

Estimating Return on Investment for SAVI (a Model-Based Virtual Integration Process)

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ABSTRACT

The System Architecture Virtual Integration (SAVI) program is a collaboration of industry, government, and academic organizations within the Aerospace Vehicle System Institute (AVSI) with the goal of structuring a new integration process that relies on a “single-truth” architectural framework. The SAVI approach of “Integrate, then Build” provides a modern distributed development environment which arrests the propagation of requirements errors through the development life cycle. It does so by capturing design assumptions and shared properties of the system design in an authoritative, annotated architectural model. This reference model provides a common, analyzable framework for confirming that system requirements remain complete, consistent, and correct at all levels of system decomposition. Core concepts of SAVI include extensive use of model-based system engineering tools and use of a “single-truth” reference architectural model.

From the outset SAVI developers anticipated that a quantified prediction of the productivity of the SAVI Virtual Integration Process (VIP) would be necessary to close the business case for using it. Therefore, the SAVI statement of work at each stage of its feasibility demonstration carried a task to estimate the Return on Investment (RoI). AVSI participants needed a prediction of what the resources poured into SAVI development and deployment would produce. This paper lays out the work done so far to produce these RoI estimates and the assumptions that have gone into them. The paper goes on to illustrate example results for two of the major types of participants in SAVI, and details the current state of the evolving estimation capability.

The most important result of this RoI work is a substantial positive RoI predicted for using SAVI's VIP. Initial estimates of RoI for a first application to a commercial aircraft development indicated an expected value of annual RoI for an OEM on the order of 40%. Later estimates gave similar, but more positive, results with modified assumptions. But the range of variation of the estimates has been reduced to less than 1/3 of the original prototype estimator's variation. Savings for suppliers heavily engaged and at risk in the development are also predicted to have double digit annual RoIs, with the exact value of annual RoI rate dependent on the level of involvement of the supplier. The minimum value of annual RoI for the same commercial airliner development was calculated to be 2%, using the initial prototype estimator, but that minimum value of annual arithmetic RoI grew to over 70% per year in the refined estimator.

INTRODUCTION

Innovations must “earn” their way onto new complex aerospace systems. Model-based systems engineering (MBSE) is an innovation with enormous potential to make system development more efficient in both cost and schedule, but it is not exempt from demonstrating its worth in the eyes of program managers. Since the integration process is a major focus for systems engineers and designers and since it often leads to cost and schedule overruns; modelers, designers, and managers look to this system development activity as ripe for improvement through improved systems engineering processes.

Recent advances in architecture modeling languages enabling quantitative analysis of architecture specifications in a standardized notation, plus a growing set of architecture analysis tools and methods have supported two SAVI

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demonstrations of virtual integration analysis capable of finding a significant set of common requirements and design errors impacting system integration. The SAVI program has demonstrated the feasibility of such an approach based on a “single-truth” reference model. From these demonstrations, SAVI has developed the expected value of such a paradigm shift.

In 2007, when the Proof of Concept Demonstration (PoCD) phase of the SAVI program began, members initiated an effort to underpin its development with a return on investment (RoI) analysis based on the development of complex, software-intensive systems (like a commercial aircraft) that included all levels of the system hierarchy. One key SAVI benefit is finding and fixing errors by performing an architecture-centric integration in a virtual environment prior to physical build and integration. The participating organizations and the Software Engineering Institute (SEI) produced a prototype RoI spreadsheet tool based on COCOMO II¹ at the end of the first phase in late 2009. This first prototype focused on software costs based on the recognition of all participants that software/system integration costs now drive system development costs. This first prototype used source lines of code (SLOC) as the key sizing parameter. The predicted returns for shifting to the SAVI virtual integration process (VIP) paradigm were higher than anticipated and prompted the team to seek a second opinion. One of the participating system integrators sought and obtained an independent review by their organization's cost estimating group. This independent assessment of the RoI for use of the VIP on a commercial aircraft development agreed well with that of the first SAVI prototype estimation.

The prototype RoI tool was improved upon during a second round of feasibility demonstrations, the Expanded Proof of Concept Demonstration (EPoCD), during 2010. This second iteration improved usability, demonstrated how the modified RoI estimator could be used by suppliers in addition to the system integrator, incorporated Monte Carlo uncertainty calculations, and began expansion of the estimation technique to include the effects of incremental and iterative development (IID) for the SAVI VIP. This second generation estimator also broadened the cost estimate to include deployment costs, not just development costs of the VIP. In both the initial and refined prototypes, the developers took great pains to stress a conservative approach in the estimator's algorithms.

This RoI estimator is presently undergoing a third round of improvements due to be completed in March 2012. This latest set of improvements includes a more detailed look at the impact of the VIP on hardware element evolution during system development. Another set of results is also sought to evaluate the effect of SAVI at all levels of the system hierarchy, whether at the system integrator (also called the

Original Equipment Manufacturer or OEM) level or the supplier (Tier 2 or Tier 3) levels. At the same time an evaluation of how much stretching out the SAVI VIP development and deployment time (through incremental iterative development or IID) will likely affect the RoI is also sought during this third round of feasibility studies.

SAVI PROOF OF CONCEPT

Why SAVI and Its Virtual Integration Process Are Important

SAVI utilizes component models integrated into an architecture centric “single-truth” reference model. SAVI utilizes this virtual framework to discover defects and/or inconsistencies that impact integrated system required capabilities and to assist in bringing about a more optimal system solution at lower cost and in less time. SAVI has been described in a number of previous papers^{2,3,4} and the latest results of demonstrations are being presented in other papers at this conference, indeed in this session^{5,6}. So this section very succinctly describes SAVI.

The SAVI VIP is based on three principles⁷ supported by the core architectural model: (1) component models that can be exchanged within the architectural reference model are used, (2) analytical methods are used wherever possible to underpin system composition incrementally throughout the development process that uses the reference model, and (3) model analyses within the domains of interest must pass results between these domains and through the “single-truth” (single, consistent representation of the architecture with critical, driving variables at the current state of design) architectural model. These principles demand that the architectural definition be neutral to domain analysis tools and thus able to capture and send data across (and in both directions) the model data exchange layer with relative ease.

Very succinctly, SAVI is a paradigm change (implemented by the VIP) that facilitates system integration. It is not a set of software tools per se. Nor is SAVI a complete MBSE system, though use of the VIP is likely to make any MBSE scheme more efficient at detecting errors and needed changes earlier in the development process.

Importance of a RoI Estimate to SAVI Success

When SAVI took on its present form in late 2007, the team knew that, to be an attractive innovation, the SAVI VIP had to give an improved business case for complex systems like modern aircraft. At the time there were several examples of new aircraft integrations not going as planned: the Airbus 380, the Boeing 787, and the Lockheed F-35, to name just three. These examples pointed up the need for the VIP, but

the cost of developing a completely new integration paradigm demanded justification of the productivity for the new process. So, the SAVI team undertook its first feasibility demonstrations (PoCD) and a working group was assigned tasks that underpinned making a realistic estimate of the return on investment for SAVI. Three of the seven tasks⁸ for this phase of SAVI development influenced this objective:

- Determine a realistic ROI for the SAVI concepts, including formalized virtual integration of avionics system components and the satisfaction of requirements prior to contracting for components, subsystems, and the actual integration process.
- Establish the feasibility of cost and time reductions for development, integration, certification, and maintenance while realizing increased performance, safety, and security.
- Document the main differences between a conventional acquisition process and the projected SAVI acquisition process and identify the potential benefits that accrue with the SAVI acquisition process.

The next phase of SAVI development (the EPoCD)⁹ started in 2010 and continued the emphasis on RoI by developing the SAVI RoI Estimation Tool (SRET).

- Address deficiencies identified in the ROI analysis framework developed during AFE 58. (Tasks 5 & 6)
 - Task 5: Identify and Prioritize Gaps in the AFE 58 RoI Analysis Framework
 - Task 6: Implement Feasible Upgrades to the RoI Analysis Framework

A continuation of the EPoCD effort¹⁰ was started in April 2011 and continues with the RoI improvement objective still intact.

- Update the Return on Investment (ROI) analysis framework developed during AFE 58 and AFE 59. (Task 6)
 - Task 6: Update the RoI Analysis Methodology

Quite clearly, SAVI members see strong value in continuing to improve the RoI estimation to help management and industry as a whole to understand the business case for SAVI. Now the discussion turns to details describing how these objectives were addressed in each phase of SAVI development.

SAVI RoI Estimation - First Iteration (PoCD)

The SAVI PoCD exercised the new model-based integration process meant to evolve into a highly modified, MBSE-centered acquisition approach. The demonstration utilized a hierarchical aircraft model comprised of three tiers: an aircraft integration (OEM) level model, aircraft system

models, and subsystem models. Analyses run within the single-truth architectural framework included both early and high level analysis integrated with detailed analysis at lower levels which were incrementally evolved during the refinement of the system specification. These analyses included representative evaluations of network loading, system latency, CPU usage, and memory usage, for example. The PoCD team was geographically representative of a system of systems (based on a hypothetical aircraft OEM, along with Tier 1 and Tier 2 suppliers) with members located in Seattle, WA, Cedar Rapids, IA, Fort Worth, TX, Pittsburgh, PA, Rochester, United Kingdom, and Toulouse, France, all working from a shared reference model hosted at Texas A&M University. The PoCD team chose an SAE standardized architecture description language with precise, well-formed semantics to support quantitative analysis [SAE AS5506 - Architecture Analysis & Design Language (AADL)¹¹] and mostly open source tools. The Software Engineering Institute (SEI) at Carnegie Melon University was contracted to develop extensions to AADL, to facilitate the demonstration, and to assist in evaluating the process shifts. Additional details of how these models evolved and how demonstrations were carried out are available in the references.

As noted above, the PoCD project established a quantitative estimate of the benefit/cost ratio generated by SAVI. Problems with integration of complex systems are widely appreciated; hence, the problem requires little motivation. However, the scope of the effort proposed for the SAVI paradigm shift dictated an estimate that would assist members in prioritizing resources. Concerns about exposing competition-sensitive cost data led to developing a RoI model based largely on publicly available data. Thus, each participating company could adapt and compare to internal estimates of costs and value of improvements to the integration process.

This first RoI model was limited by available data to early detection and mitigation of certain classes of software errors. Requirements errors were a major factor. Analyses^{12,13,14} show that these types of software defects amount to 79% (defects traced to requirements) and 16% (defects traced to design) of rework cost. Therefore software rework costs (Figure 1) represent a significant and growing cost in complex system development and simple scaling arguments were used to extend the software analysis to the full aircraft system. While significant advantages of a model-based acquisition paradigm can be projected, the claimed benefits were all related to reducing software rework costs. Conservative assumptions were made throughout the estimation to emphasize credibility of the RoI estimate¹⁵.