Main visions in the automobile industry

What’s important to customers?

- Safety
- Time
- Green driving

“Any system depending on human reliability will be unreliable”
(Source: Volvo)
Different markets pose different challenges

**USA**
- Wide roads
- Regulated traffic
- Moderate speeds

**Europe**
- Good infrastructure
- Clear traffic rules
- Higher speeds

**China**
- Partly poorly developed infrastructure
- Barely conformal behavior
- Low average speed

**Acceptance**
- USA: 60%
- Europe: 40%
- China: 87%

Source: Cisco, Audi Research
Autonomous Driving becomes reality ...

<table>
<thead>
<tr>
<th>Level 0</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Level 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>No automation</td>
<td>Driver assistance</td>
<td>Partial automation</td>
<td>Conditional automation</td>
<td>High automation</td>
<td>Full automation</td>
</tr>
<tr>
<td>(LDW, FCW)</td>
<td>(ACC, LKA)</td>
<td>(Parking assist, Tesla Autopilot)</td>
<td>(Traffic jam chauffeur)</td>
<td>(Highway pilot, valet parking)</td>
<td>(Robot taxi)</td>
</tr>
<tr>
<td></td>
<td>&quot;Feet or hands off&quot;</td>
<td>&quot;Feet and hands off&quot;</td>
<td>&quot;Eyes off&quot;</td>
<td>&quot;Brain off&quot;</td>
<td>&quot;Driverless&quot;</td>
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<tr>
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<td></td>
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</tr>
<tr>
<td>Human driver</td>
<td>ADAS in series</td>
<td>Human driver as fallback</td>
<td>No human driver as fallback</td>
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<td></td>
</tr>
<tr>
<td>for monitoring</td>
<td>production</td>
<td></td>
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</tr>
</tbody>
</table>

Automation levels according to SAE J3016™
Autonomous Driving becomes reality...

- **Level 0**: No automation (LDW, FCW)
  - Human driver for monitoring
  - Regulations defined
  - Liability lies with driver

- **Level 1**: Driver assistance (ACC, LKA)
  - "Feet or hands off"

- **Level 2**: Partial automation (Parking assist, Tesla Autopilot)
  - "Feet and hands off"

- **Level 3**: Conditional automation (Traffic jam chauffeur)
  - "Eyes off"

- **Level 4**: High automation (Highway pilot, valet parking)
  - "Brain off"

- **Level 5**: Full automation (Robot taxi)
  - "Driverless"

- Regulations (defined) if system is not active

Automation levels according to SAE J3016™
Autonomous Driving becomes reality ...

- Level 3:
  - Audi A8 in 2018 (traffic jam pilot)
  - Daimler S-Class in 2020
  - Toyota, Honda, Nissan, ... in 2020
  - BMW iNEXT in 2021

- Level 4:
  - Tesla Model S in 2020 (?)
  - Volvo, Ford in 2021

- Level 4/5 (robotaxis in defined areas/situations):
  - Waymo in 201?, Bosch in 2022 (?)
Fundamental change in the automotive industry

- From engineering to high-tech IT companies
- Software as a product – OTA updates
- Digitalization – New business models
- Change in corporate culture
- Highly dynamic (agile) development
- Artificial Intelligence, learning cars

Deep Neural Networks (DNN)
Deep Learning
Artificial Intelligence

- **Today:**
  - Detections of selected objects, such as vehicles, pedestrians and cyclist

- **Tomorrow:**
  - Semantic understanding of complete scene
  - Anticipation of traffic situations
  - Decision making

- Supercomputers required (on- or offboard)
Cooperations and alliances – Powerful supercomputers (example)

- Daimler
- Bosch
- ZF/TRW
- Hella
- Autoliv
- Zenuity
- NVIDIA
- GM
- Nissan
- Ford
- Volvo
- Audi
- VW
- Intel
- Continental
- Magna (Austria)
- Delphi
- Baidu (China)
- Tesla
- Honda
- Toyota
- Audi
- ZF/TRW
- Hella
- Autoliv
- Zenuity
- NVIDIA
- GM
- Nissan
- Ford
- Volvo
- Audi
- VW
- Intel
- Continental
- Magna (Austria)
- Delphi
- Baidu (China)
- Tesla
- Honda
- Toyota
- AMD

Apollo project (> 50 partners)
Sensing under all conditions

- Lidar
- Front radar
- Surround view cameras
- Ultrasonic sensors
- Front camera
- Electronic horizon
- Side and rear radars
- GNSS
- V2X

Complementary sensing technologies
Decentralized E/E architecture with level 1/2 systems (volume OEMs)

- Steering
- Braking
- Engine
- Transmission

HMI

GNSS, Map

LDW, TSR, VRU detection

ACC, AEB

Parking assistant

Front camera

Front radar

Surround/rear view cameras

Ultrasonic sensors

Parking assistant

Blind spot detection

ACC: Adaptive Cruise Control
AEB: Autonomous Emergency Braking
LDW: Lane Departure Warning
TSR: Traffic Sign Recognition
VRU: Vulnerable Road User
Centralized E/E architecture with level 1/2 systems (premium OEMs)

- Steering
- Braking
- Engine
- Transmission

Central control unit
- Appl. functions
- Percept., data fusion

- Front camera
- Front radar
- Surround/rear view cameras
- Ultrasonic sensors
- Rear/side radar

HMI
- GNSS, Map
Centralized E/E architecture with level 3/4/5 systems

- Redundant: Steering, Braking
- Technical fallback: Supervisor, Percept., data fusion
- Central control unit: Appl. functions, Percept., data fusion, AI
- Driver monitoring
- HMI
- GNSS, HD Map
- V2X unit (DSRC, LTE/5G)

- Front lidar
- Night vision
- Front camera
- Front radar
- Surround/rear view cameras
- Ultrasonic sensors
- Rear/side radar
Centralized E/E architecture with level 3/4/5 systems

- Adaptive AUTOSAR, functional safety
- High bandwidth, switched networks
- Service-oriented & secure communication
- Heterogeneous HW/SW architectures

**Redundant**
- Steering
- Braking

**Redundant**
- Engine
- Transmission

**Front lidar**
- Night vision
- Front camera
- Front radar
- Surround/rear view cameras
- Ultrasonic sensors
- Rear/side radar

**V2X unit** (DSRC, LTE/5G)

**HMI**

**GNSS, HD Map**

**Driver monitoring**

**HD MAP**

**Embedded Success**

dSPACE
Major challenges

- Prototyping **perception, data fusion** and function algorithms
- **Data recording** and labeling
- Validation of **sensor ECUs** that are based on **different sensing technologies**
- Exhaustive testing to ensure functional safety and system robustness (hundreds of millions of test kilometers)

**Is dSPACE the right partner?**
Major challenges

▪ Prototyping perception, data fusion and function algorithms

▪ Data recording and labeling

▪ Validation of sensor ECUs that are based on different sensing technologies

▪ Exhaustive testing to ensure functional safety and system robustness
  (hundreds of millions of test kilometers)
Prototyping perception, data fusion and function algorithms

RTMaps – Real-Time Multisensor applications

Time-stamp, process and visualize data
Prototyping perception, data fusion and function algorithms

RTMaps – Real-Time Multisensor applications

Integration in MicroAutoBox

Extension options for CAN/CANFD, WLAN, ...

Standalone version

New high performance MicroAutoBox Embedded PC

Sensors

Vehicle network

Time-stamp, process and visualize data
RTMaps on ARM based supercomputers for Autonomous Driving

NVIDIA Drive PX

Source: NVIDIA

NVIDIA Drive Works

Source: NVIDIA

Renesas HAD

Source: Renesas

NXP Bluebox

Source: NXP

Make development easier – Design your algorithms graphically
Major challenges

- Prototyping **perception, data fusion** and function algorithms
- **Data recording** and labeling
- Validation of **sensor ECUs** that are based on **different sensing technologies**
- Exhaustive testing to ensure functional safety and system robustness
  
  *(hundreds of millions of test kilometers)*
Data recording and labeling

RTMaps – Real-Time Multisensor applications

Time-stamp, pre-label and record data

New MicroAutoBox Embedded DSU
Up to 64 TB

New high performance MicroAutoBox Embedded PC

DSU: Data Storage Unit

Embedded Success dSPACE
Major Challenges

- Prototyping perception, data fusion and function algorithms
- Data recording and labeling
- Validation of sensor ECUs that are based on different sensing technologies
- Exhaustive testing to ensure functional safety and system robustness (hundreds of millions of test kilometers)
**Sensor integration options**

Option 4 (only for HIL): Stimulate sensor front end Over-the-Air (OTA)

Option 3: Insert sensor raw data

Option 2: Insert object lists

Option 1: Simulate rest bus

Real or virtual environment sensor
(Camera, radar, LiDAR, ultrasound, …)

Vehicle network

HIL testing
MIL/SIL

Open-loop data replay

Closed-loop simulation

<table>
<thead>
<tr>
<th>Option</th>
<th>Camera</th>
<th>Radar</th>
<th>Lidar</th>
<th>Ultrasound</th>
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<td>✓</td>
<td>✓</td>
<td>Open</td>
<td>GNSS RF signal</td>
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</table>
Open-loop data replay HIL system – Example Lidar project with TIER1

- Recorded data (Lidar and bus data) + time stamps
  - TCP/IP
  - Buffer: Ethernet data + time stamps
  - Simulink model, S-function

SCALEXIO HIL system

Lidar ECU

- Sensor front end
- Data processing

- UDP/IP (proprietary protocol for Lidar data)
- UDP/IP (proprietary protocol for debug data)
- Automotive Ethernet Some/IP

TCP/IP

RTMaps

Embedded Success

dSPACE
Sensor integration options

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ARSG: Automotive Radar Scenery Generator
n/a: not applicable
RF: Radio Frequency
Raw data generation for radar sensor simulation

- Import of MotionDesk scene in NVIDIA Optix on GPU
- Multiple reflections
- Ray-object interaction dependent on material properties

dSPACE real-time PC with NVIDIA® GPU and NVIDIA OptiX™ Ray Tracing Engine

Sensor configuration in the video-scene
## Sensor integration options

**Option 4 (only for HIL):** Stimulate sensor front end Over-the-Air (OTA)

**Option 3:** Insert sensor raw data

**Option 2:** Insert object lists

- Real or virtual environment sensor (Camera, radar, LiDAR, ultrasound, …)

**Option 1:** Simulate rest bus

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**ARSG:** Automotive Radar Scenery Generator  
**n/a:** not applicable  
**RF:** Radio Frequency
Radar in-the-loop HIL test bench

- Radar frequency: 24, 77, 79 GHz
- Number of targets: 4
- Properties per target: Relative distance, relative, speed, signal strength (RCS), azimuth angle
- Distance: 2 ... 1000 m
- Speed: ± 700 km/h
- Azimuth angle: ± 100°
- Update rate: 1 kHz
Sensor integration options

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ARSG: Automotive Radar Scenery Generator
n/a: not applicable
RF: Radio Frequency
Synchronous stimulation of camera and lidar ECUs

PC with GPU and MotionDesk

HDMI

Environment Sensor Interface Unit

Rest bus simulation

Central data fusion unit

Vehicle network

Object data

ECU specific POD

Image processing

Image

Imager

Lens

Environment Sensor Interface Unit

Vehicle network

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Synchronous stimulation of camera and lidar ECUs

New illumination model in MotionDesk

dSPACE real-time PC with GPU and sensor models

dSPACE real-time PC with GPU and sensor models

Environment Sensor Interface Unit

Central data fusion unit

Rest bus simulation

Vehicle network

33
Major Challenges

- Prototyping **perception, data fusion** and function algorithms
- **Data recording** and labeling
- Validation of **sensor ECUs** that are based on **different sensing technologies**
- Exhaustive testing to ensure functional safety and system robustness
  (hundreds of millions of test kilometers)
Exhaustive testing by means of simulations

<table>
<thead>
<tr>
<th></th>
<th>SIL</th>
<th>HIL</th>
<th>Real world</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closeness to reality</td>
<td>o</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Completeness of test methods</td>
<td>o</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Reproducibility</td>
<td>++</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>Scalability and variability</td>
<td>++</td>
<td>+</td>
<td>--</td>
</tr>
<tr>
<td>Costs, setup time</td>
<td>++</td>
<td>o</td>
<td>--</td>
</tr>
<tr>
<td><strong>Test kilometers per day</strong></td>
<td>++</td>
<td>o</td>
<td>--</td>
</tr>
</tbody>
</table>
SIL testing of autonomous driving

Automotive Simulation Models (ASM)

- Any number of static and dynamic objects
- Sensor models for camera, radar, lidar, ultrasound and free spaces
- Automated generation of road networks and scenarios
- Coming soon:
  - Traffic flow simulation with SUMO and PTV Vissim
  - Multi-agent simulation
PC cluster simulation with VEOS – Driving millions of test kilometers on your PC

SYNECT data management

Traffic scenario and road network

Jobs (test cases) Results

Job scheduling unit

VEOS

V-ECUs
Summary

Rapid Prototyping

SIL/HIL Simulation

Data replay tests

PC Cluster Simulation

Test benches

Data recording

dSPACE – Your Partner for Autonomous Driving
Thank you for listening!
Embedded Success dSPACE