Chapter 2-System Engineering

Topics covered

- Emergent system properties
- Systems engineering
- Organizations, people and computer systems
- Legacy systems

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

System categories

- Technical computer-based systems
  - Systems that include hardware and software but where the operators and operational processes are not normally considered to be part of the system. The system is not self-aware.
- Socio-technical systems
  - Systems that include technical systems but also operational processes and people who use and interact with the technical system. Socio-technical systems are governed by organisational policies and rules.

Types of emergent property

- Functional properties
  - These appear when all the parts of a system work together to achieve some objective. For example, a bicycle has the functional property of being a transportation device once it has been assembled from its components.
- Non-functional emergent properties
  - Examples are reliability, performance, safety, and security. These relate to the behaviour of the system in its operational environment. They are often critical for computer-based systems as failure to achieve some minimal defined level in these properties may make the system unusable.

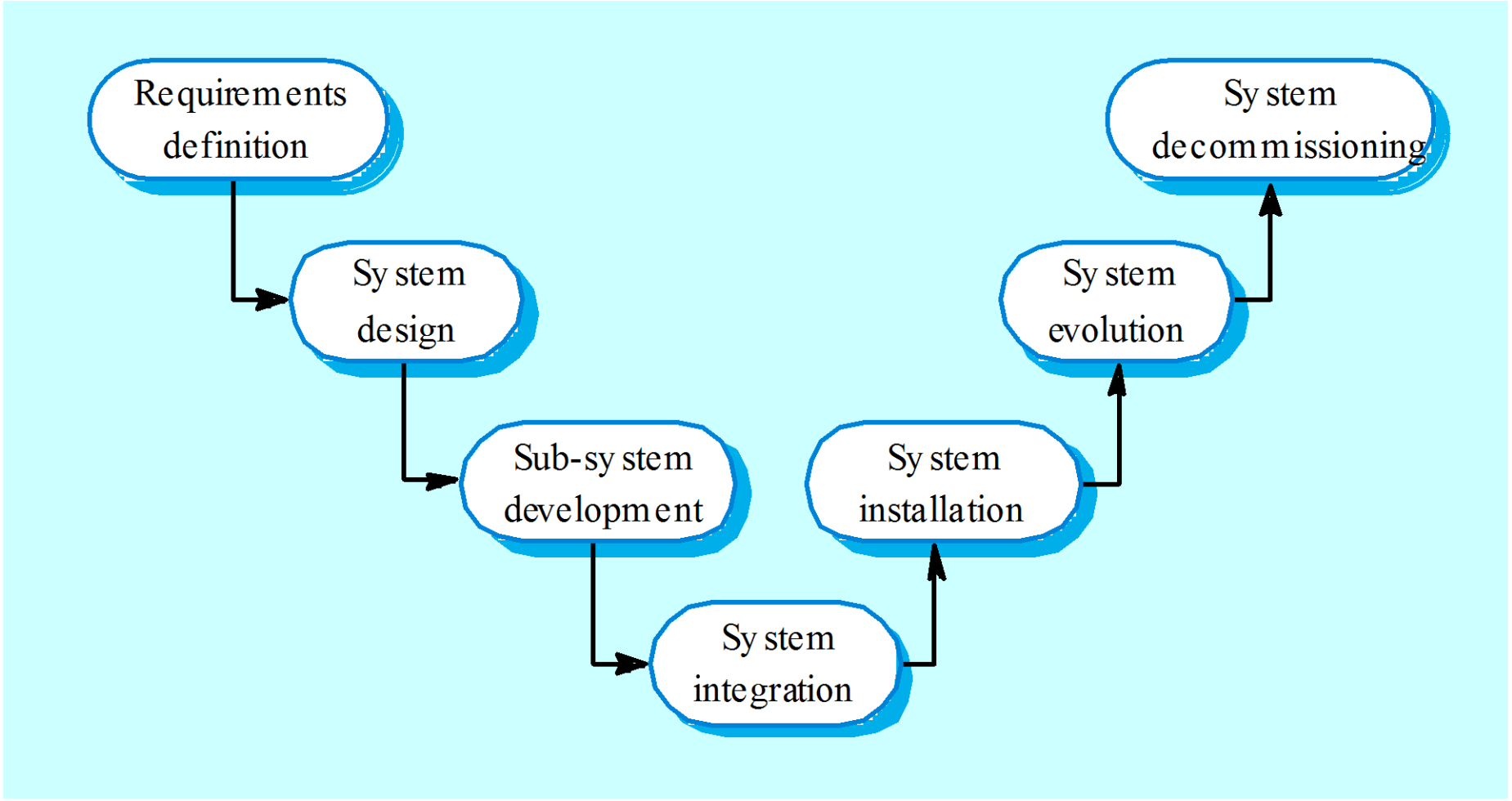
Systems engineering

- Specifying, designing, implementing, validating, deploying and maintaining socio-technical systems.
- Concerned with the services provided by the system, constraints on its construction and operation and the ways in which it is used.

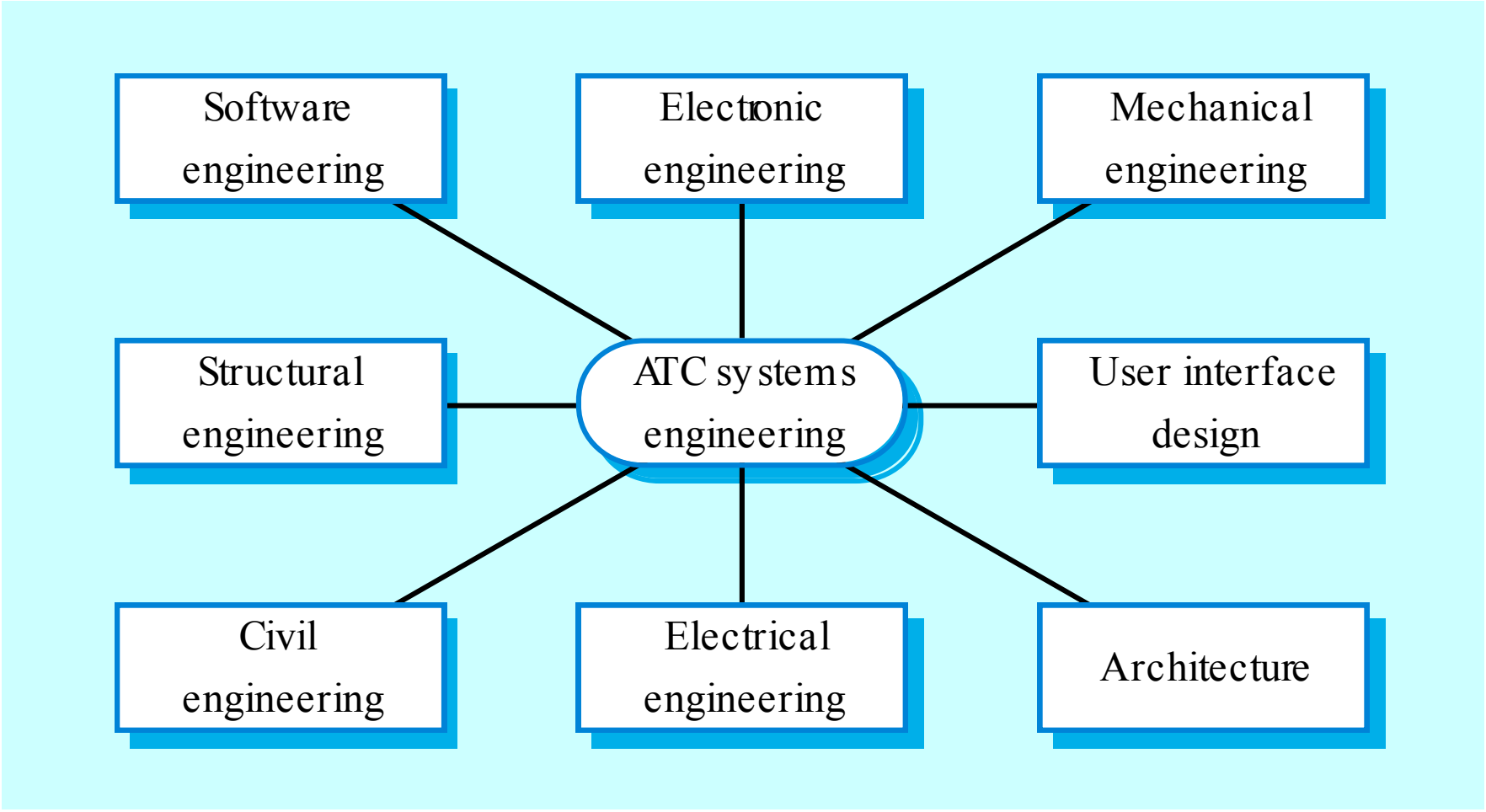
The system engineering process

- Usually follows a ‘waterfall’ model because of the need for parallel development of different parts of the system
  - Little scope for iteration between phases because hardware changes are very expensive. Software may have to compensate for hardware problems.
- Inevitably involves engineers from different disciplines who must work together
  - Much scope for misunderstanding here. Different disciplines use a different vocabulary and much negotiation is required. Engineers may have personal agendas to fulfil.

The systems engineering process



Inter-disciplinary involvement



System requirements definition

- Three types of requirement defined at this stage
  - Abstract functional requirements. System functions are defined in an abstract way;
  - System properties. Non-functional requirements for the system in general are defined;
  - Undesirable characteristics. Unacceptable system behaviour is specified.
- Should also define overall organisational objectives for the system.

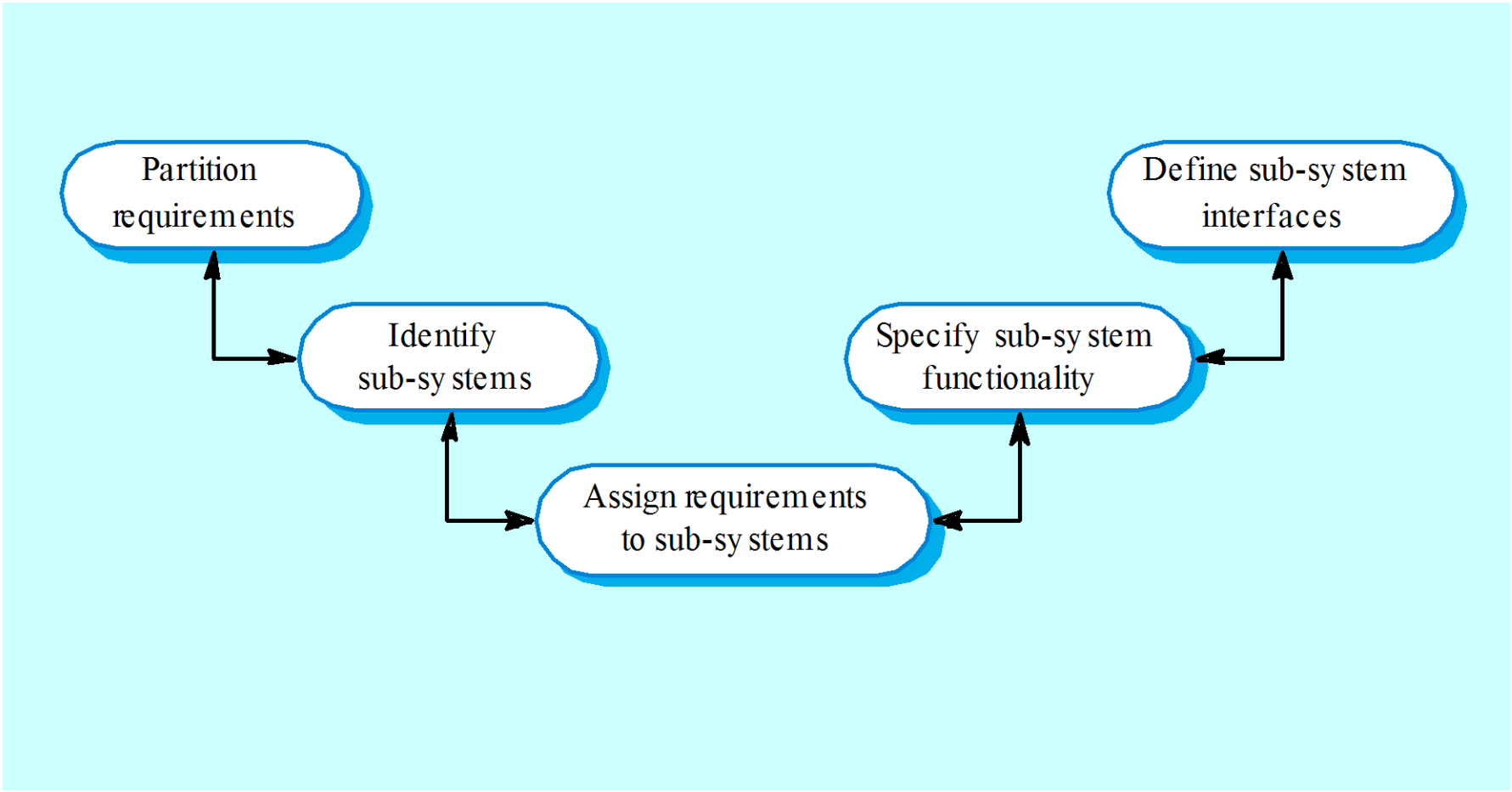
System objectives

- Should define why a system is being procured for a particular environment.
- Functional objectives
  - To provide a fire and intruder alarm system for the building which will provide internal and external warning of fire or unauthorized intrusion.
- Organisational objectives
  - To ensure that the normal functioning of work carried out in the building is not seriously disrupted by events such as fire and unauthorized intrusion.

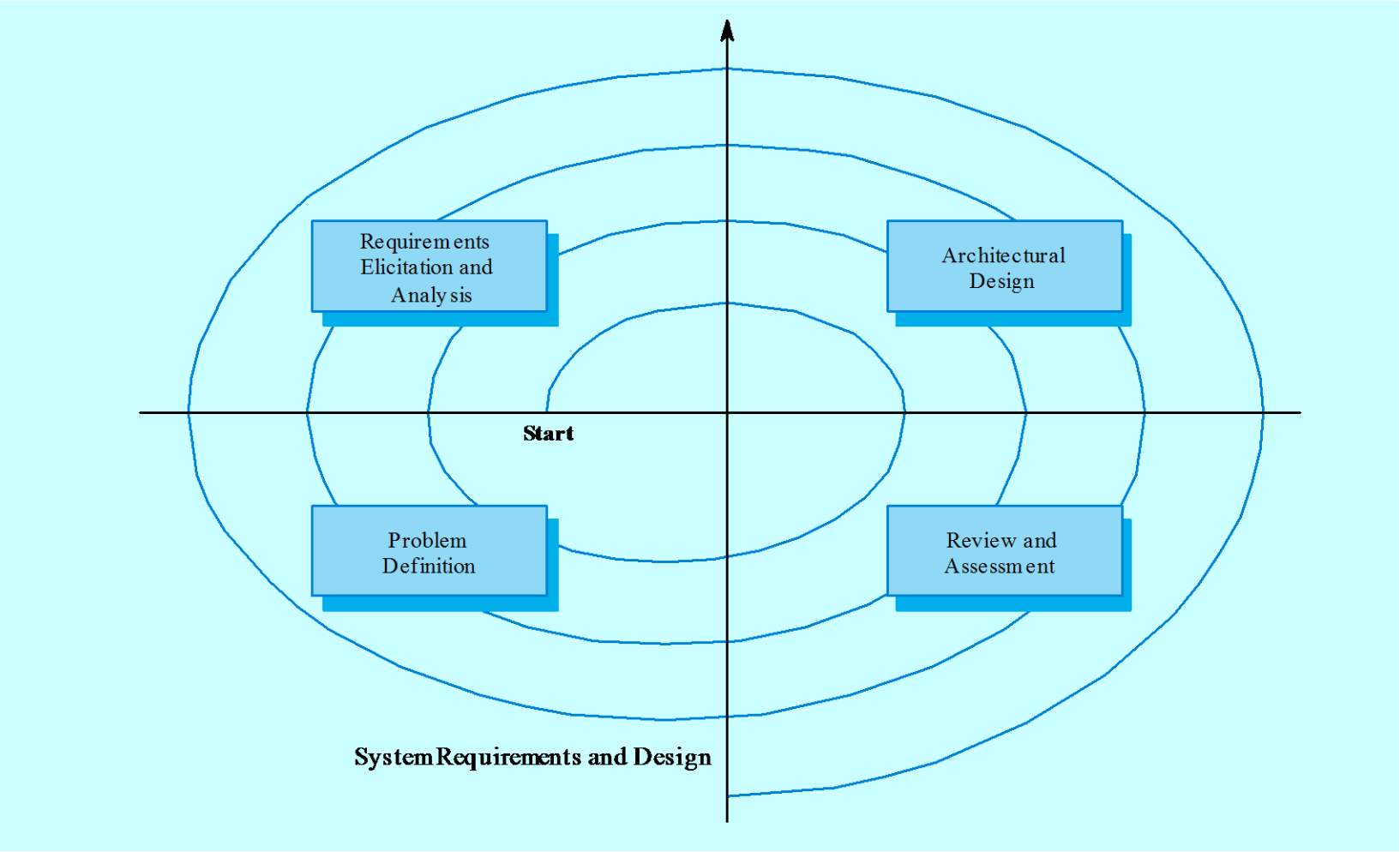
The system design process

- Partition requirements
  - Organise requirements into related groups.
- Identify sub-systems
  - Identify a set of sub-systems which collectively can meet the system requirements.
- Assign requirements to sub-systems
  - Causes particular problems when COTS are integrated.
- Specify sub-system functionality.
- Define sub-system interfaces
  - Critical activity for parallel sub-system development.

The system design process



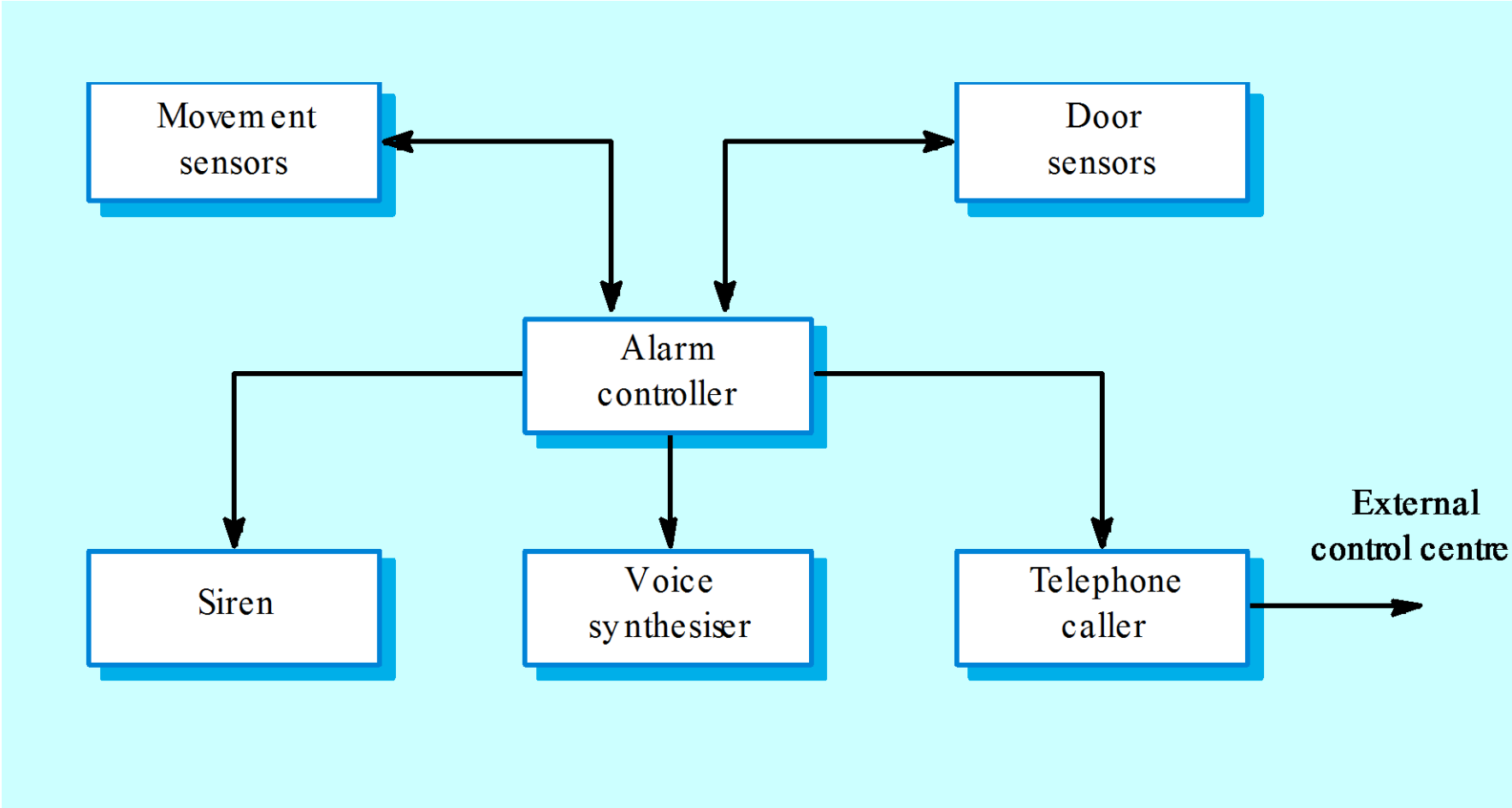
Spiral model of requirements/design



System modelling

- An architectural model presents an abstract view of the sub-systems making up a system
- May include major information flows between sub-systems
- Usually presented as a block diagram
- May identify different types of functional component in the model

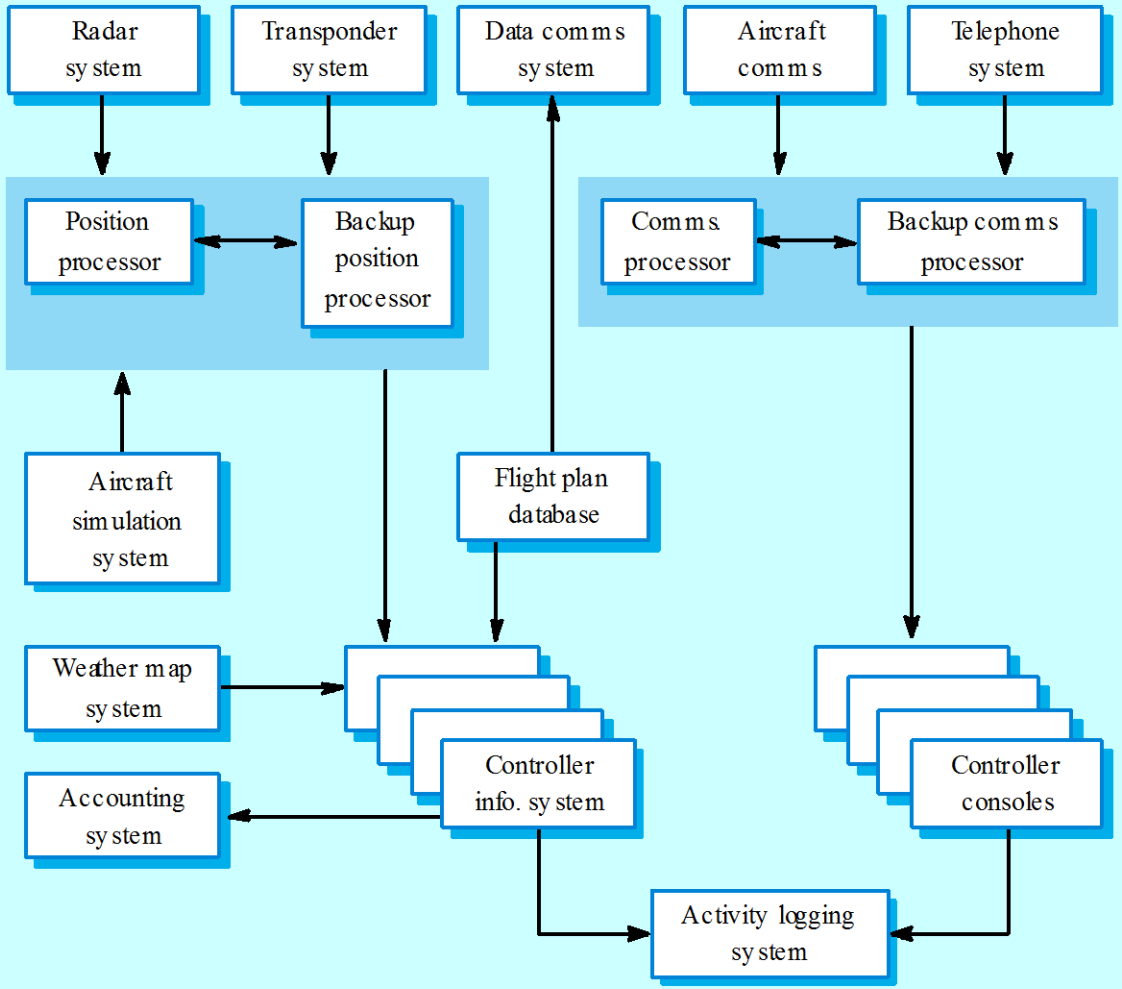
Burglar alarm system



Sub-system description

Sub-system	Description
Movement sensors	Detects movement in the rooms monitored by the system
Door sensors	Detects door opening in the external doors of the building
Alarm controller	Controls the operation of the system
Siren	Emits an audible warning when an intruder is suspected
Voice synthesizer	Synthesizes a voice message giving the location of the suspected intruder
Telephone caller	Makes external calls to notify security, the police, etc.

ATC system architecture



Sub-system development

- Typically parallel projects developing the hardware, software and communications.
- May involve some COTS (Commercial Off-the-Shelf) systems procurement.
- Lack of communication across implementation teams.
- Bureaucratic and slow mechanism for proposing system changes means that the development schedule may be extended because of the need for rework.

System integration

- The process of putting hardware, software and people together to make a system.
- Should be tackled incrementally so that sub-systems are integrated one at a time.
- Interface problems between sub-systems are usually found at this stage.
- May be problems with uncoordinated deliveries of system components.

System installation

- After completion, the system has to be installed in the customer's environment
  - Environmental assumptions may be incorrect;
  - May be human resistance to the introduction of a new system;
  - System may have to coexist with alternative systems for some time;
  - May be physical installation problems (e.g. cabling problems);
  - Operator training has to be identified.

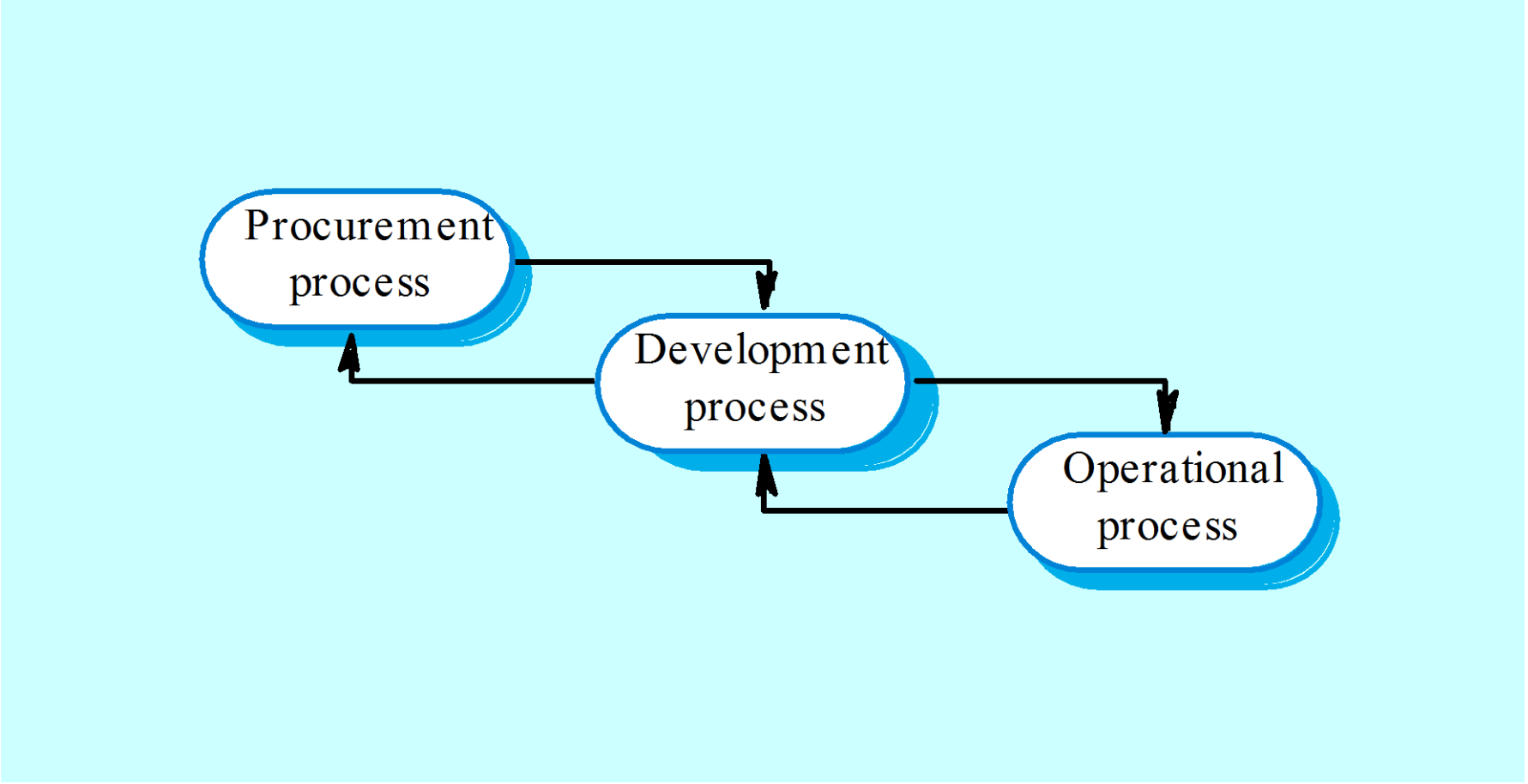
System evolution

- Large systems have a long lifetime. They must evolve to meet changing requirements.
- Evolution is inherently costly
  - Changes must be analysed from a technical and business perspective;
  - Sub-systems interact so unanticipated problems can arise;
  - There is rarely a rationale for original design decisions;
  - System structure is corrupted as changes are made to it.
- Existing systems which must be maintained are sometimes called legacy systems.

System decommissioning

- Taking the system out of service after its useful lifetime.
- May require removal of materials (e.g. dangerous chemicals) which pollute the environment
  - Should be planned for in the system design by encapsulation.
- May require data to be restructured and converted to be used in some other system.

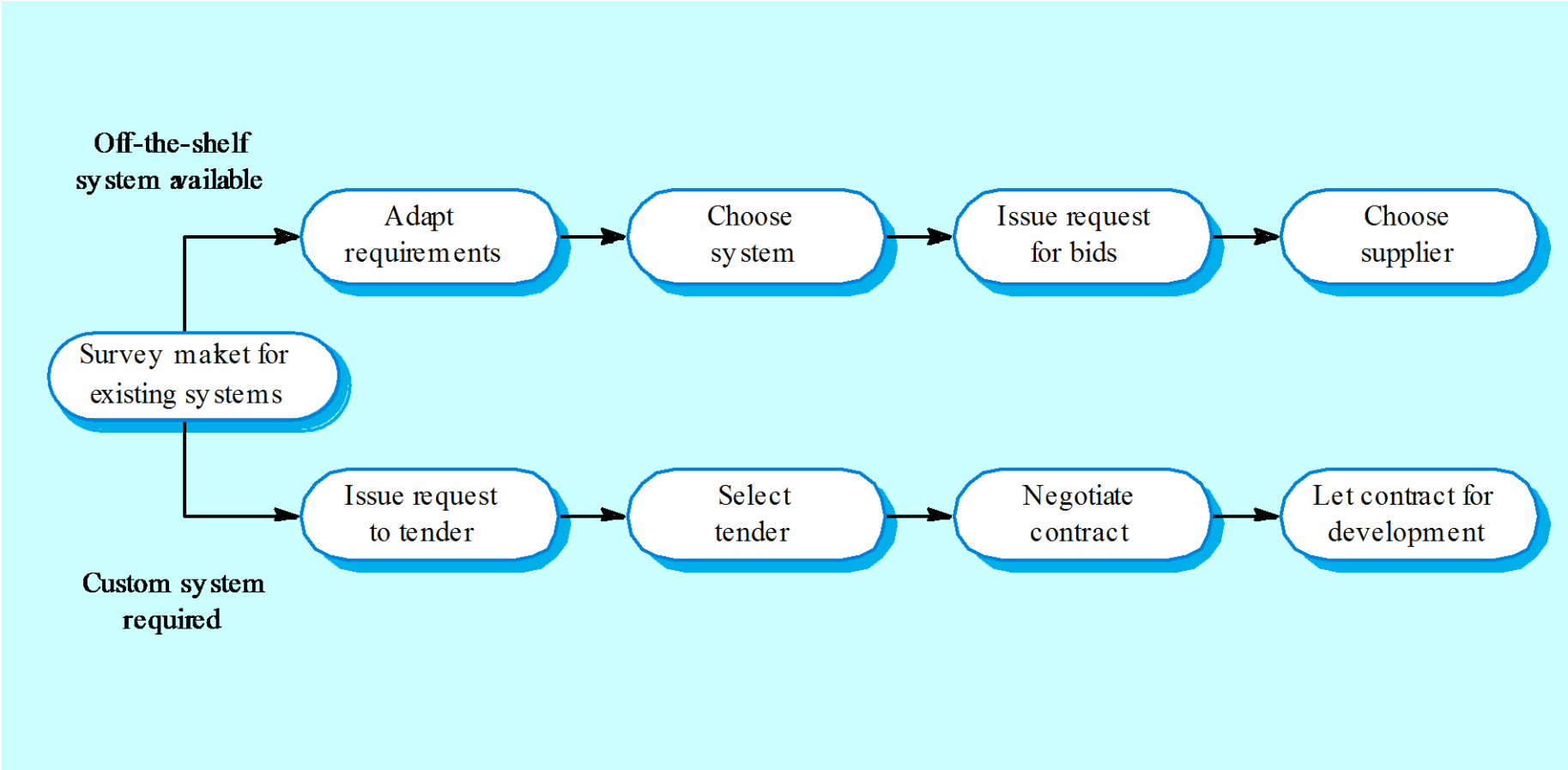
Procurement/development processes



System procurement

- Acquiring a system for an organization to meet some need
- Some system specification and architectural design is usually necessary before procurement
  - You need a specification to let a contract for system development
  - The specification may allow you to buy a commercial off-the-shelf (COTS) system. Almost always cheaper than developing a system from scratch
- Large complex systems usually consist of a mix of off the shelf and specially designed components. The procurement processes for these different types of component are usually different.

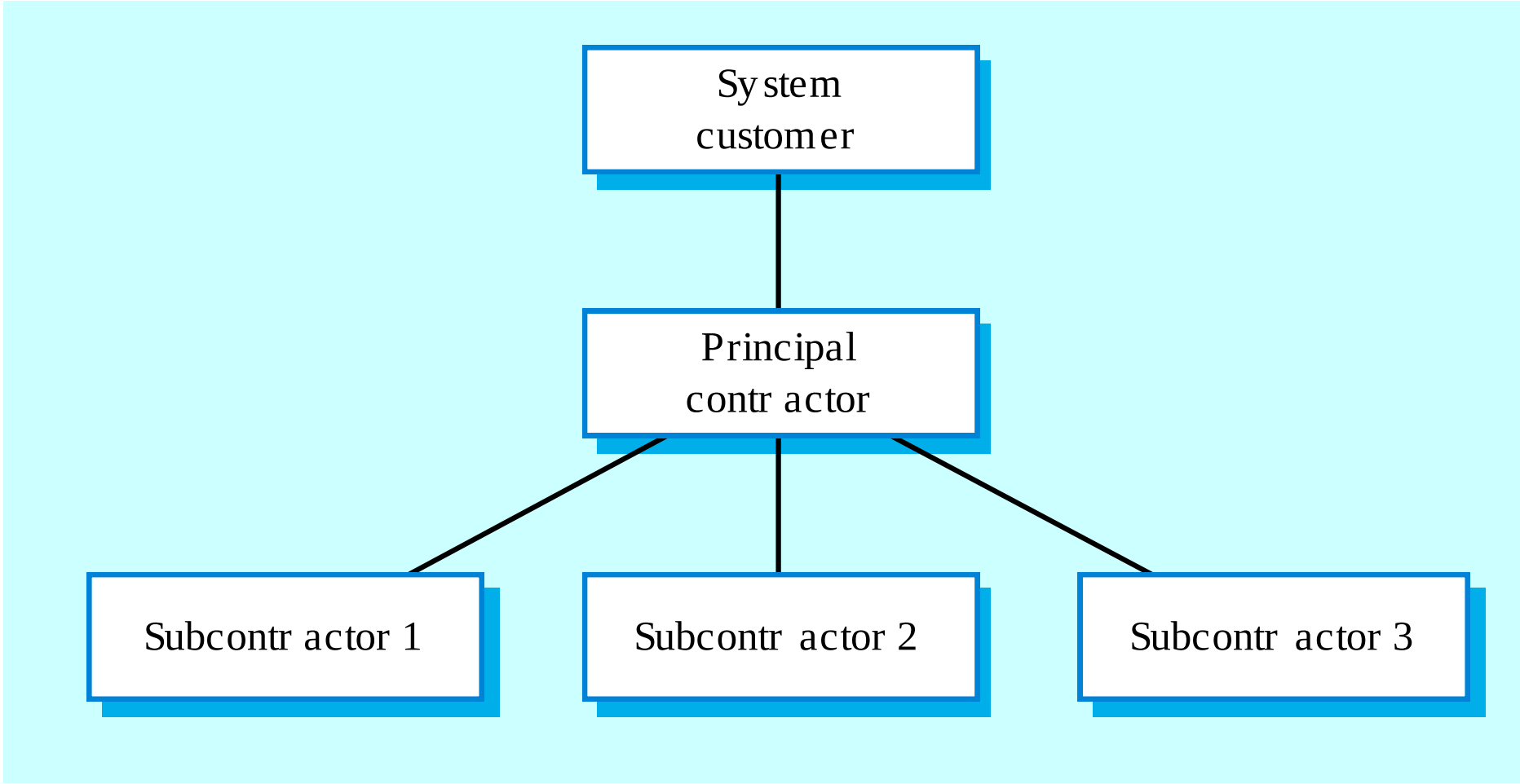
The system procurement process



Contractors and sub-contractors

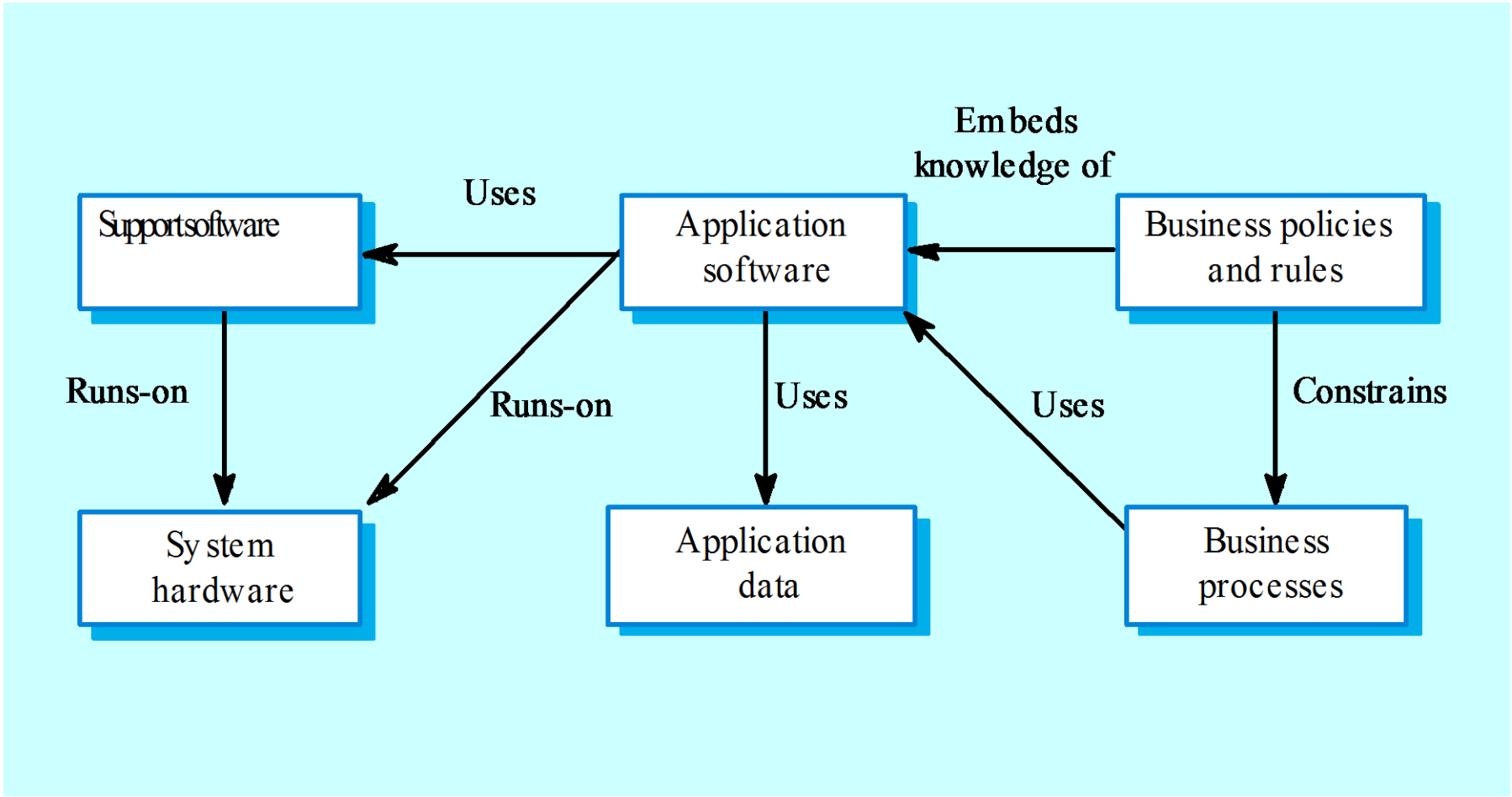
- The procurement of large hardware/software systems is usually based around some principal contractor.
- Sub-contracts are issued to other suppliers to supply parts of the system.
- Customer liases with the principal contractor and does not deal directly with sub-contractors.

Contractor/Sub-contractor model



Legacy systems

- Socio-technical systems that have been developed using old or obsolete technology.
- Crucial to the operation of a business and it is often too risky to discard these systems
  - Bank customer accounting system;
  - Aircraft maintenance system.
- Legacy systems constrain new business processes and consume a high proportion of company budgets.


Supportsoftware
Uses
Application software
Embeds knowledge of
Business policies and rules
Runs-on
Runs-on
Uses
Uses
Constrains
System hardware
Application data
Business processes

Socio-technical system