CS554
Designs for Software and Systems

Architecture Evaluation (ATAM)

Lecture Given by

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Today's Agenda

- Architecture Description Languages
  - > Team assignment for further investigation
  - > Oral presentation – OP5
- Project 2
  - > ATAM – Architecture Tradeoff Analysis Method
  - > Oral presentations – OP4, OP6

Architecture Description Languages

- Architecture Description Languages (ADLs)
  - > Describe architectures precisely
  - > About a dozen ADLs
  - > Usually with supporting toolkits
- Basic ADL Requirements
  - > ADL's must provide support for:
    - » Composition
    - » Abstraction/Closure
    - » Reusability
    - » Configuration
    - » Heterogeneity
    - » Analysis
    - » First-Class Connectors

Architecture Description Languages

- A number of architecture description languages (ADLs) have been developed in the SE community
- Each language and supporting tool set
  - > Emphasizes different aspect of arch
  - > Is good for some things; bad for others
- Some examples
  - > Rapide – Events with simulation and animation
  - > UniCon – Emphasizing heterogeneity and compilation
  - > Wright – Formal specification of connector interactions
  - > Aesop – Style-specific arch design languages
  - > ArTek – TeKnowledge description language
  - > SADL – SRI language emphasizing refinement
  - > Meta-H – Architecture description for avionics domain
  - > C-2 – Architecture style using implicit invocation

Key Features of Modern ADLs

- System structure is defined separately from individual components
  - > Parts are "context independent"
  - > Supports hierarchical design
- Components have multiple interfaces
  - > Different points of interaction with their environment
- New kinds of connectors can be defined
  - > Need not be realizable directly in a primitive of an implementation language
  - > Have rich semantics
- Can express/analyze extra-functional properties
  - > Performance, reliability, etc.
- Support for architectural styles
  - > Reusable architectural patterns

Oral Presentation – OP5

- The task - Teamwork
  - > Choose one ADL from the list
    - » Teams must make different choices
  - > Survey literature and investigate
  - > Present in the class about the ADL of your choice
    - » 30 min presentation each team
- Schedule
  - > Two teams to present on Thursday, 19 November
  - > Remaining two teams to present on Thursday, 26 November

Project 2 (Recap.)

- Design of Software Architecture
  - Prioritized utility tree
    - Scenarios
  - Proposed architecture
    - Architectural views
  - Analysis of the architecture
    - Applying to ranked utility tree
  - Architectural evaluation
    - Risks, sensitivity points, tradeoffs
    - Key architectural decisions among alternatives

Oral Presentations – OP4, OP6

- Interim presentations for project P2
  - > In-class discussion to get feedback
  - > Not graded
  - > Present in the class
    - » 15 min presentation each team
- Schedule
  - > OP4 – Thursday, 12 November
  - > OP6 – Thursday, 3 December

Architecture Evaluation

- We identify architectural patterns or styles
  - > Architectural styles, idioms, families, frameworks, patterns
- Every architect should have a standard set of architectural styles in his/her repertoire
  - > It is important to understand the essential aspects of each style
    - » When to and when not to use them
  - > Examples
    - » Pipe and filters, objects, event-based systems, blackboards, interpreters, layered systems
- Choice of style can make a big difference in the properties of a system
  - > Analysis of the differences can lead to principled choices among alternatives

Architecture Evaluation

- **Why evaluate an architectural design?**
  - > All design involves tradeoffs.
  - > A software architecture is typically the first project artifact that embodies significant design decisions.
  - > We want a method that ensures that
    - » the right questions are asked . . . *early*
    - » risks and sensitivity points within the architecture for various attributes are identified
    - » tradeoff points are explicitly identified

Architecture Evaluation

- Determining whether an architecture satisfies its requirements often involves
  - > Being very explicit about what the requirements really are
  - > Understanding where one has to make tradeoffs between different designs
  - > Applying formal analysis where possible to determine the consequences of an architectural choice
  - > Mediating between desires of different stakeholders
- These goals can be achieved by an architectural evaluation process
- We will look at an example of one such process:
  - > ATAM

ATAM

- **ATAM**
  - > Architecture Tradeoff Analysis Method
    - » An architecture evaluation method
  - > Focuses on multiple quality attributes
  - > Illuminates points in the architecture where:
    - » Sensitivity to various attributes exists
    - » Quality attribute tradeoffs occur
  - > Generates a framework for ongoing quantitative/qualitative analysis
  - > Utilizes an architecture's vested stakeholders as authorities on the quality attribute goals

The ATAM Process

1) Collect system usage scenarios from various stakeholders

2) Collect requirements/constraints/environment

   » These are the requirements for which analyses will be performed

3) Describe architectural designs

   » Describe multiple, competing architectural options

4) Perform attribute-specific analyses

   » Analyze properties of each architecture option in isolation

5) Identify sensitivities

   » Determine the sensitivity of the various attributes to the available architectural design options

6) Identify tradeoffs

   » Determine which architectural elements are sensitive to multiple attributes (e.g. # of servers affects both the cost of the system and its overall reliability)

7) Repeat…

Factors Influencing Choice of Architecture

- Structure of the development organization
  - > May influence how project can partitioned
- Enterprise goals of the development organization
  - > Influences product-lines; use of standards
- Customer requirements
  - > Determines properties that system must have
- Architect’s experience
  - > Determines what are risky and safe architectures
- Technical environment
  - > Implementor skills; development environment and platform; legacy code

ATAM and Risks

- The point of an ATAM analysis is
  - > Not to provide precise analyses
  - > But to discover areas of high risk in the architecture
- We want to find trends
  - > Correlations between architectural parameters and measurable properties
- These areas can then be made the focus of risk mitigation activities
  - > E.g., further design, further analysis, prototyping

ATAM Benefits

- We have observed a number of benefits to performing ATAM analyses:
  - > Clarified requirements
  - > Improved architecture documentation
  - > Documented basis for architectural decisions
  - > Early problem identification
  - > Increased stakeholder communication

- And, obviously, improved architectures.

Scenarios

- ATAM uses use cases and scenarios
  > To articulate the specific quality attributes that are goals for the architecture
- Use cases and scenarios are short descriptions of putting the system:
  > through a particular use
  > through a particular change
  > through a particular attack
  > through a particular failure

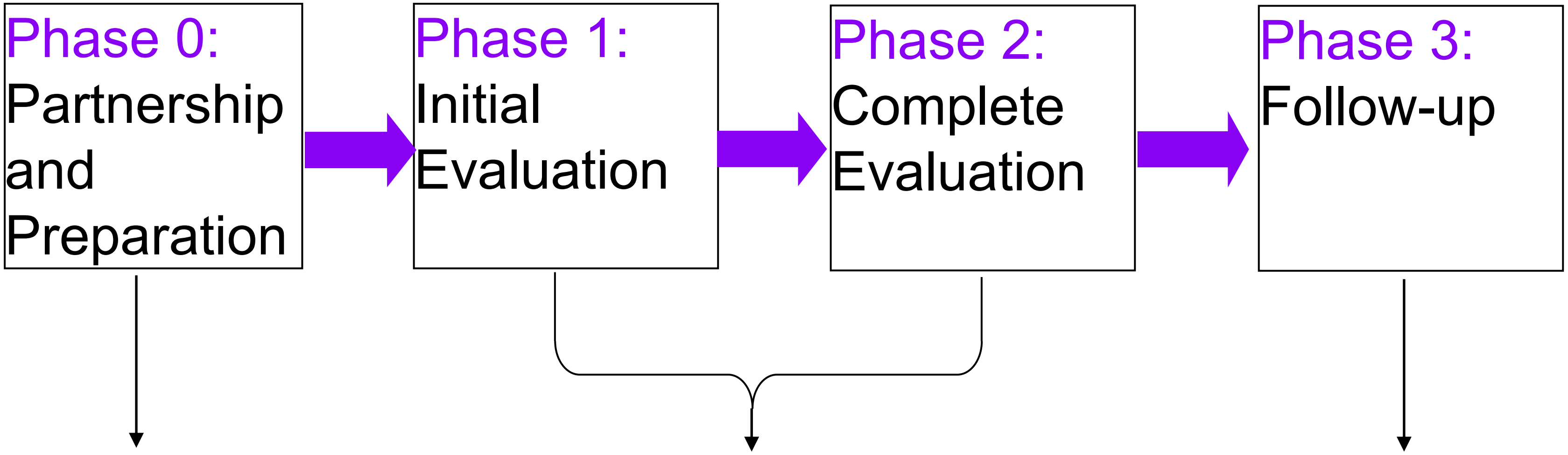
. . . from the perspective of one or more of the system's stakeholders.

Attribute Taxonomies

- To better understand each quality attribute, we need to develop attribute taxonomies.
  - > See Appendix of [KKC00] for some attributes
- For each attribute, the taxonomy describes
  - > The stimuli of interest
  - > The responses
  - > The quality attribute architectural parameters
- These provide a standard set of investigation paths to structure an analysis.

ATAM Phases

- **ATAM evaluations are conducted in four phases.**



Phase 0: Partnership and Preparation

Phase 1: Initial Evaluation

Phase 2: Complete Evaluation

Phase 3: Follow-up

Duration: varies
Meeting: primarily phone, email

Duration: 1.5 - 2 days each for Phase 1 and Phase 2
Meeting: typically conducted at customer site

Duration: varies
Meeting: primarily phone, email

ATAM Phase 0

- Phase 0: This phase precedes the technical evaluation.
  - > The customer and a subset of the evaluation team exchange understanding about the method and the system whose architecture is to be evaluated.
  - > An agreement to perform the evaluation is worked out.
  - > A core evaluation team is fielded.

ATAM Phase 1

- Phase 1: involves a small group of predominantly technically-oriented stakeholders

- Phase 1 is
  - > Architecture centric
  - > Focused on eliciting detailed architectural information and analyzing it
  - > Top down analysis

ATAM Phase 1 Steps

1. Present the ATAM
2. Present business drivers
3. Present architecture
4. Identify architectural approaches
5. Generate quality attribute utility tree
6. Analyze architectural approaches

Phase 1

7. Brainstorm and prioritize scenarios
8. Analyze architectural approaches
9. Present results

1. Present the ATAM

- The evaluation team presents an overview of the ATAM including:
  - ATAM steps in brief
  - Techniques
    - Utility tree generation
    - Architecture elicitation and analysis
    - Scenario brainstorming/mapping
  - Outputs
    - Architectural approaches
    - Utility tree and scenarios
    - Risks and “non-risks”
    - Sensitivity points and tradeoffs

2. Present Business Drivers

- ATAM customer representative describes the system’s business drivers including:
  - > Business context for the system
  - > High-level functional requirements
  - > High-level quality attribute requirements
    - » Architectural drivers – quality attributes that “shape” the architecture
    - » Critical requirements – quality attributes most central to the system’s success

3. Present Architecture

- Architect presents an overview of the architecture including:
  - > Technical constraints such as an OS, hardware, or middleware prescribed for use
  - > Other systems with which the system must interact
  - > Architectural approaches used to address quality attribute requirements
- Evaluation team begins probing for and capturing risks.

4. Identify Architectural Approaches

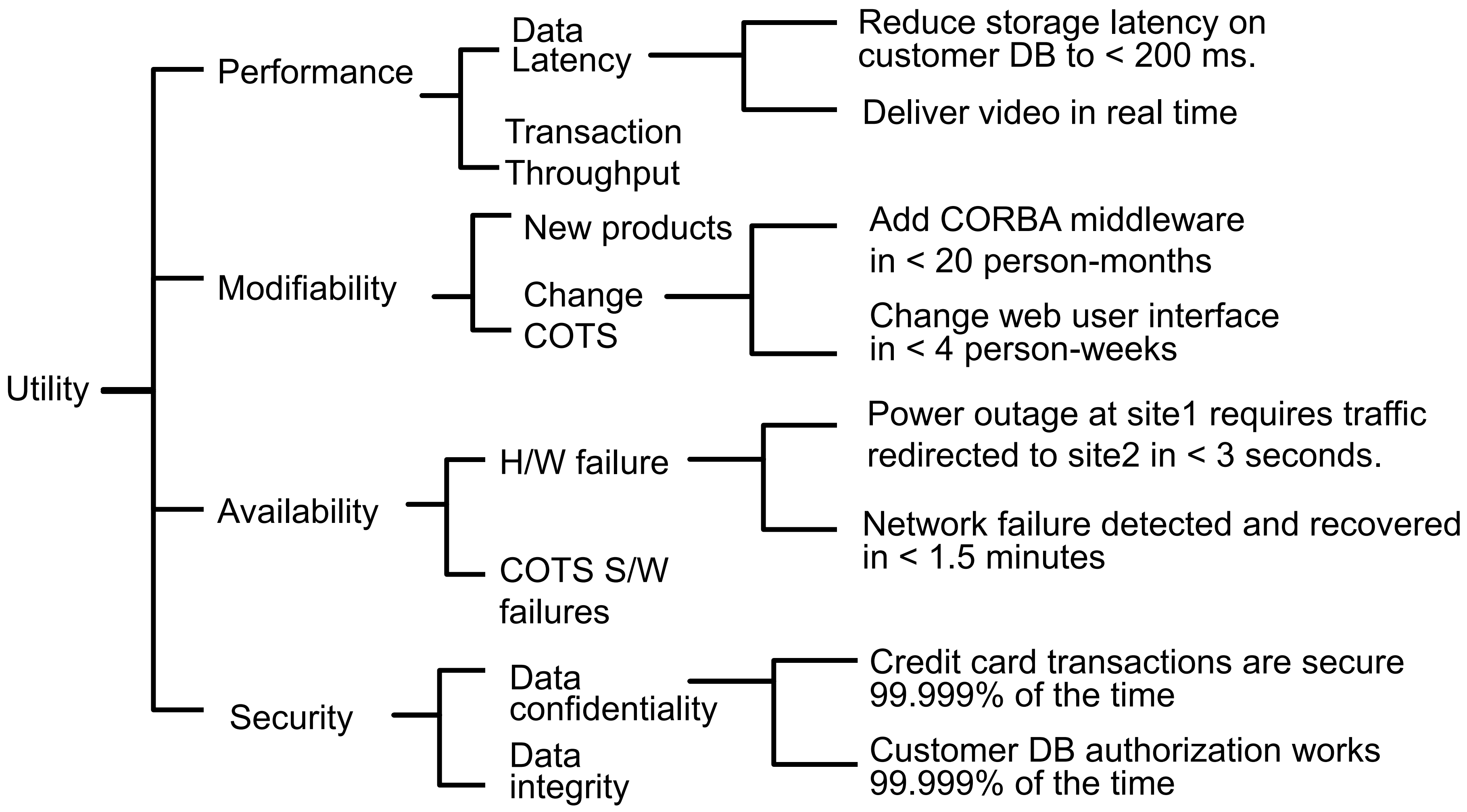
- The evaluators will begin to identify places in the architecture that are key to realizing quality attribute goals.
- Identify predominant architectural approaches such as:
  - > Client-server
  - > 3-tier
  - > Watchdog
  - > Publish-subscribe
  - > Redundant hardware

5. Generate Quality Attribute Utility Tree

- Identify, prioritize, and refine the most important quality attribute goals by building a utility tree.
  - > A utility tree is a top-down vehicle for characterizing the “driving” attribute-specific requirements.
  - > The most important quality goals are the high-level nodes (typically performance, modifiability, security, and availability).
  - > Scenarios are the leaves of the utility tree.

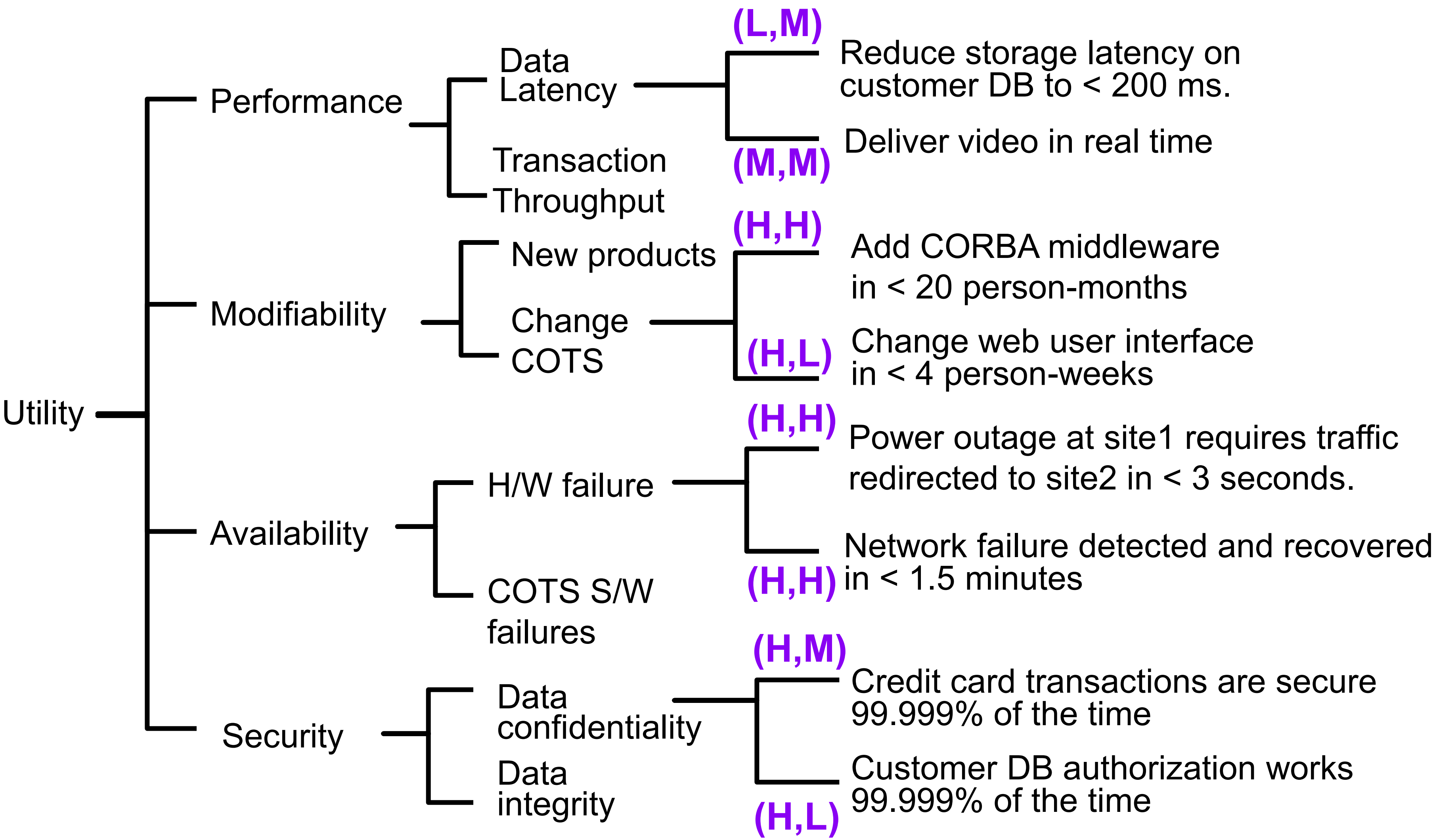
- Output: a characterization and a prioritization of specific quality attribute requirements.

Utility Tree Construction



- Utility
  - Performance
    - Data Latency
      - Reduce storage latency on customer DB to < 200 ms.
      - Deliver video in real time
    - Transaction Throughput
  - Modifiability
    - New products
    - Change COTS
      - Add CORBA middleware in < 20 person-months
      - Change web user interface in < 4 person-weeks
  - Availability
    - H/W failure
      - Power outage at site1 requires traffic redirected to site2 in < 3 seconds.
      - Network failure detected and recovered in < 1.5 minutes
    - COTS S/W failures
  - Security
    - Data confidentiality
      - Credit card transactions are secure 99.999% of the time
      - Customer DB authorization works 99.999% of the time
    - Data integrity

Utility Tree Construction



- Utility
  - Performance
    - Data Latency
      - (L,M) Reduce storage latency on customer DB to < 200 ms.
      - (M,M) Deliver video in real time
    - Transaction Throughput
  - Modifiability
    - New products
    - Change COTS
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Scenarios

- Scenarios are used to
  - > Represent stakeholders' interests
  - > Understand quality attribute requirements

- Scenarios should cover a range of
  - > Anticipated uses of (use case scenarios),
  - > Anticipated changes to (growth scenarios), or
  - > Unanticipated stresses (exploratory scenarios) to the system.

- A good scenario makes clear what the stimulus is that causes it and what responses are of interest.

Example Scenarios

- Use case scenario
  - > Remote user requests a database report via the Web during peak period and receives it within 5 seconds.
- Growth scenario
  - > Add a new data server to reduce latency in scenario 1 to 2.5 seconds within 1 person-week.
- Exploratory scenario
  - > Half of the servers go down during normal operation without affecting overall system availability.
- Scenarios should be as specific as possible.

Stimulus, *Response*, Environment

- Use case scenario
  - > Remote user requests a database report via the Web during peak period and *receives it within* 5 *seconds*.

- Growth scenario
  - > Add a new data server to reduce latency in scenario 1 to 2.5 seconds *within* 1 *person-week*.

- Exploratory scenario
  - > Half of the servers go down during normal operation *without affecting overall system availability*.

6. Analyze Architectural Approaches

- Evaluation team probes architectural approaches from the point of view of specific quality attributes to identify risks.
  - > Identify the architectural approaches
  - > Ask quality attribute specific questions for highest priority scenarios
  - > Identify and record risks and non-risks, sensitivity points and tradeoffs

Example Approach Elicitation

- Scenario: Detect and recover from HW failure of main switch
- Stimulus: A CPU fails
- Response: 0.999999 availability of switch

Architectural Approaches:	R	S	T
> Backup CPU(s)	x	x	
> Backup Data Channel	x	x	x
> Watchdog		x	
> Heartbeat		x	
> Failover Rerouting	x	x	

Example Approach Elicitation (cont'd)

- **Analysis:**
  - > Ensures no common mode failure by using different HW and OS
  - > Worst-case rollover is accomplished in 3 seconds
  - > Guaranteed to detect failure with 1 second
  - > Watchdog is simple and proven reliable

Quality Attribute Questions

- Quality attribute questions probe architectural decisions that bear on quality attribute requirements.
- These come from codified knowledge, such as ABASs.

- Performance
  - > How are priorities assigned to processes?
  - > What are the message arrival rates?

- Modifiability
  - > Are there any places where layers/facades are circumvented?
  - > What components rely on detailed knowledge of message formats?

Risks, Tradoffs, Sensitivities, Non-Risks

- A Risk is a potentially problematic architectural decision.
- Non-Risks are good architectural decisions that are frequently implicit in the architecture.
- A Sensitivity Point is a property of one or more components (and/or component relationships) that is critical for achieving a particular quality attribute response.
- A Tradeoff Point is a property that affects more than one attribute and is a sensitivity point for more than one attribute.

Risks and Tradeoffs

- Example Risk:
  - > "Rules for writing business logic modules in the second tier of your 3-tier architecture are not clearly articulated. This could result in replication of functionality thereby compromising modifiability of the third tier."

- Example Tradeoff:
  - > "Changing the level of encryption could have a significant impact on both security and performance."

Sensitivities and Non-Risks

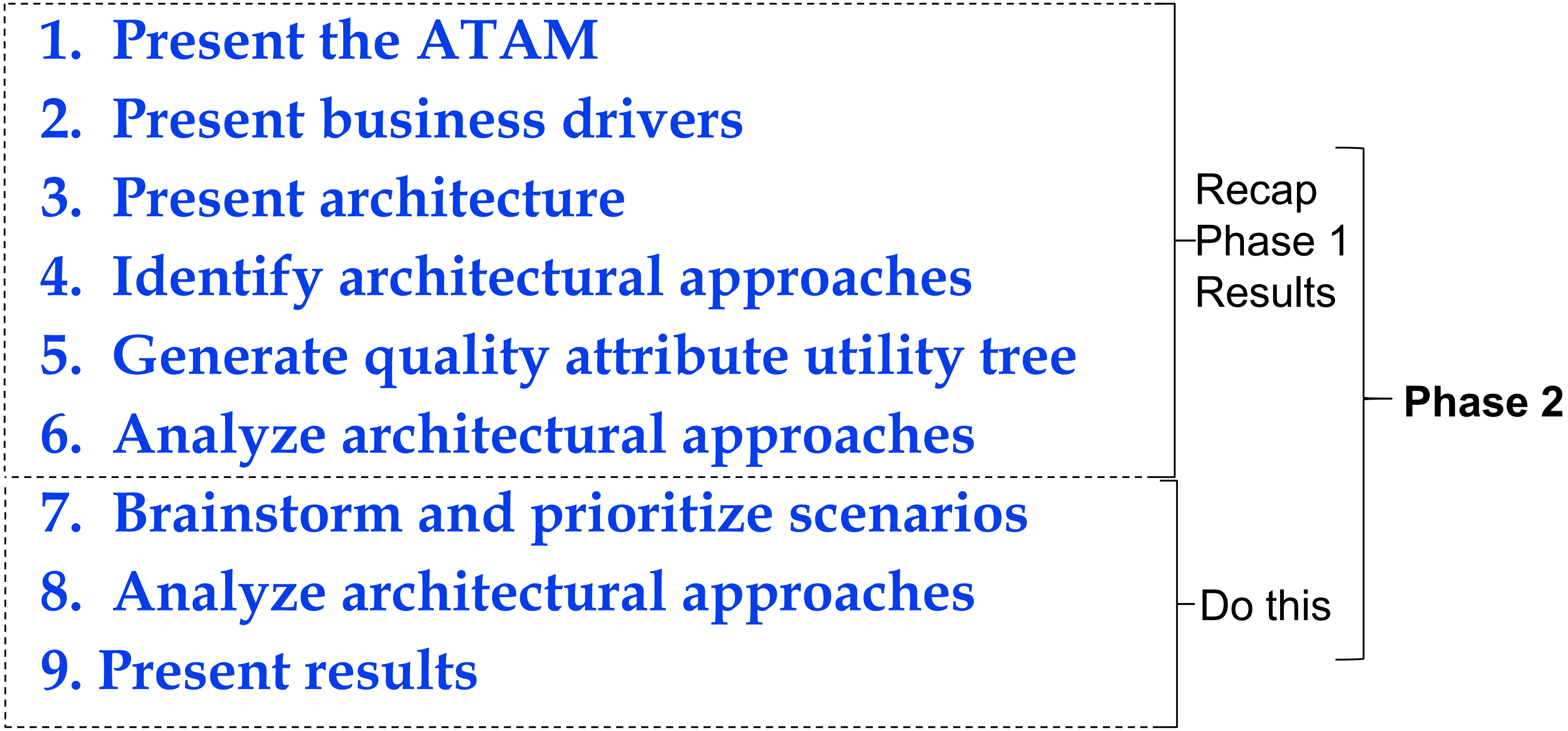
- Example Sensitivity:
  - > "The average number of person-days of effort it takes to maintain a system might be sensitive to the degree of encapsulation of its communication protocols and file formats."
- Example Non-Risk:
  - > "Assuming message arrival rates of once per second, a processing time of less than 30 ms, and the existence of one higher priority process, a 1 second soft deadline seems reasonable."

ATAM Phase 2

- Phase 2: involves a larger group of stakeholders

- Phase 2 is
  - > Stakeholder centric
  - > Focused on eliciting diverse stakeholder points of view and on verification of the Phase 1 results

ATAM Phase 2 Steps



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7. Brainstorm and Prioritize Scenarios

- Stakeholders generate scenarios using a facilitated brainstorming process.
  - > Scenarios at the leaves of the utility tree serve as examples to facilitate the step.

- In phase 2, each stakeholder is allocated a number of votes roughly equal to 0.3 x #scenarios.

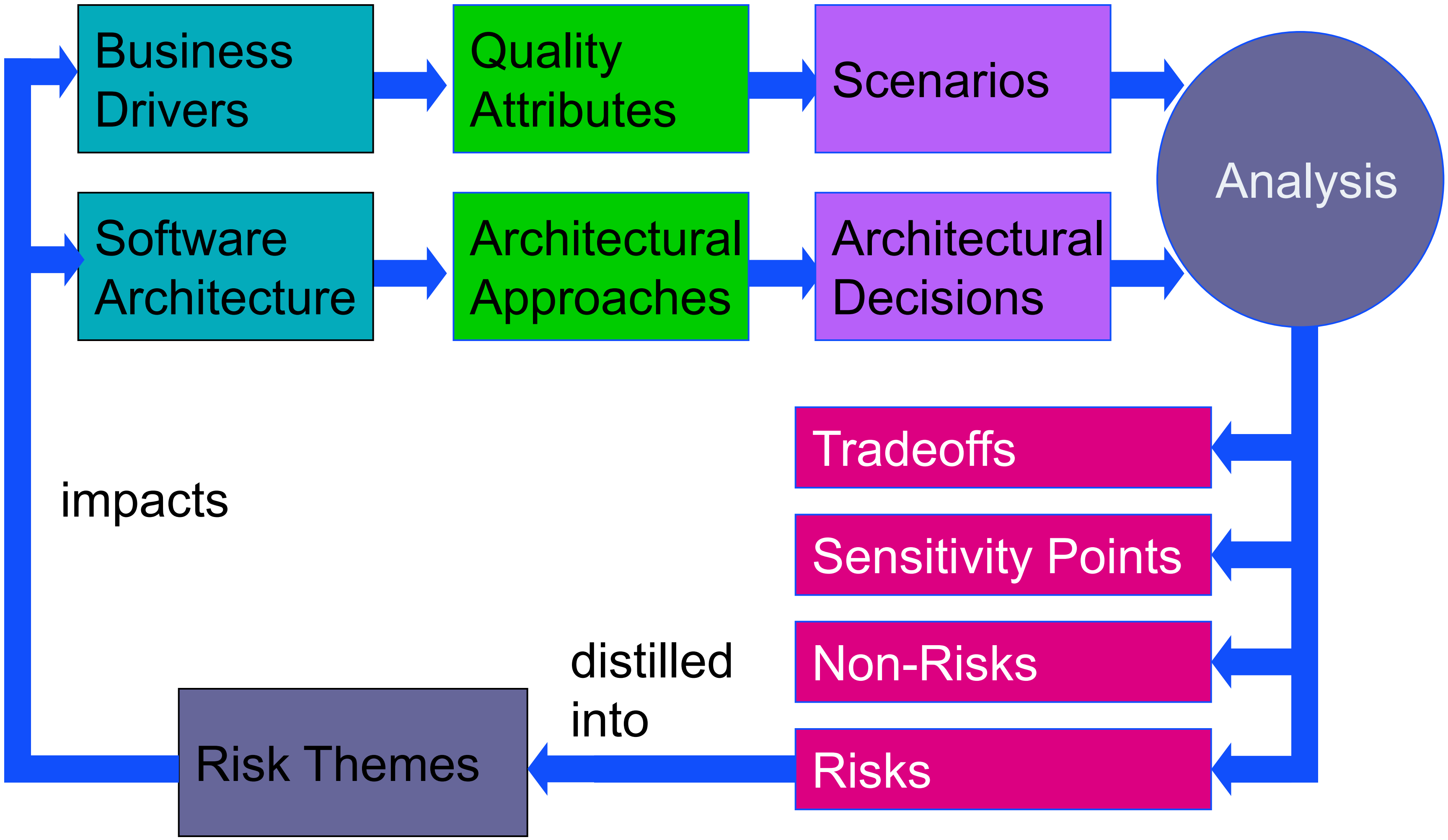
8. Analyze Architectural Approaches

- Identify the architectural approaches impacted by the scenarios generated in the previous step.
  - > This step continues the analysis started in step 6 using the new scenarios.
  - > Continue identifying risks and non-risks.
  - > Continue annotating architectural information.

9. Present Results

- Recapitulate all the steps of the ATAM and present the ATAM outputs:
  - > Architectural approaches
  - > Utility tree
  - > Scenarios
  - > Risks and non-risks
  - > Sensitivity points and tradeoffs
  - > Risk themes

Conceptual Flow of ATAM



ATAM Phase 3

- Phase 3: primarily involves producing a final report for the customer as well as reflecting upon the quality of the evaluation and the ATAM materials.
  - > If no final report was called for, then report writing is omitted.

The Final Report

- The evaluation team will typically create the final report which includes:
  - > Executive summary
  - > Description of ATAM
  - > Description of business goals and architecture
  - > List of Phase 1 and Phase 2 scenarios and utility tree
  - > Phase 1 and Phase 2 analysis: architectural approaches, decisions, risks, sensitivities, tradeoffs, and non-risks
  - > Risk Themes
  - > Next Steps

Rules of Engagement

- To complete everything and get the most from the evaluation we will need some rules of engagement:
  - > Stakeholder participation is essential.
  - > They should feel free to ask questions at anytime.
  - > Discussion is good, but the facilitator may need to cut some discussions short in the interest of time.
  - > Stakeholders should stay focused and limit side discussions.

Summary

- ATAM is a method for evaluating an architecture with respect to multiple quality attributes.
- It is an effective strategy for discovering the consequences of architectural decisions.
- The ATAM:
  - > Can be done early; can be done on legacy systems
  - > Is inexpensive
  - > Builds stakeholder confidence and buy-in
- The key to the method is looking for trends, not in making precise analyses.

Summary (cont'd)

The ATAM relies critically on

- Appropriate preparation by the customer
- Clearly-articulated quality attribute requirements
- Active stakeholder participation
- Active participation by the architect
- Familiarity with architectural approaches/styles and analytic models

Q & A

- **Questions?**