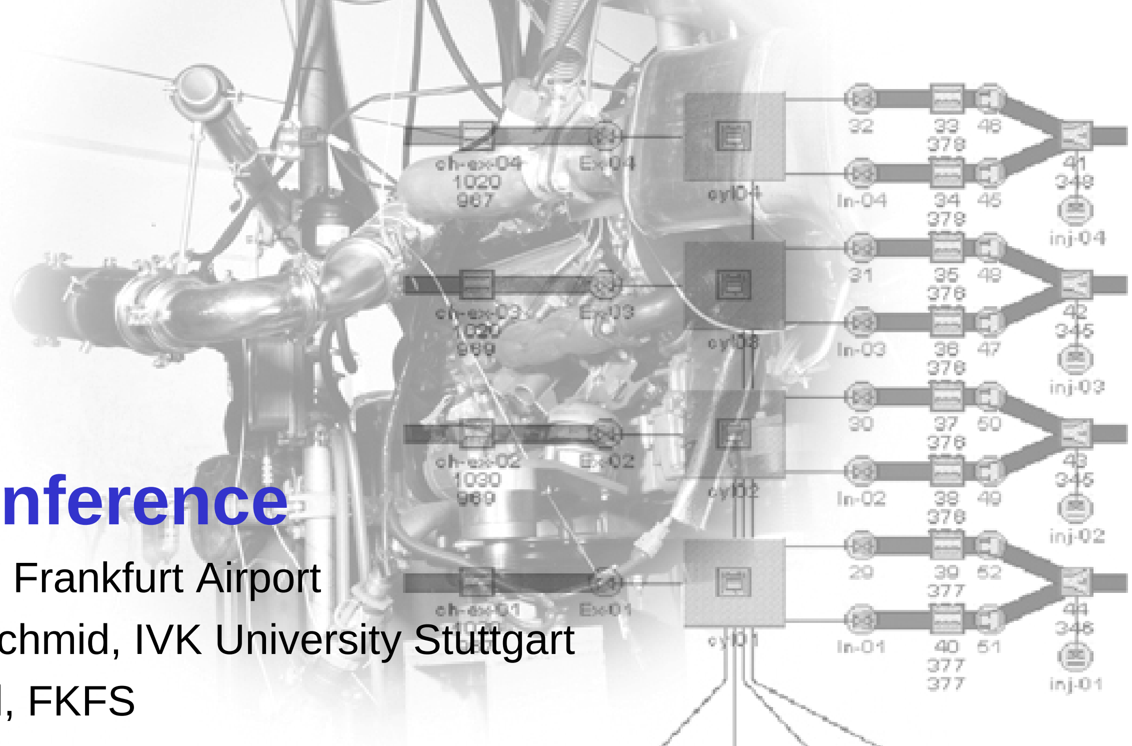
Transient and Map-Based Driving Cycle Calculation with GT-SUITE



GT-User Conference

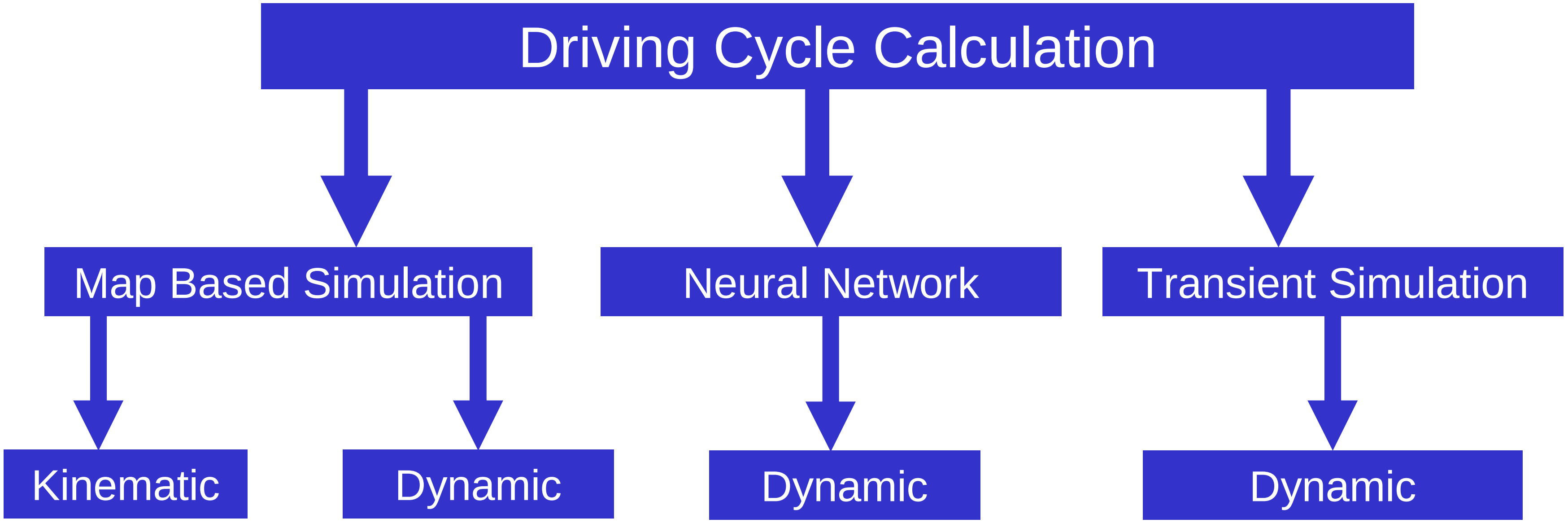
9th November 2009, Frankfurt Airport
Dipl.-Ing. Andreas Schmid, IVK University Stuttgart
Dr.-Ing. Michael Grill, FKFS
Dipl.-Ing. Hans-Jürgen Berner, FKFS
Prof. Dr.-Ing. Michael Bargende, FKFS

Overview

Overview

Introduction

Calculating the expected fuel consumption of a new vehicle in driving cycles is major simulation goal



Introduction

Dynamic Map-based simulation:

- Engine fuel consumption and emissions are measured or simulated at specific operation points (i.e. BMEP 2bar / 2000 RPM)
- Maps are used as interpolation basis

Neural Networks:

- Training neural networks in respect to different simulation boundary conditions (Temperature, Ignition Point….)
- Steady state conditions

Dynamic transient simulation:

- Direct operation of a GT-POWER engine model in a driving cycle simulation
- No steady state conditions

complexity

Introduction

Comparison Basis:

- Comparison of map-based and transient simulation of a SI-Engine

Why not Neural Networks?:

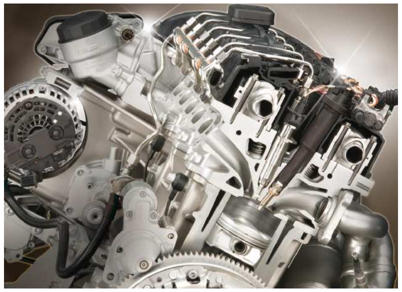
- Reasonable boundary conditions?

Inlet Temperatures:
20 – 60℃ ? Resolution?

Engine Knock? → Ignition Point Variation

External EGR-Rates?

Outlet Cam Timing Variation?



Inlet Cam Timing Variation?

Enrichment?

Turbine response?

….

- **Explosion of neural network training points**
- **No time advantage using neural networks when considering future simulation needs!**

Overview

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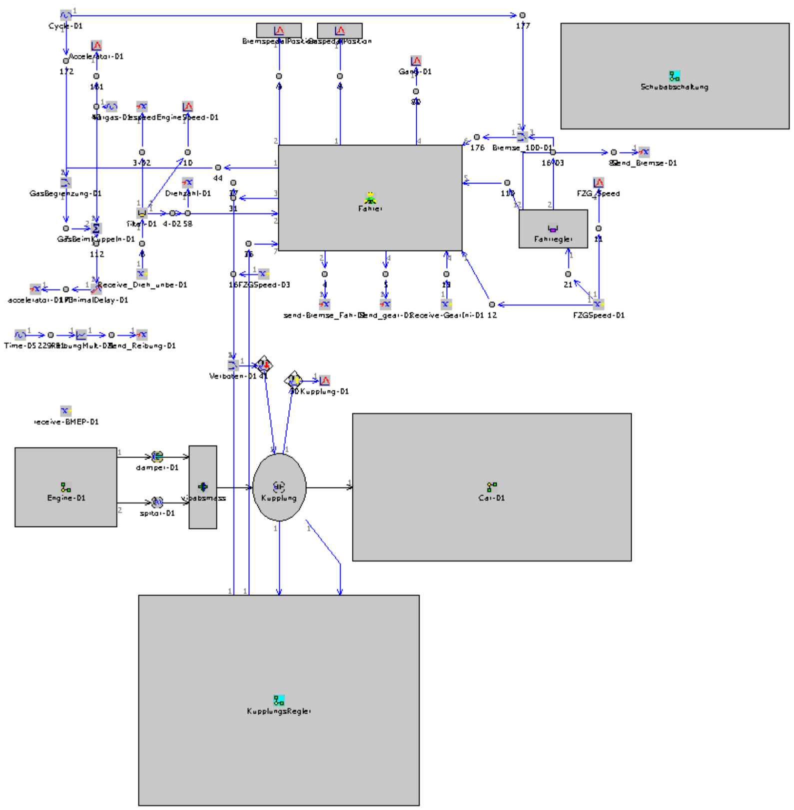
2. GT-Suite Model
3. Transient Simulation
4. Map-based Simulation
5. Comparison
6. Summary

GT-Suite Model

Highly modular GT-Suite Model is used



- Easy exchange of engine Model

➔ GT-Power engine model or map based model

- Different cars possible

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Transient Simulation

Overview

- GT-Power Model of 1.8l DI-SI engine with a single turbocharger is used
- Model is integrated in the modular GT-Suite Model
- Acceleration pedal position is directly applied as “throttle signal”
- Crank angle of 50% burn point is adjusted at 8 °CA after FTDC
- A predictable burn-rate model is used (EGR, Geometry etc.)
- Warm-up strategies are not considered (comparison!)
- Very difficult to control ➔ Main ECU functions have to be considered

➔ Long simulation duration ~ approx. 5-7 days for NEDC

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Map-based Simulation

Overview

- Identical GT-Power Model of 1.8l DI-SI engine with a single turbocharger is used
- Engine fuel map is calculated at the whole operating range of the engine
- “hot” engine conditions are used
- Simulated fuel consumption is integrated in map-based GT-Drive engine state object
- Standard GT-interpolation in fuel-maps are used

➔ Short simulation duration of driving-cycle calculation but engine map calculation is approx. 2-3 days, even at basic simulation conditions!

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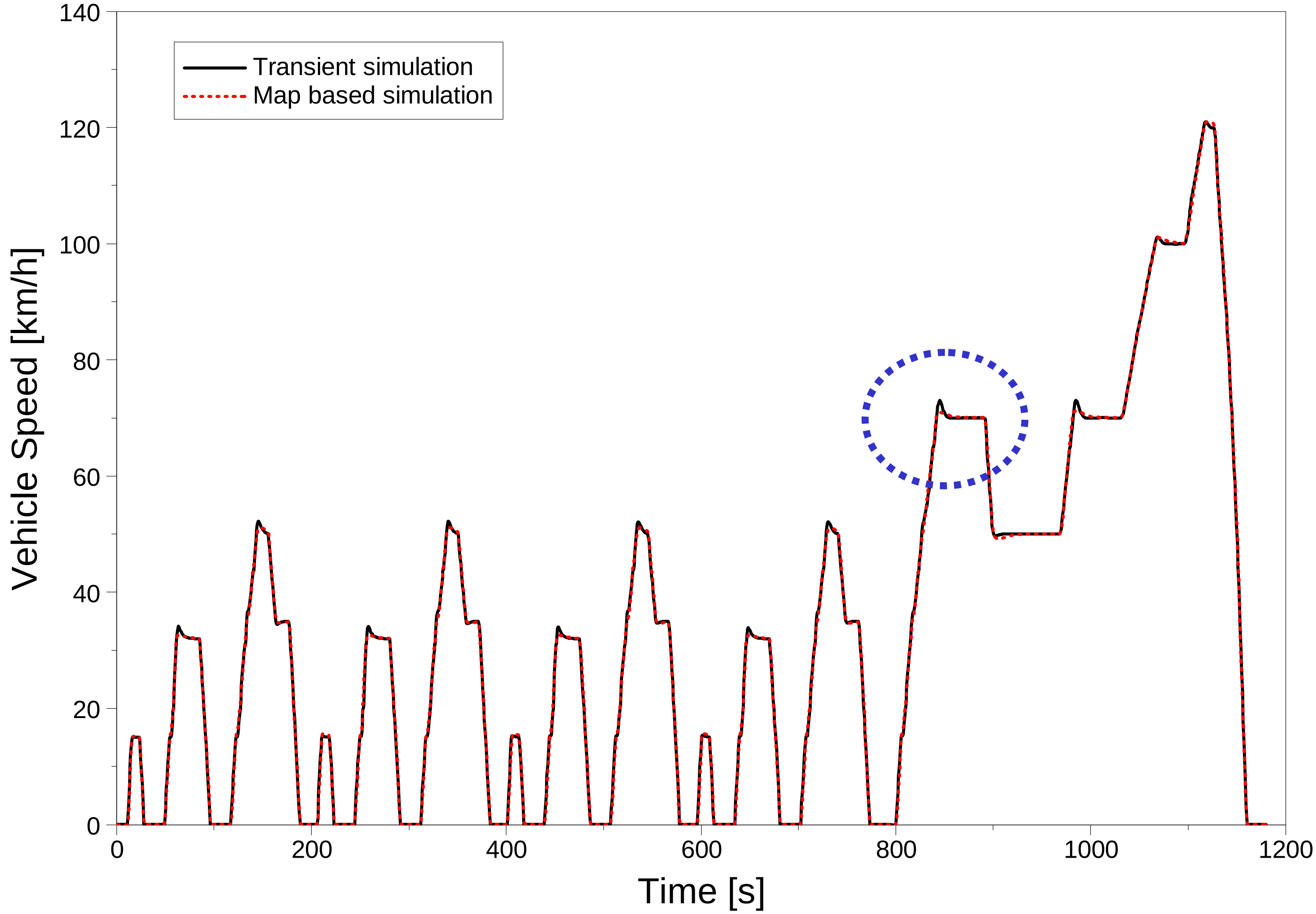
Comparison

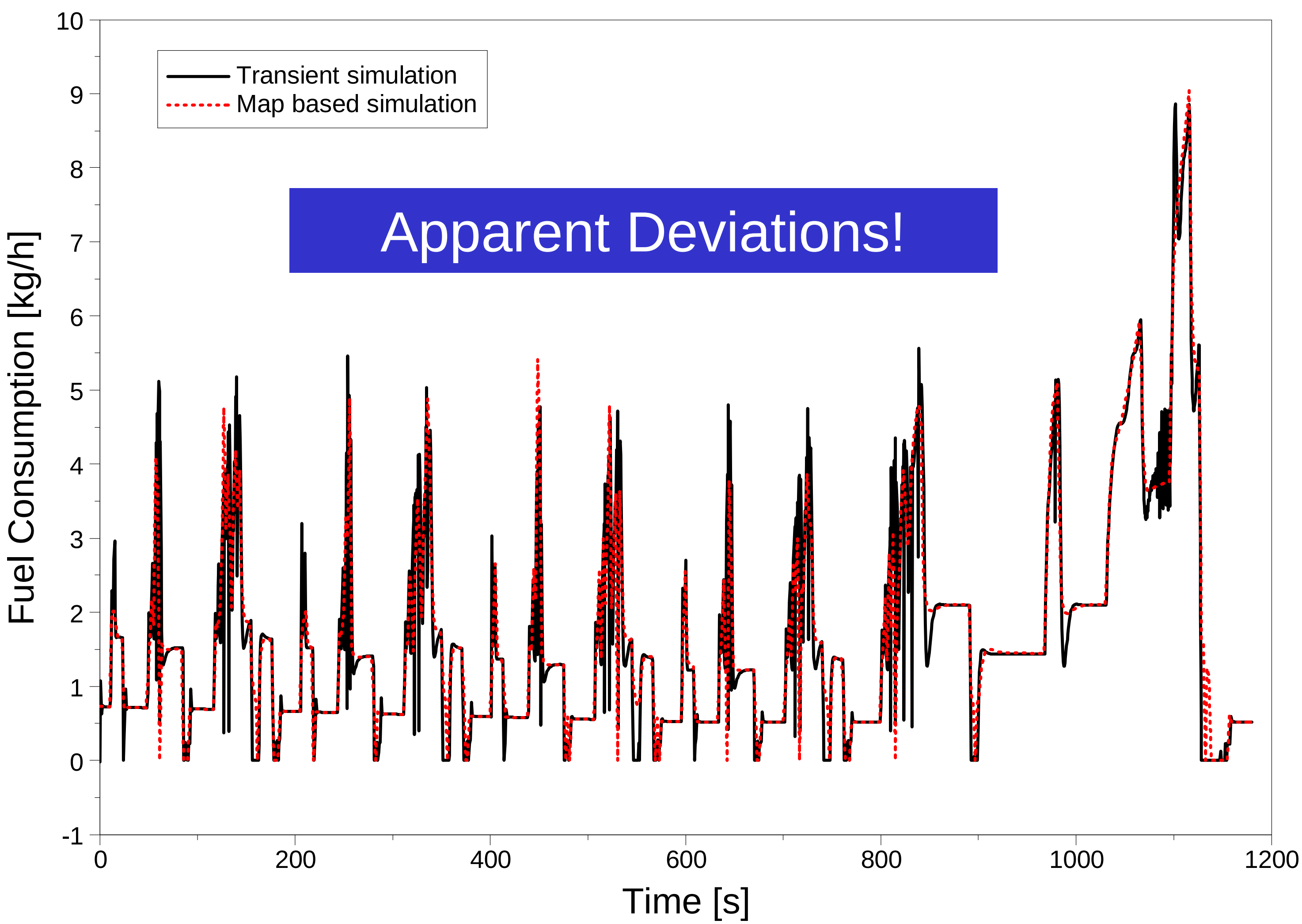
Basic conditions of simulation:

- Comparison cycle: NEDC
- Warm-up strategies are not considered
- No enrichment at start-up is used
- Automatic transmission strategy is used for best fuel economy
- identical medium-sized car is used for both simulation

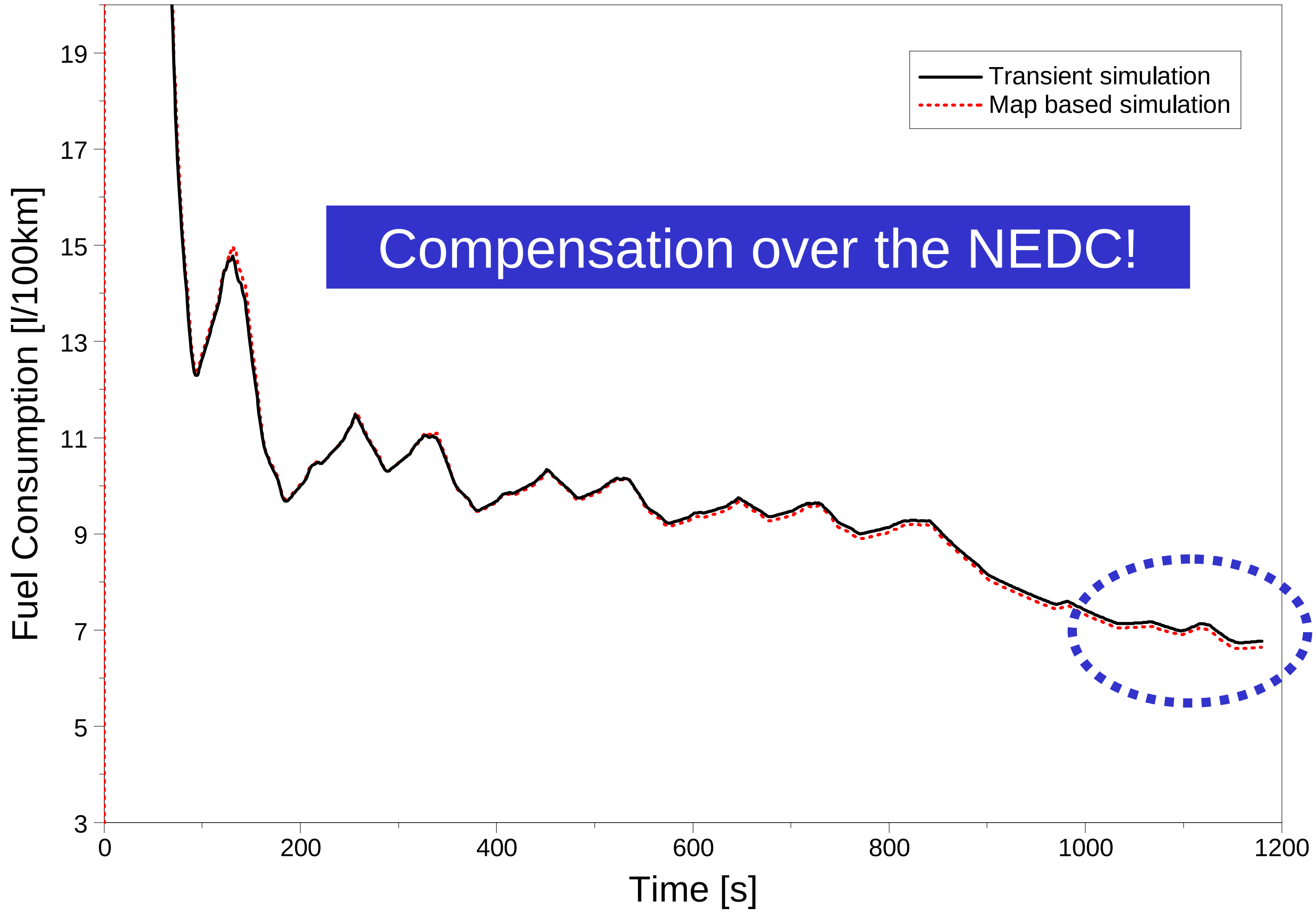
Vehicle Speed



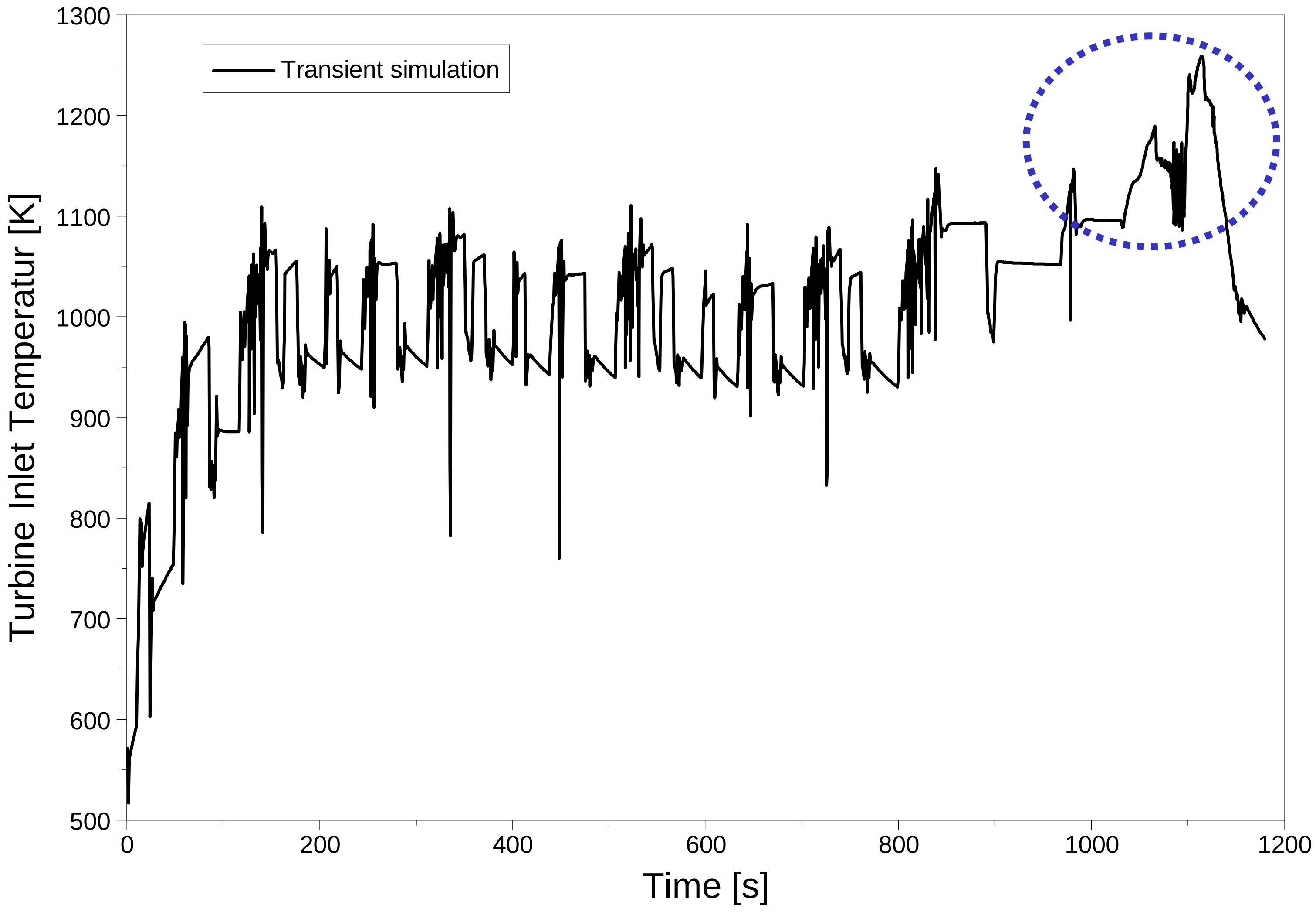
Fuel Consumption 1



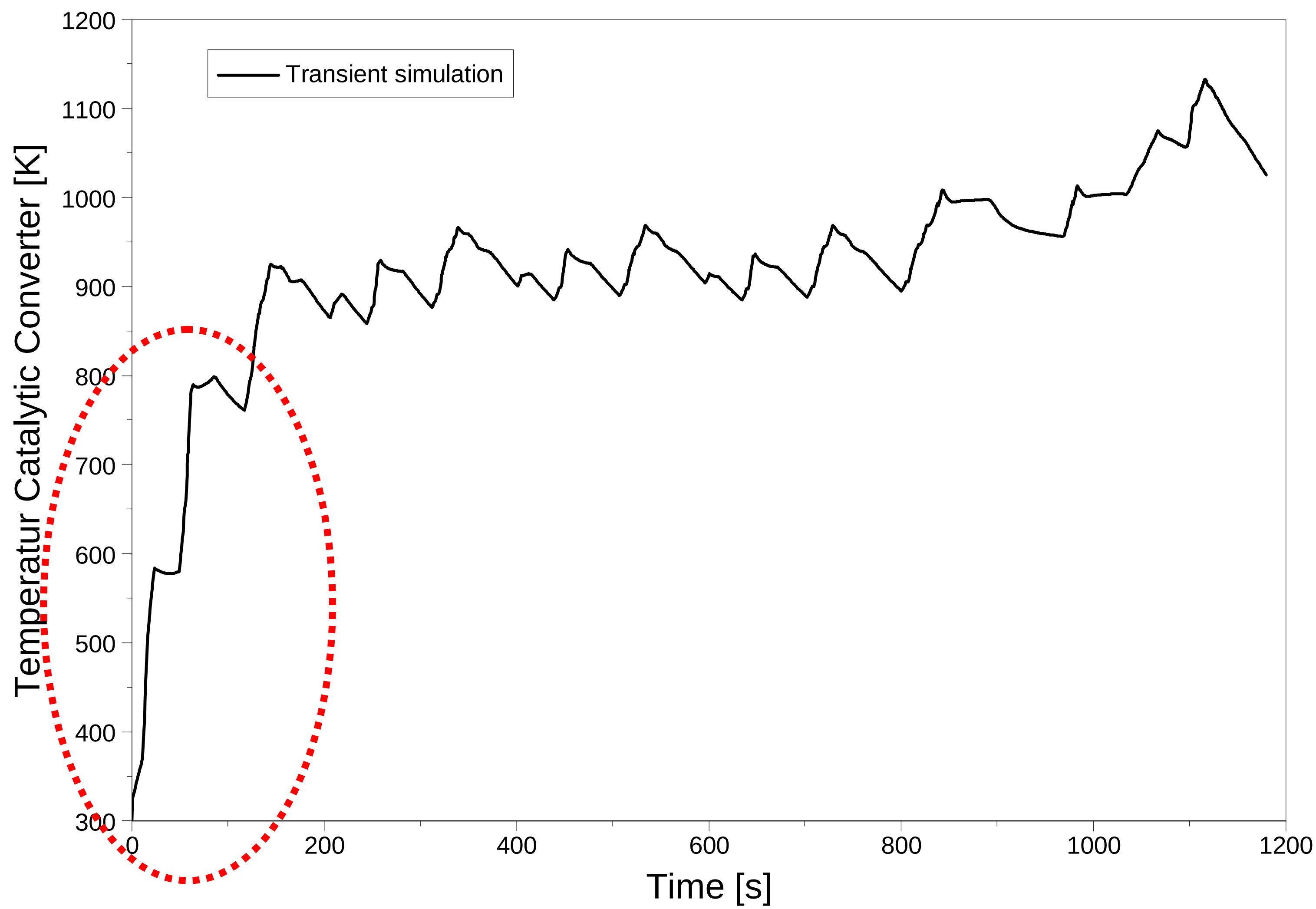
Fuel Consumption 2



Temperature Turbine



Temperature Catalytic Converter



Comparison

Comparison results:

- Just small deviations in overall fuel consumption
- Deviations during simulation just have minor effect on overall fuel consumption because of compensation

Surprising Results?

- NEDC is quite stationary
- Fuel consumption reacts linear ➔ interpolation possible

➔ Identical Model ➔ Same results!

Comparison

Transient simulation necessary?

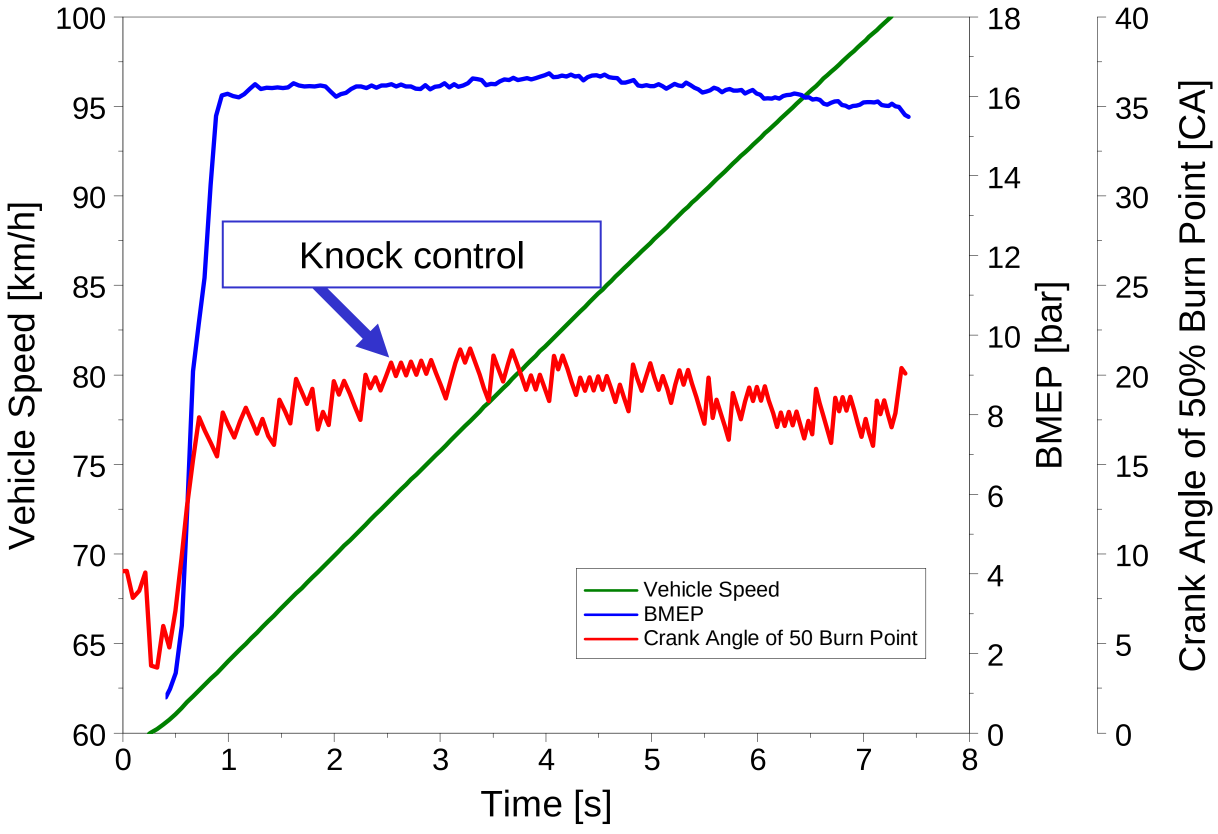
- Warm-up strategies
- Emissions (especially NO_x) nonlinear!
- Acceleration behavior of “Downsizing” engines
- Turbine response behavior
- Customer driving cycles with high engine loads
- CAI/HCCI simulation / high EGR
- Max. allowed temperature ➔ transient necessary enrichment
- Min. allowed catalytic converter temperature over cycle
- Exhaust gas treatment strategies

….

➔ Transient simulation essential for future simulation needs!

Transient Simulation

Example: Acceleration 60 → 100 km/h - Supercharged SI-Engine with anti-knock control



Direct transient simulation

→ "real"-World simulation!

Overview

Summary

- Comparison of map-based and transient NEDC simulation was realized
- Neural networks offer no time advantage if all reasonable boundary conditions for future engines are considered
- Only small deviations occur if no warm-up strategy is chosen
- Transient simulation duration is higher compared to map-based simulation if maps are existent
- Transient simulation is very difficult to handle
- <u>But</u> transient simulation offers an enormous application range
- For future simulation needs transient simulation is an essential tool

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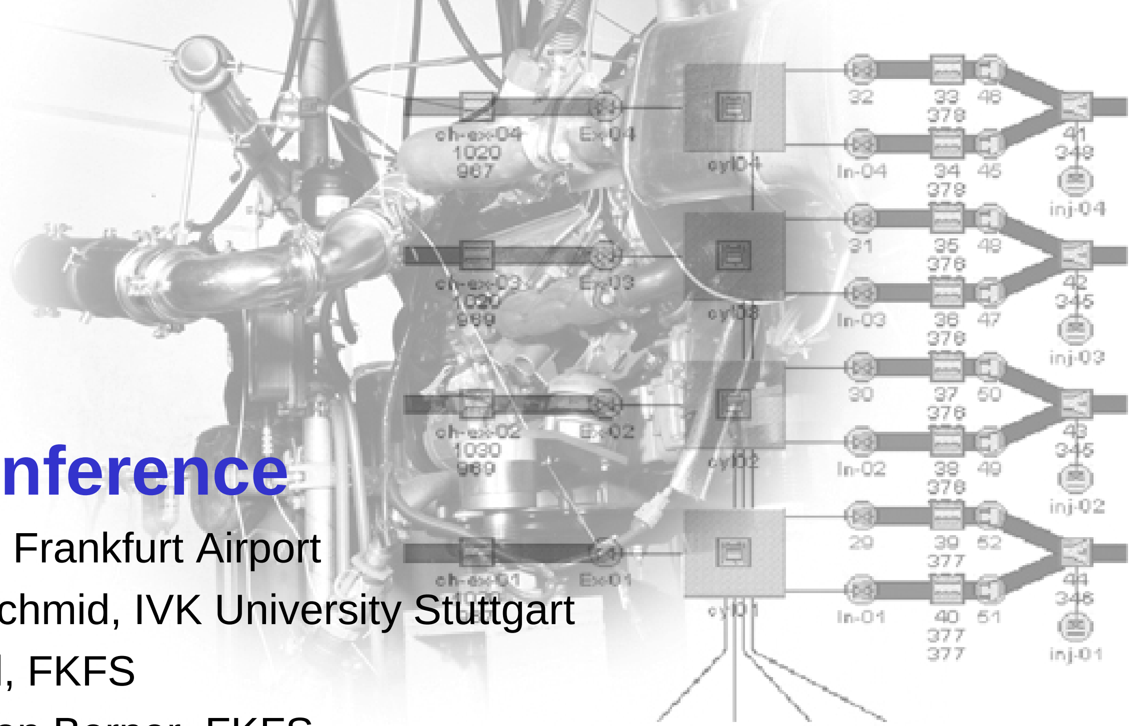

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