TECHNISCHE UNIVERSITÄT DRESDEN
Fakultät Informatik, Institut für Software- und Multimediatechnik, Lehrstuhl für Softwaretechnologie

2. Software Development as Engineering Activity

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

Prof. Dr. U. Aßmann
Technische Universität Dresden
Institut für Software- und Multimediatechnik
Gruppe Softwaretechnologie
http://st.inf.tu-dresden.de
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References

- 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

Obligatory Reading

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

Scenario of Running Example

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

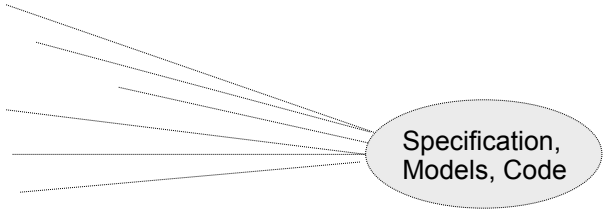
- "Our competitor Smith Car Radios has a new satellite radio. Their sales are growing, and our customers demand it, too. How quickly can you deliver me a satellite radio?"

First Ideas

- **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?**

What is Software Engineering?

- **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

The (Software) Engineer's Toolkit

- **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)*

The (Software) Engineer's Toolkit

- **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

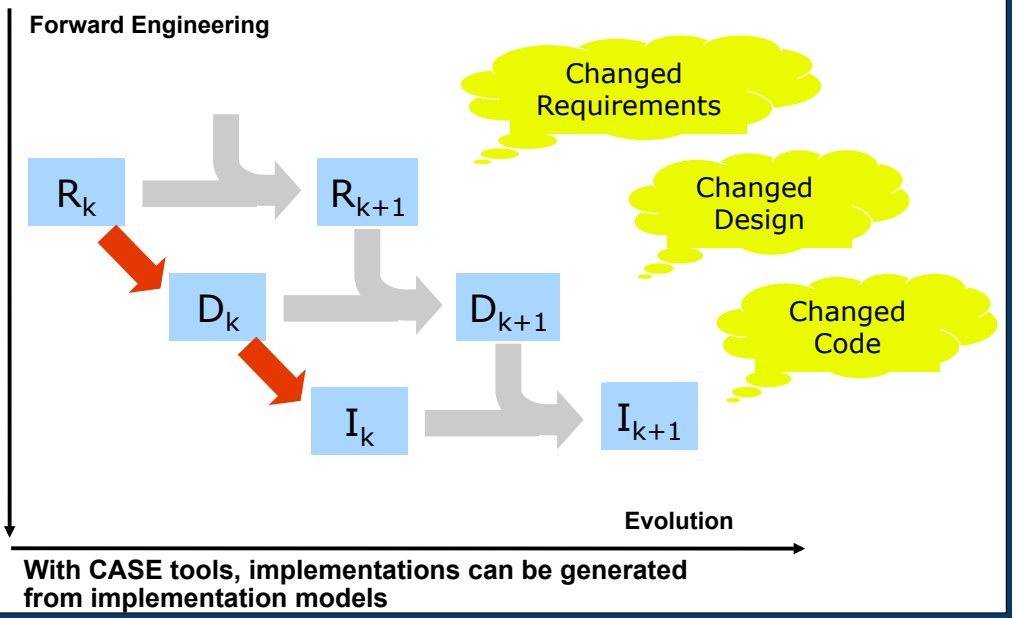
Remark: Software and Systems Engineering

- **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

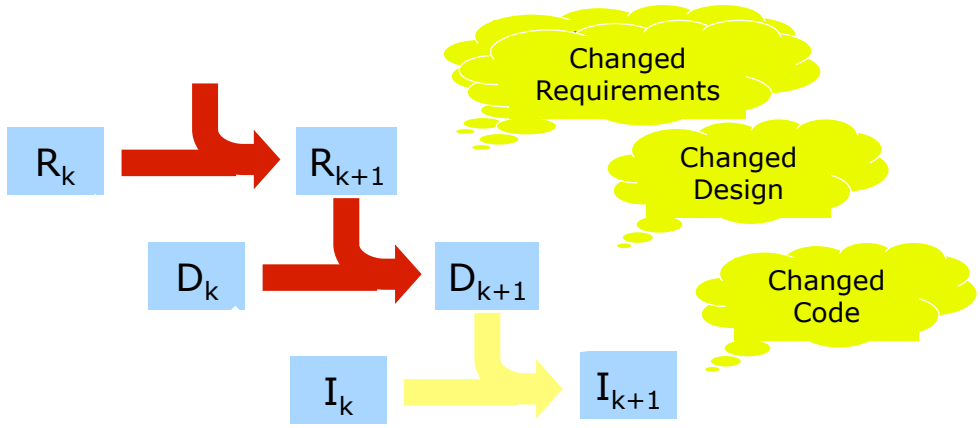
2.1. SCENARIOS OF SOFTWARE ENGINEERING

Forward Engineering and Evolution



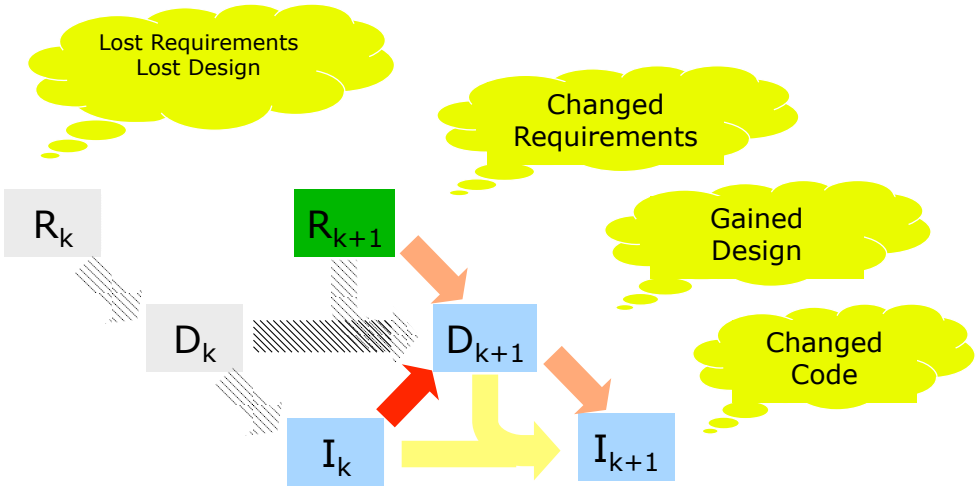
Software Evolution

- **Changed requirements require refactoring and extensions**



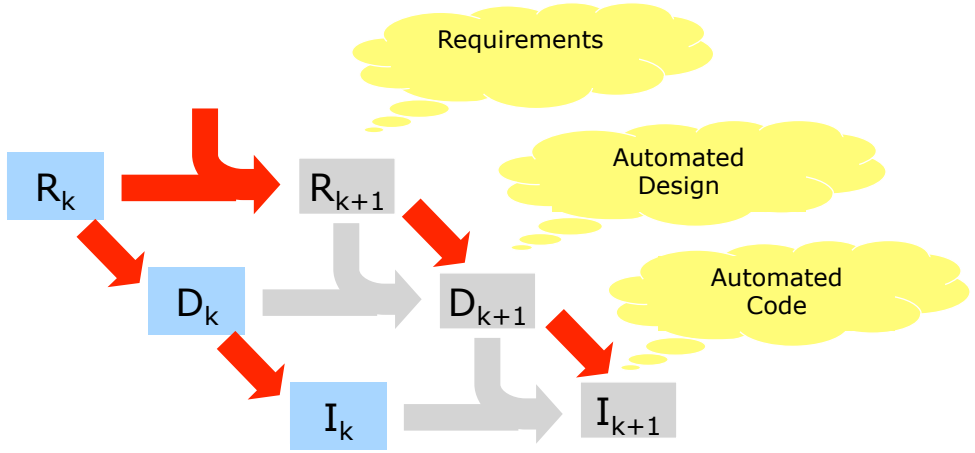
Software Reengineering

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



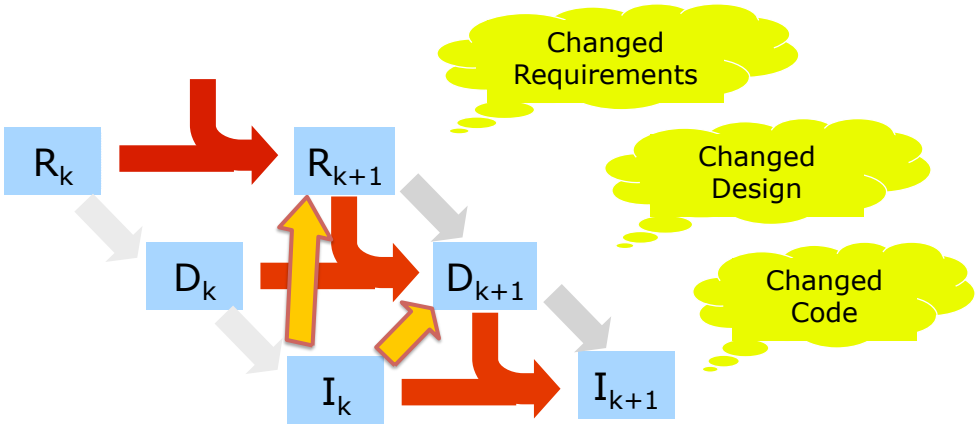
The Dream: Automated Programming

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



Round-Trip Engineering (Forward and Backward)

- **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

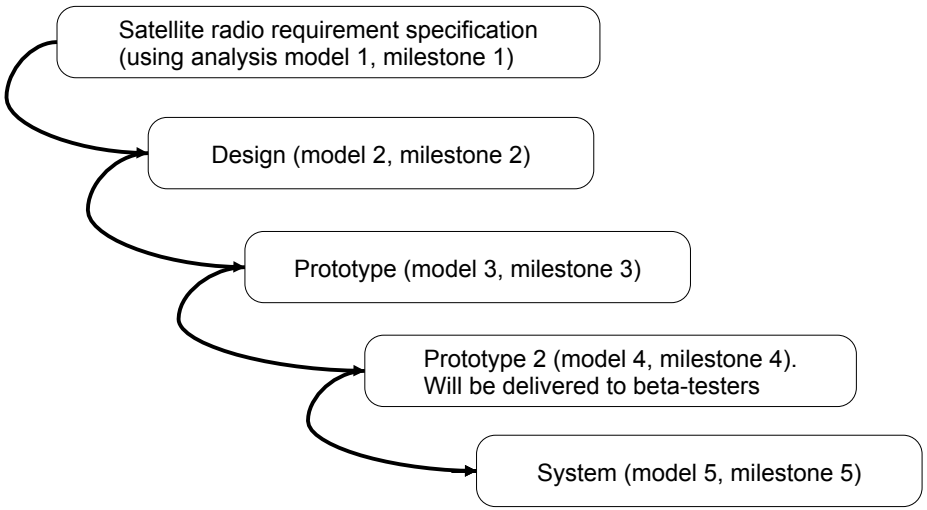
2.2.1 First Step: Analysis

- **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



But... What Is A Model?

- **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?**

To Produce Software, We Model

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

The World	Software Systems
Problem Domain *Problem Analysis*	*System Domain* *System Design*
What is the problem?	What is the solution?
Problem model (Analysis model) Models the *problem reality*	System model (Design model) Models the *system reality*
Descriptive (analytic) models	Prescriptive models (specifications)

The Satellite Radio as Example

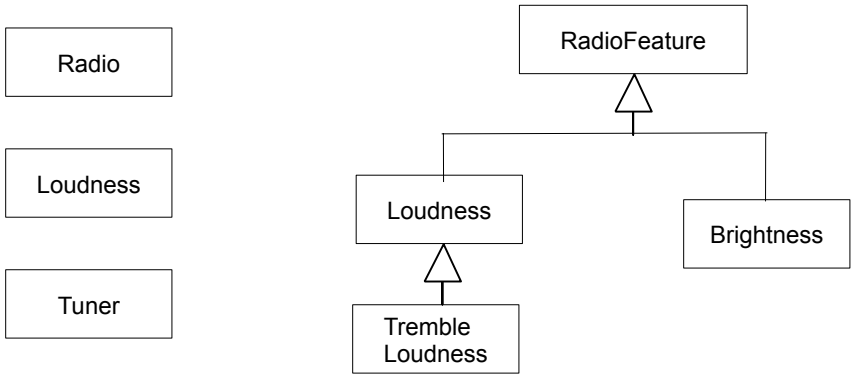
The World	Software Systems
Problem Domain *Problem Analysis*	*System Domain* *System Design*
No FM in USA	Satellite Radio
Digital radio quality required everywhere	Software-controlled embedded system

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

Descriptive Models: Glossaries, Classifications and Taxonomies

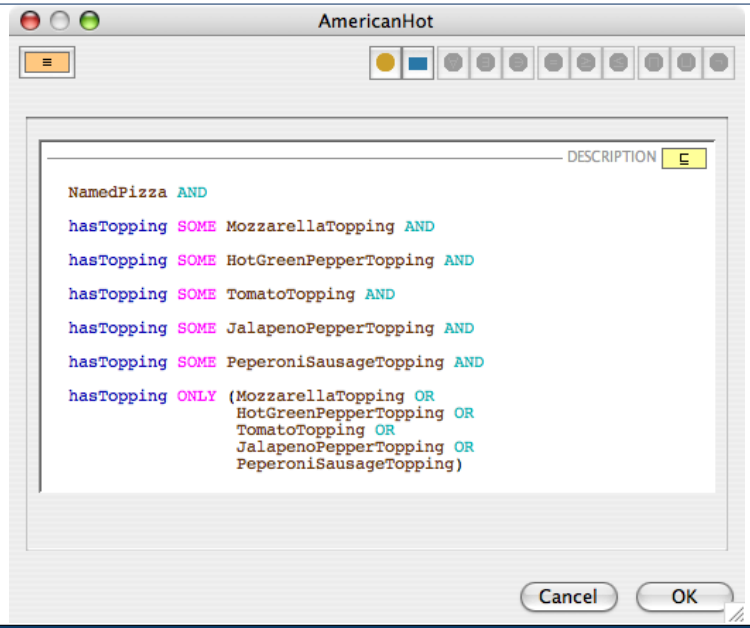
- **A glossary is a set of explained terms**
- **A classification is a grouping of the concepts of a domain into classes**
- **A taxonomy superimposes a hierarchical or acyclic is-a relationship**
  - Analyse similarity (commonality-variability analysis)



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

Ontology in OWL „Manchester Syntax"

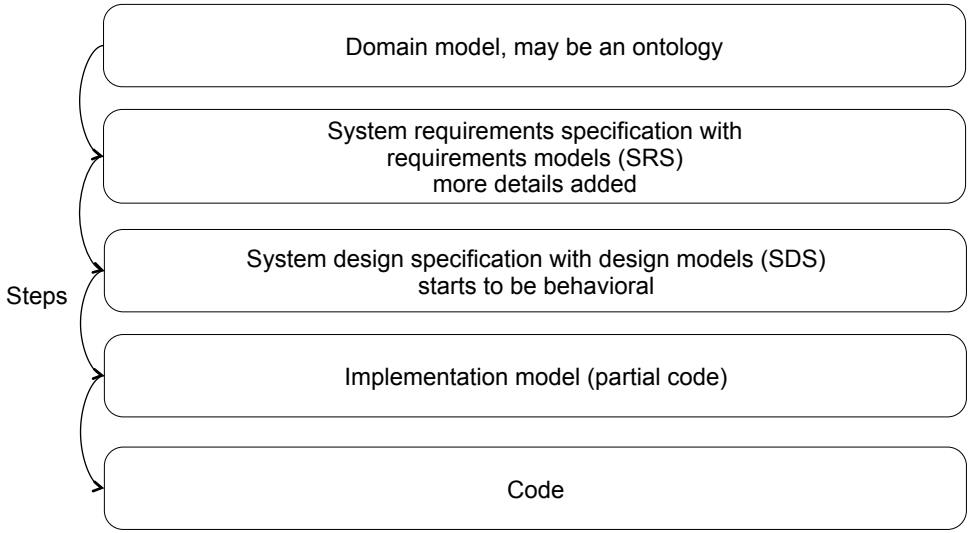


Behavioral Models

- **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

Specifications and Models in Software Engineering

- **From declarative to behavioral models**



2.2.2 Second Step: Prediction

- **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

Construction with Refinement-Based Development

- **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

Questions for the 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)

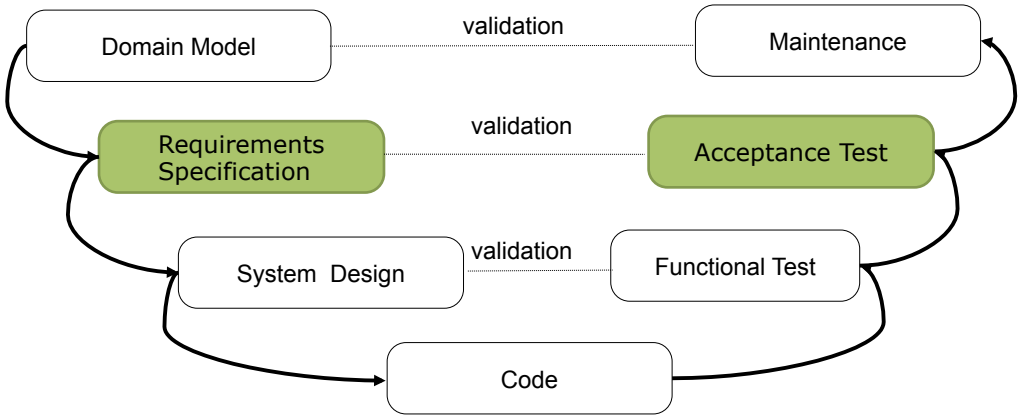
Reuse of Models and Code in Construction

- **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

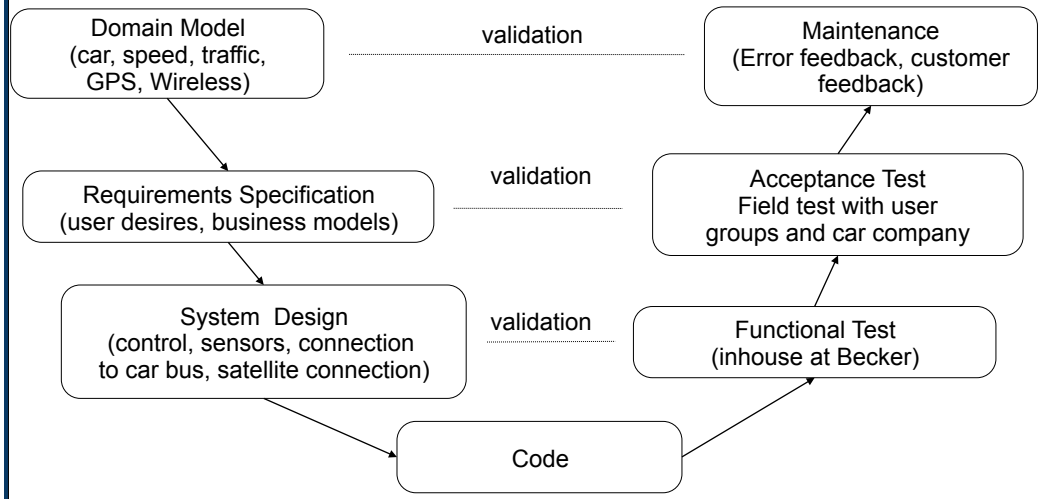
2.2.4. 4TH STEP: VALIDATION

Validation in a Software Development Process (V-Process Model)

- **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**

??

What Have We Learned?

- **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**

The End