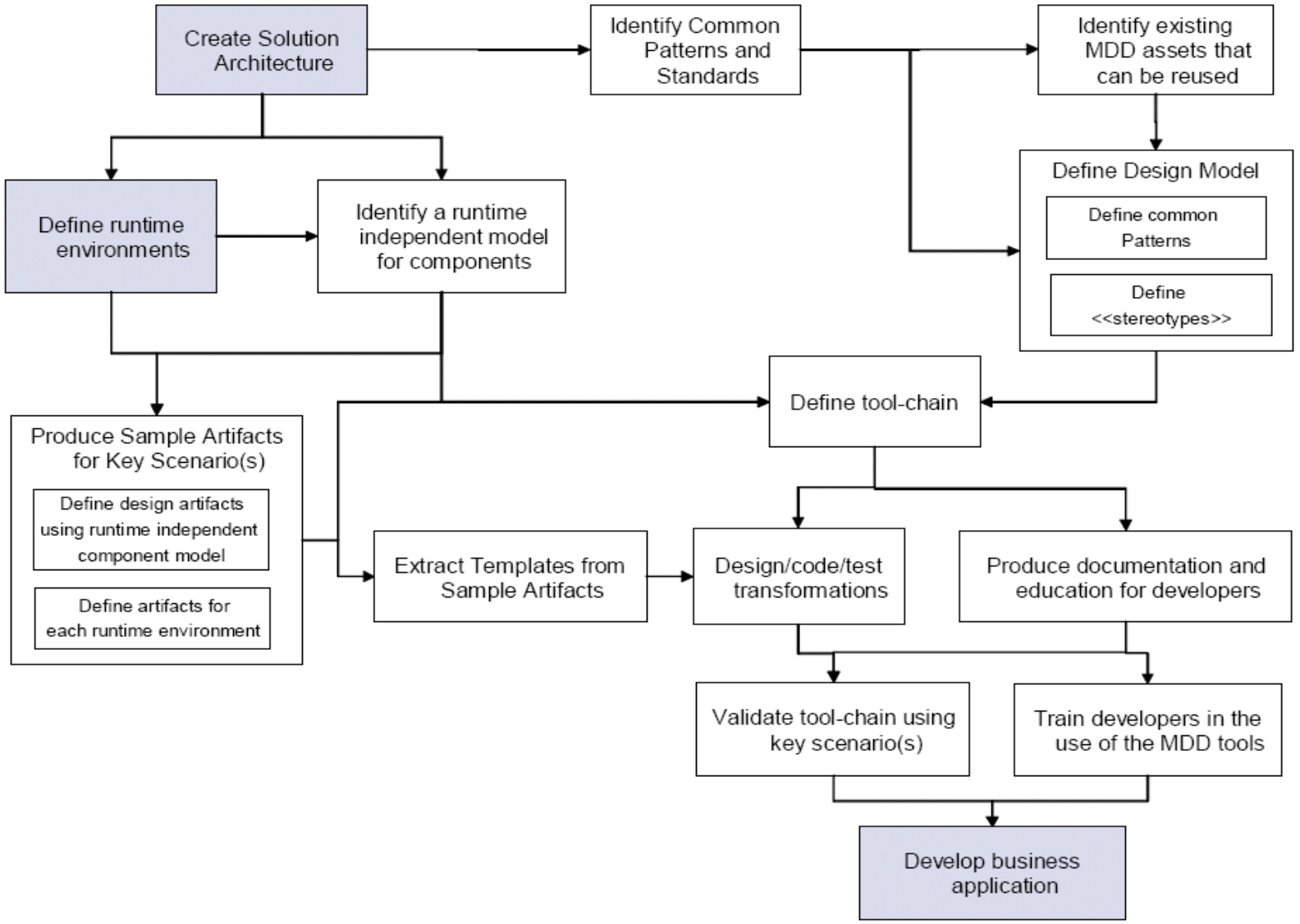
MDSD: Process

- **Changed development process**
  - Two stages of development – infrastructure and application
    - Setting up/developing infrastructure: modelling languages, platform (e.g., frameworks), model transformations, …
    - Application development: modelling, efficient reuse of infrastructure, less coding
  - Simplified application development
    - Automated code generation makes implementation tasks obsolete.
    - Tasks on code level (implementation, test, maintenance, etc.) are drastically reduced.

- **New development tools**
  - Tools for language definition, especially meta-modelling
  - Editors and transformations engines
  - Customizable tools and suites: Model editors, repositories, tools for simulation, verification, and test, etc.

Set-up of MDSD project and tooling



MDSD approaches: A short overview

- **Approaches**
  - Computer-Aided Software Engineering (CASE)
  - Executable UML
  - Model-Driven Architecture (MDA)
  - Architecture-Centric Model Driven Software Development (AC-MDSD)
  - MetaCASE
  - Software Factories

Computer-Aided Software Engineering (CASE)

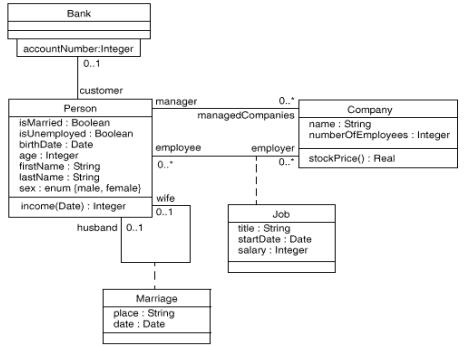
- Historical approach (end of 20th century)
  - Example: Computer Associates' AllFusion Gen
    - Support Information Engineering Method of James Martin through different diagrams types
    - Fully automatic code-generation for 3-tier architecture and some execution platforms (Mainframe, Unix, .NET, J2EE, various databases, …)
    - Advantage/disadvantage: changes to target platform not necessary/possible
- Differences to the basic architecture of MDSD
  - Meta-level description not supported or accessible to modeller
  - General-purpose graphical language representations with tool specific variants
  - Modelling languages mapped poorly onto the underlying platforms
  - No or fixed description of execution platform
- Advantages
  - Productivity, development and maintenance costs, quality, documentation
- Disadvantages
  - Proprietary modelling languages
  - Tools not interoperable and rather complex
  - Support of platforms and new features strongly depends on tool vendors
  - No standardization, no (real) abstraction levels, and DSLs
  - Limited to programs written by a single person or by a team that serializes its access to files

Executable UML

- “CASE with UML”
  - Subset of UML: class diagrams, state charts, component diagrams
  - UML Action Semantic Language (ASL) as programming language
- Niche products
  - Some specialized tool vendors like Kennedy/Carter
  - Used e.g. for developing embedded systems
- Realizes parts of the MDSD basic architecture
  - There is one predefined modelling language (xUML)
  - Transformation definitions can be changed and adapted (with ASL)
- Advantages compared to CASE
  - Standardized modelling language based on UML
- Disadvantages compared to CASE
  - Modelling language has less modelling elements

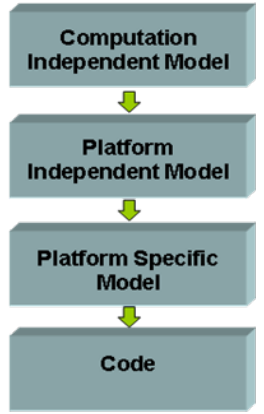
Model-Driven Architecture (MDA)

- MDA is a standard promoted by the OMG
  - A *set of specifications* defined by OMG's open, worldwide process
  - MDA looks at software development from the point of view of models
- *Models* are the core; design is the focus
- MDA supports technology-independent design
- MDA divides domain knowledge and platform knowledge



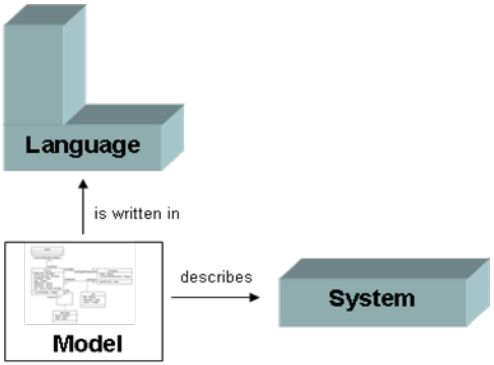
Model-Driven Architecture (MDA): Overview

- *Separates* the operational specification of a system from the details such as how the system uses the platform on which it is developed
- MDA provides the means to
  - *Specify* a system independently of its platform
  - *Specify* platforms
  - Choose a platform for the system
  - *Transform* the system specifications into a platform dependent system
- Three fundamental objectives
  - Portability
  - Interoperability
  - Reuse
  - *Productivity* (derived objective)

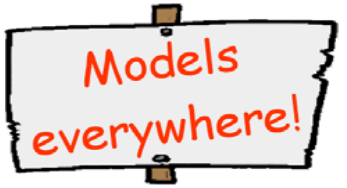


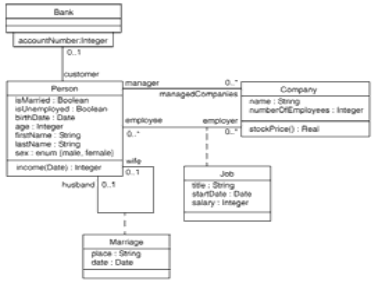
MDA basic elements: Models

- *Cornerstone* of MDA
  - *Abstraction* of reality, different from it, and that can be used for (re)producing such reality
- Expressed in a *well-defined language* (syntax and semantics) which is suitable for automated interpretation



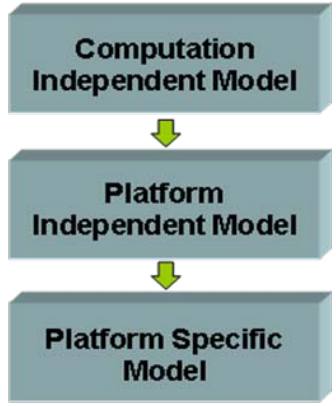
- In MDA, "**everything is a model**"
- One model may describe only part of the complete system
- A model helps
  - Focusing on essentials of a *problem* to better understand it
  - Moving towards an effective *solution*





MDA basic elements: Models

- Types of models
  - **Business models** or Computation Independent Models (**CIM**)
    - Define domains identifying fundamental **business entity types** and the **relationships** between them
    - Say *nothing* about the software systems used within the company
  - **System models**
    - These models are a description of the software system
    - Platform **independent** models (**PIM**)
      - resolves functional requirements through purely problem-space terms.
      - *No platform-specific details* are necessary.
    - Platform **specific** models (**PSM**)
      - It is a *solution model* that resolves both functional and non-functional requirements.
      - A PSM *requires information on specific platform* related concepts and technologies.
    - *Platform independence* is a relative term.

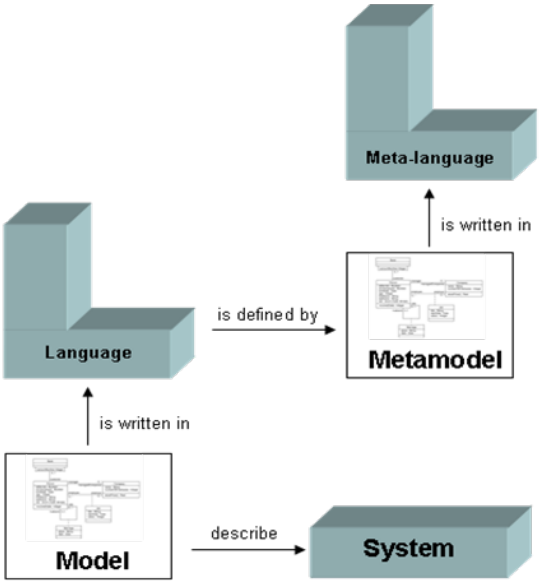


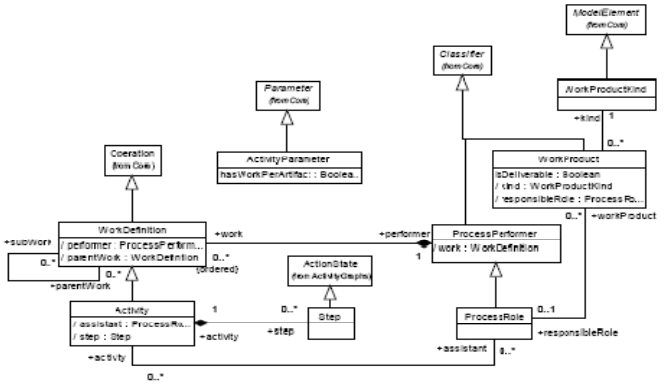
MDA basic elements: Meta-models (1)

- Meta-models allow the exchange of models among modelling tools.

- Meta-models represent specific domain elements.
  - Use of a common terminology
  - Reduce misunderstandings
  - Production of a complete documentation
  - Check of consistent processes
  - Traceability of process artefacts: impact analysis

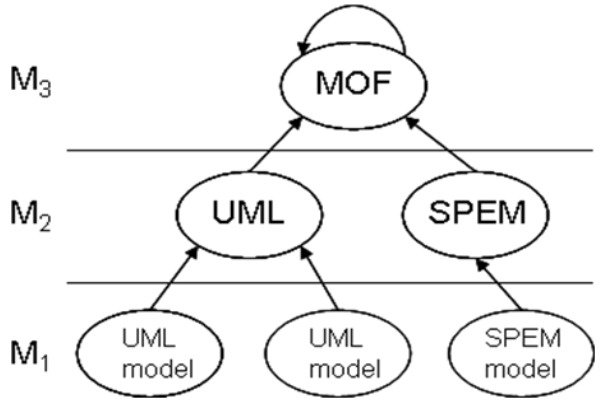
- A **meta-model**
  - is also a *model* and must be written in a well-defined language;
  - defines *structure*, *semantics* and *constraints* for a family of models.



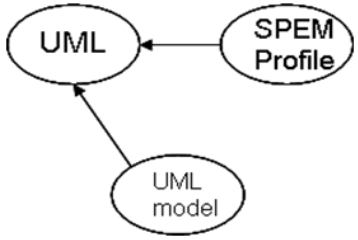


MDA basic elements: Meta-models (2)

- The three-layer architecture
  - (M3) Meta-meta-model
    - One unique meta-meta-model, the *Meta-Object Facility* (**MOF**).
    - It is some kind of “top level ontology”.
  - (M2) Meta-model
    - defines *structure*, *semantics* and *constraints* for a family of models.
  - (M1) Model
    - Each of the models is defined in the language of its *unique meta-model***.**

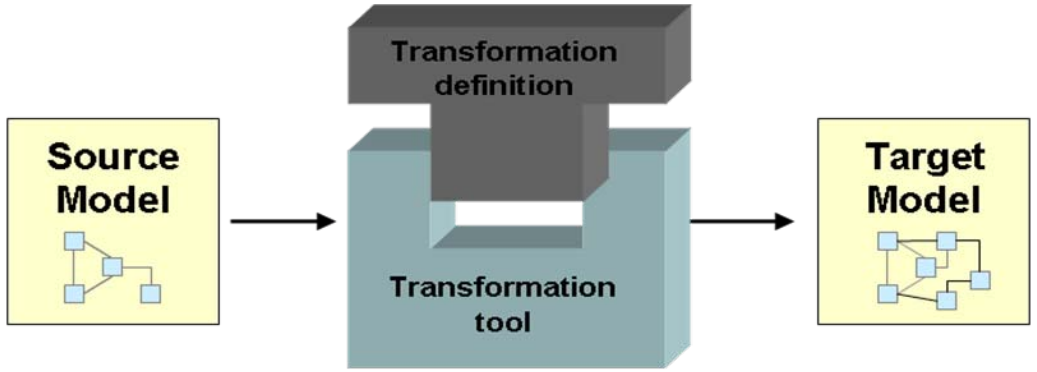


- UML profiles are *adapted modelling languages*.

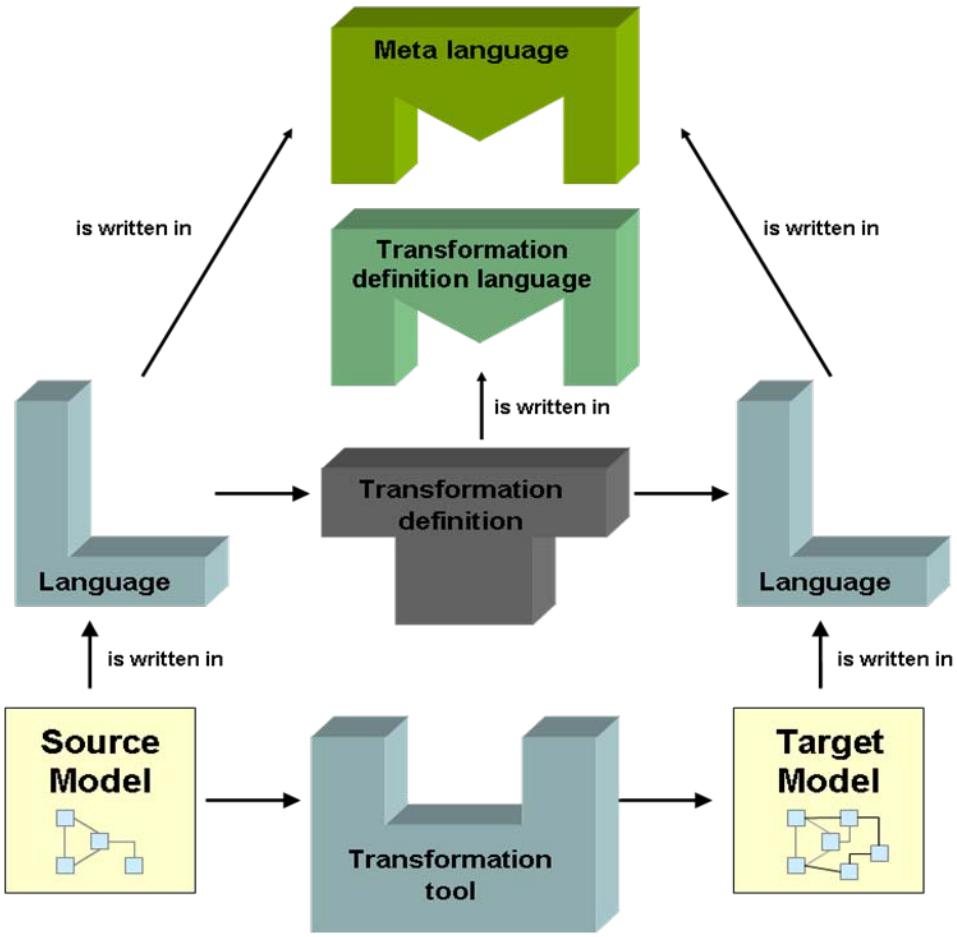


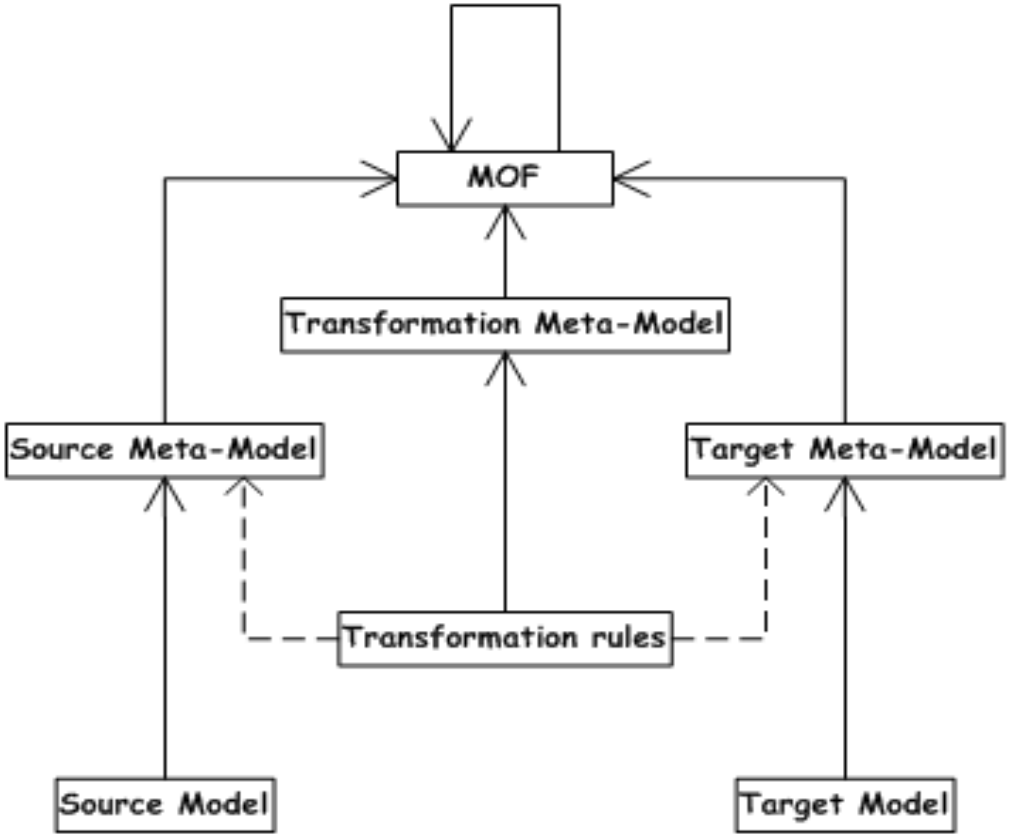
MDA basic elements: Transformations (1)

- A **transformation** is the automatic generation of a *target model* from a *source model*, according to a transformation definition.
- A *transformation definition* is a set of *transformation rules* that together describe *how* a model in the source language can be transformed into a model in the target language.
- A *transformation rule* is a description of how one or more constructs in the source language can be transformed into one or more constructs in the target language.



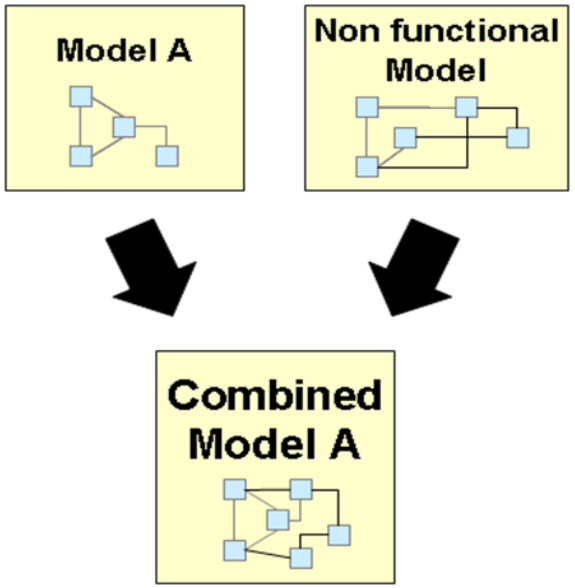
MDA basic elements: Transformations (2)

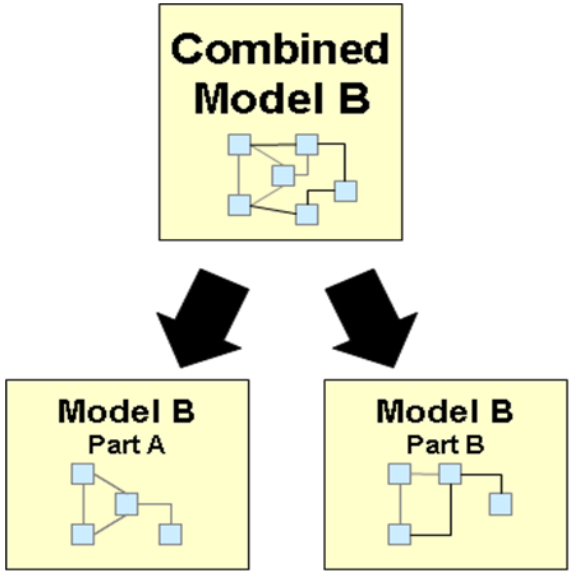




MDA basic elements: Transformations (3)

- **Composition**
  - Special case of transformation
  - allows bringing new details or “aspects” into a model.
  - allows splitting functionality across several platforms.

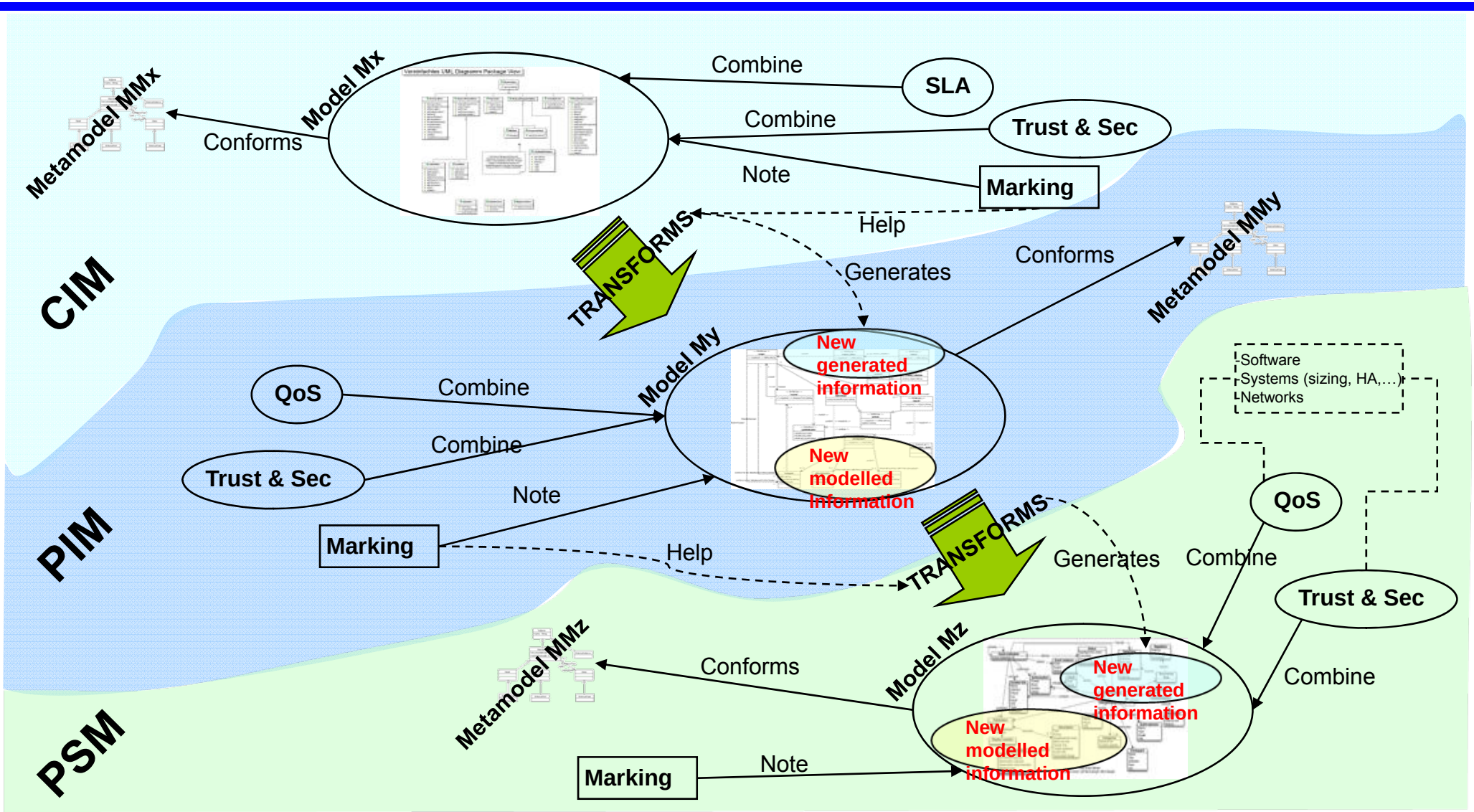




MDA technologies and standards

- **MOF**: Meta-modelling language, repository interface (JMI), interchange (XMI)
- **UML**: Standard modelling language; instance of the MOF model; for developers and "meta-developers"
- **CWM**: modelling languages for data warehousing applications (e.g. Relational DBs)
- **OCL**: expression language, extends the expressive power of UML and MOF
- **QVT**: Transformations definition language; also for Queries and Views of models.
- **SPEM**: metamodel and a UML profile used to describe a concrete software development process.

MDA development process



Architecture-Centric Model Driven Software Development

- Efficient reuse of architecture
  - Focus on efficient reuse of infrastructure/frameworks (= architecture) for multiple applications
  - Concrete methodology
    - Development of reference architectures
    - Analysis of code that is individual, has schematic repetitions, or is generic
    - Extraction of necessary modelling concepts and definition of modelling language, transformations, and platform
    - Tool support (e.g. www.openarchitectureware.org)
- Advantages to MDA
  - Supports development of individual platforms and modelling languages
- Disadvantages to MDA
  - Little support for portability

MetaCASE/MetaEdit+

- Individual configurable CASE
  - Metamodeling for developing domain-specific languages (DSLs)
  - Focuses on best support of application domain (intentional programming for e.g. cell phone software)
  - Methodology defined through DSL development
- Good (meta-)modelling support
  - Good meta-modelling support, incl. graphical editors
  - No separated support for platform development, but suggests to use components and frameworks
- Advantage
  - Domain-specific modelling
- Disadvantages
  - Tool support focused on graphical modelling
  - No tool interoperability, since proprietary M3-level (meta-meta-model)

Software Factories

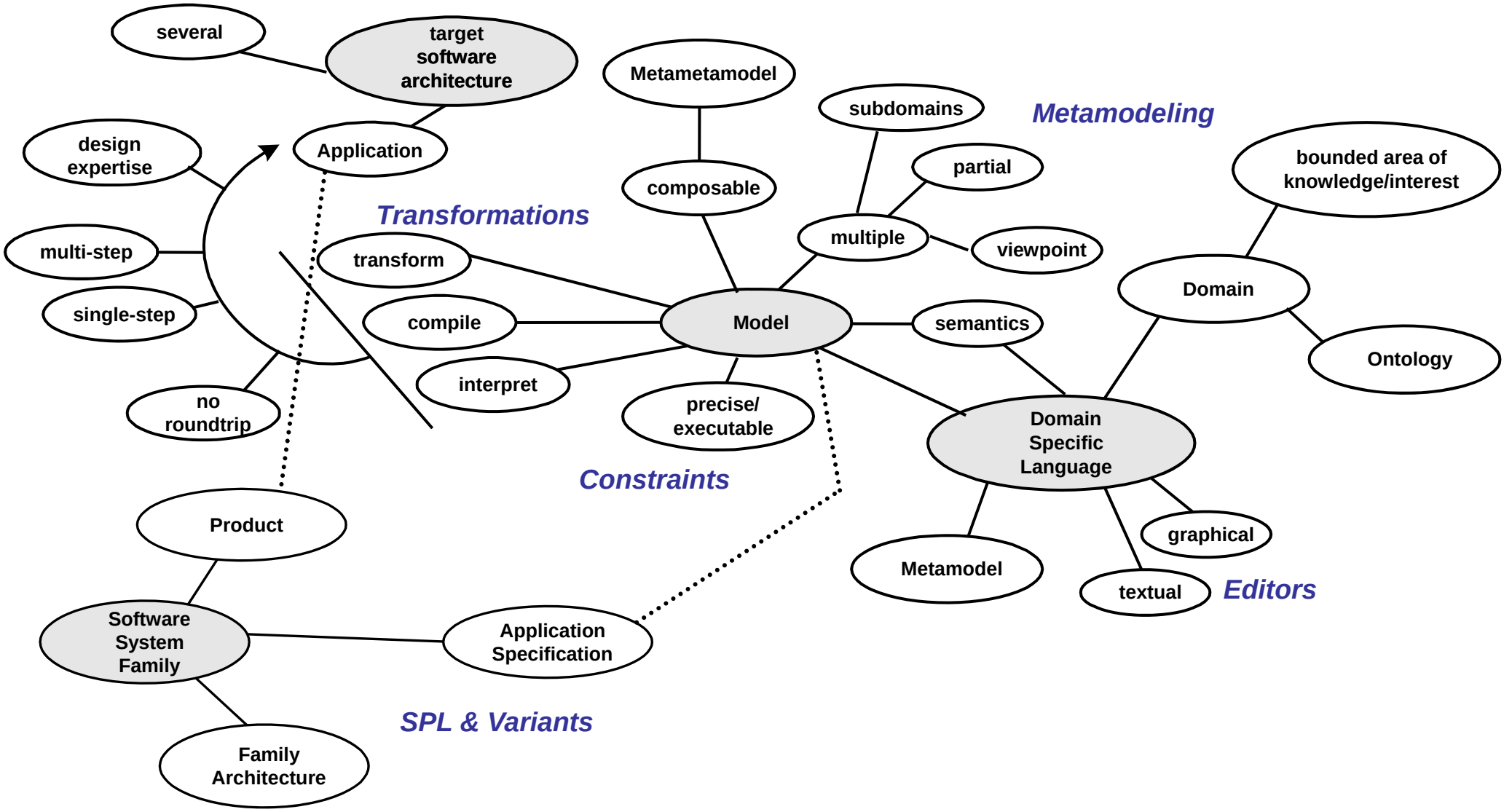
- (Industrial) manufacturing of software products
  - Combines ideas of different approaches (e.g. MDA, AC-MDSD, MetaCASE/DSLs) as well as common SW-engineering technologies (patterns, components, frameworks)
  - Objective is to support the development of software product lines (SPLs) through automation, i.e. a set of applications with a common application domain and infrastructure
  - "A **software factory** is a **software product line** that **configures extensible tools**, processes, and content […] **automates** the development and maintenance of variants of an archetypical product by **adapting, assembling, and configuring framework-based components**."
- Advantages
  - Focuses on domain-specific solutions
- Disadvantages
  - Little tool support

Acronyms / Definitions

- MDE: Model-Driven Engineering
- ME: Model Engineering
- MBDE: Model-Based Data Engineering
- MDA: Model-Driven Architecture
- MDD: Model-Driven Development
- MDSD: Model-Driven Software Development
- MDSE: Model-Driven Software Engineering
- MM: Model Management
- ADM: Architecture-Driven Modernization
- DSL: Domain-Specific Language
- DSM: Domain-Specific Modelling
- etc.

- MDE is a generic term.
- ME and MDSE more or less synonyms of MDE
- MDA™ and MDD™ are OMG trademarks; MDD is a protection trademark (no use as of today/just reserved by OMG for future use).
- MDSD like MDE is sometimes used instead of MDD when one does not wish to be associated to OMG-only technology, vocabulary and vision.
- ADM is another standard intended to be the reverse of MDA: MDA covers forward engineering while ADM covers backward engineering.
- MM mainly used in data engineering like MBDE
- DSM is more Microsoft marked but of increasing use by the academic and research community.

Map of MDSD concepts



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