National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

IMCE MOF2 / OWL2 Integration

Nicolas Rouquette
System Architectures & Behaviors Group, 313K

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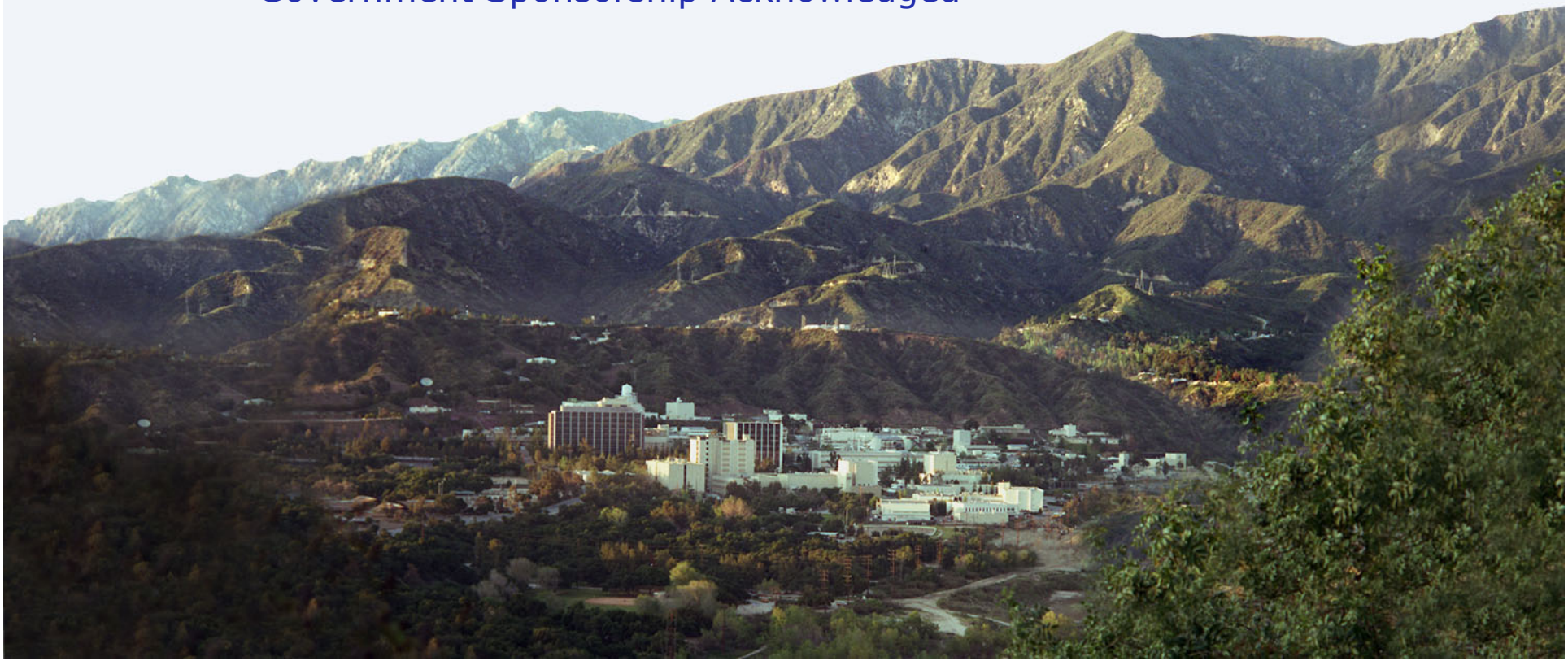


Outline

- **#1 Previous work in JPL's Integrated Model-Centric Engineering (IMCE) initiative for model-based SE**
- **#5 Systems Engineering with Controlled Vocabularies**
- **#9 Controlled vocabularies as sentences**
- **#12 Correspondences: MOF2 vs OWL2 with reification**
- **#13 MOF2/OWL2 reification for SysML BDDs & IBDs**
- **#17 Tool support**
- **#18 SysML 1.4 RTF proposals**
  - **Property reference path / block-specific type**
  - **Ontological behavior modeling extension for sysml**

What is the IMCE MagicDraw Toolkit?

- **IMCE's focus:**
  - **IMCE's methodology for MBSE is based on the integration of ontology-based modeling and modeling standards**
    - **Ontology-based modeling is essential for analyzability**
    - **Standards-based modeling is essential for affordability**

- **IMCE's strategy:**
  - **Focus on MBSE capabilities that respond to projects' needs and advance the state of practice for ontology-based MBSE @ JPL**

- **IMCE MagicDraw Toolkit:**
  - **A tactical reduction of the gap towards ontology-based MBSE:**
    - **SSCAE's standards-based SysML tool** **MagicDraw**
    - **IMCE's ontology-based SysML tool** **IMCE MagicDraw Toolkit**

This was the plan…

Intended Scope of Key Features

- **IMCE plugin key features focus on the small subset of UML that is key to IMCE's ontology-based SysML, e.g.:**
  - **Using SysML Blocks for modeling structure, ontologically**
  - **Using Associations for modeling relationship, ontologically**
  - **Using Instances for modeling descriptions, ontologically**

- **The ontological flavor of modeling makes sense**
  - **see Conrad Bock's Ontological Behavior Modeling paper**

  http://www.jot.fm/contents/issue_2011_01/article3.html

- **Challenge: how do we get there for JPL's MBSE practices?**
  - **Long term: standards is the *only* technology NASA can afford**
  - **Short term: standards have flaws; tools have bugs**

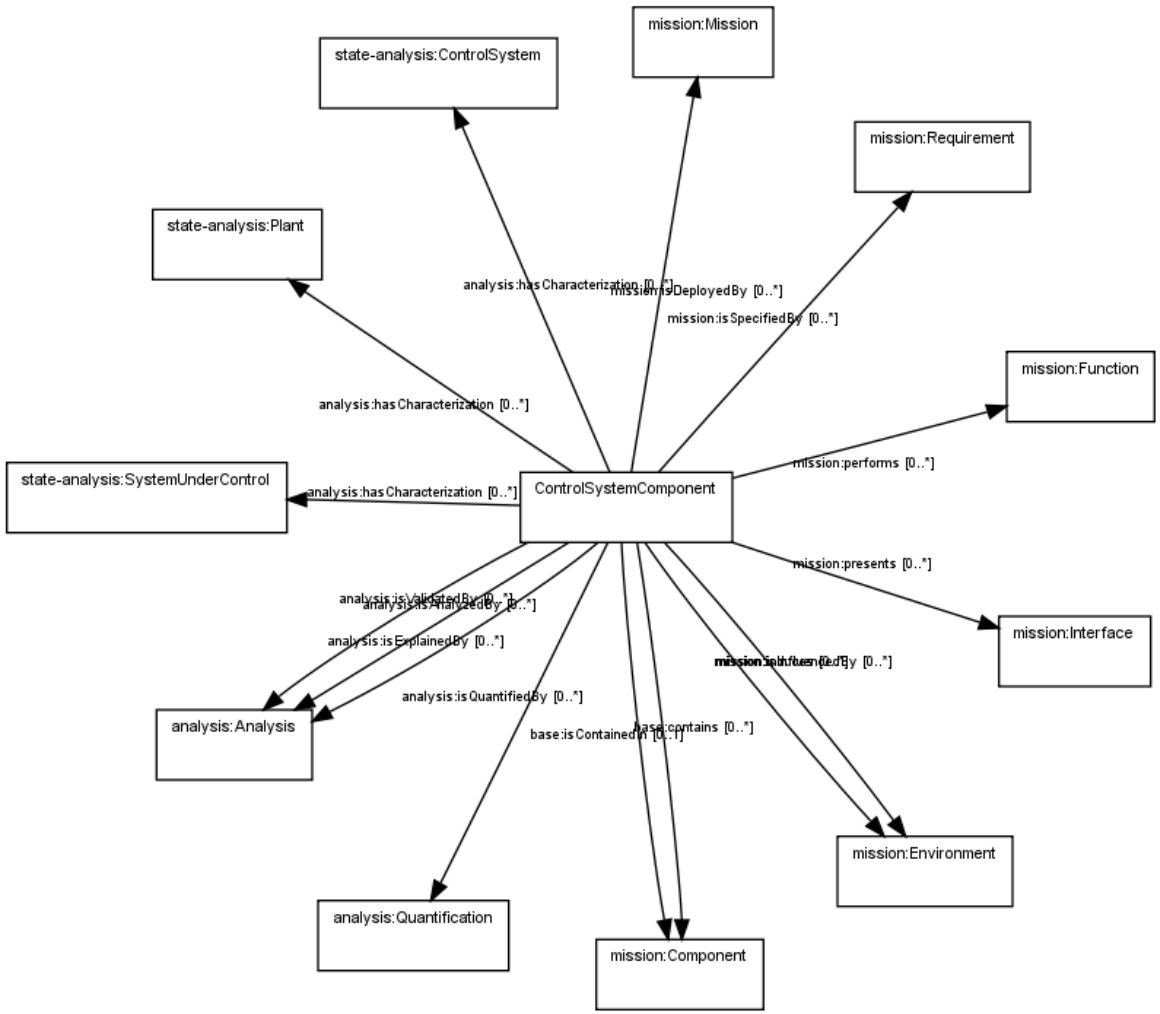
- **IMCE MagicDraw Toolkit: it's an evolving balancing act…**

Systems Engineering Vocabularies

- **An SE vocabulary is defined as an OWL2 ontology**
- **Emphasis on organizing the vocabulary in terms of SE "sentences" of the form:**
  - **<Subject> <Predicate (verb)> <Object>**
- **The S/P/O organization has been very useful:**
  - **Systems engineers prefer using a controlled vocabulary of English to using UML/SysML**
  - **S/P/O sentences have the structure of a triple in RDF**
- **The challenge has been how to adapt an ontology-friendly organization of a controlled vocabulary (S/P/O sentences) as a rigorous interpretation of UML/SysML**

Our IMCE Ontology Documentation doesn't show this important information (currently)

Figure 11. Class usage diagram for ControlSystemComponent.



Even OMG standards do not show this either…

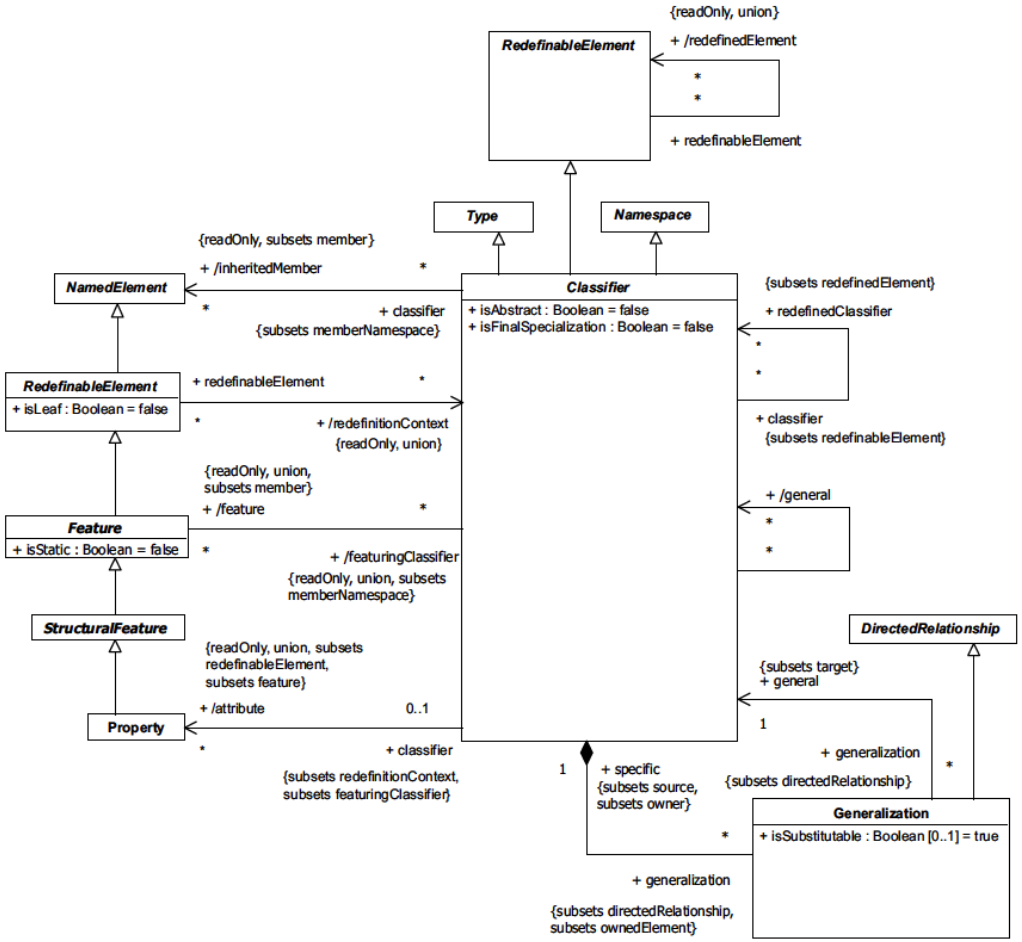
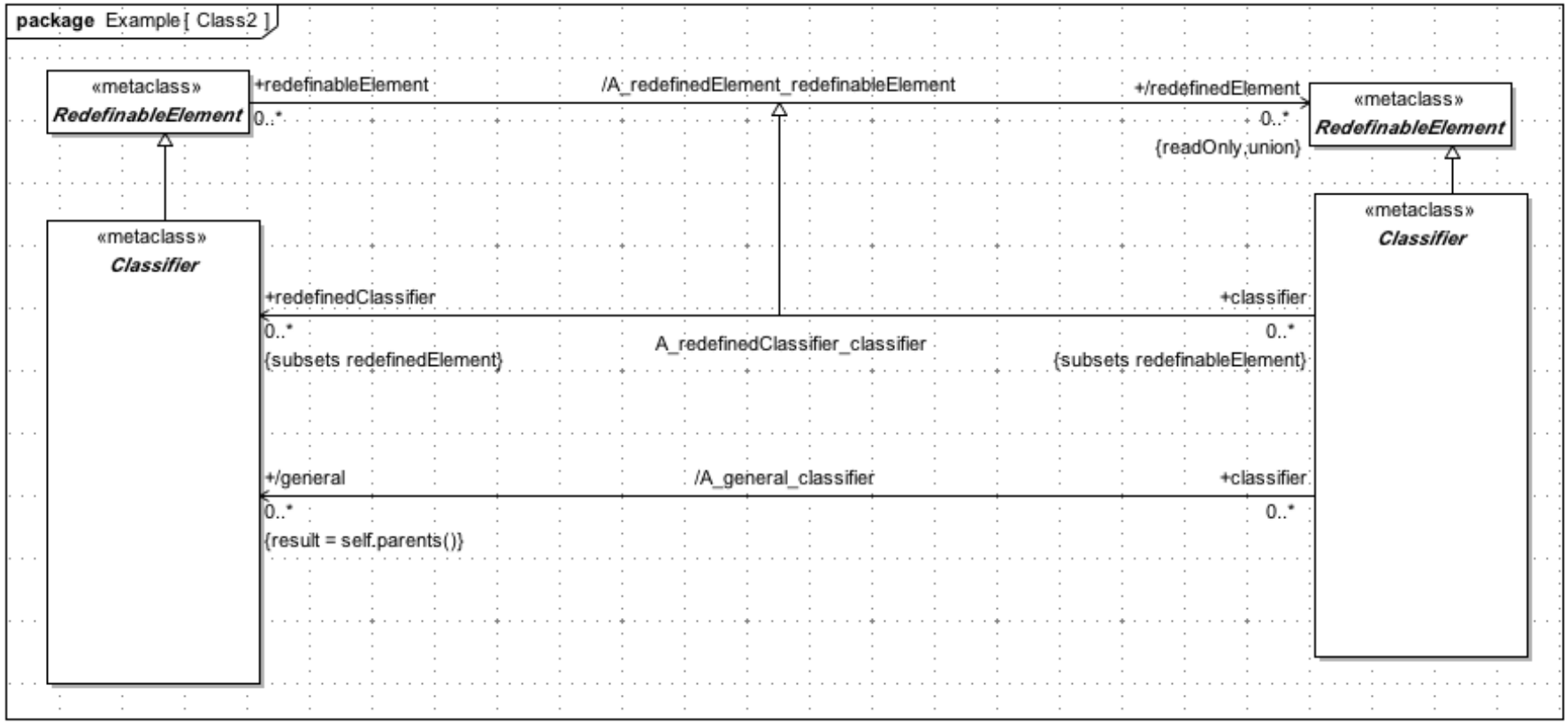


Figure 7.9 - Classifiers diagram of the Kernel package

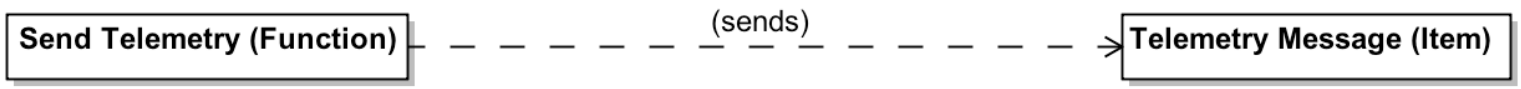
JPL's IMCE MagicDraw Toolkit can… (but it gets crowded quickly!)

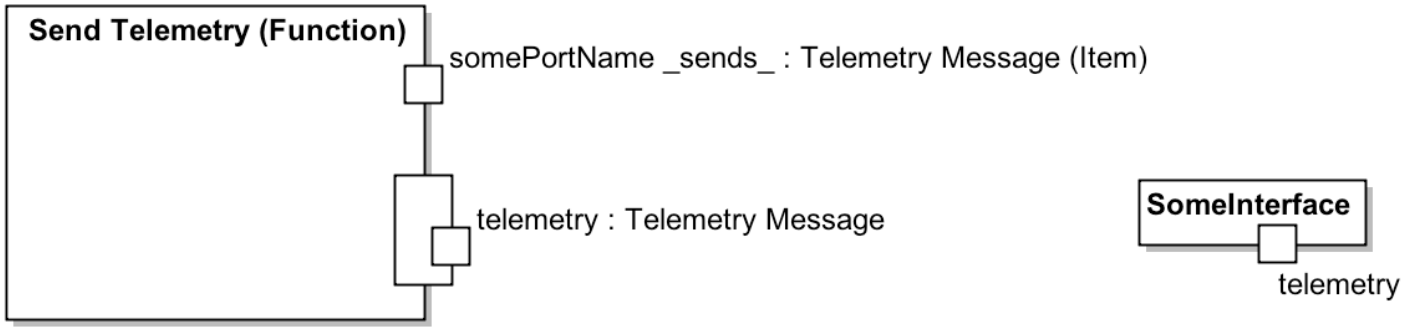


A motivating example…

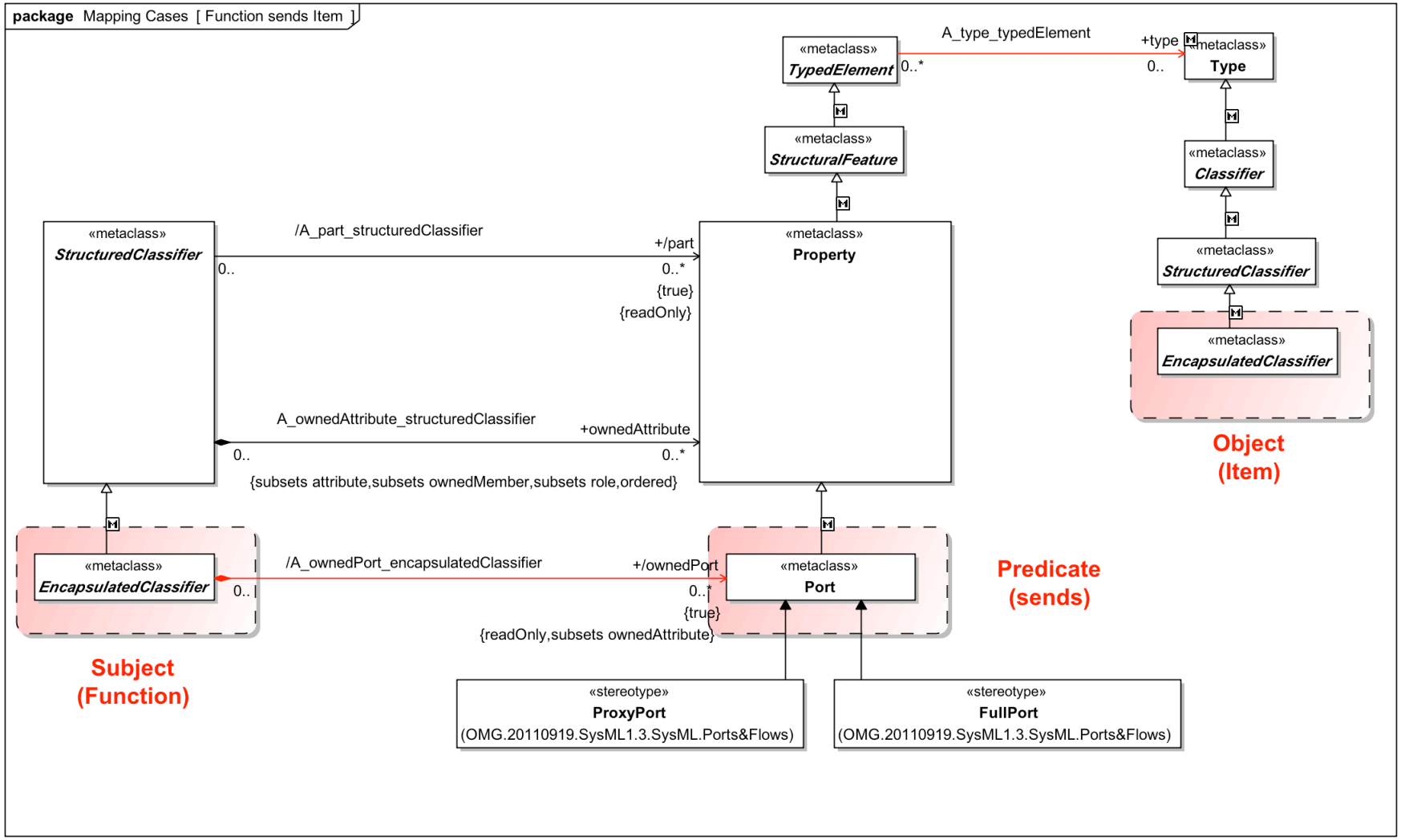
- **Example of a controlled vocabulary sentence:**
  - **Subjects:** **Function, Item, …**
  - **Predicates:** **sends, …**

- **A picture…**



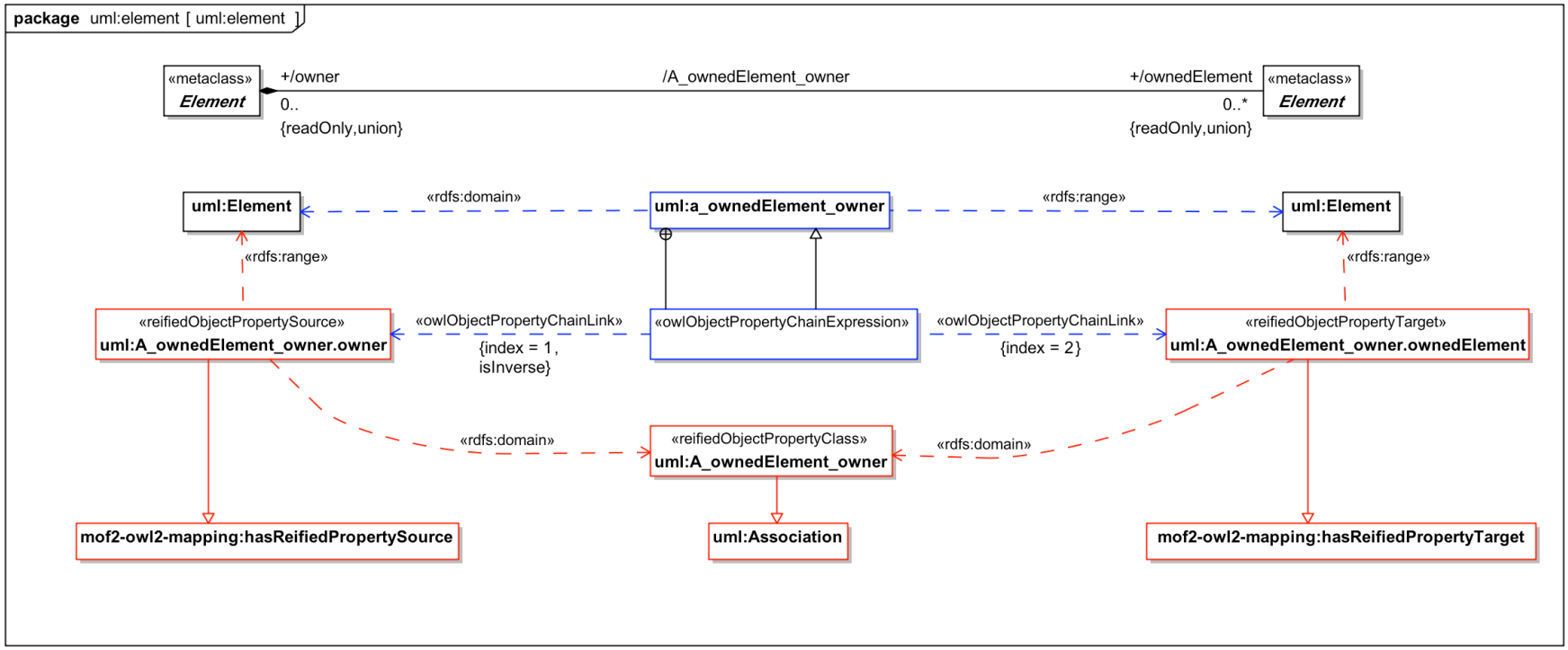


How it is done under the covers… (metamodeling)



Applying MOF2/OWL2 reification to all OMG-grade MOF2.4.1 models…

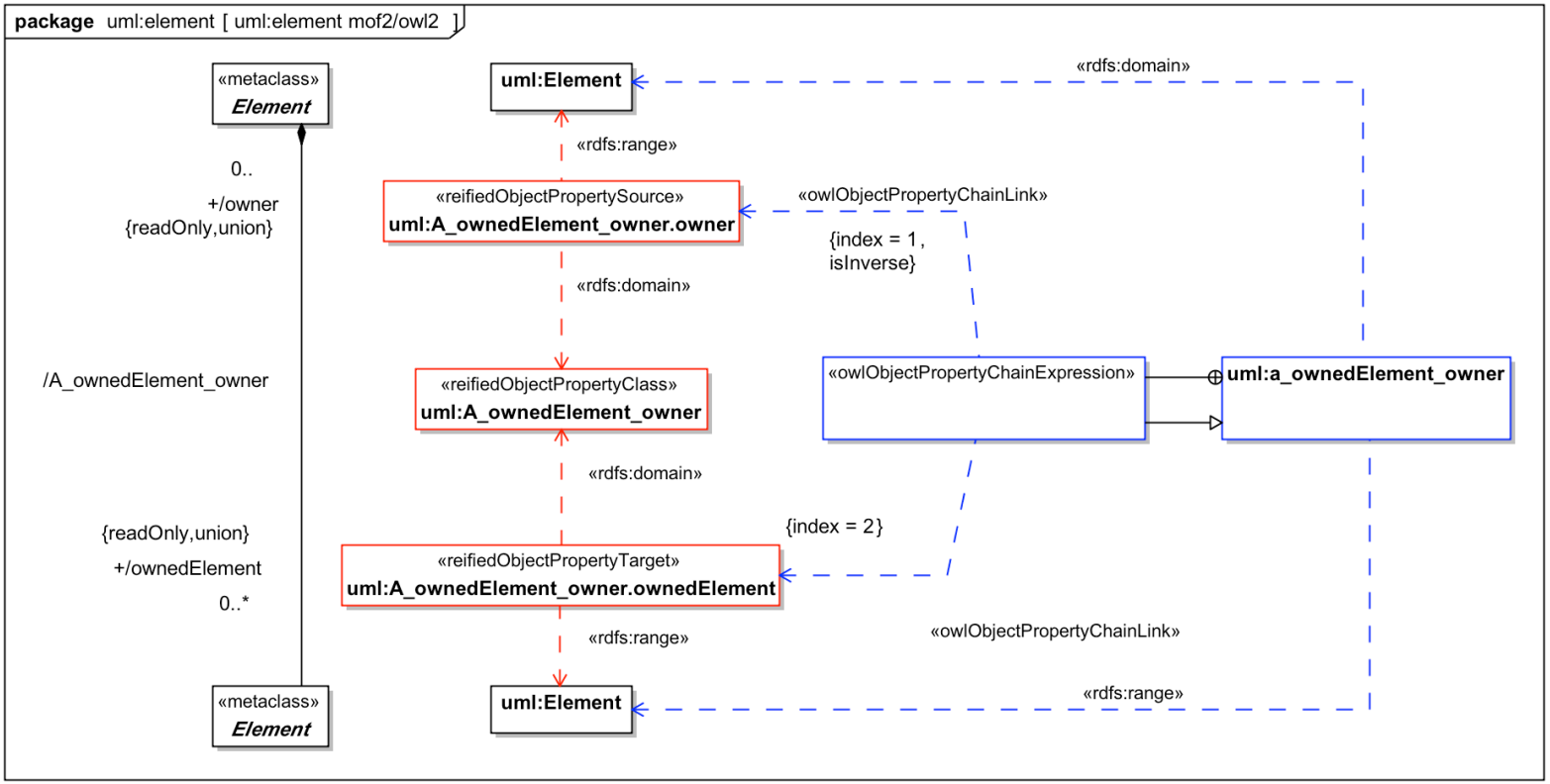
- **Example for UML's Element ownership relation**



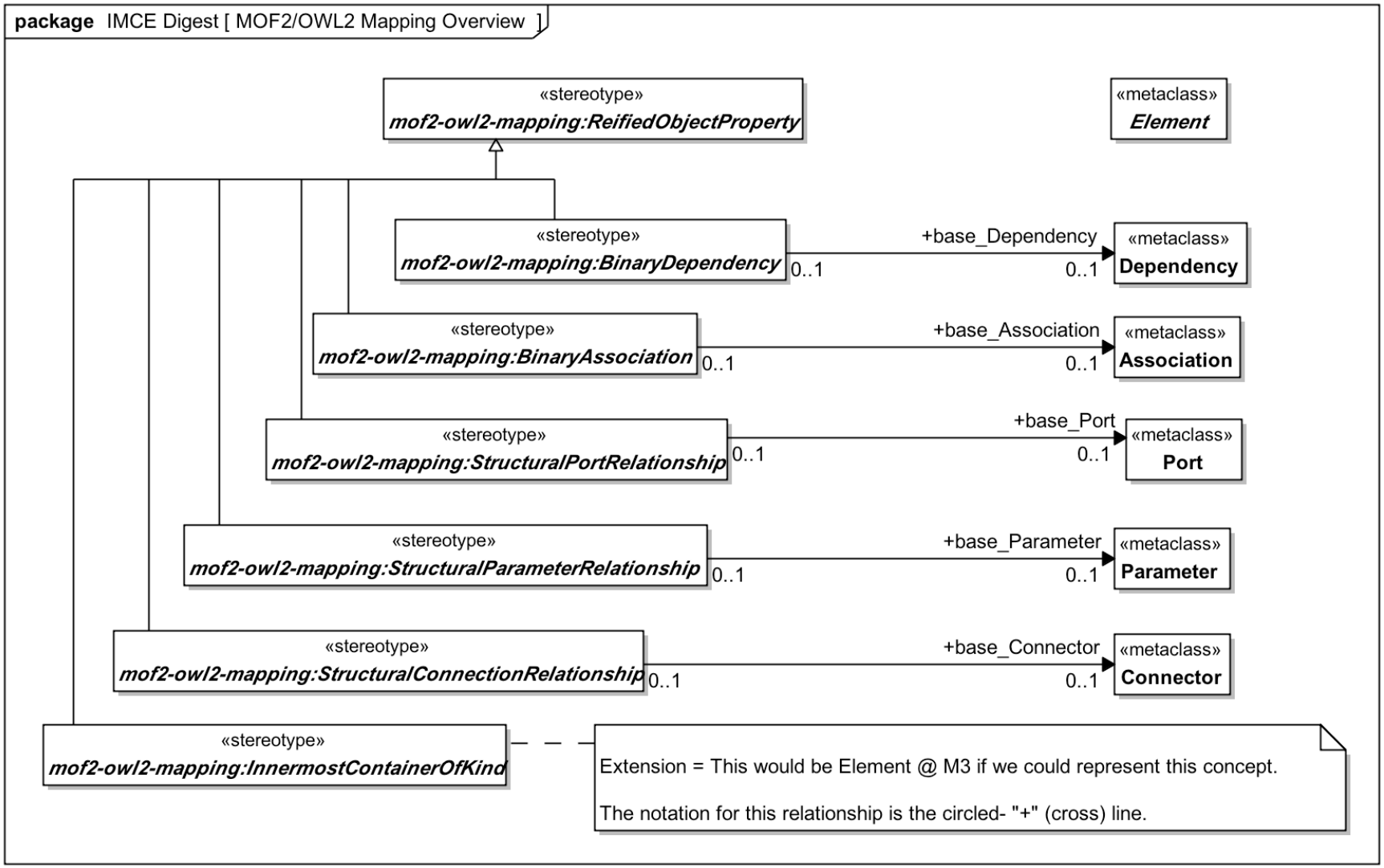
Object Property Reification: MOF2 & OWL2 similarities

- **Left = MOF2**
- **Right = OWL2**

- **IMCE's MOF2/OWL2 integration makes object property reification explicit**



The scope of MOF2/OWL2 Reification needed for SysML's BDDs and IBDs



Non-OMG vocabularies

Ontology Summary

Integrated Model-Centric Engineering

2011-12-12

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- **Currently (Dec. 2011):**
  - **4 foundation ontologies**
  - **3 discipline ontologies**
- **Each ontology includes:**
  - **Vocabulary definition (*.owl)**
  - **Reification mapping (*-mapping.owl)**
- **We use continuous integration techniques to statically analyze well-formedness properties of MOF2/OWL2 vocabularies & mappings**

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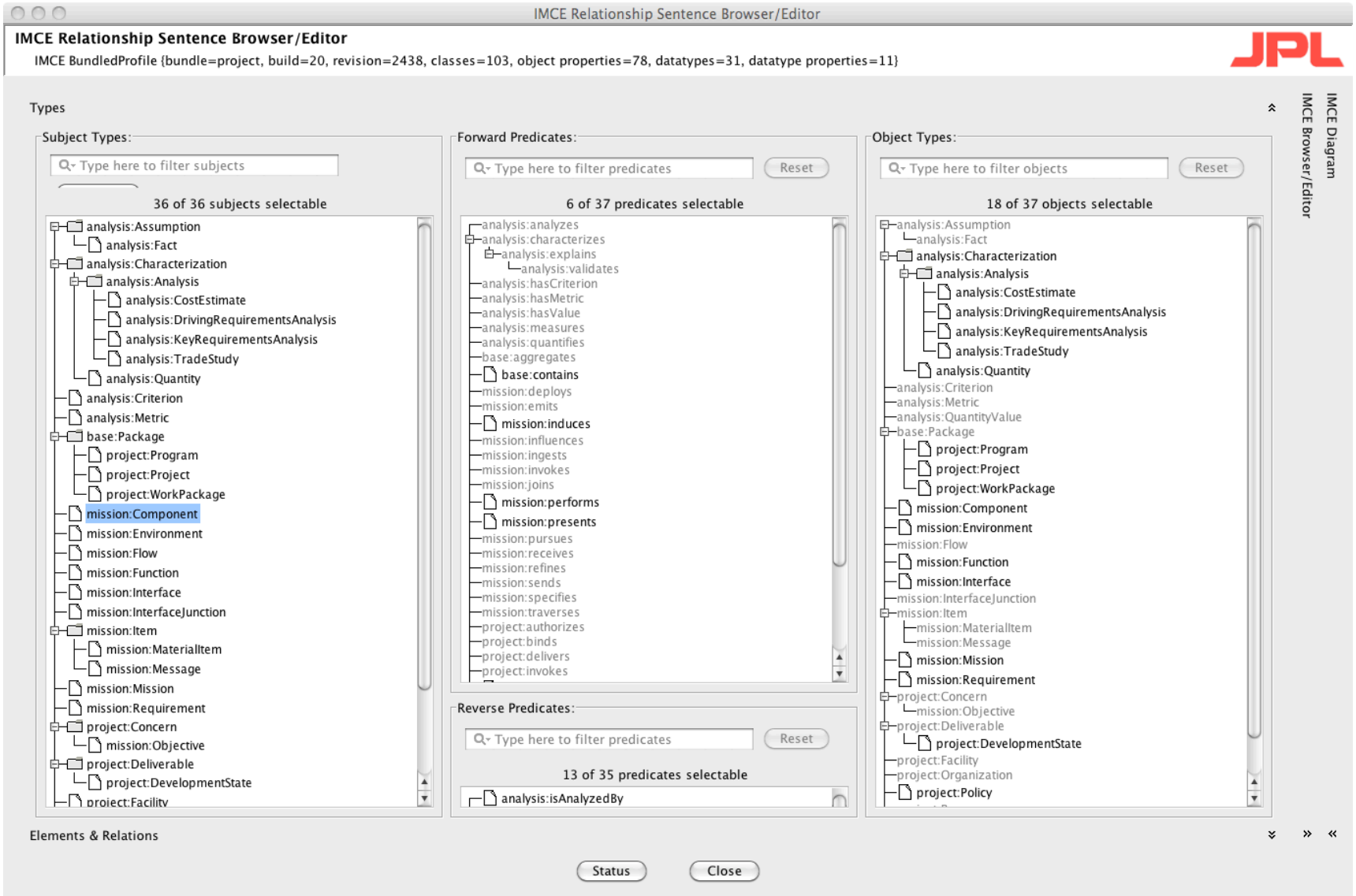
Results of static analysis of MOF2/OWL2 vocabularies & reification mappings



Compiled MOF2/OWL2 vocabularies

- **Compute all possible combinations of legal sentences:**
  - **Given a subject => legal predicates**
  - **Given a subject + predicate => legal objects**

- **...**

Tool Support

- **A MOF2.4.1-compliant metamodel for OWL2**
  - **Use net.sourceforge.owlapi (v3.2.3) to import/export OWL2 models**

- **QVT Operational transformations for:**
  - **Applies the MOF2-OWL2-mapping (meta) ontology to convert:**
    - **MOF2.4.1 => OWL2 (with MOF2-OWL2 reification)**
    - **OWL2 (w/ MOF2-OWL2 reification) => MOF2.4.1**
- **Additional tool support based on SPARQL, Pellet and SESAME**

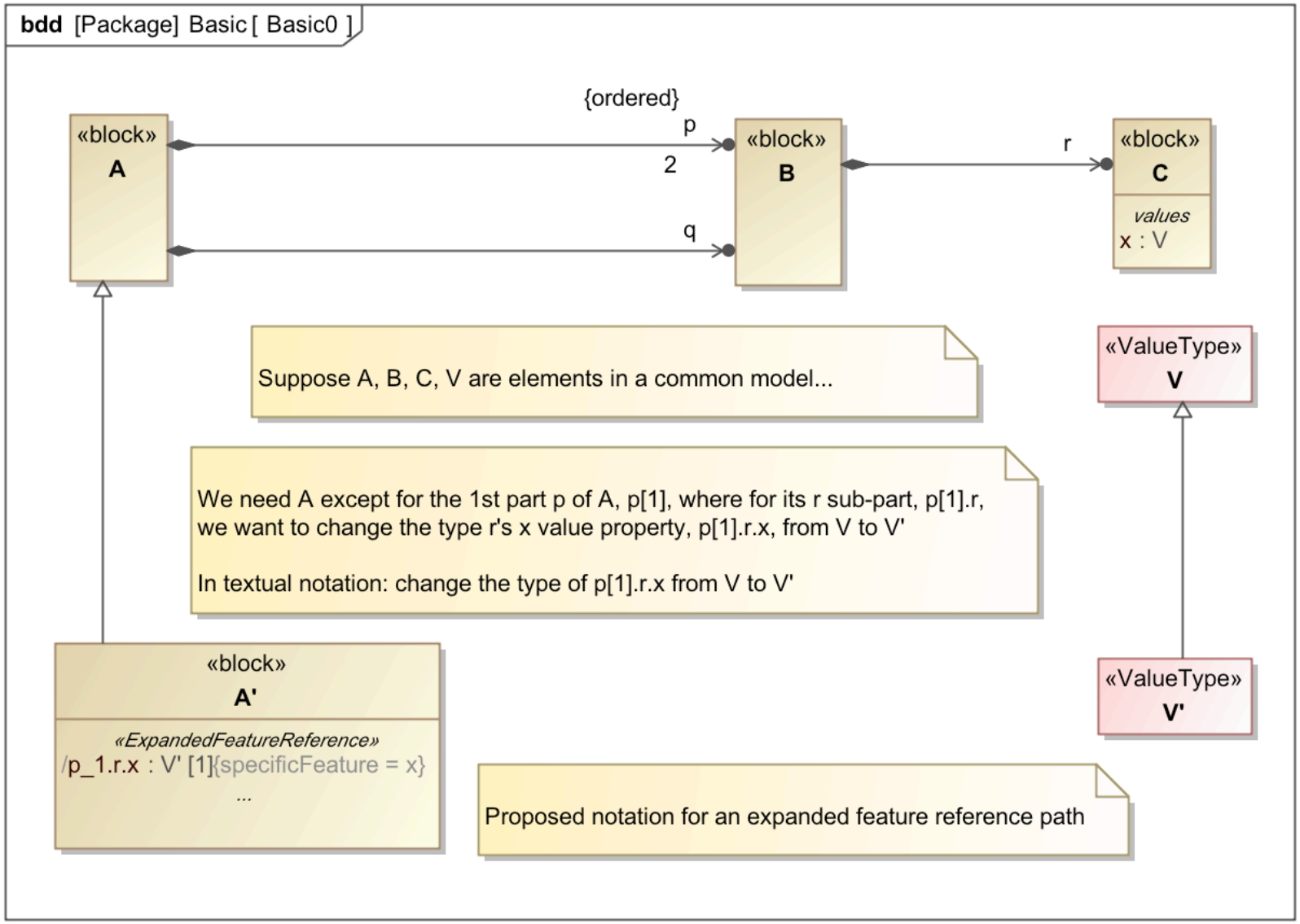
- **Current status (Dec. 2011)**
  - **OMG UML 2.4.1 (MOF2.4.1) => OMG UML2.4.1 (OWL2)**
  - **OMG SysML 1.3 (MOF2.4.1) => OMG SysML1.3 (OWL2)**
  - **+ similar for all OWL2 reified vocabularies defined at JPL**

  - **OWL2 w/ MOF2-OWL2 reification => MOF2.4.1 profiles**
    - **This applies to all "bundled" OWL2 reified vocabularies defined at JPL**

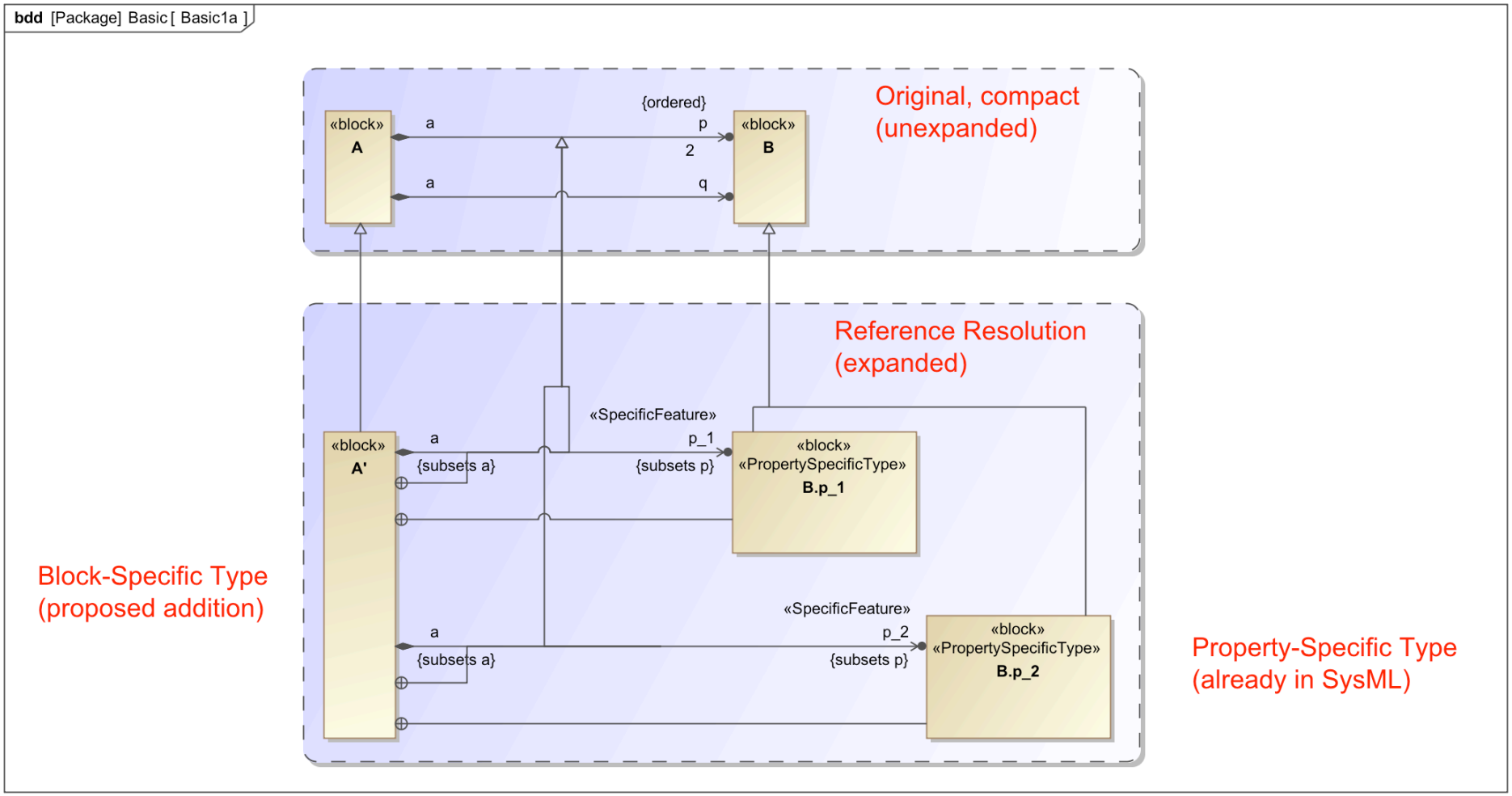
Block Specific Type & Property Reference Path

- **What:**
  - **Modeling structure, ontologically**
  - **Currently called the "Block Specific Type" (BST)**
- **How:**
  - **Model-to-Model transformations to expand recursively the structure of a block based on inheritance & specialization**
  - **Recursive expansion may be a better term if not obscure**
- **Example: modeling design variants**
  - **Modeling variants of a S/C instrument package**
    - **light science option (A only)**
    - **rich science option (A, B, C)**
- **Recently (Dec. 2011)**
  - **Use BST to define the semantics of property reference "dot" path notation**

Property Reference Path Example



Recursive expansion using Block & Property-Specific Types



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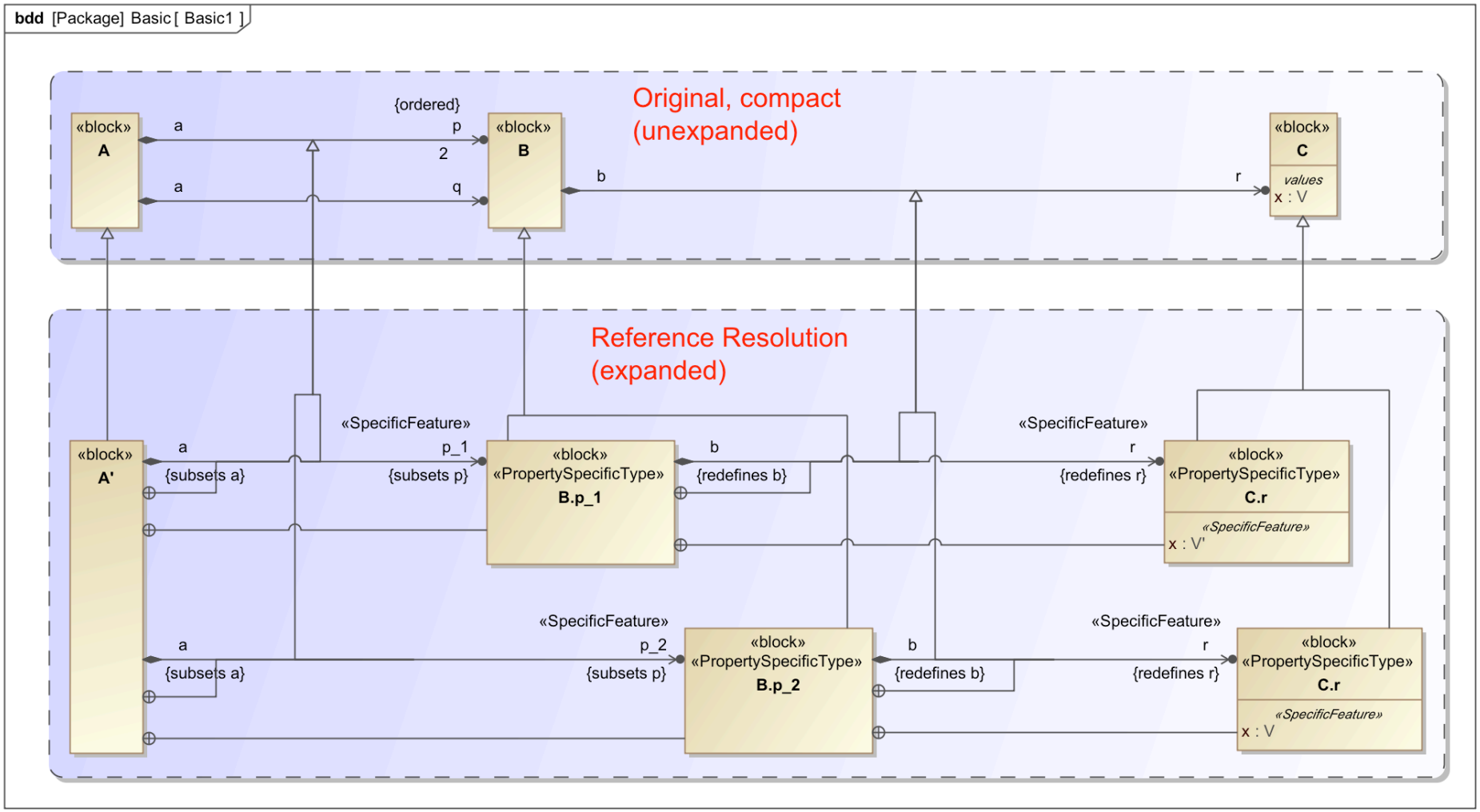
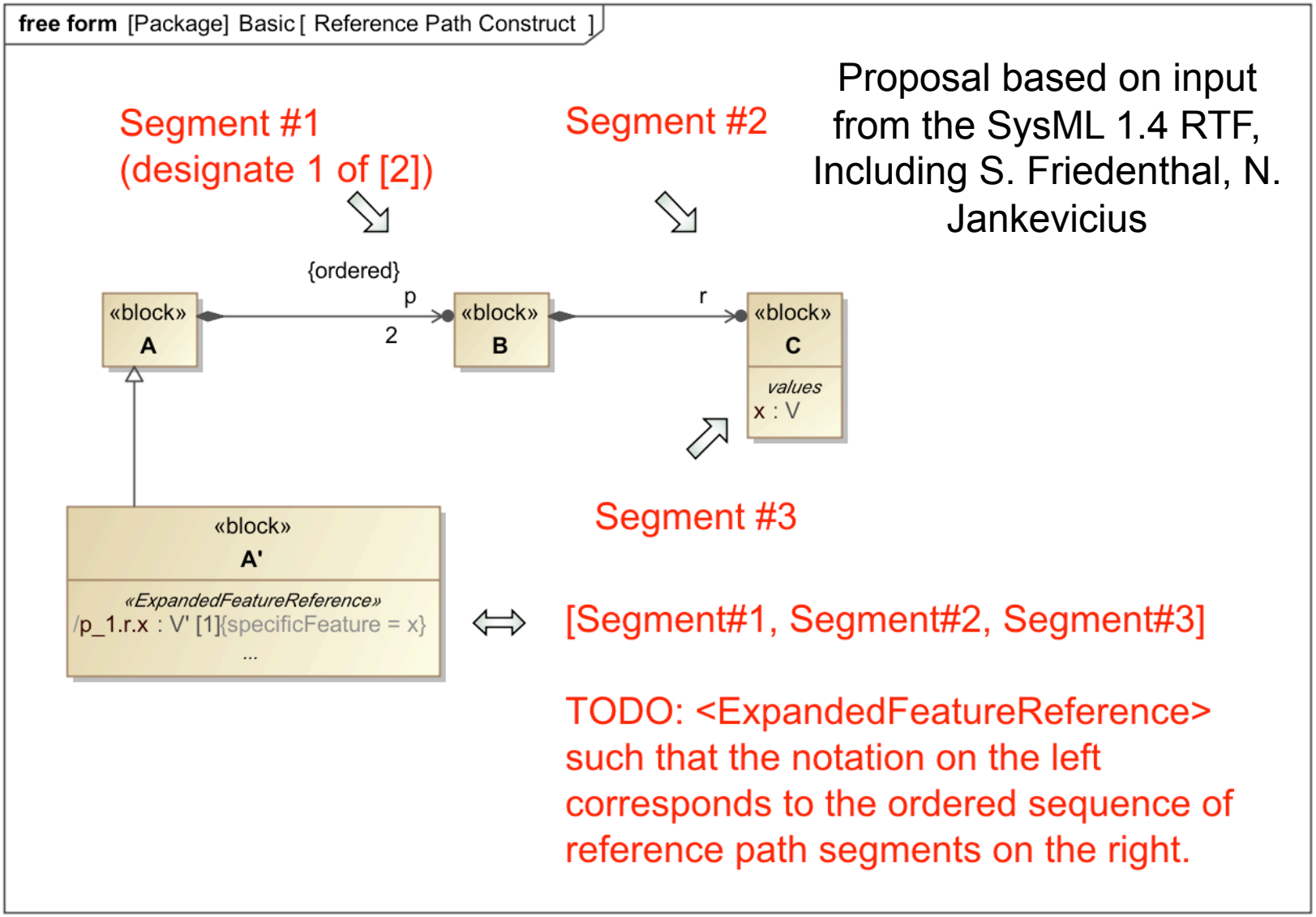
Recursive Block Specific Type expansion for resolving proposed reference paths

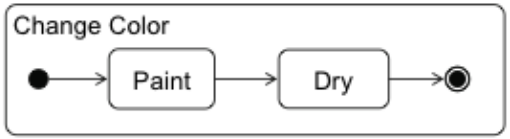


SysML1.4: Expanded Feature Reference construct & reference path notation



SysML1.4: Extensions for Ontological Behavior Modeling

http://www.jot.fm/issues/issue_2011_01/article3.pdf




```
<process name="Change Color">
    <sequence>
      <invoke operation="Paint"></invoke>
      <invoke operation="Dry"></invoke>
    </sequence>
</process>

void ChangeColor
{  Paint();
   Dry();
}
```

Figure 1: Behavior Notation Examples

1: Enhance SysML Activities for ontological behavior modeling

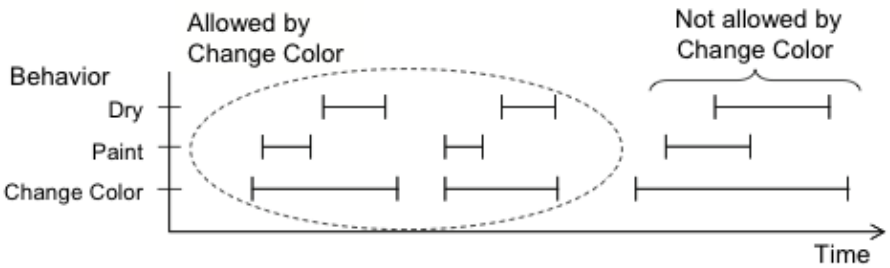


Figure 2: Behavior Occurrences

2: Define a SysML diagram for ontological behavior **occurences** (a trace of a SysML Activity)

(this would require using DI/DD to specify this new SysML diagram)