

# **Verification Technology Potential with Different Modeling and Simulation Development and Implementation Paradigms**

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**Session A1**

**Foundations for V&V in the 21st Century Workshop (Foundations '02)**

**The Johns Hopkins University Applied Physics Laboratory**

**Laurel, Maryland (USA)**

**October 22-24, 2002**

# Agenda

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- Introduction
- Overview of V&V Concepts, Processes, and Methods
- “Modern” V&V Challenges

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- VV&T Throughout the Simulation Life Cycle
- Myths about Simulation Model V&V
- Potential Future Research Directions
- Conclusions and Recommendations

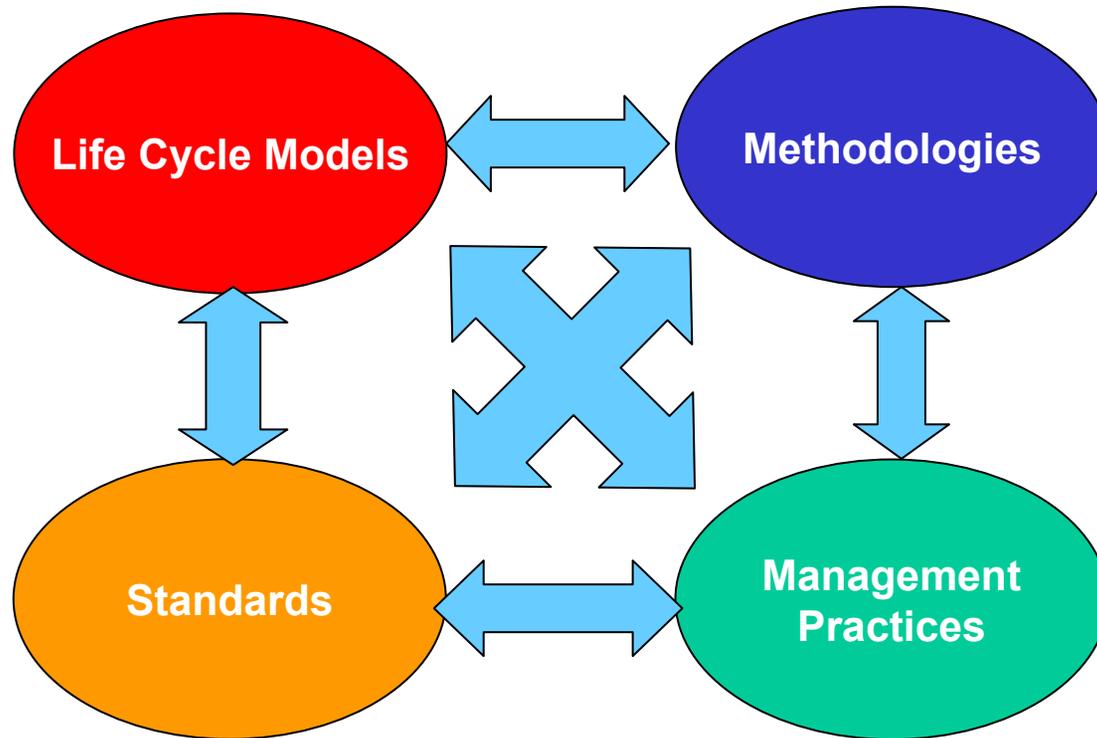
# Introduction

- ***Hypothesis 1:***
  - Traditional Verification & Validation techniques and practices must be adapted to modern software development methodologies.
- ***Hypothesis 2:***
  - The Modeling & Simulation application domain presents unique V&V challenges and opportunities.

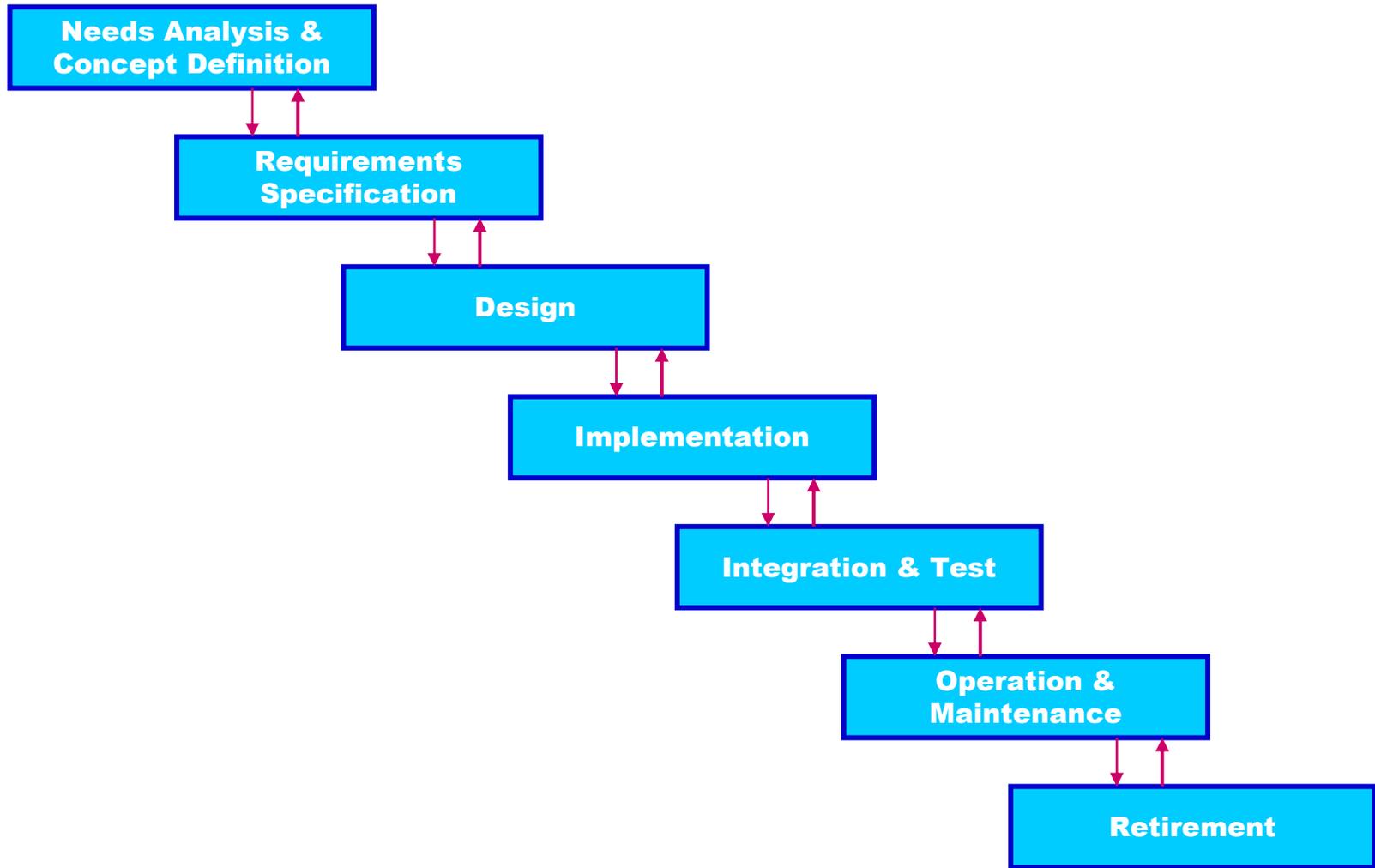
# **Software Development Life Cycle Models**

- **Staged – “Waterfall” Model**
- **Incremental Build Model**
- **Spiral Model**
- **Object-Oriented “Fountain” Model**
- **Rapid Application Development**
- **Agile Methods**

# Software Engineering Model



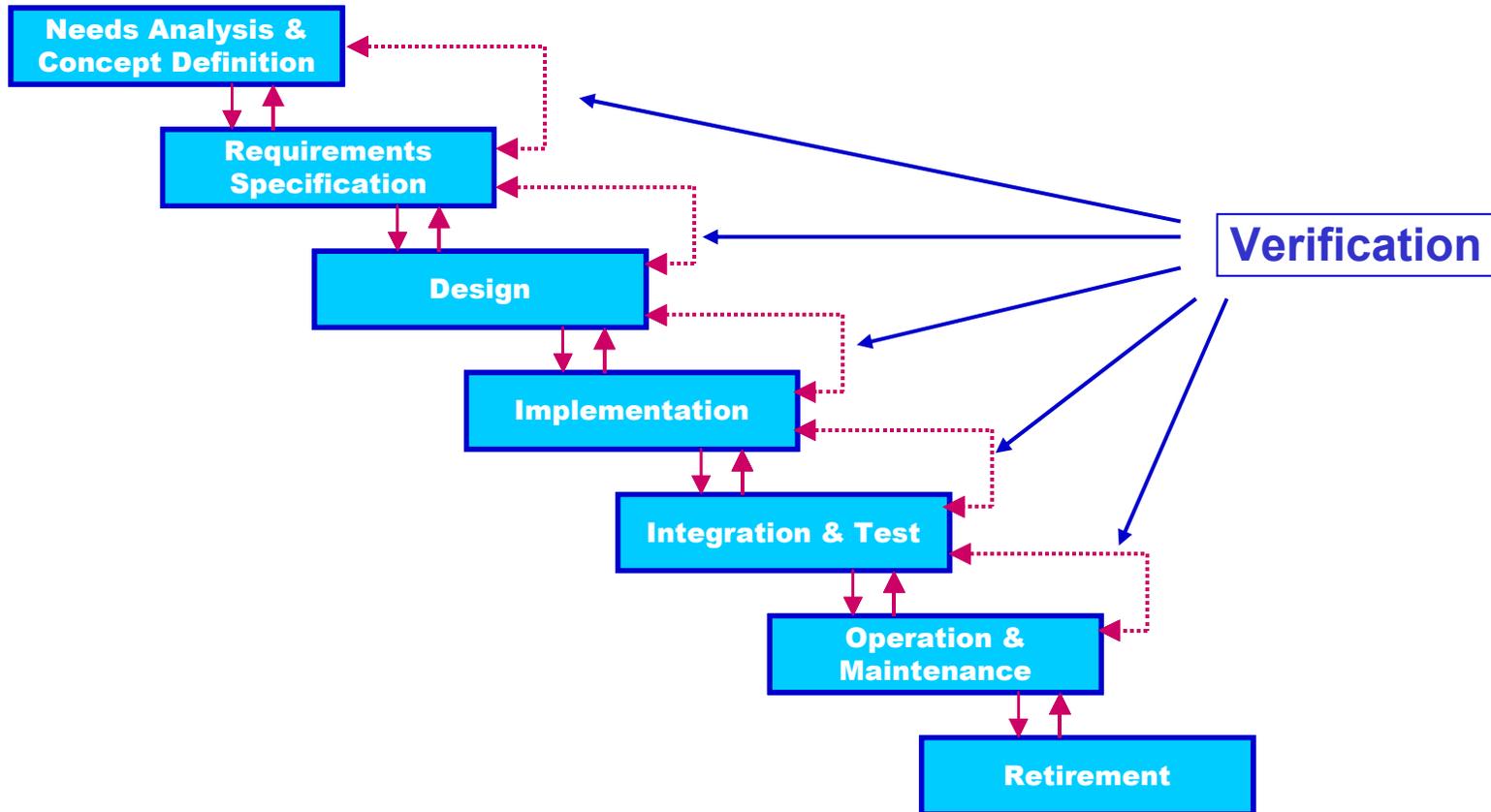
# The “Waterfall”



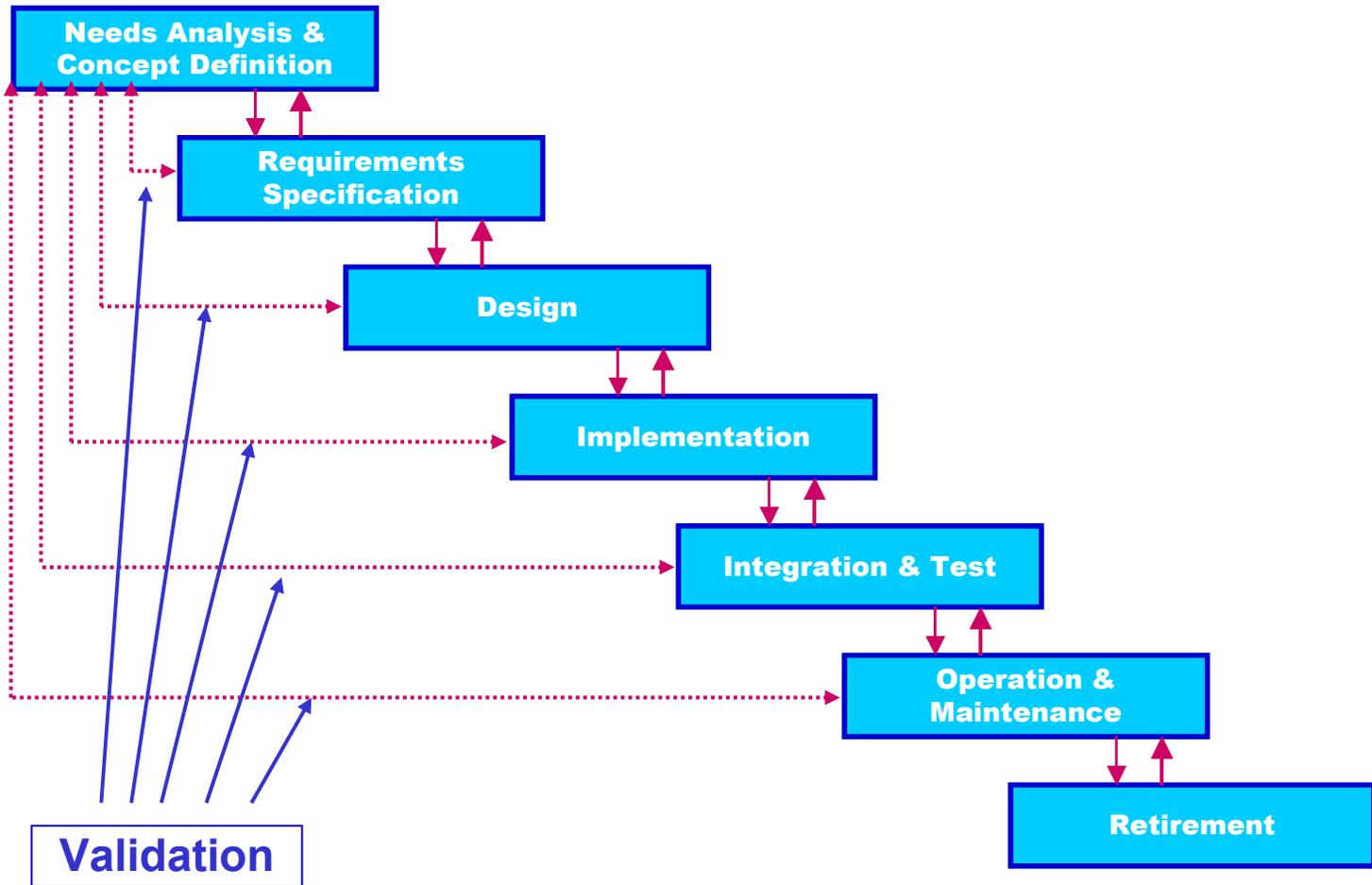
# Definitions

- **Verification:**
  - **Guaranteeing that the artifacts produced in a particular phase conform to specifications and requirements established in the preceding phase(s).**
  - ***“Build the thing right.”***
- **Validation:**
  - **Guaranteeing that the software product actually meets user needs and expectations.**
  - ***“Build the right thing.”***

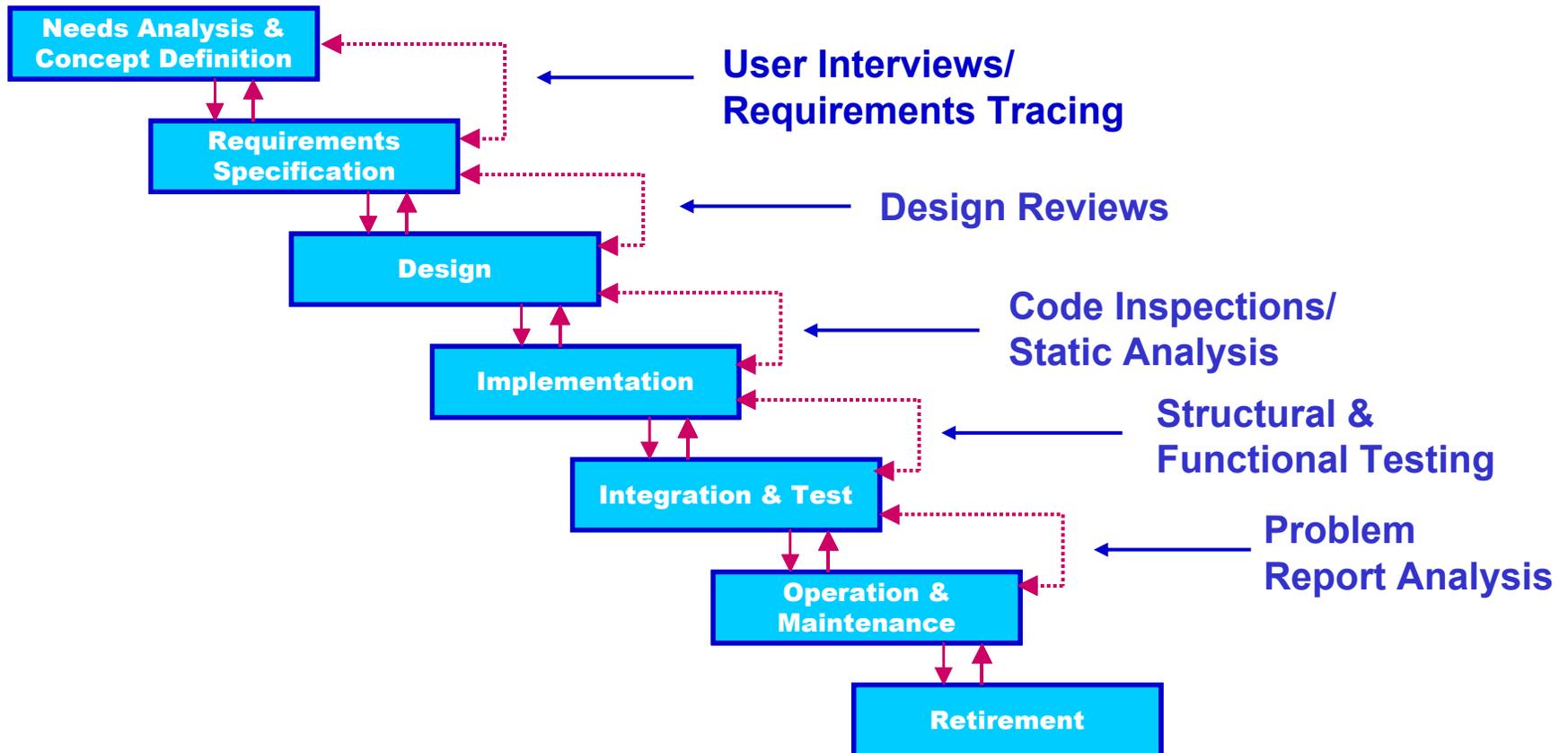
# Verification Interfaces



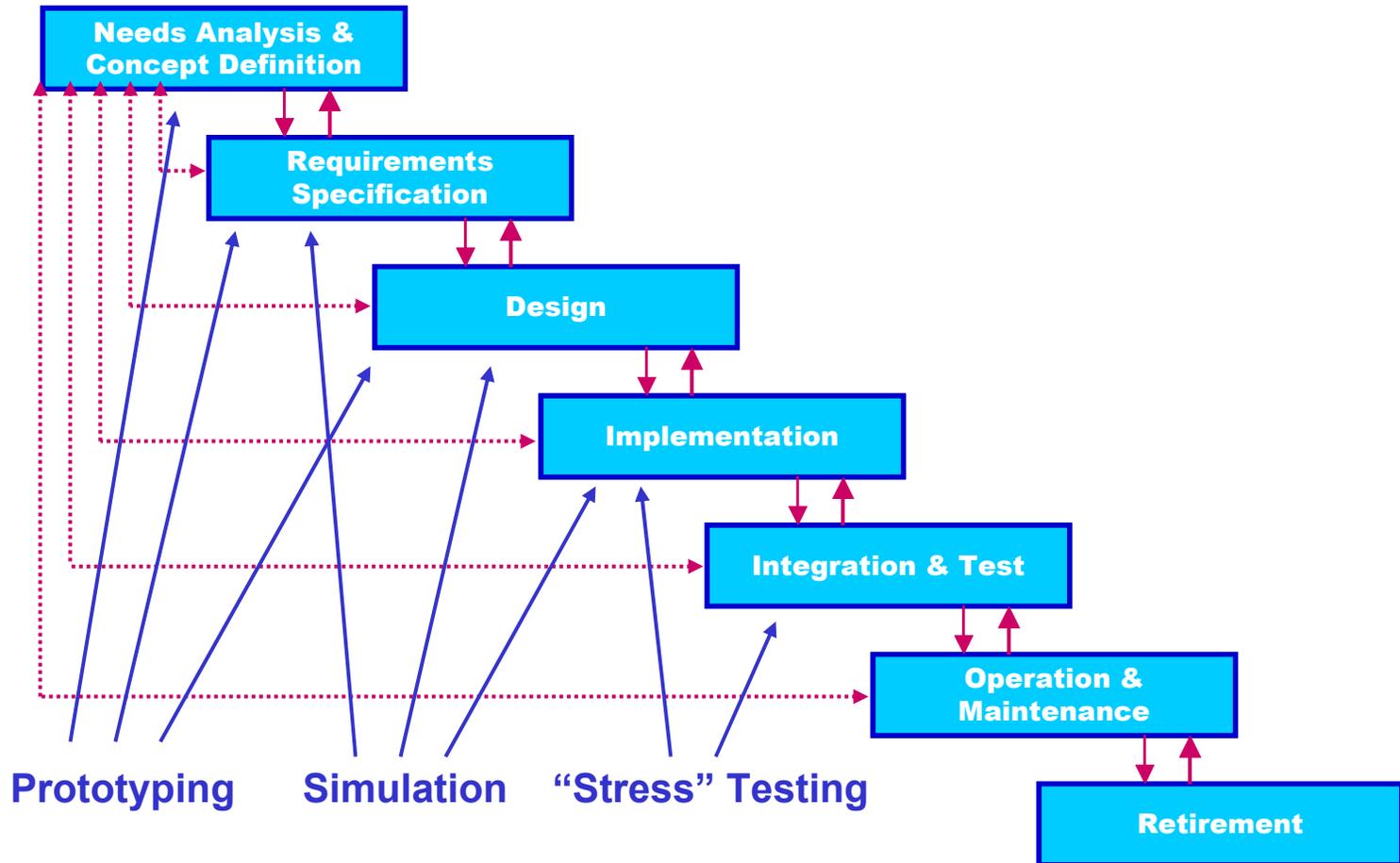
# Validation Interfaces



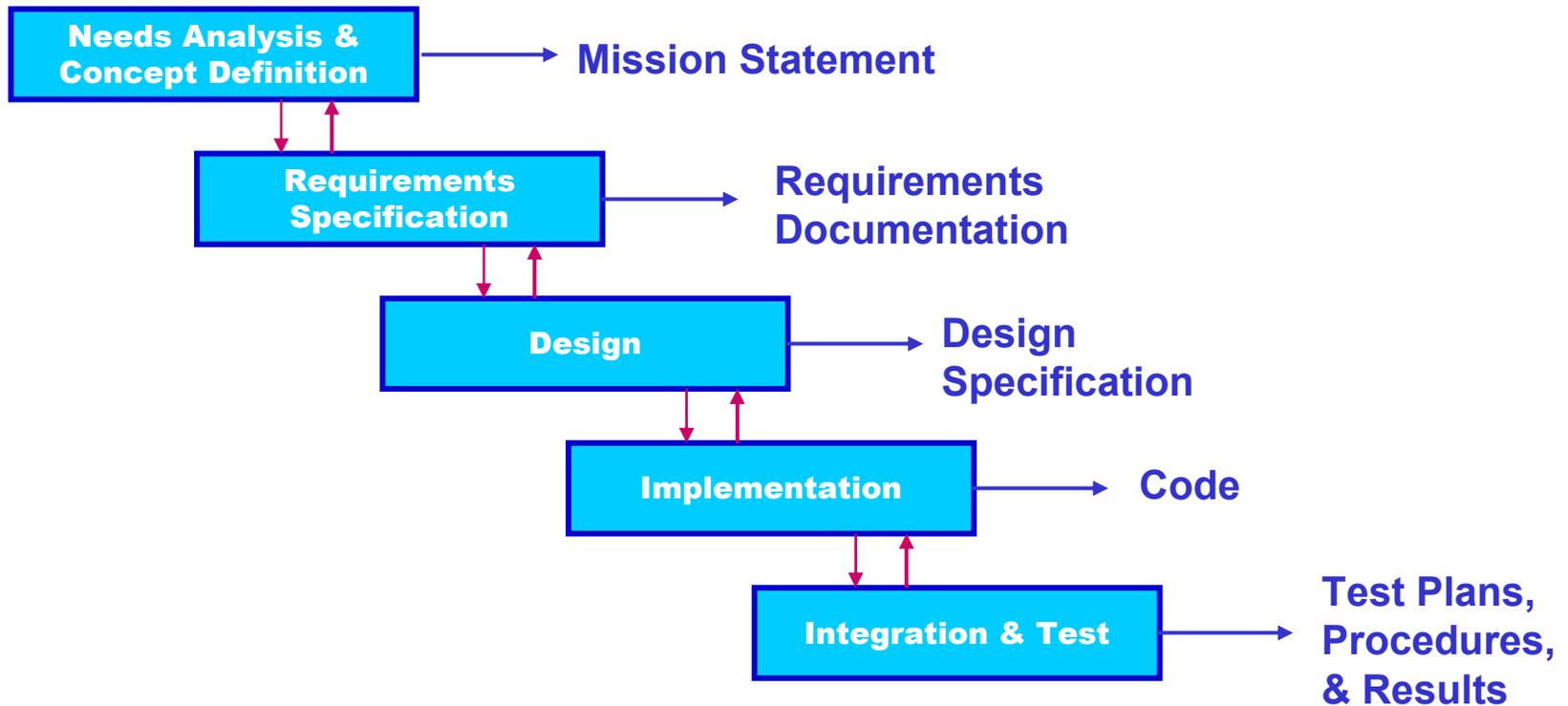
# Verification Techniques



# Validation Techniques



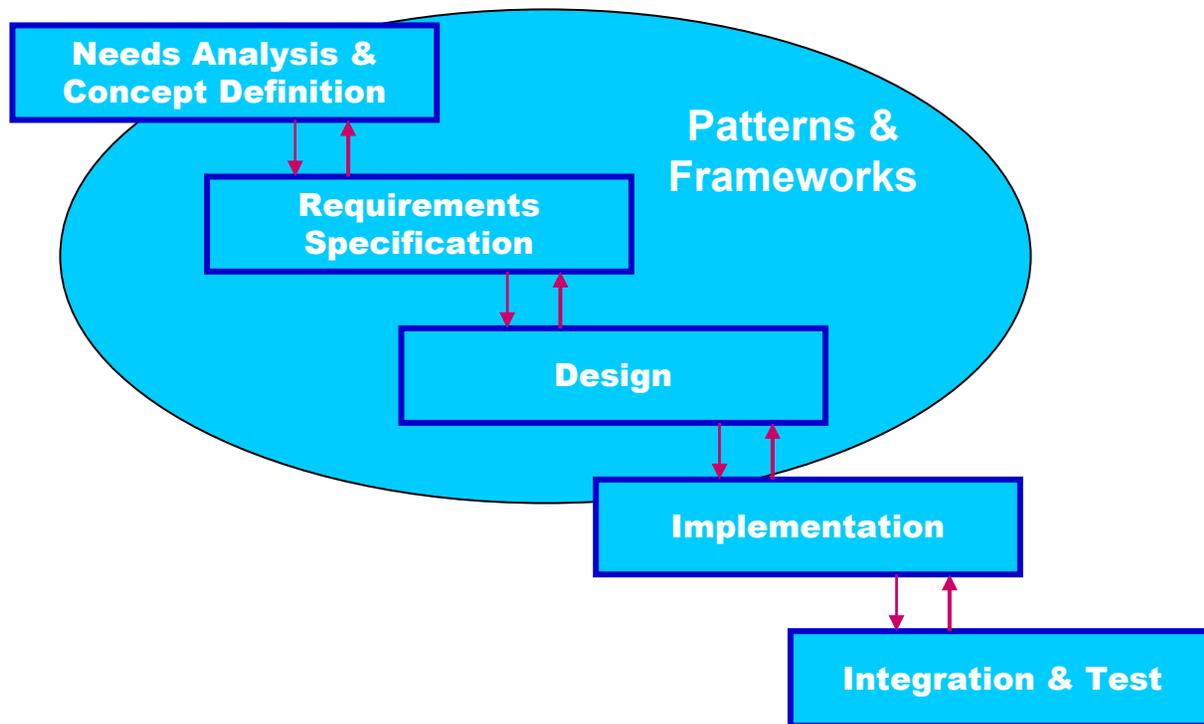
# Traditional Artifacts



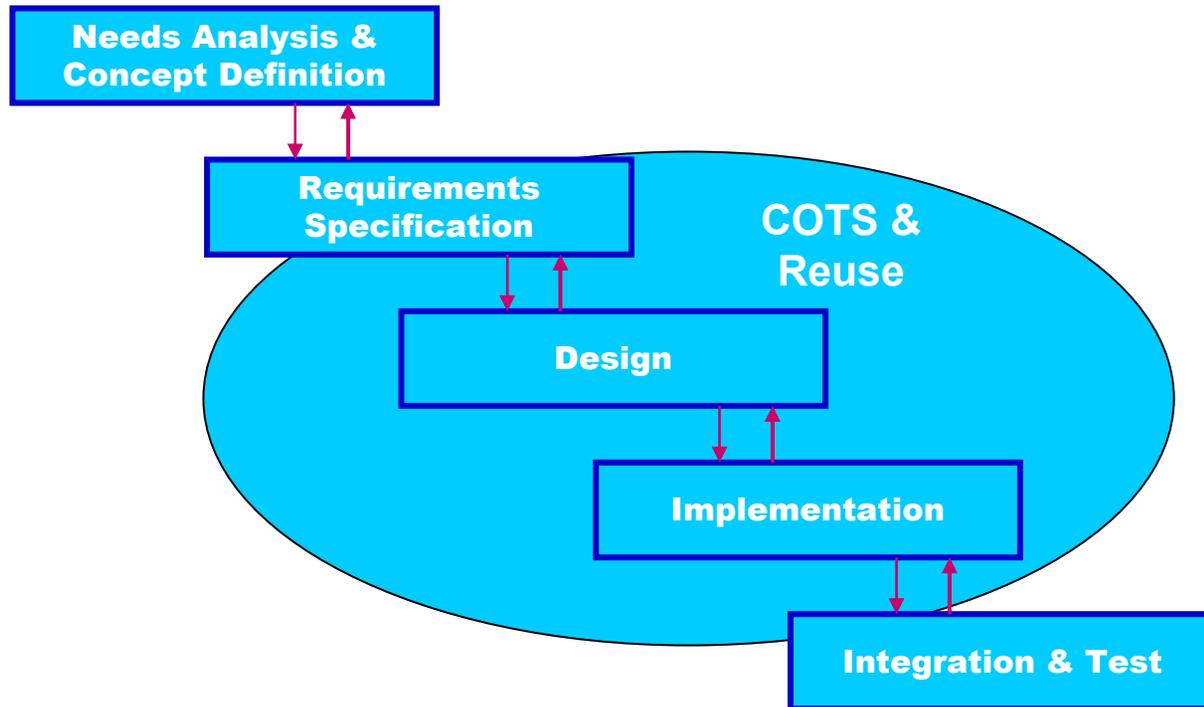
# Challenges to Traditional V&V

- **Patterns and Frameworks**
- **COTS and Reuse**
- **Agile Methods**

# Patterns & Frameworks



# COTS and Reuse



# Manifesto for Agile Software Development

- ***Individuals and interactions over processes and tools***
- ***Working software over comprehensive documentation***
- ***Customer collaboration over contract negotiation***
- ***Responding to change over following a plan***

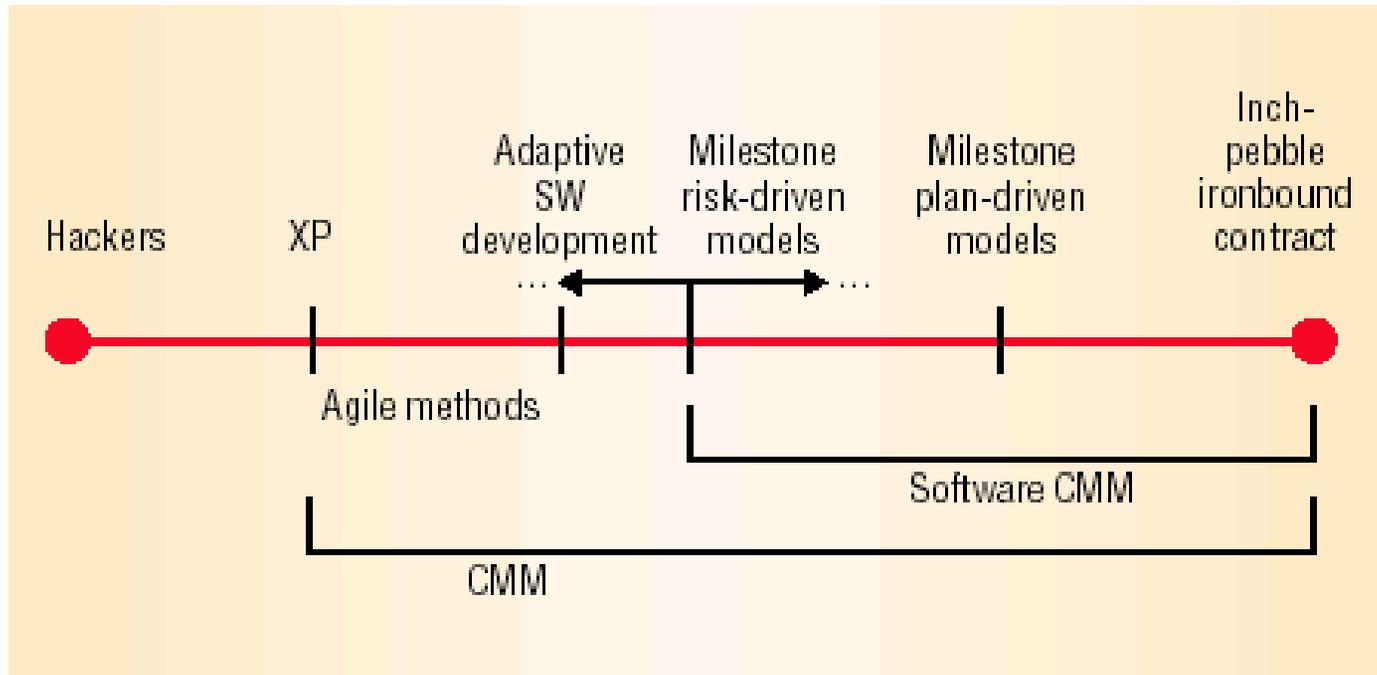
# Sample Agile Methodologies

- **Adaptive Software Development**
  - James Highsmith
- **XP (Extreme Programming)**
  - Communication, Feedback, Simplicity, Courage
  - Kent Beck
- **Crystal Family**
  - Different projects require different methodologies
  - Number of people in project and consequence of errors
  - Alistair Cockburn
- **Open Source**
  - Geared to physically distributed teams
  - Maintainer - project coordinator who can change source code

# Adaptive Development Model

- **Customer driven world where fast production changed from a competitive advantage to a competitive necessity.**
  - **Delivers quality solutions fast**
  - **Evolutionary Life Cycle**
  - **Spiral Model**

# The Planning Spectrum

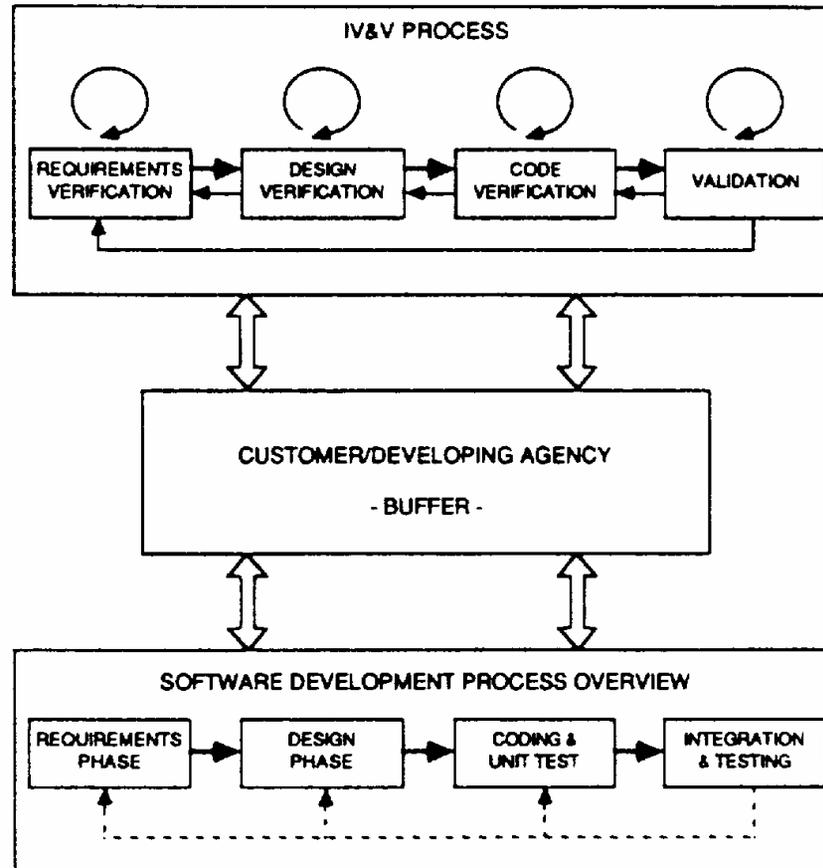


Boehm, p. 65

# When Should V&V Begin?

- **Full, In-phase V&V**
  - Requirements Definition through Acceptance Test
- **Partial V&V**
  - After Requirements are defined
- **Audit-Level V&V**
  - Review Emerging Product at key points

# Software Development - V&V Relationship

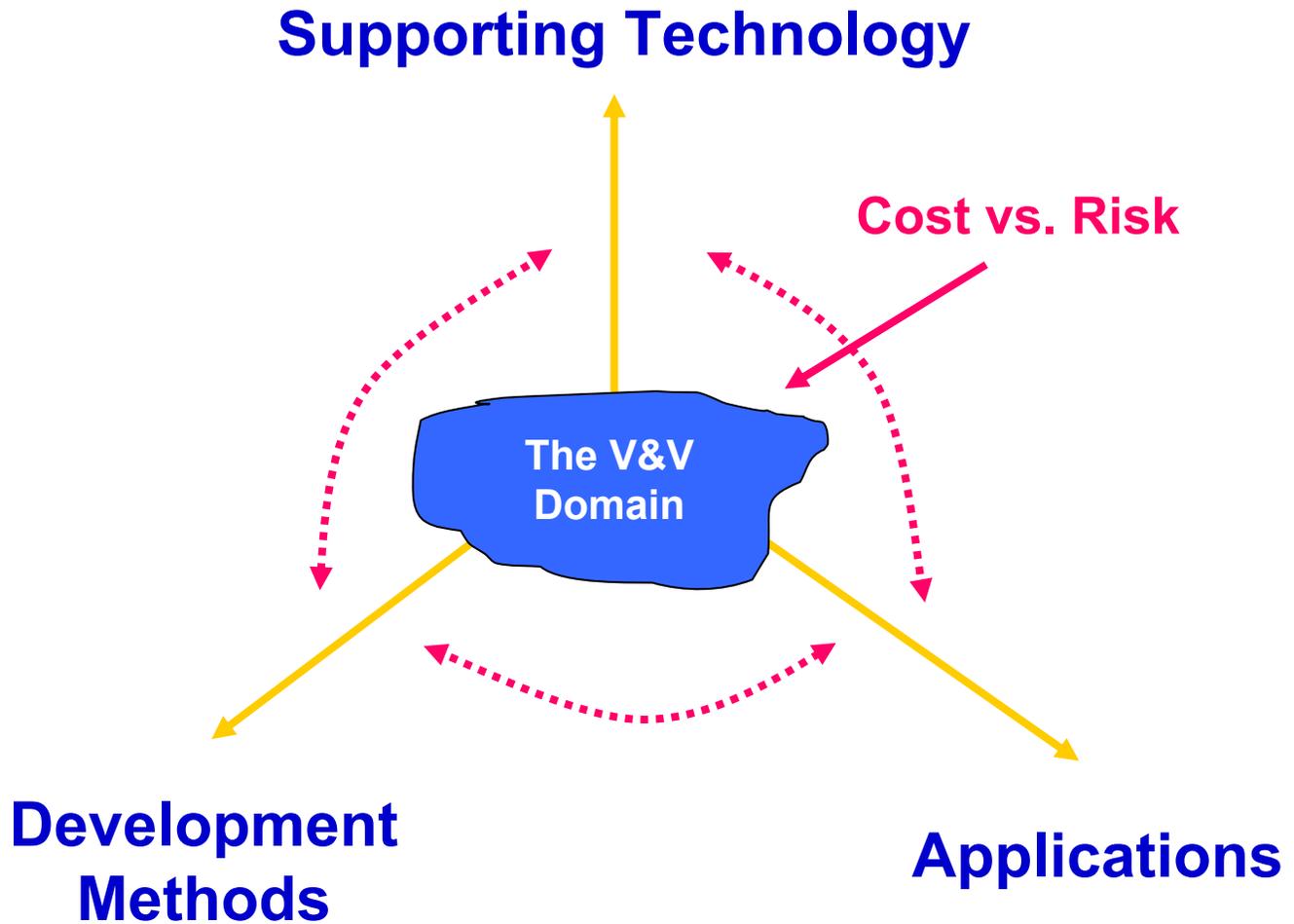


Lewis, p. 70

# V&V Organization Alternatives

- **V&V**
  - Performed by the developing organization
- **IV&V (Independent V&V)**
  - Performed by an organization independent from the developer or customer
- **IIV&V (Independent Internal V&V)**
  - Performed by a group within the developer's organization that is independent from the project organization

# Trends Affecting V&V Practice



# Agenda

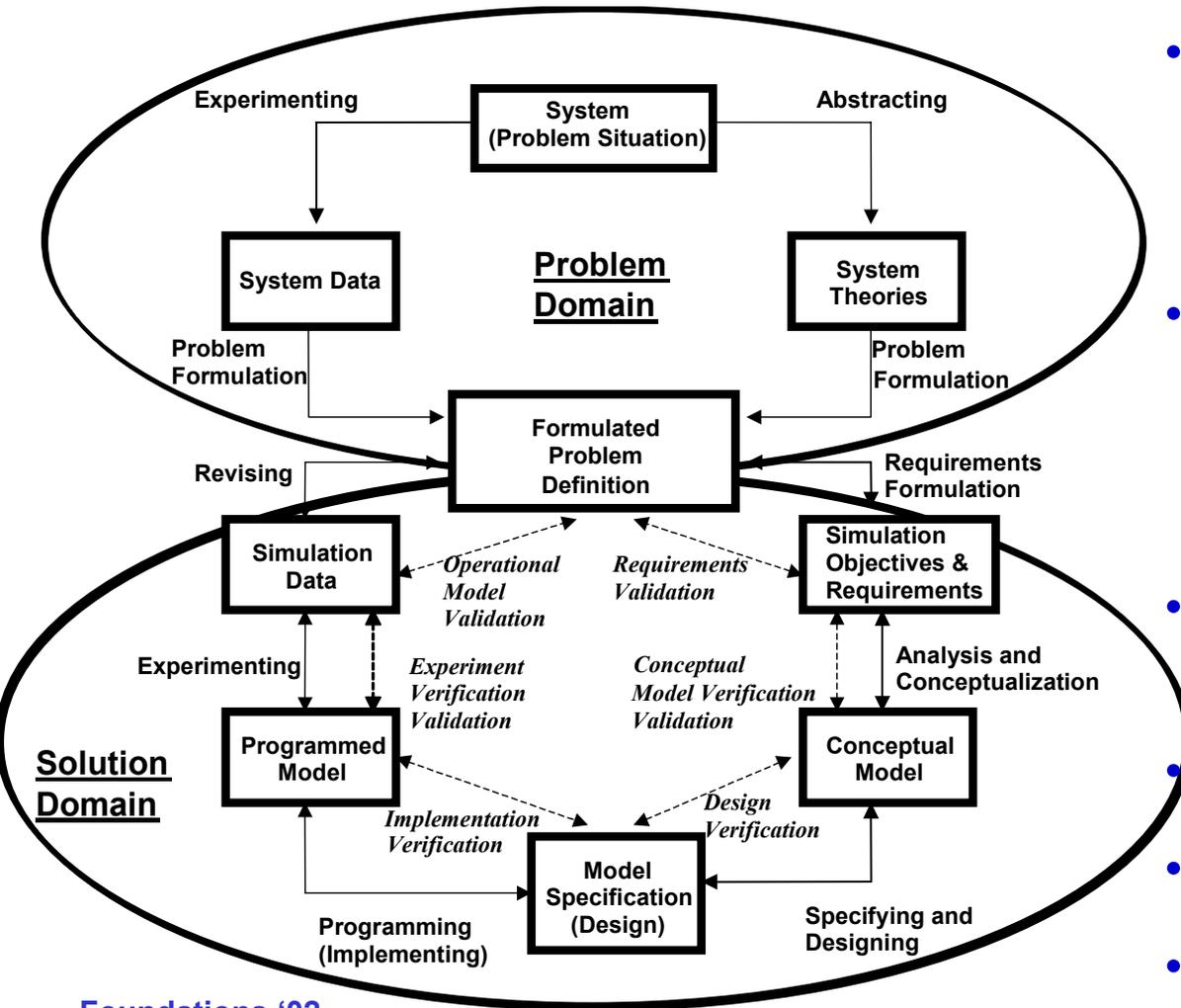
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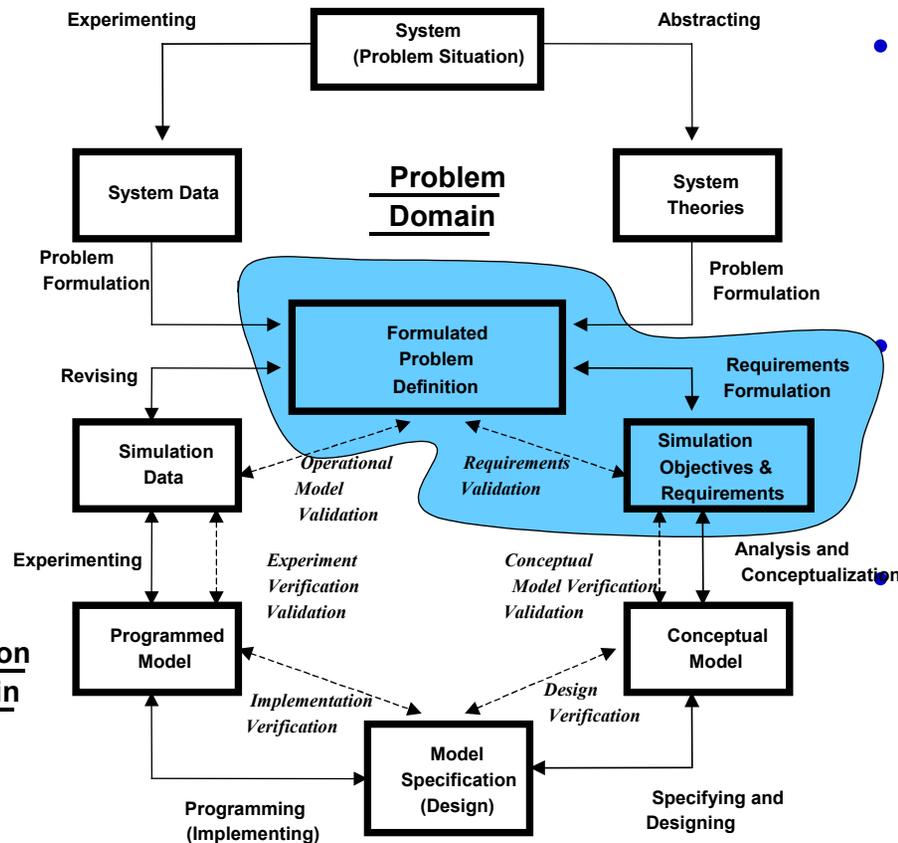
# Simulation Modeling Life Cycle



- Simulation Objectives and Requirements
  - Simulation Context
- Model Conceptualization
  - Mission Space
  - Simulation Space
- Model Specification and Design
- Model Implementation
- Experimentation, and
- Revision

# VV&T Throughout the Lifecycle

*(Simulation Objectives and Requirements Validation)*



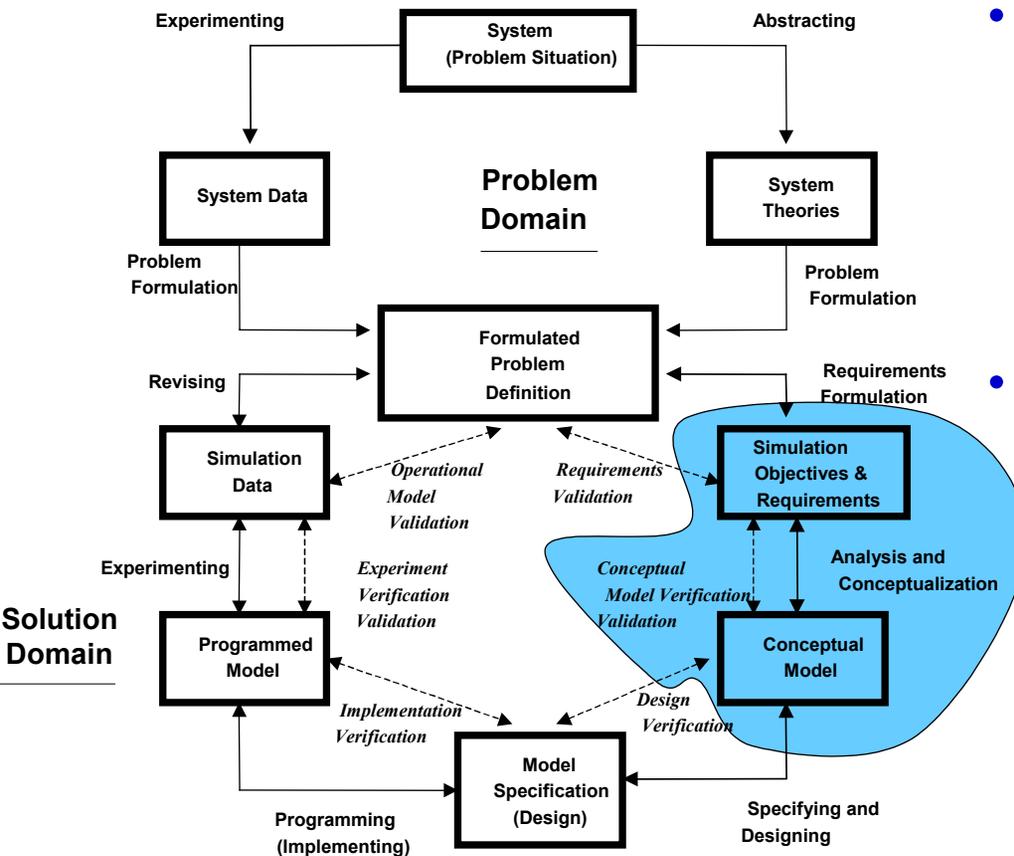
- Authoritative information, doctrine, and strategies of the system's context need to be taken into account.

Is the system's environment and boundaries identified accurately?

Interdependencies and organization of the system need to accurately characterized.

# VV&T Throughout the Lifecycle

(Simulation Conceptual Model Verification and Validation)



- Stochastic processes and their constraints such as linearity, independence, stationary, and probabilistic distributions of arrivals.

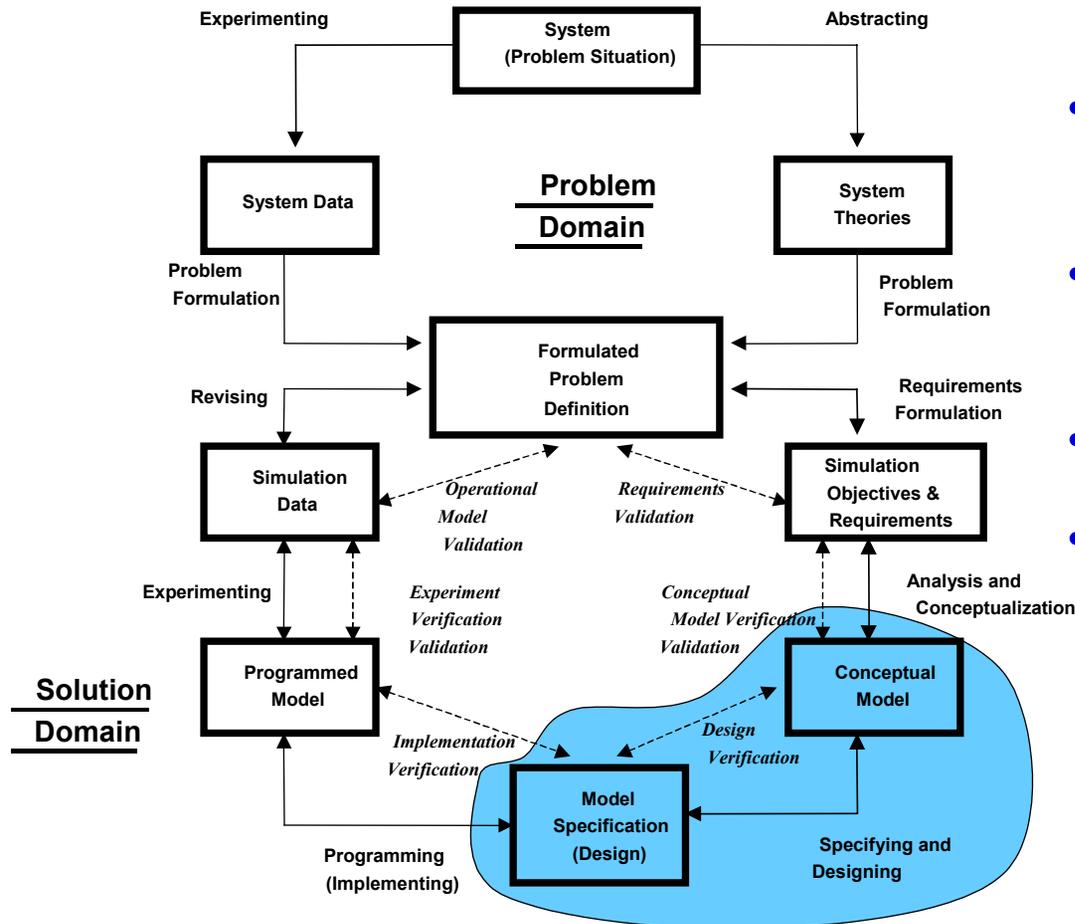
- Completeness, consistency, coherency, and correctness

Consistency and interoperability with regard to potential simulation features such as attribute/component fidelity, coordinate systems, event timing etc.

# VV&T Throughout the Lifecycle

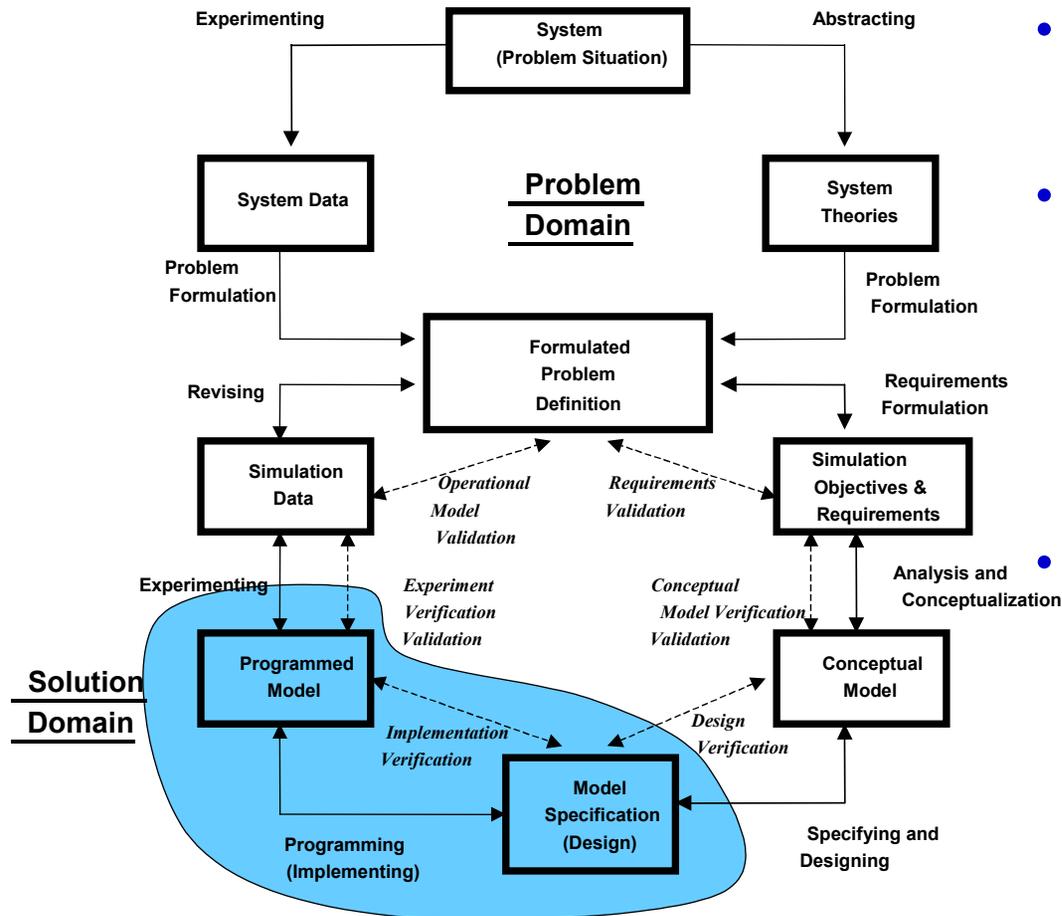
## (Simulation Model Design Verification)

- Design consistency, completeness, ambiguity
- Traceability and conformance to conceptual model
- Design Quality (Metrics)
- Formal Methods (Model Checking)



# VV&T Throughout the Lifecycle

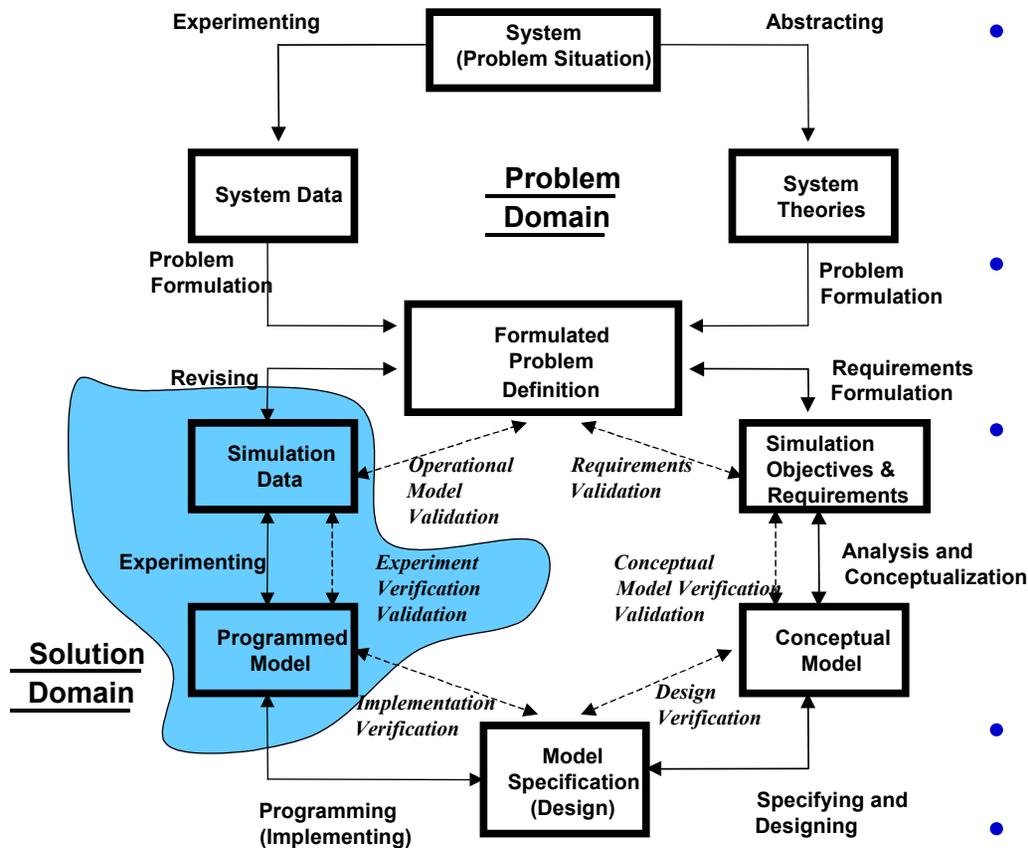
(Simulation Model Implementation Verification)



- Conformance and accuracy with respect to design
- Model analysis deals with the static analysis of the software or model realization to predict certain control and data-flow properties of interest
- Model testing, on the other hand, is performed to demonstrate the existence of errors in the model by subjecting the model to test cases

# VV&T Throughout the Lifecycle

(Simulation Model Experiment Design Verification and Validation)



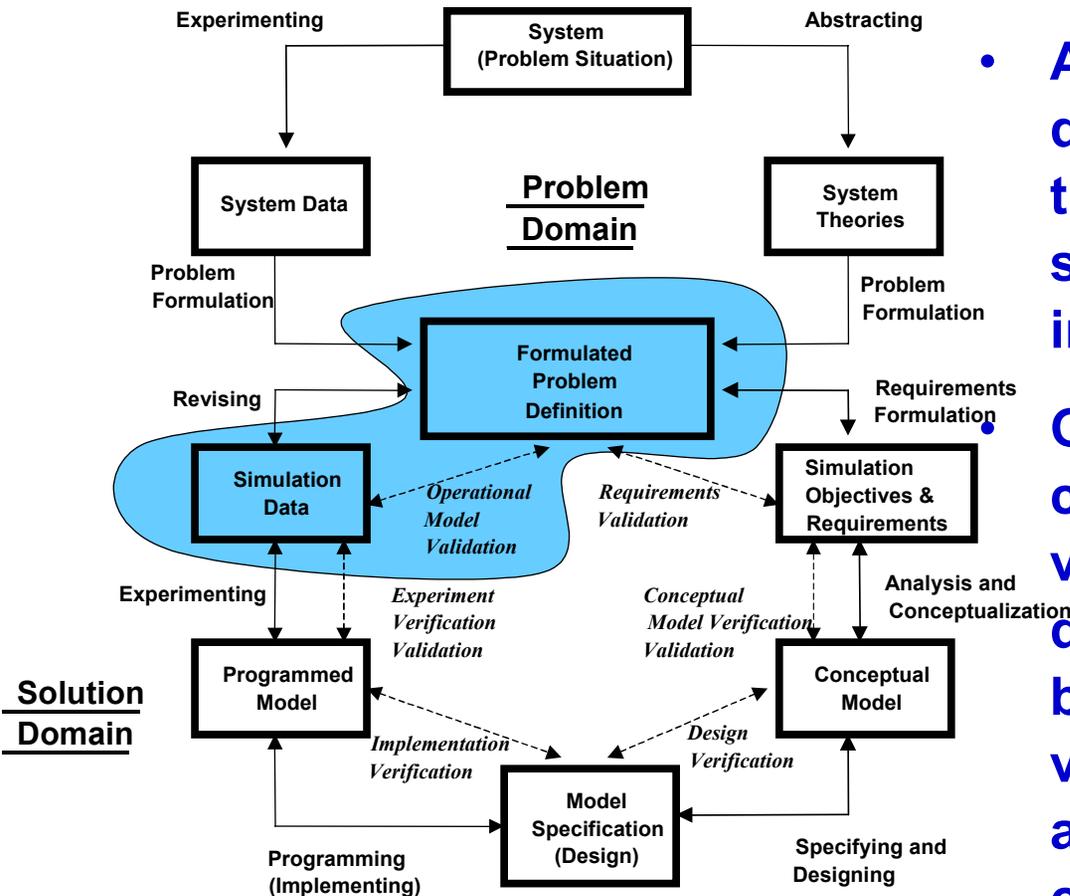
- Random variate generation accuracy and implementation correctness
- Random number generator testing
- Appropriateness of simulation experiment design and statistical techniques used for inference
- Start-up problem
- Identical experiment conditions

# VV&T Throughout the Lifecycle

## (Simulation Model Operational Validation)

- Accuracy with respect to system data, theories, and definition for the intended purpose of the simulation study over its intended domain of applicability

Graphical comparisons of data, comparisons of means, variances, maximums, and distributions, relationships between different output variables, statistical significance and hypothesis testing, and confidence intervals



# **Myths about Simulation Model Verification and Validation**

- **Myth 1: Model V&V can guarantee correctness, absolute validity, and credibility.**
- **Myth 2: Model V&V deals only with substantiating the accuracy of simulation models.**
- **Myth 3: Models can be considered valid and credible as long their response behavior is an objective reflection of the system entity.**
- **Myth 4: Model V&V requires highly trained statisticians and mathematicians.**

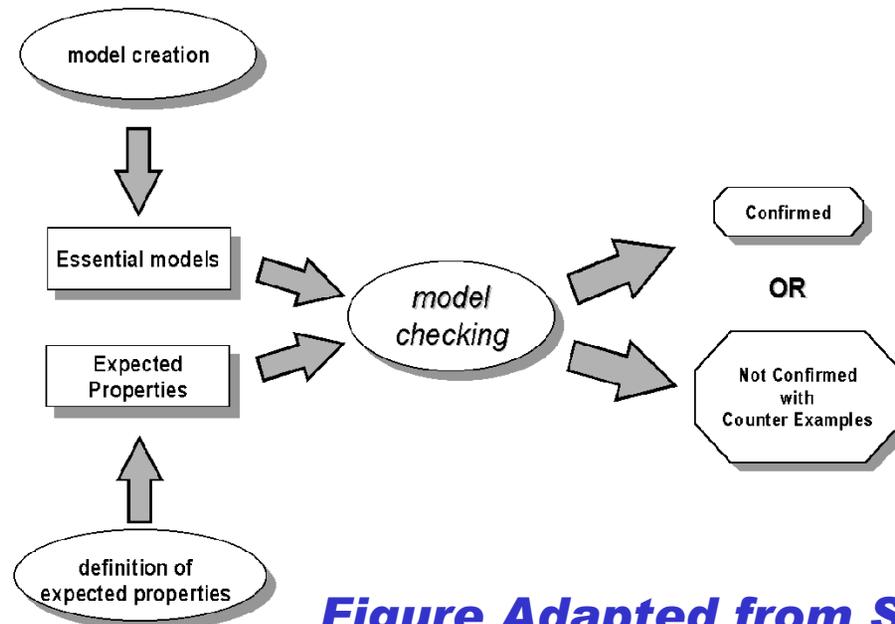
# **Myths about Simulation Model Verification and Validation**

- **Myth 5: Model V&V always increases the cost of the development.**
- **Myth 6: Model V&V always delays the development process.**
- **Myth 7: A simulation model is built and validated with respect to certain study objectives, therefore, it can not credibly be reused in a new context.**
- **Myth 8: Independent model V&V (IV&V) is not necessary since compliance to process models such as CMM guarantees high quality and credible models**

# Emerging Prospects for Model V&V Research

*(Formal and Semi-Formal Automated Methods for Model V&V)*

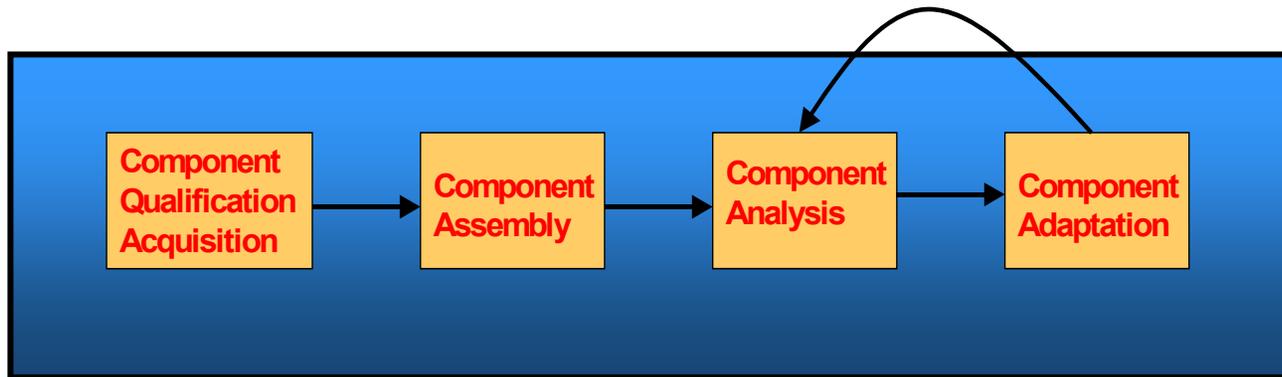
- **Mathematically based techniques that provide frameworks within which model developers can specify, reason, and verify about designs and simulations.**



**Figure Adapted from SEI MBV Initiative**

# Emerging Prospects for Model V&V Research

(Model V&V with Reuse: Connections with Interoperability)

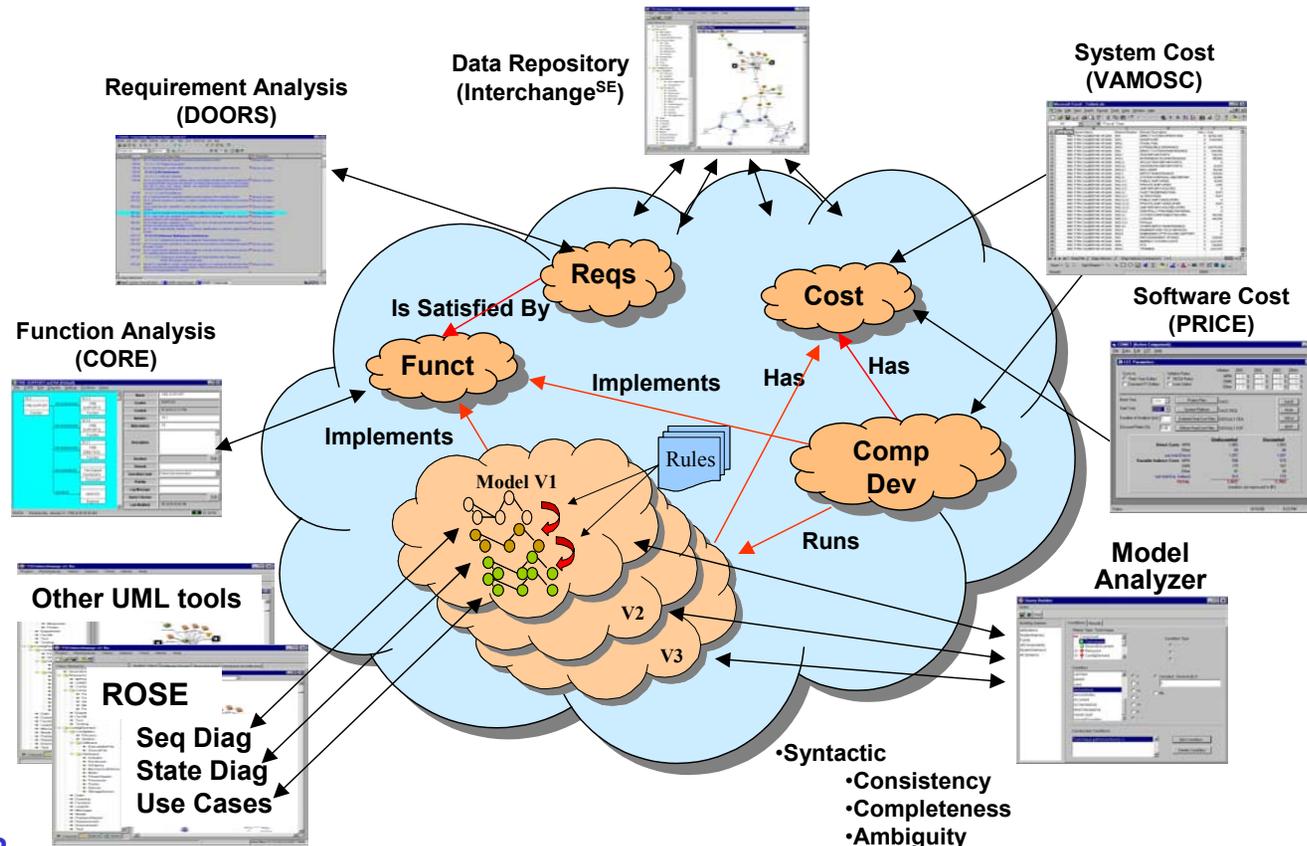


- *Qualification*: How to query and retrieve published reusable and semantically compatible components? (*Semantic vs. Syntactic Matching and Similarity Metrics*).
- *Analysis*: How do we assure that the actual components conform to formulated metadata before publishing? How can we determine if the composition is consistent and coherent?

# Emerging Prospects for Model V&V Research

## (Conceptual Model Consistency)

- Intra/Inter model consistency in distributed collaborative model engineering.



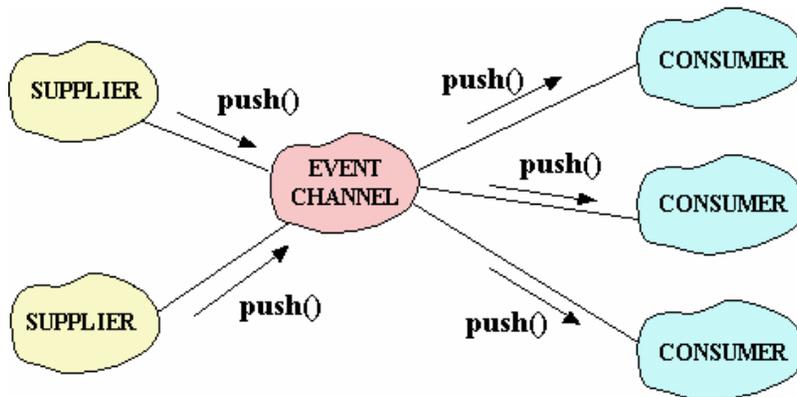
# **Emerging Prospects for Model V&V Research**

*(Emergent Issues in Agent-Based Simulation Model V&V)*

- **Agent facilitate simulation of complex adaptive systems that constitute autonomous, intelligent, reactive, proactive, and goal-directed entities.**
- **New abstraction, organization, and decomposition mechanisms for system simulation are introduced.**
  - **collaboration, coordination, task distribution, and adaptive behavior require focusing on interactions**
  - **causality, mechanism, non-linear dynamics, process, and flows need to be addressed by new V&V methodologies**

# Emerging Prospects for Model V&V Research

*(Performance Testing of Distributed Active Systems with Publish / Subscribe Architectures: HLA Performance Benchmarking )*



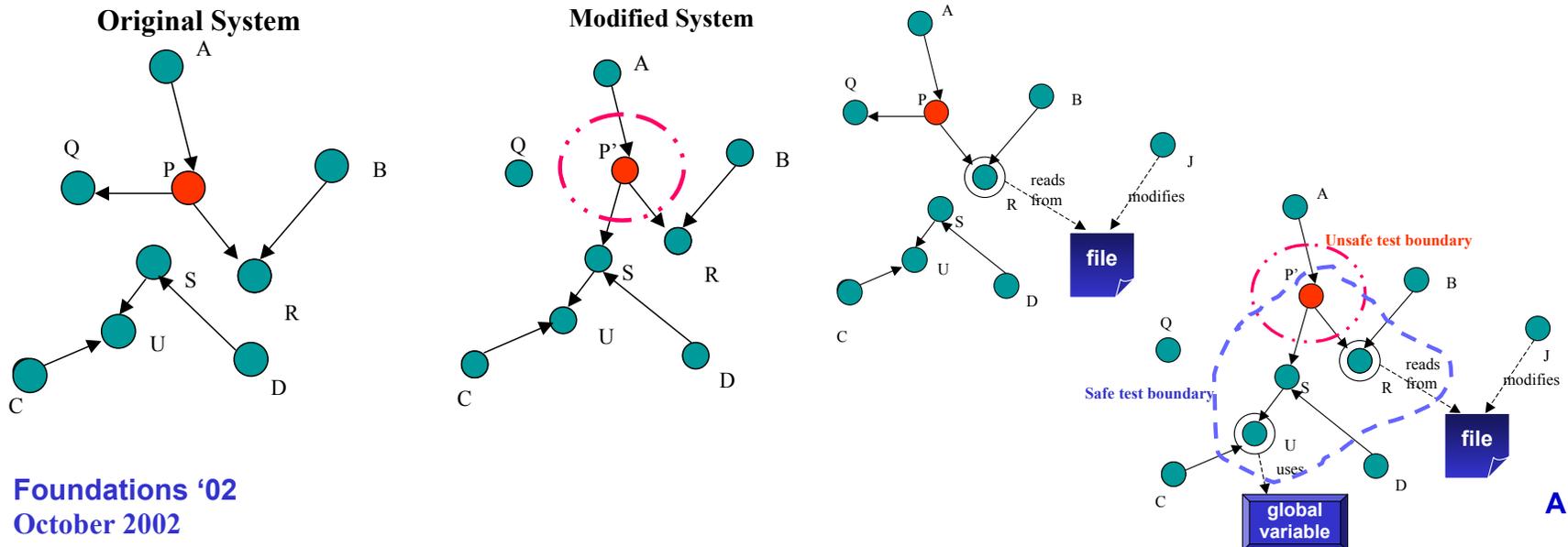
- **Need P/S performance experiment and scenario generators for HLA**
  - **Configure, execute, and monitor**
  - **Statistically and visual post analysis.**

- **Simulations are increasingly integrated with C4I.**
  - **Performance bottlenecks would result in unacceptable and ineffectual simulations.**
  - **HLA is a DAS with a P/S architecture.**

# Emerging Prospects for Model V&V Research

*(Safe Model Test Boundaries: Managing the Evolution of Models)*

- Current complex systems engineering practice is component-based and compositional. NOT top-down.
- State of the practice in complex systems development require
  - Reuse and integration of legacy models, model migration to new platforms, deployment of modernized COTS components, processor technology insertion recertification

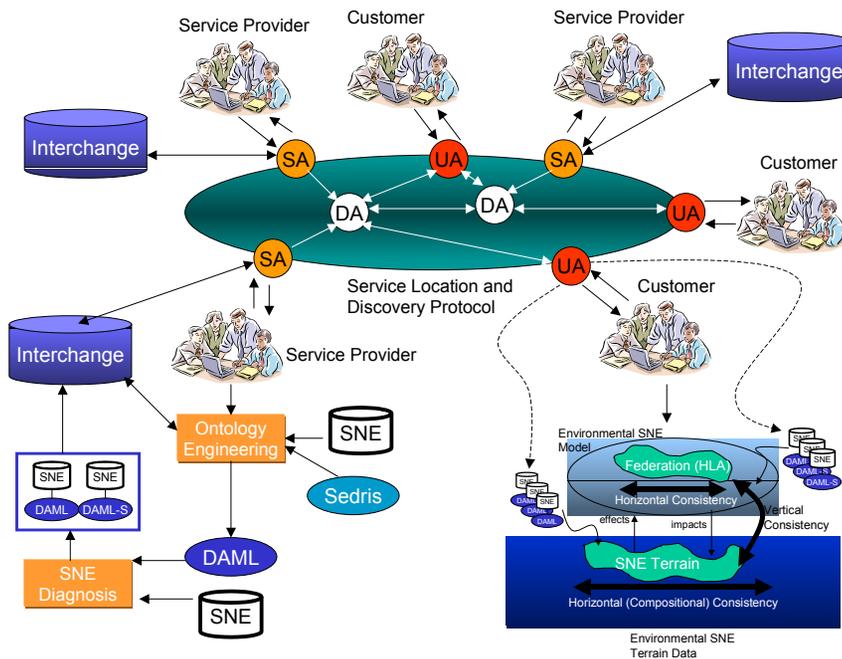


# Emerging Prospects for Model V&V Research

## *(Integrative Parameterized Modeling of SNE)*

- **Problem:** Effective retrieval and rapid composition of sufficiently consistent and interoperable SNEs

- **Solution:** Need uniform process and methods to retrieve, integrate & correlate multiple sources of SNE metadata/model specs.



**SEDRIS** is not sufficient for semantic retrieval and analysis

# Recommendations

- **Model V&V needs to be treated as a confidence building activity.**
- **Focus on quality in addition to accuracy is needed.**
- **Achieving technical, financial, and managerial independence to establish the credibility of simulation models need to be recognized.**
- **More research is needed to establish the principles of predictable compositional modeling.**
- **A career path for V&V practitioners that constitutes continuous training and learning is essential.**

# Conclusions

- **New paradigms and methodologies require new perspectives and V&V approaches.**
- **We need more fundamental research, education, and dissemination of V&V knowledge.**
- **Empirical research on the utility and benefits of IV&V is needed to convince M&S application sponsors..... then application developers will follow.**

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