Independent Verification and Validation of Large System Architectures

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Overview

- Architecture IV&V
- Architecture Analysis Research Elements
  - Architecture Perspectives
    - Topics for analytical investigation
    - Views for improving architecture specifications
  - Architecture Analysis Framework
    - Tailorable set of architecture analysis objectives
    - Methods for accomplishing objectives

NASA IV&V

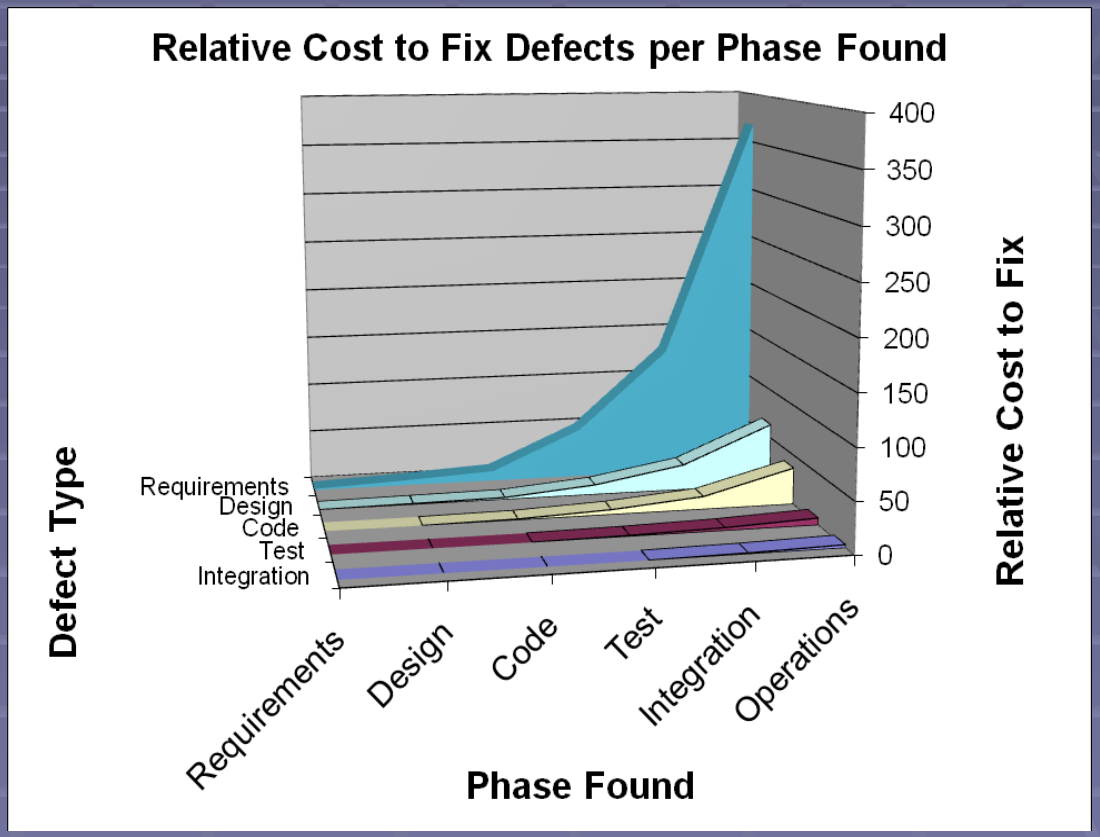
- Independent
  - Technical
  - Managerial
  - Financial
- Analytical approach to evaluate software
  - Correctness
  - Completeness
- Key information sources
  - IV&V Technical Reference
  - Developer artifacts

Architecture Specification Emphasis

- Increasing emphasis on architecture throughout NASA
  - Constellation program
    - System architecture requirements document
    - Software architecture description document
    - Flight operations scenarios annex
    - Technical performance measures plan
    - Interface control documents
  - JUNO (Jupiter Uranus Neptune Outreach)
  - SMAP (Soil Moisture Active-Passive ADD)

Impact of Architecture Phase IV&V

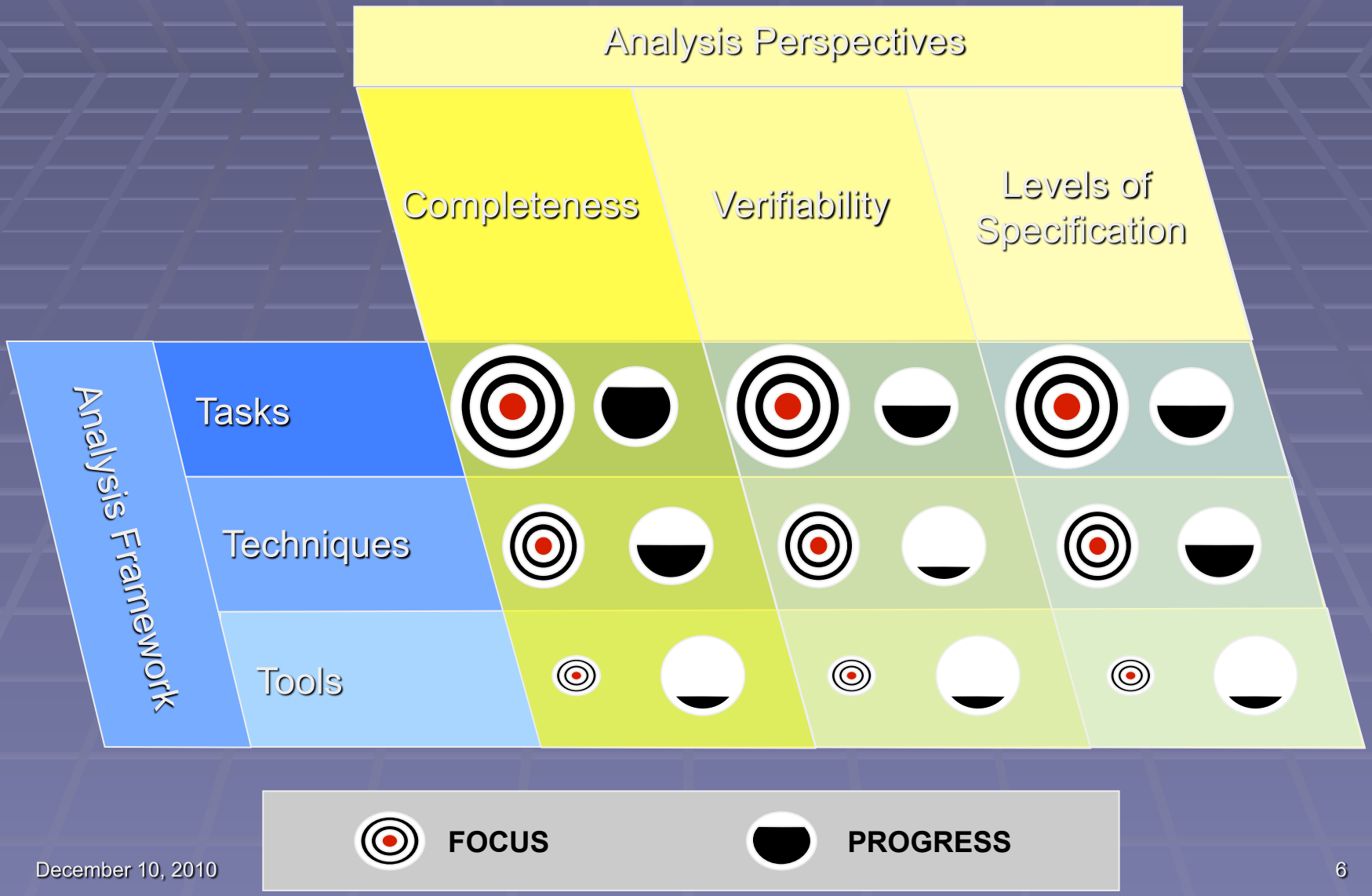
- Architectural issues are a leading source for integration problems
- Without systematic upfront analysis these problems are costly to repair
- Application of complexity, safety and dependability analysis enables addressing the issues early on
- Architectural decisions impact what is required of the software



Source: NIST Planning report 02-3, *"The Economic Impacts of Inadequate Infrastructure for Software Testing"*, May 2002.

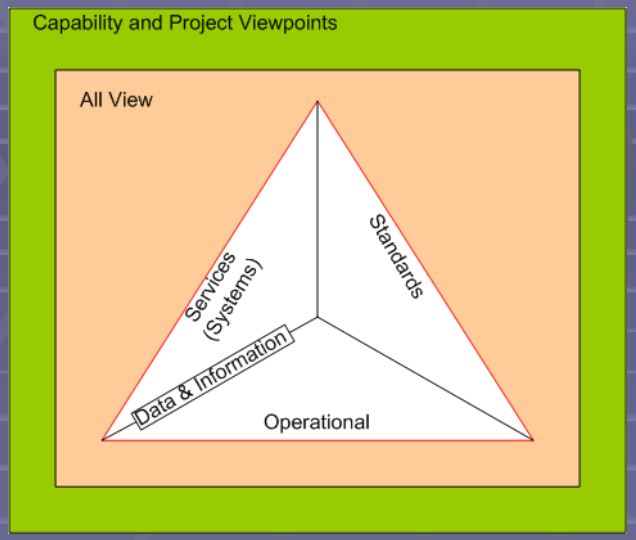
- Improved architecture specifications reduce software risk and increase IV&V's ability to validate and verify the software

Architecture Analysis Research Elements



Frameworks

DoDAF 2.0



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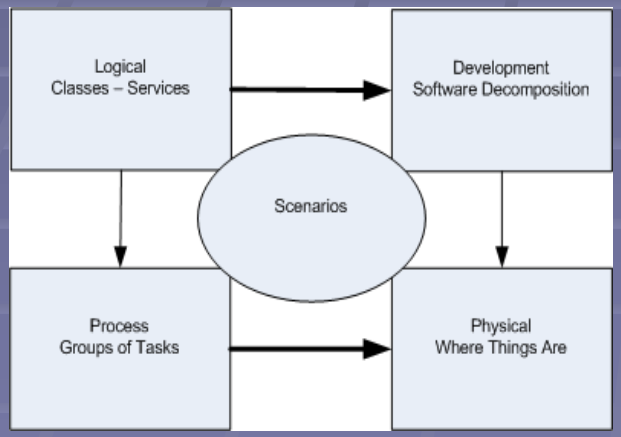
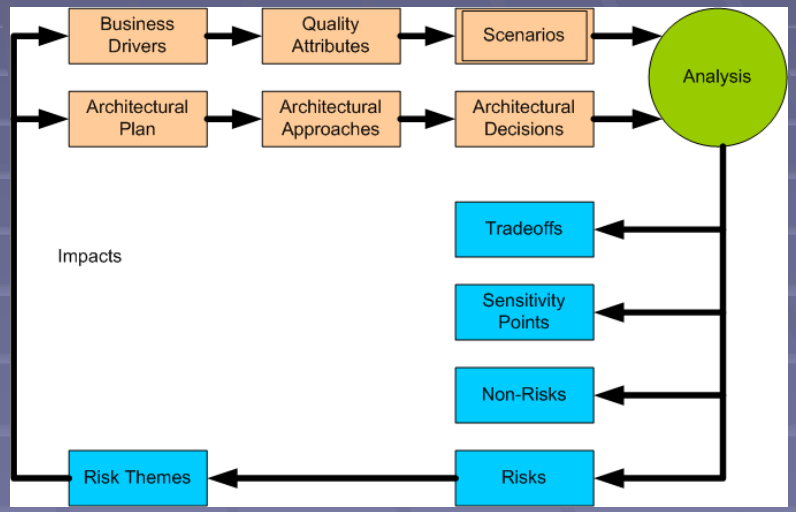


ATAM



Evaluation

Representation

Constellation Software Architecture IV&V

- CSADD Tailored from DoDAF 1.0

View	Comments
OV-2	Operational resource flow description Map to operational scenarios Hierarchical or mission phase views
OV-3	Operational resource flow matrix Decomposed by mission phase and needline type
OV-5	Operational activity model Presented via activity diagrams and flowcharts
SV-1	System interface description Systems and interfaces to realize OV-2
SV-2	Systems communication description
SV-6	Systems data exchange matrix Tabular characterization of data form SV-1 and SV-2 CSADD contains abridged SV-6

- Tailored-out viewpoints

View	Comments
AV-1	AV-1 Executive Summary Hierarchical or mission phase views
AV-2	Integrated dictionary
OV-6	Operational activity sequence & timing
SV-4	Systems functionality description Systems and interfaces to realize OV-2

Verifiability

- Features of the architecture are mapped to requirements, which are then mapped to the verification tests that verify them
  - All components have requirements that are tested
  - All component interfaces have specified requirements that are mapped to verification tests
  - All critical scenarios coverable/covered by test cases
- Technical budgets, budget allocations, and compliance to budgets expressed in observable/ measurable terms
- Risks noted for untestable capabilities, services, interactions, and scenarios and a risk mitigation approach using simulation and analysis planned

Managing Levels of Specification

- This perspective is concerned with managing
  - Properties of a system as a whole
  - Properties that are allocated to the parts from which it is composed
- Document descriptions are information subsets (i.e. abstractions) that need to fit in an organized hierarchy
- Assessing levels of specification can:
  - Detect misalignment of levels of specifications (e.g. semantics)
  - Gaps in interfacing stakeholder/developer abstractions (e.g. omissions)
  - Potential system integration issues (e.g. pattern errors)

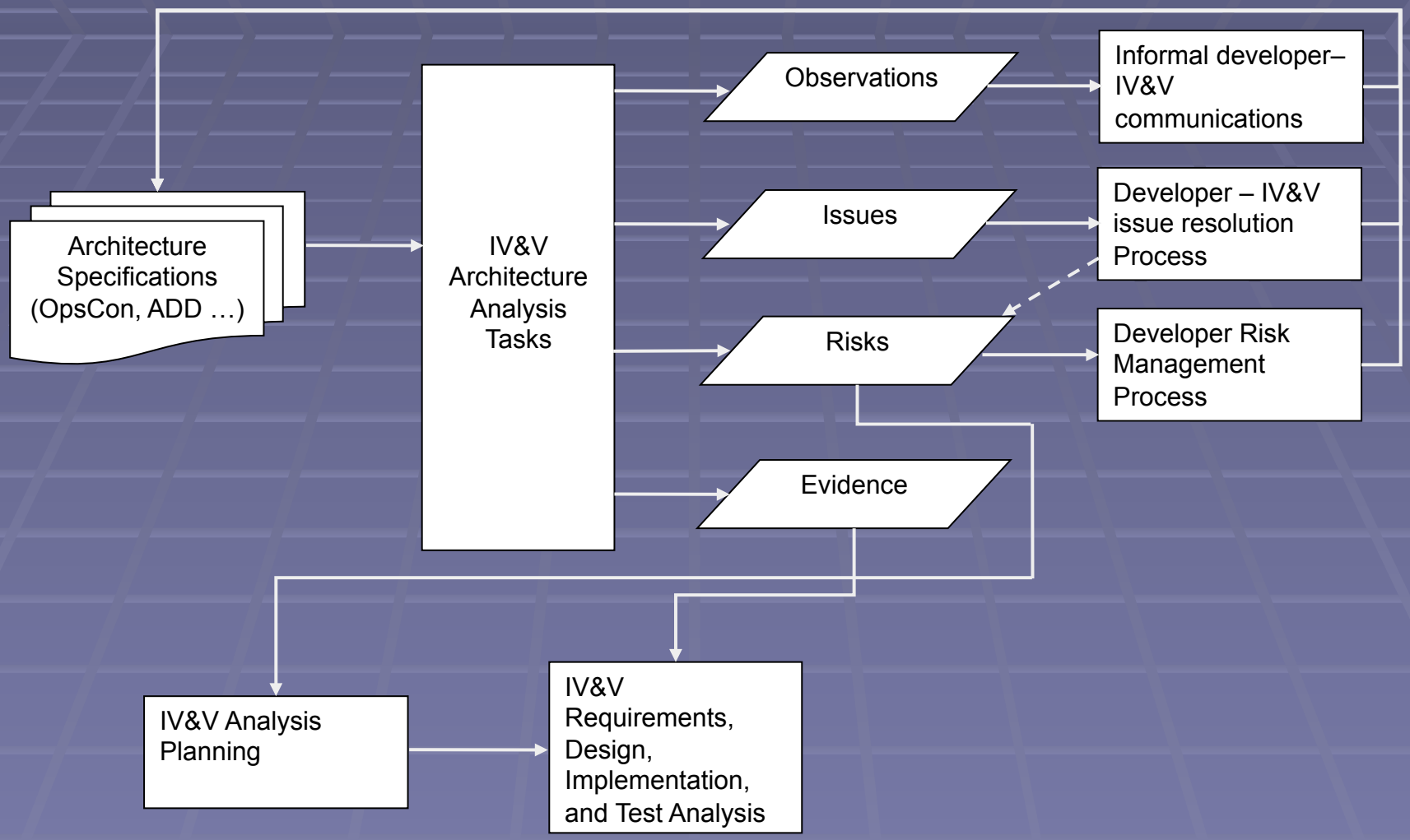
Levels of Specification and Multiple Objectives

- The primary objectives of a system should leave many degrees of freedom for design open
  - Detect stakeholder biases that introduce artificial constraints on downstream tradeoffs
    - Requirements that bias the problem space
    - Implementations that bias the solution space
- Downstream options are then eliminated on the basis of the secondary objectives of the work system
- In many systems, the primary objectives, secondary objectives, and external constraints are often conflicting
- Objectives, like safety or fault tolerance, can have conflicting implementations (e.g. “do nothing” may be safest!)

Levels of Specification and Safety Example

- When objectives, like safety or fault tolerance, have conflicting implications it was unclear in the CSADD how conflicts were resolved
- There is a risk that system level requirements like safety may merely be specified as measures of goodness at a component level
- Need to determine if interpretation of safety is consistent at different levels of specification and among system stakeholders
- Need to determine if an implementation can compromise a critical objective when mixed with other factors (either critical/non-critical)
  - E.g. scheduling of critical communications over a shared network or writing to a shared database

Architecture Analysis Context



Task Phasing

Concept Review | SRR | SDR | PDR | CDR

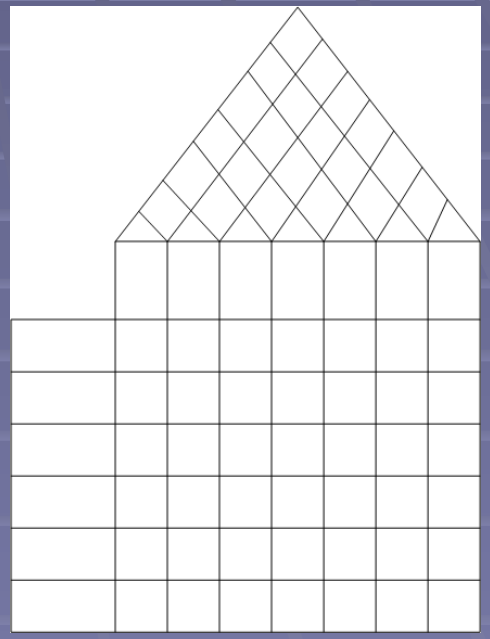
- Stakeholder analysis
- Specification Completeness SDR
- Specification Completeness PDR
- Specification Completeness CDR
- Levels of Specification Identification
- Scenario Analysis
- Key Driving Requirements Validation
- Top-level Requirements Mapping
- Fault Management and Redundancy Analysis
- Technical Budgets Analysis
- Reuse Analysis
- Functional Capability Mapping
- Dependency Mapping Analysis
- Evolvability Analysis
- Interface Requirements Traceability Analysis
- Comparison to Lower Level Architecture Specifications

IV&V Techniques

- Specification Completeness
  - DoDAF content checklists
- Levels of Specification Identification
  - Keyword and phrase pattern search vertically through document tree
- Scenario analysis
  - Scenario modeling, and simulation and test
- Fault Management and Redundancy Analysis
  - Error propagation analysis and containment
  - Coupling analysis
- Technical budgets Analysis
  - Budget identification from ADD and document tree
  - Analyze budget allocation, feasibility
- Mapping Tasks (Functional Capability Mapping, Dependency Mapping Analysis, I/F Requirements Traceability Analysis, Top-level Requirements Mapping)
  - Quality function deployment (QFD) matrix

Tool Support Opportunities

- Smart keyword search
- Budget mapping tool
- Scenario visualization and testing
- Tracing tools (implement QFD House of Quality)



Architecture Analysis Tailoring

- Involves selecting project-applicable tasks
- Guided by project manager's tailoring goals
  - Breadth vs. depth
  - Comprehensive vs. limited
- Driven by many factors
  - Overall system criticality and risk
  - Architecture style (DoDAF, 4+1, etc)
  - Mission type/System type
  - Development approach
  - Development phase
  - Artifact availability and maturity
  - Task dependencies

Summary

- Architecture IV&V essential
- CSADD-inspired ADD improvements
  - Completeness
  - Verifiability
  - Levels of abstraction
- IV&V architecture methodologies
  - Ideal task set covers all aspects of architecture
  - Techniques achieve tasks
  - Tools facilitate and automate techniques