Universität der Bundeswehr München
Department of Computer Science
Chair for Modeling and Simulation

Potenziale und Schwierigkeiten bei der Modellierung mit SysML für Untersuchungen zum operativen Betrieb von Fertigungsanlagen

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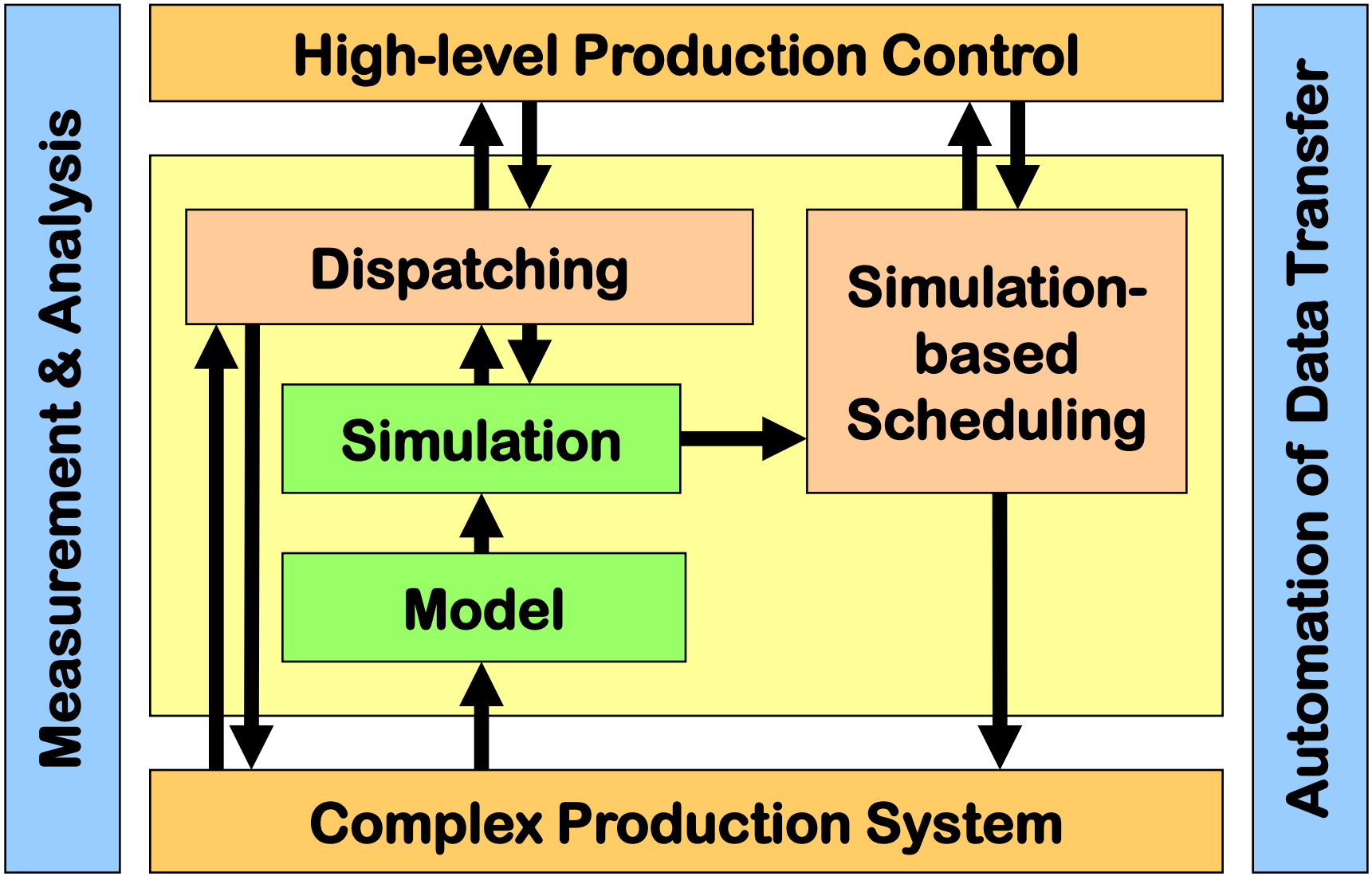
Research Overview



Our goal

- Development and application of tools, libraries, and frameworks to support
  - Solution heuristics for operational production and logistics scheduling problems: (simulation-based) **Decision Support Systems**
  - **Performance evaluation** of complex production and logistics systems
    - Fast
    - Robust
    - Comprehensive (to users!)
    - Easy to integrate
    - Applicable in a wide range of industries
    - Based on state-of-the-art software engineering technologies

Scheduling

- Scheduling in discrete logistics systems (warehouses, factories, transport systems, supply chains, ...)
  - Jobs
    - with a given (production) process, consisting of one or more steps/actions/activities
  - Resources
    - typically limited
  - Constraints
    - failures, shift regime, start dates, due dates, ...
  - Objective functions
    - minimize cost, cycle times, ...
    - maximize throughput, on-time delivery, ...
- Find optimal schedule assigning jobs to resources while meeting all constraints

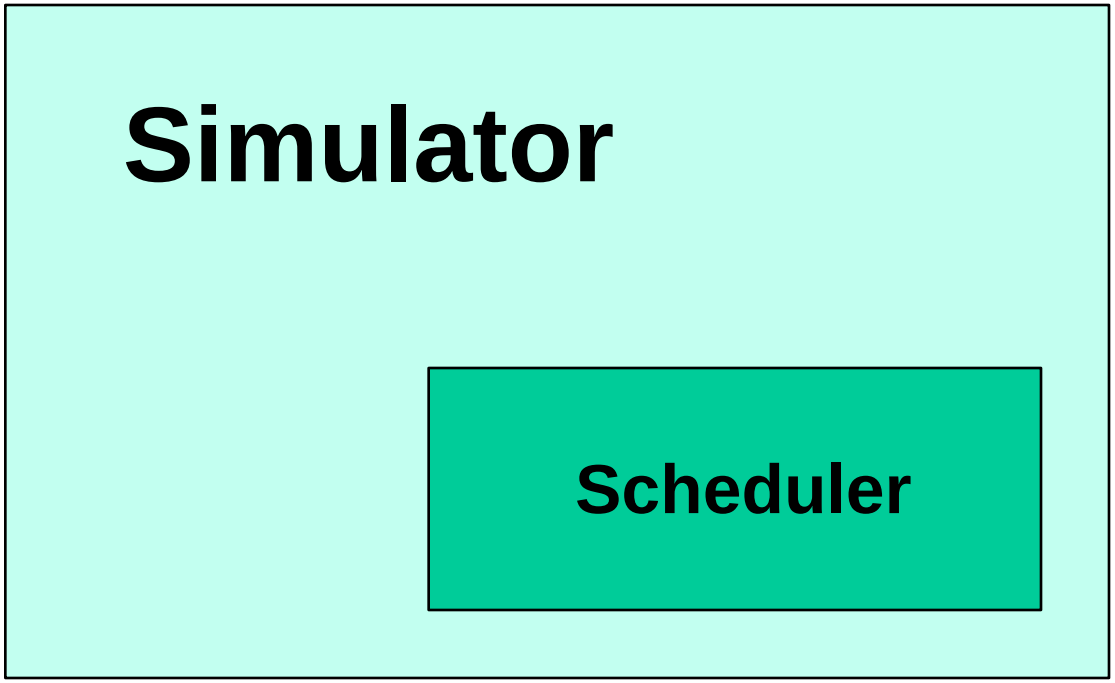
Simulation Modeling

- Advantages:
  - Model represents large amount of relevant system details (in contrast to most mathematical models)
    - Job characteristics
    - Resource characteristics
    - Constraints
    - ...
  - Commercial tools available

- Challenges:
  - No modeling standards
  - Considerable effort to validate models
  - Difficult integration into given IT infrastructure

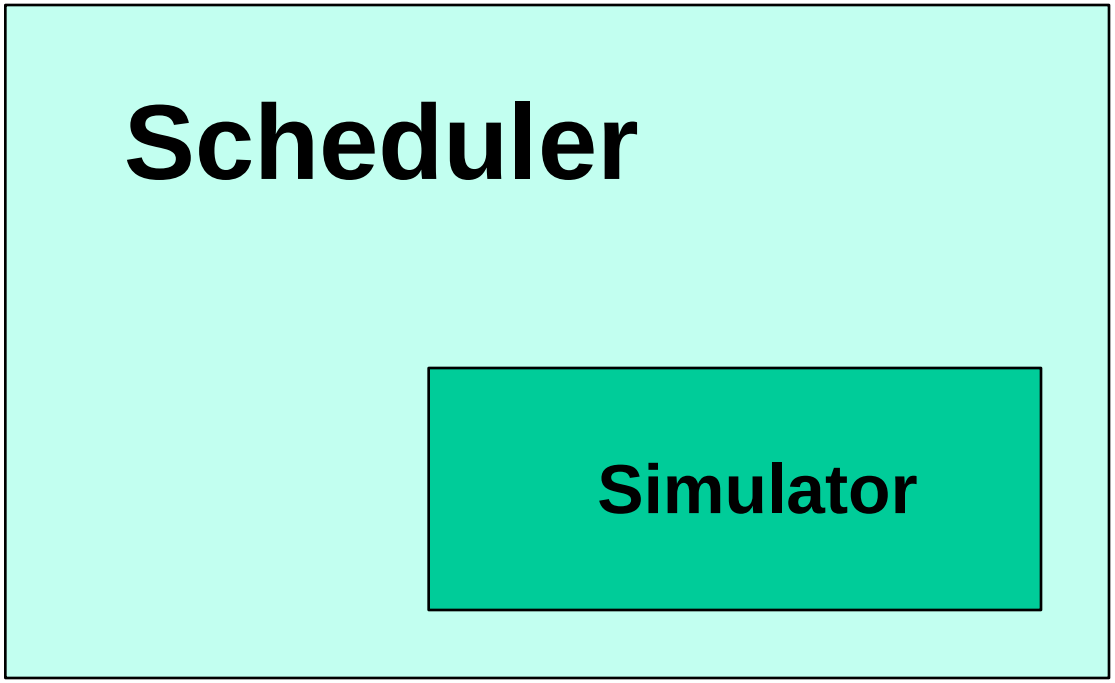
Simulator & Scheduler

- **Testing of scheduling approaches**
  - Simulator provides online test environment for scheduler

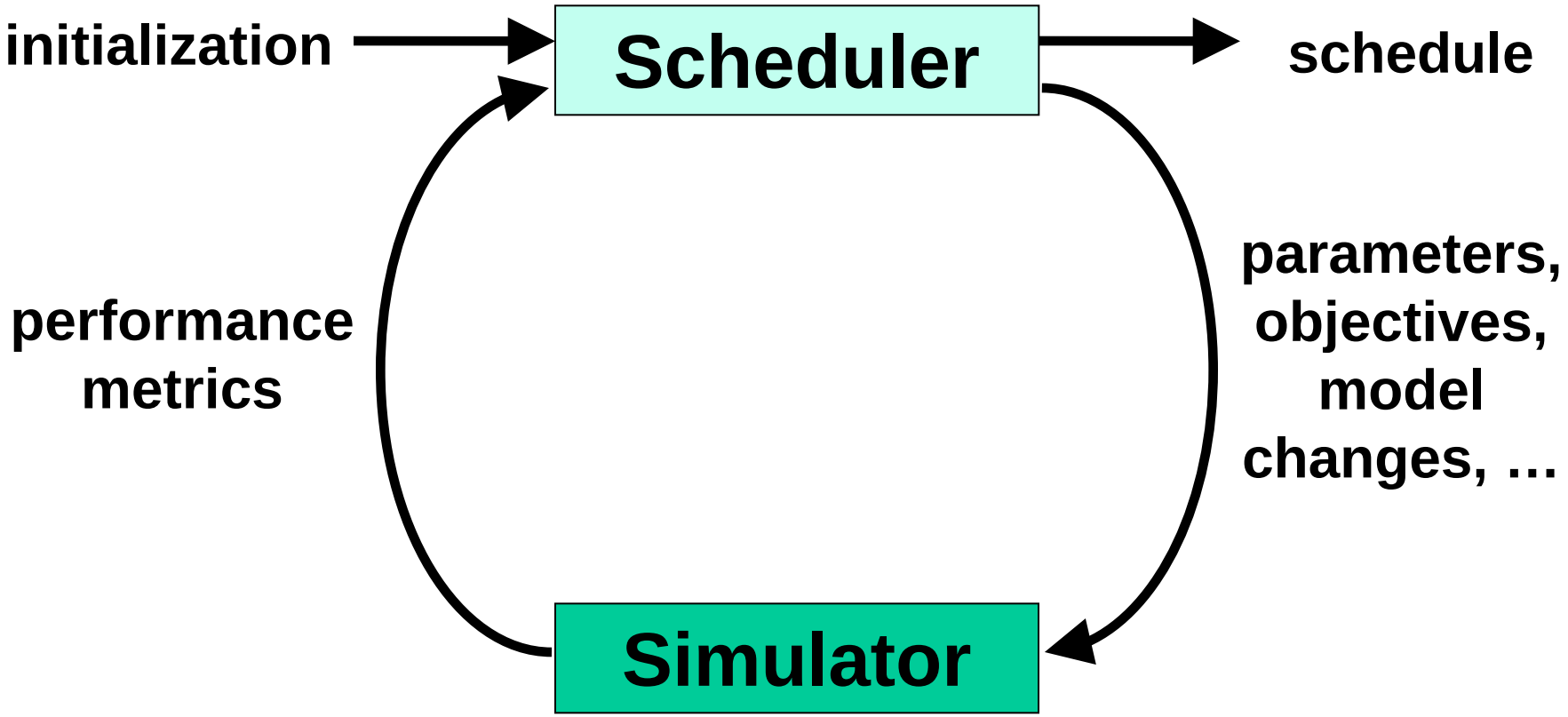


Simulator & Scheduler

- **Simulation for evaluation of schedule scenarios**
  - Simulator provides estimates for objective function
  - Operational applications (Leitstand)



Simulation-based Scheduling



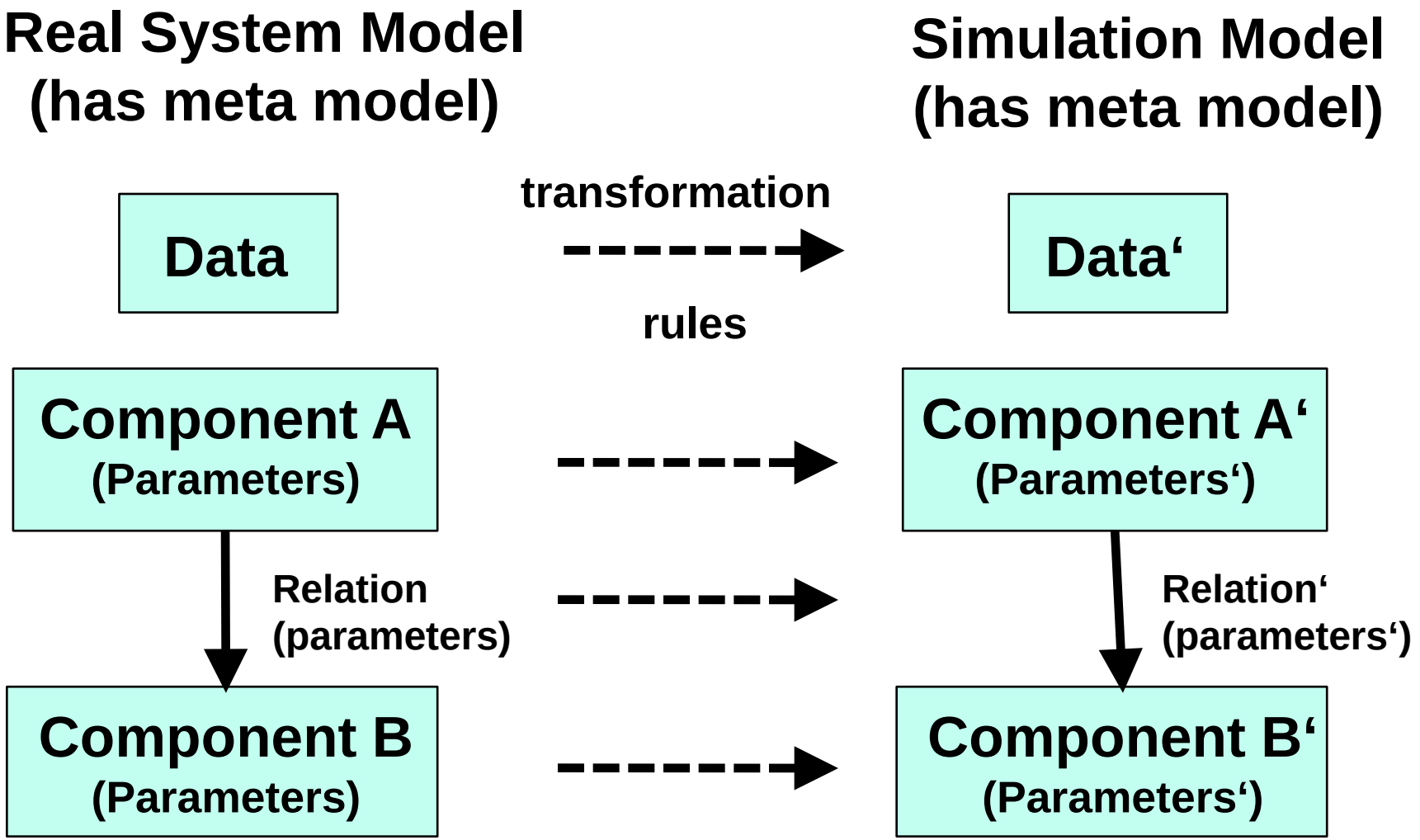
Simulation-based Scheduling

- **Challenges**
  - (Online) Data acquisition for initialization of scheduler (and simulator)
    - Interface to data of real system
    - Validation of system data
  - Simulation model generation (more on next slides)
  - Simulation model parameterization (scenario management)
  - Fast simulation runs (no stochastic components, no 3D visualization, ...)
  - Data handling for simulation results (no time-consuming repetition of runs)
  - Validation of simulation model

Simulation Model Generation

- **Alternatives**
  - Before start of scheduler
    - Only possible if system changes very seldomly
  - *Before each simulation run*
    - Requires availability of all relevant data and fast generation
  - Manually
    - Only possible if model is created before start of the scheduler
  - *Automated*
    - State-of-the-art for operational simulation-based scheduling

Automated Model Generation



Automated Model Generation

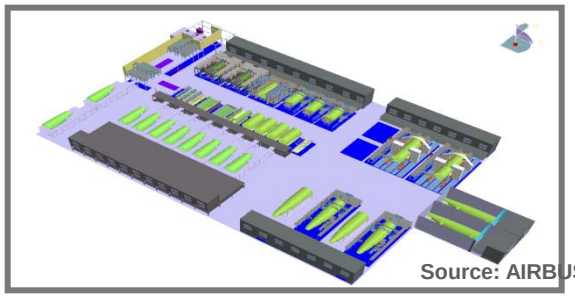
- **Requirements**
  - Source model available (and valid!)
  - Matching meta models of source and target system
    - Semantics well-defined?
      Examples: What is a “job”? What is a “tool”?
    - Meta model of commercial simulation tools?
  - Fast, flexible and extensible transformation approach
  - Valid transformation rules (danger of systematic errors due to faulty rules)

- **Applications**
  - Simulation-based scheduling
  - Simulation-based performance forecast (initialized with current system state)

Example For Simulation-based Scheduling

SIEMENS
Turbine assembly

Airbus
Fuselage assembly

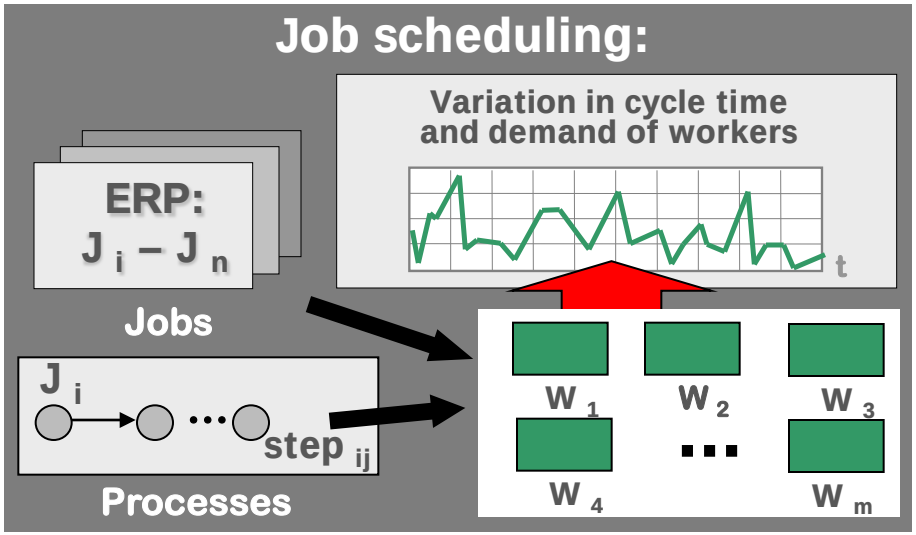


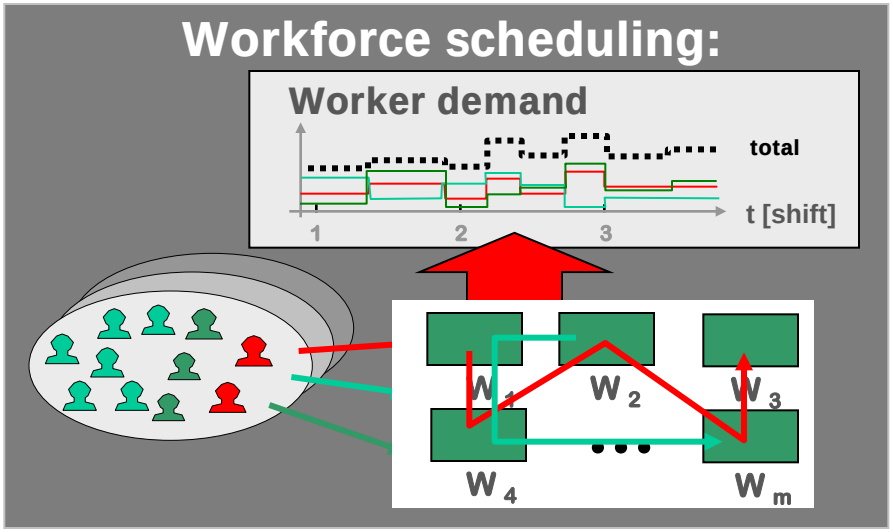
KBA Planeta
Offset printing machine assembly

Example: Problem Description

- Main focus:
  - **Workforce scheduling**
- Constraints:
  - Release dates & due dates / deadlines (from ERP system)
  - Workers with different qualification profiles, shift regimes, and costs
  - Several resource modes for each processing step
  - Solution in < 10 minutes
- Objectives:
  - Keep the due dates
  - Minimize the number of workers
  - Match of worker supply and demand
- Closest traditional problem in the literature:
  - **MRCPS**: Multi-mode resource constrained project scheduling

Example: Problem Description





Goal: Keep the due dates

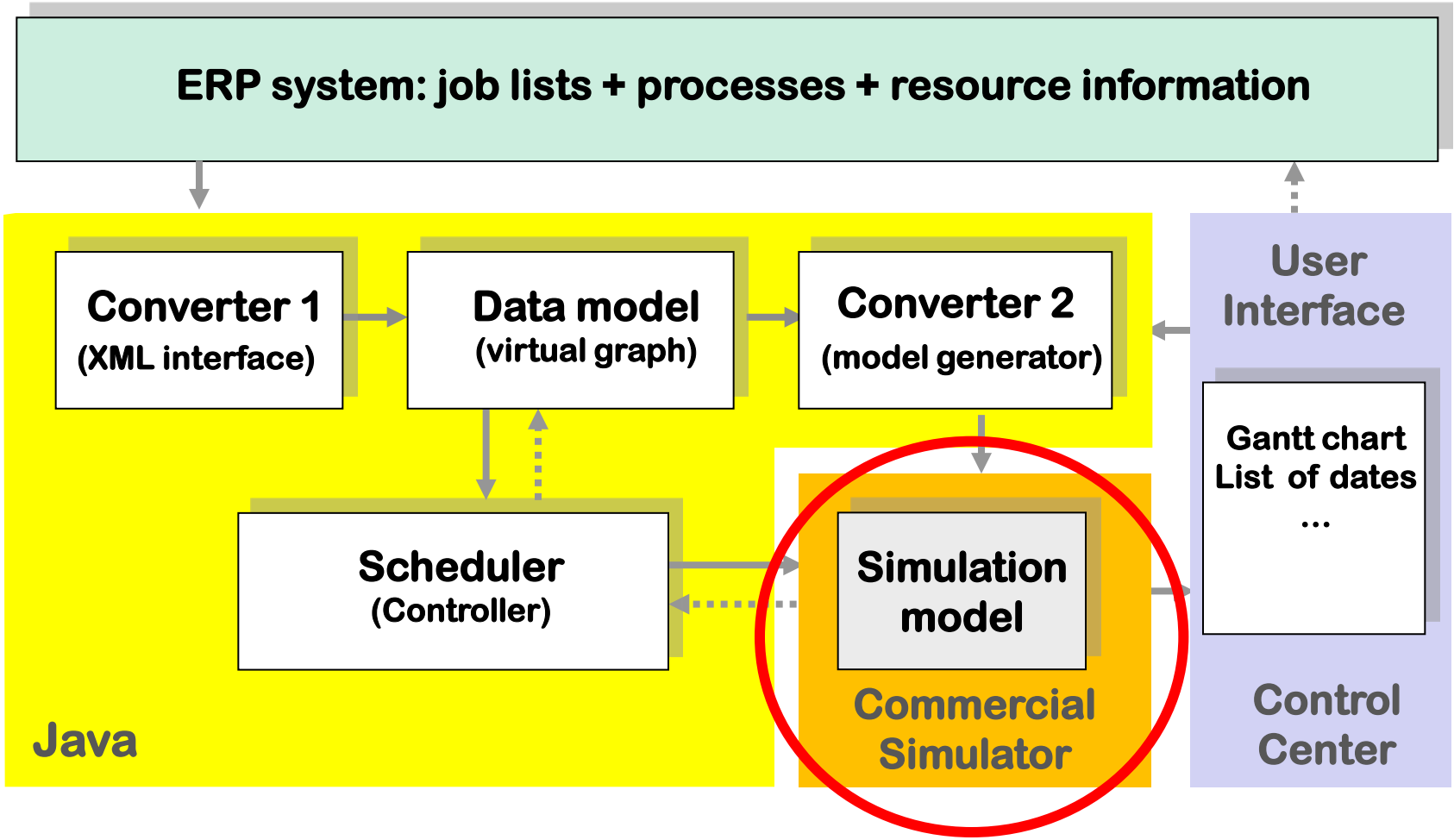
Goal: Match worker supply and demand

Conflicting goals

Sequencing problem

Knapsack problem

Example: Leitstand Architecture



Simulation Modeling Standard

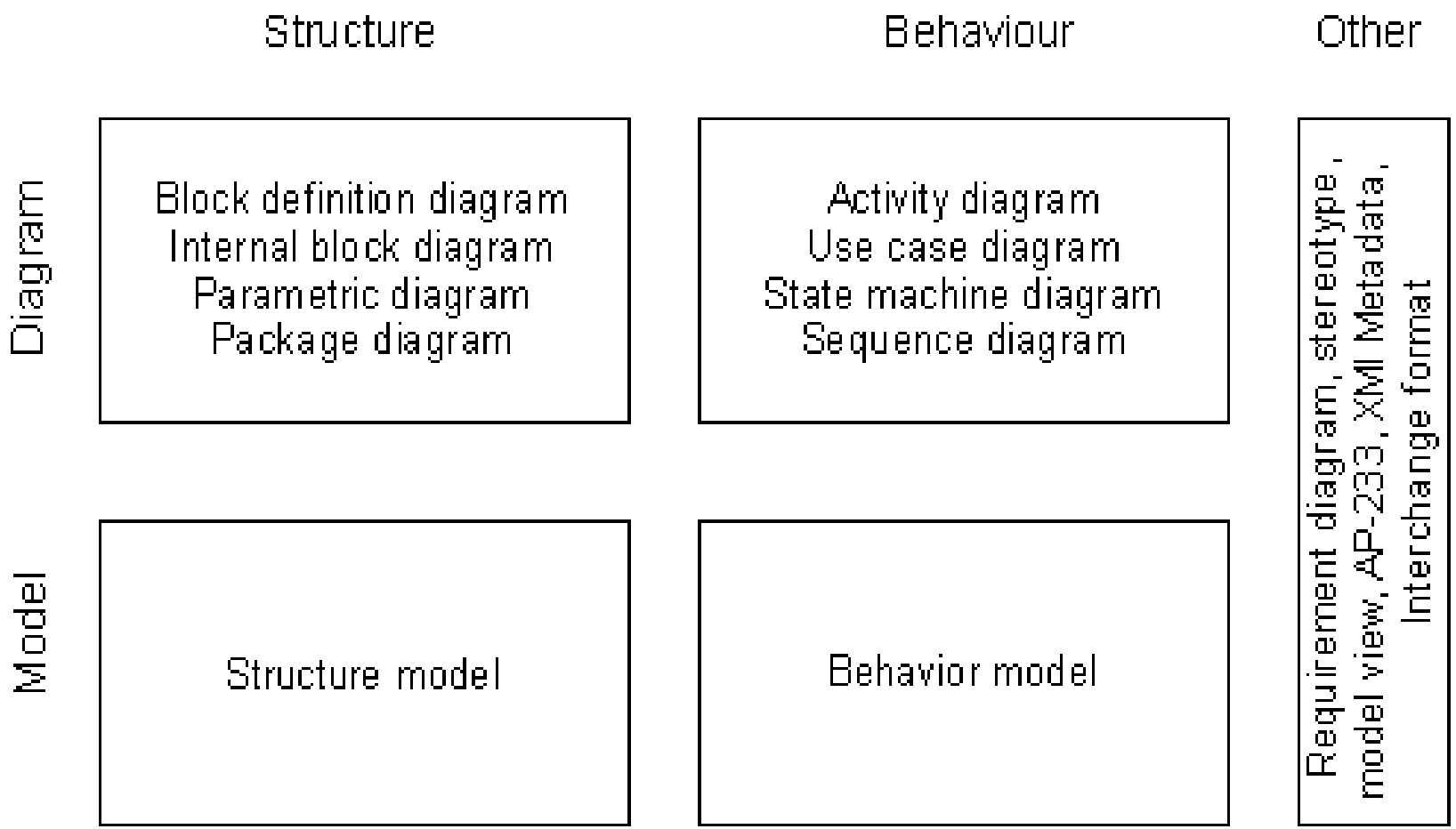
- **Motivation**
  - Independent from particular simulation package (beneficial for customers, bad for vendors?)
  - Improved model generation (standard components, standard interfaces)
  - Improved validation (standard components, well-defined semantics)
  - *Simulation education*

- **Standard(s) for Simulation Modeling Language**
  - Existing (quasi) standards? (military domain, interoperability standards, Modelica, DEVS, ...)
  - Develop new ML?
  - Use existing (general) ML (UML, SysML, BPEL, ...)?
  - General or domain specific language (DSL)?

Simulation Modeling Standard

- **SysML**
  - Already an OMG standard (v1.2, June 2010)
  - Used in industry (mainly aviation industry)
  - Editors, frameworks, transformation libraries available
  - Flexible, extensible, supports development of DSL
  - But: Semantics not always 100% clear (bad for automated model transformation)

SysML Overview



Simulation Modeling Standard

- **DSL for discrete logistics systems**
  - Close to terminology of experts in target domain
  - According to “products, processes, and resources” modeling approach
    - Jobs refer to a particular product which refers to a particular production process
    - Processes are split into steps/activities
    - Activities require resources to be executed

Simulation Modeling Standard

- **No SysML simulators available yet**
  - No adequate concept of time and space in SysML
  - Additional transformation effort needed

- **To be implemented**
  - Transformation rules from system data model to SysML model
  - Transformation rules from SysML model to (executable) model of particular simulation package
- **Requirements**
  - Meta models of real system, SysML. and target simulator have to match
  - Transformation rules for several simulation packages

Model Transformation

Biggest Challenge:

Validation of the transformation mechanism

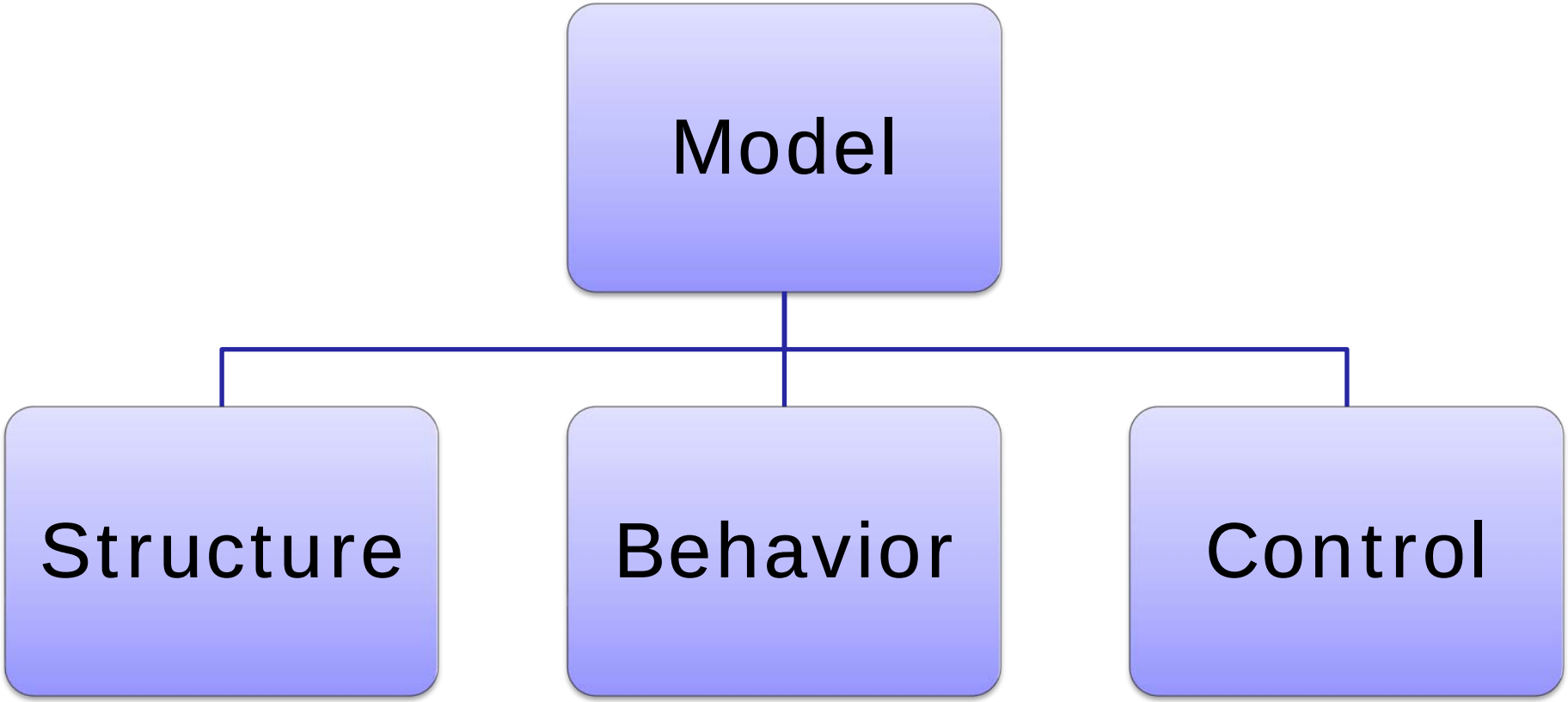
- Rules given explicitly/descriptive:
  Graph grammars
  - Validation approaches available for rather limited transformations
  - Not sufficient/applicable for industrial modeling cases

- Rules given implicitly/imperative:
  Program code
  - Only informal validation
  - Set of test models, comparison of (small) source and target models

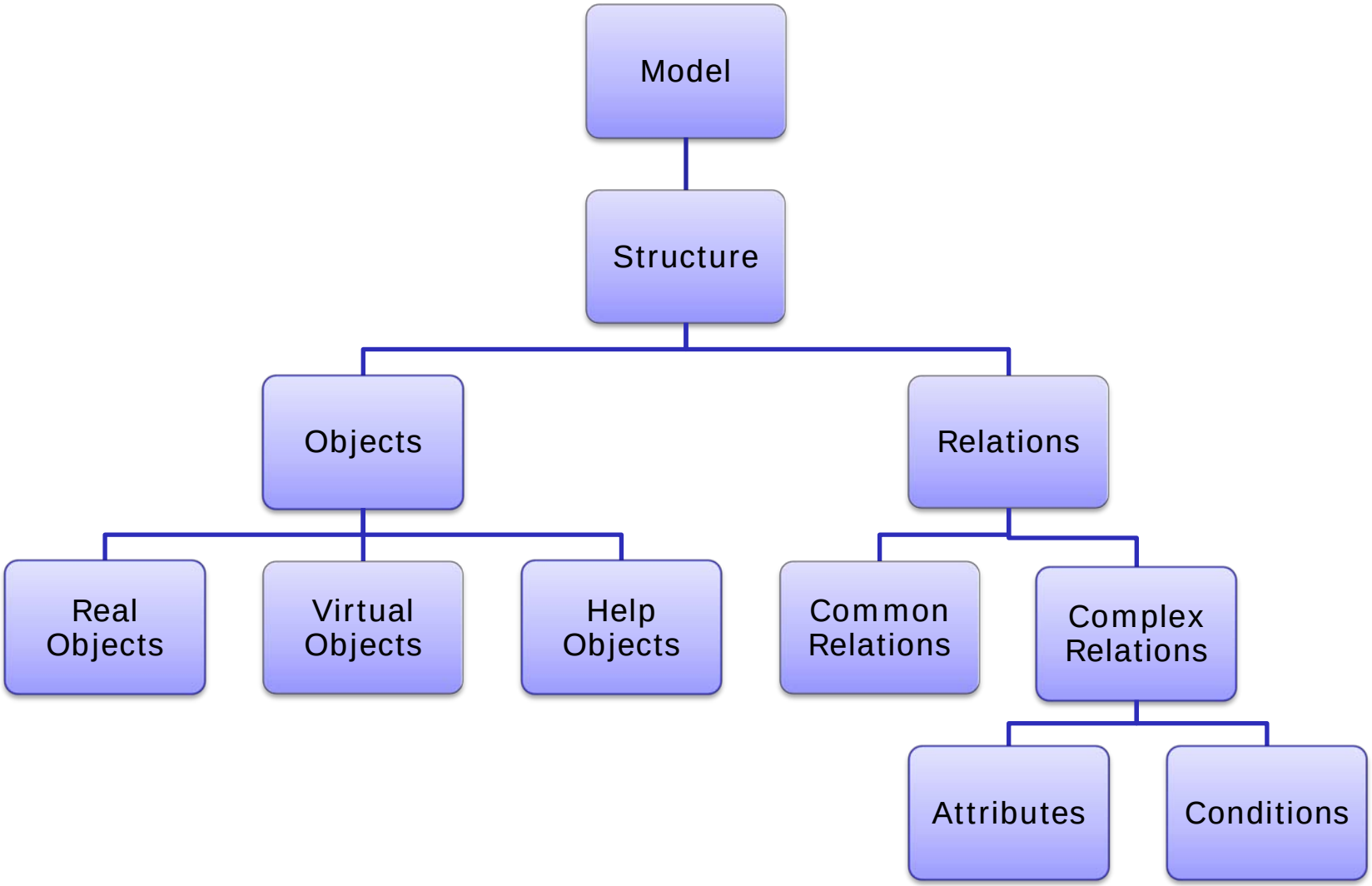
Domain Specific Languages

- Where to put the knowledge about the domain?
  - **Meta model**, user model, transformation, ...?
- Which components are domain specific?
  - Hopefully not too many
- Minimum set of general components?
  - Again: hopefully not too many
- Terminology/semantics problems
  - One definition, several terms (e.g. job and lot)
  - One term, several definitions (e.g. capacity)

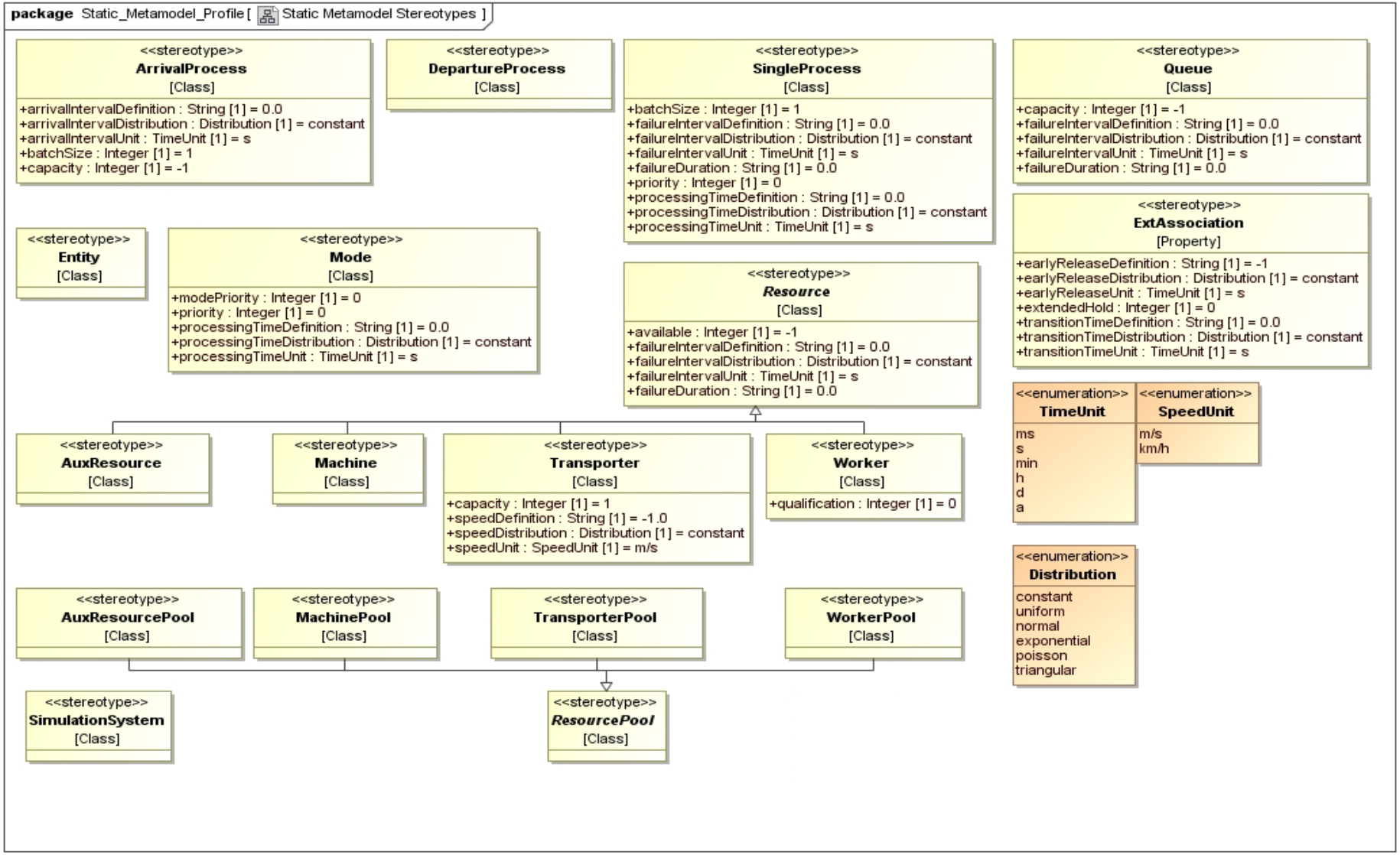
DSL for Discrete Logistics Systems



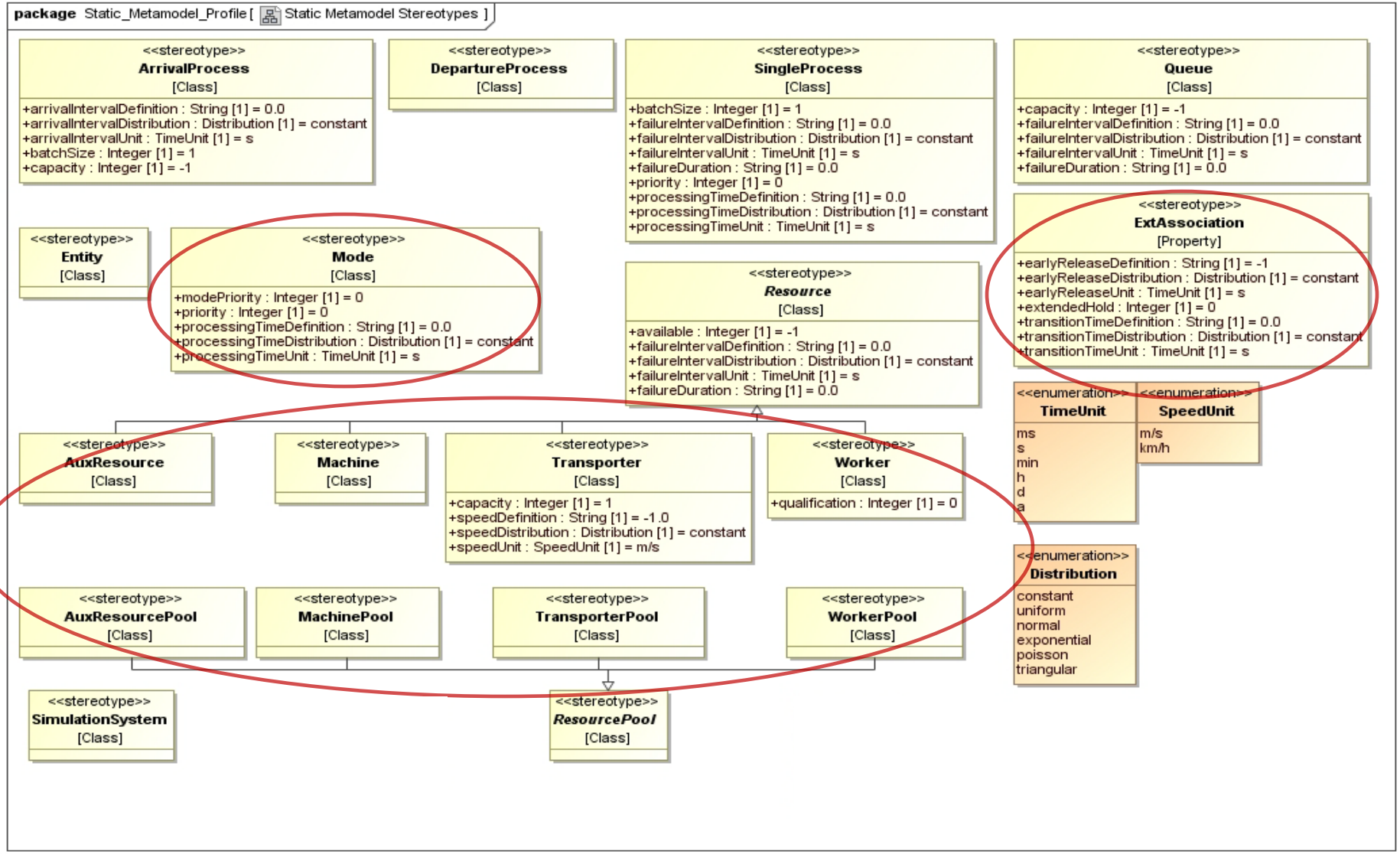
Structural Part



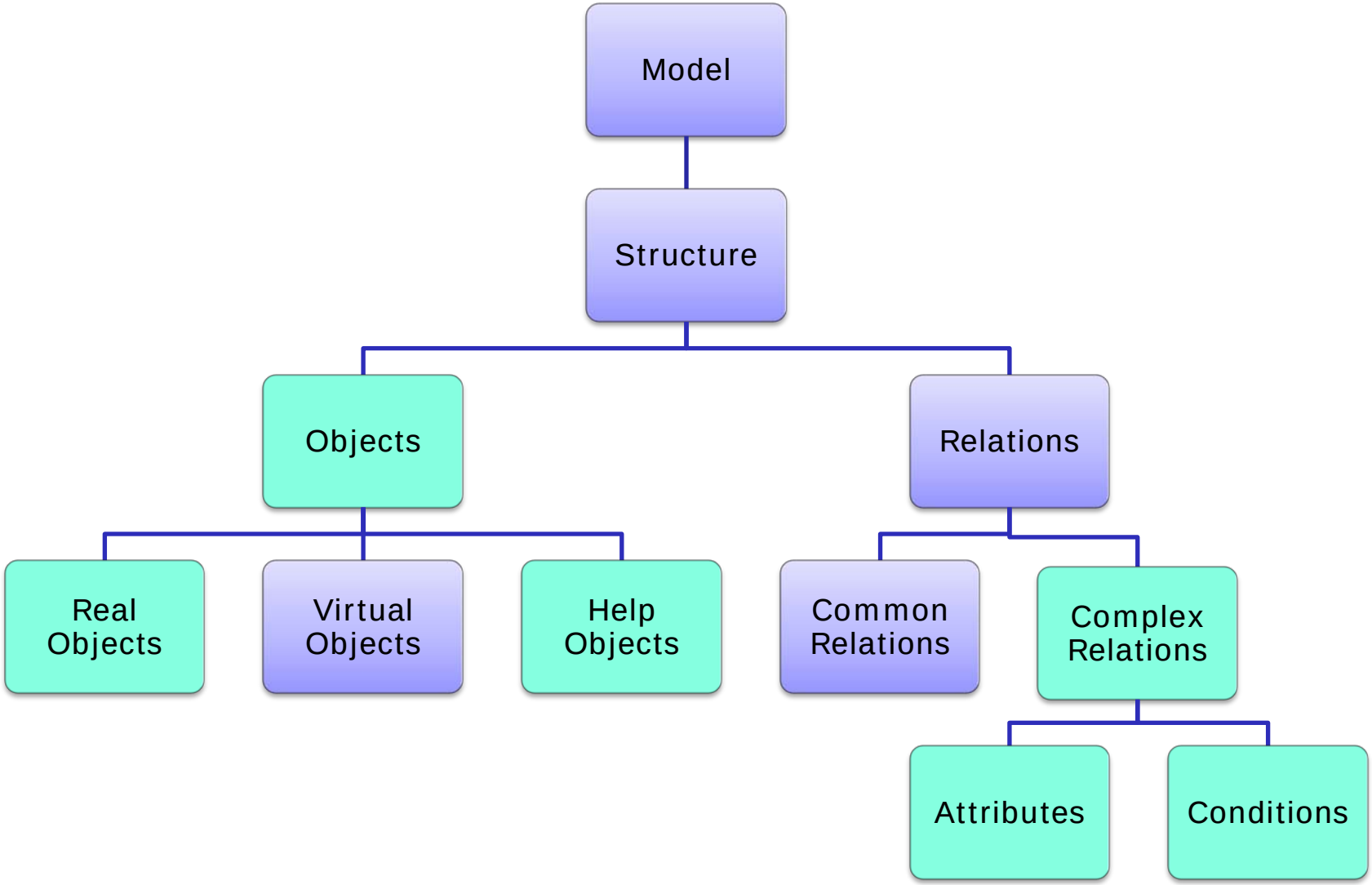
Structure Meta Model for Assembly Lines



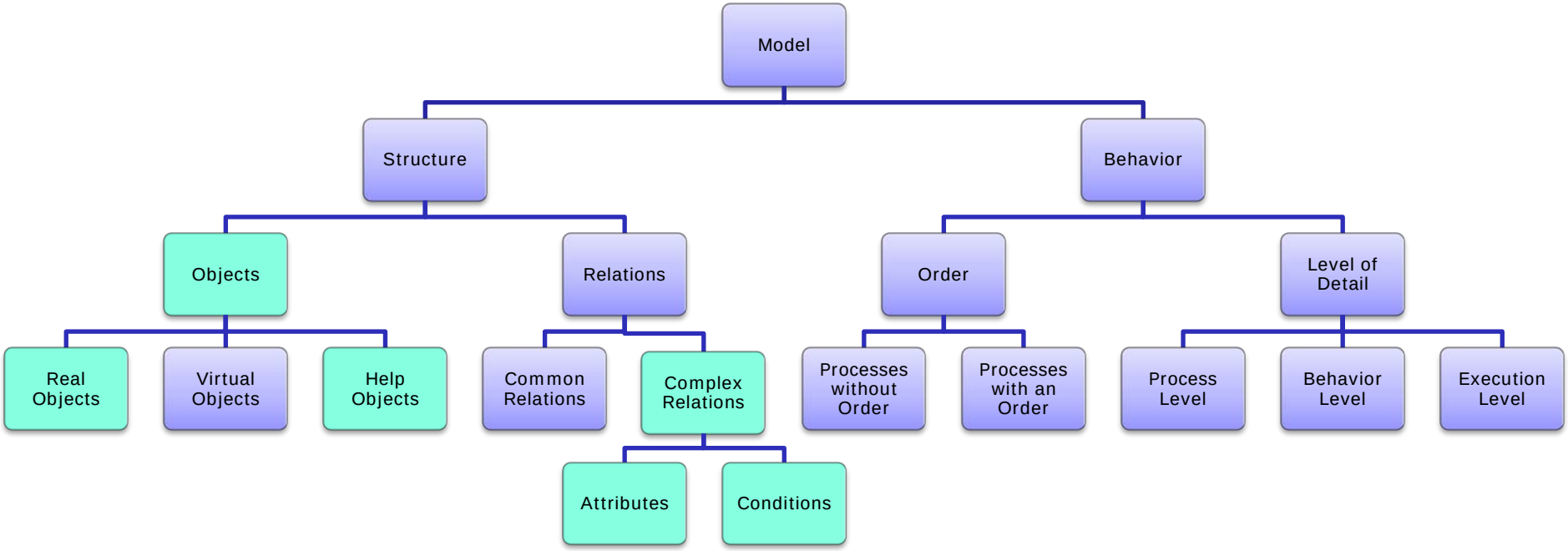
Domain Specific Components



Domain Specific Components



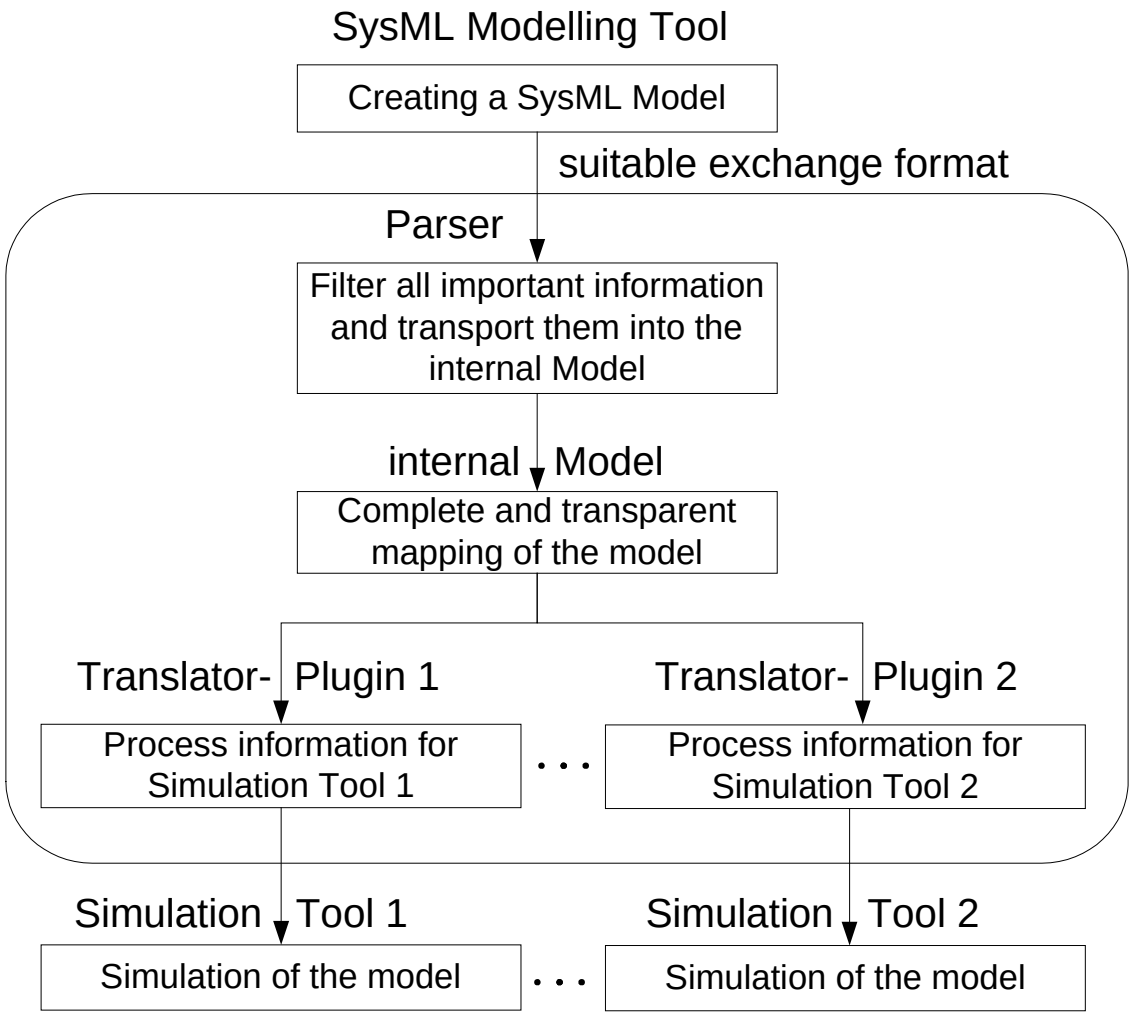
Structure and Behavior



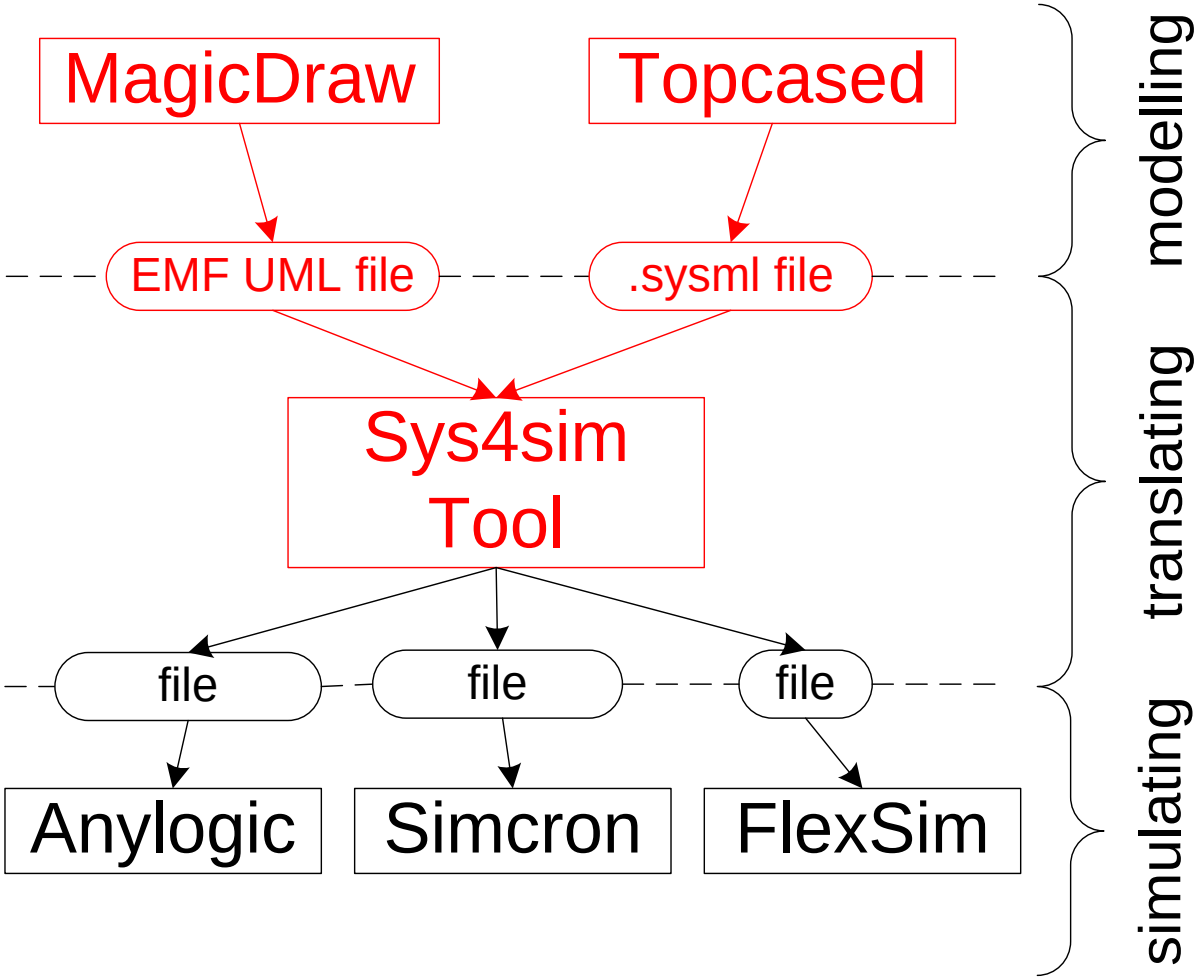
Control

- Typically controller exclusively event-driven
- Implementation of a generic event handling mechanism
- Standardized interface for data transfer
  - Export parameters to controller
  - Import results from controller
- Description of the controller algorithms (open research question)
  - SysML?
  - Program or Pseudo Code?
  - Other description language?

Architecture for Model Transformation



Implementation



Current Research

- Transformation (in both directions)
  - Prototype to transform SysML models to Anylogic, Factory Explorer, Flexsim, and Simcron Modeler
  - First results to transform simulation models to SysML

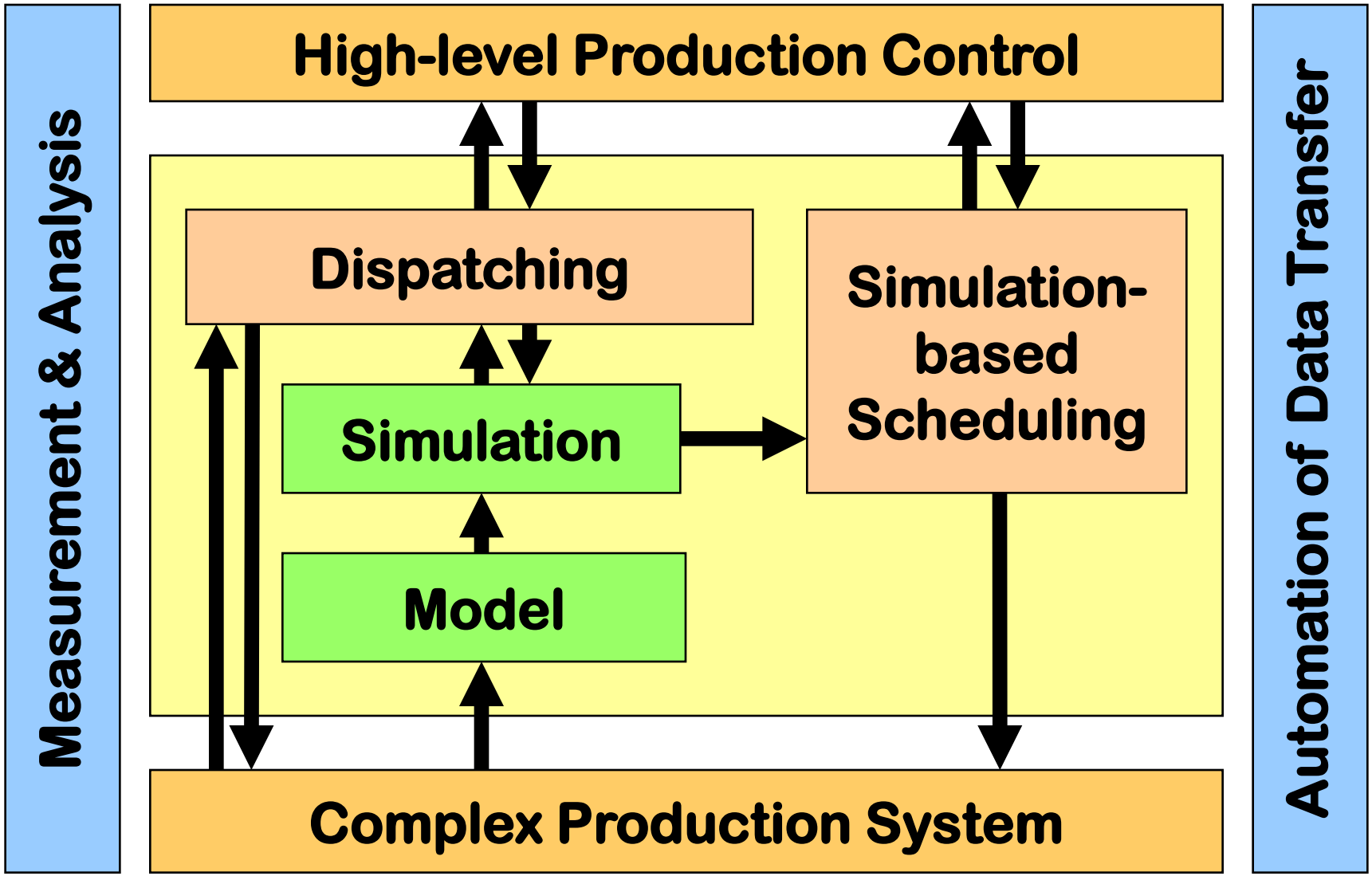
- Development of an improved SysML modeling tool
  - SysML is very powerful and complex
  - Improved usability for engineers needed
  - Working with sets of stereotypes

- Development of a SysML Simulator
  - Simulate SysML model without translation
  - Ideas from executable UML

Summary

- Promising combination of state-of-the-art software engineering technologies (mainly model driven approaches)
- Decoupling of scheduler development from commercial (simulation) products
- Great support from model-to-model transformation research community (lot of know-how but often no real industrial application cases)
- Efficient validation of models and transformation mechanisms still requires a lot of research work

Research Overview



WSC goes Europe!

44th Winter Simulation Conference
Berlin, December 9-12, 2012

First time outside of the US since 1967

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Program Chair:	Lin Uhrmacher
Local Chair:	Markus Rabe