TDDD07 Real-time Systems

Lecture 9: Dependability & Design

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Two lectures

This lecture and part of lecture 9:

- Basic notions of dependability and redundancy in fault-tolerant systems
- Fault tolerance:
  - Relating faults/redundancy to distributed systems from lectures 4-6
  - Relating timing and fault tolerance

Lecture 9:

- Fault prevention and design aspects

Treatment of faults

- Last lecture: We mentioned four approaches for treating faults in dependable systems

- This lecture:
  1. Fault prevention
  2. Fault removal
  3. Fault tolerance
  4. Fault forecasting

Reading: Section 5.1 & 5.3 of article by Avezienis et al.

Also one article on platform-independent design

System requirements

- Functional requirements
  - Describe the main objectives of the system, referred to as “correct service” earlier
- Extra-functional requirements
  - Also called non-functional properties (NFP)
  - Cover other requirements than those relating to main function, in particular dependability attributes: the frequency and severity of acceptable service failures
- Example NFP
  - Timeliness, availability, energy efficiency

Basic approach

Design for timeliness:

- define end-to-end deadlines
- define deadlines for individual tasks
- ascertain (worst case) execution/communication time for each task/message
- document assumptions/restrictions
- Prove/show that implementation satisfies requirements

So, what is so hard about this?

Layers of design

Application modelling support

Programming environment support

System software support

(kernels, communication protocols)

Hardware support

Fault prevention/removal

Where should we look to find faults prior to operation?

Historical snapshots

- Hardware design
  - 1970´s Dedicated hardware
  - 1980´s Micro computers & ASICS
  - 1990´s High performance Micro computers, FPGAs, MEMs
  - 2000 's SoCware

- Earlier predictable hardware is replaced with components that are complex to analyse (including cache, pipeline)

Layers of design

Application modelling support

Programming environment support

System software support (kernels)

Hardware support

Historical snapshots

- Scheduling principles
  - 1970´s Fixed priority scheduling
  - 1980´s Multiprocessor, Dynamic
  - 1990´s Incorporating shared resources
  - 2000´s Load variations, adaptation
    Multicore scheduling
- OS interfaces to optimise memory management, prefetching instructions to boost performance

Layers of design

Application modelling support

Programming environment support

System software support (kernels)

Hardware support

Historical snapshots

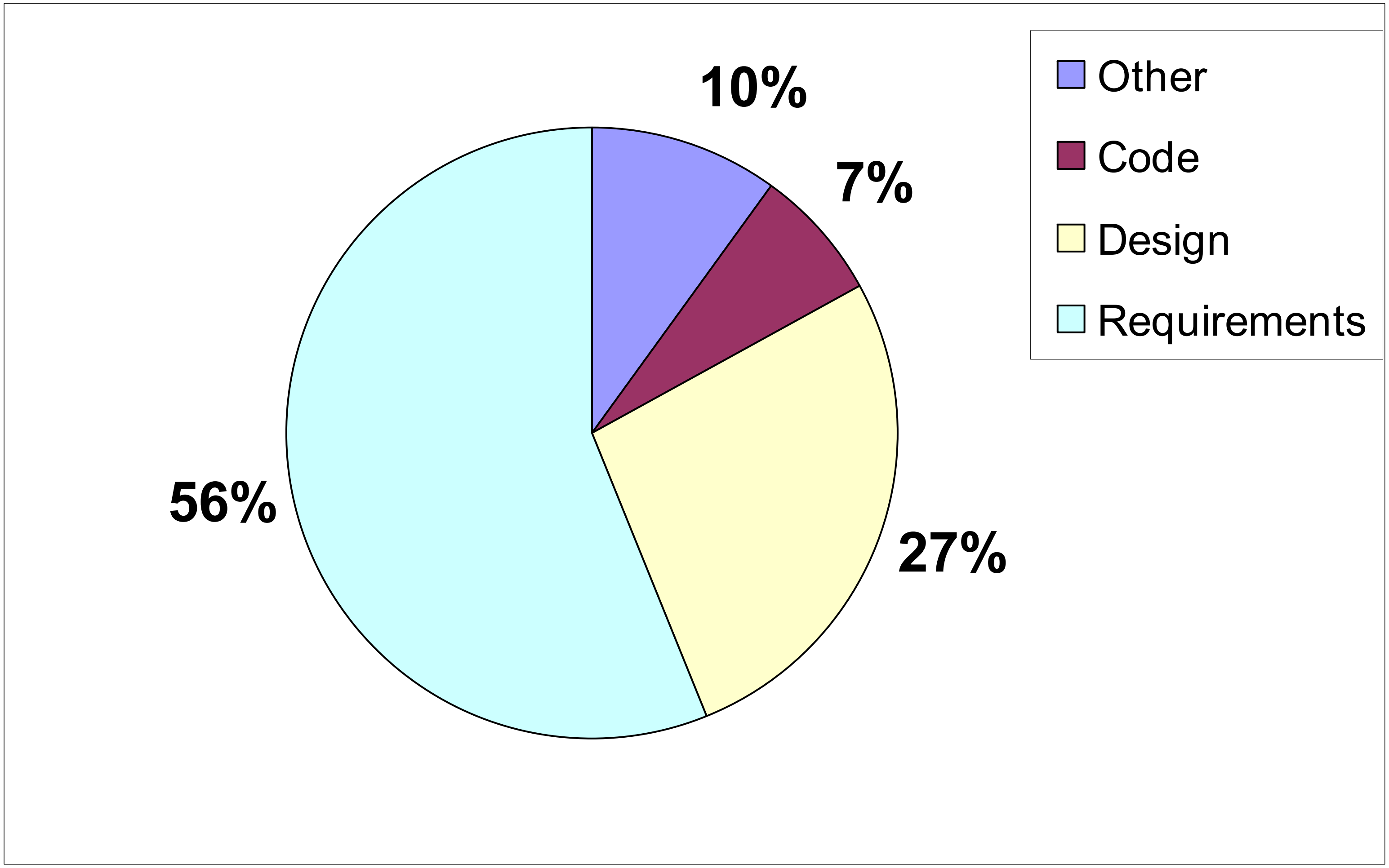
- Programming environments
  - 1970´s "High" level programming
  - 1980´s Real-time specific: Ada
  - 1990´s OO languages, languages with formal semantics
  - 2000´s Software libraries, reuse

- Industry lecture: AUTOSAR components

Engineers: Fool me once, shame on you – fool me twice, shame on me

Software developers: Fool me N times, who cares, this is complex and anyway no one expects software to work...

Frequency of faults



[Jim Cooling 2003, cited from DeMarco78]

Testing does not do …

If a test fails, what was the cause?

- Undocumented assumptions on operational conditions, external impact?
- Wrong program code?
- Unexpected impact of OS functionality?
- Hardware timing dependencies?
- Embedded test code affecting timing?

Platform-independent design

Eliminating “butterfly effect” means trying to isolate the impacts of different layers

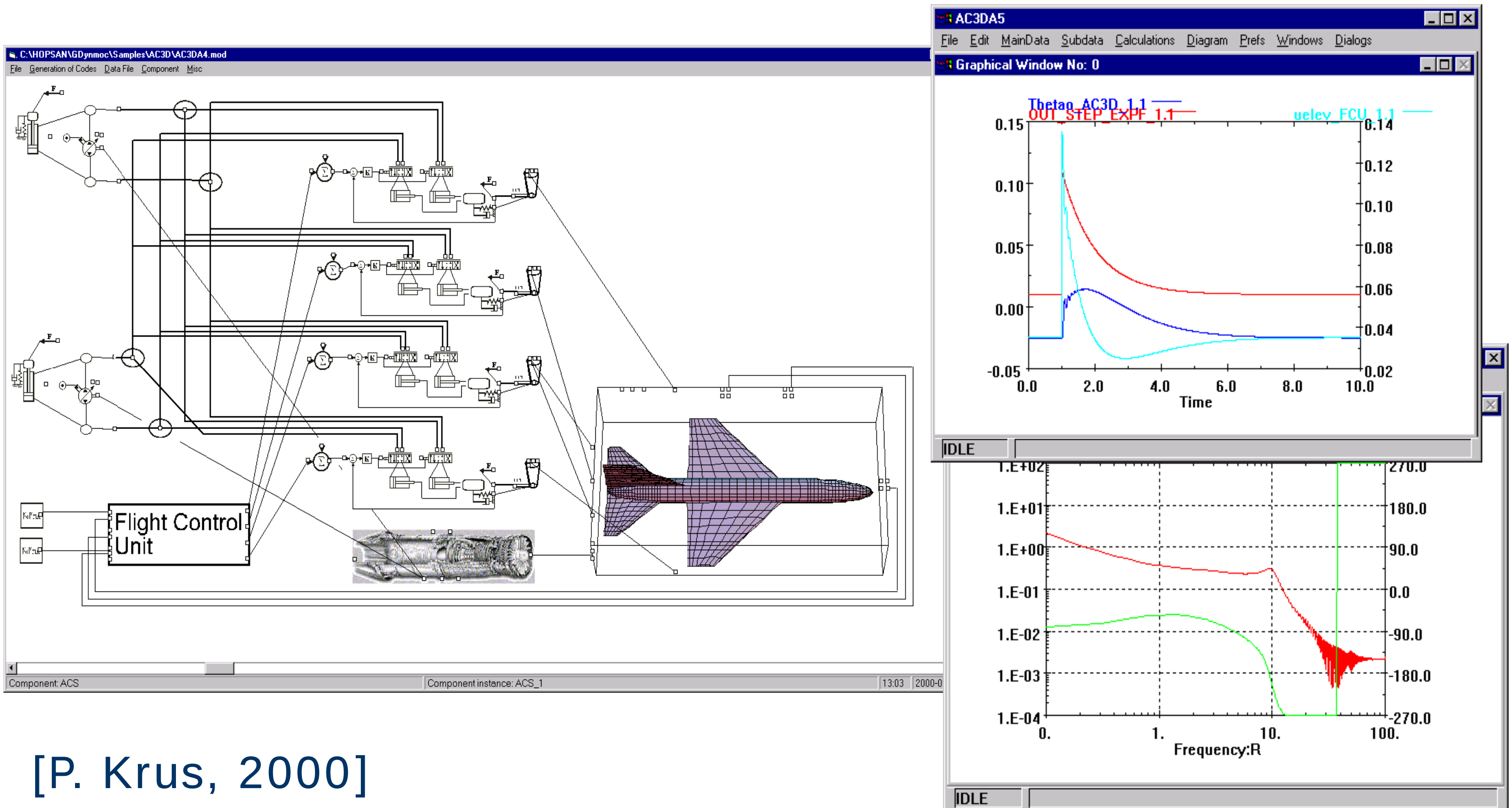
Back to basics

- define end-to-end deadlines
  - Model the environment!
- define deadlines for individual tasks
  - Specify system decomposition!
- ascertain (worst case) execution/communication time for each task/message
  - Assume hardware/bus characteristics!
- document assumptions/restrictions
  - Model, model, model!
- Prove/show that implementation satisfies requirements
  - Analyse models, then test implementation!

An engineering discipline

Using mathematics can never be wrong!

Extensive simulations of coupled aircraft flight dynamics and actuator dynamics



[P. Krus, 2000]

Model-based development

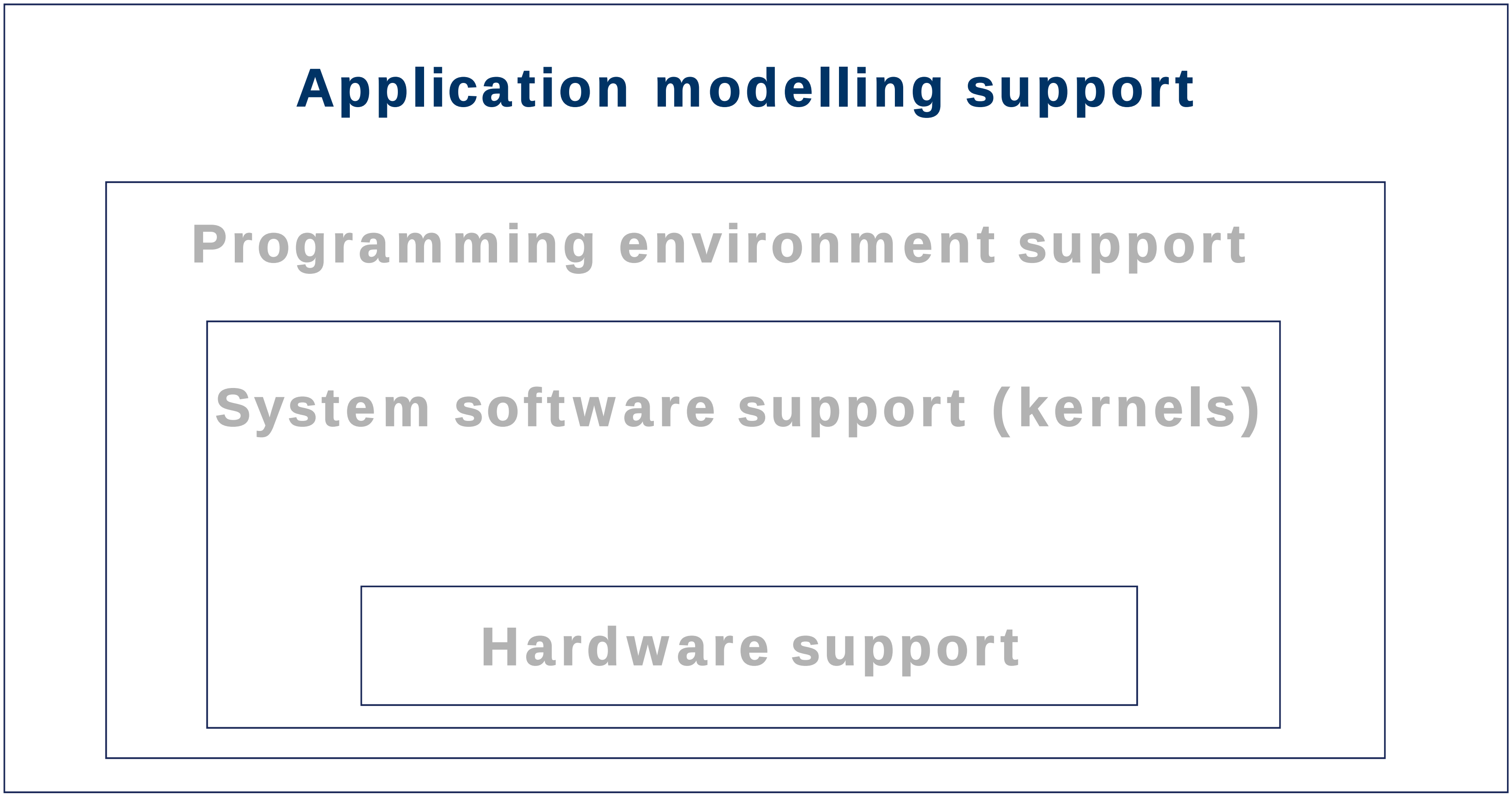
In software-intensive systems:

- Models as “higher level” programs

- Idea: use models to analyse the design, automatically generate code from the model!

- Adequate support for modularisation: Well-tested libraries with well-defined interfaces

Layers of design



Historical snapshots

- Mathematical modelling & analysis tools
  - 1970´s Sequential systems
  - 1980´s Concurrent/Distributed systems
  - 1990´s Timed models, Combining discrete & continuous, UML
  - 2000's Incorporation in CASE tools

- 2012 crossroad: Domain-specific or Unified?

UML standard

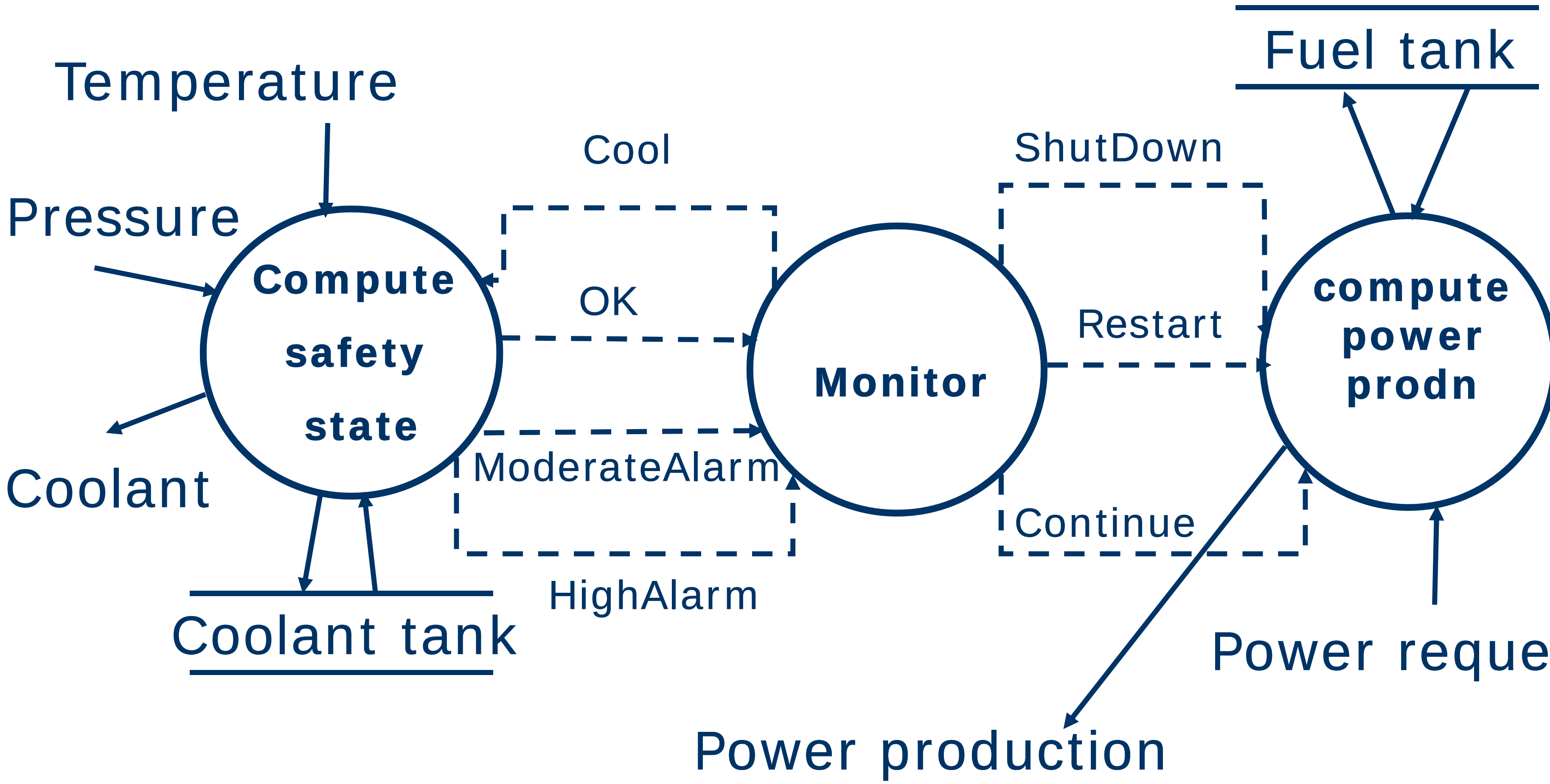
- UML 2.0 models components with required and provided interfaces

- Family of modelling techniques that are a further development of languages in early 80’s, for example: Ward & Mellor Diagrams
- Next two slides from an example

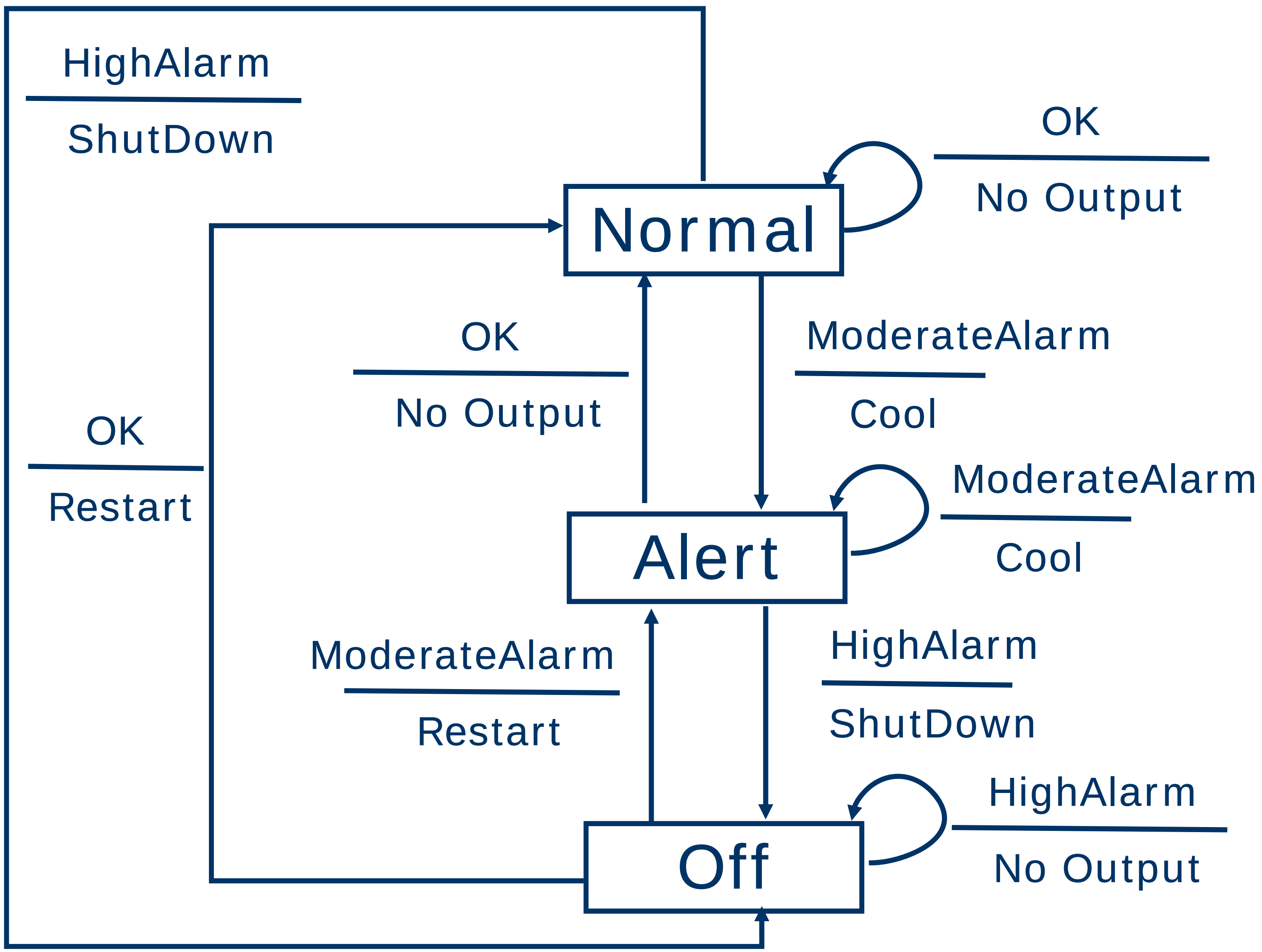
  [Heitmeyer and Mandrioli, Wiley, 1996]

Power plant

- **Transformation schemata for functional part & dynamic monitoring part**



Monitor state machine



What do we want to do with models once we create them?

Advances in 2000's

- Tools to model digital hardware and software components, support for *functional analysis* by
  - Simulations

  and sometimes...
  - Formal verification of functional properties
  - Semi-automatic code generation

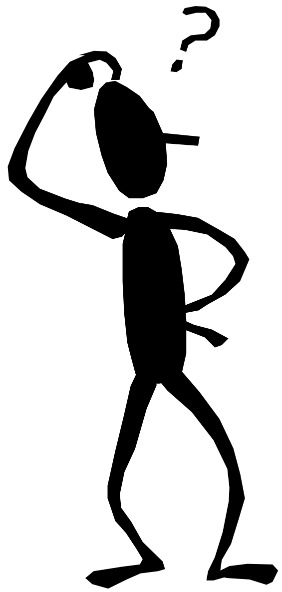
Simulations of a model

Need a unique interpretation:

- The language should be platform-independent
- The language should have (standard) operational semantics to enable "execution" of the model

Simulations

What do they show?



Formal techniques (proofs)

- **Remove** (design) faults that lead to demonstrated bad things
  - debugging the design
- But also **Prove** that *specific* bad things *never* happen
- Can be automated, but suffer from combinatorial explosion

Advanced techniques

- Smart data structures for efficient representation of state space
- Smart deduction engines (satisfiability checkers) that find proofs fast
- Smart abstractions of the design to capture the essential properties
  - Synchronous languages (e.g. Esterel, Lustre), used for Airbus 320 software

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Adding time to UML

- Still in progress...
- No industry-wide tool support

- Recent development: UML profile for Real-time and Embedded Systems (MARTE)

- Meta-models for a class of systems with timing and performance parameters

See case study paper Weissnegger et al.