Disruptive E/E Architectures (not only) for Electromobility

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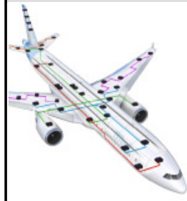
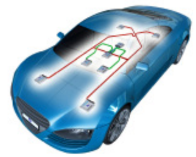
Automotive Megatrends.





Trend 1. Ever-increasing number of control systems for
- improved performance
- increased safety
- improved diagnostics and maintenance
- passenger comfort
- new services

Trend 2. Increased connectivity between control systems within a car and between vehicles / road signs / …

Trend 3. Stringent dependability requirements
- Safety (e.g. X-by-wire in all-electric cars)
- Reliability
- Fault-Tolerance
- Security (e.g. telematics)

Trend 4. Mechanical parts and electronics is increasingly replaced by **software**, which is the main driver for innovation in the automotive industry.

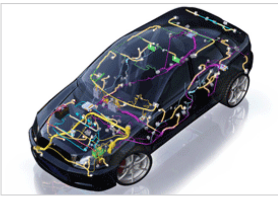
Challenges for Automotive E/E Architectures.

O(10^6) lines of code

Information Security

Components Off-the-Shelf

Hard and Soft Real-time



Software of Unknown Pedigree

Multiple Buses

Distributed control

Many computers

Multiple Safety Levels

Automotive E/E Architecture.
From Federated Architectures…

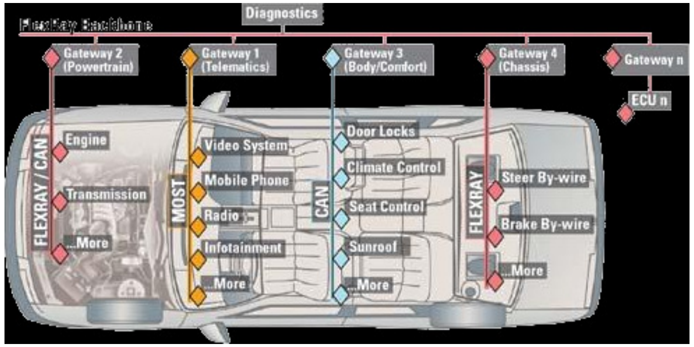
1 function = 1 computer system.
Provide each application subsystem with its own dedicated computer system and corresponding sensos/actuators.

1 point-to-point connection = 1 physical bus.
Point-to-point communication between computer systems.

Complexity of E/E architecture in modern cars tends to become over-whelming.
- around ***n = 70*** computer systems in modern premium cars
- resulting in around ***O(n*n)*** communication interfaces/wires
- integration effort is ***O(n*n*n)***

Other drawbacks.
- High **weight**, **volume**, **cost**
- High cost of **modifications** including parts obsolescence mitigation and functional upgrades.

Automotive E/E Architecture.
To Current E/E Architectures…

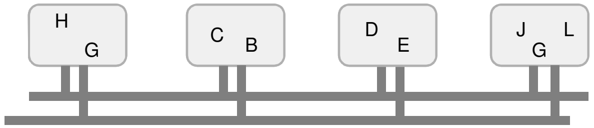


Integrated Modular Systems.
…to Integrated Modular E/E Architectures.

Multiple applications on shared processors.

Shared communication links and distributed computation with multiplexed networks.

Integrated Modular System.
Robust Partitioning.



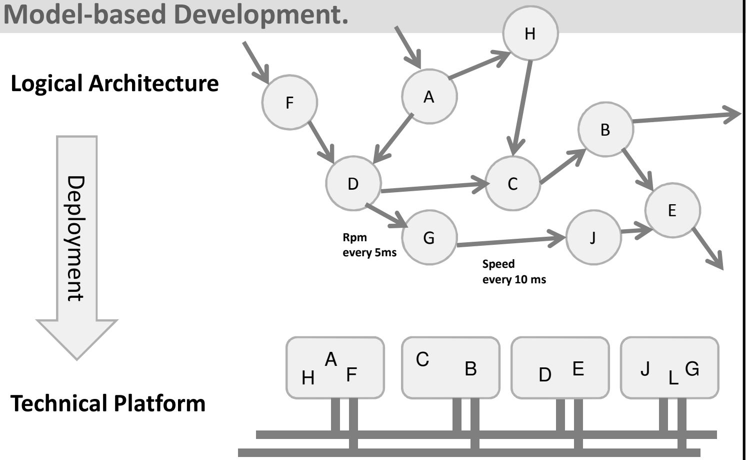
Fault isolation units

Robust partitioning

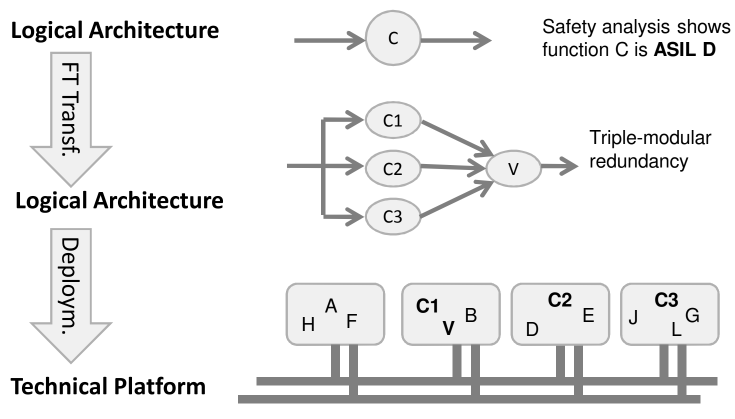
- Time and space partitioning in **shared processors**
- Time and space partitioning for **shared communications** and distributed computation

Avoid **unintended interaction** through shared resources / controlled plant.

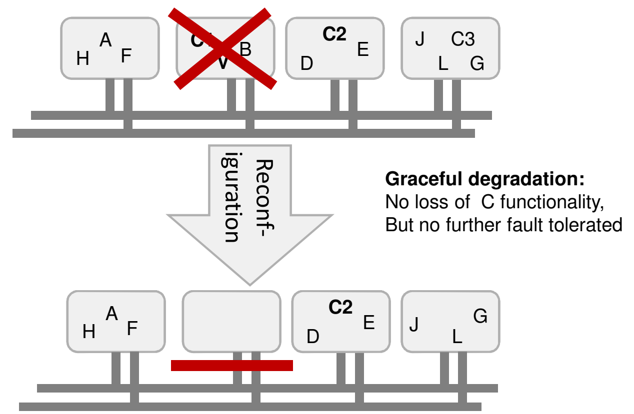
Integrated Modular System.
Model-based Development.



Integrated Modular System.
Model-based Fault-Tolerant Development.



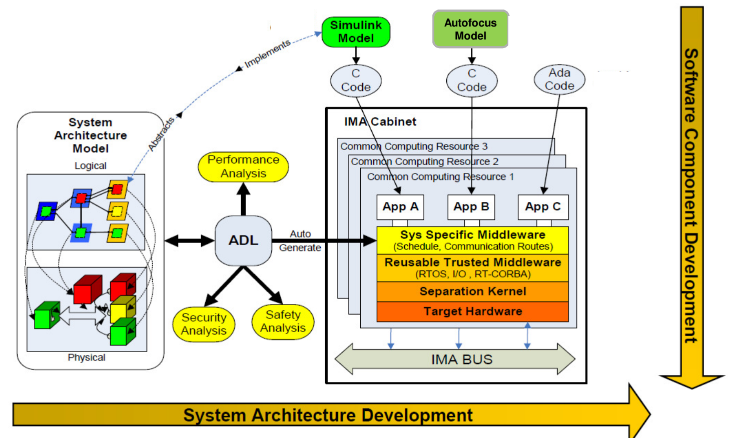
Integrated Modular System.
Reconfiguration.



Integrated Modular E/E Architectures.
Advantages.

- Reduced weight, volume, and power consumption
- Drastically reduced number of line-replaceable units leads to less spares
  - simplified logistics support
  - simplified maintenance / obsolesence management
- HW and SW ressources (re-)configurable
- Drastically reduced system integration effort.
  e.g. multi-channel FADEC integration using TTA took a few hours compared to months in a more traditional approach.
- Robust partitioning enables
  - Mixed-criticality, multi-level security systems
  - Incremental qualification / impact analysis / certification (modifications to one application have no effect on other applications)

Integrated Modular E/E Architectures.
System Development Process.



Integrated Modular E/E Architectures.
Enabling Technologies.

- Model-based SW application design
- Model-based safety, security, performance analysis
- Fault-tolerance transformation / autocoding
- Deployment of logical architecture onto IMA platform
- Online Reconfiguration / Adaptation
- Demonstrably robust partitioning for IMA platform
- Robust feedback control for tolerating jitter and clock drift in IMAs
- Compositional design.

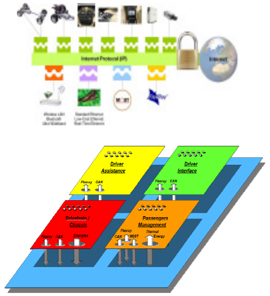
  Composability: properties of a component are preserved when it is used in a larger system.

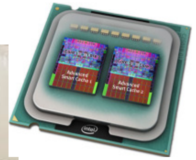
  Compositionality: properties of a system can be derived from those of its component.

Robust partitioning of IMA essential for demonstrating composability.
Demonstrating compositionality (of safety, security, stability,...) is one of **the grand challenges** of computer science.

Example.
The fortiss All-Electric Car.

„Replacing „old style“ mechanics such as combustion engines, hydraulics, drivetrain, gearbox, axles with lightweight integrated sensor-actuators networks.“





Conclusions

All-electric cars can (and should be) designed around the principles of integrated modular E/E architectures.
- Increased dependability / safety / security
- at lower cost / weight / volume / maintenance
- and richer functionality (e.g. energy management for range extension)

ASIL D software safety engineering (at reasonable cost) a key enabling technology for building all-electric vehicles.

Uptake in automotive industry requires radical change
- Product development processes (top-down, distributed OEM & suppliers)
- Product development organizations
- Procurement and supplier business models

The aerospace industry has been adapting to this disruptive technology for the last 20 years; adaptations for automotive needs/product-life cycle?

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