Reducing System Acquisition Risk with Software Architecture Analysis and Evaluation

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Topics

Introduction
Motivation for software architecture analysis
Architecture analysis methods
Integrating architecture analysis and evaluation into a system acquisition
Example of an integrated approach
RFP/contract language considerations
Summary
References
Objective

To provide guidance on integrating software architecture analysis and evaluation in DoD and Government system acquisitions.

This presentation contains both implicit and explicit guidance. We will use this icon to indicate when we are giving explicit guidance.

The guidance is based on real experience and a series of technical notes and reports that were developed by the Business and Acquisition Guidelines (BAG) group of the Product Line Systems Program at the SEI. (See References.)
Key Definition

The **software architecture** of a program or computing system is the structure or structures of the system, which comprise software elements, the externally visible properties* of those elements, and the relationships among them.

* assumptions other elements can make of a element, such as its provided services, performance characteristics, fault handling, shared resource usage, and so on

Reference:
*Software Architecture in Practice, 2nd Edition;*  
Terminology

**Architecture analysis** refers to analyzing a system’s software architecture in accordance with a prescribed method.

**Evaluation** is used strictly in an acquisition context—i.e., in reference to performing an appraisal during source selection or contract performance.

**Architecture analysis and evaluation** means analyzing an architecture (and reporting the results) and evaluating the analysis results in strict accordance with the technical evaluation criteria of Section M of the RFP or the terms of the governing contract.
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Why Is Architecture So Important?

Architecture is a common high-level communication vehicle for system stakeholders that is amenable to analysis and synthesis.

Architecture embodies the earliest set of design decisions about a system. These decisions

• are the most profound
• are the hardest to get right
• ripple through the entire software development effort
• are most costly to fix downstream
• are critical to achieving mission/business goals

The earlier we reason about tradeoffs, the better. Architecture provides a powerful way to predict system qualities.
Software Versus System Acquisition

“We buy systems, not software.”

Promoting this message to DoD acquirers translates into “don’t worry about software.”

Reality:

You should worry about software.
Software is critical to systems.
Software and software architectures drive both functionality and system quality.
Relationship of System Requirements to Software Architecture

System Specification
System Quality Attributes*

* Performance
  Security
  Interoperability
  Reliability
  Availability
  etc.

Software Architecture

System Capabilities and Software Quality

determines level of quality

drive

drives

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Being Proactive Pays Off

Architecture analysis and evaluation enables an acquisition program to

• **obtain early visibility** and technical insight into
  - system concept of operation
  - system and software design decisions and tradeoffs
  - ability to achieve desired system quality attributes

• **achieve increased stakeholder communication** across and within government and contractor organizations

• **identify and reduce risk** early on—for new and legacy systems
Justification for Architecture Analysis and Evaluation in a System Acquisition

Symbol for using architecture analysis as an "acquisition checkpoint" to reduce risk

This is consistent with acquisition reform principles.
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SEI’s Architecture Analysis Methods

The term “architecture analysis” encompasses both

Need to

• choose an analysis method that fits your approach
• implement a compatible acquisition infrastructure

\( \text{SM} \) Architecture Tradeoff Analysis Method and ATAM are service marks of Carnegie Mellon University.
The Analysis Methods

ATAM

- Purpose: to assess the consequences of architectural decisions in light of quality attribute requirements and business goals
  - uncover risks created by architectural decisions
  - surface design tradeoffs
- Requires identified business goals and a sufficiently documented software architecture

QAW

- Purpose: to help determine key quality attributes and system requirements before there is a software architecture to which the ATAM could be applied
Characteristics of ATAM and QAW

ATAM

• Uses extensive analysis of software attributes against quality drivers
• Involves broad range of stakeholders
• Requires close collaboration with architecture development team

QAW

• Complementary offshoot of ATAM
• Intended for early stages of conceptual architecture development
• Can begin while the software architecture is still being crafted
  - Elements of a system and software architecture will suffice.
• Can be done offline by developer
ATAM Benefits

Provides visibility into the consequences of architectural decisions in light of quality attribute requirements
  • risks are explicitly identified
  • architecture sensitivity points are determined
  • tradeoffs are made more explicit

Increases communication among stakeholders

Provides documented basis for making architectural decisions

The results are improved software architectures.
QAW Process
QAW Process – In DoD Environment

Legend
- QAW activity
- Other activity
- QAW Artifacts
  - Primary
  - Optional
  - Output

1. Scenario Generation
2. Test Case Development
3. Test Case Architecture Analysis
4. Analysis Results Presentation

Acquirer’s Responsibility

Supplier’s Responsibility

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QAW Benefits

Clarifies business drivers and quality attribute requirements
Allows generation of scenarios and test cases before there is a software architecture
Results in improved architecture documentation
Allows risks to be identified early in the life cycle
Provides documented basis for architectural decisions
Increases communication among stakeholders

The results are improved conceptual architectures.
Conditions for using ATAM or QAW

**ATAM**
- Stakeholders want to evaluate the software architecture.
- Business drivers and system quality attributes are well understood.
- Software architecture is suitably documented.
- Architecture development team is available for engagement.

**QAW**
- An architecture analysis is desirable to reduce risk.
- Business drivers and system quality attributes need refinement.
- There is only a conceptual architecture and limited architectural documentation.
- A very flexible analysis method is needed to allow for early intervention.
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Applying Architecture Analysis and Evaluation in a System Acquisition

In competitive acquisitions, architecture analysis and evaluation can be used to help manage the solicitation process, including source selections.

After contract award, architecture analysis can be used to help manage the contract performance process, including contractor performance and product evaluations.

How to use architecture analysis and evaluation most effectively depends on your objectives and system acquisition strategy.
Architecture Analysis and Evaluation in Solicitation

Architecture analysis and evaluation can be used as a discriminator in the source selection process. Options include evaluating each offeror’s

- related experience in architecture development and analysis
- ability to adequately plan an architecture analysis using a prescribed method
- actual progress against an approved analysis plan
- architecture analysis results
- demonstrated ability to take suitable remedial action and mitigate discovered risks
Architecture Analysis and Evaluation in Contract Performance

During *system development*, architecture analysis can be used to
• select an architecture among several candidate architectures
• assist in decision whether to upgrade or rebuild legacy system
• assist in architecture refinement once an architecture has been chosen
  - during progressive stages of software development
  - during evaluation of new system builds

During *system sustainment*, architecture analysis can be used to support system upgrades and reengineering.

During *system development and sustainment*, architecture analysis and evaluation can play a role in incentive awards to the degree specified in the contract.
Guidance: Basic Principles

Remember that

• One size doesn’t fit all.
  - The approach for integrating architecture analysis and evaluation in a system acquisition has to be adapted to the situation.
• Success will depend on carefully planning a coherent approach and integrating it with the system acquisition strategy.
• Analysis aspects must faithfully adhere to the specified architecture analysis method.
• Evaluation aspects must comply with the FAR* and be specified up front in the RFP and contractual requirements.

* Federal Acquisition Regulations
Example System Acquisition Strategy

- **Open Competition**
  - **Source Selection**
    - **Contractor A Performance**
    - **Contractor B Performance**
  - **Evaluate Deliverables**
  - **Contract Award**
    - **System Development**

- **Open Solicitation**
  - **Competitive Fly-Off**
    - **Main Contract Performance**
      - **Contract Award**
      - **RFP # 1 Awards**
      - **RFP # 2 Awards**
Potential Application of Architecture Analysis and Evaluation

Part of Oral Technical Presentations

- Architecture Walkthroughs
- Source Selection
- Contractor A Performance
- Contractor B Performance
- Architecture Analysis
- System Development
- Ongoing Software Architecture Analyses

Potential Application of Architecture Analysis

- Architecture Walkthroughs
- Source Selection
- Contractor A Performance
- Contractor B Performance
- Architecture Analysis
- System Development
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How Do You Incorporate Architecture Analysis and Evaluation in an Acquisition?

Develop an Integrated Approach that includes a Prescribed Set of Events and Artifacts

The purpose of these events and artifacts is to create a suitable acquisition infrastructure.
Guidance: Getting Started

To integrate architecture analysis and evaluation you will need to

• understand the policies and constraints that govern the acquisition

• understand the system acquisition strategy and proposed technical evaluation criteria for the RFP/contract

• have a good working knowledge of the architecture analysis method to be applied

• understand how the system’s technical requirements apply to the architecture analysis and evaluation

• strongly consider adopting a competitive fly-off strategy to reduce risk by allowing more detailed analysis (suppliers) and evaluation (acquirers)
Developing an Integrated Approach

1. Establish your objectives for incorporating architecture analysis and evaluation.
2. Review the proposed acquisition strategy.
3. Conduct a brainstorming session with stakeholders to explore how architecture analysis and evaluation can best be applied in source selection and contract performance.
4. Select the most beneficial course of action that is compatible with the selected architecture analysis method.
5. Identify what events must take place and what artifacts must be produced in each phase of the acquisition.
Developing an Integrated Approach

- Define a compatible set of roles and responsibilities for both the acquirer and supplier.

- Identify the specific tasks that the acquirer and supplier must perform in each phase of the acquisition and the artifacts that they must develop and deliver.

- Have stakeholders review and critique the proposed approach.

- Adjust the approach or acquisition strategy as necessary and obtain the approval of the contracting officer.

- Develop corresponding RFP/contract language to implement steps 4 through 9 in an effective manner.
Acquirer’s Key Events and Artifacts

In planning the approach, give due consideration to

• specifying the **business/mission drivers**
• specifying the system **quality attributes** and **architecture test cases** and **architecture documentation**
• conducting a **tutorial** on the architecture analysis method for prospective offerors before issuing the RFP
• holding a **kickoff meeting** after contract award to describe
  - government expectations for the supplier’s architecture analysis
  - rules of engagement for conducting the analysis and evaluation
• providing **formal feedback** on the analysis results
• having an **equitable basis for evaluating** the final outcome
Supplier’s Key Events and Artifacts

In planning the approach, give due consideration to

• requiring suppliers to prepare a preliminary architecture analysis plan to demonstrate their understanding of the analysis method

• requiring suppliers to conduct a dry run architecture analysis to assess their level of preparedness

• requiring the active participation of key stakeholders, including the supplier’s software architect

• incorporating an equitable means for suppliers to deliver and present their analysis results and respond to official feedback from the acquirer
Software Architecture Guidance

DoD typically mandates use of the C4ISR Framework.

This often translates to “C4ISR is sufficient to address all architectural concerns.”

Reality:

The C4ISR Framework provides important context but is not a software architecture.
Guidance: In Developing Your Specific Approach

Accommodate all aspects of the architecture analysis method in the most practical, straightforward manner.

Ensure that the RFP development team is included in all the acquisition technical planning and decision-making activities.

Include the contracting officer in the planning process.

Ensure that companies contributing to RFP/contract preparation will exclude themselves from bidding to avoid a potential protest.

If adopting a competitive fly-off approach, use a Call for Improvement (CFI) instead of issuing another RFP.
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Example System Acquisition Strategy

1. **Open Solicitation**
   - Multiple Technical Proposals
   - Bidders' Conferences
   - RFP Release

2. **Proposal Evaluation and Contract Awards**
   - Initial Down Select

3. **Competitive Solicitation**
   - Competitive Fly-Off

4. **Improved Technical Proposal**
   - Call for Improvement (CFI)
   - Supplier A Performance
   - Evaluation of Improved Technical Proposals and Contract Award

5. **Final Down Select**
   - System Implementation

6. **System Development**
   - Supplier B Performance
   - Improved Technical Proposal
   - 30 Days
   - Competitive Fly-Off

7. **Multiple Technical Proposals**

8. **Final Down Select**
   - Initial Down Select
Integrating a QAW (Part 1)

Planning and Preparation Phase

1. Scenario Generation
   - 1st Architecture Test Cases

2. Test Case Development
   - 2nd Architecture Test Cases

Competitive Solicitation

3. Bidders’ Conferences
4. QAW Tutorial
5. Initial Architecture Analysis Plan
6. Multiple Technical Proposals
7. RFP Preparation
8. Open Solicitation

Initial Down Select

Proposal Evaluation and Contract Awards

Competitive Fly-Off

Supplier A Performance

Supplier B Performance
Integrating a QAW (Part 2)

- Initial Down Select
- Competitive Fly-Off
- Final Down Select
- System Implementation


QAW Architecture Analysis

8. Supplier A Performance

8a. Test Case Architecture Analysis 3rd

8b. Analysis Results Presentation 4th

9. Evaluation Notices (ENs)

To Supplier

Dry Run

All Test Cases

7. Refined Architecture Analysis Plan

Supplier B Performance
At the request of the acquirer's evaluation team, the contracting officer issues evaluation notices (ENs) to inform contractors of

- items needing clarification
- deficiencies requiring resolution

REQUESTS FOR CLARIFICATIONS cite conditions (e.g., ambiguities, anomalies, and issues) requiring further explanation or correction by the contractor.

DEFICIENCIES cite conditions that represent potential risks in achieving the desired system quality attributes (including failure to meet expected architecture test case response in a QAW) or conditions that do not satisfy the system requirements.
Integrating a QAW (Part 2 Continued)

- Initial Down Select
- Competitive Fly-Off
- Final Down Select
- System Implementation

1. Supplier A Performance
   - 8. QAW Architecture Analysis
     - 8a. Dry Run
     - 8b. Analysis Results Presentation (4th)
   - 10. Architecture Analysis Report
2. Supplier B Performance
   - 7. Refined Architecture Analysis Plan
   - 11. Improved Technical Proposal
   - 12. Oral Presentation

- System Development
- Call for Improvement (CFI) 30 Days
- Test Case Architecture Analysis 3rd
- Evaluation Notices (ENs) To Supplier
- All Test Cases
Integrating ATAM (Part 3)

Supplier builds on QAW results, but now follows ATAM steps

Evaluation of Improved Technical Proposals and Contract Award

ATAM Architecture Analysis

ATAM Architecture Analysis

ATAM Architecture Analysis

System Implementation

System Development

Software Architecture Documented per Specification

First Software Build

First Integrated System Build

Final Down Select

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Implementing the Architecture Analysis and Evaluation Approach

What happens during solicitation and contract performance critically depends on what is included in the RFP and the resulting contract.

Appropriate RFP/contract language must be developed to make architecture analysis and evaluation an integral part of evaluating proposals as well as evaluating system aspects.

Only the RFP and contract language can give the government the means to manage the suitability of the software architecture.
Incorporating architecture analysis requires developing appropriate language for the following sections:

- **Section C**: Description, SOW*, Performance Specification
- **Section H**: Special Contract Requirements
- **Section J**: Contract Deliverables Requirements List
- **Section L**: Instructions, Conditions, and Notices to Offerors
- **Section M**: Evaluation Factors for Award

* Statement of Work
Performance Specification*

Contains two sections of interest:
- Section 1 covers the technical requirements for the acquisition.
- Section 2 describes the mechanisms for confirming that requirements have been met.

Section 1 specifies system quality requirements from which software architecture requirements (runtime and non-runtime) are derived. They must be stated in terms of
  - definition of system quality attributes
  - specification of acceptable values
  - definition of scenarios and test cases
  - specification of other requirements (e.g., C4ISR)

Section 2 includes a description of the architecture analysis method.

* System Specification or Technical Requirements Document
Section H: Special Contract Requirements

Section H will specify

- the architecture analysis requirements
- the artifacts that are to be developed
- rules of engagement (ROE)

Section H will describe

- when the architecture analysis should be performed
- how the analysis should be conducted
- contractor and government roles and responsibilities
- how the results will be used
Typical Rules of Engagement (ROE)

- Offerors will submit architecture analysis plan with proposal based on government-prescribed architecture analysis method.
- Contracting officer will notify selected suppliers of any deficiencies in their analysis plan.
- Supplier will conduct architecture analysis and present results in accordance with its approved plan.
- Contracting officer will issue evaluation notices (ENs) to suppliers following presentation of analysis results.
- Suppliers are required to respond to all ENs.
- Contract takes precedence over the architecture analysis plan.
- Analysis results are evaluated in accordance with contract or technical evaluation criteria of Section M of RFP.
Software Architecture Documentation

There are no DoD Data Item Descriptions (DIDs) specific to architecture.

However, some DoD organizations have tailored the following DIDs from DoD-2167A that contain architecture information to meet their acquisition needs:

- System/Subsystem Design Document (SSDD)
- Software Design Document (SDD)

Under acquisition reform, many contractors will describe the specific artifacts and documentation they will prepare per their own internal processes.
RFP Section L

Section L describes what offerors should address in their proposal; that is, which requirements in the RFP need a response.

Offerors prepare multiple volumes.

Volume 3

Volume 5

Volume 8

Technical

Past Performance

Pre-Award Demonstration Plan / Procedures
Specific Section L Volumes

In the **Technical volume**, you ask offerors to describe their approach for implementing and analyzing architecture requirements.

In the **Past Performance volume**, you ask offerors to describe previous work on software architecture development and architecture evaluation.

In the **Pre-Award Demonstration volume**, you give offerors requirements for demonstrating the capability of their software architecture.
RFP Section M: Evaluation Criteria

Section M tells offerors how their proposals will be evaluated.

It should specify

• the ranking of evaluation factors
• how architecture analysis is made part of the specific evaluation factors
• the evaluation criteria for judging the proposal submission and how results of the architecture analysis will be included in the technical evaluation
Guidance: Some Precautions

To avoid potential problems

• Understand the policies and criteria that the acquisition review board will use as part of the RFP review and approval process.

• Make sure the architecture analysis and evaluation approach has the “buy in” of the contracting officer.

• Firm up the acquisition strategy and technical evaluation criteria early in the acquisition planning phase.

• Resist management pressures to arbitrarily compress the acquisition schedule, including RFP preparation.

• Include personnel with domain and architecture expertise on the RFP development team.
Guidance: RFP Preparation

It takes time to carefully draft the right wording for architecture analysis and evaluation and integrate it into an RFP in a manner that is compatible with the acquisition strategy and addresses all the key issues.

If you rush your preparation of the RFP you will likely increase downstream risk and not reap all the benefits of an architecture-centric acquisition approach.
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➡️ Summary
Summary

Our acquisition example illustrates the use of software architecture analysis and evaluation in source selection and contract performance.

A prescribed set of events and artifacts can be used to integrate architecture analysis and evaluation in a system acquisition.

This approach works with any system and software development methodology.

RFP and contract language alone can give the acquirer the capability to manage the system quality of the architecture.
Summary 2

Architecture analysis and evaluation provide an effective means for

• mitigating risks in a system acquisition
• evaluating the achievement of system quality attributes that are important to the program
• changing customary program assumptions about software oversight that underlie system acquisitions
References
Architecture Books in SEI Series

*Software Architecture in Practice, 2nd Edition*

*Documenting Software Architectures: Views and Beyond*

*Evaluating Software Architectures: Methods and Case Studies*

*Software Architecture in Practice*
Technical Reports Describing Architecture Analysis Methods

CMU/SEI-2000-TR-004

*ATAM\textsuperscript{SM}: Method for Architecture Evaluation*
www.sei.cmu.edu/publications/documents/00.reports/00tr004.html

CMU/SEI-2002-TR-019

*Quality Attribute Workshops, 2\textsuperscript{nd} Edition*
www.sei.cmu.edu/publications/documents/02.reports/02tr019.html
Technical Notes on Architecture Analysis in Acquisition

CMU/SEI-2002-TN-010
Use of the Architecture Tradeoff Analysis Method\textsuperscript{SM} (ATAM\textsuperscript{SM}) in Source Selection of Software-Intensive Systems

CMU/SEI-2002-TN-013
Use of Quality Attribute Workshop (QAW) in Source Selection for a DoD System Acquisition: A Case Study

CMU/SEI-2001-TN-010
Use of the Architecture Tradeoff Analysis Method\textsuperscript{SM} (ATAM\textsuperscript{SM}) in the Acquisition of Software-Intensive Systems
Technical Notes on Architecture Analysis in Acquisition

CMU/SEI-2000-TN-010

*Using Quality Attribute Workshops to Evaluate Architectural Design Approaches in a Major System Acquisition: A Case Study*

CMU/SEI-99-TN-012

*Software Architecture Evaluation with ATAM\textsuperscript{SM} in the DoD System Acquisition Context*
Related Technical Notes and Reports

CMU/SEI-2001-TN-022
*Using the Architecture Tradeoff Analysis Method*\textsuperscript{SM} to Evaluate a War Game Simulation System: A Case Study

CMU/SEI-2000-TN-007
*Using the Architecture Tradeoff Analysis Method*\textsuperscript{SM} to Evaluate a Reference Architecture: A Case Study

CMU/SEI-99-TR-014
Architecture Tradeoff Analyses of C4ISR Products
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