Osnovi softverskog inženjerstva

P-02: Softverski procesi

2024

Topics covered

- Software process models
- Process activities
- Coping with change
- Process improvement

The software process

- **A structured set of activities required to develop a software system.**
- Many different software processes but all involve:
  - **Specification** – defining what the system should do;
  - **Design and implementation** – defining the organization of the system and implementing the system;
  - **Validation** – checking that it does what the customer wants;
  - **Evolution** – changing the system in response to changing customer needs.
- A **software process model** is an **abstract representation of a process** – it presents a description of a process from some particular perspective.

Software process descriptions

- When we describe and discuss processes, we usually talk about the **activities in these processes** such as **specifying a data model**, **designing a user interface**, etc. and **the ordering of these activities**.
- Process descriptions may also include:
  - **Products** − outcomes of a process activity;
  - **Roles** − responsibilities of the people involved in the process;
  - **Pre- and post-conditions** − statements that are true before and after a process activity has been enacted or a product produced.

Software Process Model ≡

Software Engineering Paradigm

Plan-driven and agile processes

- **Plan-driven process are processes where all of the process activities are planned in advance and progress is measured against this plan.**
- **In agile processes, planning is incremental and it is easier to change the process to reflect changing customer requirements**.
- **In practice**, most practical processes **include elements of both** plan-driven and agile approaches.
- *There are no right or wrong software processes?!*

Process activities

- **Real software processes** are **inter-leaved sequences** of **technical, collaborative and managerial activities** with the **overall goal of specifying, designing, implementing and testing a software system**.
- The **four basic process activities** of **specification**, **development**, **validation** and **evolution** are **organized differently in different development processes**.
- For example, in the waterfall model, they are organized in sequence, whereas in incremental development they are interleaved.

Classification of software process models

- **Sequential software process models**
  - Plan-driven models
  - Separate and distinct phases of specification and development
  - **Waterfall model**, **V-model**
- **Evolutionary software process models**
  - Specification, development and validation may be interleaved
  - May be plan-driven or agile
  - **Incremental model, RAD, RUP**, **Spiral model**
- **Integration and configuration**
  - The system is assembled from existing configurable components
  - May be plan-driven or agile
- **In practice**, most large systems are developed using a process that incorporates elements from all of these models

The linear software process model – **waterfall model**

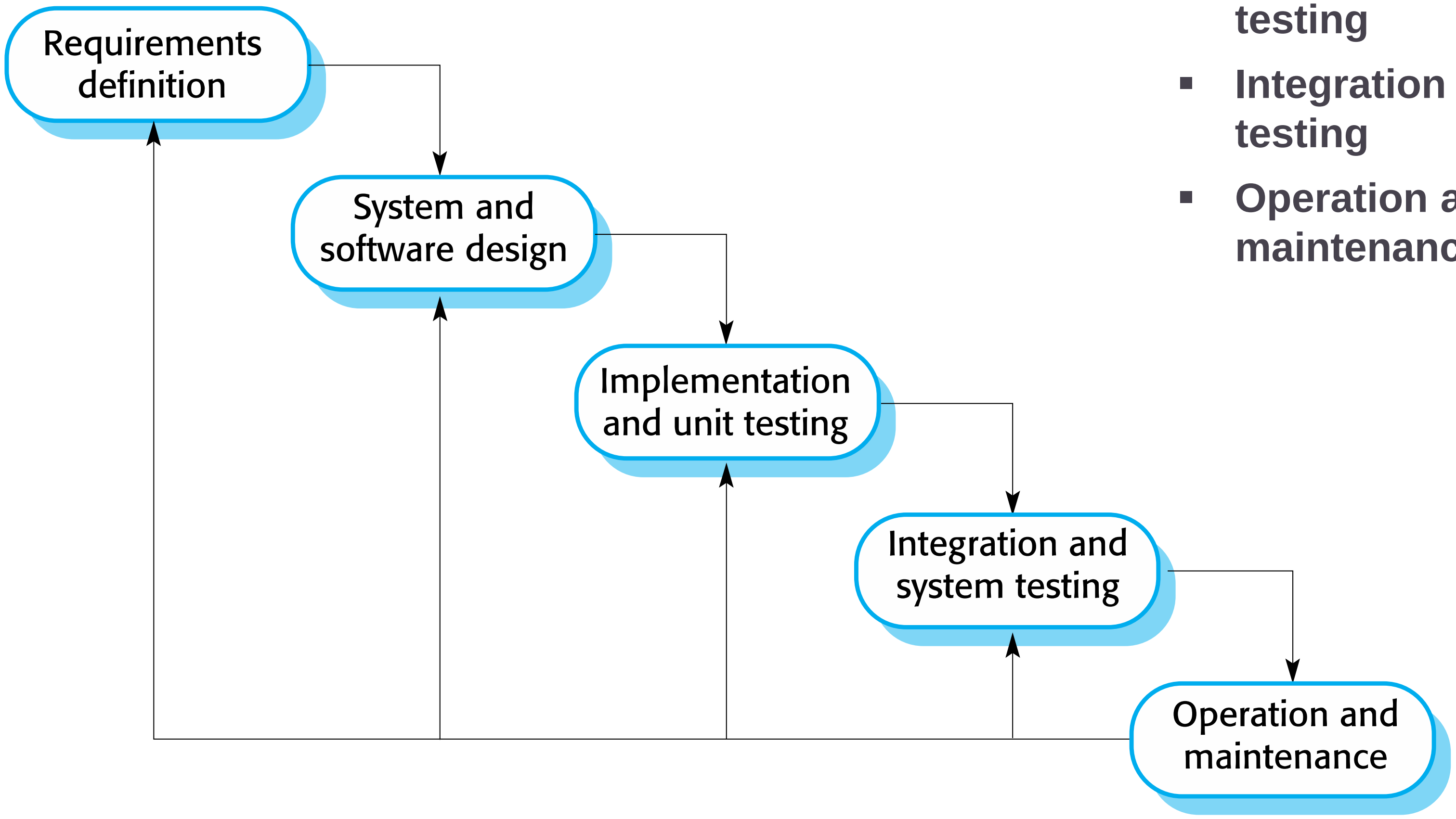
Typically called

the **classic life cycle**

the **waterfall model**

✧ There are **separate phases**:

- **Requirements analysis and definition**
- **System and software design**
- **Implementation and unit testing**
- **Integration and system testing**
- **Operation and maintenance**


Requirements definition
System and software design
Implementation and unit testing
Integration and system testing
Operation and maintenance

Waterfall model problems

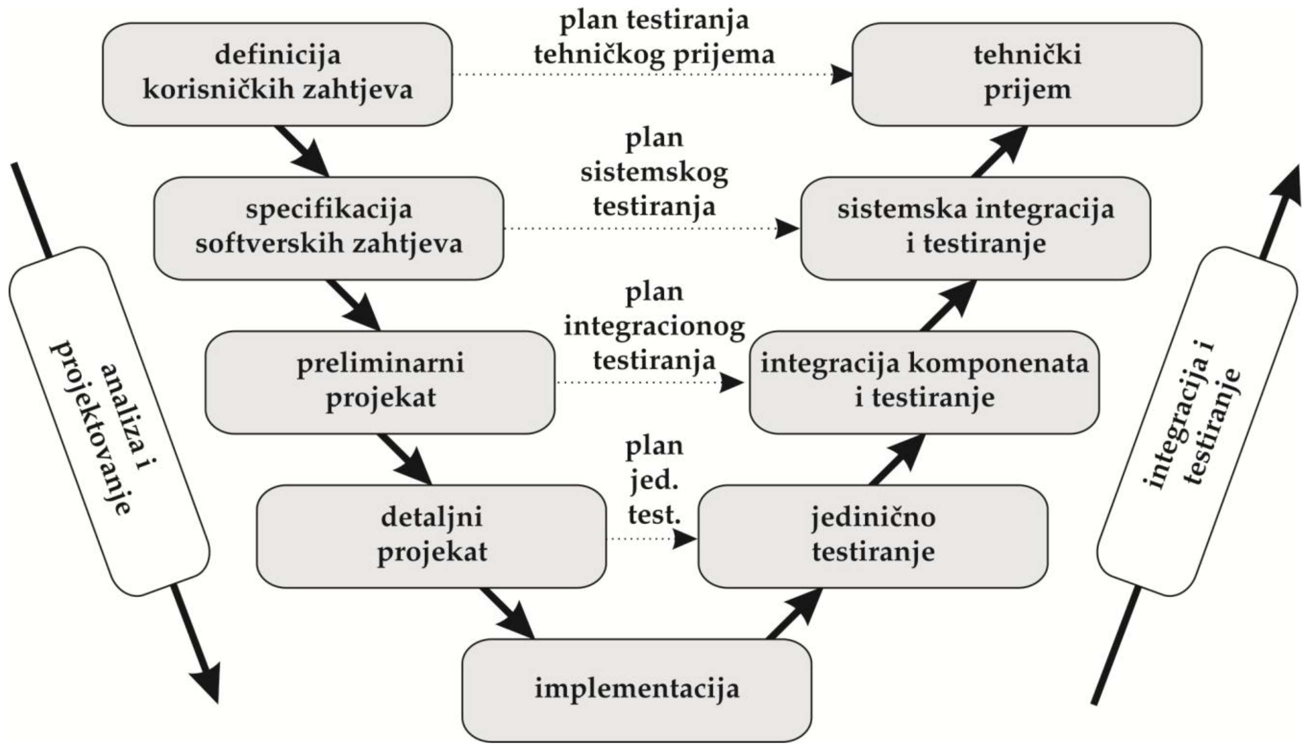
The **main drawback** of the waterfall model is the **difficulty of accommodating change** after the process is underway.

In principle, **a phase has to be complete before moving onto the next phase**.

- Inflexible partitioning of the project into distinct stages makes it **difficult to respond to changing customer requirements**.
  - **only appropriate when the requirements are well-understood** and **changes will be fairly limited during the design process**.
  - It is difficult for the customer to state all requirements explicitly. The waterfall model requires this and has difficulty accommodating the natural uncertainty that exists at the beginning of many projects.
  - **Few business systems have stable requirements**!!!
  - **Real projects rarely follow the sequential flow of activities!**
- The **customer must have patience**. A working version of the system will not be available until late in the project time-span.
- The waterfall model is **mostly used for large systems engineering** projects **where a system is developed at several sites**.
  - the **plan-driven nature** of the waterfall model **helps coordinate the work**.

V- model

- ✧ The major drawback of waterfall model is we move to the next stage only when the previous one is finished and there is no chance to go back if something is found wrong in later stages.
- ✧ **V-Model provides means of testing of software at each stage in reverse manner**.
- ✧ **At every stage, test plans and test cases are created to verify and validate the product according to the requirement of that stage.**
  - For example, in the requirement specification stage the test team prepares all the test cases in correspondence to the requirements. …



definicija korisničkih zahtjeva
plan testiranja tehničkog prijema
tehnički prijem
specifikacija softverskih zahtjeva
plan sistemskog testiranja
sistemska integracija i testiranje
preliminarni projekat
plan integracionog testiranja
integracija komponenata i testiranje
detaljni projekat
plan jed. test.
jedinično testiranje
implementacija
analiza i projektovanje
integracija i testiranje

Verification and validation go in parallel.

This model is also known as **verification and validation model.**

Evolutionary software process models

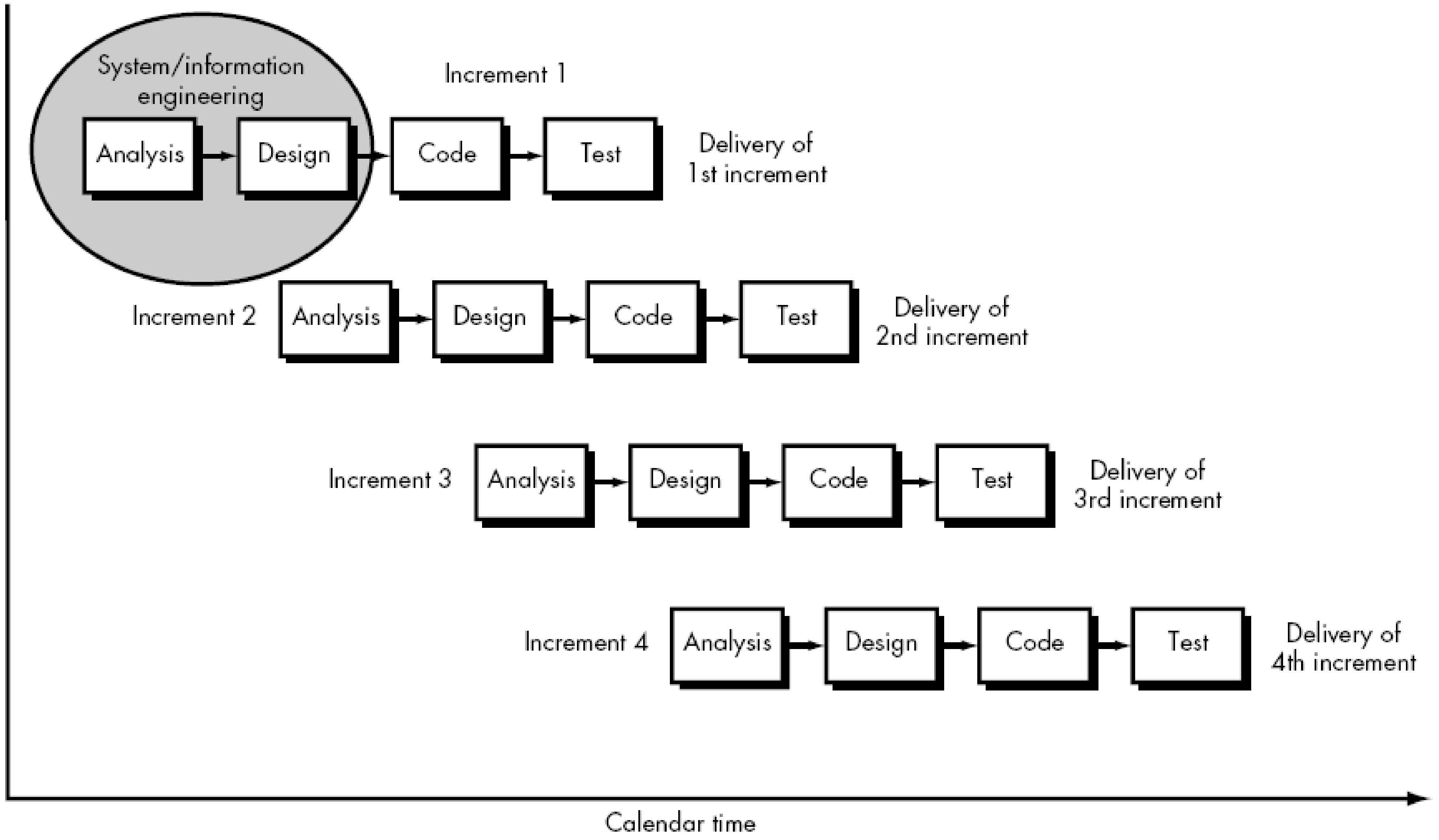
Why evolutionary process models?

- There is growing recognition that **software**, like all complex systems, **evolves over a period of time**.
- Business and **product requirements often change as development proceeds**, making a **straight path** to an end product **unrealistic**.
- **Tight market deadlines** make completion of a comprehensive software product impossible, but **a limited version must be introduced** to meet competitive or business pressure.
- **A set of core product or system requirements is well understood**, but the **details** of product or system extensions **have yet to be defined**.
- In these and similar situations, software engineers need **a process model that has been explicitly designed to accommodate a product that evolves over time**.
- Several process models:
  - **Incremental model**
  - **RUP**
  - **Spiral model**
  - …

Evolutionary software process models – The incremental model

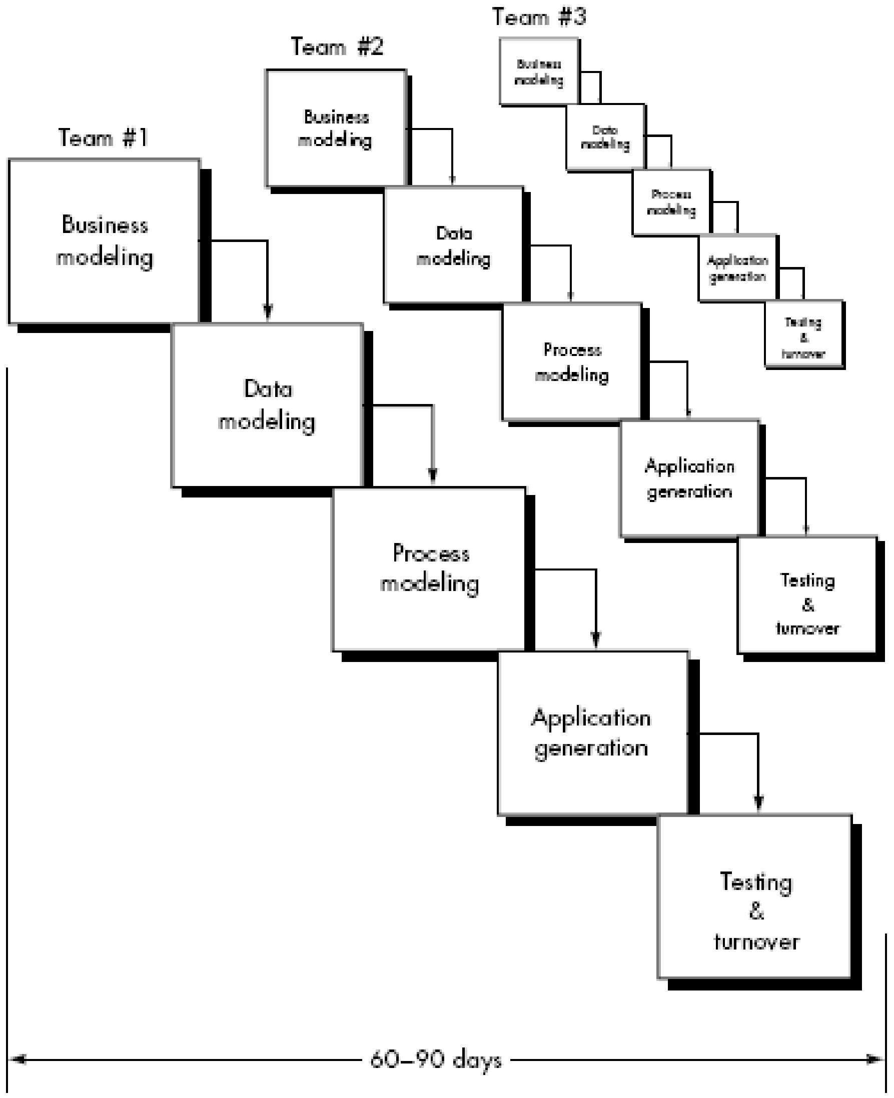
- The incremental model **combines elements of the linear sequential model** (**applied repetitively**).
- The incremental model **applies linear sequences in a staggered fashion** as calendar time progresses.
- **Each linear sequence produces a deliverable "increment" of the software**.
- For example, word-processing software developed using the incremental paradigm might deliver:
  - #1: basic file management, editing, and document production functions
  - #2: more sophisticated editing and document production capabilities;
  - #3: spelling and grammar checking;
  - #4: advanced page layout capability.
- The **first increment** is often a **core product** (basic requirements are addressed, but many supplementary features remain undelivered).
- The **core product is used by the customer** (or undergoes detailed review). As a result of use and/or evaluation, a **plan** is developed for the **next increment**.
- The plan addresses the **modification of the core product** to better meet the needs of the customer and the delivery of **additional features** and functionality.
- This **process is repeated** following the delivery of each increment, **until the complete product** is produced.

Evolutionary software process models – The incremental model



RAD model

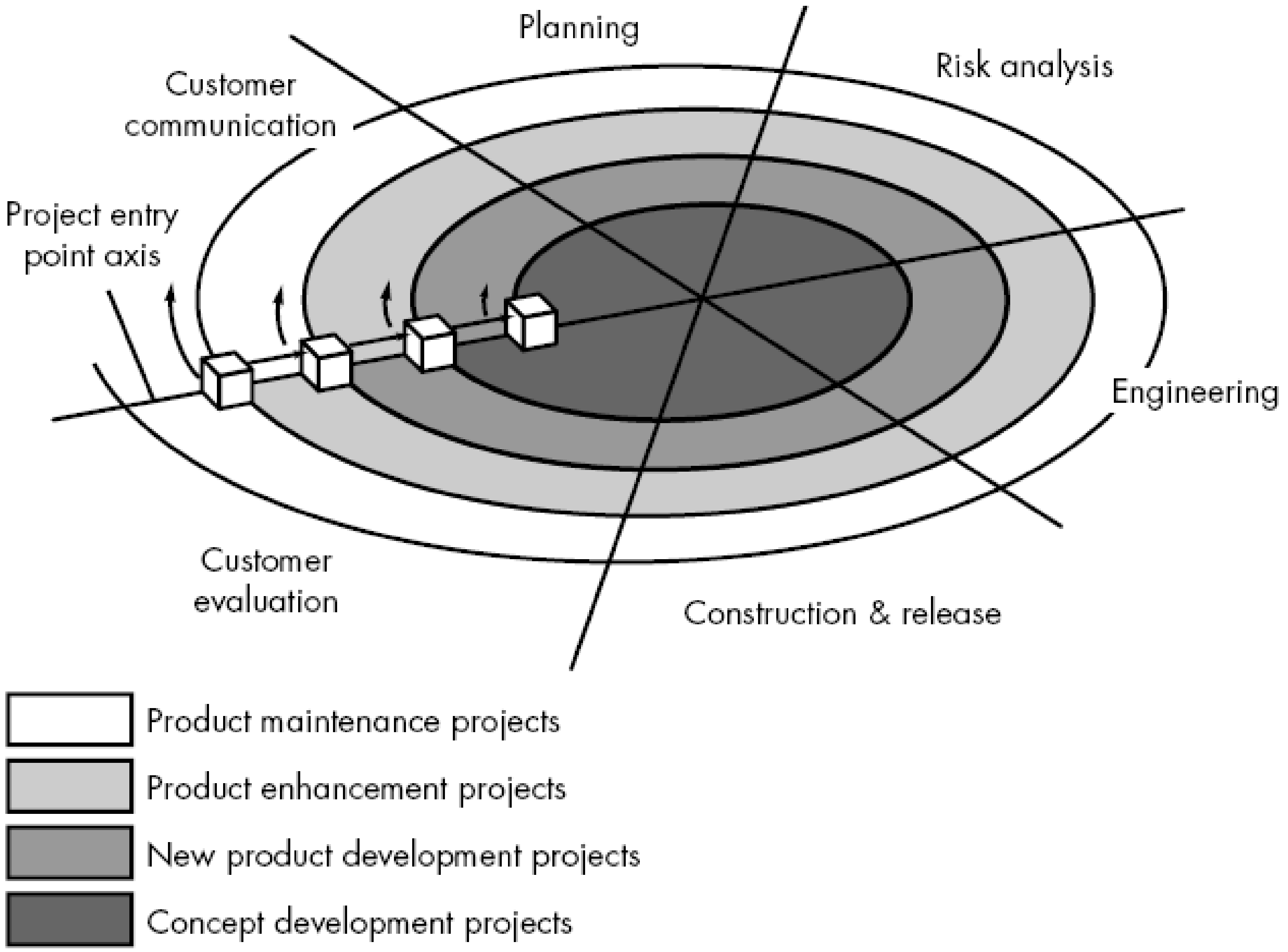
- ✧ Rapid application development (RAD) is an **incremental software development process model** that **emphasizes an extremely short development cycle**.
- ✧ The RAD model is a “**high-speed**” **adaptation of the waterfall model** in which rapid development is achieved by using **component-based construction**.
- ✧ If requirements are well understood and project scope is constrained, the RAD process enables a development team to create a **“fully functional system” within very short time periods** (e.g., 60-90 days)



Evolutionary software process models – The spiral model

- **The spiral model** (originally **proposed by Boehm**, 1988), is an **evolutionary software process model** that couples the iterative nature of prototyping with the controlled and systematic aspects of the linear sequential model.
- It provides the potential for rapid development of incremental versions of the software.
- Using the spiral model, **software is developed in a series of incremental releases**.
- During **early iterations**, the **incremental release might be a paper model or prototype**.
- During **later iterations**, increasingly **more complete versions** of the engineered system are produced.
- **The spiral model is divided into a number of framework activities, also called task regions (typically 3-6):**
  - **Customer communication**
  - **Planning**
  - **Risk analysis**
  - **Engineering**
  - **Construction and release**
  - **Customer evaluation**
- Each **task region is populated** by a **set of work tasks** (**a task set**), that are adapted to the characteristics of the project to be undertaken.
- As this evolutionary process begins, the **SE team moves around the spiral**.
  - #1 circuit might result in a product specification;
  - #2 might be used to develop a prototype, etc.

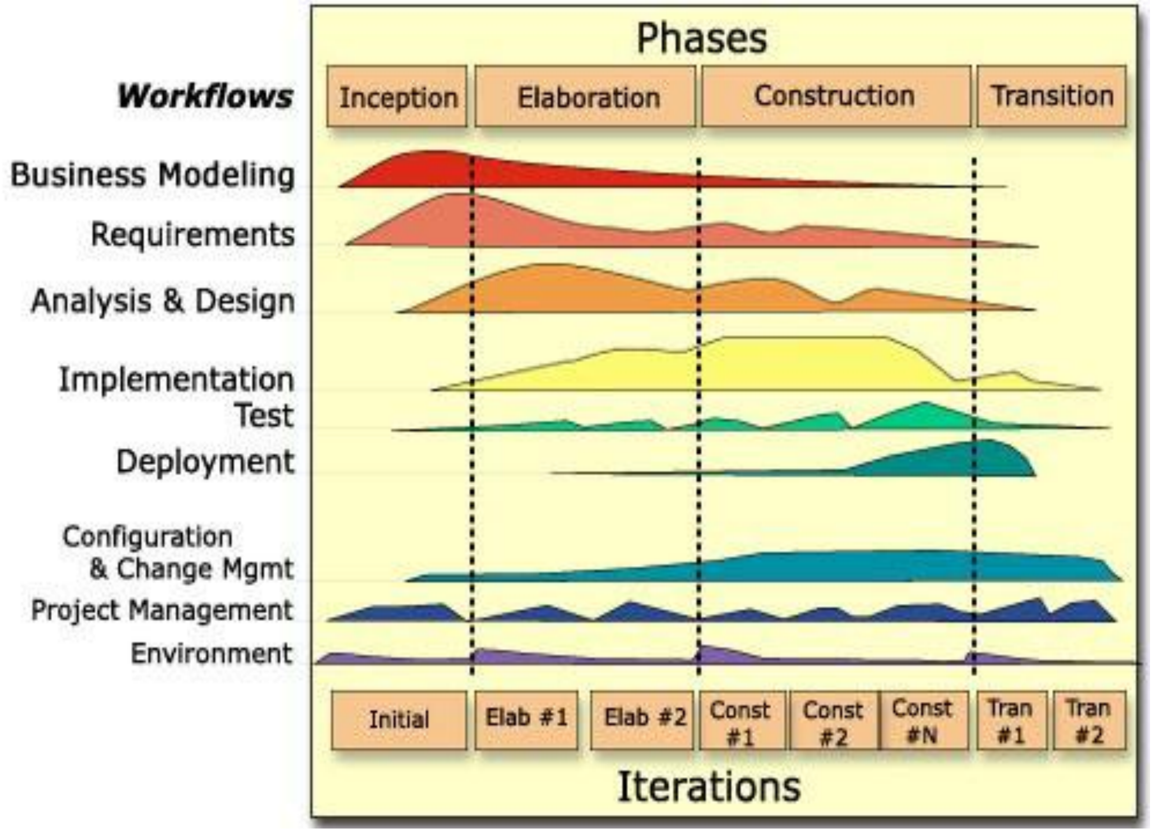
Evolutionary software process models – The spiral model



Evolutionary software process models – The RUP model

- ✧ **The Rational Unified Process – RUP** was developed at the Rational Corp. (now part of IBM) in the late 1990s.
- ✧ **It uses UML** as a tool for specification and design.

- ✧ **RUP is use-case driven, architecture centric, iterative and incremental** and includes cycles, phases, workflows, risk mitigation, quality control, project management and configuration control.
- ✧ **RUP decomposes the work of a large project into smaller slices or mini-projects,** and **each mini-project is an iteration that results in an increment to the product.**
- ✧ The iteration consists of one or more steps in the workflow and generally leads to the growth of the product.



Incremental development benefits and problems

benefits

- **The cost of accommodating changing customer requirements is reduced**.
  - The amount of analysis and documentation that has to be redone is much less than is required with the waterfall model.
- It is **easier to get customer feedback** on the development work that has been done.
  - Customers can comment on demonstrations of the software and see how much has been implemented.
- **More rapid delivery and deployment** of useful software to the customer is possible.
  - Customers are able to use and gain value from the software earlier than is possible with a waterfall process.

problems

- **The process is not visible**.
  - Managers need regular deliverables to measure progress.
  - If systems are developed quickly, it is not cost-effective to produce documents that reflect every version of the system.
- **System structure tends to degrade** as new increments are added.
  - Unless time and money is spent on refactoring to improve the software, regular change tends to corrupt its structure.
  - Incorporating further software changes becomes increasingly difficult and costly.

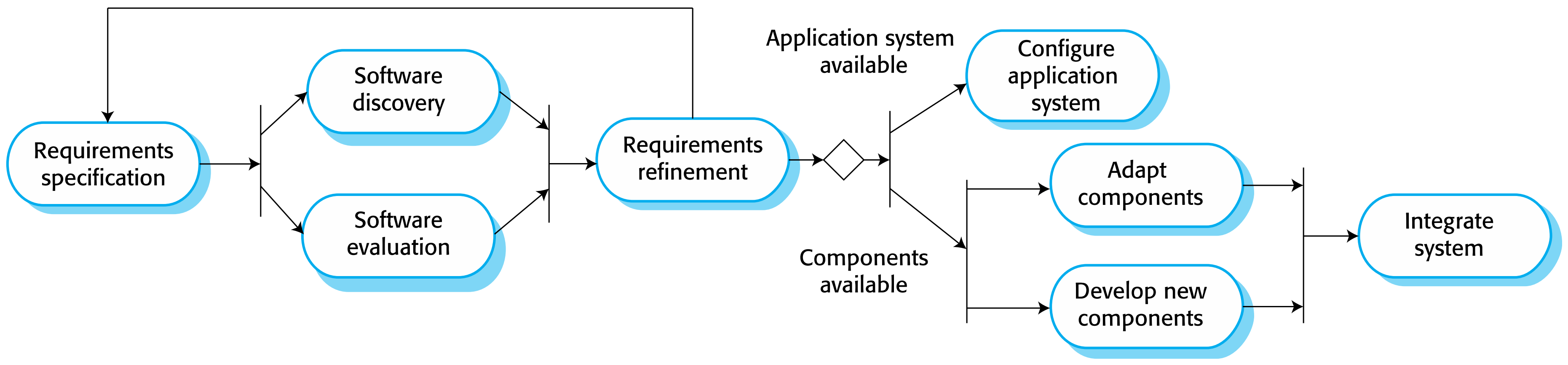
Software process models based on integration and configuration

- **Based on software reuse** where **systems are integrated from existing components or application systems** (sometimes called COTS – *Commercial-off-the-shelf systems*)
- Reused elements **may be configured** to adapt their **behaviour** and **functionality** to user's requirements
- Reuse is now the standard approach for building many types of business system

Types of reusable software

- **Stand-alone application systems** that are configured for use in a particular environment
- **Collections of objects** that are developed as a **package** to be **integrated with a component framework** such as .NET or J2EE
- **Web services** that are developed according to service standards and which are available for remote invocation.

Reuse-oriented software engineering



Key process stages

- ✧ Requirements specification
- ✧ Software discovery and evaluation
- ✧ Requirements refinement
- ✧ Application system configuration
- ✧ Component adaptation and integration

Advantages and disadvantages

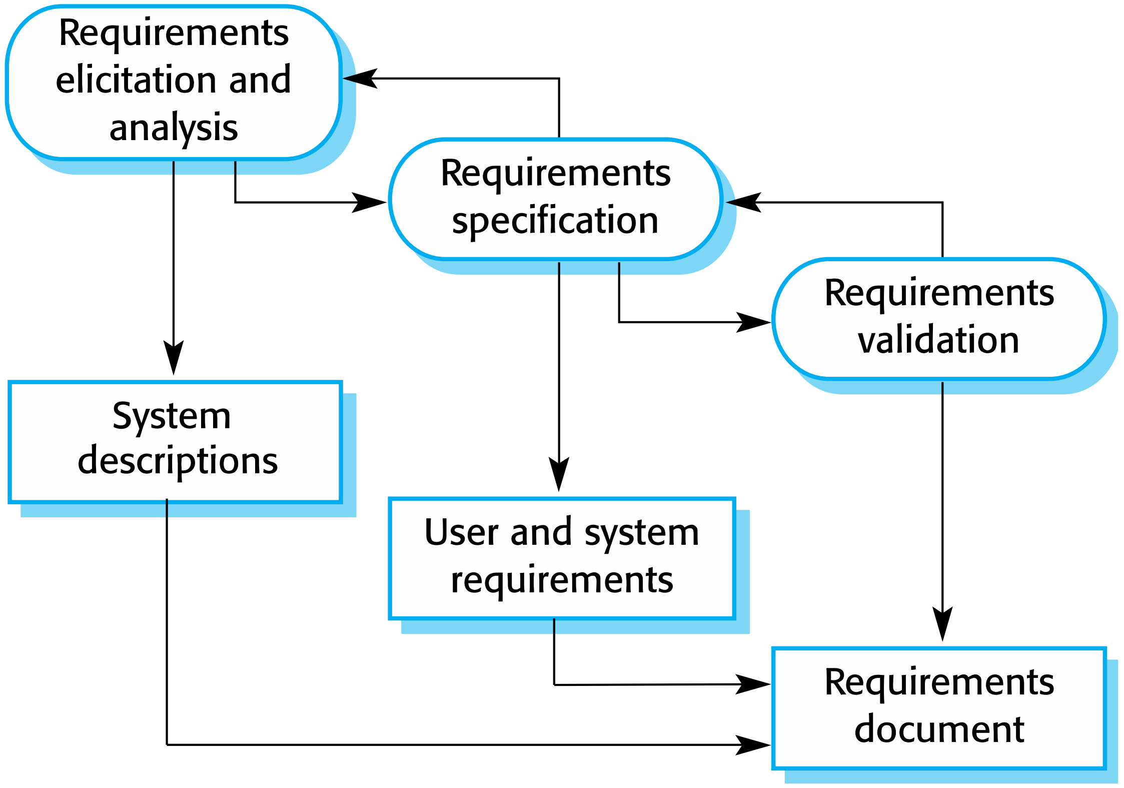
- ✧ **Reduced costs and risks** as less software is developed from scratch
- ✧ **Faster delivery and deployment** of system
- ✧ But **requirements compromises are inevitable** so **system may not meet real needs of users**
- ✧ **Loss of control over evolution of reused system elements**

Process activities

Software specification

- ✧ The **process of establishing what services are required** and the **constraints on the system's development and operation**

- ✧ **Requirements engineering process:**
  - **Requirements elicitation and analysis**
    - What do the system stakeholders require or expect from the system?
  - **Requirements specification**
    - Defining the requirements in detail
  - **Requirements validation**
    - Checking the validity of the requirements


Requirements elicitation and analysis
Requirements specification
Requirements validation
System descriptions
User and system requirements
Requirements document

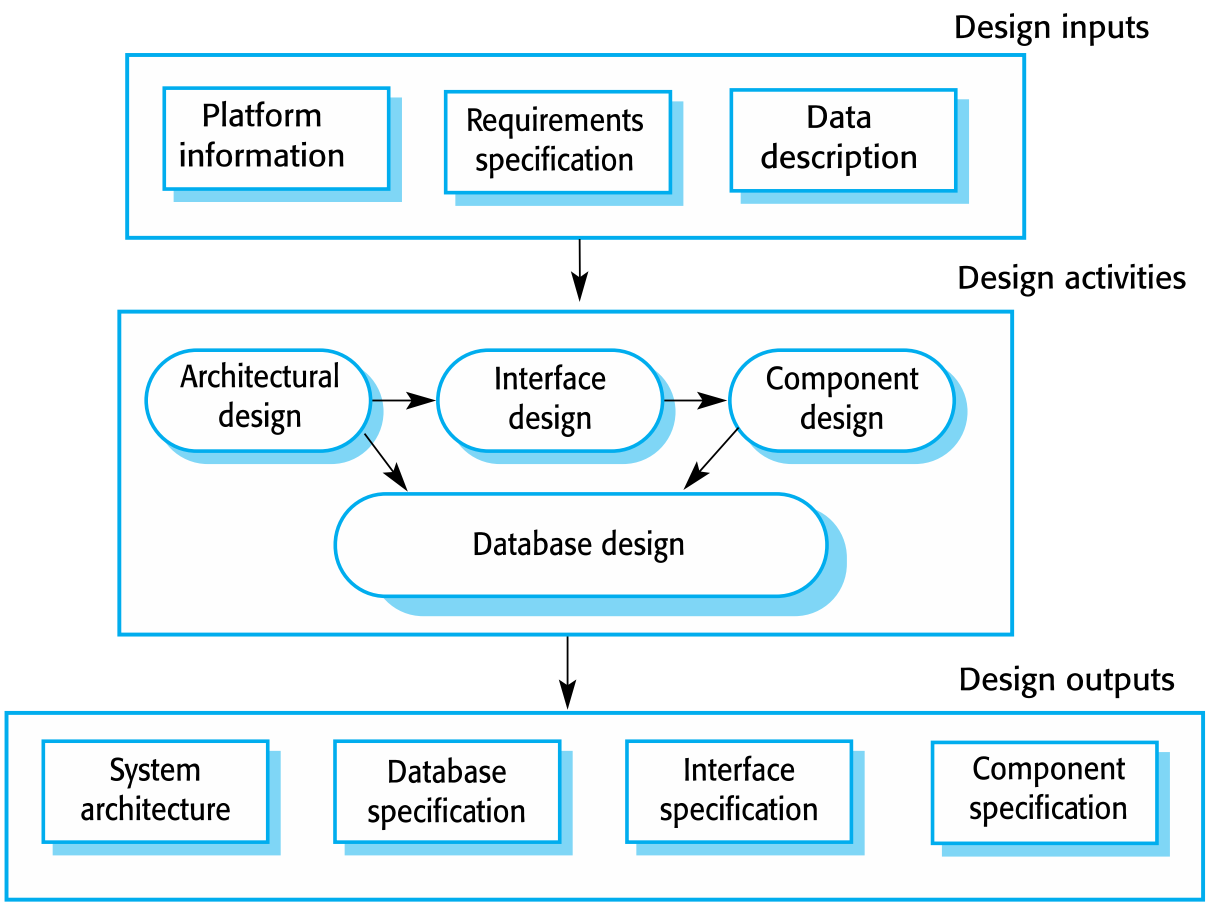
Software design and implementation

✧ **The process of converting the system specification into an executable system.**

✧ **Software design**
  - Design a software structure that realises the specification;

✧ **Implementation**
  - Translate this structure into an executable program;

✧ The activities of design and implementation are closely related and may be inter-leaved.



Design activities

- **Architectural design**, where we **identify the overall structure of the system**, the principal components (subsystems or modules), their relationships and how they are distributed.
- **Database design**, where we **design the system data structures** and how these are to be represented in a database.
- **Interface design**, where we define the interfaces between system components.
- **Component selection and design**, where we search for **reusable components**. If unavailable, we design how it will operate.

System implementation

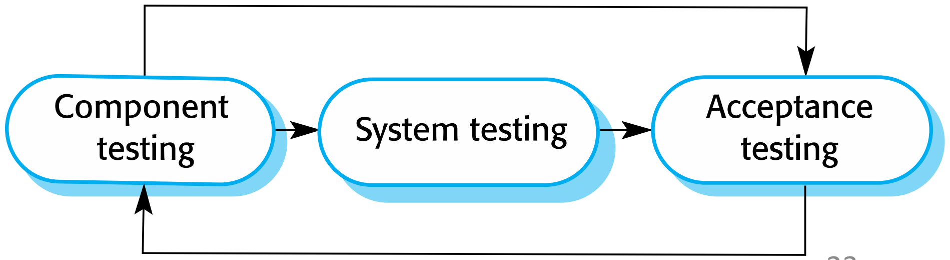
- The **software is implemented** either **by developing** a program or programs or **by configuring** an application system.
- **Design and implementation** are **interleaved activities** for most types of software system.
- **Programming is an individual activity with no standard process**.
- **Debugging** is the activity of finding program faults and correcting these faults.

Software validation

- **Verification and validation** (V & V) is intended to **show that a system conforms to its specification** and **meets the requirements** of the system customer.
- Involves **checking** and **review** processes and system **testing**.
- **System testing** involves executing the system with test cases that are derived from the specification of the real data to be processed by the system.
- Testing is the most commonly used V & V activity.

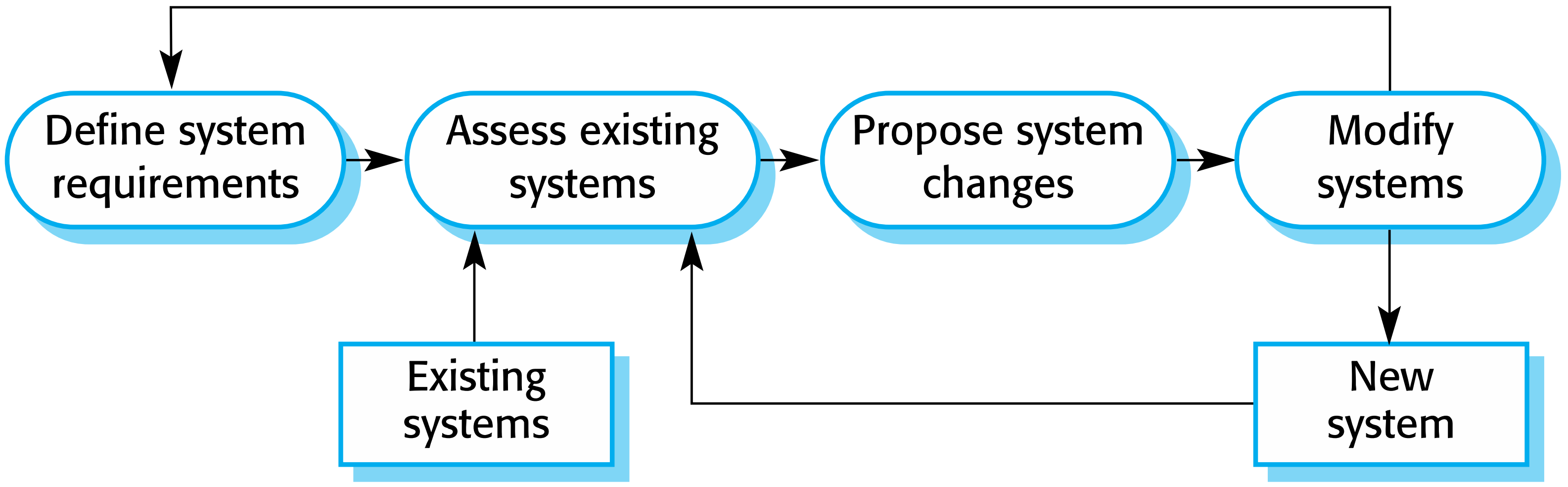
Stages of testing

- **Component (unit) testing**
  - Individual components are tested independently;
  - Components may be functions or objects or coherent groupings of these entities.
- **System (integration) testing**
  - Testing of the system as a whole. Testing of emergent properties is particularly important.
- **Customer (acceptance) testing**
  - Testing with customer data to check that the system meets the customer's needs.



Software evolution

- ✧ **Software is inherently flexible and can change**.
- ✧ As **requirements change** through changing business circumstances, the **software** that supports the business **must also evolve** and change.
- ✧ Although there has been a demarcation between development and evolution (maintenance) this is increasingly irrelevant as fewer and fewer systems are completely new.



Coping with change

Coping with change

- ✧ **Change is inevitable** in all large software projects.
  - **Business changes** lead to new and changed system requirements
  - **New technologies** open up new possibilities for improving implementations
  - **Changing platforms** require application changes
- ✧ **Change leads to rework** so the costs of change include both rework (e.g. **re-analysing requirements**) as well as the costs of **implementing new functionality**
- ✧ Two different approaches:
  - **System prototyping**
  - **Incremental delivery**

Reducing the costs of rework

- ✧ **Change anticipation**, where the **software process includes activities that can anticipate possible changes** before significant rework is required.
  - For example, a prototype system may be developed to show some key features of the system to customers.
- ✧ **Change tolerance**, where the process is designed so **that changes can be accommodated at relatively low cost**.
  - This normally involves some form of **incremental development**.
  - Proposed changes may be implemented in increments that have not yet been developed.
  - If this is impossible, then only a single increment (a small part of the system) may have be altered to incorporate the change.

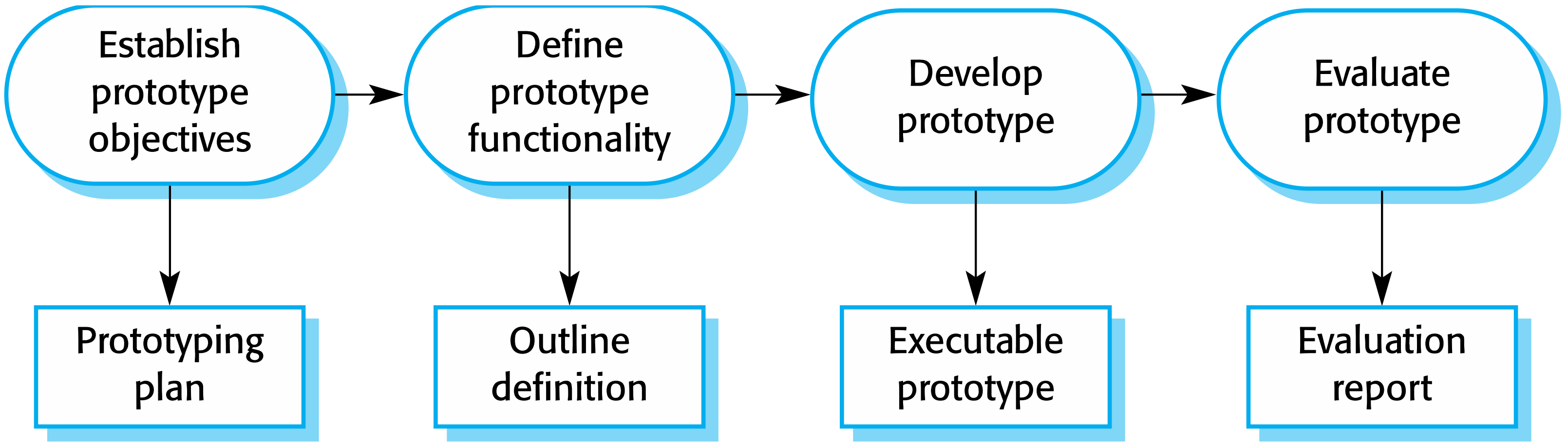
Software prototyping

- **A prototype is an initial version of a system used to demonstrate concepts and try out design options.**
- A prototype can be used:
  - in the requirements engineering to help with requirements elicitation and validation;
  - in design processes to explore options and develop a UI design;
  - in the testing process;
  - to train users.

Benefits of prototyping

- Improved system usability
- A closer match to users' real needs
- Improved design quality
- Improved maintainability
- Reduced development effort

The process of prototype development



Prototype development

- May be based on **rapid prototyping languages or tools**
- May involve leaving out functionality
  - Prototype should **focus on areas** of the product that are not well-understood
  - **Error checking and recovery may not be included** in the prototype
  - **Focus on functional rather than non-functional requirements** such as reliability and security

Throw-away (mock-up) prototypes

- **Prototypes should be discarded** after development as they are not a good basis for a production system:
  - **It may be impossible to tune the system to meet non-functional requirements**
  - Prototypes are normally **undocumented**
  - The prototype **structure** is usually **degraded** through rapid change
  - The prototype probably will **not meet** normal organisational **quality standards**

Evolutionary prototypes

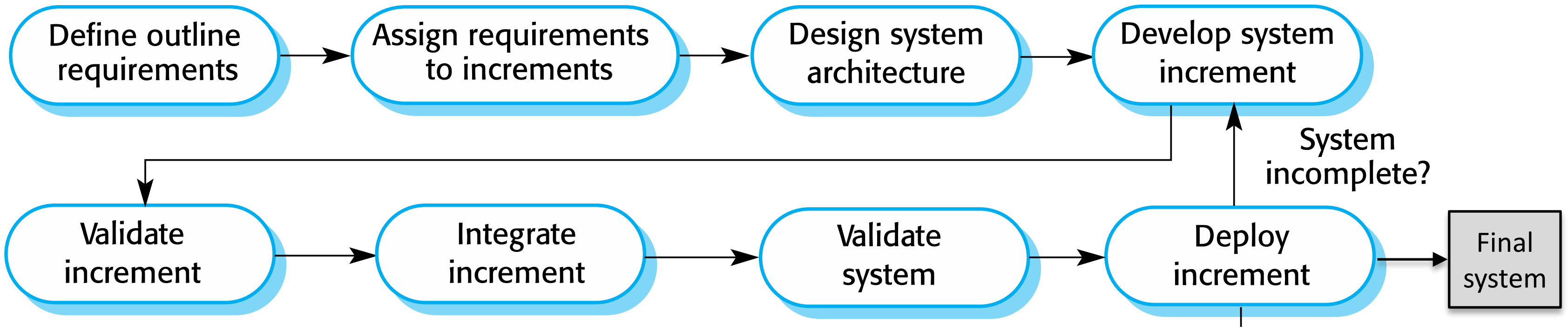
- **Prototypes that are not discarded, but used as a starting basis for development of a target system**

Incremental development and delivery

- Rather than deliver the system as a single delivery**, the development and delivery is broken down into increments** with **each increment delivering part of the required functionality.**
- **User requirements are prioritised** and the highest priority requirements are included in early increments.
- Once the development of an increment is started, the **requirements are frozen** though requirements for later increments can continue to evolve.

- **Incremental development**
  - **Develop the system in increments** and **evaluate each increment before** proceeding to the development of the **next increment**
  - Normal approach used in agile methods
  - Evaluation done by user/customer proxy
- **Incremental delivery**
  - **Deploy an increment** for use by end-users
  - More realistic evaluation about practical use of software
  - Difficult to implement for replacement systems as increments have less functionality than the system being replaced

Incremental development and delivery



Incremental delivery advantages

- ✧ Customer value can be delivered with each increment so system functionality is available earlier.
- ✧ Early increments act as a prototype to help elicit requirements for later increments.
- ✧ Lower risk of overall project failure.
- ✧ The highest priority system services tend to receive the most testing.

Incremental delivery problems

- ✧ Most systems require a set of basic facilities that are used by different parts of the system.
  - As requirements are not defined in detail until an increment is to be implemented, it can be hard to identify common facilities that are needed by all increments.
- ✧ **The essence of iterative processes is that the specification is developed in conjunction with the software**.
  - this conflicts with the procurement model of organizations, since the complete specification is part of the contract.

Process improvement

Process improvement

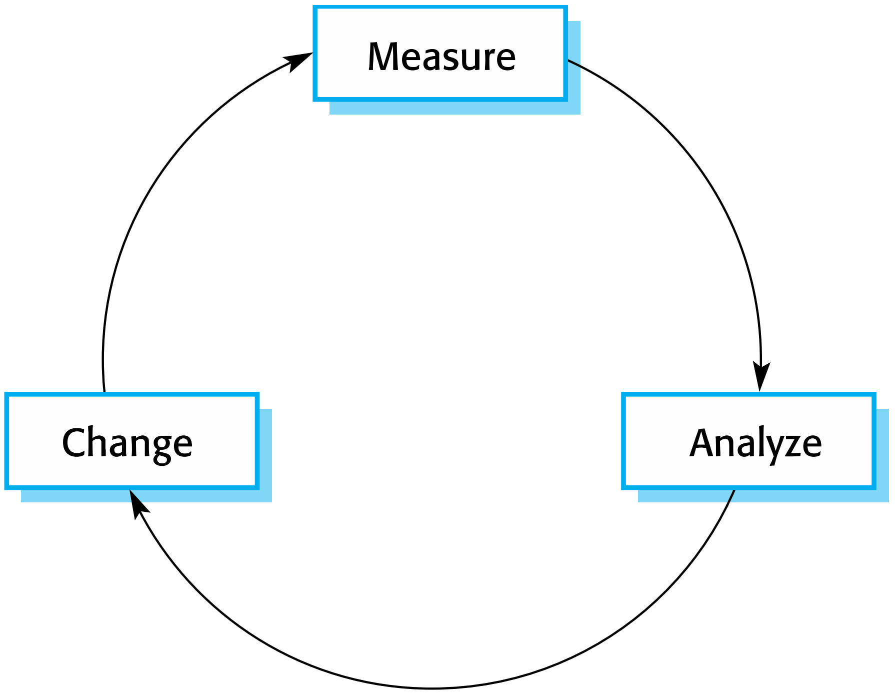
- Many software companies have turned to software process improvement as a way of:
  - **enhancing the quality of their software**,
  - **reducing costs** or
  - **accelerating their development processes**.
- **Process improvement means understanding existing processes** and **changing these processes to increase product quality** and/or **reduce costs and development time**.

Approaches to improvement

- The **process maturity approach**, which **focuses on improving process** and **project management** and **introducing good software engineering practice**.
  - The **level of process maturity** **reflects the extent to which good technical and management practice has been adopted** in organizational software development processes.
- The **agile approach**, which **focuses on iterative development and the reduction of overheads in the software process**.
  - The primary characteristics of agile methods are **rapid delivery of functionality** and **responsiveness to changing customer requirements.**

The process improvement cycle

- **Process measurement**
  - **We measure one or more attributes** of the software process or product.
  - These **measurements forms a baseline** that helps us to decide if process improvements have been effective.
- **Process analysis**
  - The **current process is assessed**, and **process weaknesses and bottlenecks** are identified.
  - Process models (sometimes called process maps) that describe the process may be developed.
- **Process change**
  - **Process changes are proposed** to address some of the identified process weaknesses.
  - **Process changes are introduced** and the cycle resumes to collect data about the effectiveness of the changes.



Process measurement

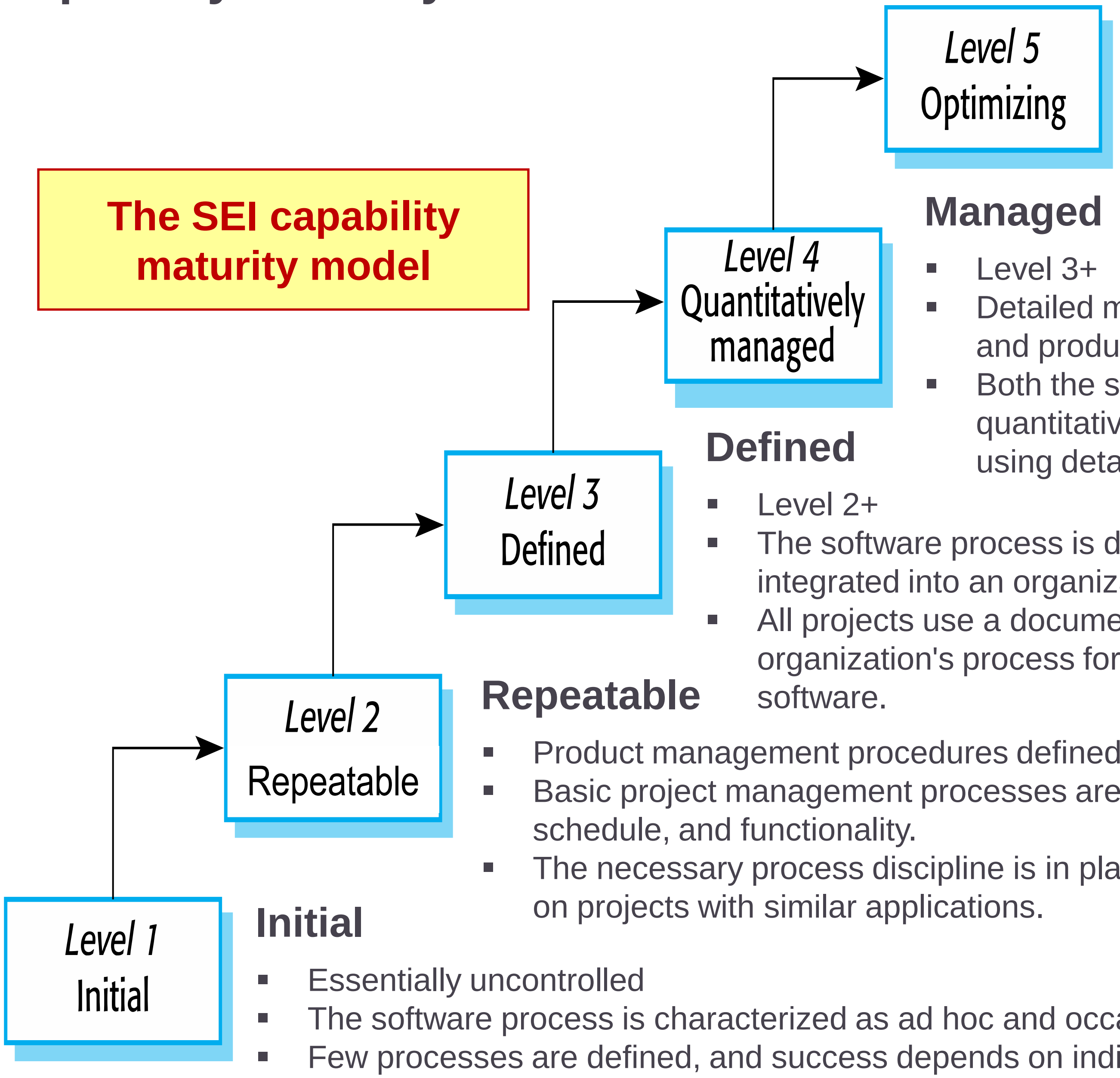
- **Wherever possible, quantitative process data should be collected**
  - However, where organisations do not have clearly defined process standards this is very difficult as you don’t know what to measure.
  - A process may have to be defined before any measurement is possible.
- **Process measurements should be used to assess process improvements**
  - But this does not mean that measurements should drive the improvements.
  - The **improvement driver should be the organizational objectives**.

Process metrics

- **Time taken for process activities to be completed**
  - E.g. Calendar time or effort to complete an activity or process.
- **Resources required for processes or activities**
  - E.g. Total effort in person-days.
- **Number of occurrences of a particular event**
  - E.g. Number of defects discovered.

Capability maturity levels

The SEI capability maturity model



Optimising

- Level 4 +
- Process improvement strategies defined and used

Managed

- Level 3+
- Detailed measures of the software process and product quality are collected.
- Both the software process and products are quantitatively understood and controlled using detailed measures.

Defined

- Level 2+
- The software process is documented, standardized, and integrated into an organization wide software process.
- All projects use a documented and approved version of the organization's process for developing and supporting software.

Repeatable

- Product management procedures defined and used
- Basic project management processes are established to track cost, schedule, and functionality.
- The necessary process discipline is in place to repeat earlier successes on projects with similar applications.

Initial

- Essentially uncontrolled
- The software process is characterized as ad hoc and occasionally even chaotic.
- Few processes are defined, and success depends on individual effort.

Key points

- Software processes are the activities involved in producing a software system. Software process models are abstract representations of these processes.
- General process models describe the organization of software processes. Examples: ‘waterfall’ model, incremental development, and reuse-oriented development.
- Requirements engineering is the process of developing a software specification.
- Design and implementation processes are concerned with transforming a requirements specification into an executable software system.
- Software validation is the process of checking that the system conforms to its specification and that it meets the real needs of the users of the system.
- Software evolution takes place when you change existing software systems to meet new requirements. The software must evolve to remain useful.
- Processes should include activities such as prototyping and incremental delivery to cope with change.
- Processes may be structured for iterative development and delivery so that changes may be made without disrupting the system as a whole.
- The principal approaches to process improvement are agile approaches, geared to reducing process overheads, and maturity-based approaches based on better process management and the use of good software engineering practice.
- The SEI process maturity framework identifies maturity levels that essentially correspond to the use of good software engineering practice.