Challenges on the Way to Automated Driving

Chassis Systems Control
### Challenges on the Way to Automated Driving

**Automated and connected – social benefits**

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reduced congestion</strong></td>
<td>Fewer traffic jams and less waiting time at intersections and lights → 80% improvement in traffic throughput¹</td>
</tr>
<tr>
<td><strong>Higher fuel efficiency</strong></td>
<td>Synchronized traffic flow → 23 to 39% improvement in highway fuel economy²</td>
</tr>
<tr>
<td><strong>Gain in productivity</strong></td>
<td>Time in transit becomes more productive → 56 minutes per day freed up for other uses (US)³</td>
</tr>
<tr>
<td><strong>Democratization of mobility</strong></td>
<td>Over-65 segment growing 50% faster than overall population → Allow a variety of age ranges to be mobile</td>
</tr>
<tr>
<td><strong>Improved safety</strong></td>
<td>Reduction in motor vehicle accident rates → 90% of all car accidents involving injury are caused by human error</td>
</tr>
</tbody>
</table>

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² Atiyeh, Clifford (2012), Predicting Traffic Patterns, One Honda at a Time, MSN Auto, June 25.

³ US Department of Transportation Highway Safety Administration (2011), Report # FHWA-PL-11-022

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Road safety – influence of driver assistance

Number of road fatalities reduced by 60% within last 14 years
- 90% of all car accidents involving injury are caused by human error
- Introduction of further driver assistance systems will amplify positive trend

Source: Bosch, DAB, ZF, Based on total vehicle fleet

1 Figures estimated
2 ACC and lane keeping support only
End customers’ acceptance increased

- Increased awareness of driver assistance technology
- High safety awareness and expectation
- Additional assistance is appreciated
- Openness to Automated Driving is given

High acceptance of Driver Assistance by end customers
- Bosch expects the market of assisted and automated driving to grow

End customer survey about Automated Driving

<table>
<thead>
<tr>
<th>Question</th>
<th>Germany</th>
<th>France</th>
<th>Italy</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good idea, but I have to be able to turn it off</td>
<td>60%</td>
<td>52%</td>
<td>63%</td>
<td>65%</td>
</tr>
<tr>
<td>Is the logical next step for driver assistance systems</td>
<td>54%</td>
<td>56%</td>
<td>50%</td>
<td>55%</td>
</tr>
<tr>
<td>Is technically feasible</td>
<td>50%</td>
<td>52%</td>
<td>48%</td>
<td>48%</td>
</tr>
<tr>
<td>Makes driving safer</td>
<td>44%</td>
<td>40%</td>
<td>42%</td>
<td>49%</td>
</tr>
</tbody>
</table>

Source: Bosch driver survey 2012
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Driver assistance – degree of automation

<table>
<thead>
<tr>
<th>Automation level</th>
<th>Customer benefit</th>
<th>Automation level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervised by driver</td>
<td>Integrated cruise assist</td>
<td>Partly automated</td>
</tr>
<tr>
<td>Reduced driver supervision</td>
<td>Highway assist</td>
<td>Highly automated</td>
</tr>
<tr>
<td>Increasing comfort, safety, and efficiency</td>
<td>Auto pilot</td>
<td>Fully automated</td>
</tr>
</tbody>
</table>

Automated driving starts with highway driving and parking functions
- Step-by-step approach – for technological and psychological reasons
- Survey: 52% in favor of automated driving as long as it can be switched off¹

¹ Bosch survey 2012 (CC)
Automated driving – already on public roads

Prototypes driving on public freeways in Germany and USA
- Bosch: first vehicles on German freeways since early 2013
- Tests in real traffic conditions accelerate the development of new functions
## Challenges on the Way to Automated Driving

### Impacts from High Automation on the Vehicle

<table>
<thead>
<tr>
<th>Stage</th>
<th>Architecture</th>
<th>Sensors</th>
<th>Actuators</th>
<th>Functional Architecture</th>
<th>E/E Architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver Only</td>
<td>fail-safe/ fail-silent</td>
<td>360° simple surround view</td>
<td>Standard brake and steering</td>
<td>Single function chain Pattern based decision structure</td>
<td>Fail safe</td>
</tr>
<tr>
<td>Assisted</td>
<td></td>
<td>Redundant sensing principles, safety decomposition</td>
<td>Fail operational brake and steering</td>
<td>Diverse functional architecture Universal decision structure</td>
<td></td>
</tr>
<tr>
<td>Partially Automated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highly Automated</td>
<td>fail-operational/ fail-degraded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fully Automated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Highly Automated Driving: It’s not a function – it’s a system.**
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Principle: Partially vs. Highly Automated

Sensor 1
Sensor 2

Sensor data fusion
Specific Environment Hypothesis
Function specific Situation classification
Desired vehicle behaviour
Target Motion
Motion Control

Desired behaviour, monitoring by driver

Sensor 1
Sensor n

Sensor data fusion
360° Environment Model: Dynamic and static objects, driveable areas, localization
Multi behavioural Trajectory calculation acc. to mission
Heuristic Trajectory Assessment
Target Trajectory
Motion Control

Mandatory behaviour, safety relevant

perception
decision
Control

Physical constraints, motion strategies

Desired behaviour, monitoring by driver

Hypothesis
Situation classification
perception
Decision
Control
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Prerequisites for automated driving – overview

- **highly robust in all use cases**
  - surround sensing

- **protection against technical failure and deliberate attacks**
  - safety and security

- **global standards and clear liability**
  - legislation

- **redundancies for sensing, ECUs, and actuation required (fail operational)**
  - system architecture

- **always precise and up-to-date**
  - map data
Surround sensing – reliability requirements

Highly automated driving raises new challenges for sensor concept
Application cases show need for a third sensor principle – however standard sensor improvements will contribute as well to a robust environment model.

Timber transport may not be detected reliably by radar sensor

Low standing sun can fade the video sensor

Tunnel entrances can affect the radar and video sensors
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Surround sensing – vehicle sensor concept

- Long-range radar
- Mid-range radar
- 3rd sensor principle
- Stereo-video
- Long-range radar
- Mid-range radar
- Near-range cameras
- Ultrasonic sensors

360° surround sensing by combination of different sensors
- Long- and mid-range radar prerequisite for driving at higher speed
- Satisfy reliability requirements by using multiple sensors for each area
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Here is why automated cars need maps

1. Planning Map: “Your lane ends at GPS position $x \; y$ (+/-10m$_{long}$)”

2. Localization Map: “You are currently at GPS position $\xi \; \psi$ (+/-10m$_{long}$)”

3. Decision Algorithm: “Merge right within the next 150mtrs”

- Preview beyond sensor range allows early adaptation to road conditions
- Lack of preview in dense traffic might lead to emergency stop at lane end

⇒ Map data is required in order to provide long range planning information
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Dynamic map data – layered approach

Highly automated driving requires latest high-precision map data
- Aggregated information processing and delivery via the cloud
Connected mobility – cloud and car2x

Benefits:
Improved road safety and new services

The automotive cloud will be an integral part of the vehicle architecture
- Car2x concepts include local danger warning and driver assistance functions
Safety and security - distinction

<table>
<thead>
<tr>
<th>Safety</th>
<th>Security</th>
</tr>
</thead>
<tbody>
<tr>
<td>➔ Protection against technical failures</td>
<td>➔ Blocking of deliberate attacks</td>
</tr>
<tr>
<td>➔ Covers malfunction aspects</td>
<td>➔ Confidentiality, integrity, availability</td>
</tr>
</tbody>
</table>

Safety (malfunction) differs in scope from security (deliberate attack)

- Leaks in security can put safety at risk
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Security – layered automotive approach

E/E architecture
- Protect and separate domains
- Secure E/E architectures, and security gateways

Connected vehicle
- Protect safety & integrity of vehicle and privacy of driver
- Vehicle firewalls and security standards

Individual ECU
- Protect integrity of ECU SW & data
- Bosch hardware security module (HSM) in µC

In-vehicle network
- Protect integrity of critical in-vehicle signals
- Truncated message authentication codes (MAC)

No automotive security standardization or agreement available yet
- Bosch offers a broad spectrum of solutions for automotive security
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Safety – reliable system architecture

Fail-safe architecture

Drivers of E/E architecture:
- increasing computing power
- demands for automated driving functionalities

Consequences:
- HW/SW repartitioning (sensor/ECU/cloud)
- use of CE components (μC, FPGA, GPU...)
- redundancies at marketable costs

Fail-operational architecture

Redundant power supply, interfaces, and processing units required
- Need for highly reliable architecture will change on-board network completely
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Safety – reliable actuation elements

- Vacuum-free boost & autonomous braking
- Modular actuation concept offers a perfect solution for automated driving

Vacuum booster → iBooster

Modulation → Recuperation

ESP® → ESPhev

Electronic power steering
ESP® ESPhev
iBooster

Redundant steering system
Redundant braking system

Redundant steering, braking, and stabilization systems required
- Modular actuation concept offers a perfect solution for automated driving
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Legislation frameworks – need for adaptation

Current legal framework

- National laws
- Geneva convention (1949)
- Vienna convention on road traffic (1968):

  Article 8 (5):
  „Every driver shall at all times be able to control his vehicle or to guide his animals“

Ongoing activities

- Legalization and regulation of automated driving decided in individual U.S. states
- Initiative in Europe by VDA
- Japan (MLIT) is exploring different possibilities (e.g. special lanes)

Legislation framework no longer reflects technical progress

- Need for adaptation to take account of highly automated driving

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Development steps – automated driving

<table>
<thead>
<tr>
<th>Degree of automation</th>
<th>Single sensor</th>
<th>Sensor-data fusion</th>
<th>Sensor-data fusion + map</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ACC/lane keeping support</strong></td>
<td>Only longitudinal or lateral control</td>
<td>Partially automated longitudinal and lateral guidance in driving lane</td>
<td>Speed range 0-130 kph</td>
</tr>
<tr>
<td><strong>Integrated cruise assist</strong></td>
<td>Partially automated longitudinal and lateral guidance</td>
<td>Lane change after driver confirmation</td>
<td>Supervision of surrounding traffic (next lane, ahead, behind)</td>
</tr>
<tr>
<td><strong>Highway assist</strong></td>
<td>Highly automated longitudinal and lateral guidance with lane changing</td>
<td>Reliable environment recognition, including in complex driving situations</td>
<td>No permanent supervision by driver</td>
</tr>
<tr>
<td><strong>Highway pilot</strong></td>
<td>Door-to-door commuting (e.g. to work) in urban traffic</td>
<td>Strictest safety requirements</td>
<td>No supervision by driver</td>
</tr>
<tr>
<td><strong>Auto pilot</strong></td>
<td>Highly automated longitudinal and lateral guidance with lane changing</td>
<td>Reliable environment recognition, including in complex driving situations</td>
<td>No permanent supervision by driver</td>
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The responsible vehicle...

- ... needs a well aligned, highly reliable sensor set
- ... needs an E/E architecture which guaranties a safe performance under all circumstances
- ... needs actuators which can mutually replace each other or are redundant
- ... needs a reliable functional architecture from perception to motion
- ... always needs to have a „plan B“
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Thank you for your interest!

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