



# Chip simulation of automotive ECUs

Jakob Mauss, QTronic GmbH

Matthias Simons, Daimler AG

9. Symposium

Steuerungssysteme für automobile Antriebe

Ulm, 12. - 14. September 2011



## Chip simulation of automotive ECUS

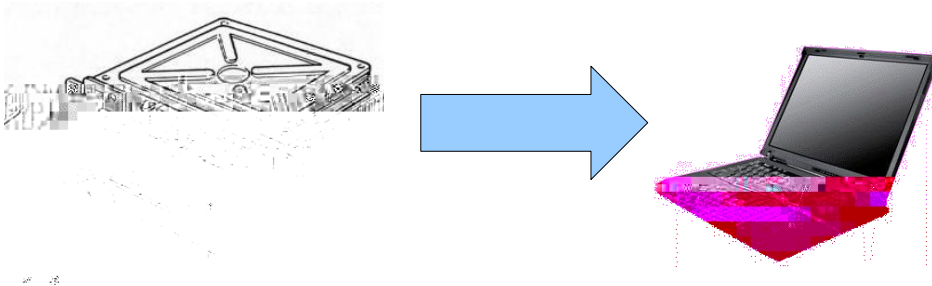
&. Motivation

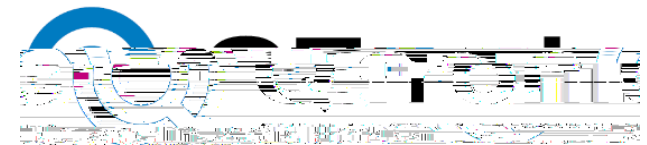
\$. Setting up a simulation

+. Performance

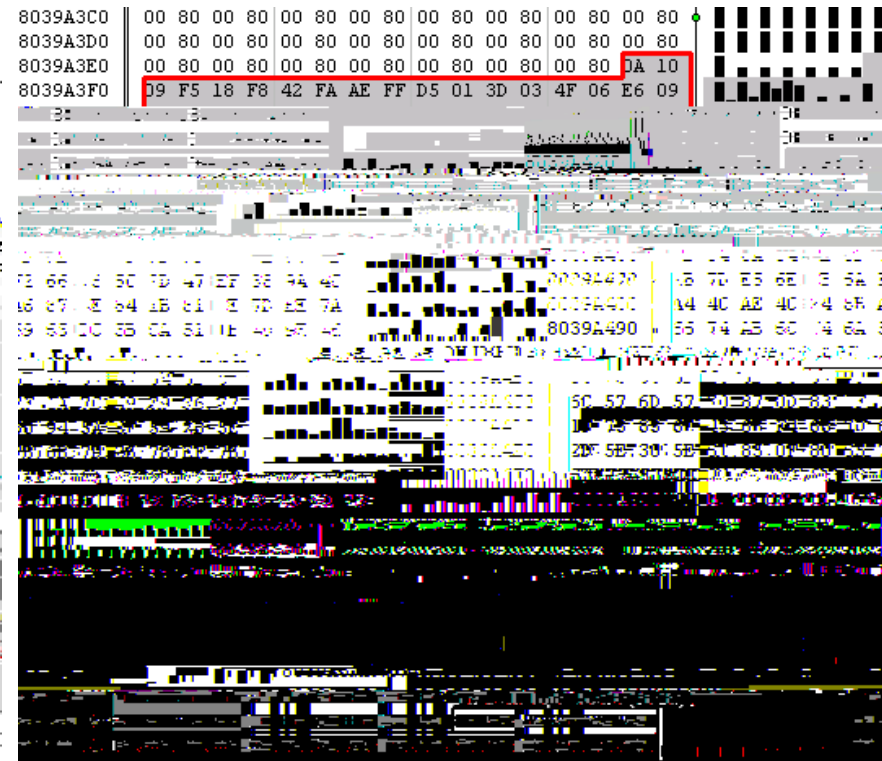
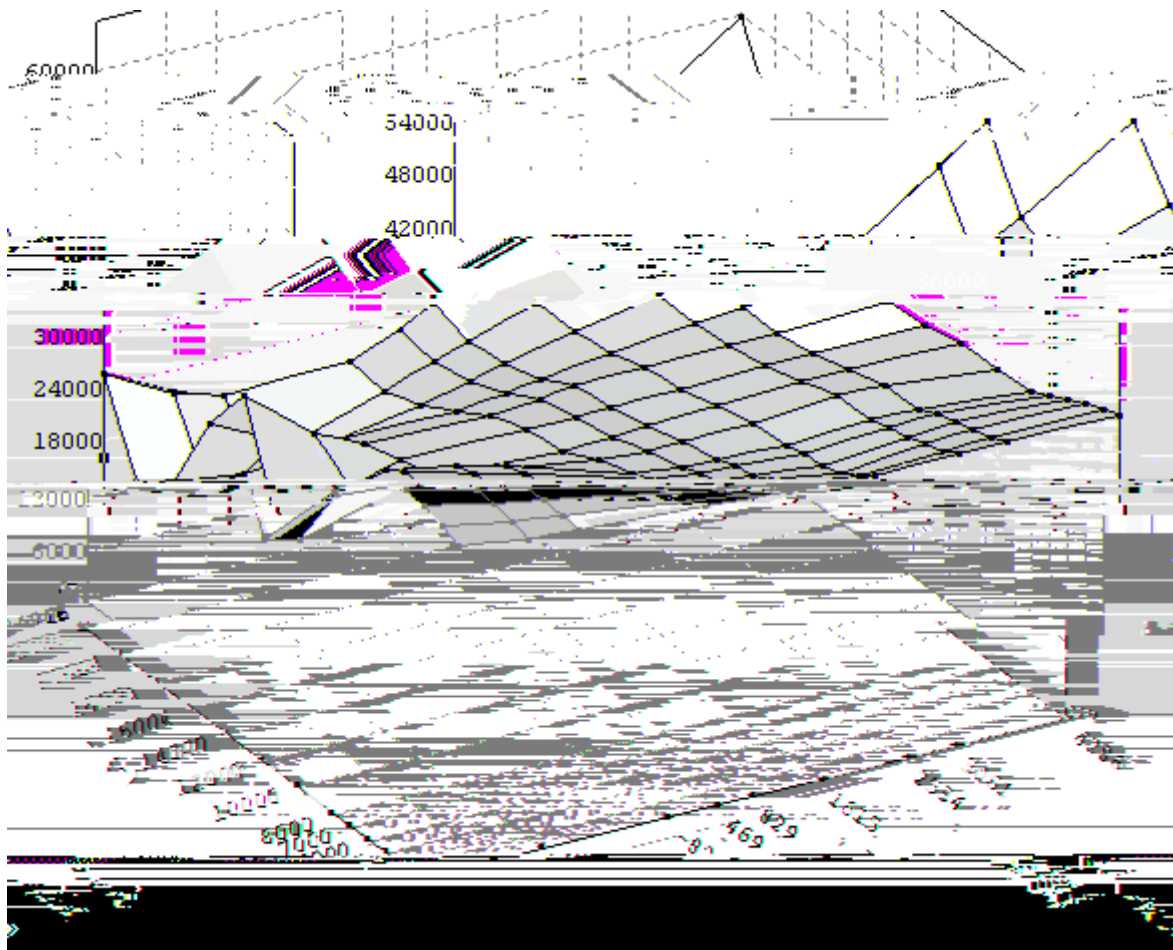
- . Limitations

/. Conclusion





## ECU: more than 30.000 software parameter



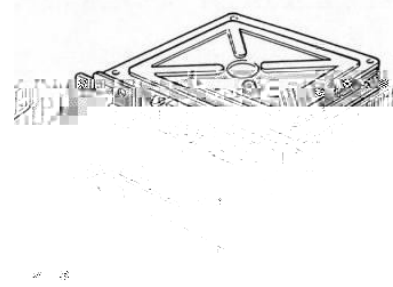
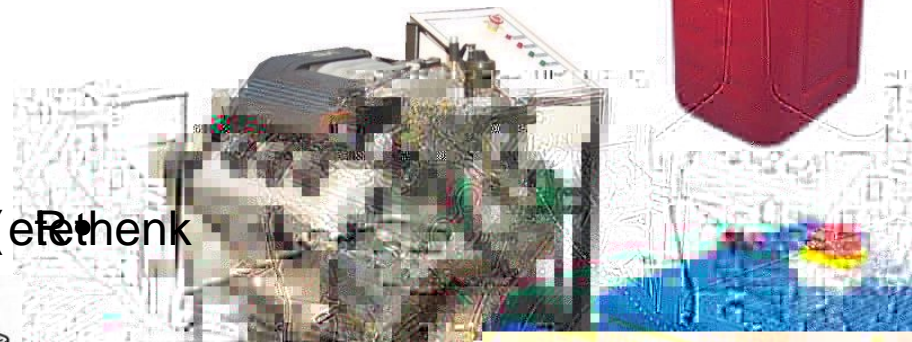


## En"ine #ali\$ration

# tune more than +%.%%% ) ' \* parameter  
 # One by the 1 ) M, not by the supplier o the ) ' \*  
 %ro#ess to ay  
 # automate0 optimi2ation o stationary states  
 # real#time test rig or (ehicle3 base0 on the real ) ' \*  
 # , ' base03 engine an0 ) ' \* both simulate0, e.g. in Simulink

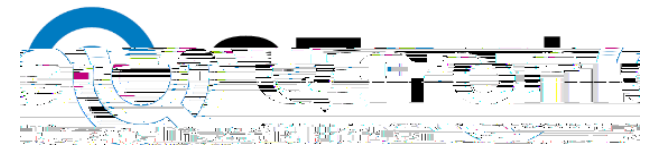
## %ro\$lems

# real#time test rig3  
 # limite0 repro0ucibility  
 # e4pensi(e 5in(est, operation6  
 # slo7 5real time6  
 # , ' 3 re(erse encodG/ !#ãP %# @Ee(eö!AGk@ersè(erehenk





# ! otivation

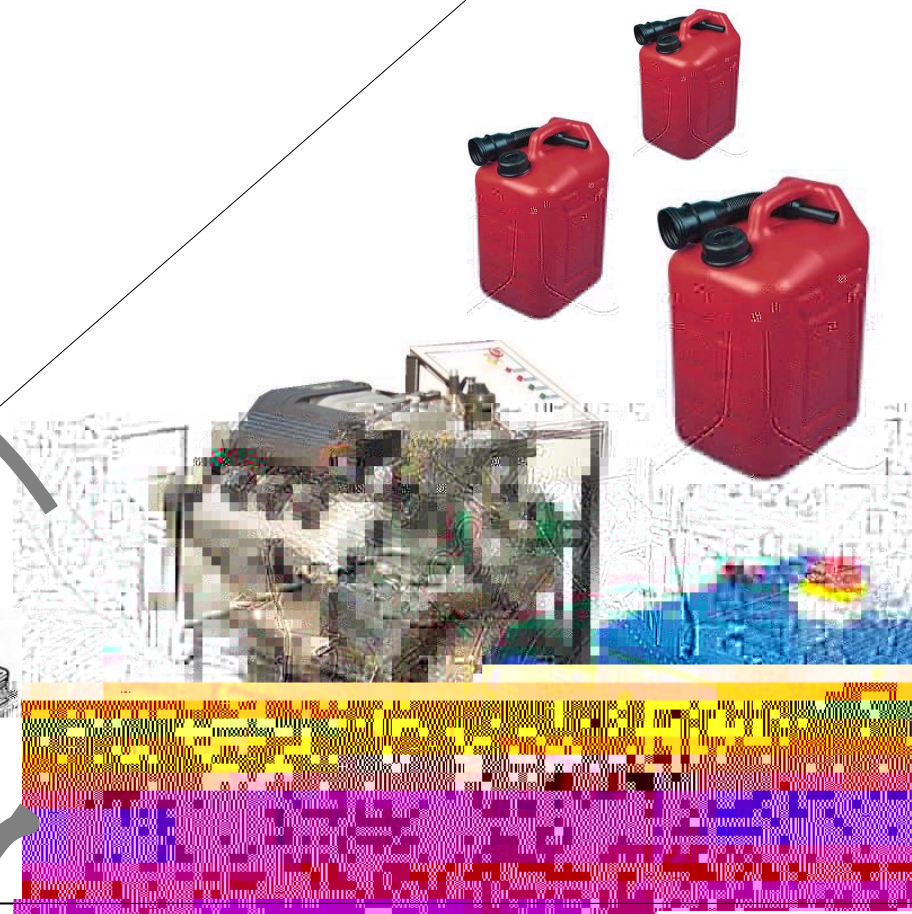
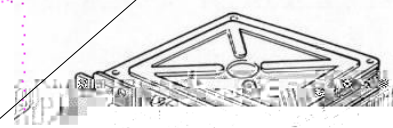
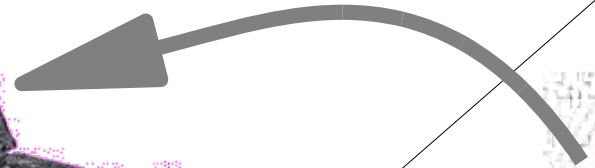


& ea

mo(e engine calibration 5an0 other 0e(elopment tasks6  
rom test rig to , '

'enefit

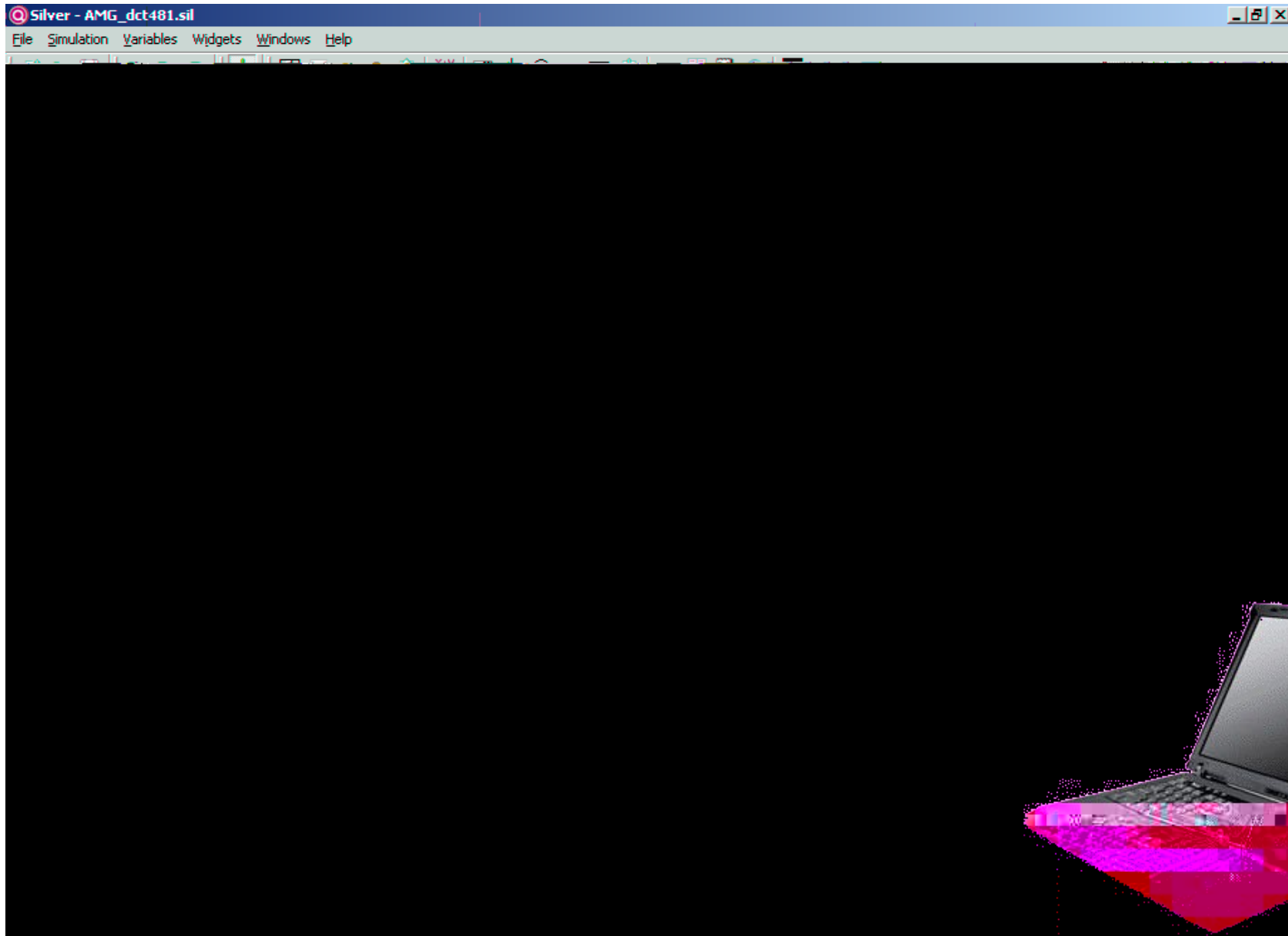
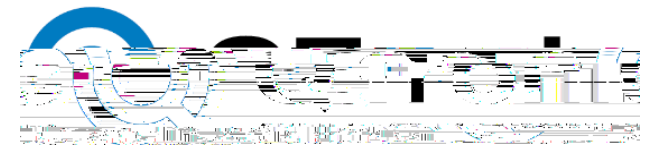
- # simulation runs much aster than real time
- # enables use o mathematical optimi2ation





' hip simulation o automoti(e ) ' \* s # Steuerungssysteme !r automobile Antriebe \$%#\$&.%9.\$&\$ # " erlin

# Example ) \*CU Control Software in Silver



# Setting up a VeriCore simulation



- &. Write spec.t4t to specify functions to run
- \$. step and debug the simulation in Sil(er debug mode)
- +. generate fast running Simulation or Sil(er module runs without a shell)



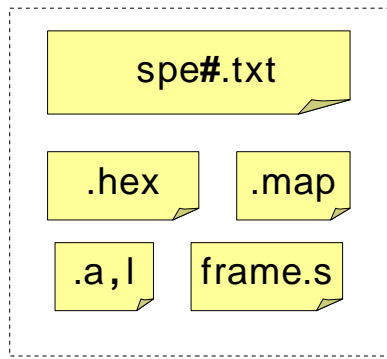
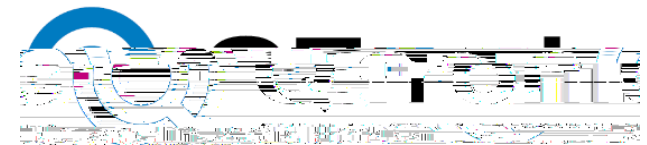
# Setting up a \*riCore simulation



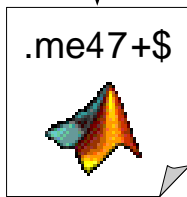
- &. Write specification to specify functions to run
- \$. step and debug the simulation in Silver module
- +. generate test running Silver module without additional help

```
01 # specification of function or Silver module
02 hex_file(m12345.hex, TriCore!1.3.1"
03 a2l_file(m12345.a2l"
04 map_file(m12345.map"      # a T#S$%&' or '&( map file
05 frame_file(frame.s"      # assembler code to emulate *T+S
06 frame_set(ST-!S%/-, 10" # Silver step size in ms
07 frame_set(T-2T!ST#*T, 0xa0000000" # location of frame code
08
09
10 # functions to be simulated, in order of execution
11 task_initial(#5 6-!ini"
12 task_initial(#5 6-!inis7n"
13 task_triggered(#5 6-!s7n, trigger!#5 6-!s7n"
14 task_periodic(#5 6-!20ms, 20, 0"
15 task_periodic(#5 6-!200ms, 200, 0"
16
17 # interface of the generated function or Silver module
18 a2l_function_inputs(#5 6-"
19 a2l_function_outputs(#5 6-"
20 a2l_function_parameters_defined(#5 6-"
```

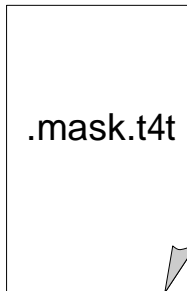
# "enerate S-unction in ! . \* / . ' 0Simulink



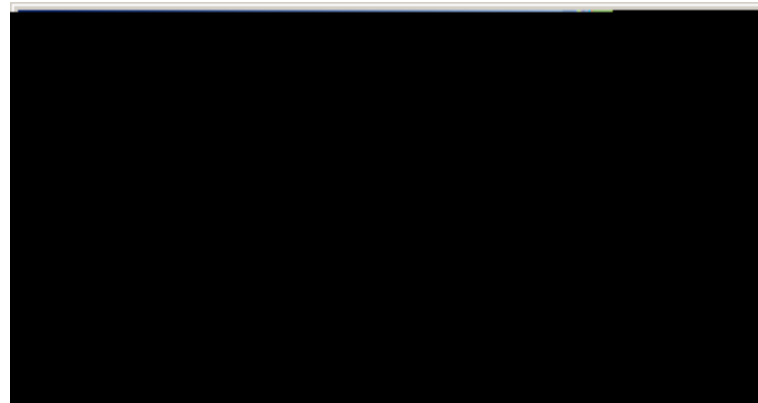
t#\$uil



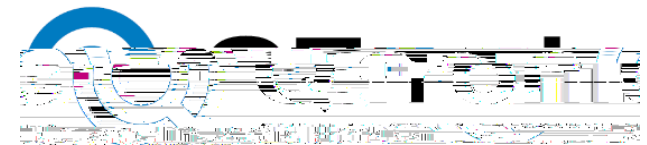
MAT.A " ;Simulink  
S# unction  
+0 !&%S



0e ault (alues or  
characteristics rom  
H) < ile as m script,  
mask or S# unction  
block an0 similar  
Simulink snippets



characteristics turne0 into  
MAT.A " 7orkspace (ariables  
# rea0 by S# unction  
# may be mo0i ie0 by script

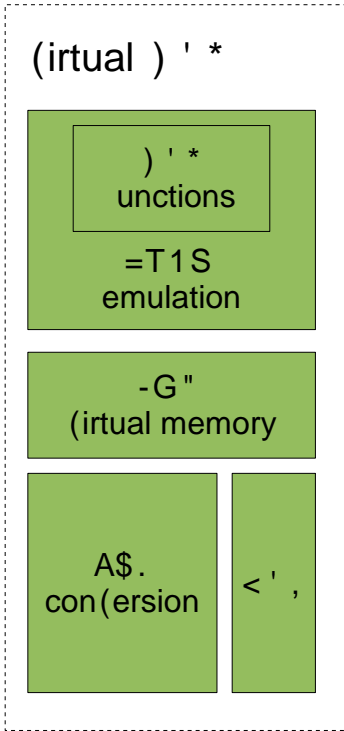


spe#.txt

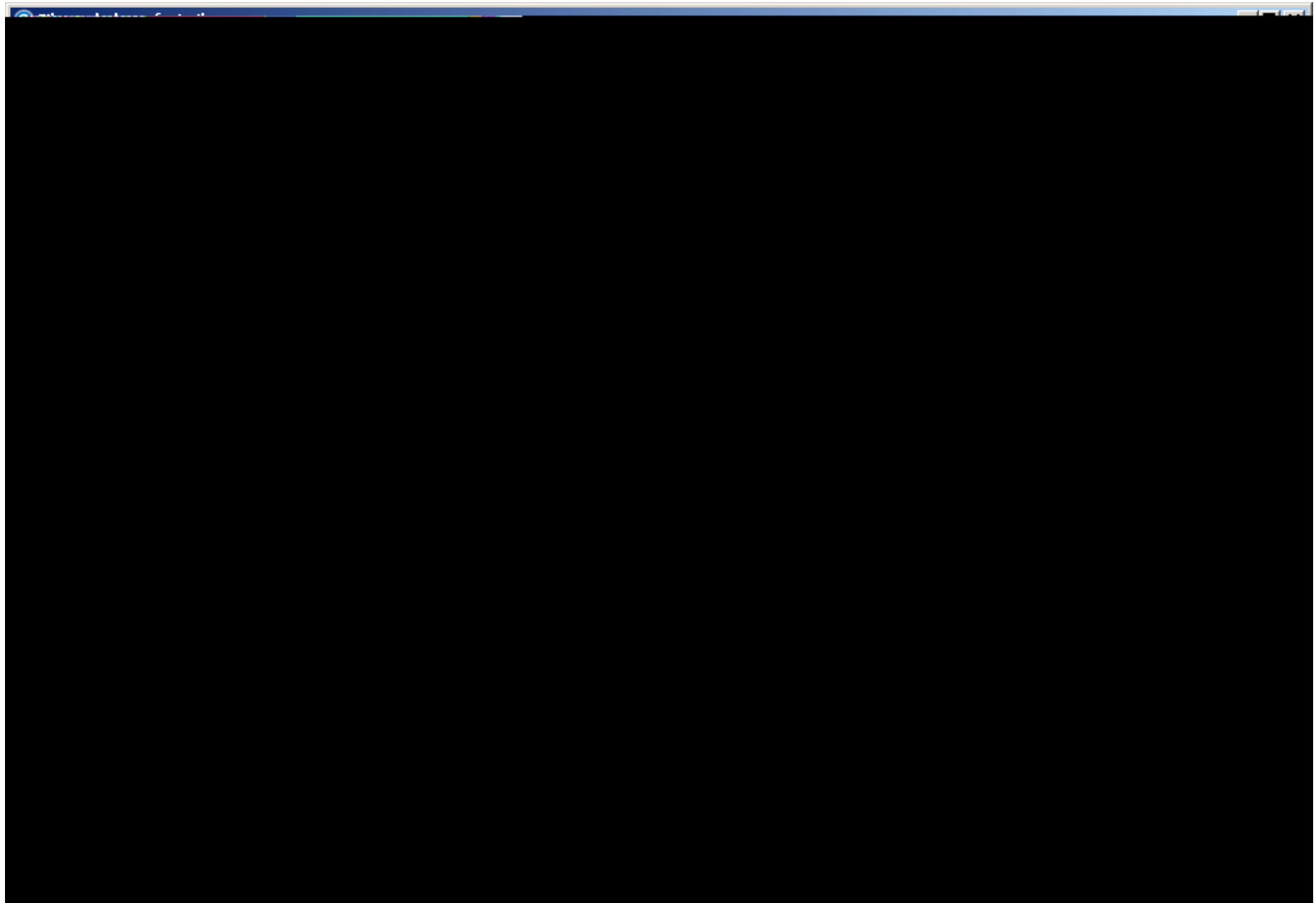
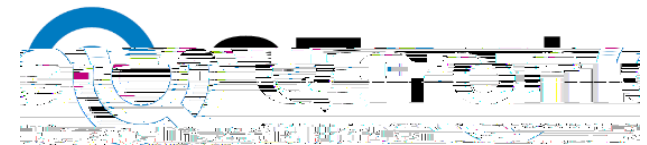
.hex

.map

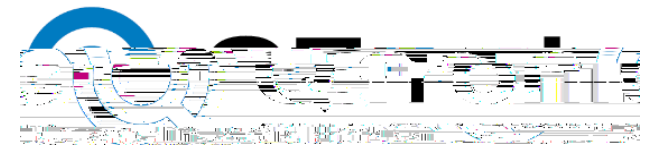
frame.s



# 1 irtual ECU runnin" in Silver: ! E213



# Performance and Limitations



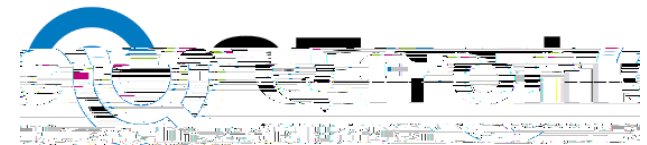
4 uncomplex function for a measure scenario 3.6 minutes

target	execution time	! %S
Silicon in debug mode	9.9. / sec	%. - &
generate Silicon module or MATLAB; Simulink S: function	9. + % sec	-%. ? %
M) D@ 7ith T' &@9@, &?% Mh2	\$&%. % % sec	\$@%

## Limitations

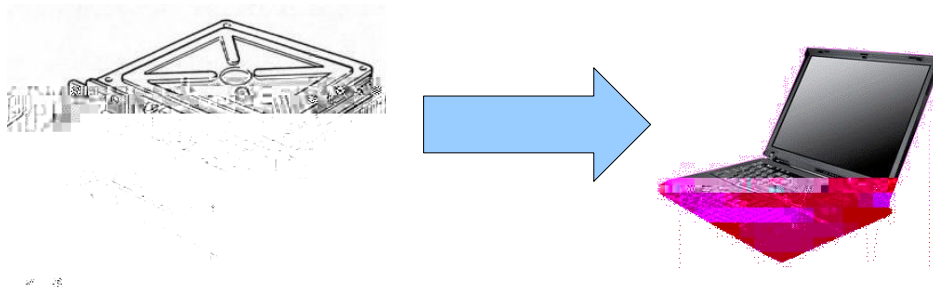
- # instruction accurate, but not cycle accurate
- # based on TriCore specification; silicon bugs are not simulated
- # , ' , , ' A > controllers and other on chip devices not modeled

# Summary



## ECU simulation on 7 in ows %C

- # 7ithout e4pensi(e re(erse engineering
- # 7ithout access to ) ' \* source files
- # base0 on H) <, MA , an0 A\$. ile
- # lo7 7ork e ort or mo0eling
- # high accuracy o mo0el
- # application e4ample3 automate0 calibration



- # 7orks or Tri ' ore processors3 T ' &@9B, T ' &@9@, T ' &@9?, ...
- # per ormance3 -% M9 , S