



Chapter 1- Introduction

Topics covered



✧ Professional software development

- What is meant by software engineering.

✧ Software engineering ethics

- A brief introduction to ethical issues that affect software engineering.

✧ Case studies

- An introduction to three examples that are used in later chapters in the book.

Software engineering



- ✧ The economies of ALL developed nations are dependent on software.
- ✧ More and more systems are software controlled
- ✧ Software engineering is concerned with theories, methods and tools for professional software development.
- ✧ Expenditure on software represents a significant fraction of GNP 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.

Software project failure



✧ *Increasing system complexity*

- As new software engineering techniques help us to build larger, more complex systems, the demands change. Systems have to be built and delivered more quickly; larger, even more complex systems are required; systems have to have new capabilities that were previously thought to be impossible.

✧ *Failure to use software engineering methods*

- It is fairly easy to write computer programs without using software engineering methods and techniques. Many companies have drifted into software development as their products and services have evolved. They do not use software engineering methods in their everyday work. Consequently, their software is often more expensive and less reliable than it should be.



Professional software development

Frequently asked questions about software engineering



Question	Answer
What is software?	Computer programs and associated documentation. Software products may be developed for a particular customer or may be developed for a general market.
What are the attributes of good software?	Good software should deliver the required functionality and performance to the user and should be maintainable, dependable and usable.
What is software engineering?	Software engineering is an engineering discipline that is concerned with all aspects of software production.
What are the fundamental software engineering activities?	Software specification, software development, software validation and software evolution.
What is the difference between software engineering and computer science?	Computer science focuses on theory and fundamentals; software engineering is concerned with the practicalities of developing and delivering useful software.
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 more general process.

Frequently asked questions about software engineering



Question	Answer
What are the key challenges facing software engineering?	Coping with increasing diversity, demands for reduced delivery times and developing trustworthy software.
What are the costs of software engineering?	Roughly 60% of software costs are development costs, 40% are testing costs. For custom software, evolution costs often exceed development costs.
What are the best software engineering techniques and methods?	While all software projects have to be professionally managed and developed, different techniques are appropriate for different types of system. For example, games should always be developed using a series of prototypes whereas safety critical control systems require a complete and analyzable specification to be developed. You can't, therefore, say that one method is better than another.
What differences has the web made to software engineering?	The web has led to the availability of software services and the possibility of developing highly distributed service-based systems. Web-based systems development has led to important advances in programming languages and software reuse.

Software products



✧ Generic products

- Stand-alone systems that are marketed and sold to any customer who wishes to buy them.
- Examples – PC software such as graphics programs, project management tools; CAD software; software for specific markets such as appointments systems for dentists.

✧ Customized products

- Software that is commissioned by a specific customer to meet their own needs.
- Examples – embedded control systems, air traffic control software, traffic monitoring systems.

Product specification



✧ Generic products

- The specification of what the software should do is owned by the software developer and decisions on software change are made by the developer.

✧ Customized products

- The specification of what the software should do is owned by the customer for the software and they make decisions on software changes that are required.

Essential attributes of good software



Product characteristic	Description
Maintainability	Software should be written in such a way so that it can evolve to meet the changing needs of customers. This is a critical attribute because software change is an inevitable requirement of a changing business environment.
Dependability and security	Software dependability includes a range of characteristics including reliability, security and safety. Dependable software should not cause physical or economic damage in the event of system failure. Malicious users should not be able to access or damage the system.
Efficiency	Software should not make wasteful use of system resources such as memory and processor cycles. Efficiency therefore includes responsiveness, processing time, memory utilisation, etc.
Acceptability	Software must be acceptable to the type of users for which it is designed. This means that it must be understandable, usable and compatible with other systems that they use.

Software engineering



- ✧ Software engineering is an engineering discipline that is concerned with all aspects of software production from the early stages of system specification through to maintaining the system after it has gone into use.
- ✧ Engineering discipline
 - Using appropriate theories and methods to solve problems bearing in mind organizational and financial constraints.
- ✧ All aspects of software production
 - Not just technical process of development. Also project management and the development of tools, methods etc. to support software production.

Importance of software engineering



- ✧ More and more, individuals and society rely on advanced software systems. We need to be able to produce reliable and trustworthy systems economically and quickly.
- ✧ It is usually cheaper, in the long run, to use software engineering methods and techniques for software systems rather than just write the programs as if it was a personal programming project. For most types of system, the majority of costs are the costs of changing the software after it has gone into use.

Software process activities



- ✧ Software specification, where customers and engineers define the software that is to be produced and the constraints on its operation.
- ✧ Software development, where the software is designed and programmed.
- ✧ Software validation, where the software is checked to ensure that it is what the customer requires.
- ✧ Software evolution, where the software is modified to reflect changing customer and market requirements.

General issues that affect software



✧ Heterogeneity

- Increasingly, systems are required to operate as distributed systems across networks that include different types of computer and mobile devices.

✧ Business and social change

- Business and society are changing incredibly quickly as emerging economies develop and new technologies become available. They need to be able to change their existing software and to rapidly develop new software.

General issues that affect software



✧ Security and trust

- As software is intertwined with all aspects of our lives, it is essential that we can trust that software.

✧ Scale

- Software has to be developed across a very wide range of scales, from very small embedded systems in portable or wearable devices through to Internet-scale, cloud-based systems that serve a global community.

Software engineering diversity



- ✧ There are many different types of software system and there is no universal set of software techniques that is applicable to all of these.
- ✧ The software engineering methods and tools used depend on the type of application being developed, the requirements of the customer and the background of the development team.

Application types



✧ Stand-alone applications

- These are application systems that run on a local computer, such as a PC. They include all necessary functionality and do not need to be connected to a network.

✧ Interactive transaction-based applications

- Applications that execute on a remote computer and are accessed by users from their own PCs or terminals. These include web applications such as e-commerce applications.

✧ Embedded control systems

- These are software control systems that control and manage hardware devices. Numerically, there are probably more embedded systems than any other type of system.

Application types



✧ Batch processing systems

- These are business systems that are designed to process data in large batches. They process large numbers of individual inputs to create corresponding outputs.

✧ Entertainment systems

- These are systems that are primarily for personal use and which are intended to entertain the user.

✧ Systems for modeling and simulation

- These are systems that are developed by scientists and engineers to model physical processes or situations, which include many, separate, interacting objects.

Application types



✧ Data collection systems

- These are systems that collect data from their environment using a set of sensors and send that data to other systems for processing.

✧ Systems of systems

- These are systems that are composed of a number of other software systems.

Software engineering fundamentals



- ✧ Some fundamental principles apply to all types of software system, irrespective of the development techniques used:
 - Systems should be developed using a managed and understood development process. Of course, different processes are used for different types of software.
 - Dependability and performance are important for all types of system.
 - Understanding and managing the software specification and requirements (what the software should do) are important.
 - Where appropriate, you should reuse software that has already been developed rather than write new software.

Internet software engineering



- ✧ The Web is now a platform for running application and organizations are increasingly developing web-based systems rather than local systems.
- ✧ Web services (discussed in Chapter 19) allow application functionality to be accessed over the web.
- ✧ Cloud computing is an approach to the provision of computer services where applications run remotely on the 'cloud'.
 - Users do not buy software but pay according to use.

Web-based software engineering



- ✧ Web-based systems are complex distributed systems but the fundamental principles of software engineering discussed previously are as applicable to them as they are to any other types of system.
- ✧ The fundamental ideas of software engineering apply to web-based software in the same way that they apply to other types of software system.

Web software engineering



✧ Software reuse

- Software reuse is the dominant approach for constructing web-based systems. When building these systems, you think about how you can assemble them from pre-existing software components and systems.

✧ Incremental and agile development

- Web-based systems should be developed and delivered incrementally. It is now generally recognized that it is impractical to specify all the requirements for such systems in advance.

Web software engineering



✧ Service-oriented systems

- Software may be implemented using service-oriented software engineering, where the software components are stand-alone web services.

✧ Rich interfaces

- Interface development technologies such as AJAX and HTML5 have emerged that support the creation of rich interfaces within a web browser.



Software engineering ethics

Software engineering ethics



- ✧ Software engineering involves wider responsibilities than simply the application of technical skills.
- ✧ Software engineers must behave in an honest and ethically responsible way if they are to be respected as professionals.
- ✧ Ethical behaviour is more than simply upholding the law but involves following a set of principles that are morally correct.

Issues of professional responsibility



✧ Confidentiality

- Engineers should normally respect the confidentiality of their employers or clients irrespective of whether or not a formal confidentiality agreement has been signed.

✧ Competence

- Engineers should not misrepresent their level of competence. They should not knowingly accept work which is outwith their competence.

Issues of professional responsibility



✧ Intellectual property rights

- Engineers should be aware of local laws governing the use of intellectual property such as patents, copyright, etc. They should be careful to ensure that the intellectual property of employers and clients is protected.

✧ Computer misuse

- Software engineers should not use their technical skills to misuse other people's computers. Computer misuse ranges from relatively trivial (game playing on an employer's machine, say) to extremely serious (dissemination of viruses).

ACM/IEEE Code of Ethics



- ✧ The professional societies in the US have cooperated to produce a code of ethical practice.
- ✧ Members of these organisations sign up to the code of practice when they join.
- ✧ The Code contains eight Principles related to the behaviour of and decisions made by professional software engineers, including practitioners, educators, managers, supervisors and policy makers, as well as trainees and students of the profession.

Rationale for the code of ethics



- *Computers have a central and growing role in commerce, industry, government, medicine, education, entertainment and society at large. Software engineers are those who contribute by direct participation or by teaching, to the analysis, specification, design, development, certification, maintenance and testing of software systems.*
- *Because of their roles in developing software systems, software engineers have significant opportunities to do good or cause harm, to enable others to do good or cause harm, or to influence others to do good or cause harm. To ensure, as much as possible, that their efforts will be used for good, software engineers must commit themselves to making software engineering a beneficial and respected profession.*

The ACM/IEEE Code of Ethics



Software Engineering Code of Ethics and Professional Practice

ACM/IEEE-CS Joint Task Force on Software Engineering Ethics and Professional Practices

PREAMBLE

The short version of the code summarizes aspirations at a high level of the abstraction; the clauses that are included in the full version give examples and details of how these aspirations change the way we act as software engineering professionals. Without the aspirations, the details can become legalistic and tedious; without the details, the aspirations can become high sounding but empty; together, the aspirations and the details form a cohesive code.

Software engineers shall commit themselves to making the analysis, specification, design, development, testing and maintenance of software a beneficial and respected profession. In accordance with their commitment to the health, safety and welfare of the public, software engineers shall adhere to the following Eight Principles:

Ethical principles



1. PUBLIC - Software engineers shall act consistently with the public interest.
2. CLIENT AND EMPLOYER - Software engineers shall act in a manner that is in the best interests of their client and employer consistent with the public interest.
3. PRODUCT - Software engineers shall ensure that their products and related modifications meet the highest professional standards possible.
4. JUDGMENT - Software engineers shall maintain integrity and independence in their professional judgment.
5. MANAGEMENT - Software engineering managers and leaders shall subscribe to and promote an ethical approach to the management of software development and maintenance.
6. PROFESSION - Software engineers shall advance the integrity and reputation of the profession consistent with the public interest.
7. COLLEAGUES - Software engineers shall be fair to and supportive of their colleagues.
8. SELF - Software engineers shall participate in lifelong learning regarding the practice of their profession and shall promote an ethical approach to the practice of the profession.

Case studies

Ethical dilemmas



- ✧ Disagreement in principle with the policies of senior management.
- ✧ Your employer acts in an unethical way and releases a safety-critical system without finishing the testing of the system.
- ✧ Participation in the development of military weapons systems or nuclear systems.

Case studies



✧ A personal insulin pump

- An embedded system in an insulin pump used by diabetics to maintain blood glucose control.

✧ A mental health case patient management system

- Mentcare. A system used to maintain records of people receiving care for mental health problems.

✧ A wilderness weather station

- A data collection system that collects data about weather conditions in remote areas.

✧ iLearn: a digital learning environment

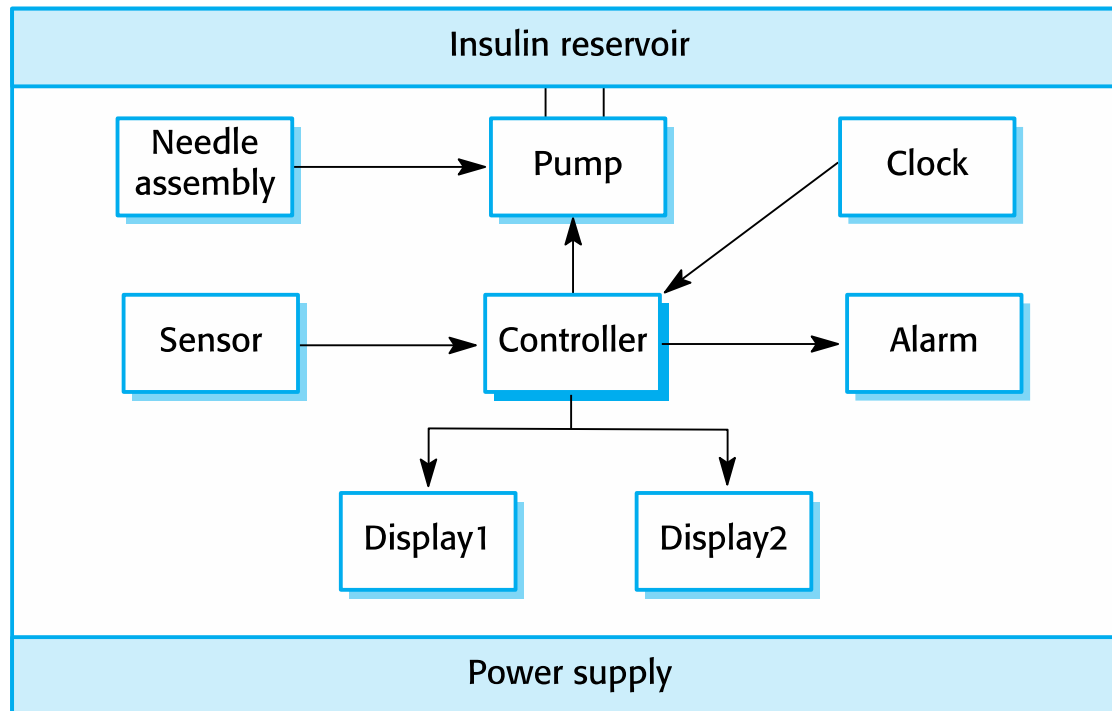
- A system to support learning in schools

Insulin pump control system

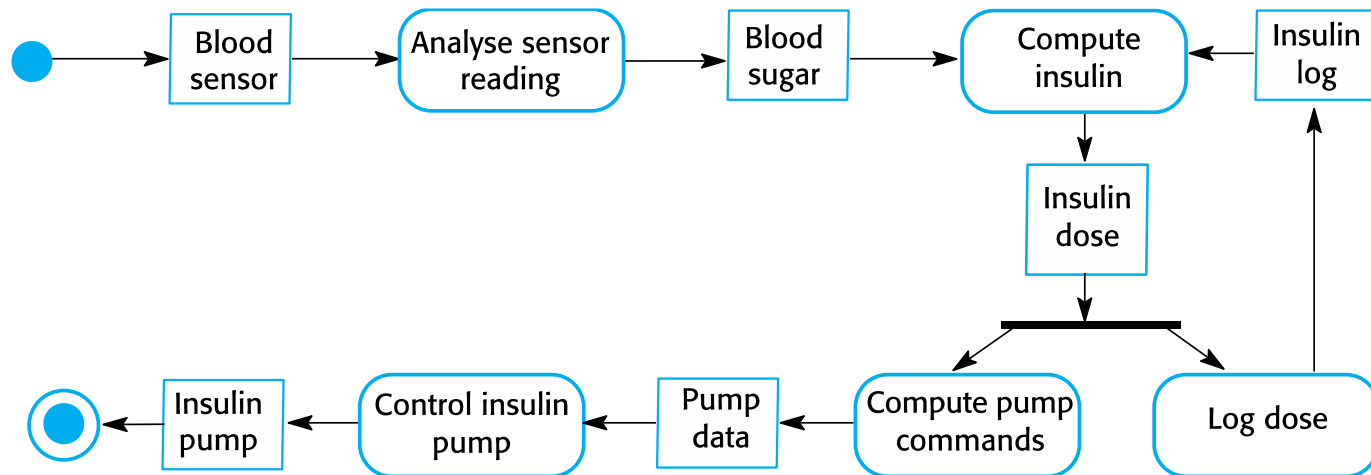


- ✧ Collects data from a blood sugar sensor and calculates the amount of insulin required to be injected.
- ✧ Calculation based on the rate of change of blood sugar levels.
- ✧ Sends signals to a micro-pump to deliver the correct dose of insulin.
- ✧ Safety-critical system as low blood sugars can lead to brain malfunctioning, coma and death; high-blood sugar levels have long-term consequences such as eye and kidney damage.

Insulin pump hardware architecture



Activity model of the insulin pump



Essential high-level requirements



- ✧ The system shall be available to deliver insulin when required.
- ✧ The system shall perform reliably and deliver the correct amount of insulin to counteract the current level of blood sugar.
- ✧ The system must therefore be designed and implemented to ensure that the system always meets these requirements.

Mentcare: A patient information system for mental health care



- ✧ A patient information system to support mental health care is a medical information system that maintains information about patients suffering from mental health problems and the treatments that they have received.
- ✧ Most mental health patients do not require dedicated hospital treatment but need to attend specialist clinics regularly where they can meet a doctor who has detailed knowledge of their problems.
- ✧ To make it easier for patients to attend, these clinics are not just run in hospitals. They may also be held in local medical practices or community centres.



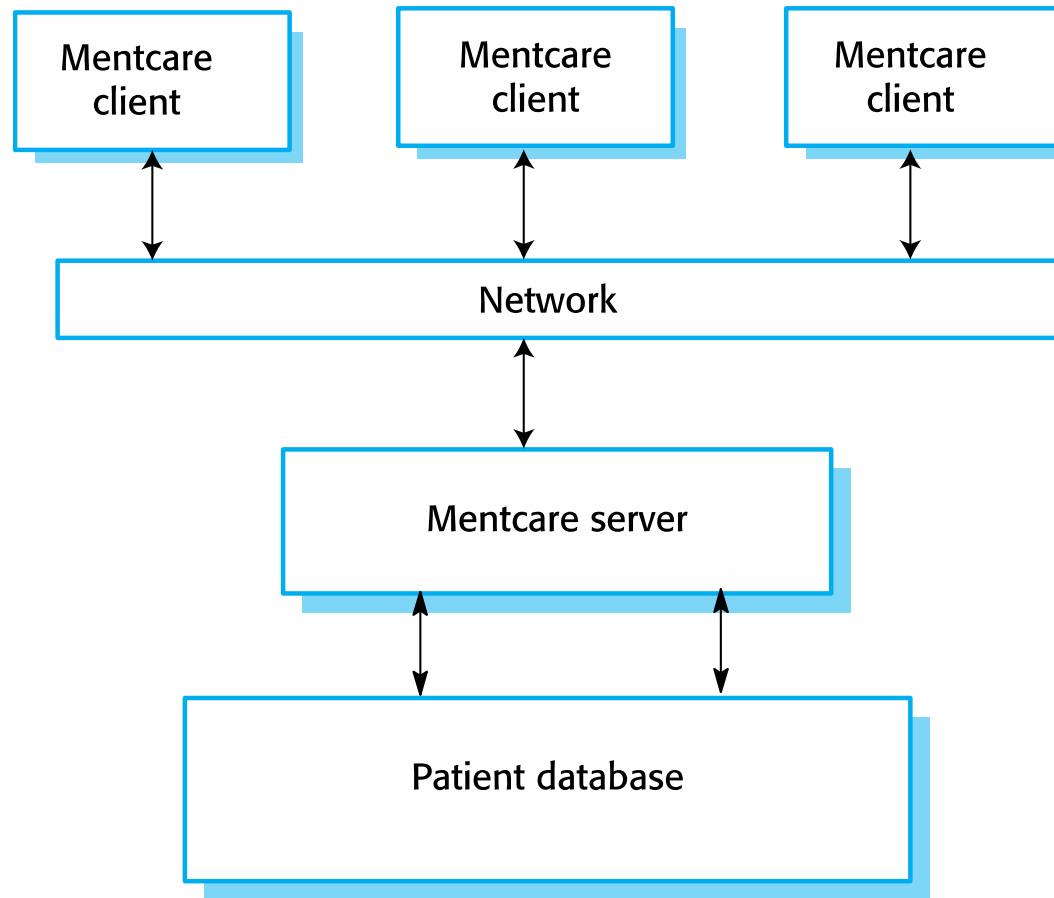
- ✧ Mentcare is an information system that is intended for use in clinics.
- ✧ It makes use of a centralized database of patient information but has also been designed to run on a PC, so that it may be accessed and used from sites that do not have secure network connectivity.
- ✧ When the local systems have secure network access, they use patient information in the database but they can download and use local copies of patient records when they are disconnected.

Mentcare goals



- ✧ To generate management information that allows health service managers to assess performance against local and government targets.
- ✧ To provide medical staff with timely information to support the treatment of patients.

The organization of the Mentcare system



Key features of the Mentcare system



✧ Individual care management

- Clinicians can create records for patients, edit the information in the system, view patient history, etc. The system supports data summaries so that doctors can quickly learn about the key problems and treatments that have been prescribed.

✧ Patient monitoring

- The system monitors the records of patients that are involved in treatment and issues warnings if possible problems are detected.

✧ Administrative reporting

- The system generates monthly management reports showing the number of patients treated at each clinic, the number of patients who have entered and left the care system, number of patients sectioned, the drugs prescribed and their costs, etc.

Mentcare system concerns



✧ Privacy

- It is essential that patient information is confidential and is never disclosed to anyone apart from authorised medical staff and the patient themselves.

✧ Safety

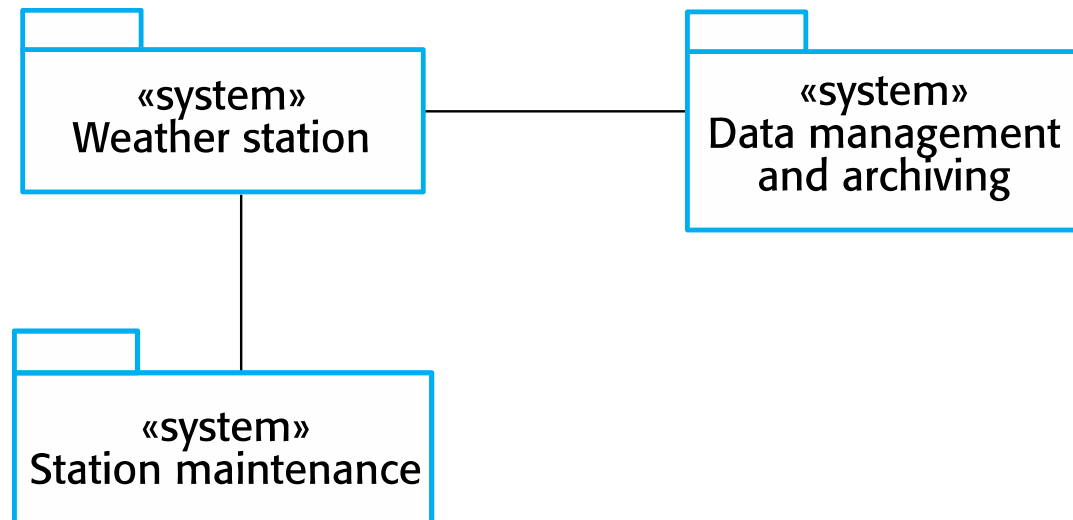
- Some mental illnesses cause patients to become suicidal or a danger to other people. Wherever possible, the system should warn medical staff about potentially suicidal or dangerous patients.
- The system must be available when needed otherwise safety may be compromised and it may be impossible to prescribe the correct medication to patients.

Wilderness weather station



- ✧ The government of a country with large areas of wilderness decides to deploy several hundred weather stations in remote areas.
- ✧ Weather stations collect data from a set of instruments that measure temperature and pressure, sunshine, rainfall, wind speed and wind direction.
 - The weather station includes a number of instruments that measure weather parameters such as the wind speed and direction, the ground and air temperatures, the barometric pressure and the rainfall over a 24-hour period. Each of these instruments is controlled by a software system that takes parameter readings periodically and manages the data collected from the instruments.

The weather station's environment



Weather information system



✧ The weather station system

- This is responsible for collecting weather data, carrying out some initial data processing and transmitting it to the data management system.

✧ The data management and archiving system

- This system collects the data from all of the wilderness weather stations, carries out data processing and analysis and archives the data.

✧ The station maintenance system

- This system can communicate by satellite with all wilderness weather stations to monitor the health of these systems and provide reports of problems.

Additional software functionality



- ✧ Monitor the instruments, power and communication hardware and report faults to the management system.
- ✧ Manage the system power, ensuring that batteries are charged whenever the environmental conditions permit but also that generators are shut down in potentially damaging weather conditions, such as high wind.
- ✧ Support dynamic reconfiguration where parts of the software are replaced with new versions and where backup instruments are switched into the system in the event of system failure.

iLearn: A digital learning environment



- ✧ A digital learning environment is a framework in which a set of general-purpose and specially designed tools for learning may be embedded plus a set of applications that are geared to the needs of the learners using the system.
- ✧ The tools included in each version of the environment are chosen by teachers and learners to suit their specific needs.
 - These can be general applications such as spreadsheets, learning management applications such as a Virtual Learning Environment (VLE) to manage homework submission and assessment, games and simulations.

Service-oriented systems



- ✧ The system is a service-oriented system with all system components considered to be a replaceable service.
- ✧ This allows the system to be updated incrementally as new services become available.
- ✧ It also makes it possible to rapidly configure the system to create versions of the environment for different groups such as very young children who cannot read, senior students, etc.



- ✧ *Utility services* that provide basic application-independent functionality and which may be used by other services in the system.
- ✧ *Application services* that provide specific applications such as email, conferencing, photo sharing etc. and access to specific educational content such as scientific films or historical resources.
- ✧ *Configuration services* that are used to adapt the environment with a specific set of application services and do define how services are shared between students, teachers and their parents.

iLearn architecture



Browser-based user interface

iLearn app

Configuration services

Group
management

Application
management

Identity
management

Application services

Email Messaging Video conferencing Newspaper archive
Word processing Simulation Video storage Resource finder
Spreadsheet Virtual learning environment History archive

Utility services

Authentication Logging and monitoring Interfacing
User storage Application storage Search

iLearn service integration



- ✧ *Integrated services* are services which offer an API (application programming interface) and which can be accessed by other services through that API. Direct service-to-service communication is therefore possible.
- ✧ *Independent services* are services which are simply accessed through a browser interface and which operate independently of other services. Information can only be shared with other services through explicit user actions such as copy and paste; re-authentication may be required for each independent service.

Key points



- ✧ Software engineering is an engineering discipline that is concerned with all aspects of software production.
- ✧ Essential software product attributes are maintainability, dependability and security, efficiency and acceptability.
- ✧ The high-level activities of specification, development, validation and evolution are part of all software processes.
- ✧ The fundamental notions of software engineering are universally applicable to all types of system development.

Key points



- ✧ There are many different types of system and each requires appropriate software engineering tools and techniques for their development.
- ✧ The fundamental ideas of software engineering are applicable to all types of software system.
- ✧ Software engineers have responsibilities to the engineering profession and society. They should not simply be concerned with technical issues.
- ✧ Professional societies publish codes of conduct which set out the standards of behaviour expected of their members.



Chapter 2 – Software Processes

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, which are the outcomes of a process activity;
 - Roles, which reflect the responsibilities of the people involved in the process;
 - Pre- and post-conditions, which are statements that are true before and after a process activity has been enacted or a product produced.

Plan-driven and agile processes



- ✧ Plan-driven processes 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.



Software process models

Software process models



✧ The waterfall model

- Plan-driven model. Separate and distinct phases of specification and development.

✧ Incremental development

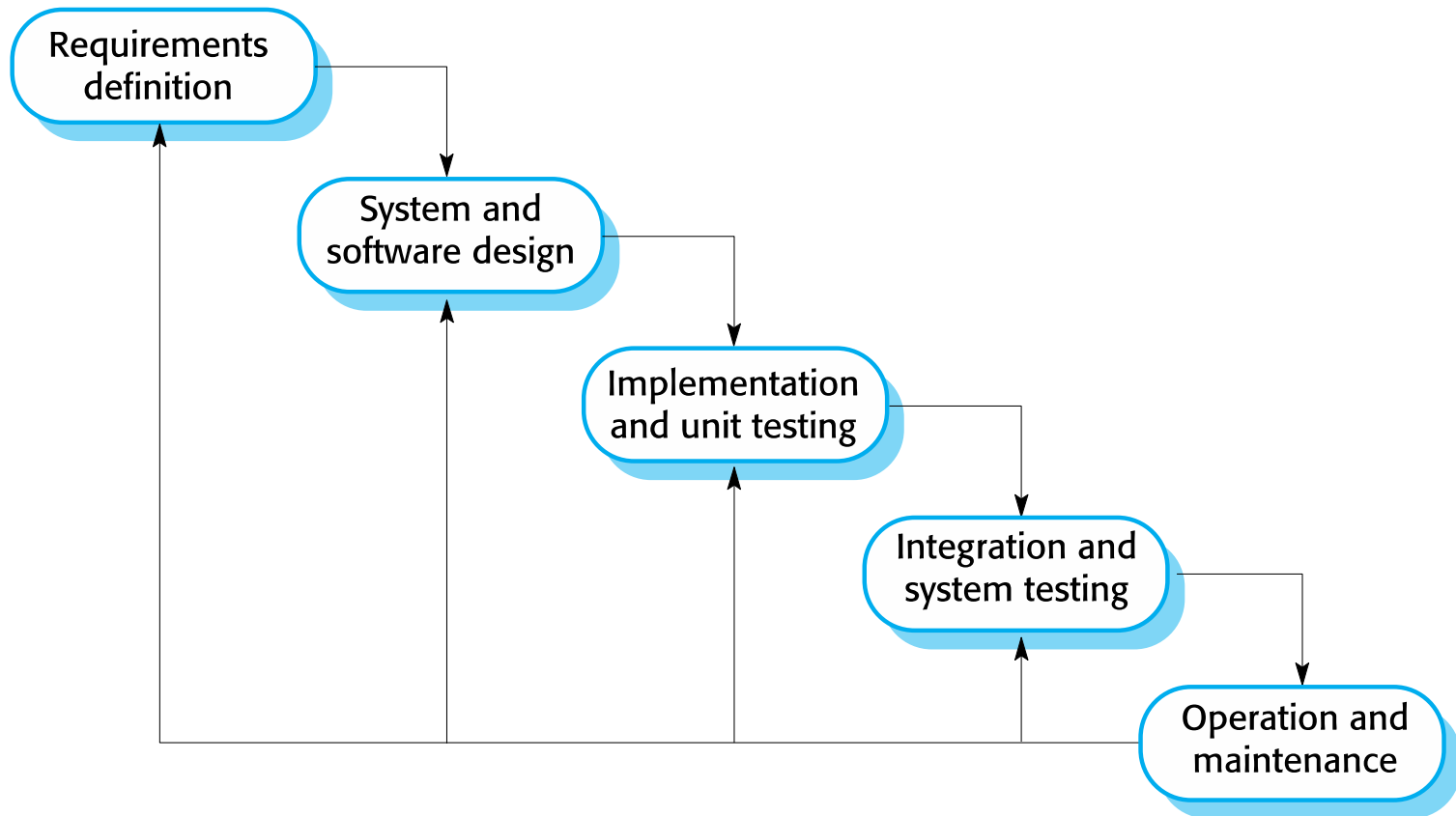
- Specification, development and validation are interleaved. May be plan-driven or agile.

✧ 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 waterfall model



Waterfall model phases



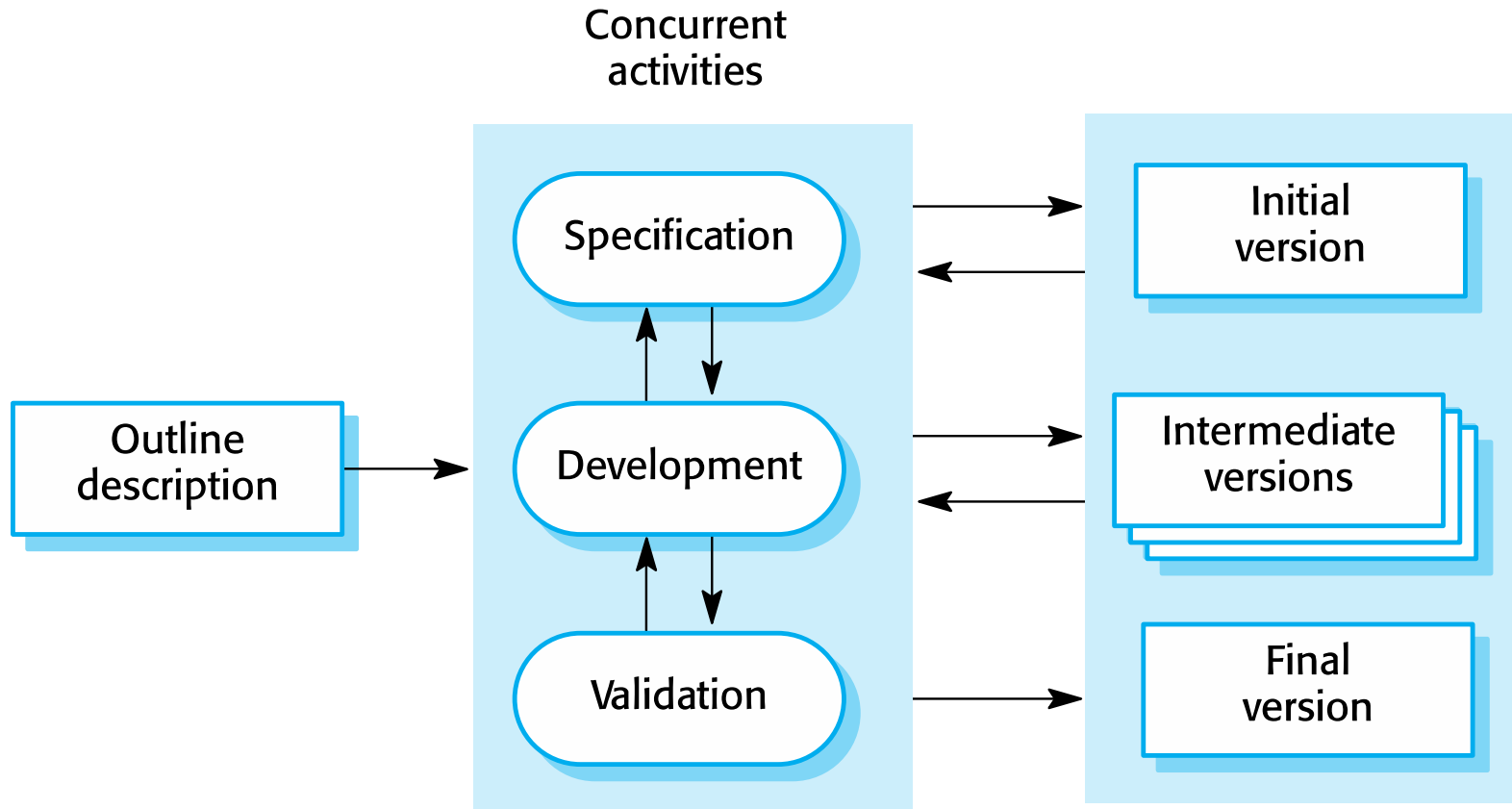
- ✧ There are separate identified phases in the waterfall model:
 - Requirements analysis and definition
 - System and software design
 - Implementation and unit testing
 - Integration and system testing
 - Operation and maintenance
- ✧ The main drawback of the waterfall model is the difficulty of accommodating change after the process is underway. In principle, a phase has to be complete before moving onto the next phase.

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.
 - In those circumstances, the plan-driven nature of the waterfall model helps coordinate the work.

Incremental development



Incremental development 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.

Incremental development 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.

Integration and configuration



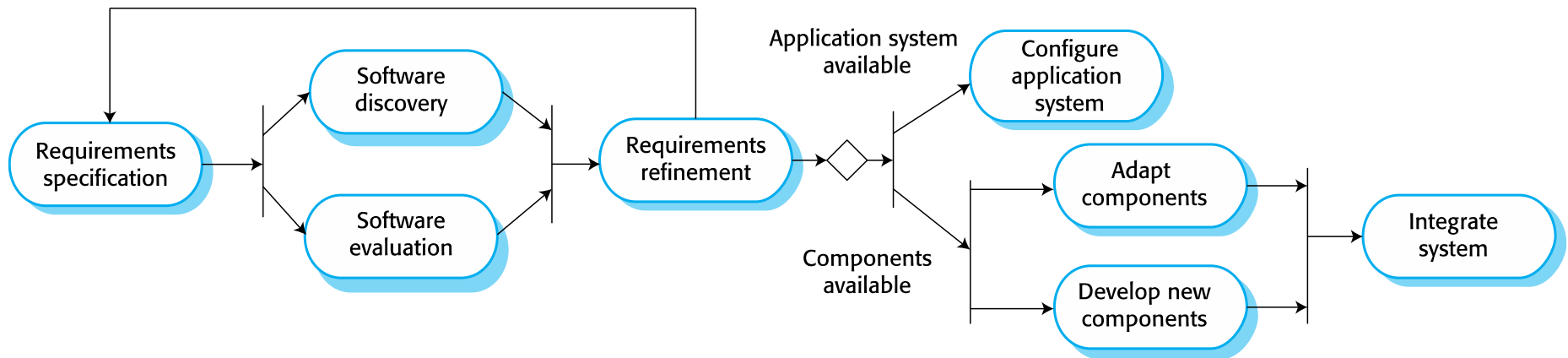
- ✧ Based on software reuse where systems are integrated from existing components or application systems (sometimes called COTS -Commercial-off-the-shelf) systems).
- ✧ Reused elements may be configured to adapt their behaviour and functionality to a user's requirements
- ✧ Reuse is now the standard approach for building many types of business system
 - Reuse covered in more depth in Chapter 15.

Types of reusable software



- ✧ Stand-alone application systems (sometimes called COTS) 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

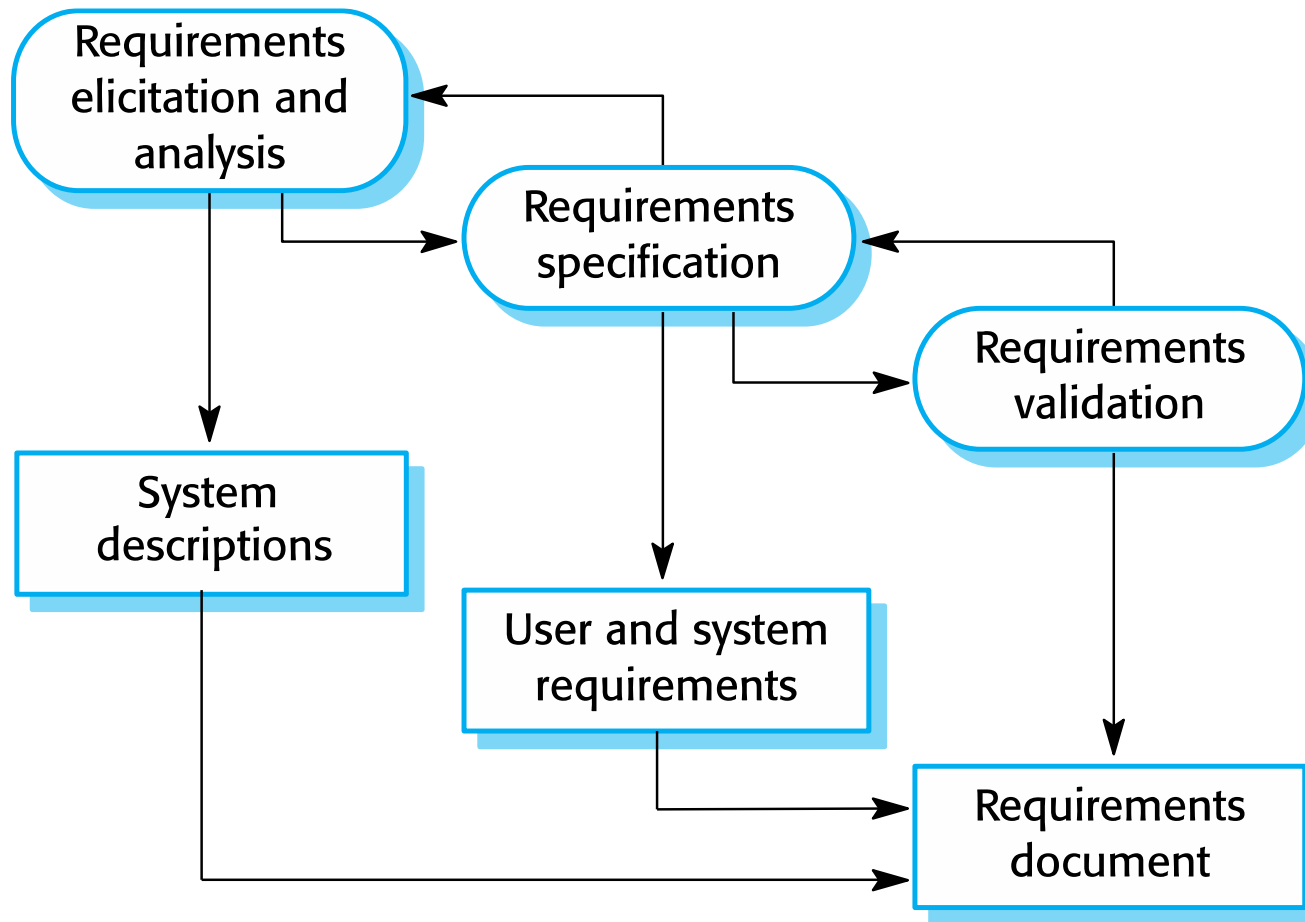
Process activities

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.

The requirements engineering process



Software specification



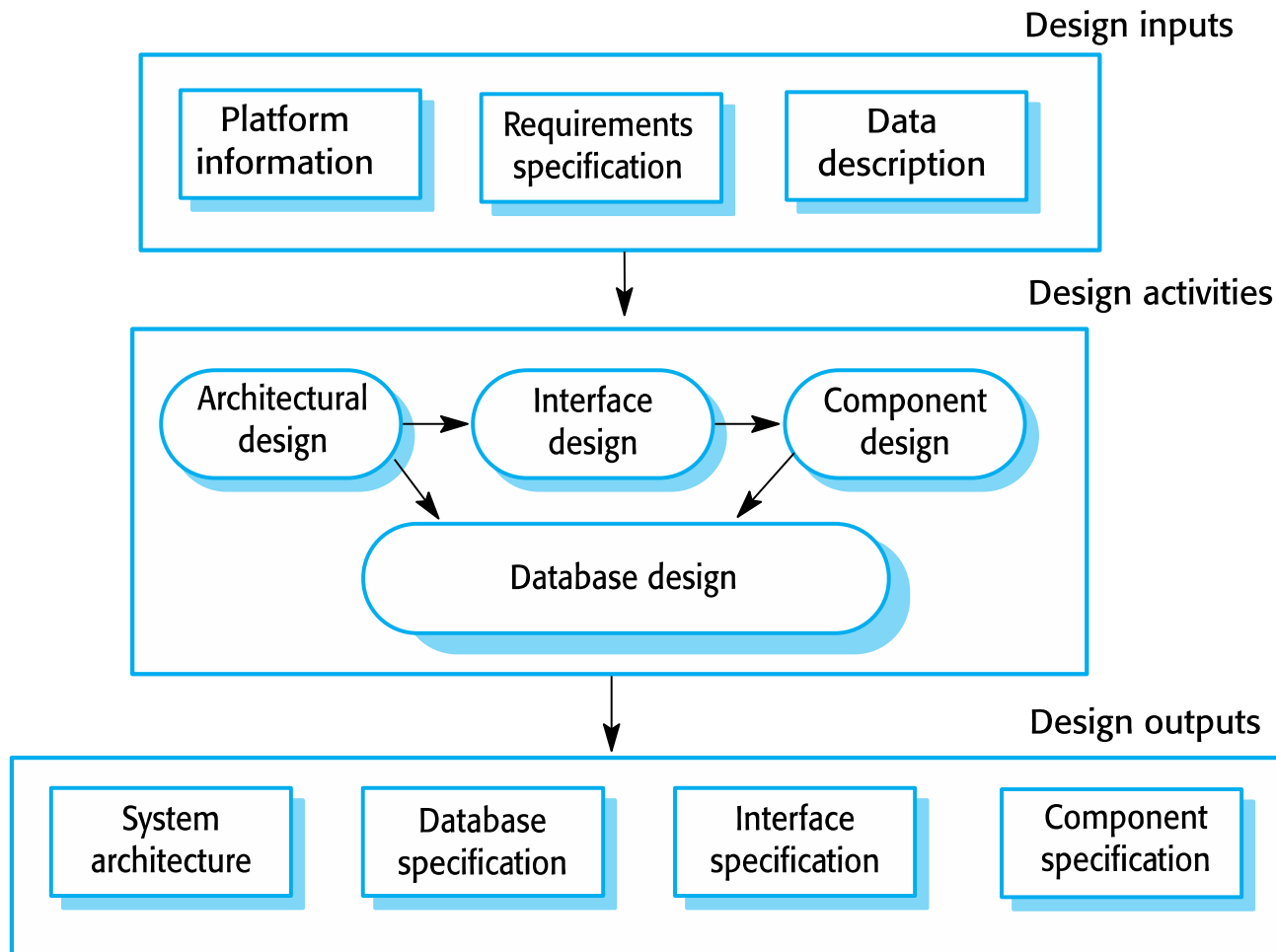
- ✧ The process of establishing what services are required and the constraints on the system's operation and development.
- ✧ Requirements engineering process
 - Requirements elicitation and analysis
 - What do the system stakeholders require or expect from the system?
 - Requirements specification
 - Defining the requirements in detail
 - Requirements validation
 - Checking the validity of the requirements

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.

A general model of the design process



Design activities



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

System implementation



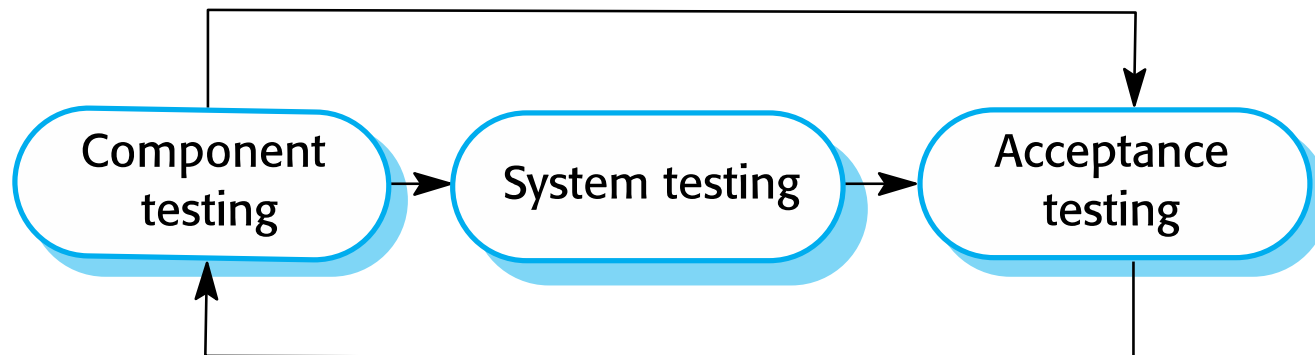
- ✧ The software is implemented either by developing a program or programs or by configuring an application system.
- ✧ Design and implementation are interleaved activities for most types of software system.
- ✧ Programming is an individual activity with no standard process.
- ✧ Debugging is the activity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



Testing stages



✧ Component testing

- Individual components are tested independently;
- Components may be functions or objects or coherent groupings of these entities.

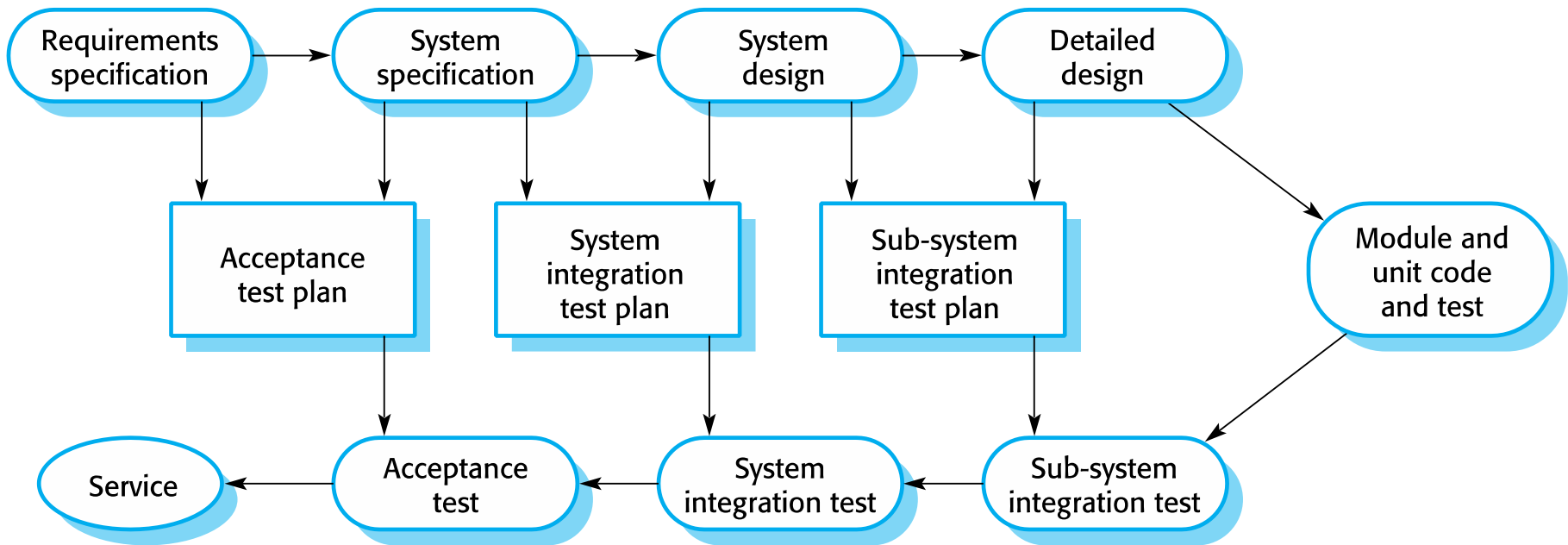
✧ System testing

- Testing of the system as a whole. Testing of emergent properties is particularly important.

✧ Customer testing

- Testing with customer data to check that the system meets the customer's needs.

Testing phases in a plan-driven software process (V-model)

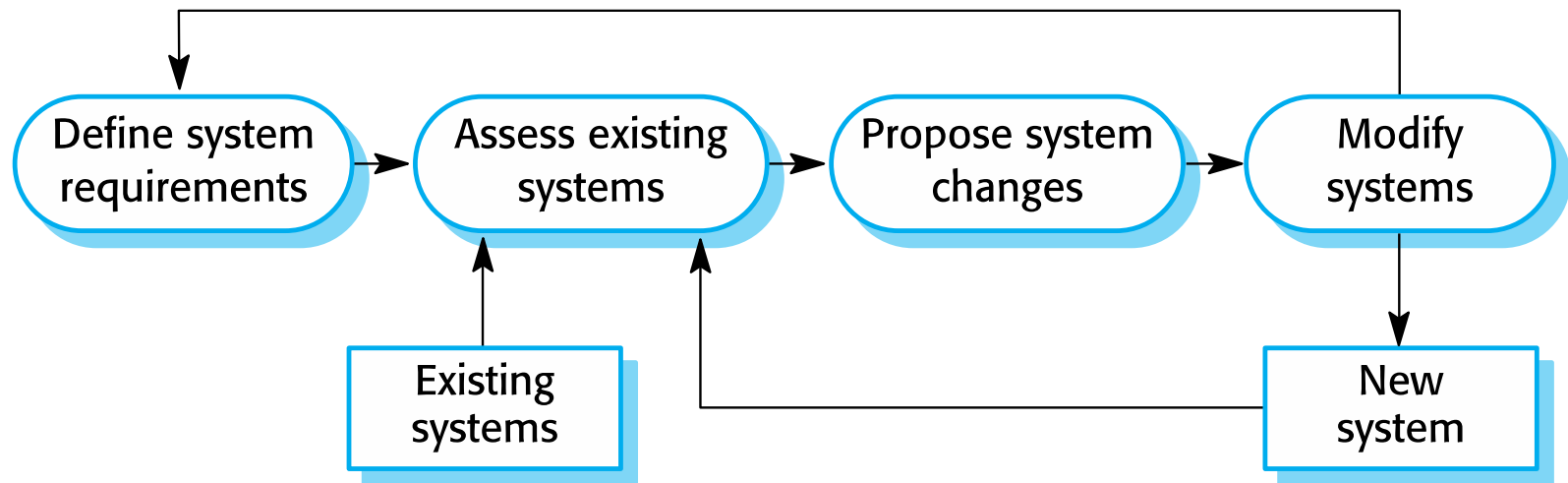


Software evolution



- ✧ 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





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

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.

Coping with changing requirements



- ✧ System prototyping, where a version of the system or part of the system is developed quickly to check the customer's requirements and the feasibility of design decisions. This approach supports change anticipation.
- ✧ Incremental delivery, where system increments are delivered to the customer for comment and experimentation. This supports both change avoidance and change tolerance.

Software prototyping



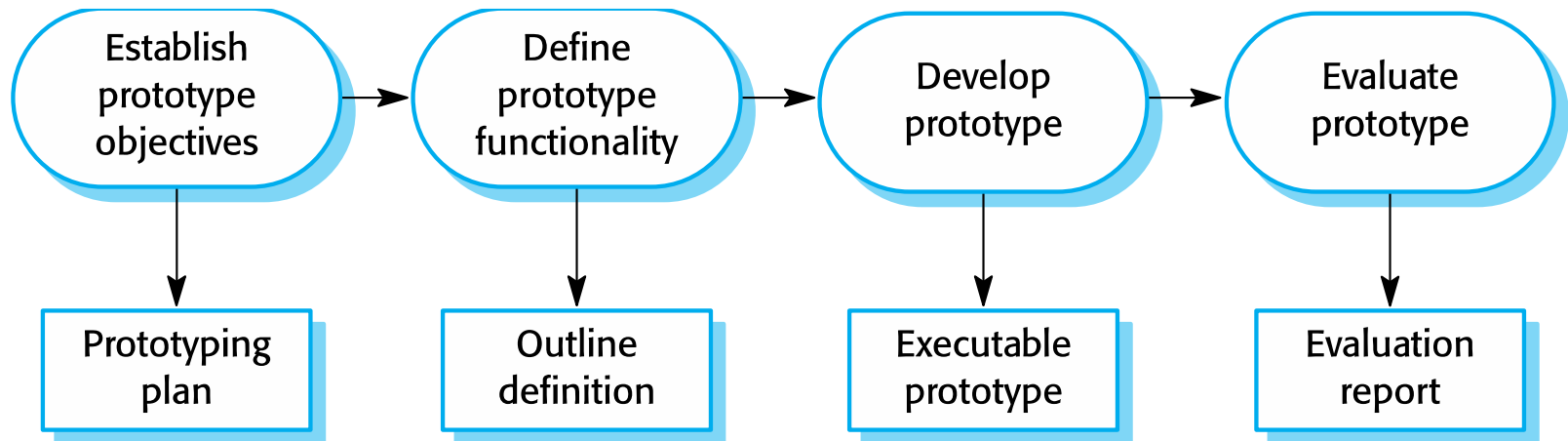
- ✧ A prototype is an initial version of a system used to demonstrate concepts and try out design options.
- ✧ A prototype can be used in:
 - The requirements engineering process to help with requirements elicitation and validation;
 - In design processes to explore options and develop a UI design;
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

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 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.

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 and delivery



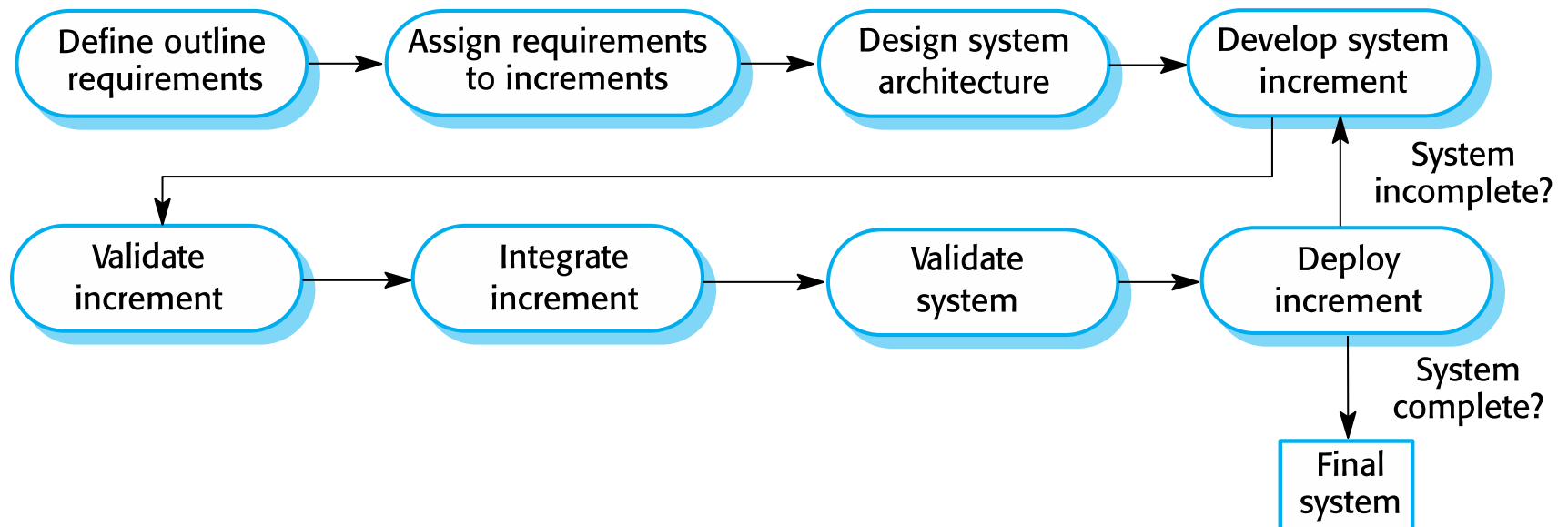
✧ Incremental development

- 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 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.
 - However, this conflicts with the procurement model of many organizations, where the complete system specification is part of the system development contract.

Process improvement

Process improvement



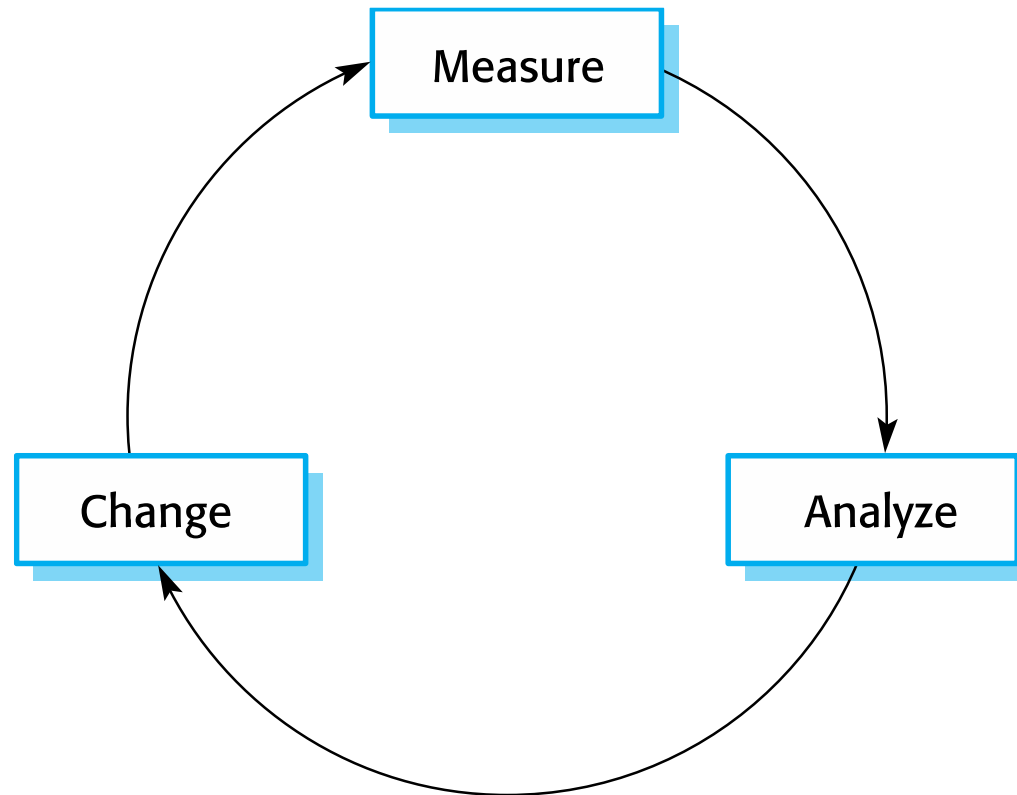
- ✧ Many software companies have turned to software process improvement as a way of enhancing the quality of their software, reducing costs or accelerating their development processes.
- ✧ Process improvement means understanding existing processes and changing these processes to increase product quality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



✧ *Process measurement*

- You measure one or more attributes of the software process or product. These measurements form a baseline that helps you 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. These are introduced and the cycle resumes to collect data about the effectiveness of the changes.

Process measurement



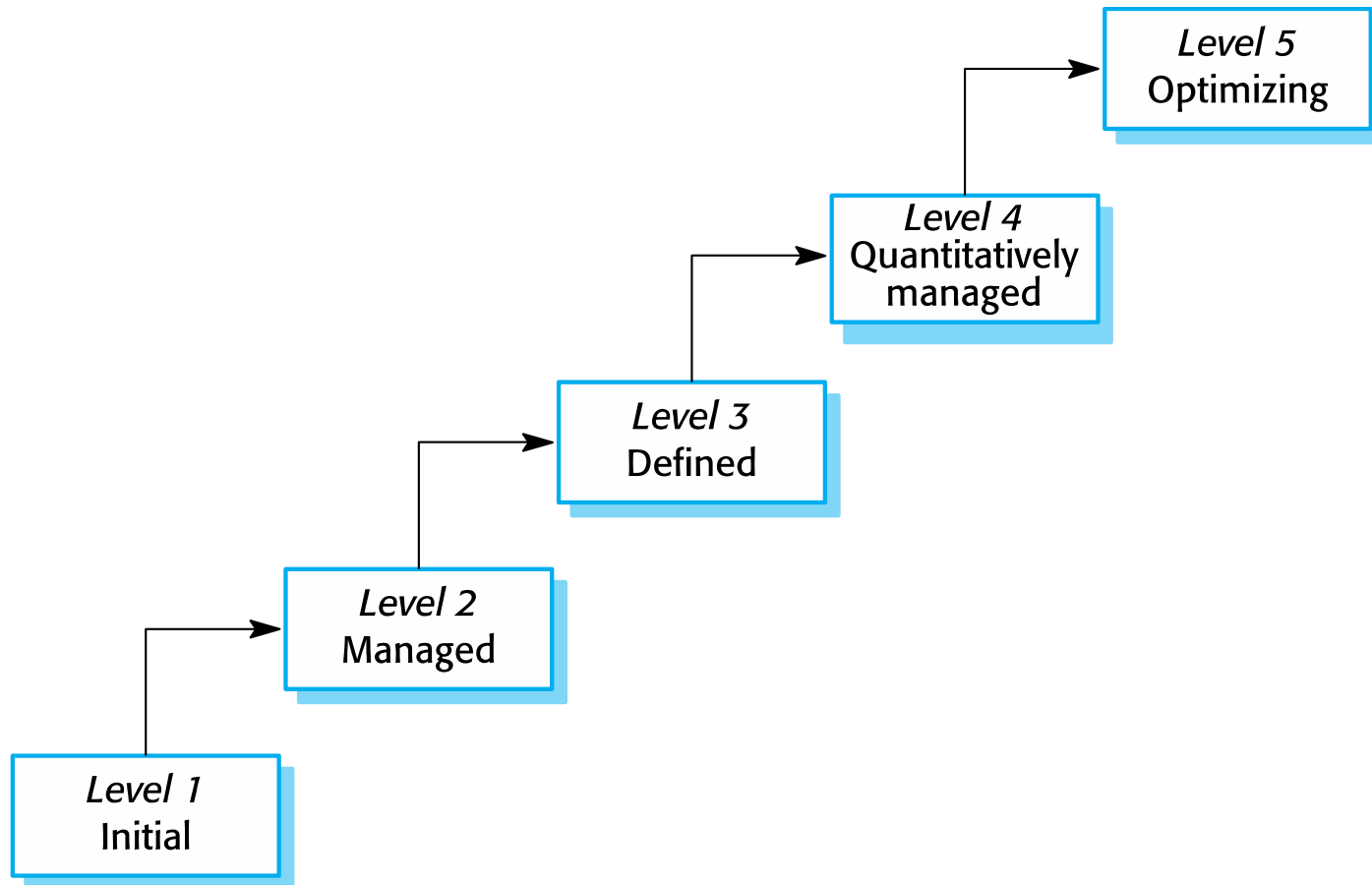
- ✧ Wherever possible, quantitative process data should be collected
 - However, where organisations do not have clearly defined process standards this is very difficult as you don't know what to measure. A process may have to be defined before any measurement is possible.
- ✧ Process measurements should 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



✧ Initial

- Essentially uncontrolled

✧ Repeatable

- Product management procedures defined and used

✧ Defined

- Process management procedures and strategies defined and used

✧ Managed

- Quality management strategies defined and used

✧ Optimising

- Process improvement strategies defined and used

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 of these general models include the 'waterfall' model, incremental development, and reuse-oriented development.
- ✧ Requirements engineering is the process of developing a software specification.

Key points



- ✧ 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.

Key points



- ✧ 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.



Chapter 3 – Agile Software Development

Topics covered



- ✧ Agile methods
- ✧ Agile development techniques
- ✧ Agile project management
- ✧ Scaling agile methods

Rapid software development



- ✧ Rapid development and delivery is now often the most important requirement for software systems
 - Businesses operate in a fast –changing requirement and it is practically impossible to produce a set of stable software requirements
 - Software has to evolve quickly to reflect changing business needs.
- ✧ Plan-driven development is essential for some types of system but does not meet these business needs.
- ✧ Agile development methods emerged in the late 1990s whose aim was to radically reduce the delivery time for working software systems

Agile development

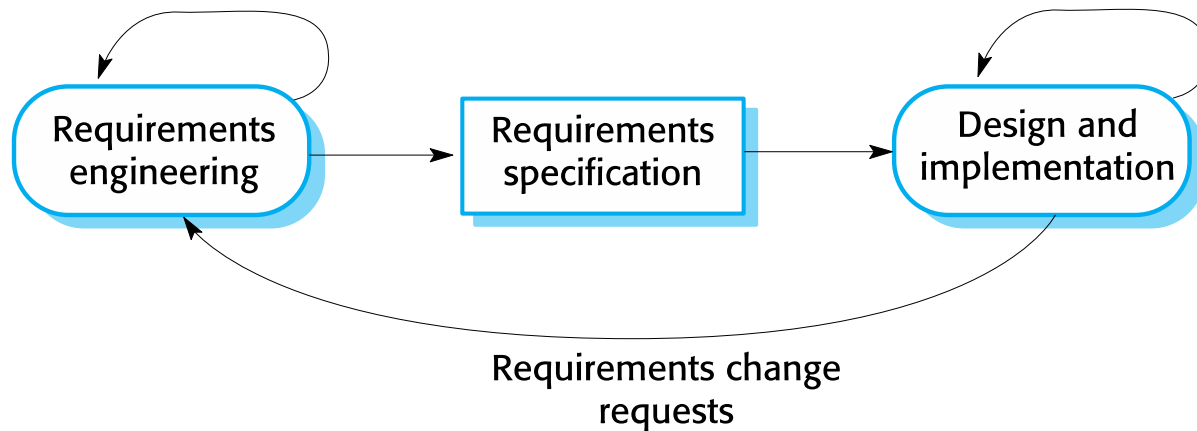


- ✧ Program specification, design and implementation are inter-leaved
- ✧ The system is developed as a series of versions or increments with stakeholders involved in version specification and evaluation
- ✧ Frequent delivery of new versions for evaluation
- ✧ Extensive tool support (e.g. automated testing tools) used to support development.
- ✧ Minimal documentation – focus on working code

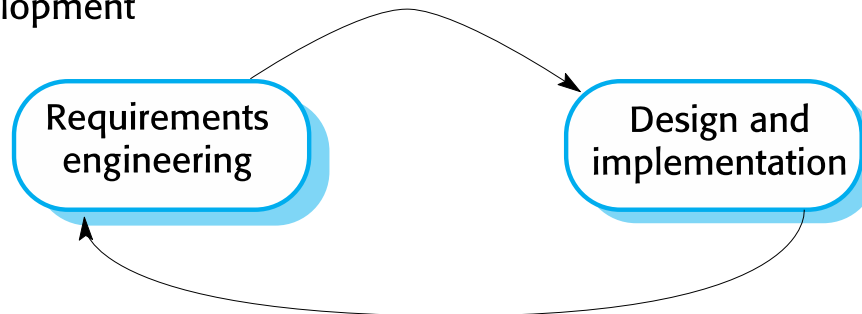
Plan-driven and agile development



Plan-based development



Agile development



Plan-driven and agile development



✧ Plan-driven development

- A plan-driven approach to software engineering is based around separate development stages with the outputs to be produced at each of these stages planned in advance.
- Not necessarily waterfall model – plan-driven, incremental development is possible
- Iteration occurs within activities.

✧ Agile development

- Specification, design, implementation and testing are interleaved and the outputs from the development process are decided through a process of negotiation during the software development process.

Agile methods

Agile methods



- ✧ Dissatisfaction with the overheads involved in software design methods of the 1980s and 1990s led to the creation of agile methods. These methods:
 - Focus on the code rather than the design
 - Are based on an iterative approach to software development
 - Are intended to deliver working software quickly and evolve this quickly to meet changing requirements.
- ✧ The aim of agile methods is to reduce overheads in the software process (e.g. by limiting documentation) and to be able to respond quickly to changing requirements without excessive rework.

Agile manifesto



- ✧ *We are uncovering better ways of developing ^[L]_{SEP} software by doing it and helping others do it. ^[L]_{SEP} Through this work we have come to value:*
 - *Individuals and interactions over processes and tools*
Working software over comprehensive documentation
Customer collaboration over contract negotiation
Responding to change over following a plan
- ✧ *That is, while there is value in the items on ^[L]_{SEP} the right, we value the items on the left more.*

The principles of agile methods



Principle	Description
Customer involvement	Customers should be closely involved throughout the development process. Their role is provide and prioritize new system requirements and to evaluate the iterations of the system.
Incremental delivery	The software is developed in increments with the customer specifying the requirements to be included in each increment.
People not process	The skills of the development team should be recognized and exploited. Team members should be left to develop their own ways of working without prescriptive processes.
Embrace change	Expect the system requirements to change and so design the system to accommodate these changes.
Maintain simplicity	Focus on simplicity in both the software being developed and in the development process. Wherever possible, actively work to eliminate complexity from the system.

Agile method applicability



- ✧ Product development where a software company is developing a small or medium-sized product for sale.
 - Virtually all software products and apps are now developed using an agile approach
- ✧ Custom system development within an organization, where there is a clear commitment from the customer to become involved in the development process and where there are few external rules and regulations that affect the software.



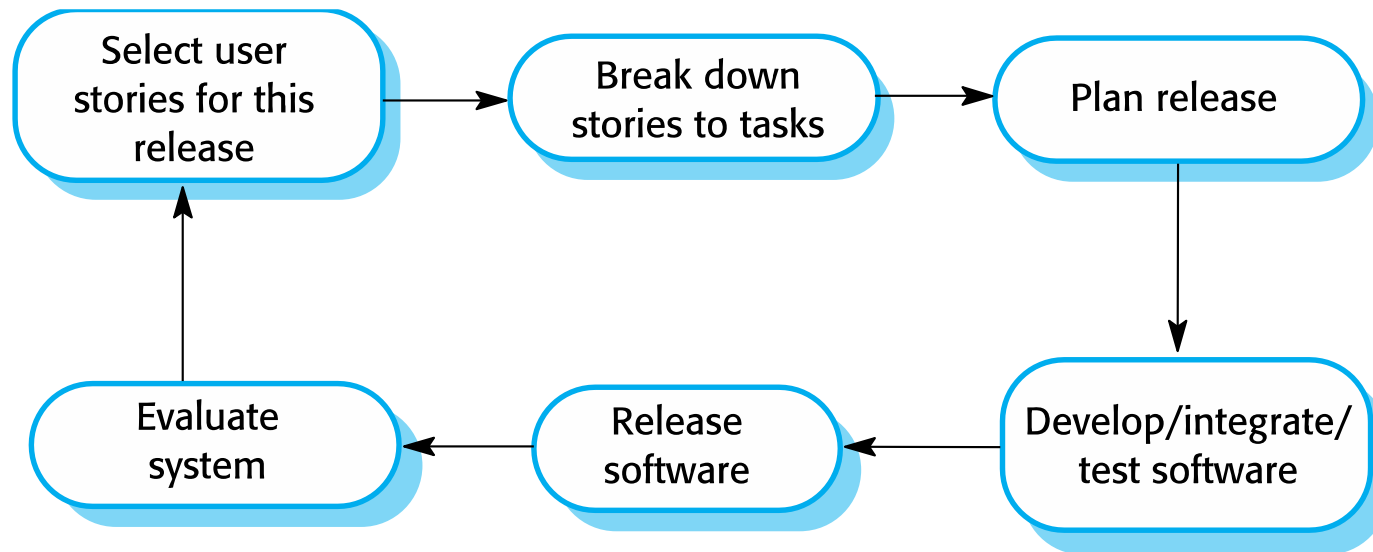
Agile development techniques

Extreme programming



- ✧ A very influential agile method, developed in the late 1990s, that introduced a range of agile development techniques.
- ✧ Extreme Programming (XP) takes an 'extreme' approach to iterative development.
 - New versions may be built several times per day;
 - Increments are delivered to customers every 2 weeks;
 - All tests must be run for every build and the build is only accepted if tests run successfully.

The extreme programming release cycle



Extreme programming practices (a)



Principle or practice	Description
Incremental planning	Requirements are recorded on story cards and the stories to be included in a release are determined by the time available and their relative priority. The developers break these stories into development 'Tasks'. See Figures 3.5 and 3.6.
Small releases	The minimal useful set of functionality that provides business value is developed first. Releases of the system are frequent and incrementally add functionality to the first release.
Simple design	Enough design is carried out to meet the current requirements and no more.
Test-first development	An automated unit test framework is used to write tests for a new piece of functionality before that functionality itself is implemented.
Refactoring	All developers are expected to refactor the code continuously as soon as possible code improvements are found. This keeps the code simple and maintainable.

Extreme programming practices (b)



Pair programming	Developers work in pairs, checking each other's work and providing the support to always do a good job.
Collective ownership	The pairs of developers work on all areas of the system, so that no islands of expertise develop and all the developers take responsibility for all of the code. Anyone can change anything.
Continuous integration	As soon as the work on a task is complete, it is integrated into the whole system. After any such integration, all the unit tests in the system must pass.
Sustainable pace	Large amounts of overtime are not considered acceptable as the net effect is often to reduce code quality and medium term productivity
On-site customer	A representative of the end-user of the system (the customer) should be available full time for the use of the XP team. In an extreme programming process, the customer is a member of the development team and is responsible for bringing system requirements to the team for implementation.

XP and agile principles



- ✧ Incremental development is supported through small, frequent system releases.
- ✧ Customer involvement means full-time customer engagement with the team.
- ✧ People not process through pair programming, collective ownership and a process that avoids long working hours.
- ✧ Change supported through regular system releases.
- ✧ Maintaining simplicity through constant refactoring of code.

Influential XP practices



- ✧ Extreme programming has a technical focus and is not easy to integrate with management practice in most organizations.
- ✧ Consequently, while agile development uses practices from XP, the method as originally defined is not widely used.
- ✧ Key practices
 - User stories for specification
 - Refactoring
 - Test-first development
 - Pair programming

User stories for requirements



- ✧ In XP, a customer or user is part of the XP team and is responsible for making decisions on requirements.
- ✧ User requirements are expressed as user stories or scenarios.
- ✧ These are written on cards and the development team break them down into implementation tasks. These tasks are the basis of schedule and cost estimates.
- ✧ The customer chooses the stories for inclusion in the next release based on their priorities and the schedule estimates.

A 'prescribing medication' story



Prescribing medication

The record of the patient must be open for input. Click on the medication field and select either 'current medication', 'new medication' or 'formulary'.

If you select 'current medication', you will be asked to check the dose; If you wish to change the dose, enter the new dose then confirm the prescription.

If you choose, 'new medication', the system assumes that you know which medication you wish to prescribe. Type the first few letters of the drug name. You will then see a list of possible drugs starting with these letters. Choose the required medication. You will then be asked to check that the medication you have selected is correct. Enter the dose then confirm the prescription.

If you choose 'formulary', you will be presented with a search box for the approved formulary. Search for the drug required then select it. You will then be asked to check that the medication you have selected is correct. Enter the dose then confirm the prescription.

In all cases, the system will check that the dose is within the approved range and will ask you to change it if it is outside the range of recommended doses.

After you have confirmed the prescription, it will be displayed for checking. Either click 'OK' or 'Change'. If you click 'OK', your prescription will be recorded on the audit database. If you click 'Change', you reenter the 'Prescribing medication' process.

Examples of task cards for prescribing medication



Task 1: Change dose of prescribed drug

Task 2: Formulary selection

Task 3: Dose checking

Dose checking is a safety precaution to check that the doctor has not prescribed a dangerously small or large dose.

Using the formulary id for the generic drug name, lookup the formulary and retrieve the recommended maximum and minimum dose.

Check the prescribed dose against the minimum and maximum. If outside the range, issue an error message saying that the dose is too high or too low. If within the range, enable the 'Confirm' button.

Refactoring



- ✧ Conventional wisdom in software engineering is to design for change. It is worth spending time and effort anticipating changes as this reduces costs later in the life cycle.
- ✧ XP, however, maintains that this is not worthwhile as changes cannot be reliably anticipated.
- ✧ Rather, it proposes constant code improvement (refactoring) to make changes easier when they have to be implemented.

Refactoring



- ✧ Programming team look for possible software improvements and make these improvements even where there is no immediate need for them.
- ✧ This improves the understandability of the software and so reduces the need for documentation.
- ✧ Changes are easier to make because the code is well-structured and clear.
- ✧ However, some changes requires architecture refactoring and this is much more expensive.

Examples of refactoring



- ✧ Re-organization of a class hierarchy to remove duplicate code.
- ✧ Tidying up and renaming attributes and methods to make them easier to understand.
- ✧ The replacement of inline code with calls to methods that have been included in a program library.

Test-first development



- ✧ Testing is central to XP and XP has developed an approach where the program is tested after every change has been made.
- ✧ XP testing features:
 - Test-first development.
 - Incremental test development from scenarios.
 - User involvement in test development and validation.
 - Automated test harnesses are used to run all component tests each time that a new release is built.

Test-driven development



- ✧ Writing tests before code clarifies the requirements to be implemented.
- ✧ Tests are written as programs rather than data so that they can be executed automatically. The test includes a check that it has executed correctly.
 - Usually relies on a testing framework such as Junit.
- ✧ All previous and new tests are run automatically when new functionality is added, thus checking that the new functionality has not introduced errors.

Customer involvement



- ✧ The role of the customer in the testing process is to help develop acceptance tests for the stories that are to be implemented in the next release of the system.
- ✧ The customer who is part of the team writes tests as development proceeds. All new code is therefore validated to ensure that it is what the customer needs.
- ✧ However, people adopting the customer role have limited time available and so cannot work full-time with the development team. They may feel that providing the requirements was enough of a contribution and so may be reluctant to get involved in the testing process.

Test case description for dose checking



Test 4: Dose checking

Input:

1. A number in mg representing a single dose of the drug.
2. A number representing the number of single doses per day.

Tests:

1. Test for inputs where the single dose is correct but the frequency is too high.
2. Test for inputs where the single dose is too high and too low.
3. Test for inputs where the single dose * frequency is too high and too low.
4. Test for inputs where single dose * frequency is in the permitted range.

Output:

OK or error message indicating that the dose is outside the safe range.

Test automation



- ✧ Test automation means that tests are written as executable components before the task is implemented
 - These testing components should be stand-alone, should simulate the submission of input to be tested and should check that the result meets the output specification. An automated test framework (e.g. Junit) is a system that makes it easy to write executable tests and submit a set of tests for execution.
- ✧ As testing is automated, there is always a set of tests that can be quickly and easily executed
 - Whenever any functionality is added to the system, the tests can be run and problems that the new code has introduced can be caught immediately.

Problems with test-first development



- ✧ Programmers prefer programming to testing and sometimes they take short cuts when writing tests. For example, they may write incomplete tests that do not check for all possible exceptions that may occur.
- ✧ Some tests can be very difficult to write incrementally. For example, in a complex user interface, it is often difficult to write unit tests for the code that implements the 'display logic' and workflow between screens.
- ✧ It difficult to judge the completeness of a set of tests. Although you may have a lot of system tests, your test set may not provide complete coverage.

Pair programming



- ✧ Pair programming involves programmers working in pairs, developing code together.
- ✧ This helps develop common ownership of code and spreads knowledge across the team.
- ✧ It serves as an informal review process as each line of code is looked at by more than 1 person.
- ✧ It encourages refactoring as the whole team can benefit from improving the system code.

Pair programming



- ✧ In pair programming, programmers sit together at the same computer to develop the software.
- ✧ Pairs are created dynamically so that all team members work with each other during the development process.
- ✧ The sharing of knowledge that happens during pair programming is very important as it reduces the overall risks to a project when team members leave.
- ✧ Pair programming is not necessarily inefficient and there is some evidence that suggests that a pair working together is more efficient than 2 programmers working separately.



Agile project management

Agile project management



- ✧ The principal responsibility of software project managers is to manage the project so that the software is delivered on time and within the planned budget for the project.
- ✧ The standard approach to project management is plan-driven. Managers draw up a plan for the project showing what should be delivered, when it should be delivered and who will work on the development of the project deliverables.
- ✧ Agile project management requires a different approach, which is adapted to incremental development and the practices used in agile methods.

Scrum



- ✧ Scrum is an agile method that focuses on managing iterative development rather than specific agile practices.
- ✧ There are three phases in Scrum.
 - The initial phase is an outline planning phase where you establish the general objectives for the project and design the software architecture.
 - This is followed by a series of sprint cycles, where each cycle develops an increment of the system.
 - The project closure phase wraps up the project, completes required documentation such as system help frames and user manuals and assesses the lessons learned from the project.



Scrum terminology (a)



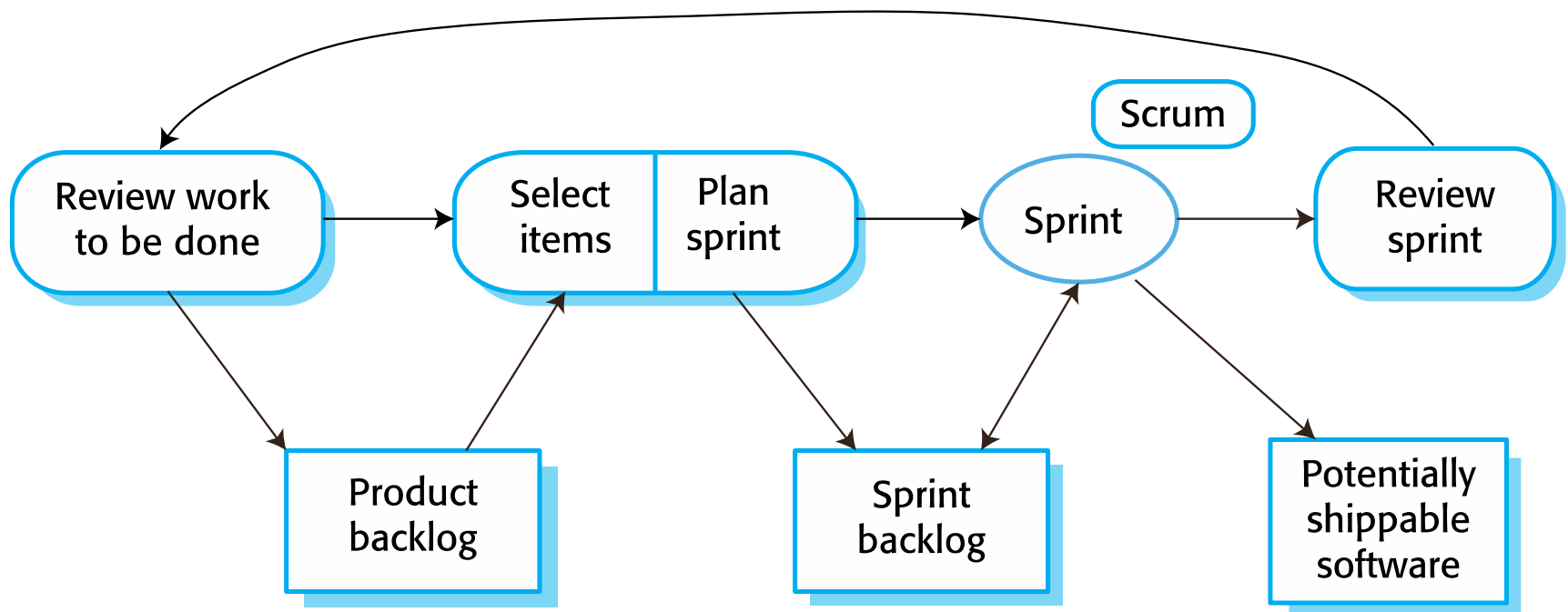
Scrum term	Definition
Development team	A self-organizing group of software developers, which should be no more than 7 people. They are responsible for developing the software and other essential project documents.
Potentially shippable product increment	The software increment that is delivered from a sprint. The idea is that this should be 'potentially shippable' which means that it is in a finished state and no further work, such as testing, is needed to incorporate it into the final product. In practice, this is not always achievable.
Product backlog	This is a list of 'to do' items which the Scrum team must tackle. They may be feature definitions for the software, software requirements, user stories or descriptions of supplementary tasks that are needed, such as architecture definition or user documentation.
Product owner	An individual (or possibly a small group) whose job is to identify product features or requirements, prioritize these for development and continuously review the product backlog to ensure that the project continues to meet critical business needs. The Product Owner can be a customer but might also be a product manager in a software company or other stakeholder representative.

Scrum terminology (b)



Scrum term	Definition
Scrum	A daily meeting of the Scrum team that reviews progress and prioritizes work to be done that day. Ideally, this should be a short face-to-face meeting that includes the whole team.
ScrumMaster	The ScrumMaster is responsible for ensuring that the Scrum process is followed and guides the team in the effective use of Scrum. He or she is responsible for interfacing with the rest of the company and for ensuring that the Scrum team is not diverted by outside interference. The Scrum developers are adamant that the ScrumMaster should not be thought of as a project manager. Others, however, may not always find it easy to see the difference.
Sprint	A development iteration. Sprints are usually 2-4 weeks long.
Velocity	An estimate of how much product backlog effort that a team can cover in a single sprint. Understanding a team's velocity helps them estimate what can be covered in a sprint and provides a basis for measuring improving performance.

Scrum sprint cycle



The Scrum sprint cycle



- ✧ Sprints are fixed length, normally 2–4 weeks.
- ✧ The starting point for planning is the product backlog, which is the list of work to be done on the project.
- ✧ The selection phase involves all of the project team who work with the customer to select the features and functionality from the product backlog to be developed during the sprint.

The Sprint cycle



- ✧ Once these are agreed, the team organize themselves to develop the software.
- ✧ During this stage the team is isolated from the customer and the organization, with all communications channelled through the so-called 'Scrum master'.
- ✧ The role of the Scrum master is to protect the development team from external distractions.
- ✧ At the end of the sprint, the work done is reviewed and presented to stakeholders. The next sprint cycle then begins.

Teamwork in Scrum



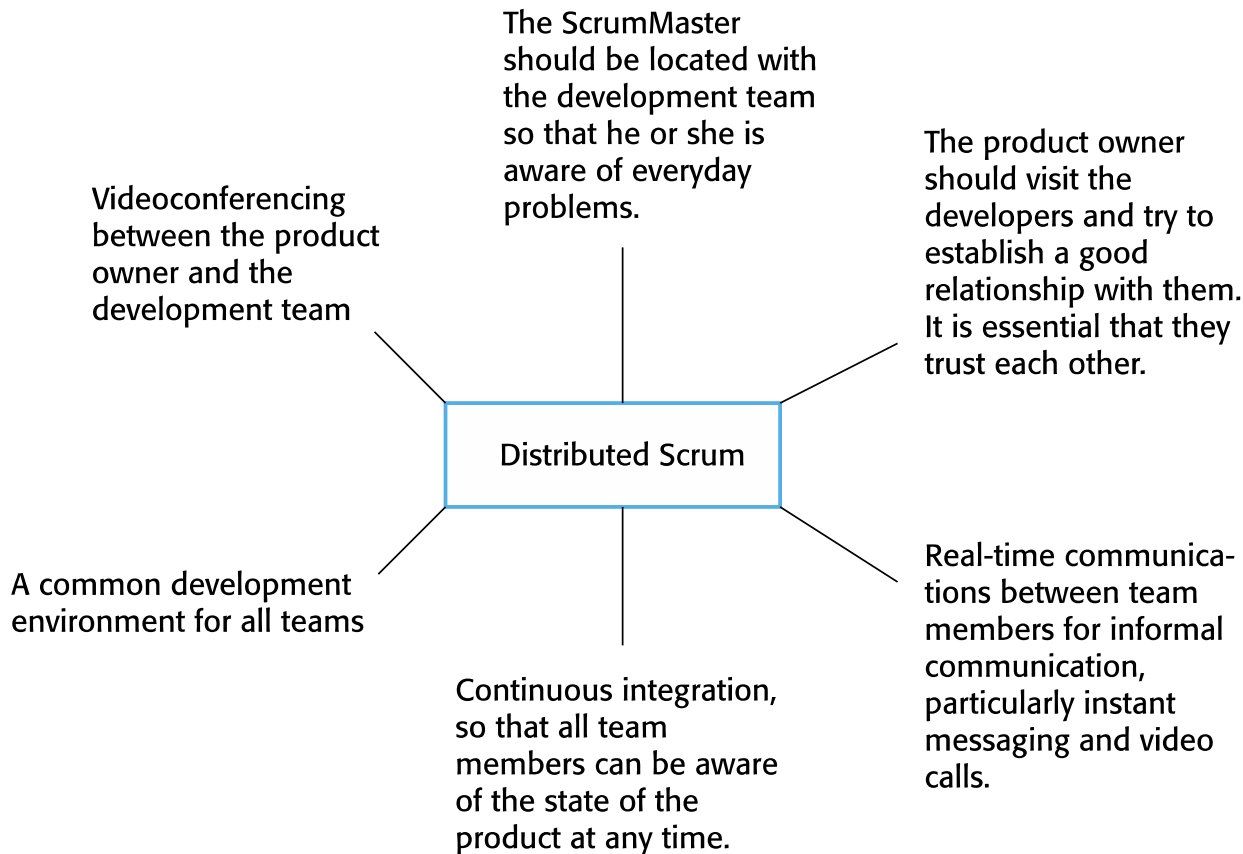
- ✧ The 'Scrum master' is a facilitator who arranges daily meetings, tracks the backlog of work to be done, records decisions, measures progress against the backlog and communicates with customers and management outside of the team.
- ✧ The whole team attends short daily meetings (Scrums) where all team members share information, describe their progress since the last meeting, problems that have arisen and what is planned for the following day.
 - This means that everyone on the team knows what is going on and, if problems arise, can re-plan short-term work to cope with them.

Scrum benefits



- ✧ The product is broken down into a set of manageable and understandable chunks.
- ✧ Unstable requirements do not hold up progress.
- ✧ The whole team have visibility of everything and consequently team communication is improved.
- ✧ Customers see on-time delivery of increments and gain feedback on how the product works.
- ✧ Trust between customers and developers is established and a positive culture is created in which everyone expects the project to succeed.

Distributed Scrum





Scaling agile methods

Scaling agile methods



- ✧ Agile methods have proved to be successful for small and medium sized projects that can be developed by a small co-located team.
- ✧ It is sometimes argued that the success of these methods comes because of improved communications which is possible when everyone is working together.
- ✧ Scaling up agile methods involves changing these to cope with larger, longer projects where there are multiple development teams, perhaps working in different locations.

Scaling out and scaling up



- ✧ 'Scaling up' is concerned with using agile methods for developing large software systems that cannot be developed by a small team.
- ✧ 'Scaling out' is concerned with how agile methods can be introduced across a large organization with many years of software development experience.
- ✧ When scaling agile methods it is important to maintain agile fundamentals:
 - Flexible planning, frequent system releases, continuous integration, test-driven development and good team communications.

Practical problems with agile methods



- ✧ The informality of agile development is incompatible with the legal approach to contract definition that is commonly used in large companies.
- ✧ Agile methods are most appropriate for new software development rather than software maintenance. Yet the majority of software costs in large companies come from maintaining their existing software systems.
- ✧ Agile methods are designed for small co-located teams yet much software development now involves worldwide distributed teams.

Contractual issues



- ✧ Most software contracts for custom systems are based around a specification, which sets out what has to be implemented by the system developer for the system customer.
- ✧ However, this precludes interleaving specification and development as is the norm in agile development.
- ✧ A contract that pays for developer time rather than functionality is required.
 - However, this is seen as a high risk by many legal departments because what has to be delivered cannot be guaranteed.

Agile methods and software maintenance



- ✧ Most organizations spend more on maintaining existing software than they do on new software development. So, if agile methods are to be successful, they have to support maintenance as well as original development.
- ✧ Two key issues:
 - Are systems that are developed using an agile approach maintainable, given the emphasis in the development process of minimizing formal documentation?
 - Can agile methods be used effectively for evolving a system in response to customer change requests?
- ✧ Problems may arise if original development team cannot be maintained.

Agile maintenance



✧ Key problems are:

- Lack of product documentation
- Keeping customers involved in the development process
- Maintaining the continuity of the development team

✧ Agile development relies on the development team knowing and understanding what has to be done.

✧ For long-lifetime systems, this is a real problem as the original developers will not always work on the system.

Agile and plan-driven methods



- ✧ Most projects include elements of plan-driven and agile processes. Deciding on the balance depends on:
- Is it important to have a very detailed specification and design before moving to implementation? If so, you probably need to use a plan-driven approach.
 - Is an incremental delivery strategy, where you deliver the software to customers and get rapid feedback from them, realistic? If so, consider using agile methods.
 - How large is the system that is being developed? Agile methods are most effective when the system can be developed with a small co-located team who can communicate informally. This may not be possible for large systems that require larger development teams so a plan-driven approach may have to be used.

Agile principles and organizational practice



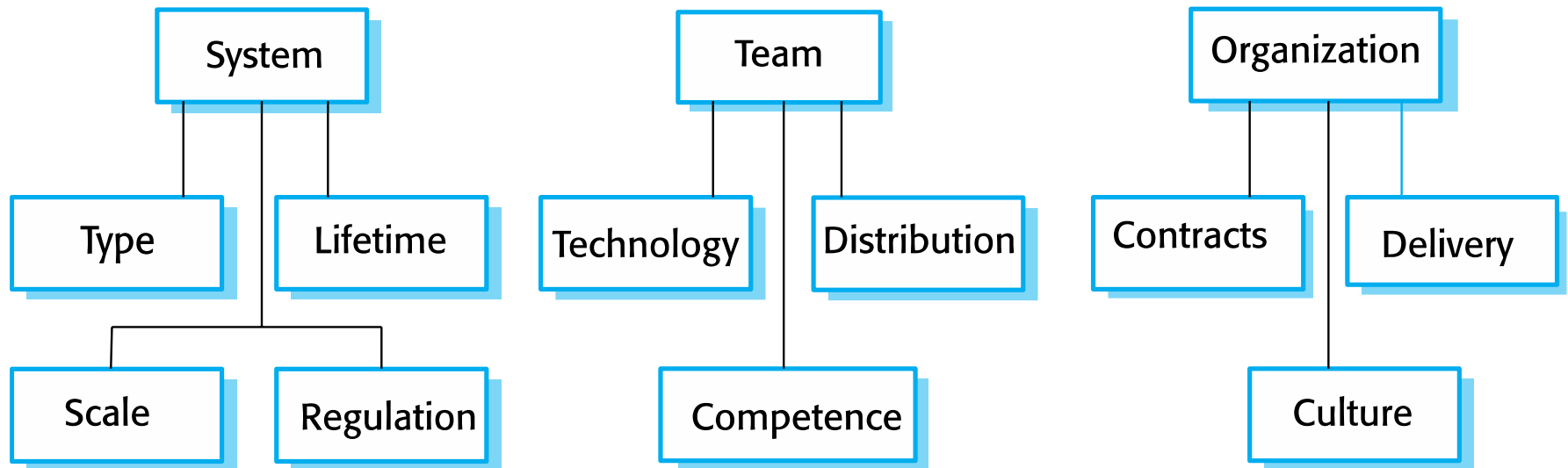
Principle	Practice
Customer involvement	<p>This depends on having a customer who is willing and able to spend time with the development team and who can represent all system stakeholders. Often, customer representatives have other demands on their time and cannot play a full part in the software development.</p> <p>Where there are external stakeholders, such as regulators, it is difficult to represent their views to the agile team.</p>
Embrace change	<p>Prioritizing changes can be extremely difficult, especially in systems for which there are many stakeholders. Typically, each stakeholder gives different priorities to different changes.</p>
Incremental delivery	<p>Rapid iterations and short-term planning for development does not always fit in with the longer-term planning cycles of business planning and marketing. Marketing managers may need to know what product features several months in advance to prepare an effective marketing campaign.</p>

Agile principles and organizational practice



Principle	Practice
Maintain simplicity	Under pressure from delivery schedules, team members may not have time to carry out desirable system simplifications.
People not process	Individual team members may not have suitable personalities for the intense involvement that is typical of agile methods, and therefore may not interact well with other team members.

Agile and plan-based factors



System issues



- ✧ How large is the system being developed?
 - Agile methods are most effective a relatively small co-located team who can communicate informally.
- ✧ What type of system is being developed?
 - Systems that require a lot of analysis before implementation need a fairly detailed design to carry out this analysis.
- ✧ What is the expected system lifetime?
 - Long-lifetime systems require documentation to communicate the intentions of the system developers to the support team.
- ✧ Is the system subject to external regulation?
 - If a system is regulated you will probably be required to produce detailed documentation as part of the system safety case.

People and teams



- ✧ How good are the designers and programmers in the development team?
 - It is sometimes argued that agile methods require higher skill levels than plan-based approaches in which programmers simply translate a detailed design into code.
- ✧ How is the development team organized?
 - Design documents may be required if the team is distributed.
- ✧ What support technologies are available?
 - IDE support for visualisation and program analysis is essential if design documentation is not available.

Organizational issues



- ✧ Traditional engineering organizations have a culture of plan-based development, as this is the norm in engineering.
- ✧ Is it standard organizational practice to develop a detailed system specification?
- ✧ Will customer representatives be available to provide feedback of system increments?
- ✧ Can informal agile development fit into the organizational culture of detailed documentation?

Agile methods for large systems



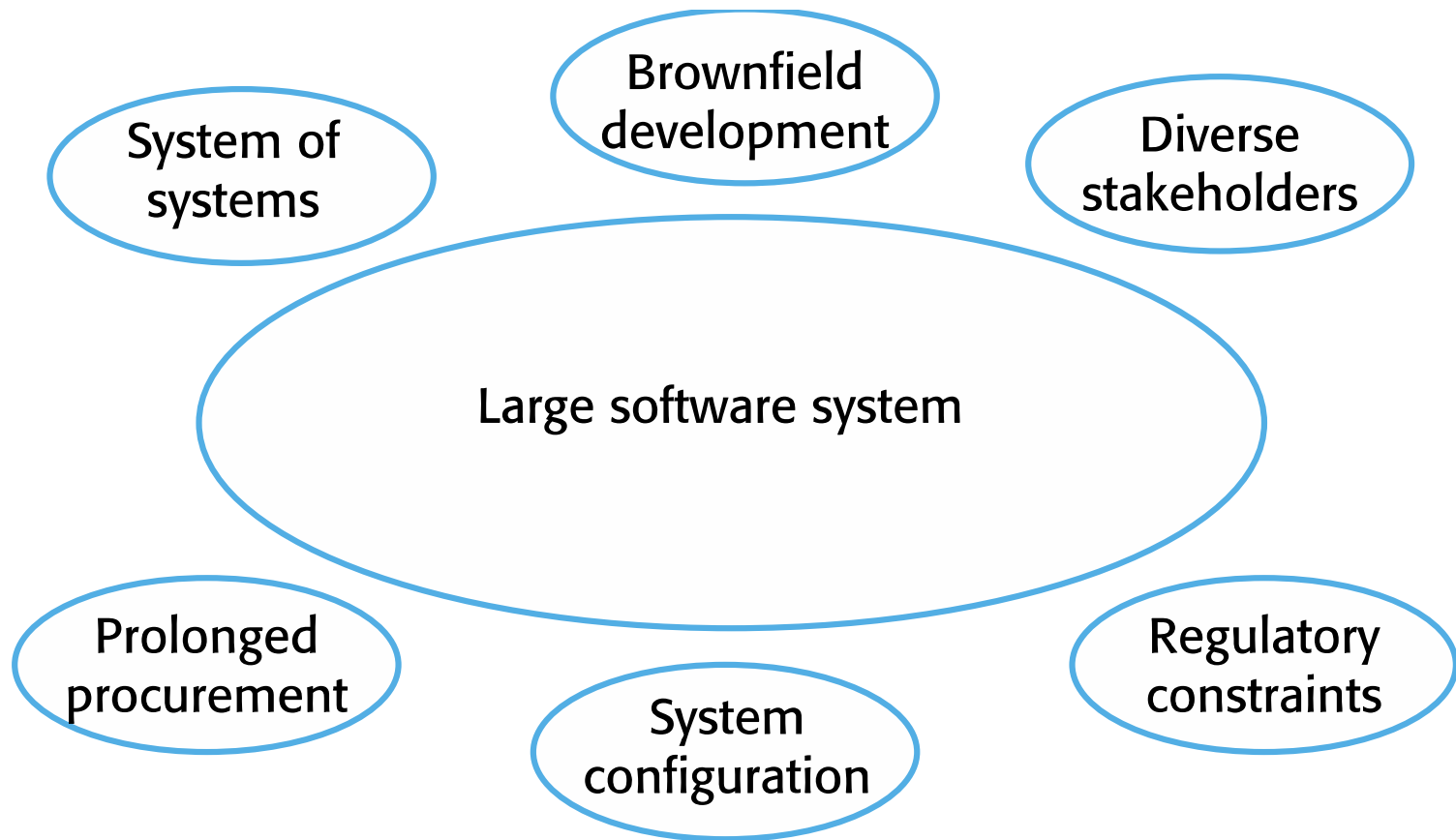
- ✧ Large systems are usually collections of separate, communicating systems, where separate teams develop each system. Frequently, these teams are working in different places, sometimes in different time zones.
- ✧ Large systems are 'brownfield systems', that is they include and interact with a number of existing systems. Many of the system requirements are concerned with this interaction and so don't really lend themselves to flexibility and incremental development.
- ✧ Where several systems are integrated to create a system, a significant fraction of the development is concerned with system configuration rather than original code development.

Large system development

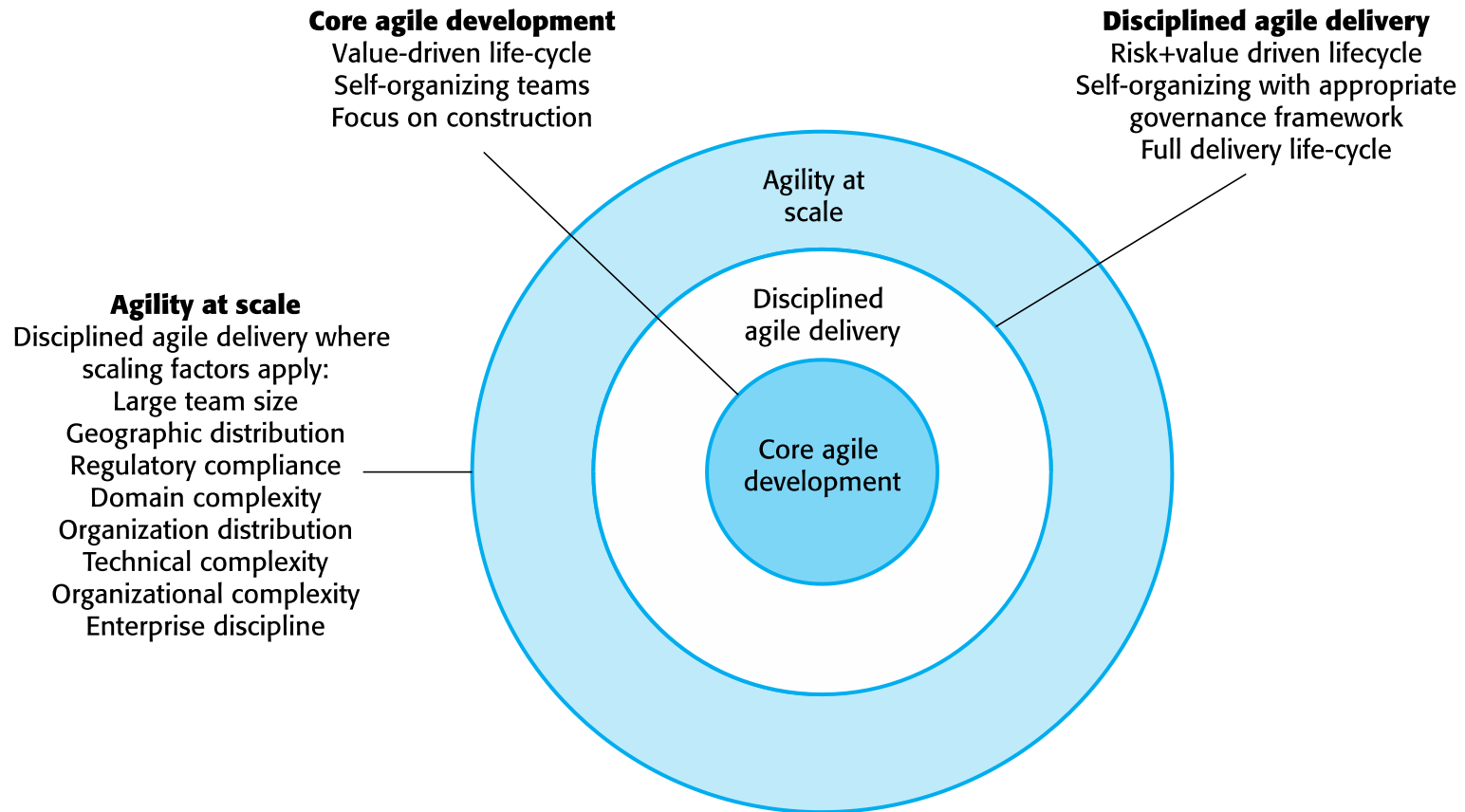


- ✧ Large systems and their development processes are often constrained by external rules and regulations limiting the way that they can be developed.
- ✧ Large systems have a long procurement and development time. It is difficult to maintain coherent teams who know about the system over that period as, inevitably, people move on to other jobs and projects.
- ✧ Large systems usually have a diverse set of stakeholders. It is practically impossible to involve all of these different stakeholders in the development process.

Factors in large systems



IBM's agility at scale model



Scaling up to large systems



- ✧ A completely incremental approach to requirements engineering is impossible.
- ✧ There cannot be a single product owner or customer representative.
- ✧ For large systems development, it is not possible to focus only on the code of the system.
- ✧ Cross-team communication mechanisms have to be designed and used.
- ✧ Continuous integration is practically impossible. However, it is essential to maintain frequent system builds and regular releases of the system.

Multi-team Scrum



✧ *Role replication*

- Each team has a Product Owner for their work component and ScrumMaster.

✧ *Product architects*

- Each team chooses a product architect and these architects collaborate to design and evolve the overall system architecture.

✧ *Release alignment*

- The dates of product releases from each team are aligned so that a demonstrable and complete system is produced.

✧ *Scrum of Scrums*

- There is a daily Scrum of Scrums where representatives from each team meet to discuss progress and plan work to be done.

Agile methods across organizations



- ✧ Project managers who do not have experience of agile methods may be reluctant to accept the risk of a new approach.
- ✧ Large organizations often have quality procedures and standards that all projects are expected to follow and, because of their bureaucratic nature, these are likely to be incompatible with agile methods.
- ✧ Agile methods seem to work best when team members have a relatively high skill level. However, within large organizations, there are likely to be a wide range of skills and abilities.
- ✧ There may be cultural resistance to agile methods, especially in those organizations that have a long history of using conventional systems engineering processes.

Key points



- ✧ Agile methods are incremental development methods that focus on rapid software development, frequent releases of the software, reducing process overheads by minimizing documentation and producing high-quality code.
- ✧ Agile development practices include
 - User stories for system specification
 - Frequent releases of the software,
 - Continuous software improvement
 - Test-first development
 - Customer participation in the development team.

Key points



- ✧ Scrum is an agile method that provides a project management framework.
 - It is centred round a set of sprints, which are fixed time periods when a system increment is developed.
- ✧ Many practical development methods are a mixture of plan-based and agile development.
- ✧ Scaling agile methods for large systems is difficult.
 - Large systems need up-front design and some documentation and organizational practice may conflict with the informality of agile approaches.