2. Software Development as Engineering Activity

1. Software Engineering Scenarios
2. A simple run through the life cycle

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- **Balzert Introduction**
- **Maciaszek/Liong Chap. 1**
- **Ghezzi Chap 5+7 or**
- **Pfleeger Chap 2+4**

- M. Pidd. Tools for Thinking. Modeling in Management Science. Wiley. Gives a good overview on modeling in general (soft and hard models)
- www.omg.org/mda Model driven architecture® is a process that structures refinement-based development, using UML
- Favre's papers on egyptology
- Seidewitz
- Refinement, decomposition, and instantiation of discrete models: Application to Event-B. JR Abrial... - Fundamenta Informaticae, 2007

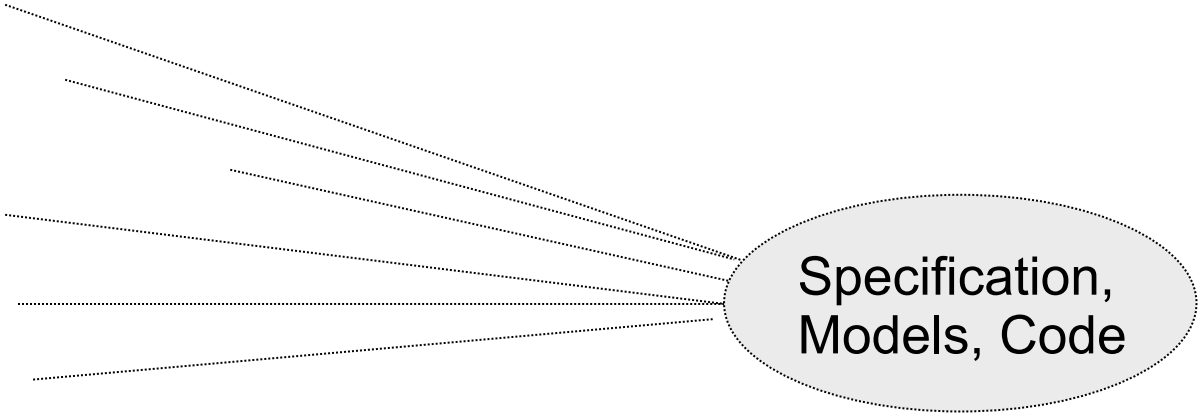
- **You are a project manager in Hamann/Becker Car Radios, Inc, Karlsruhe, Germany**
- **Your boss comes into your office and says:**

- **"Our competitor Smith Car Radios has a new satellite radio. Their sales are growing, and our customers demand it, too. How quickly can you deliver me a satellite radio?"**

- **How many people?**
  - do we have the right ones?
- **Which milestones (deadlines)?**
- **How many resources?**
- **What should the radio be able to do?**
- **Why will it better than the competitors? (competitive business edge)**

- **How can we go the way in a structured way towards the product?**
- **How can we engineer it?**

- **It teaches the production of software with engineering techniques (the engineer's toolkit)**
- **Model**
- **Analysis**
- **Prediction**
- **Construction**
- **Reuse**
- **Validation**
- **Improvement**
- **Sell**



Software engineers model, measure, predict, build, validate, improve, and sell

- **Model a domain or a system**
  - Describe or specify
  - World and problem modeling vs. system modeling
- **Analyze (measure) a model or an existing system**
  - Identifying the problem (problem analysis, goal analysis, risk analysis)
  - Measuring (Software metrics)
  - Searching and finding
  - Controlling
- **Predict features of a product from the model (form hypotheses, prove)**
  - Specifying features and requirements of a system
  - Analyzing the features of the model
  - Forming hypotheses about the system
- **Construct a product (realize, develop, invent, build)**
  - **Elaboration** (adding more details to the model to arrive at an implementation)
  - **Describing** the infinite and the unknown with finite descriptions
  - **Structure** a model (making the model more clear)
    - Refinement (making the model more precise and detailed)
    - Abstraction (leaving out detail, focusing on the essential)
    - Domain Transformation (changing representation of model)
- **Reuse parts of products**
  - Engineer a *product line (product family)*

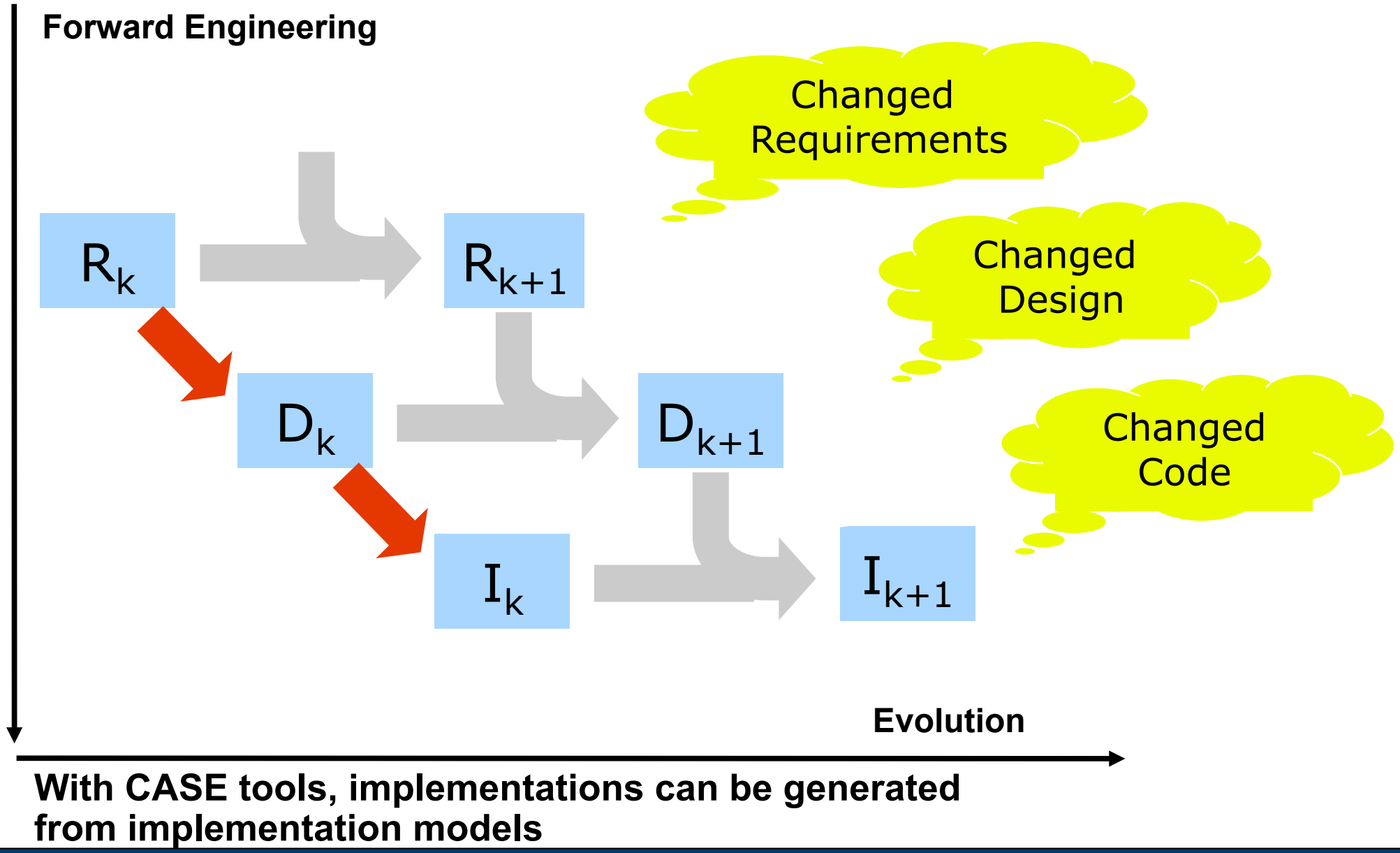
- **Validate hypotheses on the product**
  - Experimentation (empirical software engineering)
  - Checking (consistency, integrity, completeness, soundness)
  - Testing
  - Proving (formal software engineering, formal methods)
  - Statistics (not covered here)
- **Improve the product**
  - Reverse engineer
  - Restructure
  - Optimize with regard to a value model
- **Sell the product(s)**
  - The software engineer solves problems to earn money for his company and himself
  - How to come to products?
  - How to talk to customers?
  - How to see the problem of the customer?
  - How to reach a market with a product?
  - How to found a startup?
  - Often, engineers are good technicians, but fail to sell the products

Remark: Software and Systems Engineering

- **Software Engineering is closely related to a twin, the Systems Engineering**
  - Building software into a system (embedded system)
  - Many concepts can be used in both areas.
    - See study line “Distributed Systems Engineering (DSE)”.

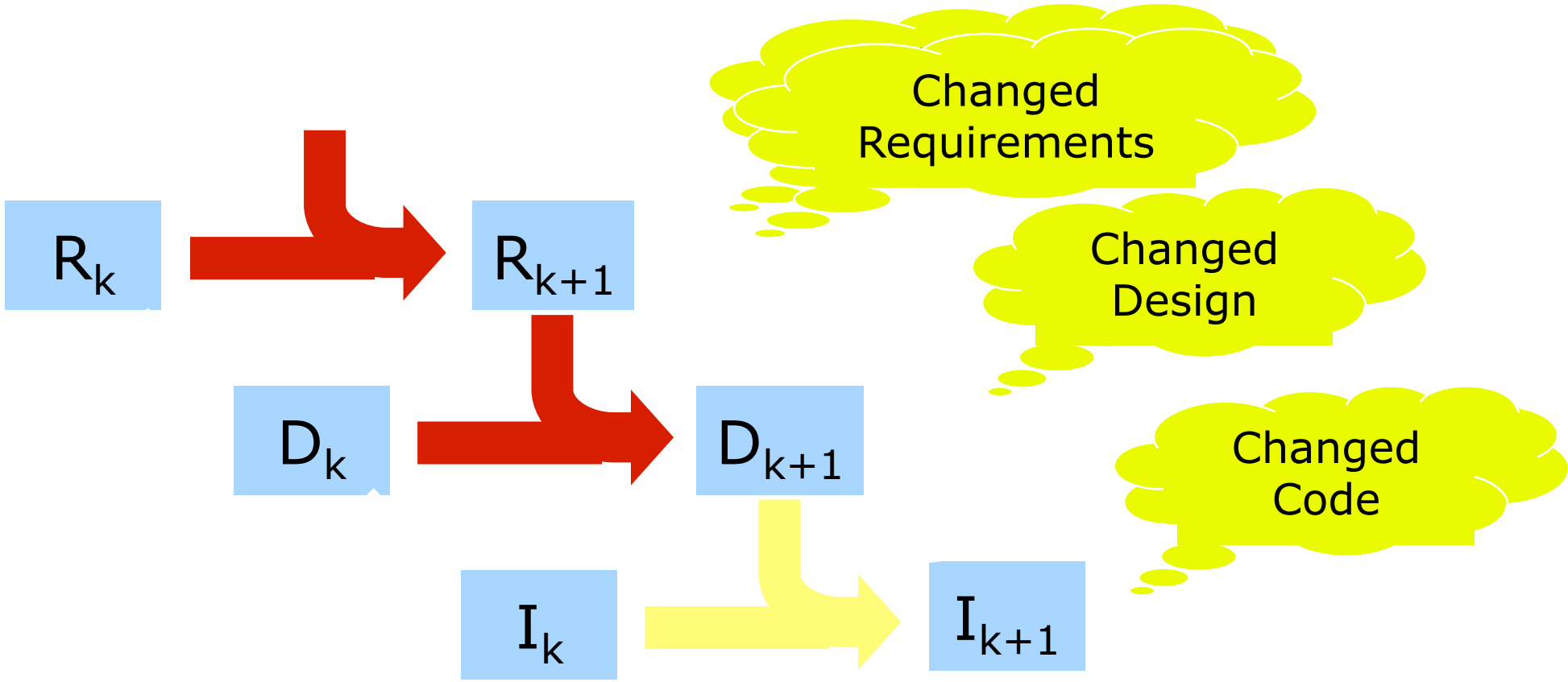
Forward Engineering, Backward Engineering, Improvement, Round-Trip Engineering

2.1. SCENARIOS OF SOFTWARE ENGINEERING

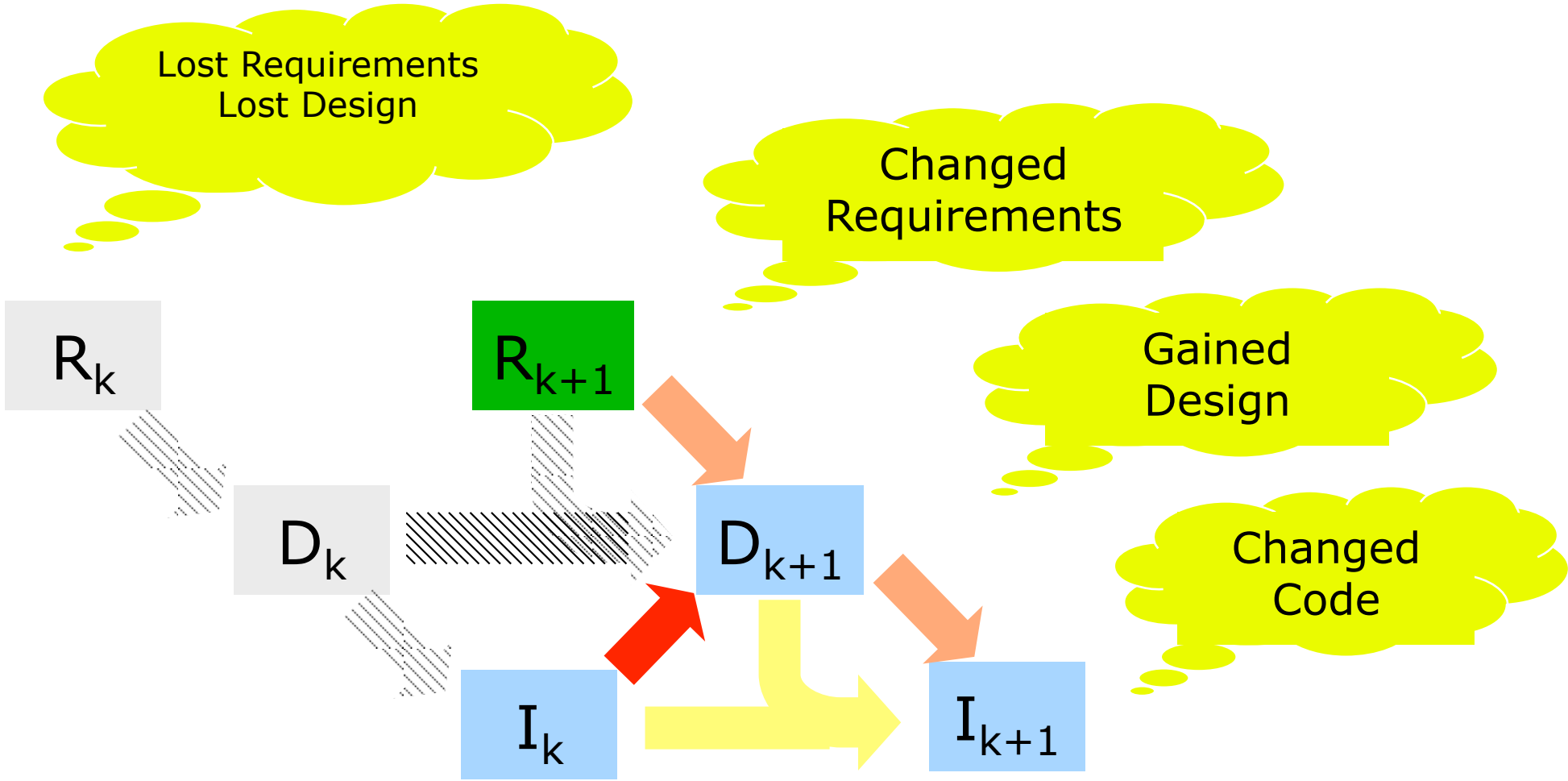


With CASE tools, implementations can be generated from implementation models

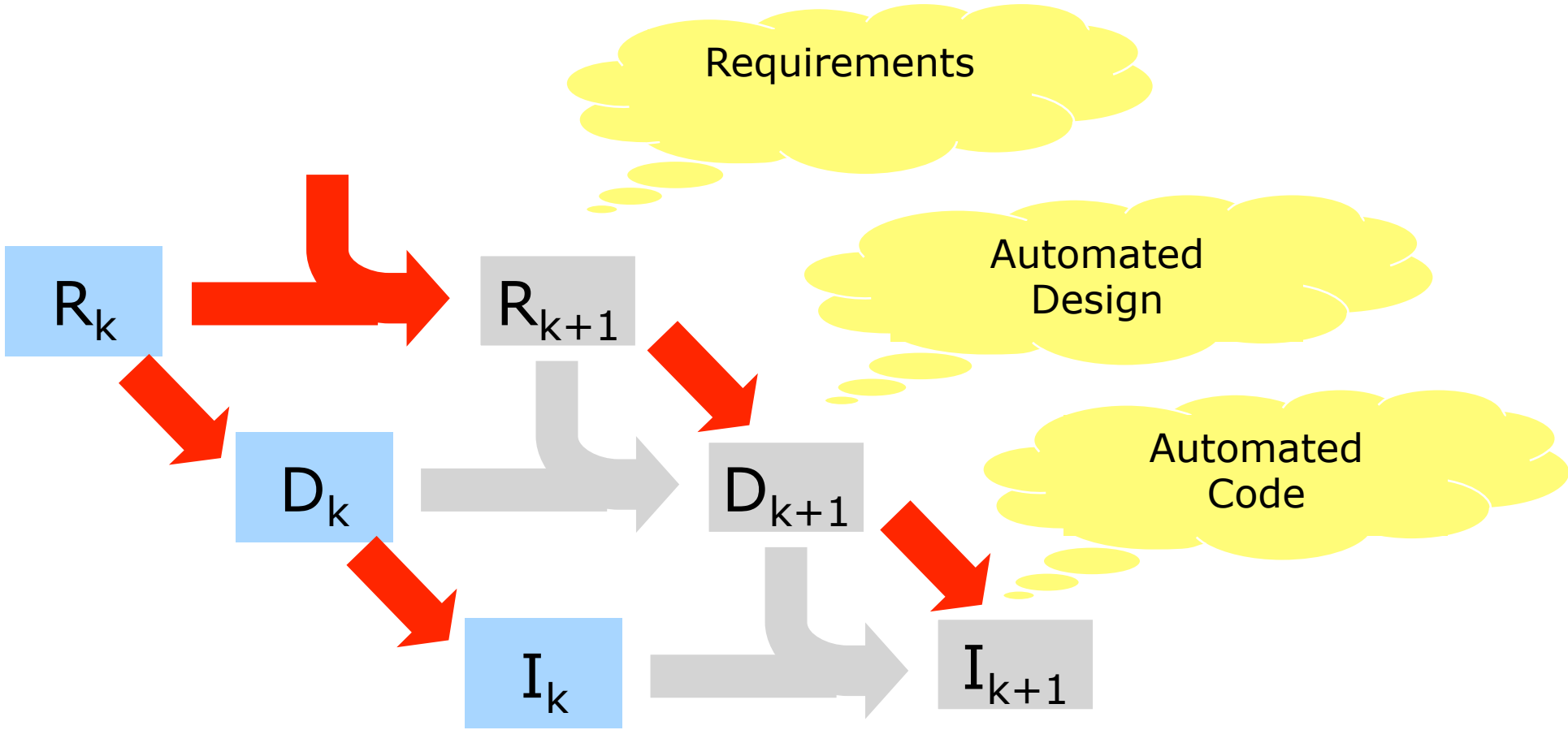
- **Changed requirements require refactoring and extensions**



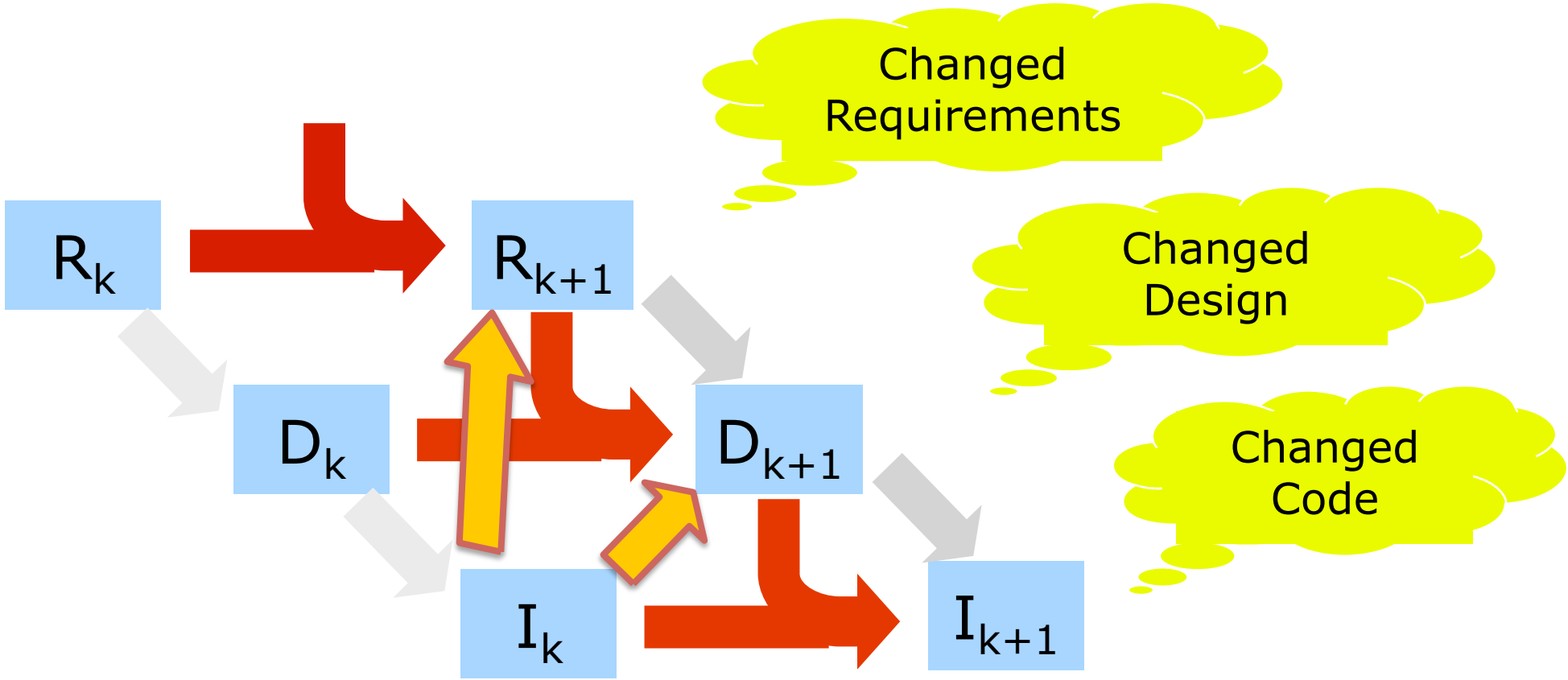
- **Reverse Engineering attempts to recover design from code**
- **Reengineering uses the gained design for further forward engineering**



- **Automated programming (generative programming) generates code from requirements automatically.**
  - It will need planning and expert system support



- **Round-trip engineering combines forward and reverse engineering**
  - It allows for editing on all levels, keeping all artefacts consistent



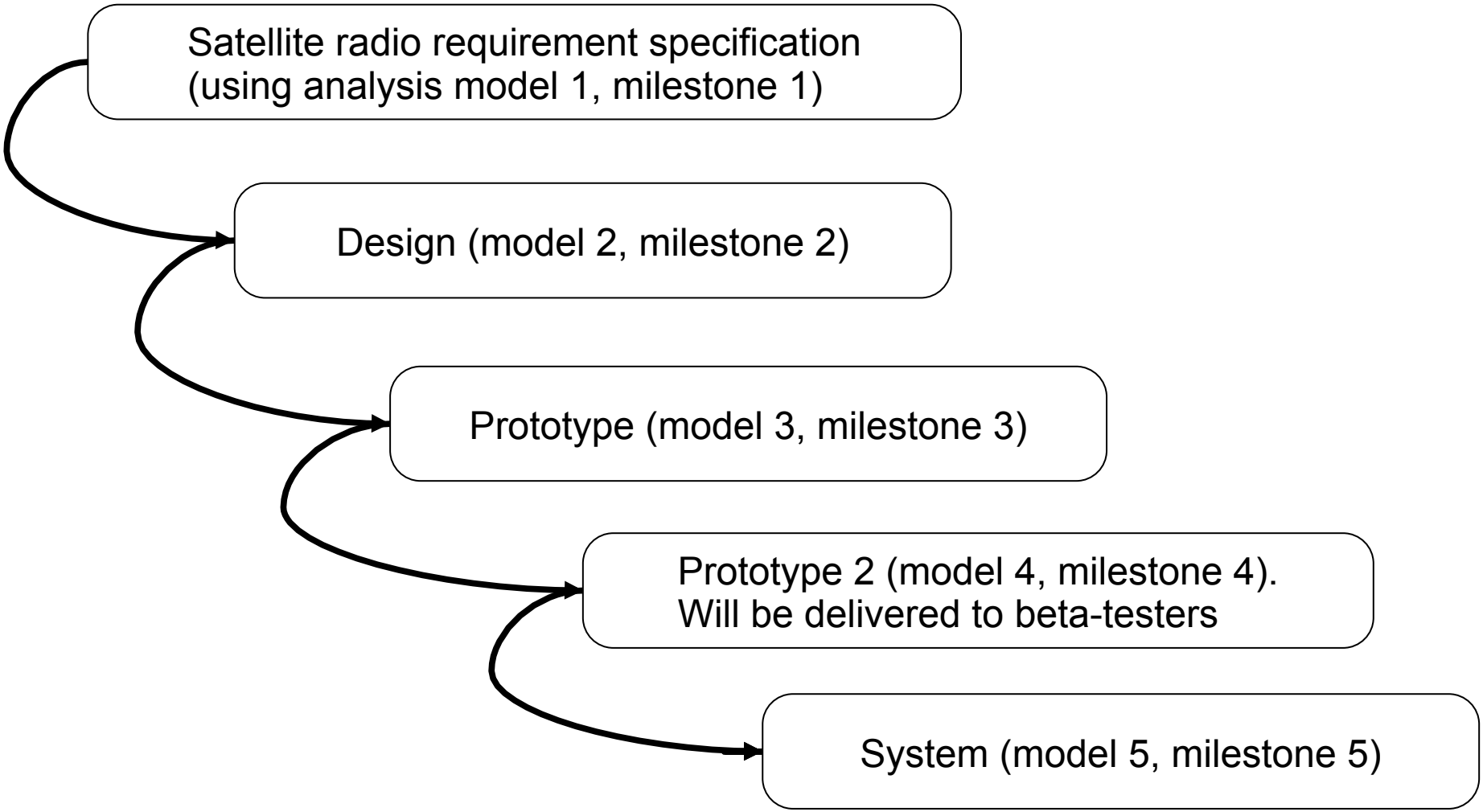
2.2 A RUN THROUGH AN ENGINEERING CYCLE

- **How do we arrive from the requirements at the product? Let's take an engineer's approach (Analysis steps):**
  - Engineers analyze problems to understand what to do
  - Engineers specify a solution and realize (construct) it
  - For both activities, engineers model the world to master it
- **Steps**
  - We fix the requirements in a requirement specification (requirements models)
  - We go step by step through different design models
  - ... until we arrive at the implementation model (which is the system)

What is a Specification?

- **A specification is a *prescriptive model (blue print)* of the system, i.e., a precise description what a system**
  - should deliver (service, delivery, postconditions, guarantees)
  - requires for the delivery (requirements, preconditions, assumptions)
  - "the truth lies in the model" (J.M. Favre)
- **A specification must be *realized (implemented)*. An implementation can be *verified* with regard to a specification**
  - showing that the implementation derives the delivery from the requirements
- **A specification contains one or several *models* of domain, problem, or parts of the system**
  - Models are abstract, partial representations of partial knowledge
- **However, often, the word specification and model are used interchangeably (which is not precise)**

Satellite Radio Example Cycle



- **Pidd suggests a hierarchy of definitions:**
  - *A model is a representation of reality*
  - A model is a representation of reality *intended for some definite purpose*
  - A model is a representation of reality intended *to be of use to someone charged with understanding, changing, managing, and controlling that reality*
  - A model is a representation of a part of reality *as seen by the people who wish to use it to understand, change, manage, and control that reality*
- **More simply:**
  - A model is a representation of a part of a domain, or of a function of a system, its structure, or behavior
  - A model is an abstraction of a system
- **Question: what does this mean for the Satellite radio?**

- **Software construction uses two kinds of models**

The World

Problem Domain

Problem Analysis

What is the problem?

Problem model
(Analysis model)
Models the *problem reality*

Software Systems

System Domain

System Design

What is the solution?

System model
(Design model)
Models the *system reality*

Descriptive (analytic) models

Prescriptive models (specifications)

The Satellite Radio as Example

The World

Problem Domain

Problem Analysis

No FM in USA

Digital radio quality required everywhere

Software Systems

System Domain

System Design

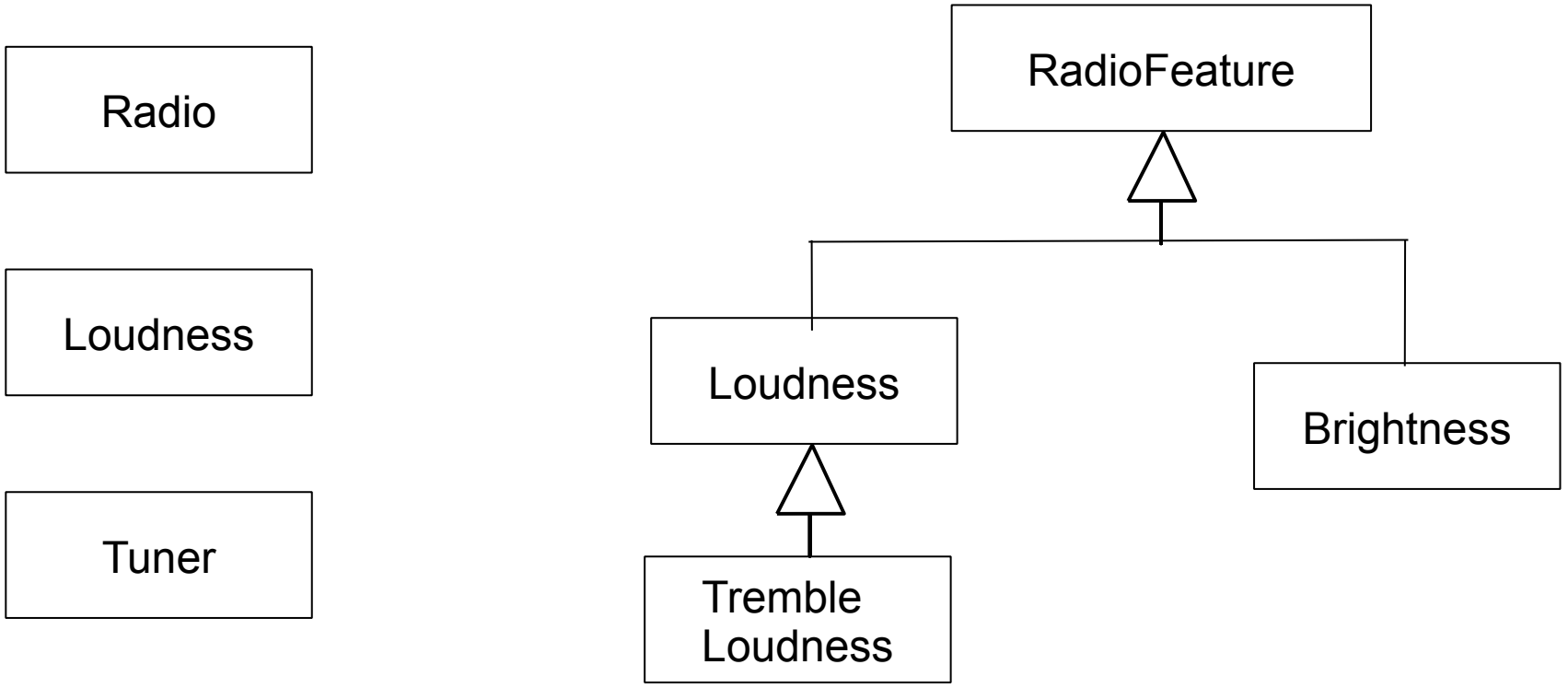
Satellite Radio

Software-controlled embedded system

Different Kinds of Specifications and Models

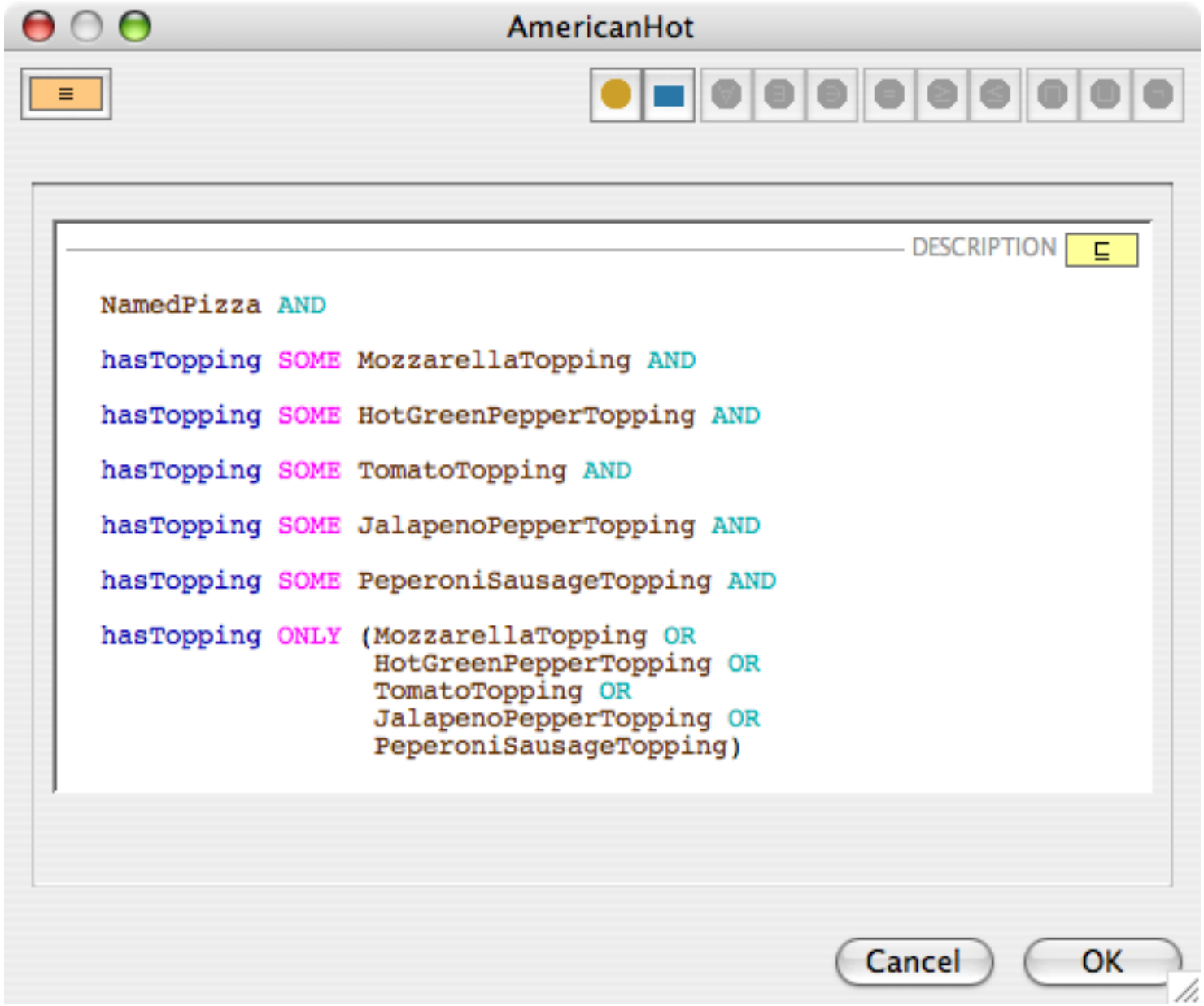
- **Analysis models**
- **Domain model:**
  - Domain analysis is the process of identifying and organizing knowledge about the application domain
- **"Real"-Problem model:**
  - Usually, the requirement specification includes a problem model – to support description and solution of these problems
- **Other models**
- **System models**
  - From the analysis models, we derive the system models.
- **Requirements specification (SRS):**
  - the specification what the system should deliver.
  - Functional requirement model: system functions
  - Non-functional requirement model: system qualities
- **Design models:**
  - abstract representation of a system on the level of a design language
- **Implementation models:**
  - partial representation of the system on the level of an implementation language

- **A glossary is a set of explained terms**
- **A classification is a grouping of the concepts of a domain into classes**
- **A taxonomy superimposes a hierarchical or acyclic is-a relationship**
  - Analyse similarity (commonality-variability analysis)



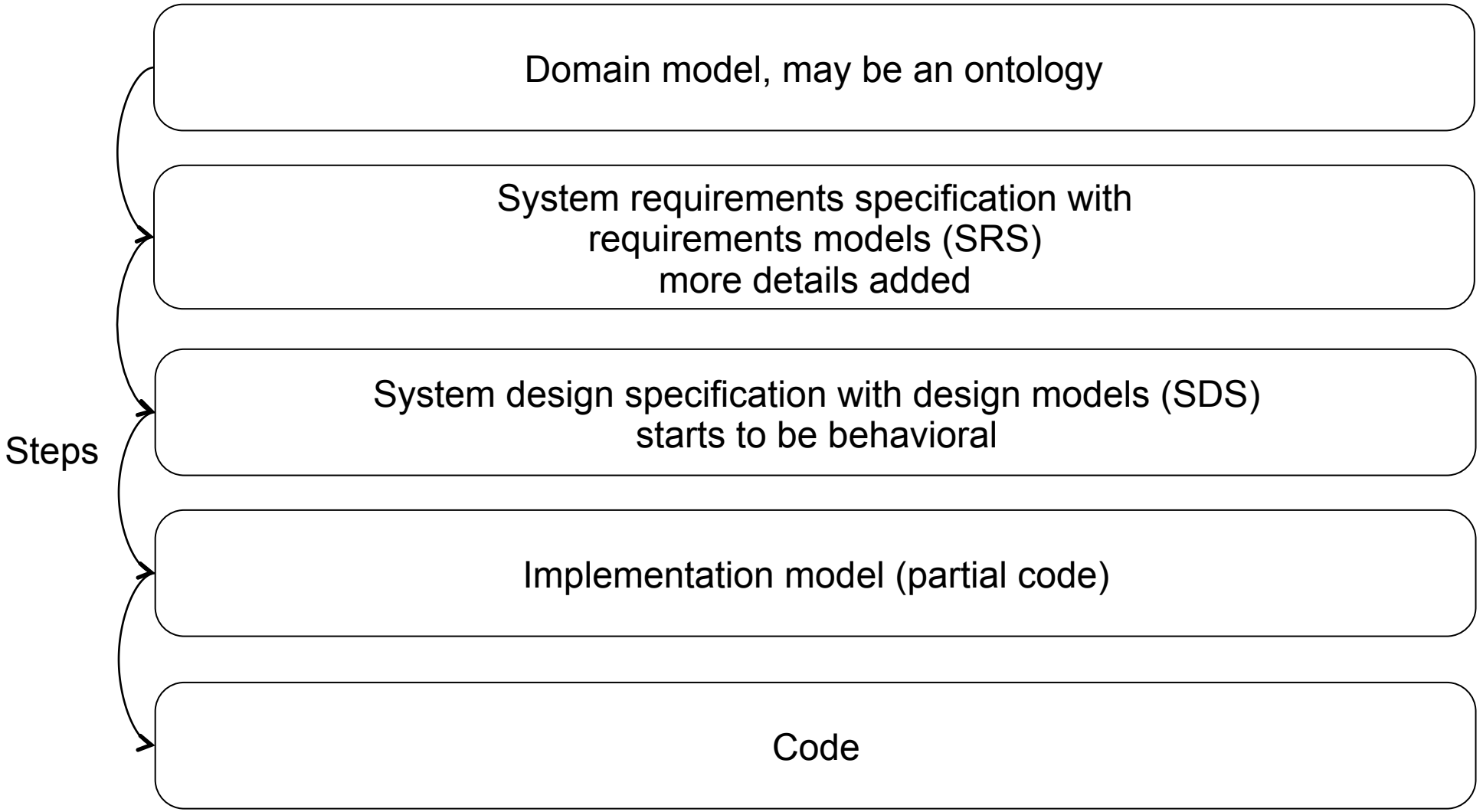
Ontologies as Standardized Domain Models

- **Ontology: A shared, standardized model for a domain.**
  - Taxonomy + integrity constraints (consistency constraints) constraining the hierarchy
  - Production rules to produce *derived parts* of the hierarchy. The derived parts are *intentionally* specified
- **Ontologies are standardized domain models and play an important role in domain analysis**
  - In general, a domain model need not necessarily be standardized
  - For many domains, domain modeling will start from these ontologies
  - *Domain engineers* produce domain ontologies
- **Example:**
  - Dublin Core ontology with concepts such as Date, Author, Comment
  - Medical ontologies, such as gopubmed.org
  - Upper ontologies (conceptual ontologies), such as SUO suo.ieee.org
  - Biochemical ontologies (Gene ontology www.geneontology.org)
- **Ontologies in the Semantic Web**
  - In 2003, the W3C has standardized the first ontology language for the web: OWL (web ontology language)
  - Used for domain models


AmericanHot
DESCRIPTION
NamedPizza AND
hasTopping SOME MozzarellaTopping AND
hasTopping SOME HotGreenPepperTopping AND
hasTopping SOME TomatoTopping AND
hasTopping SOME JalapenoPepperTopping AND
hasTopping SOME PeperoniSausageTopping AND
hasTopping ONLY (MozzarellaTopping OR
HotGreenPepperTopping OR
TomatoTopping OR
JalapenoPepperTopping OR
PeperoniSausageTopping)
Cancel
OK

- **Beyond integrity constraints, a behavioral model adds to an ontology**
  - operations
  - event-condition-action rules, specifying how a system reacts
  - a state space
- **Objects have a state space, often represented by**
  - Petri-nets (see later) and their specializations:
    - a finite state machine
    - a hierarchical state machine (state chart)
    - data-flow diagrams
  - Process algebra

- **From declarative to behavioral models**



- **Behavioral models allow for *prediction*.**
  - Graph-based models can be consistency-checked with logic reasoners
    - Integrity constraints constrain the object sets (object extents) of the classes
    - Structural constraints (reducibility, layering)
  - Petri nets can be verified with matrix theory
    - Resource consumption (memory consumption)
    - Liveness of the processes
    - Fairness of the processes
    - Deadlocking processes
  - Statecharts can be checked with model checkers
  - Real-time statecharts can be time-checked with real-time model checkers
- **This subject area is called *formal methods* of software engineering**

How to come to the next model?

2.2.3 THIRD STEP: CONSTRUCTION

- **The construction of systems starts off from Domain Model over Requirement Specification and Design Specification to Implementation Model to Code:**
  - Develop the next specification, starting from the previous ones

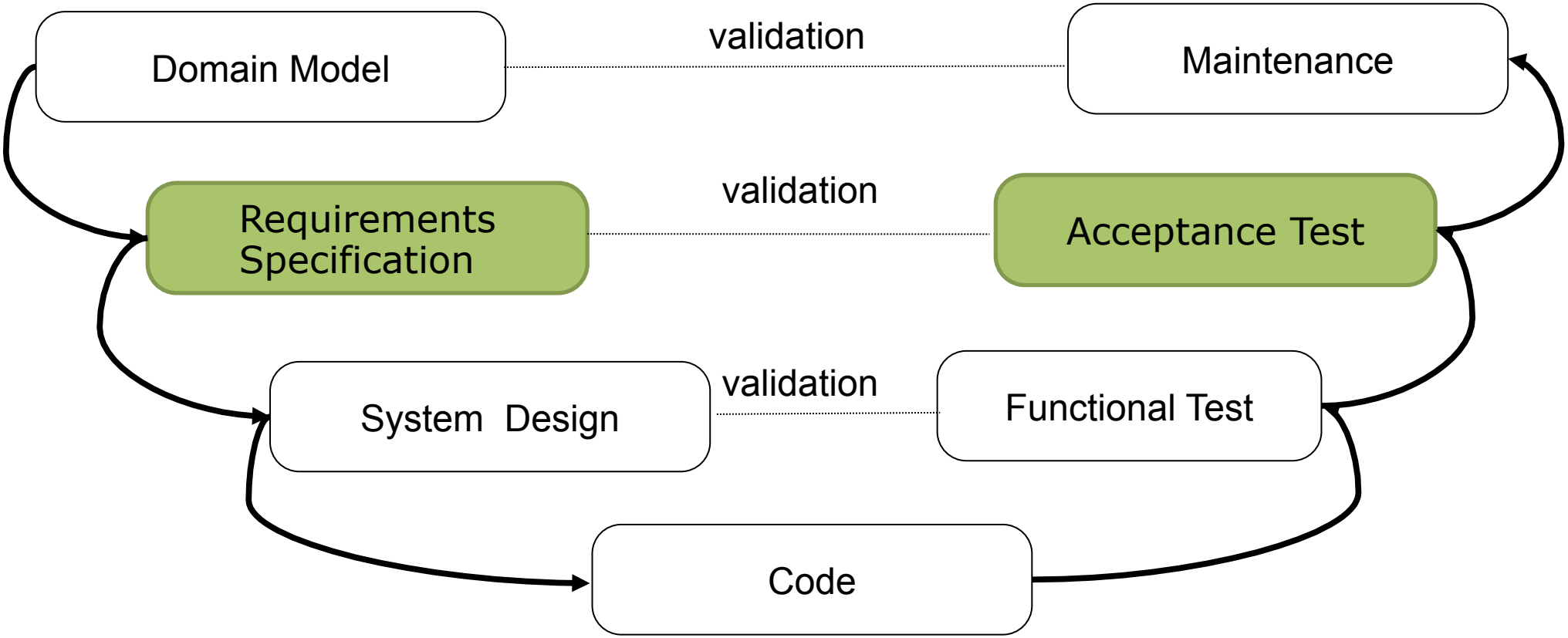
- **Construction steps:**
- **For every model, start with some simple form. Then, apply elaboration steps:**
  - **Elaboration:** Elaborate more details – enrich with more semantics
  - **Refinement**: Refine an existing specification/model, by detailing an abstract concept
  - **Check:** Check consistency of models
  - **Measure** quality and quantity of models
  - **Rotate:** Symmetry operations (semantics-preserving operations):
  - We can distinguish several methods of development

- **Elaboration: Elaborate more details**
  - Which Elaboration steps exist?
  - How do I know in which direction to elaborate?
- **Pointwise Refinements (concretizations): detailing an abstract concept**
  - With and without correctness proofs that the semantics of the abstract concept is provided by the refinement
- **Rotations: Apply a semantics-preserving change**
  - Which restructuring? (when is a specification too complex?)
  - Which representation change? (which representations are appropriate for which purpose?)
  - **Restructure** (more structure, but keep requirements and delivery, i.e., semantics)
  - **Transform Domains** (change representation, but keep semantics)

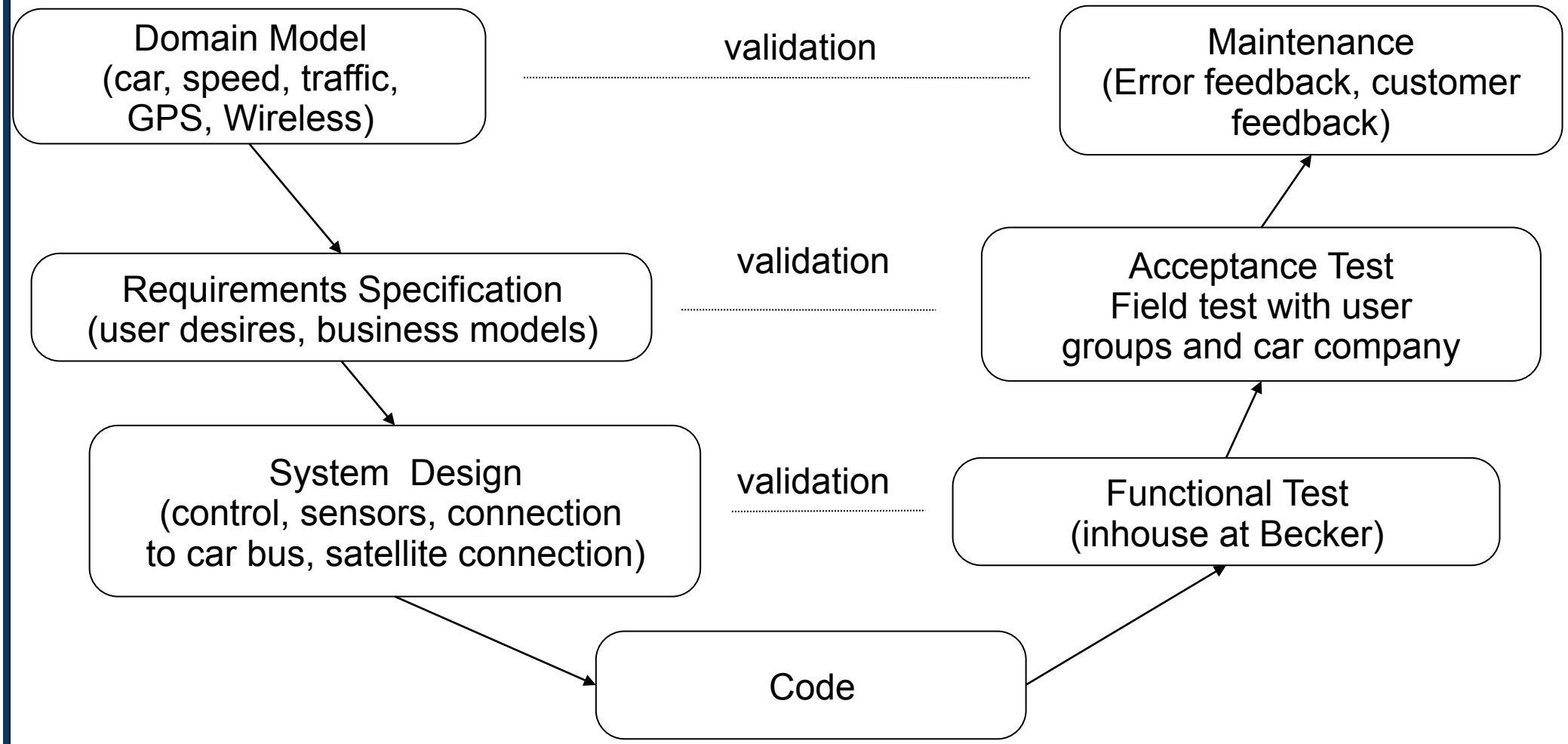
- **Engineers try to reuse well-established solutions**
  - Components (CBSE)
  - Design patterns
  - Models (model-driven architecture)
  - Best practives
- **To simplify system construction**
  - To save costs
  - To reduce testing effort

2.2.4. 4TH STEP: VALIDATION

- **All specifications and models have to be validated or formally verified.**
  - Detailed models against more abstract models
  - Implementations against specifications
- **Result: A V-like software development process**



Validation of the Satellite Radio in the V-Model



2.2.5 5TH STEP: IMPROVEMENT

- **Done via iteration, and ad-hoc**
  - Not in the focus of the course.
- **Section "Product Lines" will treat some aspects of software evolution, namely when new products should be derived from an existing product or product family.**
- **Optimization means: Improve on the qualities of the system**
  - Speed, reliability, resource consumption

Some aspects in section “Earning Money with Software”.

2.2.6 6TH STEP: SELLING SOFTWARE

- .. the one who solves a problem best
- .. the one who pretends to solve a problem best
- .. the one who solves a problem just good enough
- .. the one who solves a problem reliably

??

- **Specifications (complete representations of what the problem is or the system should do) consist of models (abstract representations of worlds)**
  - Analysis models in the problem domain
  - System models in the system domain
- **Engineers analyze, form hypotheses, construct, validate, improve, sell**
  - Detailed models are validated against their more abstract ancestors
  - Implementations are validated against specifications
- **The course is structured along these activities**