Front Loading BEV Development from Road to Rigs

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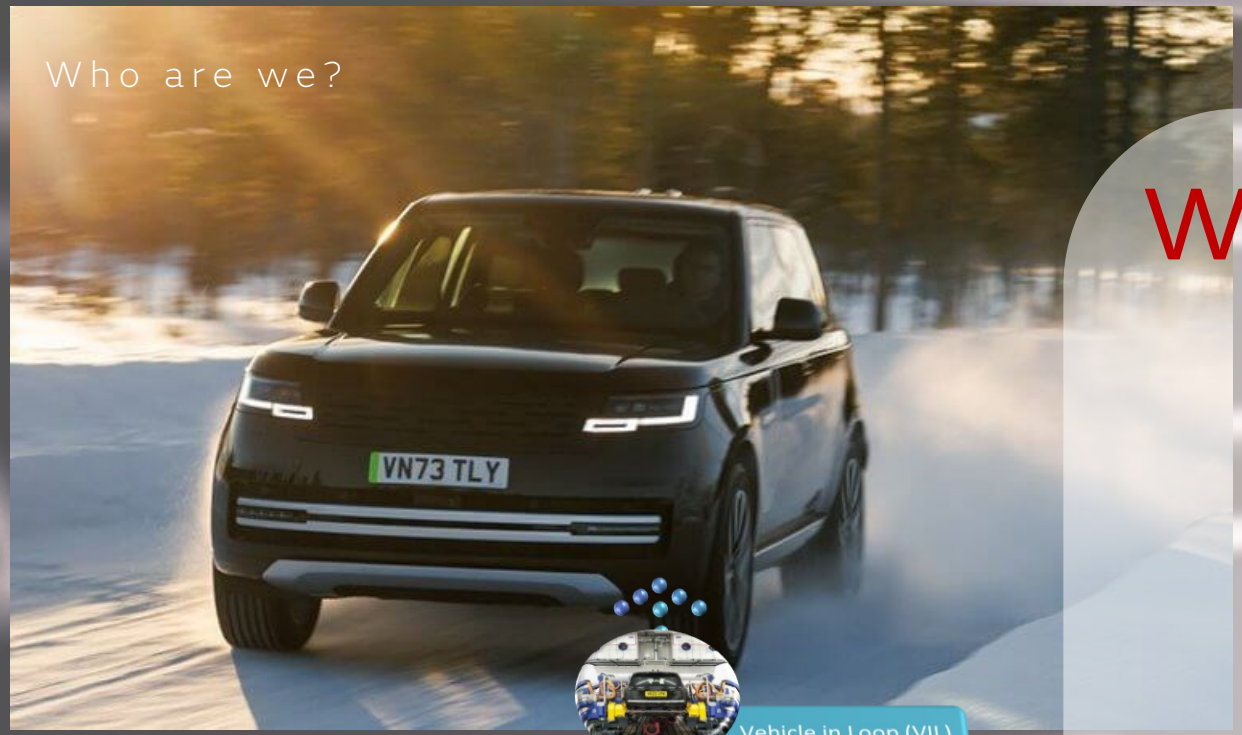


Who are we ?

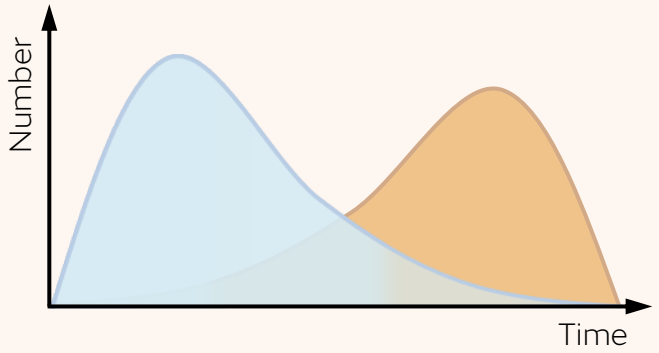
Propulsion Control System
Test Capabilities

Our goal is to enable
‘Right Test’
at the
‘Right Time’
in the
‘Right Test Environment’

Why Rig-based Testing?


RANGE ROVER

Issues identified and resolved



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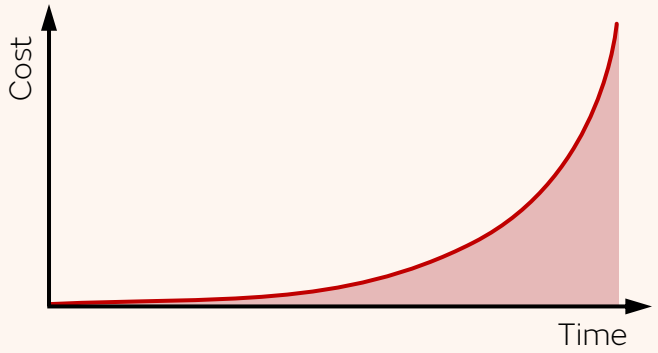
Cost of fixing issues



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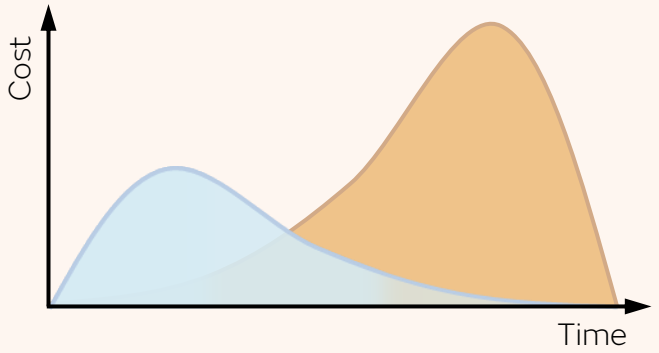
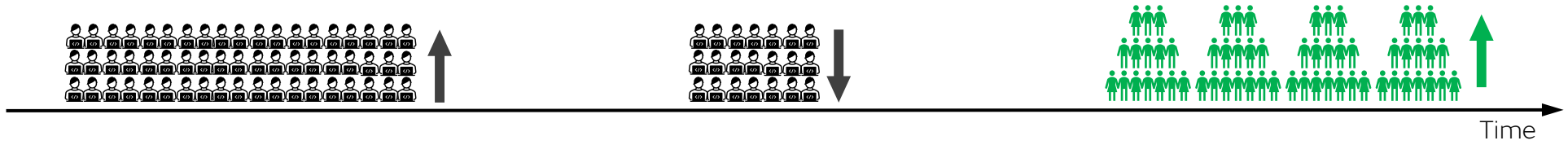
Product Development Cost



Many virtual prototypes at low cost.

Open to anyone to use.



Earlier detection enables faster time to market and lower cost.

Vertical Toolchain

Overview

PiL

Propulsion components connected to dynos with vehicle model simulated

SiL

A desktop-based environment with vECU connected with virtual vehicle model

ViL

Vehicle or Dynamic Lab Car with each wheel connected to a dyno for road simulation

HiL

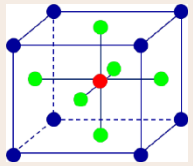
Real ECU connected to virtual vehicle model

MiL

Low fidelity Simulink models to form the vehicle model

Right Test at the Right Time!

- ❖Safe Fail Fast Environment
- ❖Signifcantly decrease development costs
- ❖Earlier software and feature development



Test Automation Method

Vehicle, Environment & Driver Model

Powertrain & NGD Model

XIL (SIL to HIL to PIL to DIL to VIL to Road) Correlation is KEY

Test Assets

Calibration developed is valid

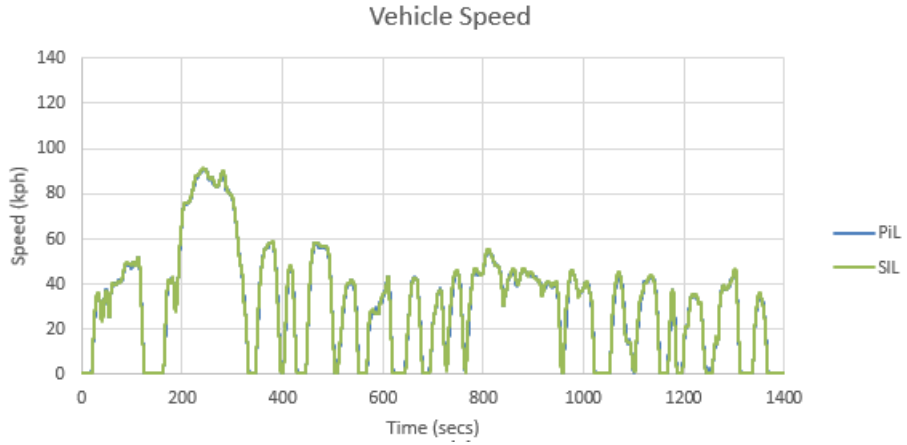
Physical data to calibrate virtual

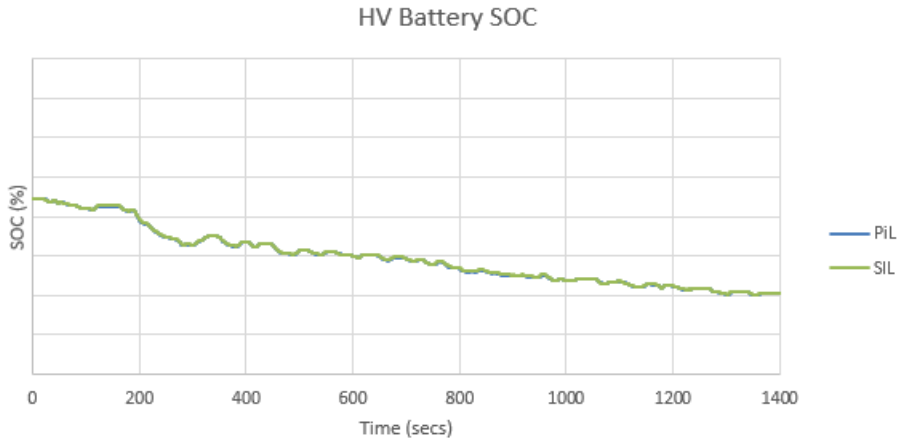
Left shift software/cal issues

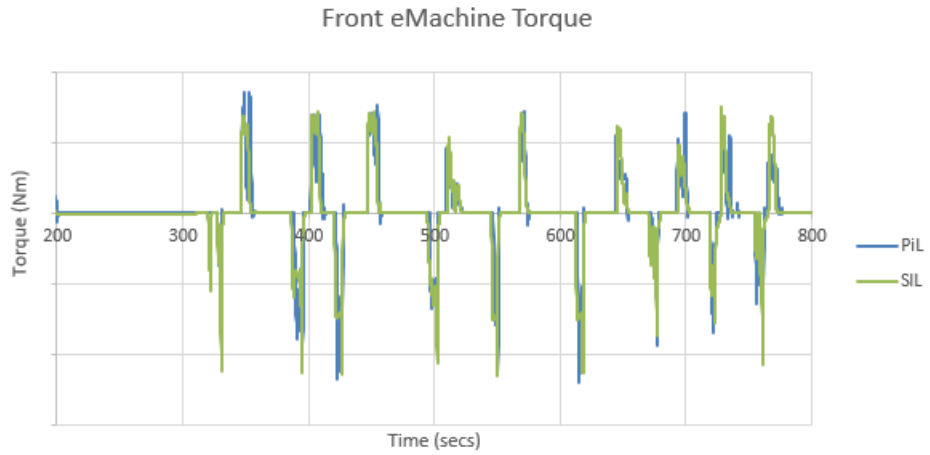
One Test, One Driver, One Model -> Correlation Powers Rig to Rig Testing

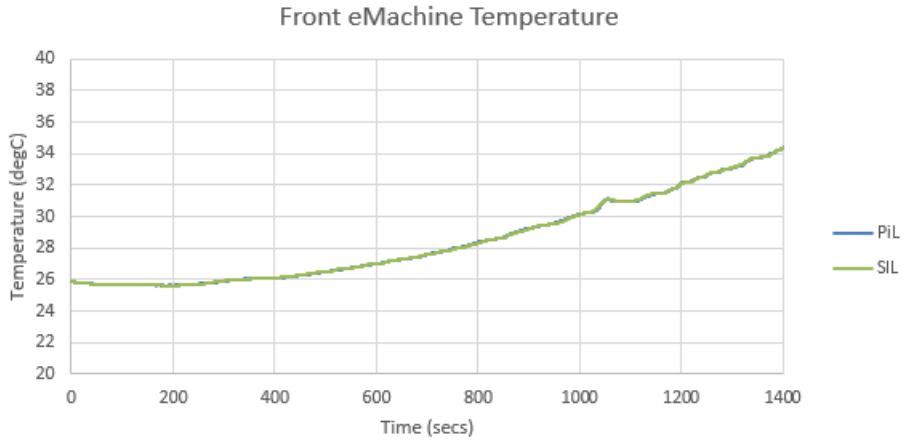
Correlation Data SIL vs PIL

SIL vs PIL Correlation – Transient Test Cycle(US Market SC03)









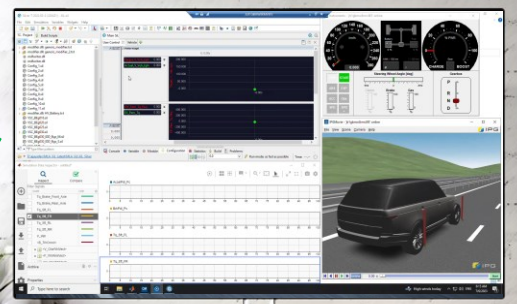
Good correlation of vehicle speed, pedal, total HV battery energy consumption, EDU torques and oil temperatures

What is Software in Loop?

What is Software-in-Loop?

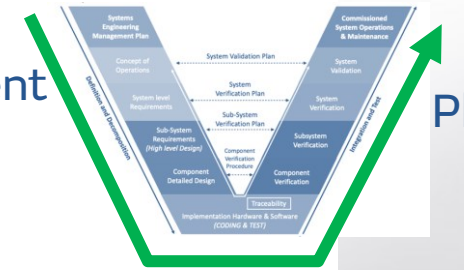
Software is in a compiled format and is part of a closed loop simulation made up of controller and plant models

System Simulation
Virtual prototypes
Digital Twin



Virtual Replicas

Design Intent



Across the System V

Physical Prototypes

Virtual ECUs

Propulsion SW

Inverter SW

Charging System SW

Virtual L3 Hardware-in-Loop Rig

Time to run a full WLTC = 1800s (real-time)

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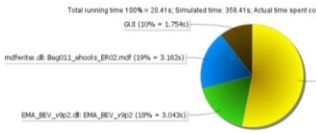
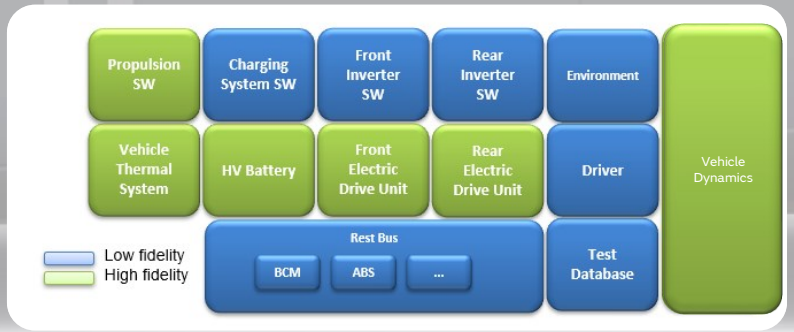
Excl. BSW, MCAL, OS, Device Drivers



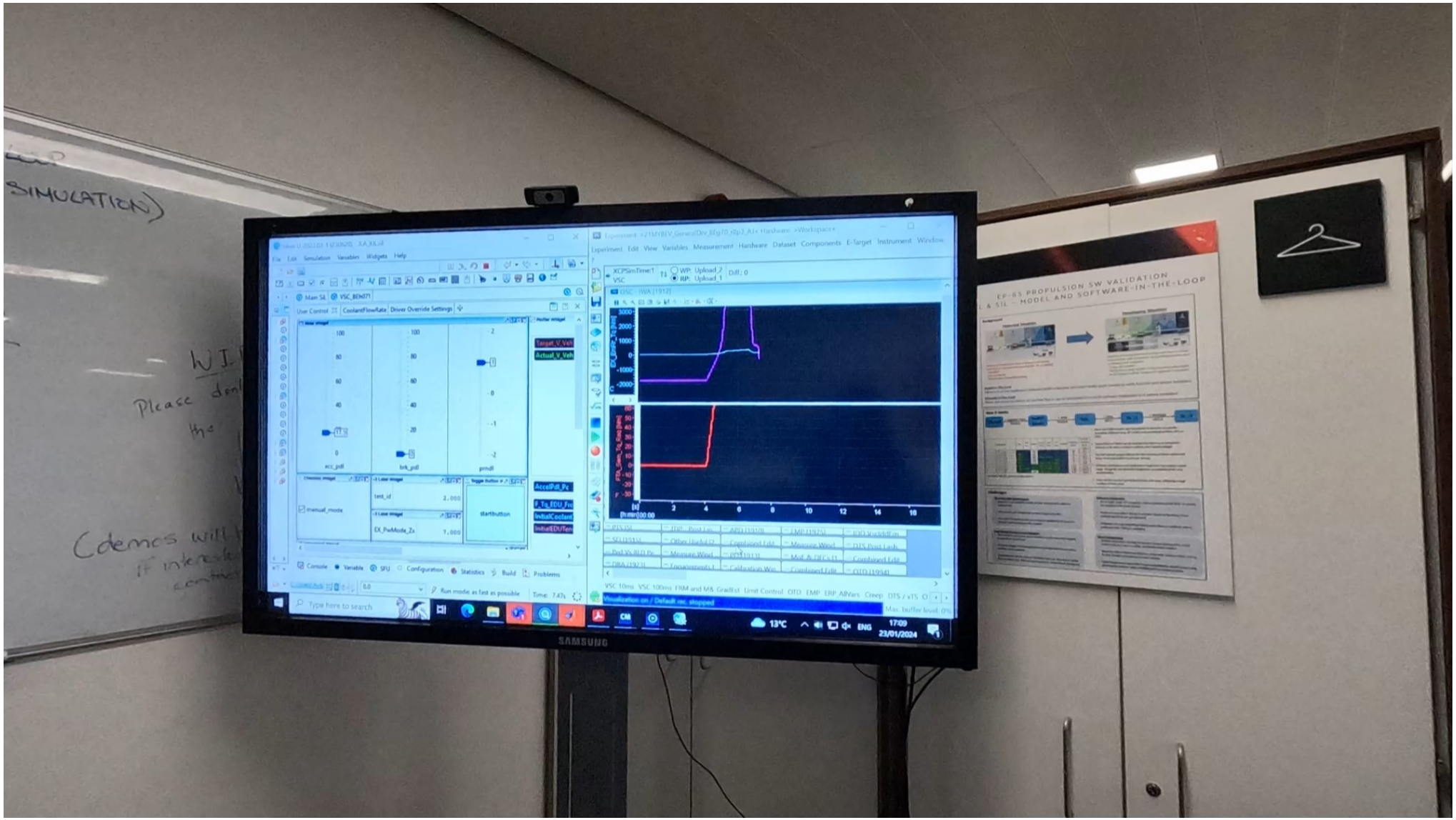
Time to run a WLTC = 72s (25x faster than real time)

Virtual Powertrain level system model



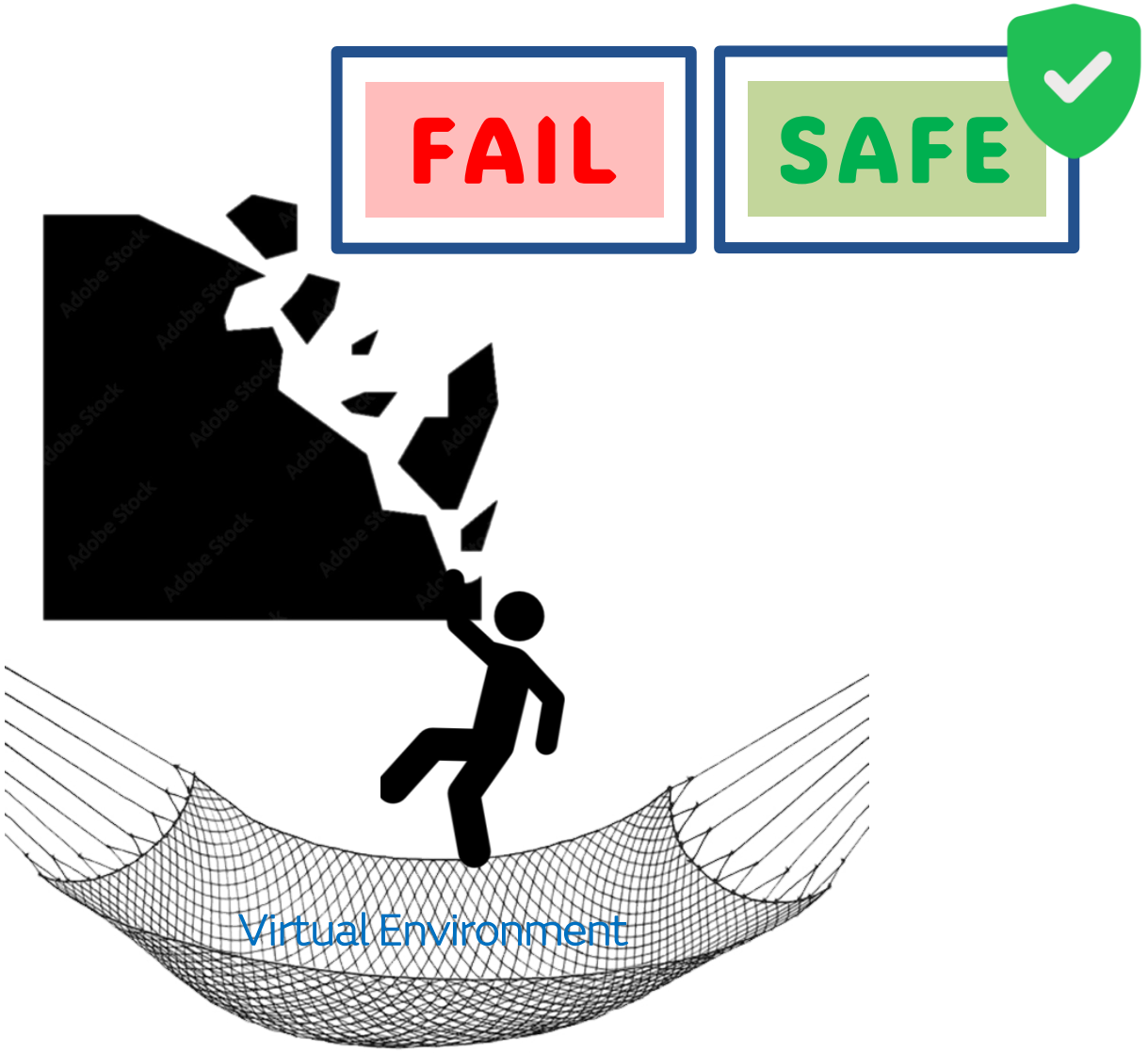
Software in Loop Use Cases

Use Case Example 1 - Static Driver in Loop Connected with a SIL Virtual Rig

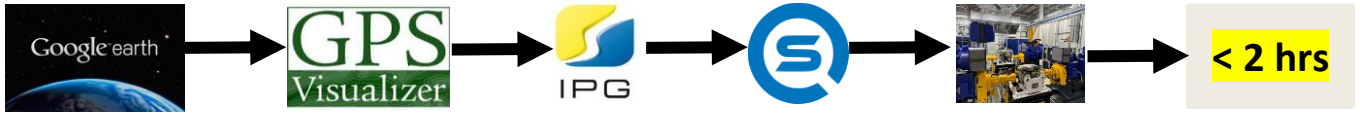


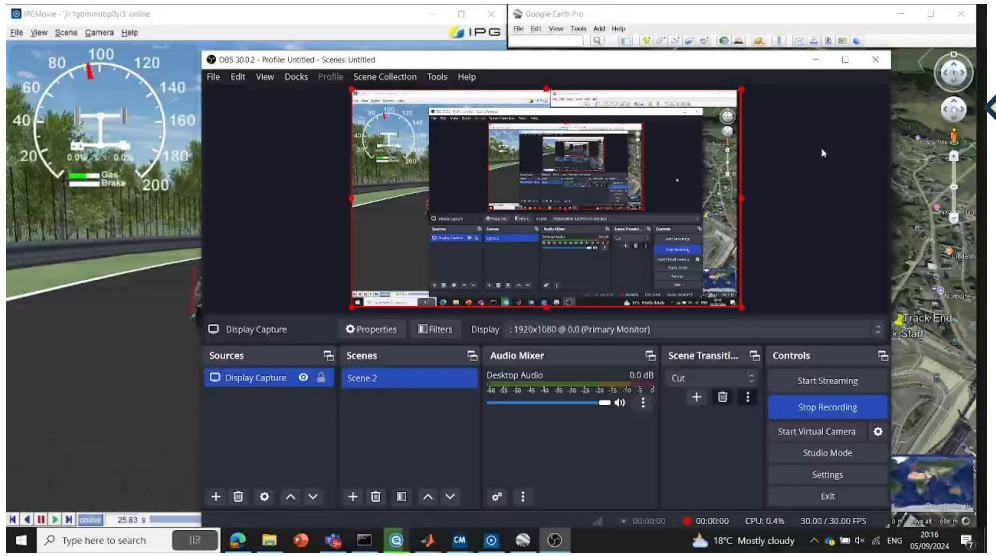
Use Case Example 1 - Static Driver in Loop Connected with a SIL Virtual Rig

- Safe environment for Fail Fast, Fix Fast
- Human element
- Fault insertion
- Identify edge cases
- Real Driving Routes
- Live Calibration
- Unified XIL toolchain (MIL >>> PIL)

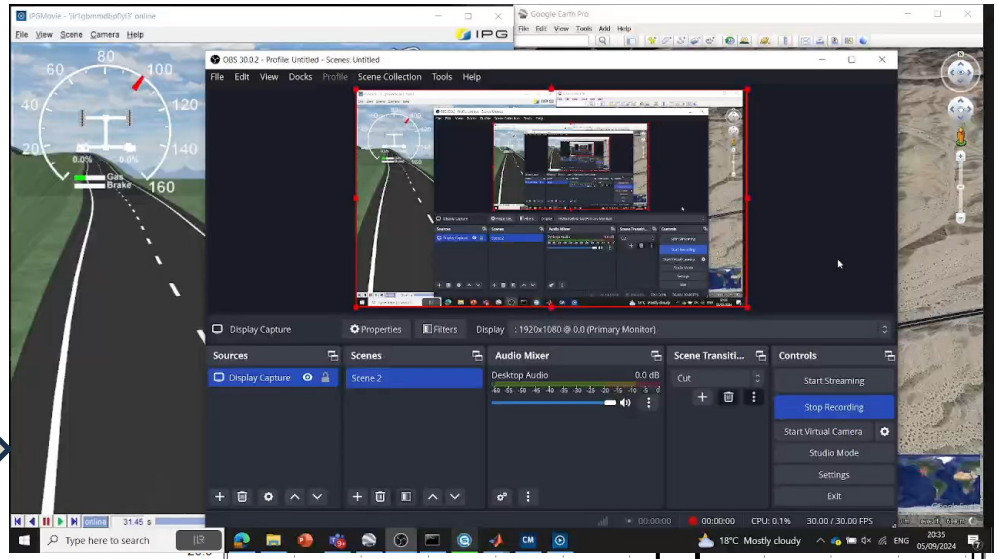


Use Case Example 2 – Vehicle attribute verification using SIL

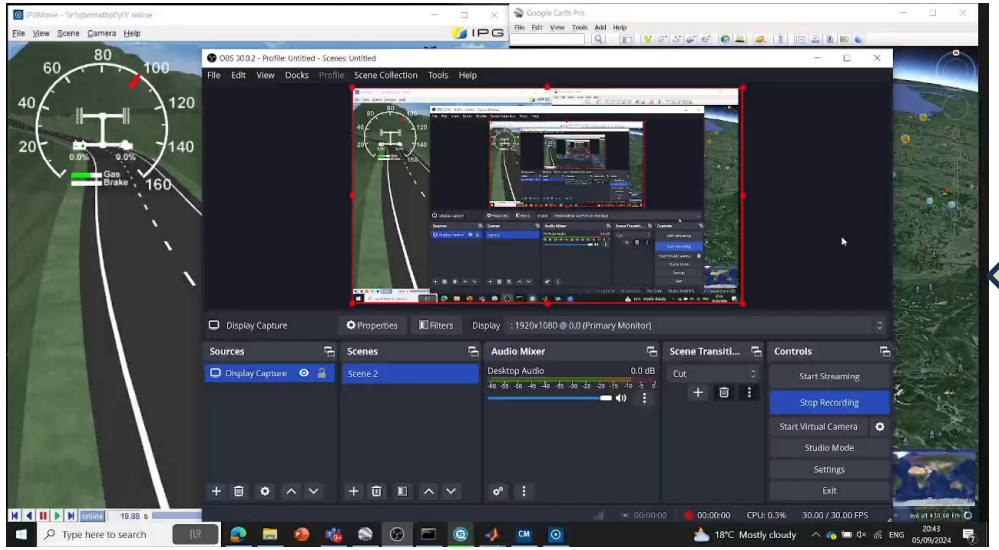




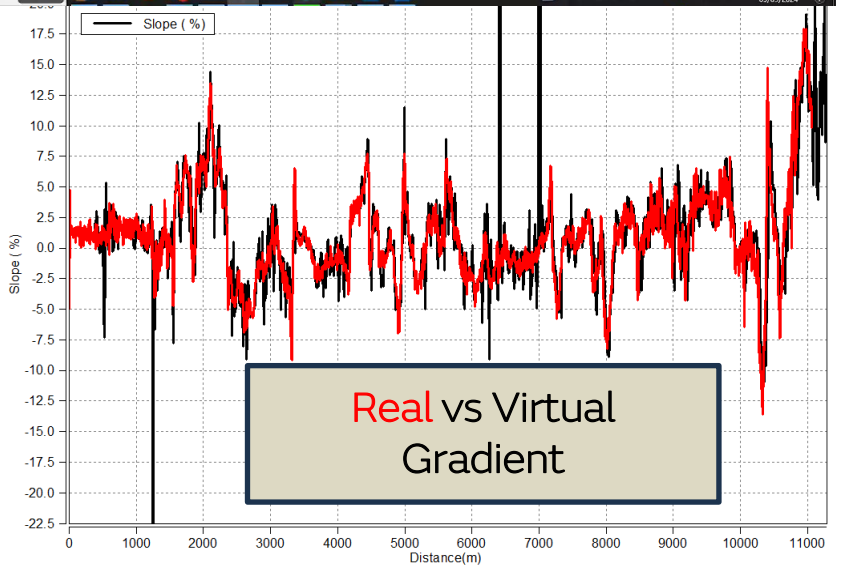
Nürburgring

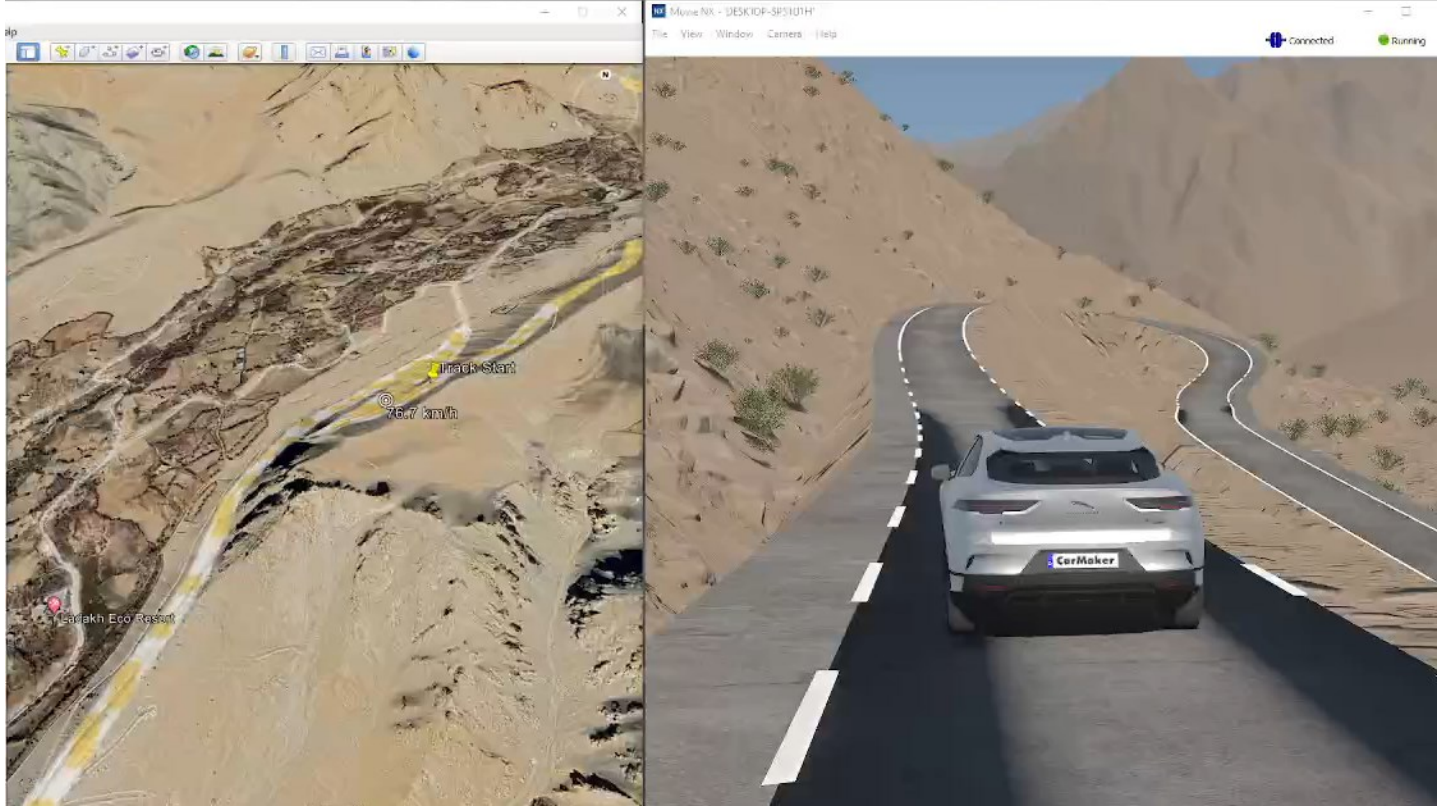


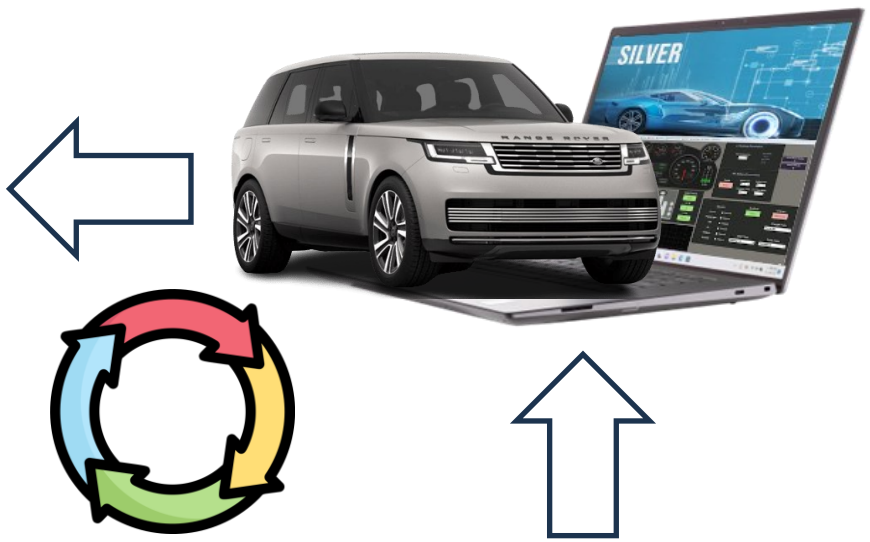
Davis Dam



Grossglockner





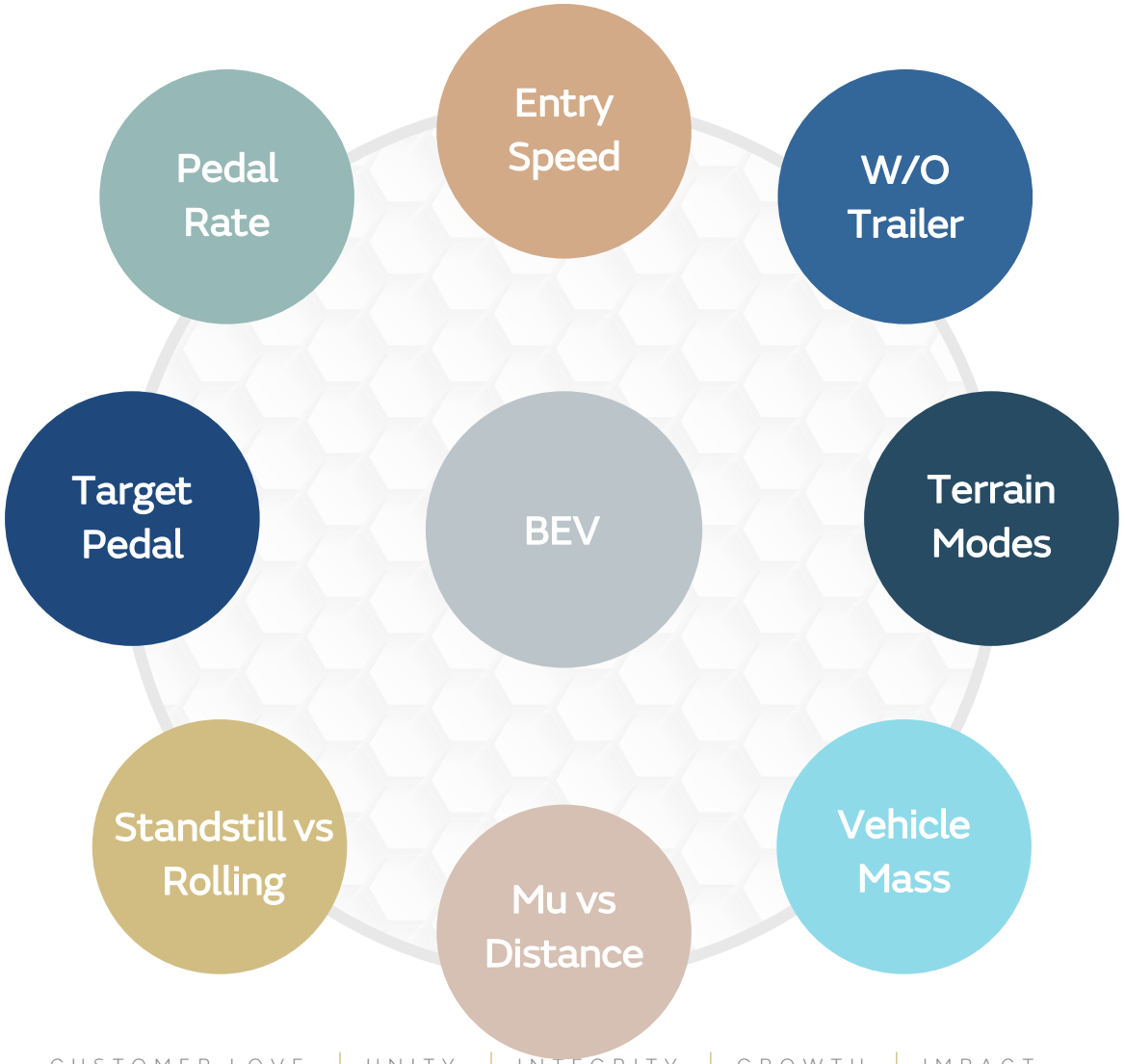


Verify & coarse calibrate sw using **SIL**

Fine tune & validate sw using **PIL**

Use Case Example 3 – Traction Launch from Standstill on Varying Road Surfaces

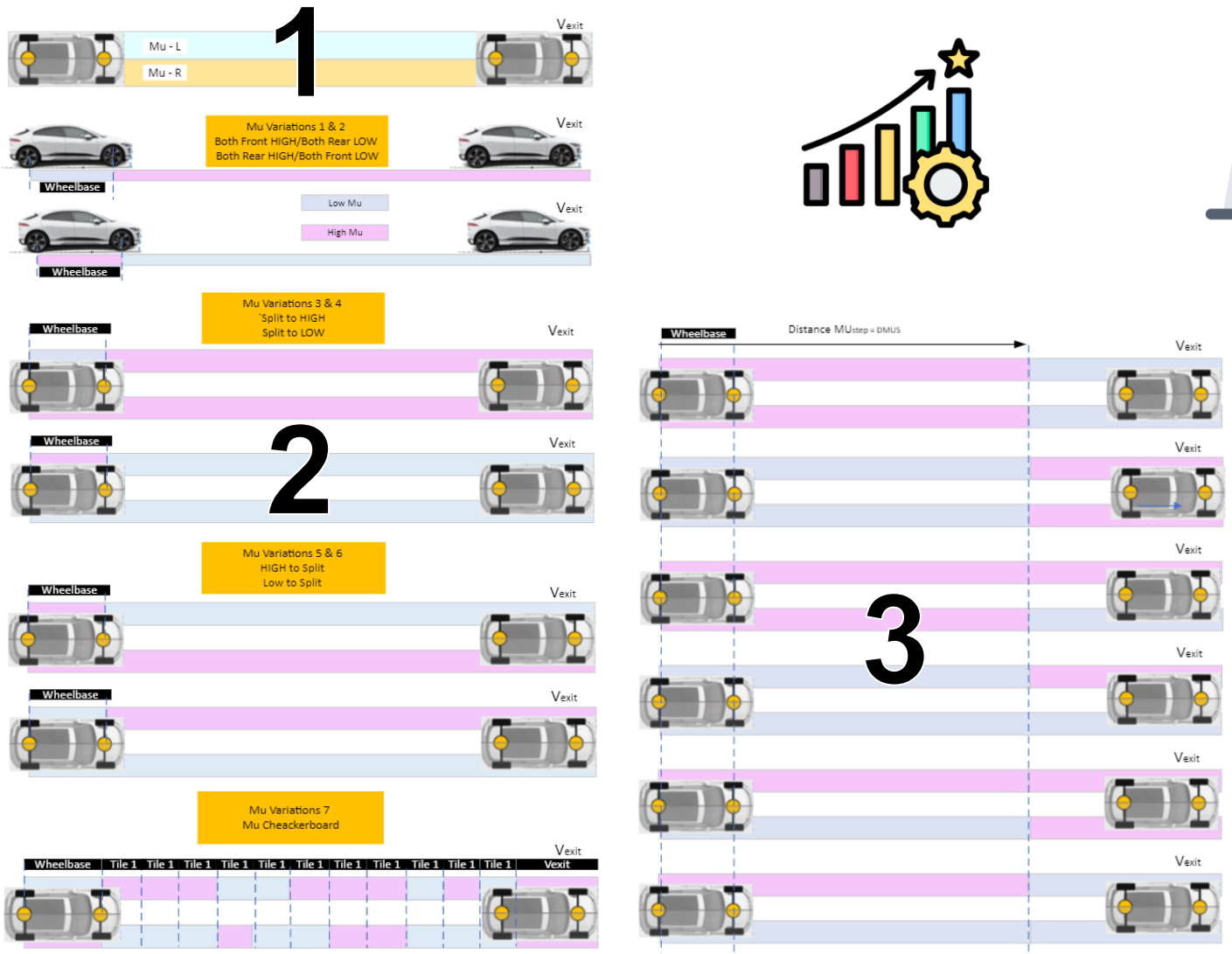
Development of BEV Traction Control Functions- Traditional Development Approach



- Typically, weeks of test time
- Constraints – environment, driver safety, driver fatigue
- Low noise factor coverage
- Testing in realtime
- Mostly – verifying software logic, software integration & course calibration activities

Use Case Example 3 – Traction Launch from Standstill on Varying Road Surfaces

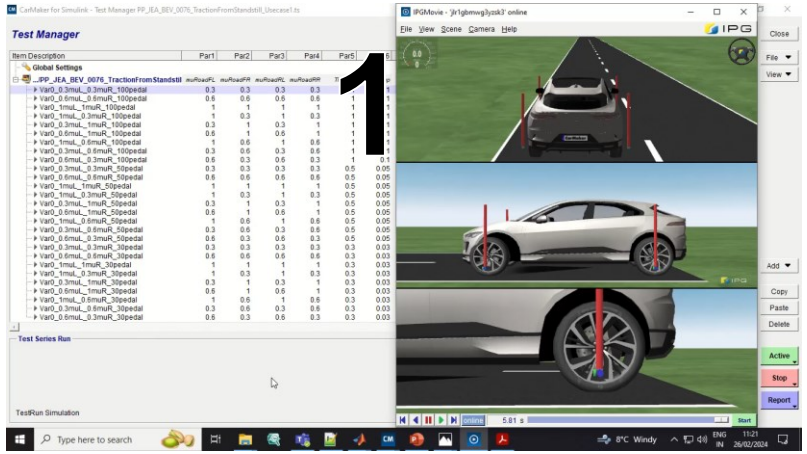
Development of BEV Traction Control Functions – Methodology

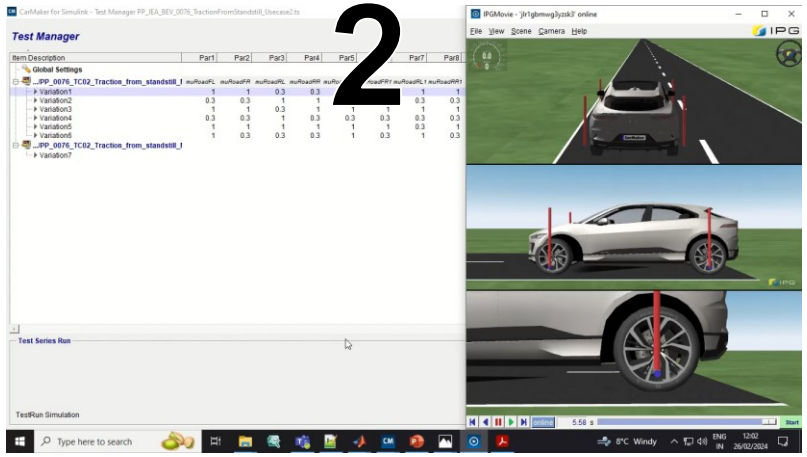


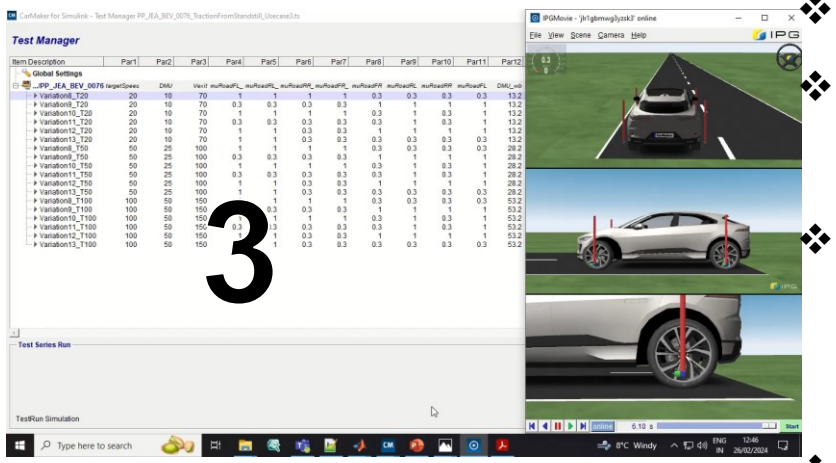
- A comprehensive DOE Methodology was created using SIL XIL Toolchain
- 6 noise factors identified
- 450+ unique noise factor combinations generated
- The DOE was executed upto **70 times faster** than realtime (3minutes of test time in total vs 3.75 hrs in real time)
- A small portion of test cases will be driven on a physical BEV rig to test robustness and fine tune the calibration content

Use Case Example 3 – Traction Launch from Standstill on Varying Road Surfaces

Development of BEV Traction Control Functions – Methodology







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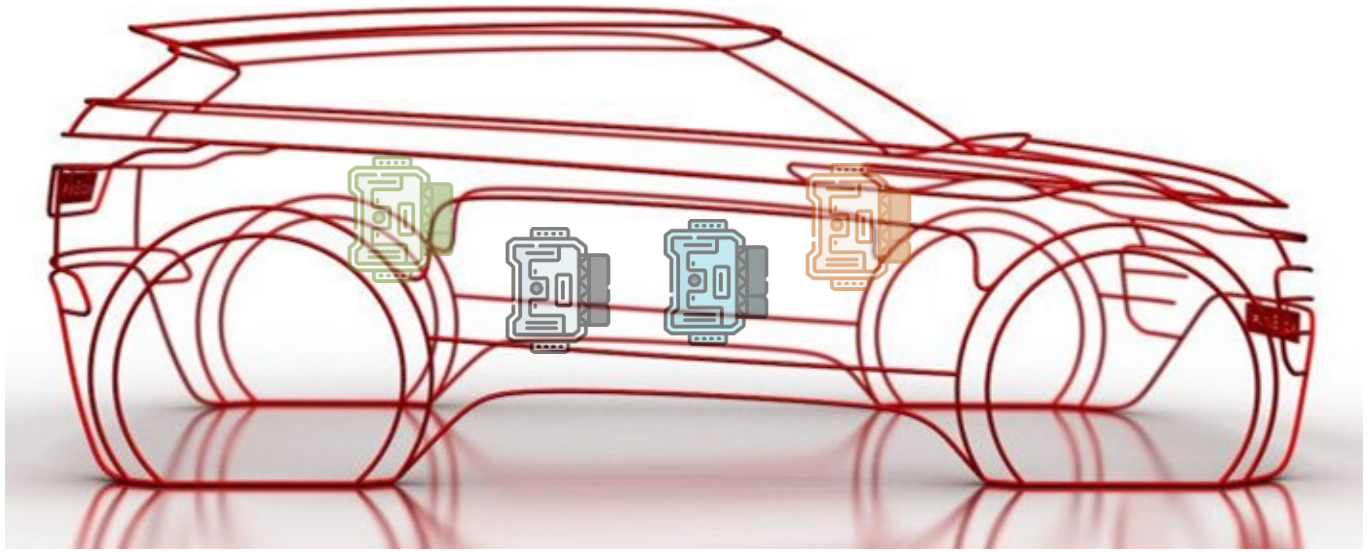
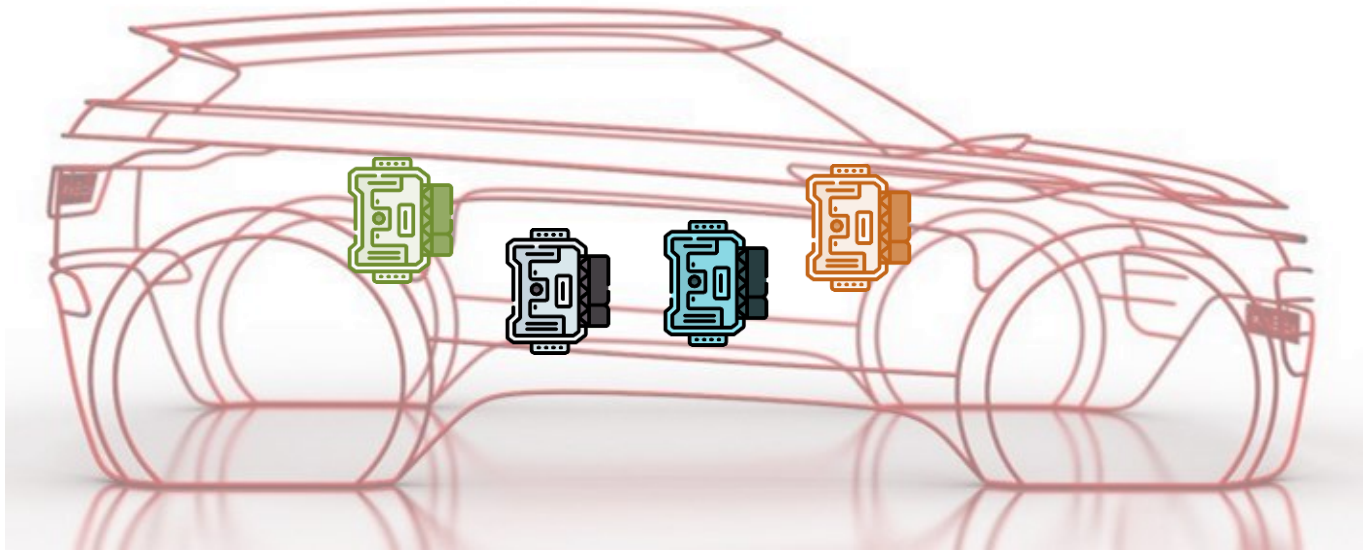
What is Hardware in Loop?

Virtual ECU



Real ECU



Introduction to Hardware-in-Loop(HIL) Capabilities

Actuators simulation

High speed simulation

Sensors simulation

HIL Simulator

Electronic Control Unit

Measuring Devices

Networks

Unified Vehicle Model

HIL is a platform to test an Electronic Control Unit(ECU) in a simulated and controlled environment

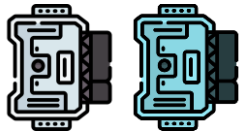
Capability to run closed loop vehicle simulation
- Software - Hardware integration level tests
- System level tests
- Baseline calibration

HiL Use Case

HIL Use Case

I would like to test features requiring interaction between Propulsion and Inverter systems

Customer



Real ECU

Propulsion HIL

Propulsion & Inverter HILs

Inverter HIL

Option 1:

2 x HILs to create a Multi-ECU HIL

Pro

Real ECUs communicate together

Cons

Hardware changes required

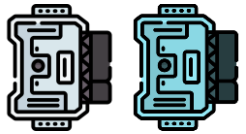
Testing paused

More cost and time

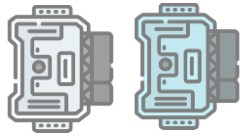
HIL Use Case

I would like to test features requiring interaction between Propulsion and Inverter systems

Customer



Real ECU



Virtual ECU

Propulsion HIL

Propulsion & Inverter HILs

Propulsion & vECU Inverter HIL

Inverter HIL

Inverter & vECU Propulsion HIL

Option 2:

Integrate the vECU on existing HIL

Pros

No Hardware changes

Utilising existing resource

Testing continues

Lower cost and time

Con

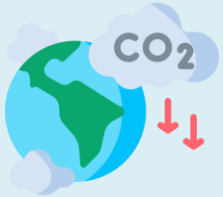
Hardware interface related issues can be missed

So What?

40% less development time

Up to 60% fewer prototype cars

£10+ billion savings



575 tonnes CO2 benefits

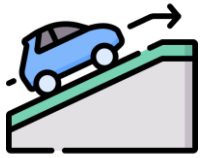
Test up to 70x faster than real time

24/7 Test Automation

Development testing equivalent to 40% of vehicle lifetime in just 14 weeks

15 tonnes less scrap

Repeatability to within 0.5%



100s of test noise factors controlled accurately

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Thank You!