NEW APPROACH FOR ENGINE CONTROL SYSTEM SOFTWARE DEVELOPMENT

6th CIMAC CASCADES 2015

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AVL Software and Functions

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SOFTWARE AND FUNCTIONS

AGENDA

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1. Engine control software development: Concept
2. Engine control software development over time
3. New approach: Model based development
   a. Model based development: phases
   b. Model based development: advantages
   c. Model based development: example
4. Conclusions

ENGINE CONTROL SOFTWARE DEVELOPMENT -CONCEPT

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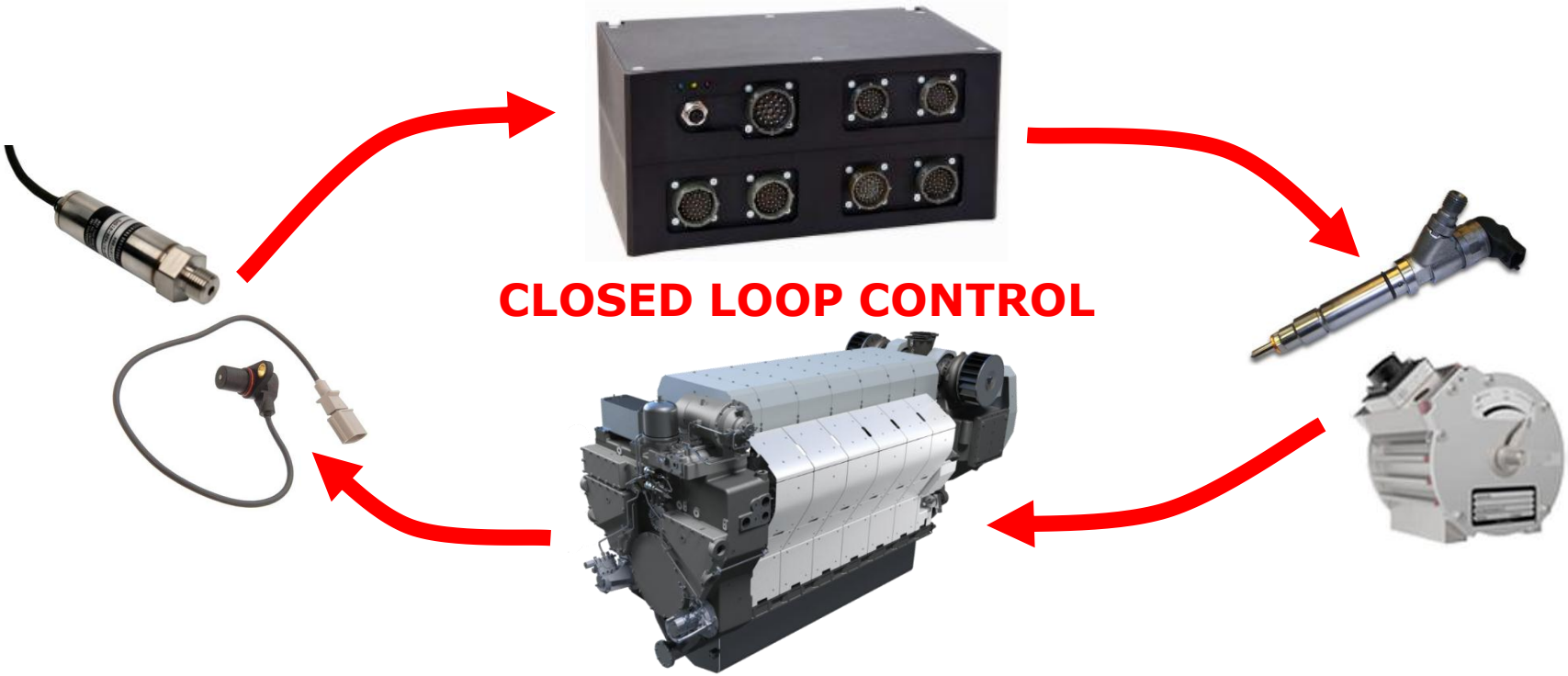
- Software to control the complete powertrain system
  - Includes: sensors and actuators needed for control strategies
- Typical control systems for large engines:
  - ✓ Rotational engine speed control
  - ✓ Rail pressure control
  - ✓ Boost pressure control
  - ✓ Monitoring and diagnosis
  - ✓ Emissions optimization
  - ✓ Consumption optimization



ENGINE CONTROL SOFTWARE DEVELOPMENT -CONCEPT

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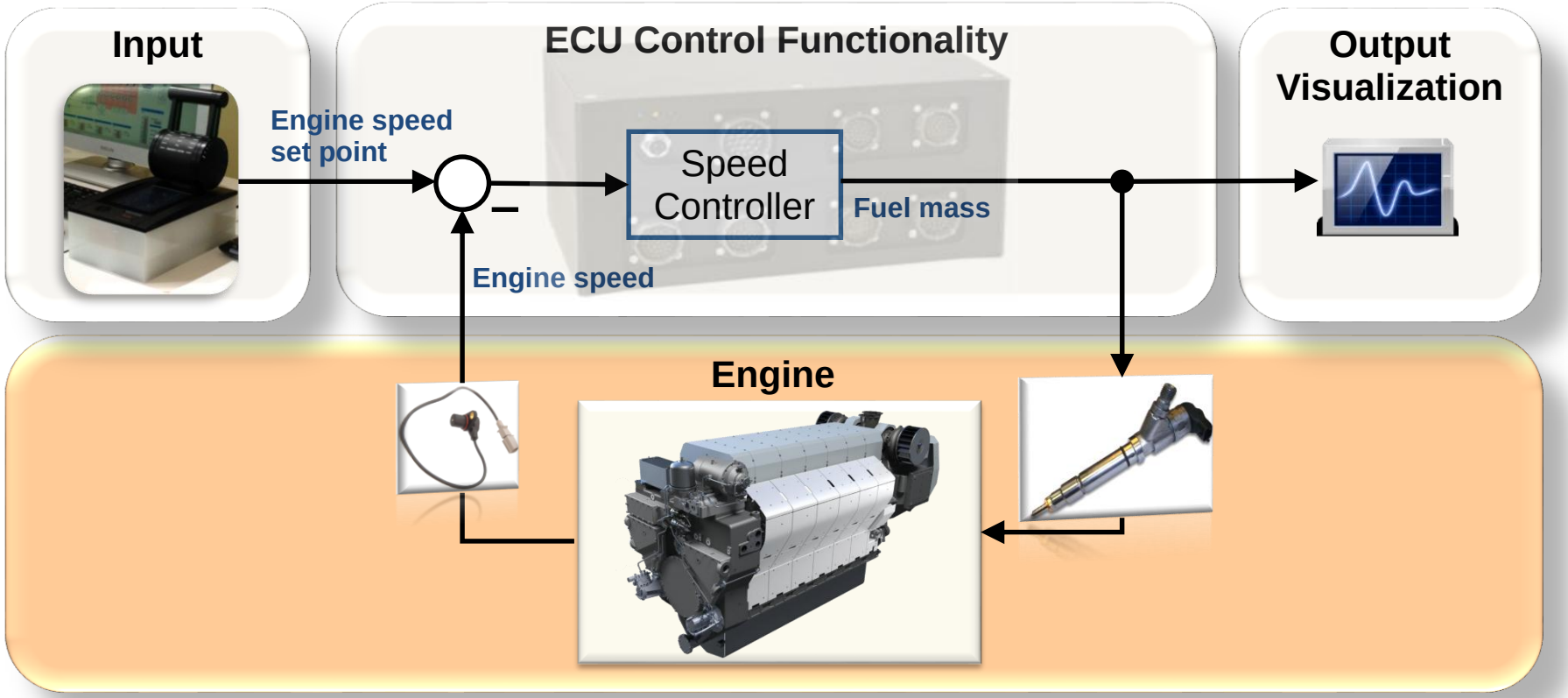
Typical example for a large engine: **rotational engine speed control**

- A lever sets an engine speed set point
- The Engine Control Unit (ECU) functionality shall keep the engine speed constant to the demand value



ENGINE CONTROL SOFTWARE DEVELOPMENT OVER TIME

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Mayor software improvements over time allowing for: shorter development time, reduce costs and increased quality

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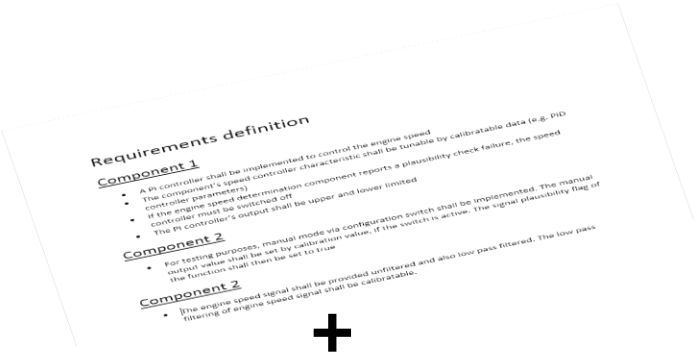

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No test of requirements

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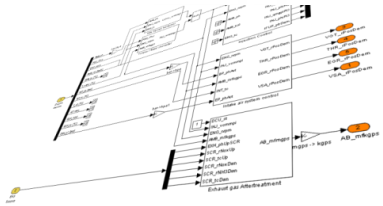
Manual code generation

- Very time consuming
- Poor overview
- Need software experts

2

MATLAB SIMULINK



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Open loop test

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Manual code generation

- Open loop test ✓
- Graphical model overview ✓
- Need software experts ☹

ENGINE CONTROL SOFTWARE DEVELOPMENT OVER TIME

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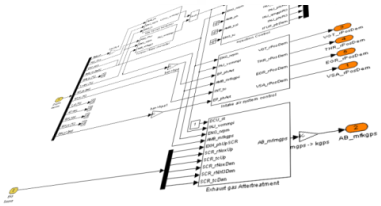
3

MATLAB SIMULINK



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Open loop test

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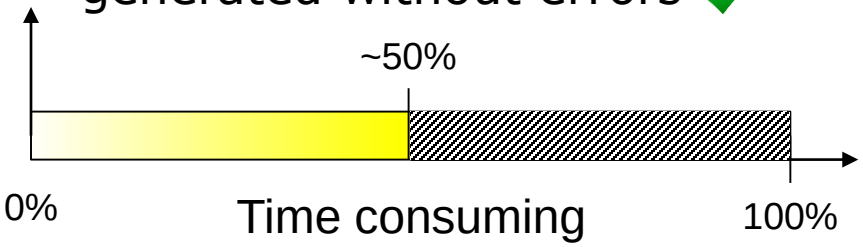
Auto code generation

- Open loop test ✓
- Graphical overview ✓
- Fast code generation. Code generated without errors ✓



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MATLAB SIMULINK

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AVL CRUISE M
Simulate anywhere.

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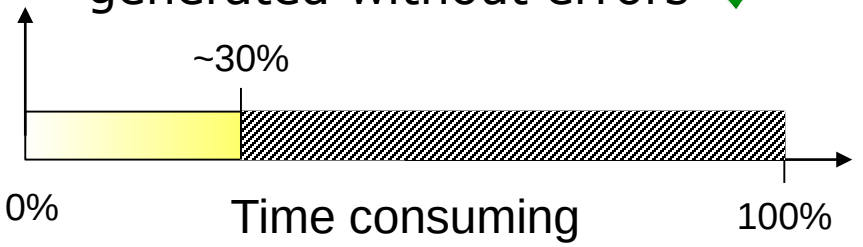
Auto code generation

- Closed loop test ✓
- Graphical overview ✓
- Fast code generation. Code generated without errors ✓



NEW APPROACH: MODEL BASED DEVELOPMENT

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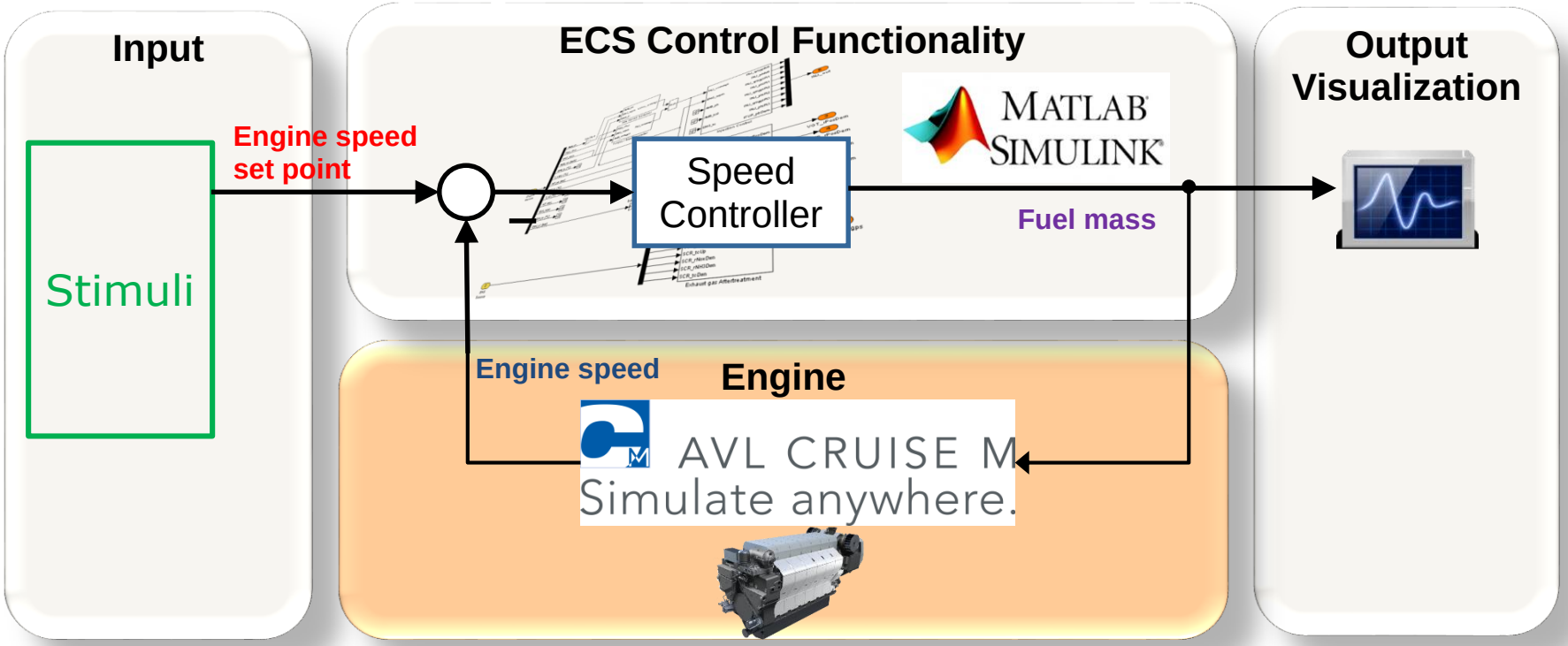
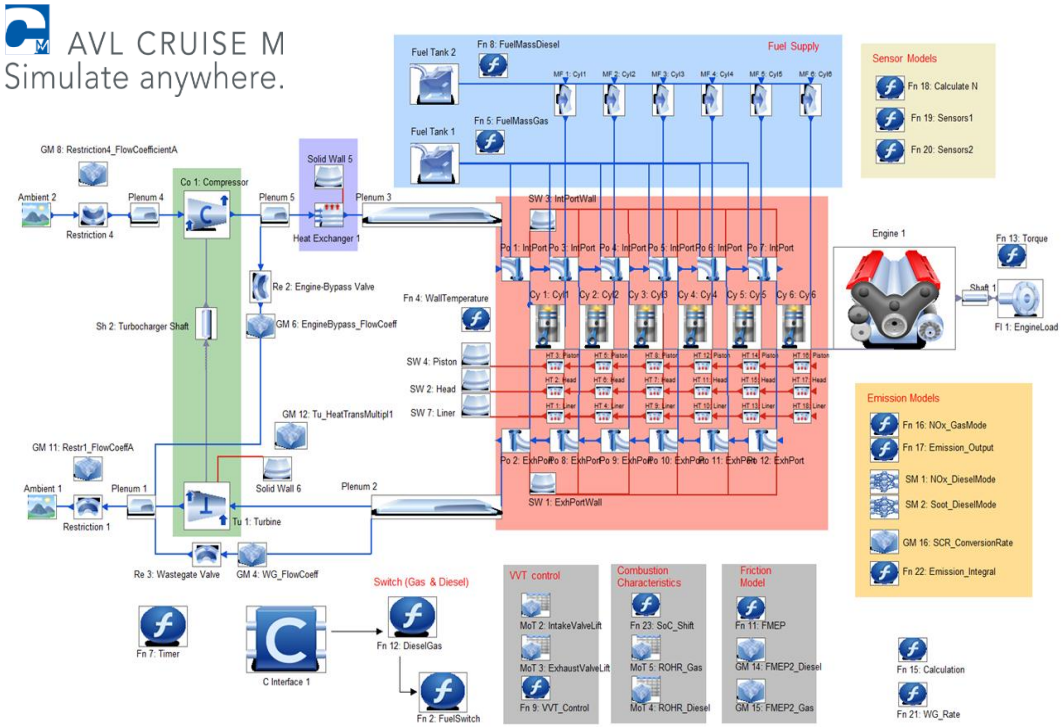
Working flow:

1. Development of software functions using a graphical programming language (e.g. Simulink) according to the customer requirements
2. **Test the software functions in Simulink using a virtual engine model (closed loop test)**
3. Generate C code and flash it into the ECU
4. Verification of software functions at engine test bench (closed loop test)



NEW APPROACH: MODEL BASED DEVELOPMENT

AVL SOFTWARE AND FUNCTIONS



- Detailed engine model: Crank angle resolution for cylinder and gas path
- Innovative, numerically-optimized approach and advanced solver technology allows real-time capability
- Multiple applications of real-time engine models in the software development process

MODEL BASED DEVELOPMENT: PHASES

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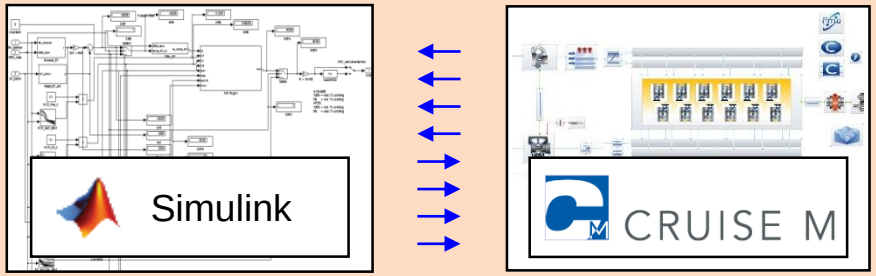
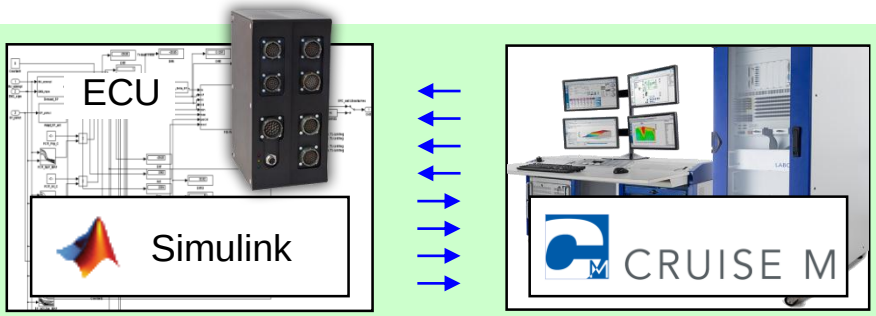
Model-in-the-Loop (MiL)

- ECU concept
- Functions and ECU development



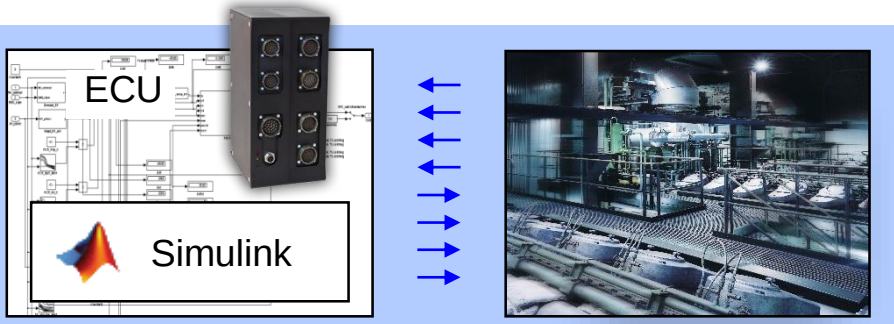
Hardware-in-the-Loop (HiL)

- ECU development
- Pre-calibration, Monitoring, OBD
- Hardware-Tests



Engine test bench

- Verification
- Refinement



MODEL BASED DEVELOPMENT: PHASES

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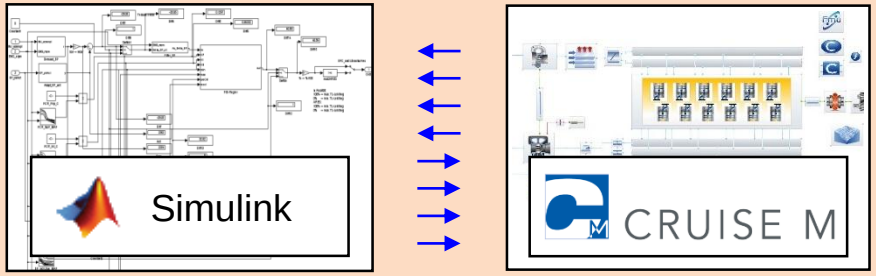
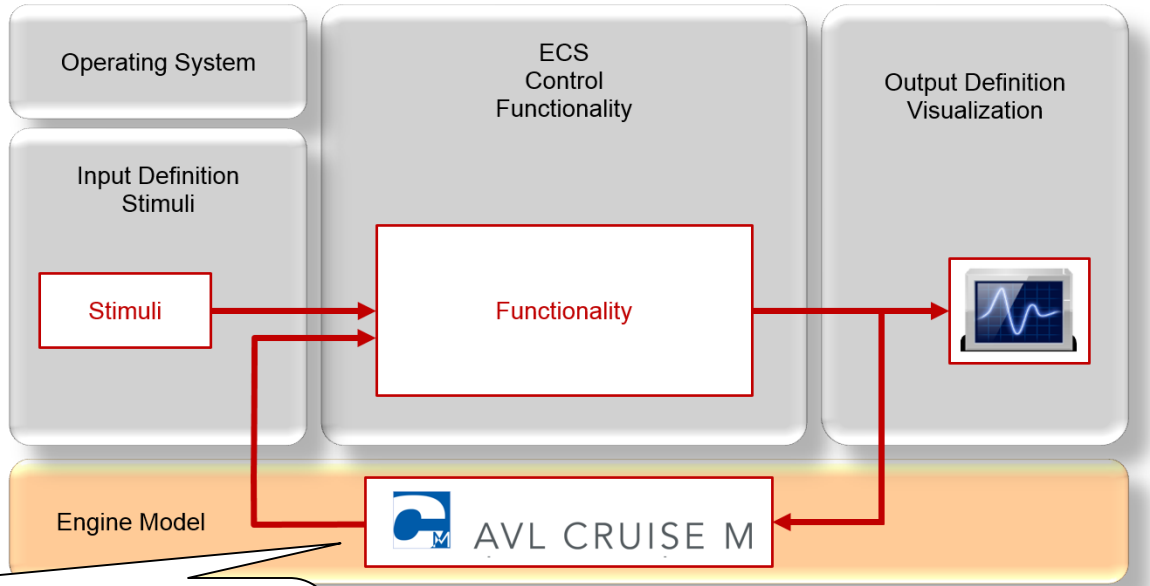


- ✓ Entire Simulink environment
- ✓ Development of functions
- ✓ Virtual engine model interface available for Simulink
- ✓ Closed loop test using virtual engine models



Motor model

State of the Art:
No model or very simple model (mean model, map)

AVL-Proposal:
Physical Model (Cylinder and air path in CRK angle resolution)

MODEL BASED DEVELOPMENT: PHASES

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Hardware-in-the-Loop (HiL)

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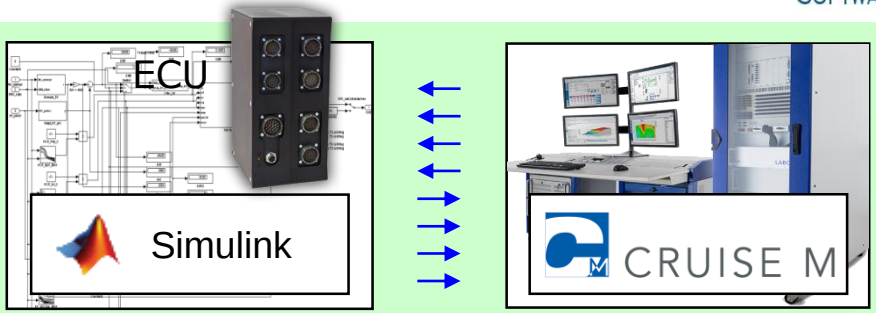
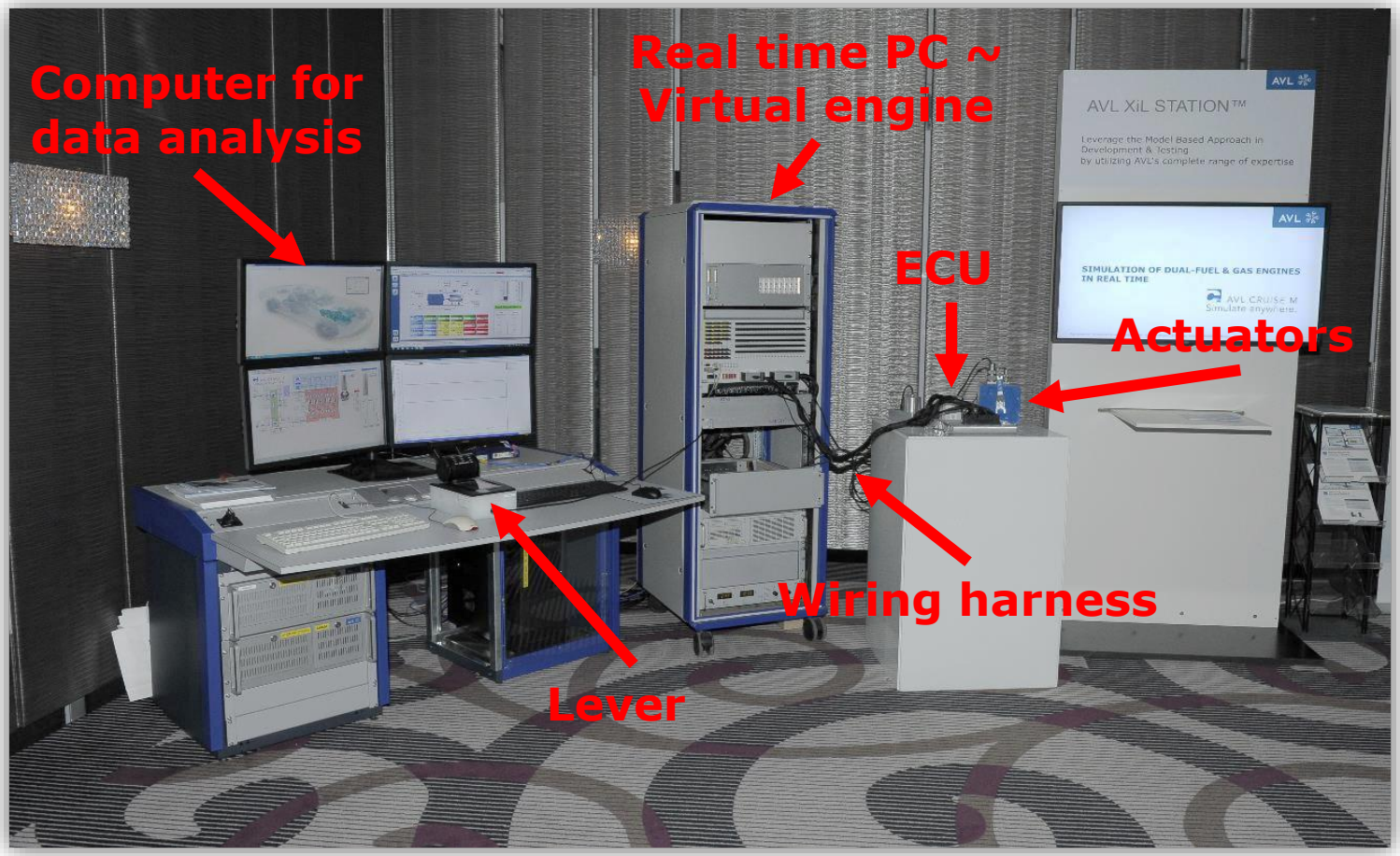
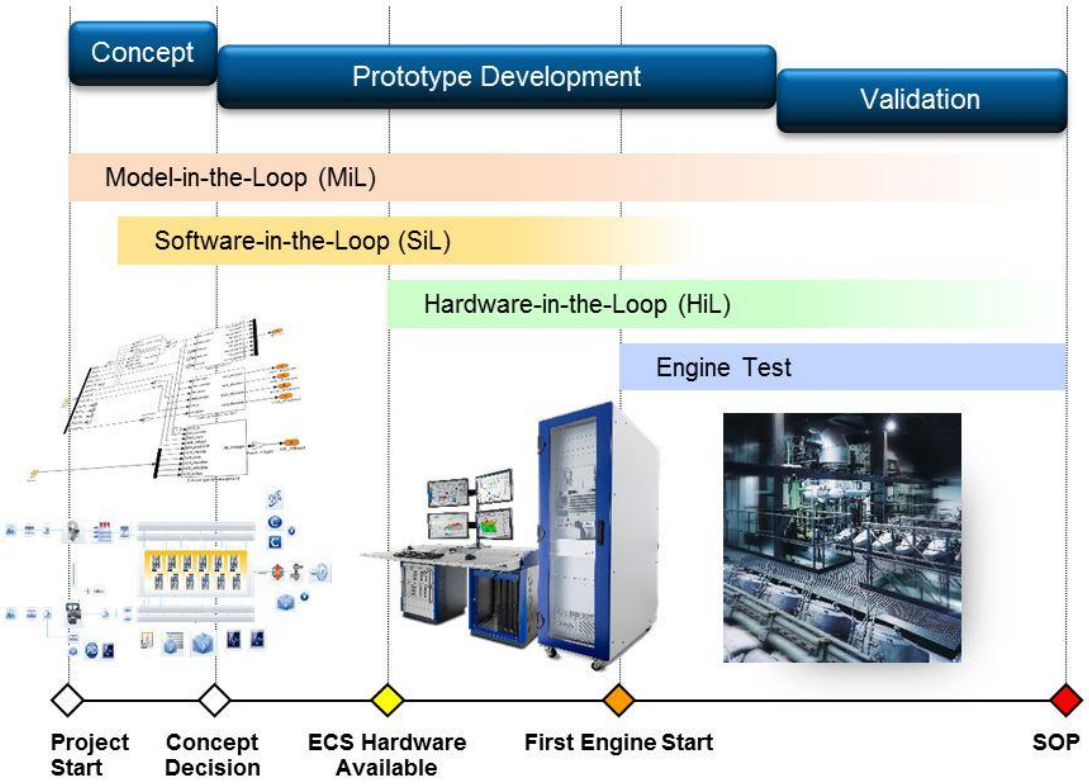




MODEL BASED DEVELOPMENT: ADVANTAGES



- **Higher maturity of engine control** achieved earlier in the development
- **No risk of engine-component damage** in MiL & HiL environment
- **Pre-calibration and validation** of control functionality are developed in **MiL & HiL** environment
- Model based software development **saves time and money and improves quality** of the software

MODEL BASED DEVELOPMENT: EXAMPLE

- Motor type (~ 1 MW per Cyl.)
  Bore > 300 mm
- Dual Fuel (Diesel, Gas)
- One stage turbo with wastegate
- Motor bypass and compressor bypass valve developed for fine λ-control
- Variable valve timing
- Generator operation, ship propulsion

MODEL BASED DEVELOPMENT: EXAMPLE

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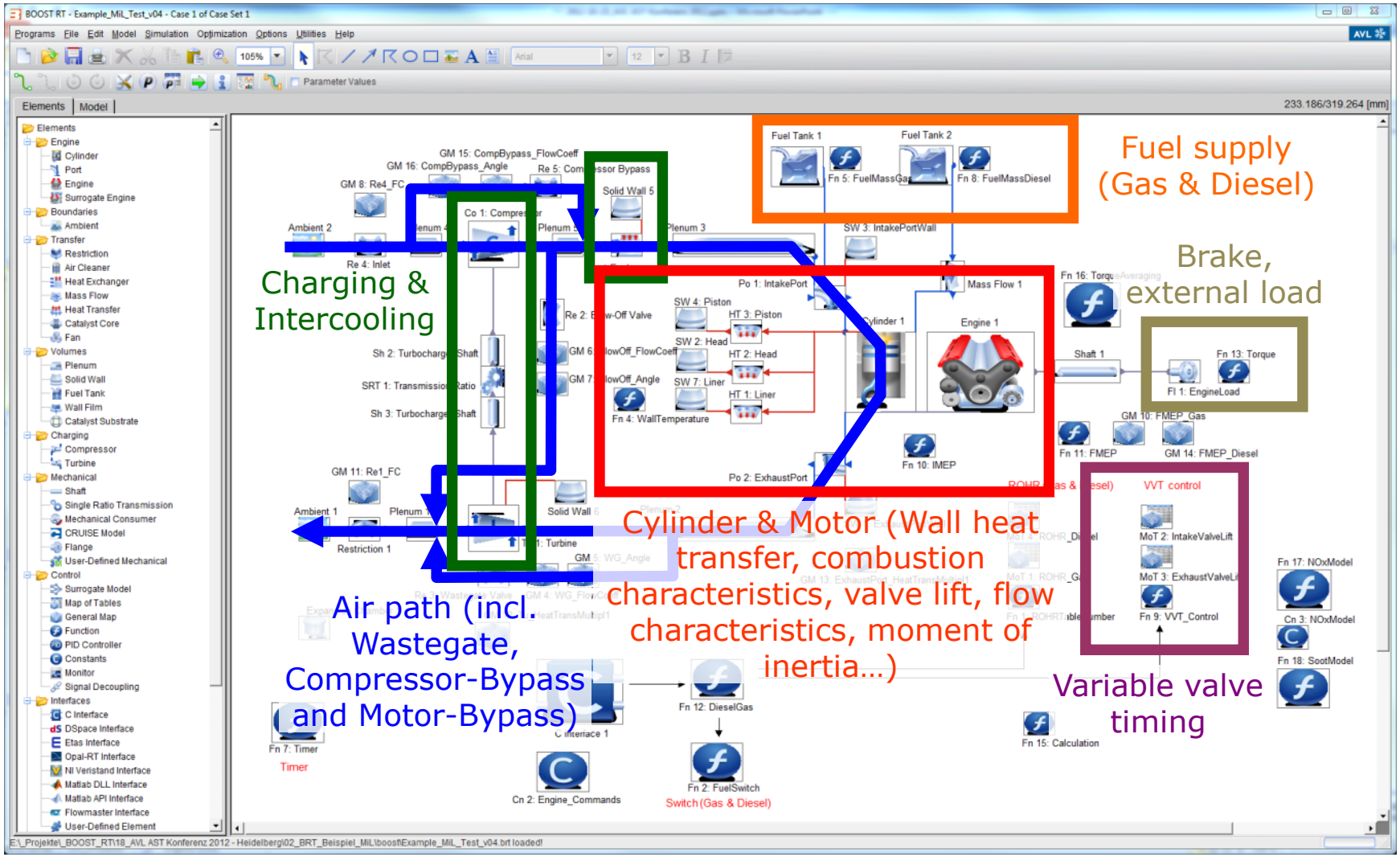
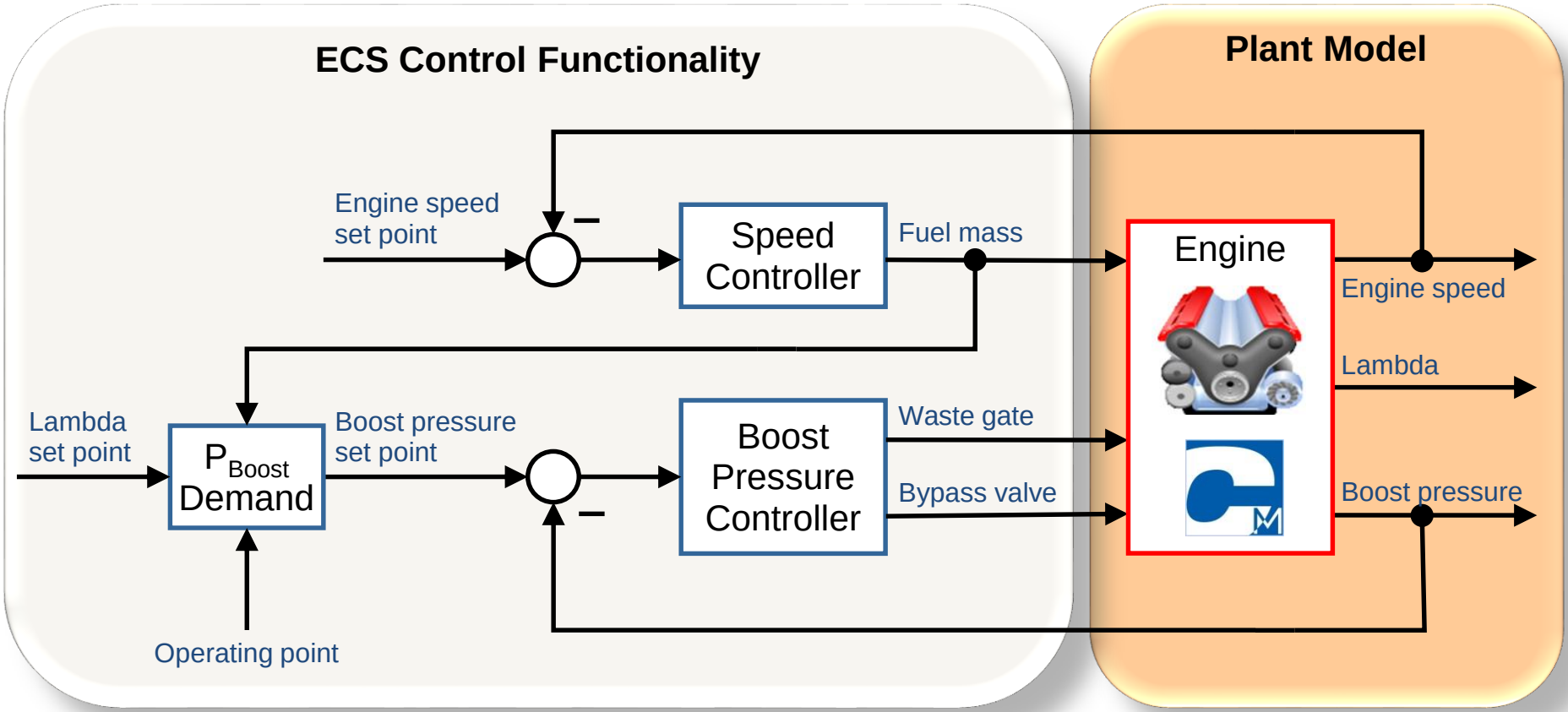
Building the model | Software development | Closed loop test (HiL)



MODEL BASED DEVELOPMENT: EXAMPLE

AVL SOFTWARE AND FUNCTIONS

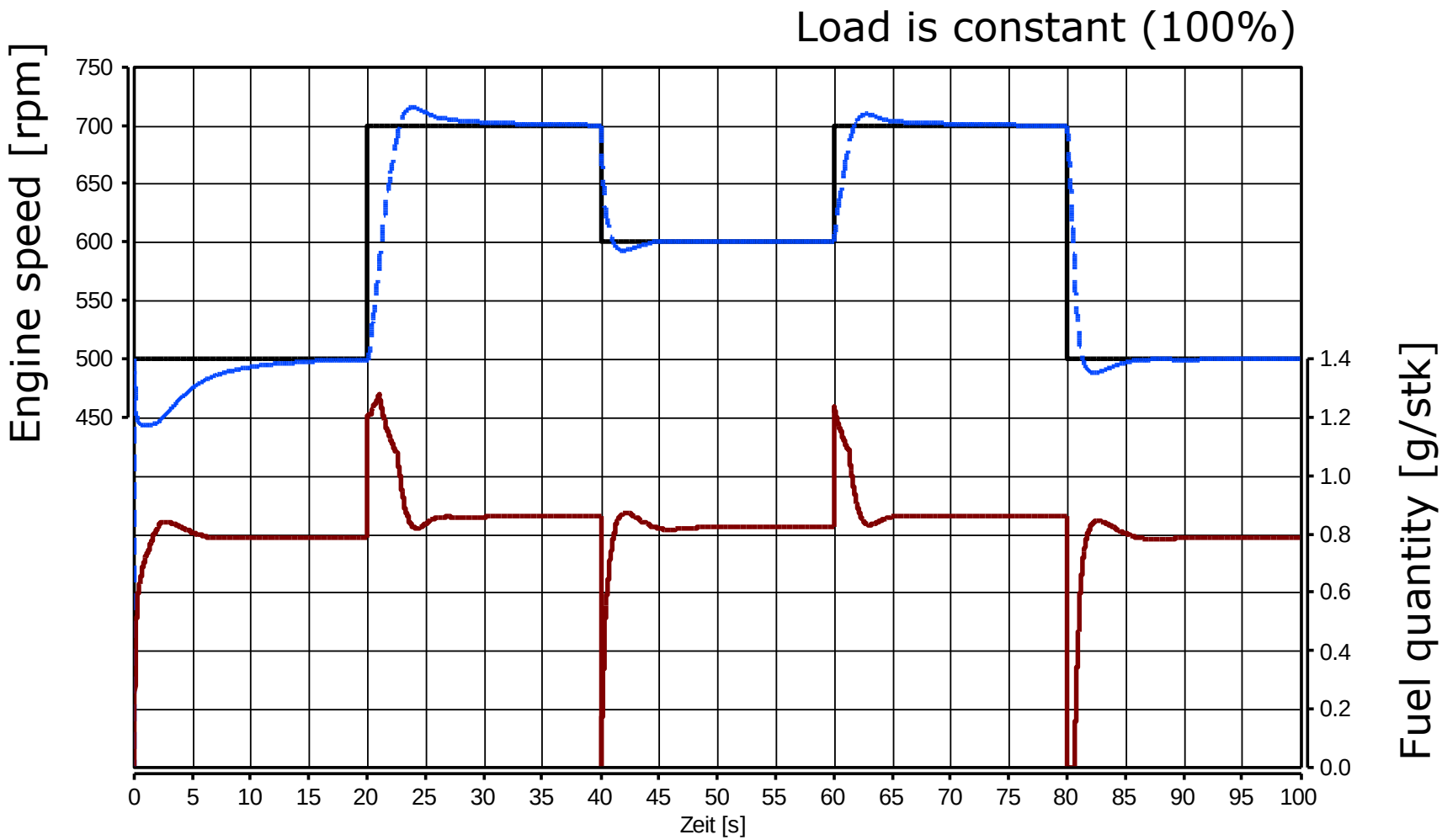
Building the model | **Software development** | Closed loop test (HiL)



MODEL BASED DEVELOPMENT: EXAMPLE

AVL SOFTWARE AND FUNCTIONS

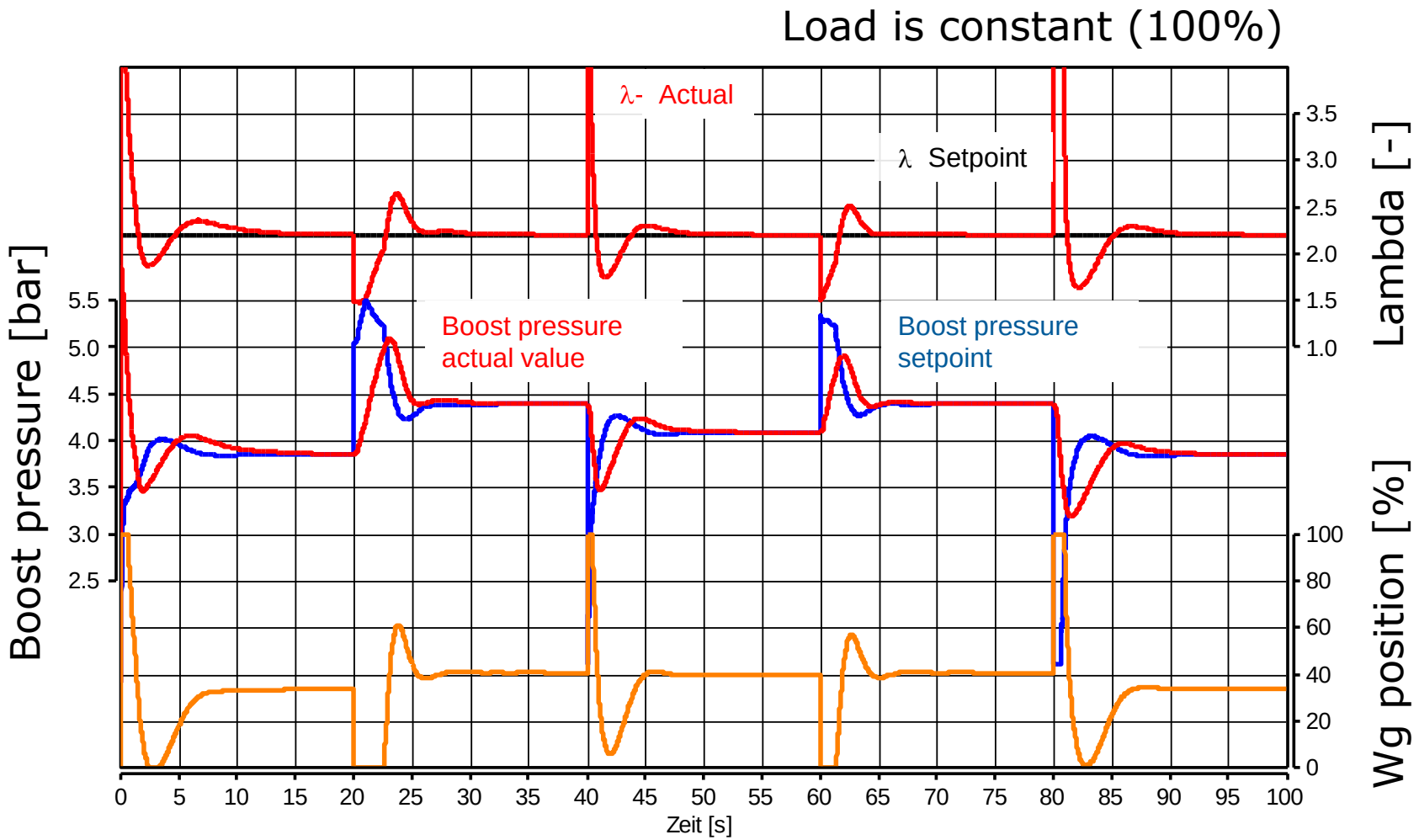
Building the model | Software development | **Closed loop test (HiL)**



MODEL BASED DEVELOPMENT: EXAMPLE

AVL SOFTWARE AND FUNCTIONS

Building the model | Software development | **Closed loop test (HiL)**



CONCLUSIONS

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- Model based software development **saves time and money** and **improves software quality**
- **Innovative, physical real-time engine models** (simulation in crank angle resolution, 0D gas dynamics) allow the observation of various motor phenomena that can not be considered with mean value models

THANK YOU

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