CSE344
Software Engineering (SWE)

Week – 5
Critical Systems
&
Their Specification

Critical Systems

- *Safety-critical systems*
  - Failure results in loss of life, injury or damage to the environment;
  - Chemical plant protection system;
- *Mission-critical systems*
  - Failure results in failure of some goal-directed activity;
  - Spacecraft navigation system;
- *Business-critical systems*
  - Failure results in high economic losses;
  - Customer accounting system in a bank;

System dependability

- For critical systems, usually the most important system property is the dependability of the system.
- The *dependability of a system* reflects the *extent of the user's confidence* that it will operate as users expect and that it will not 'fail' in normal use.
- *Usefulness* and *trustworthiness* are *not the same* thing. *A system does not have to be trusted to be useful.*

Importance of dependability

- *Undependable* (i.e., *unreliable*, *unsafe and/or insecure*) systems
  - may be *rejected by their users*.
  - may cause *information loss with a high recovery cost*.
- The costs of system failure may be very high.

Development methods for critical systems

- *The costs of critical system failure are so high that development methods may be used that are not cost-effective for other types of system.*
- Examples of development methods
  - *Formal methods of software development*
  - Static analysis
  - External quality assurance

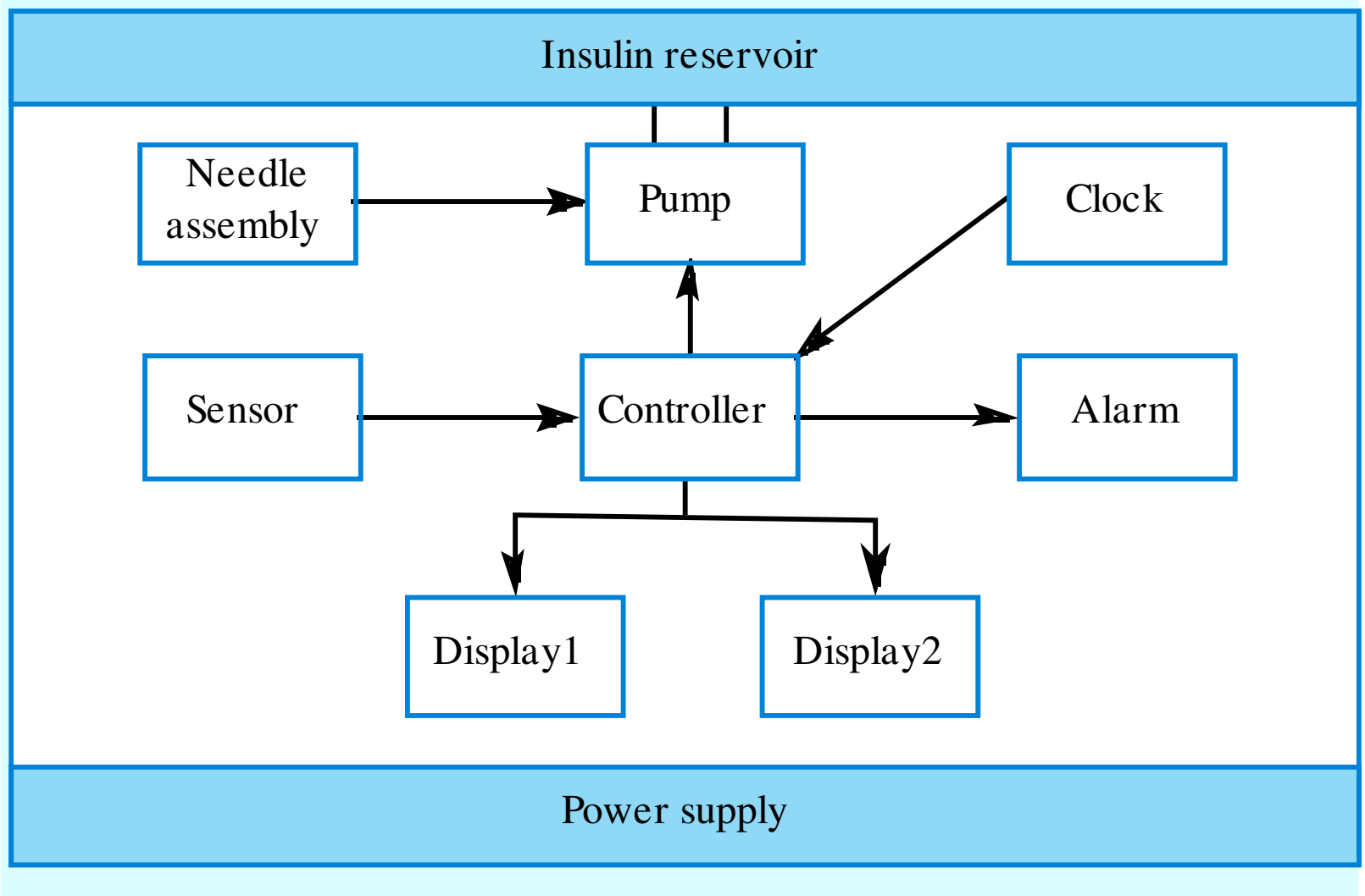
Failure types in socio-technical critical systems

- *Hardware failure*
  - Hardware fails because of design and manufacturing errors or because components have reached the end of their natural life.
- *Software failure*
  - Software fails due to errors in its specification, design or implementation.
- *Operational failure*
  - Human operators make mistakes. Now perhaps the largest single cause of system failures.

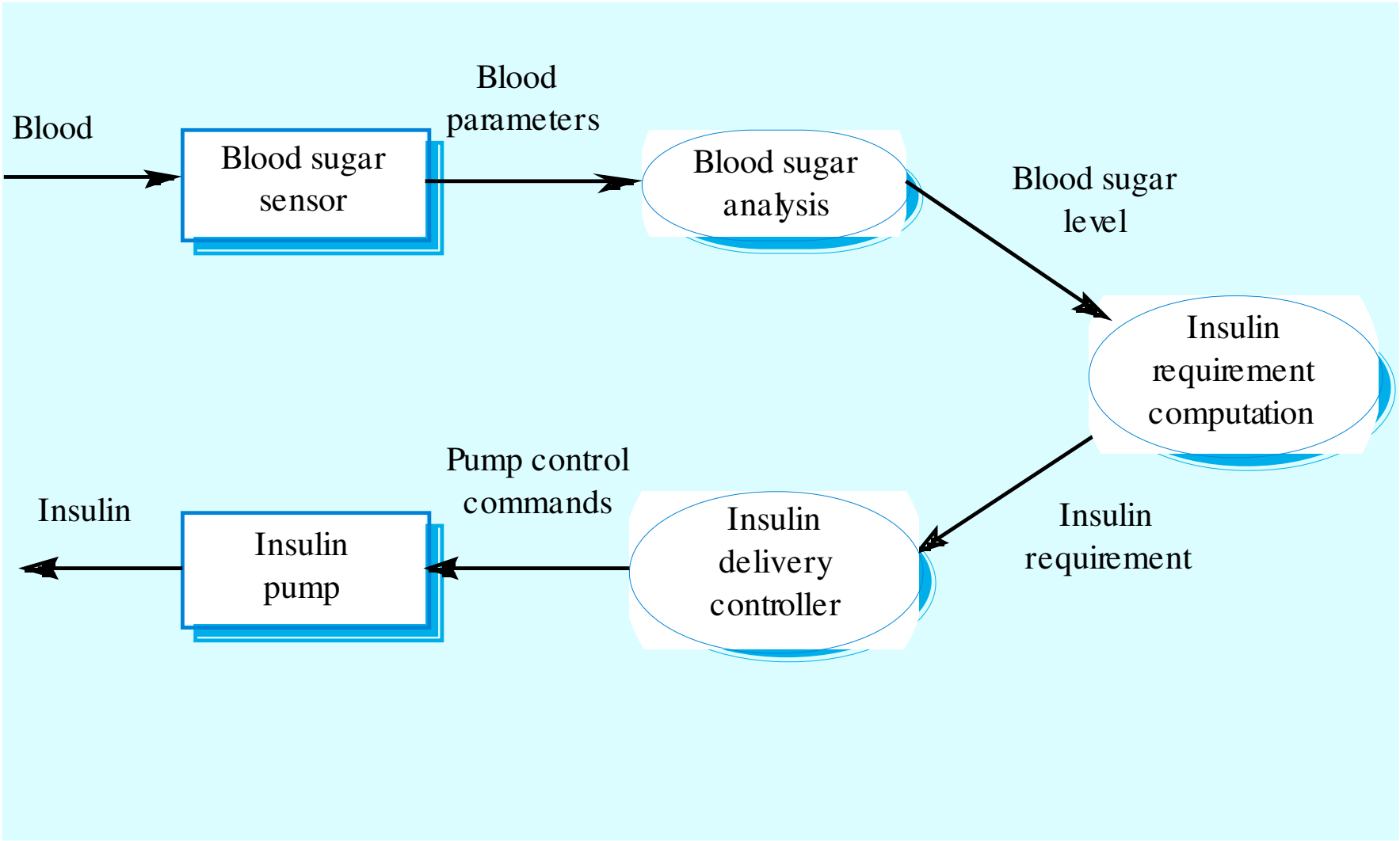
An example to critical systems: a software-controlled insulin pump

- Used by *diabetics*
- *Simulates the function of the pancreas*
  - Manufactures *insulin*,
    - an essential hormone that *metabolises blood glucose*.
  - *Measures blood glucose* (sugar) using a micro-sensor and
  - *Computes the insulin dose required* to *metabolise* the glucose.

Insulin pump organisation



Insulin pump data-flow



Dependability requirements

- ...shall be *available* to *deliver insulin when required* to do so (*availability requirement*)
- ...shall *deliver the correct amount of insulin* to counteract (neutralize) the current level of blood sugar (*reliability requirement*).
- ...shall *never deliver excessive doses of insulin* as this is potentially *life threatening* (*safety requirement*).

Dependability

- *Dependability = Trustworthiness*.
- A *dependable* system is one *trusted by its users*.
- *Principal dimensions of dependability* are:
  - *Availability*
  - *Reliability*
  - *Safety*
  - *Security*

Principal dimensions of dependability

- *The (prob)ability of the system to ...*
  - *... deliver services when requested (Availability)*
  - *... deliver services as specified (Reliability)*
  - *... operate without catastrophic failure (Safety)*
  - *... protect itself against accidental or deliberate intrusion (Security)*

Other dependability properties

- *Repairability*
  - Reflects the *extent to which the system can be repaired in the event of a failure*;
- *Maintainability*
  - Reflects the *extent to which the system can be adapted to new requirements*;
- *Survivability*
  - Reflects the *extent to which the system can deliver services whilst under hostile attack*;
- *Error tolerance*
  - Reflects the *extent to which user input errors can be avoided and tolerated*.

Maintainability

- concerned with the ease of
  - ... *repairing the system* after a failure has been discovered or
  - ... *changing the system* to include new features;
- very important for critical systems as faults are often introduced into a system because of maintenance problems
- different than other dimensions of dependability because it is a *static and not a dynamic system attribute*.

Survivability

- The ability of a system *to continue to deliver its services to users under attack*
- This is an *increasingly important attribute* for distributed systems whose security can be compromised
- Survivability subsumes the notion of ***resilience*** (flexibility, *fault tolerance*) - the ability of a system to *continue in operation in spite of component failures*

Dependability vs performance

- Untrustworthy systems may be rejected by their users
- System failure costs may be very high
- It is very difficult to tune systems to make them more dependable
- It may be possible to compensate for poor performance
- Untrustworthy systems may cause loss of valuable information

Dependability costs

- Dependability costs tend to increase exponentially as increasing levels of dependability are required
- Two reasons:
  - The *use of more expensive development techniques and hardware* required to achieve higher levels of dependability
  - The *increased testing and system validation* required to convince the system client that the required levels of dependability have been achieved

Dependability economics

- Achievement of dependability requirements costs extremely high ⇒*more cost-effective to accept untrustworthy systems* and pay for failure costs?
- *Social and political factors*: A bad reputation for products may lead to the loss of future business.
- *System type*: for *business systems* in particular, *modest levels of dependability* OK; for *medical systems highly dependable systems* are crucial.

Availability and reliability: expressible as stochastic (probabilistic) quantity

- *Reliability*
  - The *probability of failure-free system operation over a specified time in a given environment for a given purpose*
- *Availability*
  - The *probability that a system, at a point in time, will be operational and able to deliver the requested services*

Reliability terminology

Term	Description
System failure	An event that occurs at some point in time when the system does not deliver a service as expected by its users
System error	An erroneous system state that can lead to system behaviour that is unexpected by system users.
System fault	A characteristic of a software system that can lead to a system error. For example, failure to initialise a variable could lead to that variable having the wrong value when it is used.
Human error or mistake	Human behaviour that results in the introduction of faults into a system.

Faults and failures

- Failures are a usually a result of system errors that are derived from faults in the system
- However, faults do not necessarily result in system errors
  - The faulty system state may be transient and ‘corrected’ before an error arises
- Errors do not necessarily lead to system failures
  - The error can be corrected by built-in error detection and recovery
  - The failure can be protected against by built-in protection facilities. These may, for example, protect system resources from system errors

Perceptions of reliability

- The formal definition of reliability does not always reflect the user's perception of a system's reliability
  - The assumptions that are made about the environment where a system will be used may be incorrect
    - Usage of a system in an office environment is likely to be quite different from usage of the same system in a university environment
  - The consequences of system failures affects the perception of reliability
    - Unreliable windscreen wipers in a car may be irrelevant in a dry climate
    - Failures that have serious consequences (such as an engine breakdown in a car) are given greater weight by users than failures that are inconvenient

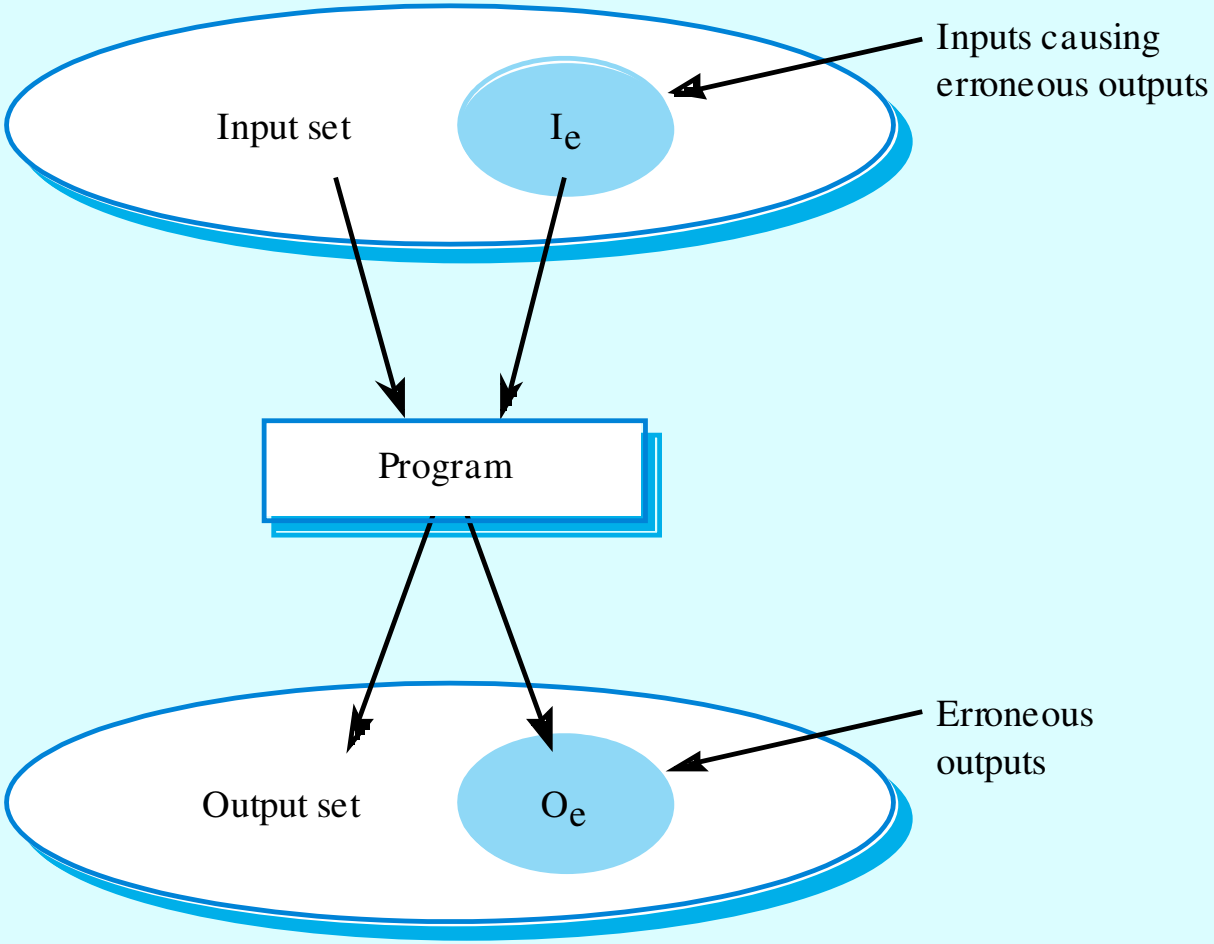
Reliability achievement

- ***Fault avoidance***
  - Development technique are used that either *minimise the possibility of mistakes* or trap mistakes before they result in the introduction of system faults
- ***Fault detection and removal***
  - Verification and validation techniques that increase the probability of *detecting and correcting errors before the system goes into service* are used
- ***Fault tolerance***
  - Run-time techniques are used to ensure that *system faults do not result in system errors and/or that system errors do not lead to system failures*

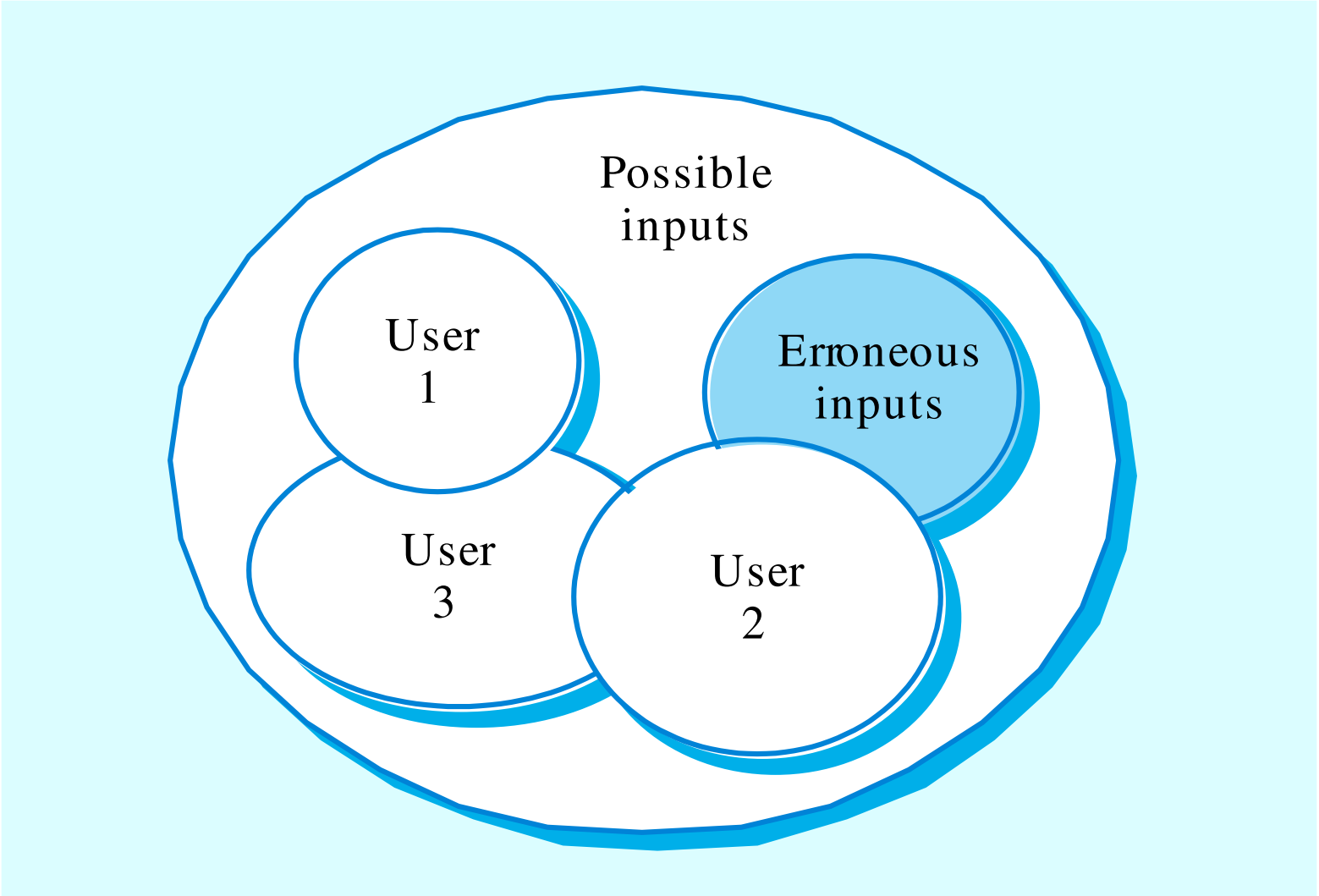
Reliability modelling

- You can model a system as an input-output mapping where some inputs will result in erroneous outputs
- The reliability of the system is the probability that a particular input will lie in the set of inputs that cause erroneous outputs
- Different people will use the system in different ways so this probability is not a static system attribute but depends on the system's environment

Input/output mapping



Reliability perception



Reliability improvement

- Removing X% of the faults in a system will not necessarily improve the reliability by X%. A study at IBM showed that removing 60% of product defects resulted in a 3% improvement in reliability
- Program defects may be in rarely executed sections of the code so may never be encountered by users. Removing these does not affect the perceived reliability
- A program with known faults may therefore still be seen as reliable by its users

Safety

- Safety is a property of a system that reflects the system's ability to operate, normally or abnormally, without danger of causing human injury or death and without damage to the system's environment
- It is increasingly important to consider software safety as more and more devices incorporate software-based control systems
- Safety requirements are exclusive requirements i.e. they exclude undesirable situations rather than specify required system services

Safety criticality

- Primary safety-critical systems
  - Embedded software systems whose failure can cause the associated hardware to fail and directly threaten people.
- Secondary safety-critical systems
  - Systems whose failure results in faults in other systems which can threaten people
- Discussion here focuses on primary safety-critical systems
  - Secondary safety-critical systems can only be considered on a one-off basis

Safety and reliability

- Safety and reliability are related but distinct
  - In general, reliability and availability are necessary but not sufficient conditions for system safety
- Reliability is concerned with conformance to a given specification and delivery of service
- Safety is concerned with ensuring system cannot cause damage irrespective of whether or not it conforms to its specification

Unsafe reliable systems

- Specification errors
  - If the system specification is incorrect then the system can behave as specified but still cause an accident
- Hardware failures generating spurious inputs
  - Hard to anticipate in the specification
- Context-sensitive commands i.e. issuing the right command at the wrong time
  - Often the result of operator error

Safety terminology

Term	Definition
Accident (or mishap)	An unplanned event or sequence of events which results in human death or injury, damage to property or to the environment. A computer-controlled machine injuring its operator is an example of an accident.
Hazard	A condition with the potential for causing or contributing to an accident. A failure of the sensor that detects an obstacle in front of a machine is an example of a hazard.
Damage	A measure of the loss resulting from a mishap. Damage can range from many people killed as a result of an accident to minor injury or property damage.
Hazard severity	An assessment of the worst possible damage that could result from a particular hazard. Hazard severity can range from catastrophic where many people are killed to minor where only minor damage results.
Hazard probability	The probability of the events occurring which create a hazard. Probability values tend to be arbitrary but range from *probable* (say 1/100 chance of a hazard occurring) to implausible (no conceivable situations are likely where the hazard could occur).
Risk	This is a measure of the probability that the system will cause an accident. The risk is assessed by considering the hazard probability, the hazard severity and the probability that a hazard will result in an accident.

Safety achievement

- Hazard avoidance
  - The system is designed so that some classes of hazard simply cannot arise.
- Hazard detection and removal
  - The system is designed so that hazards are detected and removed before they result in an accident
- Damage limitation
  - The system includes protection features that minimise the damage that may result from an accident

Normal accidents

- Accidents in complex systems rarely have a single cause as these systems are designed to be resilient to a single point of failure
  - Designing systems so that a single point of failure does not cause an accident is a fundamental principle of safe systems design
- Almost all accidents are a result of combinations of malfunctions
- It is probably the case that anticipating all problem combinations, especially, in software controlled systems is impossible so achieving complete safety is impossible

Security

- The security of a system is a system property that reflects the system's ability to protect itself from accidental or deliberate external attack
- Security is becoming increasingly important as systems are *networked* so that external access to the system through the Internet is possible
- Security is an essential pre-requisite for availability, reliability and safety

Fundamental security

- If a system is a networked system and is insecure then statements about its reliability and its safety are unreliable
- These statements depend on the executing system and the developed system being the same. However, intrusion can change the executing system and/or its data
- Therefore, the reliability and safety assurance is no longer valid

Security terminology

Term	Definition
Exposure	Possible loss or harm in a computing system. This can be loss or damage to data or can be a loss of time and effort if recovery is necessary after a security breach.
Vulnerability	A weakness in a computer-based system that may be exploited to cause loss or harm.
Attack	An exploitation of a system vulnerability. Generally, this is from outside the system and is a deliberate attempt to cause some damage.
Threats	Circumstances that have potential to cause loss or harm. You can think of these as a system vulnerability that is subjected to an attack.
Control	A protective measure that reduces a system vulnerability. Encryption would be an example of a control that reduced a vulnerability of a weak access control system.

Damage from insecurity

- Denial of service
  - The system is forced into a state where normal services are unavailable or where service provision is significantly degraded
- Corruption of programs or data
  - The programs or data in the system may be modified in an unauthorised way
- Disclosure of confidential information
  - Information that is managed by the system may be exposed to people who are not authorised to read or use that information

Security assurance

- *Vulnerability avoidance*
  - The system is designed so that vulnerabilities do not occur. For example, if there is no external network connection then external attack is impossible
- *Attack detection and elimination*
  - The system is designed so that attacks on vulnerabilities are detected and neutralised before they result in an exposure. For example, virus checkers find and remove viruses before they infect a system
- *Exposure limitation*
  - The system is designed so that the adverse consequences of a successful attack are minimised. For example, a backup policy allows damaged information to be restored

Dependability requirements

- *Functional requirements* to define error checking and recovery facilities and protection against system failures.
- *Non-functional requirements* defining the required reliability and availability of the system.
- *Excluding requirements* that define states and conditions that must not arise.

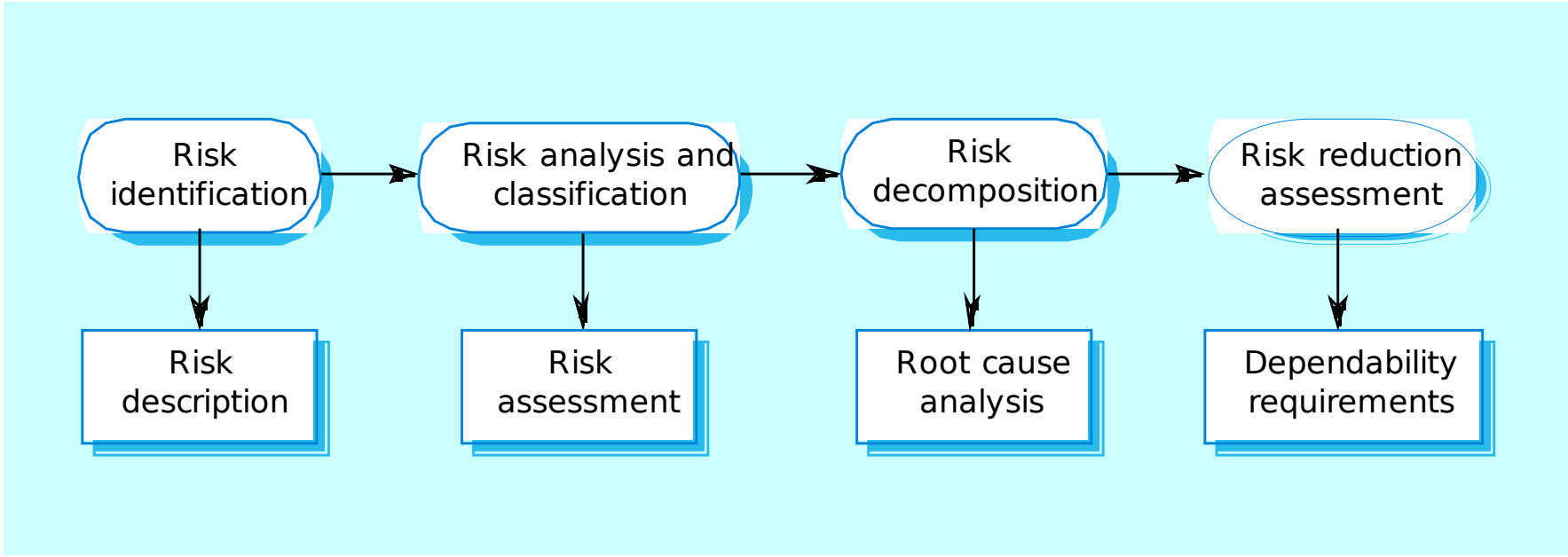
Critical systems specification...

- ...***risk-driven***.
- ...widely used in safety and security-critical systems.
- Aim of specification: to *understand the risks* (safety, security, etc.) faced by the system and to *define requirements reducing these risks*.

Stages of risk-based analysis

- *Risk identification*
  - Identify potential risks that may arise.
- *Risk analysis and classification*
  - Assess the seriousness of each risk.
- *Risk decomposition*
  - Decompose risks to discover their potential *root causes*.
- *Risk reduction assessment*
  - Define how each risk must be eliminated or reduced when the system is designed.

Risk-driven specification



Risk identification

- Safety-critical systems: risks are the hazards that can lead to accidents.
- Security-critical systems: the risks are the potential attacks on the system.
- First: identify risk classes, and
- Second: position risks in these classes
  - Service failure;
  - Electrical risks;
  - …

Insulin pump risks

- Insulin overdose (service failure).
- Insulin underdose (service failure).
- Power failure due to exhausted battery (electrical).
- Electrical interference with other medical equipment (electrical).
- Poor sensor and actuator contact (physical).
- Parts of machine break off in body (physical).
- Infection caused by introduction of machine (biological).
- Allergic reaction to materials or insulin (biological).

Risk analysis and classification

- ...concerned with understanding the likelihood of possibe risks and the potential consequences in case of any accident or incident.
- Risks categories:
  - ***Intolerable***. Must *never arise* or result in an accident
  - ***As low as reasonably practical(ALARP).*** Must *minimise the possibility of risk* given cost and schedule constraints
  - ***Acceptable.*** The *consequences of the risk are acceptable* and no extra costs should be incurred to reduce hazard probability

Risk assessment

- Estimate the risk probability and the risk severity.
- It is not normally possible to do this precisely so relative values are used such as ‘unlikely’, ‘rare’, ‘very high’, etc.
- The aim must be to exclude risks that are likely to arise or that have high severity.

Risk assessment - insulin pump

Identified hazard	Hazard probability	Hazard severity	Estimated risk	Acceptability
1. Insulin overdose	Medium	High	High	Intolerable
2. Insulin underdose	Medium	Low	Low	Acceptable
3. Power failure	High	Low	Low	Acceptable
4. Machine incorrectly fitted	High	High	High	Intolerable
5. Machine breaks in patient	Low	High	Medium	ALARP
6. Machine causes infection	Medium	Medium	Medium	ALARP
7. Electrical interference	Low	High	Medium	ALARP
8. Allergic reaction	Low	Low	Low	Acceptable

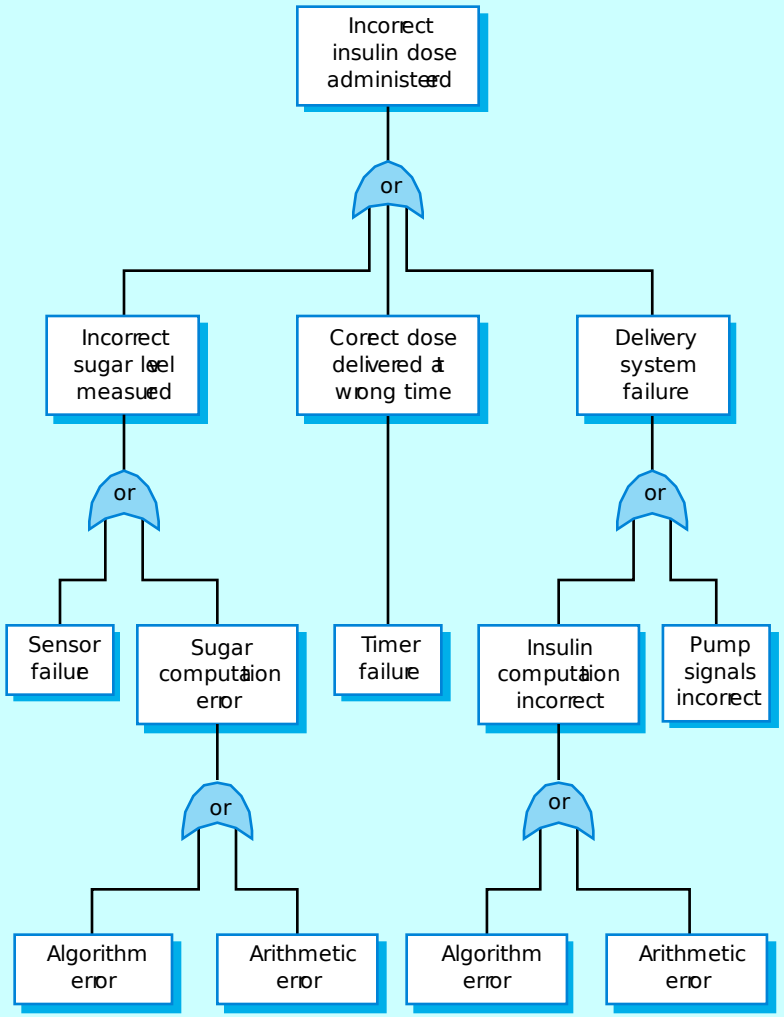
Risk decomposition...

- ...concerned with discovering the *root causes* of risks in a particular system.
- Two techniques...
  - *inductive, bottom-up techniques*.
    - start with a proposed *system failure*, and
    - assess the hazards that could arise from that failure;
  - *deductive, top-down techniques.*
    - start with a hazard, and
    - deduce what the causes of this could be.

Fault-tree analysis

- A *deductive top-down* technique.
- Put the risk or *hazard at the root of the tree* and *identify the system states that could lead to that hazard*.
- Where appropriate, *link these with ‘and’ or ‘or’* conditions.
- Goal: *minimise the number of single causes of system failure*.

Insulin pump fault tree



Risk reduction assessment

- Aim:
  - to identify dependability requirements that
    - specify how the risks should be managed, and
    - ensure that accidents/incidents do not arise.
- Risk reduction strategies
  - *Risk avoidance*;
  - *Risk detection and removal*;
  - *Damage limitation*.

Strategy use

- Normally, in critical systems, a *mix of risk reduction strategies* are used.
- In a chemical plant control system, the system will include sensors to detect and correct excess pressure in the reactor (*Risk detection and removal*).
- However, it will also include an independent protection system that opens a relief valve if dangerously high pressure is detected (*Damage limitation*).

Insulin pump - software risks

- Arithmetic error
  - A computation causes the value of a variable to overflow or underflow;
  - Maybe include an exception handler for each type of arithmetic error.
- Algorithmic error
  - Compare dose to be delivered with previous dose or safe maximum doses. Reduce dose if too high.

Safety requirements - insulin pump

SR1: The system shall not deliver a single dose of insulin that is greater than a specified maximum dose for a system user.
SR2: The system shall not deliver a daily cumulative dose of insulin that is greater than a specified maximum for a system user.
SR3: The system shall include a hardware diagnostic facility that shall be executed at least 4 times per hour.
SR4: The system shall include an exception handler for all of the exceptions that are identified in Table 3.
SR5: The audible alarm shall be sounded when any hardware or software anomaly is discovered and a diagnostic message as defined in Table 4 should be displayed.
SR6: In the event of an alarm in the system, insulin delivery shall be suspended until the user has reset the system and cleared the alarm.

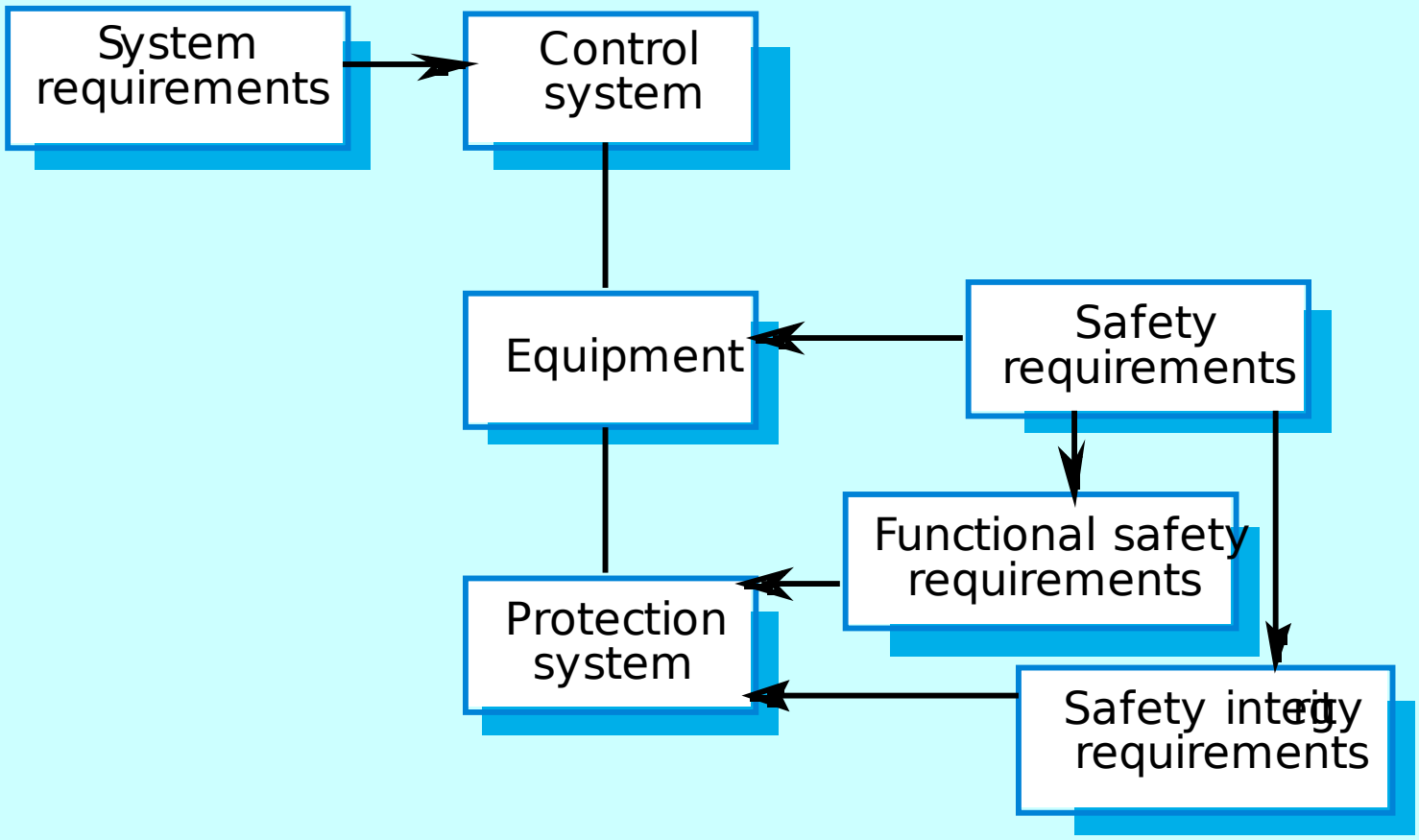
Safety specification

- The safety requirements of a system should be separately specified.
- These requirements should be based on an analysis of the possible hazards and risks as previously discussed.
- Safety requirements usually apply to the system as a whole rather than to individual sub-systems. In systems engineering terms, the safety of a system is an emergent property.

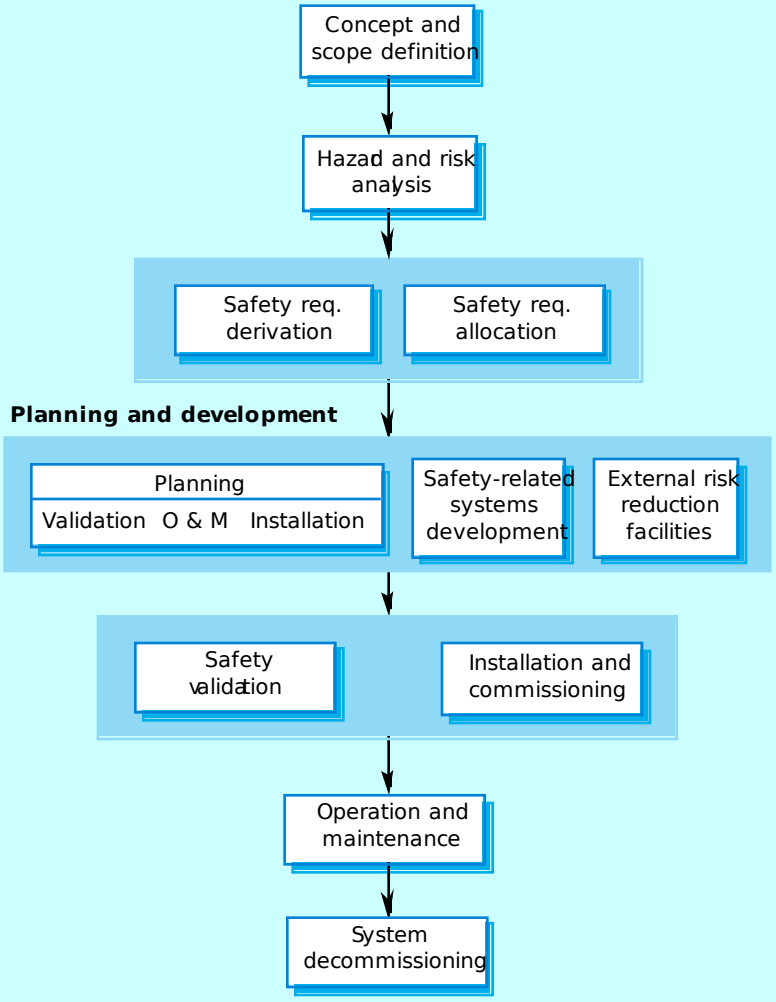
IEC 61508

- An international standard for safety management that was specifically designed for protection systems - it is not applicable to all safety-critical systems.
- Incorporates a model of the safety life cycle and covers all aspects of safety management from scope definition to system decommissioning.

Control system safety requirements



The safety life-cycle



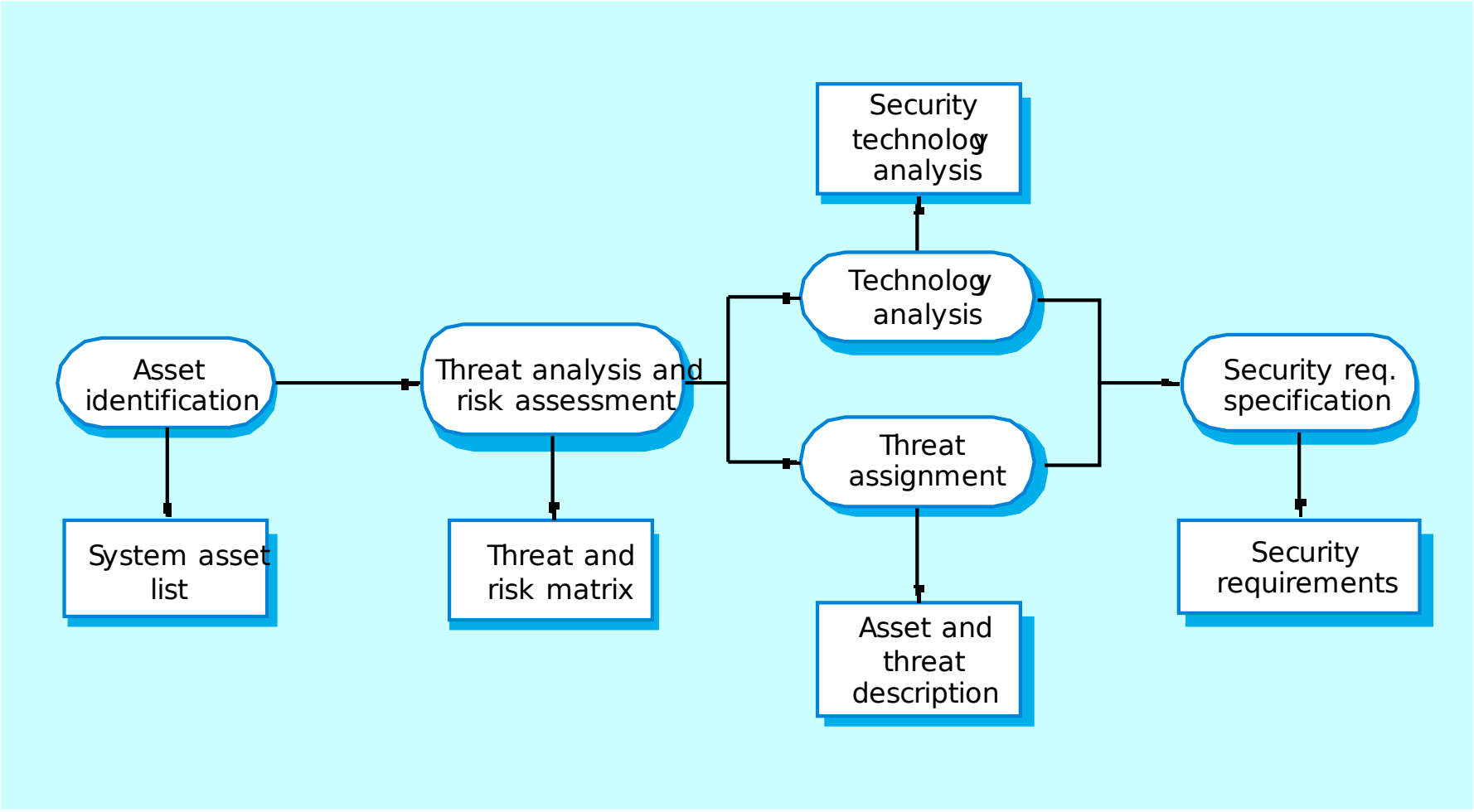
Safety requirements

- Functional safety requirements
  - These define the safety functions of the protection system i.e. the define how the system should provide protection.
- Safety integrity requirements
  - These define the reliability and availability of the protection system. They are based on expected usage and are classified using a safety integrity level from 1 to 4.

Security specification

- Has some similarities to safety specification
  - Not possible to specify security requirements quantitatively;
  - The requirements are often ‘shall not’ rather than ‘shall’ requirements.
- Differences
  - No well-defined notion of a security life cycle for security management; No standards;
  - Generic threats rather than system specific hazards;
  - Mature security technology (encryption, etc.). However, there are problems in transferring this into general use;
  - The dominance of a single supplier (Microsoft) means that huge numbers of systems may be affected by security failure.

The security specification process



Stages in security specification

- Asset identification and evaluation
  - The assets (data and programs) and their required degree of protection are identified. The degree of required protection depends on the asset value so that a password file (say) is more valuable than a set of public web pages.
- Threat analysis and risk assessment
  - Possible security threats are identified and the risks associated with each of these threats is estimated.
- Threat assignment
  - Identified threats are related to the assets so that, for each identified asset, there is a list of associated threats.

Stages in security specification

- Technology analysis
  - Available security technologies and their applicability against the identified threats are assessed.
- Security requirements specification
  - The security requirements are specified. Where appropriate, these will explicitly identified the security technologies that may be used to protect against different threats to the system.

Types of security requirement

- Identification requirements.
- Authentication requirements.
- Authorisation requirements.
- Immunity requirements.
- Integrity requirements.
- Intrusion detection requirements.
- Non-repudiation requirements.
- Privacy requirements.
- Security auditing requirements.
- System maintenance security requirements.

LIBSYS security requirements

SEC1: All system users shall be identified using their library card number and personal password.

SEC2: Users privileges shall be assigned according to the class of user (student, staff, library staff).

SEC3: Before execution of any command, LIBSYS shall check that the user has sufficient privileges to access and execute that command.

SEC4: When a user orders a document, the order request shall be logged. The log data maintained shall include the time of order, the user's identification and the articles ordered.

SEC5: All system data shall be backed up once per day and backups stored off-site in a secure storage area.

SEC6: Users shall not be permitted to have more than 1 simultaneous login to LIBSYS.

System reliability specification

- *Hardware reliability*
  - What is the probability of a hardware component failing and how long does it take to repair that component?
- *Software reliability*
  - How likely is it that a software component will produce an incorrect output? Software failures are different from hardware failures in that software does not wear out. It can continue in operation even after an incorrect result has been produced.
- *Operator reliability*
  - How likely is it that the operator of a system will make an error?

Functional reliability requirements

- A predefined range for all values that are input by the operator shall be defined and the system shall check that all operator inputs fall within this predefined range.
- The system shall check all disks for bad blocks when it is initialised.
- The system must use N-version programming to implement the braking control system.
- The system must be implemented in a safe subset of Ada and checked using static analysis.

Non-functional reliability specification

- The level of system reliability required *should be verifiable*, hence, *expressed quantitatively*.
- Reliability is a *dynamic system attribute*- reliability specifications related to the source code are meaningless.
  - No more than N faults/1000 lines;
  - This is only useful for a post-delivery process analysis where you are trying to assess how good your development techniques are.
- An appropriate reliability metric should be chosen to specify the overall system reliability.

Reliability metrics

- Reliability metrics are units of measurement of system reliability.
- *System reliability is measured by counting the number of operational failures and, where appropriate, relating these to the demands made on the system and the time that the system has been operational*.
- A *long-term measurement programme* is required *to assess the reliability of critical systems*.

Reliability metrics

- ***Probability of failure on demand (POFOD):*** *The likelihood that the system will fail when a service request is made.* A POFOD of 0.001 means that 1 out of a thousand service requests may result in failure.
- ***Rate of failure occurrence (ROCOF):*** *The frequency of occurrence with which unexpected behaviour is likely to occur.* A ROCOF of 2/100 means that 2 failures are likely to occur in each 100 operational time units. This metric is sometimes called the failure intensity.
- ***Mean time to failure (MTTF):*** *The average time between observed system failures.* An MTTF of 500 means that 1 failure can be expected every 500 time units.
- ***Availability (AVAIL):*** *The probability that the system is available for use at a given time.* Availability of 0.998 means that in every 1000 time units, the system is likely to be available for 998 of these.

Probability of failure on demand

- This is the probability that the system will fail when a service request is made. Useful when demands for service are intermittent and relatively infrequent.
- Appropriate for protection systems where services are demanded occasionally and where there are serious consequence if the service is not delivered.
- Relevant for many safety-critical systems with exception management components
  - Emergency shutdown system in a chemical plant.

Rate of fault occurrence (ROCOF)

- Reflects the rate of occurrence of failure in the system.
- ROCOF of 0.002 means 2 failures are likely in each 1000 operational time units e.g. 2 failures per 1000 hours of operation.
- Relevant for operating systems, transaction processing systems where the system has to process a large number of similar requests that are relatively frequent
  - Credit card processing system, airline booking system.

Mean time to failure

- Measure of the time between observed failures of the system. Is the reciprocal of ROCOF for stable systems.
- MTTF of 500 means that the mean time between failures is 500 time units.
- Relevant for systems with long transactions i.e. where system processing takes a long time. MTTF should be longer than transaction length
  - Computer-aided design systems where a designer will work on a design for several hours, word processor systems.

Availability

- Measure of the fraction of the time that the system is available for use.
- Takes repair and restart time into account
- Availability of 0.998 means software is available for 998 out of 1000 time units.
- Relevant for non-stop, continuously running systems
  - telephone switching systems, railway signalling systems.

Non-functional requirements spec.

- Reliability measurements do NOT take the consequences of failure into account.
- Transient faults may have no real consequences but other faults may cause data loss or corruption and loss of system service.
- May be necessary to identify different failure classes and use different metrics for each of these. The reliability specification must be structured.

Failure consequences

- When specifying reliability, it is not just the number of system failures that matter but the consequences of these failures.
- Failures that have serious consequences are clearly more damaging than those where repair and recovery is straightforward.
- In some cases, therefore, different reliability specifications for different types of failure may be defined.

Failure classification

Failure class	Description
Transient	Occurs only with certain inputs
Permanent	Occurs with all inputs
Recoverable	System can recover without operator intervention
Unrecoverable	Operator intervention needed to recover from failure
Non-corrupting	Failure does not corrupt system state or data
Corrupting	Failure corrupts system state or data

Steps to a reliability specification

- For each sub-system, analyse the consequences of possible system failures.
- From the system failure analysis, partition failures into appropriate classes.
- For each failure class identified, set out the reliability using an appropriate metric. Different metrics may be used for different reliability requirements.
- Identify functional reliability requirements to reduce the chances of critical failures.

Bank auto-teller system

- Each machine in a network is used 300 times a day
- Bank has 1000 machines
- Lifetime of software release is 2 years
- Each machine handles about 200, 000 transactions
- About 300, 000 database transactions in total per day

Reliability specification for an ATM

Failure class	Example	Reliability metric
Permanent, non-corrupting.	The system fails to operate with any card that is input. Software must be restarted to correct failure.	ROCOF 1 occurrence/1000 days
Transient, non-corrupting	The magnetic stripe data cannot be read on an undamaged card that is input.	ROCOF 1 in 1000 transactions
Transient, corrupting	A p attern of transactions across the network causes database corruption.	Unquantifiable! Should never happen in the lifetime of the system

Specification validation

- It is impossible to empirically validate very high reliability specifications.
- No database corruptions means POFOD of less than 1 in 200 million.
- If a transaction takes 1 second, then simulating one day's transactions takes 3.5 days.
- It would take longer than the system's lifetime to test it for reliability.