

# CS\_313 High Integrity Systems/ CS\_M13 Critical Systems

Course Notes

Additional Material

## Chapter 5: The Development Cycle for Safety-Critical Systems

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<http://www.cs.swan.ac.uk/~csetzer/lectures/critsys/14/index.html>

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5 (a) Life Cycle Models

5 (b) The Safety Life Cycle

5 (c) Development Methods

5 (d) Designing for Safety

5 (e) Human Factors in Safety

5 (f) Safety Analysis

5 (g) Safety Management

5 (h) The Safety Case

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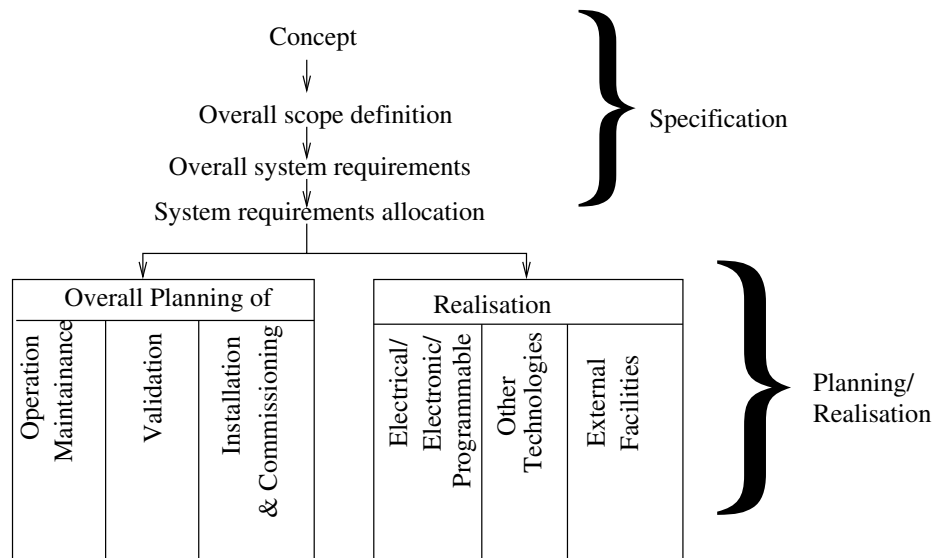
5 (g) Safety Management

5 (h) The Safety Case

## Model from IEC 1508

- ▶ This is a model from the International Electrotechnical Commission (IEC).
- ▶ The IEC 1508 standard is intended to be a generic basis for standards in all industrial sectors.
- ▶ It has three phases:
  - ▶ Design,
  - ▶ planning/realisation
  - ▶ installation/operation
- ▶ Standard describes in detail
  - ▶ the activities to be performed during each phase of the life cycle,
  - ▶ the expected inputs and outputs of each phase.

## Development Life Cycle Part 1 (IEC 1508)



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Sect. 5 (a)

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5 (a) Life Cycle Models

## Other Life Cycle Models

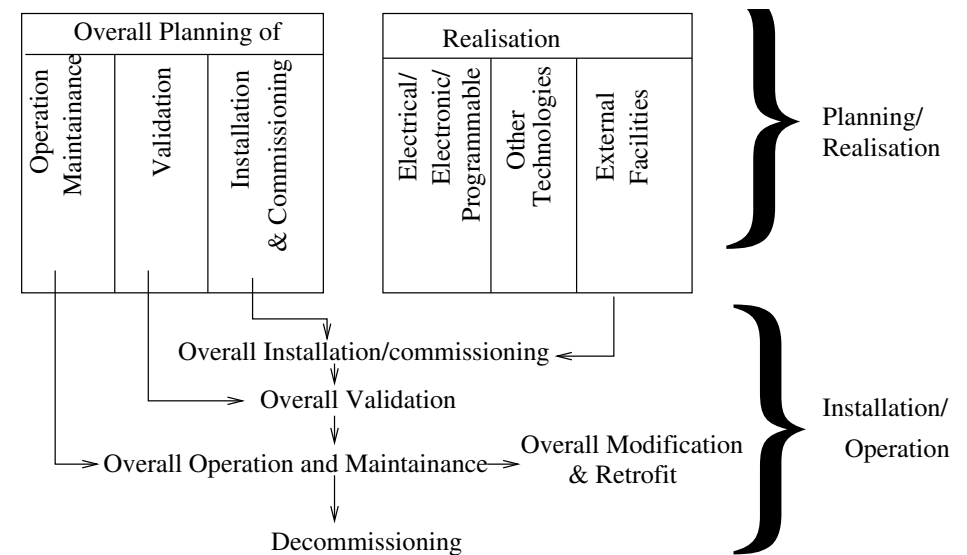
- Probably more modern **iterative models** like the **spiral model** are used nowadays in safety critical systems as well.
  - They need some adaption since they might be as they stand too loose about requirements analysis and specification.

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## Development Life Cycle Part 2 (IEC 1508)



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5 (b) The Safety Life Cycle

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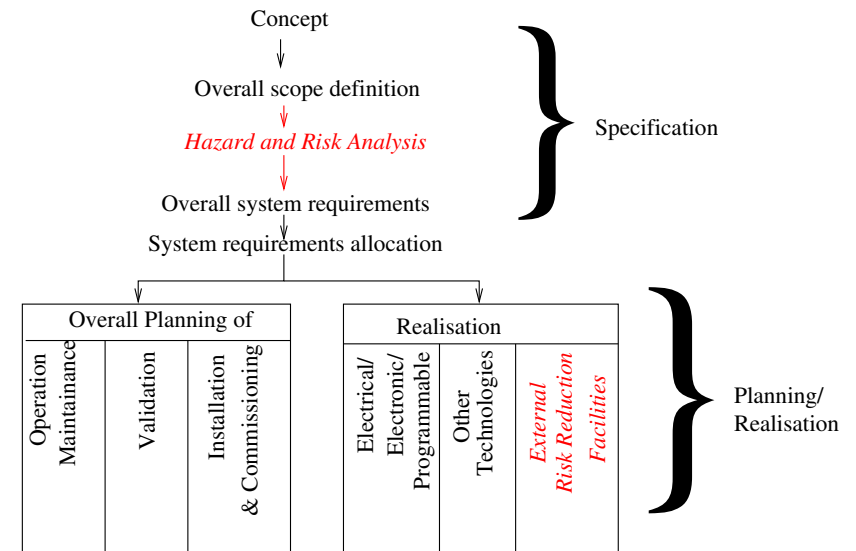
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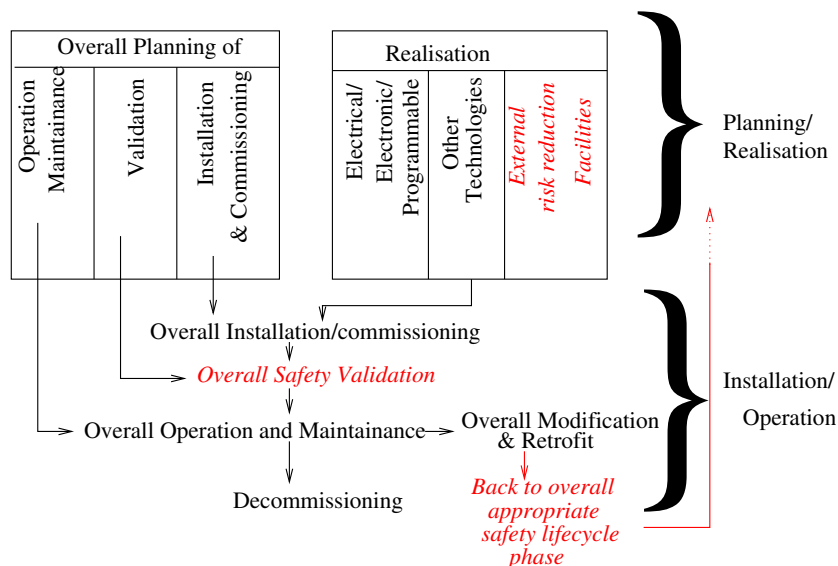
## (b) The Safety Life Cycle

- ▶ The safety life cycle is the process of safety specification and assurance.
- ▶ The next slide describes the safety life cycle according to IEC 1508.
  - ▶ It is very similar to the life cycle model of the IEC 1508.
  - ▶ Differences are marked in *red italic*.

## Safety Life Cycle Part 1 (IEC 1508)



## Safety Life Cycle Part 2 (IEC 1508)



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## (c) Development Methods

- ▶ Main elements of the development process of safety critical systems are similar to that of less critical units.
- ▶ However, the need to produce and demonstrate dependability requires that each phase is carefully structured and documented.

## Specification

See main slides

## Requirements and Hazard Analysis

- ▶ Was already discussed.

## Animation and Prototyping

- ▶ Problem of validation of specifications.
- ▶ Cannot be done formally.
- ▶ Two approaches of tackling that problem are **software animation** and **prototyping**.
- ▶ **Software prototyping** means that one builds a prototype based on the specification in order to test it.
  - ▶ Problem is that the prototype is **removed from the specification**.
  - ▶ The prototype is only one example of implementing the specification.
  - ▶ Further, when building the prototype, one might not interpret the specification correctly.  
Therefore the prototype might not fully fulfil the specification.

## Animation and Prototyping

- ▶ **Software animation** means that one directly executes or tests the specification.
  - ▶ For instance, one can check what happens if one specialises the specification to some instance, and if one executes an operation specified.
  - ▶ **Advantage** is that one works directly with the specification.
  - ▶ The **disadvantage** is that software animation might not be as concrete as prototyping.
    - ▶ One usually doesn't obtain a real system.

## Top-Level Design

- ▶ In top-level design, the following steps are carried out:
  - ▶ **Partitioning** of system functions into those carried out by hardware and those carried out by software.
  - ▶ **Decomposition** of hardware and software architecture into manageable modules.
    - ▶ Determination of interfaces between modules.
    - ▶ Specification of functions and safety features of each module.
  - ▶ **Identification of major data structures** within the software.

## Animation vs. Simulation

- ▶ Animation/prototyping are different from **simulation**.
  - ▶ **Simulation** is the development of trial software based on the design of the software, in order to test it.
  - ▶ Animation is a test of the specification.
  - ▶ Simulation is a test of the design.

## Detailed Design

- ▶ The detailed design precedes the actual implementation of the software.
- ▶ First one gathers information about the module and makes initial decisions about its form.
  - ▶ One concentrates in this period on what the module has to do rather than how this is achieved.

## Detailed Design

- ▶ The data gathered is as follows:
  - ▶ **Purpose** of the module, including primary and secondary requirements.
    - ▶ Includes behaviour in exceptional situations.
  - ▶ **Data use.**
    - ▶ Input.
    - ▶ Output.
    - ▶ External data shared with other modules.
    - ▶ Internal data shared by the functions of the module.
  - ▶ **Performance**
    - ▶ Time and space constraints of the module.
    - ▶ Often overlooked.

## Detailed Design

- ▶ Once the above data has been collected, the units are decomposed into smaller and smaller modules, until modules which can be implemented directly have been identified.

## Detailed Design

- ▶ **Fault conditions**
  - ▶ Failures which might occur within the module and its interfaces.
  - ▶ Conditions under which a failure mode can occur have to be identified.
- ▶ **Integrity level**
  - ▶ Which integrity level is to be assigned to that module.
- ▶ **Testing.**
  - ▶ Identification of, what conditions have to be verified by testing, and what level of correctness is to be achieved.

## Module Implementation and Testing

- ▶ Once the smallest units have been identified, they will be implemented.
- ▶ Special techniques used in implementing, e.g. **defensive programming**.
  - ▶ **Defensive programming** means that one adds extra tests, even if one assumes that they are not necessary, in order to catch programming errors as early as possible.
    - ▶ E.g. even if one assumes that an input parameter is always  $\geq 0$ , one still deals with the case that it might be  $< 0$ .
- ▶ Then modules will be tested, see Section 8.

## System Integration

- ▶ System integration means to assemble the complete system from its component modules.
- ▶ Then initial testing is performed, before progressing to full system testing and validation.
- ▶ There are two main techniques for system integration:
  - ▶ **Progressive integration.**
  - ▶ **The big bang method.**

## Progressive Integration

- ▶ **Disadvantage:**
  - ▶ Problems, associated with the overall system are not visible, until the complete system is assembled.
  - ▶ Then it is very expensive to deal with these problems.

## Progressive Integration

- ▶ In **progressive integration**
  - ▶ One starts with combining a small number of modules,
    - ▶ which are then tested, and problems are removed.
  - ▶ Then additional modules are added successively,
    - ▶ which are tested, and problems are removed.
  - ▶ This is done until the complete system is assembled.
- ▶ **Advantage:**
  - ▶ Problems observed in testing only involve the few modules added in the last incrementation step.
    - ▶ Therefore the reasons for those problems can be more easily identified.

## Big Bang Method

- ▶ In the **big bang method**, all modules are combined immediately, and the complete system is tested.
  - ▶ Assumption is that the design of the overall system was done carefully and that each unit was tested thoroughly.
  - ▶ Then integration shouldn't cause big problems.
- ▶ Advantages and disadvantages of the big bang method are the opposite of those for progressive integration.
- ▶ Big bang approach less common than progressive integration.

## System Test and Certification

- ▶ System testing will be treated later.
- ▶ In the certification, the development process of the system is carefully investigated
  - ▶ Usually based on some form of standard.
  - ▶ The developer has to convince the regulators that all relevant hazards have been identified and dealt with.
  - ▶ The certification process **does not**
    - ▶ prove the correctness of the system,
    - ▶ remove any of the developer's legal or moral obligations.
  - ▶ However the certification process promotes the use of approved techniques and will usually lead to safer products.

## (d) Designing for Safety

- ▶ We consider the design process with respect to safety of the overall system.
- ▶ There are four activities in the design process:
  - ▶ **Abstraction**
    - ▶ The operation of generalising and identifying the essentials.
  - ▶ **Decomposition**
    - ▶ The process of reducing an object into a number of simpler, smaller parts.
    - ▶ The analysis of interactions, interfaces and structures.
    - ▶ Modularisation.

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## Activities of the Design Proc. (Cont.)

- ▶ **Elaboration**
  - ▶ The operation of detailing, adding features.
- ▶ **Decision making**
  - ▶ Identification and selection of alternative strategies.



## Software Partitioning, Safety Kernel

This material can be found in the main slides.

## Isolation of Modules and Parallel.

- ▶ Isolation of modules requires as well that **no module can block** other modules by getting hung up.
  - ▶ By getting hung up one module with low criticality
    - ▶ e.g. a module responsible for communications in a space craft, could block another highly critical module, which operates in parallel, but is not related with the other module.

## Support of Software Isolation

- ▶ Programming languages might or might not support **isolation** of modules
  - ▶ **Assembler** and **C don't support isolation** of modules – all routines are allowed to write to all memory locations.
  - ▶ More **modern languages** like Pascal, Ada or Java **support isolation** of modules in a better way.

## Support of Software Isolation

- ▶ Problems with parallelism can be controlled by **operating systems**, which allocate time to different **threads** and therefore make sure that the system doesn't get hung up with one thread.
  - ▶ **Problematic** to use operating systems, since they are usually too complex in order to be verifiable.
- ▶ Instead one can use **runtime kernels** with a **task scheduler**, which are much smaller than usual operating systems, and have therefore higher level of integrity.
  - ▶ Acceptable for **systems of lower criticality**.

## Support of Software Isolation

- ▶ For **highest critical functions**, use of **runtime kernels** is still **not acceptable**, because they are too complex.
  - ▶ Instead one has to program the critical functions including scheduling completely by hand.

## No Additional Material

For this subsection no additional material has been added yet.

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## (f) Safety Analysis

- ▶ **Safety analysis** is the process of assessing the safety of a system by looking at the associated hazards and the methods used by the system to cope with them.
  - ▶ Also called **overall safety validation**.
- ▶ The next slide gives the steps in safety analysis according to the **Health and Safety Executive (HSE)** in **UK**.

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## Steps in Safety Analysis (HSE)

- (1) **Analyse** the **hazards**.
  - (a) identify the **potential hazards**,
  - (b) evaluate the **events** leading to these hazards.
- (2) **Identify** the **safety-related systems** within the plant.
- (3) **Design** the safety-related system using the safety integrity criteria appropriate for the specific application.
- (4) Carry out a **safety integrity analysis** to assess the level of safety integrity achieved by the safety-related systems.
- (5) **Ensure**, from the analysis of (4), that the **integrity levels** of (3) have been **achieved**.

## (g) Safety Management

- ▶ **Safety management** is the
  - ▶ **planning**,
  - ▶ **organisation**,
  - ▶ **monitoring** and
  - ▶ **evaluation**
 of safety aspects of a project.

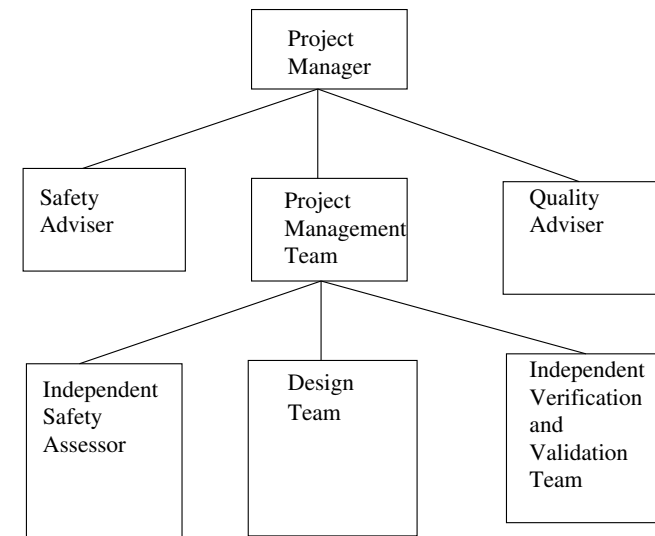
## Essentials of Safety Management

- ▶ In order to achieve a high degree of safety it is important that
  - ▶ a **safety culture** is encouraged **from the top**;
  - ▶ a well-defined **safety policy** exists in order to establish the working practices of the organisation and to ensure that these are followed;
  - ▶ **safety performance** is monitored
    - ▶ both **in-house** and by using **independent assessments** of safety systems and procedures.
- ▶ The next slide shows the management structure recommended by Interim Defence Standard 00-55 (MoD, UK, 1991).

## Safety Management Structure

- ▶ **Project Manager** bears ultimate responsibility for development of the system and its safety.
- ▶ The project manager delegates much of the task of developing the system to the **project management team**.
- ▶ This team
  - ▶ is the **design authority**;
  - ▶ will at the end **sign off** the system on behalf of the project manager;
  - ▶ is primarily responsible for administrating the **safety aspects** of the project.

## Safety Man. Struct. (Int. Def. Stan.)



## Safety Management Structure

- ▶ As part of dealing with the **safety aspects**, the project management team
  - ▶ will perform **hazard** and **risk analysis**;
  - ▶ will ensure that components are developed according to an appropriate **integrity level**;
  - ▶ will perform **verification** at each phase of the design;
  - ▶ this includes
    - ▶ preparation of a **safety plan**;
    - ▶ maintenance of the **safety log** (containing the safety activities and results of hazard analyses).

## Safety Management Structure

- ▶ The **design team** carries out the actual specification, design and implementation of the system.
- ▶ The **independent safety assessor**
  - ▶ reviews and audits all activities and documents relevant to safety.
  - ▶ provides an independent check on the activities of the project management team.
- ▶ The **independent verification and validation team (IV&V team)**
  - ▶ looks at the design at each stage;
  - ▶ provides separate check on its correctness.
  - ▶ Often, the IV&V team is from an external company, specialised in that work.
- ▶

## (h) Safety Management

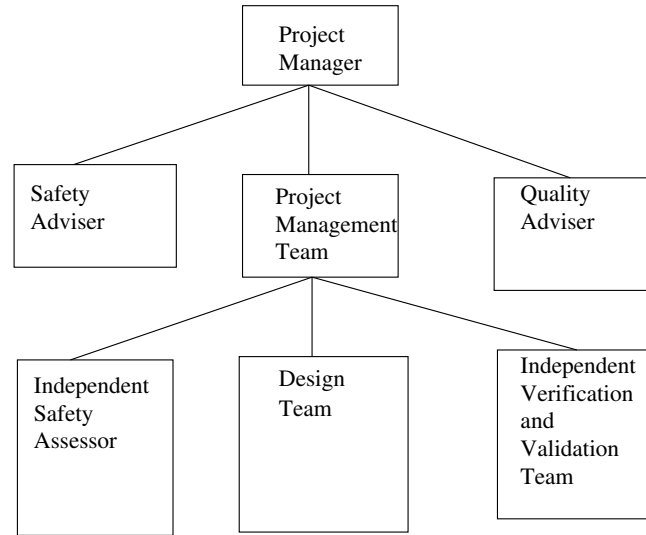
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