

Systems Modeling Language (SysML) Overview

SysML Merge Team (SMT)

March 16, 2006

Draft

These slides are in process of development by the SMT team and are subject to change as the SysML specification is finalized. Please check for current SysML status at syseng.omg.org.

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Caveat

- n This material is based on Draft V0.99 of the SysML specification and is still subject to change prior to adoption

Topics

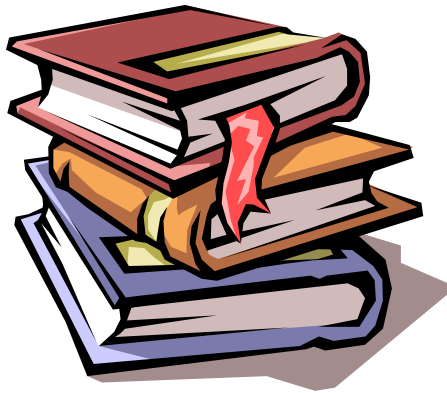
- n Motivation & Background
- n Diagram Overview
- n SysML Modeling as Part of an SE Process
- n SysML in a Standards Framework
- n Transitioning to SysML
- n Summary

A decorative L-shaped line consisting of a vertical black line on the left and a horizontal black line extending to the right, both meeting at a right-angle corner.

Motivation & Background

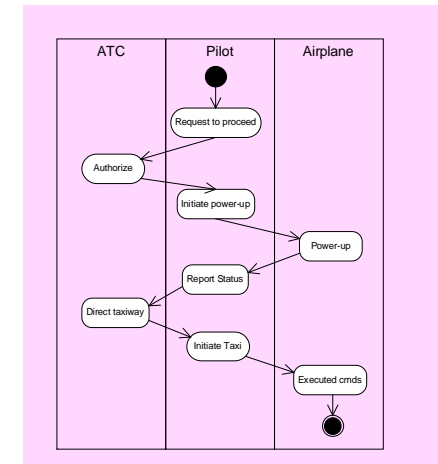
SE Practices for Describing Systems

Past



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

Future

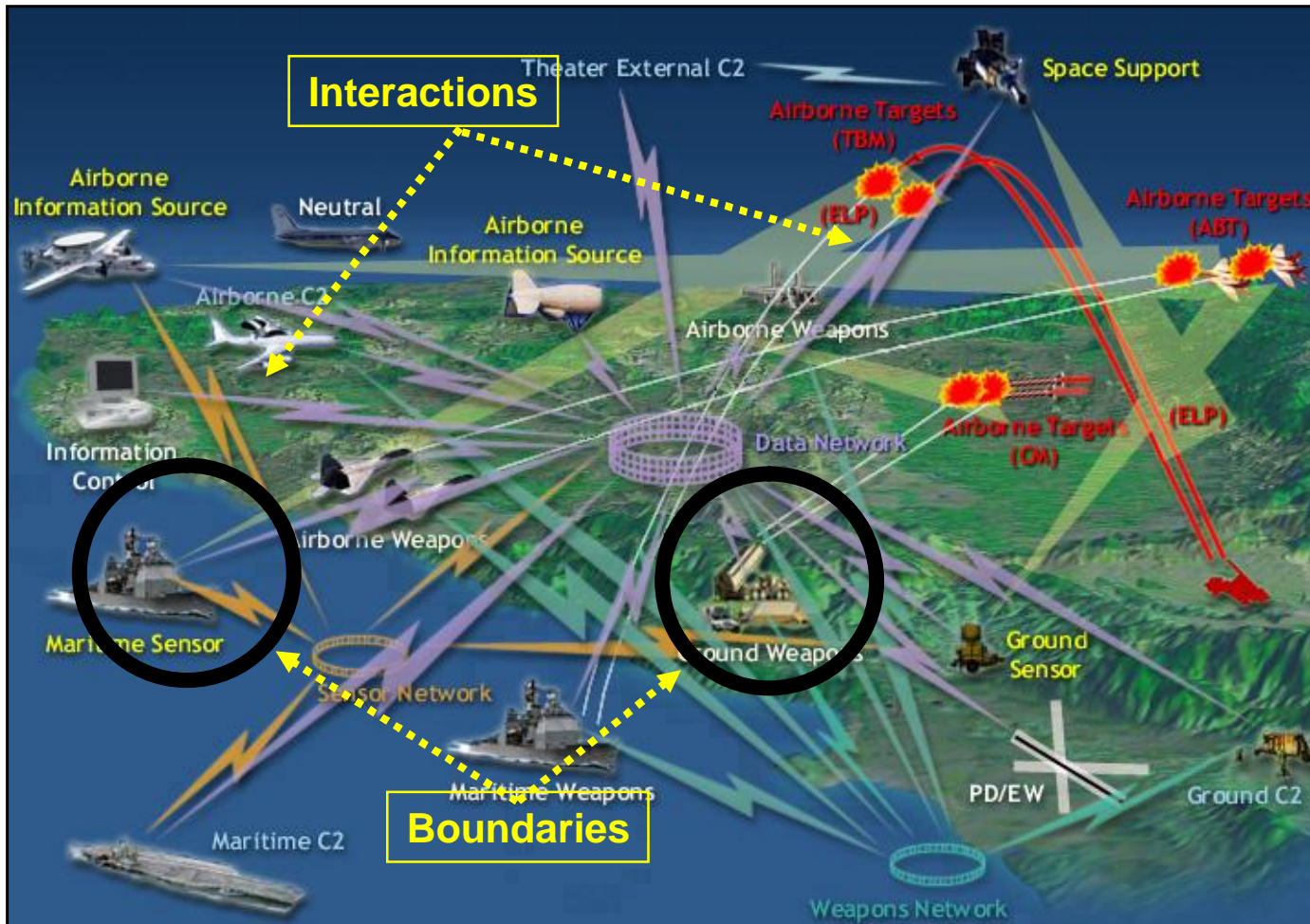


Moving from Document centric to Model centric

Model Based Engineering Benefits

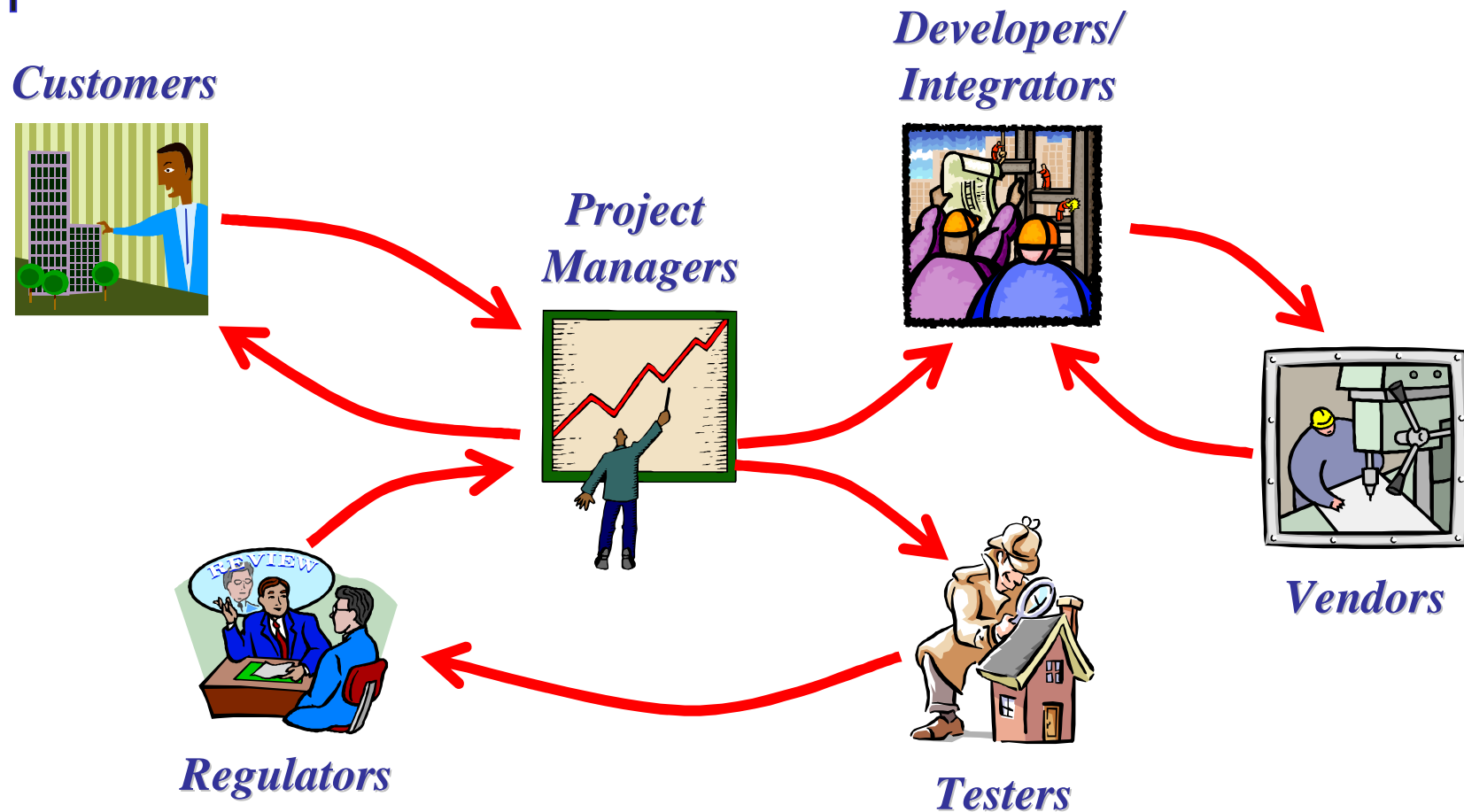
- n Improved communications
- n Improved design quality
 - n Reduced errors and ambiguity
 - n More complete representation
- n Reduced maintenance costs
- n Enhanced knowledge capture

System-of-Systems



Modeling Needed to Manage System Complexity

Stakeholders Involved in System Acquisition



Modeling Needed to Improve Communications

What is SysML?

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

SysML is Critical Enabler for Model Driven SE

UML/SysML Status

n UML V2.0

- n Updated version of UML that offers significant capability for systems engineering over previous versions
- n Finalized in 2005 (formal/05-07-04)

n UML for Systems Engineering (SE) RFP

- n Established the requirements for a system modeling language
- n Issued by the OMG in March 2003

n SysML

- n Industry Response to the UML for SE RFP
- n Addresses most of the requirements in the RFP
- n Current version 0.99 and expected to begin adoption in April '06
- n Being implemented by 5 vendors

SysML Merge Team (SMT)

n Industry & Government

- n American Systems, BAE SYSTEMS, Boeing, Deere & Company, EADS-Astrium, Eurostep, Lockheed Martin, Motorola, NIST, Northrop Grumman, oose.de, Raytheon, THALES

n Vendors

- n Artisan, EmbeddedPlus, Gentleware, IBM, I-Logix, Mentor Graphics, PivotPoint Technology, Sparx Systems, Telelogic, Vitech Corp

n Academia

- n Georgia Institute of Technology

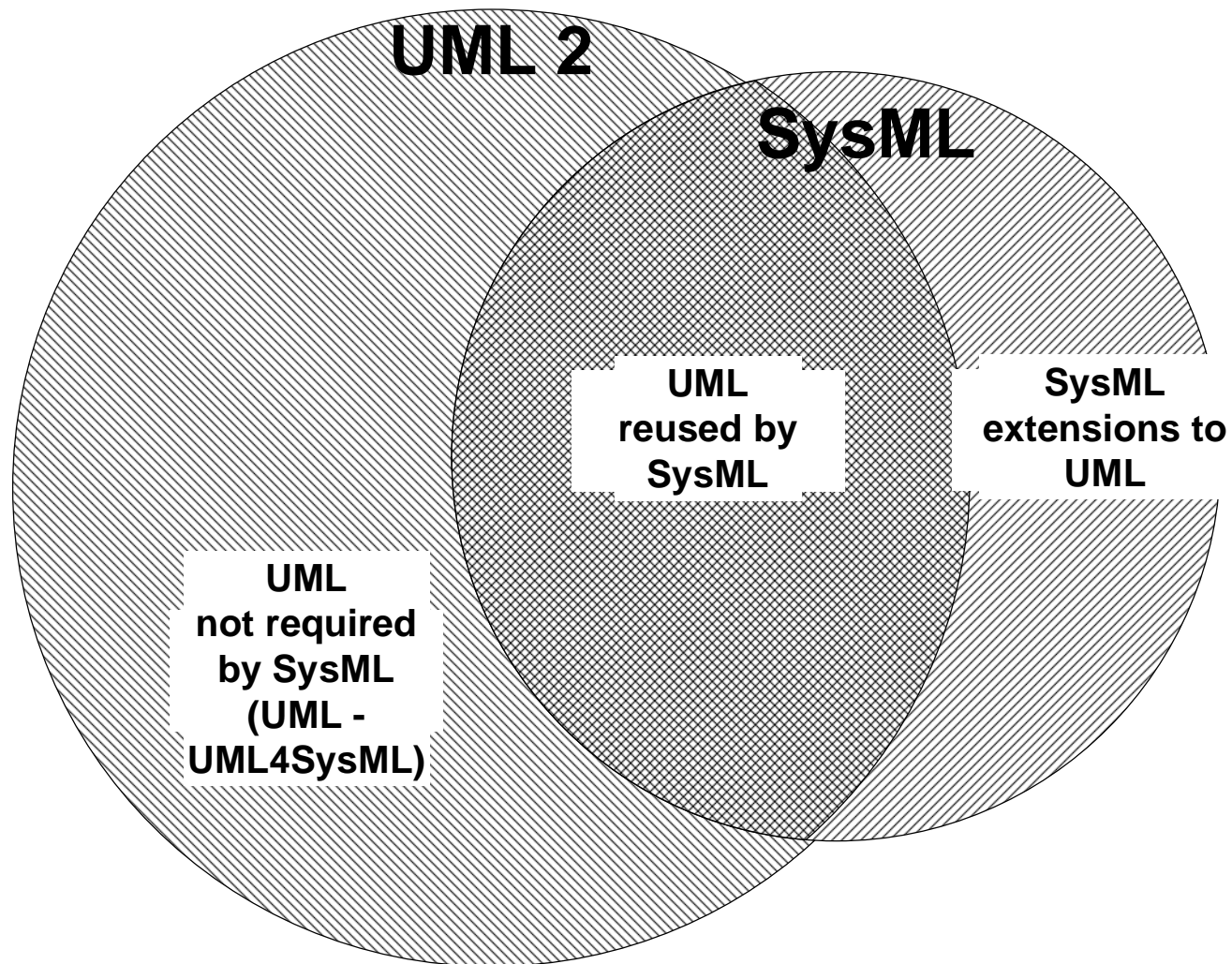
n Liaison Organizations

- n INCOSE, AP233 WG

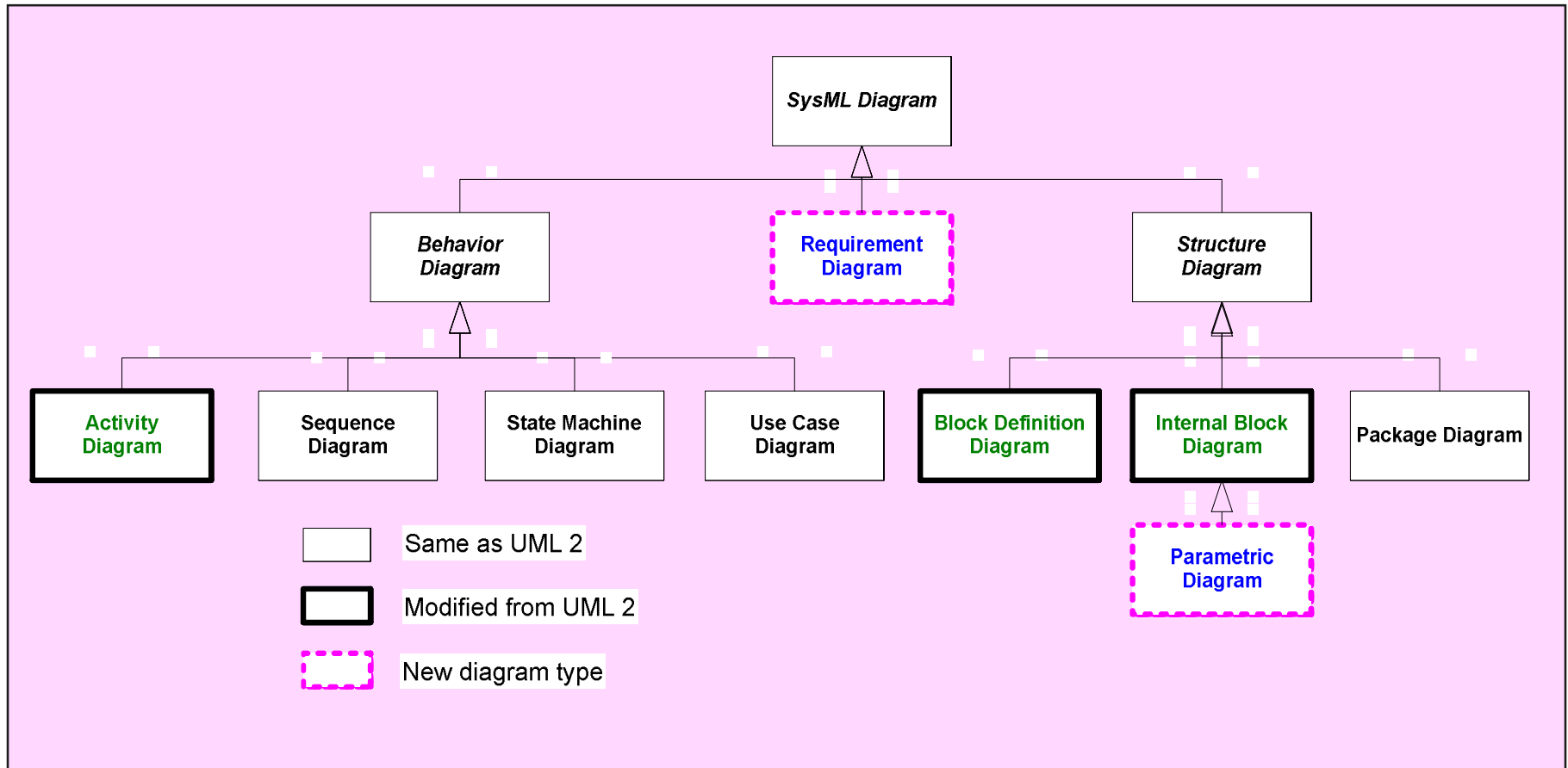
A decorative L-shaped line consisting of a vertical line segment on the left and a horizontal line segment extending to the right, both in black. The horizontal line is thicker than the vertical one.

Diagram Overview

Relationship Between SysML and UML

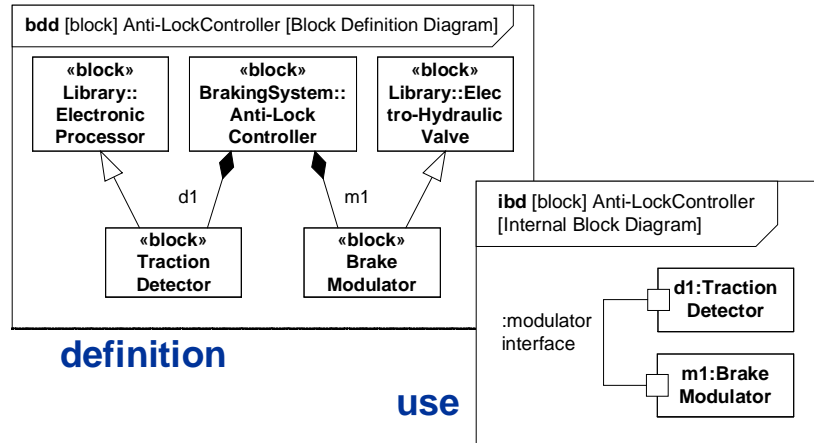


SysML Diagram Taxonomy



4 Pillars of SysML – ABS Example

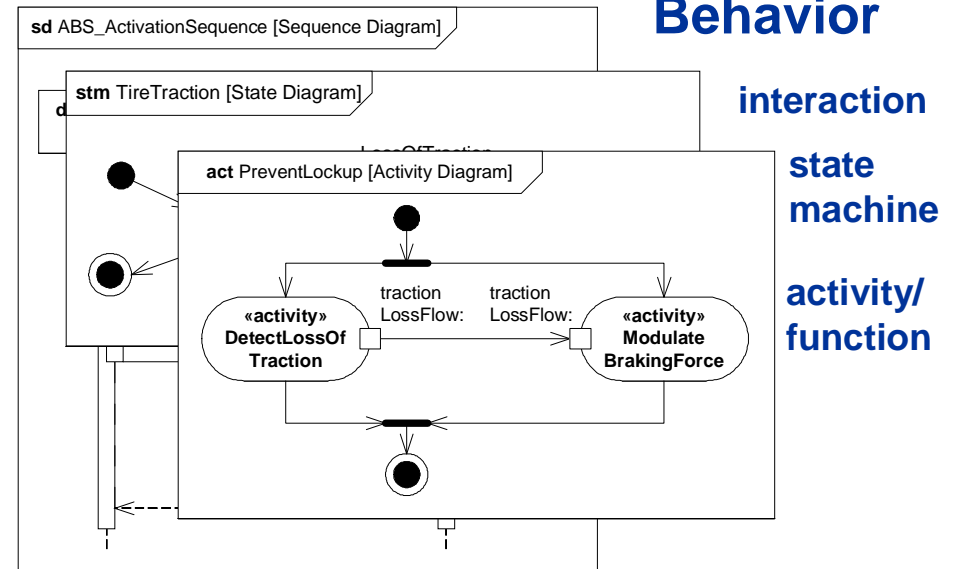
Structure



definition

use

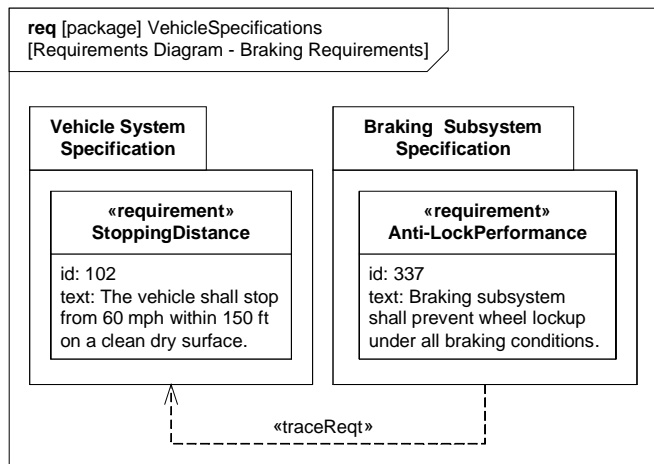
Behavior



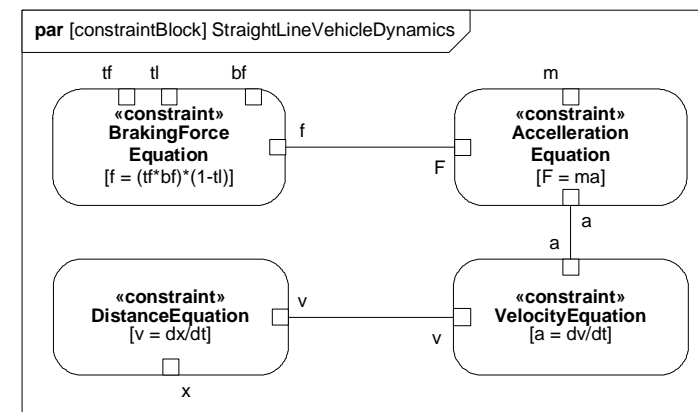
interaction

state machine

activity/function



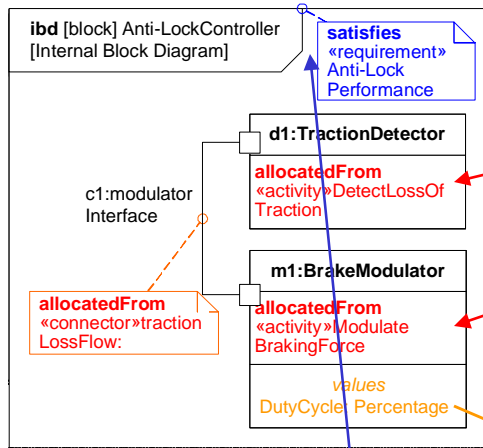
Requirements



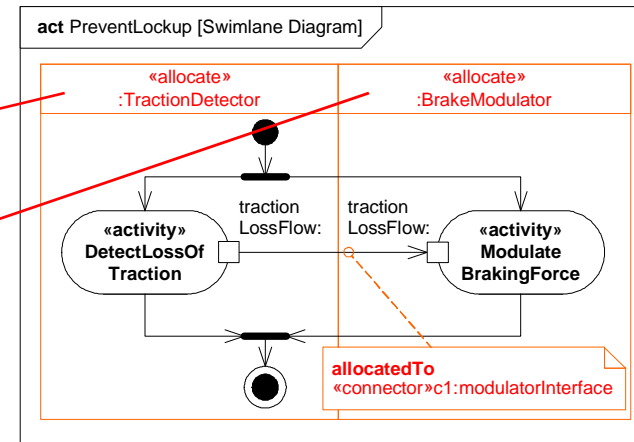
Parametrics

Cross Connecting Model Elements

Structure



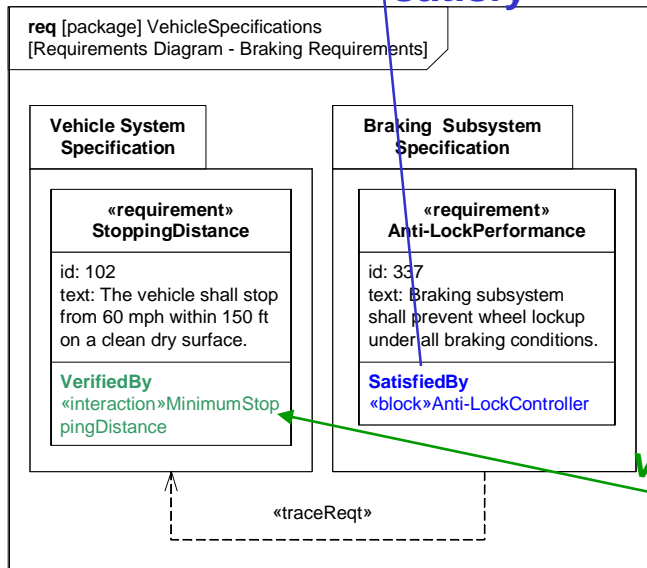
Behavior



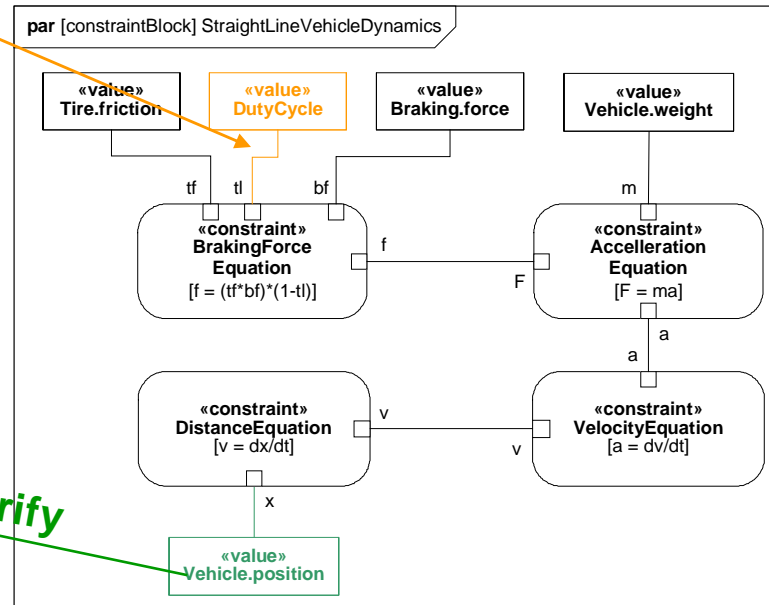
allocation

value binding

satisfy



verify

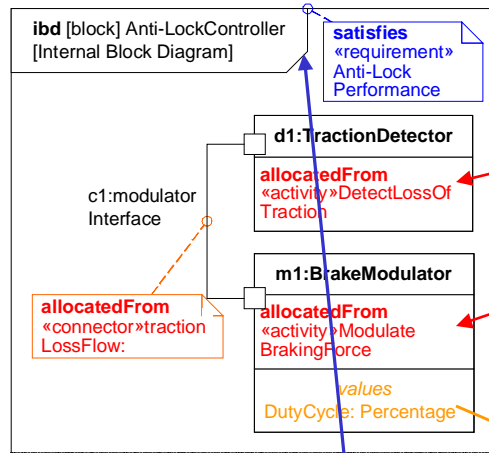


Requirements

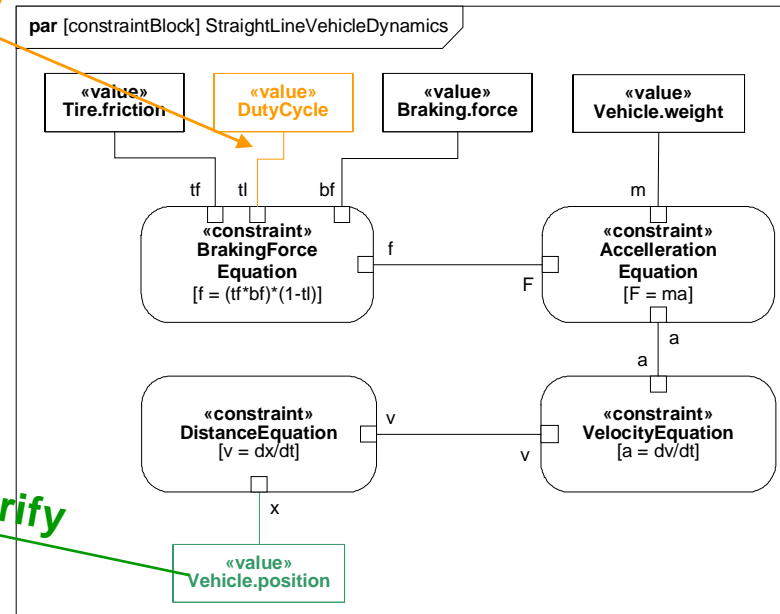
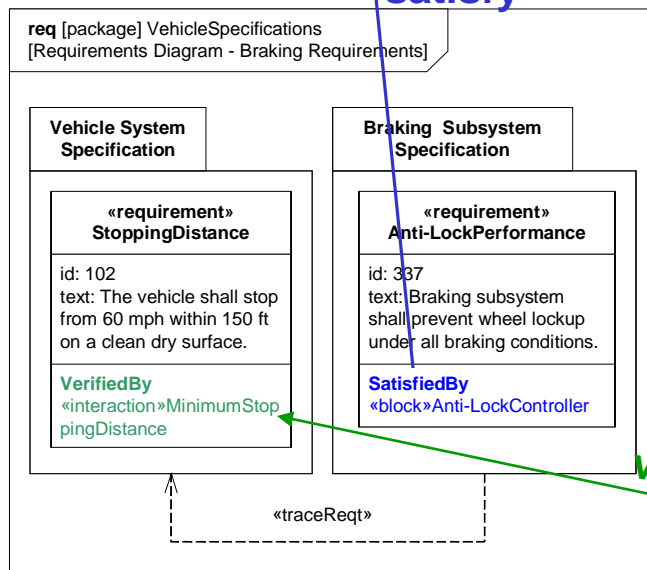
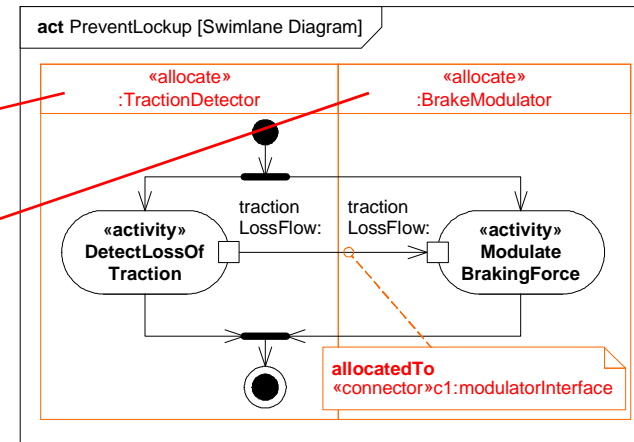
Parametrics

Cross Connecting Model Elements

Structure



Behavior



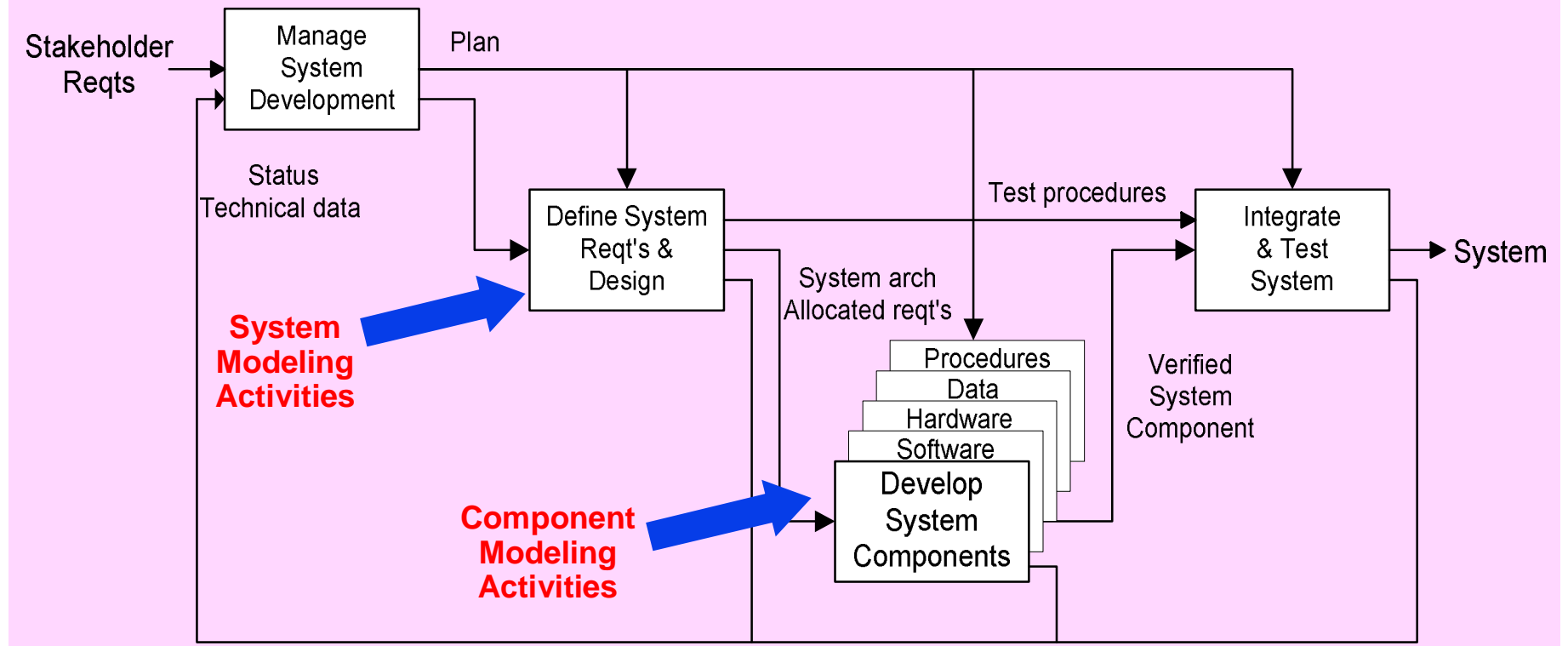
Requirements

Parametrics

SysML Modeling as Part of the SE Process



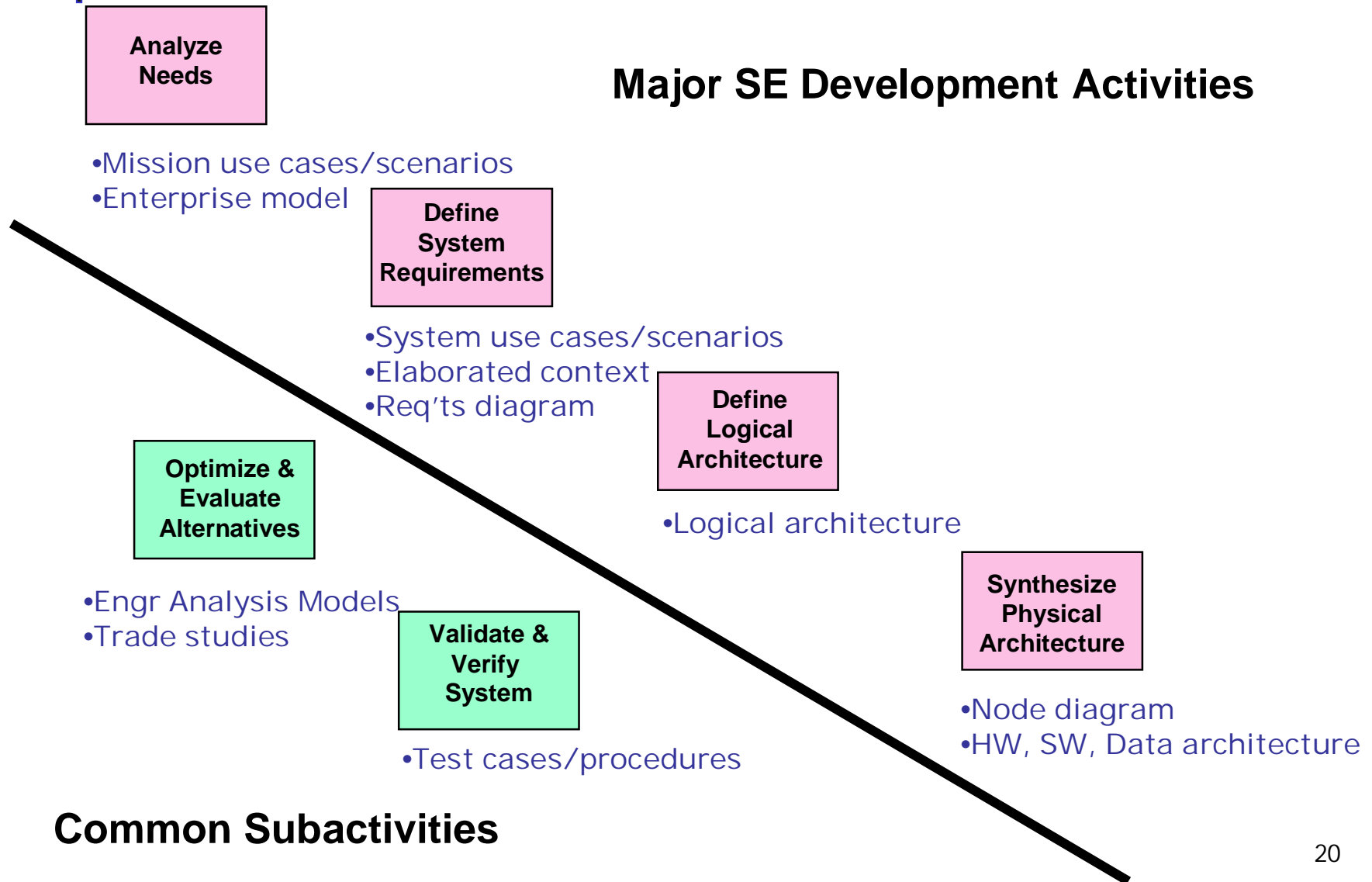
System Development Process



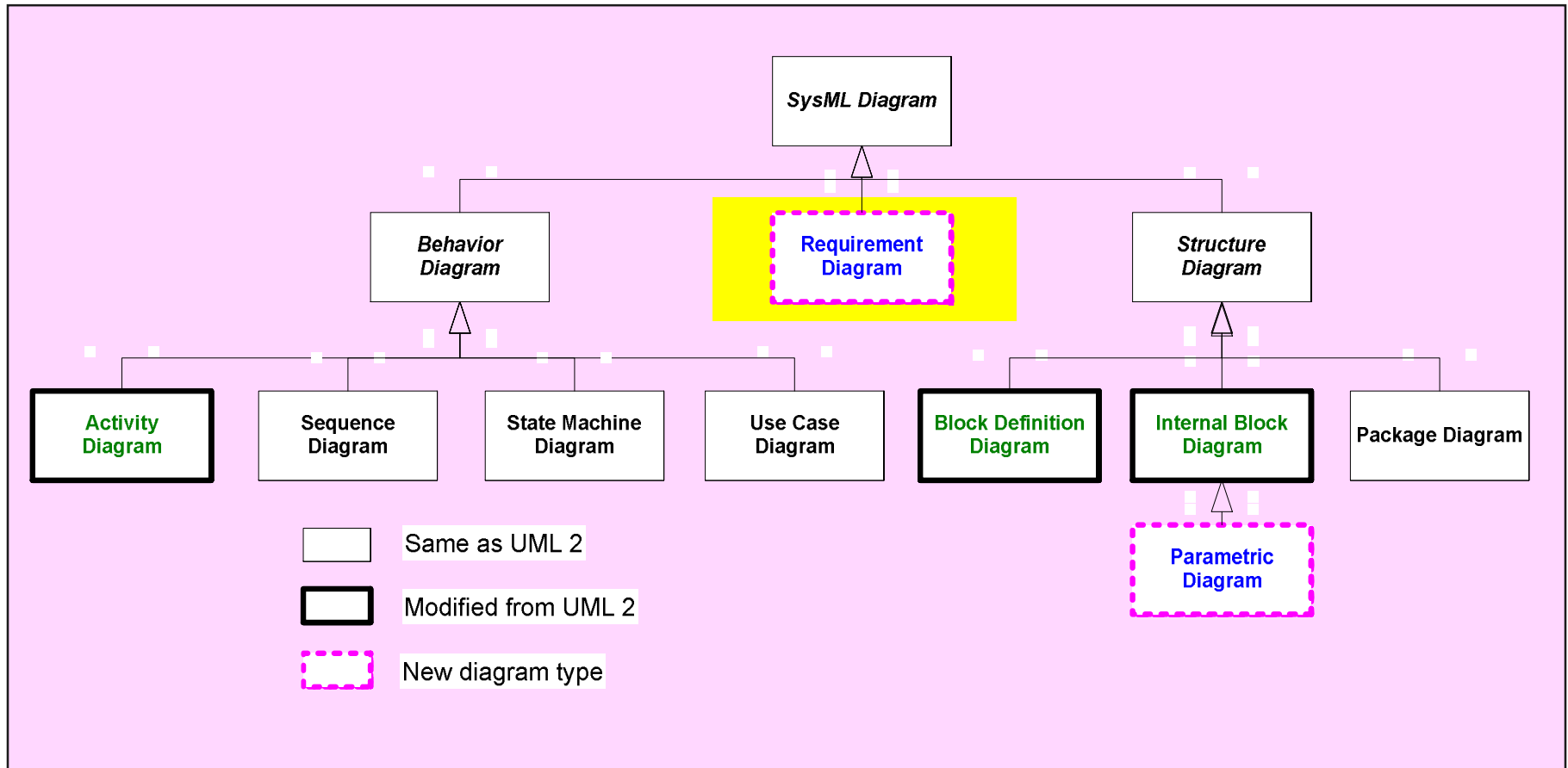
Integrated Product Development (IPD) is essential to improve communications

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

Typical Systems Modeling Activities



SysML Diagram Taxonomy



Capturing Requirements in the Model

**Artisan
Tool**

The screenshot displays the Artisan Real-time Studio interface for a SysML model. The main diagram area shows a requirement hierarchy for 'DerivedSpeedControl'. At the top is the requirement 'Speed & Acceleration' (id# = SOW 23). Below it is 'FR-17' (id# = FR-17), which is derived from 'Potentiometer Design' (id# = D-101) and 'Pedal Design' (id# = D-112). A note attached to FR-17 states: 'The speed control shall be infinitely variable from zero to maximum speed.' The left sidebar shows a project tree with 'Control speed' expanded to show 'FR-17'. The bottom panels provide detailed information for the selected requirement.

Requirement Hierarchy:

- «requirement» {id# = SOW 23} Speed & Acceleration
 - «derive» «requirement» {id# = FR-17} FR-17
 - «derive» «requirement» {id# = D-101} Potentiometer Design
 - «derive» «requirement» {id# = D-112} Pedal Design

General Custom Options Style Items requirement

Tag Definition Name	Tag Value
id#	FR-17
txt	The speed control shall be infinitely variable from zero to maximum
subRequirements	
satisfiedBy	Accelerator Pedal,Cruise Control
derivedRequirements	Potentiometer Design,Pedal Design
sourceRequirements	Speed & Acceleration

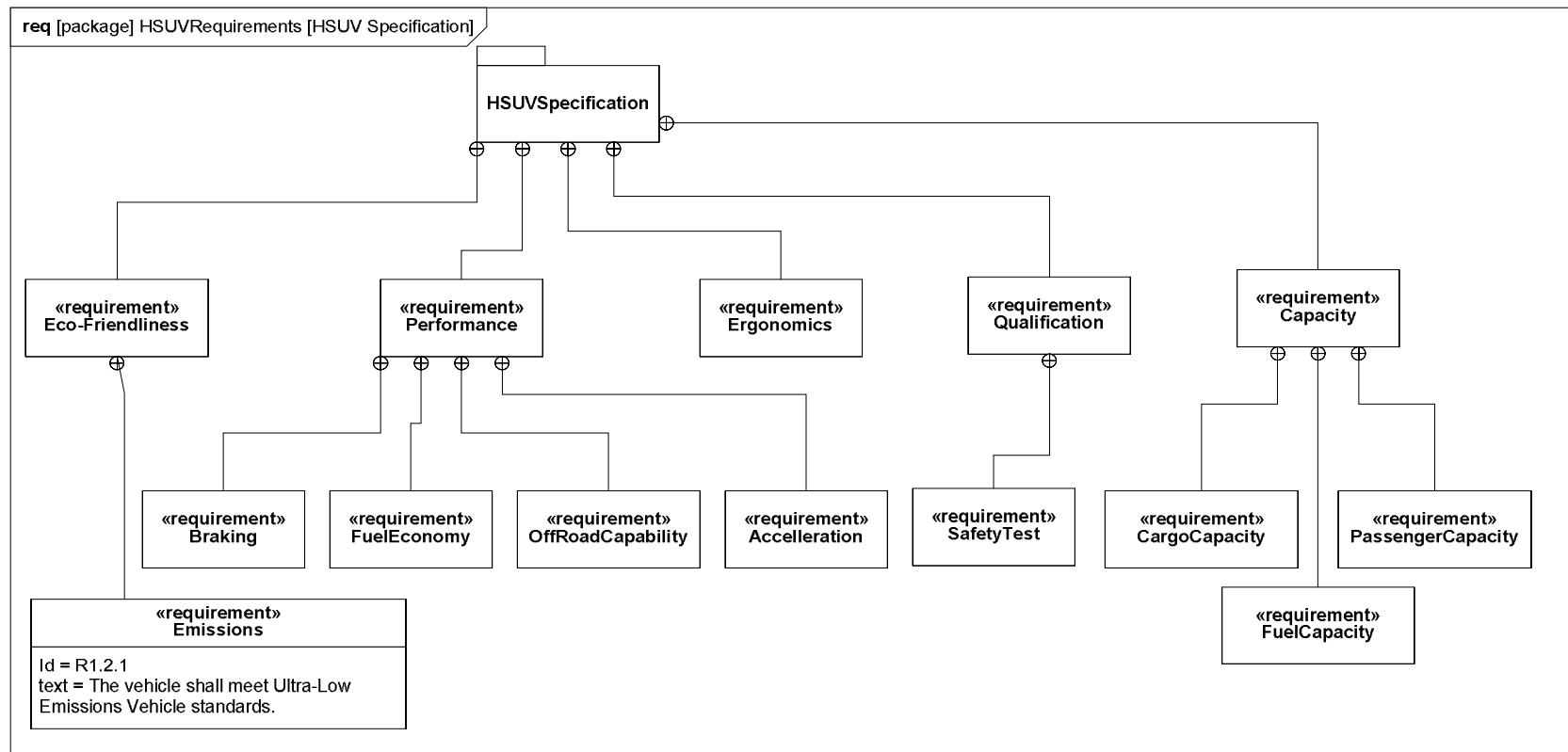
Profile Contents of

Name	id#	txt
«requirement» Pedal Design	D-112	The pedal design must support smoo...
«requirement» Potentiometer Design	D-101	Must use analogue potentiometer

Contents Results Results 2 Output

For Help, press F1

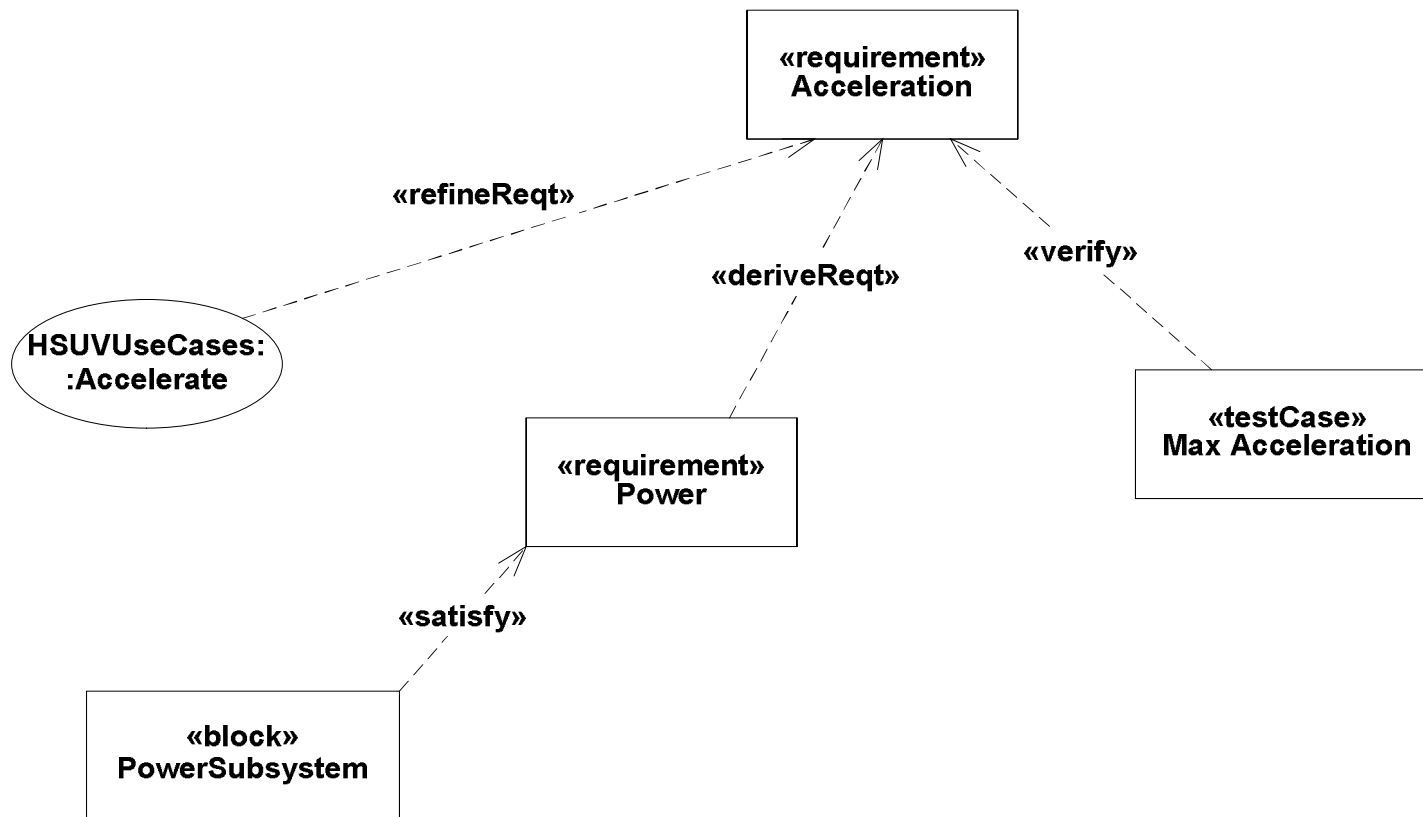
Requirements Breakdown



Containment Used to Model the Content of a Specification

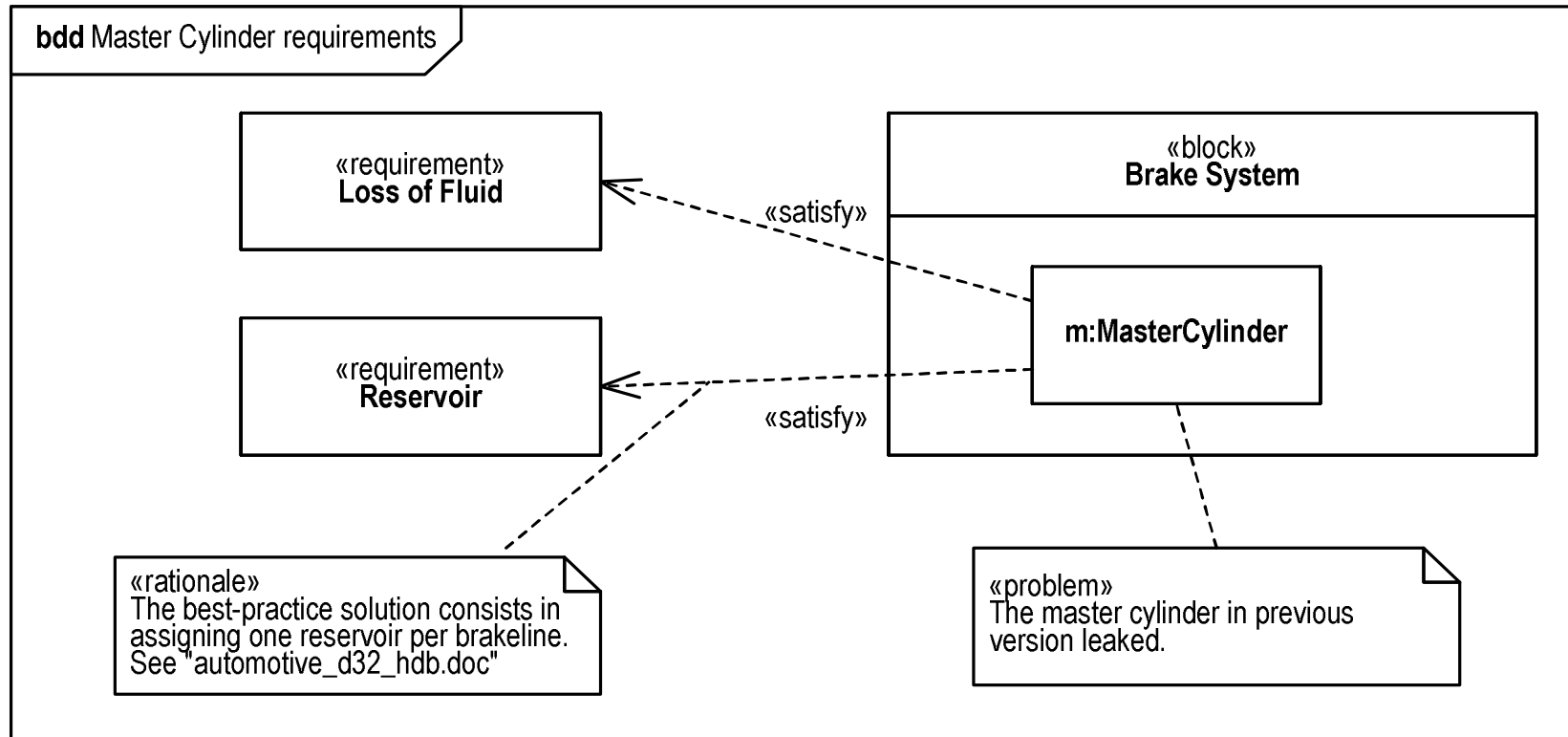
Requirements Relationships

req [package] HSUVRequirements [Acceleration Requirement Refinement and Verification]



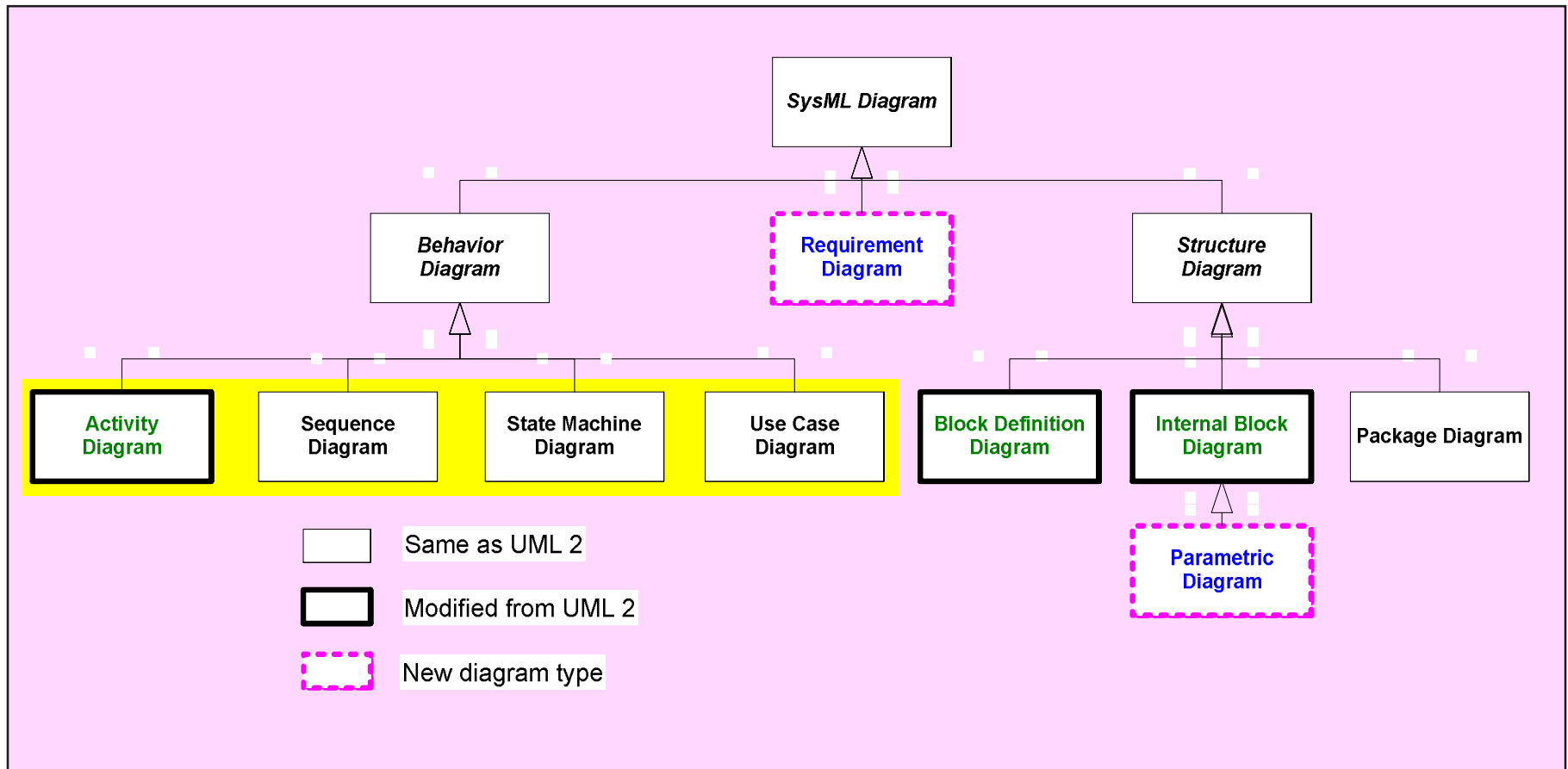
Use of Derive, Satisfy, Verify, & Refine Relationships

Problem and Rationale

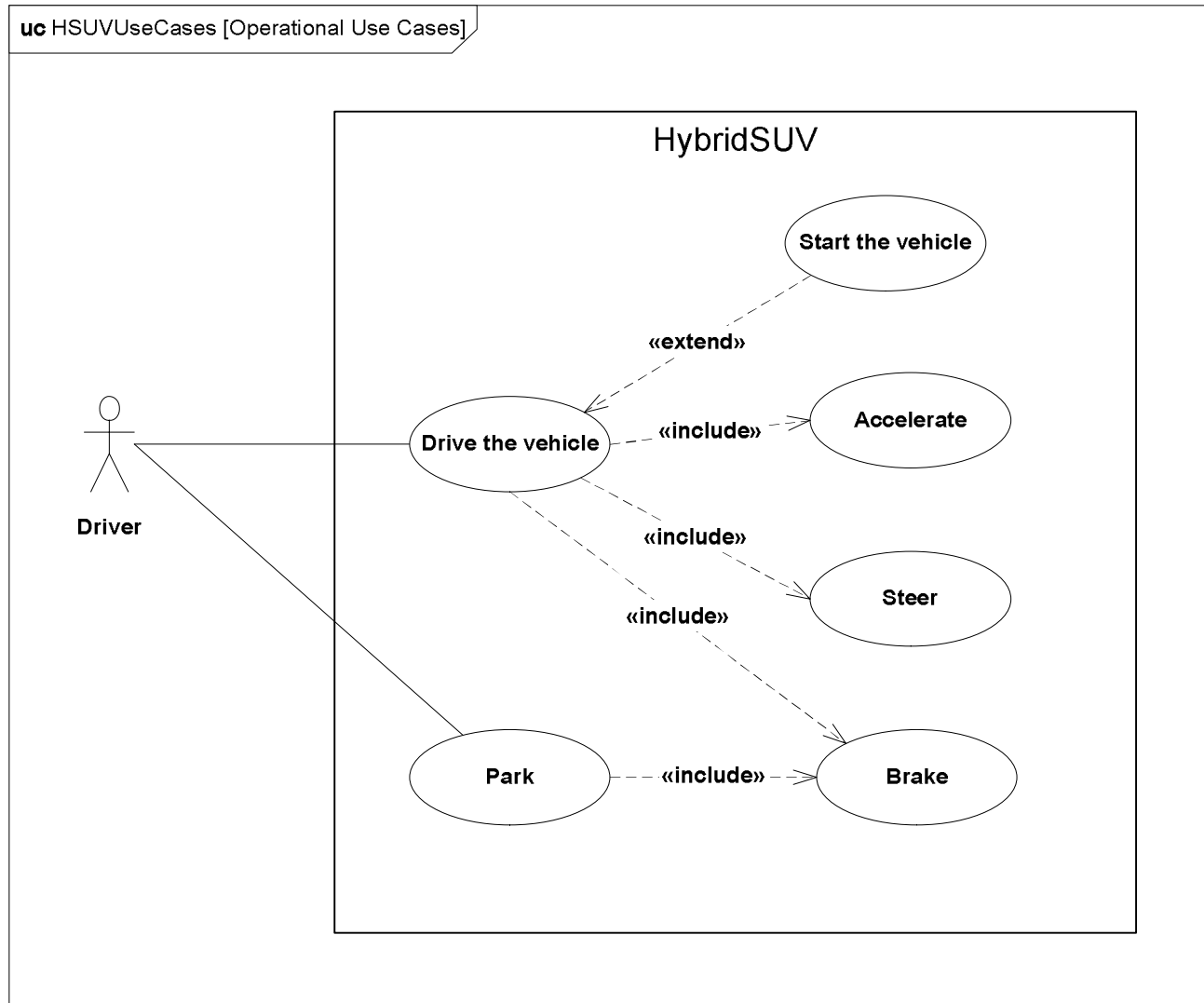


Problem and Rationale can be attached to any Model Element to Capture Issues and Decisions

SysML Diagram Taxonomy



Operational Use Cases

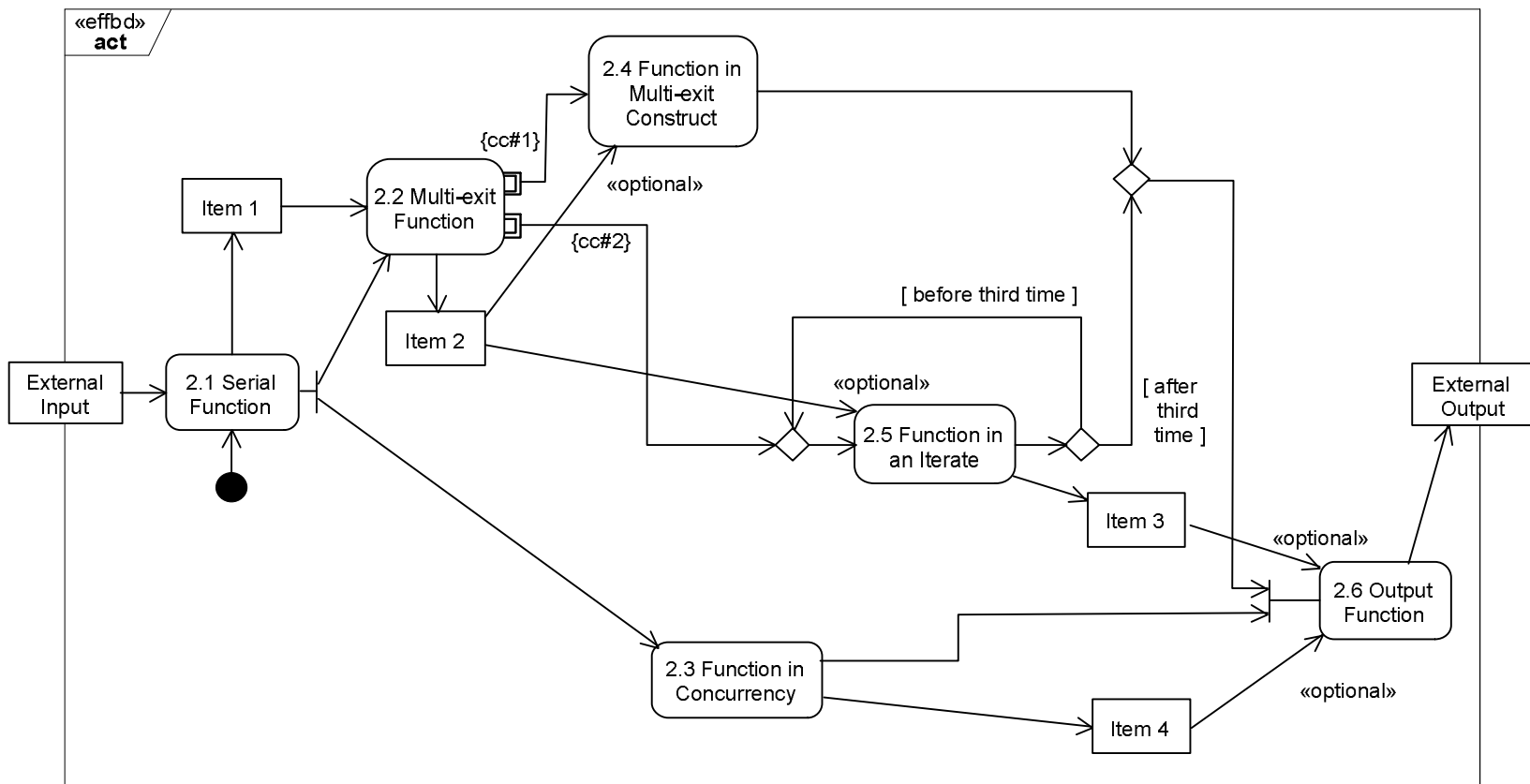


Activities

- n Activities used to specify flow of I/O and control
- n SysML extensions to Activities
 - n Support for continuous flow modeling
 - n Alignment of activities with Enhanced Functional Flow Block Diagram

SysML EFFBD Profile

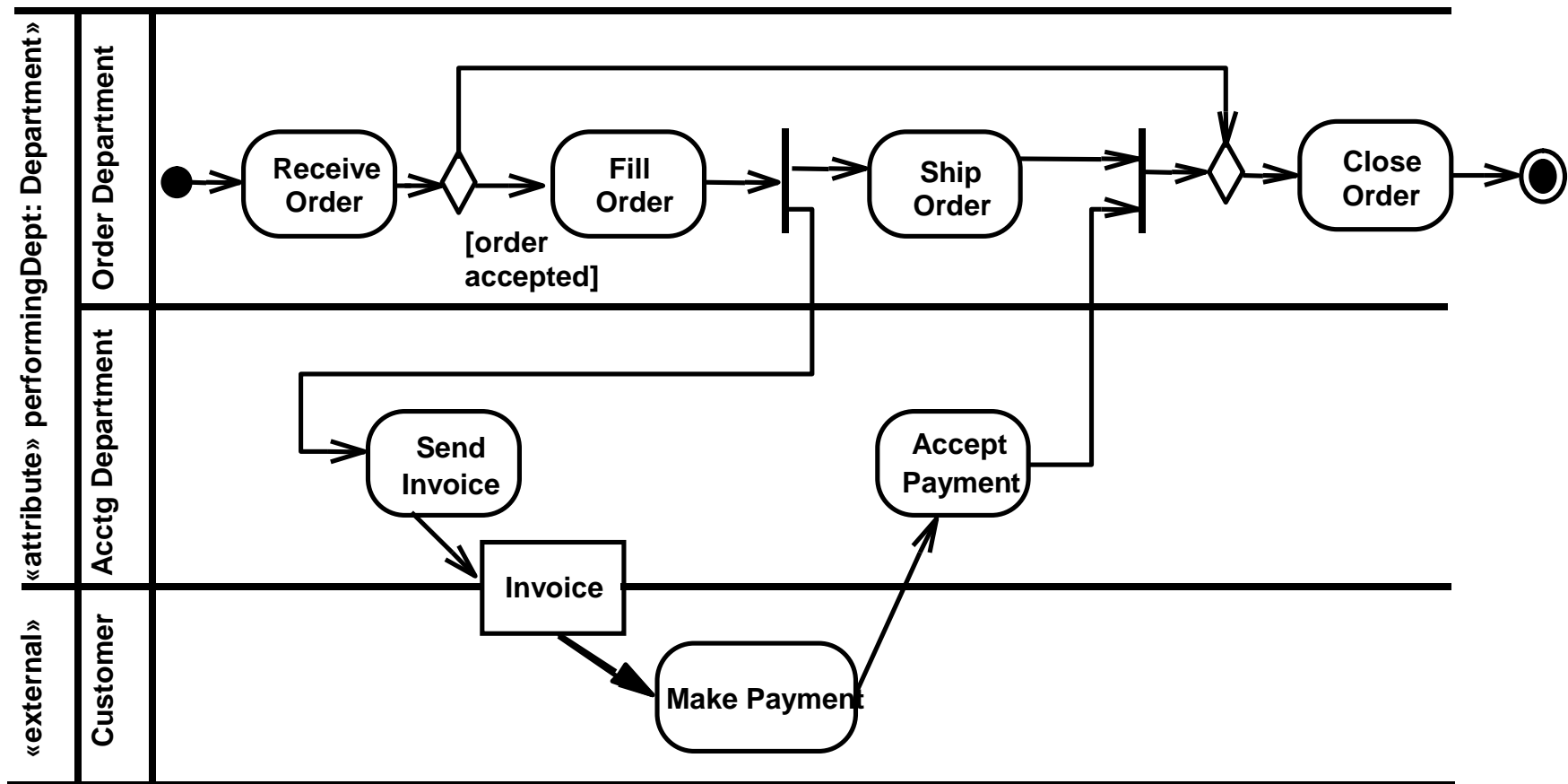
EFFBD - Enhanced Functional Flow Block Diagram



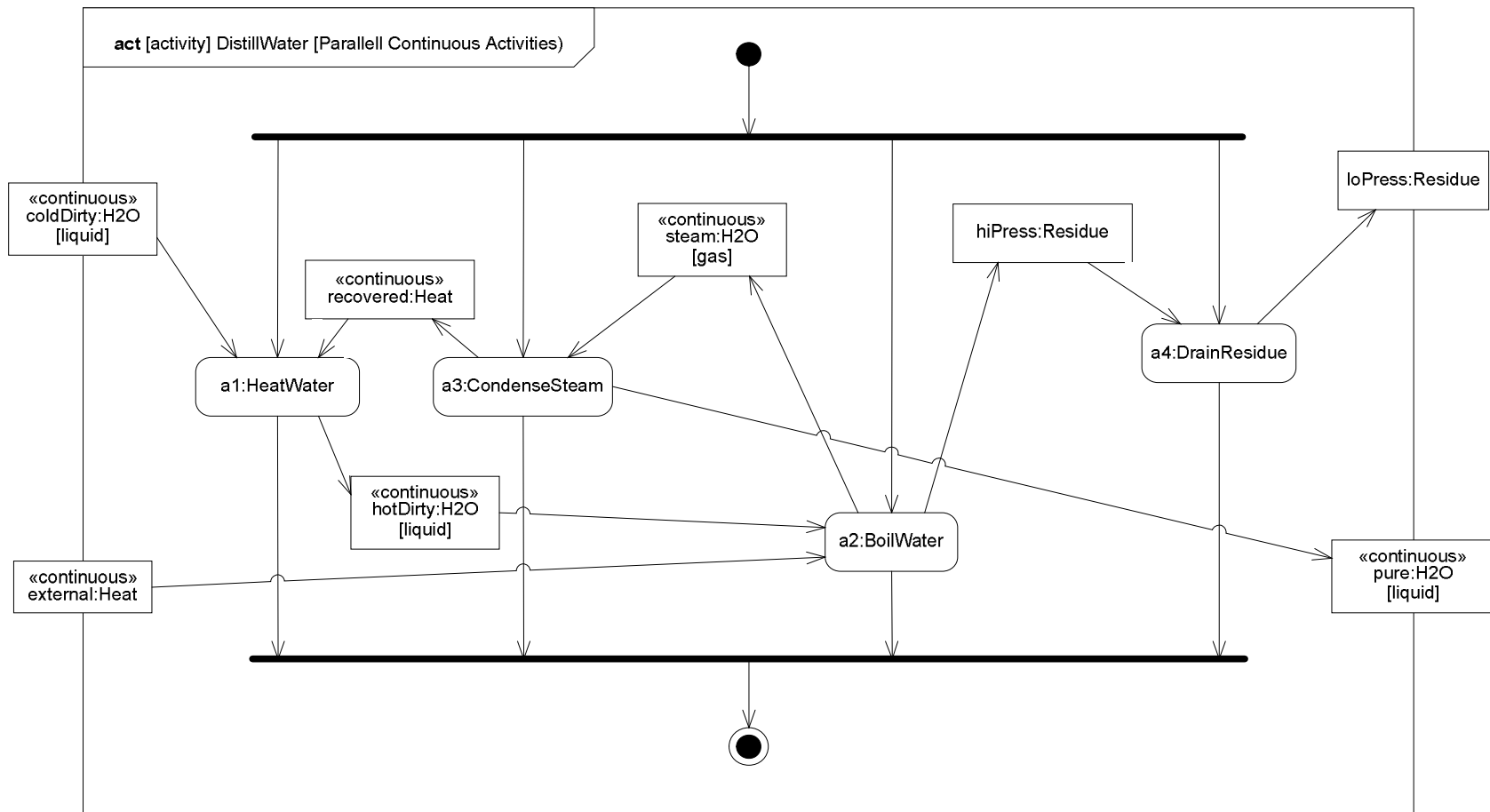
Aligning SysML with Classical Systems Engineering Techniques

Activity Modeling with Swimlanes

n allocation of parts via swim lanes



Distill Water Activity Diagram (Continuous Flow Modeling)

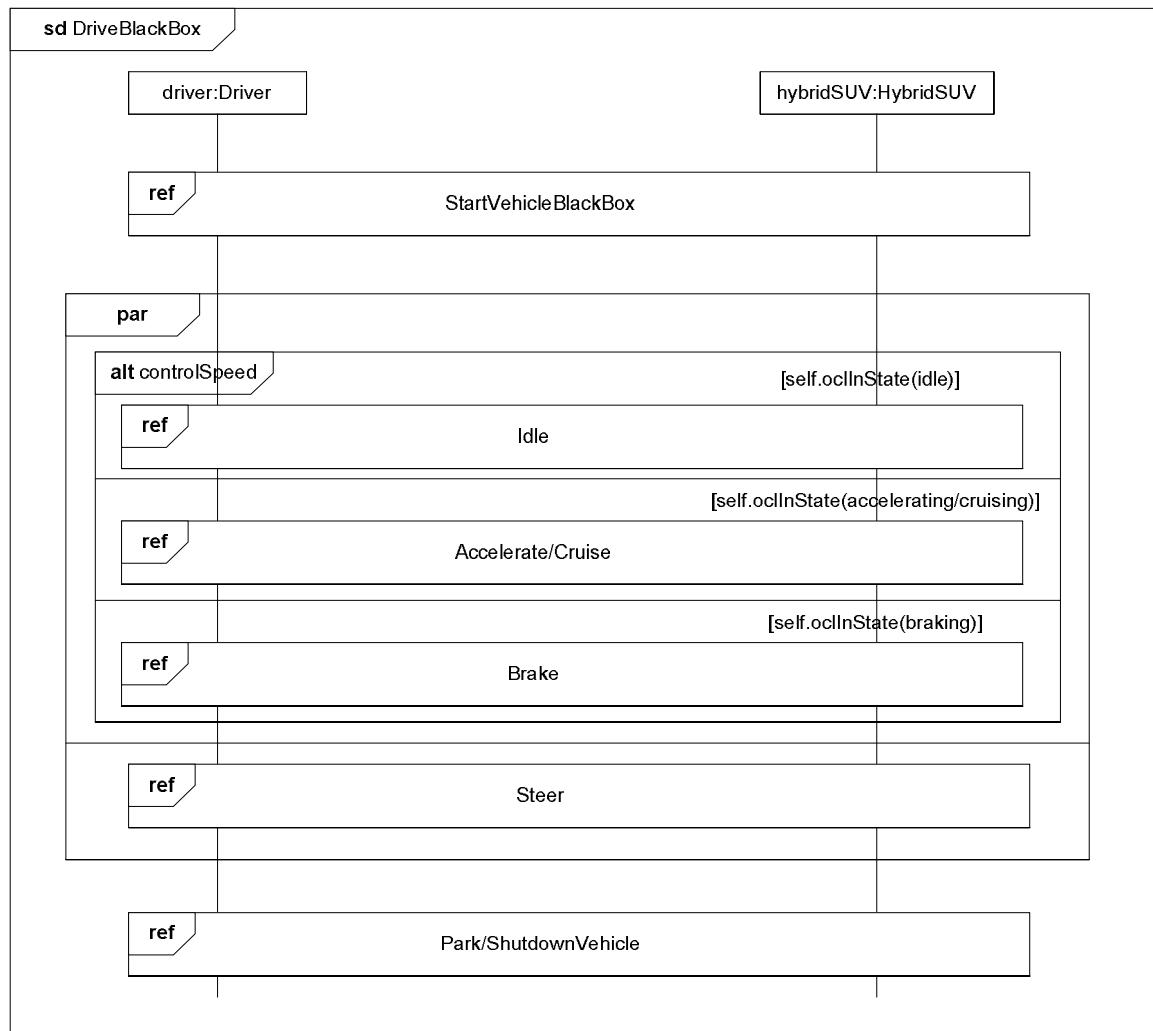


Representing Distiller Example in SysML
Using Continuous Flow Modeling

Interactions

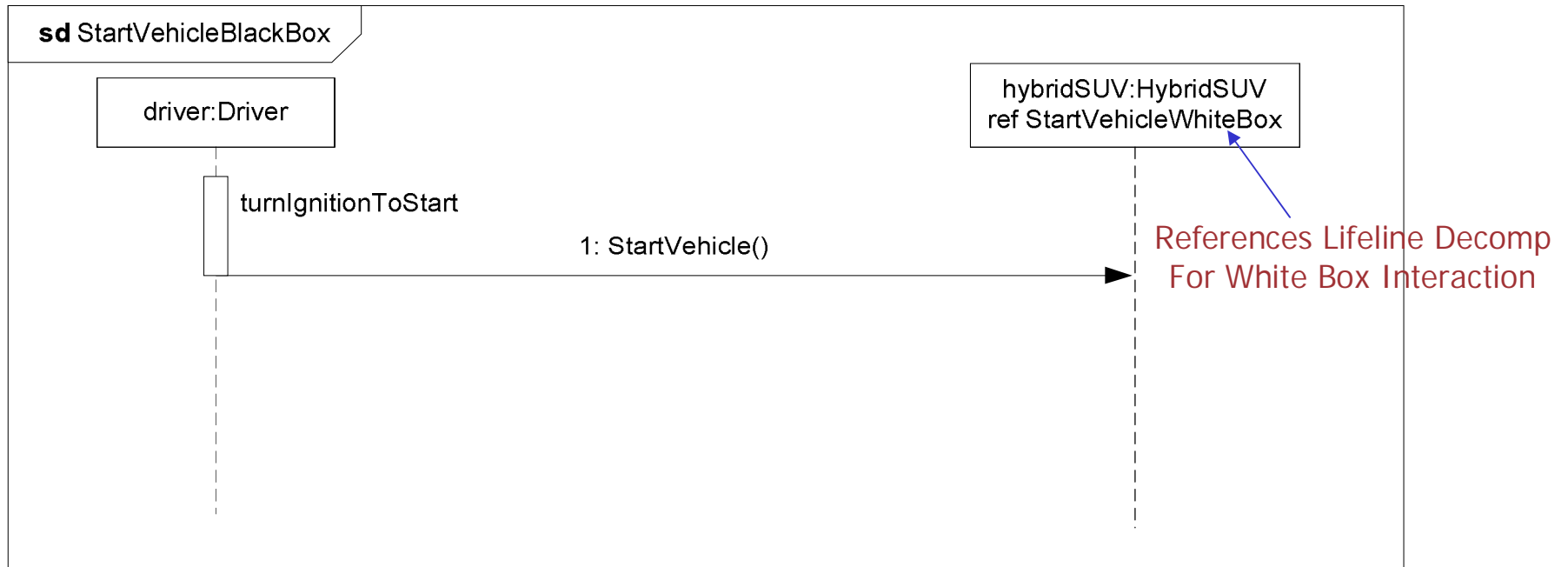
- n Sequence diagrams provide representation for message based behavior
 - n represents flow of control
- n Sequence diagrams provide key mechanisms for representing complex behavior
 - n reference sequences
 - n control logic
 - n lifeline decomposition

Black Box Interaction (Drive)



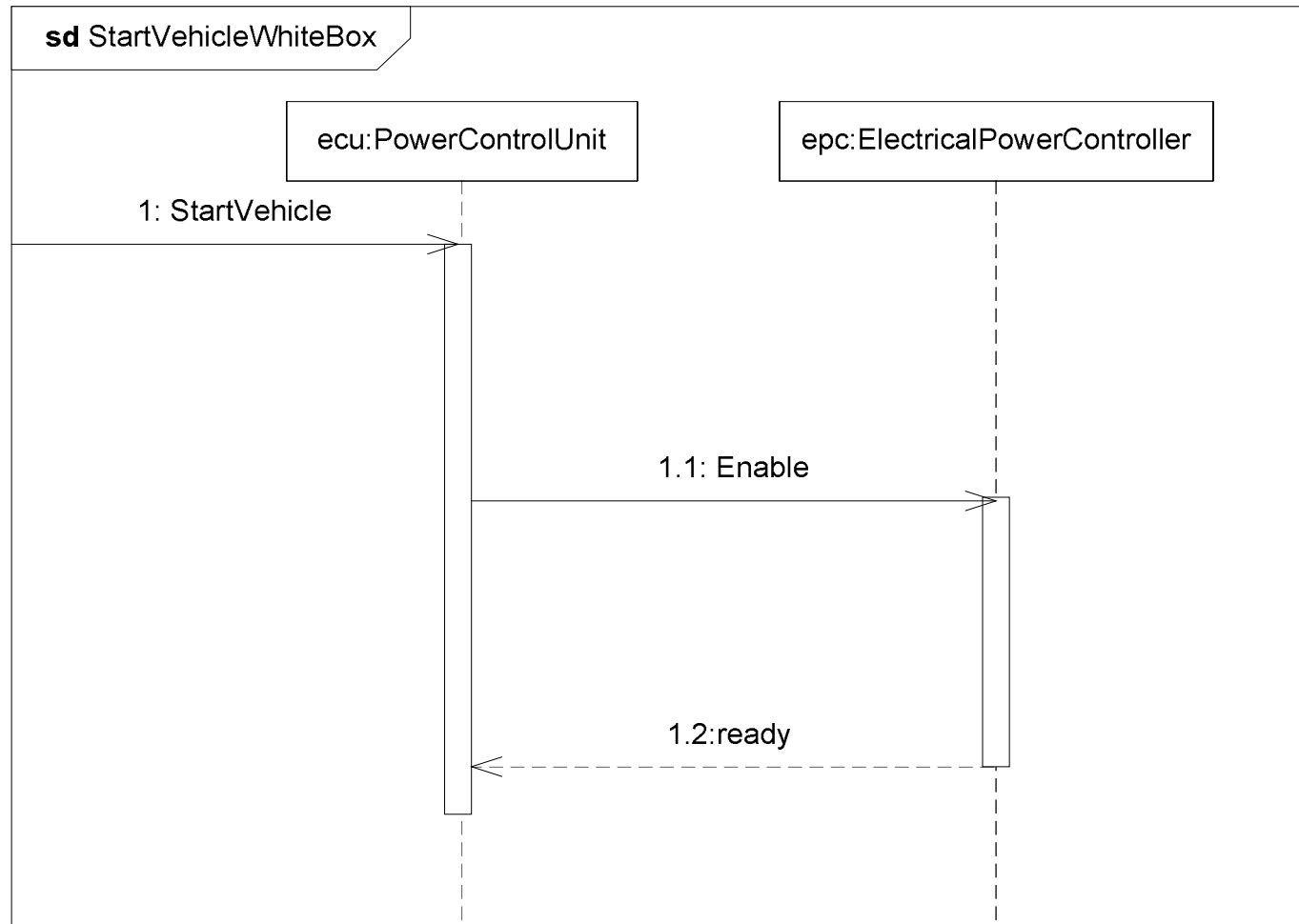
UML 2 Sequence Diagram More Scalable
by Supporting Control Logic and Reference Sequences

Black Box Sequence (StartVehicle)



Simple Black Box Interaction

White Box Sequence (StartVehicle)

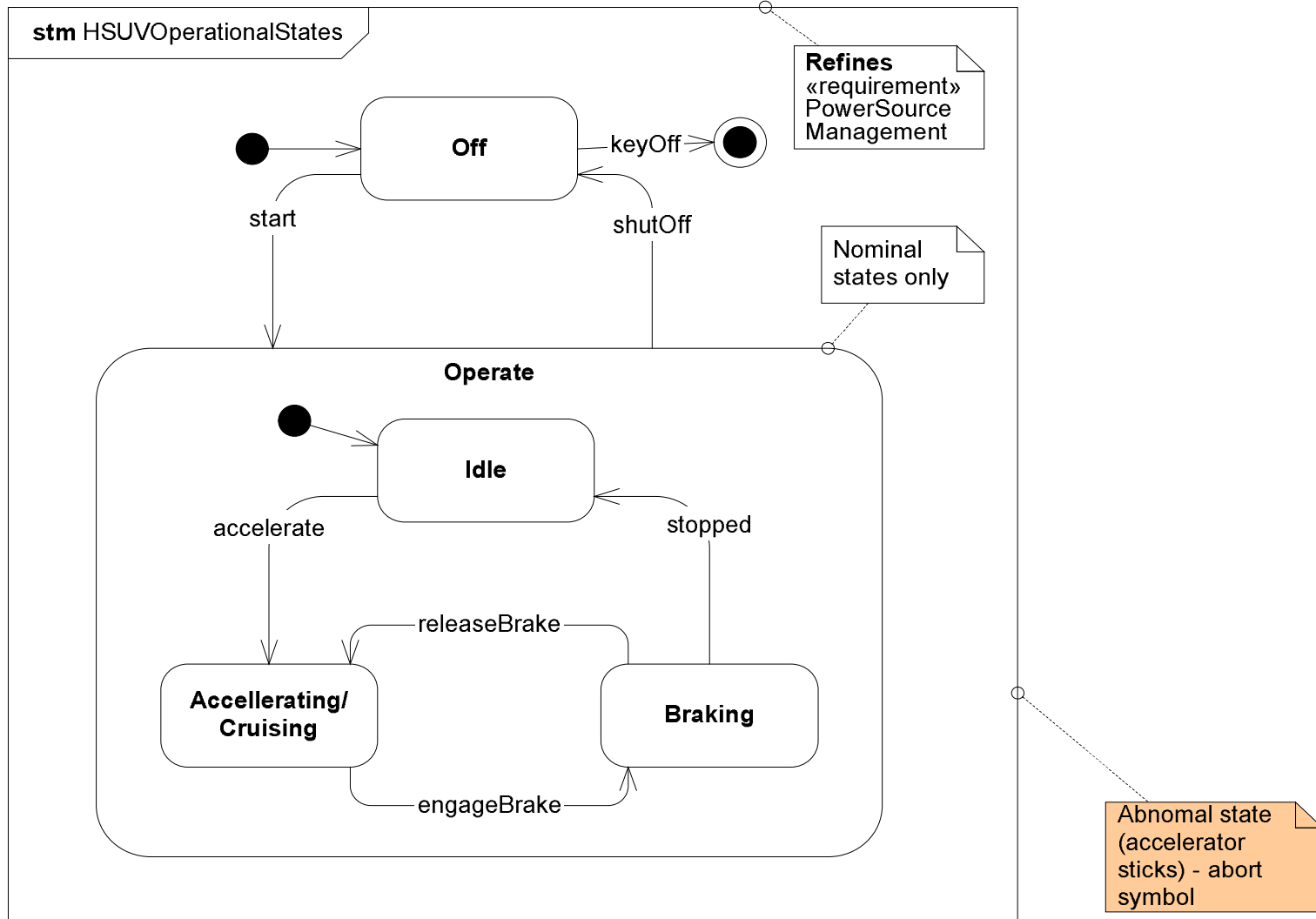


Decomposition of Black Box
Into White Box Interaction

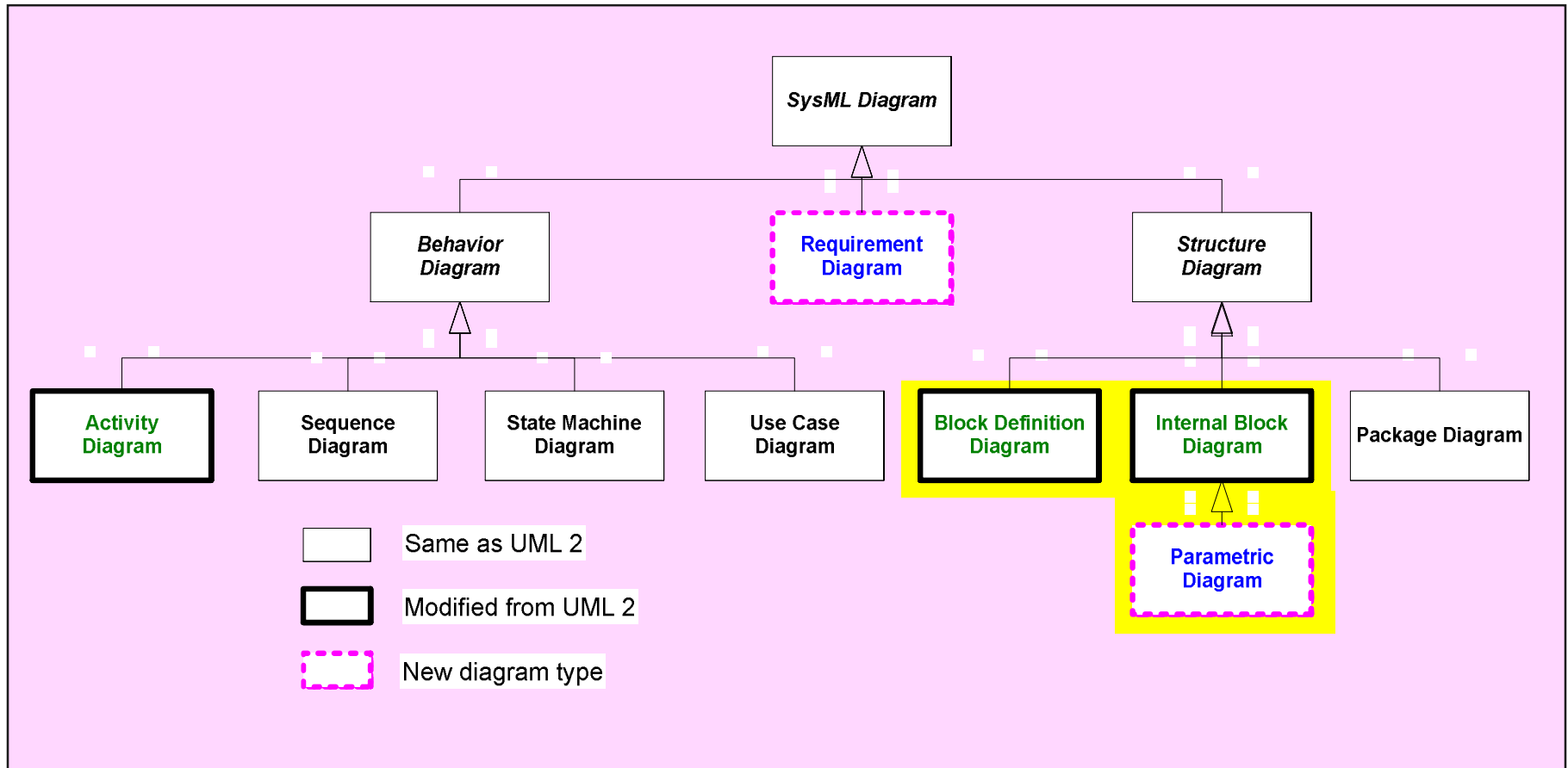
State Machines

- n Supports event based behavior (generally asynchronous)
 - n Transition with event, guard, action
 - n State with entry, exit and do-activity
 - n Can include nested sequential or concurrent states
 - n Can send/receive signals to communicate between blocks during state transitions, etc

Operational States (Drive)



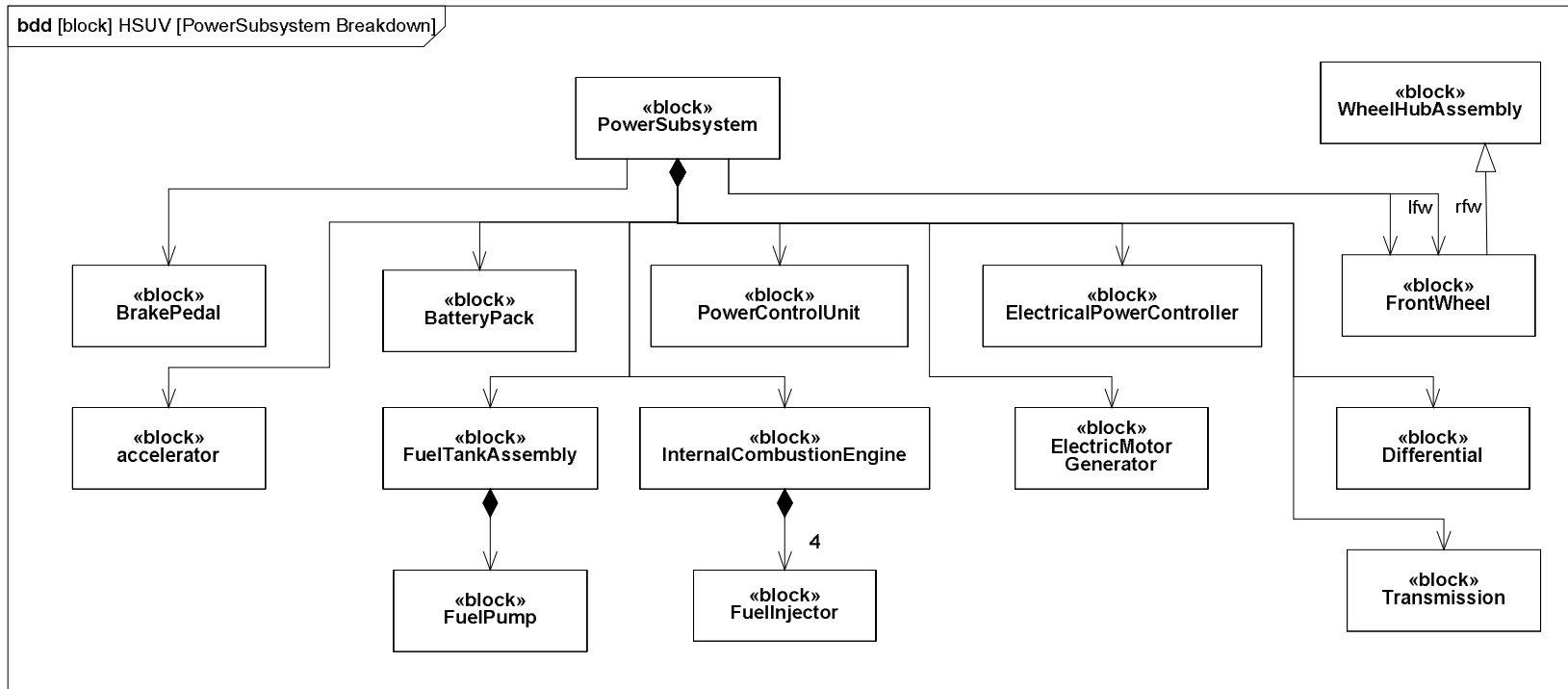
SysML Diagram Taxonomy



Blocks

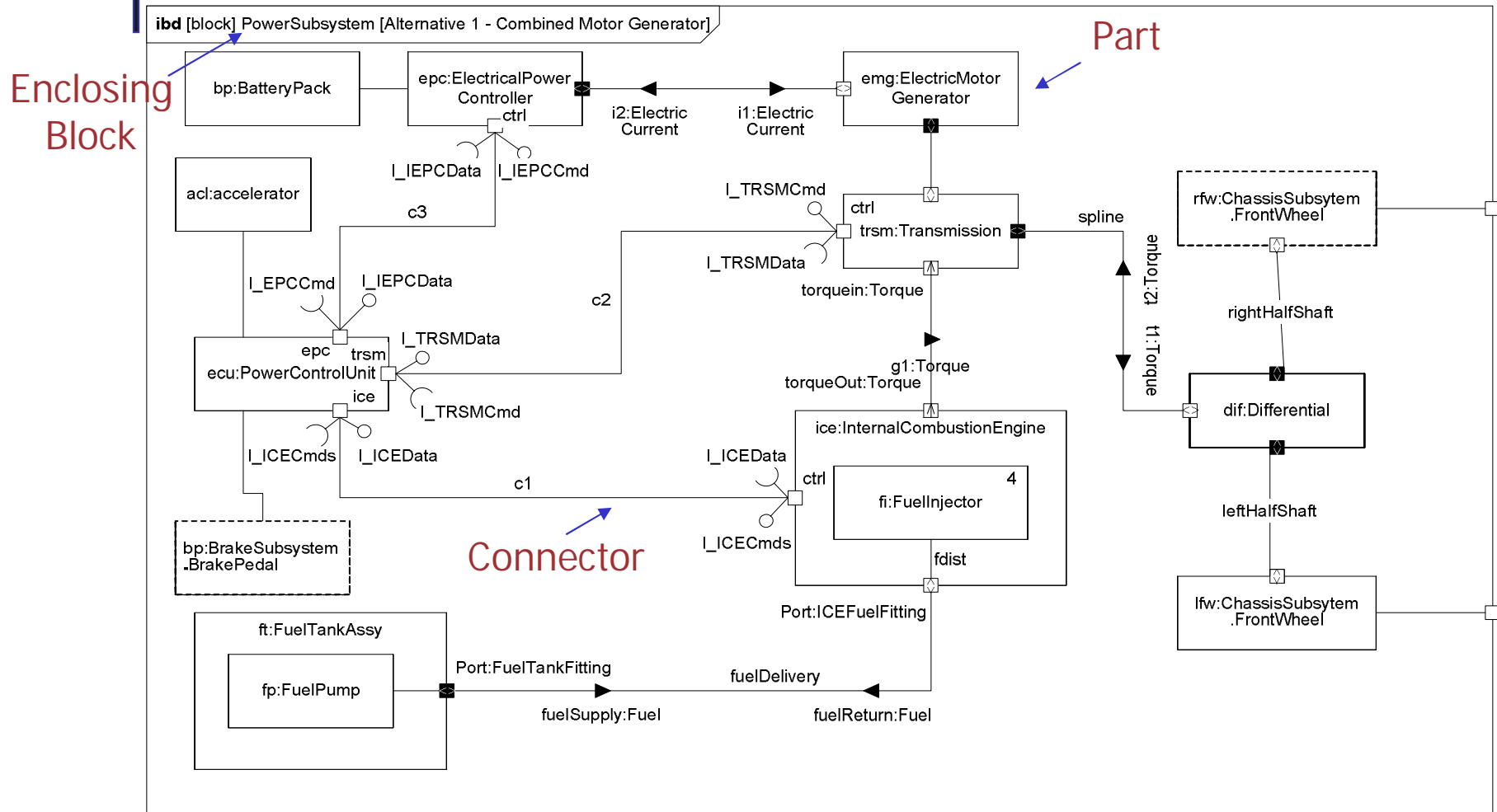
- n Used to express structure of system
 - n Backbone description of system hierarchy
 - n Either white- or black-box description
 - n Includes internal relationships and connectivity in addition to system decomposition

Power Subsystem Breakdown



Block Definition Diagram Used to Specify System Hierarchy and Classification

Power Subsystem IBD



Internal Block Diagram Used to Specify Interconnection Among Parts in Context of Enclosing Block

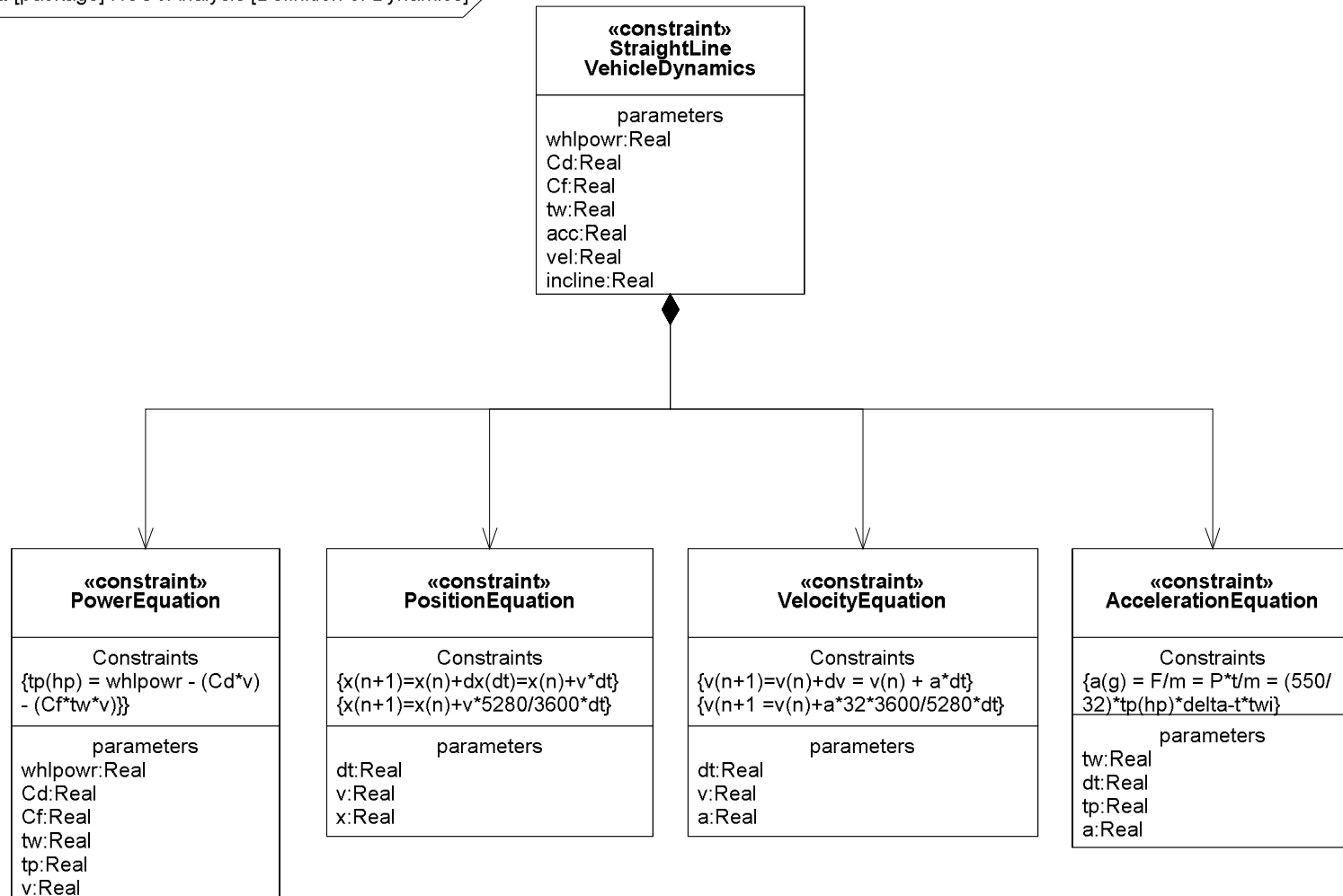
Parametrics

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

Parametrics Enable Integration of Engineering Analysis with Design Models

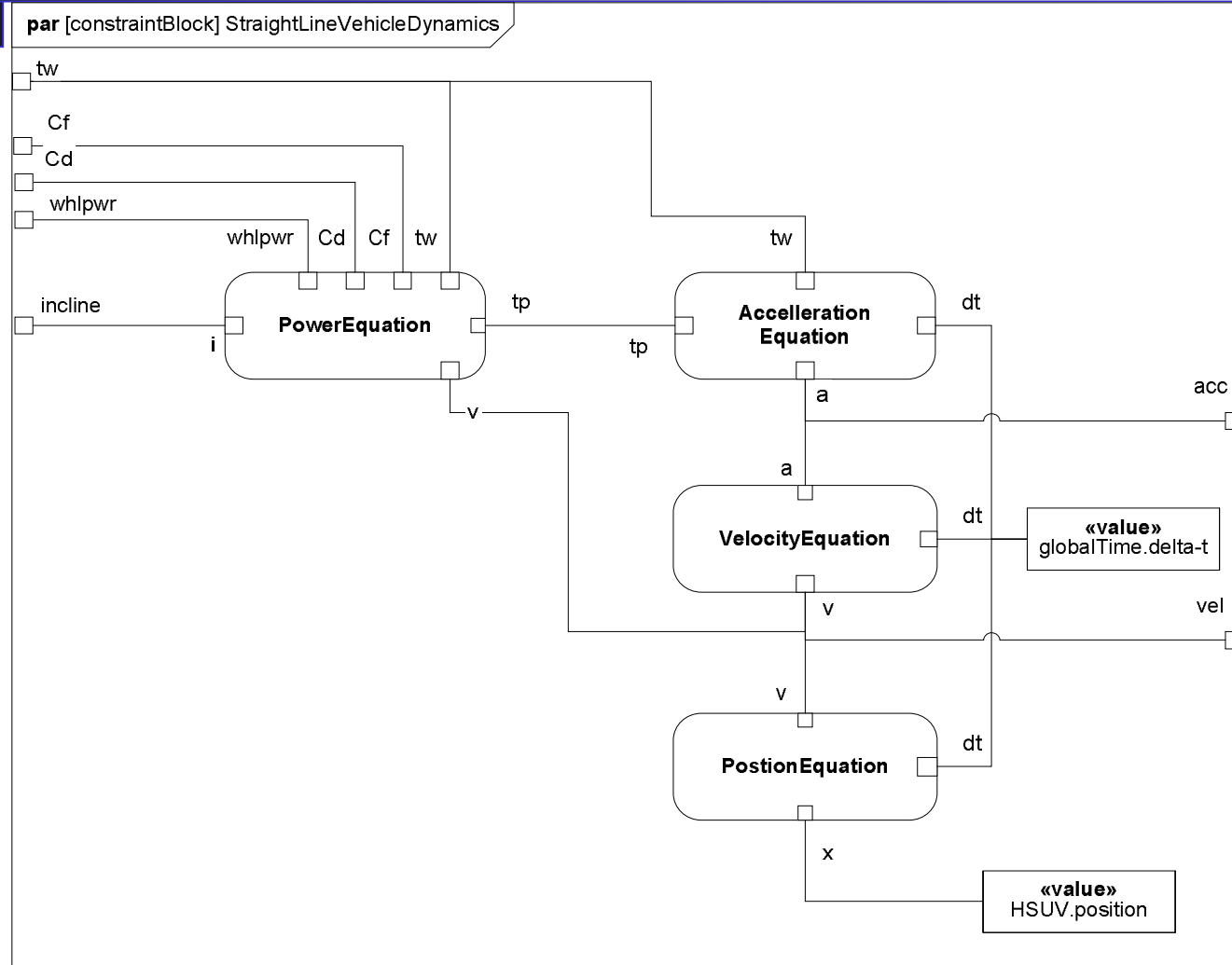
Defining Vehicle Dynamics

bdd [package] HSUVAnalysis [Definition of Dynamics]



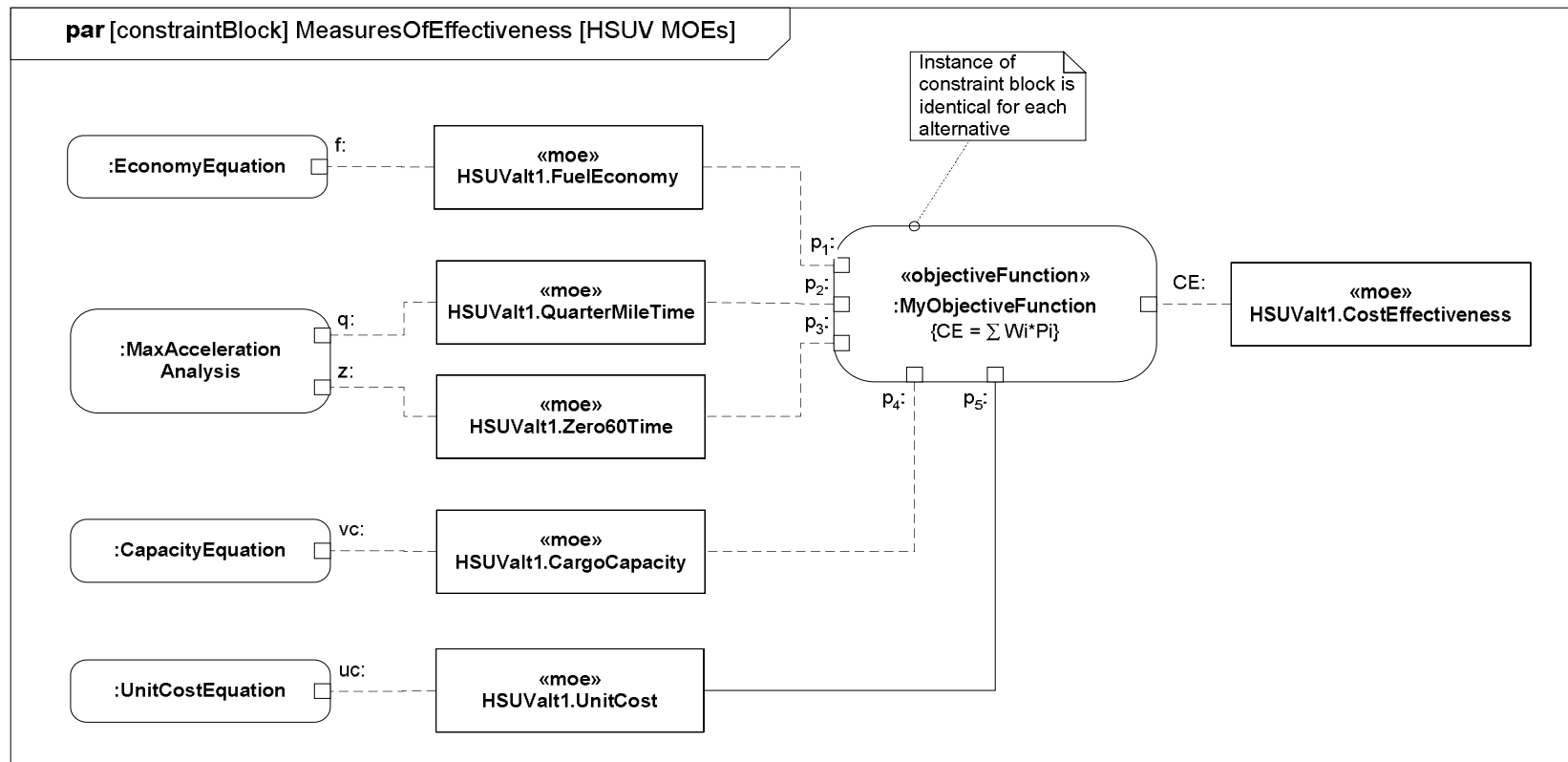
Defining Reusable Equations for Parametrics

Evaluating Vehicle Dynamics



Using the Equations in a Parametric Diagram to Constrain the Value Properties

Evaluating Measures of Effectiveness



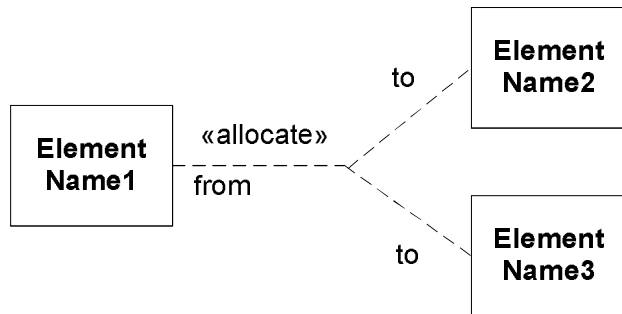
MOE's and objective function provide flexible support for trade study analysis that is fully integrated with parametrics

Allocations

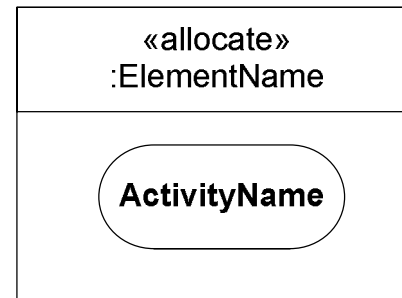
- n Provides general relationship to map one model element to another
- n Includes specific subclasses of allocation with constraints on their usage
 - n Behavioral
 - n Structural
 - n Flow
- n Explicit allocation of activities to swim lanes (e.g. activity partitions)
- n Graphical and/or tabular representations

Different Allocation Representations

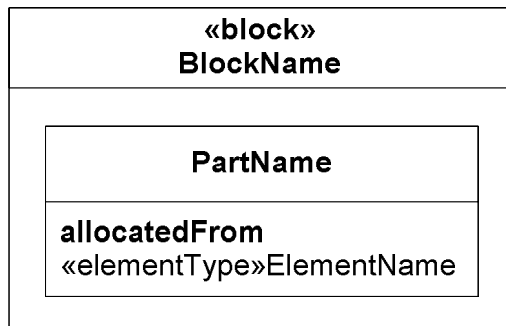
(Tabular Representation Not Shown)



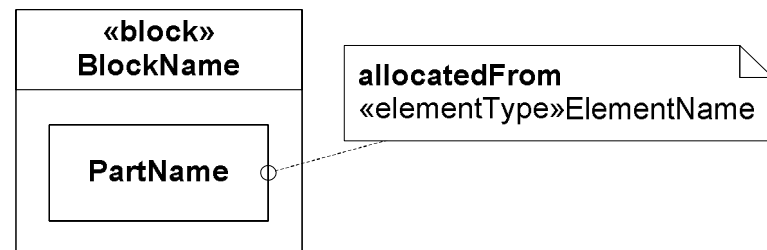
Allocate Relationship



Explicit Allocation of Activity to Swim Lane



Compartment Notation

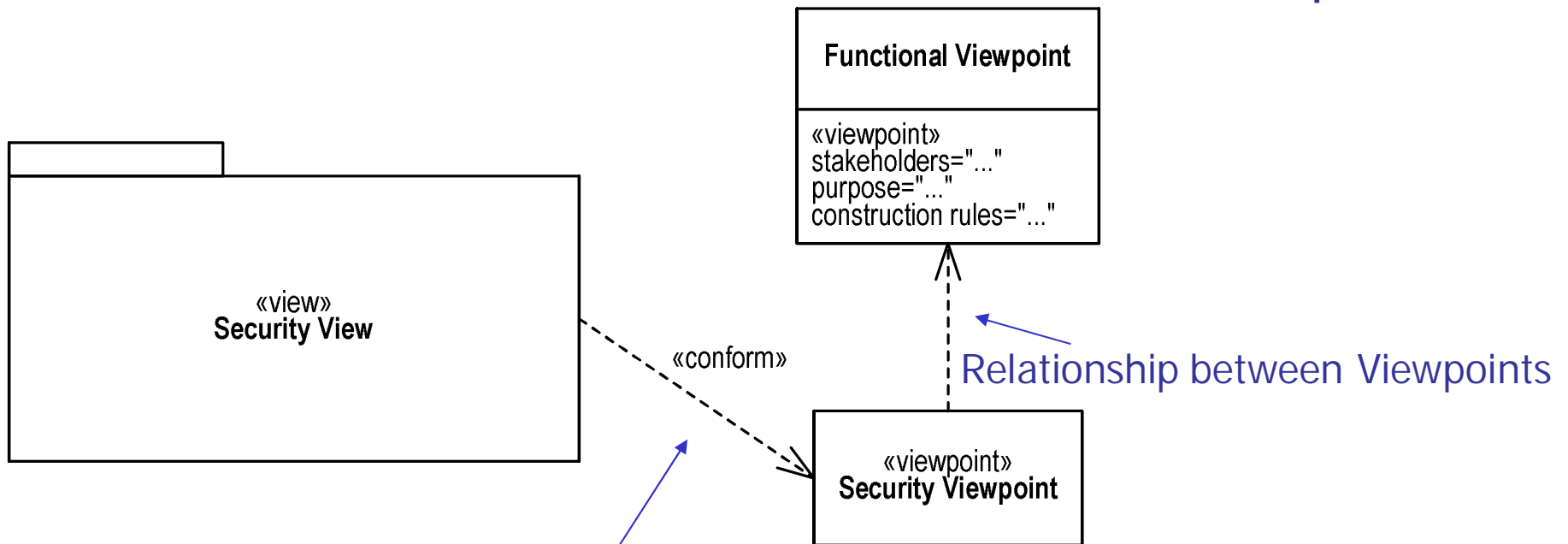


Callout Notation

View/Viewpoint

Viewpoint captures stakeholder concerns

- express concerns as requirements
- construction rules describe view which satisfies reqts



View describes system from a particular viewpoint



SysML in a Standards Framework

Systems Engineering Standards & Architecture Frameworks

Process Standards



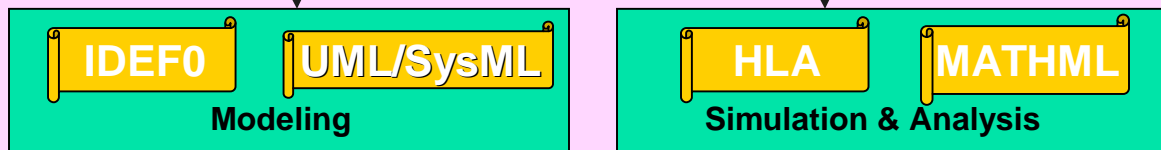
Architecture Frameworks



Modeling Methods



Modeling & Simulation Standards



Interchange Standards



Implemented By Tools

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 Reqs
Definition Process

5.5.3
Reqs 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

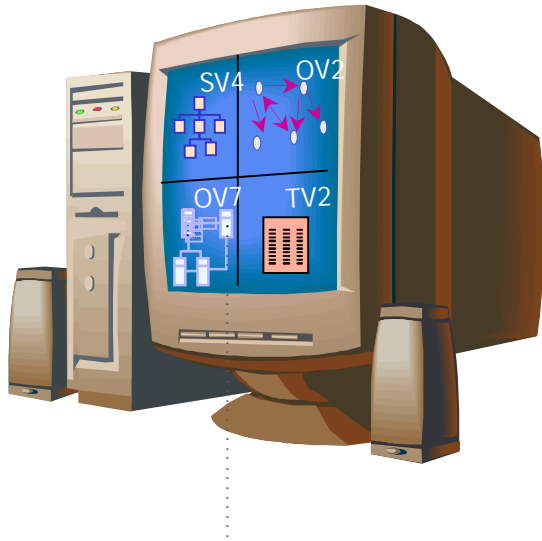
5.5.10
Operation Process

5.5.11
Maintenance Process

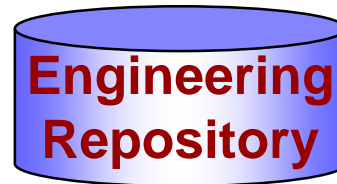
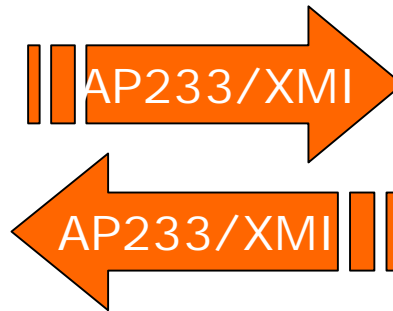
5.5.12
Disposal Process

Example Standards-based Tool Integration

Systems Modeling
Tool



Model/Data
Interchange



Other SE Engineering
Tools



Participating SysML Tool Vendors

- n Artisan
- n EmbeddedPlus
- n IBM
- n I-Logix
- n Sparx Systems
- n Telelogic
- n Vitech

UML Profile for DoDAF/MODAF Standardization

- n Current initiative underway to develop standard profile for representing DODAF and MODAF products
 - n Requirements for profile issued Sept 05
 - n Final submissions expected Dec '06
- n Multiple vendors and users participating
- n Should leverage SysML

Tool Support

Project Management IMP/IMS, Process Modeling (ISDM)								
CM/DM Product Data Management	Requirements Management	Engineering Performance Analysis	SoS / DoDAF		Risk & Opportunity Management	Verification & Validation	Measurement	Specialty Engineering
			System Modeling SysML					
			Software Modeling UML 2.0	Hardware Modeling VHDL, Verilog				

Summary

- n SysML sponsored by INCOSE/OMG with broad industry and vendor participation
- n SysML provides general purpose modeling language to support specification, analysis, design and verification of complex systems
 - n Subset of UML 2 with extensions
- n Multiple vendor implementations announced
- n Adoption expected to begin in April 2006
- n Standards based modeling approach for SE expected to improve communications, tool interoperability, and design quality

References

- n UML for SE RFP

- n OMG doc# ad/03-03-41

- n SysML specification v0.99

- n <http://syseng.omg.org/SysML.htm>

- n UML 2 Superstructure

- n OMG doc# formal/05-07-04

- n UML 2 Infrastructure

- n OMG doc# ptc/04-10-14