2. Software Development as Engineering Activity

1. **Software Engineering Scenarios**
2. **A run through the engineering life cycle**
3. **Engineers and Entrepreneurs**

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WS 12-0.4, 06.10.12

Obligatory Reading

- Balzert Introduction
- Maciaszek/Liong Chap. 1
- Ghezzi Chap 5+7 or
- Pfleeger Chap 2+4
- Ed Seidewitz. What models mean. IEEE Software, 20:26-32, September 2003.
  - http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1231147&tag=1

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:
  - Jean-Marie Favre. Foundations of model (driven) (reverse) engineering: Models - episode I: Stories of the fidus papyrus and of the solarus. In Jean Bezivin and Reiko Heckel, editors, Language Engineering for Model-Driven Software Development, number 04101 in Dagstuhl Seminar Proceedings, Dagstuhl, Germany, 2005. Internationales Begegnungs- und Forschungszentrum für Informatik (IBFI), Schloss Dagstuhl, Germany.
  - Jean-Marie Favre. Foundations of meta-pyramids: Languages vs. metamodels- episode II: Story of thotus the baboon1. In Jean Bezivin and Reiko Heckel, editors, Language Engineering for Model-Driven Software Development, number 04101 in Dagstuhl Seminar Proceedings, Dagstuhl, Germany, 2005. Internationales Begegnungs- und Forschungszentrum für Informatik (IBFI), Schloss Dagstuhl, Germany.
- JR Abrial, Stephan Hallerstede. Refinement, decomposition, and instantiation of discrete models: Application to Event-B. Fundamenta Informaticae, 2007
  - http://dl.acm.org/citation.cfm?id=1365974&CFID=49627514&CFTOKEN=73132377

Successful Engineers and Entrepreneurs

- Konrad Zuse. Mein Lebenswerk. Springer. A MUST for every student.
- Michael Lewis. The New New Thing. A book about how Jim Clark, Netscape founder, founded Healtheon. Coronet Books, Hodder & Stoughton
- R. Würth. Skript on Entrepreneurship. Interfakultatives Institut für Entrepreneurship. TU Karlsruhe. http://www.iep.uni-karlsruhe.de/260.php
- Klaus Kemper. Heinz Nixdorf. Verlag Moderne Industrie.
  - The Nixdorf foundation donated given 2 chairs to the department (multimedia, computational engineering)
- The Google story.
- Steve Jobs. about Apple. (There are several books available)
- Bill Gates. The Way Ahead. (dtsch. Der Weg nach vorn. Die Zukunft der Informationsgesellschaft) Autobiography. Hoffmann&Campe.
- D. Brandes. Konsequent einfach. Die Aldi Erfolgsstory. Heyne-Verlag.
- David Thielen. Die 12 simplen Erfolgsgeheimnisse von Microsoft. Econ-Verlag
- W. Wiedeking. *Anders ist besser. Ein Versuch über neue Wege in Wirtschaft und Politik.* Piper-Verlag, München 2006.
- D. Tapscott. Wikonomics. 2007

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?”

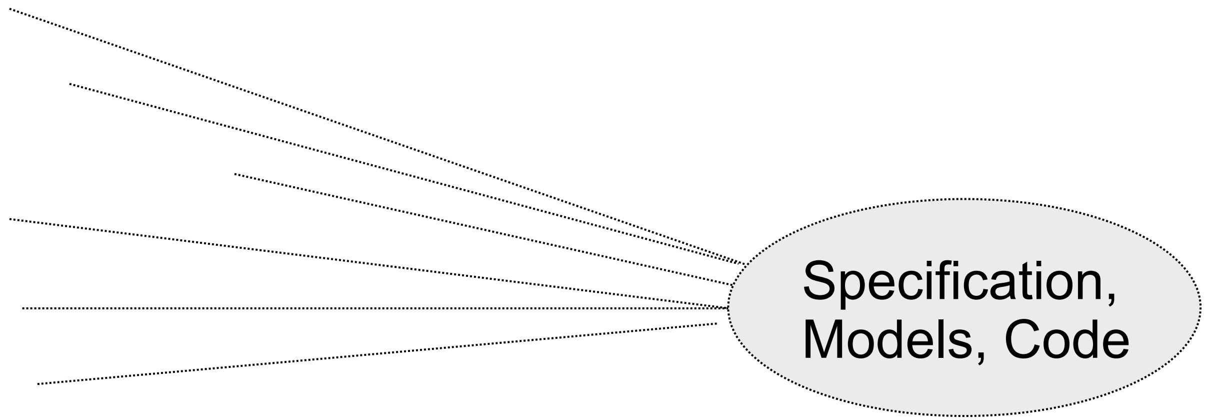
First Ideas

- 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 and Specify
- Analysis and Prediction
- Construction
- Reuse
- Validation
- Improvement
- Sell



Software engineers model, specify, analyse, predict, build, validate, improve, and sell

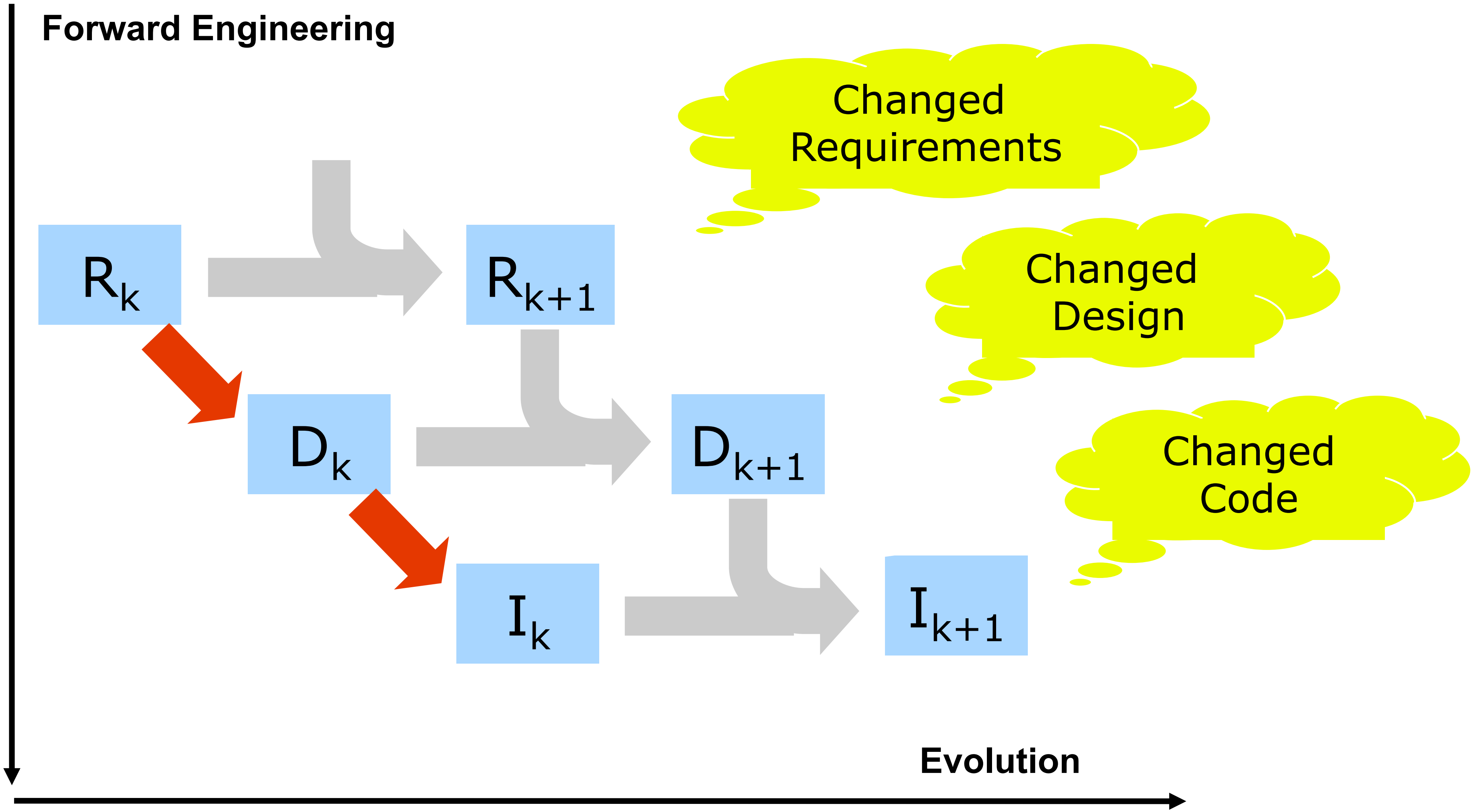
The (Software) Engineer's Toolkit

- **Model** a reality (a domain or a system in the world): Descriptive modeling
  - Describe or specify
  - World and problem modeling vs. system modeling
- **Specify** a system: Prescriptive modeling
  - Specifying features and requirements of a system
- **Analyze** (measure) a reality (a model or a system)
  - Identifying the problem (problem analysis, goal analysis, risk analysis)
  - **Measure** a system (Software metrics)
  - Searching and finding
  - Controlling
- **Predict** features of a product from the model (form hypotheses, prove)
  - Forming hypotheses about the system
- **Construct** a product (realize, develop, invent, build): apply systematic engineering steps to get a high-quality, evolvable software system
  - **Elaboration** (adding more details to the model to arrive at an implementation)
  - **Compose** a system from components
  - **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

- **Validate** hypotheses on the product
  - Experimentation (empirical software engineering)
  - Checking (consistency, integrity, wellformedness, 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

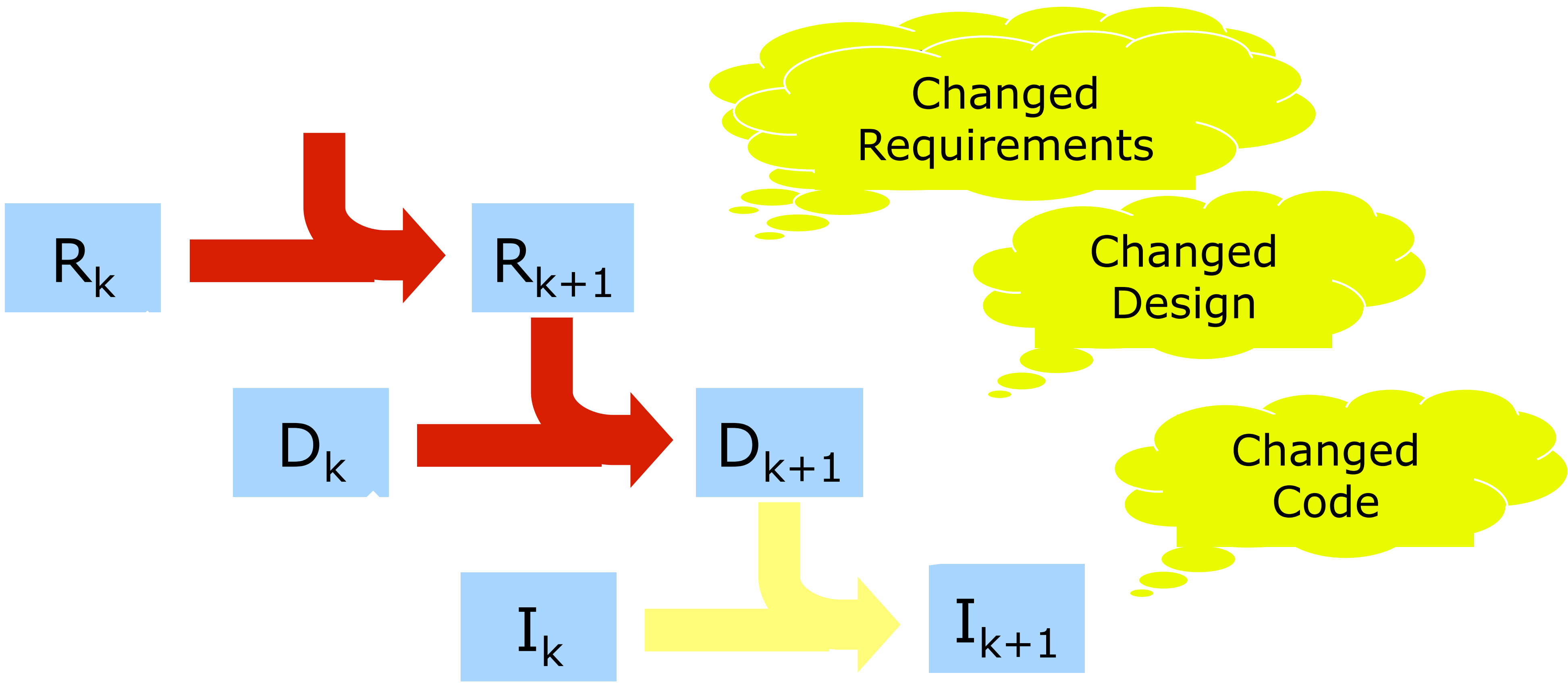
Forward Engineering, Backward Engineering, Improvement, Round-Trip Engineering

2.1. SCENARIOS OF SOFTWARE ENGINEERING

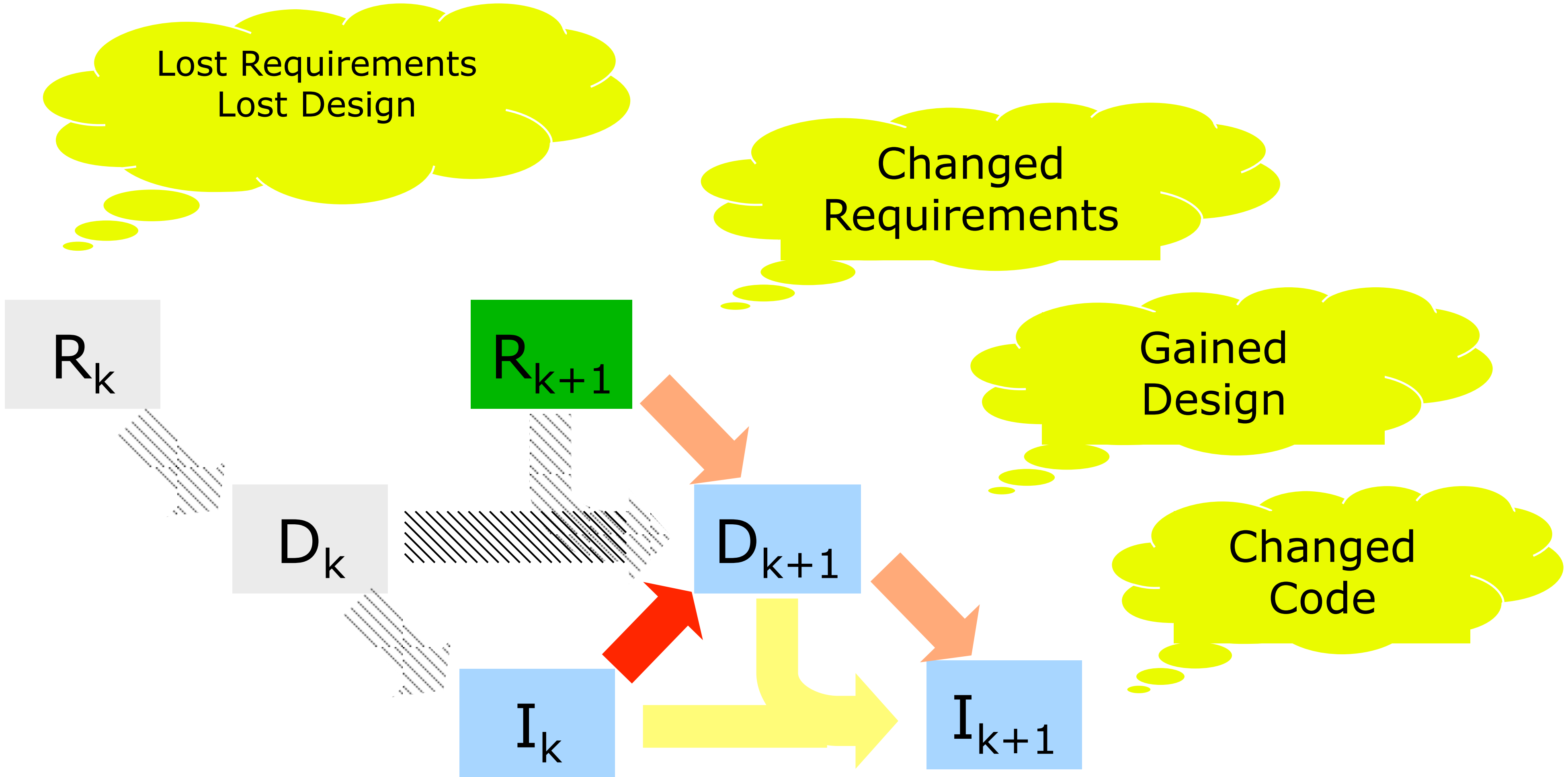


With CASE tools, implementations can be generated from implementation models

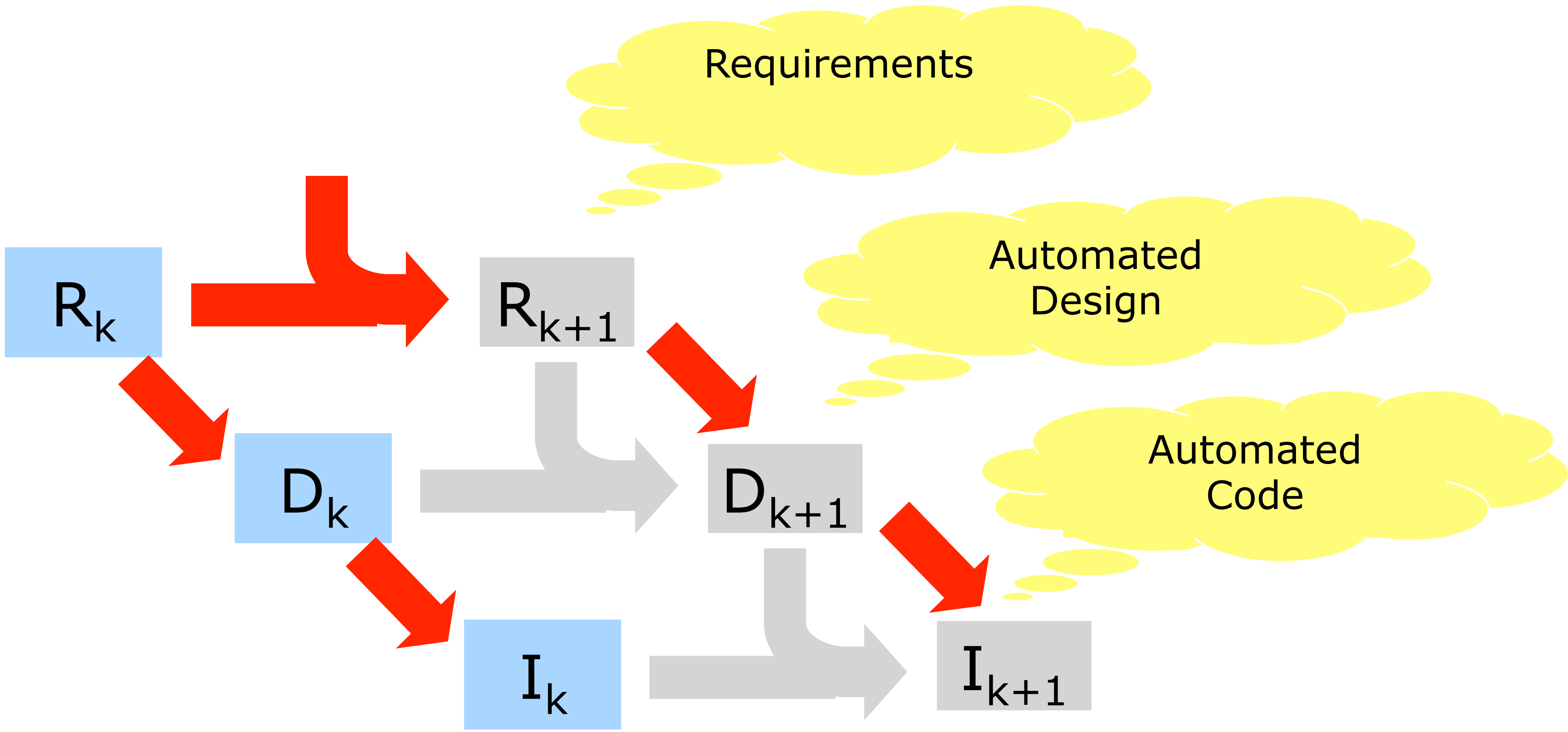
- Changed requirements require unforeseen refactoring and extensions
- Software must be structured flexibly so that it can be evolved
- Sometimes, more product variants are created and a *product line* emerges



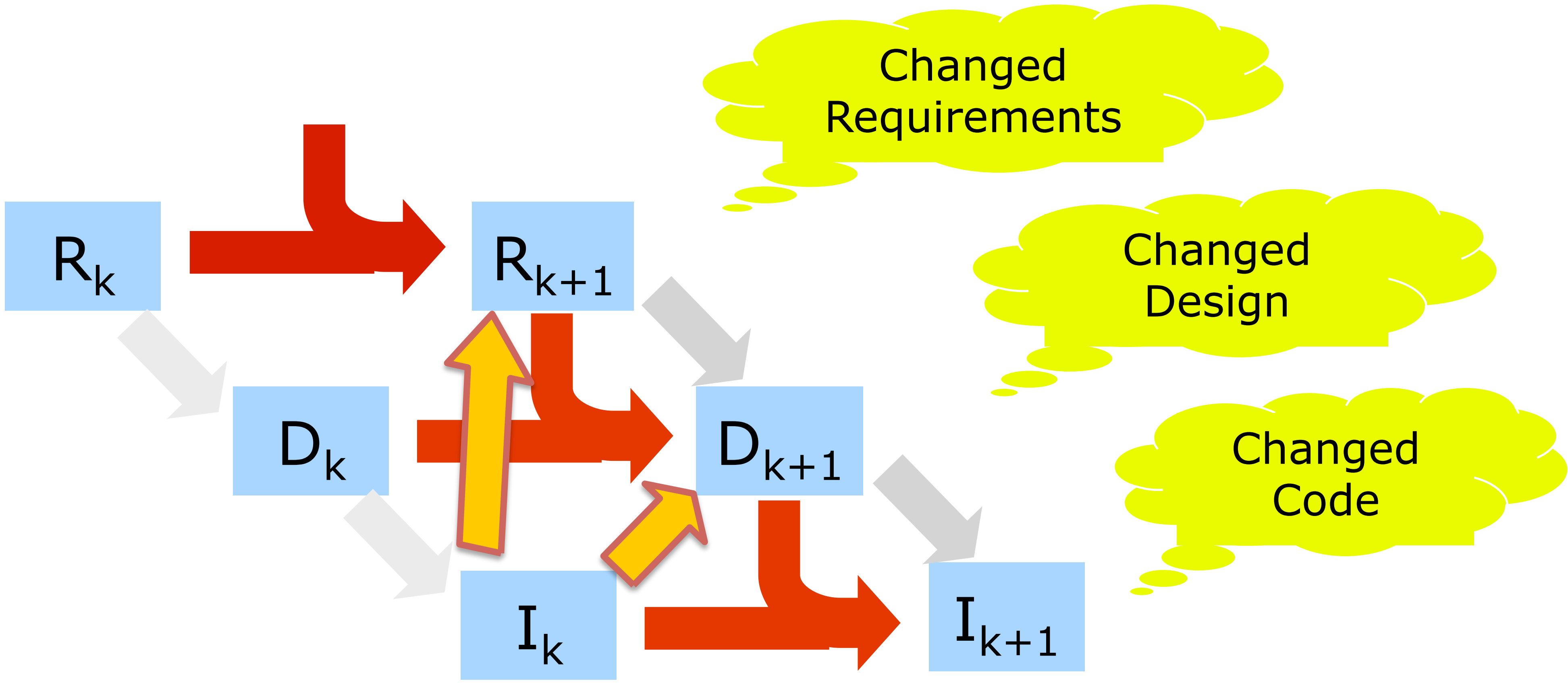
- **Reverse Engineering** attempts to recover design from code
- **Reengineering** uses the gained design for further forward engineering



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



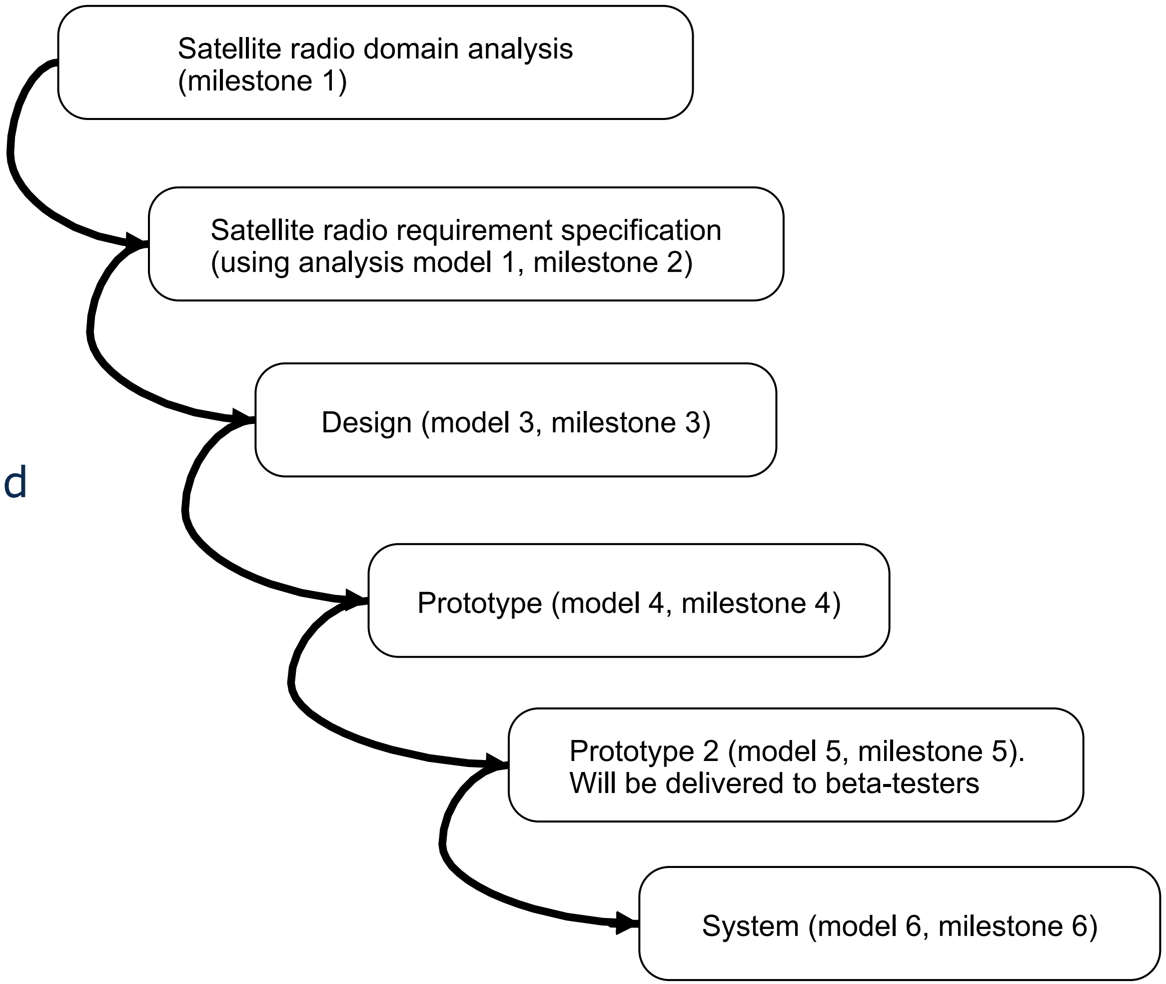
- **Round-trip engineering** combines forward and reverse engineering
  - It allows for editing on all levels, keeping all artefacts consistent



2.2 A RUN THROUGH AN ENGINEERING CYCLE

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)



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** that reality*
    - *To **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
- A model is *partial*, i.e., *abstract*, and neglects some parts of the reality
- A descriptive model allows to understand a reality
- A prescriptive model allows to change, manage, and control a reality

- 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*

Descriptive (analytic) models

Software Systems

System Domain

System Design

What is the solution?

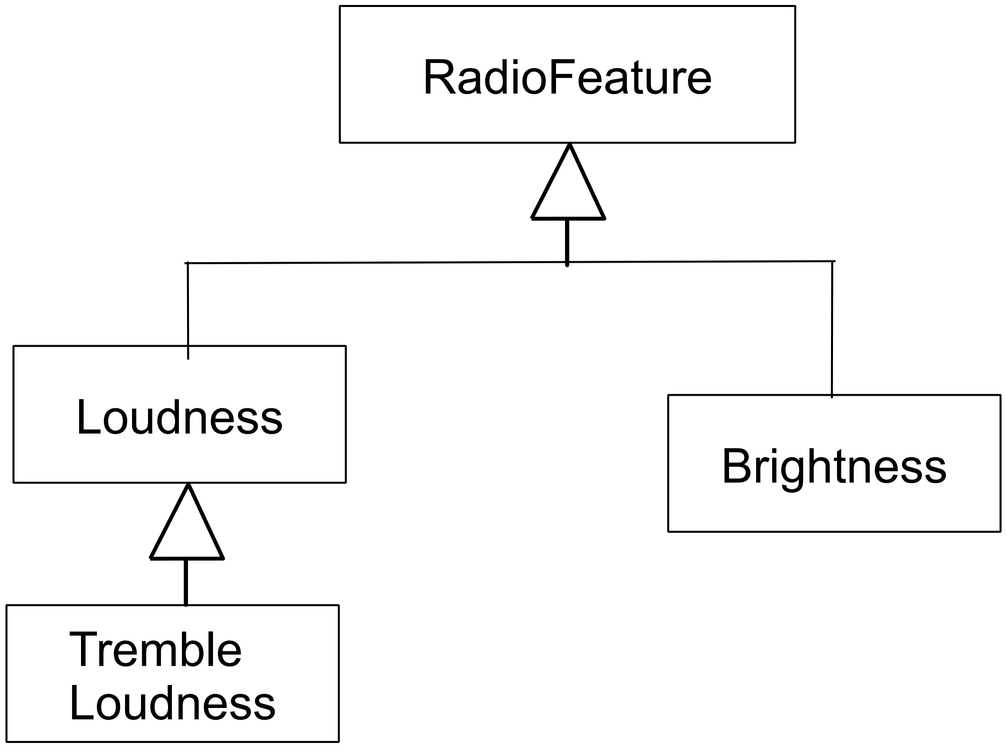
System model
(Design model)
Models the *system reality*

Prescriptive models (specifications)

The Satellite Radio as Example

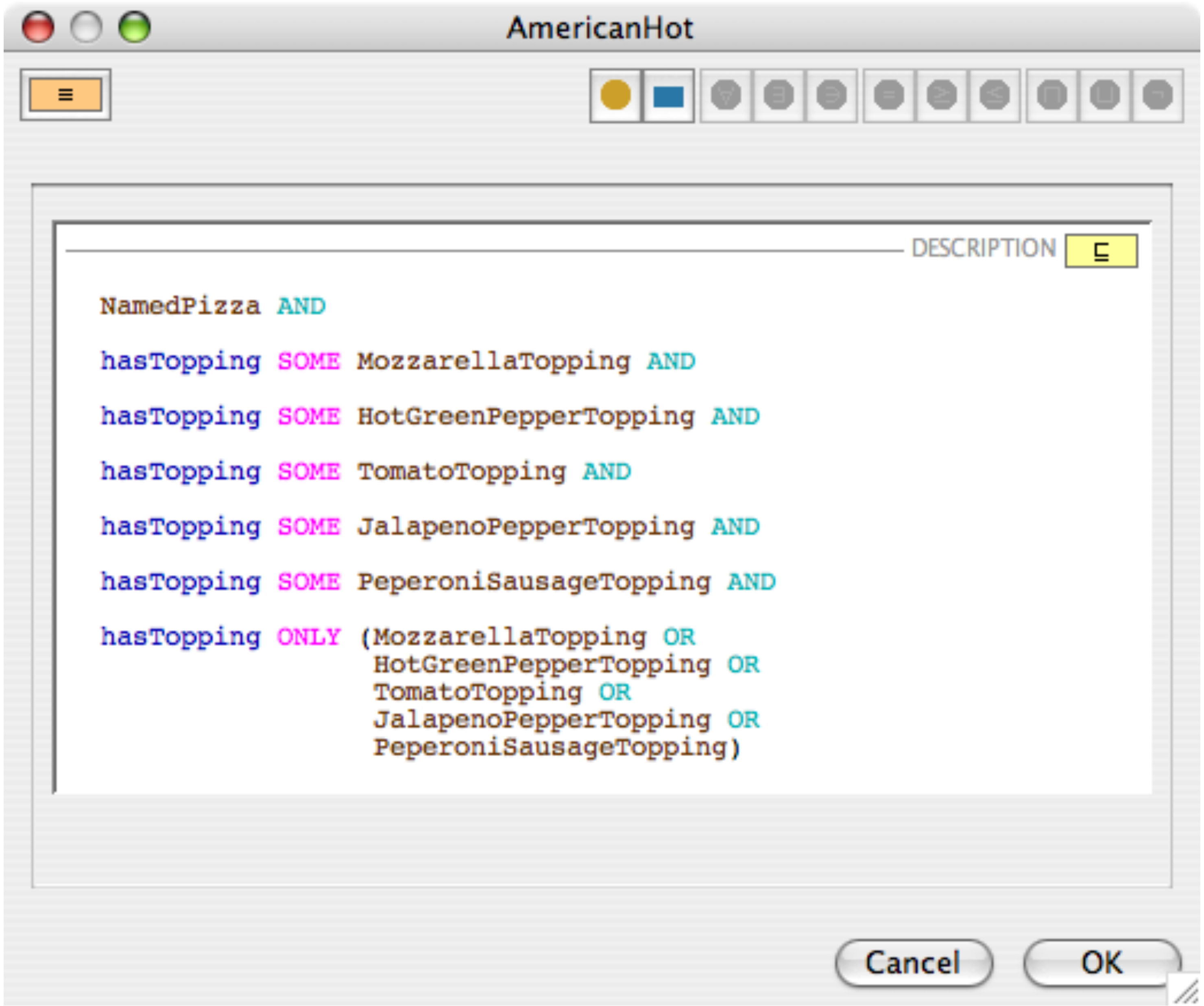
The World	Software Systems
Problem Domain *Problem Analysis*	*System Domain* *System Design*
No FM in USA	Satellite Radio
Digital radio quality required everywhere	Software-controlled embedded system

- A **glossary** is a set of explained terms
- A **classification** is a grouping of the concepts of a domain into classes
- A **taxonomy** (Begriffshierarchie) superimposes a hierarchical or acyclic is-a relationship
  - Analyse similarity (commonality-variability analysis)
- A **ontology** adds associations, class and relation expressions, and well-formedness constraints



Ontologies as Standardized Domain Models

- A **(domain) ontology** is a shared, standardized model for a domain, consisting of a taxonomy and integrity constraints (consistency constraints) constraining the hierarchy
  - 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)


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

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 the system
  - Models are abstract, partial representations of partial knowledge
- However, often, the word specification and model are used interchangeably (which is not precise)

Different Kinds of Specifications and Models

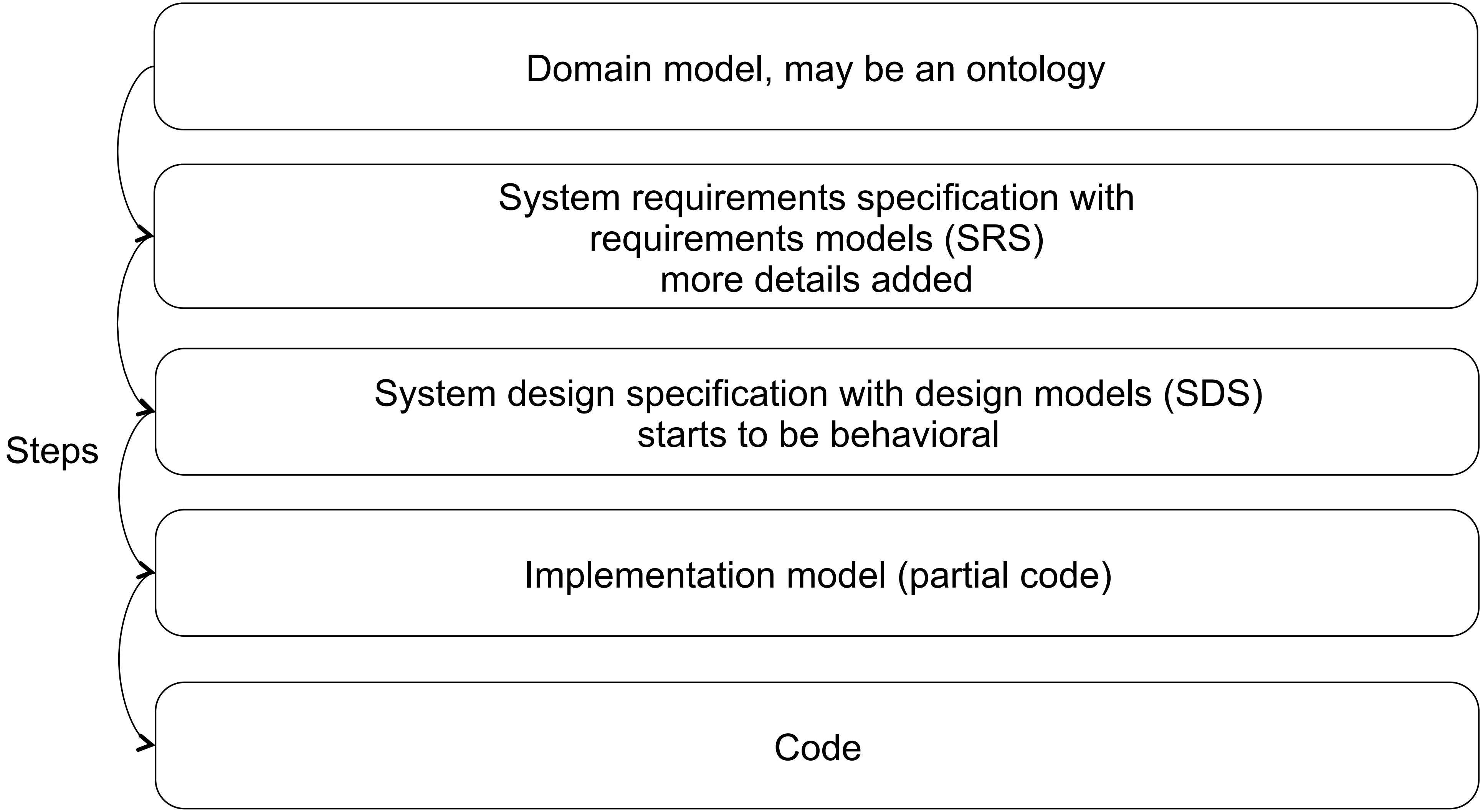
- **Descriptive (Analysis) models**
- Domain model:
  - Domain analysis is the process of identifying and organizing knowledge about the application domain
- "Real"-Problem model:
  - Usually, the requirement specification includes a problem model – to support description and solution of these problems
- Goal models
  - What do we want to achieve with the system?

- **Prescriptive models (system models, specifications)**
  - 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
- Architecture models
  - Describing the software architecture
- Implementation models:
  - partial representation of the system on the level of an implementation language

Structural vs. Behavioral Models

- A structural model captures the structure of a reality
  - Integrity constraints for well-formedness
- A behavioral model captures its behavior
- A behavioral model uses a structural model and adds a model how a reality reacts
  - operations (functions, procedures, methods, ...)
  - event-condition-action rules,
  - 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



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 area is called *formal methods* of software engineering
- Prediction is important for **critical software:**
  - Real-time software in embedded systems
  - Safety
  - Security and privacy
  - Energy efficiency

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
  - **Compose** from components
  - 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
  - **Rotate:** Symmetry operations (semantics-preserving operations)
  - **Restructure** (**refactor)** (more structure, but keep requirements and delivery, i.e., semantics)
    - Which restructuring? (when is a specification too complex?)
  - **Transform Domains** (change representation, but keep semantics)
    - Which representation change? (which representations are appropriate for which purpose?)

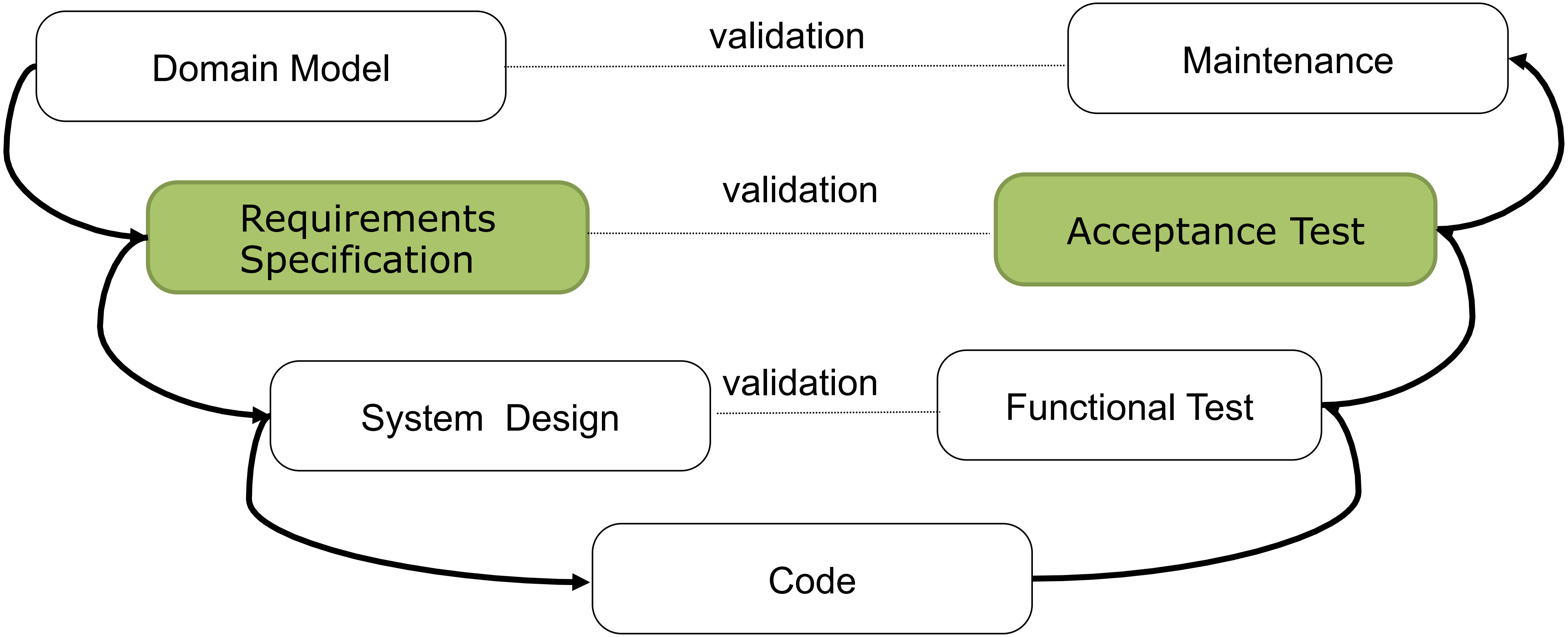
Reuse of Models and Code in Construction

- 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

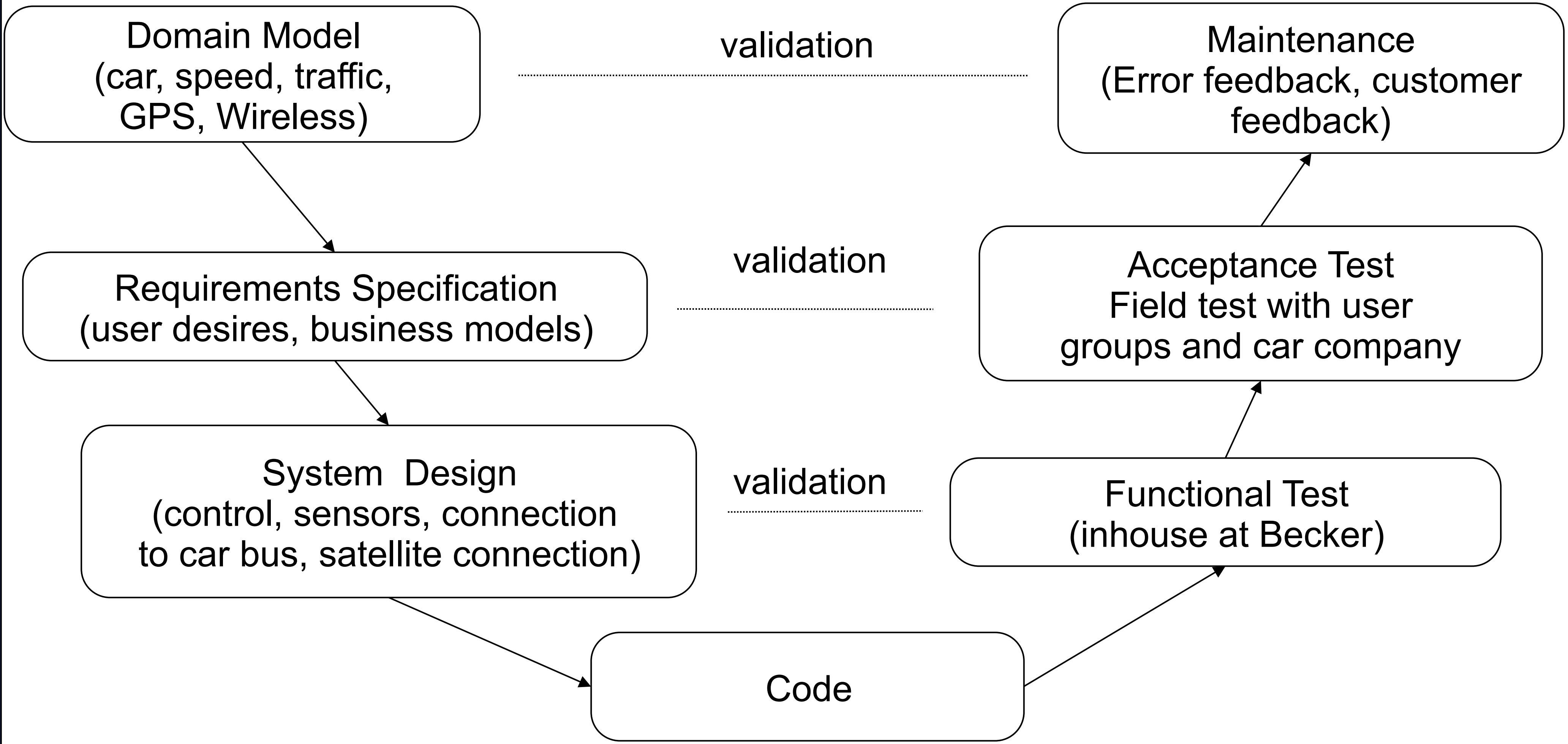
2.2.4. 4TH STEP: VALIDATION

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

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 Best Seller Is...

- .. 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

??

2.3 SOLVING PROBLEMS – A TASK FOR ENGINEERS AND ENTREPRENEURS

Why do we need to care about money?

- Calculating the cost and the price of a product is essential for an engineer
- While usually other people distribute the products on the markets („Vertrieb"), engineers must give a price for a product!

> Was sich nicht verkaufen lässt, will ich nicht erfinden.
>
> Thomas Alva Edison http://www.gratis-spruch.de/

Was ist ein Profi?

- http://www.dwds.de/pages/pages_textba/selbst_out/Selbsteinwechslung.html

Wortform: Selbsteinwechslung

- Unten der rechte Schuh, Größe 47, den Günter Netzer im Pokalfinale 1973 nach seiner berühmten Selbsteinwechslung trug - und auch hier irrt der Katalog, denn es ist eben nicht der Schuh, mit dem er kurz danach das Siegtor für Borussia Mönchengladbach schoß.
- In: o.A., Beidfüßige Lektüre, in: Frankfurter Allgemeine 24.08.2000, S. 46
- Nach: o.A., Beidfüßige Lektüre, in: F.A.Z.-Buchkritik 2000, Frankfurt a.M.: Frankfurter Allgemeine Zeitung GmbH 2000

http://www.goethe.de/ges/spr/prj/tor/fum/kdk/de297603.htm

- The difference of entrepreneurship and capitalism is
  - A capitalist wants to earn money
  - An entrepreneur solves problems
- Central question: Which problems can I solve for other people?
  - Get rid of a negative life: What do people need? Where is their **pain**?
  - Enabler for a positive life: What do people care about? Where is a **value** for the customer?

An entrepreneur solves problems of people.

“Make things that remove people’s **pain**”

Pain removers

An entrepreneur creates a **value** in the life of the customer.

“Make things that people need”

Happiness enablers

- „Die Grameen-Bank ermuntert die Kinder ihrer Kreditnehmer auch zum Schulbesuch. .. Derzeit studieren mehr als 50000 Studentinnen und Studenten mithilfe von Ausbildungskrediten der Grameen-Bank...
- Wir ermuntern diese jungen Leute, sich fest vorzunehmen, dass sie sich niemals als Arbeitssuchende auf den Arbeitsmarkt begeben werden. Sie sollen später einmal Arbeitsplätze schaffen, nicht sich um Arbeit bewerben. Wir sagen ihnen: Euren Müttern gehört eine große Bank, die Grameen-Bank. Die hat einen Haufen Geld, mit dem sich jedes Unternehmen eurer Wahl auf den Weg bringen lässt. *Warum wollt Ihr Zeit mit Arbeitssuche vergeuden, um dann für jemand anderen zu arbeiten? Werdet lieber Arbeitgeber, keine Arbeitnehmer.*
- *Die Grameen-Bank ermutigt die Menschen von Bangladesh zur unternehmerischen Selbständigkeit und wirtschaftlichen Unabhängigkeit – weg von der Abhängigkeit*."
- Mohammad Yunus – Social Business. Von der Vision zur Tat. Hanser 2010.

The Entrepreneurial Type

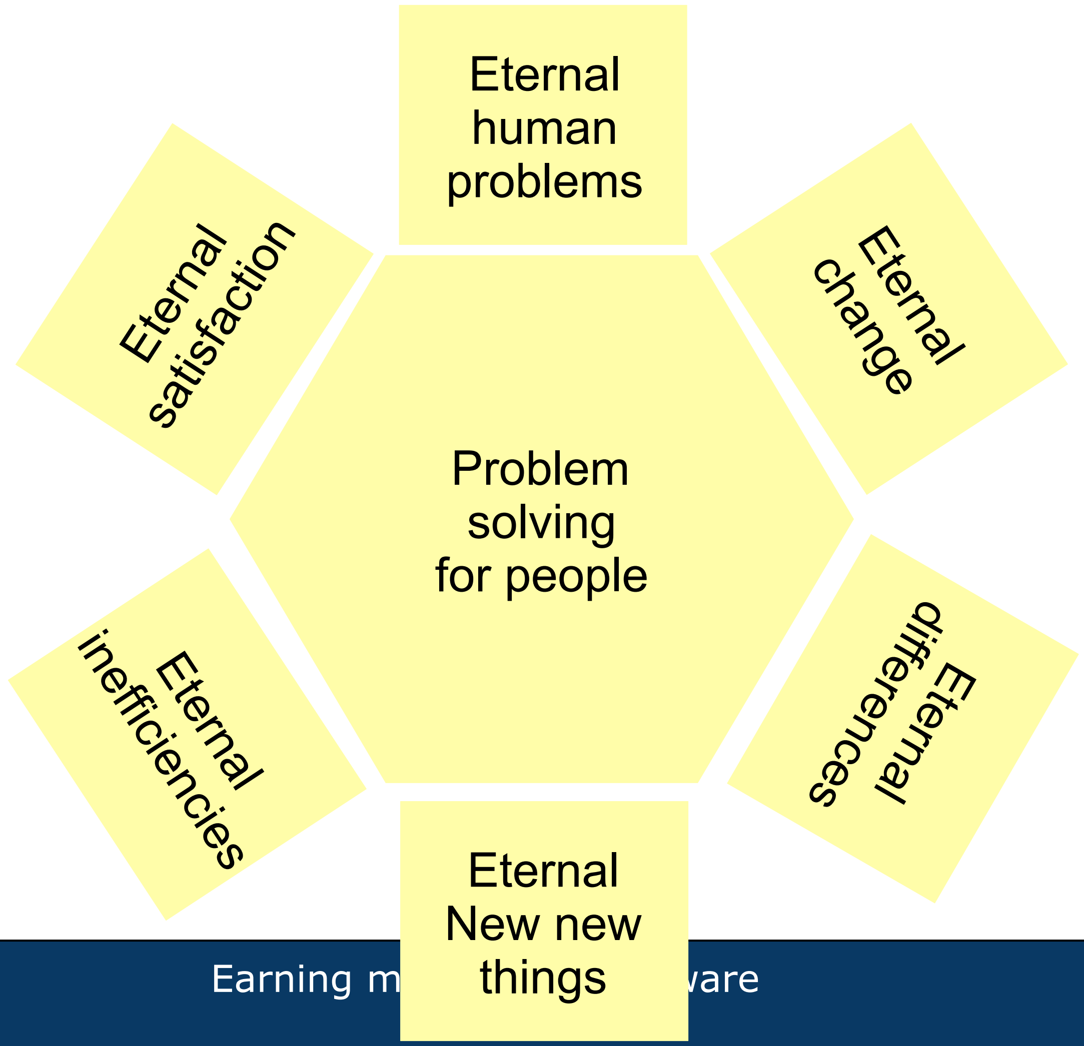
- Hard work: do you want to spent 5 years in business until your company has survived?
- An entrepreneur must long for freedom and independence
  - Uncertainty vs longing for freedom: People appear in two classes:
    - Security type: tends to avoid risks. Likes to be told what to do
    - Independence type: loves freedom, independence.
- Self discipline
- Aims realistic?

Problem Solving – A Task for the Engineer and also the Salesman

- Successful engineers and salesmen also solve problems for their customers.
  - A successful engineer or salesman can always return to a customer because he has created *satisfaction* in the customer (Kundenzufriedenheit)
- The engineer solves problem with an engineering technology
- The salesman solves problem by mediating the customer's financial situation and the engineer's solution
- In small companies, software engineers have to play the role of a salesman, too [Konrad Zuse, Mein Lebenswerk] [Klaus Kemper. Heinz Nixdorf]
- Some of the greatest entrepreneurs of the 20th century have been engineers: Werner von Siemens, Konrad Zuse, Heinz Nixdorf

2.3.2 STRATEGIES OF SOLVING PROBLEMS AND SELLING

- „When you find inefficiency, you find opportunity“ [Barrack]
- „Make things people need“



Provide Problem Solving

- “Knowing a good problem is half the business”
- “Selling drilling machines is not as important as selling holes, but these are completely different businesses” (H. Kagermann, SAP)
- Problem analysis of customers: Find out about problems, and you will earn money
  - Apply ZOPP to the Problem Area
    - Stakeholder analysis is important
    - Find out about the problems of a user group
    - Find out about their goals
    - From there, derive the product
- Try to find **pain problems**, because they create pressure on the customer

Exploit the Eternal Human Problems and Needs

- Hunger, Food, Restaurants, ...
- Love, Relationship
- Hobby
- Beauty
- Exhibiting oneself (Flickr, youtube)
- Housing
- Save money
- Overcoming the Space problem: Car, Flights,...
- Simplifying complex things
  - Overcoming bureaucracy
- Communication (Nokia "Connecting people")
- Being different from others (individualism)
- Lazyness
- Searching knowledge (expert portals)
- Relaxing
  - Tourism, Travel,..
- Events
  - Party, meeting people

Which of these problems is a need, if satisfied, makes the customer happy (happiness problem)?

Which of these problems is a pain problem?

Exploit the Eternal Change

- The markets, the customers, the competitors change.
  - Find out about change, and you will earn money
  - Old players do not recognize change, but often are too immutable
- The stock market principle: "sell when high, buy when low"
  - Investments in a crisis create value
- Embrace change
  - Use it for your purposes, or change will roll you over.
  - Some markets die after some time. Recognize the change, and change your market.
- Which of the expected changes will create pain? (**pain change**)
  - Year 2000 problem was a pain change problem with deadline.
  - Lots of problems had to be solved
- Investigate the future
  - By looking at market change forecasts, e.g., [Canton]
- Look out for **goldrushs:** A **goldrush** is a change with disruptive changes, opening many new changes
  - The German "Energiewende" is a goldrush change with deadline in 2020

Which of these changes is a pain change?

"**Nenne einen Markt, der mit 20 bis 70 Prozent waechst, und es ist fast sicher:**" meint Dr. Konrad Seitz: "**Die Deutschen sind nicht dabei.**" -

Which of these changes is a gold rush change?

Exploit Eternal Differences

- Know-how vs absent know-how
  - Consultance
- Differences in knowledge:
  - Wikonomics: sharing knowledge in a web community
- Cultural differences
- Export from one region; import to the other
  - Asian restaurants, Gyros, Döner
  - Teleconferencing

Eternal Satisfaction
IBM's secret: Customer Satisfaction

- Satisfy your customer (Customer satisfaction)
  - IBM: T. Watson, “THINK”
- Dont' loose a customer. Try to please him so that she returns.
  - It is much more easy to gain somebody who was customer before than getting a new customer
  - Quality and confidence pays off.

Over time, things become commodity which is given away very cheap or for free

- Innovation creates new new things for which customers may pay higher prices
- "New New Things" are goldrush changes
- Michael Lewis. The New New Thing. A Silicon Valley Story. Coronet Books. Hodder and Stoughton. Tells the story about Jim Clark, founder of Netscape, how he founds another company, Healtheon, end of the 90s.

2.3.2 WHAT TO SELL AS A SOFTWARE ENGINEER

Different Types of Things to Sell

What you might sell:

- Consultancy: sell your know-how
  - Analysis studies on a market, trend or strategy
- Service (Requ.analysis, testing, maintenance, modernization, reengineering)
  - Many big companies have their focus there: IBM
- Individual projects for "individual software"
  - SD&M, Accenture, Saxonia systems, …
- Product
- Product line (product family)
  - Horizontal product line: one product idea in several markets
  - Vertical product line: several products in one market
- Software platform for software ecosystem
- Enterprise landscapes (Anwendungslandschaft) with integration of many tools

Guidelines

- "Go directly to the product" (Prof. Hufenbach)
  - Always consider: which unit of my work will others want to sell?
  - What can be made to a product?
  - For products, licences can be sold
- However, it is difficult to get a software product
  - Software is often considered as a commodity, for which people do not want to pay
  - If a software technology (tool, framework, etc.) is not used, it does not immediately create pain in the customer
- Software is "Soft":
  - Does not have a production cost
  - Others may be able to easily rebuild it
- How can we nevertheless have "software products"?

- Figures of 2005 in Mrd. Euro [IX Magazine, 3/2006]
- Products
  - Software licences 2.7 (18% growth)
  - Products incl. maintenance 5.9 (ERP 1.2, CRM 0.6, SRM 0.12)
- Service
  - Consultancy 2.1
  - Training 0.3
- Turnaround (Umsatz) 8.5
- Win (Gewinn vor Steuern) 2.3
- Win net (Gewinn nach Steuern) 1.5
- Market size:
  - Currently targeted: 40 Mrd Euro
  - In 2010, with an extended product portfolio: 70 Mrd Euro

Maturity Levels of Companies

- Class 1 (work hour business): Consultancy and service and individual projects have no income out of licenses, and do not generate a dependency on vendor (vendor lock-in).
  - It is easy to switch them
  - They earn money by selling work hours
- Class 2 (licensing business): Products, product lines, software platforms, and enterprise landscapes generate license incomes
  - Ex. Kontron (embedded systems vendor) is a product and product line company, without vendor lock-in.
- Class 3 (vendor lock-in): Product lines, software platforms, and enterprise landscapes generate dependencies on the vendor.
  - Vendors are hard to switch
  - Ex. SAP is class 3

Software companies are called **mature,** if they generate license fees or maintain a vendor lock-in

Different Types of Things to Sell

What you might sell:

- Consultancy: sell your know-how
  - Analysis studies on a market, trend or strategy
- Service (Requ.analysis, testing, maintenance, modernization, reengineering)
  - Many big companies have their focus there: IBM
- Individual projects for "individual software"
  - SD&M, Accenture, Saxonia systems, ...
- Product
- Product line (product family)
  - Horizontal product line: one product idea in several markets
  - Vertical product line: several products in one market
- Software platform for software ecosystem
- Enterprise landscapes (Anwendungslandschaft) with integration of many tools

Chapter testing, requirements analysis, modeling, model structuring

Chapter "design methods"

Chapter "Product lines"

Chapter "Earning money with software"

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
- Software companies earn money with different forms of activities. Mature companies have revenues based on licensing and vendor-lock-in.
- The course is structured along these activities

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)”.