# An Introduction to Software Engineering

# Software engineering

- The economies of ALL developed nations are dependent on software.
- More and more systems are software controlled
- Sw engineering is concerned with theories, methods and tools for professional sw development.
- Expenditure on sw represents a significant fraction of GNP (The Gross National Product is the total dollar value of all final goods and services produced for consumption in society during a particular time period) in all developed countries.

# Software costs

- Software costs often dominate computer system costs. The costs of software on a PC are often greater than the hardware cost.
- Software costs more to maintain than it does to develop. For systems with a long life, maintenance costs may be several times development costs.
- Software engineering is concerned with cost-effective software development.

# FAQs about software engineering

- What is software?
- What is software engineering?
- What is the difference between software engineering and computer science?
- What is the difference between software engineering and system engineering?
- What is a software process?
- What is a software process model?

# FAQs about software engineering

- What are the costs of software engineering?
- What are software engineering methods?
- What is CASE (Computer-Aided Software Engineering)
- What are the attributes of good software?
- What are the key challenges facing software engineering?

# What is software?

- Computer programs and associated artefacts such as requirements, design models and user manuals.
- Sw products may be developed for a particular customer or for a general market.
  - Generic: sold to a range of different customers e.g. PC software such as Excel or Word.
  - Customised: developed for a single customer according to their specification.
- New software can be created by developing new programs, configuring generic software systems or reusing existing software.

# What is software engineering?

- Software engineering is an engineering discipline that is concerned with all aspects of software production.
- Software engineers should adopt a systematic and organised approach to their work and use appropriate tools and techniques depending on the problem to be solved, the development constraints and the resources available.

# What is the difference between Software Engineering and Computer Science?

- Computer science is concerned with theory and fundamentals; software engineering is concerned with the practicalities of developing and delivering useful software.
- Computer science theories are still insufficient to act as a complete underpinning for software engineering (unlike e.g. physics and electrical engineering).

# What is the difference between Software Engineering and Computer Science?

- Computer science is concerned with theory and fundamentals; software engineering is concerned with the practicalities of developing and delivering useful software.
- Computer science theories are still insufficient to act as a complete underpinning for software engineering (unlike e.g. physics and electrical engineering).

# What is the difference between Software Engineering and System Engineering?

- System engineering is concerned with all aspects of computer-based systems development including hardware, software and process engineering.
- Software engineering is part of this process concerned with developing the software infrastructure, control, applications and databases in the system.
- System engineers are involved in system specification, architectural design, integration and deployment.

# Software Processes

# Objectives

- To introduce software process models
- To describe three generic process models and when they may be used
- To describe outline process models for requirements engineering, software development, testing and evolution
- To explain the Rational Unified Process model
- To introduce CASE technology to support software process activities

# Topics covered

- Software process models
- Process iteration
- Process activities
- The Rational Unified Process
- Computer-aided software engineering

# What is a software process?

- A set of activities whose goal is the development or evolution of software.
- Generic activities in all software processes are:
  - Specification - what the system should do and its development constraints
  - Development - production of the software system
  - Validation - checking that the software is what the customer wants
  - Evolution - changing the software in response to changing demands.

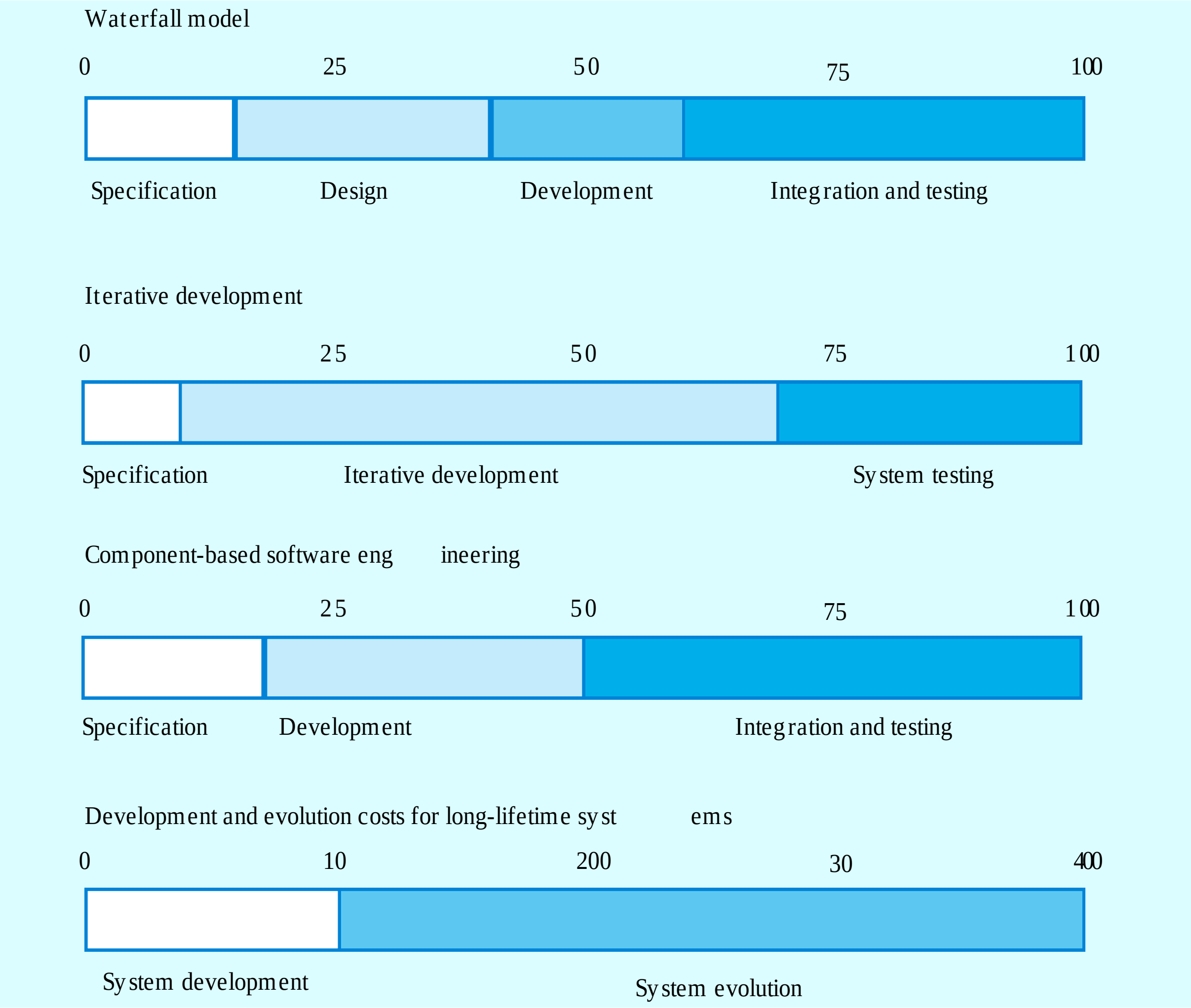
# What is a software process model?

- A software process model is an abstract representation of a process.
- A simplified representation of a software process, presented from a specific perspective.
- Examples of process perspectives are
  - Workflow perspective - sequence of activities;
  - Data-flow perspective - information flow;
  - Role/action perspective - who does what.
- Generic process models
  - Waterfall;
  - Iterative development;
  - Component-based software engineering.

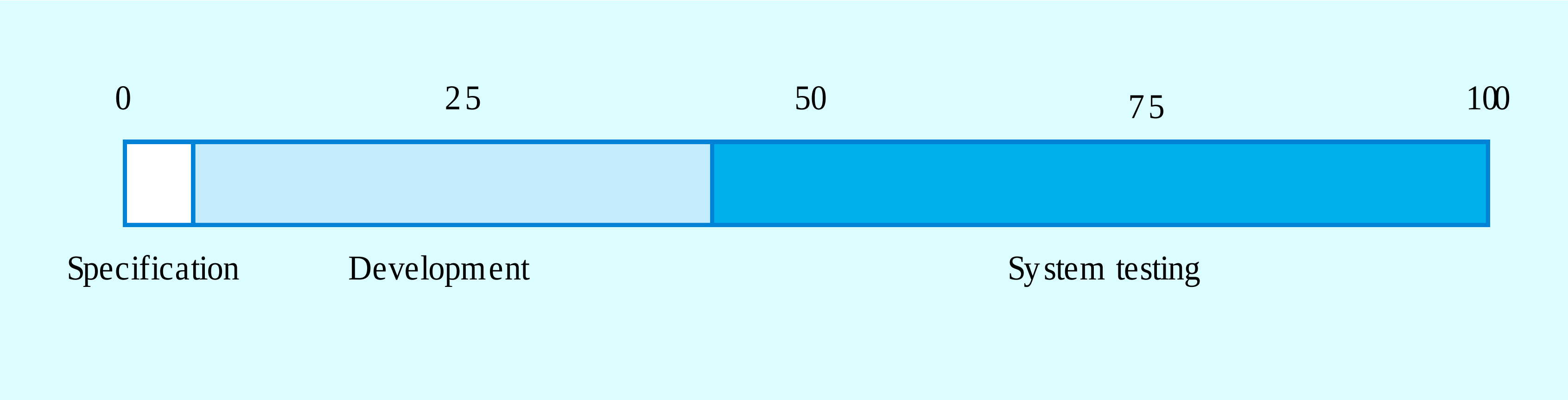
# What are the costs of software engineering?

- Roughly 60% of costs are development costs, 40% are testing costs. For custom software, evolution costs often exceed development costs.
- Costs vary depending on the type of system being developed and the requirements of system attributes such as performance and system reliability.
- Distribution of costs depends on the development model that is used.

# Activity cost distribution



# Product development costs



# What are software engineering methods?

- Structured approaches to software development which include system models, notations, rules, design advice and process guidance.
- Model descriptions
  - Descriptions of graphical models which should be produced;
- Rules
  - Constraints applied to system models;
- Recommendations
  - Advice on good design practice;
- Process guidance
  - What activities to follow.

# What are the attributes of good software?

- The software should deliver the required functionality and performance to the user and should be maintainable, dependable and acceptable.
- Maintainability
  - Software must evolve to meet changing needs;
- Dependability
  - Software must be trustworthy;
- Efficiency
  - Software should not make wasteful use of system resources;
- Acceptability
  - Software must accepted by the users for which it was designed. This means it must be understandable, usable and compatible with other systems.

# What are the key challenges facing software engineering?

- Heterogeneity, delivery and trust.
- Heterogeneity
  - Developing techniques for building software that can cope with heterogeneous platforms and execution environments;
- Delivery
  - Developing techniques that lead to faster delivery of software;
- Trust
  - Developing techniques that demonstrate that software can be trusted by its users.

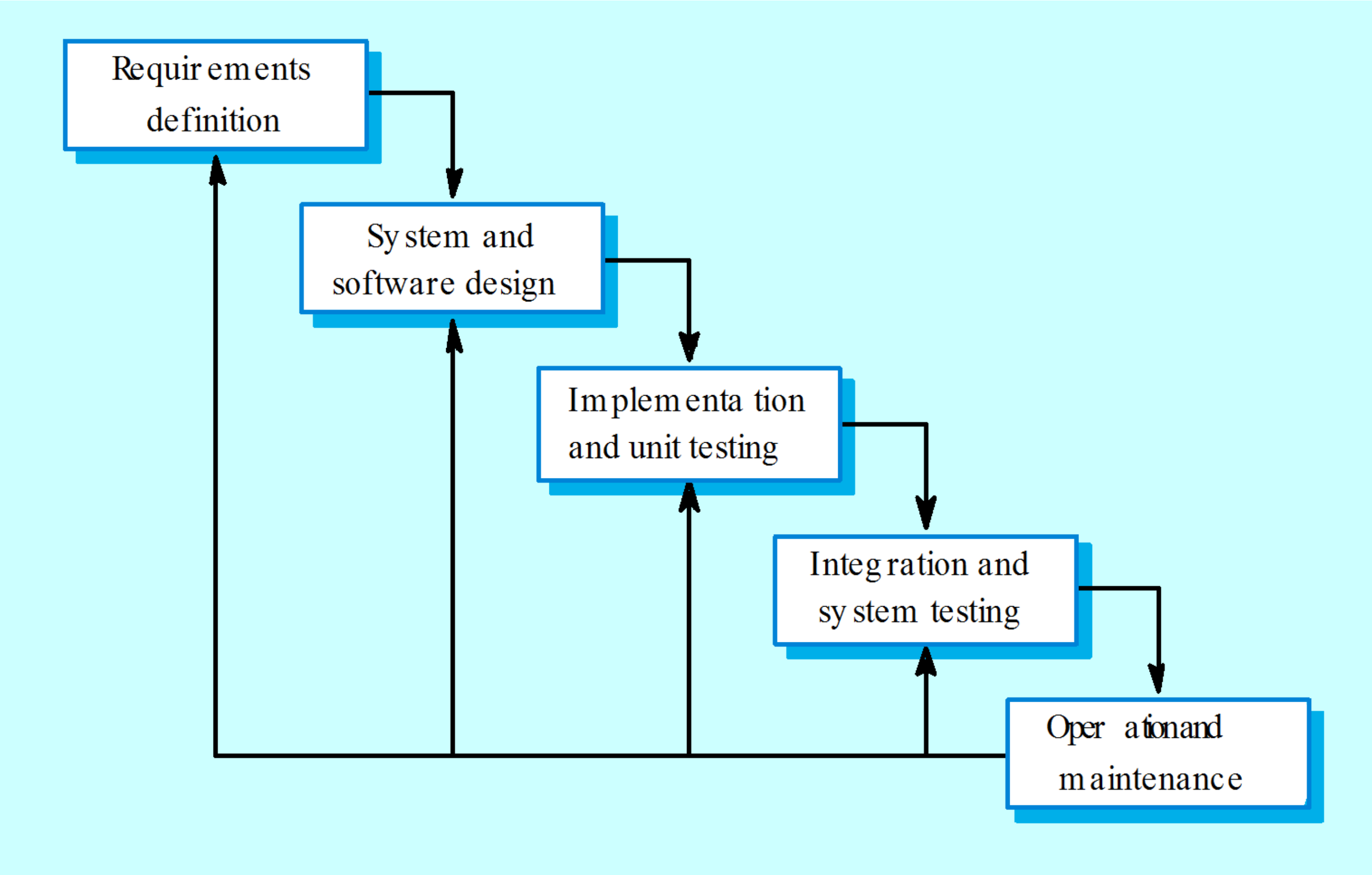
# What is a system?

- A purposeful collection of inter-related components working together to achieve some common objective.
- A system may include software, mechanical, electrical and electronic hardware and be operated by people.
- System components are dependent on other system components
- The properties and behaviour of system components are inextricably inter-mingled

# Generic software process models

- The waterfall model
  - Separate and distinct phases of specification and development.
- Evolutionary development
  - Specification, development and validation are interleaved.
- Component-based software engineering
  - The system is assembled from existing components.
- There are many variants of these models e.g. formal development where a waterfall-like process is used but the specification is a formal specification that is refined through several stages to an implementable design.

# Waterfall model



Requirements definition

System and software design

Implementation and unit testing

Integration and system testing

Operatonand maintenance

# Waterfall Model

- Royce,W.W. (1970) Managing the development of large software systems: concepts and techniques. Proc. of the IEEE WESTCON, Los Angeles CA (Ch.4).
- The main drawback of the waterfall model is the difficulty of accommodating change after the process is underway.
- One phase has to be complete before moving onto the next phase.

# (1)Requirements analysis&definition

- The system´s services, constraints and goals are established by consultation with system users.
- They are then defined in detail and serve as system specification.
- Its desirable attributes in terms of usability, performance, dependability, etc. are definded.
- What are the product requirements, not how are they going to be implemented.

# Requirement Specification Document

- This artefact is the outcome of this phase.
- The client must analyse it in order to check whether the requirements were satisfied.
- The software developers use it to develop the system.
- Another Artefact: Project Plan.

# 2)System and software design

- The system design process separates the requirements to either hardware or software.
- It establishes an overall system architecture.
- Software design involves identifying and describing the fundamental software systems abstractions and their relationships.

# (3)Implementation&Unit Testing

- During this stage, the software design is realised as a set of programs or program units.

- Unit testing involves checking that each unit meets its specification.

# Integration&System Testing

- The individual program units are integrated and tested as a complete system.
- After testing, the software system is delivered to the customer.

# (5)Operation&Maintenance

- Normally this is the longest life-cycle phase.
- The system is installed and put into practical use.
- Maintenance involves: (i) correcting errors which were not identified in earlier stages, (ii) improving the implementation of system units and (iii) implementing new requirements.

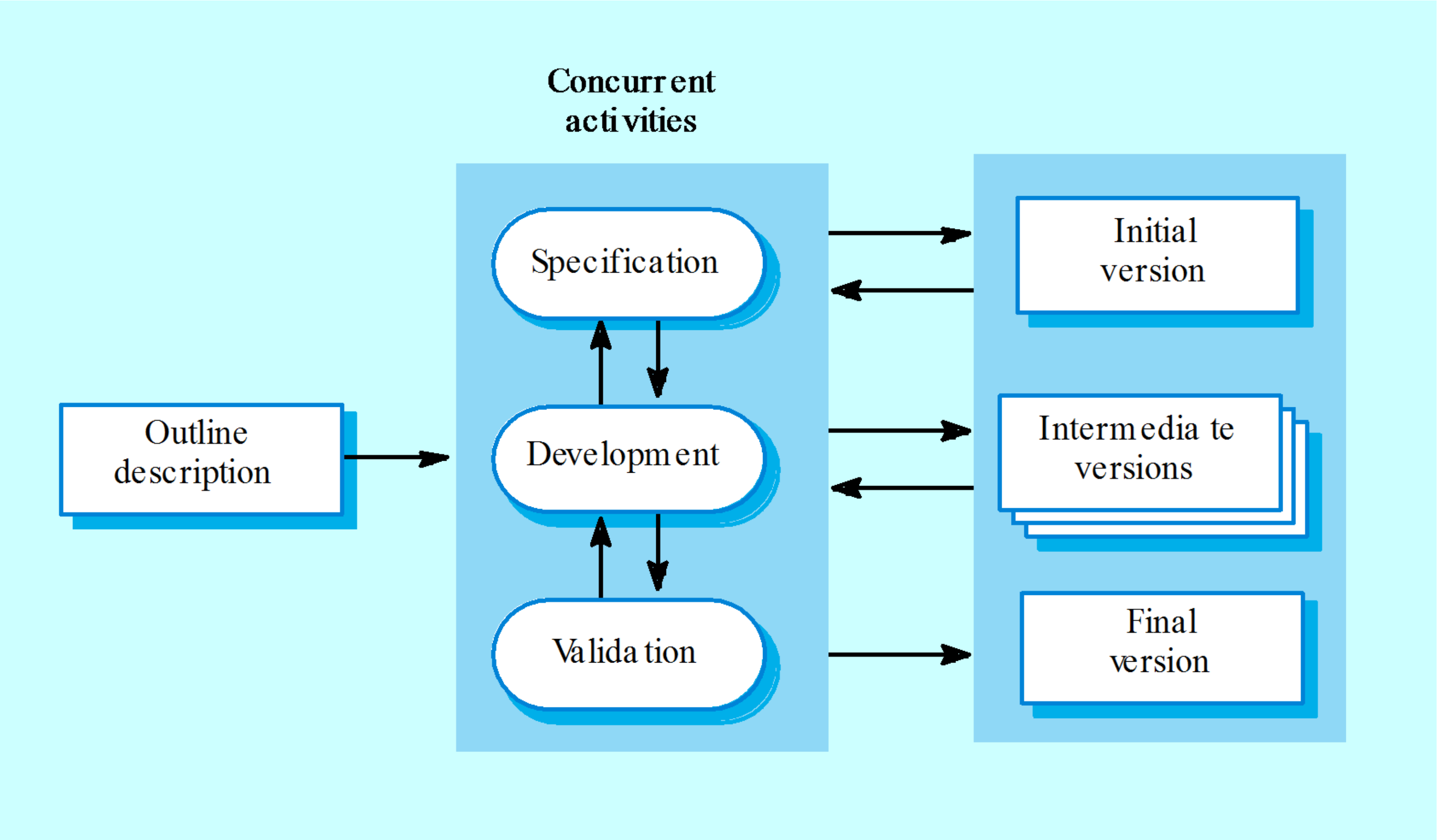
# Waterfall model problems

- Inflexible partitioning of the project into distinct stages makes it difficult to respond to changing customer requirements.
- Therefore, this model is only appropriate when the requirements are well-understood and changes will be fairly limited during the design process.
- Few business systems have stable requirements.
- The waterfall model is mostly used for large systems engineering projects where a system is developed at several sites.

# Evolutionary development

- Exploratory development
  - Objective is to work with customers and to evolve a final system from an initial outline specification. Should start with well-understood requirements and add new features as proposed by the customer.
- Throw-away prototyping
  - Objective is to understand the system requirements. Should start with poorly understood requirements to clarify what is really needed.

# Evolutionary development



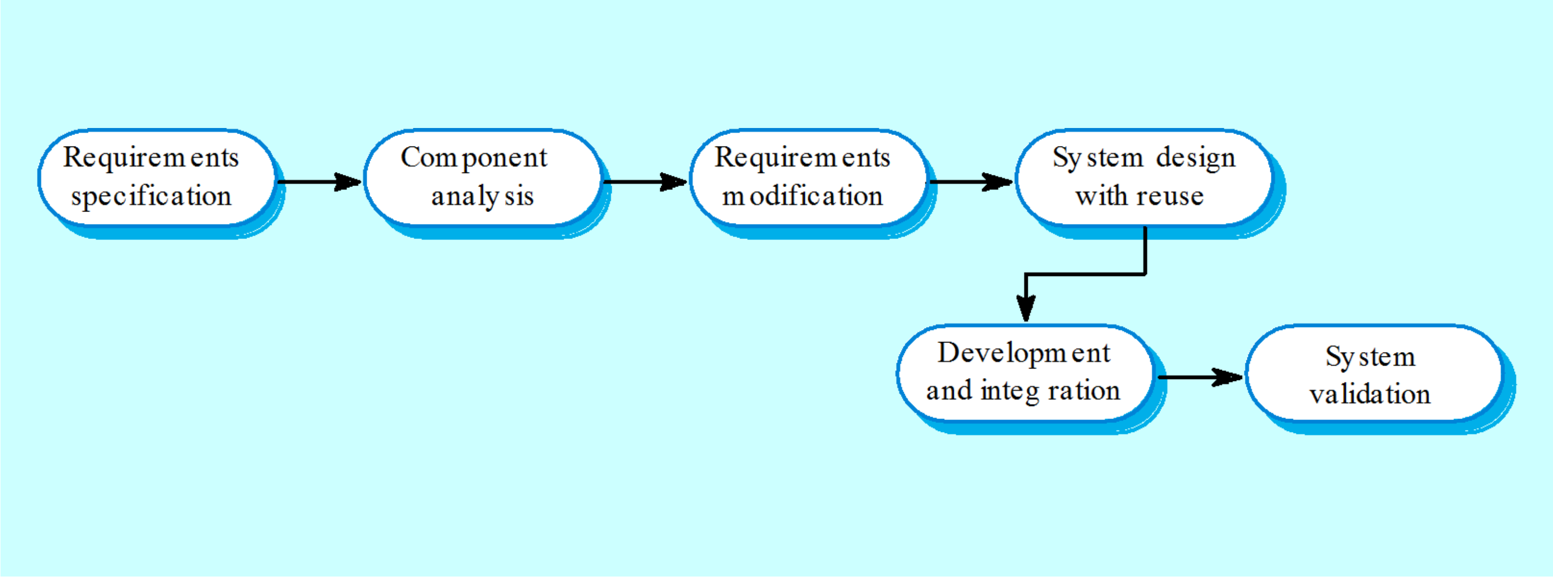
# Evolutionary development

- Problems
  - Lack of process visibility;
  - Systems are often poorly structured;
  - Special skills (e.g. in languages for rapid prototyping) may be required.
- Applicability
  - For small or medium-size interactive systems;
  - For parts of large systems (e.g. the user interface);
  - For short-lifetime systems.

# Component-based software engineering

- Based on systematic reuse where systems are integrated from existing components or COTS (Commercial-off-the-shelf) systems.
- Process stages
  - Component analysis;
  - Requirements modification;
  - System design with reuse;
  - Development and integration.
- This approach is becoming increasingly used as component standards have emerged.

# Reuse-oriented development


Requirements specification
Component analysis
Requirements modification
System design with reuse
Development and integration
System validation

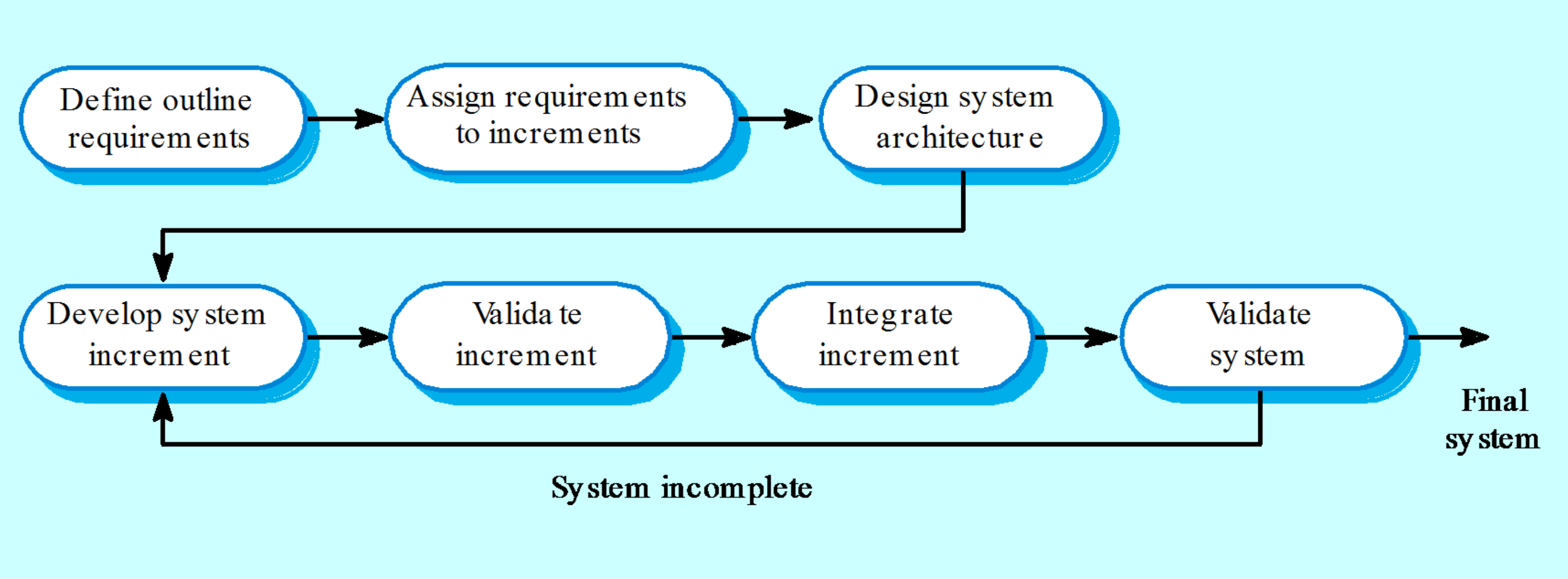
# Process iteration

- System requirements ALWAYS evolve in the course of a project so process iteration where earlier stages are reworked is always part of the process for large systems.
- Iteration can be applied to any of the generic process models.
- Two (related) approaches
  - Incremental delivery;
  - Spiral development.

# Incremental 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



# Incremental development 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.

# Agile Methods

- Extreme Programming is an approach to development based on the development and delivery of very small increments of functionality.
- Relies on constant code improvement, user involvement in the development team and pairwise programming.
- SCRUM, FDD, etc.

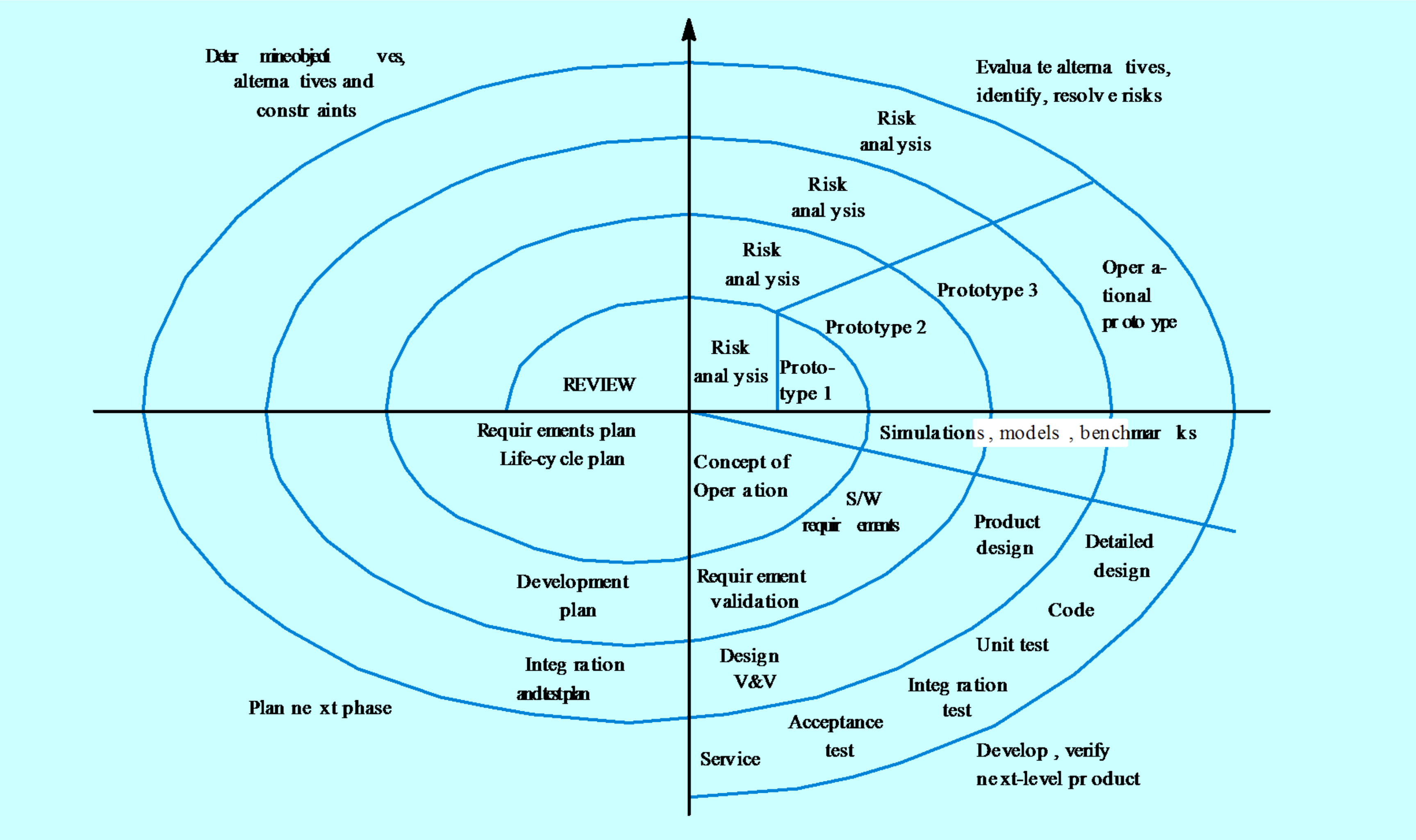
# Spiral development

- Process is represented as a spiral rather than as a sequence of activities with backtracking.
- Each loop in the spiral represents a phase in the process.
- No fixed phases such as specification or design - loops in the spiral are chosen depending on what is required.
- Risks are explicitly assessed and resolved throughout the process.

# Spiral Model

- It was originally proposed by Boehm (1988, Boehm, B. “A Spiral Model for Software Development and Enhancement”, Computer, v.21,no.5, maio 1988)

# Spiral model of the software process



# Spiral model sectors

- Objective setting
  - Specific objectives for the phase are identified.
- Risk assessment and reduction
  - Risks are assessed and activities put in place to reduce the key risks.
- Development and validation
  - A development model for the system is chosen which can be any of the generic models.
- Planning
  - The project is reviewed and the next phase of the spiral is planned.

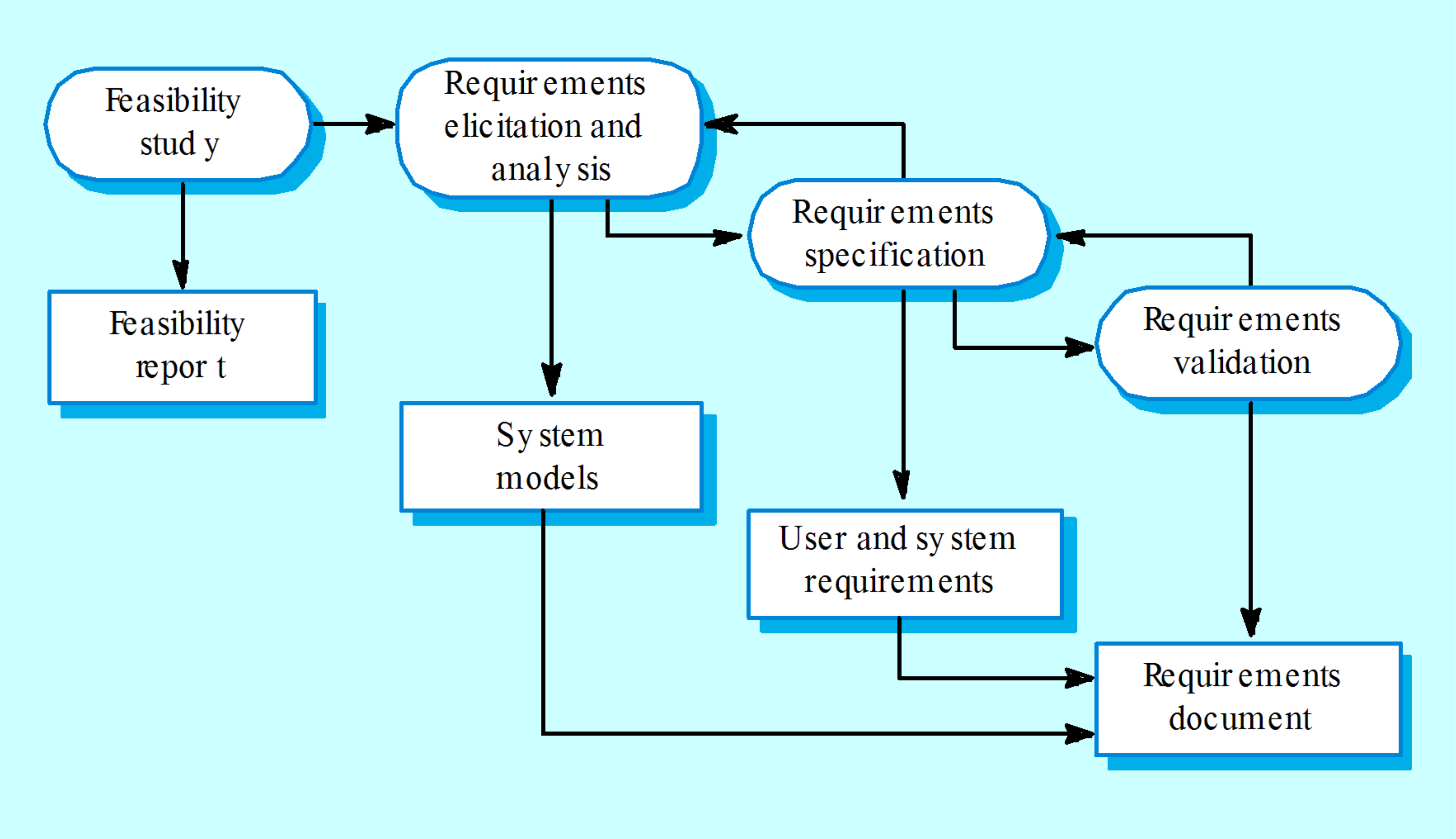
# Process activities

- Software specification
- Software design and implementation
- Software validation
- Software evolution

# Software specification

- The process of establishing what services are required and the constraints on the system’s operation and development.
- Requirements engineering process
  - Feasibility study;
  - Requirements elicitation and analysis;
  - Requirements specification;
  - Requirements validation.

# The requirements engineering process



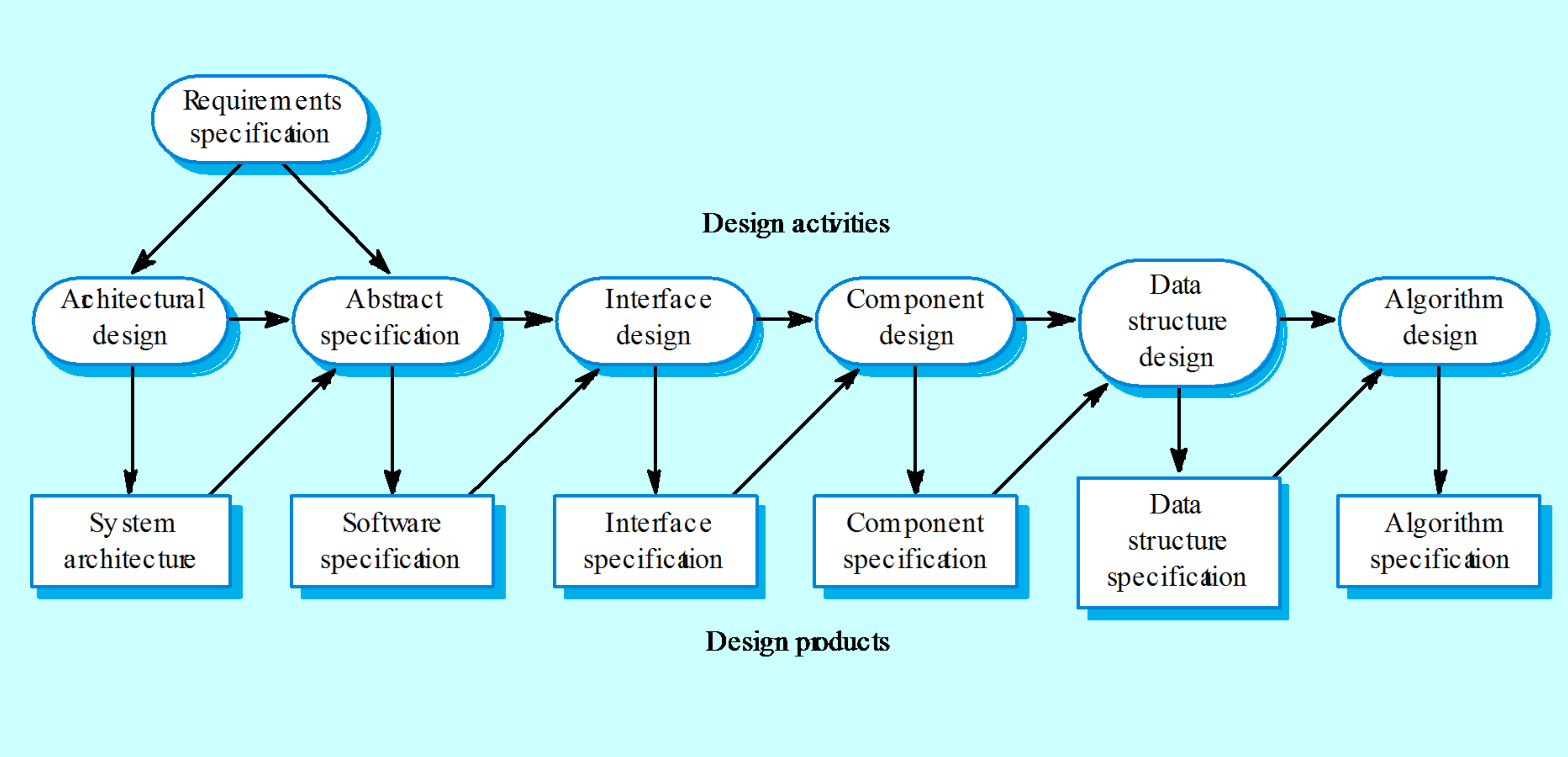
# Software design and implementation

- 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 process activities

- Architectural design
- Abstract specification
- Interface design
- Component design
- Data structure design
- Algorithm design

# The software design process



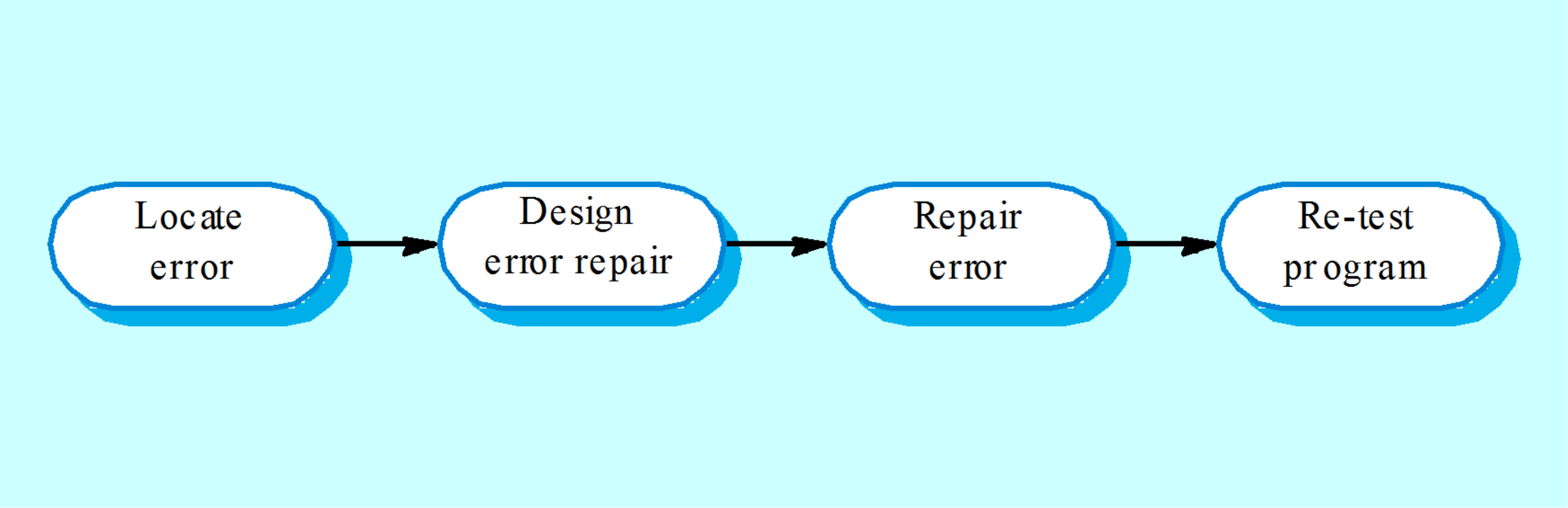
# Structured methods

- Systematic approaches to developing a software design.
- The design is usually documented as a set of graphical models.
- Possible models
  - Object model;
  - Sequence model;
  - State transition model;
  - Structural model;
  - Data-flow model.

# Programming and debugging

- Translating a design into a program and removing errors from that program.
- Programming is a personal activity - there is no generic programming process.
- Programmers carry out some program testing to discover faults in the program and remove these faults in the debugging process.

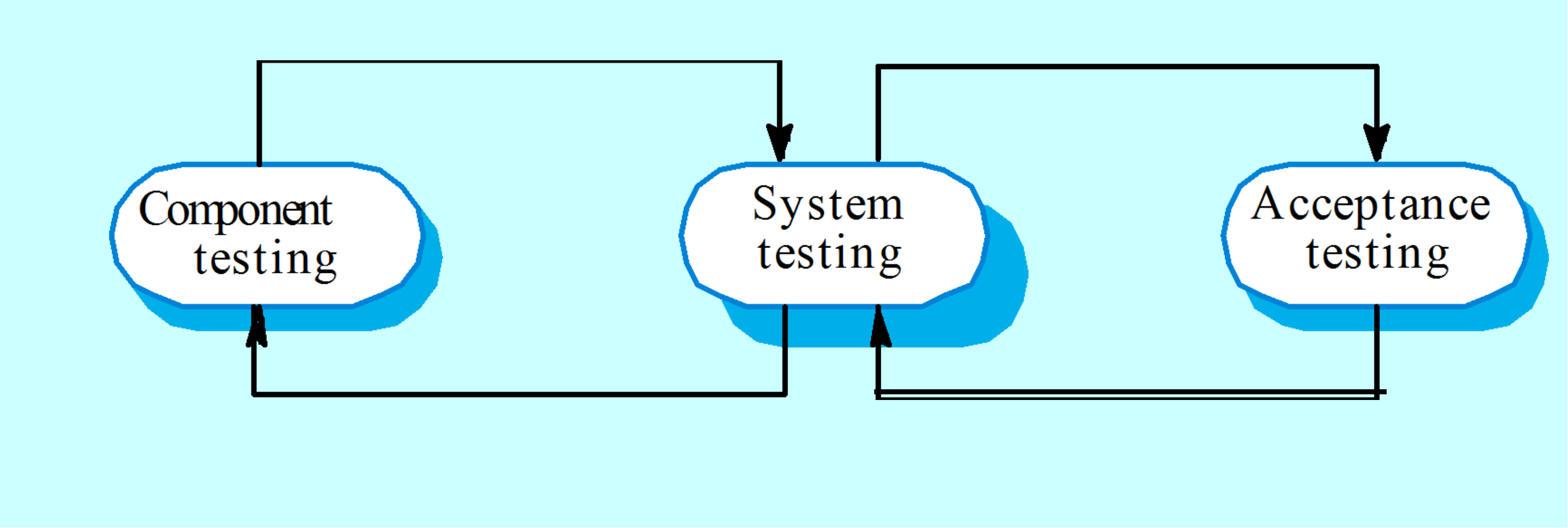
# The debugging process



# 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.

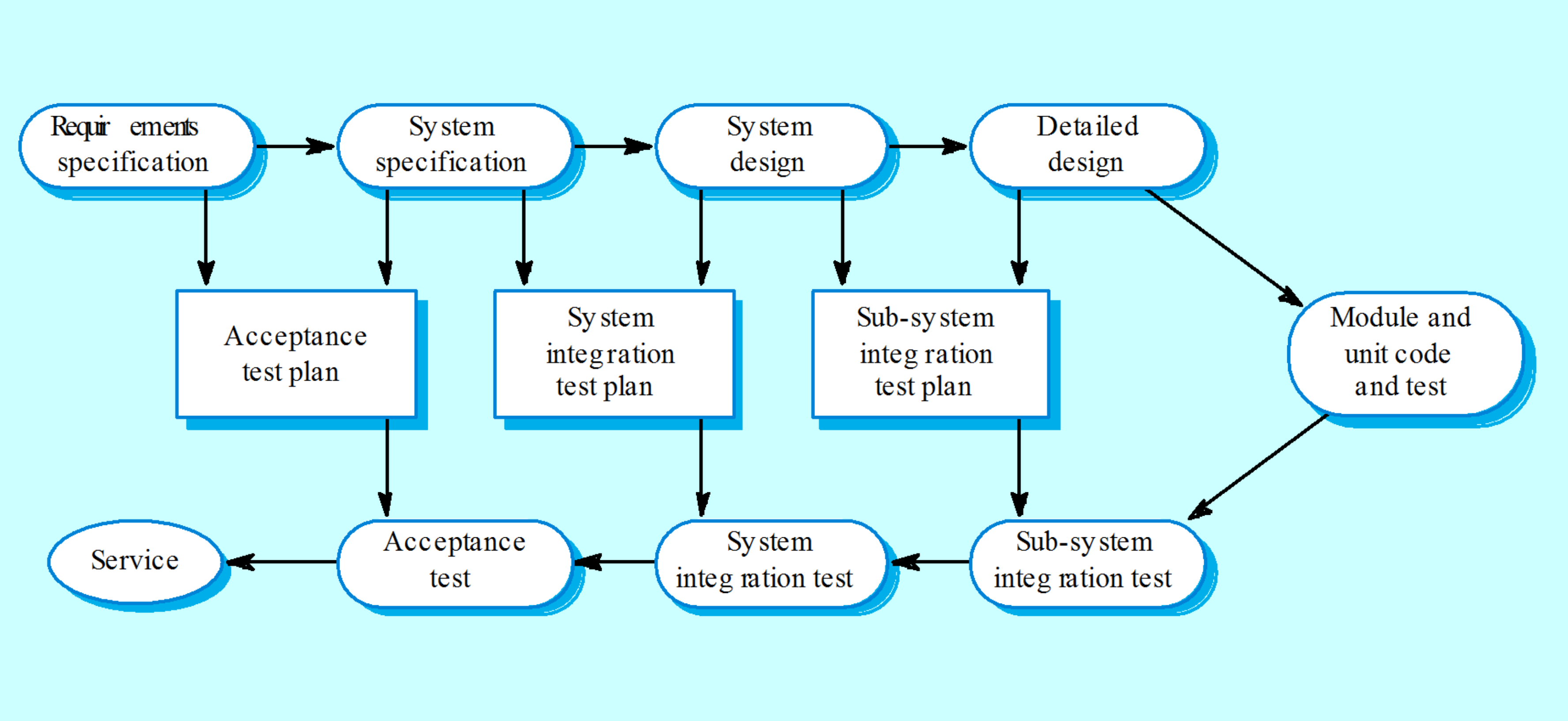
# The testing process



# Testing stages

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

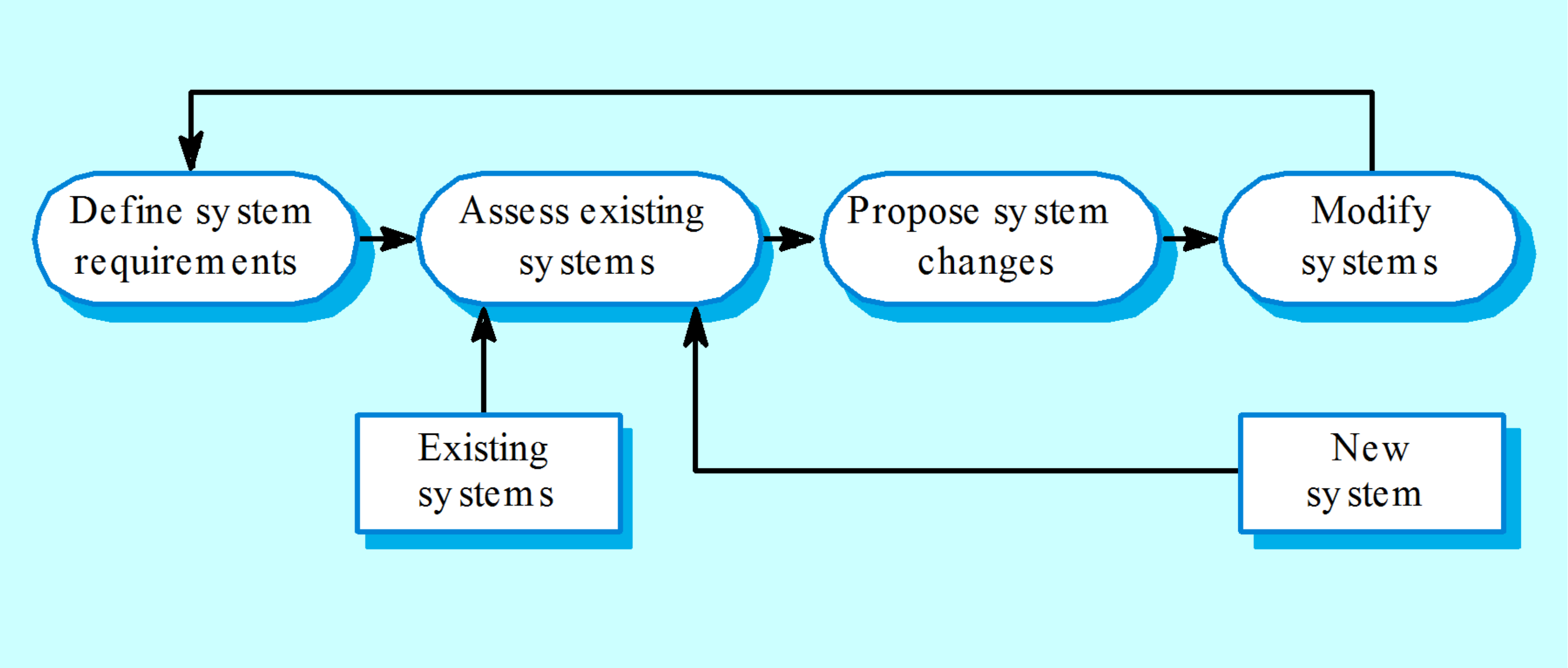
# Testing phases


Requir ements specification
System specification
System design
Detailed design
Acceptance test plan
System integration test plan
Sub-system integ ration test plan
Module and unit code and test
Service
Acceptance test
System integ ration test
Sub-system integ ration test

# 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.

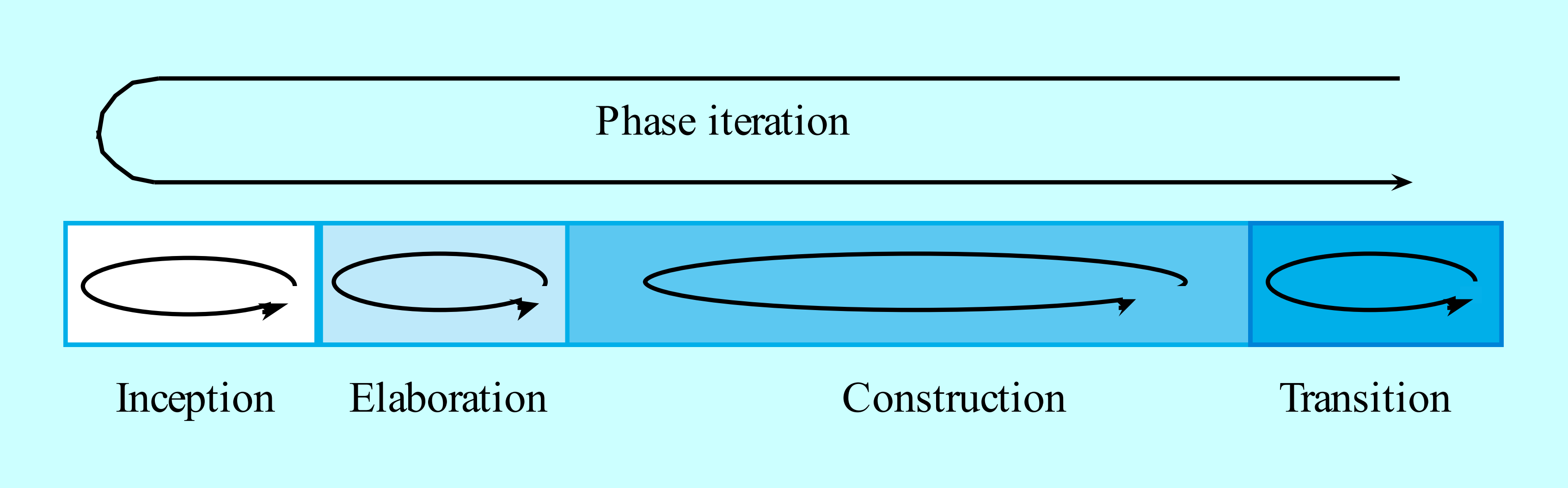
# System evolution



# The Rational Unified Process

- A modern process model derived from the work on the UML and associated process.
- Normally described from 3 perspectives
  - A dynamic perspective that shows phases over time;
  - A static perspective that shows process activities;
  - A practive perspective that suggests good practice.

# RUP phase model



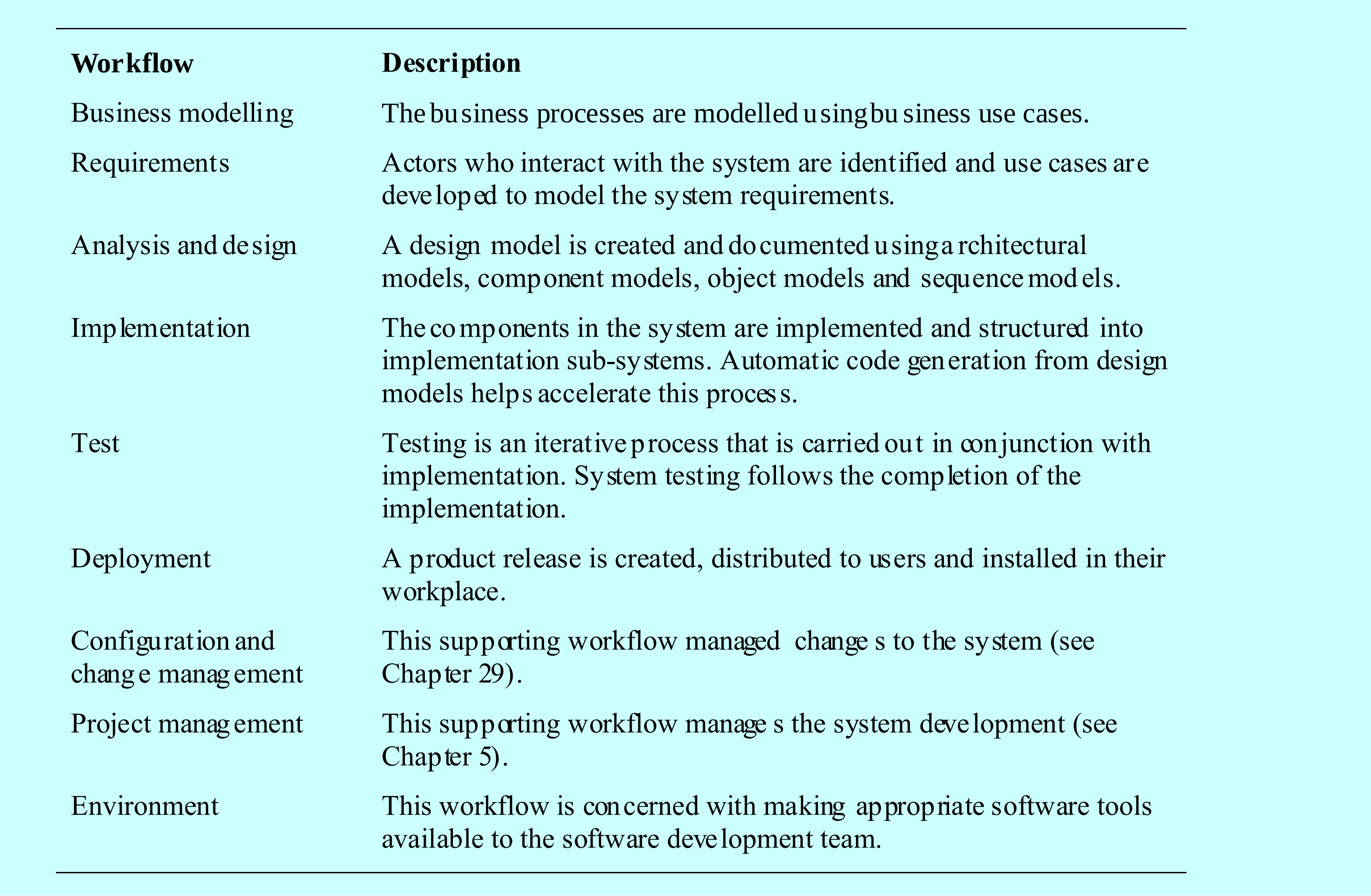
# RUP phases

- Inception
  - Establish the business case for the system.
- Elaboration
  - Develop an understanding of the problem domain and the system architecture.
- Construction
  - System design, programming and testing.
- Transition
  - Deploy the system in its operating environment.

# RUP good practice

- Develop software iteratively
- Manage requirements
- Use component-based architectures
- Visually model software
- Verify software quality
- Control changes to software

# Static workflows



| Workflow | Description |
|---|---|
| Business modelling | The business processes are modelled using business use cases. |
| Requirements | Actors who interact with the system are identified and use cases are developed to model the system requirements. |
| Analysis and design | A design model is created and documented using architectural models, component models, object models and sequence models. |
| Implementation | The components in the system are implemented and structured into implementation sub-systems. Automatic code generation from design models helps accelerate this process. |
| Test | Testing is an iterative process that is carried out in conjunction with implementation. System testing follows the completion of the implementation. |
| Deployment | A product release is created, distributed to users and installed in their workplace. |
| Configuration and change management | This supporting workflow managed changes to the system (see Chapter 29). |
| Project management | This supporting workflow manages the system development (see Chapter 5). |
| Environment | This workflow is concerned with making appropriate software tools available to the software development team. |

# Computer-aided software engineering

- Computer-aided software engineering (CASE) is software to support software development and evolution processes.
- Activity automation
  - Graphical editors for system model development;
  - Data dictionary to manage design entities;
  - Graphical UI builder for user interface construction;
  - Debuggers to support program fault finding;
  - Automated translators to generate new versions of a program.

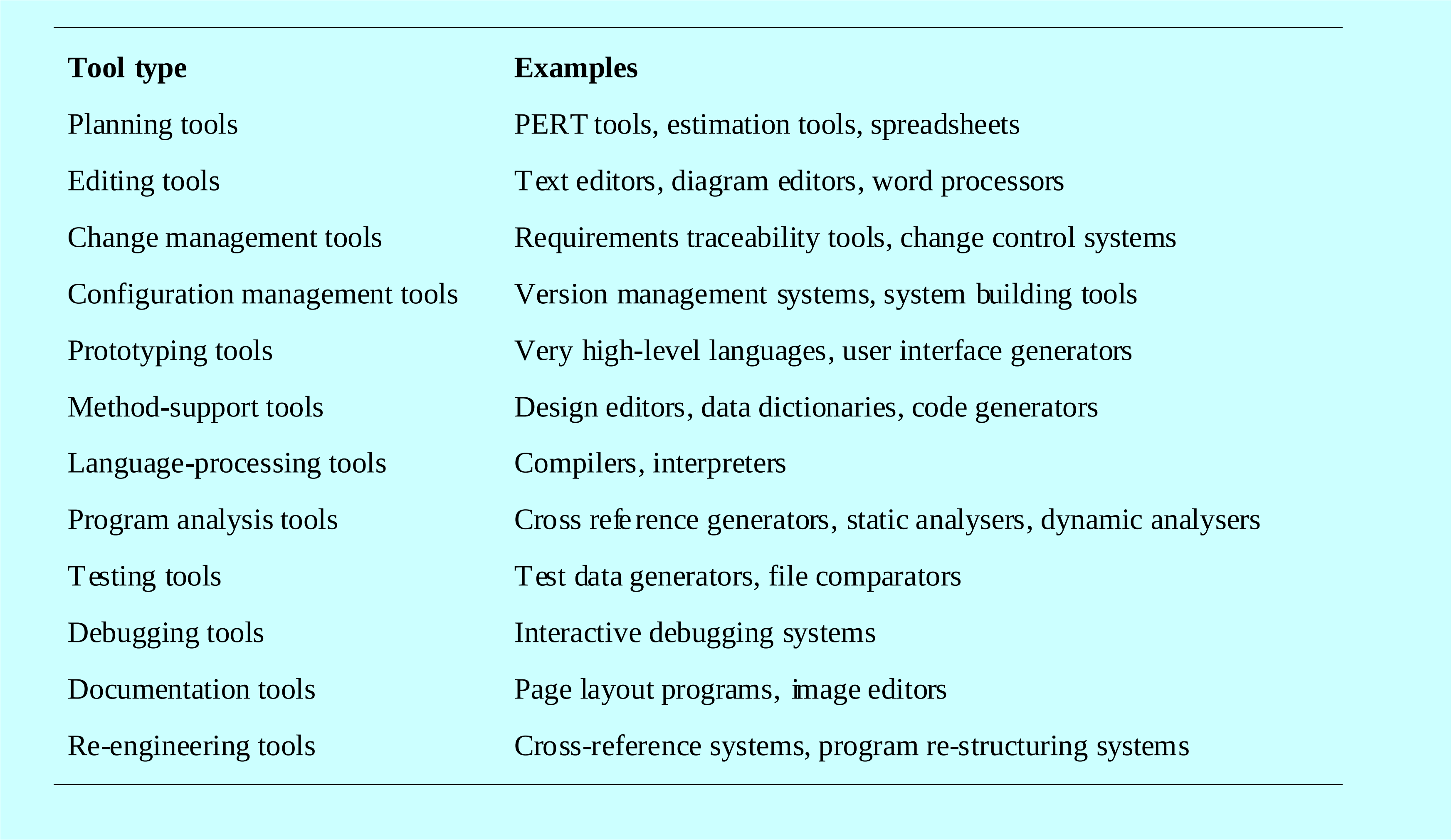
# Case technology

- Case technology has led to significant improvements in the software process. However, these are not the order of magnitude improvements that were once predicted
  - Software engineering requires creative thought - this is not readily automated;
  - Software engineering is a team activity and, for large projects, much time is spent in team interactions. CASE technology does not really support these.

# CASE classification

- Classification helps us understand the different types of CASE tools and their support for process activities.
- Functional perspective
  - Tools are classified according to their specific function.
- Process perspective
  - Tools are classified according to process activities that are supported.
- Integration perspective
  - Tools are classified according to their organisation into integrated units.

# Functional tool classification



| **Tool type** | **Examples** |
|---|---|
| Planning tools | PERT tools, estimation tools, spreadsheets |
| Editing tools | Text editors, diagram editors, word processors |
| Change management tools | Requirements traceability tools, change control systems |
| Configuration management tools | Version management systems, system building tools |
| Prototyping tools | Very high-level languages, user interface generators |
| Method-support tools | Design editors, data dictionaries, code generators |
| Language-processing tools | Compilers, interpreters |
| Program analysis tools | Cross reference generators, static analysers, dynamic analysers |
| Testing tools | Test data generators, file comparators |
| Debugging tools | Interactive debugging systems |
| Documentation tools | Page layout programs, image editors |
| Re-engineering tools | Cross-reference systems, program re-structuring systems |

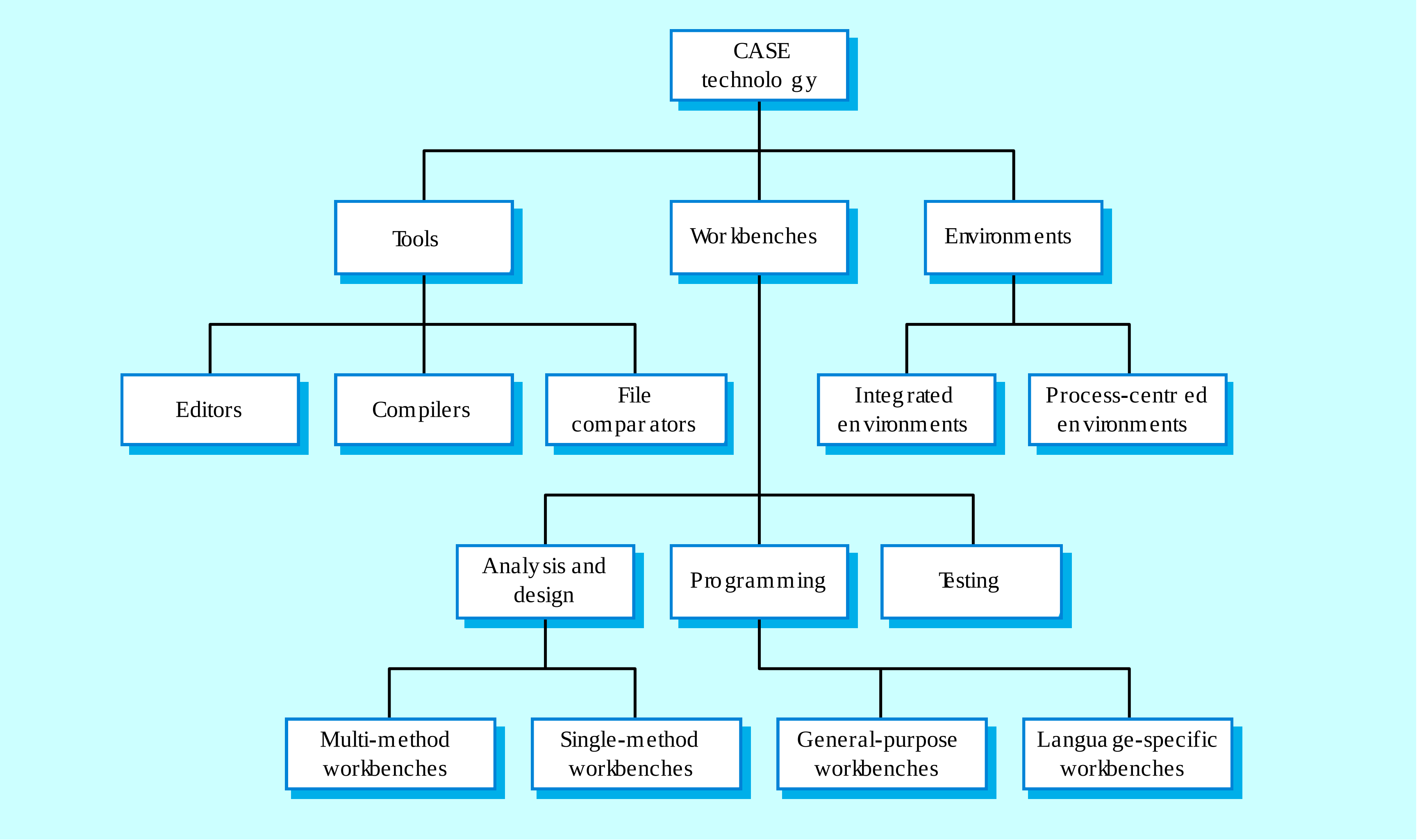
# Activity-based tool classification

| | Specification | Design | Implementation | Verification and Validation |
|---|---|---|---|---|
| Re-engineering tools | | | ● | |
| Testing tools | | | ● | ● |
| Debugging tools | | | ● | ● |
| Program analysis tools | | | ● | ● |
| Language-processing tools | | ● | ● | |
| Method support tools | ● | ● | | |
| Prototyping tools | ● | | | ● |
| Configuration management tools | | ● | ● | |
| Change management tools | ● | ● | ● | ● |
| Documentation tools | ● | ● | ● | ● |
| Editing tools | ● | ● | ● | ● |
| Planning tools | ● | ● | ● | ● |

# CASE integration

- Tools
  - Support individual process tasks such as design consistency checking, text editing, etc.
- Workbenches
  - Support a process phase such as specification or design, Normally include a number of integrated tools.
- Environments
  - Support all or a substantial part of an entire software process. Normally include several integrated workbenches.

# Tools, workbenches, environments



# Key points

- Software processes are the activities involved in producing and evolving a software system.
- Software process models are abstract representations of these processes.
- General activities are specification, design and implementation, validation and evolution.
- Generic process models describe the organisation of software processes. Examples include the waterfall model, evolutionary development and component-based software engineering.
- Iterative process models describe the software process as a cycle of activities.

# Key points

- Requirements engineering is the process of developing a software specification.
- Design and implementation processes transform the specification to an executable program.
- Validation involves checking that the system meets to its specification and user needs.
- Evolution is concerned with modifying the system after it is in use.
- The Rational Unified Process is a generic process model that separates activities from phases.
- CASE technology supports software process activities.