Critical embedded systems : trends in the design methods

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Outline

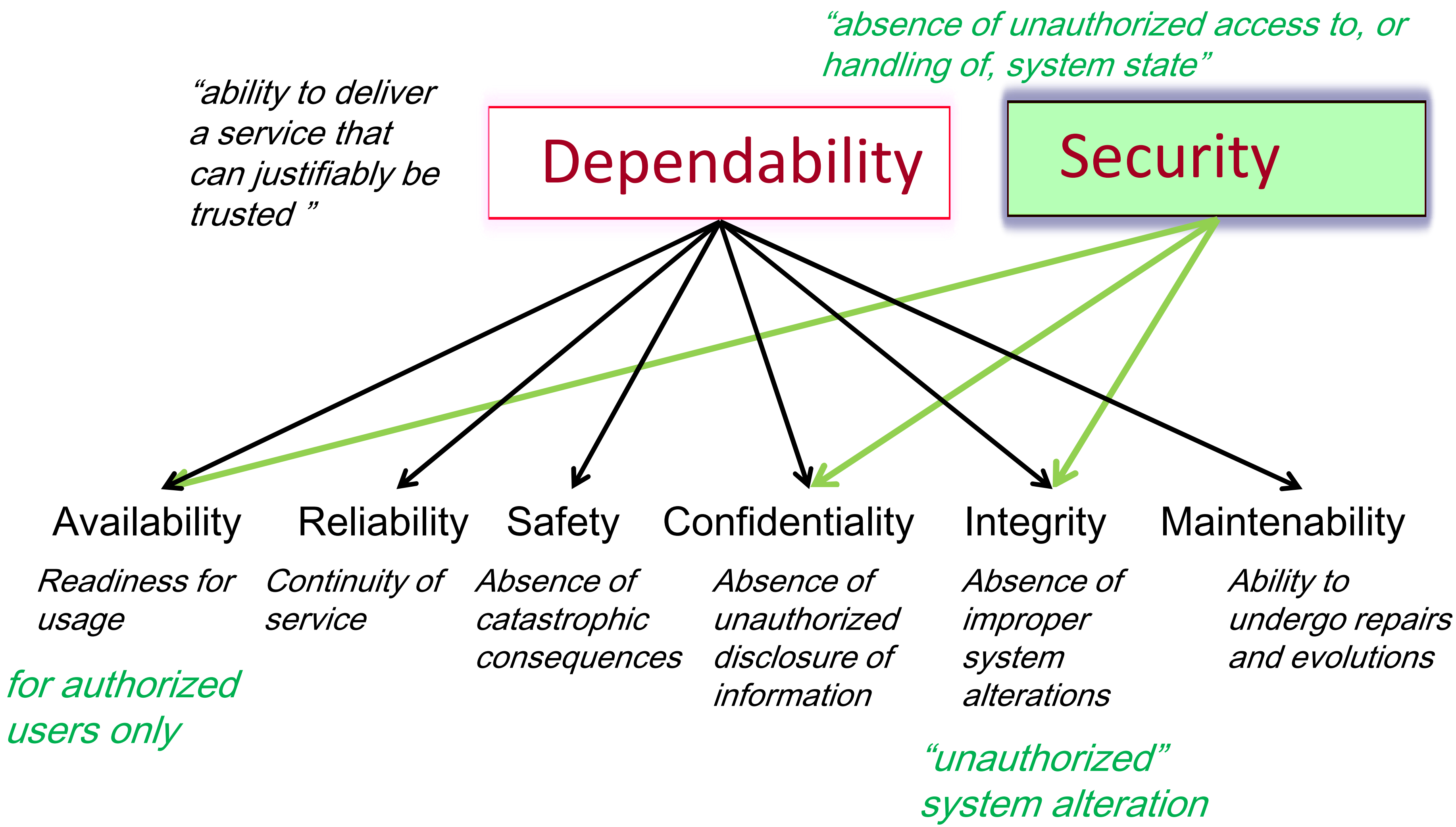
1. **Illustration : automotive embedded systems**
    - **Threats to their dependability ?**
    - **Focus on the timing constraints**

2. **Evolution technologies and practices in the design of critical embedded systems**

3. **Open and emerging problems**

Embedded systems in our day-to-day life : some of them are critical in the sense they are subject to dependability constraints

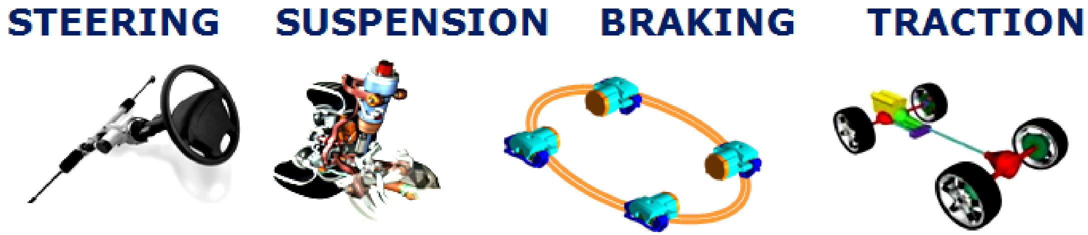
Dependability vs Security [from Laprie et al, 3]



Automotive Embedded Systems: threats to their dependability

Electronics is the driving force of innovation in automotive

Many new functions are safety critical: brake assist, cruise control, lane keeping, dynamic lights, etc

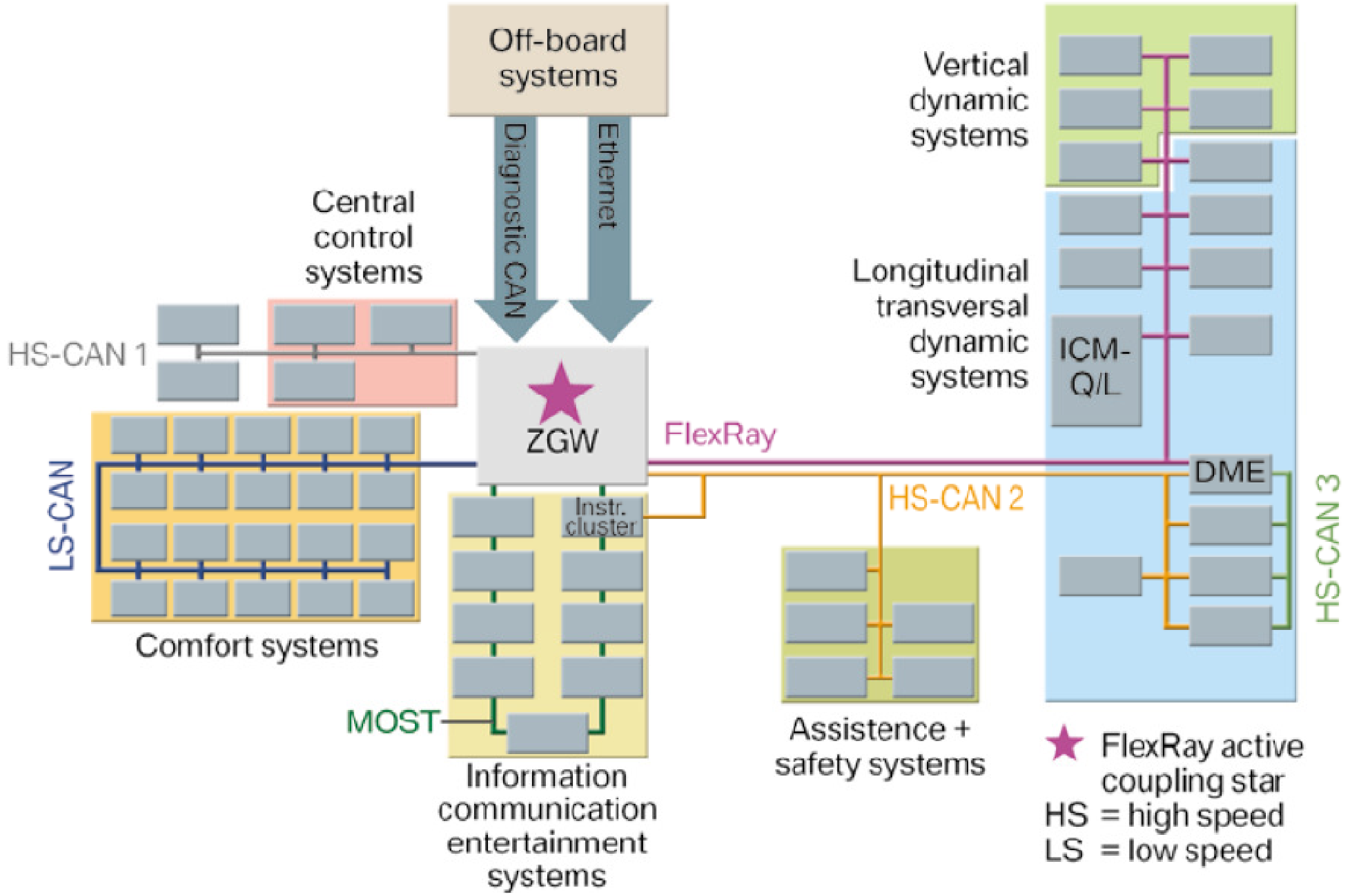


Picture from [10]

- 90% of new functions use software
- Electronics: 40% of total costs
- Huge complexity: 70 ECUs, 2500 signals, >6 comm. protocols, multi-layered run-time environment (AUTOSAR), multi-source software, multi-core CPUs, number of variants, etc

Strong costs and time-to-market constraints !

BMW 7 Series networking architecture [11]



Picture from [11]

- ZGW = central gateway
- 4 CAN buses
- 1 FlexRay Bus
- 1 MOST bus
- Several LIN Buses (not shown here)
- 1 Ethernet bus
- Wireless

Main impediments to safety imho: complexity!

Technologies: numerous, complex and not explicit. conceived for critical systems

– e.g.: more than 150 specification documents (textual) for Autosar, no two implementations can behave identically!

Size of the system!

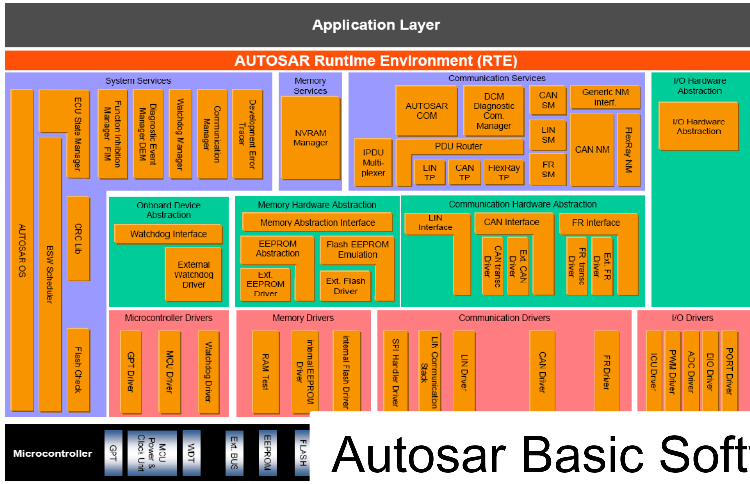
– Number of functional domains, buses, gateways, ECUs, size of code, tasks, wiring, number of variants, etc

Design process

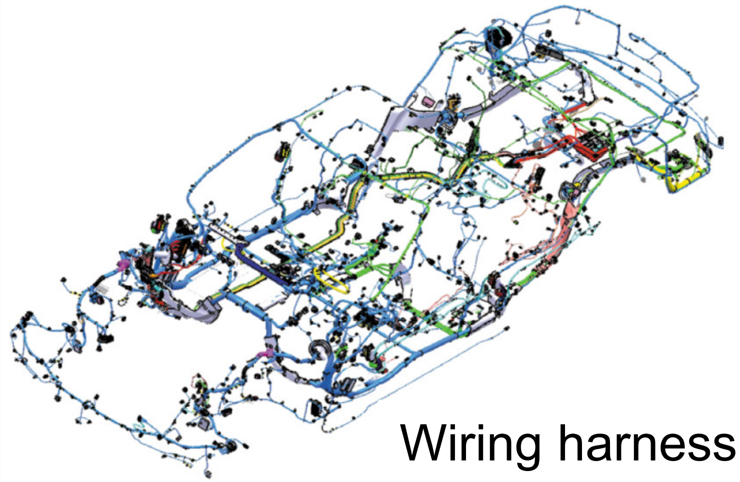
– Most developments are not done in-house : less control on externalized developments

– Carry-over / Vehicle Family Management : need to share/re-use architecture and sub-systems between several brands/models with different requirements [2]

– Optimized solutions for each component / function does not lead to a global optimal [2]



Autosar Basic Software



Wiring harness

Picture from [11]

Threats to dependability : the big picture

When faults are introduced in the development phase ?

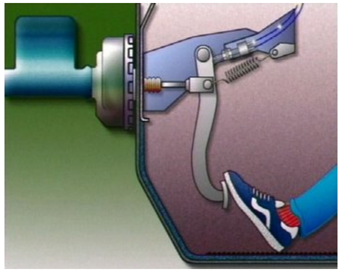
- Requirements capture (20%) + Specification (50%) + SW development: (30%) (infineon [10])
- HW development : ε

Risk factors beside complexity:

- Technologies: not all conceived with dependability as a priority
- Little hardware redundancy
- Developments are mainly externalized: incomplete knowledge for the OEM technical parameters are regarded as less important than cost for supplier / components selection [2]
- Strong cost / time-to-market pressure
- Limited regulatory constraints even with upcoming ISO26262
- Verification / validation does not ensure 100% coverage, limited used of formal methods
- Human factors
- etc

Focus on the timing constraints

Several hundreds of timing constraints – example of an end-to –end constraints



Constraint :
brake light on < 50ms

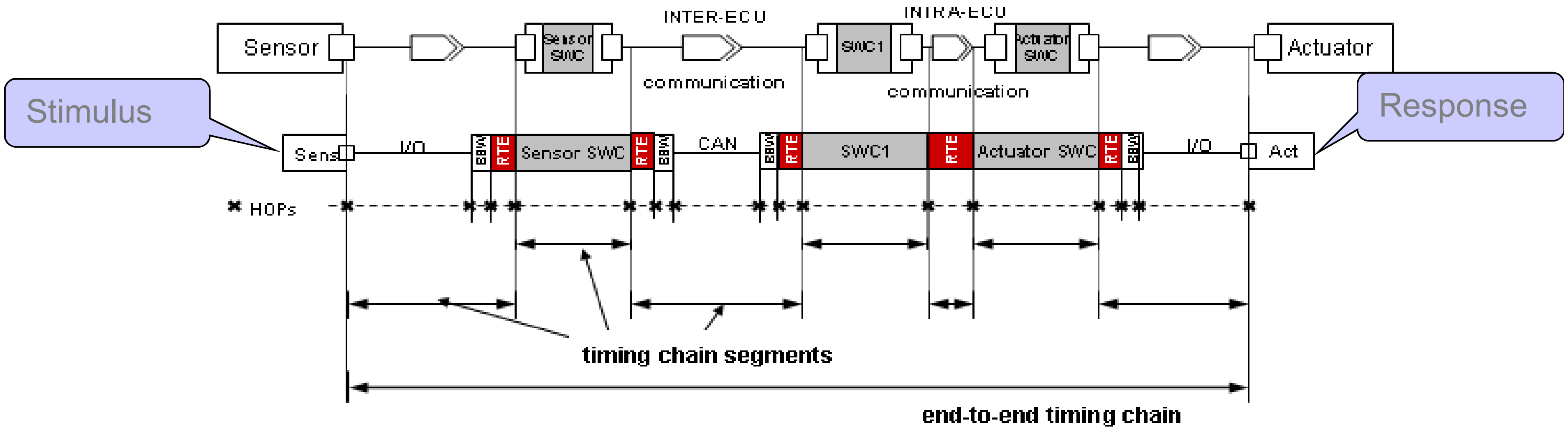
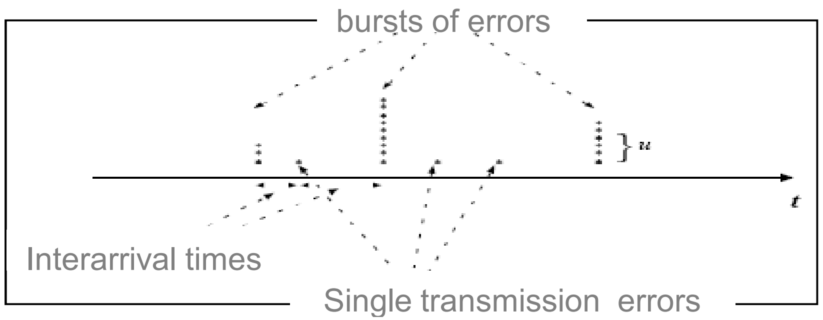


Figure from [12]

Verification of the timing constraints
Personal view / experiences



$$\eta_k = \max\{n \in \mathbb{N} \mid R_k(n) \leq D_k\}$$

Mostly ahead of us!
- « correctness by construct » and optimal synthesis
- **Probabilistic performance & safety assessment - system level**

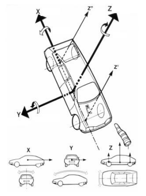
« Worst-case » deterministic analysis system level

Probabilistic analysis (sub-system)

COTS tools
- **« Worst-case » deterministic analysis (sub-system)**
- **« Smart » monitoring tools**
- **Simulation tools (SBFI)**

1995 1997 2009

Why timing constraints may not be respected occasionally?



Lack of precise specification : hard to identify the right timing requirements for each function

Lack of traceability : from the architects to the suppliers

Flaws in the verification:

– Knowledge of the system and its environment is incomplete:
  - What is done by the suppliers?
  - Implementation choices really matter and standards do not say everything
  - Environmental issues: EMI, α-particles, heat, etc
  - Traffic is not always well characterized and/or well modeled e.g. aperiodic traffic ?! see [5]

– Testing /simulation alone is not enough

– Analysis is not enough too:
  - Analytic models, especially complex ones, can be wrong (remember " CAN analysis refuted, revisited, etc" [6] ?!)
  - They are often much simplified abstraction of reality and might become optimistic: neglect FIFOs, hardware limitations

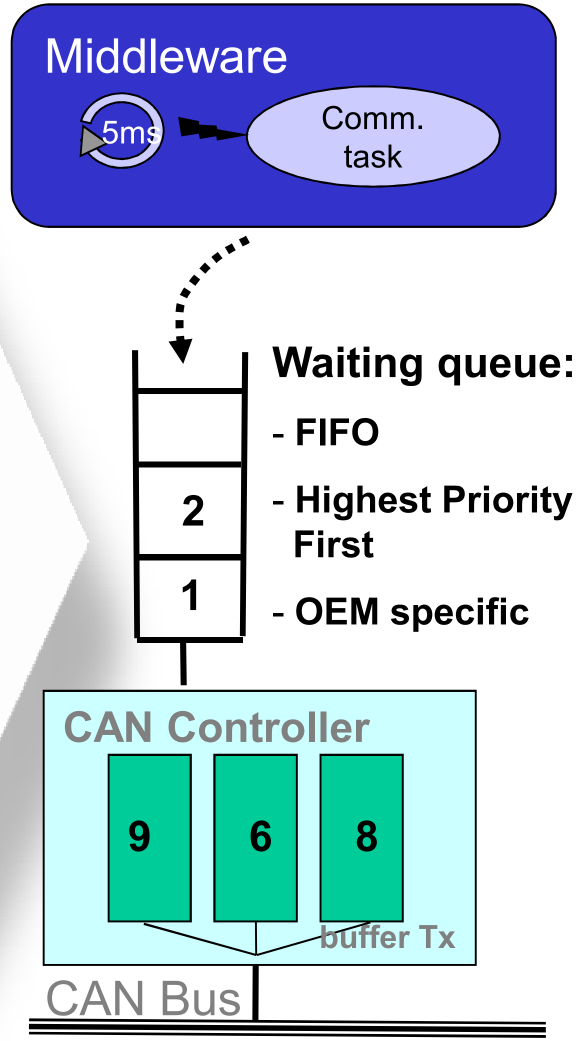
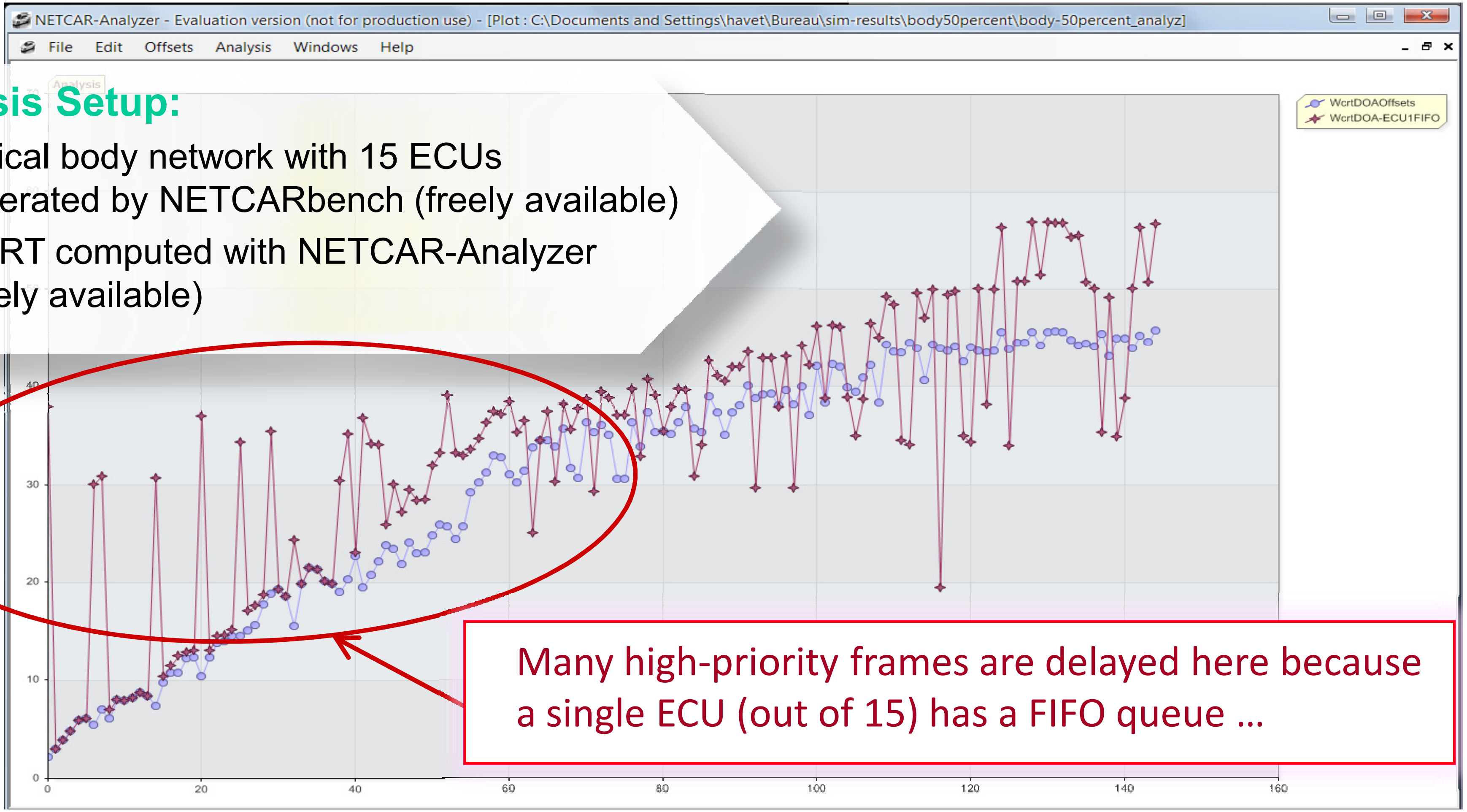


Illustration: Worst-Case Response Times on a CAN bus

Frame waiting queues are HPF, except ECU1 where queue is FIFO
the OEM does not know or verification software cannot handle it …

Analysis Setup:

- Typical body network with 15 ECUs generated by NETCARbench (freely available)
- WCRT computed with NETCAR-Analyzer (freely available)



Many high-priority frames are delayed here because a single ECU (out of 15) has a FIFO queue …

Evolution in the development of safety critical software – personal views

- Safety standards
- Design process
- Technologies, computing platforms

Safety standards and certification processes cannot be ignored

DO 178 / DO 254

EN 50126/28/29

IEC61226
IEC60880
…

ISO 26262

IEC 61508

ECSS / CNES

Airbus: 1/3 of the design costs of an airplane due to certification !

[Multi-domain comparison of safety standards, ERTSS-2010]

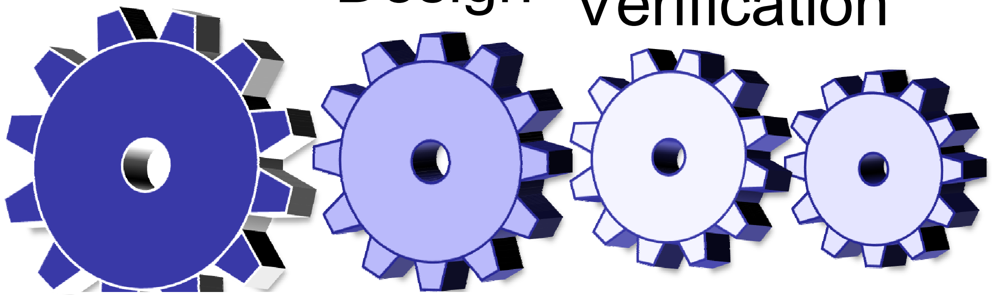
Model Based Design for dependable system development
no more hand-coded programs

Requirements

Design

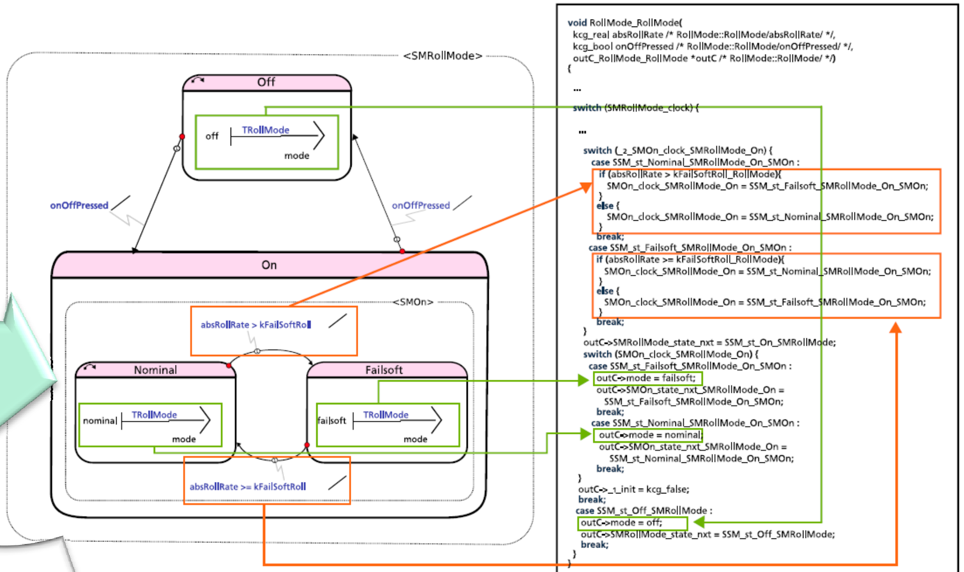
Verification

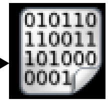
code
generation



Scade

ESTEREL Technologies





Simulation
Verification
DesignVerifyer

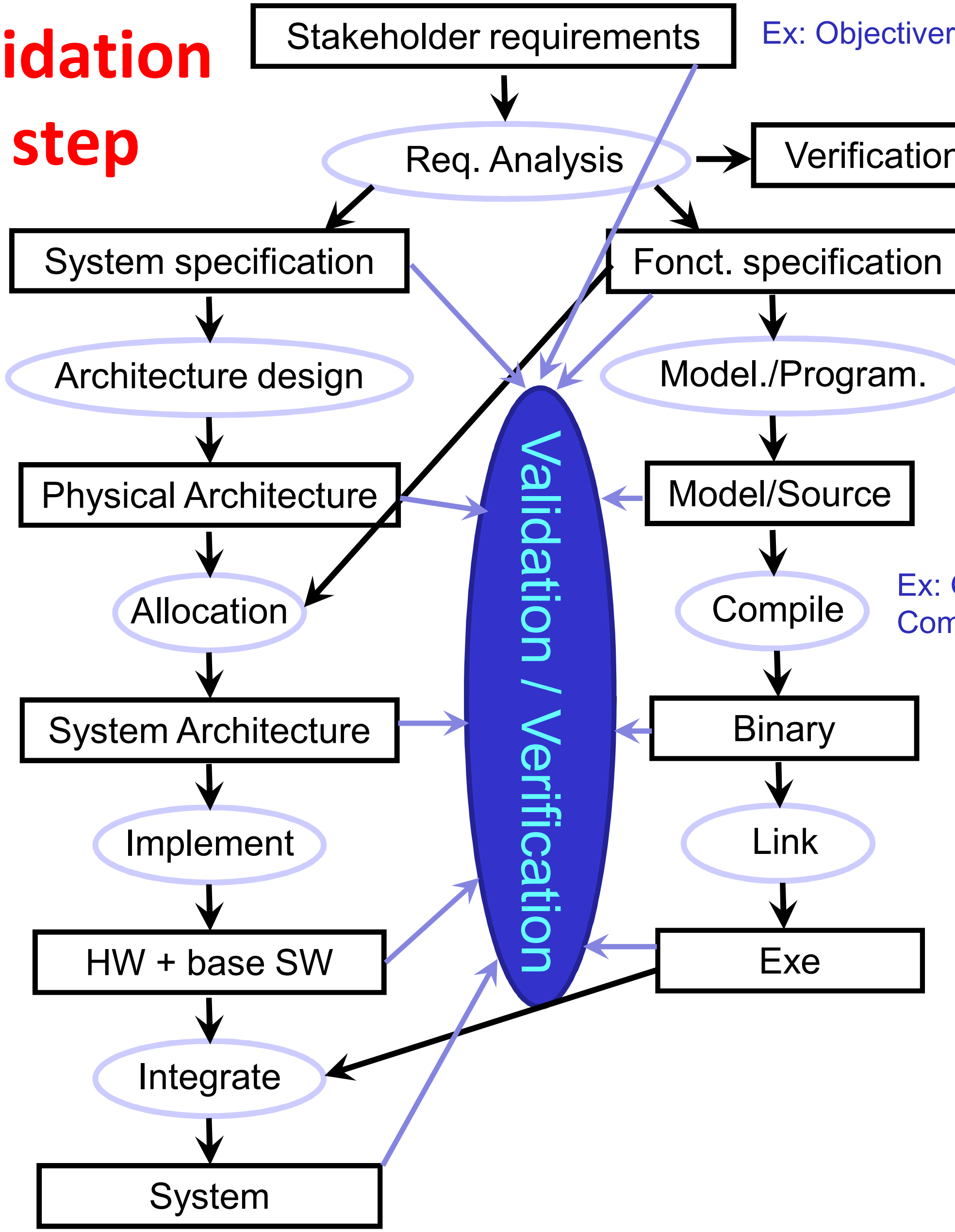
State machine to C
certified transformation tool

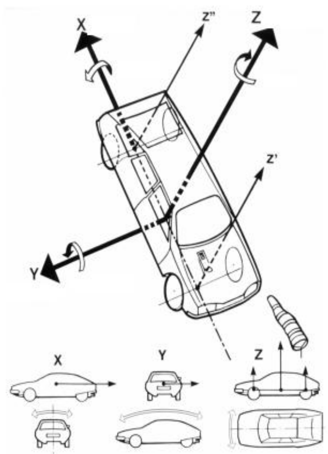
C to binary
Compiler
Certification
Kit

End-to-end design flows with proven outcomes at each step

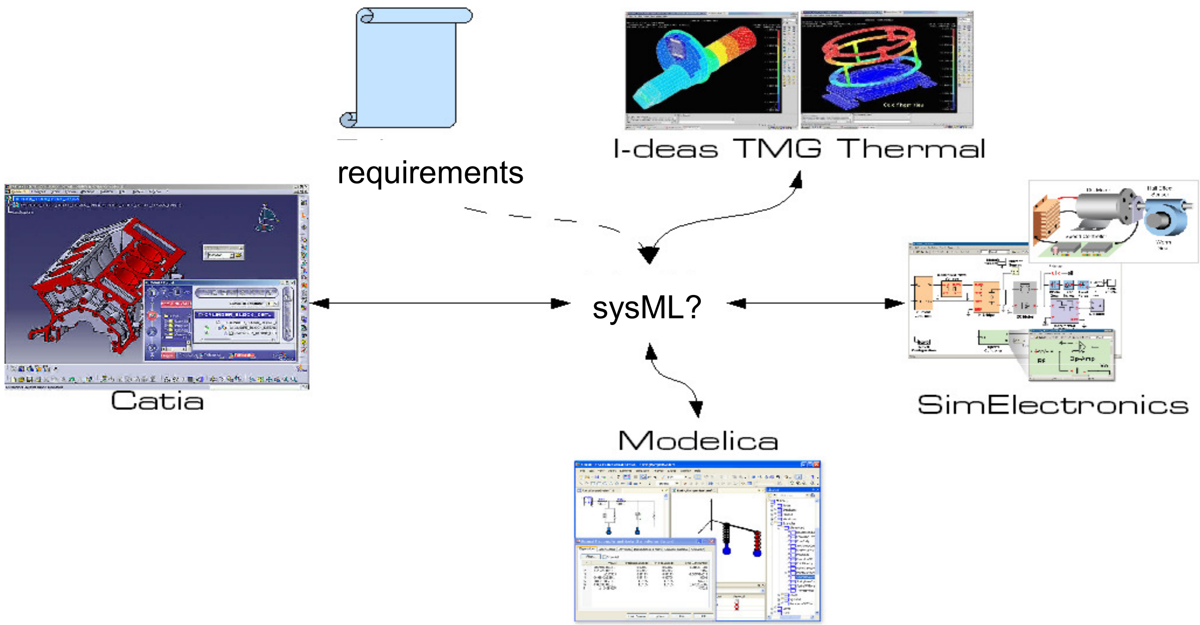
Verification & Validation is needed at each step

Simplified INCOSE approach





MBD: domain-specific models and tools must be dealt with

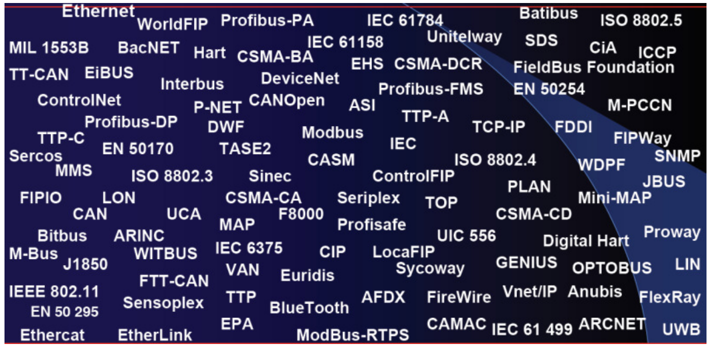


Some open issues: semantic interoperability, pivotal language? local versus global verification

Technology : from domain specific to cross-industry solutions

Today :

- Avionics: IEEE1553, AFDX, TTP, ARINC 653, ..
- Automotive: CAN, FlexRay, Autosar, Lin, ..
- Power plants: Alstom Alspa, Siemens Teleperm, ..

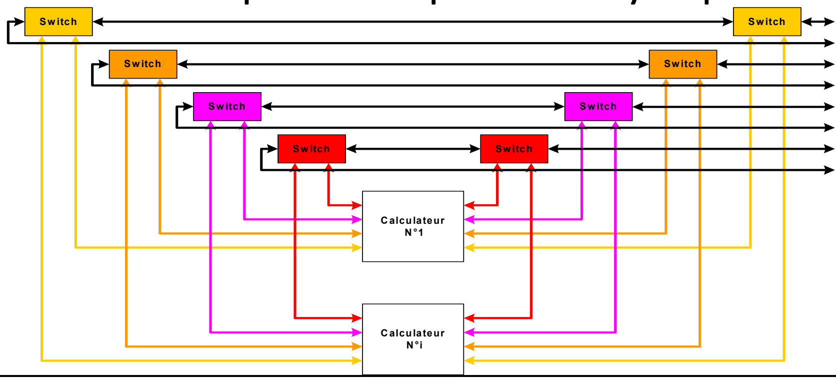


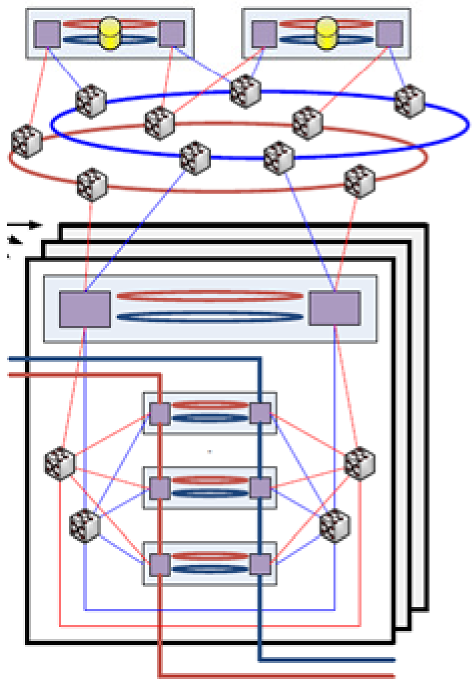
[Thomesse05]

Tomorrow :

Objective of the DDASCA consortium

- Convergence of safety standards
- Computing platforms: cross-industry solutionS with profile per application domain and scalable dependability : e.g., switched Ethernet, virtualization, etc
- Architecture patterns with specific dependability capabilities





What is needed now: achieving affordable dependability

1. A large body of techniques, development processes, tools, know-how is increasingly available – they have to become more accessible
2. Simpler systems are more amenable to verification!
3. Formal methods are now sufficiently mature to handle real-world industrial problems.

Public research : provide support to both companies and public authorities so that there is no compromise in safety

Thank you for your attention

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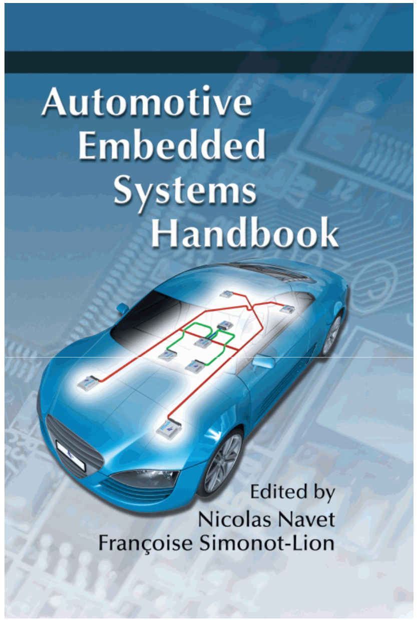
References



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