Automated Driving – Challenges and Opportunities

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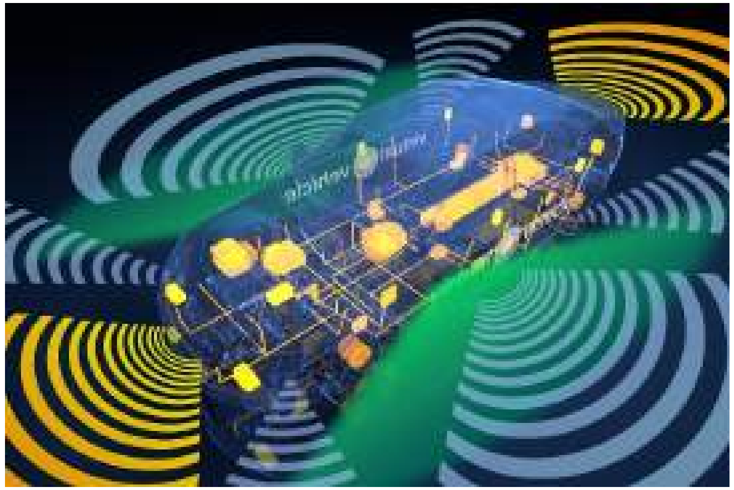

IEEE General Assembly
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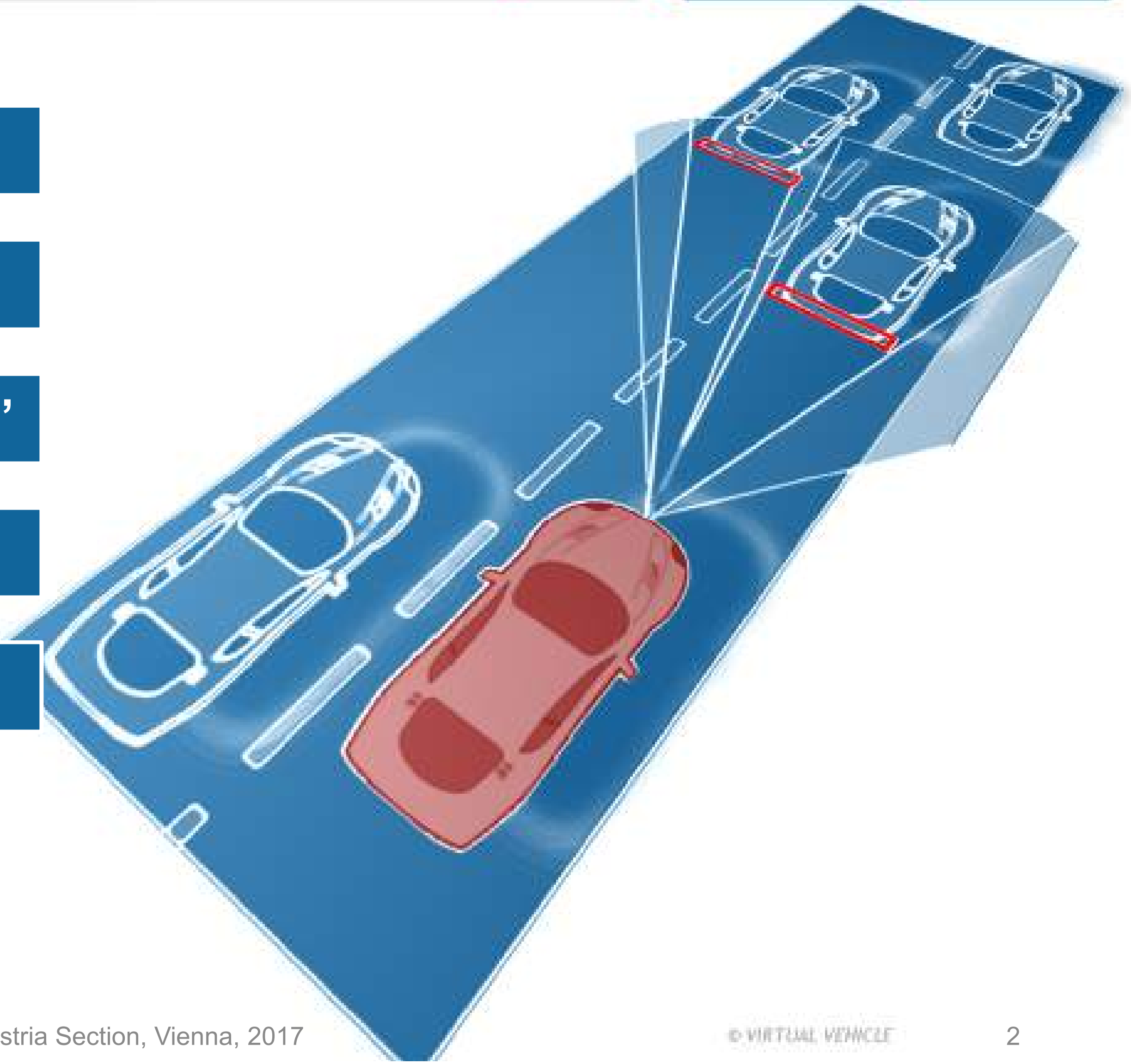
Content

- Motivation
- Roadmap
- Challenge "Fail-operational"
- Testing: ALP.Lab
- Concluding remarks



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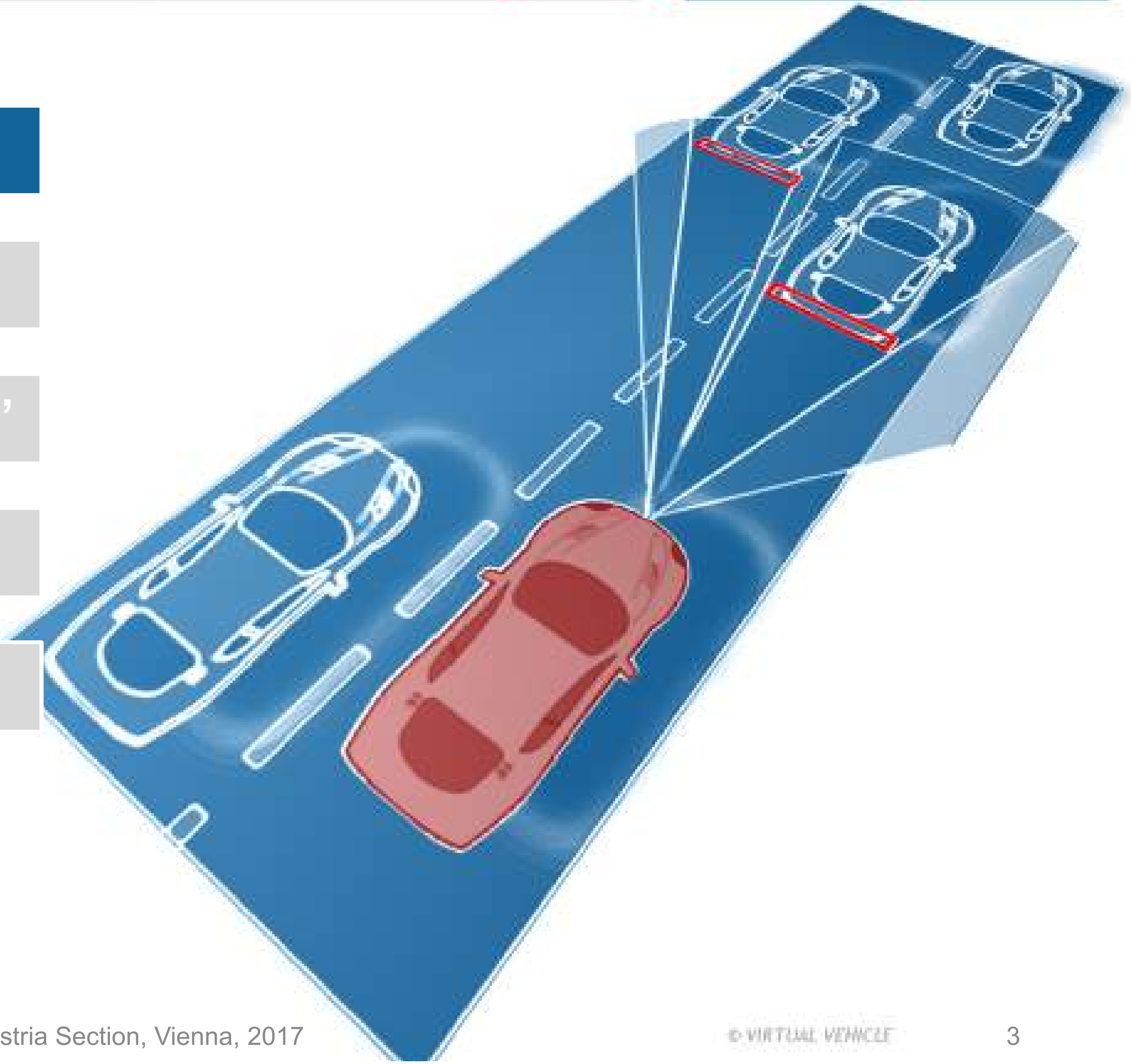


Expected benefits

- **Reducing energy use and emissions**
    - Aerodynamic “drafting”
    - Improve traffic flow dynamics

- **Improving traffic throughput**
    - Increase capacity of roadway infrastructure
    - Improve traffic flow dynamics

- **Improving safety**
    - Reduce and mitigate crashes

- It is all about **comfort** and **safety**

Reducing energy and emission

- At highway speeds, half of energy is used to overcome aerodynamic drag
  - Close-formation automated platoons can save 10% to 20% of total energy use
- Accelerate/decelerate cycles waste energy and produce excess emissions
  - Automation can eliminate stop-and-go disturbances, producing smoother and cleaner driving cycles
- BUT, this only will happen with V2V cooperation

Traffic flow

- Typical U.S. highway capacity is 2200 vehicles/hr/lane (or 750 trucks/hr/lane)
  - Governed by drivers' car following and lane changing gap acceptance needs
  - Vehicles occupy only 5% of road surface at maximum capacity
- Stop and go disturbances (shock waves) result from drivers' response delays
- V2V cooperative automation provides shorter gaps, faster responses, and more consistency
- I2V cooperation could maximize bottleneck capacity by setting most appropriate target speed

Expectations:

- Significantly higher throughput per lane
- Smooth disturbances due to merging traffic

[Source: US DOT, 2016]

Improving safety

- **94% of crashes** in the U.S. are caused by driver behavior problems (perception, judgment, response, inattention) and environment (low visibility or road surface friction)

- YES, automation is able to avoid driver „behavior" problems

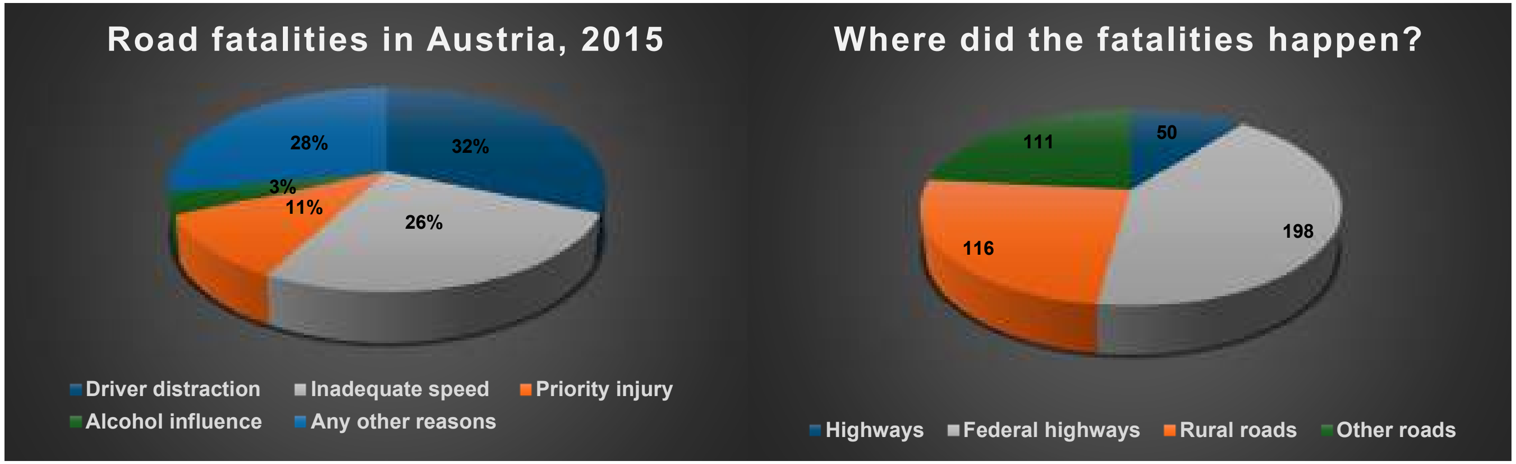
- Appropriate sensors and communications need to be weather independent

- BUT, current traffic safety **sets a very high bar**:
  - **3.4 Mio vehicle hours** between fatal crashes (390 years of non-stop driving)
  - **61,400 vehicle hours** between injury crashes (7 years of non-stop driving)

[Source: US DOT, 2016]

Road fatalities in Austria, Germany, EC-28

Road fatalities	2014	2015
Austria	430	**475**
Germany	3.377	**3.475**
EC-28	25.700	**26.000**



[Source: Austrian Federal Ministry for Transport, Innovation, and Technology, 2016]

Safety and automation

- Accidents are almost all due to human errors
- BUT: Humans do much more right when driving than they do wrong!

We have – to some success – automated to intervene when people do something wrong

→

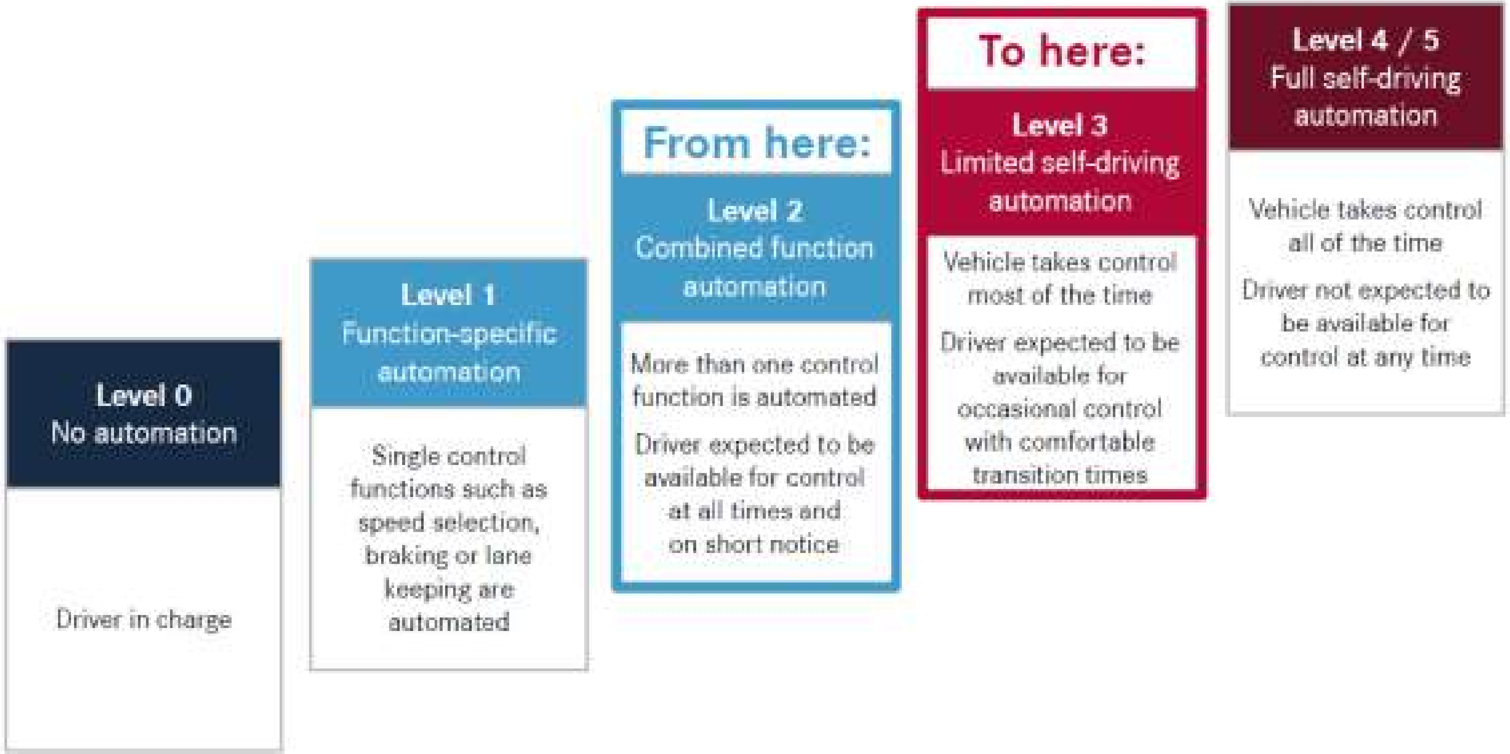
Now we have to automate those things and tasks people do right

On German Highways, every 7.5 million km we may catch an error.

We have to drive those 7.5 million km and must not fail a single time.

[Source: ADAC statistics, 2016]

Levels auf automation (NHTSA)

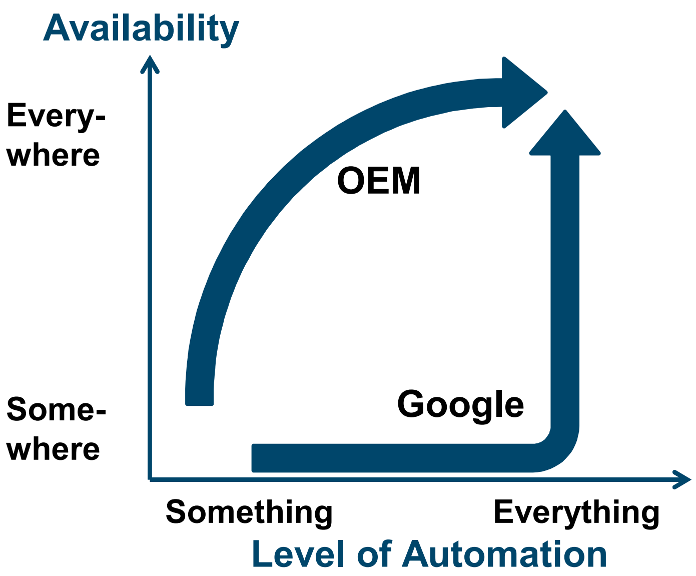


Conversion vs. Purpose Design

Availability vs. degree of automation

Where and under what conditions is the automation available?

- Not only the level of automation and the use case offer evolutionary paths
- Also an evolution in availability is reasonable
- Different approaches exist (most OEM vs. Google)



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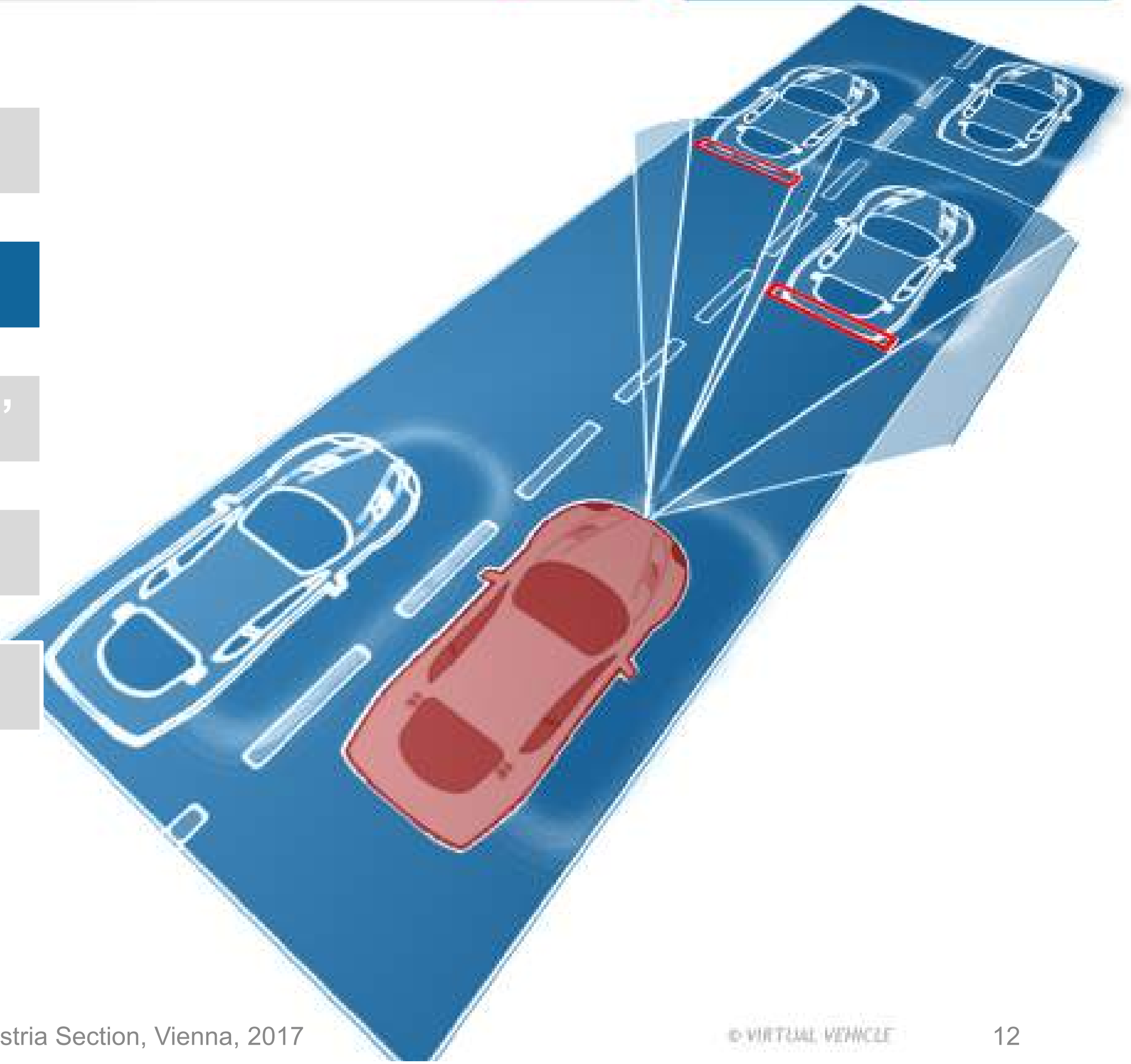
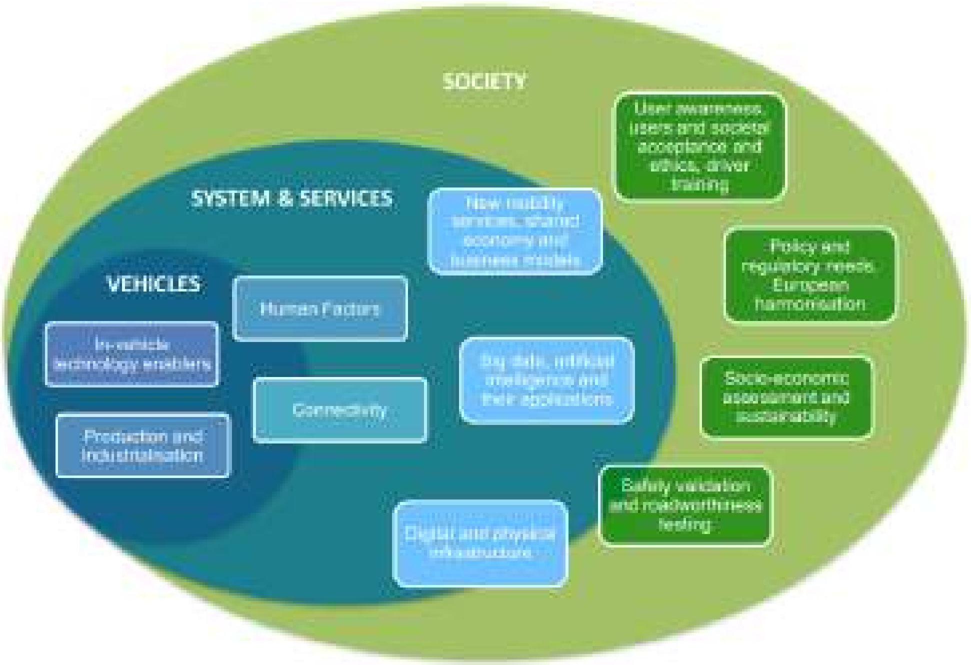


Roadmap automated driving



[Source: Key Challenges of Automated Driving, ERTRAC, Automated Driving Roadmap, 2017]

- Core enablers: **perception**, **decision making**, and **actuation**
- **Perception** systems must be **robust, complementary,** and **reliable**

Roadmap automated driving

Longterm Gens.						Urban & rural roads	Robot Taxi
					Urban & rural roads	Highway System	
Automation Gen. 2					Highway System	Valet Parking System	
Automation Gen. 1					Highway Traf. Jam-system		
ADAS new				Traffic Jam Ass. Park Ass.			
ADAS established	AEBS ABS ESC	FCW LKAS	ACC AEBS				
	Intervening only in emergency	Driver Only	Assisted	Partial Automation	Conditional Automation	High Automation	Full Automation
		0	1	2	3	4	5

Existing | Low velocity in structured environment | High velocity in structured environment | Unstructured environment

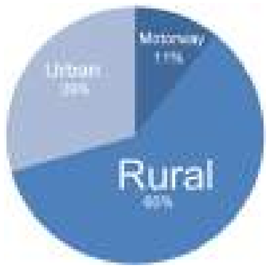
ADAS	Advanced Driver Assistance Systems	LKAS	Lane Keeping Assistance
AEBS	Advanced Emergency Braking	FCW	Forward Collision Warning
ESC	Electronic Stability Control	ACC	Adaptive Cruise Control
ABS	Antilock Braking System		

„autonomous“

- ERTRAC Roadmap Automated Driving. 2017
- Austrian R&D&I Roadmap on Automated Driving, 2016

Automation approach

	Low Velocity	High Velocity
Structured Traffic Environment	**Traffic Jam** Level 2 (limited*) already introduced **Level 3 in development**	**Highways** Level 2 (limited*) already introduced **Level 3 in development**
Unstructured (complex) Traffic Environment	**Parking and Maneuvering** Level 2 already introduced **Level 4 in research/development**	**Urban and Rural Roads** Level 2 (limited*) already introduced **Level 3 in research**



Let's recall: Fatalities on German roads.

* Current **UN R 79** allows above 10 kph **only corrective steering** (lateral assistance). Therefore steering capability of today's Level 2 functions is still limited.

Reasons for exposure of accidents

1. **Failure of components** and hardware deficiencies
2. **Deficiencies in sensing** road, traffic, and environmental conditions
3. **Deficiencies in control algorithms** (complex and difficult situations)
4. **Behavior-dependent accidents** (adequate behavior and rule compliance)
5. **Faulty driver and vehicle interaction** (mode confusion and false commanding)

[Source: H. P. Schöner, Daimler AG, 2017]

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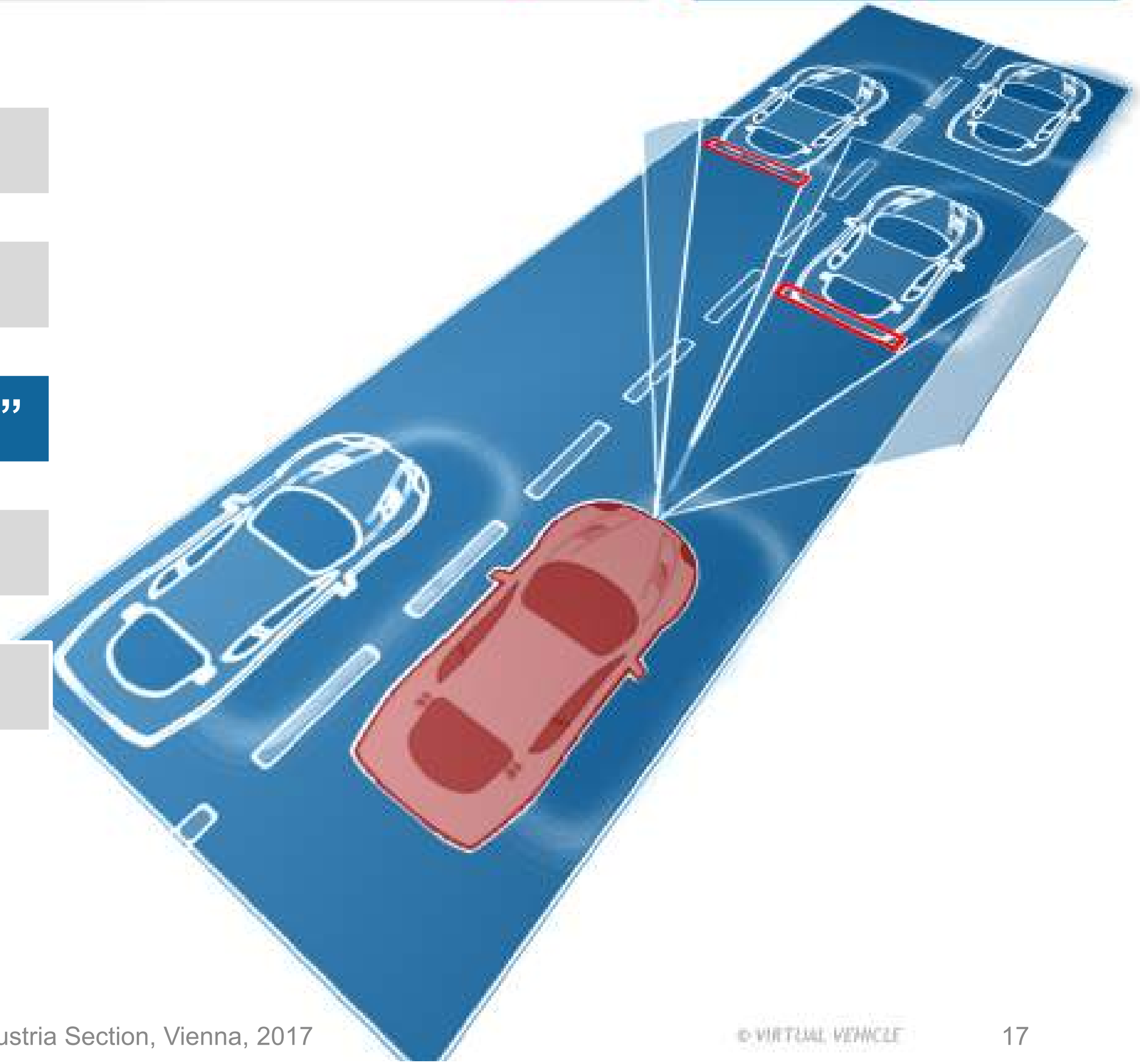
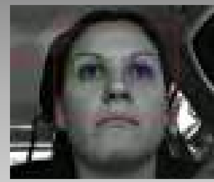


System architecture – automated driving



unpredictable conditions

fuse all input to one model

Radar | LIDAR | Cameras | Infrared | Ultrasonic | V2X | Other Sensors

Reliable sensor data processing and fusion

- Raw data analysis of all sensors
- Deliver consistent environmental model

plan safe actions under current conditions

Scene understanding, driver monitoring, decision making, and planning

- Situation and behaviour prediction
- Planning of provably safe trajectories
- Handover/takeover planning

System Performance and Driver Monitoring

- Out-of-position
- Warning
- Intervention
- Measure reliability and uncertainty
- Detection and decision on function availability
- System degradation
- Sensor self-diagnosis
- Ensuring fail-operational behaviour
- …

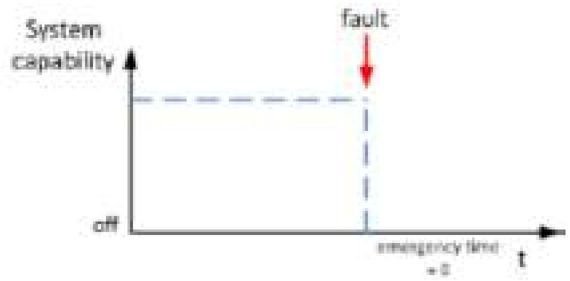
steer functions and vehicle

Fail-operational X-by-wire actuation (low level control)

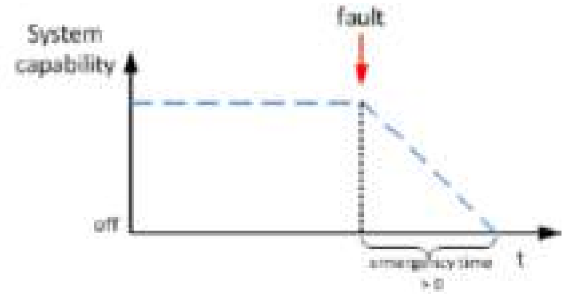
[Source: based on ECSEL Project RobustSense, 2015]

Towards fail-operational: e.g. power steering

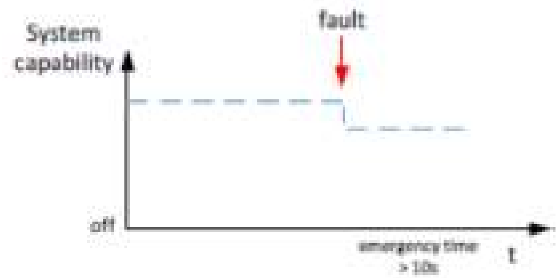
- **Fail-safe** (what we have now)
  - No emergency operation necessary
  - Safe state: system off, driver immediately in control loop



- **High-availability**
  - Safe state: system off, driver immediately in control loop
  - Emergency operation is desirable but not required
  - Minimize hazardous situation in case of potential misuse



- **Fail-operational**
  - Emergency operation is required (10-15s)
  - Eyes-off, brain-off
  - Achieved by adding measures to all vital parts



[Source: Steindl, Miedl, Safetronic, 2015]

Fail-safe vs. fail-operational

SAE level 4: “system can handle all situations automatically in the specific application case” [VDA] → even in the case of component failures!

Fail-safe

- Provides a safe state which **can be achieved** and maintained **without the support of the ECU**
- Cars (cf. ISO 26262)

Fail-operational

- Safe state **can not be achieved** and/or maintained **without the support of the ECU**
- **Aircrafts**

Tesla accident – lane merge (March 2017)

Note: Tesla's Autopilot is only a "driver assist" system and drivers are asked to keep their hands on the steering wheel, the responsibility falls on the driver.

[Source: Electrek, 2017]

Limits of sensors

As effective sensors are, they have some drawbacks

- Limited range
- Performance is susceptible to common environmental conditions (rain, fog, varying lighting conditions)
- “False positives”
- Range determination not as accurate as required
- The use of several sensor types can ensure a higher level of confidence in target detection and characterization

→ Robust sensors and sensor self-diagnosis
→ Redundancy in HW and SW (“fail-operational”)
→ Sensor fusion (automotive qualifiable!)

Single-sensor vs. multi-sensor perception

Drawbacks of single-sensor perception:

- Limited range and field of view
- Performance is susceptible to common environmental conditions
- Range determination is not as accurate as required
- Detection of artefacts, so-called *false positives*

Multi-sensor perception might compensate these, and provide:

- Increased **classication accuracy** of objects
- Improved **state estimation accuracy**
- Improved **robustness** for instance in adverse weather conditions
- Increased **availibility**
- Enlarged **field of view**

Multi-sensor perception comes with a high price, the underlying computational problems are very difficult and often require approaches based on multiple mathematical frameworks.

Sensors per car

Sensor technologies	2015 Euro-NCAP*	2018 Euro-NCAP*	Level 2	Level 3	Level 4/5
Front looking camera	0.5	1	1	1	1
Front looking radar	0.5	1	1	1	1
Front looking lidar	–	–	–	–	1
Surround camera	–	–	–	–	4
Corner radar	–	2	2	4	4
Surround radar	–	–	–	–	6
Rear looking camera	–	–	–	1	1
Rear looking radar	–	–	–	–	1
Driver monitoring Camera	–	–	–	1	1
V2X sensor	–	–	–	–	1
Parking aid	Up to 12 ultrasonic sensors per car				
Automated parking	Potential future replacement by RF CMOS radar				

[Infineon, AutoDrive, 2016]

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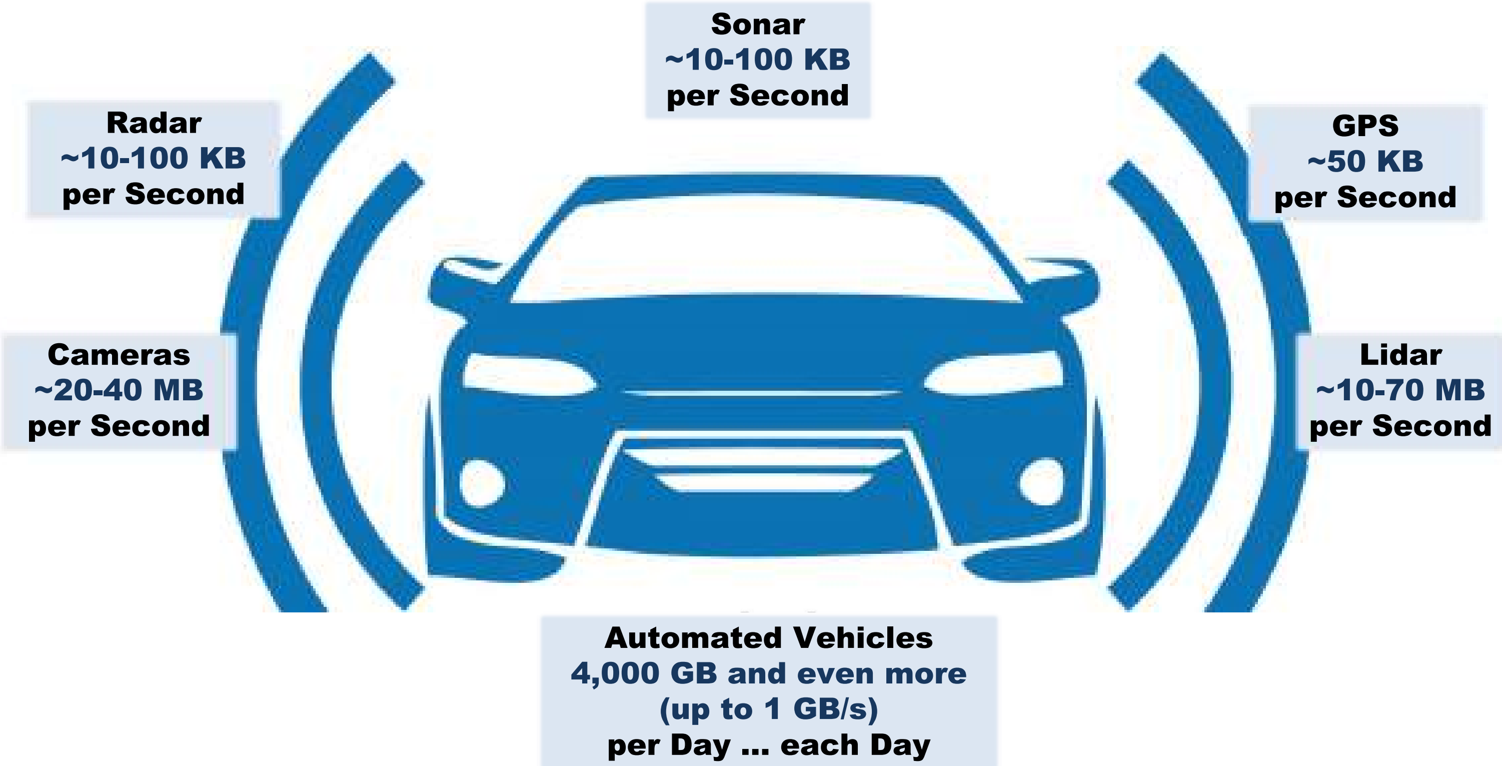
Flood of data in automated vehicles

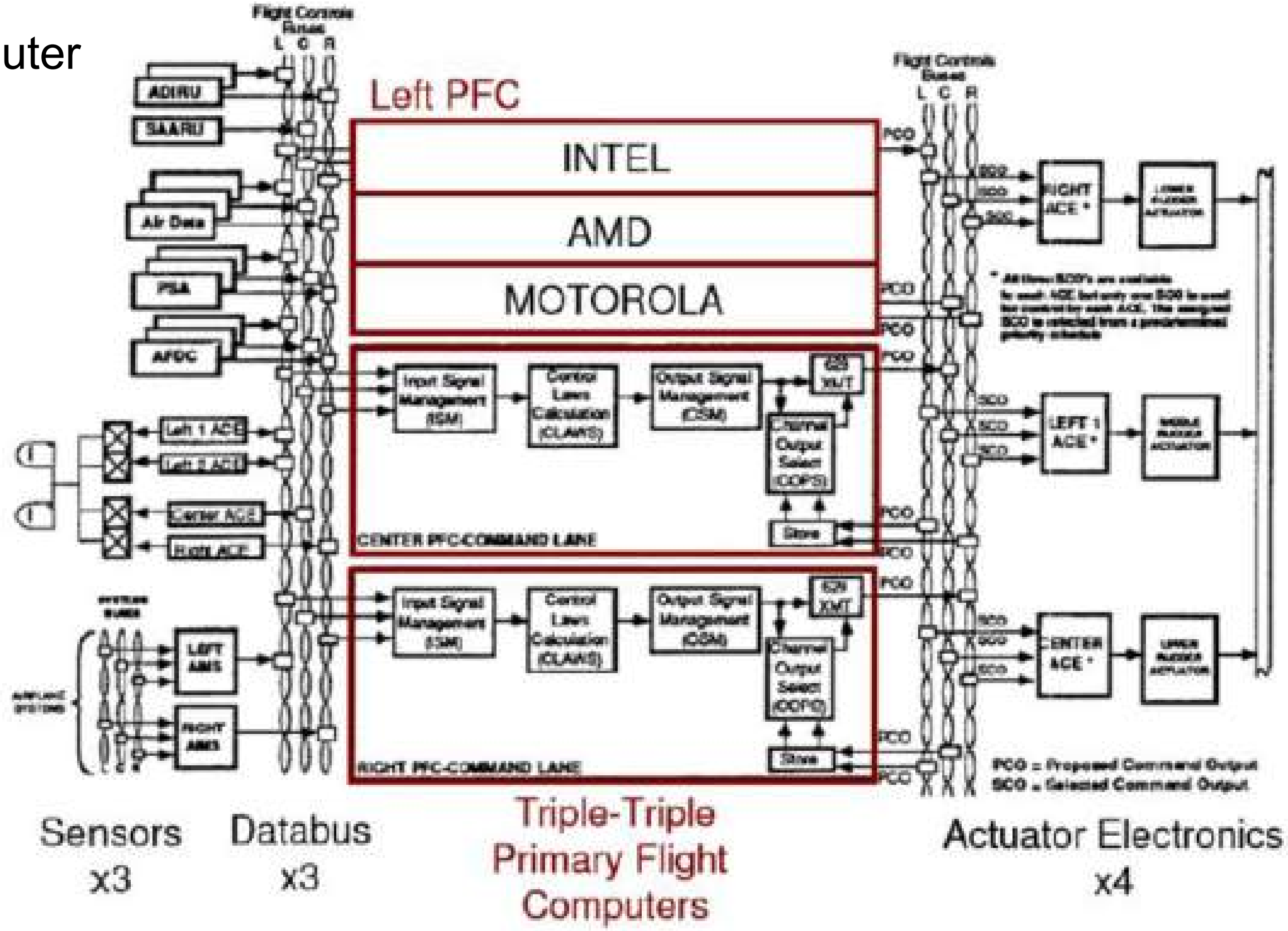


Homogeneous vs. diversity concept

- **Homogeneous redundancy**
  - uses a minimum of two equal instances in parallel
  - the effort in development can be reduced due to the identical components
  - because of the equality, this approach only protects against random faults caused by aging, deterioration or bit flips
  - probability for a complete system crash is higher than in approaches with diverse components
- **Redundancy by diversity (avionics)**
  - The calculating components are heterogeneous, e.g. from different manufacturers
  - System SW of each unit is different or uses at least different HW components
  - this system SW diversity complements functional diversity of the application SW
  - Different implementations result in a lower probability of failure for the system due to the lower probability that the diverse components show the same misbehavior at the same time

Boing 777 triple-triple architecture

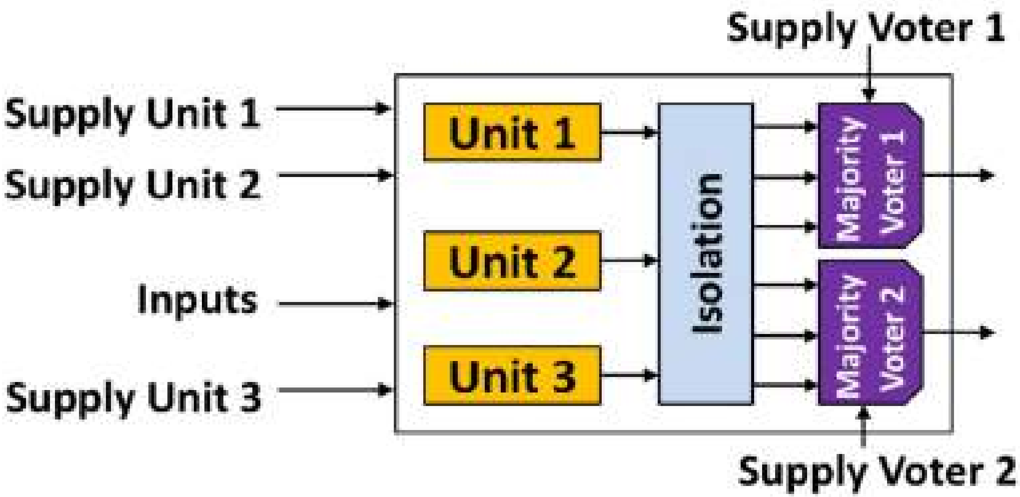
- Boing 777 flight computer
- 3x3 architecture
- HW diversity



[Source: Yey, 1996]

Two-out-of-three (2oo3)

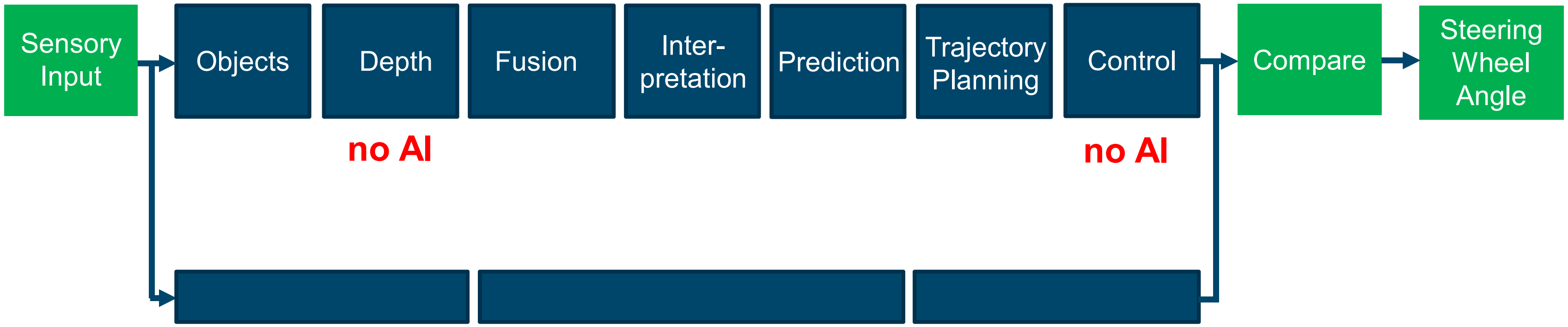
- also known as triple modular redundancy (TMR), used in avionic domain
- Three equal instances use the same algorithm for calculation
- Majority voter: if at least two instances provide the same result, the output is truthful
- This concept can be applied to SW and HW redundancy
- Each calculation unit and the voters should use a separate power supply



Architectures for AI-powered driving

End-2-end approach

Modular approach



Safety Path – collision avoidance only – **no AI** – ASIL D

Source: F. Friedmann, F. Netter, Cognitive Vehicles, Berlin, 2017.

ISO 26262 – another problem to be solved…

- **ISO 26262 – Functional Safety statements:**

… ISO 26262 addresses **possible hazards caused by malfunctioning behavior of E/E safety-related systems**, including interaction of these systems…

… *ISO 26262 does* **not address the nominal performance of E/E systems**, *even if dedicated functional performance standards exist for these systems (e.g. active and passive safety systems, brake systems, Adaptive Cruise Control)…*

- **Interpretation**
  - The scope of the ISO 26262 does not rely to the cause of a malfunctioning behavior
  - The ISO 26262 **does not provide any performance requirements** for functions
  - The **design of nominal safe functions** needs something else

→ ISO PAS*) 21448 **„SOTIF – Safety Of The Intended Functionality“**

(decided by ISO TC22/SC32/WG8 in 2016)

*) PAS…public available specification

What can we learn from avionics?

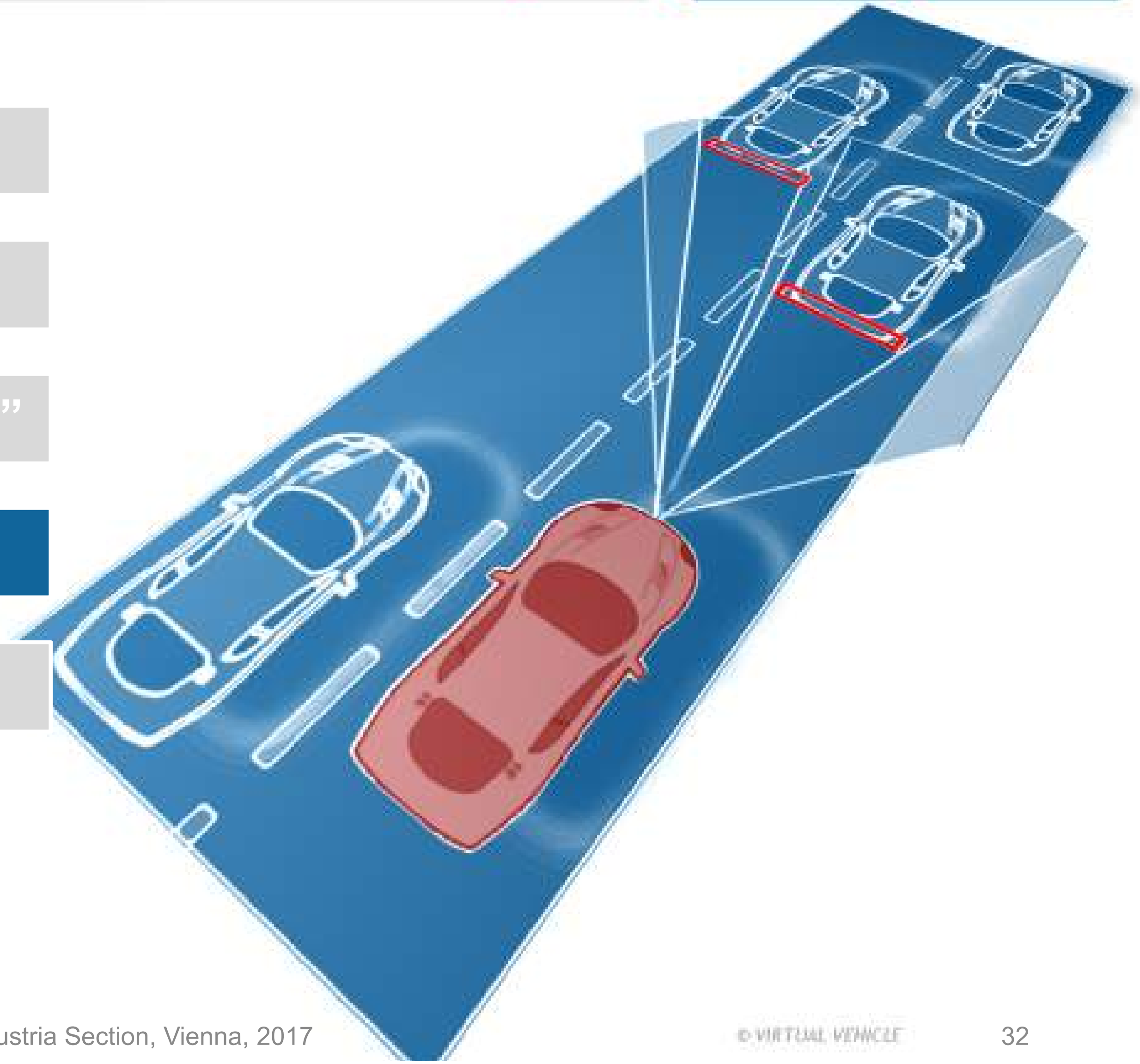
Vehicle safety topics

- At peak times there are less than **30k planes in the air worldwide** (about 6-7k peak in the US)
- At peak times in the US there are **about 20 million vehicles on the road**, and the majority of those within 50 miles of a major city.
- The number of planes that crash into one another is infinitesimally low compared to the number of vehicles that crash (considering only multi-vehicle crashes).
- Take over / hand over time
- The management problem with road vehicles in and around cities is several order of magnitude more difficult than with planes.

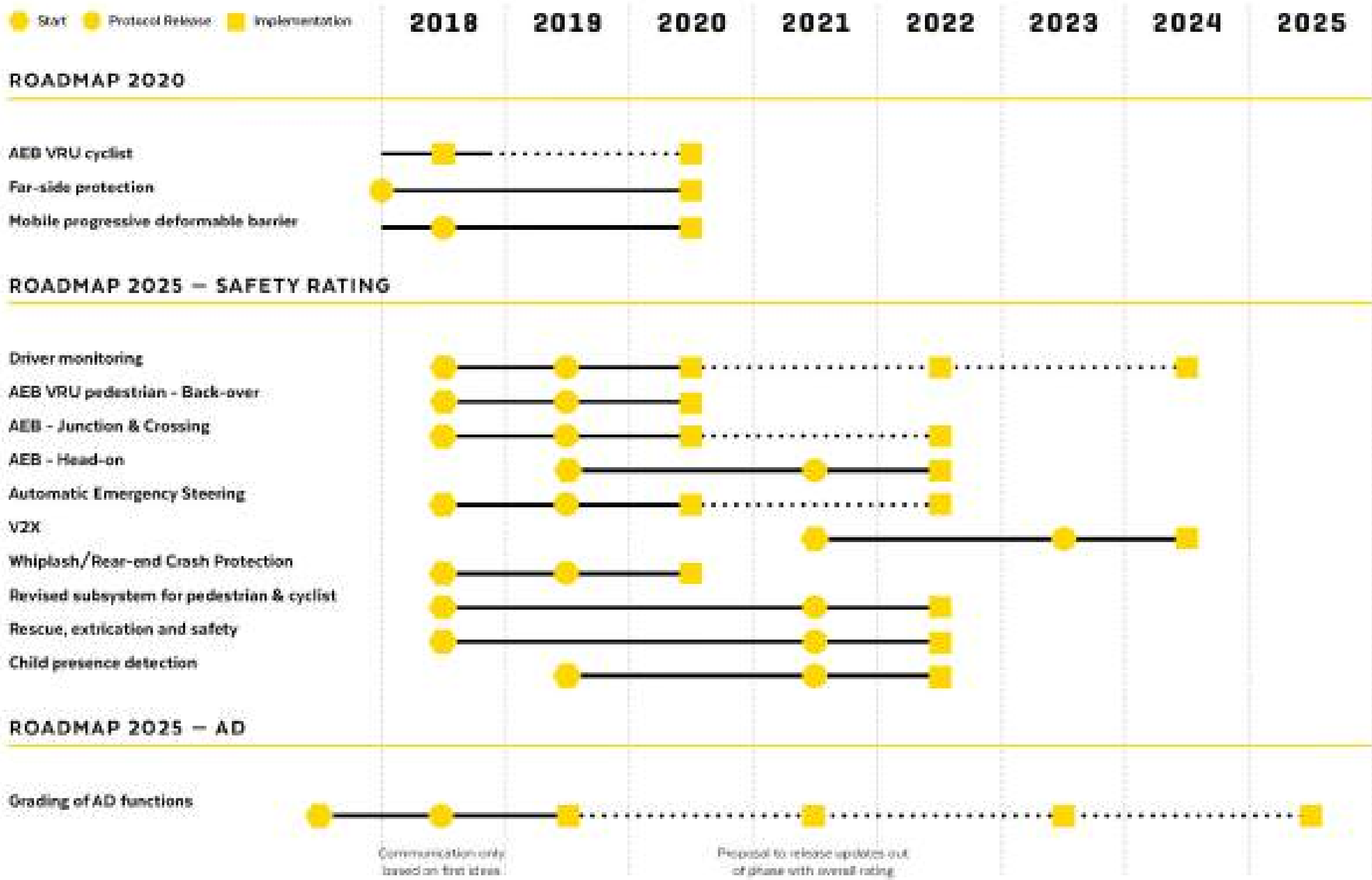
Functional safety and security

- Redundancy concepts (HW and SW)
- Security concepts

Content



Roadmap EuroNCAP 2025



Safety
- **Primary**
- **Secondary**
- **Tertiary**

ALP.Lab

Austrian Light Vehicle
Proving Region
for Automated Driving

Launched in September 2017!

AVL · MAGNA · TU Graz · virtual vehicle · JOANNEUM RESEARCH

ASFINAG · Telemotive AG · AIT · TTTech · NVIDIA · SIEMENS · TÜV AUSTRIA

ALP.Lab – Testing possibilities

Private

in preparation

Magna & AVL proving grounds,
Graz/ Styria

planned

Research@ZaB,
Eisenerz/ Styria
(tunnel)

planned

Lungau proving grounds,
Salzburg
(tunnel, toll station, snow)

planned

The Red Bull Ring,
Spielberg/ Styria

Public

in preparation

Motorway A2,
Graz-Ost – Laßnitzhöhe
Mooskirchen – Graz-Ost *(planned)*

planned

Motorway A9, A2
St. Michael – Graz-Ost
(tunnel, toll station)

planned

Motorway S6, S36, A9
Leoben – SLO
(border crossing)

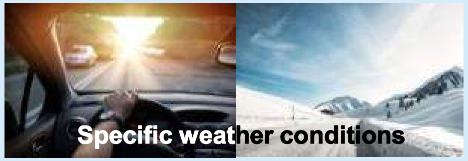
planned

City of Graz public roads,
Graz/ Styria

…with more testing grounds that will follow

ALP.Lab at a glance

Austrian specific traffic situations



Comprehensive testing stages and tool chain

All linked to a Data & Cloud Service

ALP.Lab

Overall service package

All necessary stakeholders on board

Research & development
|
Motorway and road operators
|
Automotive industry

Allowance for public camera data storage and processing

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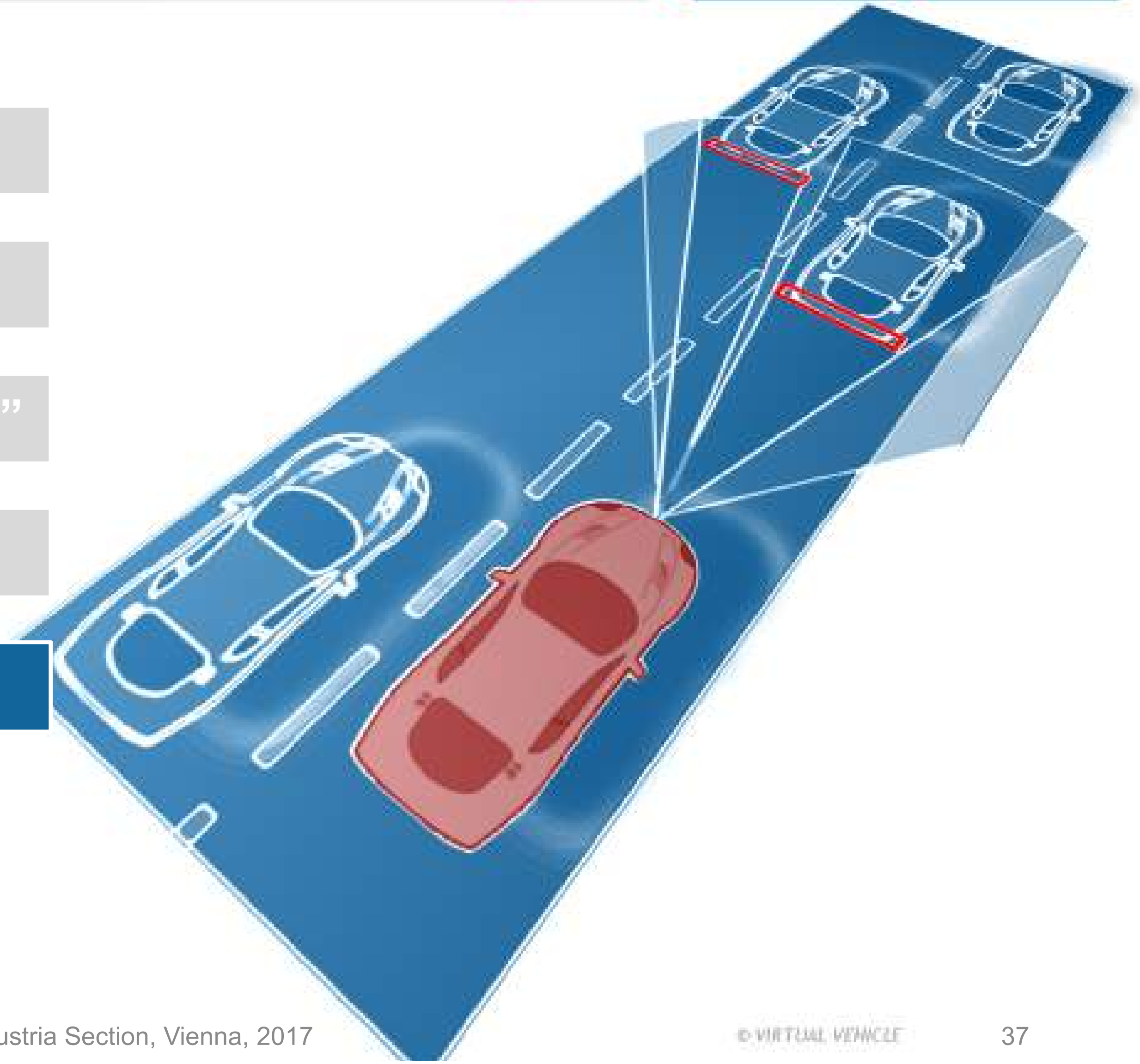

What is the problem?

- Software-intensive system
  - **no technology currently available** to verify or validate its safety under its full range of operating conditions
- Electro-mechanical elements do not benefit from Moore's Law improvements
- Cannot afford to rely on **extensive hardware redundancy** for protection from failures
  - Internal faults and functional safety challenges
- Harsh and unpredictable hazard environment
  - Dynamic external hazards
  - Environmental conditions
- **Non-professional vehicle owners and operators** cannot ensure proper maintenance and training

What do we need?

- **Software safety design, verification, and validation** methods to overcome limitations of:
  - Formal methods, brute-force testing, non-deterministic learning systems
- Robust **threat assessment sensing and signal processing**
  - to reach zero false negatives and near-zero false positives
- Robust control system **fault detection and identification**
  - within 0.1 s response
- Ethical decision making for robotics
- **Cyber-security protection**

Concluding remarks

- Automated driving requires **redundancy** (SW and HW)
  - Fail-operational architectures → ISO PAS 21448
  - Minimum redundancy but maximum reliability
  - Homogeneous redundancy vs. redundancy by diversity → trade-off
- **Complexity and number of scenarios**
  - We can’t test everything in advance
  - “Trust Center” (cf. SafeTRANS roadmap on highly automated systems, 2017)
- **Machine learning as powerful method** (in development and operation)
- Shift towards “**Virtual Approval**” (virtual homologation)
- **Optimal engagement** of virtual validation and real-world data (“field tests”)

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on Connected Vehicles & Expo
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- Dependable High Performance Computing (in-vehicle, cloud, fog)
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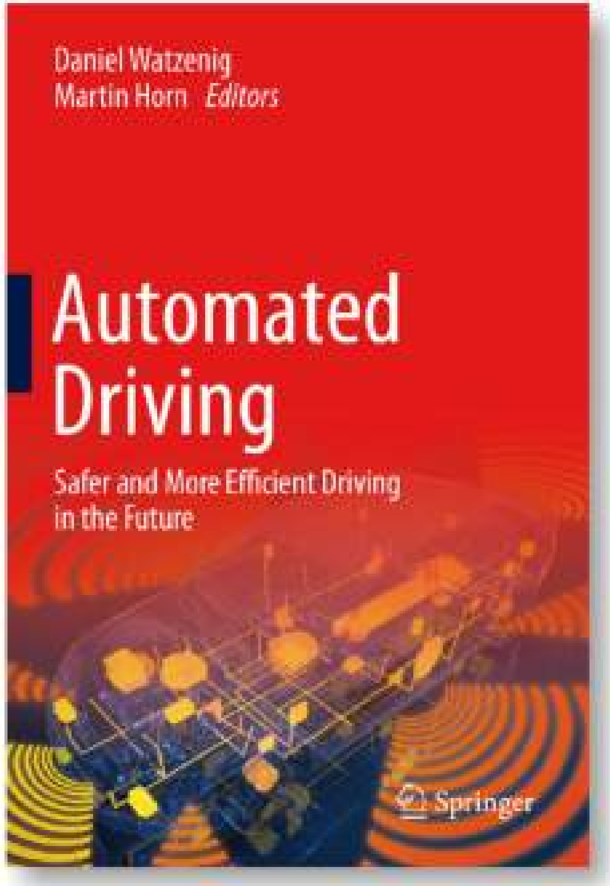

[Source: Springer, 2016]

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Vienna, October, 2017