automotive engineering iav

Powertrain Architecture Definition for Connected Vehicles

ARPA-E Powertrain Innovations in Connected and Autonomous Vehicles Workshop

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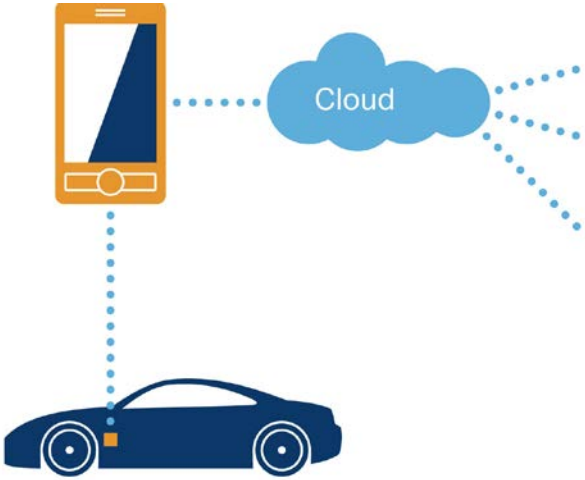
IAV Automotive Engineering Inc.

Agenda



- Introduction of Powertrain to the Cloud
- Technology Challenges to 2025
- Powertrain Hardware Architecture Definitions
- Powertrain Controls Optimization via the Cloud

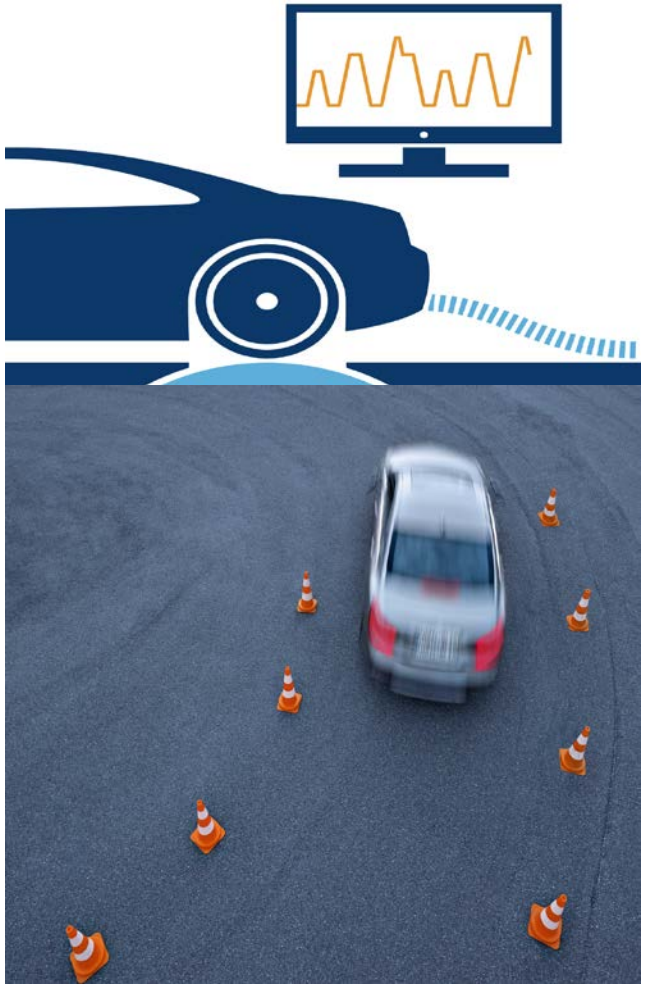
Cloud based data

Parameters available to optimize the hybrid/electric Powertrain:

- Route based weather information
- Details route characteristic (elevation profile, start/stop, acceleration)
- Street conditions (roughness, road works)
- Traffic condition (to be used with Sat Nav)
- Driver Preferences (typical routes, typical decision making (time vs cost))
- Driver Usage Patterns (weekly commute, charging locations & cost, refueling locations & costs

→This Information is or will be available in the cloud

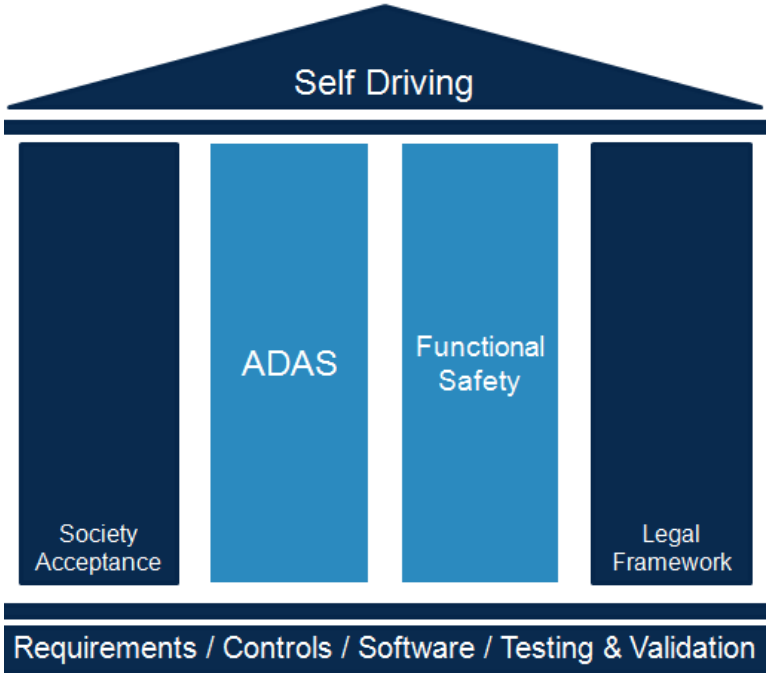
New approaches using cloud based data

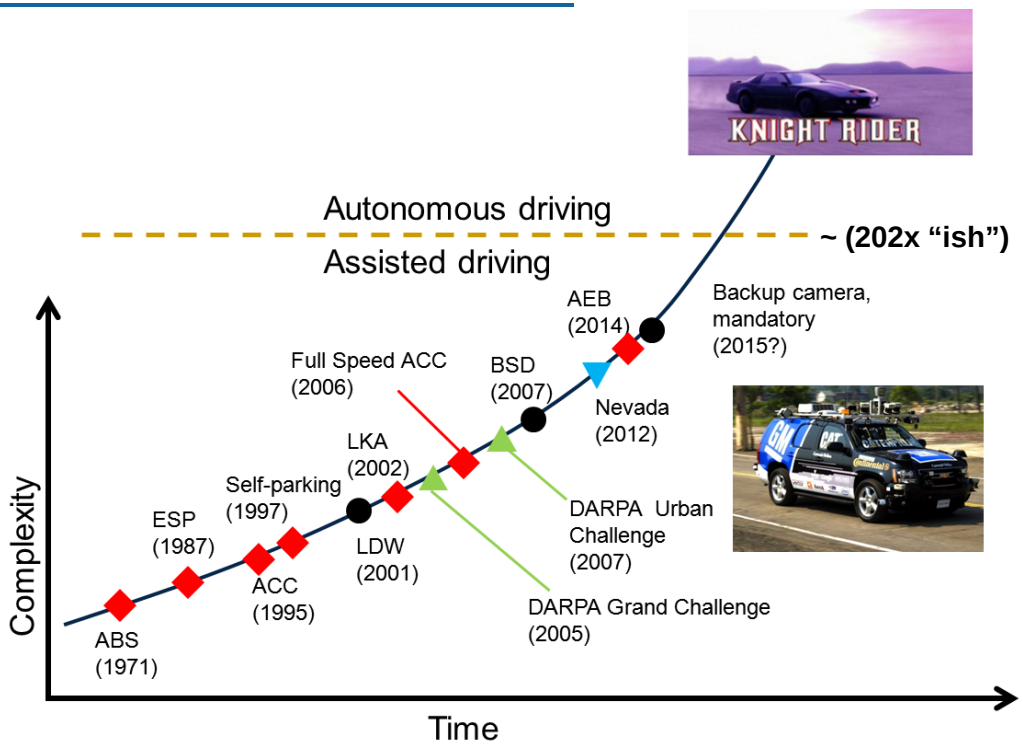


- Operation mode optimization to reduce battery and fuel cell energy consumption (and robust operation mode)
- Optimized power distribution / torque vectoring based on environment / weather (automatic calibration set changes, safety improvement)
- Optimized regeneration processes (cost reduction vs. durability, e.g. DPF)
- Thermal management: smaller radiator possible due to thermal load prediction
- Lower oil pressure possible due to load prediction

→ Cloud based data can help to adapt the PWT to the outside world in real time

Advanced Driver Assistance Systems
Progress towards Vehicles that Don't Crash

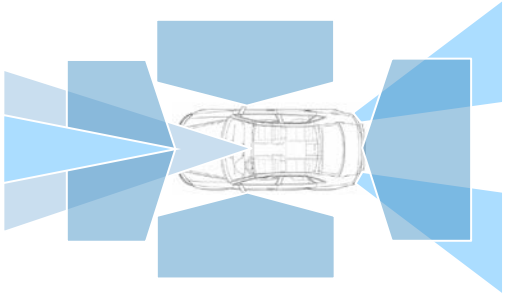


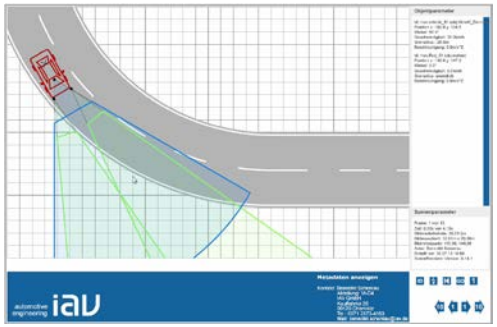


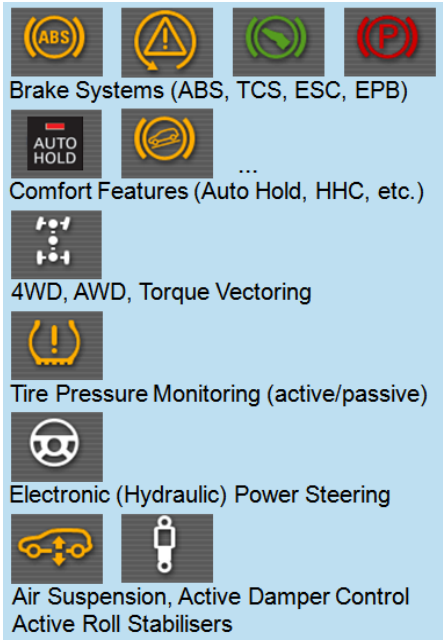
Two Pillars of Technology Enable Realization of Self Driving Vehicles

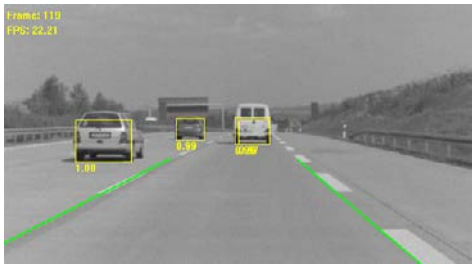
- ADAS (Advanced Drivers Assistance Systems)
- Functional Safety Systems Integration

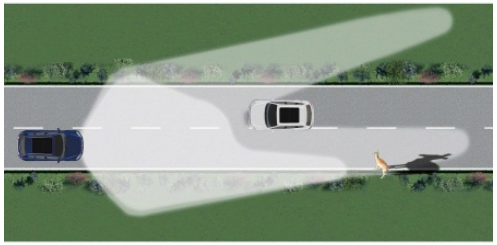
Driver Assistance & Active Safety Systems
Vehicle Integrated Functions











Sense Systems

- Image processing
- Surround View
- Sensor data processing and fusion
- Situation analysis:
  - Longitudinal and Transverse

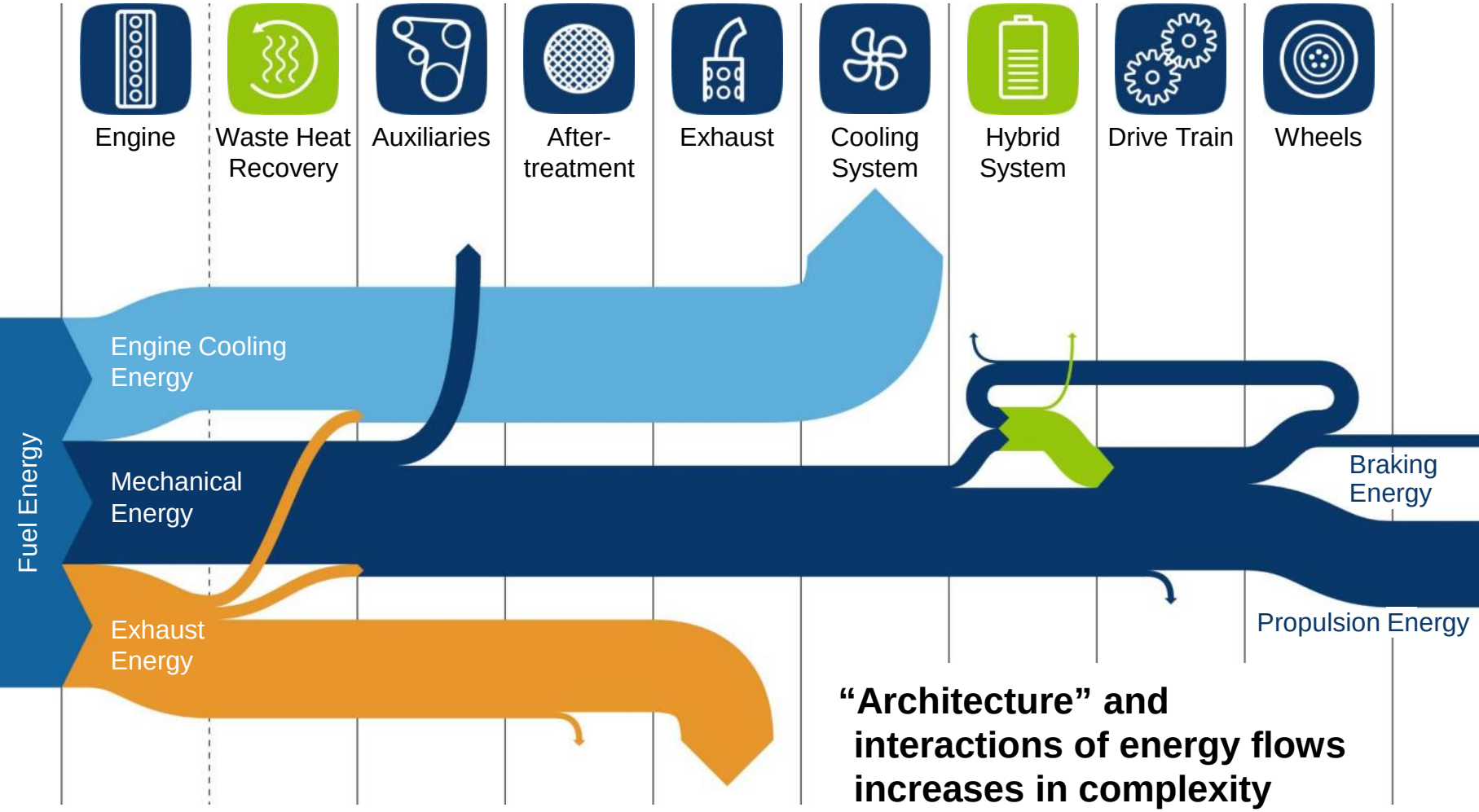
Functions & Algorithms

- Pedestrian Protection System
- Adaptive Light Controls
- Adaptive Cruise Control
- Blind Spot Detection
- Lane Keeping / Lane Change Assist
- Park Assist / Valet

Actuation & Control Systems

- Specification of Chassis Concepts
- SW Architecture & Interface Definition
- Vehicle Dynamics / Stability Controls
- Chassis Control Systems Integration
- Functional Safety Systems Engineering

Requirements of Future PT Subsystems



“Architecture” and interactions of energy flows increases in complexity

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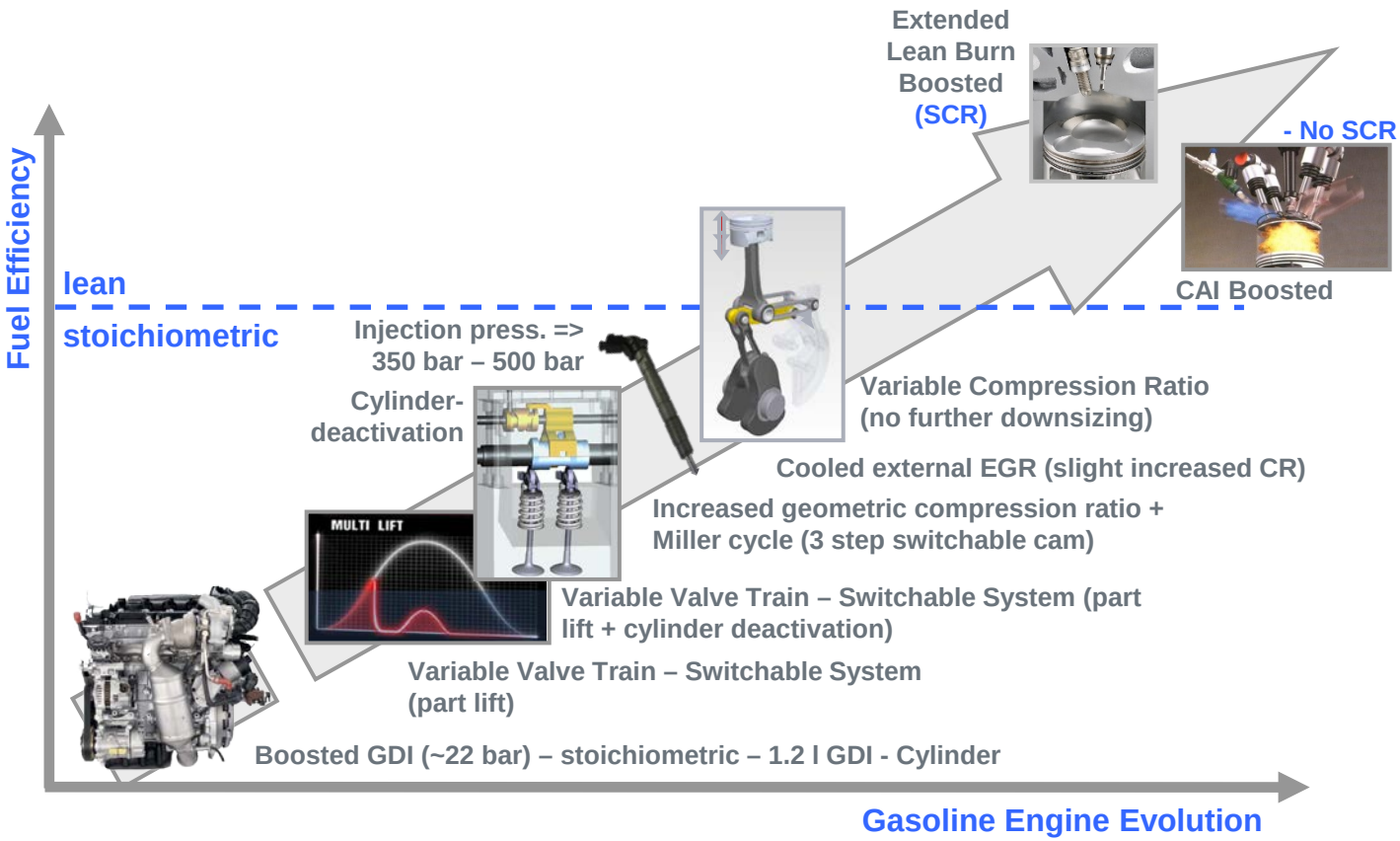
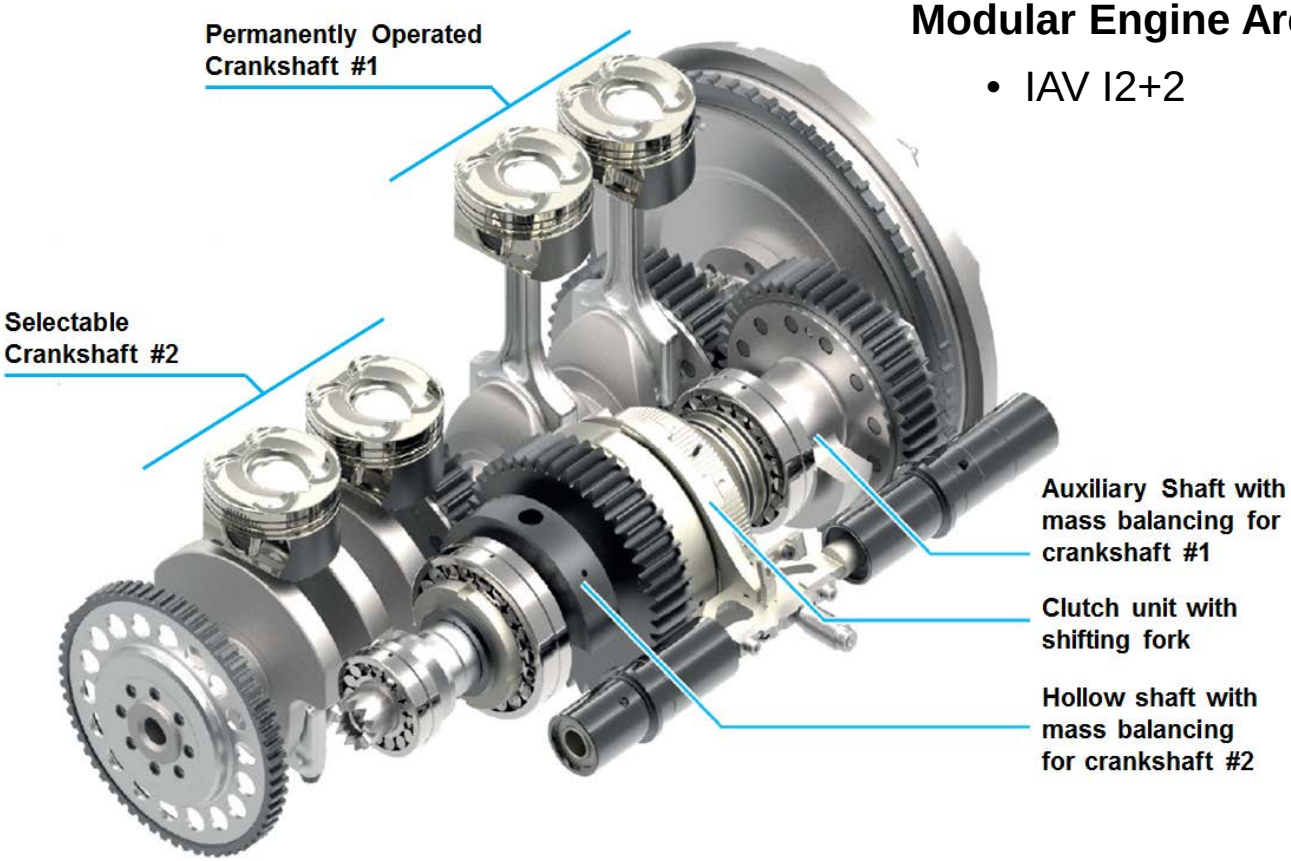
Gasoline Trends

IAV‘s view on Combustion Technologies



Other additional technologies such as Hybrid Drives, Waste Energy Recuperation, etc. are not part of these estimations

Advanced Powertrain Hardware Architectures
Case Study: Use Case Optimized Powertrain Solutions

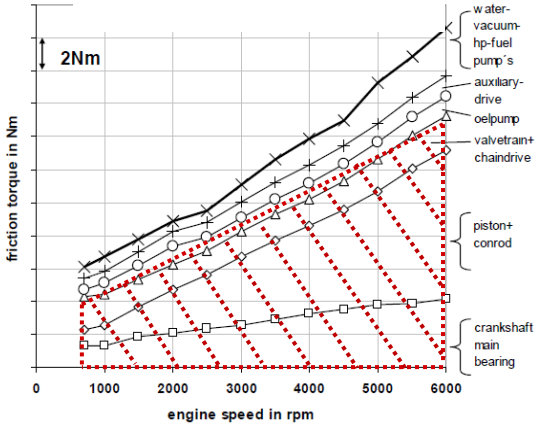


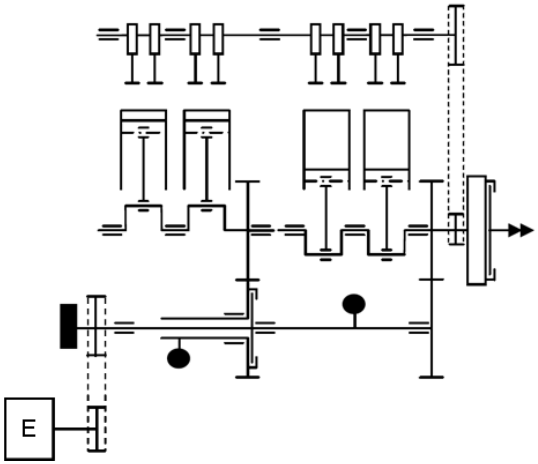
Modular Engine Architectures

- IAV I2+2

→ Use Case Optimized Engine Solutions

Advanced Powertrain Hardware Architectures
Case Study: Use Case Optimized Powertrain Solutions





Schematic sketch of I2+2 engine based on a 4-Cylinder 1.6l GDI Engine

Concept features

- Continuously working 2-cylinder engine section on drive side
- Additional clutch and balancer shaft with spur gear drive
- Additional main bearing or bearing-in-bearing-solution between cyl. 2 and 3 possible
- IAV-SlideCam system for valve deactivation
- Additional E-Motor for start of 2nd engine section if necessary

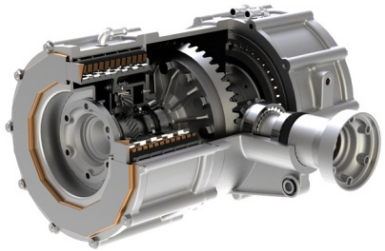
Advantages

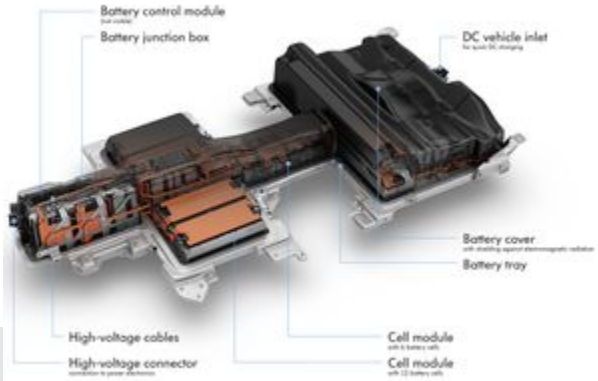
- Partial crank train shut off during 2-cylinder operation
- Conventional layout of valve train and auxiliary drive
- E-Motor can be used for Start/Stop and hybrid drive as well

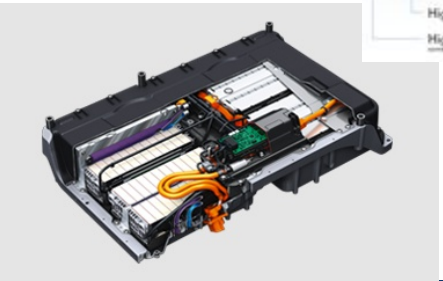
Drawbacks

- Increased friction losses in 4-cylinder mode due to balancer shaft
- Higher amount of parts → increase of costs

Advanced Powertrain Hardware Architectures
Case Study: Distributed Control / Power Delivery







Modular E-Drive Architectures

- IAV E Active Rear Axle
  - Dual Independent E-Motors integrated within traditional rear differential
- IAV DrivePac
  - Induction Machine with integrated 2 speed gearbox and differential

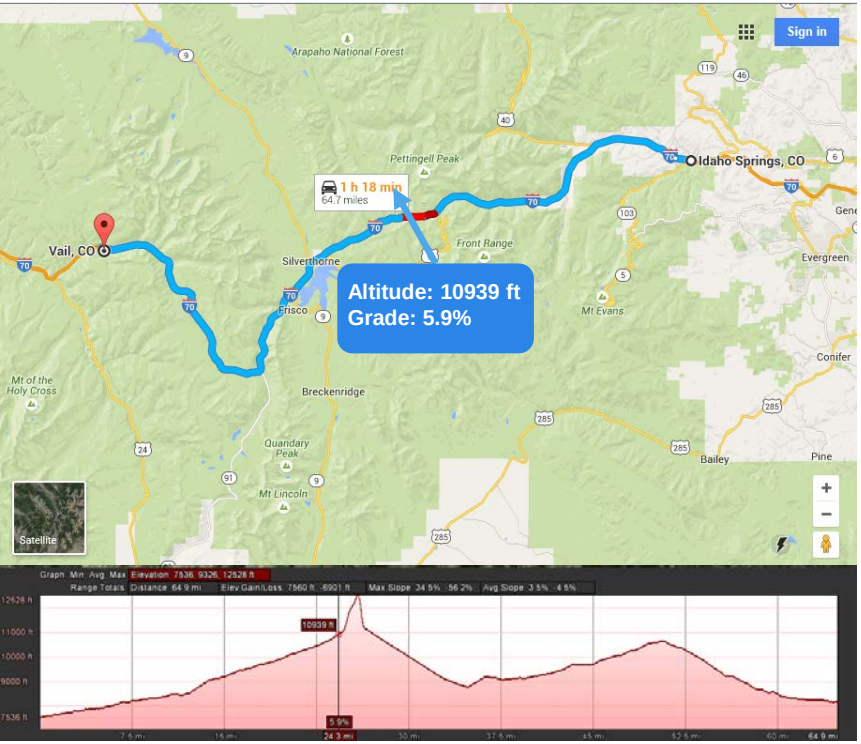
Energy Storage Systems:

- Modular Energy Storage System Solutions
  - Dual Pack (Size/Mass)
  - Dual Pack (Energy/Power)

→ Use Case Optimized E-Drive Solutions

Advanced Powertrain Hardware Architectures

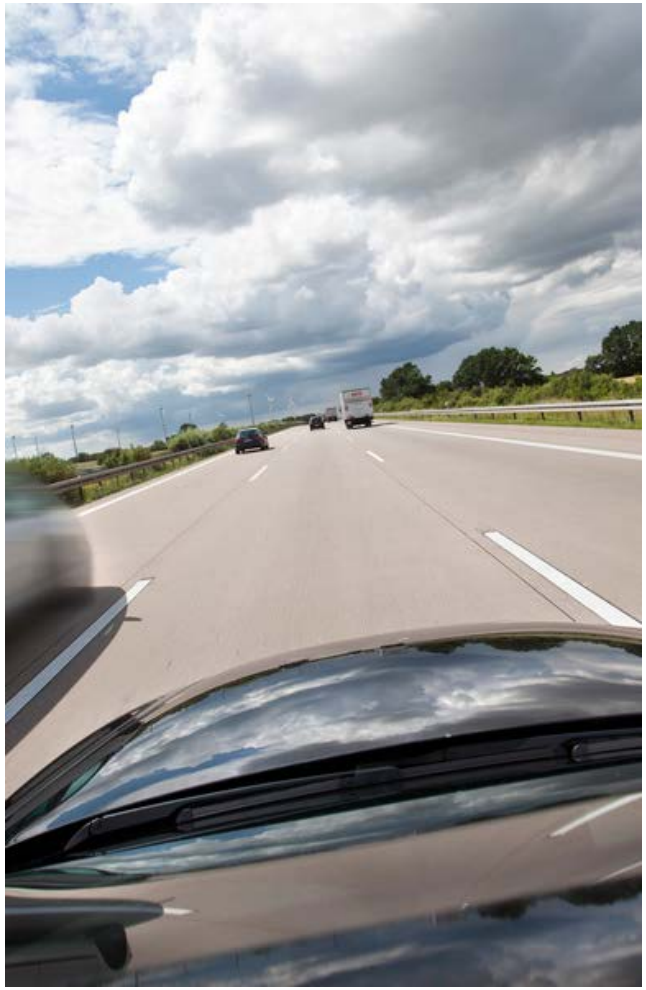
Case Study: Modular Powertrain Architectures



- Use Case – Duty Cycle Based Design Optimization (ie BMW i3 EV or i3 REV)
  - ICE
  - E-Motor + Battery
  - ICE + E-Motor + Battery
  - ICE + E-Motor (Battery, Fuel Cell, other)
- Modular Power & Energy Delivery
  - Weekly commute vs Weekend Travel
  - Ex: Idaho Springs to Vail
- Continuous Power & Time Requirement
- Transient Power & Time Requirement

→ EXAMPLE USE CASE DEFINED POWER & ENERGY

Advanced Powertrain Control Optimization
Case Study: Highway Cruise Optimization



Current Technology (Vehicle Platform):

- Target Speed (cruise control)
- Target Speed & Following Distance (Active Cruise)

Imminent Technology (Vehicle Platform):

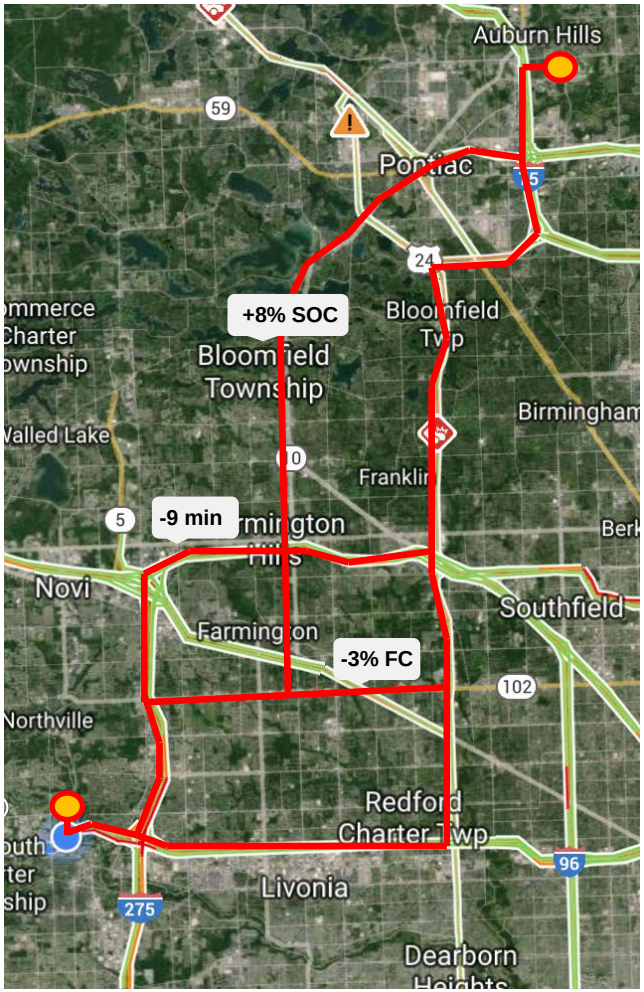
- Target Speed & Following Distance to Target Destination

Future View (Vehicle & Powertrain Platforms):

- Target Destination at Low Cost Function F($, Time, Energy)
  - **Short Term**: Energy Manager Optimized for Route, Traffic
  - **Longer Term**: Round trip efficiency, Fuel & Electricity Costs

→ **Example: Semi-Autonomous Drive from Detroit to Chicago**

Advanced Powertrain Control Optimization
Case Study: Adaptive/Dynamic Route Planning

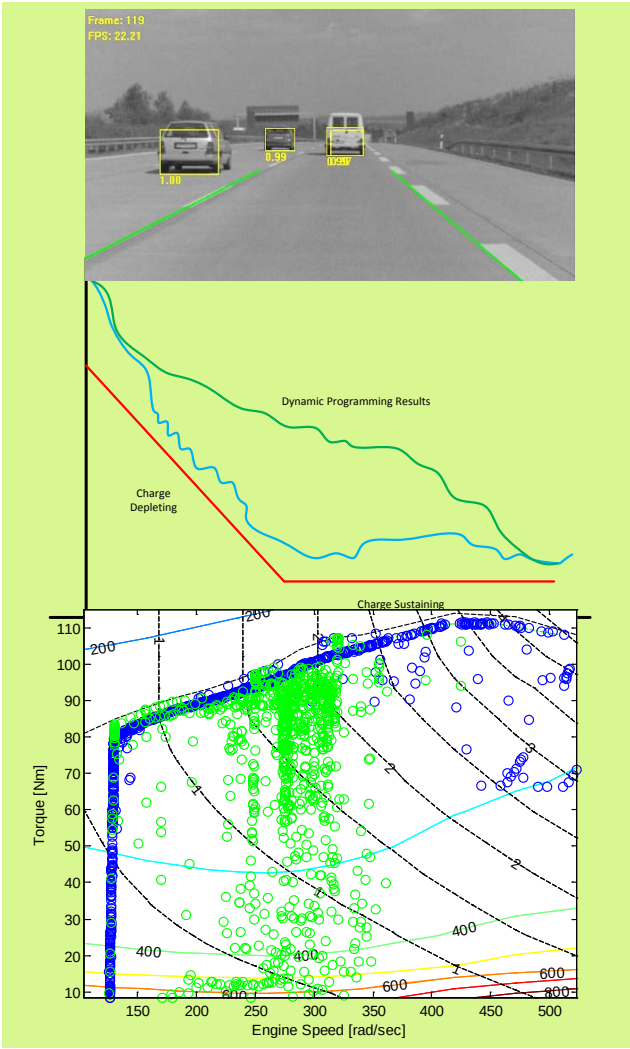


Vehicle Centric Decisions:

- Navigation:
  - Path & Route Planning
  - Traffic Adaptive
    (Re-route or Modify Energy Manager)
  - Target Speed (cruise control)

→ **Example: Optimization of Morning Commute**

Advanced Powertrain Control Optimization
Case Study: Stochastic Control



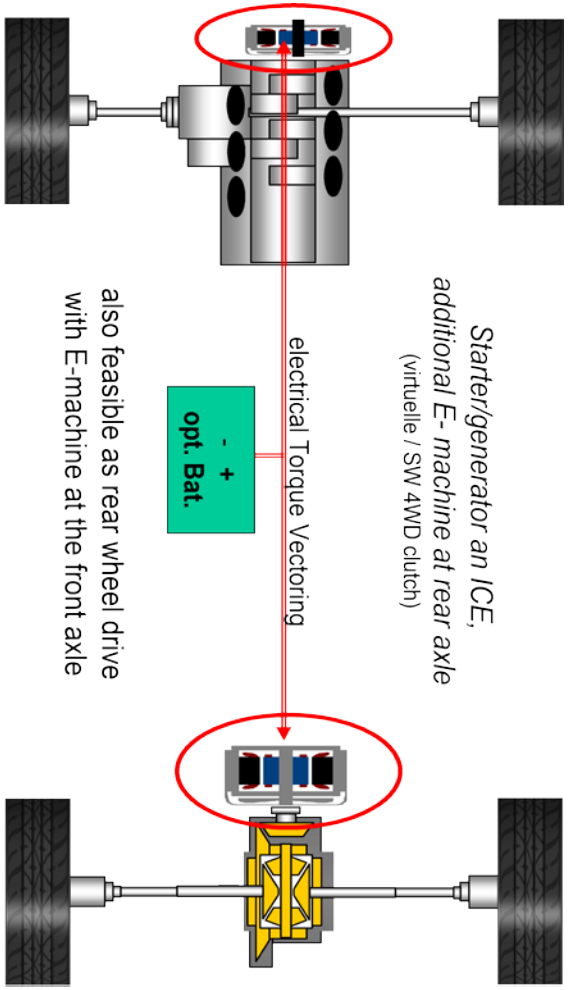
Vehicle / Cloud Centric Decisions:

- Behavior Modeling:
  - **Short Term:** Route Energy FCN(time, traffic)
    - **Commute**: Monday @ 7am vs. Friday @ 8am
  - **Long Term:** (Energy Usage Efficiency & Cost)
    - Round Trip or Time Period Based View
    - Charging Costs @Work vs. @Home
    - Refueling Costs

→ **Example: Daily or Weekly Commute Optimization**

Advanced Powertrain Control Optimization

Case Study: Lateral Dyn. Impact on Energy Management



Power Train Operation strategy for:

- Battery charge while constant driving
- Basic recuperation
- Brake energy regeneration
- Emission free electric driving
- All wheel drive strategy and acceleration boost

Safety strategy needed for:

- Torque safety
- Slip intervention by brake system (TC) on independent powertrains front/rear
- ESC- und ABS- intervention

→ 3-D Drive Cycle into Energy Analysis

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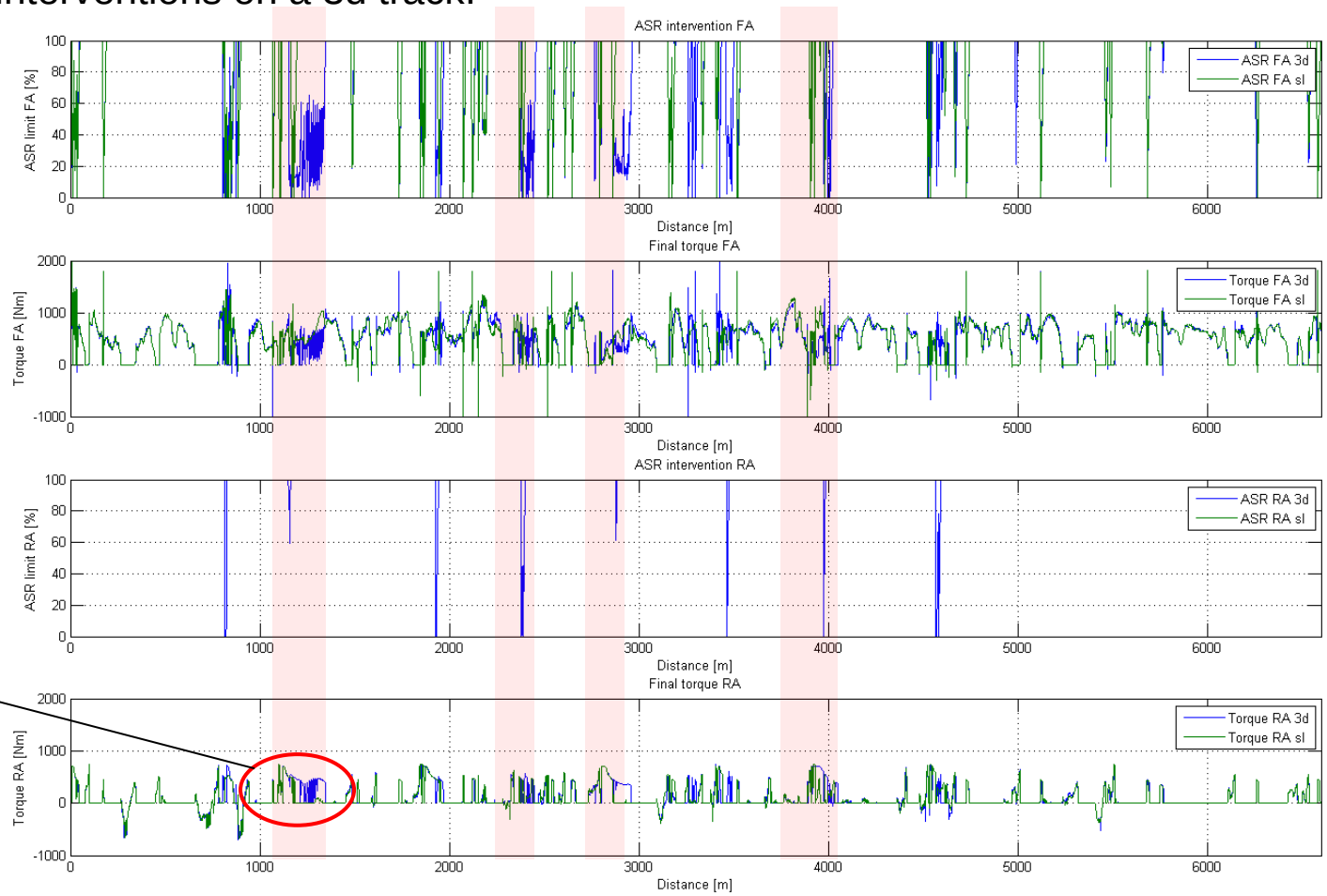
Advanced Powertrain Control Optimization

Case Study: Lateral Dyn. Impact on Energy Management

Due to the lateral acceleration while driving curves, there are more TC interventions on a 3d track.



Torque distribution to the rear axle

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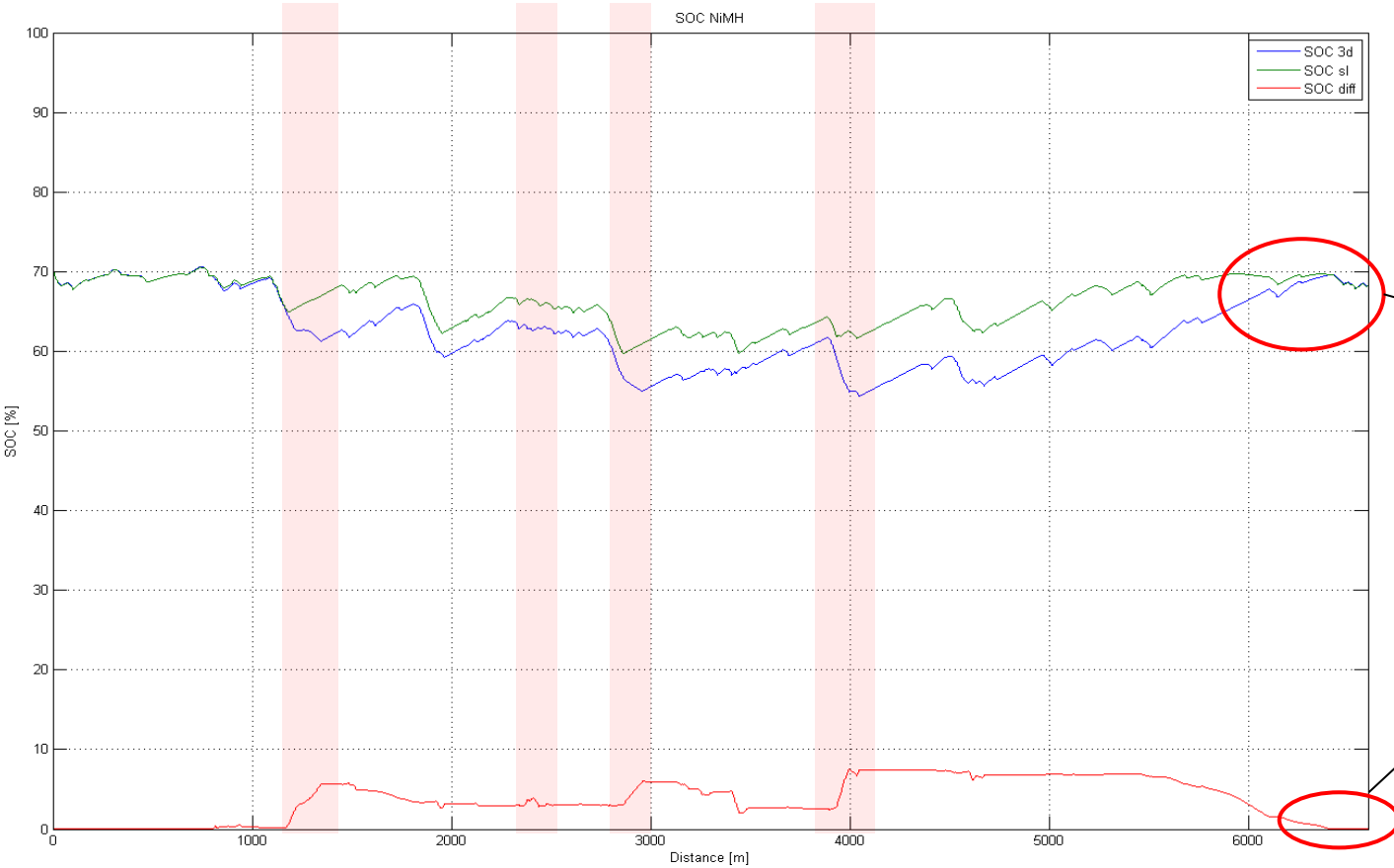
Advanced Powertrain Control Optimization

Case Study: Lateral Dyn. Impact on Energy Management

Due to the torque distribution to the rear axle, the SOC drops faster on a 3d track (max. gap = 7.6%).



Recharging by the front electrical machine.

SOC difference at the end ~ 0%

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Advanced Powertrain Control Optimization

Case Study: Lateral Dyn. Impact on Energy Management

At the end of 6600m on 3-D track:

- SOC difference ~ 0% (max. gap ~ 7.6%)
- Time difference < 1% (3d track slow)
- 5% more TC intervention on the 3d track
- 20% more power split at rear axle on the 3d track
- 2.6% more energy consumption on the 3d track

Lateral vehicle dynamics has a significant impact to the SOC and overall energy consumption!

Conclusion:

Not only for stability, lateral vehicle dynamics can have an impact to the hybrid concept design (power of elect. machines, capacity of battery) due to requirements from SOC or energy consumption as well.

Additional impacts from auxiliary loads as EPS-motor or ABS-pump to be done.

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Thank You

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