QUality Assessment of System Architectures and their Requirements (QUASAR)
Version 3.0

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, PA 15213

Donald Firesmith
13 February 2008
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Standard Form 298 (Rev. 8-98)  Preceded by ANSI Std Z39-18
Topics

Requirements and Architecture Challenges

Underlying Concepts

QUASAR Method

Reasons to use QUASAR

QUASAR – Today and Tomorrow
Requirements and Architecture Challenges

Requirements and Architecture are the first two Opportunities to make Major Engineering Mistakes.

Architecturally Significant Requirements are typically poorly engineered.

Architecture and associated Architecturally Significant Requirements Affect:

- Project Organization and Staffing (Conway’s Law)
- Downstream Design, Implementation, Integration, Testing, and Deployment Decisions

A common project-specific Quality Model is needed to drive the

- Quality Requirements, which drives the
- Quality of the System Architecture, which drives the
- Quality of the System
Requirements and Architecture Challenges

Architecturally-Significant, Quality-Related Requirements and their associated Architectural Decisions Drive the System and Component:

- Ultimate Quality
- Development Schedule
- Development Costs
- Sustainment Costs
- Maintainability and Upgradeability
- Acceptance and Usage by Stakeholders
Requirements and Architecture Challenges

System Quality is the Union of Relevant Quality Characteristics:

- Availability
- *Functionality*
- Interoperability
- Modifiability
- Performance
- Reliability
- Robustness (Environment, Error, Failure, and Fault Tolerance)
- Safety
- Security
- Scalability
- Stability
- Testability
- etc.
Requirements and Architecture Challenges

It is important to determine Actual System and Component Requirements and Architecture:

- Quality
- Maturity and Completeness
- Integrity and Consistency
- Usability

It is important to identify System and Component Requirements and Architectural Defects Early:

- Fix Defects Early
- Decrease Development and Maintenance Costs
- Decrease Schedule
Requirements and Architecture Challenges

It is important to identify (and thereby help Manage) Risks:

- Requirements and Architecture Risks
- System and Project Risks
- Business Risks

It is important to provide Acquirer/Management:

- *Visibility* into
- *Oversight* over
  
  the System and Component Requirements and Architecture

It is important to determine *Compliance*:

- Requirements and Architecture with Contract (Acquirer) Requirements
- Architecture with System and Component (Developer) Requirements
Requirements and Architecture Challenges

It is important to develop *Consensus* regarding requirements and architecture quality, status, etc.:

- Among Developers (e.g., Requirements, Architecture, and Management Teams)
- Between Acquirer and Developer Organizations
Topics

Requirements and Architecture Challenges

Underlying Concepts:

Quality Model

QUASAR Method

Reasons to use QUASAR

QUASAR – Today and Tomorrow
What is Quality?

Quality

the Degree to which a Work Product (e.g., System, Subsystem, Requirements, Architecture) Exhibits a Desired or Required Amount of Useful or Needed Characteristics and Attributes
Not just lack of defects!

Question:

What Types of Characteristics and Attributes are these?

Answer:

They are the Characteristics defined by the Project Quality Model.
Quality Model

Quality of a Work Product is defined in terms of a **Quality Model**:

- **Quality Characteristics**
  (a.k.a., Quality Factors, the ‘ilities’)
  (e.g., availability, extensibility, interoperability, maintainability, performance, portability, reliability, safety, security, and usability)

- **Quality Attributes**
  (a.k.a., Quality Subfactors)
  (e.g., the quality attributes of performance are jitter, latency, response time, schedulability, throughput)

- **Quality Measurement Scales**
  (e.g., milliseconds, transactions per second)
Quality Model

Architectural Components

System

defines the meaning of the quality of a

Quality Model

Quality Characteristics

Quality Attributes

Internal Quality Characteristics

External Quality Characteristics

Quality Measurement Scales

Quality Measurement Method

measures quality along

are measured using

are measured along

defines the meaning of a specific type of quality of a

Quality Model

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Quality Model – Quality Characteristics

Quality Factor

Development-Oriented Quality Factor
- Capacity
  - Affordability
  - Configurability

Usage-Oriented Quality Factor
- Dependability
  - Efficiency
  - Performance

- Interoperability
- Sustainability

- Defensibility
  - Safety
  - Survivability

- Soundness
  - Availability
  - Predictability

- Reliability
  - Correctness
  - Stability

- Robustness
- Security

- Usability

- Efficiency
- Performance

- Sustainability
Quality Model –
Performance Quality Attributes

- Jitter
- Latency
- Response Time
- Schedulability
- Throughput

Performance Problem Type

Performance Solution Type

- Mandated Threshold
- Failure Detection
- Failure Reaction
- Failure Adaptation

Performance Attribute

Quality Attribute

is measured along a Quality Measurement Scale

Quality Characteristic

Quality Model
Quality Model – Safety Quality Attributes

- Harm
- Accident & Safety Incident
- Nonmalicious Agent
- Internal Vulnerability
- Hazard
- Safety Risk

Safety Problem Type

Safety Solution Type

- Prevention
- Detection
- Reaction
- Adaptation

Safety Attribute
Topics

Requirements and Architecture Challenges

Underlying Concepts:

Quality Case

QUASAR Method

Reasons to use QUASAR

QUASAR – Today and Tomorrow
Quality Case - Definition

Quality Case

a Cohesive Collection of Claims, Arguments, and Evidence that Makes the Developers’ Case that their Work Product(s) have Sufficient Quality

Foundational Concept underlying QUASAR

A Generalization and Specialization of Safety Cases from the Safety Community:

More) Can Address any Quality Characteristic and/or Quality Attribute

Less) May be Restricted to only Requirements or Architecture

Useful for:

• Assessing Quality

• System Certification and Accreditation (e.g., safety and security)
Quality Cases – Components

A Quality Case consists of the following types of Components:

1. **Claims**
   Developers’ Claims that their Work Products have *Sufficient* Quality, whereby quality is defined in terms of the qualify characteristics and quality attributes defined in the official project quality model.

2. **Arguments**
   Clear, Compelling, and Relevant Developer Arguments Justifying the Assessors’ Belief in the Developers’ Claims (e.g., decisions, inventions, trade-offs, analysis and simulation results, assumptions, and associated rationales).

3. **Evidence**
   Adequate Credible Evidence Supporting the Developers’ Arguments (e.g., official project diagrams, models, requirements specifications and architecture documents; requirements repositories; analysis and simulation reports; test results; and demonstrations witnessed by the assessors).
Quality Cases – Components

make developers’ case for adequate quality of the Work Product

justifies belief in Claims supports Quality Case

is developed for Quality Characteristic Quality Attribute

Claims

Arguments

Evidence
Quality Cases – Components

Quality Case

- Quality Attributes
  - defines a part of a type of quality of a
- Quality Characteristic
  - defines a type of quality of a
  - is specific to a
- Work Product
  - makes the case for the quality of a

- Claims
  - justify belief in
- Arguments
  - supports
- Evidence
QUASAR Throughput Quality Case

- Quality Attributes
  - Quality Characteristic
    - is specific to a
    - defines a type of quality of a
      - Quality Case
        - makes the case for the quality of a
          - System
            - Subsystem

- Performance Quality Case
  - Throughput Quality Case
    - Throughput Claims
      - justify belief in
    - Throughput Arguments
      - supports
    - Throughput Evidence
Specialized QUASAR Quality Cases

QUASAR utilizes the following specialized types of Quality Cases:

1. Requirements Quality Cases
2. Architectural Quality Cases

QUASAR Version 1 only had Architectural Quality Cases.

QUASAR Versions 2 and 3 have Both Types of Quality Cases.
QUASAR Requirements Quality Cases

Requirements Quality Case

a Specialized Quality Case that is Limited to the Quality of Architecturally-Significant, Quality-Related Requirements

Makes Requirements Team’s Case that their Relevant Requirements are:

• Ready to Drive the Engineering of the Architecture:
  
  — **Sufficient Quality**
    (e.g., are Correct, Complete, Consistent, Mandatory, Unambiguous, Verifiable, Usable, etc.)

  — **Sufficient Quantity**
    (e.g., Sufficient for Current Point in Project Schedule)

• Sufficient on which to base the System/Architecture Quality Assessment
**QUASAR Requirements Quality Cases**

**System/Subsystem**

**Quality-Related Requirements**

makes requirements engineers’ case for adequate quality of the

**Claims: Quality-Related Goals Help System Meet Stakeholder Quality Needs**

**Claims: Quality-Related Requirements Help System Meet Stakeholder Quality Goals**

**Arguments: Requirements Decisions (Quality-Related Requirements), Trade-Offs, Rationales, and Assumptions**

**Evidence: Requirements Diagrams, Models, Repositories, and Specifications**

**is developed for**

**Quality Characteristic**

**Quality Attribute**

**justifies belief in**
QUASAR Requirements Quality Cases

Quality Case

- Quality-Related Requirements
  - System
  - Subsystem

- Requirements Claims
- Arguments
- Requirements
- Evidence

- Requirements Claims
  - justify belief in
- Arguments
  - supports
- Requirements
  - supports
- Quality Case
  - works on the quality of

- Requirements Quality Case
  - makes the case for

- Work Product
  - specifies required quality of

- Work Product
  - justifies belief in

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QUASAR Requirements Quality Cases

Claims:

• Quality-Related Goals Sufficiently Meet Stakeholder Quality Needs
• Quality-Related Requirements Sufficiently Operationalize Quality Goals and Higher-Level Requirements from which They are Derived

Arguments:

• Requirements Decisions and Inventions (e.g., Existence and Quality of Quality-Related Requirements)
• Requirements Engineering Trade-Offs, Assumptions, and Rationales

Evidence:

• Requirements Diagrams, Models, and Prototypes/Simulations
• Requirements Repositories and Specification Documents
• Requirements Inspection and Checking Results
Example Requirements Quality Case

Example Requirements Reliability Case Claims:

- Subsystem X Requirements Engineers claim that their Subsystem Goals Sufficiently Meet Stakeholder Reliability Needs:
  - “All Stakeholder Reliability Needs Allocated to Subsystem X have been Transformed into Subsystem X Reliability Goals.”

- Subsystem X Requirements Engineers Claim that their Subsystem Reliability Requirements Sufficiently Help the Subsystem Meet its Reliability Goals and higher-level Requirements:
  - “All Subsystem X Reliability Goals for this block/release have been Operationalized into Requirements.”
  - “All Subsystem X Reliability Requirements for this block/release have been Properly Engineered.”
Example Requirements Quality Case \textsuperscript{2}

Example Requirements \textit{Reliability Case Arguments}:

- Subsystem X Reliability Requirements are:
  - Stored in the Project Requirements Repository
  - Published in the Subsystem X Requirements Specification
- Subsystem X Reliability Requirements in the Requirements Repository have been annotated as Reliability Requirements using Requirements Metadata.
- The Subsystem X Architects have verified the Feasibility of the Reliability Requirements given available Hardware and Software Technology.
- Appropriate Availability, Reliability, and Security Requirements Trade-Offs have been made.
- The Subsystem X Reliability Requirements have been Checked against a Checklist of Necessary Quality Characteristics (e.g., Correctness, Completeness, Consistency, Necessity, Unambiguous, Verifiability, and Usability).
Example Requirements Quality Case3

Example Requirements *Reliability* Case Evidence:

- **Requirements Traceability Matrix** showing Allocation of Reliability Requirements from Parent Subsystem A to Derived Reliability Requirements in Subsystem X
- Project **Requirements Repository** with Subsystem X Reliability Requirements identified
- **Reliability Section** in Subsystem X **Requirements Specification** Document
- **Reliability Subsection** of Subsystem X **Requirements Inspection Report**
Requirements Quality Case Challenges

Most Requirements Engineers are not trained in the Proper Engineering of Non-Functional Requirements (e.g., Quality Requirements).

Vague Unverifiable Goals are often Mistaken as Requirements.

Stakeholders often do Not know where to set Thresholds on Quality Measurement Scales.

Requirements Repository is Huge and Complex.

Only Small Subset of the Requirements is Relevant to any specific Quality Characteristic or Quality Attribute for any specific Subsystem.

Tracing Quality Requirements is more Difficult than Tracing Functional Requirements.
Requirements Quality Case Challenges

Hard to know that:

- Arguments *Sufficiently* Justify Belief in Claims
- Evidence *Sufficiently* Supports Arguments
- Degree of Confidence

Need practical way to Communicate, Summarize, and Act as Index to the Quality Case Essentials.
Architecture Quality Case

a Specialized Quality Case that is Limited to the Quality of the System/Subsystem Architectures

Make Architectures Team’s Case that their Architecture(s) are:

• Ready to Drive the Engineering of the Design, Implementation, Integration, and Testing:
  
  — **Sufficient Quality**
  (e.g., Adequately Support the System’s or Subsystem’s Ability to meet its Quality-Related Requirements)

  — **Sufficient Quantity**
  (e.g., Sufficient for Current Point in Project Schedule)
QUASAR Architectural Quality Cases

Architectural Quality Case

System/Subsystem Architecture

- makes architects’ case for adequate quality of the

- make verifiable

- supports

Architectural Quality Case

- Claims: Architecture Helps System Achieve Stakeholder Quality Goals
- Claims: Architecture Helps System Meet Quality Requirements
- Arguments: Architecture Decisions (e.g., patterns, mechanisms) with Trade-Offs, Assumptions, and Rationales
- Evidence: Architectural Diagrams, Models, Documents, and Witnessed Demonstrations

- is developed for

- Quality Characteristic
  - Quality Attribute
QUASAR Architectural Quality Case

Quality Case

Architectural Claims

Architectural Arguments

Architectural Evidence

Architectural Quality Case

Claims

Arguments supports

Evidence

makes the case for the quality of a Work Product

System

Subsystem

Architectures

justifies belief in justify belief in supports

has

makes the case for the quality of the System

Architectures
QUASAR Architectural Quality Cases

Claims:

• Architectures Sufficiently Supports System/Subsystem’s Ability to Meet All Quality Goals and Quality Requirements

Arguments:

• Architectural Decisions (e.g., Architectural Mechanisms, Patterns, and Styles as well as Choice of OTS Components)
• Architectural Engineering Trade-Offs, Assumptions, and Rationales

Evidence:

• Architectural Diagrams, Models (Static and Dynamic), and Prototypes
• Architecture Documents and Architectural Whitepapers
• Properly Documented Architectural Simulation and Test Results
• Properly Witnessed Demonstrations
Example Architectural Quality Case

Example Protocol Interoperability Case

Goal Claims:

- Subsystem X Architects Claim that their Subsystem Architecture Sufficiently Supports its following derived Protocol Interoperability Goals:
  - “Subsystem X will correctly use the interface protocols of all relevant external systems.”
  - “Subsystem X will use open interface standards (i.e., industry standard protocols) when communicating with all external systems.”
Example Architectural Quality Case

Example Protocol Interoperability Architecture Case Claims:

• Subsystem X Architects Claim that their Subsystem Architecture Sufficiently Supports its following derived Protocol Interoperability Requirements:
  
  – “The subsystem shall use open interface standards (i.e., industry standard protocols) when communicating with external systems across all key interfaces identified in document X.”
  
  – “The subsystem shall use the Ethernet over RS-232 for communication across interface X with external system Y.”
  
  – “The subsystem shall use HTTPS for communicating securely when performing function X across interface Y with external system Z.”
Example Architectural Quality Case

Example Protocol Interoperability Architecture Case Arguments:

- **Layered Architecture**
  The subsystem uses a layered architecture.
  *Rationale*: Interface layer supports interoperability.

- **Modular Architecture**
  The subsystem architecture is highly modular.
  *Rationale*: Architecture includes modules (proxies) for interoperability.

- **Wrappers and Proxies**
  The subsystem architecture includes proxies that wrap the interfaces to external subsystems.
  *Rationale*: Proxies localize and wrap external interfaces.

- **Service Oriented Architecture (SOA)**
  The subsystem service oriented architecture uses XML, SOAP, and UDDI to publish and provide web services over the Internet to external client systems.
  *Rationale*: Standard languages and protocols support interoperability between heterogeneous systems.
Example Architectural Quality Case

Example Protocol Interoperability Architecture Case Evidence:

- **Context Diagram**
  (shows external interfaces requiring protocols)

- **Architectural Class Diagram**
  (shows modularity and location of proxies and web services)

- **Allocation Diagram**
  (shows allocation of software modules to hardware - modularity)

- **Layer Diagram**
  (shows architectural layers)

- **Activity/Collaboration Diagrams**
  (show proxies, wrappers, and the source and use of services)

- **Interoperability Whitepaper**

- **Vendor-Supplied Technical Documentation**
  (show COTS product support for SOA and associated protocols)
QUASAR Quality Case Responsibilities

Requirements Engineers and Architects’ Responsibilities:

- Prepare Quality Cases
- Provide Preparation Materials (including Presentation Materials and Quality Cases) to Assessors Prior to Assessment Meetings
- Present Quality Cases (Make their Case to the Assessors)
- Answer Assessors’ Questions

Assessor Responsibilities:

- Prepare for Assessments
- Actively Probe Quality Cases
- Develop Consensus regarding Assessment Results
- Determine and Report Assessment Results:
  - Present Outbriefs
  - Publish Reports
Architectural Quality Case Challenges

Huge and Complex System Architectures

Only Small Subset of the Architecture (i.e., not view but focus area) is Relevant to any one Quality Factor or Quality Attribute.

Quality Cases still Contain a Large Amount of Information.

Claims, Arguments, and a large amount of Evidence are typically Text.

Easy to get Lost in Real-World Quality Cases
Architectural Quality Case Challenges

Hard to know that:

- Arguments *Sufficiently* Justify Belief in Claims
- Evidence *Sufficiently* Supports Arguments
- Degree of Confidence

Need practical way to Communicate, Summarize, and Act as Index to the Quality Case Essentials
Quality Case Diagram

A Layered UML Class Diagram thatLabels and Summarizes the parts of a Single Quality Case:

• Classes:
  — Claims
  — Arguments
  — Evidence

• Relationships Among Them:
  — Aggregation Relationships Between Claims
  — “Justifies Belief In” Associations from Arguments to Claims
  — “Supports” Associations from Evidence to Arguments

Acts as an Index and Guide to the Quality Case
Quality Case Diagram Notation

Quality Factor A Supported <<claim>>

Quality Subfactor A₁ Supported <<claim>>
Quality Subfactor A₂ Supported <<claim>>
... Quality Subfactor Aₙ Supported <<claim>>

justifies belief in

Decision 1 <<argument>>
Decision N <<argument>>
Trade-Off 1 <<argument>>
Trade-Off N <<argument>>
Assumption 1 <<argument>>
Assumption N <<argument>>

supports

Diagram 1 <<evidence>>
Diagram N <<evidence>>
Model 1 <<evidence>>
Model N <<evidence>>
Document 1 <<evidence>>
Document N <<evidence>>
Requirements sufficiently specify Quality Factor A <<claim>>

... justifies belief in ...

Requirements sufficiently specify Quality Subfactor A_1 <<claim>>
Requirements sufficiently specify Quality Subfactor A_2 <<claim>>
... Requirements sufficiently specify Quality Subfactor A_N <<claim>>

... supports ...

Decision 1 <<argument>>
Decision N <<argument>>
Trade-Off 1 <<argument>>
Trade-Off N <<argument>>
Assumption 1 <<argument>>
Assumption N <<argument>>

... justifies belief in ...

Diagram 1 <<evidence>>
Diagram N <<evidence>>
Model 1 <<evidence>>
Model N <<evidence>>
Document 1 <<evidence>>
Document N <<evidence>>
Generic Architecture Quality Case

Architecture sufficiently supports Quality Factor A <<claim>>

justifies belief in

Architecture sufficiently supports Quality Subfactor A₁ <<claim>>

Architecture sufficiently supports Quality Subfactor A₂ <<claim>>

... 

Architecture sufficiently supports Quality Subfactor Aₙ <<claim>>

Decision 1 <<argument>>

Decision N <<argument>>

Trade-Off 1 <<argument>>

Trade-Off N <<argument>>

Assumption 1 <<argument>>

Assumption N <<argument>>

supports

Diagram 1 <<evidence>>

Diagram N <<evidence>>

Model 1 <<evidence>>

Model N <<evidence>>

Document 1 <<evidence>>

Document N <<evidence>>
Example *Partial* Architectural Performance Case Diagram

**Goal:** Architecture Supports Performance

- **Architecture Limits Jitter**
- **Architecture Supports Schedulability**
- **Architecture Limits Latency**
- **Architecture Supports Throughput**
- **Architecture Limits Response Time**

**Arguments:***
- COTS I/O Timer Board
- Deterministic Scheduling
- Real-Time Middleware
- Redundant Servers with Load Balancing
- Layered Architecture
- Real-Time Operating System
- Rate Monotonic Scheduling
- Sampled Approach for Real-Time I/O
- Hardware Selection
Architectural Interoperability Case Diagram

Claim: Architecture Supports Interoperability Goals

Meets Requirements

Claim: Physical Interoperability
Claim: Energy Interoperability
Claim: Protocol Interoperability
Claim: Syntax Interoperability
Claim: Semantics Interoperability

Arguments (Architectural Decisions)

One-Way Connections
Layered Architecture
Open Interface Standards
Service Oriented Architecture (SOA)

Fly-By-Wire
Modular Architecture
Proxies and Wrappers

Supports

Wiring Diagram
Context Diagram
Allocation Diagram
Layer Diagram
Interoperability Whitepaper

Evidence

Hardware Schematics
Configuration Diagram
Network Diagrams
Activity or Collaboration Diagrams
Vendor-Supplied Technical Documentation
Topics

Requirements and Architecture Challenges

Underlying Concepts:

System

QUASAR Method

Reasons to use QUASAR

QUASAR – Today and Tomorrow
What is a System?

**System**

a Major, Cohesive, Executable, and Integrated Set of *Architectural Elements* that Collaborate to Provide the Capability to Perform one or more related *Missions*

**Systems are Decomposed into Architectural Components (e.g., Subsystems):**

- Data
- Documentation
- Hardware
- Software
- Manual Procedures
- Personnel (e.g., Roles such as Operators and Administrators)
- Equipment, Facilities, Materials, and Tools
Systems Imply

Multiple Static and Dynamic Logical and Physical “Structures” that exist at Multiple ‘Tiers’ in the System:

- Static Functional Decomposition Logical Structure
- Static Subsystem Decomposition Physical Structure
- Hardware, Software, and Data Structures
- Allocation Structure (Software and Data to Hardware)
- Network Structure
- Concurrency (Process) Structure

Multiple Specialty Engineering Focus Areas (e.g., Performance, Reliability, Safety, and Security)

Requirements are Derived and Allocated to Lower-Level Architectural Elements
Example System
(Static Physical System Decomposition View Only!)

Tier 1
System of Systems

Tier 2
System 1 System 2 System 3 ... System N

Tier 3
Subsystem 1 Subsystem 2 Subsystem 3 ... Subsystem N

Tier 4
Segment 1 Segment 2 Segment 3 ... Segment N

Tier 5
Subsegment 1 Subsegment 2 Subsegment 3 ... Subsegment N

Tier 6
Assembly 1 Assembly 2 Assembly 3 ... Assembly N

Tier 7
Subassembly 1 Subassembly 2 Subassembly 3 ... Subassembly N

Tier 8
HW C 1 ... HW C N SW CSCI 1 ... SW CSCI N Data CI 1 ... Data CI N Facilities
Manual Procedures Roles

Tier 9
HW C 1 ... HW C N SW C 1 ... SW C N

Tier 10
Part 1 ... Part N SW Unit 1 ... SW Unit N
Example QUASAR Scope – Four Assessments

Tier 1

Tier 2

Tier 3

Tier 4

Tier 5

Tier 6

Tier 7

Tier 8

Tier 9

Tier 10
Topics

Requirements and Architecture Challenges

Underlying Concepts:

System Architecture

QUASAR Method

Reasons to use QUASAR

QUASAR – Today and Tomorrow
What is a System Architecture?₁

System Architecture

the *Most Important, Pervasive, Top-Level, Strategic Decisions, Inventions, Engineering Trade-Offs, Assumptions,* and associated *Rationales* about *How* a System’s Architectural Elements will collaborate to meet the System’s Derived and Allocated Requirements
What is a System Architecture?

System Architecture Includes:

• **The System’s Numerous Static and Dynamic, Logical and Physical Structures**
  (i.e., Essential Architectural Elements, their Relationships, their Associated Blackbox Characteristics and Behavior, and how they Collaborate to Support the System’s Mission and Requirements)

• **Architectural Decisions, Inventions, and Tradeoffs**
  (e.g., Styles, Patterns, and Mechanisms used to ensure that the System Achieves its Architecturally-Significant Product and Process Requirements (esp. Quality Requirements or ‘ilities’))

• **Strategic and Pervasive Design-Level Decisions**
  (e.g., using a *Design* Paradigm such as Object-Orientation or Mandated Widespread use of common Design Patterns)

• **Strategic and Pervasive Implementation-Level Decisions**
  (e.g., using a Safe Subset of C++)
Some Example Views of Models of Structures

- Physical Decomposition View
- Logical Functional Decomposition View
- Collaboration View
- Data Flow View
- Mode and State View
- Information View
- Services View

Architects must ensure view and model consistency.

Multifaceted architecture having multiple structures requiring multiple models providing multiple views.
## Architecture vs. Design

<table>
<thead>
<tr>
<th>Architecture</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pervasive</strong> (Multiple Components)</td>
<td><strong>Local</strong> (Single Components)</td>
</tr>
<tr>
<td><strong>Strategic</strong> Decisions and Inventions</td>
<td><strong>Tactical</strong> Decisions and Inventions</td>
</tr>
<tr>
<td><strong>Higher-Levels</strong> of System</td>
<td><strong>Lower-Levels</strong> of System</td>
</tr>
<tr>
<td><strong>Huge Impact</strong> on Quality, Cost, &amp; Schedule</td>
<td><strong>Small Impact</strong> on Quality, Cost, &amp; Schedule</td>
</tr>
<tr>
<td><strong>Drives</strong> Design and Integration Testing</td>
<td><strong>Drives</strong> Implementation and Unit Testing</td>
</tr>
<tr>
<td><strong>Driven by</strong> Requirements and Higher-Level Architecture</td>
<td><strong>Driven by</strong> Requirements, Architecture, and Higher-Level Design</td>
</tr>
<tr>
<td><strong>Mirrors</strong> Top-Level Development Team Organization (Conway’s Law)</td>
<td><strong>No Impact</strong> on Top-Level Development Team Organization</td>
</tr>
</tbody>
</table>
Architectural Documentation Current-State

System Architecture Documents:
- Mostly natural language Text with Visio-like Diagrams (Cartoons)
- Logical (functional) and Physical Architecture

DOD Architecture Framework (DODAF):
- All-Views, Operational Views, Systems Views, and Technical Standards Views for allocating Responsibilities to Systems and Supporting System Interoperability

Models (both static and dynamic; logical and physical):
- Tailored UML becoming *de facto* Industry Standard
- SysML starting to become Popular

Visio Diagrams as Wall Posters

Whitepapers, Reports, and other Specialty-Engineering Documents:
- Performance, Fault Tolerance, Reliability, Safety, Security
What an Architecture is NOT

A System Architecture is Not an Architectural:

- Plan
- Method
  (architecting procedures and architecture documentation standards)
- Team Organization Chart
  (in spite of Conway’s Law)
- Development Schedule

QUASAR assesses Actual Architectures:

- As they Currently Exist (i.e., a Snapshot in Time)
- Not Good Intentions
Topics

Requirements and Architecture Challenges

Underlying Concepts:

System Architect

QUASAR Method

Reasons to use QUASAR

QUASAR – Today and Tomorrow
What is a Systems Architect?1

A *Role* played by a *Systems Engineer*, who is Responsible for:

- *Developing* one or more System or Subsystem Architectures
- *Ensuring* the *Quality* of the System or Subsystem Architectures
- Ensuring the *Integrity* of the System or Subsystem Architectures during Design, Implementation, Manufacture, and Deployment (e.g., Installation and Configuration)
- *Communicating* the System or Subsystem Architectures to their Stakeholders
- *Maintaining* the System or Subsystem Architectures
What is a Systems Architect?  

A *Role* that:

- Requires Significant:
  - Training
  - Experience (Apprenticeship)
  - Mindset:
    - Big Picture
    - Generalist
  - Communications Ability
- Should Probably be a *Job Title*
- But may *Not* be a Job Title
Topics

Requirements and Architecture Challenges

Underlying Concepts:

Architecturally Significant Requirements

QUASAR Method

Reasons to use QUASAR

QUASAR – Today and Tomorrow
Architecturally Significant Requirement

Architecturally Significant Requirements

any Requirement that has a Significant Impact on a System / Subsystem Architecture

Architecturally Significant Requirements typically include:

• Quality Requirements, which specify a Minimum Amount of some Quality Characteristics or Quality Attribute

• Architectural Constraints

• Primary Mission Functional Requirements (Feature Sets)

Quality Requirements are often the:

• Most Important

• Least Well Engineered
Quality Requirements

Format

Conditions – Quality Criteria – Quality Thresholds

Under condition(s) X, the system/subsystem shall exhibit quality criterion Y meeting or exceeding threshold Z.

Bad Example(s)

The system shall be highly reliable, robust, safe, secure, stable, etc.

Good Example (Stability)

Under normal operating conditions*, the system shall ensure that the mean time between the failure of mission critical functionality* is at least 5,000 hours of continuous operation.

* Must be Properly defined in the Project Glossary
Quality Requirements – Components

Quality Requirement

- Quality Goal
  - states stakeholders importance of achieving a
  - quantifies a
- Subsystem
  - defines stakeholders minimum acceptable level of quality of a

Condition
- is applicable during
- determines existence of
- Quality Characteristic
  - states stakeholders importance of achieving a

Quality Criterion
- shall exceed
- Quality Attribute
  - states stakeholders importance of achieving a

Quality Threshold
- is measured along a
- Quality Measure
  - states stakeholders importance of achieving a
- Quality Metric
  - defines the meaning of the quality of a

Quality Model
  - defines stakeholders minimum acceptable level of quality of a
  - is measured using a
Topics

Requirements and Architecture Challenges

Underlying Concepts

QUASAR Method

Reasons to use QUASAR

QUASAR – Today and Tomorrow
Definition

QUality Assessment of System Architectures and their Requirements

a Well-Documented and Proven Method based on the use of Quality Cases for Independently Assessing the Quality of:

• Software-intensive System / Subsystem Architectures and the
• Architecturally Significant Requirements that Drive Them
QUASAR Versions

Version 1 (July 2006) emphasized the quality assessment of architectures over assessment of architecturally-significant requirements.

Version 2 (February 2007) addresses the quality assessment of both architectures and their architecturally-significant requirements.

Version 3 (October 2007) simplifies phases and better addresses summary reporting.
QUASAR Philosophy

Informal *Peer Reviews* are Inadequate:
- Too Informal
- Lack of *Independent* Expert Input
- Requirements and Architecture are too Important

Quality Requirements:
- Most important Architecturally-Significant Requirements
- Largely Drive the System Architecture
- Criteria against which the System Architecture is Assessed
QUASAR Philosophy

Requirements Engineers (REs) should *Make Case* to Assessors:
- REs *should* know Stakeholder Needs and Goals
- REs *should* know What they Did and Why (Architecturally-Significant Requirements, Rationales, & Assumptions)
- REs *should* Know Where they Documented their Requirements Work Products

Architects should *Make Case* to Assessors:
- Architects *should* know Architecturally-Significant Requirements
- Architects *should* know What they Did and Why (Inventions, Decisions, Rationales, Trade-Offs, and Assumptions)
- Architects *should* know Where Documented their Architectural Work Products
Assessors should *Actively* Probe Quality Cases:

- **Claims Correct and Complete?**
  Do the Claims include *all* relevant Quality Characteristics, Quality Attributes, Quality Goals, and Quality Requirements?

- **Arguments Correct, Complete, Clear, and Compelling?**
  Do the Arguments include *all* relevant Quality Factors, Quality Attributes, Quality Goals, Quality Requirements, Decisions, Inventions, Trade-offs, Assumptions, and Rationales?

- **Arguments Sufficient?**
  Are the Arguments Sufficient to Justify the Claims?

- **Evidence Sufficient?**
  Is the Evidence Sufficient to Support the Arguments?

- **Current Point in the Schedule?**
  Are the Claims, Arguments, and Evidence appropriate for the Current Point in the Schedule?
QUASAR Method – Three Phases

1. Quality Assessment Initiation (QAI)
2. Requirements Quality Assessment (RQA)
3. Architecture Quality Assessment (AQA)

repeat for system and each subsystem being assessed
QUASAR Methods – Three Tasks

Each Phase consists of 3 similar *Tasks*:

1. Preparation
2. Meeting
3. Follow-Through
QUASAR Phases and Tasks

**Phase 1) Quality Assessment Initiation (QAI)**
- Prep.
- QAI Meeting
- Follow-Through

**System Assessments**
- Phase 2) Requirements Quality Assessment (RQA)
  - Prep.
  - RQA Meeting
  - Follow-Through
- Phase 3) Architecture Quality Assessment (AQA)
  - Prep.
  - AQA Meeting
  - Follow-Through

- Subsystem 1 Assessments
  - Phase 2) Requirements Quality Assessment (RQA)
    - Prep.
    - RQA Meeting
    - Follow-Through
  - Phase 3) Architecture Quality Assessment (AQA)
    - Prep.
    - AQA Meeting
    - Follow-Through

- Subsystem N Assessments
  - Phase 2) Requirements Quality Assessment (RQA)
    - Prep.
    - RQA Meeting
    - Follow-Through
  - Phase 3) Architecture Quality Assessment (AQA)
    - Prep.
    - AQA Meeting
    - Follow-Through
Quasar Teams and their Work Products

- **System Requirements Team**
  - engineer the System-Level Architecturally-Significant Requirements
  - leads the Requirements Quality Cases
  - leads the Subsystem Requirements Team(s)
  - makes its requirements teams’ quality cases
  - makes its requirements teams’ architecture teams’ quality cases

- **Subsystem Requirements Team(s)**
  - engineer the Subsystem Architecturally-Significant Requirements
  - make their requirements teams’ quality cases
  - make their requirements teams’ architecture teams’ quality cases

- **Architecturally-Significant (e.g., Quality) Requirements**
  - are derived from the System-Level Architecturally-Significant Requirements
  - drive the Subsystem Architecturally-Significant Requirements
  - drive the Subsystem Architecture

- **System-Level Architecturally-Significant Requirements**
  - engineer the System-Level Architecturally-Significant Requirements
  - drive the Architecture

- **Architecture**
  - drive the Subsystem Architectures
  - assess the architecture teams’ quality cases

- **Subsystem Architectures**
  - engineer the Subsystem Architectures
  - assess the architecture teams’ quality cases

- **Requirements Quality Cases**
  - are derived from the Architecturally-Significant (e.g., Quality) Requirements
  - drive the Subsystem Architecture

- **Subsystem Architecture**
  - drive the Subsystem Architectures
  - assess the architecture teams’ quality cases

- **Architectural Quality Cases**
  - make their requirements teams’ quality cases
  - make their requirements teams’ architecture teams’ quality cases

- **Top-Level Architecture Team**
  - engineer the Top-Level Architecture
  - leads the Subsystem Architecture Teams
  - makes its requirements teams’ quality cases
  - makes its requirements teams’ architecture teams’ quality cases
Topics

Requirements and Architecture Challenges

Underlying Concepts

**QUASAR Method:**

*Phase 1) Quality Assessment Initiation (QAI)*

Phase 2) Requirements Quality Assessment (RQA)

Phase 3) Architecture Quality Assessment (AQA)

Reasons to use QUASAR

QUASAR – Today and Tomorrow
Quality Assessment Initiation (QAI)

- Quality Assessment Initiation

repeat for system and each subsystem being assessed

- Requirements Quality Assessment
- Architecture Quality Assessment
Phase 1) QAI – Objectives

Prepare Teams for Requirements and Architecture Assessments

Develop Consensus:

• Scope of Assessments
• Schedule Assessments
• Tailor the Assessment Method and associated Training Materials

Produce and Publish Meeting Outbrief and Minutes

Manage Action Items

Capture Lessons Learned

Tailor/Update QUASAR Method and Training Materials
Phase 1) QAI – Principles

It is Important to:

- **Develop Consensus** among Teams
- **Scope the Assessment** to meet Project-Specific Needs and Resources
- **Tailor the Assessment Method** to meet specific Needs of the Overall Assessment

Subsystem Assessments must be scheduled to **Ensure Availability** of the:

- Requirements and Architecture
- Required Resources (e.g., people and funding)
Phase 1) QAI – Challenges

Acquirer and Development Organizations may Disagree as to the:

- Need to Independently Perform Quality Assessments
- Relative Importance of Quality Factors, Quality Attributes, and Related Goals and Requirements

It can be Difficult to reach Consensus on the Scope of the Assessments in terms of the:

- Number and Identity of Subsystems to Assess
- Number and Identity of Quality Factors and Quality Attributes
- Tailoring of the QUASAR Method
Phase 1) QAI – Challenges

Quality Assessments of System and Subsystem Architectures and their Architecturally-Significant Requirements may not have been included in the Project:

- Request for Proposal (FRP)
- Contract
- Budget and Schedule

It is often very Difficult to obtain Commitment of Resources:

- Availability of Requirements Engineers and Systems Architects
- Availability of Assessors with Adequate Experience and Expertise
- Consensus on Schedule
- Budget Funding to Pay for the Assessment
Phase 1) QAI – Preparation Task

1. Management Team staffs Assessment Team

2. Process and Training Teams train Assessment Team

3. Assessment Team identifies:
   - System Requirements Team
   - System Architecture Team

4. Process and Training Teams train System Requirements and Architecture Teams

5. Assessment, Requirements, and Architecture Teams collaborate to Organize QAI Meeting (i.e., Attendees, Time, Location, Agenda)
Phase 1) QAI – Meeting Task

1. Assessment, System Requirements, and System Architecture

   Teams Collaborate to determine Assessment Scope:
   
   • Subsystems/Architectural Elements/Focus Areas to Assess (Number and Identity)
   
   • Quality Factors and Quality Attributes underlying Assessment
   
   • Assessment Resources (e.g., Staffing, Schedule, and Budget)

2. Teams Collaborate to develop Initial Assessment Schedule with regard to System schedule, Subsystem schedule, and associated milestones

3. Teams Collaborate to tailor QUASAR Method

4. Assessment Team captures Action Items
Phase 1) QAI – Follow-Through Task

1. Assessment Team develops and presents Meeting Outbrief
2. Assessment Team develops, reviews, and distributes Meeting Minutes
3. Assessment/Process/Training Teams tailor, internally review, and distribute:
   - QUASAR Procedure, Standards, and Templates
   - QUASAR Training Materials
4. Teams distribute Assessment Schedule
5. Teams obtain Needed Resources
6. Assessment Team Manages Action Items
7. Assessment Team captures Lessons Learned
Phase 1) QAI – Work Product Flow
Phase 1) QAI – Work Products

Legend
- developer work product
- assessor work product
- influences
- aggregation

Preparatory Materials
- QUASAR Training Materials
- QUASAR Standards & Procedures

Meeting Notes
- Meeting Outbrief
- Meeting Minutes

Assessment
- Scope
- Schedule

Method Tailoring

Lessons Learned
Phase 1) QAI – Team Memberships

Quality Assessment Team (Assessors):

- Assessment Team Leader
- Meeting Facilitator
- Acquirer/Customer Liaisons to Developer:
  - Requirements Teams
  - Architecture Teams
- Subject Matter Experts (SMEs) having adequate training and experience in:
  - Application Domains (e.g., avionics, sensors, telecommunications, and weapons)
  - Specialty Engineering Groups (e.g., reliability, safety, and security)
  - Requirements and Architecture Engineering (including Quality Model)
  - QUASAR
- Scribe
- Acquirer/Customer Observers
Phase 1) QAI – Team Memberships

System Requirements Team (Requirements Engineers):

- Chief System Requirements Engineer
- System Requirements Engineers
- Subsystem Requirements Engineers

System Architecture Team (Architects):

- Chief System Architect
- System Architects
- Subsystem Architects

Developer *Observers*
Phase 1) QAI – Lessons Learned

Ensure Appropriate Team Memberships (e.g., Authority)

Ensure Adequate Resources (e.g., Staffing, Budget, and Schedule)

Obtain Consensus on:

- Assessment Objectives and Scope
- Definitions (e.g., of Quality Factors, Subfactors, and Cases)

Provide Early Training:

- Method Training (QUASAR, Requirements Engineering, and Architecting)
- System/Subsystem Training (Requirements and Architecture)
Phase 1) QAI – Lessons Learned

QUASAR assessments should be Organized according to a Quality Model that defines Quality Characteristics (a.k.a., factors, “ilities’) and their Quality Attributes such as:

- Availability
- Interoperability
- Performance
  - Jitter, Response Time, Schedulability, and Throughput
- Portability
- Reliability
- Safety
- Security
- Usability
Topics

Requirements and Architecture Challenges

Underlying Concepts

QUASAR Method:

Phase 1) Quality Assessment Initiation (QAI)

Phase 2) Requirements Quality Assessment (RQA)

Phase 3) Architecture Quality Assessment (AQA)

Reasons to use QUASAR

QUASAR – Today and Tomorrow
Requirements Quality Assessment (RQA)

- Quality Assessment Initiation

repeat for system and each subsystem being assessed

- Requirements Quality Assessment
- Architecture Quality Assessment
Phase 2) ARA – Objectives

Use Requirements Quality Cases to:

- Independently assess Quality and Maturity of the Architecturally Significant Requirements:
  - Drive the Architecture
  - Form Foundation for Architecture Quality Assessment

- Help Requirements Engineers identify Requirements Defects and Weaknesses so that:
  - Defects and Weaknesses can be Corrected
  - The Architecture (and System) can be Improved
Phase 2) RQA – Objectives

Use Requirements Quality Cases to:

- Identify Requirements Risks so that they can be Managed
- Provide Visibility into the Status and Maturity of the Requirements
- Increase the Probability of Project Success

Ensure Architecture Team will be Prepared to Support the coming Architecture Quality Assessment.

Capture Lessons Learned.

Update QUASAR Method and associated Training Materials.
Phase 2) RQA – Principles

Not all Requirements are Architecturally Significant.

Quality-Related Requirements:

- Are typically Major Drivers of the System Architecture.
- Should be Unambiguous, Feasible, Complete, Consistent, Mandatory, Verifiable, Validatable, etc.
- Should Not Unnecessarily Constrain the Architecture.

Quality Requirements should Specify a Minimum Required Amount of some Quality Factor or Quality Attribute.
Phase 2) RQA – Principles

Quality Requirements should be Organized according to a Quality Model that defines Quality Characteristics (a.k.a., factors, “ilities’) and their Quality Attributes such as:

- Availability
- Interoperability
- Performance
  - Jitter, Response Time, Schedulability, and Throughput
- Portability
- Reliability
- Safety
- Security
- Usability
Phase 2) RQA – Principles

Different Quality Factors are Important for Different Components:

- Performance is Paramount for Real-Time Components.
- Security is more Important for other Components.

Engineering Quality Requirements requires Significant Effort and Resources (it cannot be accomplished during a short meeting).

Engineering Architecturally Significant Requirements is the Responsibility of the Requirements Team – Not the Architecture Team and Not the Assessment Team.

- Architects and Assessors are Not Qualified to Engineer Quality Requirements.
- Many Stakeholders have Different and Inconsistent Quality Needs.
- Requirements Assessment Time is Too Late to be Engineering Quality Requirements.
Phase 2) RQA – Challenges

Many Requirements Engineers are not taught how to Engineer Non-functional Requirements including Quality Requirements.

Although popular, Use Case Modeling is not very Effective for Engineering Quality Requirements.

Quality Requirements often require the Input from Specialty Engineering Teams (e.g., Reliability, Safety, and Security), who are not often adequately involved during Requirements Engineering.

Quality Goals are often Mistakenly Specified as Quality Requirements.

Architecturally Significant Requirements are typically:

• Incomplete
  (missing important Relevant Quality Characteristics and Attributes)
• Of Poor Quality (lack important characteristics)
Phase 2) RQA – Challenges

The typical Quality of Derived and Allocated Architecturally Significant Requirements is Poor:

- Requirements are often *Ambiguous*.
  - “The system shall be safe and secure.”
- Requirements Rarely Specify *Thresholds* on relevant Quality Measurement Scales.
  - “The system shall have adequate availability.”
- Requirements are often mutually *Inconsistent*.
  - Security vs. usability, performance vs. reliability.
- Many Requirements are *Infeasible* (or at least Impractical) if taken literally.
  - “The system shall be available 24/7 every day of the year.”
  - “The system shall have 99.9999 reliability.”
Phase 2) RQA – Challenges

Requirements are often Unstable.

Specialty Engineering Requirements (e.g., reliability, safety, security) are Often Documented Separately from the Functional Requirements.

The Architecturally Significant Requirements are often Improperly Prioritized for Implementation.

The Requirements Engineers often do Not Understand how to Prepare for a Requirements Quality Assessment:

- Too busy
- Not trained
- No standards exist
- Bias against assessments/audits
Phase 2) RQA – Challenges

Managers believe Schedule Pressures do *Not* allow Time for Requirements Quality Assessments.

Requirements Engineers may Not Understand how to give the Assessment Team what they need to assess the Requirements:

- Claims
- Arguments including Requirements Decisions, Inventions, Trade-Offs, Assumptions, and Rationales
- What is the proper Evidence?
  - Official program documentation
  - Not requirements engineering plans and procedures
  - Not hastily produced PowerPoint slides
Phase 2) RQA – Preparation Task

Process/Training Team trains the Requirements and Architecture Teams *significantly prior* to the RQA Meeting.

Requirements and Architecture Teams provide Preparatory Materials to the Quality Assessment Team *significantly prior* to the RQA Meeting:

- Summary Presentation Materials
- Requirements Quality Cases (including electronic access to evidentiary materials)
- Example of Planned Architectural Quality Case

Quality Assessment Team:
- Reads Preparatory Materials
- Generates RFIs and RFAs
Phase 2) RQA – Meeting Task

1. Requirements Team presents:
   • System Overview
   • Requirements Overview
   • Requirements Quality Cases

2. Quality Assessment Team assesses Quality and Maturity of Requirements:
   • Completeness of Quality Cases
   • Quality of Quality Cases

3. Architecture Team presents Example Architectural Quality Case

4. Quality Assessment Team recommends Improvements

5. Quality Assessment Team manages Action Items
Phase 2) RQA – Follow-Through Task

Quality Assessment Team:
1. Develops Consensus Regarding Requirements Quality
2. Produces, Reviews, and Presents Meeting Outbrief
3. Produces, Reviews, and Publishes RQA Report
4. Updates and publishes the System Quality Assessment Summary Matrix
5. Captures Lessons Learned
6. Manages Action Items

Requirements Team:
   Addresses Risks Raised in RQA Report

Process Team:
   Updates Assessment Method (e.g., Standards and Procedures)

Training Team:
   Updates Training Materials (if appropriate)
Phase 2) RQA – Work Product Workflow

- QUASAR Training Materials
- QUASAR Stds & Procedures
- RQA Checklist and Report Template
- RQA Preparatory Materials
- RQA Presentation Materials
- Requirements Quality Cases and Draft Representative Architectural Quality Case
- Questions/Answers
- Recommendations
- RQA Outbrief
- RQA Report
- Action Item List

Requirements Team
Architecture Team
Assessment Team
Training Team
Lessons Learned
System Quality Assessment Summary Matrix
Phase 2) RQA – Work Products

- RQA Presentation Materials
  - Meeting Invitation and Agenda
  - RQA Preparatory Materials
  - RQA Assessment Outbrief
  - RQA Assessment Report
  - Assessor Notes
  - Action Item List
  - Lessons Learned
  - Requirements Support Matrix
  - System Quality Assessment Summary Matrix

- System / Component Overview
- Rqmts Quality Case
- Draft Architecture Quality Case
- Requirements Overview
- Requirements Quality Cases

- Text
- Diagrams
- Models
- Documents
- Claims
- Associated Arguments
- Supporting Evidence

Legend:
- requirement work product
- assessor work product
- influences
- aggregation
- specialization
## System Quality Assessment Summary Matrix

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Phase 2) RQA – Checklist

Are the Claims:

• Based on the project Quality Model?
• Appropriate for the Current Time in the Project Development Cycle?

Are the Arguments:

• Clear (understandable to the assessors)?
• Compelling (sufficient to justify belief in the claims)?
• Relevant (to justify belief in the claims)?

Is the Evidence:

• Credible (official requirements work products under configuration control)?
• Sufficient (to support the arguments)?
Phase 2) RQA – Checklist

Are the Architecturally Significant Requirements:

- Of sufficient Quality?
- Sufficient to drive Architecture Engineering?
- Sufficient on which to base the Architecture Quality Assessment?

Does the representative draft Architecture Quality Case show that the Architects clearly understand what they need to present at the Architecture Quality Assessment?
Phase 2) RQA – Team Memberships

Quality Assessment Team (Assessors):

- Assessment Team Leader
- Meeting Facilitator
- Acquirer/Customer Liaisons to Developer:
  - Requirements Teams
  - Architecture Teams
- Subject Matter Experts (SMEs) having adequate training and experience in:
  - Application Domains (e.g., avionics, sensors, telecommunications, and weapons)
  - Specialty Engineering Groups (e.g., reliability, safety, and security)
  - Requirements and Architecture Engineering (including Quality Model)
  - QUASAR
- Scribe
- Acquirer/Customer Observers
Phase 2) RQA – Team Memberships

Requirements Team:

- Requirements Engineers
- Subject Matter Experts (if appropriate):
  - Specialty Engineering Experts
  - Application Domain Experts

Architecture Team:

- Architects
- Subject Matter Experts (if appropriate):
  - Specialty Engineering Experts
  - Application Domain Experts
Phase 2) RQA – Lessons Learned

Select, Define, and Prioritize Quality Factors and Quality Attributes (e.g., as Critical, Important, Desirable, or Relevant).

Concentrate on Quality-related Requirements (i.e., Merely Listing Quality Factors is Not Sufficient).

Architecturally-Significantly Quality Requirements must have certain Properties.

Iterative/Incremental Development implies Iterative/Incremental Requirements Assessments.

Hold Meeting Sufficiently Early for Quality Requirements to Drive the Architecture.
Topics

Requirements and Architecture Challenges

Underlying Concepts

**QUASAR Method:**

Phase 1) Quality Assessment Initiation (QAI)

Phase 2) Requirements Quality Assessment (RQA)

**Phase 3) Architecture Quality Assessment (AQA)**

Reasons to use QUASAR

QUASAR – Today and Tomorrow
Architecture Quality Assessment (AQA)

- Quality Assessment Initiation
  - repeat for system and each subsystem being assessed
  - Requirements Quality Assessment
  - Architecture Quality Assessment
Phase 3) AQA – Objectives

Use Architectural Quality Cases to:

- Independently assess Architecture Quality in terms of its Support for its Derived and Allocated Architecturally Significant Requirements
- Help Architects identify Architectural Defects and Weaknesses so that:
  - Defects and Weaknesses can be Corrected
  - The Architecture (and System) can be Improved
- Identify Architectural Risks so that they can be Managed
- Provide Visibility into the Status and Maturity of the Architecture
- Increase the Probability of Project Success
Phase 3) AQA – Principles

The Architects should know:

- The Quality Requirements *driving* the Development of the Architecture.
- What Architectural Decisions they *made* and why they made them.
- Where they *documented* their Architectural Decisions.

The Architects should already have documented this Information as a *Natural* Part of their Architecture Engineering Method.

Little *New* Documentation should be Necessary for the Architects to make their Cases to the Quality Assessment Team.

The Architects are Responsible for making their own Cases that their Architecture Sufficiently Supports its Derived and Allocated Quality Requirements.
Phase 3) AQA – Challenges

Architects may not have developed Quality Cases as a Natural Part of their Architecture Engineering Method:

- Architectural Documentation are typically not organized by Quality Factors.
- Quality Case Evidence is often buried in and scattered throughout massive amounts of Architectural Documentation.
- Architectural Models (e.g., UML) often do not address Support for Quality Requirements.

Architecture Quality Assessments may not be:

- Mandated by Contract or Development Method
- Scheduled and Funded
Phase 3) AQA – Challenges

Managers may feel that Schedule Pressures do not allow time for Architecture Quality Assessments.

Architects may not understand how to prepare for an Architecture Quality Assessment:

- Too Busy
- Not Trained
- No Standards Exist
- Bias against Assessments/Audits

Architecturally-Significant Requirements are Rarely Well Engineered.

Architectural Documentation often varies Widely in Quality and Completeness.
Phase 3) AQA – Challenges

Architecturally-Significant Requirements (esp. Quality Requirements) are rarely traced to the Architectural Elements that collaborate to Implement them.

It is difficult to determine if an Architecture sufficiently supports meeting Poorly-Specified Architecturally Significant Requirements.
Phase 3) AQA – Preparation Task

Architecture and Quality Assessment Teams organize the AQA Assessment Meeting.

Training Team provides (at appropriate time):
• QUASAR Training (if not provided prior to RQA assessment)
• AQA Assessment Checklist and Report Template

Architecture Team makes available (min. 2 weeks before meeting):
• Any Updated Quality Requirements
• Architecture Overview
• Quality Case Diagrams
• Architecture Quality Cases (Claims, Arguments, and Evidence)

Quality Assessment Team:
• Reads Preparatory Materials
• Generates RFIs and RFAs
Phase 3) AQA – Meeting Task

Architecture Team:
1. Introduces the Architecture (e.g., Context and Major Functions)
2. Briefly reviews the Architecturally Significant Requirements
3. Briefly summarizes the Architecture (e.g., Most Important Architectural Components, Relationships, Decisions, Inventions, Trade-Offs, Assumptions, and Rationales)
4. Individually Presents Architectural Quality Cases (Quality Case Diagram, Claims, Arguments, and Evidence)

Quality Assessment Team:
1. Probes Architecture (Architectural Quality Case by Quality Case)
2. Manages Action Items
Phase 3) AQA – Follow-Through Task

Quality Assessment Team:
1. Develops Consensus regarding Architecture Quality
2. Produces, reviews, and presents Meeting Outbrief
3. Produces, reviews, and publishes AQA Report
4. Updates and republishes System Quality Assessment Summary Matrix
5. Captures Lessons Learned
6. Manages Action Items

Architecture Team:
   Addresses Architectural Defects, Weaknesses, and Risks Raised in AQA Report

Process Team:
   Updates Assessment Method (if appropriate)

Training Team:
   Updates Training Materials (if appropriate)
Phase 3) AQA – Work Product Workflow

1. QUASAR Training Materials
2. QUASAR Stds & Procedures
3. AQA Checklist and Report Template
4. AQA Preparatory Materials
5. AQA Presentation Materials
6. Introductory Material and Architectural Quality Cases
7. Questions/Answers
8. Recommendations
9. AQA Outbrief
10. AQA Report
11. Action Item List

Training Team → Architecture Team

Process Team → Assessment Team

Lessons Learned → System Quality Assessment Summary Matrix
Phase 3) AQA – Primary Work Products

Legend

- architect work product
- assessor work product
- influences
- aggregation
- specialization
Phase 3) AQA – Checklist

Are the Claims:

• Based on the project Quality Model?
• Appropriate for the Current Time in the Project Development Cycle?

Are the Arguments:

• Clear (understandable to the assessors)?
• Compelling (sufficient to justify belief in the claims)?
• Relevant (to justify belief in the claims)?

Is the Evidence:

• Credible (official architecture work products under configuration control)?
• Sufficient (to support the arguments)?
Phase 3) AQA – Team Memberships

Quality Assessment Team (Assessors):

- Assessment Team Leader
- Meeting Facilitator
- Acquirer/Customer Liaisons to Developer:
  - Requirements Teams
  - Architecture Teams
- Subject Matter Experts (SMEs) having adequate training and experience in:
  - Application Domains (e.g., avionics, sensors, telecommunications, and weapons)
  - Specialty Engineering Groups (e.g., reliability, safety, and security)
  - Requirements and Architecture Engineering (including Quality Model)
  - QUASAR
- Scribe
- Acquirer/Customer Observers
Phase 3) AQA – Team Memberships

Architecture Team:

- Architects
- Subject Matter Experts (if appropriate):
  - Specialty Engineering Experts
  - Application Domain Experts
- Developer Observers
Phase 3) AQA – Lessons Learned


Provide Initial Overview of the Architecture:

- Keep Overview Short
- Present Only the Most Important Architectural Decisions, Trade-Offs between Quality Characteristics and Attributes, and Assumptions
- Mount Diagrams on Meeting Room Walls (and Leave Them Up!)
- Highlight Primary Architectural Decisions and Inventions

Focus on Assessing the Existing Architecture.

Avoid a “Trust Me” Mentality.
Phase 3) AQA – Lessons Learned

Organize Presentation by Quality Cases (i.e., Quality Characteristics and Quality Attributes) and not by Architectural Component.

Architects should present Models of relevant Logical and Physical as well as Static and Dynamic Architectural Structures.

Keep Evidence Presented and Requested within Assessment Scope.

Ensure Availability of Actual Architects.

Architects must have Electronic Access to Evidence to present Existing, Official Documentary Evidence.

Use Scenarios to Probe and Test the Architecture rather than to Introduce the Architecture.
Phase 2) AQA – Lessons Learned

Take Development Cycle, Project Schedule, and Architectural Maturity into Account.

Emphasize Assessment Results over recommending Architectural Improvements.

Ensure Reasonable Assessment Size and Schedule.

Ensure Adequate Pre-Meeting Preparation.

All Architectural Tiers are not Equal:

• Size, Complexity, Criticality, and Quality Factors/Subfactors

• Apply Different Emphasis at Different Levels of the Hierarchy.

Differentiate Architecture from Design.
Topics

Requirements and Architecture Challenges

Underlying Concepts

QUASAR Method

Reasons to use QUASAR

QUASAR – Today and Tomorrow
QUASAR Benefits

QUASAR ensures Specification of *Architecturally-Significant* Requirements.

QUASAR provides Acquirer Visibility into (and supports oversight of) the Quality of the Requirements and Architecture

QUASAR supports Certification and Accreditation

QUASAR emphasizes using a common project-specific Quality Model:

- Which drives the Quality Requirements
- Which drives the Quality of the System Architecture
- Which drives the Quality of the System
QUASAR Benefits

QUASAR Supports Process Improvement:
• Solves Major Requirements and Architecture Problems

QUASAR Provides needed Flexibility:
• Any Effective Requirements Engineering and Architecting Methods
• Uses Existing Requirements and Architecture Work Products (i.e., almost no new work products required)
• Any Subsystems based in Need and Risk (i.e., fits any system size, budget, schedule, and tier)
• Any Quality Factors and Quality Attributes

QUASAR Helps:
• Requirements Engineers Succeed
• Architects Succeed
• Program Succeed
Topics

Requirements and Architecture Challenges

Underlying Concepts

QUASAR Method

Reasons to use QUASAR

QUASAR – Today and Tomorrow
QUASAR Today

Used on Largest DoD Acquisition Program ($270,000,000,000 USD)
QUASAR Version 1 Handbook Published
http://www.sei.cmu.edu/publications/documents/06.reports/06hb001.html
Provided as SEI Service by Acquisition Support Program (ASP)
Tutorials at Conferences
Articles in Journals
QUASAR Handbook

Intended Audiences:
- Acquisition Personnel
- Developers (Architects and Requirements Engineers)
- Subject Matter Experts (domain, specialty engineering)
- Consultants
- Trainers

Objectives:
- Completely Document the QUASAR Method (Version 1)
- Enable Readers to start using QUASAR

Description:
- Very Complete
- Too Comprehensive to be Good First Introduction
QUASAR Tomorrow – Technical Plans

Quality Factors across Multiple Subsystems:

- Multiple Cross-Cutting Structures and Models
- Multiple Subsystems Collaborate to Achieve Quality Requirements

Development of Catalog of Quality Factor-Specific Architectural Styles, Patterns, and Mechanisms to use as Standardized Quality Case Arguments

Improve Objective Determination of “Sufficient Quality”

Expand Quality Cases Beyond Requirements and Architecture
QUASAR Tomorrow - Productization

More Conference Tutorials and Classes
Expanded QUASAR Training Materials
More QUASAR Articles
Use and Validation on more Projects
QUASAR Book
How the SEI Can Help You

QUASAR is Ready for Use Now.

QUASAR Handbook and Training Materials can be downloaded from SEI Website.

The SEI Acquisition Support Program (ASP) offers QUASAR as a Service:

- Consulting and Training
- Facilitation of QUASAR Assessments
- Recommended RFP and Contract Language
Questions?

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