MITRE

Affordability Engineering Framework (AEF) Overview

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Abstract

The current economic environment and mounting federal budget deficits are placing considerable economic stress on the Department of Defense (DoD) and other government agencies. Investments for new capabilities, upgrades and enhancements to existing systems as well as simple continuations of existing programs requires careful analysis and evaluation of their affordability, efficiency and effectiveness. The Affordability Engineering Framework (AEF) is being designed to help the DoD respond to these imminent fiscal realities and advance the practice of affordability engineering to improve acquisition program success.

The AEF is a structured, actionable approach with tools and techniques to address affordability challenges throughout the lifecycle. The AEF uses multi-disciplinary teams to quantitatively evaluate program affordability while identifying integrated cost, schedule and performance trade space. The AEF includes four steps: an affordability risk assessment, a validation approach for coupling Technical Baselines and program cost estimates, a deliberate tradeoff process, and the generation of preferred courses of action with a recommendation based on a portfolio analysis methodology. The AEF can provide benefit across a wide range of acquisition programs and provide the affordability information for data-driven program decision-making. In the coming months the AEF will be piloted and migrated across selected DoD programs for implementation with iterative evaluation and development.

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Background

The current economic environment and mounting federal budget deficits are placing considerable economic stress on the Department of Defense (DoD) and other Government agencies. As such, the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD (AT&L)) "Better Buying Power" memorandum for the acquisition community highlighted restoring "Affordability" as a key objective, which has since been instantiated in policy and statute[1]. Furthermore, General Accounting Office (GAO) and other sources continue to report the many DoD and agency programs that are experiencing budget and schedule overruns. As a result, investments for new capabilities, upgrades, and enhancements to existing systems, and simple continuations of existing programs will require careful analysis and evaluation of their affordability, efficiency, and effectiveness. Budget reductions are mandating difficult decisions about where to invest limited resources, how to make current programs more affordable, and whether to terminate poorly performing programs. There is a need for the DoD to respond to the imminent fiscal realities and advance the practice of affordability engineering for long-term acquisition improvement. A proposed approach to achieving affordability through a robust practice of affordability engineering is through the application of the Affordability Engineering Framework (AEF).

Purpose

The AEF is being developed to establish a structured approach with tools to address program affordability challenges. The AEF supports the USD (AT&L) focus on restoring program affordability via quantitative analysis of the products in the portfolio or mission area for the Technology Development Phase, and trade space around major affordability drivers in the Engineering & Manufacturing Phase. The framework provides an actionable process for program managers and lead engineers to assess affordability and related risks and to develop courses of action. While useful for conducting assessments, the framework will also identify areas where affordability engineering and analysis need to be inserted in program planning and execution. Affordability principles of efficiency and effectiveness to produce value and utility need to be applied in our system engineering and acquisition management practices. The long-term goal is to provide a framework for establishing an affordability engineering competency among systems

[1]USD(AT&L) Memorandum: "Better Buying Power: Mandate for Restoring Affordability and Productivity in Defense Spending", Carter, Ashton B., 28 June 2010.

engineers in acquisition programs and activities to affect timely and efficient deliveries of capabilities to the customer.

Definitions

The following terms will be used throughout this paper:

- Affordability *(At the program level)*—Acquire the user need within the budget and continue to fulfill that need throughout the life cycle of the program.
- Efficient *(At the program level)*—Acquire the user need in the most economical use of resources (e.g., funding, schedule, staffing). Provide greater military effectiveness for the same budget.
- Effective *(At the program level)*—Meet or exceed the operational need within budget and schedule.
- Program Office Estimate (POE)—Provide a detailed estimate of system acquisition and ownership costs normally required for high-level decisions. The estimate is performed early in the program and serves as the base point for all subsequent tracking and auditing purposes.
- Technical Baseline (TB)—Provide a holistic definition of the system and acquisition program accounting for all aspects that relate to cost and schedule. The TB refers, in part, to the characterization of the physical and functional representation of intended system capabilities. The *core* of *a TB* is primarily the description and decomposition of hardware, software, and integration, including non-recurring and recurring elements that make up the system. However, much more is needed in a TB to support life-cycle cost analysis in affordability engineering. Technical context, such as system dependencies, legacy capability migration and reuse, technologies, operating environment, and performance, needs to be understood. A description of the development activities, processes, resources, assets, and facilities required to engineer the system, manage the acquisition, perform test and evaluation, and ultimately deploy and sustain the system are also important components of the TB. Information assurance and other critical engineering constraints need to be translated into development activities that will be performed and contribute to the system cost. Similarly, the TB must describe production and operations fully and must support phases of the system.

- Tradeoff Analysis—Evaluate and select among system technical functions, acquisition strategy, and/or funding alternatives to achieve the desired capabilities, performance, and mission effectiveness within cost and schedule objectives.

AEF Overview

The AEF is a multi-step framework to understand a program's affordability risks and challenges, and to provide approaches for achieving affordability, efficiency, and effectiveness in an acquisition program. Figure 1 illustrates the four steps in the framework:

- Step 1—Affordability Risk Assessment
- Step 2—Affordability Evaluation
- Step 3—Tradeoff Analyses
- Step 4—Assessment and Recommendations.

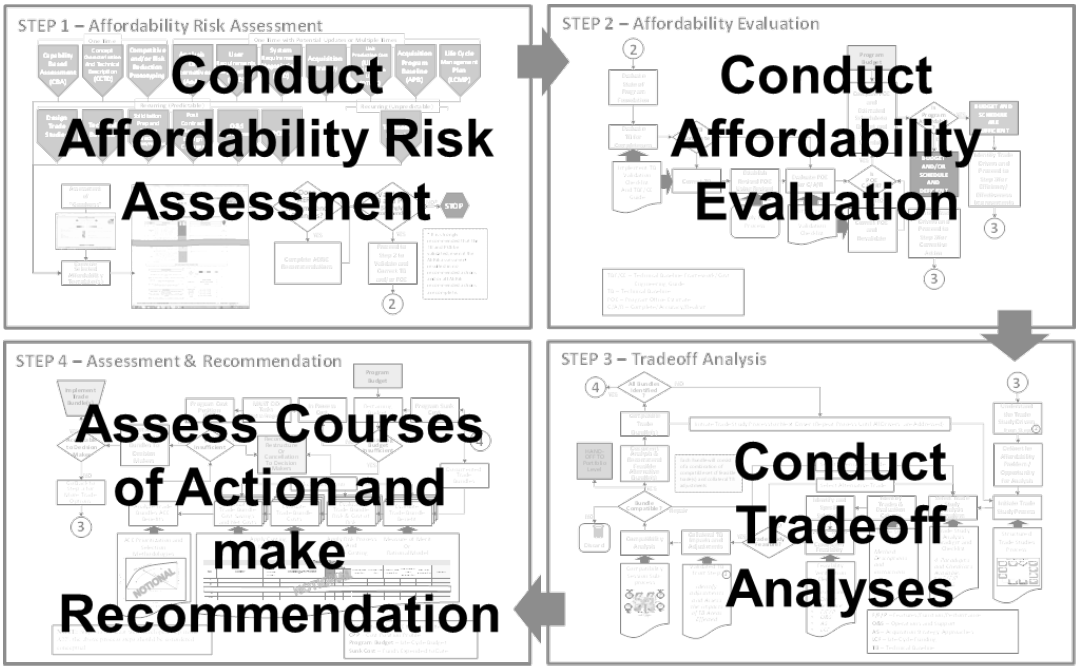

Figure 1. AEF Framework

The AEF process is conducted throughout the lifecycle and initiated via "trigger" points that occur where critical program management activities and decisions are necessary. These "trigger" points include periods of major program changes, budget preparation and submittal, and existing regulatory and statutory requirements for affordability certification. A typical program profile with "trigger" points is depicted in Figure 2 below.

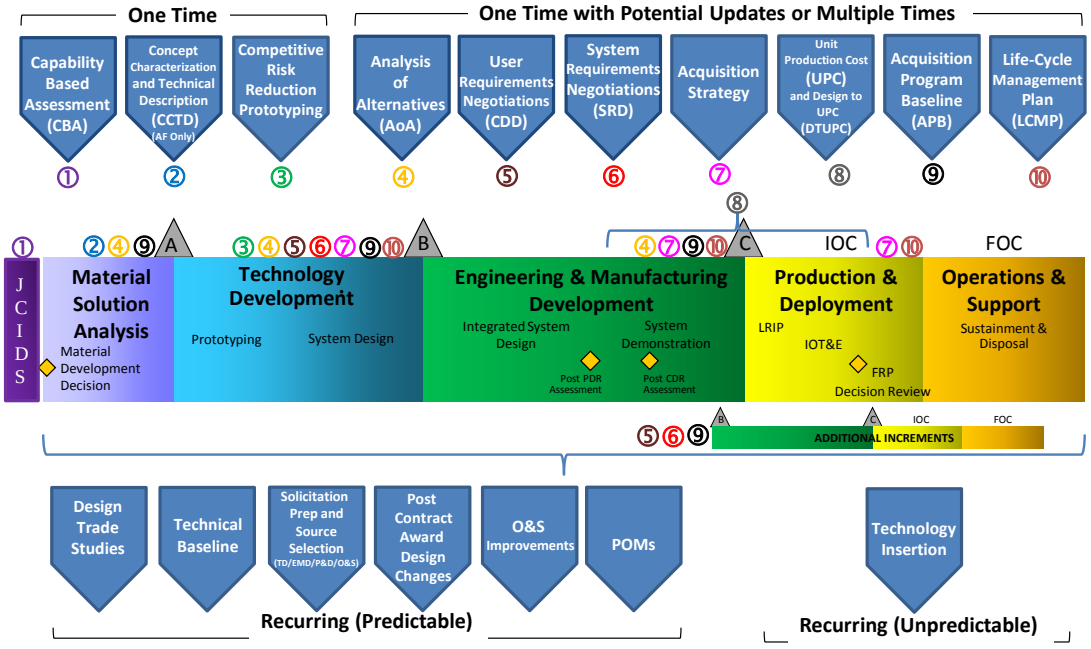

Figure 2. AEF Program Trigger Points

The AEF provides a significant increase in the number of affordability assessments relative to current requirements as there would be four or more before Milestone A, and seven or more prior to Milestone B. The increase in frequency provides two major advantages: 1) stronger coherency from assessment to assessment; and 2) assists in institutionalizing the importance of affordability.

Step 1—Affordability Risk Assessment

Step 1 is a qualitative assessment of the program affordability risk. The assessment is accomplished through questionnaire templates that refer to program documentation that would comprise the Technical Baseline (TB) as described earlier. The assessment includes both a relative maturity measure amongst the various TB elements and a maturity comparison with the program phase. An Excel-based tool referred to as the Affordability Engineering Risk Evaluation (AERiE) tool is being developed to assist in the assessment task. Figure 2 illustrates the actions taken in Step 1.

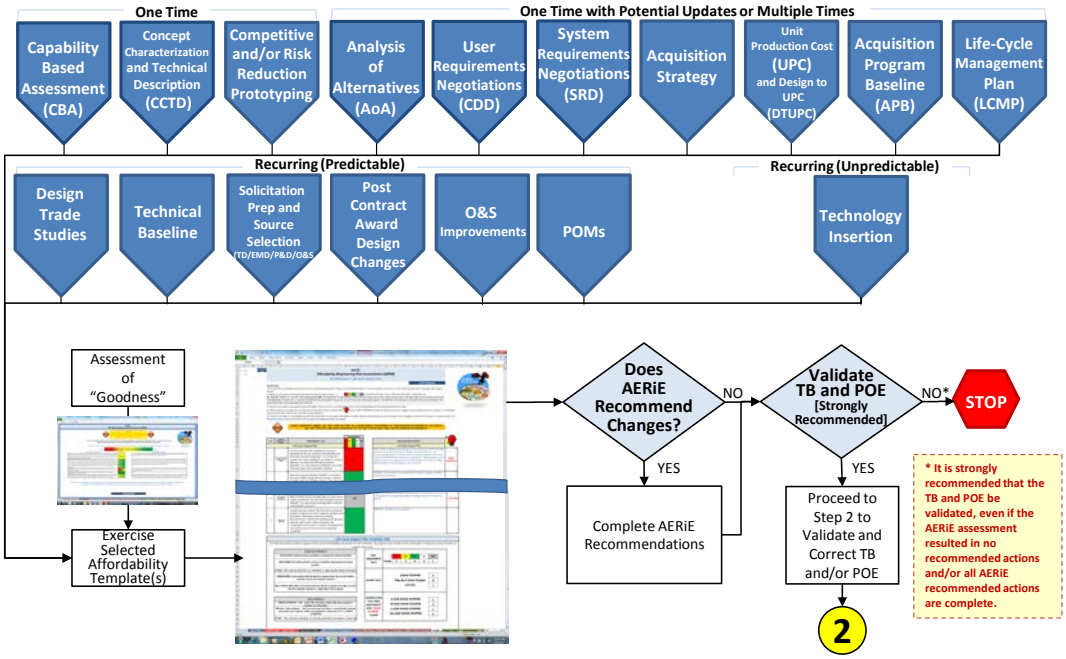

Figure 3. AEF Step 1—Affordability Risk Assessment

The first step in using the AERiE tool is assessing the program environment for managing affordability. There are five program conditions, which are guiding principles of managing for affordability and foundational to each trigger evaluation. The program team uses the following five categories of questions to assess confidence in the program management conditions of the program.

1. Where you are in the program life cycle will establish the maturity of the TB. Given the current phase of your program, is the program TB complete and well understood? Is it updated using the best engineering experience available or using representative analogy? Is it documented in a manner that it can be used in developing sound cost estimates?
2. Again, where you are in the program life cycle will establish the fidelity of your cost estimate. Given the current phase of your program, do you believe the cost estimate is sound? Is it well documented and based on a complete and well-indentured work breakdown structure? Was it developed using reasonable data and analogies? Does it have engineering-based inputs that include ranges that reflect program risk? Have appropriate costing methods have been used? Is the program implementation based upon costs that are reflective of program risks?

3. Was the program schedule developed using the same TB as the program cost estimate?
4. Does the program have a disciplined approach to risk and requirements management supported by system engineering and associated cost analysis?
5. Are the program risk, cost, schedule, and requirements management integrated so that the cost estimates always reflect the latest risk mitigations, schedule changes, and requirements baseline decisions?

Once completing program condition "goodness" checks, the program team is directed to proceed to the AERiE instruction page and begin the AERiE assessment. The program team should consider the five program conditions when rating the selected AERiE assessment templates.Each Trigger has a unique Affordability Assessment Template (see Figure 4).

Figure 2. Typical AERiE Template

Each template contains unique assessment questions that address affordability risk indicators contained in the program's technical baseline

For each question, the user selects a risk level (i.e., high, medium, low, unknown, and not applicable); unique risk-level definitions are provided for each trigger question. Upon selecting a risk level, the tool provides question-specific recommendations for possible corrective or mitigation actions. Unique recommendations are provided for each question's risk level. An assessment tally is provided upon completion of the assessment.

The assessment result provides the program team with evidence of risks, indicating the state of the program's affordability position. In addition, the tool warns of "show stoppers" that prevent the team from understanding the program affordability position as a result of the assessment. Corrective or mitigating changes are recommended, unless all the template questions are assessed as "low" risk. Once the changes are complete, the program team will validate the TB and the program office cost estimate (POE) in step 2, in the process of completing a quantitative affordability evaluation.

Step 2—Affordability Evaluation

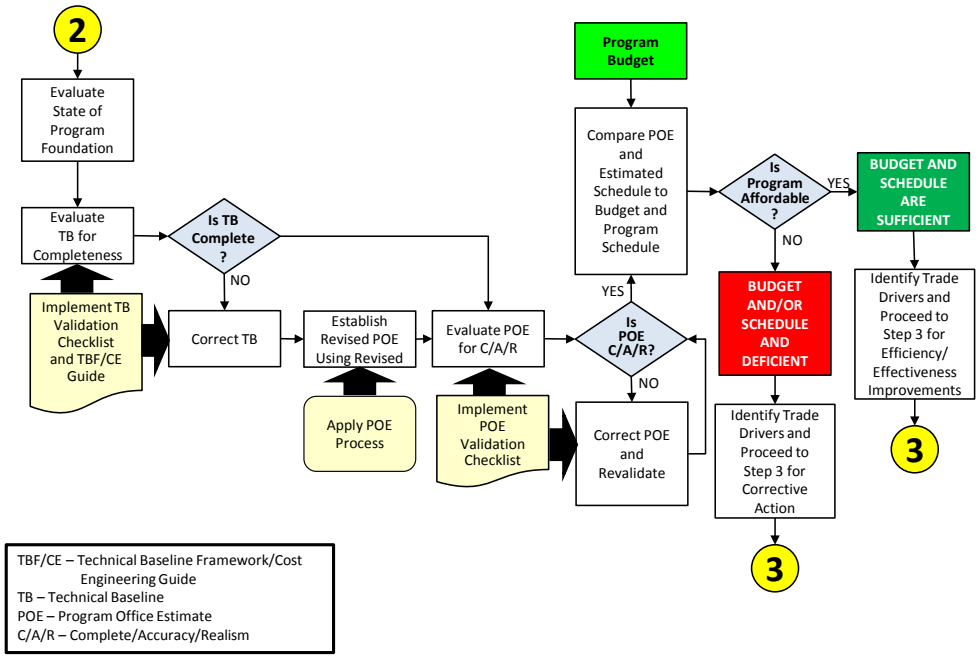

Figure 3. AEF Step 2—Affordability Evaluation

Step 2 determines the program's affordability in a quantitative manner (see Figure 5). This is accomplished by making changes as necessary to validate the TB and the POE for completeness and accuracy. Once valid, the POE and associated schedule are compared to the existing program budget.

The state of the program foundation is examined before beginning the TB validation process. This ensures the TB and POE emerging from Step 2 will be reliable. The components of this evaluation include:

- **Continuous Cost Engineering**—The program should have a disciplined approach to risk and requirements management, which includes tight integration of risk, cost, schedule, and requirements management and coordination with users and other active stakeholders. This will result in reliable tradeoffs and program cost estimates that reflect the latest risk mitigations, schedule changes, strategy updates, and requirements baseline decisions. As a corrective action, the program should improve affected processes (e.g., requirements definition, system design, program planning), if needed, while continuing with AEF Steps 2-4.

- **Soundness of Program Cornerstones**—The program should have acquisition artifacts, and engineering and management products that are consistent with its maturity in the acquisition life cycle and the requirements of DoD 5000.02. AEF users informally consider the state of their program relative to a description of the desired elements in an acquisition and look for high-level issues. Corrective actions, if needed, include: 1) improving outreach to users and acquisition stakeholders identifying their latest needs or changed acquisition context; and 2) completing or updating artifacts and incorporating changes in the TB/POE/schedule.

- **Resolution of Harmful Trends Revealed by Step 1 Affordability Risk Assessment**—An "affordability risk trend" is revealed from risks identified across different Step 1 triggers because of the coherency from assessment to assessment. The trend has an underlying cause or connection among the risks that might hinder the program in delivering affordable, timely, and effective capability to the warfighter. The revelation of a trend is accomplished by the AEF user compiling all "show stopper" and "potential show stopper" risks, and studying these risks to reveal common themes/causes. The AEF will provide exemplars by program phase or milestone, relating them to alarms/recommendations from different triggers. Each trend will reveal, by the nature of the trend, the corrective action needed and the frequency with which it should be applied.

The TB is evaluated for completeness by using a "Technical Baseline Framework and Cost Engineering (TBF&CE) Guide"[2] in development. Evaluation of the TB involves an element-by-element comparison, illustrated in Figure 6, of the current TB to the TB checklist and the TBF&CE guide, following the TB validation process.

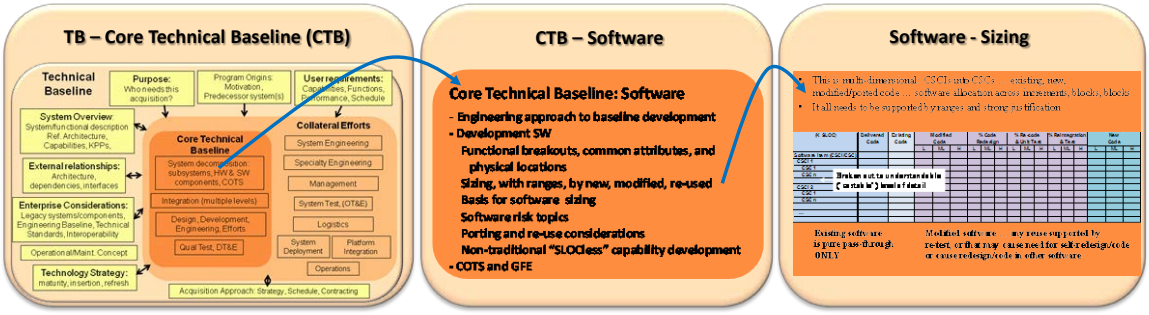

Figure 4. TB Element-by-Element Comparison Example

The TB is valid if it is complete (i.e., contains all the elements of the TB framework), characterizes all the cost elements (i.e., contains or points to the data required to cost every element), and has the appropriate level of definition and fidelity for the point in the life cycle (i.e., reflects the maturity of the system design, sustainment approach, and acquisition strategy, and portrays that maturity realistically).

If the program office has no TB or their TB is invalid, the AEF process directs corrective action to update or build a program TB. The TBF&CE Guide contains a "build your own workspace" template that guides the program through a specific correction to the TB or, if needed, the construction of a complete TB.

Once the TB has been validated, or corrected and validated, the program team can proceed with the evaluation and, if needed, the iteration of the POE. If the TB requires updating, the POE must be revised to be consistent with the TB changes prior to the team validating it.

POE—A detailed estimate of system acquisition and ownership costs normally required for high-level decisions. The initial estimate is performed early in the program. It serves as the base point for all subsequent tracking and auditing purposes.

Then the POE is valid if it is complete (i.e., estimates costs for all elements of the TB), realistic (i.e., identifies costs considering available data), and reasonable (i.e., accounts for TB assumptions and associated risks).

[2] *The Technical Baseline Framework and Cost Engineering Guide* (MP-TBD), Crawford and Dello Russo, September 2011.

The POE is evaluated using the "POE Validation Guidance (PVG)"[3] (refer to Attachment B) and products derived from the guide (e.g., *Program Office Estimate Validation Process* and *Program Office Estimate Validation Checklist*).

If the POE is not valid, the AEF process directs corrective action to update the POE and revalidate, if required. This activity is iterative and intended to reveal information that may require additional updates to the TB.

Once the POE is validated, the AEF process directs a comparison with the program budget. With a validated TB and POE, the POE and estimated schedule are compared to the program budget and program schedule.

- **Program is affordable.** If the budget or program schedule is sufficient relative to the POE and estimated schedule, (i.e., the program is affordable), the program team can exit the process or continue to Step 3 (recommended) for discovering potential efficiency and effectiveness improvements.

- **Program is unaffordable.** If the budget and/or program schedule is insufficient relative to the POE and estimated schedule, the program team will proceed to Step 3 to identify corrective action alternatives and potential efficiency and effectiveness improvements.

The validation of the TB and POE will reveal technical, performance, schedule, acquisition, and/or logistics drivers of the program. These elements have a strong influence on the feasibility and affordability of the program. These drivers may directly or indirectly drive the program's cost and schedule, or impose risk that should be mitigated. Leaving step 2, the program will have identified the program effectiveness and cost drivers as well as a quantitative affordability evaluation. These program drivers will become the subjects of tradeoff analyses conducted in Step 3.

[3] *"POE Validation Guidance (PVG)"* is a set of authoritative cost estimating and evaluation documents that have been placed in the MITRE SEPO "*Cost Estimating Toolkit*".

Step 3—Tradeoff Analyses

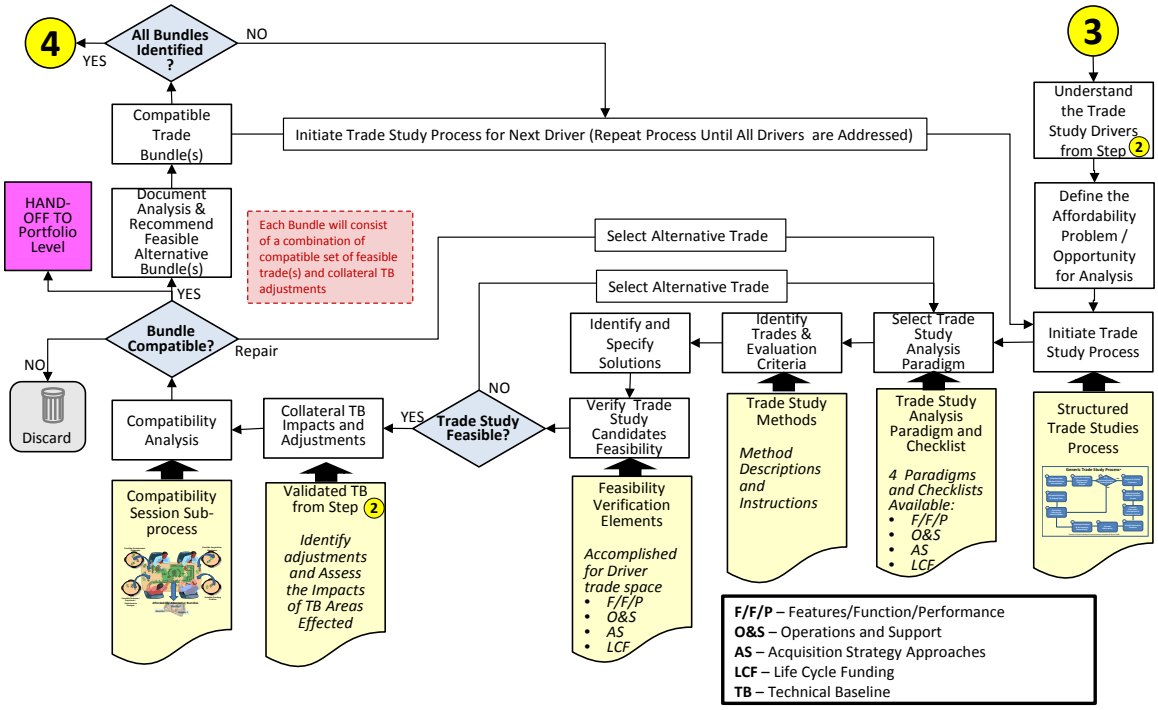

Figure 5. AEF Step 3—Tradeoff Analyses

Step 3 is designed to develop and conduct structured tradeoff analyses and walks the program team through a deliberate process. Much of this step is formative to the tradeoff analysis process, identifying, structuring, evaluating, and determining candidate trade studies that should move to Step 4 for final analysis.

Tradeoff Analysis—The process of evaluating and selecting among system technical features, acquisition strategy, and/or funding alternatives to achieve the desired capabilities, performance, and mission effectiveness within cost and schedule objectives.

In Step 3, the program team reviews the trade study cost and effectiveness drivers that were identified in Step 2. This ensures that the team understands the affordability issues/challenges and/or AEE opportunities with a program life-cycle perspective.

For each of the drivers, the user defines the integrated (cost, schedule, performance) trade space[4] that needs to be examined and the candidate trades that may exist in that trade space. If the budget or program schedule is sufficient relative to the POE and estimated schedule, (i.e., the program is affordable) the user will focus on trade opportunities that can be analyzed to achieve cost savings/avoidance and/or to improve the effectiveness of the system required. If the budget or program schedule is insufficient relative to the POE and estimated schedule (i.e., the program is unaffordable), the user will focus on cost/schedule reduction trades that will allow the program budget to be sufficient (i.e., deliver the warfighter capability within the program budget). The generic trade study process is shown in figure 8.

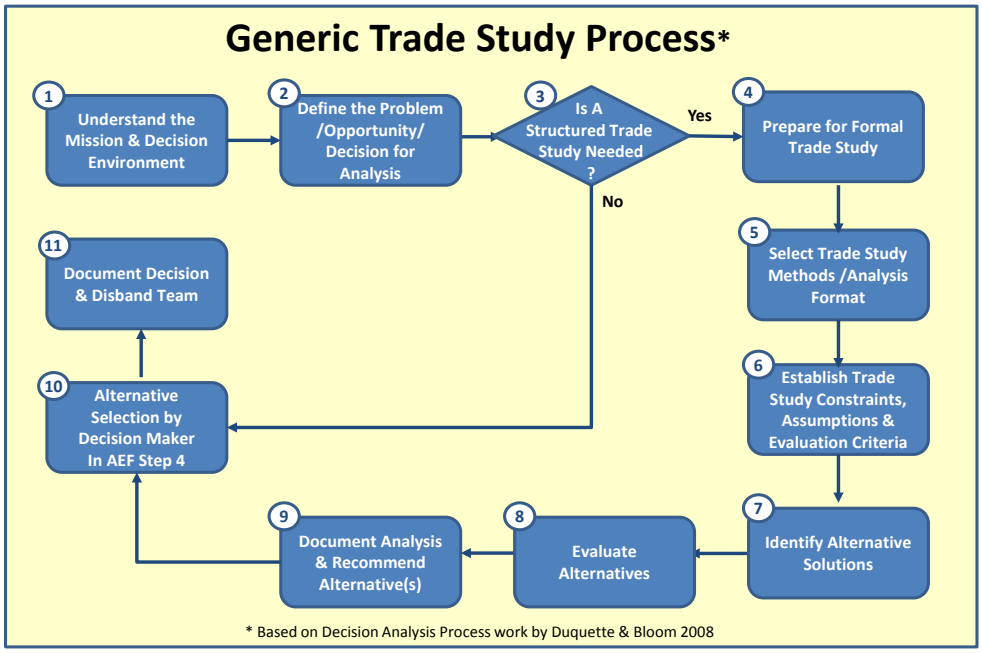

Figure 6. Generic Trade Study Process

The Trade Study Process is an overarching process for Step 3. Detailed actions are specified for each step to guide the program team through a rigorous evaluation of the trade alternatives. The next series of actions in Step 3 is the first stage of the trade study analysis.

[4] Trade Space—The multivariable set of fiscal, temporal, legal, political, operational, sustainment, program and system parameters, attributes, and performance characteristics required to satisfy user needs that are used by decision makers to make informed and structured program or portfolio decisions.

The user first selects the "Trade Study Analysis Paradigm and Checklist."[5] Four paradigms and checklists will be available for the program team:

- Features/Functions/Performance
- Operations and Support
- Acquisition Strategy
- Life-Cycle Funding.

The user then identifies the trade options and selection criteria through a set of defined methods. For example, one trade in Features/Functions/Performance might be a non-development item (NDI) versus development.

The next action (Step 9 in Figure 8) specifies a set of alternative solutions that will satisfy the challenges/issues and/or opportunities posed by the driver.

The tradeoff alternative solutions are then evaluated for feasibility and compatibility.

A feasibility determination is accomplished by using "Feasibility Verification Elements." Figure 9 is an example of the feasibility verification elements for an acquisition strategy. For example, if the production approach (number 13) is far left or right on the scale, the acquisition strategy trade is significantly constrained.

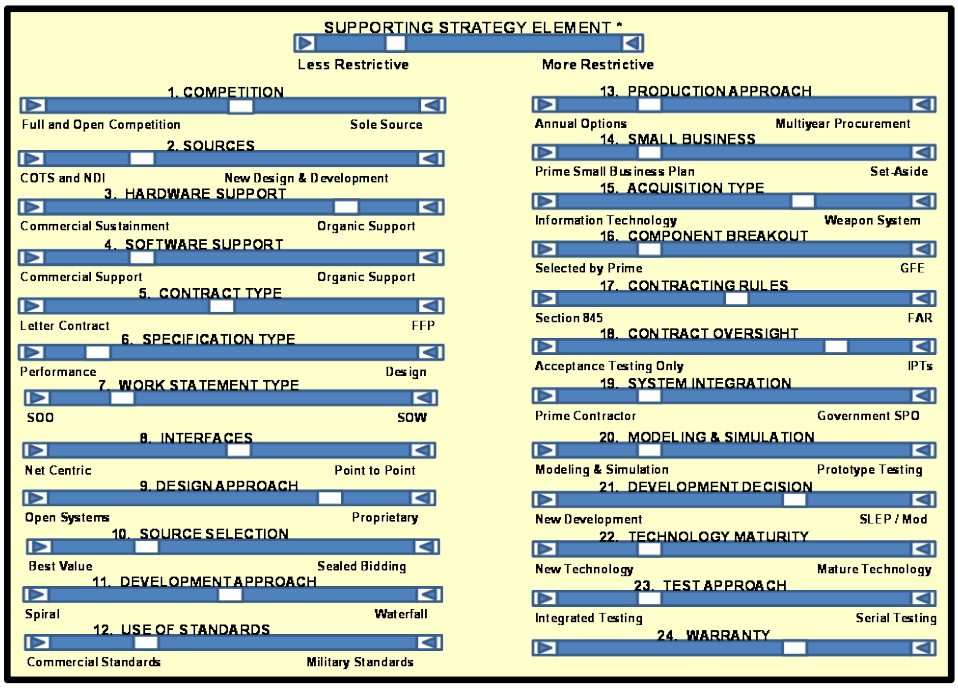

Figure 9. Trade off Alternative Feasibility Verification Example

[5] The "Trade Study Analysis Paradigm and Checklist" provide the context and actions necessary to carry out a trade study for the four paradigms.

If the trade is not feasible, the program team selects an alternate trade. If the trade study is feasible, a compatibility check against the validated TB is performed. The program team identifies adjustments to the TB, enabling the specific trade and its alternative solutions. For example, if the trade is a Features/Functions/Performance (F/F/P) trade, adjustments may be required to the acquisition strategy, sustainment strategy, funding profiles, etc., to implement the alternate solutions. All collateral impacts and adjustments to the TB relating to the trade are identified.

Compatibility is now evaluated by subject matter experts. The process determines tradeoffs that need to be bundled due to coupling amongst individual trades. The changes to the TB are also determined. Each tradeoff bundle will consist of a combination of compatible feasible tradeoffs (i.e., the applicable set of the four Trade Study Analysis Paradigms and their collateral TB adjustments).

Tradeoff bundle elements are compatible if the combination of feasible trades and collateral TB adjustments provide a workable alternative to the existing condition. If the tradeoff bundle is compatible and can be implemented at the program level, the next action in Step 3 is to document the analysis and the recommended feasible tradeoff bundle. If the tradeoff bundle is better suited to a portfolio implementation, it is deferred to the portfolio level for consideration. If the tradeoff bundle is not compatible**,** it is revised, if possible, and reevaluated for compatibility.

The user repeats the Step 3 process to generate feasible and compatible tradeoff bundles for each of the cost and effectiveness drivers that were identified in Step 2.

Step 4—Assessment and Recommendations

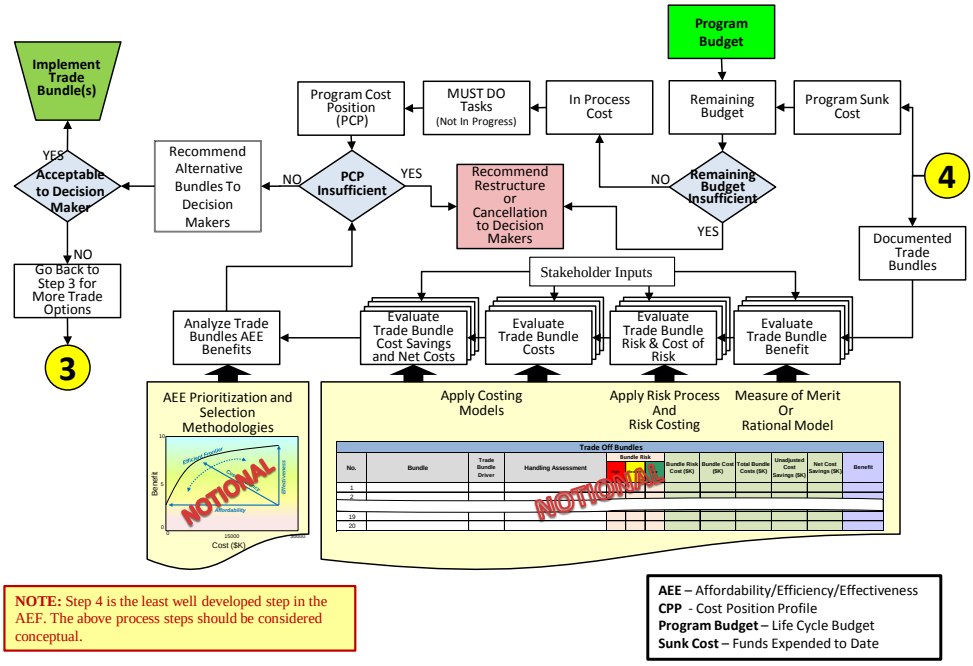

Figure 10. AEF Step 4—Assessment and Recommendations

The objective of Step 4 (figure 10) is to select the tradeoff bundles that deliver the capabilities that the end user needs efficiently and effectively within the established budget and timeline. These recommendations are based upon benefit, risk, cost, and schedule impacts.

If the program was determined unaffordable in Step 2, the program team assesses feasibility/effectiveness of the various trade bundles established in Step 3 to define an affordable program. If the program was determined affordable in Step 2, the program team will evaluate the tradeoff bundles to improve the affordability position of the program through improvements in efficiency and effectiveness.

Recommendations are made by considering the tradeoff bundles or set of bundle alternatives' ability to meet affordability goals, efficiency in meeting these goals, and the effectiveness in delivering needed mission capabilities.

In Step 4, conducting the analysis of each tradeoff bundle requires the following costing and evaluation activities:

- Evaluate the risk of the trade bundle by applying the program risk management process.[6]
- Determine the costs associated with the risks identified in the bundle.
- Determine the cost and risk of implementing the tradeoff bundle[7].
- Determine net cost saving if the bundle was implemented.
- Determine the benefit of the Bundle.

There are a variety of assessment tools being evaluated that can be adapted to evaluate the cost, risk, and benefit data that has been developed in this step. Available tools include:

- Portfolio Analysis Machine (PALMA™)
- Desk Top Return on Investment
- Kepner-Tregoe Method
- Investment Portfolio Analysis Model (IPAM)

The relationships/dependencies among affordability, efficiency, and effectiveness (AE&E) are illustrated on a cost-benefit graphic in Figure 11. The figure 11 efficient frontier curve describes the most efficient state possible for a given benefit/cost combination. The trade space is the area of the graphic bounded by the efficient frontier and the effectiveness and affordability vectors. The objective is to move in the direction of increased efficiency which can be quantitatively measured by the assessment tools identified above. Devising solutions to address affordability challenges requires understanding what drives each dimension and how developing alternatives in the different tradeoff paradigms can move a program along a specific vector. The AEF is being designed to enable exploration of this AE&E trade space, while providing how-to guidance for identifying and addressing affordability.

[6] Use the Risk Management Process like the following: http://www.mitre.org/work/sepo/toolkits/risk/.
[7] Bundled Risk Cost can be evaluated with the "Measuring Economic Returns of Risk-benefit Tradeoffs in System Acquisitions—An Affordability, Effectiveness, and Efficiency Perspective," Paul R. Garvey, The MITRE Corporation, 28 February 2012.

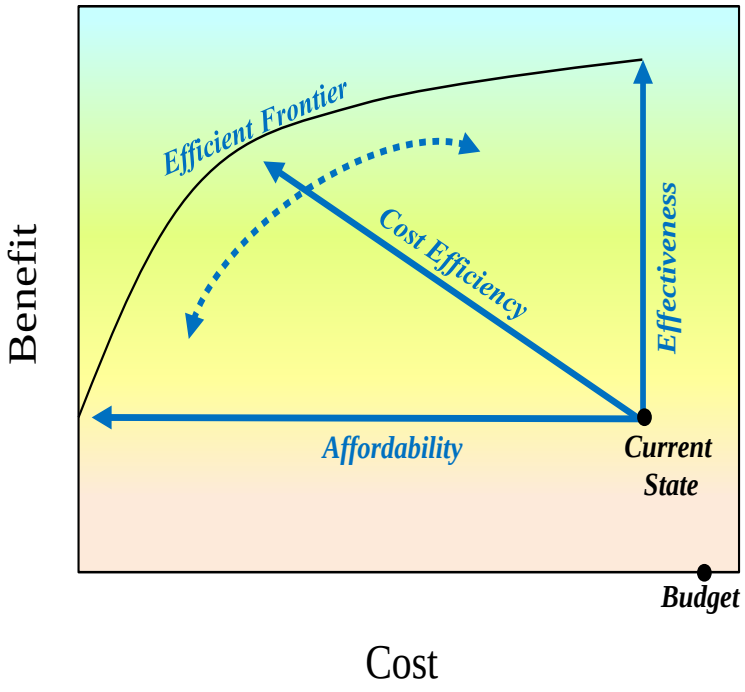

Figure 7. AE&E Relationships

The bundled tradeoff alternatives are evaluated against the program cost position for improved efficiency and affordability. Recommendations are provided to decision-makers for determination. If the decision makers accept the recommended set of alternative tradeoff bundles, the program team designs the implementation.

Status and Implementation of the AEF

The AEF development is planned to be completed by September 2012. The step-wise framework permits incremental evaluation via "piloting" within existing acquisition programs prior to completion. The piloting activity is planned for June through September 2012 within representative programs across the Navy, Army and Air Force. To facilitate the "piloting" a quick-start guide will be developed.

The actual implementation will vary from program to program but will have the following common tenets:

- A single Technical Baseline definition for cost, schedule and performance planning, modeling, executing and reporting.
- Incorporation of cost and schedule into the traditional engineering trade space.
- Leverage of the integrated trade space to develop bundled tradeoff alternatives for program decision makers.
- Actionable framework with appropriately detailed tools.

- Execution via integrated system engineering and cost analyst teams.

The program systems engineering and financial management processes will require modification for implementation of the above tenets. As with most changes, successful implementation will require priority from program leadership. The AEF crosses multiple disciplines and should be led by the Program Manager (PM). The outcome of a successful AEF implementation is an execution that will be measurably more efficient in the dimensions of affordability (cost) and effectiveness (benefit).

Summary

The Affordability Engineering Framework is designed to provide a rigorous approach for proactively achieving program affordability. The AEF supports the (USD) AT&L mandate to restore acquisition program affordability and control cost growth. It does so by a multi-step process that qualitatively and quantitatively measures program affordability risk, developing a set of targeted tradeoffs that are bundled, evaluated for compatibility, and then recommended for implementation. The AEF is designed to be actionable with tools and templates to guide program teams during execution. The AEF is conducted in a manner that increases the frequency of affordability assessment to improve assessment quality, with integrated multi-disciplinary program teams to institutionalize the management of integrated cost, schedule and performance trade-space. The primary objective is to increase the probability of program success in a challenging budget environment through increased execution efficiency throughout the life cycle and provide program managers with data-driven rationale for program change recommendations.