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"Nothing is Permanent except Change" – How Software Architects can embrace Change

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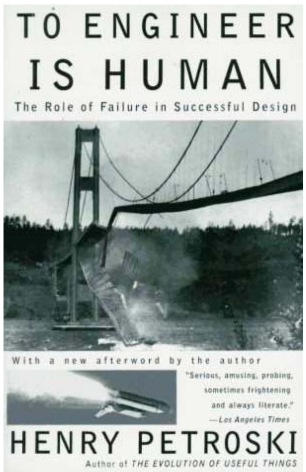
Learning from failure

Failure and understanding failure is a key factor for successful design!

[Henry Petroski]



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Last chance to escape!

Warning: This presentation is about pragmatic software development projects. It only contains very few scientific insights

Or as an unknown scientist called Einstein once said: In theory, theory and practice are the same. In practice, they are not

But I will provide the first ~~Perpetuum Mobile~~ Silver Bullet for optimizing systems:

The Silver Bullet

There actually IS a silver bullet for boosting software engineering productivity: shoot the right person

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One Side of the Coin: System & Software Architecture Design

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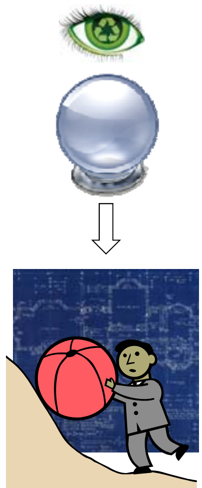
- You could design the best architecture if you knew **everything** in advance – **i.e., we could anticipate change**
- In that case, the Waterfall model would be a perfect fit
- Unfortunately, the real world is not perfect. **It is changing in unanticipated ways. That's what we call evolution**
- But for sustainable software architecture we need at least a stable base, i.e. core design that does only change rarely



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Can we balance both sustainable architecture design and need for change?

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Agenda

- A bit of architecture change
- Requirements Engineering and its impact on design
- **Some other architecture viewpoints**
- *And now for something completely different: testing*
- More architecture issues I forgot to cover so far
-
- **Premature refactoring**
- But here the talk is over, maybe ☹
- *Did I already mention change*?

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JUST KIDDING!

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**Change and Architecture?
- Two Ends of the Spectrum**

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Architecture design from day 1 in a total agile approach

Architecture with Big Design Up Front

Unstable architecture!

Nice but either unsuitable or overengineered architecture!

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Quo Vadis, Architect?

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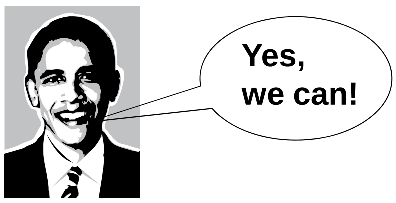
- Is agile architecture a kind of magic only gurus and wizards can master?

As designers we like to get the best of both worlds:

obtain a stable, sustainable core,

AND embrace change.

Can we achieve this objectives and, if yes, how would we proceed?



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Let‘s dig deeper

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Process Models – Iterative-Incremental Model

The iterative incremental life cycle

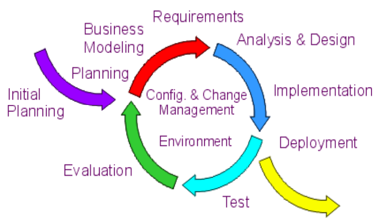
- evolutionary model
- releases created as prototypes in an iterative approach based on accurately defined rules

An iteration

- a sequence of activities or tasks performed within a period of time (4-8 weeks)
- typically requirements analysis (at least partially), design, implementation, integration, testing (partially)

An increment is a

- stable, executable and testable software release
- provides new functionality that moves the product closer to its completion



Iterative **means** ***re-do:***
a rework scheduling strategy which helps to improve the (quality of the) product

Incremental **means** ***add onto*****:**
a staging and scheduling strategy which helps to improve the process and feature set by avoiding a big-bang Integration

→ We should use both approaches together, i.e. we use the benefits of both!!!

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Introducing a Change-Based Quality Feedback Loop

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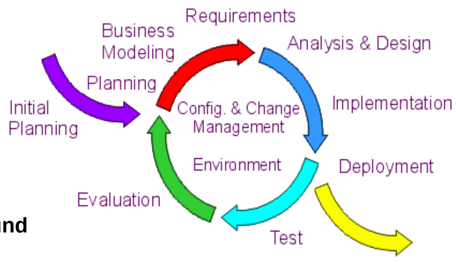
Define and realize a software architecture using an iterative, risk-driven, requirements-driven, and test-driven development process, in which

- **An iterative, time-boxed approach provides continuous feedback**
- **Risk- and requirements orientation ensures that the most important aspects of the system's realization are addressed first**
- **A test-driven approach provides concrete feedback on the quality of the architecture and its realization**



The goal of each iteration is to produce product quality and less risk, so that the next iteration can be taken on safe ground

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Why we should care about Architecture

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If you think good architecture is expensive, try bad architecture

[Brian Foote and Joseph Yoder]

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Architecture versus Design (according to Len Bass)

"Design is a continuous activity of making decisions beginning with a collection of decisions that have broad system wide scope and moving to a collection of decisions that have very narrow scope

I would characterize a decision as architectural if it has one or more of the following properties:

- *it has system wide impact*
- *it affects the achievement of a quality attribute important to the system"*

„Architecture is about the important things" [Martin Fowler]

„Architecture is about everything costly to change" [Grady Booch]

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Strategic and Tactical Design

Strategic design focuses on global system scope

At the beginning consider only strategic requirements, i.e., requirements with systemic and strategic impact:

- All functional requirements
- All operational requirements

Tactical Design encompasses all local design decisions with non-systemic impact

Tactical requirements are requirements with local scope such as developmental requirements (e.g., modifiability)

„Stable" Strategy but Tactical Adaptations

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The Art of Architecture

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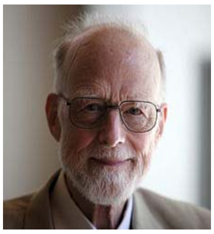

There are two ways of constructing a software design: One way is to make it so simple that there are obviously no deficiencies, and the other way is to make it so complicated that there are no obvious deficiencies. The first method is far more difficult

[C.A.R Hoare]

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Some Advice from an Expert: Frederik P. Brooks

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Design comprises three phases:

1. Formulation of conceptual constructs
2. Implementation in real media
3. Interaction with real users

Iterative evolutionary design is essential

In the first months requirements engineering and architecture design should go hand in hand, because

While architects don‘t fully understand the requirements, customers don‘t fully understand the design

Write down all assumptions about users and their uses in the beginning

Learn from your predecessors

Maintain a sketch book with your ideas, concepts

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An Architecture Process from 10000 feet that addresses Change

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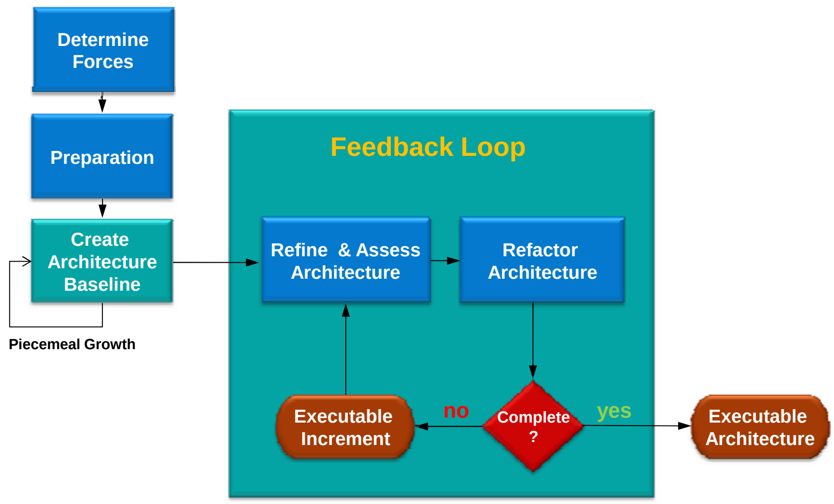

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Architecture approach in detail

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The Onion Model – Two Core Principles: Priority Driven & Strategic before tactical design

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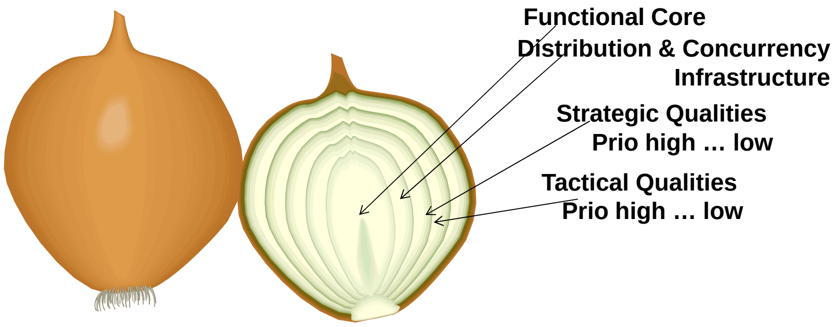
Architecture design follows an onion model:
- start with the inner core
- incrementally continue with outer layers



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No Deep Dive - The Pyramid Model

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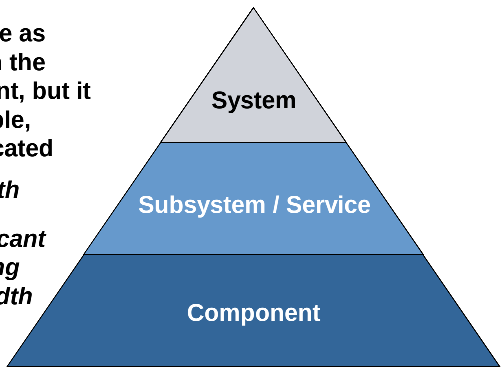
How deep do we need to go?

The baseline architecture must be as complete as necessary to govern the subsequent software development, but it must also be as simple as possible, otherwise it cannot be communicated

Three levels of detail to limit depth

A focus on architecturally significant requirements and corresponding architecture views to limit breadth



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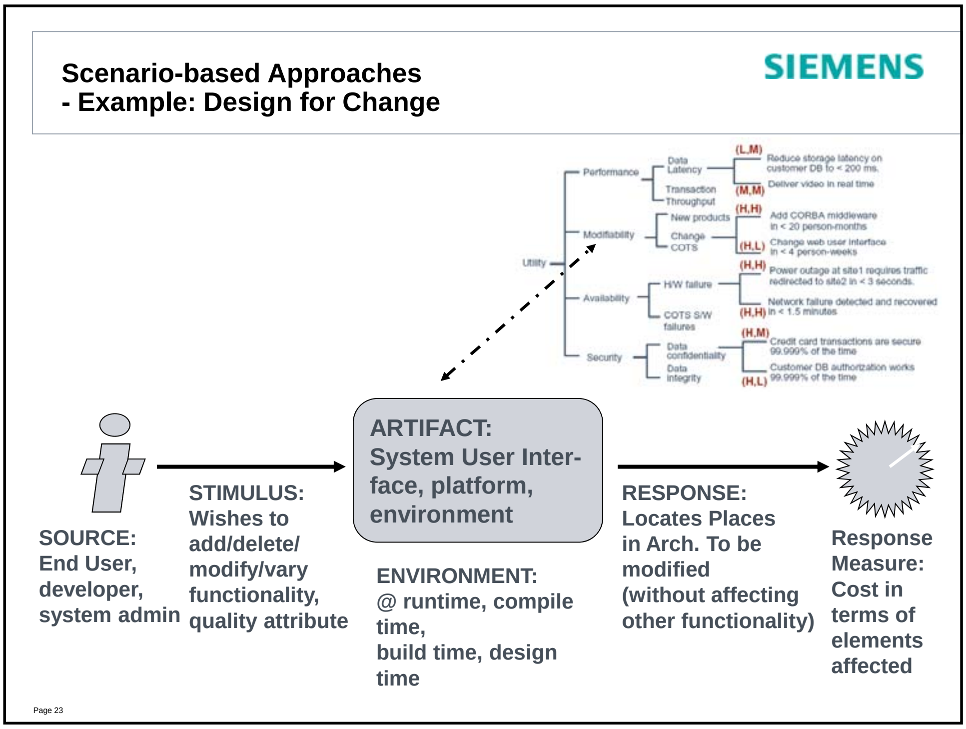
Scenario-based Approaches
- Example: Design for Change
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Utility
Performance
Data Latency
Transaction Throughput
(L,M)
Reduce storage latency on customer DB to < 200 ms.
(M,M)
Deliver video in real time
Modifiability
New products
Change COTS
(H,H)
Add CORBA middleware in < 20 person-months
(H,L)
Change web user interface in < 4 person-weeks
Availability
H/W failure
COTS S/W failures
(H,H)
Power outage at site1 requires traffic redirected to site2 in < 3 seconds.
(H,H)
Network failure detected and recovered in < 1.5 minutes
Security
Data confidentiality
Data integrity
(H,M)
Credit card transactions are secure 99.999% of the time
(H,L)
Customer DB authorization works 99.999% of the time
SOURCE: End User, developer, system admin
STIMULUS: Wishes to add/delete/ modify/vary functionality, quality attribute
ARTIFACT: System User Inter-face, platform, environment
ENVIRONMENT: @ runtime, compile time, build time, design time
RESPONSE: Locates Places in Arch. To be modified (without affecting other functionality)
Response Measure: Cost in terms of elements affected
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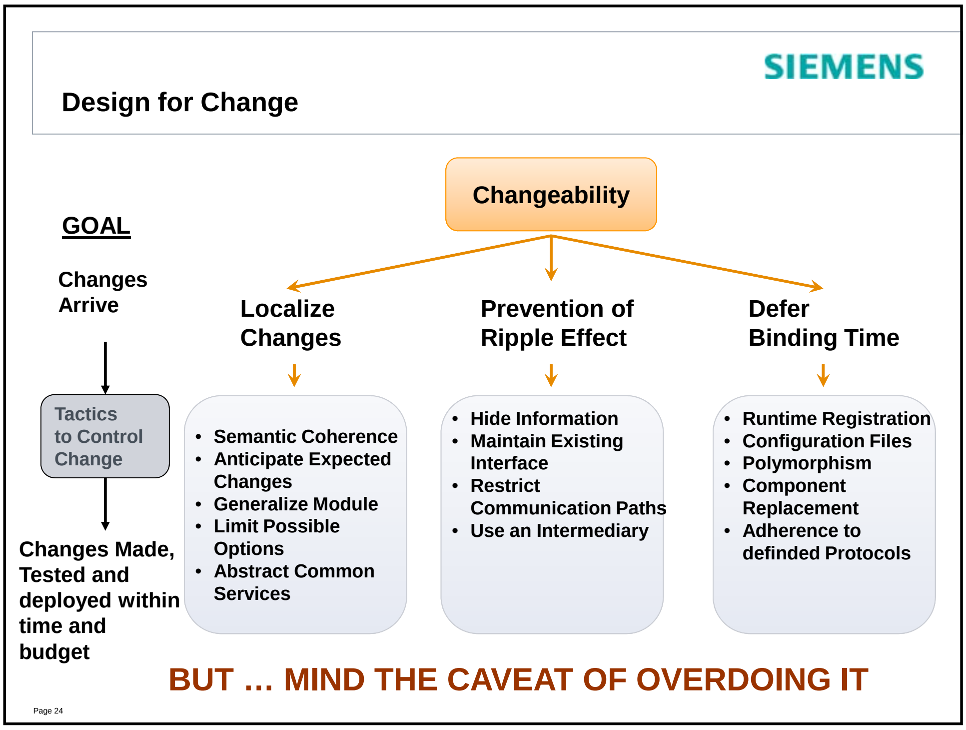
Design for Change
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GOAL
Changes Arrive
Tactics to Control Change
Changes Made, Tested and deployed within time and budget
Changeability
Localize Changes
Prevention of Ripple Effect
Defer Binding Time
• Semantic Coherence
• Anticipate Expected Changes
• Generalize Module
• Limit Possible Options
• Abstract Common Services
• Hide Information
• Maintain Existing Interface
• Restrict Communication Paths
• Use an Intermediary
• Runtime Registration
• Configuration Files
• Polymorphism
• Component Replacement
• Adherence to definded Protocols
BUT … MIND THE CAVEAT OF OVERDOING IT
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(Re-)Use is Essential

Human beings, who are almost unique in having the ability to learn from the experience of others, are also remarkable for their apparent disinclination to do so.

[Douglas Adams. 1952-2001. *Last Chance to See]*

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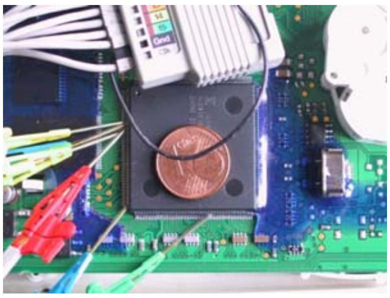
Some Words about Dealing with Technology and Hardware Changes

- Use feasibilty prototypes for technologies that are mission critical
  - Especially to check for quality attributes
- Use simulations if you are in a system engineering / embedded system context:
  - Simulate what is missing or difficult to test otherwise
  - Do not only test at Q Gates



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An Architect's Framework

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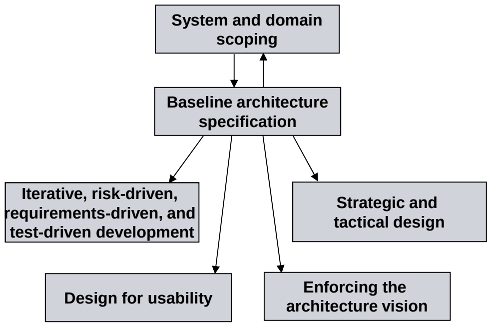
The mindset, activities, practices, methods, and technologies for defining and realizing software architectures form a best practice framework for software architects to …

- Specify and implement a software architecture systematically and in a timely fashion
- Check and ensure the appropriate architectural quality
- Respond to changes of all kinds, such as changing requirements and priorities
- Deal with problems that arise during the definition and realization of the software architecture



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Panta rhei - Evolutionary Design embraces Change

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There is nothing permanent except change

[Heraclitus, 535–475 BC]

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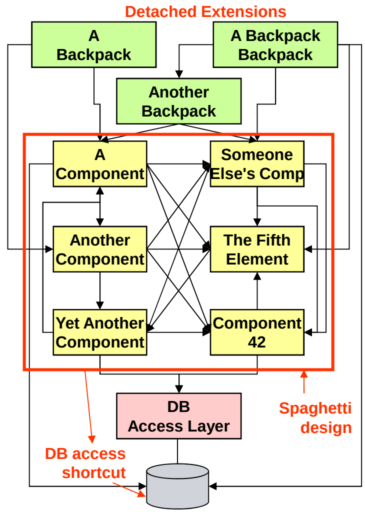
Design erosion is the root of evil

In the lifecycle of a software system changes are the rule and not the exception

Unsystematic approaches ("workarounds") cure the symptom but not the problem

After applying several workarounds, software systems often suffer from design erosion

Such systems are doomed to fail (negative impact on operational & developmental properties)



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How do we know we must improve?

Lack of Internal or External Quality

- Quality Attributes (use methods like ATAM), and,
- Structural quality indicators which include
  - Economy
  - Visibility
  - Spacing
  - Symmetry
  - Emergence
- Consequently, the goal of architecture improvement is to achieve or meet such qualities

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There is a strange Smell

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If it stinks, there must be something we need to clean up

Architecture smells

- Duplicate design artifacts
- Hammer&Nail syndrome
- Unclear roles of entities
- Inexpressive or complex architecture
- Everything centralized
- Home-grown solutions instead of best practices
- Over-generic design
- Asymmetric structure or behavior
- Dependency cycles
- Design violations (such as relaxed instead of strict layering)
- Inadequate partitioning of functionality
- Unnecessary dependencies

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Example of Architecture Problem

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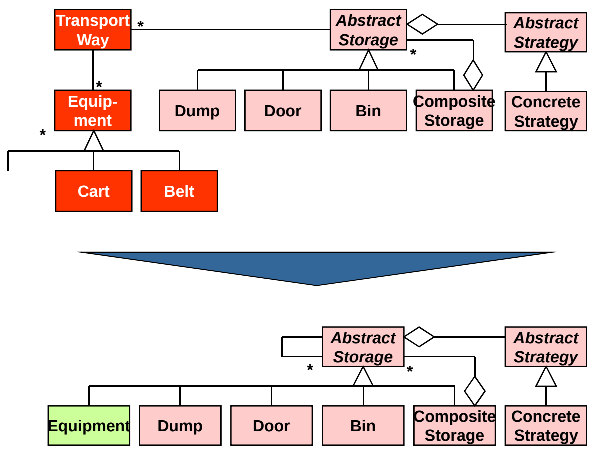
A true story: In this example architects introduced Transport Way as an additional abstraction. But can't we consider transport ways as just as another kind of storage? As a consequence the unnecessary abstraction was removed, leading to a simpler and cleaner design.



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Possible Refactoring Pattern

Context
- Eliminating unnecessary design abstractions

Problem
- Minimalism is an important goal of software architecture, because minimalism increases simplicity and expressiveness
- If the software architecture comprises abstractions that could also be considered abstractions derived from other abstractions, then better remove these abstractions

General solution idea
- Determine whether abstractions / design artifacts exist that could also be derived from other abstractions
- If this is the case, remove superfluous abstractions and derive from existing abstractions instead

Caveat
- Don't generalize too much (such as introducing one single hierarchy level: "All classes are directly derived from Object")

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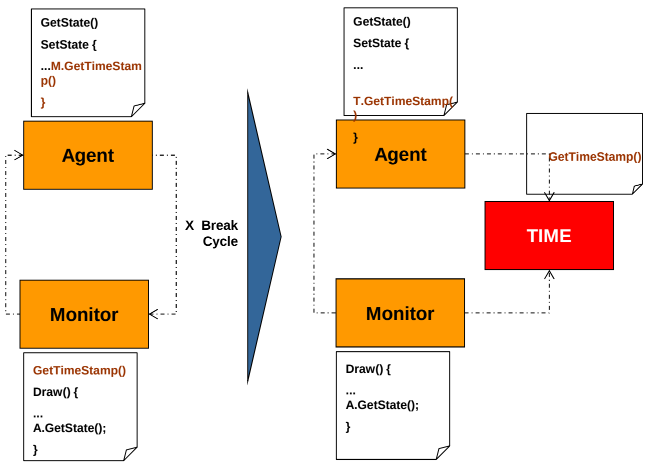
Yet another example

Monitors need to access agents to control the network

Agents change their internal state and create events

To have a common clock architects decided to enhance the monitor

... which leads to a cycle



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Yet Another Refactoring Pattern

Context

- Cyclic dependencies between subsystems

Problem

- System reveals at least one dependency cycle between subsystems
- Subsystem A may either depend directly or indirectly on subsystem B (e.g., A depends on C which depends on B) which is why we always need
to consider the transitive hull
- Dependency cycles make systems less maintainable, changeable, reusable, testable, understandable

General solution idea

- Get rid of the dependency cycle by removing or inverting dependencies

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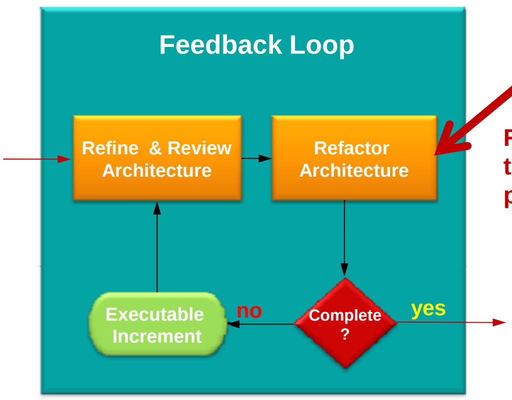
Change needs Refactoring



Refactoring is integrated into the architecture design process:

- It improves the structure
- It supports a risk-, requirements- and test-driven approach

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After refactoring check for correctness

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To check the correctness of refactorings, we should use a **test-driven approach**.

Available options:

- **Formal approach**: Prove semantics and correctness of program transformation
- **Implementation approach**: Leverage unit and regression tests to verify that the resulting implementation still meets the specification
- **Architecture analysis**: Check the resulting software architecture for its equivalence with the initial architecture (consider requirements)

Use at least the latter two methods to ensure quality

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Frequently discussed Obstacles to Refactoring

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Organization / management

- Featuritis: Considering improvement by refactoring as less important than features
- “Organization drives architecture” problem

Process support

- No refactoring activities defined in process
- Refactorings not checked for correctness, test manager not involved

Technologies and tools

- Unavailability of tools: refactoring must be done manually
- Unavailability of refactoring catalog

Applicability

- Refactoring used instead of reengineering
- Wrong order of refactorings

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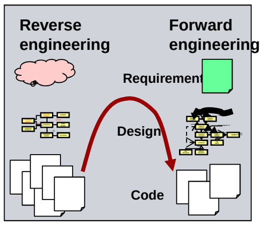
Reengineering – when and how to use it

Use Reengineering when

- The system's documentation is missing or obsolete
- The team has only limited understanding of the system, its architecture, and implementation
- A bug fix in one place causes bugs in other places
- New system-level requirements and functions cannot be addressed or integrated appropriately

Process

- *Phase I*: Reverse engineering
  - Analysis / recovery: determine existing architecture (consider using CQM)
  - SWOT analysis
  - Decisions: what to keep, what to change or throw away
- *Phase II*: Forward engineering



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Rewriting in a Nutshell

Rewriting is a radical and fresh restart: existing design and code is trashed and replaced by a whole new design and implementation. Depending on focus:

- Improves structure regarding:
  - Simplicity, visibility, spacing, symmetry, emergence
  - Maintainability, readability, extensibility
  - Bug fixing
- Provides new functionality
- Improves its operational qualities
- Improves design and code stability

As a consequence, rewriting addresses all types of software quality: functional, operational, and the various developmental qualities

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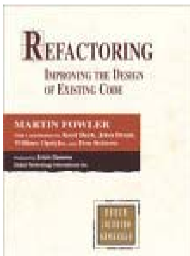
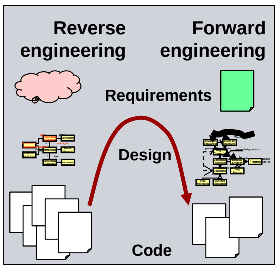
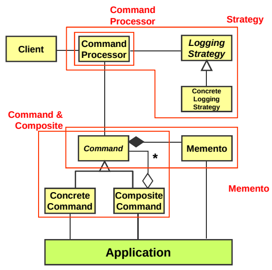
Refactoring, reengineering, and rewriting comparison (1)

Refactoring, reengineering, and rewriting are complementary approaches to sustain architecture and code quality

Start with refactoring – it is cheap and (mostly) under the radar
Consider reengineering when refactoring does not help – but it is expensive
Consider rewriting when reengineering does not help – but it is expensive and often risky







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Refactoring, reengineering, and rewriting comparison (2)

	Refactoring	Reengineering	Rewriting
Scope	▪ Many local effects	▪ Systemic effect	▪ Systemic or local effect
Process	▪ Structure transforming ▪ Behavior / semantics preserving	▪ Disassembly / reassambly	▪ Replacement
Results	▪ Improved structure ▪ Identical behavior	▪ New system	▪ New system or new component
Improved qualities	▪ Developmental (might change Operational Quality)	▪ Functional ▪ Operational ▪ Developmental	▪ Functional ▪ Operational ▪ Developmental
Drivers	▪ Complicated design / code evolution ▪ When fixing bugs ▪ When design and code smell bad	▪ Refactoring is insufficient ▪ Bug fixes cause rippling effect ▪ New functional and operational requirements ▪ Changed business case	▪ Refactoring and reengineering are insufficient or inappropriate ▪ Unstable code and design ▪ New functional and operational requirements ▪ Changed business case
When	▪ Part of daily work ▪ At the end of each iteration ▪ Dedicated refactoring iterations in response to reviews ▪ It is the 3rd step of TDD	▪ Requires a dedicated project	▪ Requires dedicated effort or a dedicated project, depending on scope

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Mind your Architecture Governance

Without Architecture Governance the System is subject to uncontrolled Change and Extension

Introduce countermeasures, e.g.,:

- Architecture Guidelines and Policies as well as their Enforcement
- Means to ensure Requirements Traceability
- No Checking-in without other Persons reviewing Code and Documents
- Test-Driven-Design
- Risk-Based Analysis & Test

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Software Architect's Dilemma

Life must be understood backwards; but ... it must be lived forward

[Søren Aabye Kierkegaard, Danish philosopher and theologian, 1813-1855]

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Reviews help finding the Bad Smells

Quantitative Architecture Reviews
- Code quality assessment
- Simulations
- Prototypes

Qualitative Architecture Reviews
- Scenario-based approaches
- Experience-based approaches

An Architecture Assessment or Review should *not* be considered an afterthought.

It is a means to check a system regularly and find problems early

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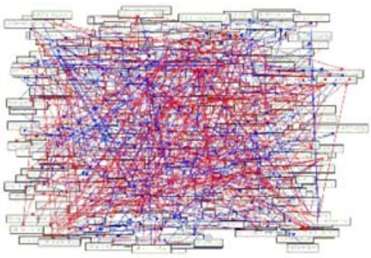
Visualization Tools help keeping the system in good Shape

In many projects the responsibility for internal code and design quality is not well defined

The software architect has to ensure that the required CQM activities are established

The software architect should be the protector of the quality of the software system!

Use Visualization Tools at least in larger code bases



By the way: this is a real system

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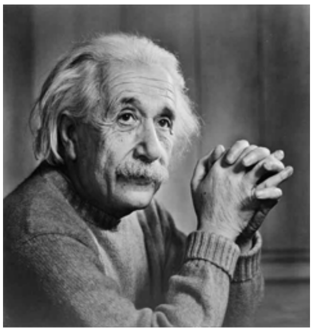
“Preventive Maintenance”

Experts solve problems, geniuses avoid them

[Albert Einstein]



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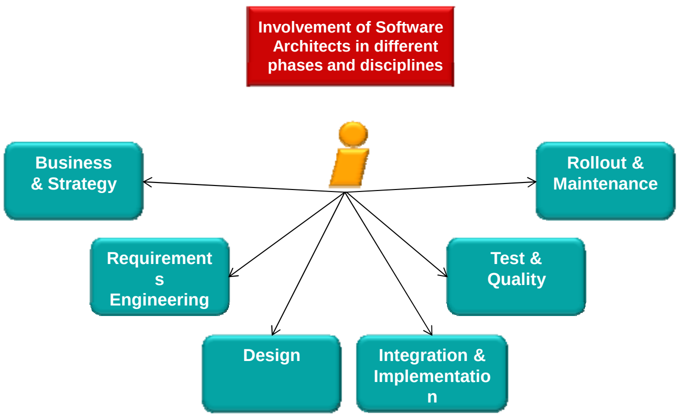
Architecture Quality is also influenced by other aspects



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Architects & Requirements – Problem 1: Understanding the Requirements

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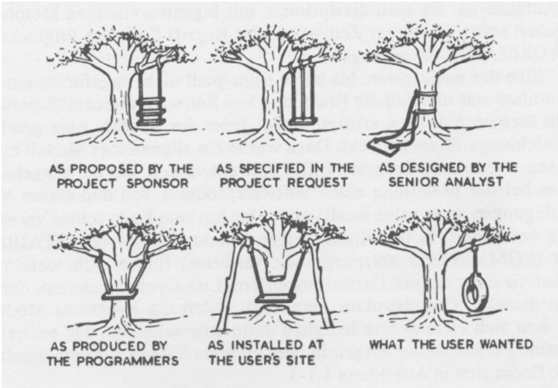

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Architects & Requirements – Problem 2: Implementing the Requirements

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A program which perfectly meets a lousy specification is a lousy program

[Cem Kaner, Software Engineering Professor and Consumer Advocate]

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Problem 3: Sources of Requirements

The system needs to support timezones

Did I tell them we have only 4 weeks

The system should be faster than light

The system should offer an interface

The system should be cheap AND offer 24 x 7

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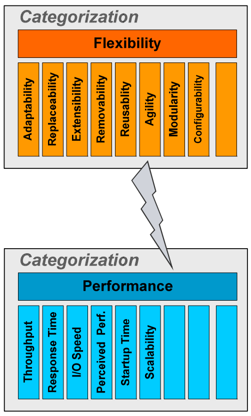
=> Requirements must have high Quality

Quality of Requirements determines Quality of Software Architecture

- *Cohesive*
- *Complete*
- *Consistent*
- *Correct*
- *Current*
- *Externally Observable*
- *Feasible*
- *Unambiguous*
- *Mandatory*
- *Verifiable*



Upon frequent change, quality of requirements is essential!

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No Risk – No Fun?

The most likely way for the world to be destroyed, most experts agree, is by accident. That's where we come in; we're computer professionals. We cause accidents

Nathaniel Borenstein, US Programmer

Needless to say, ad-hoc changes imply higher accidental complexity

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Mind all Risks and conduct a Risk Analysis early

Approach for risk analysis according to Christine Hofmeister (“Applied Software Architecture”):

- **Description of risk**: e.g., dependence on persistence layer
- **Influential factors that lead to this risk**: e.g., requirement to decouple business from persistence layer, not enough technology skills in team
- **Solution approach**: e.g., introduce data access layer
- **Possible strategies**: e.g., give subproject to external company, use open source solution, use platform-specific solution
- **Related topics and strategies**: e.g., decoupling business logic from other backend layers

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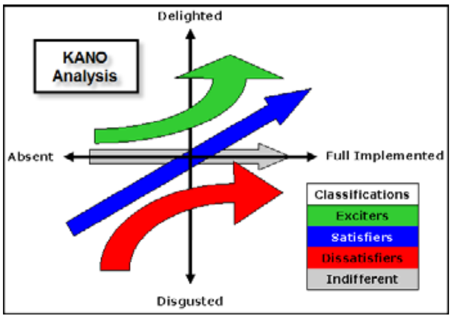
Knowing the expectations is essential

At least at project begin,

- Architects don't understand requirements very well
- Customers tell what they want, not what they need
- Architects may even not know the implicit requirements

Hence,

- Keep in touch with Customers
- Apply a KANO Analysis
- Understand your Business Goals
- Develop Design and Requirements in parallel



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Testing as a never ending story

Testing is an infinite process of comparing the invisible to the ambiguous in order to avoid the unthinkable happening to the anonymous

[James Bach, Test Guru]

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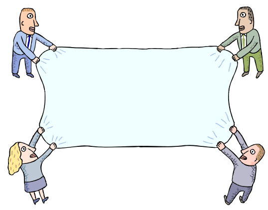
Testing is about Safety Nets not about Control

Observation (Peter Zimmerer):
Software products are never released – they escape!

Consequence: Mind the testing necessities during architecture design:

- Test Driven Design
- Test Exit Criteria
- Code Quality Management
- Appropriate Test Methods

Risk-Based Test Strategies are a good approach



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Risk Based Test Strategy

- Evaluate risks:
  - What is the risk
  - Which part of the system does it affect
  - How likely is the risk
  - How big is the possible damage
  - What priority does the risk have
  - Can it be tested? If yes, when and using what method
  - Can the test be automated
  - Which resources (budget, time, ---) are required

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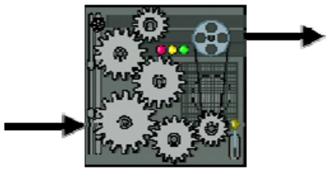
Design for testability – Practical definition

Visibility / observability

What you see is what you test

Ability to observe the outputs, states, internals, resource usage, and other side effects of the software under test

Interaction with the system under test through observation points



Control(lability)

The better we can control the software, the more testing can be automated and optimized

Ability to apply inputs to the software under test or place it in specified states (for example reset to start state)

Interaction with the system under test through control points

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Communication is essential

Software Development is a collaborative game

[Alistair Cockburn]

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Change-based Design requires Effective Agile Communication

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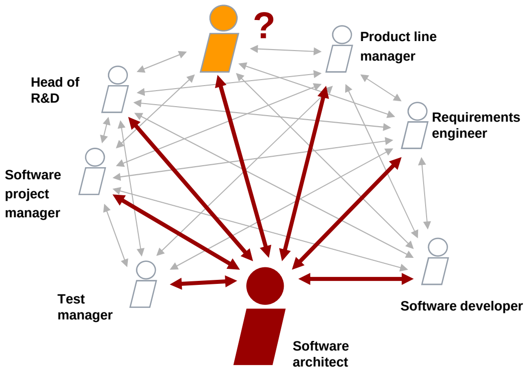
Leadership, and communication and interaction with other roles in software development, are probably the most time-intensive and most important responsibilities of a Software Architect

The roles with whom the architect interacts,

the topics about which they interact with these roles,

and the intensity of the interaction

depend on the concrete development workflow and activity performed in a software project



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Conclusions

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Architecture Change should be considered in the whole lifecycle, not only at the end - it is a crosscutting concern.

- The Development and the Architecture Design Process must support change
- There must be a balance between change and architectural stability
- Piecemeal Growth needs to be combined with Architecture Assessment
- Test Driven Design introduces Safety Nets
- Change requires Agile Communication

This is what Agile Architecture is about

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A departing thought

Each problem that I solved became a rule which served afterwards to solve other problems.

[René Descartes, 1596–1650, in "Discours de la Methode"]

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