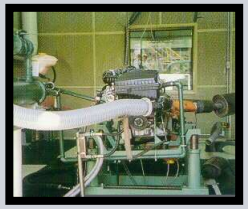
Siemens VDO Presentation

Thierry Dalon
Powertrain, Test Center, Engine Test Bench

Christian Falkenberg
Powertrain, Engineering Group

2007-11-19
Regensburg, Germany

SV Organization



"online"

Test Center, Engine Test Bench

Provide automatic efficient test procedures

"offline"

SPT Engineering Group
System Parameterization Technology (SPT)

Provide tools and methods to improve calibration process and quality to application engineers.

Internal Customers:
Engineering Services
GS,DS

Outline

- Test Center Presentation (T. Dalon)
  - Online DOE and Online Optimization
  - Tool chain for standard procedures: examples
- Engineering Group (C. Falkenberg)

  SPT Overview

SIEMENS VDO

Calibration User Group Meeting 2

Siemens VDO approach for DOE measurement and Online Optimization at Engine Test Bench

Thierry Dalon
Siemens VDO Automotive AG
Powertrain, Test Center, Engine Test Bench
2007-11-19
Regensburg, Germany

Tool landscape for ETB automation

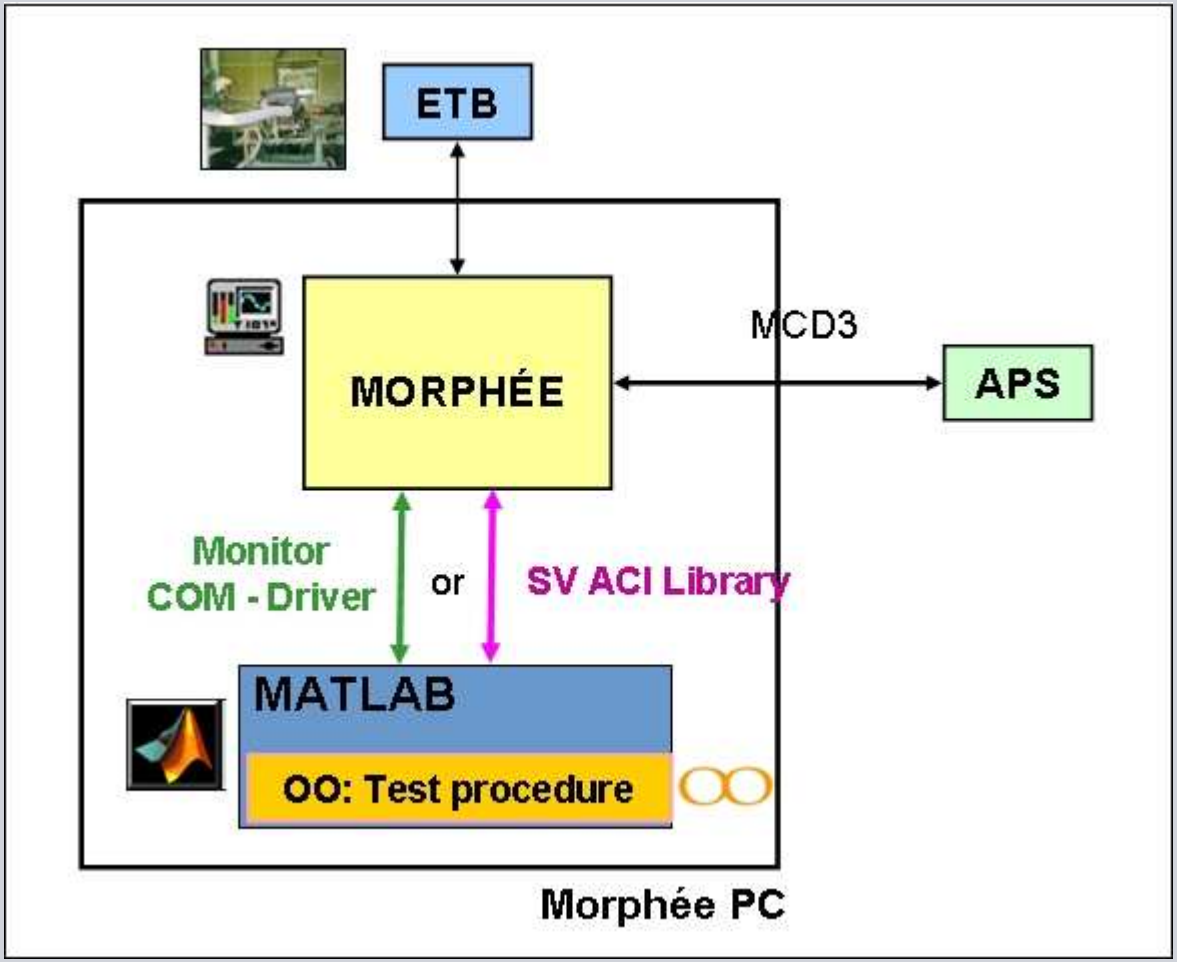
Automation System Worldwide: D2T Morphée
TC Regensburg: 4 AVL CAMEO 2.2 licenses
1 license for DOE Screening and 1 license for Adaptive OnlineDOE (not used)

Because CAMEO did not meet SV requirements for automatic DOE tests and Online Optimization and because we need a **flexible** an **open** tool we decided to develop our own **MATLAB**-based Tool:
"Online Optimizer" (in short OO), development started in 2001.

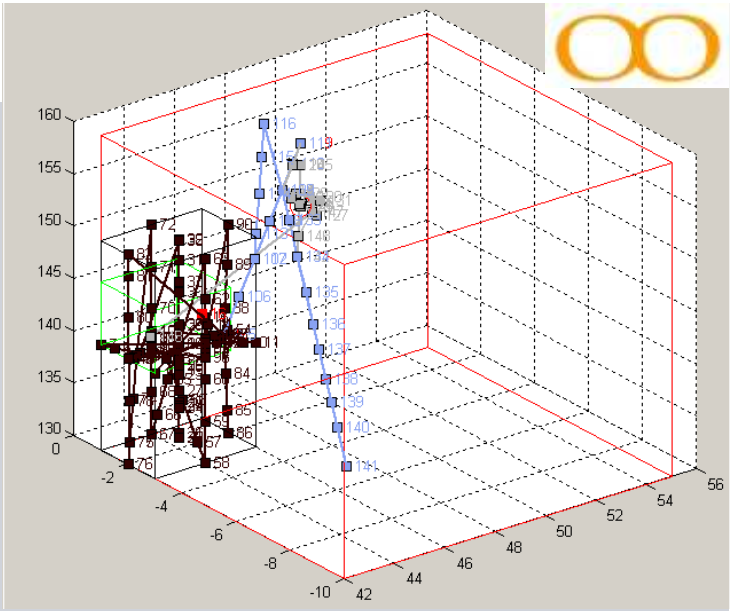
This tool is used for Online DOE as well as Online Optimization tests. The platform is also used for specific tests like ETB Controller identification and will be used for Rapid Measurement procedure.

With our ACI library we can replace CAMEO by our Matlab Tool.

OO - Tool Interfaces

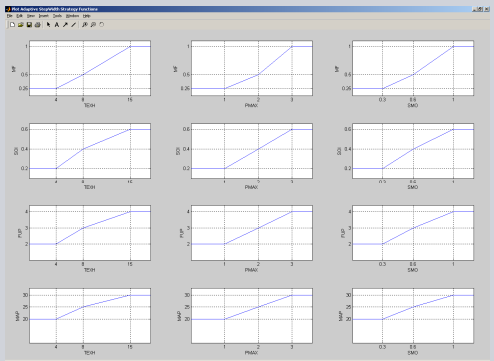


Adjustment strategy
DOE Screening

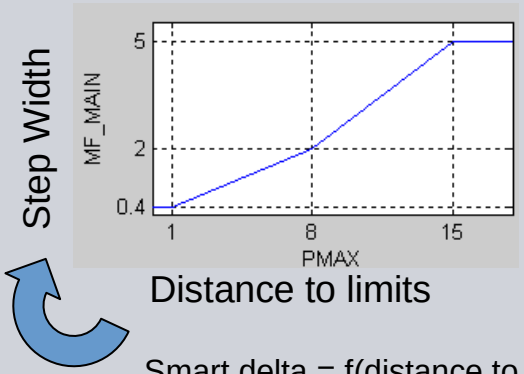


Currently for online DOE we use a stepwise linear adjustment strategy with stability criteria, adaptive step-width and optimized start point.

These features are not implemented in CAMEO DOE Screening.



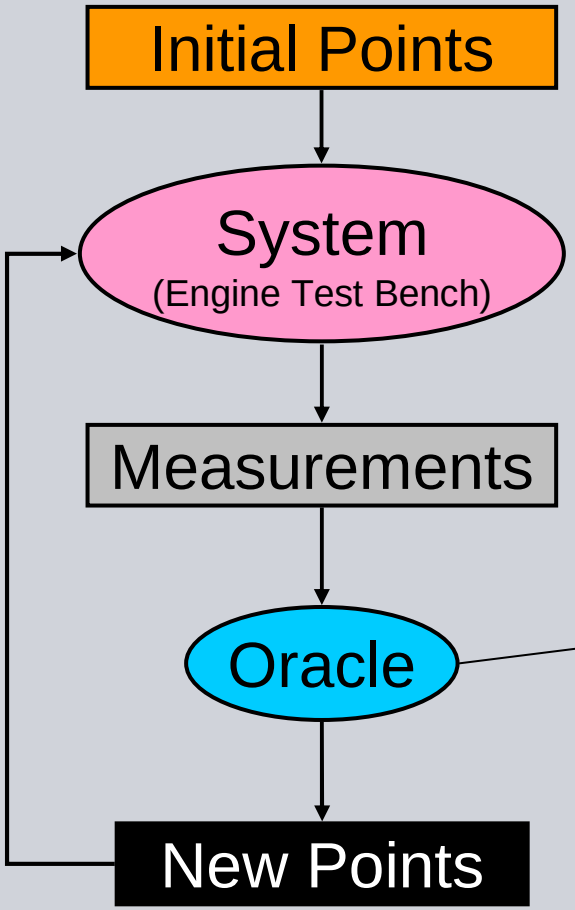
Relationship functions



Smart delta = f(distance to limits)

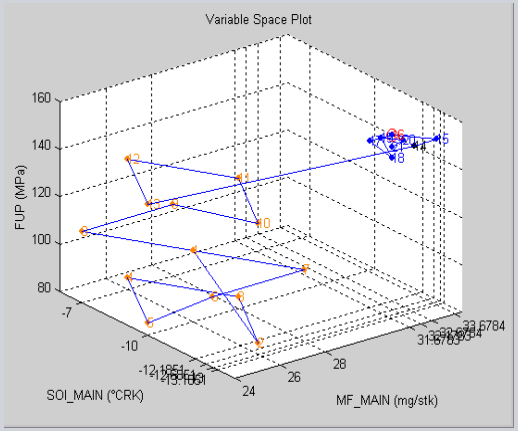
typically linear saturated

Online Adaption- Oracle Principle

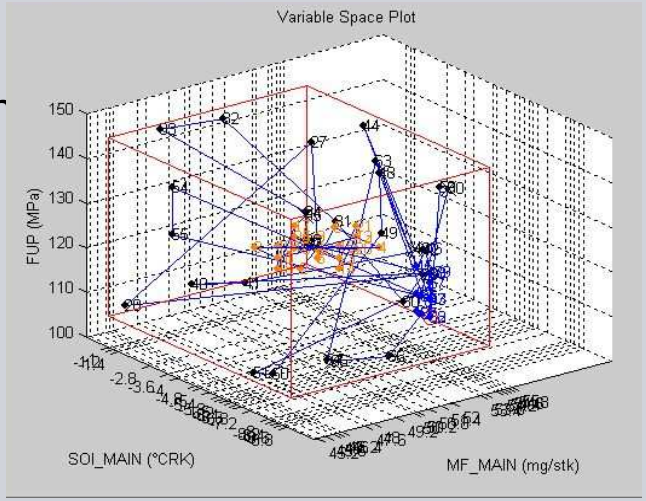


Different criteria possible:

- optimization criterion
- space-filling design criterion
- model quality/ confidence
- statistical criterion
- query criterion



Pure greedy optimization criterion



Balanced local-global search

See presentation paper for references.

Practical Example of Online Optimization
Diesel Full Load Optimization

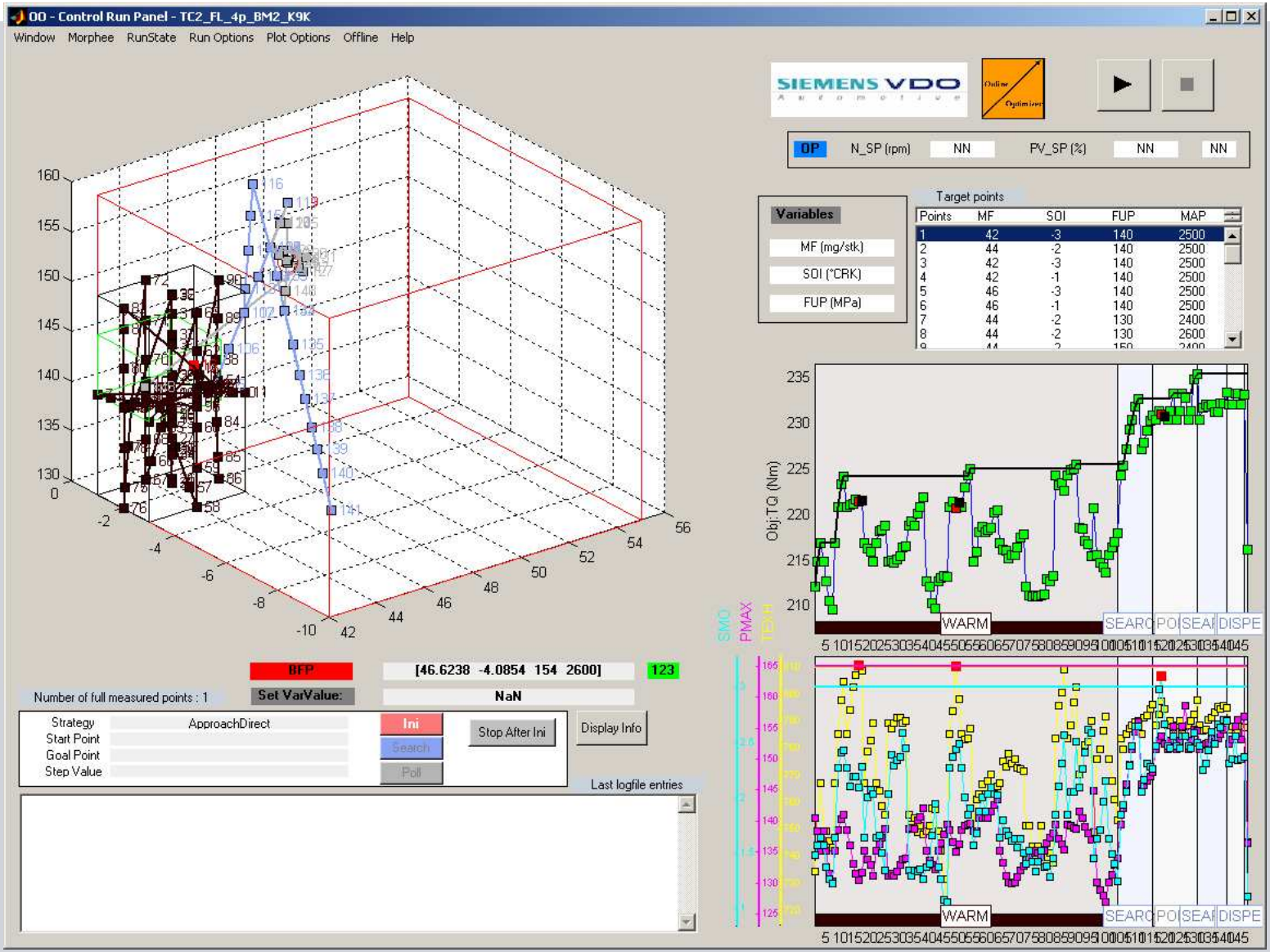
SIEMENS VDO

DS Full Load optimization
Variables (6p): SOI_MAIN, MF_MAIN, SOI_PREV, MF_PREV, FUP, MAP
Objective : TQ→ max
Constraints: TEXH, SMO, Pcyl
Limits: same as constraints...

DS Full Load optimization
Variables (6p): SOI_MAIN, MF_MAIN, SOI_PREV, MF_PREV, FUP, MAP
Objective : CSE→ min
Constraints: TEXH, SMO, Pcyl
TQ=TQ_target±tol.
Limits: TEXH, SMO, Pcyl

Application of Generalized Pattern Search algorithm:
- fixed POLL order based on experience
-with SEARCH step using quadratic response surface models as surrogates and SQP algorithm
- derivative information base on qualitative knowledge to speed up the POLL local step

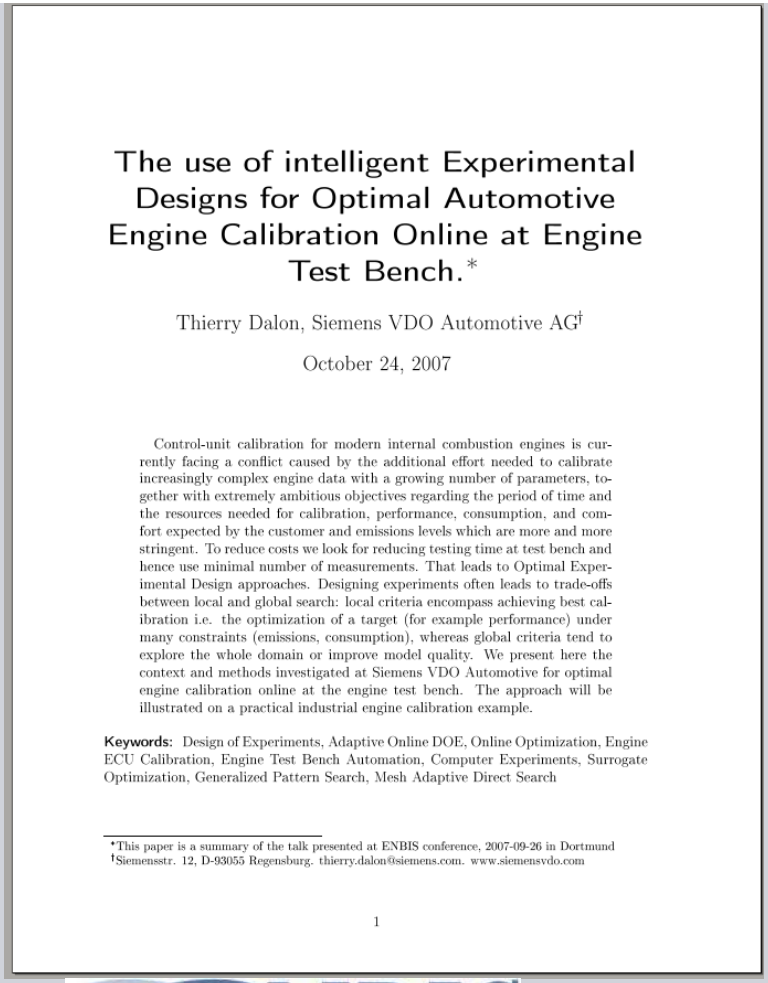
Practical Example
Diesel Full Load Optimization. Figure



SIEMENS VDO

Reference

Presentation at last ENBIS conference:
Paper available with all references.



The use of intelligent Experimental Designs for Optimal Automotive Engine Calibration Online at Engine Test Bench.*

Thierry Dalon, Siemens VDO Automotive AG†

October 24, 2007

Control-unit calibration for modern internal combustion engines is currently facing a conflict caused by the additional effort needed to calibrate increasingly complex engine data with a growing number of parameters, together with extremely ambitious objectives regarding the period of time and the resources needed for calibration, performance, consumption, and comfort expected by the customer and emissions levels which are more and more stringent. To reduce costs we look for reducing testing time at test bench and hence use minimal number of measurements. That leads to Optimal Experimental Design approaches. Designing experiments often leads to trade-offs between local and global search: local criteria encompass achieving best calibration i.e. the optimization of a target (for example performance) under many constraints (emissions, consumption), whereas global criteria tend to explore the whole domain or improve model quality. We present here the context and methods investigated at Siemens VDO Automotive for optimal engine calibration online at the engine test bench. The approach will be illustrated on a practical industrial engine calibration example.

Keywords: Design of Experiments, Adaptive Online DOE, Online Optimization, Engine ECU Calibration, Engine Test Bench Automation, Computer Experiments, Surrogate Optimization, Generalized Pattern Search, Mesh Adaptive Direct Search

*This paper is a summary of the talk presented at ENBIS conference, 2007-09-26 in Dortmund

†Siemensstr. 12, D-93055 Regensburg. thierry.dalon@siemens.com. www.siemensvdo.com

1

ENBIS 2007

SIEMENS VDO

Calibration User Group Meeting 2

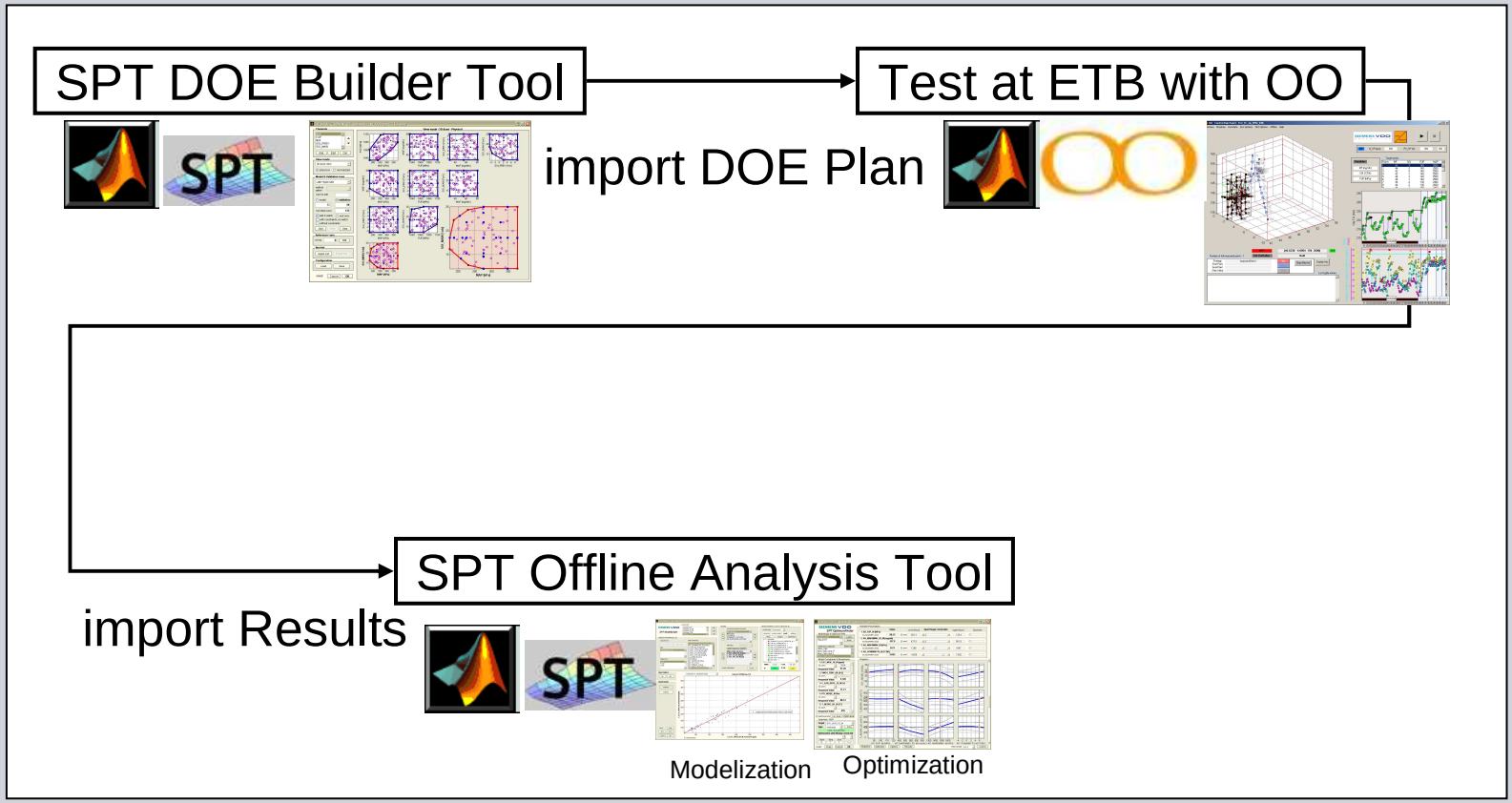
Example of calibration workflow and tool chains

Thierry Dalon
Siemens VDO Automotive AG
Powertrain, Test Center, Engine Test Bench
2007-11-19
Regensburg, Germany

DOE Tool Chain

SIEMENS VDO

Offline and Online Tools are **internal** solutions developed under Matlab.



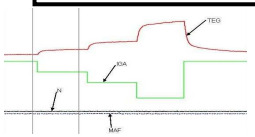
Tool chain for
Exhaust Temperature Model Calibration

SIEMENS VDO

or

Morphée for Windows

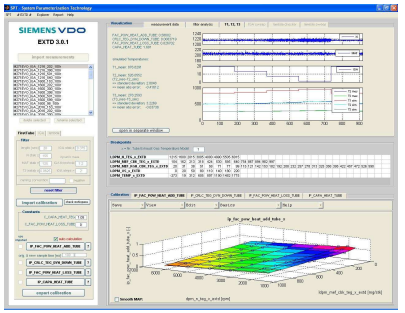
Test at ETB with CAMEO or OO with ACI/Morphée



INCA Measurement Files

SPT Offline Analysis Tool

SPT



Intelligent Automatic procedure for Exhaust temperature model calibration

SIEMENS VDO

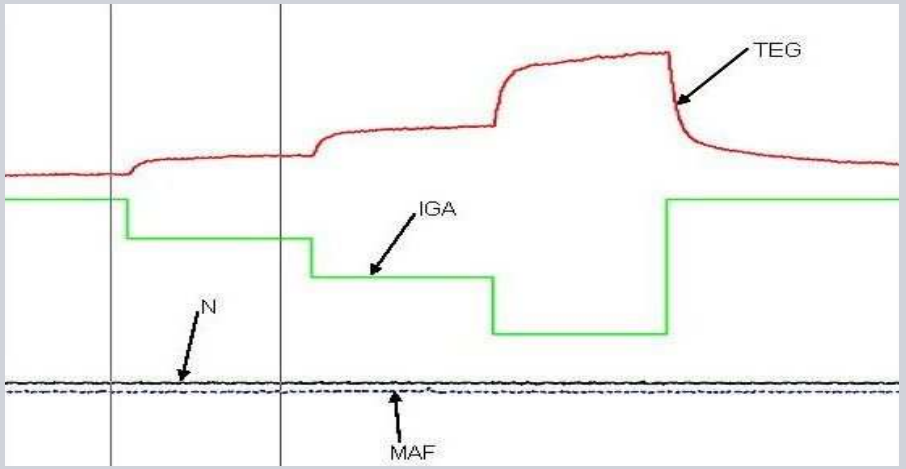
Use of Real-Time controllers:

- optimized IGA start value for the iga variations
- test robust against KNK and TEX limits

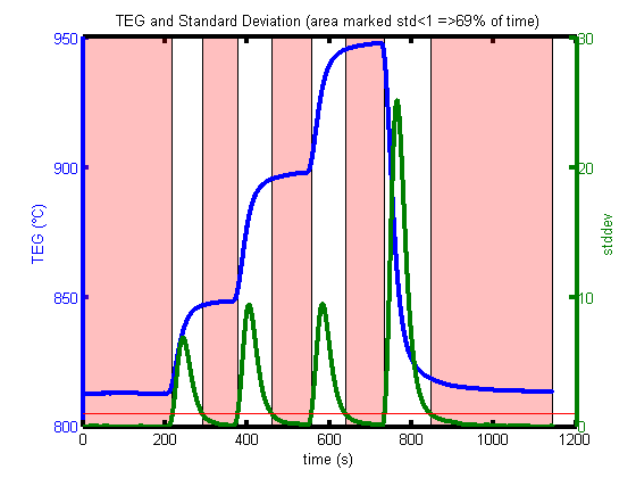
Online search IGA min/best lambda procedure => automatic self-parameterization

Stability criterion => improve test time or measurement quality

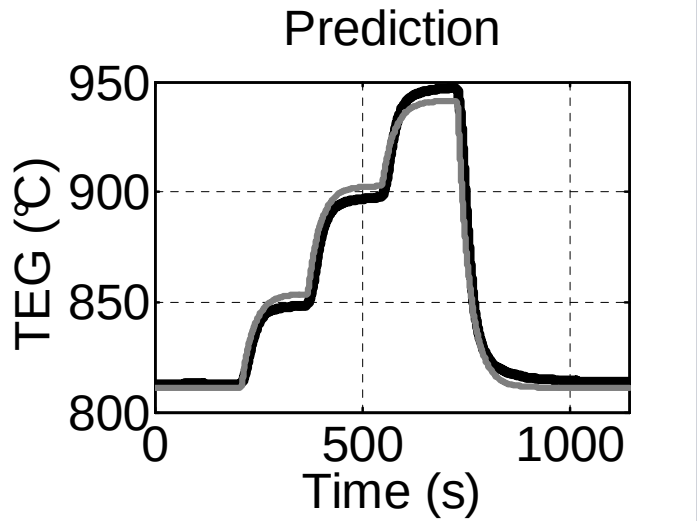
Optimized lambda measurement distribution



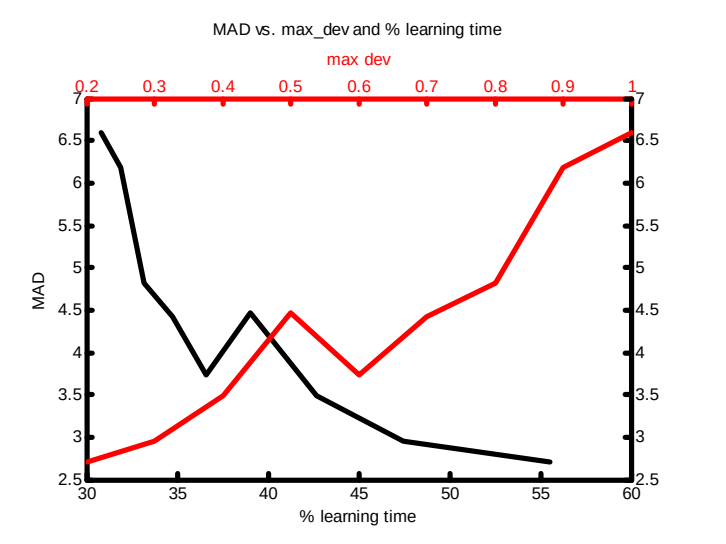
Exhaust Temperature Model with Rapid Measurement



Measurement criterion= only "high" dynamic part.



Dynamic Modeling: NARX



Trade-off curve time reduction vs. model quality.

Thank you for your attention!

Questions?

Contact:
Thierry Dalon
thierry.dalon@siemens.com
+49 941 790 - 7605