VIRTUAL ECUS AND COVERAGE DRIVEN TESTING FOR ELECTRIC PROPULSION

Electric Drive – Volvo Car Corporation

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ELECTRIC PROPULSION SYSTEM AT VOLVO

- Electrical Machines & Inverters (propulsion/regeneration)
- Battery
- On-board chargers

Inhouse SW – Development & Testing

- Model-Based Design & Testing – MIL Simulink & SIL Silver vECUs
- Aim for Continuous Integration

FOCUS ON ELECTRIC DRIVE

- Functionalities for limiting Torque Request
    (temperature, current, power, speed ...)

- Mode manager & Interface components (Standby, Torque/Speed Control ...)

- Dynamics control (Anti-spin, Active Damping ...)

- Integration & Complete SW

- Diagnostics

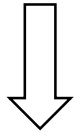# MOTIVATIONS FOR VIRTUAL TESTING

- Verify integration of SWCs with Requirements-based verification
- Allows testing at early stages of the development cycle (coverage)
- Better use of Rigs/Cars (e.g. calibration, driveability)

- Cheaper/faster way to find bugs
- Reduce future quality issues
- ***Number of scenarios***
  (complexity of the system)
- ***Short-time events (~0.01-1ms)***

Cost to fix a bug

Requirements   Analysis and Design   Coding   Testing in Car   Production
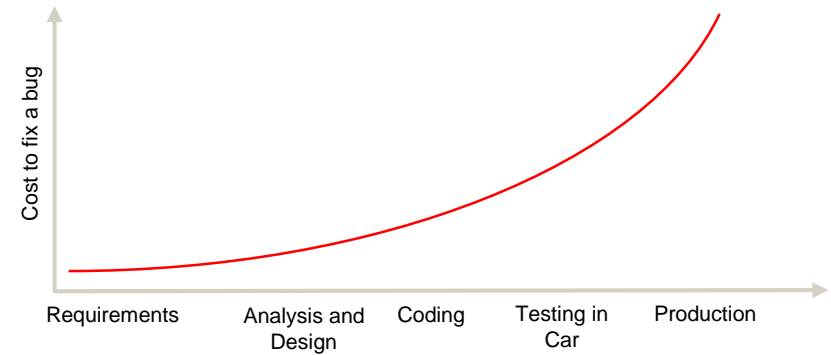
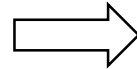# EXAMPLE – COOLING SYSTEM

Fault injected in cooling system and applied maximum torque

⬇

Increase in EM temperature ⟹ Torque limited OK

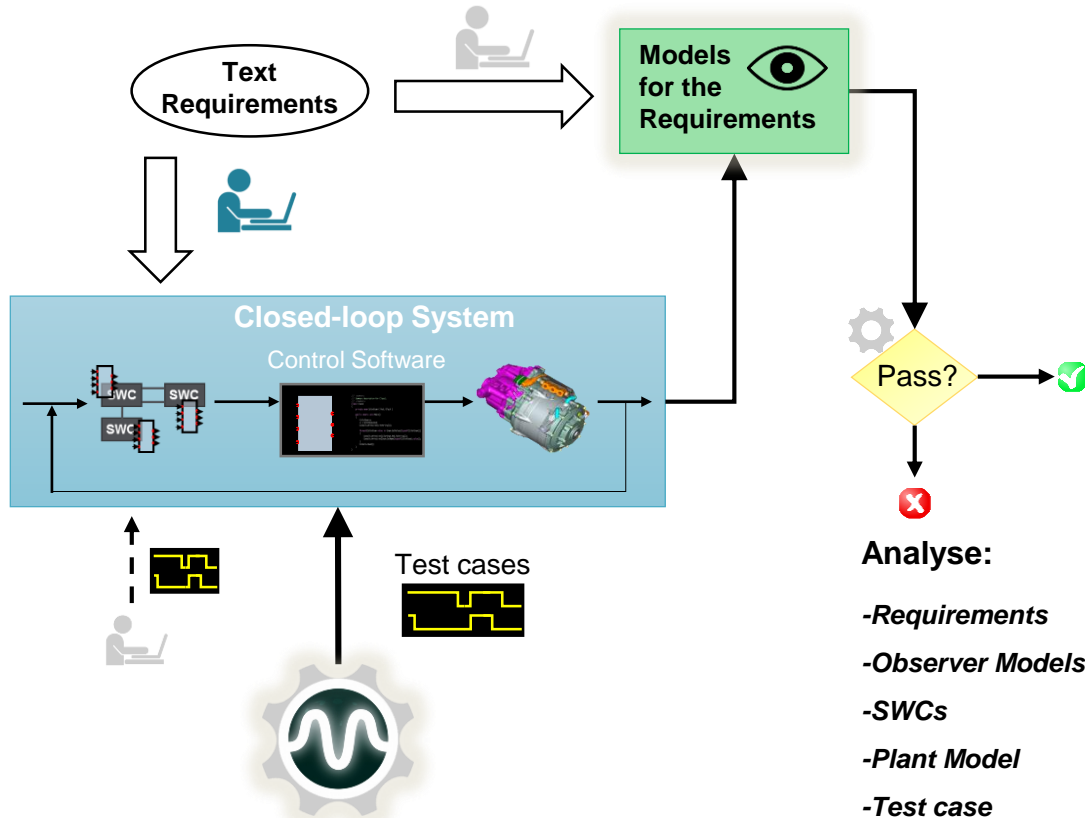Anti-spin   NOK
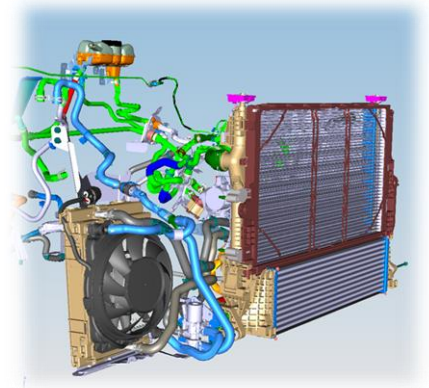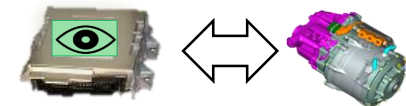
STATE OF THE ART AT ELECTRIC PROPULSION

Text Requirements

Models for the Requirements 👁

Closed-loop System
Control Software
SWC SWC
SWC

Test cases

Pass?
✓
✗

Analyse:

-Requirements

-Observer Models

-SWCs

-Plant Model

-Test case

- Code generated **automatically**

- Test cases executed **auto.**

(& manually)

- Fulfillment checked **auto.**

- **Virtual ECU**

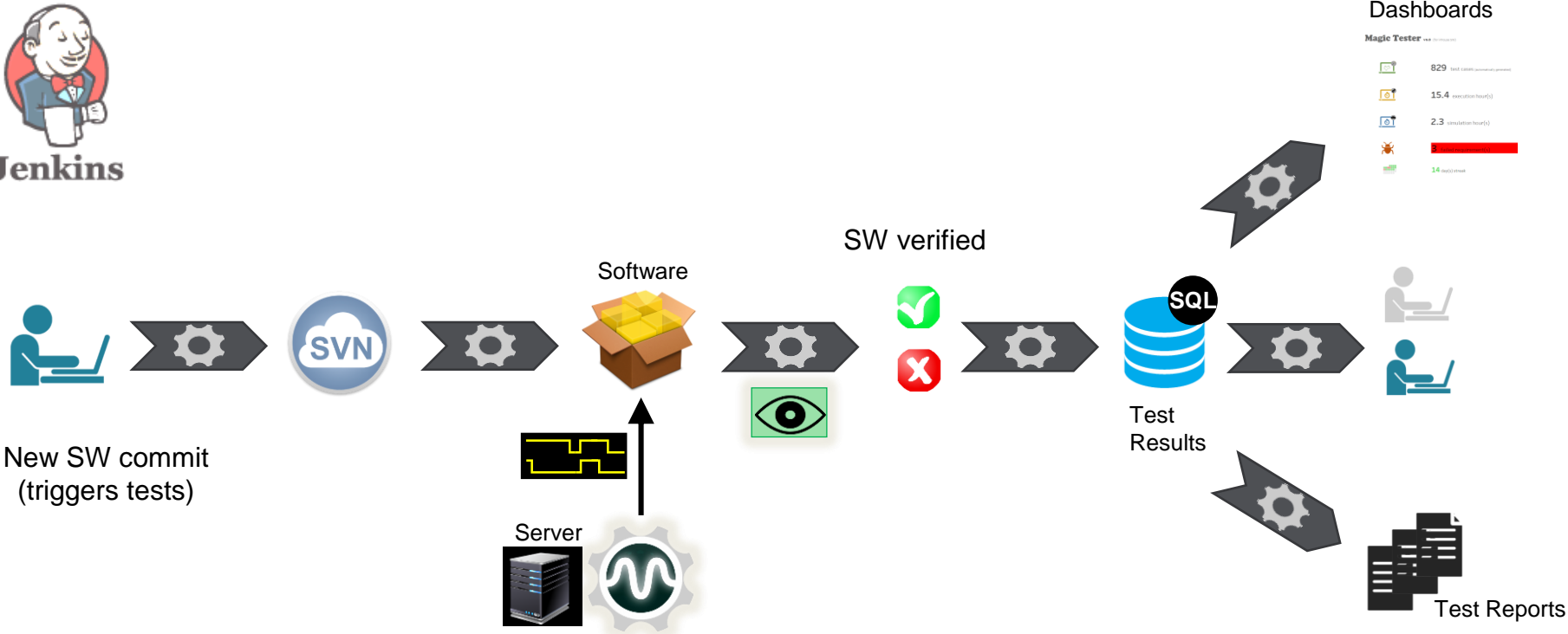# PIPELINE FOR SW UPDATES

Dashboards

Software
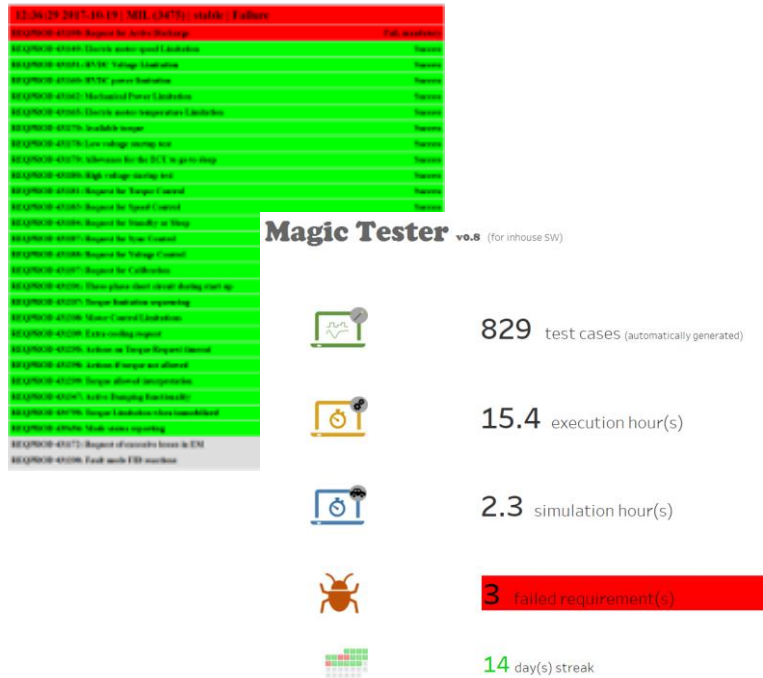
SW verified

New SW commit
(triggers tests)

Server

Test
Results

Test Reports

TEST RESULTS REPORTS

- Combination of
  verified & *activated* signals

- Automated for all projects

- All Requirement Models tested
  continuously

DYNAMIC STIMULUS FOR INPUT SIGNALS (CHOOSERS)

- Mode Status & Request

- Torque/Speed/Voltage Request

- Torque Allowed (propulsive and/or regenerative)

- Torque Available (from Limitations)

- Battery signals (Available Voltage, contactor status...)

- External conditions (e.g. road slope, friction...)

- Automatically generated by TestWeaver

- Thousands of combinations & sequences

COVERAGE FROM TESTWEAVER

- Heat maps (e.g. Electric Machine Speed vs Power)

- Robustness (Out of Range, addition of disturbances)

    - Evaluate behavior for incorrect signal values

- Focus on specific Requirements to orientate
  TestWeaver

- **Large amount of bugs found quickly at the beginning of design & development**
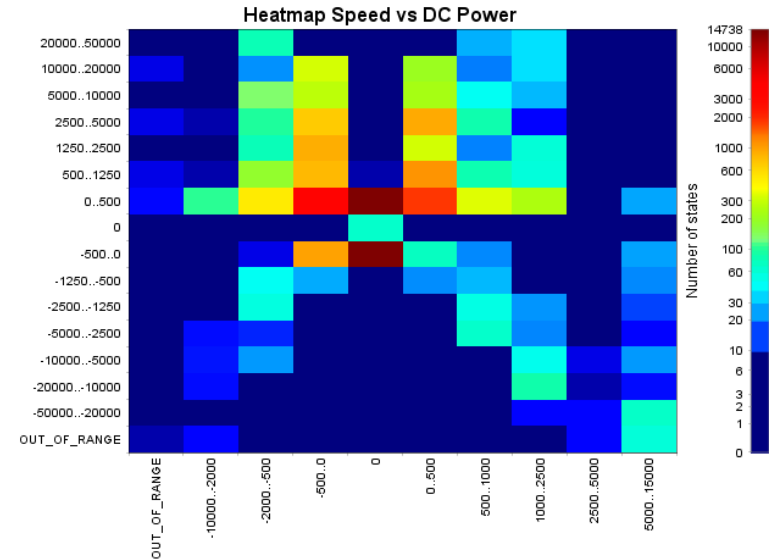
EXAMPLE – SPEED CONTROL

- Hybrids – gear change mode

- Margin as a Requirement

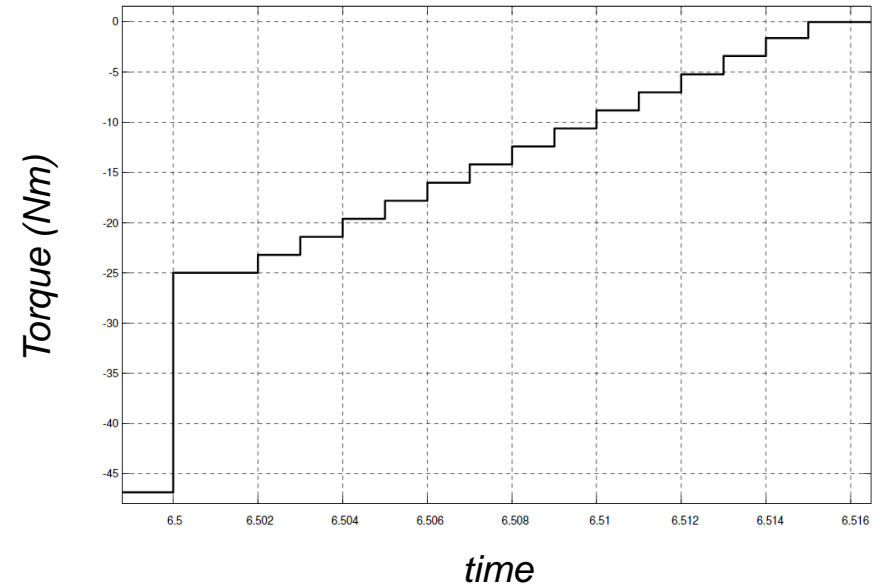- Issue: over time tolerance

- *Improvement of regulator*
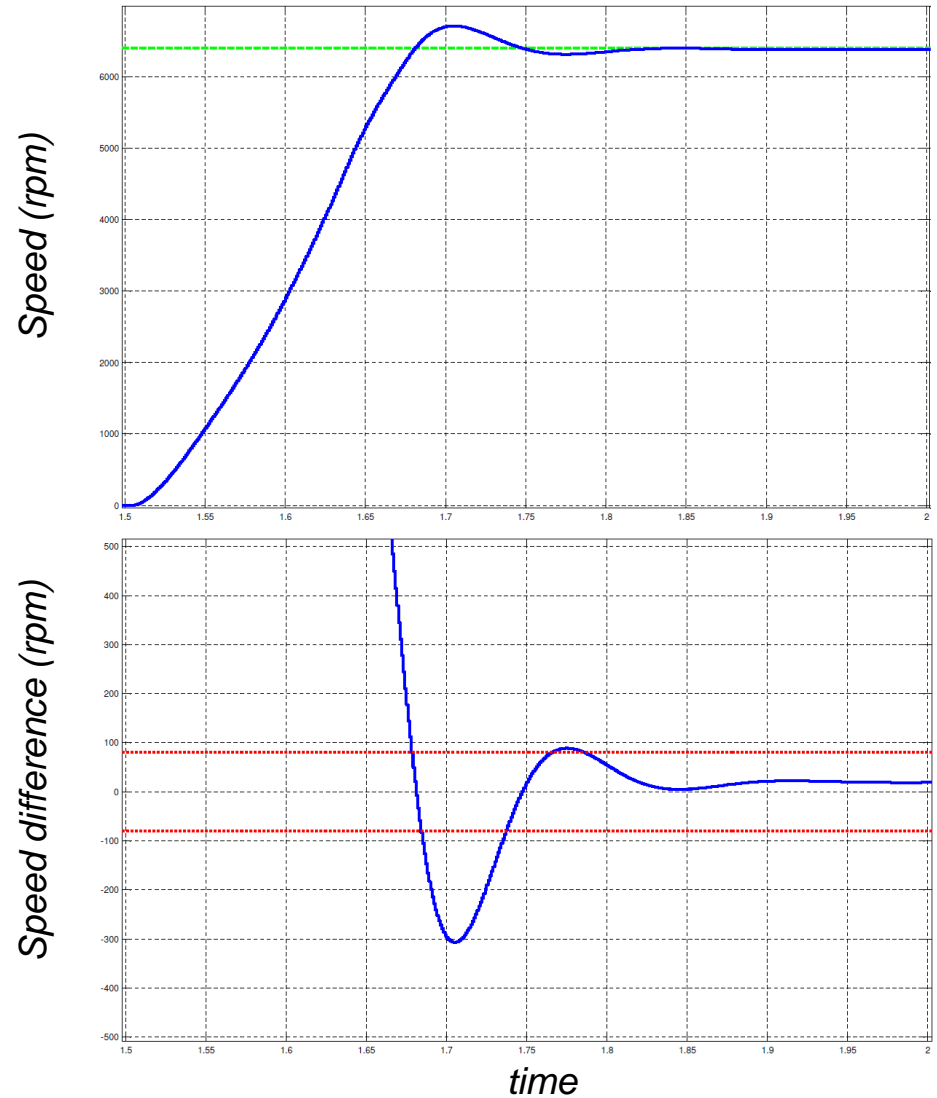
EXAMPLE – REQUEST FOR STANDBY MODE

• Torque ramping rate as Requirement

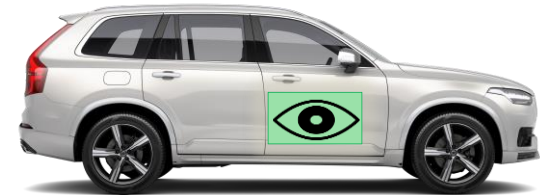• Ramping down tolerance included

    -Update on Requirement & SW

(*Agile way of working)

CURRENT STEPS

- Implementation of Observer Models in the car
  - -"Every driver will be a tester"
  - (Volvo Technology Awards)

- Implementation of Calibration parameters in the pipeline

- Explore capabilities of TestWeaver-Silver

- Request Supplier's code for full vECU testing

FUTURE STEPS

- *Complete Propulsion System*

  - Perform tests for several ECUs (OBC-BECM-ED)
    (Inclusion of ECM)

- Improvement of Plant Models
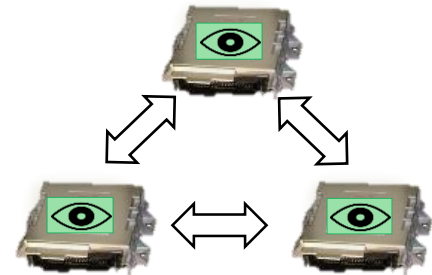
Tack så mycket! (Thank you)

Daniel Albernaz / Andreas Andersson