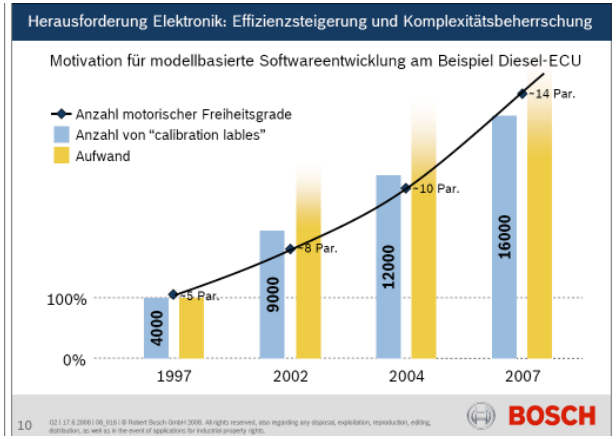
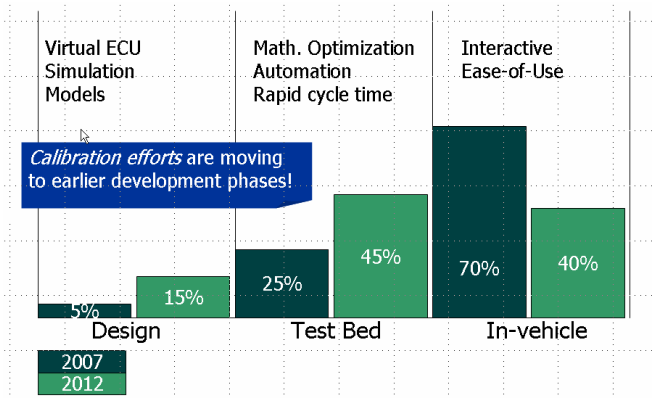
CaliAV© - Autopilot to efficient best-practice MCD
A new approach for process-oriented and tool based automation of calibration tasks for modern powertrain systems

Market Trends

- Continuously increasing number of the application tasks
  - More software control functions
  - New diagnostics functions
  - Increased environmental regulations
- Growing complexity of application
  - More complex controllers
  - Model-based functions require calibration
- Increased quality requirements
  - Quality depends from the individual expertise
  - Calibration results are rarely reproducible
  - Additional workload through retrospect documentation





Guided Calibration
Calibration efforts become the cost-driver in projects

- Although calibration & validation tasks move to test cells and virtual environments, in-vehicle calibration is and will be indispensable

- Today invehicle-calibration is still
  - Largely manually performed by calibration engineers
  - Informal process driven by expert know how
  - Growing number of functions through diagnostics and environmental requirements
  - Increasing complexity of software control functions
  - Distributed know-how across teams
  - Requires repetition for software-releases and variants
  - Narrow project schedules and reduced test vehicles
  - Intense manual documentation of work results at delivery

- Some OEM/Tier1 automate and standardize selected tasks with scripts, this requires IT skills AND calibration skills

- "Guided calibration" addresses the automation of routine-tasks and the use of best-practice for calibrators by supporting structured, controlled and repeatable processes

Guided Calibration
Shortcomings of traditional automation approaches

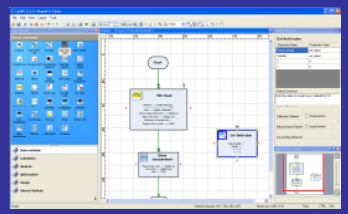
- Software development collides with calibration expertise
  - Skills rarely combined in one person
  - Requirement management from calibrator to developer is required
  - Work procedure becomes software code -> hard to understand
  - IT Support required for calibration departments
  - Software maintenance required
    - new MATLAB release
    - New ECU software release
    - New INCA release
  - Budget required!
- Unsatisfactory flexibility in the car
  - Calibration engineer has no chance to apply -even minor- modifications
  - Unclear transparency (black-box)
- Opposition from calibration engineers

Guided Calibration
Structuring the application process

Design

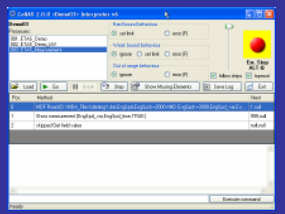
Planning & Design of the required work steps for the application task

Modeling



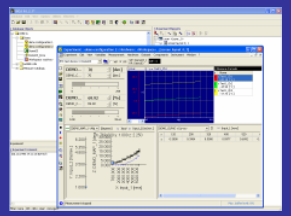
Graphical modeling with ready-to-use building blocks for automotive application task

Implementation



Generation of stand-alone executable for distribution

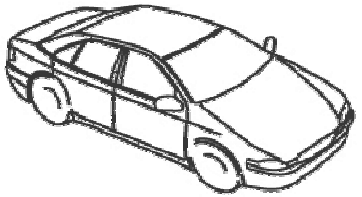
Execution



Online application in the vehicle or at the test bed

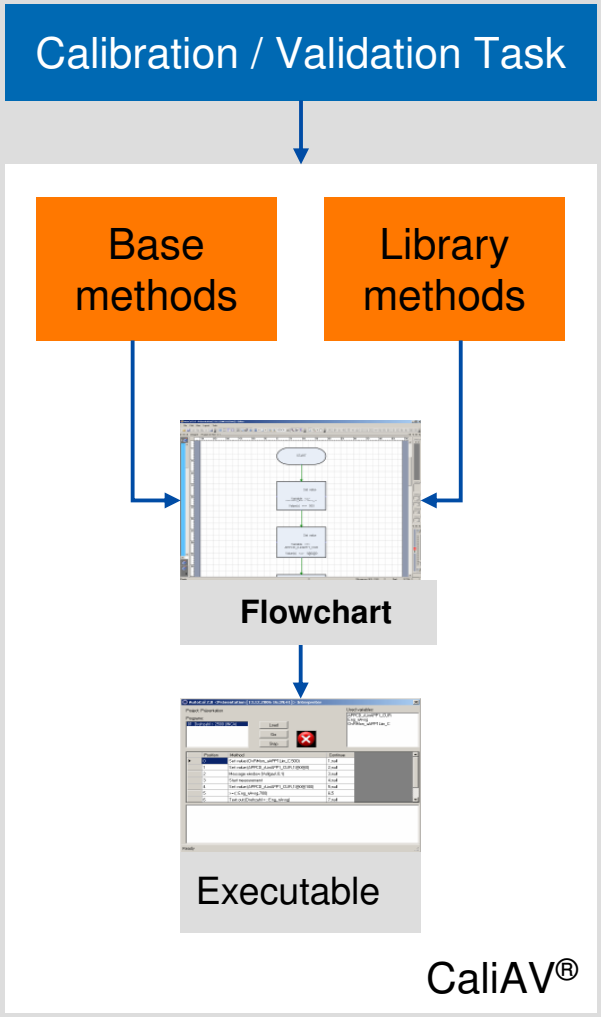
Documentation

Detailed preparation of calibration and validation work in the office



Less time in vehicle required

CaliAV – Guided Calibration for INCA
Overview



Base methods

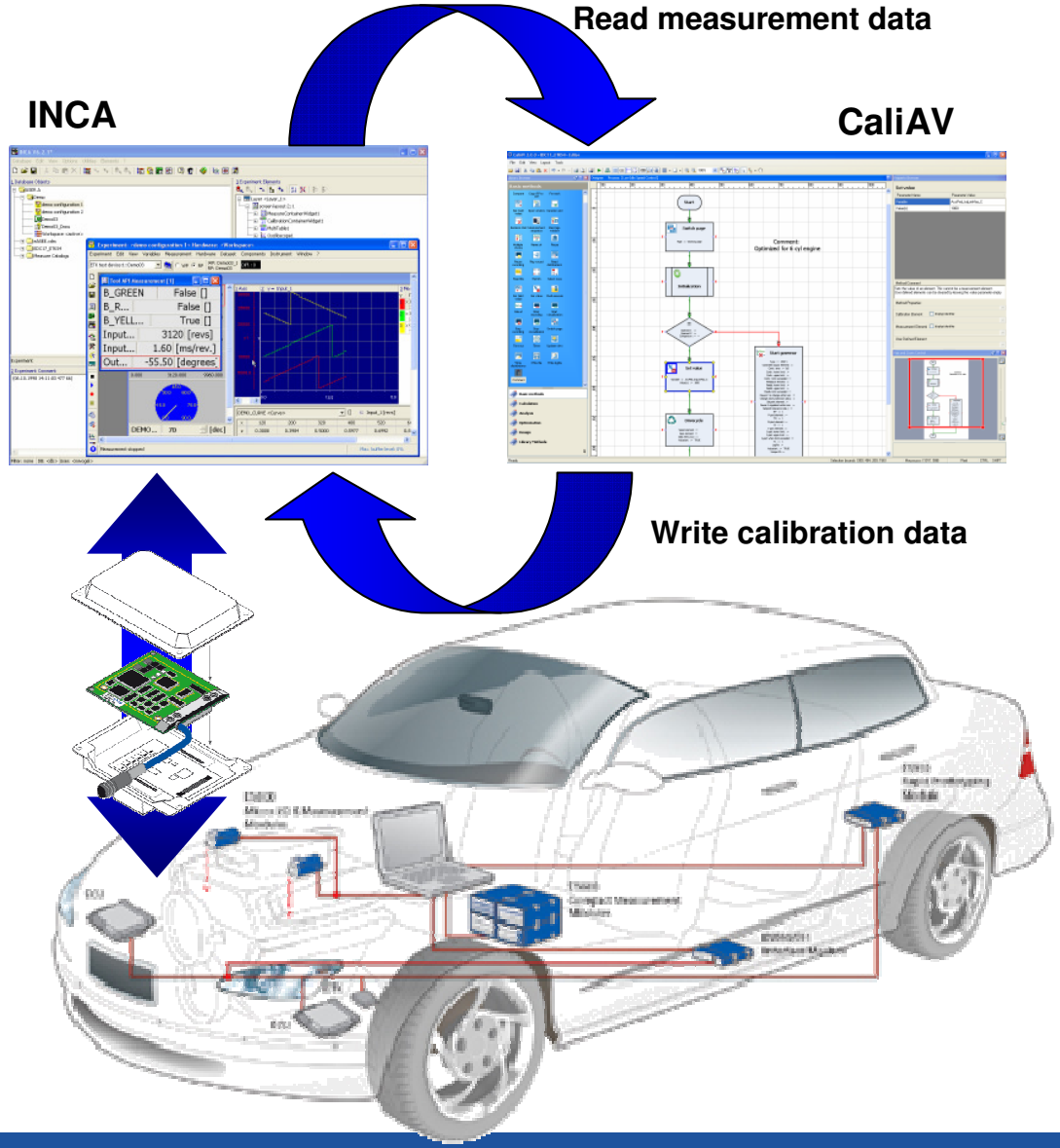
- Read / Write of characteristics and signals
- User input/output functions
- Design methods (i.e.. Polyfit)
- Optimization methods (i.e. Simplex algorithm)
- Iterations (i.e. loops)
- Bypass methods (i.e. configurable PID govenor)
- Stimuli generation (i.e. sine-wave, APRBS)
- Drive-cycle generation (i.e. FTP75-cycle)
- Interface to MATLAB®
- Mathematical and statistical methods (formula editor, fourrier transformation, filters, histogram, mean-/min-/max value etc.)
- Visualization methods (oscilloscope, histogram generation and modification of curves and maps)

Library methods

- For re-use of commonly used sub-sequences

CaliAV creates graphical and executable specifications for application processes!

CaliAV – Guided Calibration for INCA
Overview



Guided Calibration
Solution Building Blocks

- Creation environment
  - Create or modify sequences
  - Graphical modeling
- Execution environment
  - Closely connected with MCD-Tool (INCA)
  - Run sequences with or w/o interaction
  - Interact with calibrator and display results
- Management environment
  - Administrate a repository of sequences and base functions
  - Hardware and label abstraction layer
- Guided sequences
  - Provided by a solution expert or crafted by the customer

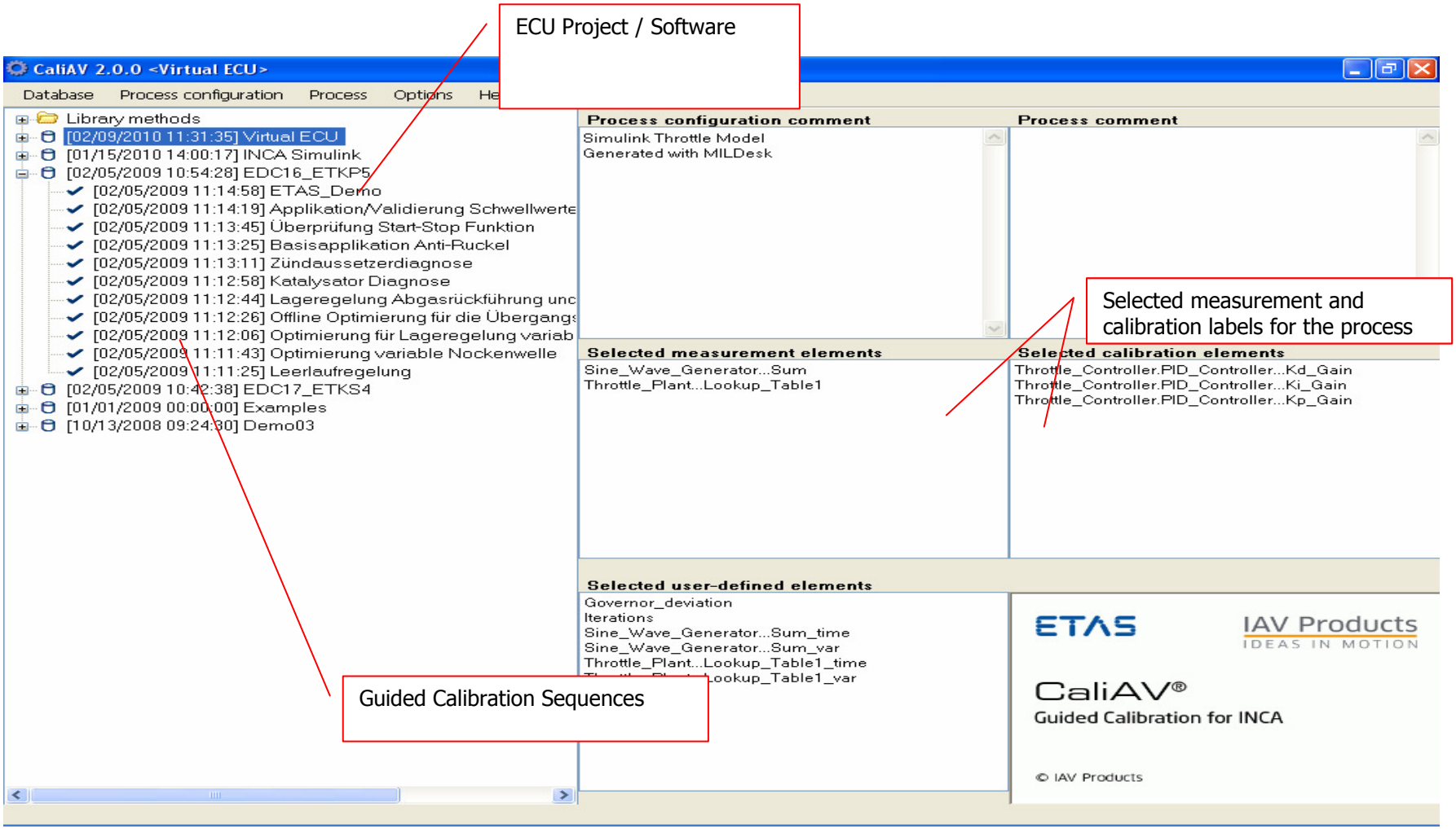
CaliAV – Guided Calibration for INCA
Existing real-world examples

- Low-idle speed control
- Online optimization for variable camshaft
- Online optimization for variable valve lift control
- On- and offline optimization for transitional correction
- Anti surge control
- Exhaust recirculation and boost pressure control
- Engine smoothness control
- Catalytic converter diagnostic
- Misfire detection
- Offline optimization of lambda probe
- Lambda sensor diagnostics
- System analysis of exhaust recirculation valve
- Drivability analysis and base calibration load alteration
- Monitoring of start-stop function
- Automatic calibration & validation of thresholds for sensor diagnostics

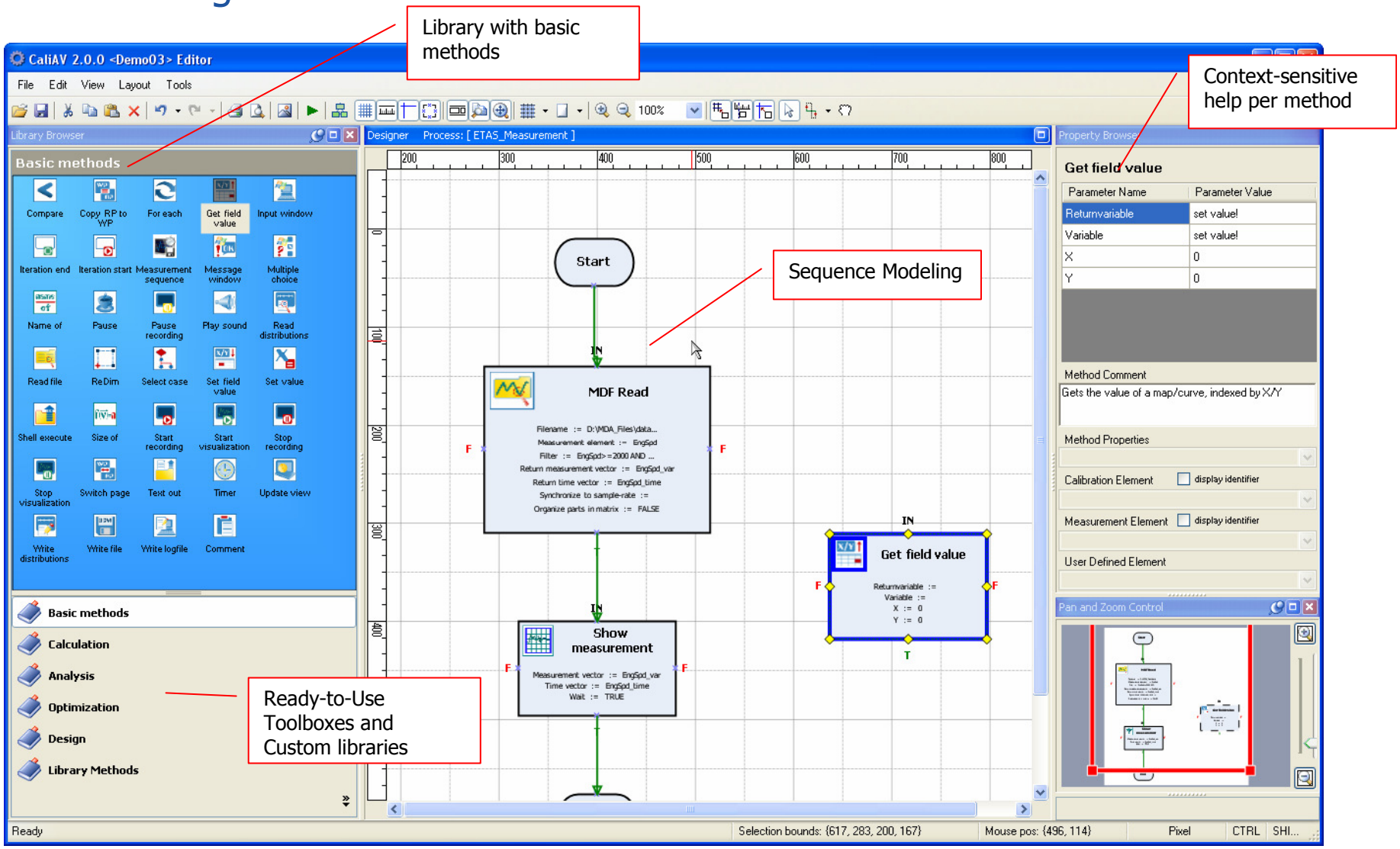
Guided Calibration
Benefits

- Improved calibration quality
  - Reproducible for each function and measurement
  - Reduction of application errors
  - Validation of work results
  - Easily repeatable for each variant
  - Highly accepted by calibrators as they can specify the degree of complexity and automation
  - Easy creation of sequences
- Reduced vehicle-usage
  - Planning of calibration tasks in the office
- Process documentation
  - Improved skill-up phase for new calibrators
  - Process conformity to test bench and dyno cells
  - Global best-practice for all ECUs, software releases and functions

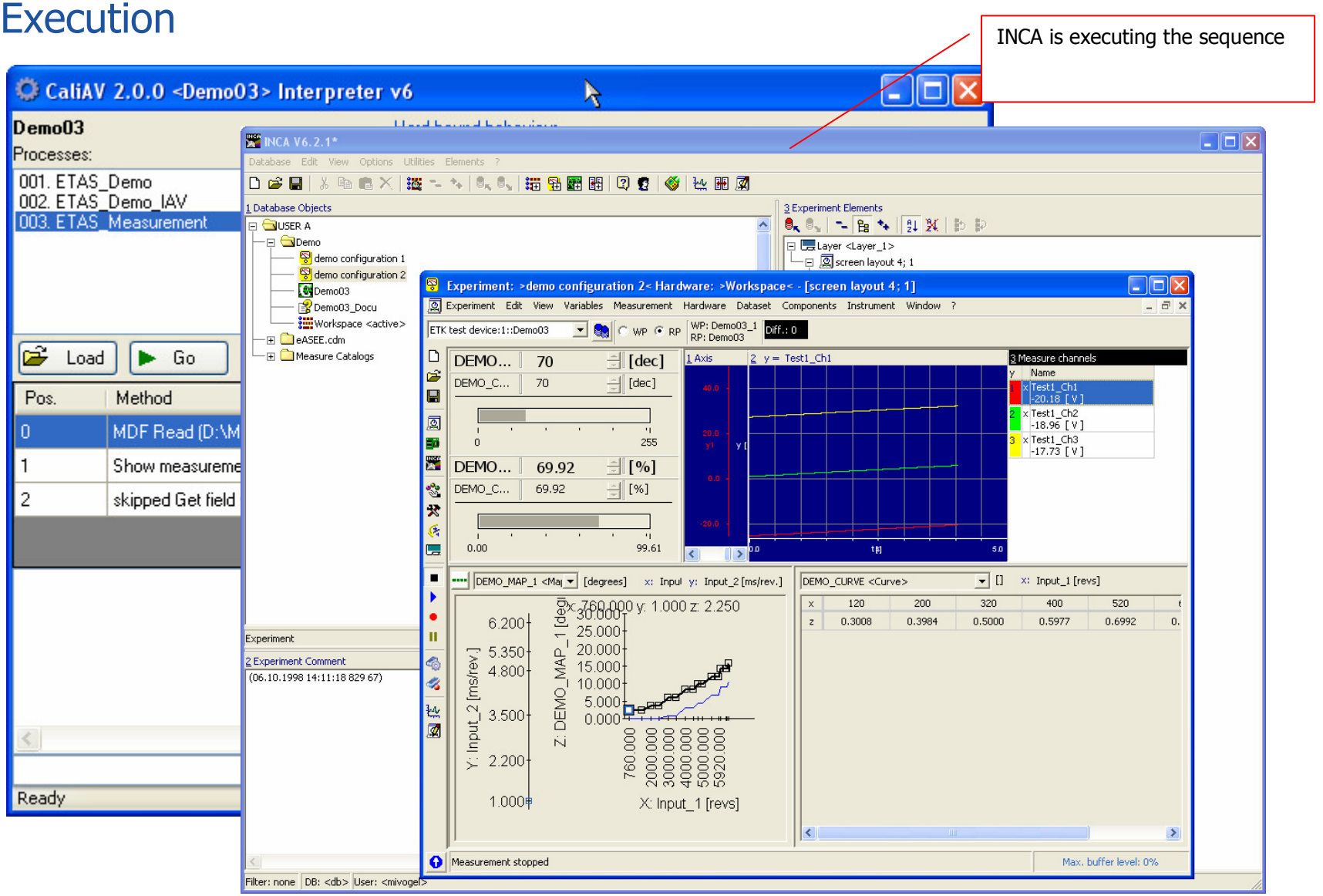
CaliAV V2.0
Project Management



CaliAV V2.0
Process Design



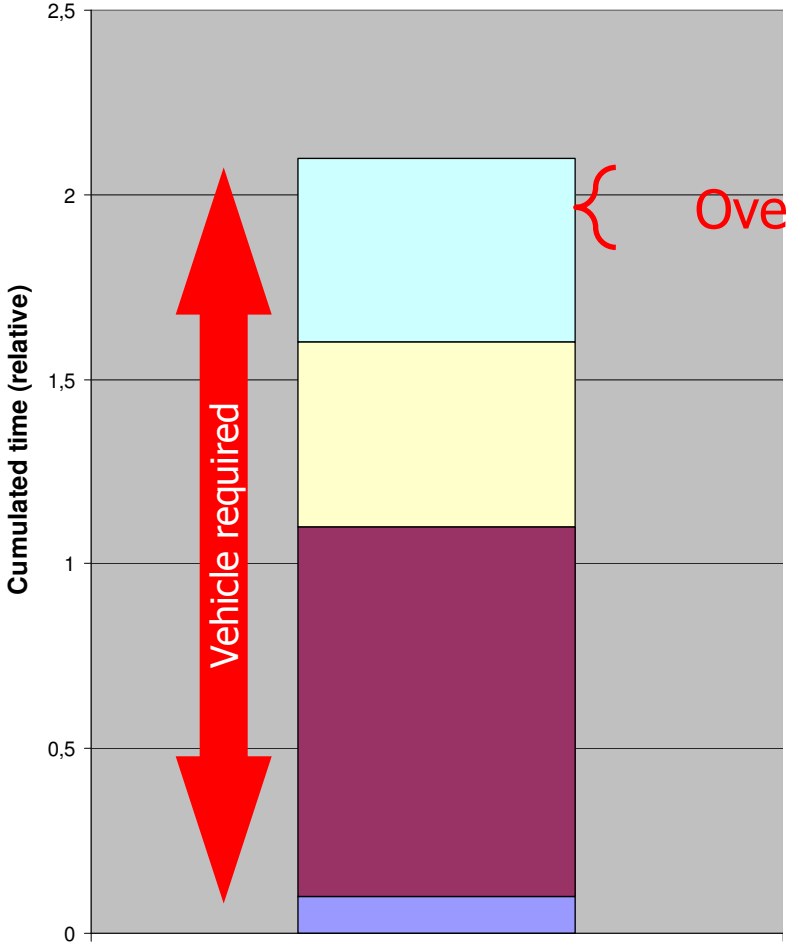
CaliAV V2.0
Execution



Guided calibration
Cost saving potential

- Repeatable processes
  - Initial effort to model the sequence, offline at the desk
  - Effort pays off for each variant and ECU software release
  - Best-practice for all departments, teams, suppliers
- Reproducible results
- Reduction of error
  - Manual inputs and data transfers are reduced
  - Constraints and conditions can be covered in the sequence
- Coordination efficiencies
  - Test vehicles are used more efficiently

Guided Calibration
Calibration efforts for a catalytic converter for 3 vehicle variants



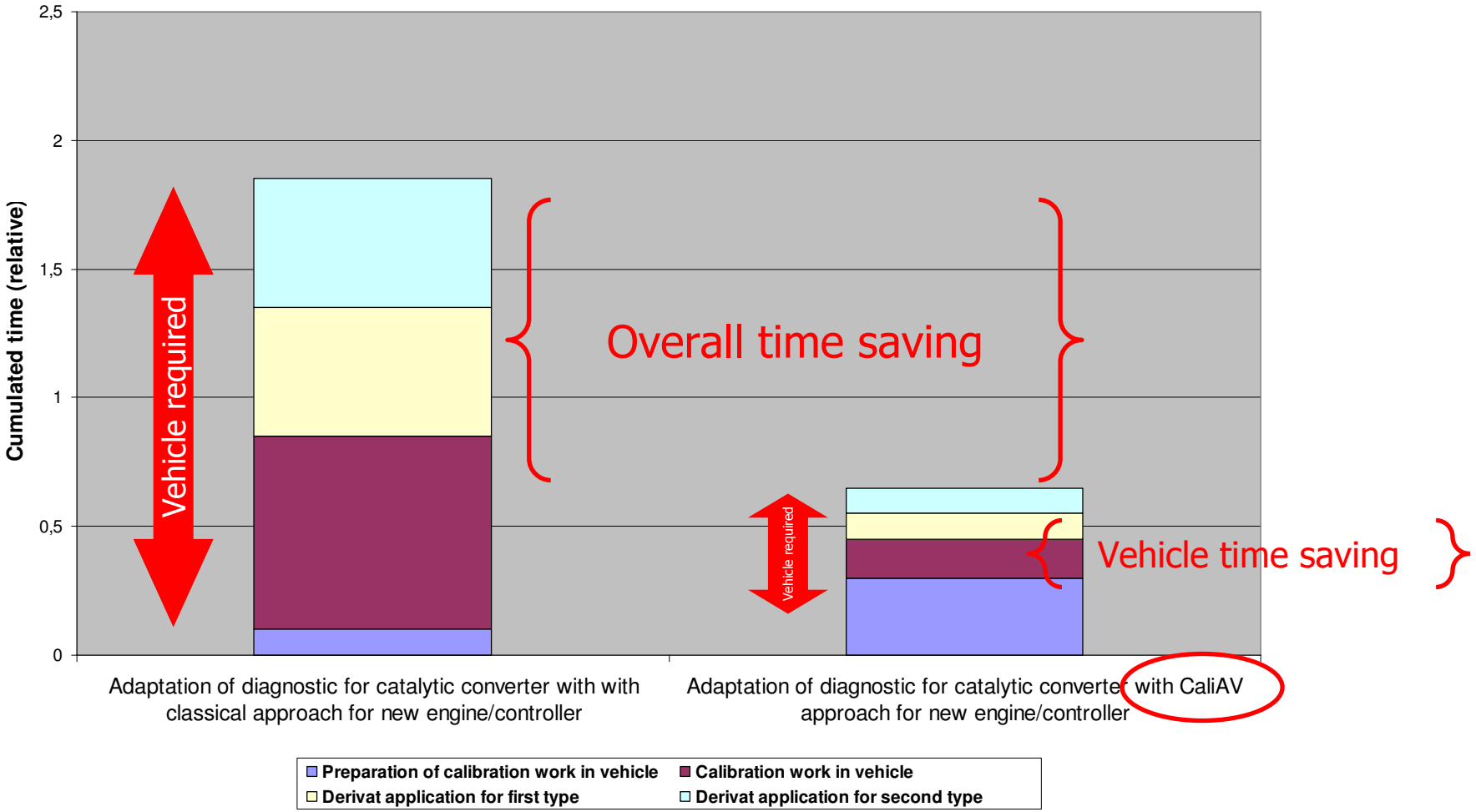
Overall time saving

Vehicle required

Vehicle time saving

Preparation of calibration work
Calibration work in vehicle
Derivat application for first type
Derivat application for second type

Guided Calibration
Efforts after a new ECU software release



Guided calibration
Cost savings compared to traditional approaches

- Calibration Domain-experts do not require software development support
  - No meetings/discussions/clarification/budgets required
- Graphical procedures are easy to understand
  - Simple maintenance, easy to adopt, ready for documentation
  - Reuse and skill-transfer of existing sequences
- Domain-specific out-of-the-box blocks readily available for modeling
  - CaliAV provides >80 base methods to access and manipulate ECU labels
  - INCA tool adapter and ECU software project administration
- True differentiators (cannot be build with MATLAB)
  - Drivecycle generators
  - Parallel controllers (interrupt driven)
- Complete integration with ETAS INCA
  - Ensures compatibility of both tools
  - Same requisitioning and support channel

Thank you for your attention