



Chip simulation of automotive ECUs

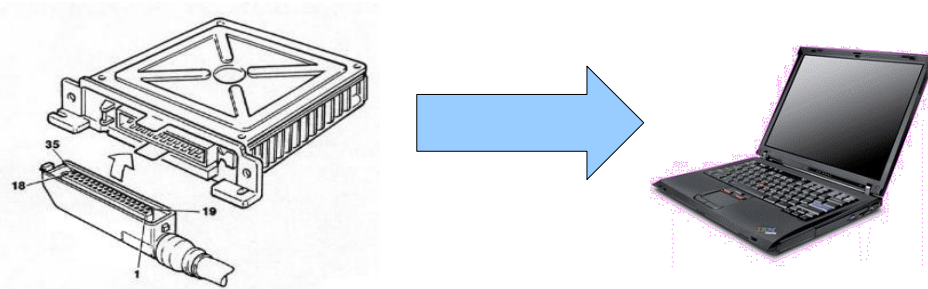
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Chip simulation of automotive ECUS

1. Motivation
2. Setting up a simulation
3. Performance
4. Limitations
5. Conclusion



Engine calibration

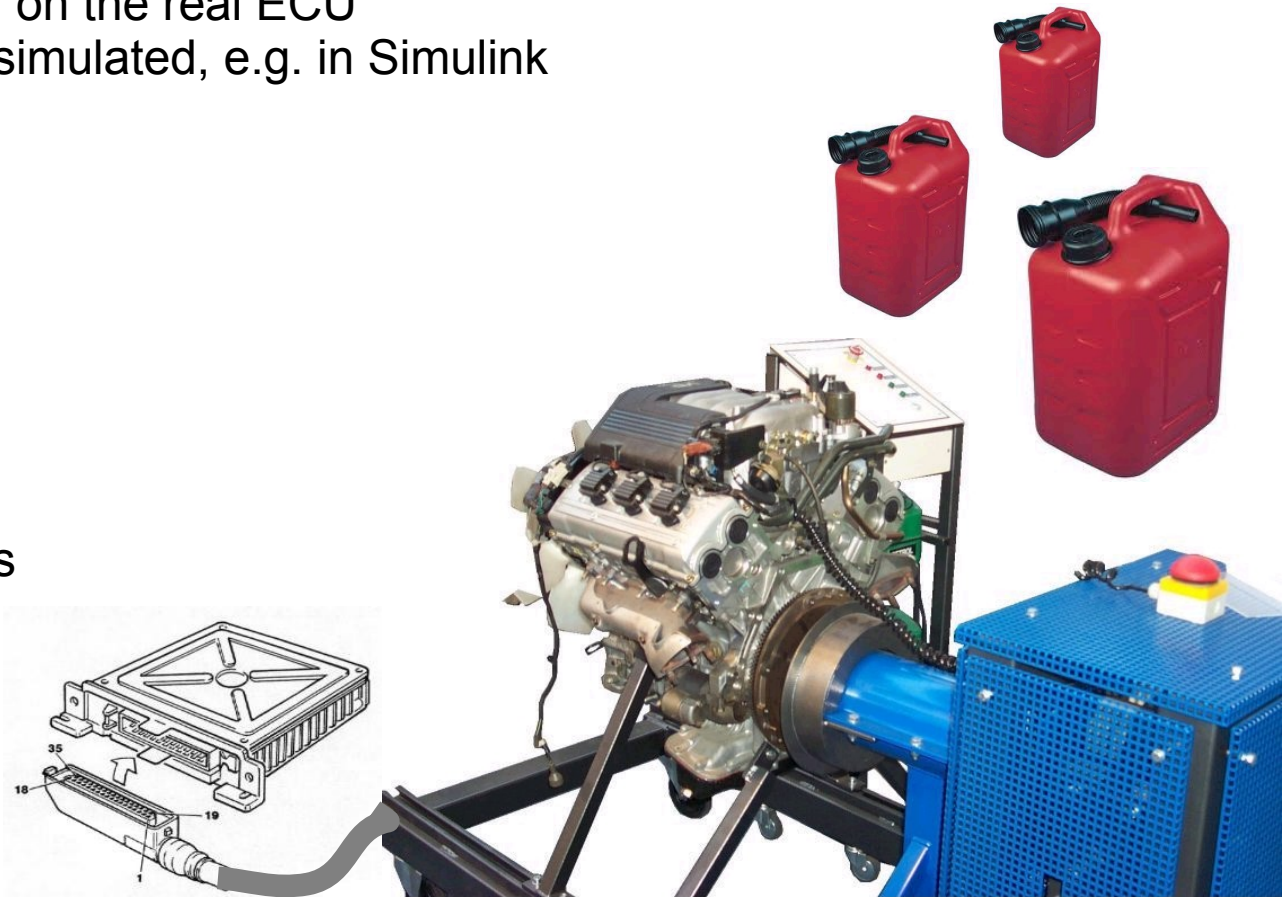
- tune more than 30.000 ECU parameter
- done by the OEM, not by the supplier of the ECU

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

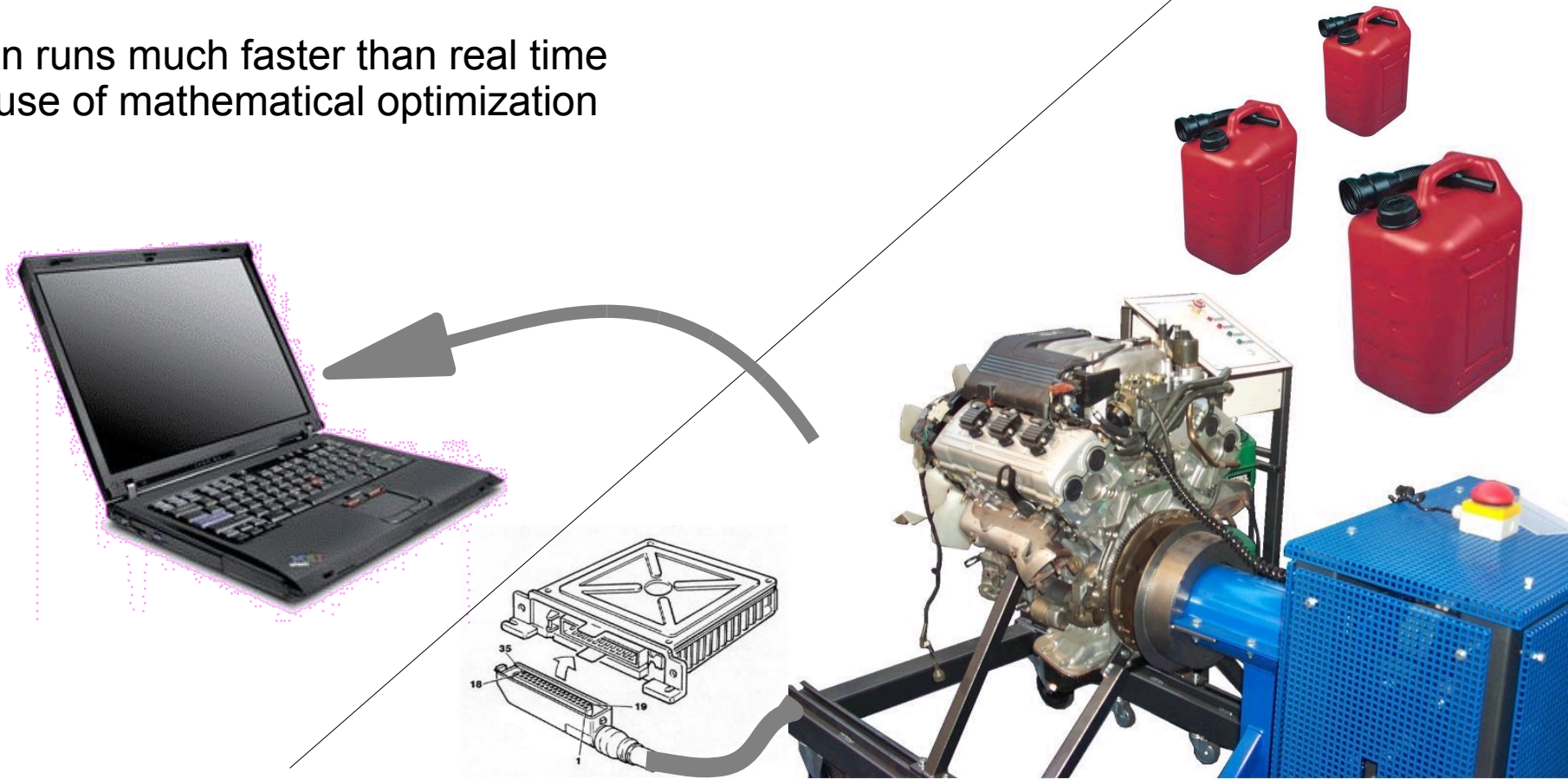


Idea

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

Benefit

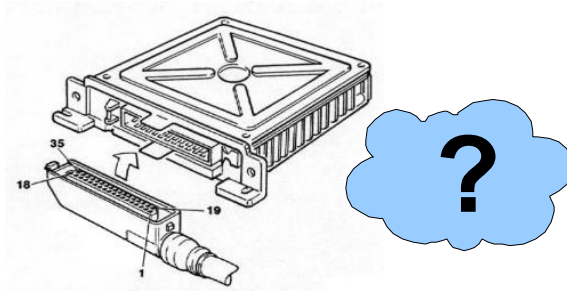
- simulation runs much faster than real time
- enables use of mathematical optimization



Simulation of ECUs on PC:

Problem:

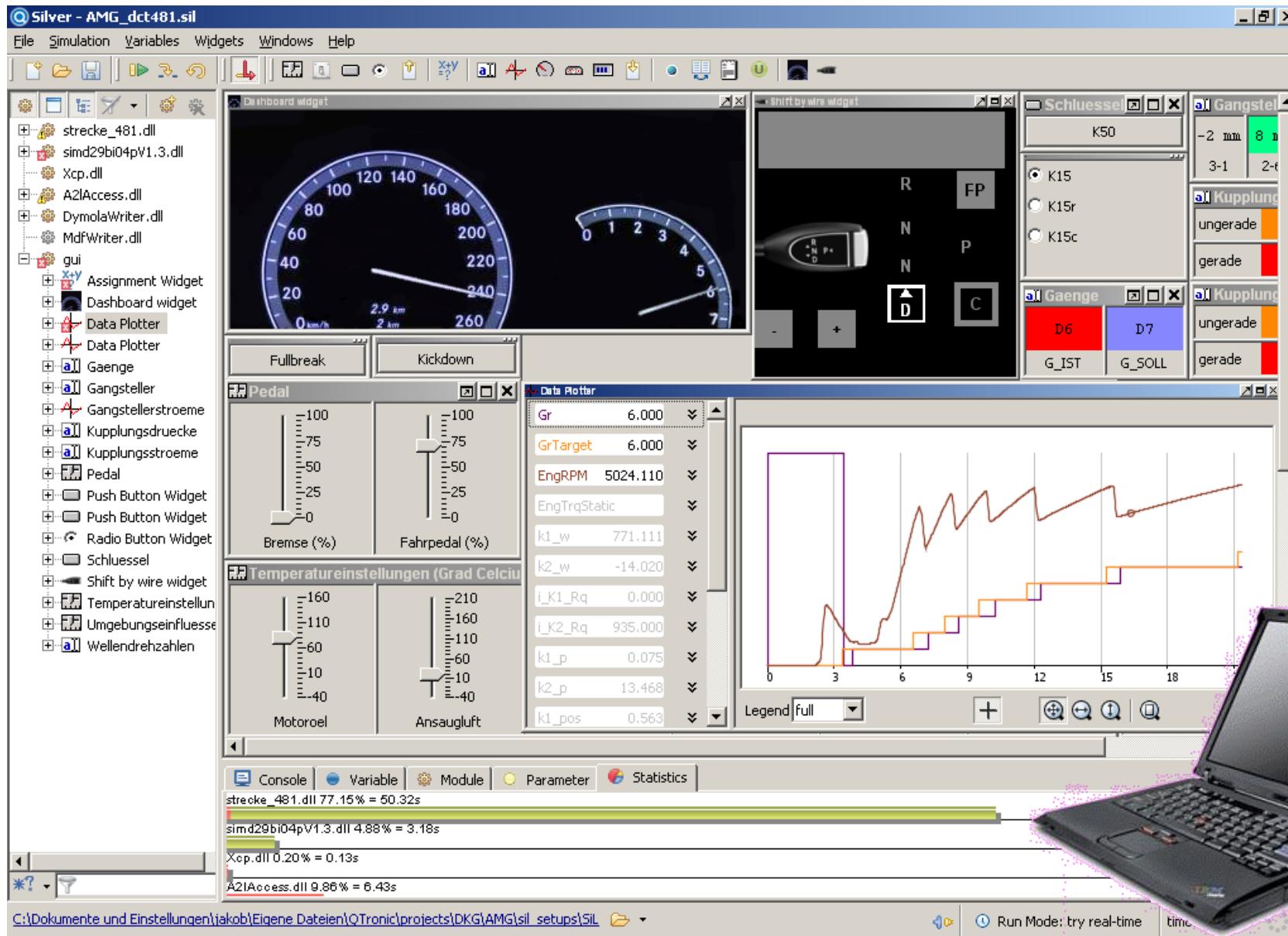
How to simulate ECU if no C source or model is available ?



Ideas:

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

Example - TCU Control Software in Silver

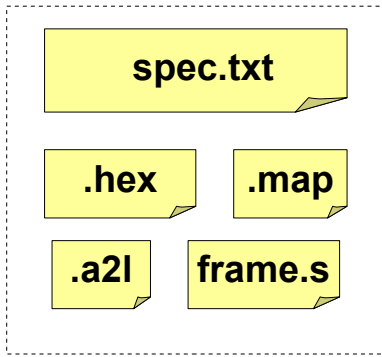


1. write spec.txt to specify what functions to run
2. step and debug the simulation in Silver debug mode
3. generate fast running SFunction or Silver module: runs without a2l and hex

1. write spec.txt to specify what functions to run
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```
01 # specification of sfunction or Silver module
02 hex_file(m12345.hex, TriCore_1.3.1)
03 a2l_file(m12345.a2l)
04 map_file(m12345.map)      # a TASKING or GNU map file
05 frame_file(frame.s)      # assembler code to emulate RTOS
06 frame_set(STEP_SIZE, 10) # Silver step size in ms
07 frame_set(TEXT_START, 0xa0000000) # location of frame code
08
09 # functions to be simulated, in order of execution
10 task_initial(ABCDE_ini)
11 task_initial(ABCDE_inisyn)
12 task_triggered(ABCDE_syn, trigger_ABCDE_syn)
13 task_periodic(ABCDE_20ms, 20, 0)
14 task_periodic(ABCDE_200ms, 200, 0)
15
16 # interface of the generated sfunction or Silver module
17 a2l_function_inputs(ABCDE)
18 a2l_function_outputs(ABCDE)
19 a2l_function_parameters_defined(ABCDE)
```

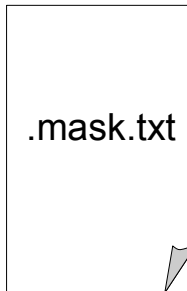
generated SFunction in MATLAB/Simulink



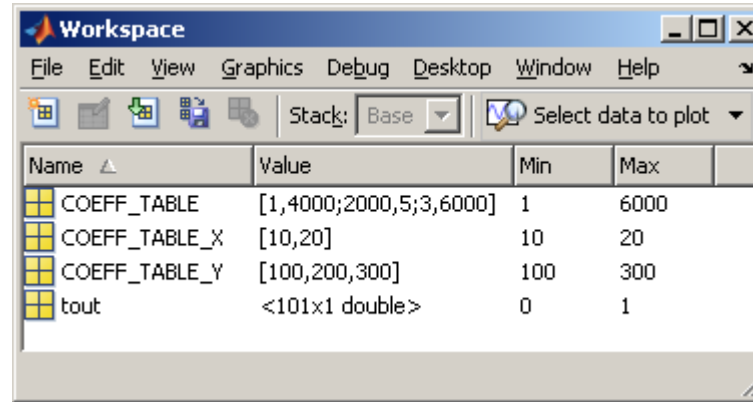
tcbuild



MATLAB/Simulink
S-function
40 MIPS

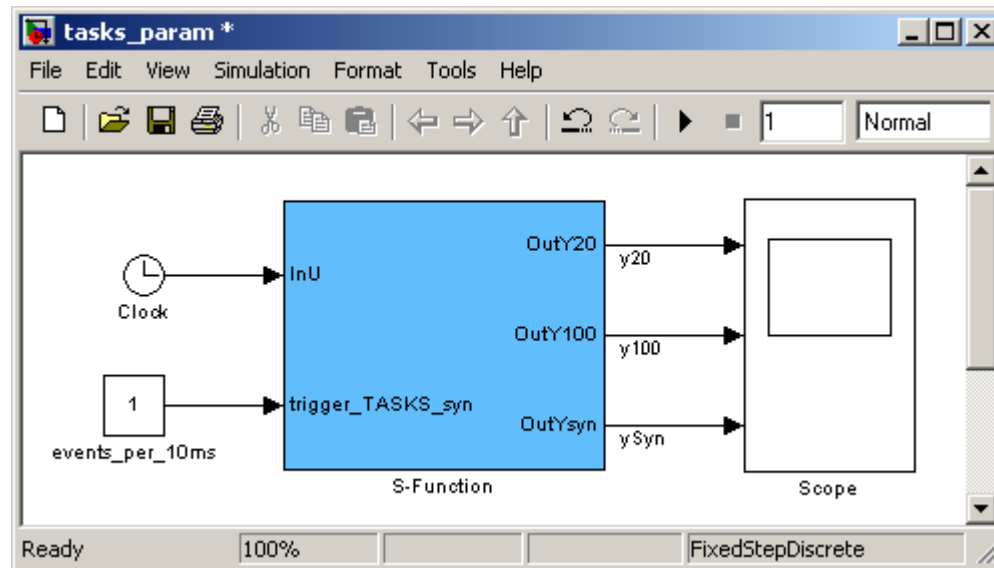


default values for
characteristics from
HEX file as m script,
mask for S-function
block and similar
Simulink snippets

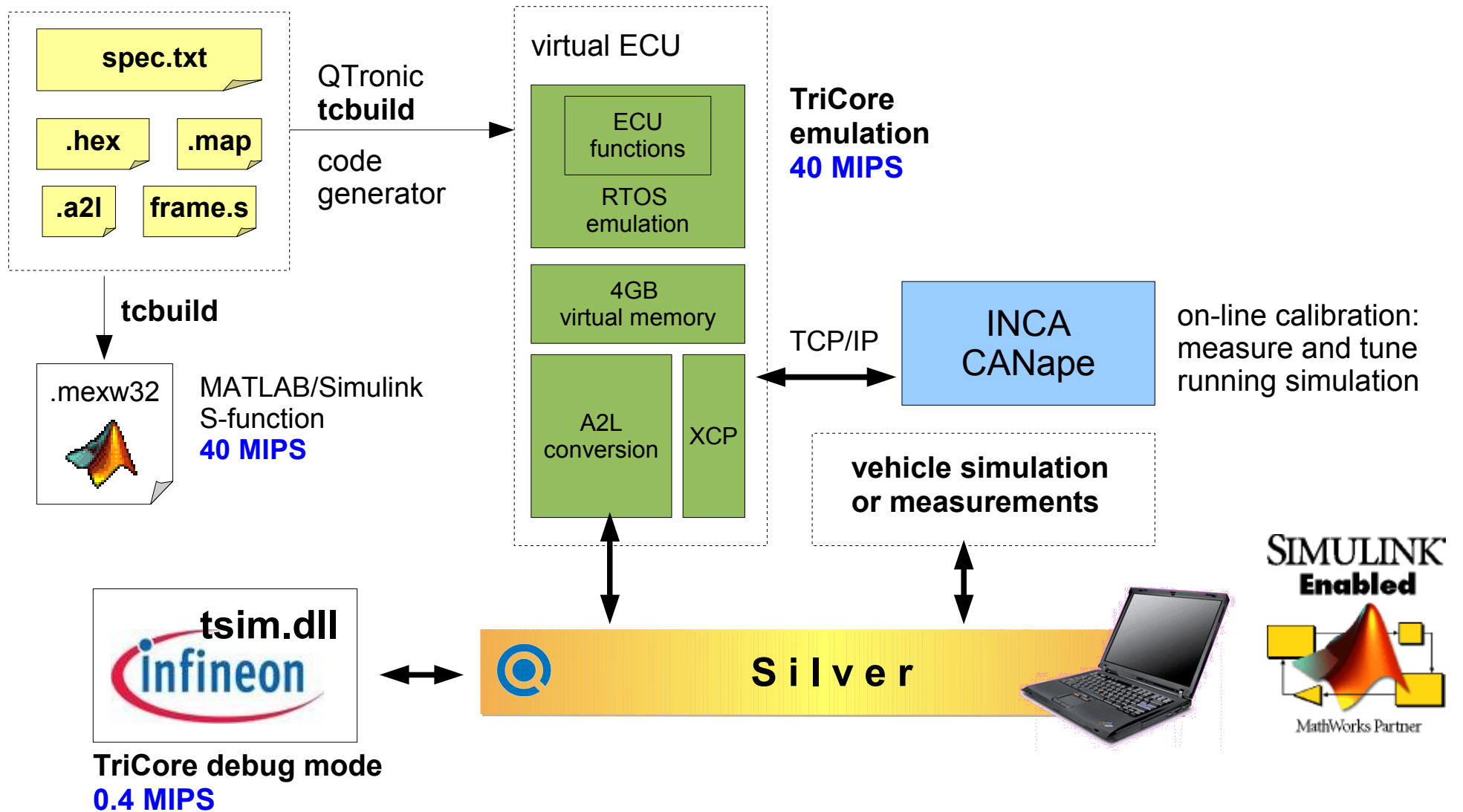


Name	Value	Min	Max
COEFF_TABLE	[1,4000;2000,5;3,6000]	1	6000
COEFF_TABLE_X	[10,20]	10	20
COEFF_TABLE_Y	[100,200,300]	100	300
tout	<101x1 double>	0	1

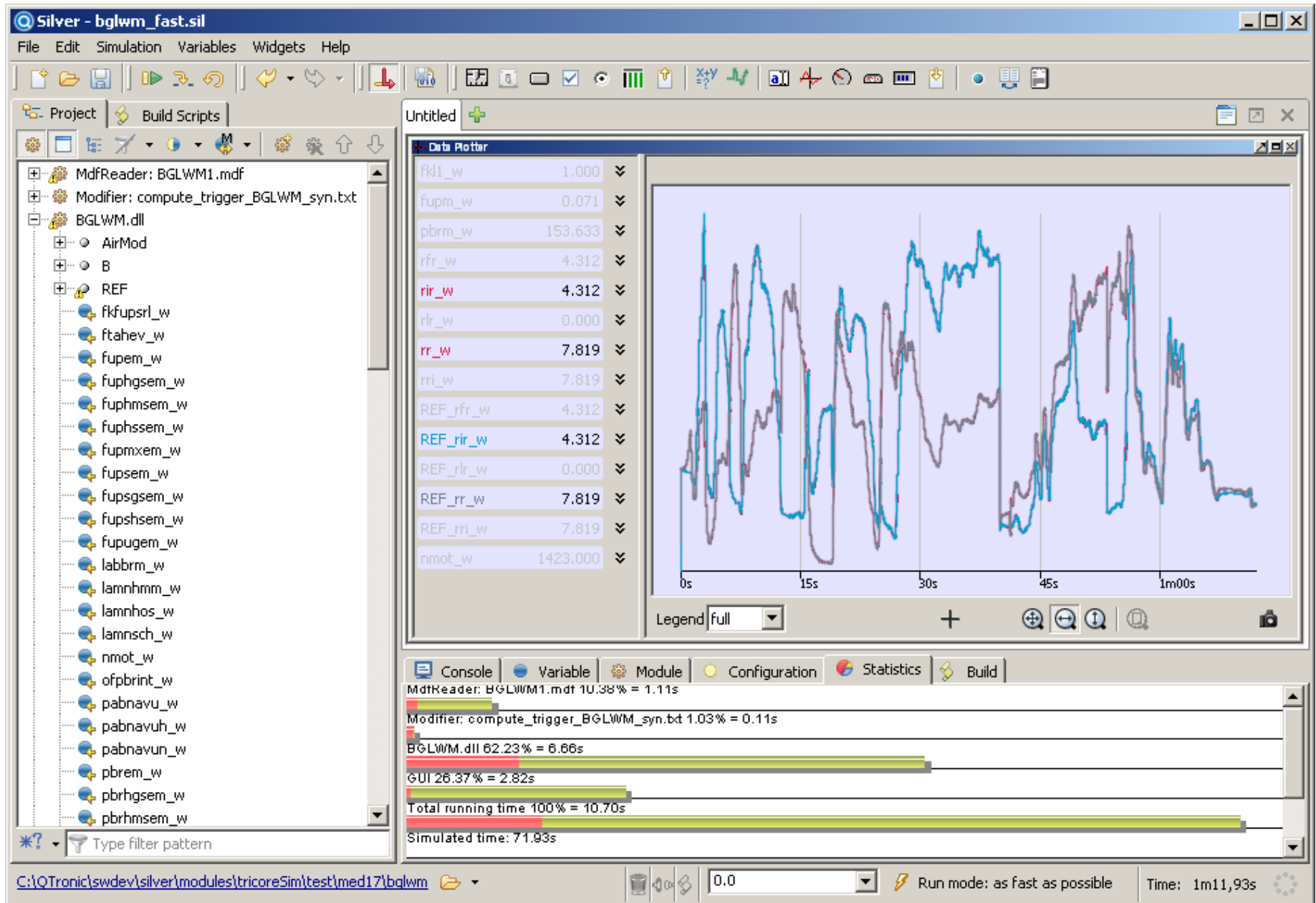
characteristics turned into
MATLAB workspace variables
- read by S-function
- may be modified by script



generated virtual ECU in Silver



Virtual ECU running in Silver: MED17



Run complex function for a measured scenario, 3.5 minutes

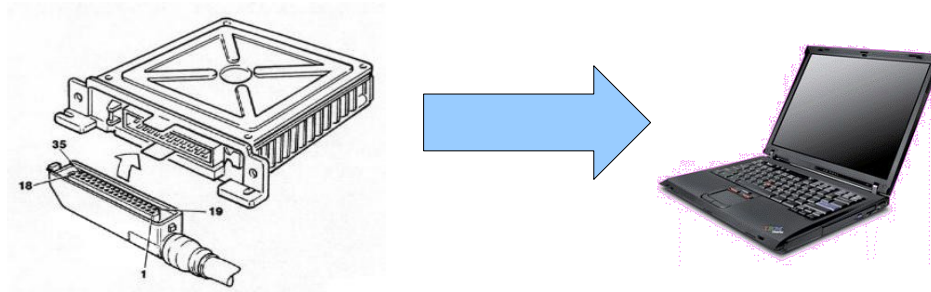
target	execution time	MIPS
Silver in debug mode	919.15 sec	0.41
generated Silver module or MATLAB/Simulink SFunction	9.30 sec	40.80
MED17 with TC1797, 180 Mhz	210.00 sec	270

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

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