Use of the Architecture Tradeoff Analysis Method[SM] (ATAM[SM]) in the Acquisition of Software-Intensive Systems

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About the Technical Note Series on Architecture Evaluation in the Department of Defense

The Product Line Systems Program is publishing a series of technical notes designed to condense knowledge about architecture evaluation practices into a concise and usable form for the Department of Defense (DoD) acquisition manager and practitioner. This series is a companion to the Software Engineering Institute (SEI) series on product line acquisition and business practices [Bergey 99].

Each technical note in the series will focus on the use of architecture evaluation and, in particular, on applying the SEI's architecture tradeoff analysis technology in the DoD. Our objective is to provide practical guidance on ways to integrate sound architecture evaluation practices into their acquisitions. This series of technical notes will lay down a conceptual foundation for DoD architecture evaluation practice.

Abstract

Software architecture is critical to the quality of a software-intensive system. For an acquisition organization, such as the Department of Defense (DoD), the ability to evaluate software architectures early in an acquisition can have a favorable impact on the delivered system. This technical note discusses the role of software architecture evaluations in a system acquisition and describes the contractual elements that are needed to accommodate architecture evaluations in an acquisition. The note then provides an example of contractual language that incorporates the Architecture Tradeoff Analysis Method[SM] (ATAM[SM]) as a software architecture evaluation method in a system acquisition.

[SM] Architecture Tradeoff Analysis Method and ATAM are service marks of Carnegie Mellon University.

1 Introduction

The software architecture of a system significantly influences the overall functionality, performance, and quality of that system. The use of software architecture evaluations early in a system acquisition can help mitigate many of the technical risks associated with system development, thereby improving the ability of the acquisition to achieve the stated system objectives [Fisher 98]. In an acquisition context, these evaluations

- provide a proactive means of gaining early visibility into critical design decisions that will drive the entire system-development effort
- can be performed before a system is built (e.g., during engineering design processes) to determine if the system will satisfy its desired qualities

This technical note discusses where the Architecture Tradeoff Analysis Method[SM] (ATAM[SM]) or other architecture evaluation methods can be employed most advantageously in a system acquisition. It also reviews the steps of the ATAM and provides sample acquisition language[1] (i.e., contractual wording for a statement of work [SOW] and system specification) that will enable an acquirer to apply an architecture evaluation method such as the ATAM, during the post-award phases of an acquisition.[2]

[SM] Architecture Tradeoff Analysis Method and ATAM are service marks of Carnegie Mellon University.

1 Every acquisition is considered unique. The acquisition language provided in this technical note should not be applied directly to all acquisitions. It is strongly recommended that the language be adapted by the acquirer to his/her specific needs.

2 Future technical notes will provide language for using the ATAM in other acquisition phases and with other system acquisition strategies.

2 Software Architecture Evaluation in System Acquisitions

In this technical note, we consider the activities corresponding to three phases of an acquisition: pre-award, award, and post-award [Bergey 99]. These activities are illustrated in Figure 1. Software architecture evaluation can potentially play a role in the award and post-award phases to help lower the risks associated with an acquisition.

During the award phase, architecture evaluations can be used to evaluate suppliers' overall approaches to system design, to assess the strengths and weaknesses of competing architectures, and to identify risks to the program.

After contract award, software architecture evaluations can be used for contract management, by enabling acquirers to evaluate both supplier and product performance.

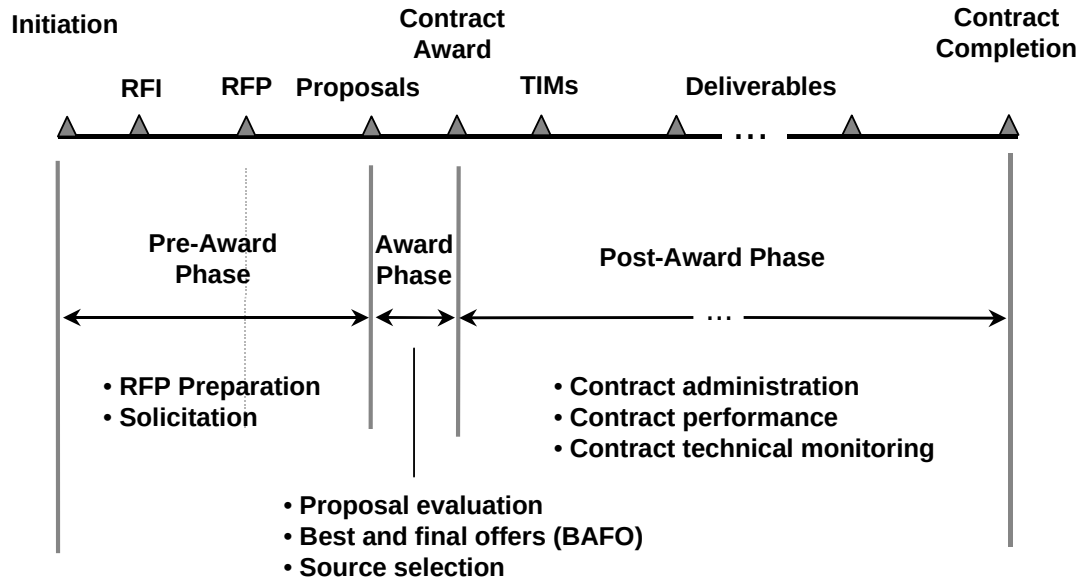

Figure 1: Phases of an Acquisition

To use software architecture evaluation in either the award phase (e.g., source selections) or the post-award phase (e.g., contract management), the solicitation package must contain the criteria for proposal and product evaluation and include the architecture evaluation method to be used as part of the architecture requirements.

2.1 Pre-Award and Award Phase for a System-Development Contract

Acquisition planning precedes the entire solicitation process and includes generating and validating product requirements (e.g., functional and quality requirements such as reliability or performance).

In the pre-award phase, a solicitation package is developed. It tells potential suppliers what the requirements[3] of the acquisition are, how to prepare their proposals, how proposals will be evaluated, and when to submit their proposals [Cooper 99]. Solicitation packages take various forms and are referred to differently. However, they all have the same characteristics noted here. We will use the common term "request for proposals" (RFP) to refer to solicitation packages.

As shown in Figure 2, the RFP typically contains sections A through M. These sections provide information that must be distributed to potential suppliers. Depending upon the acquiring organization's policies and processes, the sections may be incorporated in different ways. Most RFPs, however, contain the same type of information.

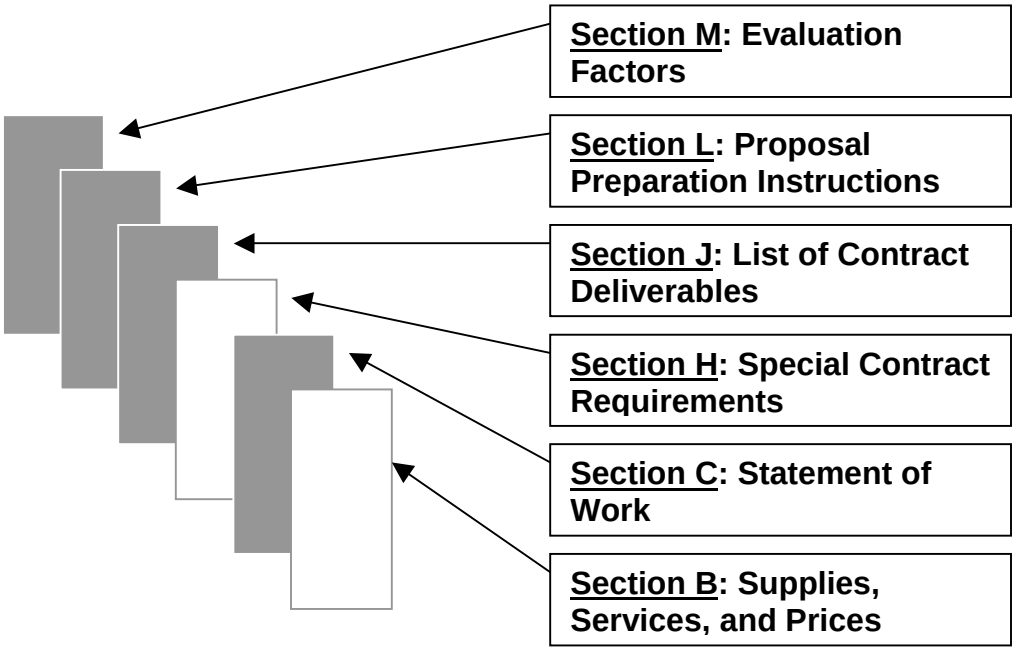

Figure 2: Contents of Request for Proposals (RFPs)

[3] The term "requirements" encompasses all requirements of the acquisition, including product requirements, where the term product may mean a specific system or services [Cooper 99].

The RFP and eventual contract language should

- address the acquisition requirements of the project
- comply with regulations, policies, and other guidance
- clearly describe product requirements in terms of functionality, performance, and quality
- protect the interests of both the acquirer (buyer) and the supplier (contractor)

What goes into an RFP and the resulting contract depends largely upon the acquirer's knowledge and objectives for the acquisition. For our interest, the RFP sections must include the requirement for a software architecture evaluation. As a result, in this technical note, we are interested in Sections C, L, and M. We will discuss these sections to demonstrate some of the considerations needed to incorporate a software architecture evaluation into an acquisition.

2.1.1 Section C

Section C contains supplier work requirements in the form of a statement of objectives (SOO) or statement of work (SOW) along with product requirements such as a system performance specification (containing functional and quality requirements). If an architecture evaluation method is to be required, both the SOW and the product requirements must properly define the specific method, such as the ATAM, as well as how the software architecture evaluation method will be used and implemented. This information must be integrated and compatible with other acquisition requirements that are part of the RFP.

Statement of Work (SOW)

The statement of work (SOW) describes what the supplier must accomplish. In terms of an evaluation method, the SOW describes which evaluation steps are the supplier's responsibilities. The evaluation steps in the SOW must be consistent with the overall acquisition. In addition, it should indicate if certain evaluation steps are to be performed jointly by the acquirer and the system supplier.

Product Requirements

A system specification typically has two main sections of interest. Section 1 specifies functional and quality requirements for the system. Here, quality requirements refer to those quality attributes of the system and their respective characterizations. Modifiability, reliability, and security are examples of the types of system quality attributes that may be considered. For example, if reliability is a required quality attribute, a characterization might be that "the system will not fail under maximum load conditions." Eliciting the quality attributes of primary interest as well as their characterizations for the system in question are part of the ATAM.

Section 2 of the system specification describes the software architecture evaluation methods, such as the ATAM, to be used in determining if the software architecture can support the satisfaction of the requirements in Section 1.

2.1.2 Section L

Section L (Proposal Preparation Instructions) describes what potential suppliers should address in their proposals and the response that is required. Typically, the acquirer would ask the potential suppliers for responses in several volumes, such as a technical volume, past performance volume, management volume, and cost volume. There are no set rules for what these volumes exactly contain. In the technical volume, an acquirer may ask potential suppliers to describe their proposed approach for implementing the software architecture requirements and performing an architecture evaluation. In the past performance volume, an acquirer may ask suppliers to describe previous work on software architecture development and architecture evaluation.

2.1.3 Section M

Section M (Evaluation Factors for Award) tells potential suppliers how their proposals will be evaluated. This typically includes specifying

- what areas (i.e., factors and subfactors) of the supplier's proposed approach are to be evaluated as part of the proposal evaluation
- the specific criteria to be used for judging the supplier's proposed approach to meeting the RFP/contract requirements for these factors and subfactors

To incorporate architecture evaluation, Section M must specify how the architecture evaluation will relate to the factors and subfactors. And, it must specify the criteria to be used in judging the bidder's approach to satisfying the RFP/contract architecture requirements.

From a contracting officer's perspective, releasing the RFP defines the official beginning of the solicitation. After the solicitation period formally closes, source selection commences with a proposal evaluation and ends with a contract award. Specifying an architecture evaluation as part of the source selection process can be an effective way to evaluate the risks associated with the proposed software architecture. The results can be used as part of the evaluation of the proposals as long as the evaluation criteria are stated to accommodate these results.

2.2 Post-Award Phase for a System-Development Contract

Making architecture evaluation a contractual checkpoint is an effective way to gain insight into the architecture's ability to satisfy system requirements early in its development. Such an evaluation can help the acquirer and supplier

- select an architecture from among several candidate architectures
- surface and mitigate risks associated with architectural decisions prior to development
- better understand the ability of the software architecture to support system requirements
- better understand architectural decisions
- improve architectural approaches
- evaluate the quality of evolving products as required by contract
- resolve issues through an acquirer–supplier team approach

It is important to note that what happens during the post-award phase critically depends on what has been included in the RFP and the resulting contract. Ultimately, the negotiated contract will govern what is permissible during the contract performance phase and what tasks and products will be the supplier's responsibility. Figure 3 shows an example of where architectures and their evaluations may come into play.

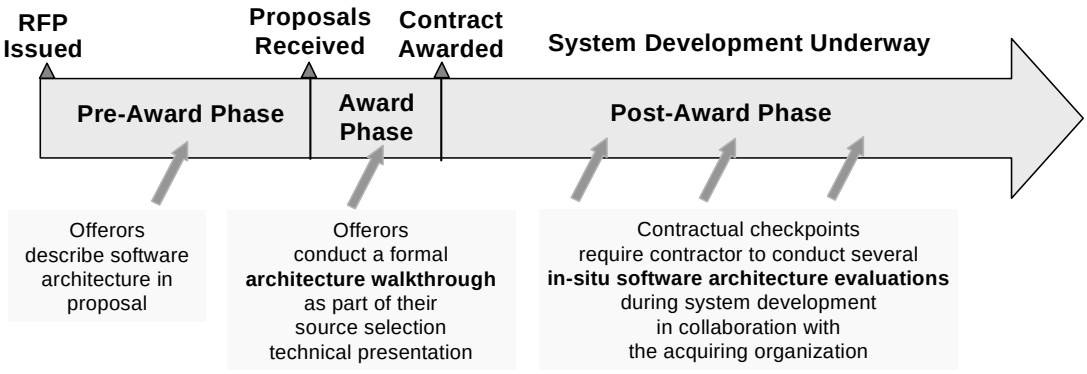

Figure 3: Acquisition Opportunities for Conducting Architecture Evaluations

There are certainly other ways to incorporate architecture evaluation in an acquisition depending on the acquisition strategy. For example, an evaluation can be included in a two-phase acquisition with a "down select" to award the final contract.

3 Architecture Tradeoff Analysis Method (ATAM)

The Architecture Tradeoff Analysis Method (ATAM) is a technique for evaluating software architecture. The technical staff of the Software Engineering Institute (SEI) developed and refined this method over the past five years [Kazman 00]. The ATAM not only can evaluate specific architecture quality attributes, it allows engineering tradeoffs to be made among possibly conflicting system quality goals. In this way, the ATAM evaluation can detect areas of potential risk within the architecture of a complex software-intensive system.

The Architecture Tradeoff Analysis Method has several advantages. It can be done early in the software-development life cycle. It can be performed quickly and inexpensively. The method involves project decision-makers, other stakeholders including managers, developers, maintainers, testers, re-users, end users, customers, and an architecture evaluation team. These groups collaborate to determine the critical quality attributes of the system. The ATAM provides an effective means to evaluate the consequences of alternative architecture decisions in light of specified quality attributes.[4] The method ensures that the right questions are asked to uncover

- risks—architecture decisions that might create future problems in some quality attribute
- sensitivity points—properties of one or more components (and/or component relationships) that are critical for achieving a particular quality attribute response (i.e., a slight change in a property can make a significant difference in a quality attribute)
- tradeoffs—decisions affecting more than one quality attribute

There are nine specific steps in the ATAM evaluation that fall into four general types of activities, which are described on pages 7-8.

Presentation

Step 1: Present the ATAM. The method is described to the assembled stakeholders (typically customer representatives, the architect or architecture team, user representatives, maintainers, administrators, managers, testers, integrators, etc.).

[4] The ATAM is not a precise mathematical analysis. It is intended to analyze an architecture with respect to its quality attributes, not its functional correctness.

Step 2: Present business drivers. The project manager describes the business goals that are motivating the development effort and hence the primary architecture drivers (e.g., high availability, time to market, high security, etc.).

Step 3: Present architecture. The architect describes the proposed architecture, focusing on how it addresses the business drivers.

Investigation and Analysis

Step 4: Identify architecture approaches. Architecture approaches are identified by the architect, but are not analyzed.

Step 5: Generate quality attribute utility tree. The quality attributes that comprise system "utility" (performance, reliability, security, modifiability, etc.) are elicited. These are specified down to the level of scenarios, annotated with stimuli and responses, and prioritized.

Step 6: Analyze architecture approaches. Based upon the high-priority factors identified in Step 5, the architecture approaches that address those factors are elicited and analyzed. For example, an architecture approach aimed at meeting performance goals will be subjected to a performance analysis. During this step, architecture risks, sensitivity points, and tradeoff points are identified.

Testing

Step 7: Brainstorm and prioritize scenarios. Based upon the example scenarios generated in the utility tree step, a larger set of scenarios is elicited from the entire group of stakeholders. This set of scenarios is prioritized via a voting process involving the entire stakeholder group.

Step 8: Analyze architecture approaches. This step reiterates Step 6; but here, the highly ranked scenarios from Step 7 are considered to be test cases for architecture approaches determined thus far. These test case scenarios may uncover additional architecture approaches, risks, sensitivity points, and tradeoff points that are then documented.

Reporting

Step 9: Present results. Based upon the information collected in the ATAM (styles, scenarios, attribute-specific questions, the utility tree, risks, sensitivity points, tradeoffs), the evaluation team presents its findings to the assembled stakeholders and details this information, along with any proposed mitigation strategies, in a written report.

The timing and the parties responsible for performing each of these steps will depend upon the acquisition strategy of the acquirer and the technical resources available. It is important to have the roles and responsibilities understood before incorporating the ATAM or any software evaluation method in an acquisition. The sections of the RFP and, ultimately, the contract must clearly reflect this understanding.

4 Using the ATAM in a System Acquisition: An Example

As we have indicated, there are many ways to incorporate architecture evaluations into an acquisition. In this section, we have selected one approach to illustrate applying the ATAM in an acquisition. We will initially describe the acquisition approach and highlight appropriate RFP language. Examples of the language are given in the appendices.[5] It must be remembered that software architecture requirements and design contribute substantially to the achievement of system requirements. So, the language in the appendices must be viewed as only a portion of the RFP language and be integrated into the overall context of the system acquisition. If a software-only system is being acquired, developing the appropriate language is much easier; this is not the norm, however, in the DoD environment.

4.1 Example Architecture Evaluation Approach for a System Acquisition

The acquisition approach we will use is illustrated in Figure 4, along with an indication of how an architecture evaluation is related to the typical system development tasks specified in an SOW. The approach is based on using software architecture evaluations as contractual checkpoints for both the architecture development (initial system development) and the full system implementation tasks. Architects can use the results of the evaluation to take corrective action early in the development cycle, thereby minimizing or even avoiding the cost and effort of later rework.

[5] Every acquisition is considered unique. The acquisition language provided in this technical note should not be applied directly to all acquisitions. It is strongly recommended that the language be tailored to the acquirer's specific needs.

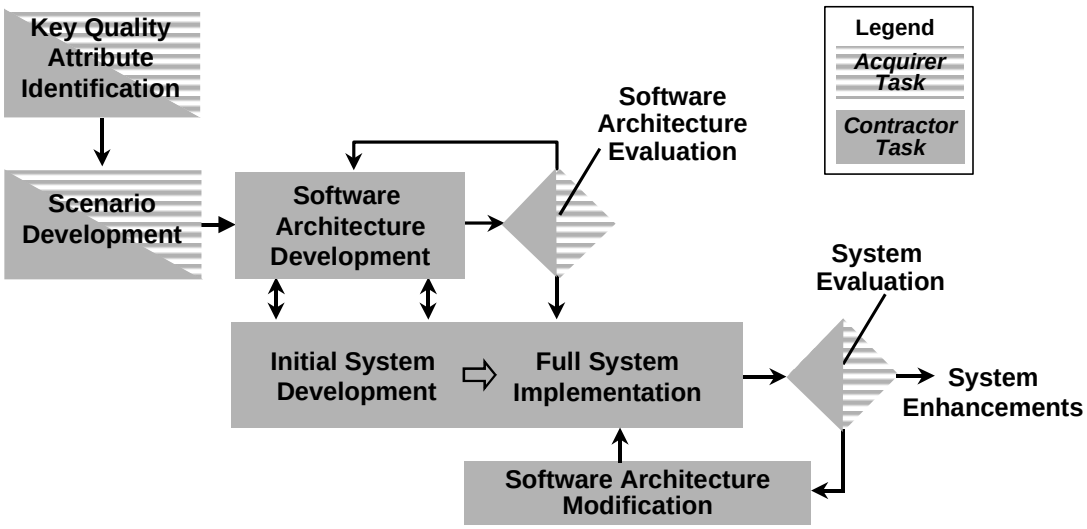

Figure 4: Integration of Architecture Evaluation with System Development Tasks and Evaluations

1) In this example, the acquirer is expected to include preliminary business drivers as part of the product requirements of the RFP. These business drivers correspond to the business goals that are motivating the system acquisition and, in turn, will drive the specification of the system's quality attributes. Examples of business drivers include

- time to deploy
- ability to accommodate operational upgrades
- integration of new subsystems
- compatibility with Defense Information Infrastructure (DII) Common Operating Environment (COE) or Command, Control, Communications, Computer Intelligence, Surveillance, Reconnaissance (C4ISR) framework
- reduced maintenance (i.e., modifiability)

Along with the preliminary business case, the acquirer documents some preliminary quality attributes and associated scenarios.

2) The supplier uses the preliminary business drivers and preliminary quality attributes to identify the system quality attributes to be evaluated. The acquirer should promote or be amenable to having the supplier augment the business drivers to reflect internal (or derived) business drivers that will enhance the system. The system quality attributes become contractually binding in accordance with the SOW requirements and the contract deliverables. This activity occurs during the ATAM step of identifying, prioritizing, and refining the most important quality attribute goals in a utility tree. The figure illustrates this

step as the activities associated with identification of key quality attributes. Note that the acquirer and supplier jointly conduct this step.

3) Next, the supplier, in conjunction with the acquirer, refines and develops scenarios and associated test cases to help evaluate the identified key quality attributes.

4) An analysis readiness review (ARR) is typically used to determine the timing of the ATAM evaluation, and ensures that the evaluation does not occur until the supplier is actually ready. The readiness review may be conducted to determine the maturity of the software architecture, the sufficiency of the architecture documentation, and the adequacy of the architecture evaluation plan. These responsibilities must be clearly delineated in the RFP.

Our example, shown in Figure 4, positions evaluations at the beginning and at the end of the software architecture development phase. Evaluations can occur at other points in system development as well. The flow coming out of the last evaluation checkpoint shows that the intent is to allow corrective action to take place as necessary.

After the initial evaluation, the software architecture is typically placed under configuration control, and all subsequent system builds conform to the software architecture.

Architecture status can be presented at regularly scheduled acquisition reviews. Event-driven reviews are held to resolve issues. Formal contract adjustments may be required as both the acquirer's and supplier's understanding of system requirements and relevant engineering tradeoffs evolve.

4.2 RFP/Contract Language for Acquisition Example

For our example and with the approach discussed above, we describe language that typically is included in Section C of the RFP.

Statement of Work (SOW)

1) Early after contract award, the SOW requires the supplier to deliver a plan for conducting the ATAM evaluation. The plan must describe

- what—specific tasks to be accomplished
- where—locations and facilities at which the ATAM will be conducted
- when—when the architecture evaluations are to take place and a schedule of all related tasks and events, including the architecture readiness review
- who—roles and responsibilities of stakeholders, including the acquirer
- how—specific procedure descriptions for each task, detailing the inputs, steps, expected outcomes

These features are not unique to planning architecture evaluations; they are characteristic of good planning practices and planning artifacts.

2) Next in Section C, the supplier is asked to use the preliminary business drivers and preliminary quality attributes and scenarios to refine and develop additional business drivers and quality attributes for the system. The result is documented in a quality attribute tree that categorized and prioritizes the attributes.

3) With the quality attribute tree, the supplier is asked to detail, refine, and develop scenarios to be used to evaluate the architecture.

4) The supplier then begins initial design of the system and associated software architecture.

5) Once the initial design is formulated and documented, an analysis readiness review is held to ensure that the supplier has sufficient capability and capacity to conduct the ATAM evaluation.

6) The supplier and acquirer use the initial design and jointly conduct a software architecture evaluation, in this case using the ATAM.

Although Figure 4 shows two evaluations, one after the initial design and one at the end of the system implementation, this technical note and the RFP/contract language provided in the appendices focus on the initial evaluation.

Product Requirements

The product requirements are described in the system specification that is also part of Section C. These requirements contain the preliminary business drivers and preliminary quality attributes for the system. From the SOW above, the supplier must abstract, or augment, these requirements to identify the business drivers at a level that is more expressive.

We note again that the SOW language and system specification language here focus on the use of an ATAM evaluation and must be set in the context of the entire acquisition. There are other requirements that are needed for the acquisition.

5 Summary

In this note, we have discussed how a software architecture evaluation, such as an ATAM evaluation, might be used to reduce risk in a system acquisition. We have given examples of RFP language that may be adapted for a particular acquisition. Future technical notes will include RFP language covering additional source selection documents, Sections M and L.

The SEI is collaborating with several acquisition organizations on the use of the ATAM to help them adopt and integrate the architecture evaluations into their own organizations. This includes identifying the appropriate language to include in an RFP to make an architecture evaluation an integral part of evaluating proposals as well as system developments.

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Appendix A Architecture Tradeoff Analysis Method Statement of Work (SOW)

ATAM

The supplier, in conjunction with the acquirer, shall plan and conduct the ATAM evaluation for the software architecture of the system being acquired. The supplier shall follow the principles and steps specified in the Technical Report: Kazman, R. *ATAM: Method for Architecture Evaluation* (CMU/SEI-2000-TR-004). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 2000. See Attachment A of this SOW. The supplier shall analyze and use the Business Drivers provided in the system specification for the system being acquired. These Business Drivers and other desired quality attributes of the system are specified as part of the System Specification of this RFP/Contract.

ATAM Planning

The supplier shall develop a plan to conduct the ATAM evaluations for the system being developed. The plan shall document the

- overall approach used to conduct the ATAM evaluations
- specific tasks to be accomplished, including an analysis readiness review (ARR)
- locations and facilities at which the ATAM evaluations will be conducted
- schedule of all related tasks and events, including the analysis readiness review
- roles and responsibilities of stakeholders, including of the acquirer
- specific procedure descriptions for each task, detailing the inputs, steps, and expected outcomes

The supplier shall include all the ATAM steps in this planning activity. (See Attachment A to this SOW.)

Generation of Quality Attribute Utility Tree

The supplier, in conjunction with the acquirer, and using the Business Drivers and other quality attributes specified in the system specification, shall identify, prioritize, and refine the system's important quality attributes. (These quality attributes constitute system "utility" [e.g., performance, reliability, security, modifiability] as defined in the system specification.) At the supplier's request, the acquirer will make available representative personnel (stakeholders) to assist the supplier in understanding requirements for generating the utility tree.

Scenario Development

In conjunction with the acquirer, the supplier shall develop and document initial scenarios, to be used in architecture tradeoff analysis (hereafter referred to as analysis). Scenarios developed will be sufficiently defined and documented to be employed in the analysis. Scenarios will be developed to fully exercise the system and software architecture to determine the degree to which the specified system requirements, including quality attributes, are or will be satisfied.

Following the design of these scenarios, the supplier and the acquirer shall conduct a technical exchange meeting, assessing the scenarios to determine whether they are sufficient to be utilized in the ATAM process. Weaknesses or deficiencies in these scenarios found during this review will be entered into the supplier's corrective action system and resolved by the supplier prior to conducting the ATAM evaluation.

System/Software Architecture Development

The supplier shall develop the software architecture in conjunction with the development of the system and system architecture. The software architecture will be designed to satisfy or support the Business Drivers, and system requirements, including all quality attributes, specified in the System Specification. This engineering effort may utilize prototyping methods or implementing selected components to enable tradeoffs and mitigate high-risk areas in order to ensure the software architecture design will satisfy system requirements. The supplier will conduct technical exchange meetings with the acquirer, as appropriate, during system and software architecture development to convey status of the development effort, identify risks, and mutually resolve issues.

During this development, the supplier will document the software architecture. The documentation must be sufficient to support the ATAM.

The software architecture design will be completed and the ATAM evaluation conducted prior to the supplier proceeding with full system implementation. Completion of this architecture definition and evaluation effort will provide an initial design of the software architecture in which

- software components in each architecture have been identified and interfaces to those software components have been described
- architecture relationships among the software components have been described, such as data flow, process synchronization, usage, and resource sharing
- allocation of functionality to software components has been resolved and allocation documented
- key architecture conflicts among software components have been identified and resolved
- conflicts with satisfaction of quality attributes have been identified and resolved
- documentation of the architecture is sufficient for evaluation
- rationale for the design decisions present in the architecture has been described

Analysis Readiness Review (ARR)

As part of conducting the ATAM evaluation and following the completion of the software architecture design, the supplier shall plan and jointly conduct with the acquirer an analysis readiness review (ARR) to determine that the software architecture design is sufficiently complete and properly documented to enable the ATAM evaluation to be conducted and to identify any issues in the design. The ARR will include an assessment of the software architecture documentation and the supplier's plan for the evaluation. Weaknesses or deficiencies—in the architecture, its documentation, or the ATAM plan—found during this review will be entered into the supplier's corrective action system and resolved by the supplier prior to the ATAM evaluation.

Conduct the ATAM Evaluation

After resolving issues identified during the ARR, the supplier shall finalize the ATAM plan and jointly conduct the ATAM evaluation with the acquirer. The supplier shall follow the principles and steps specified in the Technical Report: Kazman, R. *ATAM: Method for Architecture Evaluation* (CMU/SEI-2000-TR-004). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 2000. See Attachment A of this SOW. The analysis is intended to identify tradeoff points in software architecture (i.e., those elements that affect multiple quality attributes of the system and software). The analysis will be used to determine

the extent to which the software architecture satisfies or supports the contractual requirements and whether

- the models of the attributes need to be refined and more analyses conducted
- the architecture needs to be refined
- the models need to be changed to reflect these refinements
- the system requirements and contract requirements need to be changed

The analysis will use the supplier-generated use cases and scenarios developed as stated above. The supplier will be responsible for recording the results of the analysis (e.g., sensitivity points, tradeoff points, risks, and issues). Any risks or issues will be entered into the supplier's tracking/corrective-action system with plans for resolution or mitigation. All issues are to be resolved by the supplier prior to implementation of the system. Following the analysis and resolution of issues, and planning the mitigation of risks identified during the analysis, the supplier shall place the software architecture under configuration control, using the supplier's configuration management system.

Any changes or impacts to supplier work efforts resulting from this analysis will be entered into the supplier's effort-tracking system and formally communicated to the acquirer in accordance with standard contractual procedures and specific terms of the contract agreement.

Incremental System Development

Following the analysis and making of any changes to the system or software architecture requirements resulting from and recommended by the analysis, the supplier shall incrementally implement builds to the system according to the schedule of builds specified in the System Engineering Plan. Changes to the software architecture during system implementation shall be controlled using the supplier's configuration management system, including documented rationale for the changes.

Documentation of Engineering Efforts

The engineering efforts during the development of the software architecture, including all evaluations and analyses, will be documented and will include the rationale for both design decisions and changes to the baseline architecture. Documentation will be sufficient to support the architecture evaluation method and the tracking of changes to the baselined software architecture. Specific information about the architectures must include, but is not limited to, module structure, component interfaces, process structure, and data-flow structure. In each structure, the view-specific relationships among the entities must be documented. For

the module structure, relationship information includes, but is not limited to, the unique information that is encapsulated in each module. For the process structure, the relationship information includes, but is not limited to, synchronization and concurrency relationships. For the data-flow structure, relationship information includes, but is not limited to, a high-level description of the data that is produced, stored, consumed, or transformed.

Reviews and Technical Interchange Meetings

The supplier shall address the progress of the software architecture development effort at normally scheduled acquisition reviews, and, as required, resolve software architecture-related issues. In addition, the supplier shall conduct technical interchange meetings with the acquirer at specified times.

Adjustment to Contractual Requirements

As a result of the design effort, or as the understanding of the system and the software architecture improves, adjustments to the contractual requirements may be made upon mutual agreement between the supplier and the acquirer. Adjustments to the contractual requirements will be made through established contractual means.

Appendix B Product Requirements

Specification Section: Requirements

Program scope: a new radar system acquisition that includes developing a production-quality software architecture. The following are Business Goals and initial Quality Attributes for the program:

Business Goals

The program expects significant enhancements to follow the first system delivery. Affordability of these enhancements is critical.

The program expects that the system can

- keep pace with changing requirements
- keep pace with changing computer platforms
- keep pace with commercial technology. Commercial components will be integrated in the software where appropriate to keep pace with commercially available technology.

The program expects that the system will resist intrusion into and operation of the system by non-authorized sources while still providing its services to legitimate users.

The program expects the system will ensure operation under maximum load conditions (i.e., tracking specified number of targets simultaneously).

Quality Attributes

The following quality attributes for the system are derived from the Business Drivers for the program.

Run-Time Requirements: The software architecture will ensure achievement of system functions and the quality requirements of modifiability, reliability, and security, as described in this specification. See glossary of this document for definitions of these quality attributes as used in this acquisition.

Non-Run-Time Requirements: The software will be compliant with DII COE.

Potential Evaluation Scenarios

The software architecture will also ensure achievement of the system quality attributes shown in the following potential evaluation scenarios:

Quality Attribute	Potential Evaluation Scenarios
Modifiability	The system is expected to have changes in the following areas: • output data formats • radar signal inputs • radar search control signals • incorporation of COTS for DBMS functionality
Reliability	Target information will be simulated to overload the system with 50 targets simultaneously.
Security	Attempts to compromise the system will be made by an unauthorized operator and through the communication system connected to an external client.

Specification Section: Qualification

Analysis of the system quality attributes will use the ATAM described in the Technical Report: Kazman, R. *ATAM: Method for Architecture Evaluation* (CMU/SEI-2000-TR-004). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 2000, using the change scenarios described herein.

Glossary

Functionality The ability of the system to do the work for which it was intended.

Modifiability The extent to which the system can be changed quickly and cost-effectively.

Performance The responsiveness of the system – the time required to respond to stimuli (events), or the number of events processed in some interval of time.

Reliability A measure of the proportion of time the system is up and running.

Scenario A brief description of a stakeholder's interaction with a system; how a system behaves or interacts with the stakeholders to accomplish desired objectives or stated requirements.

Security A measure of the system's ability to resist unauthorized attempts at usage and denial of service, while still providing its services to legitimate users.

Software Architecture System and the structure or structures of the system, which comprise software components, the externally visible properties of those components, and the relationships among them.

Feedback and Contact

Comments or suggestions about this document or the series of technical notes on architecture evaluation in the Department of Defense are welcome. We want this series to be responsive to the needs of DoD and government personnel. To that end, comments concerning this technical note, inclusion of other topics, or any other issues or concerns will be of great value in continuing this series. Comments or suggestions should be sent to

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Software architecture is critical to the quality of a software-intensive system. For an acquisition organization, such as the Department of Defense (DoD), the ability to evaluate software architectures early in an acquisition can have a favorable impact on the delivered system. This technical note discusses the role of software architecture evaluations in a system acquisition and describes the contractual elements that are needed to accommodate architecture evaluations in an acquisition. The note then provides an example of contractual language that incorporates the Architecture Tradeoff Analysis Method[SM] (ATAM[SM]) as a software architecture evaluation method in a system acquisition.

[SM] Architecture Tradeoff Analysis Method and ATAM are service marks of Carnegie Mellon University.

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