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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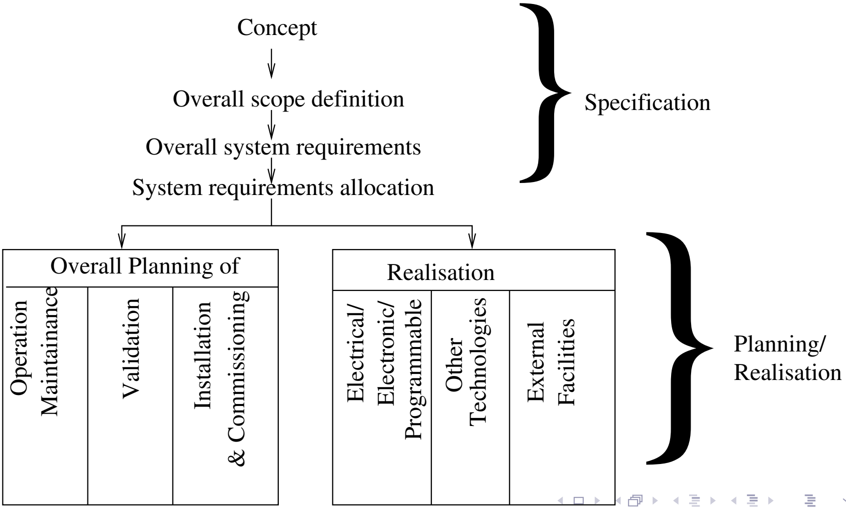
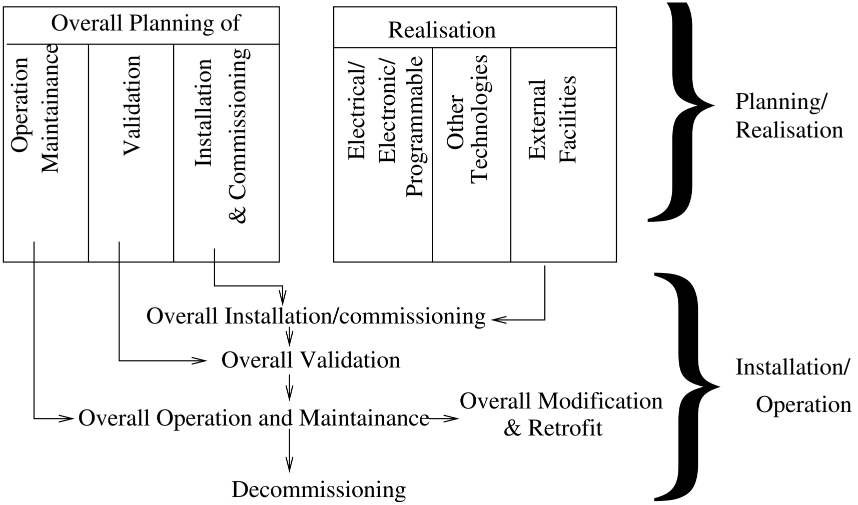
Model from IEC 1508

- This is a model from the International Electrotechnical Commission (IEC).
- The IEC 1508 standard is a 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.

Develoment Life Cycle Part 1 (IEC 1508)



Development Life Cycle Part 2 (IEC 1508)



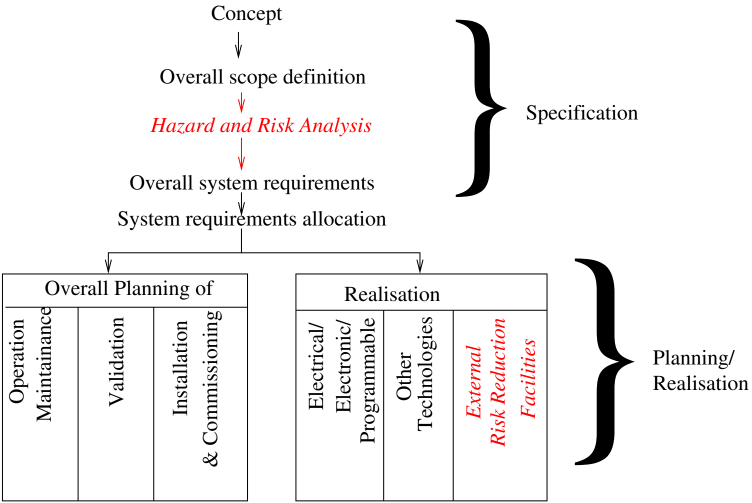
Other Life Cycle Models

- 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.

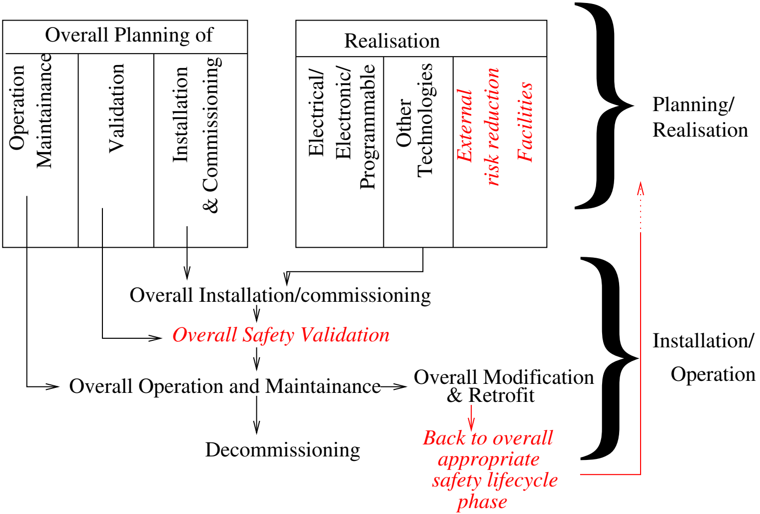
(b) The Safety Life Cycle

- 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)



(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.

Requirements and Hazard Analysis

- Was already discussed.

Specification

See main slides

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.

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.

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.

Detailed Design

- The detailed design precedes the actual implementation of the software.
- First one gathers information about the module and makes initial decisions about it 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

- **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.

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.

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 is always ≥ 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

- 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.

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.

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.

Activities of the Design Proc. (Cont.)

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

Softwer Partitioning, Safety Kernel

This material can be found in the main slides.

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.

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

- 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.

(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**.

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

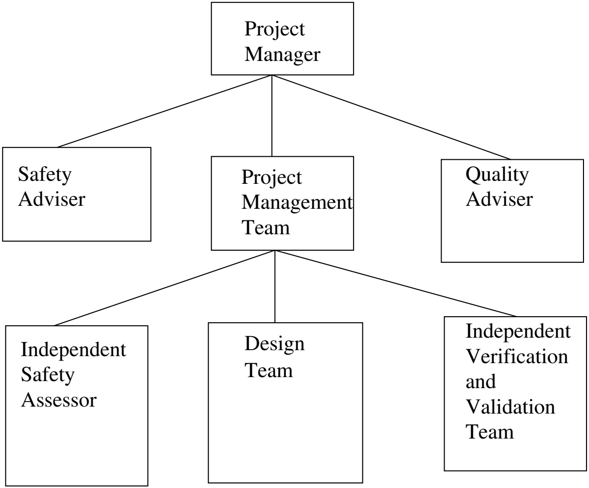
- **Safety management** is the
  - **planning,**
  - **organisation,**
  - **monitoring** and
  - **evaluation**

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



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 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.
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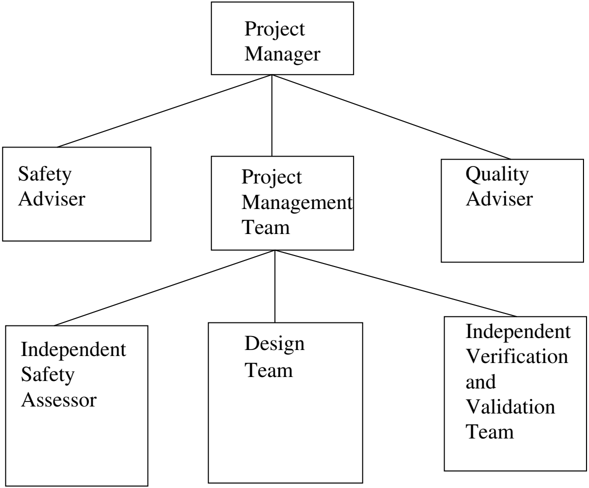

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