Chip simulation of automotive ECUs

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9. Symposium
Steuerungssysteme für automobile Antriebe
Berlin-Tempelhof, 20.-21.09.2012

Chip simulation of automotive ECUS

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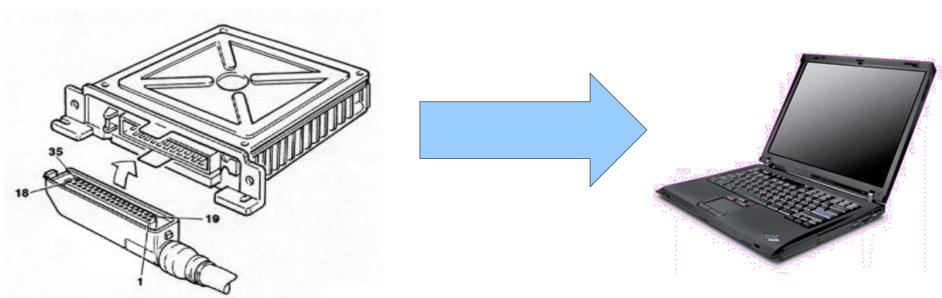
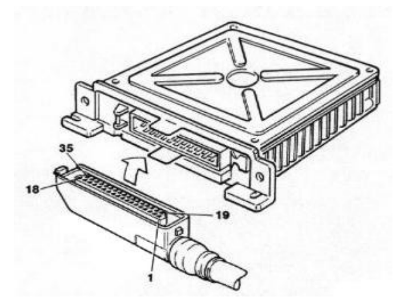
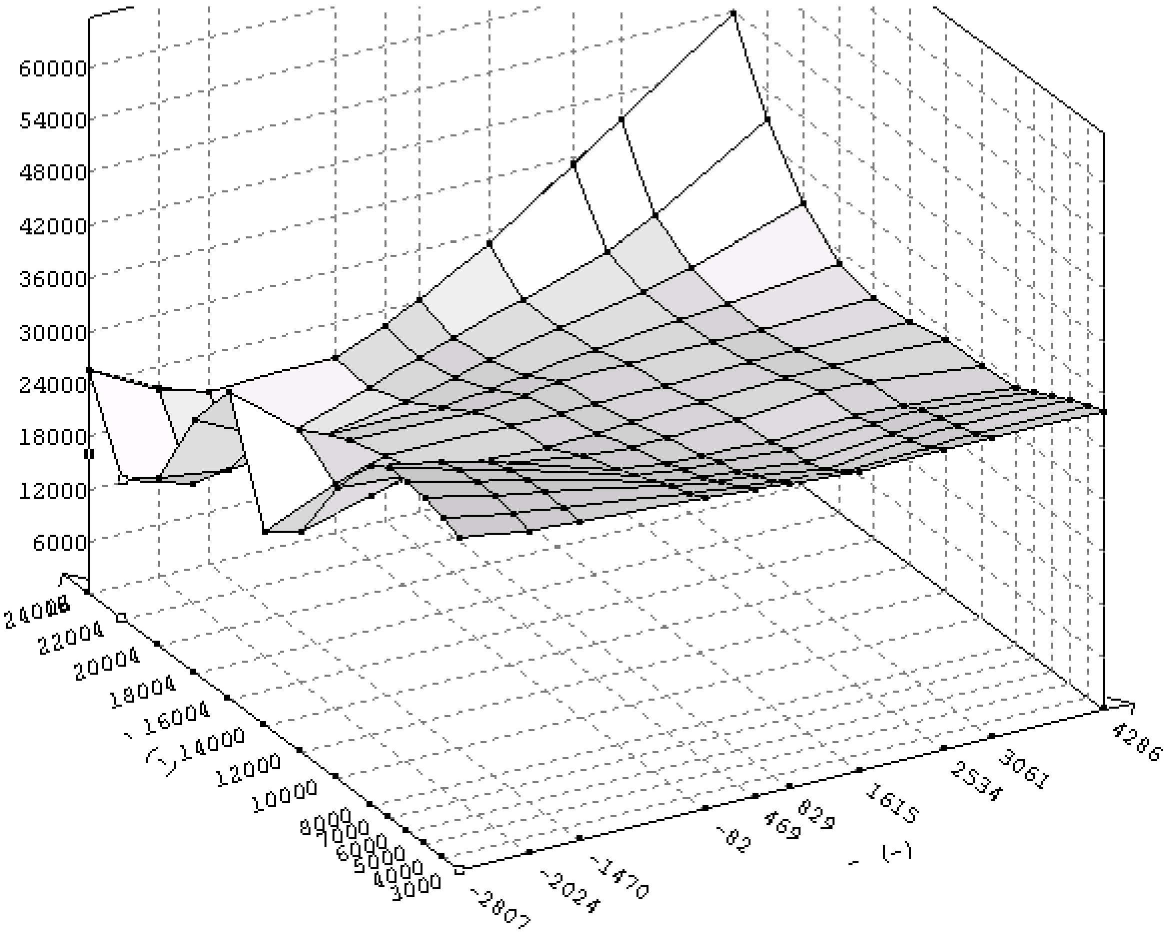


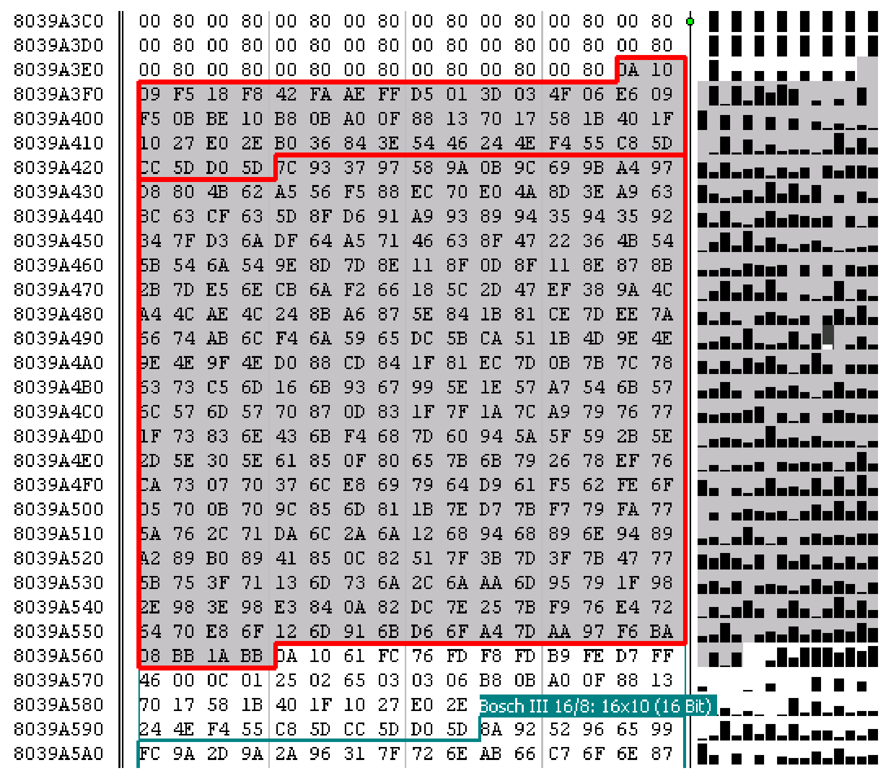
Motivation

ECU: more than 30.000 software parameter

Example: 16 x 10 map







ECU memory dump

Motivation

Engine calibration

- tune more than 30.000 ECU parameter
- done by the OEM, not by the supplier of the ECU

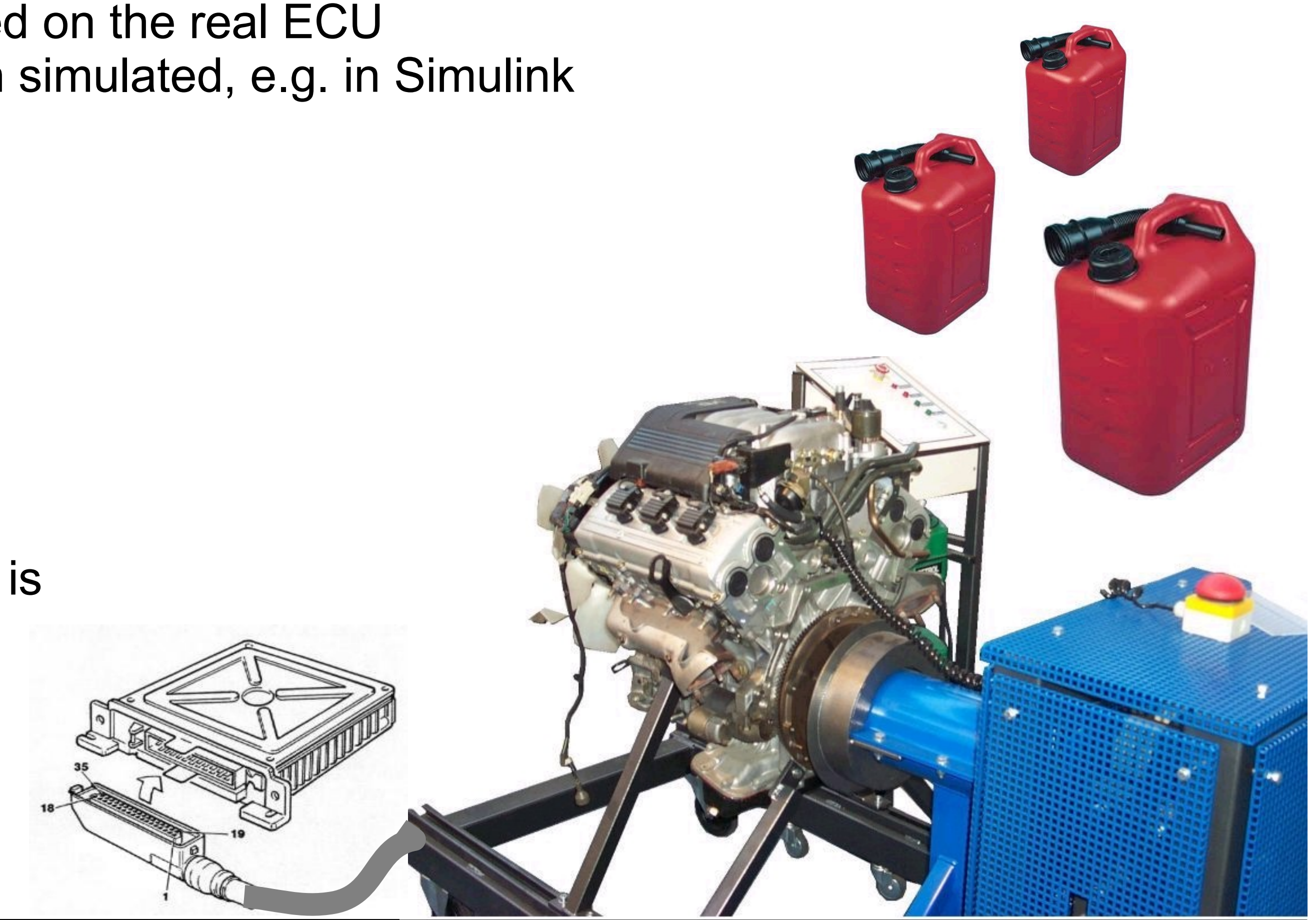
Process today

- automated optimization of stationary states
- real-time test rig or vehicle: based on the real ECU
- PC based: engine and ECU both simulated, e.g. in Simulink

Problems

- real-time test rig:
  - limited reproducibility
  - expensive (invest, operation)
  - slow (real time)

- PC: reverse engineering of ECU is
  - time consuming
  - complex
  - error prone



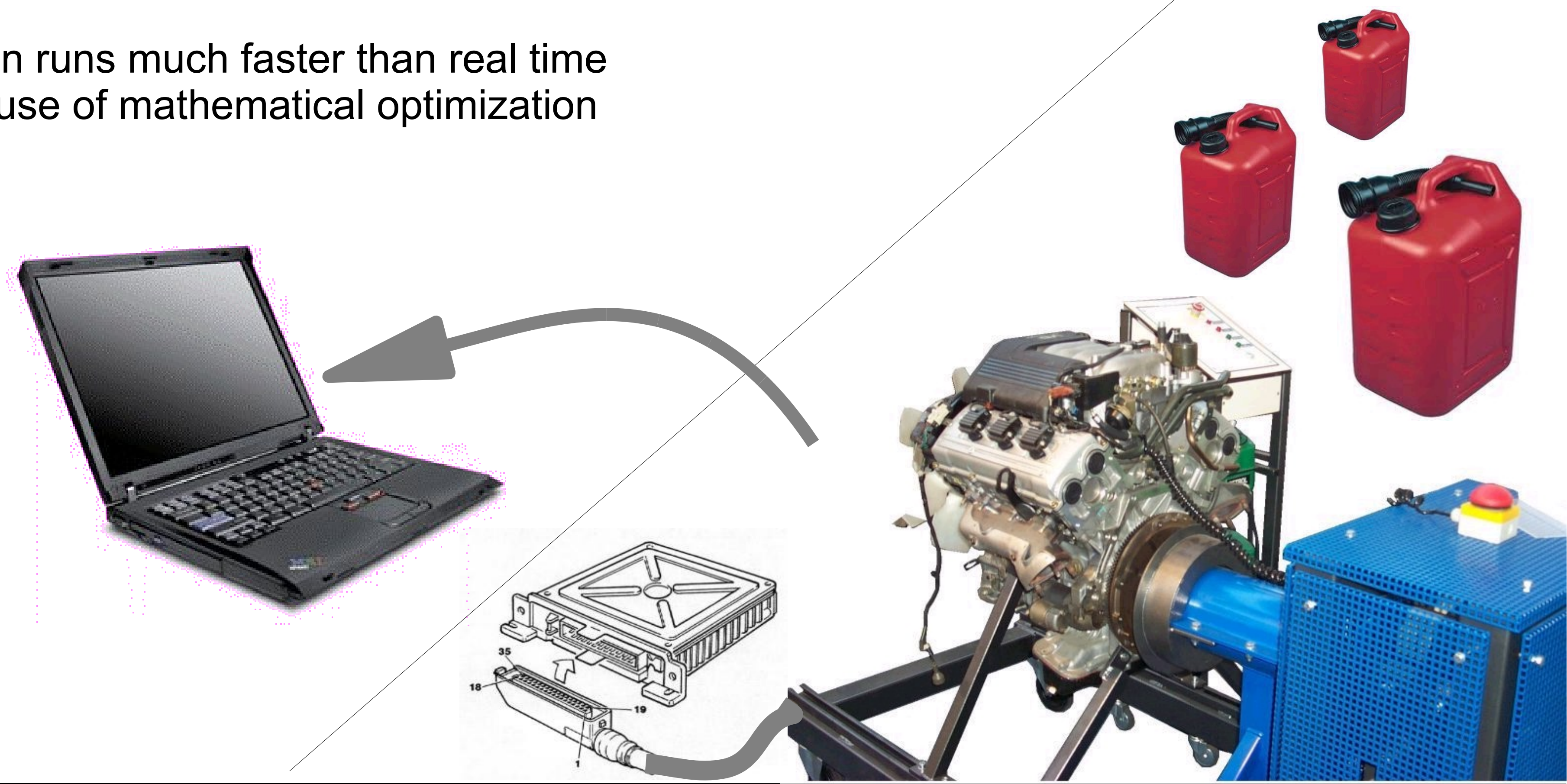
Motivation

Idea

move engine calibration (and other development tasks)
from test rig to PC

Benefit

- simulation runs much faster than real time
- enables use of mathematical optimization

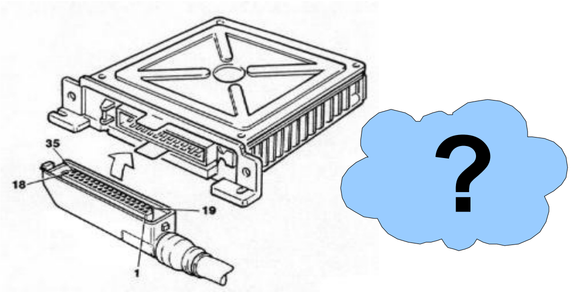


Motivation

Simulation of ECUs on PC:

Problem:

How to simulate ECU if **no C source or model** is available ?

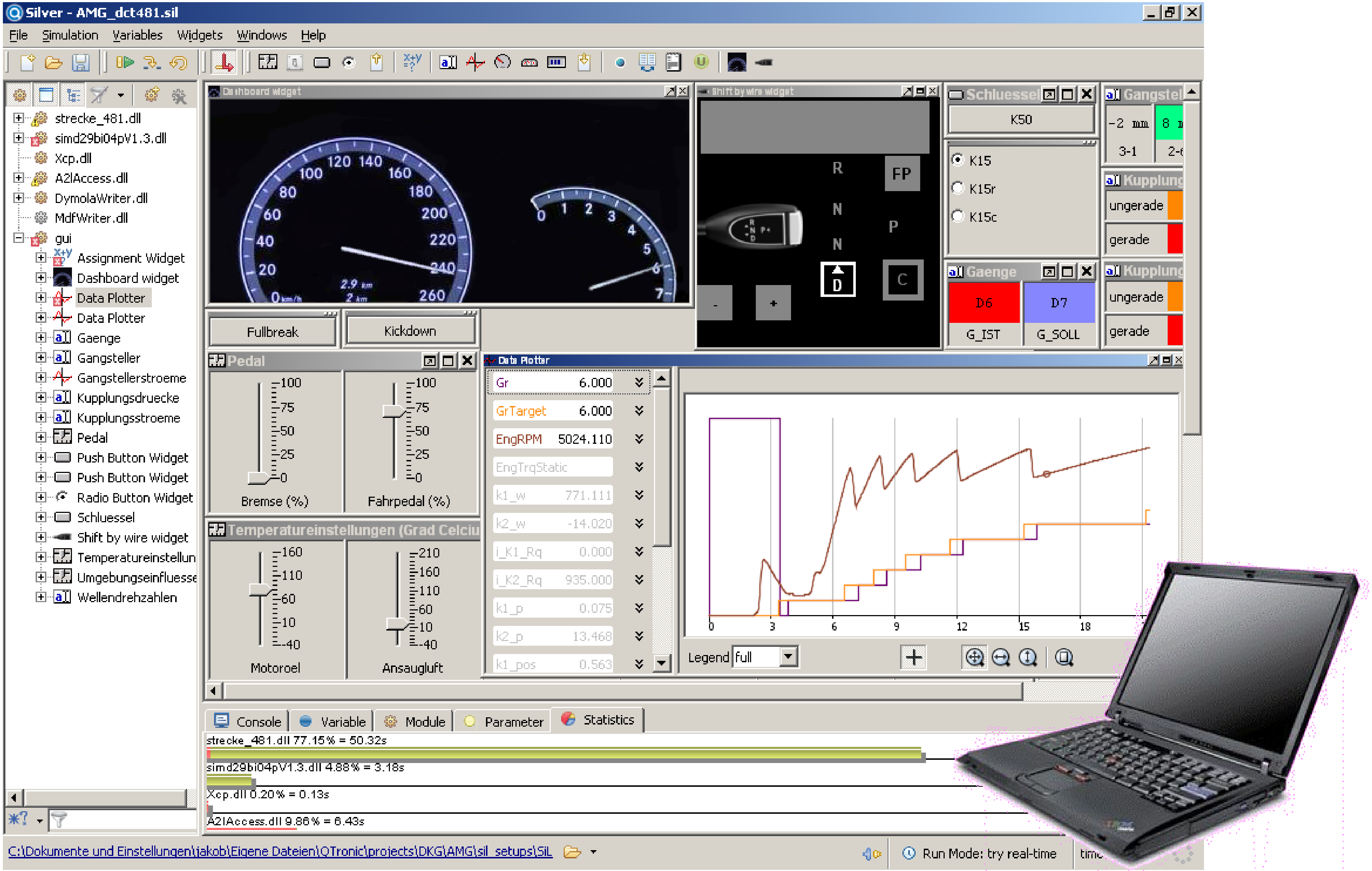


Ideas:

- Simulate the CPU based on the hex file
- Integrate this feature into MATLAB and QTronic Silver

Example - TCU Control Software in Silver

QTronic SIMULATION FOR ENGINEERING



Setting up a TriCore simulation

1. write spec.txt to specify what functions to run
2. step and debug the simulation in Silver debug mode
3. generate fast running SFunction or Silver module: runs without a2l and hex

Setting up a TriCore simulation

QTronic
SIMULATION FOR ENGINEERING

1. write spec.txt to specify what functions to run
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3. generate fast running SFunction or Silver module: runs without a2l and hex

```
# specification of sfunction or Silver module
hex_file(m12345.hex, TriCore_1.3.1)
a2l_file(m12345.a2l)
map_file(m12345.map)      # a TASKING or GNU map file
frame_file(frame.s)       # assembler code to emulate RTOS
frame_set(STEP_SIZE, 10) # Silver step size in ms
frame_set(TEXT_START, 0xa0000000) # location of frame code

# functions to be simulated, in order of execution
task_initial(ABCDE_ini)
task_initial(ABCDE_inisyn)
task_triggered(ABCDE_syn, trigger_ABCDE_syn)
task_periodic(ABCDE_20ms, 20, 0)
task_periodic(ABCDE_200ms, 200, 0)

# interface of the generated sfunction or Silver module
a2l_function_inputs(ABCDE)
a2l_function_outputs(ABCDE)
a2l_function_parameters_defined(ABCDE)
```

generated SFunction in MATLAB/Simulink

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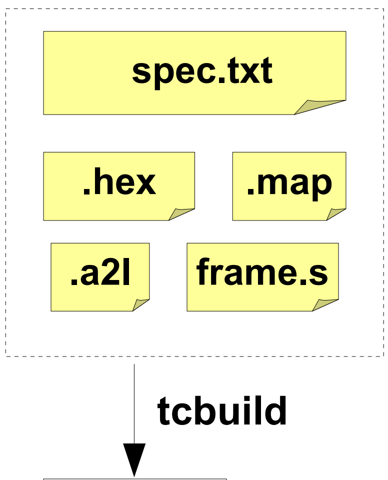
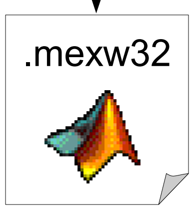
SIMULATION FOR ENGINEERING

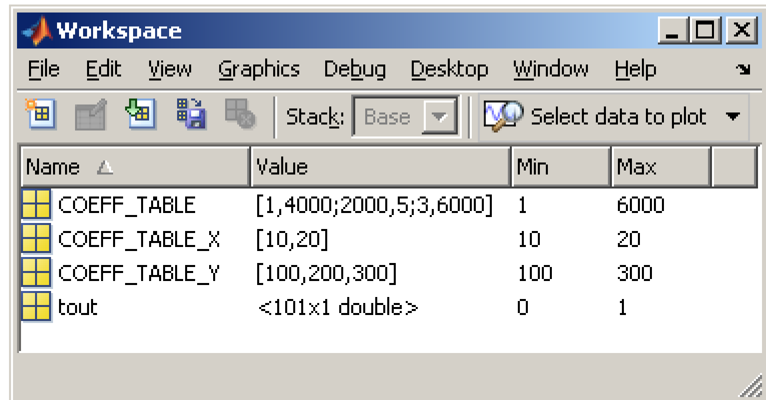




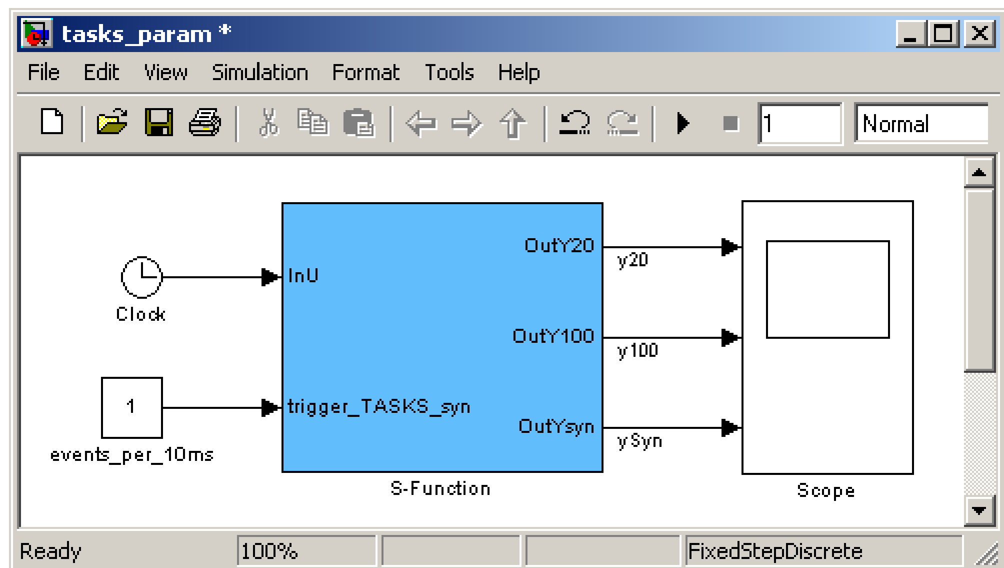
MATLAB/Simulink S-function
40 MIPS

default values for characteristics from HEX file as m script,

mask for S-function block and similar Simulink snippets



characteristics turned into MATLAB workspace variables
- read by S-function
- may be modified by script



generated virtual ECU in Silver

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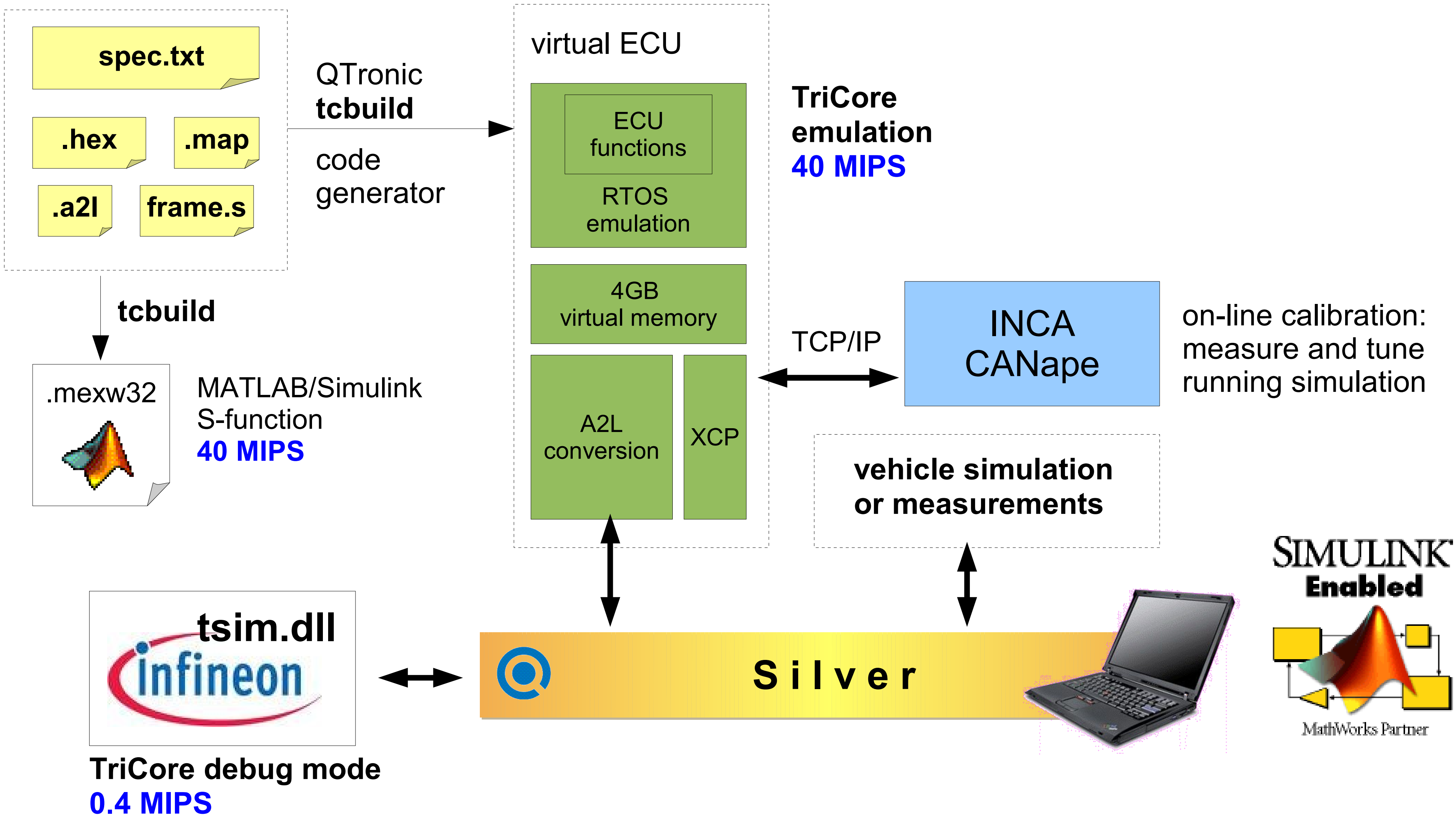
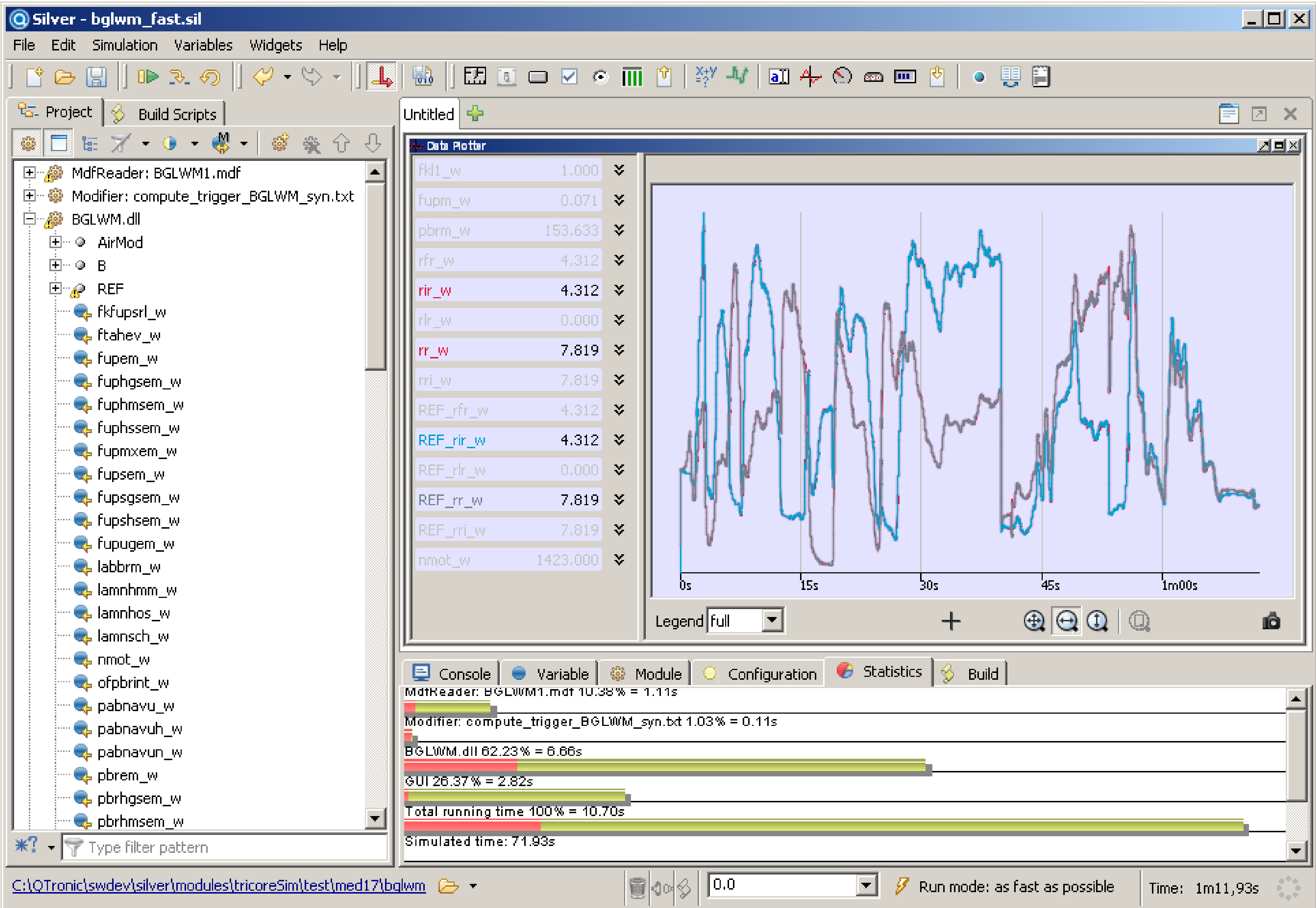
SIMULATION FOR ENGINEERING



Virtual ECU running in Silver: MED17



Performance and Limitations

QTronic SIMULATION FOR ENGINEERING

Run complex function for a measured scenario, 3.5 minutes

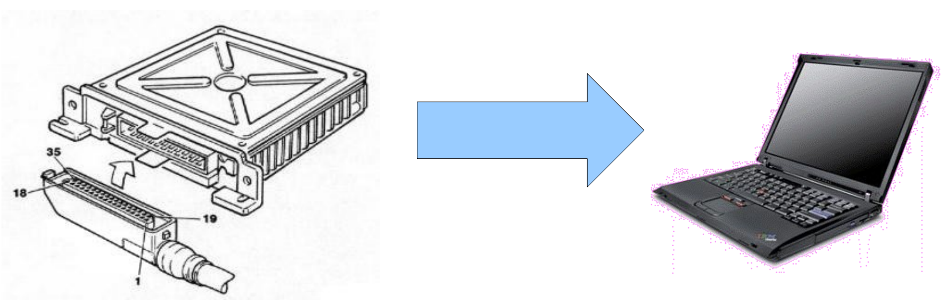
target	**execution time**	**MIPS**
Silver in debug mode	919.15 sec	0.41
generated Silver module or MATLAB/Simulink SFunction	9.30 sec	40.80
MED17 with TC1797, 180 Mhz	210.00 sec	270

Limitations:
- instruction accurate, but not cycle accurate
- based on TriCore specification: 'silicon bugs' are not simulated
- PCP, CAN controllers and other on chip devices not modeled

Summary

ECU simulation on Windows PC

- without expensive reverse engineering
- without access to ECU source files
- based on HEX, MAP and A2L file
- low work effort for modeling
- high accuracy of model
- application example: automated calibration



- works for TriCore processors: TC1796, TC1797, TC1798, ...
- performance: 40 MIPS