Online-Seminar

Autonomes Fahren – Methoden, Prozesse und Werkzeuge für die Fahrzeugentwicklung

Helge Tielbörger

An old pursuit…

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1956:

GM imagined how driving might be like in another 20 years

Trends driving innovation in today's vehicle market

Challenging vehicle engineering teams

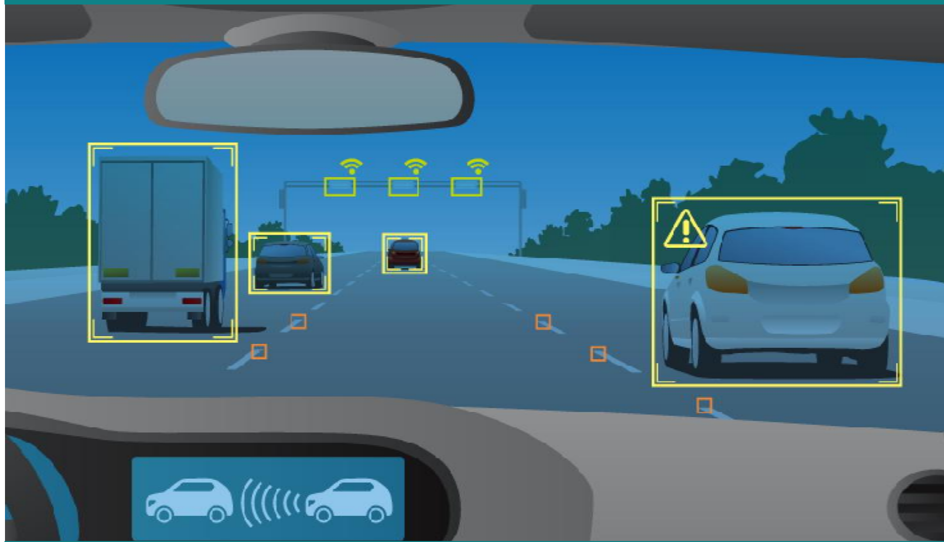
Towards Automated Driving…

Systems Performance

…yet Managing Expected Vehicle Performance

Managing Complexity of Required Mechatronic System Innovations…

Mechatronic Complexity



…and Guarantee Quality of Integration

The autonomous driving car as a system of systems
Enabling series production of autonomous vehicles

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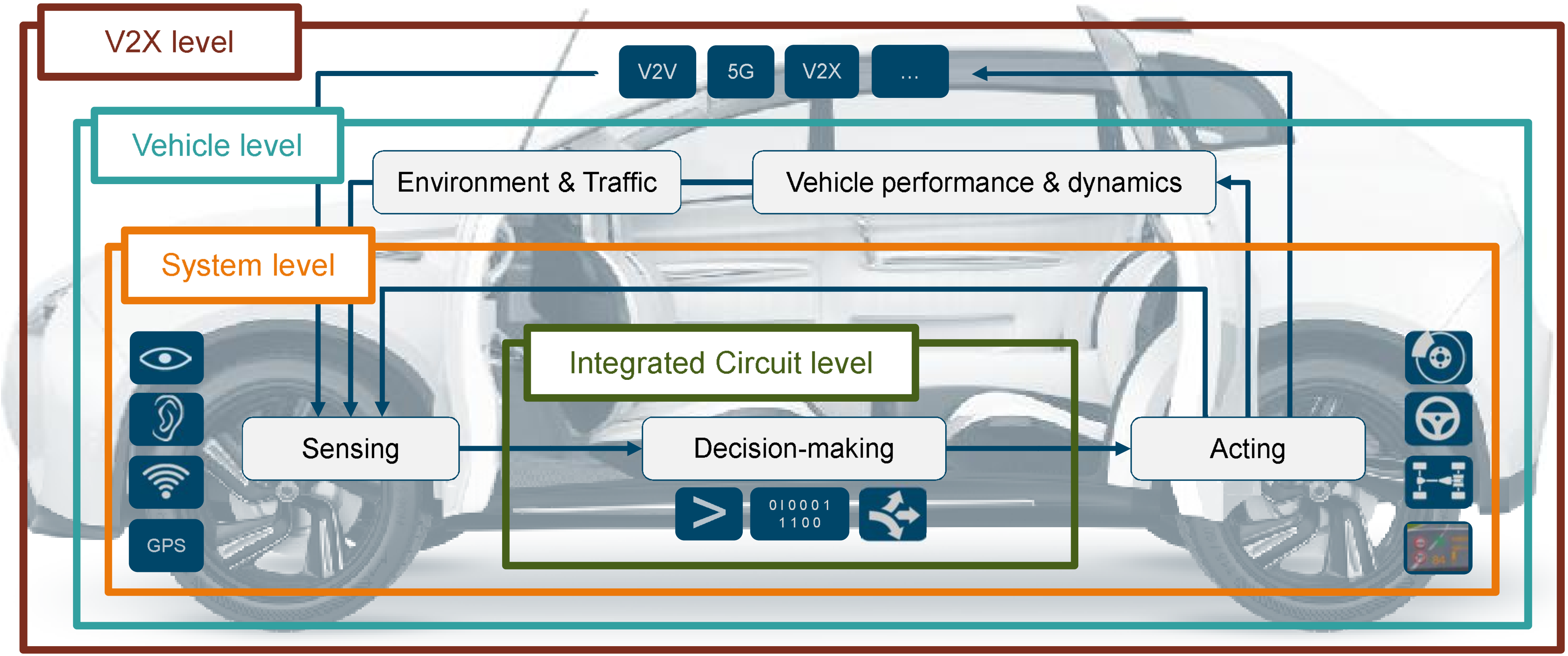

Our solutions support autonomous vehicle development needs

Across all engineering domains

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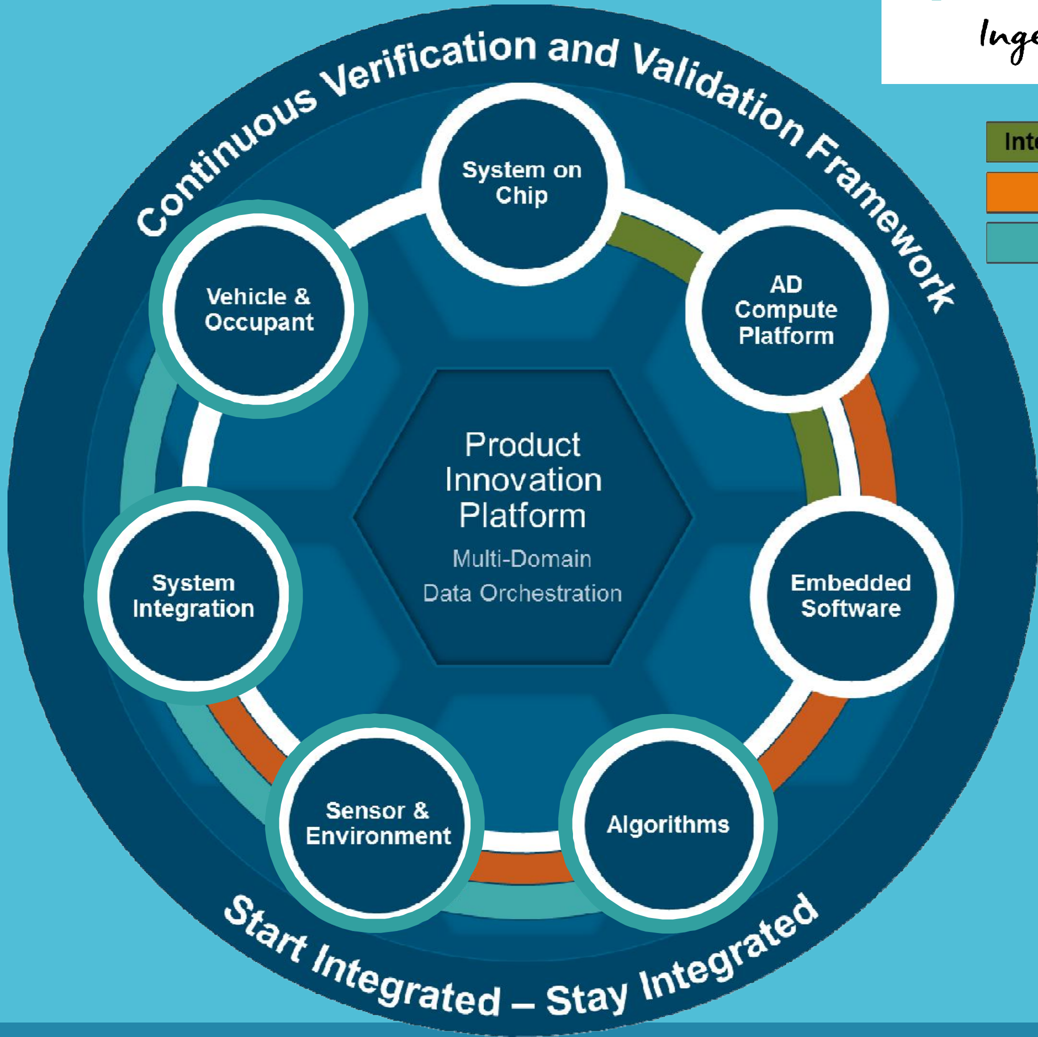


Integrated Circuit level
Systems Level
Vehicle Level

Ensuring digital continuity, multi-domain traceability and functional safety of autonomous systems

Addressing challenges for autonomous driving vehicle development

FROM ADAS TO AUTONOMOUS DRIVING

“+25% CAGR (through 2030) for Sensors”

Roland Berger , on “Autonomous Driving”, 2014

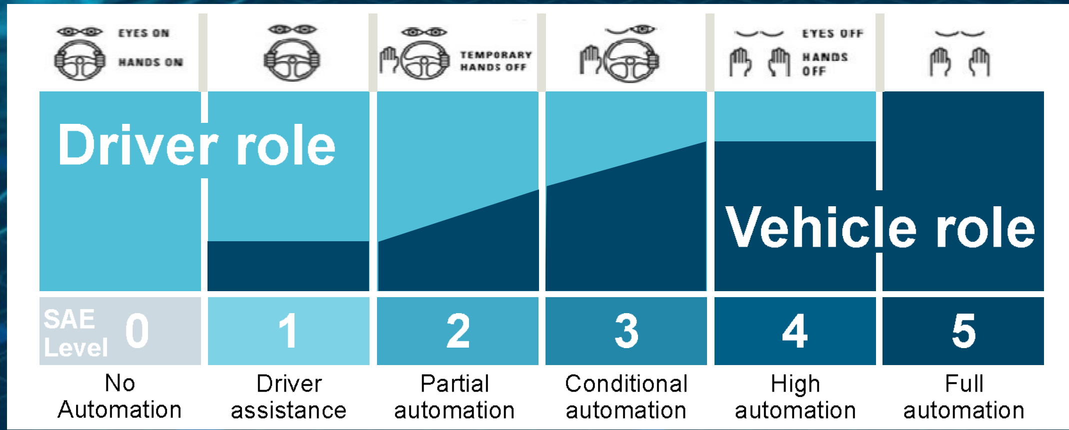
…

“14.2 billion kilometers of testing is needed”

Akio Toyoda, CEO of Toyota
Paris Auto Show 2016

“Design validation will be a major – if not the largest – cost component”

Roland Berger
“Autonomous Driving” 2014



Engineering implications of the AV development challenge

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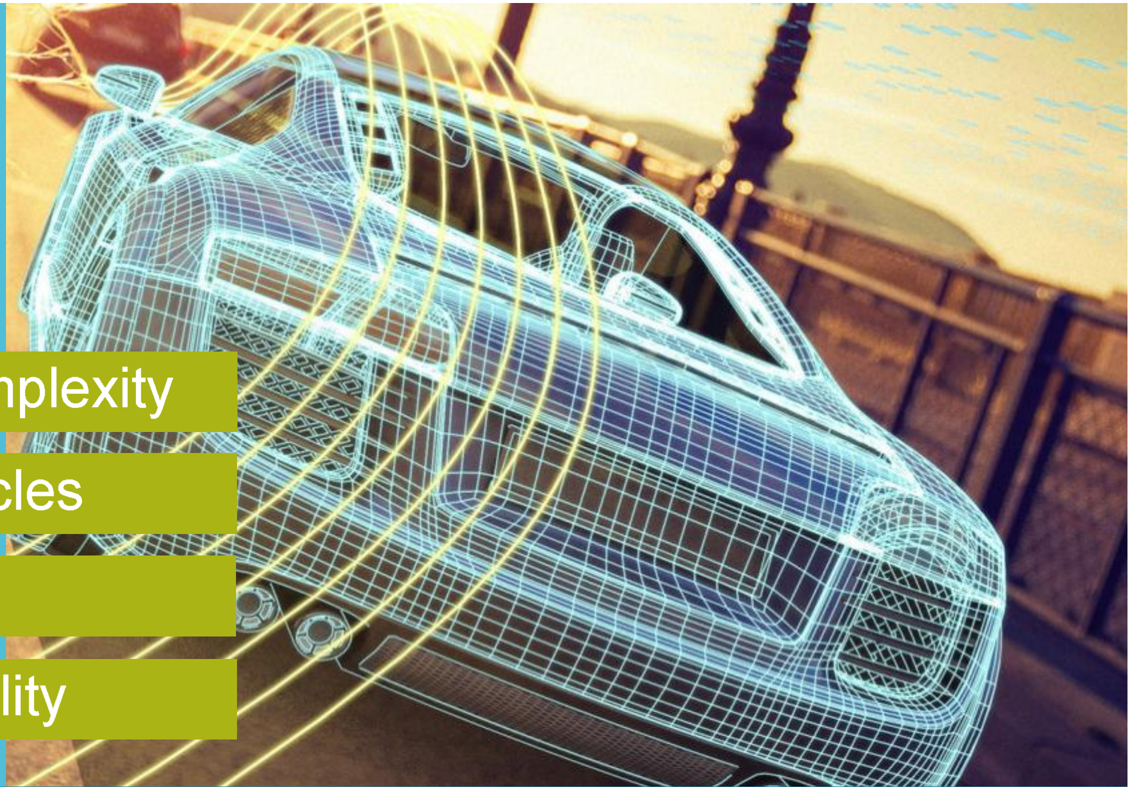
Rethink the vehicle development processes



- Increased hardware and software complexity
- Massive validation and verification cycles
- Regular over-the-air software updates
- Reconciling agility with better traceability

While balancing safety, comfort and efficiency performances

Vehicle Performance Engineering for AV

Solution areas

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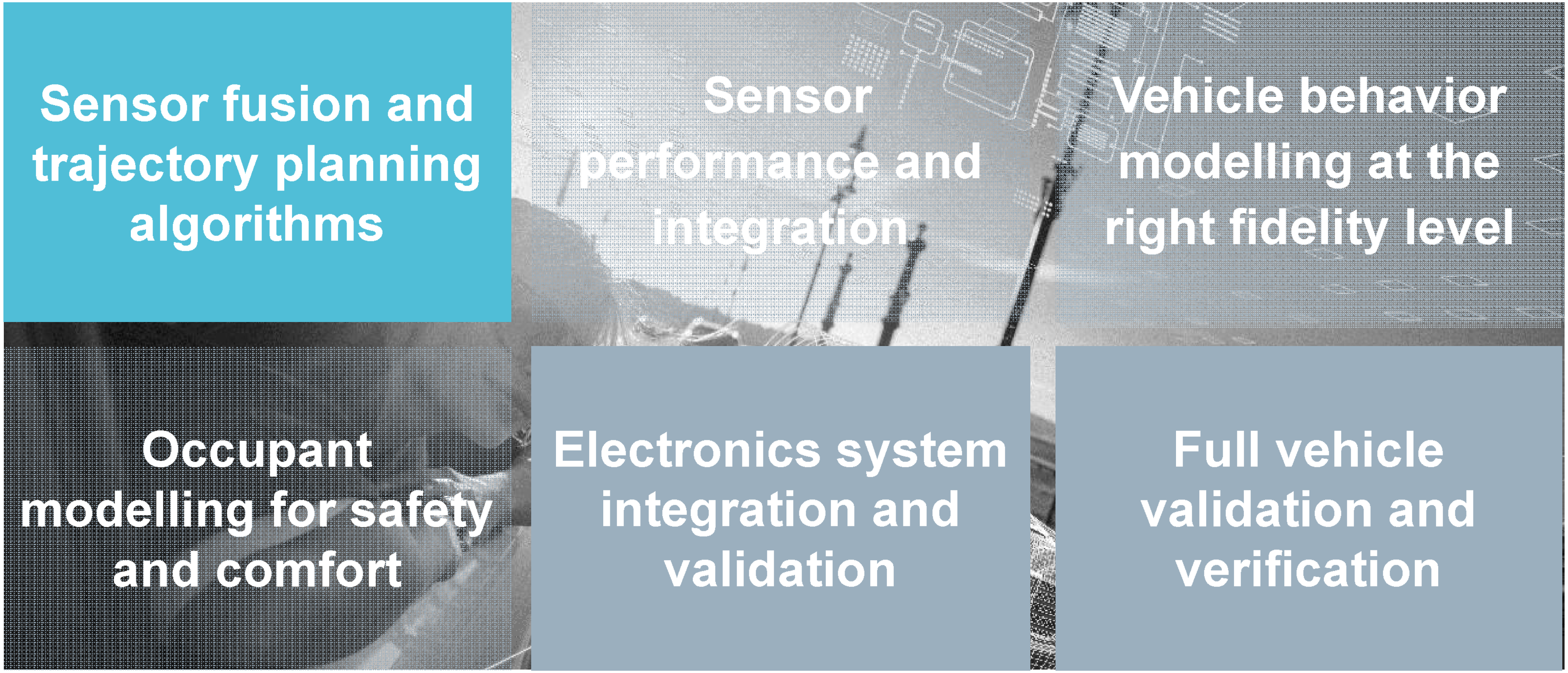
- Sensor fusion and trajectory planning algorithms
- Sensor performance and integration
- Vehicle behavior modelling at the right fidelity level
- Occupant modelling for safety and comfort
- Electronics system integration and validation
- Full vehicle validation and verification

Vehicle Performance Engineering for AV

Solution areas



Sensor fusion and trajectory planning algorithms

Engineering services for smart perception and driving strategies

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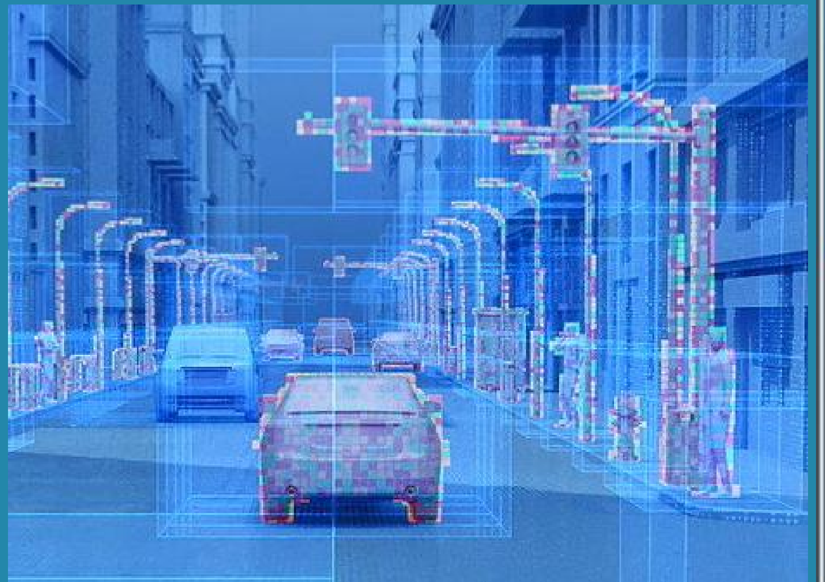
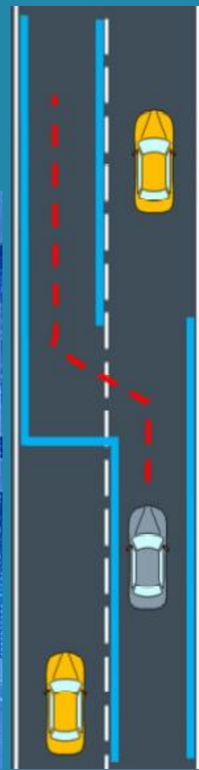
Get up to speed instantly with advanced controls for autonomous driving functions

- Fuse raw sensor data and develop data classification algorithms for centralized system architectures

Sensor fusion, data classification, free space detection and trajectory planning





Sensor fusion and trajectory planning algorithms

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Get up to speed instantly with advanced controls for autonomous driving functions

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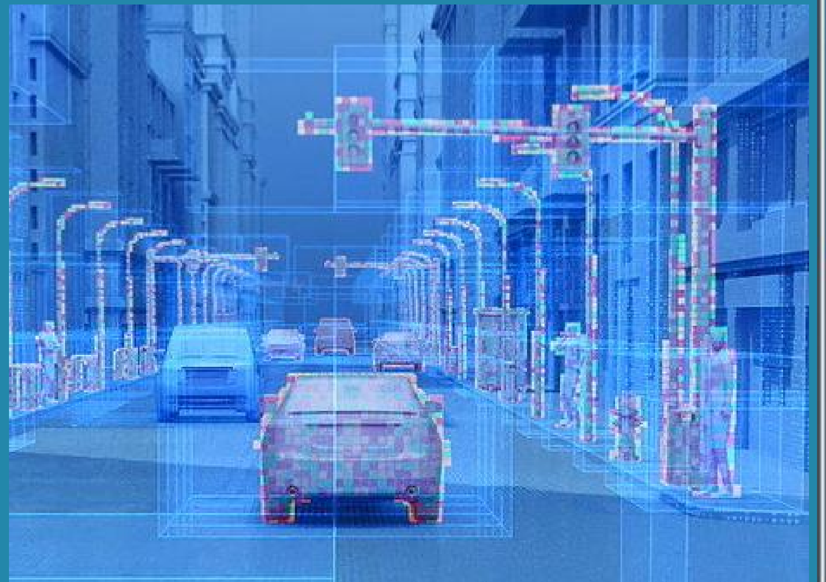
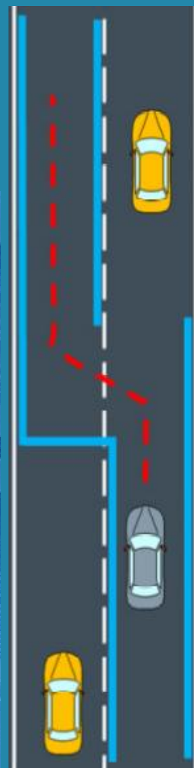
- Develop free space detection and trajectory planning algorithms for highway, city driving and valet parking maneuvers

Sensor fusion, data classification, free space detection and trajectory planning





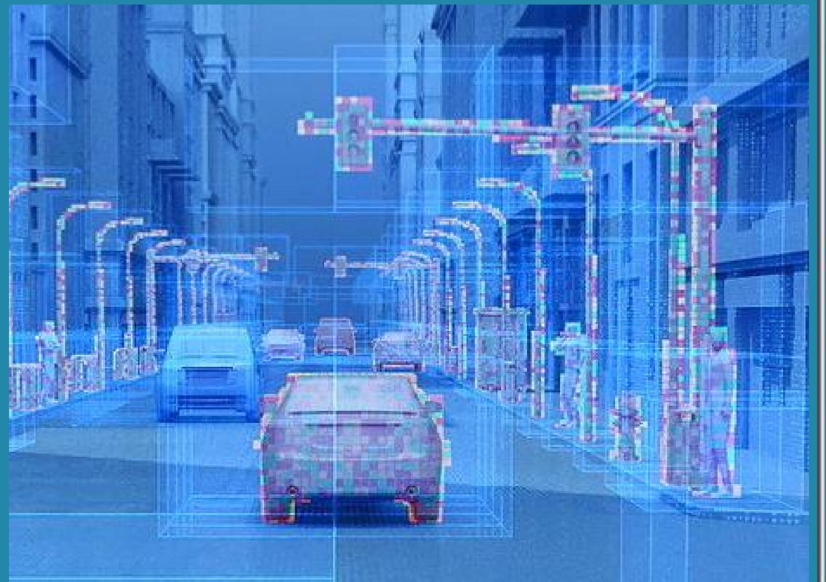
Sensor fusion and trajectory planning algorithms

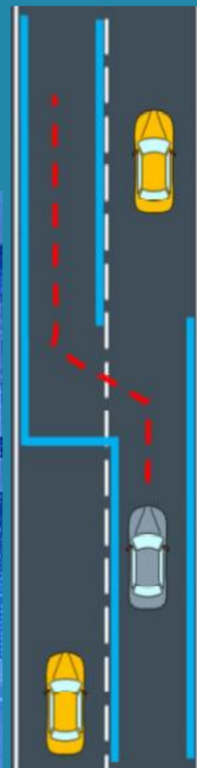
Engineering services for smart perception and driving strategies

Get up to speed instantly with advanced controls for autonomous driving functions

- Fuse raw sensor data and develop data classification algorithms for centralized system architectures
- Develop free space detection and trajectory planning algorithms for highway, city driving and valet parking maneuvers
- Use machine learning, deep learning and model predictive control (MPC) technology for robust automated driving systems

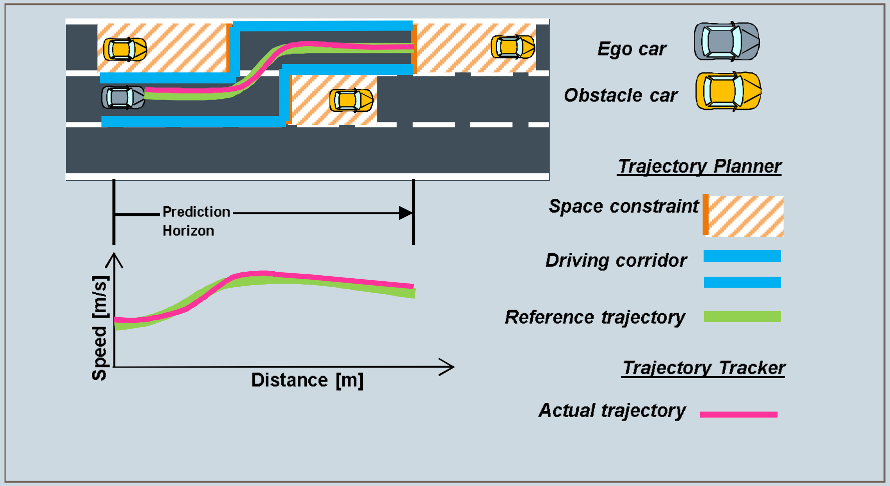
Sensor fusion, data classification, free space detection and trajectory planning

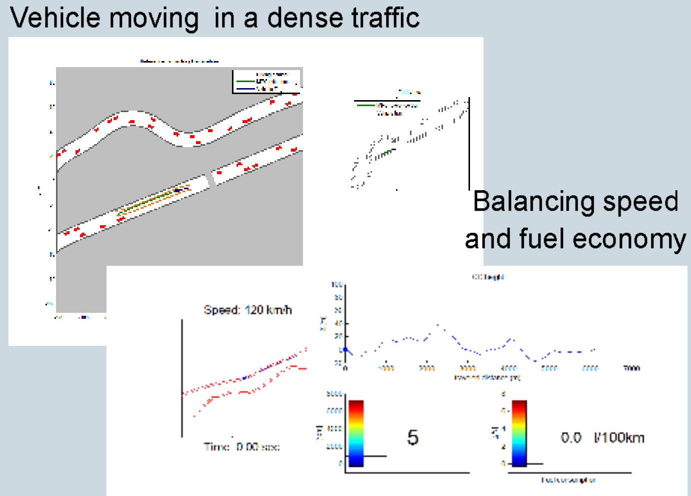


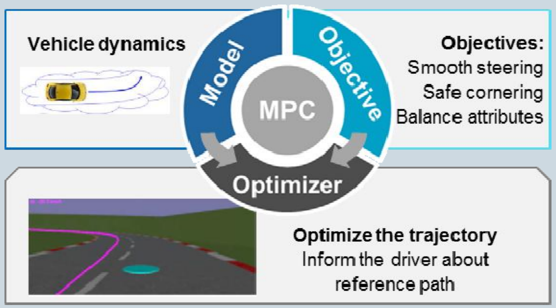


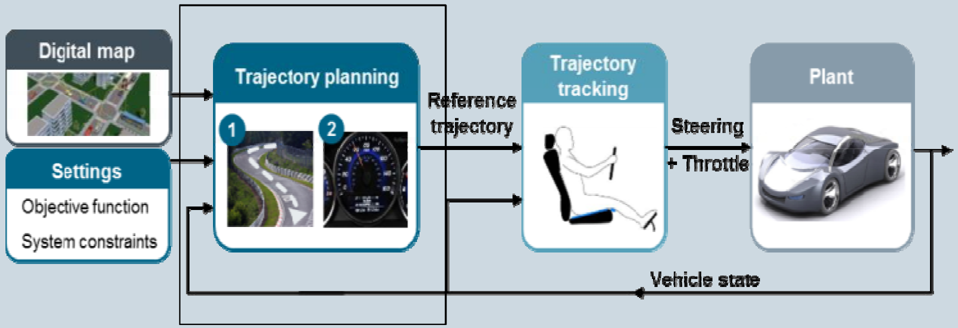
Controls
Trajectory Planner Using Model Predictive Control

Controls logic Model Predictive Control technology in driver strategy intelligence









Use case
Valet Parking Planning and Control

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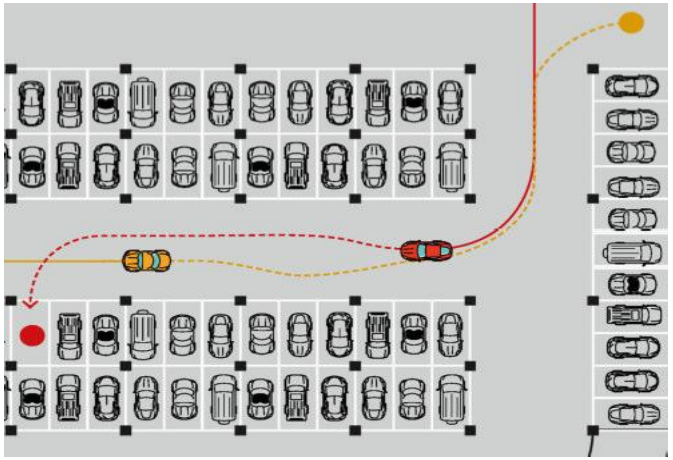
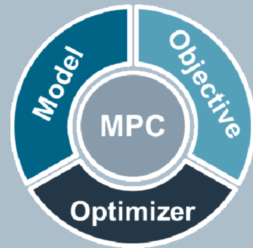
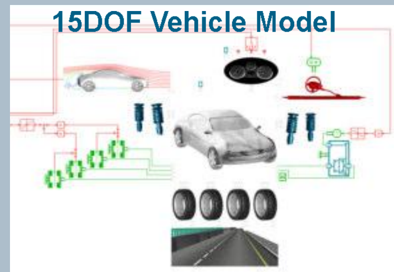


- **Fully take over control of the vehicle with the Parking Assist Module. The vehicle is driven through the parking area until it comes to the designated parking position and parks it self.**





Development done of Model predictive control (MPC) algorithms for motion and path planning, parking maneuvering, learning control, collision avoidance (pedestrians, cyclists,…) including a distributed motion planning for multiple cars

Co-simulation

High fidelity and realistic models (vehicle dynamics, sensors, tyres, traffic environment.)

Experiments

Real-time implementations, embedded planning and control algorithms

Enable S3

AV System Performance Engineering

Solution areas

Sensor fusion and trajectory planning algorithms	Sensor performance and integration	Vehicle behavior modelling at the right fidelity level
Occupant modelling for safety and comfort	Electronics system integration and validation	Full vehicle validation and verification

Sensor performance and integration

Simulation of sensors at a large array of fidelity levels and applications

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Predict multi-attribute, multi-physics system performance

- Reduce sensors cost, improve and demonstrate automotive-grade reliability of sensors to accelerate their introduction

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Simulation of sensors at a large array of fidelity levels and applications

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- Gain confidence in achieving 360º sensing with the sensors ecosystem in vehicle for any number of traffic/test scenarios

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Sensor ecosystem performance verification and validation

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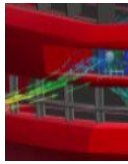
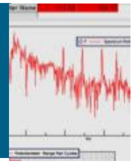
Sensor ecosystem performance verification and validation

Vehicle integration and multi-attributes design



Location optimization, impact of weather elements

Fatigue analysis and durability



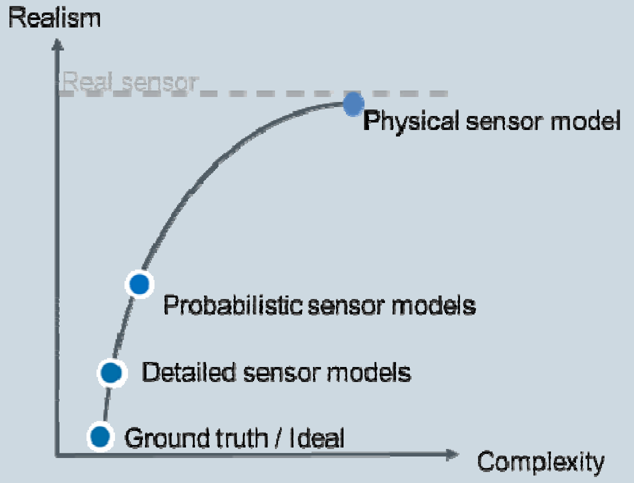
Thermal stress, vibration, impact analysis

Mechanics	Electronics	Thermal	Electro-magnetics	Acoustics

Sensors in Environment

Varying fidelity level sensor modelling

Balancing accuracy and computation time of sensor simulations



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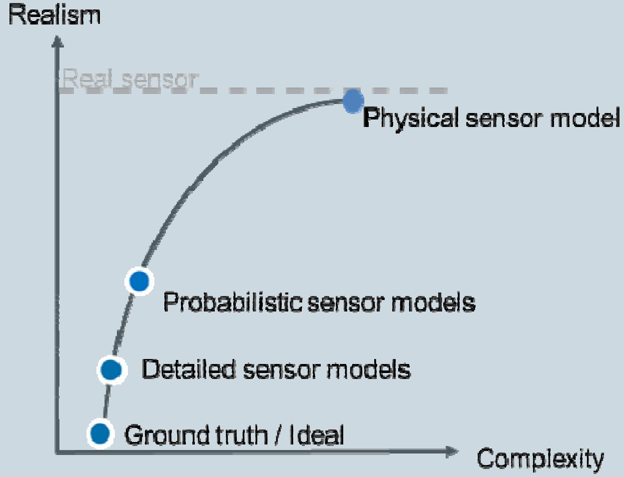
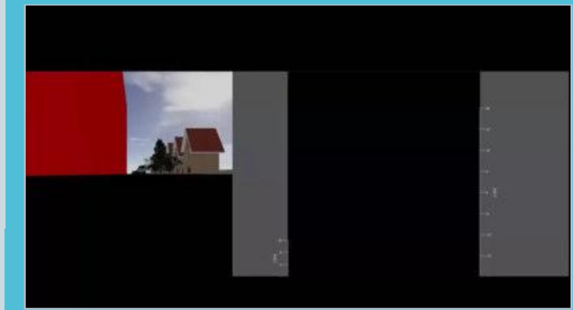
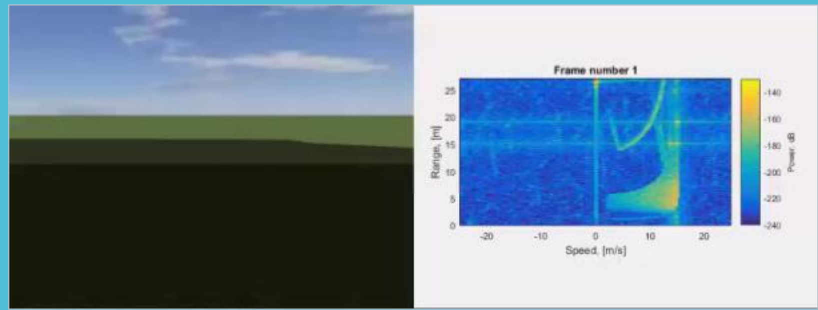




Lidar (spinning and solid-state)



Physics-based Radar simulation

Example: during night-time driving

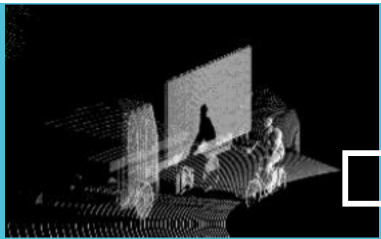
Example: during tunnel entrance/exit

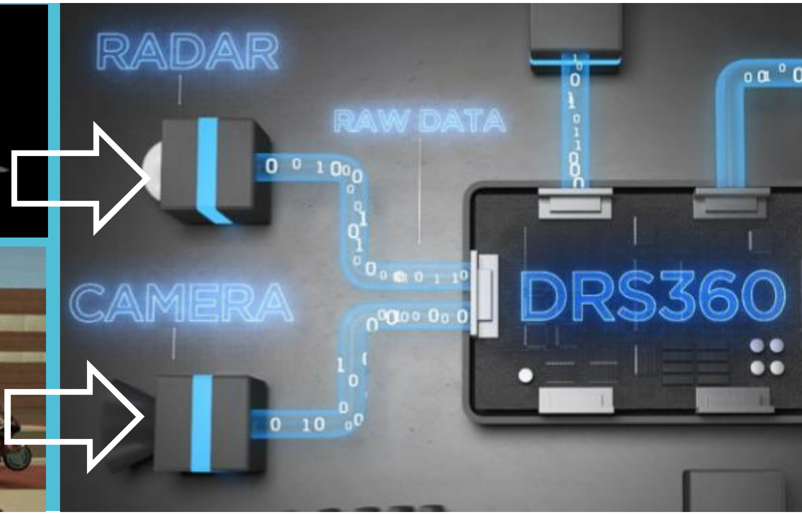
PreScan Physics Based Camera (PBC) simulation

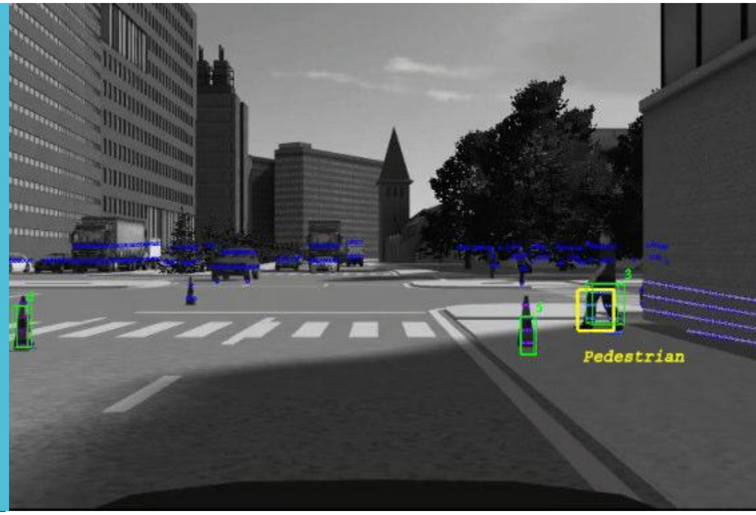
Mentor DRS360 – Simcenter PreScan
Enabling Multi-Sensor Image Classification Based on AI

Simcenter PreScan

Virtual Sensor Image Generation (LiDAR, Camera)







PreScan - Virtual Sensor Image Generation to Limit Physical Testing

DRS360 – Machine Learning Automates Classification Based on Fusion of Multi-sensor Data (LiDAR, Camera …)

Demonstrated at "The Global Stage of Innovation", CES 2018, Las Vegas

AV Sensors Design and Vehicle Integration

Bringing electronics and mechanical verticals together

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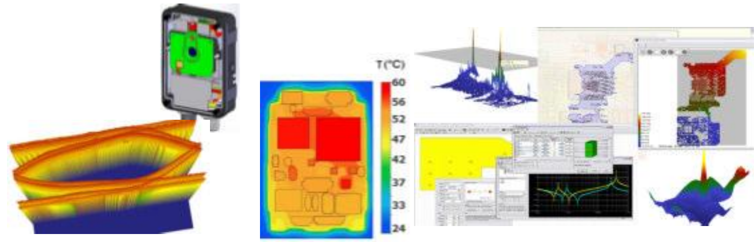
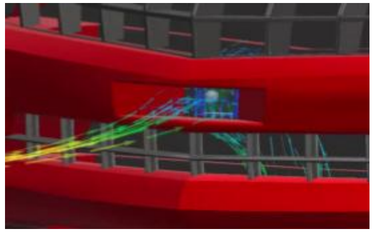
Design and optimize AV sensors

- **Unparalleled EDA and MCAD collaboration** to accelerate **sensor design** and **vehicle integration** accounting for multiple attributes: electronics, thermal, electromagnetics, acoustics, optics
- Guarantee reliable installation of sensors taking weather elements (rain, mist, dirt) and vehicle integration location into account
- Virtual and physical validation of sensor performance

Electronics and thermal design



Vehicle integration dependent design implications



Radar and ultrasonic sensor array design and EMI

Real-world Testing of Sensors Ecosystem in a Vehicle
Engineering services to enable sensor vendors with in-vehicle testing

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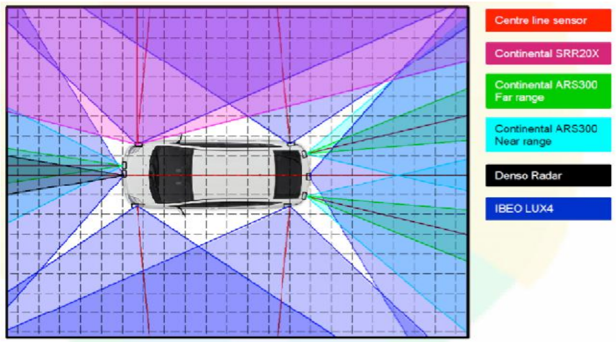
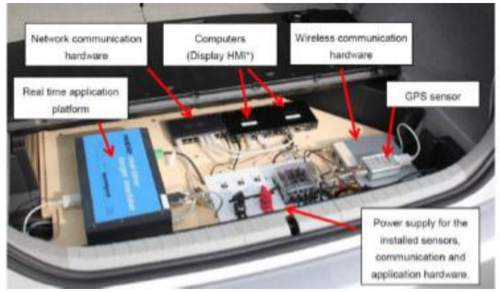
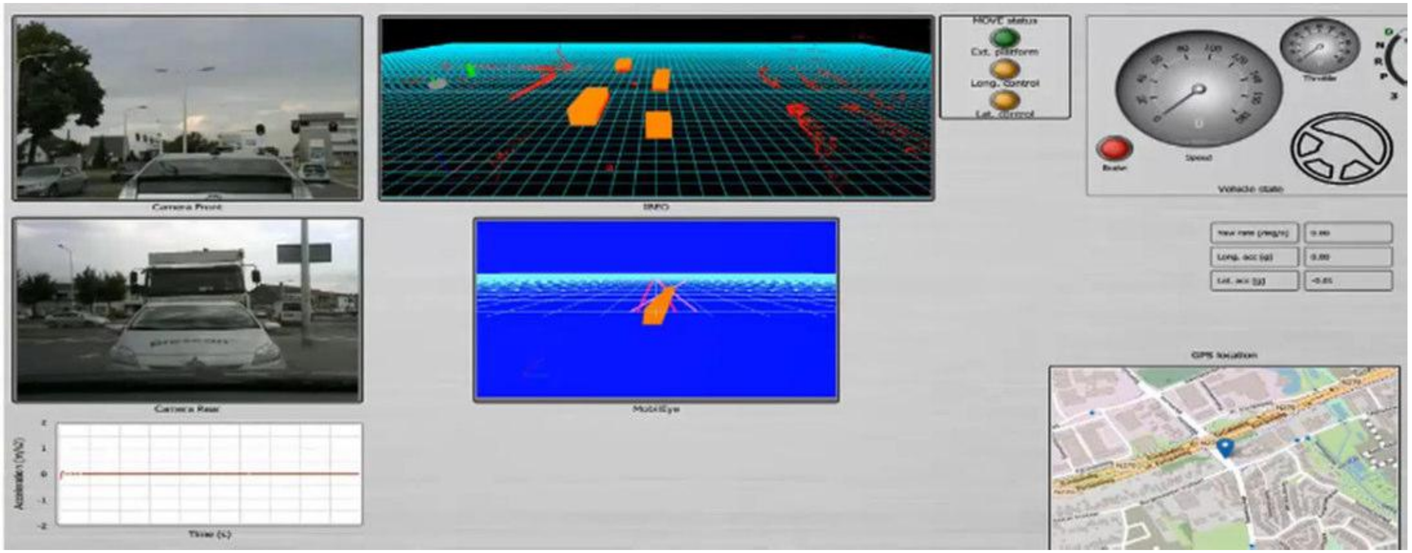




Rapid prototyping platform for sensors testing and prove out in real world

Siemens TASS dedicated test site in Eindhoven region for autonomous driving in highway and urban driving environment



Valeo

Bringing Ultrasonic to the Mass Market

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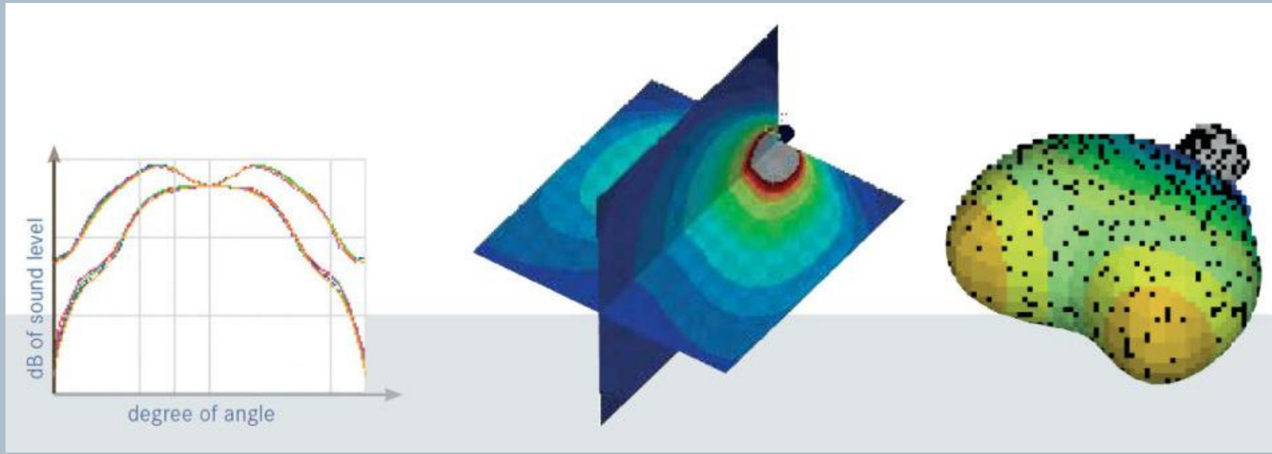
- Engineers must establish the effectiveness of the emitted sound of the sensor, embedded in the bumper, to ensure proper operation.
- With Simcenter, engineers know for sure how the product behaves and can refine the design before prototypes are built



- The hemispheric surface output (right) gives Valeo engineers greater insight into the shape and intensity of the acoustic field in three dimensions compared to outputs displayed in two planes (center) or as line graphs (left).

"Acoustic simulation allows us to more efficiently develop acoustic sensing systems for the mass market with faster turnaround times, greater economy, and designs that are both optimal and innovative"

Dr. Richard Rapp, Manager of Simulation at the Switches and Sensing Systems Division at VALEO

AV System Performance Engineering

Solution areas

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Sensor fusion and trajectory planning algorithms	Sensor performance and integration	Vehicle behavior modelling at the right fidelity level
Occupant modelling for safety and comfort	Electronics system integration and validation	Full vehicle validation and verification

Vehicle behavior modelling at the right fidelity level

Virtual validation requires accurate vehicle dynamics models

Model driving dynamics behavior supporting virtual validation of automated driving systems

Vehicle behavior modelling at the right fidelity level
Virtual validation requires accurate vehicle dynamics models

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Model driving dynamics behavior supporting virtual validation of automated driving systems

- Validate automated driving systems under large numbers of conditions in a virtual environment

Vehicle behavior modelling at the right fidelity level

Virtual validation requires accurate vehicle dynamics models

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Model driving dynamics behavior supporting virtual validation of automated driving systems

- Validate automated driving systems under large numbers of conditions in a virtual environment
- Add accuracy to chassis system and tire models to simulate braking and steering behavior and body movements

Vehicle behavior modelling at the right fidelity level

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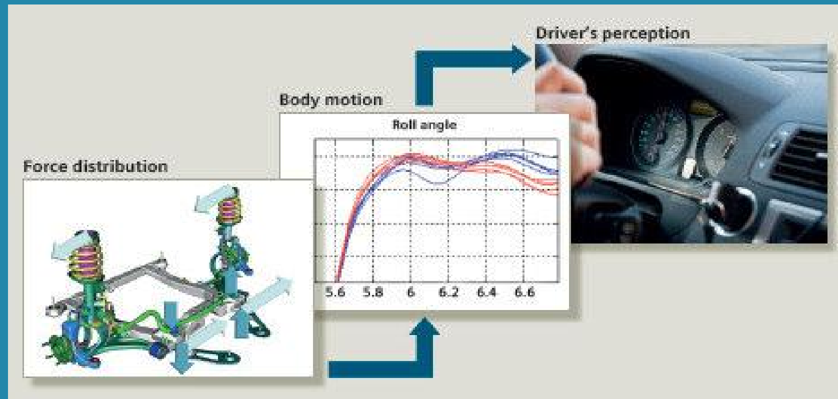
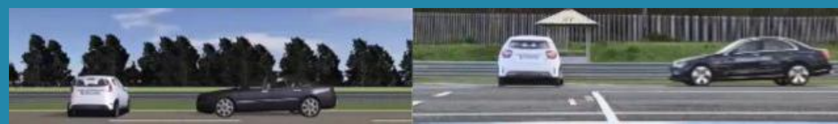
Translation of subjective definitions of comfort into objective data

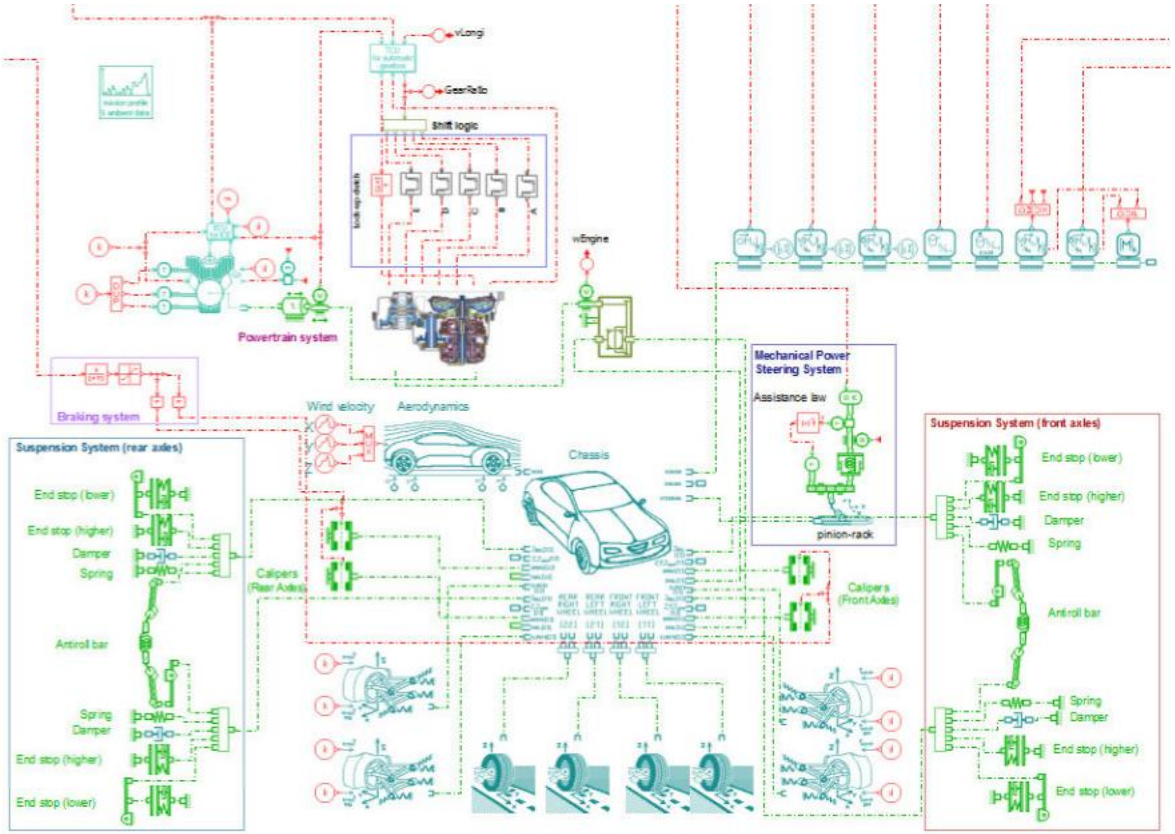


Accurate braking distance prediction



Vehicle and Occupants

Optimum fidelity powertrain and vehicle dynamics modelling



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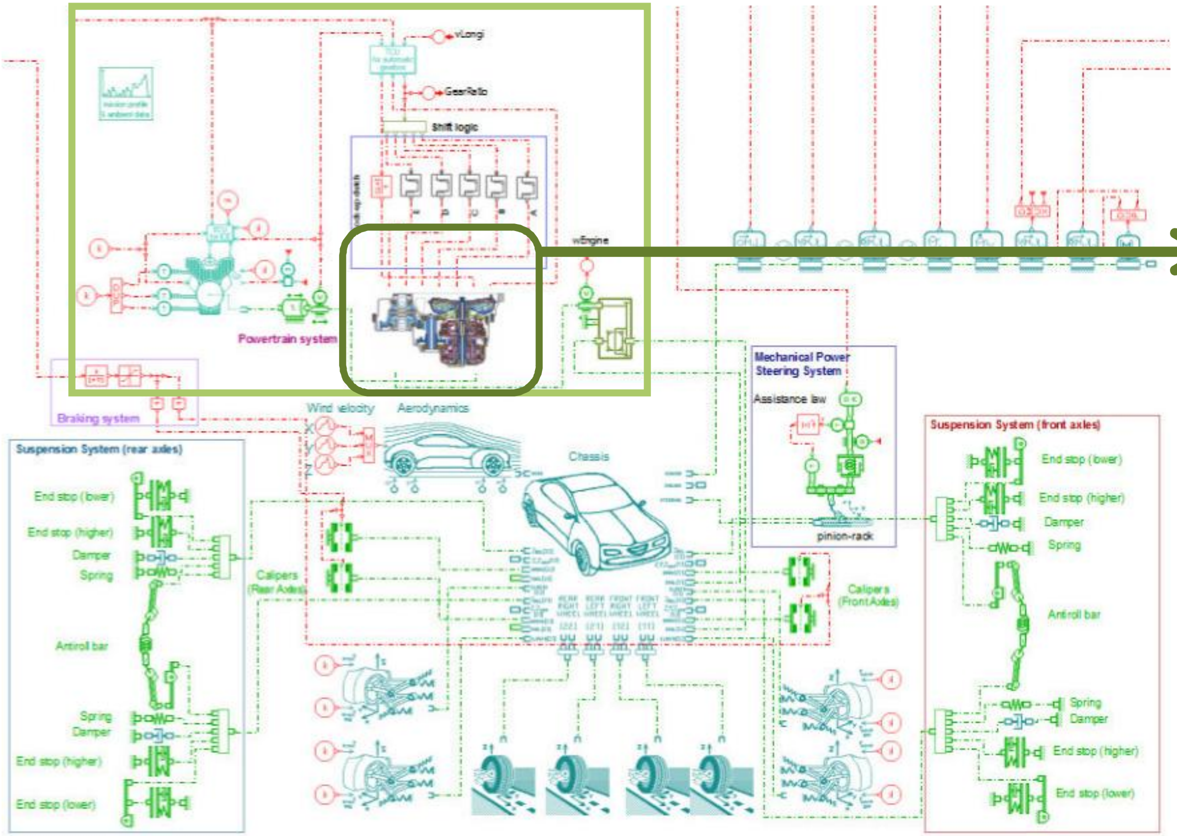

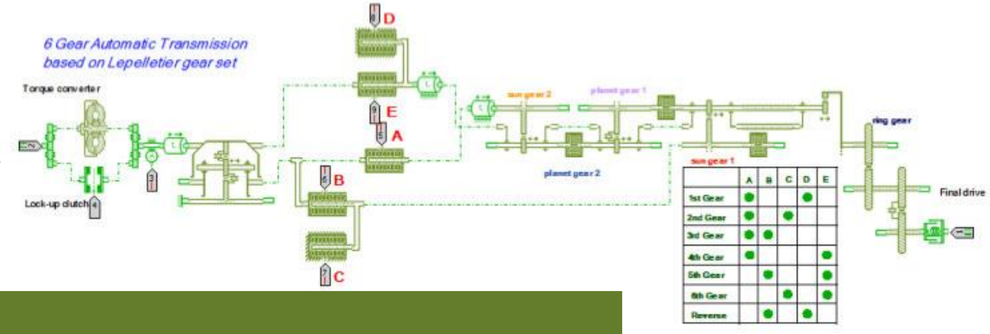

6 gear automatic gearbox

Semi detailed driveline modeling

first driveline mode (shaft stiffness and inertiae),

torque converter and lock-up clutch,

gearbox control (engagements of clutches),

simple engine

Vehicle and Occupants

Optimum fidelity powertrain and vehicle dynamics modelling

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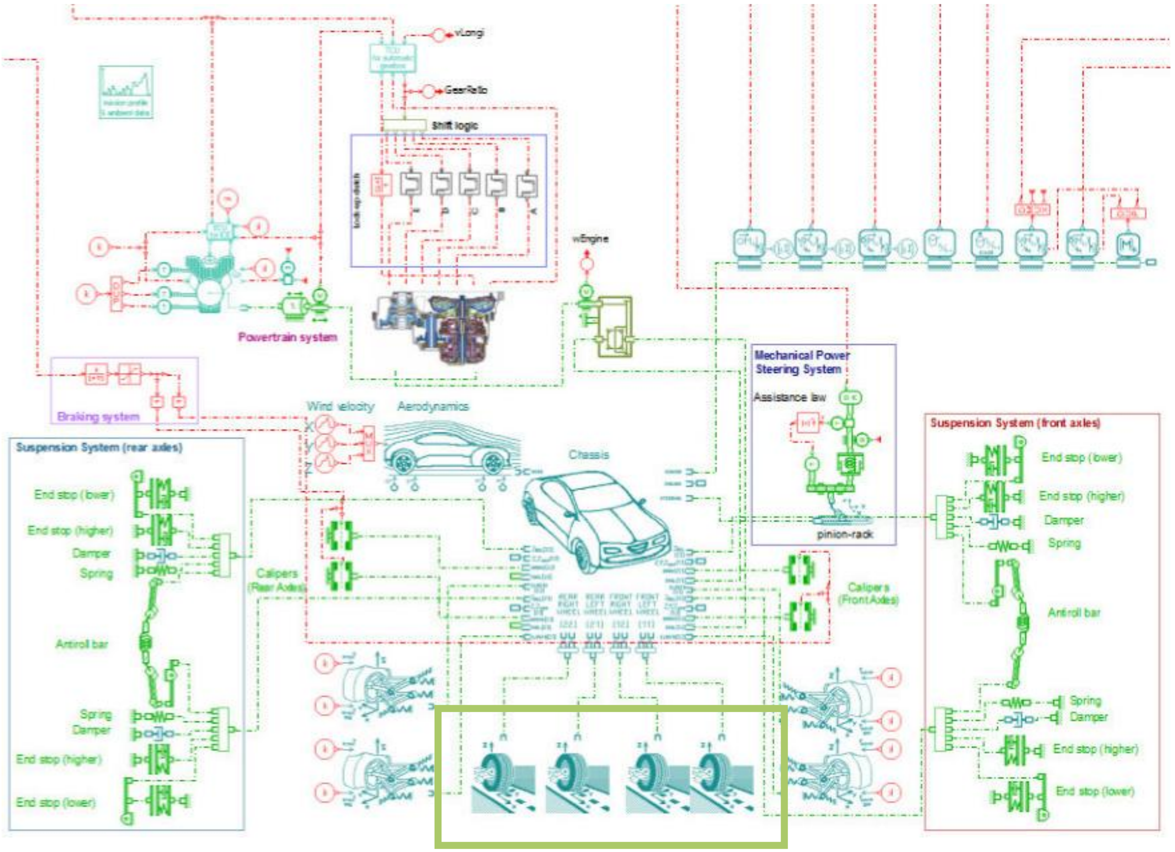
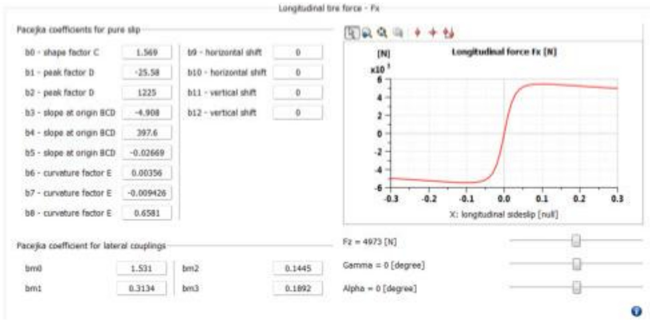


Pacejka tire model

- industry standard, characterization process is known
- adequate for emergency maneuvers
- local grip modulation possible (split µ for oil slick…)
- real time compatible (and faster)
- lateral – longitudinal coupling for complex situations (driver swerves while AEBS is braking)
- transients (lateral and longitudinal relaxation length)



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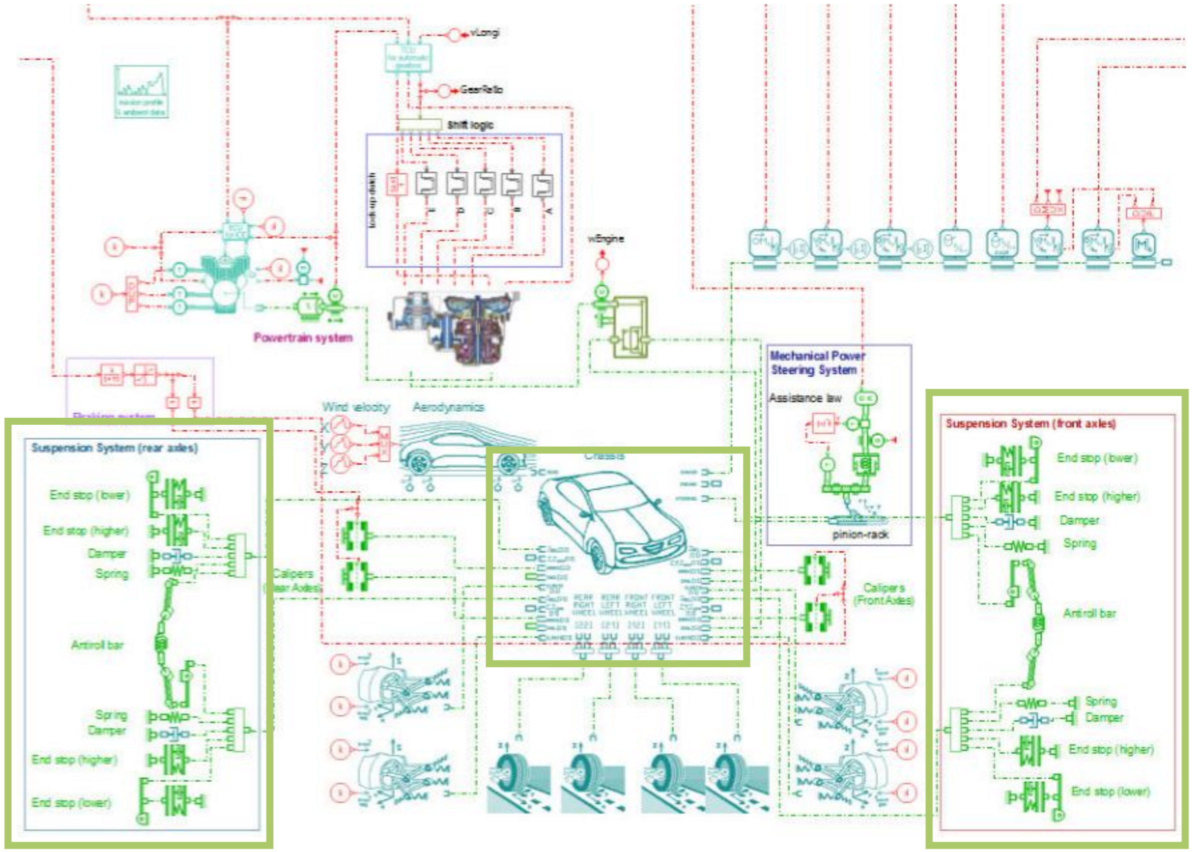
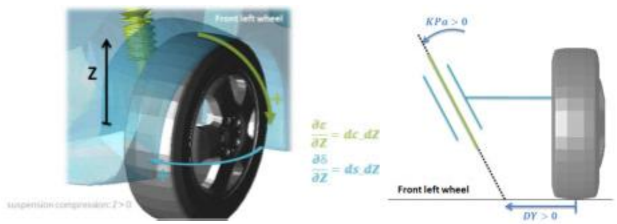


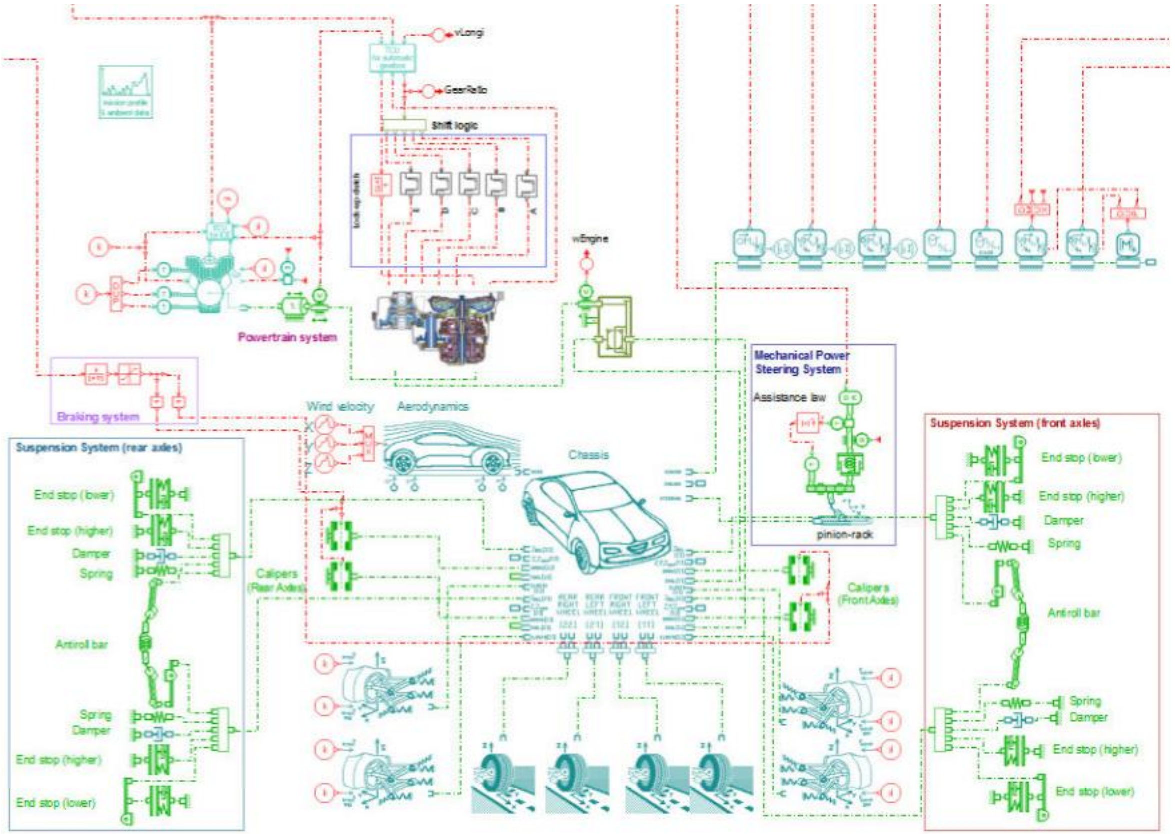
Kinematic and suspension

- anti-dive, anti-squat kinematic effects (fully general kinematic and compliance model)
- non linearities (end stop)
- transients and weight transfer
- simple damper extensible to:
  - detailed 1D model
  - complex velocity ratio
  - active and semi active suspension



Vehicle and Occupants

Optimum fidelity powertrain and vehicle dynamics modelling



Faster than real time

Covers large domain:

- low, mid, high accelerations
- lateral - longitudinal coupling
- transients (>10Hz)

Good for safety or comfort assessments

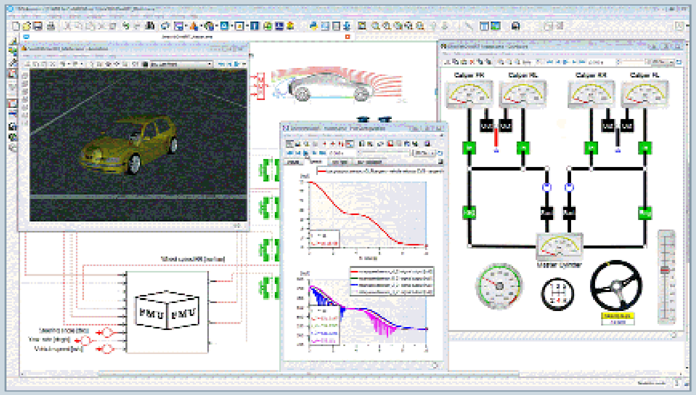
Good sensor carrier

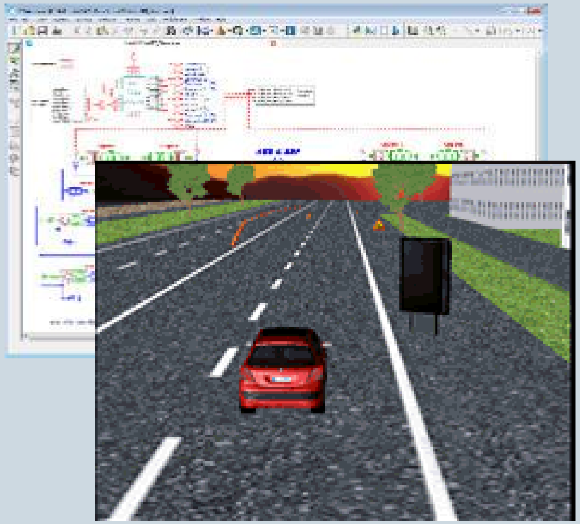
Developing for automated driving

Simcenter for vehicle performance engineering

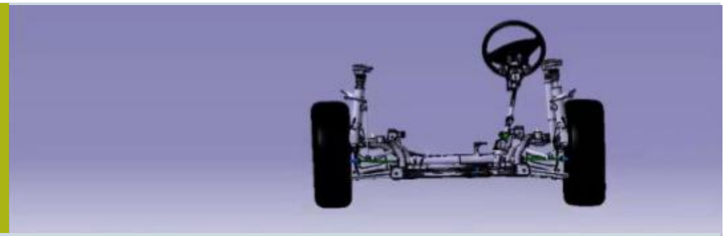
Scalable model based frontloading
for active braking, steering, handling

FMU imported into complete vehicle model

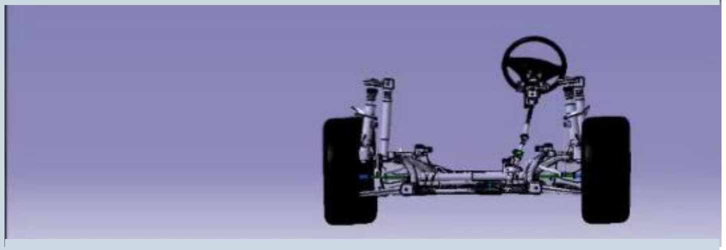




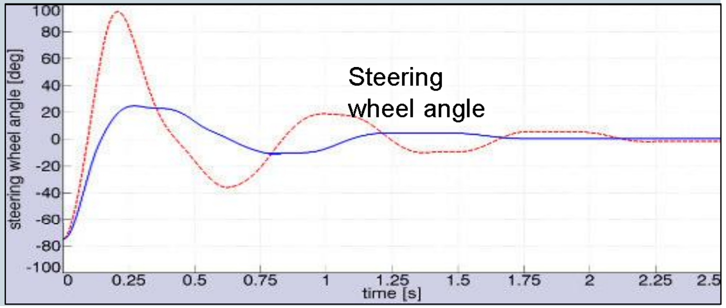
ESC & ABS model with hydraulic circuit



ESC off



ESC on



Use case
Adding braking and suspension fidelity to ADAS controls validation

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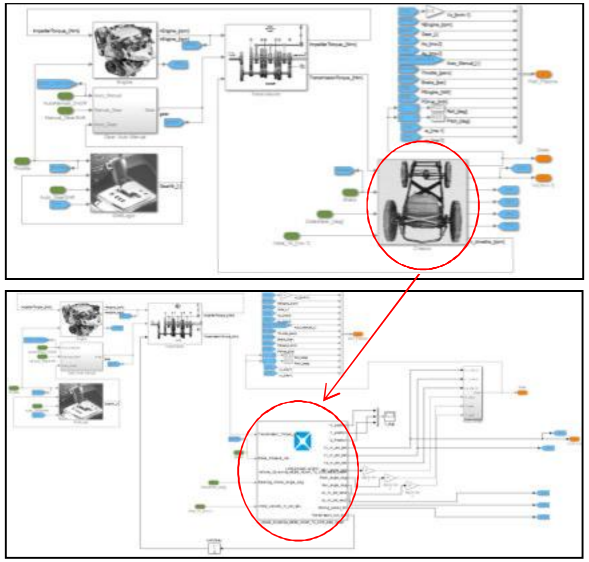
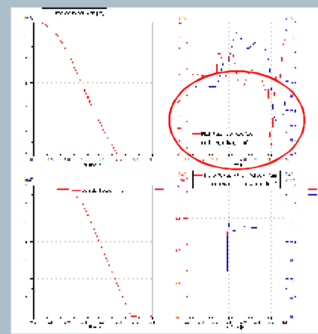


- Replacing the standard Simulink chassis models by high fidelity Simcenter Amesim suspension and braking system models
- Results are drastically impacted

Standard vehicle model

Simcenter Amesim detailed chassis models

- Simcenter Amesim plots show rear wheel slip and hence the ABS limits braking torque on the rear wheels
- Redesign of the controls solve the safety critical issue



BMW

Trajectory planning in automated parking scenarios with TASS Delft-Tyre

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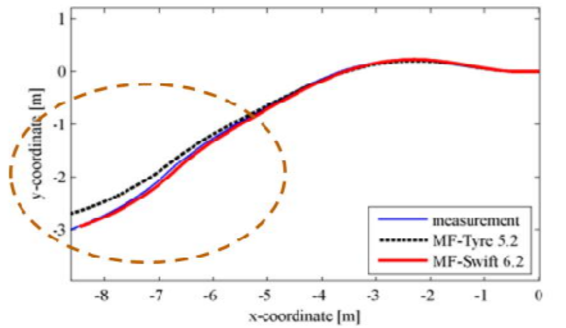
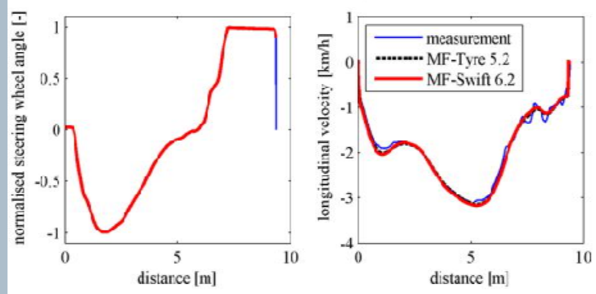
- **Tyre behavior in slow speed parking manoeuvers significantly influences the trajectory of the parking car**
- **For the design and validation of automated parking scenarios dynamic tyre behavior prediction is critical**

Validation by means of instrumented vehicle tests



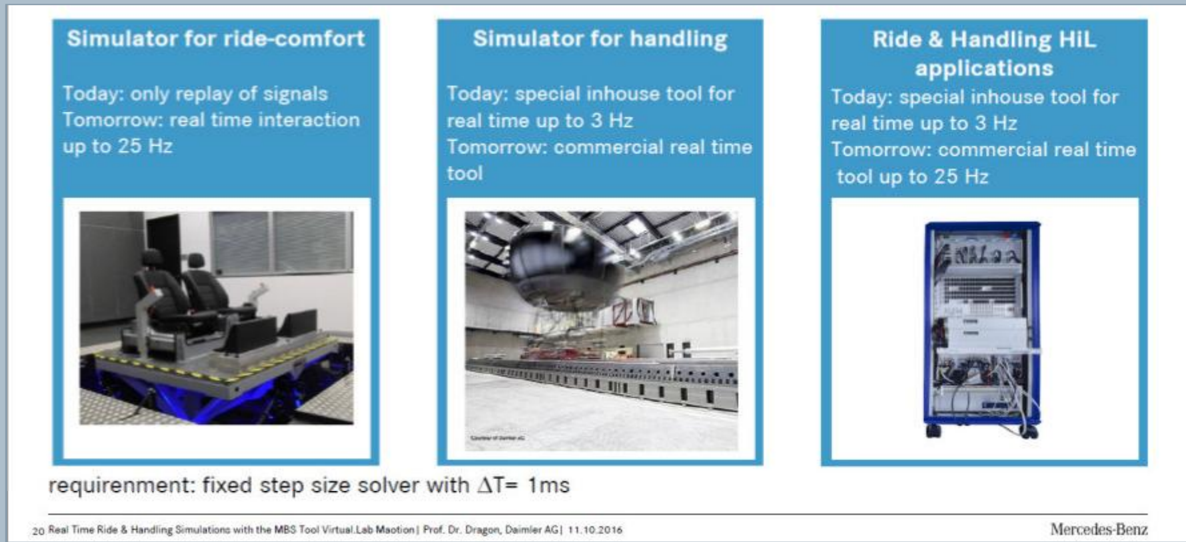


Example: Ramp steer test at 5 km/h

- Prescribed steering angle and velocity
- Measured trajectory (x,y)
- Measurements done on the vehicle to validate the Delft-Tyre models
- Comparison with MF-Tyre 5.2 (no turn slip functionality)
- Significantly improved response with MF-Swift 6.2 (with turn slip)

Daimler AG

Real time capable Multi Body Simulation and 1D models



- **Real-time Capable to satisfy Offline and Online targets in simulator and HIL testing**
- **Combined Simcenter 1D and 3D models for chassis systems and body dynamics simulation**
- **System integration as driver for change in simulation process solutions**

“These simulators enable us to evaluate ride and handling well before the first hardware prototype is built. Ride and handling are much about subjective feelings, which are difficult to systematically test.“

Prof. Dr. Ludger Dragon, senior manager of the Ride Comfort Division

AV System Performance Engineering

Solution areas

- Sensor fusion and trajectory planning algorithms
- Sensor performance and integration
- Vehicle behavior modelling at the right fidelity level
- Occupant modelling for safety and comfort
- Electronics system integration and validation
- Full vehicle validation and verification

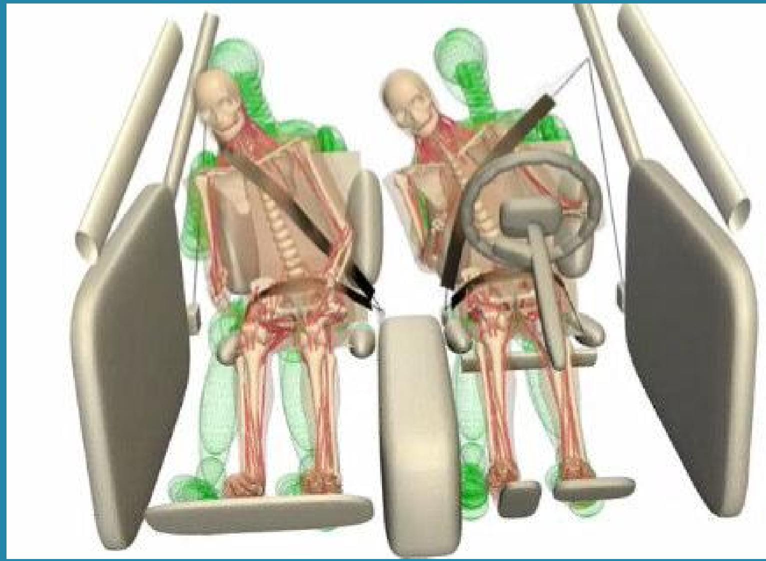
Occupant modelling for safety and comfort

Accurate prediction of occupant movements in maneuvers

Model human behavior in autonomous driving maneuvers

- Predict realistic humans responses for a broad range of conditions where no physical test dummy exists for
- Represent responses of living human beings with model components like spine joint restraints and muscles with passive stiffness characteristics and active control
- Accurately simulate occupant behavior in pre-crash emergency braking and crash avoidance maneuvers

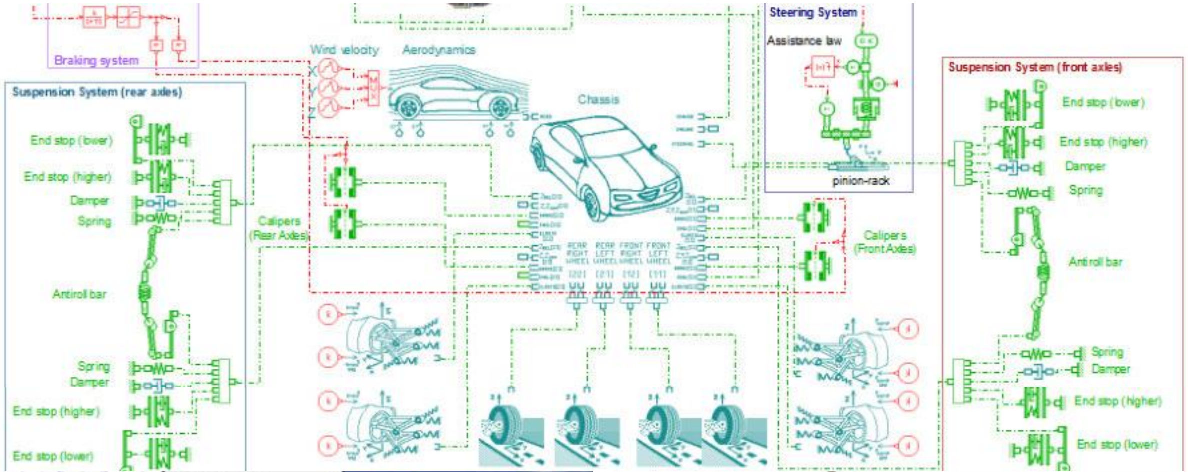
Human models for pre-crash behavior prediction

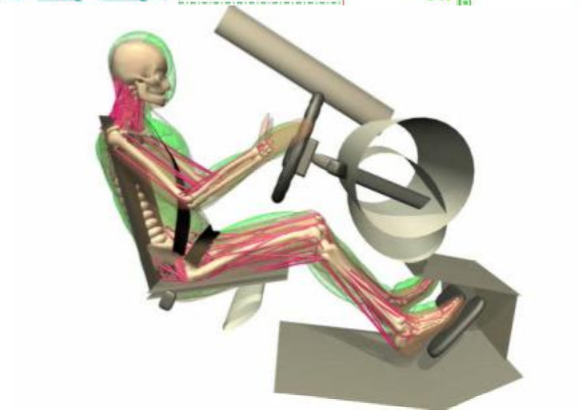


Occupant modelling for safety and comfort

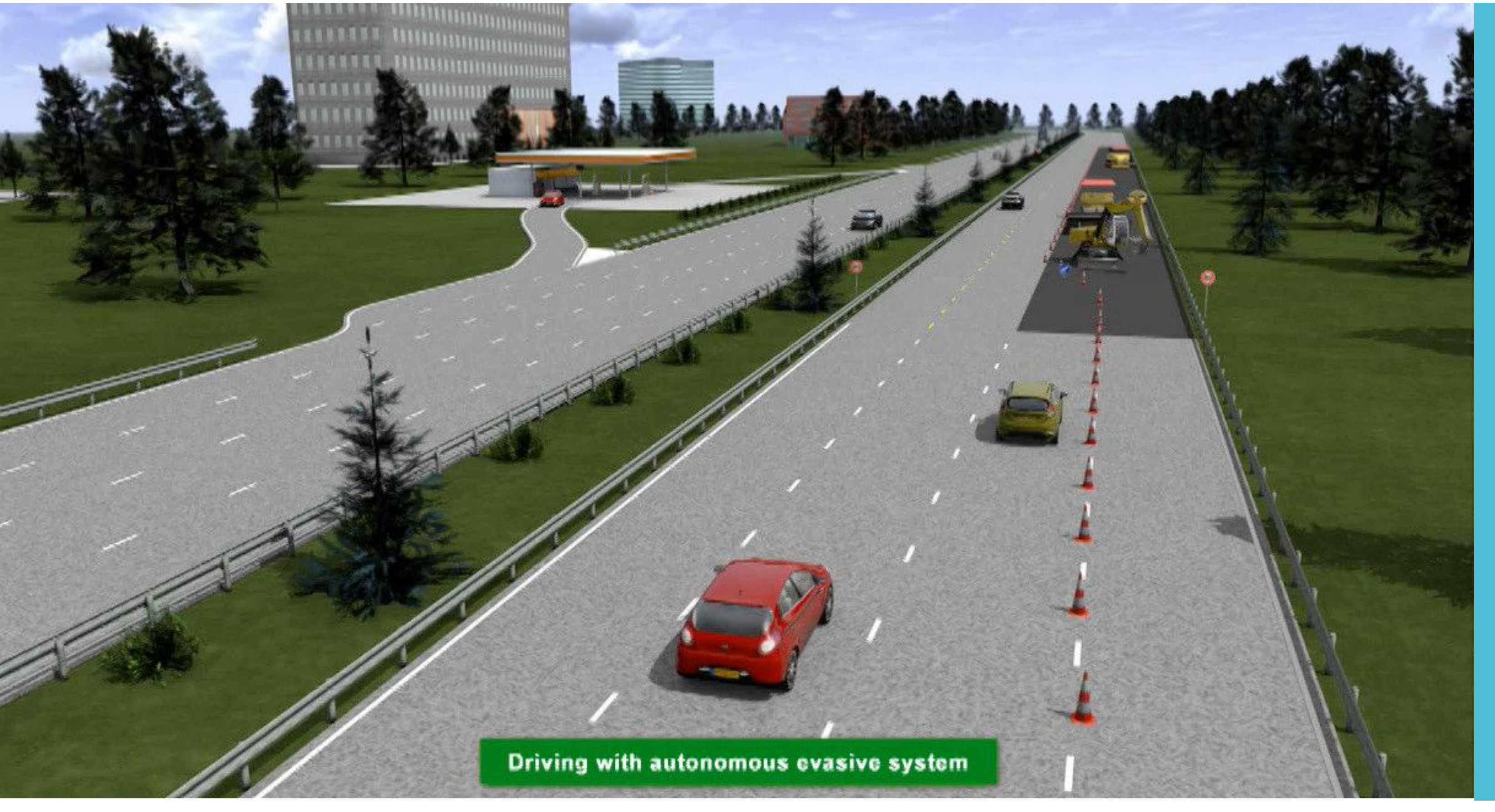
Braking example for AV

Autonomous controls simulation combined with accurate vehicle dynamics modelling to predict human behavior in pre-crash and crash stages





Occupant modelling for safety and comfort



Active human modelling in an autonomous evasive lane change scenario

AV System Performance Engineering

Solution areas

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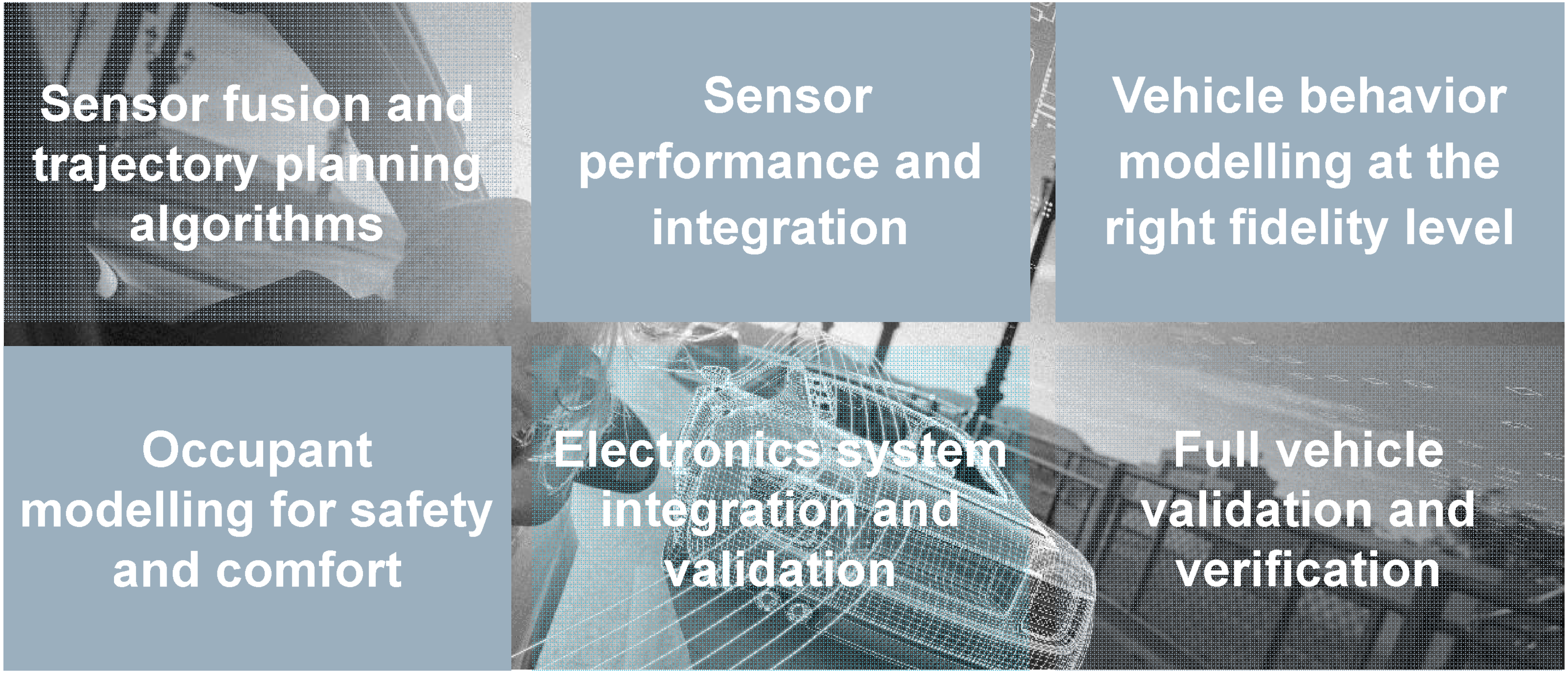

Autonomous Drives EE Complexity
Hugely increased complexity of EE architectures

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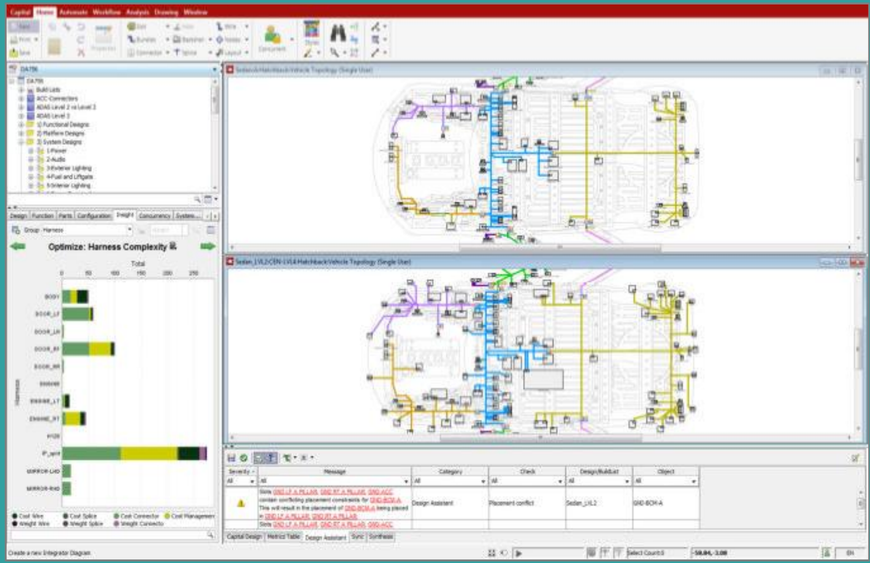
- 40% new additional hardware content, including 30-40 new sensors, drives **explosion in connectivity**, but within same space constraints



Autonomous Drives EE Complexity

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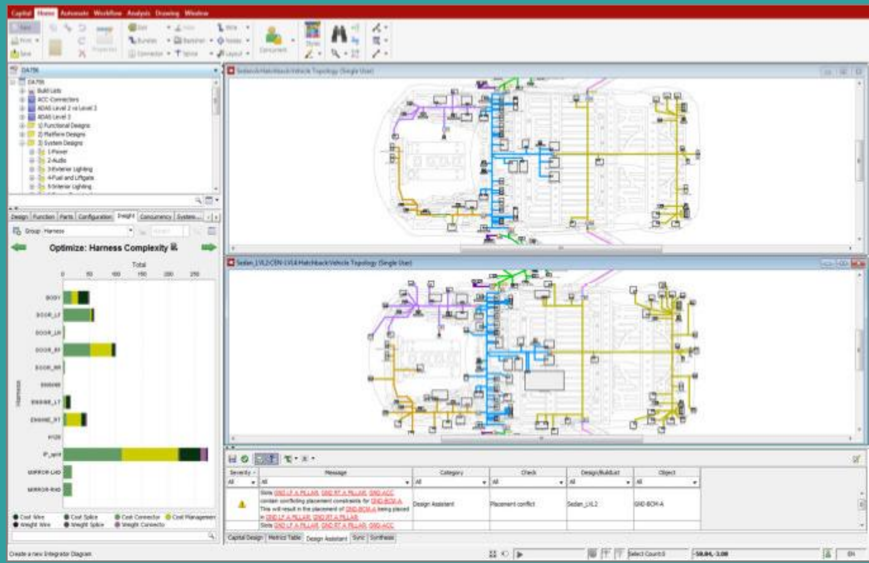
- 40% new additional hardware content, including 30-40 new sensors, drives **explosion in connectivity**, but within same space constraints
- **New architectures** being design now for future platforms
  - Distributed / Centralised / Zonal Architectures
  - Greater interdependence between electrical, network and embedded software



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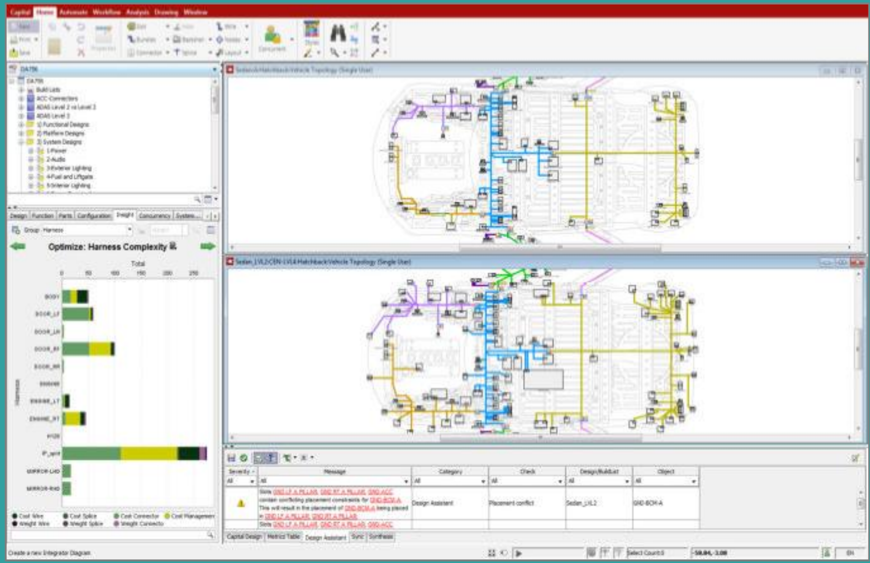
- **Data network content** moves from mega to gigabits. New communications and power network technologies, e.g. Ethernet, CAN FD, LVDS



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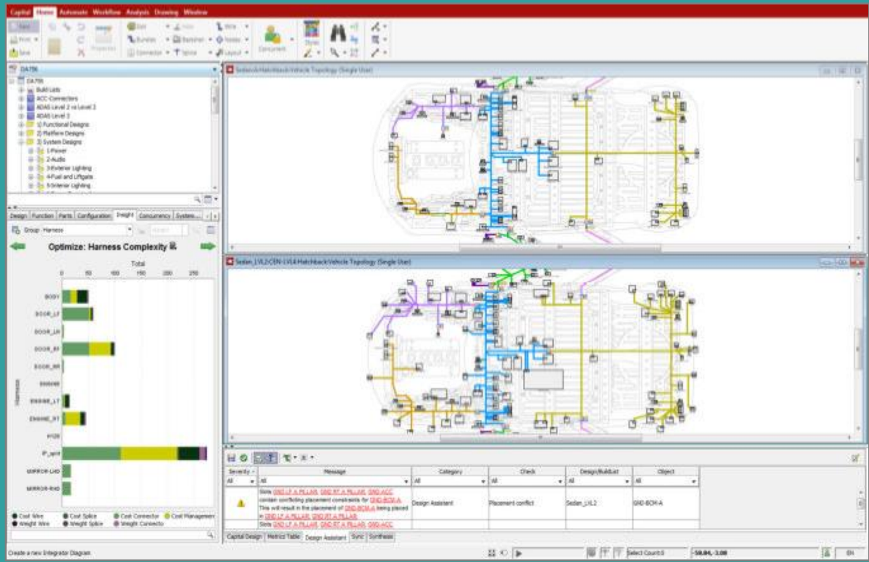
- **Data network content** moves from mega to gigabits. New communications and power network technologies, e.g. Ethernet, CAN FD, LVDS
- New vehicle **safety, security & validation** testing challenges
  - Consideration must be given to redundancy, ISO 26262, minimising Attack Surfaces, DRCs, correct-by-construction



AV / EV: Electrical System Factors

Electrical System = Power, Signals, Communication

EE System Implementation

- Requirements traceability & verification
- Functional verification
- Signal routing & separation; redundancy
- Electrical FMEA
- Correct-by-construction, simulation & checking
- Design change control & release management
- Manufacturing traceability & verification
- Diagnostics, maintenance & repair support

▶ Implementation complexity

▶ Simulation and analysis

▶ Safety assurance & Traceability

Faraday Futures FF91 harness (supporting Level 4 autonomy)

Source: Ulrike Hoff Lead EDS engineer, Faraday Futures

EE Architecture and Systems Integration

Developing the complete EE system

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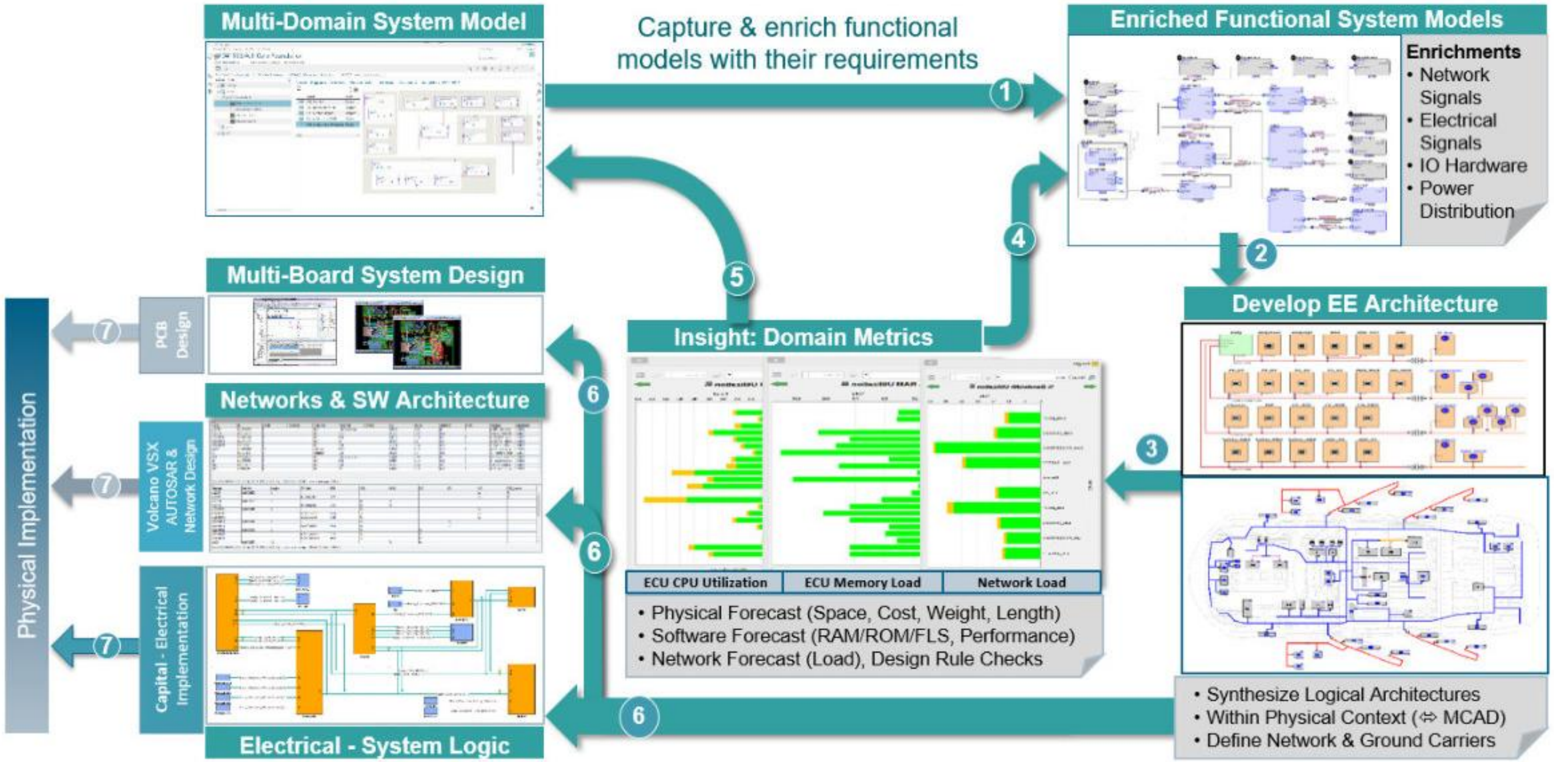

Front-loaded **generative** development of logical and physical architectures

Trade studies enable optimisation

Rapid Trade Study Iteration – Enable Architectural Optimization – Reduce Cost, Drive Quality

EE Architecture
Platform-level definition

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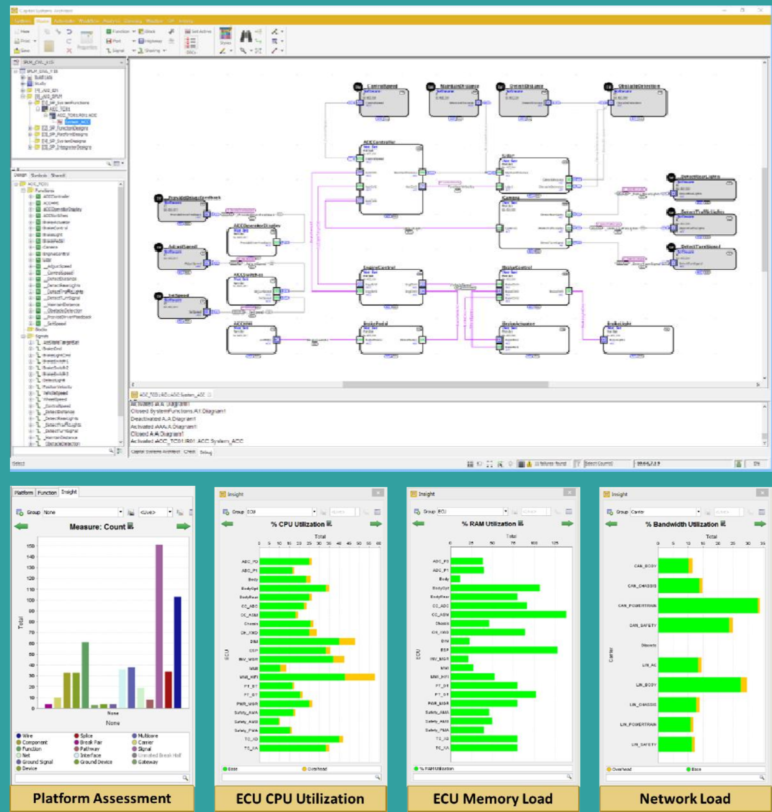
Autonomous Vehicles significantly increase EE content

- E.g. GM/Cruise stated 40% increase in hardware and 40 new sensors required for level 4 autonomy

Capital Systems enables EE architecture optimization

- Optimize vehicle platforms at the design stage
- Verify functional architectural design
- Make architectural attribute trade-off’s at the platform level
- Analyse device placements for impact on network, CPU and memory load, cost and weight

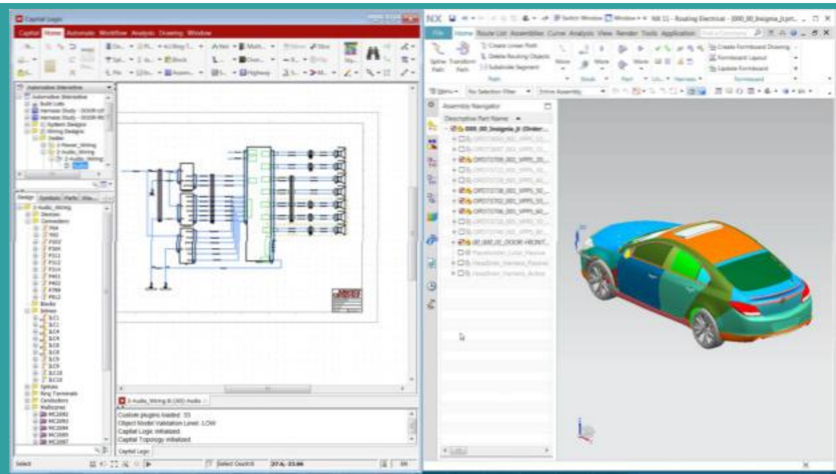


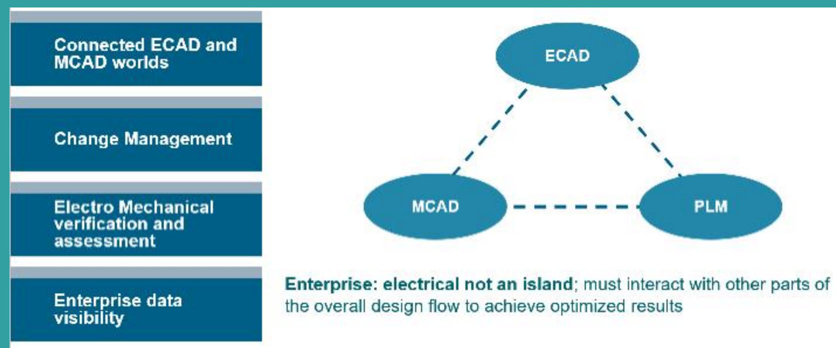
Integrated Electrical and Mechanical Design

Support space reservation & electrical/mechanical co-design

Early electro-mechanical design, verification and assessment is vital for Autonomous Vehicles

- Key questions asked by electrical and mechanical designers
  - Have I reserved enough space and is routing acceptable?
  - Can paths satisfy signal connectivity?
  - Is the signal path susceptible to EMI?
- Capital enables electrical to influence space allocation before mechanical design is finalized, preventing costly and time-consuming rework





Model-based generative design

Advanced verification at the design stage

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Electrical Simulation & Verification is a key driver of design quality

- Functional verification; DC simulation; component sizing (examples: wires, fuses)
- Electrical FMEA generation
- Single/multiple designs, whole vehicle & multi configuration simulation; batching & scripting
- Simple or sophisticated behavior models (example: VHDL-AMS)
- Configurable, customizable DRCs & cross abstraction consistency checking

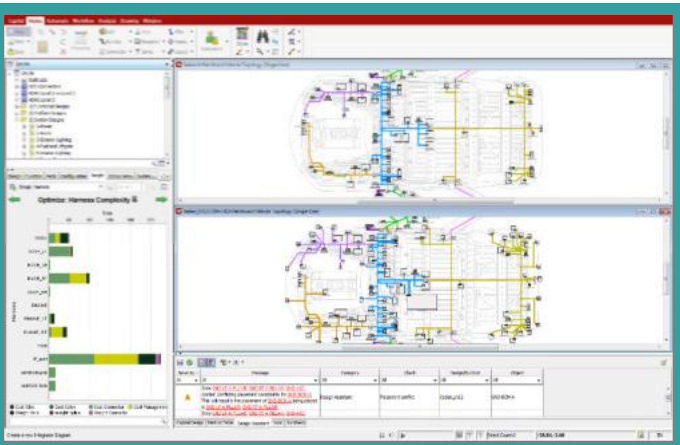


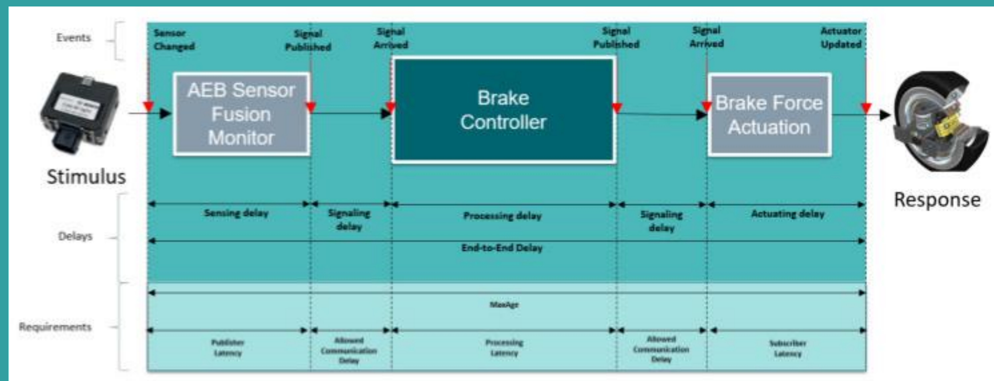
image courtesy Chandrashekaran R, Caresoft

Next generation data networks

Design, analysis and verification of in-vehicle networks

Detailed network data analysis is required to enable ‘orders of magnitude’ data increase

- Data networks in AVs are dealing with unprecedented amounts of data, e.g. Intel estimates up to 4TB / day
- Mentor’s VSA-COM tool enables companies to ‘future-proof’ their data networks by optimizing the bus partitioning, loading and implementation
- Coupling Capital Systems with VSA-COM enables true systems engineering approaches to be applied to EE design



Source: https://newsroom.intel.com/editorials/krzanich-the-future-of-automated-driving

Tesla
Long term user of Mentor Capital

- Mentor Capital is used by many EV and autonomous vehicle companies and new entrant OEMs.
- Integrating with suppliers and being able to exchange data with suppliers in a seamless way enables companies to get to market faster with higher quality and less re-work.

DEFINE | DESIGN | MANAGE | PRODUCE | MAINTAIN

Three Founding Principles

Data Coherency

Built to Integrate

Advanced Automation

- Companies like Tesla, as well as many other startups, suppliers and OEMs all value the principles on which Capital has been developed over the last two decades and have realized the business benefits these tools bring to their organizations.
- The importance of data coherency, easy integrations and advanced automation provide a compelling benefit for companies in this time of unprecedented change in the automotive industry.

AV System Performance Engineering

Solution areas

- Sensor fusion and trajectory planning algorithms
- Sensor performance and integration
- Vehicle behavior modelling at the right fidelity level
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- Electronics system integration and validation
- Full vehicle validation and verification

Massive validation & verification cycles

Scenarios to validate controls will explode from SAE automation level 1 to level 5.

Controls virtual validation (MiL, SiL)

~10^2 scenarios → SAE level 1 to 5 → **~10^6 scenarios**

Massive validation & verification cycles

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Ingenuity for life

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Controls virtual validation (MiL, SiL)

~10^2 scenarios → SAE level 1 to 5 → ~10^6 scenarios

Semi Virtual validation test bench (HiL, DiL, VehiL)

~10^2 scenarios → SAE level 1 to 5 → ~10^3 scenarios

Massive validation & verification cycles

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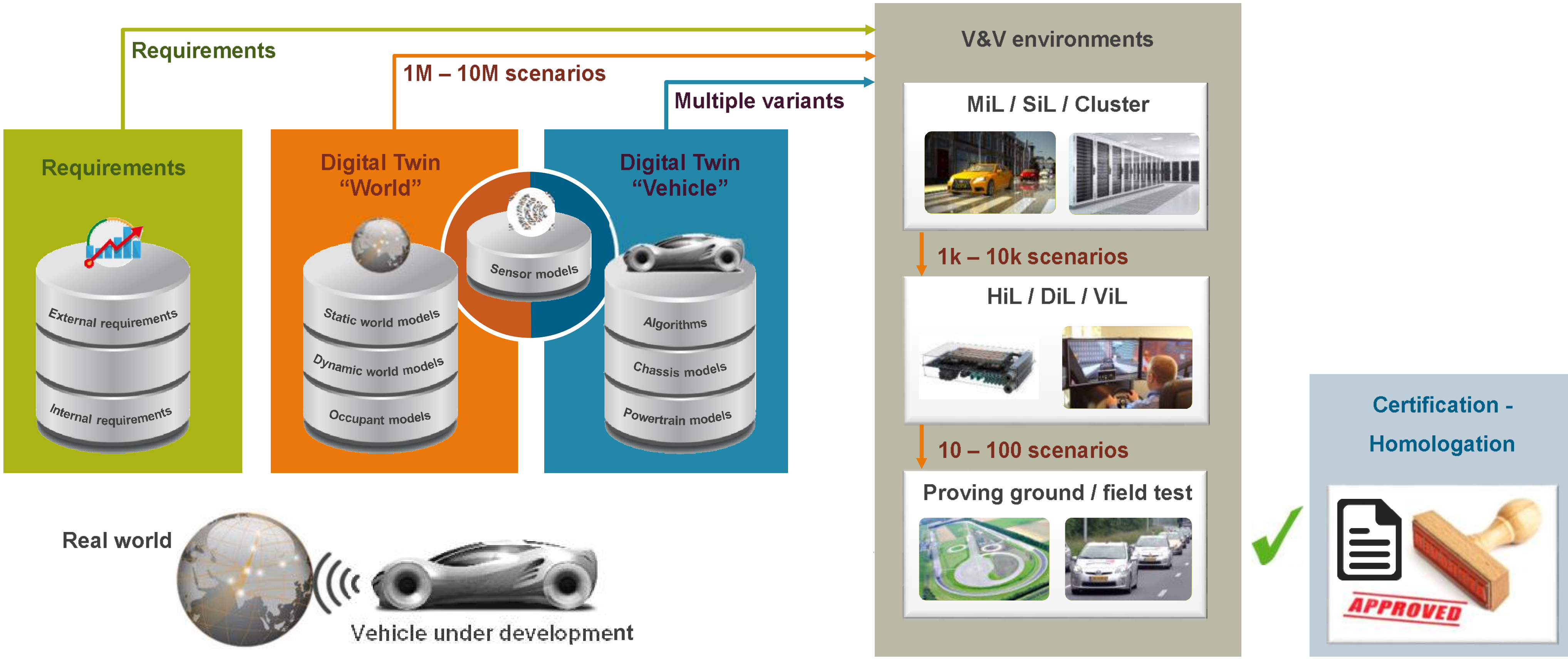
Semi Virtual validation test bench (HiL, DiL, VehiL)

~10^2 scenarios → SAE level 1 to 5 → ~10^3 scenarios

Real validation vehicle testing (proving ground, public road)

~10^2 scenarios → SAE level 1 to 5 → ~10^2 scenarios

Validation and Verification framework for AVs



Validation and Verification – Towards 100% test coverage

Combining Real Life + Synthetic Data

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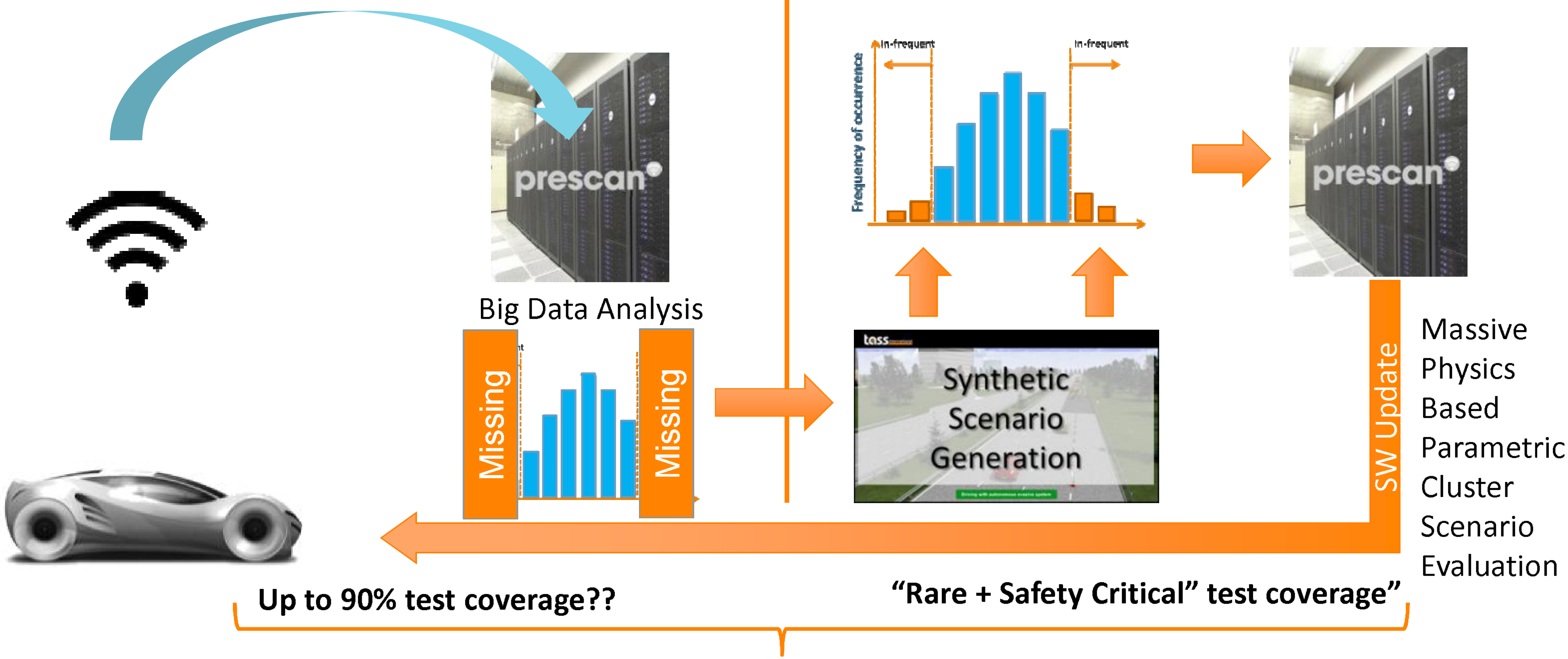
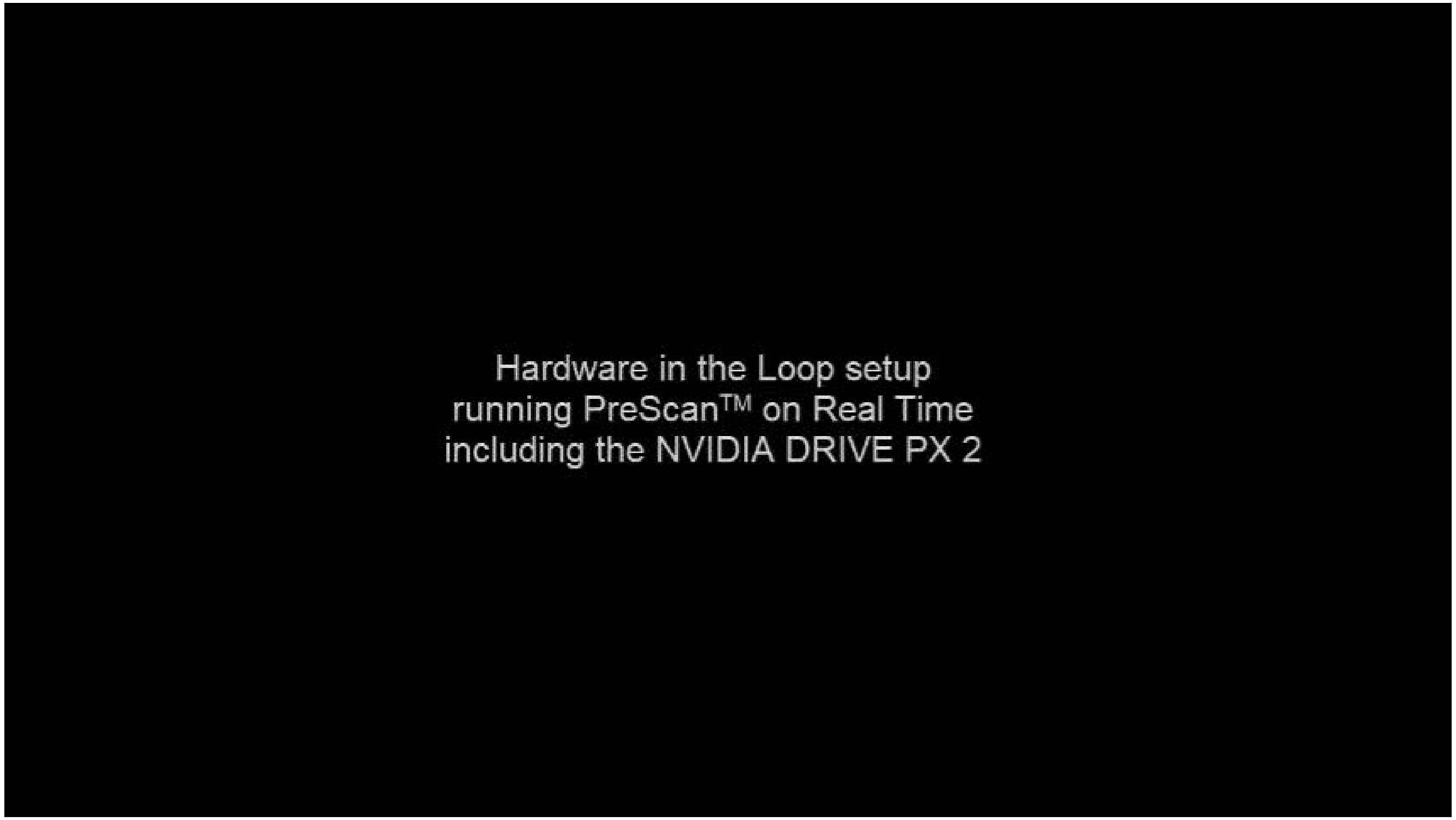
Field Data Analysis

Simulation Corner Cases



Objective "close to" 100% test coverage

Validation and Verification
Real-Time Models – HIL Testing – Driver in the Loop testing



Validation and Verification up to Certification
Proving ground testing of autonomous vehicle technology

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Laboratory testing	**validating modules & systems in a controlled environment**
Closed test-site testing	**validating complete vehicle in a pre-conditioned environment**
Open test-site testing	**validating the networked system in a realistic environment**

EuroNCAP active safety testing

Euro NCAP has devised more and more complex scenarios and stricter requirements for ADAS testing
2018 test protocols can be executed now

A270 Instrumented Motorway, Rural & Urban

In Summary

Siemens solutions enable autonomous vehicle development

from chip to system to full vehicle across all engineering domains

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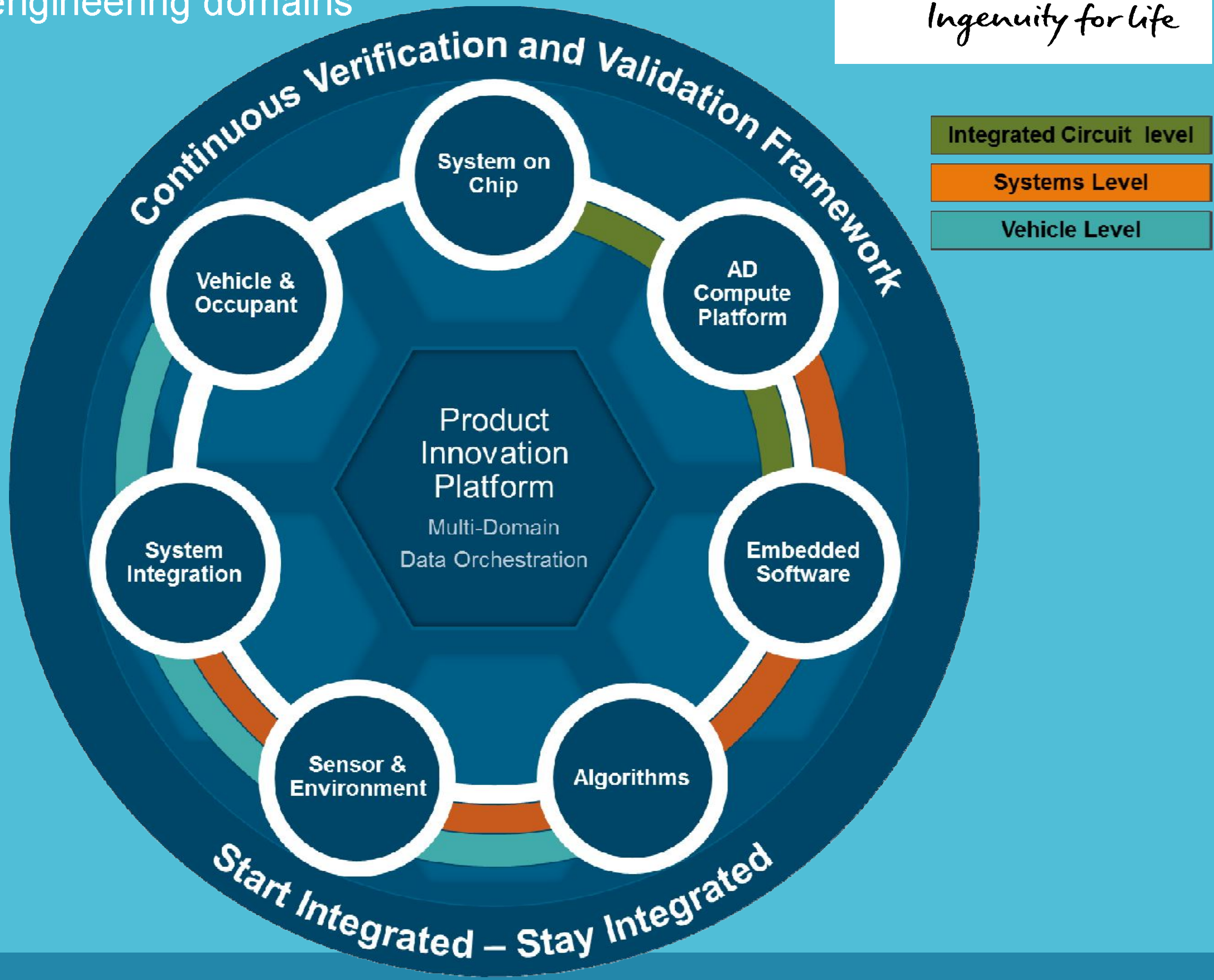

Ensuring digital continuity, multi-domain traceability and functional safety of autonomous systems

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Realize innovation.