Review 5281217

System Behavior Specification Using IEEE Std 1175.4

27 April 2010

Dr. Dwayne L. Knirk
Distinguished Member Technical Staff
Sandia National Laboratories

1. REPORT DATE **27 APR 2010**	2. REPORT TYPE	3. DATES COVERED **00-00-2010 to 00-00-2010**
4. TITLE AND SUBTITLE **System Behavior Specification Using IEEE Std 1175.4**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Sandia National Laboratories,PO Box 5800,Albuquerque,NM,87185**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES **Presented at the 22nd Systems and Software Technology Conference (SSTC), 26-29 April 2010, Salt Lake City, UT. Sponsored in part by the USAF. U.S. Government or Federal Rights License**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**30**	

Prologue

- **System behavior is what delivers value into an application domain, but frequently it is not well understood even after the system has been realized**

- **The concepts and language for describing system behavior are not adequately addressed in many system development methodologies**

- **IEEE Std 1175.4™-2008 provides a conceptual model for describing the behavior of many kinds of engineered systems**

27 April 2010

Sandia National Laboratories

Questions to be Addressed

About System Behavior Description

- What is the System?
- What is System Behavior?
- What is a System Behavior Description?
- Where does it fit the Development Life Cycle?

About IEEE Std 1175.4

- What does 1175.4 standardize?
- What descriptive concepts does it provide?
- What can be learned from a Behavior Description?

About Using Behavior Descriptions

- What use is a Behavior Description?
- How can you use it?

27 April 2010

Sandia National Laboratories

What is the System?

ISO/IEC 15288, Clause 5.1.2

- **The system [is] man-made, created and utilized to provide products and/or services in defined environments for the benefit of users and other stakeholders.**

Why

- **Purpose is to alter some stakeholders' environment(s)**
- **Value is the benefit of change to those stakeholders**

How

- **Through interactions with the environment**

27 April 2010

Sandia
National
Laboratories

What is System Behavior?

A Scientist's View of the Philosophy of Science

- **Behavior is the ongoing interaction of the individual with its environment; It is transient**

- **The environment with which the individual interacts must be described and understood**

- **The science of behavior must be descriptive and classificatory**

- **The key to both the methods and concepts of behavior science is measurement**

William S. Verplanck (http://web.utk.edu/~wverplan/apapaper.html)

27 April 2010

Sandia National Laboratories

What is a System Behavior Description?

A Model

- Represents some aspects of the system, but is simpler
- Enhances understanding and agreement about those aspects
- Does not misrepresent the system

Behavior Description

- Represents the interactions of system with its environment and the rules governing the relationships among them (behavior)
- Does not allow inferences about system design
- When quantified, provides product specifications

27 April 2010

Sandia National Laboratories

What is a System Behavior Description?

Black – Box Description ☑

- Describes the behavior patterns of an individual
- Is expressed in terms perceptible outside the system
- Identifies cause-effect and functional relationships

White – Box Description ☒

- Describes the behavior patterns of a collection, given the behavior patterns of the individuals
- Is expressed in terms perceptible inside the system, but outside the individuals
- Identifies causal chains and functional compositions

Sandia National Laboratories

Where Does It Fit the Development Life Cycle?

Problem Domain: Need for a Result

– **Product Criteria, describes desired effects**

– **Stakeholder Requirements**

**Solution Domain: Concept for a Thing**

– **Product Requirements, describes offered capability**

– **System Requirements**

   behavioral, structural, environmental

Boundary between Domains is the System Boundary

• Requirements and Specifications, Michael Jackson (Addison-Wesley, 1995)
• ISO/IEC 15288:2008 Systems and software engineering — System life cycle processes

Sandia
National
Laboratories

Where Does It Fit the Development Life Cycle?
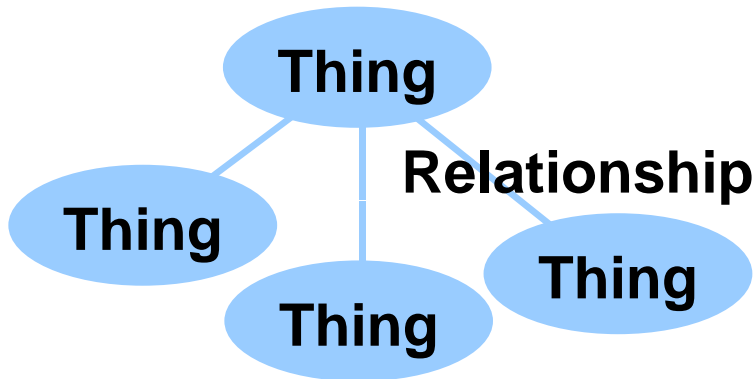
Problem Domain = Things with properties and relationships

Product Criteria = Effects created in the problem domain (new things, properties, and relationships)

Thing

Relationship

Thing

Thing

Thing

System

Interactions

Thing

Thing

Thing

Thing

Thing

Thing
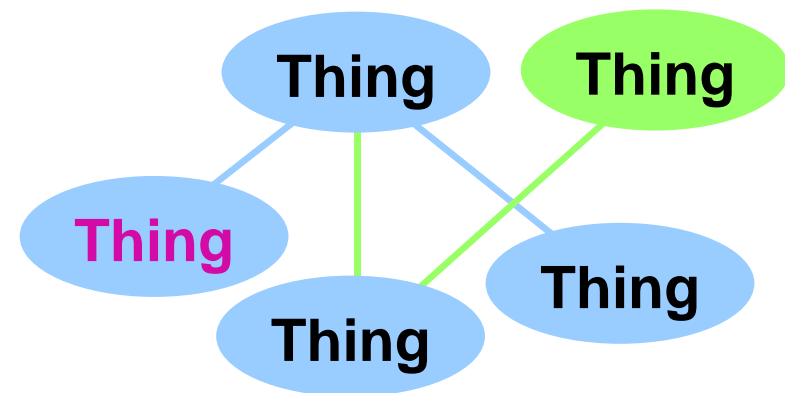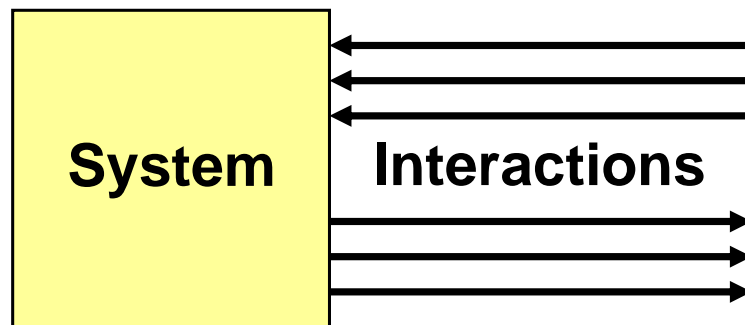
Solution Domain = System capability interacts with problem domain to bring about required effects

Sandia National Laboratories

Where Does It Fit the Development Life Cycle?

Conception	Formulation	Implementation	Evaluation

Mechanization

Software Design → Software Implementation

Problem Requirements → **Behavior Description** → Software Design

Trace and Pass / Fail

Testware Design → Testware Implementation

Demonstration

4/2/201027 April 2010

Sandia National Laboratories
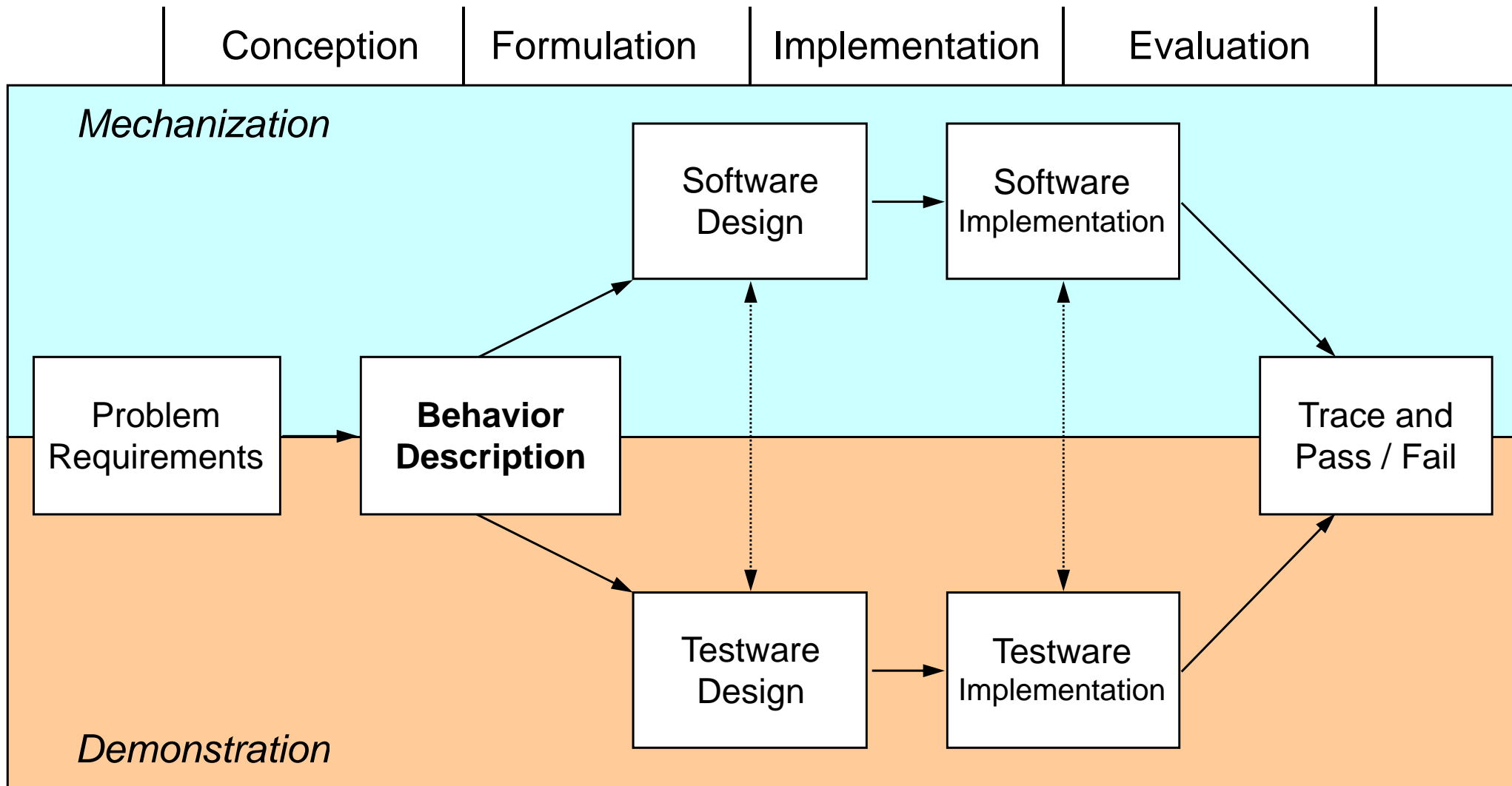
What Does 1175.4 Standardize?

Descriptive Model of System Behavior
- – **Not a design model for mechanism construction**
- – **Not a mathematical model for proof construction**

Goal is Understanding and Agreement
- – **Identify observables at the system interface**
- – **Identify repeatable patterns of relationships**
- – **Description of all possible lifelines**

To Answer
- – **How will the system be affected by the problem domain, and how will it affect the problem domain?**

27 April 2010

Sandia
National
Laboratories

What Does 1175.4 Standardize?

Presentation

| Graphical Display | Tabular Display | Natural Language | Dynamic Simulation |

Select information presentation

Viewpoint

| State Transition | • • • | Entity - Relationship | Data Flow | • • • | Performance |

Select information subset

Concept

IEEE Std 1175.4
- ◆ Unit, Port, Interaction
- ◆ Interaction, Obligation
- ◆ Action, State
- ◆ Property, Event, Condition
- ◆ Assembly, Couple, Aliases

© IEEE Std 1175.2™-2006   27 April 2010

Sandia National Laboratories

What Descriptive Concepts Does it Provide?

What Descriptive Concepts Does it Provide?

- **Packaging of Behavior**
  - **Units, Ports, Interactions**
  - **Assembly, Couple, and Aliases**

- **Observables of Behavior**
  - **Interactions, Coordination Patterns**
  - **Properties, events, conditions**

- **Patterns of Behavior**
  - **Functionality, causality**
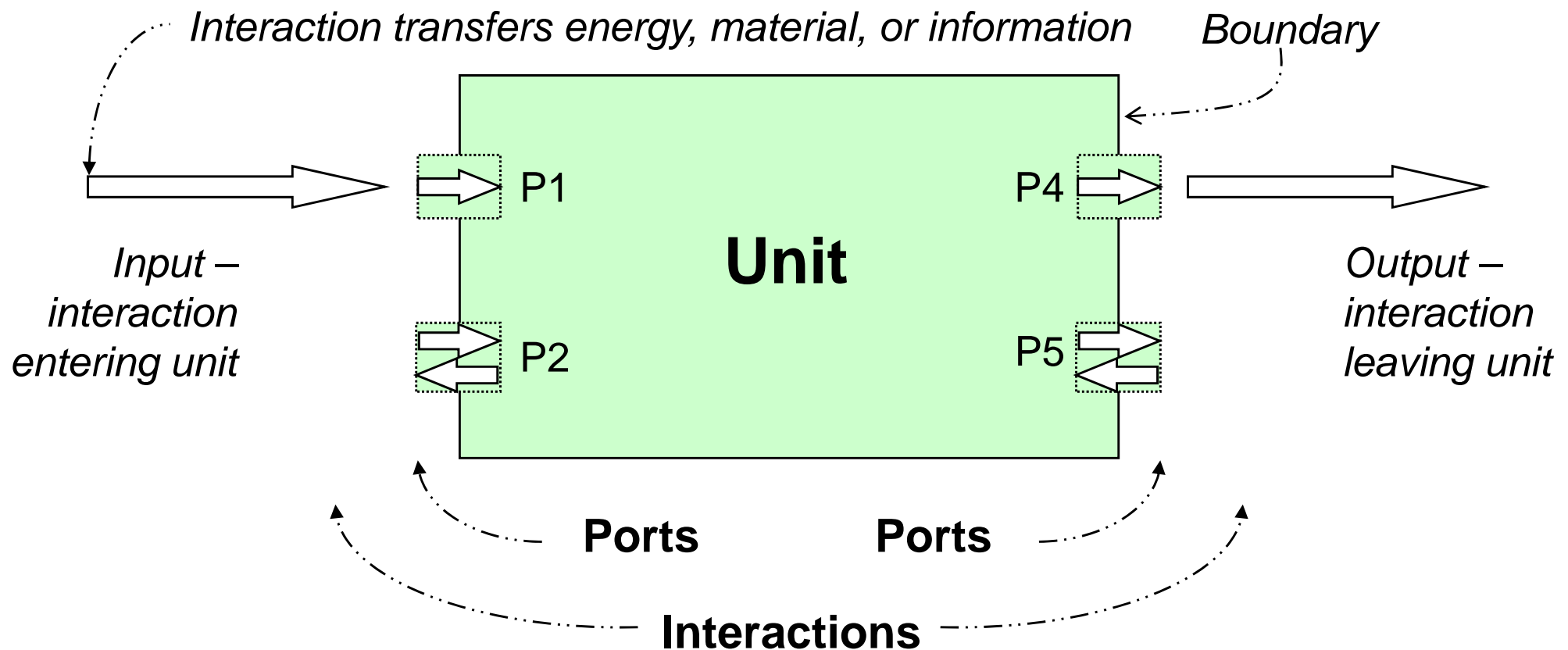 - **History dependence**

27 April 2010

Sandia National Laboratories

How is Behavior Packaged?

Units, Ports, Interactions

Interaction transfers energy, material, or information *Boundary*

Input – interaction entering unit

Unit

P1

P2

P4

P5

Output – interaction leaving unit

Ports   **Ports**

Interactions

27 April 2010

Sandia National Laboratories

How is Behavior Packaged?

Unit

- **Recursive architectural element**
- **System, subsystem, component, module**

Port

- **Means of interconnection**
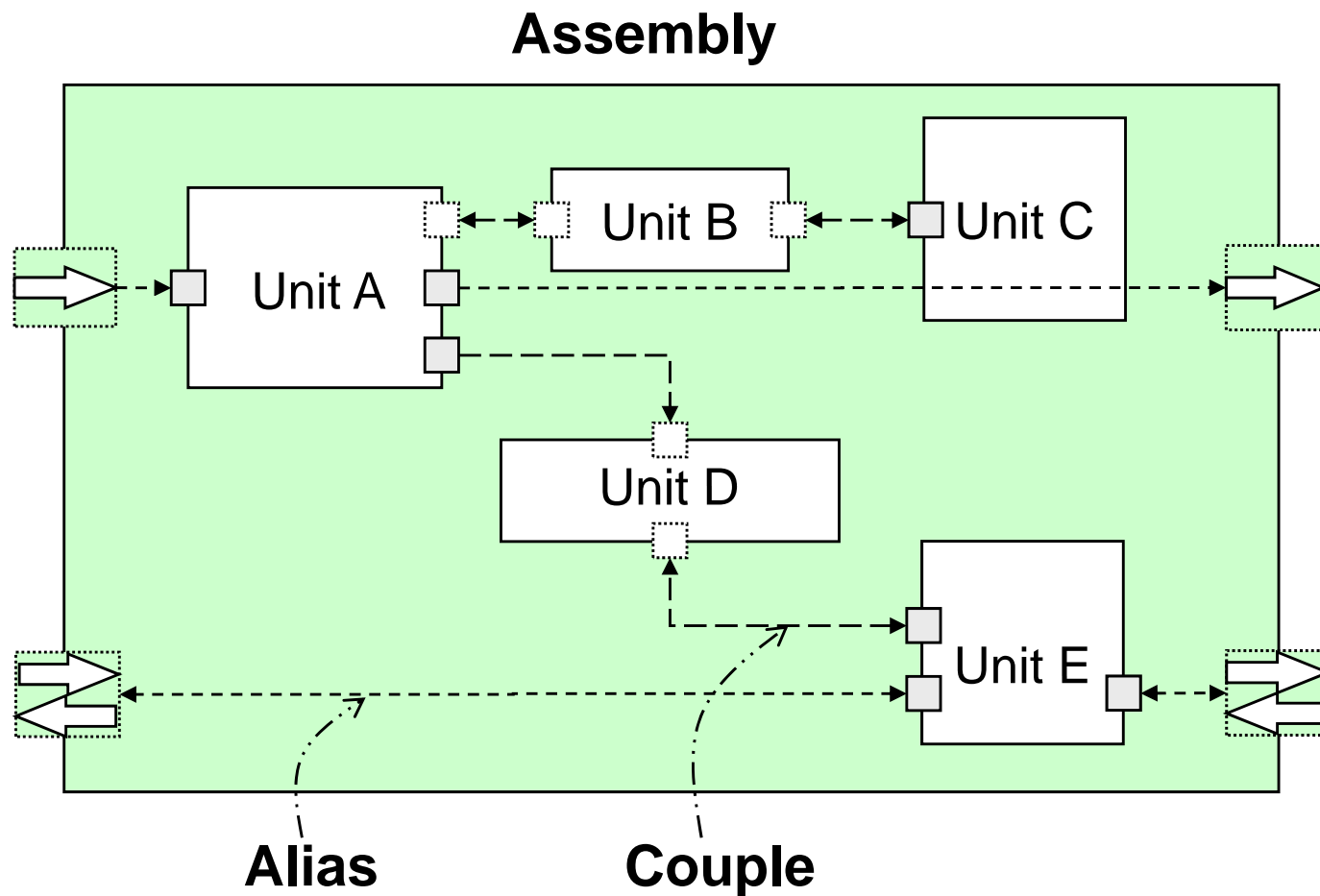- **Serialization of interactions**
- **Unidirectional or bidirectional**
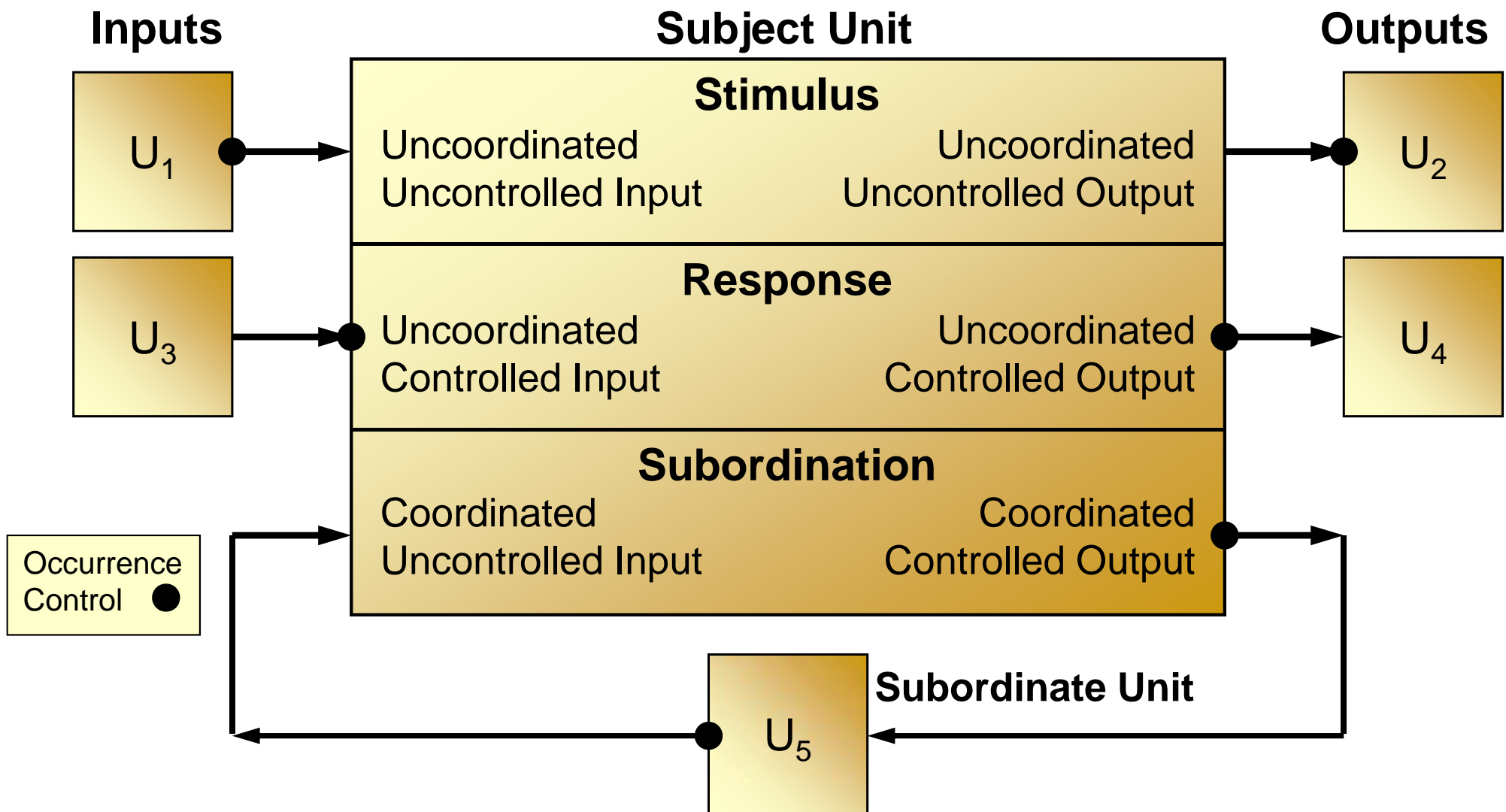
Interaction

- **Phenomenon shared between unit and environment**
- **Occurrence events, content properties or structures**
- **Interaction is point-time or extended-time**

27 April 2010

Sandia
National
Laboratories

How is Behavior Compounded?

Assembly, Alias, Couple

27 April 2010

Sandia National Laboratories

How are Behaviors Coordinated?

Inputs   **Subject Unit**   **Outputs**

U_1

Stimulus

Uncoordinated Uncontrolled Input   Uncoordinated Uncontrolled Output

U_2

Response

Uncoordinated Controlled Input   Uncoordinated Controlled Output

U_3

U_4

Subordination

Coordinated Uncontrolled Input   Coordinated Controlled Output

Occurrence Control ●

Subordinate Unit

U_5

Sandia National Laboratories

How Are Interactions Quantified?

Property

- **Measurable (observable) phenomenon of interaction**
- **Constant or time-varying, simple or compound, discrete or continuous**

Event

- **Marker for time when an observable change occurs**
- **Interaction occurrence, time-dependent property changes, or time changes**

Condition

- **Assertion about properties, events, or other conditions that is observably True/False at a given time**

27 April 2010

Sandia
National
Laboratories

What Is a Behavior Occurrence?

Cause	**implies**	**Effect**
This event		Those events
with these inputs		with those outputs
and satisfying these criteria		and making these guarantees

A Simplified Table Format

A#	X0		C0	E0	X1		C1
An	input		pre condition	trigger	output		post condition

27 April 2010

Sandia National Laboratories

What Is a Behavior Pattern?

- **Abstraction of Behavior Occurrences**
  - **Common set of interactions**
  - **Common set of conditions**
  - **Common trigger event**
  - **Different property values and event times, but within well-defined domain boundaries**
  - **Same True preconditions**

- **Action**
  - **A behavior pattern**
  - **Describes causal and affective relationships among a set of possible interactions**

Sandia National Laboratories

What Is a Behavior Pattern?

27 April 2010

Sandia National Laboratories
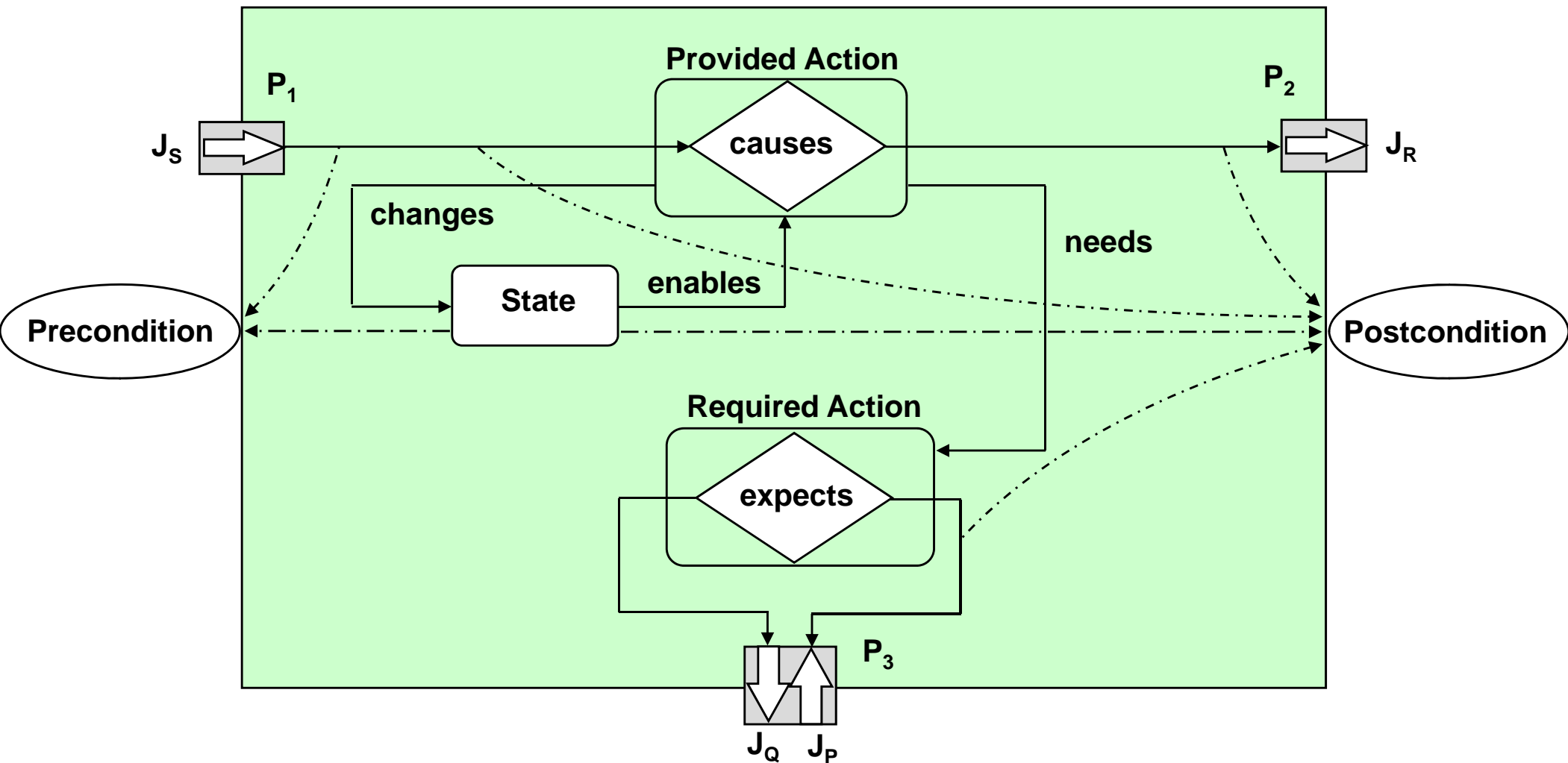
How is History Dependence Described?

- **Modification of Causal Dependencies**
  - **Behavior State**

- **Modification of Functional Dependencies**
  - **Property State**

- **Modification of Event Dependencies**
  - **Temporal State**

- **Modification of Interaction Dependencies**
  - **Port State**

Sandia
National
Laboratories

How is History Dependence Described?

Cause   **implies**   **Effect**

This event

with these inputs

at this point in unit history

and satisfying these criteria

→ Those events

with those outputs

advancing unit history

and making these guarantees

A Simplified Table Format

A#	X0	S0	C0	E0	X1	S1	C1
An	input	initial state	pre condition	trigger	output	final state	post condition

Sandia National Laboratories

What is a System Behavior Description?

Unit: ⟨Name⟩

- **Specification of Ports, Interactions**
- **Specification of Properties, Events, Conditions, States**
- **Specification of unique cause-effect and functional relationships with a catalog of Action patterns, e.g.**

A#	X0	S0	C0	E0	X1	S1	C1
An	input	initial state	pre condition	trigger	output	final state	post condition
A101	N1, N2	Sa	Ca	E1	---	Sb	Cb
A102	N1, N2	Sa	Cc	E1	U1	Sa	Cd
A103	N4	Sb	Ce	E4	U2	Sa	Cf

27 April 2010

Sandia National Laboratories

What Use Is a Behavior Description?

For Informal Understanding

– **Suppose I do ⟨treatment of unit⟩**

What should I expect to be the result?

– **Suppose I want ⟨effect in my world⟩**

How could I get that result?

Sandia National Laboratories

What Use Is a Behavior Description?

For Formal Checking

– **Will Unit deliver expected value into problem domain?**

Subject Unit Behavior
$\wedge$ **Environment Assumptions**
$\wedge$ **External Unit Behavior** ➜ **Desired Result ?**

– **Will Unit design provide the Unit behavior?**

Component Unit Behaviors
$\wedge$ **Interconnection Structure** ➜ **Subject Unit Behavior?**

27 April 2010

Sandia
National
Laboratories

How Can You Use It?

Framing Requirements Analysis Work

- – **Concept instances to be found and identified**
- – **Questions to be asked and answered**
- – **Specifications to be determined**

Guiding Test Case Design Work

- – **Interaction samples for stimuli**
- – **Interaction observations for responses**
- – **Behavior sequences for historical dependencies**

A Job Aid

27 April 2010

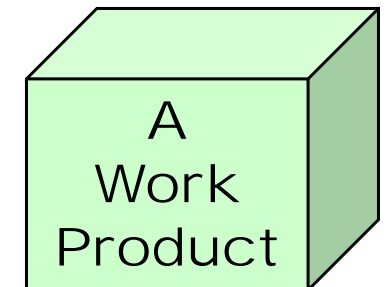Sandia National Laboratories
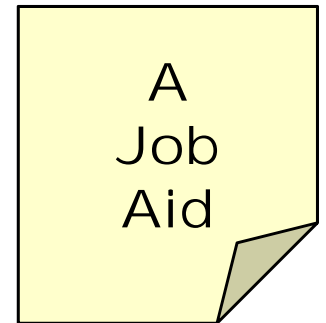
How Can You Use It?

Define as a Product Artifact

- **Product "Scope and Vision" satisfying product criteria**
- **Target for product architecture and design**
- **Target for test architecture and design**

Use a Data Metamodel (IEEE P1175.5*)

- **Formalized expressions for concepts**
- **Formalized entity-relation-attribute/object-role-model**
- **Formalized model consistency verification**
- **Presentation-level support**

A Work Product

* Discuss participation in 1175WG with the presenter after this session

27 April 2010

Sandia National Laboratories

Questions?

27 April 2010

Sandia
National
Laboratories