

The Lifecycle Integration Framework
Extending Affordability Simulation through Cost and Engineering Model Interoperability
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CAIV is a methodology for reducing Total Ownership Cost and improving performance. It involves developing, setting, and refining aggressive unit production cost objectives and O&S objectives while meeting warfighter requirements. It is essential to involve the user community in the tradeoff process from the beginning to achieving the best outcome for all parties involved. – Office of the Secretary of Defense

The original concept of CAIV was proposed by the DoD Defense Manufacturing Council in 1995 and became part of the DoD 5000 Series (DoD 5000.2R) in 1996. The basic tenet of CAIV describes a “strategy for setting aggressive, realistic cost objectives for acquiring defense systems and managing the associated risks”.ⁱⁱ In 1996, the Flagship Programs Workshop under the Office of the Secretary of Defense (OSD) met to identify CAIV Flagship Programs. These programs were managed using the principles of CAIV. Early work done by the Institute of Defense Analysisⁱⁱⁱ defined the five basic tenets of CAIV as follows:

- Requirements vs. Cost Performance Trades – Setting Aggressive Cost Targets
- Competitive Acquisition Strategy
- Concurrent Engineering/Integrated Product Development
- Contractor Enterprise Re-Engineering
- Commercial Specifications and Practices

Central to the concept, is the establishment of the CAIV *trade space* to evaluate performance vs. cost. Typically in the trade space, Total Ownership Cost (TOC), the *independent variable* is evaluated against the *dependent variable* of performance. The TOC objective established by the program reflects a realistic, yet achievable goal but usually represents a challenge to the program. The objectives and thresholds established for the program are known as the Key Performance Parameters (KPPs).

Each KPP identifies the expected objective and threshold goals for each parameter including cost. Typically, cost and performance models are concurrently iterated to evaluate many scenarios to establish the point of diminishing marginal returns – or where adding additional costs results in less performance gains. This is known as the “knee of the curve” region. Solutions in this region fall within cost and performance objectives and thresholds.

Figure 1 exemplifies the CAIV construct. The center region, labeled “*trade space*” contains the solutions meeting both performance and cost objectives. The region to the lower level labeled “*unacceptable performance*” contains solutions that while clearly meeting cost objectives, does not meet the threshold performance requirements. Conversely, solutions in the upper right region labeled “*unacceptable cost*” while meeting or exceeding performance goals are not affordable.

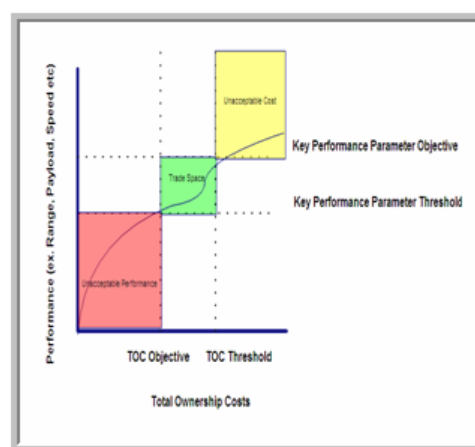


Figure 1 CAIV Construct

As we can see in Figure 1, the CAIV construct treats Total Ownership Cost as a design parameter linked directly to performance. While in theory this construct leads to affordable programs meeting key performance parameters, in practice history has not fully supported the expected results – especially when reviewing the original CAIV Flagship programs.

In 1996, it was expected by the DoD that mandating CAIV tenets would provide program cost savings of 50% or greater.^{iv} Supporting that goal, the DoD “Flagship” programs were identified to demonstrate how the principles of CAIV would achieve these savings. The flagship programs, including their status^v in 1996 are displayed in Figure 2.

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PROGRAM	PROGRAM DESCRIPTION	PROGRAM STATUS
EELV	A more cost-effective space launch vehicle for medium and heavy lift requirements	Pre-EMD start Dec. 1996
AIM-9X	Next generation Sidewinder air-to-air missile	EMD start Jan. 1997
TACHS-BAT P3I	Upgrade of tactical ground-to-ground missile - new seeker	Currently in PDRR EMD start in 1998
MIDS	Third generation secure, jam-resistant, communications system for NATO family	EMD contract awarded in Mar 1994 Restructured Jun. 1994 CDR in-process
JASSM	Long-range air-to-surface standoff missile	Entered 2-year competitive PDRR
CRUSADER	155MM self-propelled Howitzer and armored resupply vehicle	Completion of PDRR in FY 2000 Single contractor team
JSF	Advanced Strike Fighter Aircraft	Pre-PDRR
SBIRS	Space-based infrared surveillance system for missile defense	Entered EMD for GEO in FY 1996 PDRR for LEO with MS II in FY 1999

Figure 2 CAIV Flagship Programs

Within the CAIV Flagship programs, the key tenets of CAIV were implemented. Now that thirteen years have elapsed since the original CAIV Flagship programs were identified, it is interesting to update the status of several of the Flagship programs to see if CAIV tenets were successful in controlling program cost, or in fact reducing cost by 50% as originally envisioned by DoD. Figure 3 below shows the status of six of the original CAIV Flagship programs within the last several years.

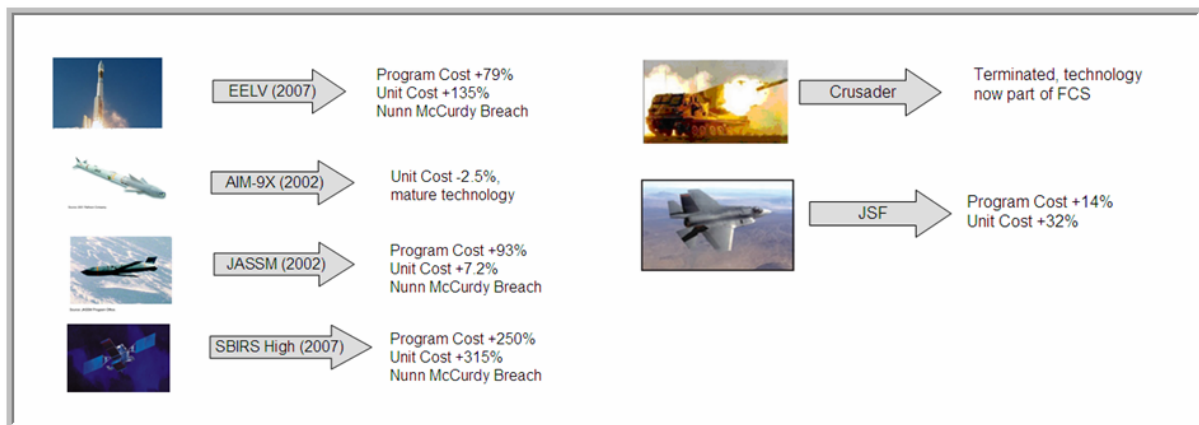


Figure 3 Status of CAIV Flagship Programs

Of the six programs examined, half experienced a Nunn-McCurdy Cost Breach. This happens when a Major Defense Acquisition Program (MDAP) experiences at least a 15% increase in program acquisition unit cost or average procurement unit costs above the program baseline. None of the programs reviewed achieved a 50% savings as was originally envisioned in 1996. Only the AIM-9X achieved a 2.5% reduction in unit cost attributed to mature technology^{vi}.

There are many reasons that the original Flagship Programs did not achieve the savings forecasted by implementing CAIV tenets. Issues with program schedules, configuration changes, changing military strategies and technological risk are all contributors. However, the DoD continues to require that 100% of defense programs incorporate a CAIV plan.^{vii} Part of this strategy is to have each program identify a minimum set of

KPPs continually traded against TOC along with balancing program risk. However, even with the strictest of CAIV principles and practices, recent programs such as Littoral Combat Ship are still experiencing termination due to cost growth. In examining the failure experienced by both the CAIV Flagship programs and the more recent LCS example, it would appear on the surface that CAIV is not delivering its promise to control cost and deliver affordable weapon systems optimized for performance and cost. Should CAIV then be abandoned in favor of developing new acquisition strategies?

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The answer is a resounding “no”! While CAIV principles are sound, it is the *implementation* of CAIV practices that are failing. In today’s environment, CAIV is used mostly in the pre-concept phases of the programs lifecycle, but once the program transitions into the manufacturing phase, it is difficult to sustain CAIV practices. To sustain CAIV practices over the lifecycle, automated linkages must be consistently and pervasively established between cost estimating and engineering tools from the earliest concept design through manufacturing operations, support and eventually disposal.

Programs must continually and automatically assess CAIV Key Performance Parameters and surface problems much earlier before costly decisions are made. Engineers need the ability to understand the impact of program changes in real time not only to performance and schedule, but to program cost as well.

For example, developing the CAIV trade space between cost and performance and ultimately “optimizing” a design requires that engineering and cost estimating tools actually integrate with each other. Going further, once a design is optimized, the *interoperability* between cost estimating and engineering tools must continue over the lifecycle of the program so programmatic/configuration changes are immediately assessed and evaluated. With current technology, this is mostly a manual, tedious process. A consistent framework is required to link engineering tools to cost estimating tools. Development of a standard for interoperability allowing for the integration of any cost estimating model with any engineering tool is needed so that CAIV management and reporting is automatic through the lifecycle of a program.

PRICE Systems has coined the term “Life Cycle Interoperability Framework” (LCIF) to describe the technology needed to facilitate standardized cost interoperability. Compromising the LCIF are two major XML schemas. The first, known as the Activity Based Costing XML or ABC-XML deals with a standardized way of enabling interoperability of applications with a cost modeling framework such as TruePlanning. The second, Activity Based Modeling XML or ABM-XML deals with a standardized way of integrating cost/performance models (e.g. homegrown EXCEL spreadsheets or MathCad models) within a cost modeling framework such as TruePlanning.

Figure #4 below shows an example of how the ABC-XML is used to both export and import data between the TruePlanning framework and an application such as Pro/E.

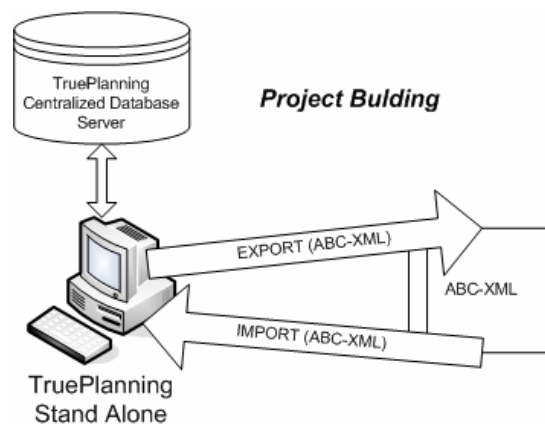


Figure 4 ABC-XML for Application Integration

In addition to integrating applications between TruePlanning and external applications, the LCIF architecture also allows us to import cost/performance models directly into the TruePlanning framework for incorporation with other cost objects. Because of the standardized XML approach, those models may also be exported from the TruePlanning framework for use or incorporation with other tools. This standardized XML is known as the Activity Based Modeling XML or ABM-XML. We are implementing the ABM-XML within our existing TrueAnalyst tool. Figure 5 below shows an example of how the ABM-XML is used to both import and export models into the TruePlanning Framework via TrueAnalyst.

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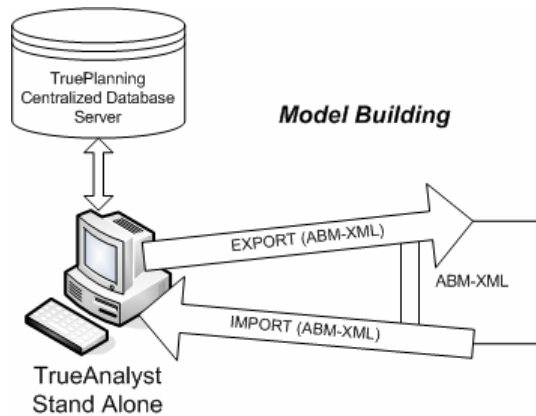


Figure 5 ABM-XML for Model Building

Figure 6 below presents a high level view of the LCIF as applied to the TruePlanning framework and displays several existing engineering tools that have integrations to the TruePlanning framework. Through a standardized architecture (TruePlanning XML Web Services and IIS Server, we are able to integrate TruePlanning with other applications.

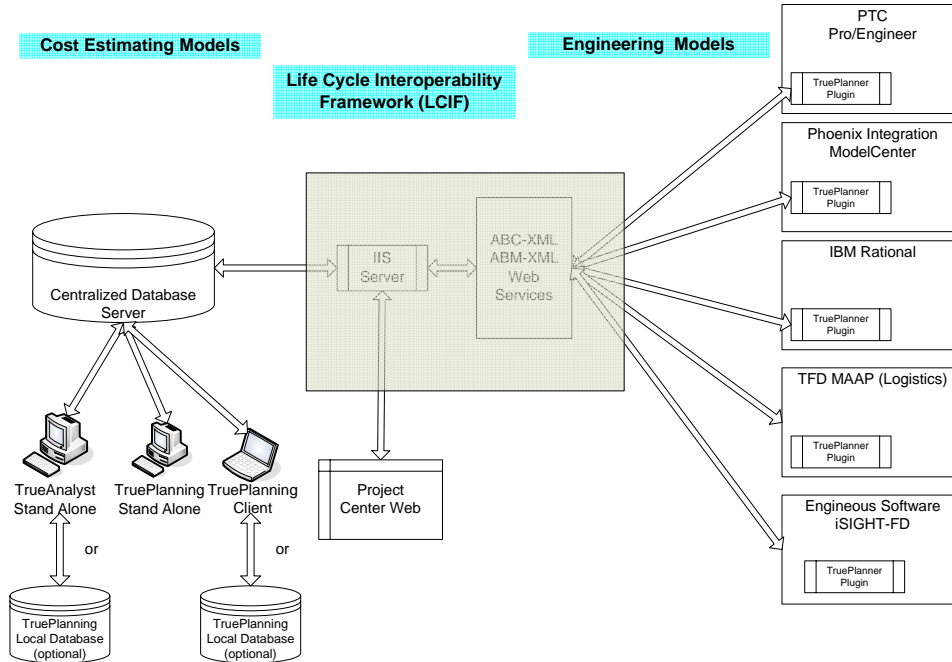


Figure 6 Life Cycle Integration Framework

Thus, the ability to conduct and evaluate CAIV studies at any phase of the program lifecycle is quickly and consistently communicated to the engineering, program management and cost estimating communities for

evaluation.

Extending CAIV Effectiveness – True Cost Engineering

Some of most recent integrations accomplished by PRICE Systems demonstrate how engineering design and cost estimating tools effectively and automatically communicate with each other through the LCIF. A recent success story in cost interoperability was completed at PRICE Systems between Pro/Engineer and TruePlanning Manufacturing. The Affordability Modeling Companion (AMC) System (developed by PRICE) is invoked from the Pro/Engineer during the design process, the Affordability Modeling Companion directly interacts with the design engineer to capture essential program parameters. The capability allows engineers the ability to trade off between performance and cost in real time before unaffordable designs are established.

TruePlanning Manufacturing

TruePlanning Manufacturing is an activity based model enabling cost estimating and analysis generated directly from the artifacts contained in a MCAD tool. Figure 7 below shows where the TruePlanning Manufacturing model “fits” into the TruePlanning framework. Typically the True Manufacturing is used as early as the demonstration phase of the program through In-Service. It is not typically used in the pre-concept, concept or assessment phases of a program as the types of detailed information required by the model is not known at the early stages of a program.

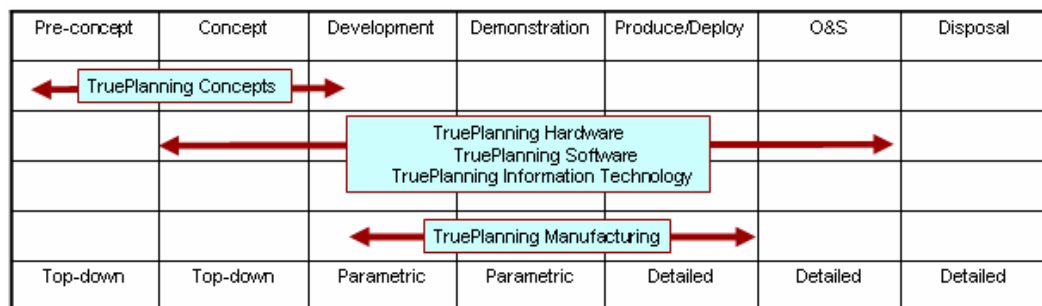


Figure 7 - Different Estimating Philosophy, Same Framework

The TruePlanning Manufacturing catalog contains two cost objects: Mechanical Assembly and Part. The interaction of these two cost objects is used to both summarize the Bill of Material found within an MCAD model and describes the detailed manufacturing process. The Mechanical Assembly is a parent cost object containing one or more Part cost objects and is used to describe/estimate processes and materials involved in handling and joining parts into an assembly to meet specified requirements. The part cost object, estimates costs for “core” prototype development and production of a part using geometric data available directly from the MCAD tool along with manufacturing process parameters. The TruePlanning Manufacturing Cost Objects can be combined with cost objects from TruePlanning Systems catalog to capture other activities (such as system requirements, system I&T, vendor management, etc.) to develop complete systems of systems estimates. In addition, downstream cost interoperability with optimization models such as Phoenix Integration’s ModelCenter and Engineous’ FIPER are also possible.

TruePlanning Manufacturing can be directly populated with inputs from engineering detailed design models such as Pro/E, CATIA, UGS, Autodesk etc. Facilitated with newly developed cost estimating relationships, the catalog is capable of estimating new builds and process/material type trade studies. However, the catalog does require the manual input of a detailed product work breakdown structure and/or mapping of the bill of material into that structure. In addition, the cost estimator must populate a large number of detailed inputs for each part. For example, Figure 8 displays the some of the detailed input parameters required by manufacturing process.

Input Parameter	Machining	Die Casting	Injection Molding	Forging	Sheet Metal Forming
Initial Slug Volume	x				
Cycle Time		x	x	x	x
Parts per Cycle		x	x		x
Finished Surface Area	x				
Material Removal Tool Width	x				
Finishing Tool Width	x				
Material Removal Toolset Cost	x				
Finishing Toolset Cost	x				
Parting Line Complexity		x	x		
Features		x	x		
Number of Lifters		x	x		
Number of Piercing Stations					x
Number of Forming Stations					x
Number of Trimming Stations					x

Figure 8 Inputs by Manufacturing Process

The TruePlanning Affordability Companion

To automate the process of transferring data from an engineering design tool such as Pro/E, an “Affordability Companion” was developed. Working directly within the engineer’s design toolset the Affordability Companion interacts with the design engineer to seamlessly capture and automatically populate the essential design parameters required by the TruePlanning Manufacturing cost model. The results of the cost estimate from the TruePlanning model are automatically returned directly to the engineer’s workstation for further analysis and trade studies. The first Affordability Companion developed at PRICE Systems works specifically with Pro/E Wildfire 3.0 engineering design tool. Additional Affordability Companions are planned for integration with other engineering tools based on the standardized LCIF framework. Figure 9 below displays a screenshot of Pro/E Wildfire 3.0 integrated with the Affordability Companion.

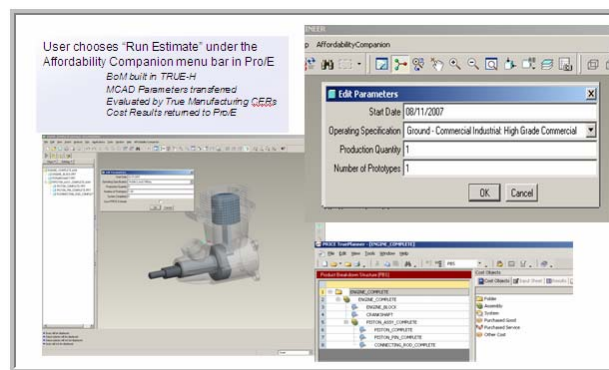


Figure 9 TruePlanning Affordability Companion

As displayed in Figure 9, the engineer invokes the Affordability Companion from the Pro/E menu bar. With only answering a few basic questions, the engineer runs the Affordability Companion. The Pro/E Bill of Material (BoM) along with other significant Pro/E geometry and/or user generated parameters is automatically summarized and transferred to the TruePlanning Manufacturing model for cost evaluation. It is important to note that the Affordability Companion develops a Product Breakdown Structure from the BoM that contains the unique instances of each part along with the correct quantities and quantity next high assembly calculations. In addition parameters such as weight and volume are calculated from the part geometry and the manufacturing process for each part selected.

Overall, TruePlanning Manufacturing provides an integrated, interoperable solution that offers early information on unaffordable designs and allows engineers to rapidly see the effect to design decisions on cost over the lifecycle of the program. This approach enables engineers with the ability to trade capabilities – risk, schedule, and cost – in system design and conduct acquisition simulations. The capability represented evolves affordability analysis from merely estimating total cost of ownership to total cost knowledge across the entire product lifecycle.

The solution is truly innovative as the engineer does not need to become a cost expert, and cost estimating subject matter experts easily maintain the cost model. The entire solution can also run in a distributed environment – the engineer only needs the Pro/E workstation integrated with the Affordability Modeling Companion, engineers do not require TruePlanning running on the workstation.

Summary - Extending CAIV through Cost Interoperability

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Through development of the Life Cycle Integration Framework and XML standards, any cost model could be rapidly integrated with any engineering tool enabling comprehensive CAIV analysis across the lifecycle providing concurrent affordability analysis. When fully integrated, cost and engineering models surfaces cost/performance problems much earlier where solutions are less costly – helping to prevent future program failures due to unexpected cost growth. PRICE Systems recent development of True Cost Engineer highlights a recent success in the cost interoperability arena and demonstrates the need to rapidly extend cost interoperability to many more engineering tools.

ENDNOTES

ⁱ Office of the Secretary of Defense, CAIV Templates, 3 June 2002

ⁱⁱ Dr. Benjamin Rush, Cost As An Independent Variable: Concepts and Risks, Acquisition Review Quarterly, Spring 1997, page 161

ⁱⁱⁱ Bell, G. (1996, July 11). Institute for Defense Analyses presentation to Flagship Programs Workshop.

^{iv} Dr. Benjamin Rush, Cost As An Independent Variable: Concepts and Risks, Acquisition Review Quarterly, Spring 1997, page 164

^v Dr. Benjamin Rush, Cost As An Independent Variable: Concepts and Risks, Acquisition Review Quarterly, Spring 1997, page 163

^{vi} US GAO, Defense Acquisitions, Assessments of Major Weapons Programs, May 2003, page 23

^{vii} Office of the Secretary of Defense, CAIV Templates, 3 June 2002