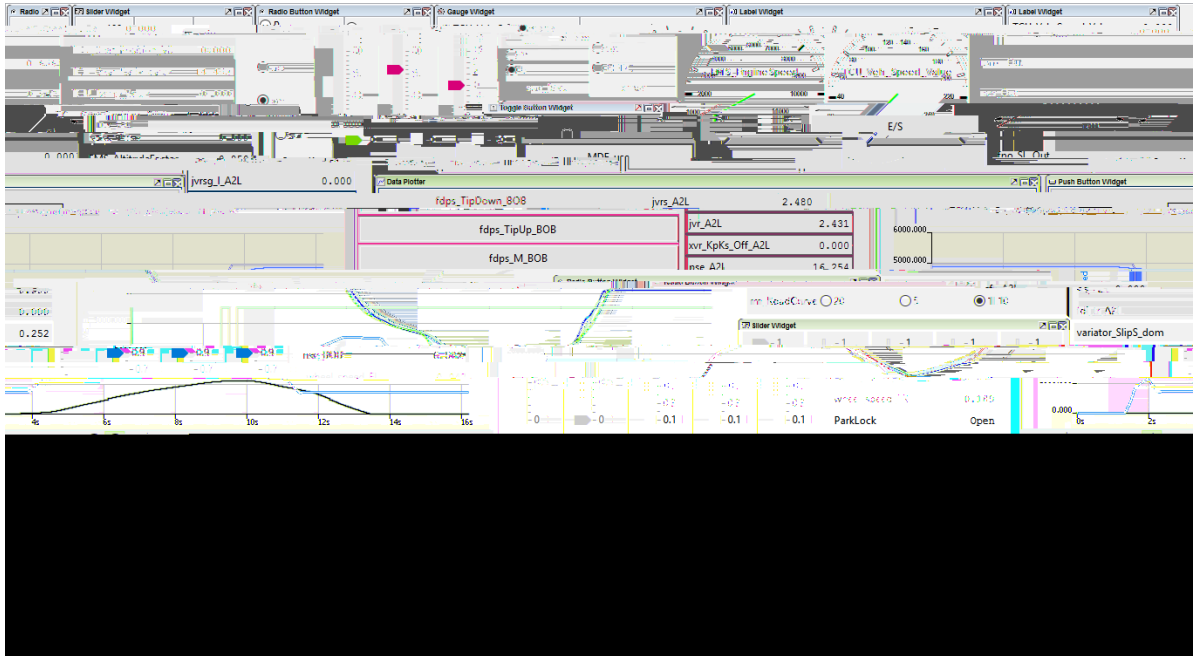
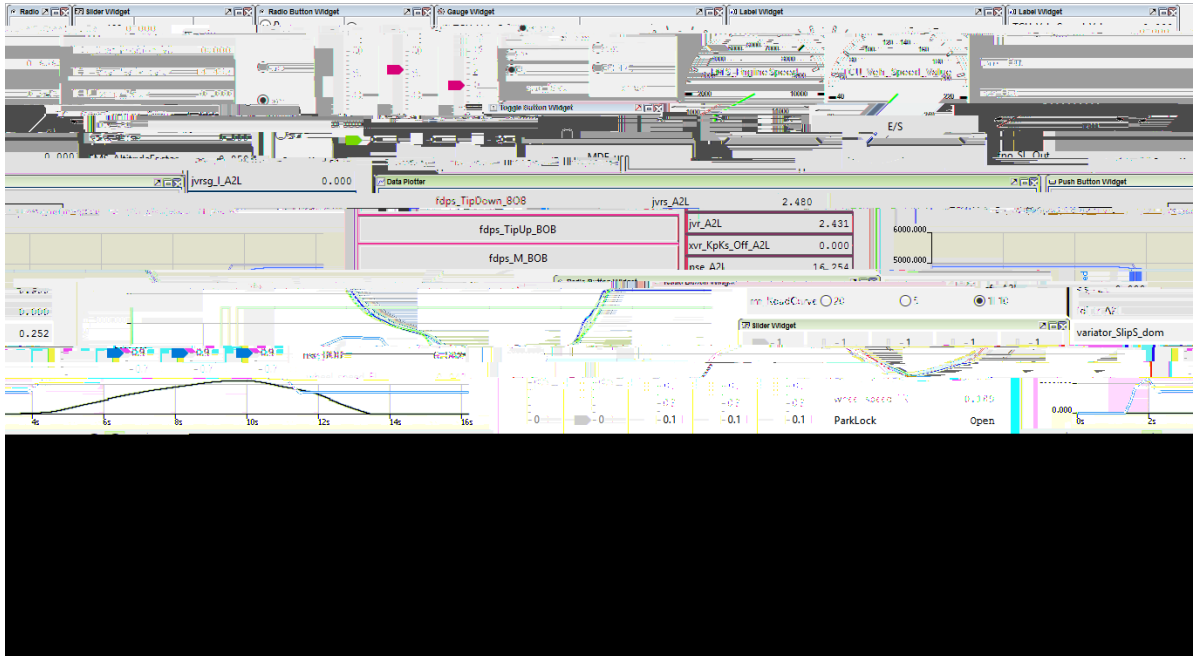


CVT control software testing

Lionel Belmon, Liu Fei – Global Crown Technology, Beijing
Zeng Weihua - Jianglu Rongda, Changsha



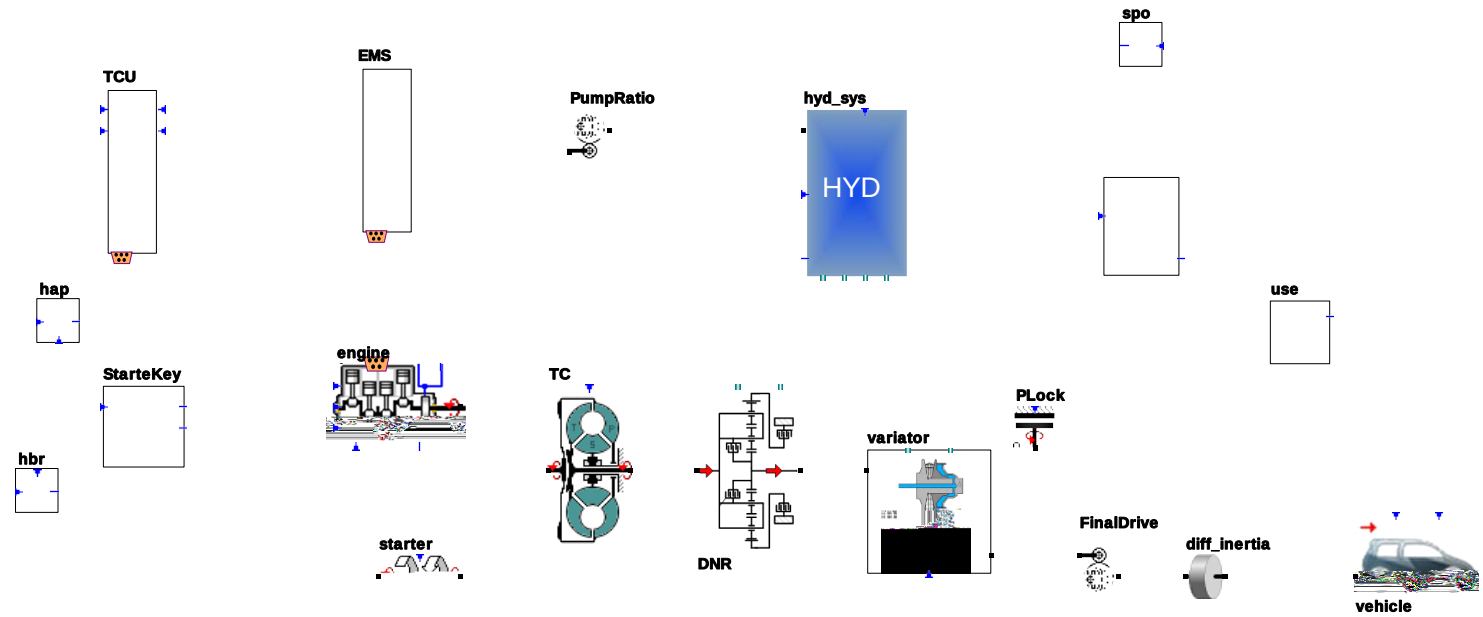
Vehicle plant model

Vehicle model overview

Driver

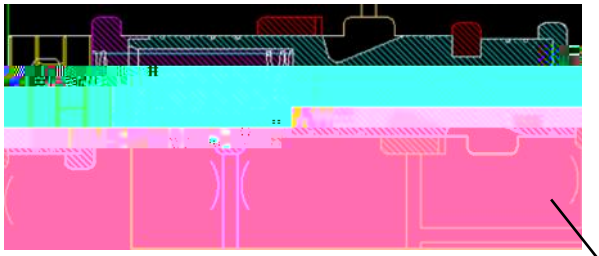
CAN

Hydraulics



Longitudinal Vehicle dynamics with left/rign1u81 0 0

Hydraulic module



Extraction of CAD parameters

Torque converter lock-up

RND clutches

Primary / Secondary pistons for variator

Main flow pressure dynamics

Spool valves characteristics

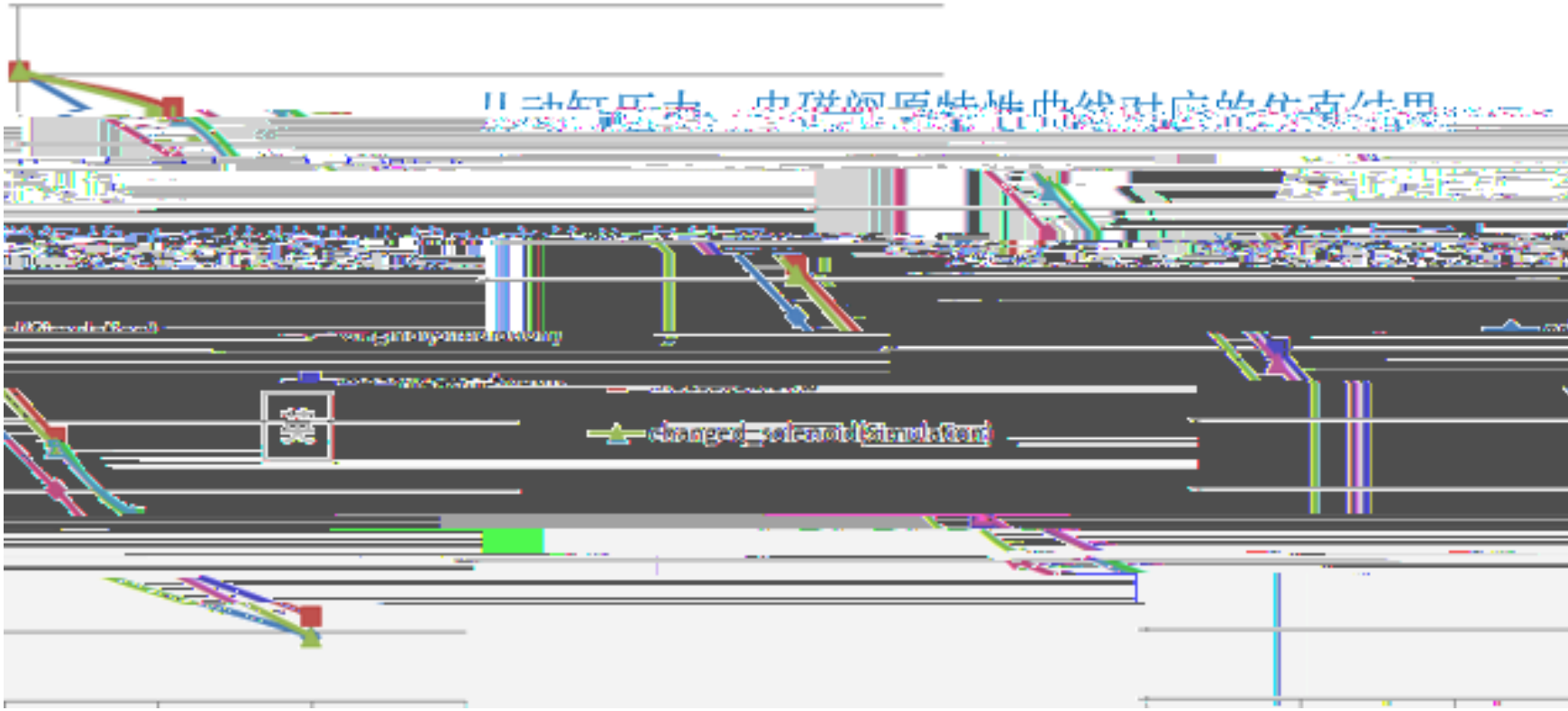
Solenoid valve - pilot pressures

Solenoid pilot valves

Hydraulic Unit tests and validation

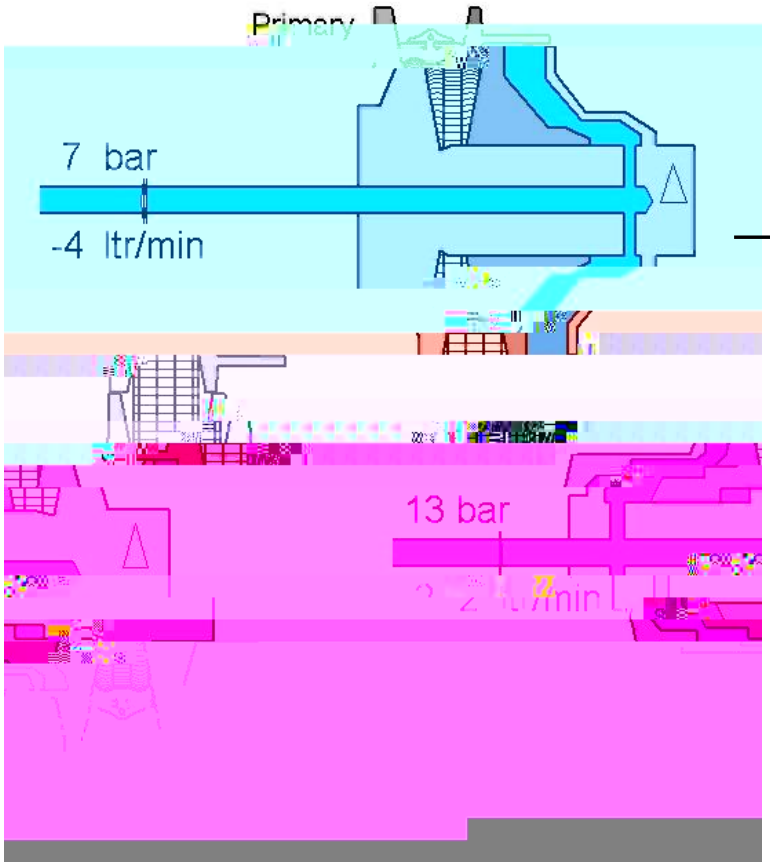
Adjustment of solenoid characteristics

Primary cylinder pressure



Solenoid current

Variator belt model concept



Variator ratio change by controlling primary/secondary pressure

Actual force

steady-state force required

$$P_{\sec mx} = \frac{T_{pri} \quad \cos}{2 \quad {}_{\sec} R_{pri} A_{\sec}}$$

Max torque limit depends on pressure !

Real-time simulation

Adjustment of hydraulic volumes and mechanical stiffness

Fixed-step solver – 0.5 ms

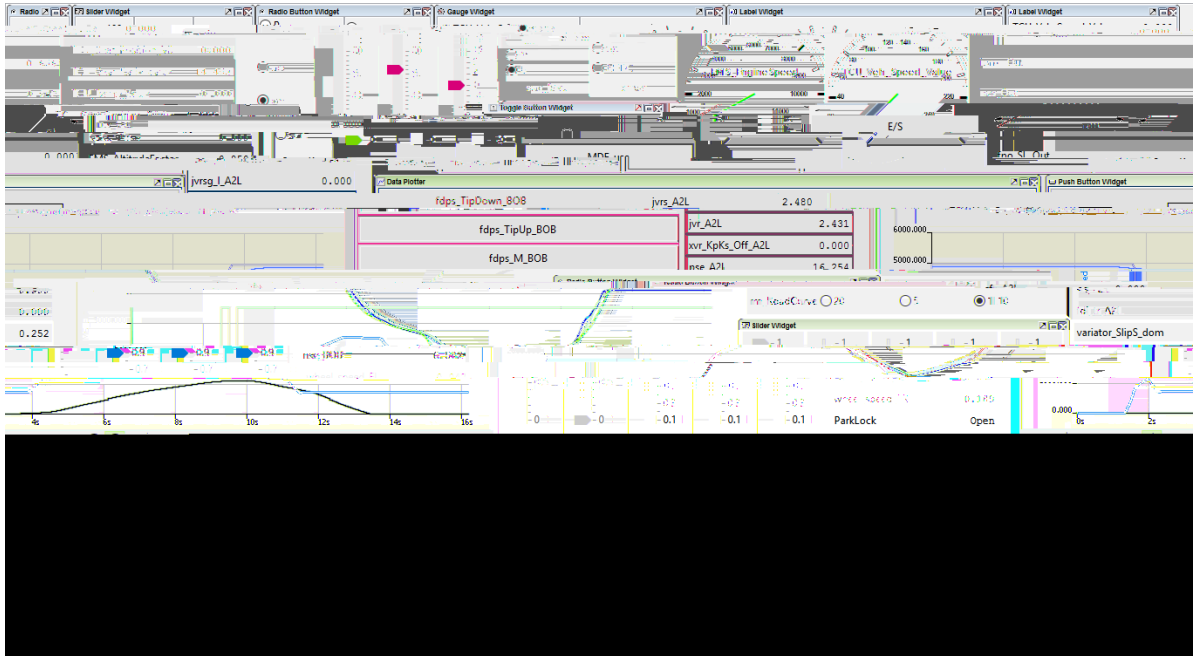
~80 ODE state variables

~200 inputs/outputs variables (CAN, sensors, actuators)

Code generation from SimulationX **to FMU cosimulation**

Execution in QTronic Silver

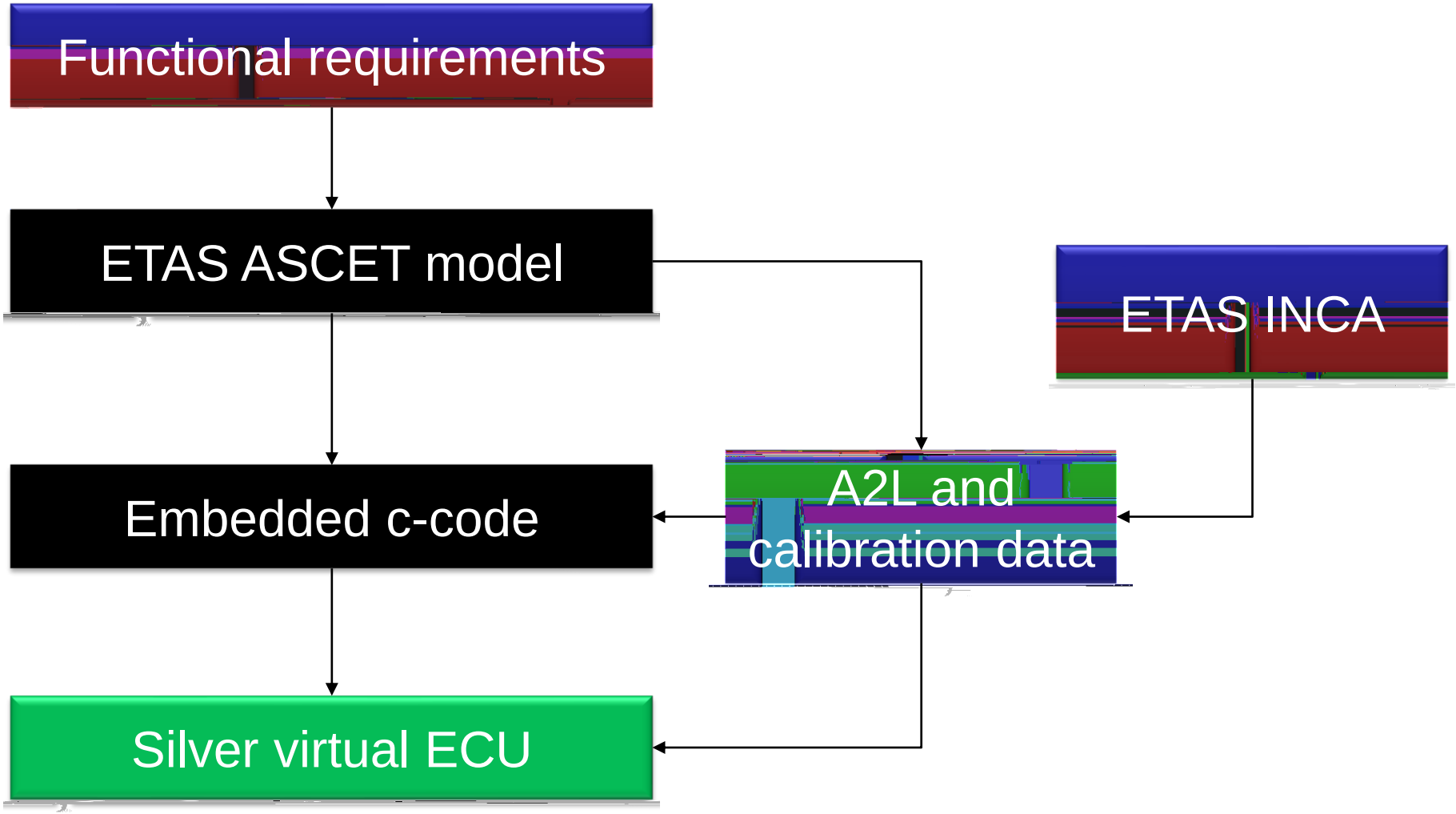
Simulated time: 98.38s; Actual time spent computing: 18.62s; Speedup factor: 5.28



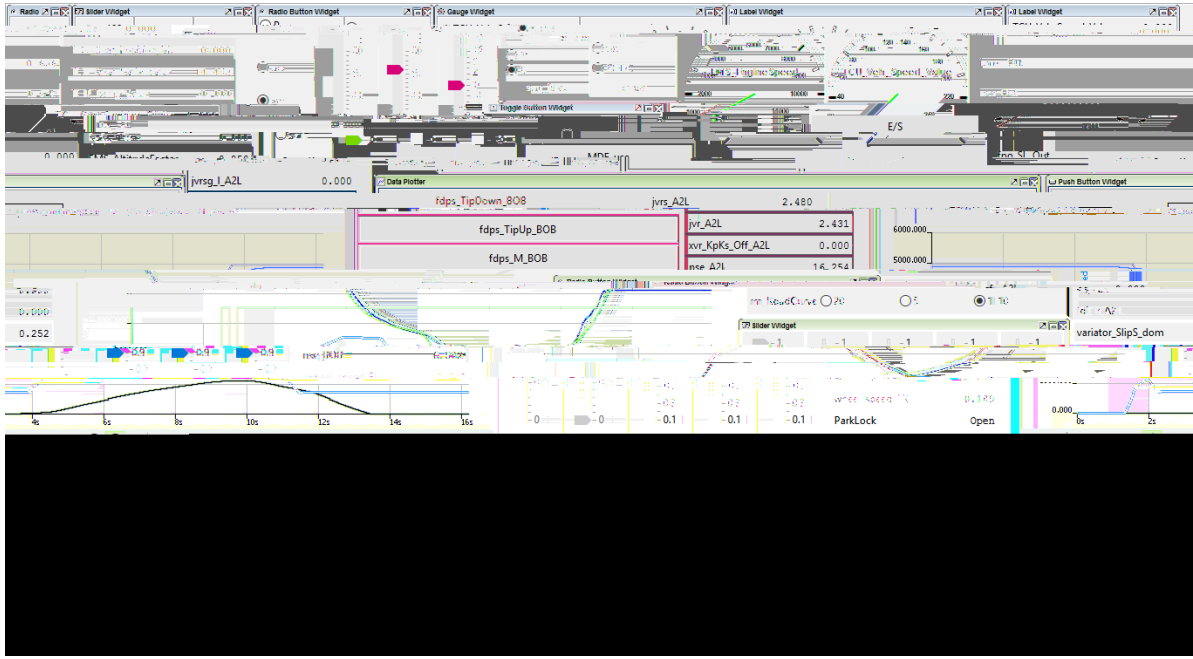
TCU embedded software

TCU softwa generation process

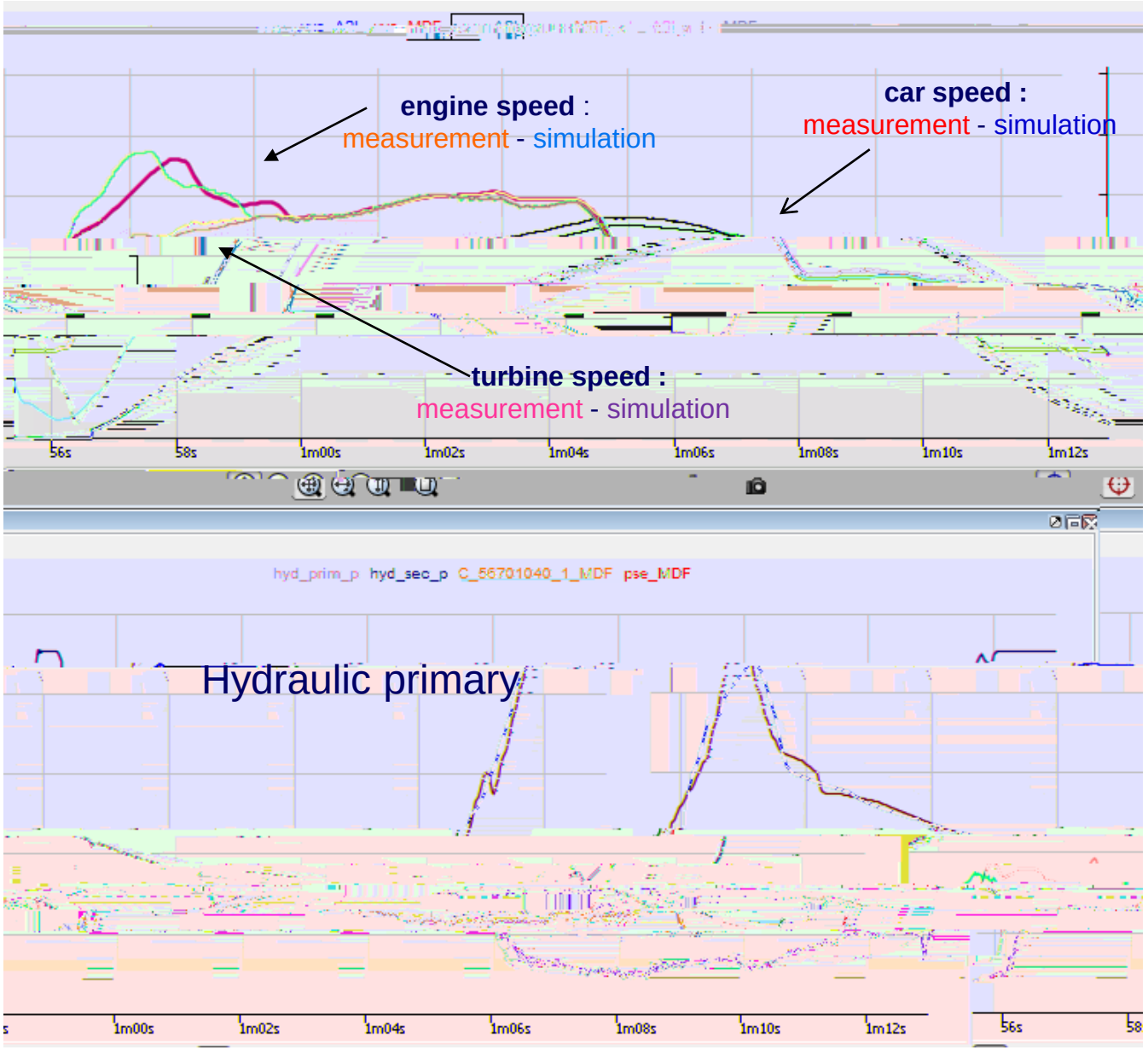
Virtual TCU with Silver



Virtual TCU platform


Radio
Slider Widget
Radio Button Widget
Gauge Widget
Label Widget
Toggle Button Widget
E/S
jvrsg_I_A2L
0.000
Data Plotter
Push Button Widget
fdps_TipDown_BOB
jvrs_A2L
2.480
fdps_TipUp_BOB
jvr_A2L
2.431
fdps_M_BOB
xvr_KpKs_Off_A2L
0.000
6000.000
5000.000
0.252
Slider Widget
variator_SlipS_dom
4s
6s
8s
10s
12s
14s
16s
0.1
ParkLock
Open
0.000
0s
2s

Example of test drive validation



TCU embedded software testing

Test requirements

Usual test drive cases

NEDC, 100km/h acceleration…

Calibration parameters

Software functions activation/deactivation

Various environment conditions :

- slope, snow/water…

Fault monitoring and reaction

Fault insertion

Wheel sensor faults

Solenoid and hyd faults

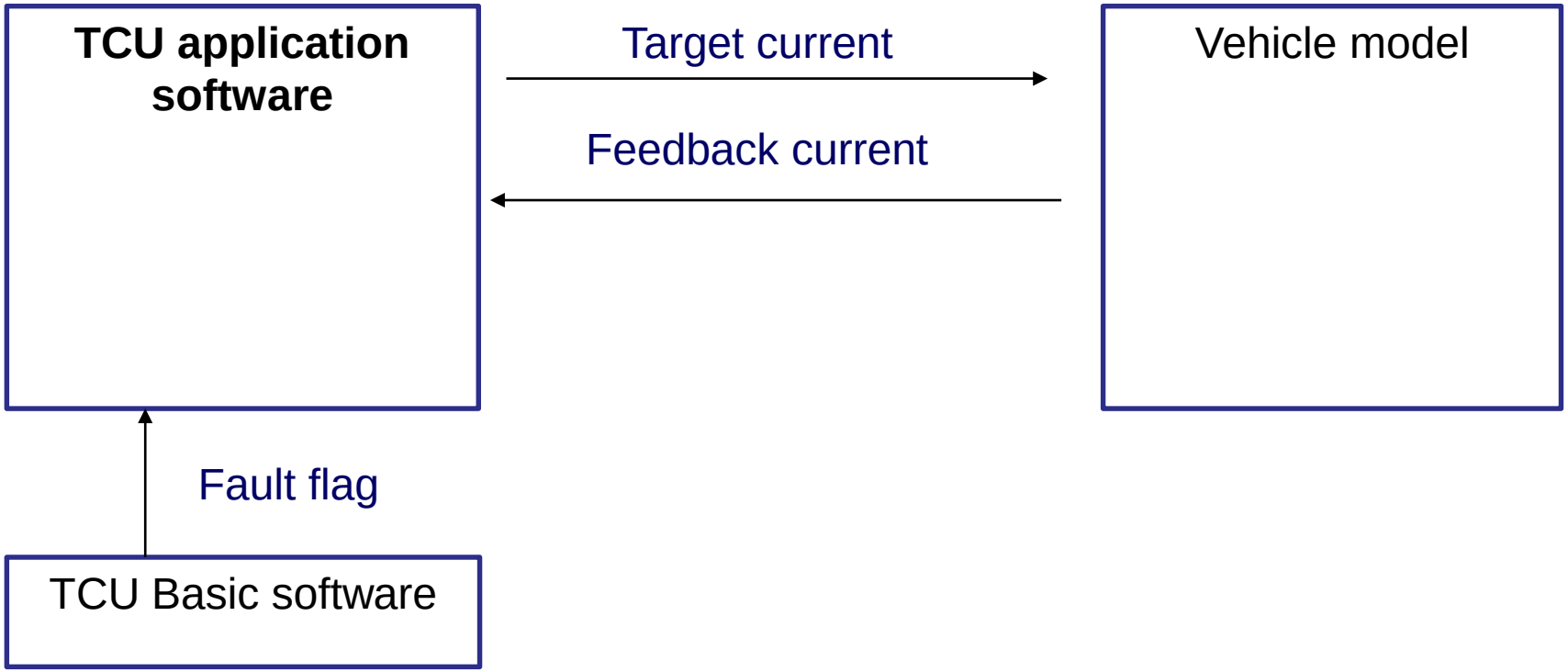
bus faults

Temperature sensors faults

Speed sensors faults

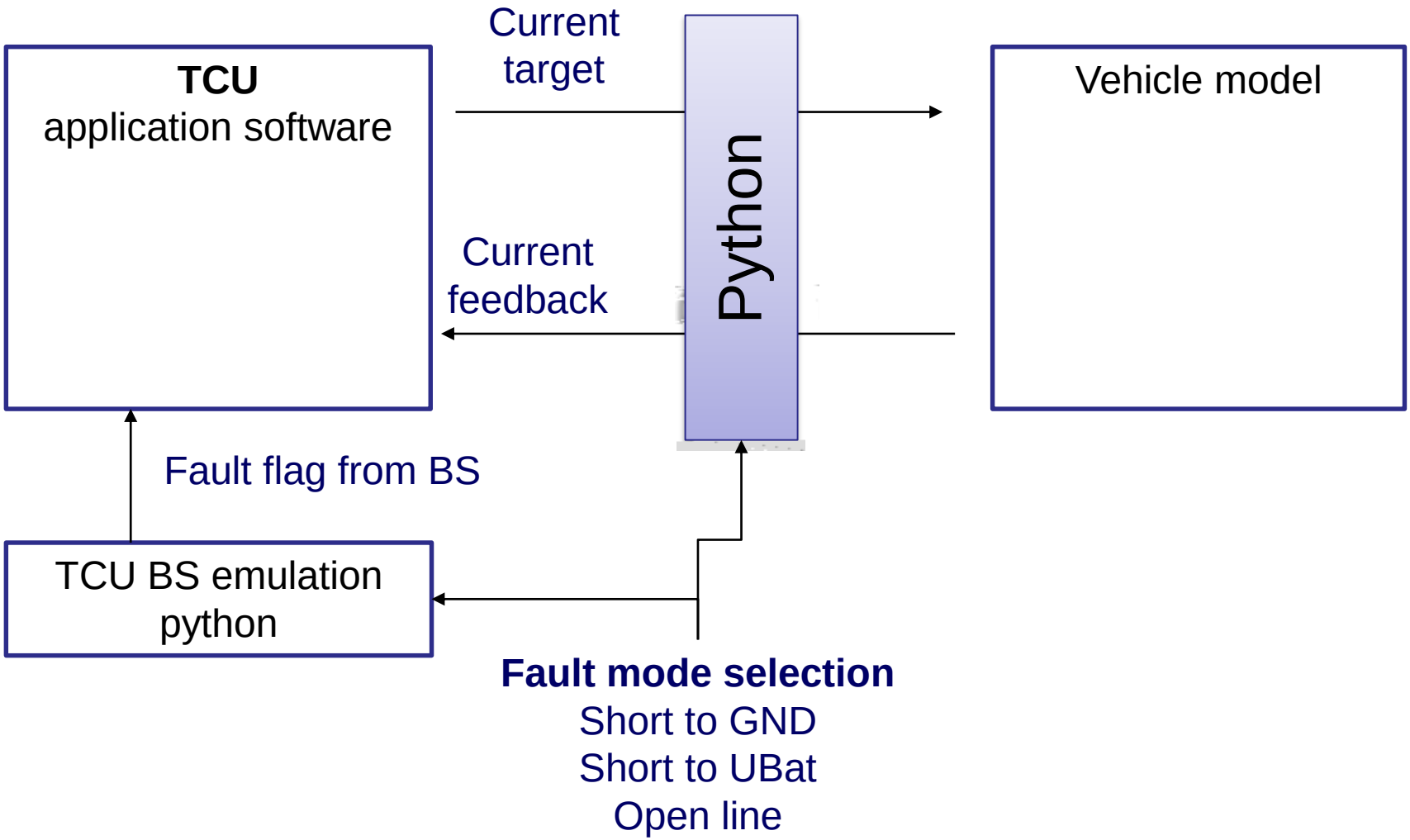
Fault insertion – how it works

Example on solenoid valve fault



Fault insertion – how it works

Example on solenoid valve fault

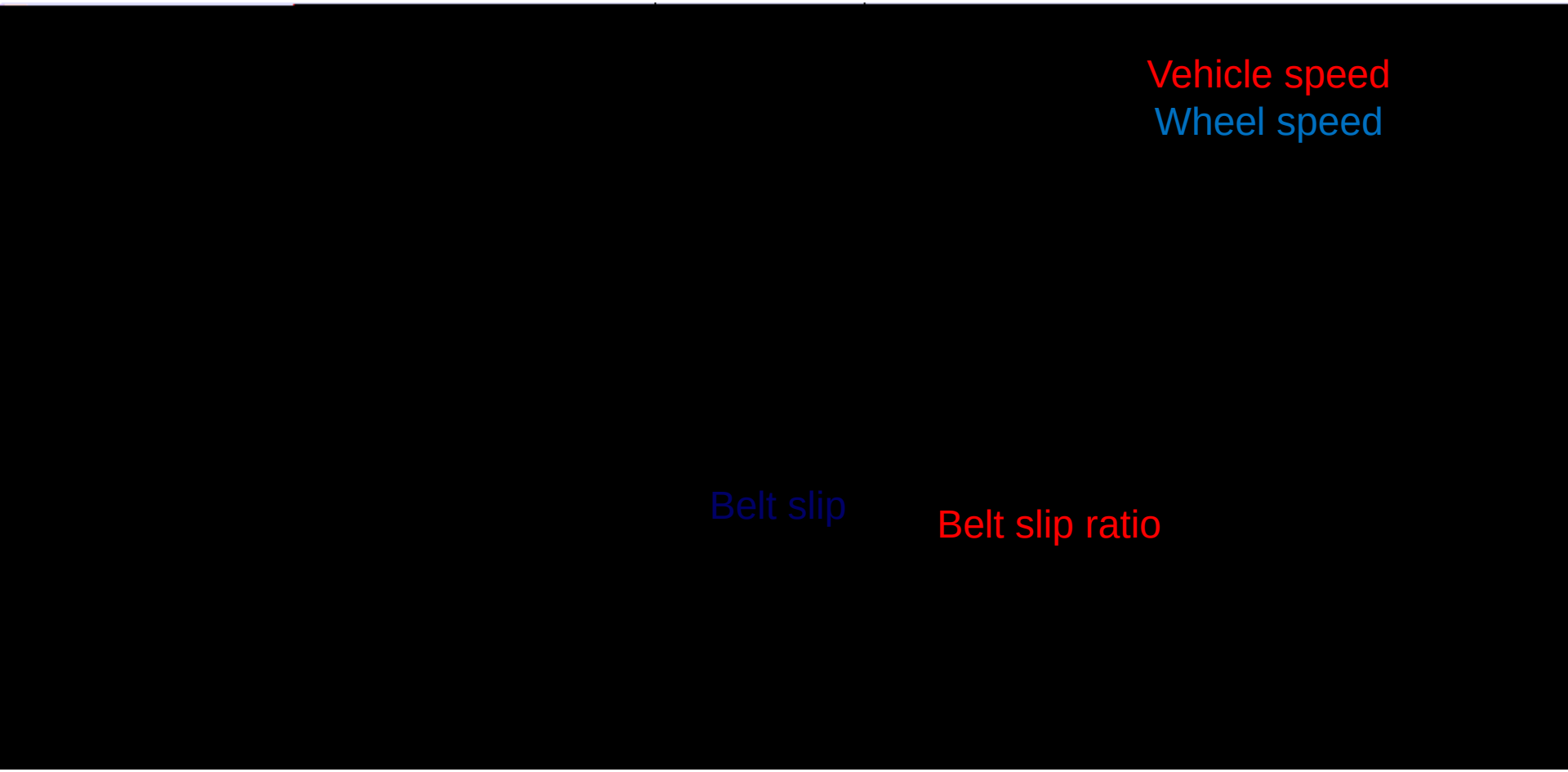


Use of QTronic TestWeaver

- Formal requirements monitoring
- Hand written test scripts
- Automatic test cases generation
- Automatic test report generation

ABS simulation example

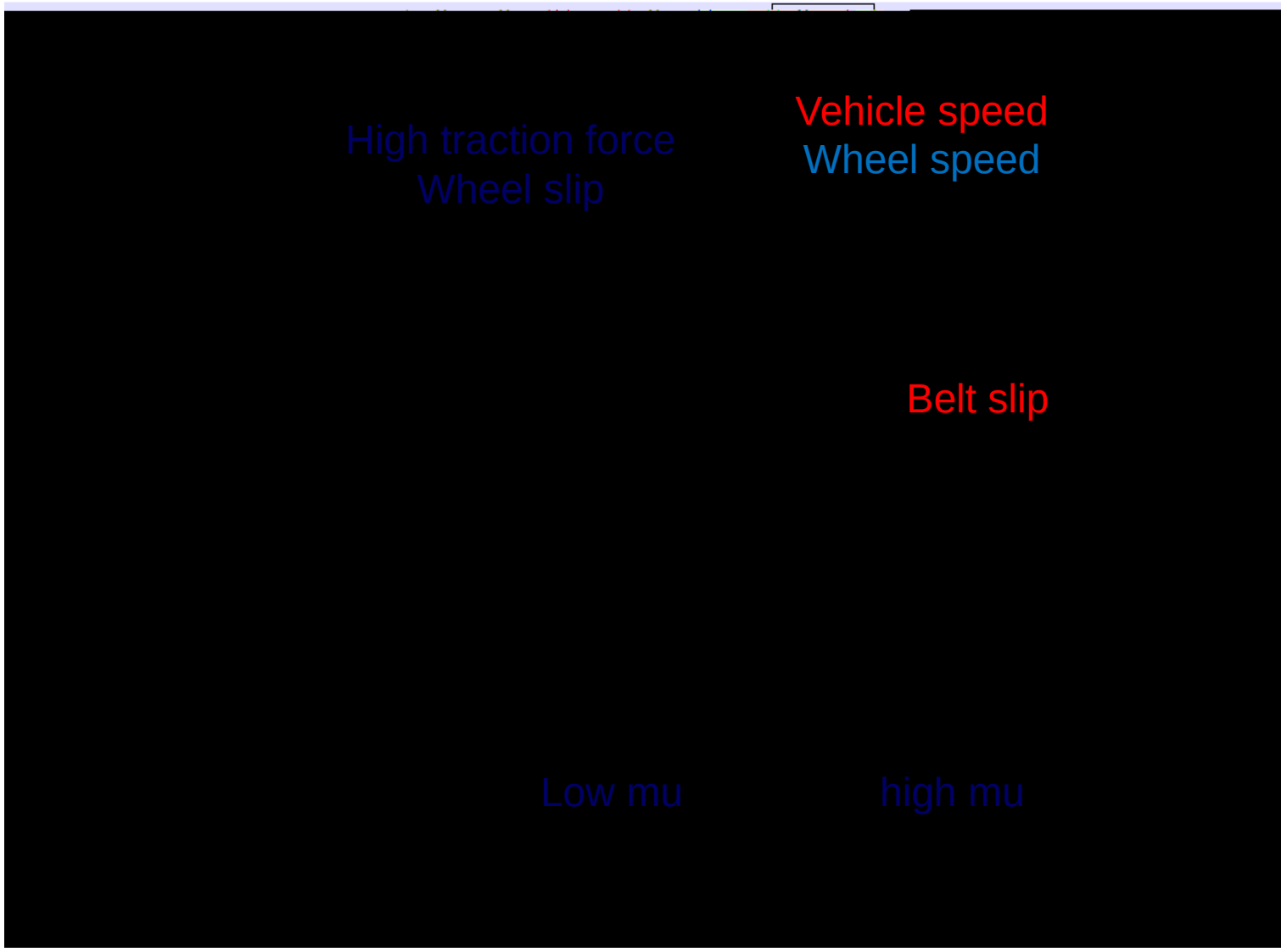
Clutch locked + Strong braking → Wheel block → **strong engine deceleration**
→ Transmission torque exceeded → belt Slip !



→ Belt slips are reported automatically in TestWeaver reports

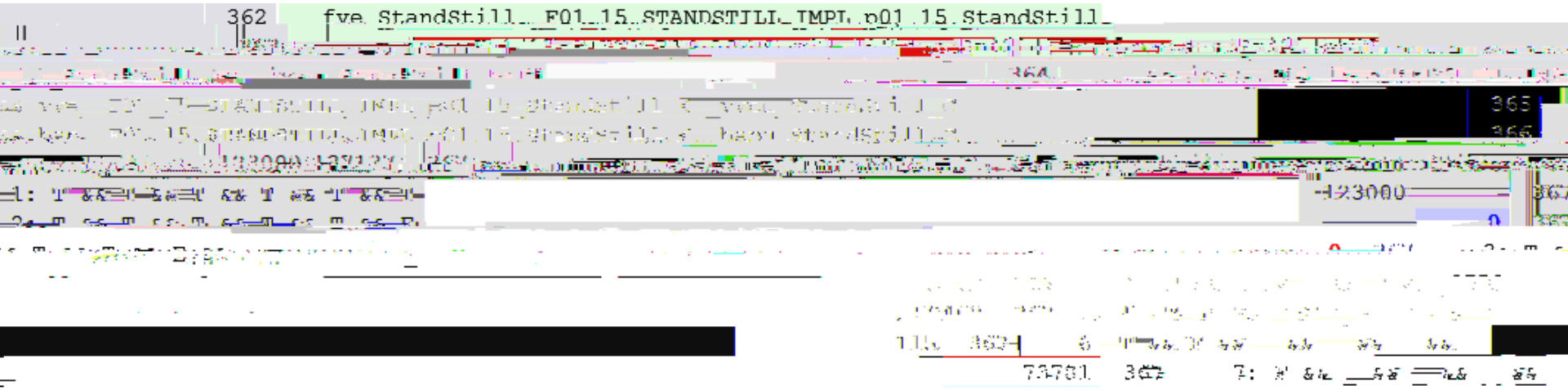
Test case generation

QTronic TestWeaver automatically generates drive sequences
Example of Belt Slip found by TestWeaver



Code coverage with CTC++

MC/DC coverage



Conclusion

Realistic simulation – complex scenarios

Vehicle model + TCU + calibration :

validated simulation , reproduce very well the actual execution of TCU in the real vehicle

Fault insertion and validation of TCU fault management

Automatic **generation** and **evaluation** of test cases
TestWeaver + requirements modeling

Very efficient support for TCU development and testing !

Thank you