bertrandt

www.seriouswheels.com

Calibration of modern combustion engines – advantage by technology

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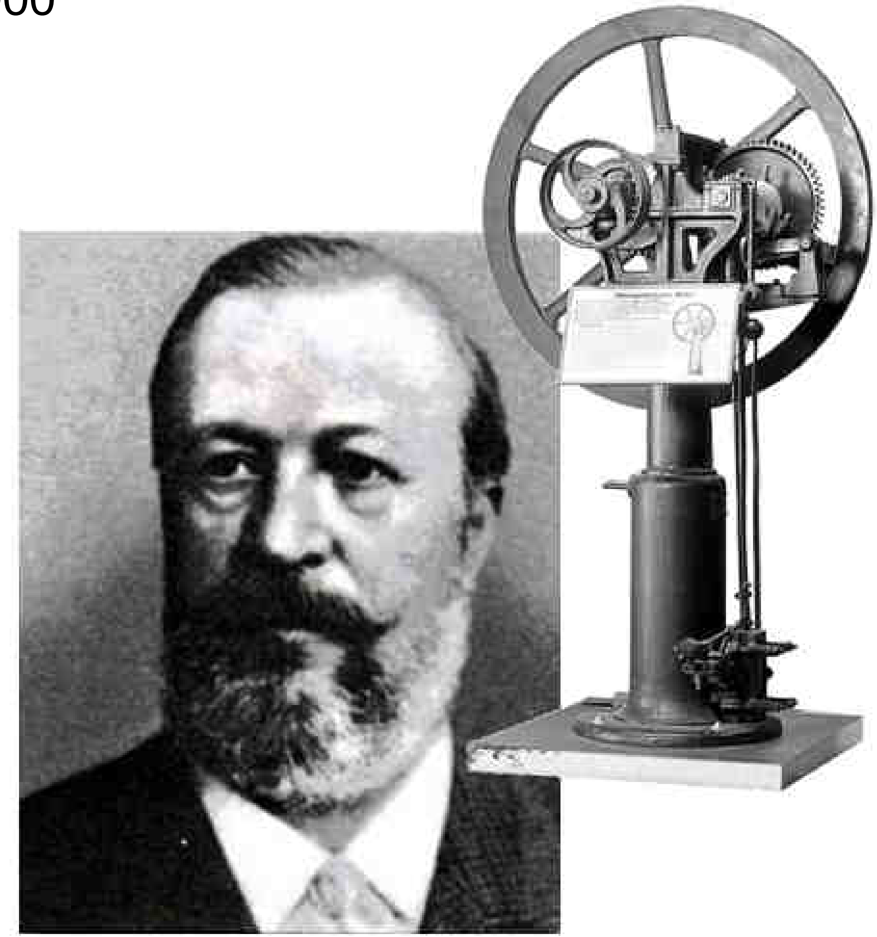
Automotive Colloquium HTW Dresden, 31.05.2011, 3 pm, L 211

History of the combustion engine: 1900

Rudolf Diesel



Nikolaus Otto

Quelle: www.wissen.de, u.a.

History of the combustion engine: 2011

Rudolf Diesel 2011

Quelle: seriouswheels.com, audi.de, u.a.

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  - Model based calibration with DoE (design of experiments)
  - Alternative calibration processes
- Automobile calibration
  - Loading and oxidation of DPF systems
  - Misfire detection diagnosis of gasoline engines
- Summary and outlook

Quelle: www.audi.de

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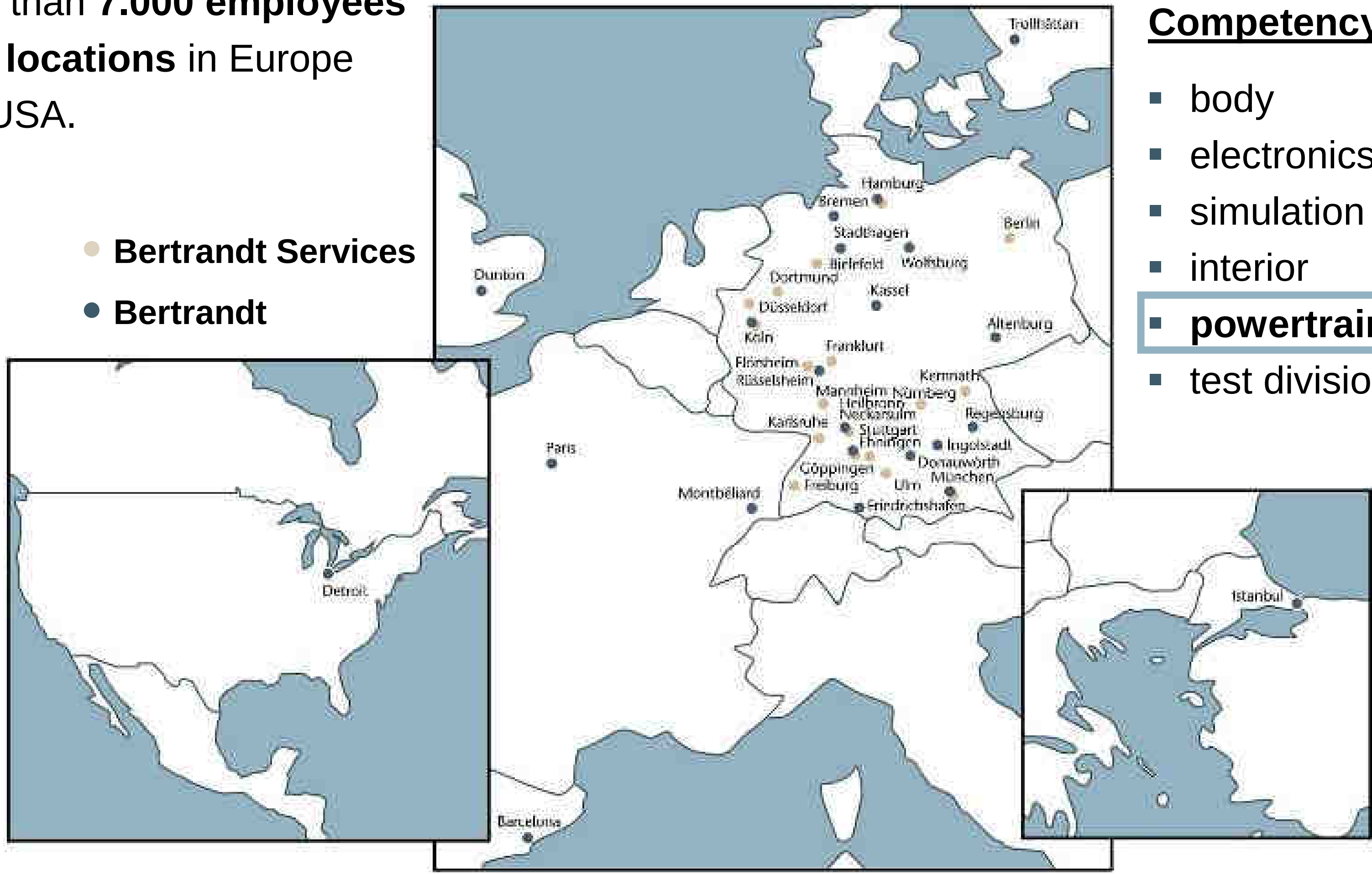
Come in and find out…;-)

Quelle: Bertrandt, Douglas

Closeness to our costumers is import for us – decentralized organization

more than **7.000 employees** in **35 locations** in Europe and USA.



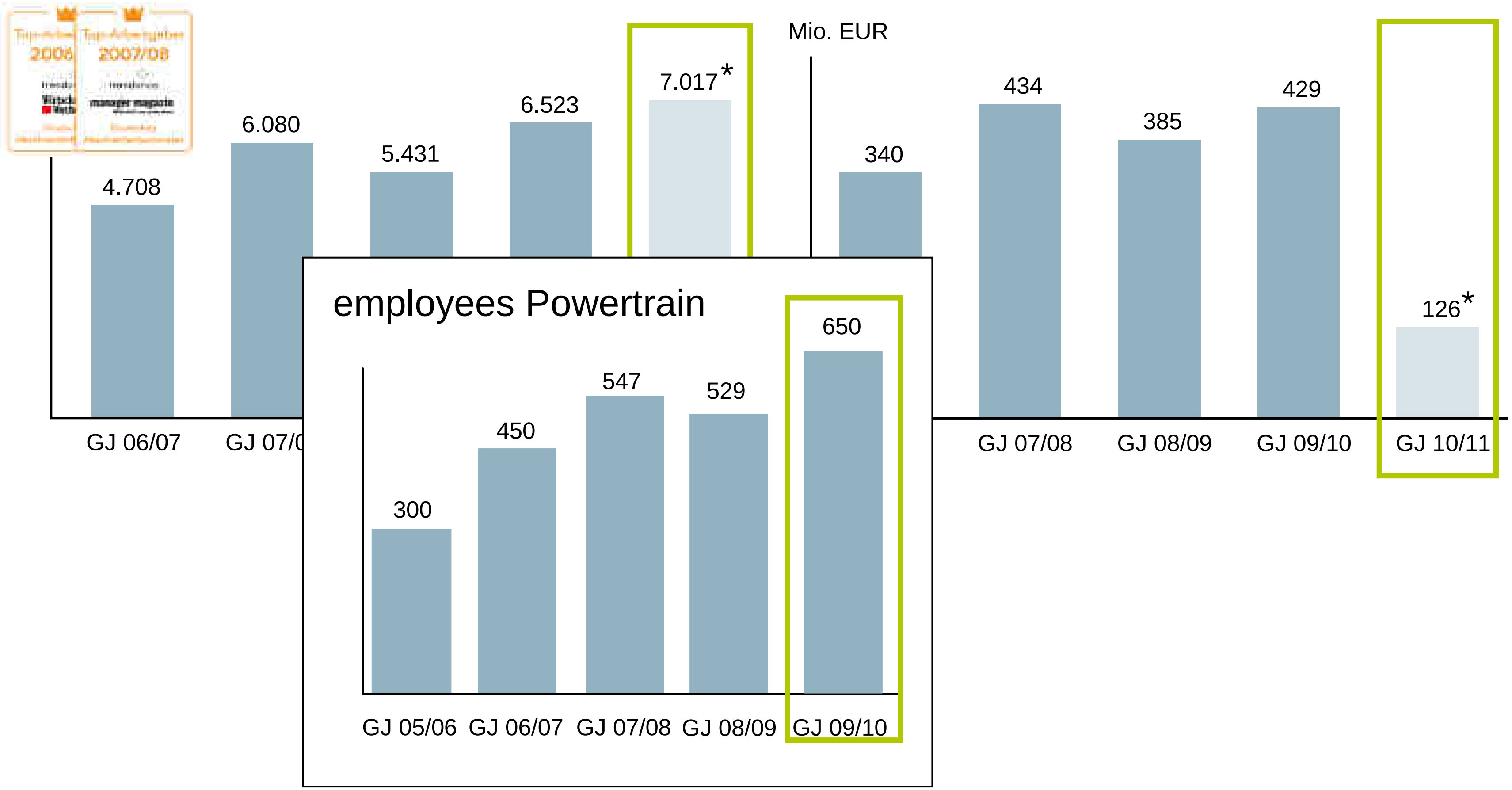
Competency

- body
- electronics
- simulation
- interior
- **powertrain**
- test division

Indices – sustained positive and successful development

number of employees Bertrandt AG

concern sales in Mio. EUR



* Data of the first quarter 2010/2011

Structure of shareholder

Aktionärsstruktur in %

*Angaben beruhen auf den der Gesellschaft zugegangenen Mitteilungen nach §§ 21 ff. WpHG.
Stand: 1. März 2011

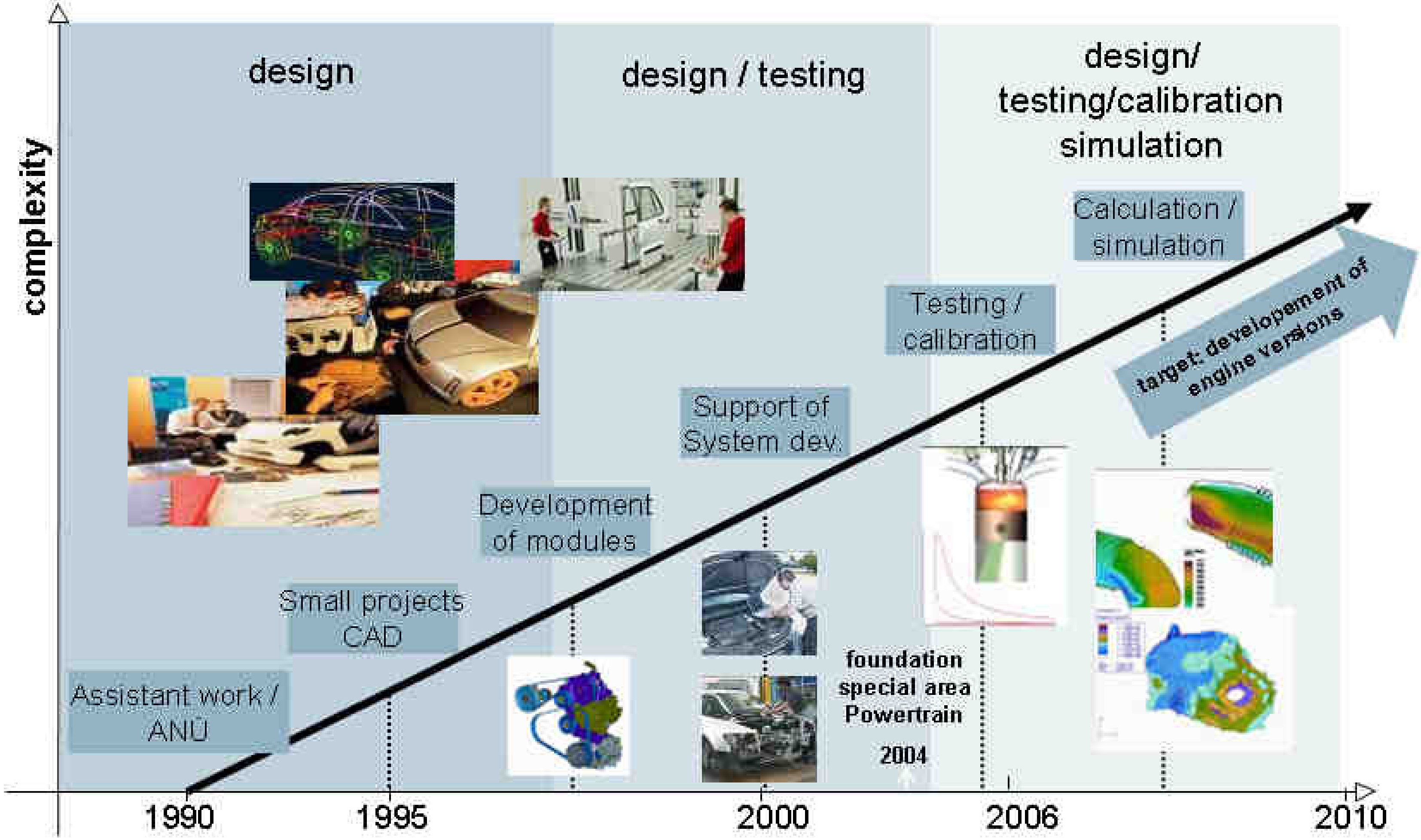
History

- 1974 — foundation through Harry Bertrandt
  business area: body, interior, prototype manufacturing, test division, trial, rapid prototyping

- 1990 — activities in motor and gearbox development for OEM and system supplier

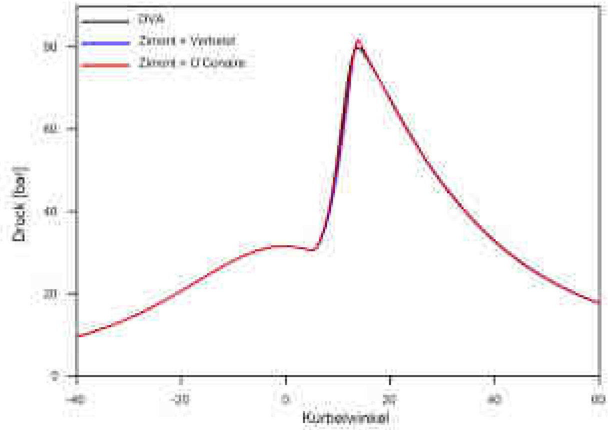
- since 2004 — definition of the special area Powertrain for the entire Bertrandt group
  - Germany
    - Ingolstadt
    - Neckarsulm
    - München
    - Ehningen
    - Wolfsburg
    - Köln
    - Rüsselsheim
  - France
    - Paris (Bièvres)
  - Great Britain
    - Dunton
  - Spain
    - Barcelona

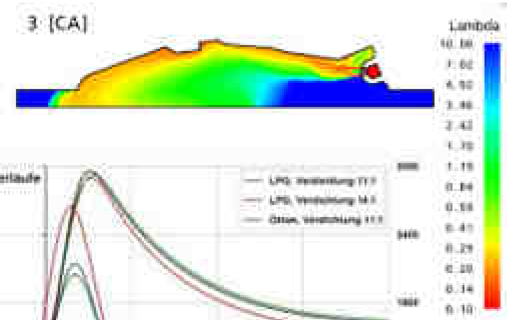
Fields of competence in powertrain development – now and in the future

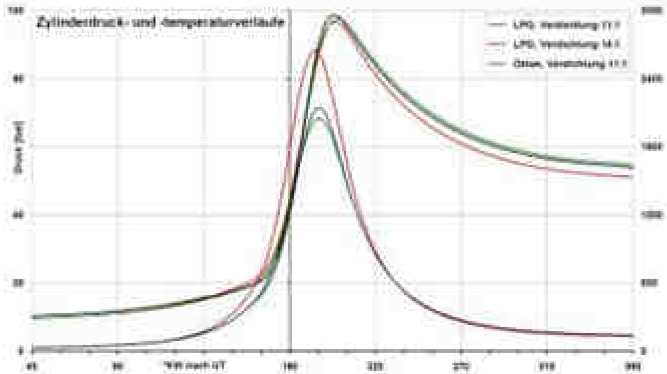


Simulation – engine process calculation

- development of engine models (with and without charge exchange simulation)
- pressure and heat-release development analysis, vibe-calculation
- simulation of premixed combustion with flame speed models (homogeneous and stratified)
- creating of correlations for laminar flame speed based on measurements or kinetic reaction simulations (eg hydrogen)
- functional design of engine components

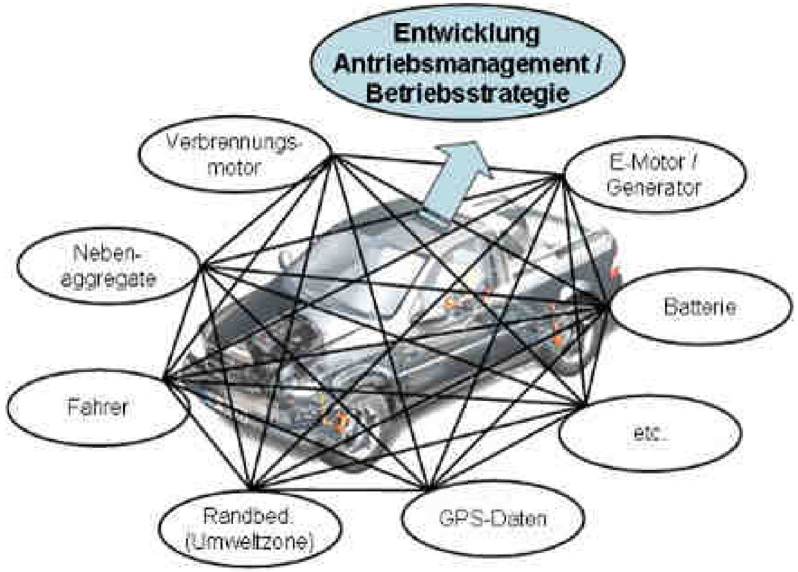


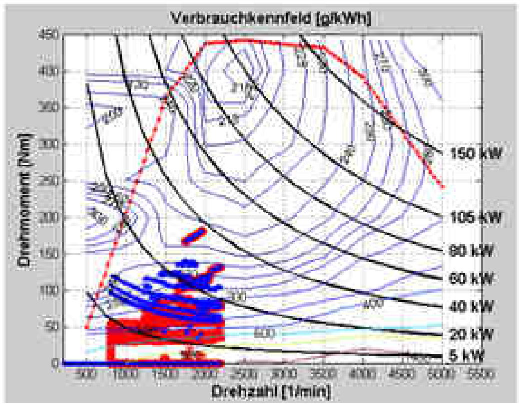




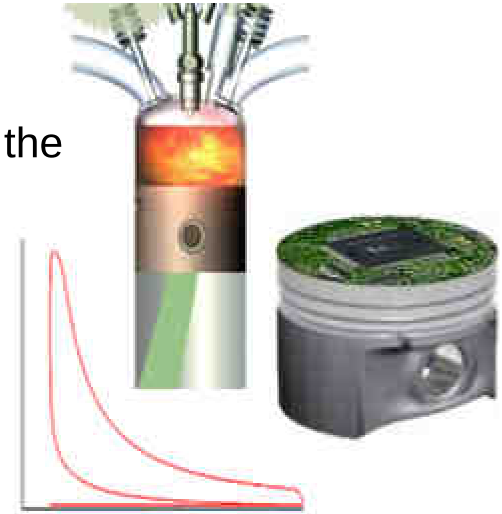
Simulation – development of powertrain management

- quantitative estimation of different drive concepts
- interpretation of individual components of different powertrain configurations
- integration of additional information signals (GPS, traffic, environment, …) in the drive management
- estimates and analysis of fuel consumption and emission potentials
- development of operational strategy

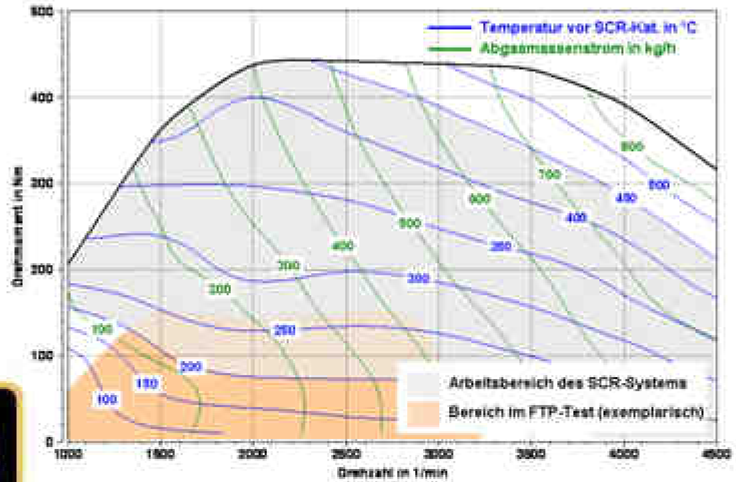




Engine calibration



- calibration, thermodynamics and exhaust aftertreatment on the engine test stand and in the vehicle
- combustion process development (gasoline, diesel, HCCI, PCCI, CAI)
- exhaust aftertreatment (DPF, SCR, …)
- gas exchange analysis, pressure analysis
- functional development and testing
- Adaptation of calibration to fuels
- vehicle start-up / exhaust measurements
- endurance run monitoring
- DoE (Design of Experiments)
- OBD development
- measuring data acquisition and processing

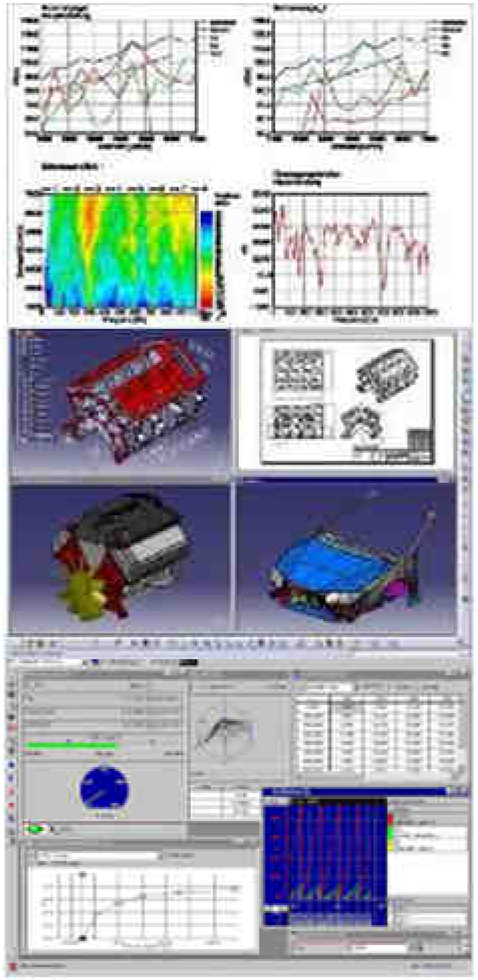


Workshop

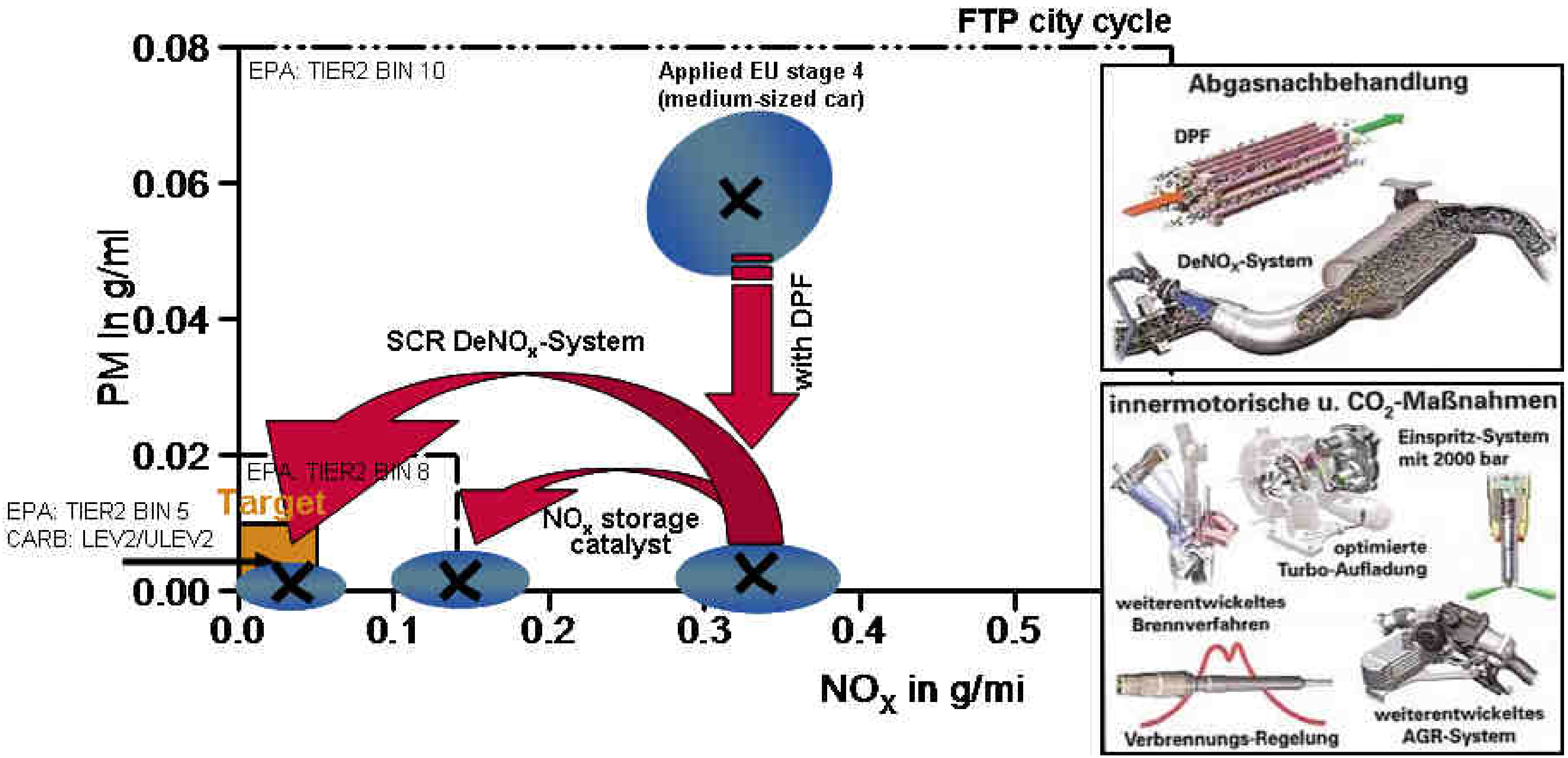
- reconstruction / rebuilding of test vehicles and prototypes
  (components fittings, electrification, start-up, …)
- measurement engineering installation in test vehicles
- engine replacement and accordingly change of components on functional vehicles
- prototype assembly of components
- wiring harness production for function vehicles

Tools

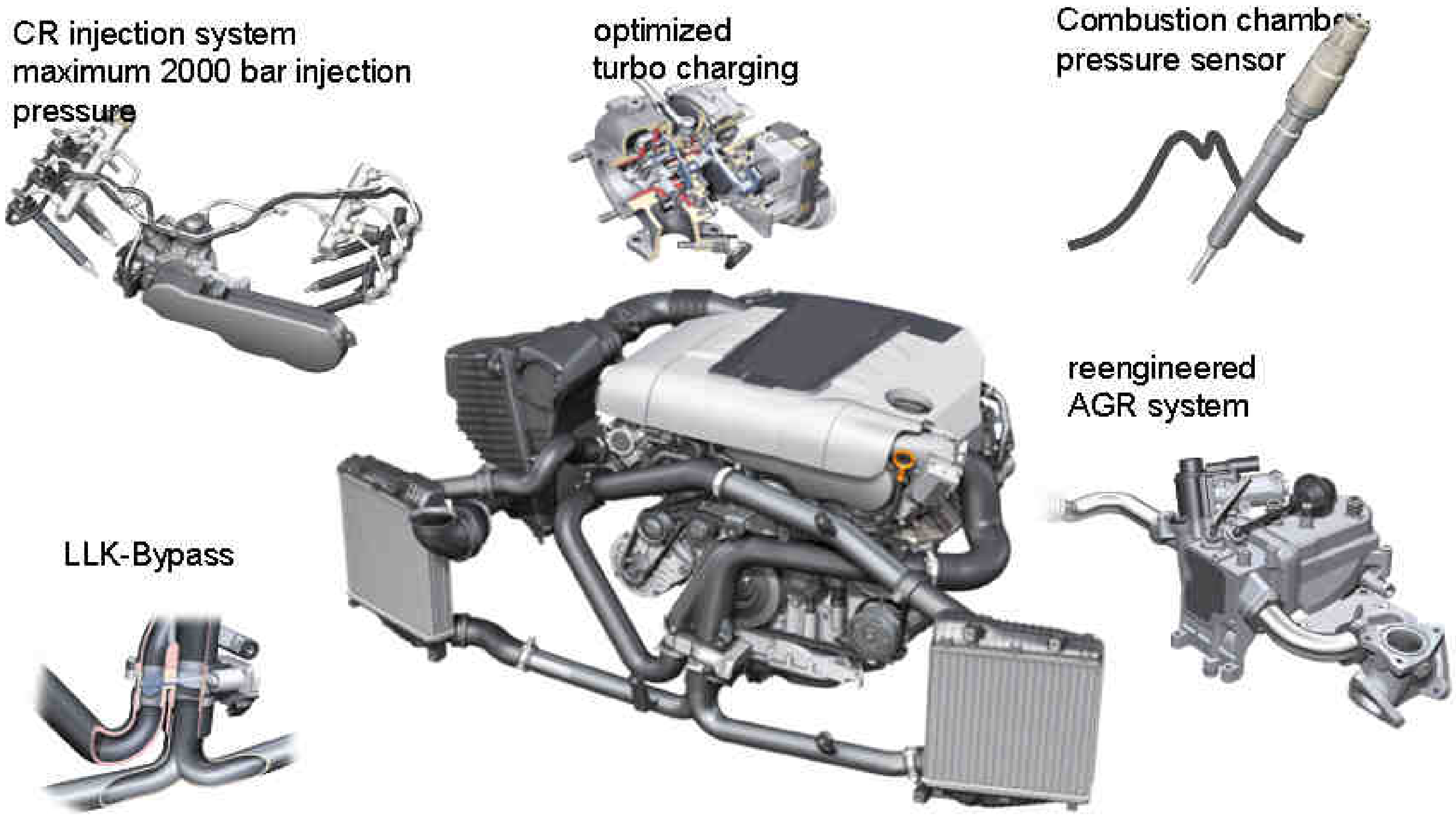
- CAD systems:
  - CATIA V4/ V5
  - ICEM Surf
  - Pro/ENGINEER
  - I-DEAS
  - Unigraphics
- Measuring engineering tools:
  - DIAdem
  - Canon
  - LINoe
  - INCA
  - LabVIEW
- calibration tools:
  - INCA
  - DiagRA
  - LABCAR
  - Codes
  - AVL PUMA
  - AVL CONCERTO
- simulation tools:
  - MSC/NASTRAN
  - ABAQUS
  - OptiStruct
  - STAR-CD
  - Flowmaster
  - Dymola
  - Kuli
  - ADAMS
- developement tools:
  - MATLAB/Simulink
  - TargetLink
  - ASCET
  - AVL CAMEO



Future emissions regulation:
Diesel engine development tasks

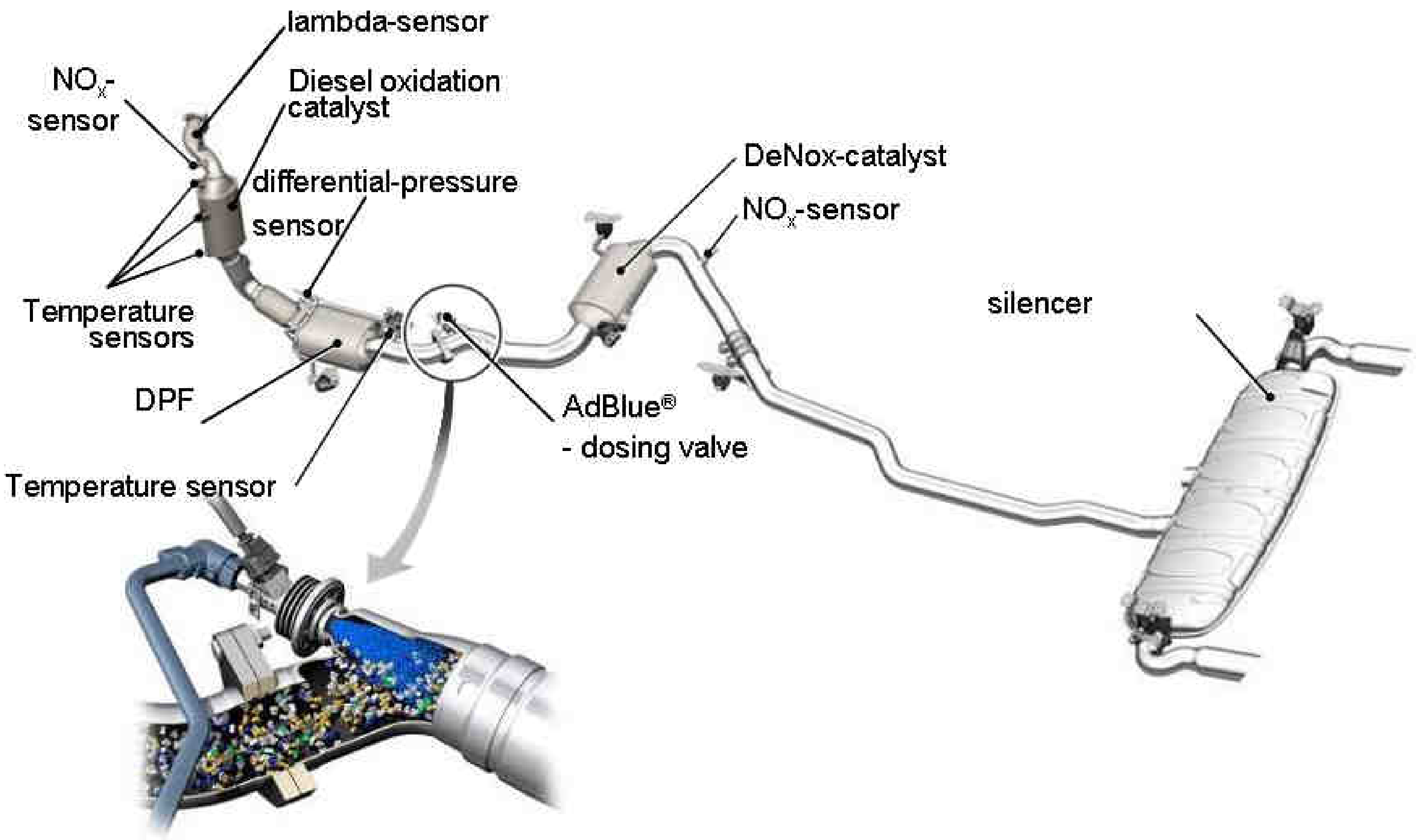


Development for customers (exemplary)



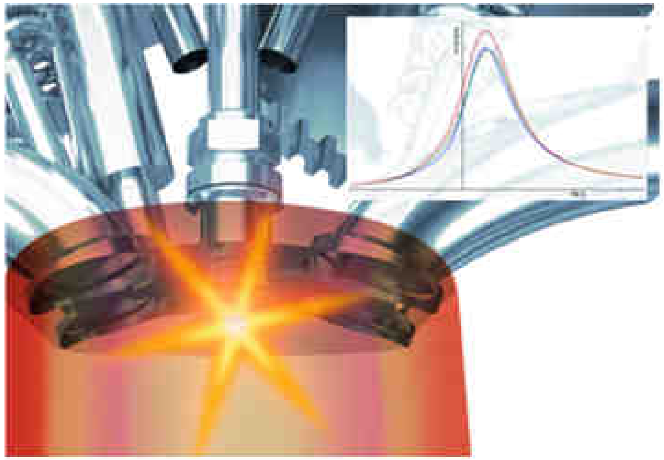
Quelle: Audi AG

Development for customers (exemplary)



Quelle: Audi AG

Content



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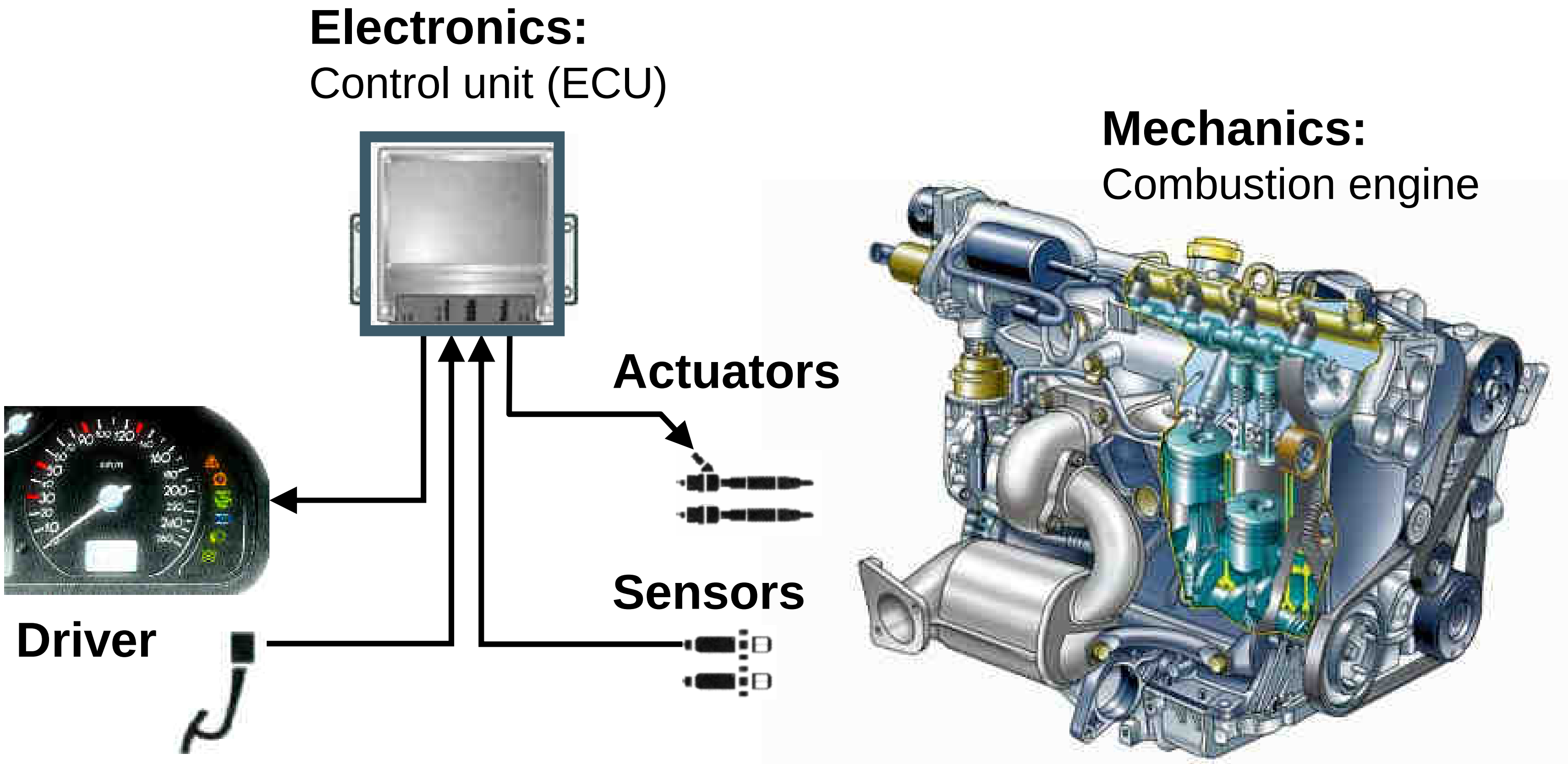
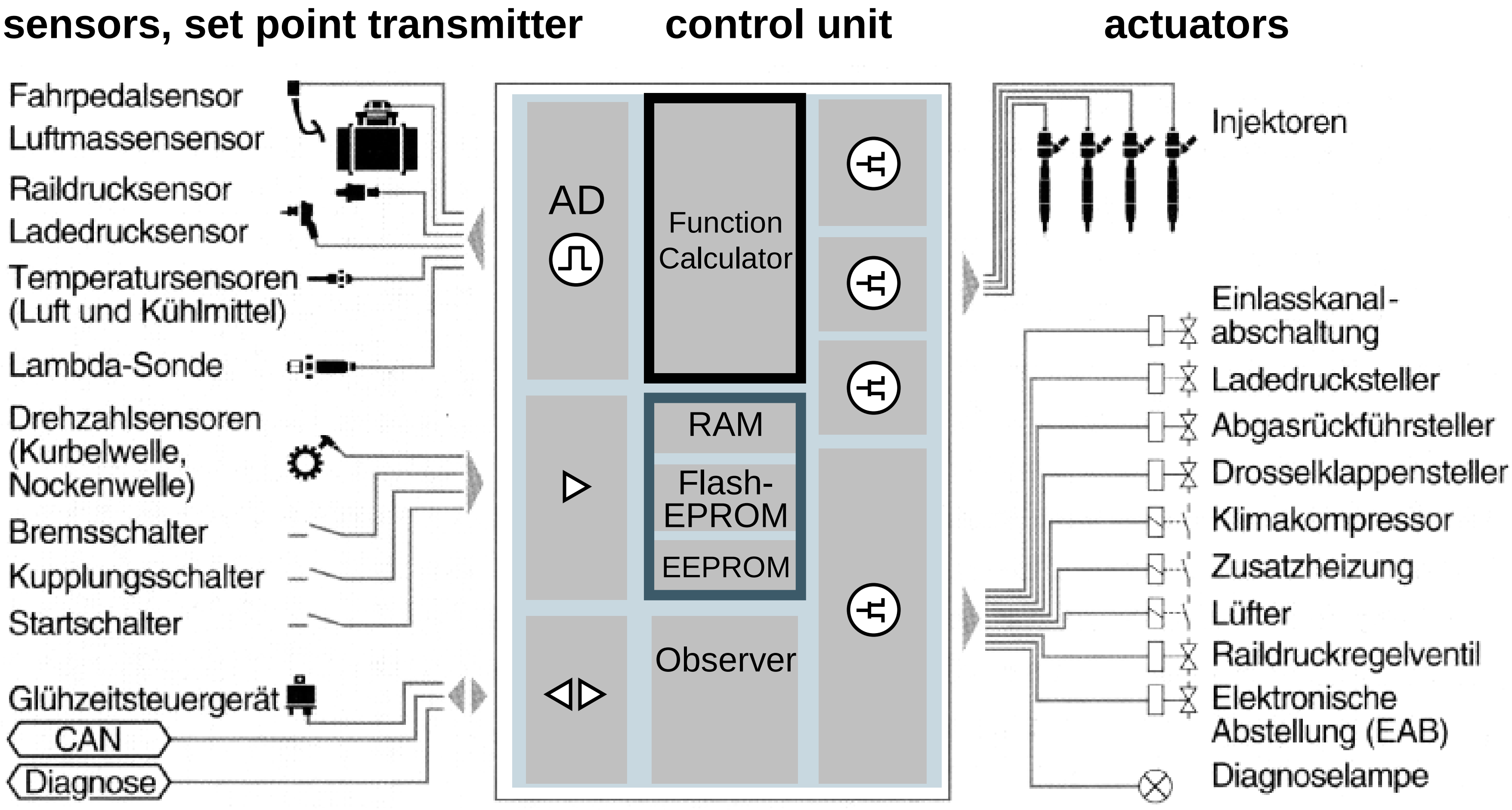
Quelle: www.audi.de

Development process of control unit software
mechatronic system control unit - engine



Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007, Renault / Bosch / VKA / TU Dresden (IVK)

Development process of control unit software
System blocks ECU (Common Rail System)

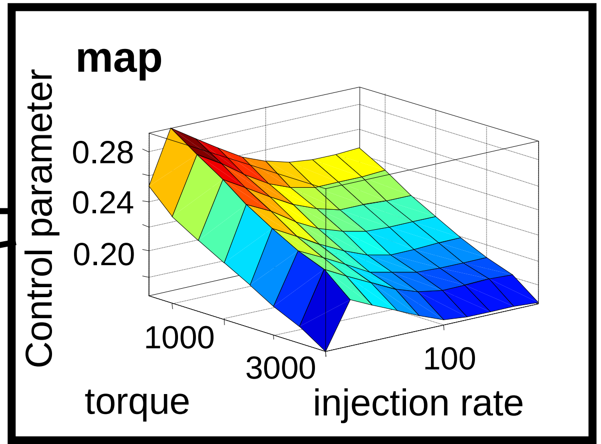


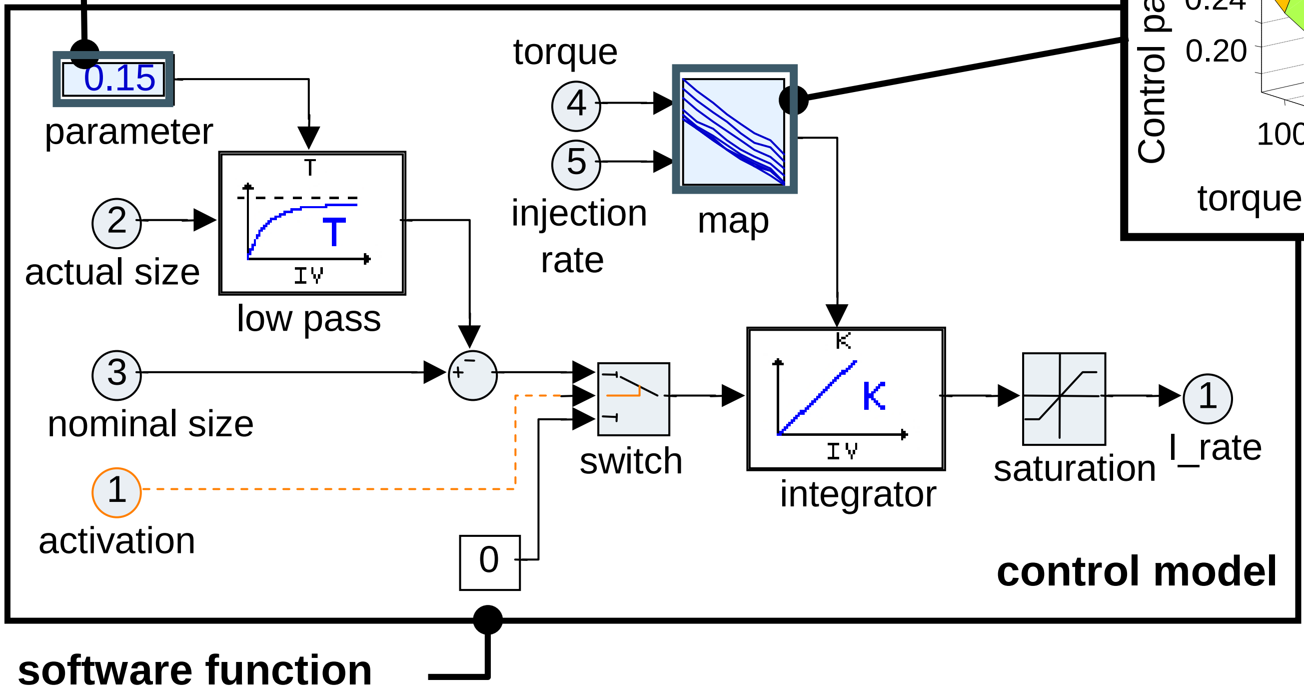
Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007 Vieweg Dieselmotor-Management / Bosch

Example: control unit function (I-rate controller)

data set

- adapted by calibration engineer
- access to control unit using special software





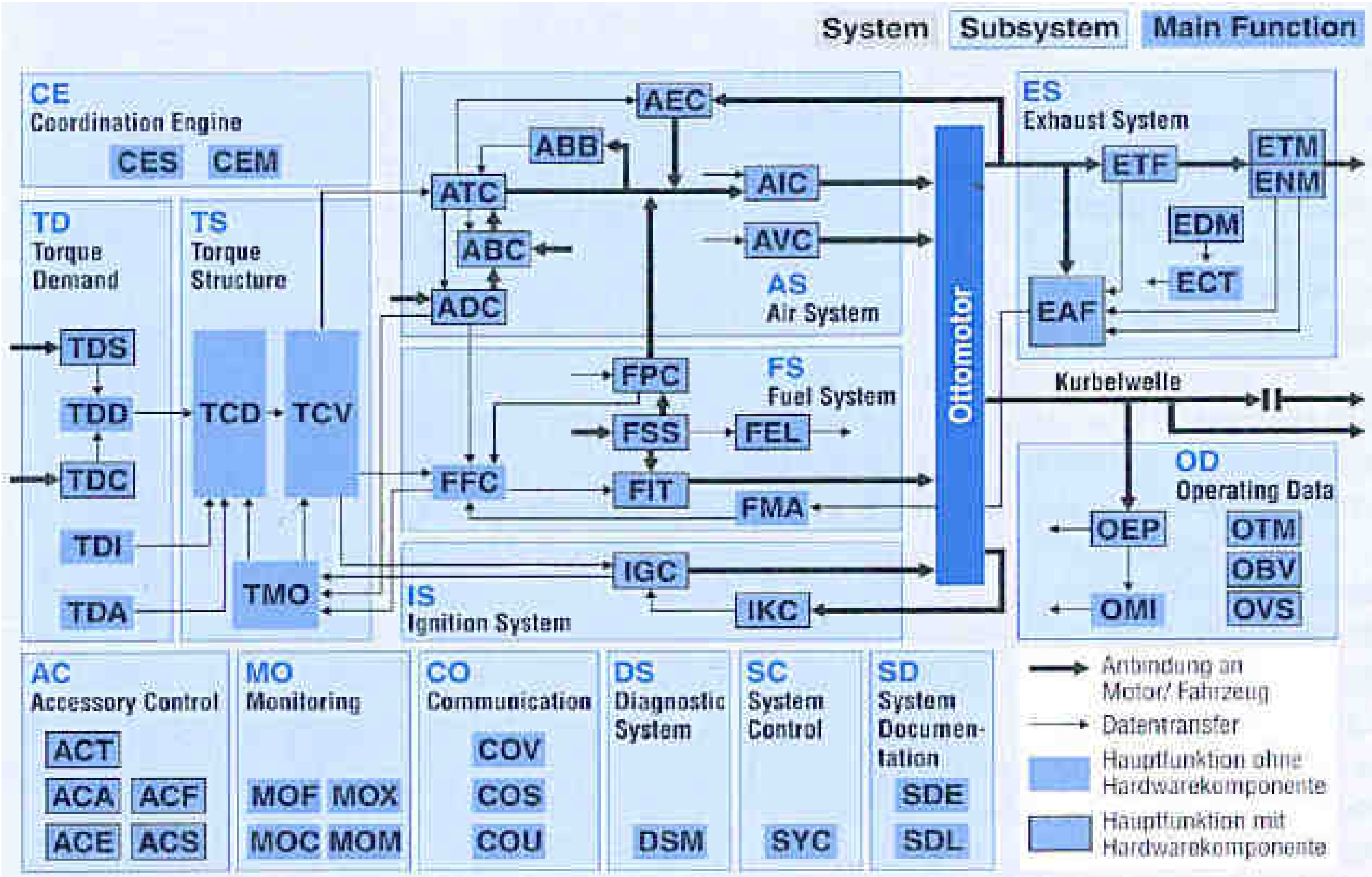
software function

- contains structural information, inputs and outputs, calculation blocks
- compiled by control equipment manufacturers
- no access by calibration engineer

Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007 Vieweg Dieselmotor-Management / Bosch

Structure of an engine control system

- system structure of the BOSCH Motronic:



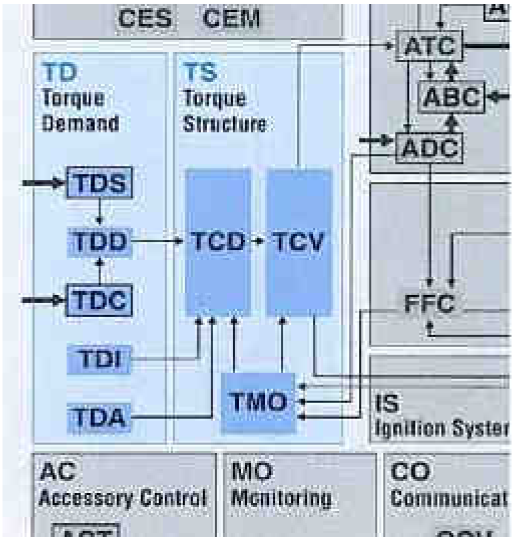
Quelle: Vieweg Otto/Dieselmotor-Management / Bosch

Structure of an engine control system

TD Torque Demand: captures all the torque requirements for the engine

- **TDS** Torque Demand Signal Conditioning: detection of the accelerator pedal position (E-Gas)
- **TDD** Torque Demand Driver: calculates a target engine torque from the accelerator pedal position. Sets the accelerator pedal characteristic.
- **TDC** Torque Demand Cruise Control: regulates the motor torque to maintain a constant speed by using the cruise control operation
- **TDI** Torque Demand Idle Speed Control: controlling the idle speed by calculating the required torque
- **TDA** Torque Demand Auxiliary Functions:

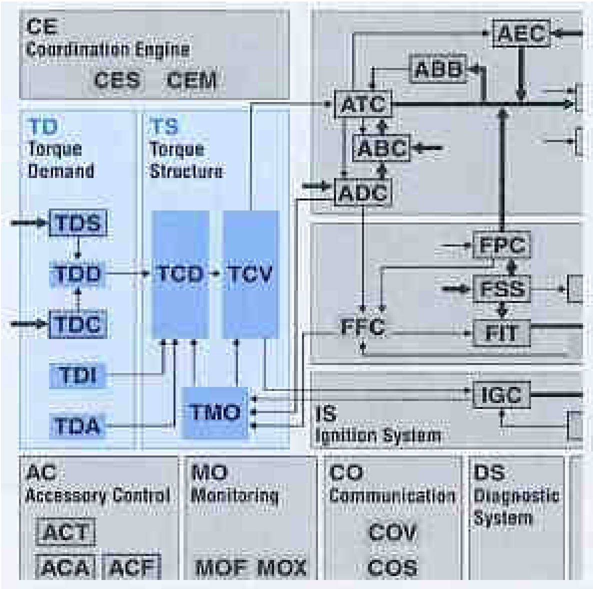
  generates internal torque limitations and requirements (eg torque limit)



Quelle: Vieweg Otto/Dieselmotor-Management / Bosch

Structure of an engine control system

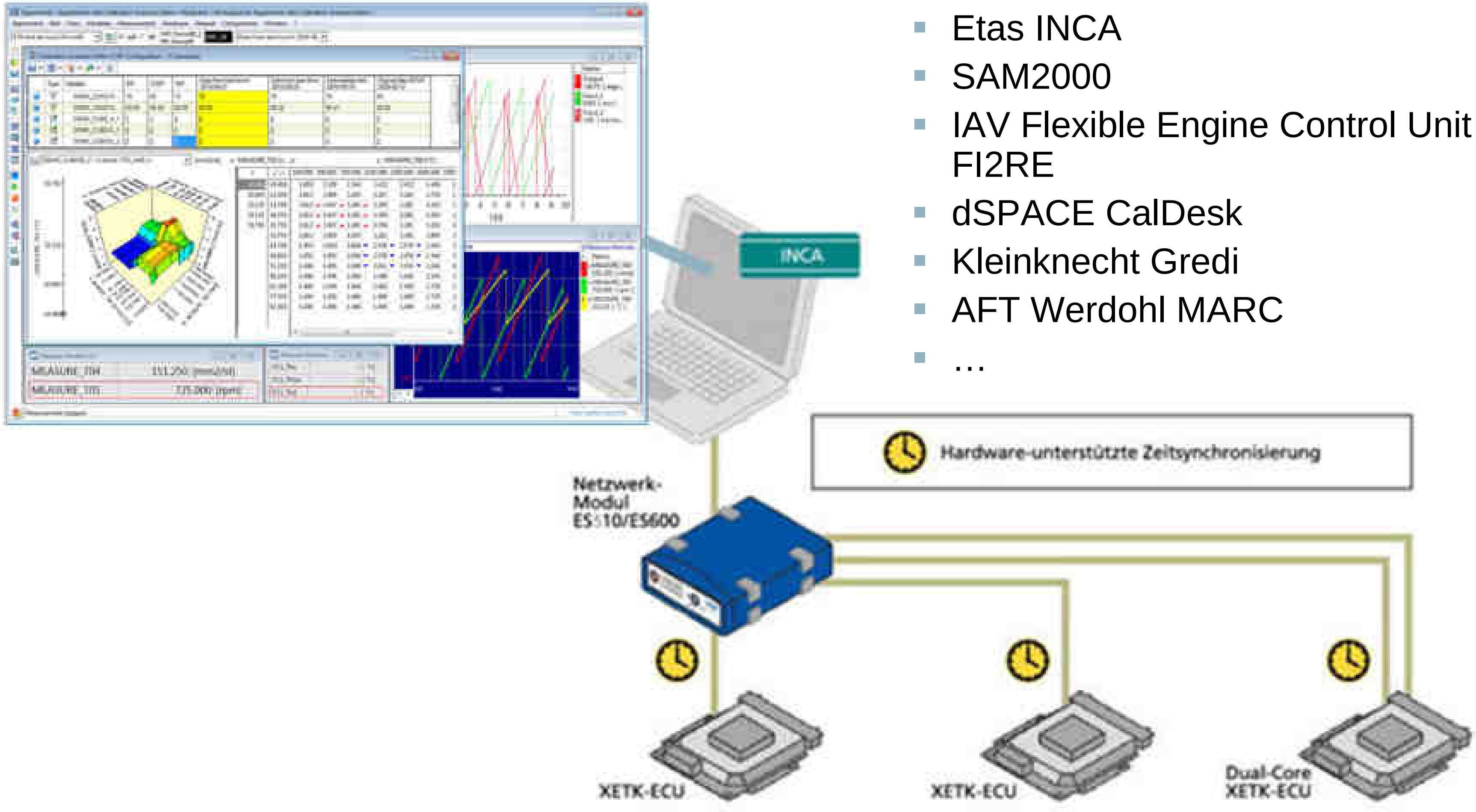
- **TS** Torque Structure: torque requirements are coordinated
  - **TCD** Torque Coordination: prioritization of the torque requirements
  - **TCV** Torque Conversion: calculates values for the required air mass, and the desired ignition angle and target lambda from the desired torque
  - **TMO** Torque Modeling: calculates the current torque from current measurements (lambda, air mass, ignition, torque)



Quelle: Vieweg Otto/Dieselmotor-Management / Bosch

Calibration of a ECU function

- systems on the market
  - Etas INCA
  - SAM2000
  - IAV Flexible Engine Control Unit FI2RE
  - dSPACE CalDesk
  - Kleinknecht Gredi
  - AFT Werdohl MARC
  - …



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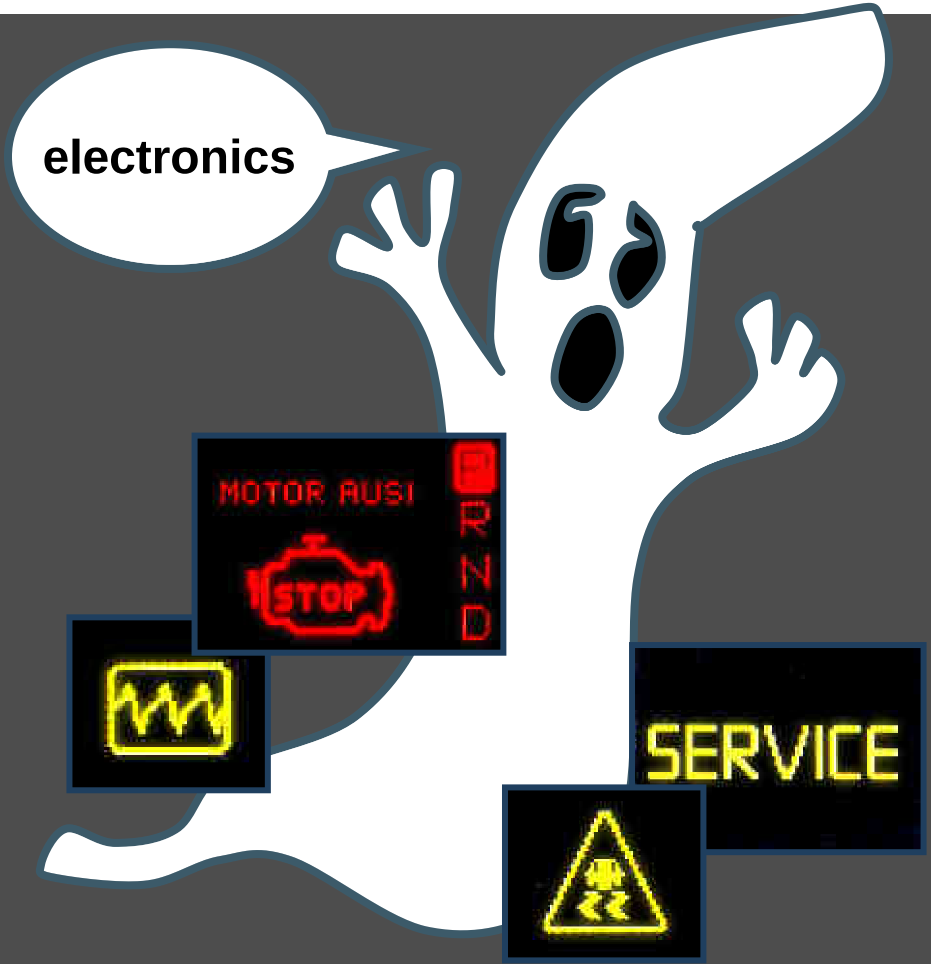
Quelle: www.seriouswheels.com

Electronics and software in the automobile and the customer acceptance



Cause and consequence

functionality

complexity

⚡ understanding

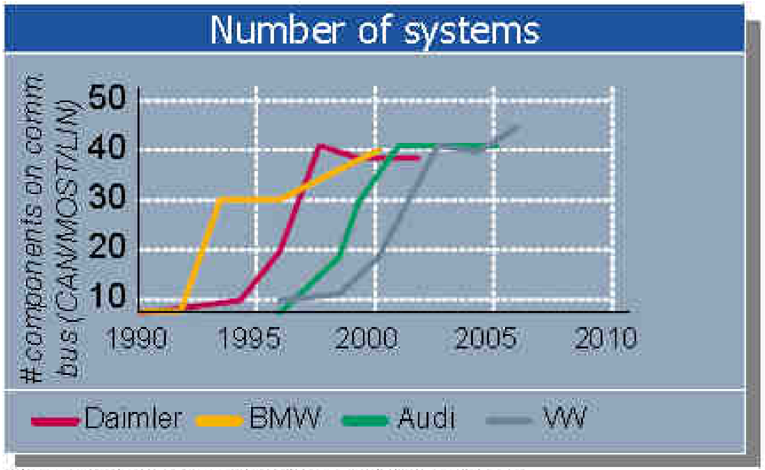
quality

reliability

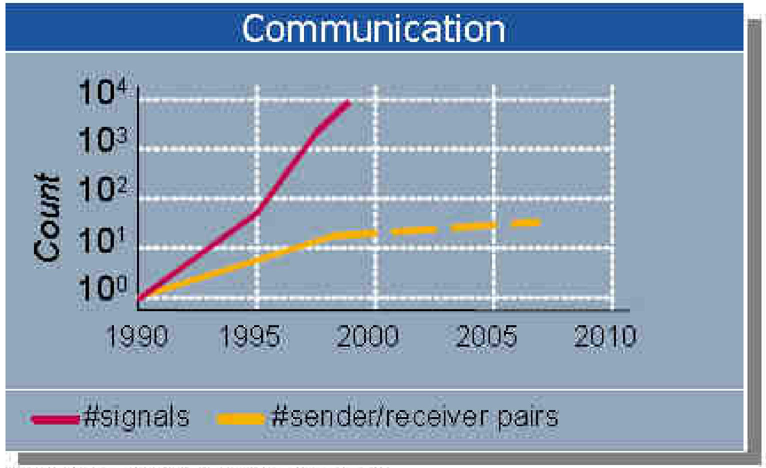
⚡ trust

Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007

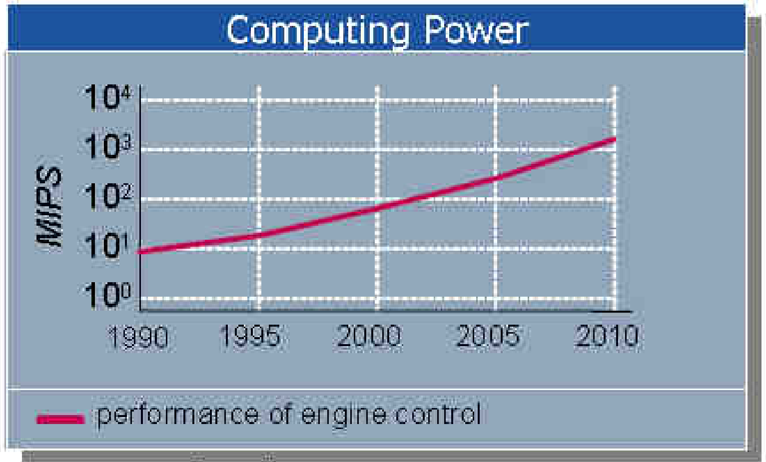
Motivation – increasing calibration effort



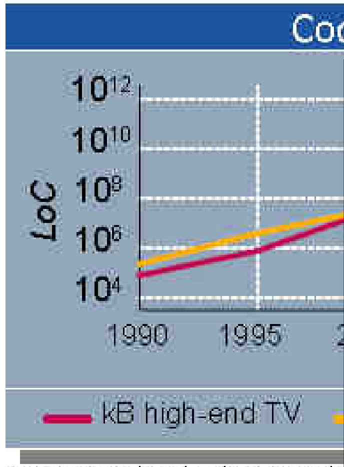
Source: VW 2005, Fachkongreß Automobil-Elektronik



Source: BMW, Frischkorn, BoCSE 2002



Source: NEC, 2006 (TOP57)



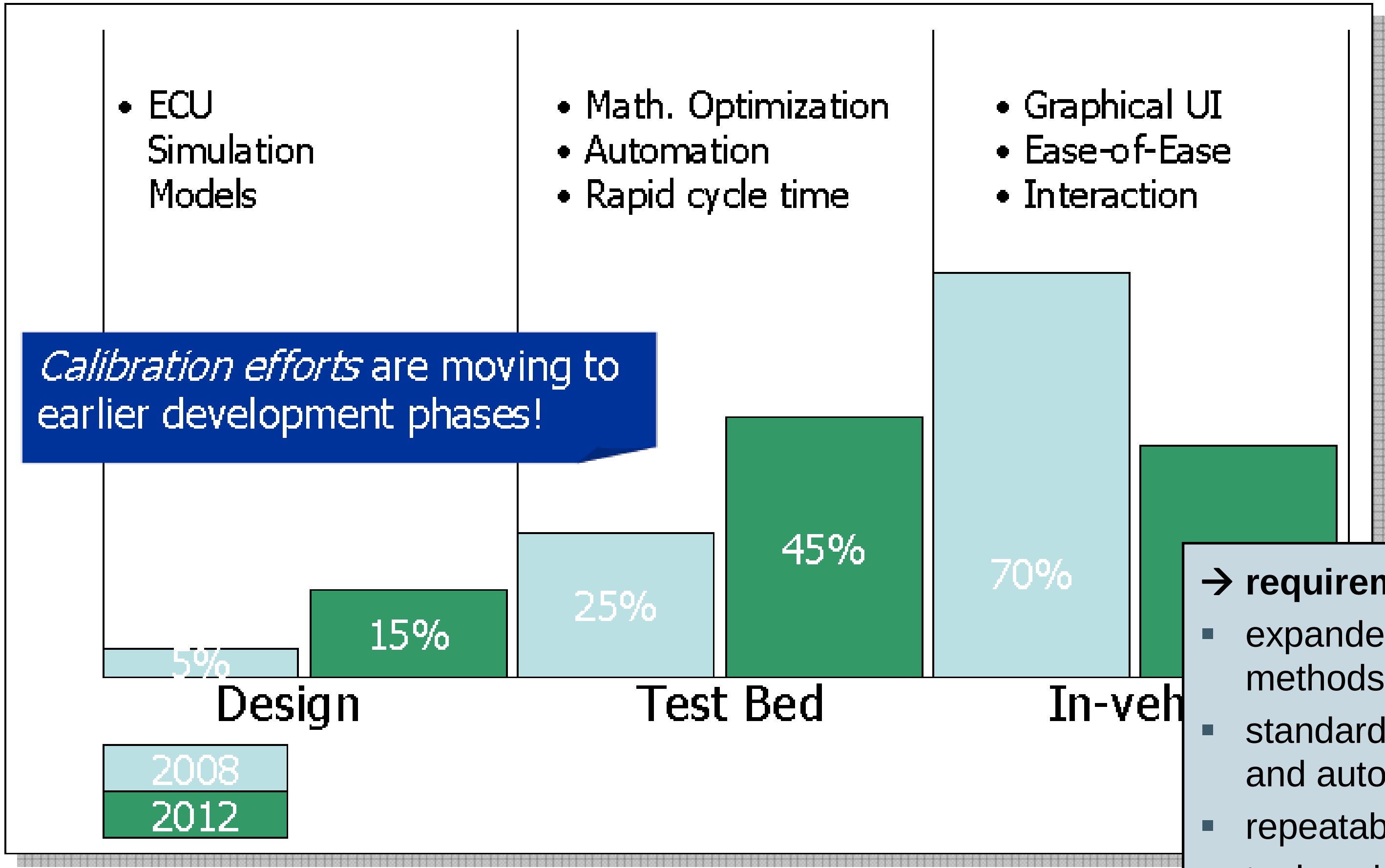
Source: Daimler-Chrysler 2004; Ph

→ requirement

- management of increasing complexity (understanding, data amount)
- ensuring quality and reliability
- reduction of development time and costs (e.g. prototype vehicles)

Quelle: Fast ECU Access via EtherCAT, Schnellbacher, ETAS GmbH

Motivation – shift to earlier stages of development



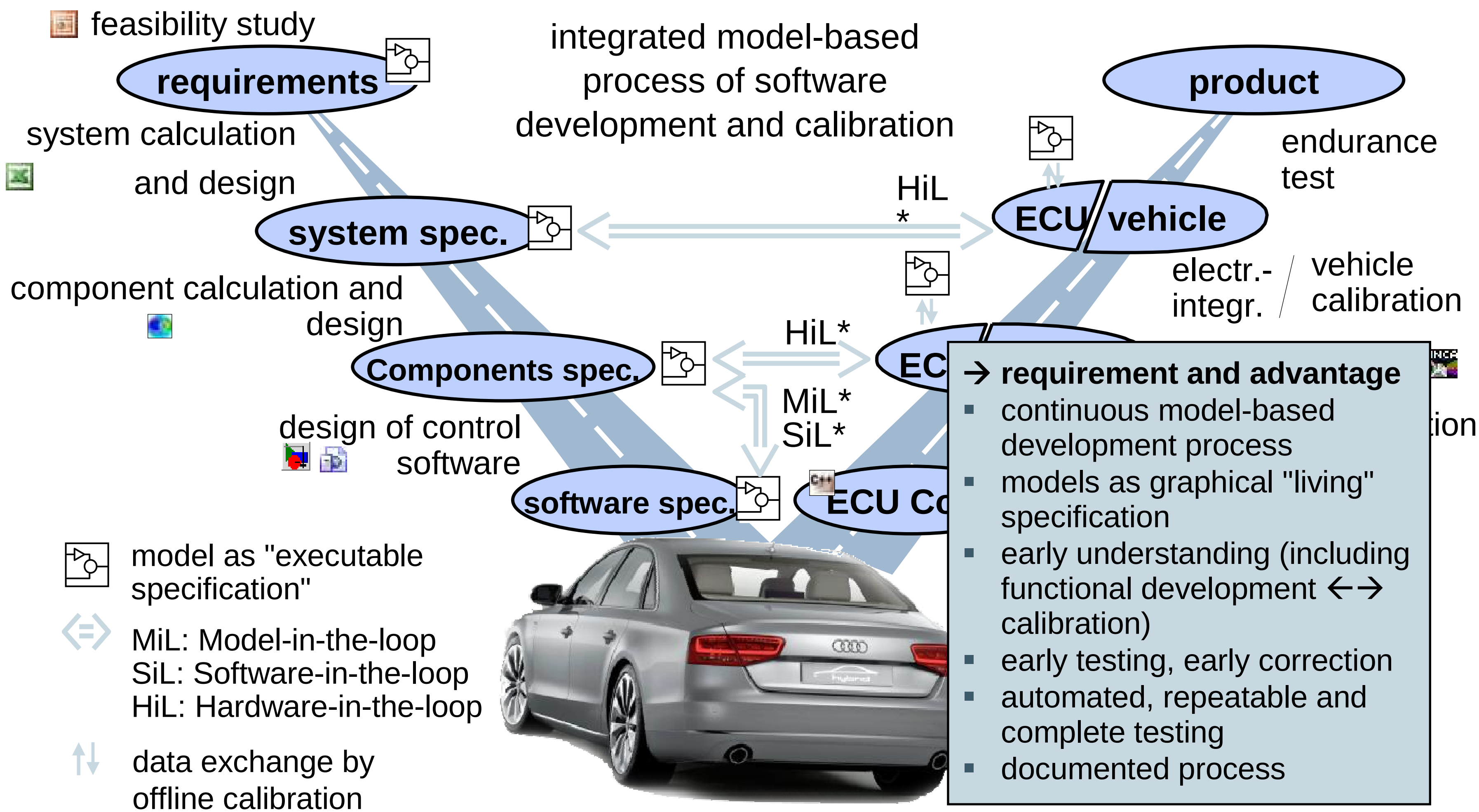
Source: ETAS internal Study

→ requirement

- expanded use of simulation methods
- standardized processes and automated procedures
- repeatability, portability
- tool-assisted optimization

Quelle: ETAS

Developement process - V-model (with calibration phases)



→ requirement and advantage

- continuous model-based development process
- models as graphical "living" specification
- early understanding (including functional development ←→ calibration)
- early testing, early correction
- automated, repeatable and complete testing
- documented process

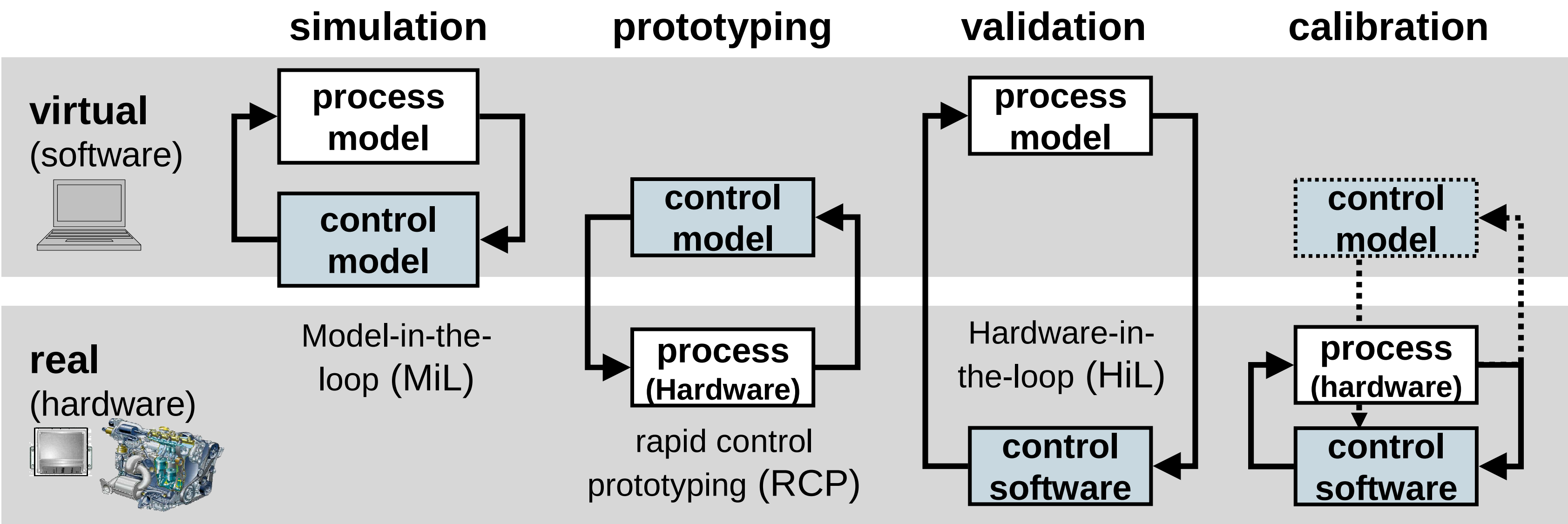
model as "executable specification"

MiL: Model-in-the-loop
SiL: Software-in-the-loop
HiL: Hardware-in-the-loop

data exchange by offline calibration

Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007

Development process of software for control units
Models in function development & calibration



<u>process models</u>

- physical models
  - formula relationships
  - physical effective direction
- non-physical models
  - characteristic fields from measurements
  - analytical (polynomial models, etc.)

<u>control models</u>

- physical models
  - Formula relationships (inverse)
  - model-based predictive control
- non-physical models
  - characteristic maps / curves
  - analytical (e.g. neural networks)

Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007

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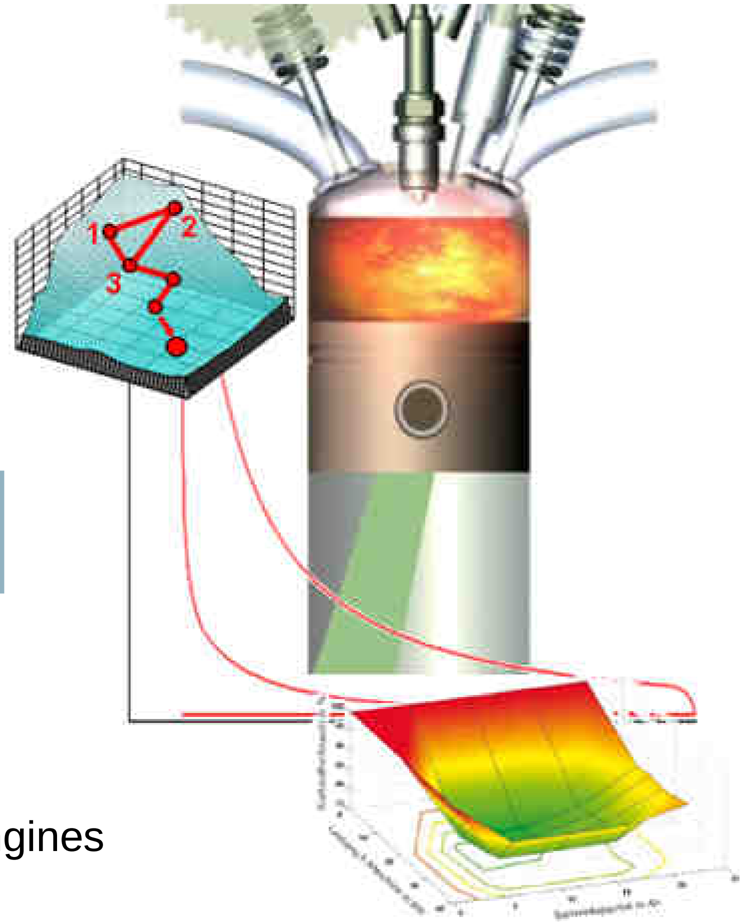
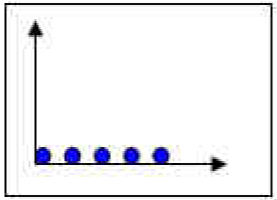


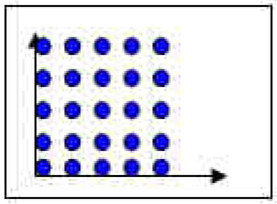
Quelle: Bertrandt

Why DoE ? – increasing measurement effort

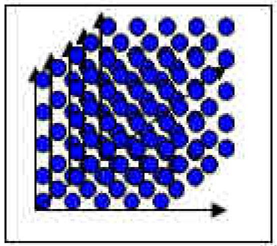
Dependency of the number of measurements on the variation parameters



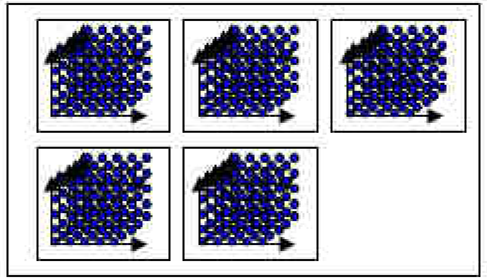
1 parameter
start of injection
=> 5 measurements



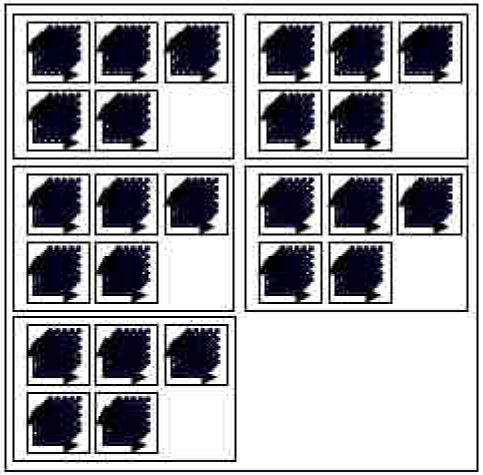
2 parameter
start of injection
rail pressure
=> 25 measurements



3 parameter
start of injection
rail pressure
EGR
=> 125 measurements



4 parameter
start of injection
rail pressure
EGR
boost pressure
=> 625 measurements



5 Parameter
start of injection
rail pressure
EGR
boost pressure
SL mass
=> 3000 measurements

Quelle: Bertrandt Applikationsschulung

Engine models for the emission calibration - tasks of models

requirements:

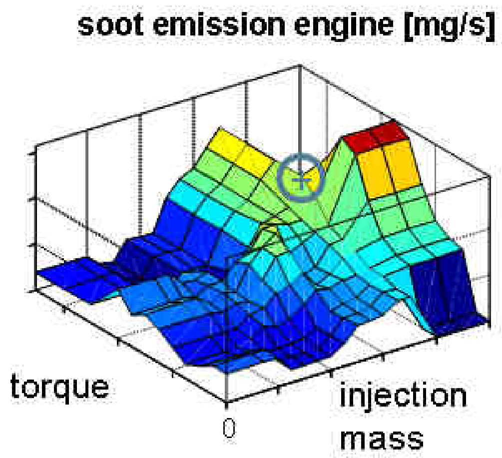
- description of the engine behavior (virtual engines)
- high number of input values (rail pressure, injection timing, pre-, post-injection, boost pressure, air mass, etc.)
- several output values (e.g. black smoke, NOx, CO, consumption)

target:

- reasonable measurement effort
- extracting the maximum amount of information from the measurement data
- minimizing the influence of measurement errors
- optimization of individual operating points

model:

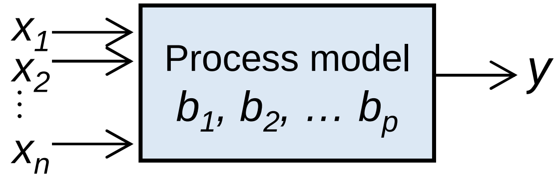
- physical models are not used (e.g. polynomial models)



Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007

Engine models for emission optimization – process models

In general:



Coefficients (to be calcul.)

Output value, measured (e.g. soot emission SZBO*)

*SZBO: Schwarzrauch, gemessen über Filtertrübung, korrelierbar zu Partikelmassenemissionen

Linear model:

$$y = \sum_{i=1}^{p} b_i \cdot f_i(x_1, \ldots, x_n)$$

- *n* inputs, *p* coefficients, to be calculated, one measured output value
- For each output value an own model is setup

Polynominal model:

$$y = b_1 + b_2 \cdot x_1 + b_3 \cdot x_2 + b_4 \cdot x_1 \cdot x_2 + b_5 \cdot x_1^2 + b_6 \cdot x_2^2 \qquad \text{(Bsp.)}$$

- Quadratic model for 2 input values
- Good behaviour, easy calculation
- Bad extrapolation behaviour

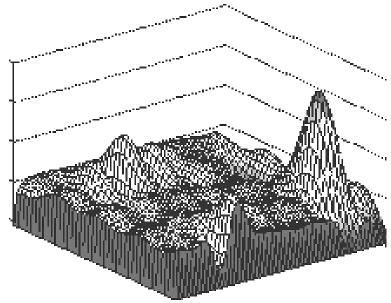
Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007

Engine models for emission optimization – Other types of models

Radial basis functions:

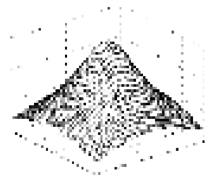
- Plane with „mountains“
- Advances possibilities in complexity
- Use as hybrid models (mixture of RBF and linear)

$$y = \sum_{i=1}^{p} b_i \cdot \phi\left(\|x - c_i\|\right)$$



mit ϕ (univariant functions):

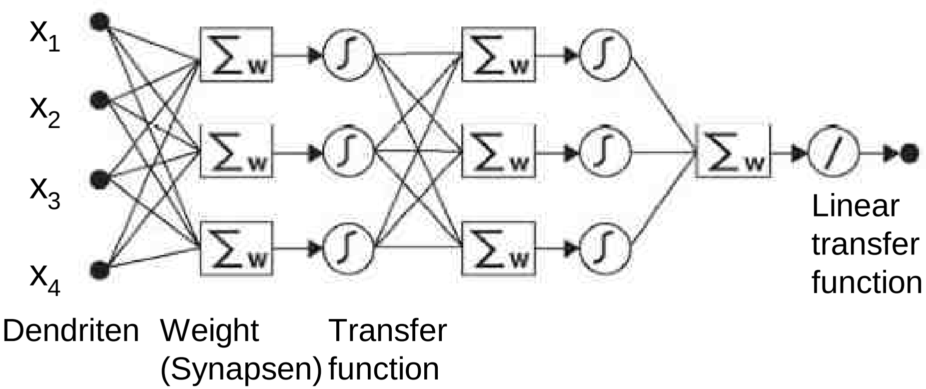
$$\phi = \frac{1}{\sqrt{r^2 + w^2}}$$



p: Number of terms, b: Weigthing, c: Center, ||..|| euclidic distance, w: Width

Neuronal network:

- Calculation units with weights
- Learning by connections, weights, thresholds
- Interpretation difficult



Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007

Engine models for emission optimization – calculation of a linear model

Calculation of the coefficients of a linear model

- p coefficients require a minimum of p measurements
- Linear regression for higher number n of measurements (over determined)

Linear regression $\sum (y_i - \hat{y}_i)^2 \stackrel{!}{=} \text{Minimum}$

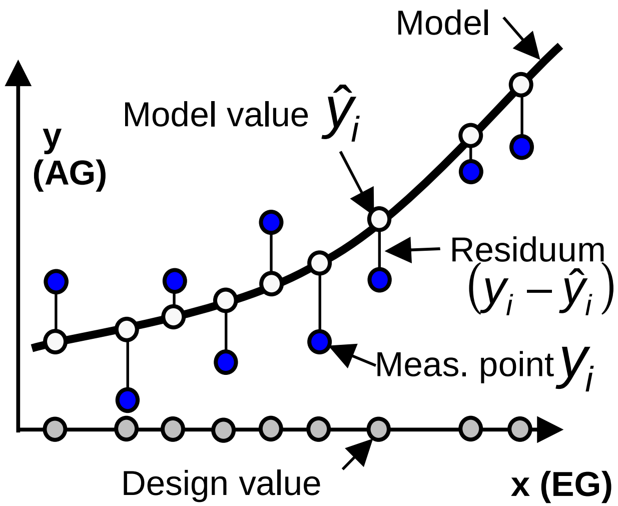
- Minimization of the sum of the quadratic distances between measurement values and model predictions
- Measurements at all points (**x**: vector):

$$\underbrace{\begin{pmatrix} y_1 \\ \vdots \\ y_n \end{pmatrix}}_{\mathbf{y}} = \underbrace{\begin{pmatrix} f_1(\mathbf{x}_1) & \cdots & f_p(\mathbf{x}_1) \\ \vdots & \ddots & \vdots \\ f_1(\mathbf{x}_n) & \cdots & f_p(\mathbf{x}_n) \end{pmatrix}}_{\mathbf{X}} \cdot \underbrace{\begin{pmatrix} b_1 \\ \vdots \\ b_p \end{pmatrix}}_{\boldsymbol{\beta}} + \underbrace{\begin{pmatrix} \varepsilon_1 \\ \vdots \\ \varepsilon_n \end{pmatrix}}_{\boldsymbol{\varepsilon}}$$

$$\hat{\mathbf{y}} = \mathbf{X}\hat{\boldsymbol{\beta}}$$

$$\sum (y_i - \hat{y}_i)^2 = (\mathbf{y} - \hat{\mathbf{y}})^2 = (\mathbf{y} - \mathbf{X}\hat{\boldsymbol{\beta}})^2 \stackrel{!}{=} \text{Minimum}$$

$$\hat{\boldsymbol{\beta}} = (\mathbf{X}^T\mathbf{X})^{-1}\mathbf{X}^T \cdot \mathbf{y}$$



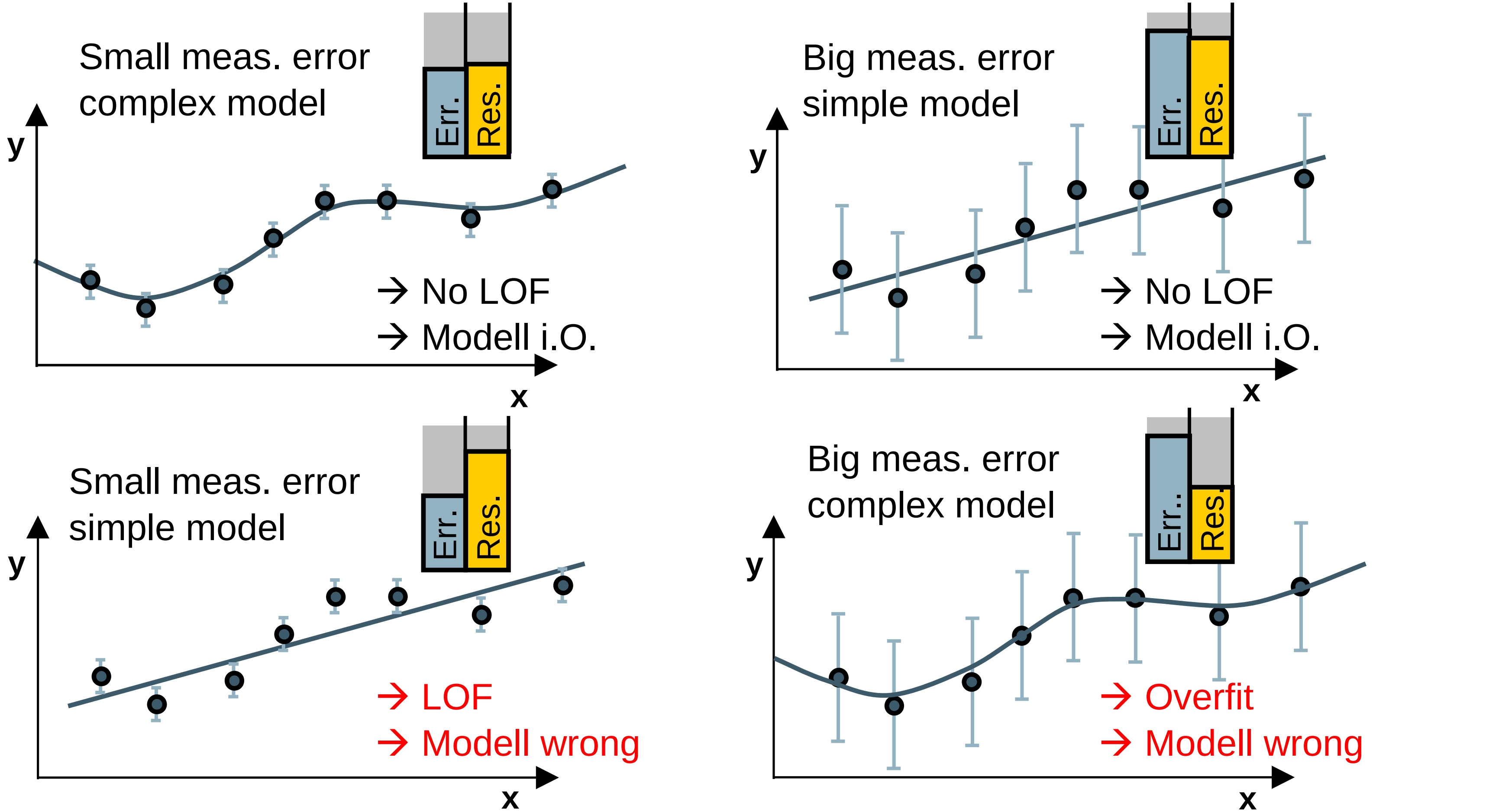
X: Design matrix ($p \times n$) depends on measurement points

β: Vector of model coefficients

ε: unknown statistical measurement error

Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007

Engine models for emission optimization – lack of fit



Err.: Pure Error
Res.: Residuum between model and measurement

Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007

Engine models for emission optimization – procedure

Model structure

- Choose of a model structure for the specific task (and each output value, like NOx, PM, etc.)

Design space

- Input values, 3-8 typical for Diesel engines (injection quantity, timings, rail pressure, air mass / EGR)
- Definition of the boundaries

Measurement points

- Design of Experiments (DoE)

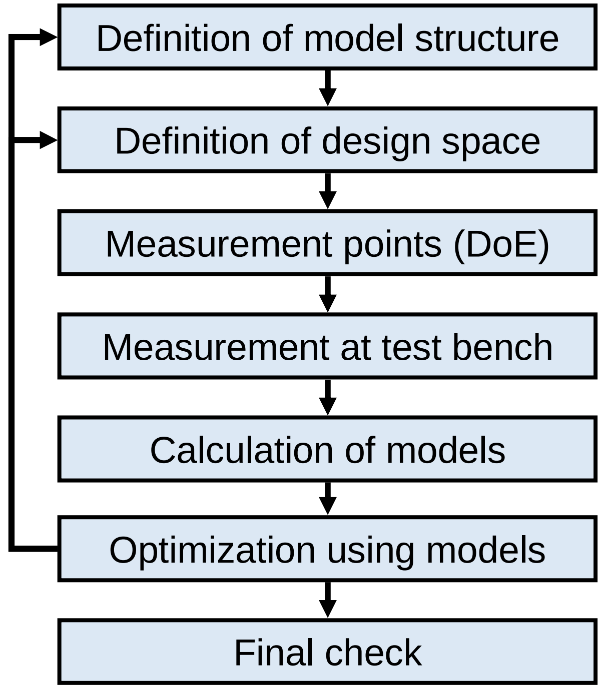
Calucation of the models

Optimization

- Definition of criteria and conditions
- Definition of a cost function
- Determination of the optimum values

Map calculation

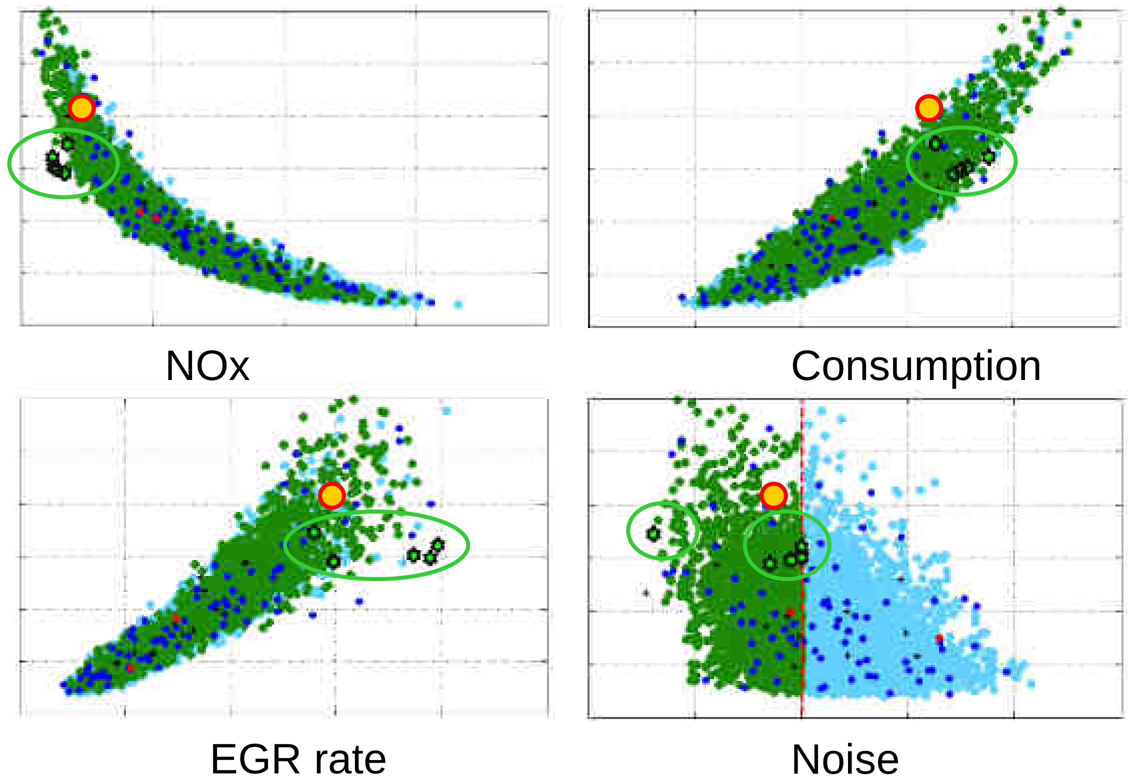
- After the optimization for each operational point
- Calculation with regard to map smoothness



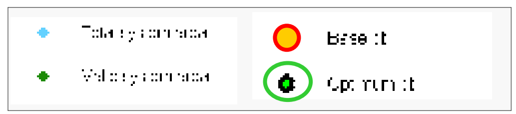
Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007

Engine models for emission optimization – trade off

Soot emission



- Black soot emission
- Variation of 8 input variables
- Optimization regarding NOx minization



- Optimization leads to lower NOx and soot emissions, but also slightly increasing fuel consumption
- Additional reduction of particulate emissions by aftertreatment

Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007, FEV PROcal

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- Introduction
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- Calibration on the engine test stand
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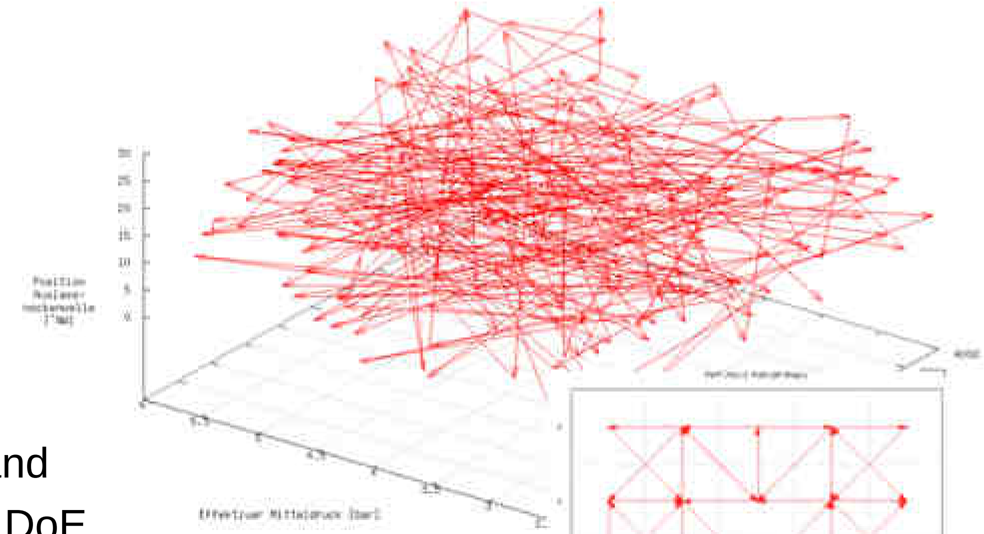
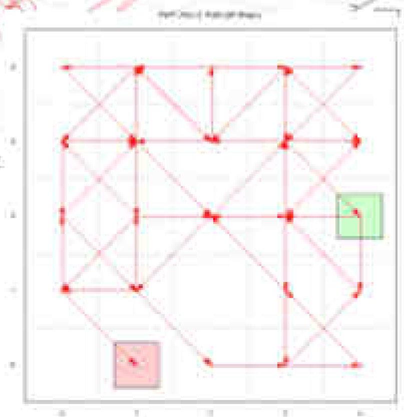
  - **Alternative calibration processes**
- Automobile calibration
  - Loading and oxidation of DPF systems
  - Misfire detection diagnosis of gasoline engines
- Summary and outlook



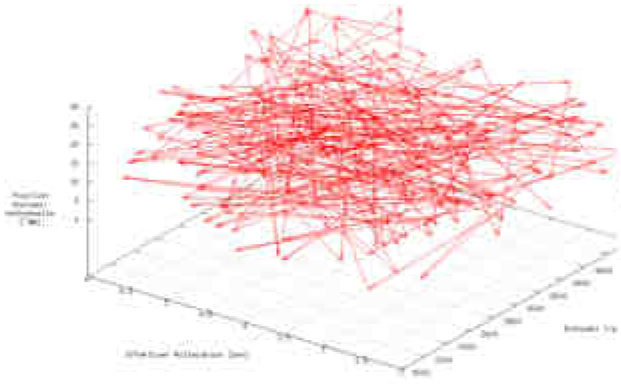


Quelle: Bertrandt, TU Darmstadt

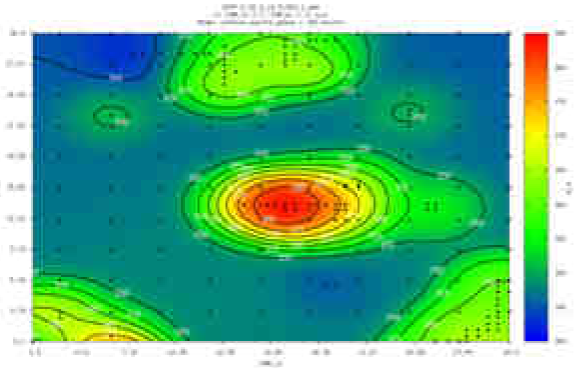
Base calibration with multidimensional engine measurements - Task

- Bertrandt in cooperation with a PhD studie (TU Darmstadt)
- Task (like model-base calibration using DoE)
  - Solving of n-dimensional optimization problems
- Tool design for the calibration procedure and its automation

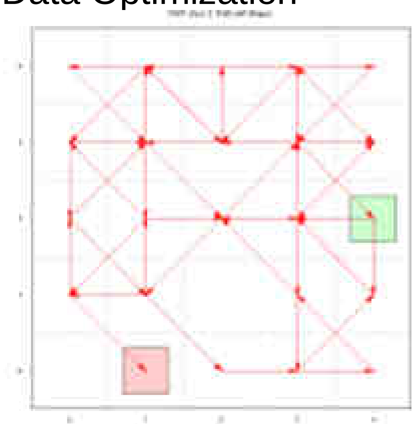
Data Acquisition



Data Analysis



Data Optimization



Quelle: Bertrandt, TU Darmstadt

Base calibration with multidimensional engine measurements - Method

Test plan

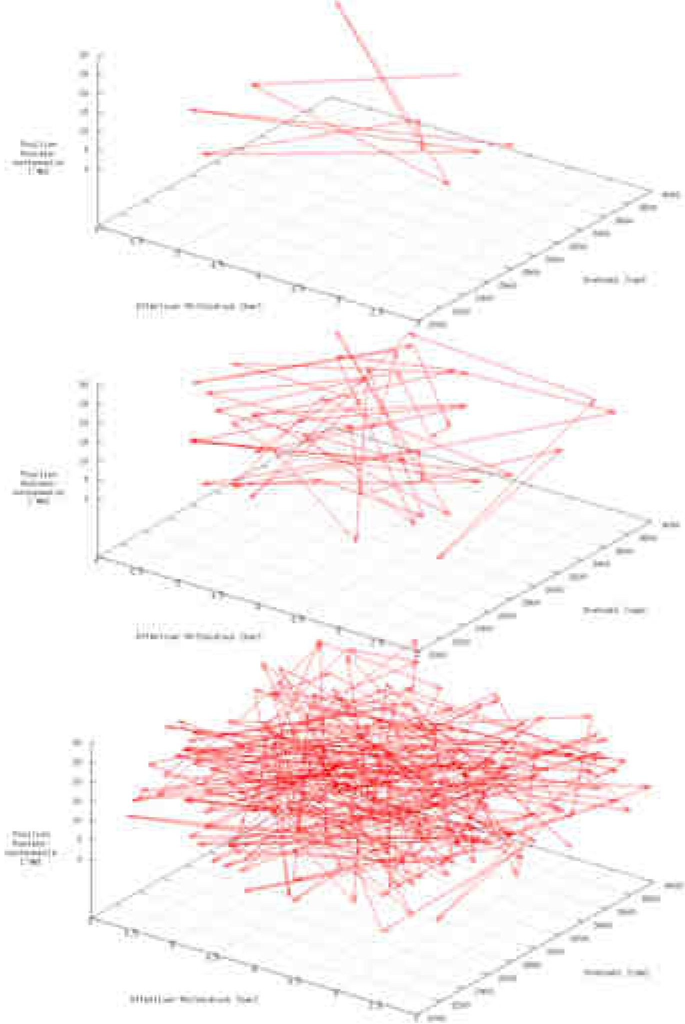
- Simulation of the spreading of the measurement points
- Definition of the variation limits and the gradients

Measurements

Evaluation

- Plausibility (limits, elimination of oszillations)
- Weight factors (stationary optimum)
- Limitation of maximum gradients of actuator signals (transient optimum)
- Automated map calculation and optimization with regard to map smoothness

Avaliable as tool (software)



Quelle: Bertrandt, TU Darmstadt

Base calibration with multidimensional engine measurements - Evaluation

Test plan

- Simulation of the spreading of the measurement points
- Definition of the variation limits and the gradients

Measurements

Evaluation

- Plausibility (limits, elimination of oszillations)
- Weight factors (stationary optimum)
- Limitation of maximum gradients of actuator signals (transient optimum)
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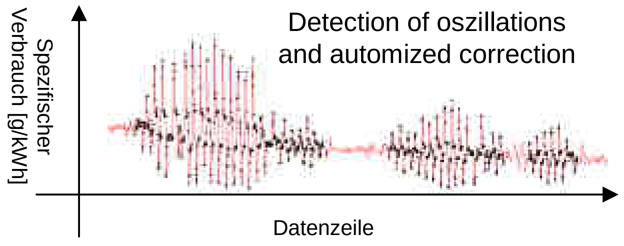
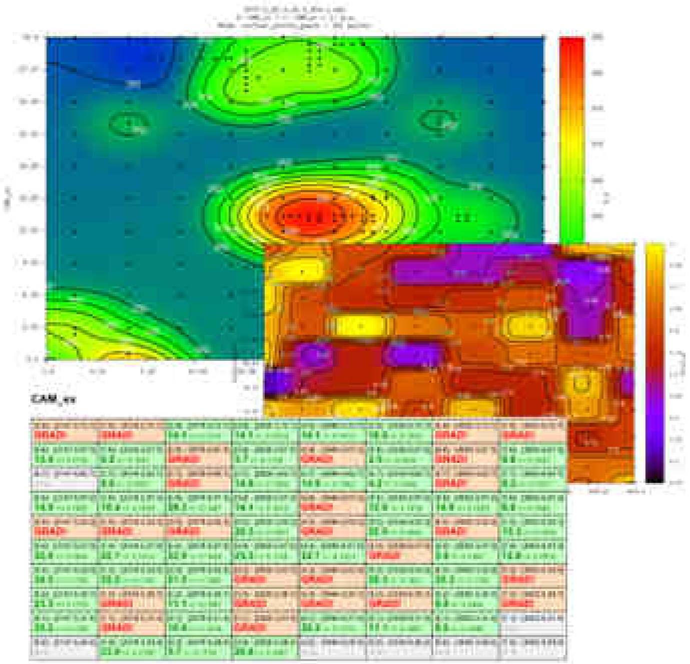
Avaliable as tool (software)





Detection of valid gradients and optimization

Quelle: Bertrandt, TU Darmstadt

Base calibration with multidimensional engine measurements – Software tool

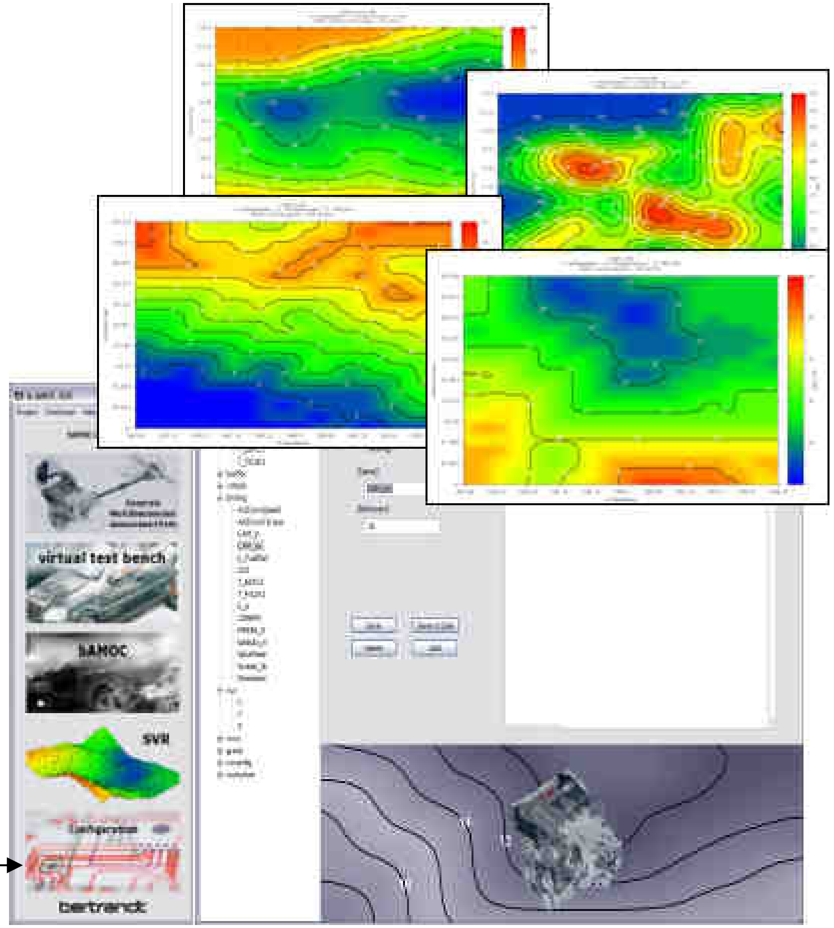
Test plan

- Simulation of the spreading of the measurement points
- Definition of the variation limits and the gradients

Measurements

Evaluation

- Plausibility (limits, elimination of oszillations)
- Weight factors (stationary optimum)
- Limitation of maximum gradients of actuator signals (transient optimum)
- Automated map calculation and optimization with regard to map smoothness



Avaliable as tool (software)

Quelle: Bertrandt, TU Darmstadt

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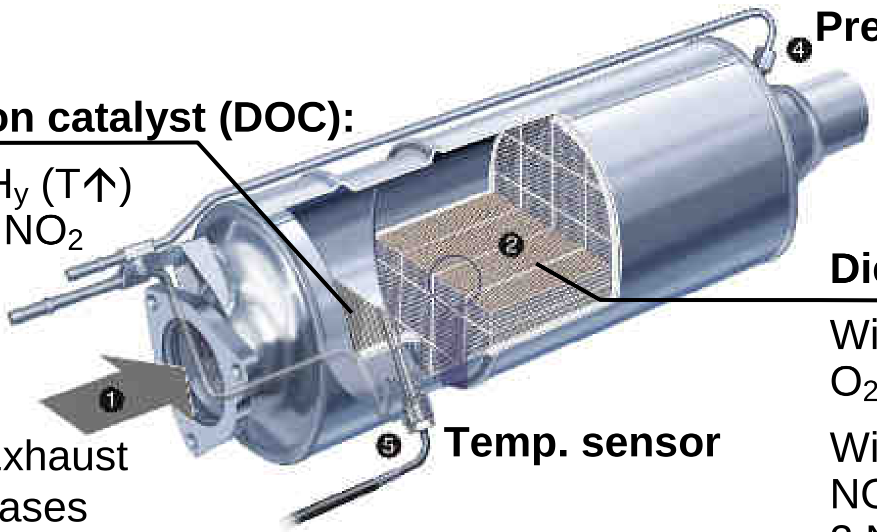
  - **Loading and oxidation of DPF systems**
  - Misfire detection diagnosis of gasoline engines
- Summary and outlook

Quelle: Opel / Auto-Reporter.net, u.a.

Calibration of DPF Systems in the vehicle – Function of a DPF

- Reduction of soot particles from the exhaust gas
- Accumulation of soot particles (**adsorption**) causes increasing back pressure
- Periodical oxidation of stored soot particles necessary (**regeneration**)
  - Increasing the temperature in DOC for **Light-off** (HC conversion)
  - Additional temperature increase to ignition temperature of soot in DPF
- Continous oxidation by CRT or NO2 effect



Pressure sensor

Diesel oxidation catalyst (DOC):

oxidation of C_xH_y (T↑)
$2\ NO + O_2 \rightarrow 2\ NO_2$
(CRT, 320℃)

Exhaust gases

Temp. sensor

Diesel particulate filt. (DPF):

With Oxygen (ca. 630℃)
$O_2 + C \rightarrow CO_2$

With NO2
$NO_2 + C \rightarrow CO + NO$
$2\ NO_2 + C \rightarrow CO_2 + 2\ NO$

Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007

Calibration of DPF Systems in the vehicle – State machine

State machine

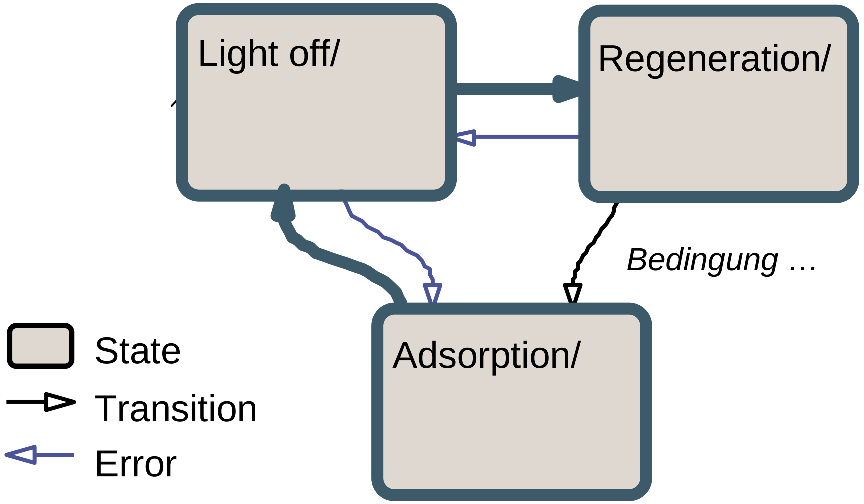
- Controls the states and the prodedures
- Change of the state by conditions

Conditions in normal model:

- Detection of full DPF by threshold → State change (transition) to Light Off
- Light-off temperature reached → State change to regeneration
- Detection of oxidation complete → State change to adsorption (normal) with following ash detection

In case of problems:

- E.g. temperature too high
- State changes backwards

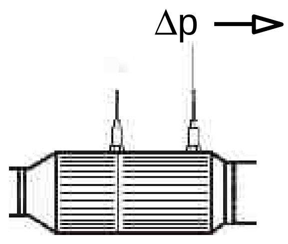


Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007

Calibration of DPF Systems in the vehicle – Loading model

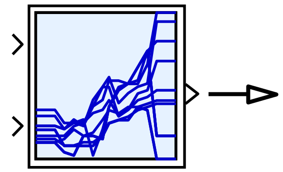
Delta-p model

- Mearsurment of differential pressure over DPF for calucation of the soot load
- Ash correction also by differential pressure after successful regeneration



Soot simulation model

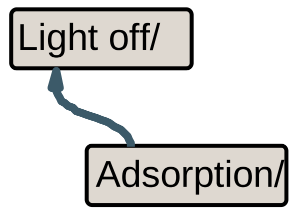
- Calculation of the soot load by actual emissions from engine (integrated soot emission massflow)
- Map-based, depending on driving cycle



Soot emission from engine

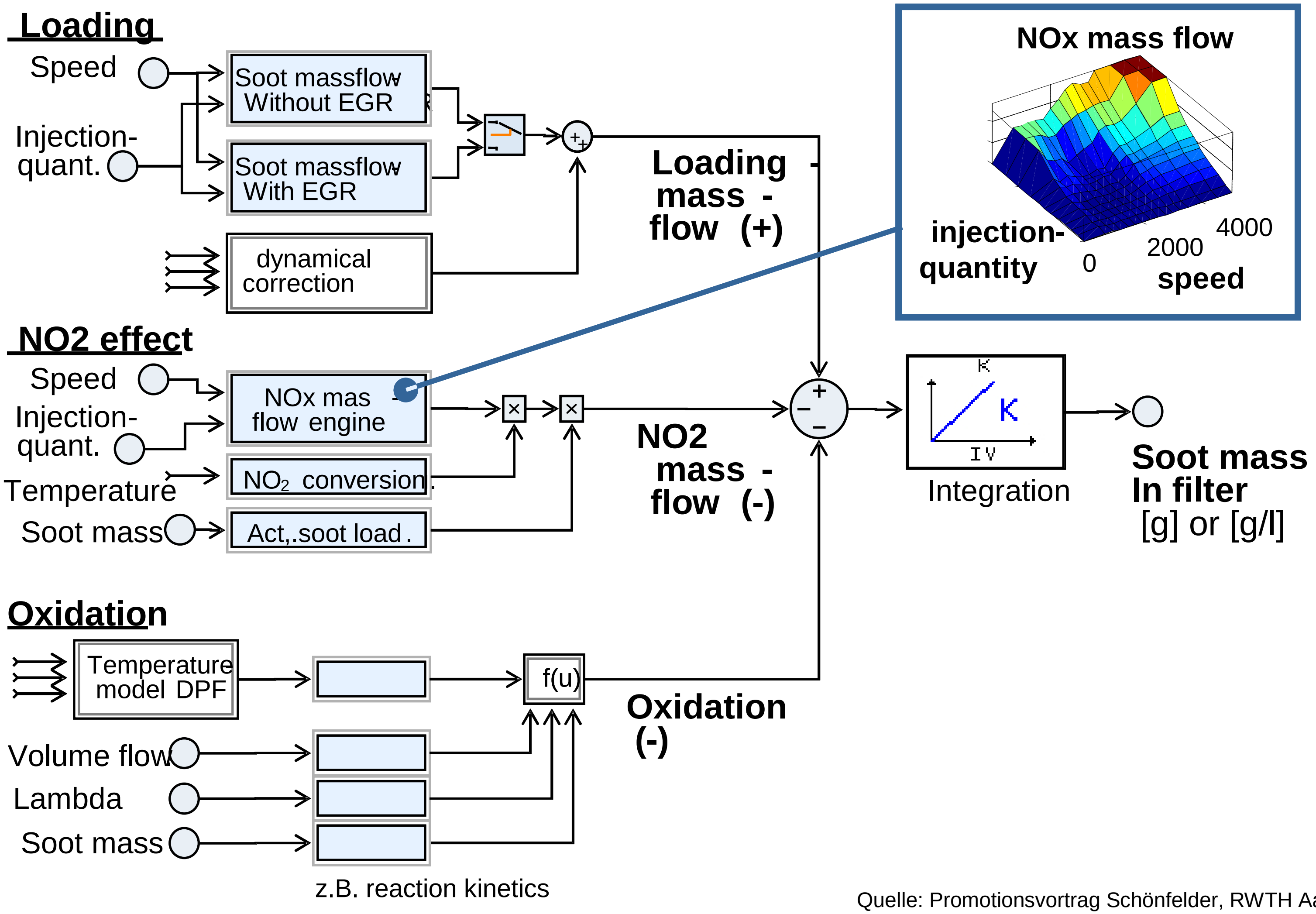
Start of regeneration request

- Soot load from delta-p or soot simulation model exceeds a threshold
- Additional criteria:
  driving distance, fuel consumption, driving cycle, manual service request



Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007

Calibration of DPF Systems in the vehicle – Soot simulation model



Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007

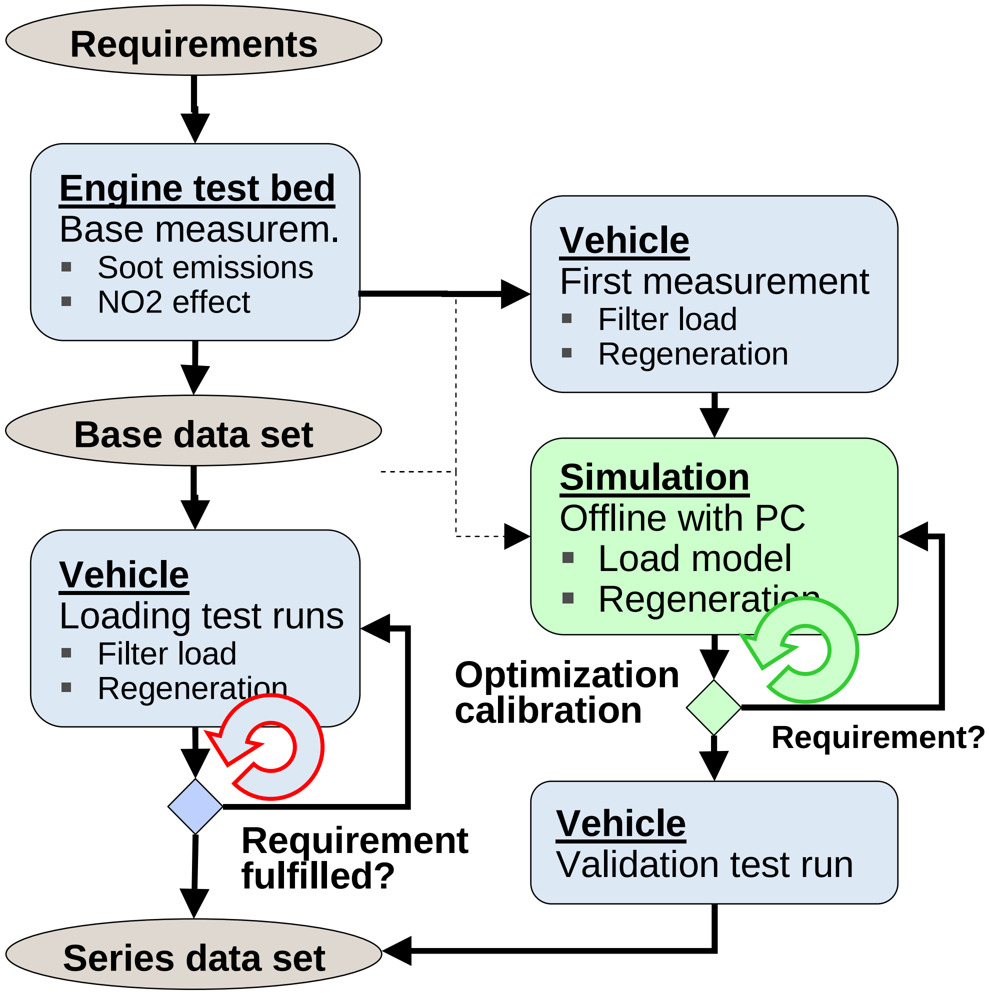
Calibration of DPF Systems in the vehicle – Calibration process

Conventional

- Many test runs
- Time for development
- High costs

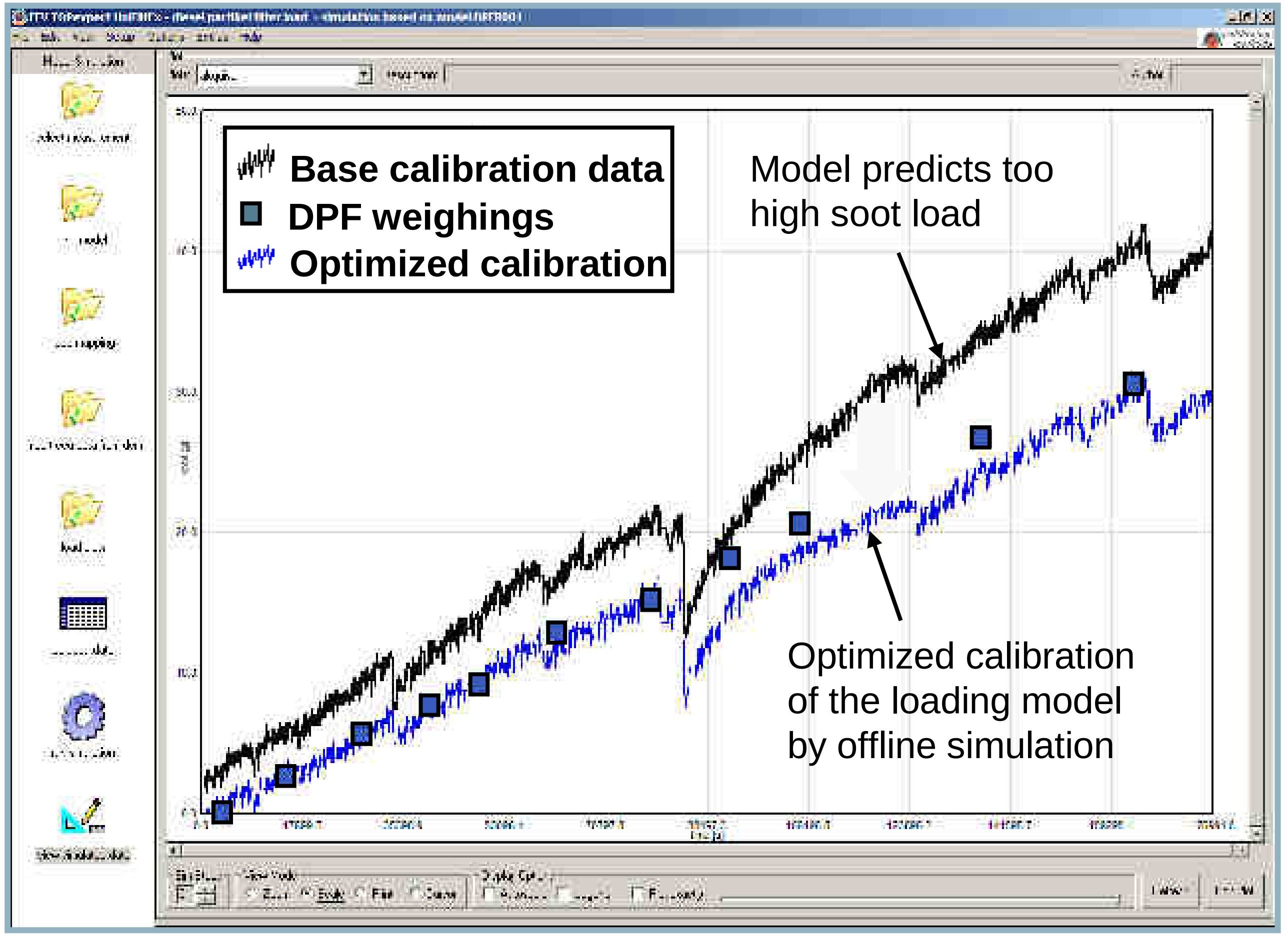
Model supported

- Decoupling from test bench and vehicle
- Fewer prototype vehicles
- Reduction of time and costs
- Increasing quality
- Automation of process



Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007

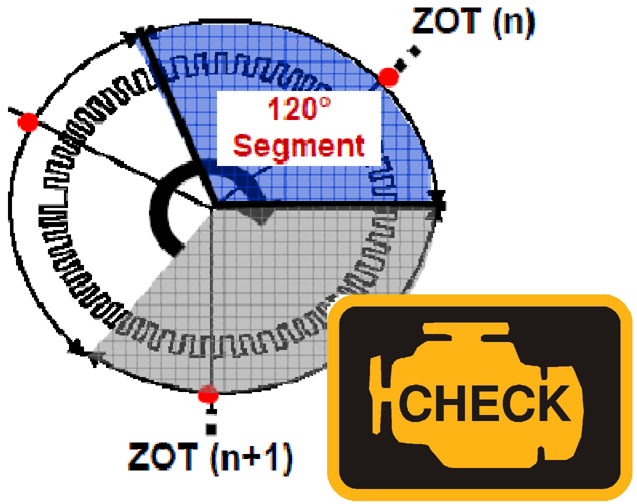
Calibration of DPF Systems in the vehicle – Example of a offline simulation



- 6-day test run
- ECU model of the sool loading
- Simulation of the ECU model and optimization of the calibration by a software tool

Quelle: Promotionsvortrag Schönfelder, RWTH Aachen 2007, FEV TOPexpert vehicle suite

Content



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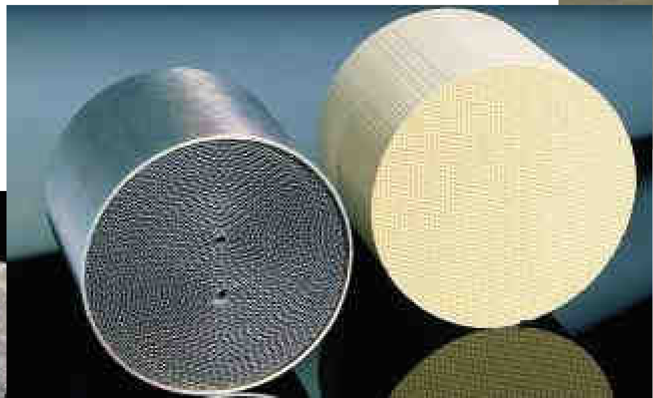
- Summary and outlook

Quelle: div.

Diagnosis Misfire Detection - Misfire

Reason:

- Failure of the ignition
  - Malfunction in the ignition system (ign.- coil, ign.- plug)
  - Bad fuel-mixture generation (λ, airflow meter, throttle)
- Failure of the fuel supply
  - Malfunction in the fuel injection system (inj.- valve, fuel pressure)

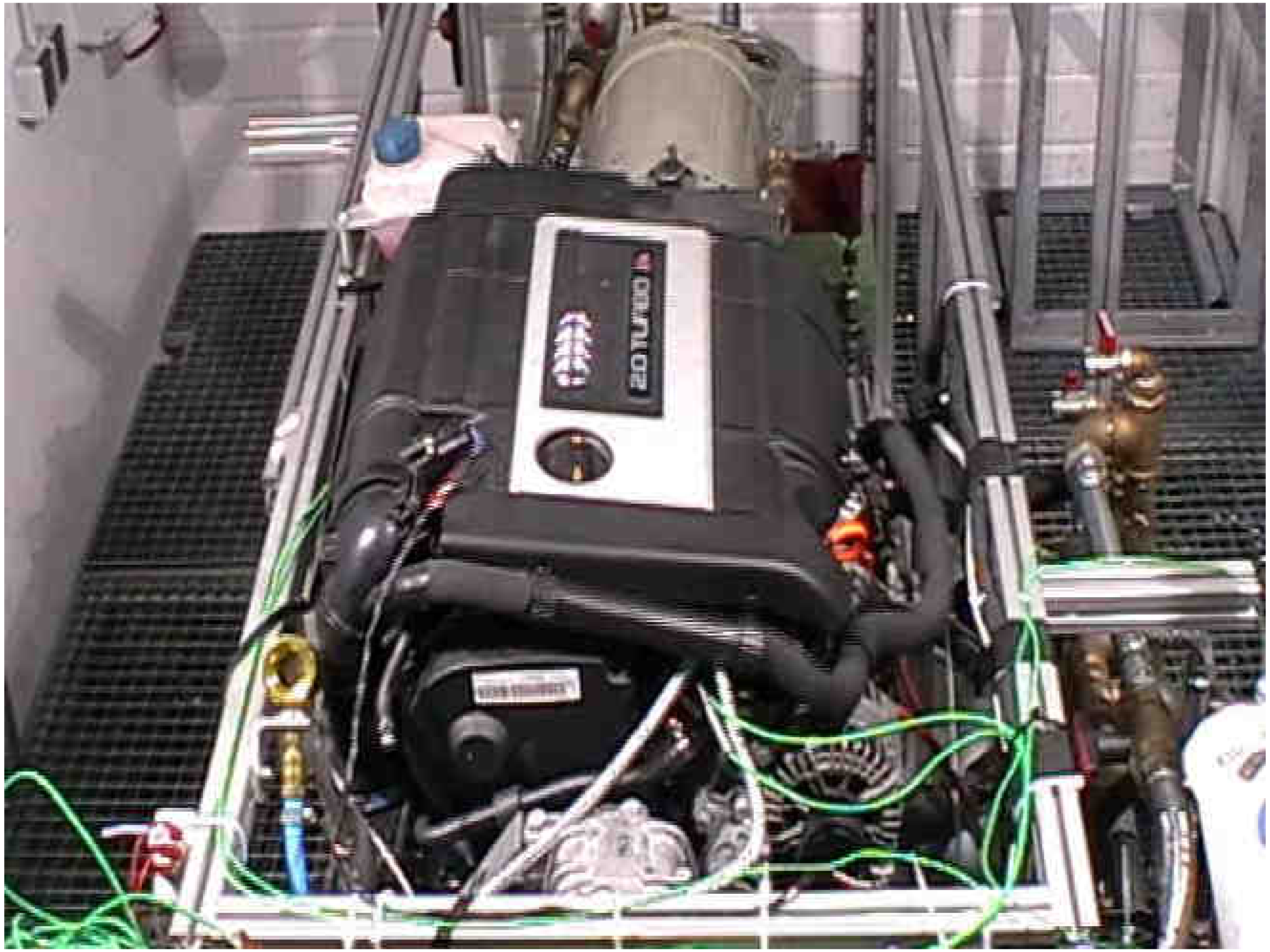


Consequence:

- Unburned fuel into exhaust
  - → Raised exhaust emissions
  - → Catalyst destruction by overheating
- Lost Power
- Disturbed engine running

Quelle: Diplomarbeit Jan Brycki, Bertrandt Ingolstadt, KFZ-Technik SEUBERT

Diagnosis Misfire Detection - Video



Quelle: Diplomarbeit Jan Brycki, Bertrandt Ingolstadt

Diagnosis Misfire Detection - Legislation

OBD Legislation →

- Continuous monitoring of all exhaust emissions components in all vehicles
- Collecting and reporting of exhaust increases during the hole vehicle operating time
- Warranty of low emissions
- Component protection, e.g. the catalyst during misfires
- Saving errordata
- Allocate an interface to readout fault memory and actual measurement data

→ Diagnosis in the ECU

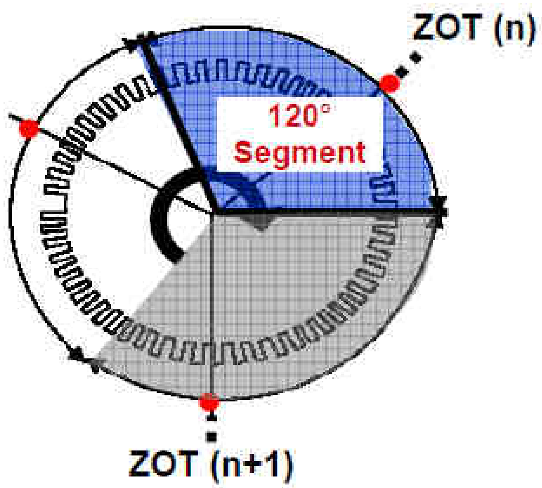
- Due to the fact that there is no direct method to measure misfires, the detection occurs indirectly through the analysis of the engine roughness.
- The result of a misfire is a reduced torque within the affected combustion cycle. The effect is a lower angular speed.
- This delay is measurable.

Quelle: Diplomarbeit Jan Brycki, Bertrandt Ingolstadt

Diagnosis Misfire Detection – Principle of misfire detection

Measurement of Segment times → Calculation of engine roughness → Calculation of Thresholds → Rating of engine roughness

example: six-cylinder engine



Kurbelwellen - Geberrad

- The segment time tells the time which a particular segment of the KW pulse-generator wheel needs to overtake the speed sensor.
- For each ignition a segment time is determined. Segment start and segment length can be defined with application variables.
- Every 120 °KW there is a combustion. For 4-cyl. corresponding to every 180 °KW

Quelle: Diplomarbeit Jan Brycki, Bertrandt Ingolstadt

Diagnosis Misfire Detection – Engine Roughness

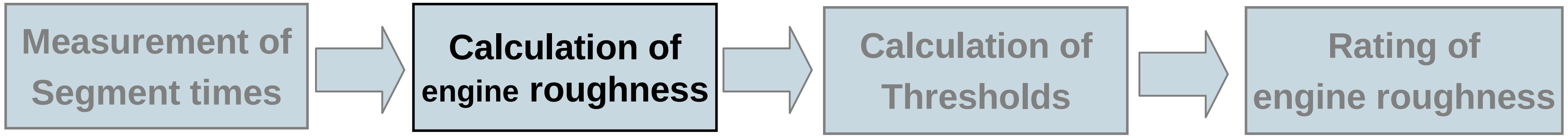
Measurement of Segment times → **Calculation of engine roughness** → Calculation of Thresholds → Rating of engine roughness

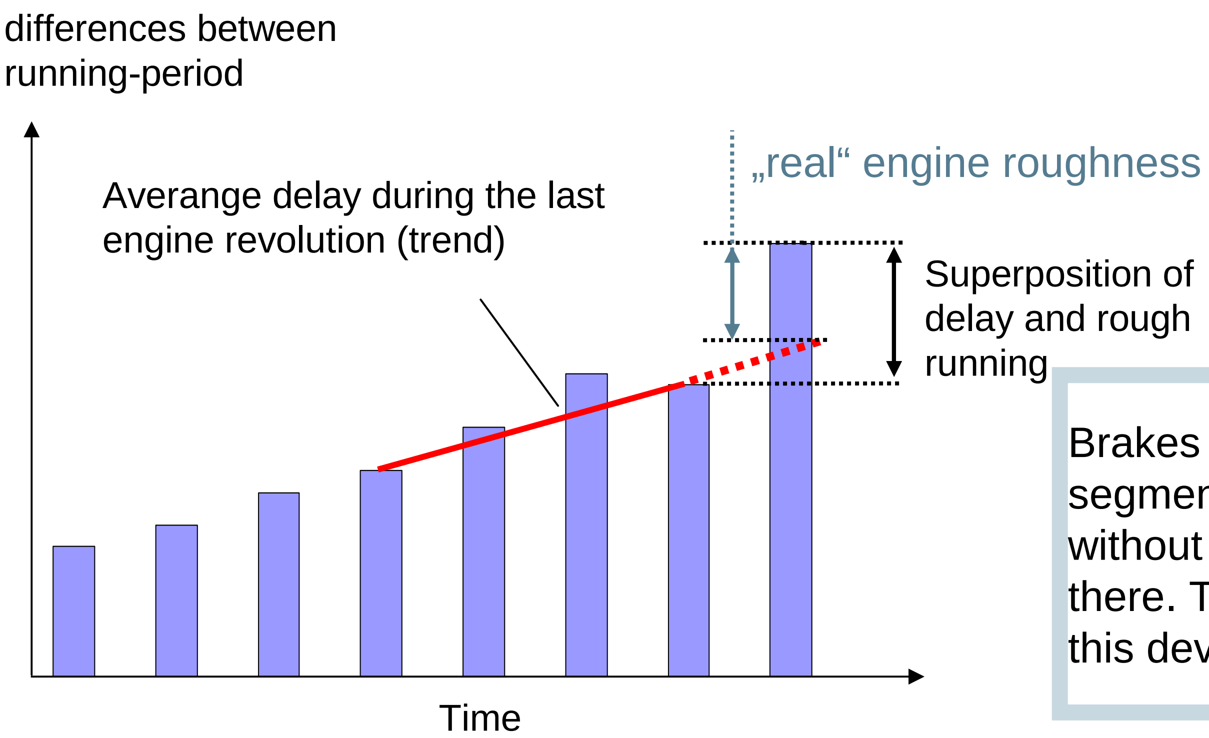
Engine roughness = Segment time (n +1) - Segment Time (s) - Compensation time

The difference between the stored segment time and the current segment time taking into account of dynamic processes (accelerating or braking) results in rough running for each cycle. The rough running is normally zero.

Quelle: Diplomarbeit Jan Brycki, Bertrandt Ingolstadt

Diagnosis Misfire Detection – Rough running



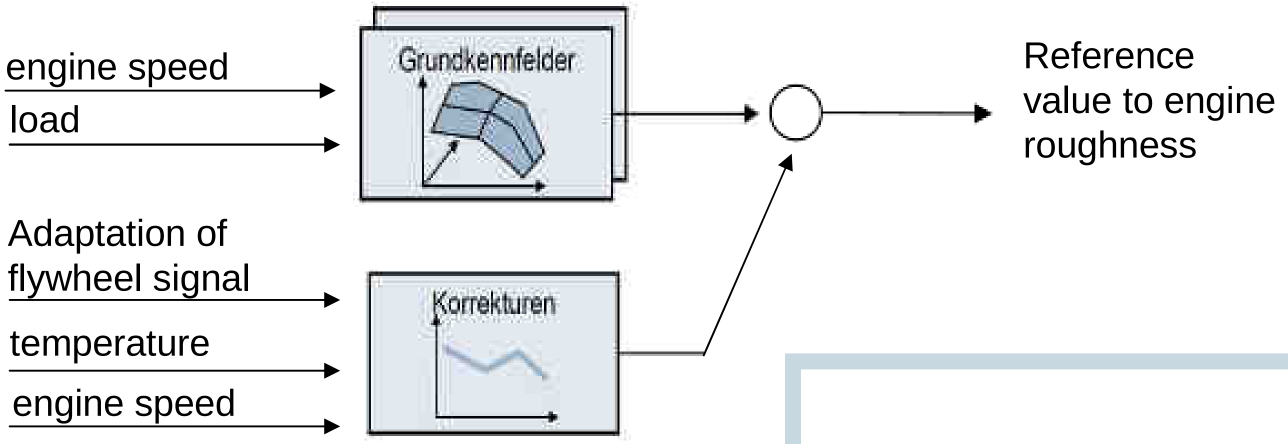


Brakes the vehicle, the segment time increases without any rough running there. To avoid misdiagnosis this deviation is corrected.

Quelle: Diplomarbeit Jan Brycki, Bertrandt Ingolstadt

Diagnosis Misfire Detection – Threshold

Measurement of Segment times → Calculation of engine roughness → **Calculation of Thresholds** → Rating of engine roughness

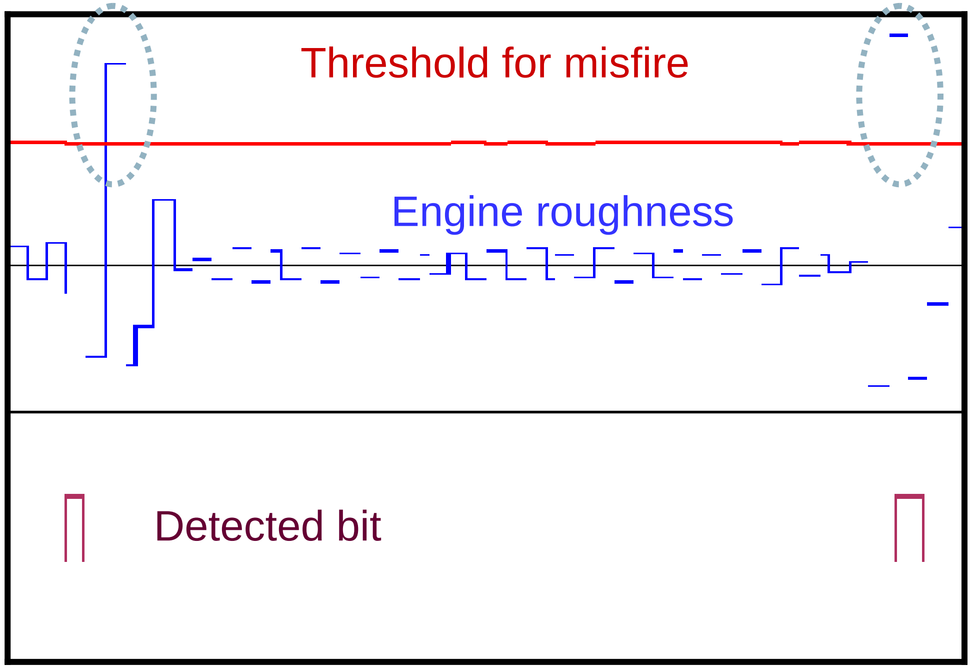


The threshold value is calculated from a speed and load dependent base map. Corrections in the form of offsets are added if the flywheel correction is not settled.

Quelle: Diplomarbeit Jan Brycki, Bertrandt Ingolstadt

Diagnosis Misfire Detection – Rating of the engine roughness

Measurement of Segment times → Calculation of engine roughness → Calculation of Thresholds → **Rating of engine roughness**

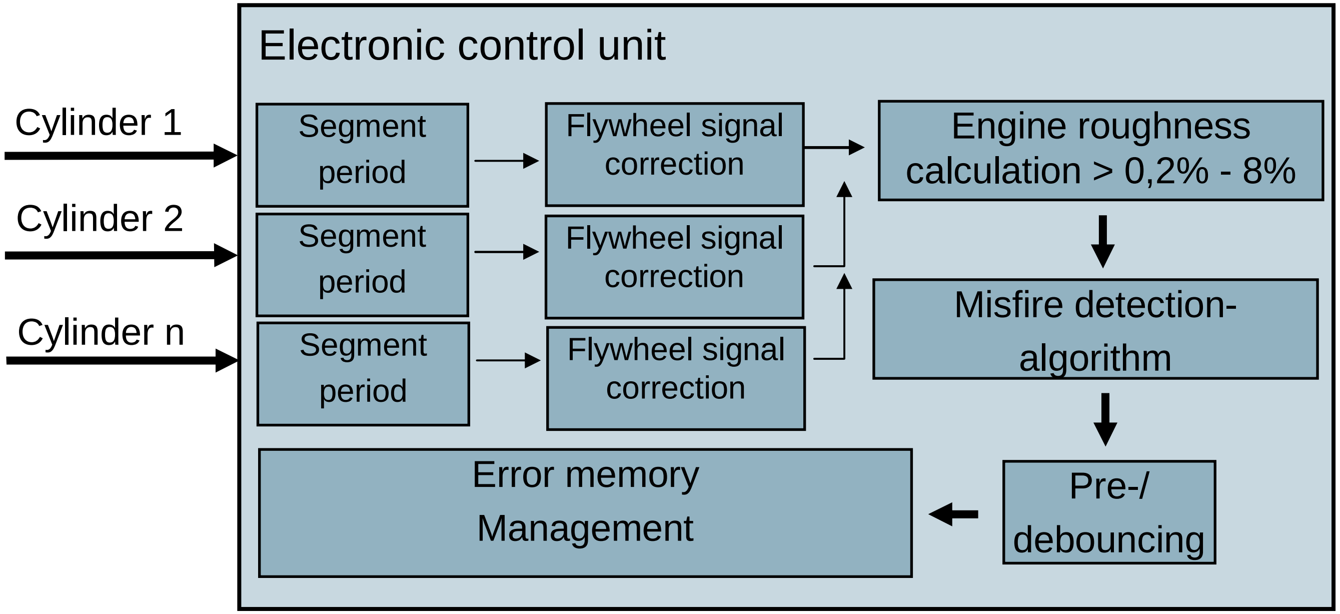


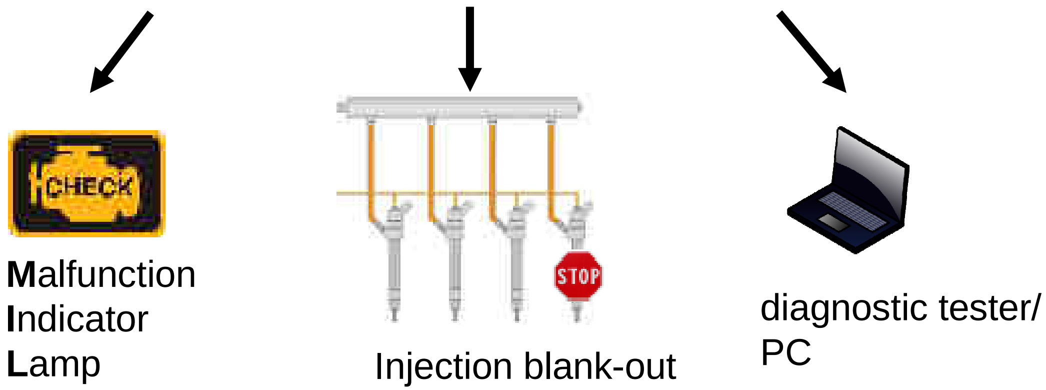
If the engine roughness exceeds the threshold value, the event is rated as detected misfire

Bosch: Threshold exceeded → Misfire detected
Conti: Threshold underrun → Misfire detected

Quelle: Diplomarbeit Jan Brycki, Bertrandt Ingolstadt

Diagnosis Misfire Detection – Error Response

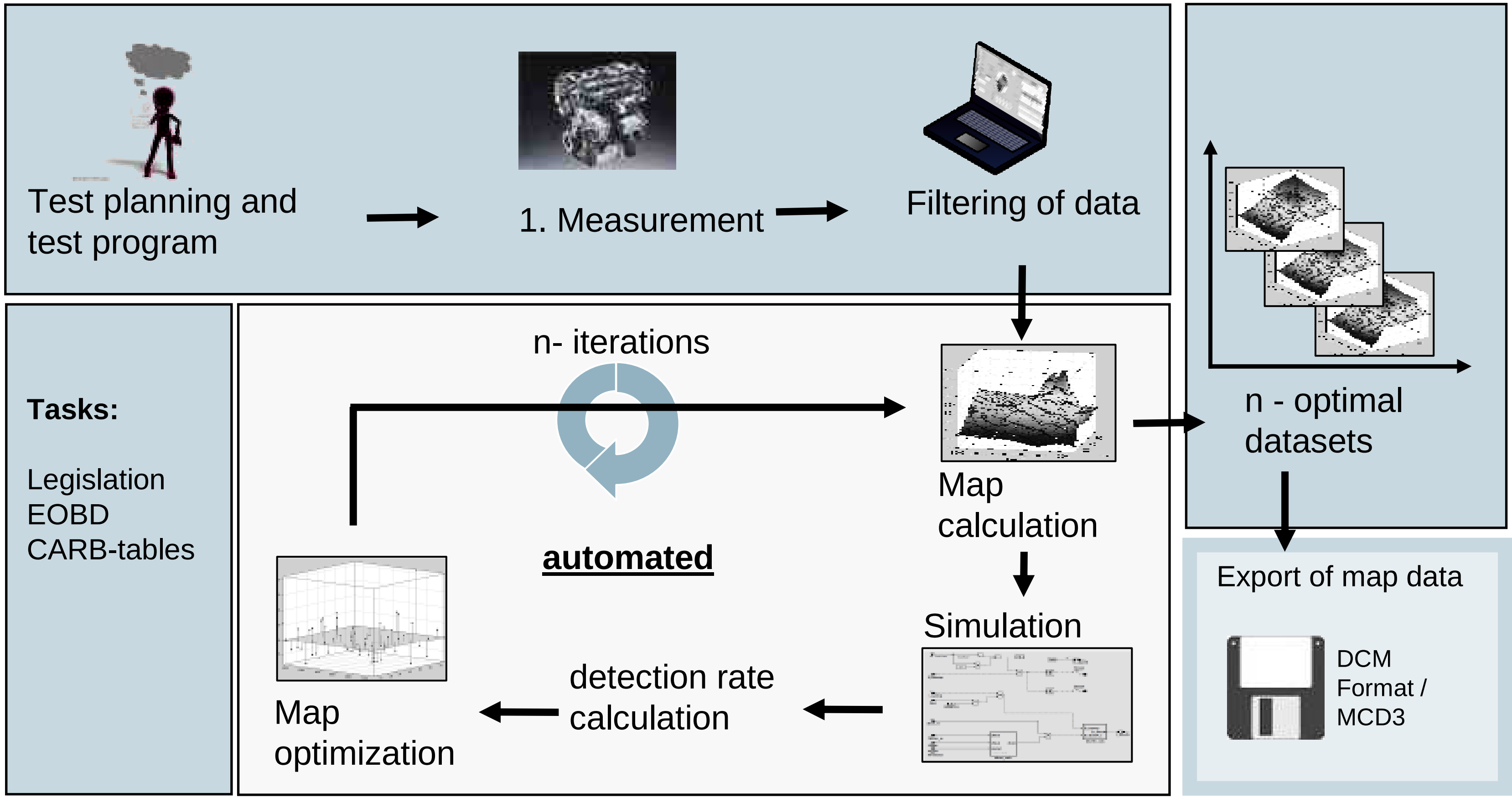




- → Entry in the error memory
- → At too high rates of misfires, the corresponding cylinder is deactivated to prevent the damages of the catalyst

Quelle: Diplomarbeit Jan Brycki, Bertrandt Ingolstadt

Diagnosis Misfire Detection – Model-Based Calibration

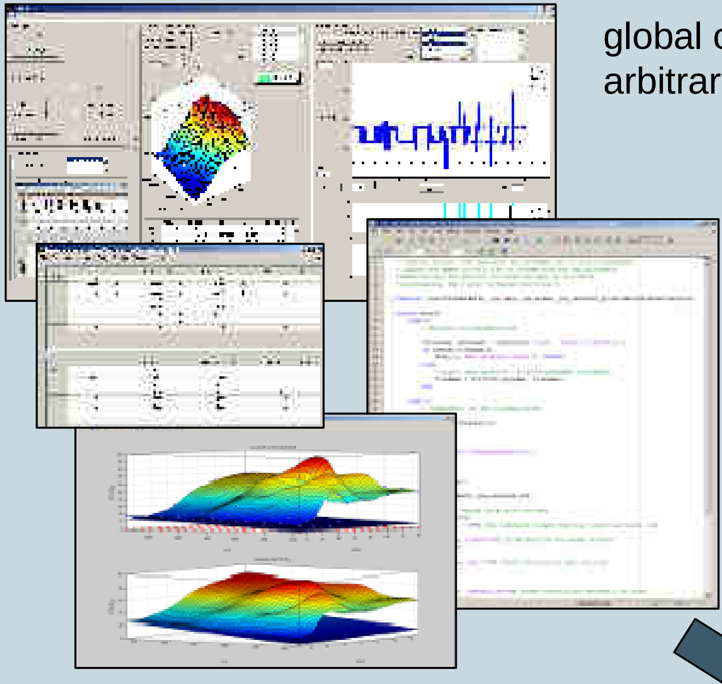


Advantages:

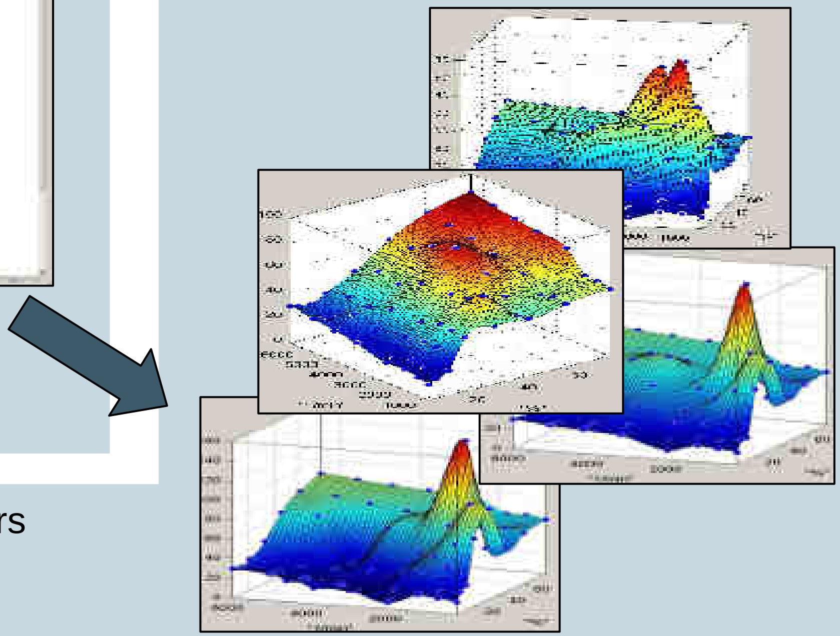
- Reduction of measurement effort, increase in quality, reproducibility, automated calibration

Quelle: Diplomarbeit Jan Brycki, Bertrandt Ingolstadt

Diagnosis Misfire Detection – Map calculation and optimization



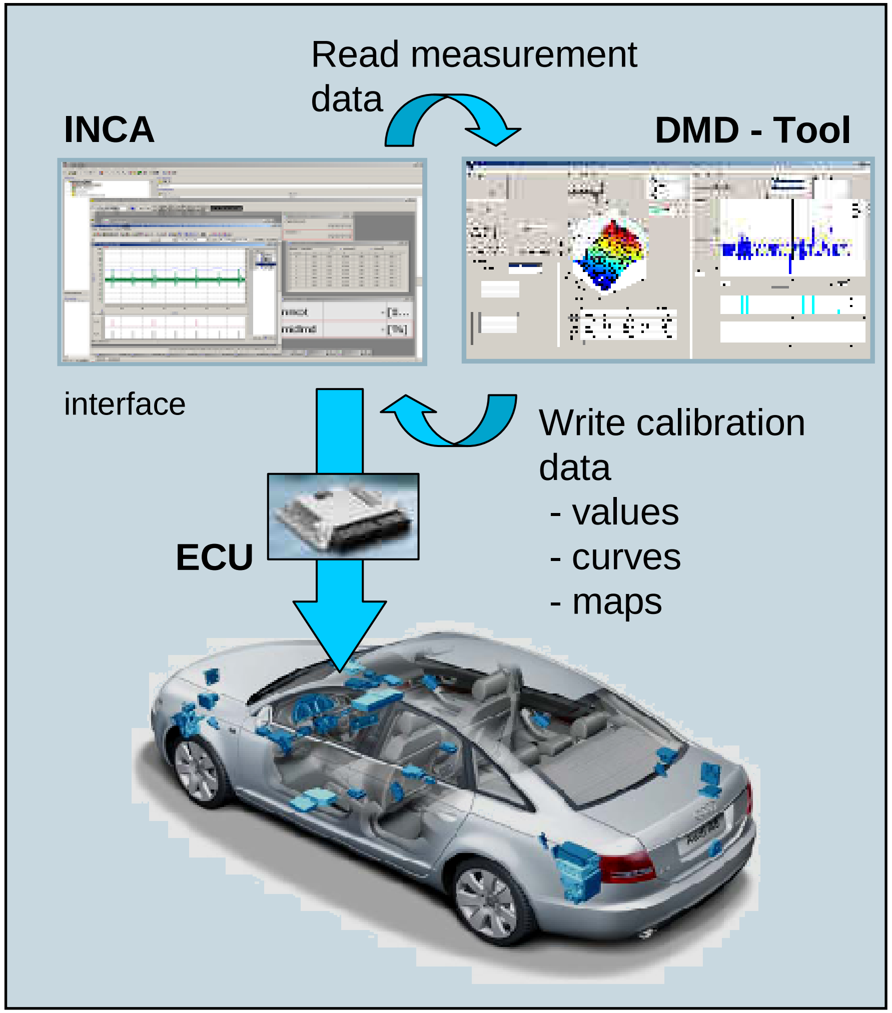
global optimization by automated calculation on arbitrary operating points



Results are optimal maps of all parameters according to the optimization criteria

Quelle: Diplomarbeit Jan Brycki, Bertrandt Ingolstadt

Diagnosis Misfire Detection – Calibration procedure



Quelle: Handbuch KFZ Elektronik

- Stationary / dynamic measurements
- Recording of the engine roughness with and without general suspension by ZAG
- Tool support during the calibration
- Automatic filtering of measurement data
- Offline calibration of the threshold values based on measurements
- Offline optimization using simulation models of the ECU-function (DMD)
- Statistical analysis of simulation results → detection rates
- Evaluation of detection quality based on the detection rates and false positive rates

Thanks to Mr. Brycki (Diploma Thesis Bertrandt Ingolstadt)

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  - Misfire detection diagnosis of gasoline engines
- **Summary and outlook**

Quelle: www.seriouswheels.com

Summary and outlook

- The drivetrain of future vehicles is one of the most interesting development task in the automobile world
- Calibration is the central position in the drivetrain development
  - Thermodynamics, mechanics, E/E, software, methods
- Using intelligent technologies like the model-based calibration it's possible to…
  - …realize more functionalities
  - …reduce additional engineering effort
  - …decrease emissions and consumption
  - …increase fun to drive
  - …last but not least: earn money

Calibration of modern combustion engines
– advantage by technology


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