

System Behavior Specification Using IEEE Std 1175.4

27 April 2010

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

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.



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

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?

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

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/apaper.html>)

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

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

Where Does It Fit the Development Life Cycle?

Problem Domain: Need for a Result

- **Product Criteria, describes desired effects**
- **Stakeholder Requirements**

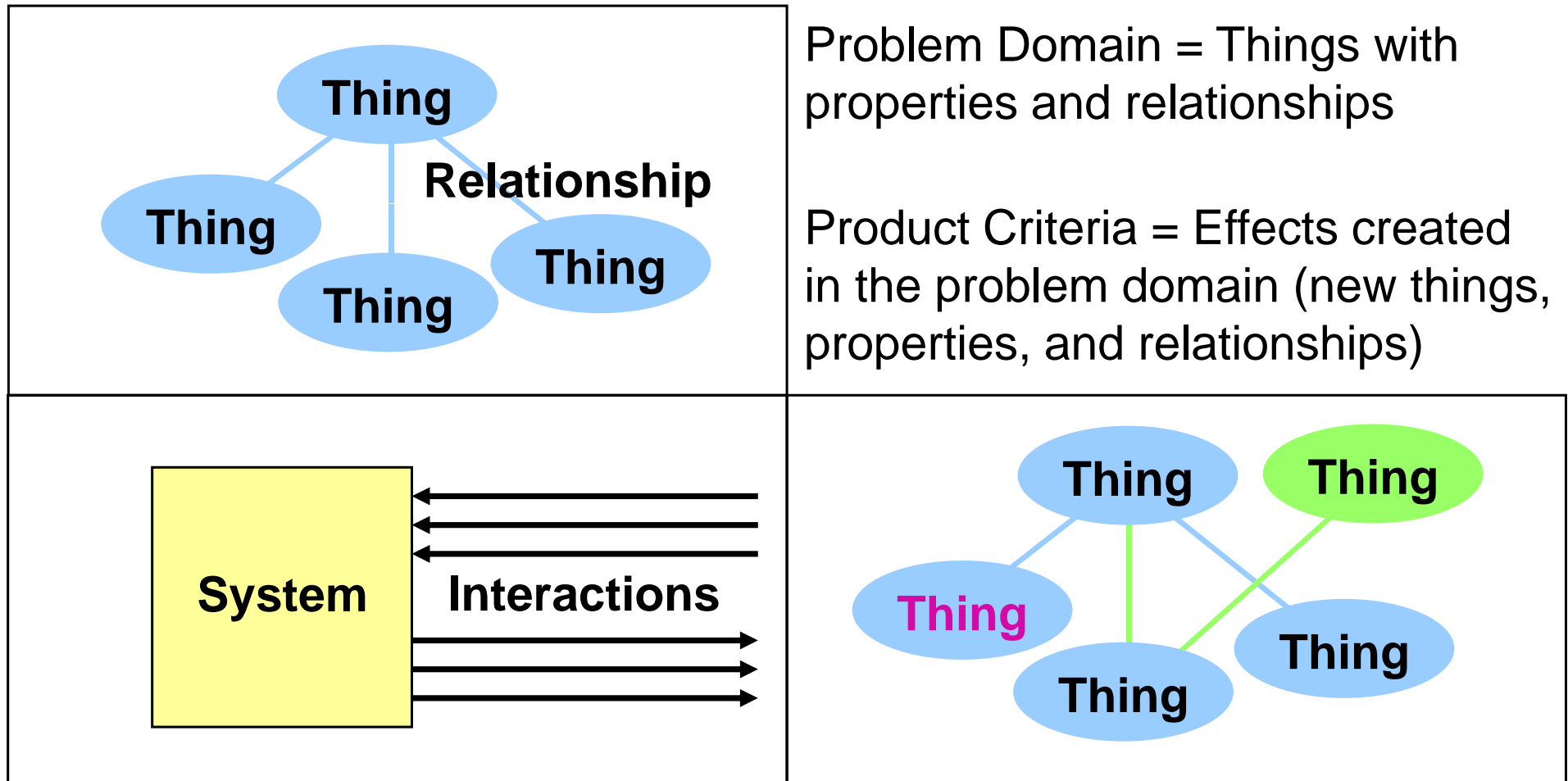
Solution Domain: Concept for a Thing

- **Product Requirements, describes offered capability**
- **System Requirements**
behavioral, structural, environmental

Boundary between Domains is the System Boundary

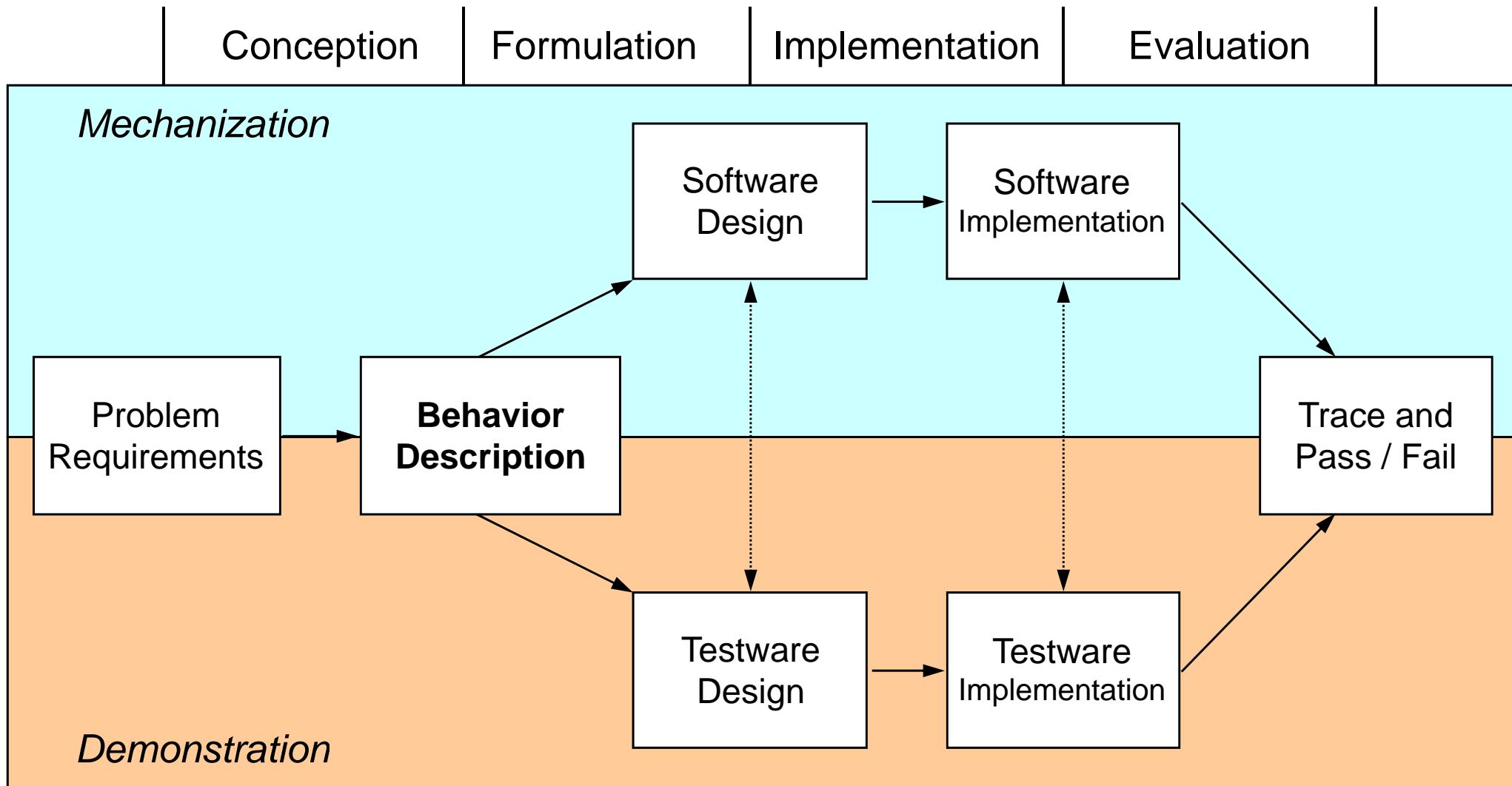
- Requirements and Specifications, Michael Jackson (Addison-Wesley, 1995)
- ISO/IEC 15288:2008 Systems and software engineering — System life cycle processes

Where Does It Fit the Development Life Cycle?



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

Where Does It Fit the Development Life Cycle?



What Does 1175.4 Standardize?

Descriptive Model of System Behavior

- Not a design model for mechanism construction
- Not a mathematical model for proof construction

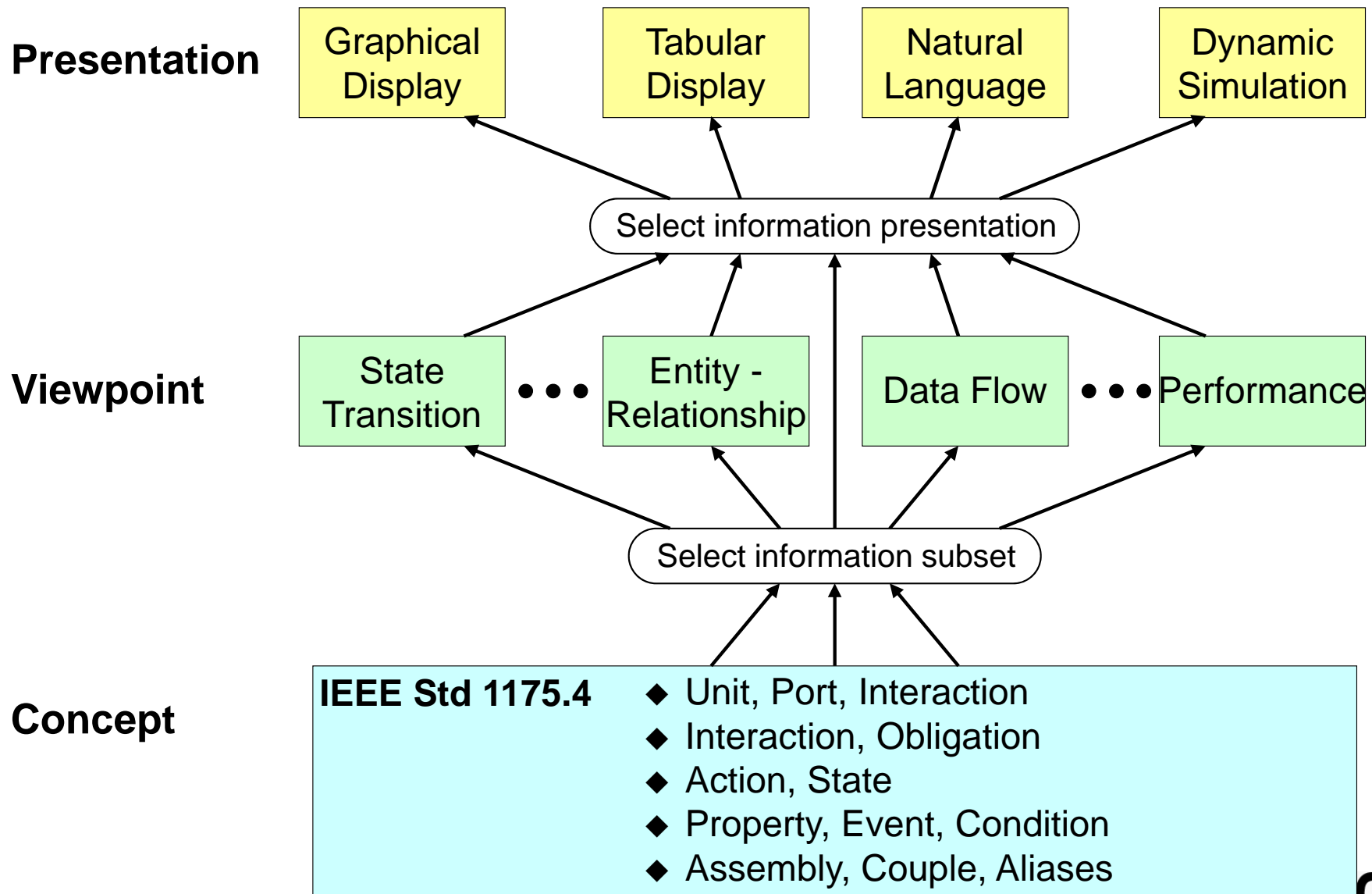
Goal is Understanding and Agreement

- Identify observables at the system interface
- Identify repeatable patterns of relationships
- Description of all possible lifelines

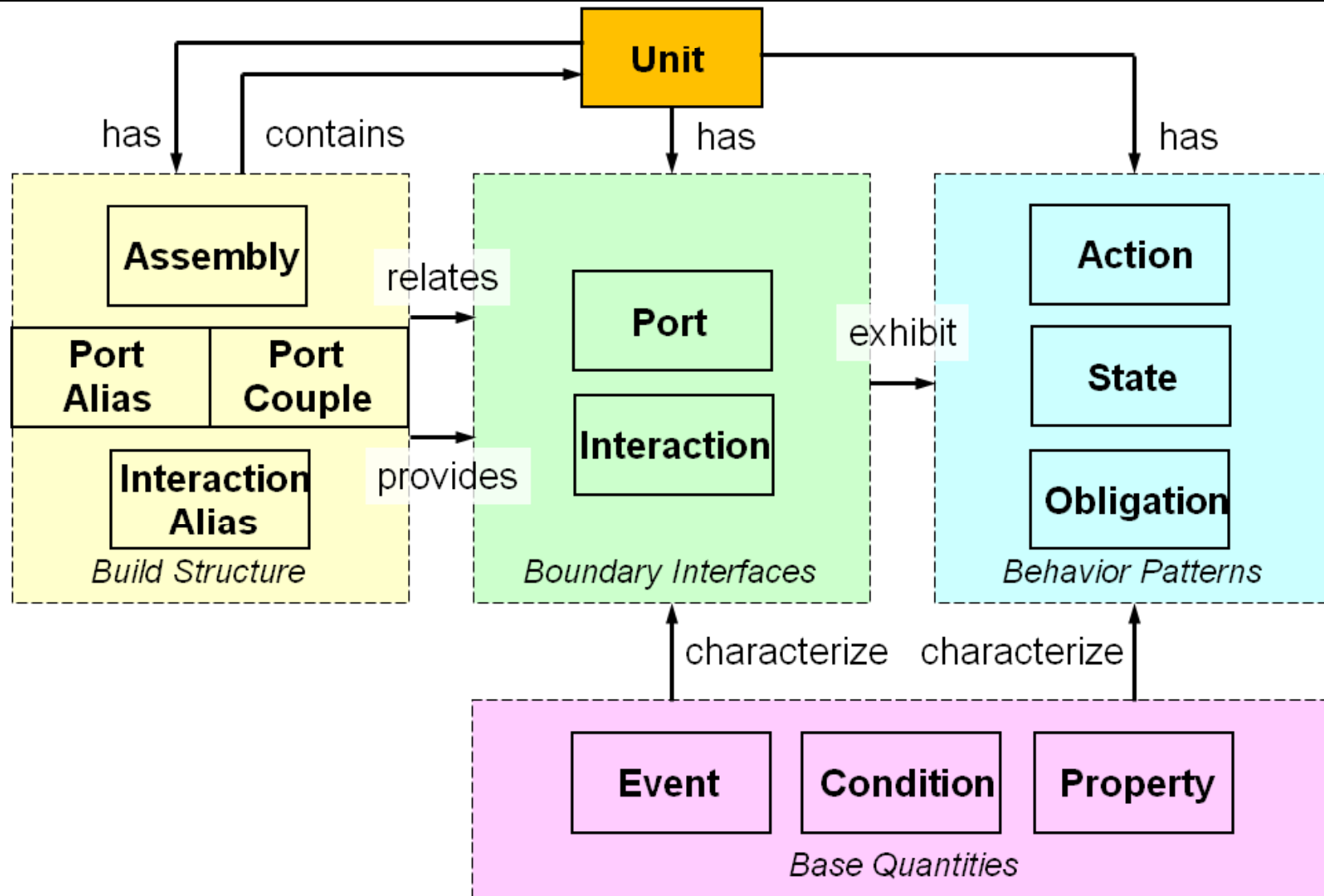
To Answer

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

What Does 1175.4 Standardize?



What Descriptive Concepts Does it Provide?



What Descriptive Concepts Does it Provide?

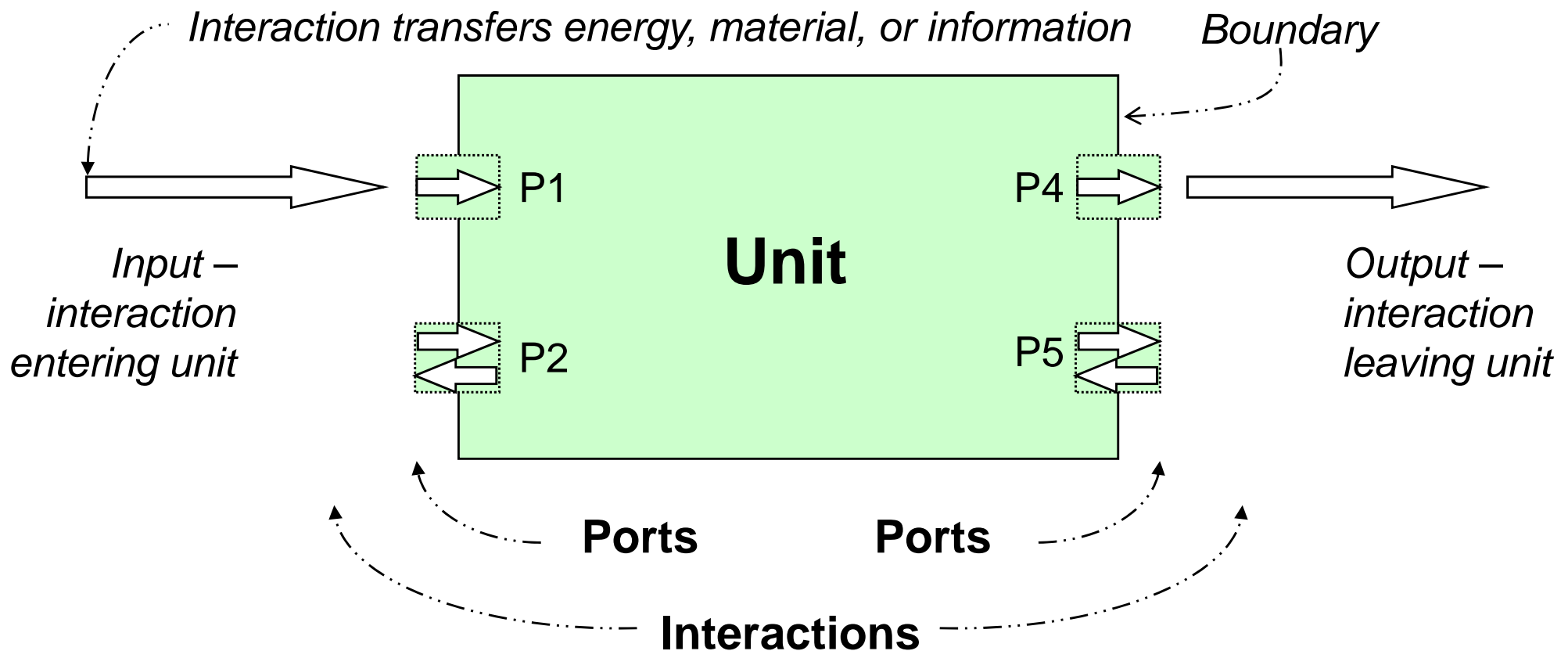
- **Packaging of Behavior**
 - **Units, Ports, Interactions**
 - **Assembly, Couple, and Aliases**

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

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

How is Behavior Packaged?

Units, Ports, Interactions



How is Behavior Packaged?

Unit

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

Port

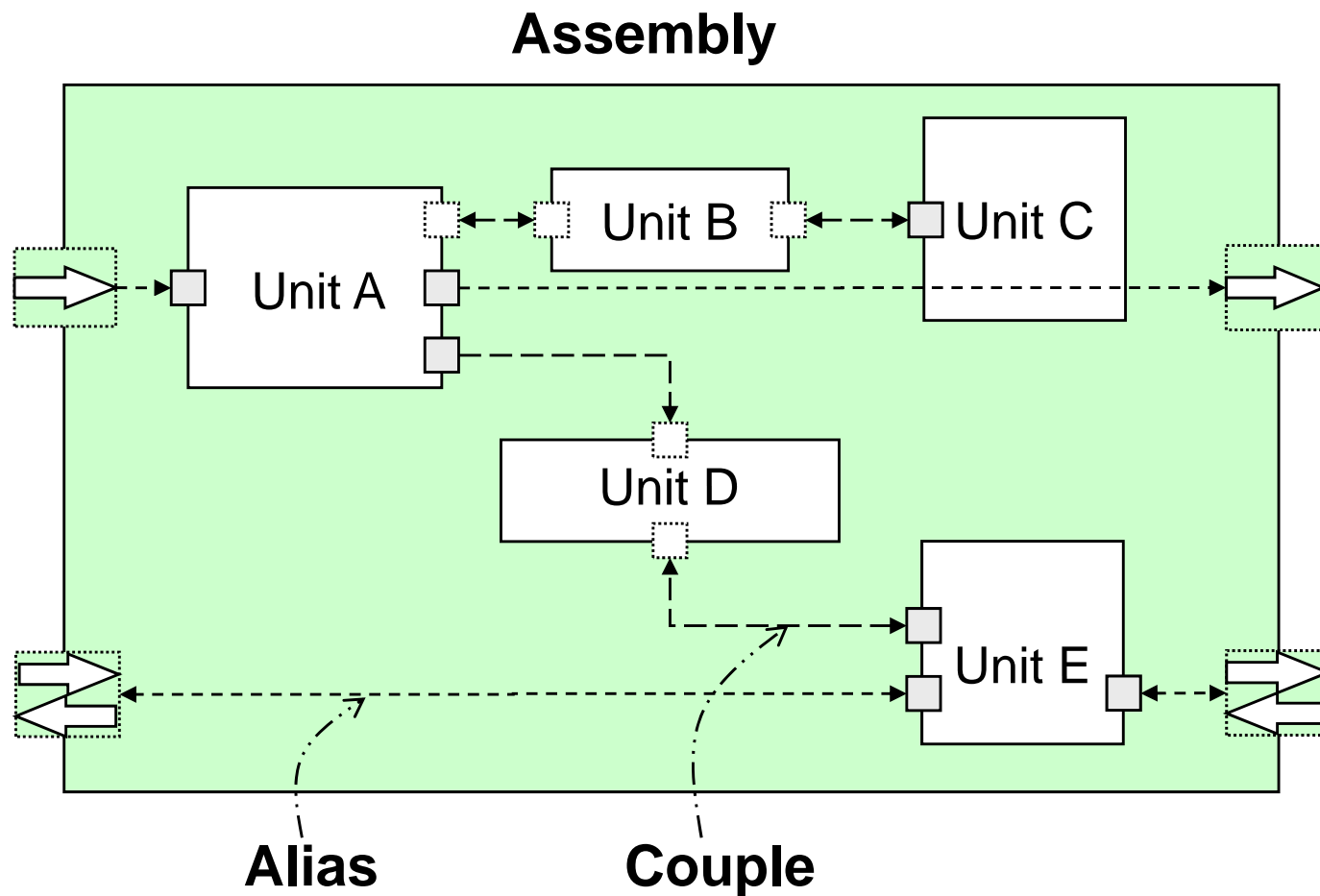
- Means of interconnection
- **Serialization of interactions**
- **Unidirectional or bidirectional**

Interaction

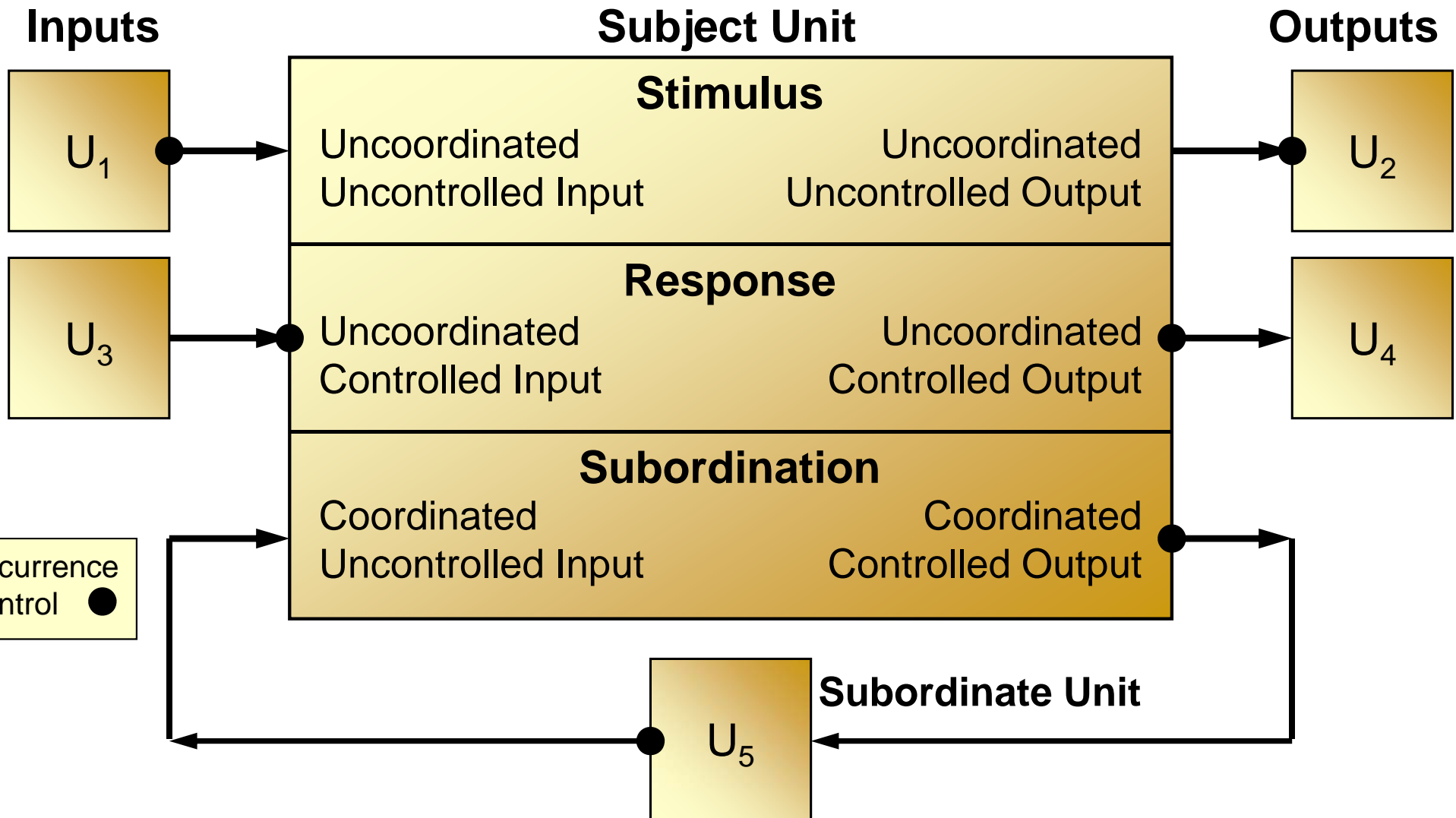
- Phenomenon shared between unit and environment
- **Occurrence events, content properties or structures**
- **Interaction is point-time or extended-time**

How is Behavior Compounded?

Assembly, Alias, Couple



How are Behaviors Coordinated?





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**

What Is a Behavior Occurrence?

Cause

implies

Effect

This event
with these inputs
and satisfying these criteria



Those events
with those outputs
and making these guarantees

A Simplified Table Format

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

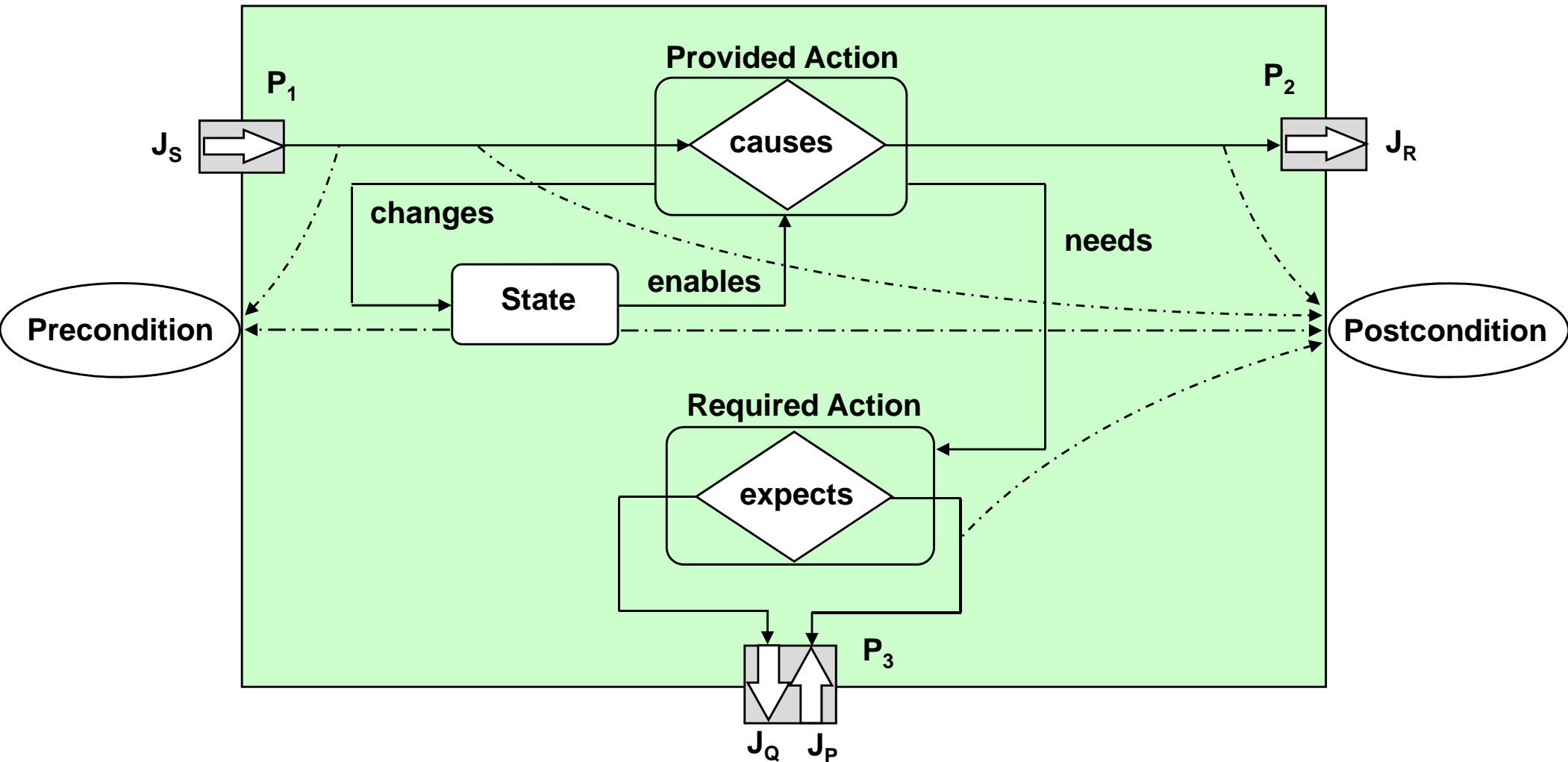


What Is a Behavior Pattern?

- **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

What Is a Behavior Pattern?





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

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

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

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?

What Use Is a Behavior Description?

For Formal Checking

- Will Unit deliver expected value into problem domain?

Subject Unit Behavior

^ Environment Assumptions

^ External Unit Behavior → Desired Result ?

- Will Unit design provide the Unit behavior?

Component Unit Behaviors

^ Interconnection Structure → Subject Unit Behavior?

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

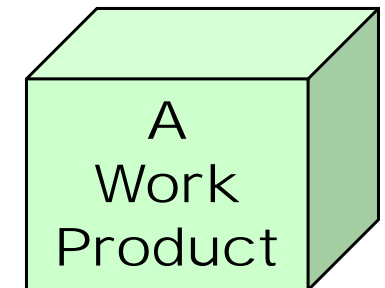


A
Job
Aid

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

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

Questions?

