



# **System Behavior Specification Using IEEE Std 1175.4**

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| Report Documentation Page                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                    |                                     |                                                                  | Form Approved<br>OMB No. 0704-0188                  |                                    |
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## Prologue

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- **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<sup>TM</sup>-2008 provides a conceptual model for describing the behavior of many kinds of engineered systems**



# Questions to be Addressed

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## 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?

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## 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?

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## 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>)

# **What is a System Behavior Description?**

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## **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?

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## 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**

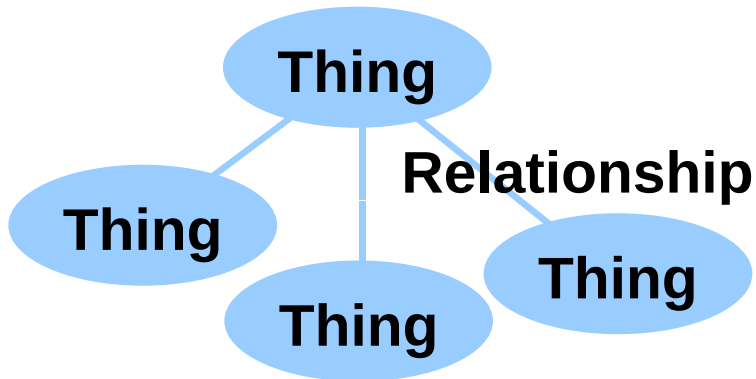
## **Solution Domain: Concept for a Thing**

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

## **Boundary between Domains is the System Boundary**

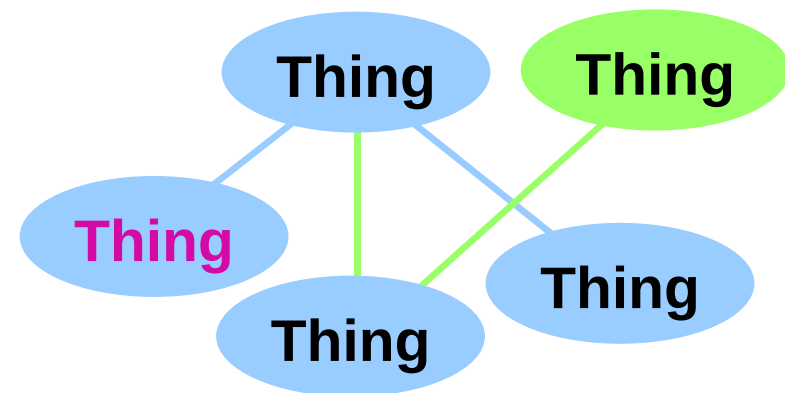
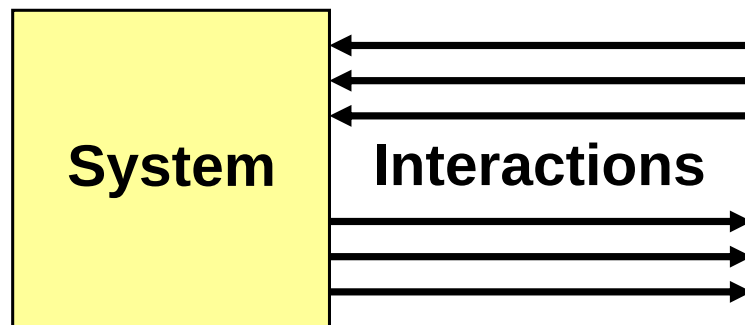
- Requirements and Specifications, Michael Jackson (Addison-Wesley, 1995)
- ISO/IEC 15288:2008 Systems and software engineering — System life cycle processes

# Where Does It Fit the Development Life Cycle?



Problem Domain = Things with properties and relationships

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



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





# **What Does 1175.4 Standardize?**

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## **Descriptive Model of System Behavior**

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

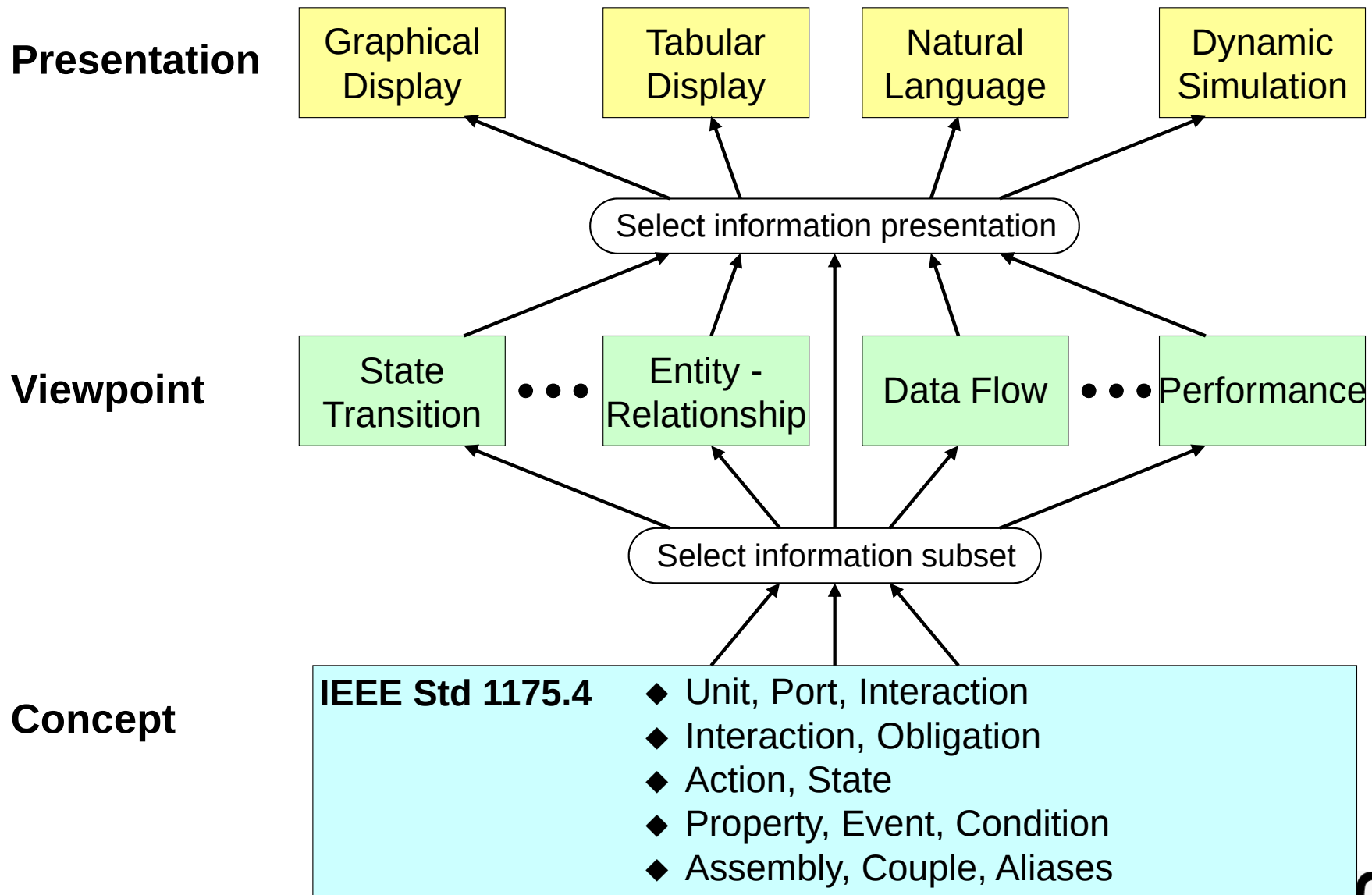
## **Goal is Understanding and Agreement**

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

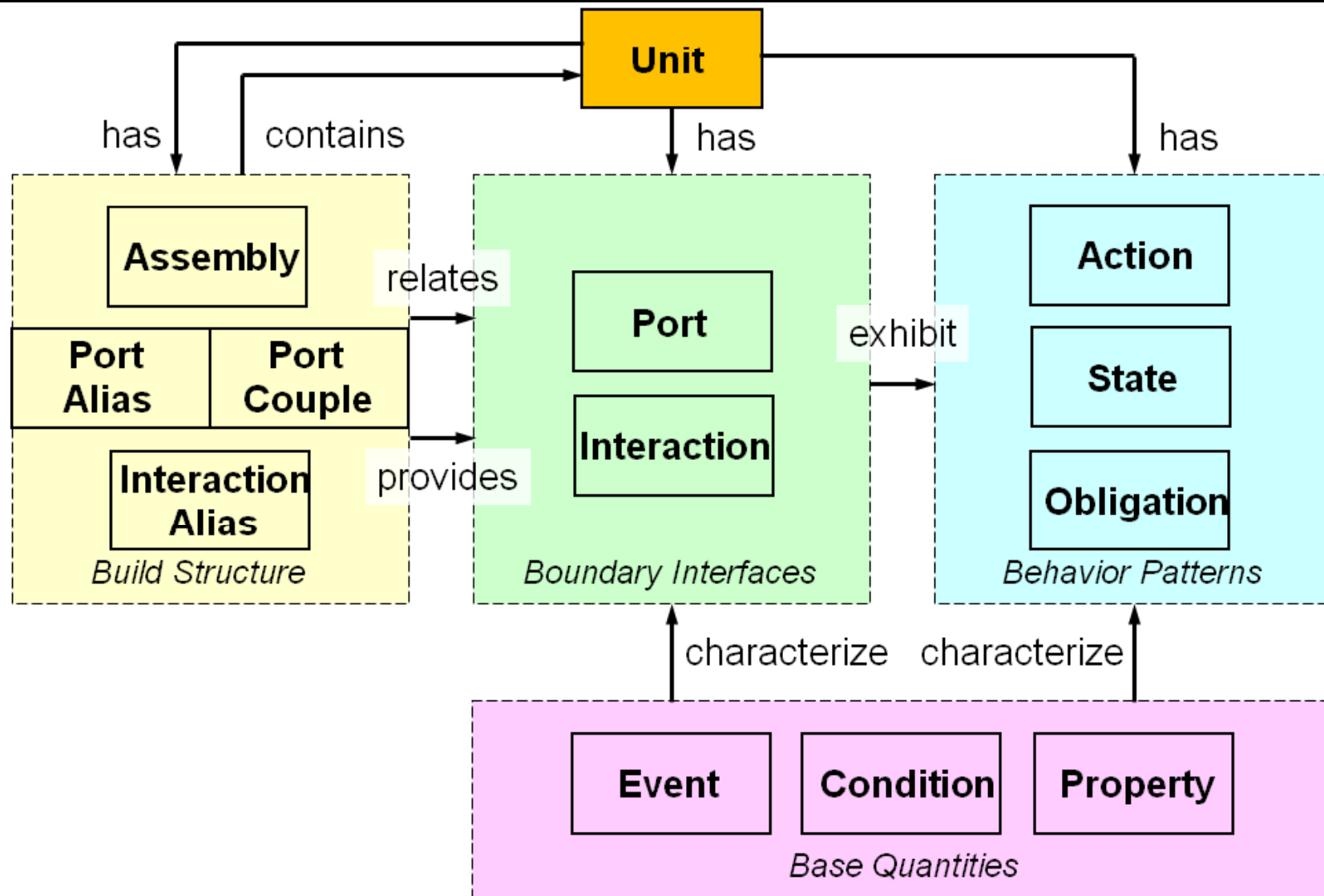
## **To Answer**

- 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?



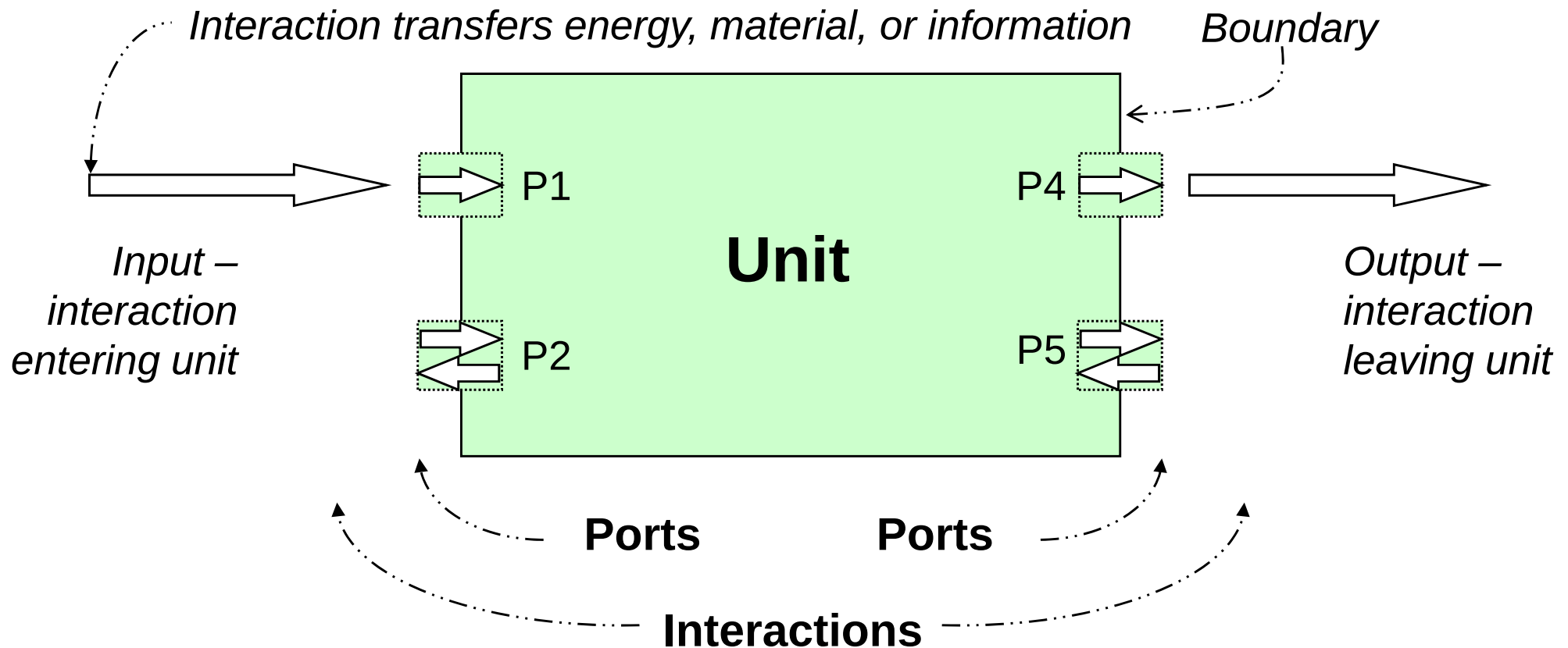


## **What Descriptive Concepts Does it Provide?**

- **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?

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## Unit

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

## Port

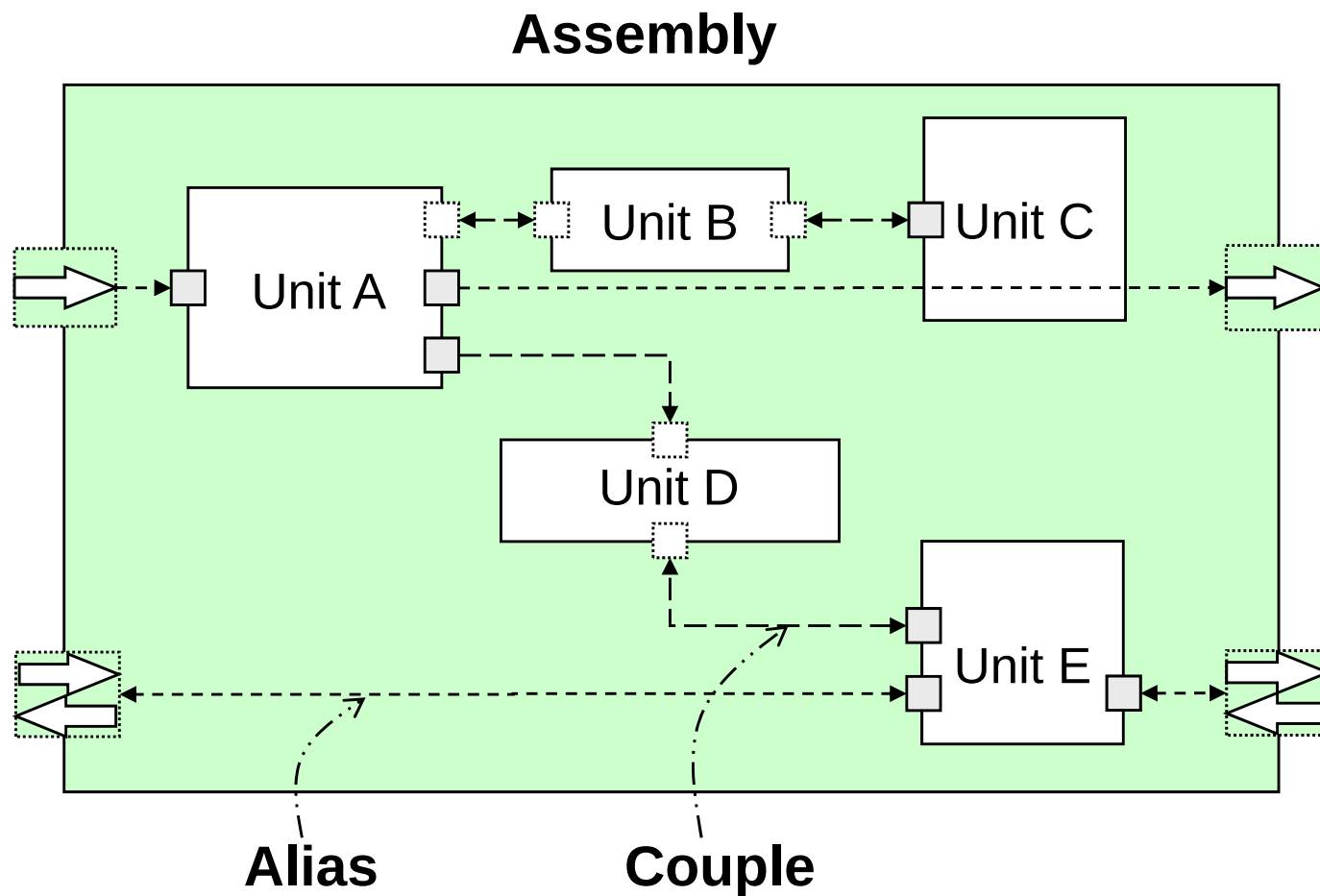
- Means of interconnection
- Serialization of interactions
- Unidirectional or bidirectional

## Interaction

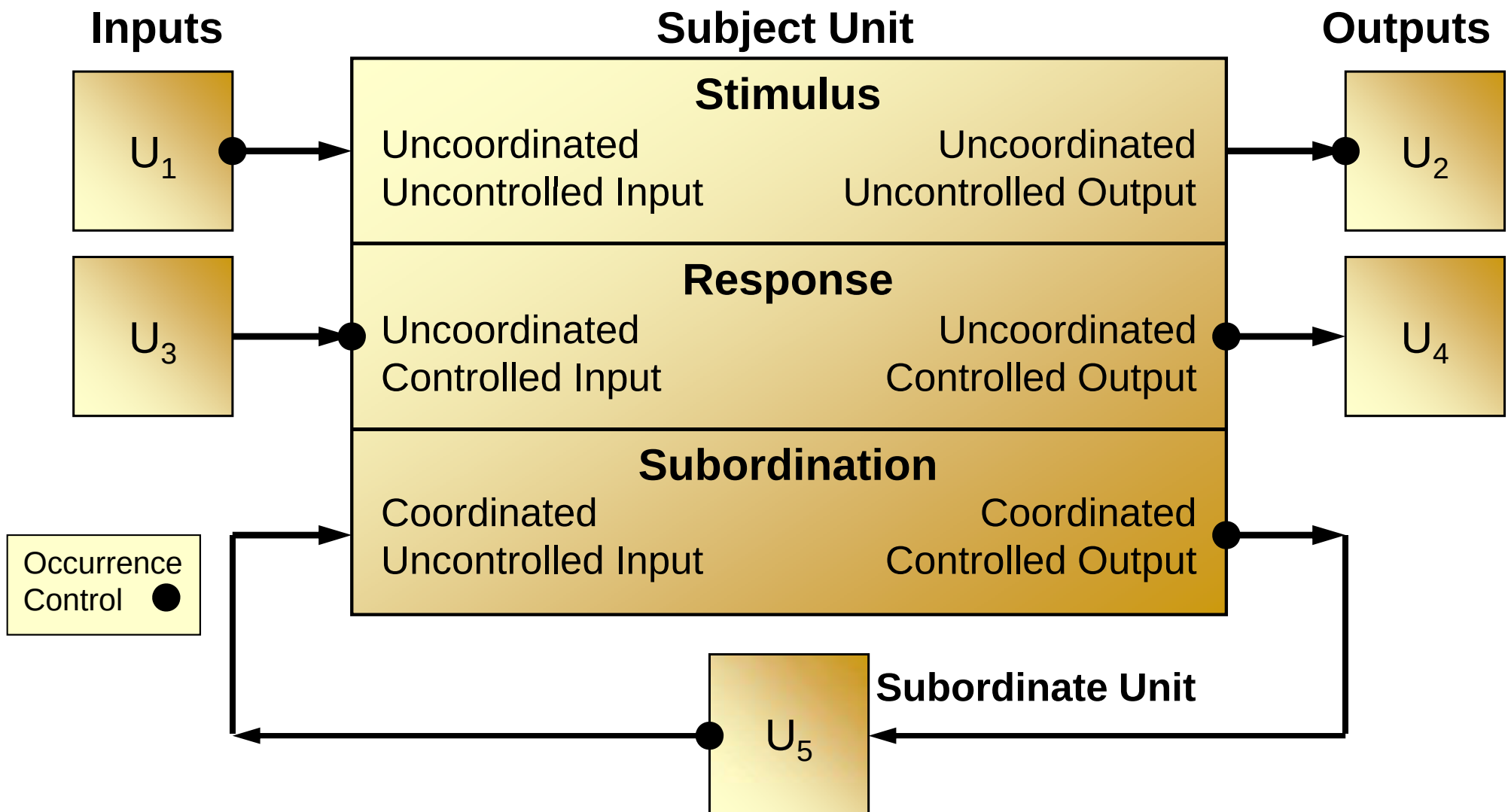
- Phenomenon shared between unit and environment
- Occurrence events, content properties or structures
- Interaction is point-time or extended-time

# How is Behavior Compounded?

## Assembly, Alias, Couple



# How are Behaviors Coordinated?



# How Are Interactions Quantified?

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## 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?

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**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

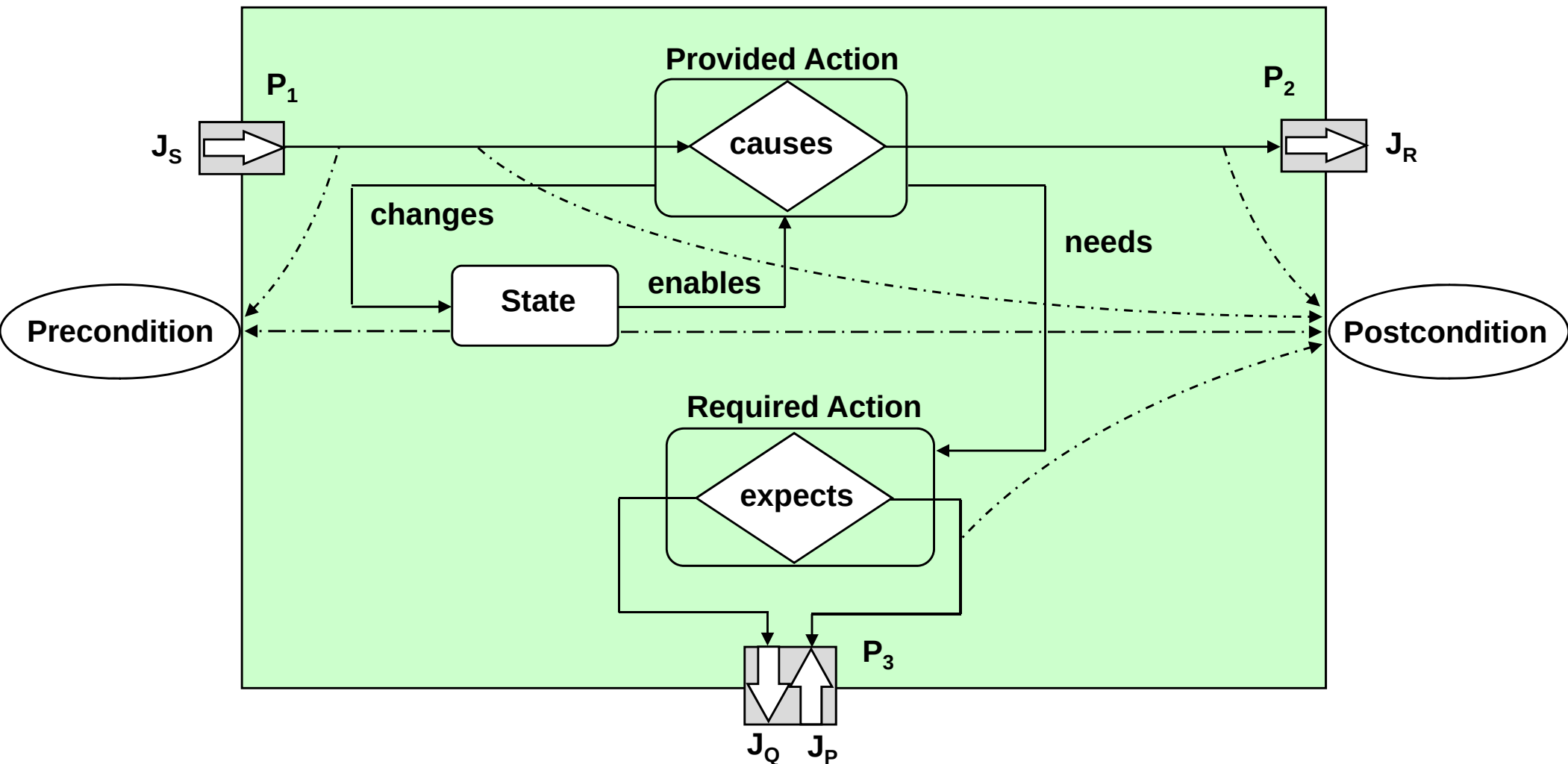
| <b>A#</b> | <b>X0</b> |  | <b>C0</b>        | <b>E0</b> | <b>X1</b> |  | <b>C1</b>         |
|-----------|-----------|--|------------------|-----------|-----------|--|-------------------|
| An        | input     |  | pre<br>condition | trigger   | output    |  | post<br>condition |

# What Is a Behavior Pattern?

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- **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?**

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- **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

| <b>A#</b> | <b>X0</b> | <b>S0</b>        | <b>C0</b>        | <b>E0</b> | <b>X1</b> | <b>S1</b>      | <b>C1</b>         |
|-----------|-----------|------------------|------------------|-----------|-----------|----------------|-------------------|
| An        | input     | initial<br>state | pre<br>condition | trigger   | output    | final<br>state | post<br>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.

| <b>A#</b> | <b>X0</b> | <b>S0</b>     | <b>C0</b>     | <b>E0</b> | <b>X1</b> | <b>S1</b>   | <b>C1</b>      |
|-----------|-----------|---------------|---------------|-----------|-----------|-------------|----------------|
| 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?**

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## **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?

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## For Formal Checking

- Will Unit deliver expected value into problem domain?

**Subject Unit Behavior**

$\wedge$  Environment Assumptions

$\wedge$  External Unit Behavior  $\rightarrow$  Desired Result ?

- Will Unit design provide the Unit behavior?

**Component Unit Behaviors**

$\wedge$  Interconnection Structure  $\rightarrow$  Subject Unit Behavior?

# How Can You Use It?

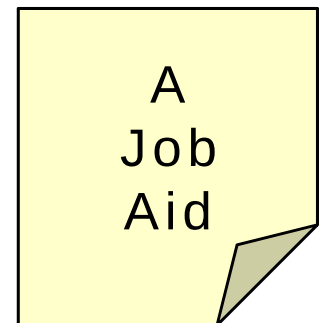
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## **Framing Requirements Analysis Work**

- 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**



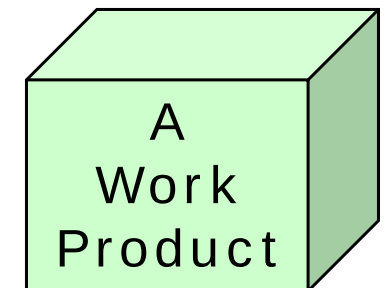


# How Can You Use It?

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## 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?

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