Challenges in Engineering Automotive Software and Competency Requirements

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Reinventing the Automobiles

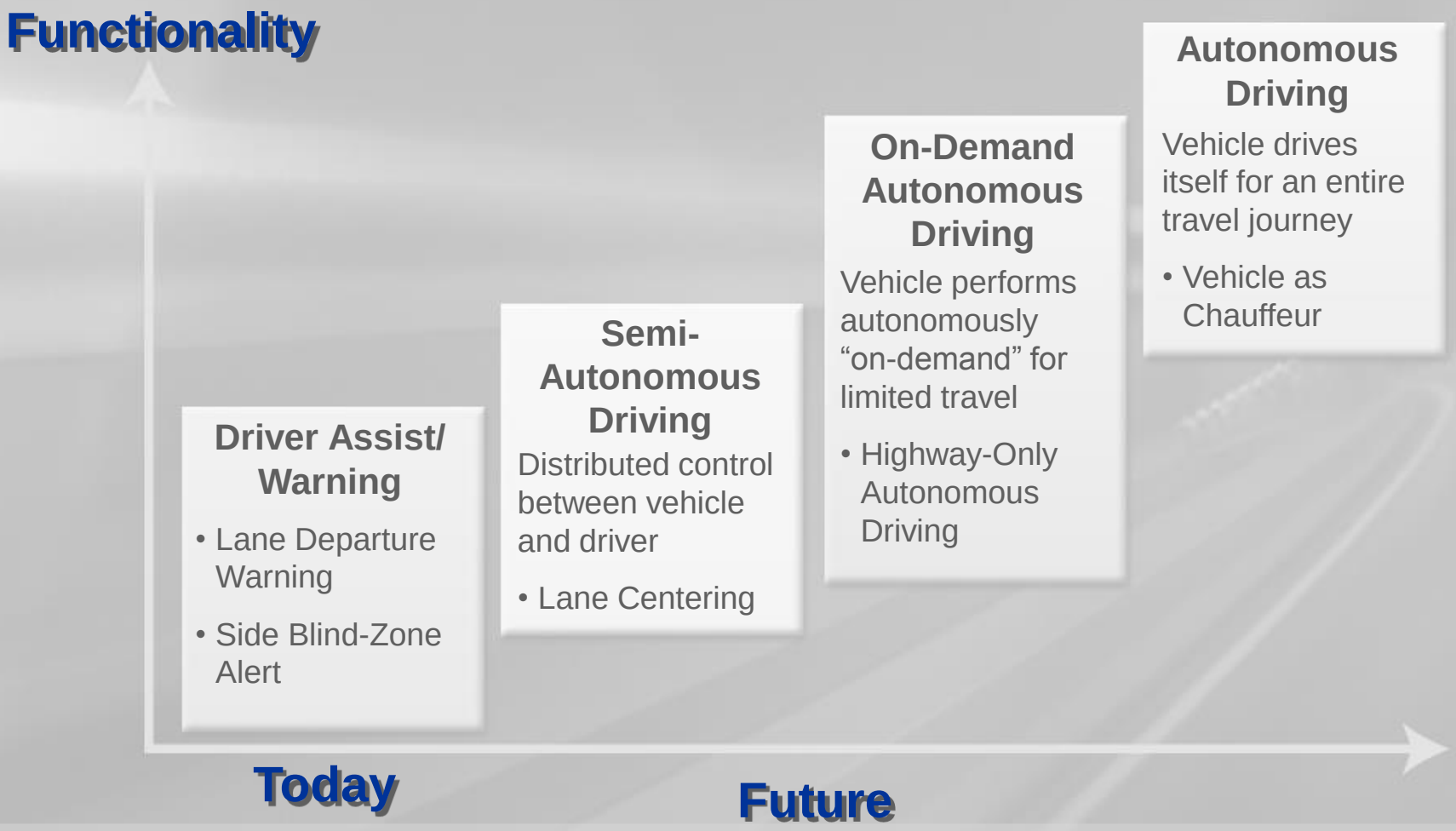
- **Personal Mobility undergoing fundamental changes**
- **Triggered by societal, environmental and personal pressures**
  - Energy, Emisson, safety, congestion, cost, personalization
- **Safety, Congestion and Convenience**
  - Key Enablers: advances in Electronics, Communication and SW Technologies

OEM Challenges

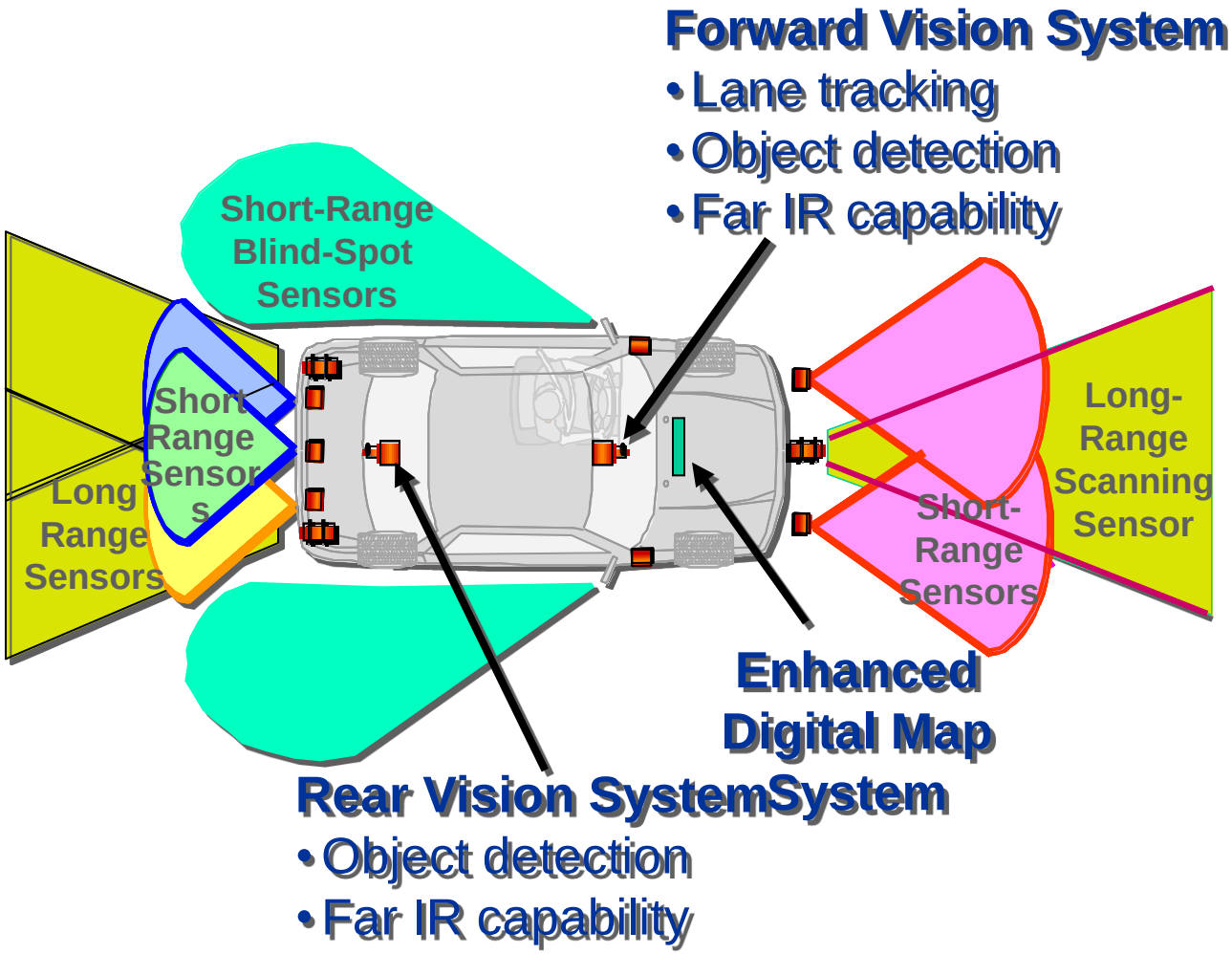
- **Cars increasing with population increase**
  - Population: 6B (now) – 7.5B (2020) – 9B (2050)
  - From 12% (now) - 15% (2020) - 20% (2050)
  - Cars: 700M (now) – 1B (2020) – 1.5B (2050)
- **1B to 1.5B vehicles is not sustainable!**
  - Environment, Energy
  - Safety, Congestion

- **Crash avoidance features (Blind spot detection, Lane Depart. Warning, side-view assistance, adaptive headlights) avoided 1/3 fatal crashes, 1/5 serious/moderate injury crashes**
  - US Insurance Institute for Highway Safety

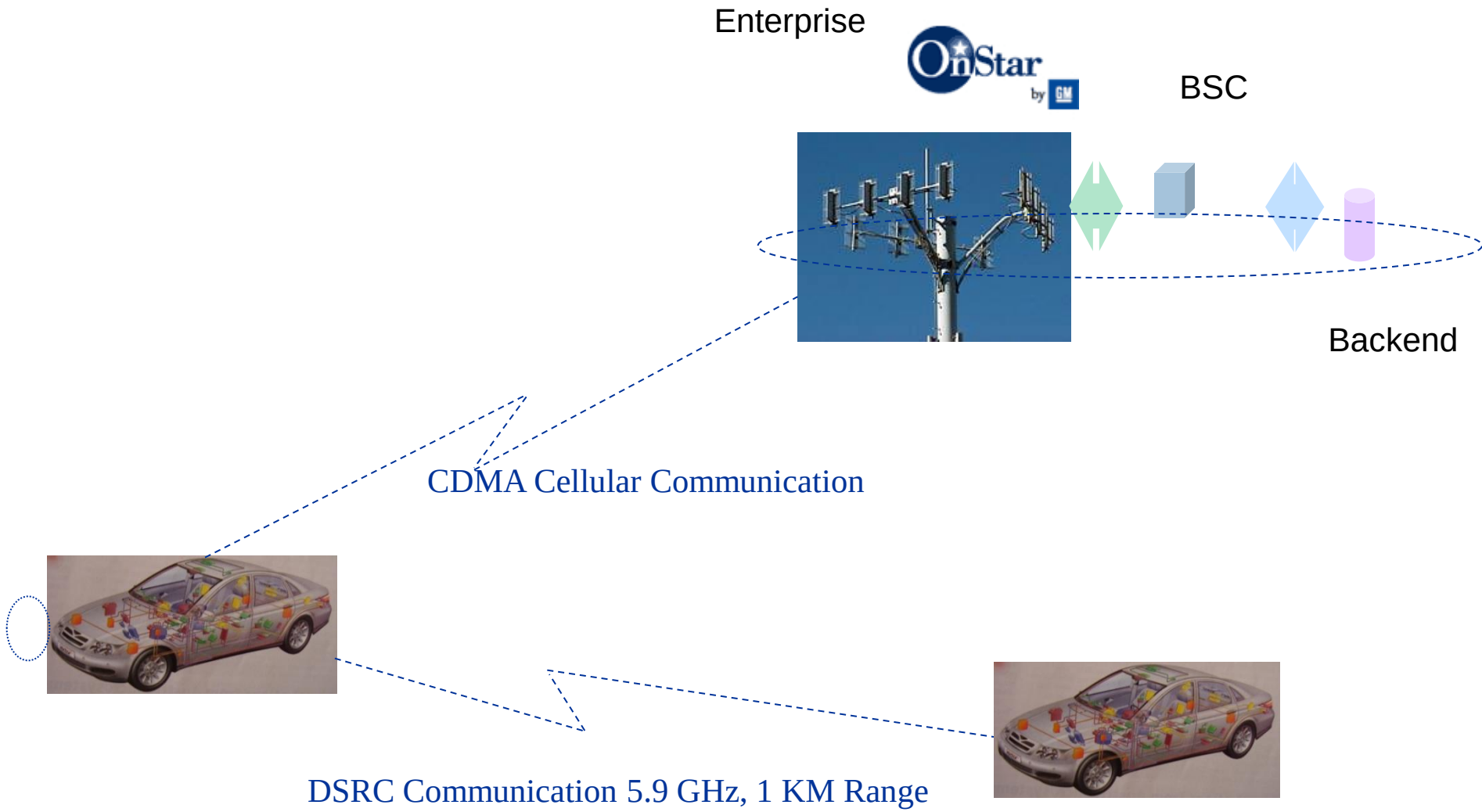
Roadmap to Safety and Convenience



360° Safety with Integrated Sensors



Vehicular Information Systems



V2I already exists

- CDMA based Network
- Hands-free Communication
- Turn-by-turn navigation
- In-vehicle security
- Remote Diagnostics
- emergency Services

Autonomous Vehicles

“BOSS”

“EN-V”

Vehicles That Drive Themselves

Where am I – GPS + digital maps

What's around me – 360° sensing (sensors + "V2V")

Take me where I want to go – Software algorithms + electronic controls and actuators

Electronic and SW Vehicle

- **Electronics and SW play major role**
- **Introduced a decade ago, it has proliferated the vehicle subsystems**
  - 7000 Ft. of wire length in today's cars
- **90% innovation in automobiles is in electronics (Kopetz 2000)**
- **More electronics than in the first airbus**
  - 10s of processors (ECUs), 100s of sensors/actuators
  - 4-5 different communication buses, 100 millions of lines of code
  - 10 Mbytes of SW
  - % Cost of SW: 1% (1980), 20% (2004), 40% (2015)

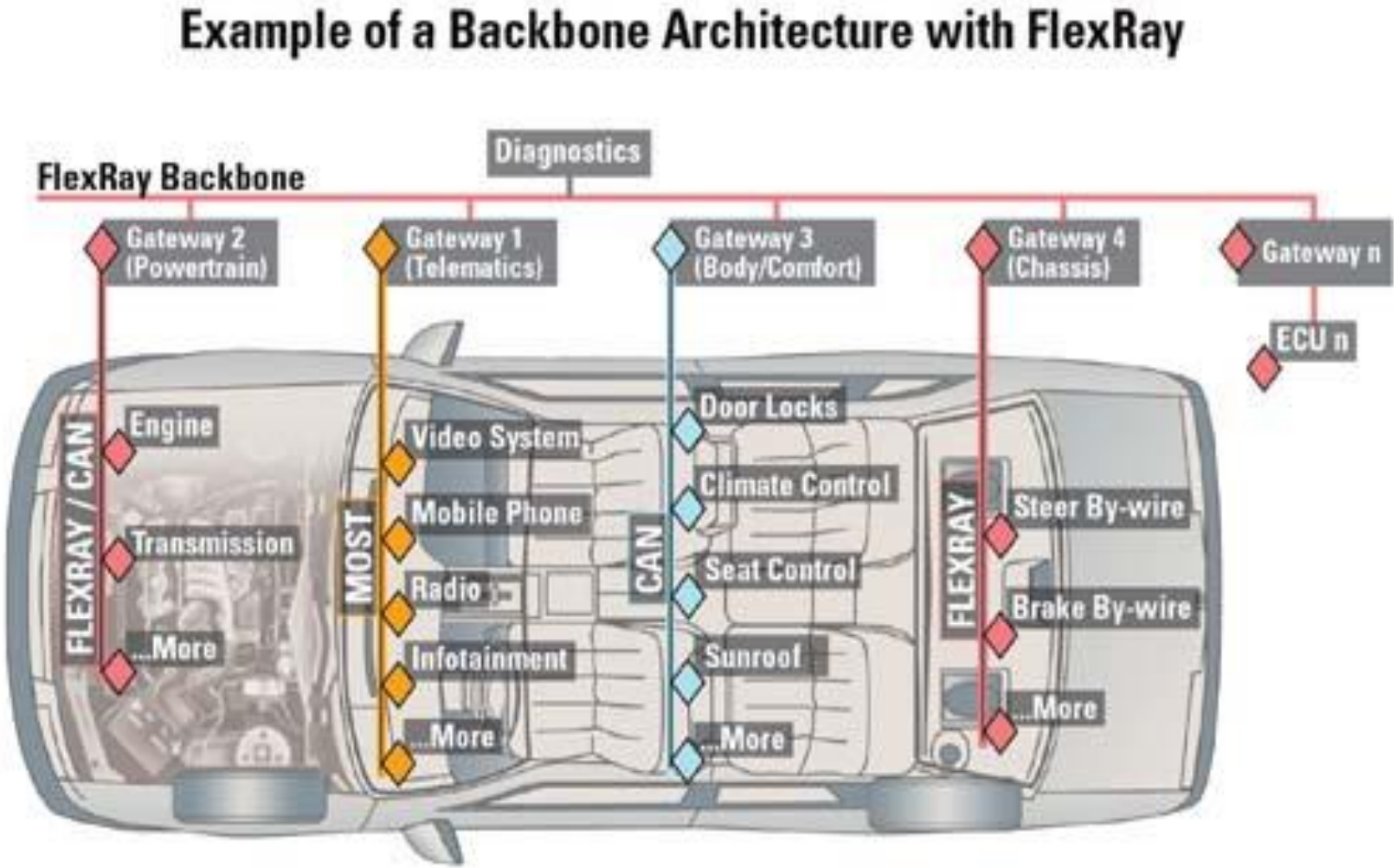
Electronics & Software Functions

- **Four diverse categories**
- **Powertrain control functions**
  - Engine control for fuel efficiency
  - Hybrid System, Hard Real Time (micro-,milliseconds)
- **Chassis control**
  - ABS,ESP, By-wire
  - Hybrid System, Hard Real Time(milliseconds)
- **Body electronics**
  - Lights, doors, windows, dashboard, seats, mirrors
  - Discrete, Reactive (seconds)
- **Telematics**
  - Navigation, infotainment (radio, phone, video)

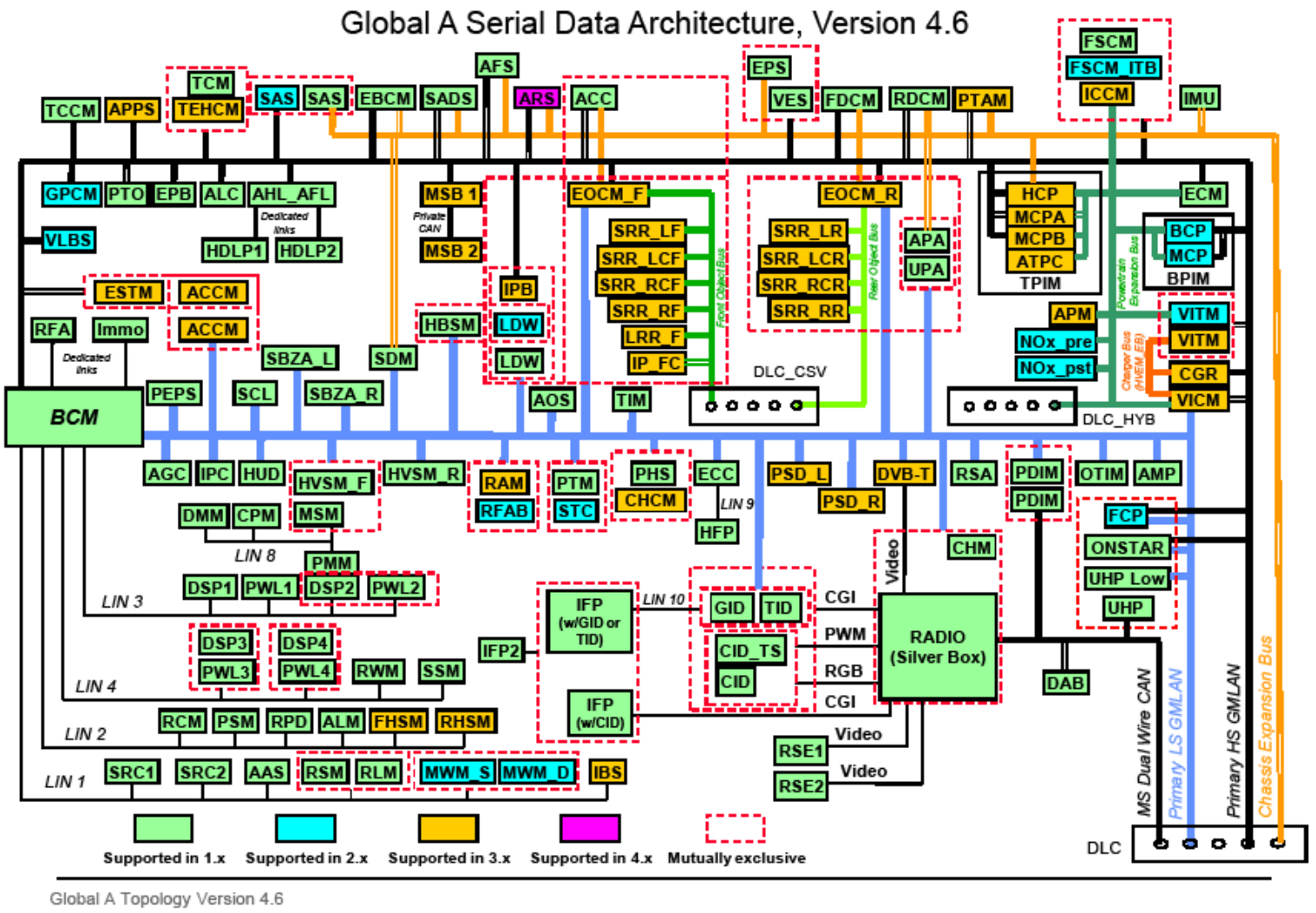
Software Vehicle

- Complex embedded system
- Multiple processors with real-time tasks
- RTOS and middleware : OSEK–RT
- CAN and time-triggered communication buses
- Gateways, routers and protocol stack
- Enormous design and verification challenges

Distributed Embedded Systems



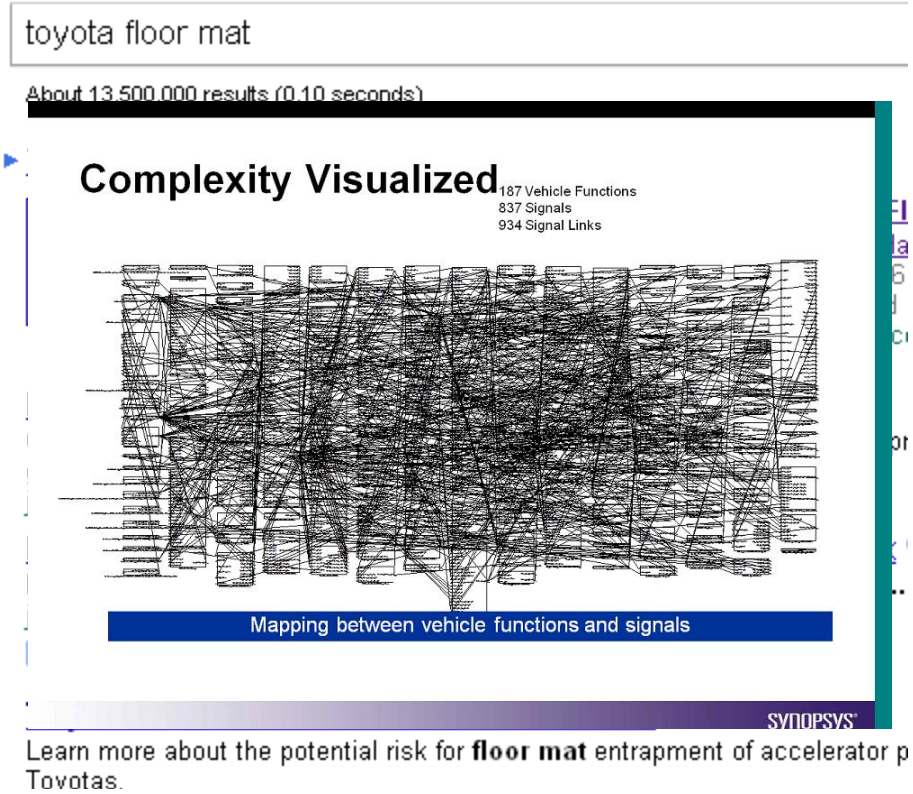
More than 100 ECUs in the superset definition



Global A Topology Version 4.6

Active Safety to Autonomy

- **Complexity increase**
  - Increased scope for faults
- **Failures NOTICED**
  - Business Critical, if not safety-critical
  - Leads to loss of image, confidence, sales



General Motors is recalling certain model year 2011 Buick Lacrosse and Cadillac SRX vehicles for failing to comply with the requirements of Federal Motor Vehicle Safety Standard No. 103, "Windshield Defrosting and Defogging Systems". On these vehicles, the software in the electronic climate control (ECC) module may disable the ability to adjust the heating, ventilation, and air conditioning (HVAC) system settings. If this happens, the driver will not be able to control the heating, cooling, and ventilation for the vehicle. If this condition affects the defrost system when it is required, it may decrease the driver's visibility, and could possibly result in a crash. Dealers will reprogram the ECC module free of charge.

Design and Verification Challenges

- **How do we arrive at these products?**
  - Correct, reliable and efficient
- **Correctness**
  - Untrained users, arbitrary environments, large volume
- **Reliability and dependability**
  - Cost effective and large volume
- **Efficiency**
  - Hardware resources
  - Software development efforts

SW Functions

- **Controllers implemented in SW**
- **Controllers in multiple Domains**
  - Powertrain, Body, Safety, Telematics, Infotainment
  - Varied in nature, criticality, functionality
    - Discrete and Reactive (Body)
    - Continuous, Hard Real Time (Safety and PT)
    - Discrete and Soft Real Time (Telematics)

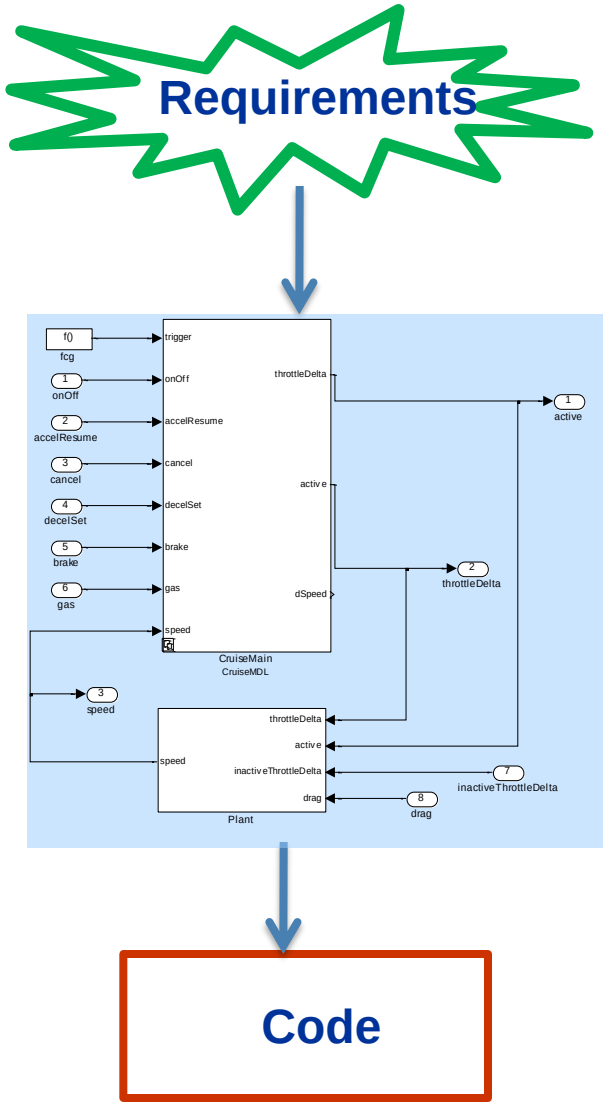
SW Architecture

- **Current**
  - Federated Architecture
    - One Function per box
    - Independent boxes supplied by different suppliers
    - OEMs assemble and integrate the boxes
    - Different boxes share communication infrastructure
      - *Hi and Low Speed CAN and LIN Buses*
- **Future**
  - Distributed Architectures
    - Functionality mixed up in a single box
    - OEM need to assemble individual as well as entire system
  - Autosar (component-based Infrastructure) enhance and enable distributed implementation
    - Functions as Components with std. interfaces
    - VFB for component communication and interaction
    - Manages the complexity of distribution with multiple suppliers

Distributed Platform

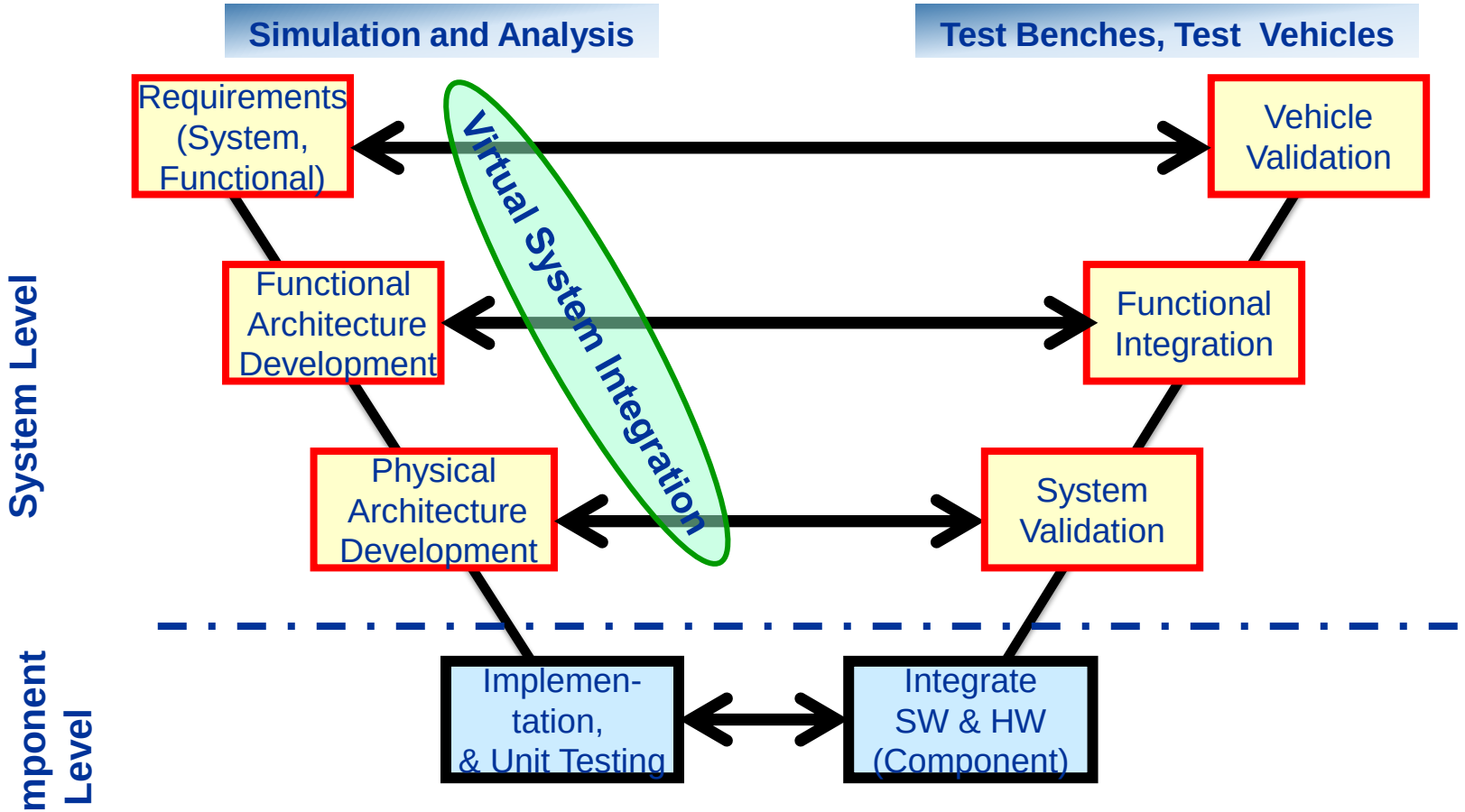
- **Controller implemented as a distributed system**
  - Multiple ECUs, and communication buses
- **Single Function in many ECUs**
- **Many functions in a single ECU**
- **ECUs connected by constrained buses**
  - CAN, Flexray, Ethernet, Most
- **ECUs have scheduling constraints which also lead to delays**
- **Traditional control design abstraction of inst. Reaction and feedback less valid**
- **Feature Interaction**

Current Practices



- ***Model-based Development***
- ***Executable models used as intermediate step***
  - *Simulink/SF, UML*
- ***Code auto-generated***
- ***Gap Still exists between Requirements and Design Models***
- ***V&V focused only on code***

V – cycle of Development and V&V



- ***Focus on Integration testing (Domain & Vehicle level testing)***
- ***Many artifacts are informal and ambiguous***
- ***Test generation manual***

Next Gen Activities

- **Requirement Engineering**
  - Requirements captured in DOORs
- **Move Towards Integrated Architecture**
- **Component-based SW Infrastructure**
  - Autosar
- **Fail Silent and Fail safe systems**
- **Enhanced System Engineering**
  - Functional Safety, ISO 26262
  - Security
- **Enhanced Virtualization and Early analysis**
- **Shift from ECU oriented development to feature oriented development**

Gaps Still Remains

- **Rigorous and Extensive Analysis of Requirements**
  - Systems level requirements to component-level requirement
- **System Level modeling and Analysis**
  - Relating Unit level testing and subsystem and system level testing
- **Incremental Development of Systems or Functionality**
  - Compositionality
  - Feature interaction
- **Conformance of implementation to system models**

People and Competencies

- **Present Skill set:**
  - Degree in CS/EE
    - Basics of Programming, Operating System, Embedded Systems, Basics in Communication, Networking and Control System Design
  - Project Experience in
    - Embedded Software Development, and System building
    - Configuration and Maintenance
- **Required/Desired Skill set:**
  - Knowledge and experience in
    - Requirement Engineering
      - *Early modeling and analysis*
      - *Thinking independent of implementation platform or architecture*
    - System Engineering
      - *Safety and Security Issues*
      - *Comprehensive knowledge of S/A, physical systems and computational systems*
      - *Control systems and Distributed SW implementation*
    - Modeling and Meta-modeling at software and system level
    - Standards and Processes for Safety and security-critical systems