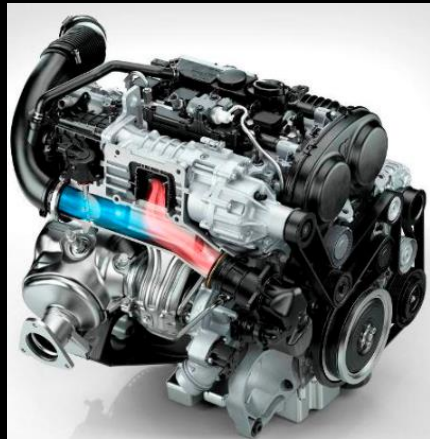


# PROPULSION SiL IN CI



Continuous Integration and Validation Using Closed-Loop SiL Simulation for Propulsion Control and Calibration



Mattias Eriksson, Johannes Foufas, Neda Nickmehr  
Volvo Cars, Göteborg, Sweden

Michael Hartmann  
QTronic GmbH, Berlin, Germany

# IN THE BEGINNING

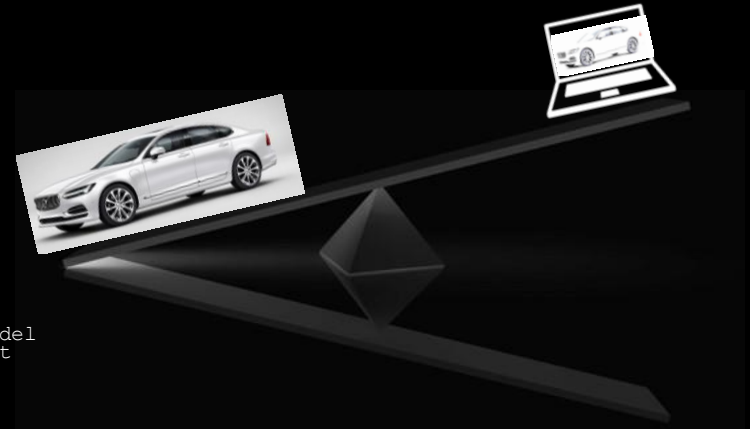
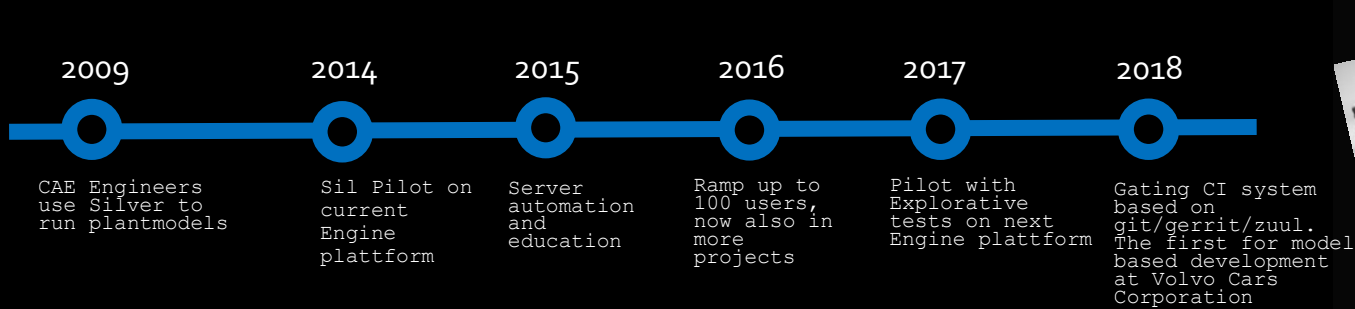


- Started 2002
- 10 model developers
- SourceSafe/Vault
  - Used as a network storage
- Manual starting bat files for code gen and building



# HISTORY

- Prior to the current engine generation, most tests done in car
- During the development of the current engine generation, automatic unit and system tests were introduced.
  - Aftertreatment SW solely developed in Sil platform.
  - One senior SW developer said: *now I know it will work when we test in the car...*



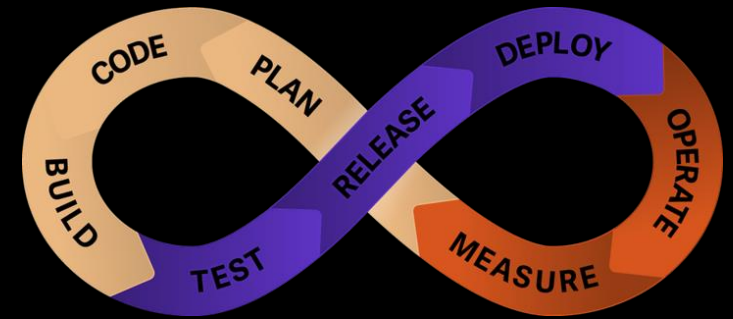
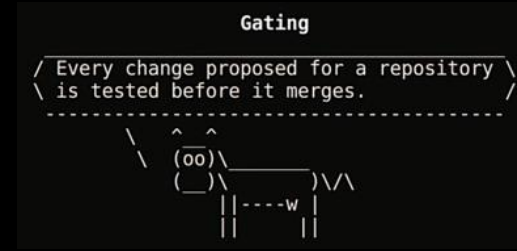
# SOFTWARE IN THE ENGINE CONTROL MODULE



- The Software in current generation ECMs is structured into around 500 modules
- A small part of the application code is still made by the HW suppliers

# CI/CD SYSTEM

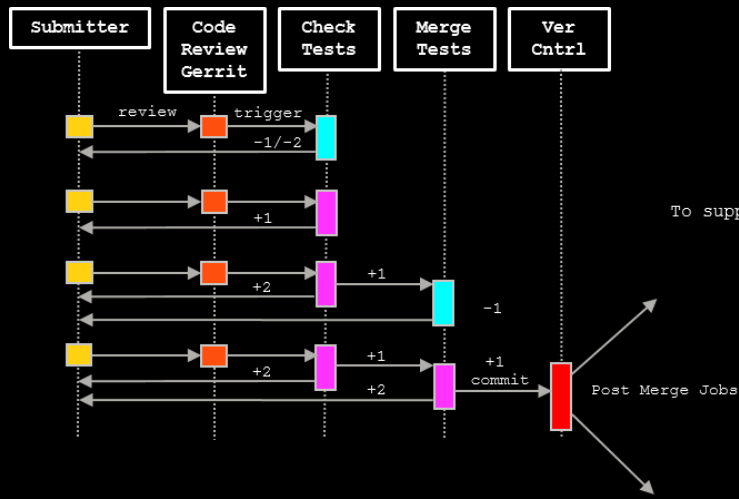
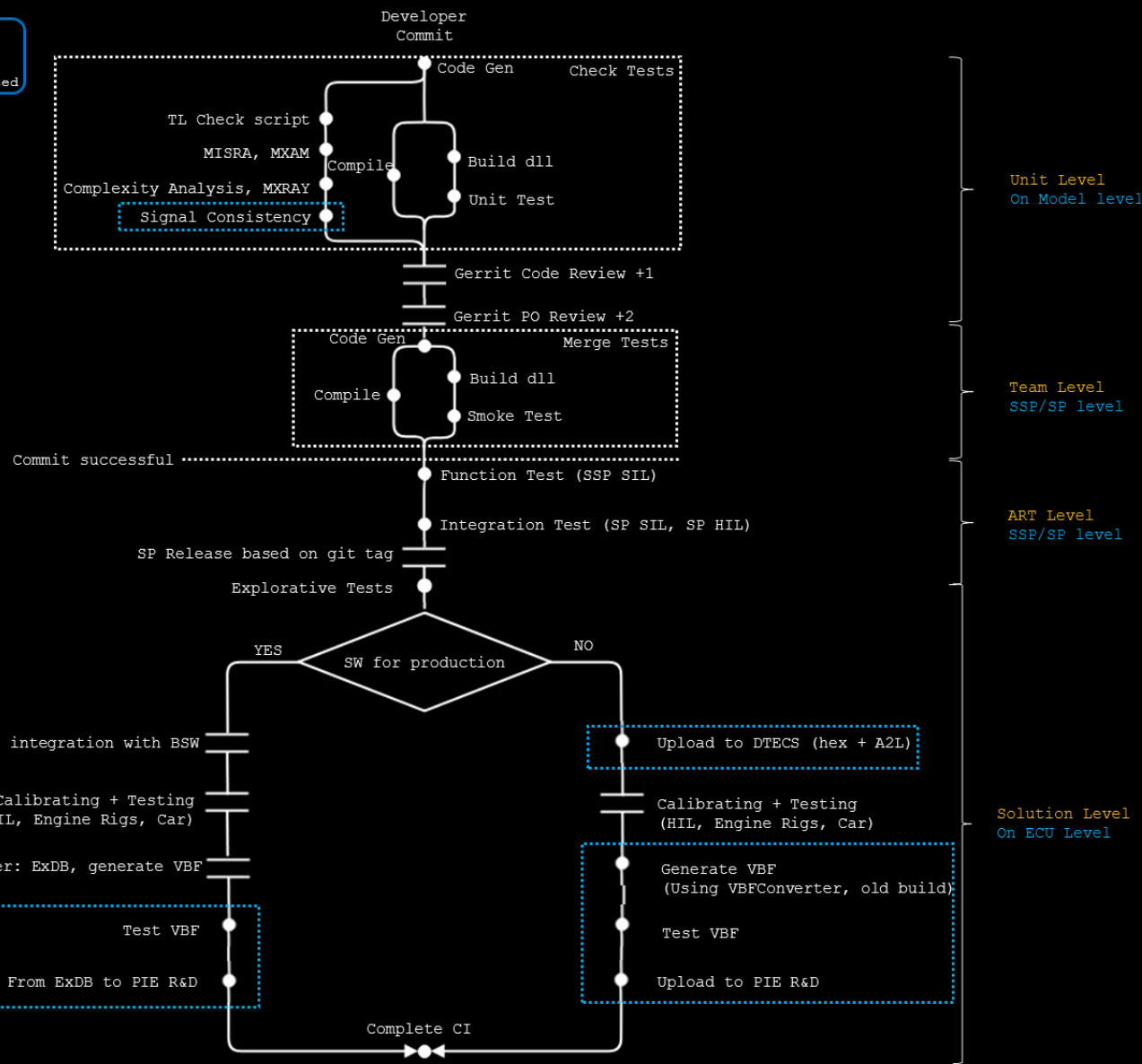
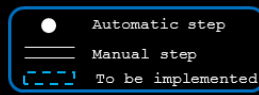
- Ensuring the integrity is not dependent on a single individual making the right call. It is ensured by the system.
- **Fast Feedback**, small changes often, automatic testing
- **Transparency**, Follow your commit
- **CI/CD system as code**, using Python plugin Jenkins job builder and YAML files as pipeline configuration



# CI/CD SYSTEM

## CI system structure

Build dll, unit tests, Merge tests and Exploratory tests executed by Silver and TestWeaver



# CI/CD SYSTEM

```
MINGW64/c/git/pt_pcc
jfoufas1@GOTCND7163LJN MINGW64 /c/git/pt_pcc (master)
$ git pull --rebase
remote: Counting objects: 10734, done
remote: Finding sources: 100% (202/202)
remote: Total 202 (delta 89), reused 202 (delta 89)
Receiving objects: 100% (202/202), 877.23 KiB | 6.91 MiB/s, done.
Resolving deltas: 100% (89/89), completed with 49 local objects.
From ssh://gotsv11415.got.volvocars.net:29431/pt_pcc
  53d2c762..7abe00fe  master           -> origin/master
  d89216f4..3670d2a4  feature/HCT_APG_VEP4_GEN3-54_1 -> origin/feature/HCT_APG_VEP4_GEN3-54_1
* [new branch]      feature/VED4_GEN3-82_fsjoblom -> origin/feature/VED4_GEN3-82_fsjoblom
* [new branch]      feature/VED4_GEN3-82_fsjoblom_2 -> origin/feature/VED4_GEN3-82_fsjoblom_2
* [new branch]      feature/VED4_GEN3-82_p3Max_from_boost_sensor -> origin/feature/VED4_GEN3-82_p3Max_from_boost_sensor
* [new branch]      feature/p3Max_bliang1 -> origin/feature/p3Max_bliang1
* [new tag]         VEP4_GEN3-55 -> VEP4_GEN3-55
Updating 7c1d391c..7abe00fe
Fast-Forward
Models/SSPDL/VcDc\CvcMd1\c_src\VcDc\Cvc.a2l | 4 +-
Models/SSPDL/VcDc\CvcMd1\tests\test_simple.py | 10 +
Models/SSPDL/VcDc\Hep7Md1\VcDc\Hep7Md1_par.m | 2 +-
Models/SSPDL/VcDc\Hep7Md1\VcDc\Hep7Md1_sgp.xml | 1029 ++++++
```

# CI/CD SYSTEM

The screenshot displays the Gerrit web interface for a merged change. The browser address bar shows the URL `https://pt.gerrit.cm.volvocars.biz/#/c/2079/`. The page title is "Change 2079 - Merged".

**Change Details:**

- Change-Id:** Iaffbd5e2c5aad8f57390cb578cd389570947bf8f
- Project:** pt\_pcc
- Branch:** master
- Updated:** 16 hours ago

**Commit Information:**

Author	Committer	Parent(s)	Change-Id	Timestamp
Nilsson	Zuul <zuul@pt.gerrit.cm.volvocars.biz>	8d15c3cd93f91a763af58b213d30ebcb02fd62d	Iaffbd5e2c5aad8f57390cb578cd389570947bf8f	Aug 21, 2018 1:18 PM
		2fd4901a1fccaa9eb8a3dc0813abf02d18532a1c		Aug 23, 2018 4:30 PM

**Code-Review:** +2 (Nilsson, I), +1 (Olsson), Verified +2 (Zuul)

**Files:**

File Path	Comments	Size
Commit Message		
Script/SubFunctions/Merge_Parfiles.m	11	
Script/SubFunctions/TL2SL_Gui.m	16	
<b>Total</b>	<b>+5, -22</b>	

**History:**

Author	Action	Timestamp
Nilsson	Uploaded patch set 1.	Aug 21 1:19 PM
Zuul	Patch Set 1: Starting check jobs.	Aug 21 1:19 PM
swint_swint	Patch Set 1: Cppcheck Results.	Aug 21 1:37 PM
swint_swint	Patch Set 1: Cppcheck Results.	Aug 21 1:40 PM
swint_swint	Patch Set 1: VED4_GEN3 software.	Aug 21 1:41 PM
swint_swint	Patch Set 1: VEP4_GEN3 software.	Aug 21 1:44 PM
Zuul	Patch Set 1: Verified+1 Build succeeded.	Aug 21 1:44 PM
Olsson, I	Patch Set 1: Code-Review+1	Aug 21 4:23 PM
Nilsson	Patch Set 1: Code-Review+2	Aug 23 4:13 PM
Zuul	Patch Set 1: -Verified Starting gate jobs.	Aug 23 4:13 PM
swint_swint	Patch Set 1: VEP4_GEN3 software.	Aug 23 4:22 PM
swint_swint	Patch Set 1: VED4_GEN3 software.	Aug 23 4:24 PM
swint_swint	Patch Set 1: MergeTests Report.	Aug 23 4:30 PM
swint_swint	Patch Set 1: MergeTests Report.	Aug 23 4:30 PM
Zuul	Patch Set 1: Verified+2 Build succeeded.	Aug 23 4:30 PM
Zuul	Change has been successfully rebased and submitted as 2fd4901a1fccaa9eb8a3dc0813abf02d18532a1c by Zuul	Aug 23 4:30 PM



# CI/CD SYSTEM

## Zuul Status

Real-time status monitor of Zuul, the pipeline manager between Gerrit and Workers.

Queue lengths: 0 events, 0 results.

Filters  Expand by default:

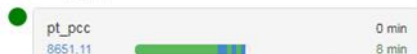
### check

Newly uploaded patchsets enter this pipeline to receive an initial +/-1 Verified vote from Jenkins. You can retrigger this check by commenting "recheck" in Gerrit

Queue: [pt\\_pcc](#)



Queue: [pt\\_pcc](#)

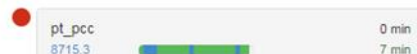


VED4_GEN3-013_Checkscript	SUCCESS
VED4_GEN3-010_Generate_Code	SUCCESS
VED4_GEN3-012_CPP_Check	SUCCESS
VED4_GEN3-022_Compile	SUCCESS
VED4_GEN3-030_UnitBuild_UnitTests	SUCCESS
VEP4_GEN3-013_Checkscript	SUCCESS
VEP4_GEN3-010_Generate_Code	SUCCESS
VEP4_GEN3-012_CPP_Check	SUCCESS
VEP4_GEN3-022_Compile	SUCCESS
VEP4_GEN3-030_UnitBuild_UnitTests	SUCCESS
GEP3_..._Checkscript	SUCCESS
GEP3_..._Generate_Code	SUCCESS
GEP3_..._CPP_Check	SUCCESS
GEP3_..._UnitBuild_UnitTests	SUCCESS
GEP3_..._Checkscript	SUCCESS
GEP3_..._Generate_Code	SUCCESS
GEP3_..._CPP_Check	SUCCESS
GEP3_..._UnitBuild_UnitTests	SUCCESS
GEP3_..._0_Generate_Code	
SIMDIFF	
MXRAY_Report	SUCCESS
MXAM_Report	
CI_of_CI	SUCCESS
pybuild_upgrade	

### gate

Changes that have been approved by core developers are enqueued in order in this pipeline.

Queue: [pt\\_pcc](#)



VED4_GEN3-010_Generate_Code	SUCCESS
VED4_GEN3-022_Compile	aborted
VED4_GEN3-041_Mem_Map	skipped
VED4_GEN3-032_CompleteBuild_DLL	
VED4_GEN3-033_Run_MergeTests	queued
VEP4_GEN3-010_Generate_Code	SUCCESS
VEP4_GEN3-022_Compile	SUCCESS
VEP4_GEN3-041_Mem_Map	SUCCESS
VEP4_GEN3-032_CompleteBuild_DLL	SUCCESS
VEP4_GEN3-033_Run_MergeTests	SUCCESS
GEP3_..._Generate_Code	SUCCESS
GEP3_..._Compile	SUCCESS
GEP3_..._Mem_Map	
GEP3_..._CompleteBuild_DLL	SUCCESS
GEP3_..._Run_MergeTests	SUCCESS
GEP3_..._Generate_Code	SUCCESS
GEP3_..._Compile	SUCCESS
GEP3_..._Mem_Map	
GEP3_..._CompleteBuild_DLL	SUCCESS
GEP3_..._Run_MergeTests	SUCCESS
GEP3_..._1_Generate_Code	SUCCESS
GEP3_..._2_Compile	SUCCESS
GEP3_..._1_Mem_Map	
GEP3_..._2_CompleteBuild_DLL	SUCCESS
GEP3_..._3_Run_MergeTests	SUCCESS

### build\_mxam\_report

Generate MXAM report, start this by commenting "build mxam\_report" in Gerrit

### build\_gep3\_

Build GEP3\_SPA\_7DCT, start this by commenting "build gep3\_spa\_7dct" in Gerrit

### build\_gep3\_

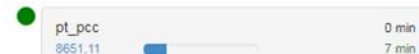
Build GEP3\_SPA, start this by commenting "build gep3\_spa" in Gerrit

### build\_gep3\_

Build GEP3\_HRE, start this by commenting "build gep3\_hre" in Gerrit

### build\_gep3\_

Build GEP3\_HEP7, start this by commenting "build gep3\_hep7" in Gerrit



GEP3_..._D10_Generate_Code	
GEP3_..._D12_CPP_Check	queued
GEP3_..._D13_Checkscript	queued
GEP3_..._D22_Compile	queued
GEP3_..._D30_UnitBuild_UnitTests	queued

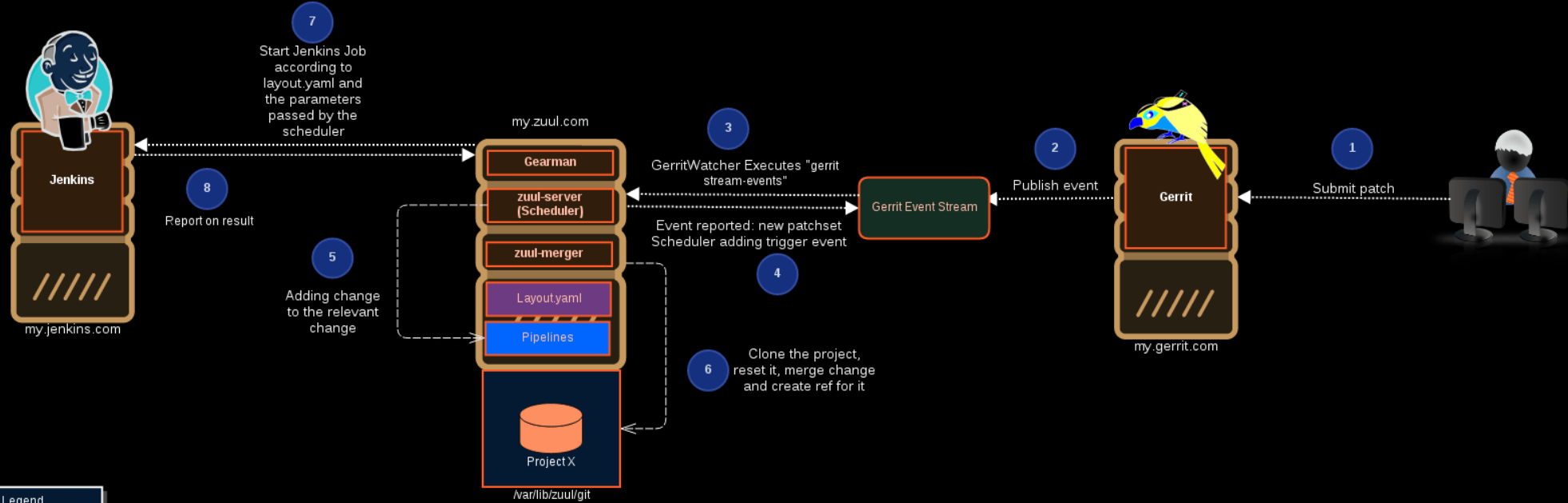
### build\_gep3\_

Build GEP3\_BEV, start this by commenting "build gep3\_bev" in Gerrit

### build\_gep3\_pf1\_hev

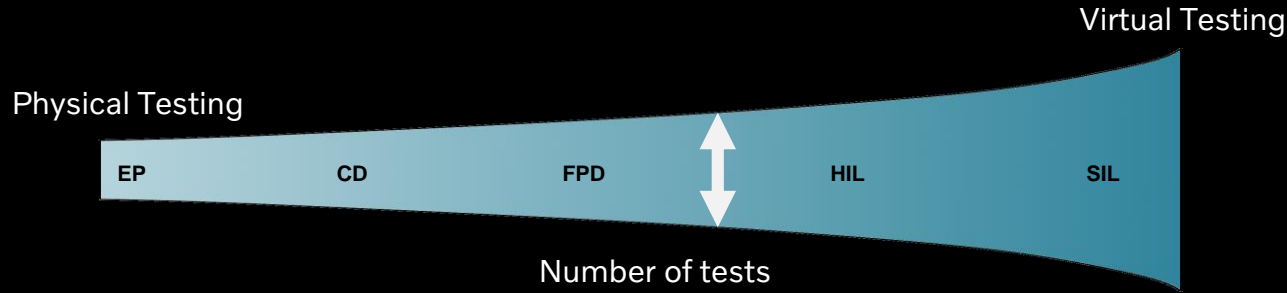
Build GEP3\_PFI\_HEV, start this by commenting "build gep3\_pf1\_hev" in Gerrit

# CI/CD SYSTEM

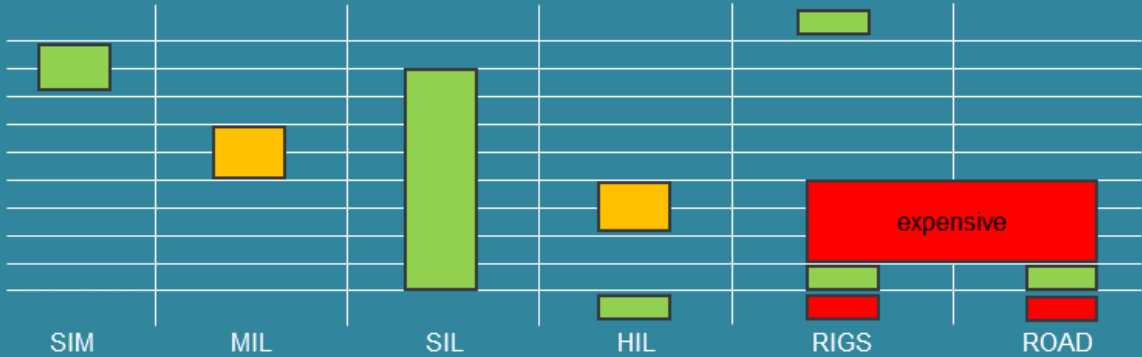


Legend
zuul service
conf file
zuul internal

# SIL, THE CORE OF THE CI SYSTEM



- Standardized Data Collection
- Plant Modelling
- Model Calibration
- Conceptual SW design
- Integrated SW design
- Diagnosis development
- SW Validation
- SW Calibration
- Attribute Validation
- HW and diagnostic validation



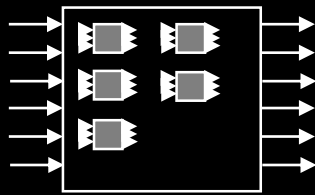
# SIL TEST LEVELS



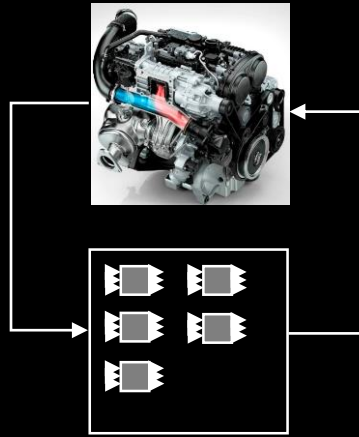
- Unit-, Module- and ECM-level tests
- ECM includes supplier SW
- With or without plant models



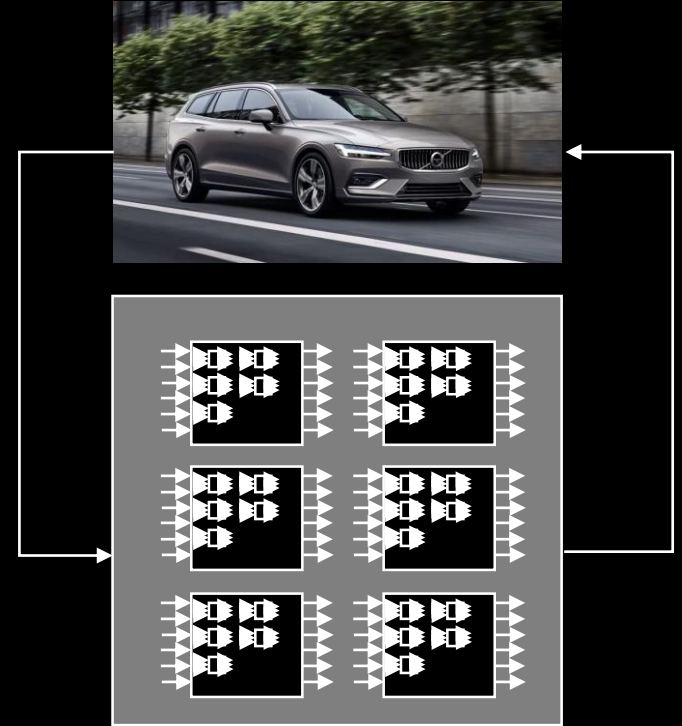
Unit SIL test  
Open-loop



Module SIL test  
Open-loop



Module SIL test  
Closed-loop



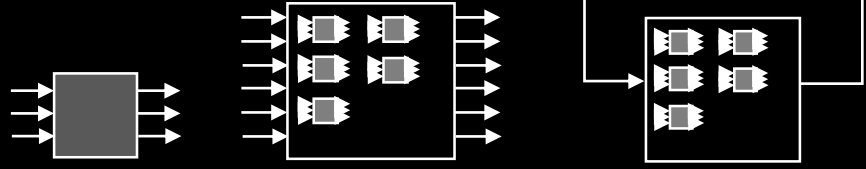
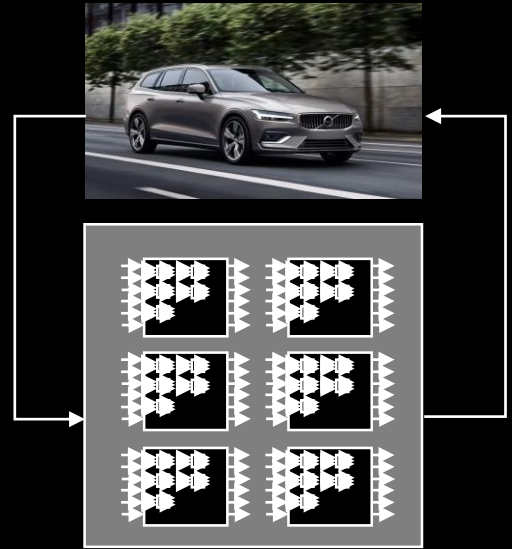
ECM SIL test  
Closed-loop

# TEST EXECUTION FRAMEWORK



- All SIL tests – from open-loop unit tests to closed-loop ECM tests are using the same toolchain
- Tests defined in TestWeaver
  - Stimulus files in Python
  - Test-level invariant requirement watchers (RML)
- Test execution in Silver

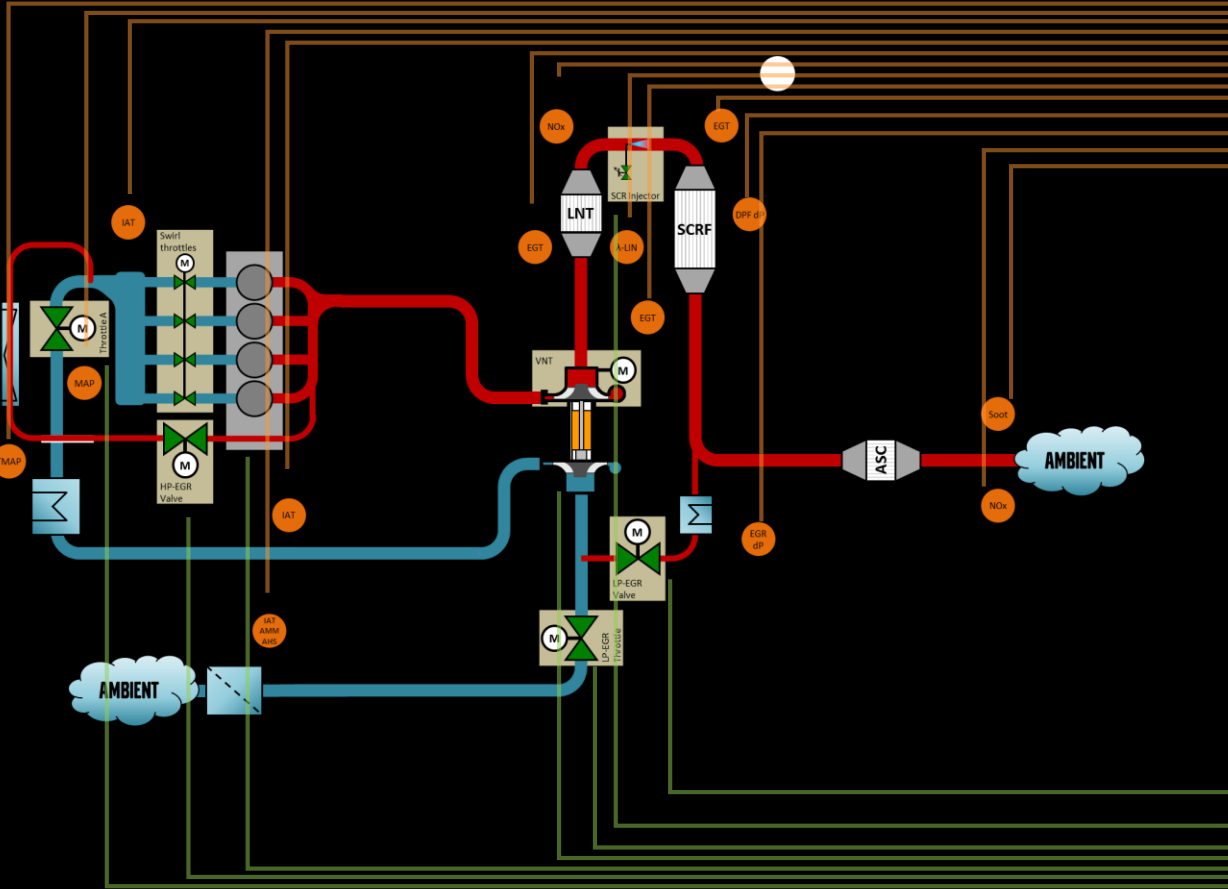
```
5
6 w = WatcherFSM( tw,                # top-level watchers must set a WeaverConnection
7   'Watcher_engine_max_speed',      # name in TestWeaver
8   description = ('Checks if the engine RPM does not overspeed'),
9   while_condition = (lambda: True, ''),
10  pass_condition = (lambda: rpm.Value < 5000, 'Check engine RPM.'),
11  autoreset = False,                # continue to check the pass_condition
12  tolerance_time = 1)
13 w.set_req_id('')
14
```



# ECM SIL - ENGINE PLANT MODEL



sensors



Engine Control Module

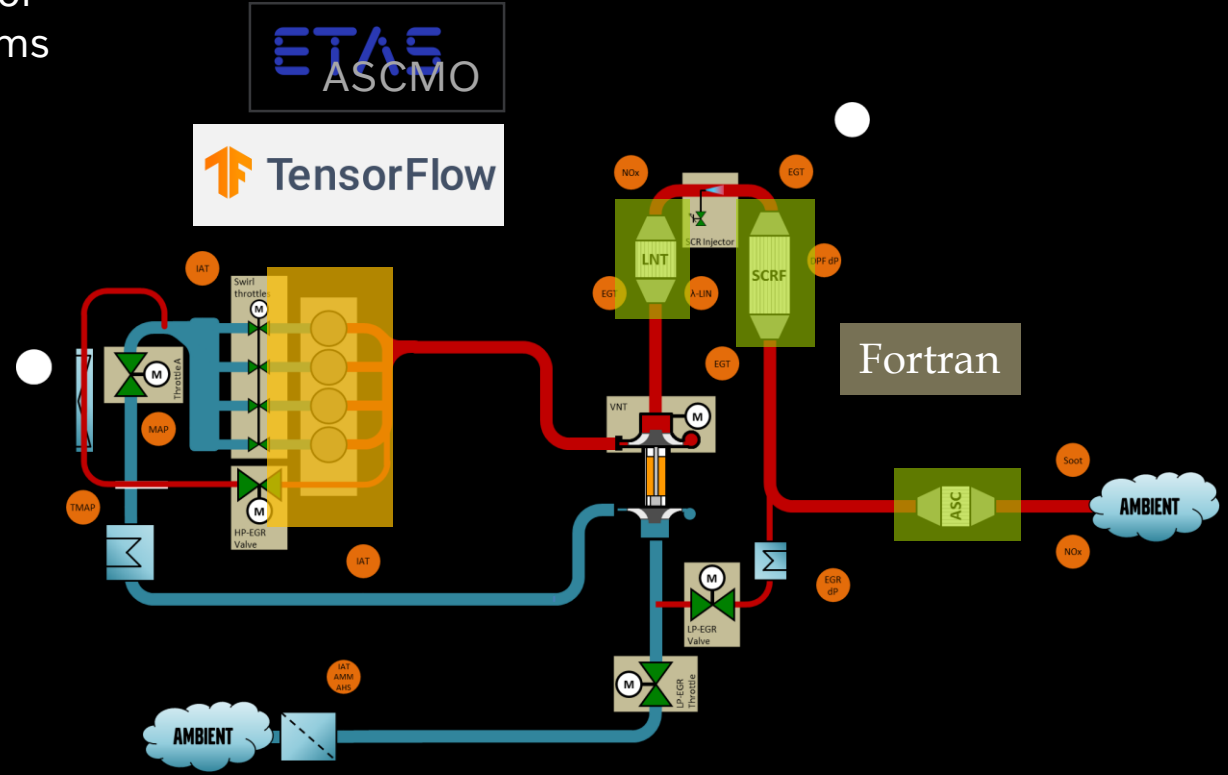
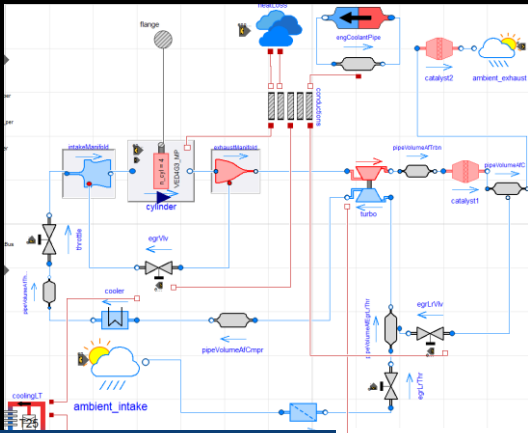
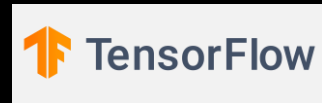
SIL d11

actuators

# ENGINE PLANT MODEL - PARTS



- In-house developed Dymola model for torque, air-charge and cooling systems
- Supplier catalyst models, blackbox
- Data-driven emission models  
ETAS ASCMO, Neural networks



Fortran

AMBIENT

NOx

EGT

PF dp

A-LIN

SCR Injector

LNT

SCRF

EGT

NOx

SOot

NOx

EGT

EGT

HP-EGR Valve

Swirl throttle

MAP

TMAP

IAT

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LP-EGR Valve

LP-EGR Throttle

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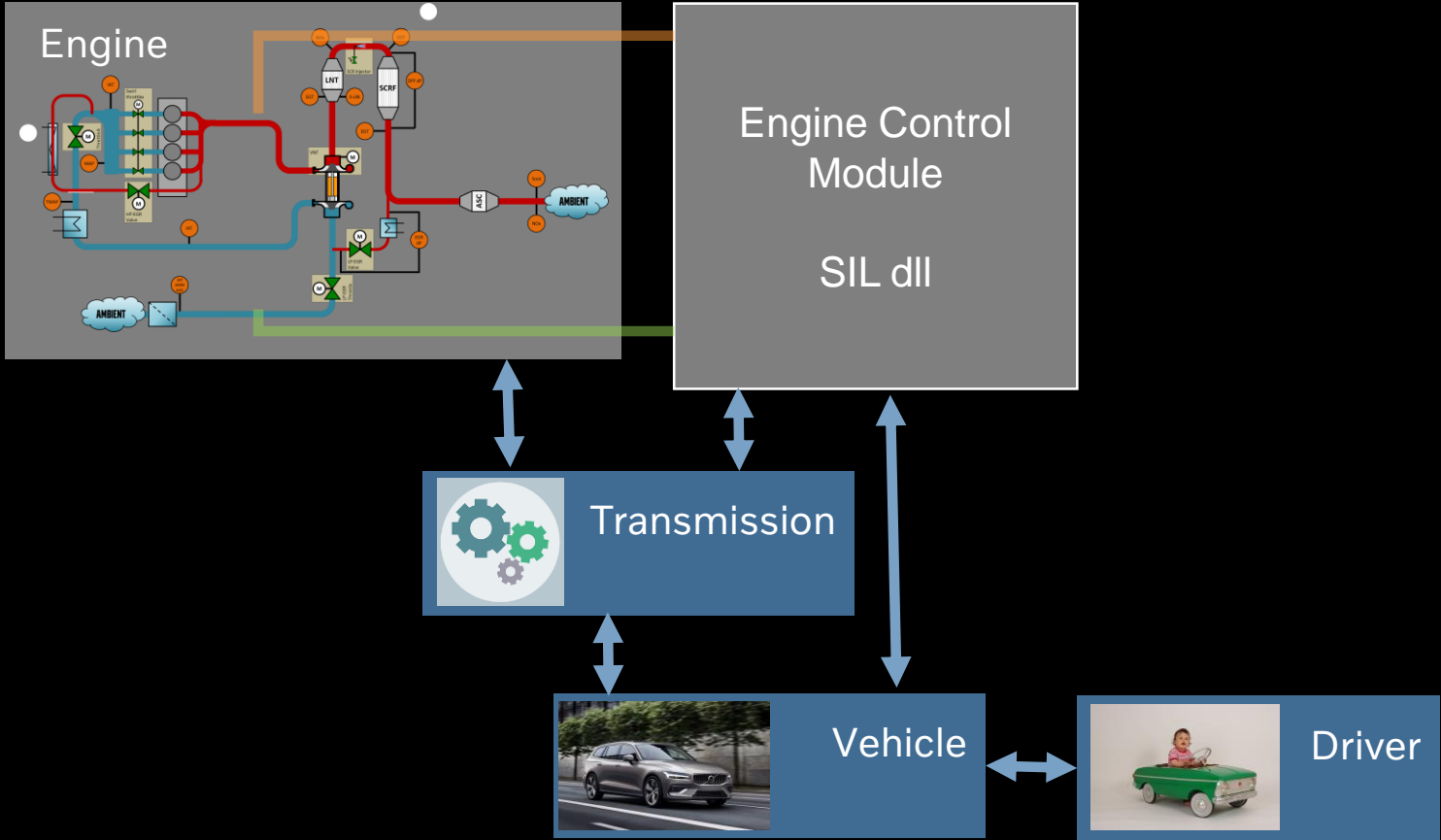
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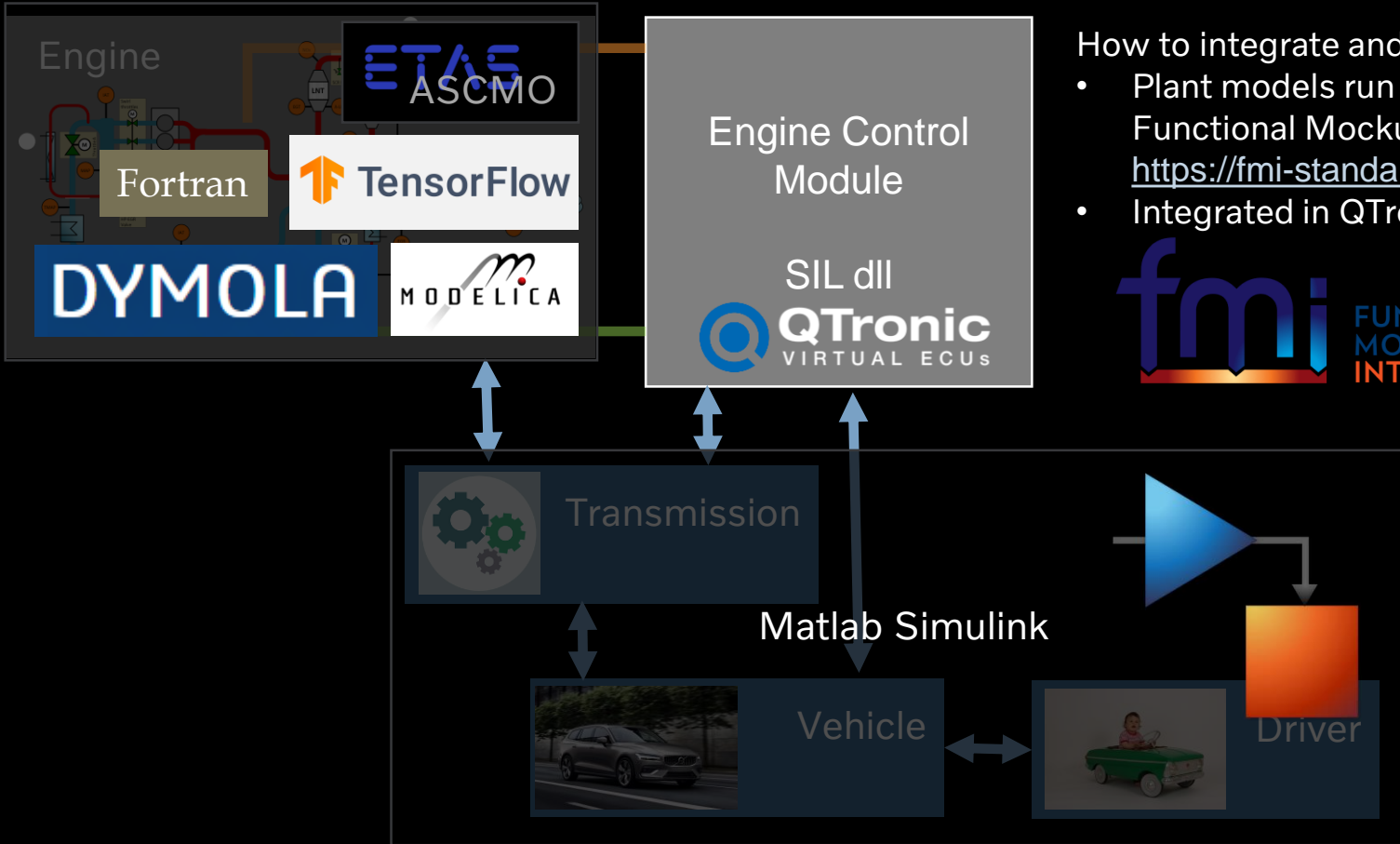
AMBIENT

# ECM SIL – THE FULL SYSTEM





# ECM SIL - THE FULL SYSTEM



How to integrate and simulate all this together?

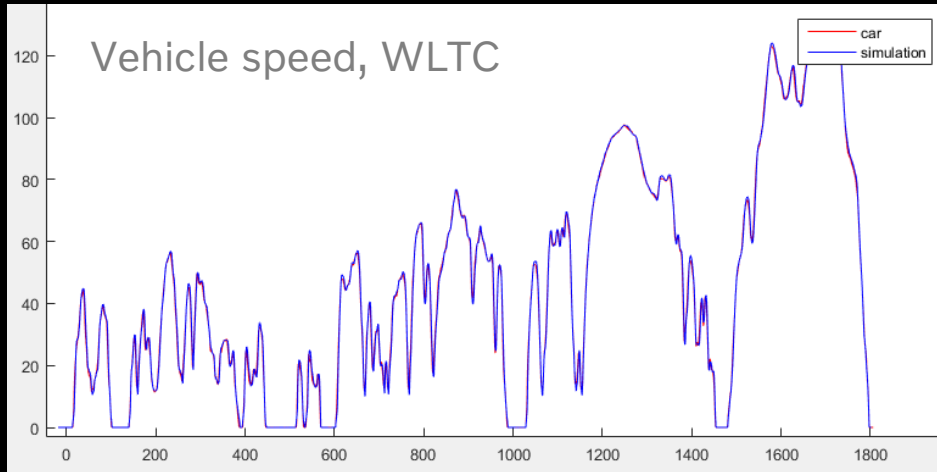
- Plant models run as Functional Mockup Units (FMU:s) <https://fmi-standard.org/>
- Integrated in QTronic Silver



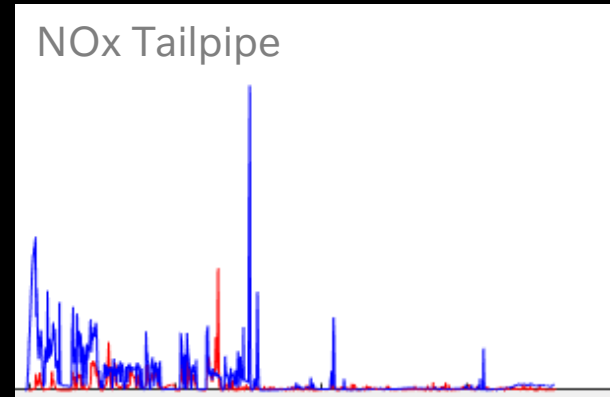
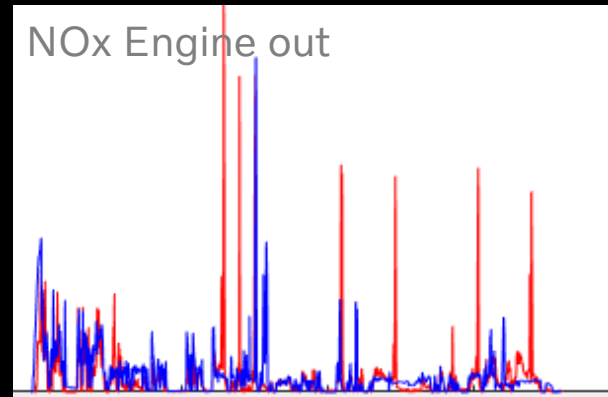
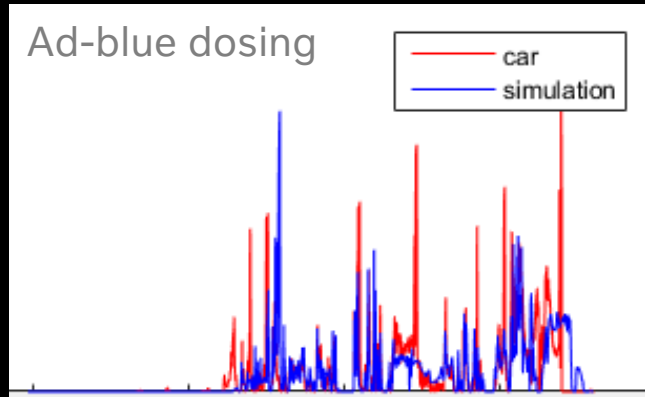
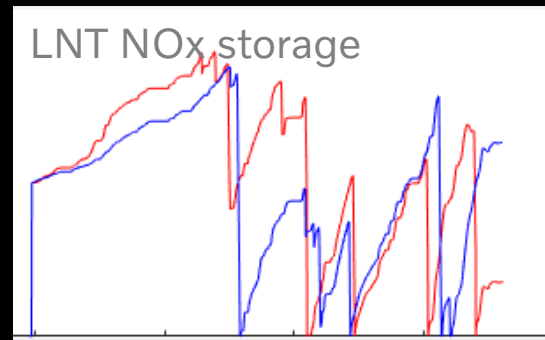
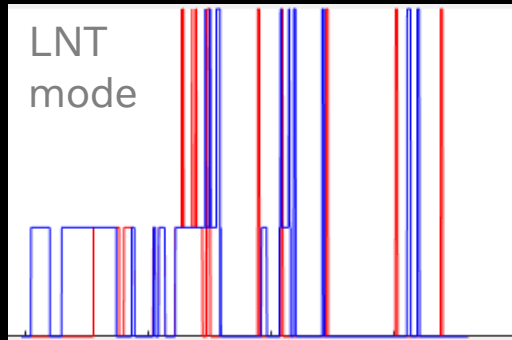
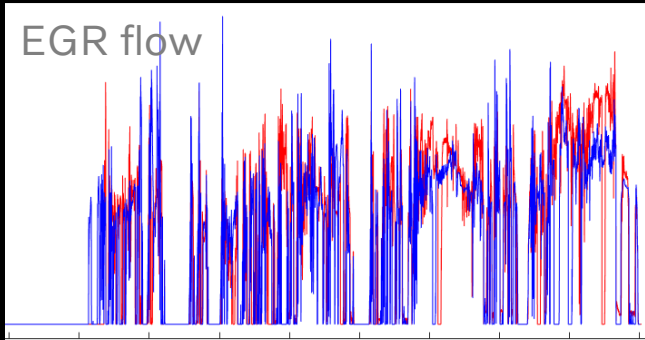
# RESULTS, WLTC



- WLTC cycle comparison
- ECM SIL vs. Prototype vehicle rig measurement
- Input: WLTC velocity profile
- Including emissions
- Focus on triggering software functionality, not absolute quantities



# RESULTS, WLTC





**THANK YOU!**

