SIMULATION -DRIVEN CALIBRATION OF VEHICLE CONTROL SYSTEMS FOR HIGH-PERFORMANCE VEHICLE

GCF R&D
21/05/2026

AGENDA

- Introduction
- Activity workflow
- Results
- Conclusion

INTRODUCTION

SENSIFY™

SENSIFY VIRTUAL CALIBRATION ON HIGH PERFORMANCE VEHICLE MODEL

Customer input

- Obfuscated vehicle model
- Active systems
- Tyre models (2 specs)

Brembo input

- Full virtual Sensify system

Architecture

- 4x EHA (Brembo)
- 4x BCU (Brembo)
- 1x Main VCU (OEM)
- 1x Redundant VCU (OEM)

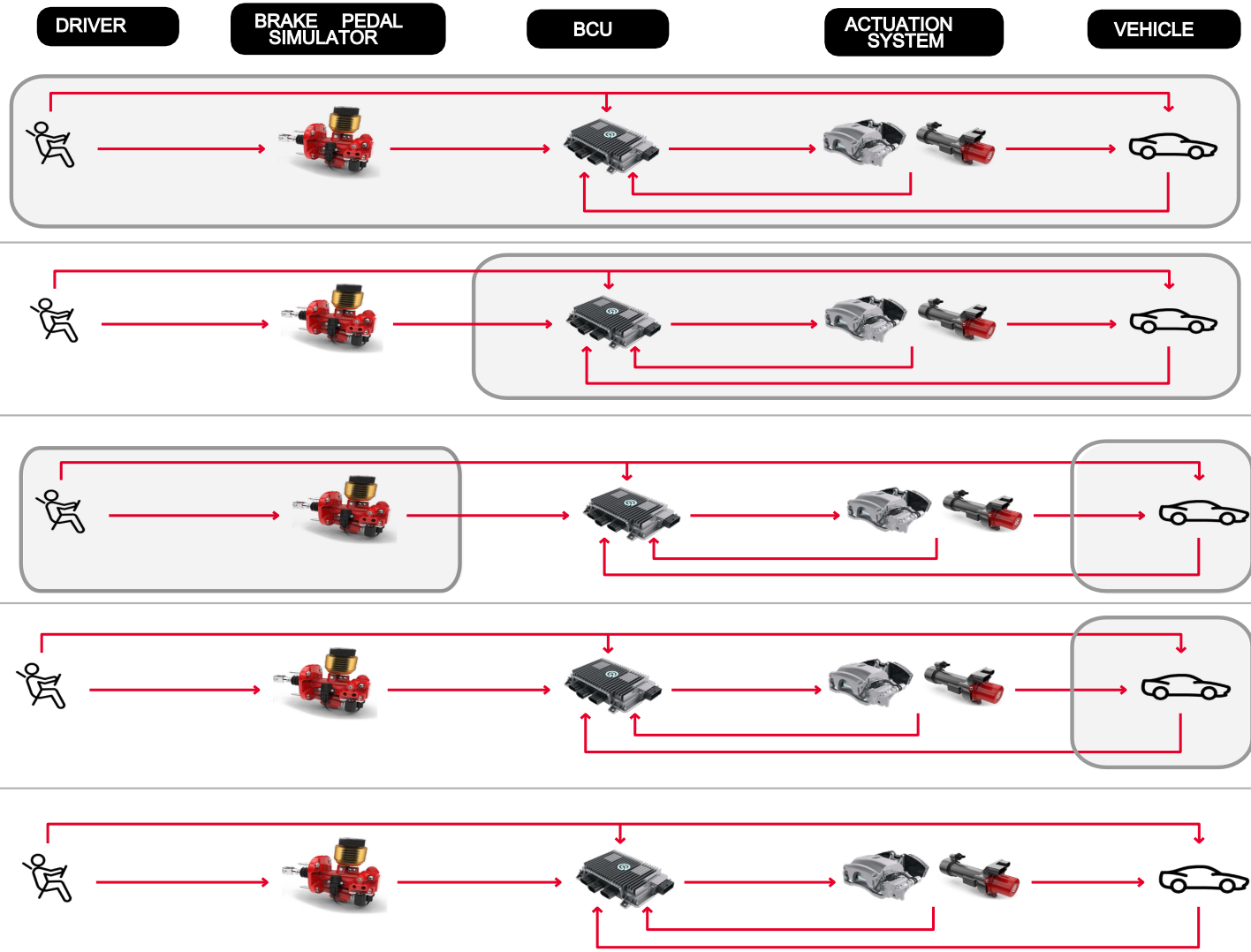
Controls

- L2 SW: Vehicle controls
- L1 SW: Corner control
- L0 SW: Actuator control

- ✓ WET Sensify architecture used in the activity to direct compare the performance with respect to the customer state of the art centralized system.
- ✓ A Sensify DRY architecture would have enhanced additional improvements at vehicle level thanks to the better actuation performance.

INTRODUCTION

VIRTUAL



MIL — MODEL IN THE LOOP

- Control functions and estimators for early stage development and precalibration

DIL — DRIVER IN THE LOOP

- Vehicle control development
- Failure analysis

HIL — HARDWARE IN THE LOOP

- System validation

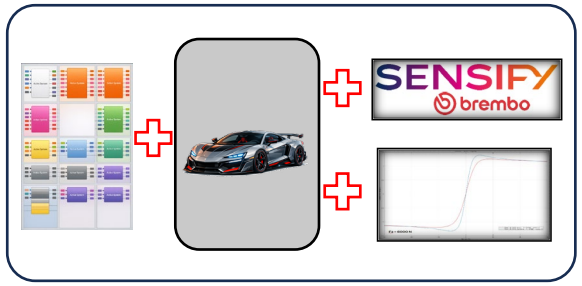
DHIL — DRIVER HARDWARE IN THE LOOP

- Vehicle control calibration
- Failure analysis

VEHICLE

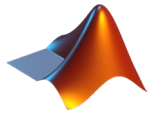
- Vehicle control fine tuning
- Final validation

WORKFLOW



MiL platform

VI-GRADE



DiL (Static) platform

concurrent REAL-TIME

DiL (Dynamic) platform

concurrent REAL-TIME

1. **Environment setup :**
   - Vehicle model and OE active systems integration on Brembo MIL and DIL platforms with Sensify.
   - Manoeuvres generation.

2. **ABS/EBD/ESC tuning with two different tyre specs:**
   - Scenario: longitudinal, lateral, combined dedicated manoeuvres .
   - KPI evaluation .
   - Comparison with experimental results .

3. **ABS/EBD/ESC fine tuning on Brembo static simulator :**
   - Scenario: Brembo custom scenario .
   - Driver subjective evaluation .

4. **Final test on customer simulator :**
   - Scenario: Customer Reference track .
   - Customer driver subjective evaluation .

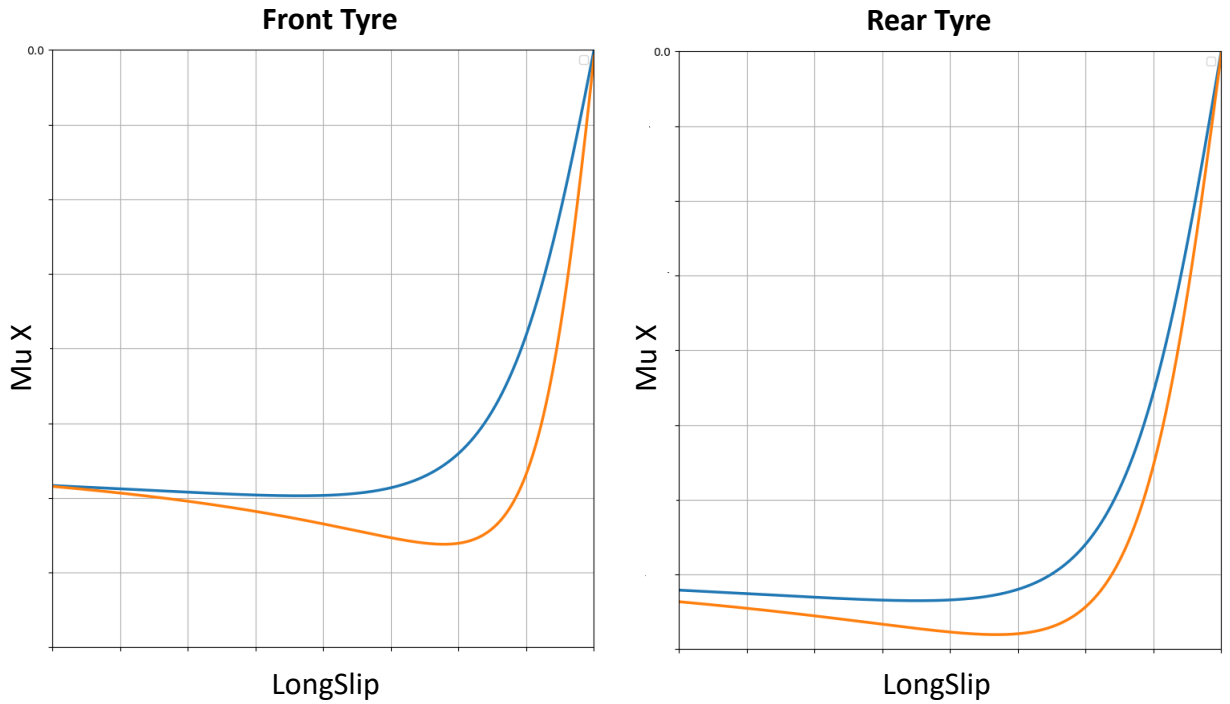
MIL MANOEUVRES

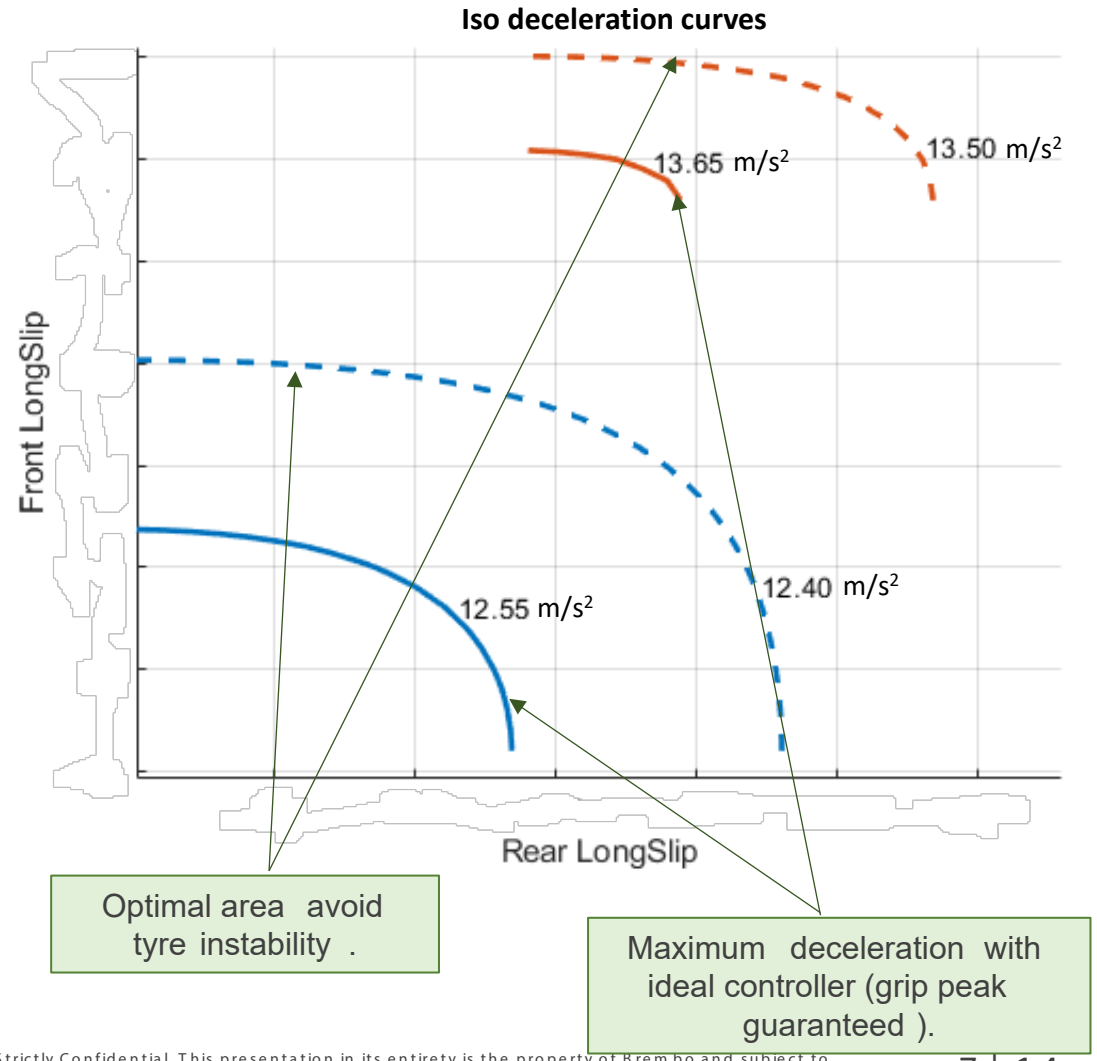
Cluster	Maneuver	Adherence	Calibrated function
Longitudinal	ABS straight line 200 - 0 km/h	DRY	ABS/EBD
	ABS straight line 100 - 0 km/h	DRY	ABS/EBD
	ABS straight line 100 - 0 km/h	WET	ABS/EBD
	Jump ABS 100 - 0 km/h	DRY / WET	ABS/EBD
	Split ABS 100 - 0 km/h	DRY / WET	ABS/EBD
	Jump - Split ABS 100 - 0 km/h	DRY / WET	ABS/EBD
Lateral	Sine with dwell 80 km/h, 128°	DRY	ESC
	DLC 110 km/h	DRY	ESC
Combined	Cornering (Ay= 0.4g) ABS 80-0 km/h	DRY	ABS/EBD/ESC
	DLC - Partial brake 110 km/h	DRY	ABS/EBD/ESC
	DLC - ABS 110 km/h	DRY	ABS/EBD/ESC

- Specific maneuvers for the calibration of each control function has been defined and shared with the customer, following a process equivalent to the one adopted by real vehicle testing.
- Virtual environment enables a quick calibration check through different tyre spec. with high repeatability .

TYRE MODELS

PRE CALIBRATION ANALYSIS ON TWO DIFFERENT TYRE SPECS

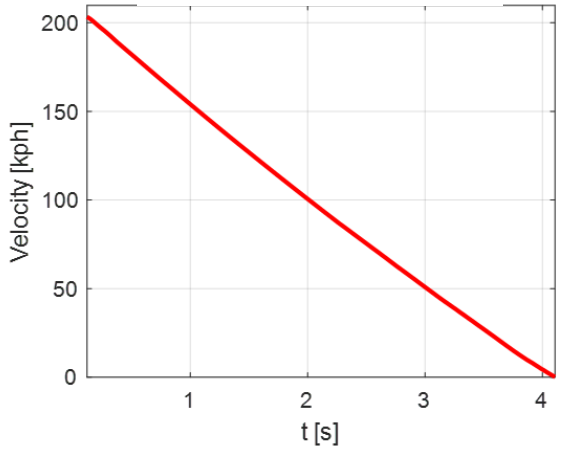




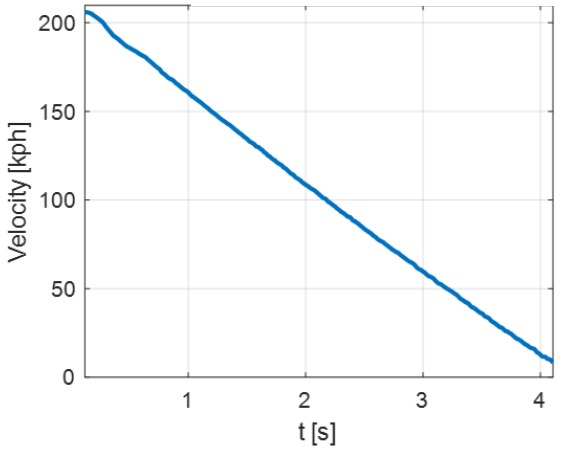
ABS/EBD CALIBRATION: MIL

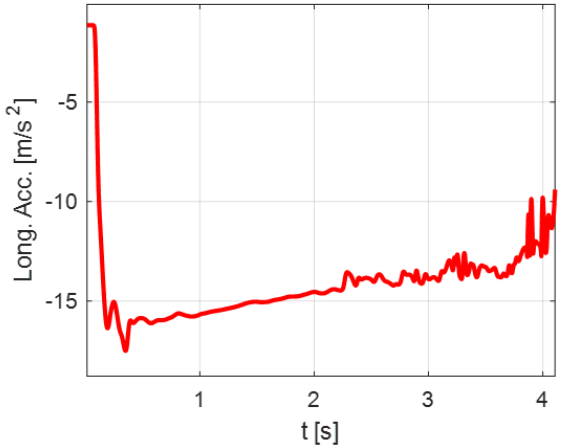
HIGH ADHERENCE – SPIKE ABS 200 -0 KPH

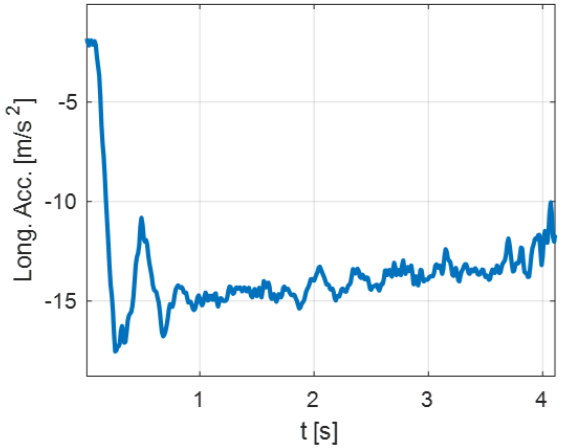
Sensify – MIL simulation



OE – Vehicle test





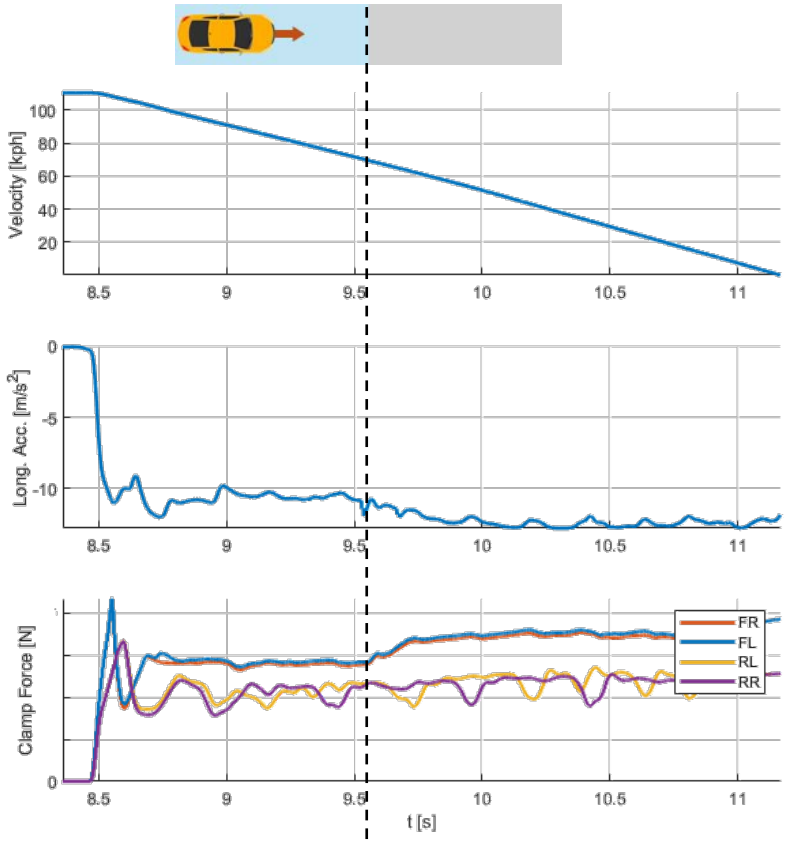


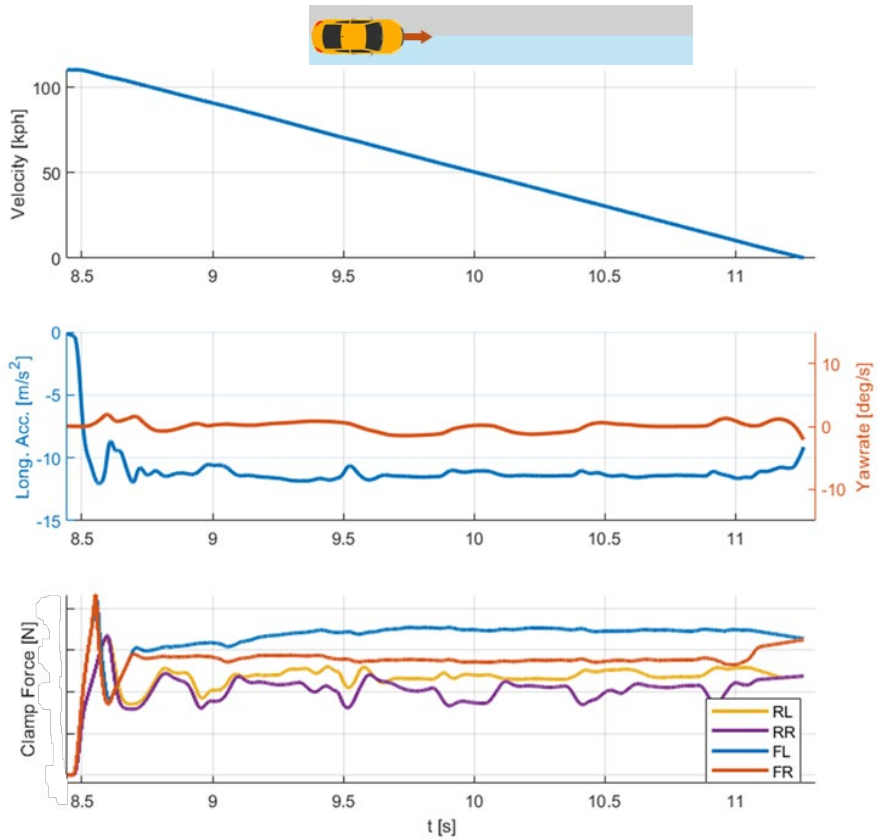
Braking system	Sensify	OE
MFDD [m/s^2]	14.4	14.0
Stopping Dist [m]	103.8	107.5
Efficiency [%]	96.5	94.2

Better braking performances ensuring a higher brake comfort

ABS/EBD CALIBRATION: MIL

DRY - WET ADHERENCE SPLIT/JUMP

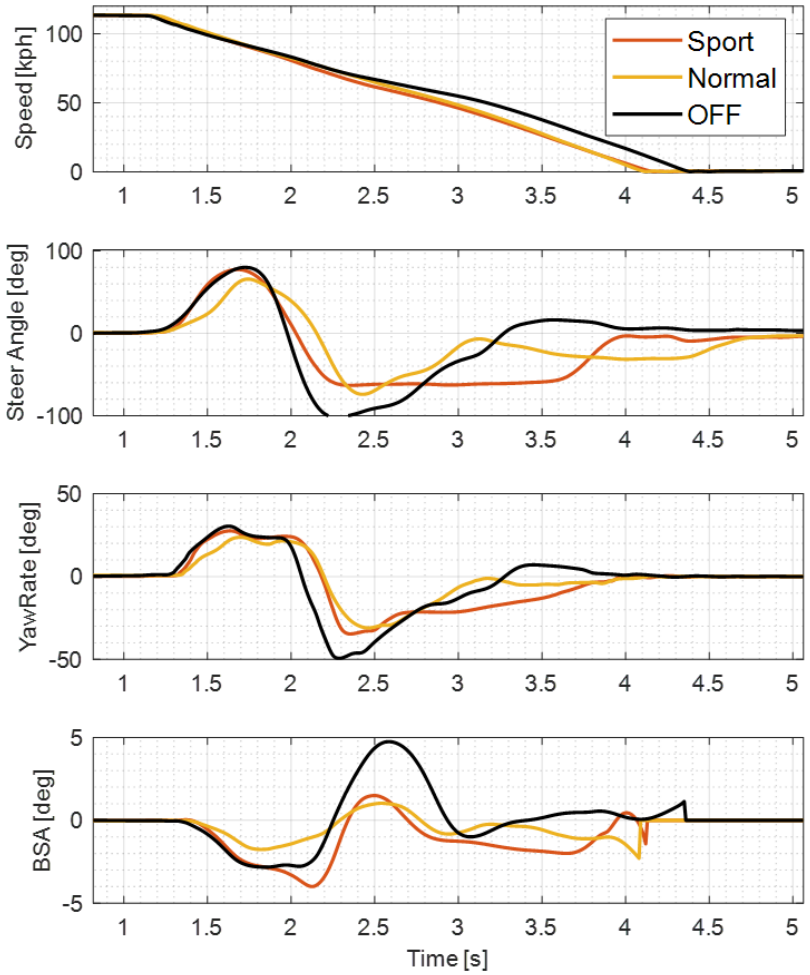




- The ABS calibration has been optimized to ensure an optimal trade -off between performance and stability during wet-to-dry jump transitions and in split -μ conditions

ESC CALIBRATION: DIL

DIL FINE TUNING AND DRIVING MODE SETUP

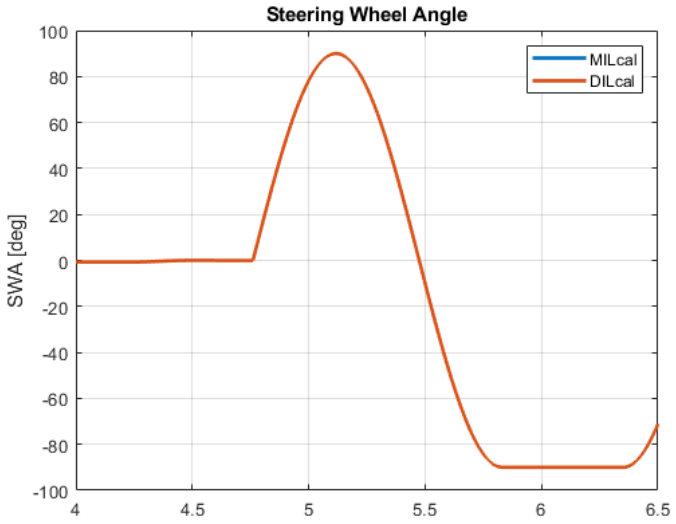


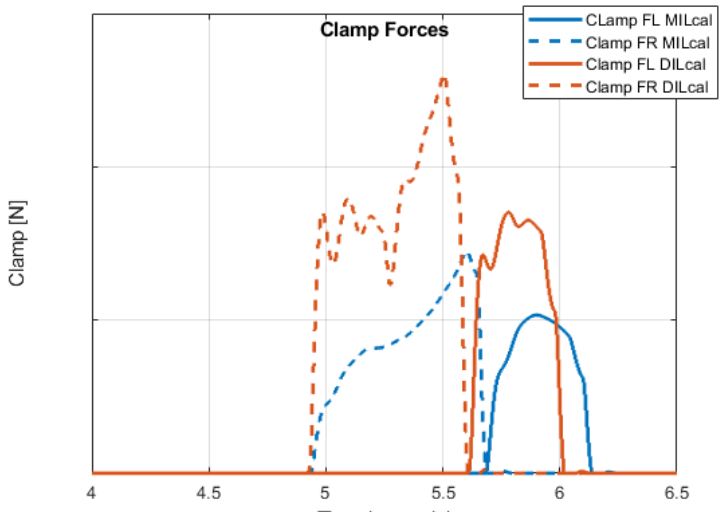
Brembo static driving simulator sessions has been used for collecting the real skilled driver perception on 3 different calibrations setup and for proposing a fine tuning:

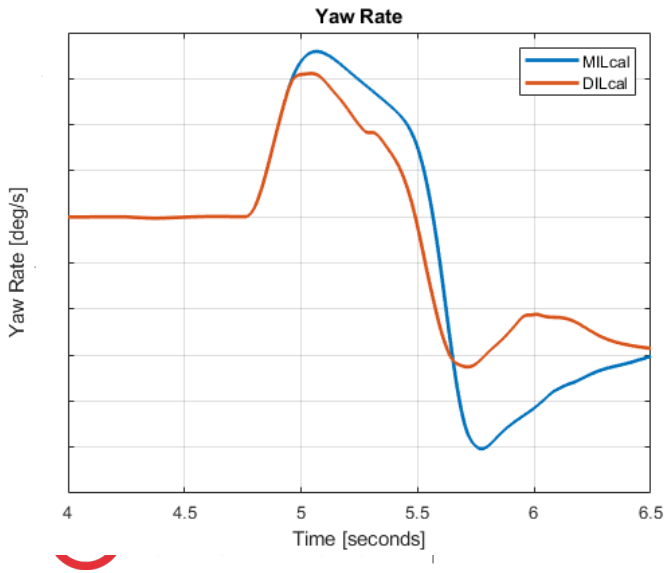
- **Off**: maximum driver correction is required, with higher peaks in yaw rate and BSAA.
- **Sport**: the system applies minimal corrections, only to ensure vehicle stability.
- **Normal**: driver interventions are minimized in both peak and duration over time, while yaw rate and BSA peaks are reduced.

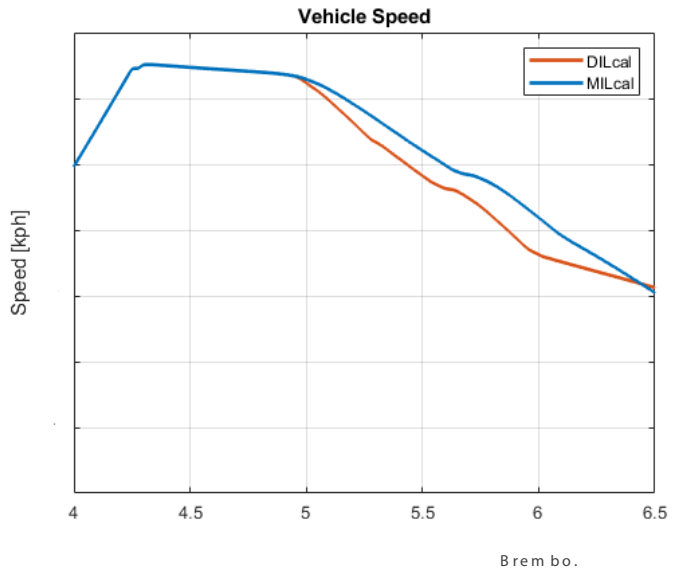
ESC CALIBRATION: DIL

SINE WITH D -WELL 90 °









- The introduction of drivers' feedback through DIL environment enabled further optimization compared to the initial MIL - based calibration.
- Higher stability has been achieved (lower body side YawRate without performance drop

Brembo.

FINAL TEST: DIL

Brake & controls:

- CRT
- Sensify

ESC calibrations :

- Normal
- Sport
- Comfort
- (ESC OFF)

Customer DIL environment lap time session

Main goal:

- Subjective evaluation of Sensify in virtual environment
- Real time fine tuning based on customer driver's feedback
- Calibration robustness with different tyre specs tests

Main Outcomes :

- The dynamic driving simulator allows an higher perception of the vehicle transient behavior during the control logic interven tio n
- ABS / EBD matches driver's requests for brake pedal feeling and intervention during longitudinal and lateral maneuver
- ESC ensures vehicle stability. For a track driving optimized configuration, a more sport -oriented calibration could be fine -tune d

CONCLUSIONS

- The high level of shareability of Sensify models and the vehicle model enabled a smooth transition across Brembo simulation platforms, up to the customer's simulation environment.
- Virtual development flow enables Sensify calibration allowing real -time tuning of all control functions based on the driver's input without the need of a real vehicle
- A virtual calibration of Sensify system has shown better performance and comfort if compared to OE real vehicle state of the art
- The customer's simulator session highlighted that Sensify control are effective in ensuring vehicle stability. Further calibration development could be done for an optimal match with the customer super sport DNA

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THANK
YOU