OMG Systems Modeling Language (OMG SysML™) Tutorial

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(emails included in references at end)

OMG SysML™ Specification

- Specification status
  - Adopted by OMG in May ’06
  - Available Specification v1.0 in Sept ’07
  - Available Specification v1.1 in Nov ‘08
  - Revision task force for v1.2 in process
- Multiple vendor implementations available
- This tutorial is based on the OMG SysML available specification (formal/2007-09-01)
- This tutorial, the specifications, papers, and vendor info can be found on the OMG SysML Website at http://www.omgsysml.org/
- Refer to “A Practical Guide to SysML” by Friedenthal, Moore, and Steiner for language details and reference

Objectives & Intended Audience

At the end of this tutorial, you should have an awareness of:

- Motivation of model-based systems engineering approach
- SysML diagrams and language concepts
- How to apply SysML as part of a model based SE process
- Basic considerations for transitioning to SysML

This course is <u>not</u> intended to make you a systems modeler!

You must <u>use</u> the language.

Intended Audience:

- Practicing Systems Engineers interested in system modeling
- Software Engineers who want to better understand how to integrate software and system models
- Familiarity with UML is not required, but it helps

Topics

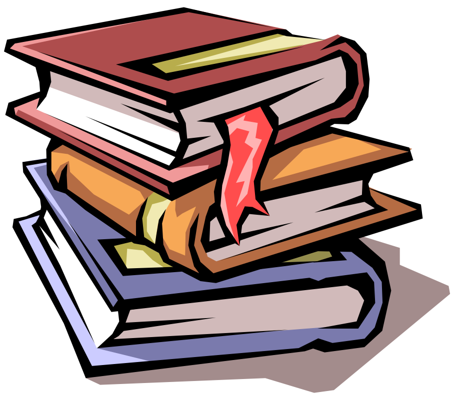
- Motivation & Background
- Diagram Overview and Language Concepts
- SysML Modeling as Part of SE Process
  - Structured Analysis – Distiller Example
  - OOSEM – Enhanced Security System Example
- SysML in a Standards Framework
- Transitioning to SysML
- Summary

- Class Exercise

Motivation & Background

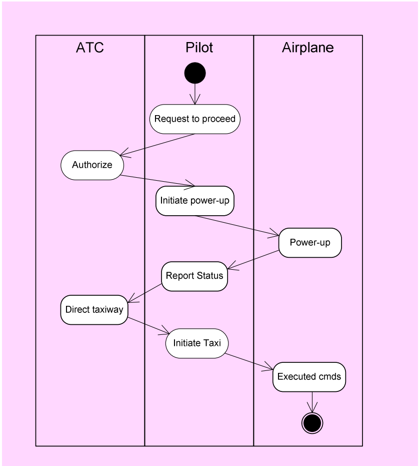
SE Practices for Describing Systems

Past



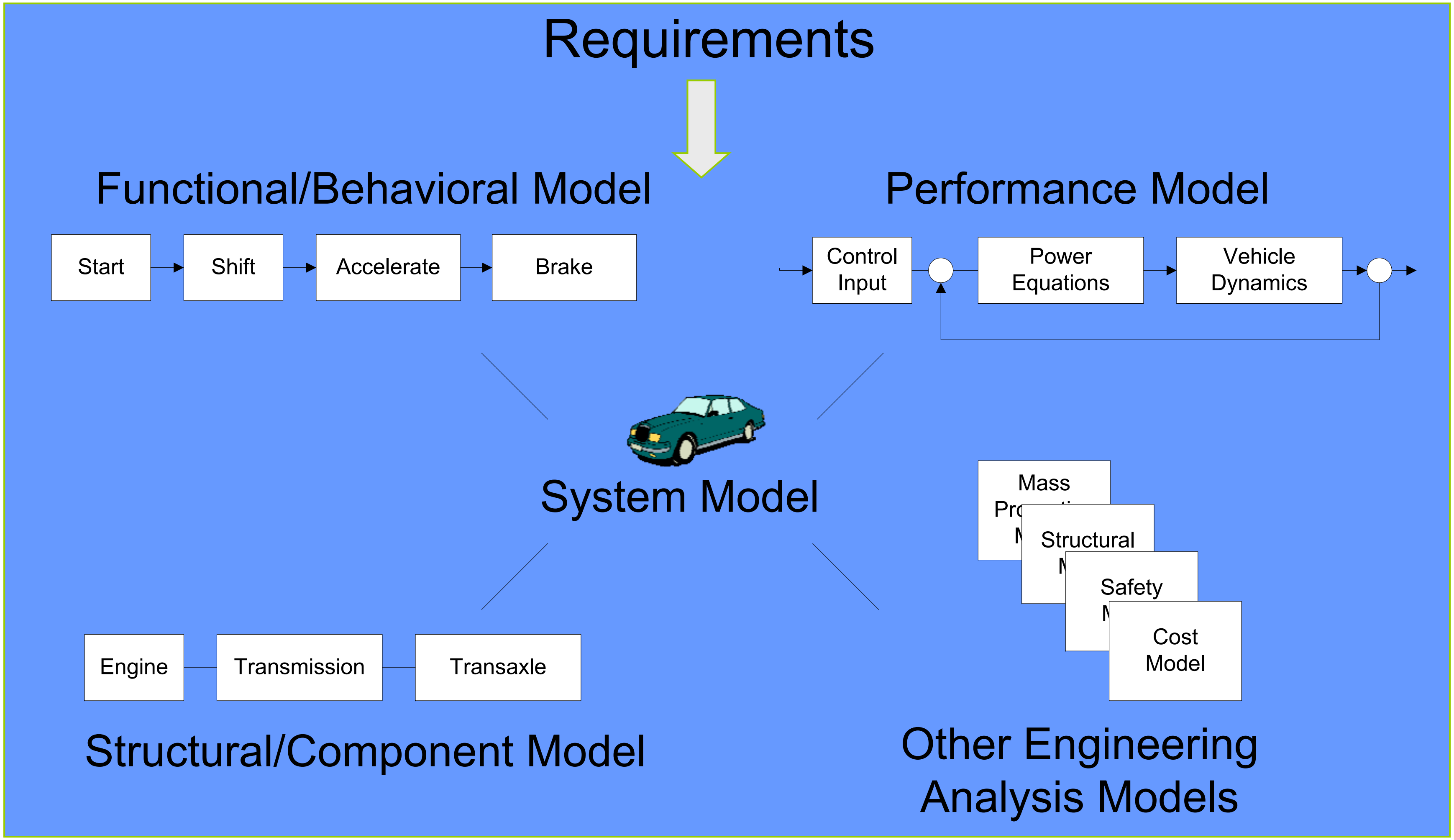
- **Specifications**
- **Interface requirements**
- **System design**
- **Analysis & Trade-off**
- **Test plans**

Future



Moving from Document centric to Model centric

System Modeling

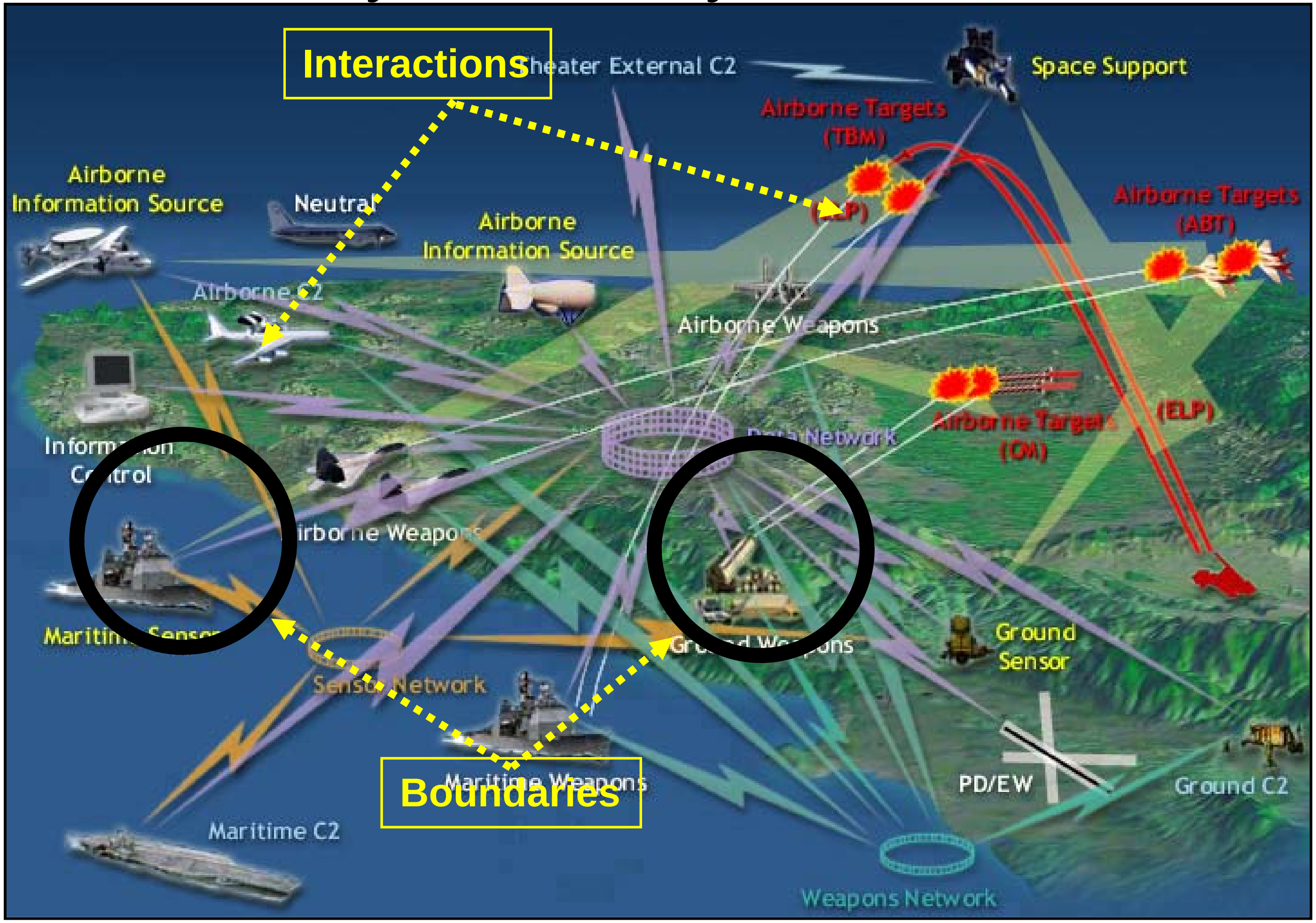


Integrated System Model Must Address Multiple Aspects of a System

Model Based Systems Engineering Benefits

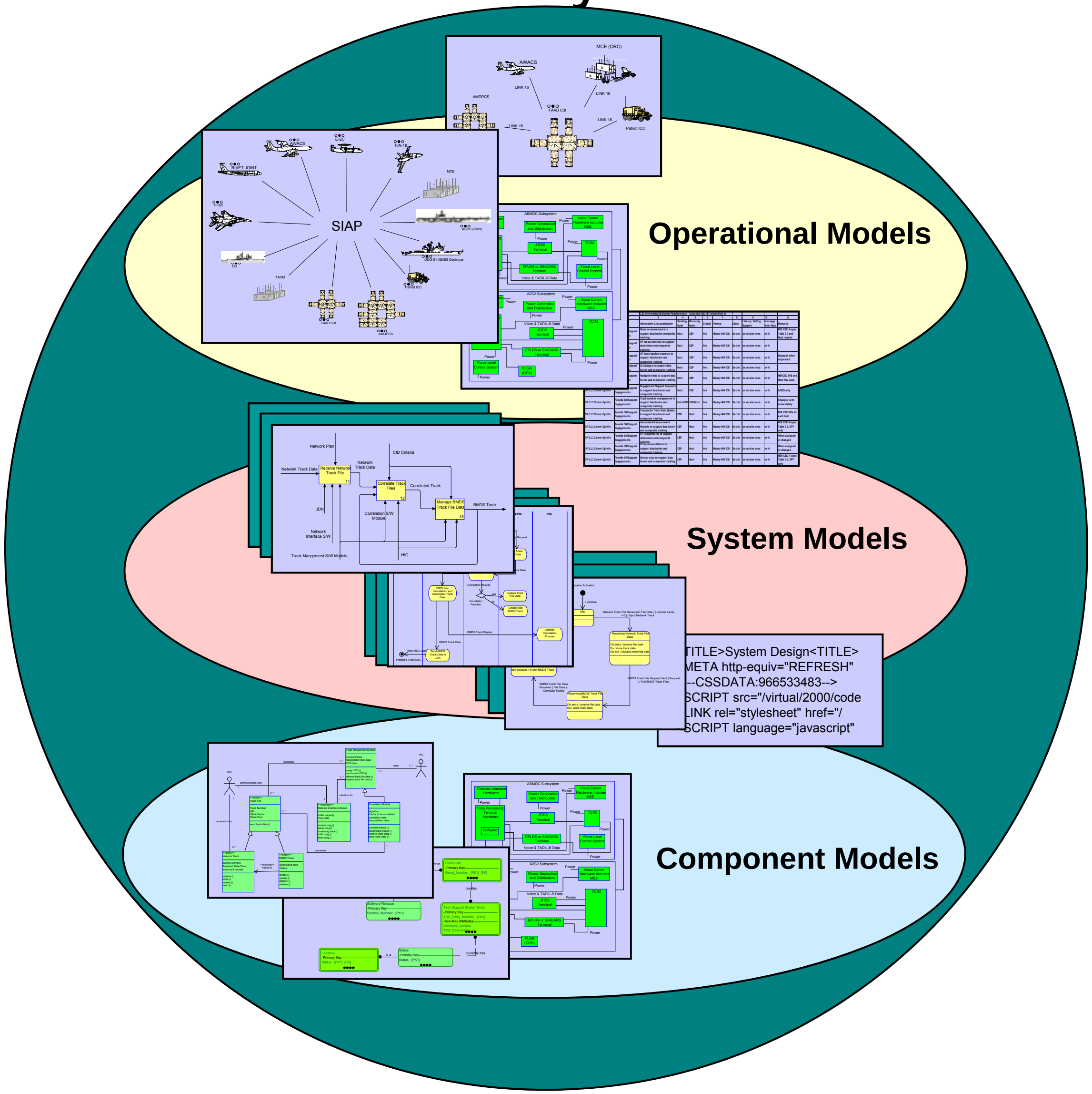
- Shared understanding of system requirements and design
  - Validation of requirements
  - Common basis for analysis and design
  - Facilitates identification of risks
- Assists in managing complex system development
  - Separation of concerns via multiple views of integrated model
  - Supports traceability through hierarchical system models
  - Facilitates impact analysis of requirements and design changes
  - Supports incremental development & evolutionary acquisition
- Improved design quality
  - Reduced errors and ambiguity
  - More complete representation
- Supports early and on-going verification & validation to reduce risk
- Provides value through life cycle (e.g., training)
- Enhances knowledge capture

System-of-Systems

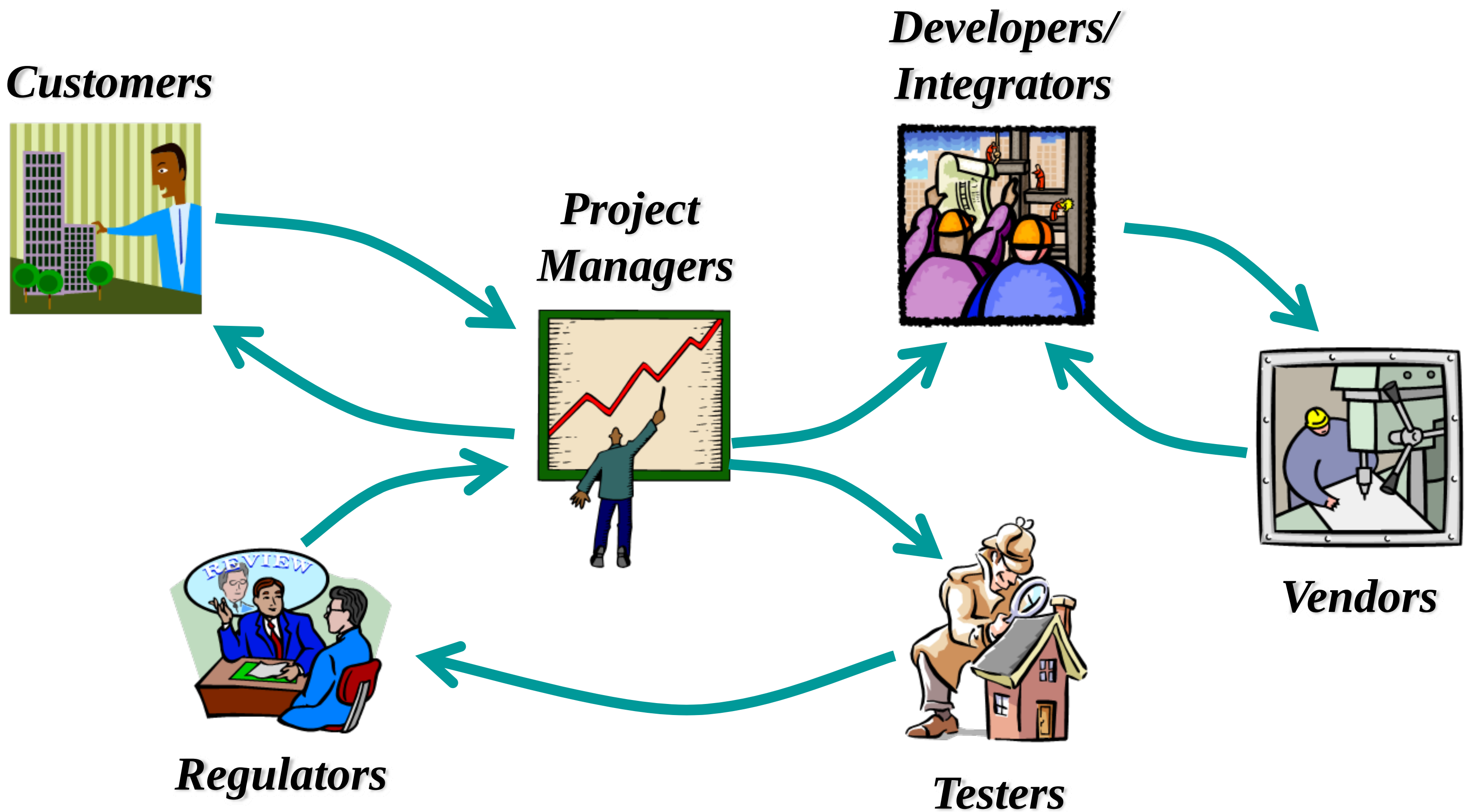


Modeling Needed to Manage System Complexity

Modeling at Multiple Levels of the System



Stakeholders Involved in System Acquisition



Modeling Needed to Improve Communications

What is SysML?

- A graphical modelling language in response to the UML for Systems Engineering RFP developed by the OMG, INCOSE, and AP233
  - a UML Profile that represents a subset of UML 2 with extensions
- Supports the specification, analysis, design, verification, and validation of systems that include hardware, software, data, personnel, procedures, and facilities
- Supports model and data interchange via XML Metadata Interchange (XMI®) and the evolving AP233 standard (in-process)

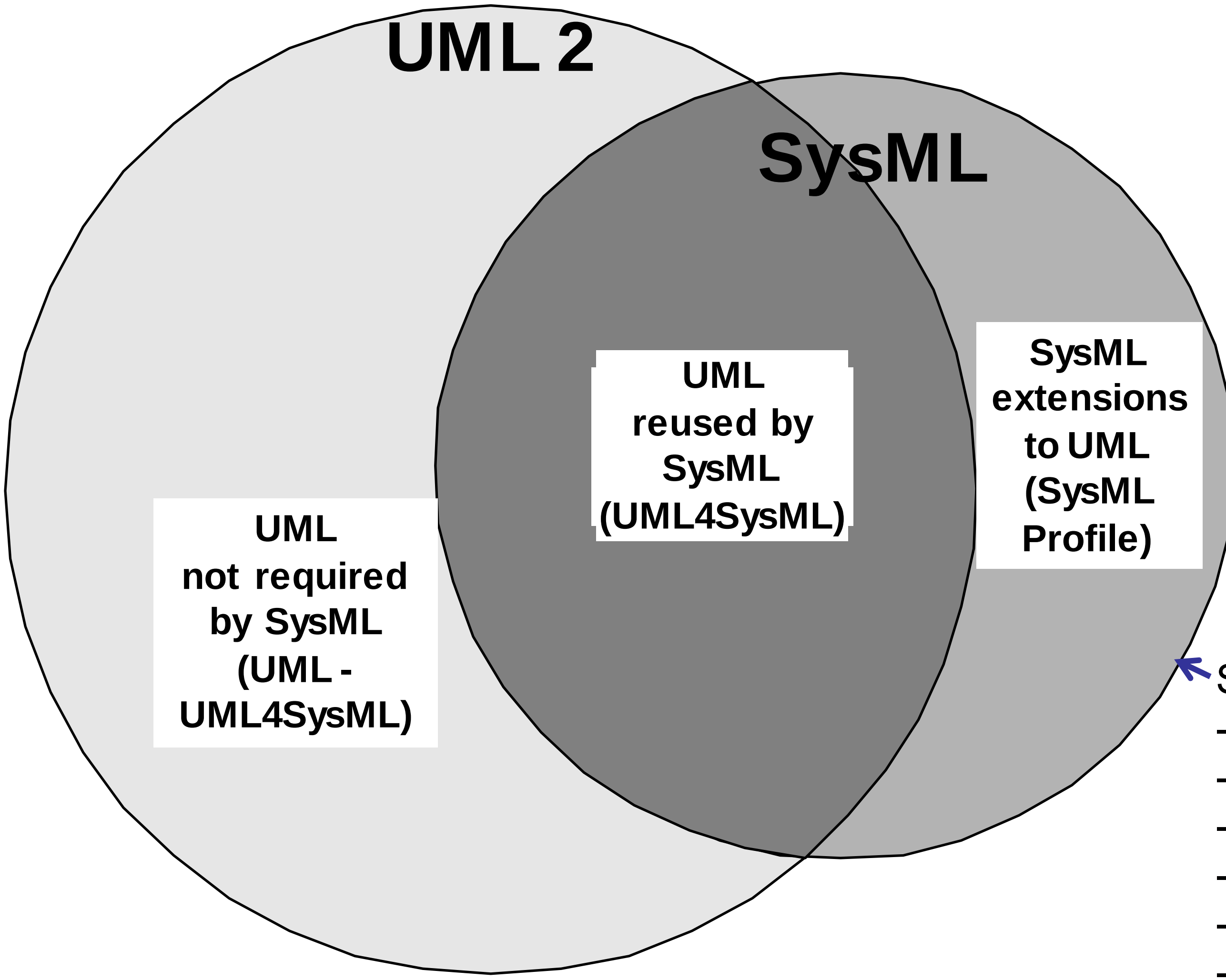
SysML is Critical Enabler for Model Driven SE

What is SysML (cont.)

- ***Is*** a visual modeling language that provides
  - Semantics = meaning
  - Notation = representation of meaning
- ***Is not*** a methodology or a tool
  - SysML is methodology and tool independent

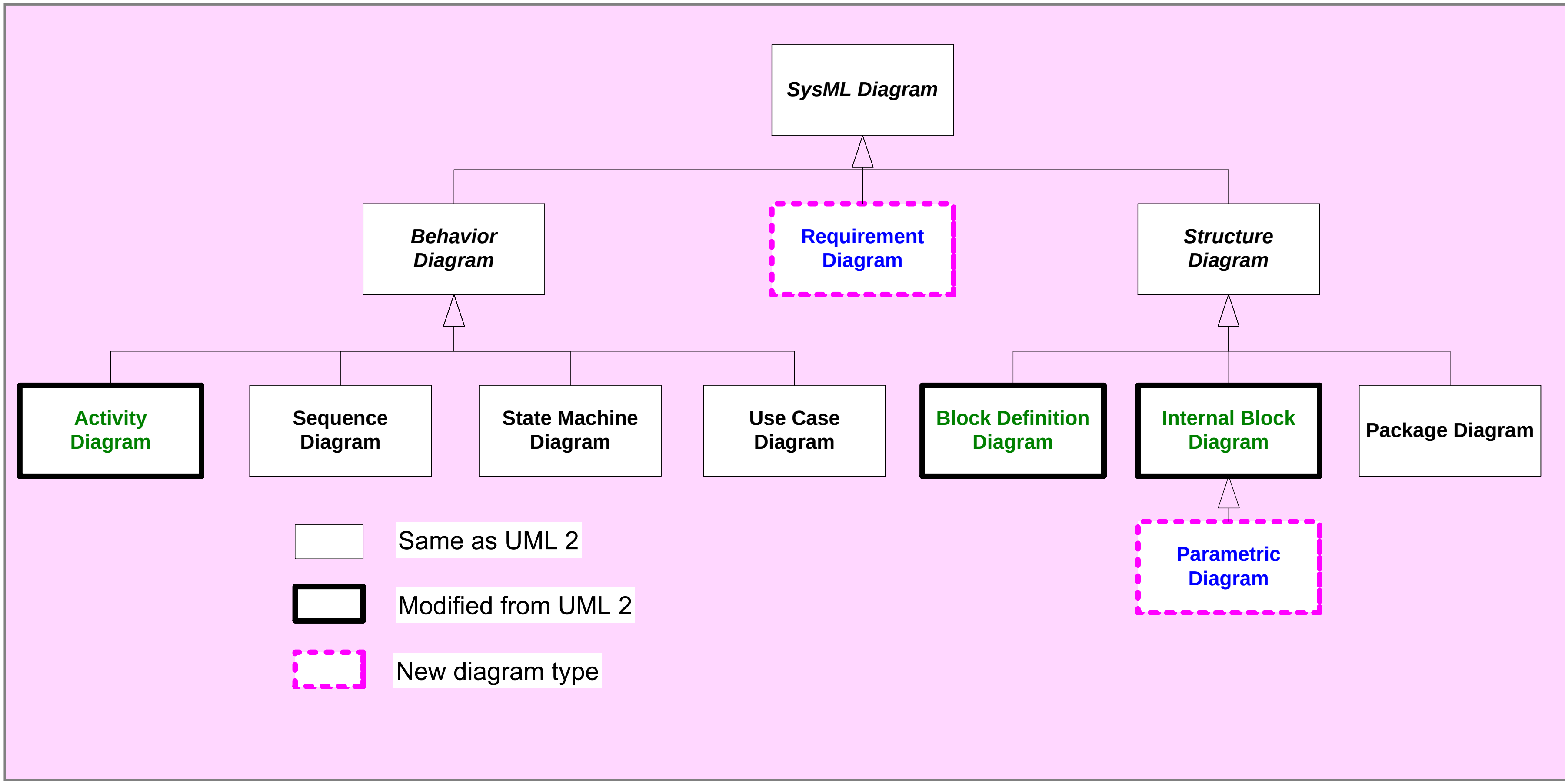
Diagram Overview & Language Concepts

Relationship Between SysML and UML

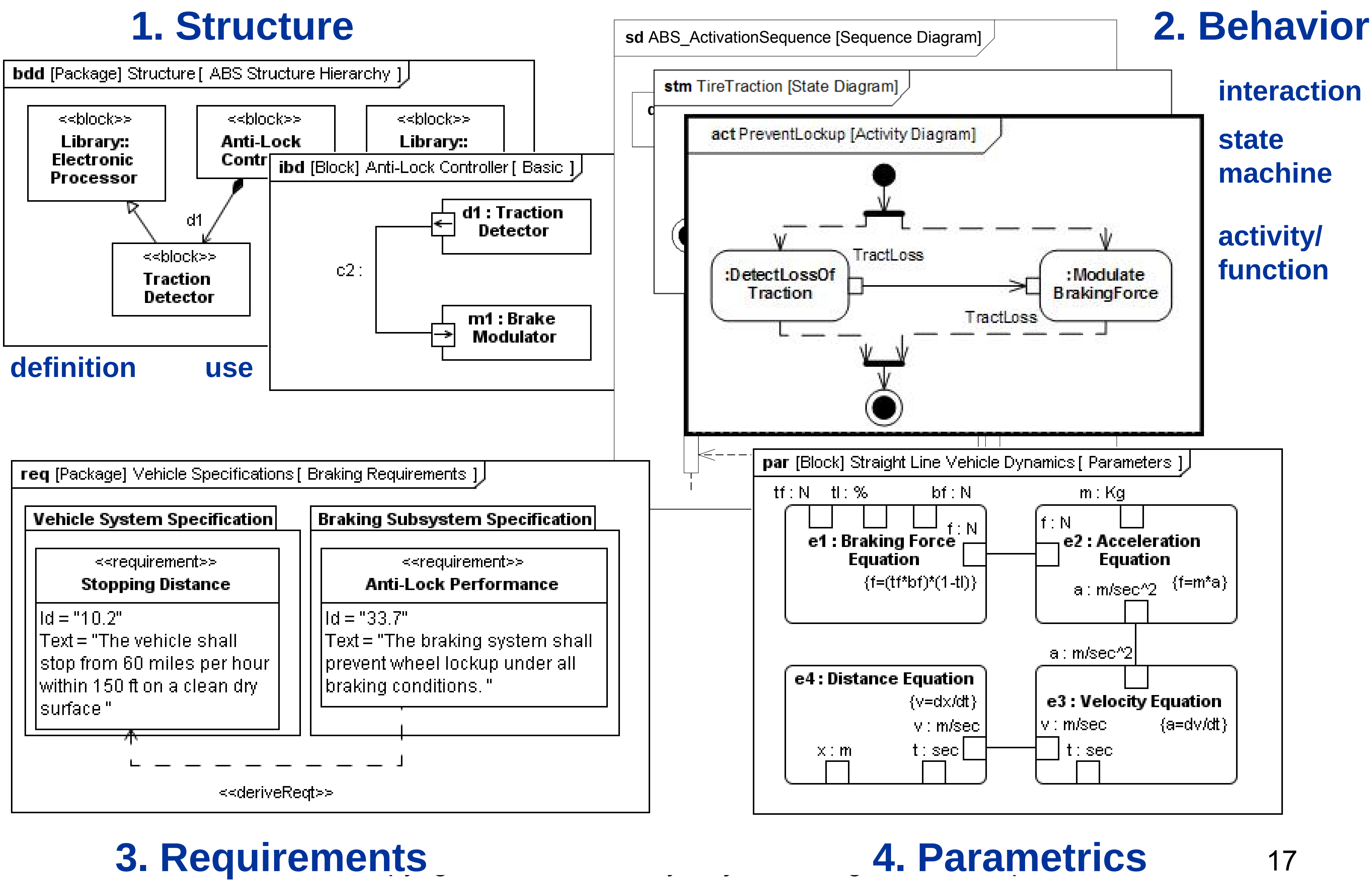


SysML Extensions
-Blocks
-Item flows
-Value properties
-Allocations
-Requirements
-Parametrics
-Continuous flows
-…

SysML Diagram Taxonomy

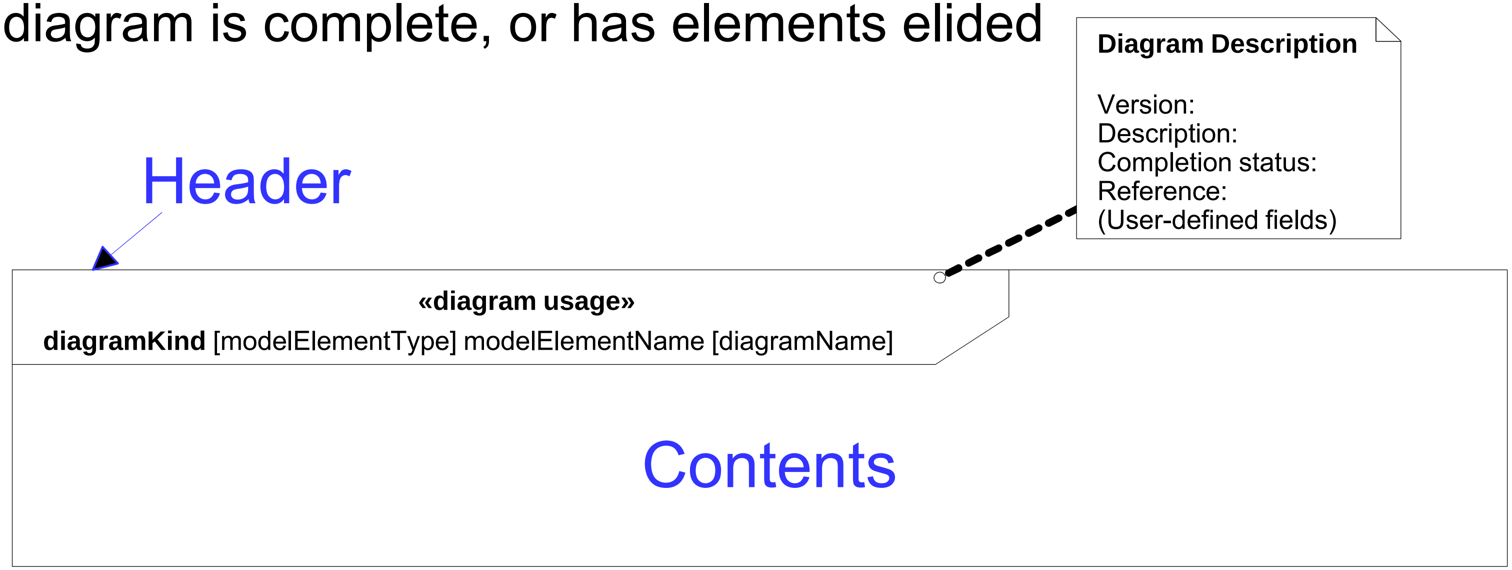


4 Pillars of SysML – ABS Example

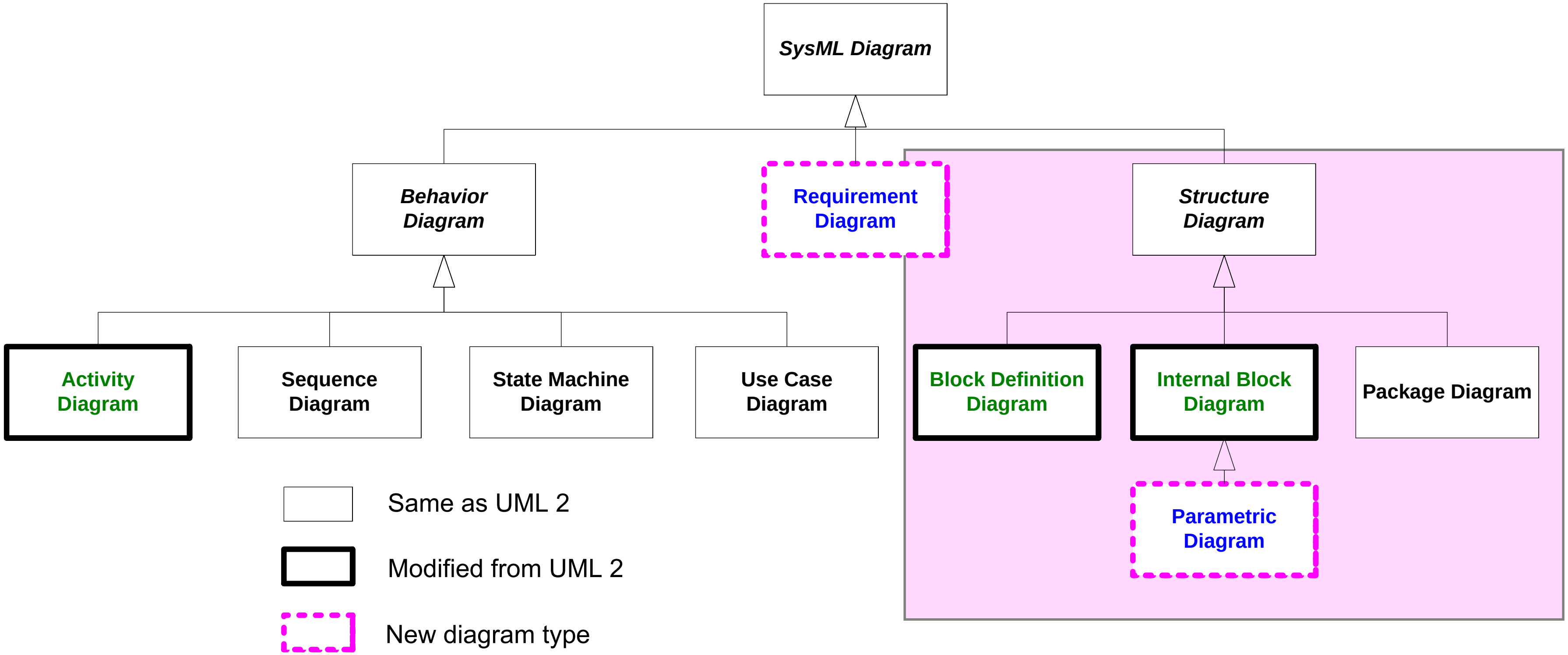


SysML Diagram Frames

- Each SysML diagram represents a model element
- Each SysML Diagram must have a Diagram Frame
- Diagram context is indicated in the header:
  - Diagram kind (act, bdd, ibd, sd, etc.)
  - Model element type (package, block, activity, etc.)
  - Model element name
  - User defined diagram name or view name
- A separate diagram description block is used to indicate if the diagram is complete, or has elements elided



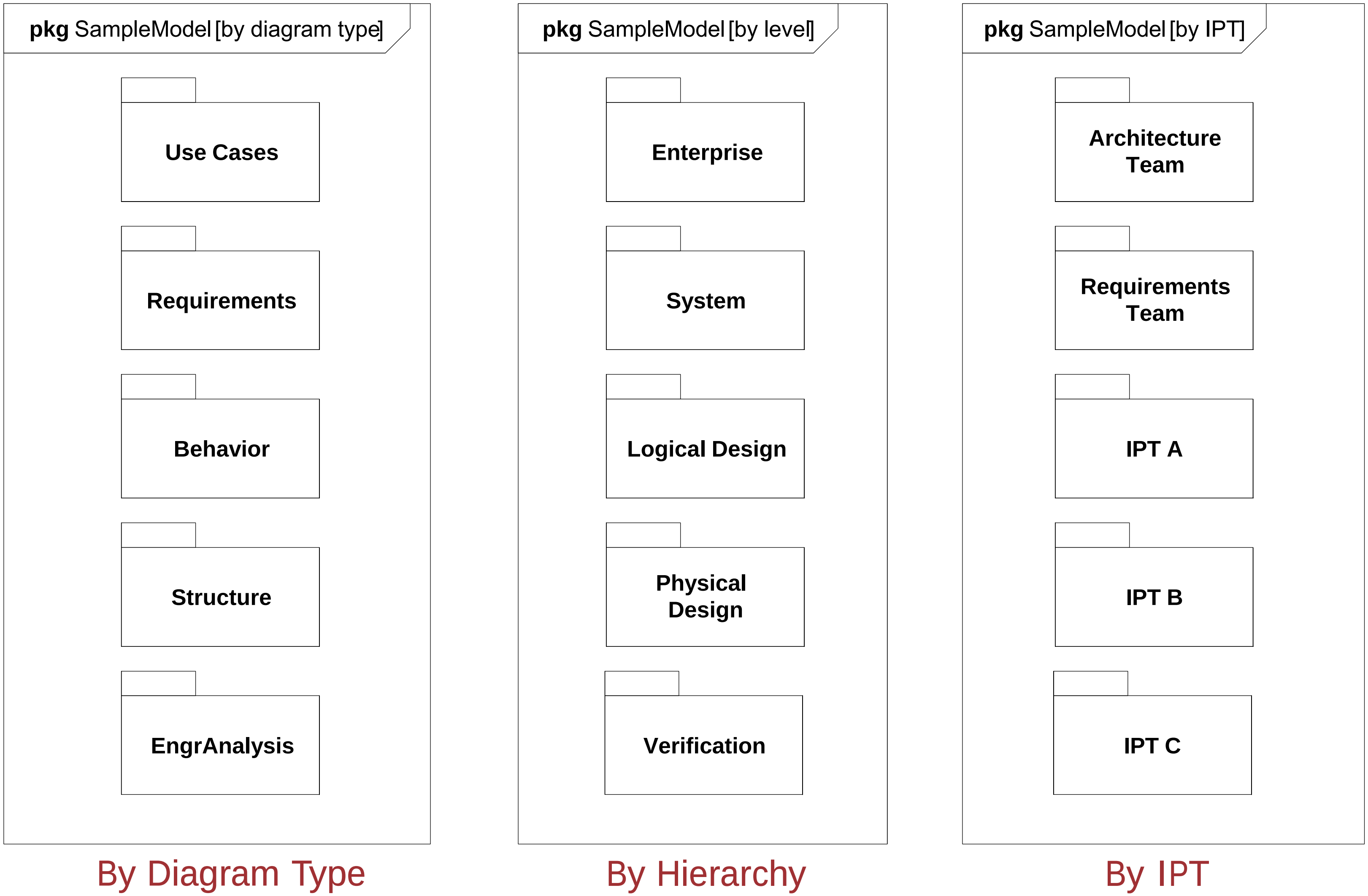
Structural Diagrams



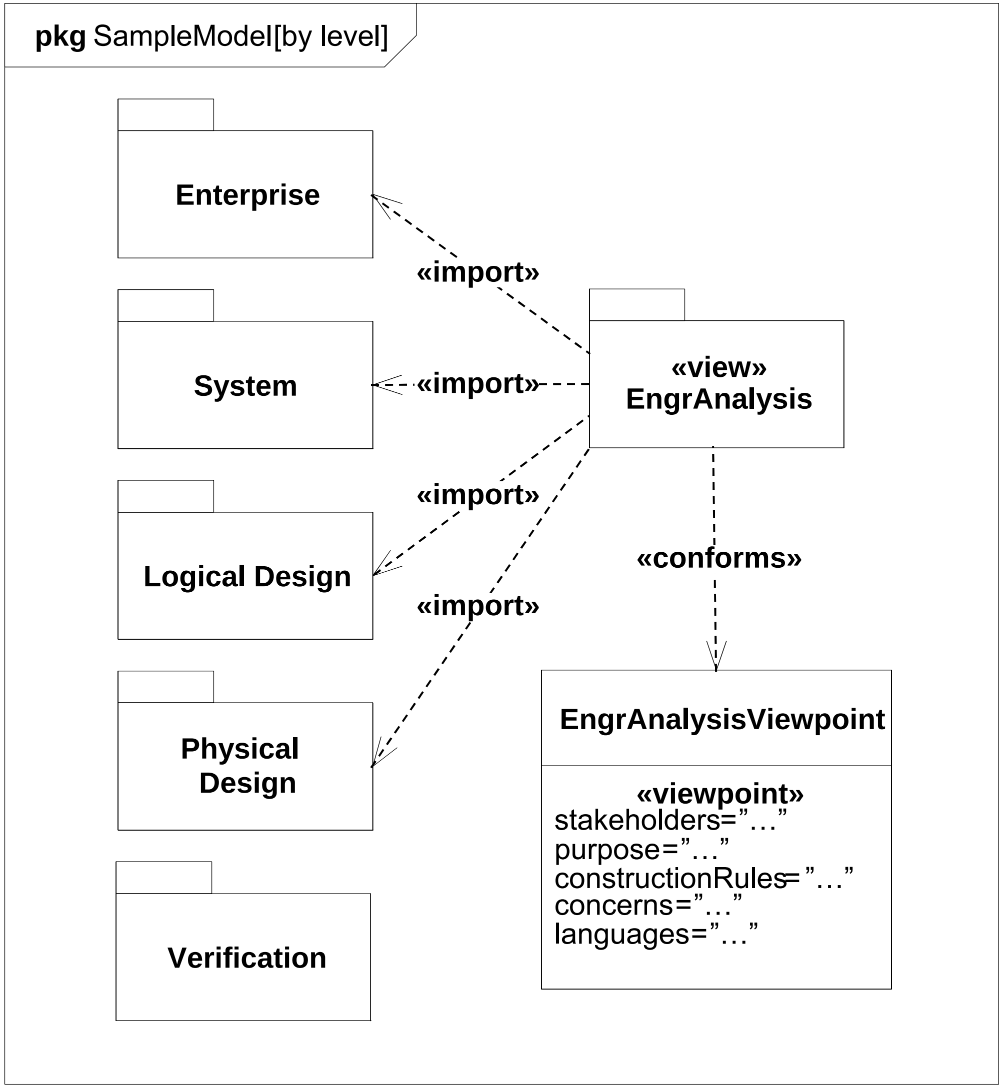
Package Diagram

- Package diagram is used to organize the model
  - Groups model elements into a name space
  - Often represented in tool browser
  - Supports model configuration management (check-in/out)
- Model can be organized in multiple ways
  - By System hierarchy (e.g., enterprise, system, component)
  - By diagram kine (e.g., requirements, use cases, behavior)
  - Use viewpoints to augment model organization
- Import relationship reduces need for fully qualified name (package1::class1)

Package Diagram
Organizing the Model



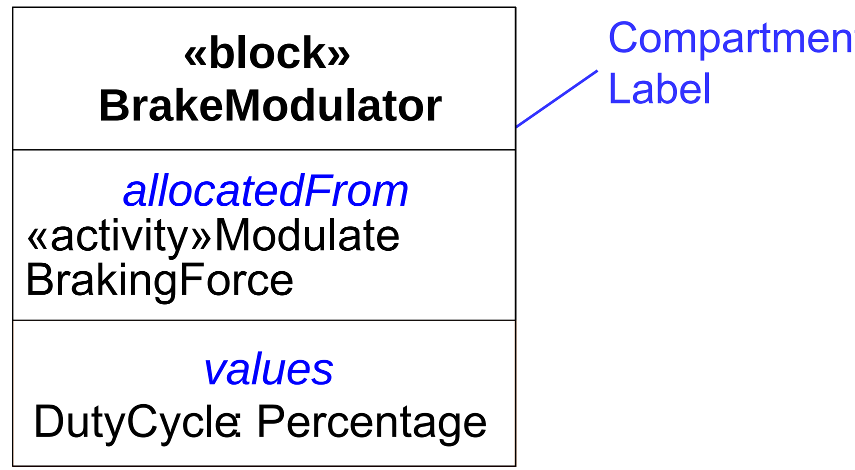
Package Diagram - Views



- Viewpoint represents the stakeholder perspective
- View conforms to a particular viewpoint
  - Imports model elements from multiple packages
  - Can represent a model query based on query criteria
- View and Viewpoint consistent with IEEE 1471 definitions

Blocks are Basic Structural Elements

- Provides a unifying concept to describe the structure of an element or system
  - System
  - Hardware
  - Software
  - Data
  - Procedure
  - Facility
  - Person



- Multiple standard compartments can describe the block characteristics
  - Properties (parts, references, values, ports)
  - Operations
  - Constraints
  - Allocations from/to other model elements (e.g. activities)
  - Requirements the block satisfies
  - User defined compartments

Property Types

- Property is a structural feature of a block
  - **Part property** aka. part (typed by a block)
    - Usage of a block in the context of the enclosing (composite) block
    - Example - right-front:wheel
  - **Reference property** (typed by a block)
    - A part that is not owned by the enclosing block (not composition)
    - Example – aggregation of components into logical subsystem
  - **Value property** (typed by value type)
    - A quantifiable property with units, dimensions, and probability distribution
    - Example
      - *Non-distributed value:* tirePressure:psi=30
      - *Distributed value:* «uniform» {min=28,max=32} tirePressure:psi

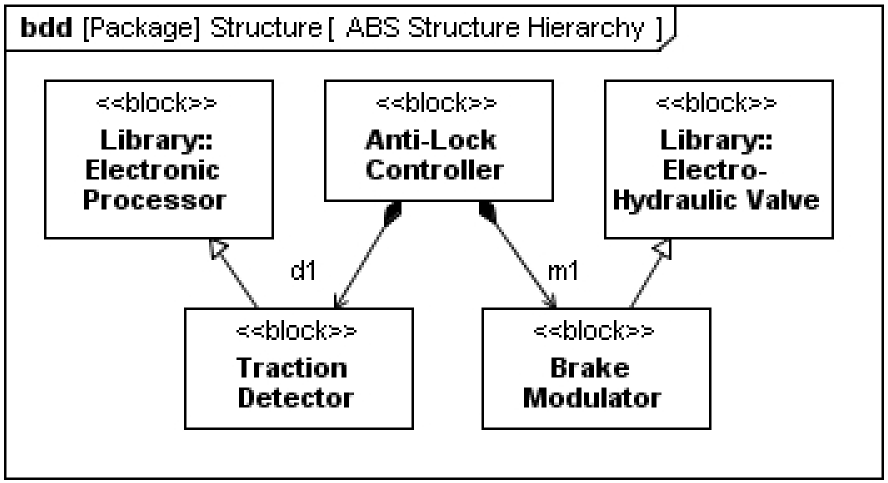
Using Blocks

- Based on UML Class from UML Composite Structure
  - Supports unique features (e.g., flow ports, value properties)
- Block definition diagram describes the relationship among blocks (e.g., composition, association, specialization)
- Internal block diagram describes the internal structure of a block in terms of its properties and connectors
- Behavior can be allocated to blocks

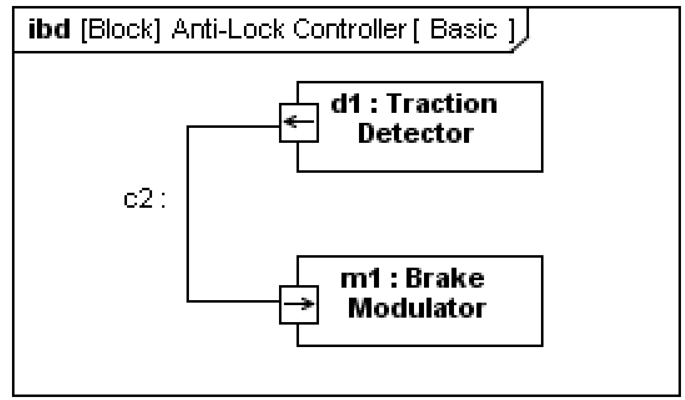
Blocks Used to Specify Hierarchies and Interconnection

Block Definition vs. Usage

Block Definition Diagram



Internal Block Diagram



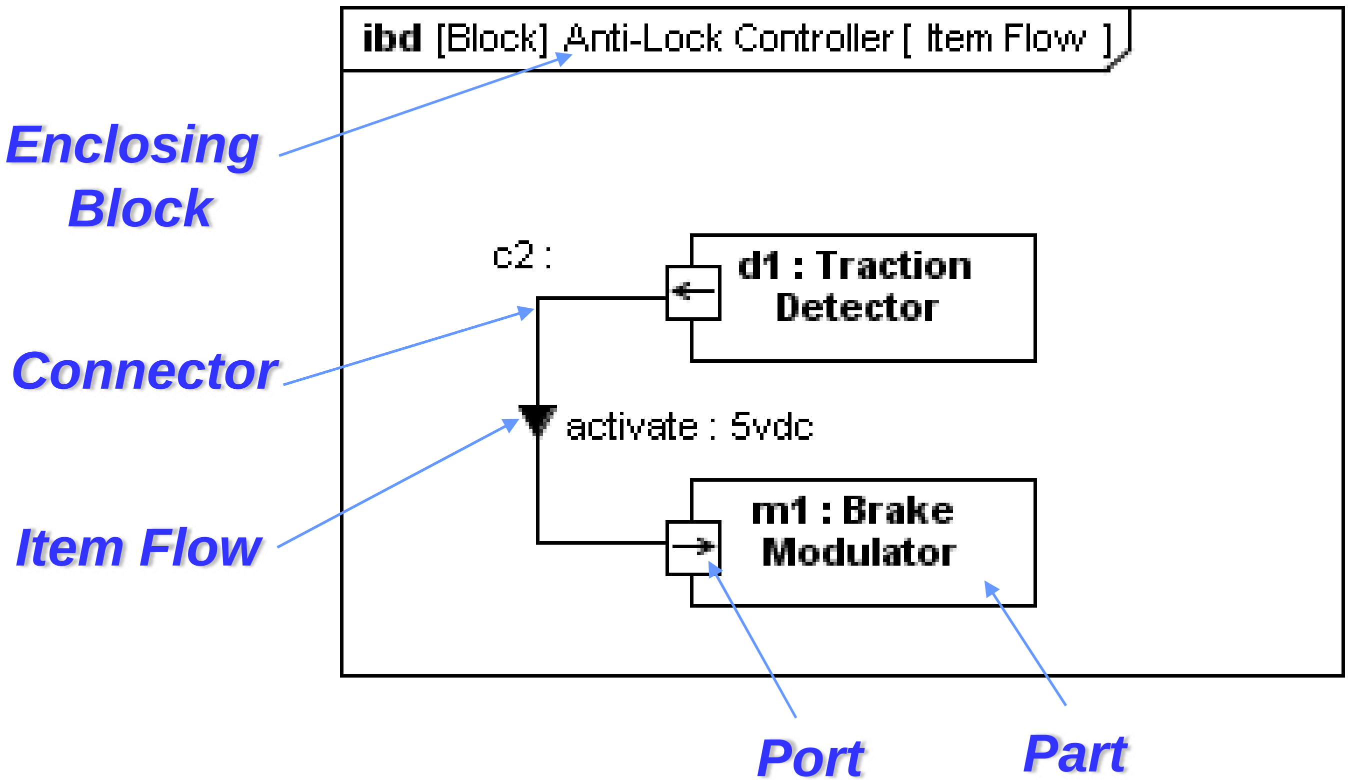
Definition

- Block is a definition/type
- Captures properties, etc.
- Reused in multiple contexts

Usage

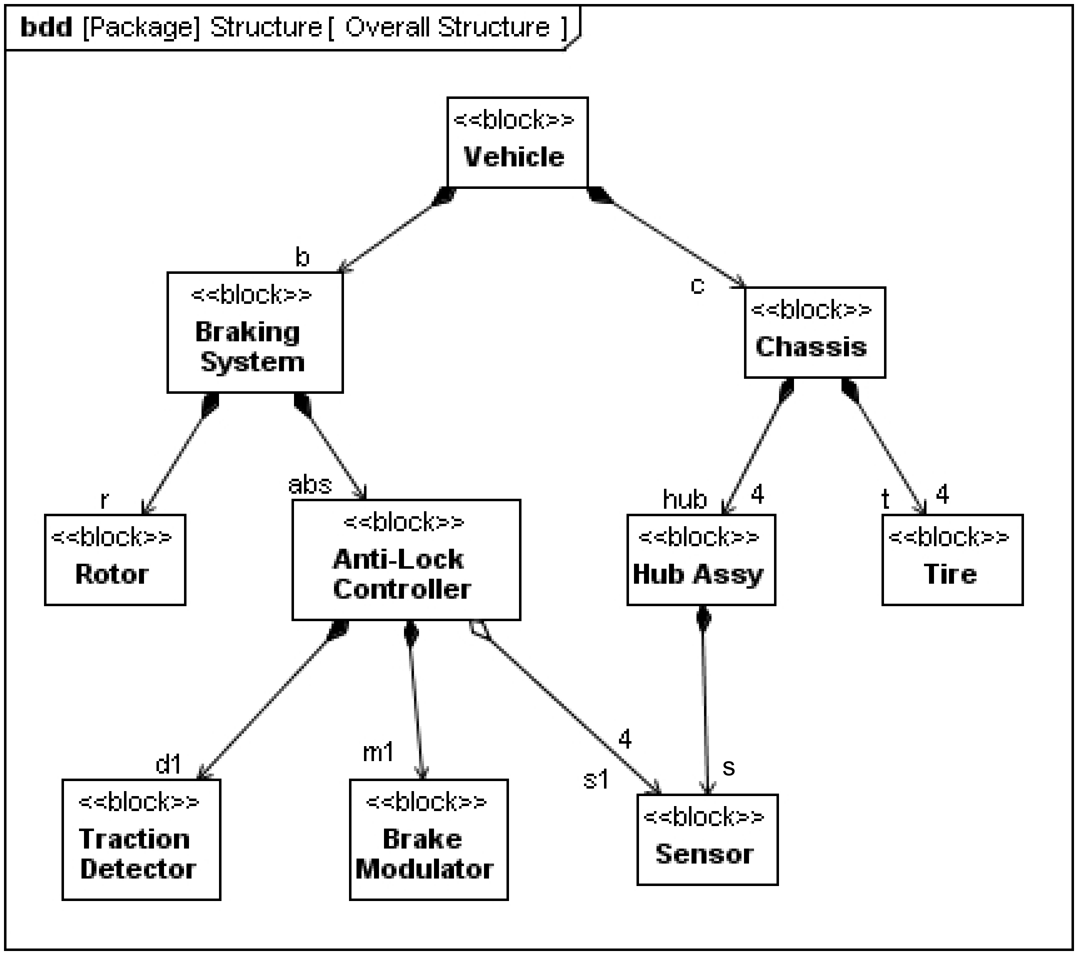
- Part is the usage of a block in the context of a composing block
- Also known as a role

Internal Block Diagram (ibd)
Blocks, Parts, Ports, Connectors & Flows

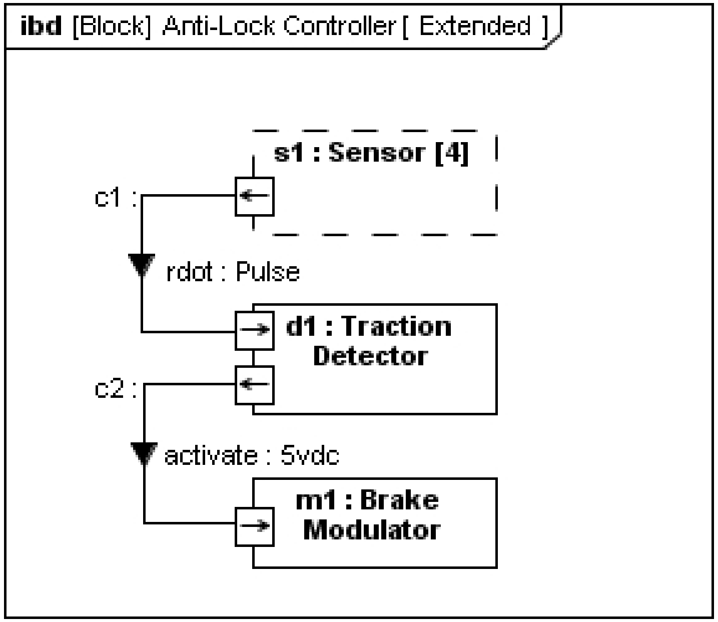


Internal Block Diagram Specifies Interconnection of Parts

Reference Property Explained



- •S1 is a reference part*
- •Shown in dashed outline box



*Actual name is reference property

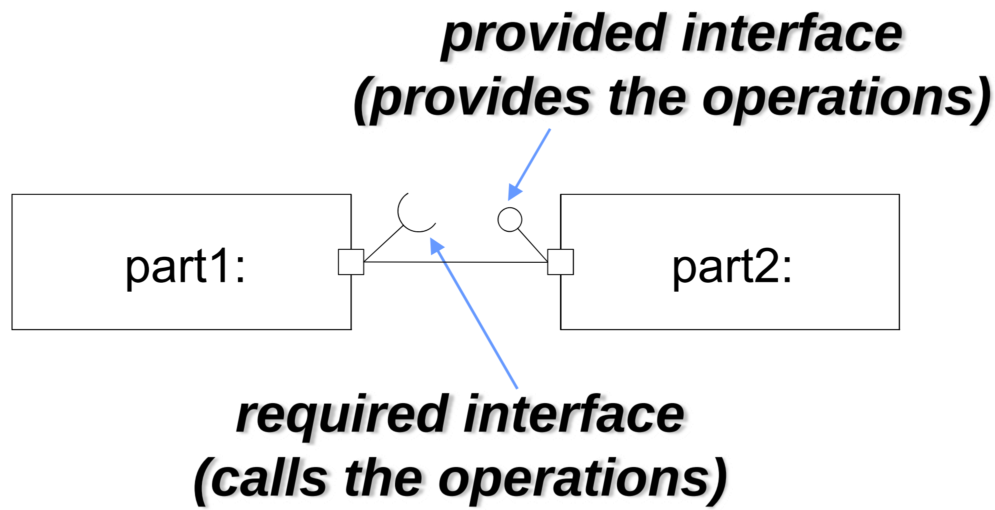
SysML Ports

- Specifies interaction points on blocks and parts
  - Integrates behavior with structure
  - portName:TypeName
- Kinds of ports
  - Standard (UML) Port
    - Specifies a set of required or provided operations and/or signals
    - Typed by a UML interface
  - Flow Port
    - Specifies what can flow in or out of block/part
    - Typed by a block, value type, or flow specification
    - Atomic, non-atomic, and conjugate variations

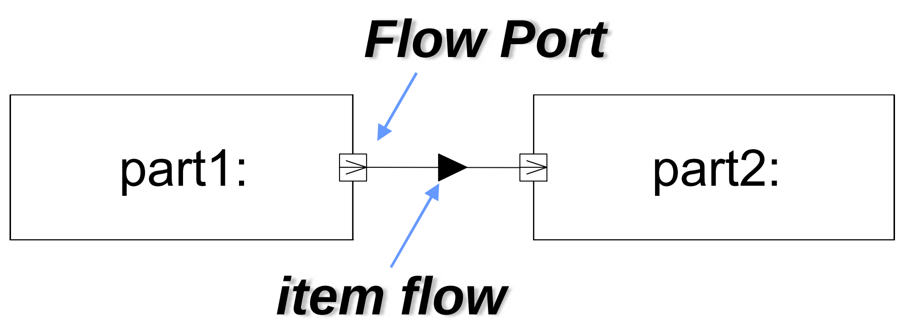
Standard Port and Flow Port Support Different Interface Concepts

Port Notation

Standard Port

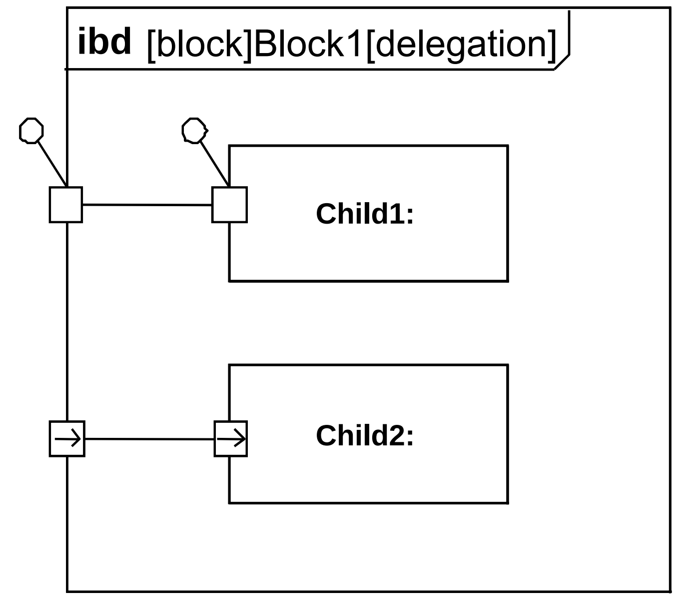


Flow Port



Delegation Through Ports

- Delegation can be used to preserve encapsulation of block (black box vs white box)
- Interactions at outer ports of Block1 are delegated to ports of child parts
- Ports must match (same kind, type, direction, etc.)
- Connectors _can_ cross boundary without requiring ports at each level of nested hierarchy

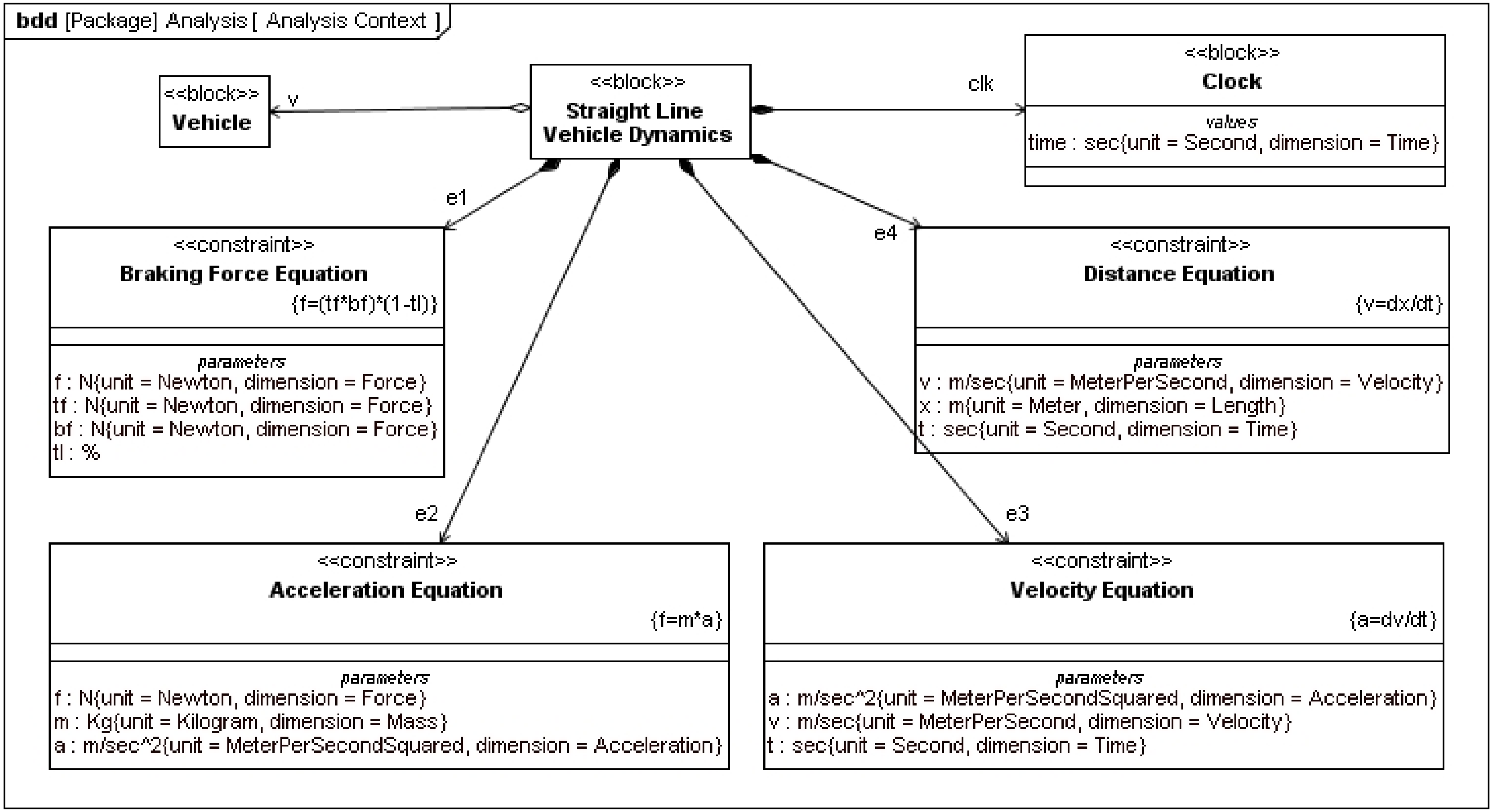


Parametrics

- Used to express constraints (equations) between value properties
  - Provides support for engineering analysis (e.g., performance, reliability)
  - Facilitates identification of critical performance properties
- Constraint block captures equations
  - Expression language can be formal (e.g., MathML, OCL) or informal
  - Computational engine is provided by applicable analysis tool and not by SysML
- Parametric diagram represents the usage of the constraints in an analysis context
  - Binding of constraint parameters to value properties of blocks (e.g., vehicle mass bound to parameter 'm' in $F = m \times a$)

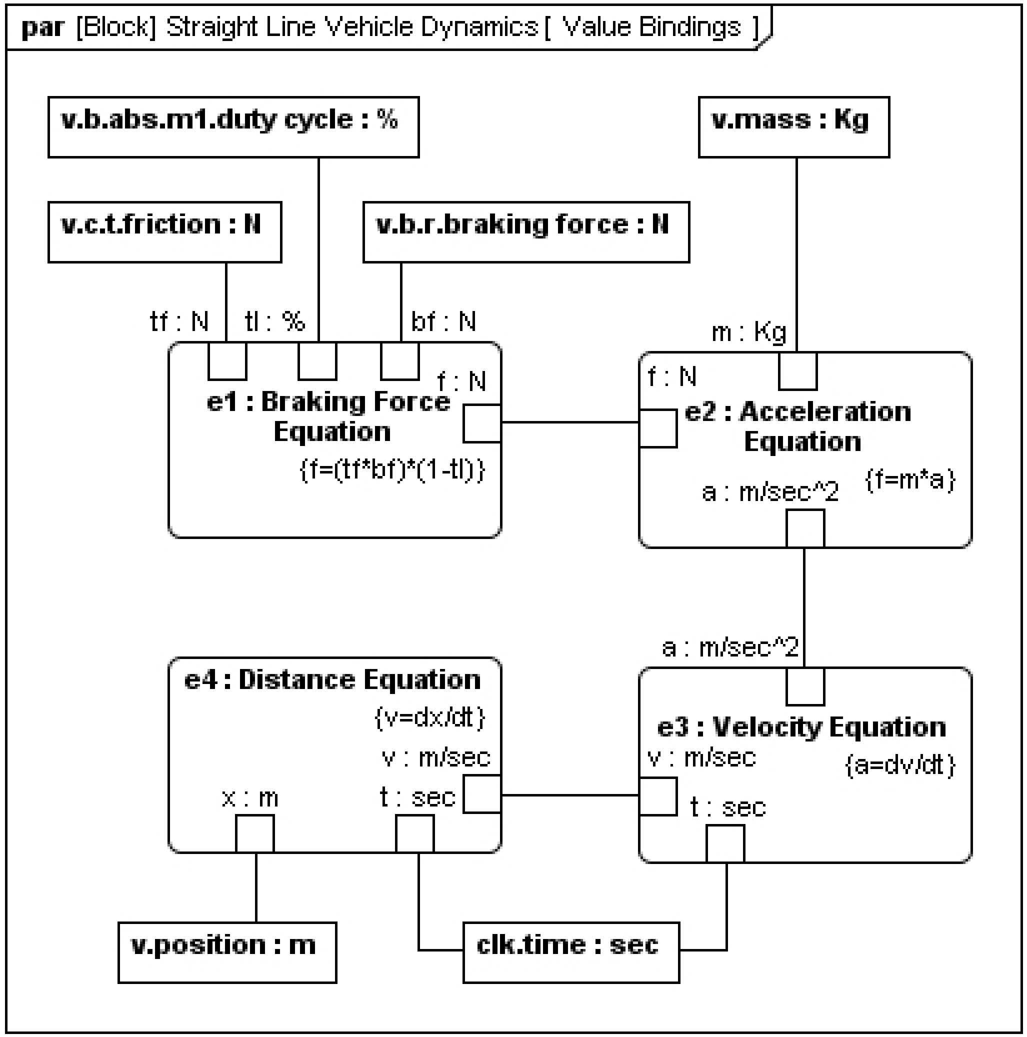
Parametrics Enable Integration of Engineering Analysis with Design Models

Defining Vehicle Dynamics



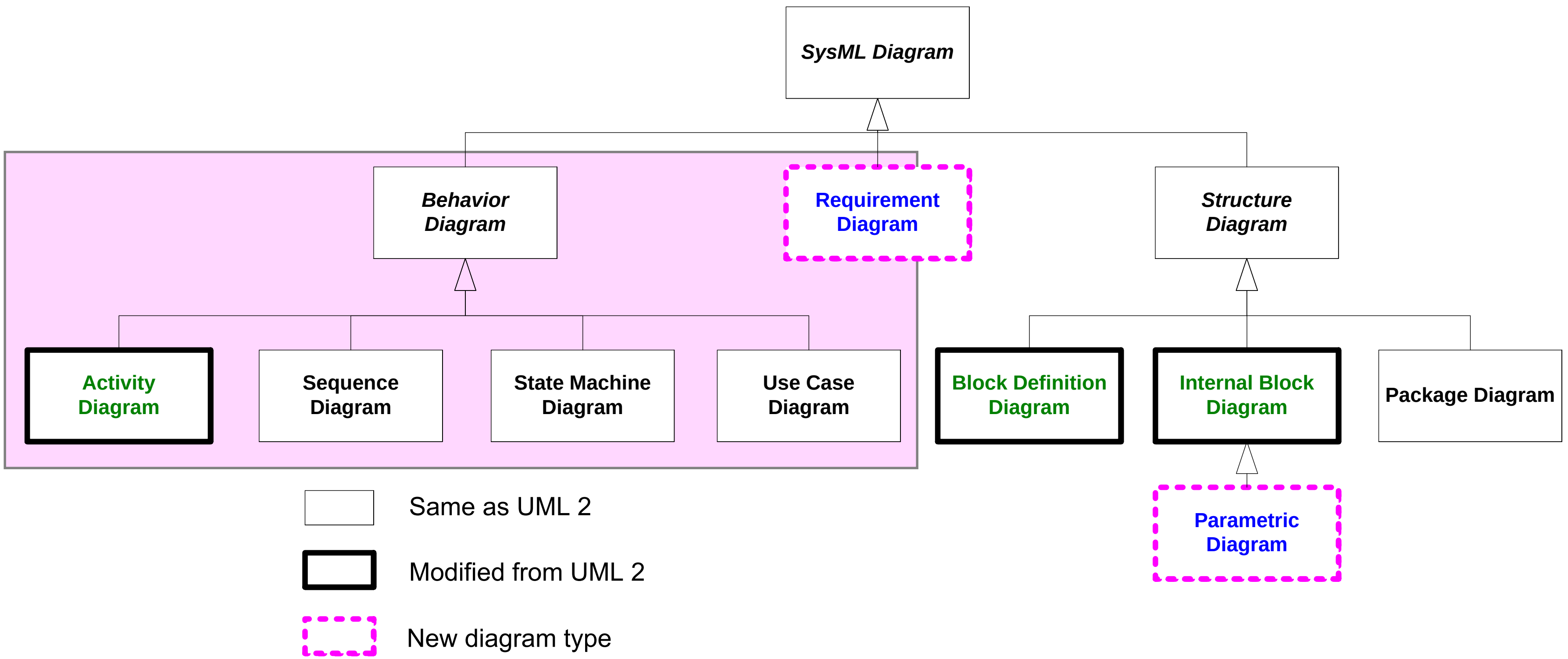
Defining Reusable Equations for Parametrics

Vehicle Dynamics Analysis



Using the Equations in a Parametric Diagram to Constrain Value Properties

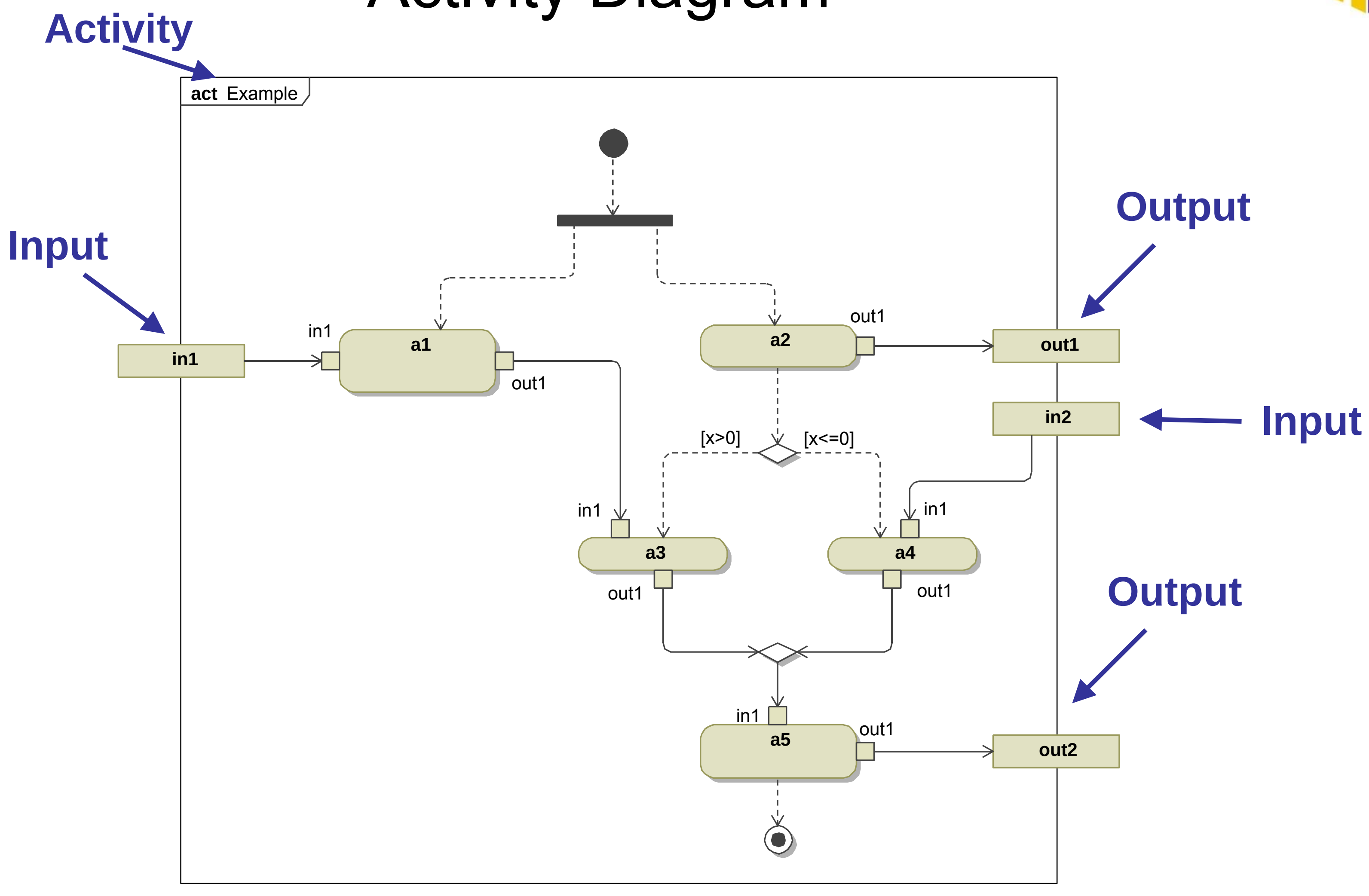
Behavioral Diagrams



Activities

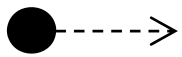
- Activity specifies transformation of inputs to outputs through a controlled sequence of actions
- Secondary constructs show responsibilities for the activities using activity partitions (i.e., swim lanes)
- SysML extensions to Activities
  - Support for continuous flow modeling
  - Alignment of activities with Enhanced Functional Flow Block Diagram (EFFBD)

Activity Diagram

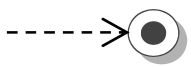


Activity Diagram Specifies Controlled Sequence of Actions

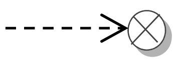
Routing Flows



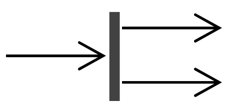
Initial Node – On execution of parent control token placed on outgoing control flows



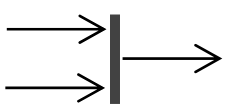
Activity Final Node – Receipt of a control token terminates parent



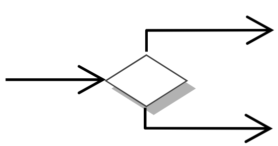
Flow Final Node – Sink for control tokens



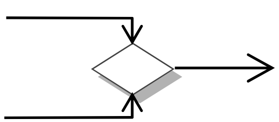
Fork Node – Duplicates input (control or object) tokens from its input flow onto all outgoing flows



Join Node – Waits for an input (control or object) token on all input flows and then places them all on the outgoing flow



Decision Node – Waits for an input (control or object) token on its input flow and places it on one outgoing flow based on guards

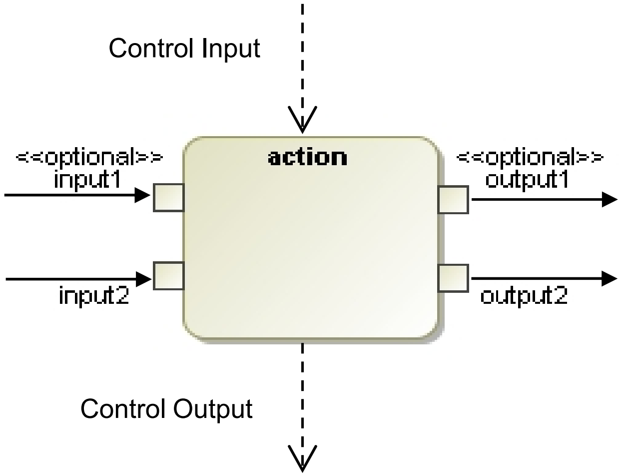


Merge Node – Waits for an input (control or object) token on any input flows and then places it on the outgoing flow

Guard expressions can be applied on all flows

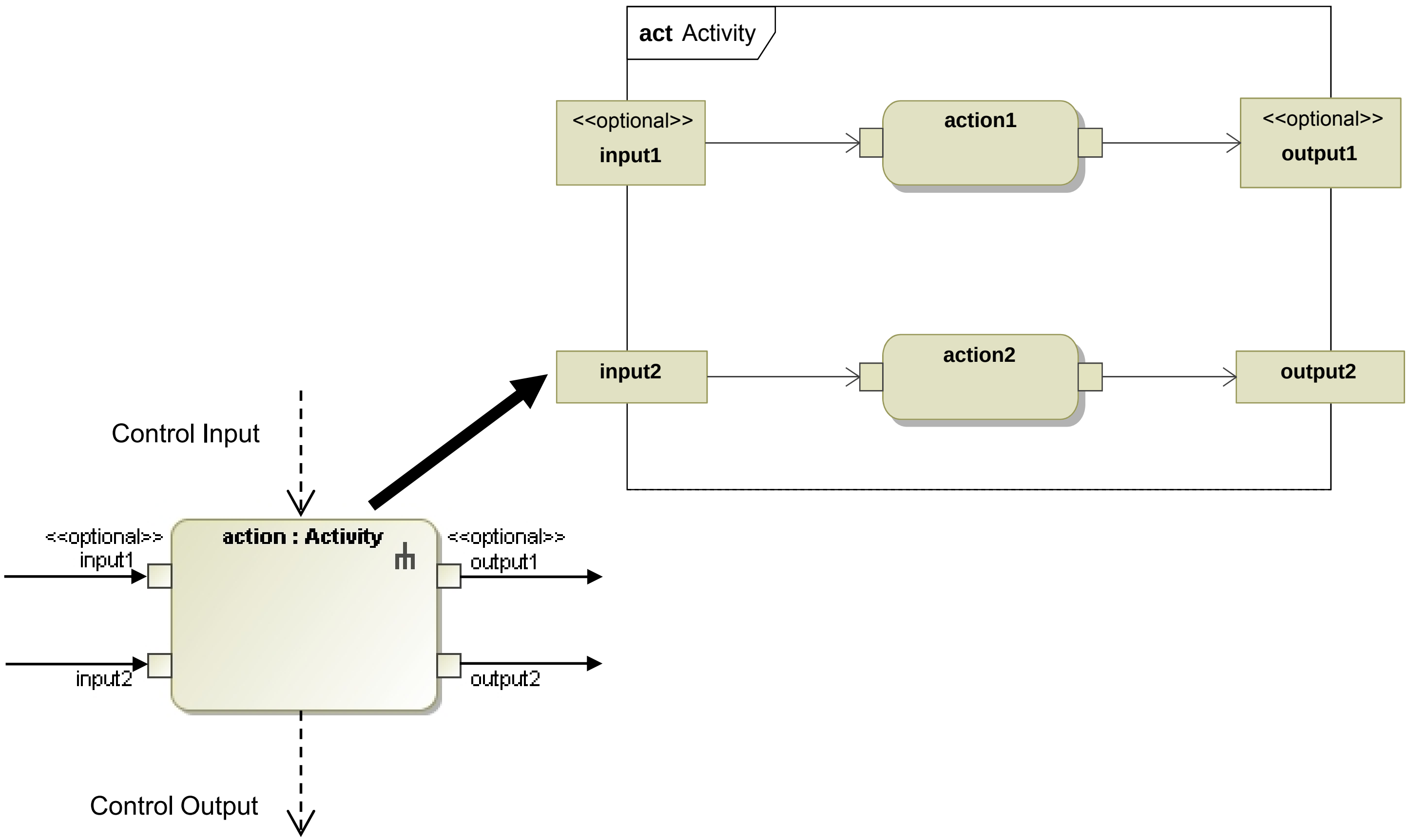
Actions Process Flow of Control and Data

- **Two types of flow**
  - **Object / Data**
  - **Control**
- **Unit of flow is called a "token"** (consumed & produced by actions)



Actions Execution Begins When Tokens Are Available on "all" Control Inputs and Required Inputs

An Action Can Invoke Another Activity



Activity is Invoked When an Action Begins to Execute

Semantics for Activity Invocation

A call behavior action can have

- 0..* control inputs & outputs
- 0 ..* optional item inputs & outputs
- 0..* required item inputs & outputs
- 0..* streaming (and continuous) item inputs & outputs

Note: The summary is an approximation of the semantics.
The detailed semantics are specified in the UML and SysML specification.

Starting an action:

- An action starts when a token is placed on all of its control inputs and all of its required inputs (must meet minimum multiplicity of its input pins) and the previous invoked activity has completed
- An action invokes an activity when it starts, and passes the tokens from its input pins to the input parameter nodes of the invoked activity

During an execution:

- An action continues to accept streaming inputs and produce streaming outputs

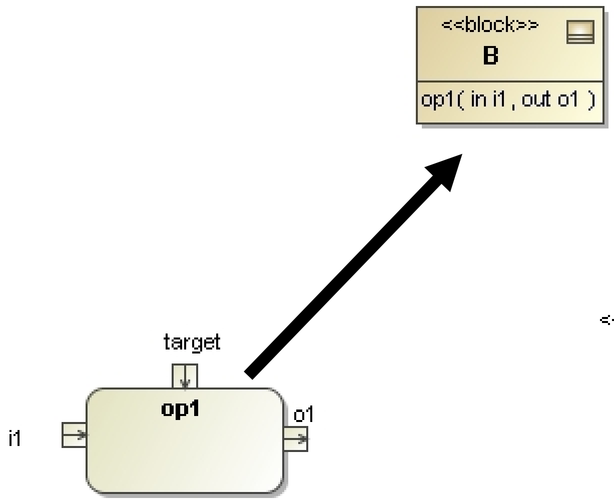
Terminating an action:

- An action terminates when its invoked activity reaches an activity final, or when the action receives a control disable, or as a side affect of other behaviors of the parent activity
- The tokens on the output parameter nodes of the activity are placed on the output pins of the action and a control token is placed on each of the control outputs of the action

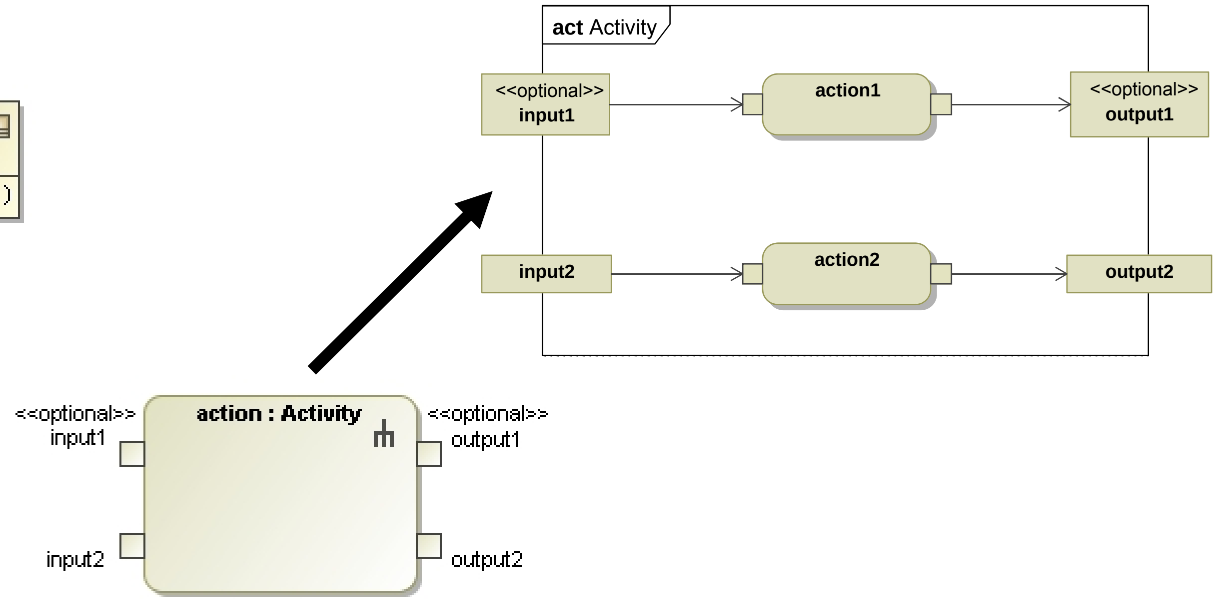
Following action termination:

- The tokens on the output pins and control outputs of the action are moved to the input pins of the next actions when they are ready to start per above
- The action can restart and invoke the activity again when the starting conditions are satisfied per above

Common Actions

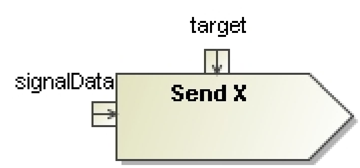


Call Operation Action
(can call leaf level function)



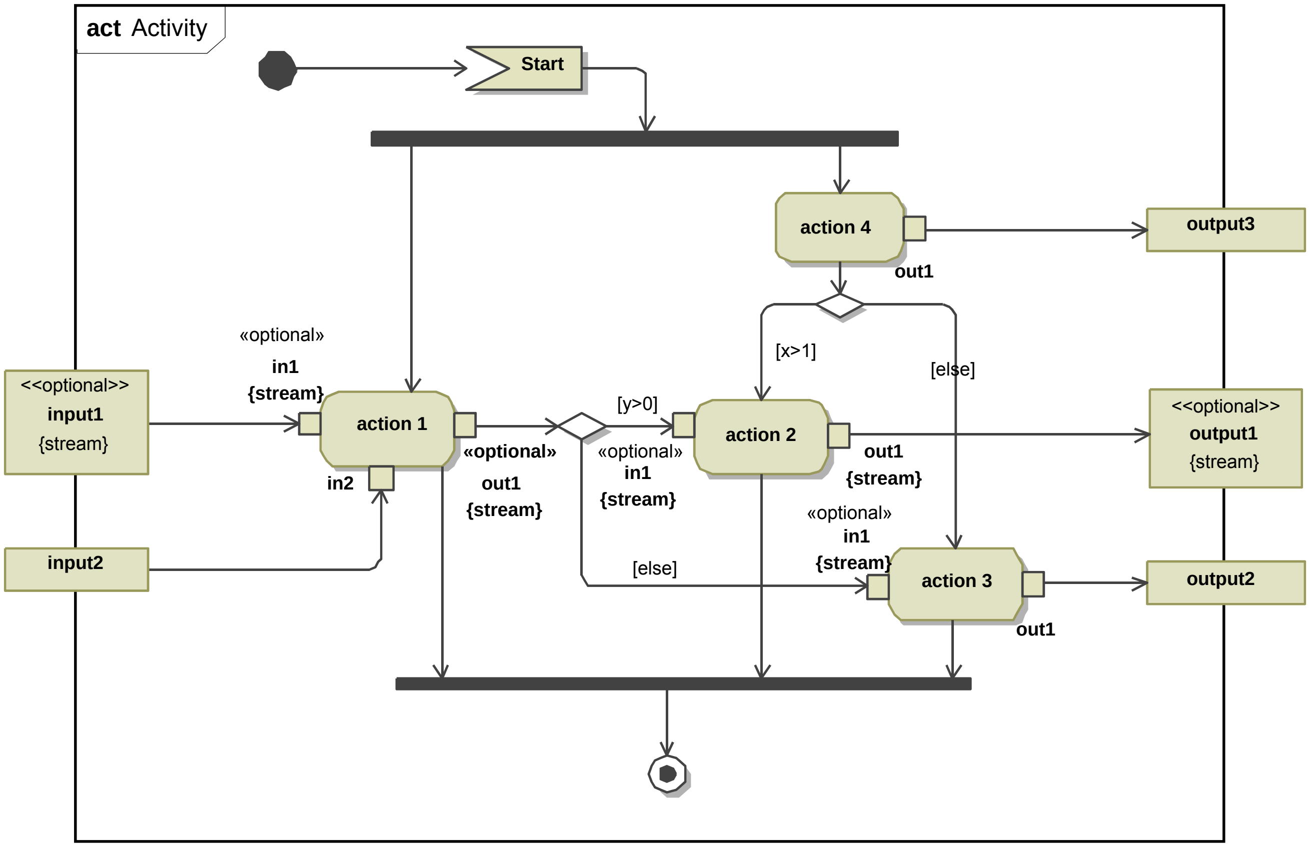
Call Behavior Action

Accept Event Action
(Event Data Pin often elided)



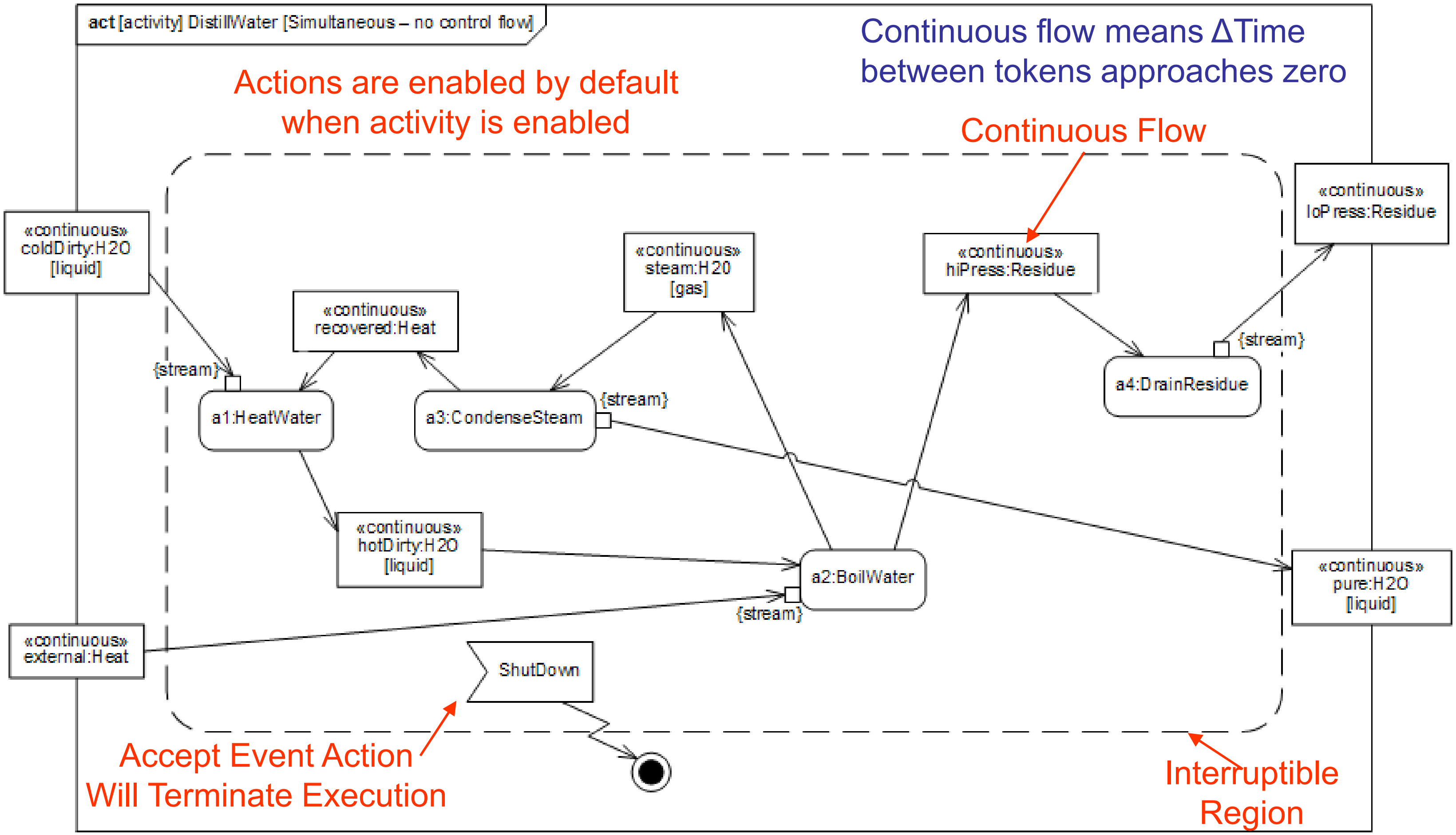
Send Signal Action
(Pins often elided)

Activity Diagram Example
With Streaming Inputs and Outputs



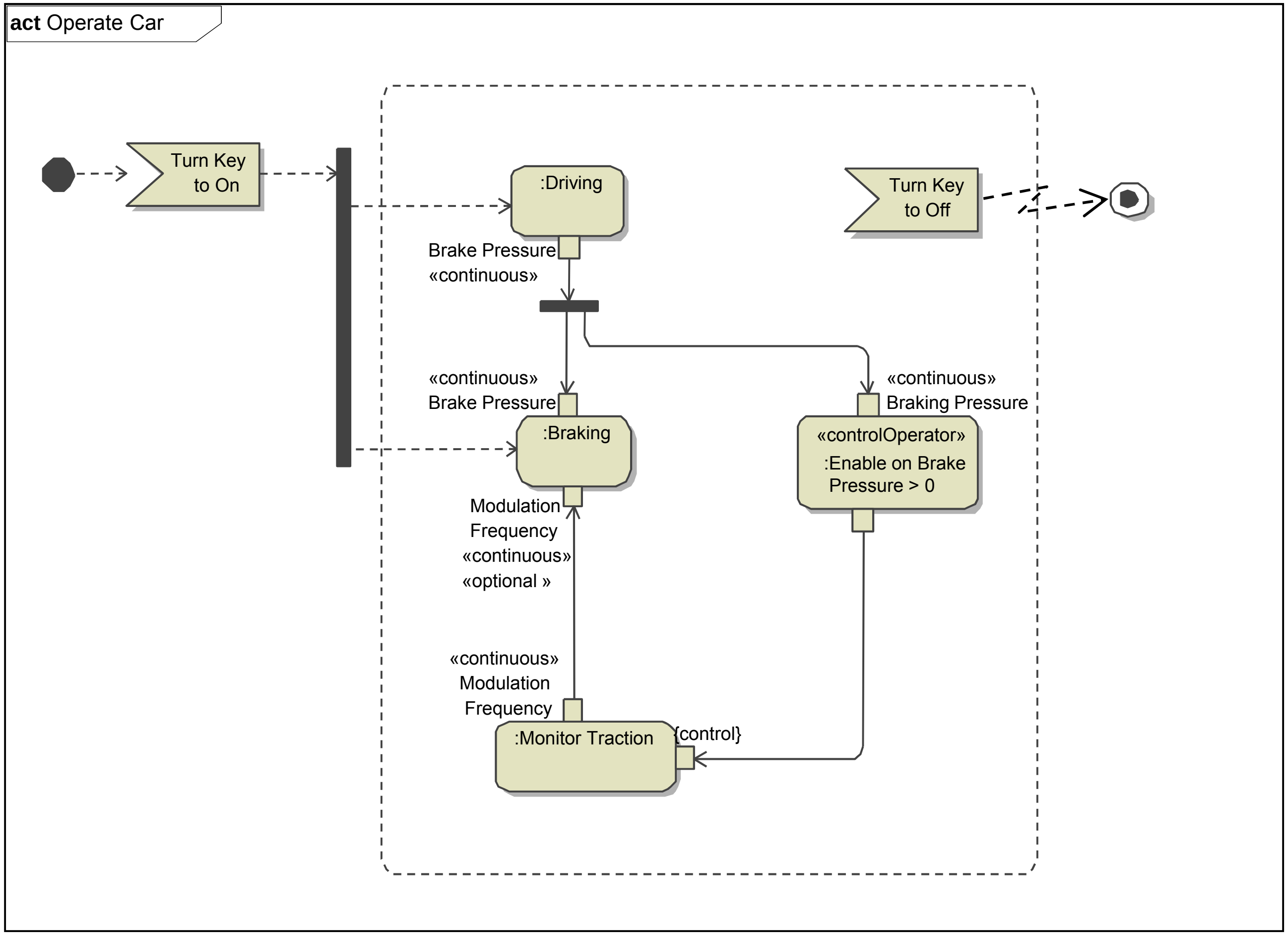
Streaming Inputs and Outputs Continue to Be Consumed and Produced While the Action is Executing

Distill Water Activity Diagram (Continuous Flow Modeling)



Continuous Flow Is Representative of Many Physical Processes

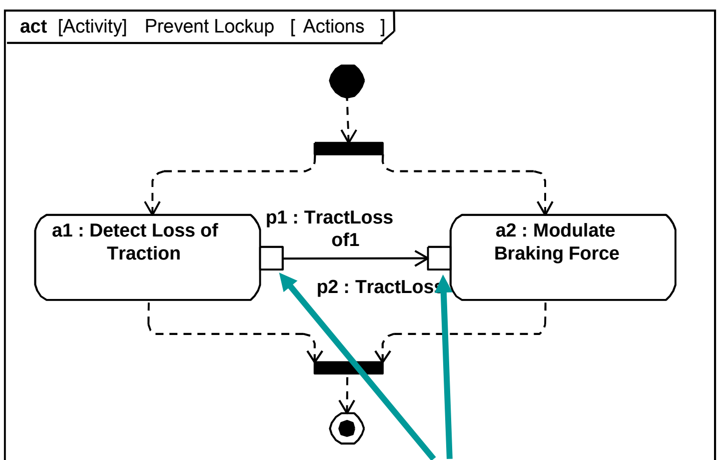
Example – Operate Car



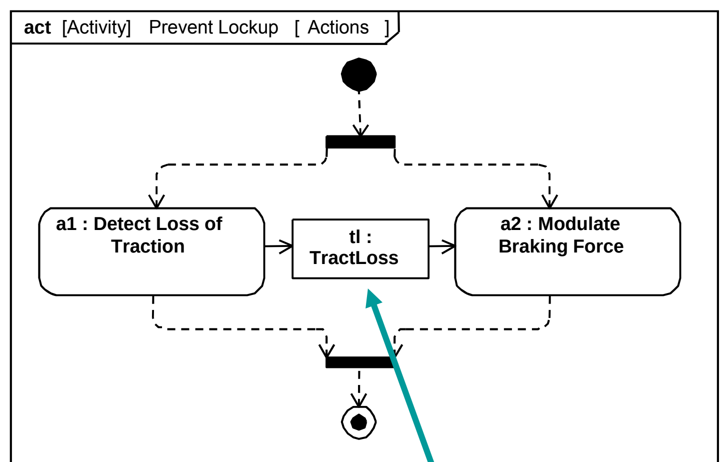
Enabling and Disabling Actions With Control Operators

Activity Diagrams
Pin vs. Object Node Notation

- Pins are kinds of Object Nodes
  - Used to specify inputs and outputs of actions
  - Typed by a block or value type
  - Object flows connect object nodes
- Object flows between pins have two diagrammatic forms
  - Pins shown with object flow between them
  - Pins elided and object node shown with flow arrows in and out



Pins

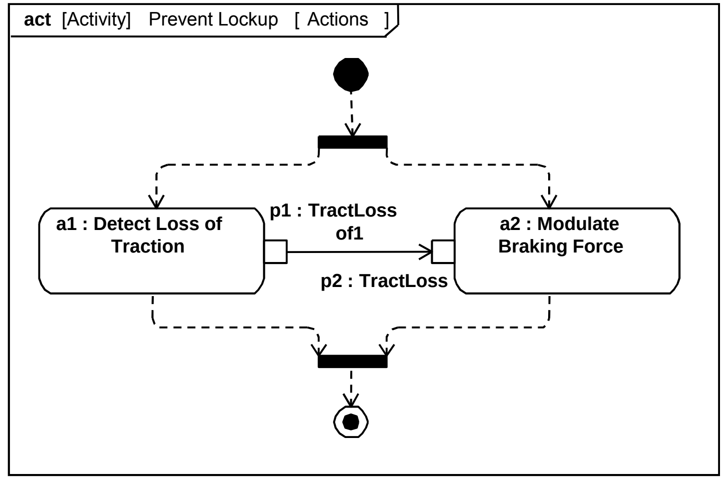


ObjectNode

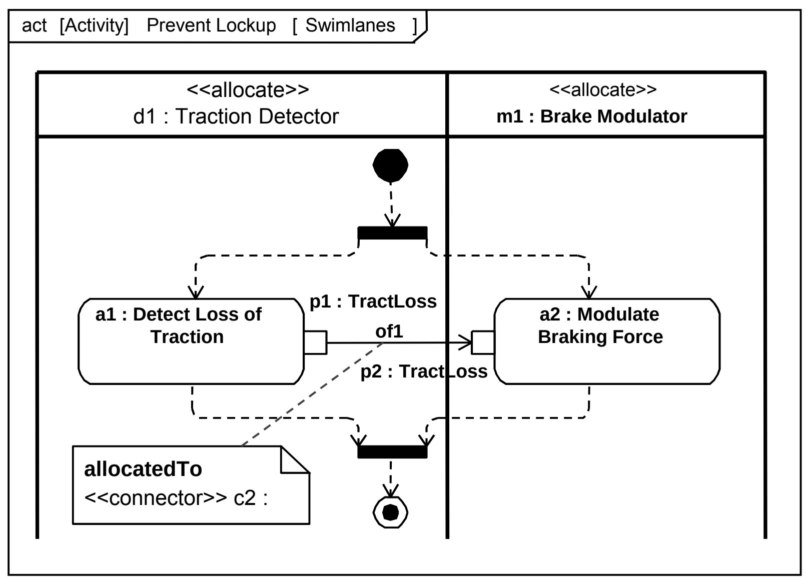
Pins must have same characteristics (name, type etc.)

Explicit Allocation of Behavior to Structure Using Swimlanes

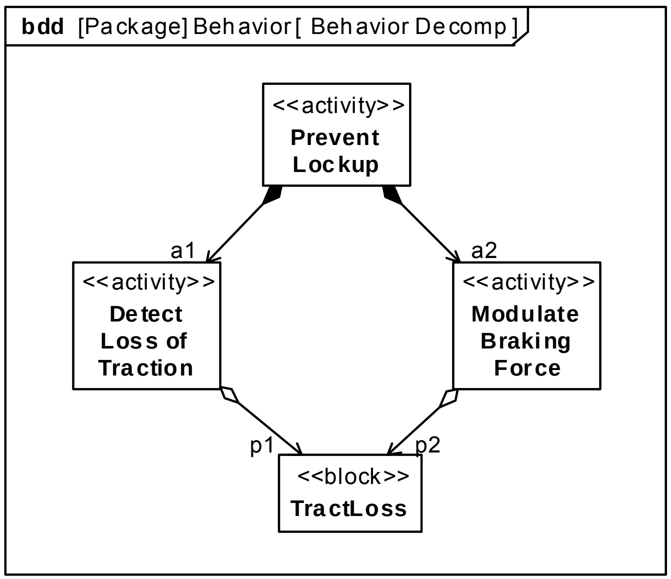
Activity Diagram (without Swimlanes)

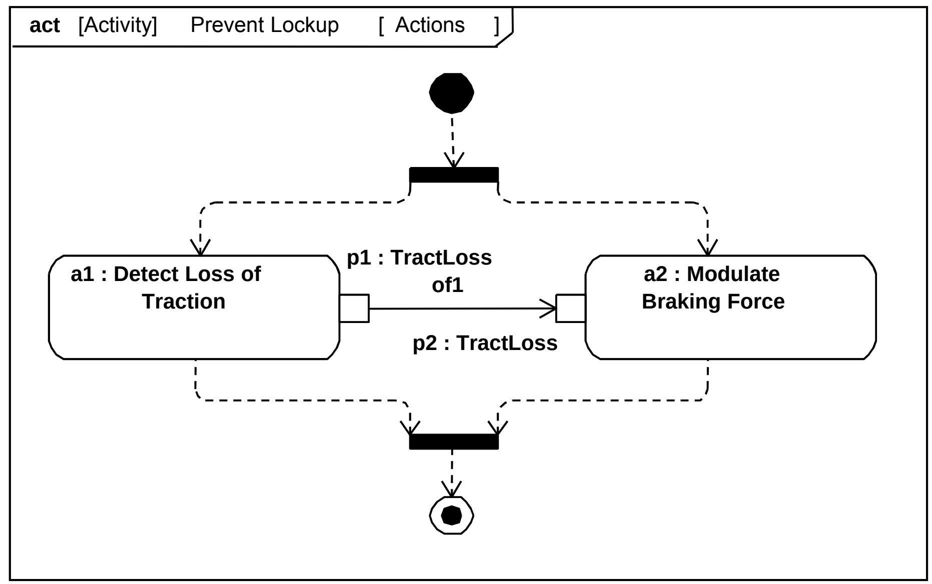


Activity Diagram (with Swimlanes)



Activity Decomposition

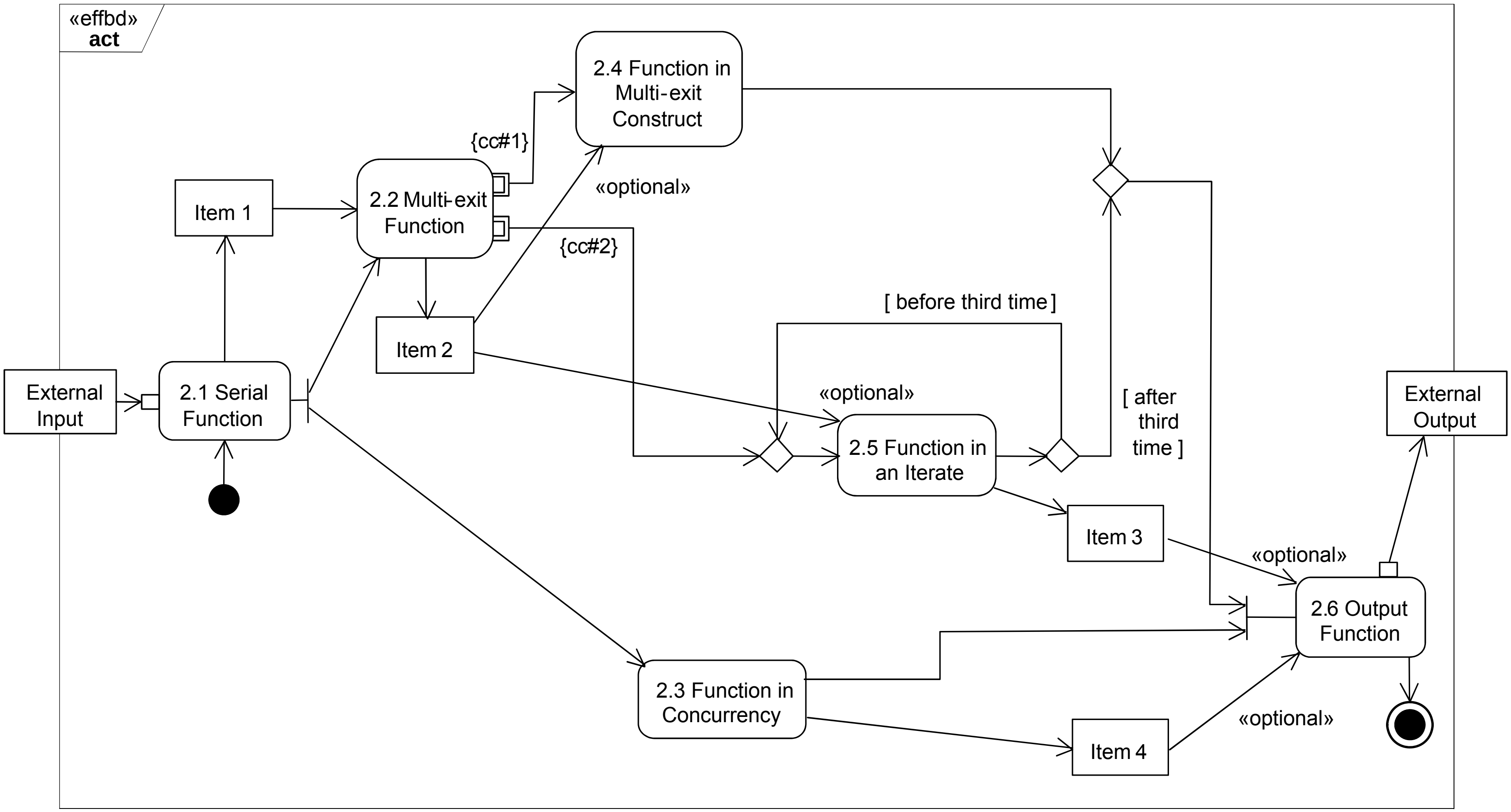




Definition

Use

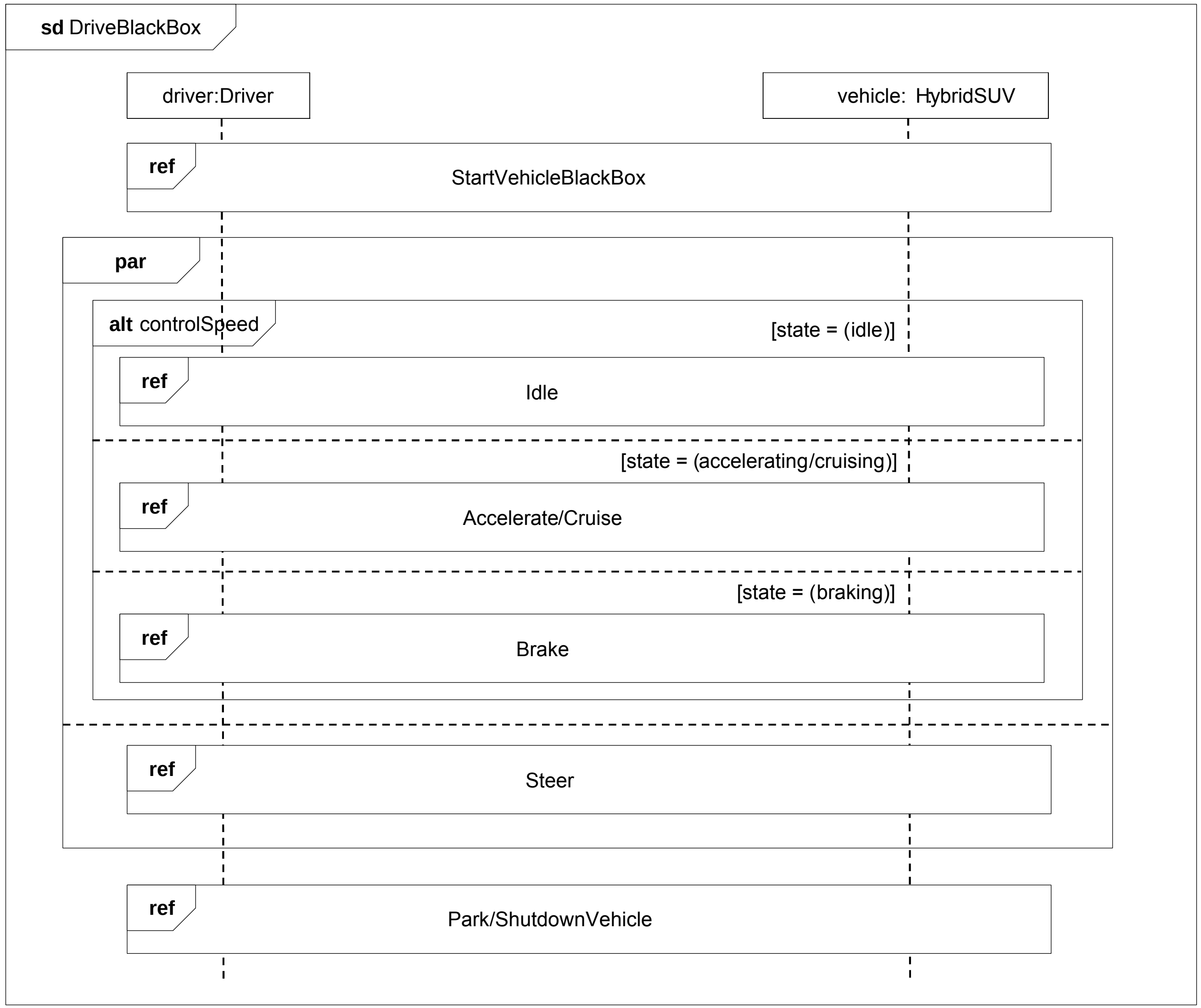
EFFBD - Enhanced Functional Flow Block Diagram



Interactions

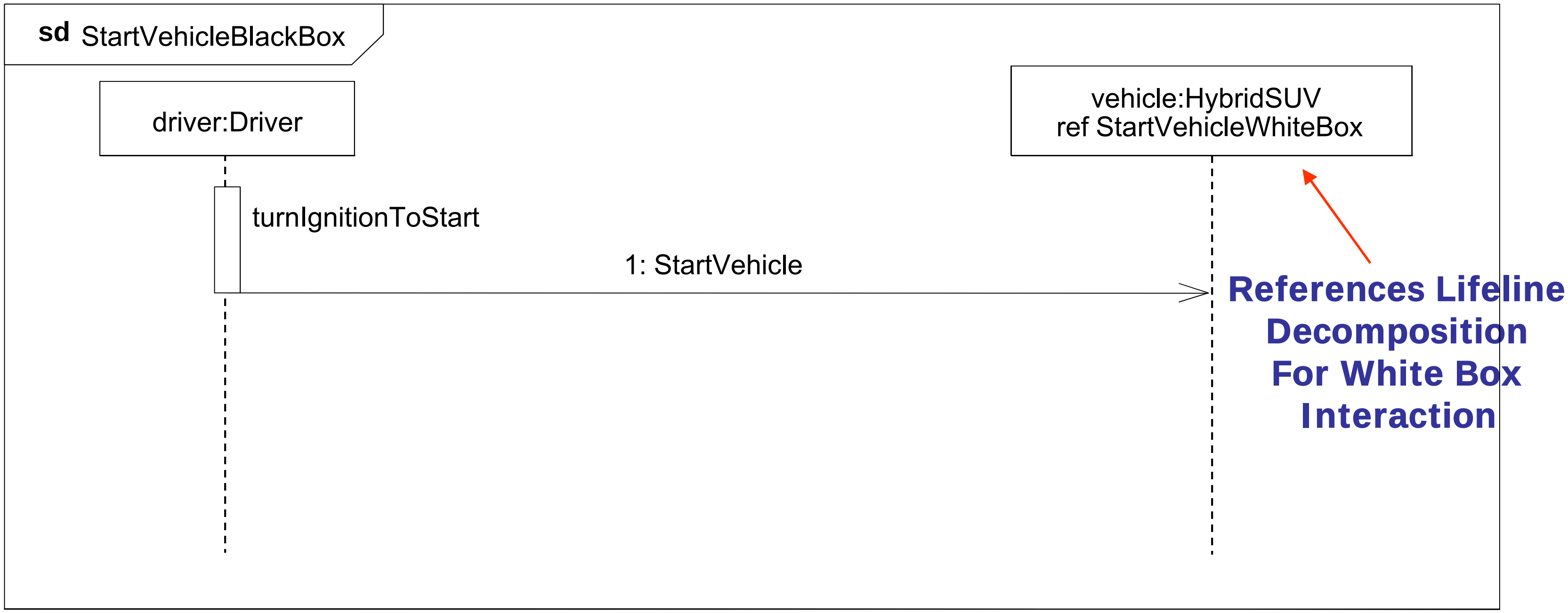
- Sequence diagrams provide representations of message based behavior
  - represent flow of control
  - describe interactions between parts
- Sequence diagrams provide mechanisms for representing complex scenarios
  - reference sequences
  - control logic
  - lifeline decomposition
- SysML does not include timing, interaction overview, and communications diagram

Black Box Interaction (Drive)



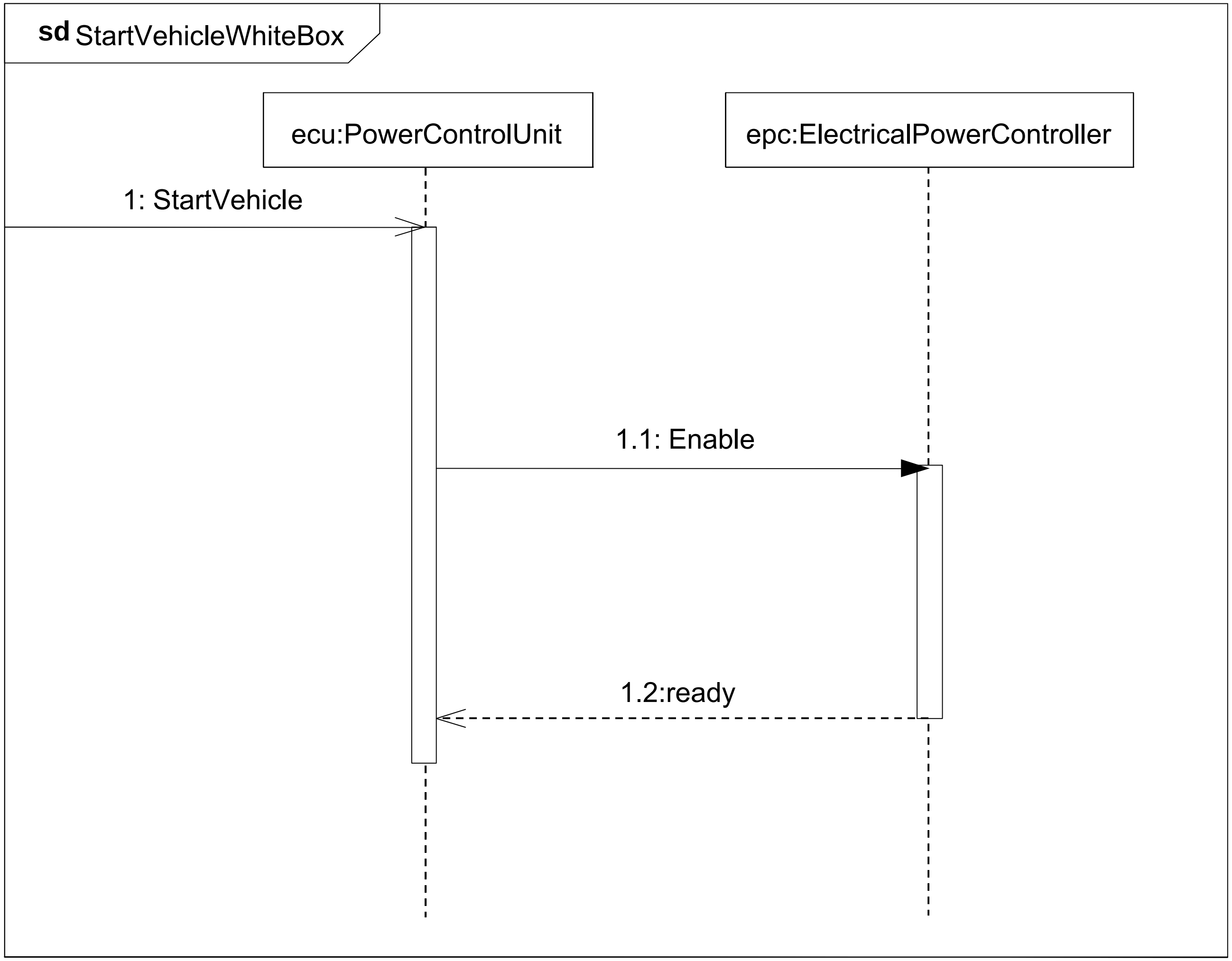
UML 2 Sequence Diagram Scales by Supporting Control Logic and Reference Sequences

Black Box Sequence (StartVehicle)



Simple Black Box Interaction

White Box Sequence (StartVehicle)



Decomposition of Black Box Into White Box Interaction

Primary Interaction Operators

- **ref** name
  - reference to a sequence diagram fragment defined elsewhere
- **opt** [condition]
  - has 1 part that may be executed based on a condition/state value
- **alt**
  - has 2 or more parts, but only one executes based on a condition/state
  - an operand fragment labeled [else] is executed if no other condition is true
- **par**
  - has 2 or more parts that execute concurrently
    - Concurrence indicates does not require simultaneous, just that the order is undetermined. If there is only one processor the behavior could be (A then B), (B then A), or (A and B interleaving) …
- **loop** min..max [escape]
  - Has a minimum # of executions, and optional maximum # of executions, and optional escape condition
- **break** [condition]
  - Has an optional guard. If true, the contents (if any) are executed, and the remainder of the enclosing operator is not executed

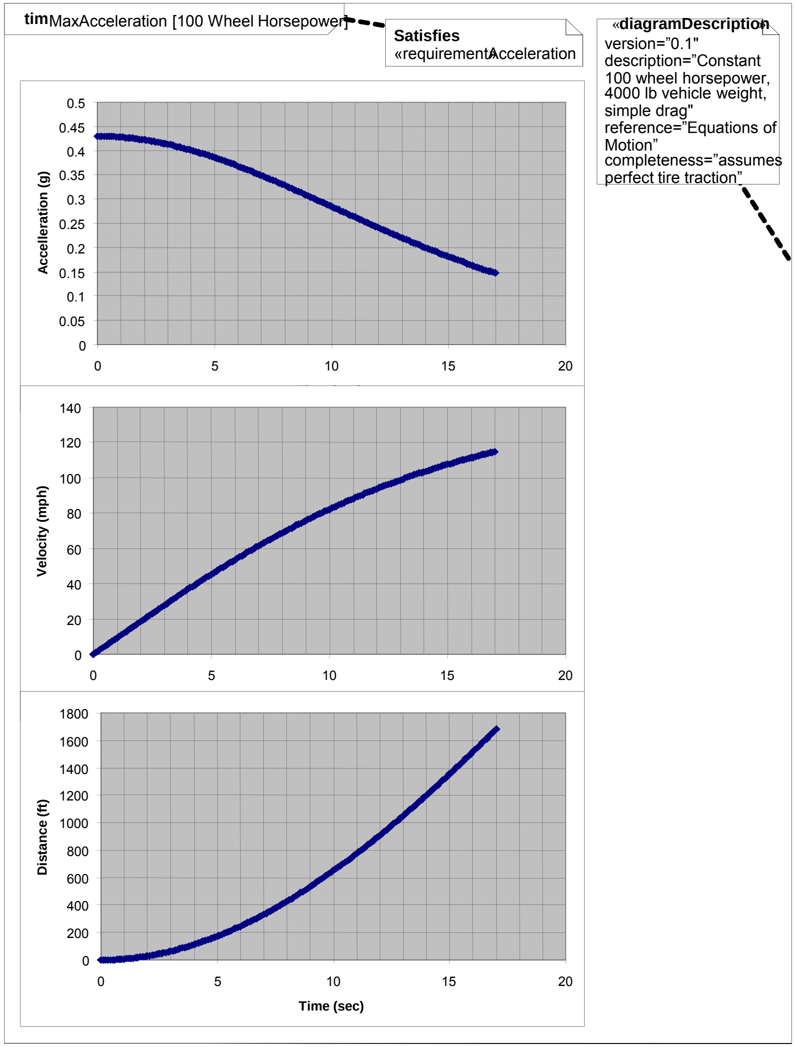
Provided by Michael Chonoles

Other Interaction Operators

- **critical**
  - The sequence diagram fragment is a critical region. It is treated as atomic – no interleaving with parallel regions
- **neg**
  - The sequence diagram fragment is forbidden. Either it is impossible to occur, or it is the intent of the requirements to prevent it from occurring
- **assert**
  - The sequence diagram fragment is the only one possible (or legal)
- **seq** (weak, the default)
  strict
  - Strict: The message exchange occurs in the order described
  - Weak: Each lifeline may see different orders for the exchange (subject to causality)
- **consider** (list of messages)
  ignore (list of messages)
  - Consider: List the messages that are relevant in this sequence fragment
  - Ignored: List the messages that may arrive, but are not interesting here

Provided by Michael Chonoles

Trial Result of Vehicle Dynamics



Lifeline are value properties

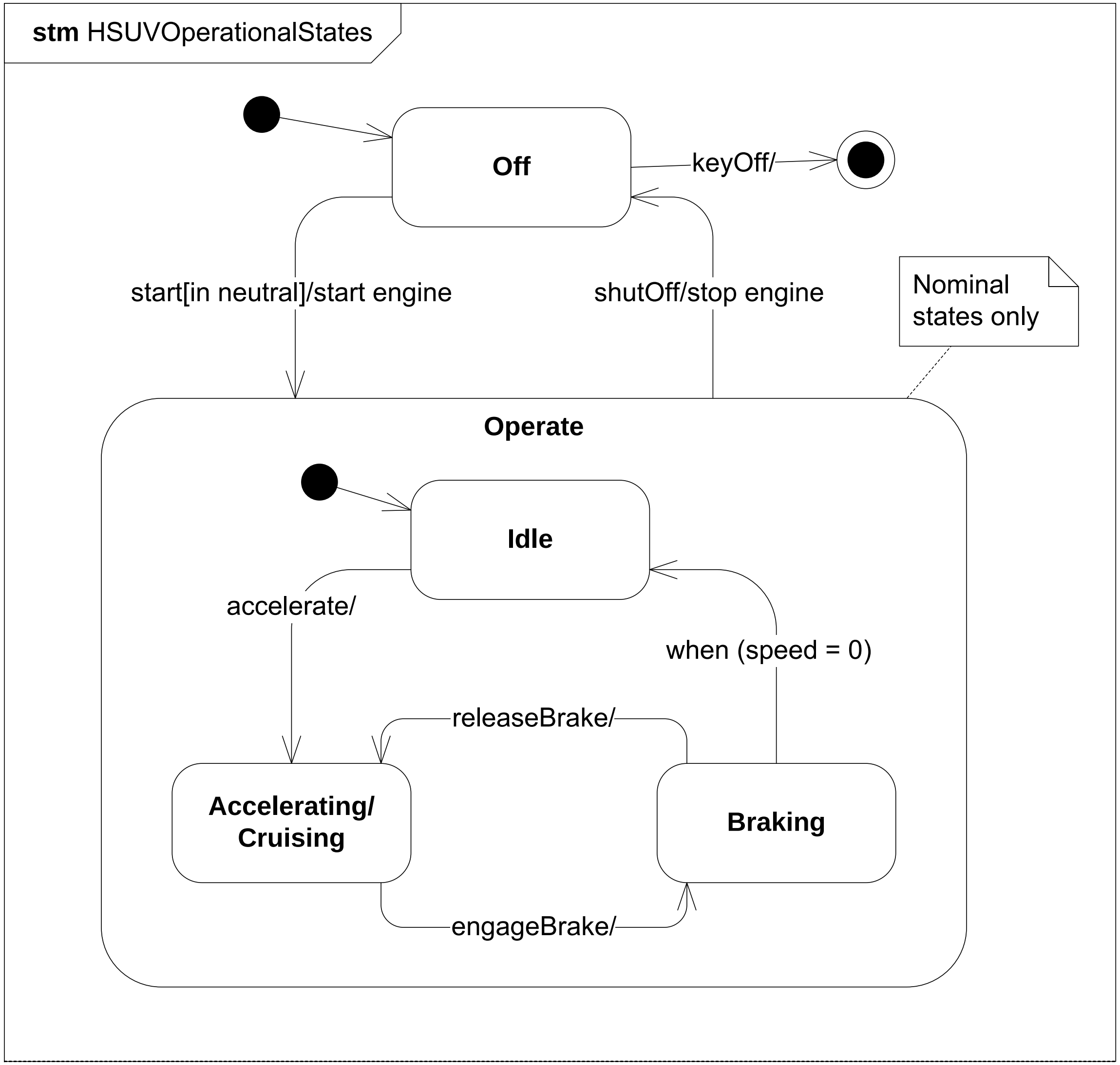
Timing Diagram Not Part of SysML

Typical Example of a Timing Diagram

State Machines

- Typically used to represent the life cycle of a block
- Support event-based behavior (generally asynchronous)
  - Transition with trigger, guard, action
  - State with entry, exit, and do-activity
  - Can include nested sequential or concurrent states
  - Can send/receive signals to communicate between blocks during state transitions, etc.
- Event types
  - Change event
  - Time event
  - Signal event

Operational States (Drive)

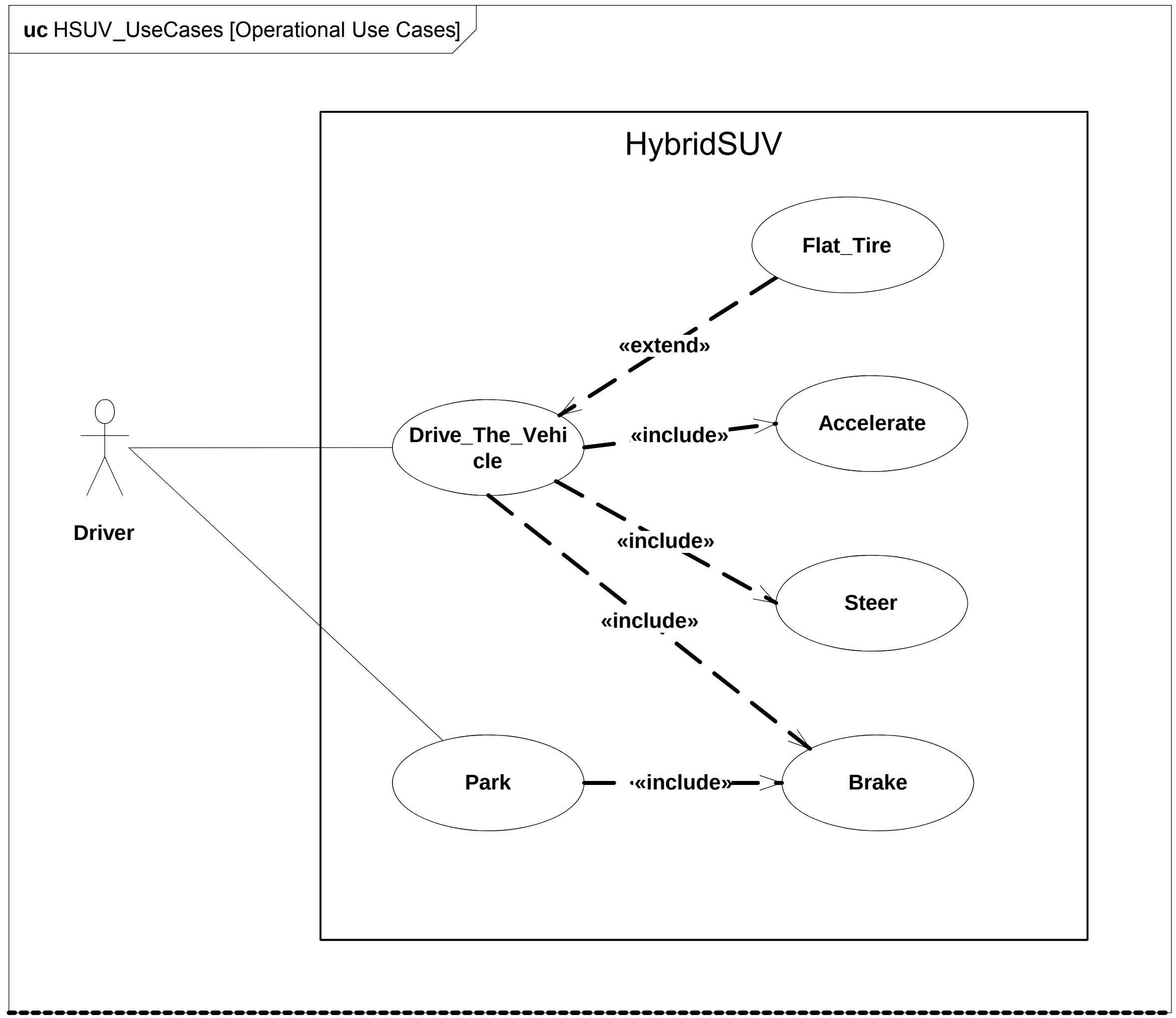


Transition notation: trigger[guard]/action

Use Cases

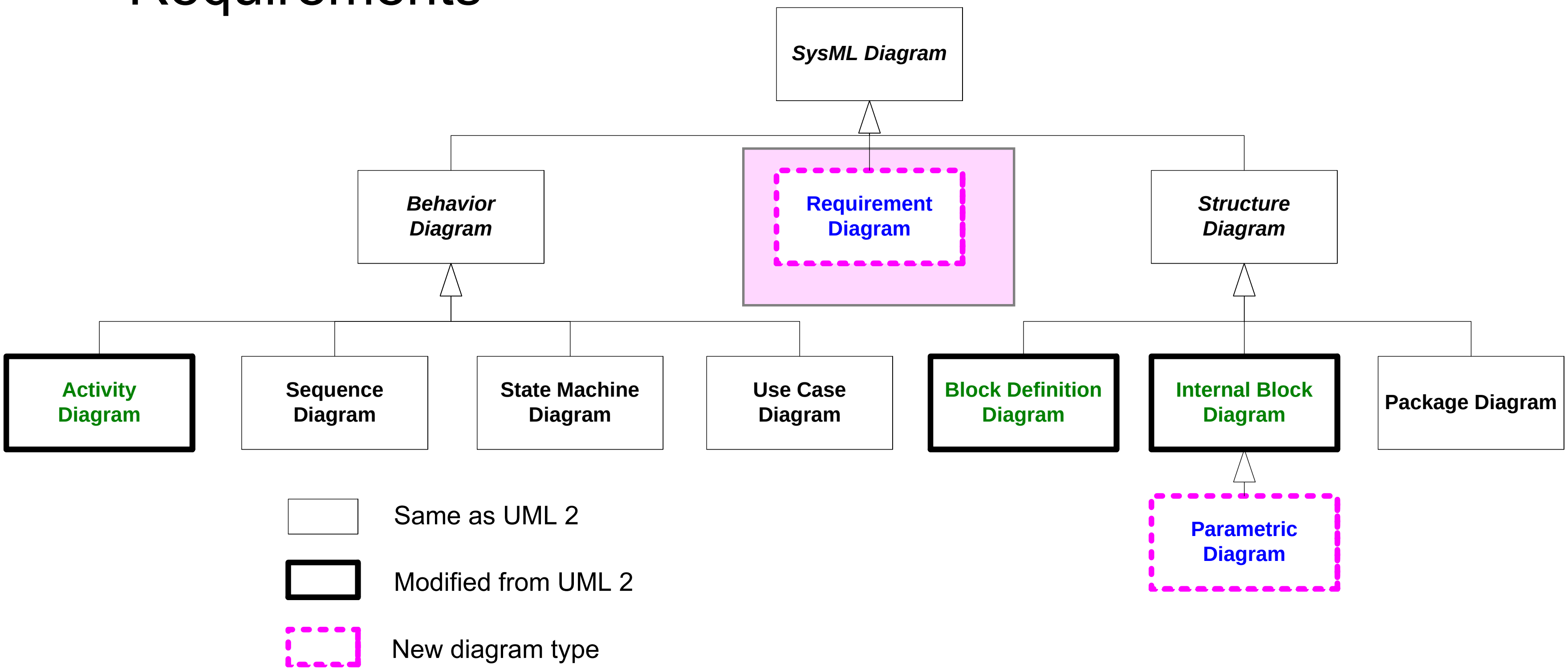
- Provide means for describing basic functionality in terms of usages/goals of the system by actors
  - Use is methodology dependent
  - Often accompanied by use case descriptions
- Common functionality can be factored out via «include» and «extend» relationships
- Elaborated via other behavioral representations to describe detailed scenarios
- No change to UML

Operational Use Cases



Cross-cutting Constructs

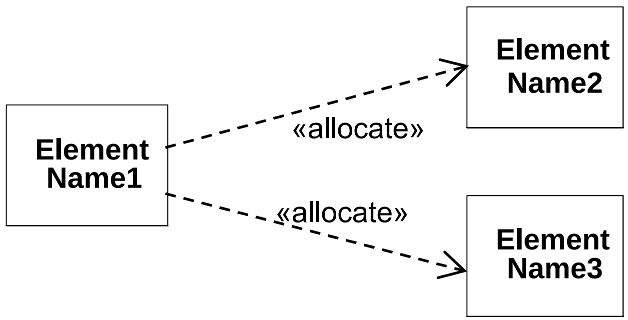
- Allocations
- Requirements



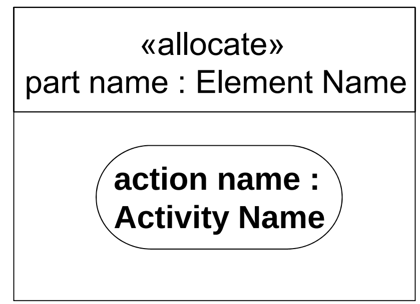
Allocations

- Represent general relationships that map one model element to another
- Different types of allocation are:
  - Behavioral (i.e., function to component)
  - Structural (i.e., logical to physical)
  - Software to Hardware
  - ….
- Explicit allocation of activities to structure via swim lanes (i.e., activity partitions)
- Both graphical and tabular representations are specified

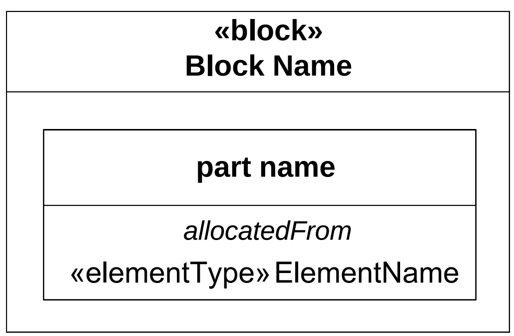
Different Allocation Representations (Tabular Representation Not Shown)



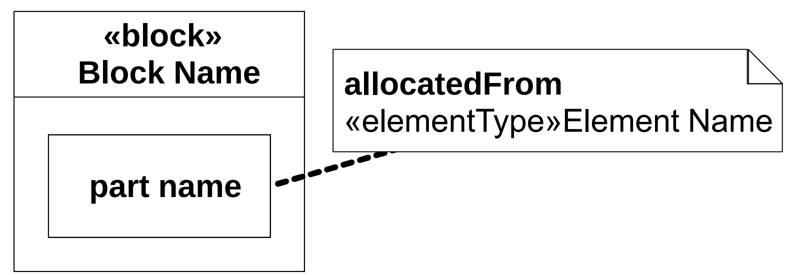
Allocate Relationship



Explicit Allocation of Action to Part Property



Compartment Notation

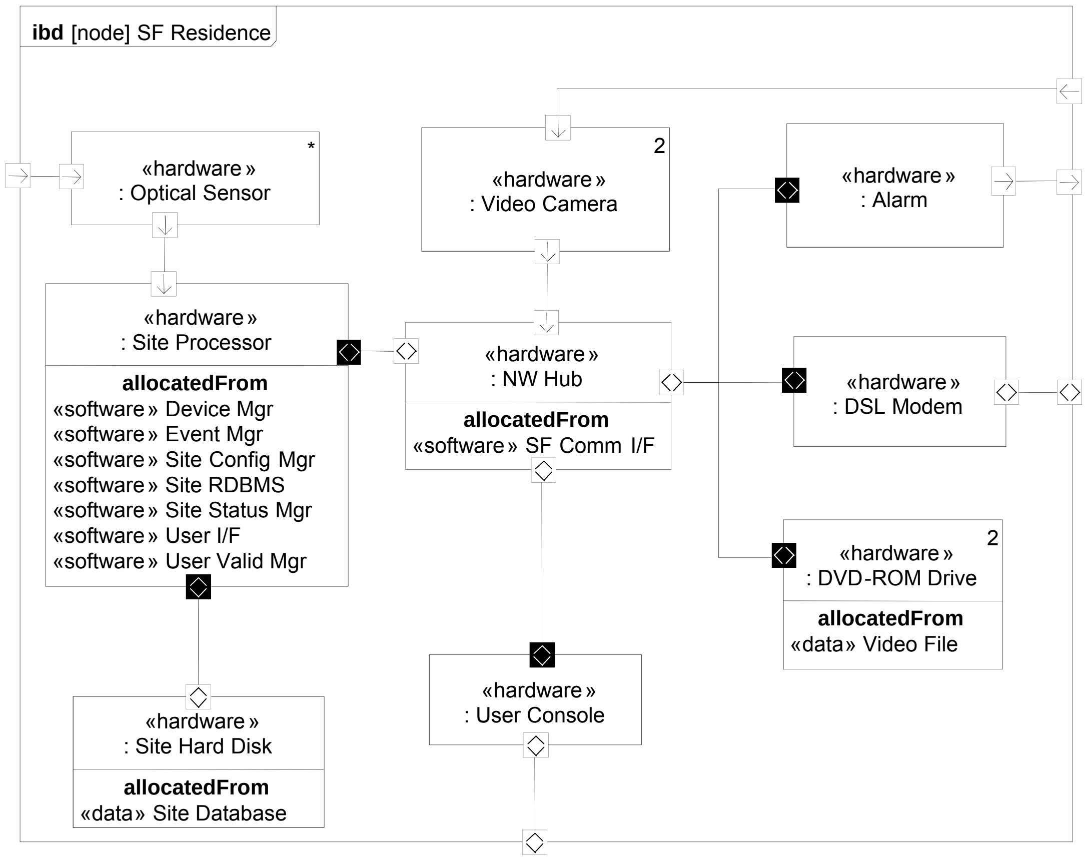


Callout Notation

Read as follows: “part name has constraints that are allocated to/from an <<element type>> Element Name”

SysML Allocation of SW to HW

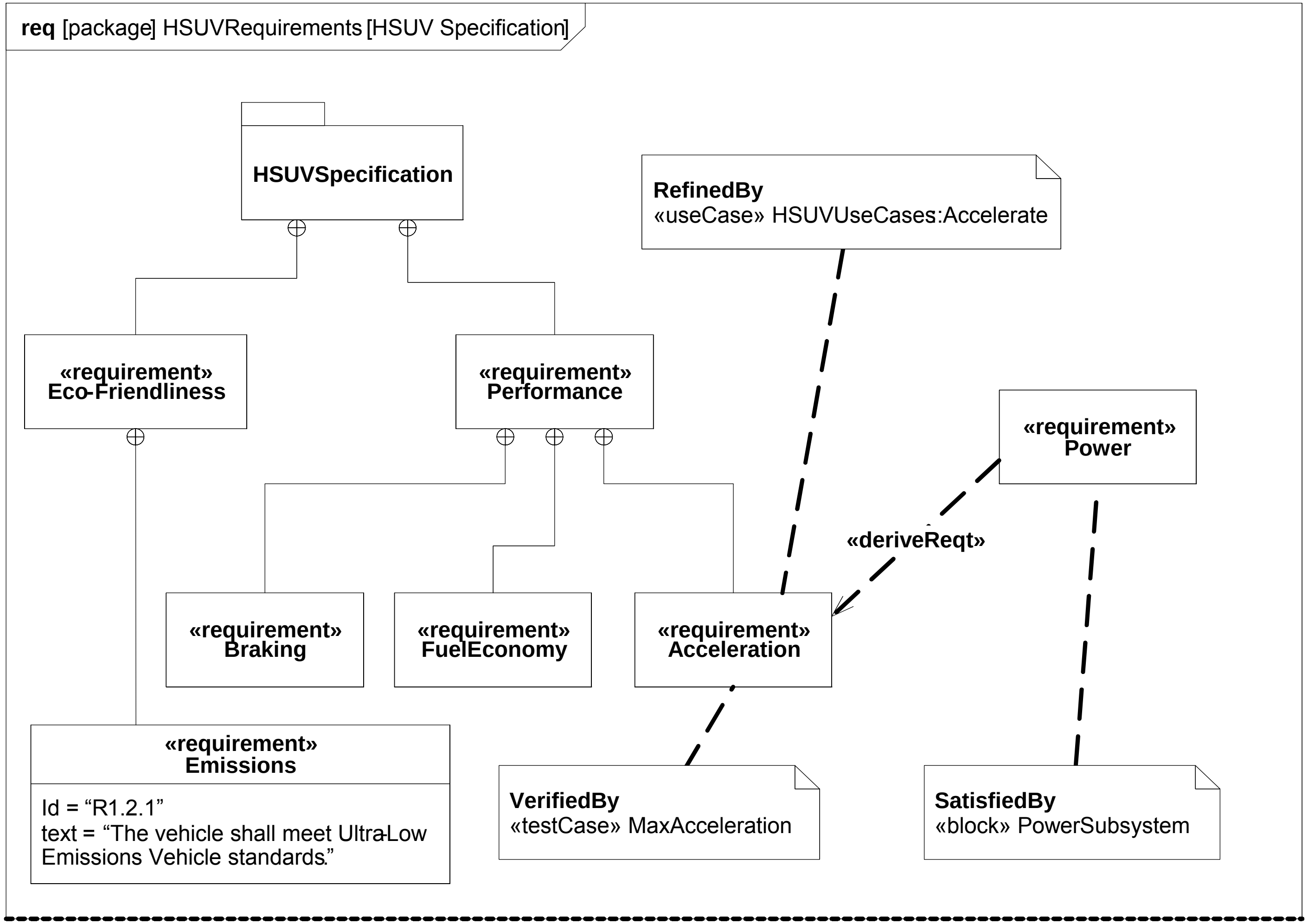
- In UML, the deployment diagram is used to deploy artifacts to nodes
- In SysML, «allocation» on an **ibd** and **bdd** is used to deploy software/data to hardware



Requirements

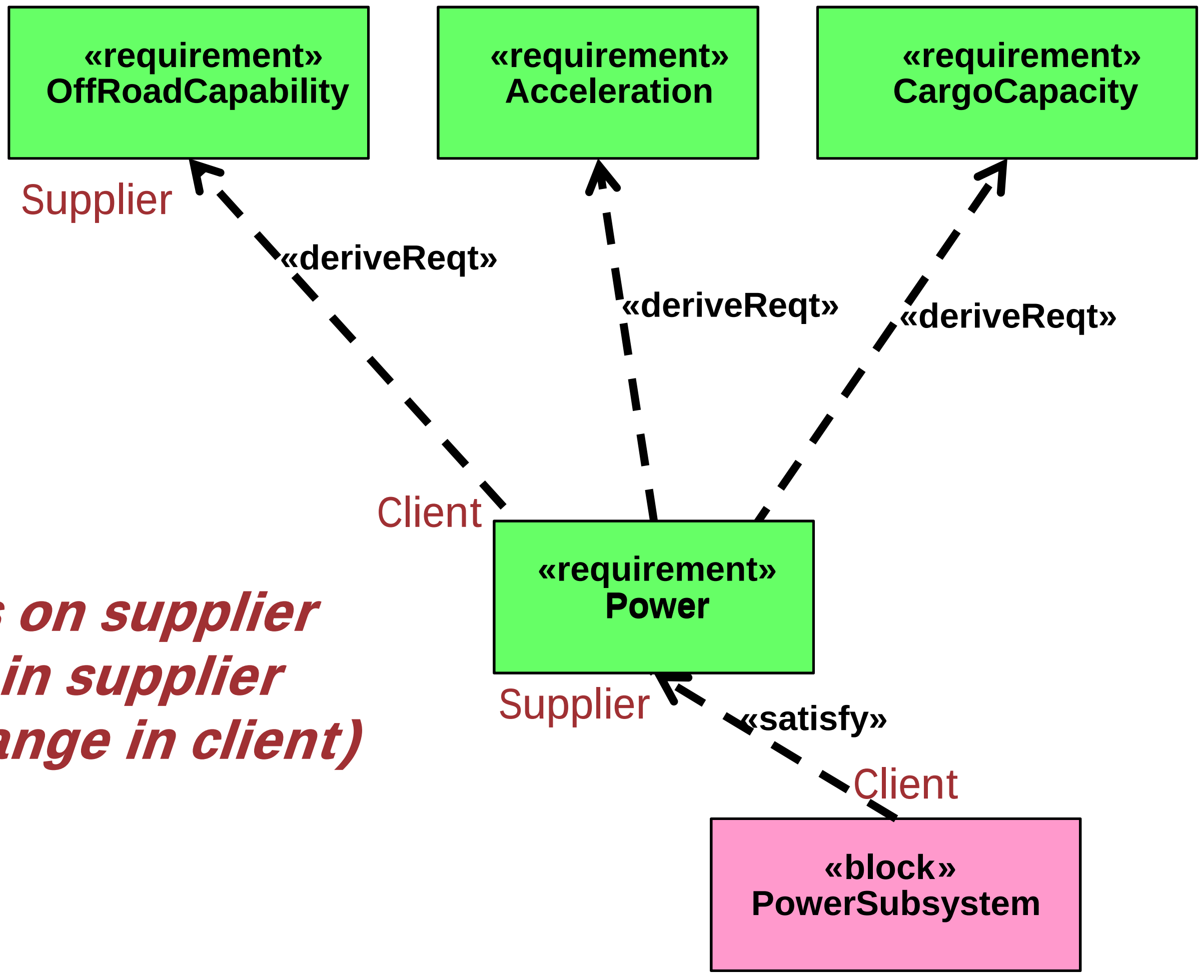
- The «requirement» stereotype represents a text based requirement
  - Includes id and text properties
  - Can add user defined properties such as verification method
  - Can add user defined requirements categories (e.g., functional, interface, performance)
- Requirements hierarchy describes requirements contained in a specification
- Requirements relationships include DeriveReqt, Satisfy, Verify, Refine, Trace, Copy

Requirements Breakdown



Requirement Relationships Model the Content of a Specification

Example of Derive/Satisfy Requirement Dependencies

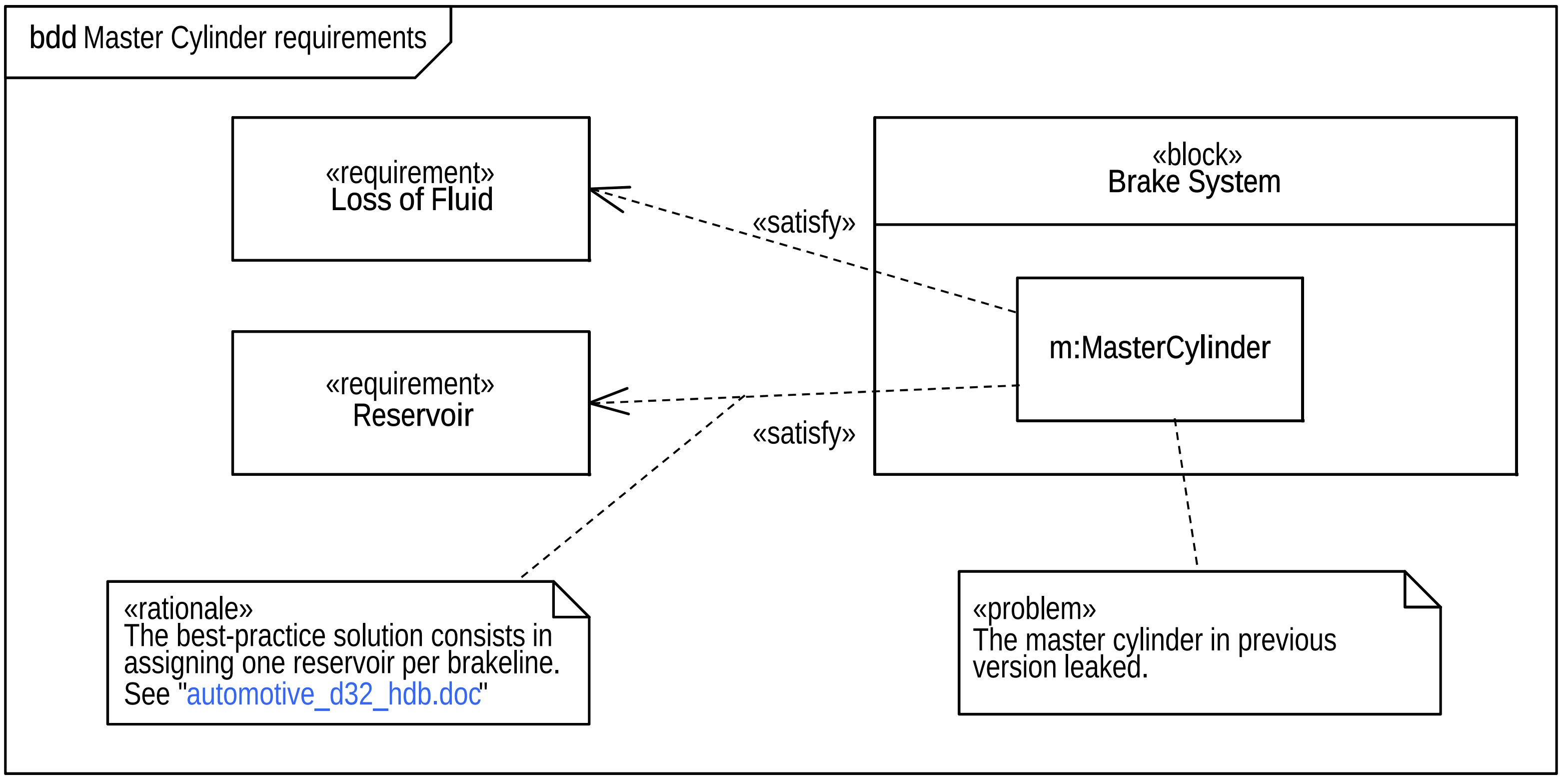


Client depends on supplier (i.e., a change in supplier results in a change in client)

from OMG

Arrow Direction Opposite Typical Requirements Flow-Down

Problem and Rationale

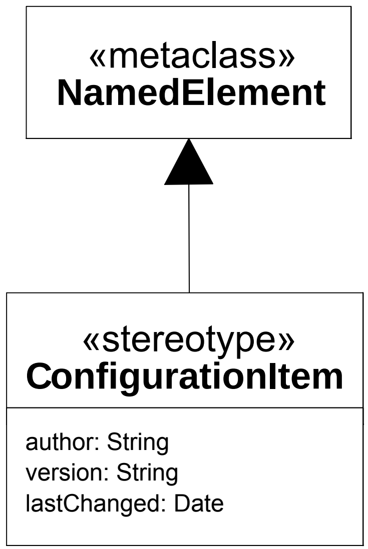


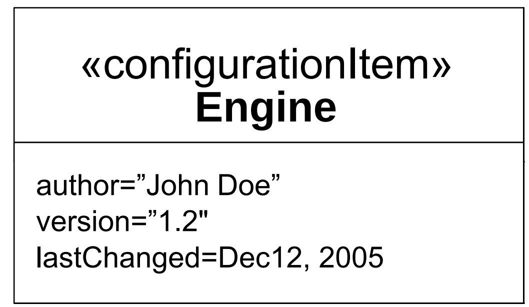
Problem and Rationale can be attached to any Model Element to Capture Issues and Decisions

Stereotypes & Model Libraries

- Mechanisms for further customizing SysML
- Profiles represent extensions to the language
  - Stereotypes extend meta-classes with properties and constraints
    - Stereotype properties capture metadata about the model element
  - Profile is applied to user model
  - Profile can also restrict the subset of the meta-model used when the profile is applied
- Model Libraries represent reusable libraries of model elements

Stereotypes

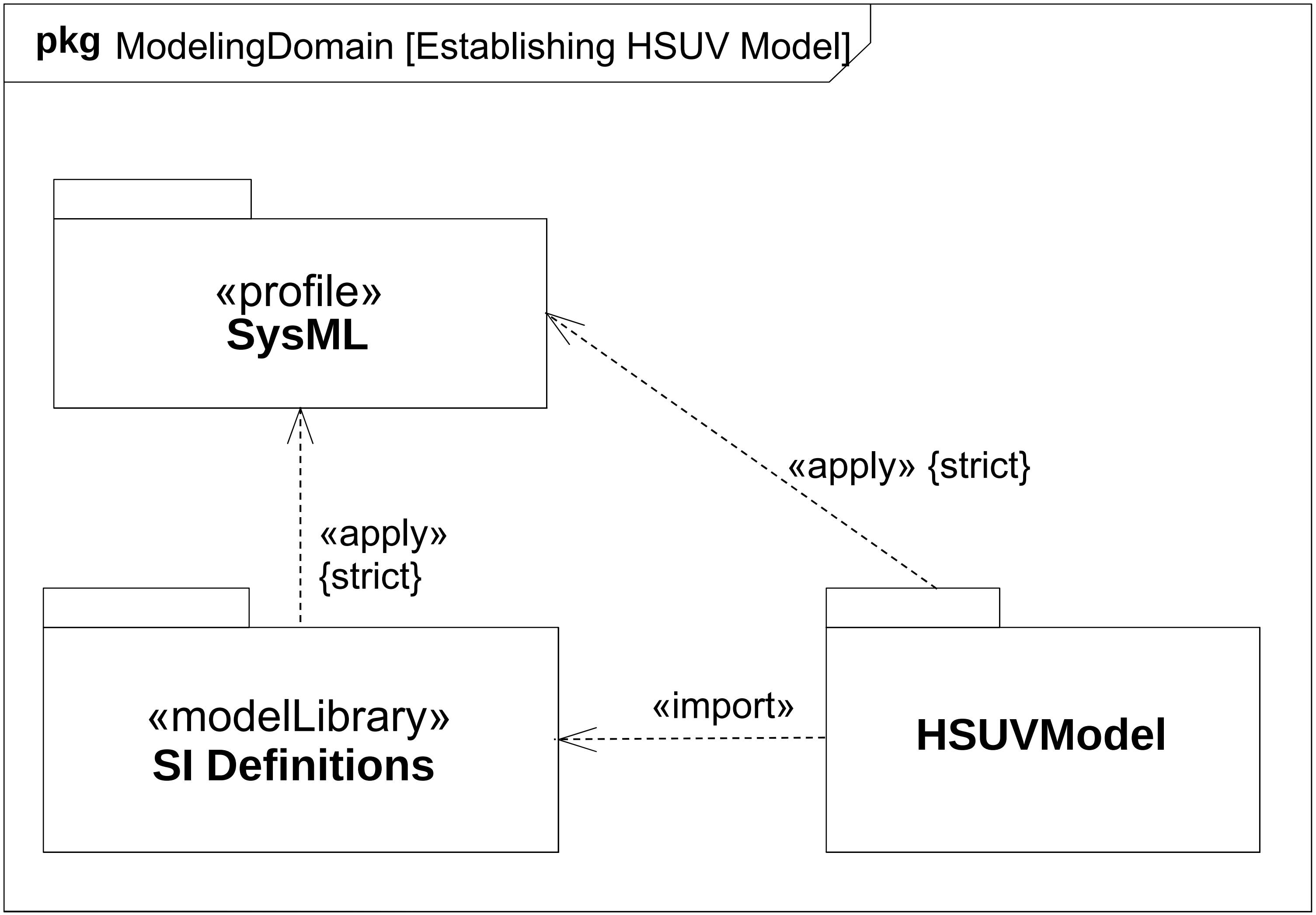




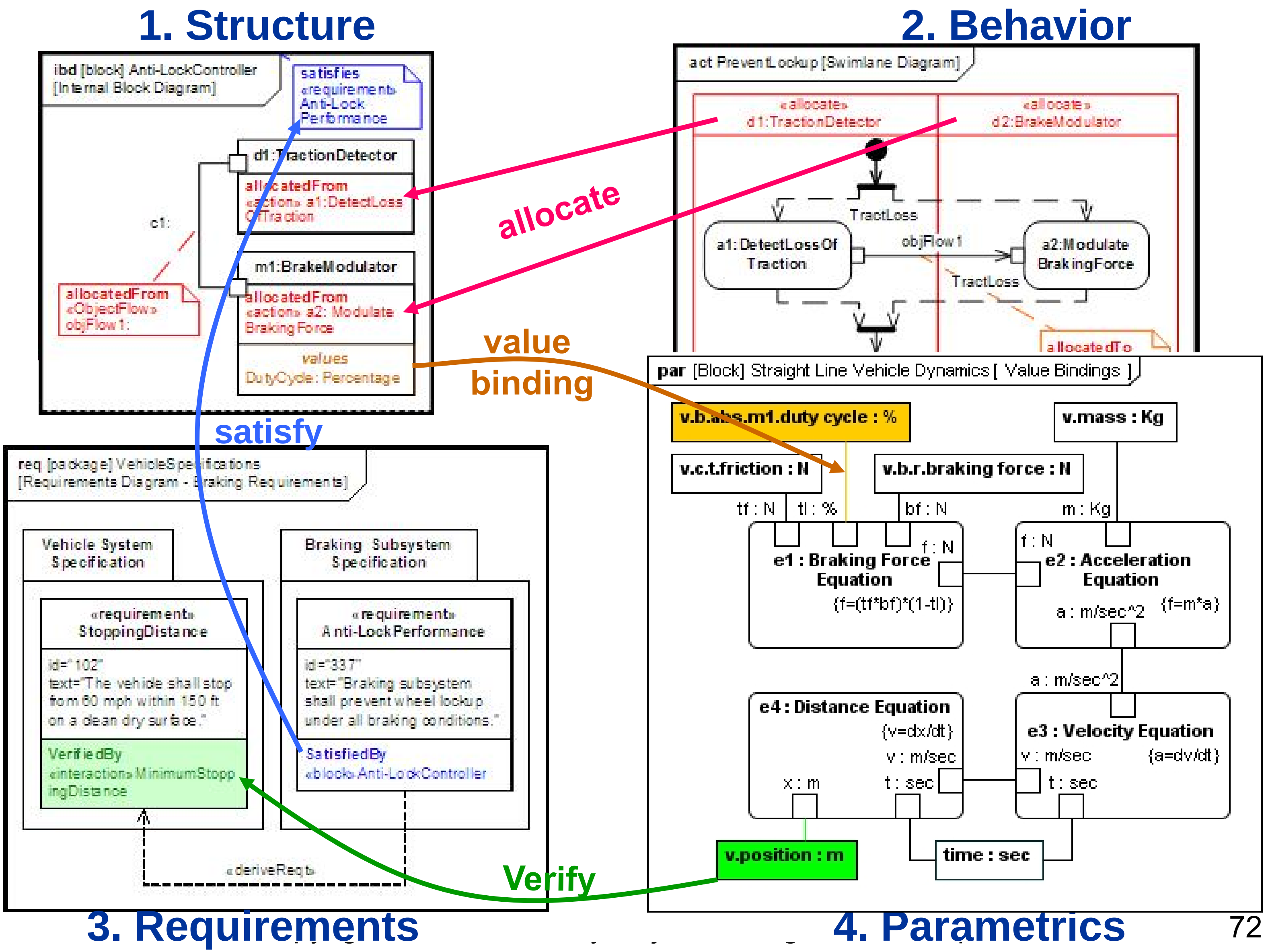
Defining the Stereotype

Applying the Stereotype

Applying a Profile and Importing a Model Library



Cross Connecting Model Elements



SysML Modeling
as Part of the SE Process

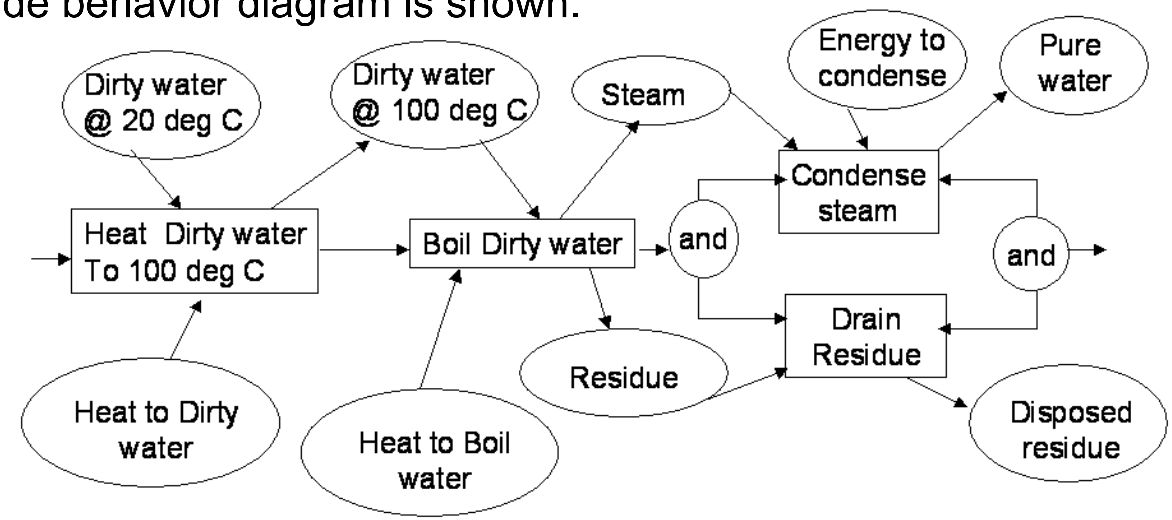
Distiller Sample Problem

Refer to Chapter 15

"A Practical Guide to SysML"

Distiller Problem Statement

- The following problem was posed to the SysMLteam in Dec ’05 by D. Oliver:
- Describe a system for purifying dirty water.
  - Heat dirty water and condense steam are performed by a Counter Flow Heat Exchanger
  - Boil dirty water is performed by a Boiler
  - Drain residue is performed by a Drain
  - The water has properties: vol = 1 liter, density 1 gm/cm3, temp 20 deg C, specific heat 1cal/gm deg C, heat of vaporization 540 cal/gm.
- A crude behavior diagram is shown.

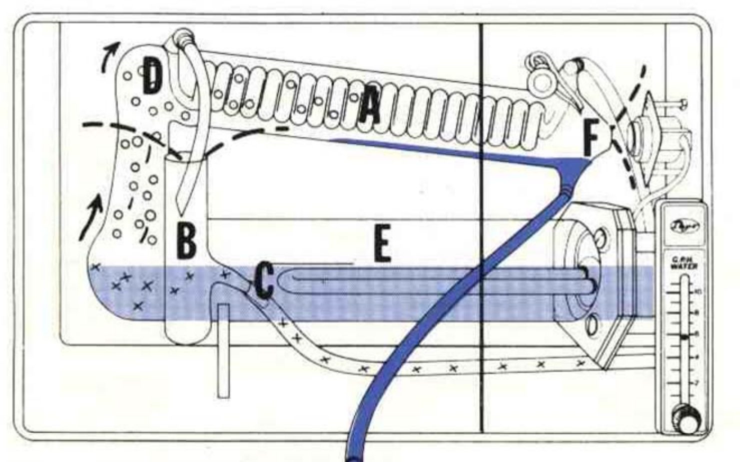


What are the real requirements?
How do we design the system?

Distiller Types

Batch Distiller

Continuous Distiller

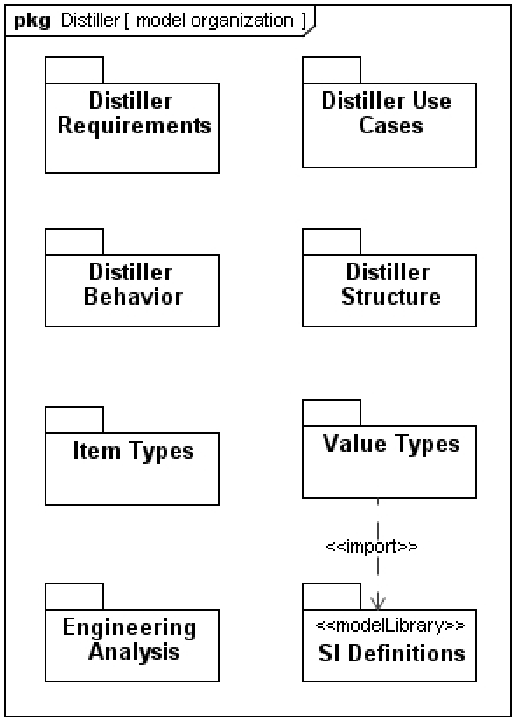


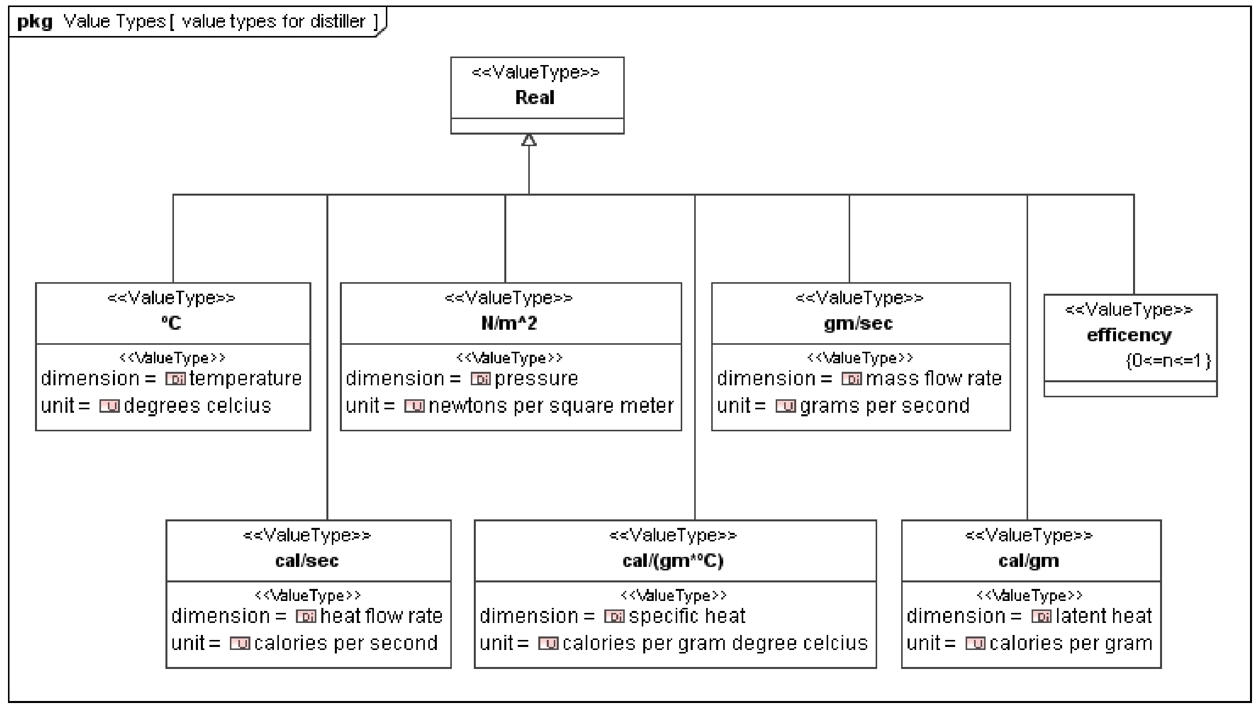
Note: Not all aspects of the distiller are modeled in the example

Distiller Problem – Process Used

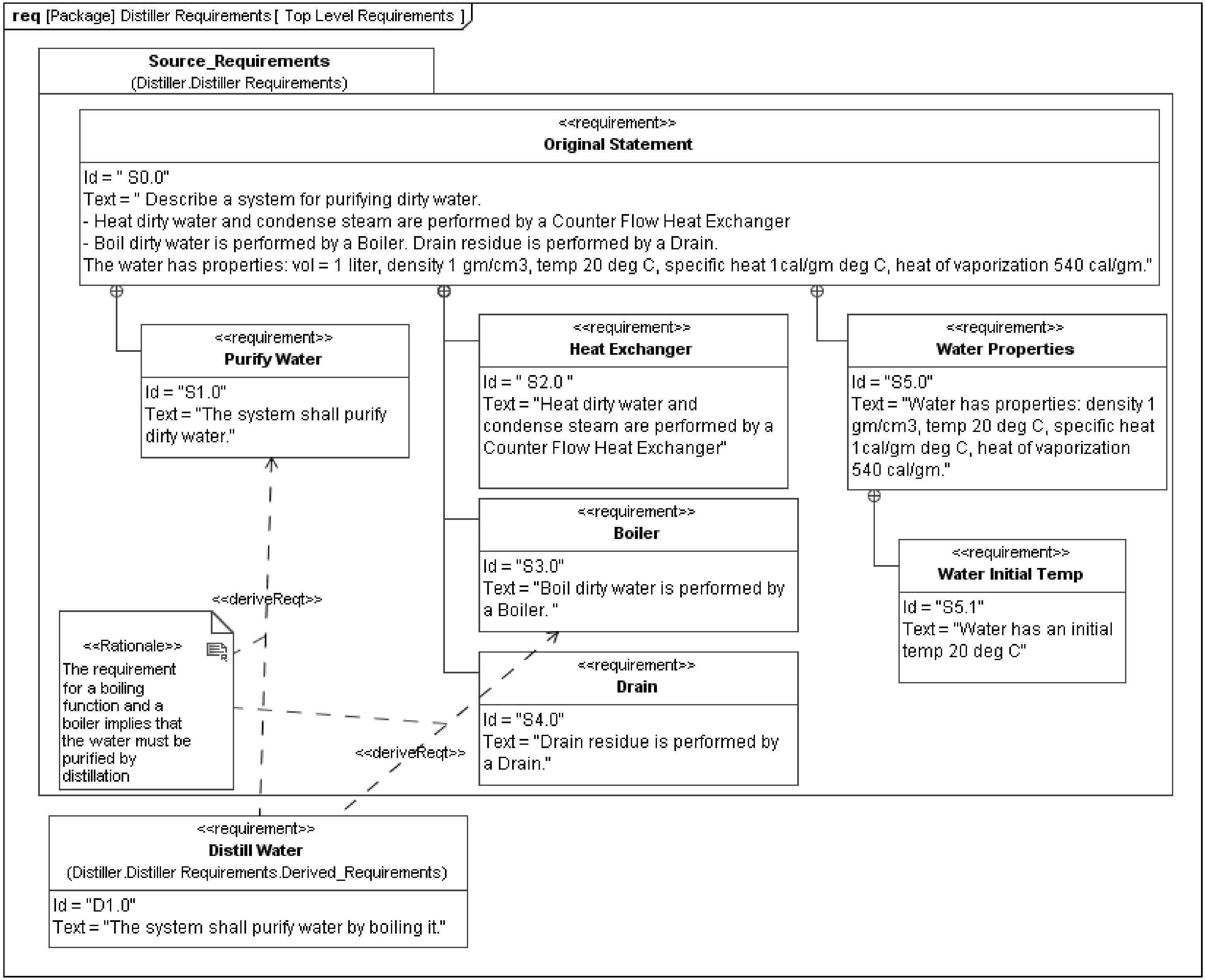
- Organize the model, identify libraries needed
- List requirements and assumptions
- Model behavior
  - In similar form to problem statement
  - Elaborate as necessary
- Model structure
  - Capture implied inputs and outputs
    - segregate I/O from behavioral flows
  - Allocate behavior onto structure, flow onto I/O
- Capture and evaluate parametric constraints
  - Heat balance equation
- Modify design as required to meet constraints
- Model the user interaction
- Modify design to reflect user interaction

Distiller Problem – Package Diagram: Model Structure and Libraries





Distiller Example Requirements Diagram



Distiller Example: Requirements Tables

table [requirement]OriginalStatement[Decomposition of OriginalStatement]

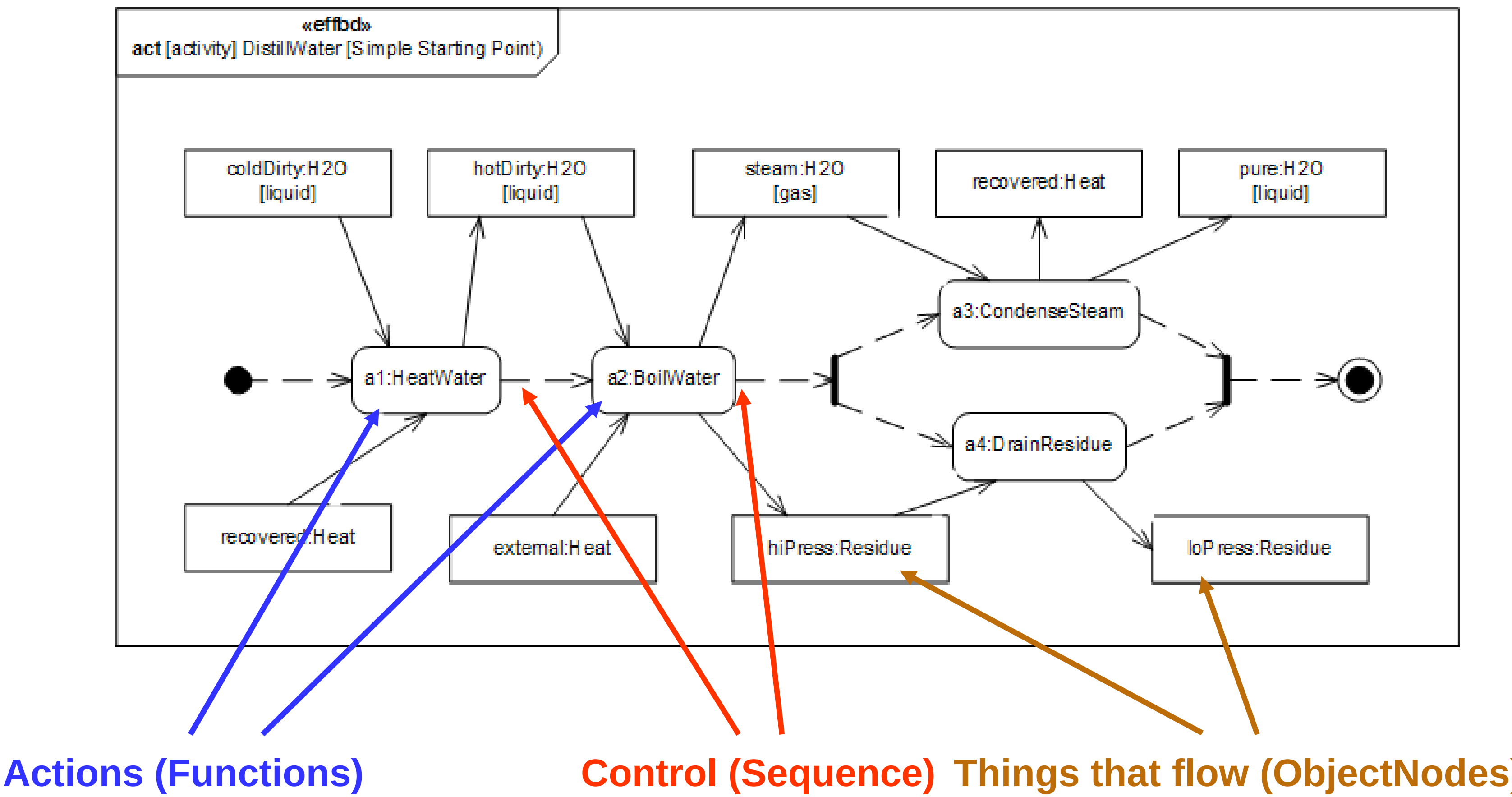
id	name	text
S0.0	OriginalStatement	Describe a system for purifying dirty water. …
S1.0	PurifyWater	The system shall purify dirty water.
S2.0	HeatExchanger	Heat dirty water and condense steam are performed by a …
S3.0	Boiler	Boil dirty water is performed by a Boiler.
S4.0	Drain	Drain residue is performed by a Drain.
S5.0	WaterProperties	water has properties: density 1 gm/cm3, temp 20 deg C, …
S5.1	WaterInitialTemp	water has an initial temp 20 deg C

table [requirement] PurifyWater[Requirements Tree]

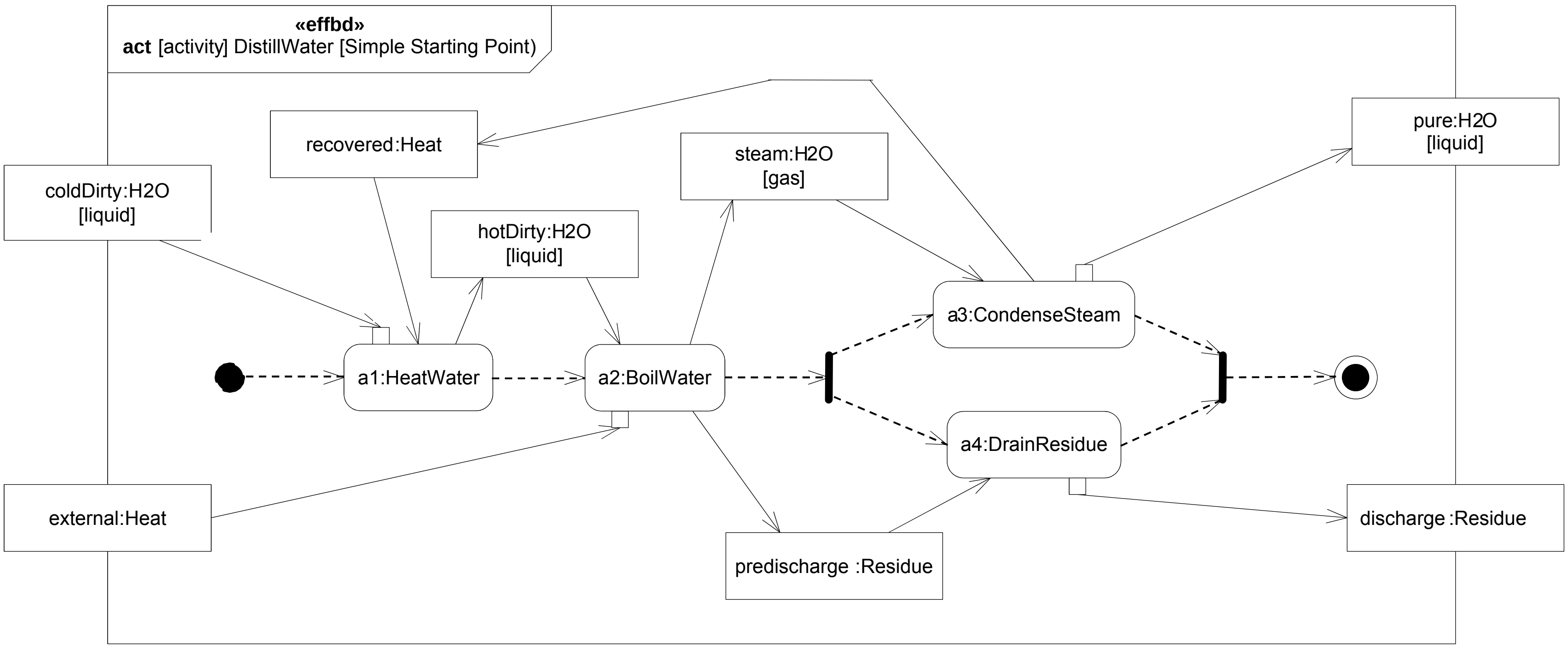
id	name	relation	id	name	Rationale
S1.0	PurifyWater	deriveReqt	D1.0	DistillWater	The requirement for a boiling function and a boiler implies that the water must be purified by distillation

Distiller Example – Activity Diagram: Initial Diagram for DistillWater

- This activity diagram applies the SysML EFFBD profile, and formalizes the diagram in the problem statement.



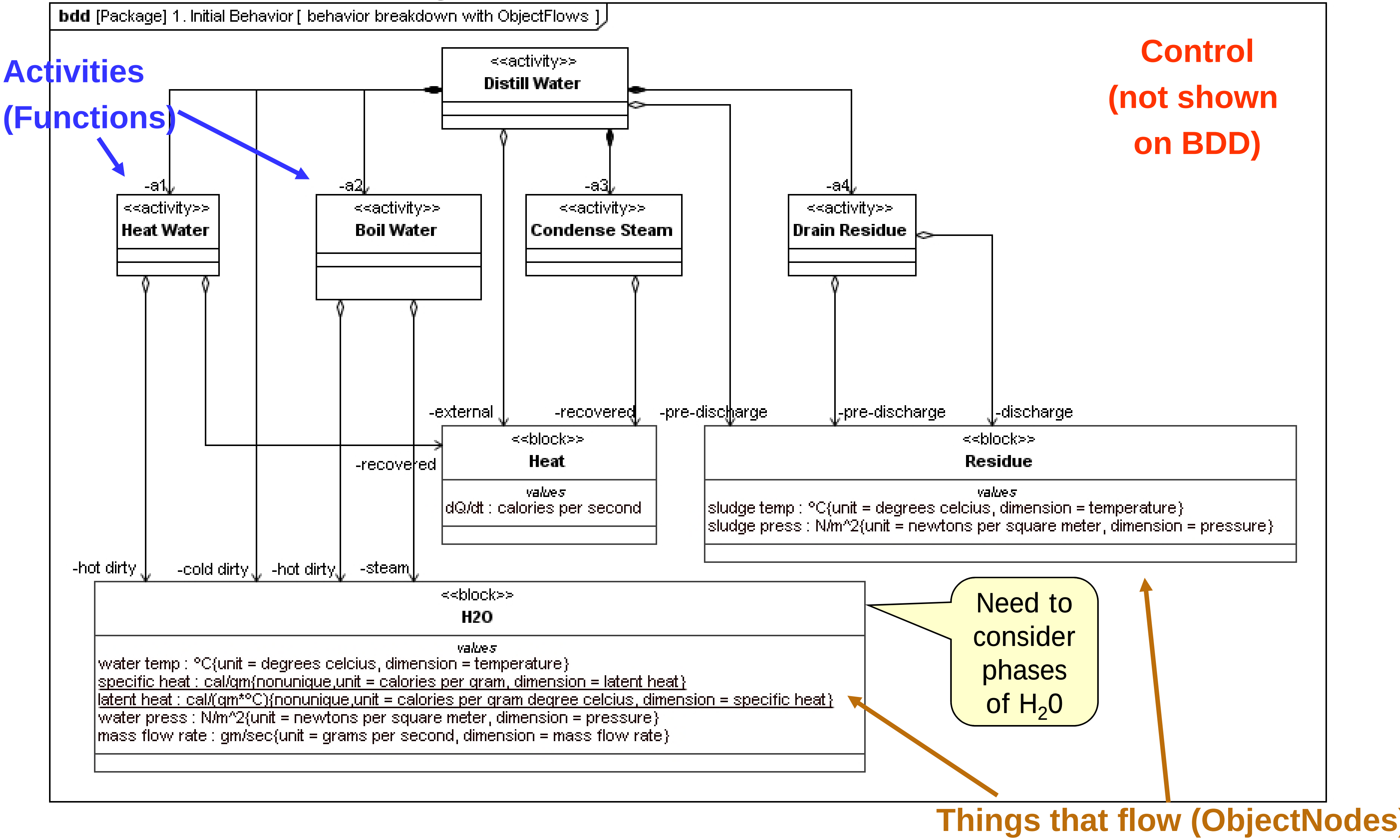
Distiller Example – Activity Diagram: Control-Driven: Serial Behavior



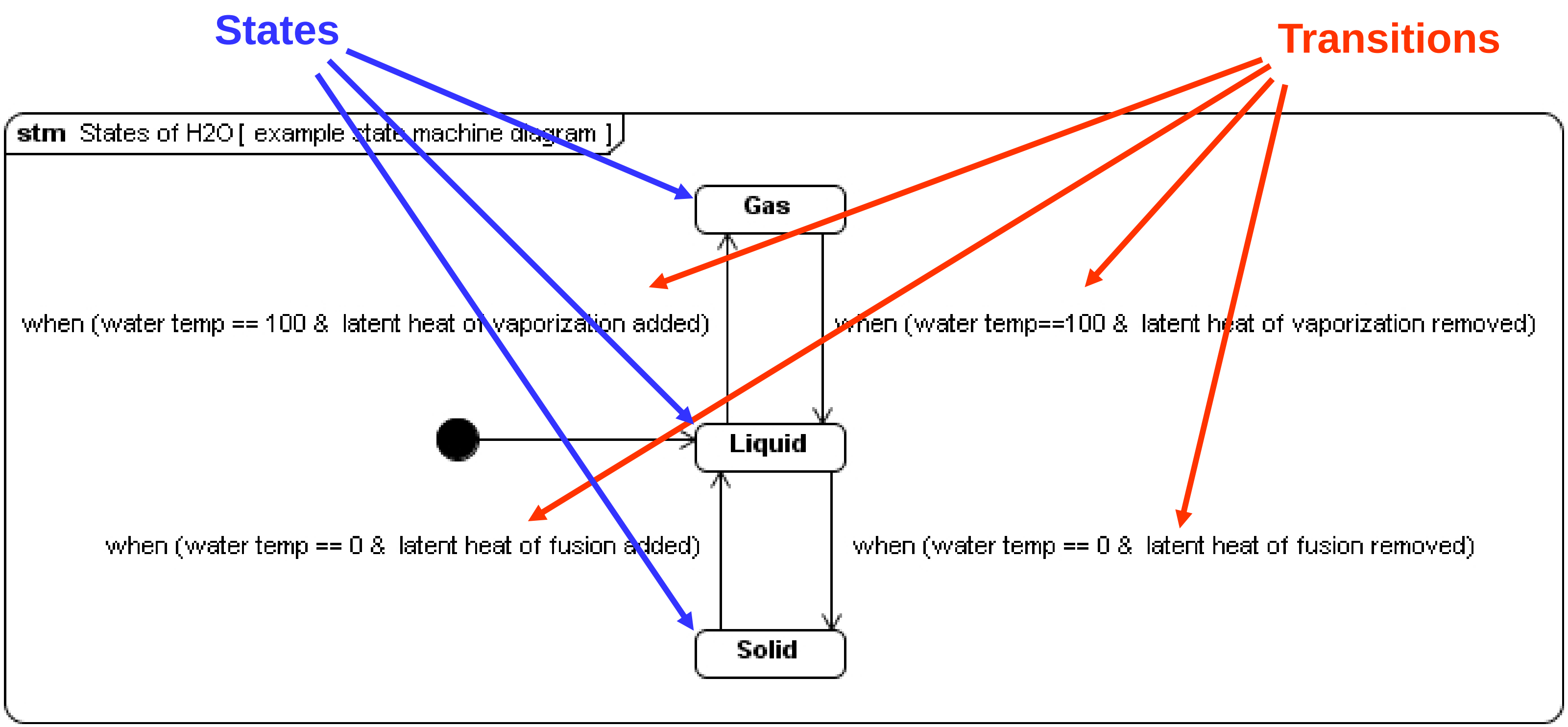
Continuous Distiller Here

Batch Distiller

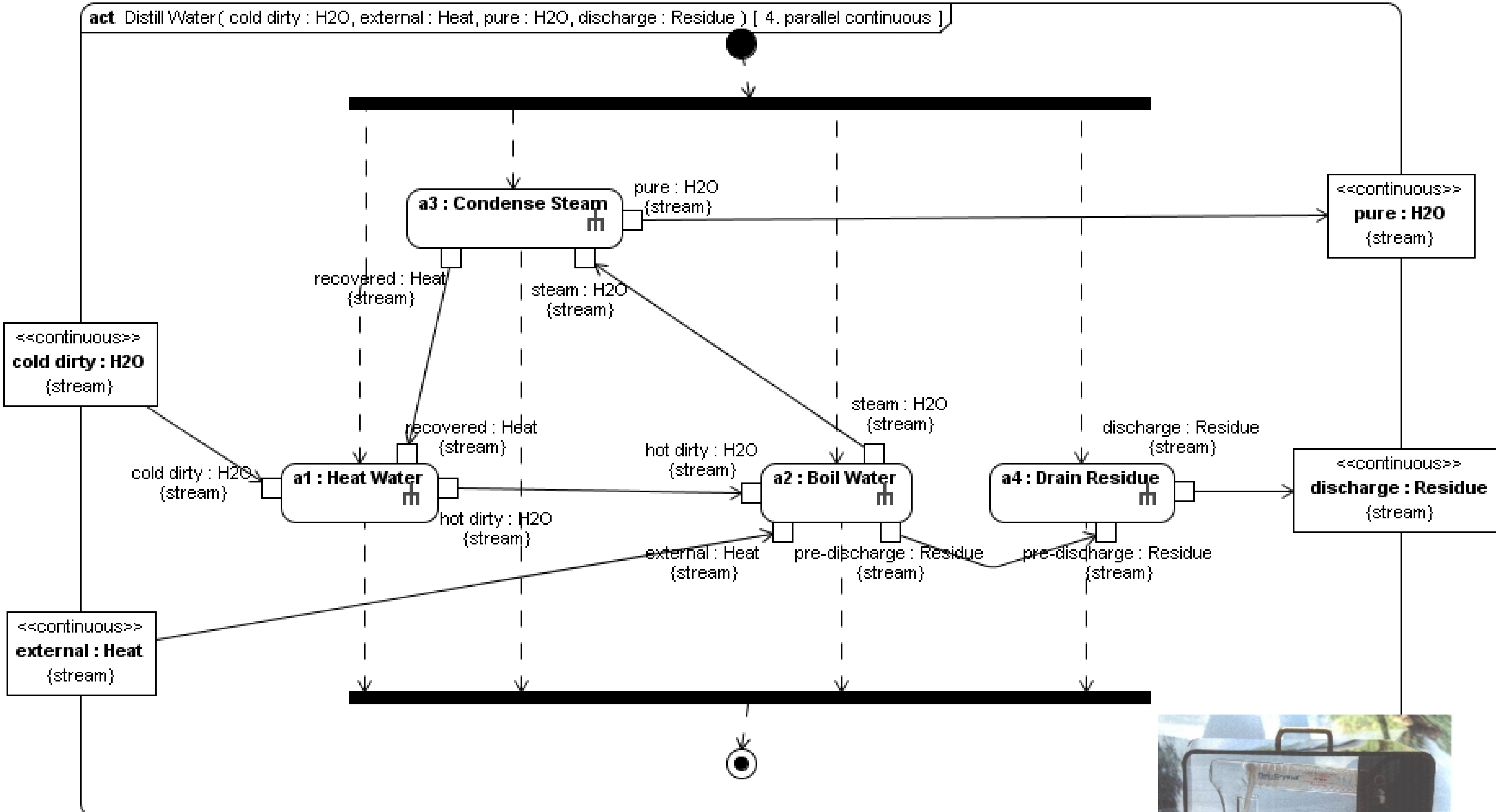
Distiller Example – Block Definition Diagram: DistillerBehavior



Distiller Example – State Machine Diagram: States of H2O



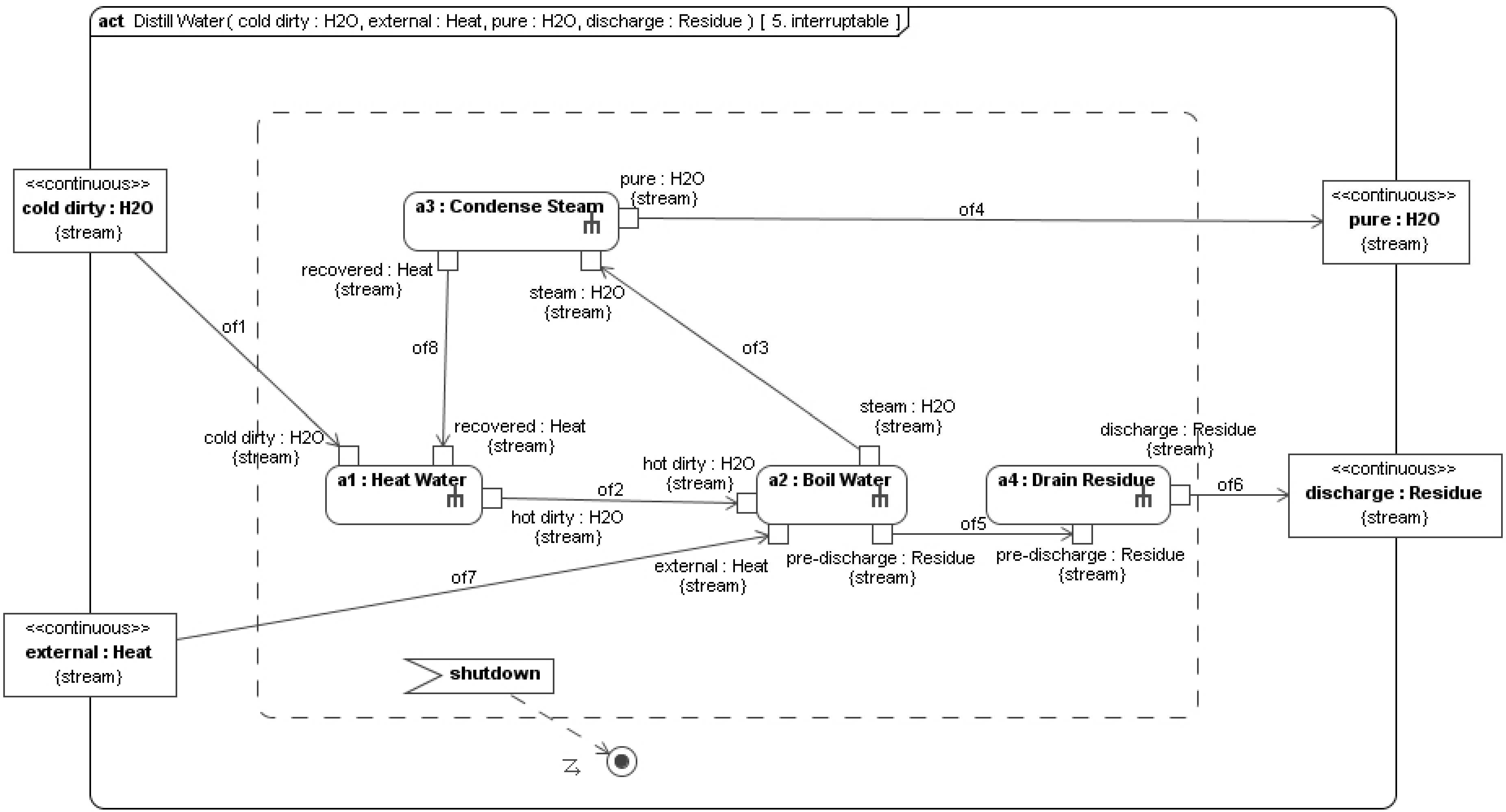
Distiller Example – Activity Diagram: I/O Driven: Continuous Parallel Behavior



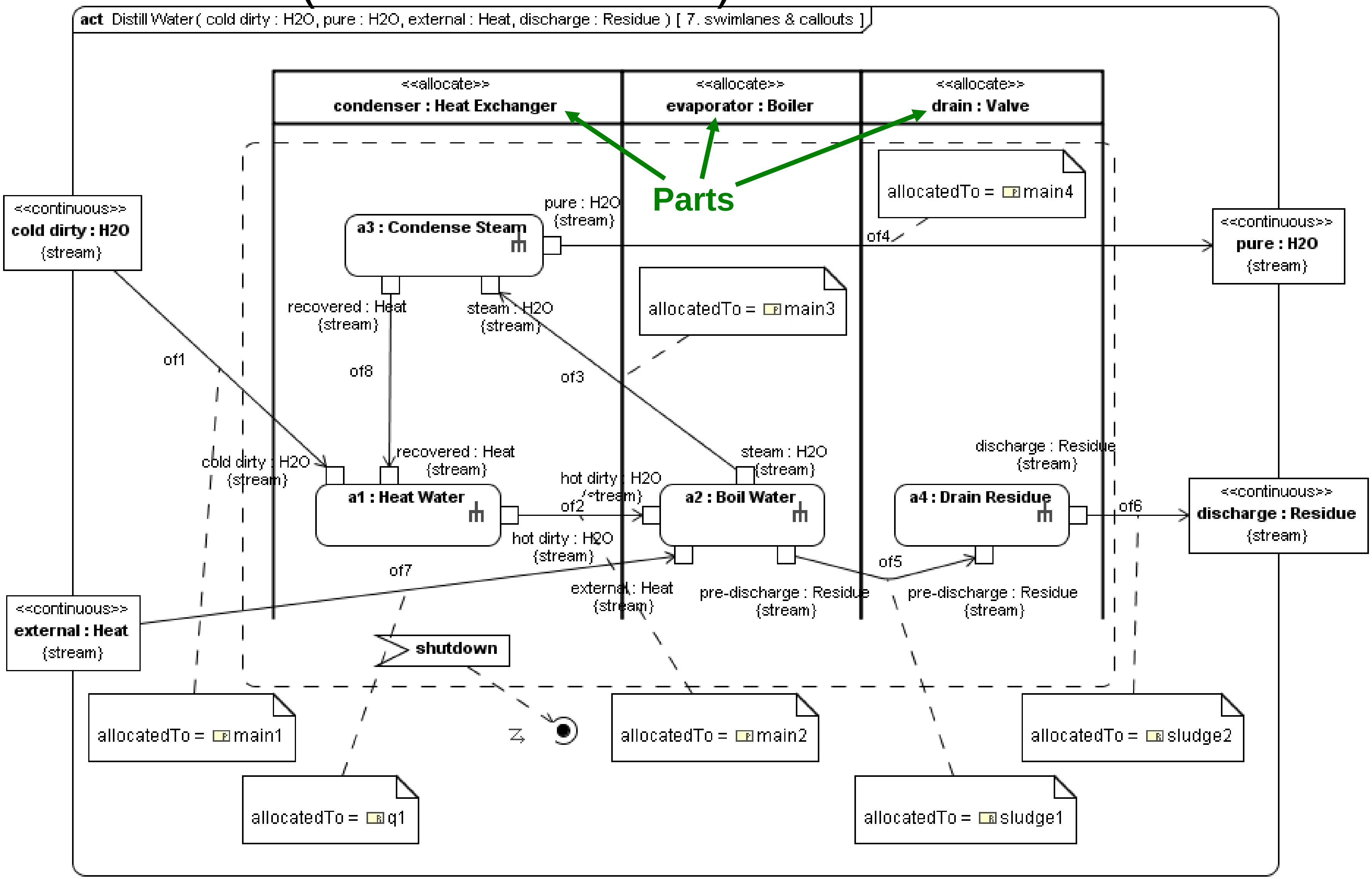
Batch Distiller Here

Continuous Distiller

Distiller Example – Activity Diagram: No Control Flow, ActionPin Notation, Simultaneous Behavior

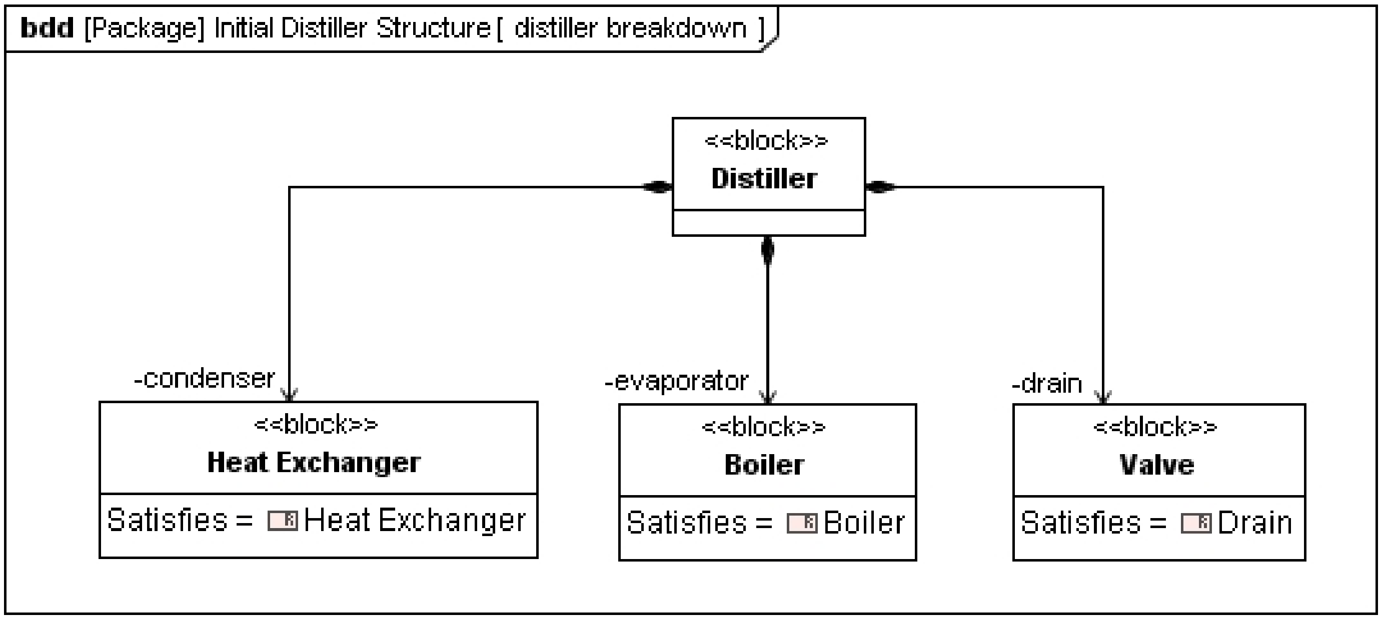


Distiller Example – Activity Diagram (with Swimlanes): DistillWater

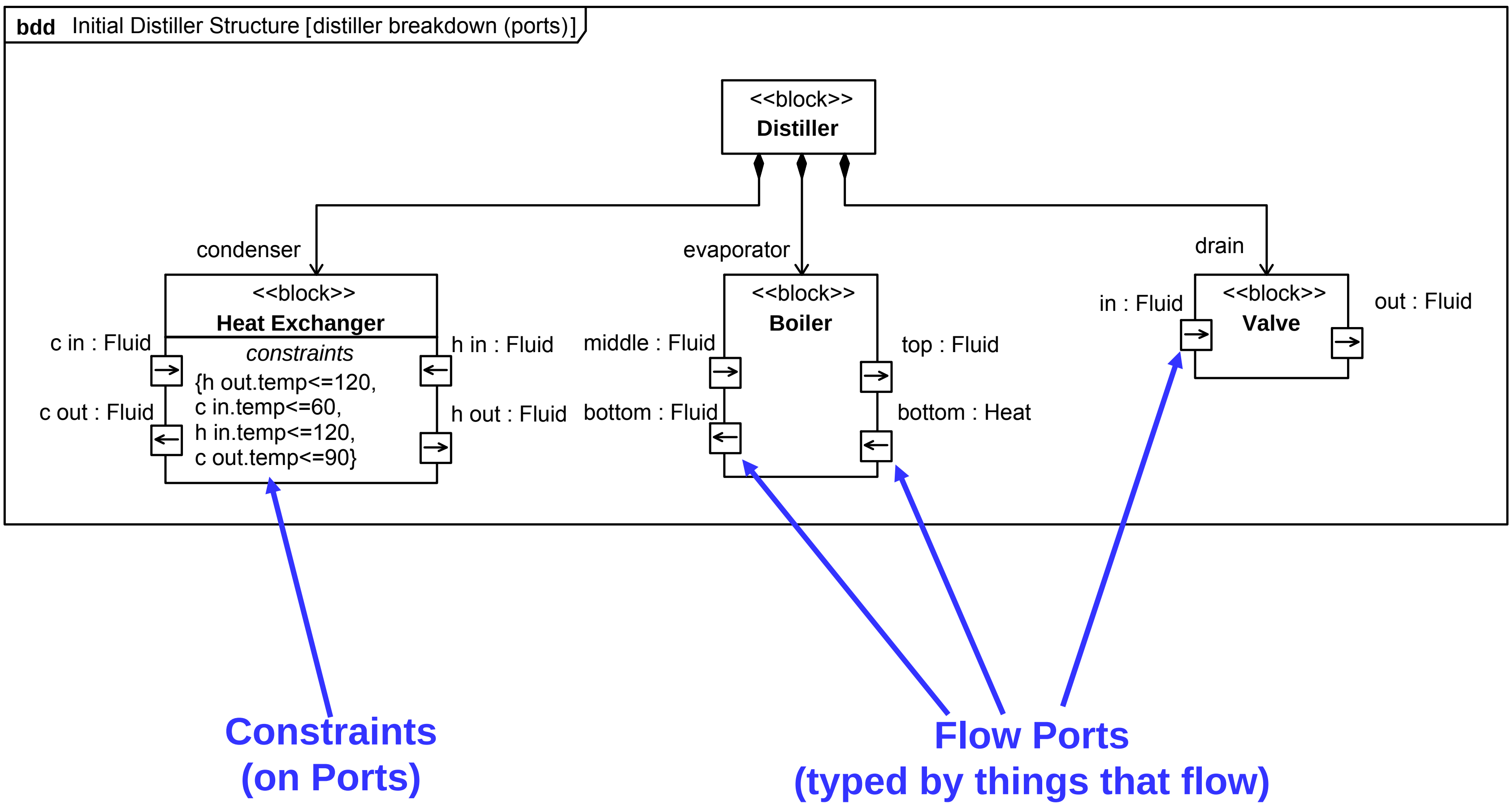


Allocated **ibd**

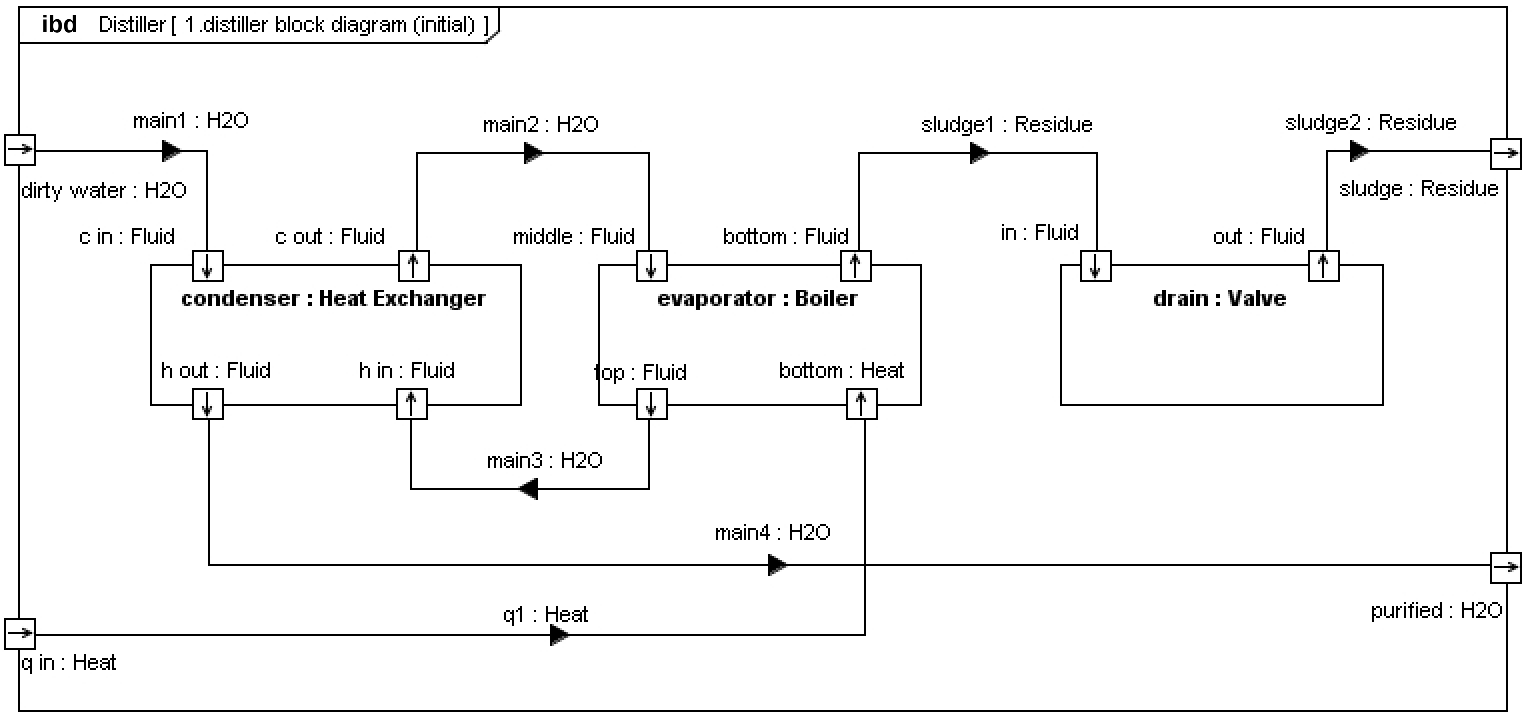
Distiller Example – Block Definition Diagram: DistillerStructure



Distiller Example – Block Definition Diagram: Heat Exchanger Flow Ports



Distiller Example – Internal Block Diagram: Distiller Initial Design



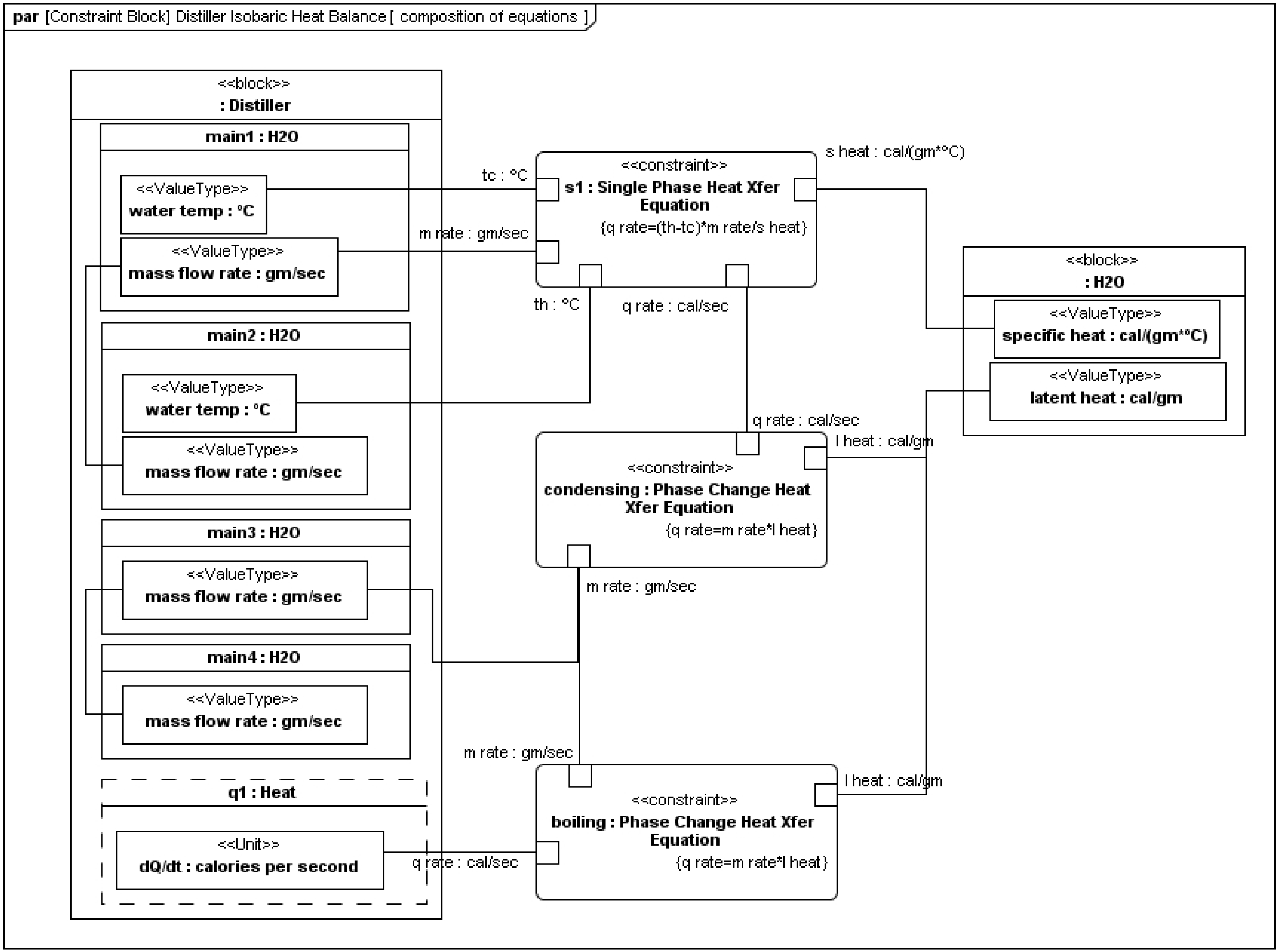
Distiller Example –Table: Functional Allocation

	Object Flow:of1[...	Object Flow:of2[...	Object Flow:of3[...	Object Flow:of4[...	Object Flow:of5[...	Object Flow:of6[...	Object Flow:of7[...	-a1 : Distiller::Dis...	-a2 : Distiller::Dis...	-a3 : Distiller::Dis...	-a4 : Distiller::Dis...
Initial Distiller Structure[Distill...											
Distiller [Distiller::Distiller St...											
-condenser : Distiller::D...								↙		↙	
-drain : Distiller::Distiller...											↙
-evaporator : Distiller::...									↙		
-main1 : Distiller::Item ...	↙										
-main2 : Distiller::Item ...		↙									
-main3 : Distiller::Item ...			↙								
-main4 : Distiller::Item ...				↙							
-q1 : Distiller::Item Typ...							↙				
-sludge1 : Distiller::Ite...					↙						
-sludge2 : Distiller::Ite...						↙					

Swimlane Diagram

Exercise for student:
Is allocation complete?
Where is "«objectFlow»of8"?

Parametric Diagram: Heat Balance



Distiller Example – Heat Balance Results

table IsobaricHeatBalance1 [Results of Isobaric Heat Balance]

specific heat cal/gm-°C	**1**
latent heat cal/cm	**540**

Satisfies «requirement» WaterSpecificHeat

Satisfies «requirement» WaterHeatOfVaporization

Satisfies «requirement» WaterInitialTemp

	main1 : H2O	main2 : H2O frm condenser	main2 : H2O into evap	main3 : H2O	main4 : H2O
mass flow rate gm/sec	6.8	**6.8**	1	1	1
temp °C	20	100	100	100	100

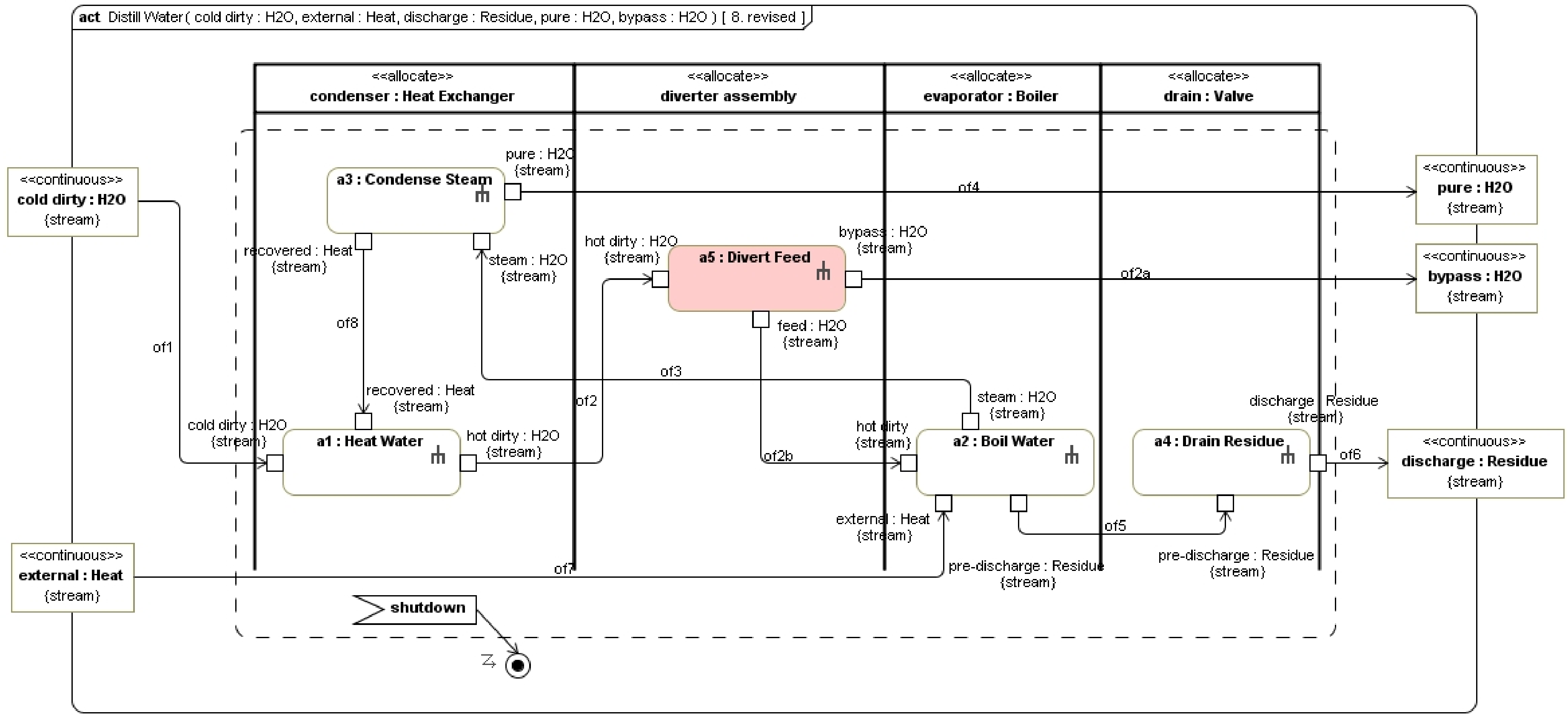
dQ/dt cooling water cal/sec	540
dQ/dt steam-condensate cal/sec	540
condenser efficency	1
heat deficit	0

dQ/dt condensate-steam cal/sec	540
boiler efficiency	1
dQ/dt in boiler cal/sec	540

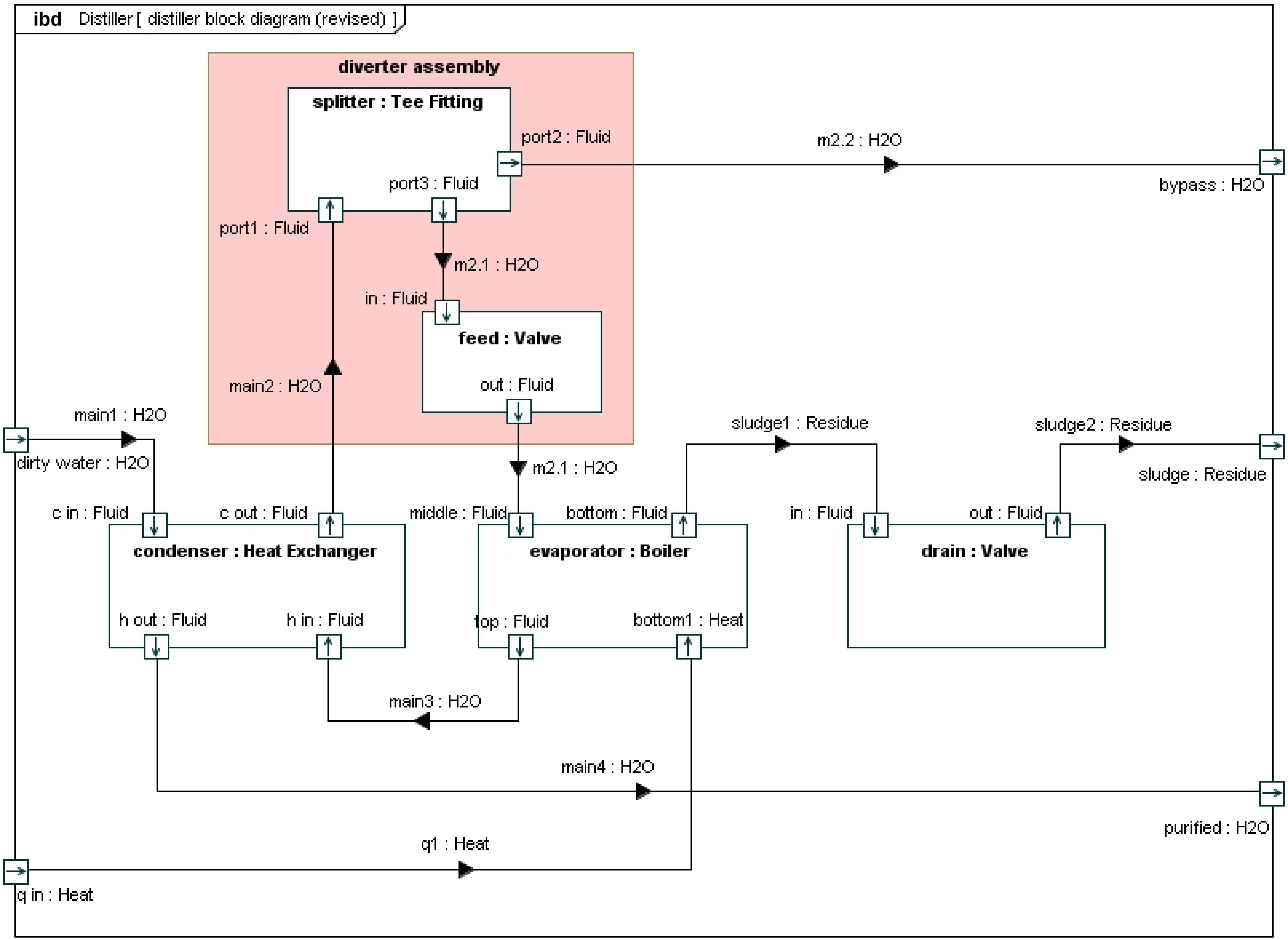
Note: Cooling water needs to have 6.75x flow of steam!
Need bypass between hx_water_out and bx_water_in!

1. Set these (steady state)
2. Solve for these

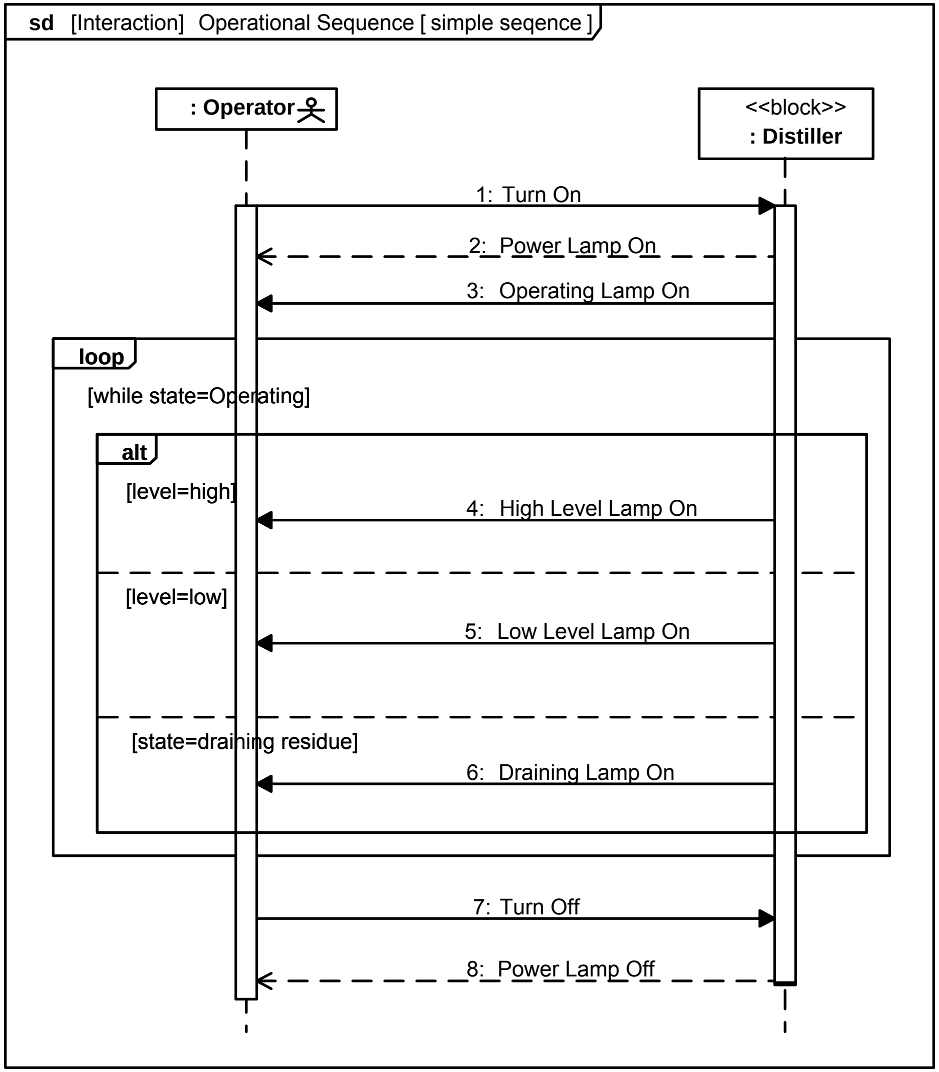
Distiller Example – Activity Diagram: Updated DistillWater

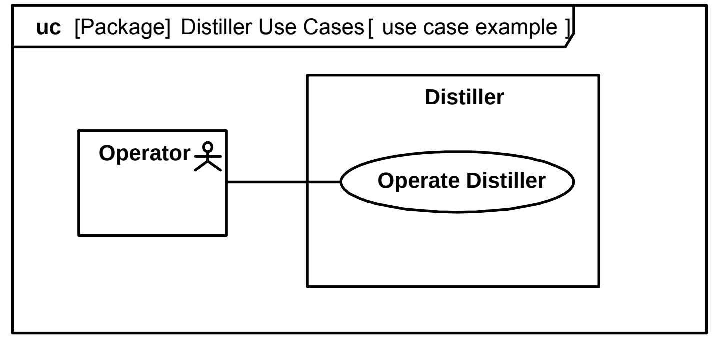


Distiller Example – Internal Block Diagram: Updated Distiller

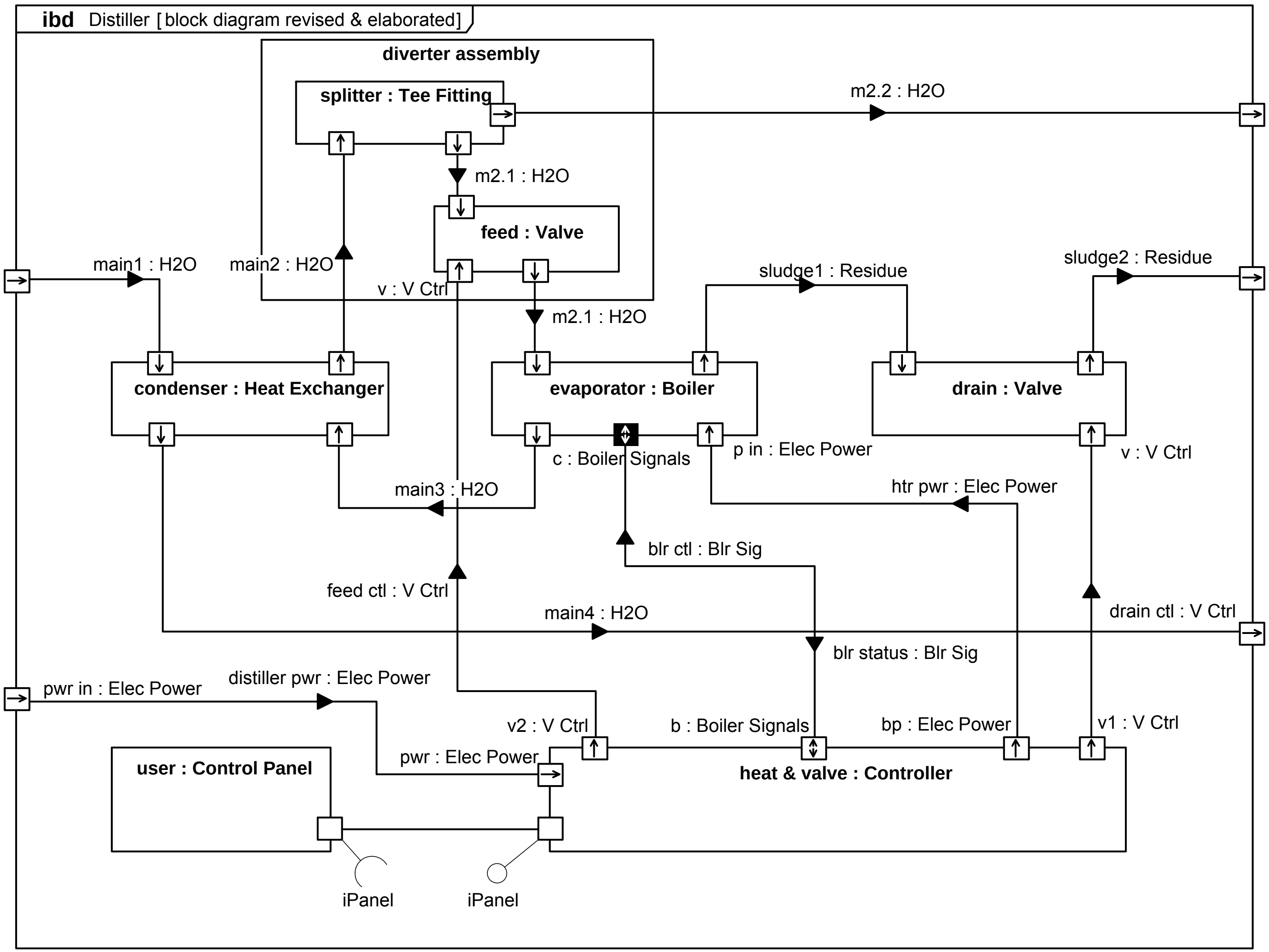


Distiller Example – Use Case and Sequence Diagrams

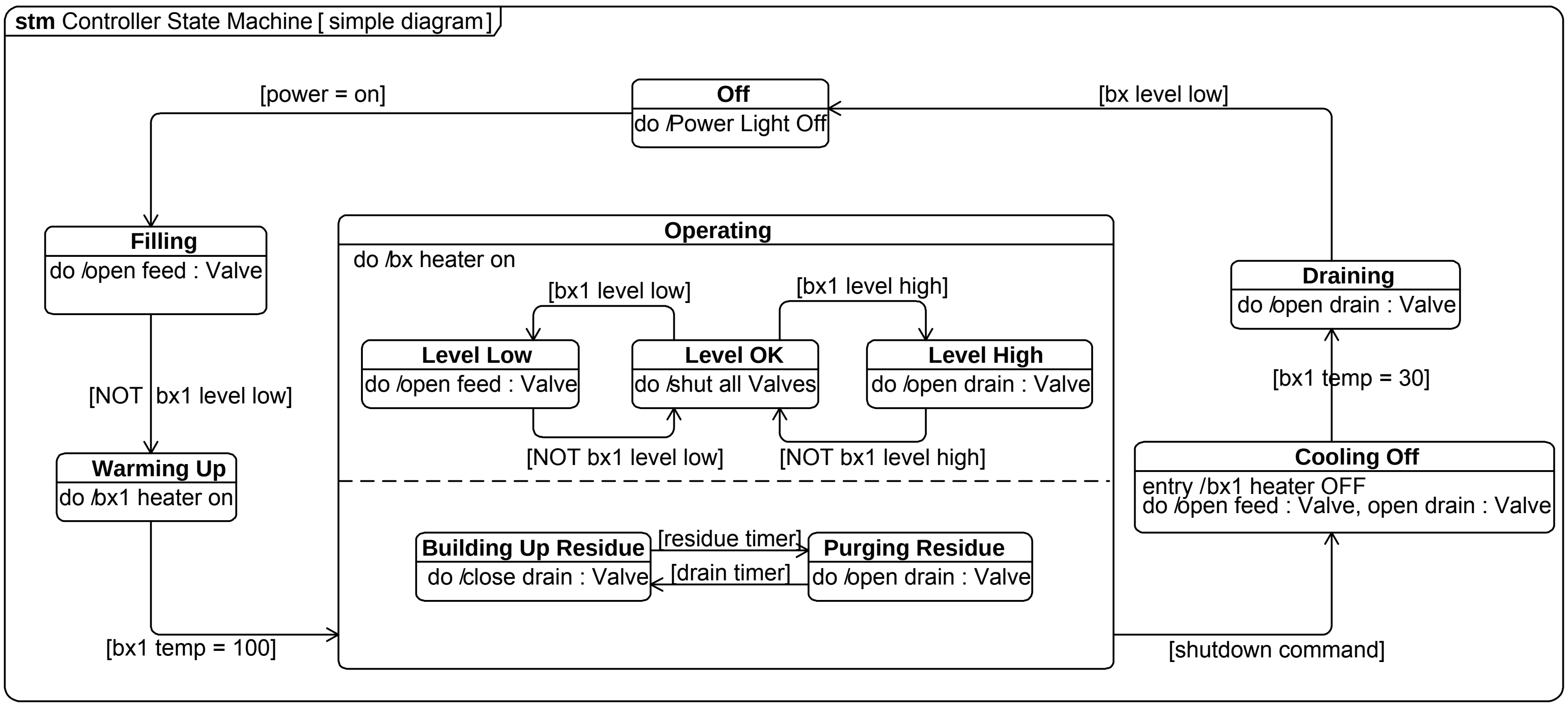




Distiller Example – Internal Block Diagram: Distiller Controller



Distiller Example – State Machine Diagram: Distiller Controller

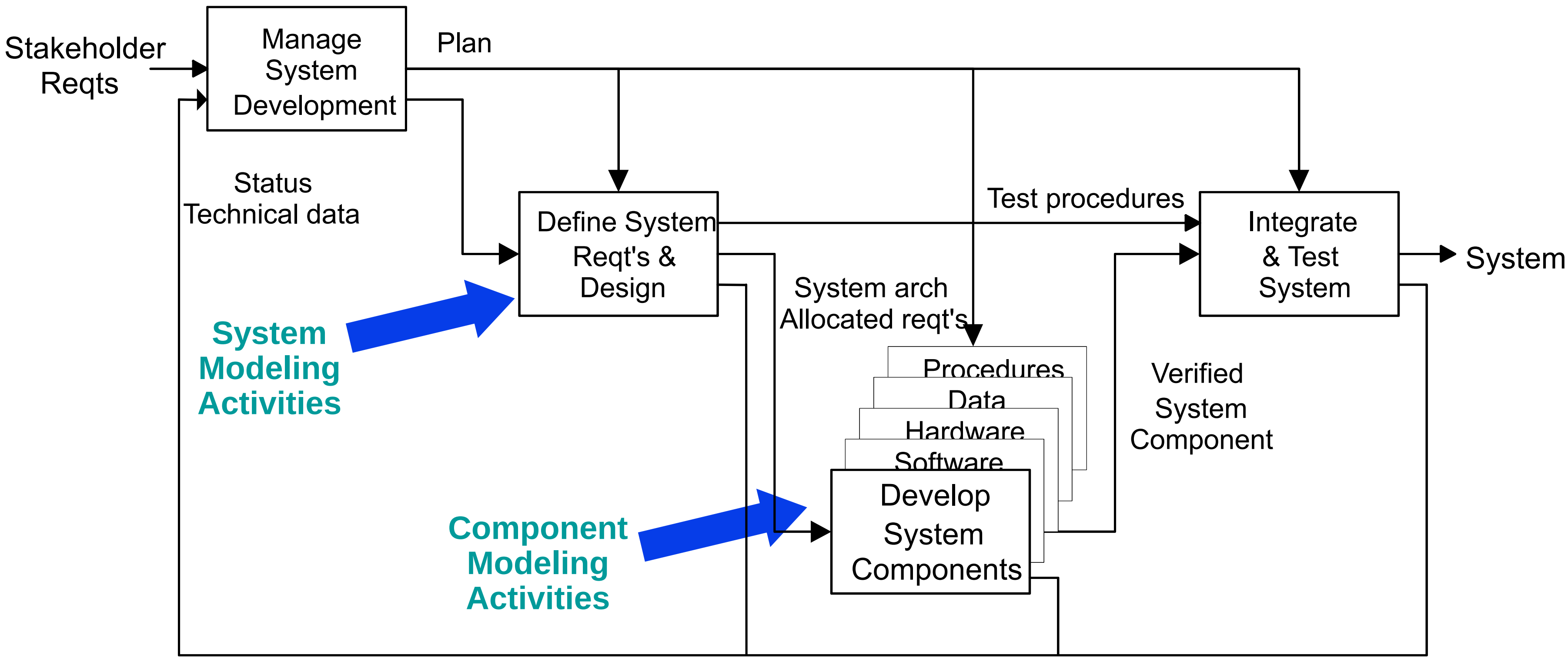


OOSEM – ESS Example

Refer to Chapter 16

“A Practical Guide to SysML”

System Development Process



Integrated Product Development (IPD) is essential to improve communications

A Recursive V process that can be applied to multiple levels of the system hierarchy

System Modeling Activities – OOSEM
Integrating MBSE into the SE Process

Major SE Development Activities

Analyze Needs
- Causal analysis
- Mission use cases/scenarios
- Enterprise model

Define System Requirements
- System use cases/scenarios
- Elaborated context

Define Logical Architecture
- Logical decomposition
- Logical scenarios
- Logical subsystems

Synthesize Allocated Architecture
- Node diagram
- HW, SW, Data arch
- System deployment

Optimize & Evaluate Alternatives
- Parametric Diag
- Trade study

Manage Requirements
- Reqt's Diagram & tables

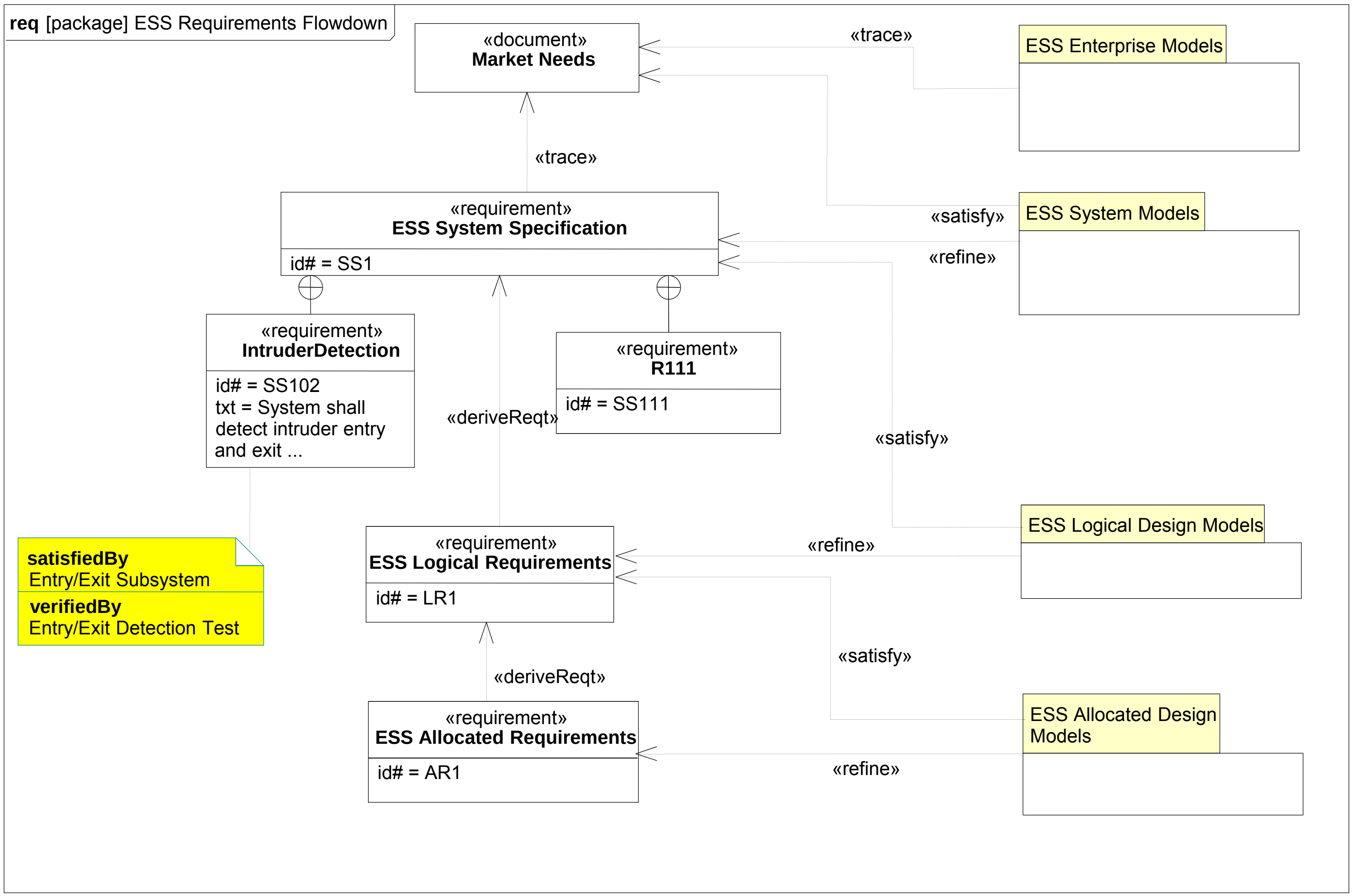
Support Validation & Verification
- Test cases
- Test procedures

Common Subactivities

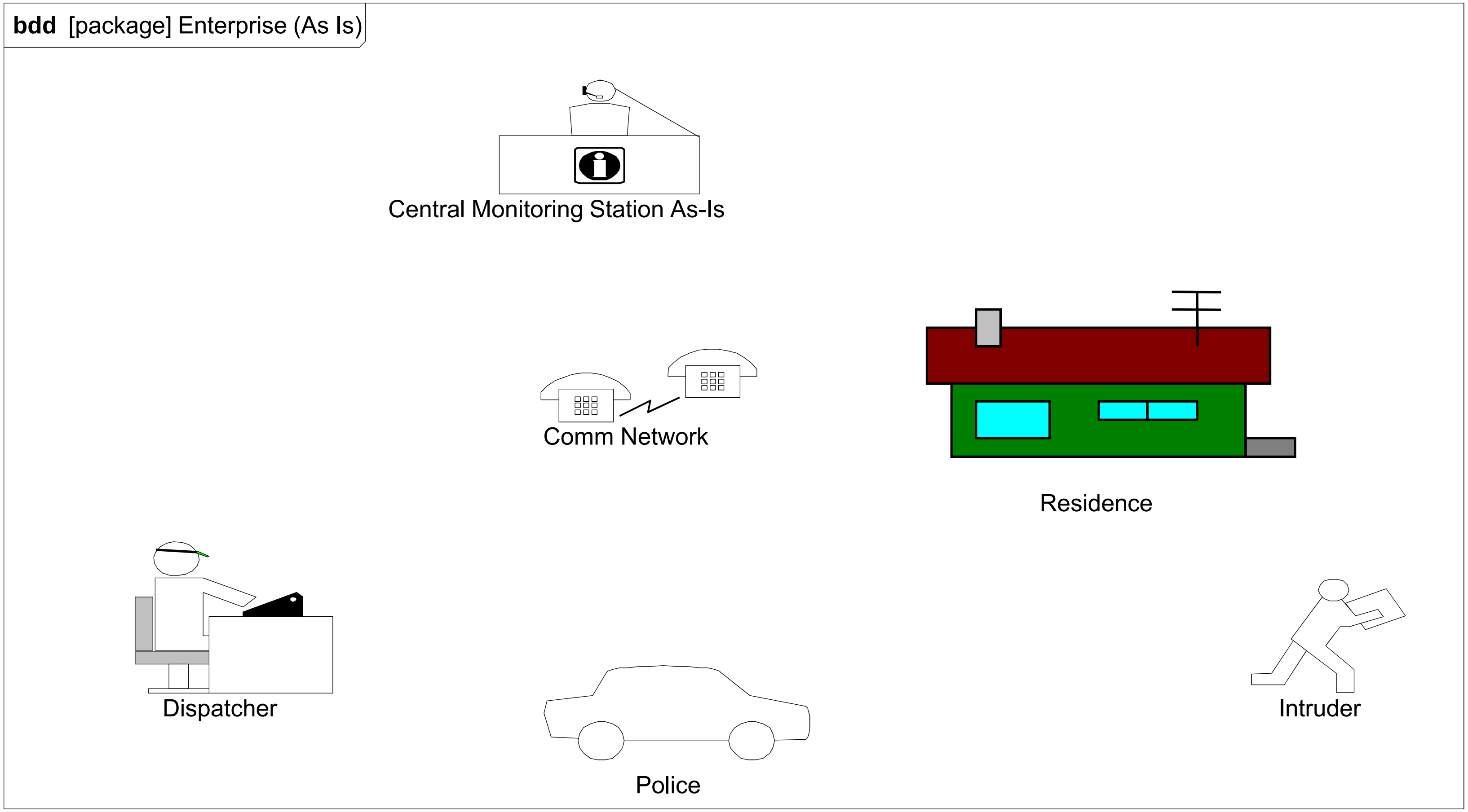
Enhanced Security System Example

- The Enhanced Security System is the example for the OOSEM material
  - Problem fragments used to demonstrate principles
  - Utilizes Artisan RTS™ Tool (early version) for the SysML artifacts

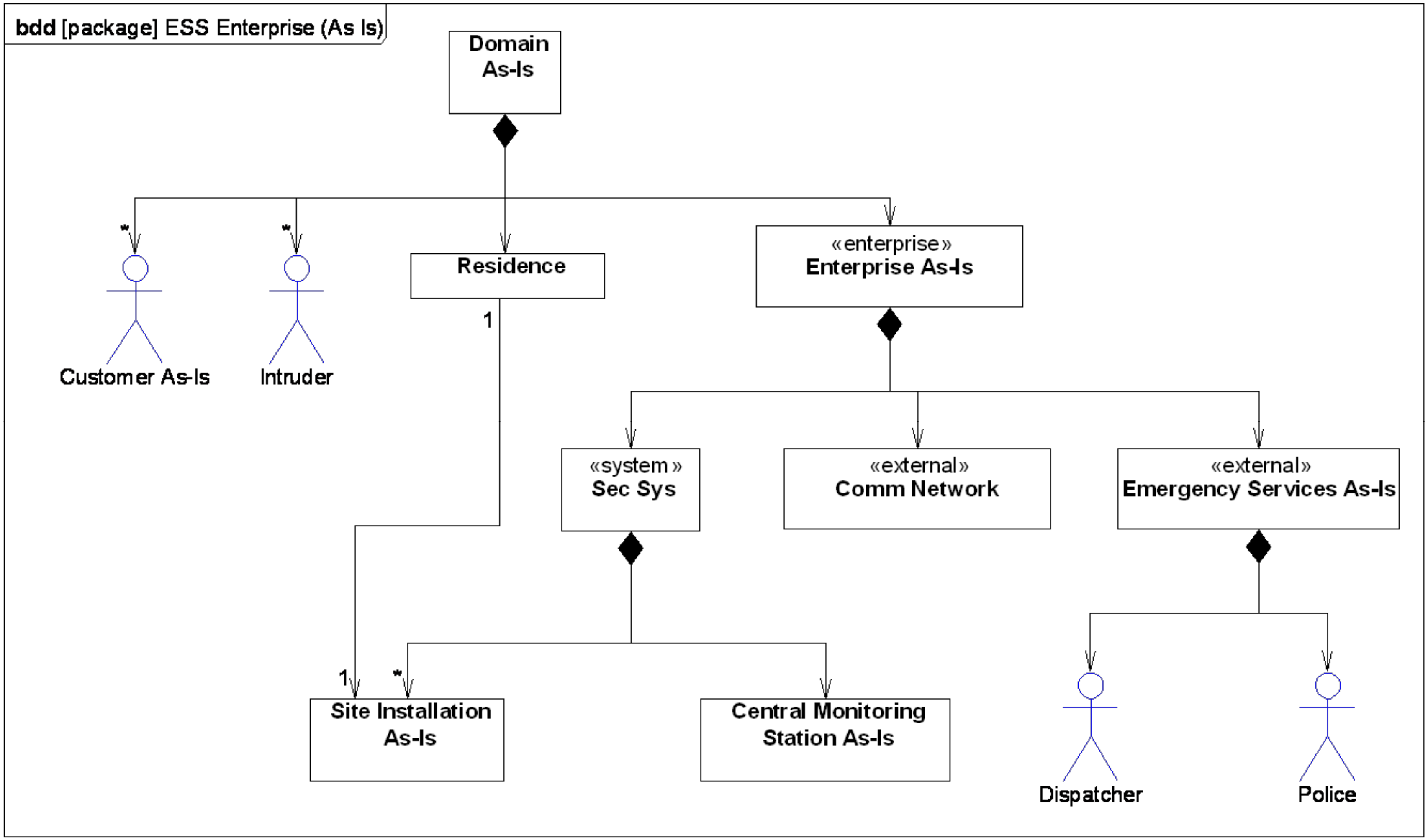
ESS Requirements Flowdown



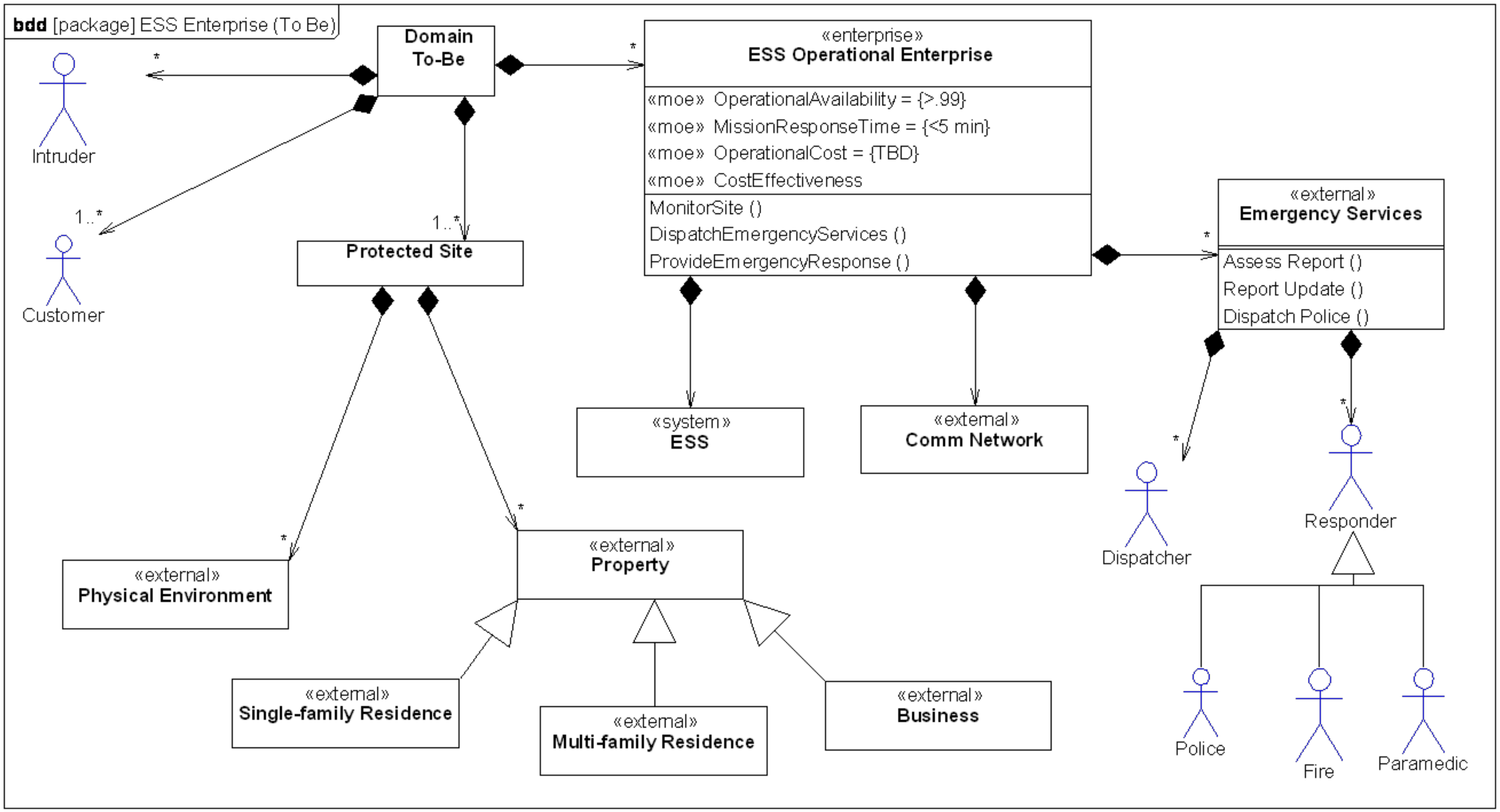
Operational View Depiction



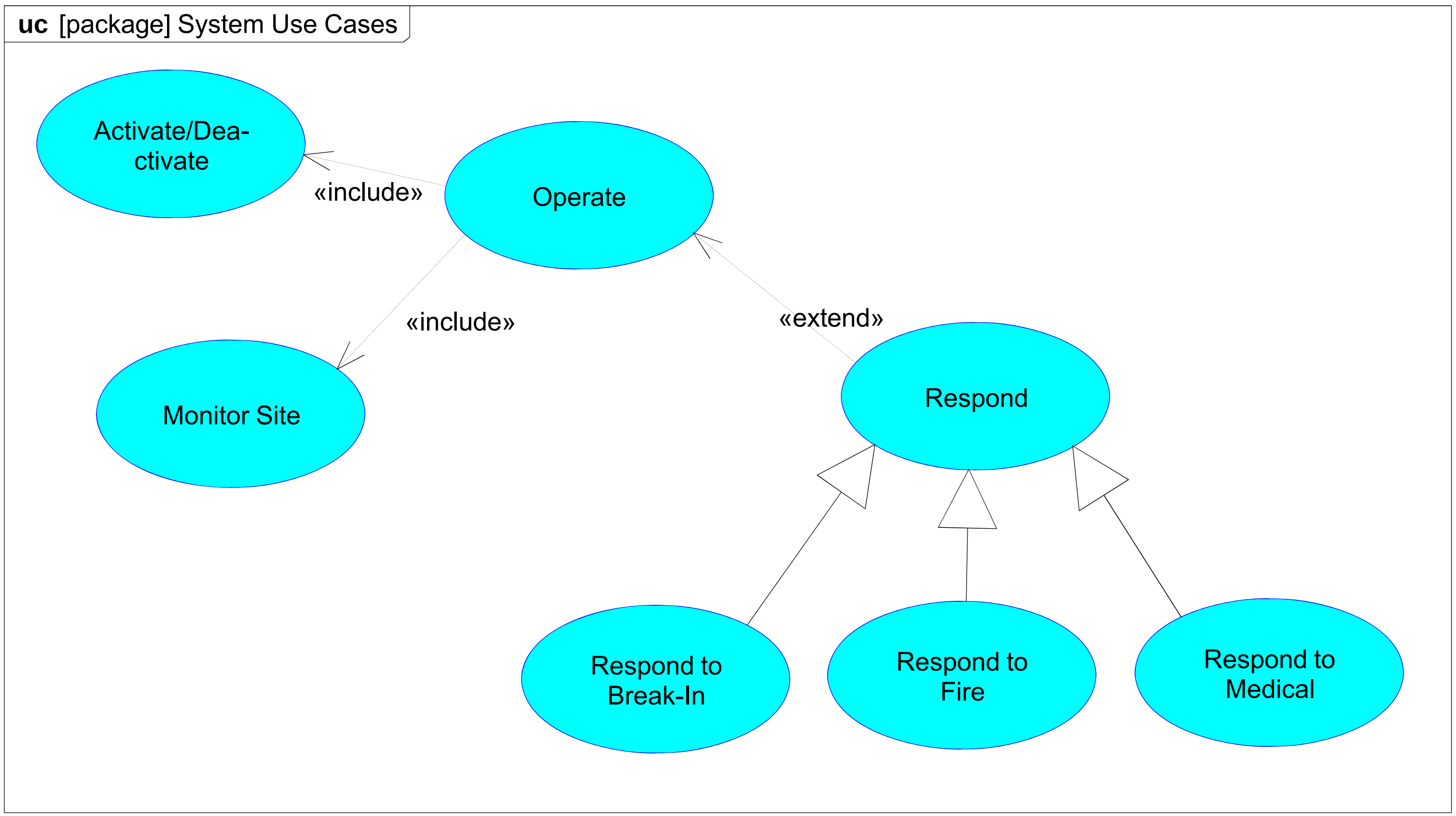
ESS Enterprise As-Is Model



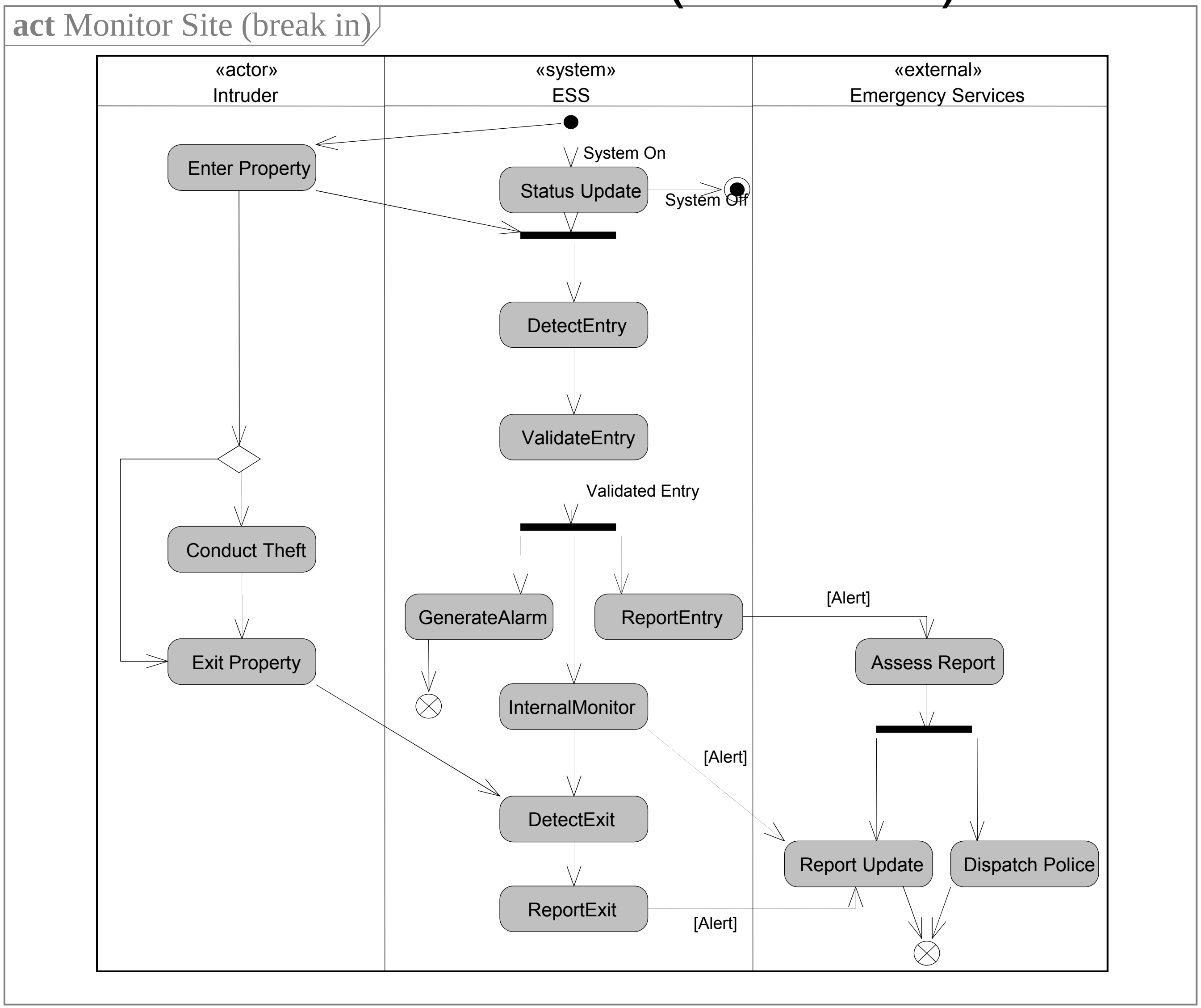
ESS Operational Enterprise To-Be Model



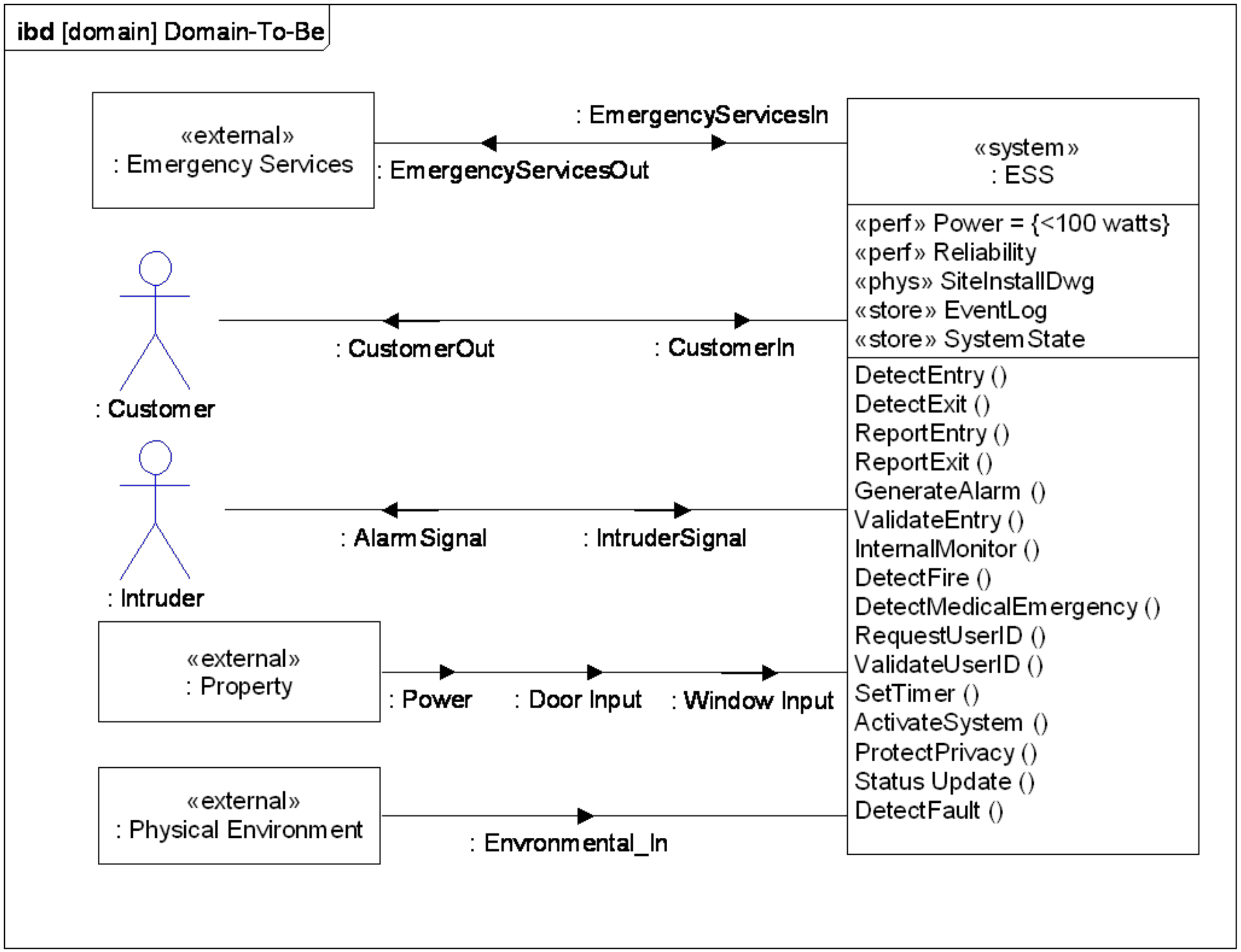
System Use Cases - Operate



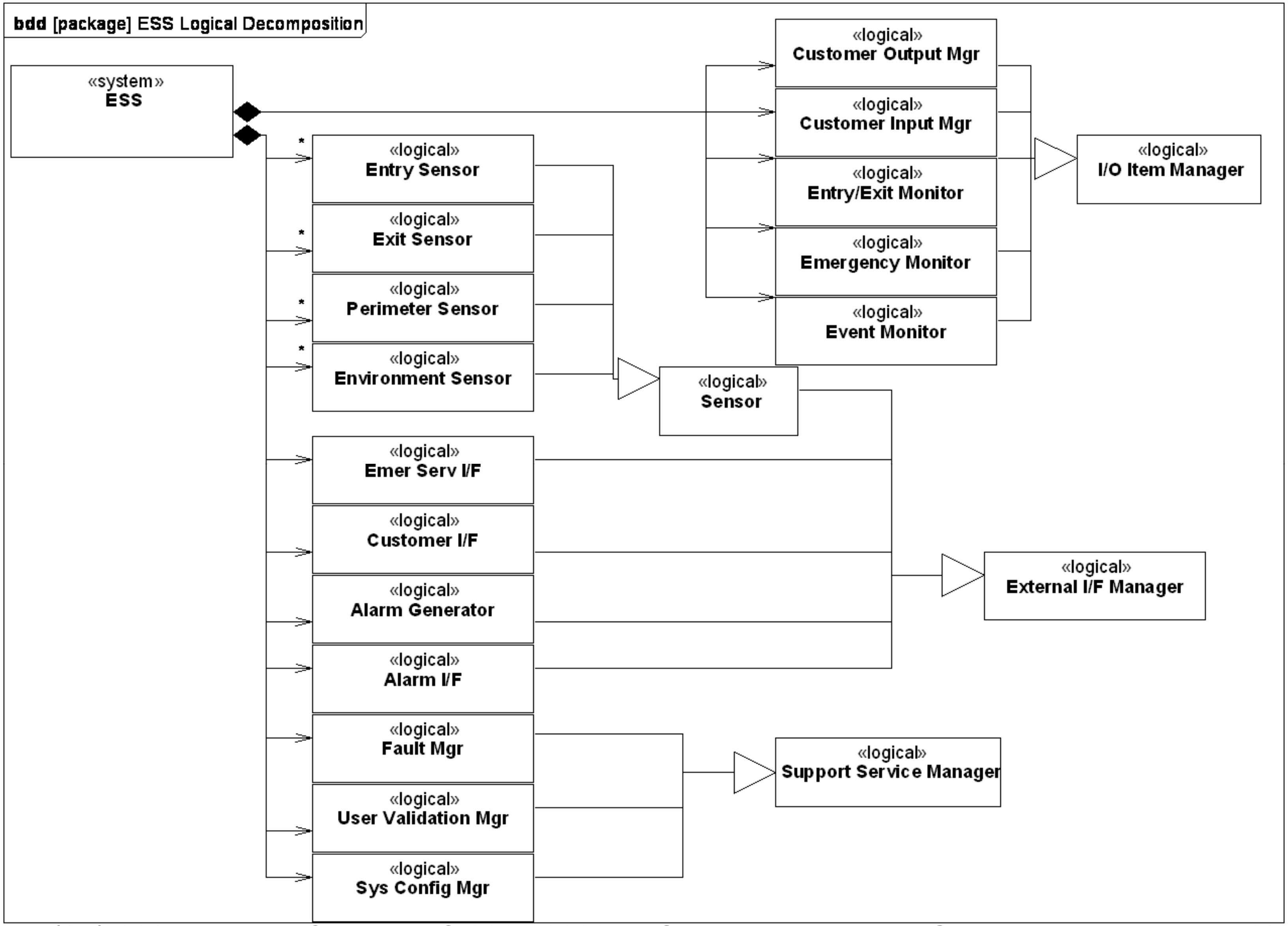
System Scenario: Activity Diagram Monitor Site (Break-In)



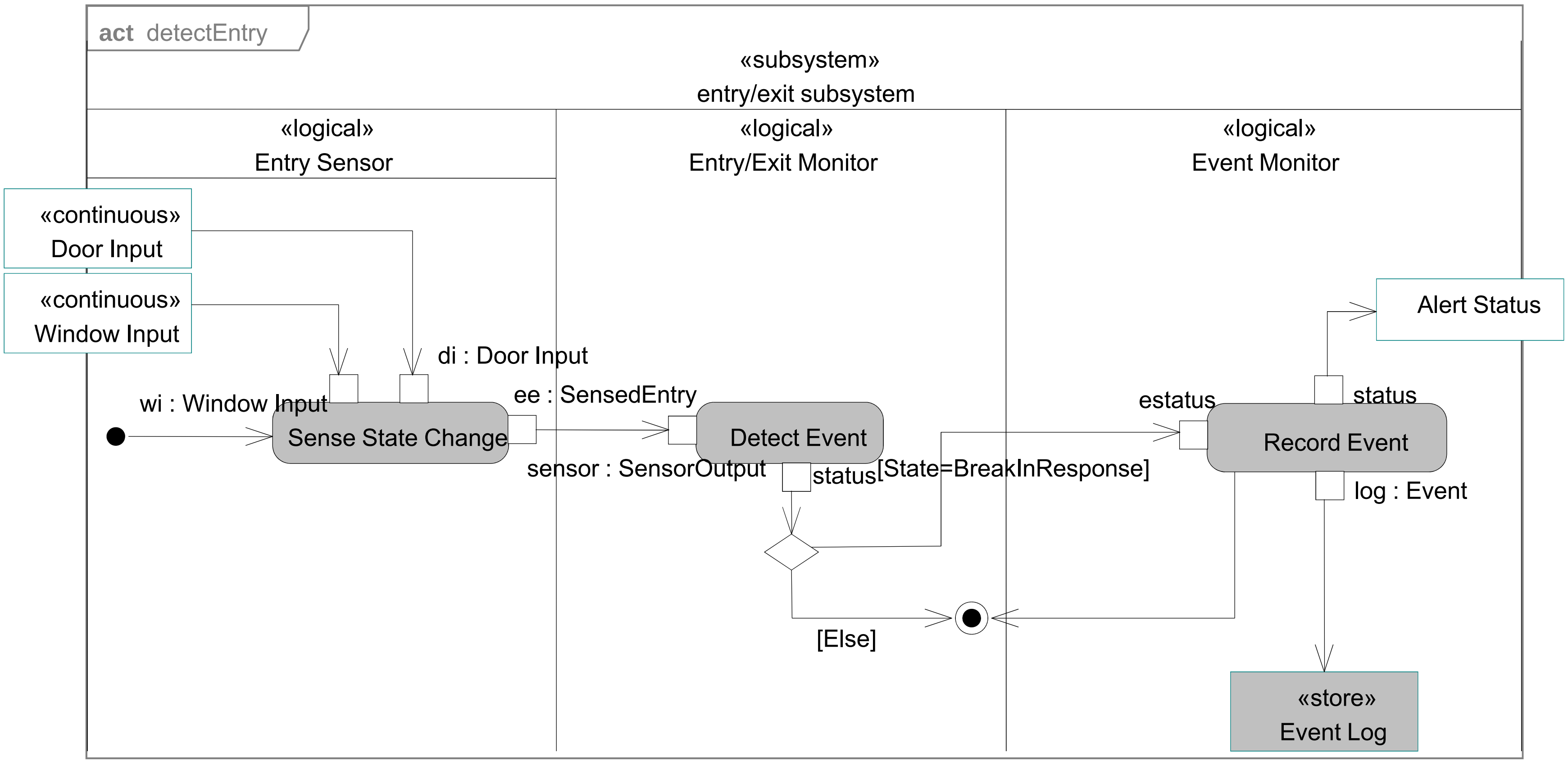
ESS Elaborated Context Diagram



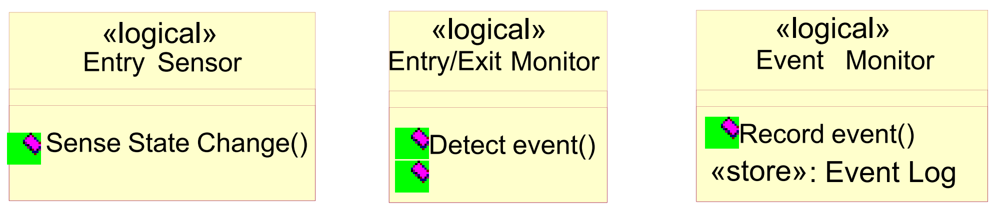
ESS Logical Decomposition (Partial)



Detect Entry Scenario

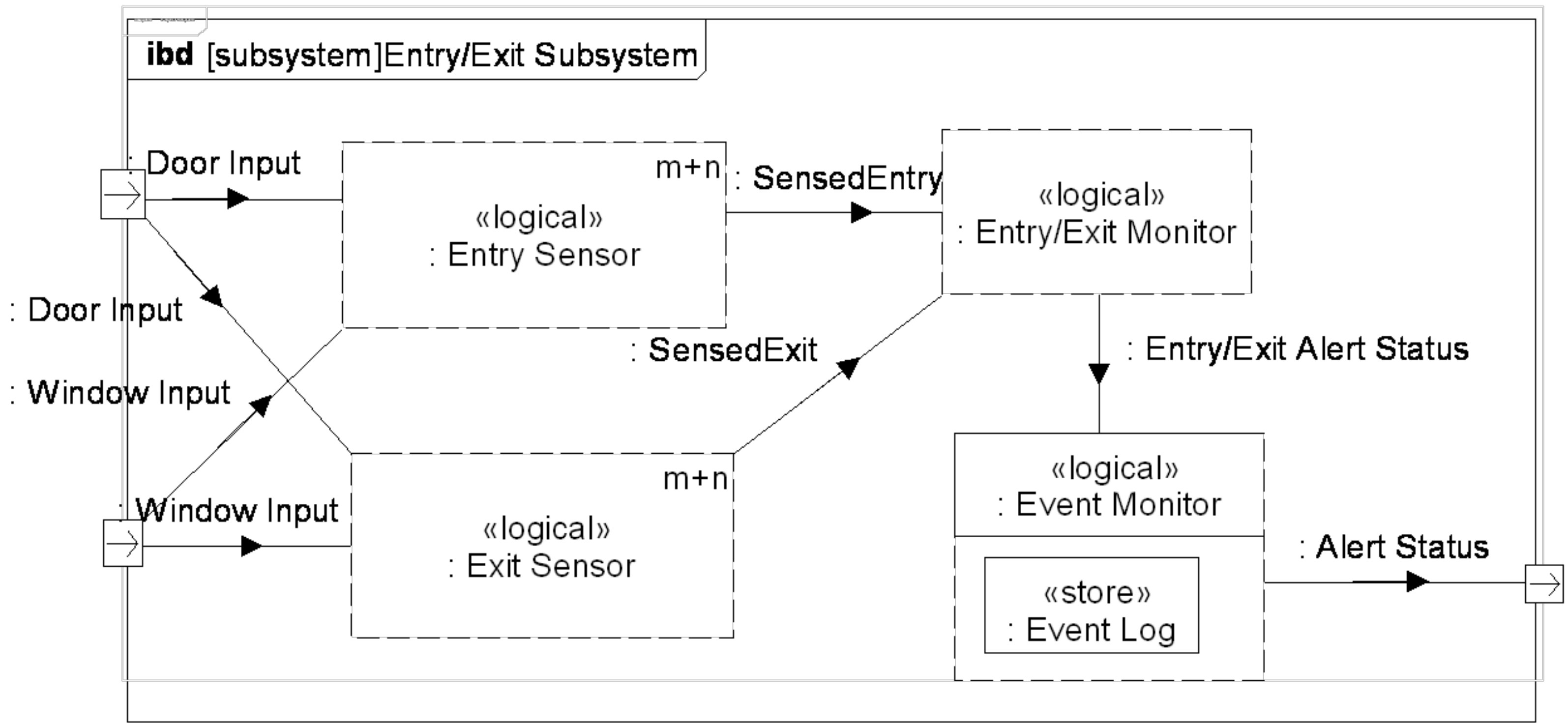


Elaborating Logical Component

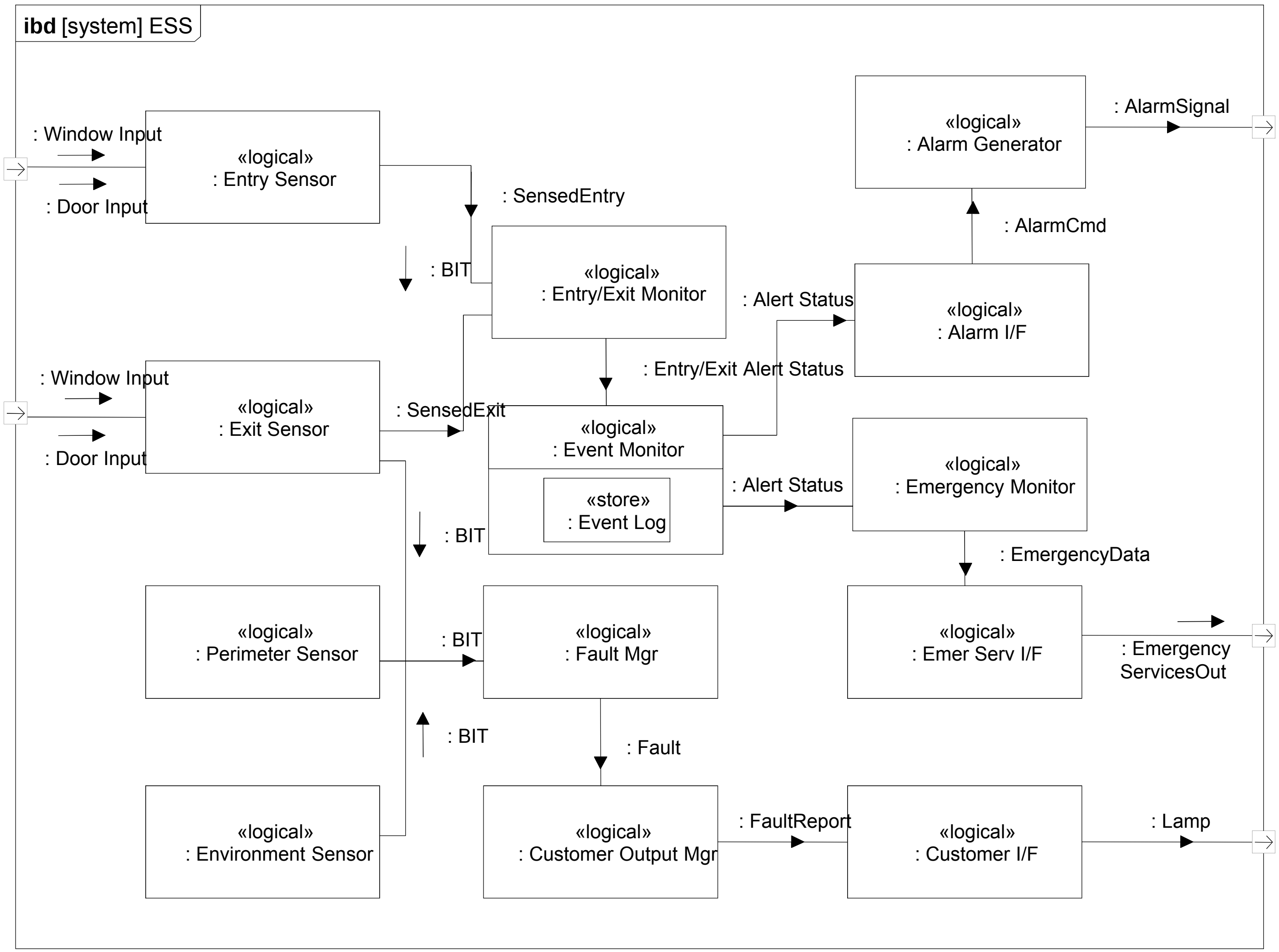


- *Added operations from Detect Entry / Detect Exit logical scenario*
- *These operations support entry/exit subsystem*

ESS Logical Design – Example Subsystem



ESS Logical Design (Partial)

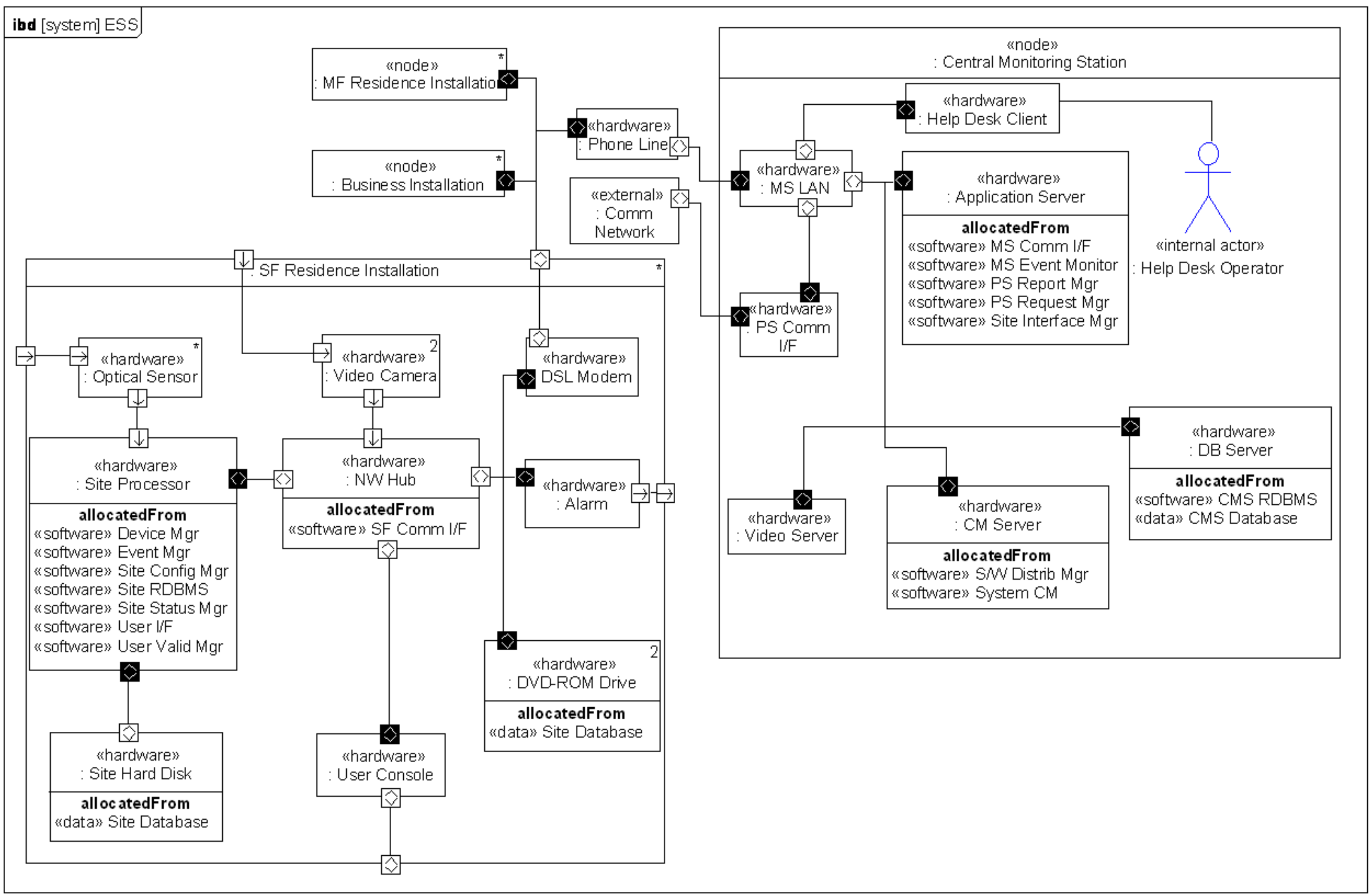


ESS Allocation Table (partial)

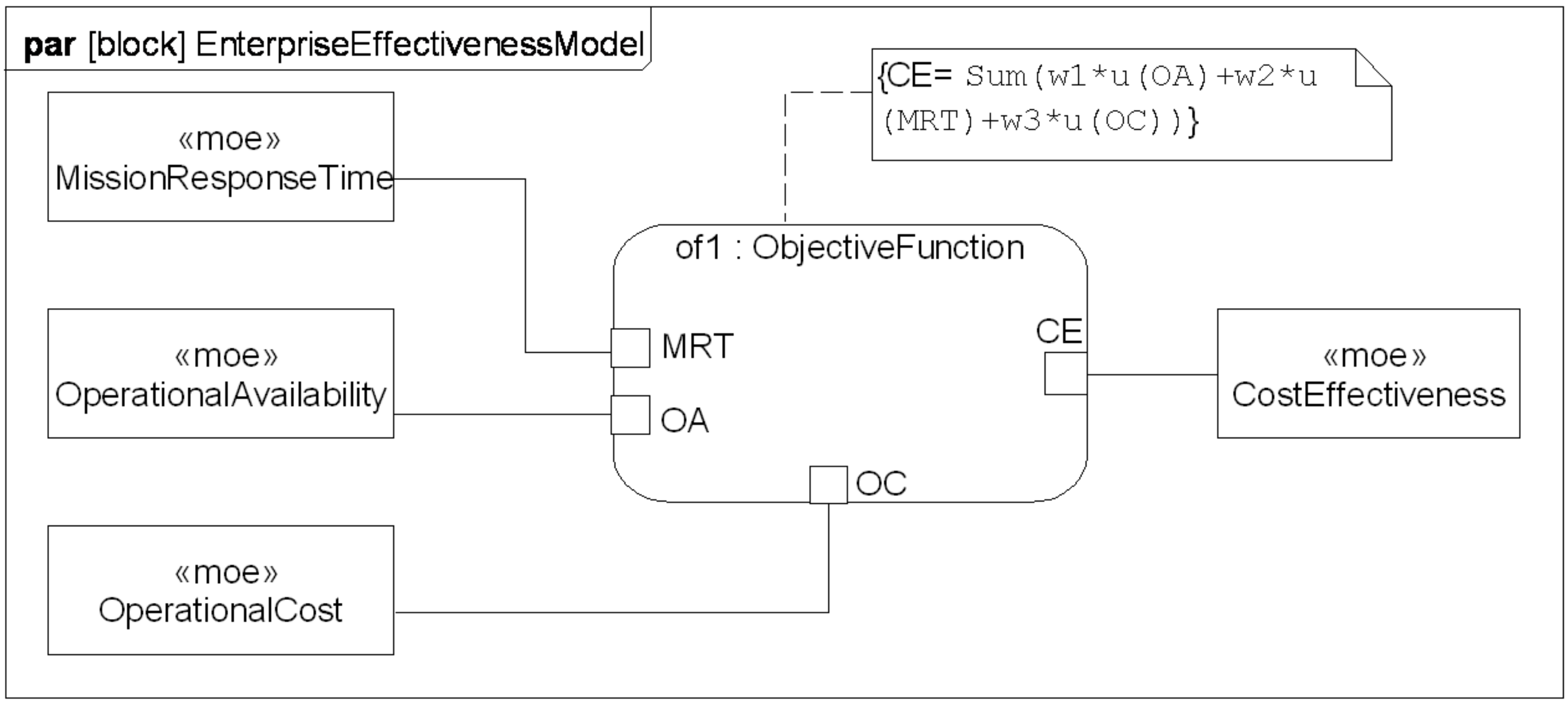
- Allocating Logical Components to HW, SW, Data, and Procedures components

			Logical Components												
Physical Components	Type		Entry Sensor	Exit Sensor	Perimeter Sensor	Entry/Exit Monitor	Event Monitor	Site Comms I/F	Event Log	Customer I/F	Customer Output Mgr	System Status	Fault Mgr	Alarm Generator	Alarm I/F
	«software»	Device Mgr													X
		SF Comm I/F						X							
		User I/F									X				
		Event Mgr				X	X								
		Site Status Mgr											X		
		Site RDBMS							X			X			
		CMS RDBMS							X						
	«data»	Video File							X						
		CMS Database							X						
		Site Database							X			X			
	«hardware»	Optical Sensor	X	X											
		DSL Modem						X							
		User Console								X					
		Video Camera			X										
		Alarm												X	

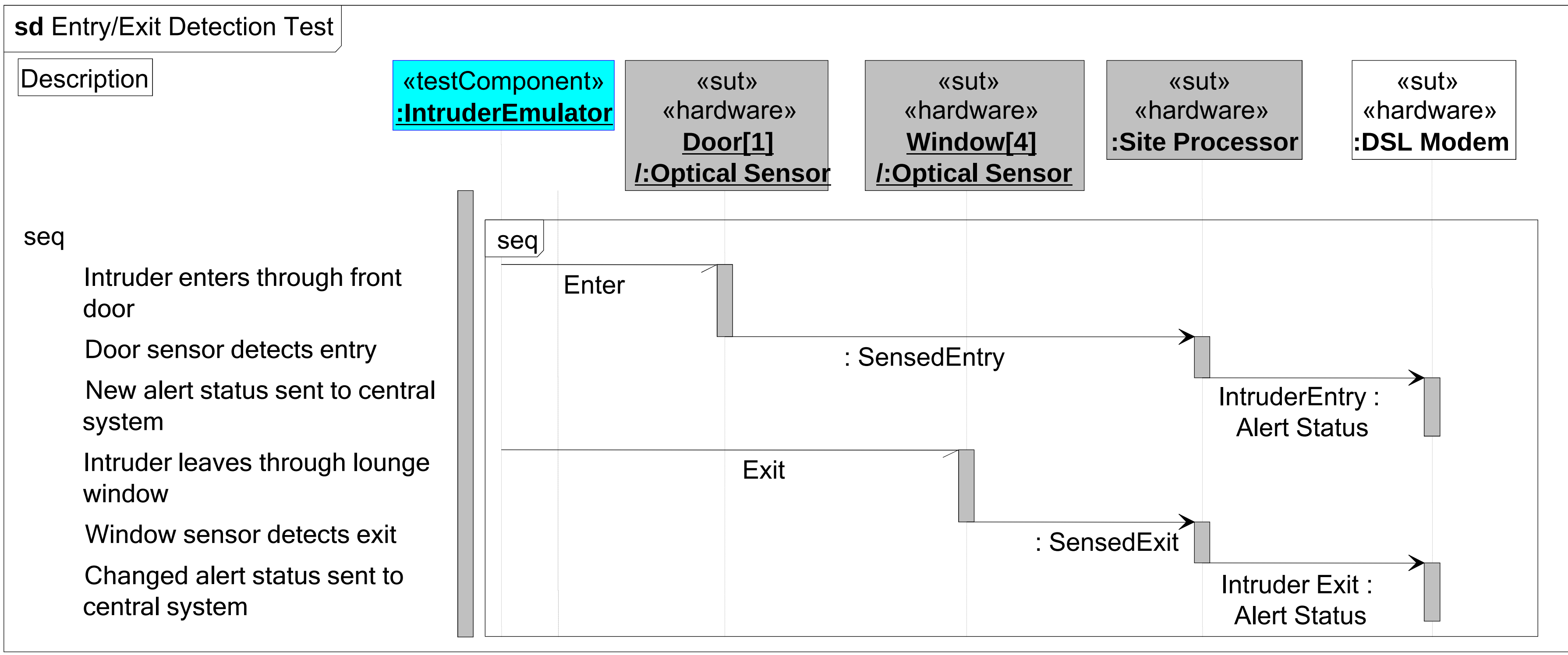
ESS Deployment View



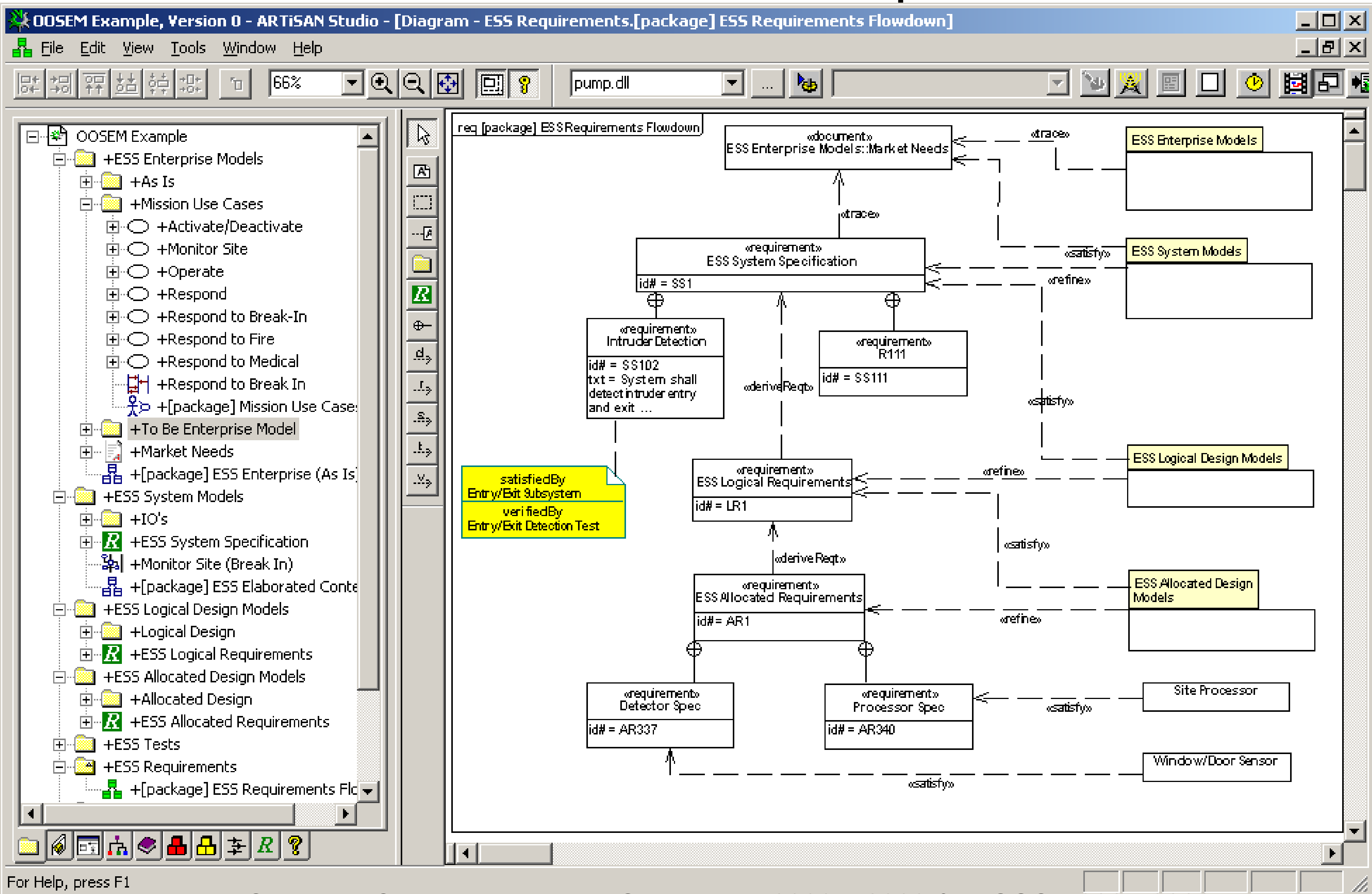
ESS Parametric Diagram
To Support Trade-off Analysis



Entry/Exit Test Case

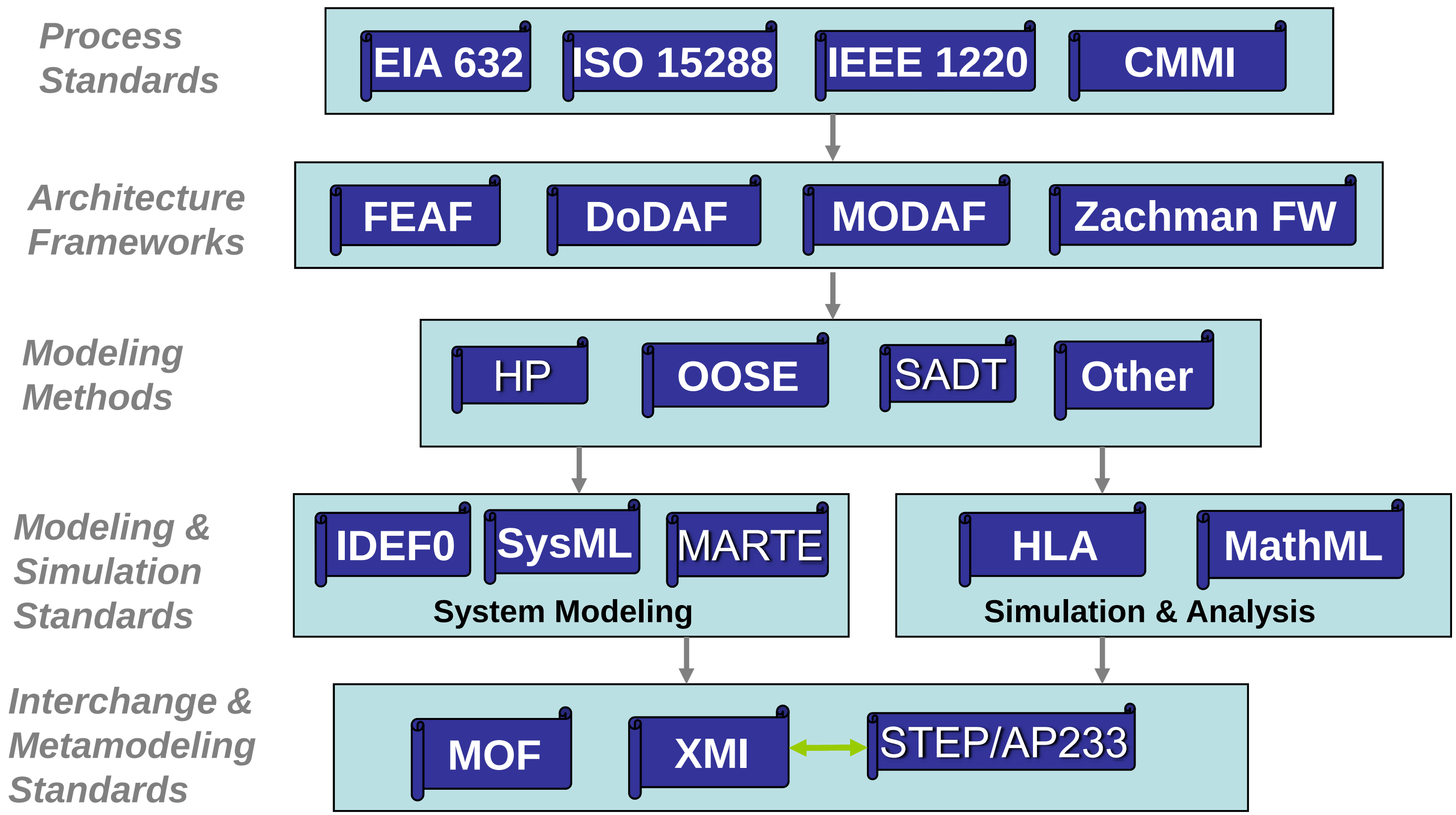


OOSEM Browser View
Artisan Studio™ Example



SysML in a Standards Framework

Systems Engineering Standards Framework (Partial List)



ISO/IEC 15288
System Life Cycle Processes

Enterprise Processes

- 5.3.2 Enterprise Environment Management Process
- 5.3.3 Investment Management Process
- 5.3.4 System Life Cycle Processes Management
- 5.3.5 Quality Management Process
- 5.3.6 Resource Management Process

Agreement Processes

- 5.2.2 Acquisition Process
- 5.2.3 Supply Process

Project Processes

- 5.4.2 Project Planning Process
- 5.4.3 Project Assessment Process
- 5.4.4 Project Control Process
- 5.4.5 Decision-Making Process
- 5.4.6 Risk Management Process
- 5.4.7 Configuration Management Process
- 5.4.8 Information Management Process

Technical Processes

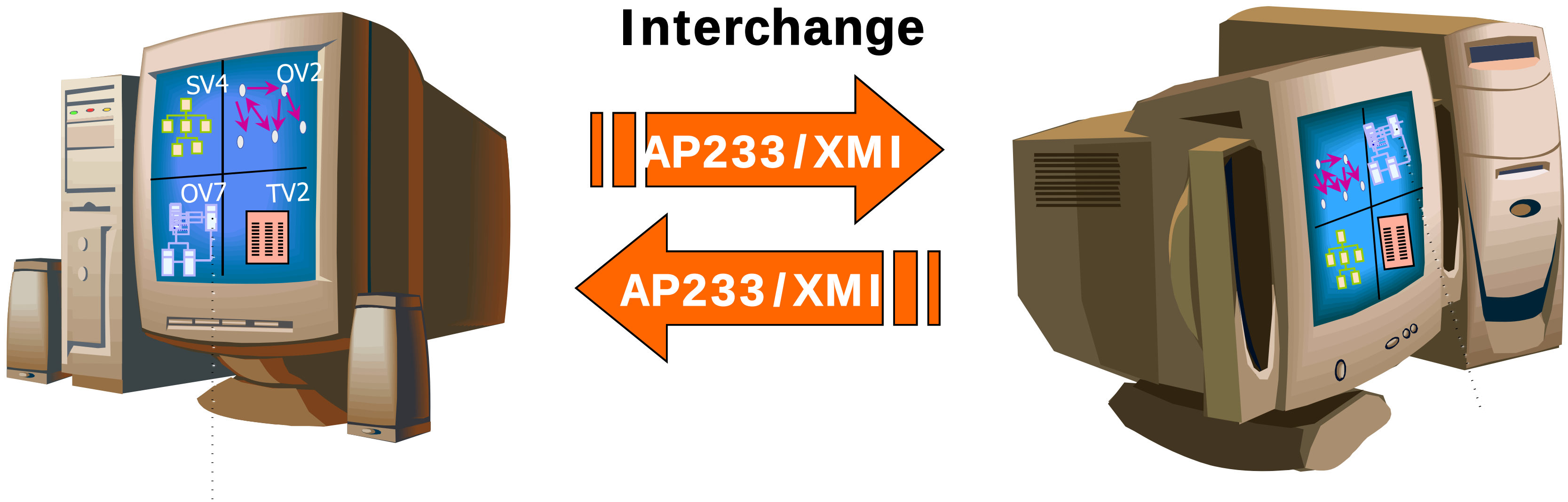
- 5.5.2 Stakeholder Reqts Definition Process
- 5.5.3 Reqts Analysis Process
- 5.5.4 Architectural Design Process
- 5.5.5 Implementation Process
- 5.5.6 Integration Process
- 5.5.7 Verification Process
- 5.5.8 Transition Process
- 5.5.9 Validation Process
- 5.5.10 Operation Process
- 5.5.11 Maintenance Process
- 5.5.12 Disposal Process

Standards-based Tool Integration with SysML

Systems Modeling Tool

Other Engineering Tools

Model / Data Interchange

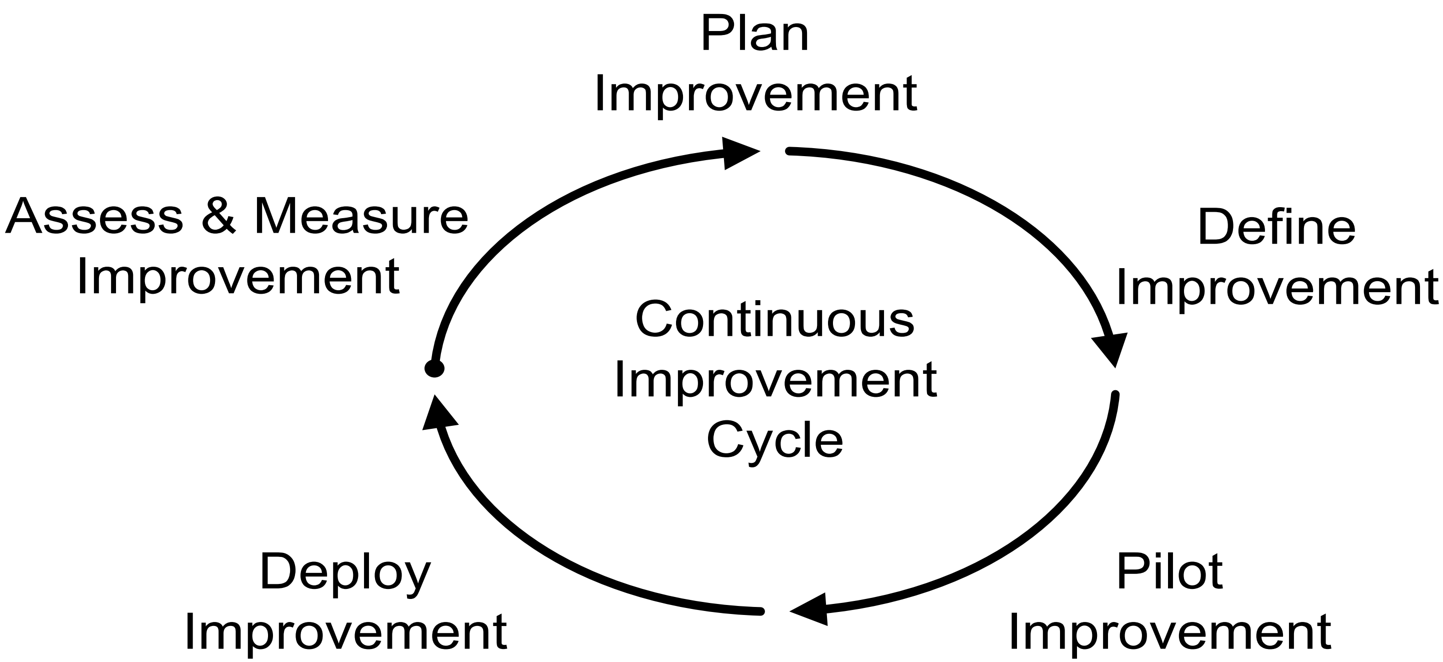


Participating SysML Tool Vendors

- Artisan (Studio)
- EmbeddedPlus (SysML Toolkit)
  - 3rd party IBM vendor
- No Magic (Magic Draw)
- Sparx Systems (Enterprise Architect)
- IBM (Tau and Rhapsody)
- TopCased
- Visio SysML template

Transitioning to SysML

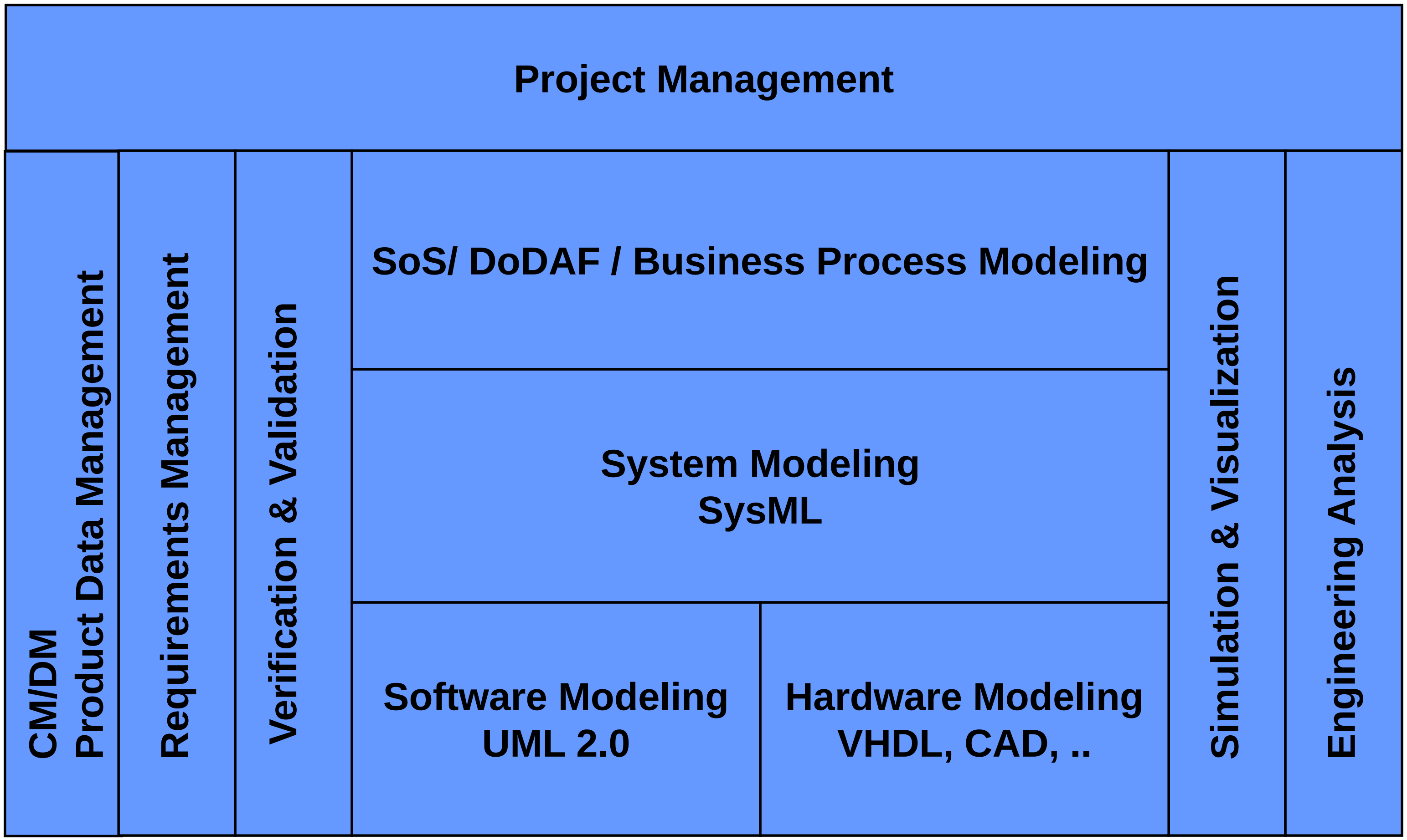
Using Process Improvement To Transition to SysML



MBSE Transition Plan

- MBSE Scope
- MBSE Responsibilities/Staffing
- Process guidance
  - High level process flow (capture in SEMP)
  - Model artifact checklist
  - Tool specific guidance
- Tool support
  - Modeling tool
  - Requirements management
  - CM
- Training
- Schedule

Typical Integrated Tool Environment



Summary and Wrap up

Summary

- SysML sponsored by INCOSE/OMG with broad industry and vendor participation and adopted in 2006
- SysML provides a general purpose modeling language to support specification, analysis, design and verification of complex systems
  - Subset of UML 2 with extensions
  - 4 Pillars of SysML include modeling of requirements, behavior, structure, and parametrics
- Multiple vendor implementations available
- Standards based modeling approach for SE expected to improve communications, tool interoperability, and design quality
- Plan SysML transition as part of overall MBSE approach
- Continue to evolve SysML based on user/vendor/researcher feedback and lessons learned

References

- **OMG SysML website**
  - http://www.omgsysml.org
  - Refer to current version of SysML specification, vendor links, tutorial, and papers
- A Practical Guide to SysML (Morgan Kaufmann) by Friedenthal, Moore, Steiner
  - http://www.elsevierconnect.com/companion.jsp?ISBN=9780123743794
- UML for Systems Engineering RFP
  - OMG doc# ad/03-03-41
- UML 2 Superstructure v2.1.2
  - OMG doc# formal/2007-11-02
- UML 2 Infrastructure v2.1.2
  - OMG doc# formal/2007-11-04
- OMG SysML Information Days Presentations (Dec 8-11, 2008)
  - http://www.omg.org/news/meetings/tc/santa_clara/special-events/SysML_Agenda.htm

PAPERS

- Integrating Models and Simulations of Continous Dynamics into SysML
  - Thomas Johnson, Christiaan Paredis, Roger Burkhart, Jan ‘2008
- Simulation-Based Design Using SysML - Part 1: A Parametrics Primer
  - RS Peak, RM Burkhart, SA Friedenthal, MW Wilson, M Bajaj, I Kim
- Simulation-Based Design Using SysML - Part 2: Celebrating Diversity by Example
  - RS Peak, RM Burkhart, SA Friedenthal, MW Wilson, M Bajaj, I Kim
- SysML and UML 2.0 Support for Activity Modeling,
  - Bock. C., vol. 9 no.2, pp. 160-186, Journal of International Council of Systems Engineering, 2006.
- The Systems Modeling Language,
  - Matthew Hause, Alan Moore, June ' 2006.
- An Overview of the Systems ModelIng Language for Products and Systems Development,
  - Laurent Balmelli, Oct ' 2006.
- Model-driven systems development,
  - L. Balmelli, D. Brown, M. Cantor, M. Mott, July ' 2006.

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Class Exercise Dishwasher Example Sample Artifacts

Primary

- Requirement diagram – dishwasher spec
- Block definition diagram – top level
- Internal block diagram – dishwasher black box
- Use case diagram
- Activity diagram – black box scenario
- Block definition diagram – input/output definitions
- Block definition diagram – dishwasher hierarchy
- Internal block diagram – dishwasher white box
- Activity diagram – white box scenario
- Requirement diagram - traceability

Optional

- Parametric diagram
- State machine diagram
- Sequence diagram