The OMG SysML-Modelica Transformation Specification:

Supporting Model-Based Systems Engineering with SysML and Modelica

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www.pslm.gatech.edu/courses
www.omg.org/ocsmp

SysML-Modelica Transformation Specification: Context & Objective

- Two complementary languages for Systems Engineering:
  - Descriptive modeling in SysML
  - Formal equation-based modeling for analyses and trade studies in Modelica

- Objective:
  - Leverage the strengths of both SysML and Modelica by integrating them to create a more expressive and formal MBSE language.
  - Define a formal Transformation Specification:
    - » a SysML4Modelica profile
    - » a Modelica abstract syntax metamodel
    - » a mapping between Modelica and the profile

Presentation Overview

- What is SysML?
- What is Modelica?

- Motivating Example: Design & Analysis of Robot

- SysML-Modelica Transformation Specification
- Transformations in Model-Based Systems Modeling
- Summary

Acknowledgements

Working Group Members

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- Peter Fritzson (Linköping University)
- Nerijus Jankevicius (No Magic)
- Alek Kerzhner (Georgia Tech)
- Andreas Korff (Atego)
- Chris Paredis (Georgia Tech)
- Axel Reichwein (Georgia Tech)
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- Wladimir Schamai (EADS)

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- Sebastian Herzig
- Alek Kerzhner
- Ben Lee
- Roxanne Moore
- Axel Reichwein
- Wladimir Schamai

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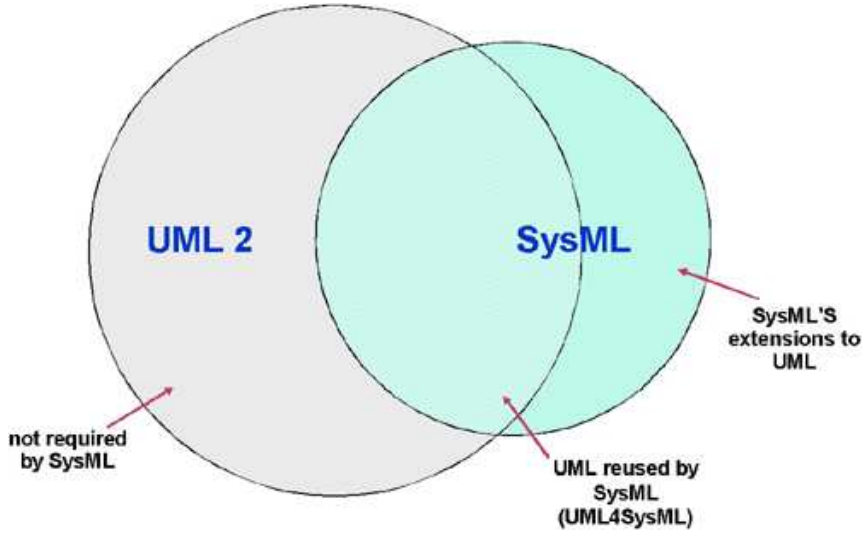
Systems Modeling Language: SysML

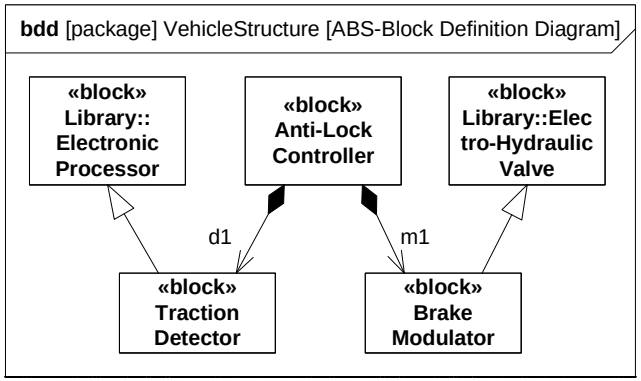
- SysML is an extension of the Unified Modeling Language.
- Supports the modeling of physical systems – not just software
- It is not a methodology or tool
- Improves the ability to exchange systems engineering information among tools and people



(Source: Friedenthal, www.omgsysml.org)

Pillars of SysML: 4 Main Diagram Types

1. Structure



definition

2. Behavior

4. Requirements

3. Parametrics

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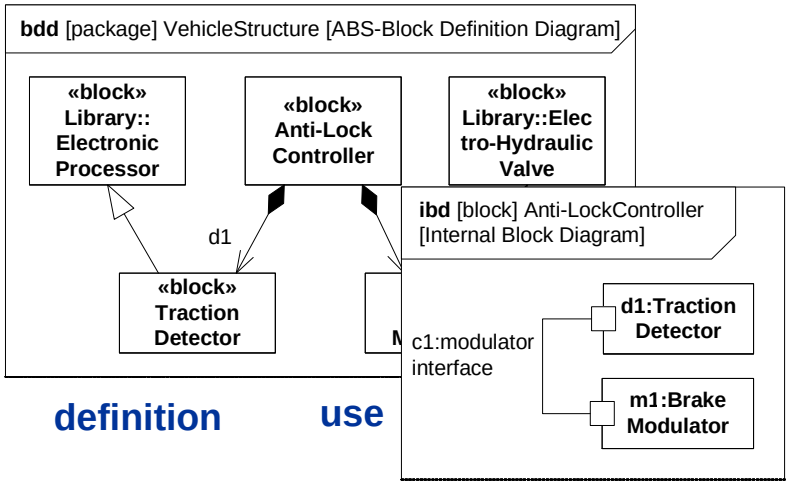
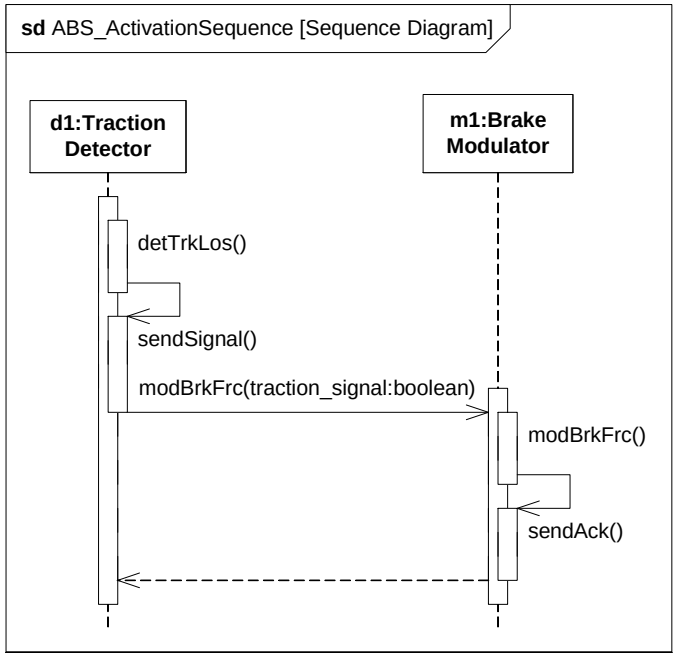


definition **use**



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interaction

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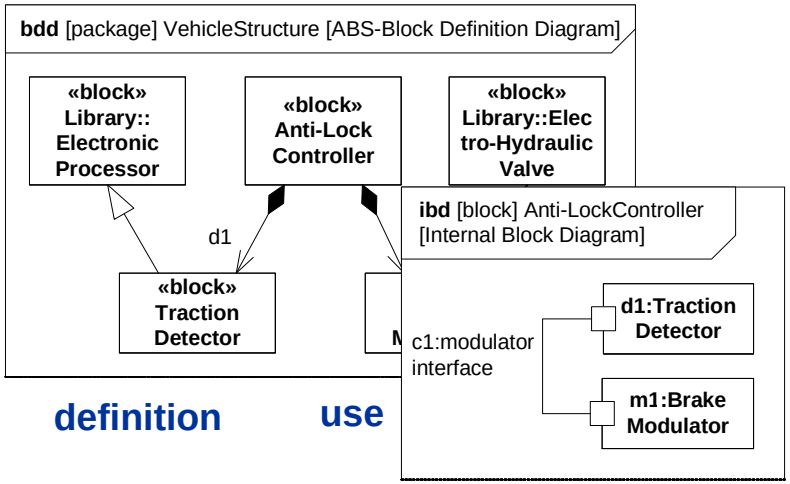
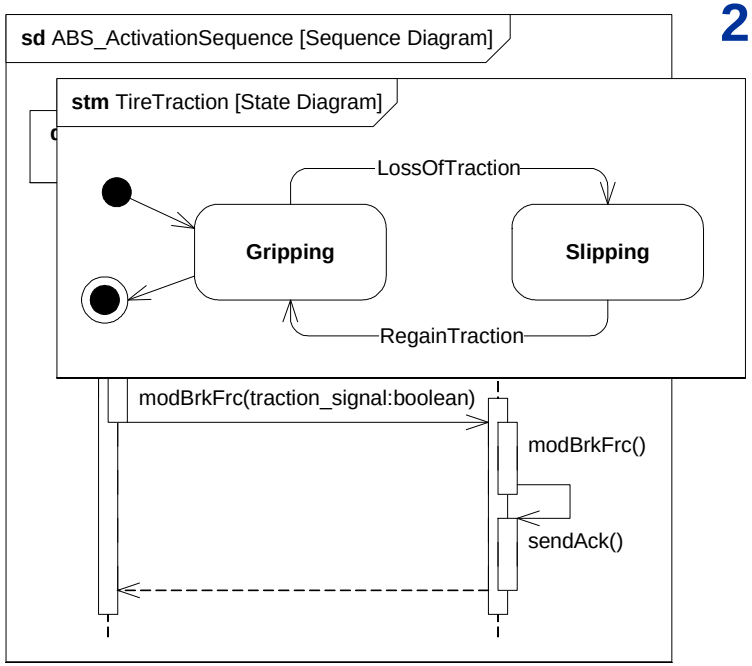


definition **use**

2. Behavior



interaction

state machine

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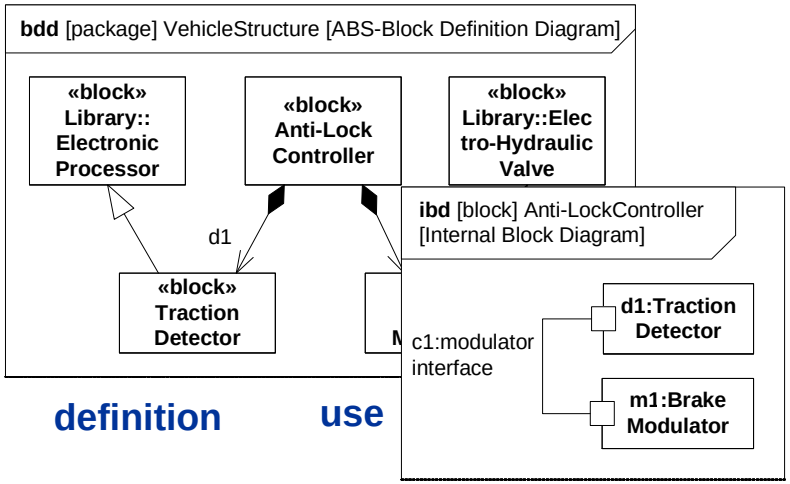

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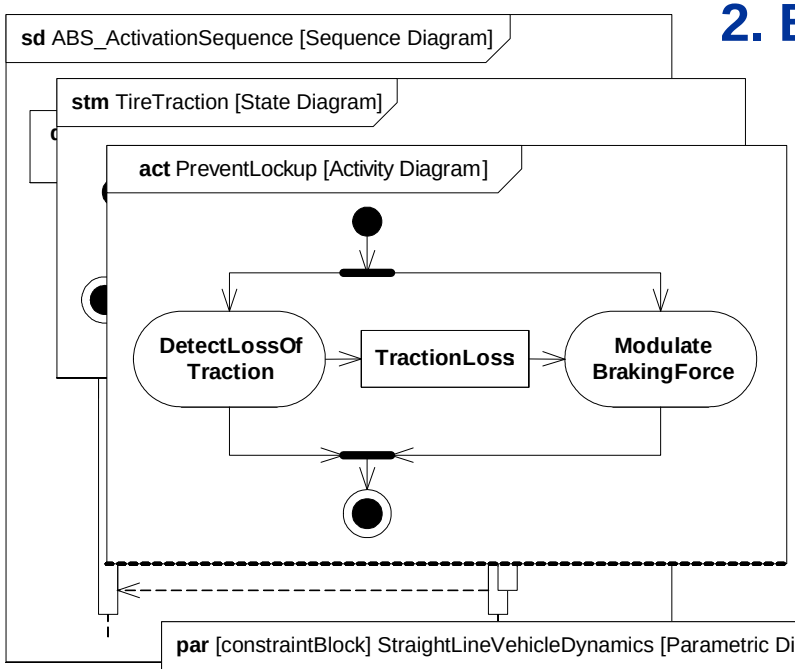
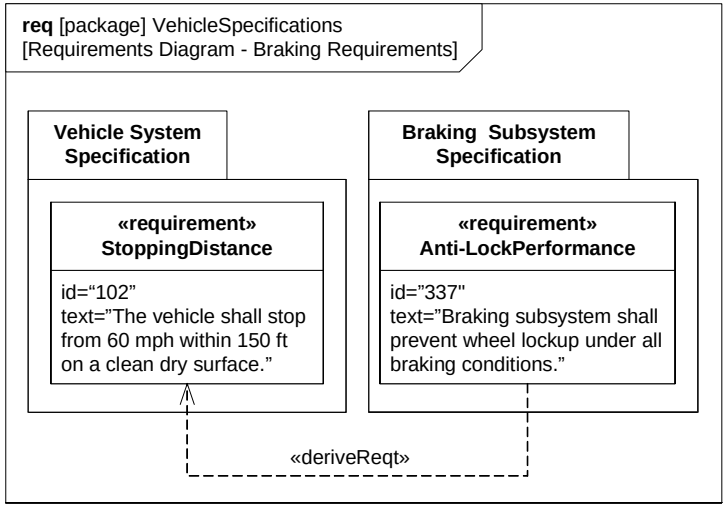


interaction

state machine

activity/ function



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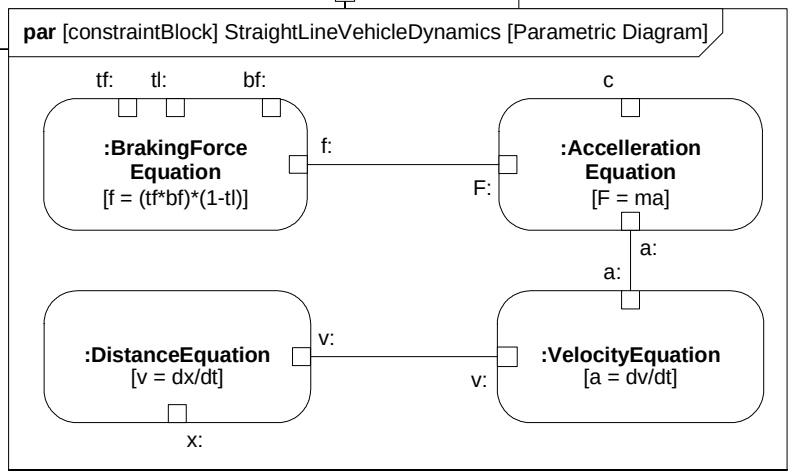

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Cross Connecting Model Elements

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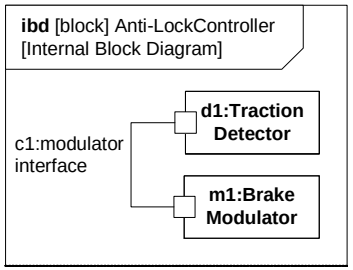

allocate

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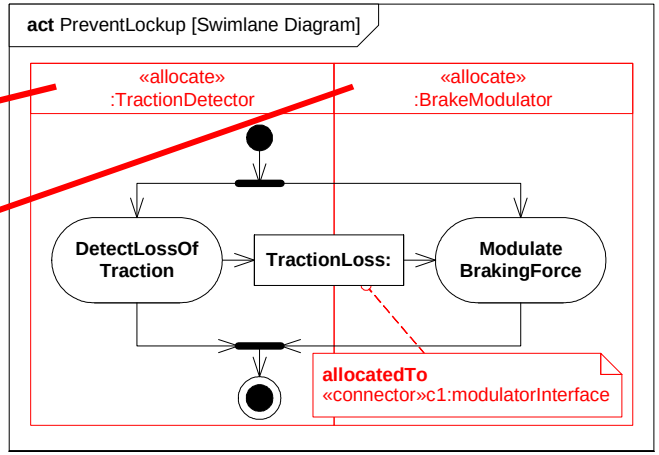

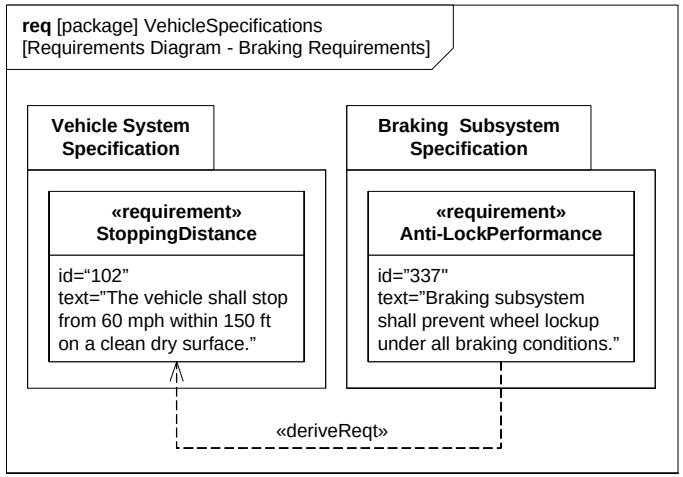

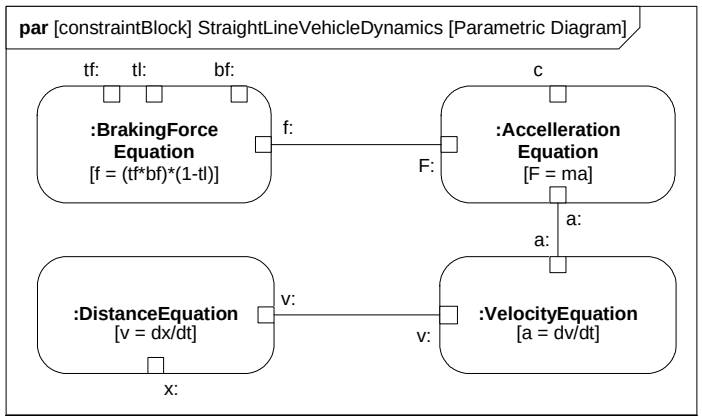

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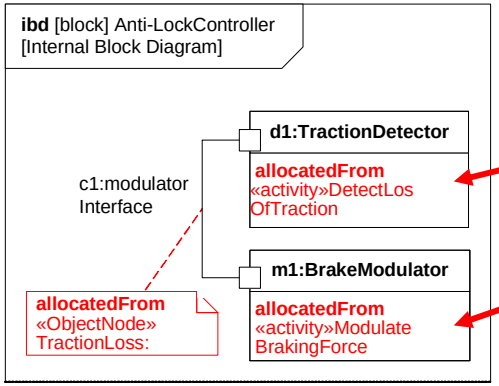

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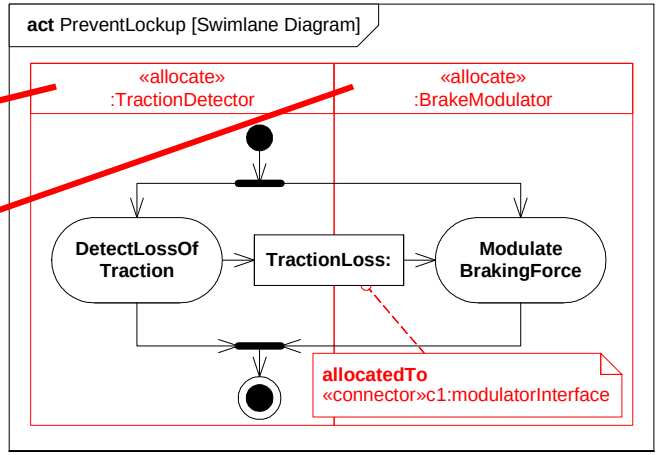

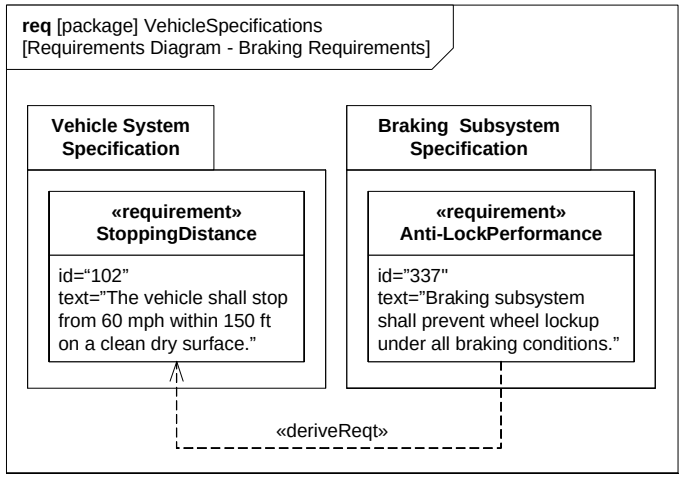

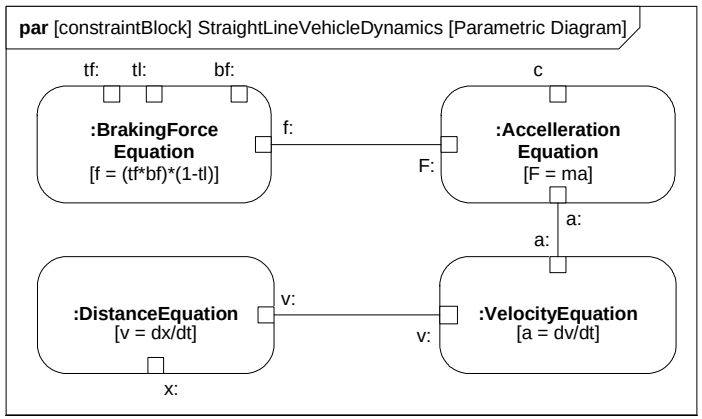

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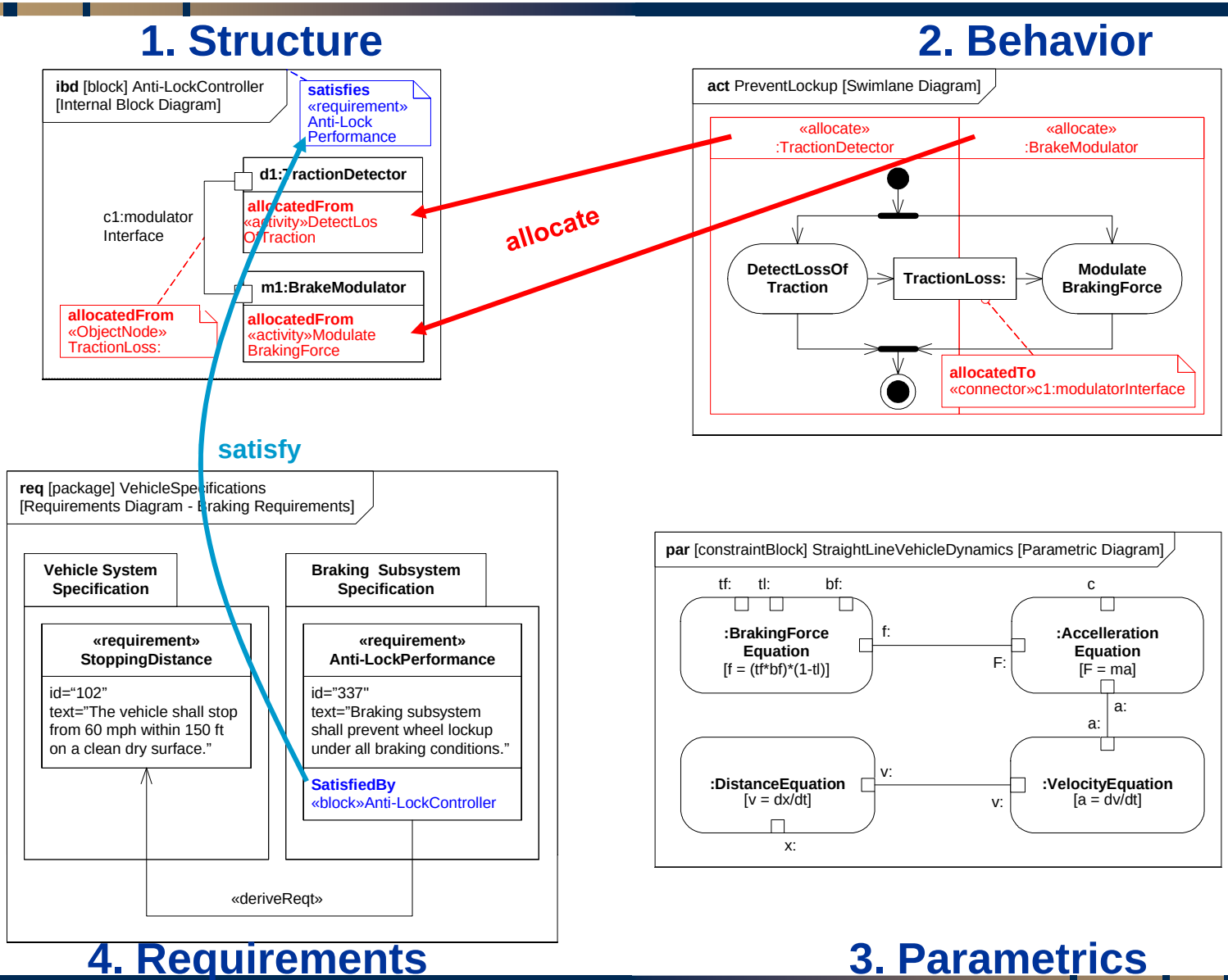

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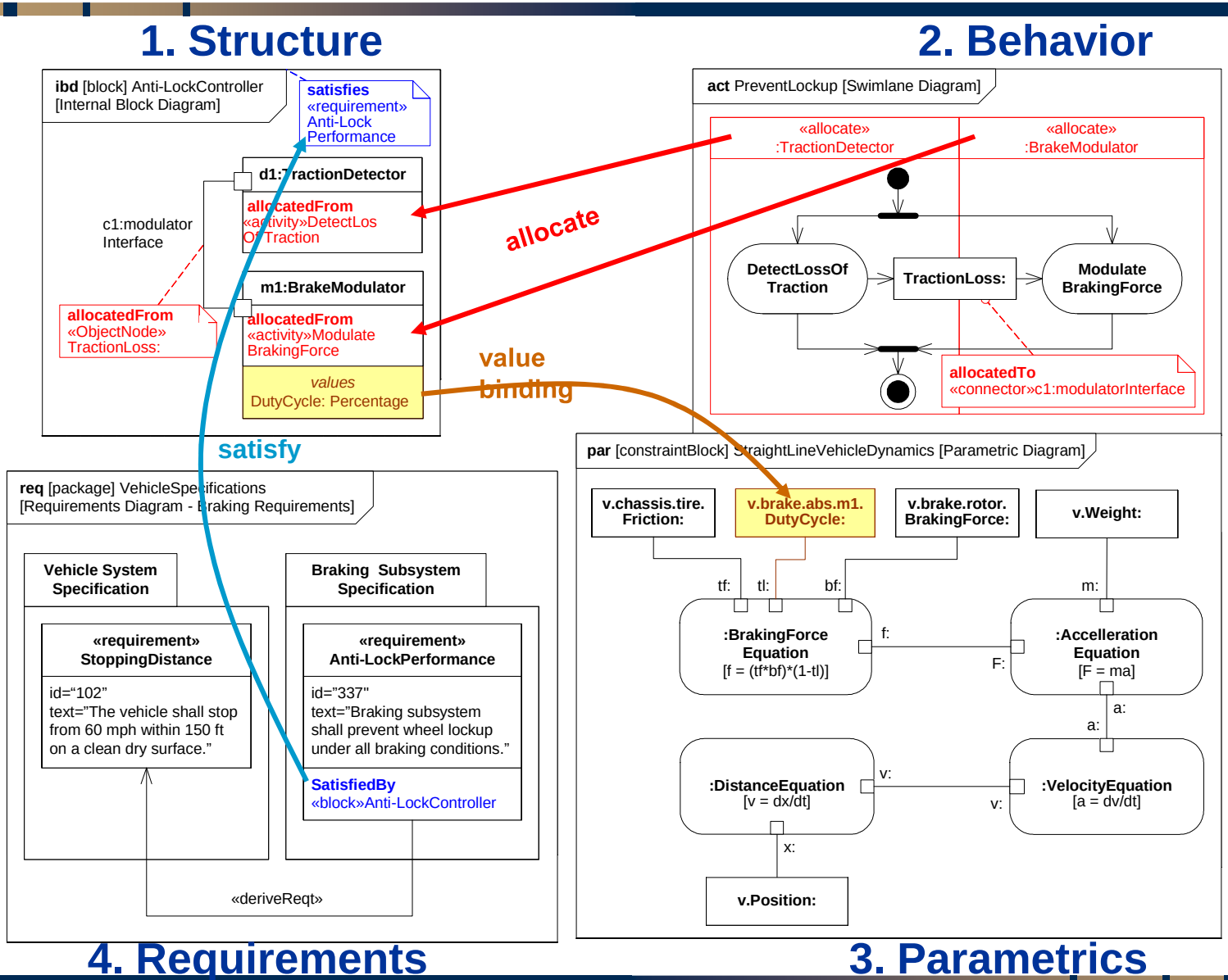

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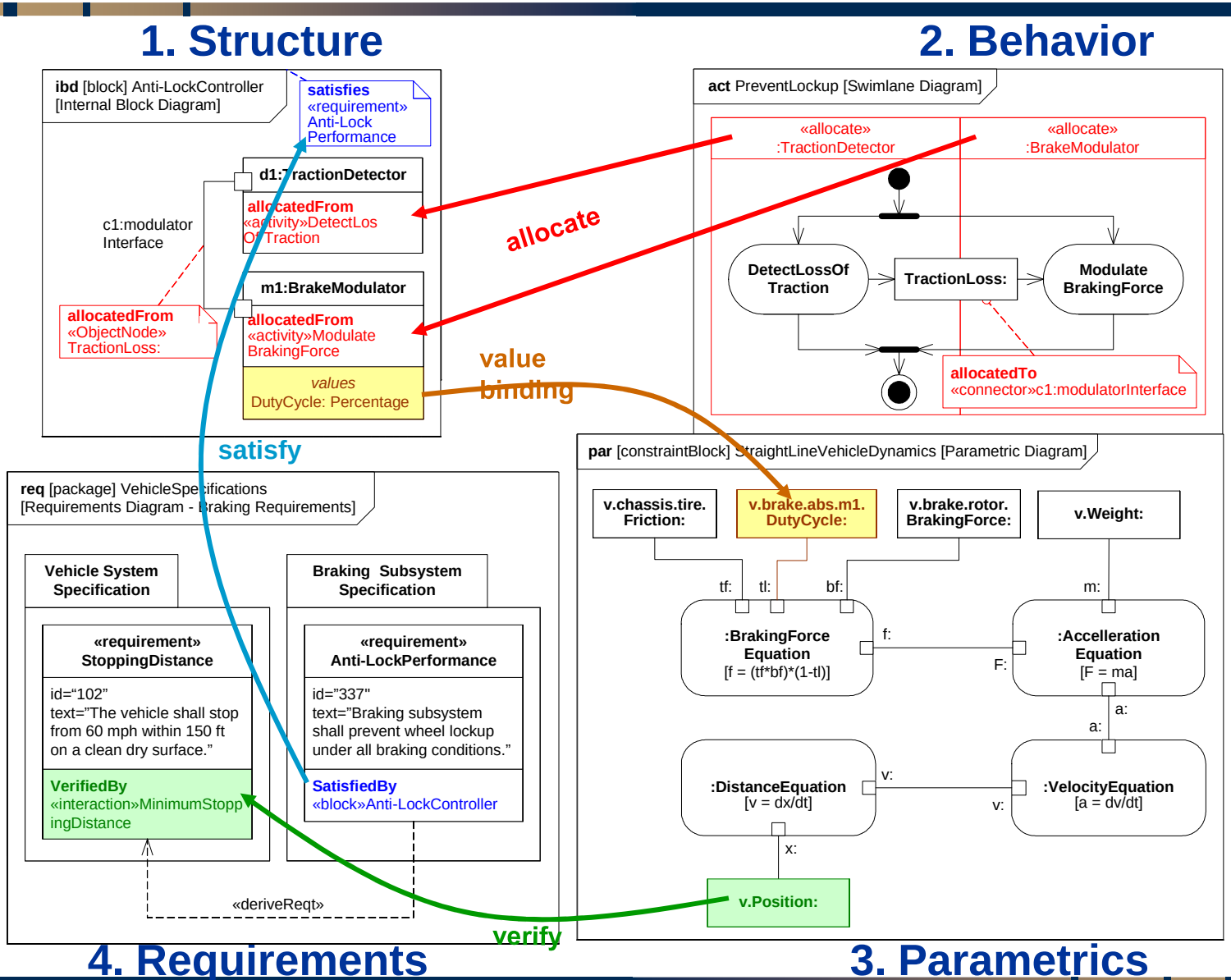


What is Modelica?
(www.modelica.org)

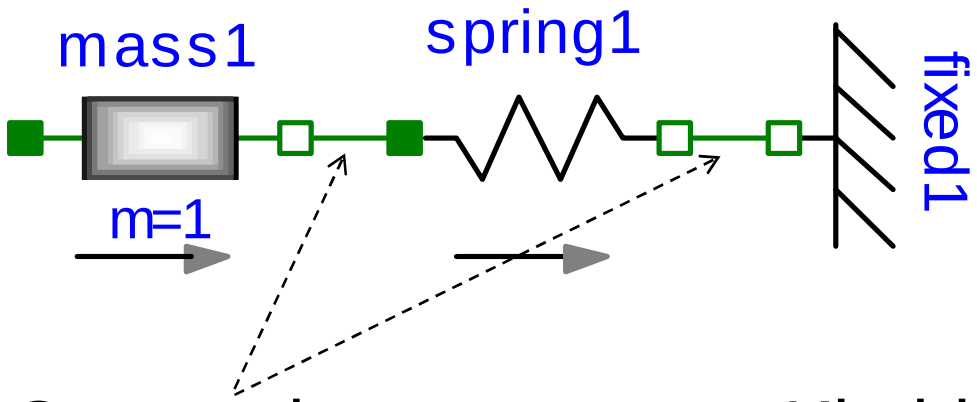
- State-of-the-art Modeling Language for System Dynamics
  - Differential Algebraic Equations (DAE)
  - Discrete Events

- Represents DAE models in an object-oriented, engineering-oriented language
- Multi-(physical)-domain modeling
- Ports represent energy flow (undirected) or signal flow (directed)
- Acausal, equation-based, declarative (f-m*a=0)

Modelica Semantics and Textual Syntax

```
model Spring "Linear 1D translational spring"
  extends Translational.Interfaces.PartialCompliant;
  parameter SI.TranslationalSpringConstant c(final min=0, start = 1)
    "spring constant ";
  parameter SI.Distance s_rel0=0 "unstretched spring length";

equation
  f = c*(s_rel - s_rel0);
end Spring;
```



Graphical symbols defined as annotations in textual models

- Connections represent Kirchhoff semantics
  - Across variables (voltage, pressure,…) are equal
  - Through variables (current, flow rate,…) add to zero

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- What is Modelica?

➡ Motivating Example: Design & Analysis of Robot

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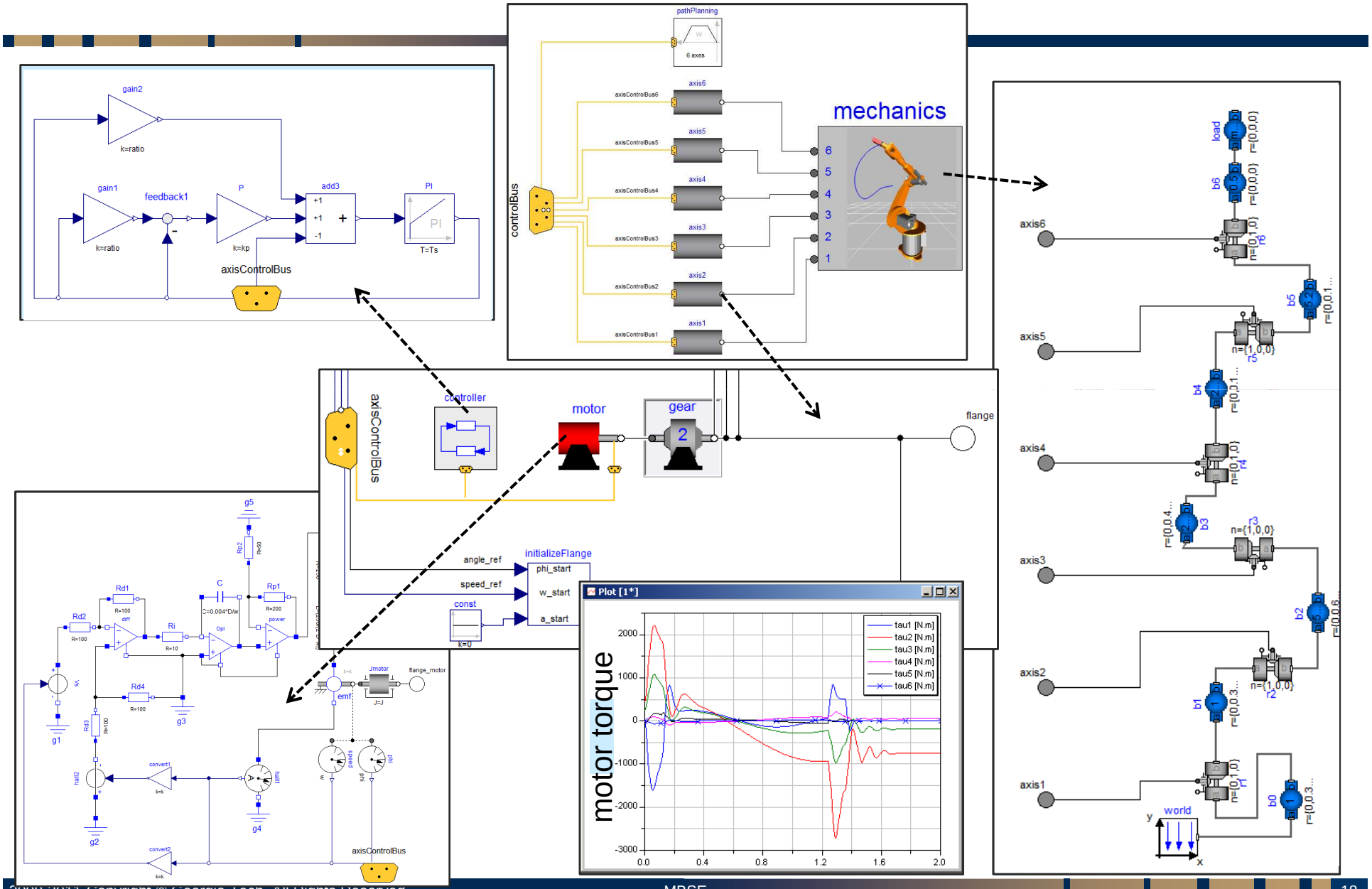
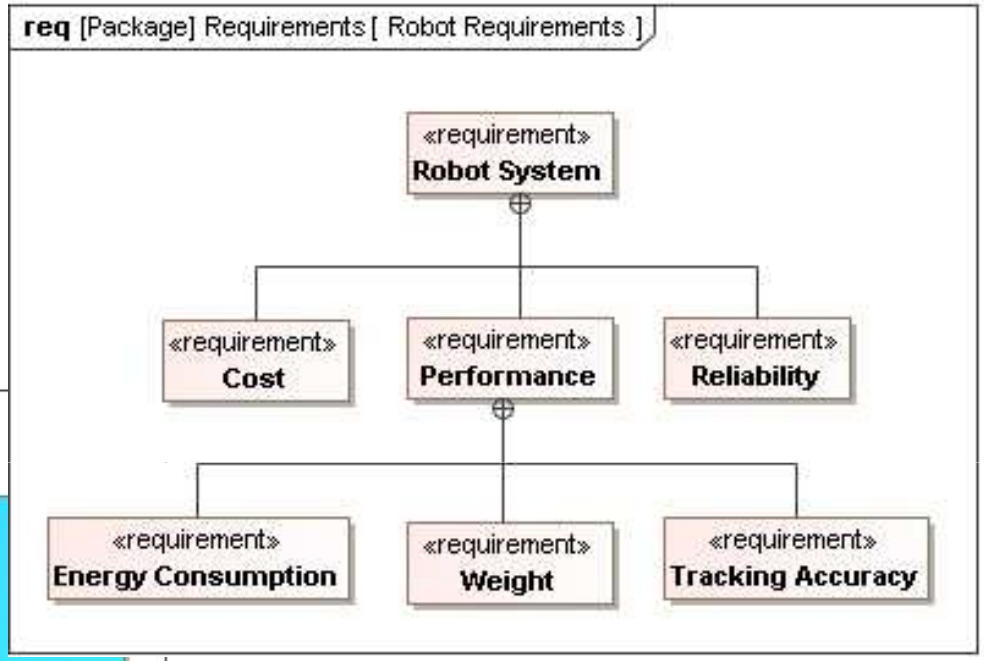
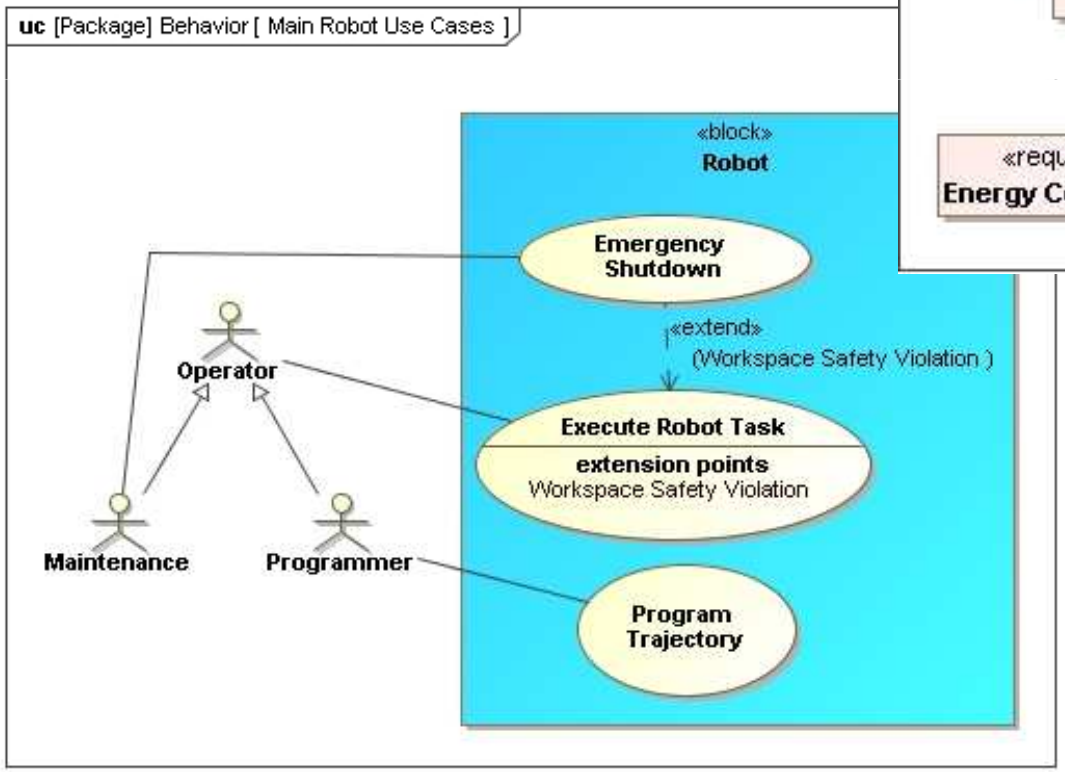
A Robot Example in Modelica

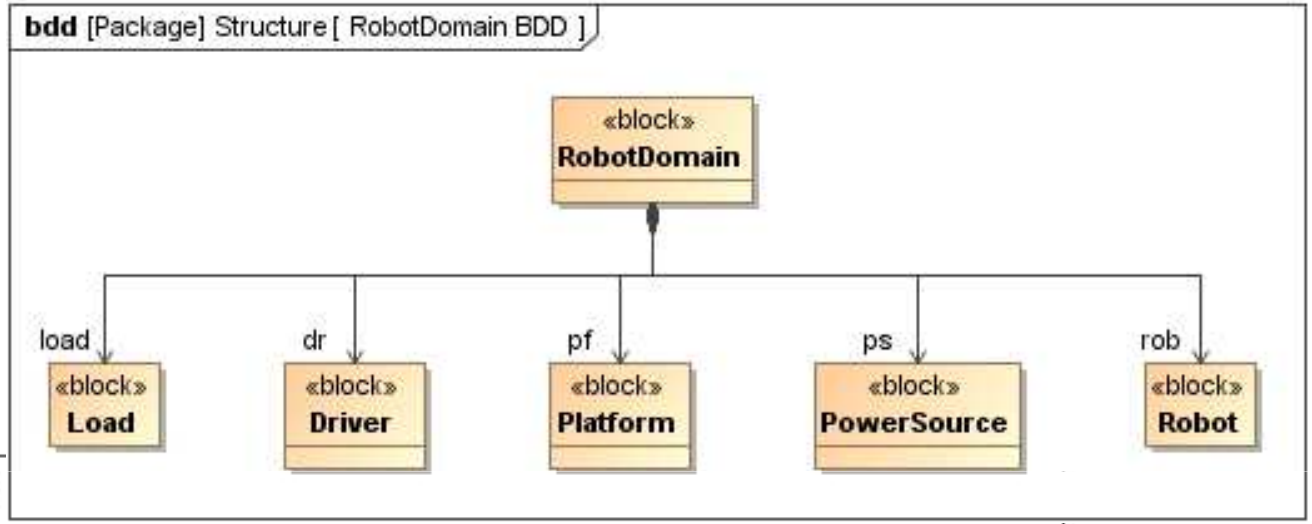


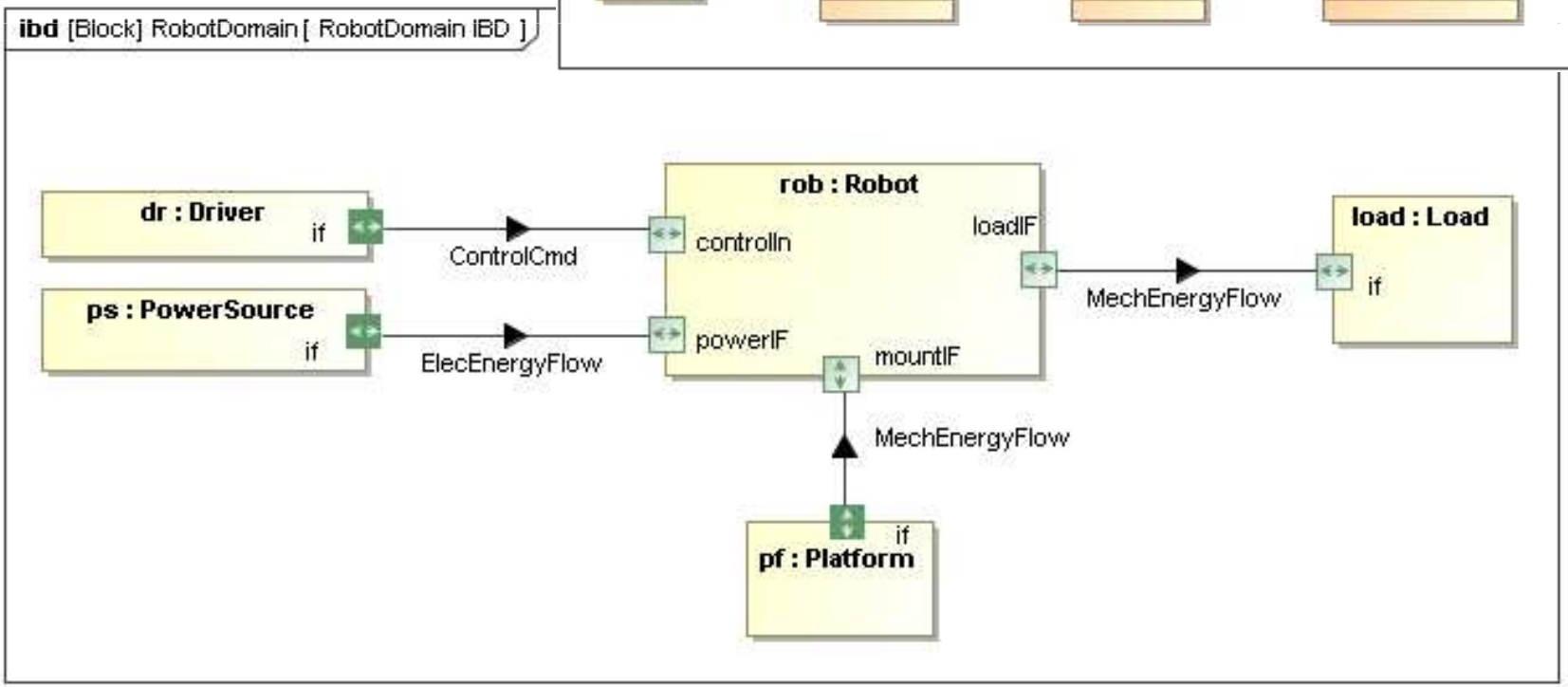
SysML-Modelica Robot Example: UseCases & Requirements





SysML-Modelica Robot Example: Robot Domain BDD & IBD





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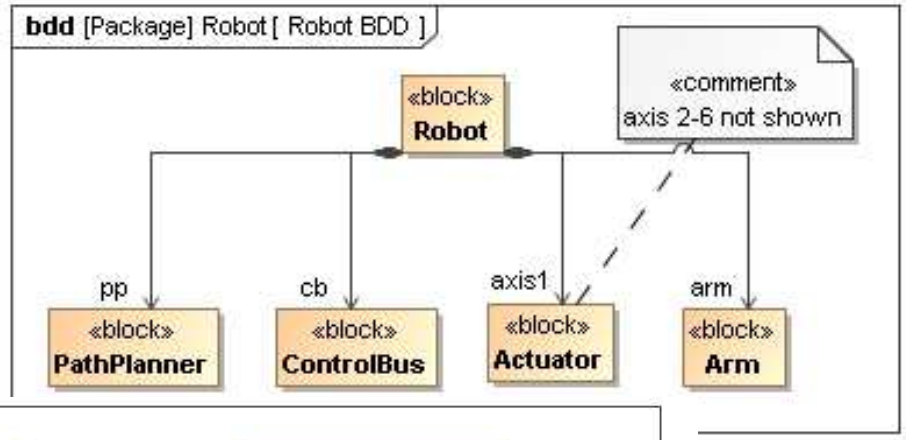
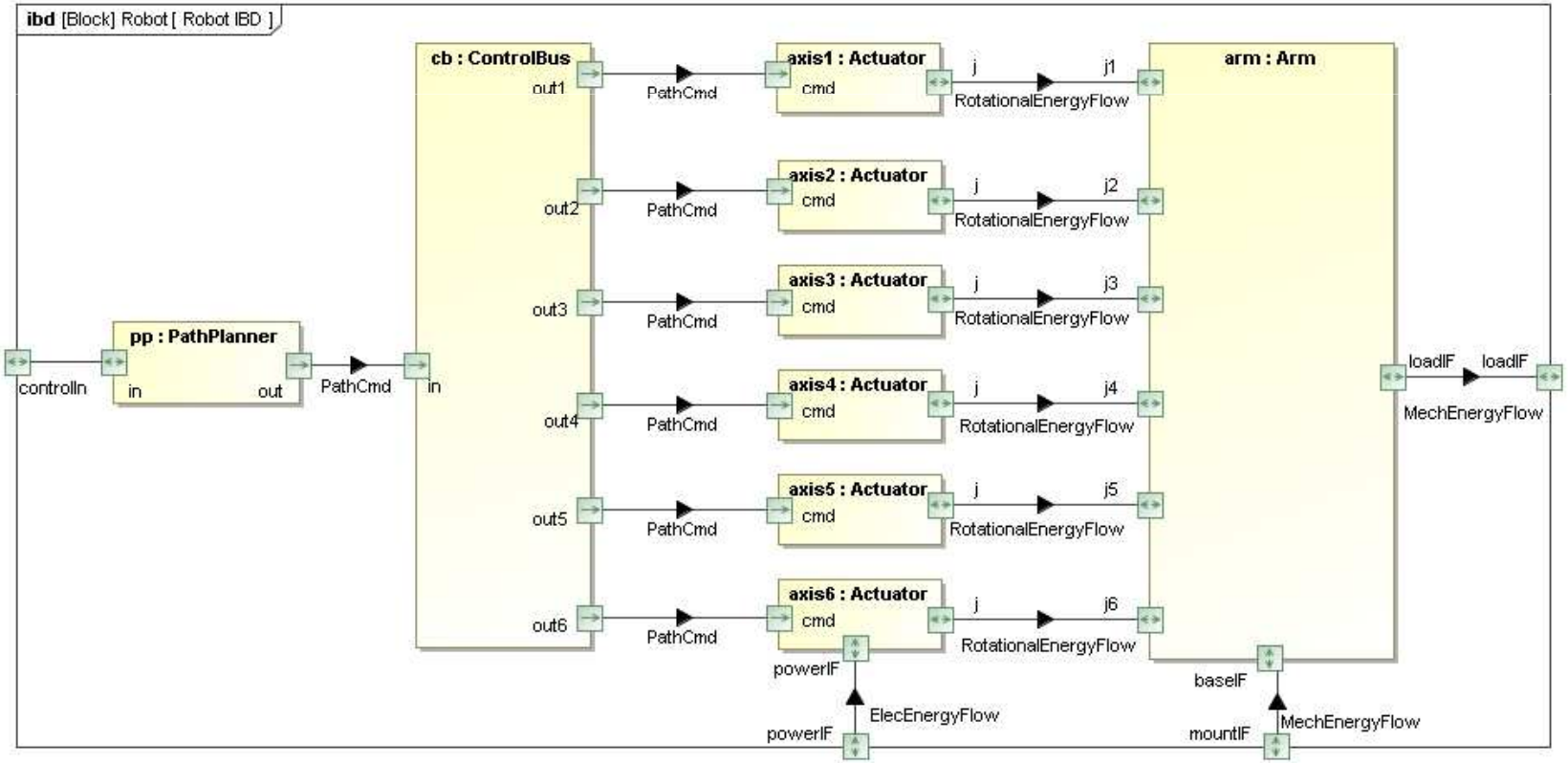
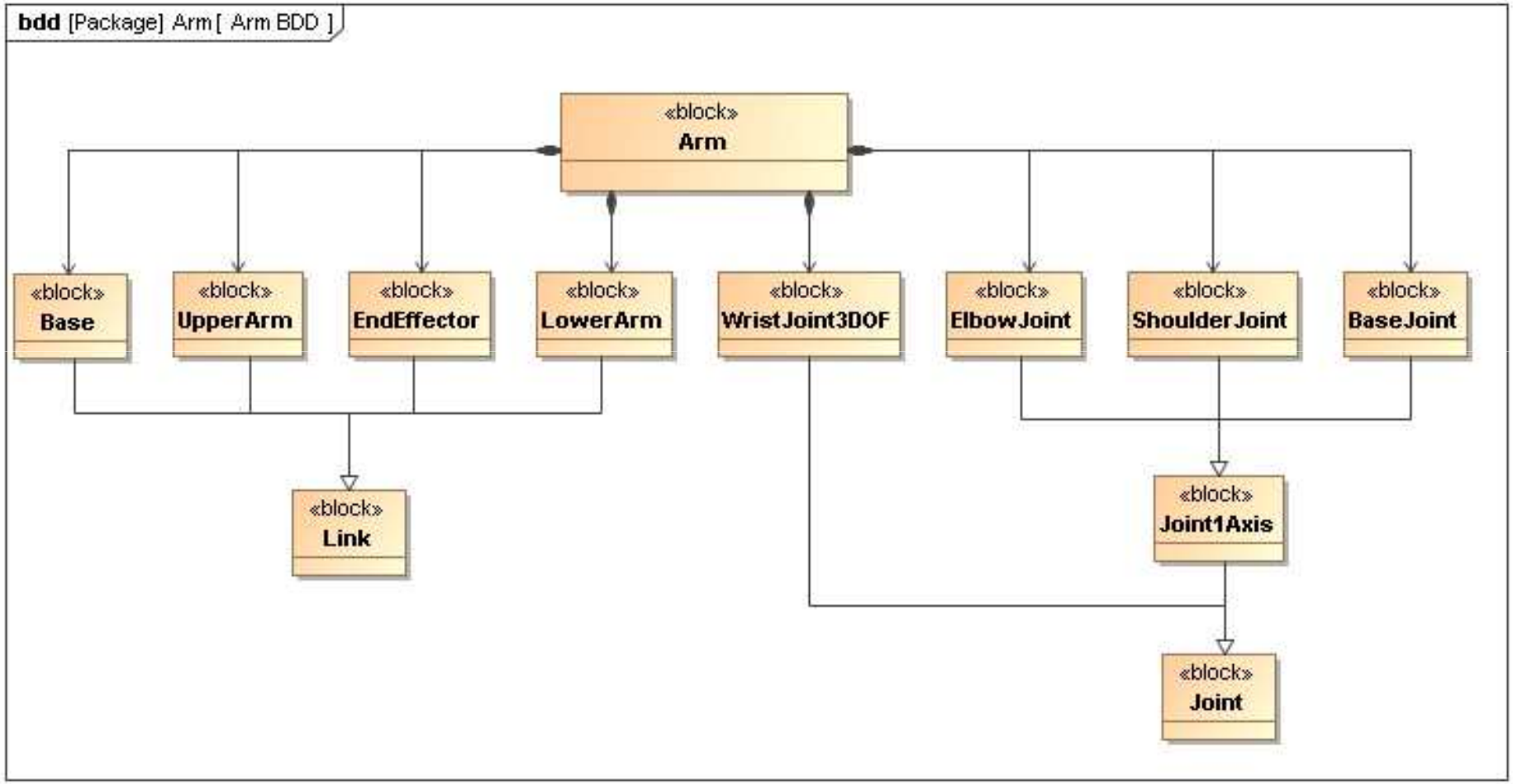
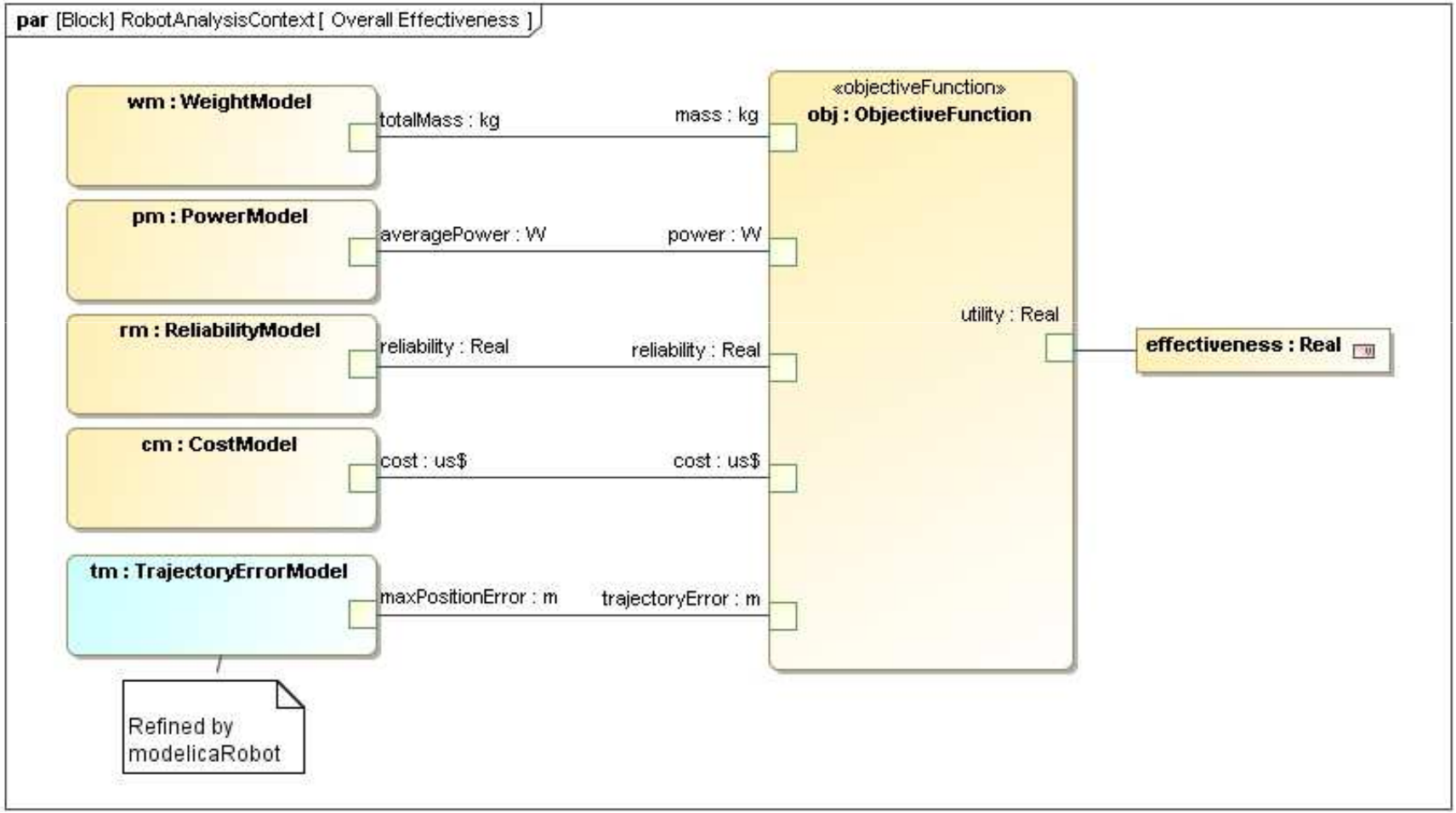




SysML-Modelica Robot Example: Robot Arm BDD

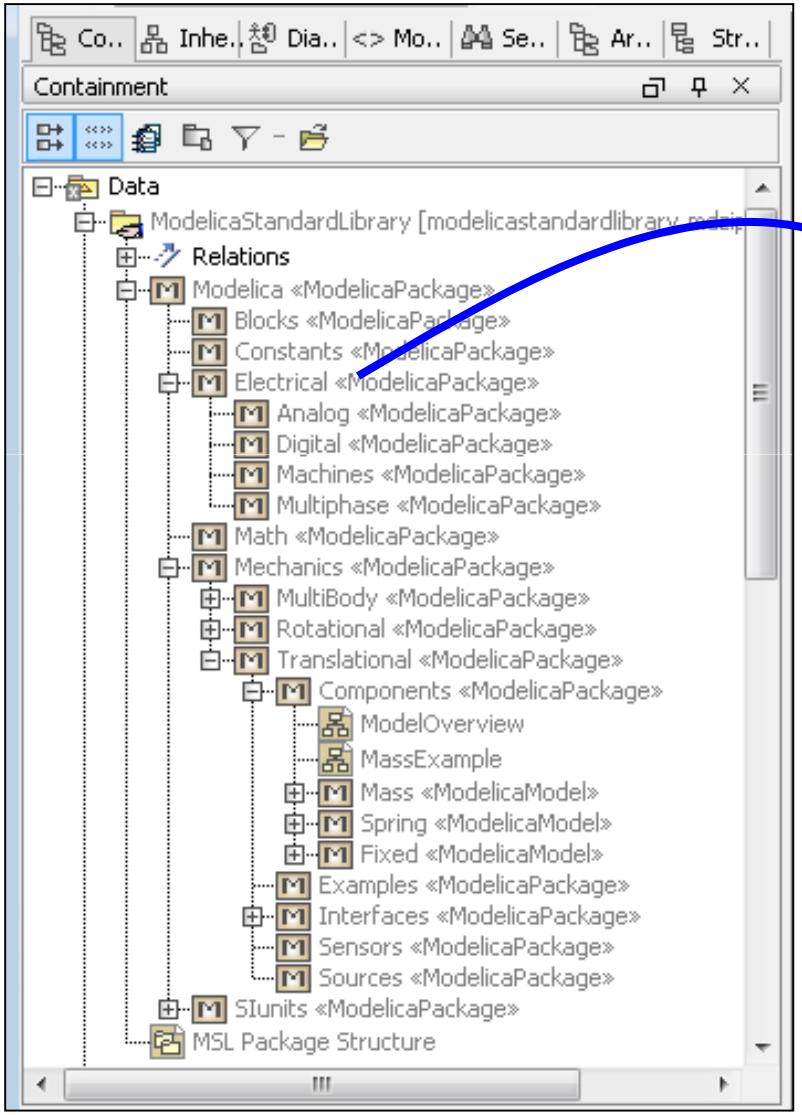


SysML-Modelica Robot Example: Analysis and Trade Study

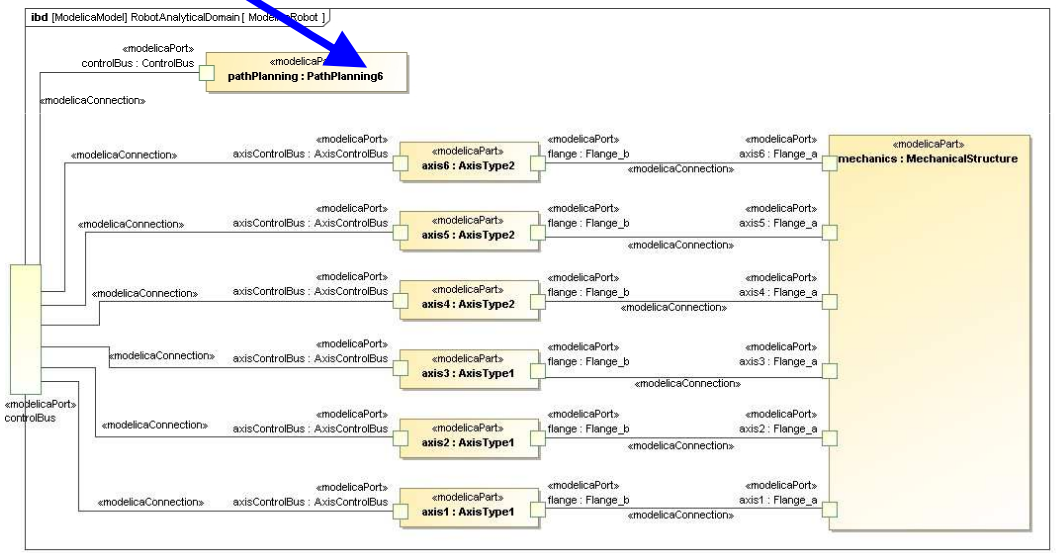


Analysis models depend on descriptive models

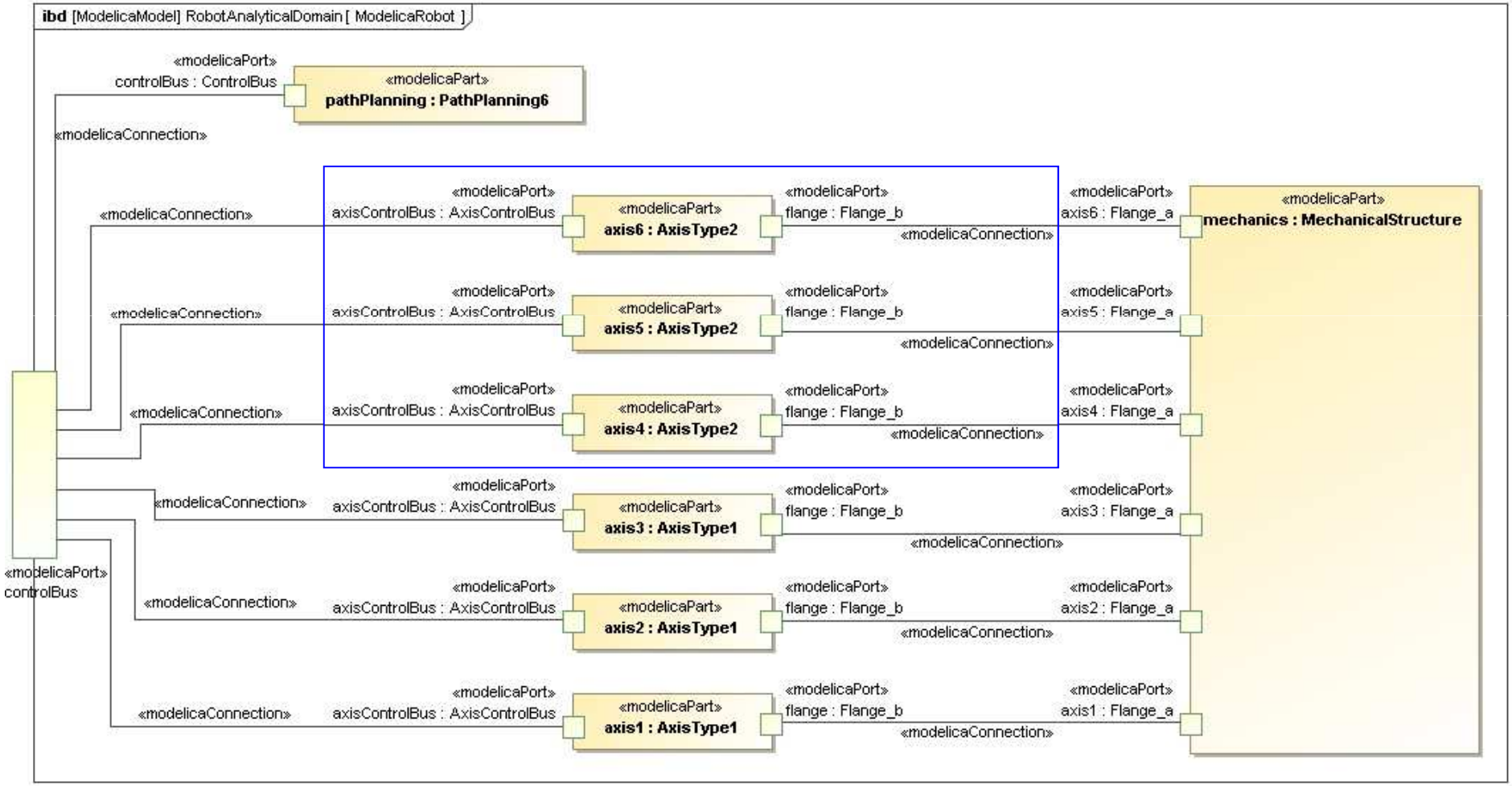
SysML4Modelica Analytical Model: Compose Model from Standard Library



Drag and drop into IBD «ModelicaModel»



SysML4Modelica Analytical Model: Detailed IBD



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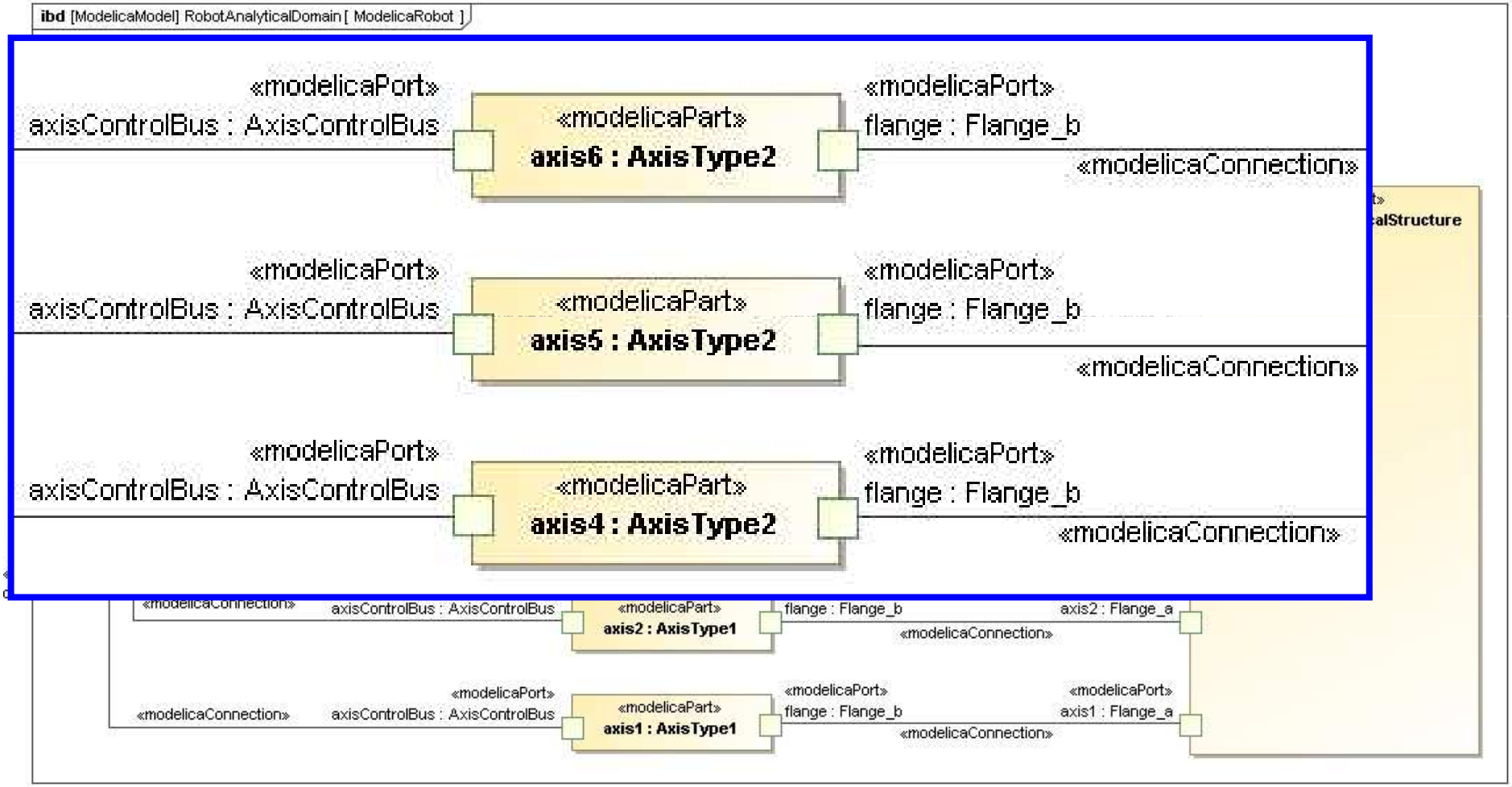
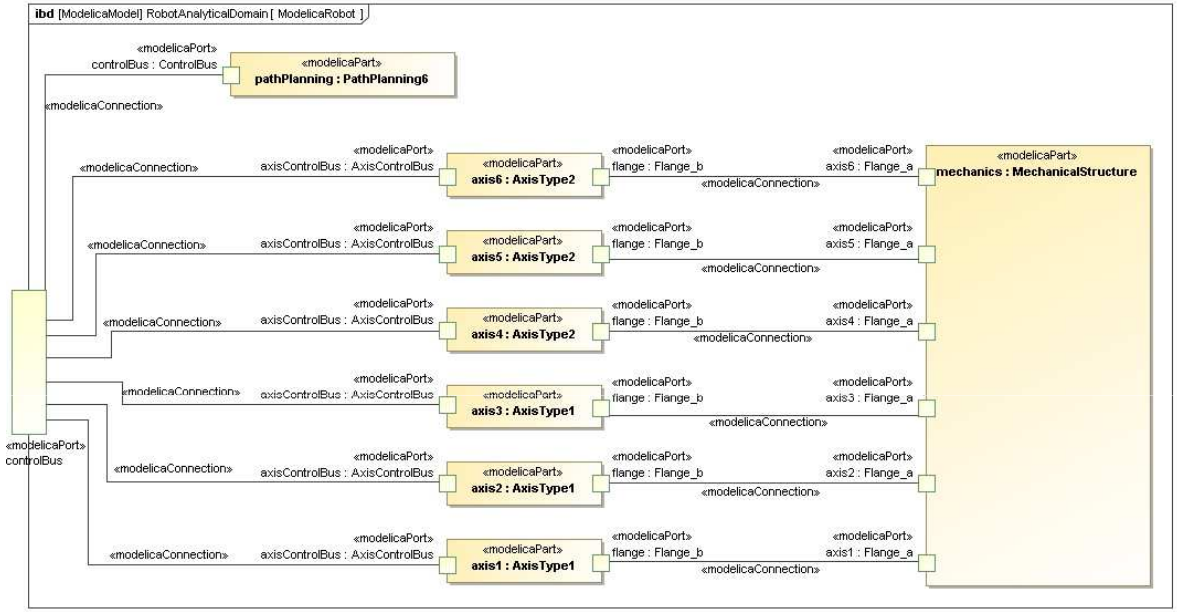
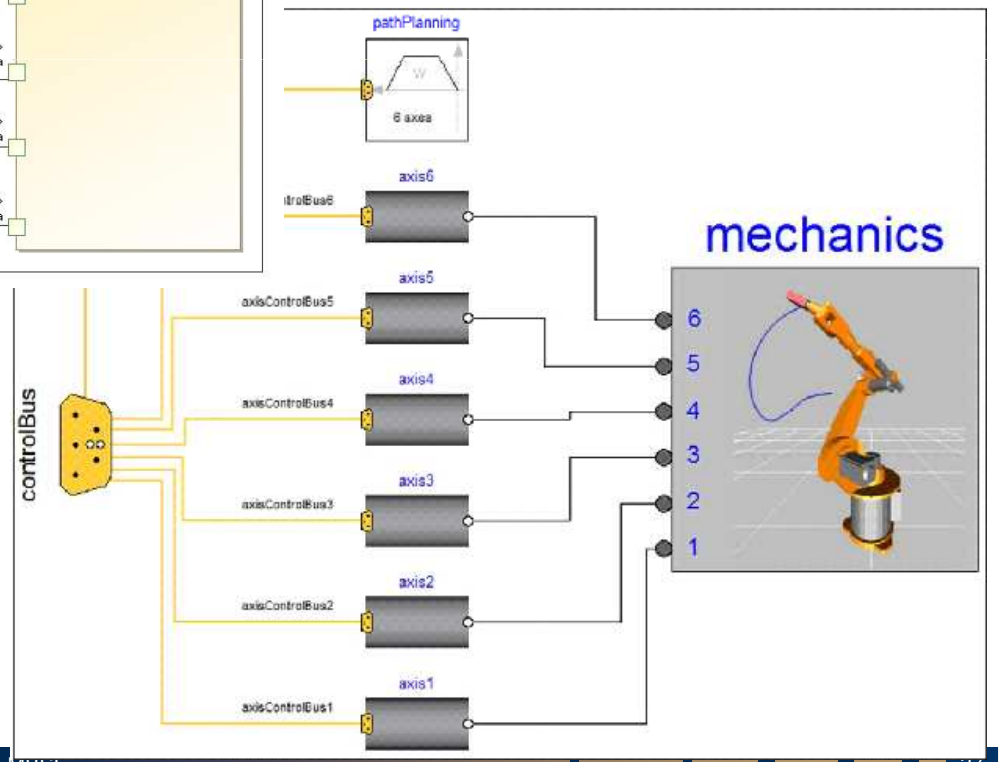
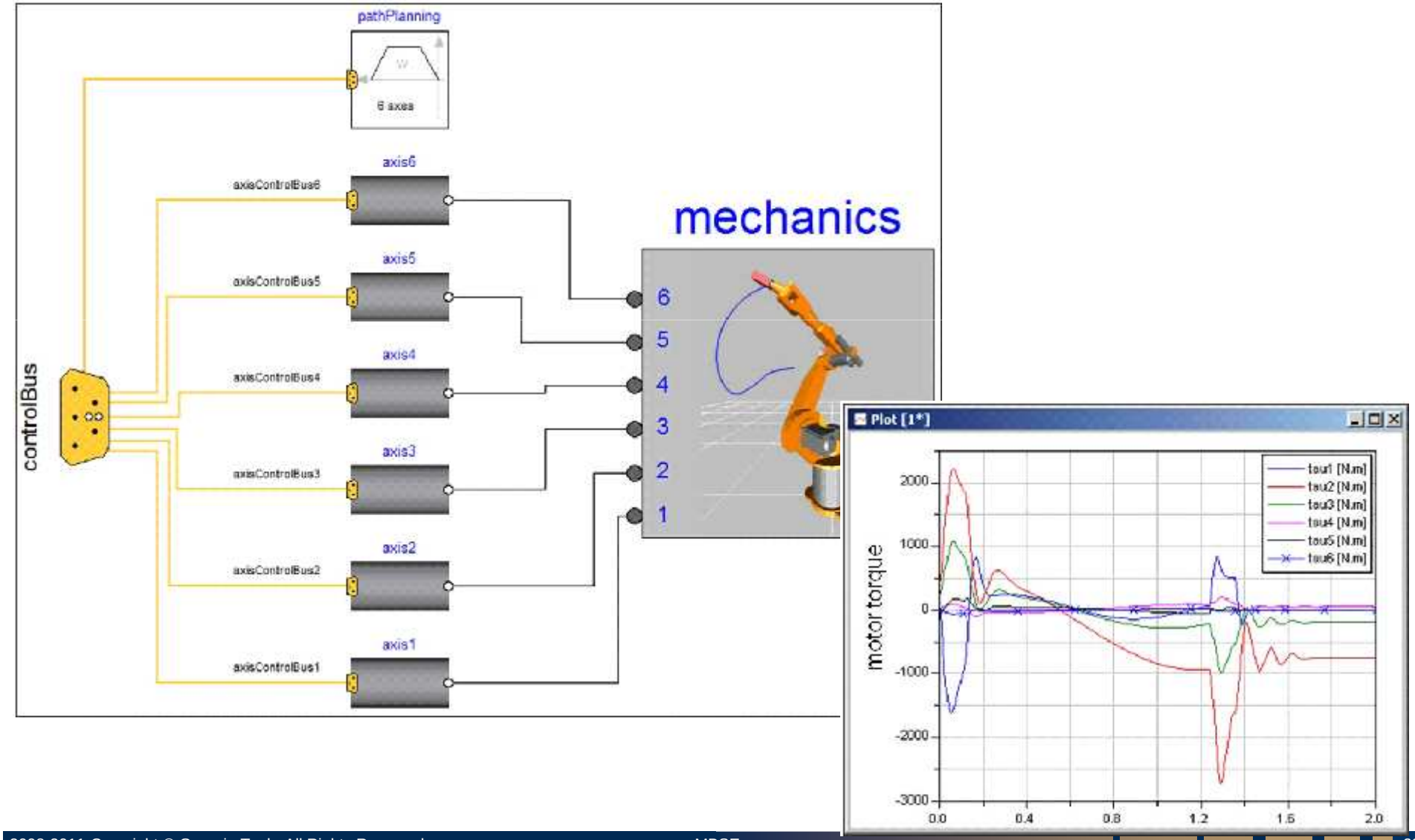


SysML4Modelica Analytical Model: Relation to Modelica Native Model

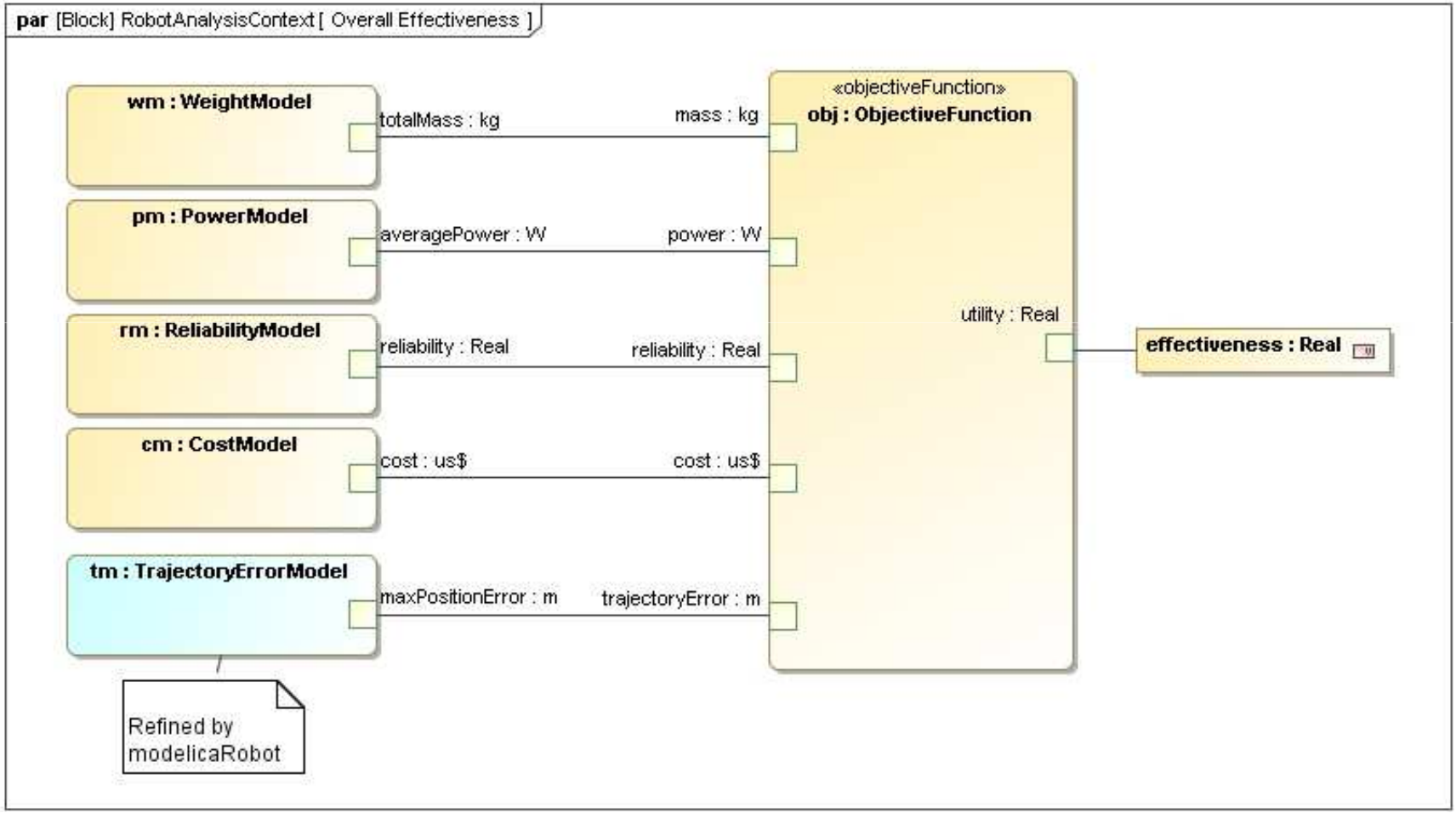




SysML-Modelica Robot Example: Modelica model with simulation results

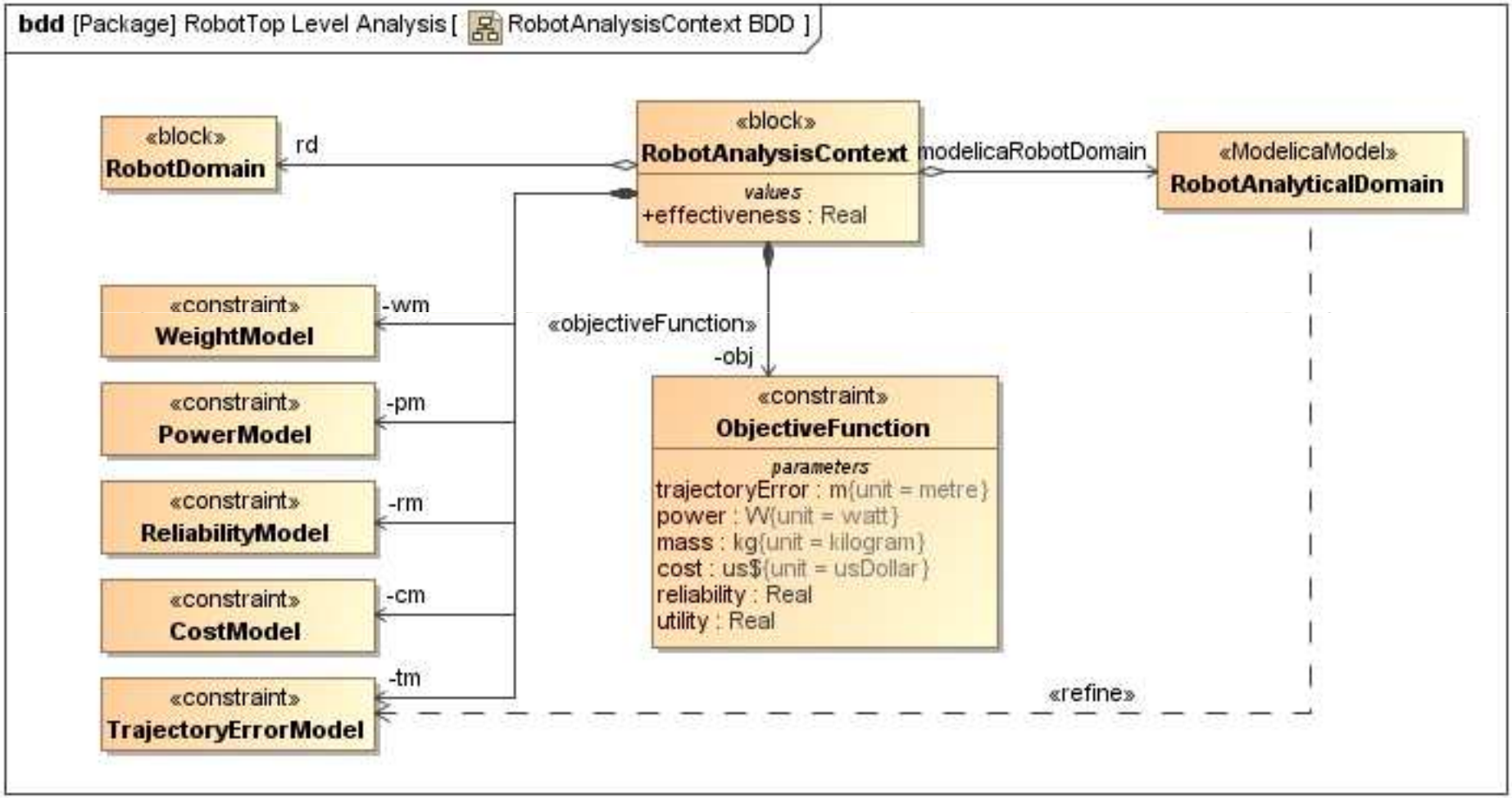


SysML-Modelica Robot Example: Analysis and Trade Study

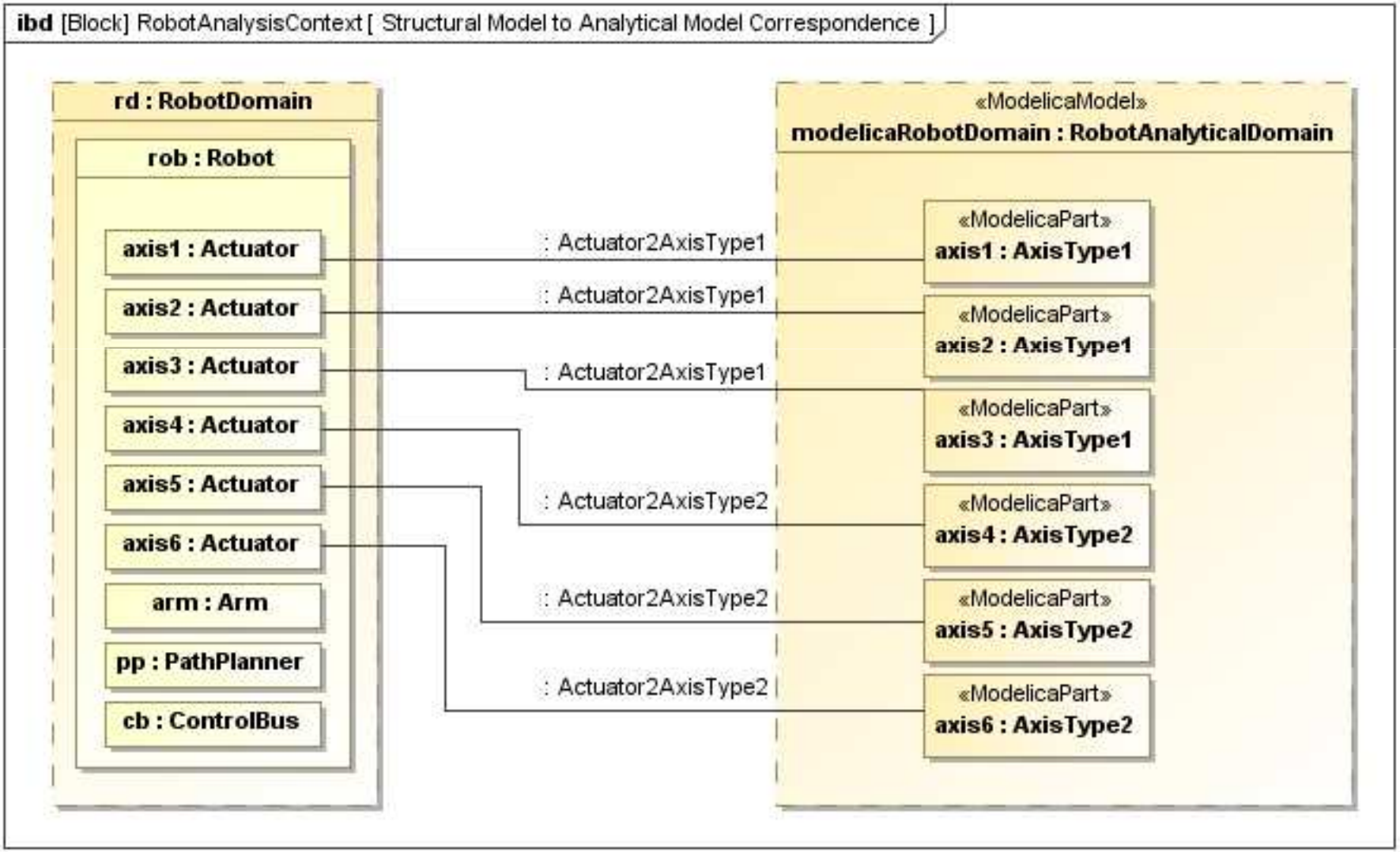


Analysis results are incorporated in Trade Study

SysML-Modelica Robot Example: An Analysis Context



SysML-Modelica Robot Example: Dependencies between Models



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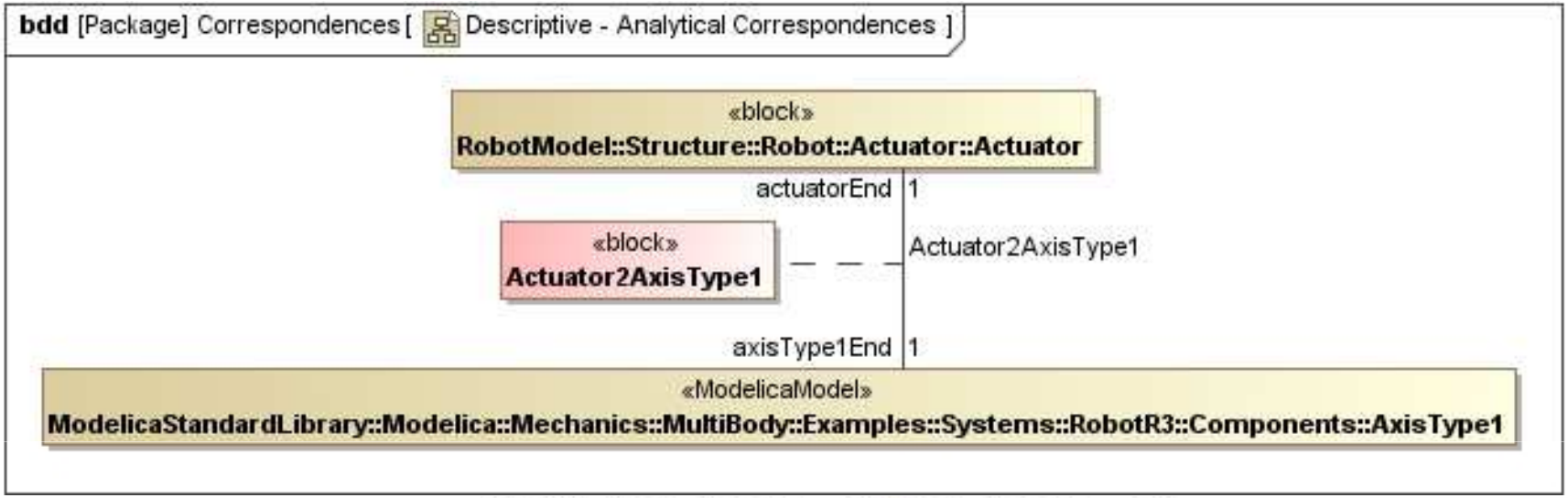

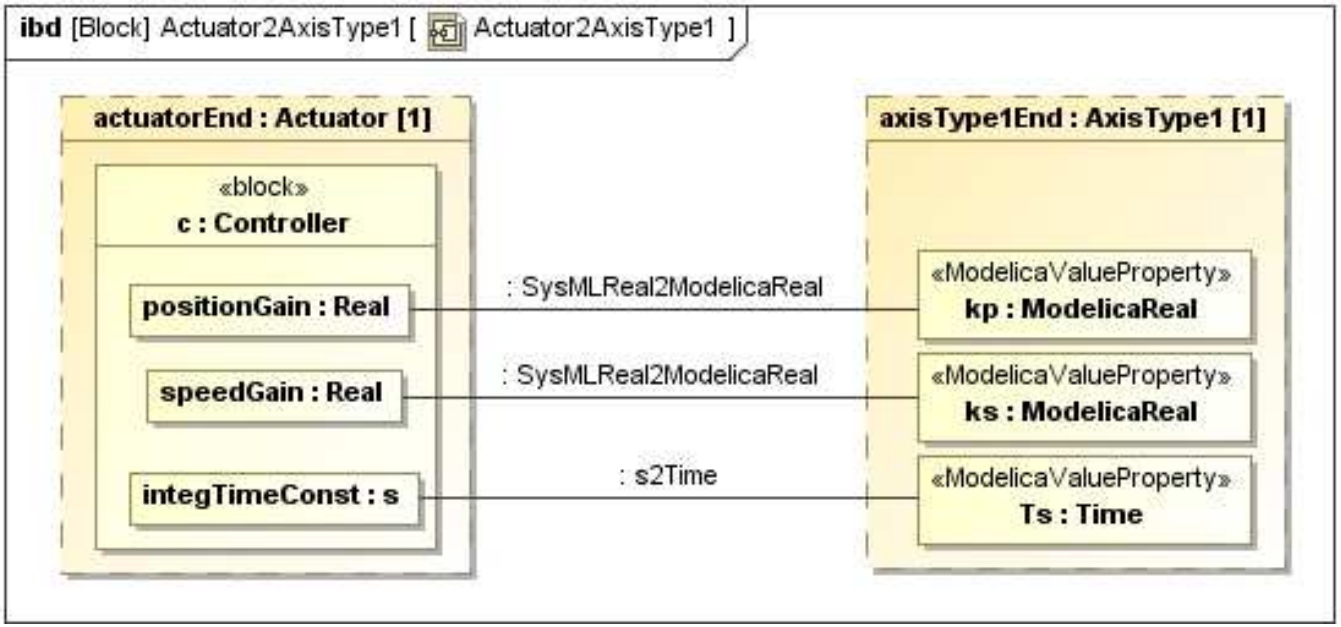

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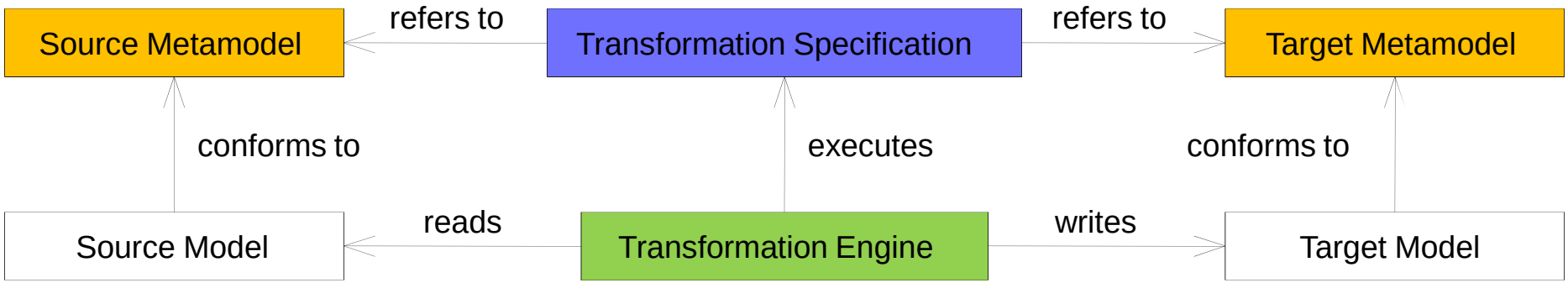
Model Transformation

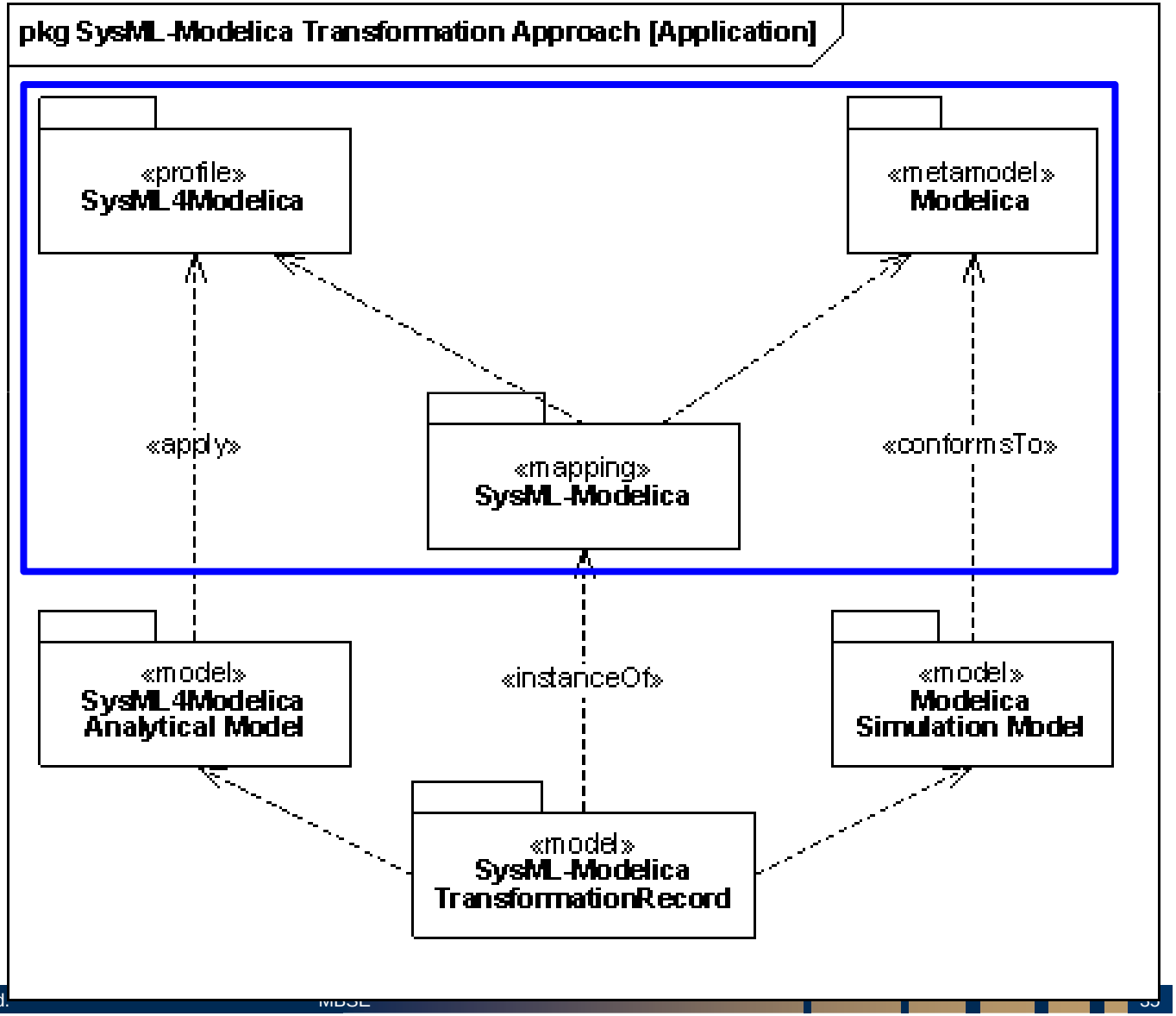


(Czarnecki, K., & Hellen, S., 2006)

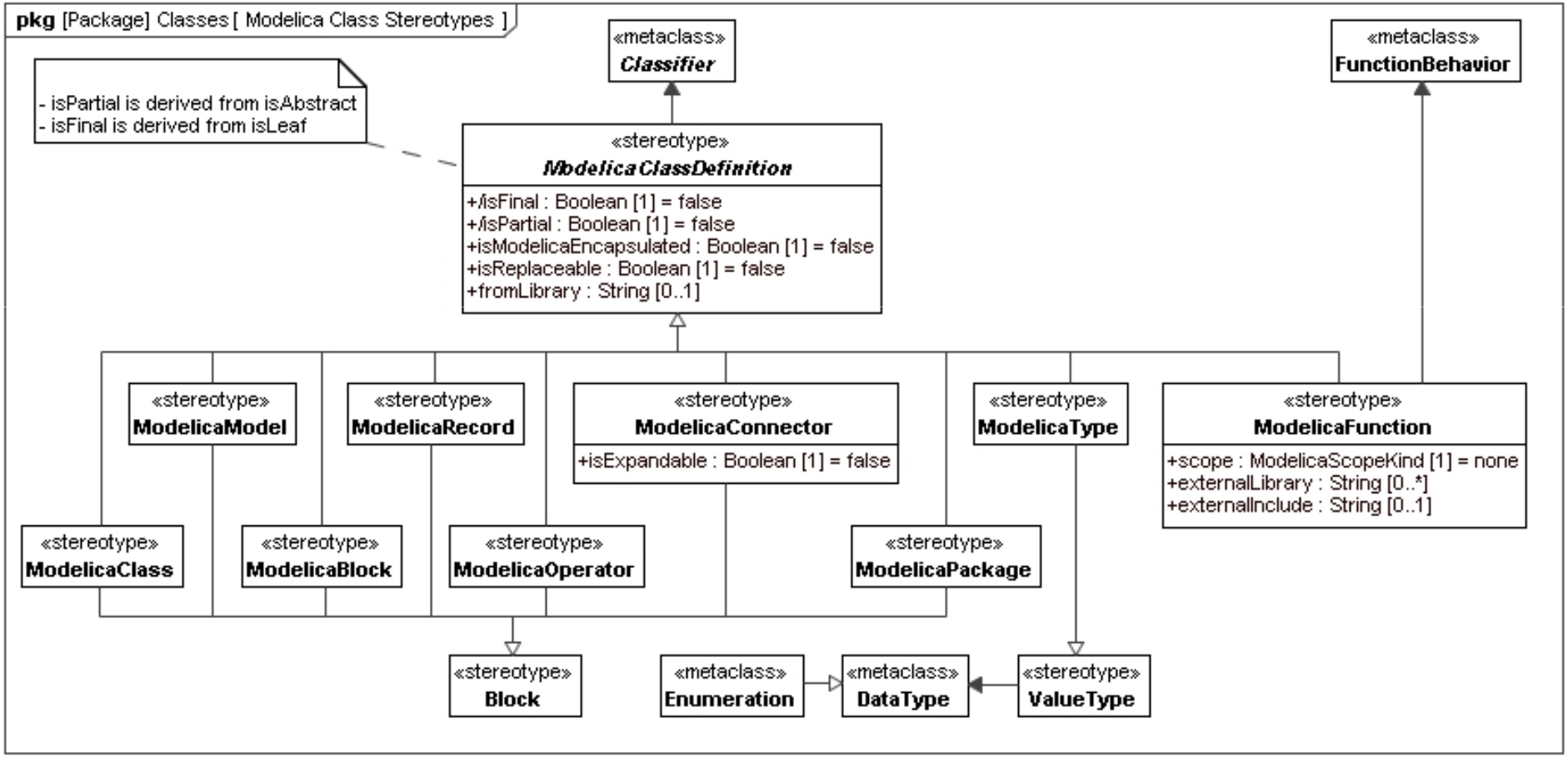
- Model Driven Architecture / Engineering
- Transformation Specification = Model
  → automated generation of transformation engine code
- Tools: MOFLON, QVTo, ATL, Kermeta, VIATRA2, …

SysML-Modelica Transformation Specification

SysML-Modelica Transformation follows the principles of Model-Driven Architecture (MDA)



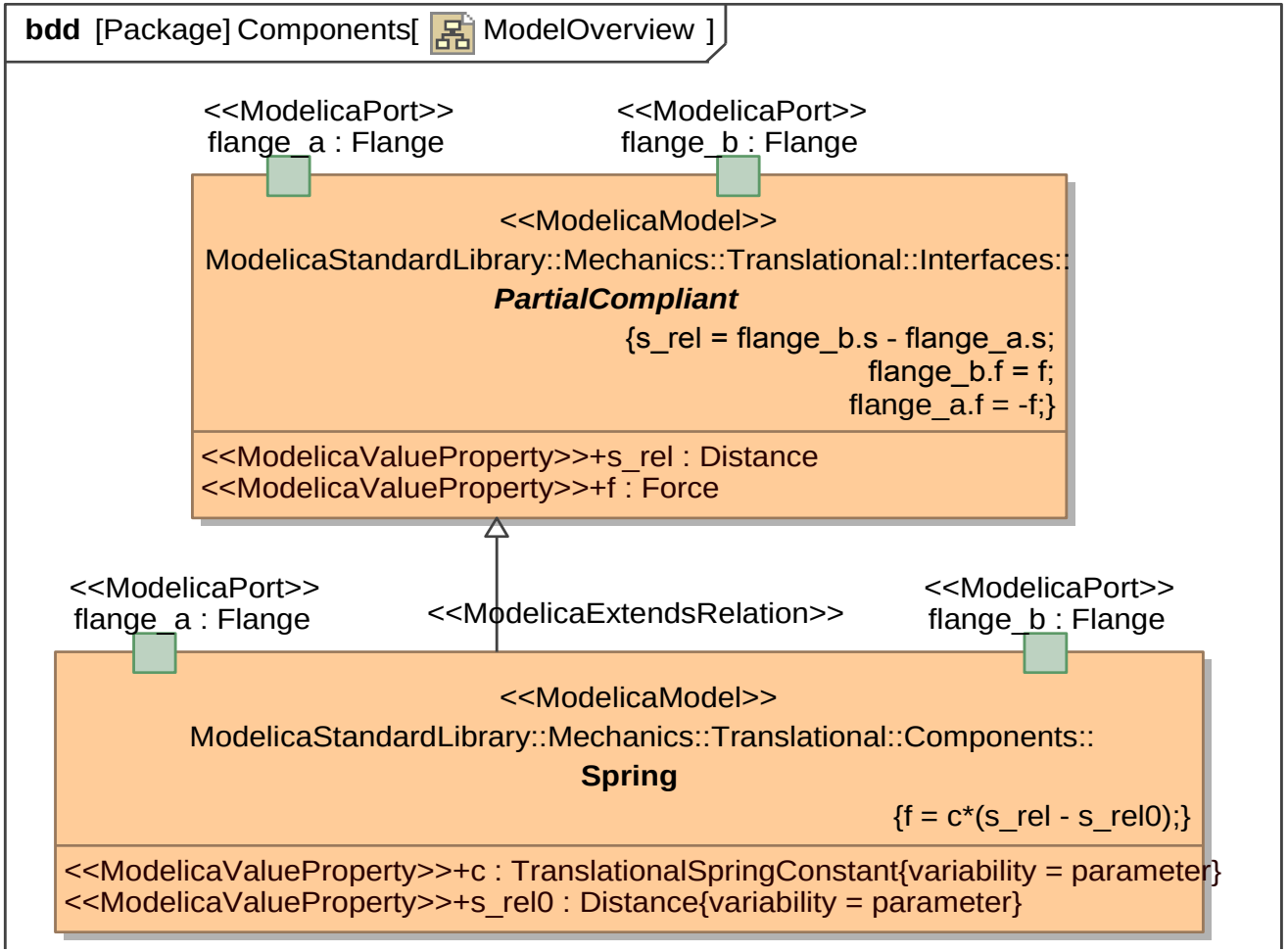
SysML4Modelica Profile



SysML4Modelica

Formal mapping

Modelica

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equation
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end Spring;
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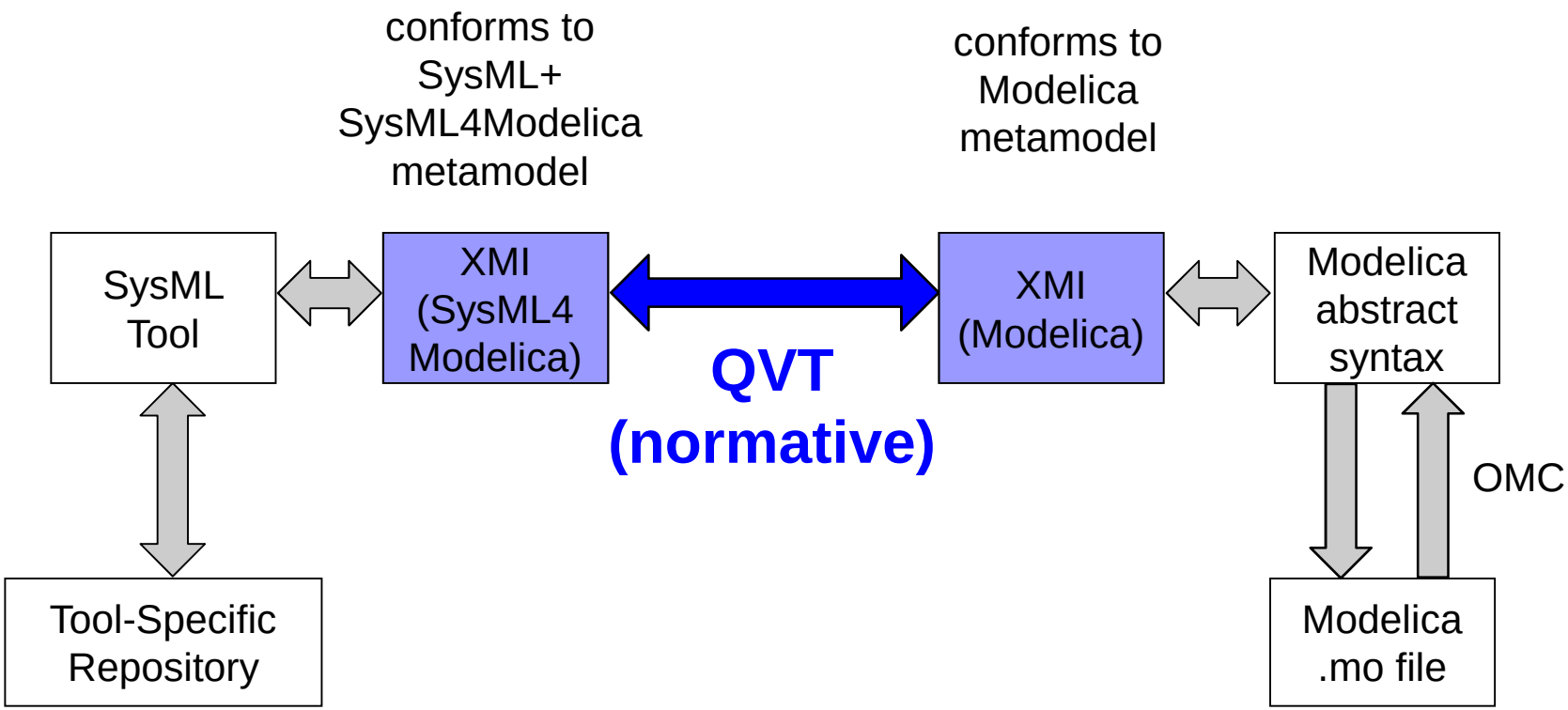
Reference implementation: Based on OMG QVT



QVT = Query / View / Transformation

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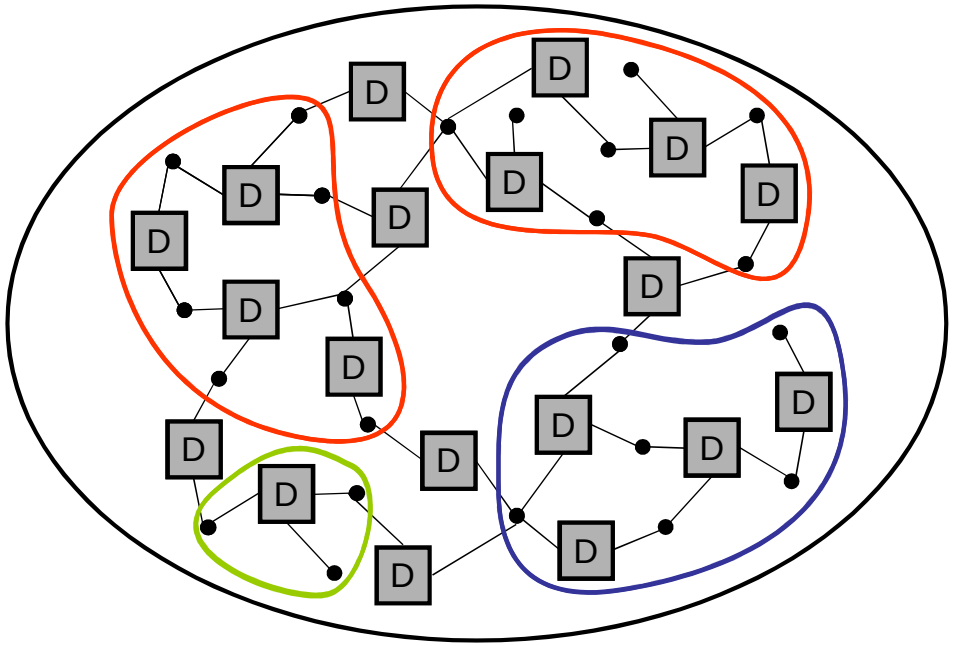
- Motivating Example: Design & Analysis of Robot

- SysML-Modelica Transformation Specification
- Transformations in Model-Based Systems Modeling
- Summary

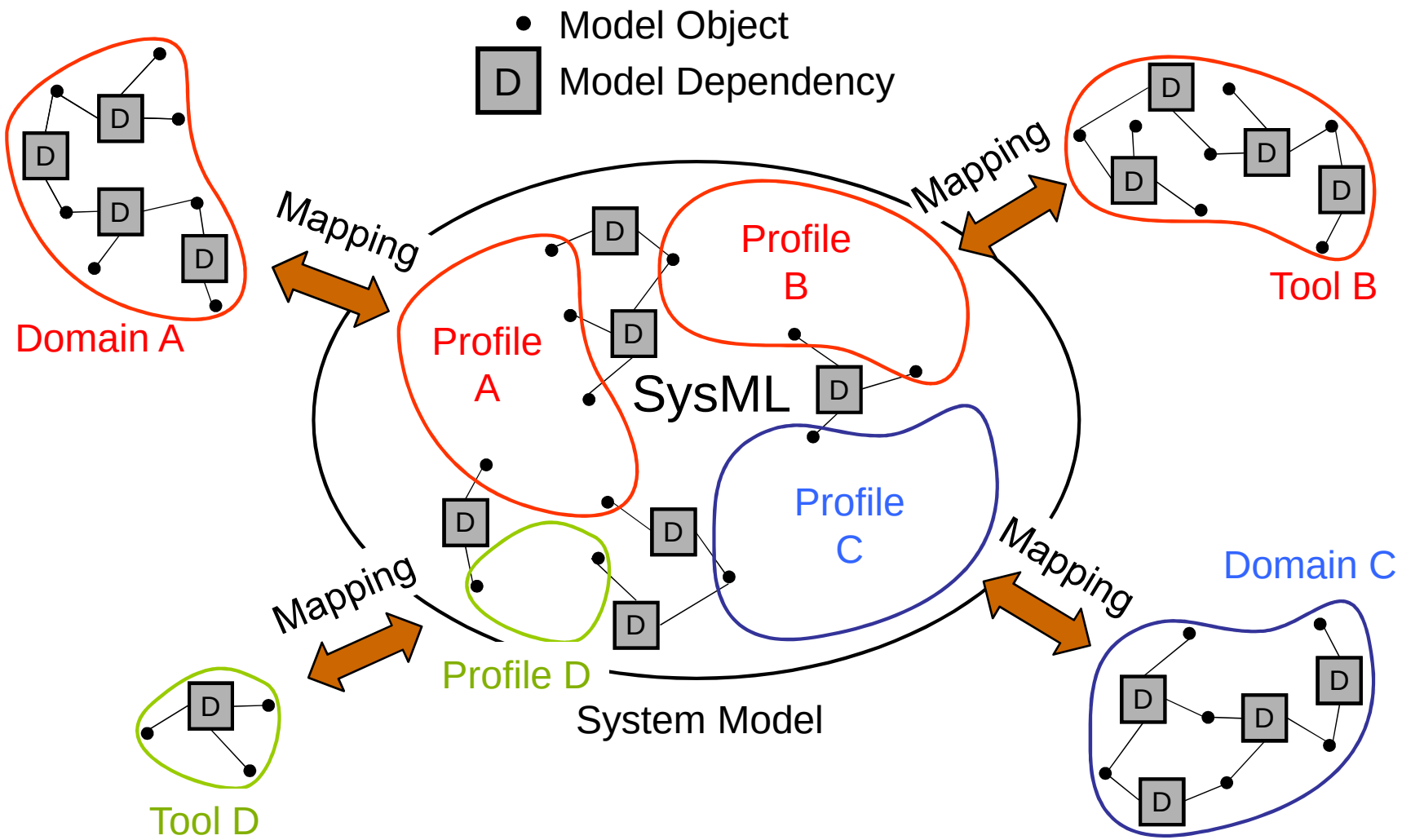
Model Transformations in MBSE

- Model Object
- D Model Dependency

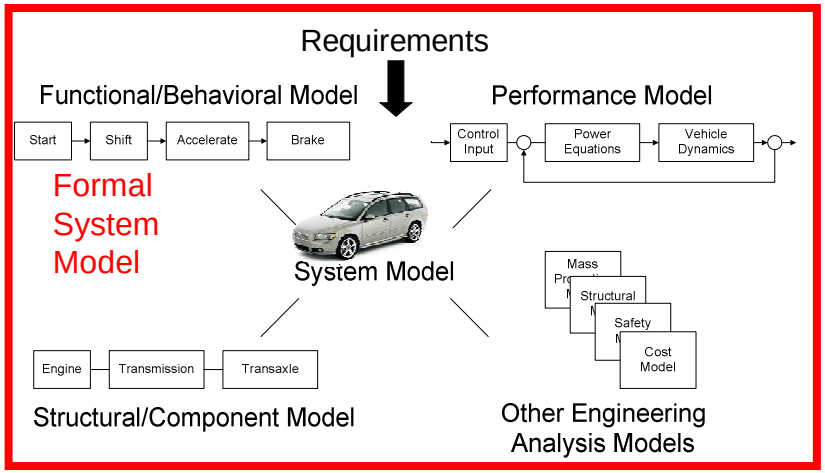


System Model

Model Transformations in MBSE: Federated Models



Model Transformations in MBSE



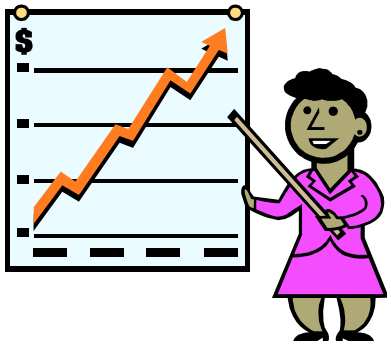
Transformation

Stage-Gate Documents

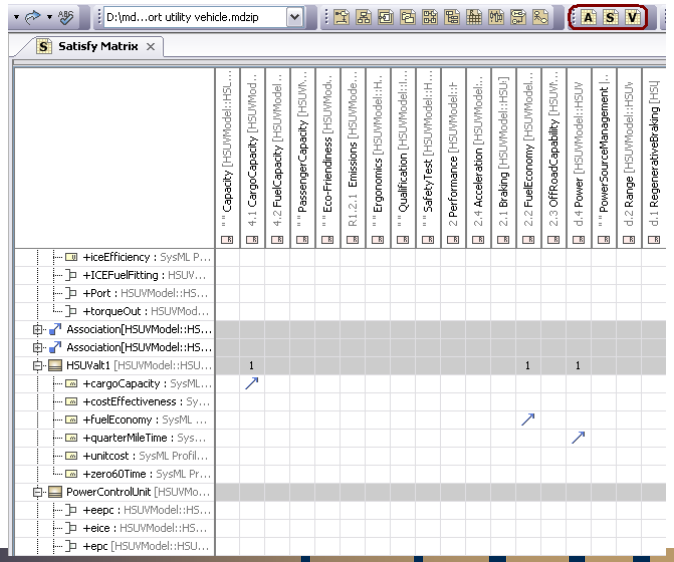
Transformation

Transformation

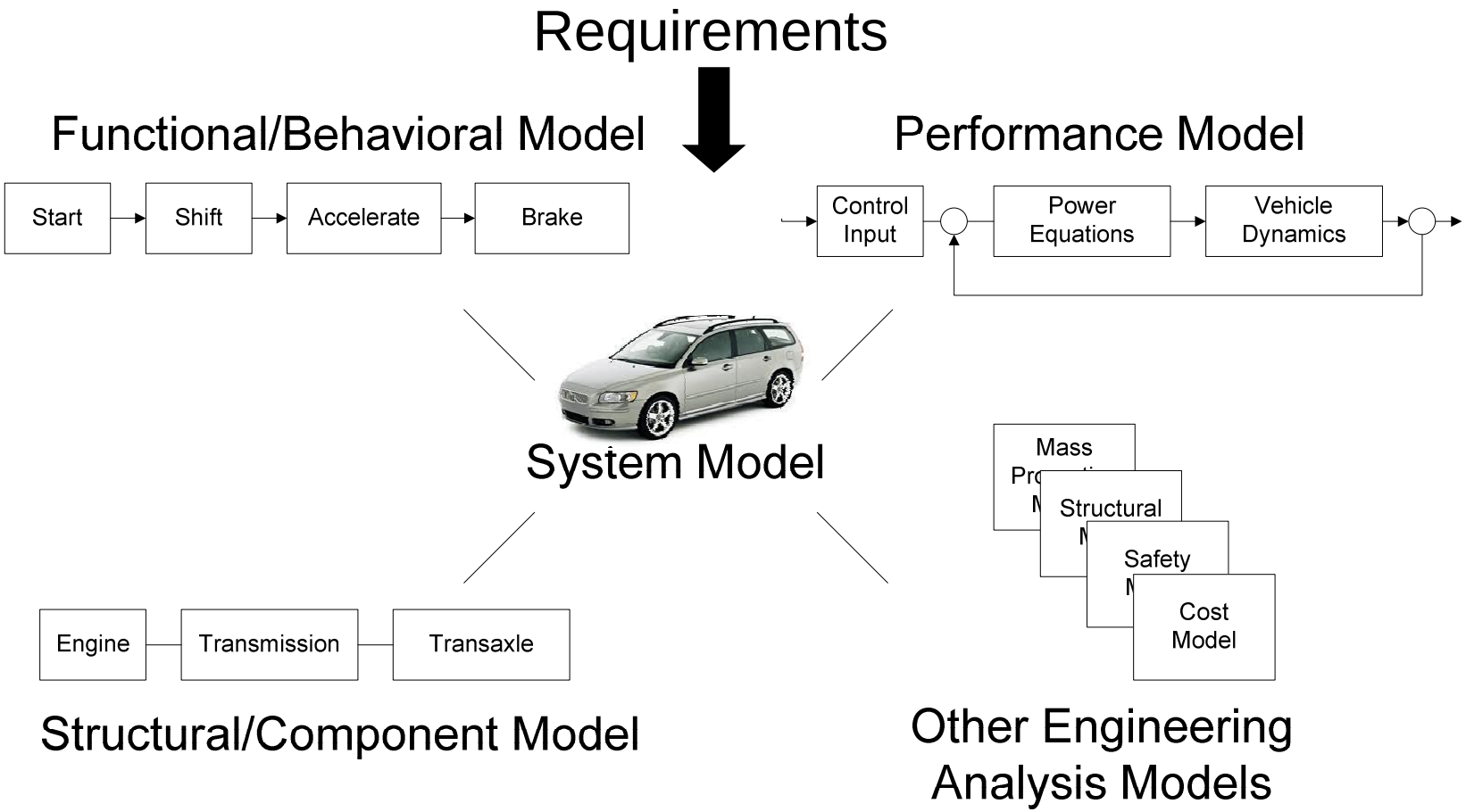
Project Management Metrics



Verification & Consistency Management



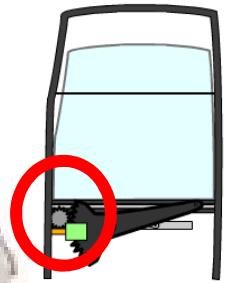
Model Transformations in MBSE: Reusable Models



Creating Models is Expensive and Time-Consuming

Model Transformations in MBSE: Applying Reuse Patterns

- Physical components are reused
- Portions of the system model repeat
- Patterns for instantiating these portions



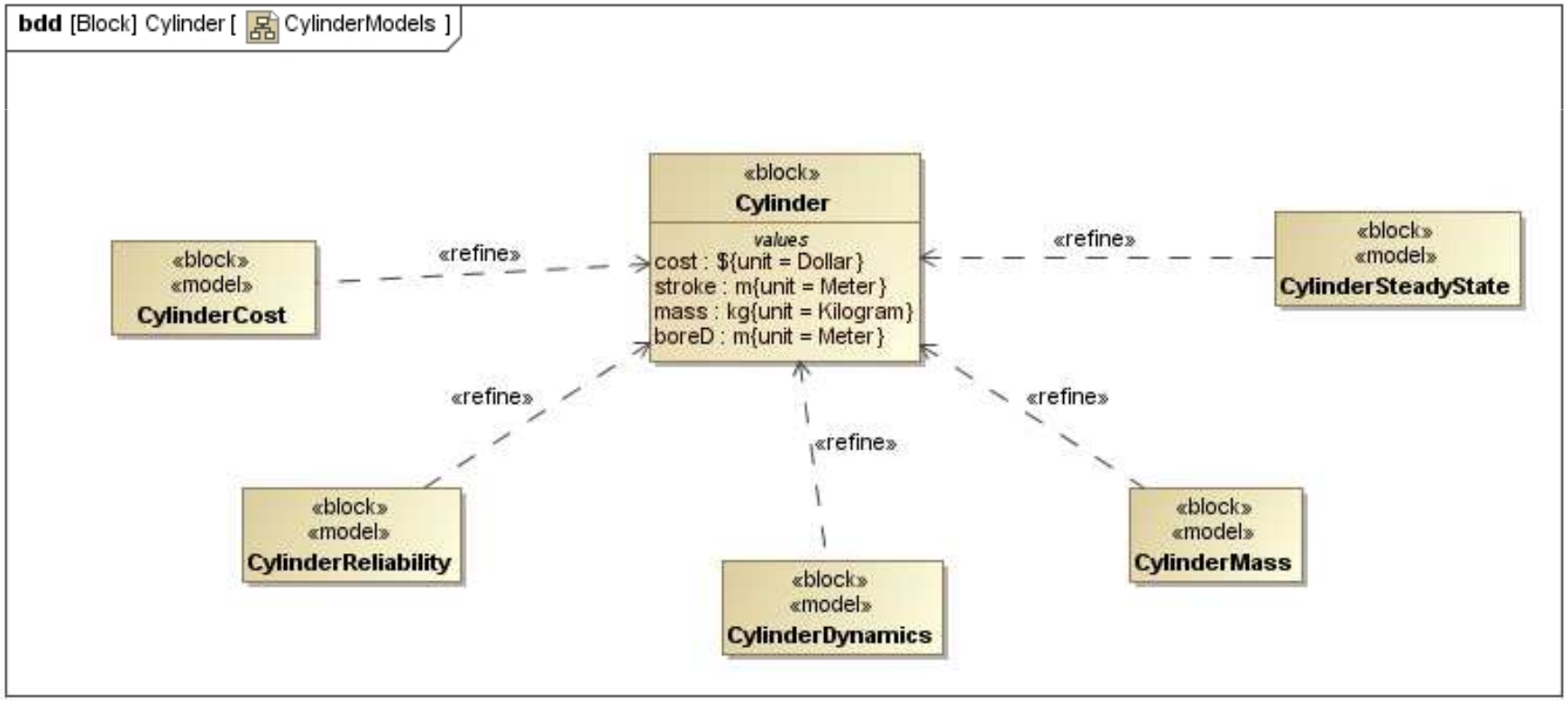
Electric Motors

- Component models → Domain specific model libraries
- Application of pattern = model transformations

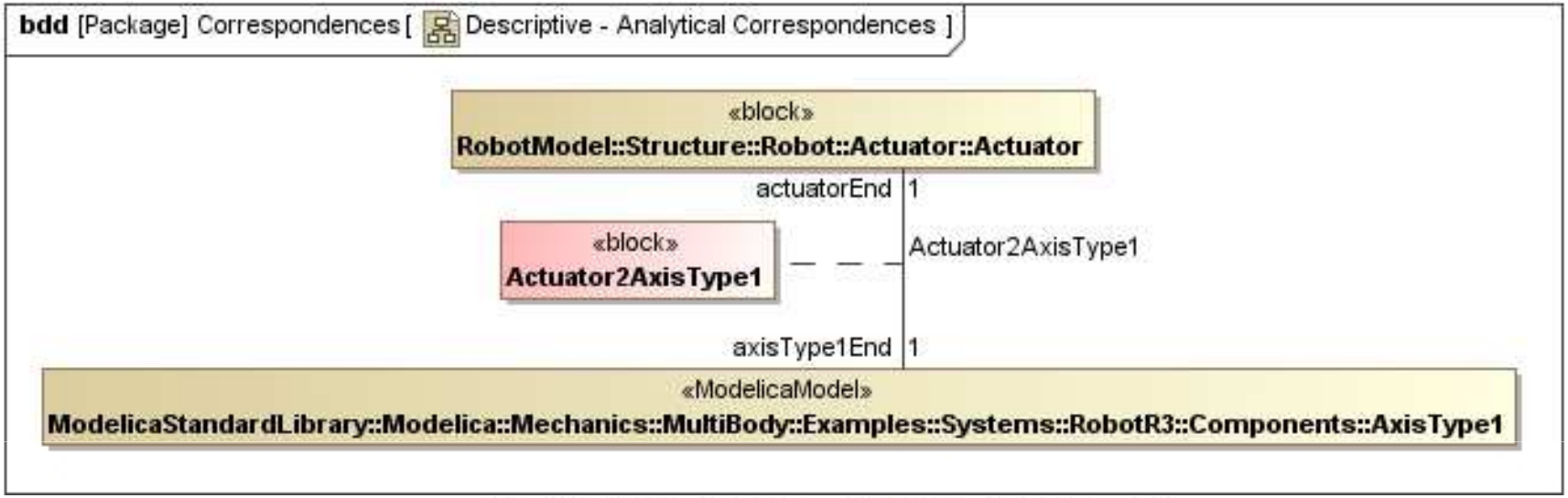
Model Transformations in MBSE: Applying Reuse Patterns

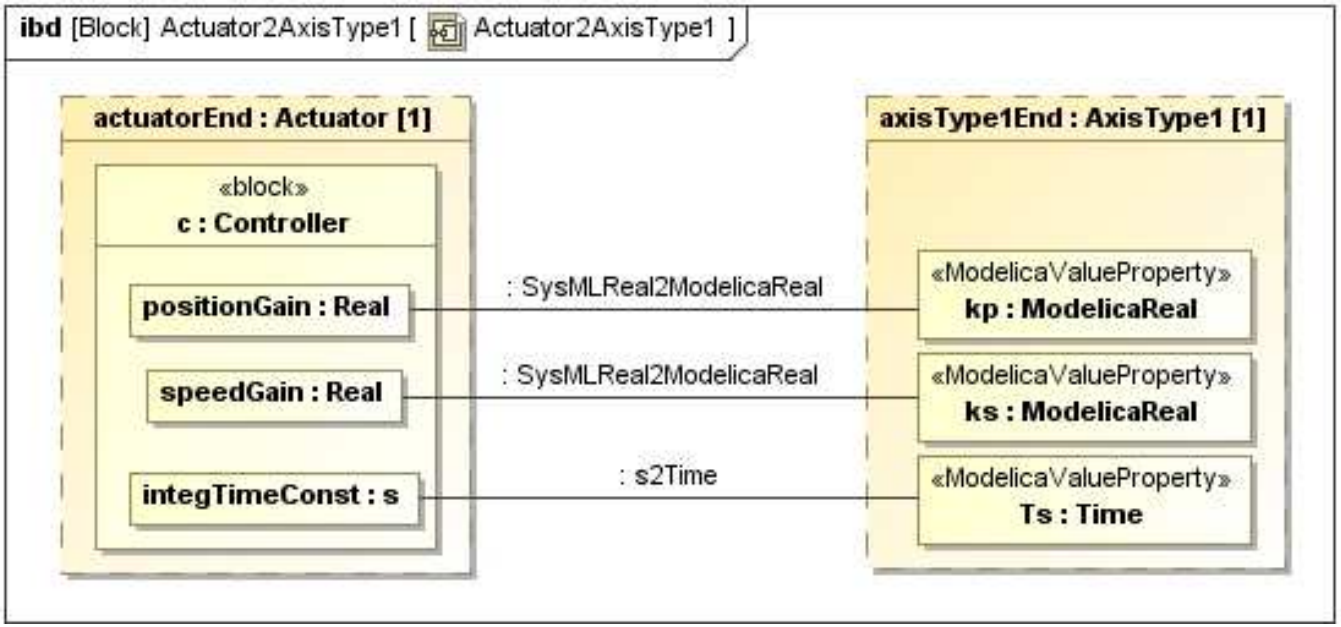
- When cylinder is used, other corresponding models are often used also

→ Capture the reuse pattern

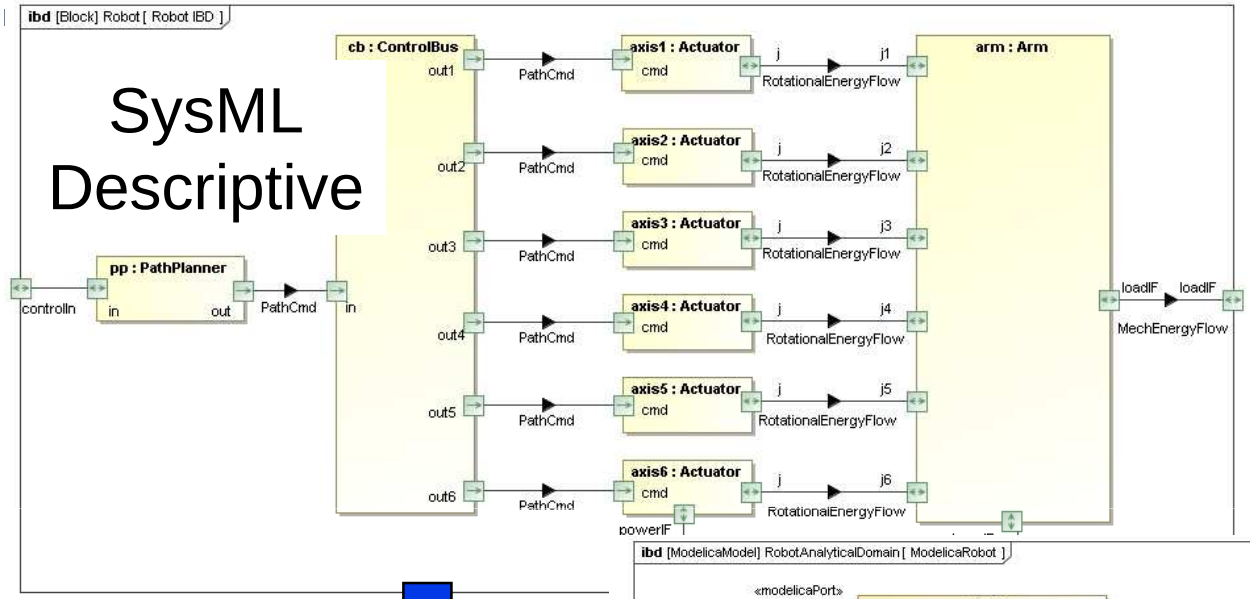


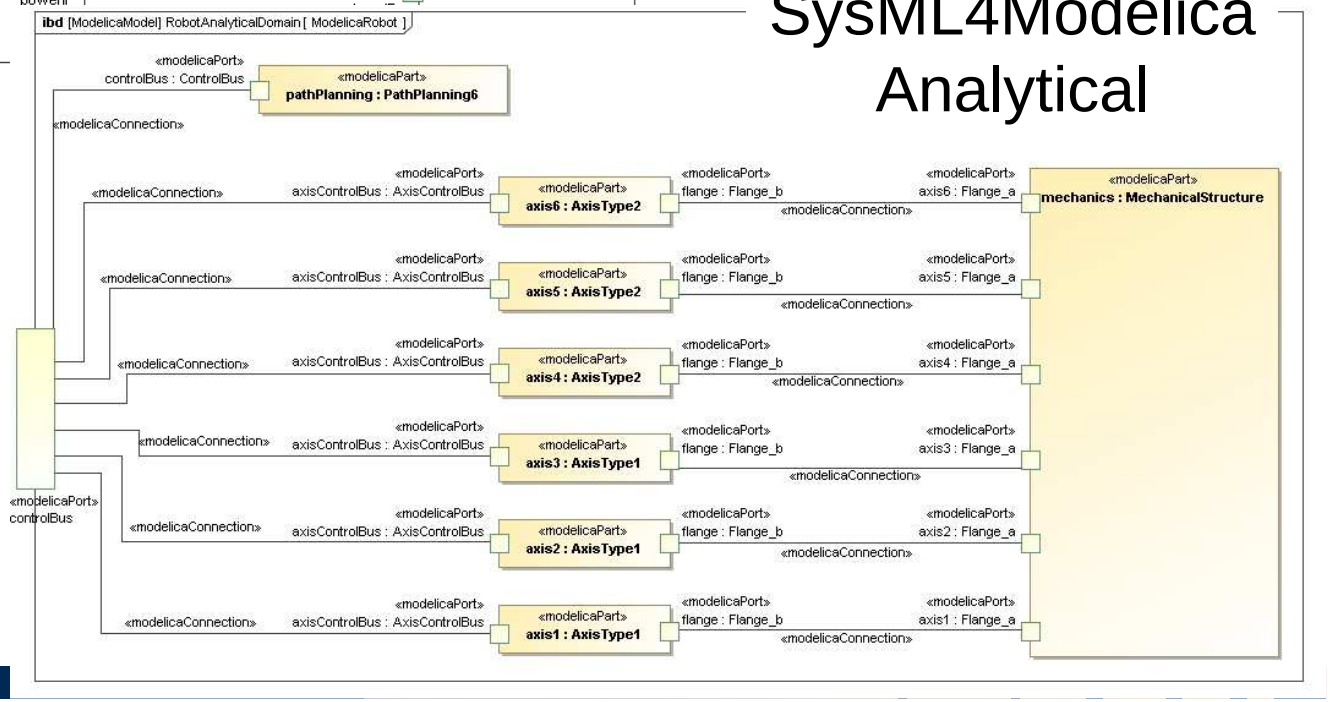
Model Transformations in MBSE: Applying Reuse Patterns

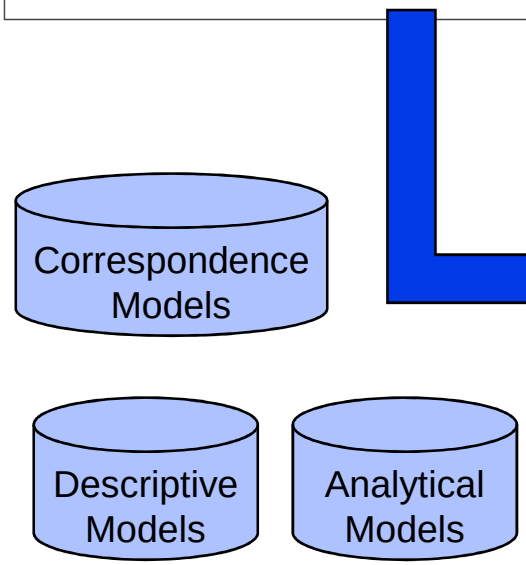




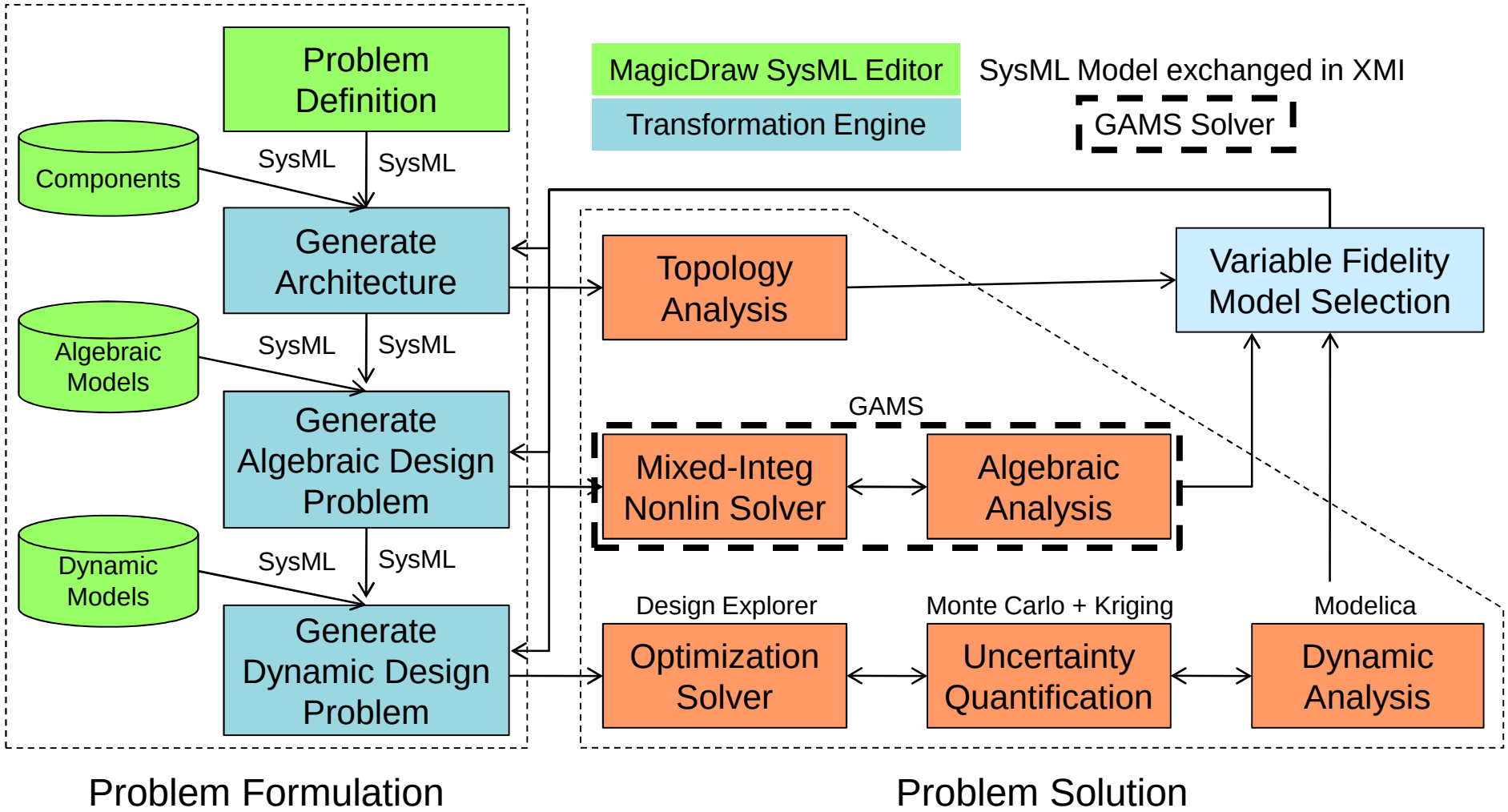
Model Transformations in MBSE: Descriptive to Analytical Transformation







Model Transformations in MBSE: Architecture Exploration



Summary

- Objective:
  - Leverage the strengths of both SysML and Modelica by integrating them to create a more expressive and formal MBSE language.

Descriptive Modeling in SysML

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Formal Equation-Based Modeling for Analyses and Trade Studies in Modelica

http://www.omg.org/spec/SyM/