23: Safety-critical systems

Therac-25

- Computerized radiation delivery system in the 1980s
- Well-documented* example of how SW process failure can lead to serious consequences
- Great retrospective summary: http://sunnyday.mit.edu/papers/therac.pdf

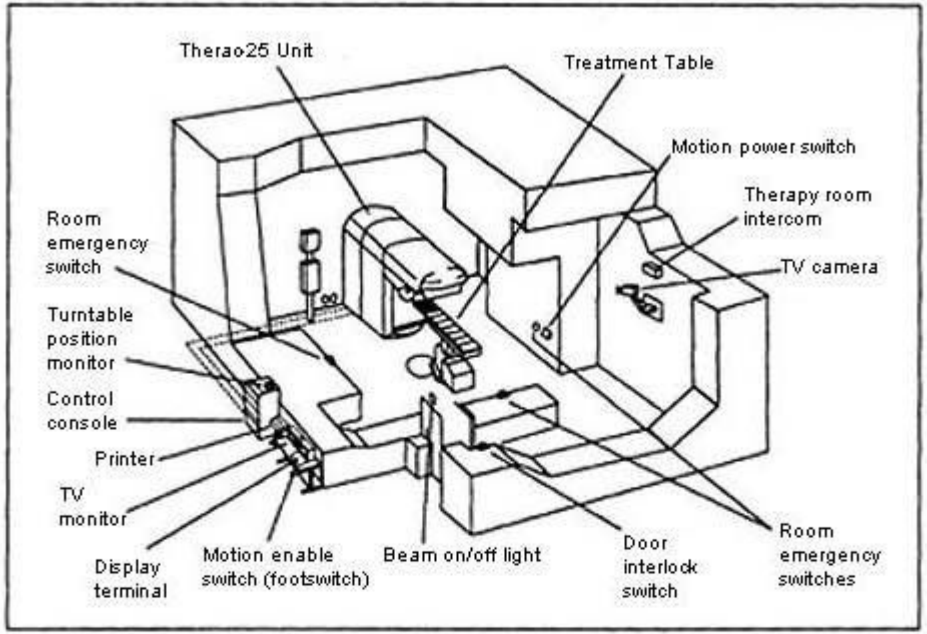


Figure 1. Typical Therac-25 facility

Image source

Therac-25 summary of mistakes

- Homebrew OS, non-atomic mutexes
- Reuse software from Therac-6
- No reviews in software process
- Cryptic error messages that were ignored by operators (false idea that frequent shutdown means system is safe)
- System testing only
- No hardware cross-check
- Overflow for flag variable
- Assumed one bug fix meant system was now safe

Safety-critical systems

Systems where failure of operation can cause serious harm or death

- Direct contact with humans (cars, robots, medical devices)
- Affect human well-being (power plants, HVAC systems)

*Disclaimer: this lecture is a **starting point** for reasoning about safety-critical software. For true safety-critical development, **apply a well-known standard** as part of a safety-focused development culture*

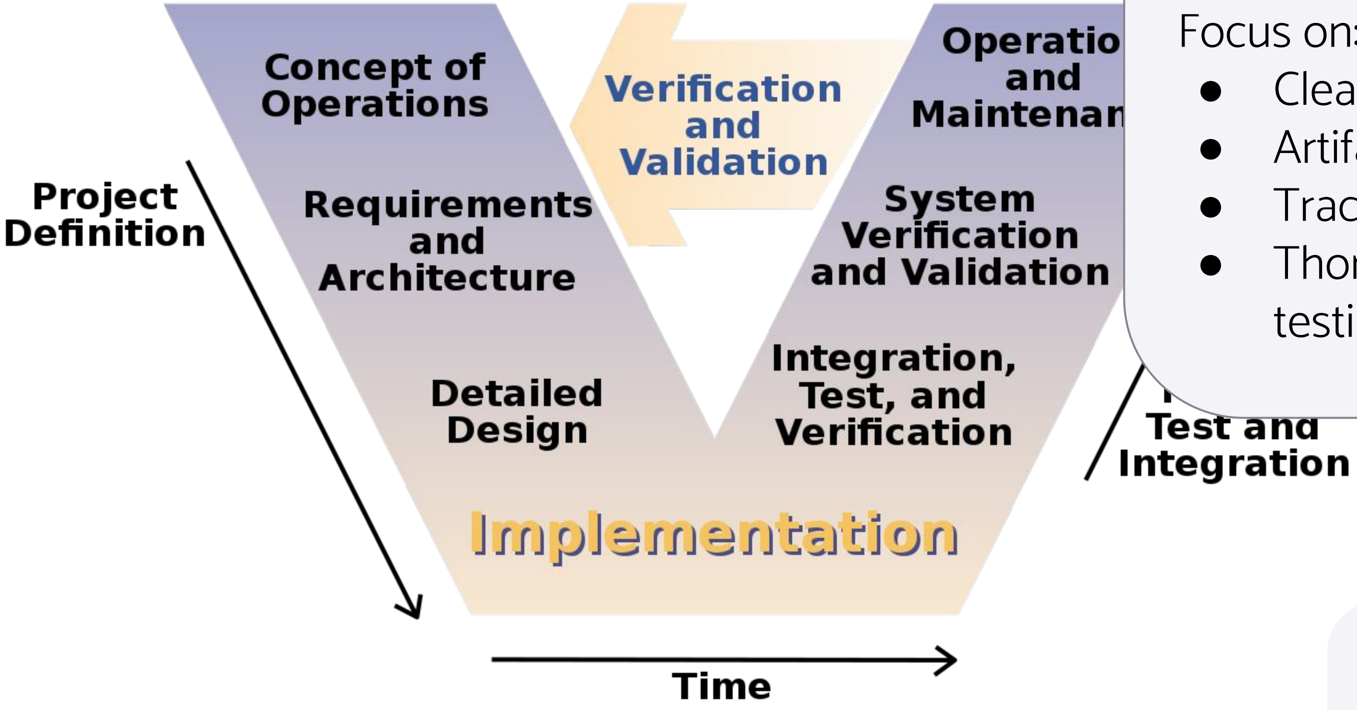
Safety plans and safety requirements

System is assumed unsafe unless engineered for safety

Safety is part of the **entire** SW engineering lifecycle

- If you are only evaluating safety at the testing stage, you are not engineering for safety
- Safety is built-in, not added
- Safety requirements are not an afterthought
- “Working system” is not the same thing as a “safe” system

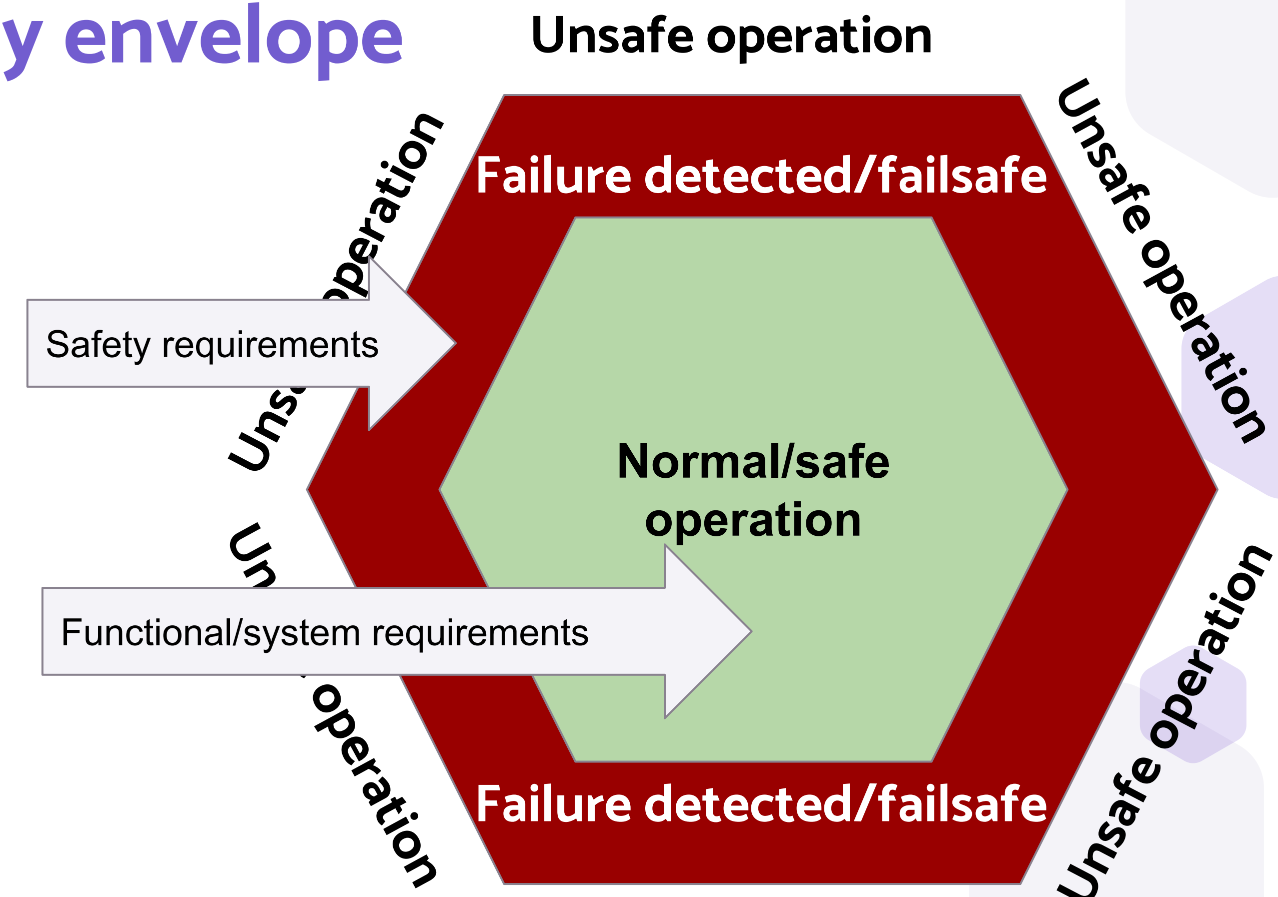
Not all is lost


Concept of Operations
Verification and Validation
Operatio and Maintenan
Project Definition
Requirements and Architecture
System Verification and Validation
Detailed Design
Integration, Test, and Verification
Test and Integration
Implementation
Time

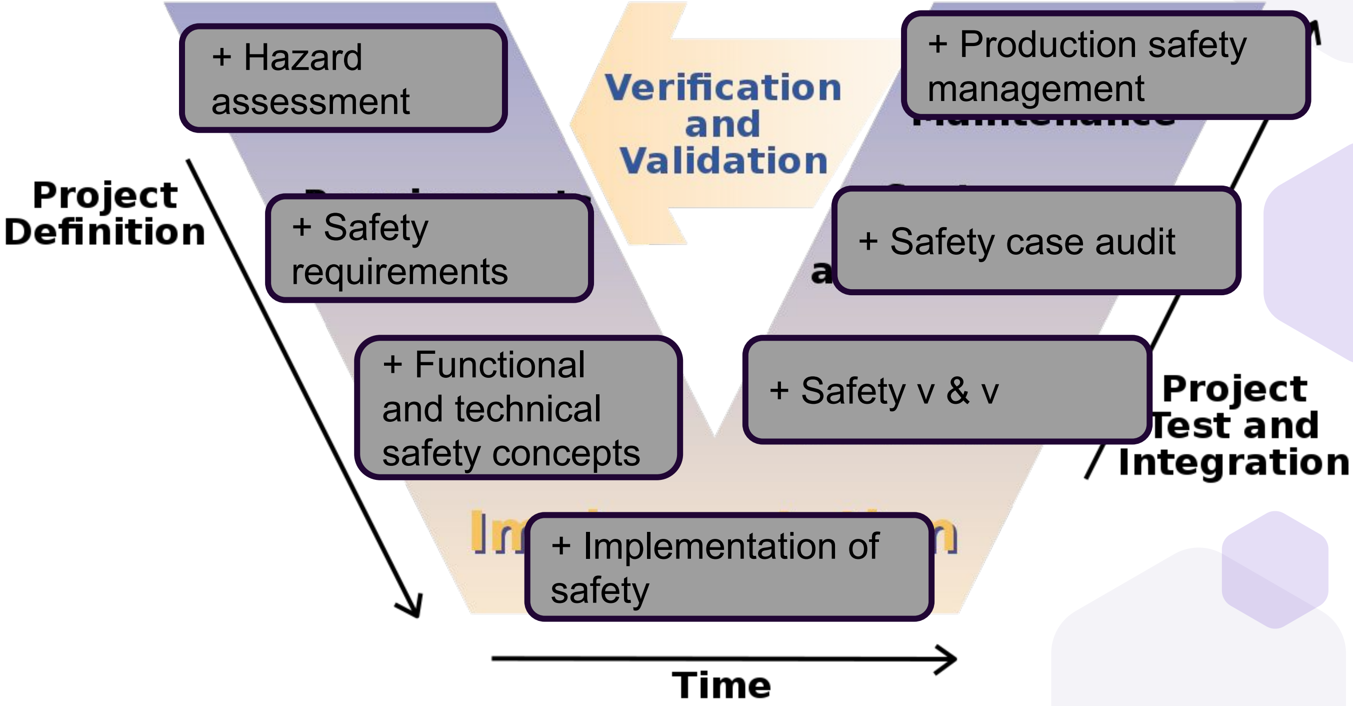
SW engineering process we’ve been learning makes a great foundation for engineering for safety!
Focus on:

- Clear + confirmable design
- Artifacts at every stage
- Traceability between stages
- Thorough peer review and testing

Safety envelope



Safety V model (applies to security as well)

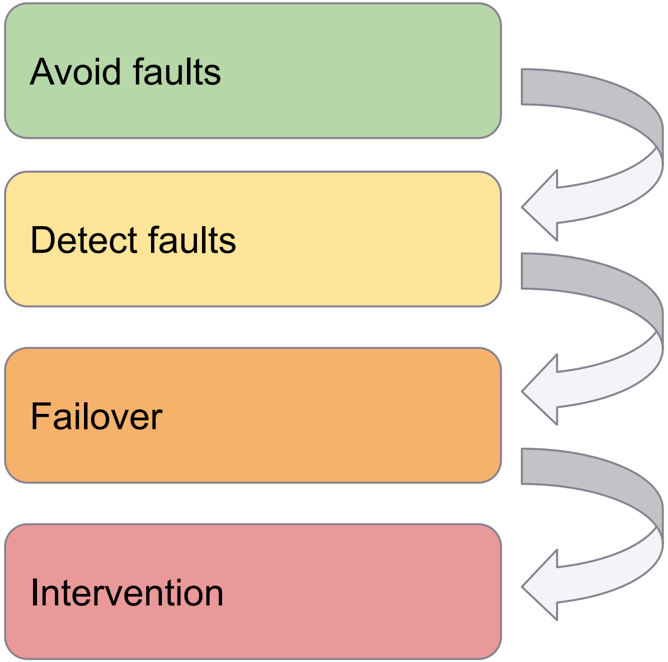


+ Hazard assessment
Verification and Validation
+ Production safety management
Project Definition
+ Safety requirements
+ Safety case audit
+ Functional and technical safety concepts
+ Safety v & v
Project Test and Integration
+ Implementation of safety
Time

What different ways can you think of that an e-scooter (hardware/software) might fail?

Image source

Escalation of safety-critical fault management



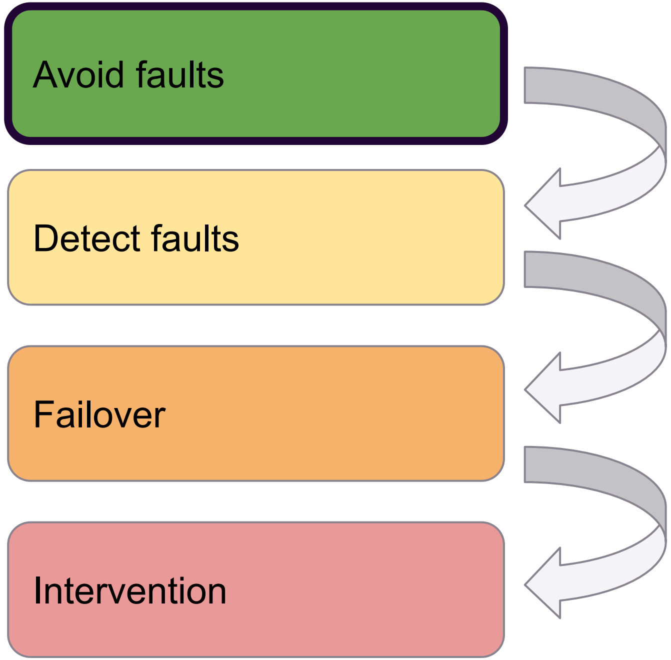
Avoid faults

Detect faults

Failover

Intervention

Escalation of safety-critical fault management



Avoid faults

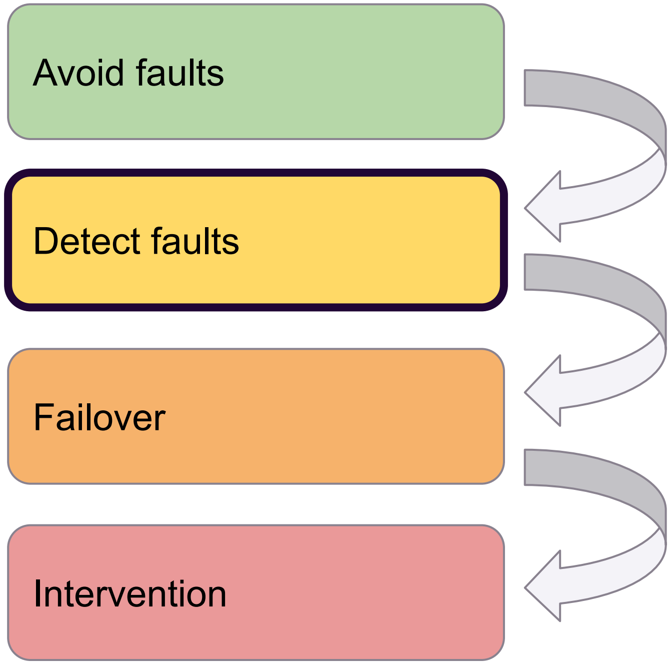
Detect faults

Failover

Intervention

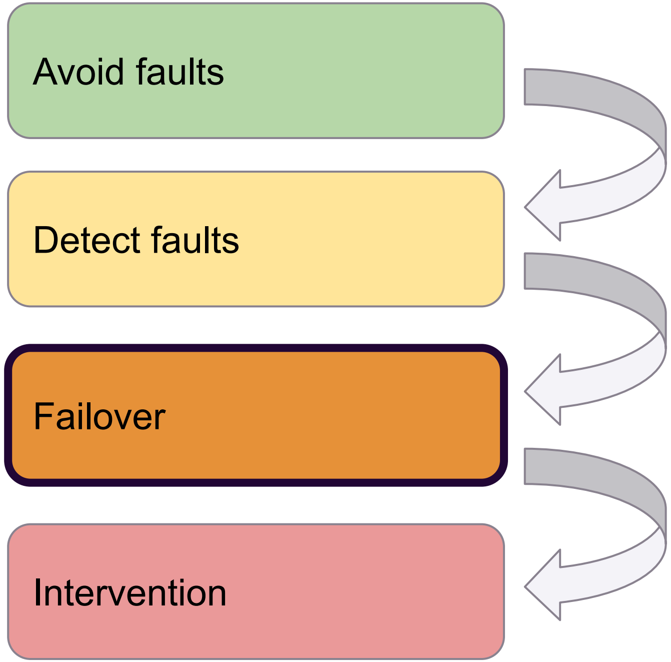
Pick a scooter software failure. How would you avoid it?

Escalation of safety-critical fault management



What are ways you can think of detecting one of the scooter faults?

Escalation of safety-critical fault management



Avoid faults

Detect faults

Failover

Intervention

Single points of failure

A single point of failure happens when a failure of one component renders the entire system unsafe

Avoid single points of failure by using redundancy (later this week)

- Hidden sources of correlation: shared libraries, shared power, shared connections, shared defective requirements....