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VIATRA2: A Model Transformation Framework

Introduction & Tool Demonstration

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DESEREC

Dependable Security by Enhanced Reconfigurability

Information Society
Technologies

Talk Outline

1. Introduction, motivation
2. VIATRA2
3. Qualitative Fault Modeling, Model Transformations & Resilient Systems
4. Tool demonstration

Introduction

Introduction

What are 'model transformations'?

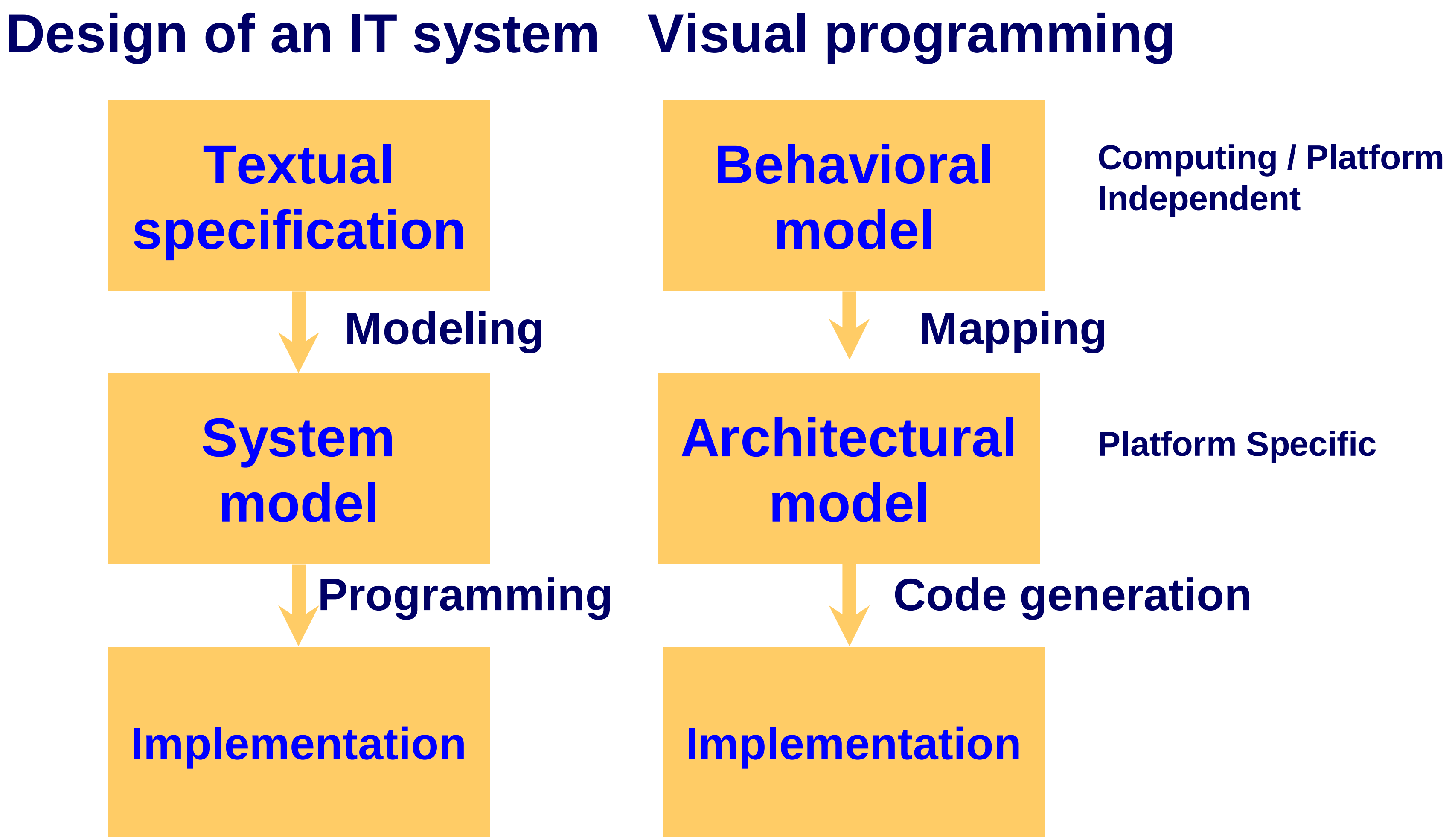
- Model Driven Engineering:
  - 'The systematic use of models as primary engineering artifacts throughout the engineering lifecycle.'
- Best known initiative: OMG Model Driven Architecture
- Metamodel: a collection of notions of a given domain
  - For engineering purposes: precisely defined modeling languages
  - Metametamodels: the languages for model language definition
  - We all know some of them
    - MOF for UML
    - XML Schema for XML languages
    - …

Introduction

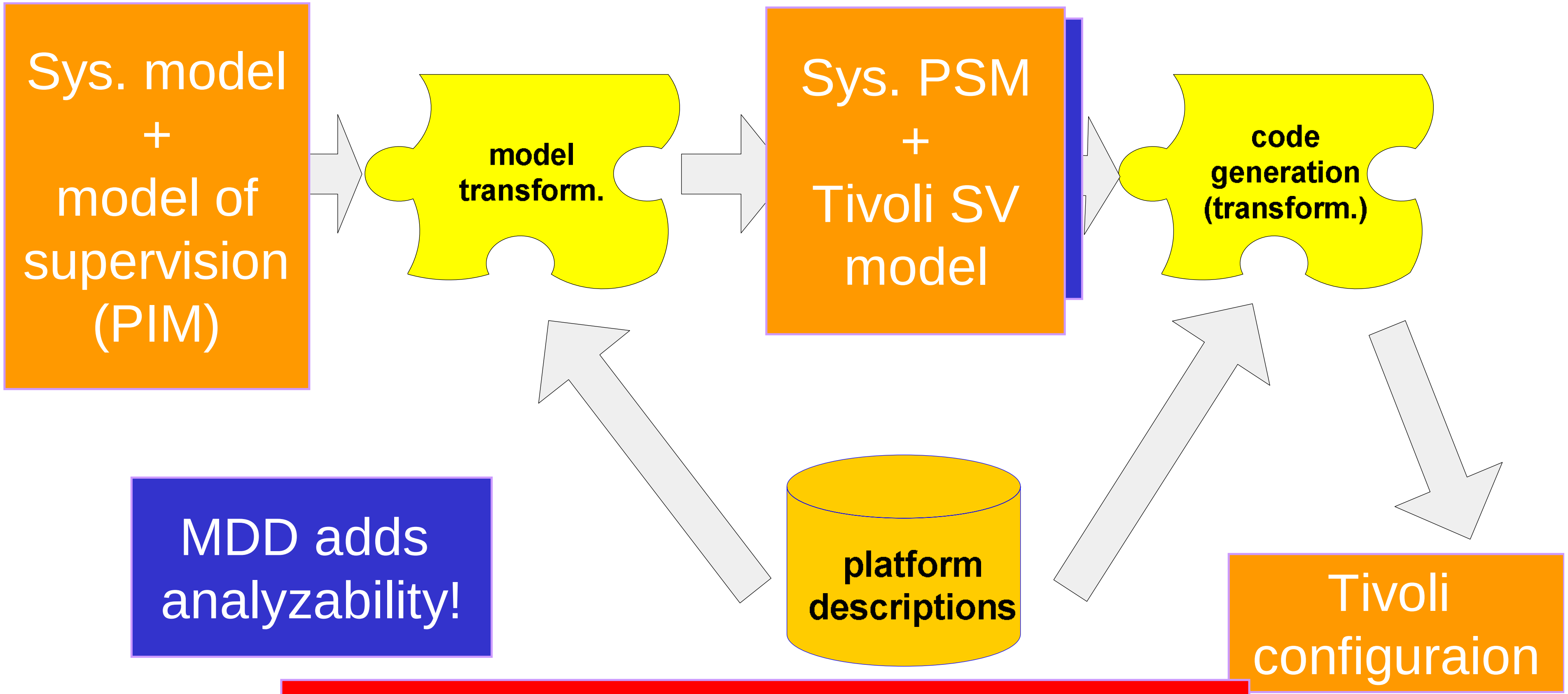
What are ‘model transformations’?

- Model transformations
  - Transformations of models of a given metamodel to models of another metamodel
  - Less cryptically: UML to C++ code, EJB to RDB, MIB to CIM, ...
- Supporting frameworks reaching industrial strength nowadays
  - Mathematically precise language definitions, efficient execution
  - VIATRA2
- For motivation: some applications of model transformations, extensions to resilient system design
  - PIM – PSM – code mapping in MDA
  - ‘Hidden’ formal methods
  - Model transformations in dependability workflows
  - Meta-level fault and dependability mechanisms

Traditional approach vs. MDA



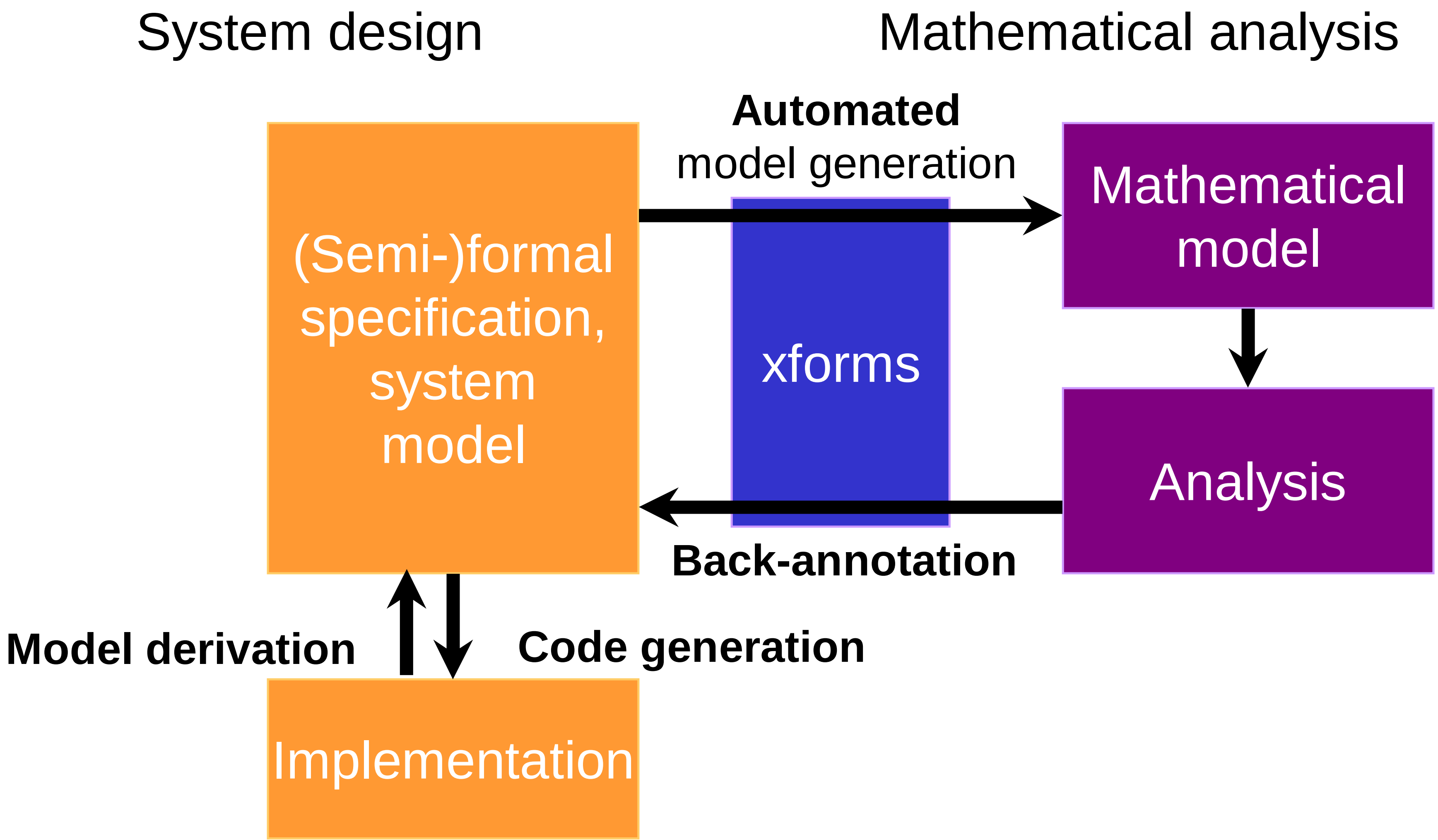
The OMG Model Driven Architecture: Automated Mappings



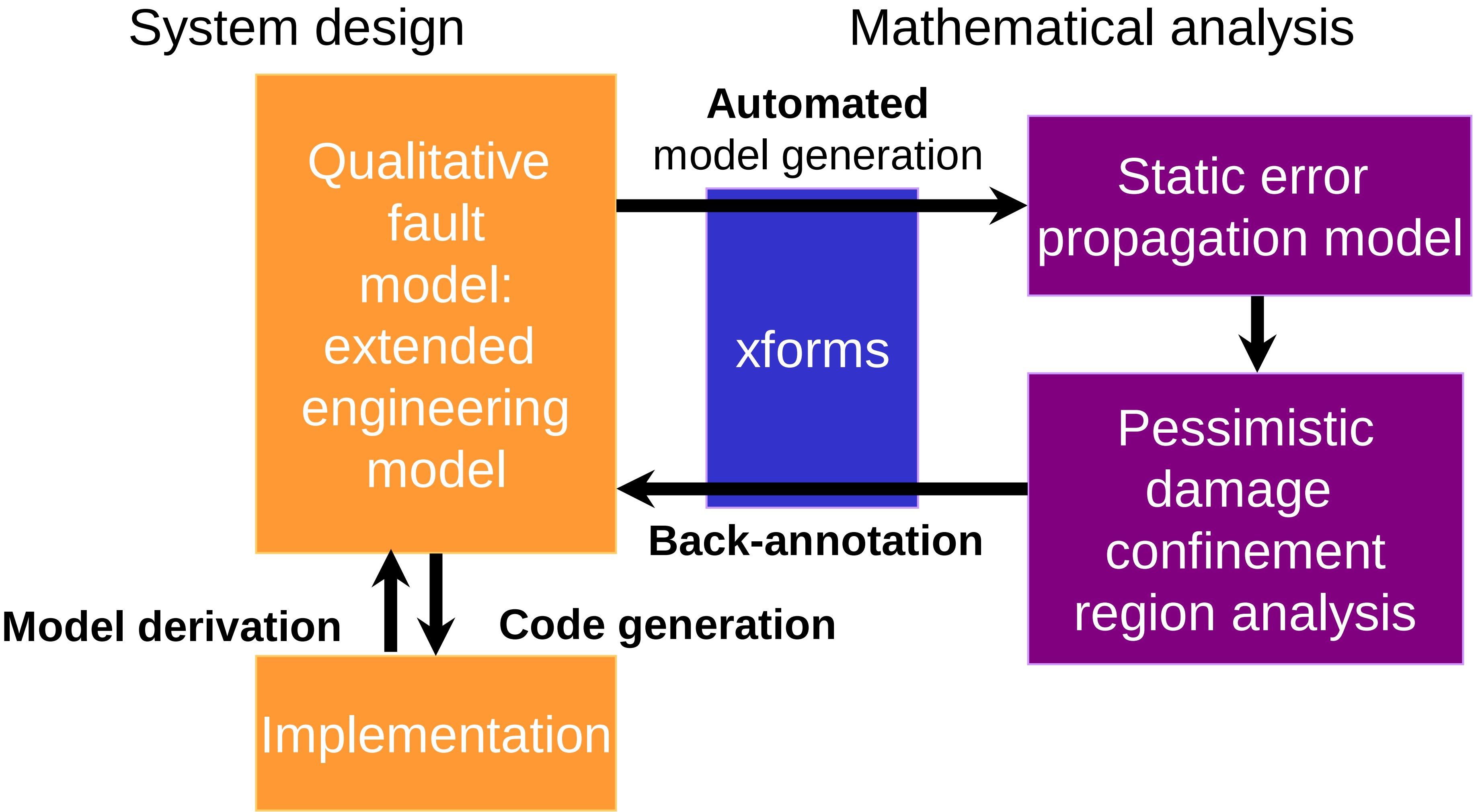
For de … lity
The … ?

MDA for supervised architectures / model based system management: active research at FTSRG (IBM Faculty Award)

Hidden Formal Methods

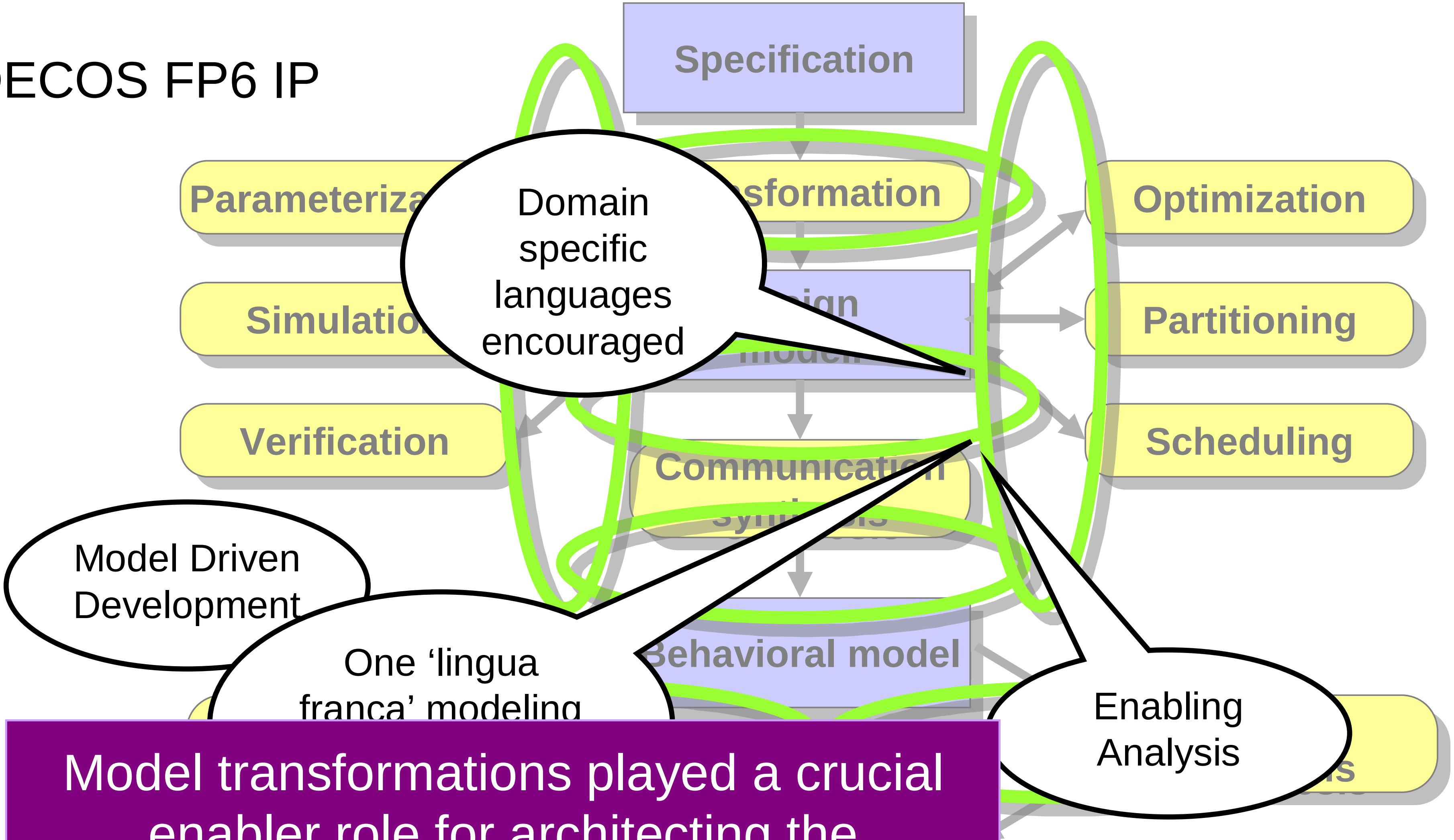


Hidden Formal Methods - Example



Model Transformations in Dependability Workflows

DECOS FP6 IP



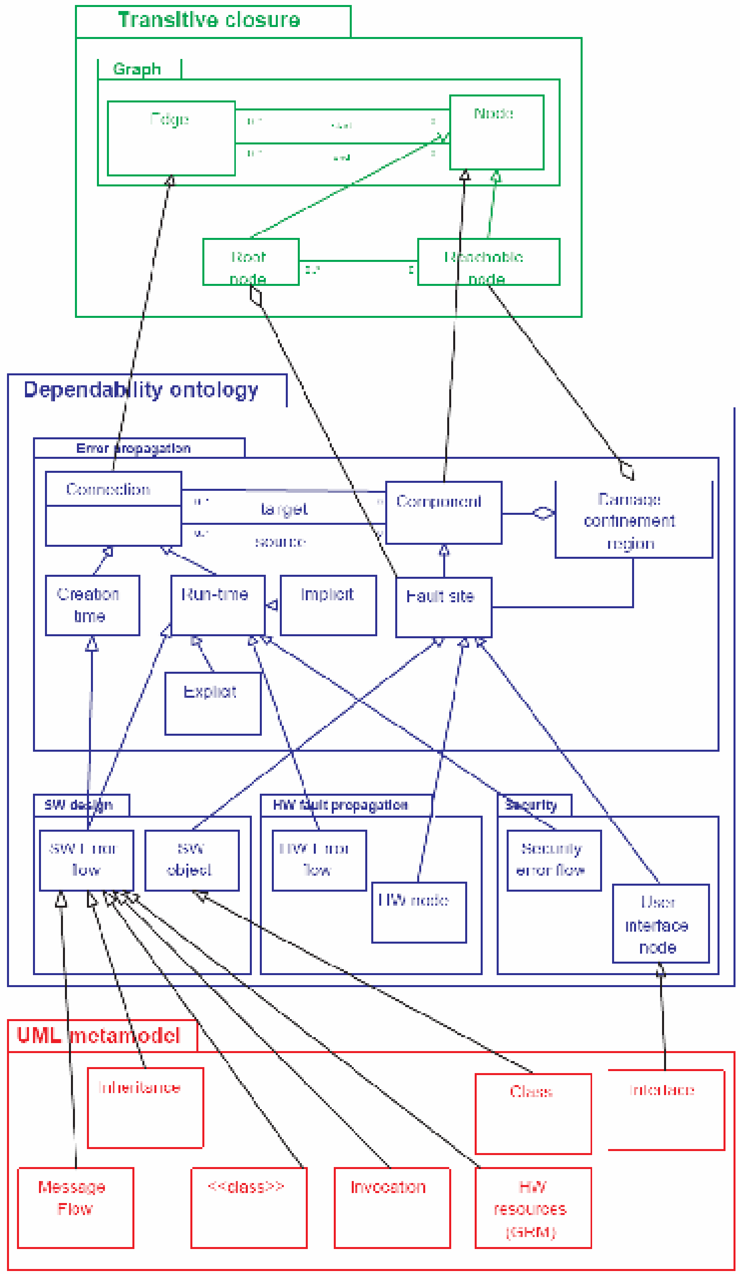
Model transformations played a crucial enabler role for architecting the dependability workflow

Meta-Level Fault Mechanisms

- Faults and the error propagation characteristics are typically largely technology-agnostic and architectural issues

- Thus, can be formulated for classes of (sub)systems in a generalized way
  - Key factors: platform descriptions (PSM), analysis-domain ontologies and (meta)transformations

- New research direction; unexplored area



Tooling: VIATRA2

Analysis of Business Process Models

- Verification by MC
- Fault simulation
- Security analysis (Bell-LaPadula)
- BPEL generation

è *IBM Faculty Award*

Embedded Systems

- PIM & PSM for dependable embedded systems
- PIM & PSM model store
- PIM-to-PSM mapping
- PIM & PSM validation
- Middleware code generation

è *DECOS IP*

SOA

- Performance & Availability analysis
- Configuration generation
- Service Analysis and Deployment

è *SA Forum + SENSORIA IP*

Other

- Design and transformation of domain specific languages
- Model-based generation of graphical user interfaces

VIATRA2

Release 2

Outline

- Introduction
- Features
- The VIATRA2 Framework
- Core concepts
  - Visual and Precise Metamodeling: VPM
  - Transformation definition & execution
  - Code generation
  - Importers
- GUI
- VIATRA2 as an application component

VIATRA =
VIsual Automated model TRAnsformations

- a general-purpose model transformation engineering (*transware*) framework
- that will support the entire life-cycle for transformations
  - *specification*
  - *design*
  - *execution*
  - *validation*
  - *maintenance*
- within and between various modeling languages

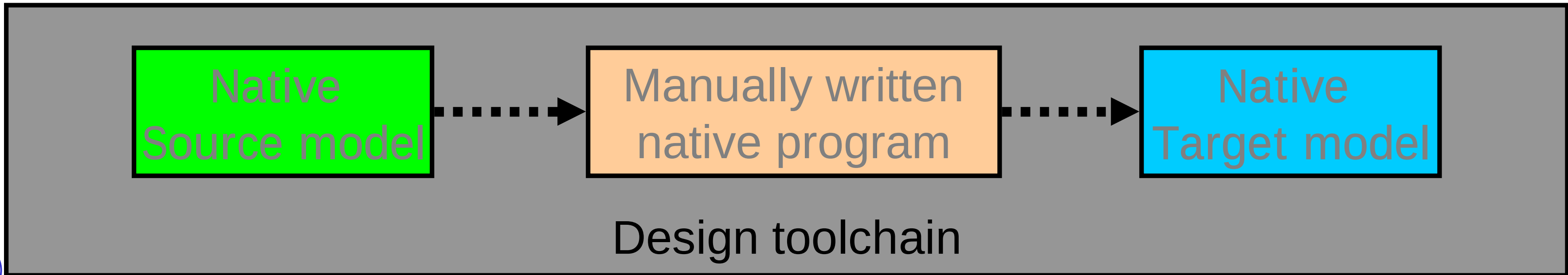
Feautures of the VIATRA2 R2 Framework

- Precise and visual description of source and target modeling languages (metamodeling)
- Precise and visual specification of transformation rules (graph transformation)
- Back-annotation / reverse transformations
- Model transformation engine
  (automatic generation of target models)

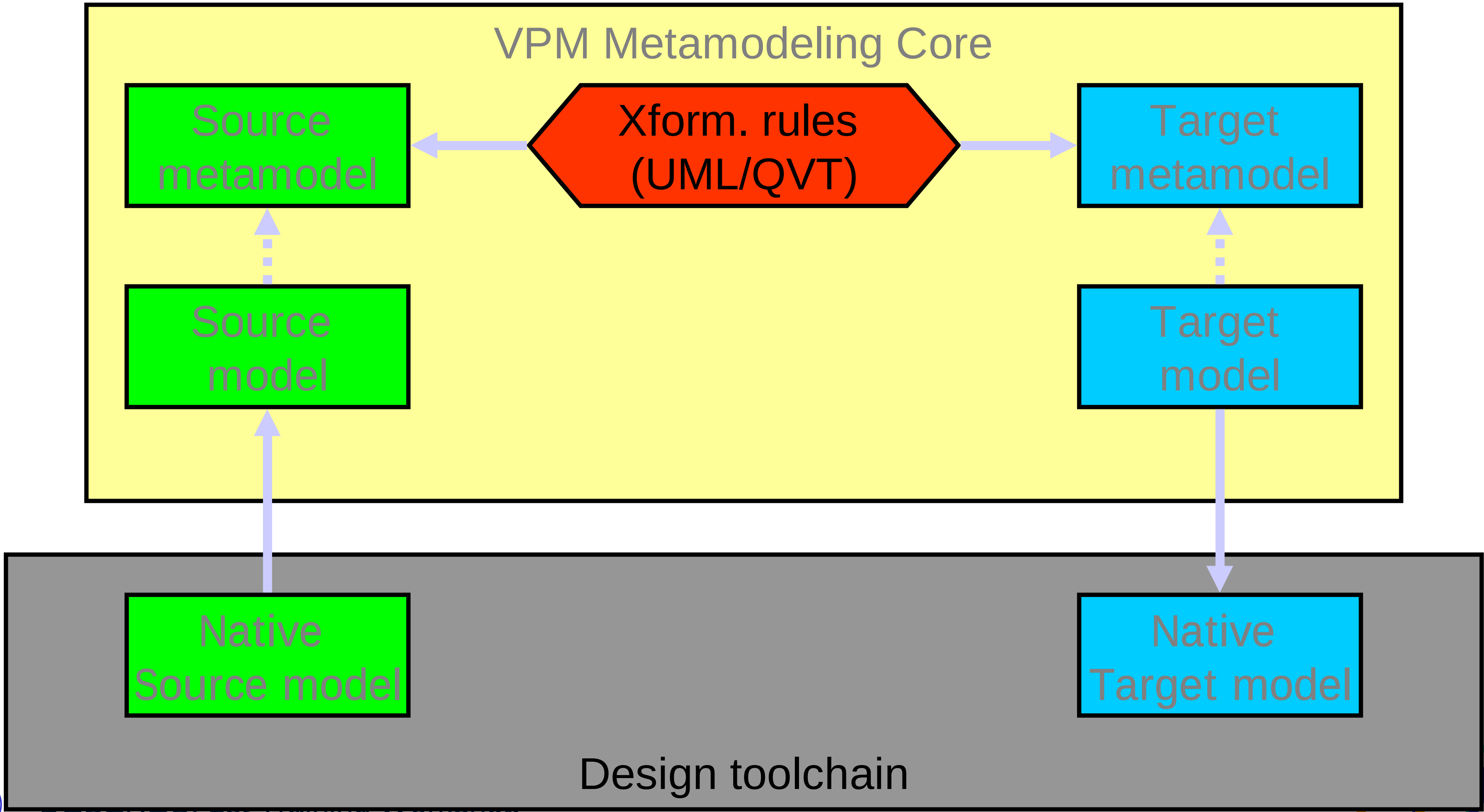
Ongoing research/development:

- Automated generation of platform specific transformers
- Proving correctness and completeness of transformations

The VIATRA 2.0 framework



The VIATRA 2.0 framework



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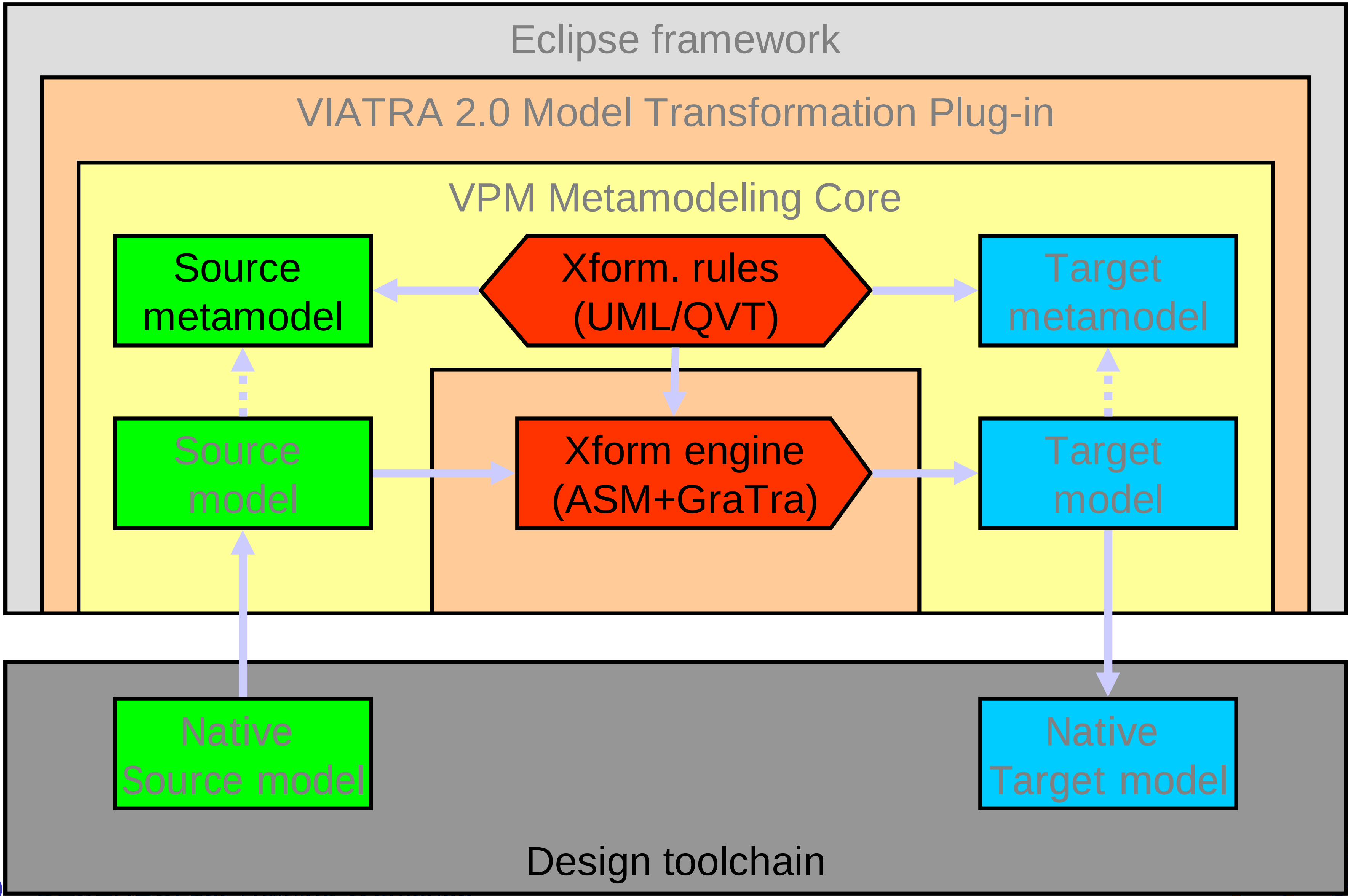

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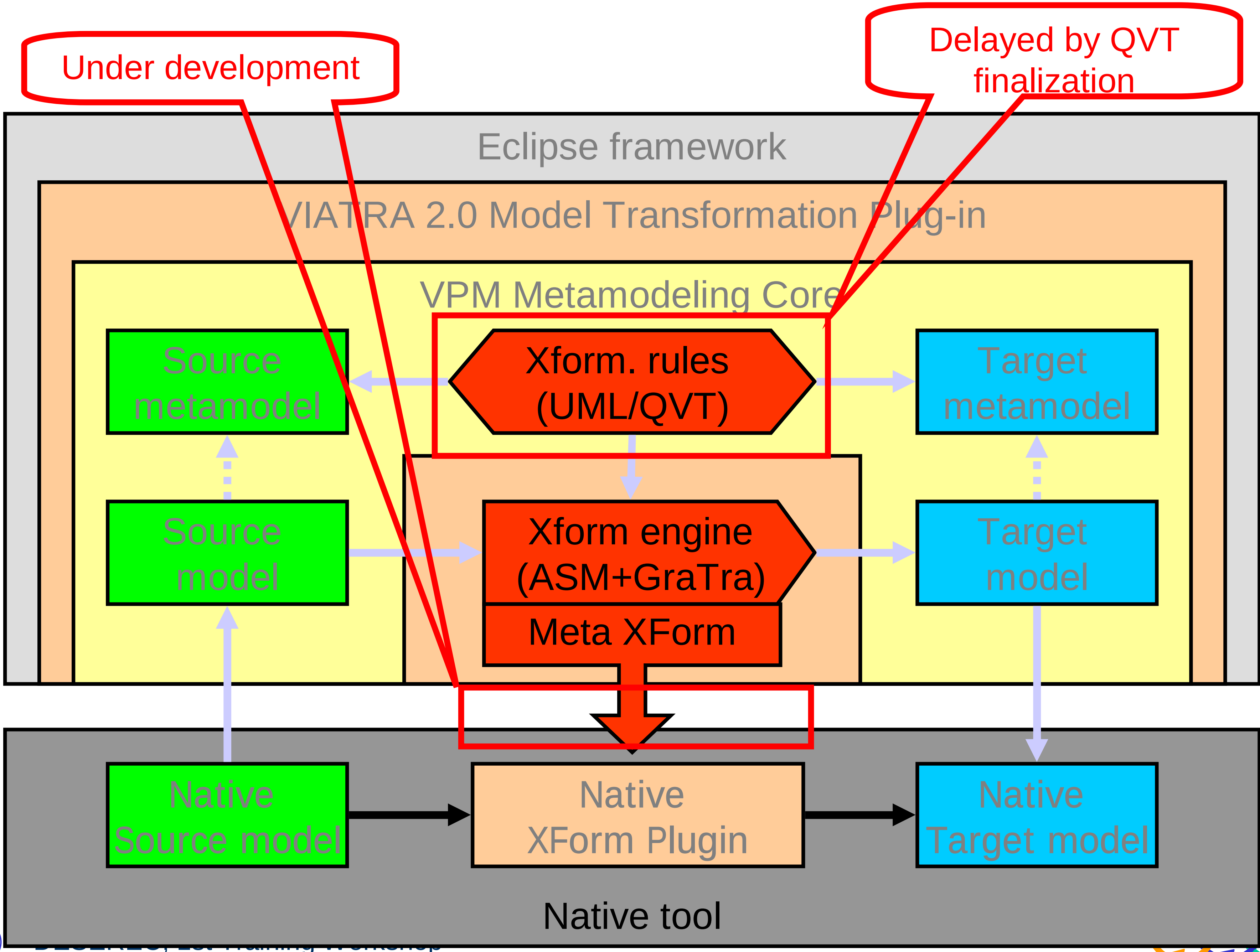


VIATRA2 and Eclipse

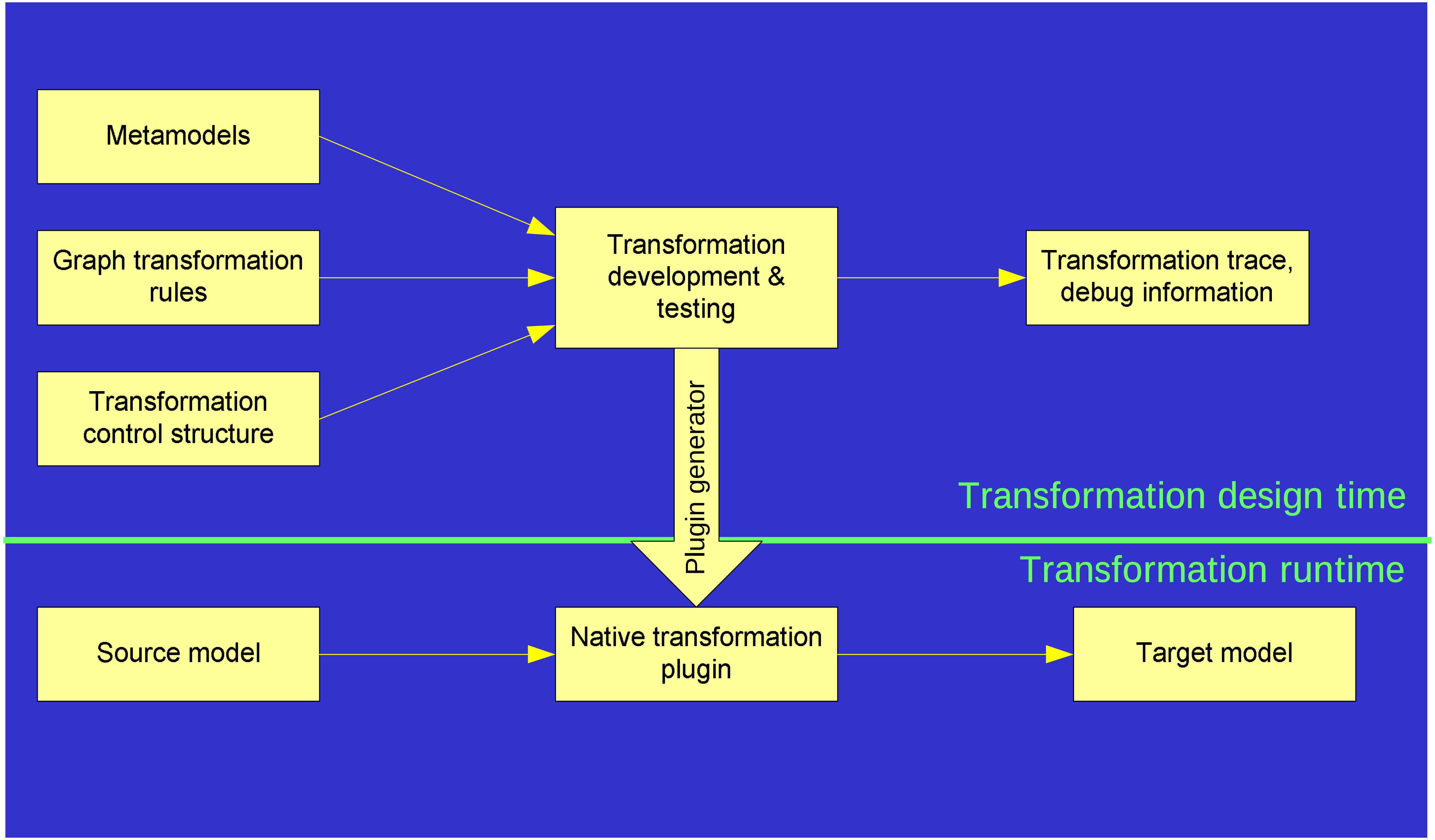
Eclipse quick facts:

- Component-based (‘plugins’)
- Free & Open Source
- Multi-Purpose Development Framework
  - IDE, thin client, application, …
  - A true platform in itself
- THE platform for tool integration today

VIATRA2: an official Eclipse Generative Modeling Tools project

- Realization: a set of Eclipse plugins
- Integration with other Eclipse-based solutions is supported
- Extendability & extension mechanisms
- http://www.eclipse.org/gmt/ (soon to be updated)

Transformation development



Models, Model Manipulation and the 'Last Mile'

Model management:

- **Model space**: Unified, global view of models, metamodels and transformations
  - Hierarchical graph model
  - Complex type hierarchy
  - Multilevel metamodeling

Model manipulation and transformations:
integration of two mathematically precise,
rule and **pattern-based** formalisms

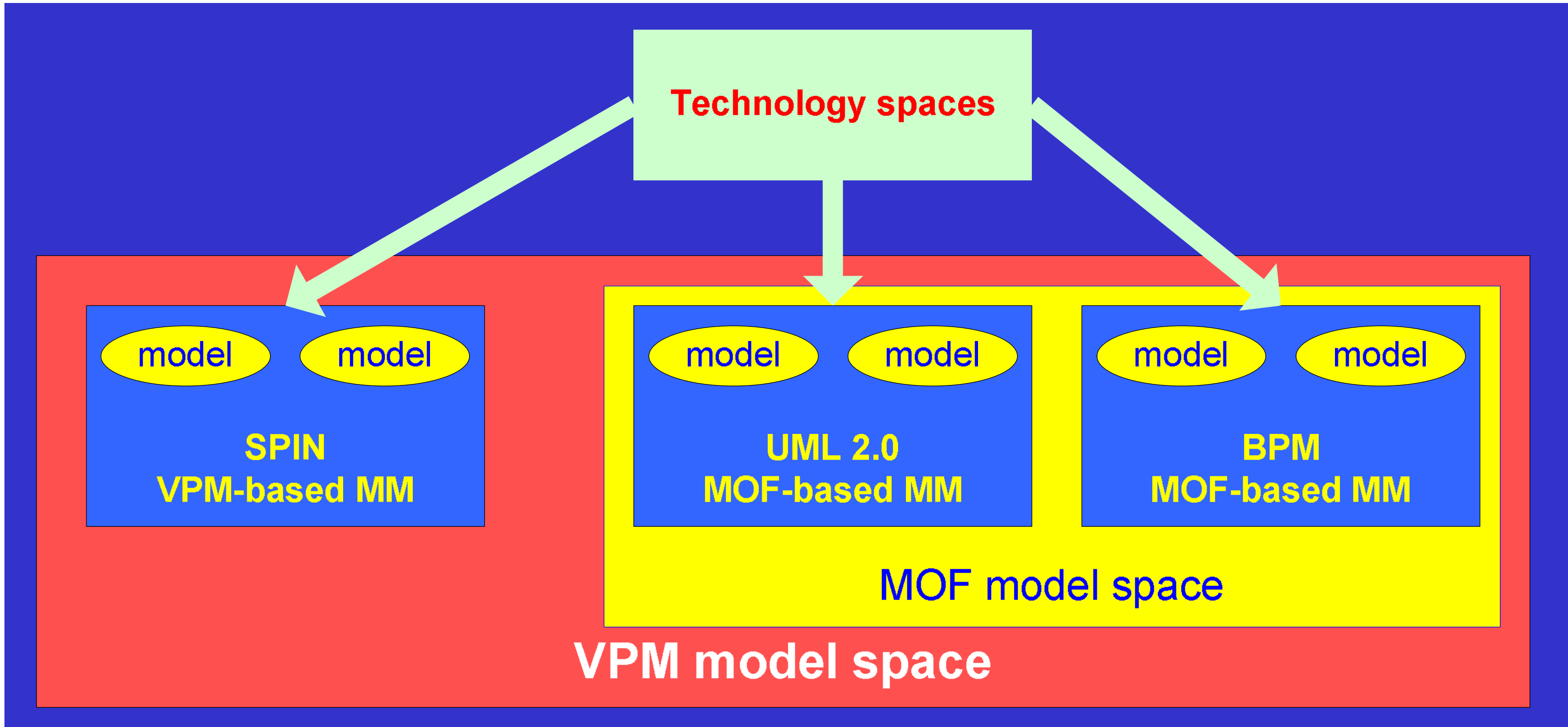
- Graph patterns (GP): structural conditions
- Graph transformation rules (GT): elementary xform steps
- Abstract state machines (ASM): complex xform programs

Code generation:

- Special model transformations with
- Code templates and code formatters

VPM: Visual and Precise Metamodeling

- Simple, visual metamodel desing
- Precise semantics
- Multi-level metamodeling: arbitrary meta-level depth
- Simultaneous support of multiple modeling languages



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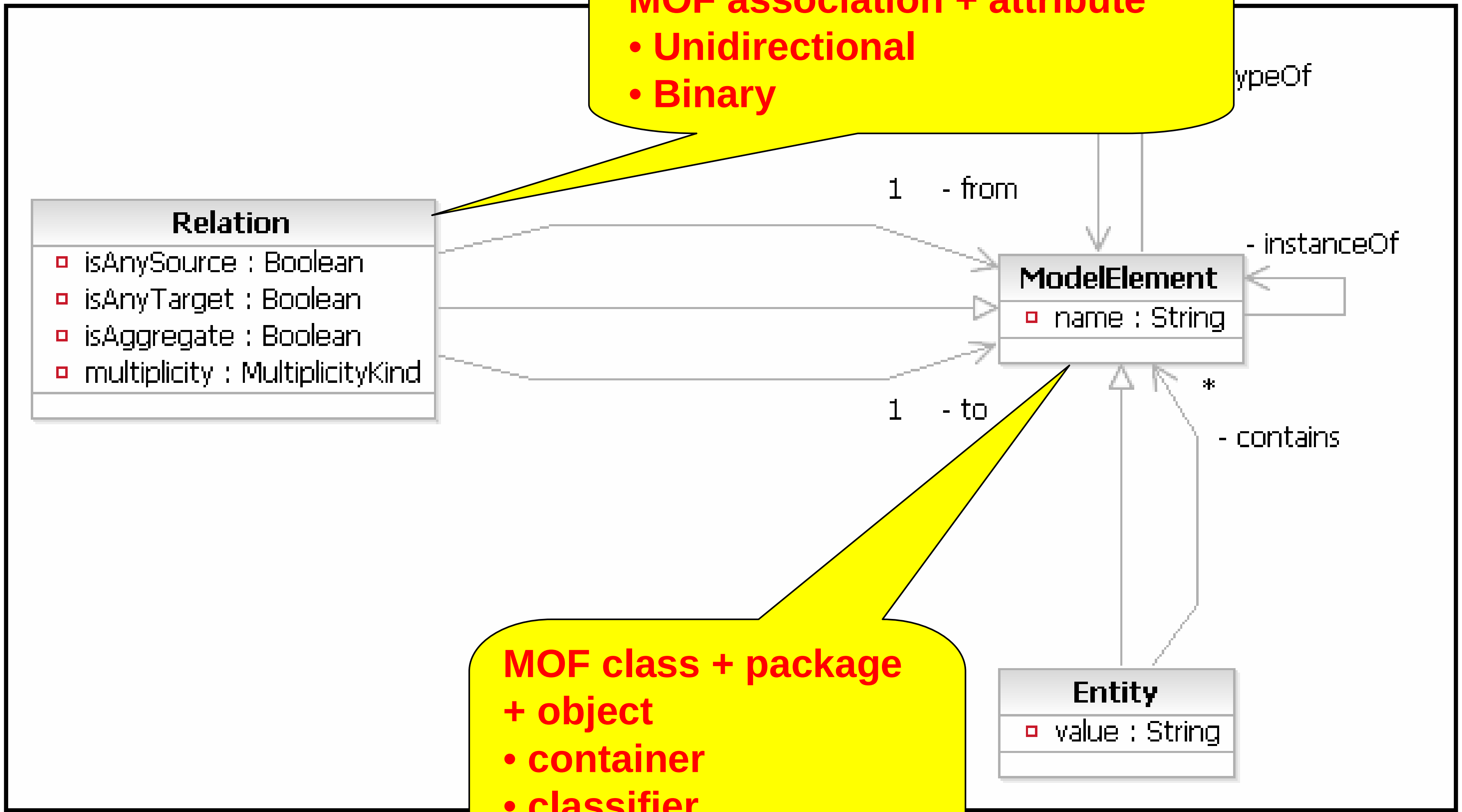
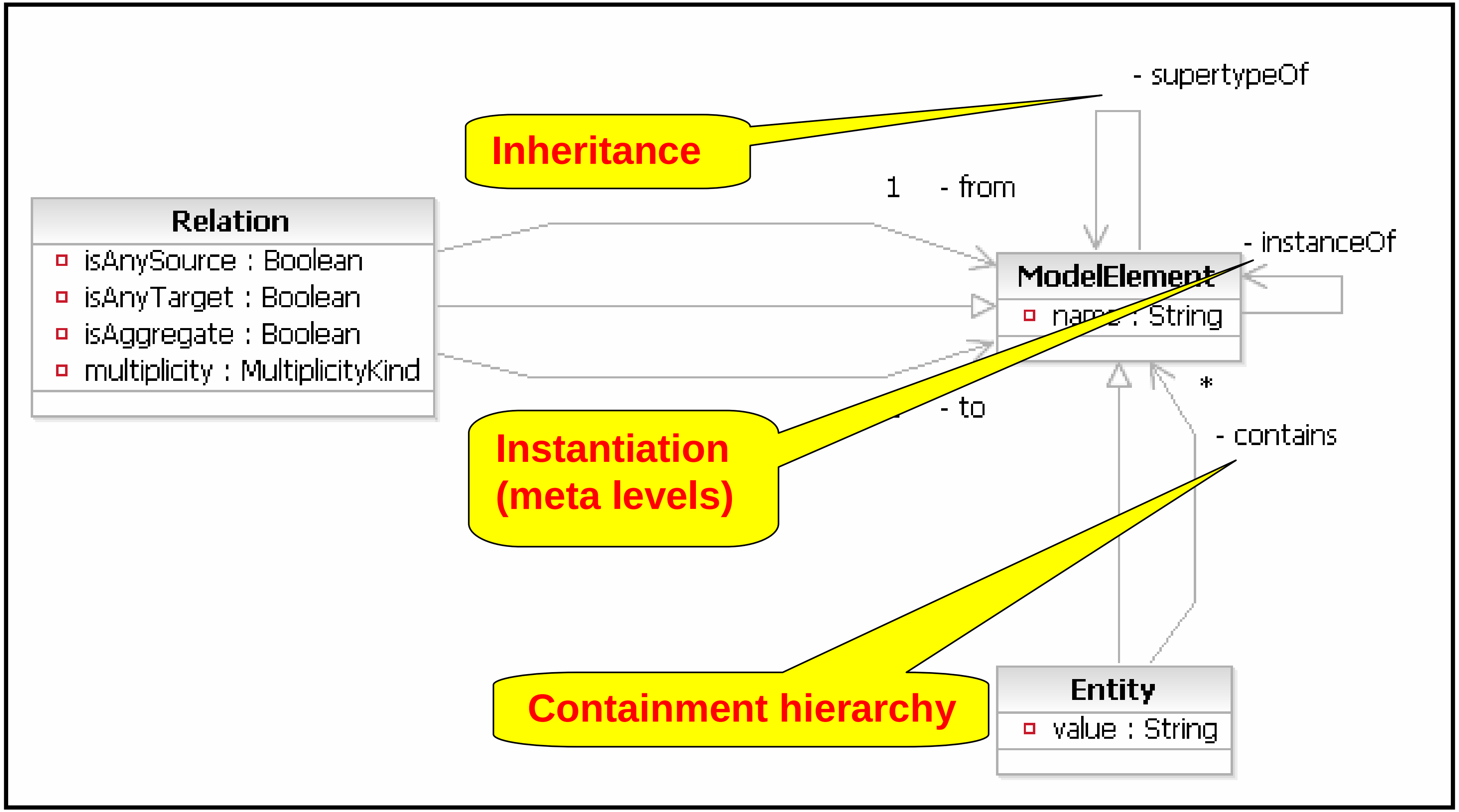


MOF association + attribute
- **Unidirectional**
- **Binary**

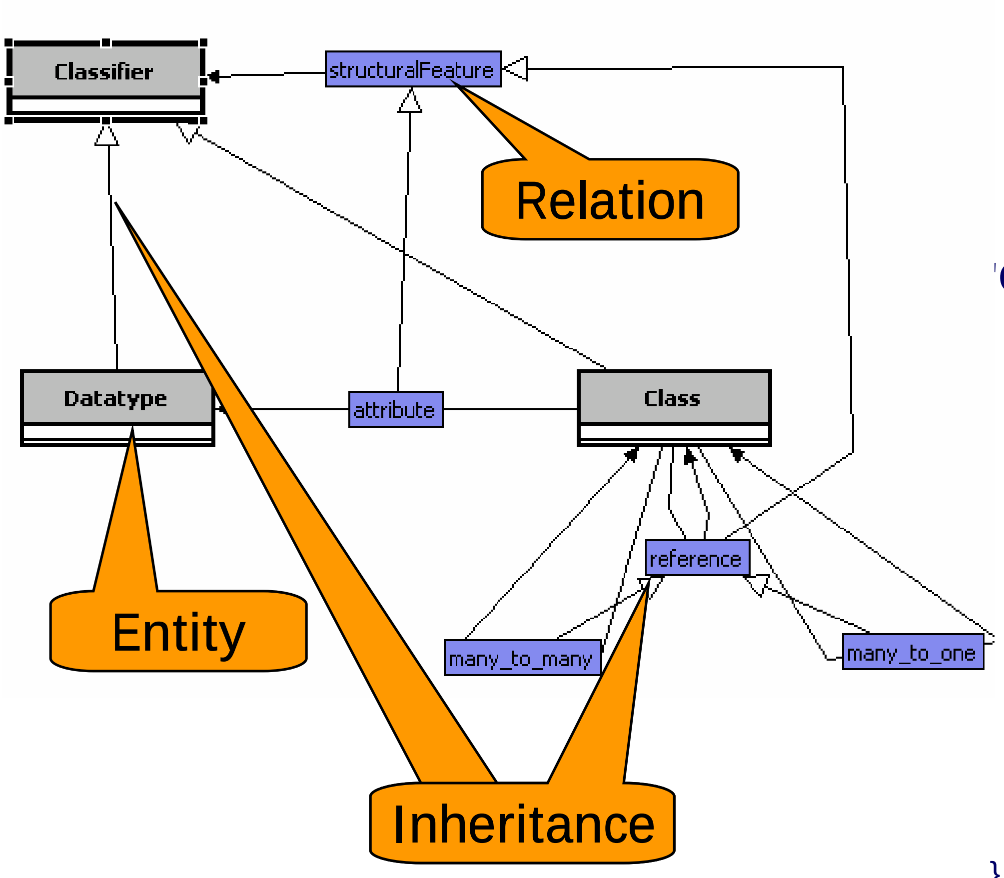
MOF class + package + object
- **container**
- **classifier**
- **constant**
- **object instance**

VPM: Visual and Precise Metamodeling



VTML: VIATRA Textual Metamodeling Language

Example: Ecore Metamodel

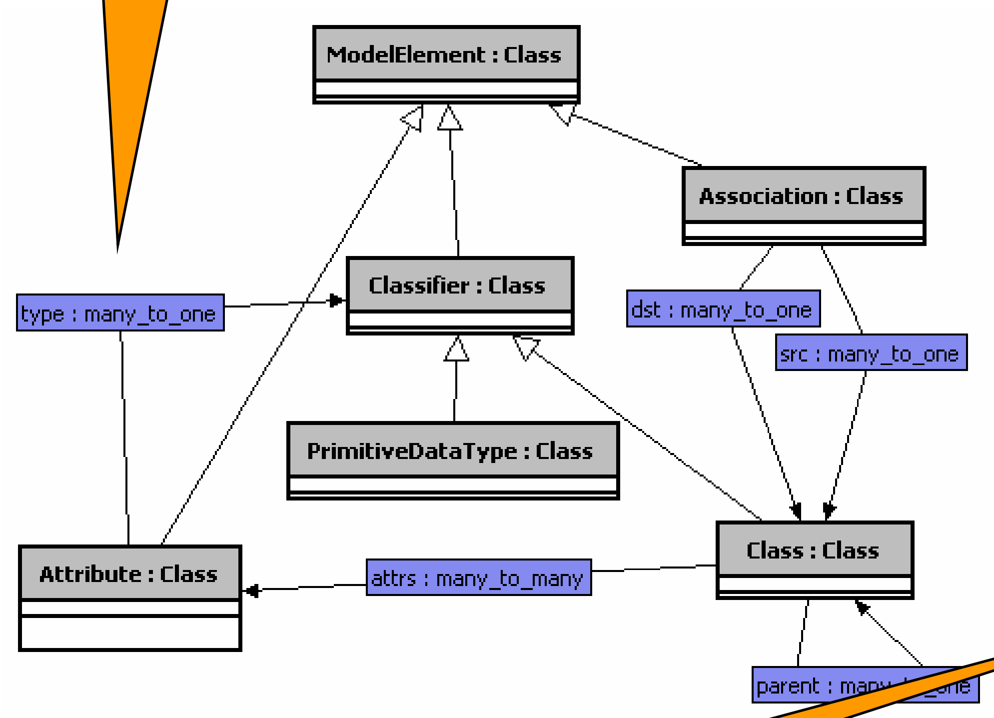


Containment

```
entity(emf) {
  entity(ecore) {
   entity('Classifier');
   entity('Class');
   entity('Datatype');
   relation('structuralFeature', 'Classifier',
'Classifier');
   relation('attribute', 'Class', 'Datatype');
   relation('reference', 'Class', 'Class');
   relation('many_to_one', 'Class', 'Class');
   relation('many_to_many', 'Class', 'Class');
   supertypeOf('Classifier', 'Class');
   supertypeOf('Classifier', 'Datatype');
   supertypeOf('structuralFeature', 'attribute');
   supertypeOf('structuralFeature', 'reference');
   supertypeOf('reference', 'many_to_one');
   supertypeOf('reference', 'many_to_many');
  }
}
```

Example: UML Metamodel as Instance of Ecore

InstanceOf



Metamodel specific types

```
import emf;

entity(uml_class) {
  entity(metamodel)  {
    ecore.'Class'('ModelElement');
    ecore.'Class'('Classifier');
    supertypeOf('ModelElement','Classifier');
    ecore.'Class'('Class') {
      ecore.attribute(name, 'Classifier', 'String');
      ecore.attribute(isPersistent, 'Class', 'Bool');
    }
    supertypeOf('Classifier', 'Class');

    ecore.many_to_one(parent, 'Class', 'Class');
    ecore.many_to_many(attrs, 'Class',
'Attribute');
  }
}
```

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VTML

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VTCL

Architecture ready to integrate alternative transformation languages (via new interpreters)

Code genera ion

- Special model t
- Code templates

Distinguishing feature: Metatransformations (rules that manipulate rules as models)

Ongoing: declarative transformations (description logic, QVT)

Graph patterns

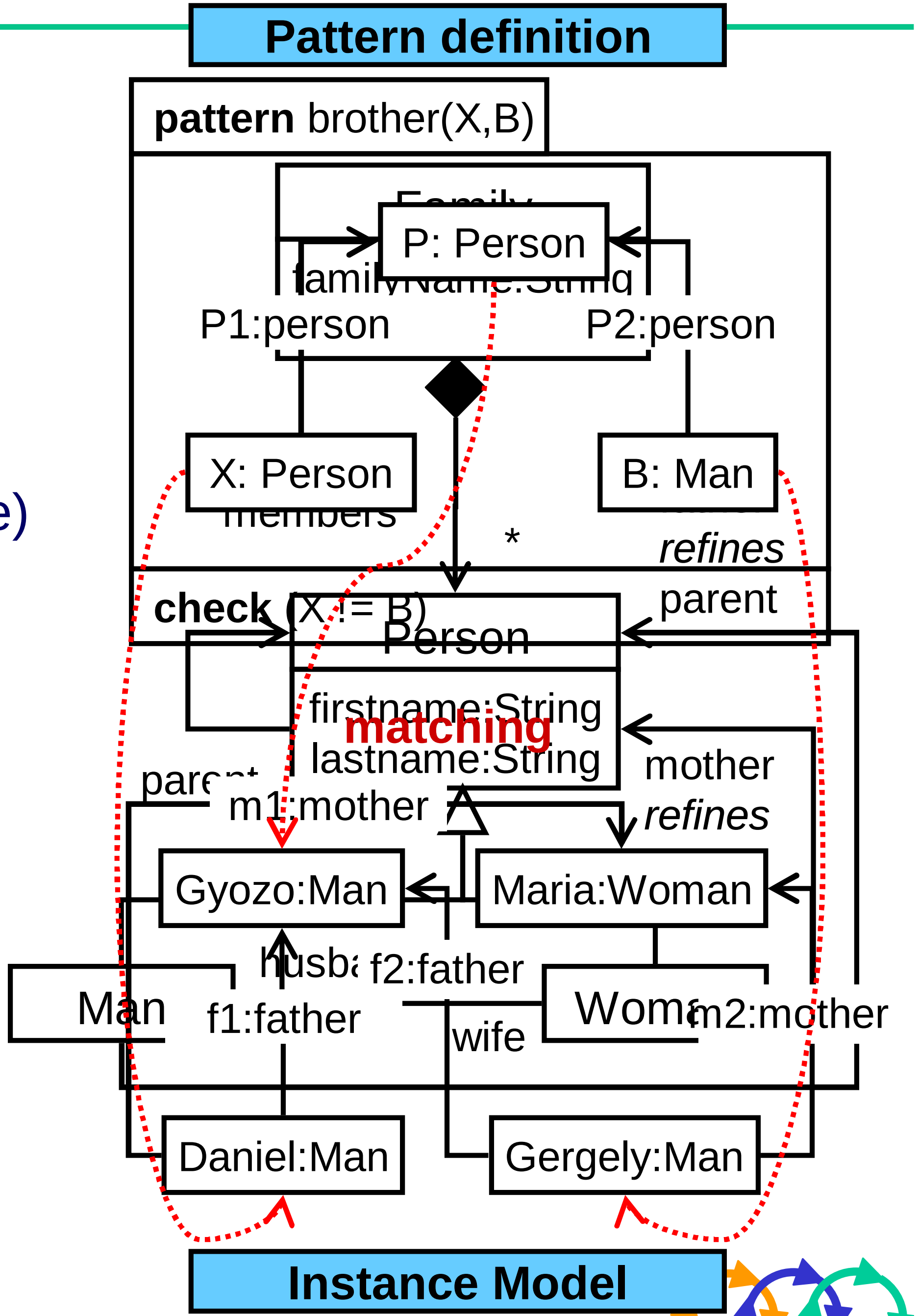
Graph Pattern

- Structural conditions that have to be fulfilled by a part of the model space

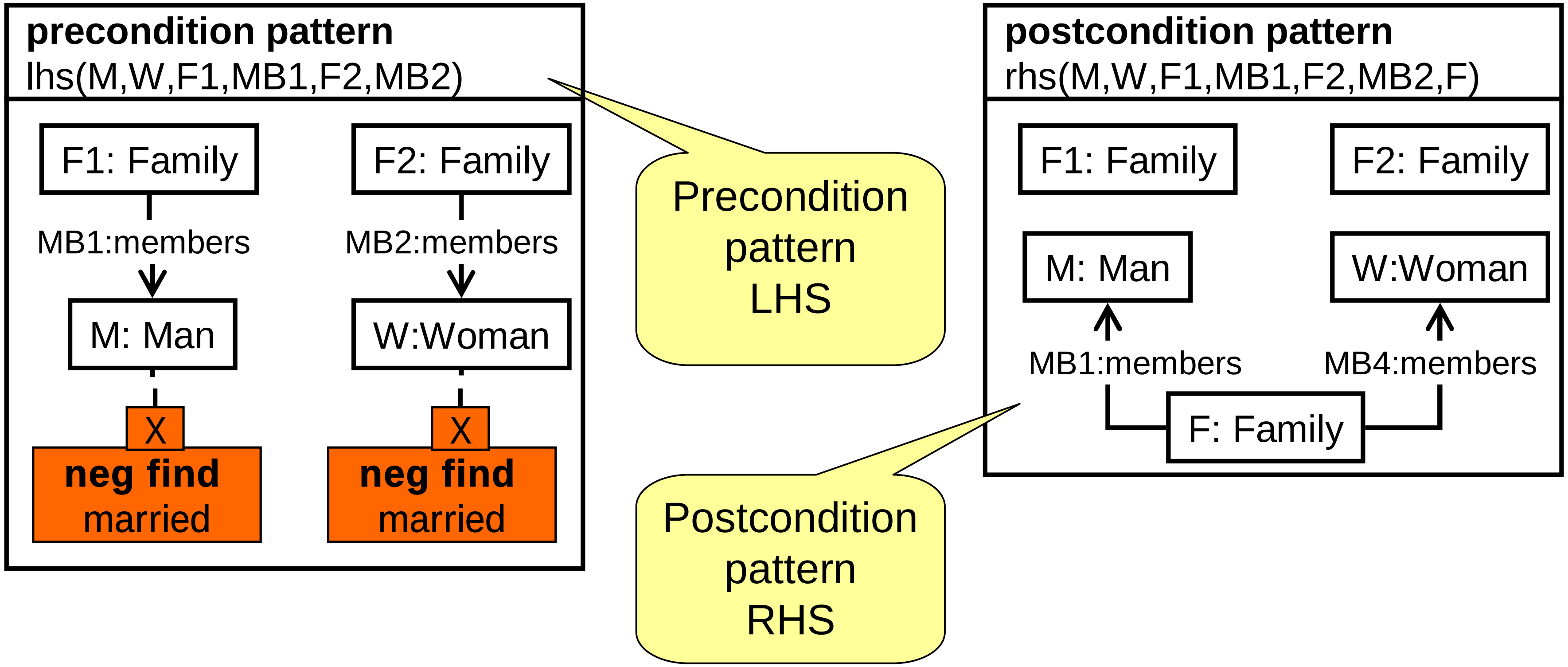
Graph pattern matching

- A model (i.e. part of the model space) can satisfy a graph pattern,
- if the pattern can be matched to a subgraph of the model

- Note that we omit here the 'fine detail' (recursion, OR-patterns, neg-pattern hierarchy,..)



Graph Transformation Rules



Three different kinds

- LHS + RHS
- LHS + actions (ASM, follows)
- Merged LHS-RHS (new, del annotations)

Abstract State Machines

ASM: high-level programming language

- Control structure for xform
- Integrated with GT rules

Examples

- **update** *location* = *term*;
- **parallel** {…} / **seq** {…}
- **let** *var* = *term* **in** *rule*;
- **if** (*formula*) *rule1*; **else** *rule2*;
- **iterate** *rule;*
- **forall/choose** *variables* **with** *formula* **do** *rule*;
- **forall/choose** *variables* **apply** *gtrule* **do** *rule*;

```
forall X below people.models,
        B below people.models
        with find brother(X, B) do seq {
          print(name(X) + "->" + name(B));
        }

let X = people.models.Varro1.Daniel,
Y = people.models.Gyapay1.Szilvia,
F = undef, F2 = undef in
choose Z below people.models
apply marry(X, Y, F) do seq {
          rename(F, "Varro2");
          move(F, people.models);
          iterate
            choose M below people.models,
       W below people.models
        apply marry(M, W, F2) do
                move(F2, people.models);
```

Models, Model Manipulation and the 'Last Mile'

VTML

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Model manipulation and transformations: integration of two mathematically precise, **rule** and **pattern-based** formalisms

VTCL

- Graph patterns (GP): structural conditions
- Graph transformation rules (GT): el
- Abstract state machines (ASM): co

Automatically transformed to VTCL

Code generation:

- Special model transformations with
- Code templates and code formatters

VTTL

Code templates

Code generation

- Code templates
- Code formatters

Code templates

- Text block with references to GTASM patterns, rules
- Compiled into GTASM programs with prints
  - Velocity templates

Code formatters

- Split output code into multiple files
- Pretty printing

```
template printClass(in C) =
{
public class $C {
#(forall At,Typ with attrib(C,At,Typ) do seq{)
private $Typ $At;
#(})
}
}

// Generated
rule printClass(in C) = seq {
        print("public class " + C + "{");
        forall At,Typ with attrib(C,At,Typ)
do
          seq {
            print("private " + Typ + " " + At +
";");
          }
        print("}");
}
```

VIATRA Importers

The step from concrete to abstract syntax!

Model import modules

- Specific to a tool version
- Eclipse plugins
- Can be easily customized, upgrad
- Can be installed/uninstalled separate fro framework

Ease of extendability was of priority (small and easy to use API)

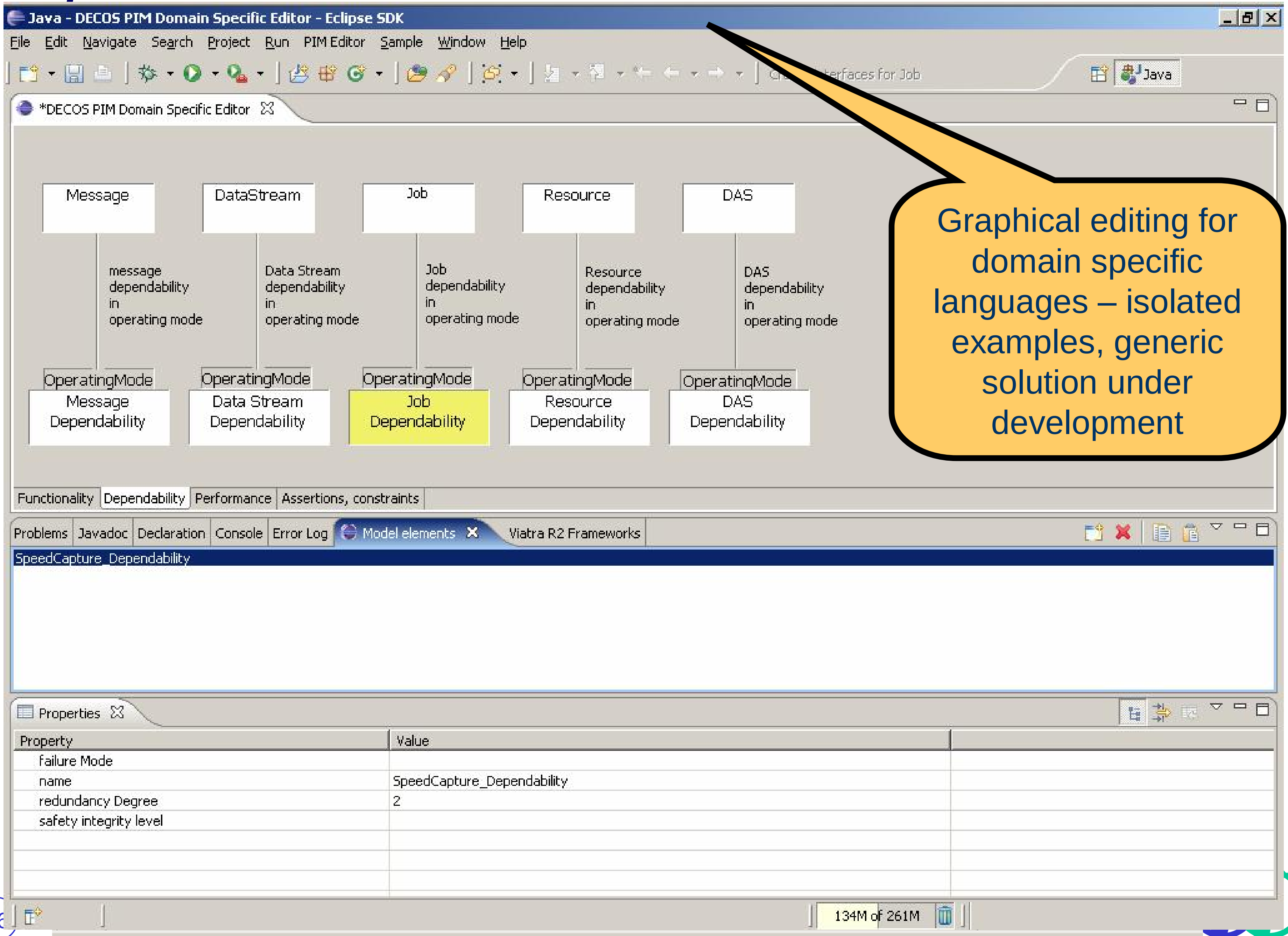
UML 1.x

- Importers for
  - IBM Rational Rose 2002
  - IBM Rational XDE 2003
  - Sparx Systems Enterprise Architect 4.0

UML 2.0

- New metamodel
- Importer for Rational Software Architect 6.0

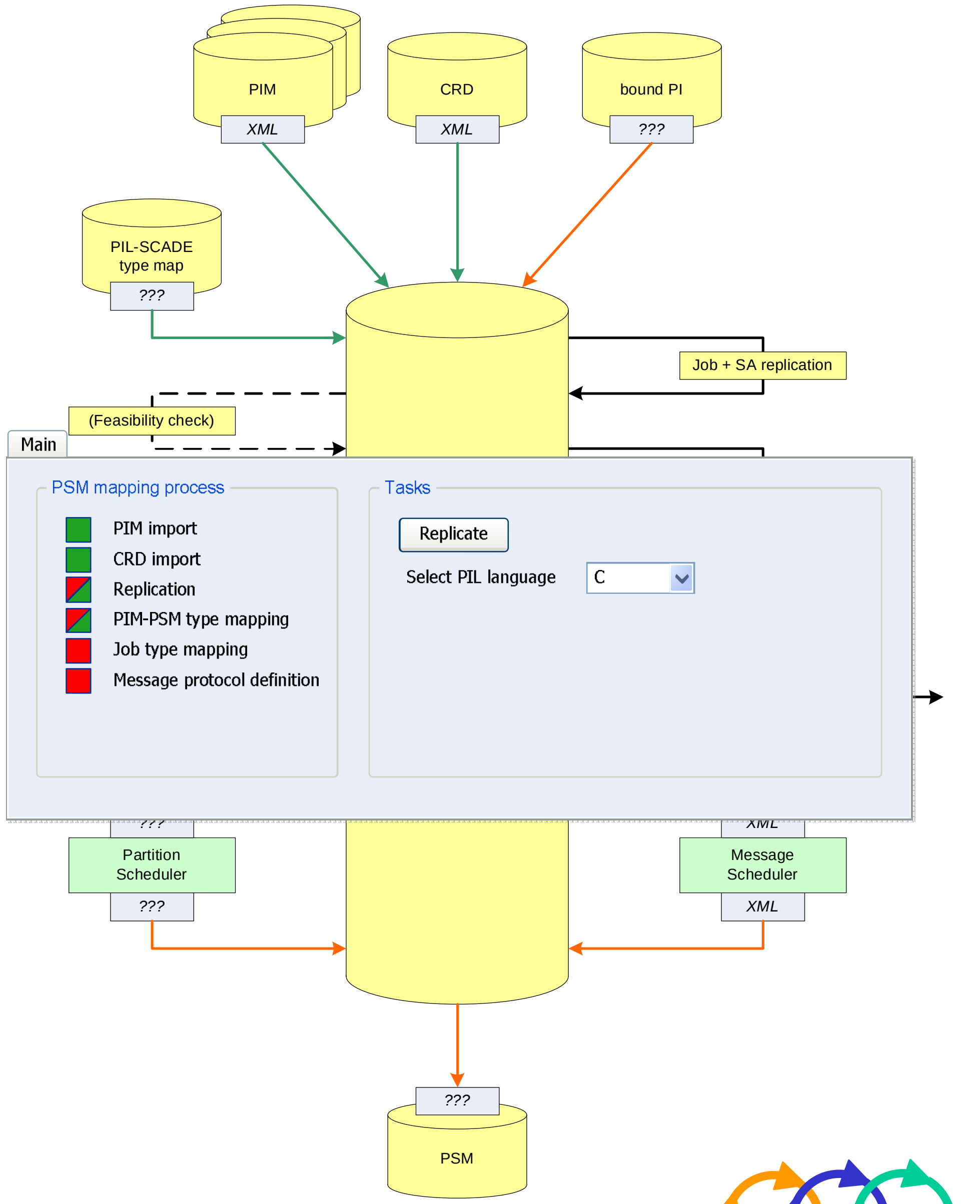
Eclipse-based GUI



–*VIATRA as an Application Component*

"VIATRA application"

- Custom UI above the general framework
- Contains more transformation descriptions and metamodels
- The control flow of transformations can depend on user input
- Example: complex PIM-PSM mapping



Qualitative Fault Modeling, Transformations and Resilient Systems

Qualitative fault modeling

Basis: Architecture design

Metamodel-based fault modeling

- UML General Resource Model (GRM):
  Resource types (active, passive, protected etc.),
  Usage scenarios
- Operational faults are considered
- Faults are introduced here systematically

Common cause failures:

- Introduced by resource sharing

Applications

Origins: mid-nineties (York, TUB)

- A few qualitative values (good, faulty, early, late)

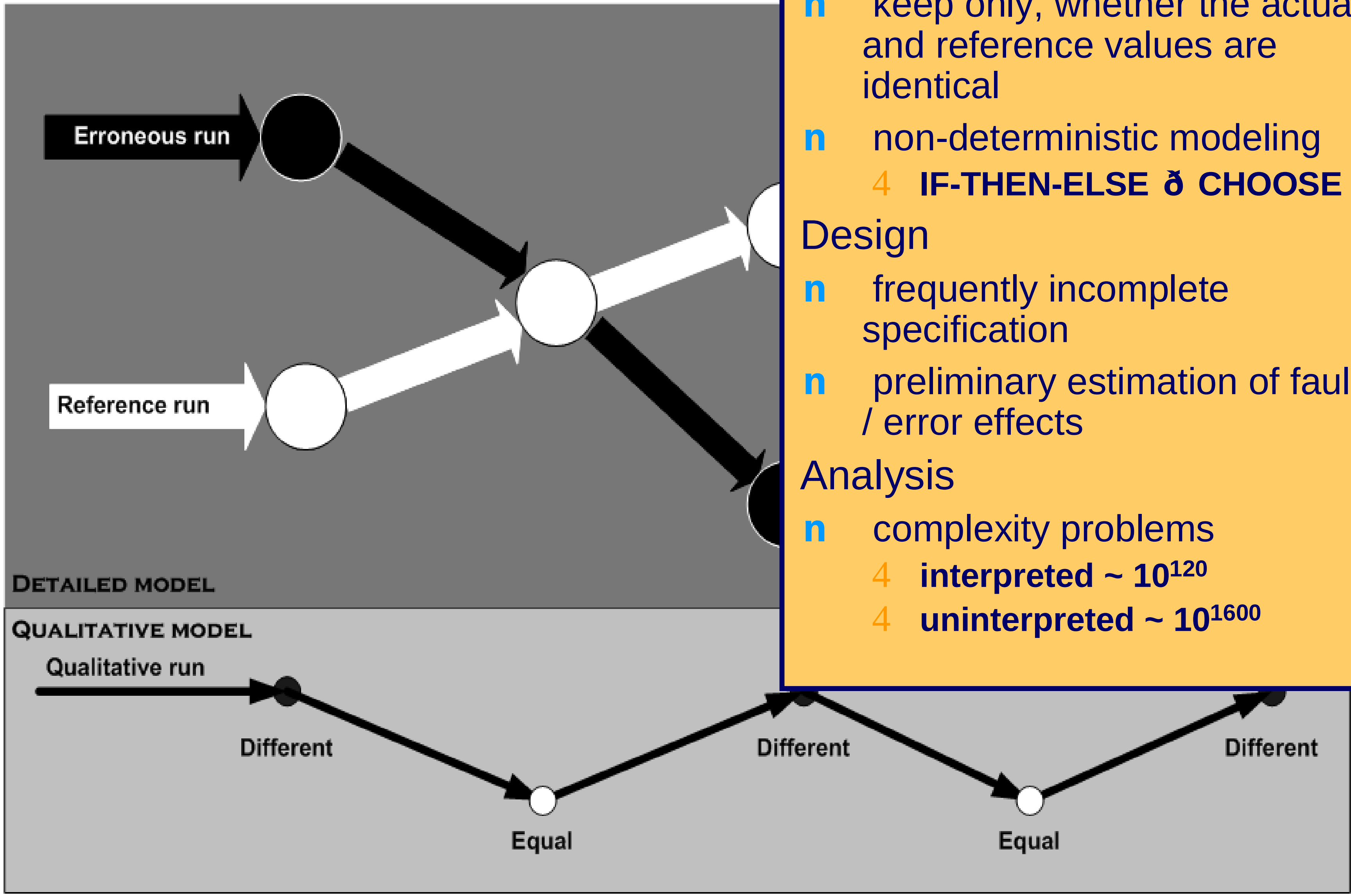
Applications:

- industrial models
- railway interlocking systems
- e-Business processes

Experiences:

- effective both in modelling and analysis (as briefly follows)

Basic idea of qualitative fault modeling



Basic idea:

- keep only, whether the actual and reference values are identical
- non-deterministic modeling
  - **IF-THEN-ELSE ð CHOOSE**

Design

- frequently incomplete specification
- preliminary estimation of fault / error effects

Analysis

- complexity problems
  - **interpreted ~ 10^{120}**
  - **uninterpreted ~ 10^{1600}**

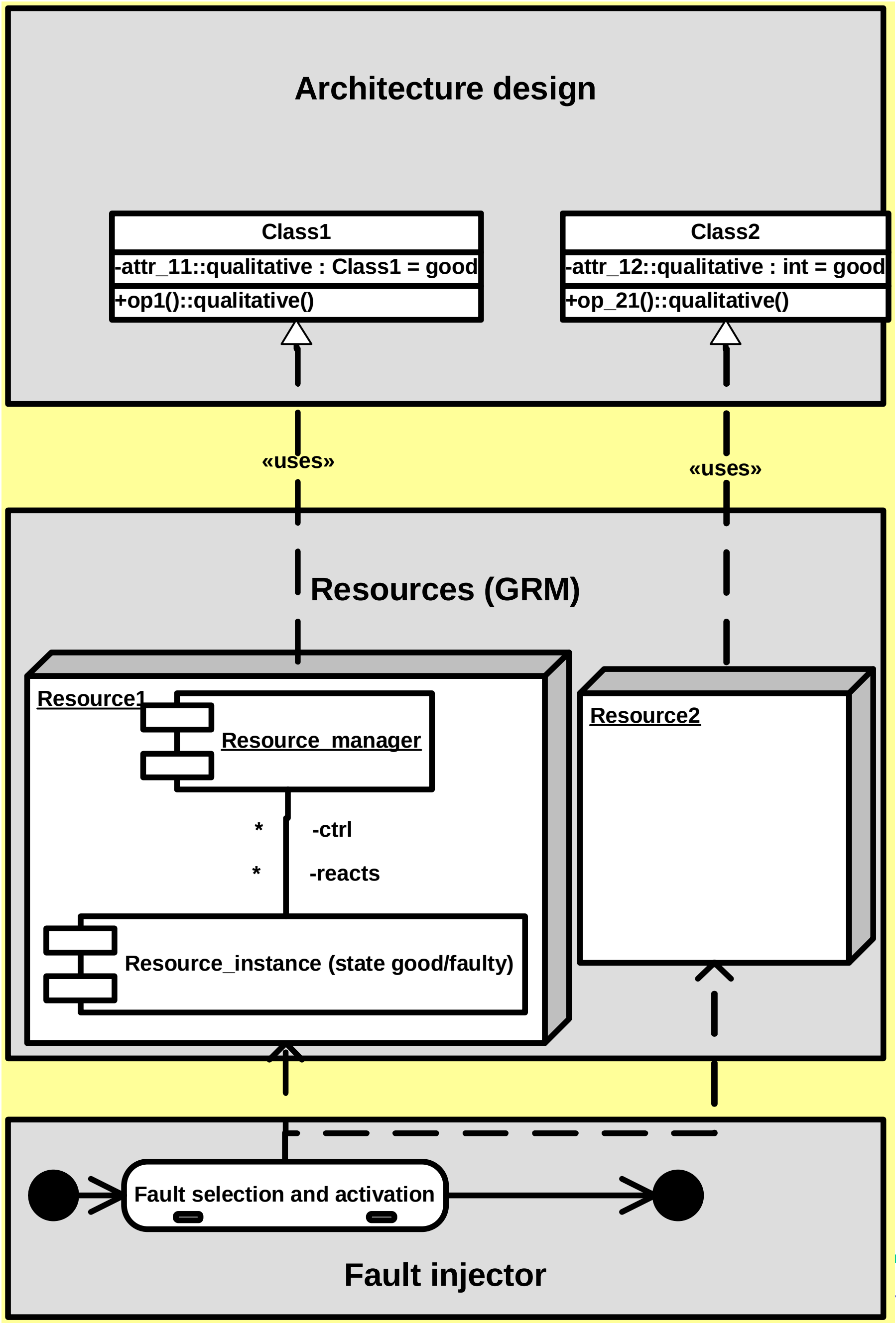
Part of a UML Profile

Model of the inter-actions with resources via GRM

Insertion of (qualitative) faults at the resources

Error propagation through the scenarios

Qualitative fault modeling is tried & tested – the task is to integrate it with MDD



Analysis of error propagation

Extension of the architectural model:
fault effects + error propagation rules

Checking high-level (abstract) operation
in the presence of anticipated faults
(fault simulation)

Estimating system properties:

- Coverage of fault tolerance techniques
- Testability, diagnosability of faults
- Potentially catastrophic fault effects

Dependability analysis

Basis: Architecture design (PSM)

Quantitative reliability/availability analysis:

- Comparison of alternatives
- Elimination of bottlenecks
- Sensitivity analysis

Qualitative dependability analysis:

- Rule-based prediction of faulty behavior

Design patterns for dependability
(redundancy management)

Formal verification of behavior

Basis: Behavioral model (control flow)

- Complex control algorithms
- Event driven, asynchronous operation

→ Exhaustive testing is infeasible

Classical reachability analysis:

- Temporal logic model checking
(general and application-specific requirements)

Additional improvements:

- Semi-decision techniques
(handling large state spaces by

Conclusion: many (classic) V&V activities meaningful in the DESEREC context; to the least tool & process integration can benefit from transformation support

Live Tool Demonstration