FRENEMIES: OPM AND SYSML TOGETHER IN AN MBSE MODEL

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ptc

AGENDA

- Introduction
- MBSE
- SysML
- OPM
- An OPM Profile in a SysML tool
- Conclusions
- Questions and Answers?

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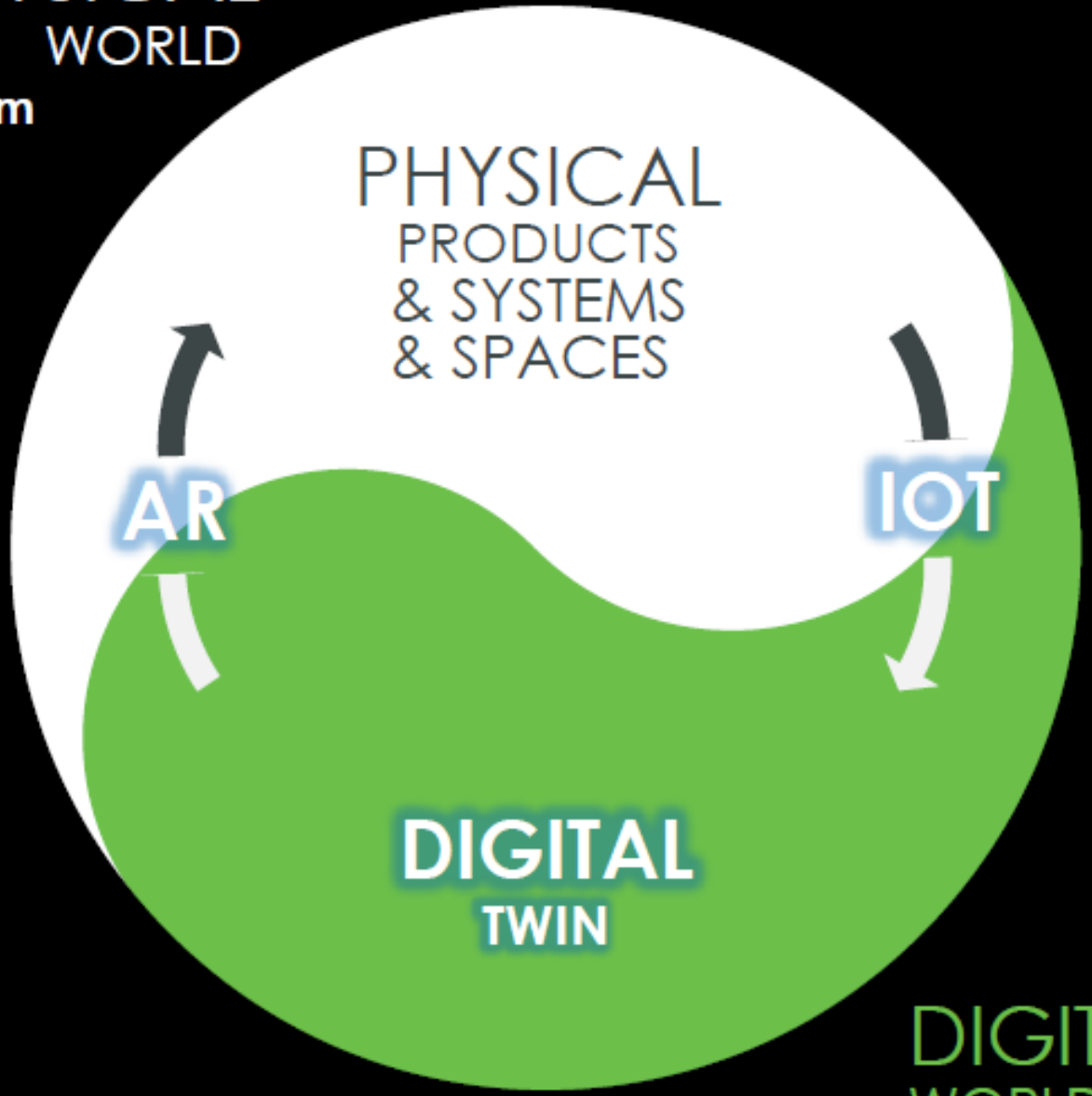
PHYSICAL WORLD

Industrial Innovation Platform
>$100M Revenue
> 50% Bookings Growth FY16
1,200 End Customers
250 OEMs/Resellers
Ecosystem of SI's, partners

IoT & ANALYTICS | thingworx
AUGMENTED REALITY | vuforia
INDUSTRIAL CONNECTIVITY | kepware



DIGITAL WORLD

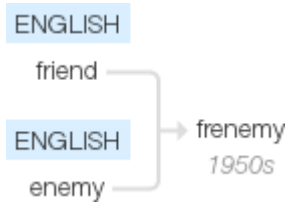
PLM Solutions
>$1B Revenue
10% Bookings Growth FY16
28,000 End Customers
70% Direct Sales
30% VARs (~400)
Ecosystem of SI's, partners

CAD | creo
PLM | windchill
ALM | integrity
SLM | servigistics

WHAT IS A FRENEMY?

fren·e·my
/ˈfrenəmi/
noun
INFORMAL
noun: **frenemy**; plural noun: **frenemies**
a person with whom one is friendly despite a fundamental dislike or rivalry.
(Note: In this case more rivalry than dislike.)

Origin



1950s: blend of friend and enemy.

- OPM and SysML are different means of achieving MBSE, each with their own benefits, issues, supporters and detractors.
- But first, let's look at some definitions.

MODEL-BASED SYSTEMS ENGINEERING (MBSE)

- The NDIA defines Model-Based Systems Engineering (MBSE) as "an approach to engineering that uses models as an integral part of the technical baseline that includes the requirements, analysis, design, implementation, and verification of a capability, system, and/or product throughout the acquisition life cycle."
  - There are a variety of methods in use
  - Some are standards based and others are proprietary
  - Different tools can be used at different points in the lifecycle and for different purposes.
    - Like mechanical tools, no single MBSE tool is best for all purposes
    - A mix of tools may be necessary for a single task

THE SYSTEMS MODELING LANGUAGE (SYSML)

- Diagrams for system requirements, behavior, structure and parametric relationships.
  - Used to define high-level abstract systems down to detailed physical systems.
- Developed by the Object Management Group (OMG) and INCOSE.
  - Organizations from industry, academia, government, standards organizations, etc.
  - Many books on its basic notation and how to use SysML in large complex systems.
  - More than 10 commercial implementations of SysML tools are available, as well as freeware and shareware.
- Integrations between SysML tools and other SE tools such as Matlab, requirements engineering tools, PLM tools, process tools, etc.
  - Open System Lifecycle Collaboration (OSLC) has provided a standardized means of connecting tools that do not require point to point integrations.
  - Mandated for the development of many different military systems.
- SysML V2 is under development now.

OBJECT PROCESS METHODOLOGY (OPM)

- "Conceptual modeling language and methodology for capturing knowledge and designing systems.
  - Based on a minimal universal ontology of stateful objects and processes that transform them
  - OPM can be used to formally specify the function, structure, and behavior of artificial and natural systems in a large variety of domains.
  - A software package called OPCAT, for generating OPD and OPL, is freely available.
  - OPCAT is the only OPM tool, and integration with other SE tools is limited.
    - *(Note: I am happy to be corrected on this point.)*

MOTIVATION FOR THE PAPER

- OPM is used in systems engineering graduate courses at both the California Institute of Technology (CalTech) and the Massachusetts Institute of Technology (MIT).
  - Students graduating from these institutions are struggling to integrate the differing styles, philosophies, concepts and processes of SysML and OPM.
- A literature search reveals some papers that contrast SysML and OPM, but none that describe how the two can work together.
- This presentation discusses a synergy rather than promoting one language over another.

Ref: Systems Modeling Languages: OPM Versus SysML

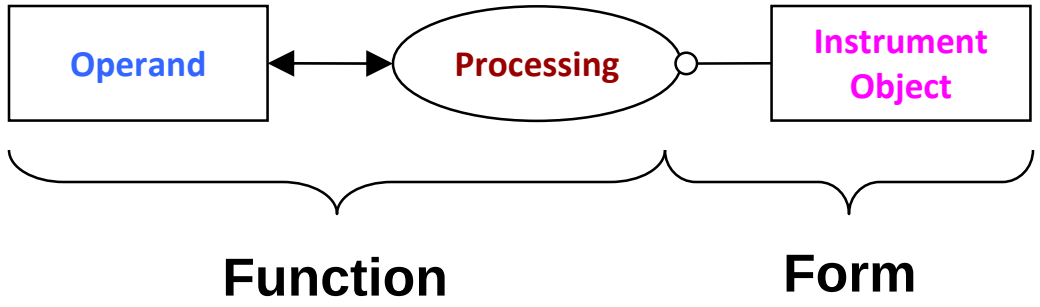
Yariv Grobshtein, Valeriya Perelman, Eliyahu Safra, Dov Dori

OPM

OBJECT PROCESS METHODOLOGY (OPM)

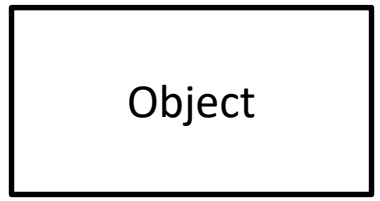
- OPM model represents the system under design or study in graphics and text for improved representation, understanding, communication, and learning.
  - In OPM, an object is a thing that exists, or might exist, physically or informatically.
  - A process is a thing that transforms an object by creating or consuming it, or by changing its state.
- The main author of OPM is Dov Dori
- OPM is bimodal; it is expressed both visually/graphically in Object-Process Diagrams (OPD) and verbally/textually in Object-Process Language (OPL), a set of automatically-generated sentences in a subset of English.
- OPM is an ISO standard OPM ISO 19450
- OPM is being further developed

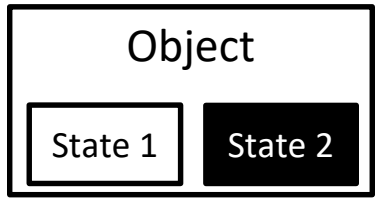
Canonical Architecture Representation with OPD

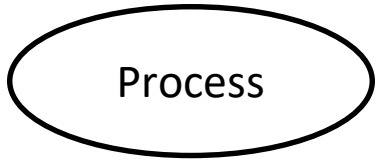


- Architecture is made up of operands + processes (functions) plus instrument objects (form)
- Examples:
  - Image is captured by digital camera
  - Homeowner is sheltered by a house
  - Traveler is safeguarded by evacuation instructions
  - Vehicle is supported (in transit) by bridge

(Basic) OPM Cheat Sheet







Structural Links
Object-Object
(don't forget to label)

Transforming (Procedural) Link
Object-Process
(no need to label)

Agent (who/what is doing it)

Instrument (what is required)

Enabling Links
(Object-Process)

Decomposition/Aggregation

Specialization/Generalization
(Seen in concepts)

Exhibition/Characterization

Classification/Instantiation

\+ **Remember to <u>always</u> indicate the system boundary**

MITsdm

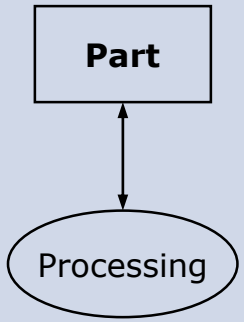
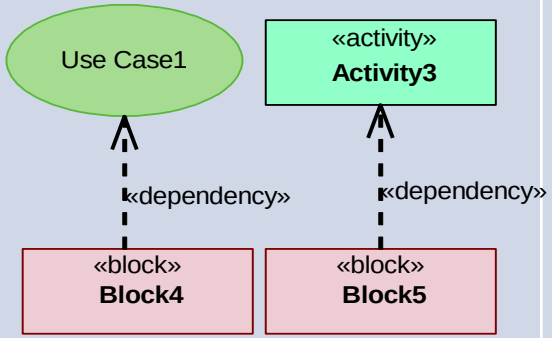
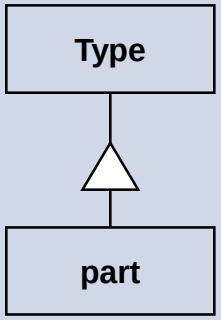
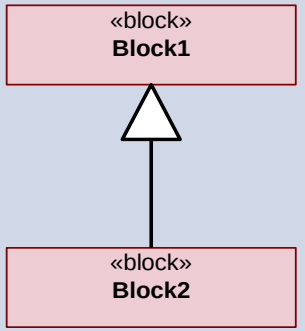
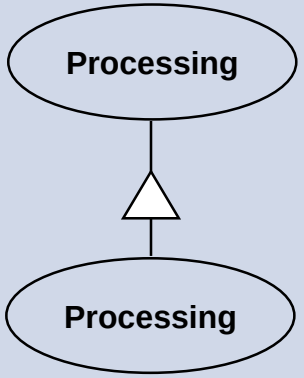
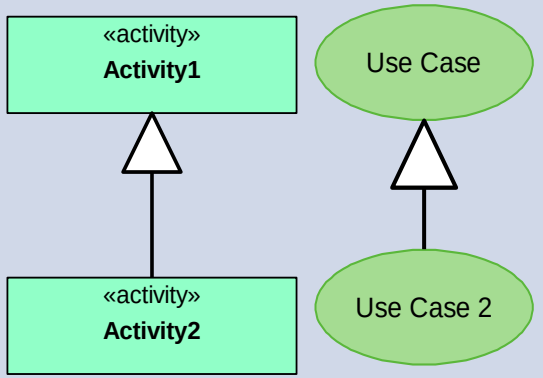
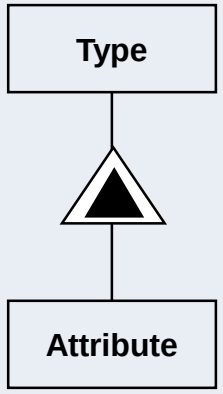
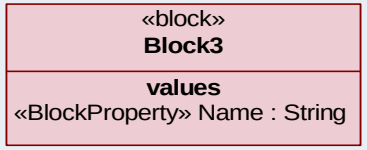
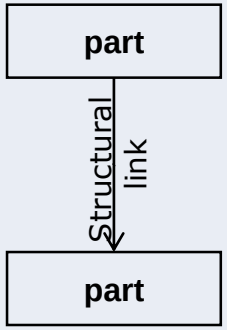
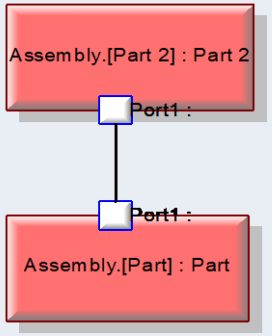
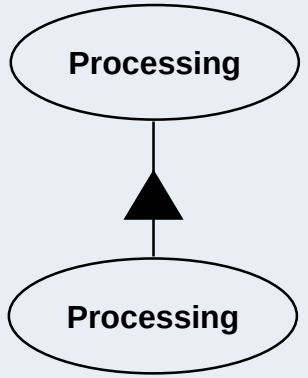
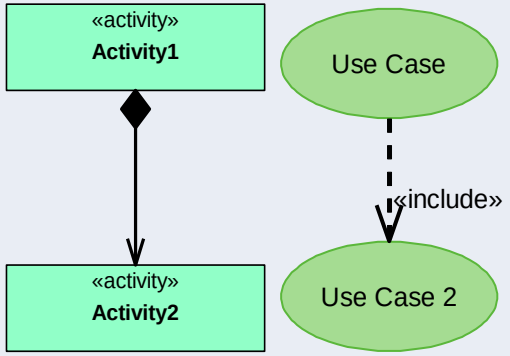
There is more to it! Additional Resources (for those interested):

- https://en.wikipedia.org/wiki/Object_Process_Methodology
- ISO 19450 (New!)
- Dov Dori's book (available at libraries.mit.edu)

Two Common languages for modeling: SysML v/s OPM (notations)

	OPM	SysML	OPM	SysML	OPM	SysML
Element	Object	«block» ::Block	Processing	«activity» Activity	Use Case	Object State 1 State 2	State
	Structure		Behavior		States	
Relationships	Assembly / part	«block» ::Assembly 1 1 «block» ::Part	part / Structural link / part	Assembly.[Part 2] : Part 2 Port1 : Port1 : Assembly.[Part] : Part	«block» ::Part 2 «allocate» «activity» Activity	object instrument Required processing / object instrument Provided processing
	Aggregation		Structure Links Interface/Flow		Object/Behavior Link	

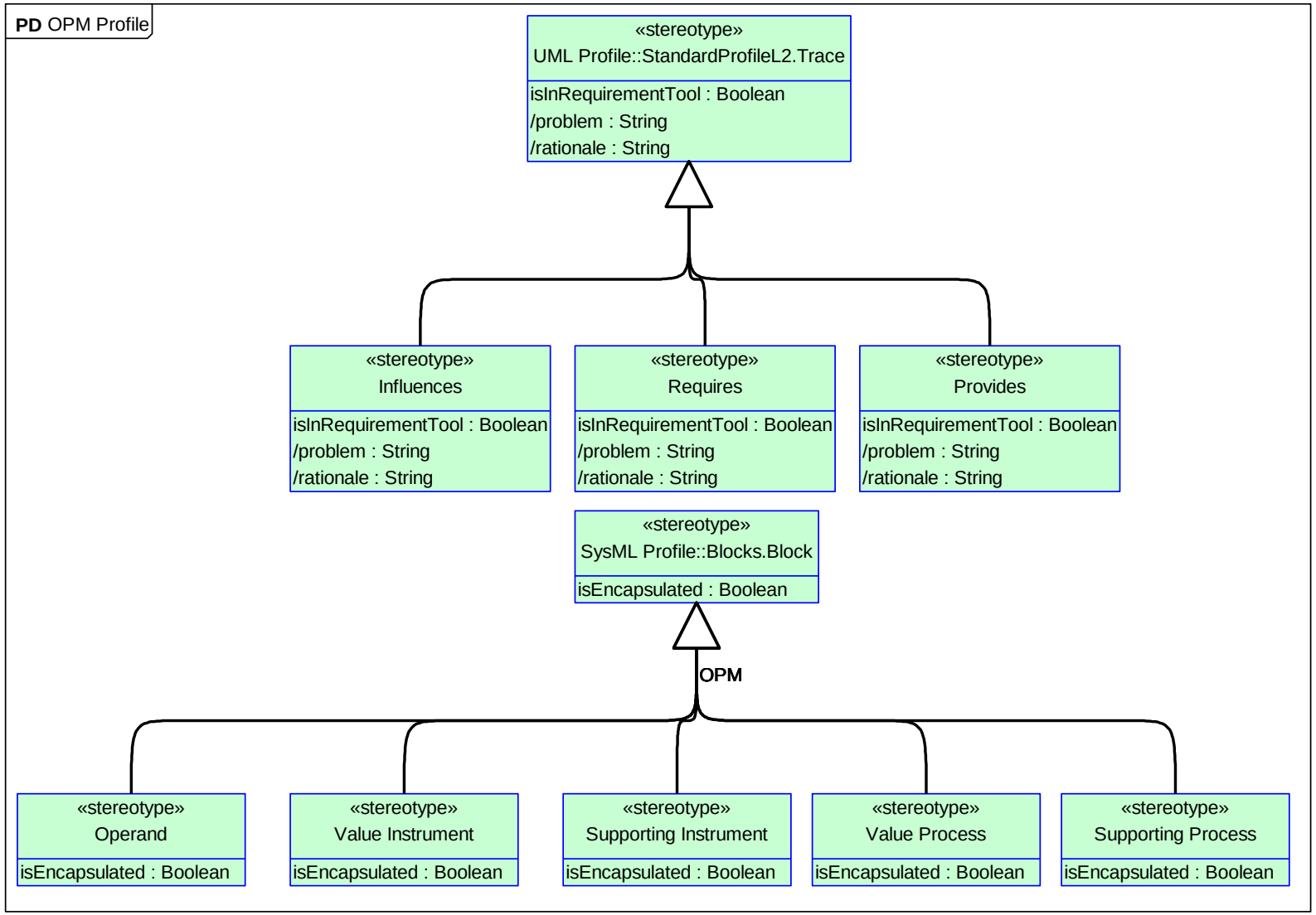
Two Common languages for modeling SysML v/s OPM (notations)

	OPM	SysML	OPM	SysML	OPM	SysML
Relationships						
	Process – Part Flow	A link between the behavior and structure could only be done via the dependency		Generalization/ Specialization		Generalization/ Specialization
Relationships						
	Attribute			Structure Links Interface/Flow		Behavior Aggregation

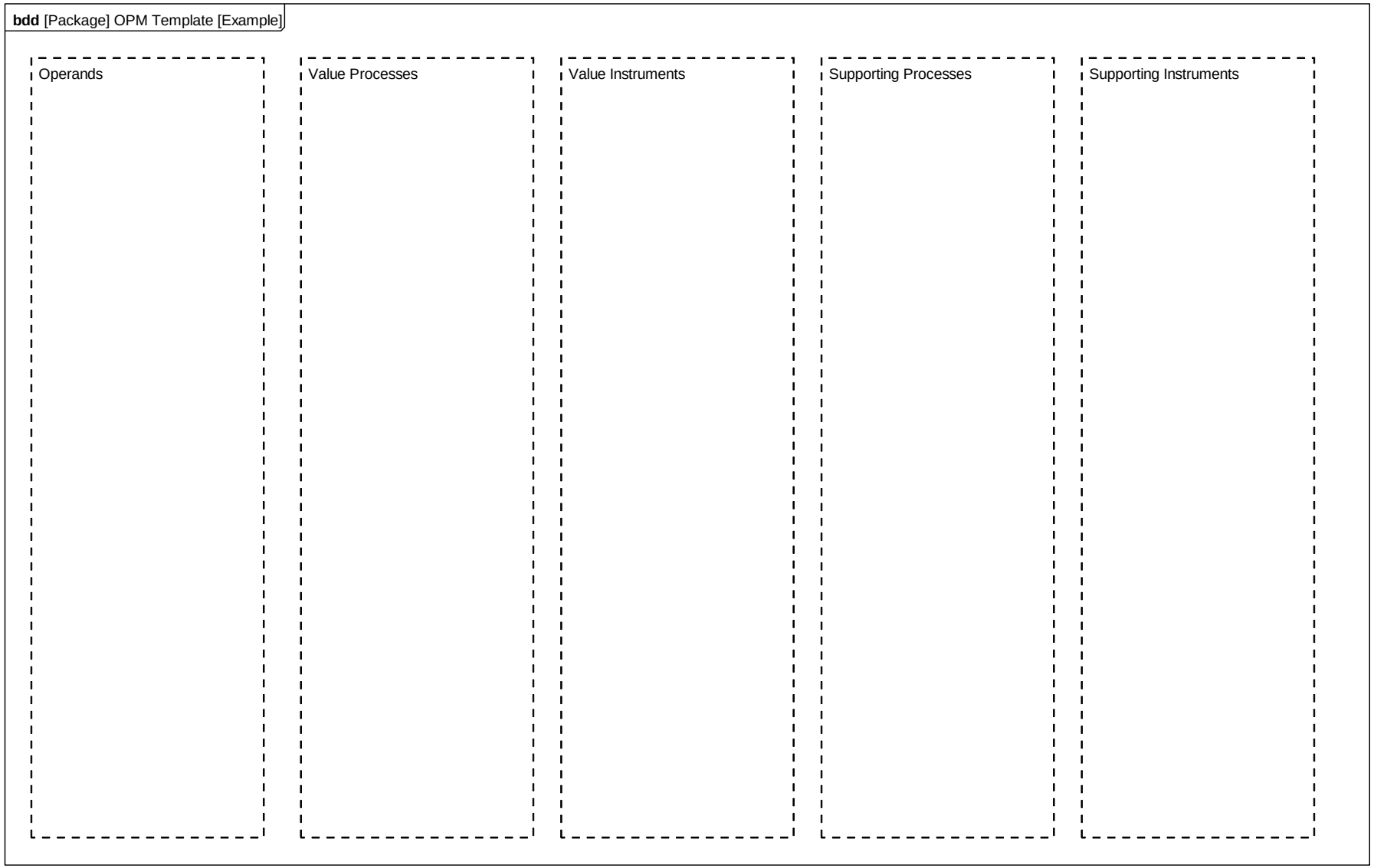
COMBINING THE TWO

PROFILE DIAGRAM

- Simple Profile
  - Extends SysML
  - Defines elements as extensions of Blocks
  - Processes modeled as blocks as well
  - Relationships are extensions of Trace
  - "Open Dot" is requires, "Closed Dot" is provides
- Elements can be used as part of SysML model
- Basic diagram is the BDD
  - Uses SysML notation
- Some limitations

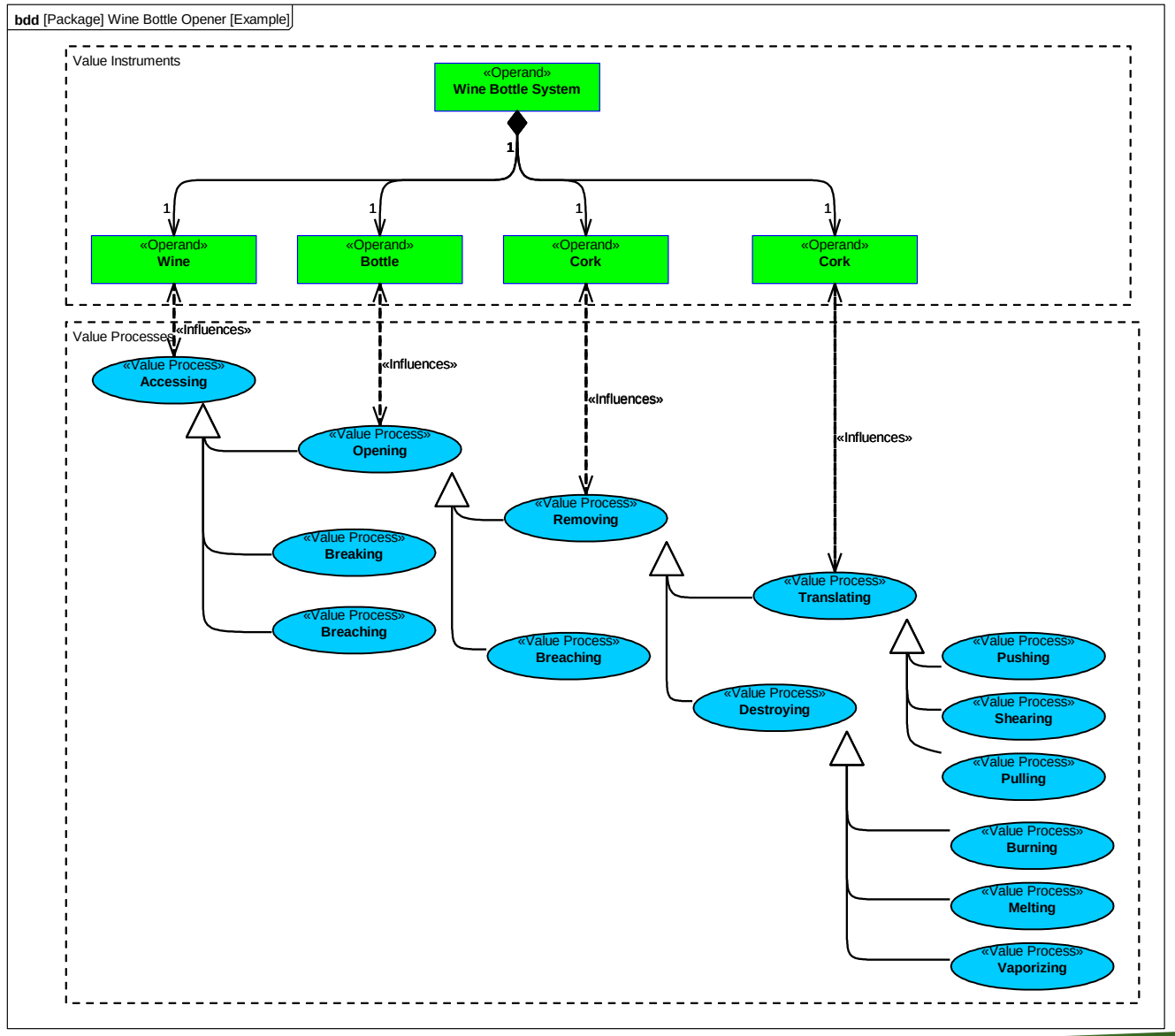


TEMPLATE FOR DIAGRAMS



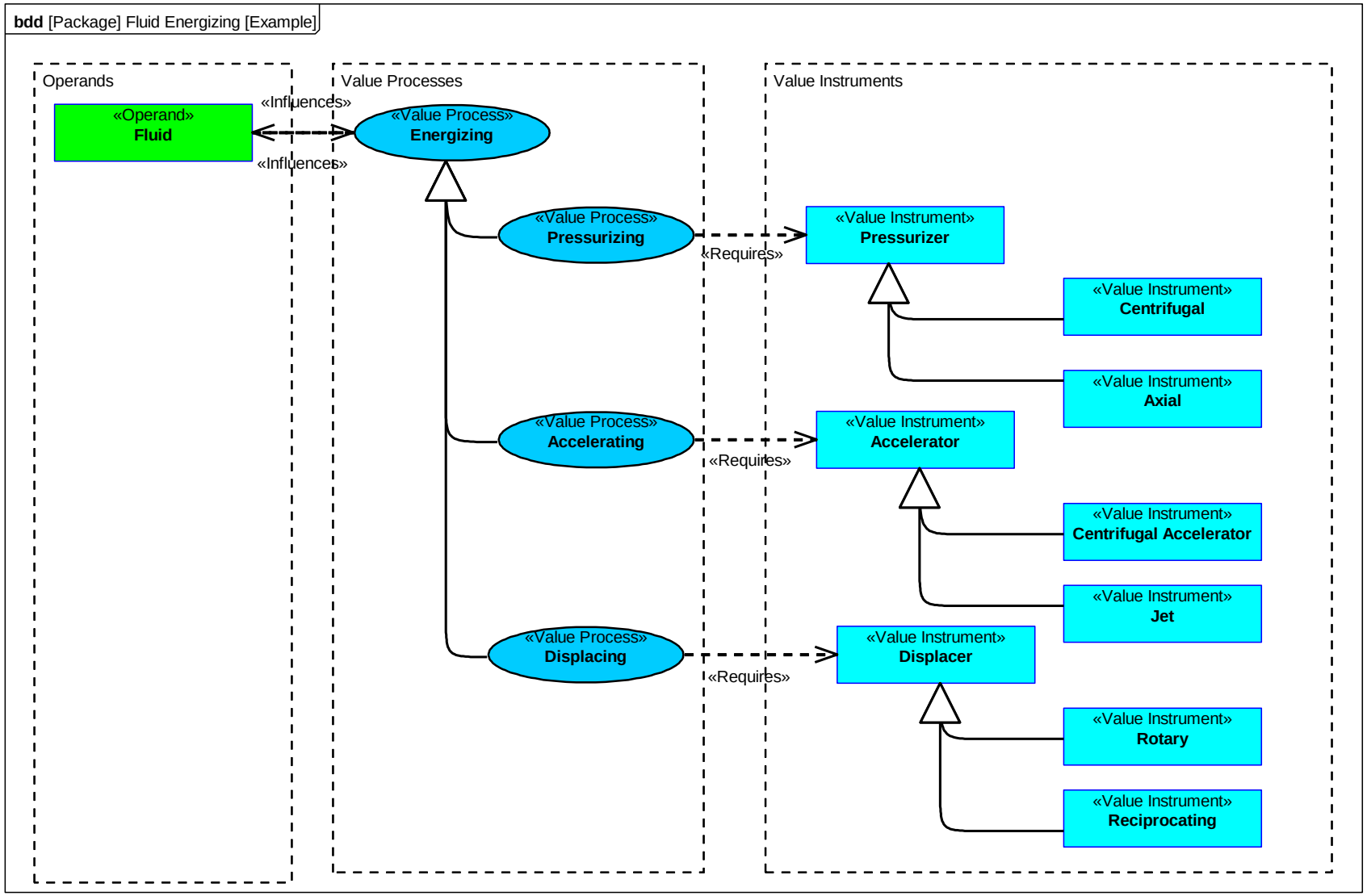
BOTTLE OPENER EXAMPLE

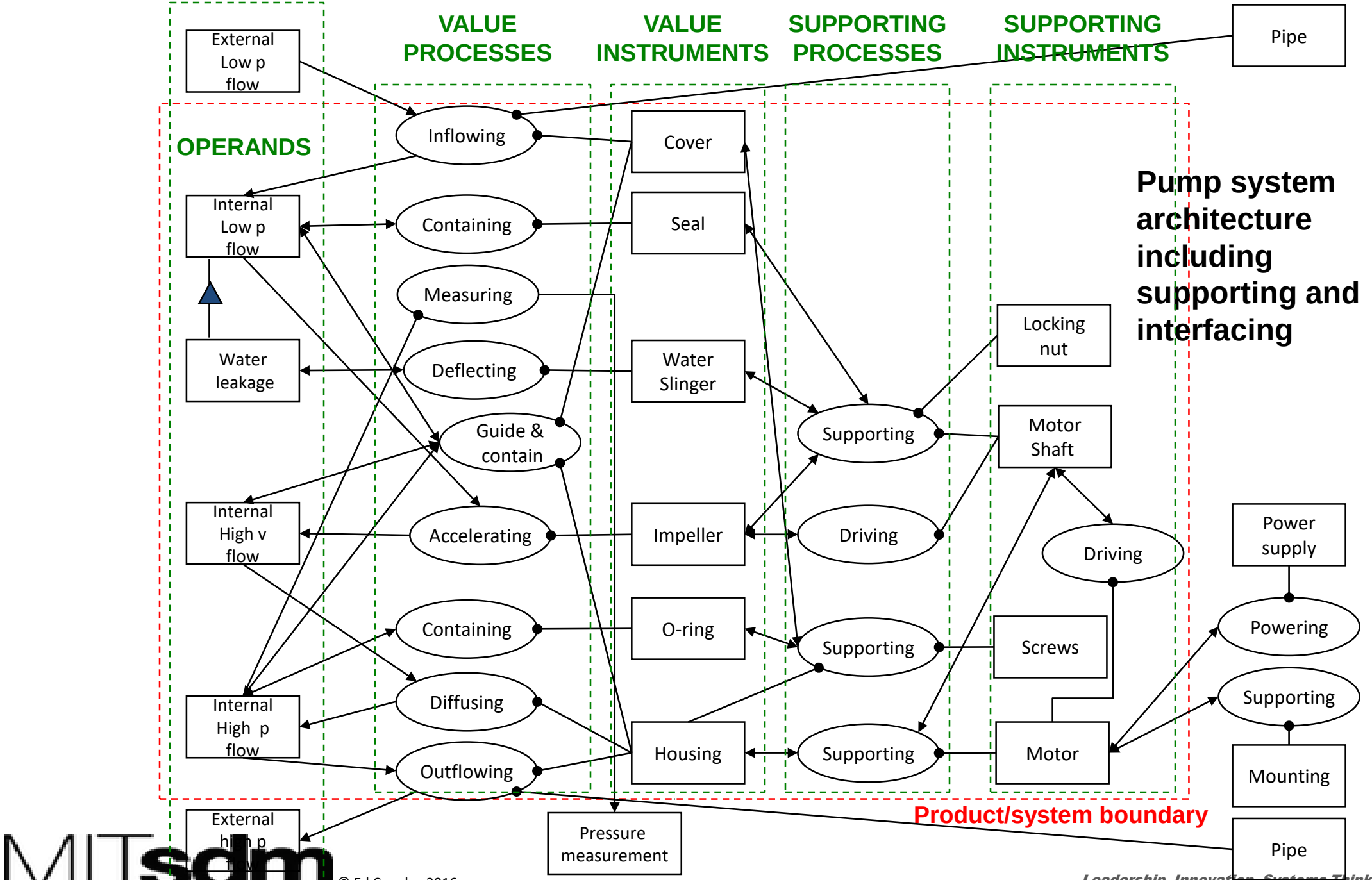
- Defines components of Wine Bottle system
- Defines processes of different varieties for opening wine bottles
  - Opening, removing, breaching, destroying, vaporizing, etc.
  - Defined using inheritance.



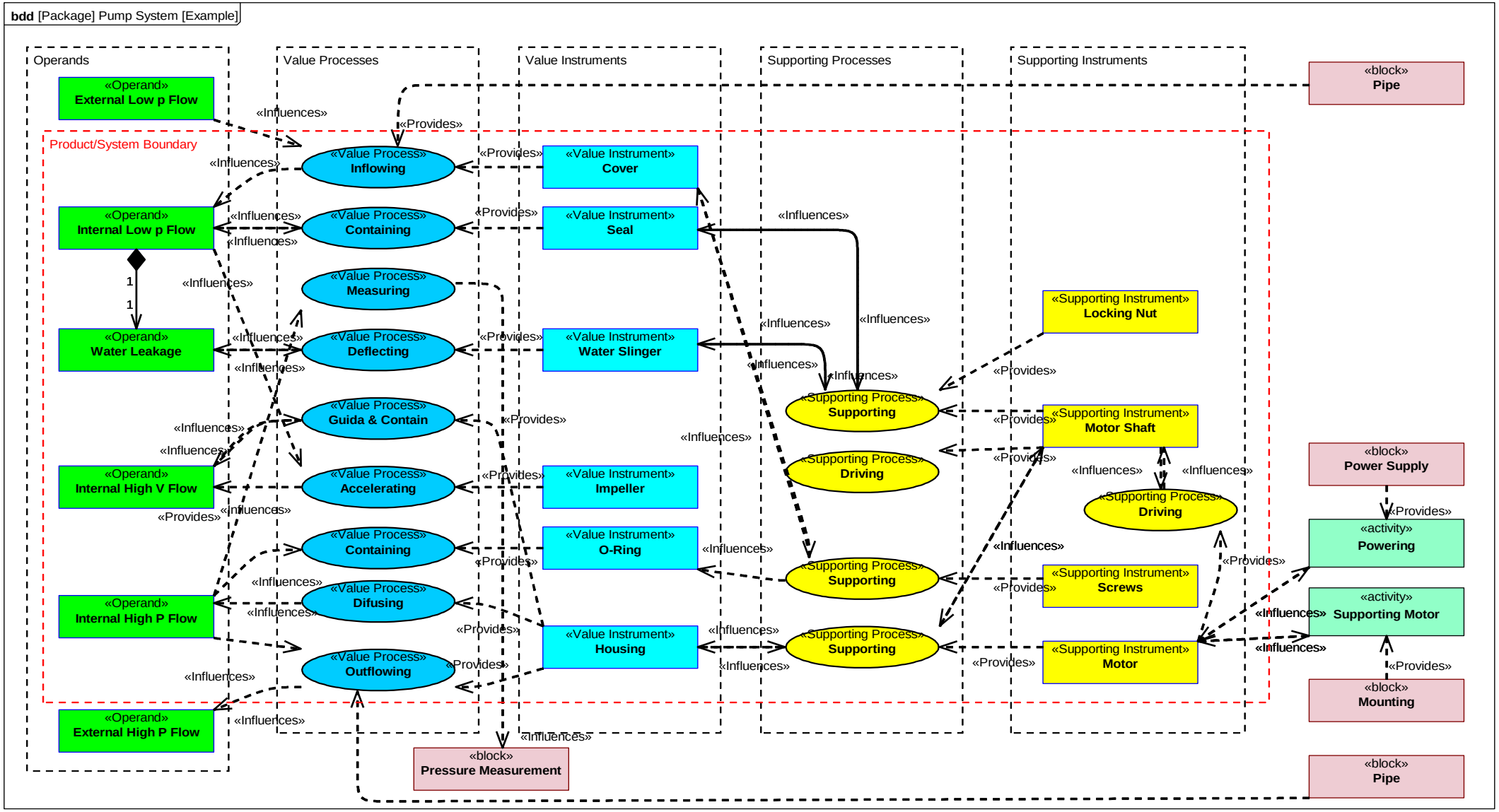
FLUID ENERGIZING EXAMPLE

- Defines the Fluid operand and methods of energizing it
- Defines Value Instruments for achieving processes



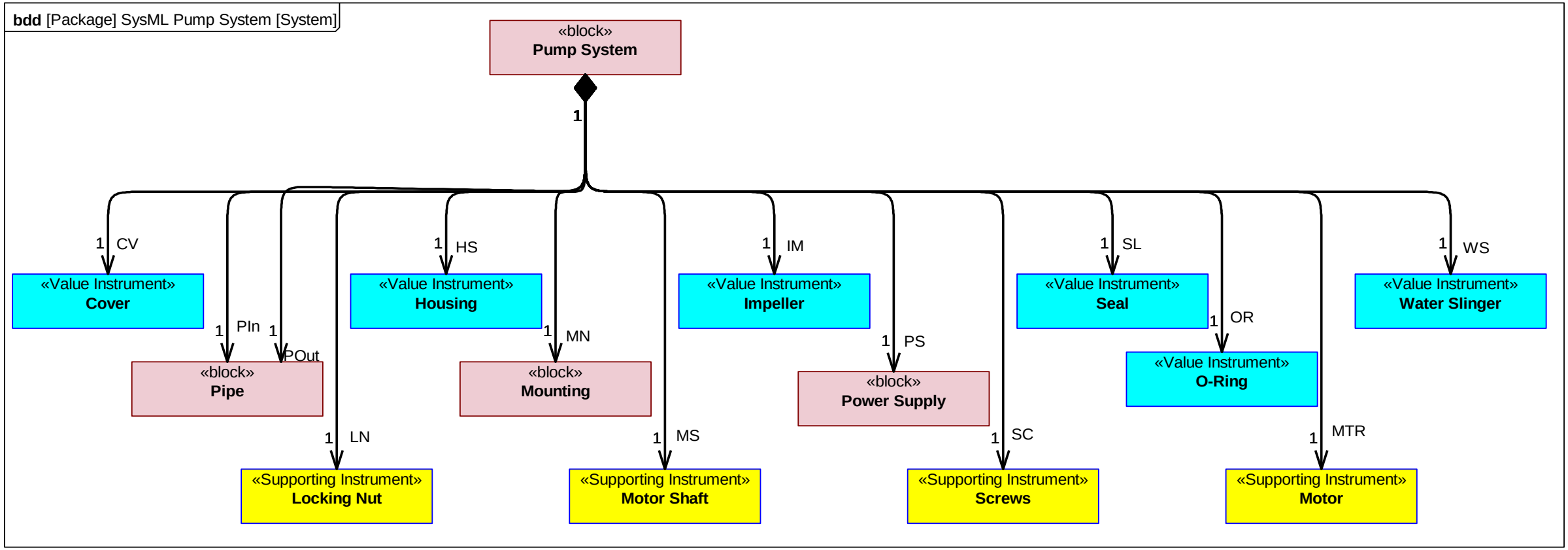


PUMP SYSTEM EXAMPLE

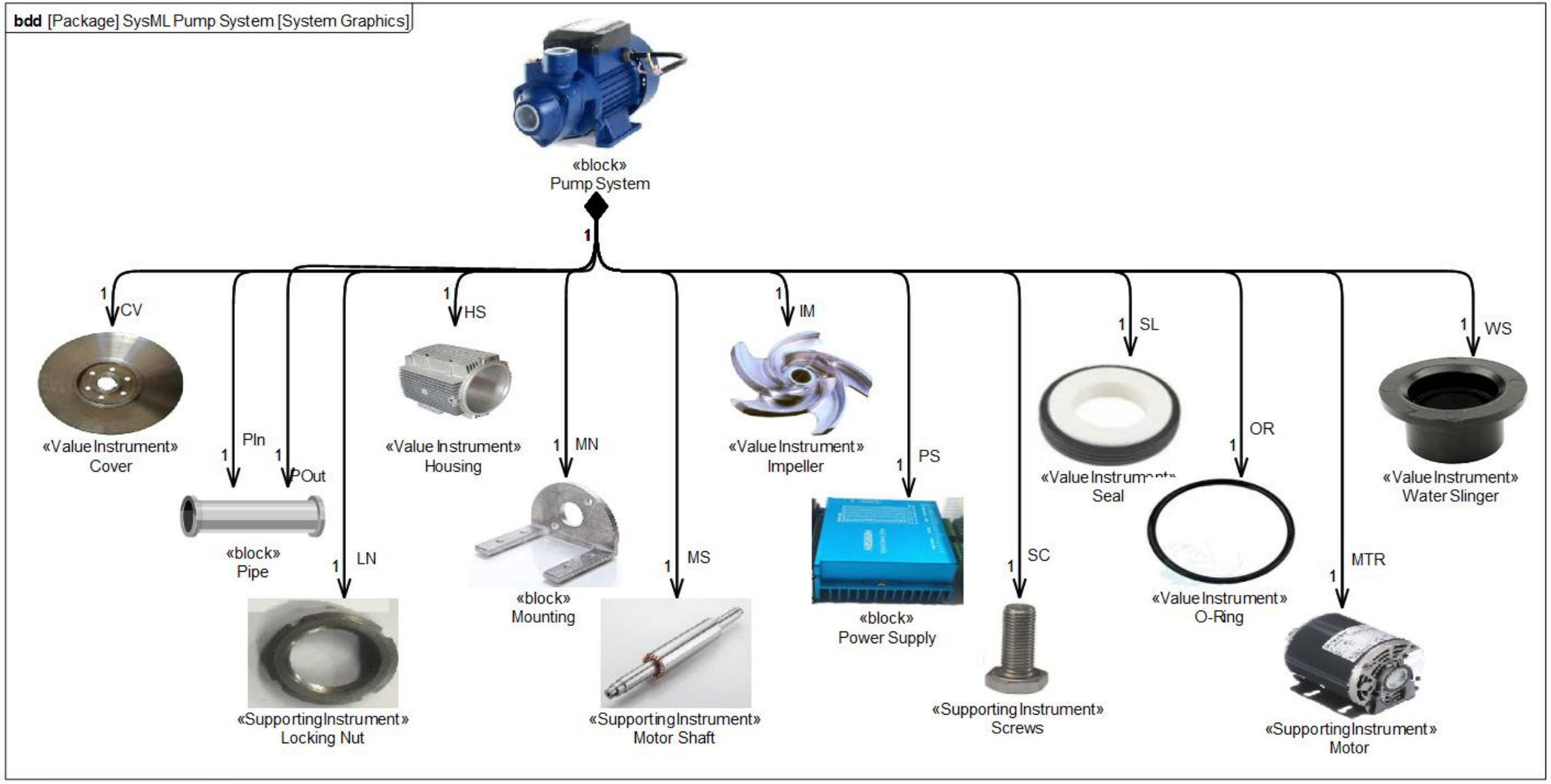


PUMP SYSTEM STRUCTURAL BREAKDOWN

- Pump System and its components.
- A combination of Value and Supporting Instruments and Blocks

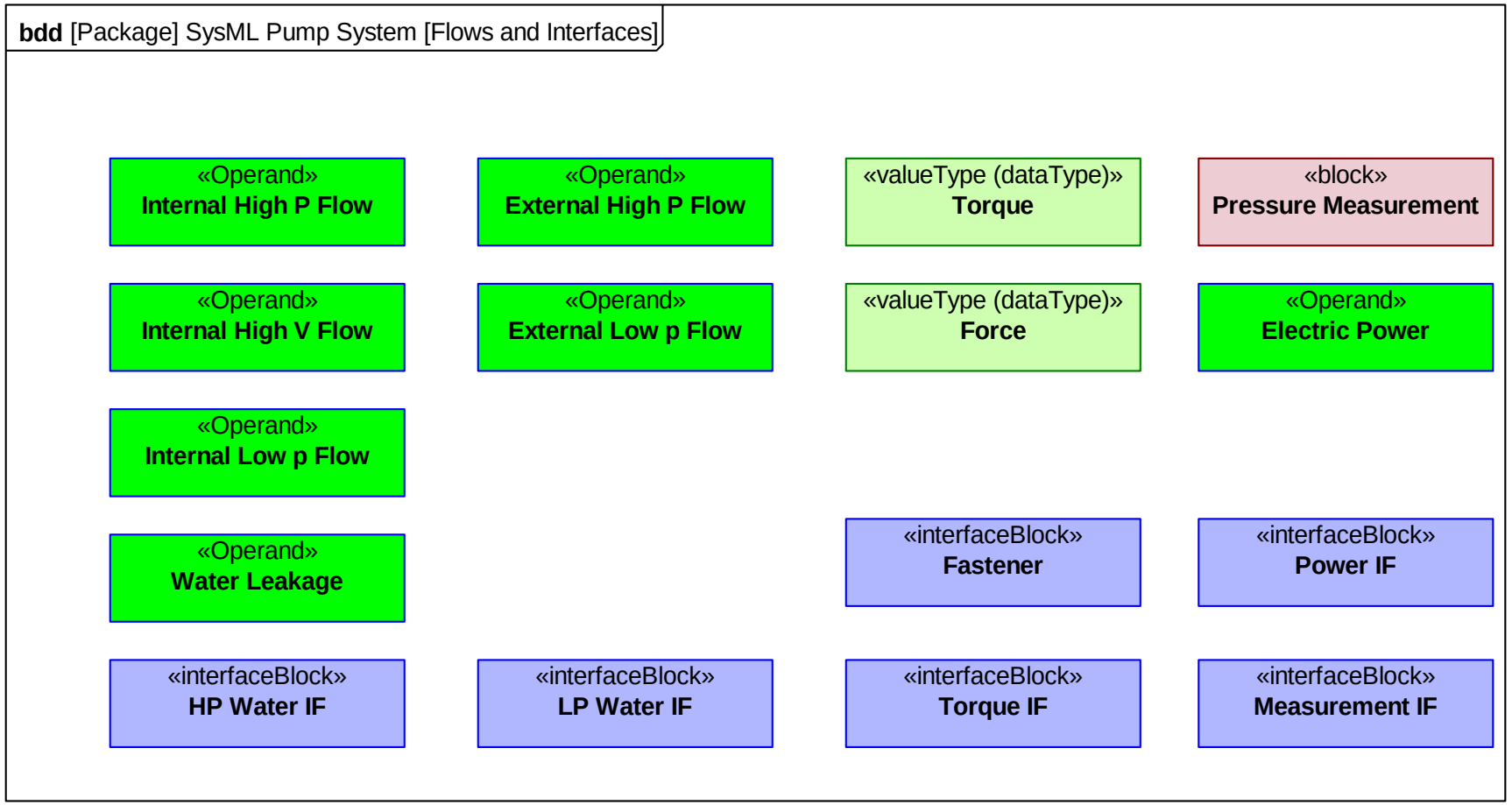


PUMP SYSTEM STRUCTURAL BREAKDOWN W/GRAPHICS

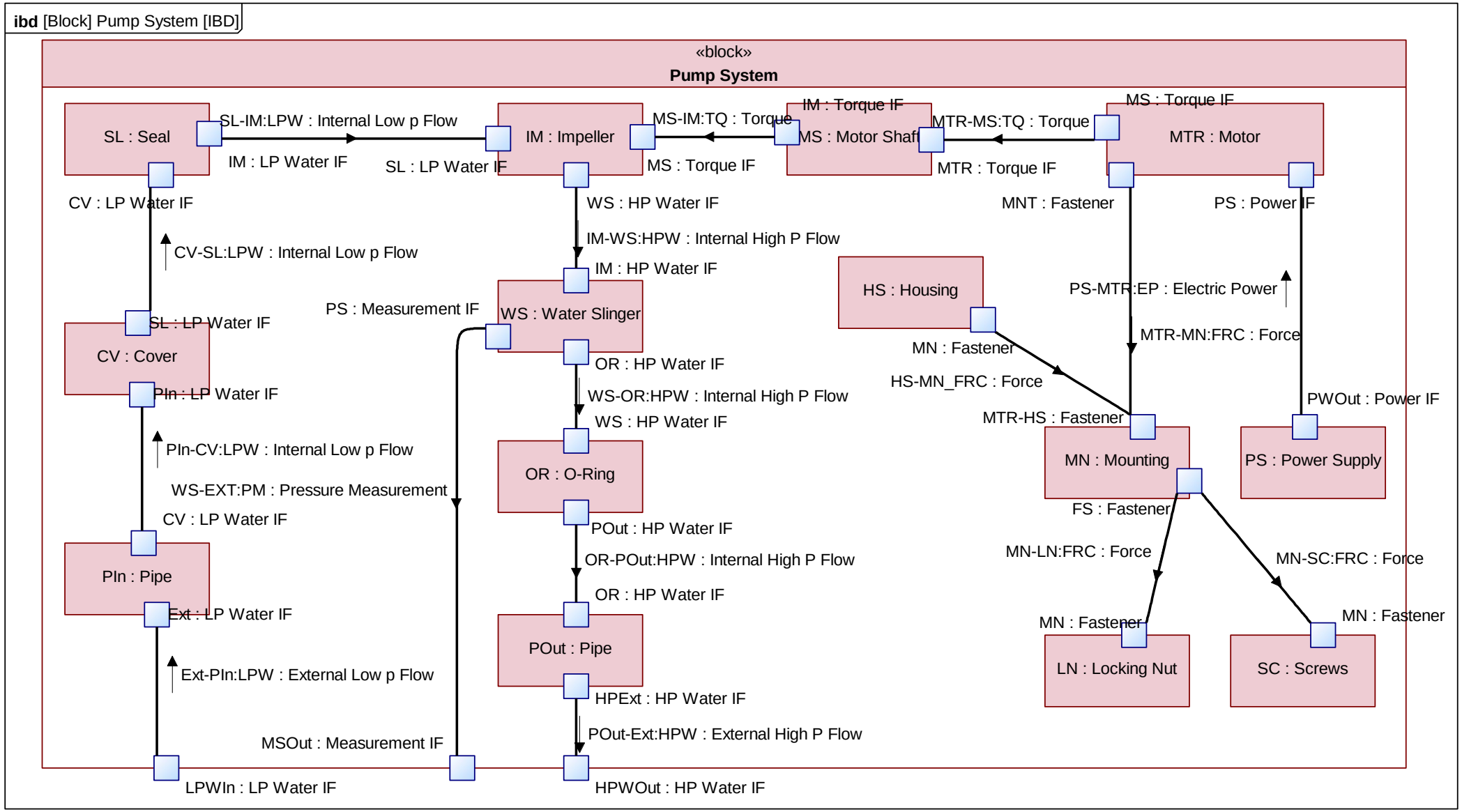


FLOWS AND INTERFACES

- Elements taken from the OPM example
- Torque and Force added as Value Types
- Interfaces added to define how systems interact

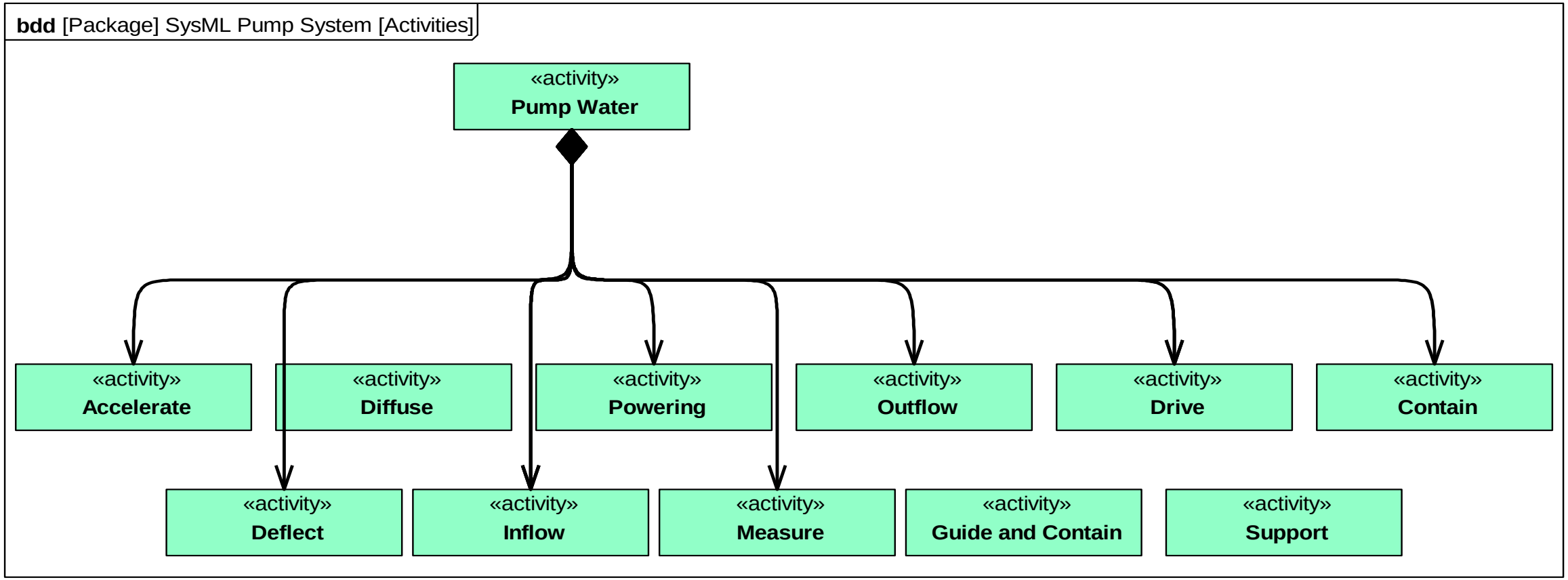


SYSTEM INTERNAL STRUCTURE



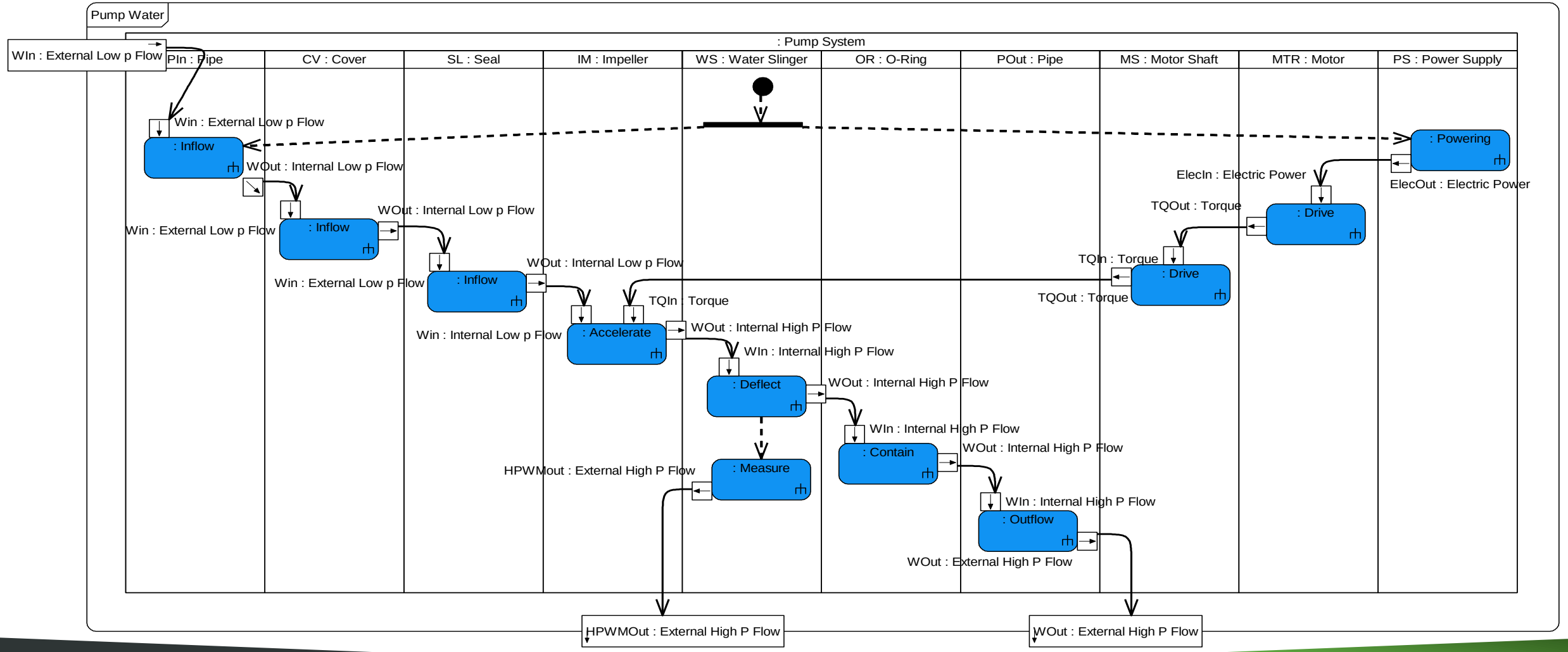
SYSTEM FUNCTIONAL BREAKDOWN

- Activities created from the original OPM elements
- Guide and Contain, and Support were not used.



SYSTEM ACTIVITY DIAGRAM

- Defined as a continuous, parallel sequence.
- Similar to the SysML V1 Distiller example



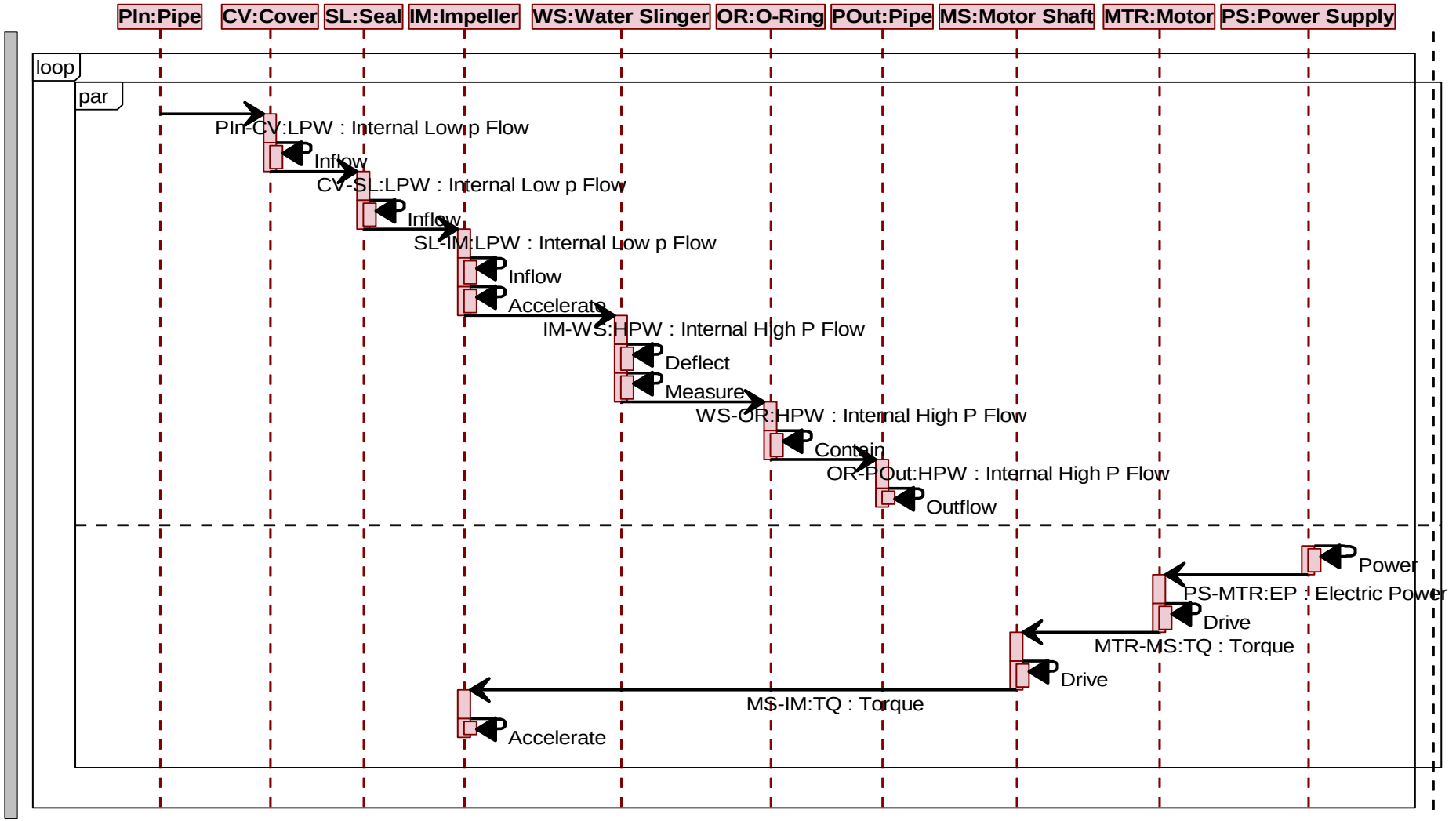
PUMP SEQUENCE DIAGRAM

- Defines the system interactions in a defined order and links behavior.

Description

loop
- par
  - Low P water flow
  - Flow thru
  - Low P water flow
  - Flow thru
  - Low P water flow
  - Flow thru
  - Energize water
  - High P water flow
  - Deflect
  - Measure Pressure
  - High P water flow
  - Contain Water
  - High P water flow
  - Flow thru
- also par
  - Generate Power
  - Power Motor
  - Drive Motor
  - Torque transfer
  - Drive Motor Shaft
  - High P water flow
  - Energize water
- end par

Until Shutdown



WHY IS THIS USEFUL?

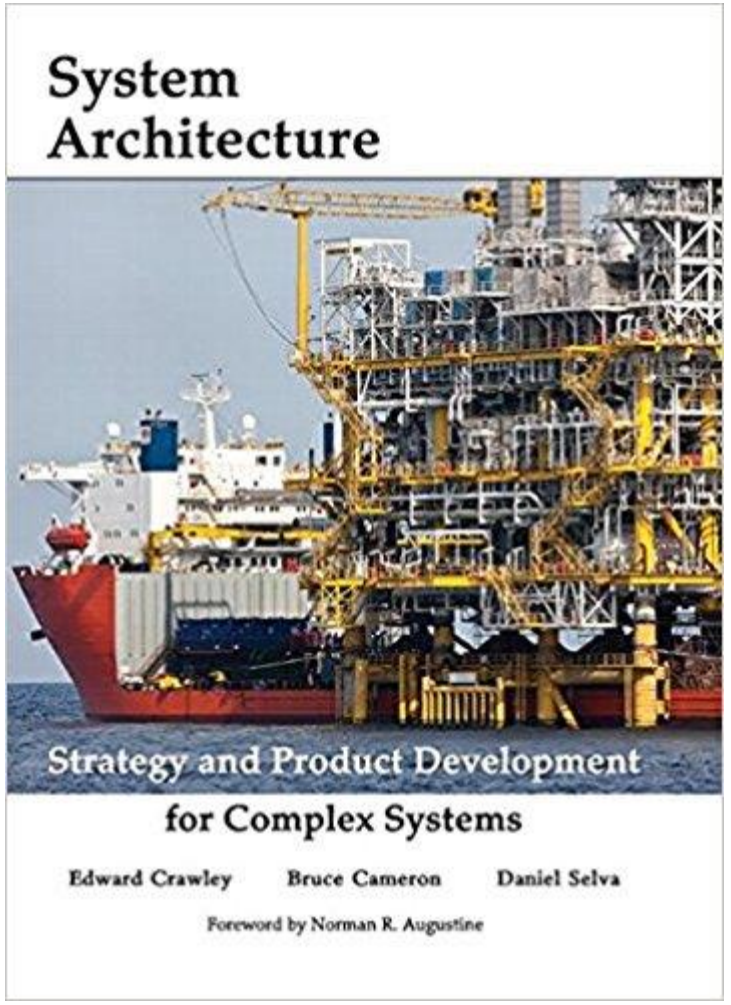
- Demonstrates that the different languages can be used together in a single tool
  - Alternative would be to create the OPM model in OPCAT use printout as a basis for traceability
  - The integrated approach means that true impact analysis and traceability can be done.
- An OPM Model can created as a starting point with SysML used to refine the concepts
  - The elements were then used to create the SysML diagrams
  - Some additions and changes were needed
  - Alternative would be to create separate OPM and SysML models and create trace links between them
- Other concepts can be added such as parametrics, executable state machines, traceability to requirements, analysis and PLM tools, etc.

CONCLUSIONS

- Many of the concepts in OPM can be duplicated in a SysML tool
  - There is some cognitive dissonance
  - Provide an alternative means of looking at a system
  - Provide a starting point for people familiar with OPM
  - Both are useful
- The models demonstrate that the languages can be used together
  - OPM as a starting point can be used to develop a detailed SysML model
- More work and research are needed
  - ALL OPM concepts were not added as this was more of a proof of concept than a solution.
  - The text portion of OPM (OPL) was not implemented.
  - "Finally, defining a hybrid methodology exploiting the advantages of the two languages seems to be a challenging issue." *Systems Modeling Languages: OPM Versus SysML*

ACKNOWLEDGEMENT AND THANKS

- Examples were taken from the Edward Crawley et al Book System Architecture: Strategy and Product Development for Complex Systems
- MIT SDM course slides
- Rob Day and John Deere for their help in creating the model and gaining an understanding of OPM
- Tutorials and papers by Dov Dori



WORKING TOGETHER TO ACHIEVE COMMON GOALS

THE GOLDEN SPIKE

THE CHANNEL TUNNEL

FAMOUS FRENEMIES

- **Nicole Richie and Paris Hilton**

- **Jennifer Aniston and Courteney Cox**

- **Lauren Conrad and Heidi Montag**

- **Paris Hilton and Lindsay Lohan**

- **Selena Gomez and Miley Cyrus**

- **Whitney Port and Olivia Palermo**

- **Winona Ryder and Gwyneth Paltrow**

- **Selena Gomez and Demi Lovato**

http://www.zimbio.com/Famous+Frenemies/articles

Q&A

Thank You!

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