PTC® PRODUCT & SERVICE ADVANTAGE®

Infrastructure Bridge Model

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Introduction

- Model Purpose
  - Investigate whether MBSE provides benefits to infrastructure projects
  - Provide concrete examples of infrastructure issues
  - Clarify requirements
  - Elicit discussion
- Implemented using PTC Integrity Modeler (Formerly Atego Artisan Studio)
  - UPDM for the high level architecture
  - SysML for the detailed view
  - Explanation and commentary are contained in the notes section of each slide.
- For more information contact
  - MHause@PTC.com

Problem Statement

- 1. General Background

  The city of Autoville has just elected a new city council with a mandate to build a drawbridge connecting two points across the Tiger river at Jones Landing. The bridge has to allow for automobile, commuter rail, pedestrian, and bicycle traffic. The bridge must accommodate vessel of a category 4 up to 50 feet in height. After receiving a grant of $1 Billion from the federal government, the council must deliver this bridge by Jan 30, 2018. Construction must start before the next council election.

Requirements

- The requirements specified by the management are:
  - Expected daily rail ridership is 100,000 passengers
  - AM peak is 6:30 to 9:30 and PM peak is 4:00 to 7:00, and peak unidirectional ridership is 10,000 passengers per hour
  - Expected vehicular traffic is 1,000 cars per hour in the inbound direction in the AM peak, and 1,250 cars in the outbound direction in the PM peak. Six lanes of traffic, three in each directions to be provided
  - Pedestrian and bicycle traffic across the bridge shall be provided and shall be separated from vehicular traffic
  - Manned operations with 10 expected openings per day, with a vertical lift type.
  - Height of the bridge to be determined, consistent with size 4 vessel types
  - Commercial (ASASHTO HL93) heavy vehicle traffic is allowed throughout the day.

Requirements

- The requirements specified by the management are:
  - Provide access for emergency vehicles
  - Provide capability to coordinate vessel movement and drawbridge operations.
  - 12 hours a day operation provided by an Operator House
  - The system has to operate under all weather conditions
  - The system must be available 99.99% for all functions when called upon
  - System must meet all applicable federal and state laws and regulations
  - The system shall have an operational life of not less than 50 years.
  - The capital cost of the system shall not exceed $1 Billion.
  - The operations and maintenance cost of the system shall not exceed $10M per year.
  - The system shall be operational by Jan 30th, 2018.

Changes in Systems Engineering Practice

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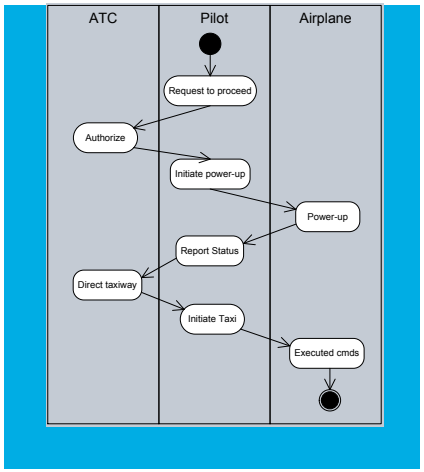
Change from Document centric to Model centric

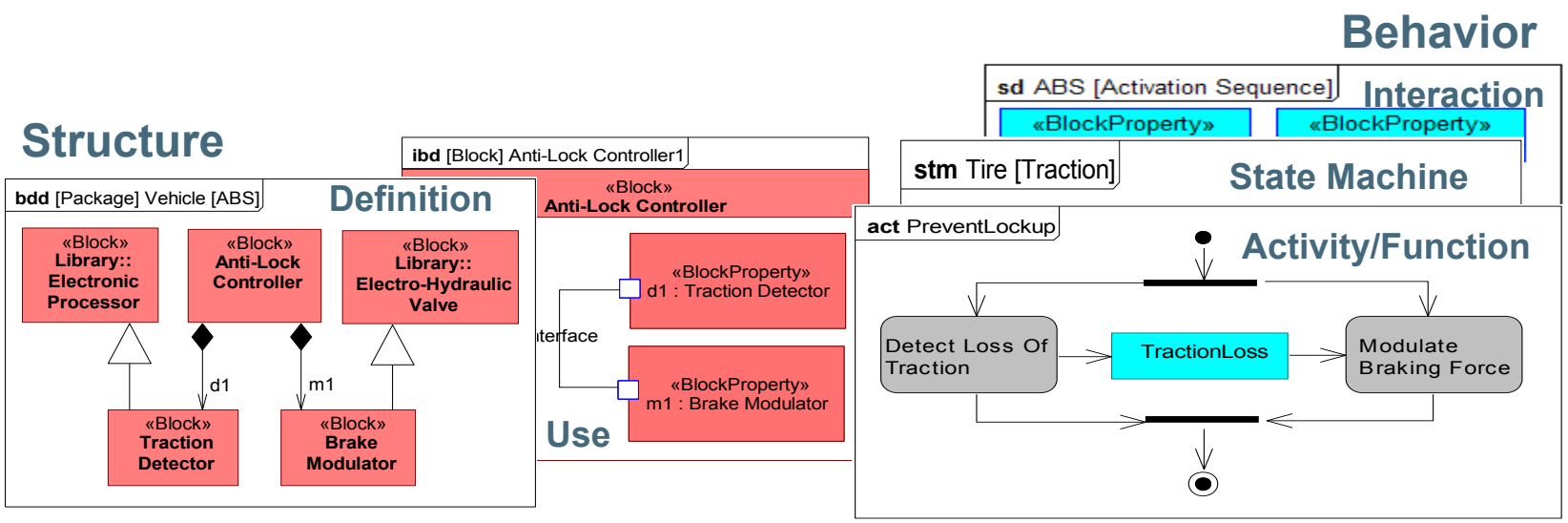
Requirement Specifications
Interface Definitions
System Architecture
System Functionality
Trade-off Analysis
Test Specifications
Etc.

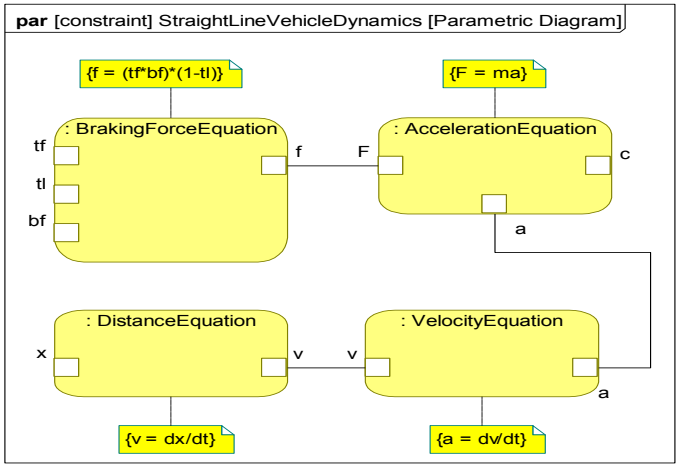


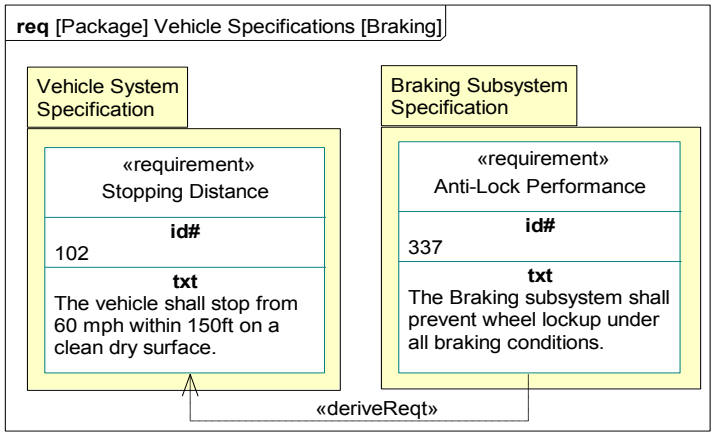
Old Approach

New Approach

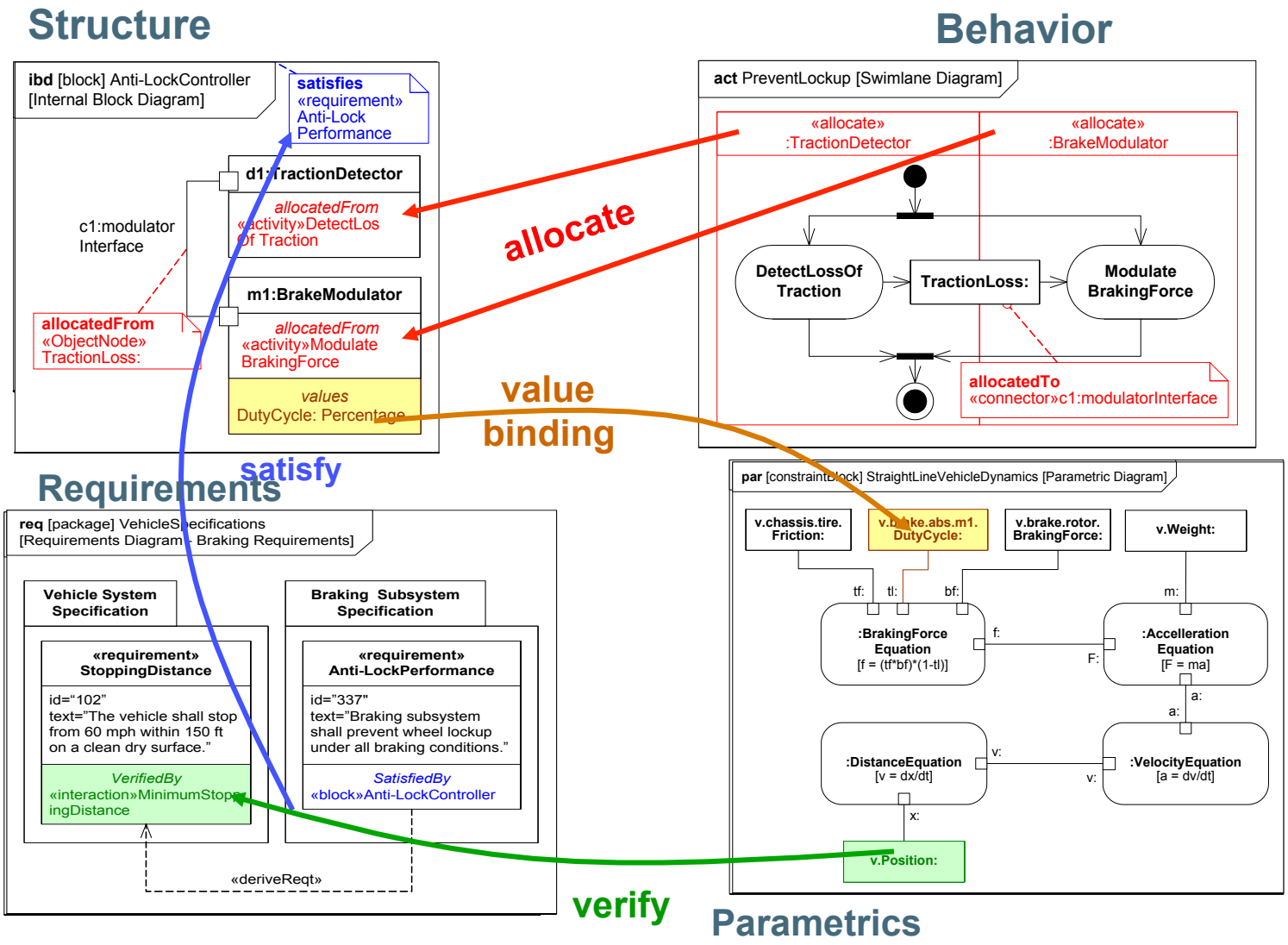
The Four Pillars of SysML







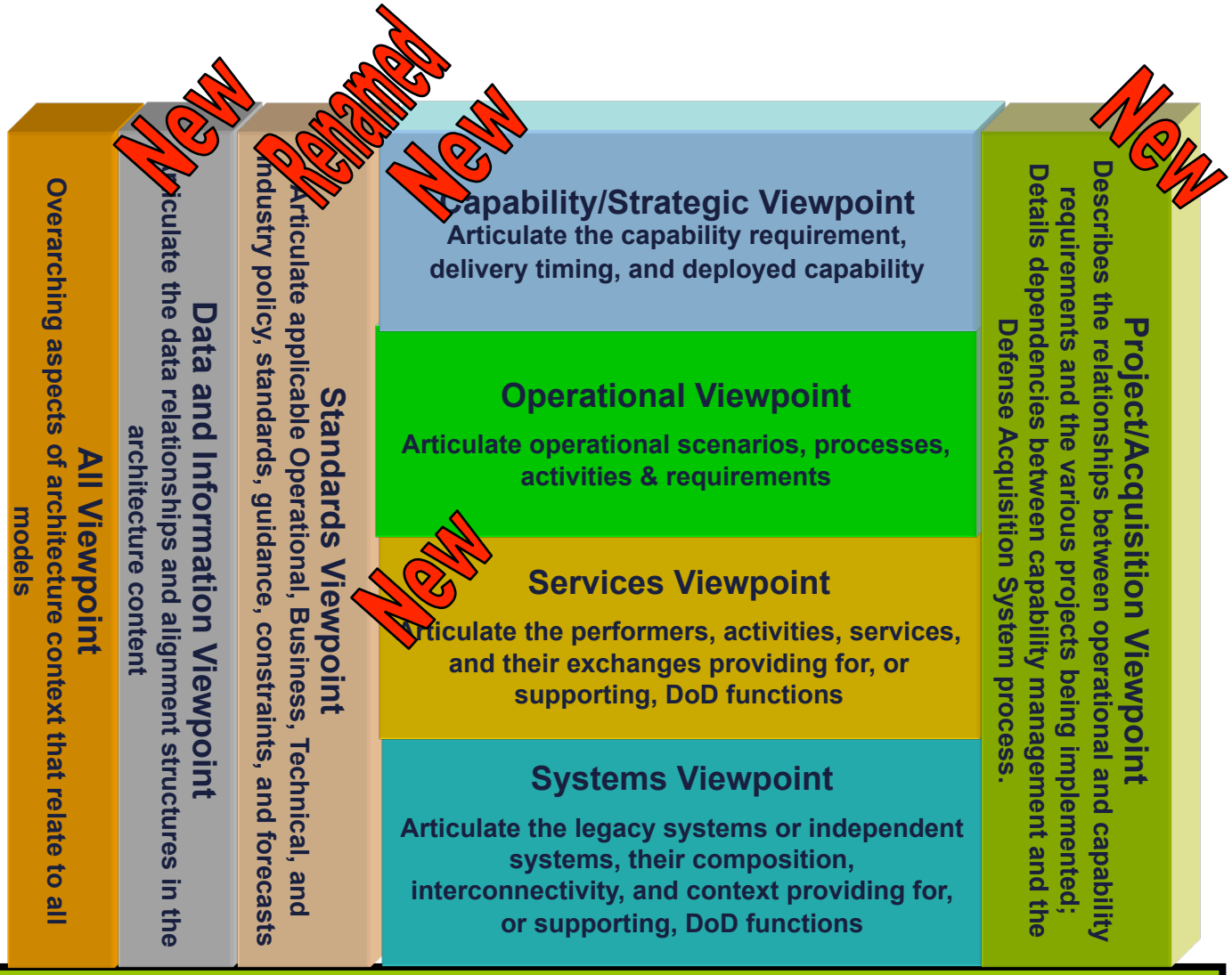
Cross Connecting Model Elements



What is UPDM? - Summary

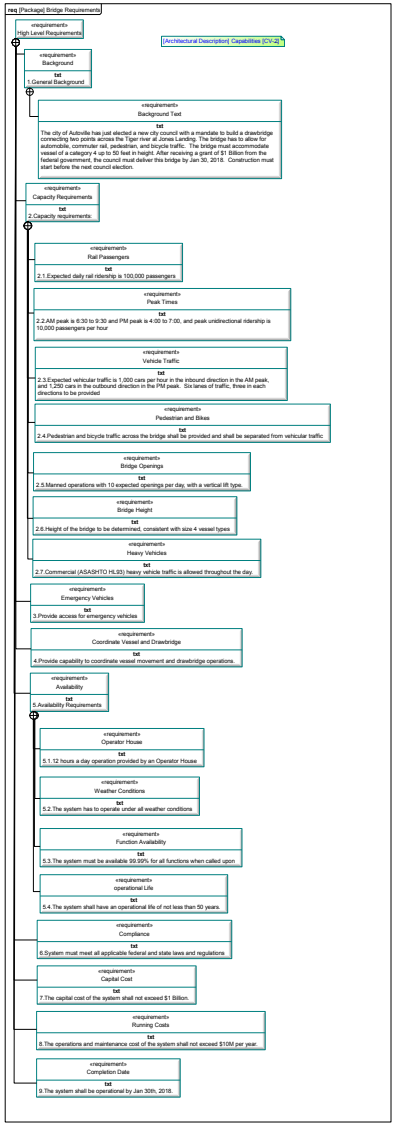
- UPDM is a standardized way of expressing DoDAF and MODAF artefacts using UML and SysML
  - UPDM is ***NOT*** a new Architectural Framework
  - UPDM is not a methodology or a process
  - UPDM 2.0 supports DoDAF 2.0, MODAF 1.2, NAF 3.x,
- UPDM was developed by members of the OMG with help from industry and government domain experts.
- UPDM is now a DoD mandated standard
- UPDM has been implemented by multiple tool vendors.
  - Tools supporting UPDM are available now, including of course by Atego.

Select the Viewpoints That Fit-the-Purpose



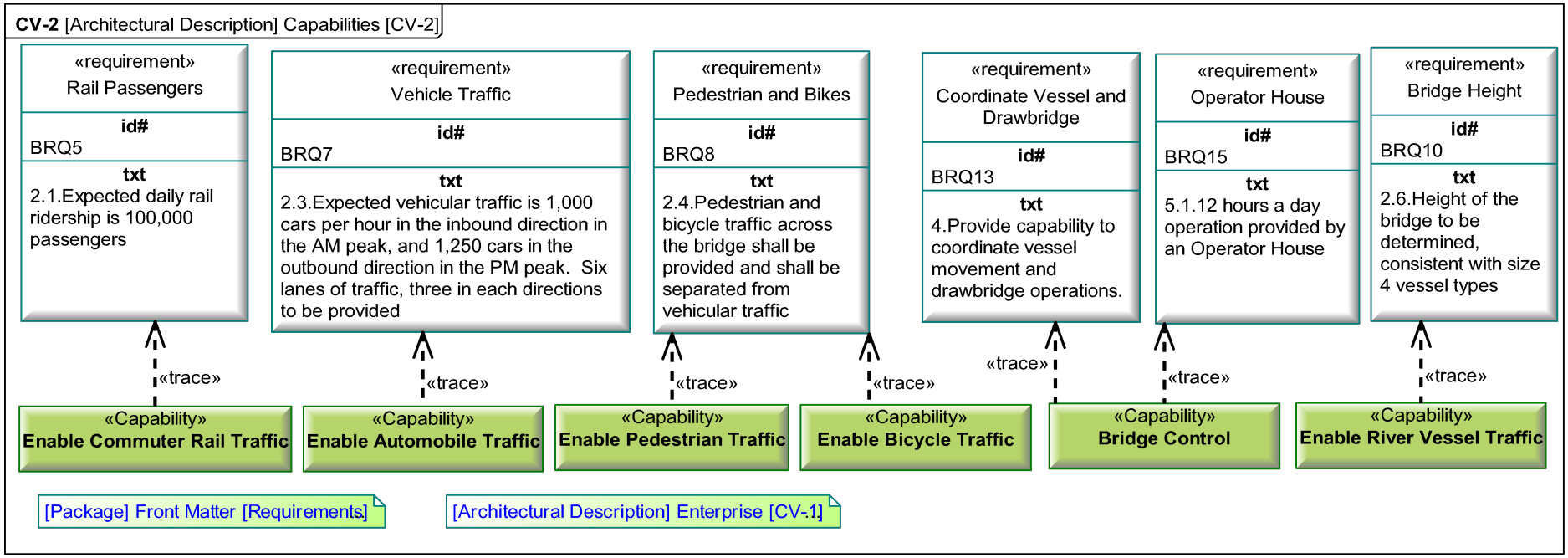
Architecture viewpoints are composed of data that has been organized to facilitate understanding.

Requirements Diagram – Can also show traceability



- Shows requirements traceability
- Can be linked to requirements management tools such as PTC Integrity

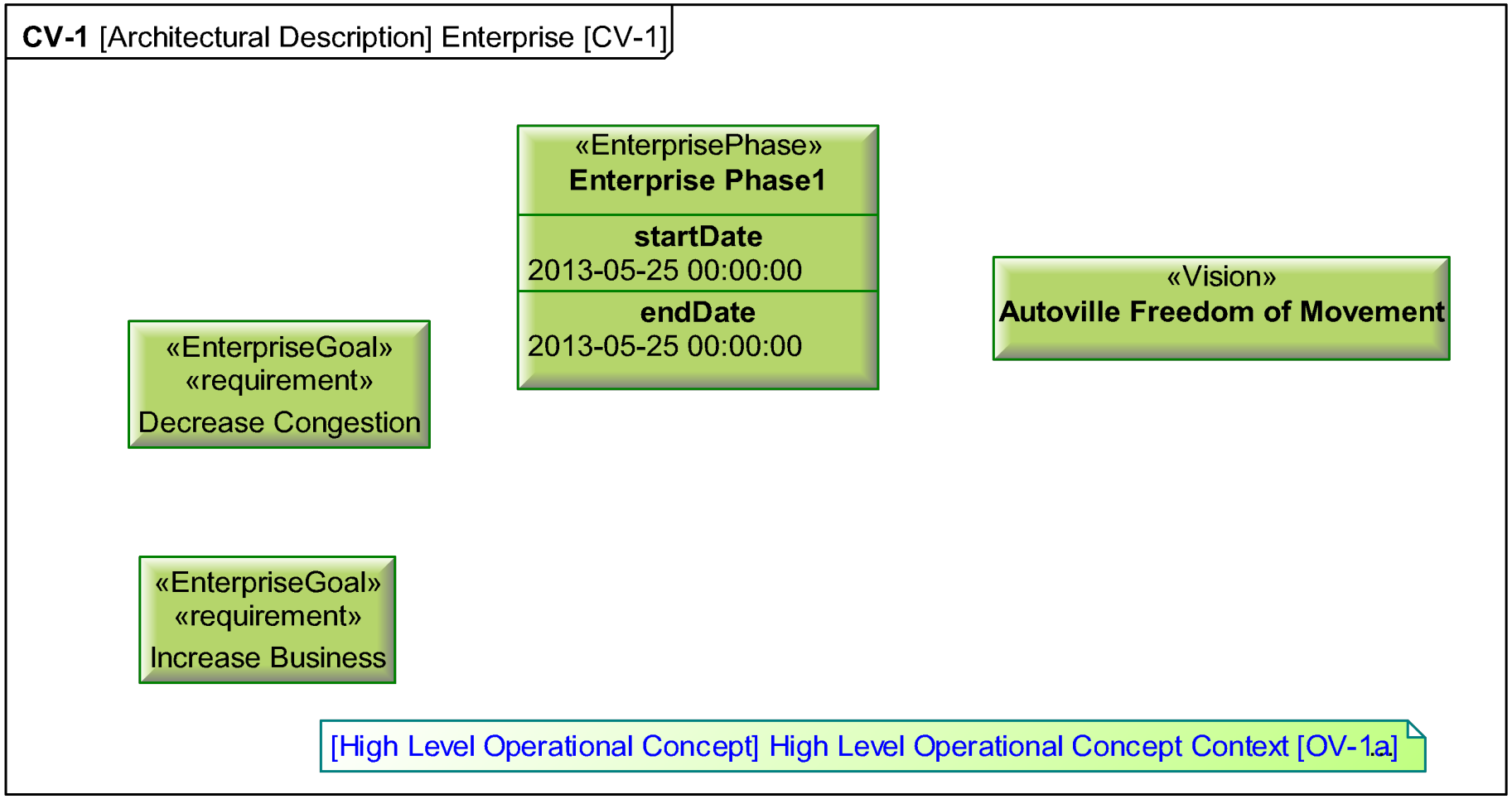
Bridge System Capabilities



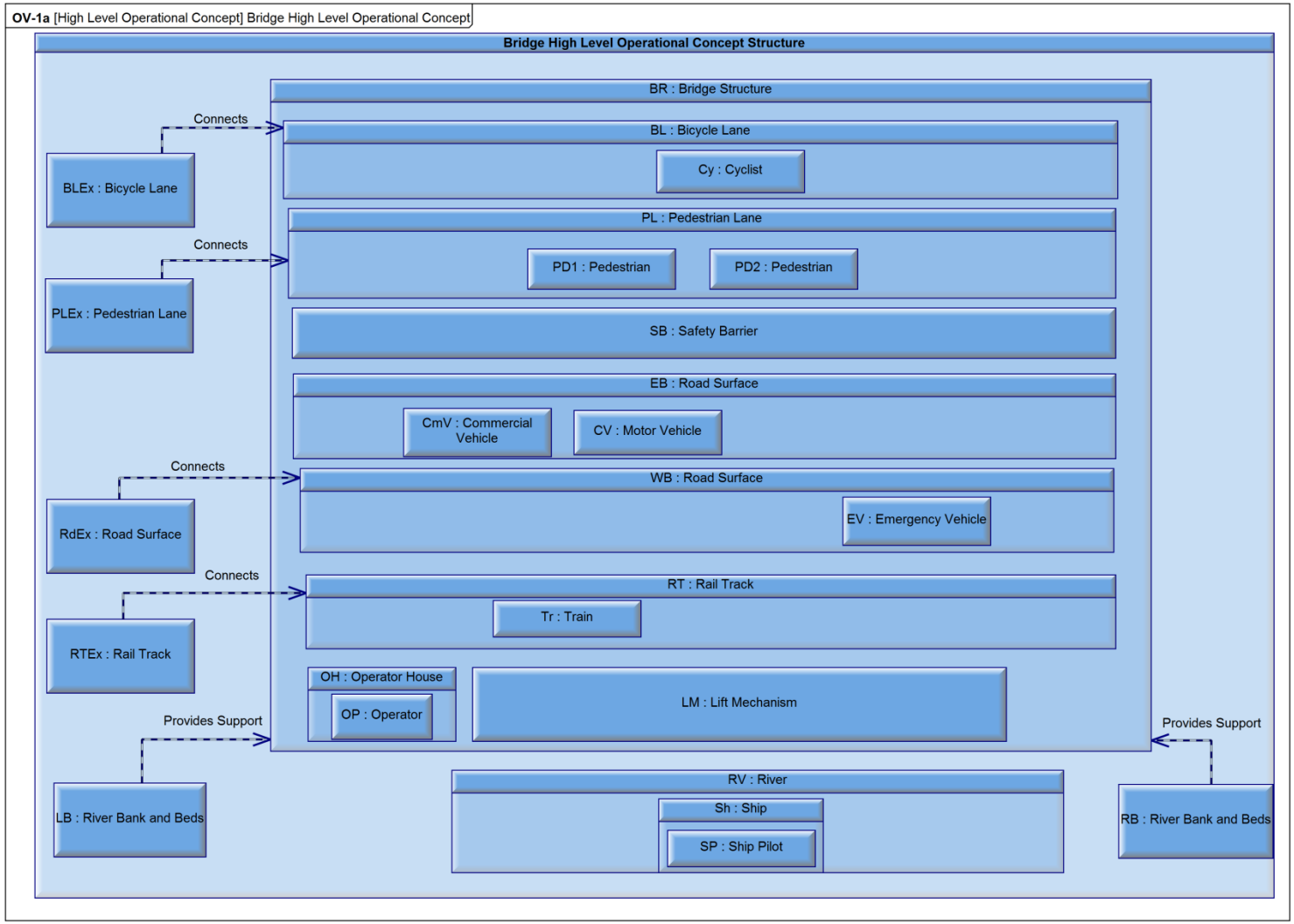
Requirements Traceability Table

Name	Txt	Satisfied By	Traces From
High Level Requirements	The System shall do...		
Background	1. General Background		
Capacity Requirements	2. Capacity requirements:		
Emergency Vehicles	3. Provide access for emergency vehicles		
Coordinate Vessel and Drawbridge	4. Provide capability to coordinate vessel movement and drawbridge operations.		«Capability» Bridge Control (Bridge Architecture::Strategy::Capabilities)
Availability	5. Availability Requirements		
Compliance	6. System must meet all applicable federal and state laws and regulations		
Capital Cost	7. The capital cost of the system shall not exceed $1 Billion.		
Running Costs	8. The operations and maintenance cost of the system shall not exceed $10M per year.		
Completion Date	9. The system shall be operational by Jan 30th, 2018.		
Background Text	The city of Autoville has just elected a new city council with a mandate to build a drawbridge connecting two points across the Tiger river at Jones Landing. The bridge has to allow for automobile, commuter rail, pedestrian, and bicycle traffic. The bridge must accommodate vessel of a category 4 up to 50 feet in height. After receiving a grant of $1 Billion from the federal government, the council must deliver this bridge by Jan 30, 2018. Construction must start before the next council election.		
Rail Passengers	2.1. Expected daily rail ridership is 100,000 passengers		«Capability» Enable Commuter Rail Traffic (Bridge Architecture::Strategy::Capabilities)
Peak Times	2.2. AM peak is 6:30 to 9:30 and PM peak is 4:00 to 7:00, and peak unidirectional ridership is 10,000 passengers per hour		
Vehicle Traffic	2.3. Expected vehicular traffic is 1,000 cars per hour in the inbound direction in the AM peak, and 1,250 cars in the outbound direction in the PM peak. Six lanes of traffic, three in each directions to be provided		«Capability» Enable Automobile Traffic (Bridge Architecture::Strategy::Capabilities)
Pedestrian and Bikes	2.4. Pedestrian and bicycle traffic across the bridge shall be provided and shall be separated from vehicular traffic		«Capability» Enable Bicycle Traffic (Bridge Architecture::Strategy::Capabilities) «Capability» Enable Pedestrian Traffic (Bridge Architecture::Strategy::Capabilities)
Bridge Openings	2.5. Manned operations with 10 expected openings per day, with a vertical lift type.		
Bridge Height	2.6. Height of the bridge to be determined, consistent with size 4 vessel types		«Capability» Enable River Vessel Traffic (Bridge Architecture::Strategy::Capabilities)
Heavy Vehicles	2.7. Commercial (ASASHTO HL93) heavy vehicle traffic is allowed throughout the day.		
Operator House	5.1. 12 hours a day operation provided by an Operator House		«Capability» Bridge Control (Bridge Architecture::Strategy::Capabilities)
Weather Conditions	5.2. The system has to operate under all weather conditions		
Function Availability	5.3. The system must be available 99.99% for all functions when called upon		
operational Life	5.4. The system shall have an operational life of not less than 50 years.		

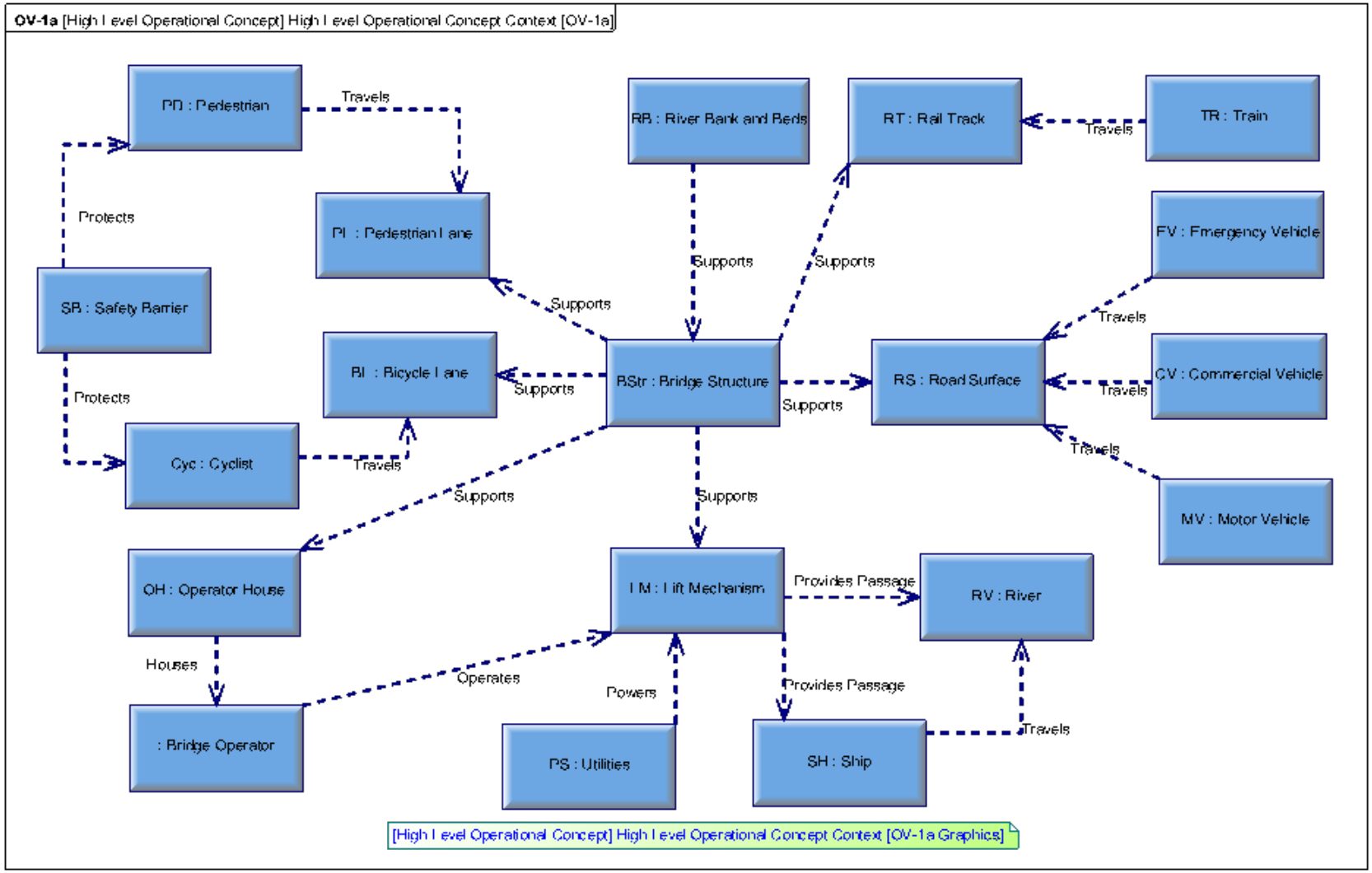
Goals and Visions



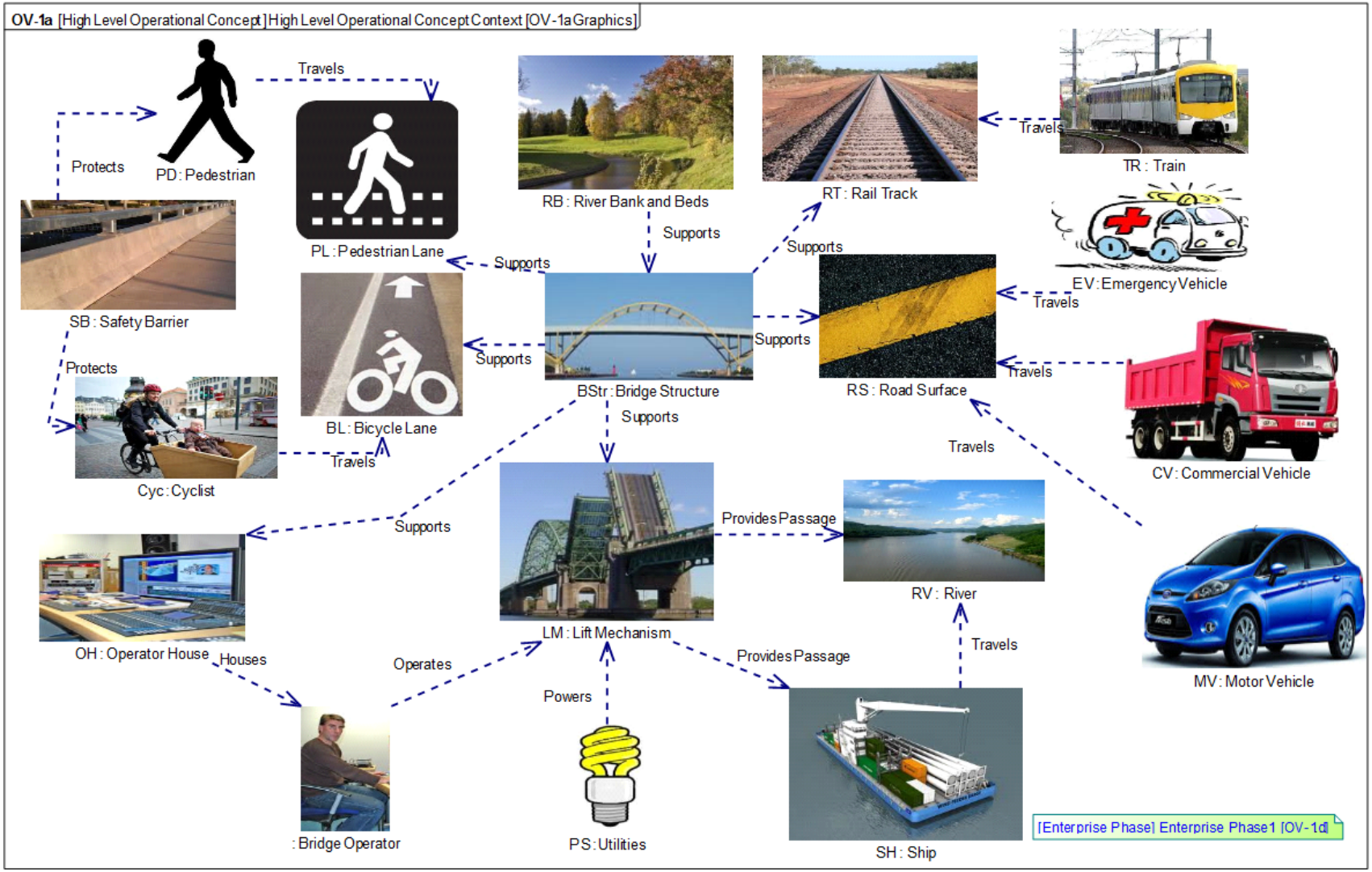
Concept Elements in Structural Format



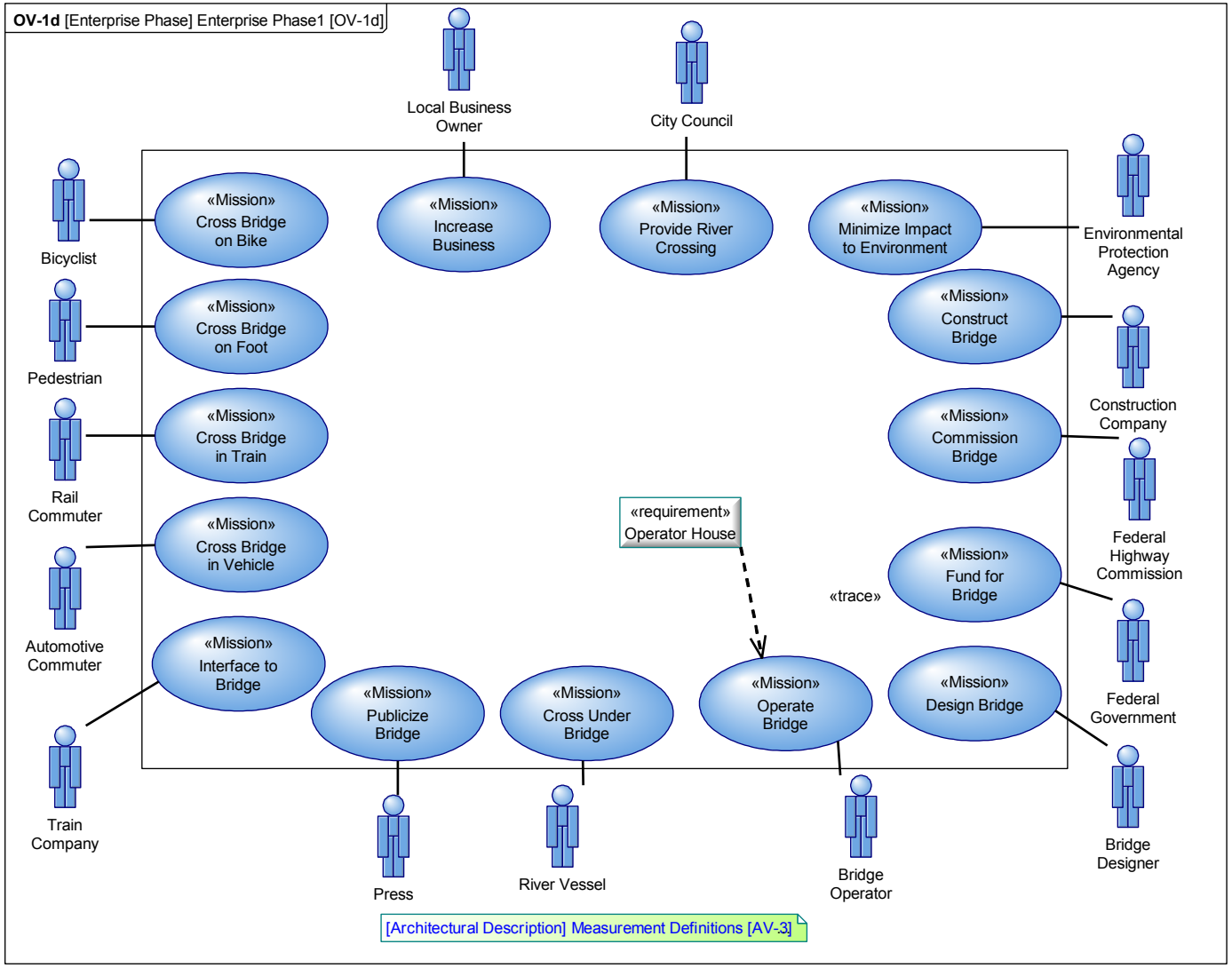
Bridge Concept Element Relationships



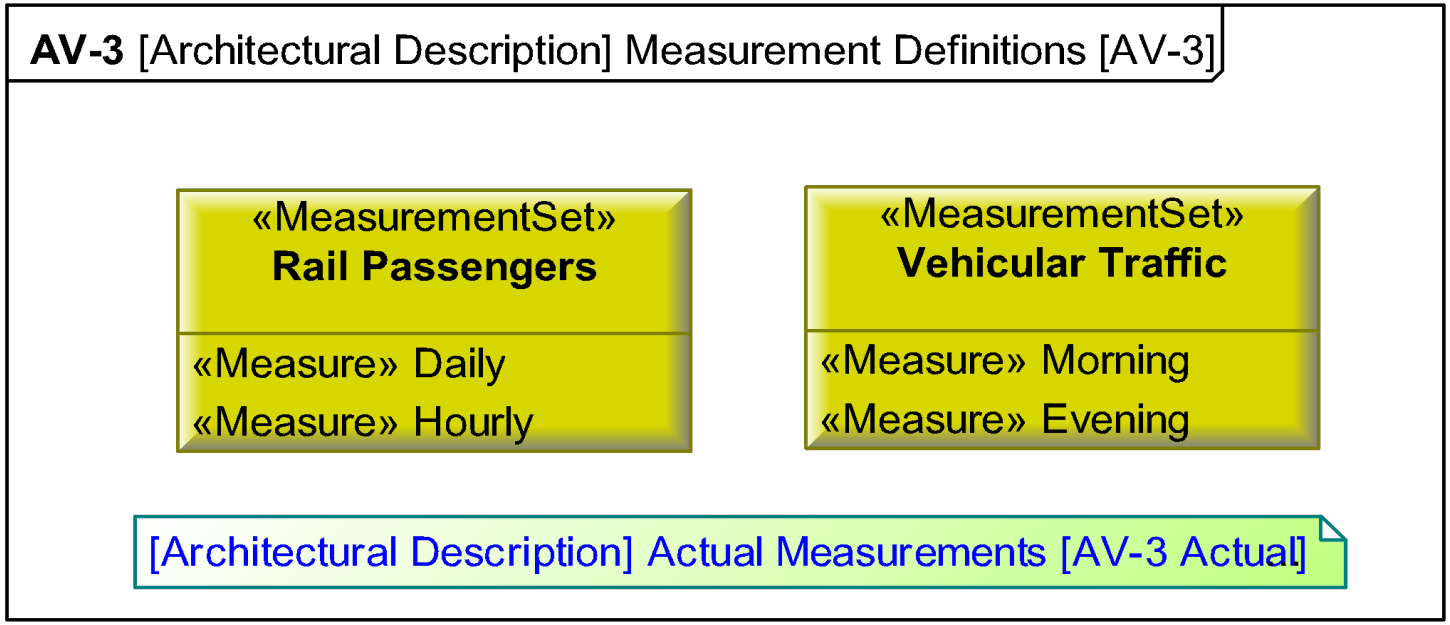
Concept Elements with added graphics



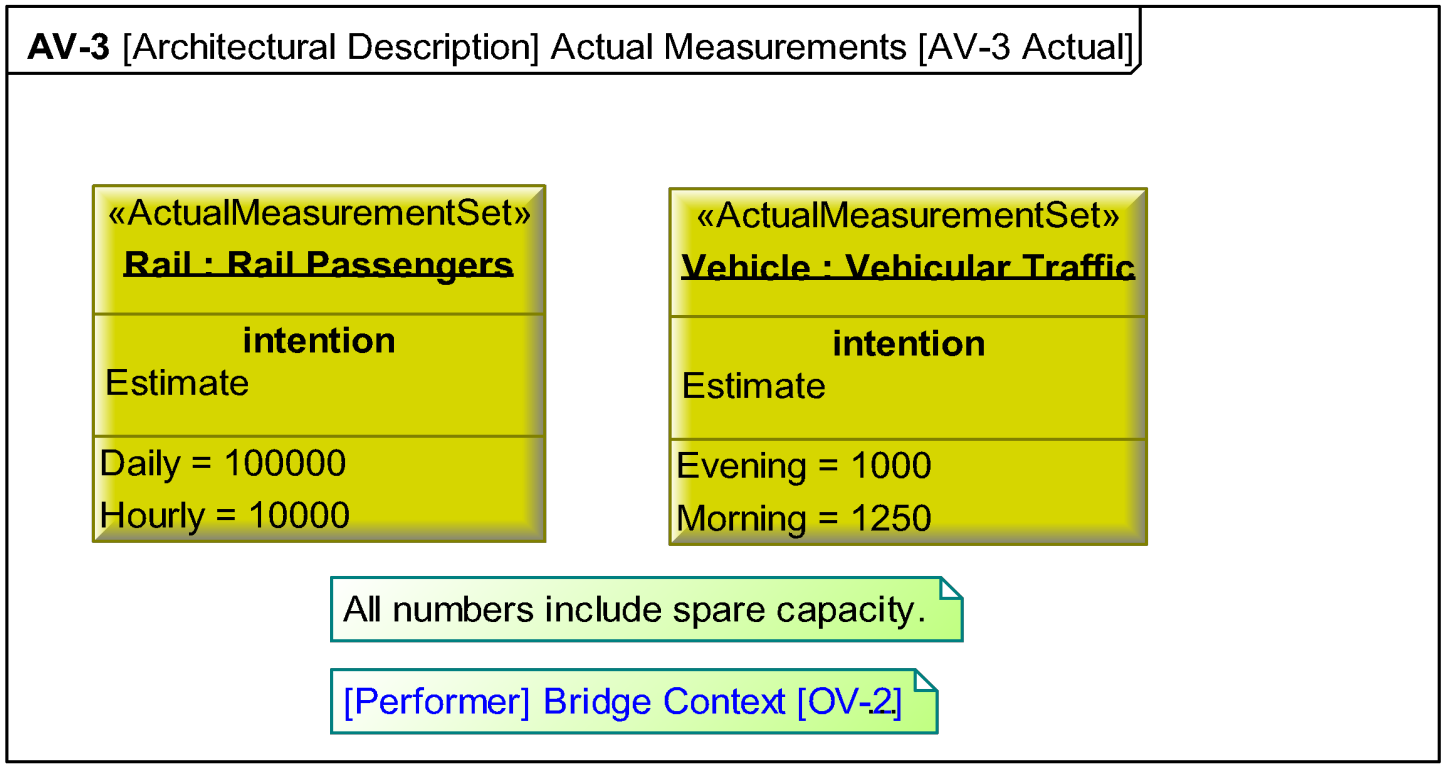
Sample Stakeholders and Their Associated Goals Shown in Use Case Format



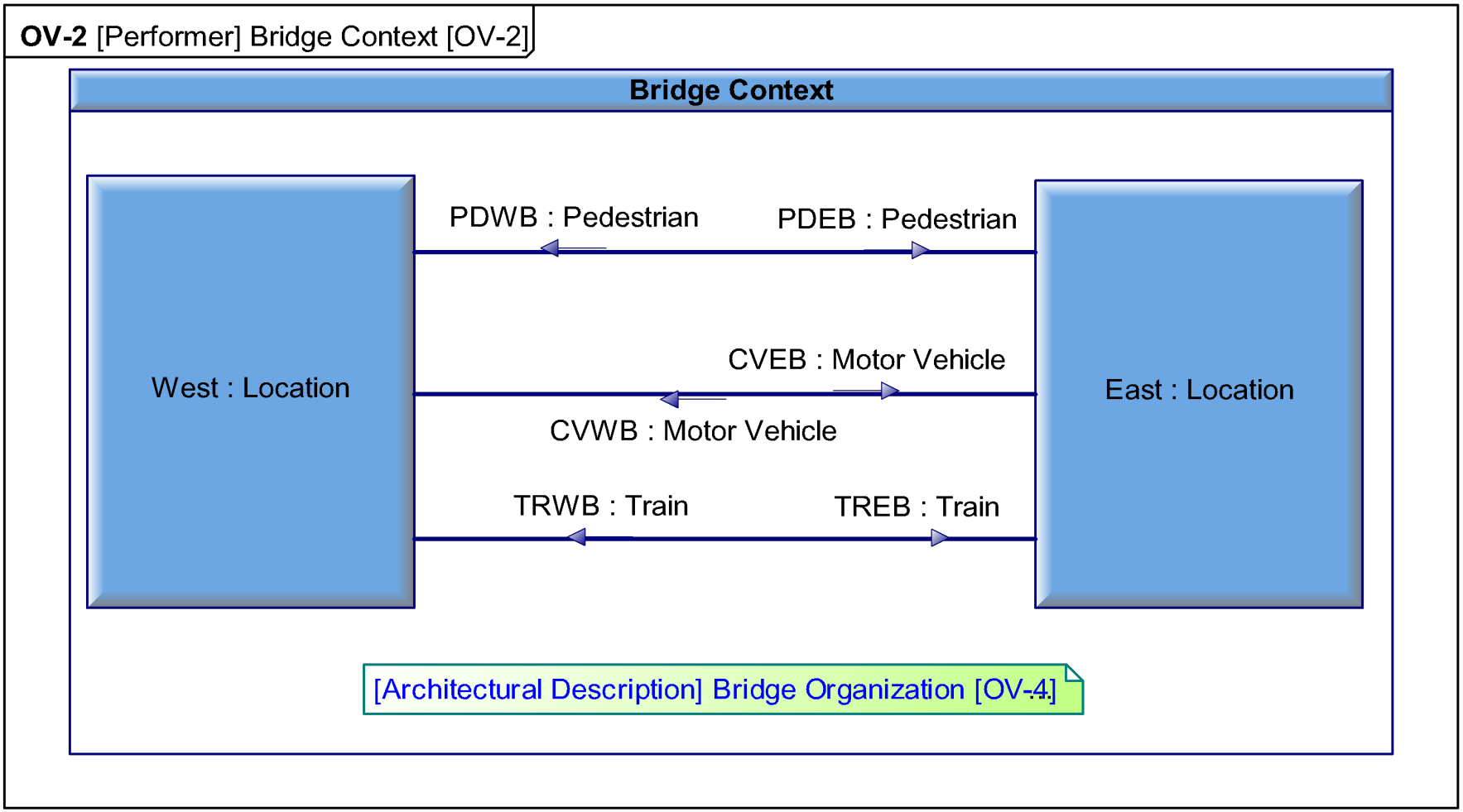
Measurement Definitions



Actual Measurements

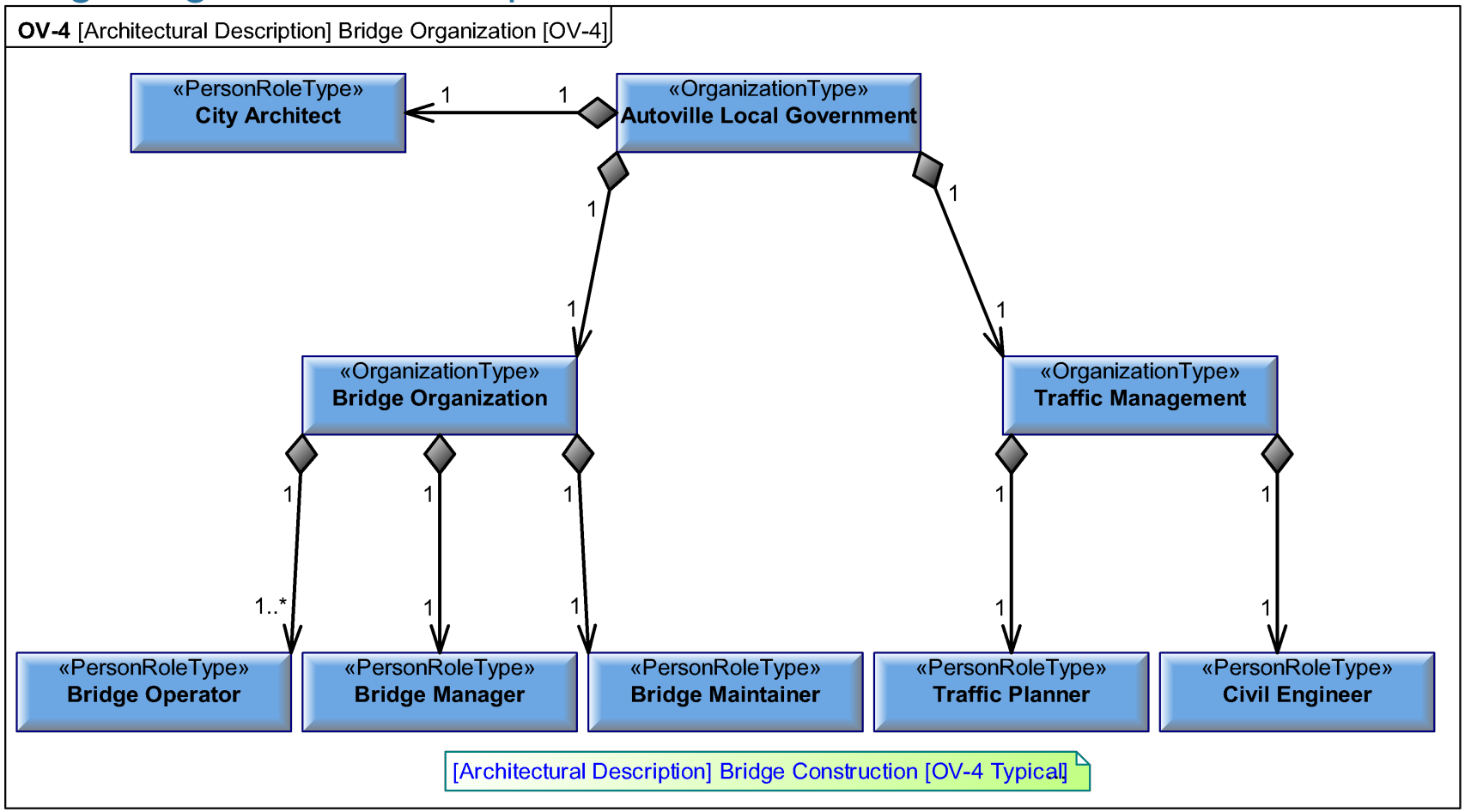


Some Example Exchanges

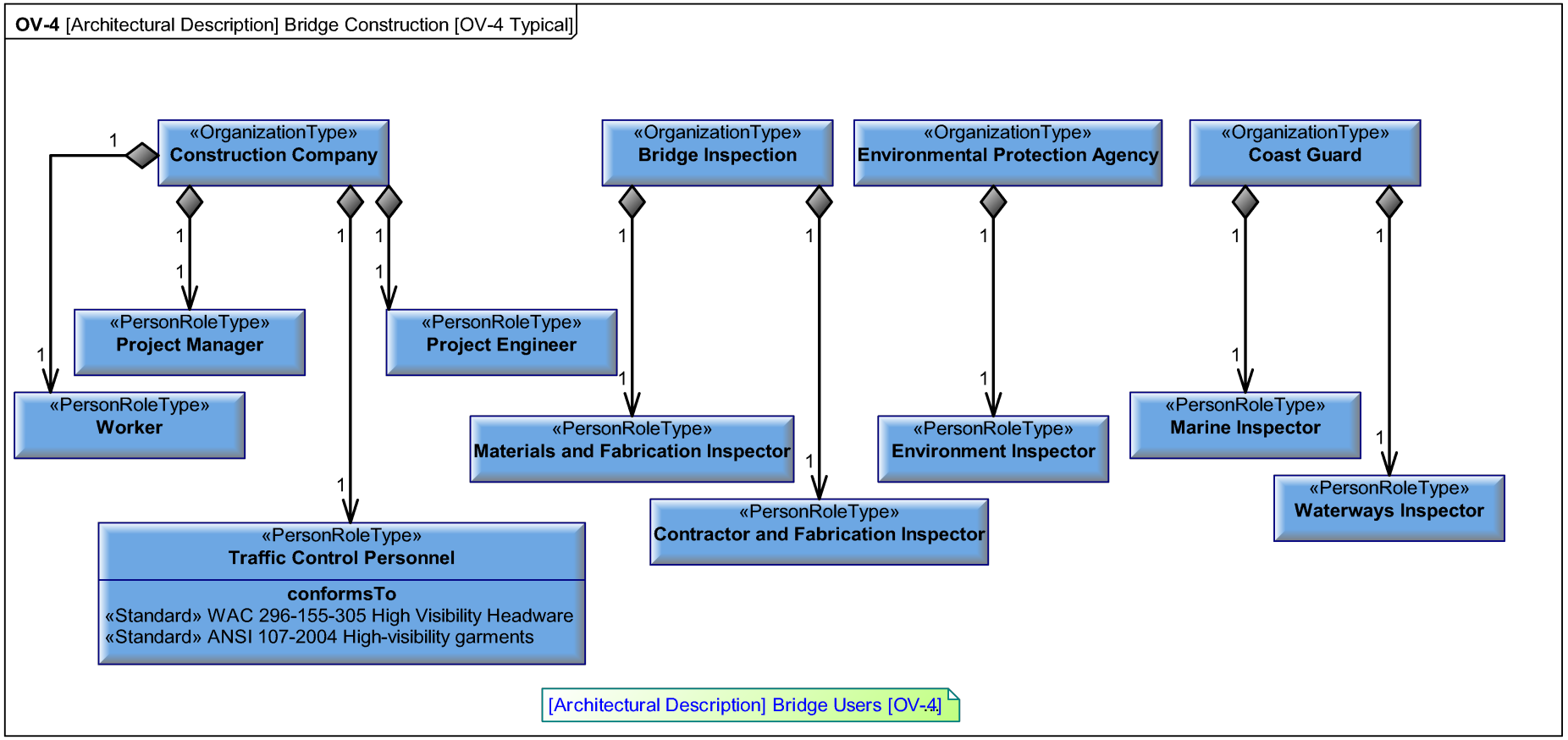


Organizations

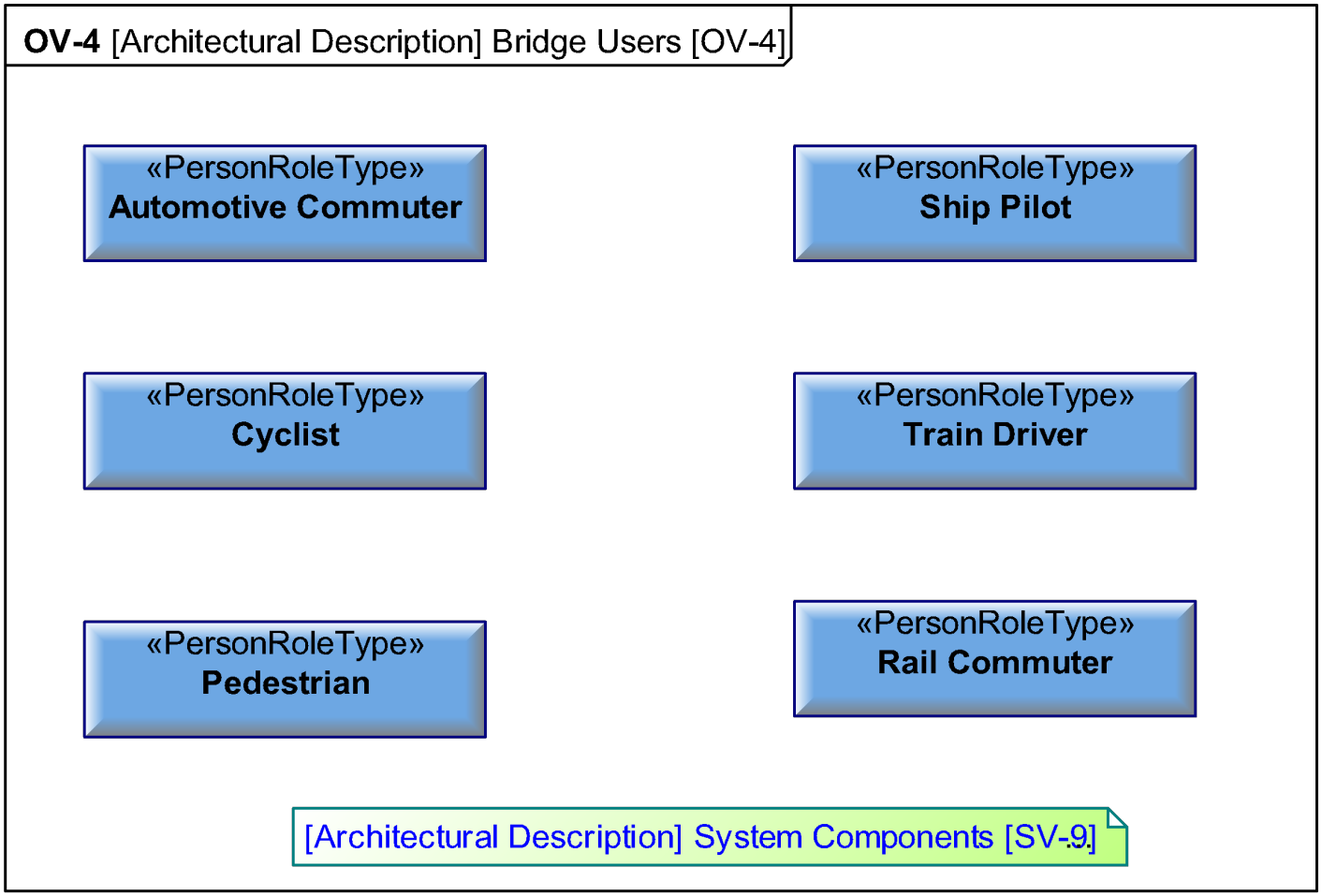
- Bridge Organization for Operations



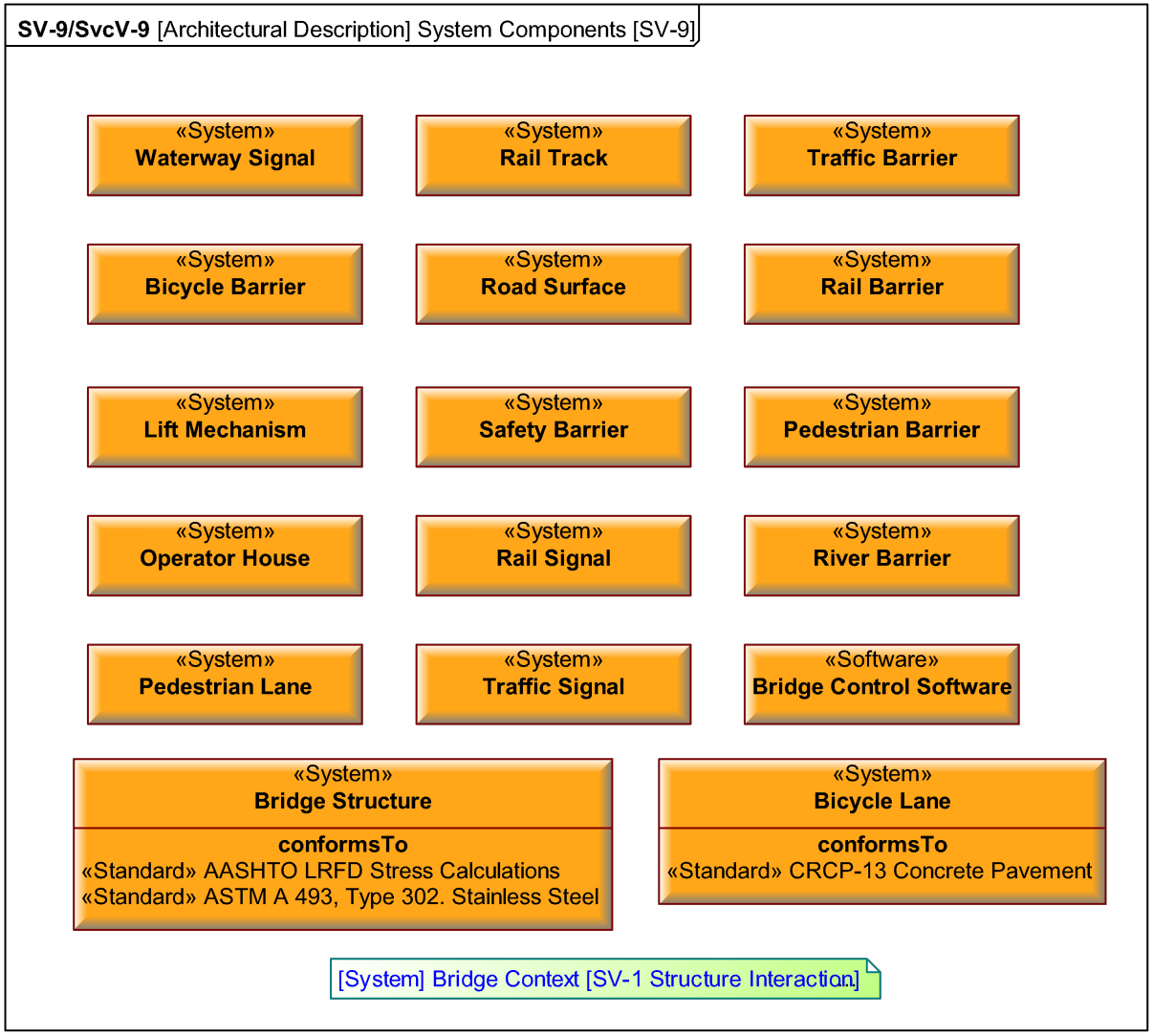
Construction and Inspection Organizations



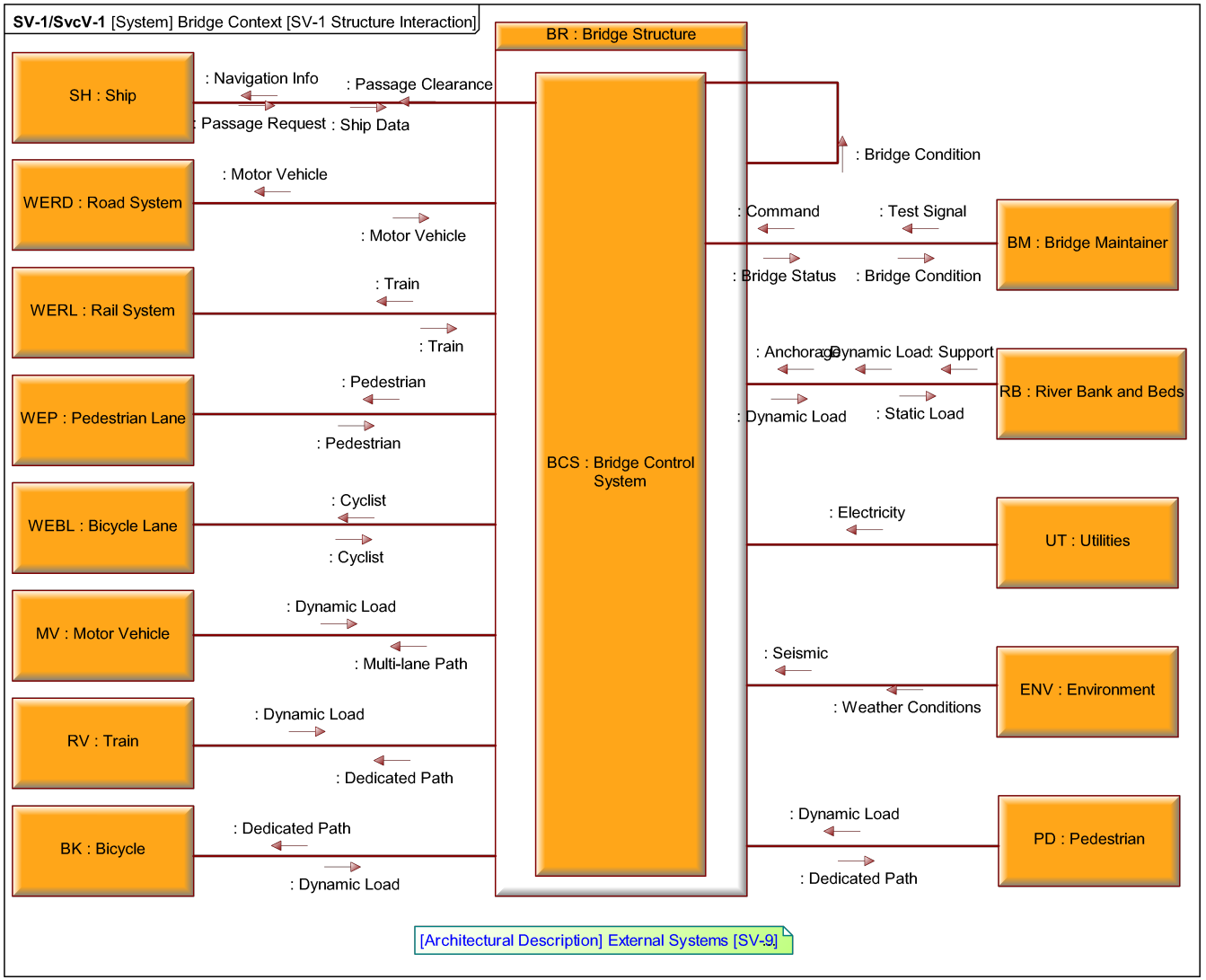
Users of the Bridge



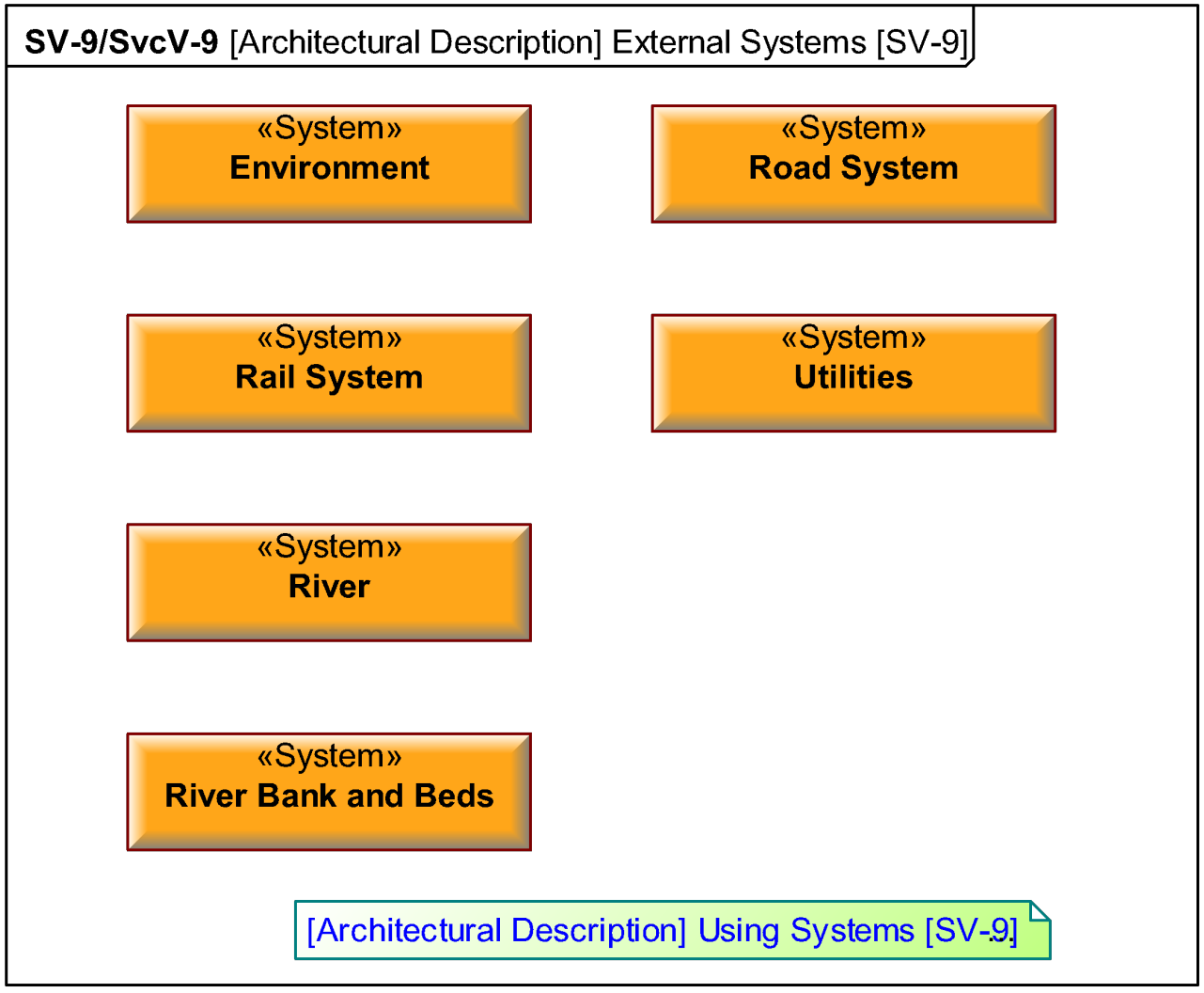
System Components



System Context Diagram

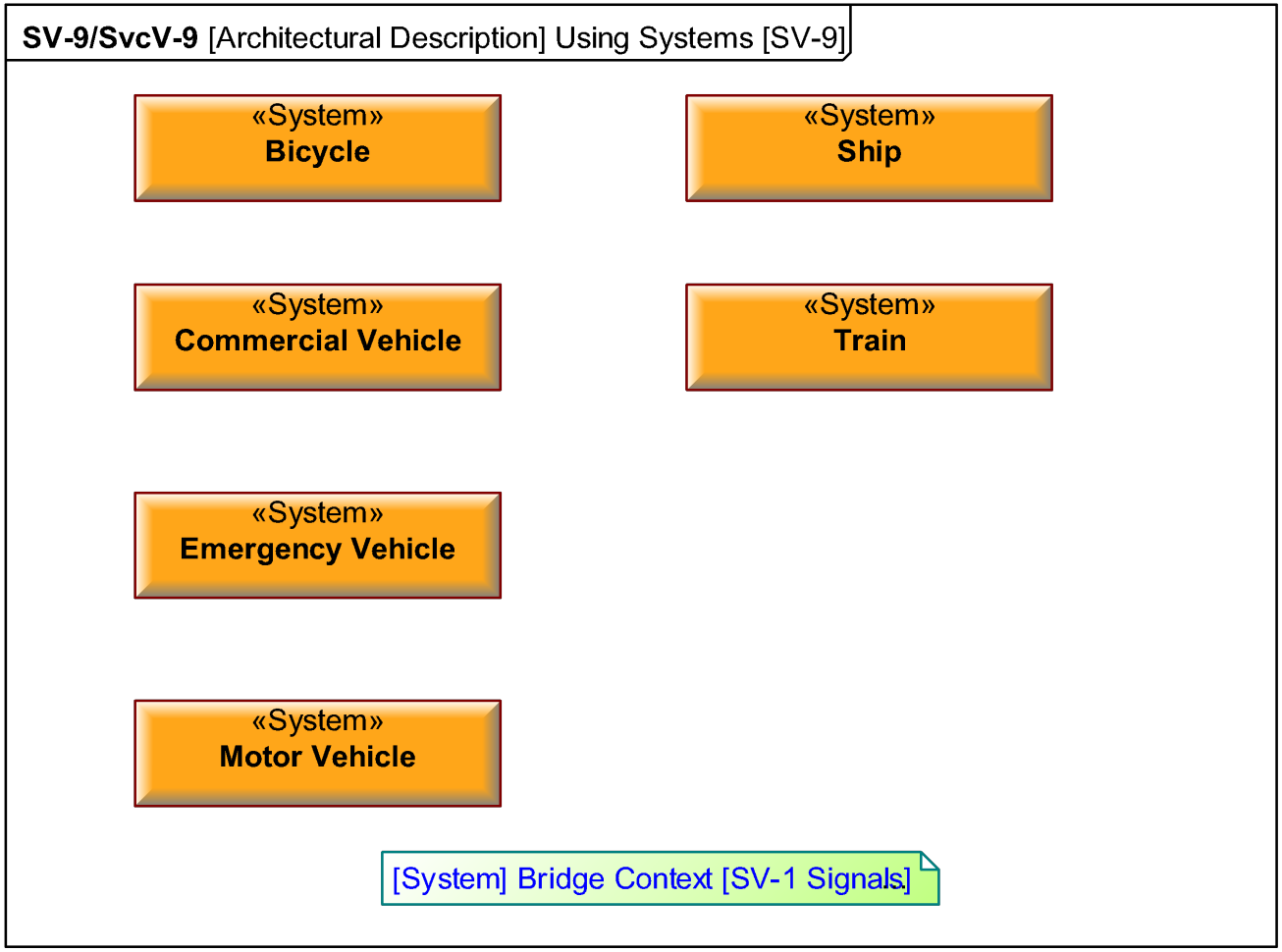


External Interfacing Systems

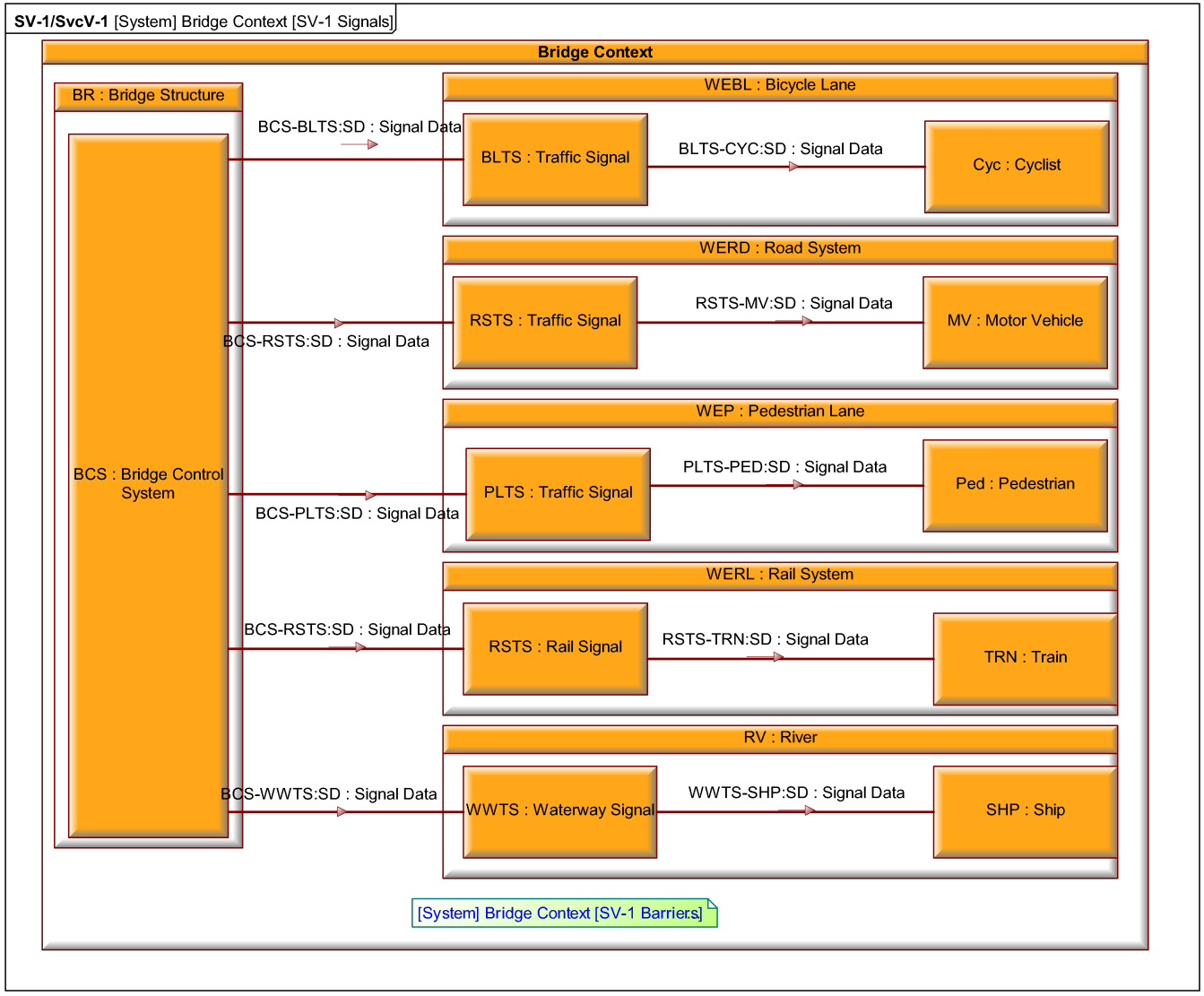


Using Systems

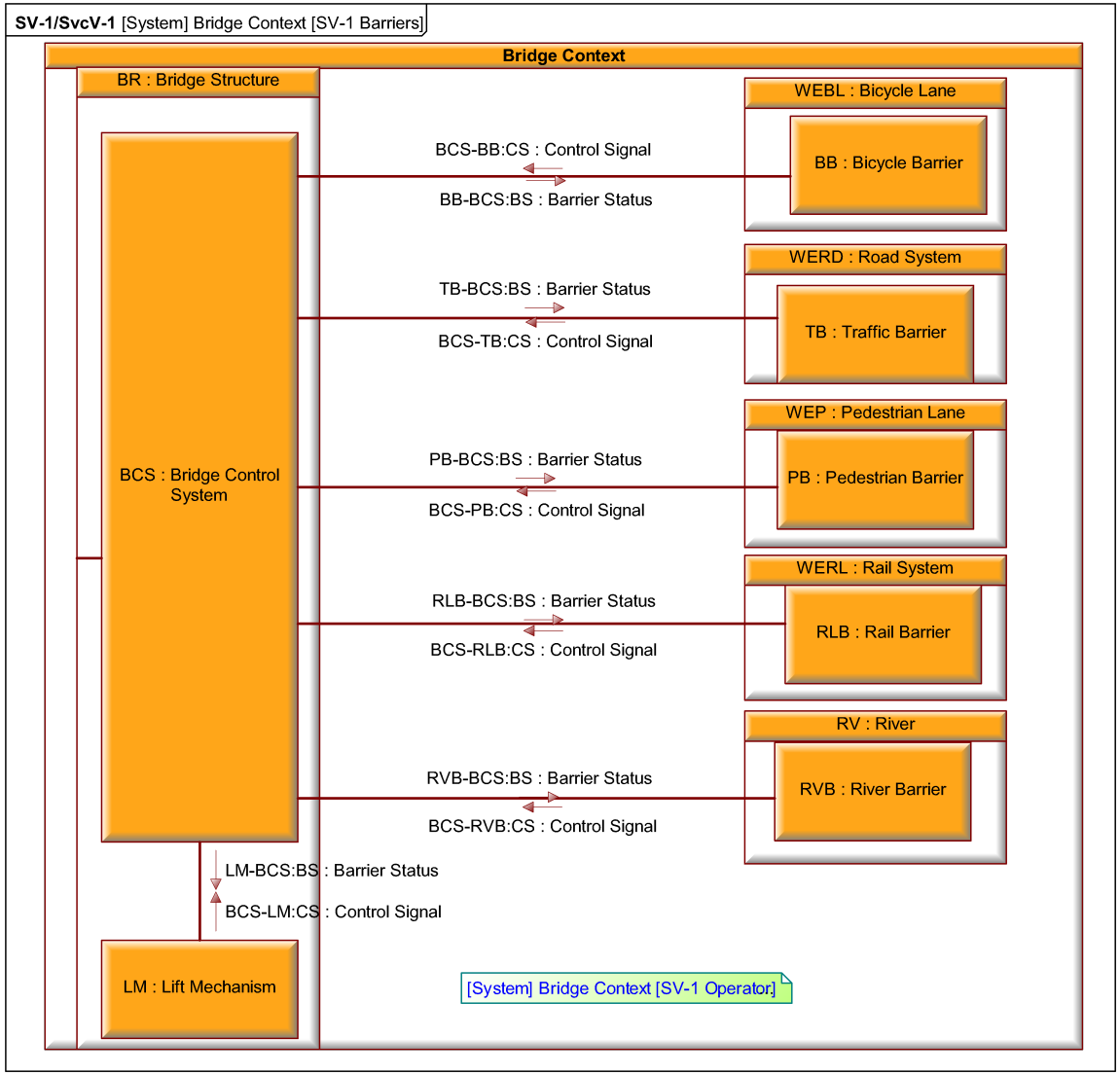
- Systems and users of the bridge



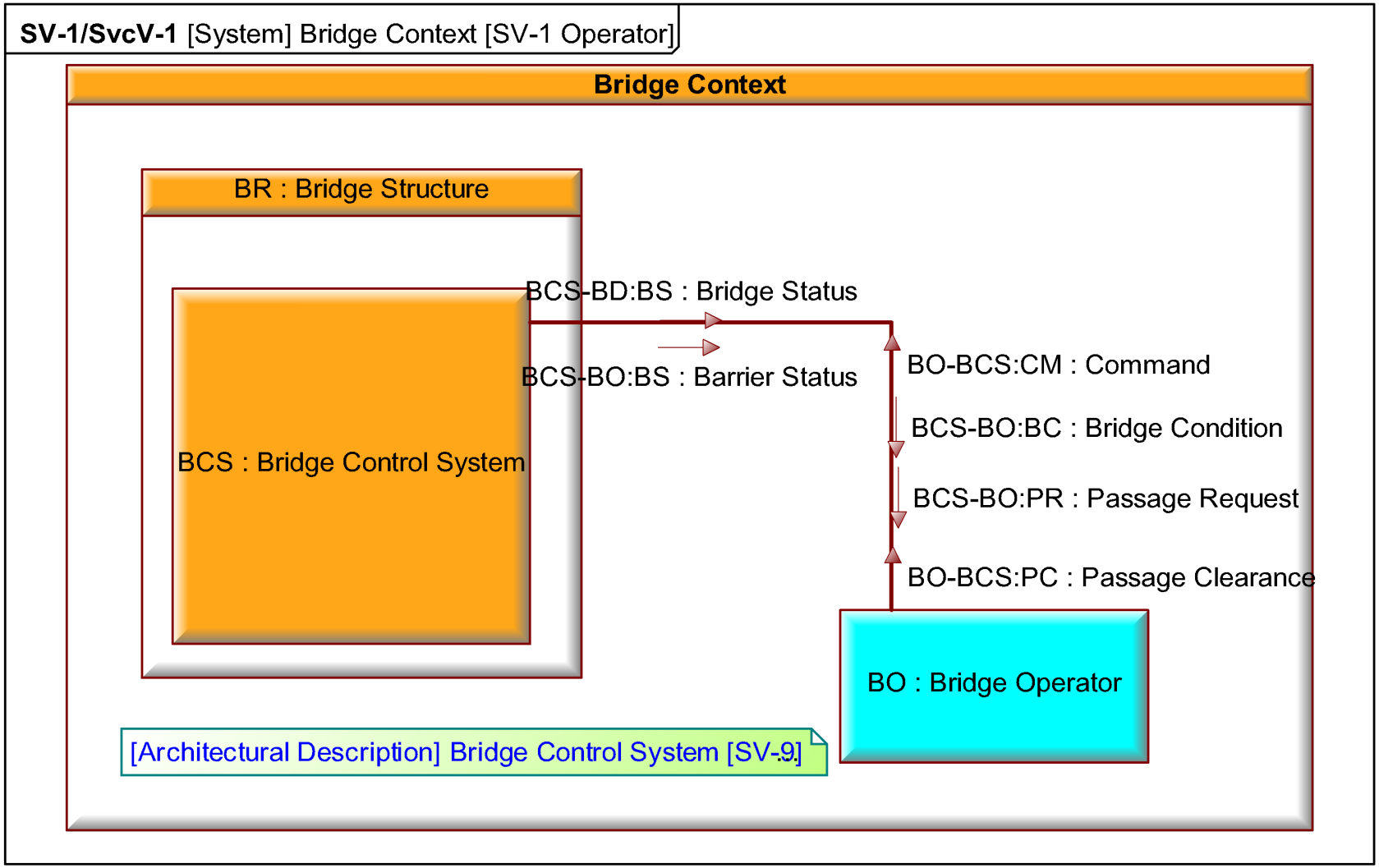
Signaling Systems



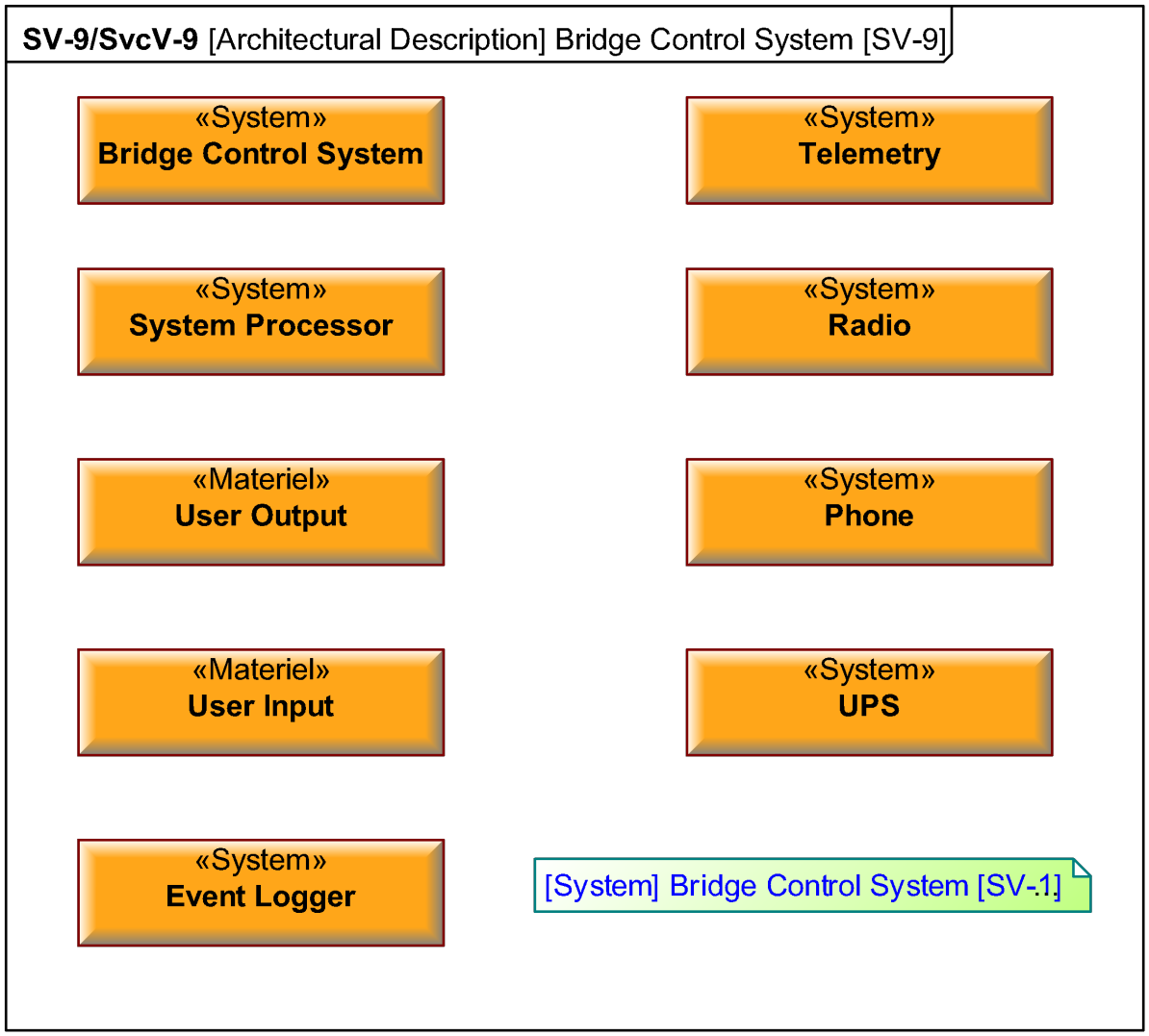
SV-1 Barriers



Operator Interactions



Bridge Control Systems



Bridge Control Systems

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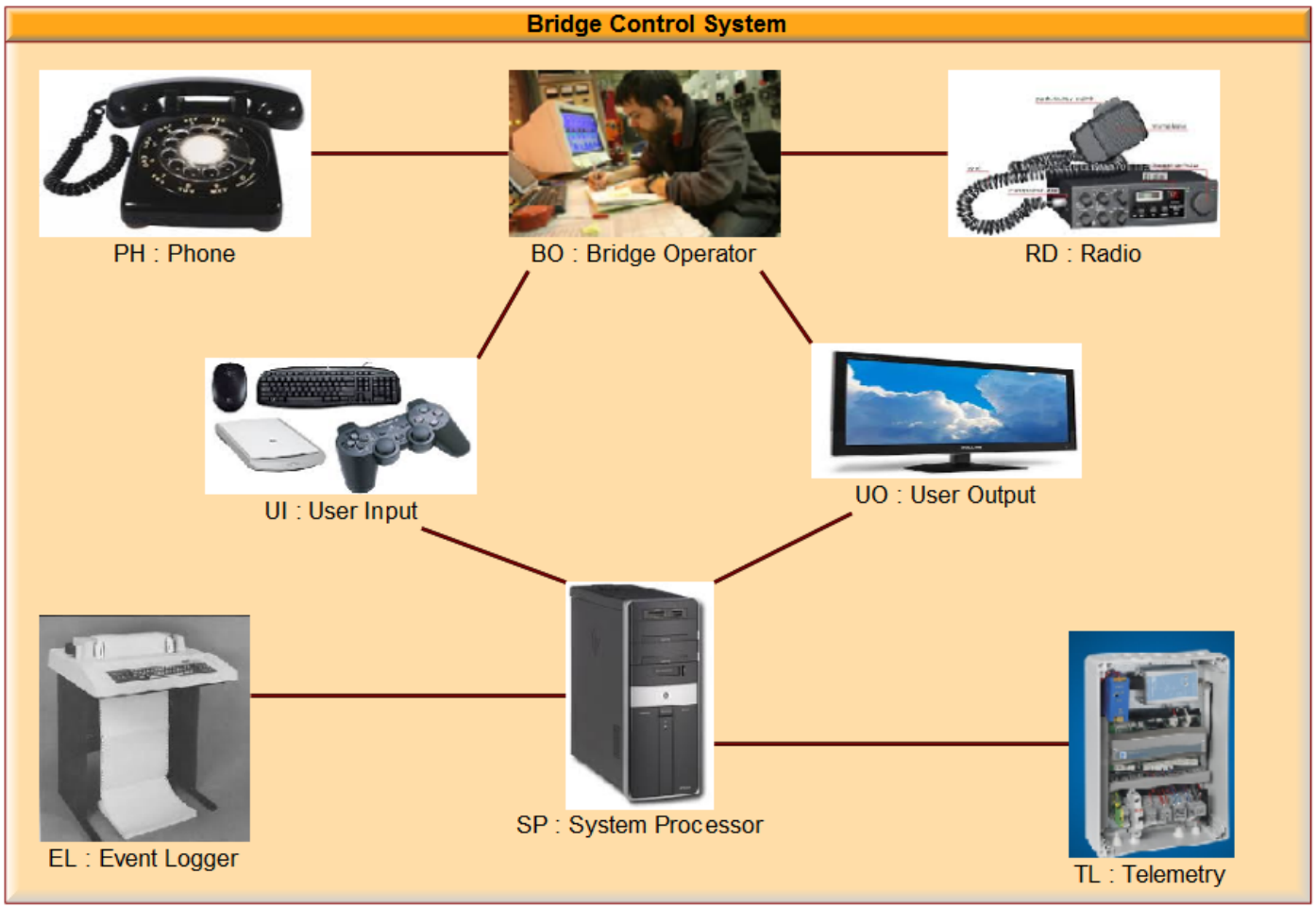
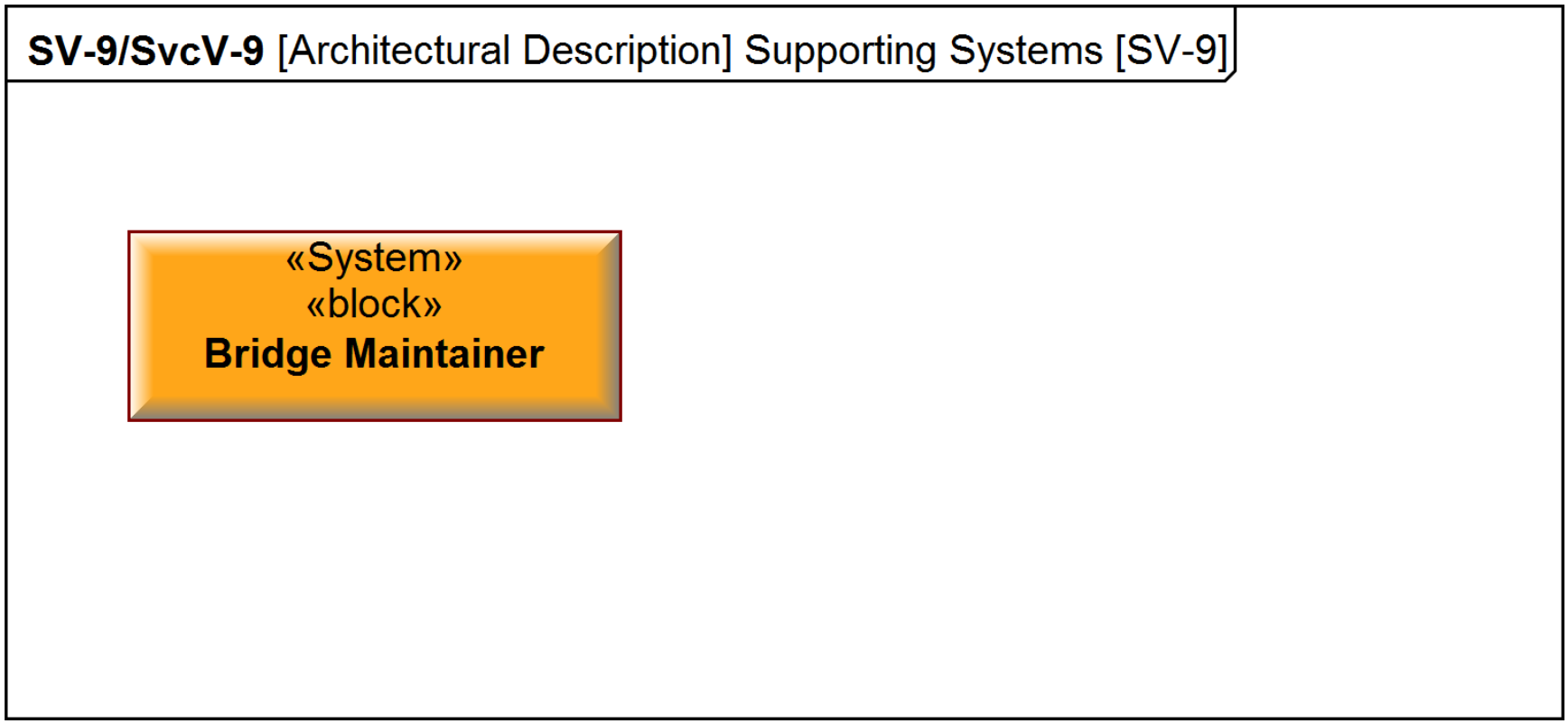
SV-1/SvcV-1 [System] Bridge Control System [SV-1]



[System] Bridge Context [SV-10c Ship Passing Sequence]

Supporting Systems



Ship Passing Sequence

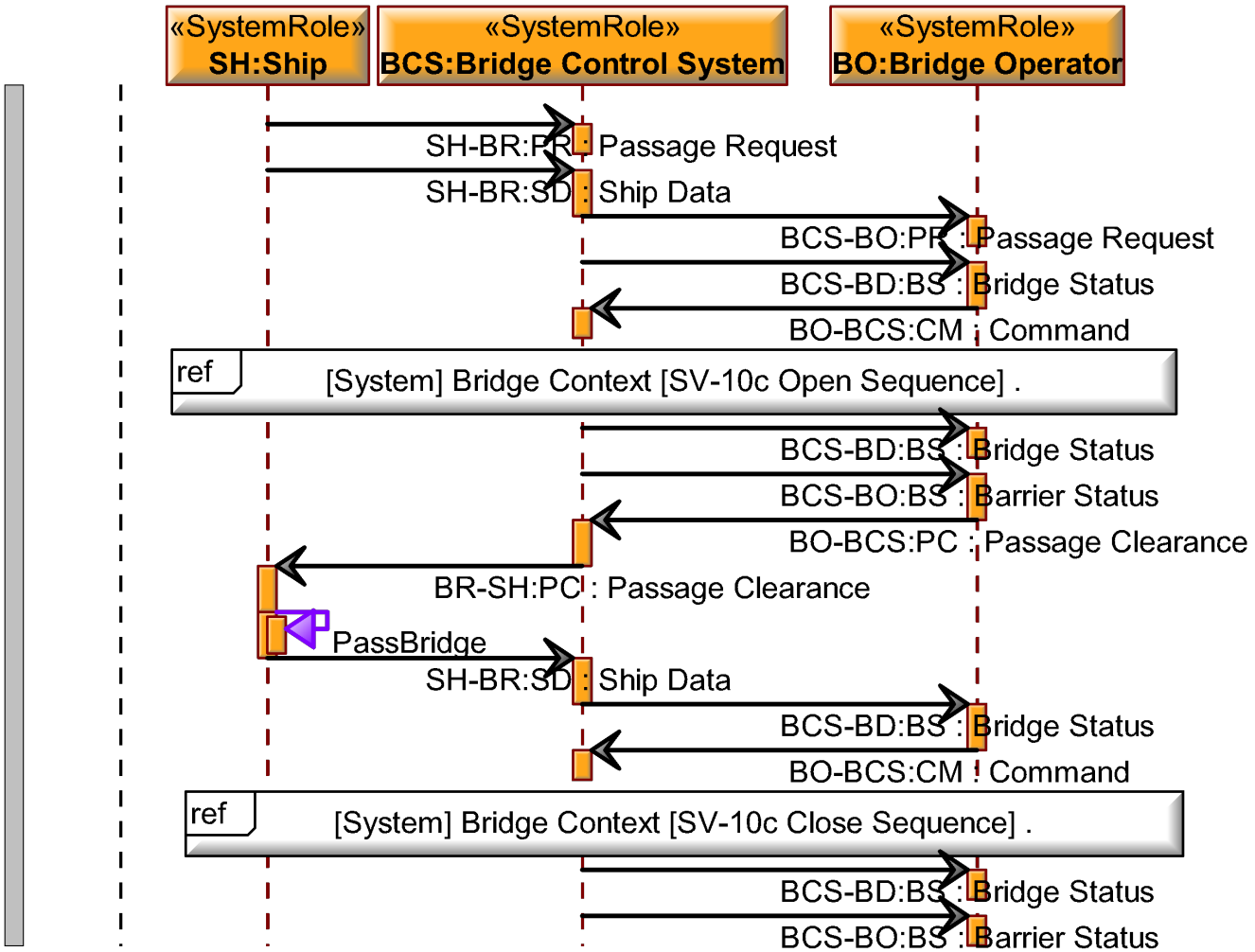
Bridge Context

Description

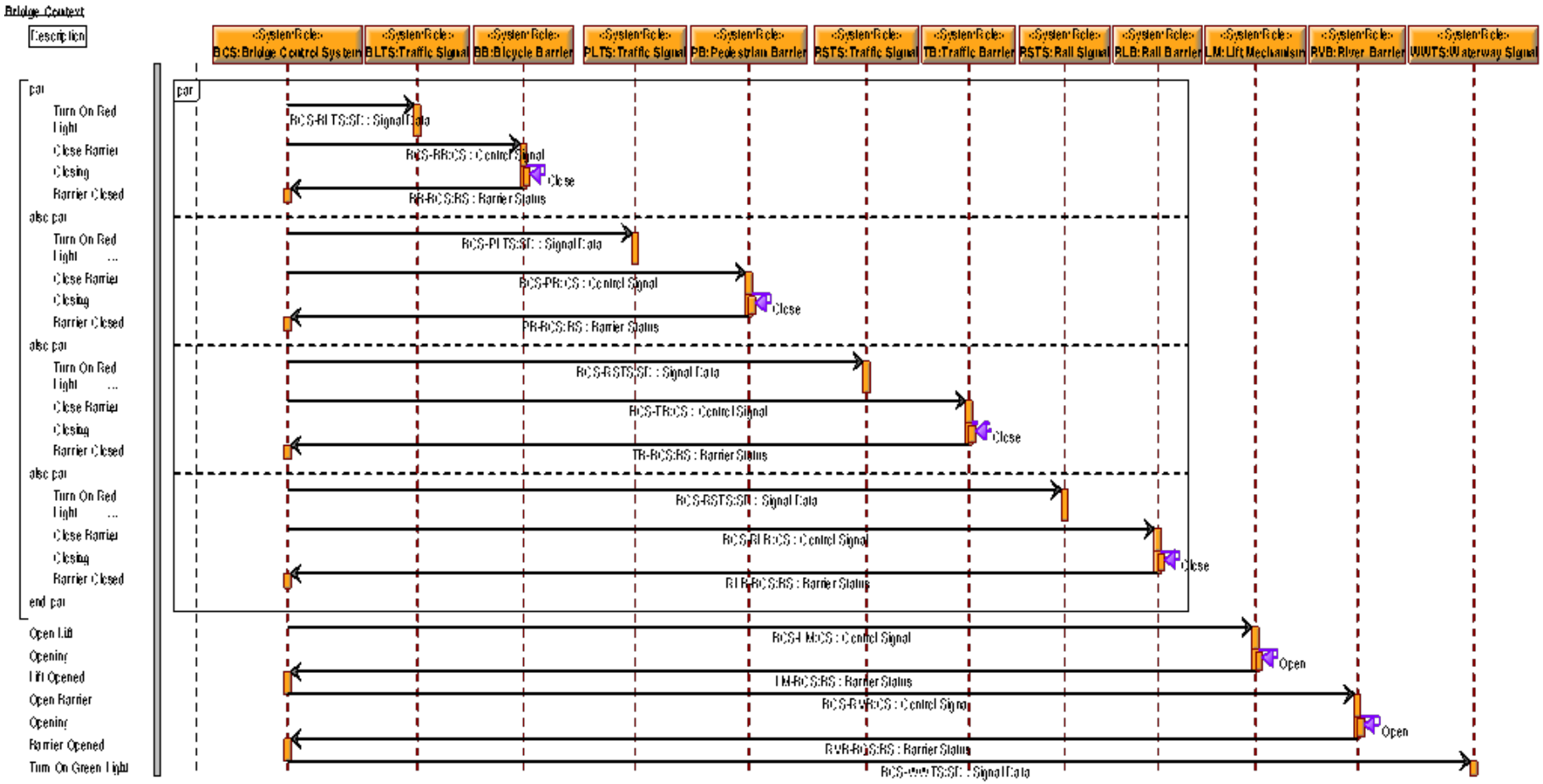
Ship Requests Passage
Ship Data Sent
Received Passage Request
Review Bridge Status
Request Bridge Lift Open
Bridge Open Sequence

Received Bridge Status
Received Lift Open
Grant Passage
Passage Granted
Ship Passes
Ship Passed
Receive Ship Passed
Request Bridge Lift Close
Bridge Close Sequence

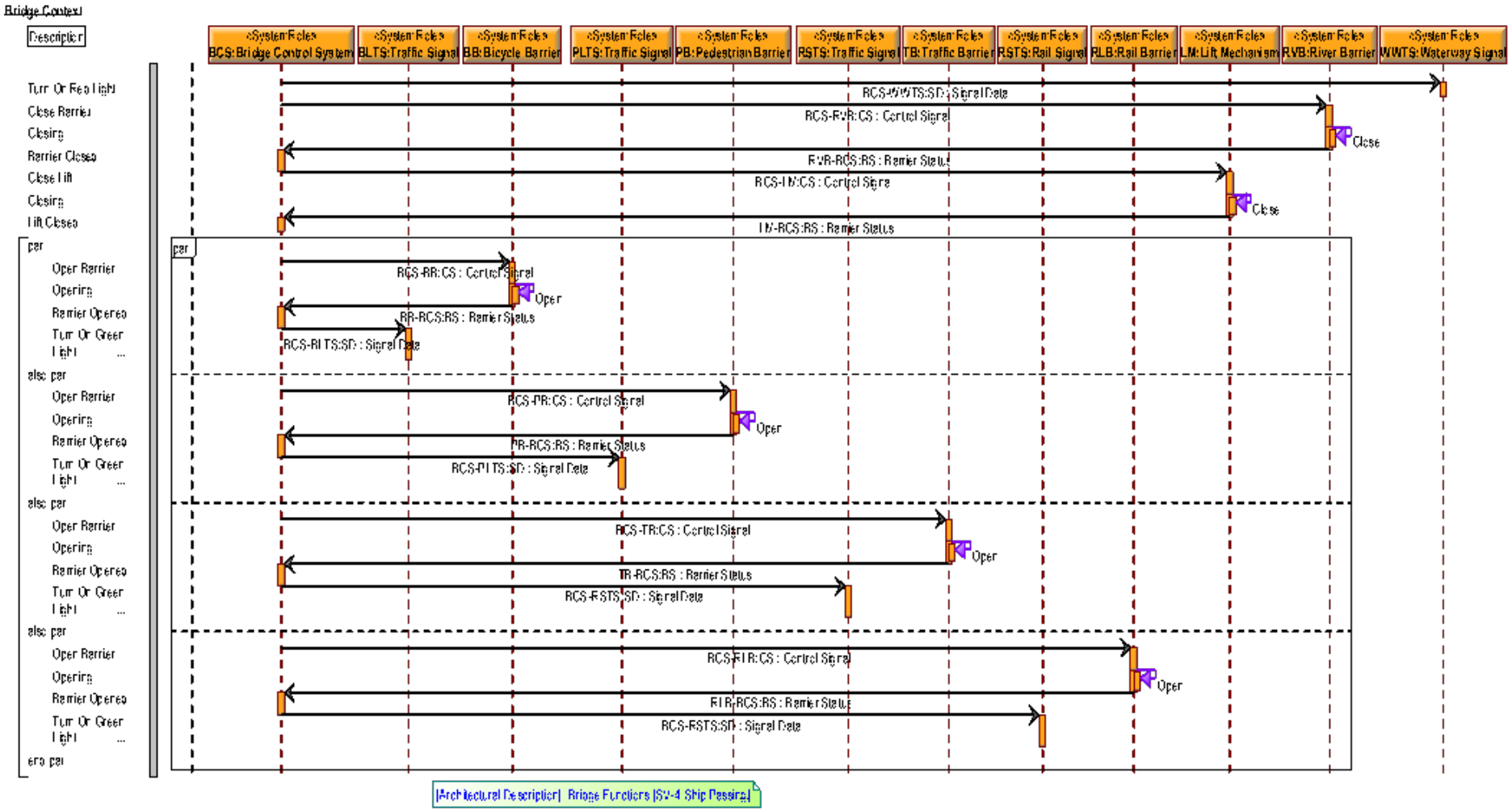
Received Bridge Status
Received Lift Status



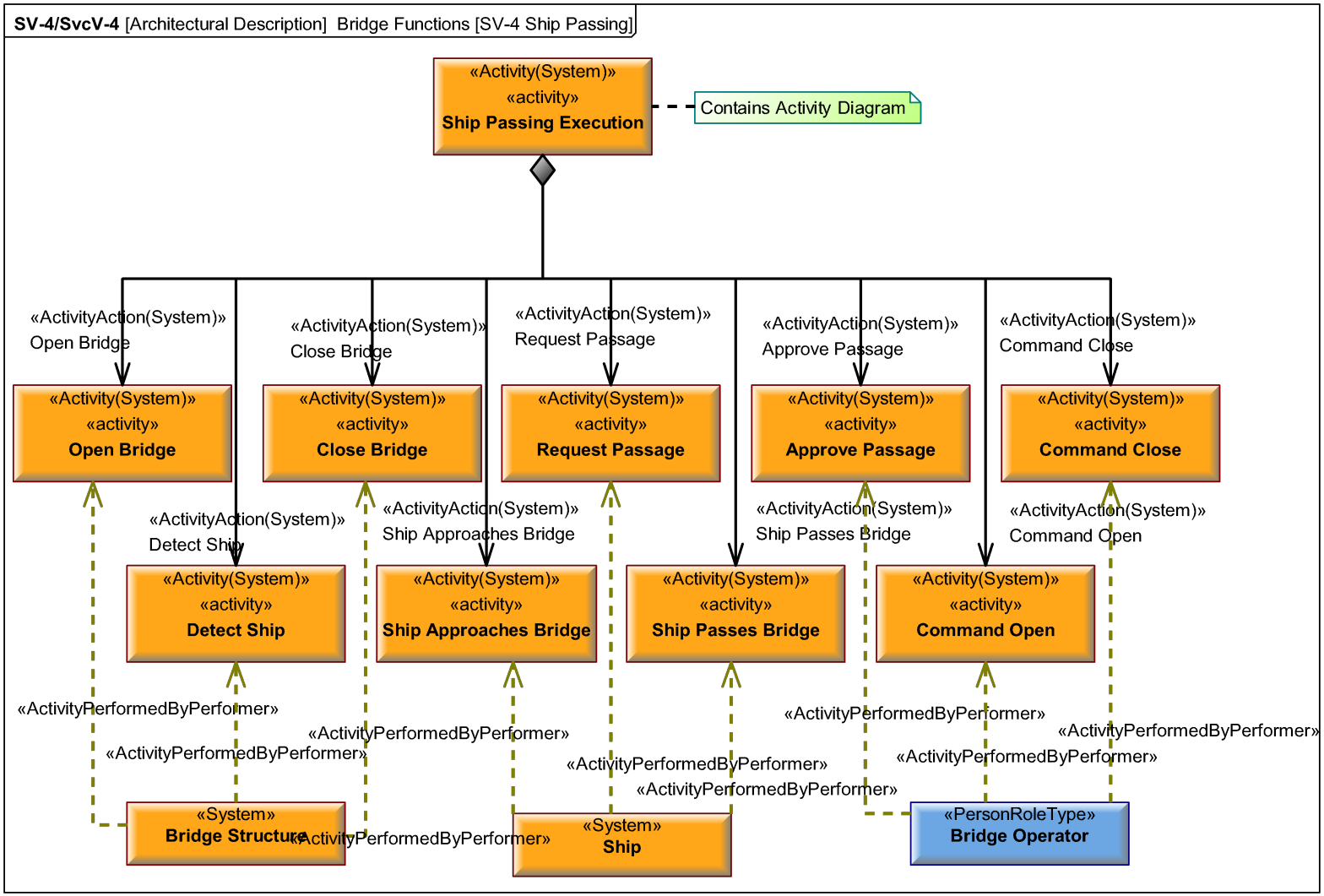
Open Drawbridge



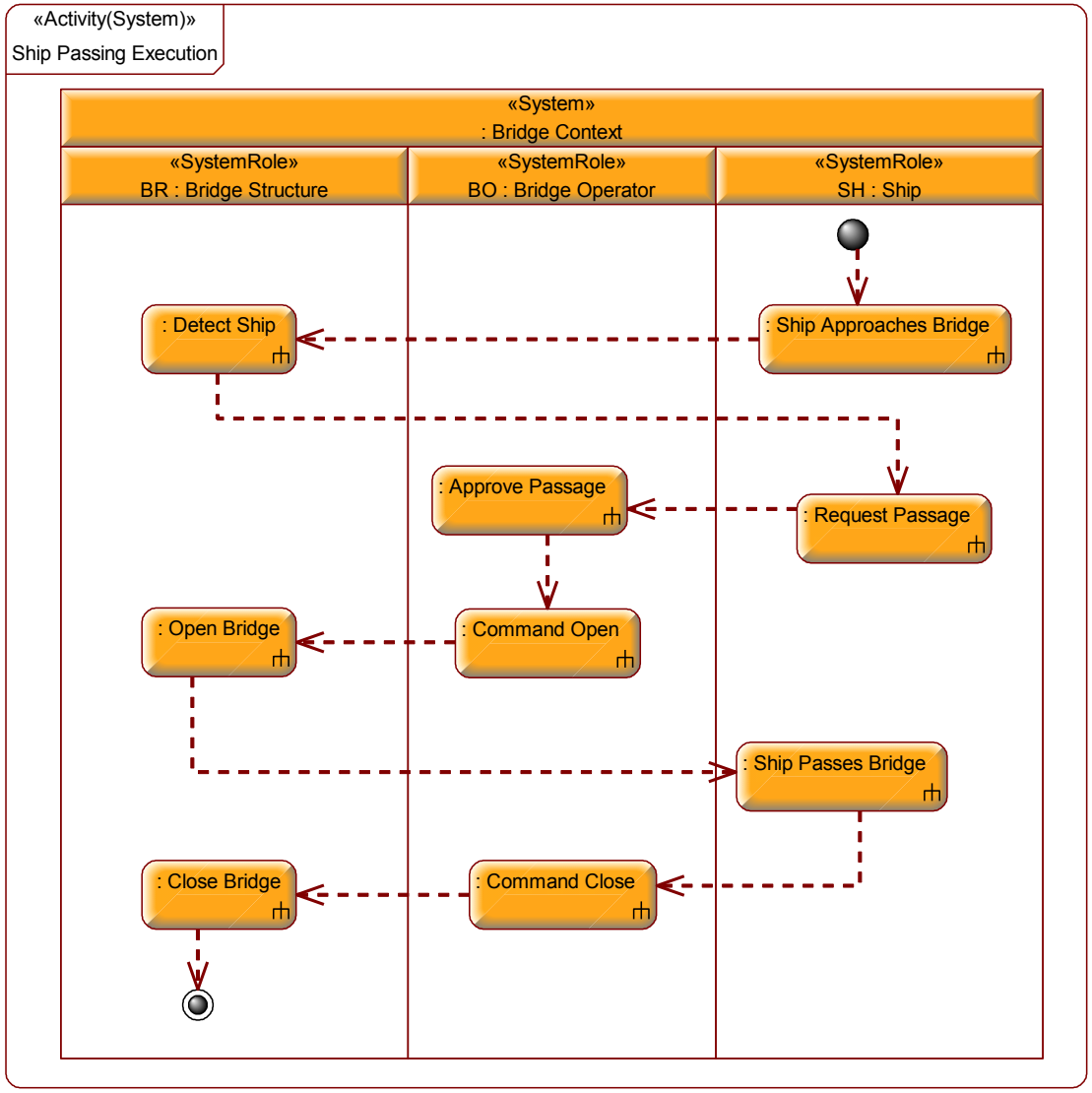
Close Drawbridge



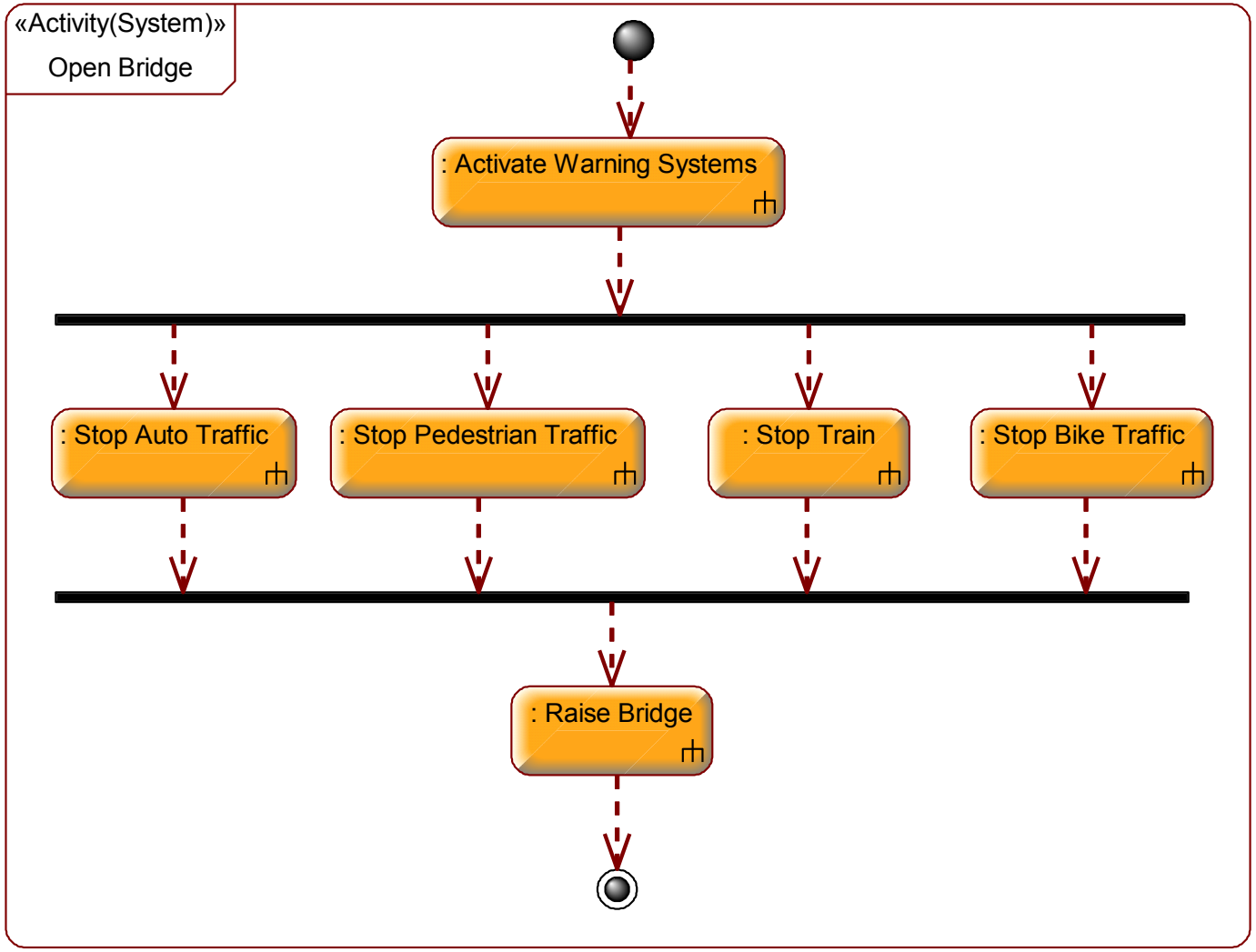
Functions of Bridge and Systems



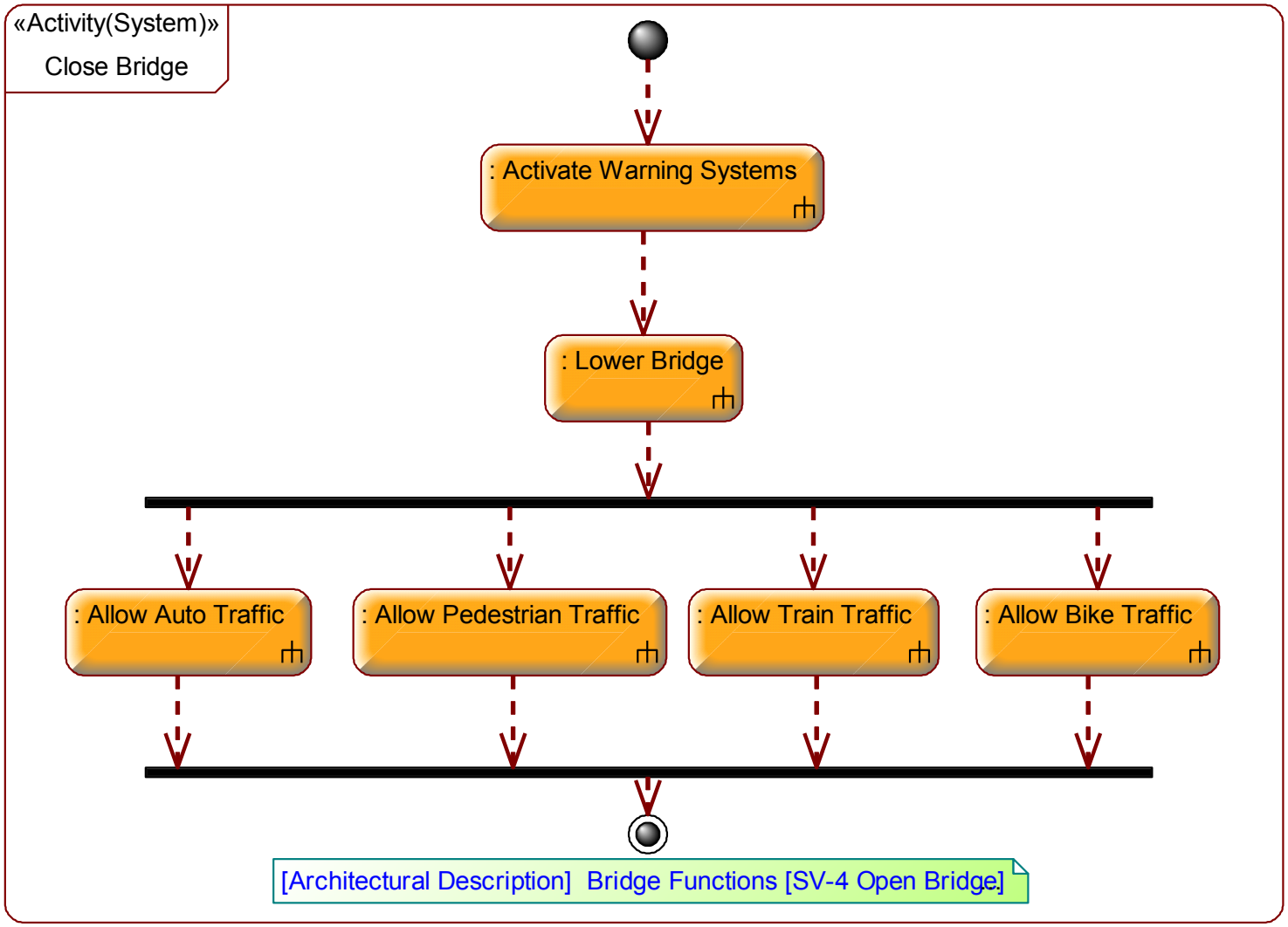
Ship Passing Sequence Activities



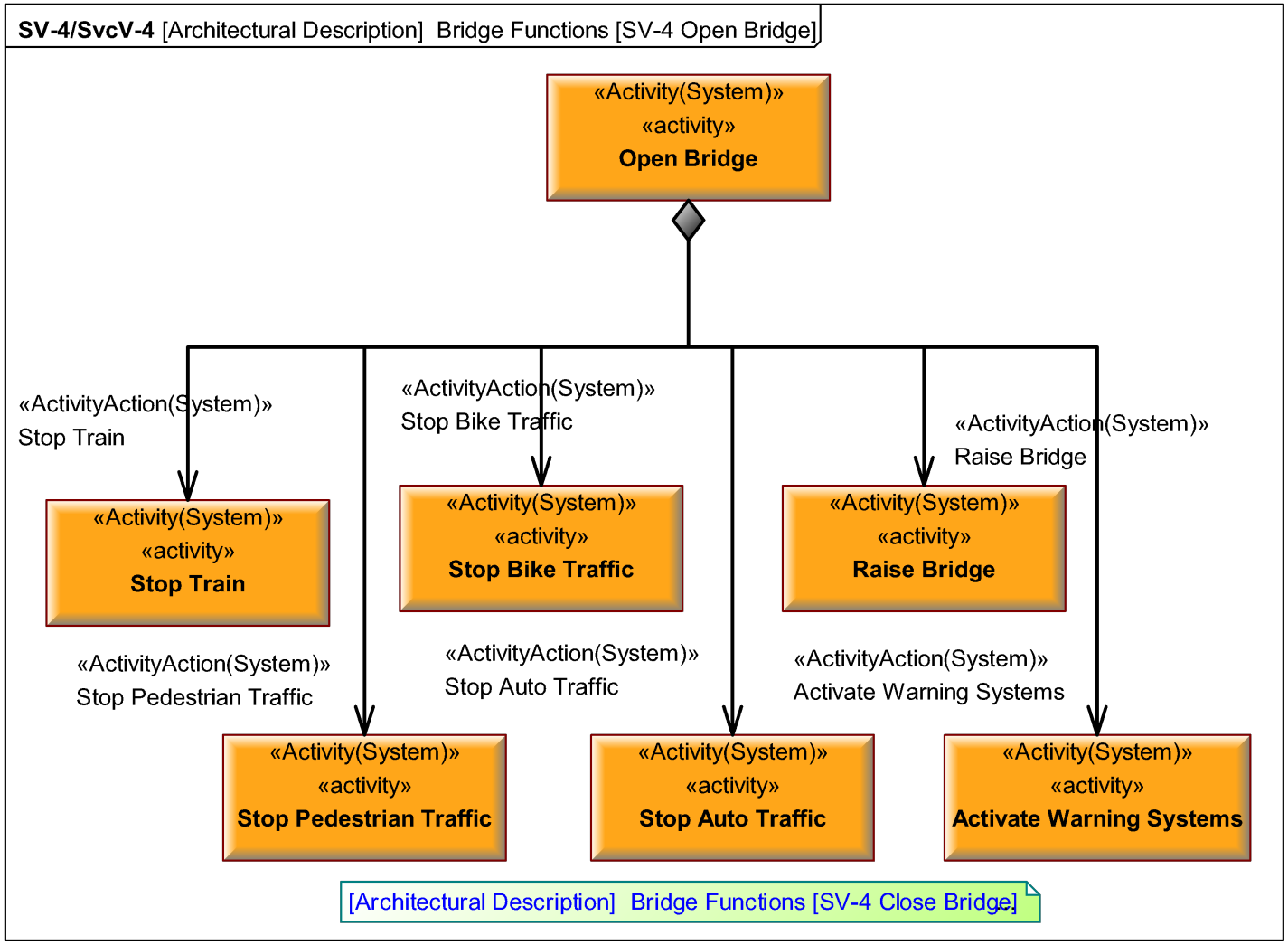
Open Bridge Activity Sequence



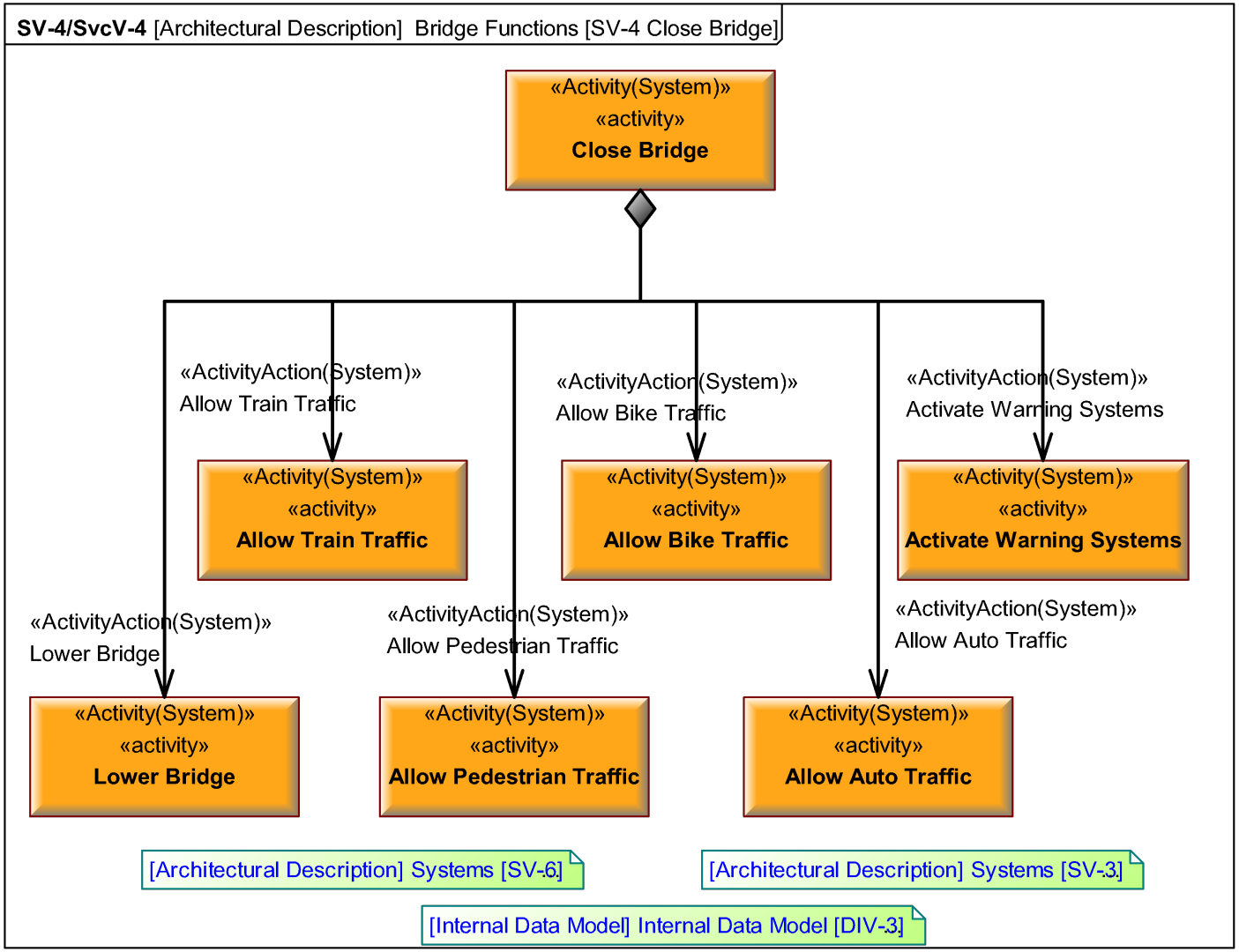
Close Bridge Activity Sequence



Functional Hierarchy of Open Bridge Activity



Functional Hierarchy of Close Bridge Activity



Generated Interface Report (Partial)

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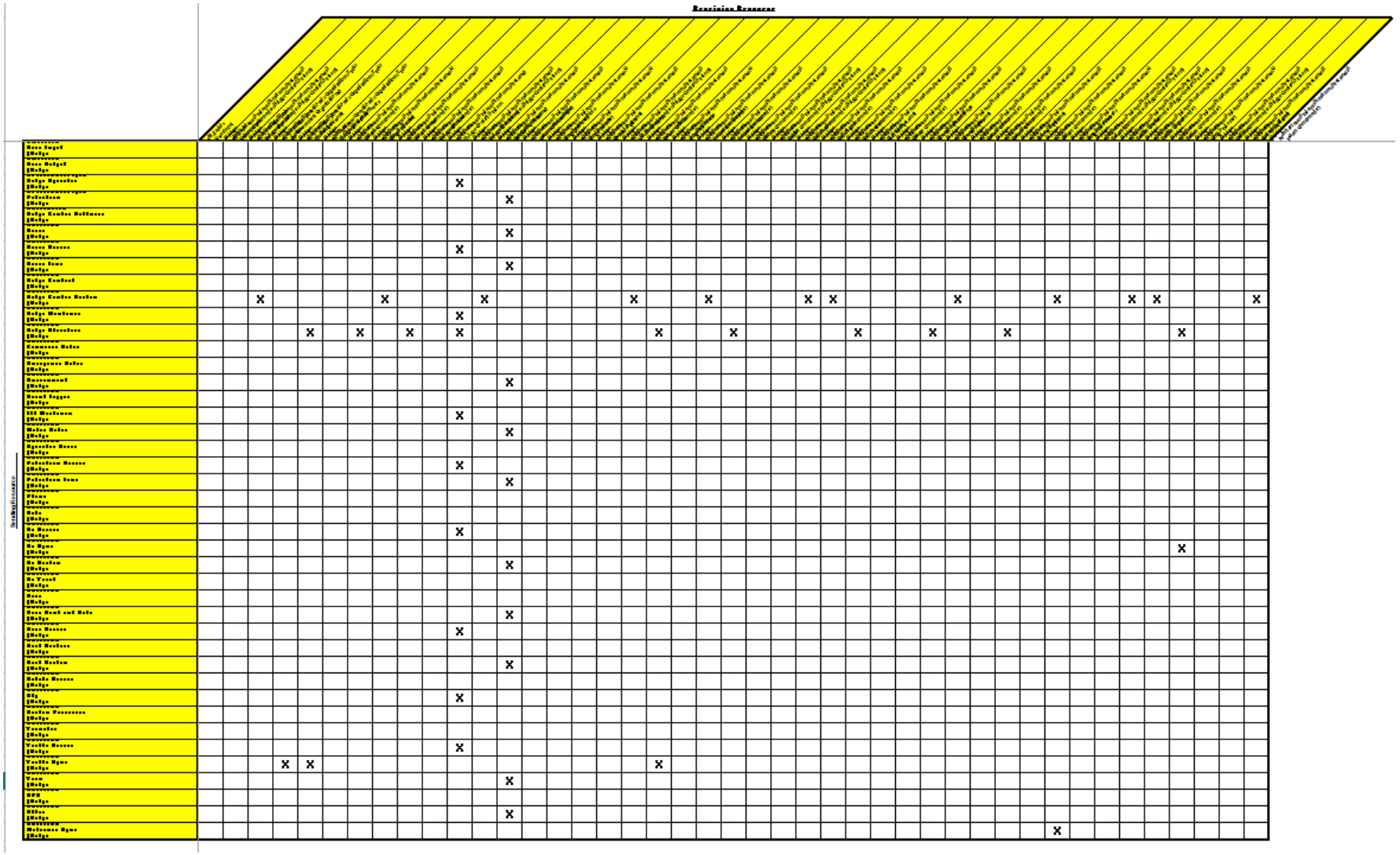
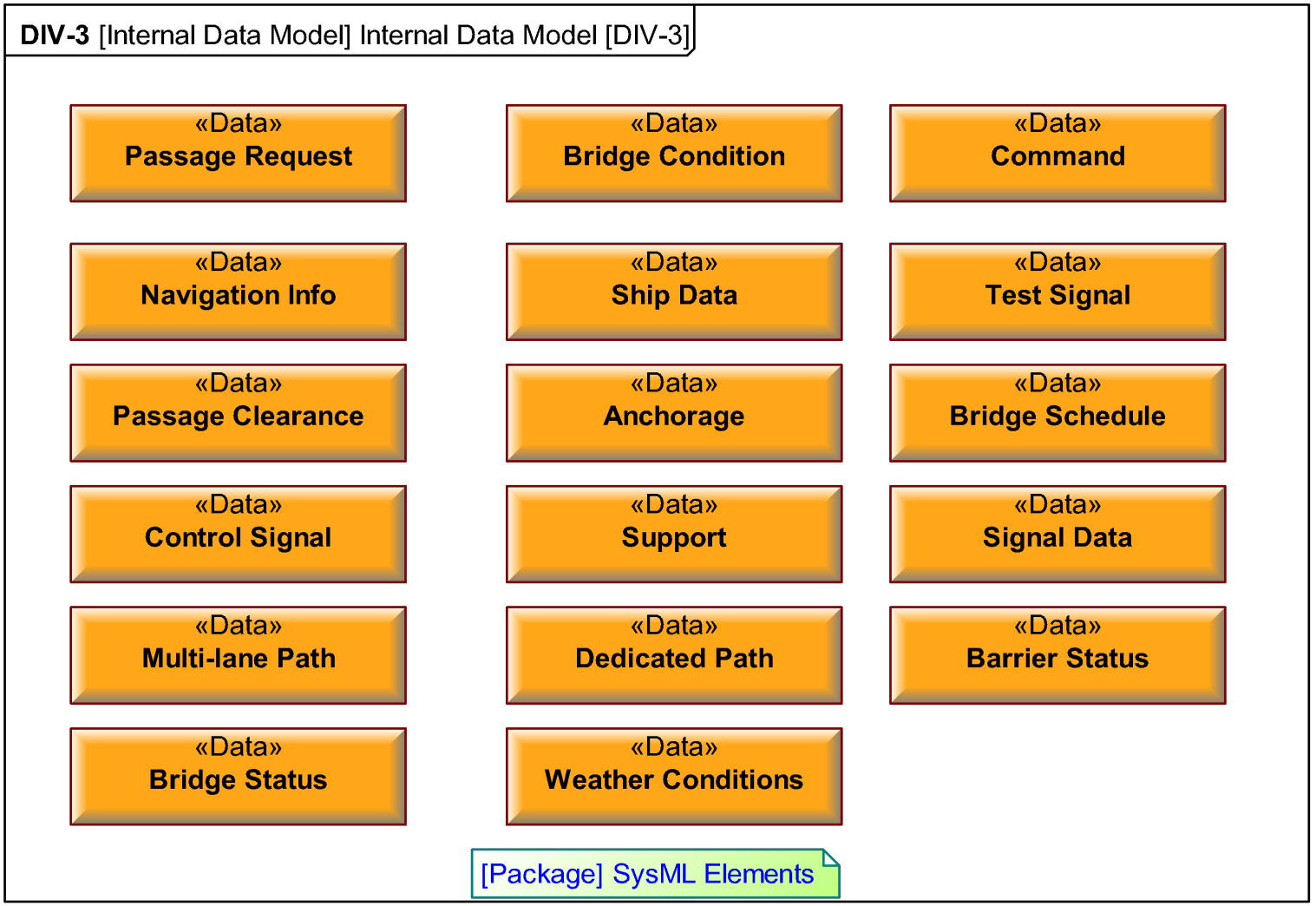
[Architectural Description] Systems [SV-6]

Resource Interaction		Producer		Connector /		Consumer	
Name	Conveyed	Resource	Activity (System)	Name	Protocol	Resource	Activity (System)
BB-BCS:BS	«Data» Barrier Status	«System» Bicycle Barrier		System Interface		«System» Bridge Control System	
BCS-BB:CS	«Data» Control Signal	«System» Bridge Control System		System Interface		«System» Bicycle Barrier	
BCS-BD:BS	«Data» Bridge Status	«System» Bridge Control System		System Interface		«Person Role Type» Bridge Operator	
BCS-BLTS:SD	«Data» Signal Data	«System» Bridge Control System		System Interface		«System» Traffic Signal	
BCS-BO:BC	«Data» Bridge Condition	«System» Bridge Control System		System Interface		«Person Role Type» Bridge Operator	
BCS-BO:BS	«Data» Barrier Status	«System» Bridge Control System		System Interface		«Person Role Type» Bridge Operator	
BCS-BO:PR	«Data» Passage Request	«System» Bridge Control System		System Interface		«Person Role Type» Bridge Operator	
BCS-PB:CS	«Data» Control Signal	«System» Bridge Control System		System Interface		«System» Pedestrian Barrier	
BCS-PLTS:SD	«Data» Signal Data	«System» Bridge Control System		System Interface		«System» Traffic Signal	
BCS-RLB:CS	«Data» Control Signal	«System» Bridge Control System		System Interface		«System» Rail Barrier	
BCS-RSTS:SD	«Data» Signal Data	«System» Bridge Control System		System Interface		«System» Traffic Signal	
BCS-RSTS:SD	«Data» Signal Data	«System» Bridge Control System		System Interface		«System» Rail Signal	
BCS-RVB:CS	«Data» Control Signal	«System» Bridge Control System		System Interface		«System» River Barrier	
BCS-TB:CS	«Data» Control Signal	«System» Bridge Control System		System Interface		«System» Traffic Barrier	
BCS-WWTS:SD	«Data» Signal Data	«System» Bridge Control System		System Interface		«System» Waterway Signal	
BK-BR:DL	«Energy» Dynamic Load	«System» Bicycle		System Interface		«System» Bridge Structure	

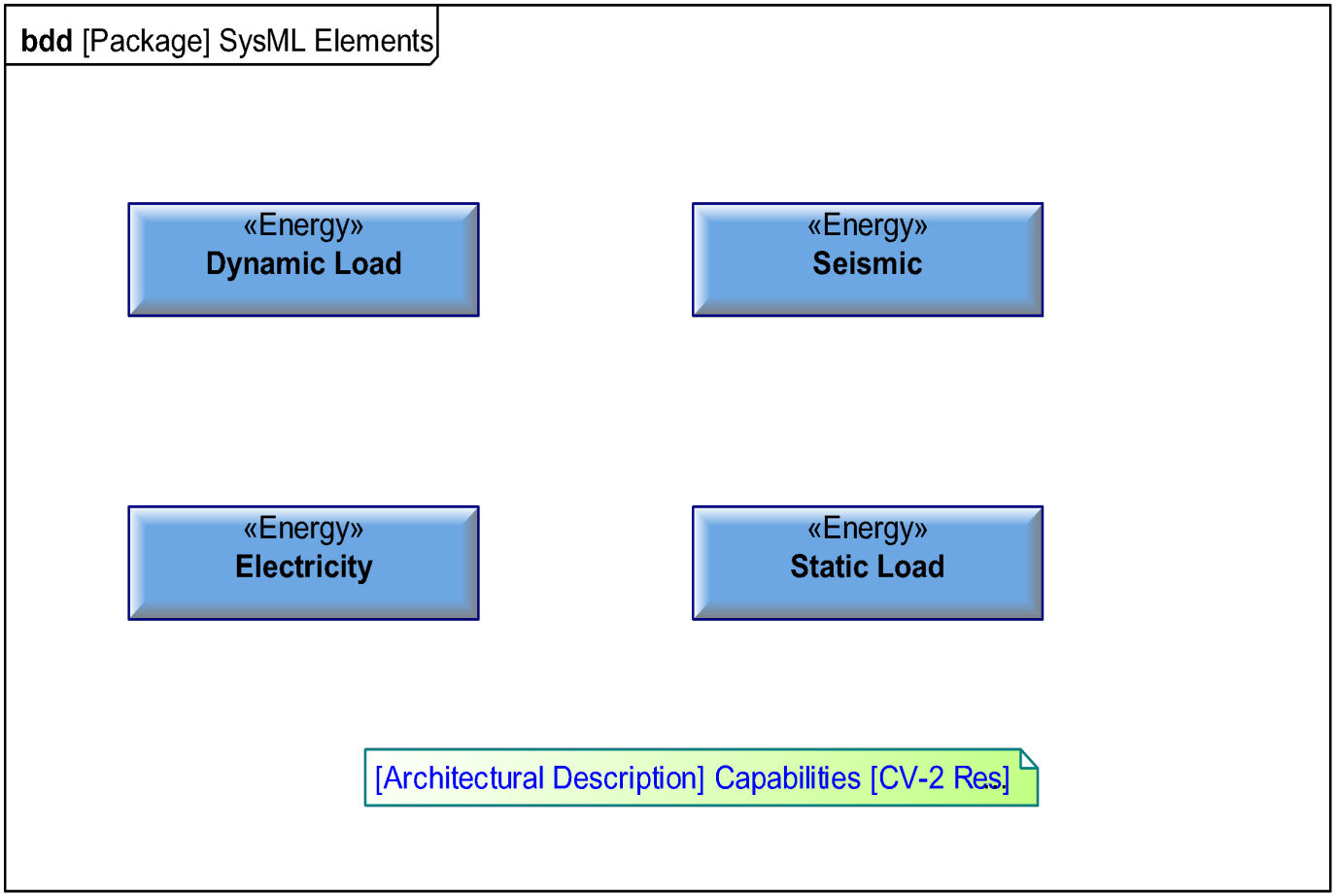
SV-3 Bridge Systems Interface Matrix



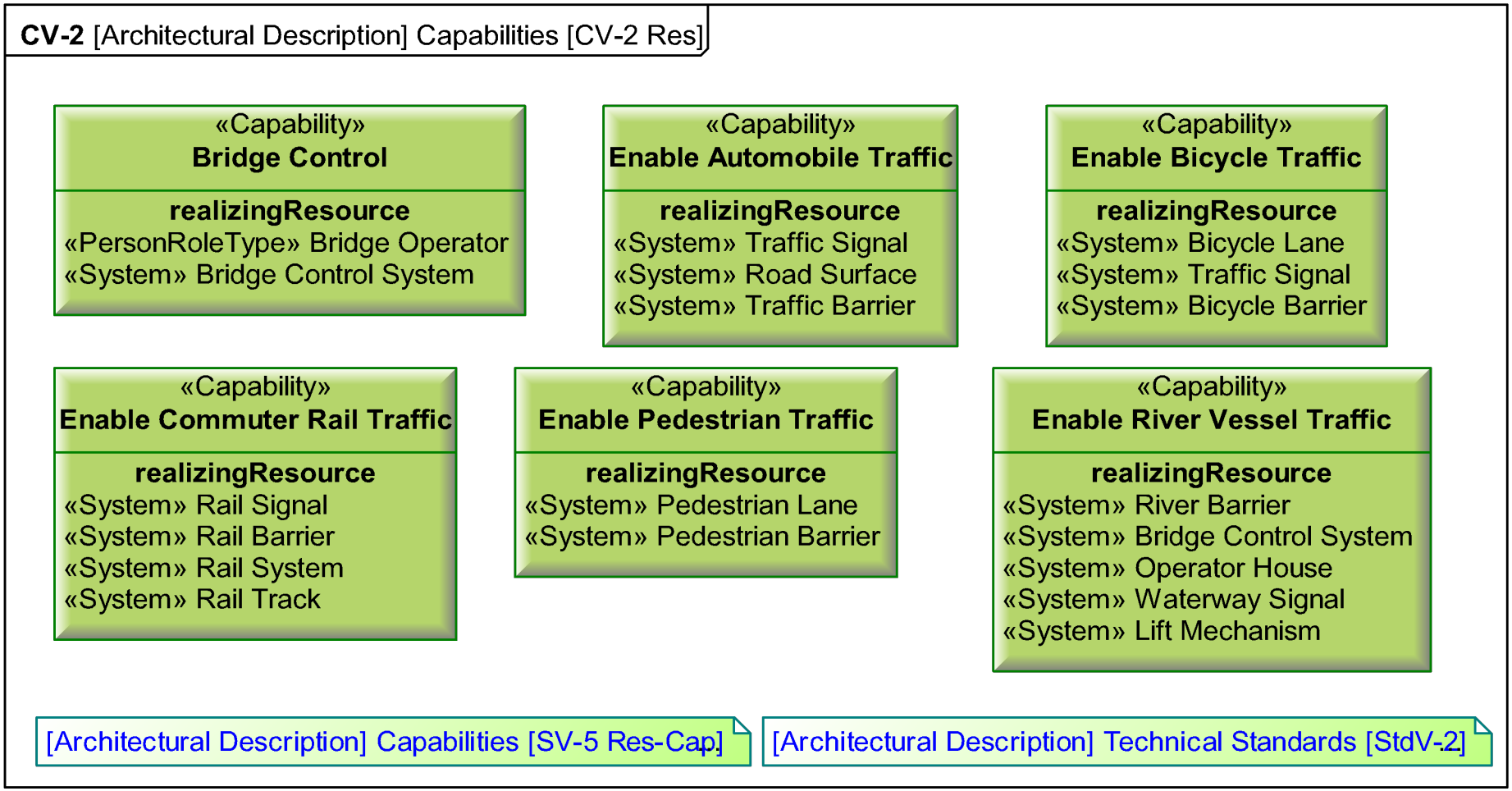
Bridge Data


DIV-3 [Internal Data Model] Internal Data Model [DIV-3]
«Data» Passage Request
«Data» Bridge Condition
«Data» Command
«Data» Navigation Info
«Data» Ship Data
«Data» Test Signal
«Data» Passage Clearance
«Data» Anchorage
«Data» Bridge Schedule
«Data» Control Signal
«Data» Support
«Data» Signal Data
«Data» Multi-lane Path
«Data» Dedicated Path
«Data» Barrier Status
«Data» Bridge Status
«Data» Weather Conditions
[Package] SysML Elements

Non-Data Interface Definitions



Bridge Capabilities and Supporting Systems



System to Capabilities Cross Reference Matrix

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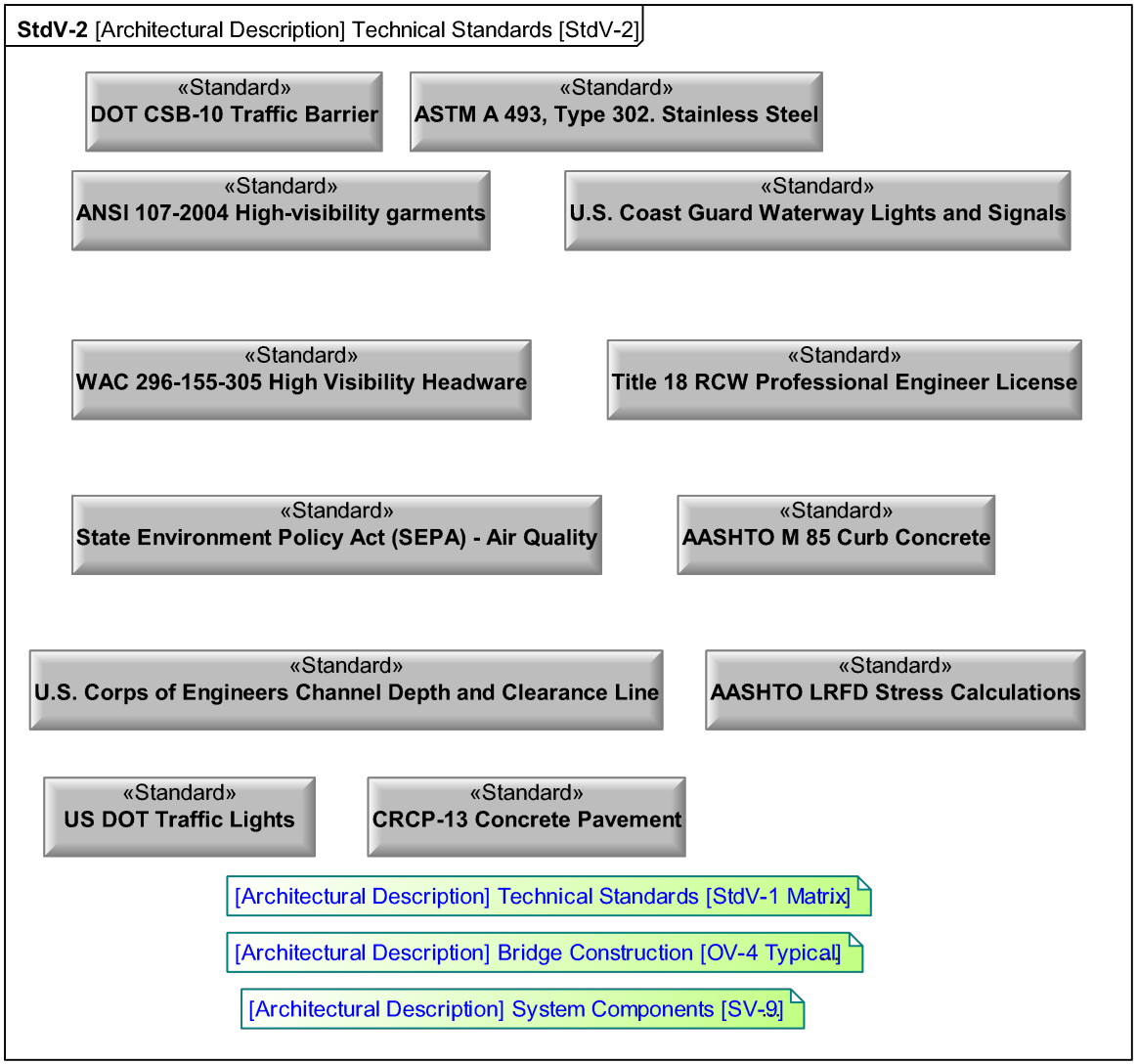
[Architectural Description] Capabilities [SV-5 Res-Cap]

Realizing Resource	«Capability» Bridge Control	«Capability» Enable Automobile Traffic	«Capability» Enable Bicycle Traffic	«Capability» Enable Commuter Rail Traffic	«Capability» Enable Pedestrian Traffic	«Capability» Enable River Vessel Traffic
«PersonRoleType» Bridge Operator	X					
«System» Bicycle Barrier			X			
«System» Bicycle Lane			X			
Bridge Control System	X					X
«System» Lift Mechanism						X
«System» Operator House						X
«System» Pedestrian Barrier					X	
«System» Pedestrian Lane					X	
«System» Rail Barrier				X		
«System» Rail Signal				X		
«System» Rail System				X		
«System» Rail Track				X		
«System» River Barrier						X
«System» Road Surface		X				
«System» Traffic Barrier		X				
«System» Traffic Signal		X	X			
«System» Waterway Signal						X

Construction and Operational Standards



Standards Compliance Matrix

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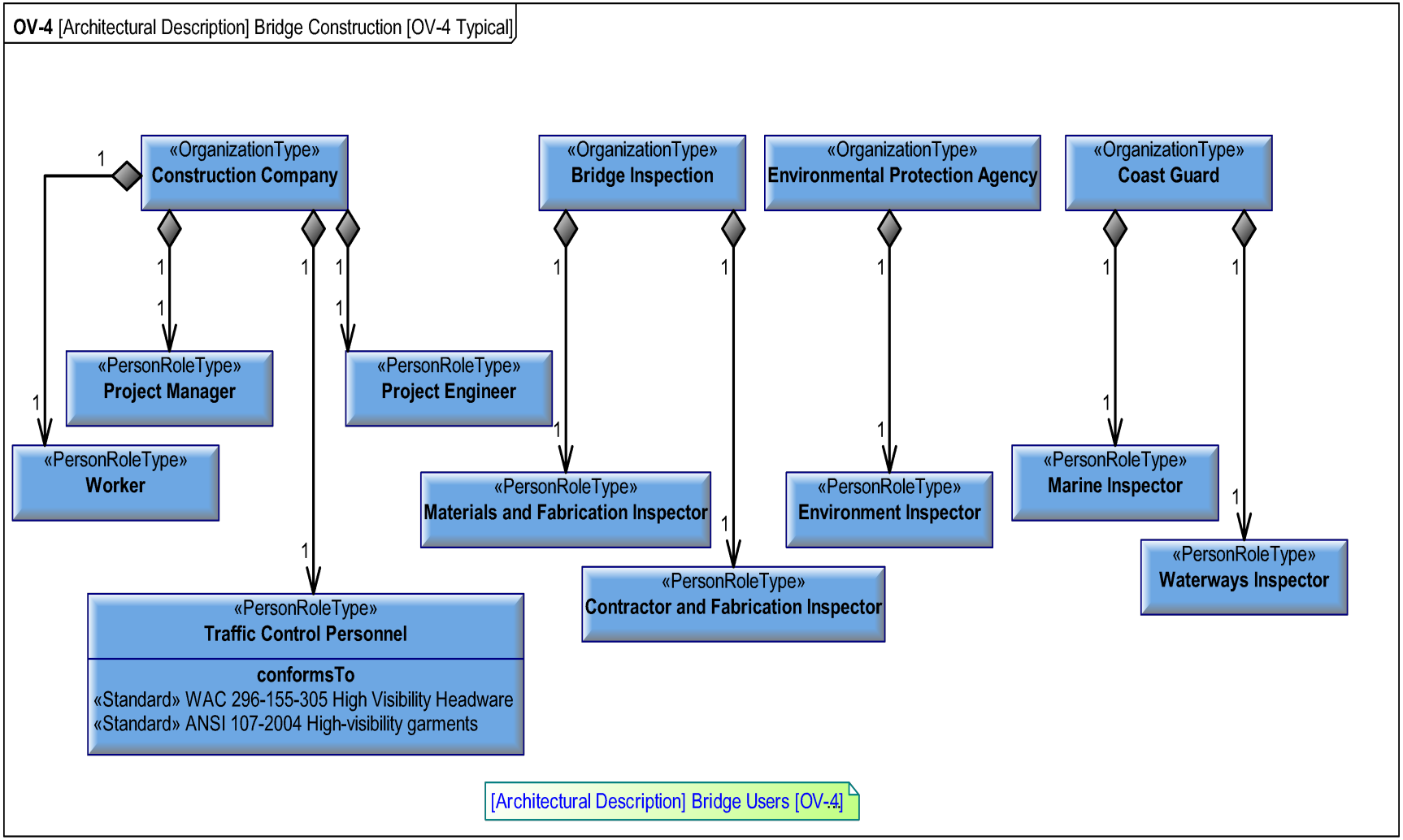
[Architectural Description] Technical Standards [StdV-1 Matrix]

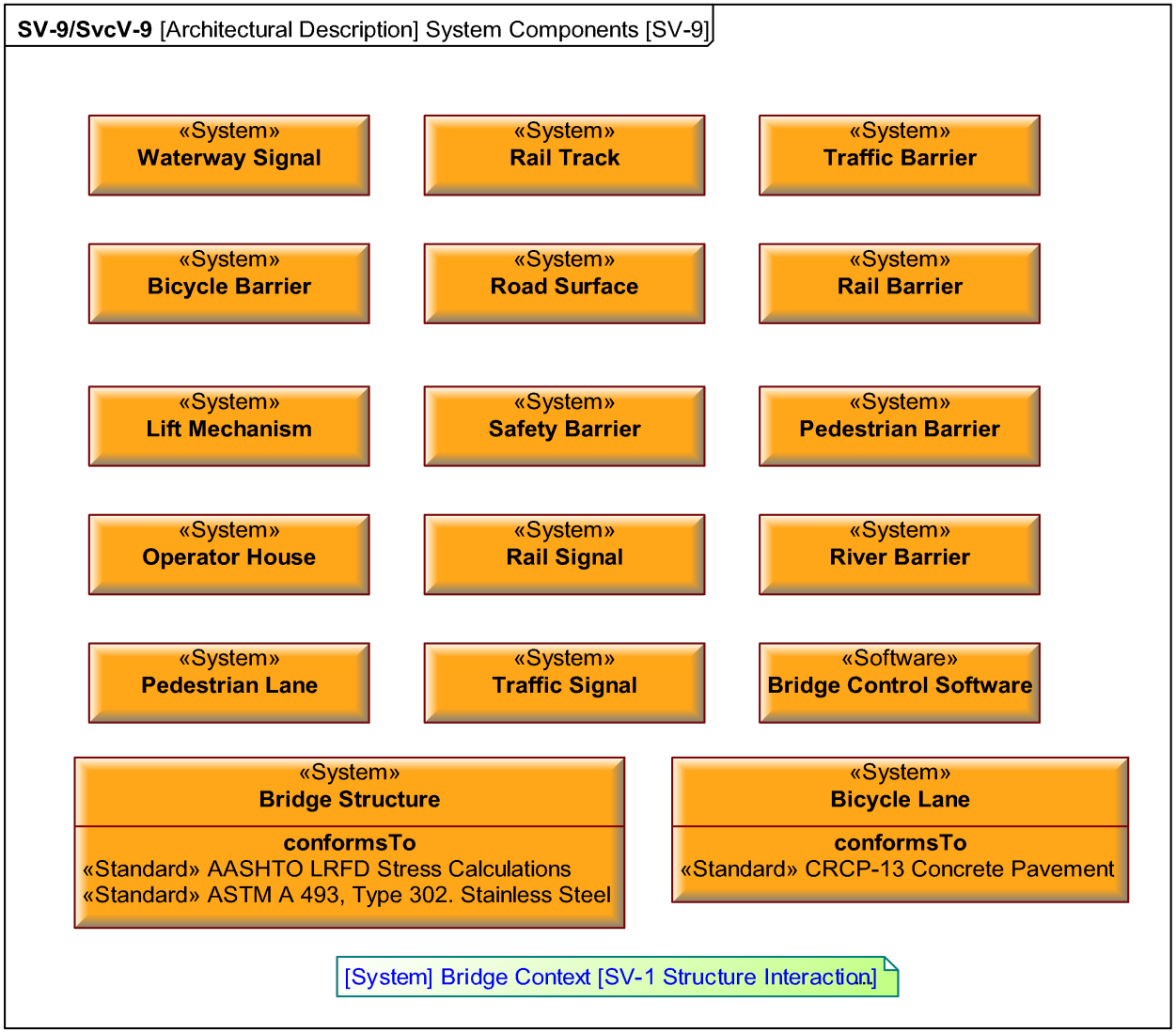
Standards

Conforming Elements	«Standard» AASHTO LRFD Stress Calculations (Bridge Architecture::Technical Standards)	«Standard» AASHTO M 85 Curb Concrete (Bridge Architecture::Technical Standards)	«Standard» ANSI 107-2004 High-visibility garments (Bridge Architecture::Technical Standards)	«Standard» ASTM A 493, Type 302, Stainless Steel (Bridge Architecture::Technical Standards)	«Standard» CRCP-13 Concrete Pavement (Bridge Architecture::Technical Standards)	«Standard» DOT CSD-10 Traffic Barrier (Bridge Architecture::Technical Standards)	«Standard» State Environment Policy Act (SEPA) - Air Quality (Bridge Architecture::Technical Standards)	«Standard» Title 18 RCW Professional Engineer Licenses (Bridge Architecture::Technical Standards)	«Standard» U.S. Coast Guard Waterway Lights and Signals (Bridge Architecture::Technical Standards)	«Standard» U.S. Corps of Engineers Channel Depth and Clearance Line (Bridge Architecture::Technical Standards)	«Standard» US DOT Traffic Lights (Bridge Architecture::Technical Standards)	«Standard» WAC 296-155-305 High Visibility Headware (Bridge Architecture::Technical Standards)
Bicycle Lane (Bridge Architecture::System::Structure::Systems::System Components)					X							
Bridge Structure (Bridge Architecture::System::Structure::Systems::System Components)	X			X								
Environment (Bridge Architecture::System::Structure::Systems::External Systems)							X					
Pedestrian Lane (Bridge Architecture::System::Structure::Systems::System Components)					X							
Project Engineer (Bridge Architecture::Operational::Organization::Typical::Bridge								X				
Project Manager (Bridge Architecture::Operational::Organization::Typical::Bridge								X				
River (Bridge Architecture::System::Structure::Systems::External Systems)										X		
Road Surface (Bridge Architecture::System::Structure::Systems::System Components)		X			X							
Safety Barrier (Bridge Architecture::System::Structure::Systems::System Components)						X						
Traffic Control Personnel (Bridge Architecture::Operational::Organization::Typical::Bridge			X									X
Traffic Signal (Bridge Architecture::System::Structure::Systems::System Components)											X	
Waterway Signal (Bridge Architecture::System::Structure::Systems::System Components)									X			
Worker (Bridge Architecture::Operational::Organization::Typical::Bridge			X									X

Standards Conformance Example – Human



Standards Conformance Example – System

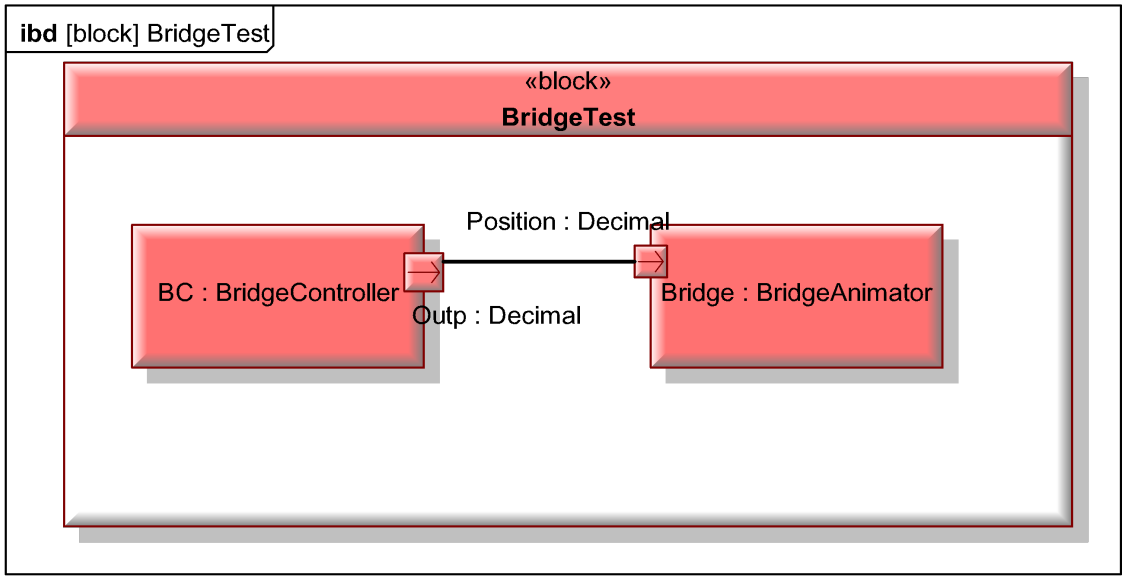


System Simulation - Overview

- Done with behavior-based diagrams
  - State Diagrams
  - Activity Diagrams
- Useful to:
  - Verify system functionality
  - Validate user requirements
  - Create user interface prototypes
- Implementation largely dependent on individual tools

System Simulation – Simulation Context

- The BridgeTest Block defines the context for the simulation
  - Made up of a Bridge Controller and Bridge Animator
  - Behavior is executed with state diagrams
  - A very simple example to elicit further discussion

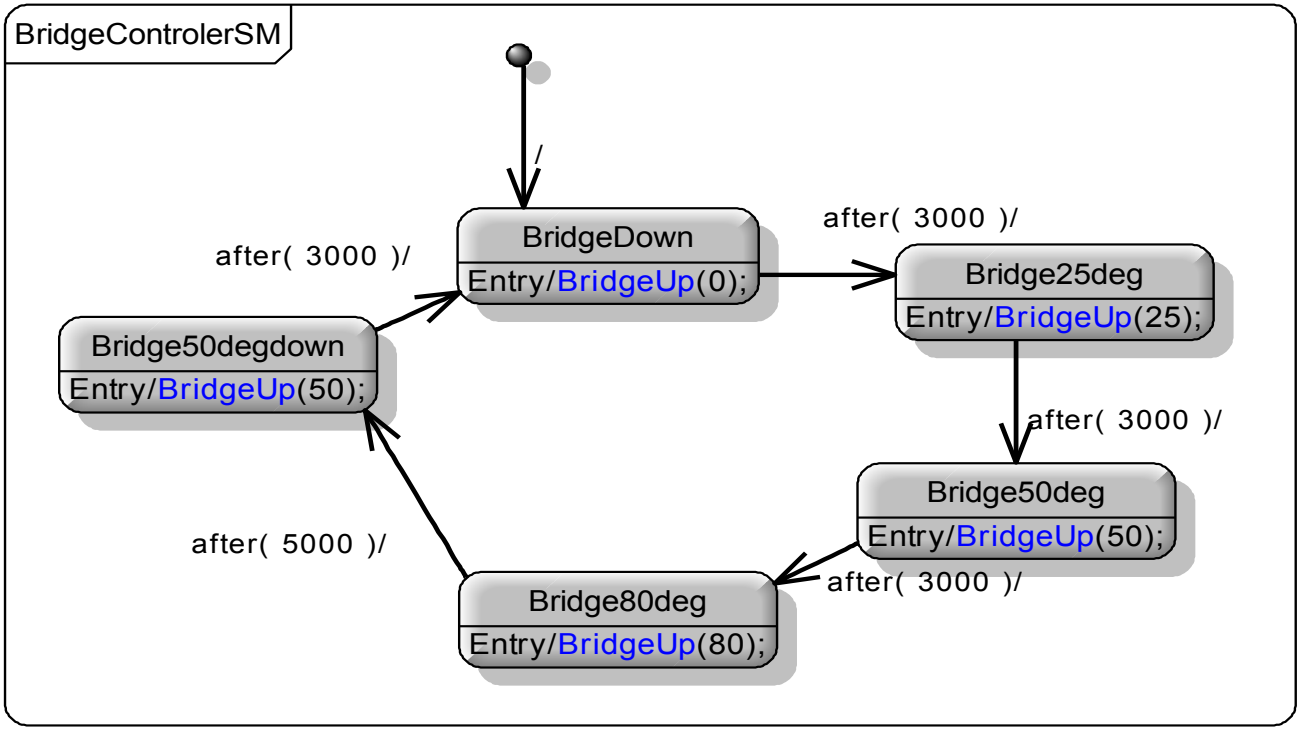


System Simulation – Controller State Diagram

- Defines the various states of the system

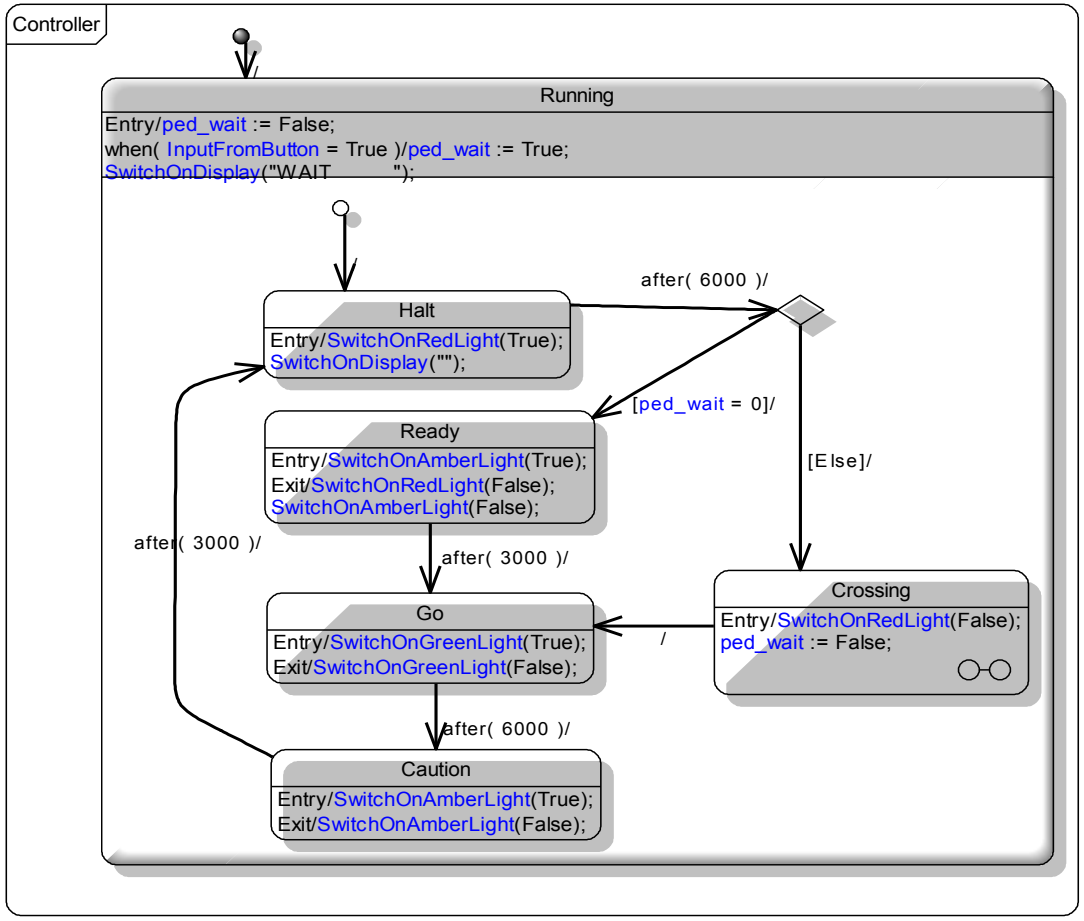
  In this simple example, the bridge is raised and lowered periodically.
  - Time based simulation

  Controls can be added to simulate a user interface
  - Event based simulation

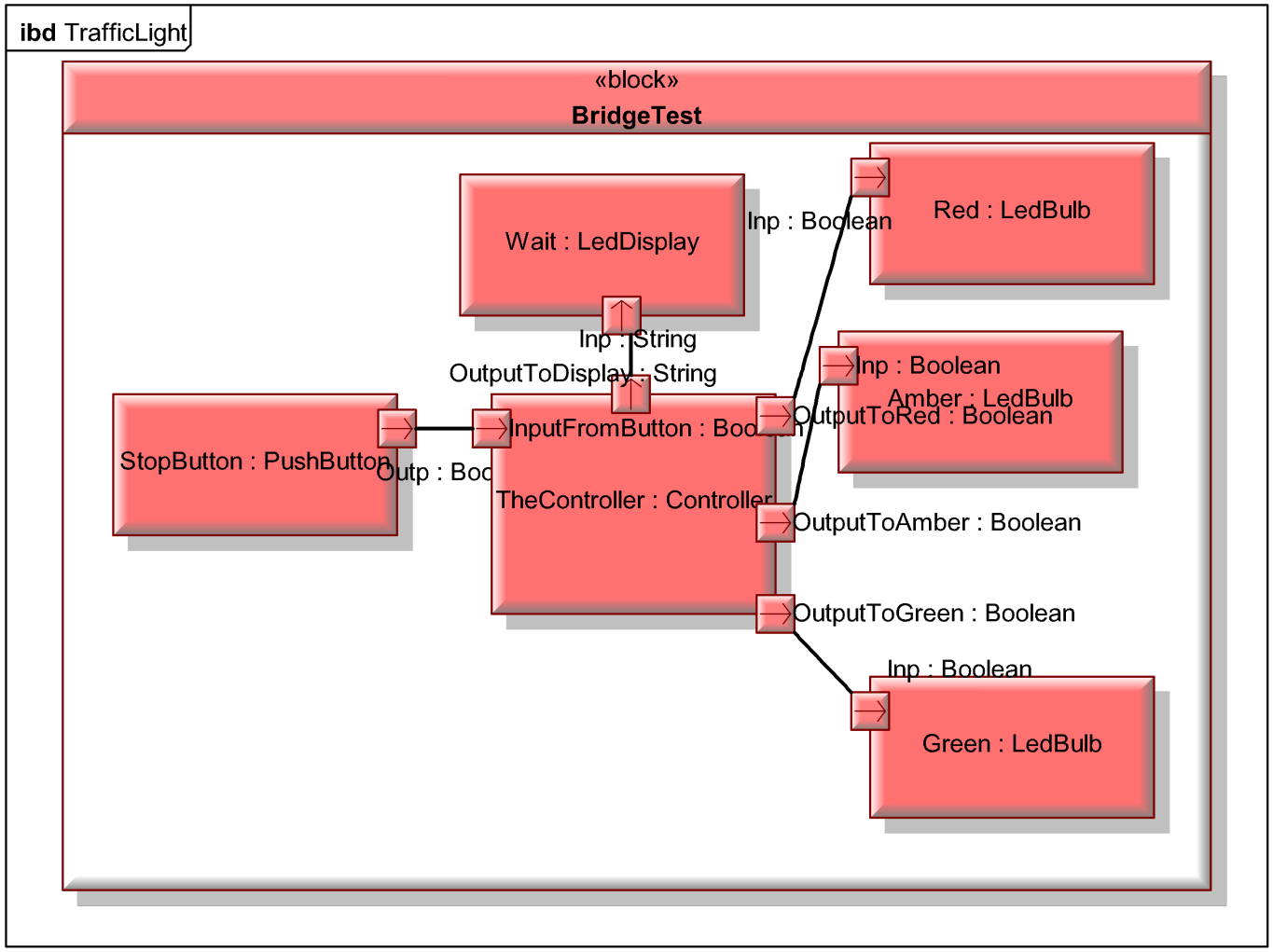


System Simulation – Traffic Light State Diagram

- Warning light state diagram – also time driven.

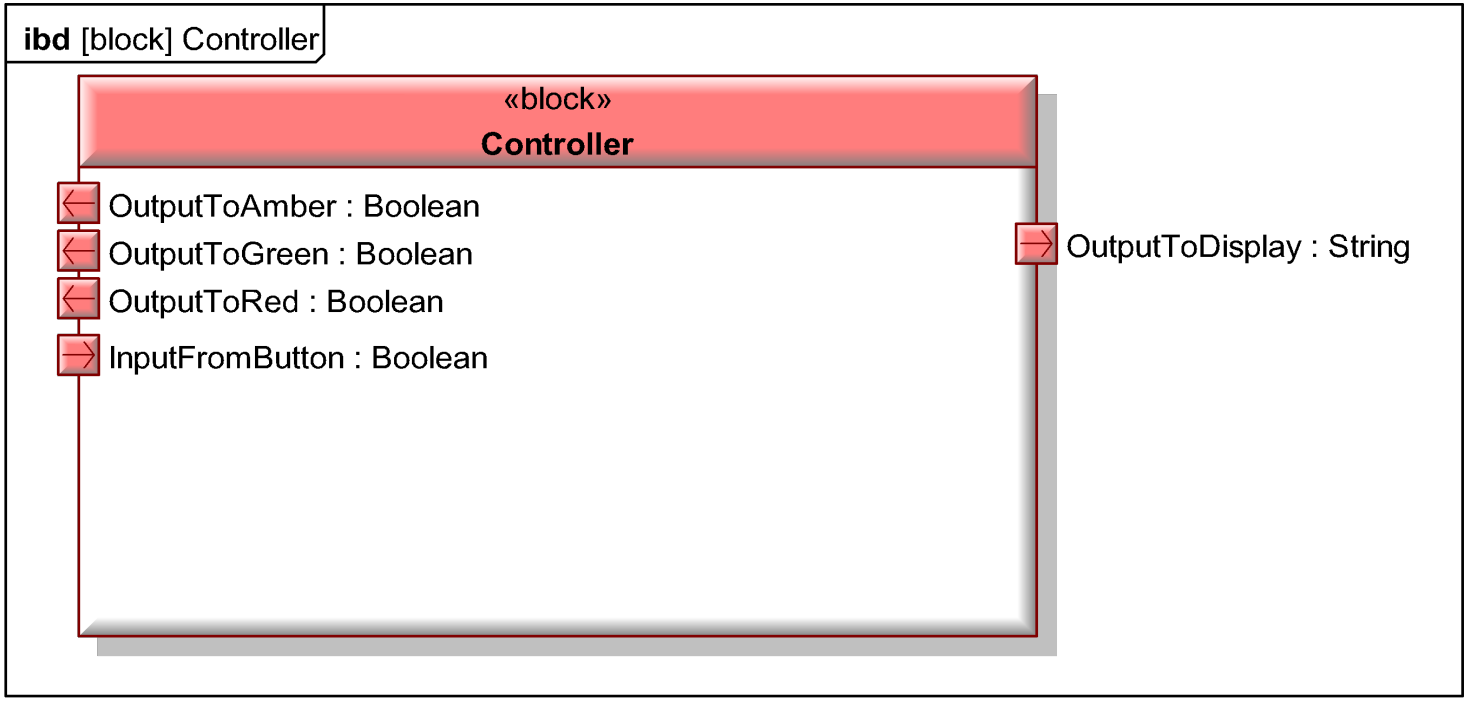


System Simulation – Main Structures



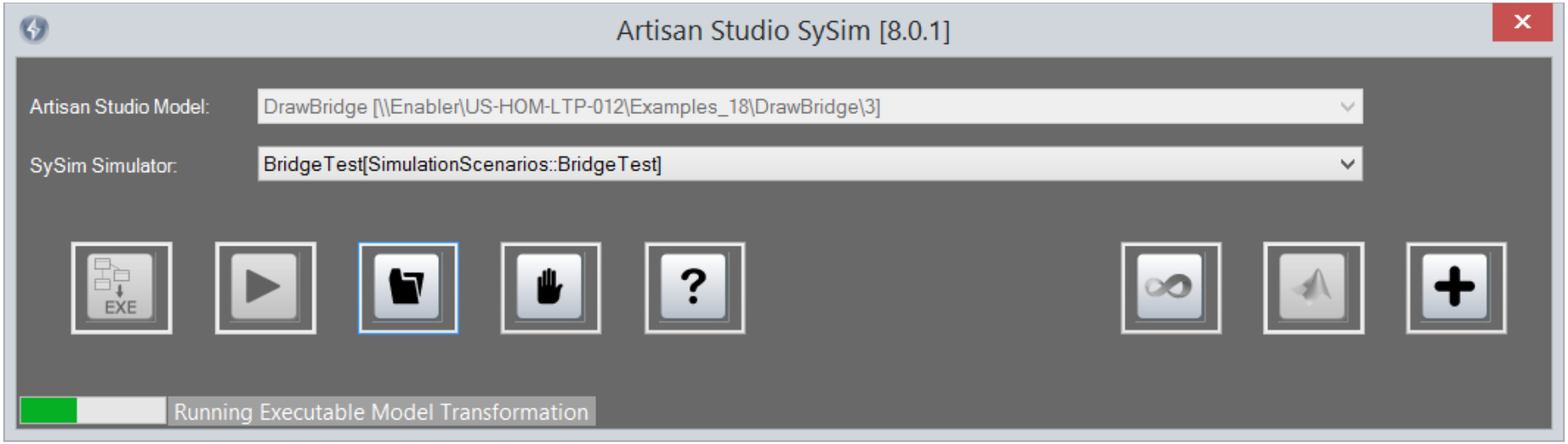
System Simulation – Example Interface

- Example Controller simulation block showing the inputs and outputs.
  Interfaces are defined using SysML ports



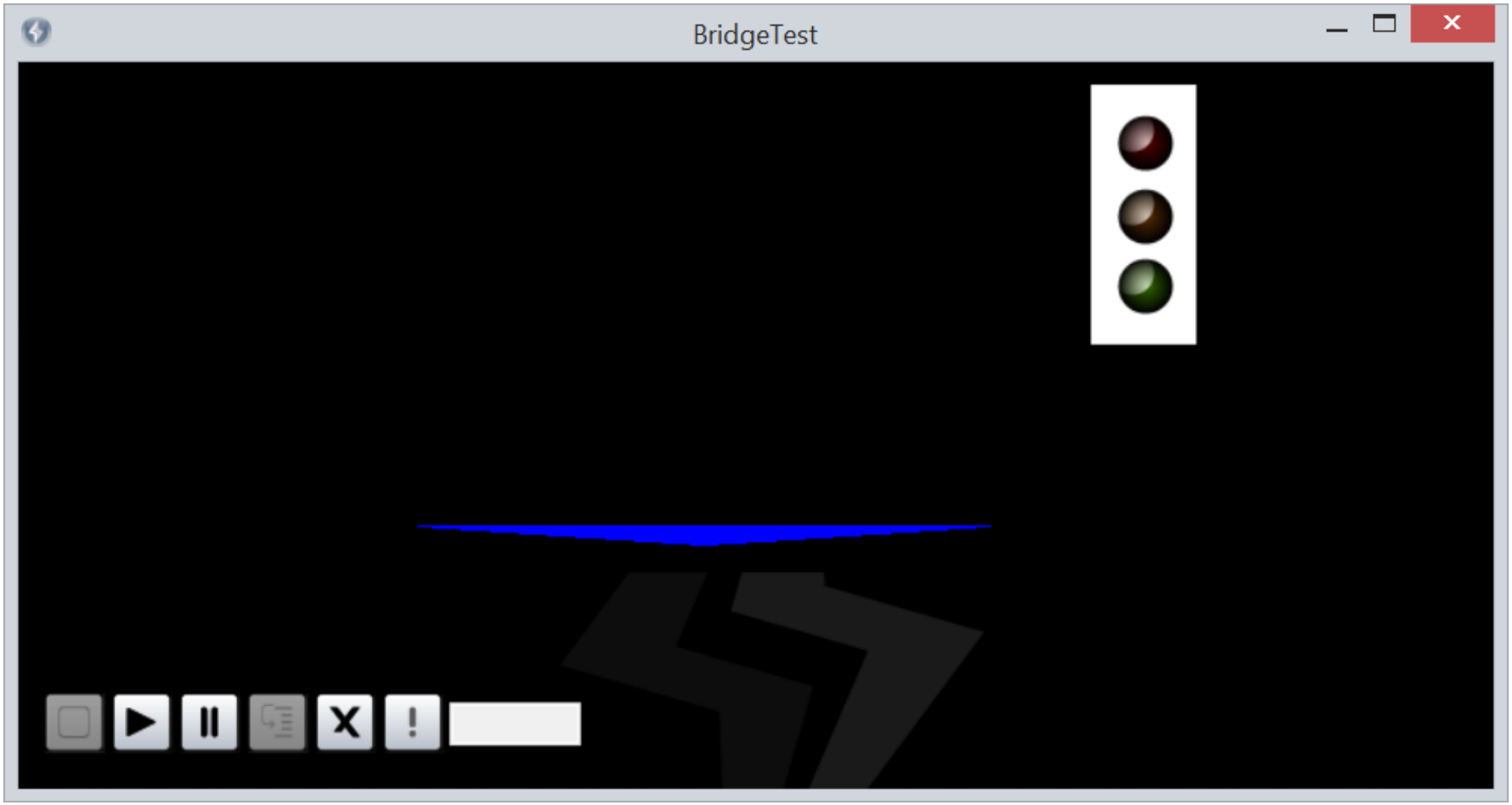
System Simulation SySim Interface

- SySim is designed for systems engineers
  - No programming necessary
  - Generate and run with a single button
  - Provides user interface components using Visual Studio

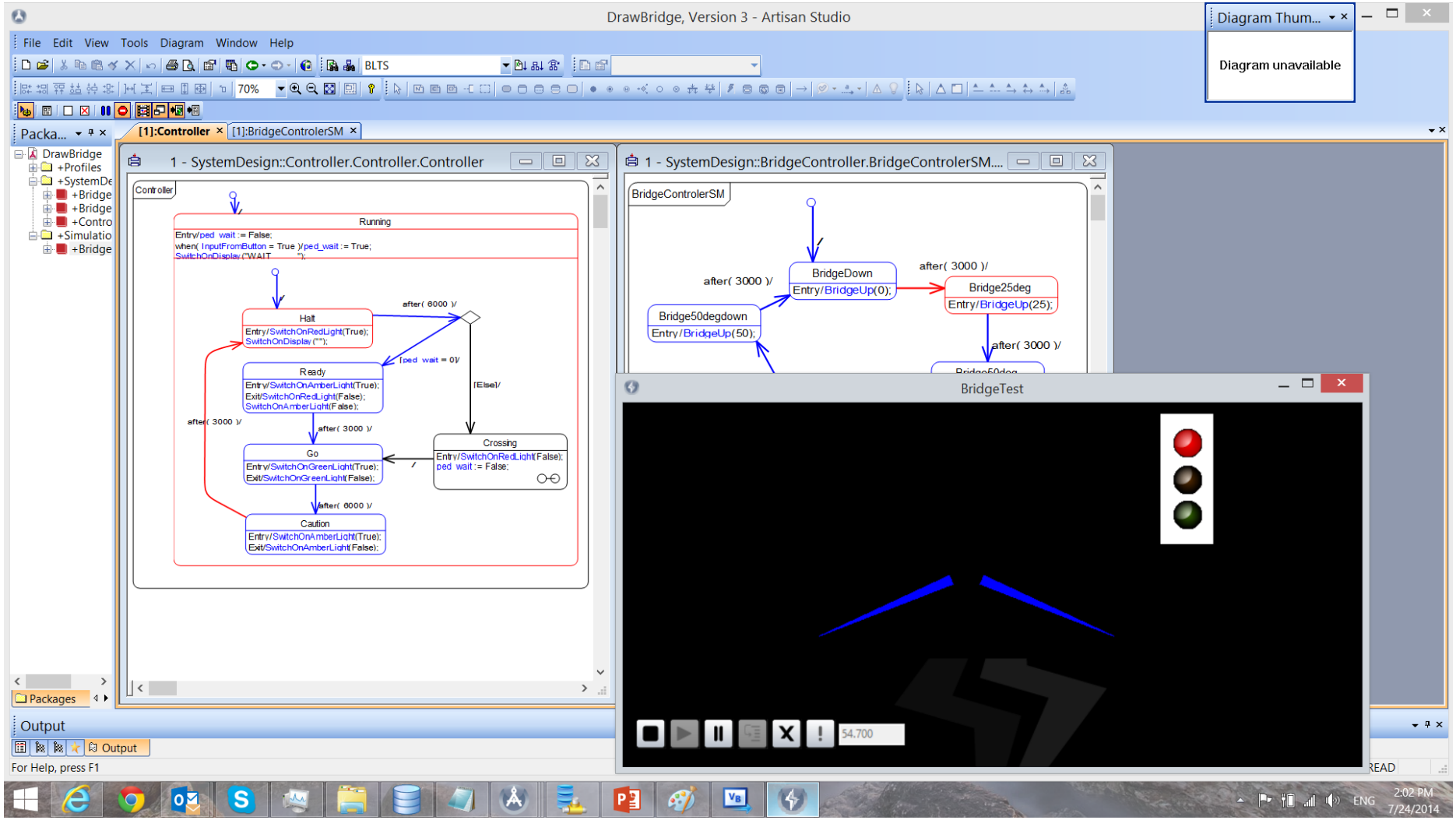


System Simulation – Example User Interface

- Simple Traffic Light and Bridge Lift Mechanism



System Simulation – Execution of Simulation



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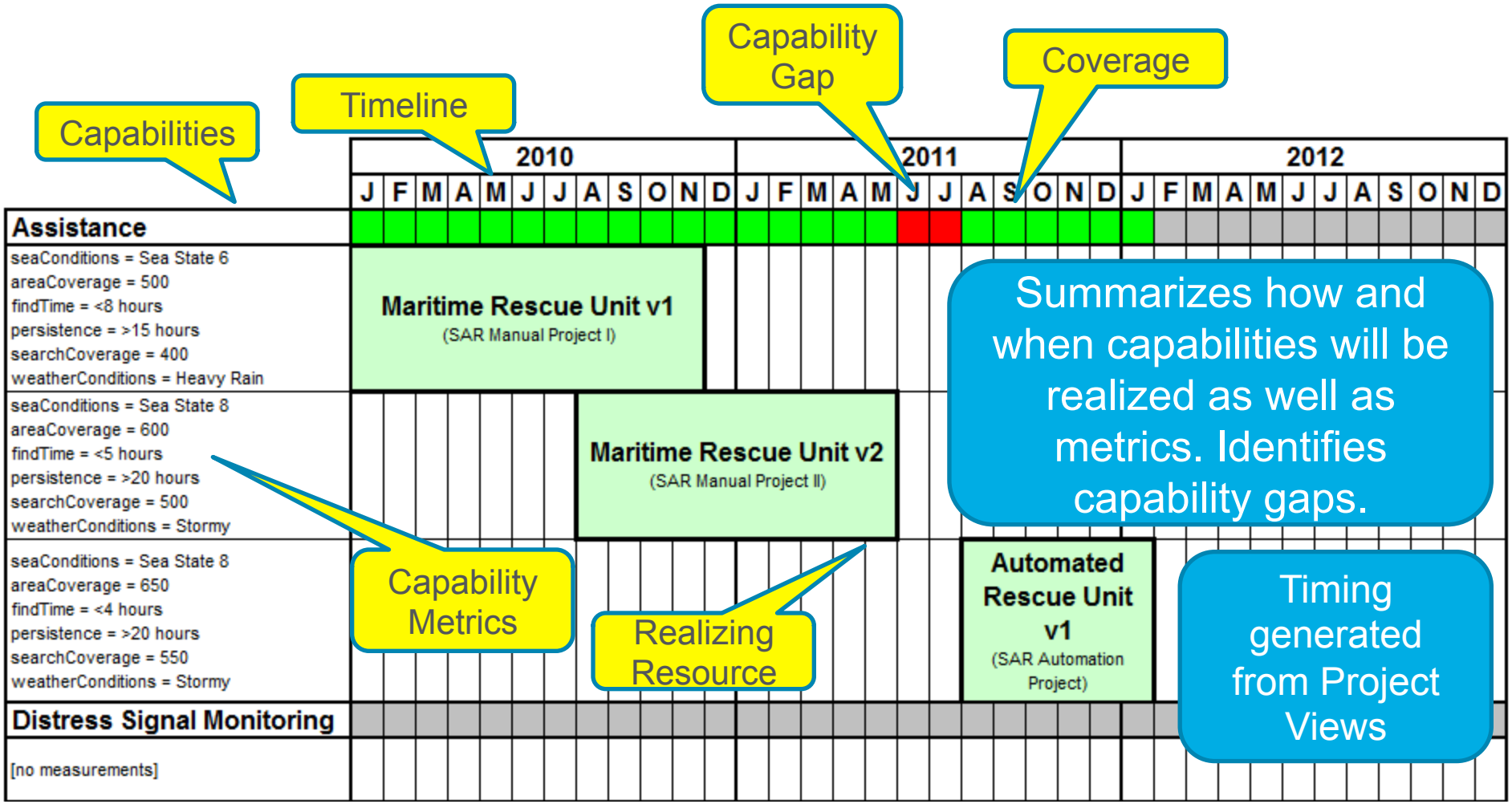
Infrastructure Bridge Model Additional Views

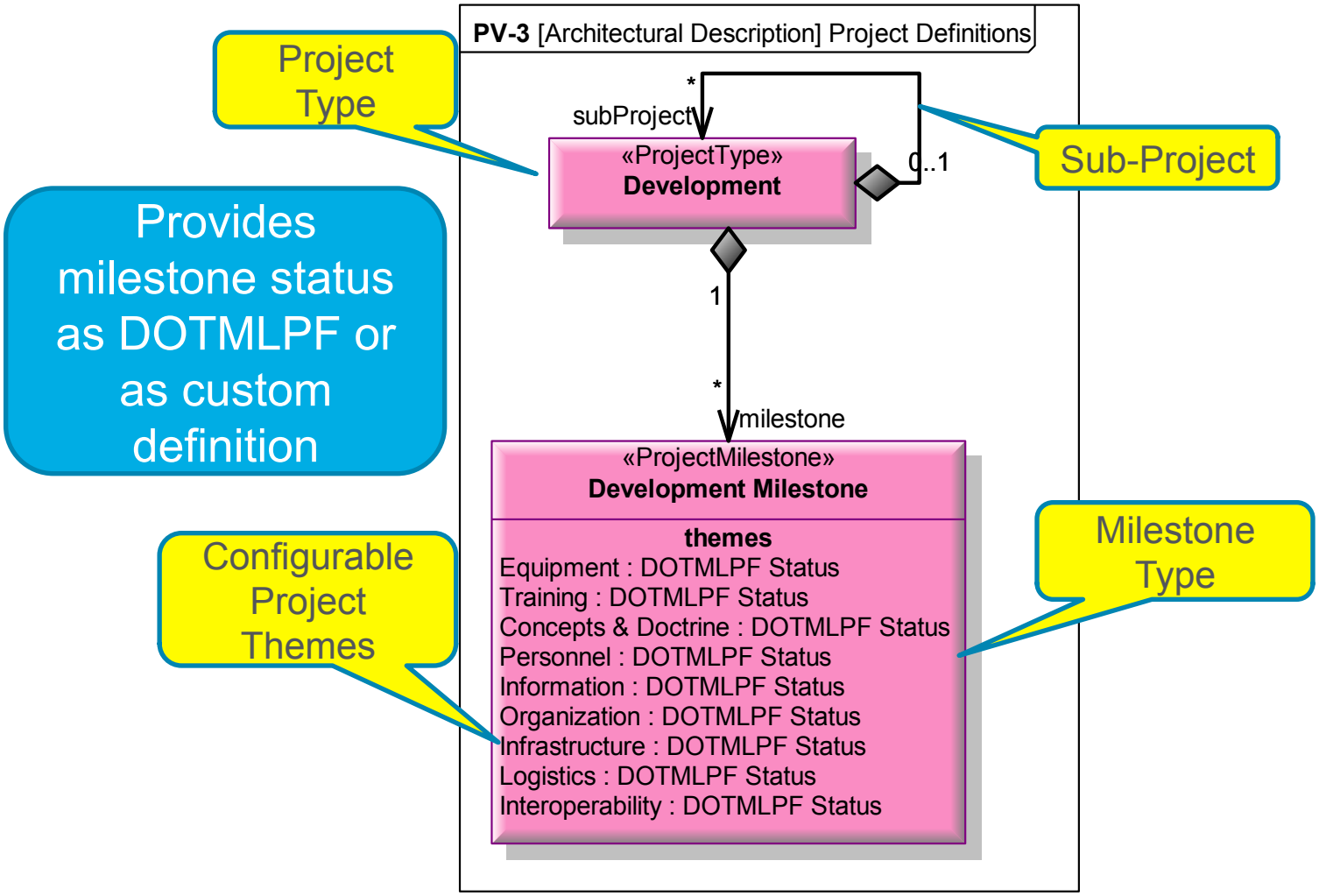
Note that these are NOT Bridge Model Views

Matthew Hause
GTM Solutions Specialist, Fellow

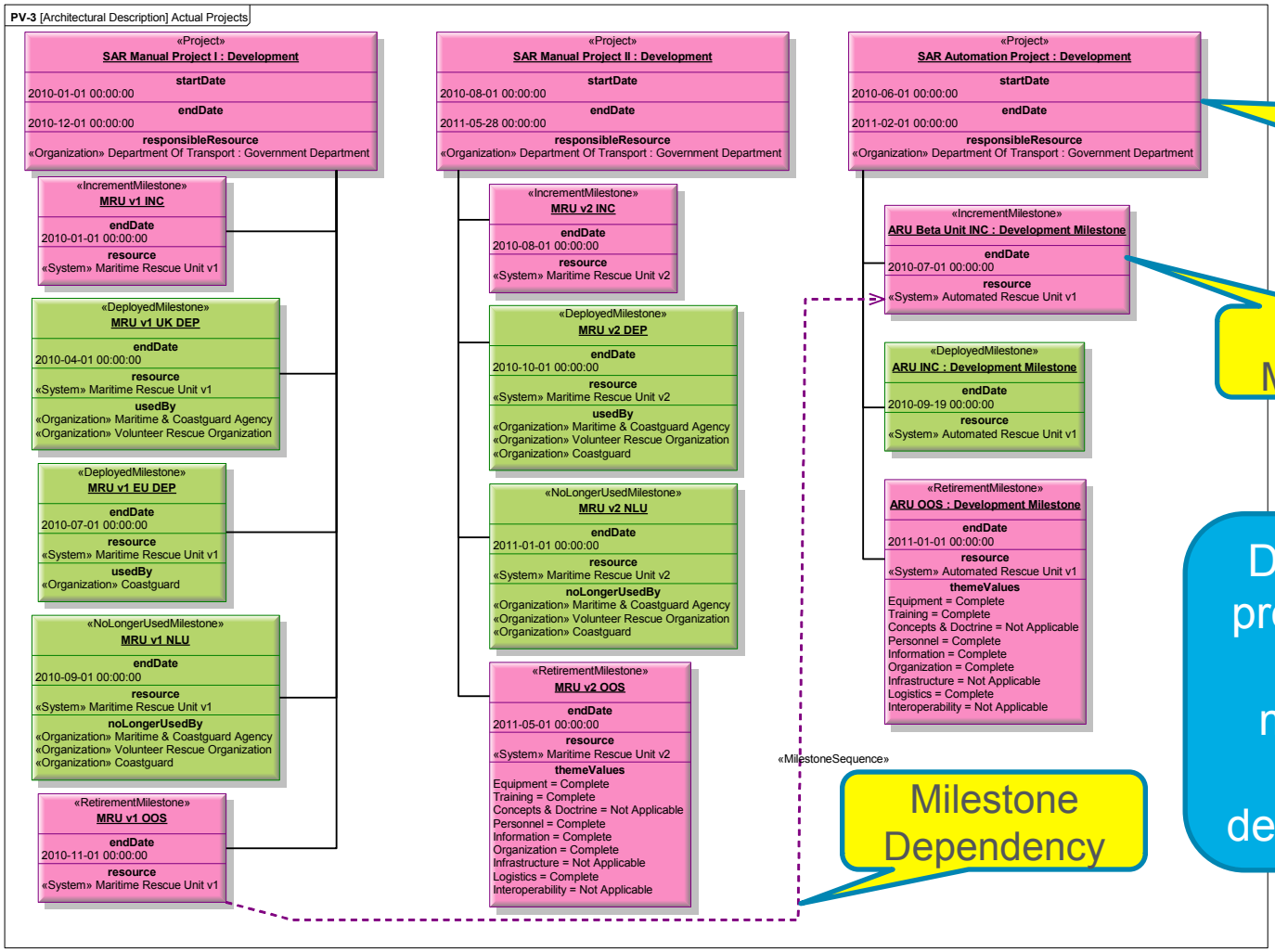
CV-3/StV-3 Capability Phasing (Fragment)



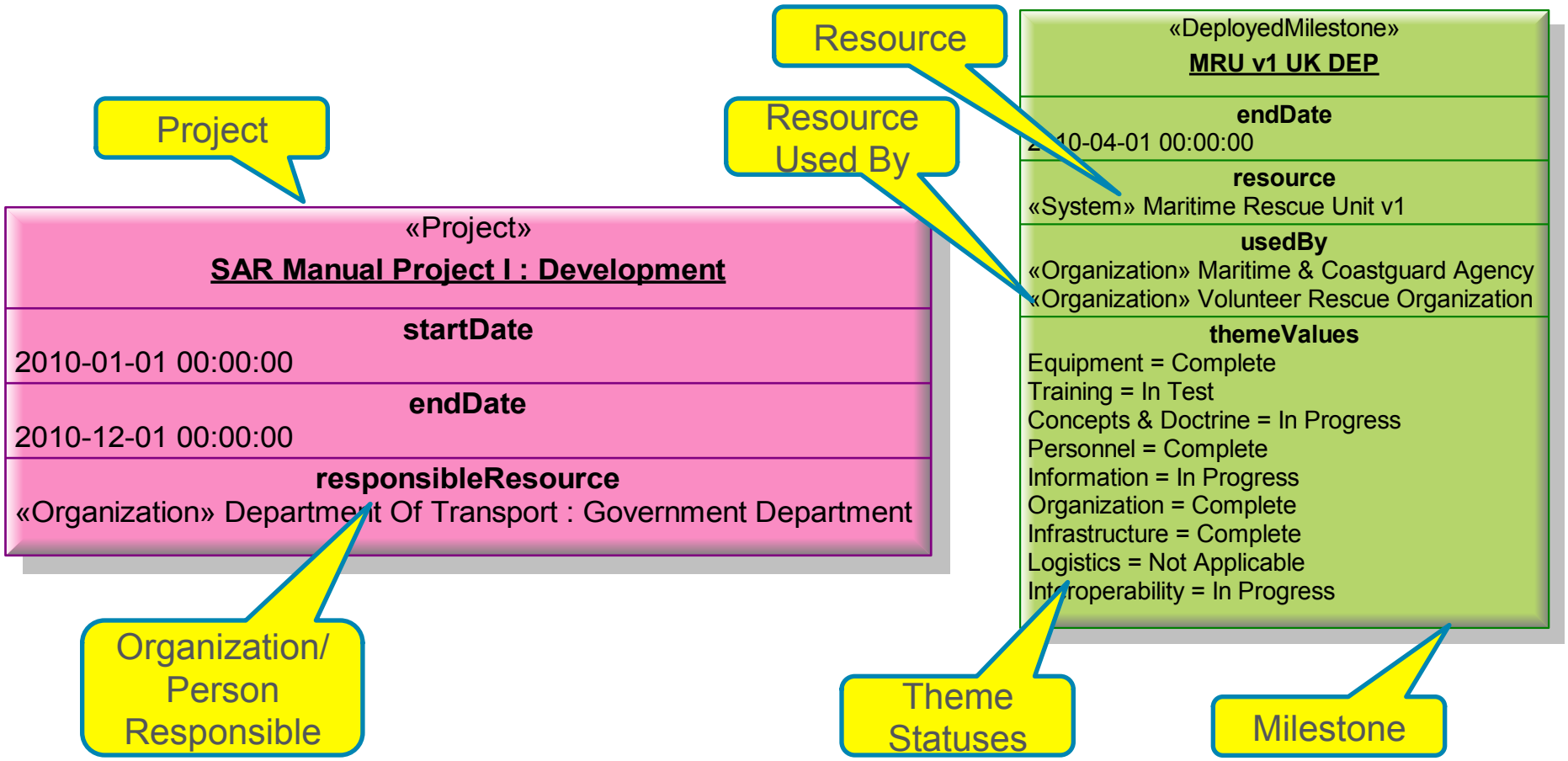
PV-1/AcV-1 Project Definition



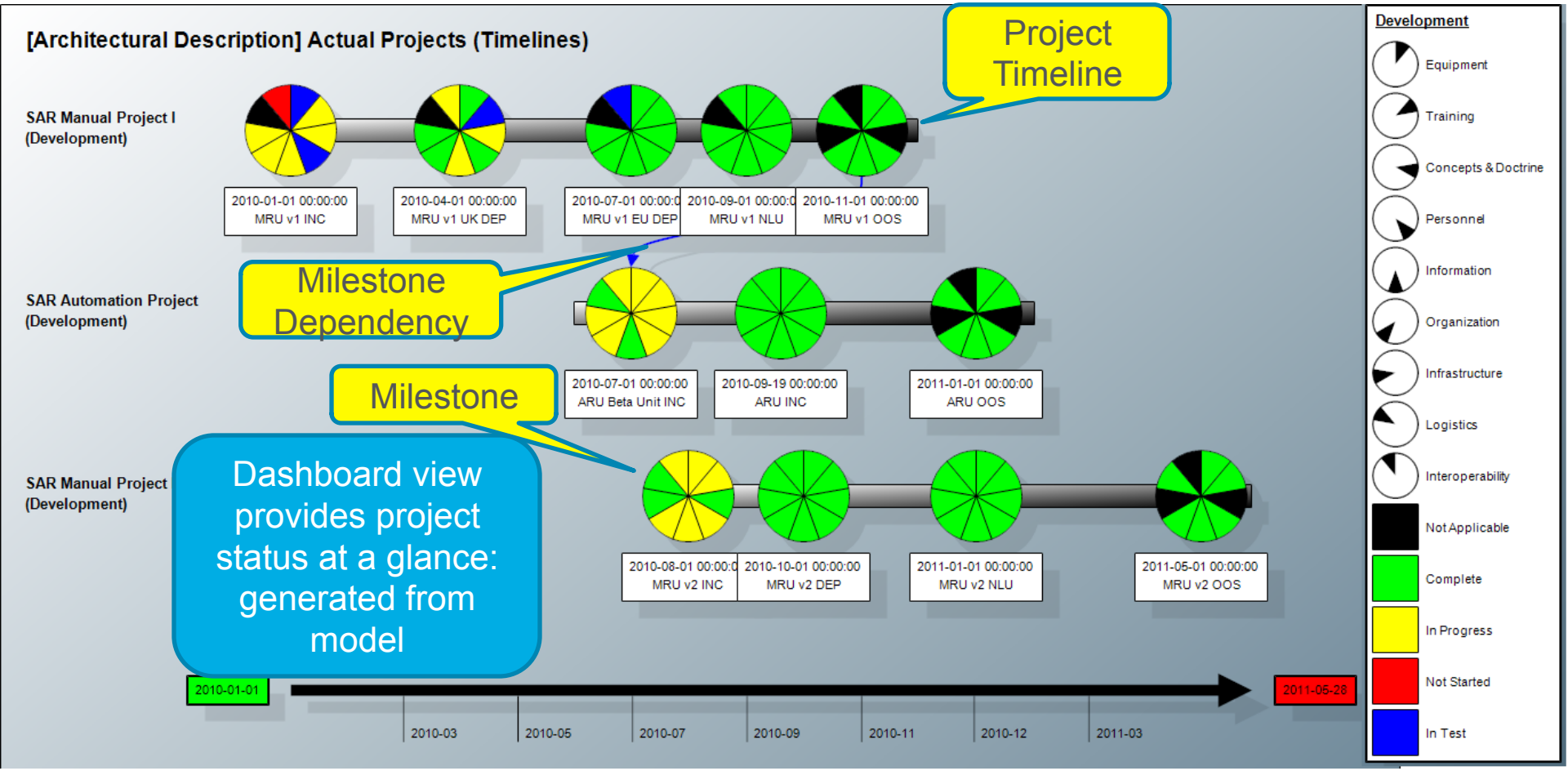
PV-1/AcV-1 Actual Project



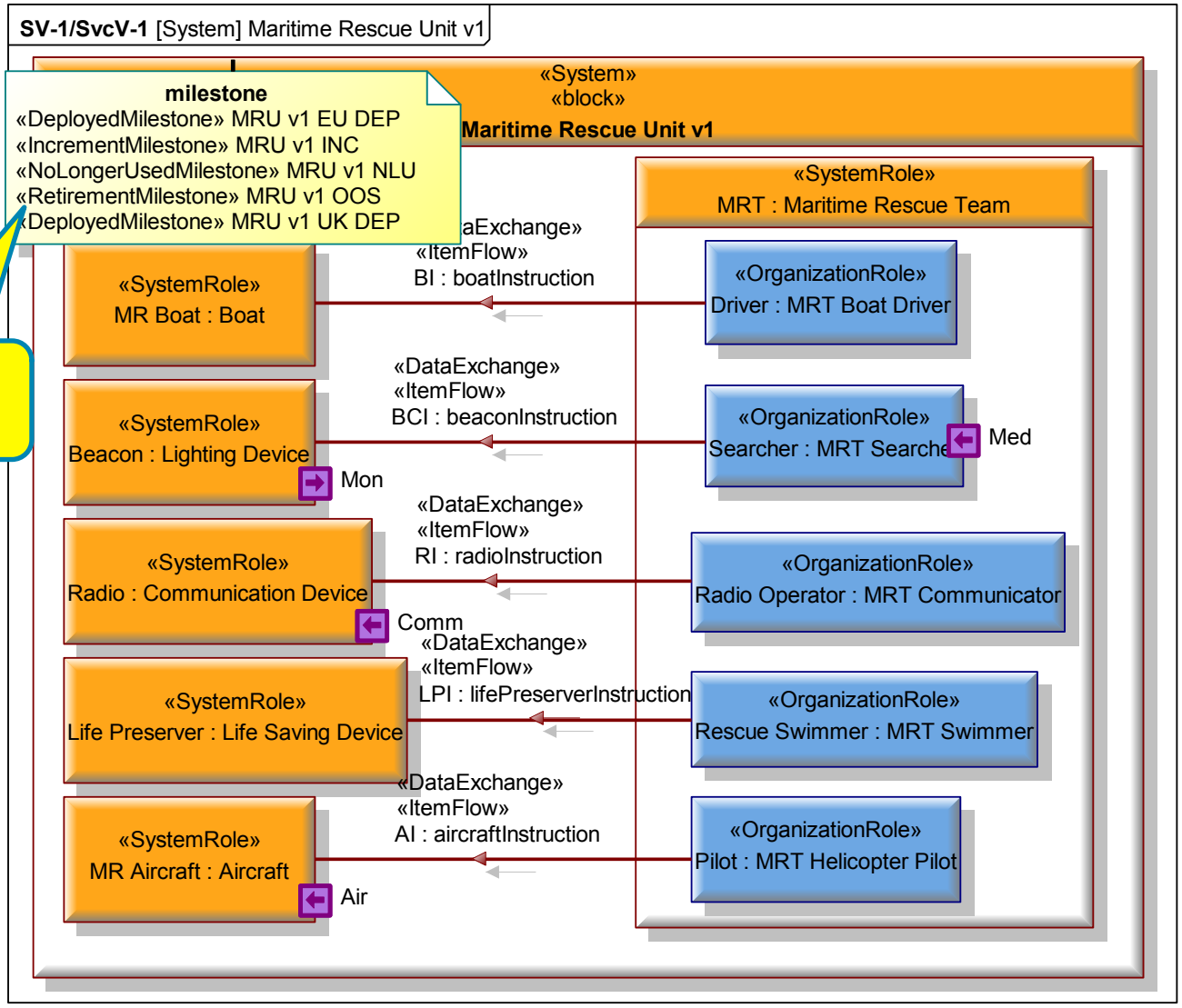
PV-1/AcV-1 Project Detail



PV-2/AcV-1 Project Timelines



SV-1: Resource Interaction Specification



Variant Modeling

- Variant Diagram
  - Variation on all Diagrams
  - Simple Notation

Variation Point

Variant

Variability Dependency

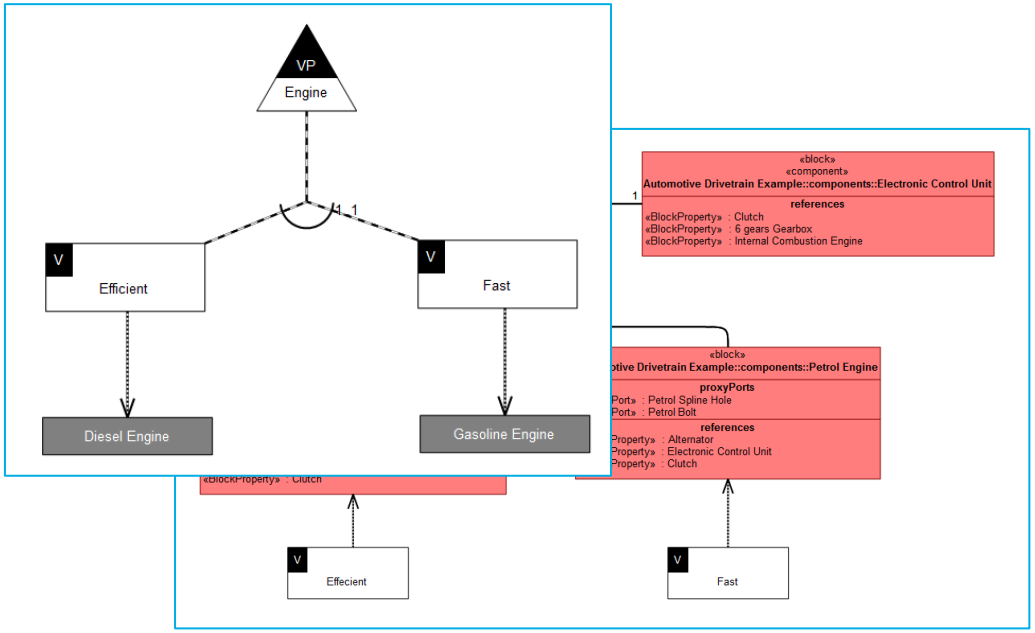
Mandatory/Optional

Requires Dependency

Excludes Dependency

Artifact Dependency

Alternate Choice

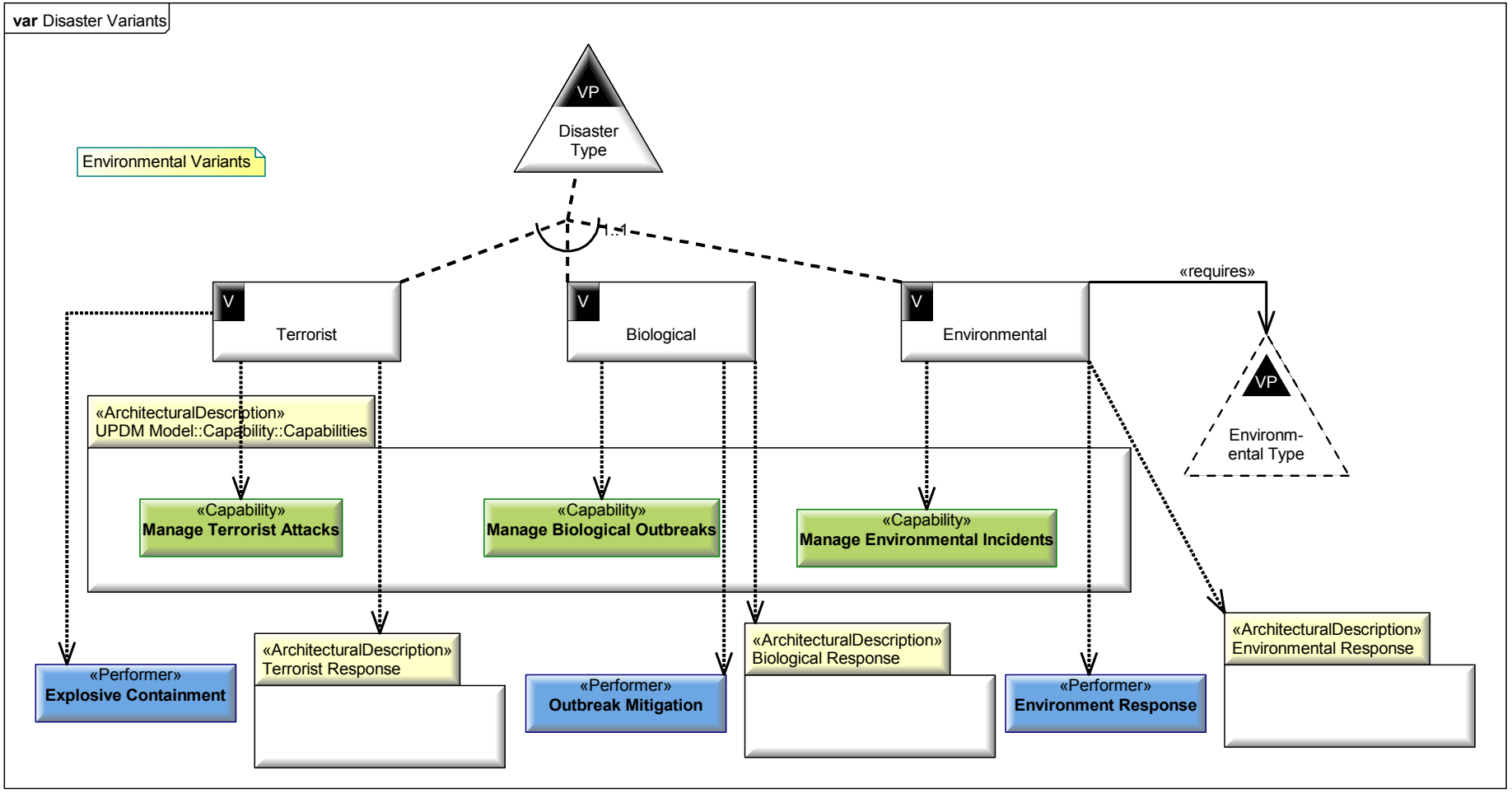


- OVM

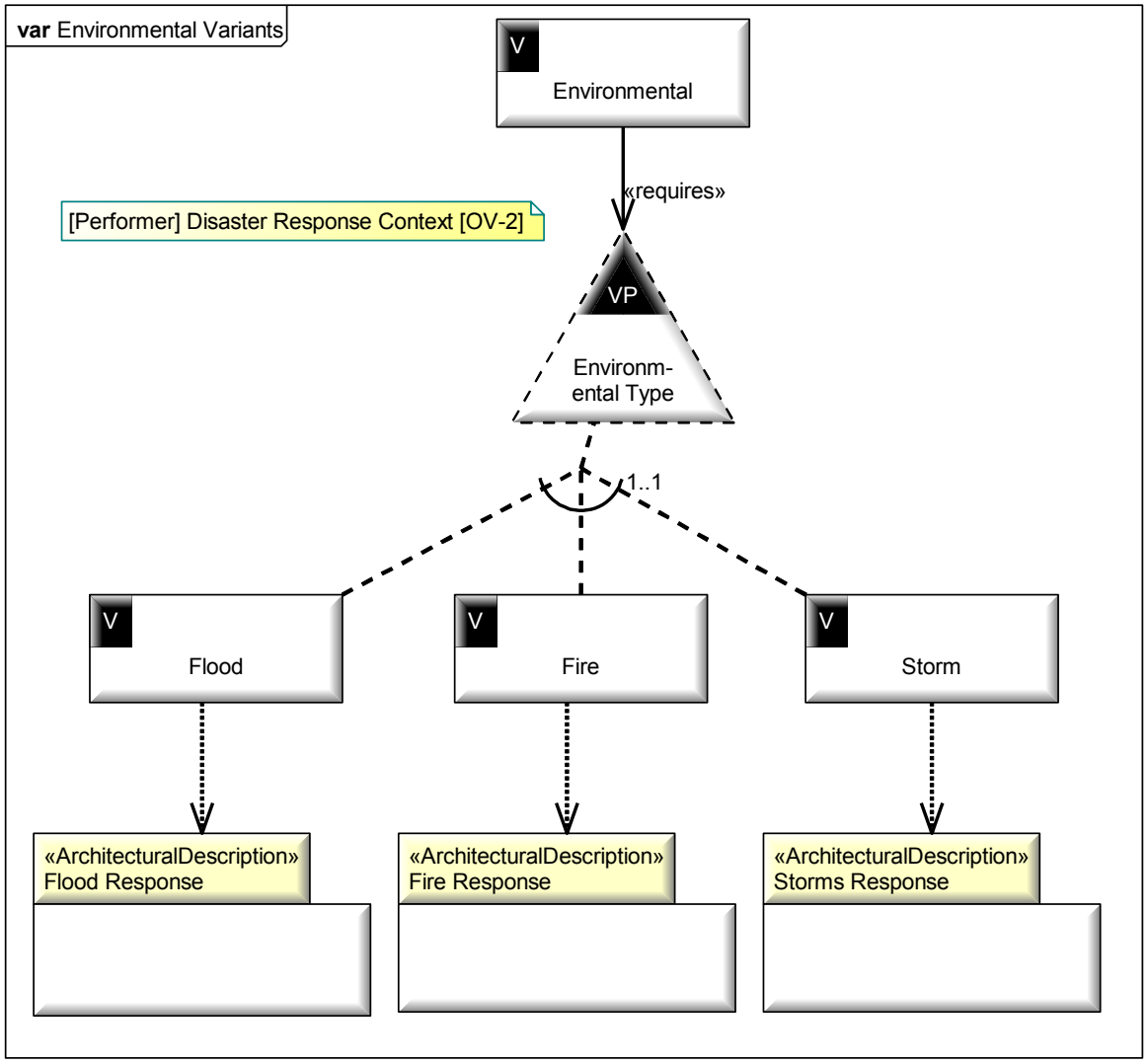
PALUNO, The Ruhr Institute of Software Technology

Software Product Line Engineering (Pohl et al - Springer 2005)

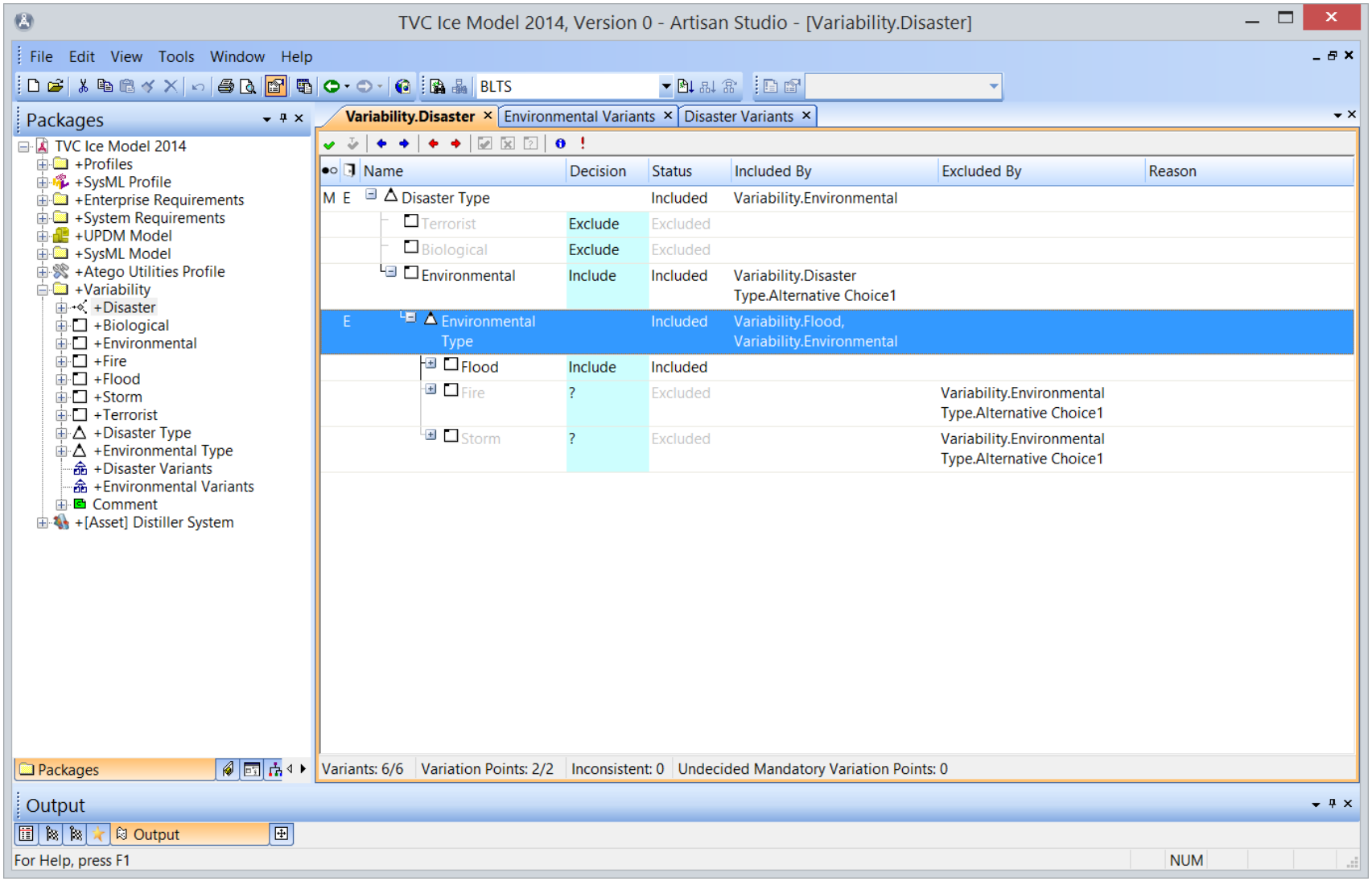
Evaluation of Architectures



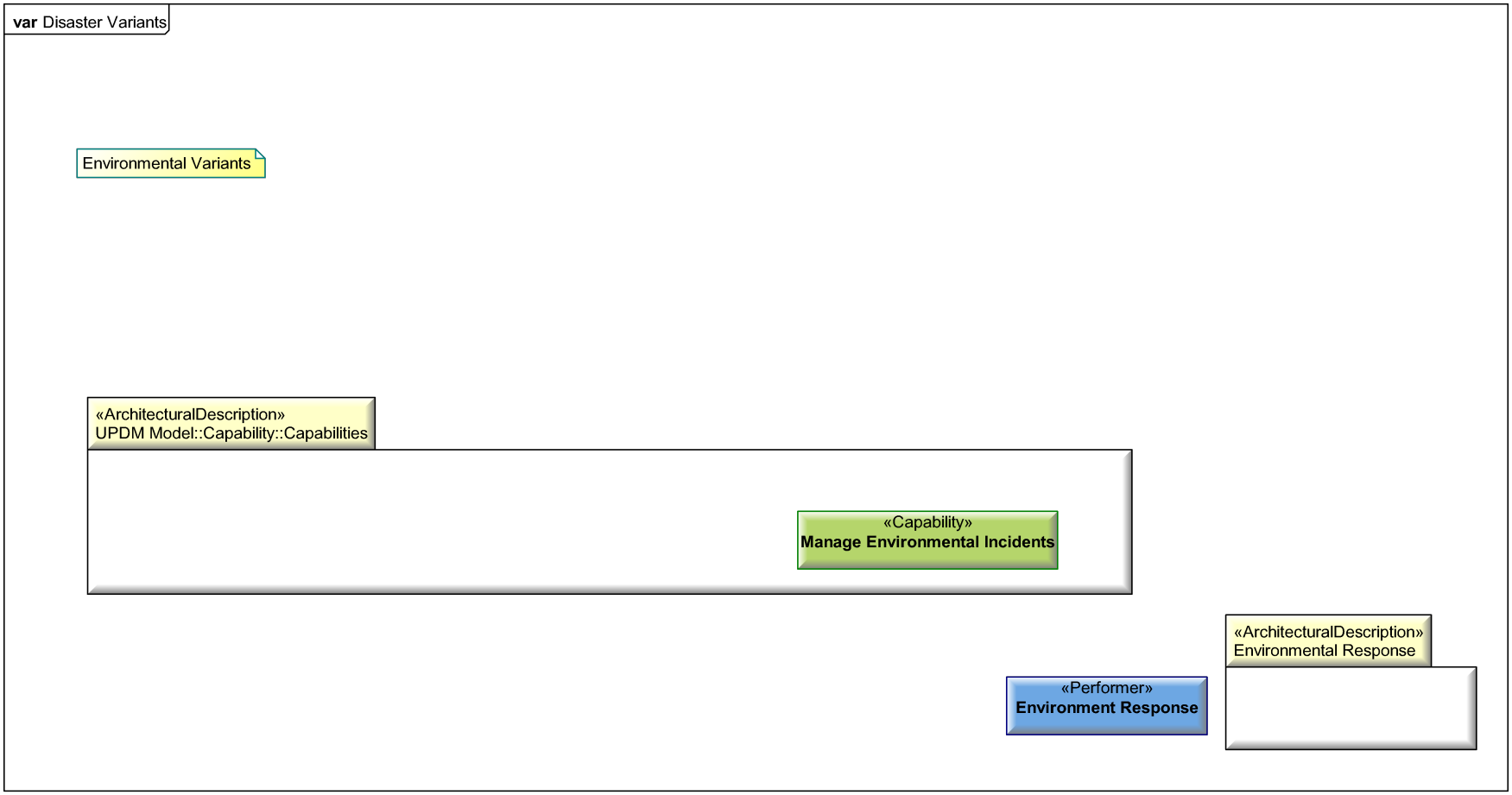
Evaluation of Architectures



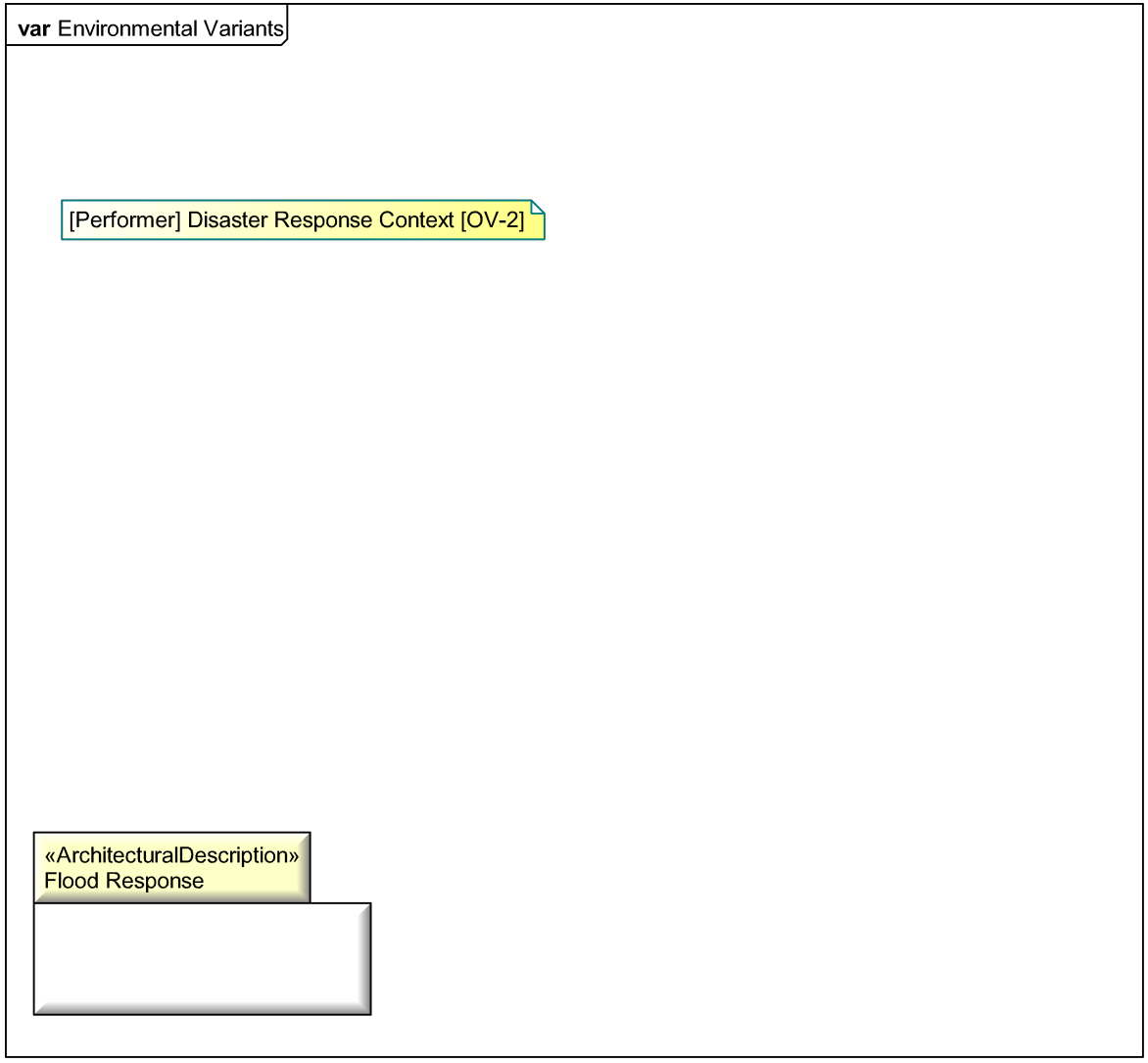
Decision Editor



Evaluation of Architectures

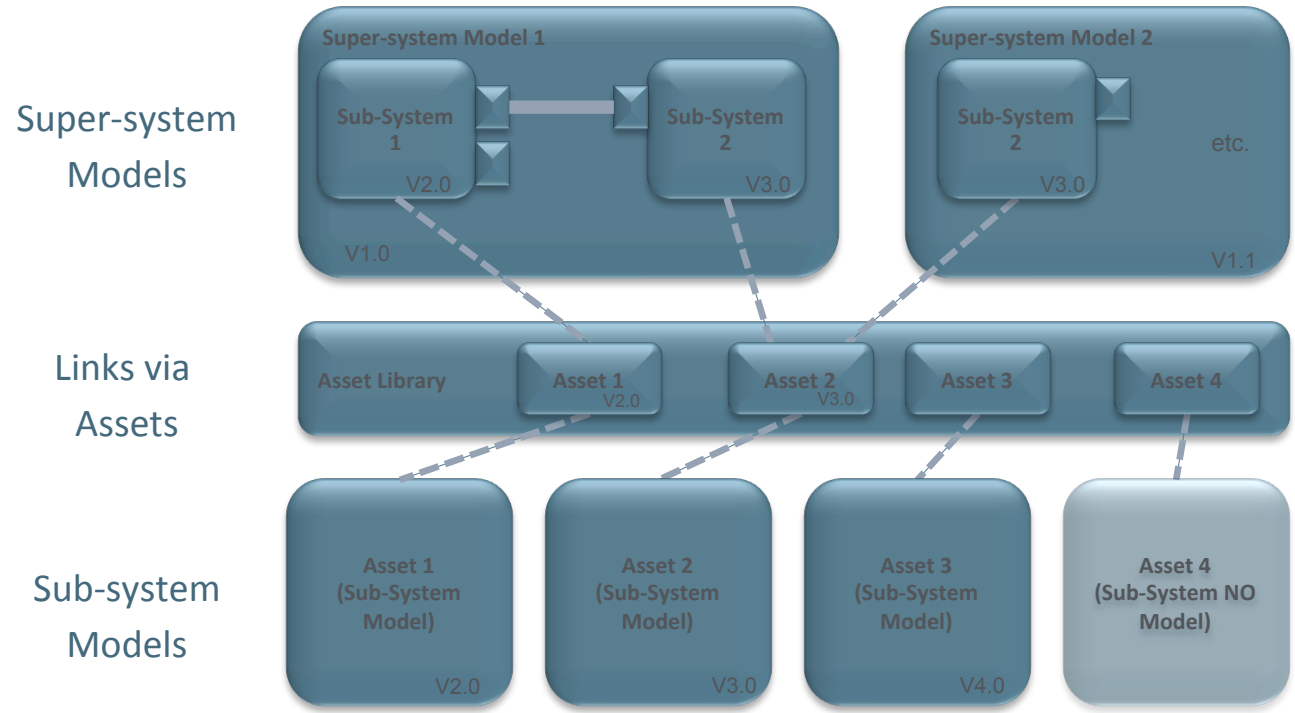


Evaluation of Architectures



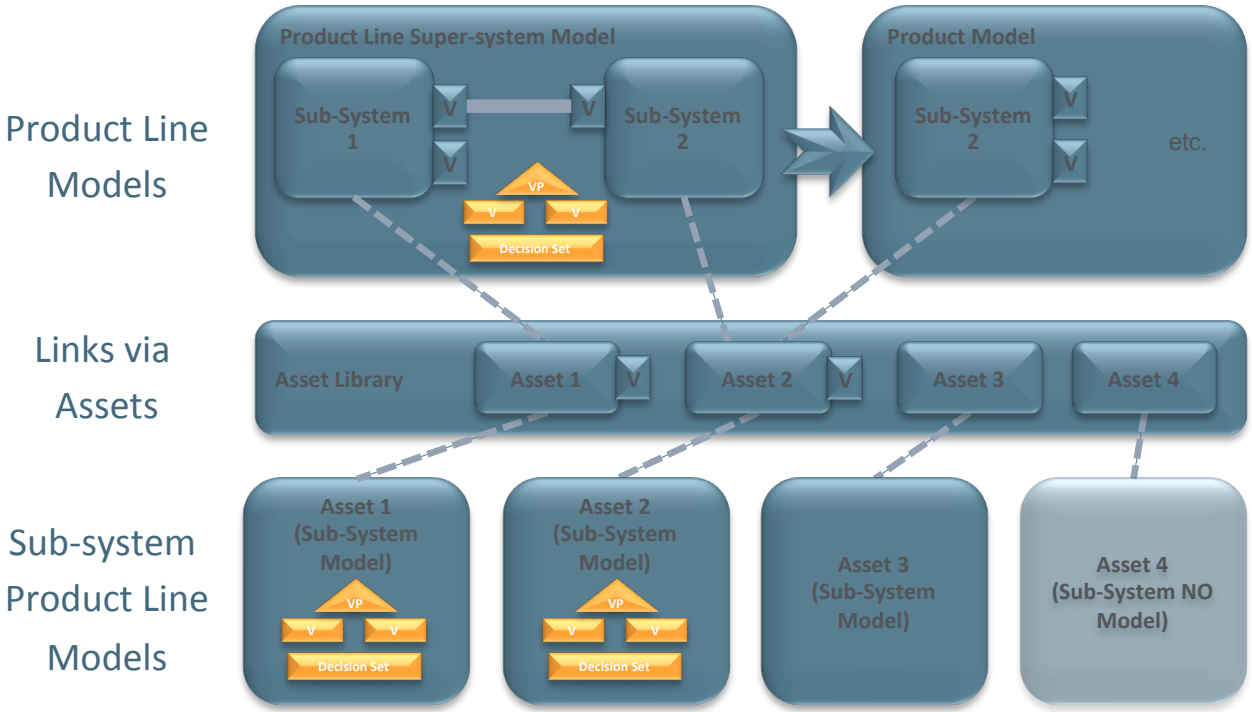
Asset-based Modular Design

- Super-system Model = Configuration of Versioned Sub-systems



Modeling-based Product Line Engineering

- Integrated MBSE, Modular Design & Variability Modeling = Model-based Product Line Engineering



Next?

- Your feedback on the model would be useful.

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