Connected Energy Based Powertrain Control - A Cross Domain Approach
Marcus Boumans, Dr. Uta C. Fischer
Diesel Gasoline Systems – Electronic Controls
Global Drivers for CO₂ Saving Features

- Legislative
  - Driver: politics (energy, foreign, city, …)
- Fleet consumption
- Taxes, Limitations...
- Fuel cost
- Customer
- Image
- Lobby

- Increasing number of technologies / products / components (Variety)
  - ICE Optimization
  - Electrification (Hybrid/EV, …)
  - Fuel Cell
  - Alternatives (CNG, Bio gas, H₂, …)

CO₂ – Cost – Safety requirements lead to an increase of Cross Domain functions
Connected Domains – Challenge and Opportunity
Driven by CO₂: Develop a vehicle wide Energy Management Powertrain Control to

- Minimize CO₂-emissions by SW-Functions only (“Cross Domain”)
- Master Variance and Complexity of cross domain SW („cost“ €)
**Connected Energy-based Powertrain Control**

**Proceeding**

**Search Fields**
- Relevant Ideas
- Theoretical potential
- PoC in simulation
- Car Prototype

**Potential Analysis**
- Connected Energy-based Powertrain Control

**Concept Study**
- Diesel Gasoline Systems
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**Concept Validation**
- BOSCH

**Business Unit**

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**A powerful CO₂-minimization Cross Domain approach, vehicle topology & components are degrees of freedom**

**EPC: Energy Management Powertrain Control**

**PoC: Proof of concept**

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**Diagram:**
- Energy Management
  - Mechanical Energy
  - Thermal Energy
  - Electrical Energy
- Driving
  - Temperature
  - Adjustment time
  - Air quality
  - Humidity
- Cabin tempering
  - Consumer 1: on/off/level
  - Consumer 2: on/off/level
- Safety/Comfort
- Powertrain
  - ICE on/off
  - Clutch open/closed
  - Gear ratio
  - Torque e-machine
- Heat/Cool System
  - EL water pump on/off/level
  - Valves on/off/level
  - Level climate compressor
- 12V-Supply
  - Power/torque Generator
  - Power DC/DC

**Table:**

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Result (estimated CO₂-Savings)</th>
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<tr>
<td>HEV CO₂ saving potential DOF: torque split</td>
<td>20 - 25%</td>
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<tr>
<td>Assisted driving CO₂ potential, DOF: velocity</td>
<td>up to 10%</td>
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<td>Comparison Blended/Depleting-Sustaining Mode PHEV</td>
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<td>CO₂ saving potential thermal management measures</td>
<td>1 - 5%</td>
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<td>Prediction CO₂ saving potential min. 4%, DOF: route selection</td>
<td>up to 4%</td>
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<tr>
<td>Potential of shifting auxiliaries loads</td>
<td>&lt; 1%</td>
</tr>
<tr>
<td>Potential Considering cold engine in ECMS (optimal torque split) (HEV)</td>
<td>&lt; 1%</td>
</tr>
</tbody>
</table>

**Gasoline**
- Parallel P2 Strong HEV

**Focus:** Optimized Powertrain Control
Focus on cross domain optimization using all vehicle DoF AND predictive / surround data for different sensor and powertrain topologies (Diesel, Gasoline) - modular extendible feature kit available
Connected Energy-based Powertrain Control

Prediction “Enabler” Framework

Sensor Data

Predictive Enabler Structure

Predictive Functions

DATA RECONSTRUCTION

DATA FUSION

SURROUND MODEL

SITUATION ANALYSIS

SELF-LEARNING PREDICTION MODEL

Long Horizon

Medium Horizon

Short Horizon

Prediction “Enabler” Framework: A scalable approach w.r.t. available sensor and cloud data

Diesel Gasoline Systems

ADAS: Advanced Driver Assistance System
ADASIS: ADAS Interface Specification

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Cross Domain Feature Development and Verification

Cross Domain Simulation Environment

Development & Validation: Roller Dyno including Navi

Connected Energy-based Powertrain Control

Gasoline Parallel P2 Strong HEV
Focus: Optimized Thermal Management

Gasoline Parallel P2 Strong HEV
Focus: Optimized Powertrain Control

Diesel Axle Split PlugIn HEV
Optimized Powertrain Control w.r.t. CO₂ / NOx emissions

Cross Domain Function Development and Concept Proof in simulation & Concept Car considering different powertrain topologies, optimized component layouts, sensor/actor variance

Diesel Gasoline Systems

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Example: Map-based ecoACC Cross Domain Verification in Simulation

Simulation scenario:
- No traffic ahead
- Vary driver & optimizer
- CO₂ saving: ~10% (depends on traffic)

Simulation scenario:
- Varying traffic
- Different road types
- CO₂ saving: 2% - 5% (depends on traffic)

Reproducible CO₂ Potential determination for Map-based ecoACC possible
Connected Energy-based Powertrain Control

Master Variance and Complexity of Cross Domain Functions

Cross Domain Functions
- Human Driver
- Cruise Control
- Eco. Driving
- Energy bas. PT Control
- ADAS
- Parking Assist
- Autom. Driving

“Vehicle Motion Control”

Actuators
- Trans-mission
- IC Engine
- E-Drive
- Steering
- Brake

Drivers ‘Next Generation’ (E/E and SW) Architecture design

Powertrain Electrification
- Automated driving
- Energy management
- Connectivity

SW Updates FOTA
High-speed-Communication
Safety & Security

Technical drivers
- Introduction of complex cross domain or cloud-based functions
- Emission reduction, Powertrain Electrification and Automated driving and Connectivity
- Variant management

Strategic drivers
- Fast innovation cycles
- Integration of SW from different sources
- Scalable, modular platform concepts
- Corporate affairs, Web-based services
Connected Energy-based Powertrain Control

Our advanced E/E Architecture Design Approach

1. **Requirements & Use Cases**
   - Definition of relevant use-cases and of the functional requirements for the electric and electronic systems

2. **Functional Network**
   - Derive main functional cause-effect relationships and define functional networking with optimized functional cluster

3. **Technology & Components**
   - Transfer functional clusters on physical E/E components and domains. Consider technological and strategic criteria, such as weight, cost, flexibility, innovation cycle, safety and security requirements, ..

4. **Vehicle Network**

Reference architecture – Todays solutions

**Goal:** get ready for the future with sustainable E/E- and SW Architecture
Connected Energy-based Powertrain Control

Degree Of Freedom potential / benefit analysis for vehicles
- Selection of systems under investigation
- Theoretical potential analysis → most promising DoF

Concept Development e.g. Energy Management in Simulation
- System optimization w.r.t. (energy) features and components
- E/E-Architecture, Hybrid operation strategy / predictive functions

Electronic Control Units
- Electronic engine control unit powertrain
- Vehicle Control Unit VCU, Rapid Prototyping Hardware

Setup Concept Car / Demonstrators
- Demo vehicle systems integration & test, test instrumentation
- function prototypes, analysis and documentation of CO₂ benefit(s)

Calibration services electrified powertrain
- Calibration of work packages, Real Drive Roller Test Bench
- Test trip support + system readiness (“Systembereitstellung”)

Provide Connected Cross Domain Development & Services – internally and for our customers
Thank you very much for your attention!