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Software Engineering

Definitions
The process and product
Phases of the development process

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Why software engineering is important

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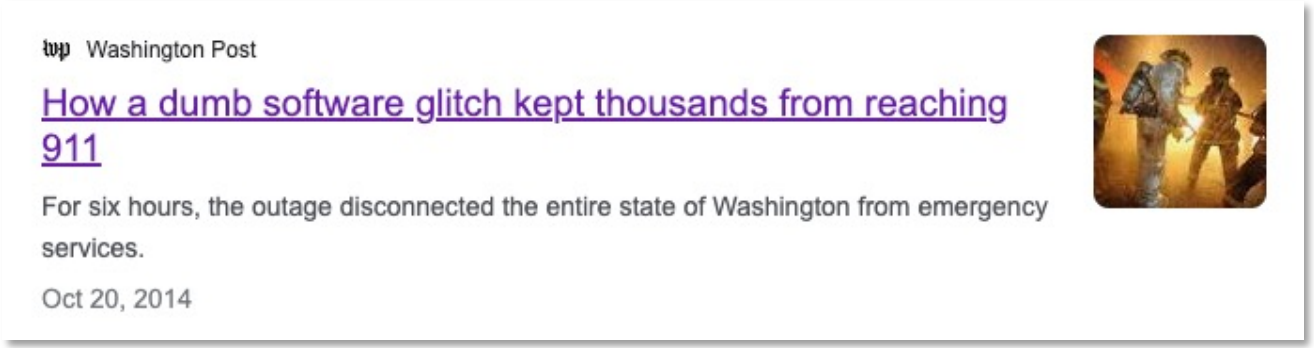
- Software is everywhere and our society is now totally dependent on software-intensive systems
- Society could not function without software
  - Transportation systems
  - Energy Systems
  - Manufacturing Systems
- Software failures cannot be tolerated

911 Outage on April 2014

- [April 10, 2014] Washington State had **no 911 service for six hours**
  - 911 is the phone number for emergency service in USA
  - People calling were getting the busy signal
    - A woman called more than 37 times while a stranger was breaking into her house
  - People at the central office were not aware of the problem
  - More at: https://www.theatlantic.com/technology/archive/2017/09/saving-the-world-from-code/540393/



911 Outage on April 2014

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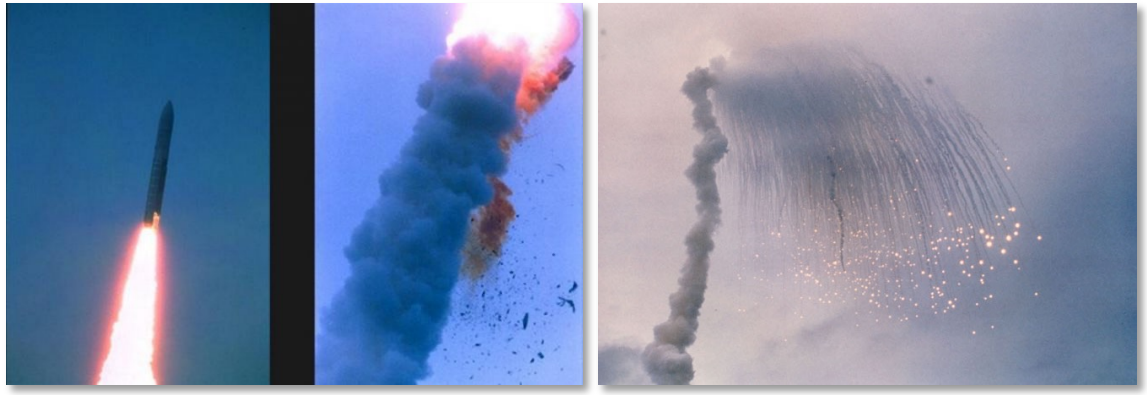
- Why did this happen? **Software issue!**
  - The software dispatching the calls had a counter used to assign a unique identifier to each call
  - The counter went over the threshold defined by developers…
  - All calls from that moment on were rejected

More on failures… Ariane 5, 1996

- [June 4, 1996] 40s after take off, Ariane 5 broke up and exploded
  - The total cost for developing the launcher has been of 8000M$
  - The launcher contained a cluster of satellites for a value of 500M$
  - More at
    - http://sunnyday.mit.edu/accidents/Ariane5accidentreport.html (accident tech report)
    - https://www.youtube.com/watch?v=PK_yguLapgA (video)



More on failures… Ariane 5, 1996

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- The explosion has been caused by a software failure
- From the tech report:
  - “The failure […] was caused by the complete loss of guidance and altitude information […]. This loss of information was due to **specification and design errors** in the software of the inertial reference system.”
  - “The extensive reviews and tests carried out during the Ariane 5 Development Programme **did not include adequate analysis and testing** of the inertial reference system or of the complete flight control system, which could have detected the potential failure.”

Software engineering: definition

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- Field of computer science dealing with software systems
  - large and complex
  - built by teams
  - exist in many versions
  - last many years
  - undergo changes
- Multi-person construction of multi-version software

Software engineer: required skills

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- **Programming skills not enough!**
  - Programmer:
    - develops a complete program
    - works on known specifications
    - works individually
  - Software engineer:
    - identifies requirements and develops specifications
    - designs a component to be combined with other components, developed, maintained, used by others; component can become part of several systems
    - works in a team

Skills of software engineers

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- Technical
- Project management
- Cognitive
- Enterprise organization
- Interaction with different cultures
- Domain knowledge

- The quality of human resources is of primary importance

Process and product

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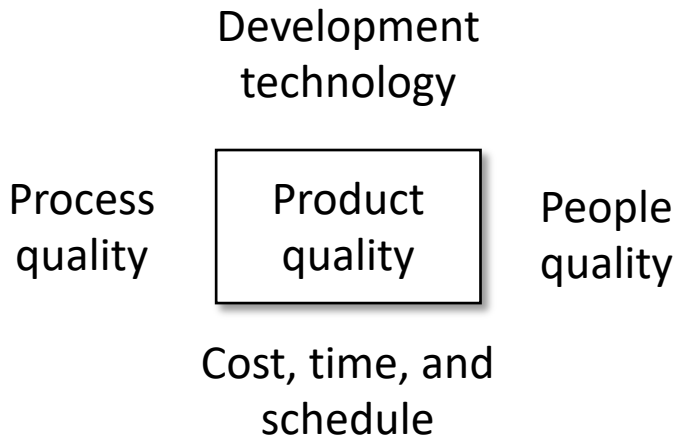
- Our goal is to develop **software products**
- The **process** is how we do it
- Both are extremely important, due to the nature of the software product
- Both have qualities
  - in addition, quality of process affects quality of product
  - …even though, other aspects such as the quality of the development team are important as well

The software product

- Different from traditional types of products
  - intangible
    - difficult to describe and evaluate
  - malleable
  - human intensive
    - does not involve any trivial manufacturing process
- Aspects affecting product quality



Software product qualities – ISO/IEC 25010:2011 Software Quality Model

https://iso25000.com/index.php/en/iso-25000-standards/iso-25010

Process qualities: productivity

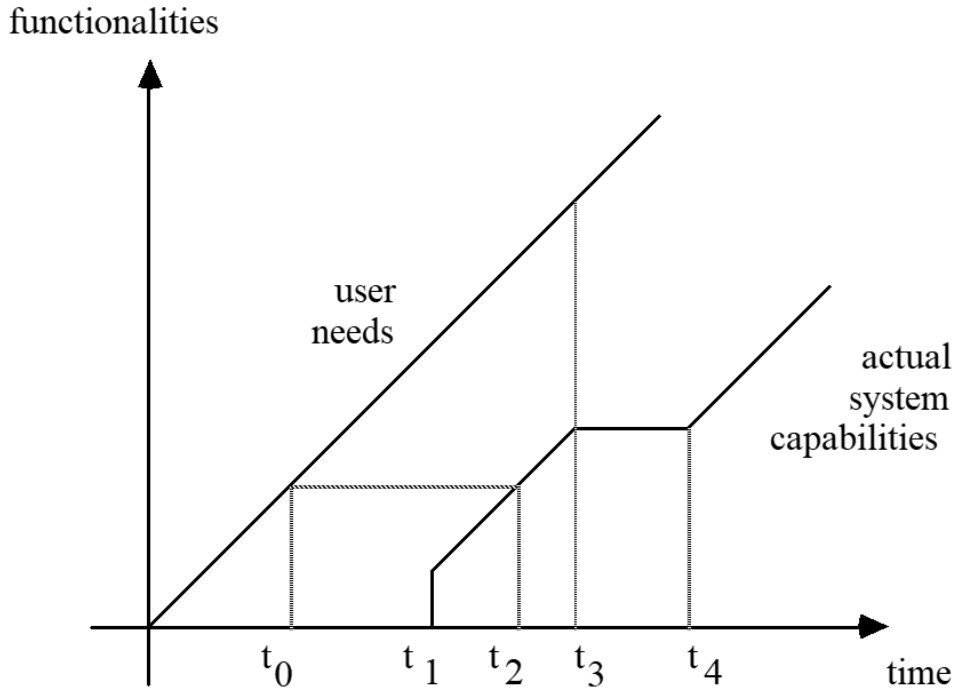
- Ability to produce a “good” amount of product
- How can we measure it? → Delivered items by unit of effort

lines of code (and variations)
function points

person month
WARNING: persons and months cannot be interchanged

Process qualities: timeliness

- Ability to respond to change requests in a timely fashion



Software lifecycles

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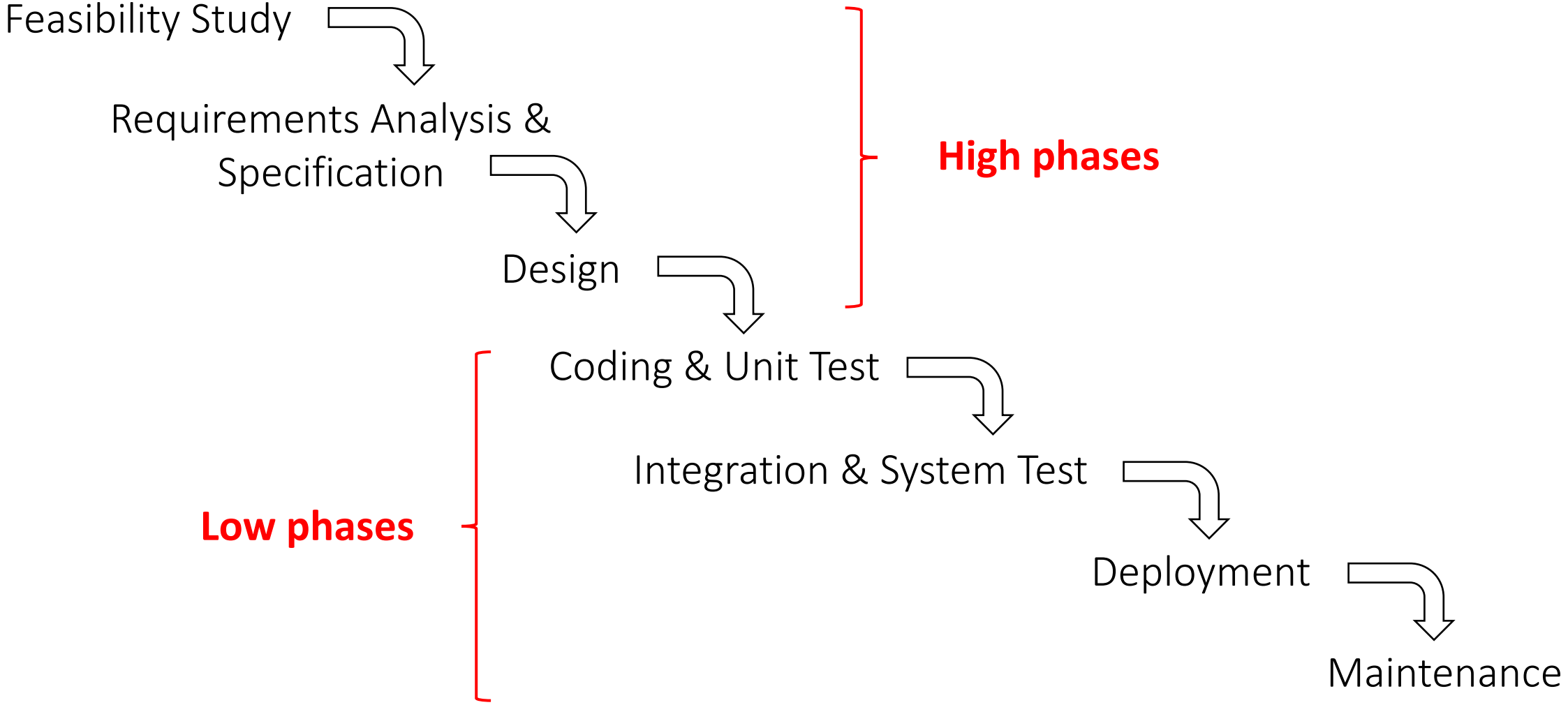
- Initially, no reference model: Just code & fix
- As a reaction to the many problems: traditional “waterfall” model
  - identify phases and activities
  - force linear progression from a phase to the next
  - no returns (they are harmful)
    - better planning and control
  - standardize outputs (artifacts) from each phase
  - Software like manufacturing
- Then, flexible processes: iterative models, agile methods, DevOps

A waterfall organization



Feasibility study & project estimation

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- Cost/benefit analysis
- Determines whether the project should be started (e.g., buy vs make), possible alternatives, needed resources
- Outcome
  - **Feasibility Study Document**
    - Preliminary problem description
    - Scenarios describing possible solutions
    - Costs and schedule for the different alternatives

Requirement analysis and specification

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- Analyze the domain in which the application takes place
- Identify requirements
- Derive specifications for the software
  - Requires an (continuous) interaction with the user
  - Requires an understanding of the properties of the domain
- Outcome
  - **Requirements Analysis and Specification Document (RASD)**

Design

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- Defines the software architecture
  - Components (modules)
  - Relations among components
  - Interactions among components
- Goal
  - Support concurrent development, separate responsibilities
- Outcome
  - **Design Document**

Coding&Unit level quality assurance

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- Each module is implemented using the chosen programming language
- Each module is tested in isolation by the module developer
- Inspection can be used as an additional quality assurance approach
- Programs include their documentation

Integration&System test

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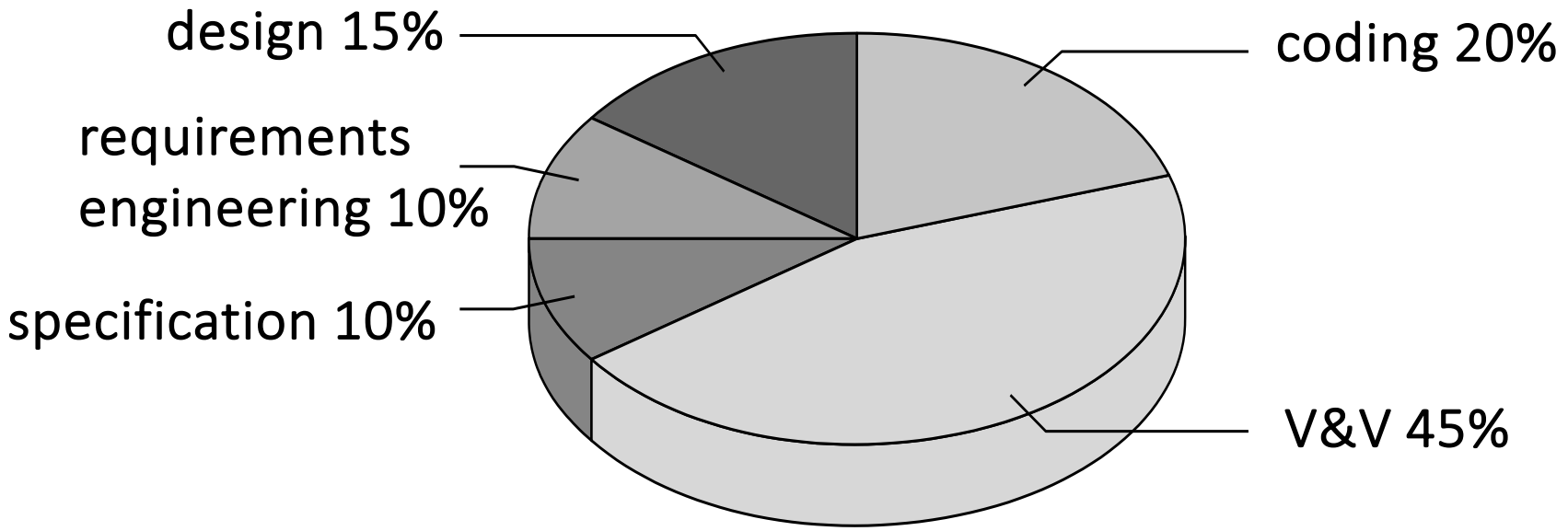
- Modules are integrated into (sub)systems
- Integrated (sub)systems are tested
- Follows an incremental implementation scheme
- Complete system test needed to verify overall properties
- Sometimes we have **alpha test** and **beta test**

Effort distribution (van Vliet 2008)



Maintenance

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- Corrective maintenance: deals with the repair of faults or defects found ≈ 20%
- Evolution
  - **adaptive** maintenance: consists of adapting software to changes in the environment (the hardware or the operating system, business rules, government policies…) ≈ 20%
  - **perfective** maintenance: mainly deals with accommodating to new or changed user requirements ≈ 50%
  - **preventive** maintenance: concerns activities aimed at increasing the system's maintainability ≈ 10%

Correction vs evolution

- Distinction can be unclear, because specifications are often incomplete and ambiguous
- This causes problems because specs are often part of a contract between developer and customer
  - early frozen specs can be problematic, because they are more likely to be wrong

Problems of software evolution

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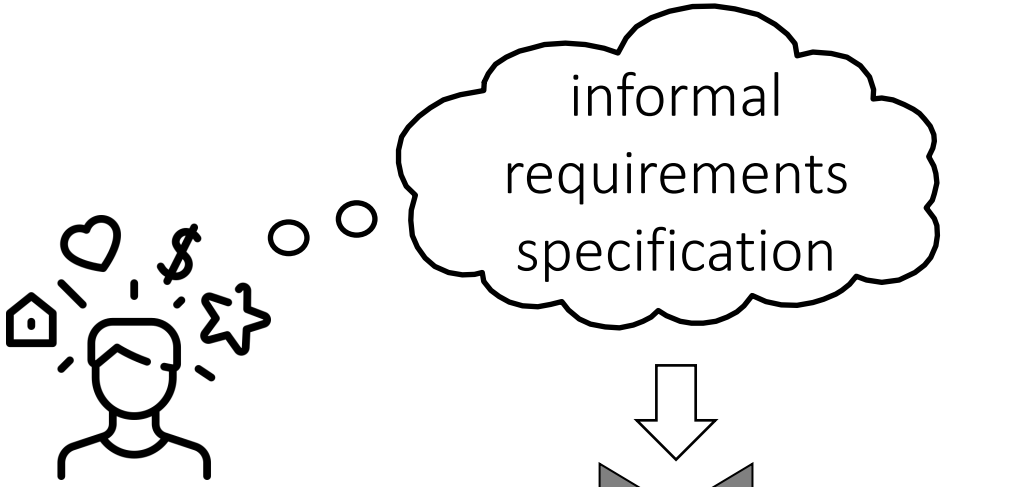
- It is (almost) never anticipated and planned; this causes disasters
- Software is very easy to change
  - often, under emergency, changes are applied directly to code
  - inconsistent state of project documents

How to face evolution

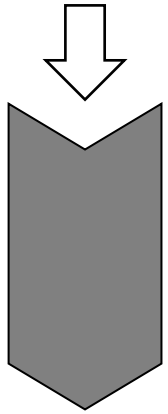
- Good engineering practice:
  - first modify design, then change implementation
  - apply changes consistently in all documents
- Likely changes must be anticipated
- Software must be designed to accommodate changes in a cost-effective way

- **This is one of the main goals of software engineering**

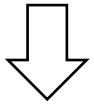
Waterfall is “black box”



informal requirements specification



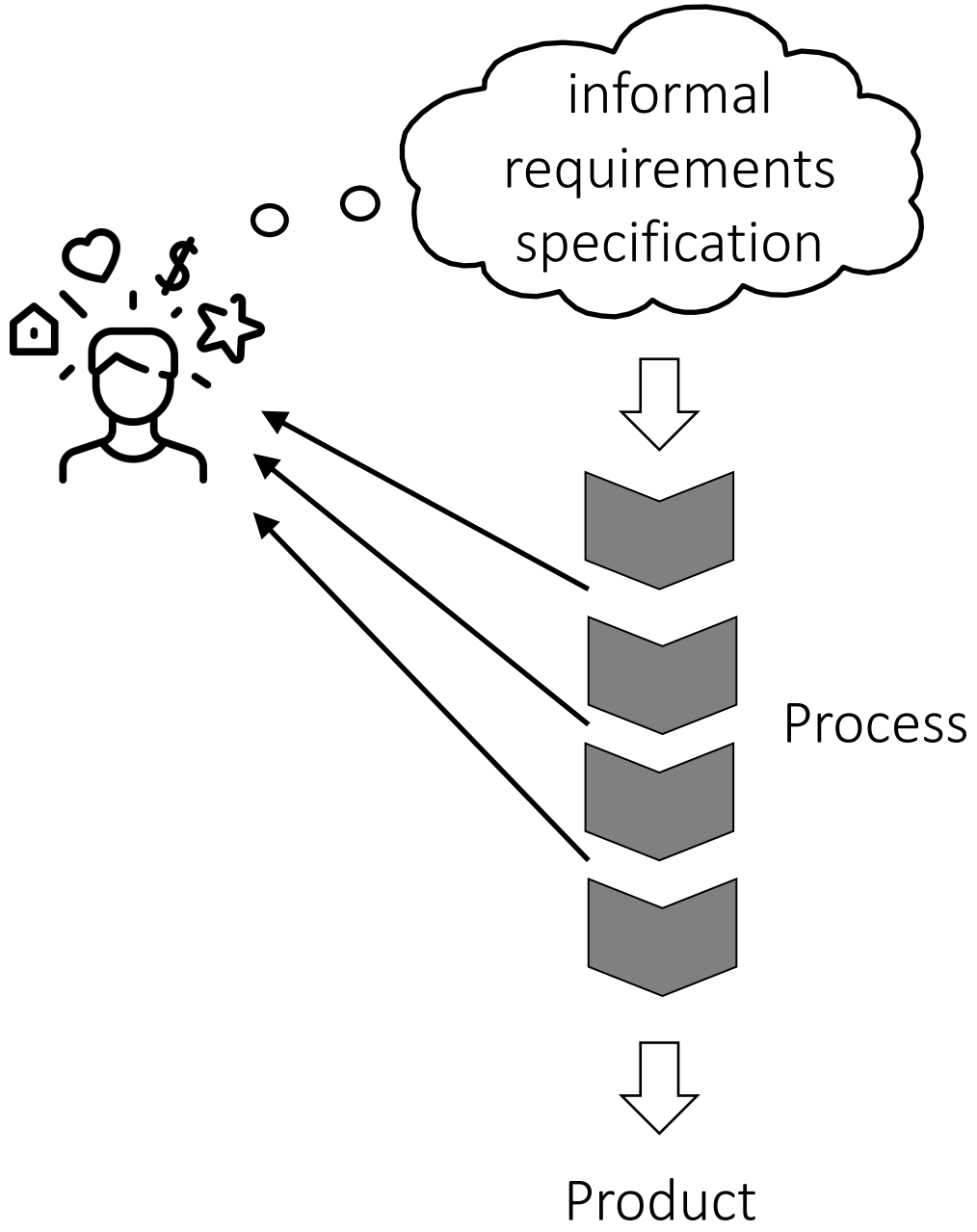
Process



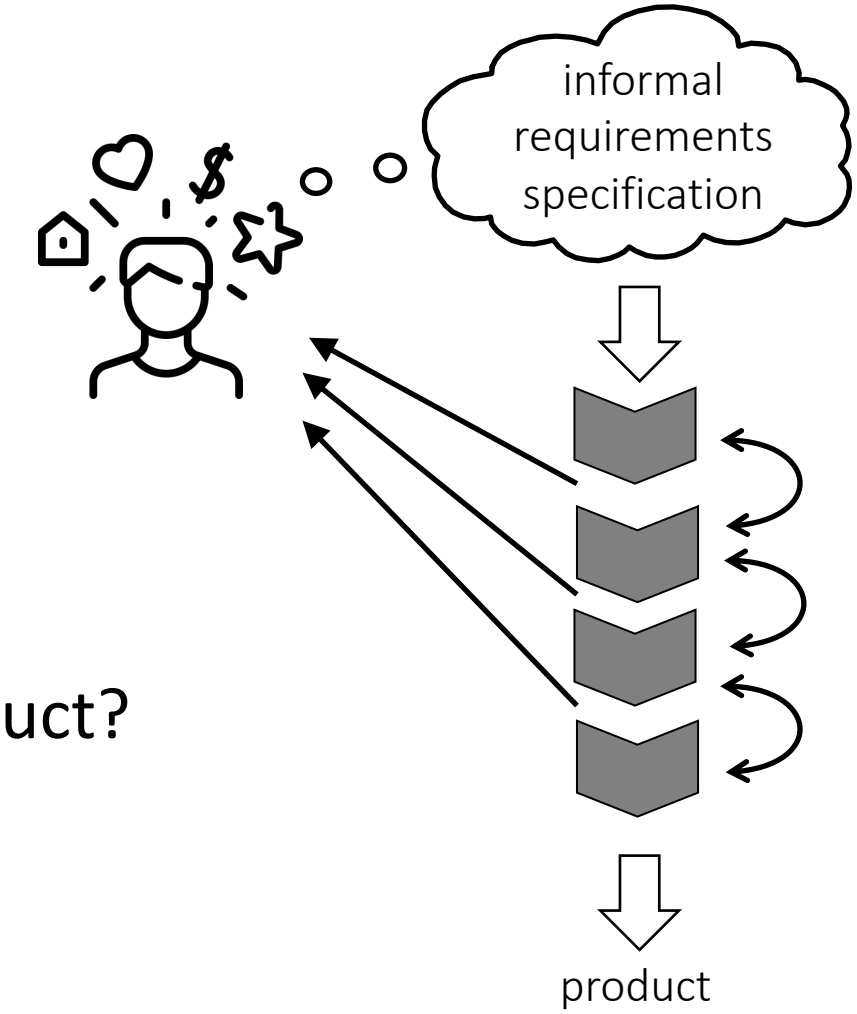
Product

Need for transparency

- Transparency allows early check and change via feedback
- It supports flexibility



Verification and validation



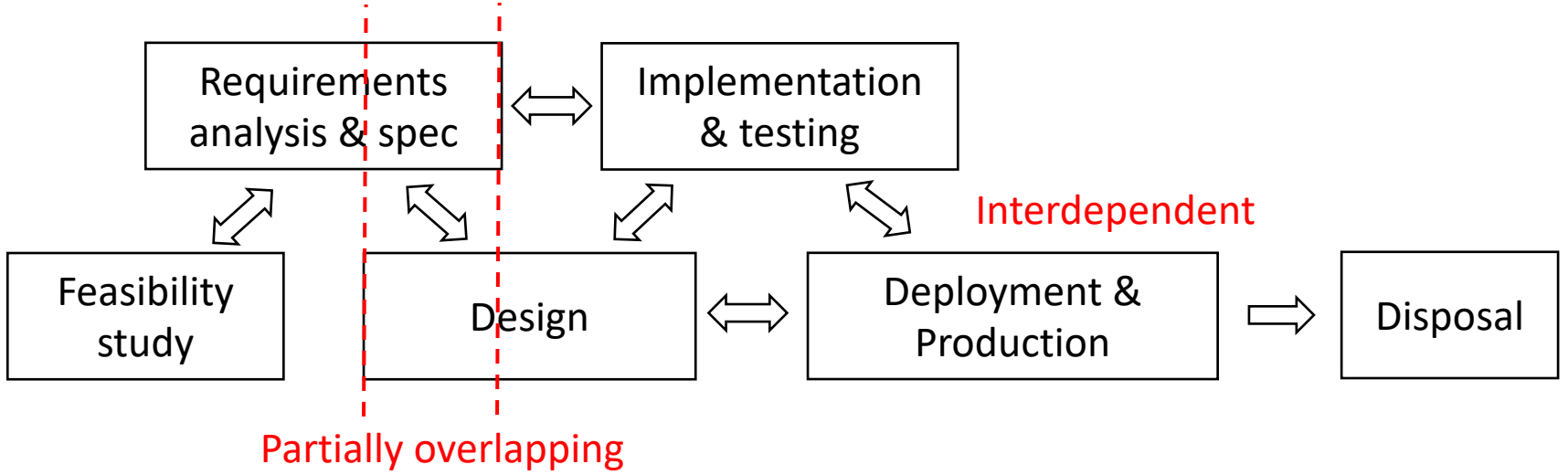
Validation:
are we making
the ”right” product?

Verification:
are we doing
the product right?

Flexible processes

- Main goal: adapt to changes (especially in requirements and specs)
- The very idea:
  - stages are not necessarily sequential
  - processes become iterative and incremental

Example



Flexible processes

- Exist in many forms
  - eXtreme Programming (XP)
  - SCRUM
  - DevOps
  - etc.
- Effective in dynamic contexts
  - Many changes per week
  - Example:
    - Web-based applications
    - Mobile applications