# Cesta k vozidlu bez řidiče

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# Autonomous Cars and Their Technologies

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# Motivation for Automated Driving

| | | | |
|---|---|---|---|
| 1 | *Road Safety: Vision Zero* | Road safety improvements by reducing human driving errors |  |
| 2 | *Traffic management* | - Optimization of traffic flow management<br>- Convenient, time efficient driving via automation |  |
| 3 | *Reducing Emissions* | Reduction of fuel consumption & CO2 emission (through optimization of traffic flow management) |  |
| 4 | *Demographic Change* | - Support unconfident drivers<br>- Enhance mobility for elderly people |  |
| 5 | *Innovation High technology* | - New economic paradigm – supporting innovation policies of regions, nations<br>- Competitiveness / high skill employment |  |

https://www.youtube.com/watch?v=Ym8Iuhn-0zo

# Warning and Intervening Functions

Categories A and B of BASt (Federal Highway Research Institute, Germany)

- Side assist – category A
  - signals a vehicle which is in the blind spot for a lane change.
- Area view – category A
  - creates fish-eye view of car surrounding from 4 cameras.
- Front assist – category B
  - breaks/avoids the collisions with objects in front of the car.

# Automated Functions
# Category C

- Adaptive Cruise Control
  - adjusts the speed to maintain a distance from vehicles ahead.


- Lane Keeping Assist
  - keeps the car in the middle of the lanes.

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# Roadmap Automated Driving - Example Functions

| | Intervening only in Emergency | Driver Only | Assisted | Partial Automation | Conditional Automation | High Automation | Full Automation |
|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 |
| *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 | FCW | ACC | | | | |
| | ABS ESC | LKAS | Park Steer Ass. | | | | |

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

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

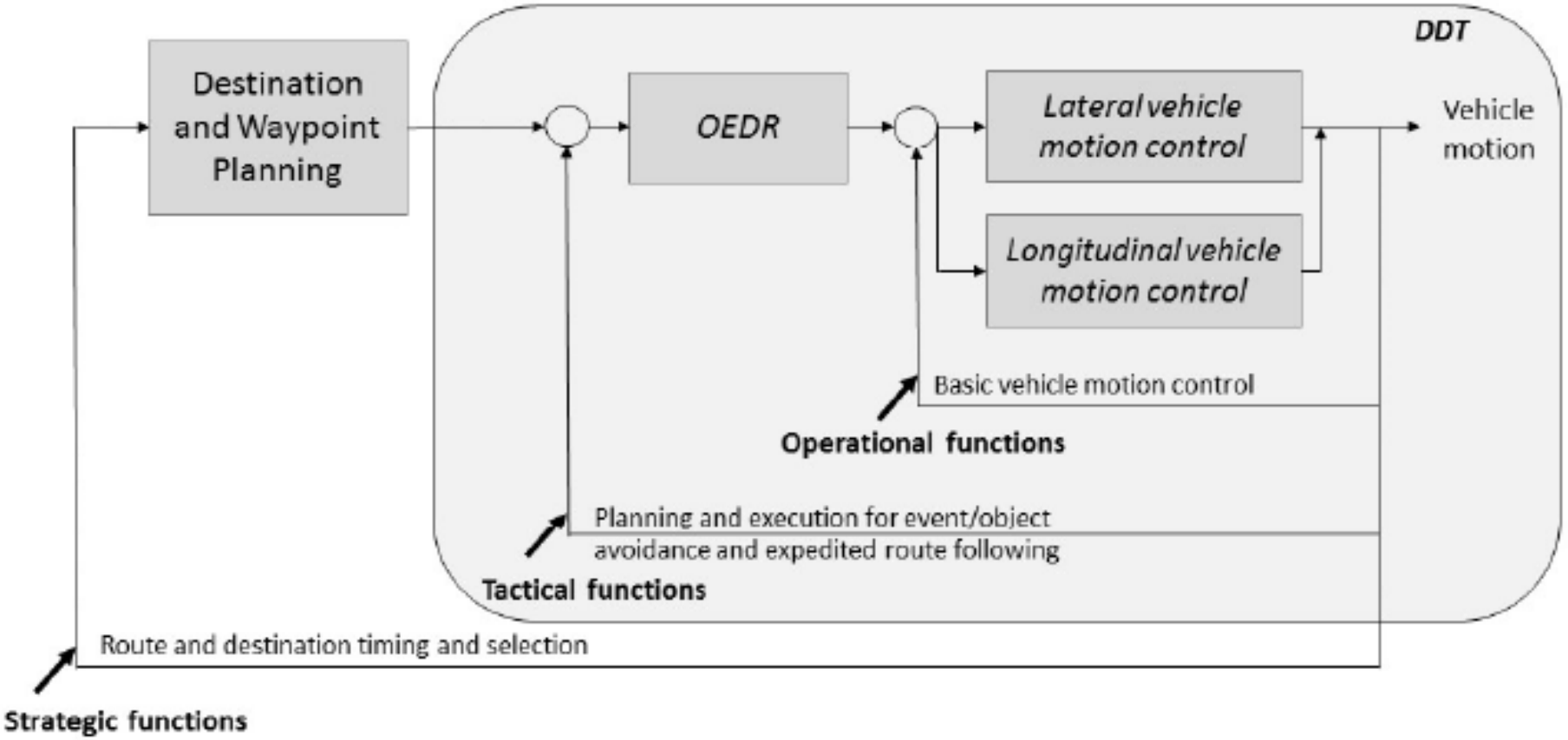
# SAE J3016

## Taxonomy and Definitions for Terms Related to Driving Automation

| Level | Name | Narrative definition | Execution of steering and acceleration/ deceleration | Monitoring of driving environment | Fallback performance of *dynamic driving task* | System capability (*driving modes*) | BASt level | NHTSA level |
|---|---|---|---|---|---|---|---|---|
| ***Human driver*** **monitors the driving environment** | | | | | | | | |
| 0 | **No Automation** | the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems | Human driver | Human driver | Human driver | n/a | Driver only | 0 |
| 1 | **Driver Assistance** | the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task* | Human driver and system | Human driver | Human driver | Some driving modes | Assisted | 1 |
| 2 | **Partial Automation** | the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task* | **System** | Human driver | Human driver | Some driving modes | Partially automated | 2 |
| ***Automated driving system*** **("system") monitors the driving environment** | | | | | | | | |
| 3 | **Conditional Automation** | the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task* with the expectation that the *human driver* will respond appropriately to a *request to intervene* | System | **System** | Human driver | Some driving modes | Highly automated | 3 |
| 4 | **High Automation** | the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene* | System | System | **System** | Some driving modes | Fully automated | 3/4 |
| 5 | **Full Automation** | the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver* | System | System | System | **All driving modes** | - | |

http://cyberlaw.stanford.edu/loda

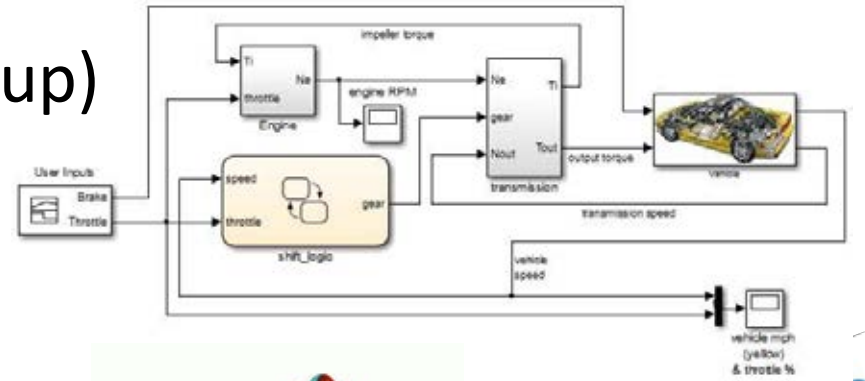
# DDT – Dynamic Driving Task

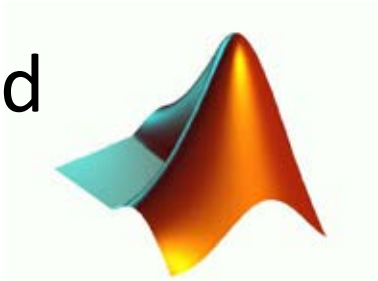



*OEDR - object and event detection and response*

# Current Vehicular Systems

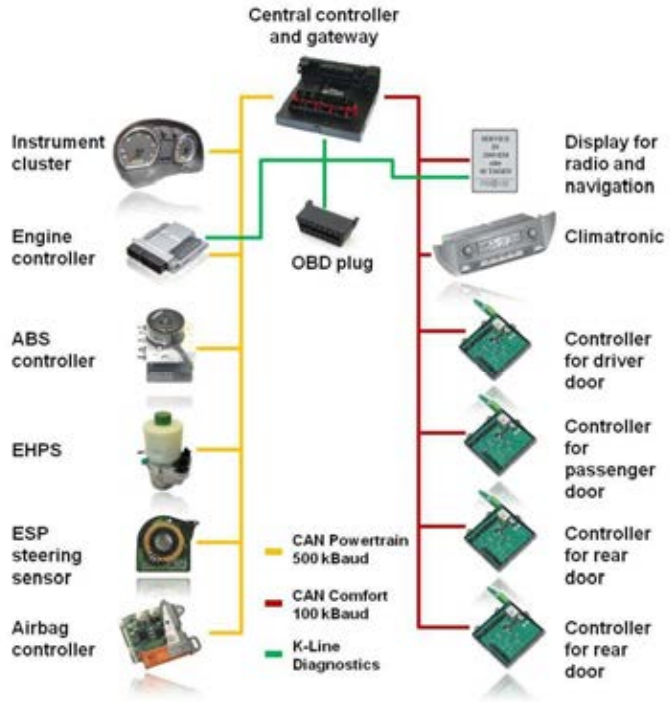
- Electronic Control Unit
  - 2 x LIN (wakeup)
  - 2 channel FlexRay
  - 1 x Ethernet Interface
  - 3 x CAN High speed (wakeup)
- Model Based Design
  - Rapid prototyping
- ISO 26262 requirements and ASIL D for functional safety



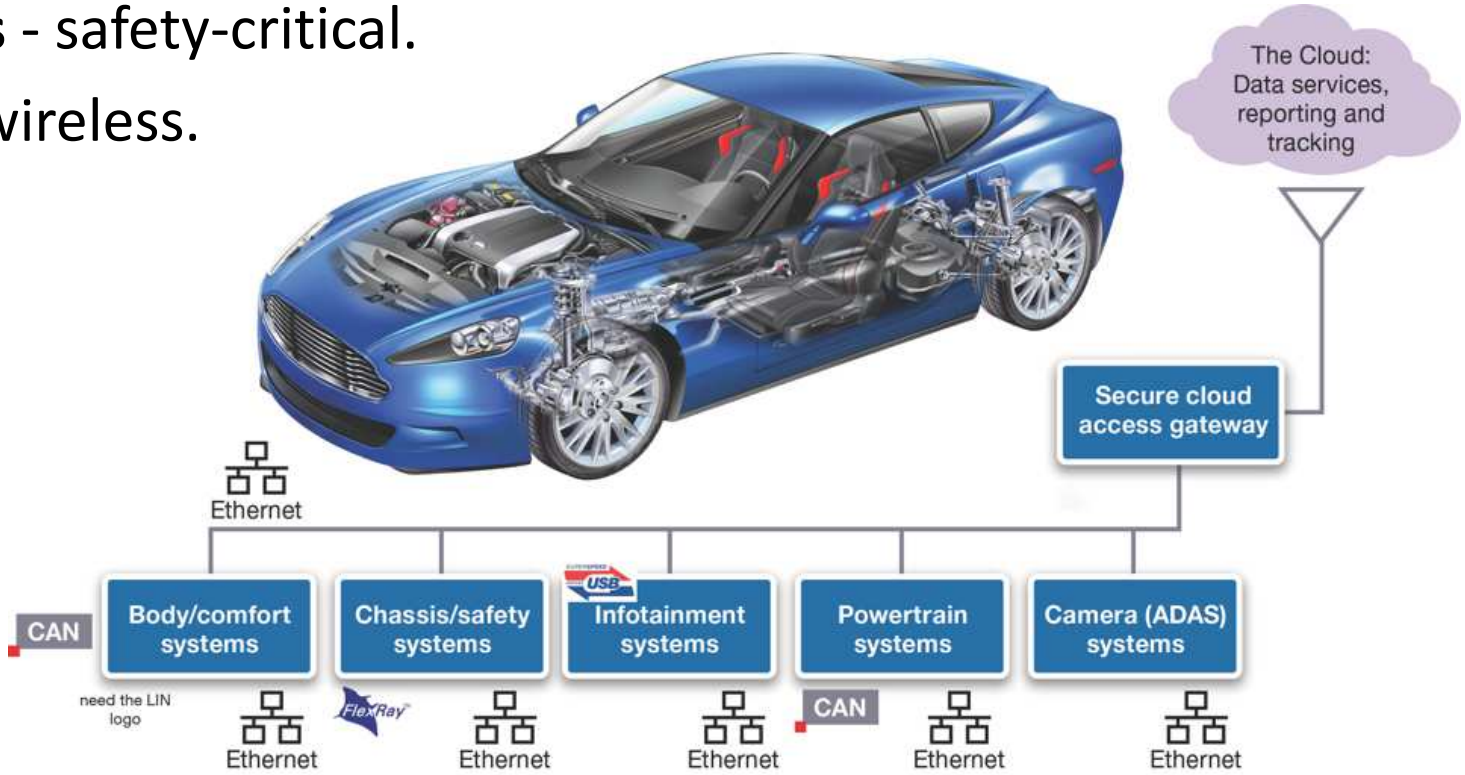
# Current Infrastructure

- CAN engine – CAN chassis – CAN comfort – CAN infotainment
- MOST infotainment - high bandwidth demanding systems
- LIN interconnects small independent subsytems



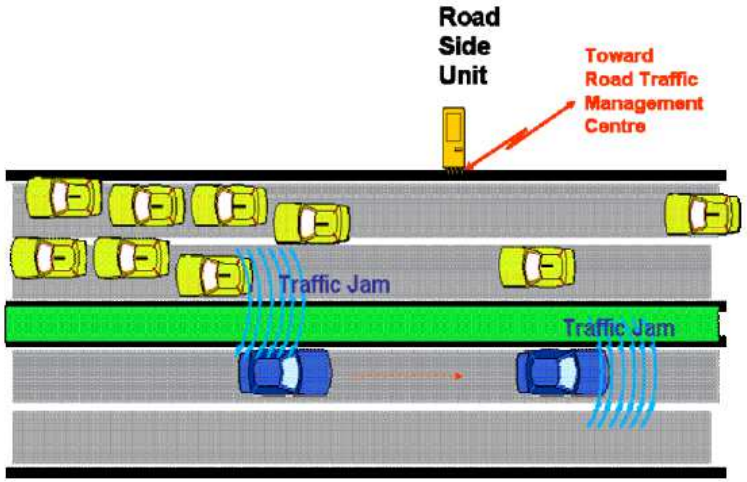

# Upcoming Infrastructure

- In-Car Application Servers (**ICAS**) will use Adaptive AUTOSAR/**DDS**
- **BroadR-Reach** Ethernet is going to replace MOST diagnostic CAN
- CAN bus will be replaced by **CAN FD (Flexible Data rate)**.
- **FlexRay bus** - safety-critical.
- **Car-to-car** wireless.

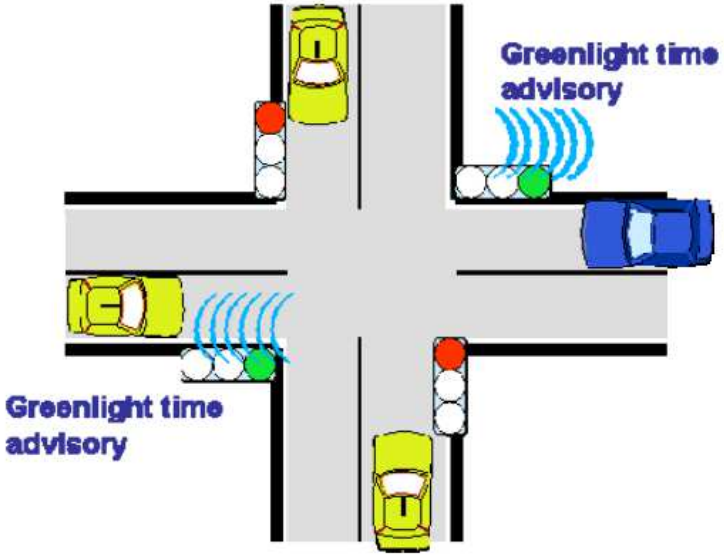


# Car2X Usecases

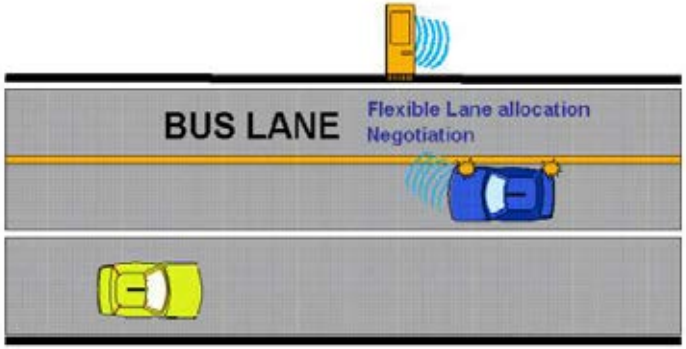
ETSI TR 102 638 Intelligent Transport Systems (ITS) Vehicular Communications



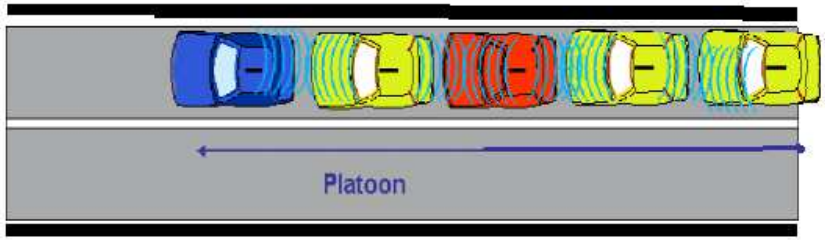

Traffic condition warning




Traffic light optimal speed advisory

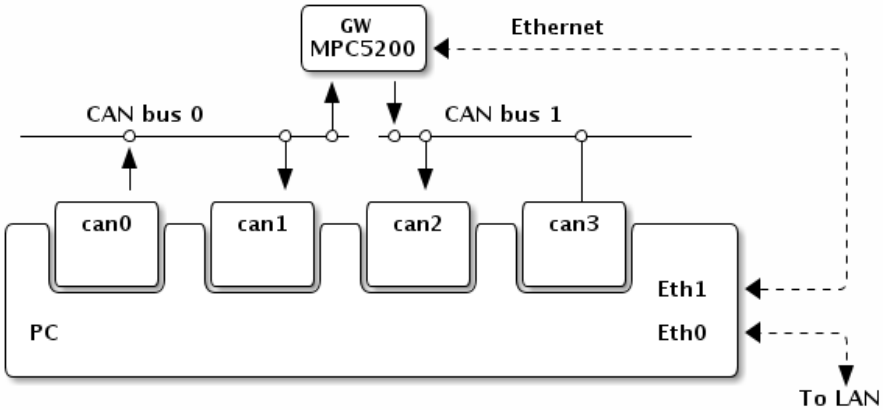



Co-operative flexible lane change




Platoon

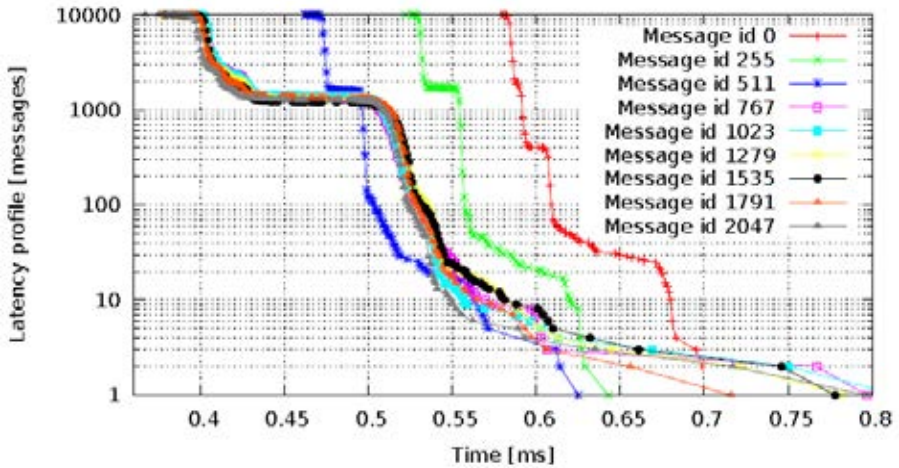
# Communication Protocols for Automotive – VW gateway



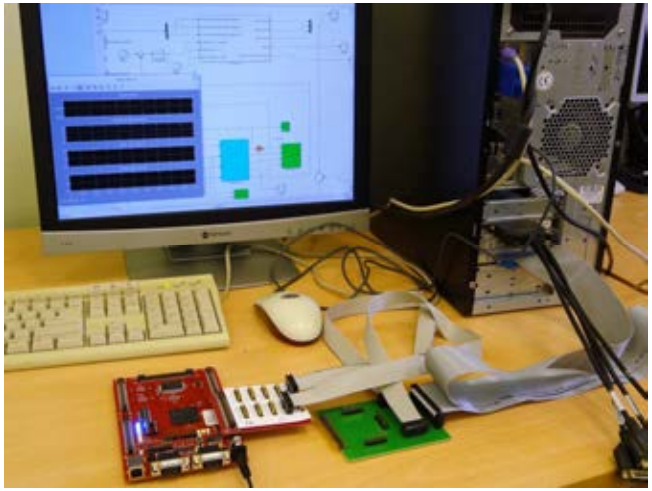

<u>Open-source implementation</u>

- Linux
- Real-time properties
- Timing analysis
- VW Contracts 2010, 2011, 2012, 2013, 2014, 2015

- Implementation of queuing disciplines
- Cyber-security in automotive communication busses
- Car2Car communication

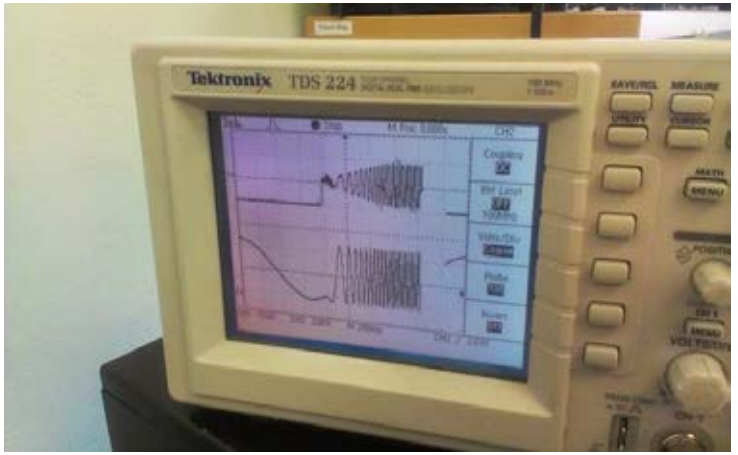



# SESAMO
# Safety and Security Modelling



- Electric motor controller (HW/SW)
- AUTOSAR Complex Device Driver
- Electric motor is simulated in a PC (I/O interface card)
- Simulink – real-time (external mode) simulation running on rt_preempt Linux

- Message authentication CAN protocol
- Experimental assessment of safety properties under presence of faults and attacks
- ISO 26262



# Car2Car Communication

- ITS-G5 European standard
  - Vehicle-to-vehicle communication
  - Vehicle-to-infrastructure communication
  - Built on top of existing IEEE 802.11p standard

- What we do
  - Implementation of the ITS-G5 for the mainline Linux kernel “mac80211” subsystem
  - Industrial computer + regular laptop as a test-bed

# Hercules Project – Horizon 2020

**High-Performance Embedded Real-time Architectures for Low-Power Many-Core Systems**

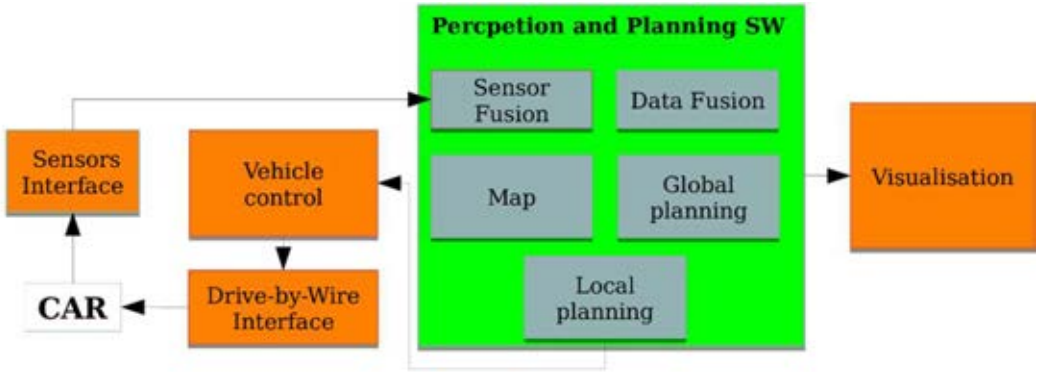
- Autonomous Cars
- RT Operating Systems
- Scheduling
- Multi-core Platforms
- Parallel Programming

University of Modena
CTU in Prague
ETH Zurich
Evidence
Pitom Srl
Airbus Gmbh
Magneti Marelli

# Formula 1/10th the scale
# 10 times the fun

Scaled down model for experiments

- Ubuntu and Robot Operating System (ROS) on NVIDIA Jetson TX2
- sensors: LiDAR, Inertial unit
- actuators: servo and moment controlled 3-phase Brushless DC motor




Our experiments:

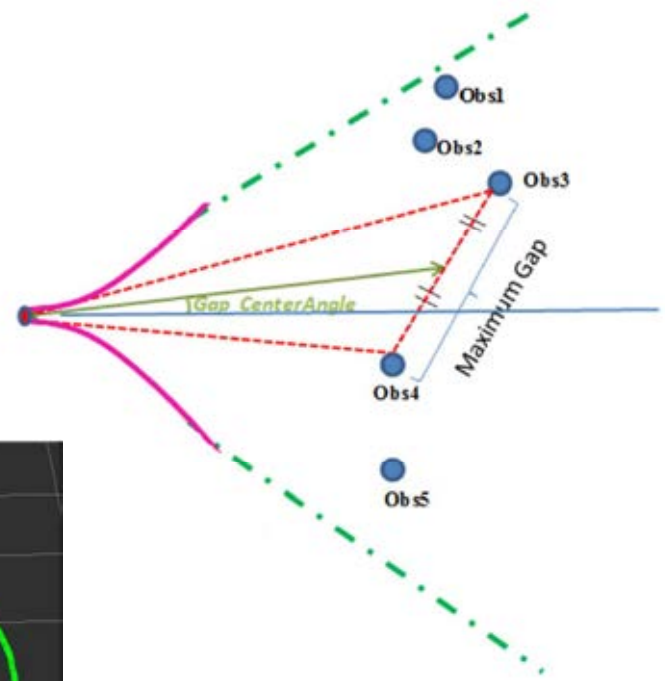
- Trajectory planning
- Indoor GPS
- Sensor/data fusion
- Dynamics and MPC

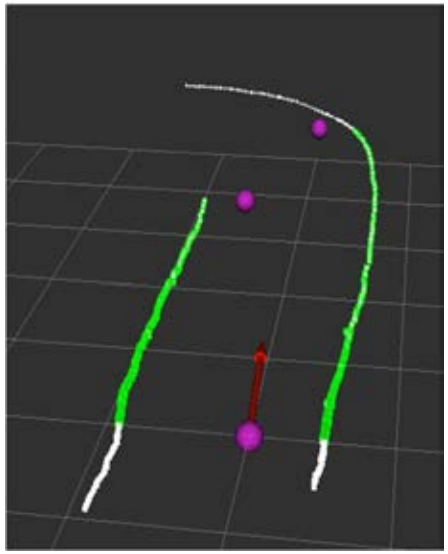
https://www.youtube.com/channel/UCZyPNe4hEb1-JKQGL9KuBBQ

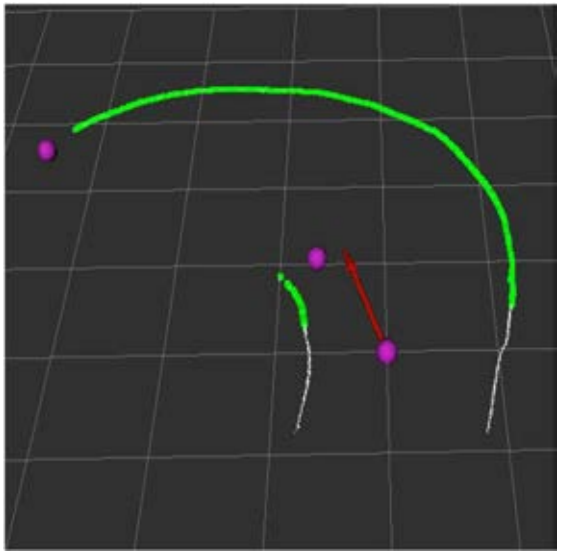
# Reactive Trajectory Planning

Follow the Gap Trajectory Planning

1. Find obstacles
2. Find largest gap (by angle)
3. Calculate angle to gap center
4. Calculate final heading angle



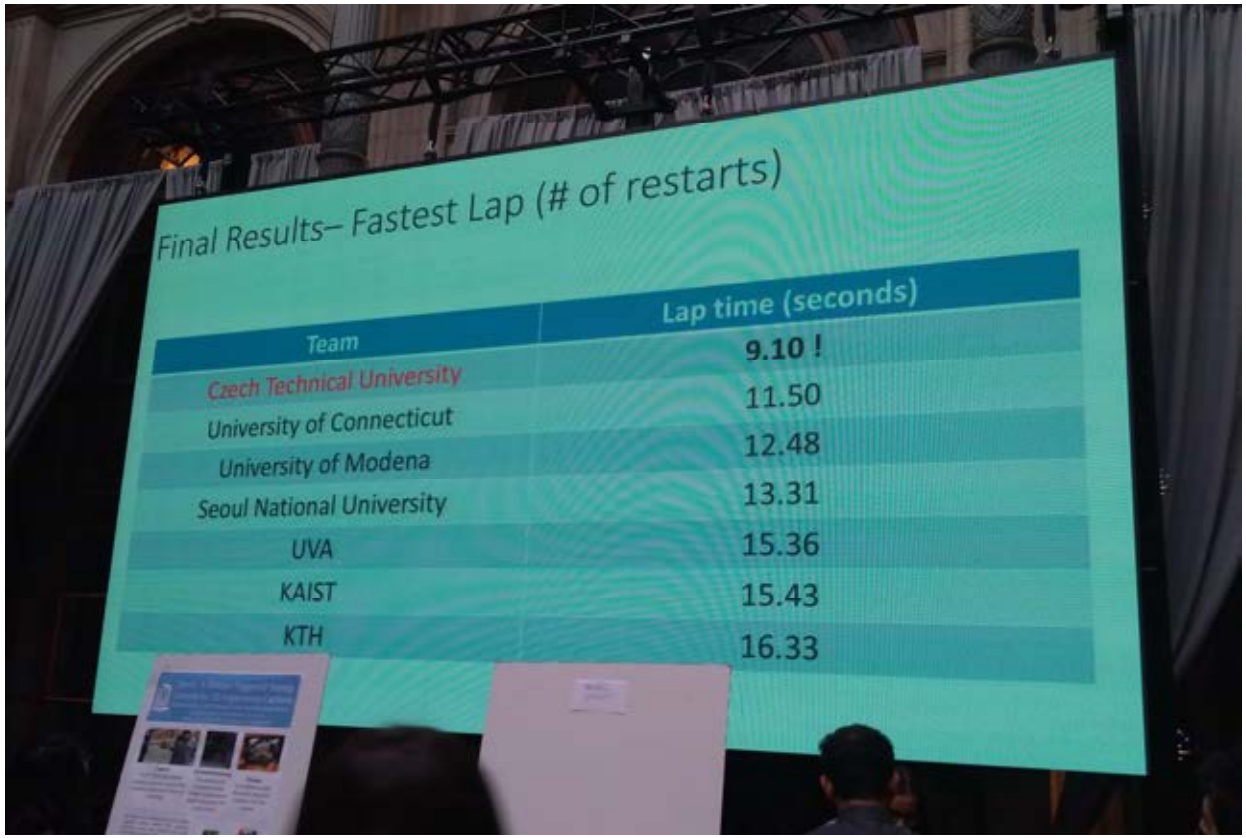





Follow the Corner Alg.

- solves the sharp turns and corners

# Formula 1/10 Autonomous Racing Competition




Organizers:

- University of Pennsilvania, USA
- University of Virginia, USA
- University of Modena, Italy

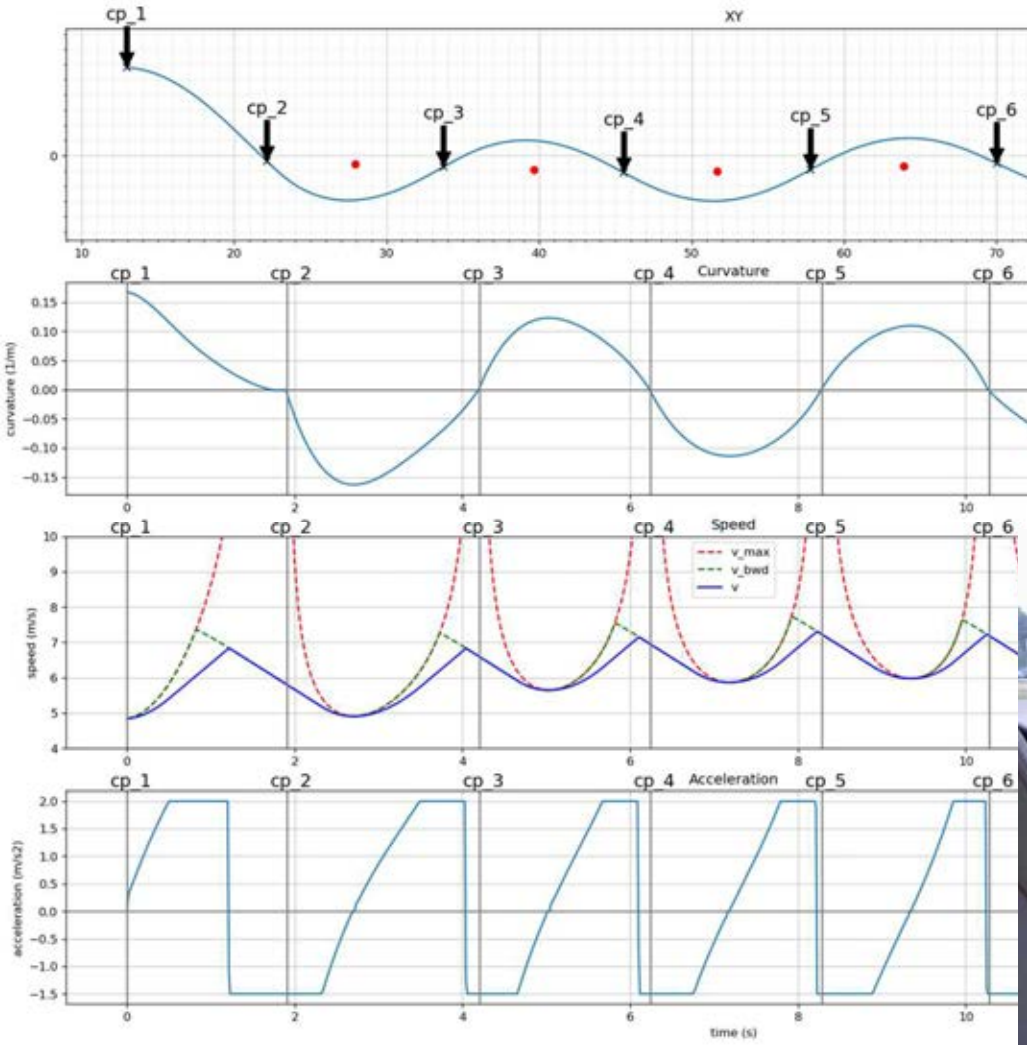
Our team at CPS Week, Porto April 2018: Jan Bednář, Jaroslav Klapálek, David Kopecký, Anders Solberg Pedersen, Joel Matějka, Martin Vajnar

# Autonomous Driving with Porsche Panamera

- sensing (camera, lidar)
- reference trajectory planning
- trajectory following controller
- obstacle avoidance

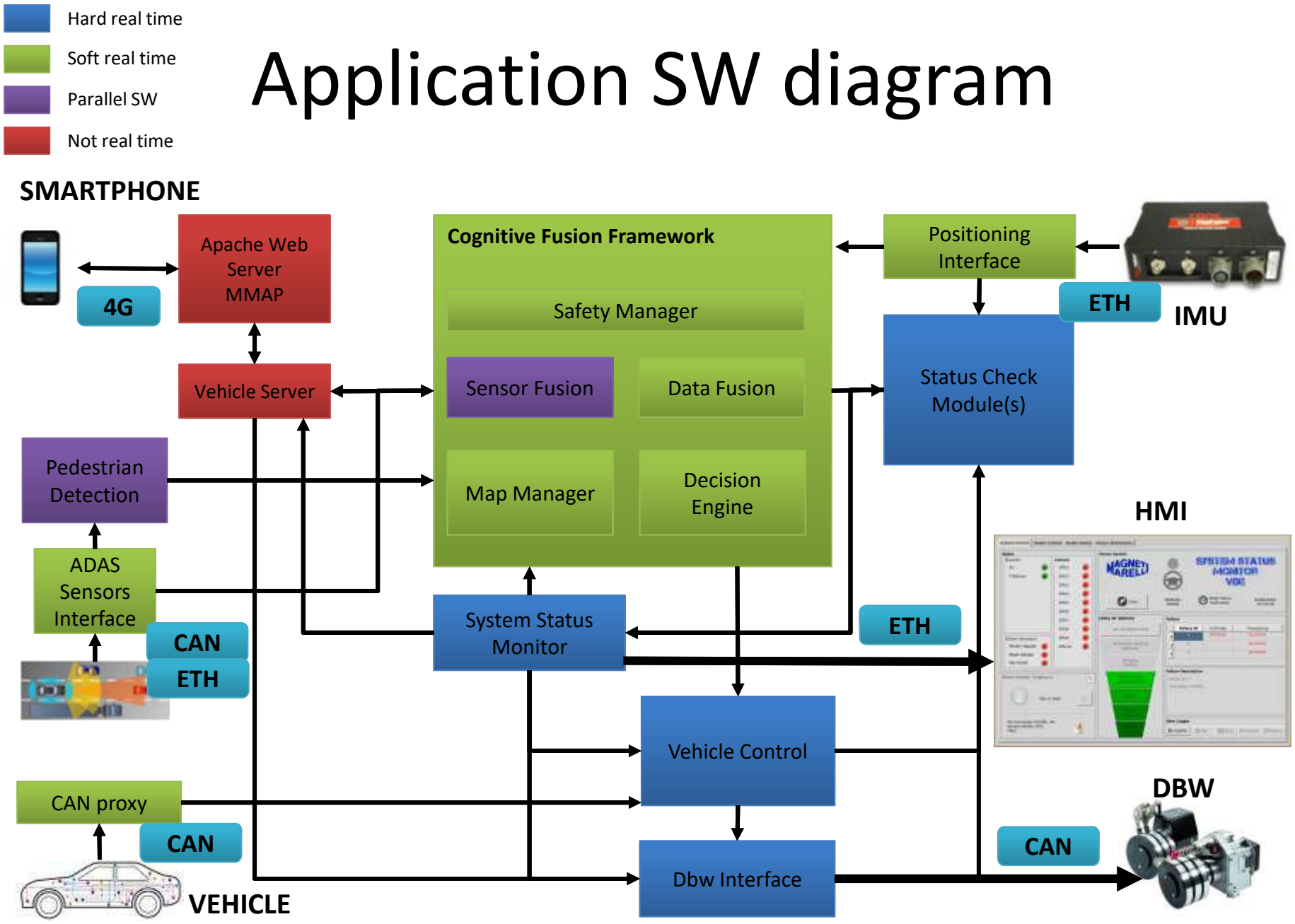
- experiments with Porsche Panamera
- implementation of FlexRay interface to ECUs
- cone slalom

# Experiments with Porsche Panamera



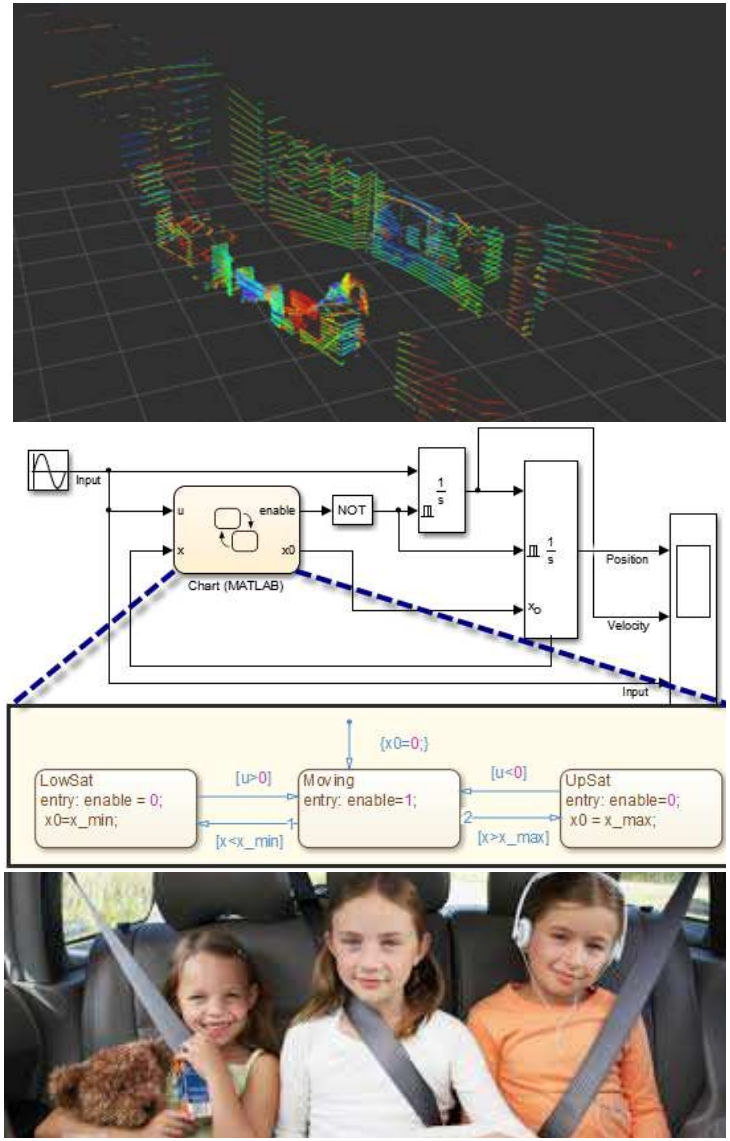

- [trajectory planning simulation]

# Application SW diagram



# Technical Obstacles

- Software **reliability**.
- Susceptibility to different types of **weather**.
- **Cybersecurity**. A car's computer communication system between cars.
- Requires high-quality **specialized maps** to operate properly.
- Current **road infrastructure** may need changes.
- Competition for the **radio spectrum** desired for the car's communication.



# Societal Obstacles

- **Liability** placed on manufacturer of software driving the vehicle.
- How to turn an existing fleet of vehicles **from nonautonomous to autonomous**.
- **Resistance by individuals** to forfeit control of their cars.
- Implementation of **legal framework** and establishment of government regulations.
- **Inexperienced drivers** if complex situations require manual driving.
- Loss of driving-related **jobs**.
- Loss of **privacy**. Sharing of information through Car-2-X.
- **Ethical problems** in situations where an autonomous car's software is forced to choose between multiple harmful courses of action.

# Questions ?

Zdeněk Hanzálek

1991-now, professor at CTU in Prague

- 35 papers in impacted journals
- 20 graduated Ph.D. students
- Rapid Prototyping Platform for Porsche Engineering Services
- CAN Gateway and Car2Car communication for Volkswagen Wolfsburg

2004-now, co-founder of Merica s.r.o.

- Scheduling algorithms – personnel in ANS, production in EPT, …
- Embedded systems – HP Charging for Porsche Engineering, testing robot for Skoda

2011-2014, Porsche Engineering Services

- founder and head of the mechatronics group with 16 employees in Prague
- Battery Management System – used in VW e-UP
- Chassis stabilization – part of the concern platform
- EV (Electric Vehicle) manager ECU – used in prototype car by Skoda