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An Overview of the SysML-Modelica Transformation Specification

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SysML-Modelica Transformation Specification: Context & Objective

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- 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 Systems Modeling
- Model reuse and composition
- Summary

What is SysML?

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- The Systems Modeling Language (OMG SysML™) is a *visual, general purpose modeling language*

- ***Is*** a modeling language that provides
  - Semantics = meaning
  - Notation = representation of meaning

- ***Is not*** a methodology or a tool
  - SysML is methodology and tool independent

- Developed by the Object Management Group to support Model-Based Systems Engineering

What Can be Expressed in SysML?

- SysML is a language to express the information and knowledge generated and processed during the application of a systems development methodology

  - Specification
  - Analysis
  - Design
  - Verification
  - Validation
  - Hardware
  - Software
  - Data
  - Personnel
  - Procedures
  - Facilities

SysML Diagram Taxonomy

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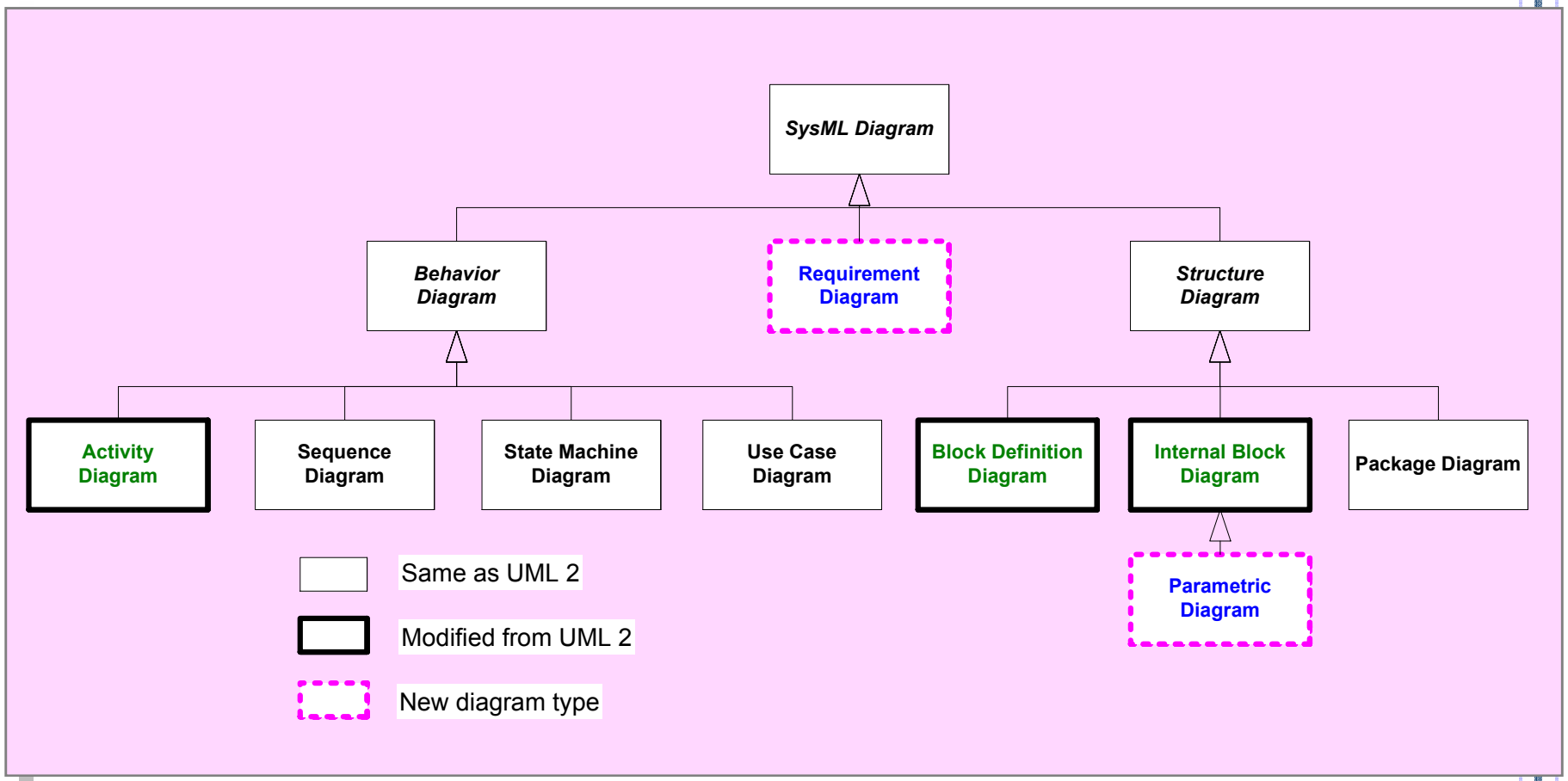
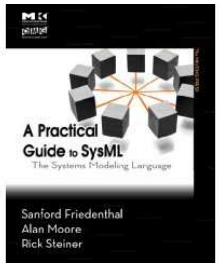
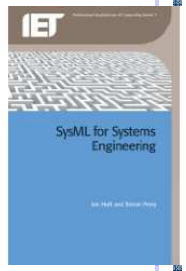


Think of SysML as an integrated collection of languages…

Some History…

- Specification: http://www.omg.org/spec/SysML/
  - v1.0: 2007-09
  - v1.1: 2008-11
  - v1.2: 2010-06
  - v2.x: RFI preparation workshop - 2008-12
- Strong vendor support
  - MagicDraw (No Magic), Artisan Studio (Atego), Enterprise Architect (Sparx Systems), Rhapsody (IBM),…
- Good learning infrastructure
  - Books, short courses, academic courses, INCOSE/OMG tutorial, public examples, etc.
- OMG Certified Systems Modeling Professional
  - http://www.omg.org/ocsmp/





What is SysML? (www.omgsysml.org)

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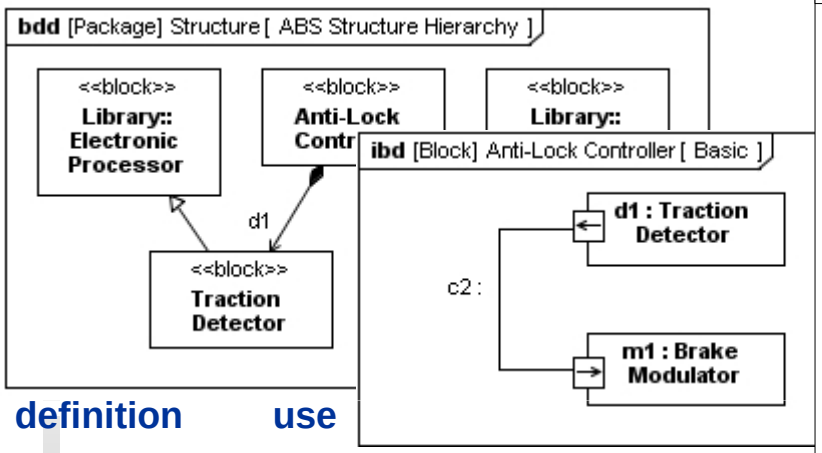
1. Structure

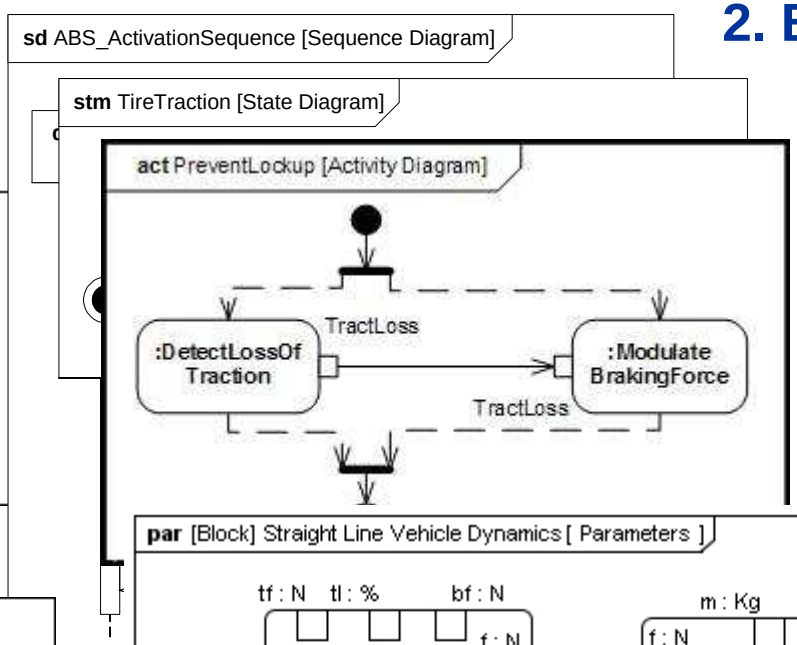


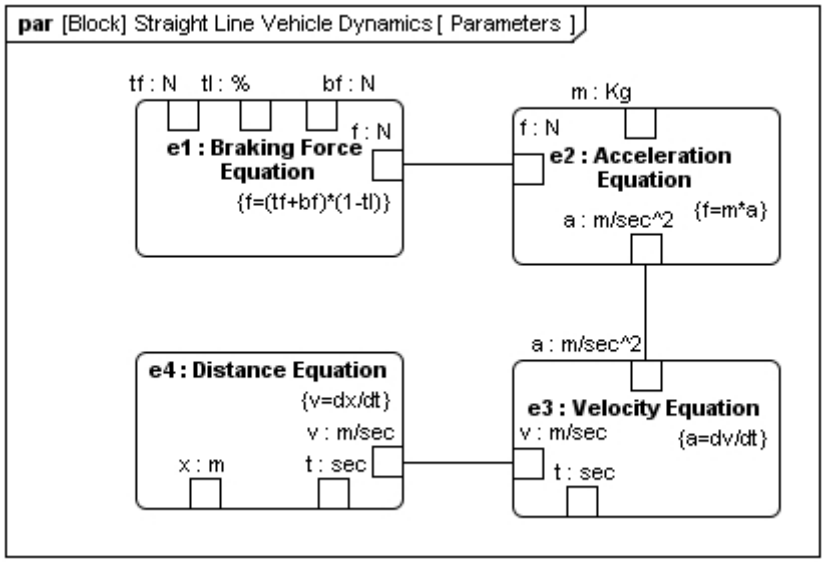
2. Behavior

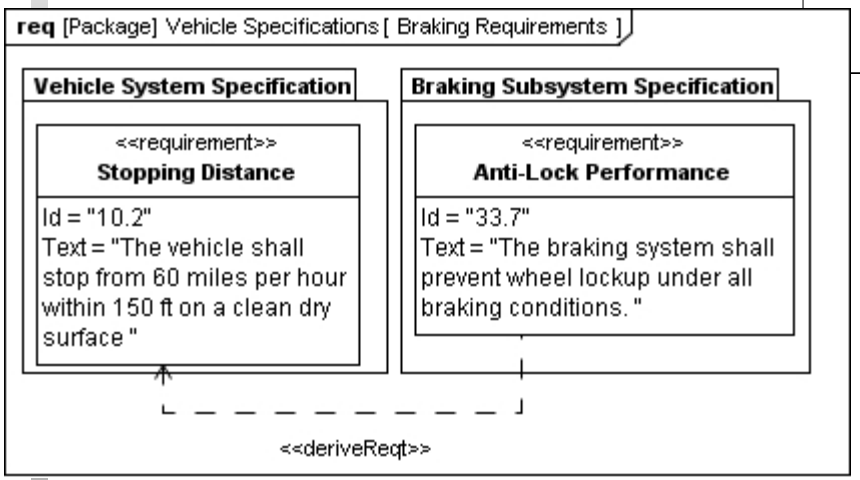
interaction

state machine

activity/ function







3. Requirements

4. Parametrics

What is SysML? (www.omgsysml.org)

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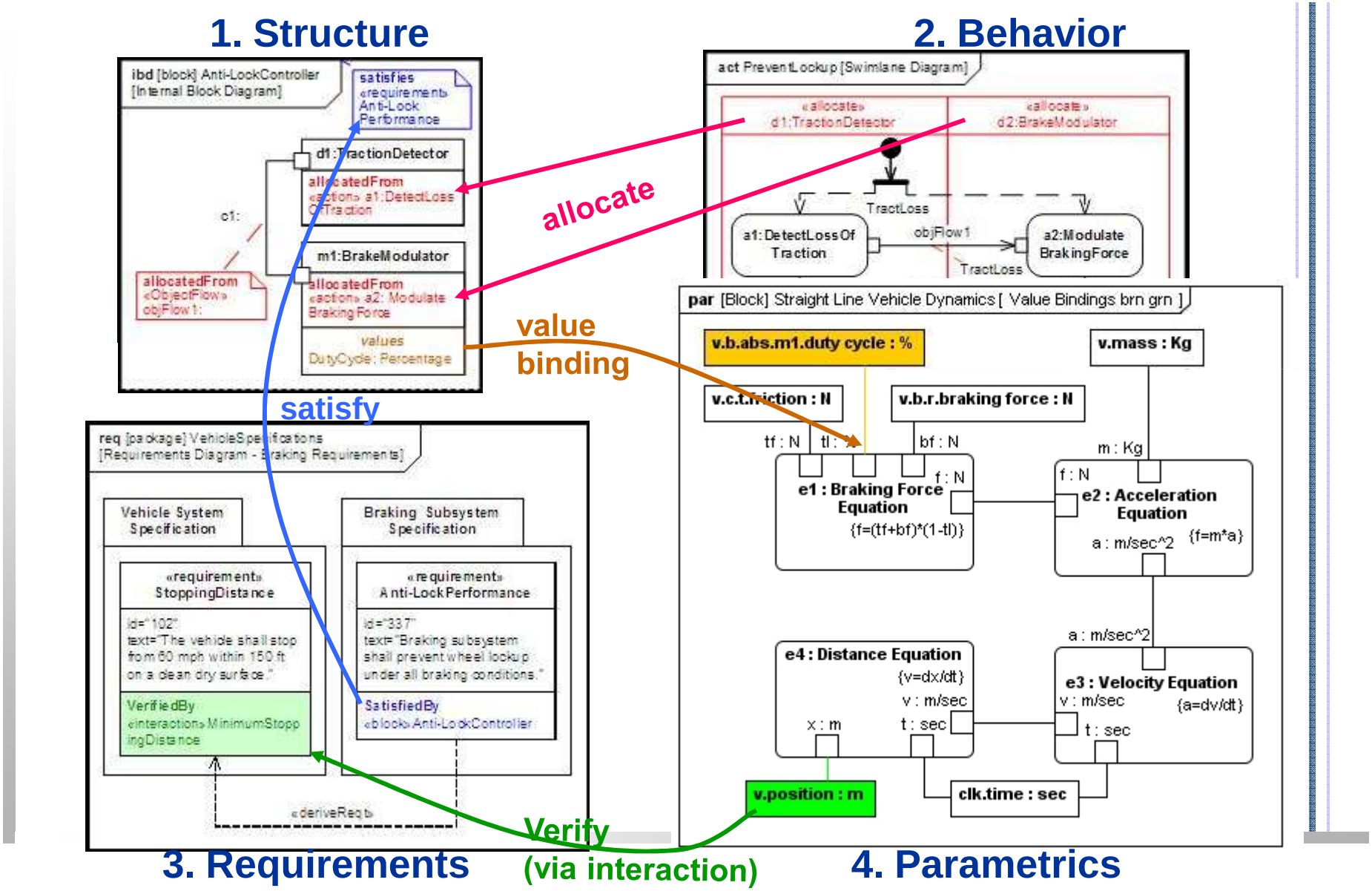
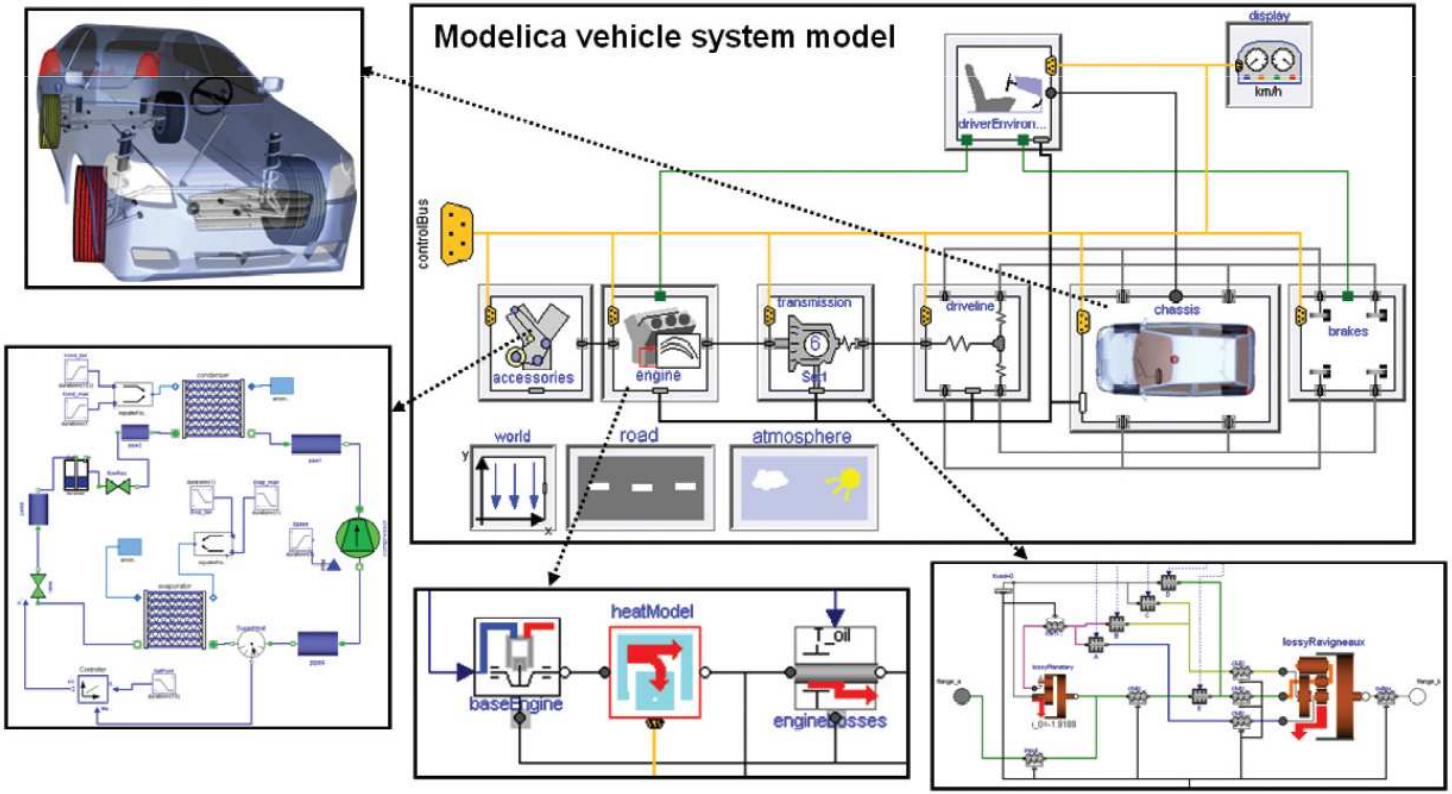


What is Modelica? (www.modelica.org)

- State-of-the-art Modeling Language for System Dynamics
  - Differential Algebraic Equations (DAE)
  - Discrete Events
- Formal, object-oriented language
- Standardized by the Modelica Association
  - Open language specification – tool independent
- Multi-domain modeling
- Ports represent energy flow (undirected) or signal flow (directed)
- Acausal, equation-based, declarative (f-m*a=0)

Modelica: Active and Mature Community

- Modelica association — 20+ free libs (www.modelica.org)
- 6 commercial solvers, 3 open-source solvers (Dymola, MapleSim, SimulationX, OpenModelica,…)
- EUROSYSLIB project — 20+ libs under development (http://www.itea2.org/public/project_leaflets/EUROSYSLIB_profile_oct-07.pdf)



A Robot Example in Modelica

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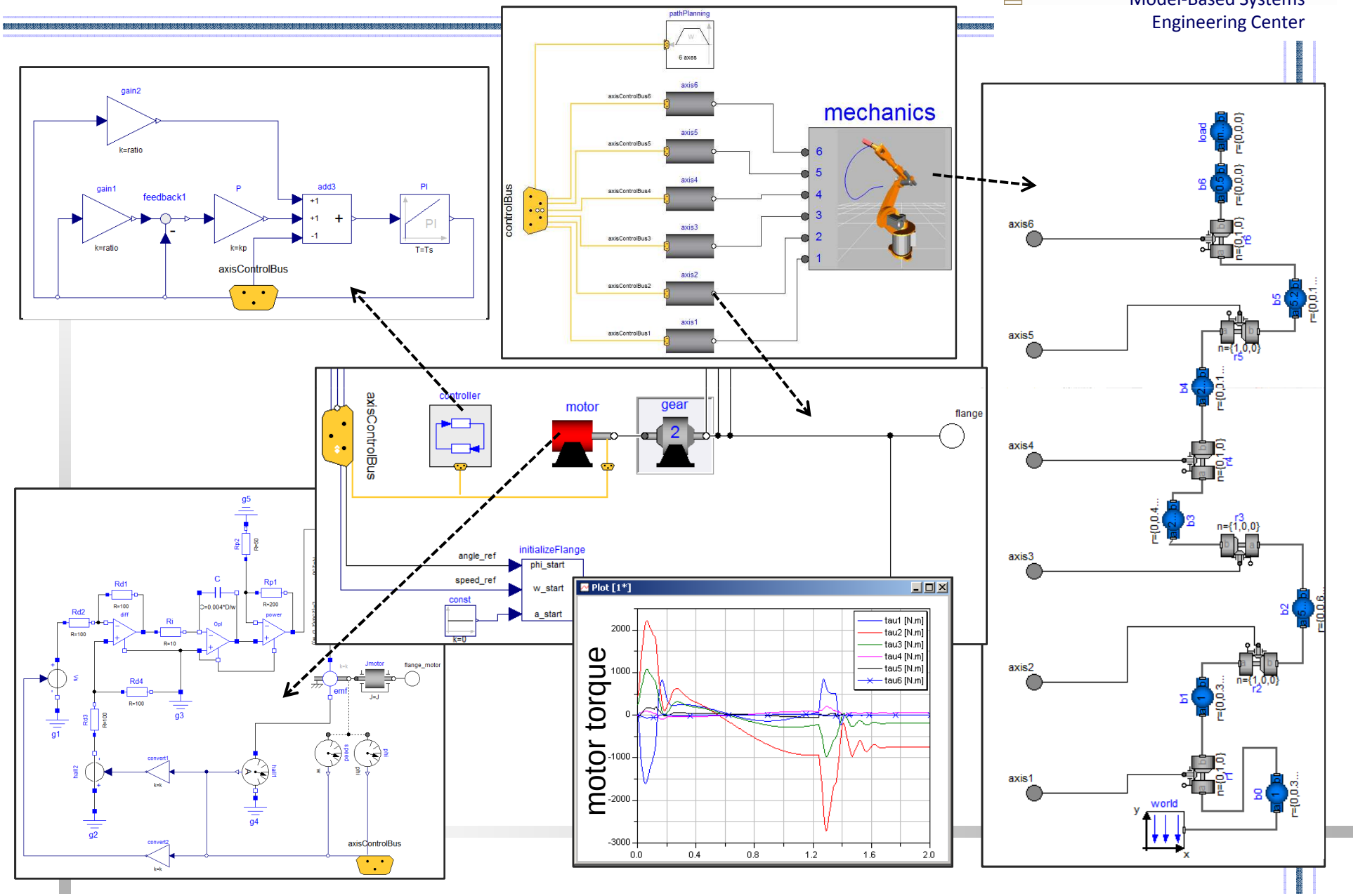

Modelica Semantics and Textual Syntax


```
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);
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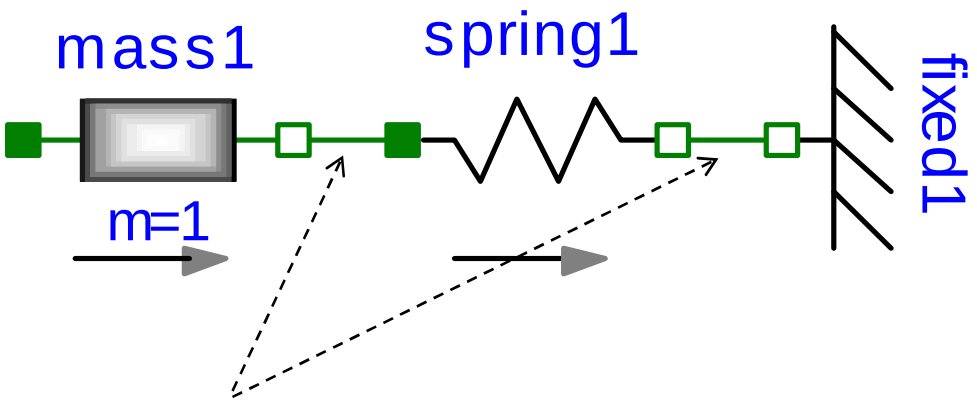

Graphical symbols defined as annotations in textual models

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

Presentation Overview

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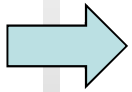

- Motivating Example: Design & Analysis of Robot

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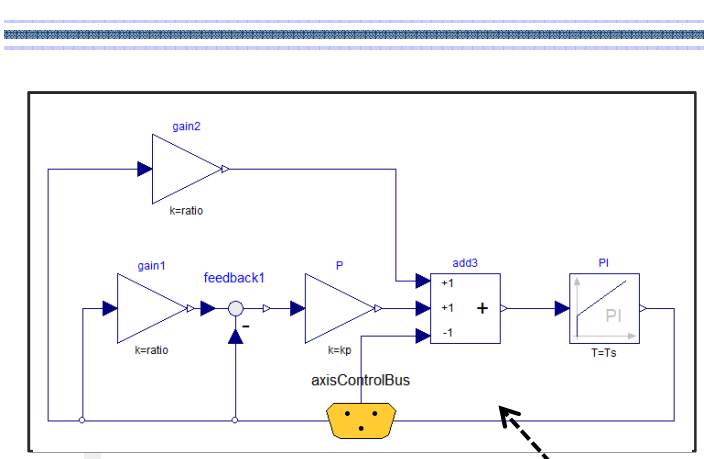
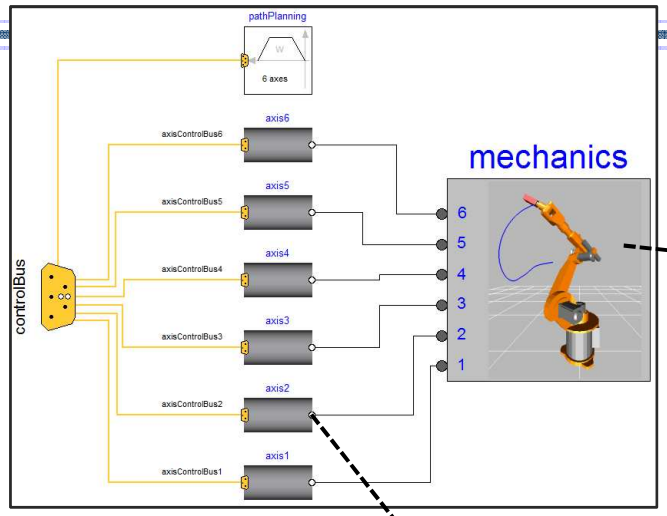
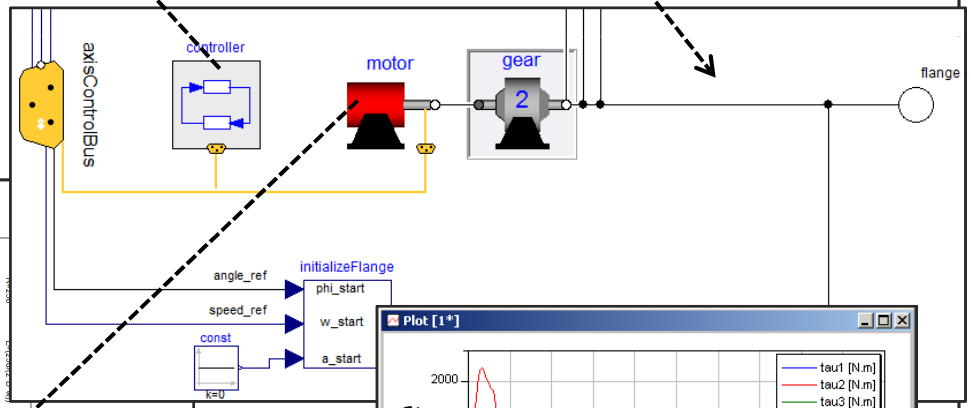
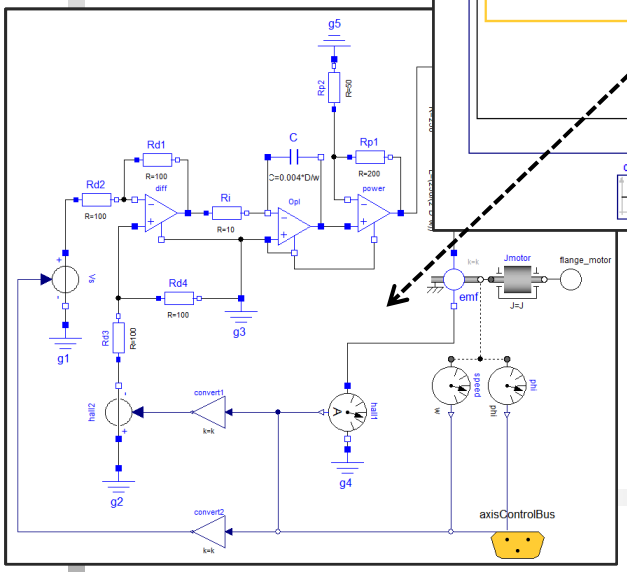
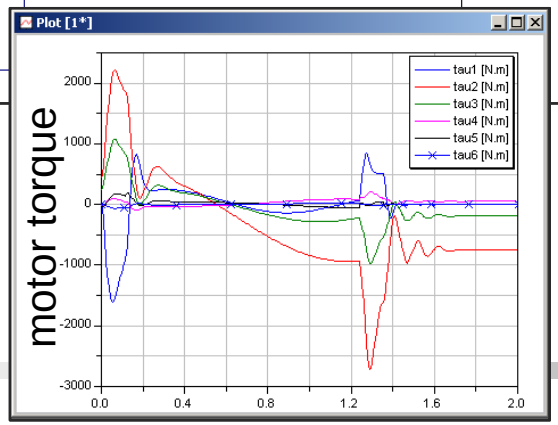
A Robot Example in Modelica

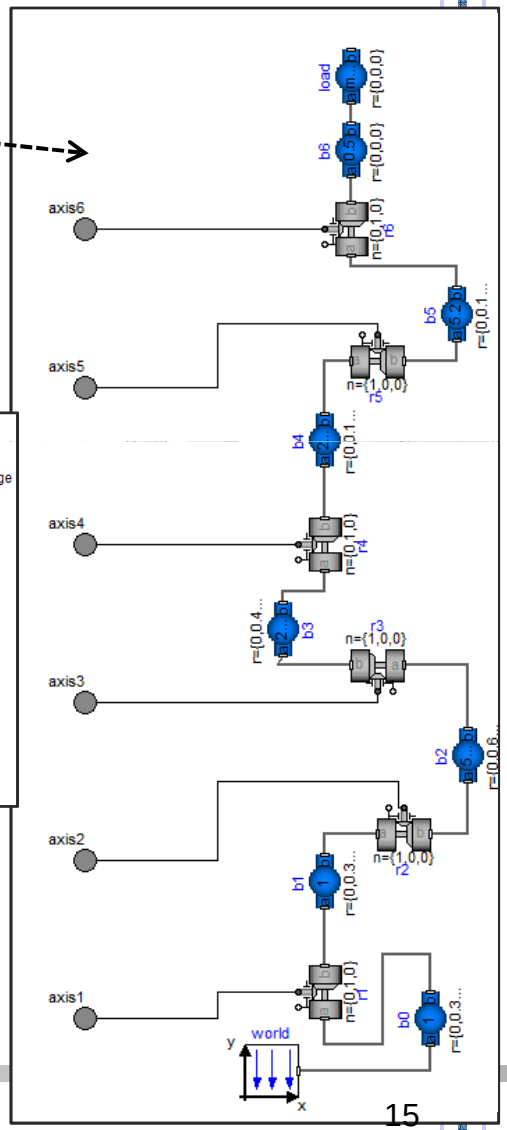












SysML-Modelica Robot Example: UseCases & Requirements

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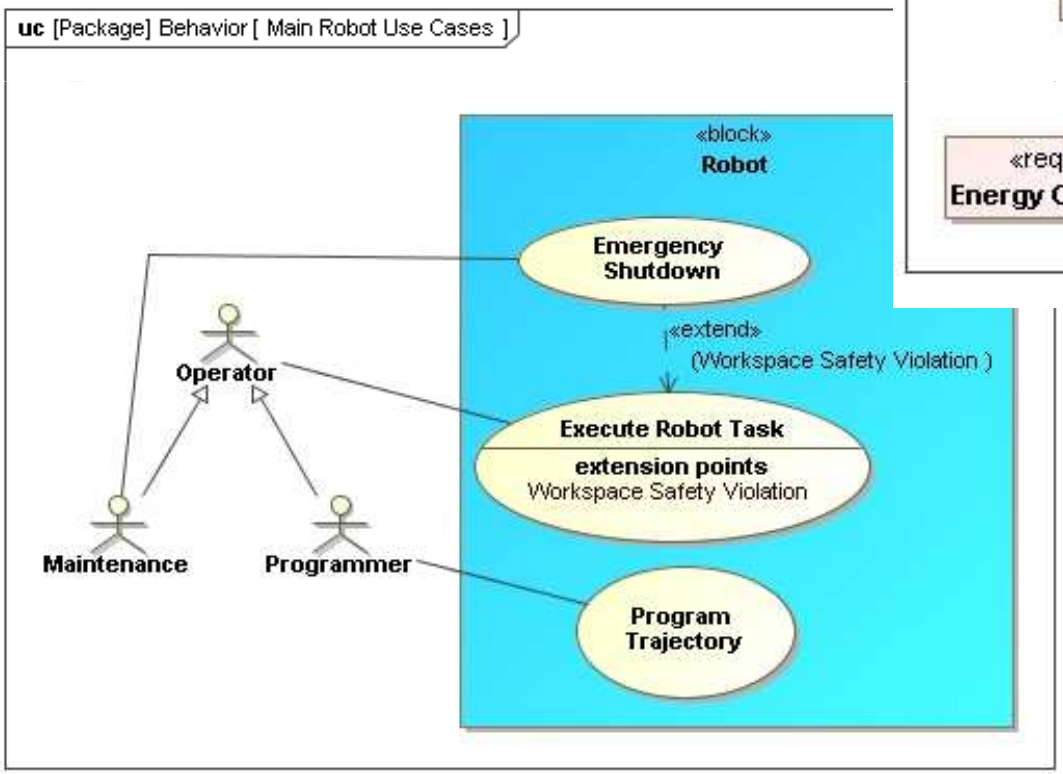

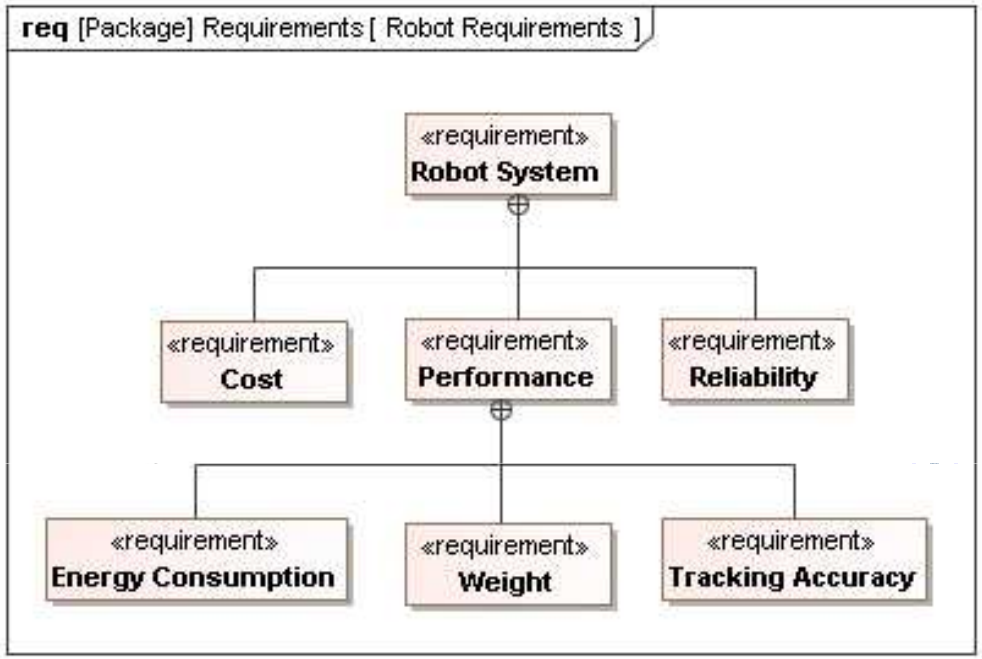

SysML-Modelica Robot Example: Robot Domain BDD & IBD

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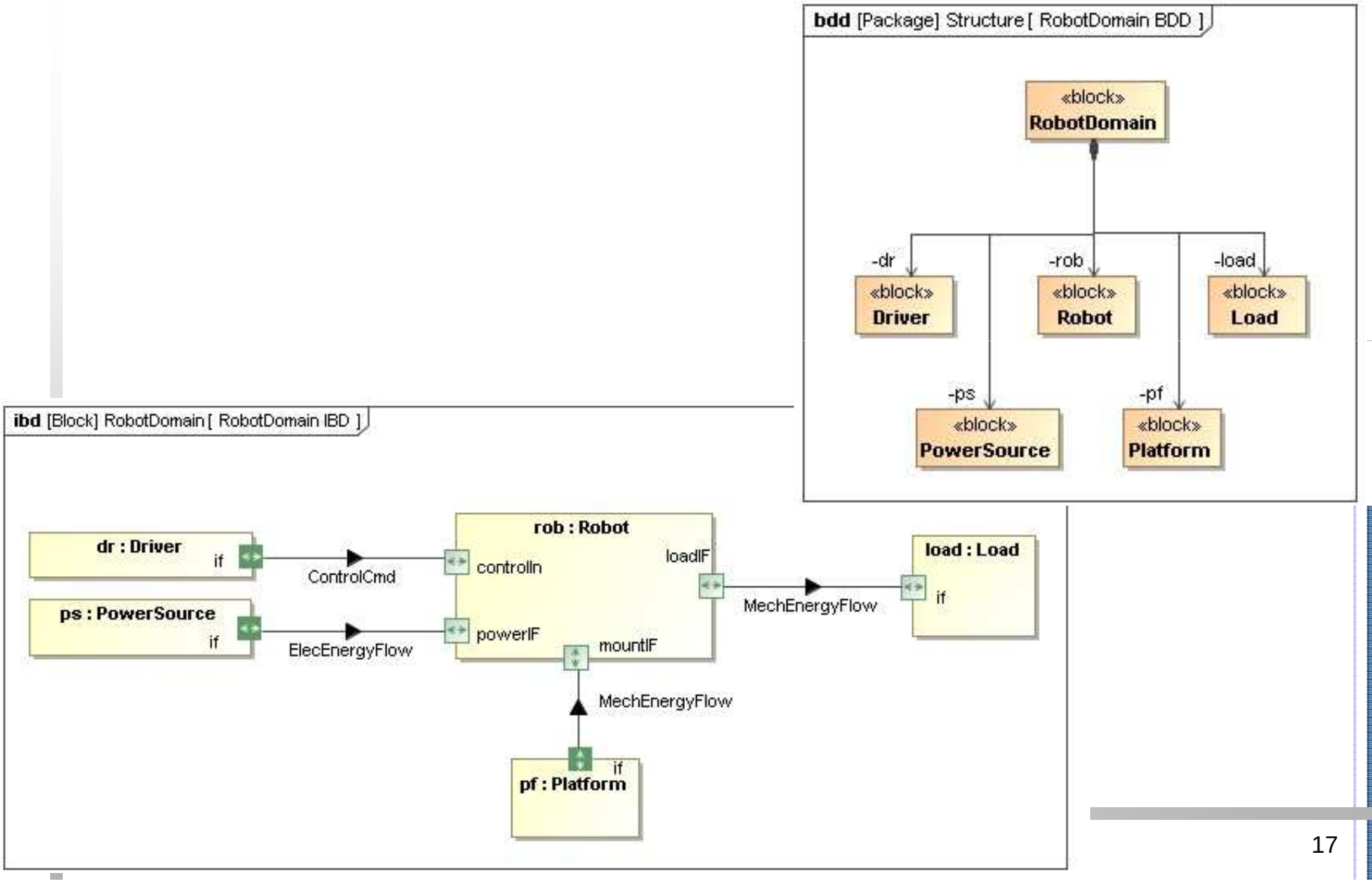

SysML-Modelica Robot Example: Robot BDD & IBD

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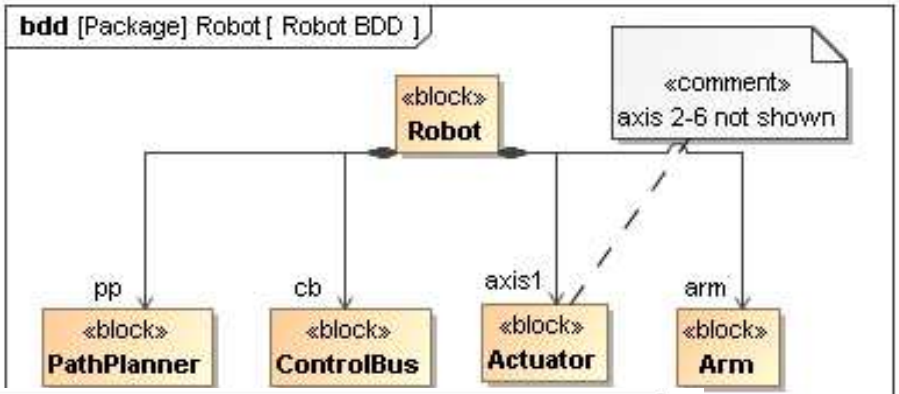

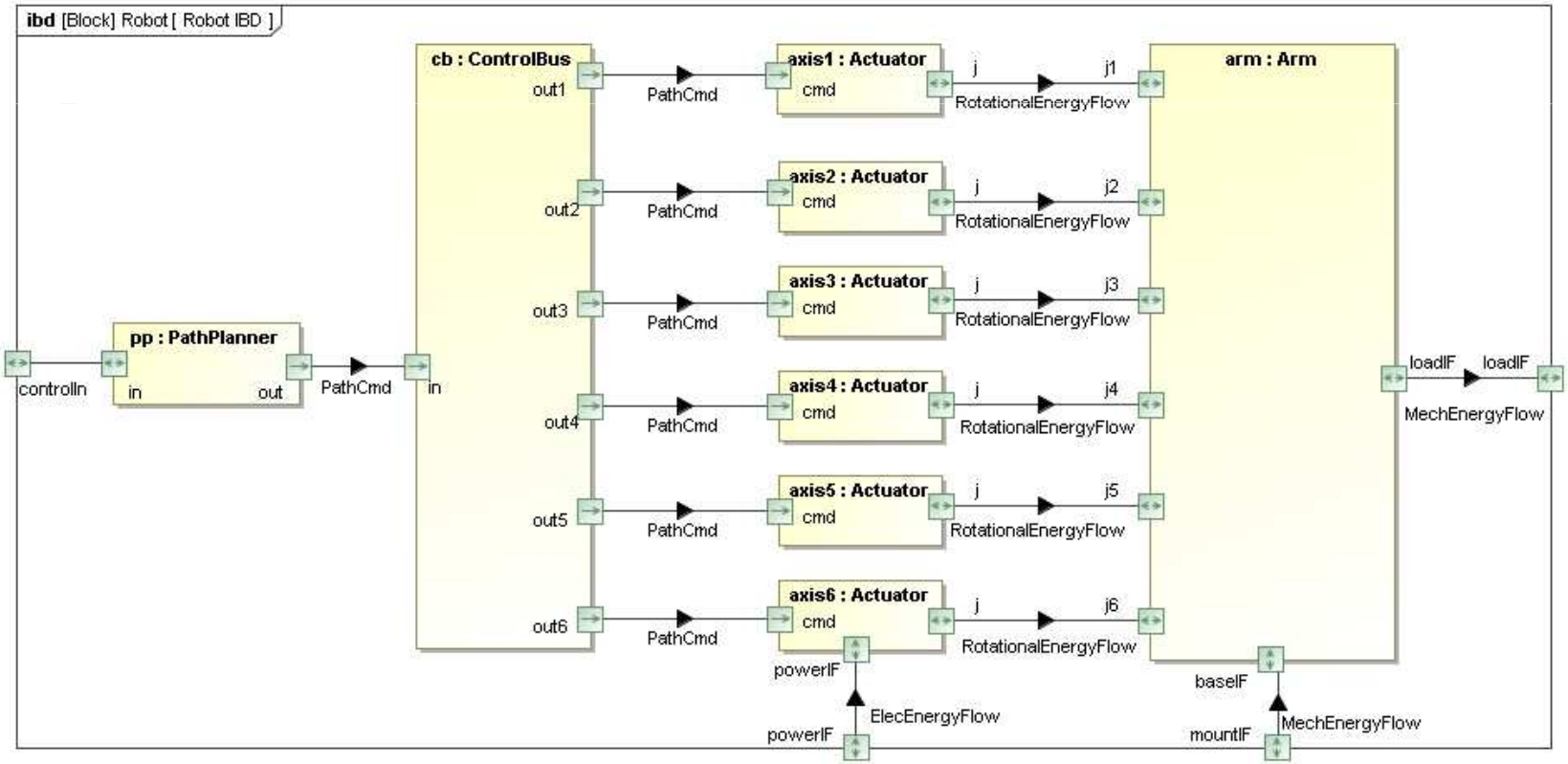

SysML-Modelica Robot Example: Robot Arm BDD

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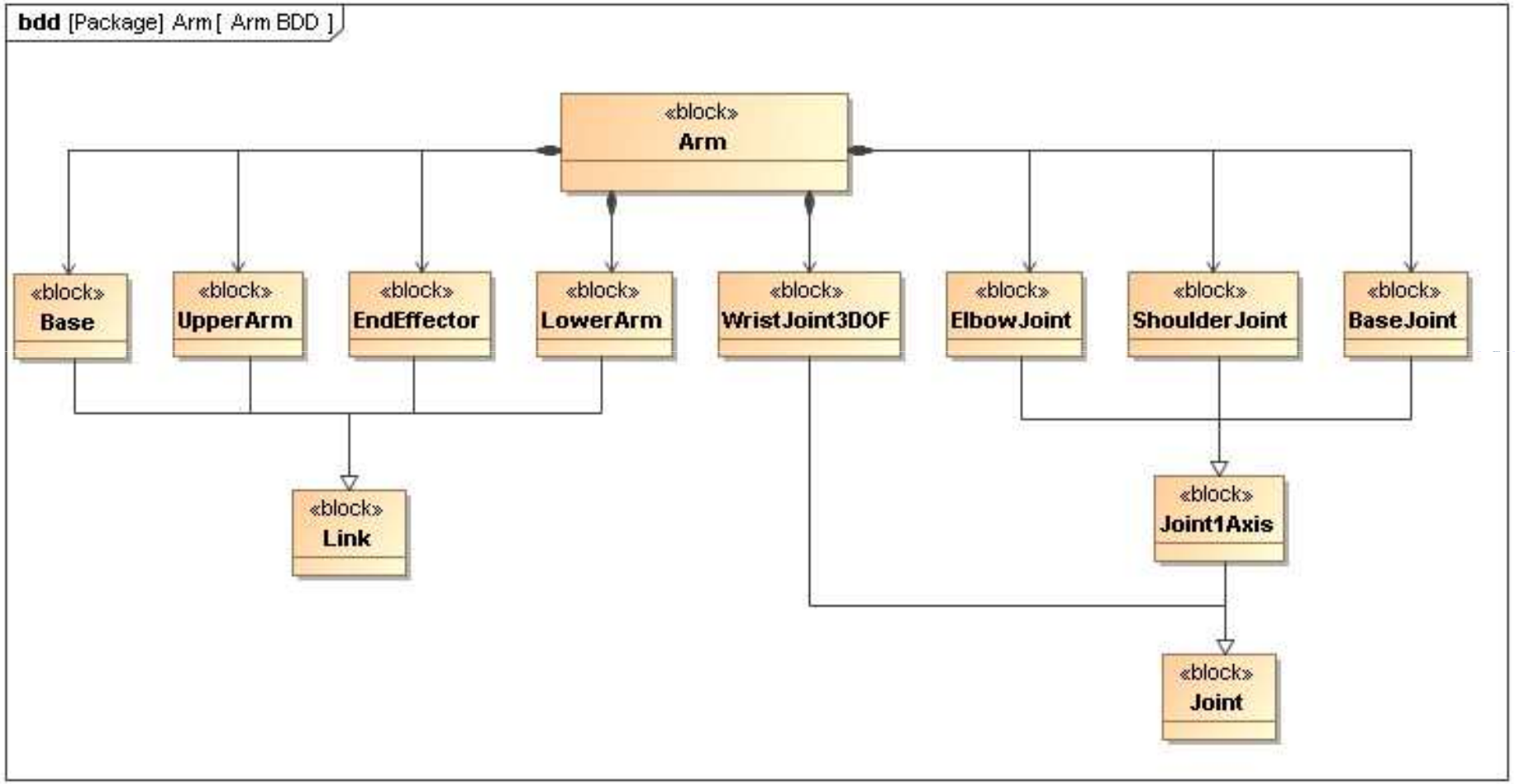

SysML-Modelica Robot Example: Analysis and Trade Study

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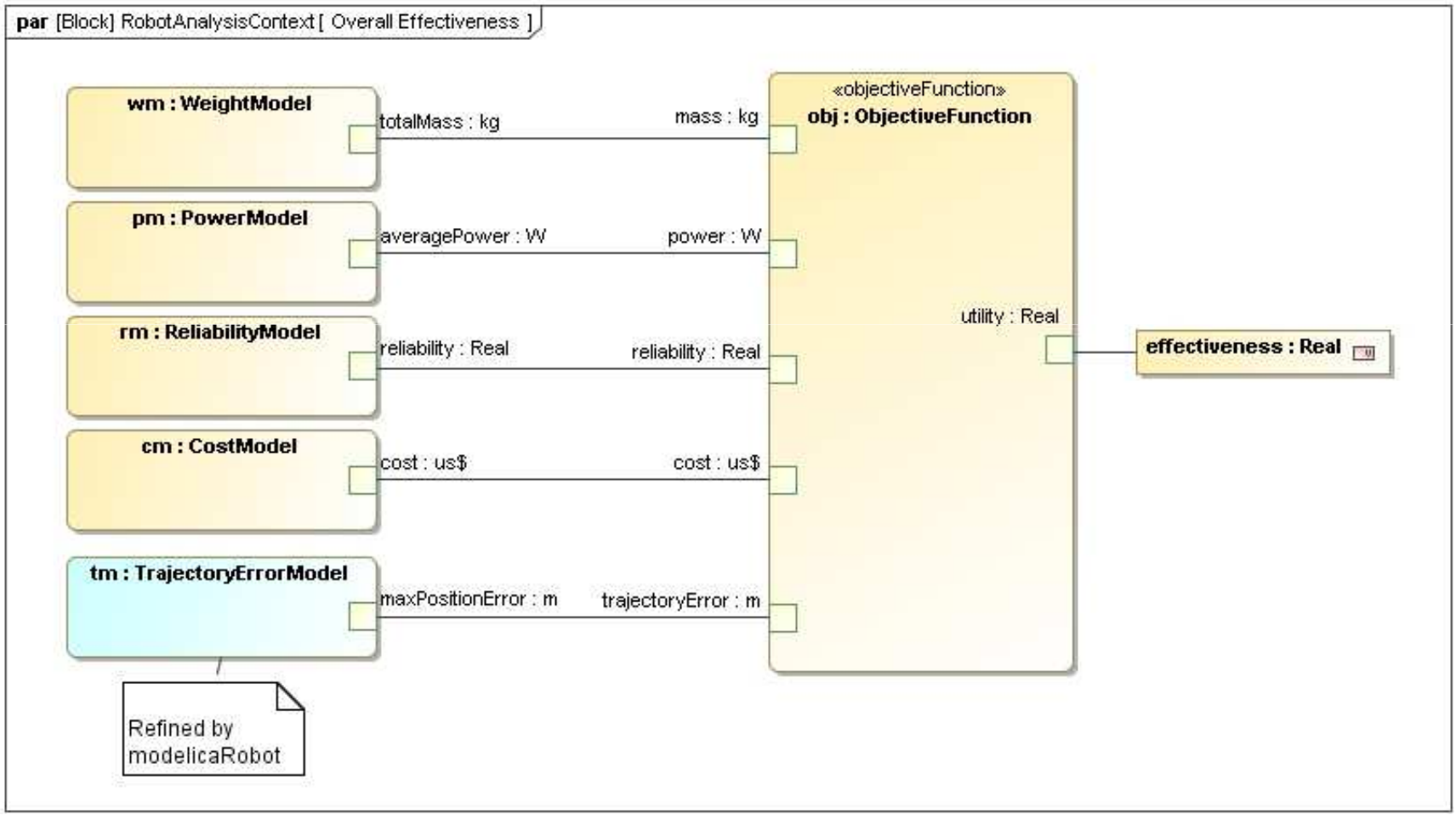

Analysis models depend on descriptive models

SysML4Modelica Analytical Model: Compose Model from Standard Library

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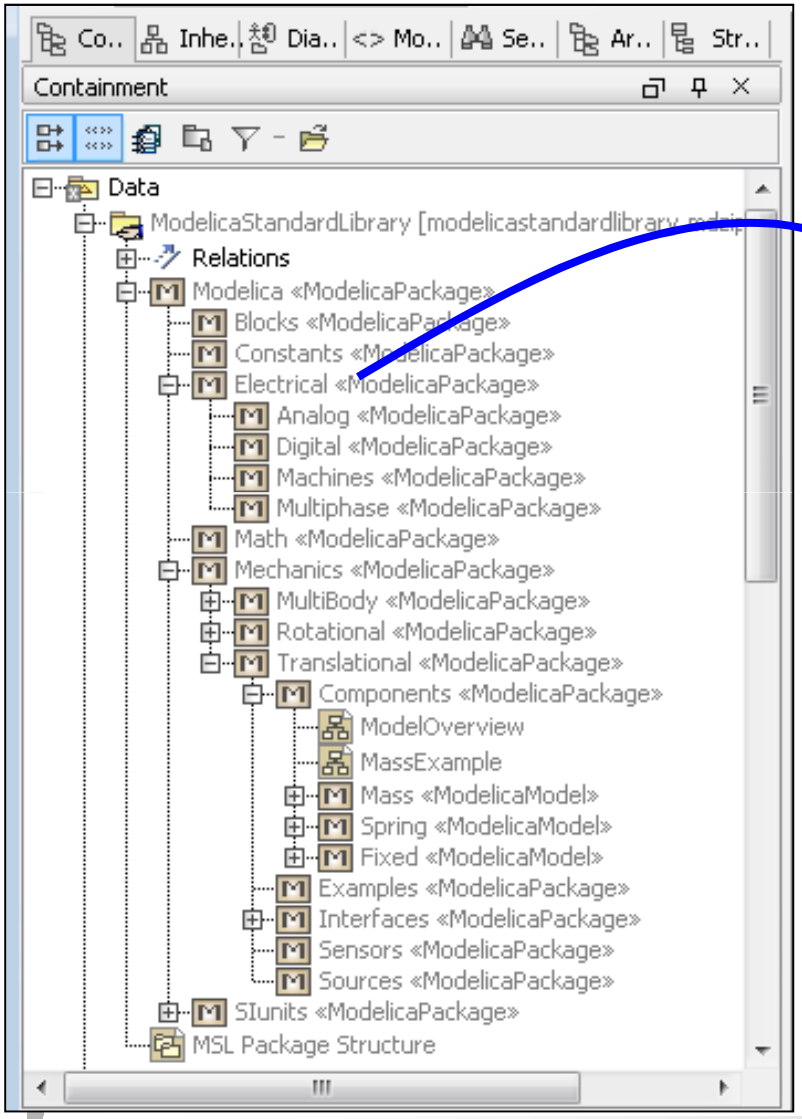
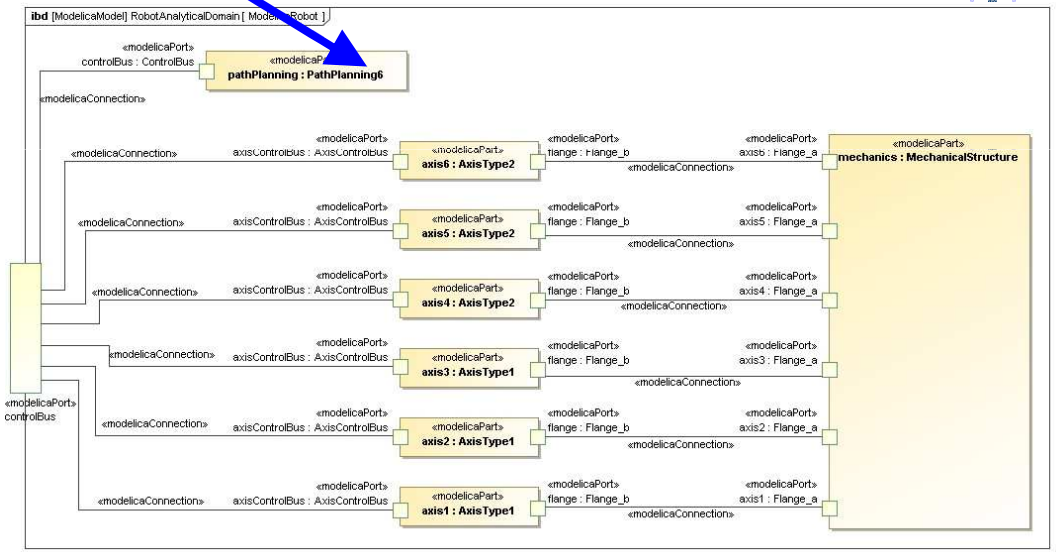


Drag and drop into IBD «ModelicaModel»



SysML4Modelica Analytical Model: Detailed IBD

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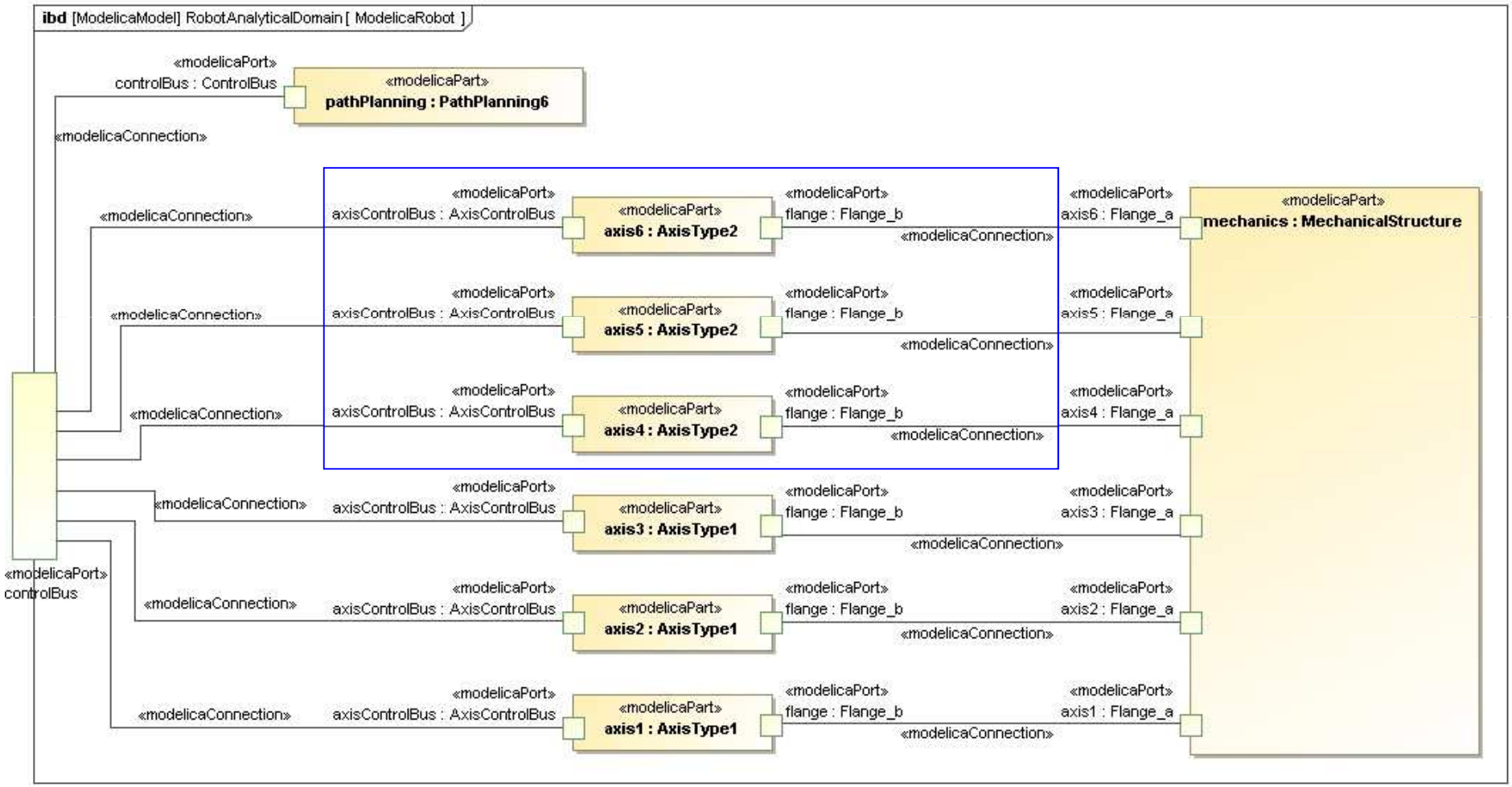

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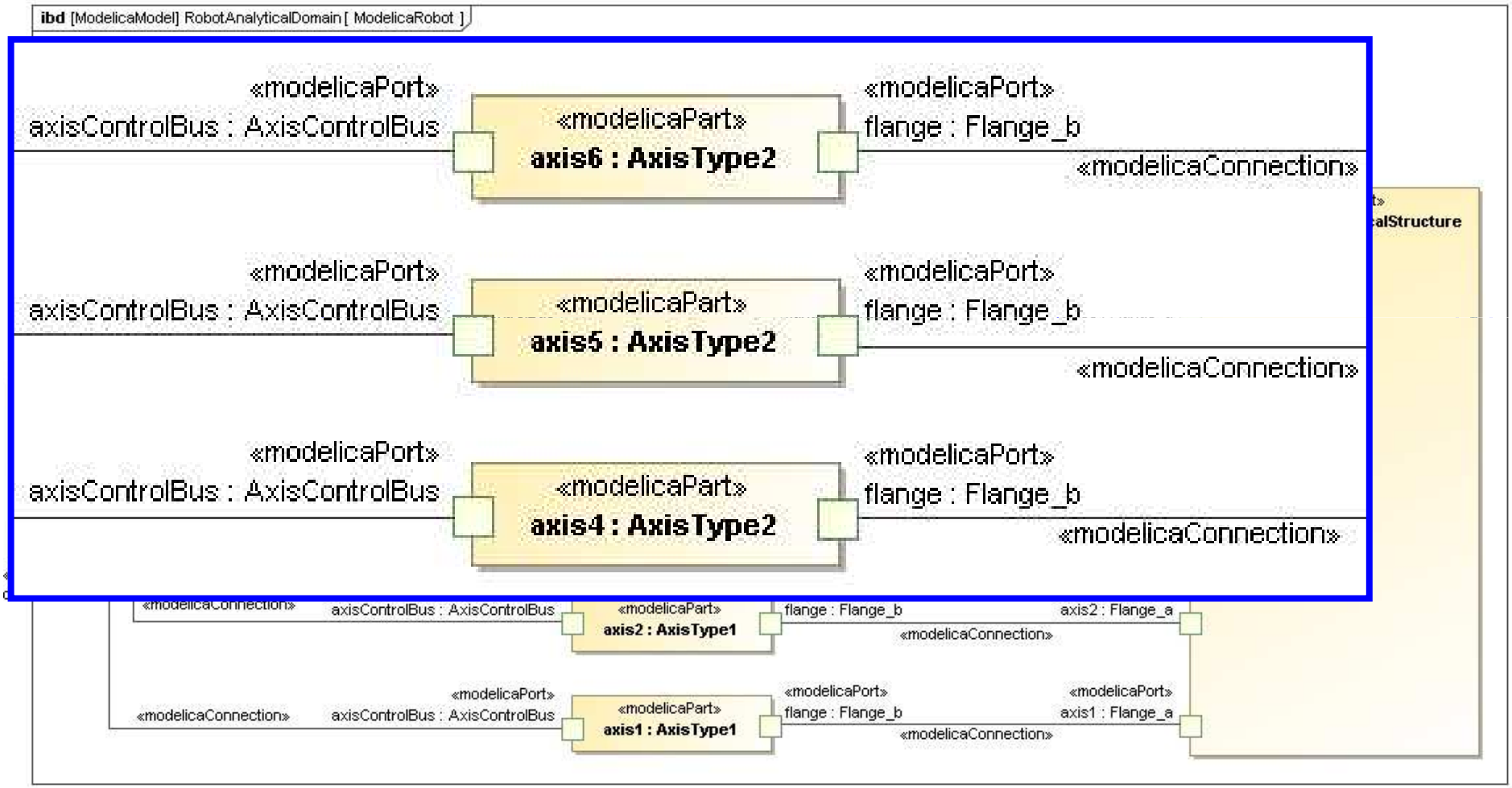

SysML4Modelica Analytical Model: Relation to Modelica Native Model

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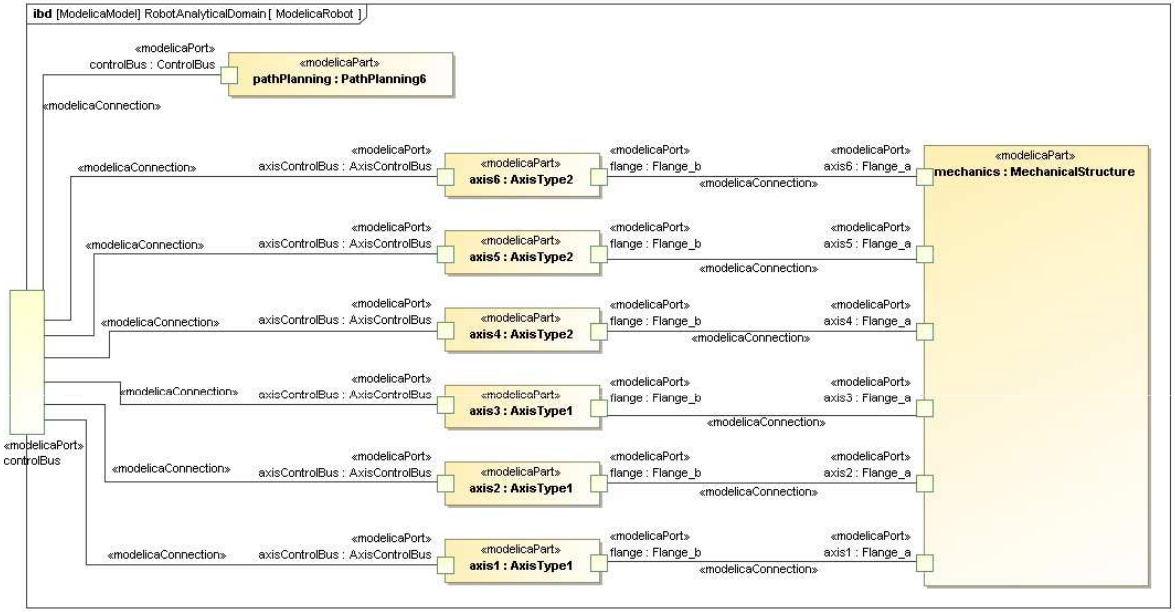

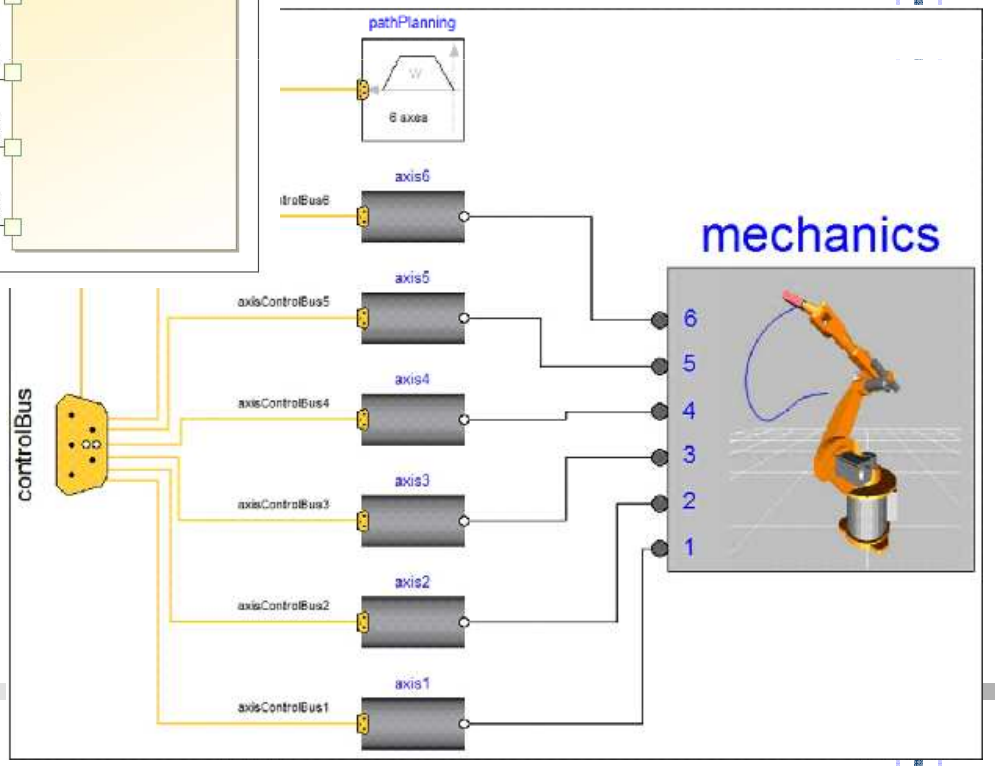

SysML4Modelica Analytical Model: Allocation

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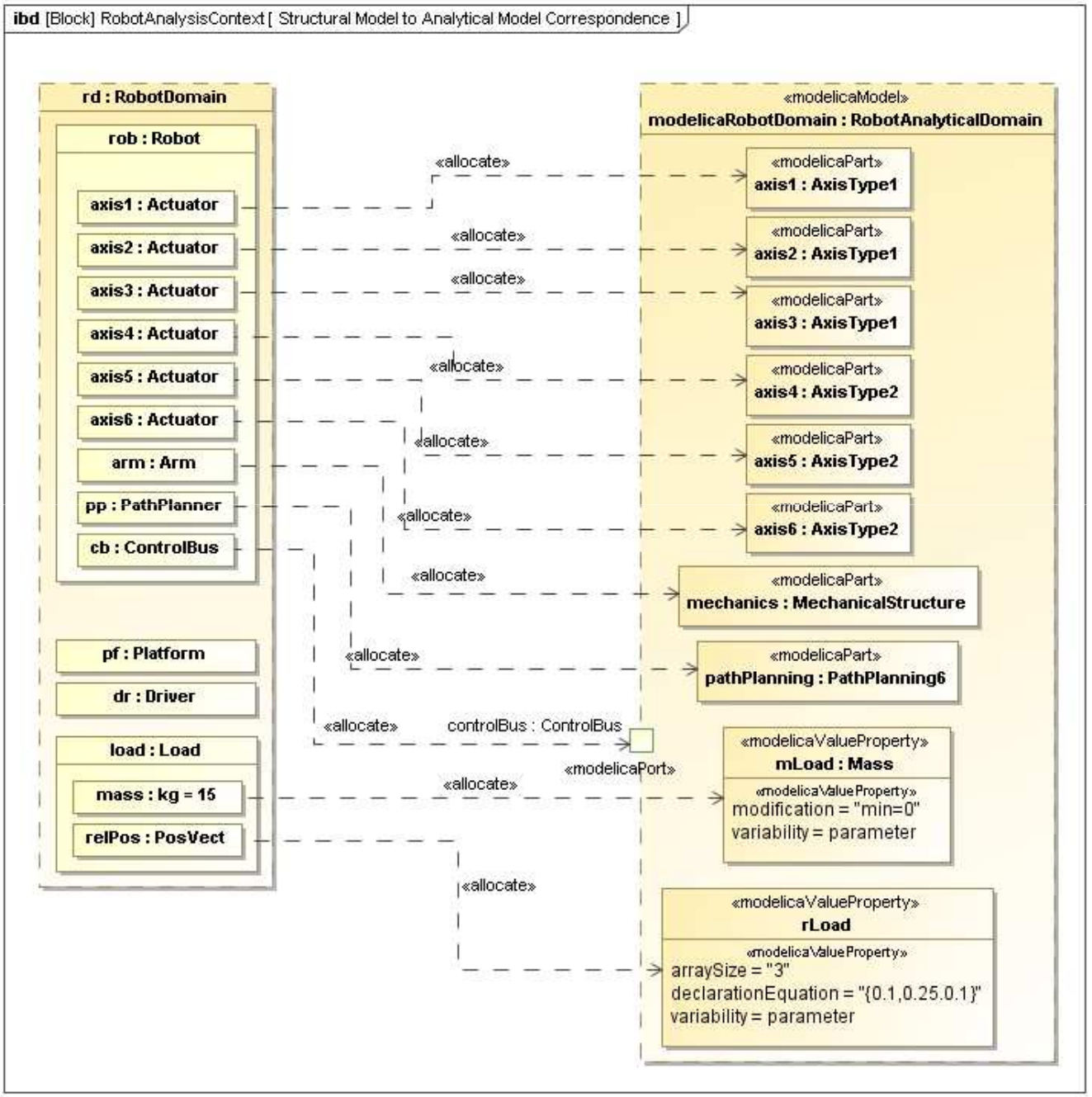

SysML-Modelica Robot Example: Modelica model with simulation results

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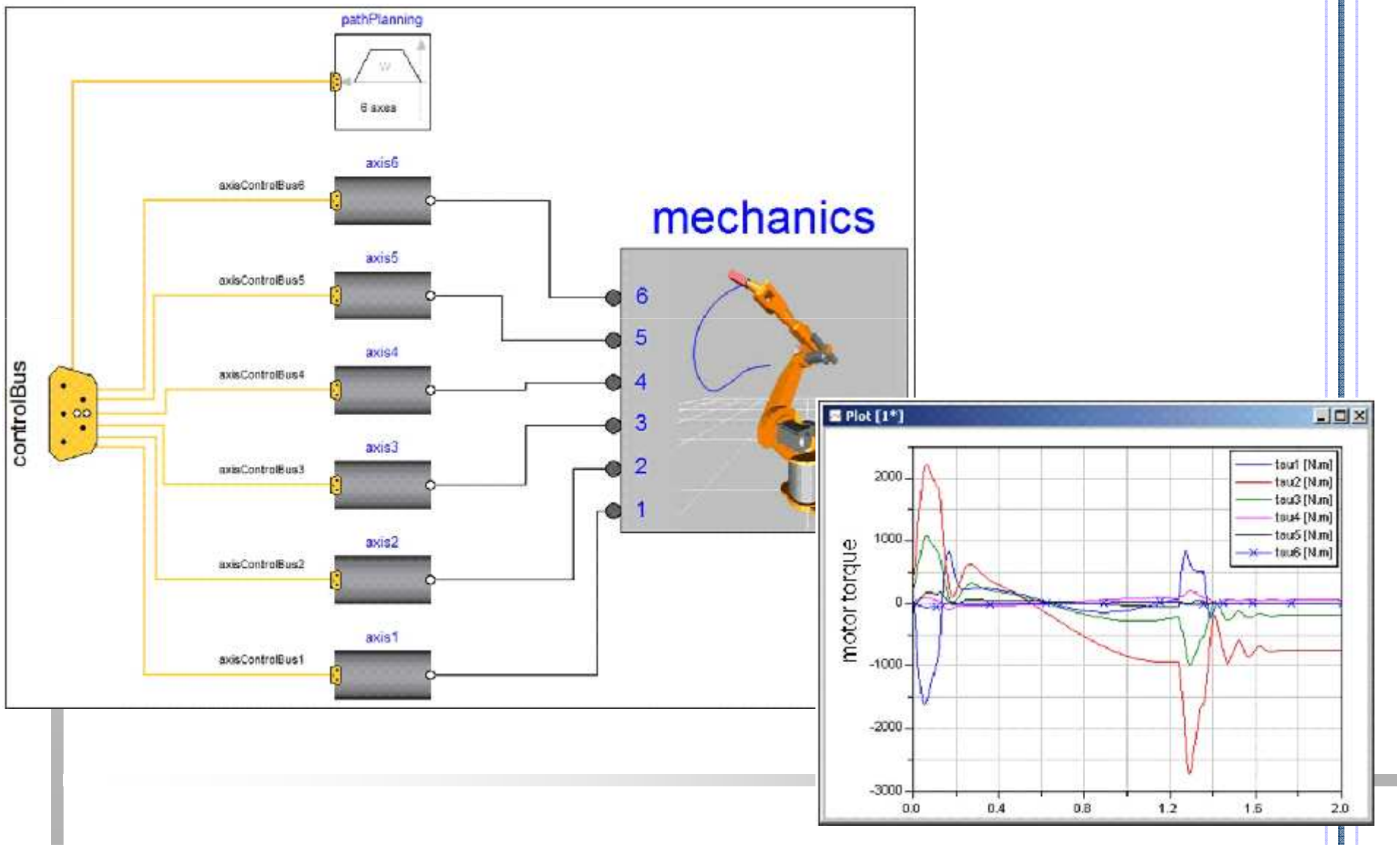

SysML-Modelica Robot Example: Analysis and Trade Study

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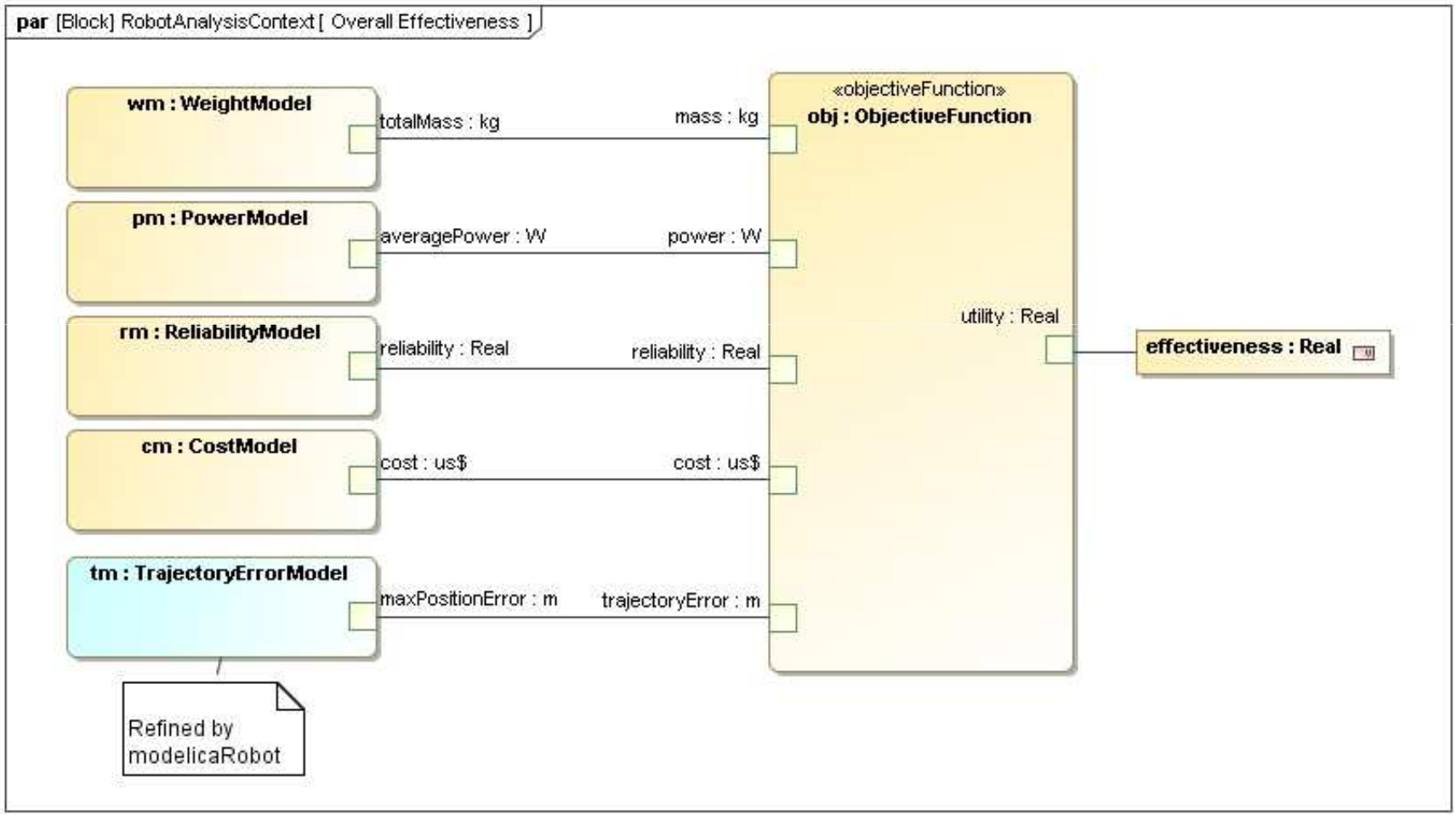

Analysis results are incorporated in Trade Study

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SysML-Modelica Transformation Specification

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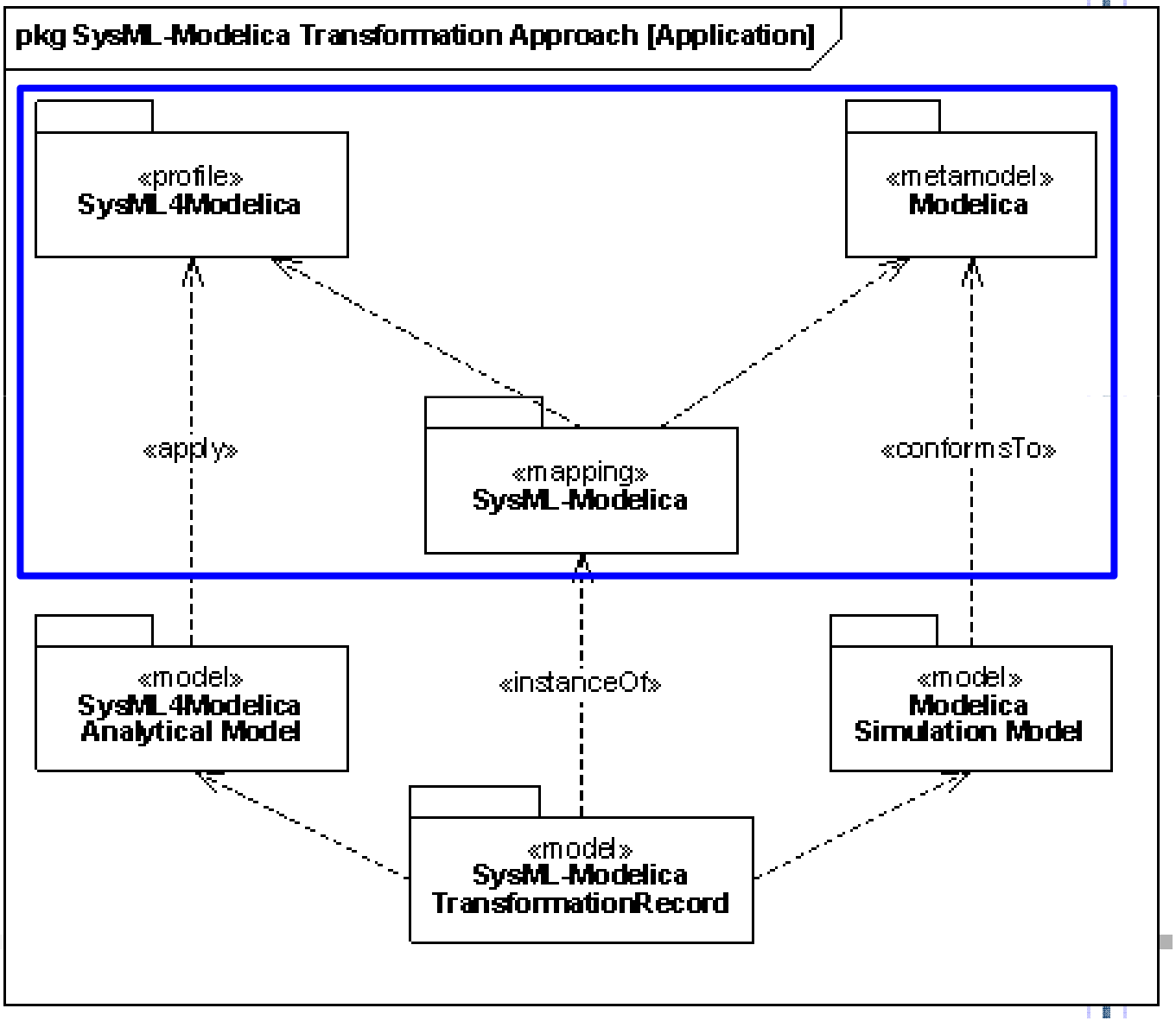
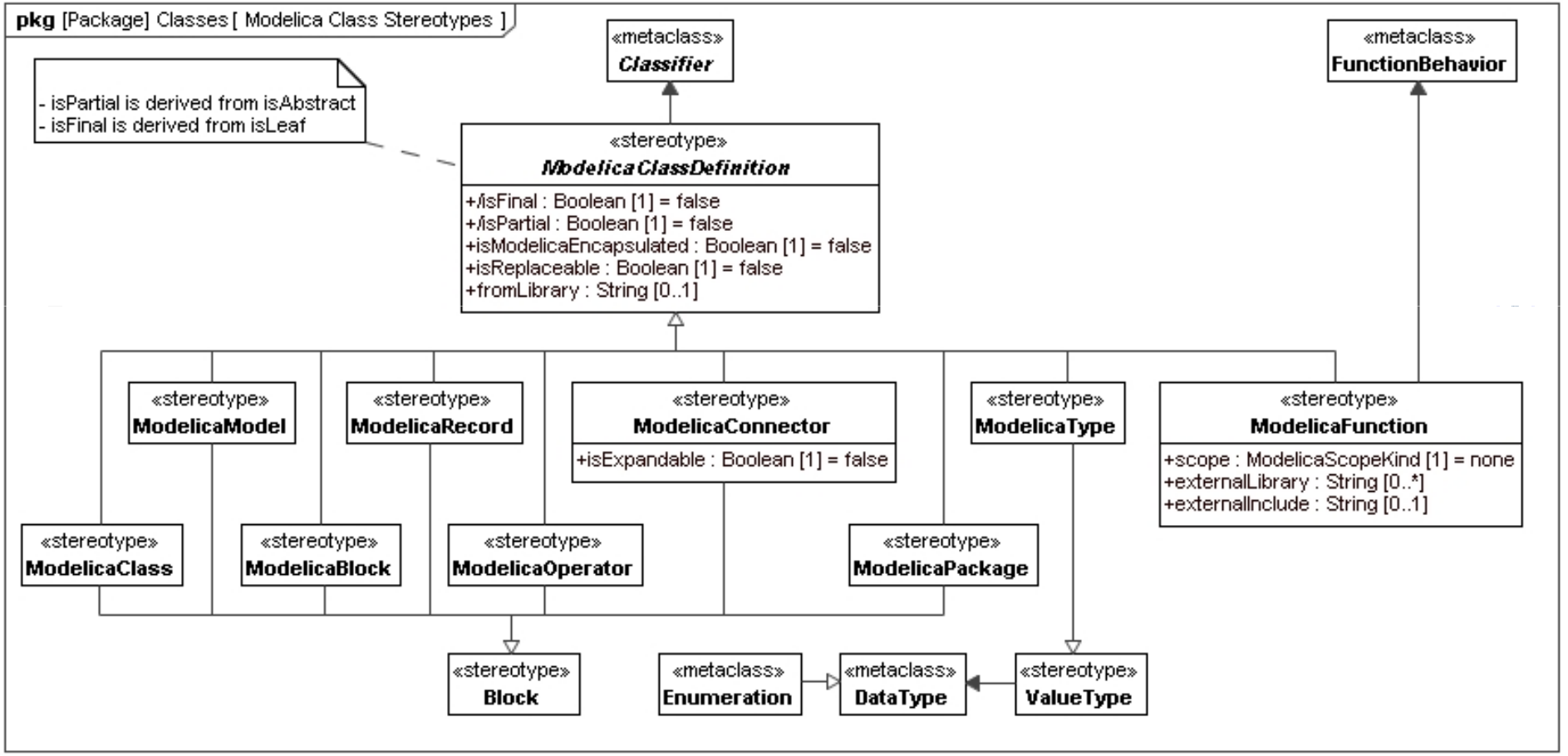
SysML-Modelica Transformation follows the principles of Model-Driven Architecture (MDA)



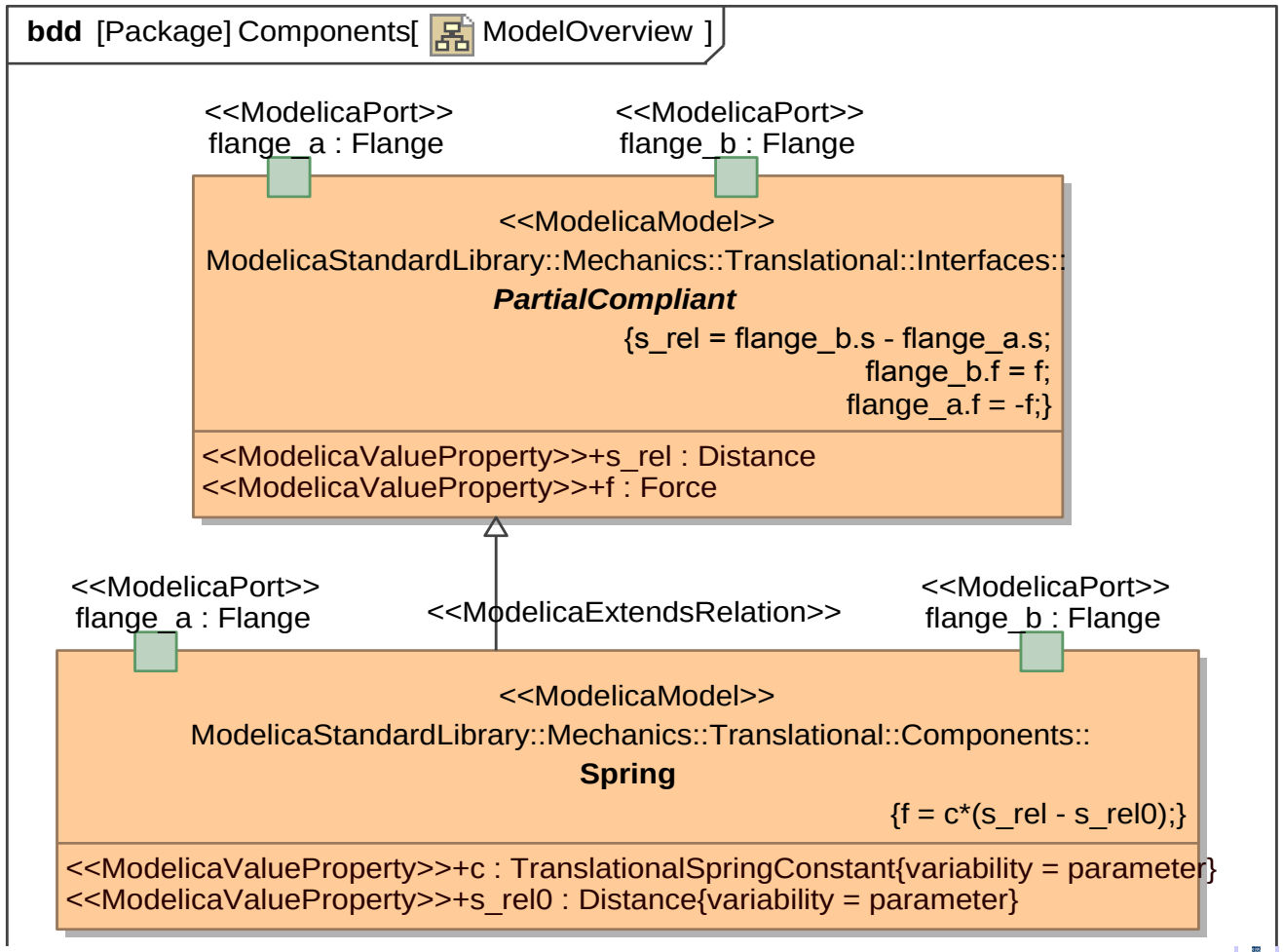
SysML4Modelica Profile



SysML4Modelica

Formal mapping

Modelica




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

Reference implementation: Based on OMG QVT

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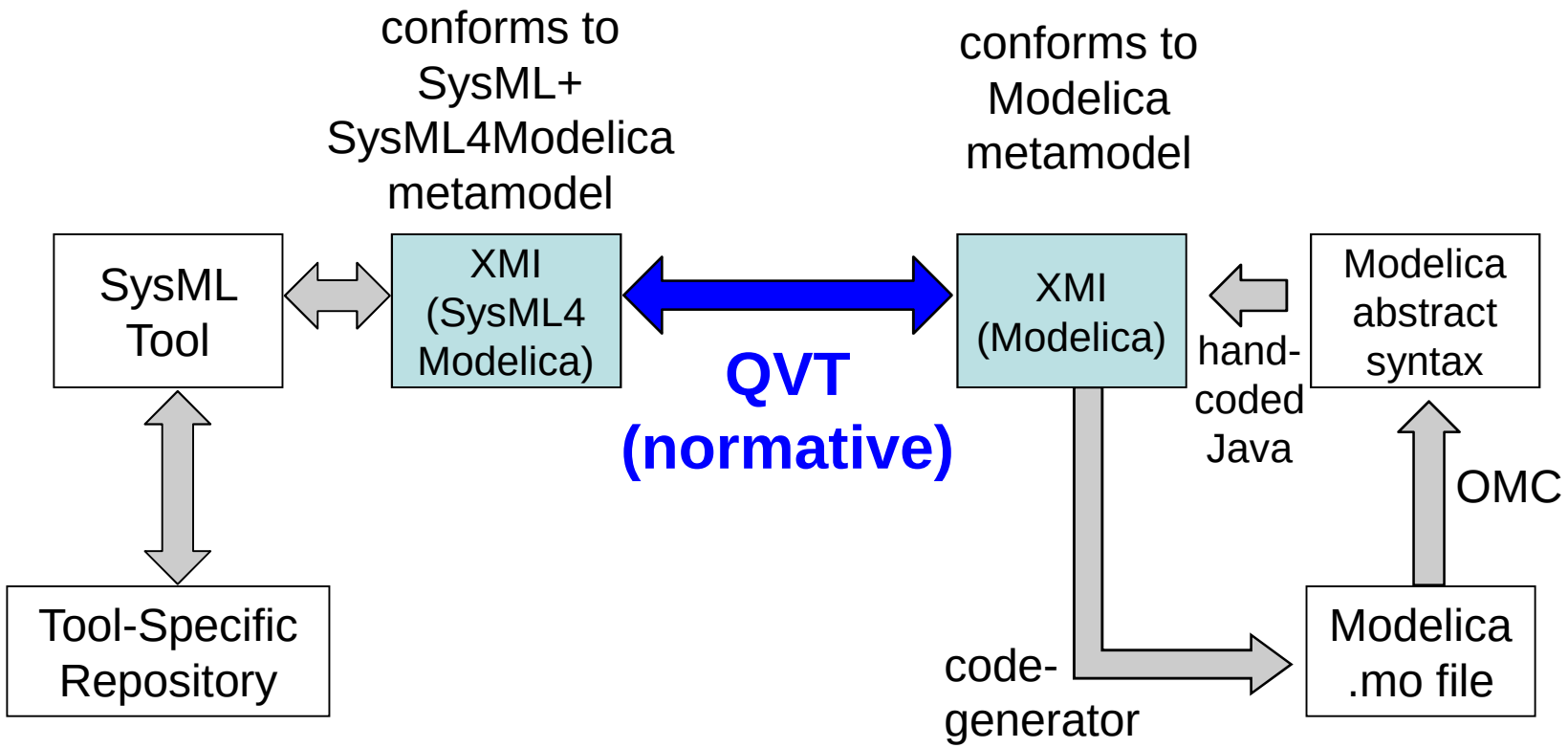
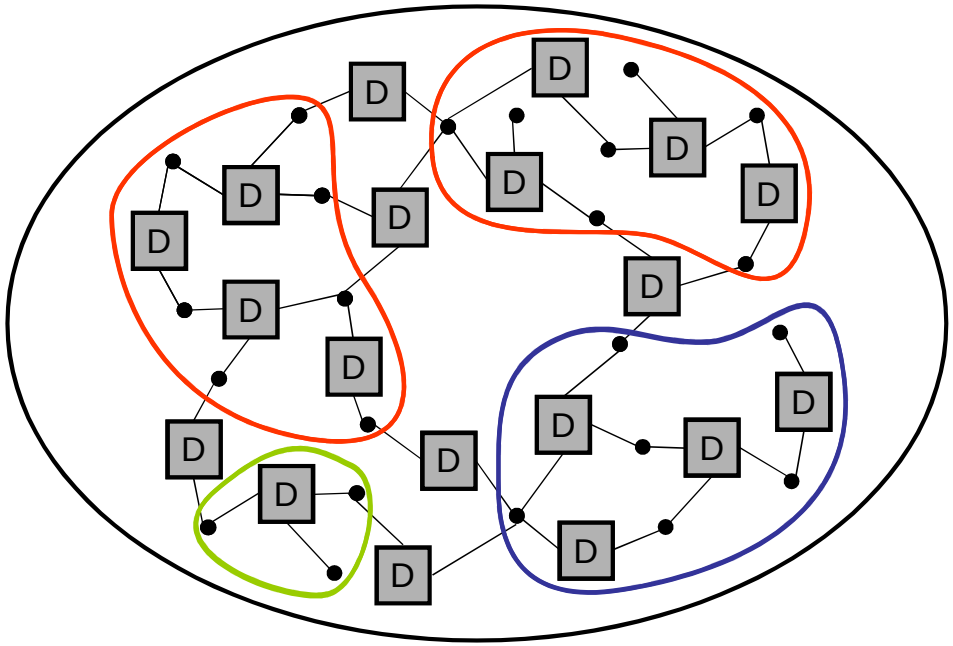


QVT = Query / View / Transformation

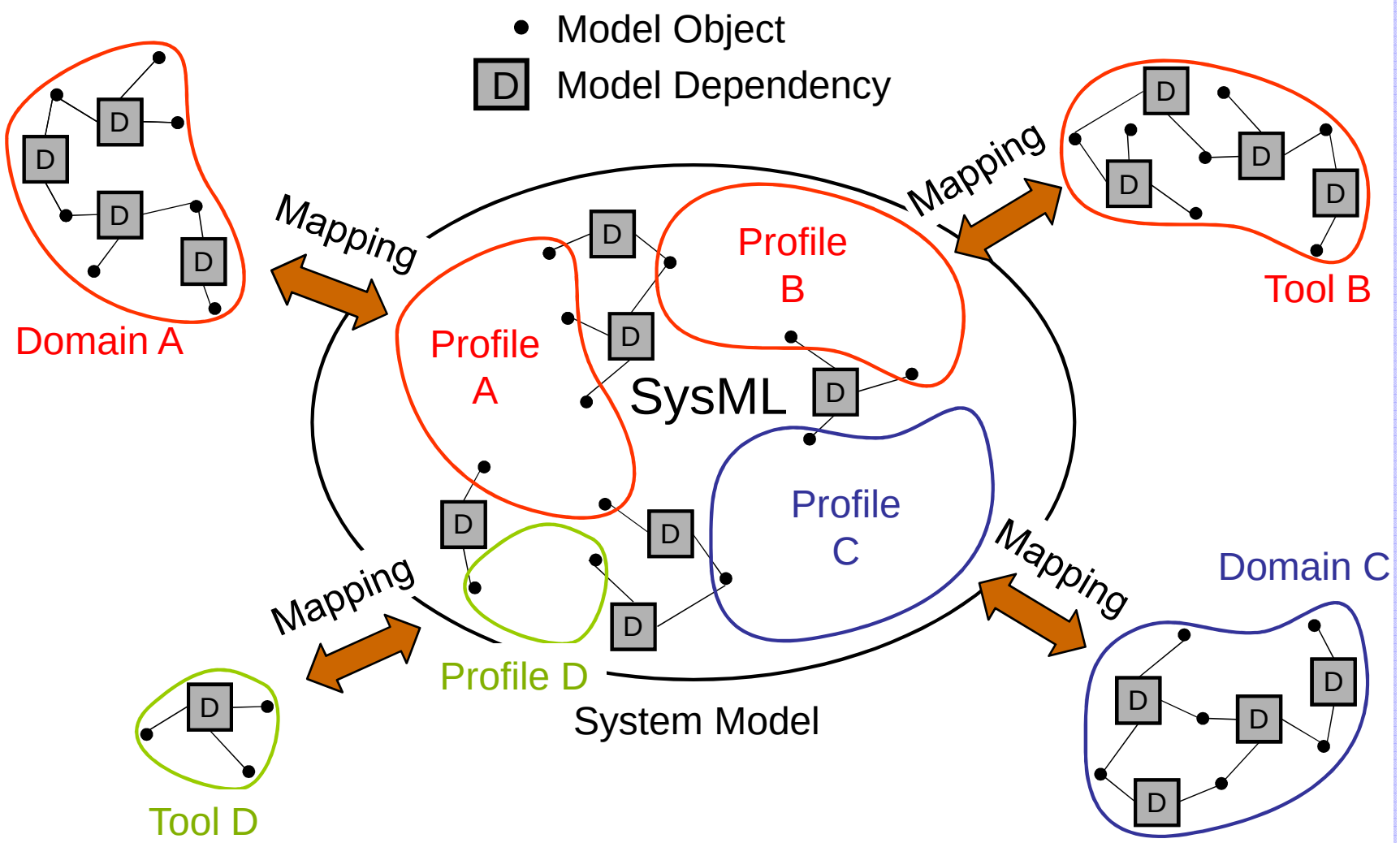
Transformations in Systems Modeling

- Model Object
- D Model Dependency

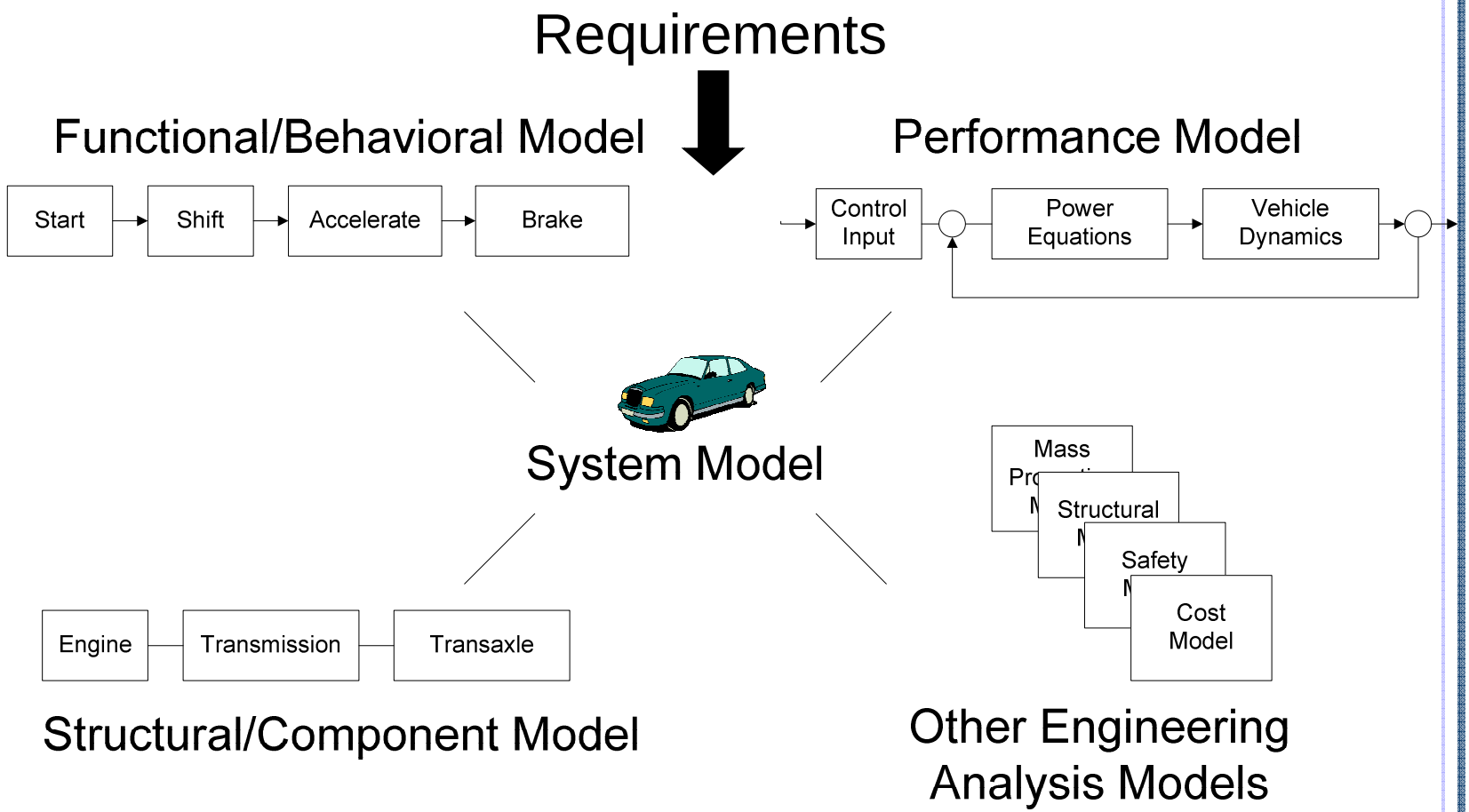


System Model

Transformations in Systems Modeling



Model Reuse in MBSE



Creating Models is Expensive and Time-Consuming

Reusable Models in MBSE

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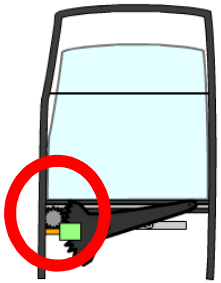
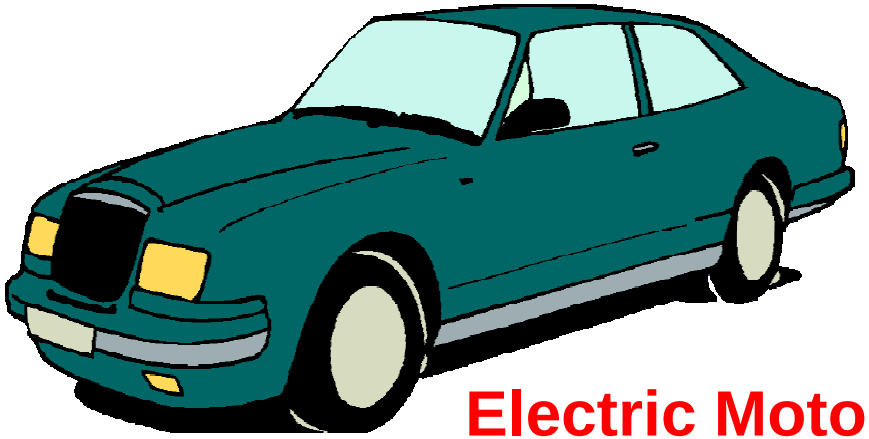
- Physical components are reused
- Portions of the systems model repeat
- Patterns for instantiating these portions





Electric Motors

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

Model Library of Hydraulic Components

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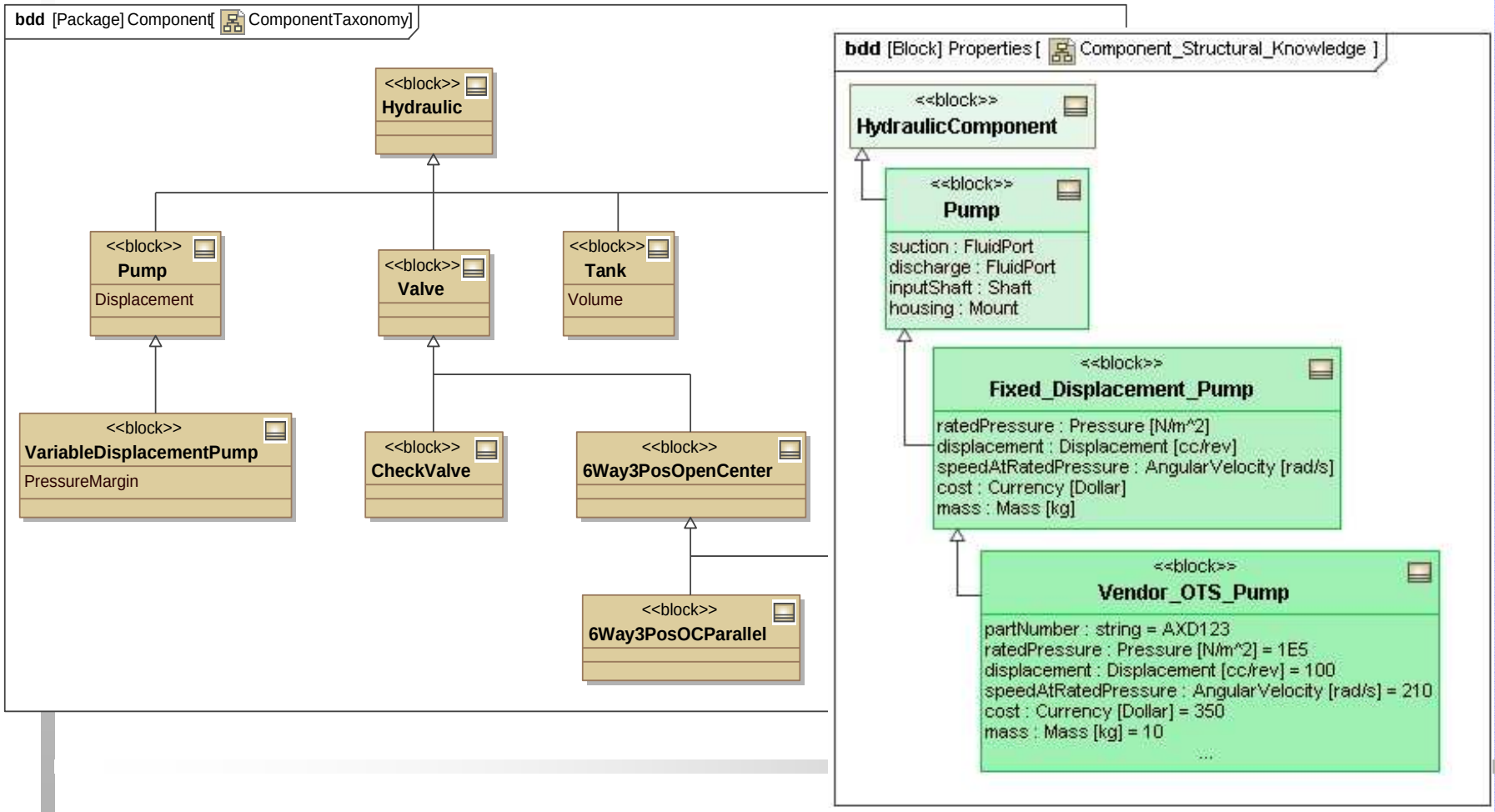
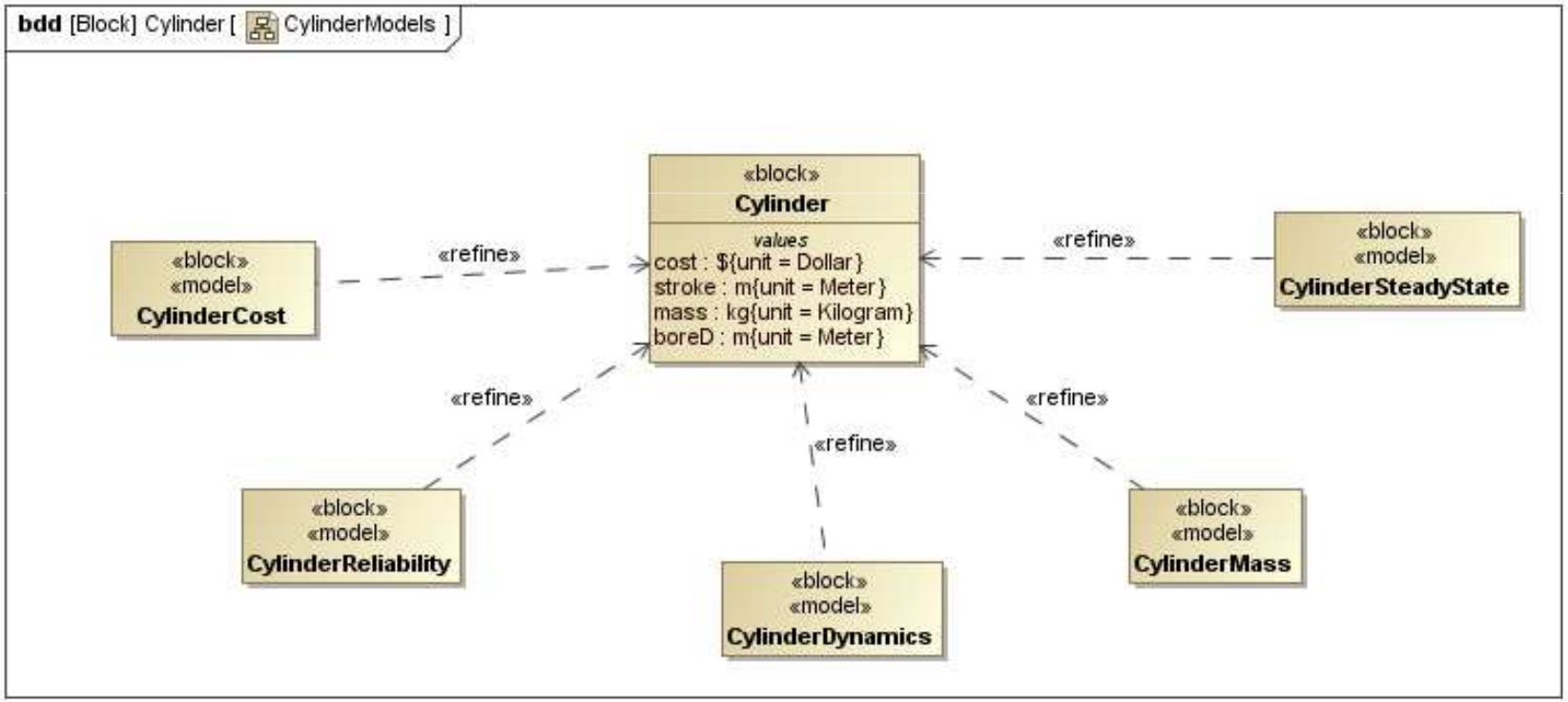
- Needs to be carefully designed and managed
- Encodes domain knowledge



Other Perspectives of Cylinder are Reusable

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

→ Capture the reuse pattern



Correspondence Patterns

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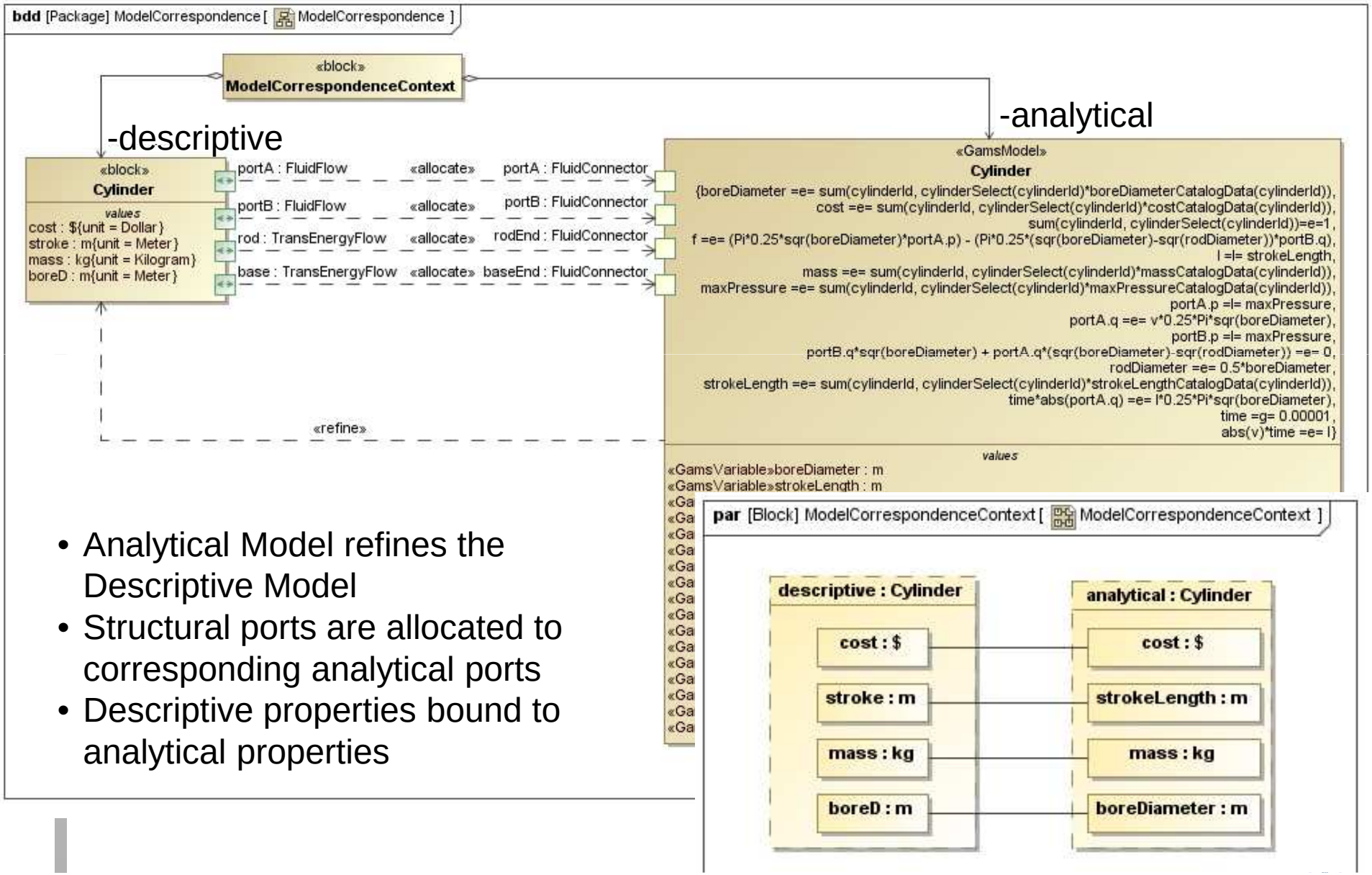

- Analytical Model refines the Descriptive Model
- Structural ports are allocated to corresponding analytical ports
- Descriptive properties bound to analytical properties

Model Composition using Model Transformations

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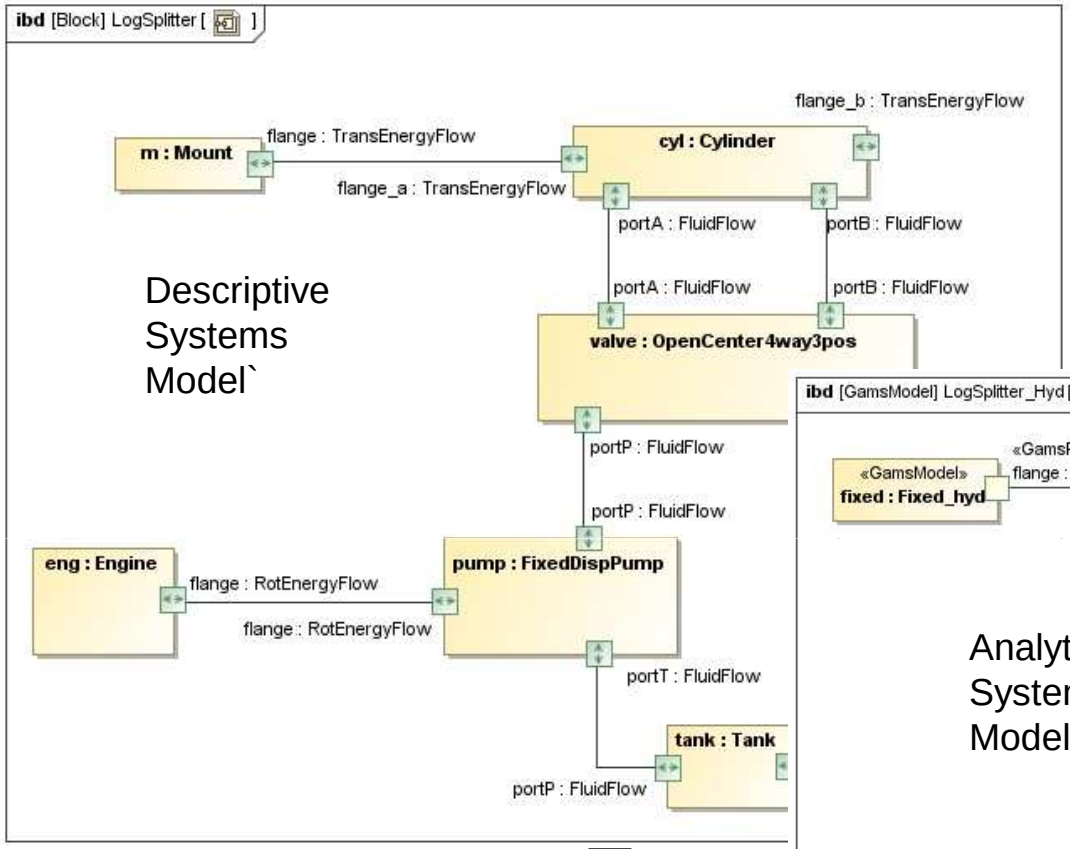
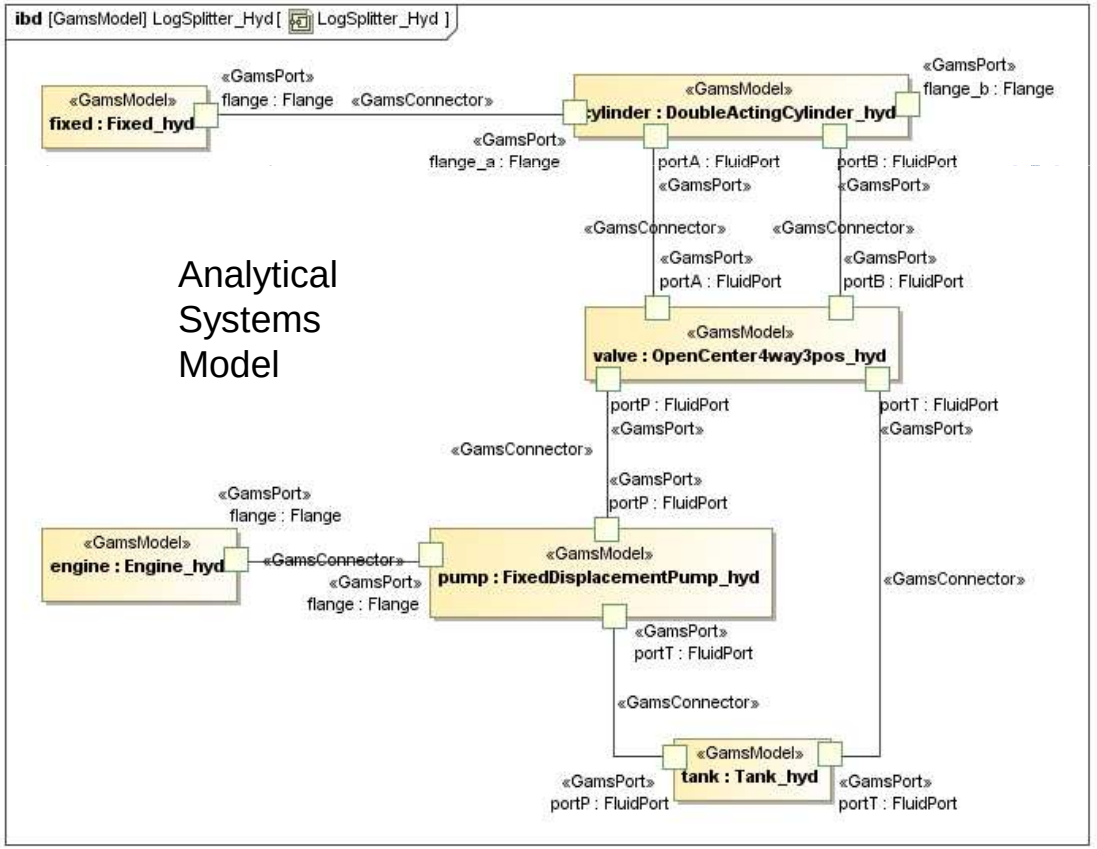
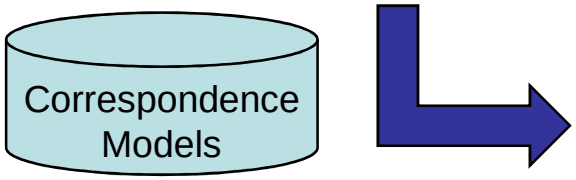
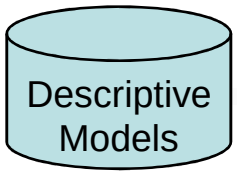


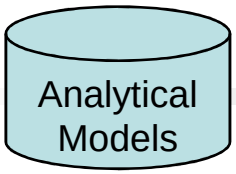
Descriptive Systems Model`



Analytical Systems Model







Descriptive to Analytical Transformation

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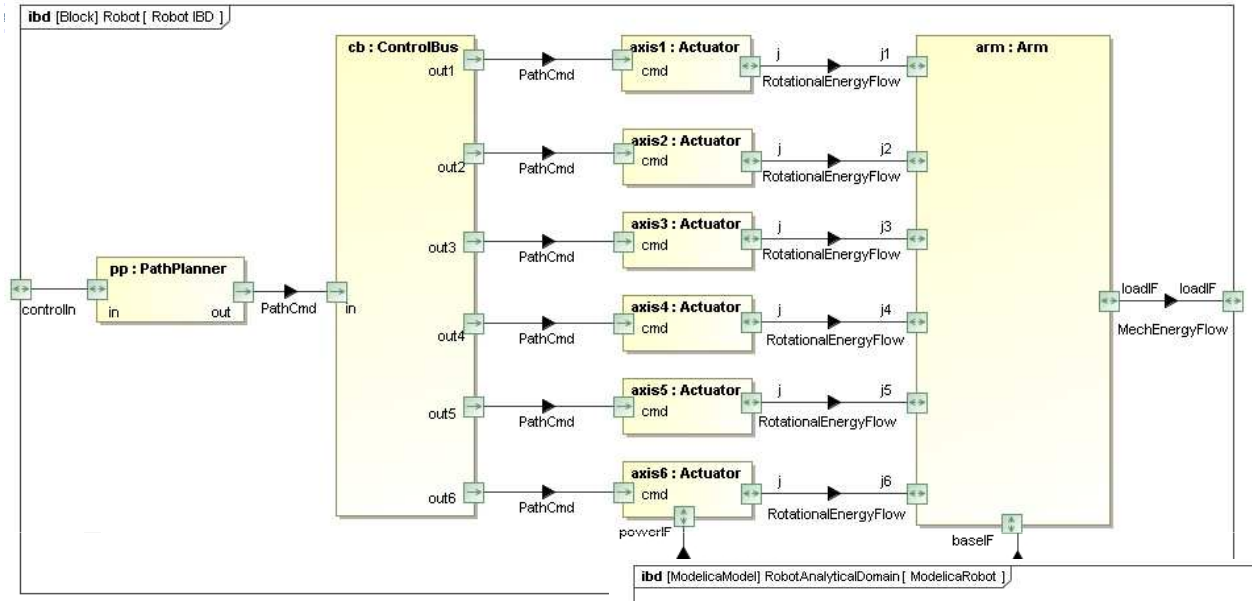

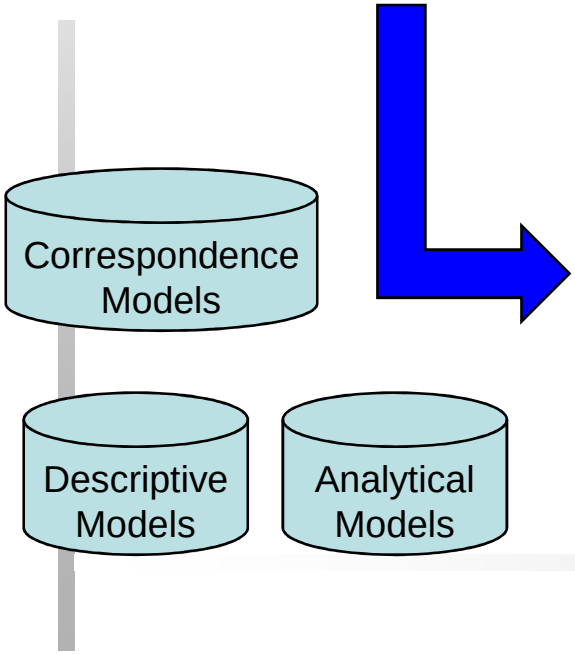

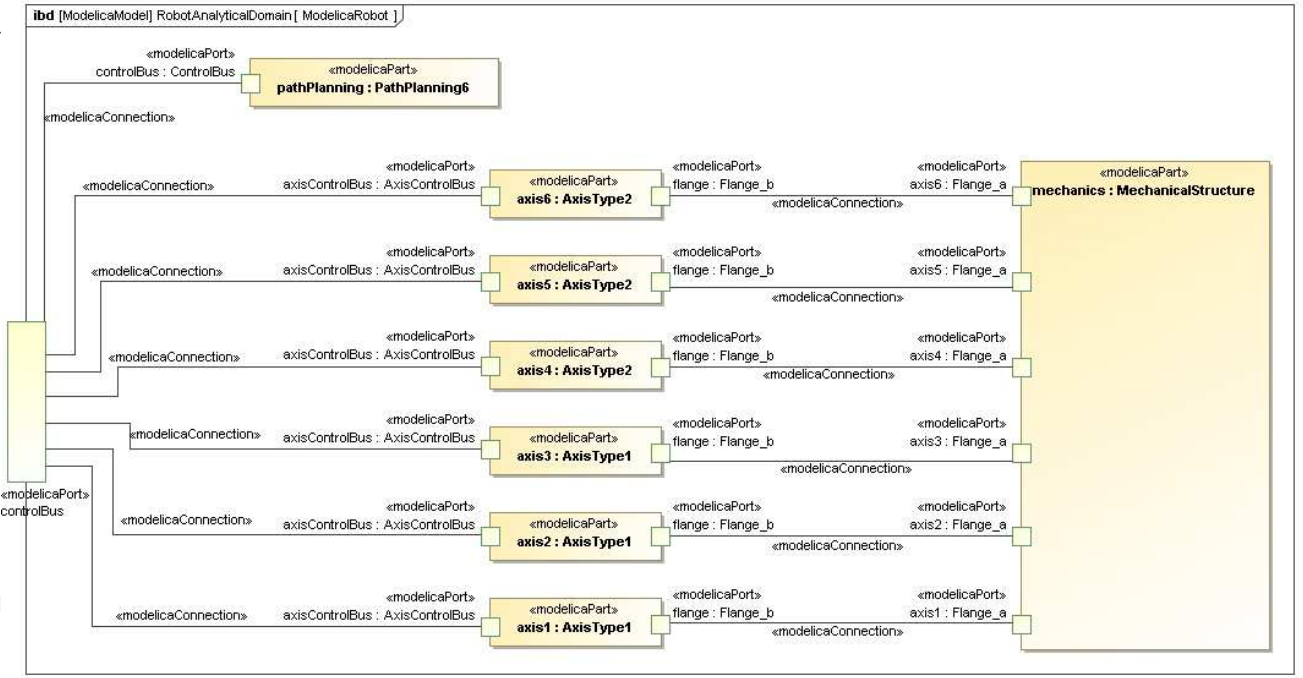

Summary

- 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://doc.omg.org/syseng/2010-6-8

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