CHAPTER 2 - MDSE Principles

Software Methodologies
for Distributed Systems

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MDSE aim at large

- MDSE considers models as first-class citizens in software engineering
- The way in which models are defined and managed is based on the actual needs that they will address.
- MDSE defines sound engineering approaches to the definition of
  - » models
  - » transformations
  - » development process

Concepts
Principles and objectives

- Abstraction from specific realization technologies
  - » Requires modeling languages, which do not hold specific concepts of realization technologies (e.g., Java EJB)
  - » Improved portability of software to new/changing technologies – model once, build everywhere
  - » Interoperability between different technologies can be automated (so called Technology Bridges)

- Automated code generation from abstract models
  - » e.g., generation of Java-APIs, XML Schemas, etc. from UML
  - » Requires expressive und precise models
  - » Increased productivity and efficiency (models stay up-to-date)

- Separate development of application and infrastructure
  - » Separation of application-code and infrastructure-code (e.g. Application Framework) increases reusability
  - » Flexible development cycles as well as different development roles possible

Benefits of MDSD

- Increased productivity
  - » MDSD increases productivity of software development by generating code and artifacts from models
  - » Careful planning needs to ensure that there is an overall cost reduction

- Maintainability
  - » MDSD helps to develop maintainable architectures where changes are made rapidly and consistently, enabling more efficient migration of components onto new technologies.
  - » Keeping the high-level models free of implementation detail makes it easier to handle changes in the underlying platform technology and its technical architecture
  - » A change in the technical architecture of the implementation is made by updating a transformation

- Reuse of legacy
  - » One can consistently model existing legacy platforms in UML
  - » Reverse transformations from the components to UML
  - » Migrating the components to a new platform or generating wrappers to enable the legacy component to be accessed via integration technologies such as Web services

Benefits of MDSD

- Adaptability
  - » By using an MDD approach, adding or modifying a business function is quite straight forward since the investment in automation was already made
  - » When adding new business function, one only develops the behavior specific to that capability
  - » The remaining information to generate implementation artifacts was captured in transformations
- Consistency
  - » Manually applying coding practices and architectural decisions is an error prone activity
  - » MDSD ensures that artifacts are generated consistently
- Repeatability
  - » ROI from developing the transformations increases each time they are reused
  - » The use of tried and tested transformations
    - Increases the predictability of developing new functions
    - Reduces the risk since the architectural and technical issues were already resolved

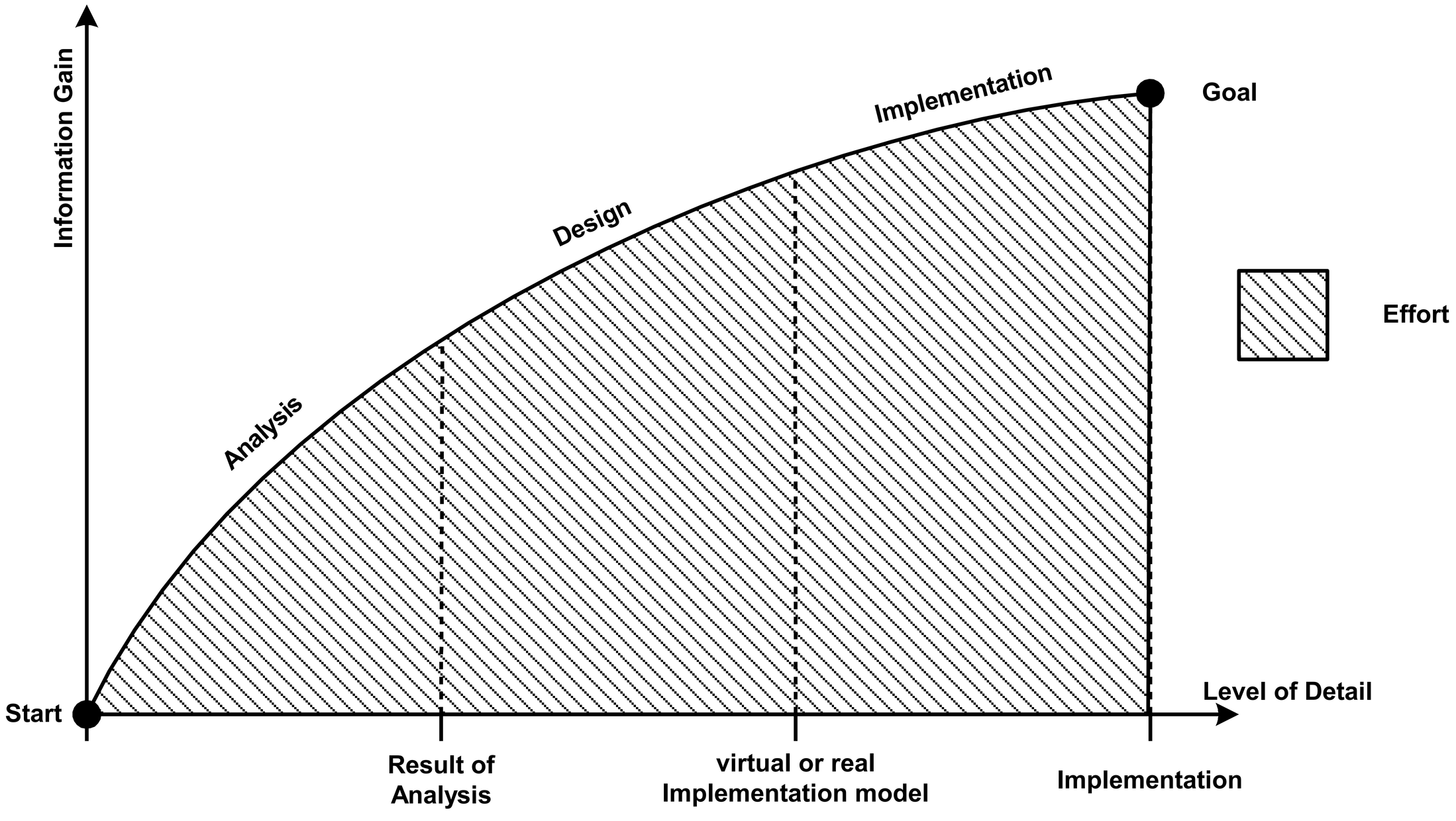
Benefits of MDSD

- Improved stakeholder communication
  - » Models omit implementation detail not relevant to understand the logical behavior of a system
  - » Models are closer to the problem domain reducing the semantic gap between the concepts that are understood by stakeholders and the language in which the solution is expressed
  - » Facilitates the delivery of solutions that are better aligned to business objectives
- Improved design communication
  - » Models facilitate understanding and reasoning about systems at the design level
  - » Improved discussion making and communication about a system
- Expertise capture
  - » Projects or organizations often depend on best practice decisions of key experts
  - » Their expertise is captured in patterns and transformations
  - » When sufficient documentation accompanies the transformations, the knowledge of an organization is maintained in the patterns and transformations

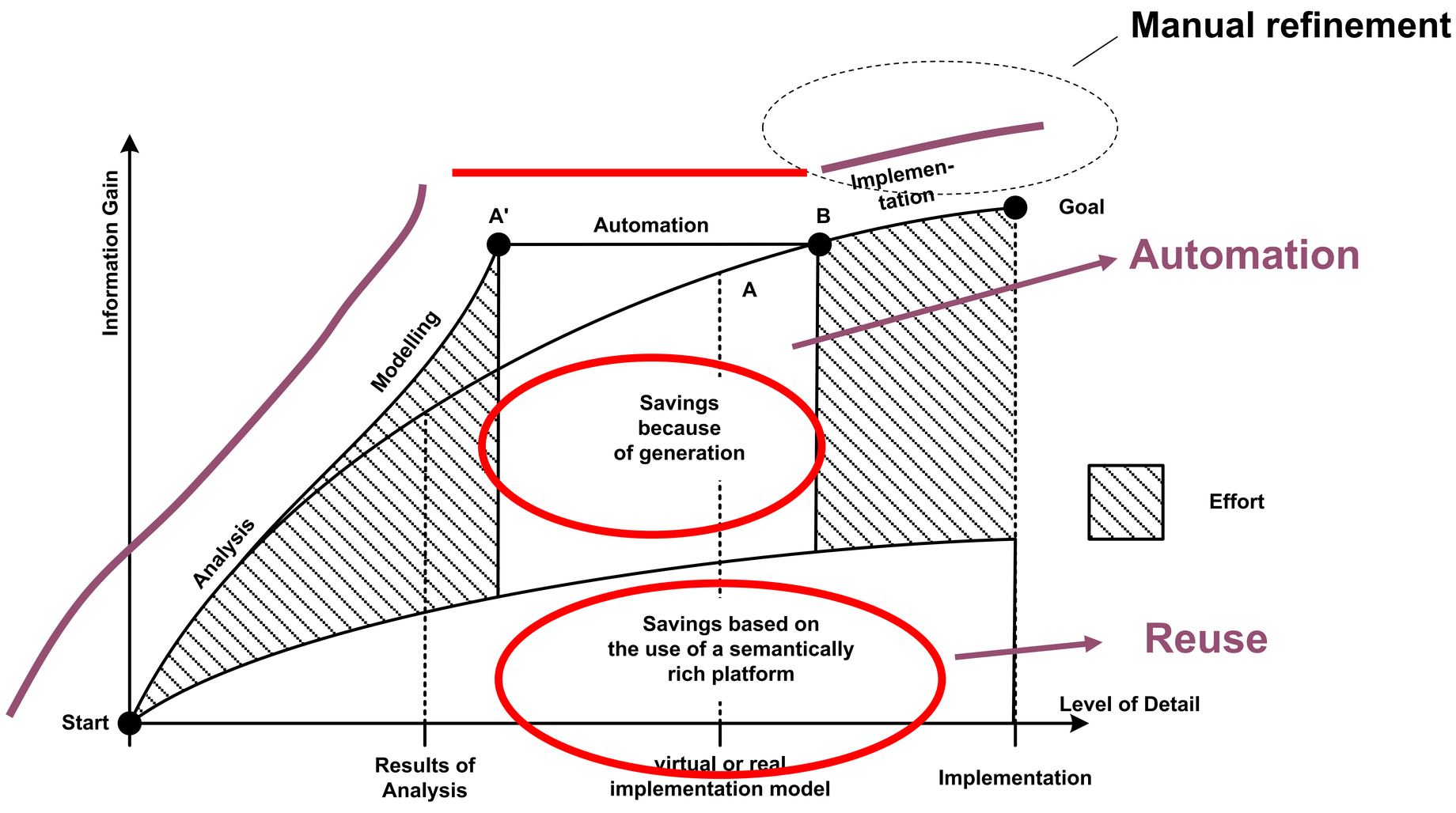
Benefits of MDSD

- Models as long-term assets
  - » In MDSD, models are important assets that capture what the IT systems of an organization do
  - » High-level models are resilient to changes at the state-of-the-art platform level. They change only when business requirements change.
- Ability to delay technology decisions
  - » When using an MDSD approach, early application development is focused on modeling activities
  - » It is possible to delay the choice of a specific technology platform or product version until a later point when further information is available.
  - » This is crucial in domains with extremely long development cycles, such as air traffic control systems

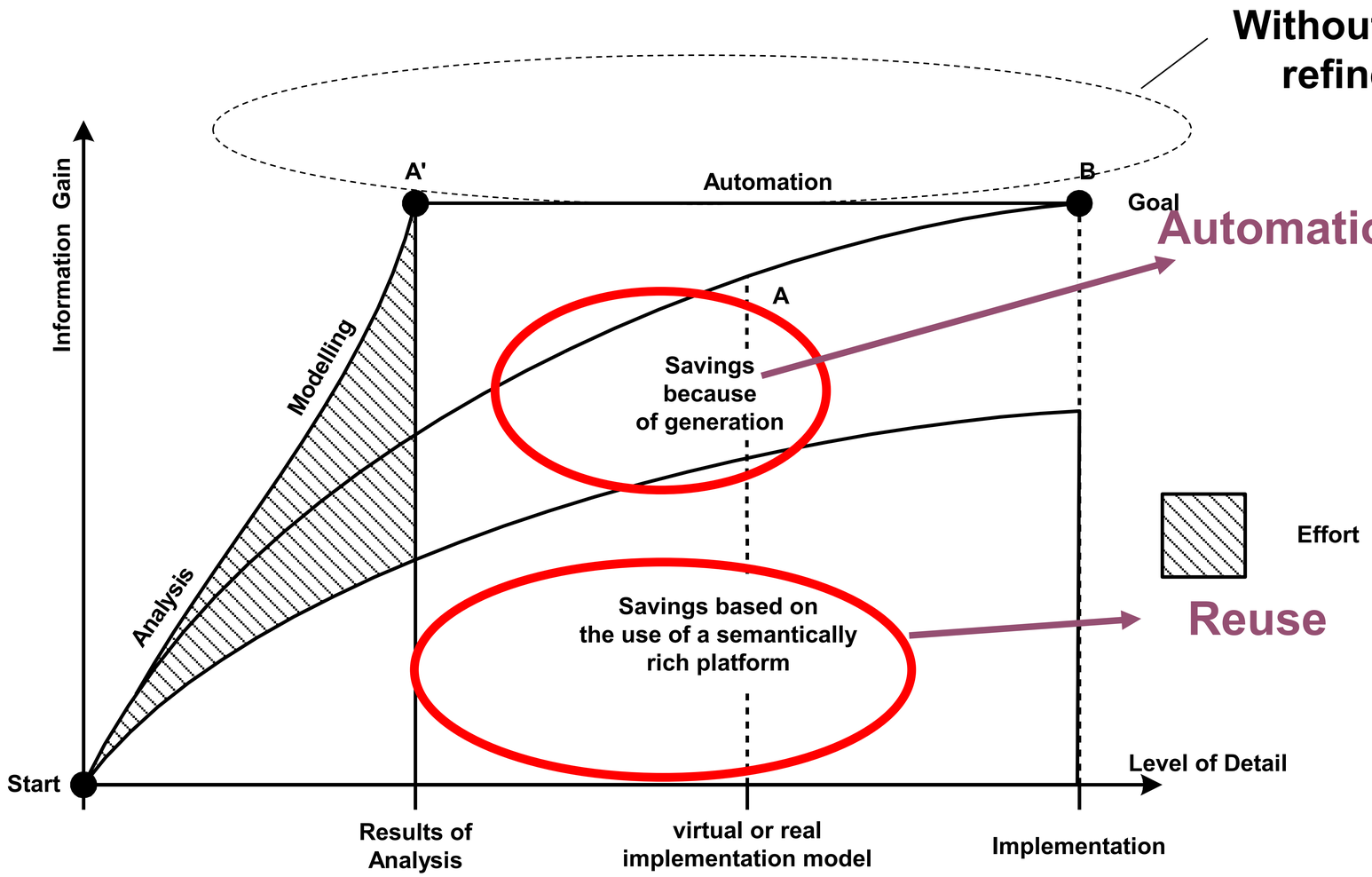
“normal” Software Development



MDSD effort (stage 1)



MDSD effort (stage 2)



MDSE methodology ingredients

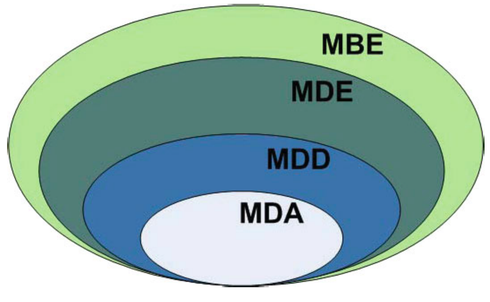
- Concepts: The components that build up the methodology
- Notations: The way in which concepts are represented
- Process and rules: The activities that lead to the production of the final product
- Tools: Applications that ease the execution of activities or their coordination

MDSE Equation

Models + Transformations = Software

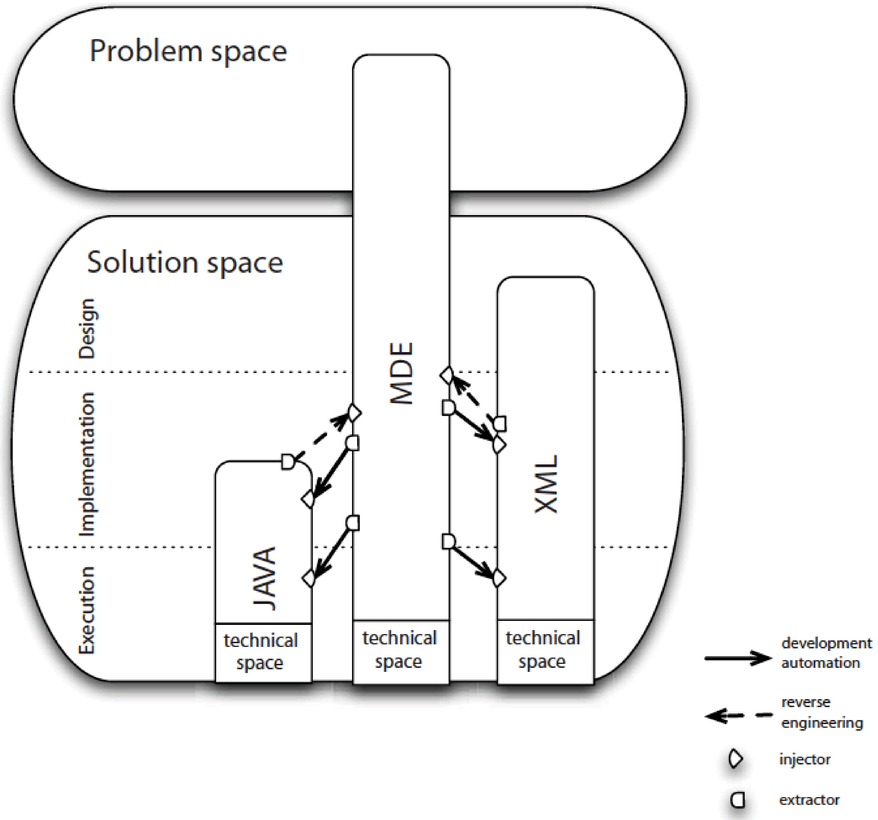
The MD* Jungle of Acronyms

- Model-driven Architecture (MDA) is the particular vision of MDD proposed by the Object Management Group (OMG)
- Model-Driven Development (MDD) is a development paradigm that uses models as the primary artifact of the development process.
- Model-Driven Engineering (MDE) is a superset of MDD because it goes beyond of the pure development
- Model-Based Engineering (or “model-based development”) (MBE) is a softer version of ME, where models do not “drive” the process.



Target of MDSE

- The Problem Domain is defined as the field or area of expertise that needs to be examined to solve a problem.
- The Domain Model is the conceptual model of the problem domain
- Technical Spaces represent specific working contexts for the specification, implementation, and deployment of applications.



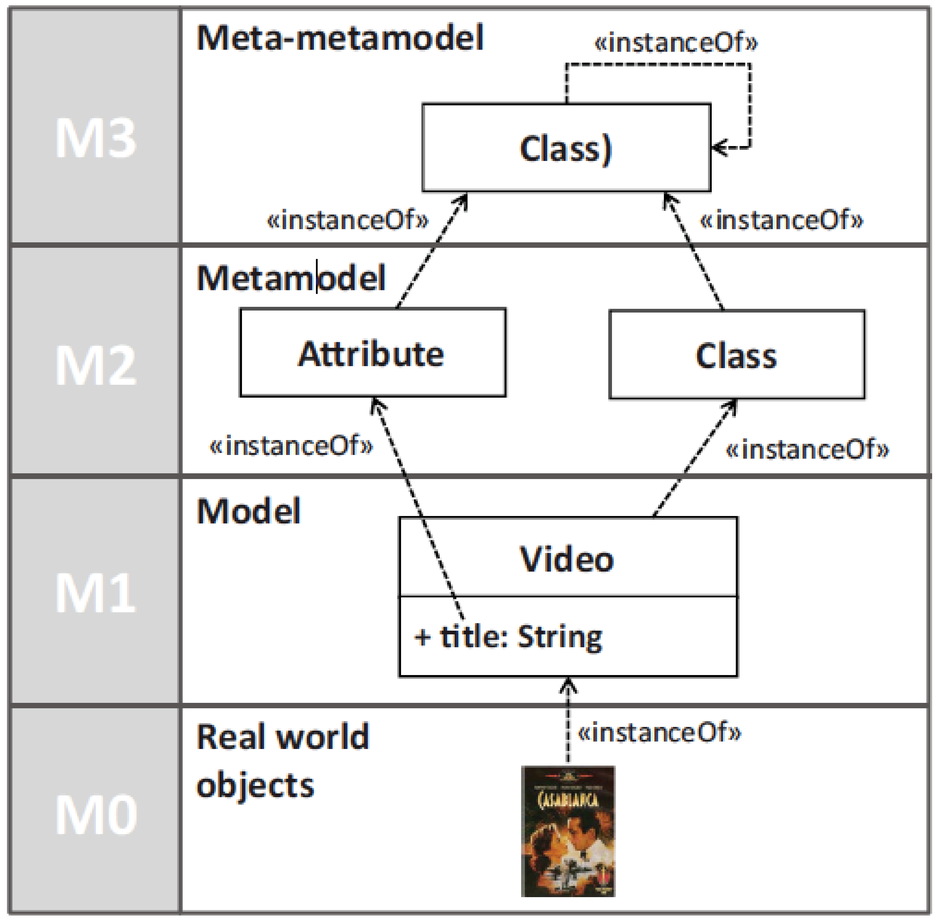
Modeling Languages

- Domain-Specific Languages (DSLs): languages that are designed specifically for a certain domain or context
- DSLs have been largely used in computer science. Examples: HTML, Logo, VHDL, Mathematica, SQL

- General Purpose Modeling Languages (GPMLs, GMLs, or GPLs): languages that can be applied to any sector or domain for (software) modeling purposes
- The typical examples are: UML, Petri-nets, or state machines

Metamodeling

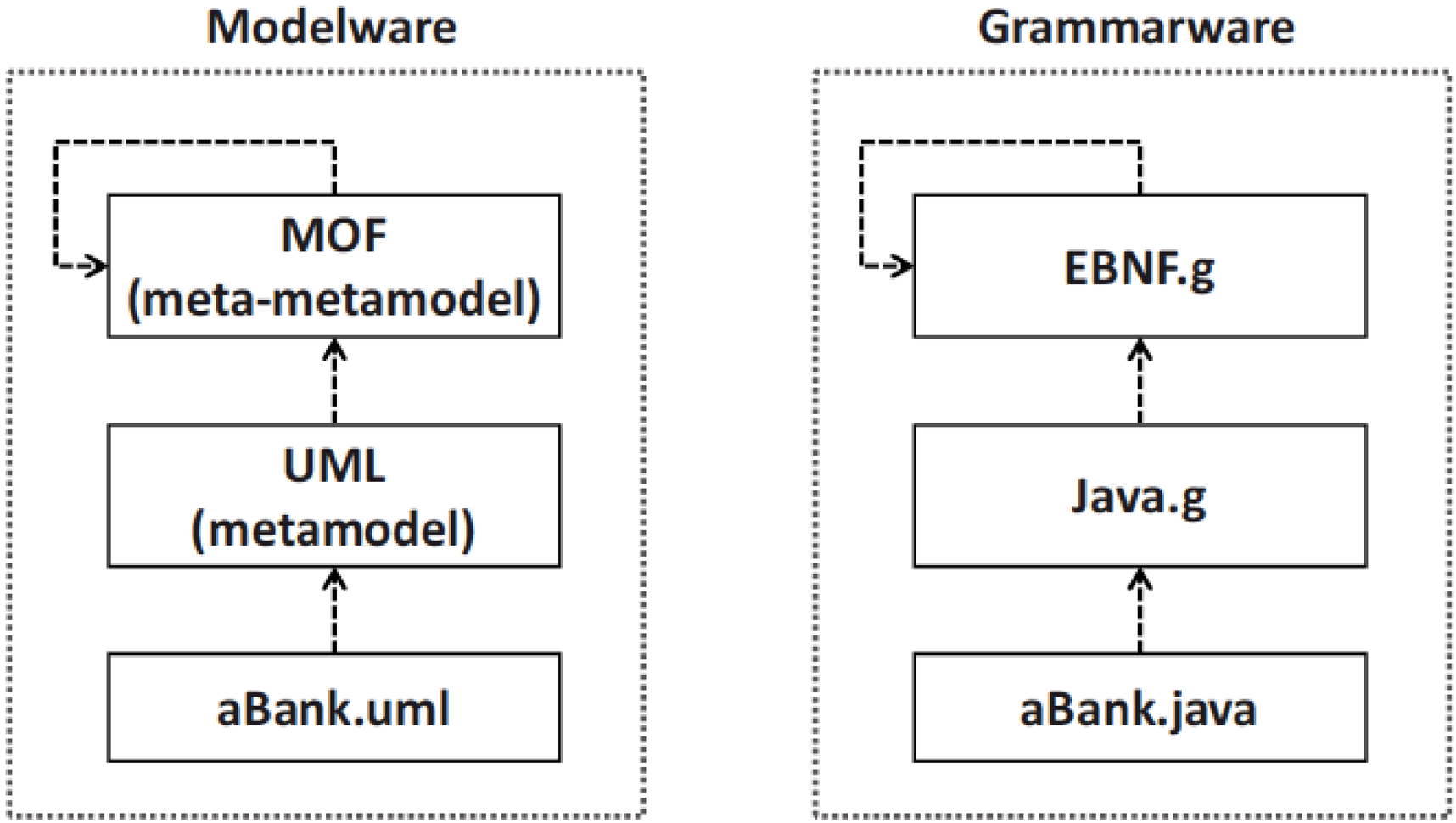
- To represent the models themselves as “instances” of some more abstract models.
- Metamodel = yet another abstraction, highlighting properties of the model itself



- Metamodels can be used for:
  - » defining new languages
  - » defining new properties or features of existing information (metadata)

Modelware vs. Grammarware

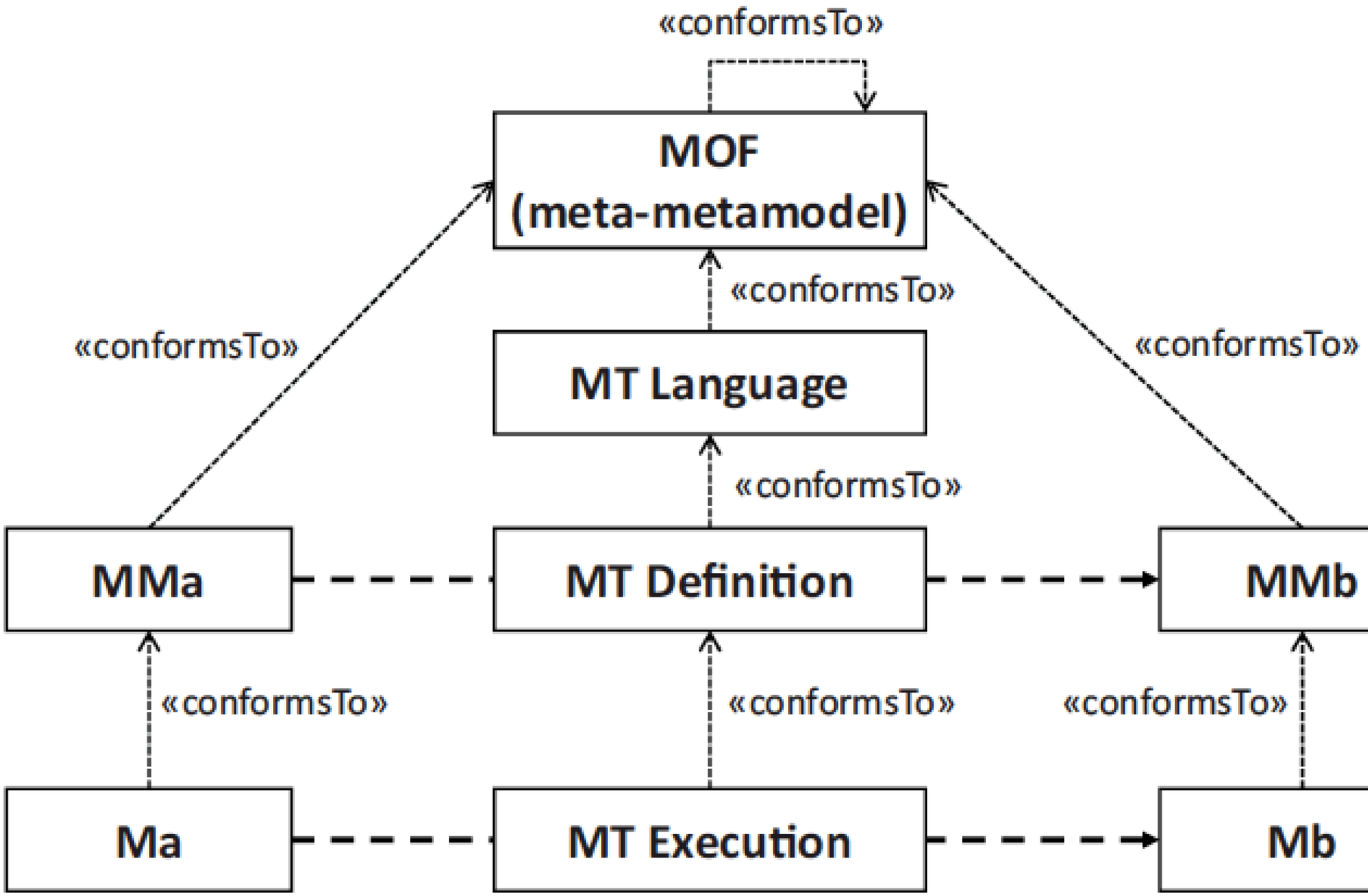
- Two technical spaces



Model Transformations

- Transforming items
- MDSE provides appropriate languages for defining model transformation rules
- Rules can be written manually from scratch by a developer, or can be defined as a refined specification of an existing one.
- Alternatively, transformations themselves can be produced automatically out of some higher level mapping rules between models
  - » defining a mapping between elements of a model to elements to another one (model mapping or model weaving)
  - » automating the generation of the actual transformation rules through a system that receives as input the two model definitions and the mapping
- Transformations themselves can be seen as models!!

Model Transformations



Types of models

- Static models: Focus on the static aspects of the system in terms of managed data and of structural shape and architecture of the system.
- Dynamic models: Emphasize the dynamic behavior of the system by showing the execution

- Just think about UML!

Concepts
Consequences or Preconditions

- Modified development process
  - » Two levels of development – application and infrastructure
    - Infrastructure development involves modeling language, platform (e.g. framework) and transformation definition
    - Application development only involves modeling – efficient reuse of the infrastructure(s)
  - » Strongly simplified application development
    - Automatic code generation replaces programmer
    - Working on the code level (implementation, testing, maintenance) becomes unnecessary
    - Under which conditions is this realistic … or just futuristic?
- New development tools
  - » Tools for language definition, in particular meta modeling
  - » Editor and engine for model transformations
  - » Customizable tools like model editors, repositories, simulation, verification, and testing tools

Approaches Overview

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

- Distinguishing features
  - Special objectives and fields of application
  - Restrictions or extensions of the basic architecture
  - Concrete procedures
  - Specific technologies, languages, tools

Approaches
CASE

- Historic approach (end of 20th century)
- Example: Computer Associates' AllFusion Gen
  - » Supports the Information Engineering Method by James Martin by a series of diagram types (incl. user interface)
  - » Fully automated code generation for one architecture (3-Tier) and plenty of execution platforms (Mainframe, Unix, .NET, J2EE, different databases, …)
  - » Advantage/Disadvantage: no handling with the target platform required/possible
- Different implementation versions of the basic architecture
  - » Meta-Level often not supported / not accessible
  - » Modeling language often fixed, tool specific versions
  - » Execution platform often not considered or fixed
- Advantages
  - » Productivity, development and maintenance costs, quality, documentation
- Disadvantages
  - » Proprietary (version of a) modeling language
  - » Tool interoperability nonexistent
  - » Strongly dependent on the tool vendor regarding execution platforms, further development
  - » Tools are highly complex

Approaches
Executable UML

- “CASE with UML”
  - » UML-Subset: Class Diagram, State Machine, Package/Component Diagram, as well as
  - » UML Action Semantic Language (ASL) as programming language
- Niche product
  - » Several specialized vendors like Kennedy/Carter
  - » Mainly used for the development of Embedded Systems
- One part of the basic architecture implemented
  - » Modeling language is predetermined (xUML)
  - » Transformation definitions can be adapted or can be established by the user (via ASL)
- Advantages compared to CASE
  - » Standardized modeling language based on the UML
- Disadvantages compared to CASE
  - » Limited extent of the modeling language

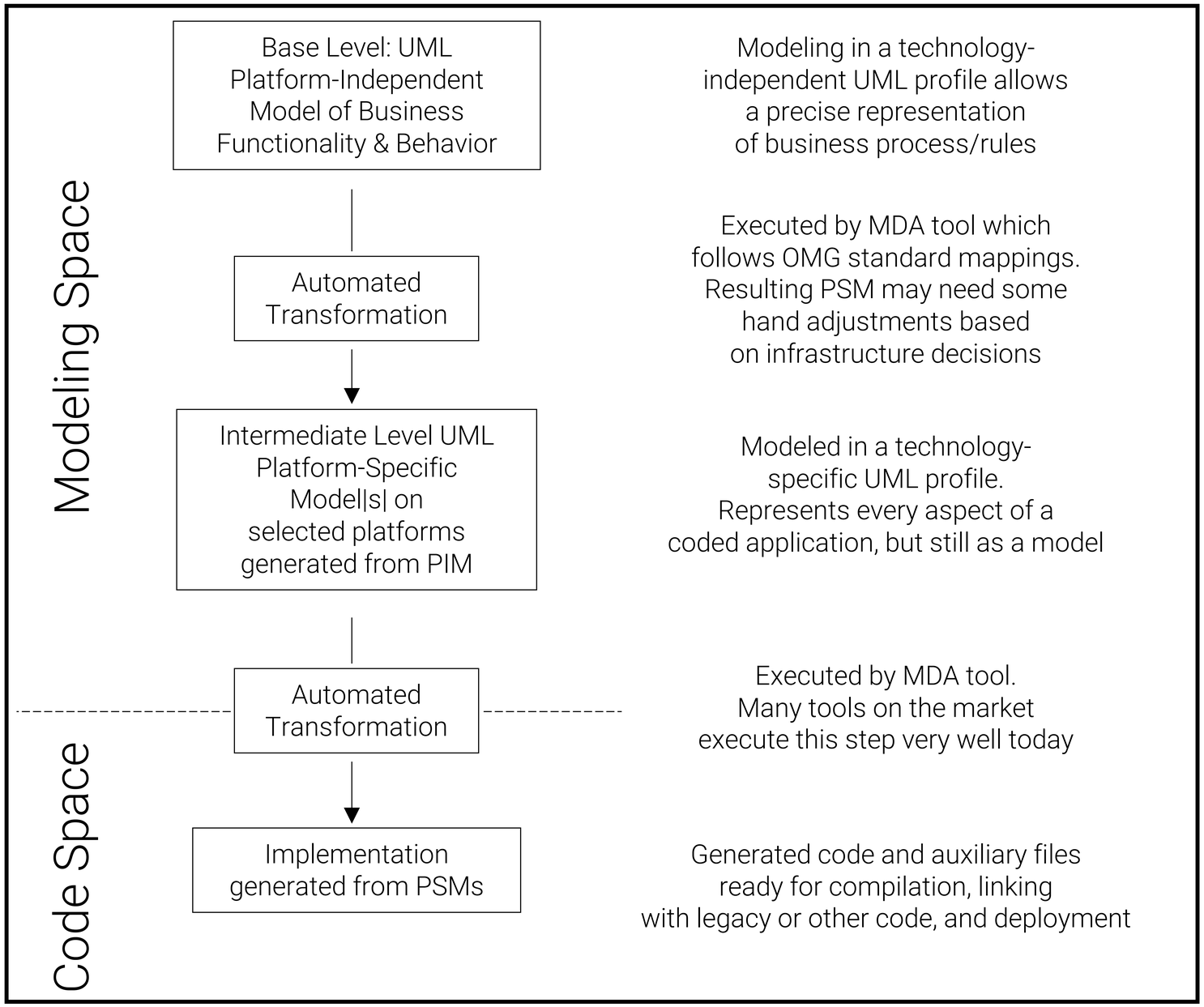
[S.J. Mellor, M.J. Balcer: Executable UML: a foundation for model-driven architecture. Addison-Wesley, 2002]

Approaches
MDA

- Interoperability through platform independent models
  - » Standardization initiative of the Object Management Group (OMG), based on OMG Standards, particularly UML
  - » Counterpart to CORBA on the modeling level: interoperability between different platforms
  - » Applications which can be installed on different platforms → portability, no problems with changing technologies, integration of different platforms, etc.
- Modifications to the basic architecture
  - » Segmentation of the model level
    - Platform Independent Models (PIM): valid for a set of (similar) platforms
    - Platform Specific Models (PSM): special adjustments for one specific platform
  - » Requires model-to-model transformation (PIM-PSM; compare QVT) and model-to-code transformation (PSM-Code)
  - » Platform development is not taken into consideration – in general industry standards like J2EE, .NET, CORBA are considered as platforms

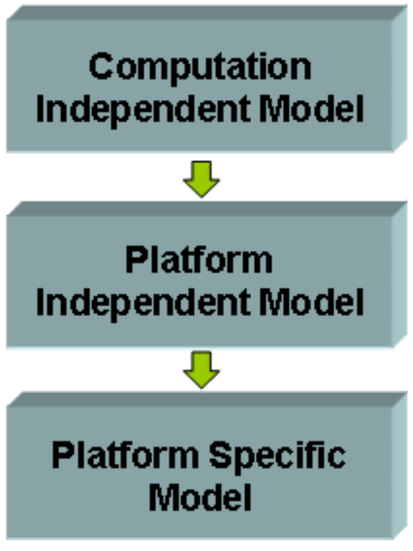
[www.omg.org/mda/]

Approaches
MDA development cycle



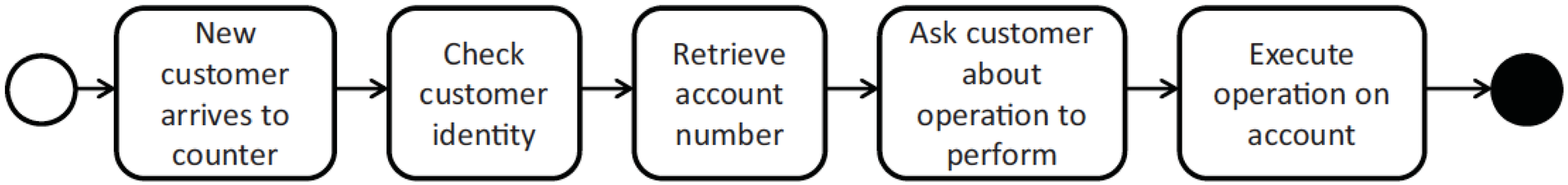
Modeling Levels
CIM, PIM, PSM

- Computation independent (CIM): describe requirements and needs at a very abstract level, without any reference to implementation aspects (e.g., description of user requirements or business objectives);
- Platform independent (PIM): define the behavior of the systems in terms of stored data and performed algorithms, without any technical or technological details;
- Platform specific (PSM): define all the technological aspects in detail.



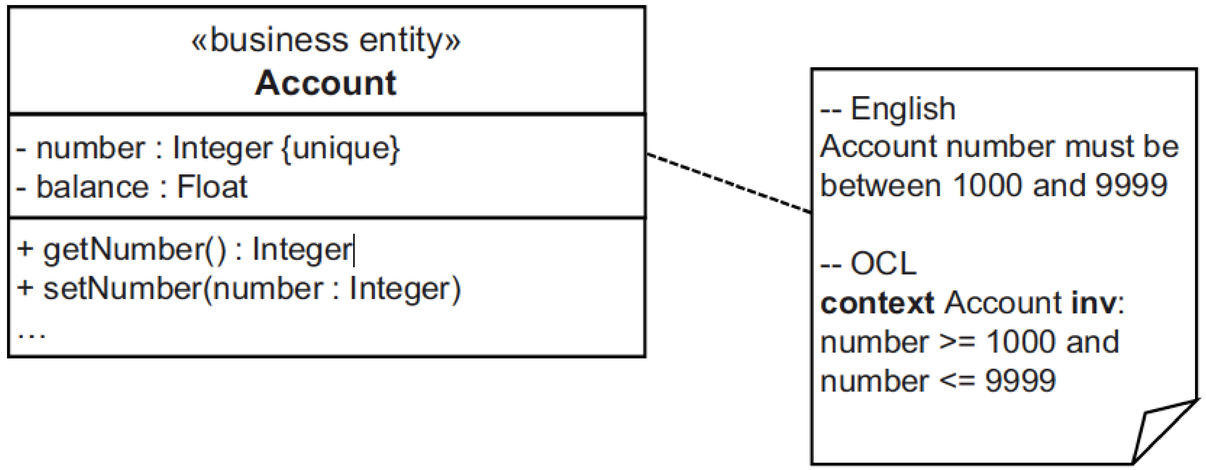
Modeling levels - MDA Computational Independent Model (CIM)

- E.g., business process



Modeling levels
MDA Platform Independent Model (PIM)

- Specification of structure and behaviour of a system, abstracted from technological details

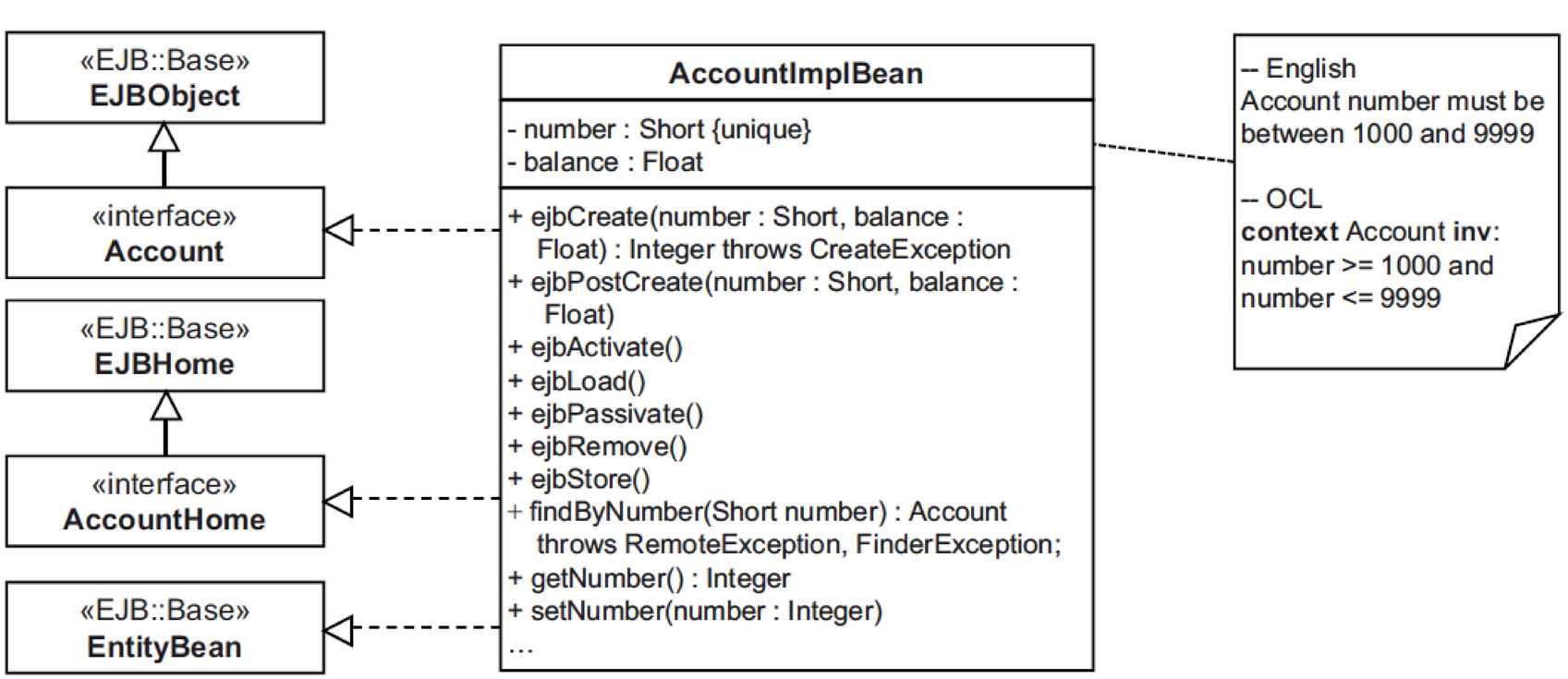


- Using the UML (optional)

- Abstraction of structure and behaviour of a system with the PIM simplifies the following:
  - » Validation for correctness of the model
  - » Create implementations on different platforms
  - » Tool support during implementation

Modeling levels
MDA Platform Specific Model (PSM)

- Specifies how the functionality described in the PIM is realized on a certain platform
- Using a UML-Profile for the selected platform, e.g., EJB



Approaches - MDA with UML

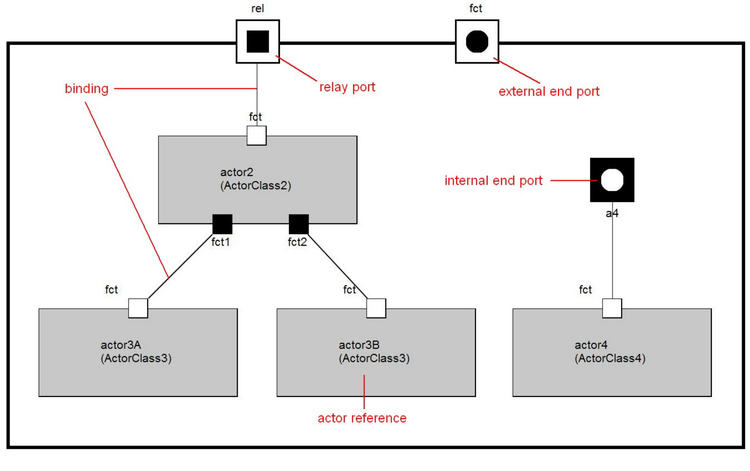
- Problems when using UML as PIM/PSM
  - » Method bodies?
  - » Incomplete diagrams, e.g. missing attributes
  - » Inconsistent diagrams
  - » For the usage of the UML in Model Engineering special guidelines have to be defined and adhered to
- Different requirements to code generation
  - » get/set methods
  - » Serialization or persistence of an object
  - » Security features, e.g. Java Security Policy
  - » Using adaptable code generators or PIM-to-PSM transformations
- Expressiveness of the UML
  - » UML is mainly suitable for “generic” software platforms like Java, EJB, .NET
  - » Lack of support for user interfaces, code, etc.
  - » MDA tools often use proprietary extensions

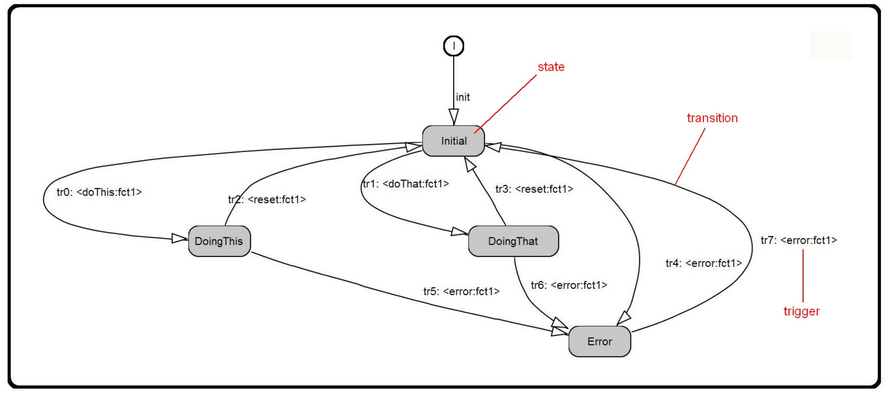
Approaches - MDA

- Many UML tools are expanded to MDA tools
  - » UML profiles and code generators
  - » Stage of development partly still similar to CASE: proprietary UML profiles and transformations, limited adaptability
- Advantages of MDA
  - » Standardization of the Meta-Level
  - » Separation of platform independent and platform specific models (reuse)
- Disadvantages of MDA
  - » No special support for the development of the execution platform and the modeling language
  - » Modeling language practically limited to UML with profiles
  - » Therefore limited code generation (typically no method bodies, user interface)

Approaches - ROOM

- Real-Time Object-Oriented Modeling (ROOM) is a domain specific language
  - » ROOM is a modeling language for the definition of software systems.
  - » complete code generation for the whole system from the model.
  - » textual as well as with graphical notation.
- Typically the generated code is accompanied with manually written code, e.g. for graphical user interfaces (GUI).
- The code is compiled and linked against a runtime library which provides base classes and basic services (e.g. messaging).
- ROOM describes a software system along three dimensions (Wikipedia):
  - » structure,
  - » behavior and
  - » inheritance.





Approaches - AC-MDSD

- Efficient reuse of architectures
  - » Special attention to the efficient reuse of infrastructures/frameworks (= architectures) for a series of applications
  - » Specific procedure model
    - Development of a reference application
    - Analysis in individual code, schematically recurring code and generic code (equal for all applications)
    - Extraction of the required modeling concepts and definition of the modeling language, transformations and platform
  - » Software support (www.openarchitectureware.org)
- Basic architecture almost completely covered
  - » When using UML profiles there is the problem of the method bodies
  - » The recommended procedure is to rework these method bodies not in the model but in the generated code
- Advantages compared to MDA
  - » Support for platform- and modeling language development
- Disadvantages compared to MDA
  - » Platform independence and/or portability not considered

Approaches - MetaCASE/MetaEdit+

- Free configurable CASE
  - » Meta modeling for the development of domain-specific modeling languages (DSLs)
  - » The focus is on the ideal support of the application area, e.g. mobile-phone application, traffic light pre-emption, digital clock – Intentional Programming
  - » Procedural method driven by the DSL development
- Support in particular for the modeling level
  - » Strong Support for meta modeling, e.g. graphical editors
  - » Platform development not assisted specifically, the usage of components and frameworks is recommended
- Advantages
  - » Domain-specific languages
- Disadvantages
  - » Tool support only focuses on graphical modeling

[www.metacase.com]

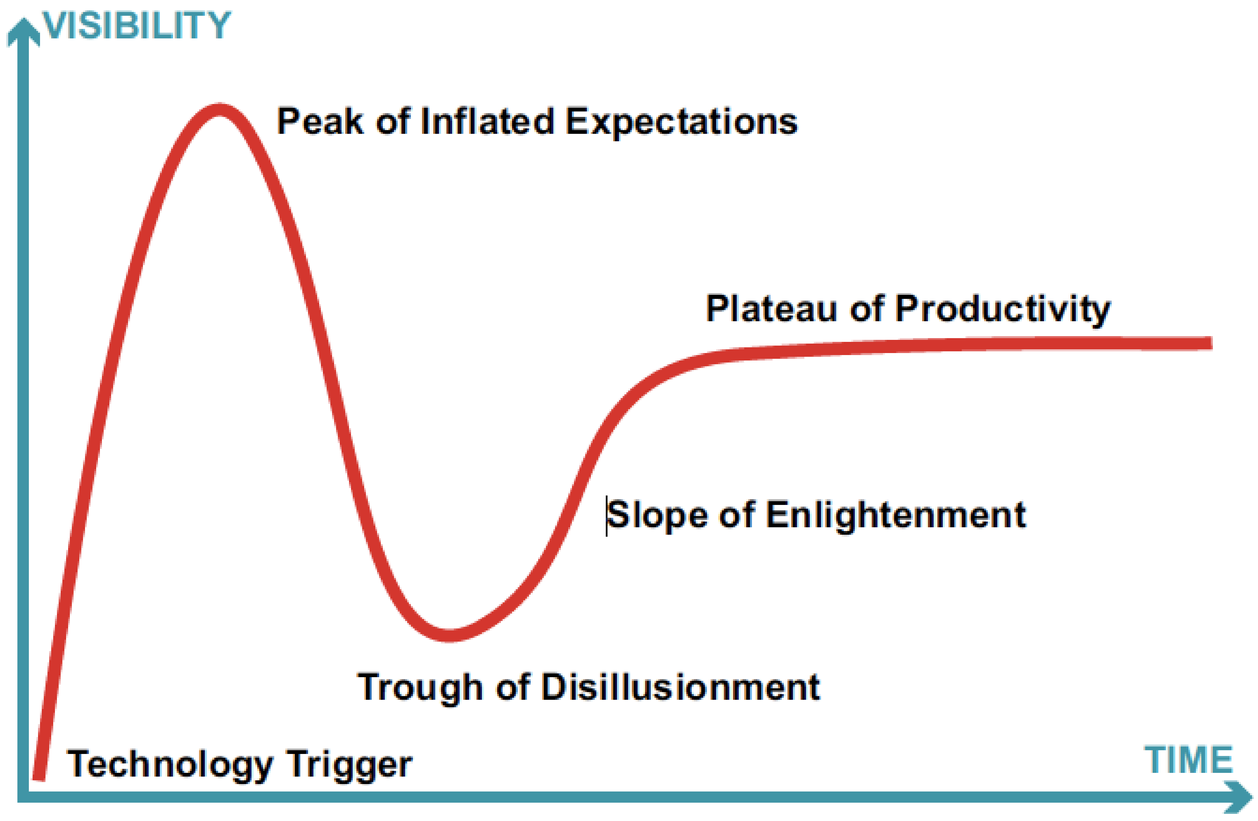
Approaches - Software Factories

- Series production of software products
  - » Combines the ideas of different approaches (MDA, AC-MDSD, MetaCASE/DSLs) as well as popular SWD-technologies (patterns, components, frameworks)
  - » Objective is the automatically processed development of software product series, i.e., a series of applications with the same application area and the same infrastructure
  - » The SW-Factory as a marketable product
- Support of the complete basic architecture
  - » Refinements in particular on the realization level, e.g. deployment
- Advantages
  - » Comprehensive approach
- Disadvantages
  - » Approach not clearly delimited (similar MDA)
  - » Only little tool support

[J. Greenfield, K. Short: Software Factories. Wiley, 2004]

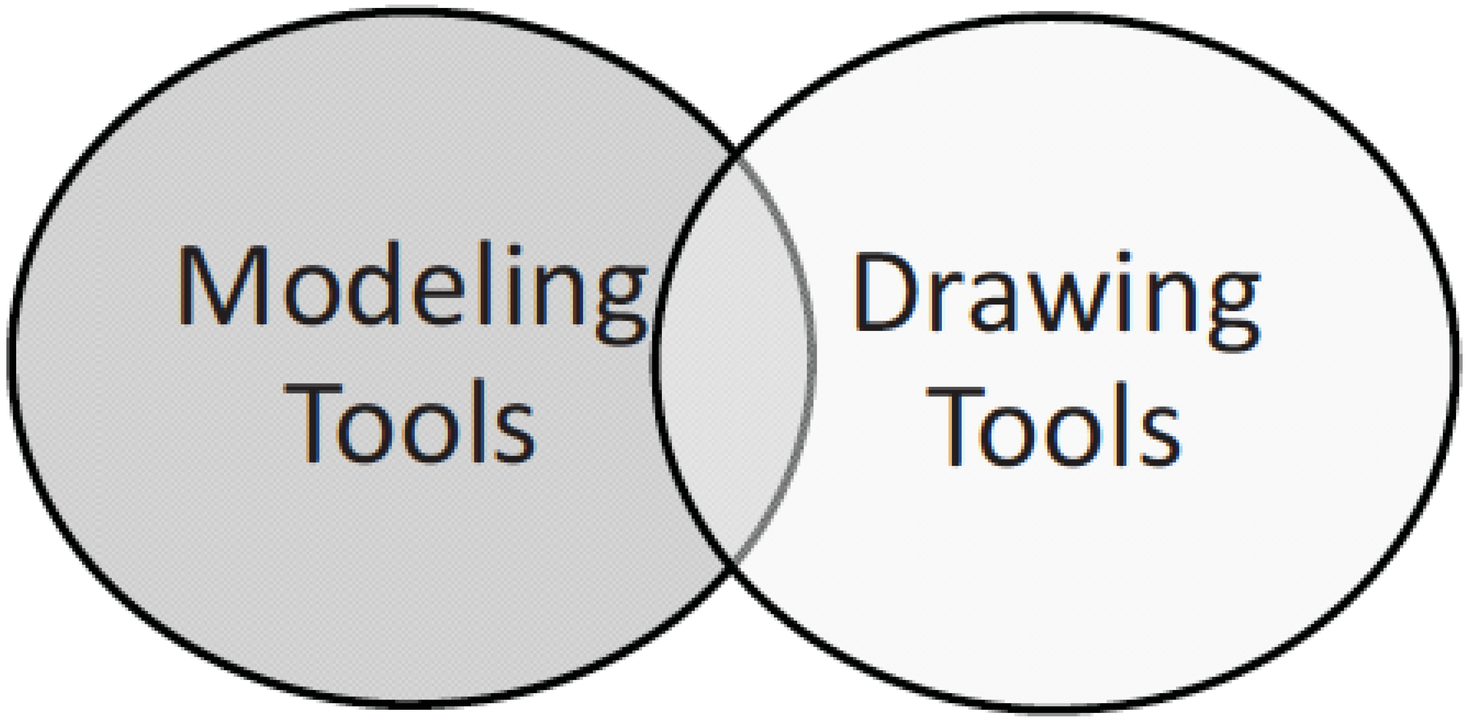
MDSE industry
Adoption and acceptance (hype)

- Not yet mainstream in all industries
- Strong in core industry (embedded, business, avionics, …)



Tool support

- Drawing vs. modeling



Eclipse and EMF

- Eclipse Modeling Framework
- Full support for metamodeling and language design
- Fully MD (vs. programming-based tools)
- Used in this course!

Conclusion
Modeling in the last century

- Critical Statements of Software Developers

- »When it comes down to it, the real point of software development is cutting code«

- »Diagrams are, after all, just pretty pictures«

- »No user is going to thank you for pretty pictures;
  what a user wants is software that executes«

- M. Fowler, ”UML Distilled”, 1st edition, Addison Wesley, 1997