct the operational effectiveness and cost analysis. CONOPS should be developed in collaboration with and be approved by users/operators or their representatives.

Beware of Subdivision into Subsystems

It is sometimes tempting to divide complex system alternatives into subsystems, perhaps where one subsystem performs one mission task and a second subsystem performs another. However, this results in multiplicative recombination to create full alternative systems. For each combination, new CONOPS combinations and associated cost may need to be recalculated. Even if there are convenient analytics for combining subsystems, representing the range of full system alternatives may prove daunting. Whenever system alternatives are broken into subsystems, look quickly to mechanisms that winnow possible combinations of these subsystems.

Summary of Key Issues in Identifying Alternatives

By consolidating DHS guidance with key HSSAI observations, one can create a hierarchy of study objectives that should help guide the identification of alternatives:

- Description of the baseline system
- Viability of alternatives:
  - Identify objective criteria for inclusion of alternatives.
- Feasibility of comparison:
  - Develop consistent CONOPS for system alternatives.
  - Identify prospective measures for prospective alternatives.
- Reasonable study scope:
  - Establish or define system scope.
  - Define the “scale” of alternatives.
  - Beware of subdivision into subsystems
- Process for eliminating alternatives:
  - Identify objective criteria for inclusion of alternatives
o Develop lists of prospective alternatives

o Develop consistent CONOPS for system alternatives

To summarize, DHS guidance for AoAs recommends that the AoA team conduct an initial down-selection process to identify the most promising three to five alternatives for comprehensive evaluation within the AoA. This is important for practical reasons because, as the list grows, the complexity of the AoA and the resources required to conduct the AoA also grow. Regardless, the team should fully document the process and the reasons for eliminating a particular alternative from further consideration.\(^{54}\)

DEFINING OPERATIONAL SCENARIOS AND CONOPS

Operational scenarios and CONOPS describe how the alternatives will be used in the field and identify the characteristics and constraints of the operating environment. This results in a description of the operating environment and a specific viable CONOPS for each alternative. This CONOPS shapes the development of the analytic framework for analyzing each alternative’s operational effectiveness as well as cost implications. As opposed to the “threat” discussed in a previous section of this document, this area focuses primarily on what DHS can control and how its operators apply the alternatives to counter a threat.

A CONOPS describes a proposed system in terms of the user needs it will fulfill, its relationship to existing systems or procedures, and the ways it will be used. An operational scenario is an examination of the CONOPS in action, given a particular situation and from a particular stakeholder’s point of view.

Overview of DHS Guidance on Defining Operational Scenarios and CONOPS

DHS Acquisition Instruction/Guidebook Number 102-01-001: Appendix F, Concept of Operations (CONOPS) provides guidance for developing CONOPS and operational scenarios. Within the acquisition management process, developing and documenting CONOPS and scenarios is a user and operator responsibility. Governance constructs and coordination with stakeholders should ensure that the AoA study team has adequate access to users and operators to help to define CONOPS. Developing CONOPS and scenarios is an iterative process that culminates during the “analyze/select” phase, likely after completing the AoA.

The AoA simultaneously relies on and influences CONOPS and scenario development. CONOPS and scenarios provide the AoA study team with the operational context for analyzing the alternatives. Operating components may develop draft CONOPS and scenarios (as well as alternatives) during the “needs” phase that leads to ADE-1. If these are well developed by ADE-1, the ADA may approve the performance of an AA, reducing the scope of the study team’s effort as compared to an AoA. Often, however, alternatives and their CONOPS are formally developed and finalized for analysis during the AoA. Usually, the study team works with users and operators to iteratively develop the alternatives, their CONOPS, and the scenarios that will be used to analyze their

performance. All three of these elements, or the plan for their development, are reviewed and approved (as part of the study plan) prior to conducting the actual analysis.\textsuperscript{57}

In practice, performing the analysis may lead to discoveries that provide new knowledge that justifies revision of the CONOPS or scenario. Upon discovery, the study team should discuss these revisions with the users and operators and present justified revision recommendations for approval to the appropriate decision maker. The study team includes descriptions of the CONOPS and scenarios that were used for their analysis in their AoA report.\textsuperscript{58} In turn, once the ADA identifies the preferred alternative, the users and operators should leverage the AoA report when finalizing their CONOPS documentation that will support approval at ADE-2.

**Key Analytic Considerations in Defining Operational Scenarios and CONOPS**

Just as a specific description of the threat aids in defining the mission tasks, measures of effectiveness, and measures of performance, describing the operational scenarios and CONOPS allows the full team to understand how to evaluate the effectiveness and costs of using the alternatives. Operator involvement will ordinarily be required to determine details of the operational environment and constraints to operations that may limit the effectiveness of an alternative. While it is sometimes difficult to understand the impact of these constraints on a newly developed alternative, time spent defining and refining the scenarios and CONOPS can lead to better assessments.

Other important scenario considerations include:

- **Scenarios should describe realistic operating environments that reflect the full mission scope.** The analytic team must consider the operational environment to fully understand how it affects operational effectiveness, suitability, and costs. Many factors go into the full description of the environment, including:
  - How will the equipment be utilized and applied to counter the threat?
  - Will manpower or other resource needs change?
  - Under what environmental conditions (temperature extremes, moisture, radiation, vibration, etc.) will the equipment operate?
  - What is the full scope of the mission?

  The answers to these questions can have implications for all of the analytic areas, not just for operational effectiveness.

- **Scenarios may reflect several possible modes of operation based on threat type or degree of threat.** An example of this is the difference between detecting and identifying a radiological source (or a person near the border). The task of

\textsuperscript{57} Ibid., 39-40.
\textsuperscript{58} Ibid., “Appendix G,” G-5 – G-6.
detection may require a different mode of operation than identification after detection. As a result, the different modes of operation may require the team to apply different data and criteria in the effectiveness evaluation.

- **The analytic team may have to consider several established operational alert categories (e.g., routine operations, specified threat, and heightened alert)** and the alternative systems may be operated and applied to the task differently during these specific conditions. These cases may need specific CONOPS or adaptations of the general CONOPS to describe the different application of an alternative in each category. As a result, the team should define the differences between these alert categories (i.e., the decisions and/or conditions that define each state) and characterize the impact on the task being evaluated.

- **It may be difficult to consider dramatic changes in CONOPS at this stage of the acquisition cycle.** No potential operators will have experience with the proposed CONOPS, and they may have difficulty envisioning how it would be implemented. Of course, historical timing, manpower, cost, and effectiveness data will also be nonexistent. As a result, the analytic team may have to pursue a more in-depth study to understand that CONOPS and its operational implications in detail. Close collaboration with sponsor and stakeholders can help to identify major potential CONOPS changes and their impact. Operator involvement can aid in CONOPS definition, but it may be difficult to assess the impacts of dramatic changes without close collaboration between the operators, stakeholders, and system engineers.

- **Alternatives may be evaluated by scenarios.** The study team must be aware that their choices at this point drive the AoA scope. Multiple potential CONOPS, variations on alternatives, and the number of threat scenarios multiply the burden of data collection, testing, simulation, and analysis (both effectiveness and cost). While the matching of study scope to resources cannot be fully accomplished at this stage, it should be considered.

- **Measurement of effectiveness and estimation of cost must use the same CONOPS.** As a practical matter, cost estimation and analysis of effectiveness may be conducted by different subteams within the study team. It is essential that both teams follow the same CONOPS assumptions so that their results align properly. For example, if operational performance (related to a measure of effectiveness) requires a certain number of operators, the cost estimation should use the same assumption of operator count.
CONDUCTING THE OPERATIONAL EFFECTIVENESS ANALYSIS

The operational effectiveness analysis and the cost analysis (discussed in the next section) are the two key objectives of the AoA. Taken together, integrating considerations of suitability and risk, they provide the basis for the acquisition decision. The operational effectiveness analysis explores the performance of each alternative using the defined CONOPS in the context of the threat and the operational scenarios.

Overview of DHS Guidance on Conducting Operational Effectiveness Analysis

Although appendix G of the DHS Acquisition Management Instruction/Guidebook provides a short overview and concise reporting template for AoAs and AAs, it was not intended to provide specific direction about how to perform these analyses. Appendix G briefly discusses the use of measures of effectiveness (MOEs) and measures of performance (MOPs). In addition, appendix G provides a page of high-level guidance under a section labeled “Analyze Solution Alternatives,” and it describes the need for a sensitivity analysis for effectiveness (and cost).\(^5^9\) Finally, the online DHS course Intermediate Systems Acquisition also contains a few slides that discuss the analysis and both MOEs and MOPs.\(^6^0\) All of these are worth reviewing briefly, but they do not contain details.

While by no means exhaustive, the rest of this section offers additional detail regarding some of the more important aspects of conducting operational effectiveness analyses.

Considerations for AA Studies

Framing the operational effectiveness analysis for an AA is almost the same as framing it for an AoA. However, designing and performing the operational effectiveness analysis for an AA is relatively less complex, given its narrower focus on the comparison of designated material solutions. An AA study team may also be able to leverage existing work not usually available for an AoA. In deciding to pursue an AA rather than an AoA, the government may have conducted an initial operational effectiveness analysis to narrow the broader set of potential alternatives down to the material solutions selected for consideration in the AA. If so, the requirements, measures of effectiveness, and measures of performance that the government developed as a basis for this first down-selection

\(^5^9\) Ibid., “Appendix G,” G-16.
process may be available to the AA team to refine into the final framework for evaluating operational effectiveness in the AA.\footnote{Department of Homeland Security, \textit{DHS Acquisition Instruction/Guidebook Number 102-01-001, “Appendix G,”} G-3.}

**Key Analytic Considerations in Conducting Operational Effectiveness Analysis**

Effectiveness analysis is the most involved and time-consuming part of an AoA. Because the analysis will likely rely on extensive data sets, testing results, or simulations, the acquisition organization must plan this effort properly, well in advance of the AoA start date. If this is not done, ensuing delays in completing the AoA may delay the entire acquisition.

The goal is an objective, analytically defensible, and understandable comparison of the operational capabilities of the alternatives. The operational effectiveness team generates metrics, which inform and are informed by the work of the CONOPS, alternatives, and scenario development teams. The process then requires data that will support those metrics. Analyses of various types validate the results, evaluate uncertainty, and display information that a decision maker can use.

**Mission Tasks**

Establishing mission tasks (MTs) is the first step in an operational effectiveness assessment. An MT is an overarching capability requirement that an alternative must be able to perform. MTs are typically found in or derived from the MNS or policy documents. The set of MTs should be developed in cooperation with the entire acquisition enterprise and should be approved by the oversight committee since they likely will be used in testing, engineering specification development, and elsewhere.

Given the nature of homeland security responsibilities, there are three general forms of MTs commonly found across DHS. First, there will frequently be one or more MTs that address the primary mission of the organization. For example, \textit{effectively control U.S. air, land, and sea borders} is a DHS goal articulated in the \textit{Quadrennial Homeland Security Review} (QHSR). However, these kinds of goals or missions often conflict to some degree with others. For example, \textit{safeguard lawful trade and travel} is another QHSR goal that is just as important and in tension with controlling borders. Accordingly, the second MT form is seen when one or more MTs address the impact on the general public, such as avoiding delays in legitimate trade and transport or interference with safe operations. Thirdly, there often is a need to create an MT addressing operational suitability, a consideration discussed below.

Defining a clear MT requires consideration of alternate perspectives. For example, “operate efficiently” could be interpreted very differently by various parties. Is it the federal government operation that is to be efficient or the adversely affected private industry operation? Different government agencies (federal, state, and local), businesses,
unions, and other constituencies each come to the table with different needs and perspectives on “goodness.”

Unintended Consequences

For a homeland security AoA, developing measures of effectiveness that only capture the federal government’s view of a particular alternative (usually security and cost) can easily lead to unintended consequences—the inadvertent impact (usually cost) on state and local governments or on business and commerce.

Given DHS’s mission set, considering the impact of performing security missions from multiple perspectives is particularly important for the department. Emergency management, law enforcement, and illegal immigration issues often affect state and local governments, while airline security, customs, border protection, and legal immigration almost always have an impact on business and/or commerce. This is an important distinction for many DHS studies and a necessary complication as compared to most Department of Defense AoAs.

Since these overlapping interests (e.g., security from a DHS point of view and cost or efficiency from a business point of view) are frequently at odds with one another, it is important that they be handled appropriately. Hence, for credible DHS AoAs, the study team usually has to develop MTs, MOEs, and MOPs not only for measuring security (or DHS operational effectiveness); it also needs to do the same for the inadvertent impacts on “bystanders.”

To avoid ambiguity, the study should capture the potential conflict between the MTs and make efficiency measurable. Thus, it is better to create separate MTs that address each key stakeholder.

Metric Framework

Using the MTs as a starting point, the team should draft a metric framework. This framework is a hierarchy that connects overarching requirements to the data that are needed. The hierarchy consists of:

- **mission tasks (MTs)** as discussed above.
- **measures of effectiveness (MOEs)** – MOEs are a qualitative or quantitative measure of a alternative’s performance or characteristic that indicates the degree to which it performs the task or meets a requirement under specified conditions.62
- **measures of performance (MOPs)** – an MOP is a quantitative measure of a system characteristic (e.g. range, speed, logistics footprint, etc.) chosen to support one or more MOEs.63

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It is important that the hierarchy be clear and accurate. It is also important that the MOEs supporting an MT collectively address all aspects of that MT. The same applies to MOPs supporting an MOE. It is essential that the hierarchy allow for an understanding of how well mission needs are achieved, given the appropriate data. It is not vital that the classification of an MT, MOE, or MOP be adhered to precisely; whether a given measure is technically better described as an MOE or MOP is a minor consideration. The goal of the AoA is to build a view of the decision space that allows the decision maker to see how well each alternative performs each MT as measured by the supporting MOEs. Table 1 provides a notional example of an AoA construct.

**Table 1. Notional use of MTs and MOEs**

<table>
<thead>
<tr>
<th>Mission Task (MT) #1</th>
<th>Mission Task (MT) #2</th>
<th>Mission Task (MT) #3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MOE 1</td>
<td>MOE 2</td>
</tr>
<tr>
<td>Alternative A</td>
<td></td>
<td></td>
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<tr>
<td>Alternative B</td>
<td></td>
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<tr>
<td>Alternative C</td>
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<tr>
<td>Alternative D</td>
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<td></td>
</tr>
<tr>
<td>Alternative E</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As an example, consider the MT, “Detect nuclear material smuggled in cargo containers carried by truck over the U.S. border.” One might consider four subgoals and construct reasonable MOEs from them:

- MOE 1: ability of the system to scan all trucks coming over the border
- MOE 2: ability of the system to scan all parts of the container
- MOE 3: ability of the system to detect radiation from a specified source within a container
- MOE 4: ability of the system to distinguish licit from illicit nuclear material

One might consider several possible MOPs for MOE 2:

- MOP 2.1: percentage of container volume that the scanner can reach in testing
- MOP 2.2: percentage of container volume in which one can place a particular source and obtain a successful detection during testing
- MOP 2.3: percentage of successful simulation runs that result in successful detection if a particular source is placed at random in the container 10,000 times

For this particular MOE, it is possible that one MOP is sufficient to provide the information necessary to evaluate it. It looks as though these three might be largely redundant, providing little unique additional information. On the other hand, each of the three appears measureable and directly connected to the MOE. In addition, the general
process for measuring each is clearly described. That said, it is not always obvious beforehand which MOPs should be eliminated. Frequently, as the analysis progresses, culling decisions become clearer.

There are three good rules of thumb for culling useless MOEs. They are interrelated and include:

1. An MOE should be an operationally significant indicator of the ability of an alternative to perform an MT. It does not matter if alternative A is 100 times better than alternative B in one narrow measure if it turns out that measure has an insignificant role in MT accomplishment.

2. An MOE must distinguish between alternatives. The MOE may be highly significant to the success of some MT, but if all alternatives produce the same success, this MOE serves no purpose in distinguishing them. However, it may still be that such an MOE serves a purpose. If they are all deficient with respect to that MOE, this is important information. Beyond the AoA, non-distinguishing results may be important input to the other programmatic documents, such as the ORD.

3. An MOE must contribute unique information. If two MOEs provide essentially the same information, it may be advisable to drop one or merge the measures.64

Note: Because operational testing results are often used in AoAs, two other terms are frequently encountered. A critical operating issue (COI) is an overarching concern to be addressed through testing; it therefore resembles an MT. A key performance parameter (KPP) is a basic quantity to be measured through testing and therefore resembles an MOP.

Traceability is also important to MOE selection. One should choose MOEs that are easily traceable from the approved needs identified in the acquisition documents65 and can be easily explained to a decision maker. For that reason, an MOE should only be transformed to a new measure if it serves an essential purpose. Transforming MOEs, for example, to place them all on a 0-to-1 scale may create more problems than it solves. The same is true for artificially reorienting an MOE so that “up is better.” A good reason for transforming data would be that the scale does not properly reflect the results. An example of this would be the creation of the logarithmic Richter scale for earthquake severity, which is much more indicative of destructive effects than the untransformed linear scale.

64 If two MOEs are linearly related (i.e., one can be predicted to some extent from the other with a linear equation), then the square of the correlation coefficient (often called R-squared) is a very good measure of how much common information two MOEs contribute. Values near 1 indicate that the two essentially are contributing the same information, and one can be eliminated. In the simplest case, retaining both of two highly correlated measures runs the risk of having one attribute counted double - or being canceled out altogether if the correlation is close to -1. It might also mean that a careful tradeoff is required. As a result, a correlation analysis should always be a part of an AoA.

The metric structure is an evolving construct, but it should be started early in the AoA since it has the potential to inform the development of CONOPS and alternatives. Those, in turn, will affect the metrics. It should also be completed early since the measures drive data collection—much of which needs significant lead time.

It is important to ensure that each MOE actually measures the right things. If the decision maker is basing his or her decision on second- or third-order operational metrics because the primary first-order metric data are not readily available, it is entirely possible that the decision will be wrong. It is easy to fall into an analytic trap where the analyst chooses measures that are widely understood or that have ample, accessible data, instead of the ones that are most relevant. For instance, if the MT is to “reduce gun smuggling across the southwest border,” then the MOE “reduction in number of arrests of gun smugglers” is by itself inadequate. No doubt the data are more readily available, but how can one tell if an improvement in the metric is due to reduced smuggling, less effective apprehension, or both? MOEs that are indirect measures (indicators) of MT success may be necessary sometimes, but if possible, they should be avoided because they add to the risk of drawing incorrect conclusions.

**Target Values and Constraints**

Sometimes MOPs include target values (e.g., “must be at least this tall to ride”), but those targets should be questioned. The analyst needs to know the source of the target and the intent or rationale behind it. Was a given target derived analytically or is it fairly arbitrary? For example, if the requirement is that a system must detect 90 percent of all threats, the analyst will want to know if 89 percent is still acceptable, and whether the user would be satisfied (or indifferent) about 91 percent. If the target value was derived analytically, that may be an excellent start for gaining insights as to how that MOP quantitatively affects the MOEs.

MOPs with target values could just as easily be addressed as constraints (e.g., eliminate the alternative from further consideration if it cannot detect at least 90 percent of all threats.) A constraint approach can work particularly well for operational suitability issues, but any plan that has the potential to eliminate alternatives from consideration should be carefully coordinated with the oversight committee.

**Operational Suitability**

Operational suitability deals with how well a system is expected to operate within the anticipated environment. While it is not a mission task, it is often best addressed in the metric framework at the same level as MTs as another overarching goal. Typical focus areas within operational suitability include system availability, compatibility, transportability, interoperability, reliability, usage rates, maintainability, safety, human factors, manpower supportability, logistics supportability, environmental effects, documentation (e.g., usefulness of manuals), and training requirements.

Operational suitability issues often interact with cost issues, and the analyst should coordinate these carefully with the cost team. For example, if an alternative is somehow incompatible with existing equipment, the question arises: Should this be raised as an
operational suitability issue, or should the cost of remedying the problem be included in the alternative’s overall cost? This cost approach is ideal since suitability issues are otherwise hard to quantify. Realistically, though, it may be too difficult or too time-consuming to put a cost on all of the operational suitability issues identified. It depends on the time and resources available to conduct the AoA.

Manpower is an important area in which suitability and cost interact. Some aspects are clearly cost issues alone. For example, additional manpower to support an alternative adds cost. Some potential manpower issues, however, are not as clearly tied to cost. Will there be union problems? Are people with the right skill sets available in the areas of interest? Some manpower issues fall in between the two. Are the facilities large enough to support additional people without crowding? How will additional training needs be addressed?

It is also important to avoid double-counting within the AoA. If an issue is treated within the suitability framework, it should not also be used to develop the cost. Otherwise, its impact will be overstated within the AoA, and that error will be difficult to spot. To be clear, though, suitability issues can have both a degraded effectiveness impact and a cost impact. It is just important not to double-count, capturing both the degraded effectiveness caused by the suitability issue and the cost of mitigating that degraded effectiveness.

Data

The metric structure should be the basis of a data collection plan. In an ideal situation, MOEs and MOPs should dictate data requirements and analytic tools. This collection plan describes where the data for an MOP will come from, how the MOP will be calculated, and possibly include timing. In practice, however, sometimes data nonavailability constrains the analytic choices and forces the analyst to choose other MOPs and MOEs or leads the analyst to other data sources. There are numerous sources for these data, including:

- previous testing and studies
- current testing
- simulation results
- manufacturer technical data
- exercises
- surveys

Some of these are more reliable than others.

The analyst must also try to collect information on the variability of the data. Sometimes this may not be possible; test results may be recorded as averages and the source data are unavailable, or the data are produced by a deterministic simulation. Nevertheless, a value developed from data, whether it comes from tests, simulations, or expert judgment, is
always only an approximation. It is always good to know the dependability of that approximation.

Simulation and Testing

This document does not address constructing, executing, or validating models. It also does not address designing and conducting tests. Experts in these areas should be available to help the team, but tests and simulations may be the predominant sources of data for the AoA. If they are, there are some important considerations.

Tests provide actual data, given situations that approximate the operational environment. Simulations provide approximate data given situations that approximate the operational environment. Tests would be preferable to simulations for AoA data, except that they frequently:

- take too long and cost too much to plan and execute
- address only a limited number of operational situations, and often not the ones of interest to the AoA team.
- generate too few data
- are not fully reproducible, which can be critical if an error is discovered
- are subject to uncontrolled external factors (related to reproducibility)
- address only alternatives that already exist or can be physically approximated

Ordinarily, because of AoA time constraints, conducting and building new AoA-tailored tests or simulations would usually be unrealistic. All but the simplest simulations take months or years to develop, and months more to validate. Tests, from conception to final report, more often take years than months. Ideally, as a result, by the time the AoA study team first convenes, necessary simulations should already be available to meet AoA data needs and testing should already be underway.

Due to the evolutionary development of the MOEs and MOPs described earlier, these previously developed simulations and tests are only starting points. The team may discover a need for modifications to evaluate key MOPs.

On a related note, the analyst should exercise extreme caution when considering combining one type of data with another to generate results. For example, it may be tempting to augment simulation runs of alternatives A and B with test data on alternative C. After all, test data may be more reliable than simulation data. Even if that is true, it misses the point. Both the test and the simulation contribute some degree of systematic error (bias) to results, and the extent is usually unknown. If results for alternative C have less bias, then it is impossible to tell if the results reflect actual differences with alternative C or simply reflect the different degrees of bias between the simulation and the test. This is a common error when the study team is looking for scarce data to support its MOEs and MOPs, but it can invalidate the study. It can happen just as easily when
combining any other two data sources, for example, the results of two different simulations.

**Validation and Verification**

Validation and verification (V&V) is an important step toward certification, or at least general acceptance of computer simulation results. V&V is the establishment of how well the simulation reflects reality, but it is not an absolute. It cannot ensure “truth”; it can only provide increased confidence of the simulation’s reliability.

Validation procedures include:

- comparing simulation results to operational data
- comparing simulation results to test data
- comparing simulation results to those of another simulation
- ensuring that the simulation produces reasonable results across all input values
- seeing if varying inputs results in expected behavior (e.g., does a plot of results versus inputs behave as expected.)

Verification, for purposes of the AoA, is the process of determining if the simulation does what it is supposed to do. Verification processes include:

- ensuring outputs occur under all combinations of inputs
- comparing theoretical output versus input plots with those produced by the simulation
- tracing the logic path
- testing individual routines

Ideally, V&V should be conducted on each simulation before data collection starts. Not doing so risks discovering later that the ground that the team built the AoA’s foundation on has shifted or disappeared. Conducting V&V on a simulation after data collection has started is equivalent to repairing or rebuilding an airplane while it is in flight.

Finally, the model-test-model process may be used to establish valid and accurate simulation and modeling. In the model-test-model process, test results are compared to initial model results with a comparative analysis specifying modifications to the model. The model is then rerun within the new configuration and compared anew to the test results. In general, an AoA does not directly employ the model-test-model process, but validation within the V&V process often will incorporate at least model-test comparison.

**Combining Measures**

“Rolling up” is the colloquial term for combining two or more measures into another measure that attempts to capture the relevant analytic essence of those being combined.
This may entail a weighted average or some other more complex function of component measures. A roll-up makes perfect sense in some situations to simplify the analysis or to make the results easier to understand, but it can be a mistake in other situations. Since this topic arises in virtually every AoA, it is important to discuss the hazards associated with performing roll-ups.

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**Caution on Roll-Ups**

A simple real-world home-buying example might help clarify the hazards. In considering the process of buying a home in a metropolitan area, most potential homebuyers would consider any number of factors when deciding which home to buy. These “MOEs” might include cost, house size, the neighborhood, the commute, and the quality of nearby schools.

If the home buyers have narrowed their search to four homes (i.e., alternatives) based on an evaluation of these five factors, how many of them would feel comfortable taking their analysis a step further by rolling their results up into a single “answer” and then using that answer to make their buying decision? Not many. Instinctively, even if they cannot articulate it, most people grasp two fundamental problems.

First, how would they perform a roll-up when the MOEs measure different things and use different units of measure (i.e., dollars, square footage, minutes, and “good,” “bad,” or “average”)? Would they normalize from 0 to 1 and then average those (i.e., assuming equal weights for each factor), or would they assign different weights based on the perceived importance of each factor? If so, who assigns the weights?

Second, the factors are not independent. That is, the appropriate weighting assigned to one factor can change depending on the values (i.e., actual number of dollars, square footage, or minutes) assigned to the other factors. Furthermore, weights assigned by one person or one group may vary dramatically from those assigned by another person or another group—even within the same organization (or household).

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For these and other reasons, a roll-up process becomes an immediate and appropriate target for scrutiny.Sometimes it is necessary, but analysts should avoid the temptation to do a final roll-up of disparate measures because the roll-up, as described above, will not help the unbiased decision maker and, without it, the AoA will be seen as more credible.

On the other hand, sometimes a roll-up (usually of MOPs or sub-MOPs) is necessary and desirable. In the home-buying example above, if two measures share the same units, (e.g., commute time for the husband in minutes and commute time for the wife in minutes), then it might make sense to roll those up instead of having two separate MOEs to capture them. (Note: This may be an excellent example of why the metrics should not be combined, as doing so might hide whether one person had a larger burden.) Of course, the analyst still must decide how best to roll them up. If they both commute five days per week, maybe a simple average is best. If not, perhaps different weights are appropriate, based on the number of days they each commute. Unfortunately, it is not always that simple. Sometimes, even when weights can be derived analytically, they can be derived
in different ways. Furthermore, sometimes they simply cannot be derived analytically and weighting becomes more subjective.

When that happens, it is important to realize that there are tools available to help with the subjectivity. Two common tools are conjoint analysis and analytical hierarchy process (AHP). Each addresses different situations and provides a different kind of result.

**Dealing with Uncertainty**

Uncertainty is an integral part of an AoA, but, since it creates risk within the AoA and potentially obscures the decision, effort should be taken to reduce or quantify the uncertainty. There are five primary sources of uncertainty in any AoA enterprise: missing information, unreliable information, conflicting information, noisy information, and confusing information. Strategies for dealing with AoA uncertainties include:

- seeking further data (either to reduce noise or to quantify bias)
- filling a data gap using reasonable assumptions
- bounding the results (e.g., by assuming a worst case or a best case, or both)
- Using an alternate or surrogate MOE in place of the primary MOE choice that proves unsuitable for some reason
- Comparing alternate data sources (e.g., by augmenting a test with modeling)
- Focusing oversight committee attention on the problem and the risk it imposes
- Accepting the uncertainty, but trying to quantify its range and implications, using sensitivity analysis to evaluate the overall impact on comparative results

**Sensitivity Analyses**

Sensitivity refers to how much an MOE might change as another operational metric is varied. Of greatest interest are operational metrics that, when varied, produce opposing trends in two MOEs. For instance, if something increases the gain (i.e., sensitivity) of a sensor, it is likely to improve detection of illicit material or people, but it will also inevitably increase the number of false alarms, either slowing down licit trade or wasting resources trying to locate a “ghost.” One then might discover, for example, that a different alternative comes out as the best performer, depending entirely on the threshold set for the sensor. A sensitivity analysis (of sensor sensitivity, in this case) will quantify this shifting among alternatives.

A sensitivity analysis is normally advisable if one does not know the value of an MOE precisely due to (systematic or random) error in data. As a result, the analyst should

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identify when data within the feasibility range for one metric cause a sufficient change in the MOEs so that a different alternative comes out on top.

Finally, if a weighted average is used to roll up MOEs, the relative performance of alternatives will often vary when the weights are changed. Given that subjective weights are seldom known accurately, a sensitivity analysis is also advisable to test the effects of variations in the weights.

**Characterizing the Trade Space and Representing Analytic Results**

Results of MOE assessments can be displayed in a variety of ways. Any display should clarify the actual differences between alternatives. One might display MOEs singly in tables or plots, or show two or more MOEs on a single plot.

The main challenge in displaying results is dimensionality. The alternatives themselves represent one dimension; this one dimension is needed in any display. One might need two or more additional dimensions just to capture the performance of the alternatives for the various scenarios and for other key operational variables. One might also have several MOEs of interest, each requiring a dimension to display. Unfortunately, a piece of paper can only display three or four dimensions, depending on the depiction, the analyst, and how astute the decision maker will be in understanding the display. It is always a challenge to determine how many and which displays are best. Experience and creativity (i.e., the ability to visualize and create concise, effective depictions of the most important results) are important in this stage of the analysis. This is where early consideration of the trade space—with concurrence or approval by the oversight committee—can serve as a guide to representing the results.

Regardless of the form chosen for the display (plots, graphs, etc.), it is also important to avoid common mistakes in creating charts for an AoA. It is often tempting, for example, to curtail portions of a plot that contain no “action.” If values for a particular MOE all lie between 100 and 110, then someone may suggest that the chart “zoom in” on the 100-110 range so it is easier to see the differences between the alternatives. In some environments, it may be acceptable to create charts like this to visually emphasize the advantage of one system over another. This should not be done in an AoA, however, because the choice of origin can significantly skew a decision maker’s perspective. It might make one alternative appear to have a dramatic advantage over another alternative, when, in fact, the difference is negligible. Often, zero has a clear, physical meaning for a given metric, and an AoA should preserve that meaning.

**Summary of Key Issues in Operational Effectiveness Analysis**

To summarize, these are some of the most important points to remember:

- Effectiveness analysis is the most involved and time-consuming part of the AoA. Its goal is an objective, defensible, understandable comparison of the operational capabilities of the alternatives.

- The first step in an operational effectiveness assessment is to establish the MTs.
• Using the MTs as a starting point, the team should draft a metric framework. This framework is a hierarchy that connects overarching requirements to the data that are needed.

• It is important that the hierarchy be clear and accurate. It is also important that the MOEs supporting an MT collectively address all aspects of that MT.

• Traceability and clarity are also important in MOE selection. It is also critical to ensure that each MOE actually measures the right things.

• The study scope should determine whether operational suitability is framed as a constraint on alternatives, treated as parameters affecting cost, or captured in the metric framework.

• The metric structure is the basis for the data collection plan. In an ideal situation, MOEs and MOPs dictate data requirements.

• The analyst must also try to collect information on the variability of the data.

• Tests and simulations may be the predominant sources of data for the AoA. If they are, there are some important considerations.

• V&V is important too because it justifies the use of a tool or simulation.

• An analytic weighted roll-up of MOEs makes perfect sense in some situations, but it can be inappropriate in others.

• Quantifying uncertainty may be critical to the AoA. Sensitivity analysis should assess the impact of uncertainty on the comparative results.

• Effectiveness results can be displayed in a variety of ways. The ones selected should clarify the important differences between alternatives in terms most important to the decision maker.
CONDUCTING COST ANALYSIS

As discussed earlier, the product of an AoA is a report that includes analysis performed by a team that is independent of the program manager and the Acquisition Decision Authority (ADA). The analysis does not make the decision, but it informs the ADA’s selection of a preferred alternative. Although the AoA report includes cost estimation and analysis, there are other cost-related documents that the program manager must develop external to the AoA in preparation for ADE-2A.

Upon close examination, ADE-2A – the acquisition decision event at the end of the analyze/select phase – is more of a program-approval milestone decision than simply a selection from among competing alternatives that meet program requirements. The AoA is only one of seven documents that the program manager submits for DHS program review or approval at ADE-2A. Three of these documents are programmatic: the Acquisition Plan, the Acquisition Program Baseline (ABP), and the Cost Estimating Baseline Document (CEBD)/Life Cycle Cost Estimate (LCCE).

Although related, the differing purposes of these documents and the iterative sequence of their development create complexities for cost estimation and analysis, including those performed for the AoA. For example, on one hand, the AoA seeks only enough detail to discriminate among the alternatives, with DHS cost-estimation guidance using language such as “high-level” (as in broad) and “rough order of magnitude” to describe the cost estimation. On the other hand, ADE-2A should only approve affordable, cost-beneficial programs that are properly funded. This requires appropriate financial analyses of credible life-cycle estimates of the overall program’s cost and a good understanding of the component’s budget. According to the GAO Cost Estimating and Assessment Guide, “a cost estimate is the summation of individual cost elements, using established methods and valid data, to estimate the future costs of a program, based on what is known today.” In fact, DHS adapted Figure 8 below from the same GAO guide to illustrate the point in the context of the overall acquisition process.

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67 DHS Acquisition Instruction/Guidebook Number 102-01-001 provides a separate appendix and template for the development of each of these seven documents. Of these seven, the AoA (including the subsequent selection of a preferred alternative) and CONOPS are actually approved at the component level prior to DHS-level review. The other five documents are based upon the selected alternative and are subject to ADA approval at the DHS-level ARB that supports ADE-2A. Department of Homeland Security, DHS Acquisition Management Instruction/Guidebook Number 102-01-001, 26.
68 Ibid., 42.
69 Ibid., 45-46.
As part of the post-AoA requirements, the program manager will likely be required to refine the program and update the independent AoA cost estimates in order to meet other programmatic considerations. Given a selected alternative, the program manager will build a more specific CEBD and program, refine AoA costs accordingly, and create or update the necessary programmatic documents for ADE-2A.

Given these complexities, program managers should carefully plan and organize the cost estimation and analysis efforts that will be needed to meet designated acquisition guidance and subsequent program justification. The program manager should consider what is known prior to conducting the AoA, what information is expected to be developed during the AoA, and the timeline for meeting the broader set of ADE-2A documentation. In particular, the program manager should provide clarification and guidance for scheduling and assigning the desired level of detailed cost estimation and analysis, including the desired cost-benefit and financial analyses.

Our experience at HSSAI has been with AoAs in which the independent analysis team compared the high-level life cycle cost and operational effectiveness of alternative systems, while detailed programmatic costs and financial analysis were performed by the program office in parallel with or subsequent to the AoA. Regardless, it is important that the analysis provides what the Component Acquisition Executive (CAE) needs to make a decision regarding the preferred alternative and also what the Acquisition Review Board needs to support the ADE-2A decision. We recommend that the CAE, program manager, and

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Figure 8. Uncertainty in cost estimates\textsuperscript{71}

DHS PARM, analysis team, and other key stakeholders discuss and agree upon the appropriate scope and requirements at the onset of any AoA.

**Overview of DHS Guidance on Conducting the Cost Analysis**

As with the operational effectiveness analysis, the DHS AoA documentation provides some general guidance on performing the AoA cost analysis. While more specific guidance on performing the analysis is available elsewhere, the DHS guidance includes the following:

- An AoA develops a cost estimate over a designated life cycle that is common to all alternatives (i.e., an LCCE). A comprehensive LCCE would consider costs associated with research, development, testing, production, facilities, operations, maintenance, personnel, environmental compliance, and disposal.

- The AoA team establishes a set of ground rules and assumptions that are specifically relevant to the cost analysis and then develops a work breakdown structure that characterizes each alternative.

- Cost analysis in an AoA must balance the need for traceability with the fact that specific cost information may not be available for all alternatives, such as technologies that are still in development. Parametric analysis, engineering buildup, analogy, and expert opinion elicitation may be required to compensate for gaps in the available data.

- “Sensitivity analyses on both cost and effectiveness measures will be performed to determine which measures have the greatest effect on a given alternative.” In addition to cost uncertainty, this may also help identify the “cost drivers,” or “those variables a program manager needs to pay the most attention to as the solution is implemented.”

DHS guidance provides latitude for employing different cost analysis techniques, depending upon what is appropriate for the given AoA. Program managers should consult with component and departmental authorities and decide early on whether the AoA study

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75 Ibid. The work breakdown structure (WBS) or a product breakdown structure represents those elements of an alternative that are associated with resource utilization and reflect cost elements.


team will conduct a cost-benefit analysis in addition to a cost-effectiveness analysis. Cost-benefit is the preferred formal economic analysis technique for analyzing programs. Under the right conditions – as when the benefits of each alternative are the same (or should be held constant) – a cost-effectiveness analysis may be all that is necessary for the AoA.78

When cost-benefits are included in the AoA, the financial analysis should include calculations for the present value of the costs, the present value of the benefits (operational and other), the net present value (NPV), the return on investment (ROI), the break-even point, and the payback period.79 If cost-benefits are omitted from the AoA, some of these elements of financial analysis should also be omitted or modified. As a result, program managers should be clear about the elements to be included in the AoA’s financial analysis.

General Approach to AoA Cost Estimation80

During an AoA, as briefly described earlier, a cost estimate is required for each alternative. Without these cost estimates, it is impossible to conduct a cost-effectiveness analysis. Cost estimates developed in support of an AoA should be accurate enough to discriminate between the alternatives under consideration. Like the effectiveness analysis discussed in the previous section, the cost analysis uses a common basis for comparing each alternative. Each alternative’s cost estimate includes the same items, the same period of consideration, and the same basis year for the estimate. Cost elements that may be included in an estimate are:

- **Acquisition.** This may include research, development, test and evaluation, as well as the initial purchase of units of equipment and associated spares, construction, and labor associated with installation and initial deployment.

- **Maintenance.** This includes labor and material at the relevant levels of maintenance. It may include costs associated with warranties.

- **Support.** This generally includes sustaining support such as training and support equipment replacement. It also includes continuing system improvements for reasons of performance, reliability, etc.

- **Operations.** This generally includes day-to-day costs associated with the deployed alternative. It can include salary and benefits of operators, fuel, electricity, or other expenses.

- **Disposal.** This includes the cost to dispose of a system at the end of its useful life. These costs can be ignored unless disposal of the system involves relatively

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78 Ibid., G-14-15.
79 Ibid., G-15.
expensive handling for hazardous materials or accounts for a relatively large share
of life cycle cost.

Cost analysis is conducted for a life cycle, a period of time considered representative of
the alternatives’ planned deployment. The life cycle should be the same length (or longer)
than the longest natural life span of the alternatives. For instance, when comparing
something with a five-year life span to a system with a 10-year life span, the AoA should
assume at least a 10-year life cycle (presumably with replacement for the alternative that
lasts five years). Selecting a life cycle that is shorter than the longest alternative life cycle
can make that alternative seem artificially expensive since the acquisition investment is
spread out over a longer period.

During the effectiveness analysis, the AoA may have to address certain questions that
define important operational characteristics for the alternatives. Examples include:

- How frequently will the system be operated?
- How long it will be used?
- How many people are required to operate it?
- When will one subsystem be used while others are not?

These characteristics can drive maintenance and operating costs. The values (frequency,
duration, operators, etc.) used in the cost analysis should be the same as for the
effectiveness analysis.

**General Methods for Cost Estimation**

There are four general methods for cost estimation. Each method is selected based on the
best available data. Table 2 lists these four methods in descending level of typical data
availability.

<table>
<thead>
<tr>
<th>Method</th>
<th>Data availability (i.e., use when . . .)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price lists and vendor prices</td>
<td>Cost data directly describing elements of an alternative are available.</td>
</tr>
<tr>
<td>Analogy</td>
<td>Cost data describing similar systems are available, and</td>
</tr>
<tr>
<td></td>
<td>Relationships between alternatives and other systems are identifiable.</td>
</tr>
<tr>
<td>Parametric</td>
<td>Insufficient cost data exist on the system(s) of interest or the alternative, but</td>
</tr>
<tr>
<td></td>
<td>Historical cost data on systems of a similar type (e.g., aircraft, computer, etc.) are available.</td>
</tr>
<tr>
<td>Engineering buildup</td>
<td>There is mixed data availability on systems and subsystems.</td>
</tr>
</tbody>
</table>

Here we provide a brief explanation of each method, with an example for each:

- **Price lists and vendor prices.** Price lists can be used when considering the
  acquisition costs for an available system. For instance, if an AoA were
considering the purchase or maintenance of a computer system, corporate or government-approved price lists may be an option.

- **Analogy.** The analogy method estimates costs for an alternative by first identifying a similar system with available cost data. Then the analogy method adjusts for differences between the alternative under consideration and the other system with available cost data.

  For example, suppose the analyst is estimating the cost of a new truck. This truck is similar to an existing truck with available cost data. However, the new truck consumes less fuel (possibly reducing operations costs), but has a more complex engine (possibly increasing maintenance costs). The cost team would start with the costs for the existing truck and adjust the historical cost data to address these two differences.

- **Parametric.** Parametric estimation utilizes cost-estimating relationships and can often be implemented when estimating the cost of new, novel, or complex systems, where engineering buildup or analogy methods prove difficult or impossible. Parametric estimation relies on statistical correlations between historical costs and certain descriptive variables. These variables will vary by system, but may include characteristics like:

  o weight

  o size

  o number of electronic components

  o lines of software code

  Parametric estimation extrapolates the cost of a new system from historical trends for systems of the same type (e.g., to estimate building construction costs by using cost per square foot). This requires access to historical data for the relevant class of systems. Figure 9 illustrates a parametric estimation example:
Figure 9. Parametric cost estimation example

This figure illustrates parametric cost estimation for a new building. There are four historical data points (in red) for previous construction projects. The proposed building will be 80,000 square feet. A linear regression (blue line) is used to extrapolate the new building cost from the historical data points based on the statistical cost estimating relationship between construction cost and building square footage. In practice, the linear regression could use an unlimited number of variables, depending on the type of system under consideration. The regression may also be nonlinear, depending on the nature of the problem and the data.

- **Engineering buildup.** In engineering buildup, cost estimates are developed for each component in a system using one of the other three cost methods. Then the component costs are summed together to estimate the cost of the entire system.

The engineering buildup approach is frequently used when an alternative is composed of fundamentally separate subsystems, or subsystems that require different cost estimation methods. For instance, to estimate the cost of a surveillance aircraft with state-of-the-art radar, the analogy method may be used to estimate costs associated with the aircraft itself, while the parametric method may be used to estimate costs for the radar. Then the subsystem costs are added together to provide the overall system cost estimate.

**Cost-Risk Analysis**

As briefly described in the introduction, risk analysis is important for both the operational effectiveness analysis and the cost analysis. As opposed to the operational effectiveness analysis, the cost-risk analysis should try to capture the impact of cost uncertainties. Assuming there are data to support this, it is always better to provide a range of estimates for cost rather than a simple point estimate. Among others, sources of cost uncertainty may include variability in:
- cost of construction materials
- vendor price quotes
- maintenance costs
- research and development costs

Historical cost data may indicate various possible costs for certain items. For example, maintenance for a subsystem may have a high probability of being near average, but a low probability of costing more or less than what is typical. The AoA team calculates the distribution of possible total costs based on such distributions for various subsystems.

Table 3 illustrates this with a simple example with three possible costs (high, medium, and low) for each of four cost categories. In practice, there may be hundreds of subsystem components with different costs and their own cost distributions.

Table 3. Example of inputs to Monte Carlo simulation

<table>
<thead>
<tr>
<th>Cost</th>
<th>Acquisition</th>
<th>Maintenance</th>
<th>Operations</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>$125</td>
<td>50%</td>
<td>$35</td>
<td>25%</td>
</tr>
<tr>
<td>Medium</td>
<td>$105</td>
<td>40%</td>
<td>$15</td>
<td>50%</td>
</tr>
<tr>
<td>Low</td>
<td>$95</td>
<td>10%</td>
<td>$10</td>
<td>25%</td>
</tr>
</tbody>
</table>

This table lists notional inputs for a Monte Carlo cost-risk analysis. In this example, the cost estimators identified three values for each cost category (acquisition, maintenance, operations, and support). In practice, a number of values could be identified. Each value (in dollars) has an associated probability. By calculating a large sample of possible scenarios, a distribution of outputs can be generated. Using a Monte Carlo analysis, we present the results of these inputs in Figure 10.
Figure 10. Example of Monte Carlo outputs

This graph illustrates the outputs of the Monte Carlo values listed in Table 3. Taller bars represent high-probability life cycle costs for a notional alternative. Shorter bars are low-probability values. The blue line illustrates the cumulative output.

TRL Considerations

Alternatives with lower TRLs will usually require a more complex engineering effort, which leads to both increased expected cost and more uncertainty in cost. Solid cost data themselves are also harder to obtain. Sophisticated cost models usually have the capability to account for TRL differences.

A lower TRL also translates into greater risk of schedule slippage and higher probability of outright failure to reach the desired operational capability. There have been studies connecting TRL to time to initial operating capability (IOC), and these may be incorporated into programmatic risk assessments.  

Cost Sensitivity Analysis

In practice, the cost-risk analysis described above is quite similar to a cost sensitivity analysis. For both, the costs vary and that variance and uncertainty is captured. For the risk analysis, the cost uncertainty is not related to changes in specific operational effectiveness measures. It is a result of other uncertainties (e.g., vendor price quotes, manufacturing unknowns, etc.) The sensitivity analysis, on the other hand, explicitly examines the cost impact of changes in key operational measures.

Similar to the effectiveness analysis, the cost analysis may include a sensitivity analysis to test the impact of variations in key operational variables. For example, differences and

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81 See, for example, C. Robert Kenley and Bernard El-Khoury, “An Analysis of TRL-Based Cost and Schedule Models,” paper presented at the Ninth Annual Acquisition Research Symposium, Seaside, CA (May 2012). Also see Malone, Smoker, and Apgar, “Application of TRL Metrics.”
uncertainties in a secondary inspection referral rate at a port of entry or at a container terminal might have little impact on effectiveness or efficiency. However, due to manpower expenses, they could cause a significant swing in overall cost for one alternative as compared to others. This, in turn, may change the rank ordering of alternatives in the final AoA report. As a result, it is important to recognize and include those high-impact measures in the cost sensitivity analysis.

Figure 11 illustrates an example where two alternatives (A and B) may take on a high or low cost due to operational uncertainties. Cost sensitivity analysis may not change the rank ordering of costs among alternatives, but it may make an alternative more cost-effective. (Note: We define “cost-effective” as providing the same or greater incremental effectiveness for the same marginal cost.)

Summary of Key Issues in Cost Analysis

Here are the key questions to remember when conducting an AoA cost analysis:

- Have relevant background documents such as a CONOPS or CDP been considered?
- Have ground rules and assumptions been established and coordinated?
- Has the configuration of each alternative (its primary assets and other resources, and life-spans) been documented and coordinated?
- Has an estimating structure for each alternative been established?
- Has a work breakdown structure been established?
- Have data been reviewed for reliability?
- Have all of the appropriate estimating methodologies been considered?
- Has a sensitivity analysis been conducted on appropriate inputs?
- Have the point estimates been adjusted for cost-risk?
DEVELOPING FINAL RESULTS OF COST-EFFECTIVENESS ANALYSIS

Once each MOE has been assigned a value and the cost of each alternative has been determined, the task to determine the best alternative in every situation still may not be straightforward. The problem, as noted in the operational effectiveness section, is dimensionality. Each alternative must be examined from a number of different viewpoints. The goal is to depict the cost-effectiveness of the alternatives across multiple scenarios when effectiveness is some cumulative combination of multiple MOEs. It can be fairly simple to construct charts that depict the performance of all the alternatives against a single MOE. The difficulty lies in determining the best way to depict the alternatives across multiple MOEs while incorporating cost. This can become a challenge even with the simplest of AoAs. However, regardless of how it is accomplished, the goal of the cost-effectiveness analysis is to develop insights and recommendations and to display those in a compelling way for decision makers.

Overview of DHS Guidance on Final Results of Cost-Effectiveness Analysis

DHS acquisition documents provide some general AoA guidance relevant to the cost-effectiveness analysis, and some of that is captured below.

- “Analyses conducted during the AoA/AA (e.g., trade studies, modeling, simulation, and experimentation) must be completed at a sufficient level of transparency and traceability to clearly show the effectiveness, suitability, and financial justification for each alternative considered.”

- “The AoA is an analytical comparison (from a high-level cost and performance perspective) of selected solution alternatives for fulfilling the specific capability gaps/needs. The AoA explores these alternatives with the goal of identifying the most promising approach to achieve user-required capabilities within practical performance, cost, schedule, and risk boundaries. Within this decision space, it trades-off these variables to achieve a balanced solution.”

- “To the extent possible, benefits [of an alternative solution] should be expressed in terms that enable a comparison between effectiveness and costs.”

There is little specific DHS guidance on how to present the final results of the AoA—that is, the results of the cost-effectiveness analysis. Those few specifics, however, are

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82 Composed of location, threat scenario, CONOPS variation, et al.
84 Ibid., 34.
85 Ibid., 35.
identified in appendix G of *DHS Acquisition Management Instruction/Guidebook Number 102-01-001* and include:\(^86\)

- “Provide an objective presentation of the analysis results. These should be in tabular or graphical form to clearly display differences for each analyzed alternative.”

- “Provide the recommended alternative and provide the detailed rationale for this recommendation, based on analytic results. Identify key parameters and conditions that drove the selection, and may impact the acquisition.” (Note: As highlighted earlier in this document, the AoA may not always identify a single “best” solution, but it should strive to do so.)

The 2011 version of appendix G (as compared to the 2008 version), also includes more language describing the contents of the presentation. In essence, it says that all the analysis that has been conducted for the AoA (effectiveness, cost, and risk) should be wrapped up as part of a comprehensive and insightful comparison of the alternatives.\(^87\)

### Key Analytic Considerations in Final Results of Cost-Effectiveness Analysis

#### Winnowing

One strategy for reducing the data to a more manageable form is to cull out alternatives that do not meet minimum thresholds. As stated previously, it may not have been feasible before this point to remove them from consideration entirely, but this is the point in the analysis where all unacceptable deficiencies must be identified.

Often, one alternative is “dominated” by a second alternative; that is, for every MOE and for cost, in every situation, the second is better than the first. Such uniformly inferior alternatives should also be removed from consideration.

Another approach is to generate a set of cost versus MOE charts. The slope of the line from the point representing one alternative to another indicates the marginal cost of improving that MOE. When that slope is very steep—that is, there is a high price to pay for very little improvement in MOE—there may be cause for rejecting that improvement and choosing the lesser alternative.

Sensitivity analysis of the weighting of the MOEs and cost is another commonly used tool. For some particular range of linear weightings, one alternative is best, while for another range, another may come out on top. Displaying these ranges may help the decision maker to focus on a small subset of alternatives.

In all of these analyses, guidance from the decision maker may help considerably, as long as independence is preserved. The balancing of risks, schedule, flexibility, and other

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\(^{86}\) Ibid., “Appendix G,” G-16.

\(^{87}\) Ibid.
factors of concern to the decision maker may require information outside the purview of the AoA.  

**Consolidating Final Results**

The complexity of considering a wide range of trade-offs between alternatives can create pressure to roll up MOEs until the results for each alternative are represented by only a small number of values. Some decision makers may even want just a single value. The discussion of roll-up in the operational effectiveness section pertains here, as do the warnings. Three impediments to roll-up should be emphasized:

- **The process of consolidating measures may be time- and labor-intensive for both stakeholders and the AoA team.** Roll-up typically entails linear combination (weighted average) of the MOEs and/or cost, requiring the AoA team to elicit the weights from decision makers and stakeholders. Designing and calibrating the data collection instrument for this purpose is challenging at best. Its success depends upon establishing that stakeholders share a common understanding of the measures they are considering, that the weighting scale is applicable across disparate measures, and that stakeholders are applying the scale in a uniform manner. Validating this may require multiple rounds of elicitation with the stakeholders, and the process and results continue to carry an element of subjectivity that make them particularly challenging to communicate and defend.

- **It may not be possible to reconcile competing stakeholders’ goals or even priorities for a single stakeholder.** Balancing the need for security against public access, the need for facilitating business versus the public good, cost versus safety, human life versus property – all these are daunting trade-offs to comprehend, much less to agree upon. Further, it may not be in the best interest of DHS to explicitly make those policy trade-offs. Regardless, it is difficult to assign credible weights to such measures.

- **Roll-ups often obscure key interactions between measures.** A linear combination can mask nonlinearities that create synergies between MOEs.

These may be some of the reasons that the Air Force Office of Aerospace Studies (a widely recognized authority on the conduct of AoAs) recommends against using a weighted average for any type of roll up, finding that the results of applying this method are “almost always … misleading.”

Finally, it is important, early in the planning stages of the AoA, for the government and the AoA team to envision the final product. To the extent possible, they should discuss the trade-offs between showing more information (i.e., better-informed decision makers) and reducing the variables being depicted (i.e., less-confused decision makers), since this

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decision may drive the execution of the AoA. This decision should then be documented in the AoA study plan.

Summary of Key Issues in the Final Results of Cost-Effectiveness Analysis

The final presentation of AoA results should provide decision makers with a detailed view of the trade space. This enables decision makers to identify and potentially eliminate alternatives that do not meet one or more of the basic performance requirements. After making this initial cut (if any), decision makers must conduct a more nuanced down-selection process that involves weighing not only the remaining alternatives’ costs and operational effectiveness results, but also their risks, schedule, flexibility, and any other factors of concern to the decision maker. This may (and often does) require the decision maker to consider other sources of information in addition to the AoA results. In this way, the AoA significantly informs the government’s final selection, but does not, by itself, necessarily identify a single optimal solution.

The old adage “how you say something is as important as what you say” applies to an AoA. How results are presented can be as important as the results themselves. In fact, the presentation is critical. Hastily pulling together standard tables and charts that fail to highlight the most important analytic issues can simply cloud the trade space. On the other hand, well-conceived charts and tables visually separate the important information from the extraneous information, making difficult concepts easier to understand. The goal is to present compelling analytical results for decision makers.

Post-AoA Support

When the AoA is complete, it is likely that the presentation of results is just beginning. This is important to understand early in the AoA planning process, particularly if the study team is heavily composed of contractors. If the contract ends with delivery of the report, the government may be left unsupported at an inopportune time. Often, following completion of an AoA, there is a need to brief other audiences (i.e., parent organizations, stakeholders, state or local governments, and congressional entities). If the study team is no longer available, the government sponsor must create the briefings and present the study without the benefit of the input from the team who performed the analyses. This may involve considerable effort because the presentation of results may have to be tailored for each audience based on background and level of technical sophistication.


AOA REFERENCES


