A MULTIPHYSICS APPROACH IN REAL-TIME SIMULATIONS FOR THE ENHANCEMENT OF THE VEHICLE AND TIRES CONJUNCT DEVELOPMENT

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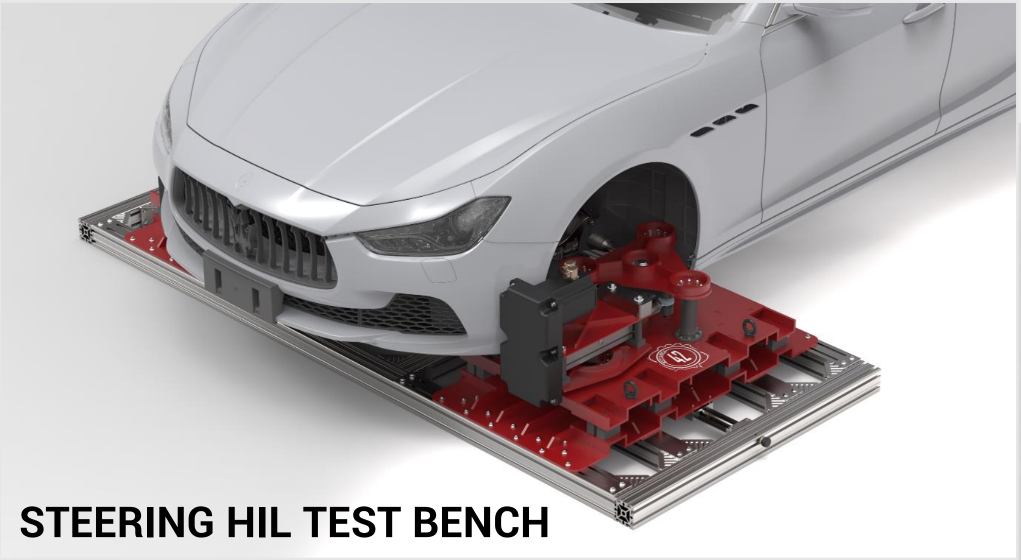
Maserati Innovation Lab:
Virtual Vehicle Dynamics Approach

Maserati Innovation Lab:
- Dynamic Simulator DiM 250
- Static Simulator
- Compact HMI Simulator

Maserati Innovation Lab: Virtual Vehicle Dynamics Approach

Main Activities:

- Handling & Comfort
- Tires Development
- HiLs for Active Systems Calibration and Fault Injection
- Brake Performance and Pedal Feel
- Advanced HiL: DiM Connection with Physical Dyno Test Bench

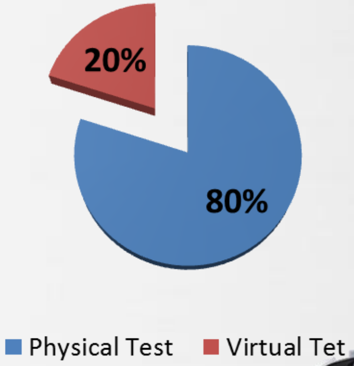


STEERING HIL TEST BENCH

Maserati Innovation Lab:
Virtual Vehicle Dynamics Approach

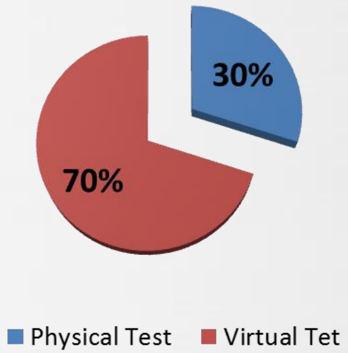
OLD APPROACH

3 - 3 ½ Years



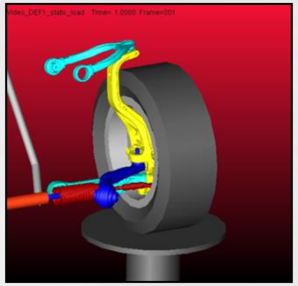
NEW APPROACH

2 Years

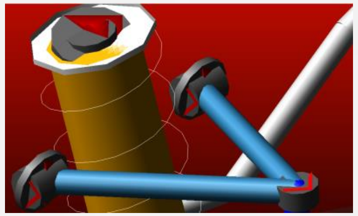


Maserati Innovation Lab:
Vehicle Dynamics Virtual Development

- Suspension Setup



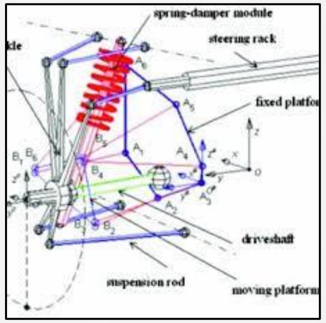
Hardpoints/Stiffness Variation



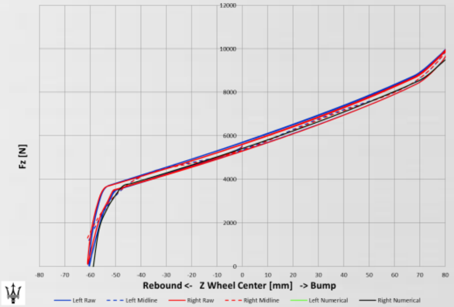
Impact on KnC Performance

Driver Feedback

- Primary Ride (Spring/Dampers and ARB)

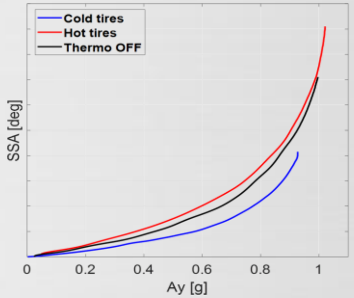


Impact on KnC Performance

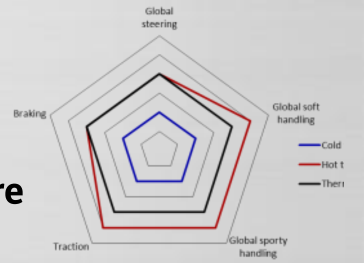


- Tires Development

Impact on Handling Performances

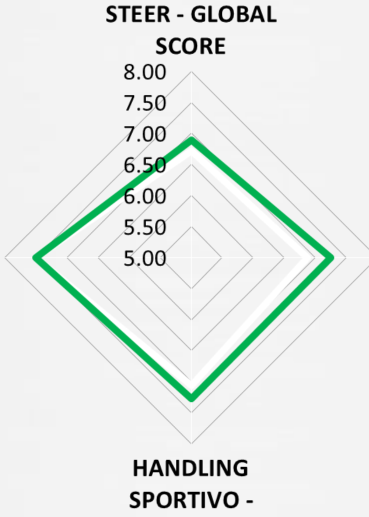


Score



Maserati & MegaRide – the technical synergy

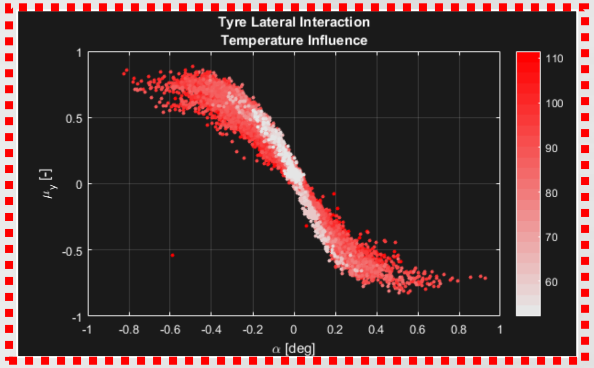
Vehicle Target Setting Definition

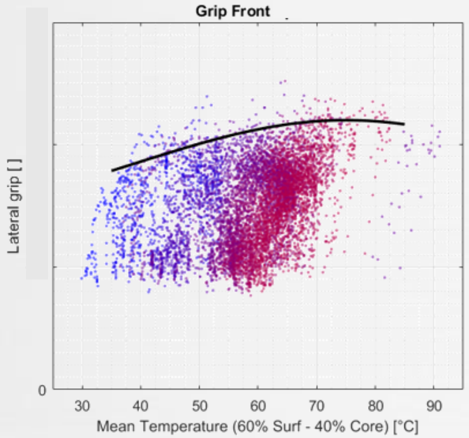


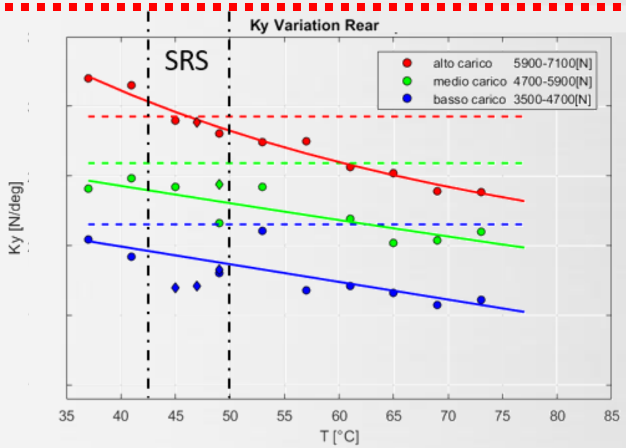
Target Deployment on Tire Performances

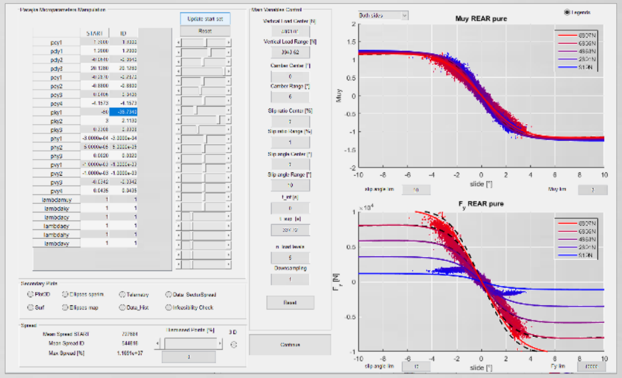
Identification of VD Performances Affected by Tire:

- Linear Handling
- Sporty Handling
- Wear & Degradation
- Thermal Effects
- ...









Maserati & MegaRide – the technical synergy

MEGARIDE
APPLIED VEHICLE RESEARCH

an official

Università degli Studi di Napoli Federico II

spinoff company

COMPANY HIGHLIGHTS

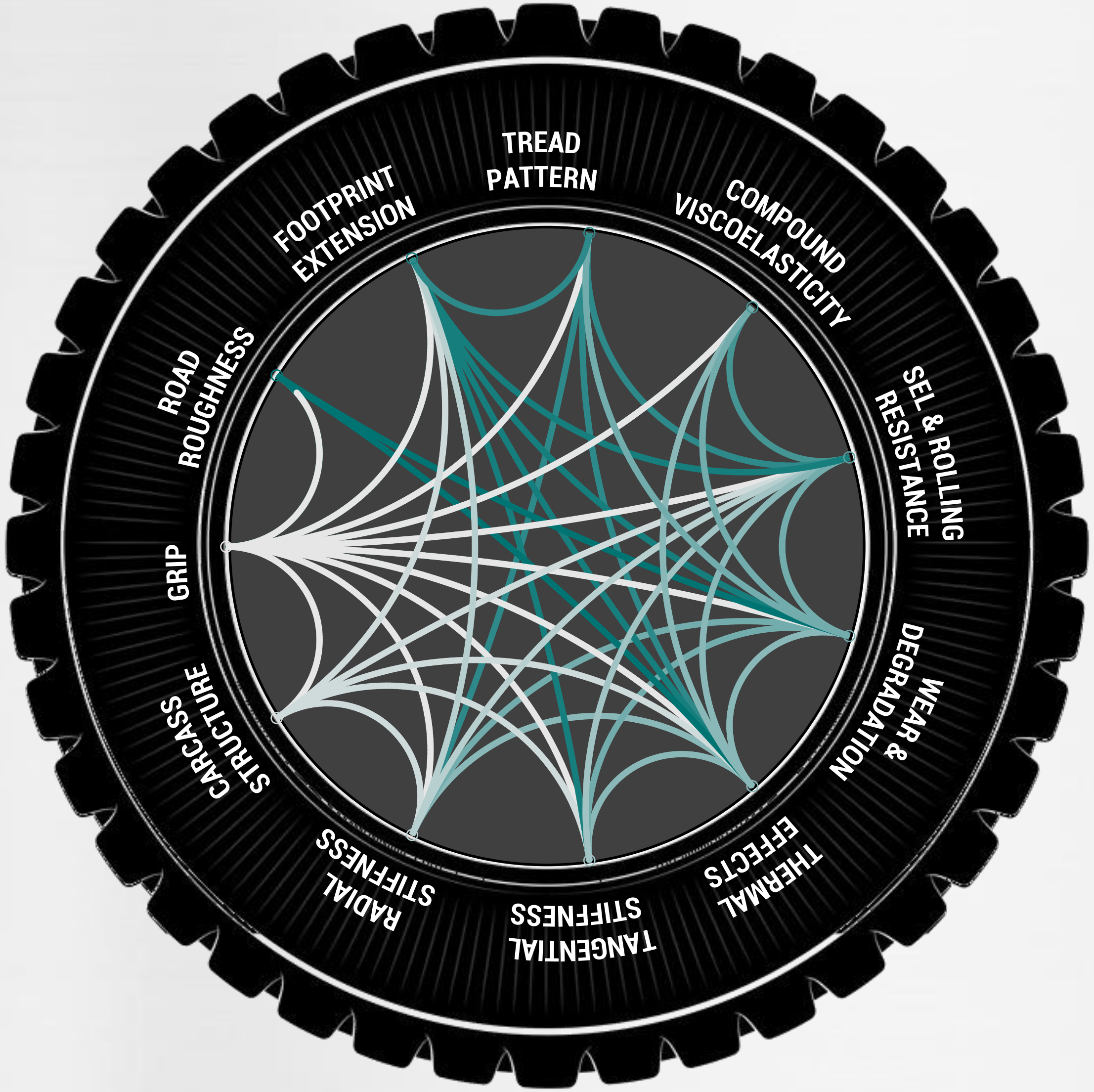
- "TIRE TECHNOLOGY OF THE YEAR" @ TIRE TECHNOLOGY EXPO 2018
- "DEVELOPMENT TOOL OF THE YEAR" @ VEHICLE DYNAMICS INTERNATIONAL AWARDS 2019
- GROWING TEAM (x4) AND REVENUES (x10) IN 3 YEARS WITH NO DEBT / NO EQUITY

Maserati & MegaRide – the technical synergy

COOPERATION HIGHLIGHTS

- RESEARCH PROJECT AND PhD ACTIVE SINCE 2018
- "FIRST CONTACT" AT MASERATI LIVE INNOVATION STARTUP PROGRAM
- SUPPORT OF "TYRE LAB" UNIVERSITY FACILITY FOR EXPERIMENTAL ACTIVITIES

Technological Overview

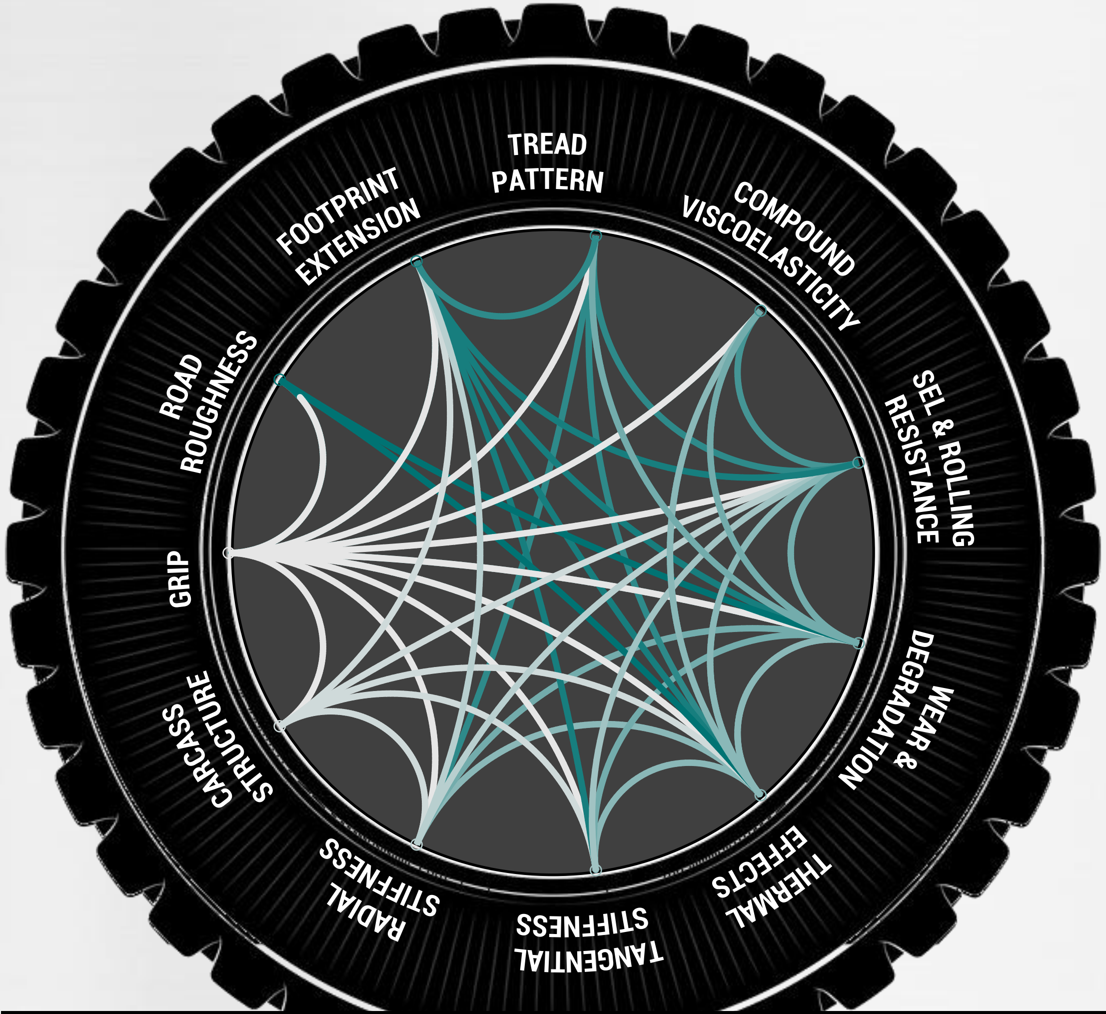


"For every complex problem there is a solution that is clear, simple, and wrong"

H. L. Mencken

TIRES AND VEHICLE DYNAMICS NEED TO BE ANALYSED AND MODELLED ACCOUNTING FOR THE MUTUALLY INTERACTING PHYSICAL PHENOMENA ARISING AT ROAD CONTACT

Technological Overview

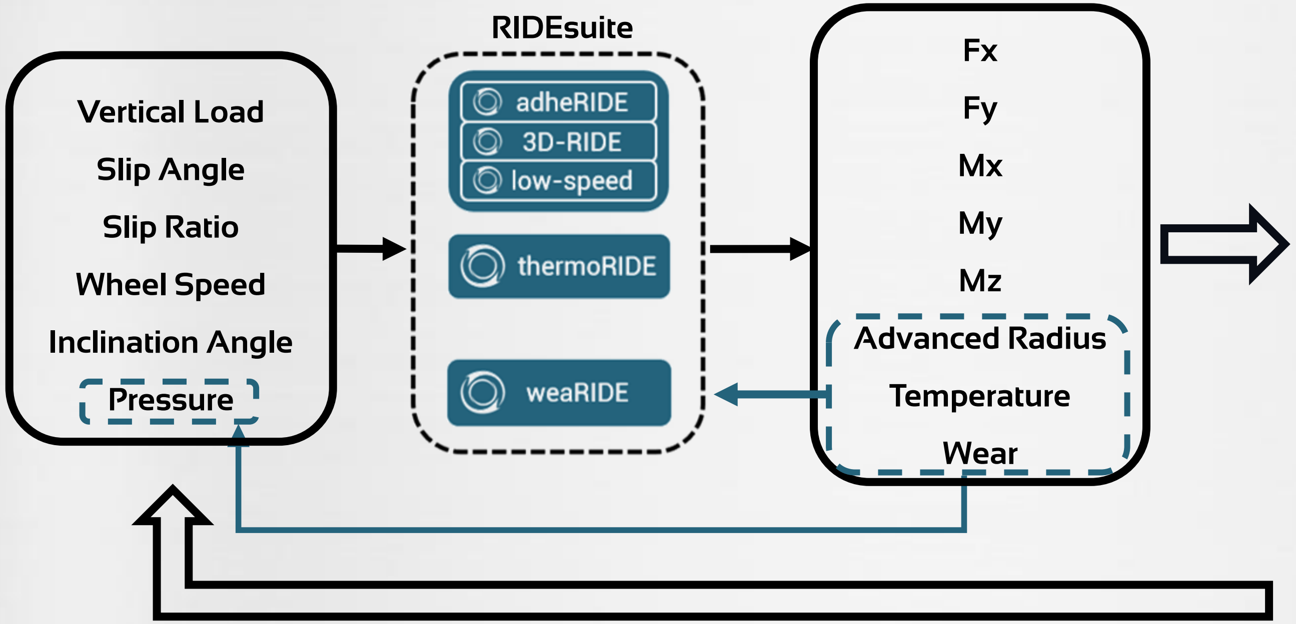


RIDEsuite Tire Sim Platform

DiM 250 @ Maserati Innovation Lab

Technological Overview

RIDEsuite: a modular multiphysical platform
for a holistic view of tires behavior



DiM 250 @ Maserati Innovation Lab

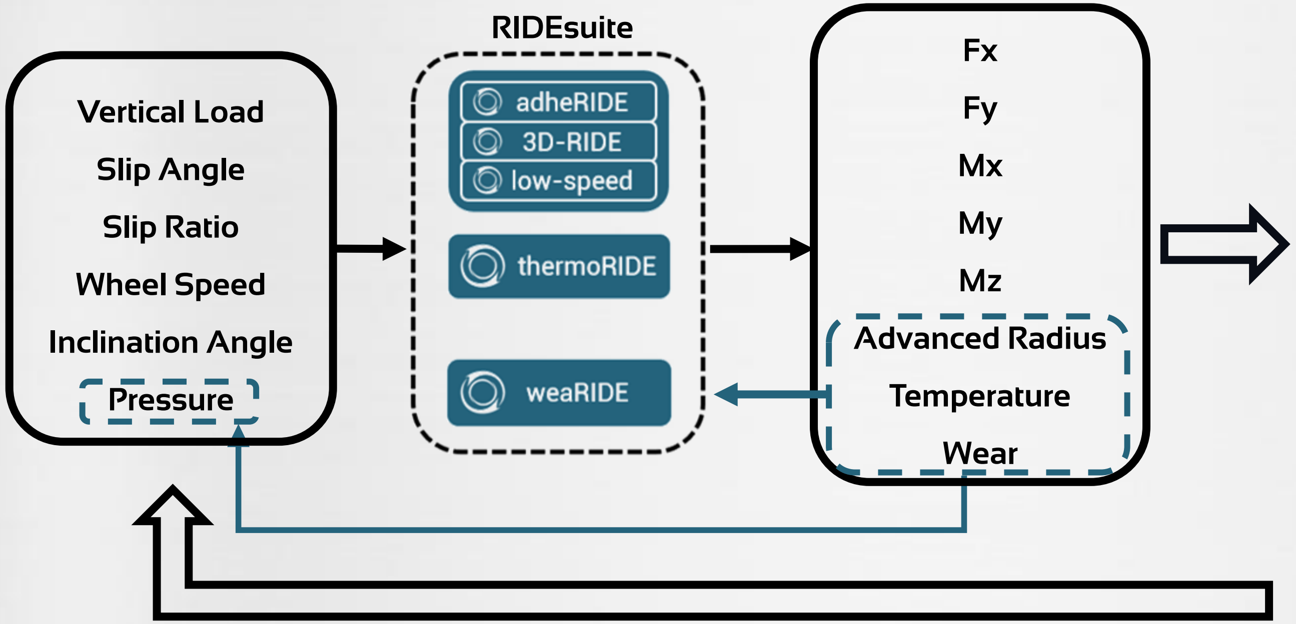
Technological Overview

adheRIDE advanced Pacejka's MF model

physical wear and degradation model **weaRIDE**

thermoRIDE energy-based local thermal model

multi-point footprint contact model **threedeeRIDE**



*** each model can work:

- as a desktop offline tool
- inside MaxPerformance logics
- as a realtime solution in DiL sessions

DiM 250 @ Maserati Innovation Lab

Target and Roadmap of the Project

PARAMETERIZATION OF THE TARGET VEHICLE

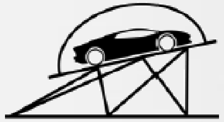
TIRES TESTING AT UNINA TIRE LAB

OUTDOOR TESTING SESSION

PHYSICAL MODELS CALIBRATION

thermoRIDE / adheRIDE / threedeeRIDE IMPLEMENTATION

@ MASERATI INNOVATION LAB

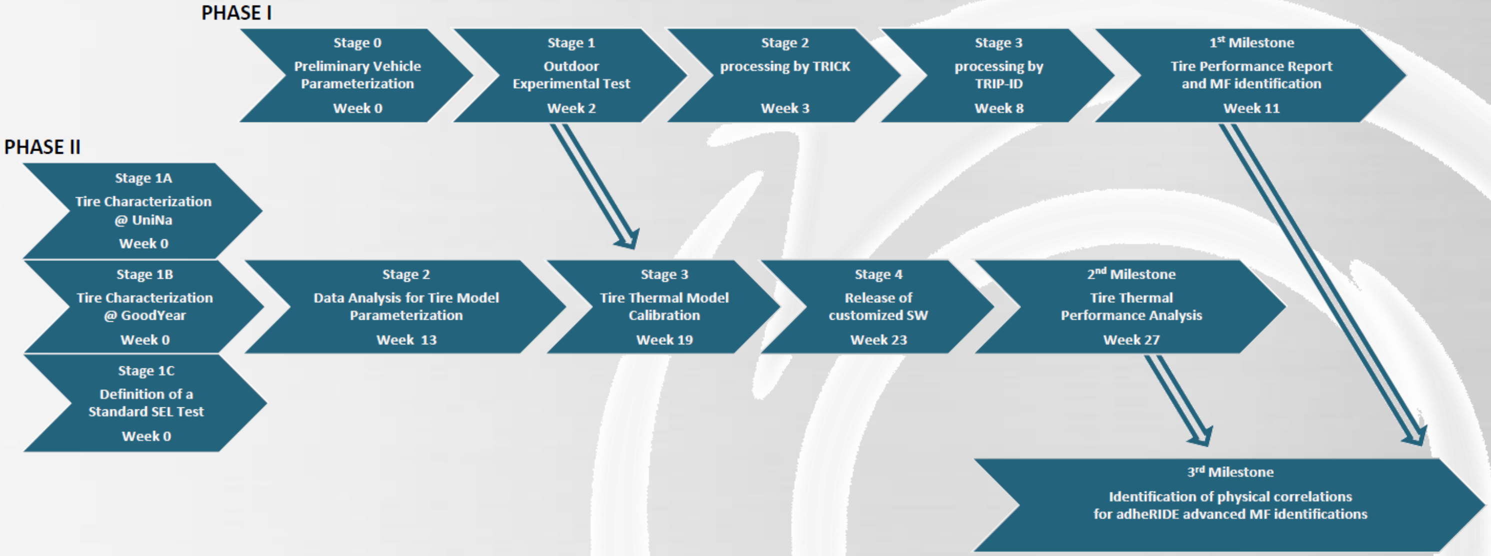


Parameterization of the Target Vehicle

MASERATI VEHICLE PROTOTYPE

- Internal Combustion Engine
  - Rear Wheel Drive
- Front Tire Size: 245/35R20
- Rear Tire Size: 285/35R20

dati veicolo	
Specifica pneumatico front	
Specifica pneumatico rear	
Raggio indeformato pneumatico front	[m]
Raggio indeformato pneumatico rear	[m]
Raggio di rotolamenteo pneumatico front	[m]
Raggio di rotolamento pneumatico rear	[m]
Massa veicolo a secco	[kg]
Massa liquidi a serbatoio pieno	[kg]
Massa ruota anteriore	[kg]
Massa ruota posteriore	[kg]
Momento d'inerzia assiale veicolo rispetto all'asse Z	[kg*m^2]
Momento d'inerzia assiale ruota anteriore rispetto all'asse di rotazione	[kg*m^2]
Momento d'inerzia assiale ruota posteriore rispetto all'asse di rotazione	[kg*m^2]
passo	[m]
semipasso anteriore	[m]
carreggiata anteriore	[m]
carreggiata posteriore	[m]
altezza baricentro	[m]
rigidezza al rollio assale anteriore	[N/deg]
rigidezza al rollio assale posteriore	[N/deg]
rapporto di sterzo nominale	[-]
sezione resistente frontale (da impiegare con cx)	[m^2]
cx	[-]
cz front	[-]
cz rear	[-]
roll rate	[deg/G]
altezza del punto di intersezione tra l'asse di rollio ed il piano baricentrico yz	[m]
camber statico	[deg]
toe statico	[deg]
coordinate datron	[m, m, m]
curve rolling resistance	

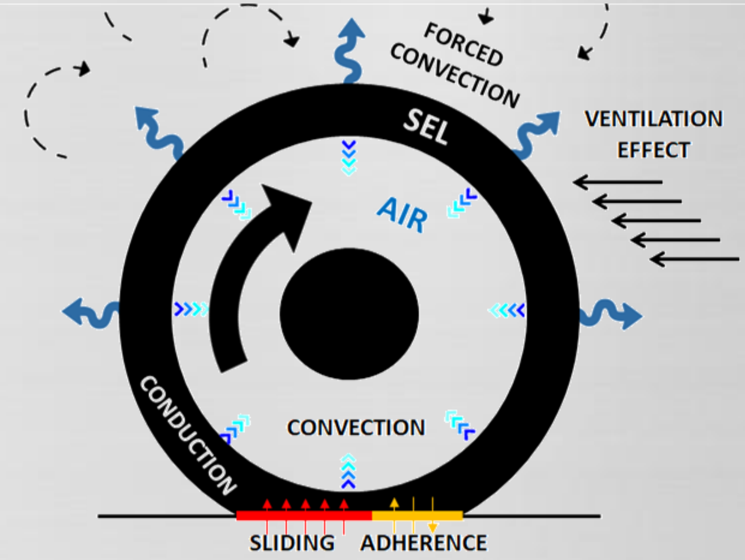


Tires Testing at UniNa Tire Lab

- thermoRIDE: MODEL CHARACTERIZATION

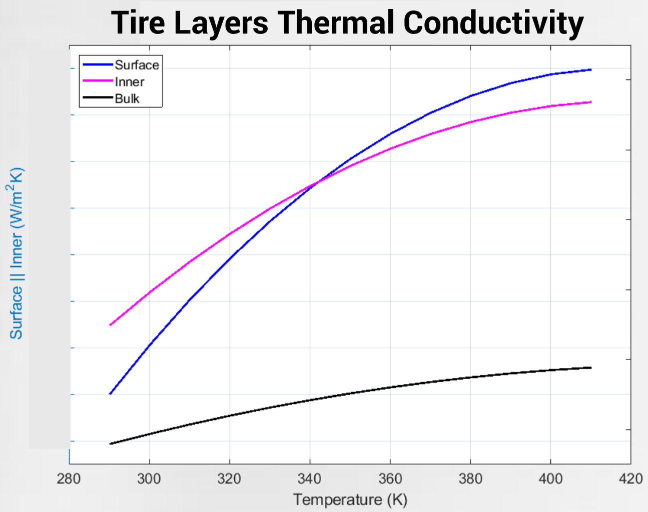
- Physical Parameterization
  - Footprints Data (from bench or tiremakers)
  - Thermodynamic Coefficients (from proprietary nondestructive methodology)
  - Tread Viscoelasticity and Carcass Structure (from outdoor data analysis or bench)

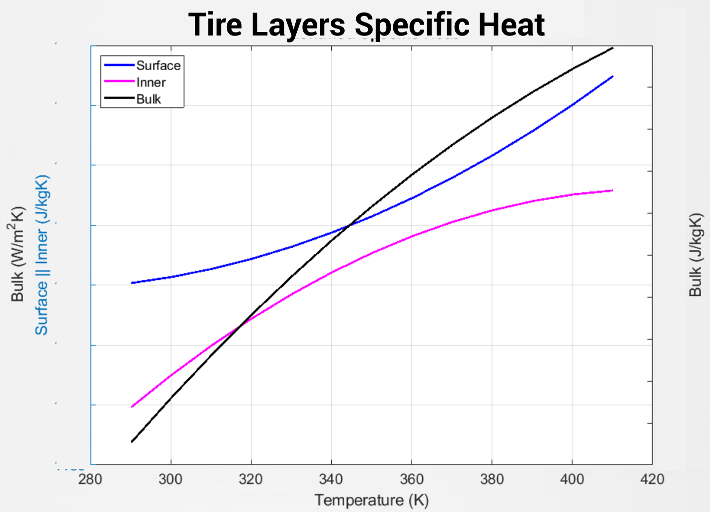
- Model Calibration and Validation
  - Specific Outdoor Routines for the Scan of the various Physical Phenomena

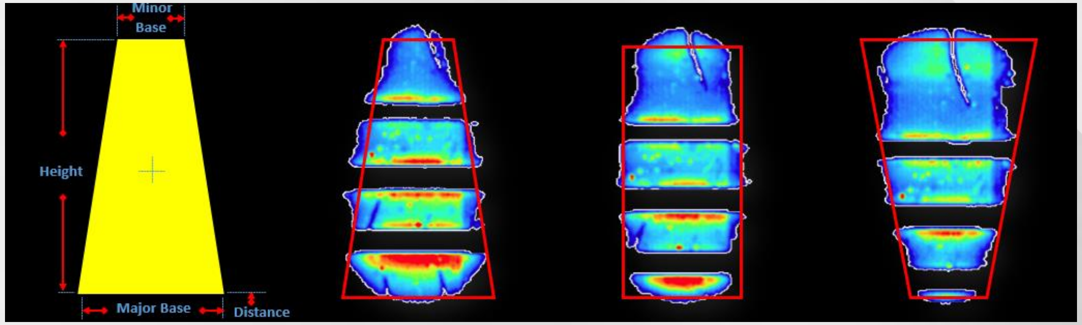


Tires Testing at UniNa Tire Lab

- **thermoRIDE: MODEL CHARACTERIZATION**







- **Physical Parameterization**
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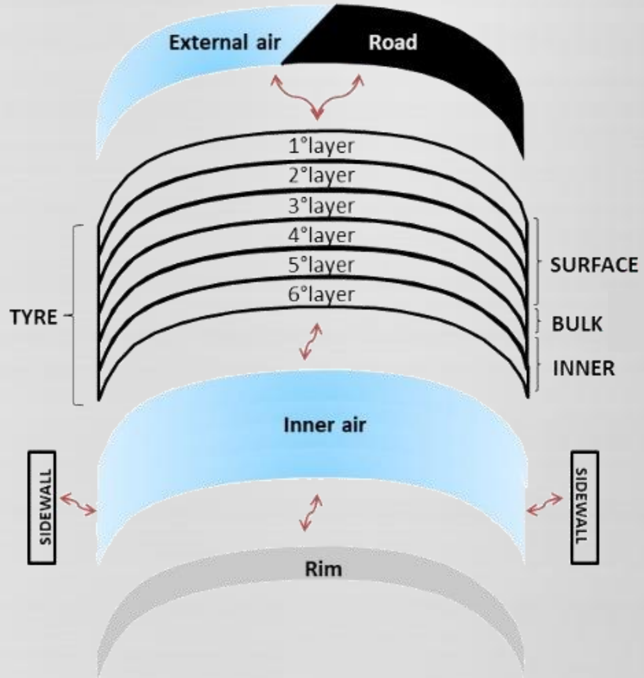
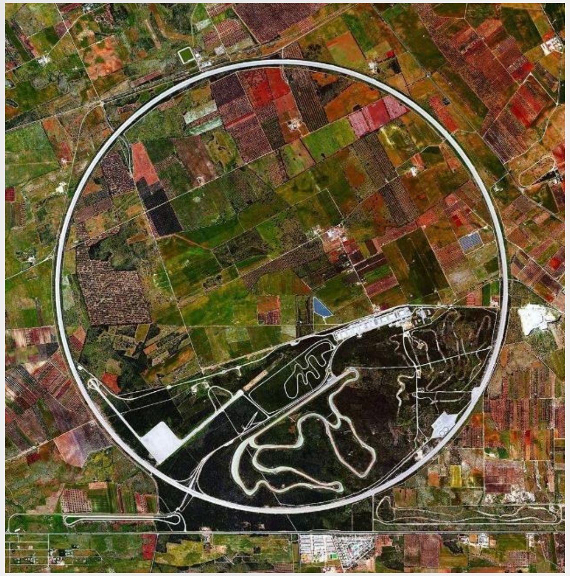
  - **Tread Viscoelasticity and Carcass Structure (from outdoor data analysis or bench)**



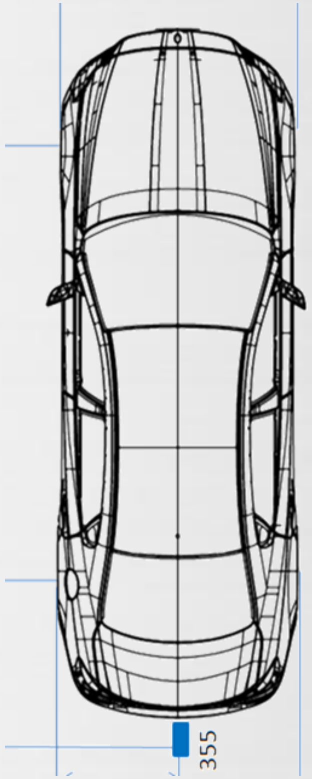
- **Model Calibration and Validation**
  - **Specific Outdoor Routines for the Scan of the various Physical Phenomena**

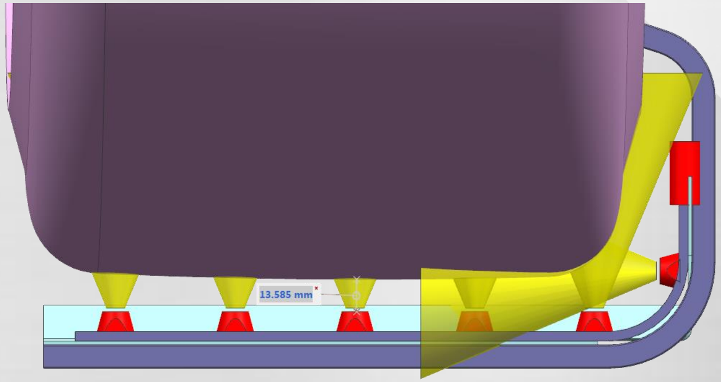
Outdoor Testing Session

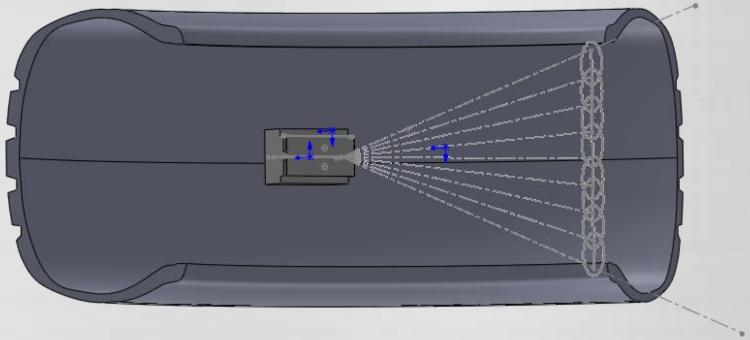


#SET HANDLING: TS1_H
H00 - Offset
H01 - Gentleman driving
H02 - Pure Lateral
H03 - Max Perf (x2)
H04 - Sliding
H05 - Gentleman driving
H06 - Pure Lateral
MISURA USURA

#SET DINAMICO: TS1_D
T00 - Offset
T01 - Launch with slip (cold T)
T02 - Fast Cooling
T03 - Launch with slip (cold T)
T04 - Sinusoidal Sweep Input (5x)
T05 - Slow Ramp Steer (5x)
T06 - Launch with slip (opt T) (x2)
T07 - Launch with slip (max T) (x2)
T08 - ABS Braking (x5)
T09 - NO ABS Braking (attempt)
T10 - Long Cooling
T11 - Static Offset
T12 - No ABS Full Braking (cold T)
T13 - Fast Cooling
T14 - No ABS Full Braking (cold T)
T15 - Heating (Sinusoidal 1Hz)
T16 - No ABS Full Braking (opt T) (x2)
T17 - No ABS Full Braking (max T) (x2)
MISURA USURA





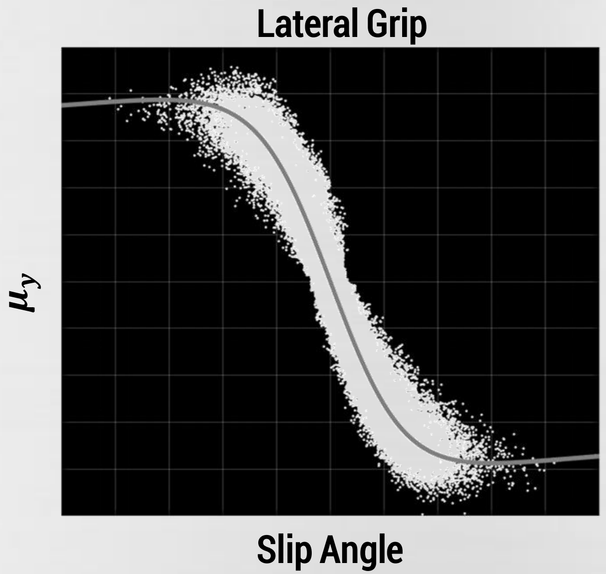


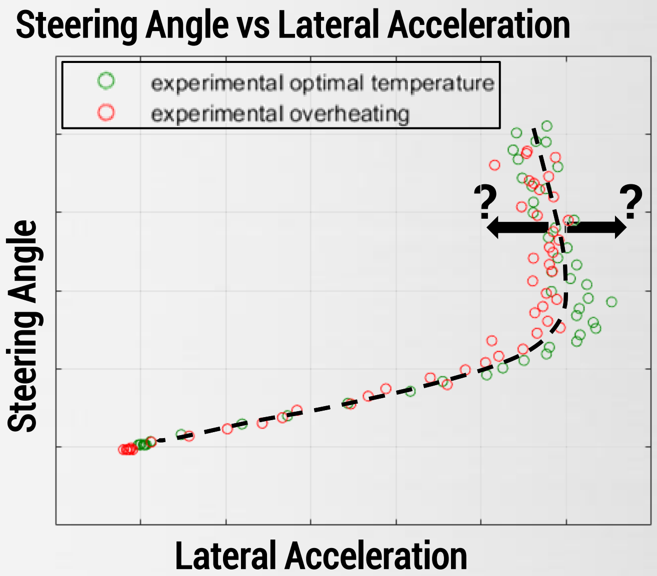
Instrumental Equipment:
- CAN bus reader
- Inertial Platform
- Optical Sideslip Sensor
- Advanced Thermal Setup
- double GPS

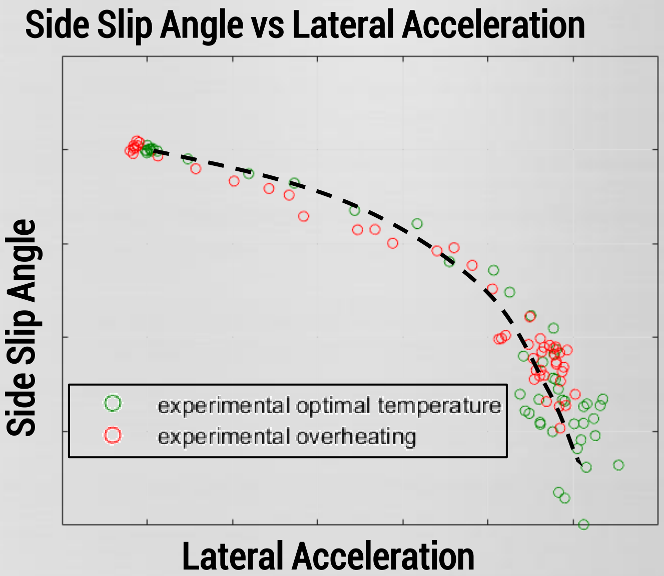
Physical Models Calibration - SRS

OBJECTIVE MANEUVERS – PURE LATERAL
SLOW RAMP STEER

- **Slow Ramp Steer maneuvers show that optimal tire temperature allows to reach higher lateral acceleration.**
- **Moreover, as expected, cornering stiffness decreases while tires becomes hotter.**
- **<u>A "standard" MF model is not able to reproduce such fundamental variabilities.</u>**

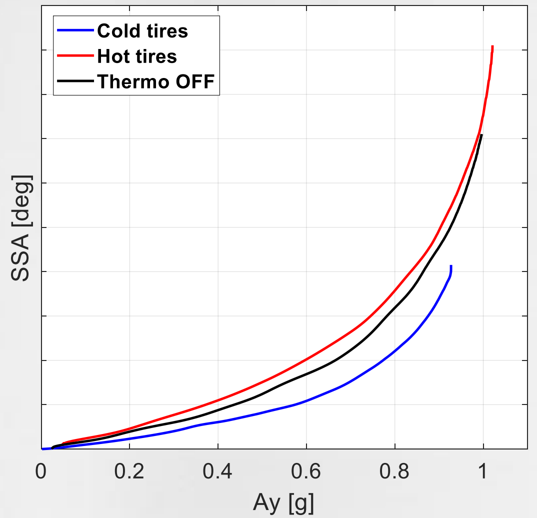






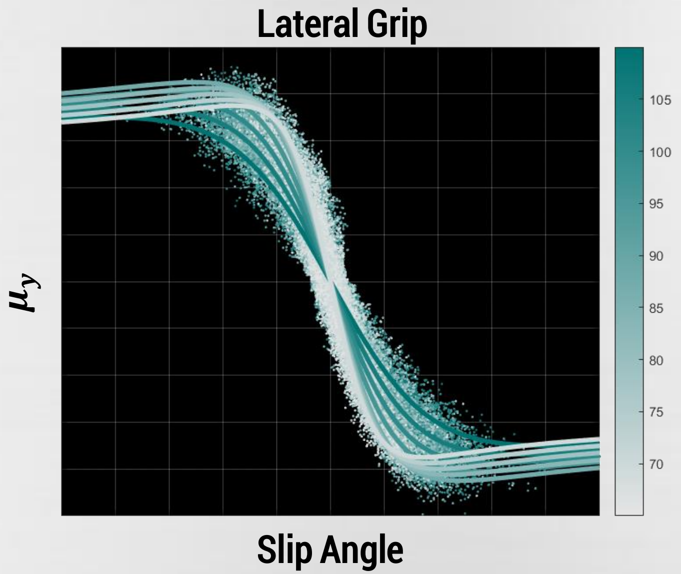
Physical Models Calibration - SRS

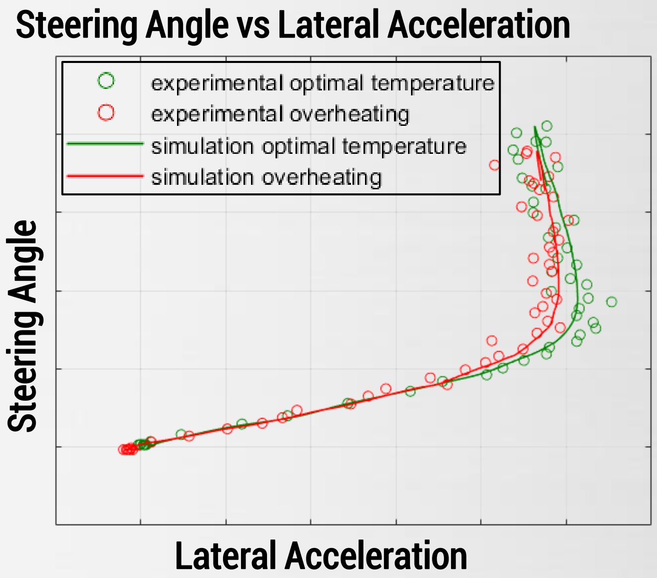
OBJECTIVE MANEUVERS – PURE LATERAL SLOW RAMP STEER

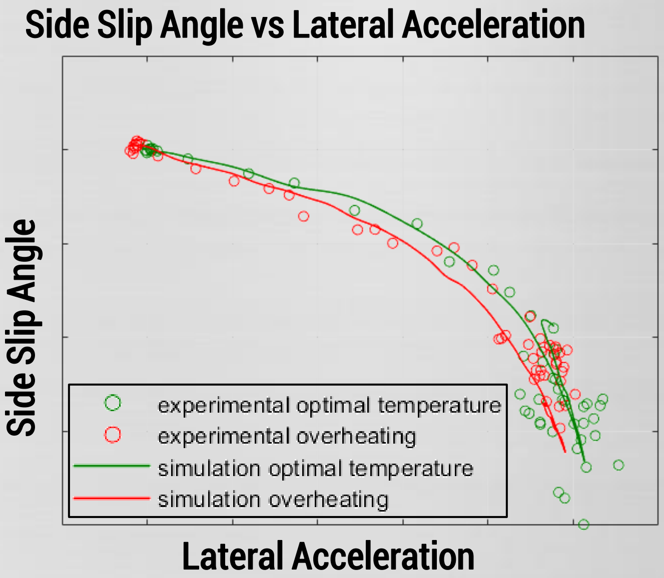


A multiphysical model allows to reproduce the whole conditions variability, with the expected effects on Vehicle Dynamics

Condition	K_β
Thermo OFF	Reference
Cold tire	+62%
Hot tire	-40%



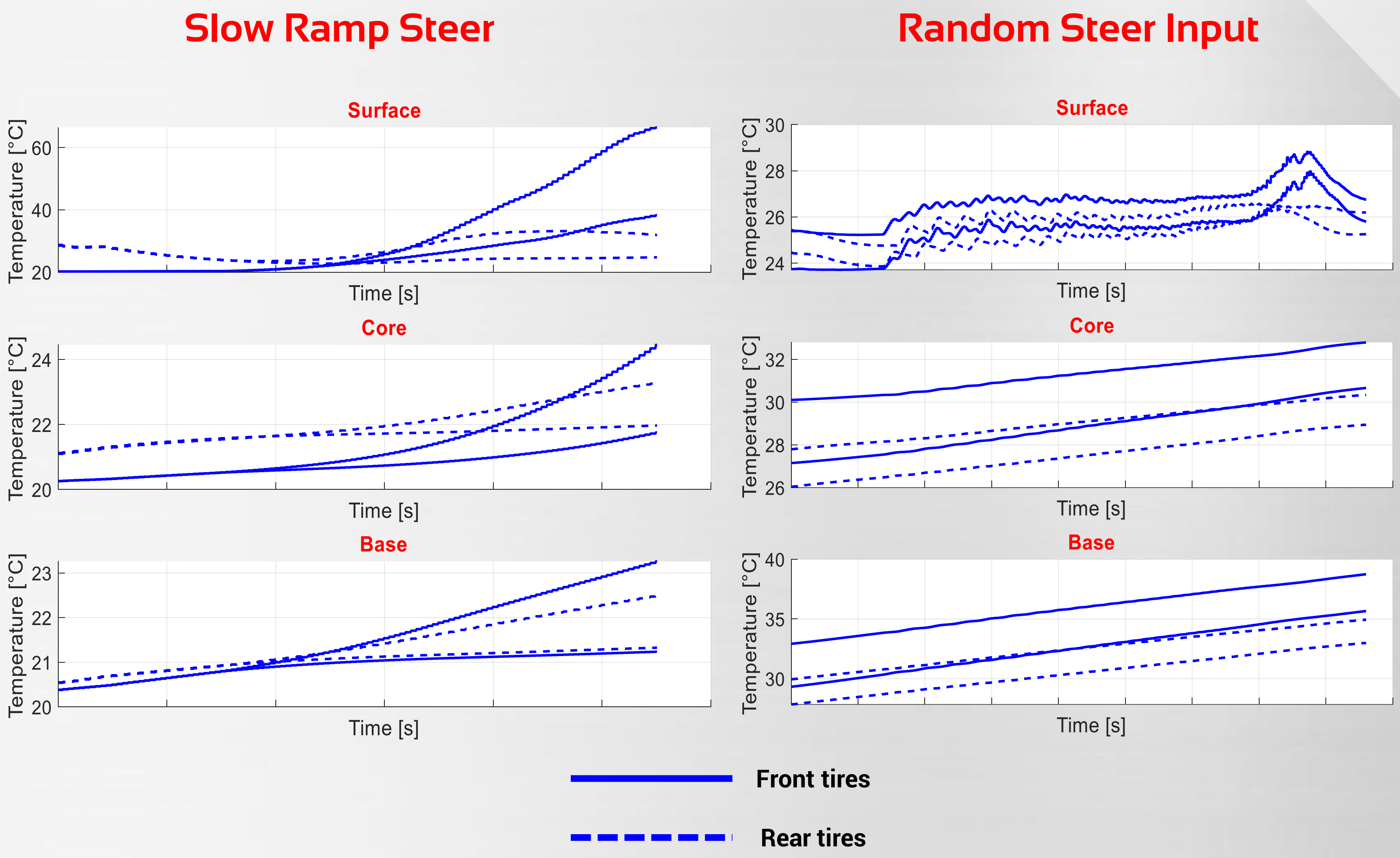




Lateral Maneuvers Thermal Sensitivity

- **SRS maneuvers mainly affect the surface temperature of front tires. For such reason a proper test plan for tires characterization needs to be carried out for several thermal levels.**

- **Random steer maneuvers heat tires in a more uniform way through all the layers, with surface temperature almost constant during the whole test.**



Physical Models Calibration - Transients

Experimental Data

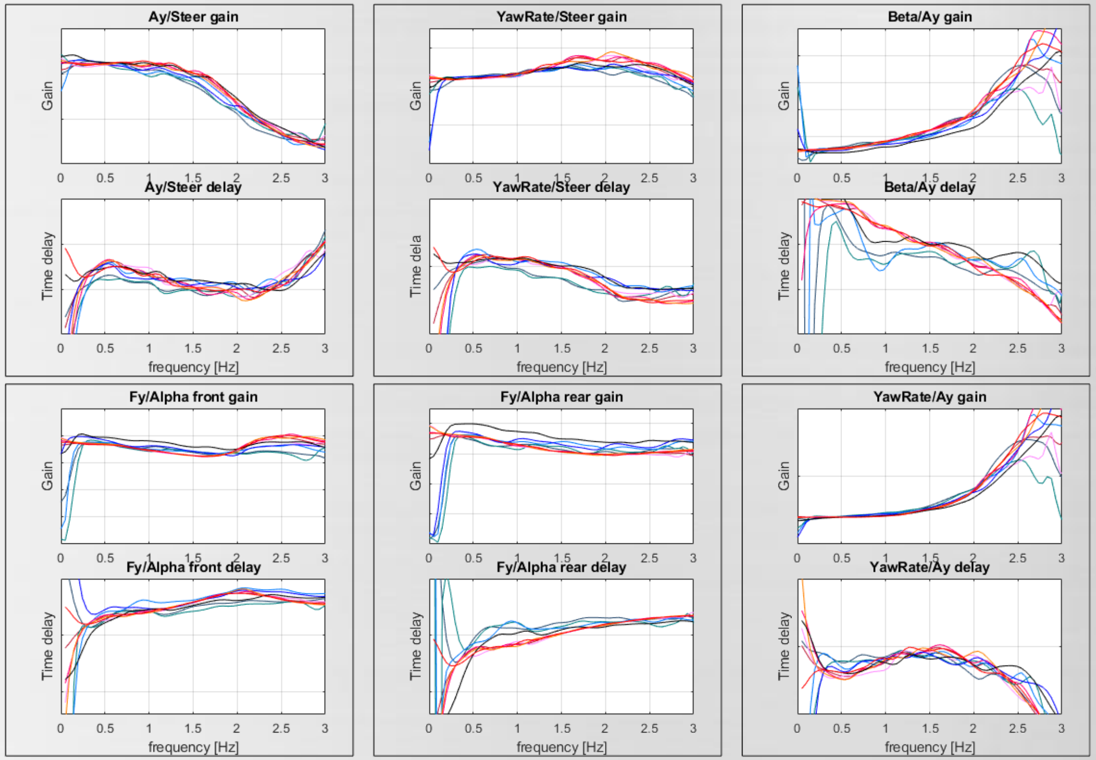
Model Output

Correlation

Relaxation Parameters Identification

In the research context provided by a cooperative PhD path, a procedure to identify tire relaxation length parameters from vehicle data has been developed.

A vehicle model with light parametrization, but sensitive to transient behavior, is calibrated focusing on tire response in the frequency domain till the global vehicle data coincide with experimental ones.



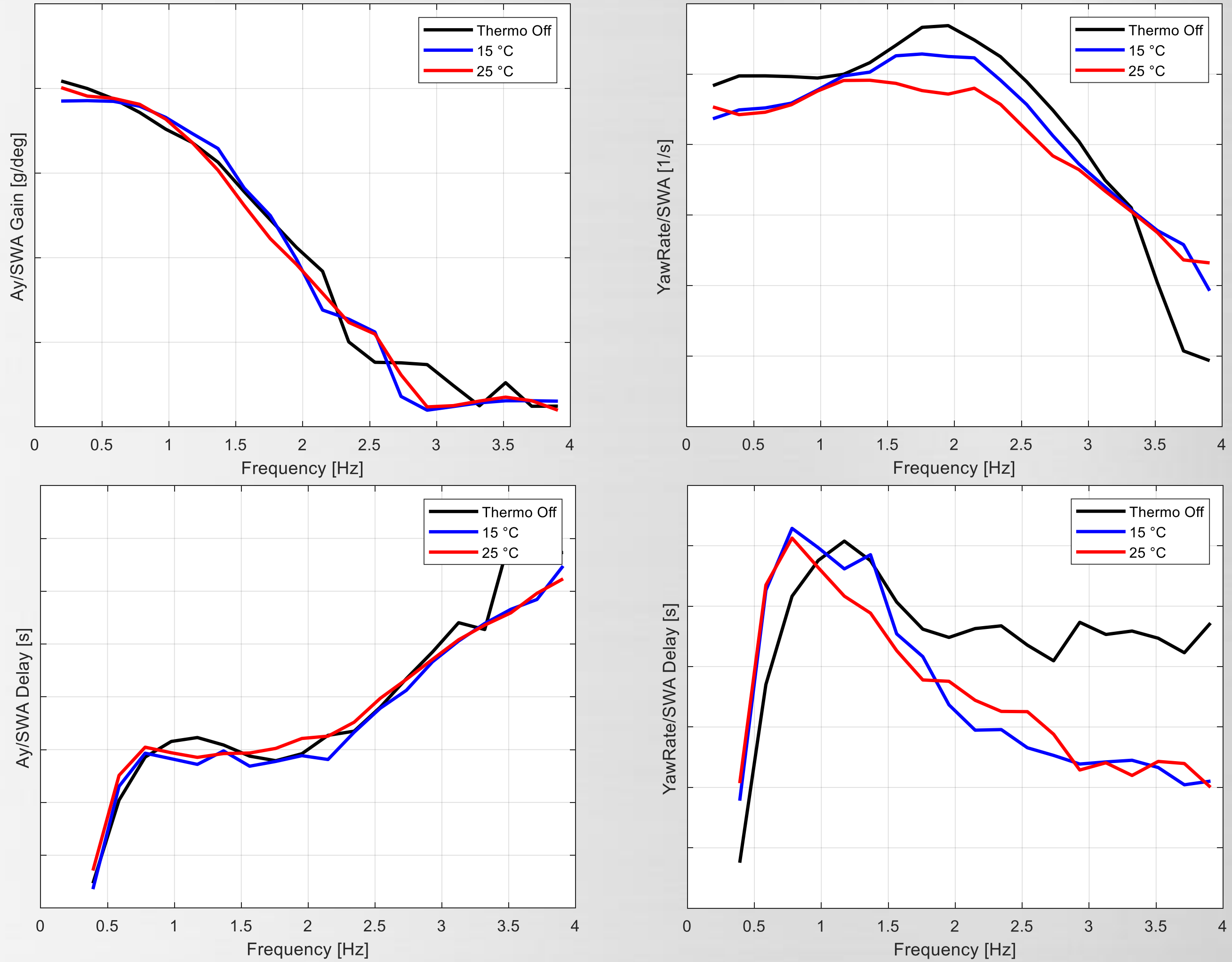
	Test 1	Test 2	Test 3	Test 4	Test 5
Experimental					
Simulation					

Physical Models Calibration - Transients

- **As already showed Random Steering Input maneuver does not affect significantly thermodynamic status of the tire.**

- **Vehicle's transient response in linear range (0.3 - 0.4 g) does not change w.r.t. "Thermo Off" case.**

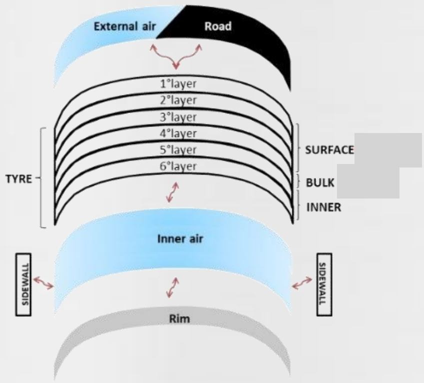
$$\frac{a_Y}{\vartheta_{SWA}} \qquad \frac{\dot{\Psi}}{\vartheta_{SWA}}$$

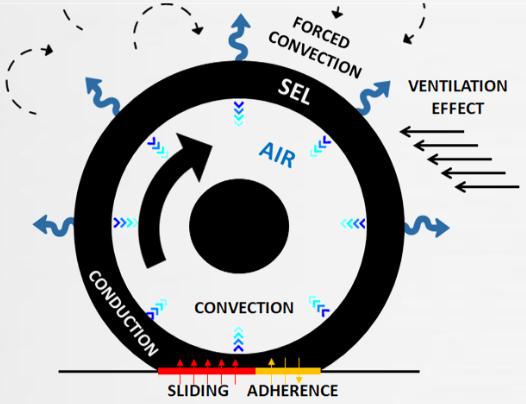


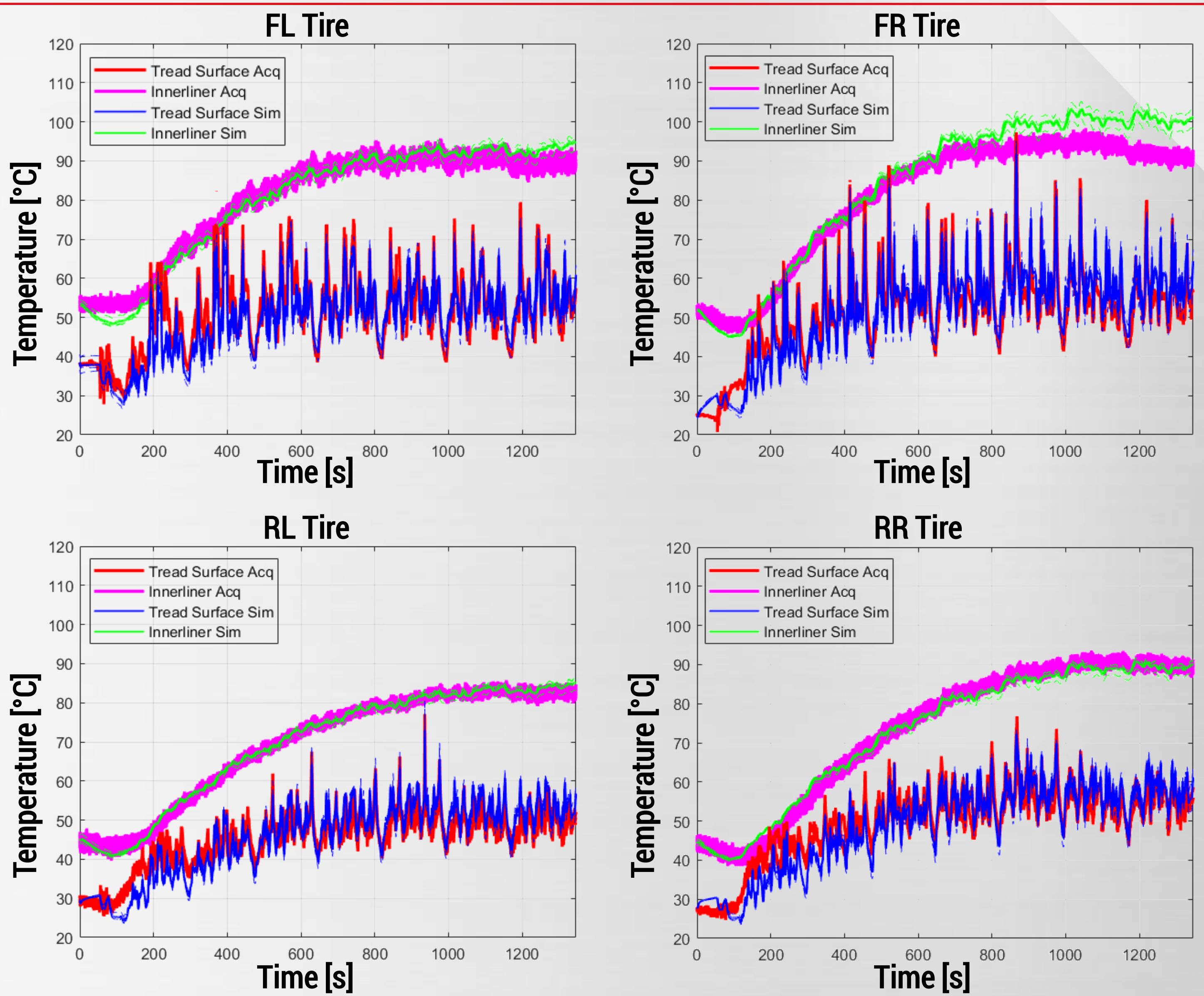
Physical Models Calibration - Handling

- **Handling runs allow to calibrate the thermal model thanks to the channels acquired at inner liner and external surface layers.**

- **Specific runs aimed to highlight wear phenomena are used to parameterize the weaRIDE model.**

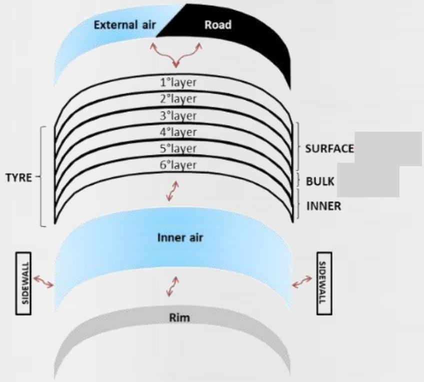


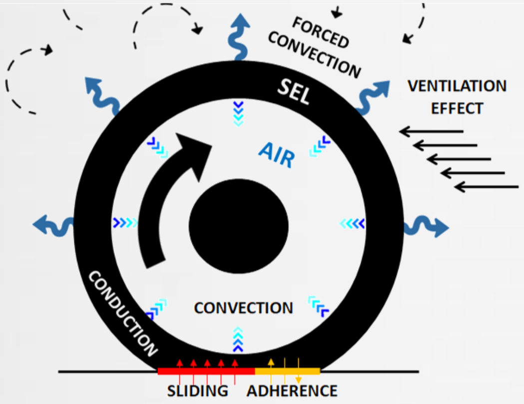


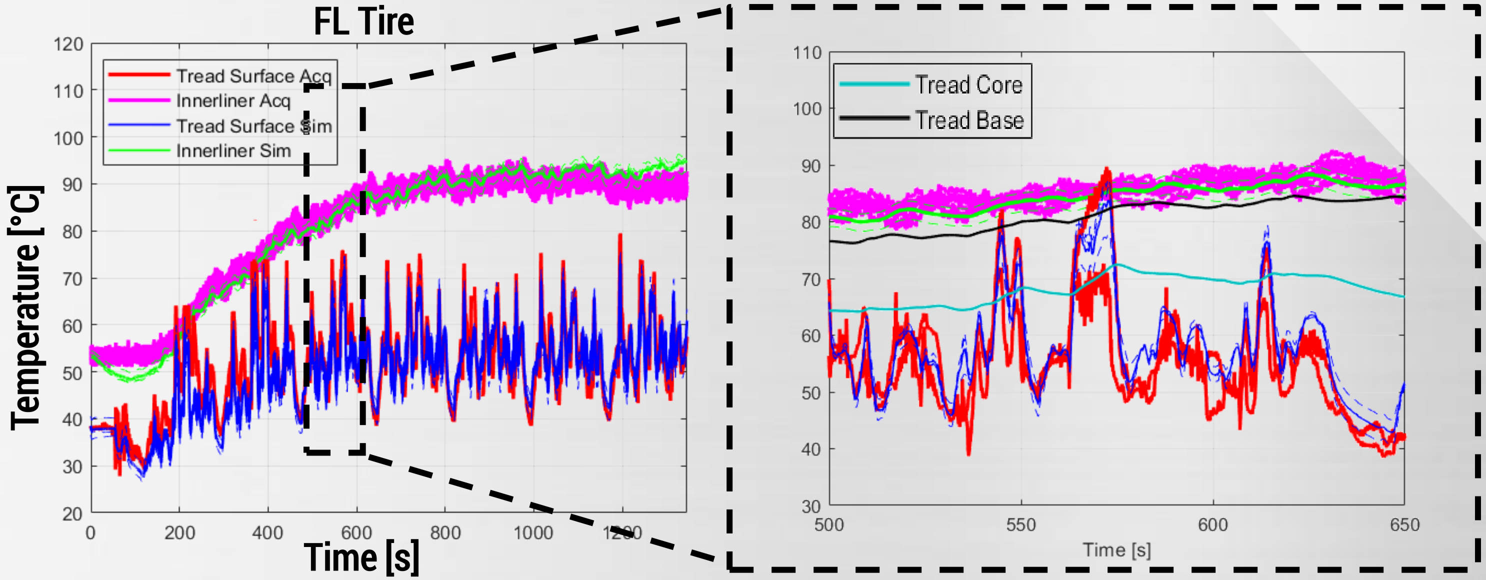


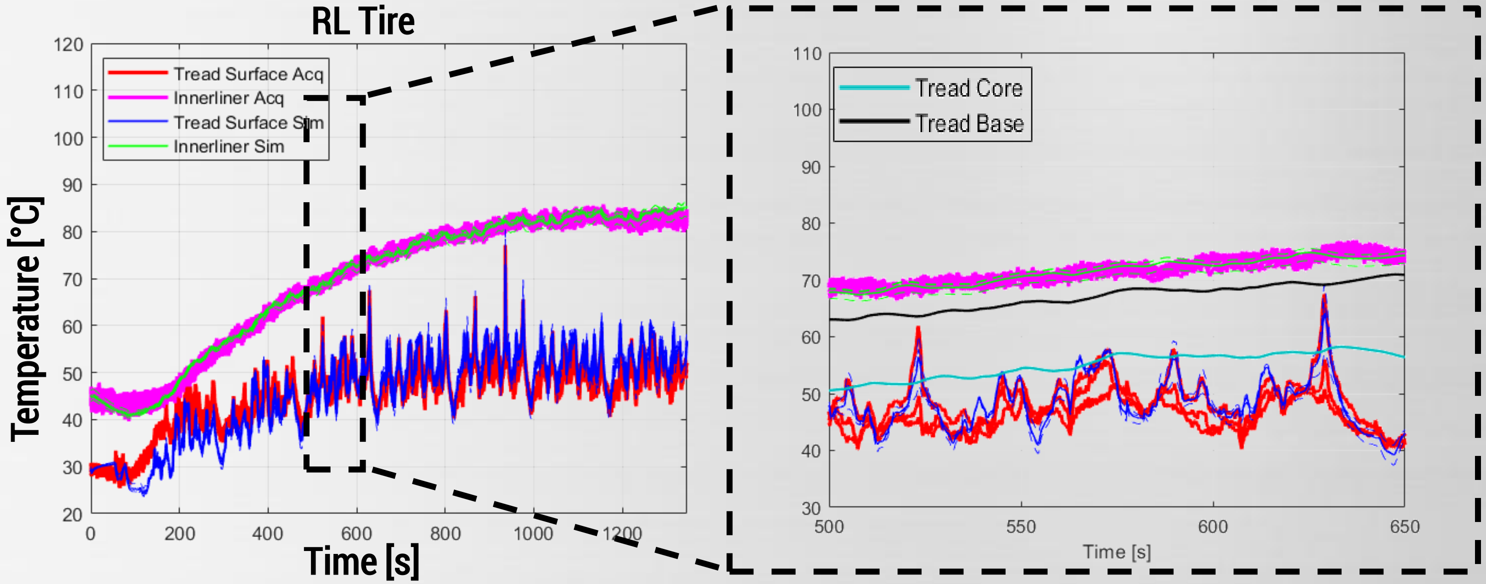
Physical Models Calibration - Handling

- **Once properly validated, the model allows to provide real-time temperature of the inner tire layers, accounting for local contact phenomena thanks to multi-ribbed structure.**





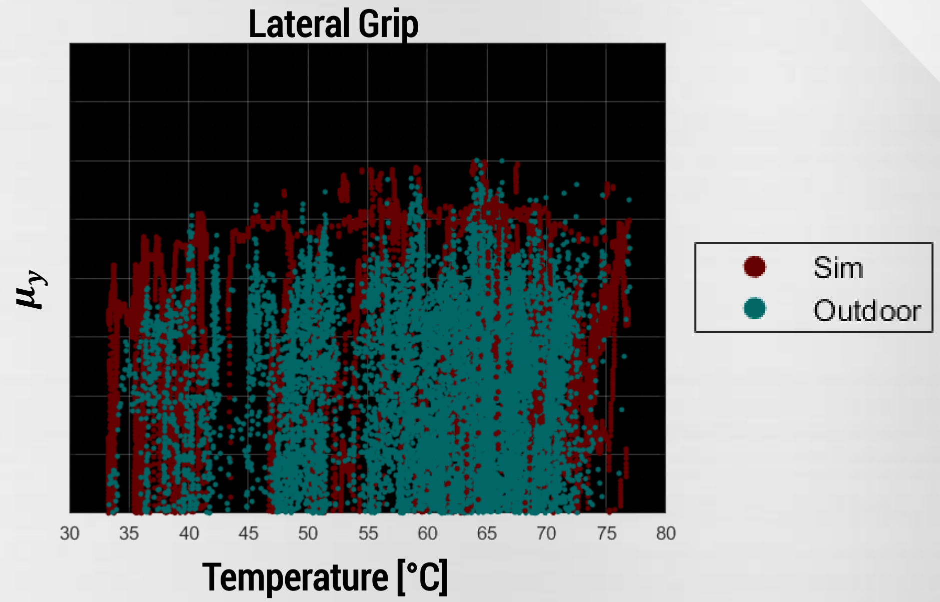


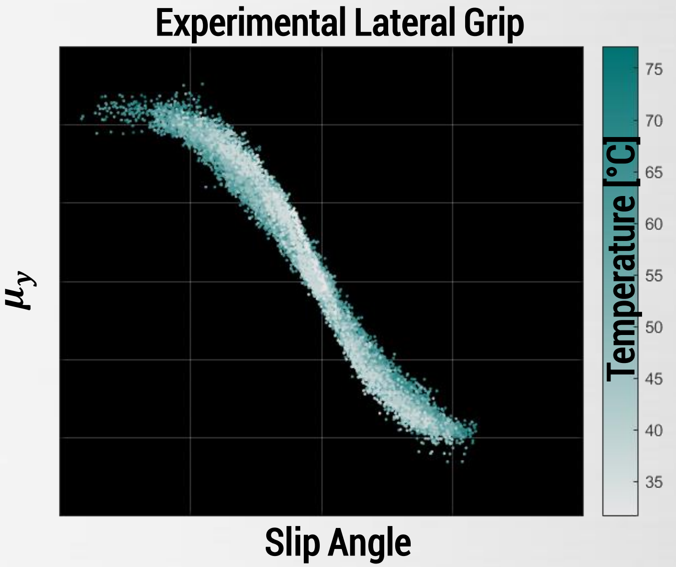


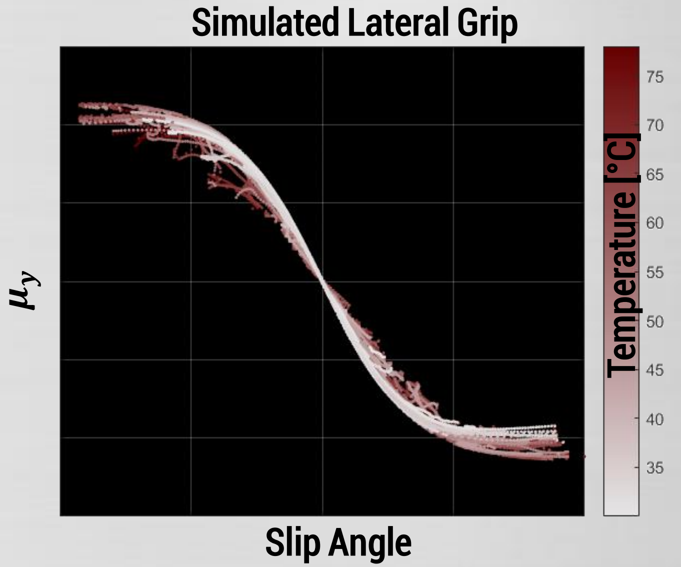
Physical Models Calibration - Handling

- **Once properly validated, the model allows to provide real-time temperature of the inner tire layers, accounting for local contact phenomena thanks to multi-ribbed structure.**

- **The temperature of such inner layers are highly correlated to grip, stiffness and peak shape of the interaction curves, allowing to identify the optimal working range and the dynamic effects to be reproduced in the sim environment.**

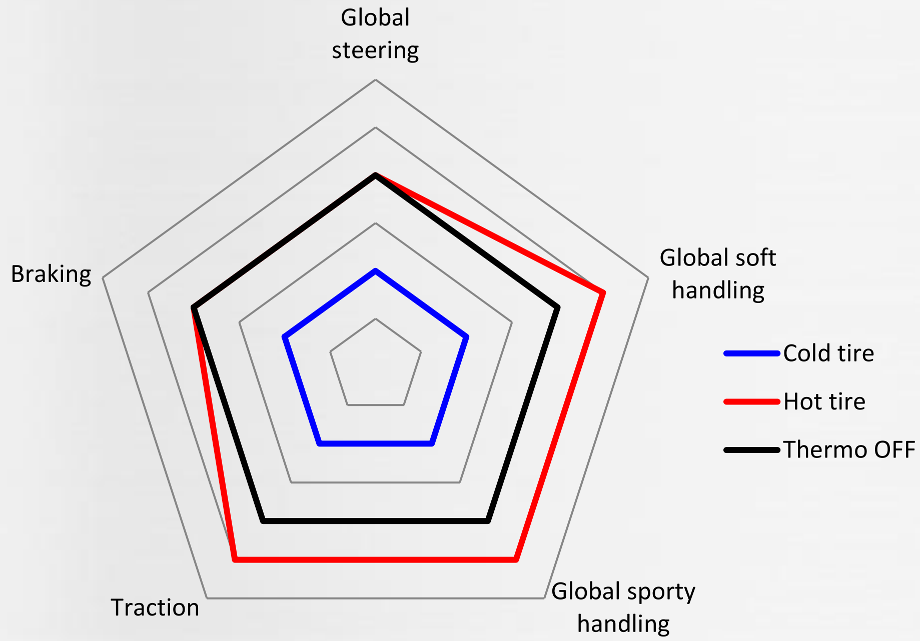






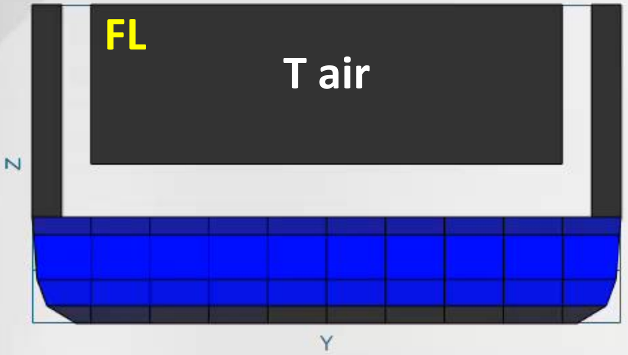
Tire Performances: Driver Feedback

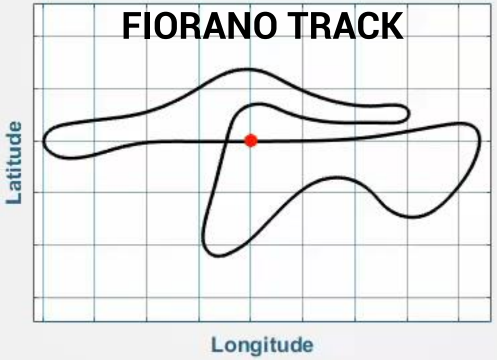
- adheRIDE real-time model has been tested on DIM250 with thermoRIDE and threedeeRIDE modules in order to understand if driver's feeling is able to perceive:
  - Modification of vehicle balance due to cornering stiffness variation function of vehicle thermal status
  - Modification of vehicle performances due to tire grip variation vs tire temperature

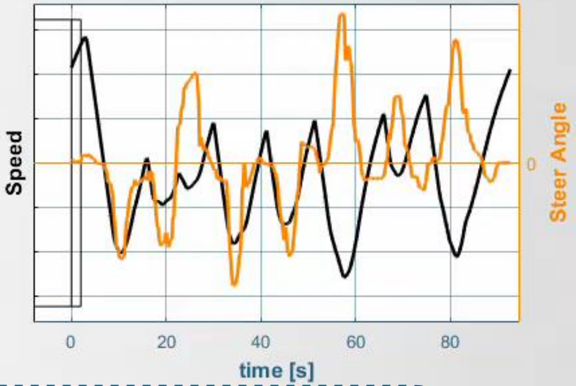


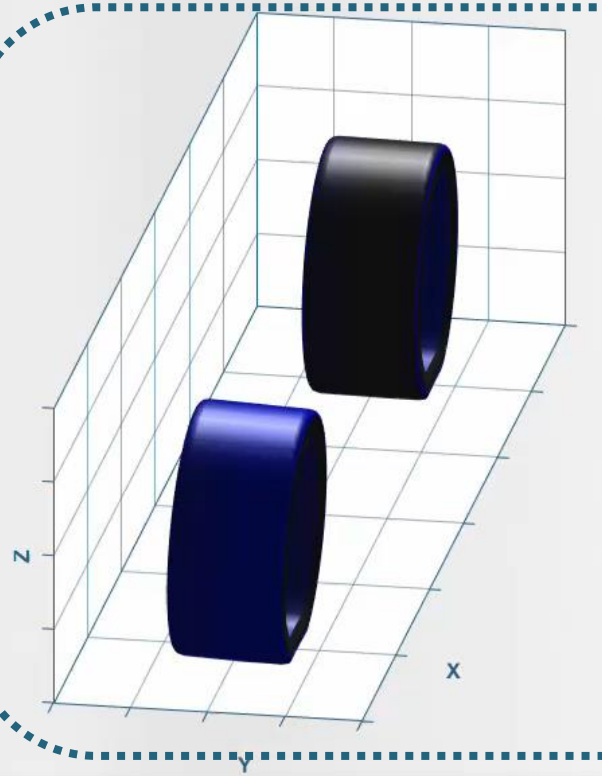
	Comments
Test1 (15°C)	Low response in soft handling due to not perfect balance between axles; **overall grip is quite low** so maximum performance are not satisfying; it takes several laps to reach a good level of grip; when tire gets hot there is anyway a not perfect balance of axles' performance during different cornering phases
Test2 (25°C)	There is a better balance in linear handling since first lap, anyway tires reach best performance window in less time. Very **good behavior in all cornering** phases maintains for more laps; capability of traction during cornering exit has really improved; best lateral thermical window does not correspond to the longitudinal one
Thermo OFF	Behavior is constantly quite similar to the best thermal window of hot tire but axles' balance e traction capability is slightly lower
General about thermal behavior	Best thermal window reaching is detected thanks to progressive reduction of understeer; first signals of performance decay come from oversteer phenomena, especially during power on

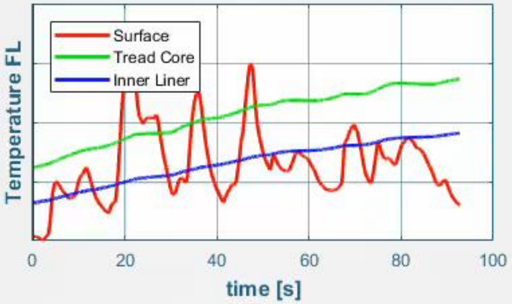
Models Implementation @ Innovation Lab

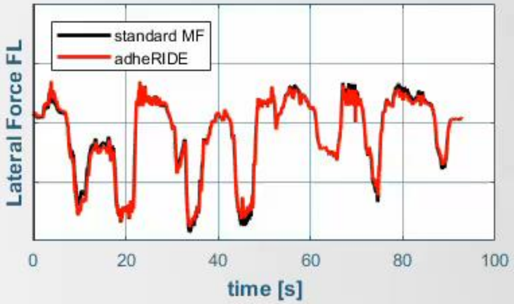


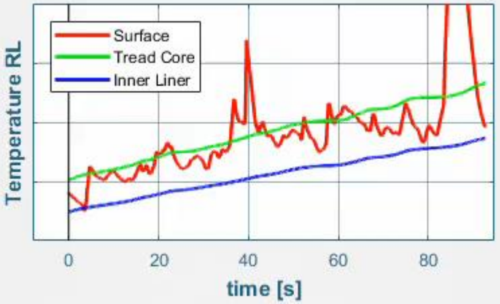


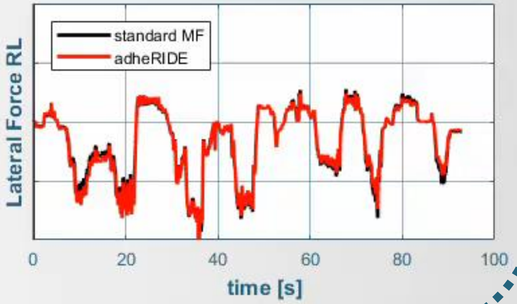


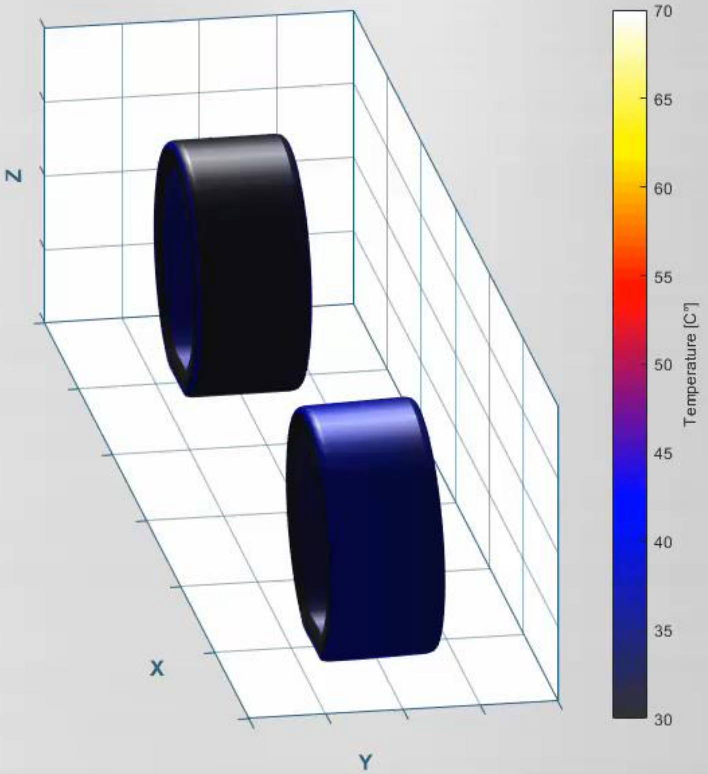












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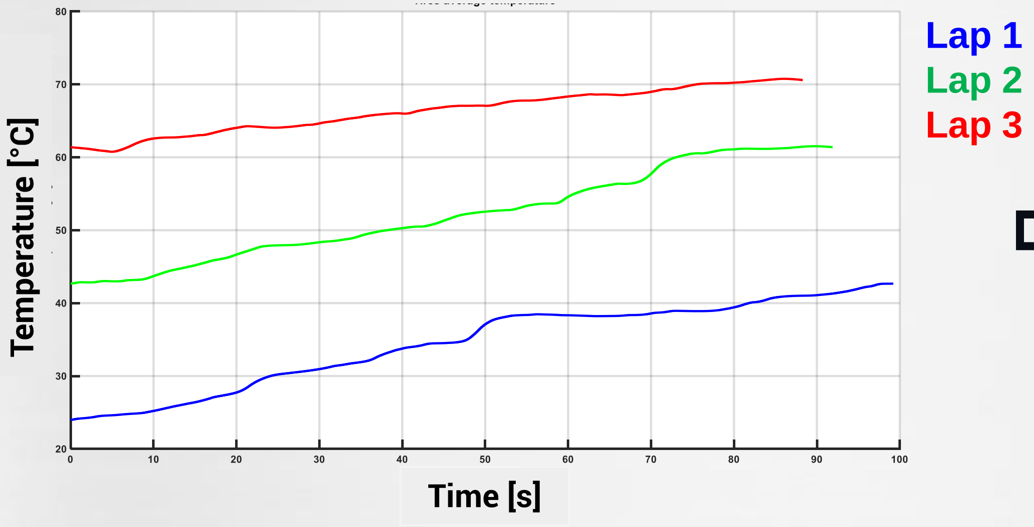

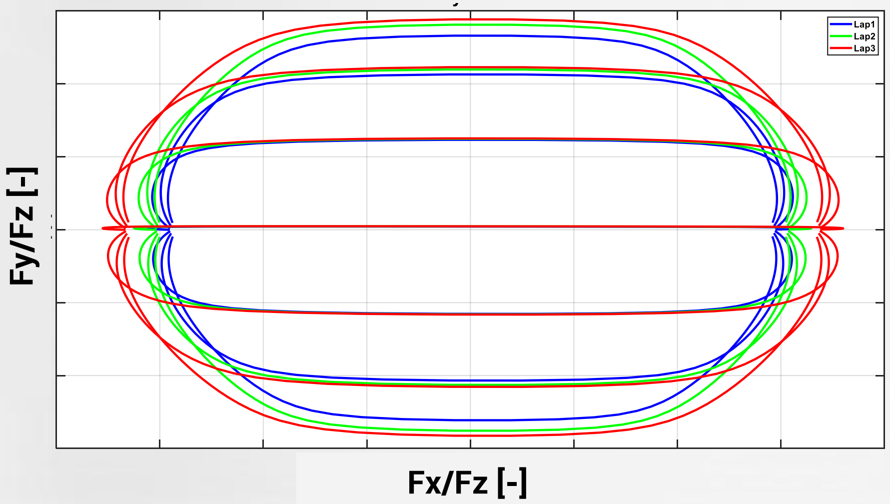

The plots show three warmup laps on Fiorano Track. First Lap starts with very cold tires.

	Lap Time [s]	Min Ax [g]	Max Ay [g]
Lap1	99.21 (ref)	-1.26	1.15
Lap2	ref - 7.31	-1.31	1.28
Lap3	ref - 10.92	-1.42	1.33

- At the end of the second lap, tires average tread temperature is almost in the optimal range.
- The ellipses show that both longitudinal and lateral grip increase as the tires heat up in the warmup phase, resulting in higher maximum acceleration and lower lap times.
- Once properly set the physical system, the tires and vehicle setup development loop can be carried out.

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