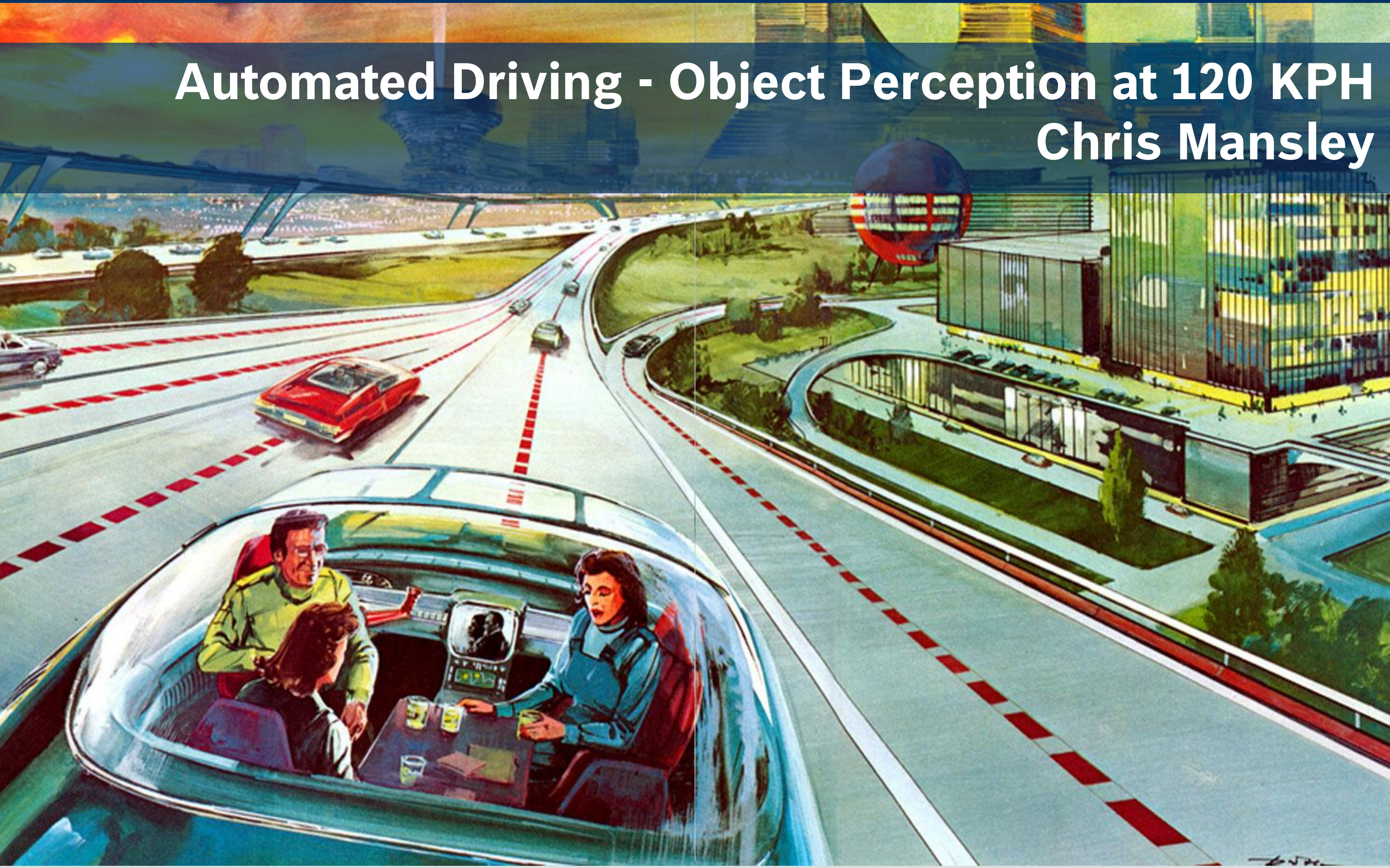
# Automated Driving - Object Perception at 120 KPH

Chris Mansley



Chassis Systems Control

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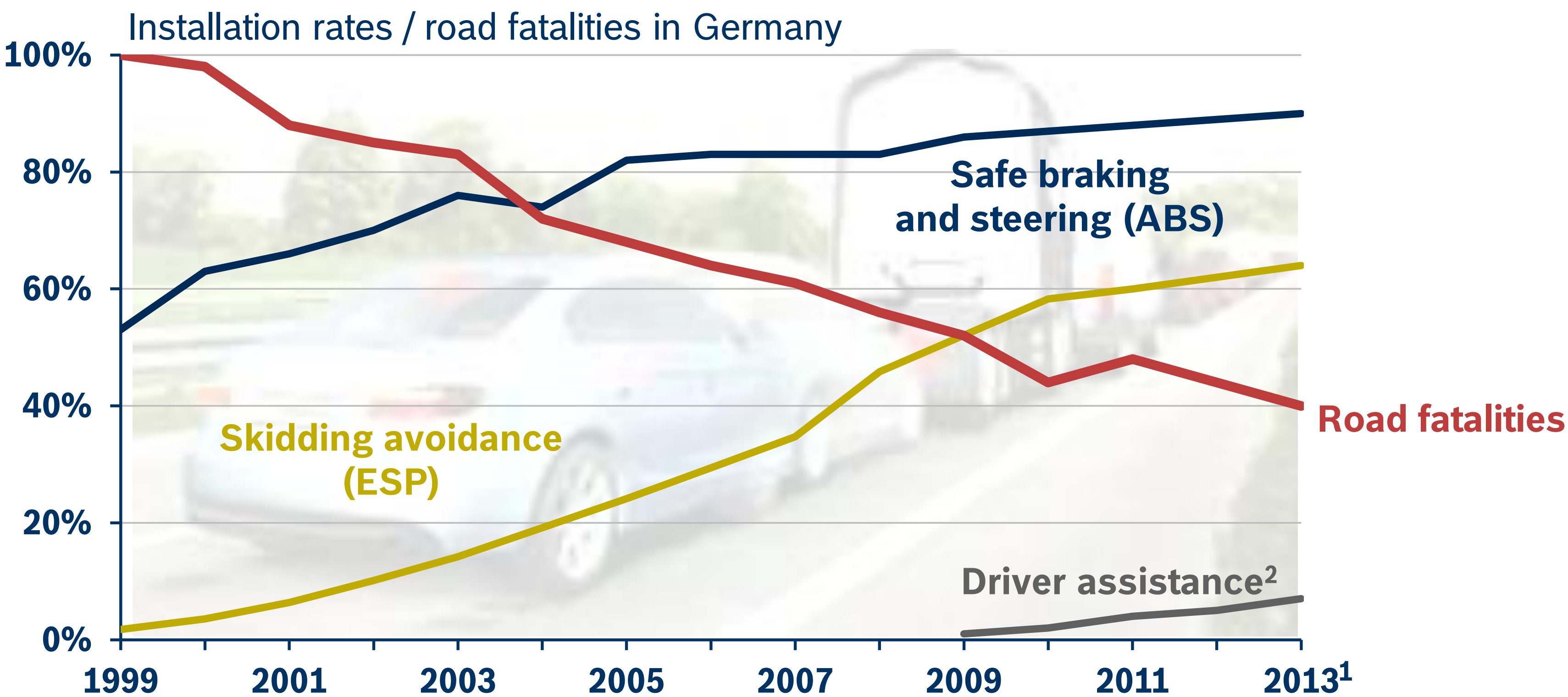
# Road safety – influence of driver assistance




**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, DAT, BASt. Based on total vehicle fleet.
[1] Figures estimated [2] ACC and lane keeping support only

# Bosch in Automated Driving

- First involvement in automated driving 1990s
- DARPA Urban Challenge 2007
- Corporate Research, Palo Alto until 2011
- Engineering in Abstatt (DE) and Palo Alto (US) since 2011

**Palo Alto**
-Mapping/Localization
-Perception
-Planning

**Germany**
-Motion control
-Mapping
-Architecture
-Validation
-Radars
-Cameras
-Sensor Dev.

# Development steps – automated driving

Degree of automation

- Single sensor
- Sensor-data fusion
- Sensor-data fusion + map

**ACC/lane keeping support**

Only longitudinal or lateral control

**Integrated cruise assist**

Partially automated longitudinal and lateral guidance in driving lane
Speed range 0-130 kph

**Highway assist**

Partially automatic longitudinal and lateral guidance

Lane change after driver confirmation

Supervision of surrounding traffic (next lane, ahead, behind)

**Highway pilot**

Highly automated longitudinal and lateral guidance with lane changing

Reliable environment recognition, including in complex driving situations

No permanent supervision by driver

**Auto pilot**

Door-to-door commuting (e.g. to work) in urban traffic

Strictest safety requirements

No supervision by driver

Series introduction





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# Partial vs. Full automation

| | Partial Automation | Full Automation |
|---|---|---|
| Execution /control | System | System |
| Monitoring | Driver | System |
| Driver Availability | Immediately | Not required |
| Failure to take over | Not acceptable | Safe state by system |
| System failure | Fail safe | Fail operational |

- **Electronics:** Fail operational with redundant bus & power supply
- **Actuators:** Electronic/Electric fallback instead of mechanical fallback (driver)
- **Sensing:** Redundant sensing, multi-modal perception/localization
- **Computing:** Fail operational, automotive-grade (ECC memory, supervisor)
- **Functional Safety/Release Methods:** Novel system validation methods

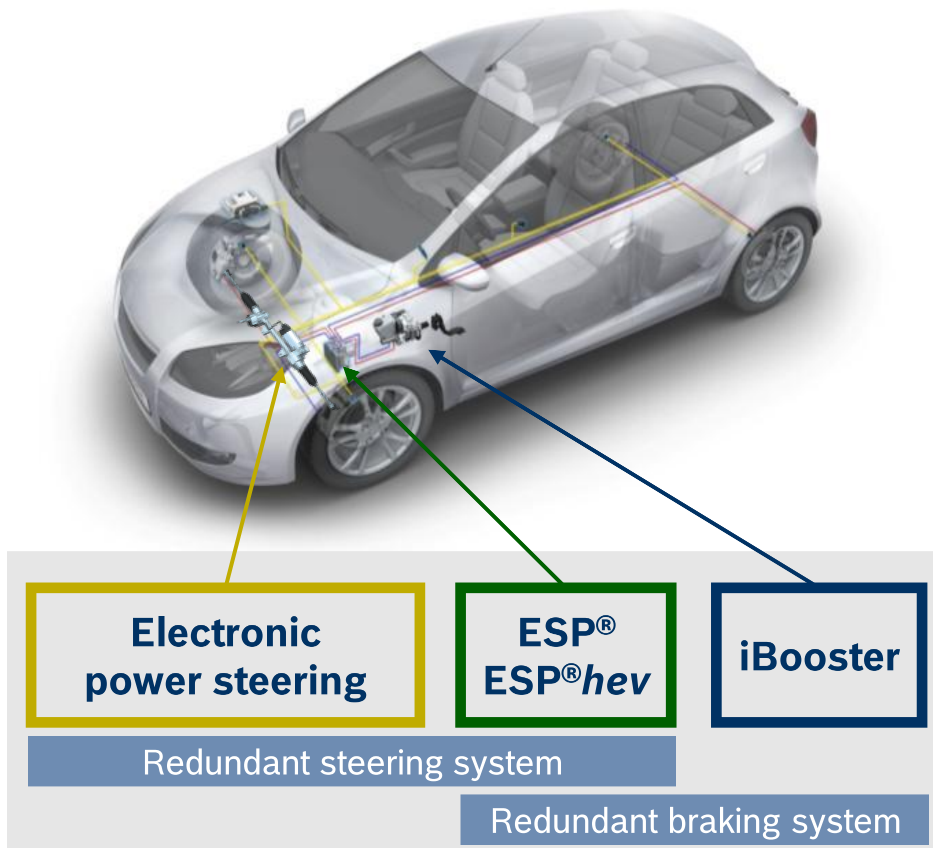
# Hardware Redundancy – Actuation

| Brake boost | Vacuum-free boost & autonomous braking |
| --- | --- |



| Modulation | Recuperation |
| --- | --- |

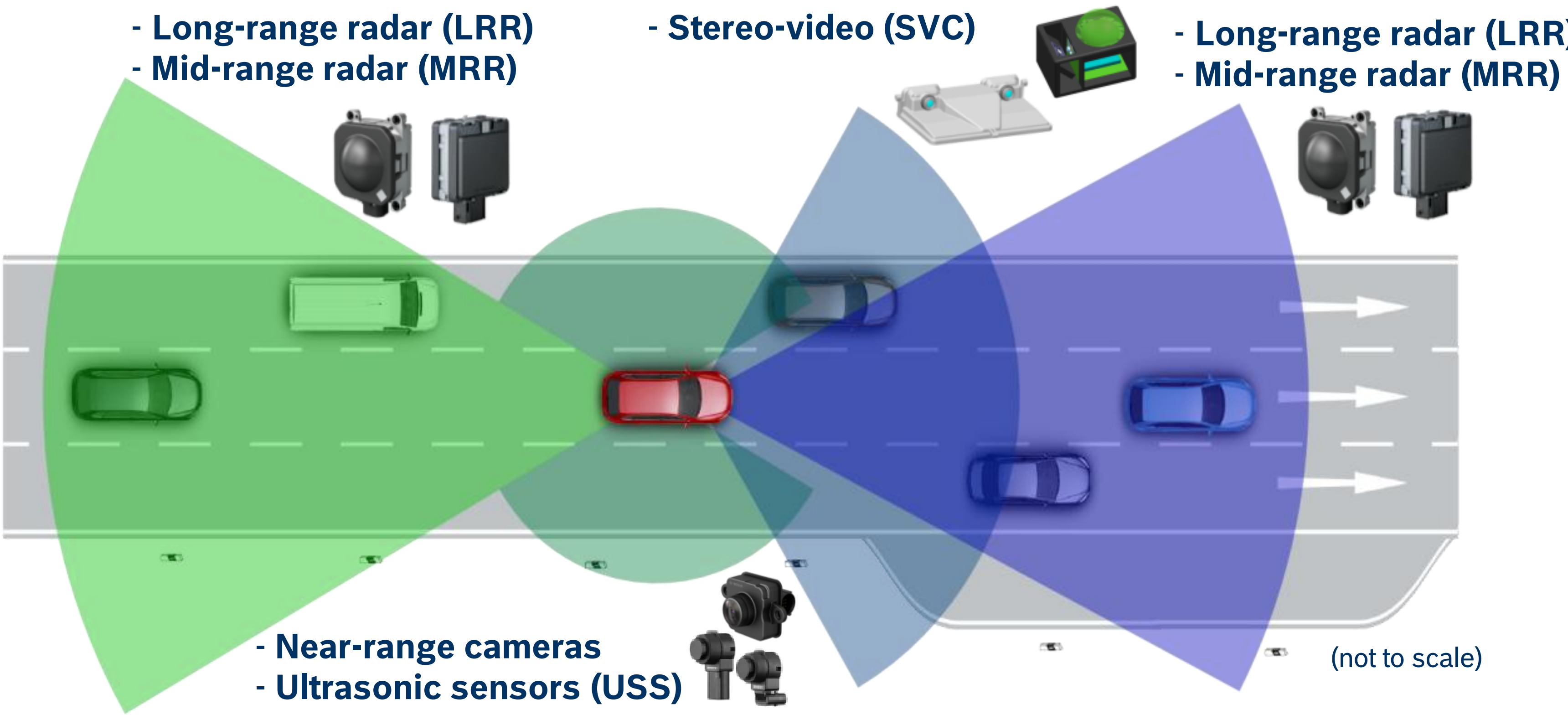





**Redundant steering, braking, and stabilization systems required**

· Modular actuation concept offers a perfect solution for automated driving

# Hardware Redundancy – Sensing

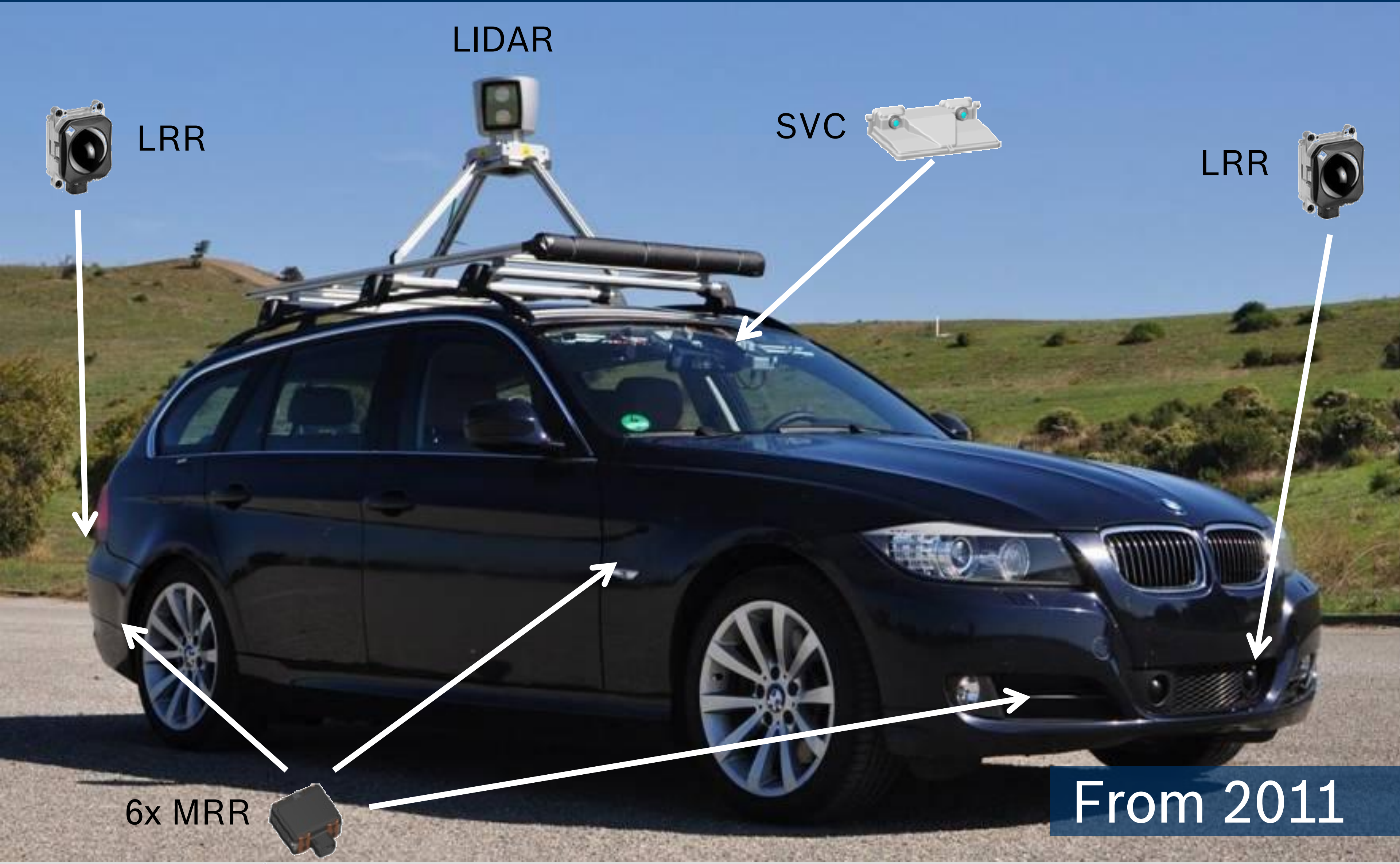



**360° surround sensing by combination of different sensors**

- Long- and mid-range radar prerequisite for driving at higher speed
- Satisfy reliability requirements by using multiple sensors for each area

# Object Perception @ 120 KPH




Chassis Systems Control





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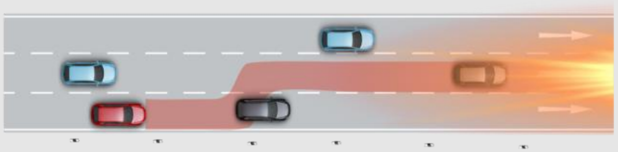
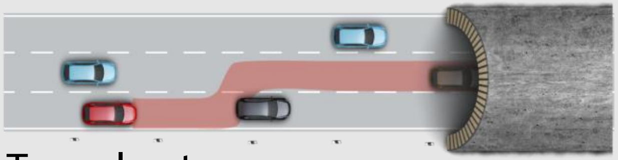
# Requirements for Sensing

- Automated driving use cases require
  - 360°surround view
  - 3D information
  - Shape and surface measurement
  - High reliability
  - Low sensitivity to weather and light
  - Physical redundancy

**Example use cases:**



Environment conditions (low sun)



Tunnel entrances

Uncommon obstacles (lumber truck)

**Highly automated driving raises new challenges for sensor concept**

# Example: Perception in High-speed Traffic

- **Challenge**
  - Timely response to fast approaching traffic

- Example scenario:
  - Other German highway drivers at up to 250 km/h (70 m/s)
  - Assuming a perception cycle time of (say) 25ms
  - Assuming a need for multiple detections to achieve object presence confidence and to converge to velocity estimate

- At (say) 4 cycles with instantaneous (and in-step) decision making **the object has traveled 7 meters.**
  - Not accounting for object prediction and trajectory computation

# Object Perception @ 120 KPH

## Approach

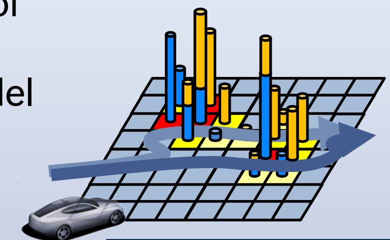
### Surround sensors

Precise and reliable information on vehicle surroundings, e.g.

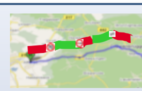
- ➔ Obstacle positions and velocity
- ➔ Obstacle classes, (vehicle, pedestrian, ….)
- ➔ Object shape

### Perception

Probabilistic fusion of all information into a single surround model



### Situational Data



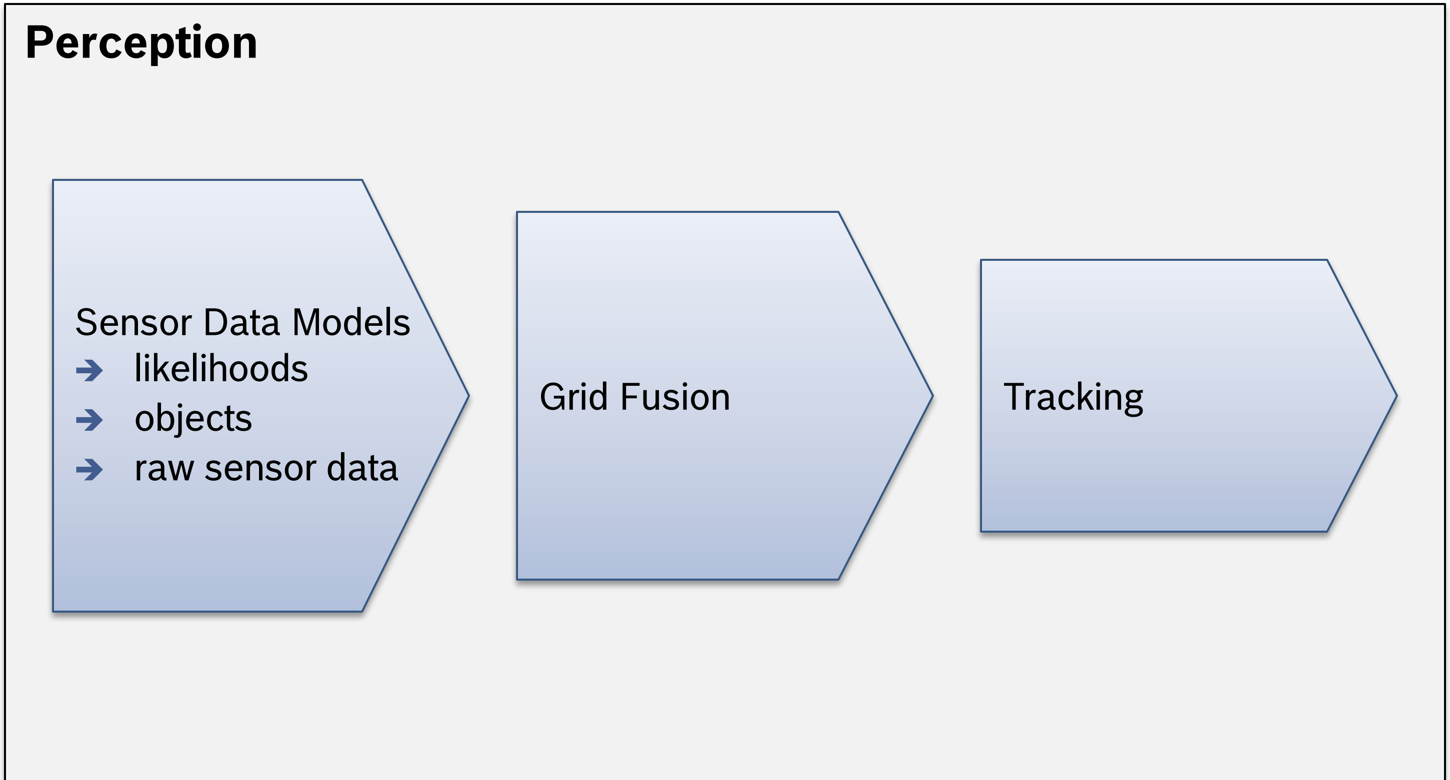
Additional (long-term, long-range) e.g.

- ➔ speed limits
- ➔ intersections
- ➔ road course


### Decision Making

Context-aware, probabilistic interpretation of fused environmental model from perception and situational data

# Perception Subsystem







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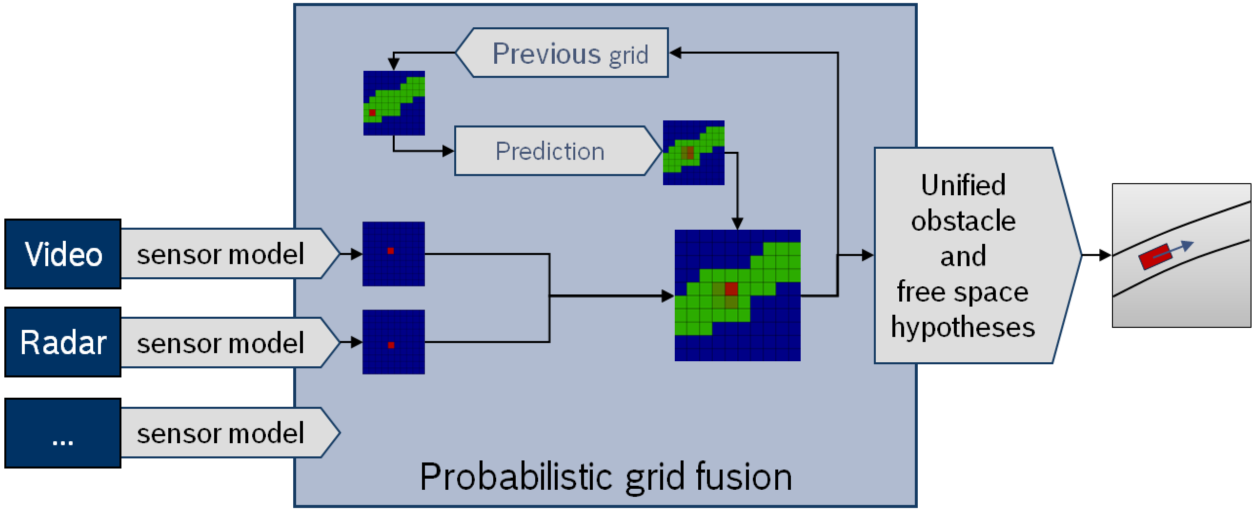
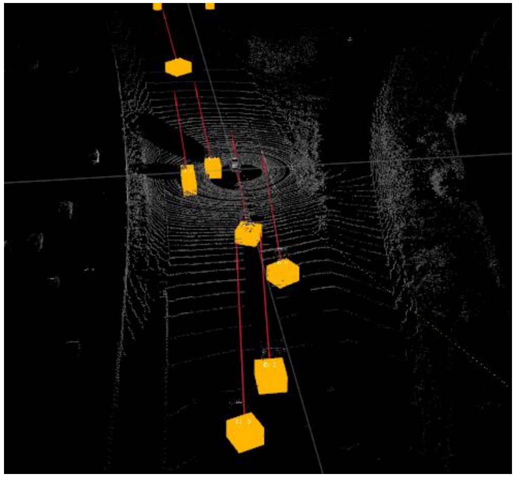
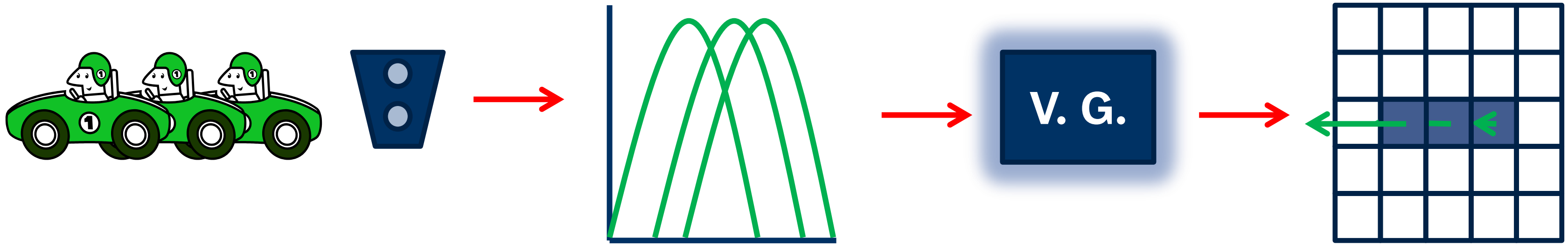
# Grid Fusion



➔ Grid based data fusion determines the occupancy probability of a cell by evaluating the current sensor reading and the history from past cycles

# Why velocity grids?



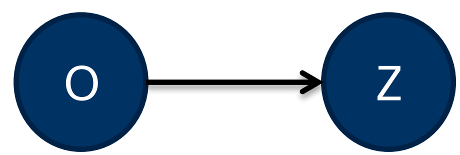

A velocity grid representation provides a **probabilistic framework** for fusing **multiple sensors** with **different models**, while representing **uncertainty** and **avoiding data association**

# Occupancy Grids

- Represent the map as a field of binary random variables corresponding to the occupancy

p(occupancy)

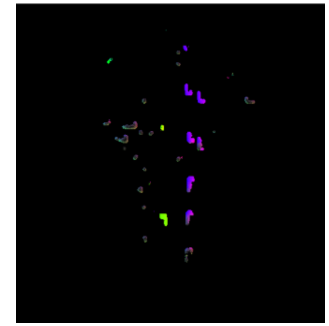
| | | |
|---|---|---|
| 0.5 | 1.0 | 0.7 |
| 0.5 | 1.0 | 0.7 |
| 0.5 | 0.1 | 0.1 |




- Assumptions :
  - Static map
  - Each cell is independent
  - Robot location is known

# Velocity Grids

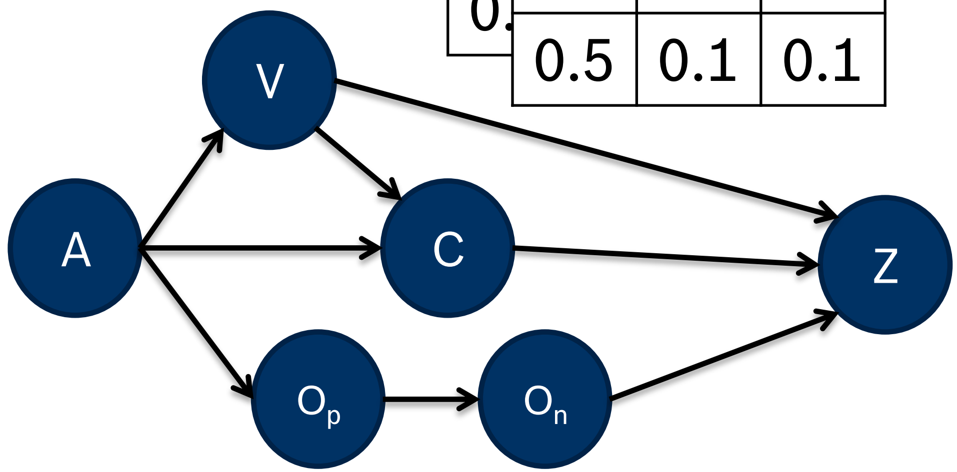


- ➔ Represent the map as a field of binary and discrete/continuous random variables corresponding to the occupancy and the velocity

p(occupancy={0,1}, velocity=5)

| | | |
|---|---|---|
| 0.5 | 0.0 | 0.1 |
| 0.5 | 0.0 | 0.7 |
| 0.5 | 0.1 | 0.1 |

- ➔ Assumptions :
  - Dynamic map
  - Cells are correlated
  - Robot location is known



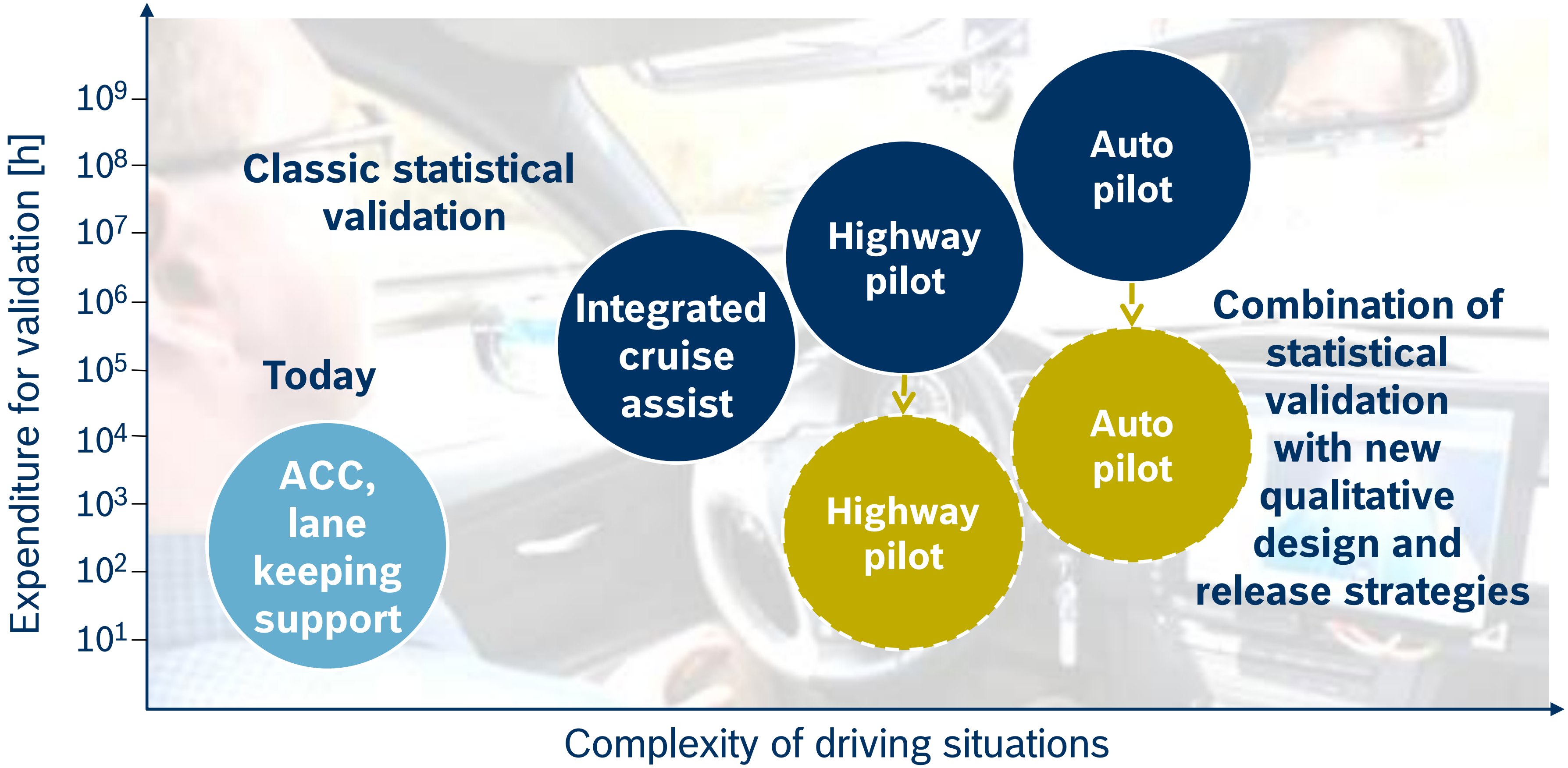
# Software

- On-going **algorithm development:**
  - **Perception:**
    - High-speed traffic situations
    - Classification to support traffic prediction (e.g. indicator cue)
    - Map inconsistency detection (localization/planning)
  - **Decision making:**
    - Traffic prediction
    - Safe-stop (potentially high-dynamic maneuvers)

- **Validation** of system behavior

- On-going **system engineering:**
  - Addressing **scale** in object number, computational demands
  - Redundancy in computation: **system supervision**

# Validation and release process – challenges




**Expenditure for validation will increase by a factor of $10^6$ to $10^7$**

- Traditional statistical validation not suitable for higher degree of automation
- Highly automated systems require completely new release strategies

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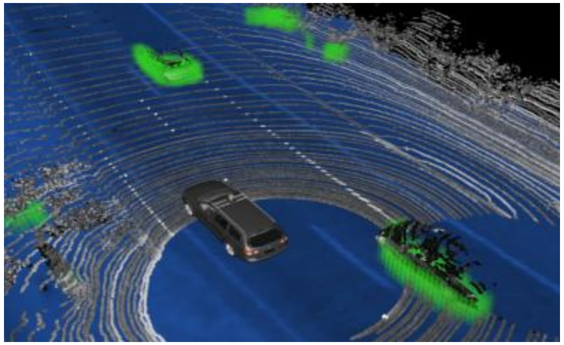
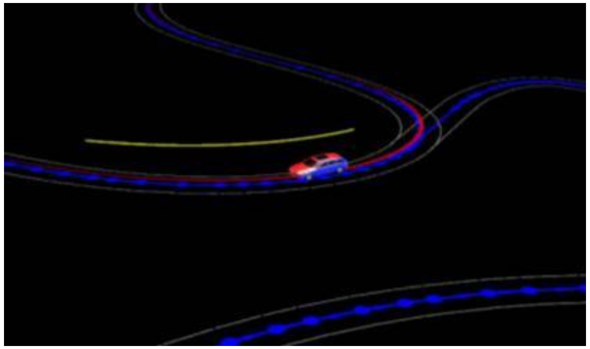
# Summary

- Automated driving functions will irreversibly change vehicle architecture (hardware, software) and system validation
- Technical and legal challenges still exist and need to be solved
  - Sensors, actuators, E/E architecture and driver monitoring
  - Algorithm development
- Stepwise implementation starting with Automated Highway Driving









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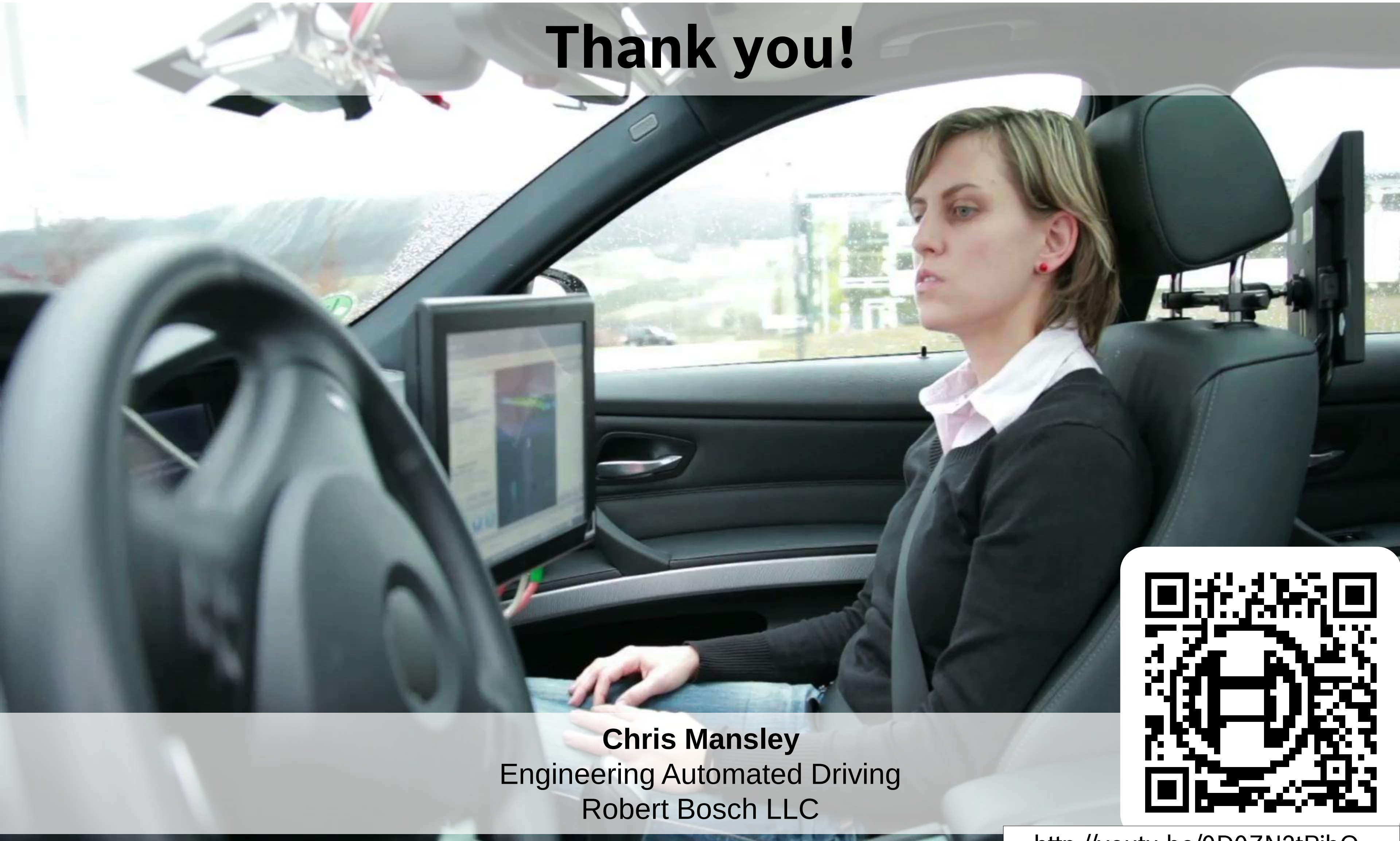
# Thank you!



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http://youtu.be/0D0ZN2tPihQ





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