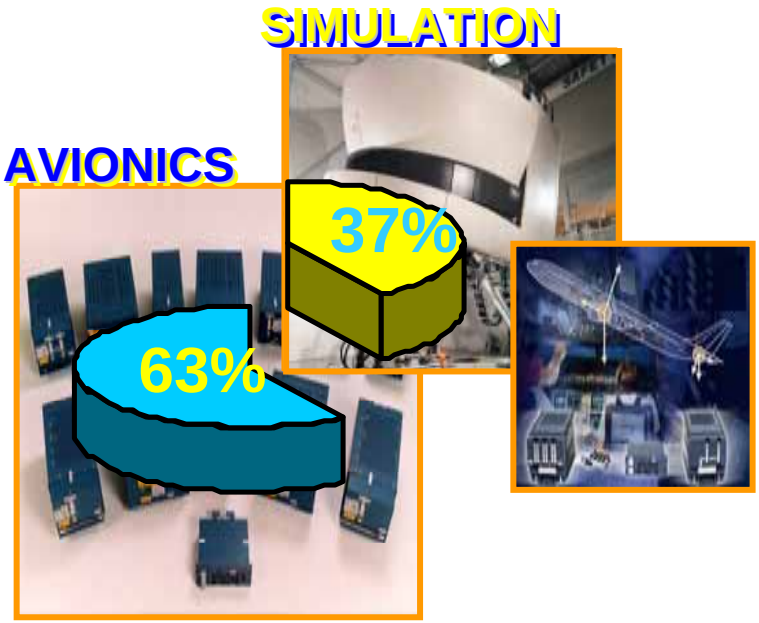
Presented by

Famantanantsoa Randimbivololona

Avionics and Simulation Products
AIRBUS FRANCE

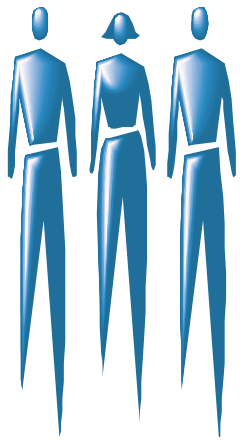
Deploying formal methods ...

Who we are ?



Avionics and Simulation Products

EMPLOYEES



- Electronics : **140**
- Software : **200**
- Manufacturing : **115**
- Other : **220**

Center of Competences for :

- Electronics and on board Software in real time applications
- Avionics and Simulation

Business Center

- Developing and selling products

AIRBUS

Our avionics products

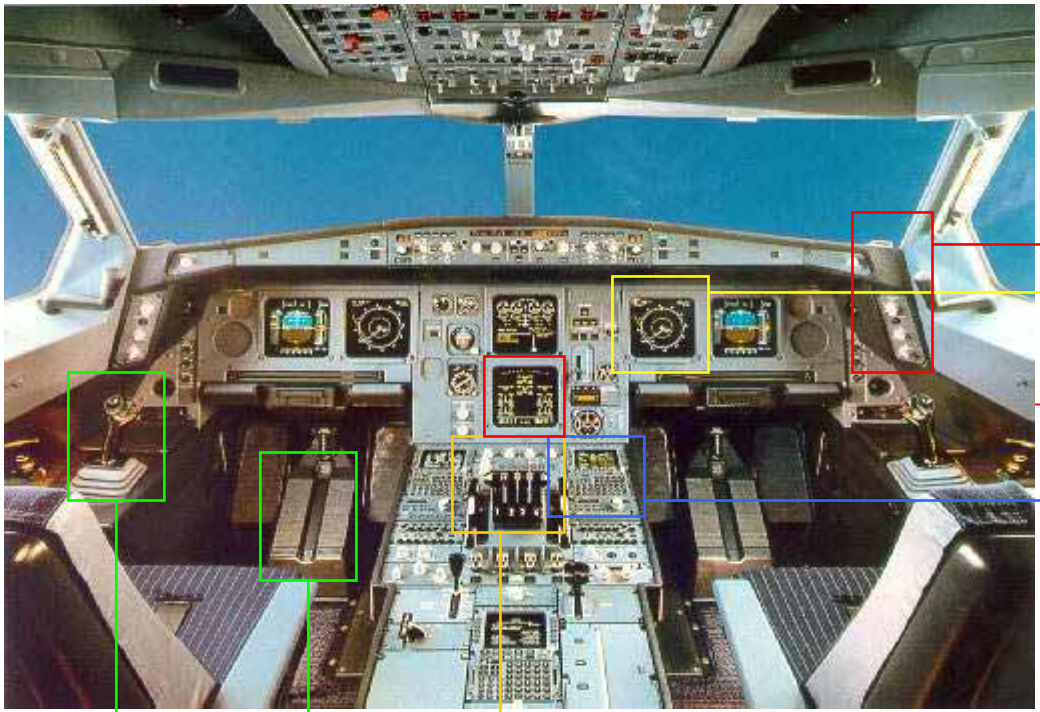
Products / Equipment's sets

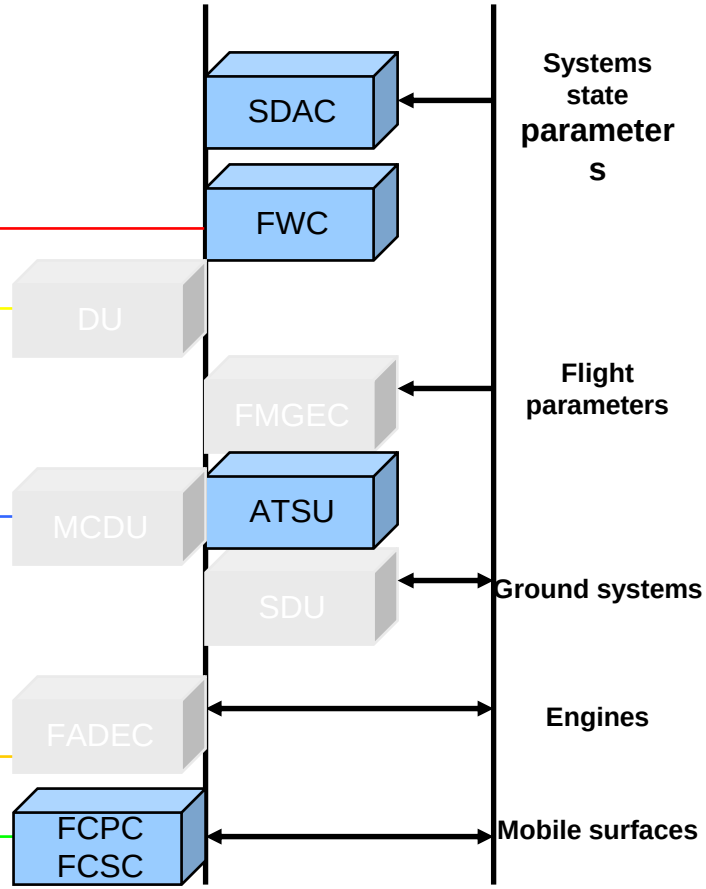
DOMAINS

- Flight control
- Warnings
- Maintenance
- Communication

Elements on avionics

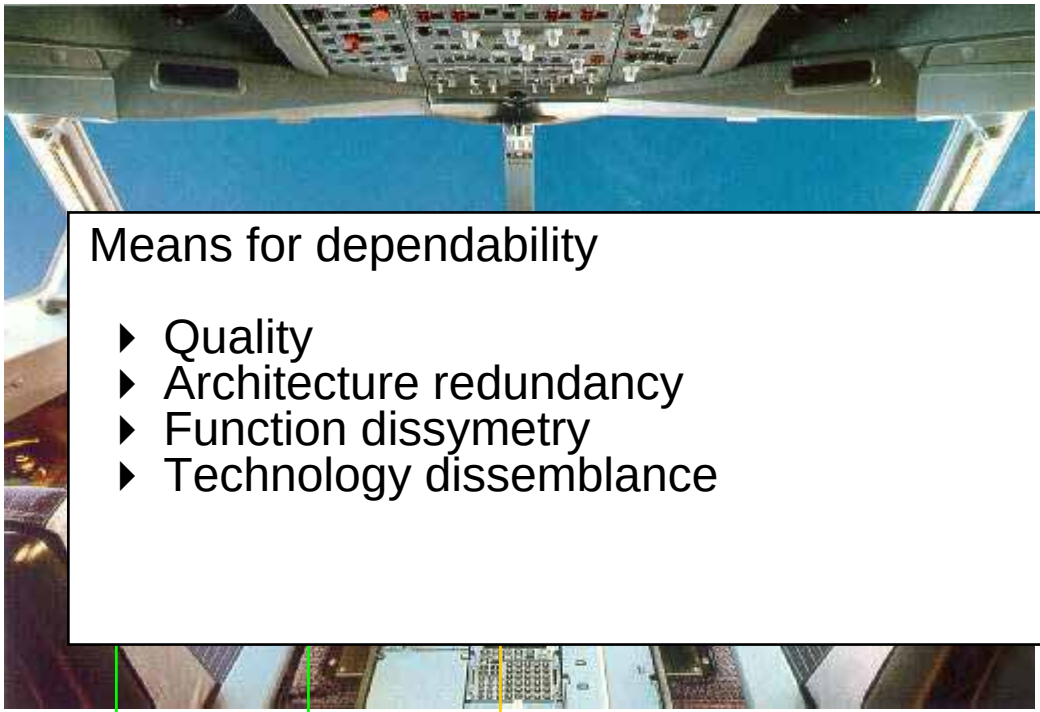
Architecture overview for the A330/340





Elements on avionics

Architecture overview for the A330/340

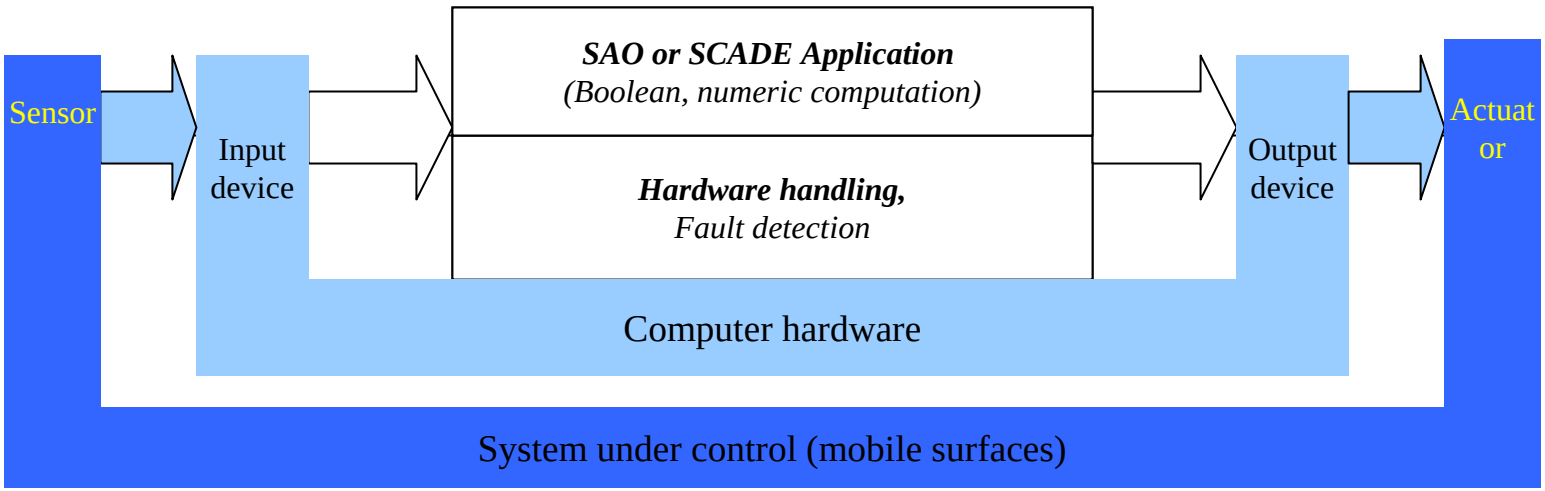


Means for dependability

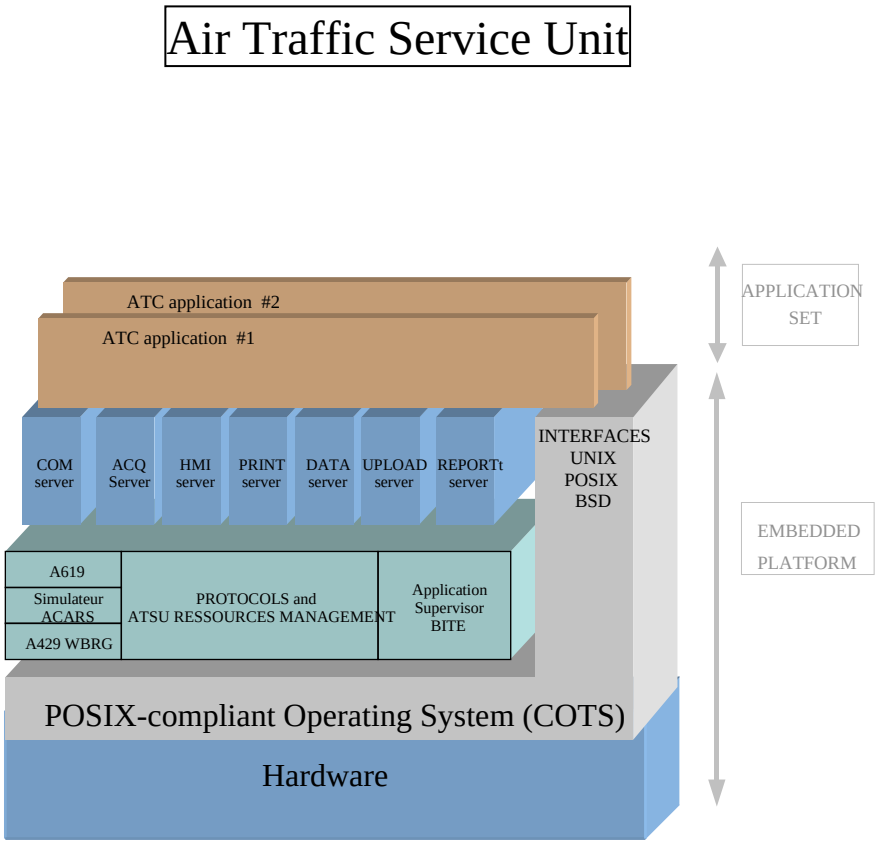
- Quality
- Architecture redundancy
- Function dissymetry
- Technology dissemblance

From the most critical ...

- Electrical Flight Control
- Safety level: critical (A)
- Mono-application
- Sequential time-triggered application
- Hard realtime constraints



… To less critical



- A/C – Ground data communications
- Safety level: essential (C)
- Several independant applications
- Multitask asynchronous application
- « Soft » realtime constraints (communication timeouts)

Today's engineering ...

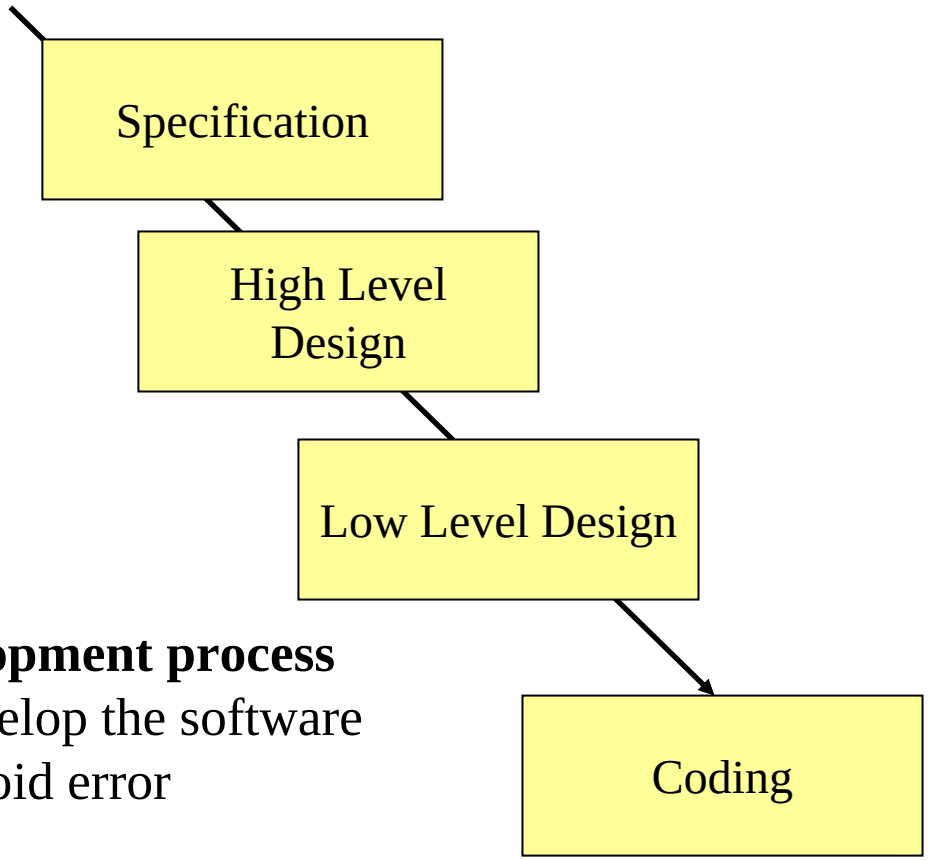
Based on DO-178B/ED-12B standards

- Guidance for satisfying airworthiness requirements
- Define processes and processes data
- Level of assurance and completion criteria depend on software level
- Industry-accepted techniques and methods
- Otherwise equivalence demonstration for alternative means

Regular revision of DO-178_/ED-12_

- Next coming will be DO-178C

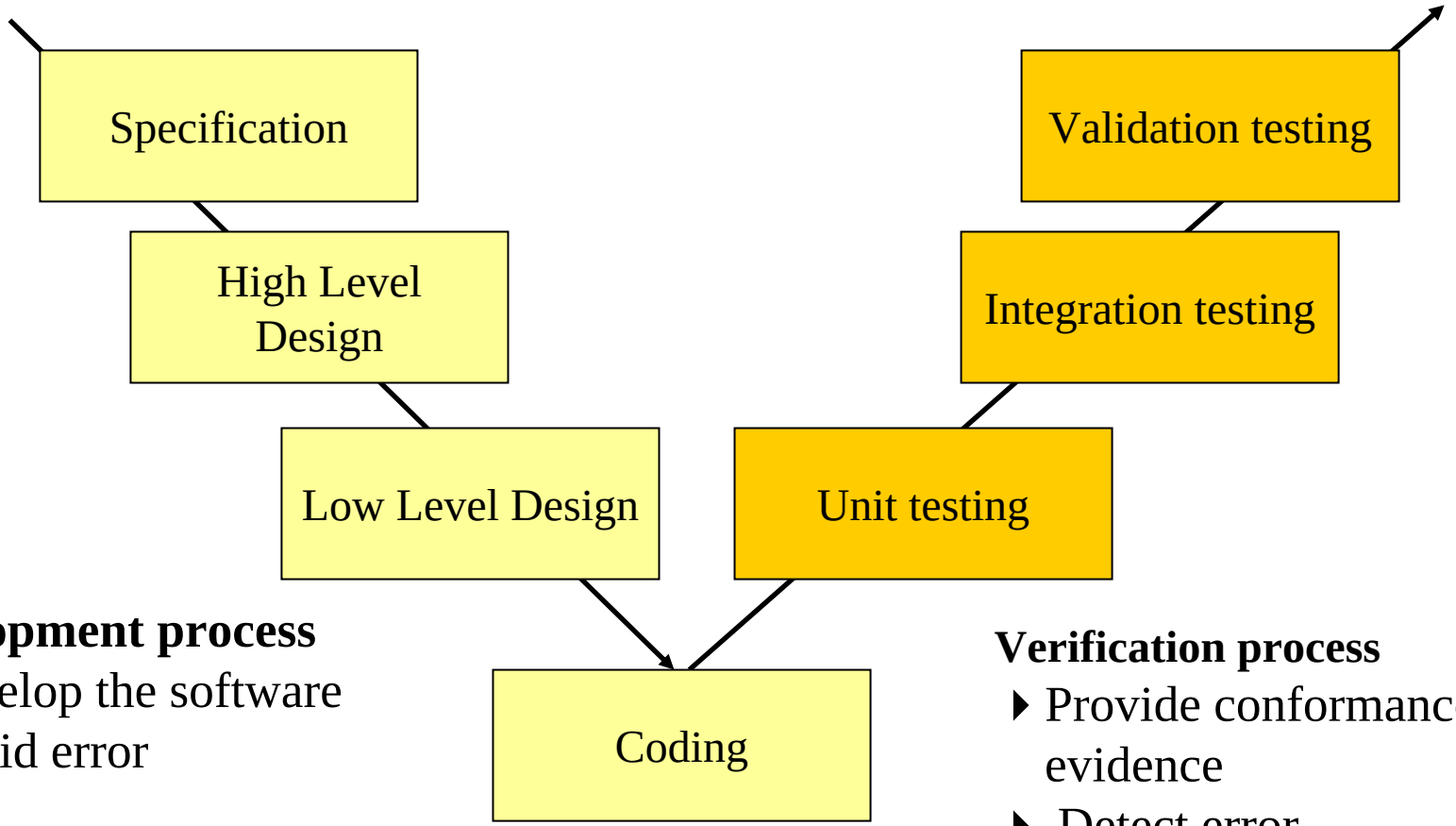
Life cycle: the “V” model



Development process

- Develop the software
- Avoid error

… Life cycle: the “V” model



Development process

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Verification process

- Provide conformance evidence
- Detect error

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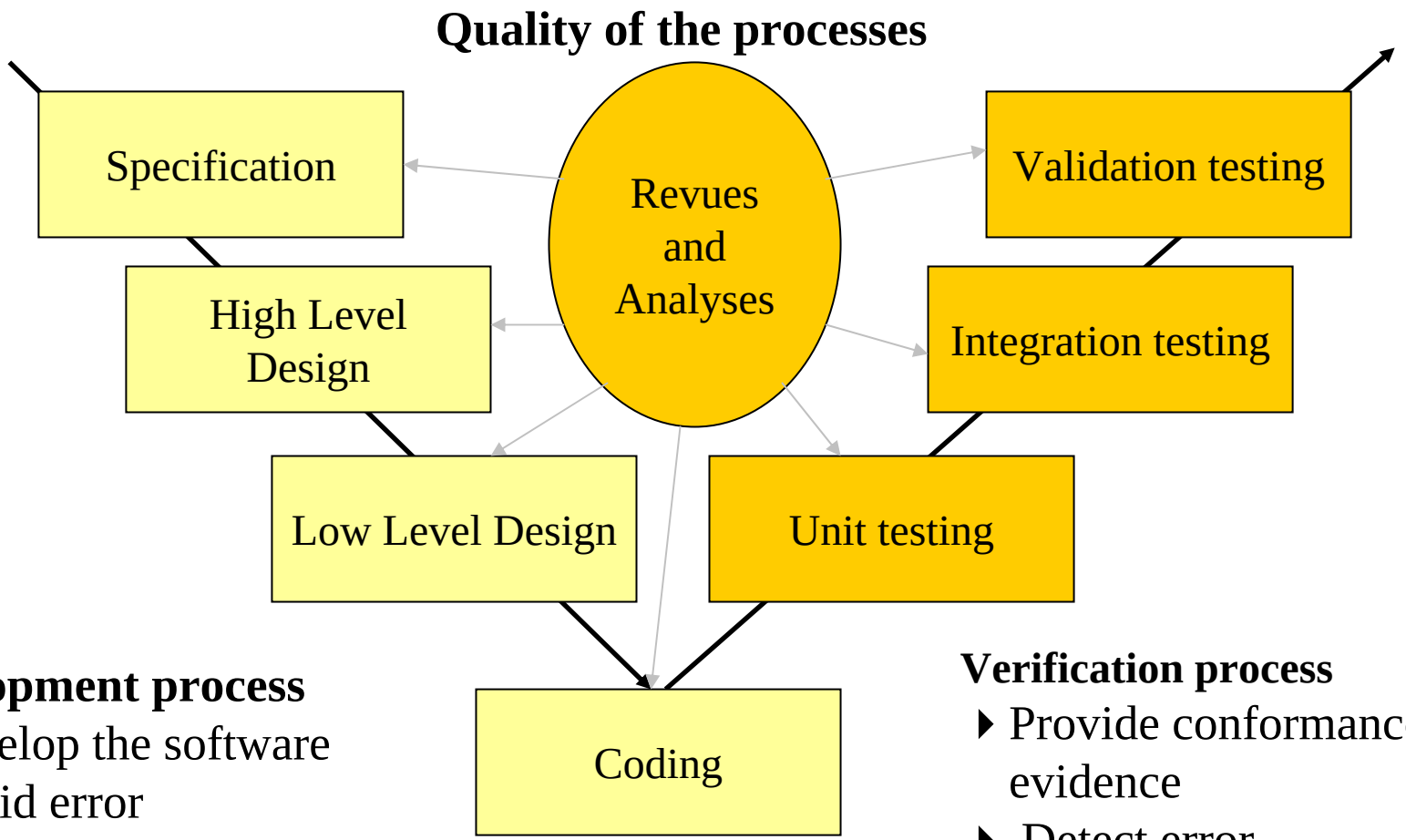

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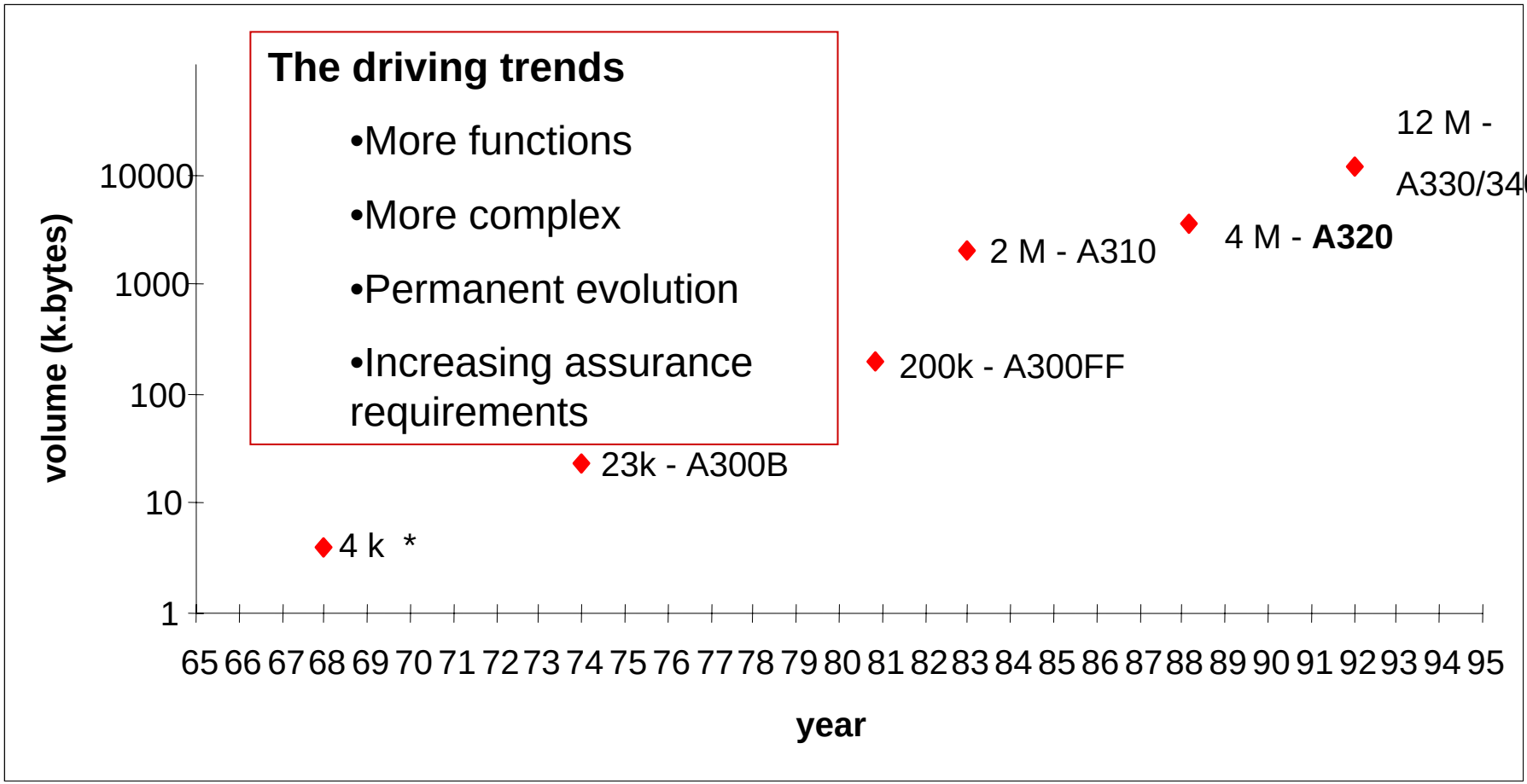
Towards highly software-intensive avionics



Motivation for formal verification technique

- Recurrent problems with test-based verification
  - Costs: test means and tools, test software, coverage completion
  - Intrinsic difficulties on: robustness checks, determination of computer-resources upper-bounds, computation safety => suboptimal architecture, resources-consuming fault-tolerance mechanisms
- The problems are increasing
  - Trend towards software-intensive systems: more functions implemented in software, more sophisticated functions, new functions
  - Evolution of underlying hardware technology: integration level, modern processor architecture, floating-point operators

… Motivation for formal verification

- As a consequence
  - Test alone will not cover all future needs in software verification
  - But test will still remain
- Introduction of static analysis
  - Main idea: all dynamic properties are « present » in the code of the program
  - **Analyse the source code - at compilation-time - to check execution-time properties**
    - exhaustive (notion of proof => maximum coverage)
    - highly automatized
  - **Grounded on so-called « formal methods »**
    - Well-founded on scientific theory
    - Hoare logic, theorem proving
    - Abstract interpretation

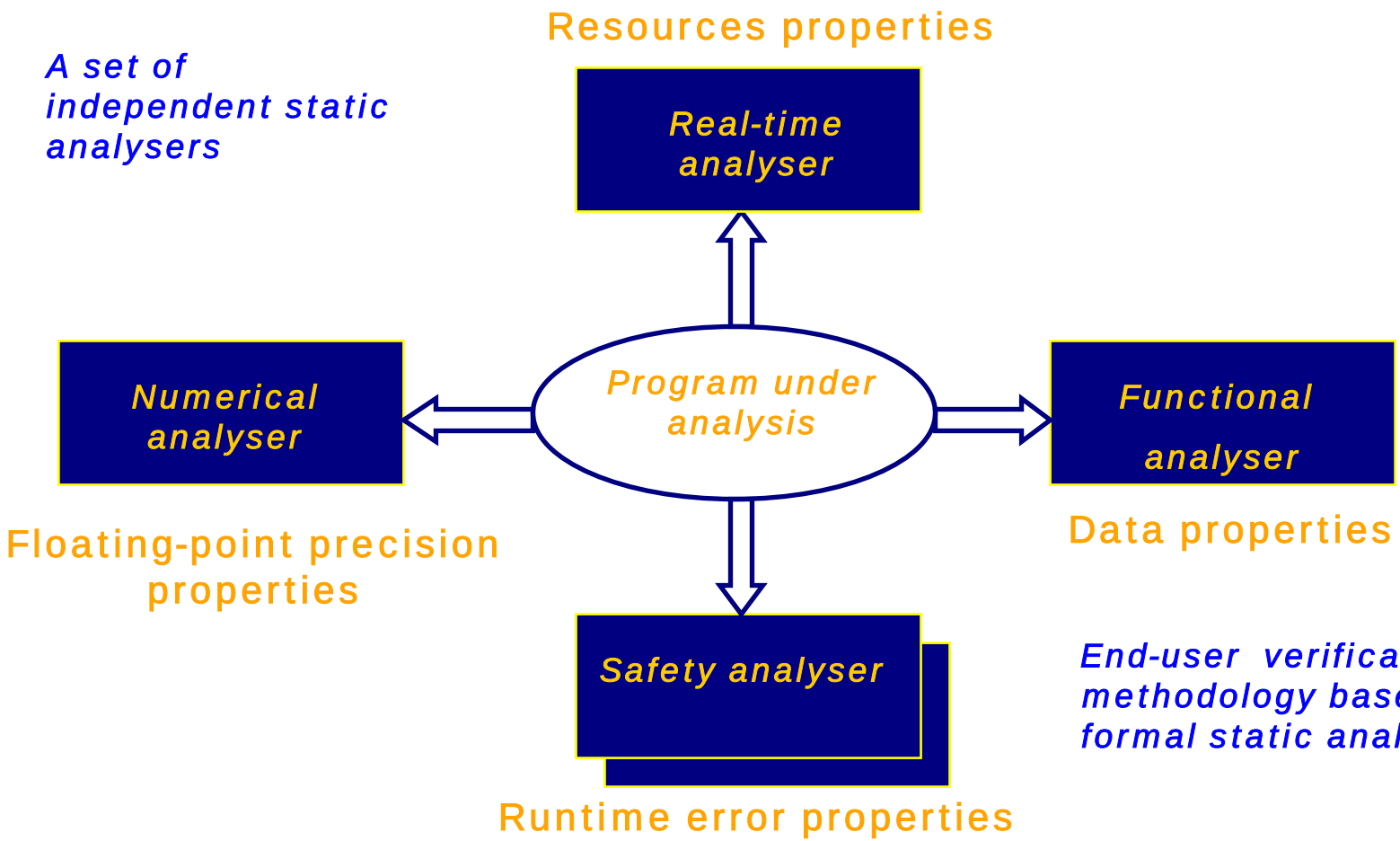
Objectives

- Improve verification processes
- Priority
  - Safety-critical software
- Operational use
  - Early deployment on A3xx program
  - Generalisation of use on mid-term A/C program

Orientation

- Ease of learning and use.
  « Standard » avionics software developers must be able to use the tools
- Early payback.
  New process must have better characteristics (productivity, quality-effectiveness)
- Easy integration.
  The use of the tools should not break down the actual verification process and environment
- Ability to cope with real program.
  The tools must be able to analyze program without any modification
  C programming language
  Assembly language or binary code as required
- Scale-up to real size program.
  Analyze at least a 100000 LOC-program (whole-program tools)
  Analyze an unmodified elementary service (unit-service tools)

Properties of interest

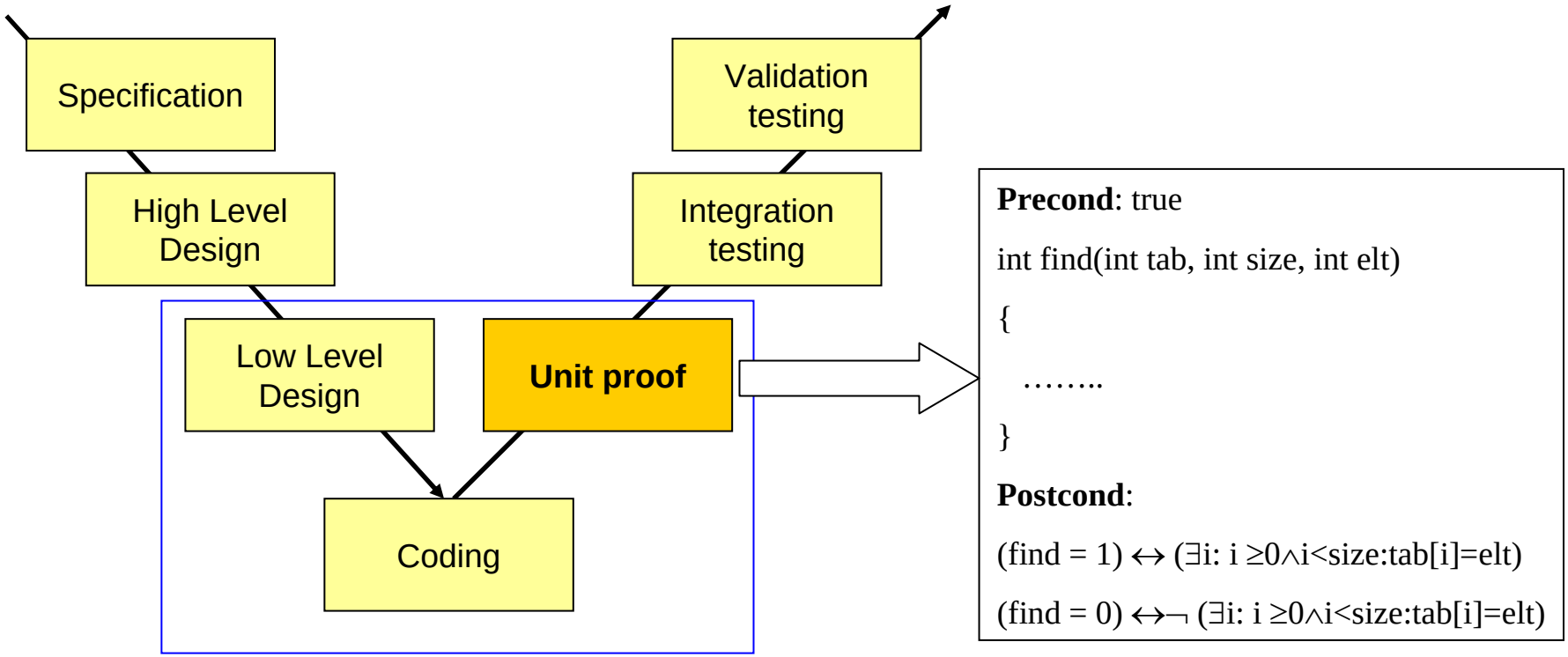


Main steps

- Start in 1996
- Research and Development step
  - Industrial transfer driven by industry
  - Separate short-term and mid-term problems
  - Strong partnership with academics, spin-off
  - Develop real-sized methods and tools
- Transfer to operational projects (2001)
  - A380 A/C program
  - Adaptation to real projects conditions
    - Partial implementation, knowledge transfer, ..
- Integration within the verification workbench (2003)
  - Part of the “normal” verification techniques
  - Maintenance, training, qualification
  - End-user support
  - ...

Functional properties

- CAVEAT tool based on Hoare logic
  - Low level requirements checks
  - Automatic theorem proving + interactive proof-assistant



Place in the development cycle

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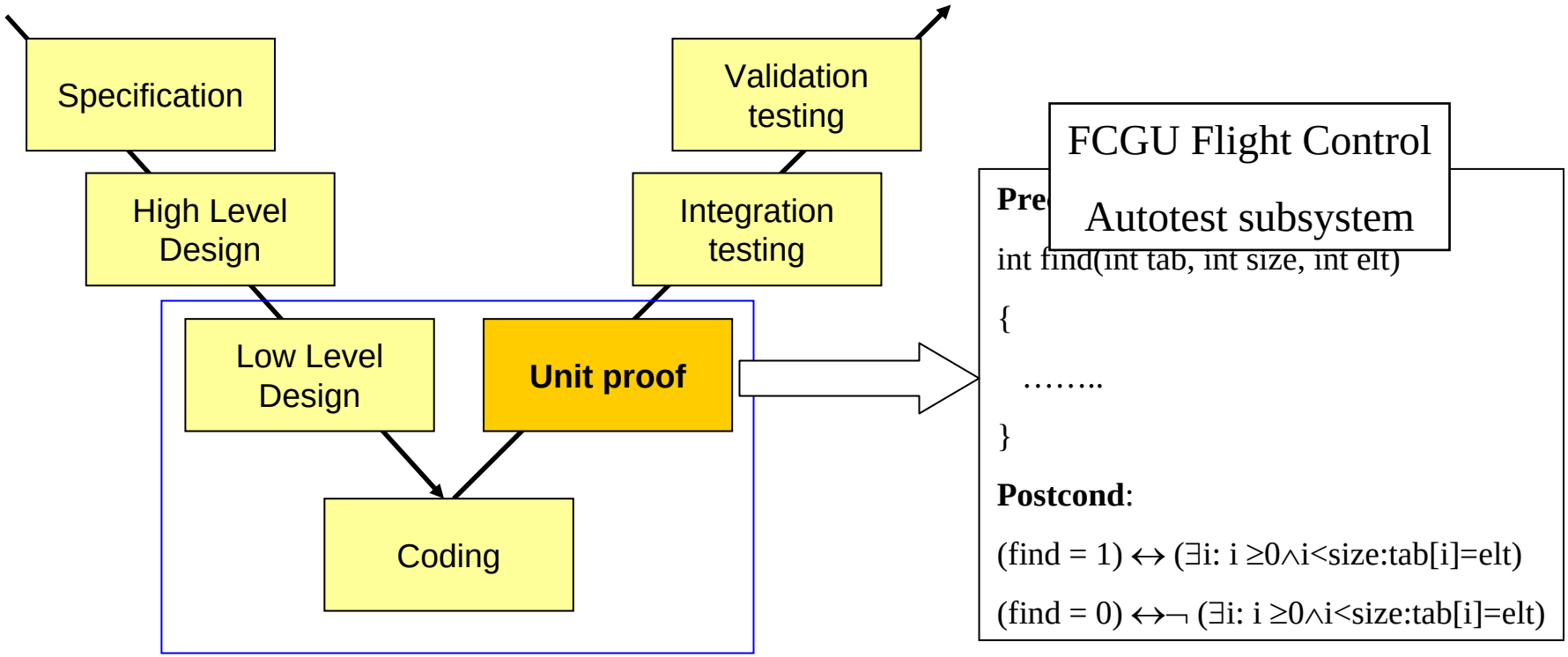
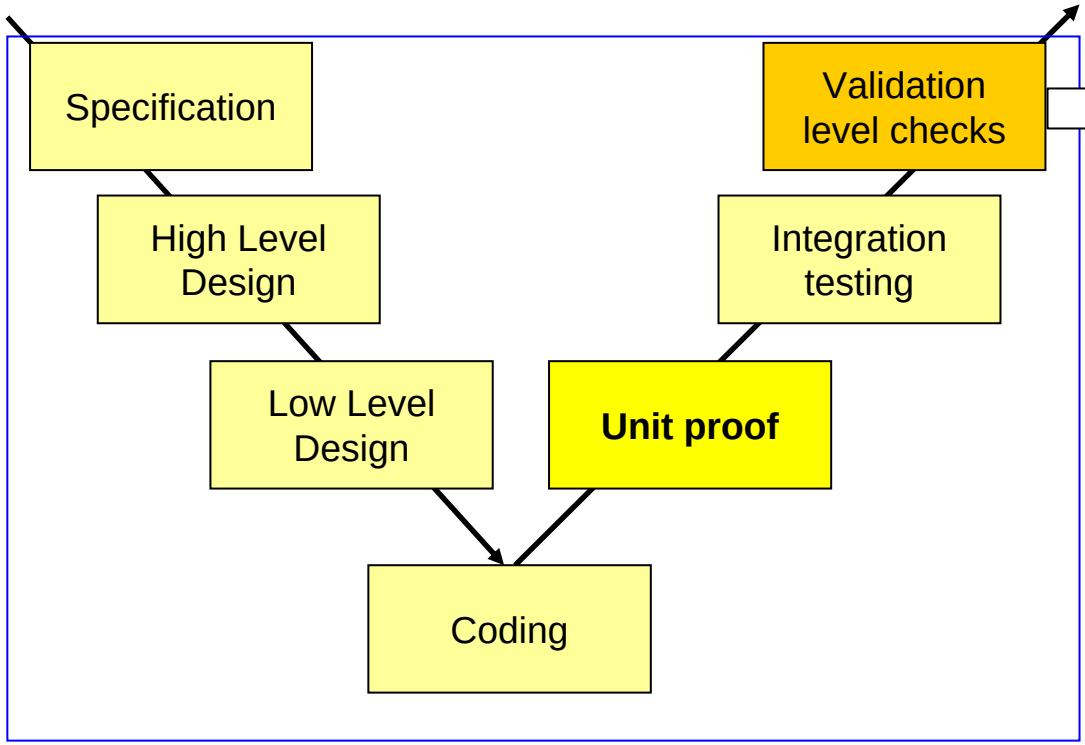


Place in the development cycle

Resources properties

- AiT and Stack tools based on abstract interpretation
  - Stack for execution stacks upperbounds
  - AiT for Worst-Case Execution Time
  - Both analyse the binary executable code



Whole binary code of a > 120000 loc program

Stack usage ≤ Stack upperbound

WCET value ≤ WCET upperbound

Place in the development cycle

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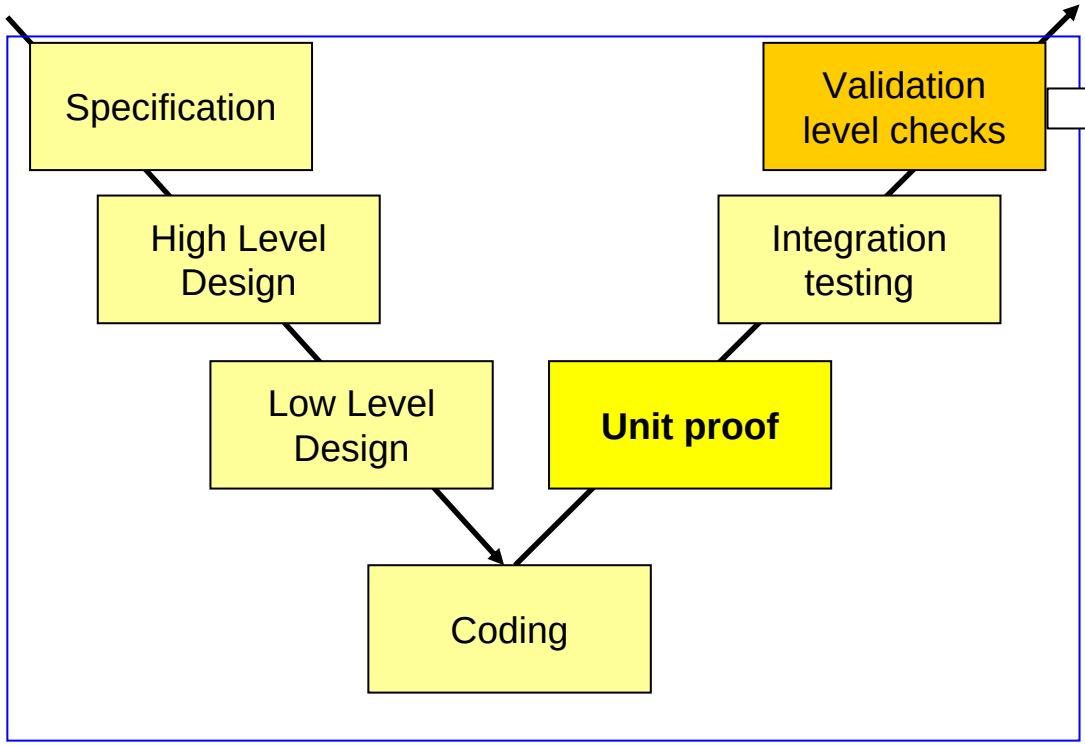


Whole binary code of a > 120000 loc program

Stack usage ≤ Stack upperbound

WCET : Flight Control

Stack: Flight Control

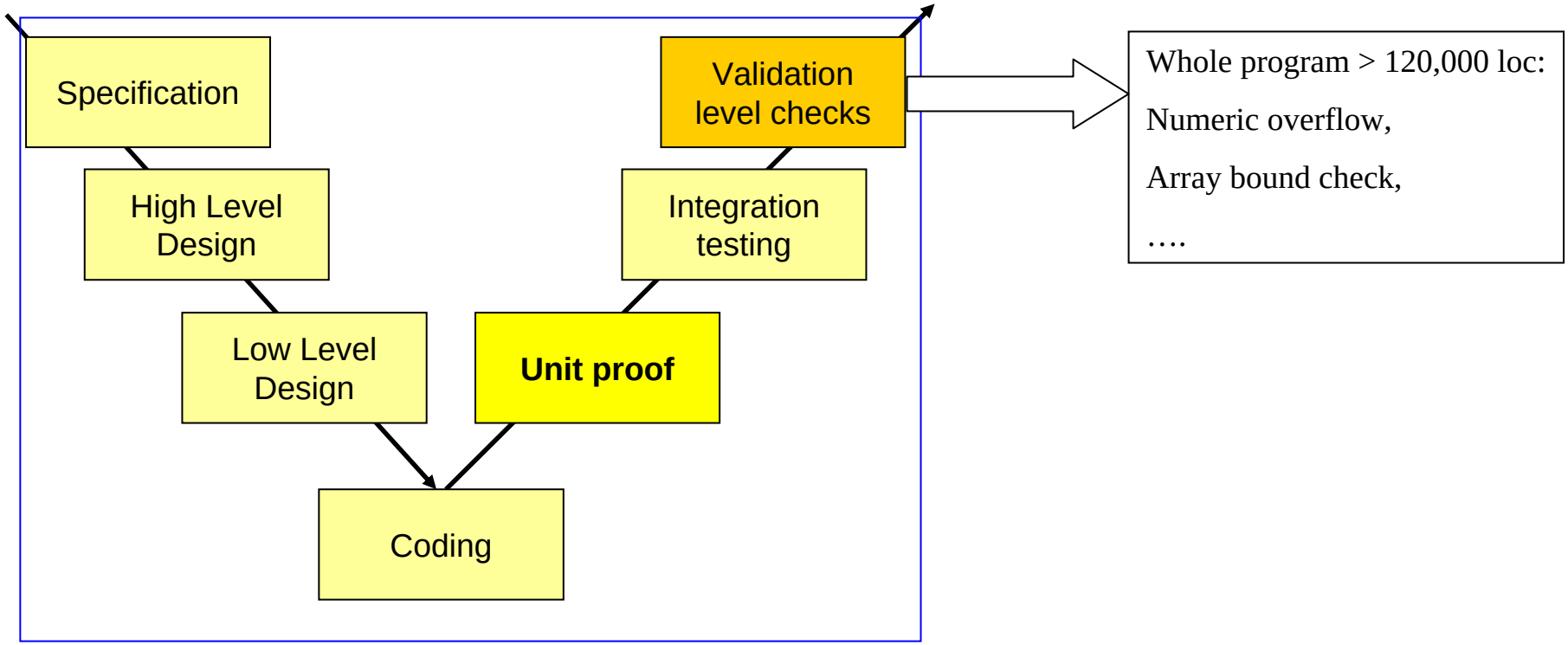
Warning

Communication

Place in the development cycle

Computation safety properties

- ASTREE tool based on abstract interpretation
  - Prove the absence of runtime errors on synchronous program
  - Fully automatic, zero false alarm (under development)



Place in the development cycle

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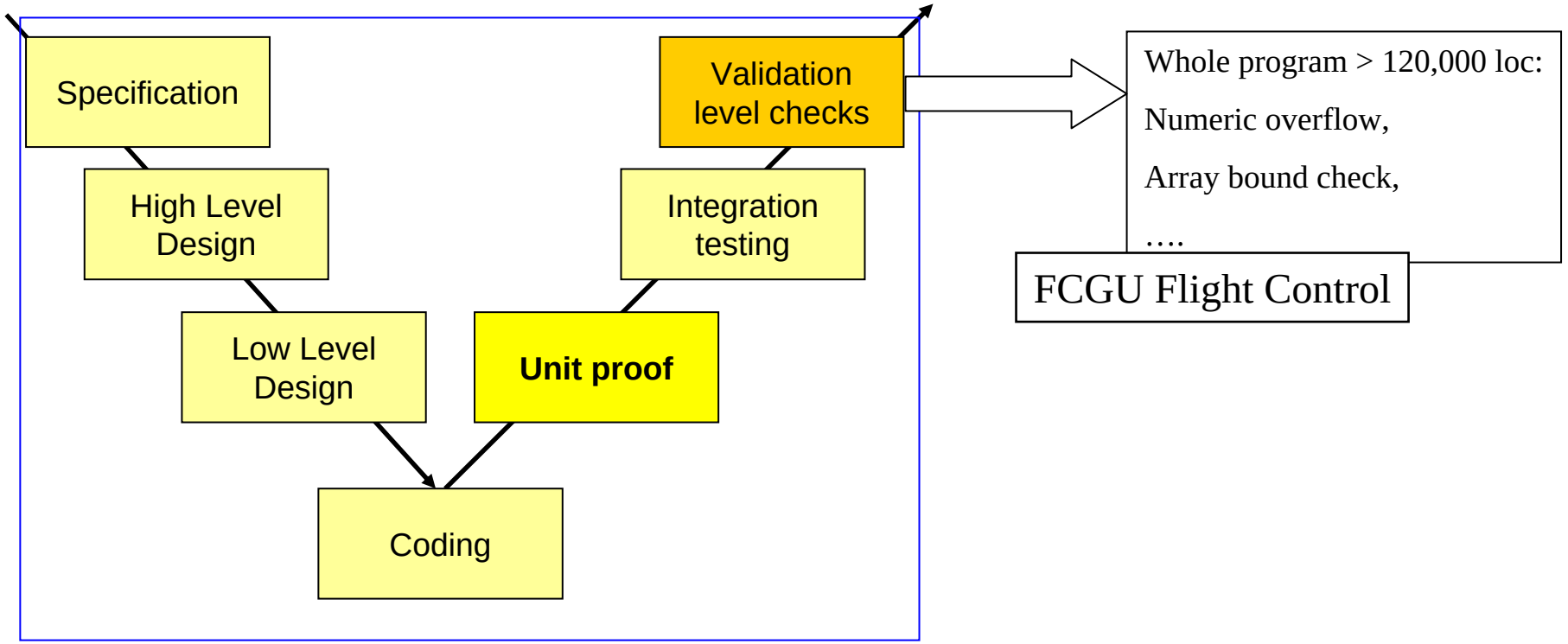

Place in the development cycle

Conclusion

- Current status
  - Introduction of static analysis well accepted
    - If clear and concrete benefits
    - If local impacts on activities and processes
  - Positive first feedbacks from partial implementation on A380
  - Formal verification reconducted on A400M
- The future
  - Generalisation (all classes of software) for next mid-term A/C
  - Extension of tools (classes of properties)
  - What could be the best-fitted certification framework ?
- More details on tools
  - CAVEAT [CEA Laboratory: www-drt.cea.fr]
  - ASTREE [ENS Laboratory: www.astree.ens.fr]
  - AiT, Stack [Absint Company: www.absint.com]

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WITH BAE SYSTEMS