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APPLIED VEHICLE RESEARCH

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DIPARTIMENTO DI INGEGNERIA INDUSTRIALE
UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

turn-key approach to tire digital twin multi-physical modelling: a journey from road data to XiL

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CEO & co-founder @ MegaRide
Vehicle Dynamics researcher @ UniNa

2021 VI-grade ZERO PROTOTYPES SUMMIT - MAY 20th/21st, 2021

MEGARIDE®

APPLIED VEHICLE RESEARCH

an official UniNa spinoff company

UniNa Vehicle Dynamics research group

MULTI-PHYSICAL TIRE MODELS

MODULAR SIMULATION PLATFORM

SCIENCE APPLIED TO RACES

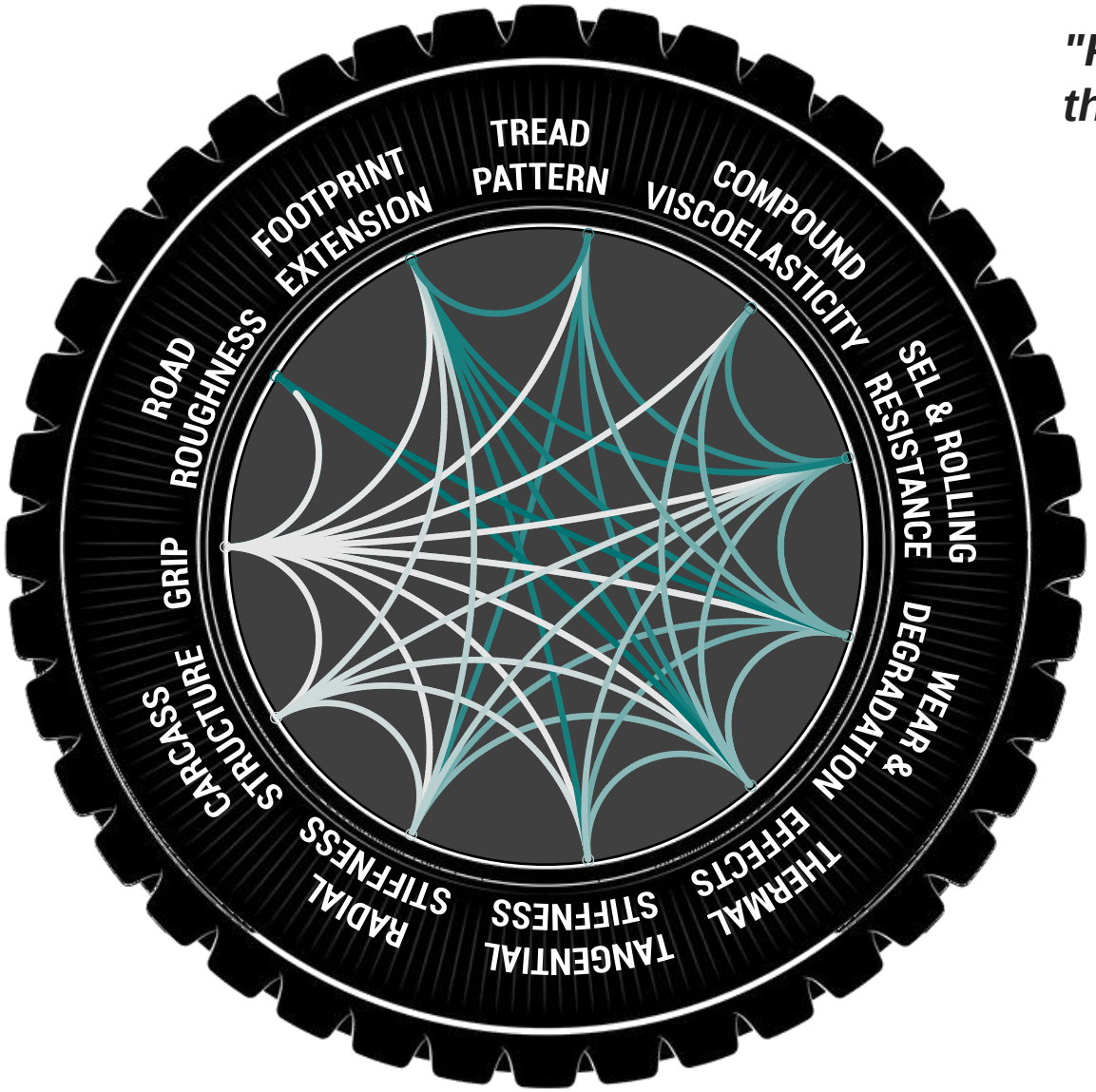
COMPANY HIGHLIGHTS

- “TIRE TECHNOLOGY OF THE YEAR 2018" AND "VD DEVELOPMENT TOOL OF THE YEAR 2019"
- GROWING TEAM (> 25 PPL) AND BUSINESS (EBITDA > 20%) IN 4 YEARS WITH NO DEBT / NO EQUITY GIVEN
- 5 F1 / 2 MOTOGP / 3 FOE / 2 WEC / 1 NASCAR / 2 DTM / 1 F2-F3 (IN EXCLUSIVE) / 4 TIREMAKERS / 5 CARMAKERS

RESEARCH HIGHLIGHTS

- TEAM AWARDED BY “M.I.T. YOUNG INNOVATORS UNDER 35”
- 6 PhD / 15+ MSc / 25+ BSc PER YEAR ON VD AND TIRE SIMULATION TOPICS
- SUPPORT OF “TYRE LAB” UNIVERSITY FACILITY FOR EXPERIMENTAL ACTIVITIES

A HOLISTIC VIEW IN TIRE MODELLING



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

H. L. Mencken

7(+) TOOLS FOR A MODULAR TIRE PLATFORM

2 PERFORMANCE TOOLS

T.R.I.C.K.
from vehicle onboard sensors to tire data

adheLAB
multiphysical tire data analysis and MF-ID

4 PHYSICAL MODELS (RIDEsuite)

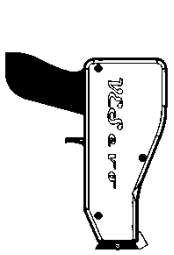
thermoRIDE
tire thermal model

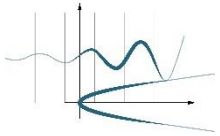
adheRIDE
advanced MF

threedeeRIDE
multicontact model

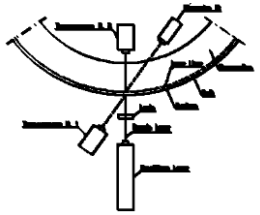
weaRIDE
tire wear model

1 INNOVATIVE DEVICE + TESTBENCHES



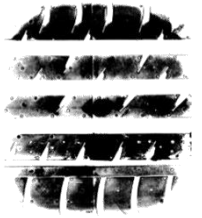


VESevo
nondestructive tread compound analyzer



thermobench
tire thermal analysis

footprints-ID
shape & contact pressure

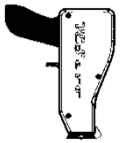


THE JOURNEY TO THE TIRE DIGITAL TWIN

GETTING TIRE DATA

WEEK 1

CHARACTERIZING MULTIPHYSICS



WEEK 3

MODELLING MULTIPHYSICS

WEEK 4

CALIBRATION AND VALIDATION

WEEK 6

TIRE DIGITAL TWIN

ONCE CONSOLIDATED PRODUCTS PLATFORM…

… FOCUS ON PROCEDURES AND STANDARDIZATION

THE JOURNEY TO THE TIRE DIGITAL TWIN

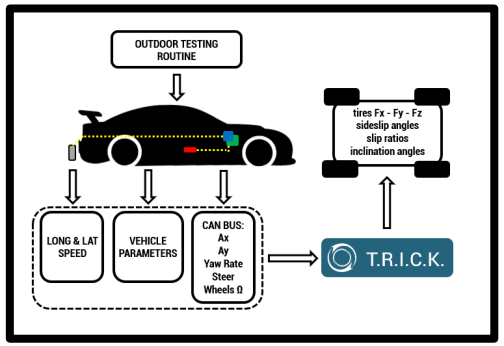
GETTING TIRE DATA

1

- from outdoor vehicle data (T.R.I.C.K.)
- from state observers (smartRIDE)
- from tire test bench
- from dyno-hubs
- from trailers
- …

CHARACTERIZING MULTIPHYSICS

MODELLING MULTIPHYSICS



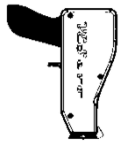
CALIBRATION AND VALIDATION

TIRE DIGITAL TWIN

THE JOURNEY TO THE TIRE DIGITAL TWIN

GETTING TIRE DATA

CHARACTERIZING MULTIPHYSICS



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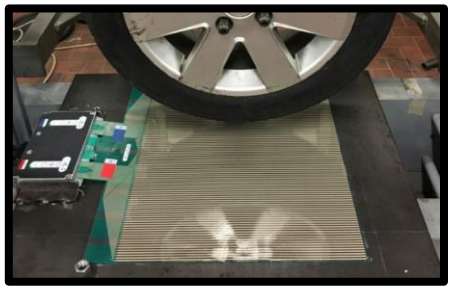
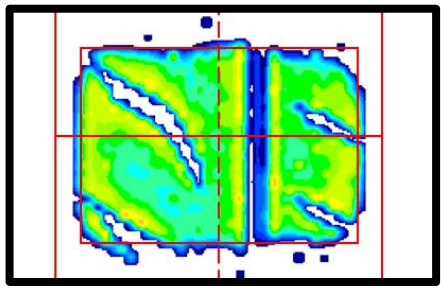
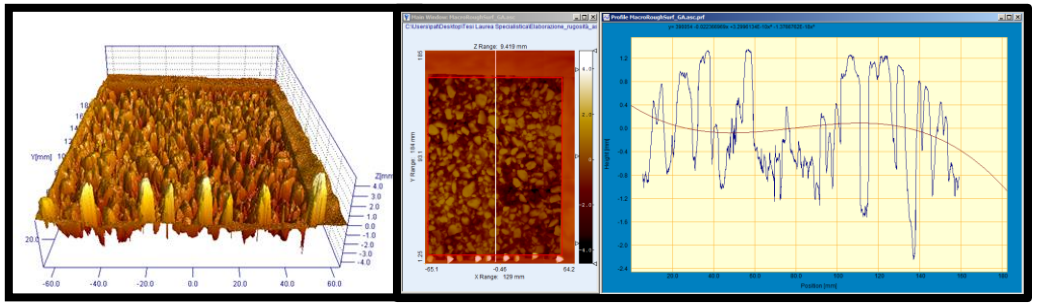






MODELLING MULTIPHYSICS

CALIBRATION AND VALIDATION

- tire thermal characterization (for thermoRIDE & adheRIDE)
- tire footprints characterization (for thermoRIDE & weaRIDE)
- tire viscoelastic characterization (for VESevo activities & weaRIDE)
- road roughness characterization (for threedeeRIDE & weaRIDE)

TIRE DIGITAL TWIN

THE JOURNEY TO THE TIRE DIGITAL TWIN

GETTING TIRE DATA

CHARACTERIZING MULTIPHYSICS

adheLAB

RIDEsuite

adheRIDE

3D-RIDE

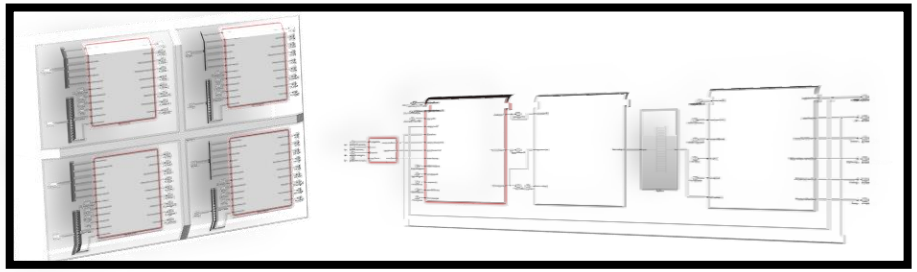
low-speed

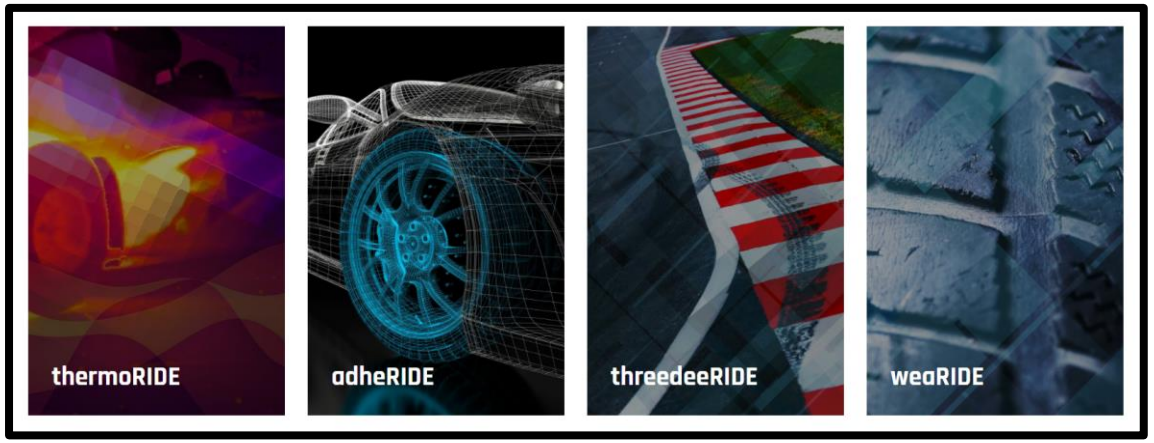
thermoRIDE

weaRIDE

MODELLING MULTIPHYSICS

3





CALIBRATION AND VALIDATION

RIDEsuite modules comprise:

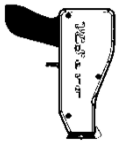
- MF-evo
- thermal model
- multicontact model
- tread wear&degradation model

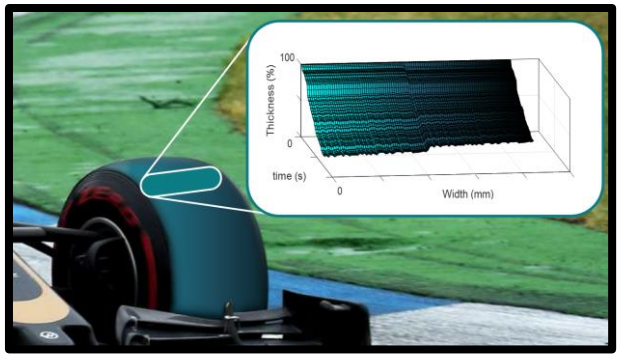
TIRE DIGITAL TWIN

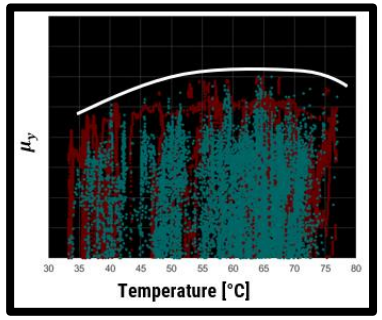
THE JOURNEY TO THE TIRE DIGITAL TWIN

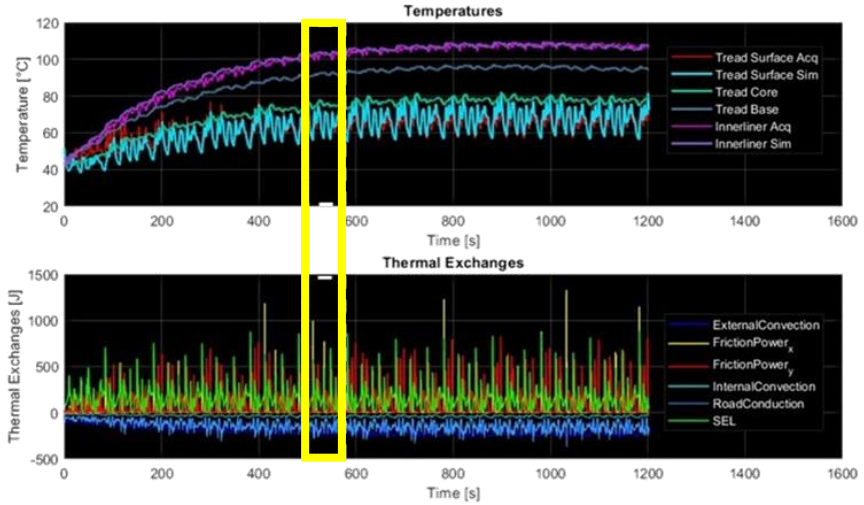
GETTING TIRE DATA

CHARACTERIZING MULTIPHYSICS

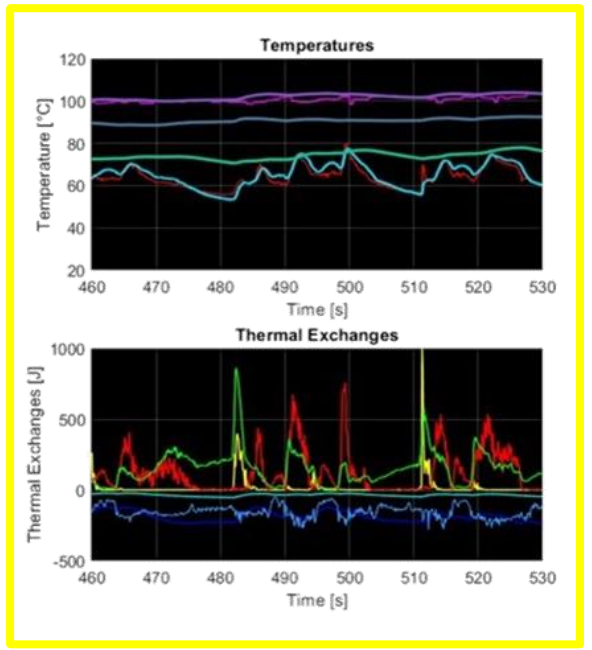








MODELLING MULTIPHYSICS



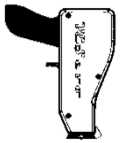
CALIBRATION AND VALIDATION

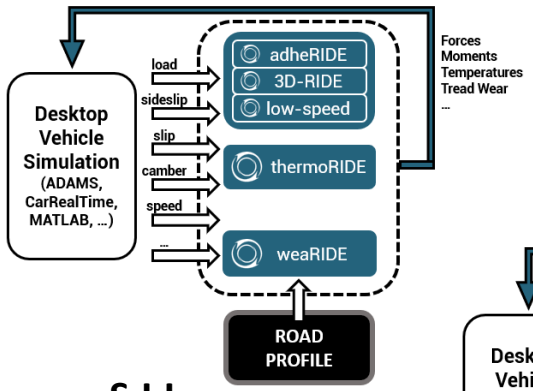
4

THE JOURNEY TO THE TIRE DIGITAL TWIN

GETTING TIRE DATA

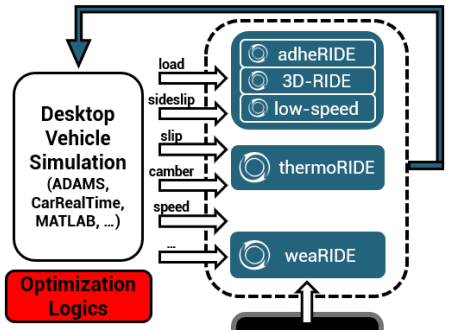
CHARACTERIZING MULTIPHYSICS



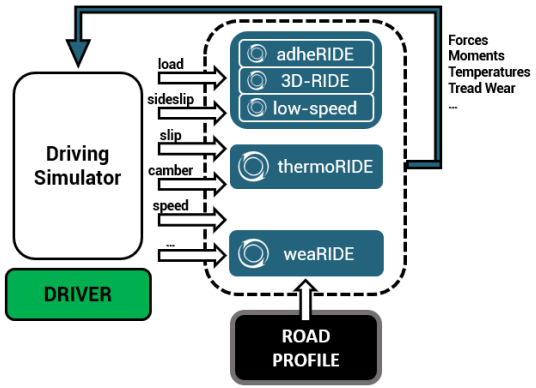


S.I.L. SCENARIO

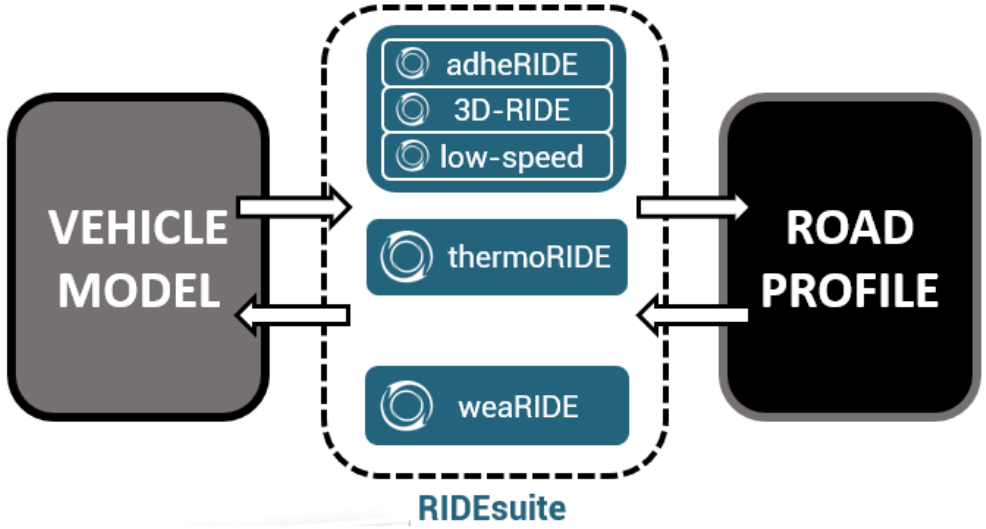
MODELLING MULTIPHYSICS



LAPTIME OPT. SCENARIO



D.I.L. SCENARIO



CALIBRATION AND VALIDATION

TIRE DIGITAL TWIN

COMPLIANCE WITH ANY INPUT SOLUTION

1. GETTING TIRE DATA

2. CHARACTERIZING MULTIPHYSICS

3. MODELLING MULTIPHYSICS

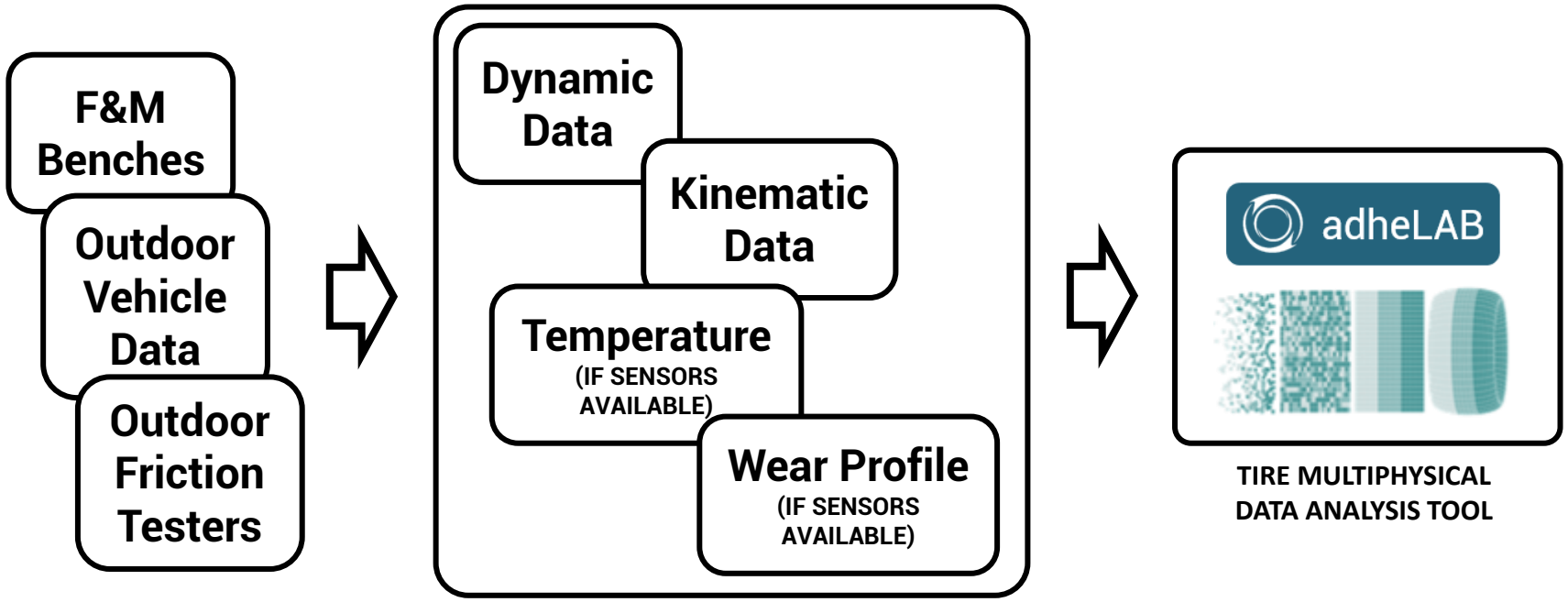
4. CALIBRATION AND VALIDATION

5. TIRE DIGITAL TWIN

The first step to "meet" the tire involves getting dynamic/kinematic data from it

Several methodologies currently allow to do it

MegaRide data analysis platform is compliant with tire data coming from any kind of acquisition system: benches, trailers or instrumented wheels



COMPLIANCE WITH ANY INPUT SOLUTION

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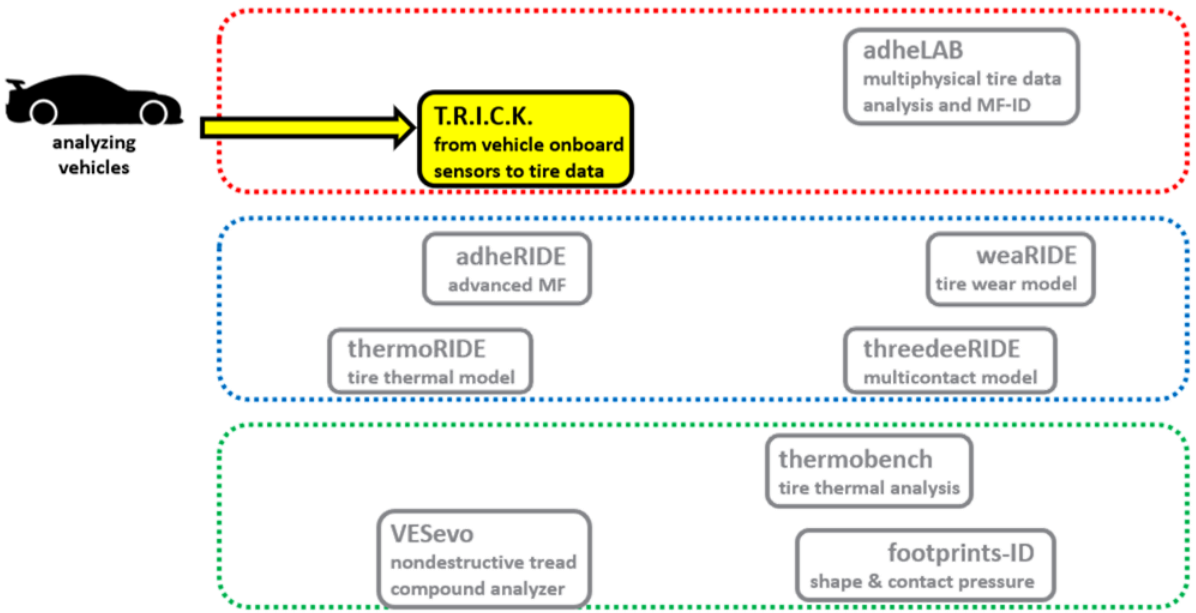
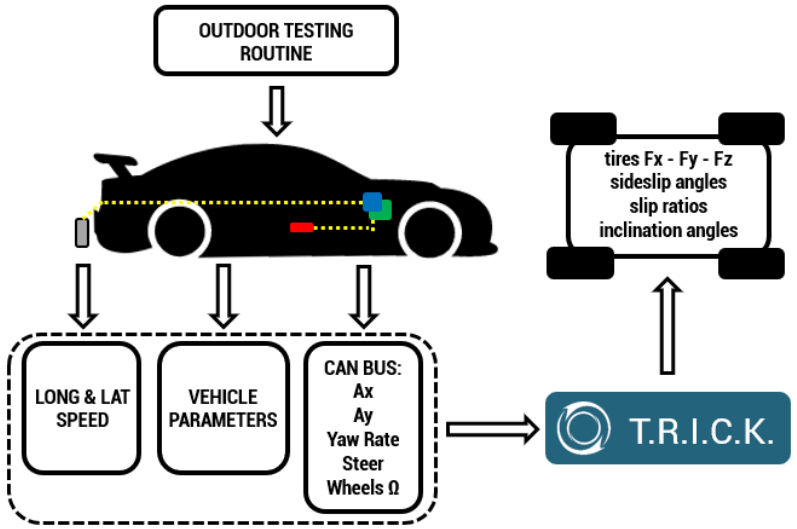
In case technologies for tire interaction forces measurement and evaluation are not available, the first step will concern the implementation of TRICK tool, able to "convert" vehicle sensors data in tire data, useful to analyze performance and to feed the processing tools





- **PHYSICAL VEHICLE MODEL**
- **FROM ONBOARD STANDARD SENSORS TO TIRE FORCES EVALUATION**
- **SPECIFIC OUTDOOR TESTING PROCEDURE**
- **REAL TIRES / REAL ROAD / REAL CONDITIONS**

* for further info:
F. Farroni – T.R.I.C.K.: Tire/Road Interaction Characterization & Knowledge – A tool for the evaluation of tire and vehicle performances in outdoor test sessions – Mechanical Systems and Signal Processing – 72-73 808-831 (2016)

COMPLIANCE WITH ANY INPUT SOLUTION

1. GETTING TIRE DATA

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4. CALIBRATION AND VALIDATION

5. TIRE DIGITAL TWIN

In the last 2 years, thanks to cooperations with partner companies, new specific releases of TRICK tool were developed:

- **TRICK4TRUCK (for heavy vehicles applications)** ⇨
- **TRICK4BIKE (for 2 wheeled vehicles)**
- **TRICK2.0 (working with CAN FD / CAN XL)**

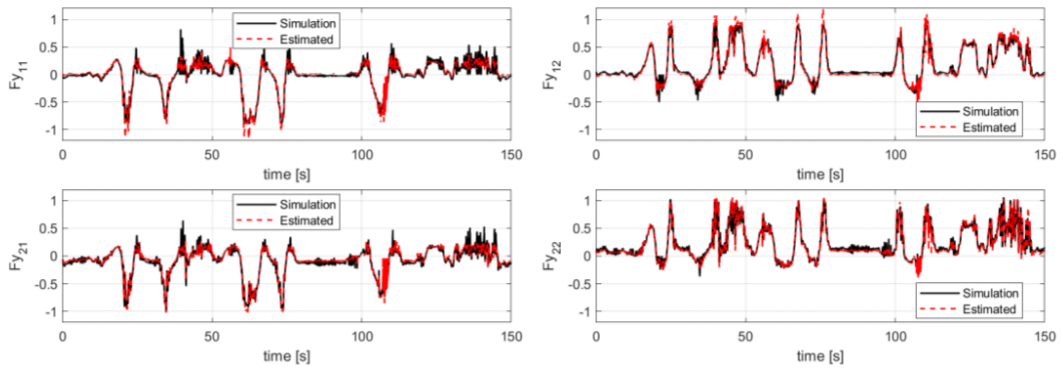


Figure 7. Simulated and estimated tire lateral force

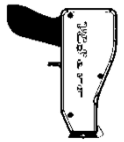
Further experiences with car manufacturers and smart tires producers, pushed our development of real-time onboard state observers, supporting TRICK in tire data creation from vehicle data

* for further info:
L. Mosconi, F. Farroni, A. Sakhnevych, F. Timpone, F. S. Gerbino – Adaptive vehicle dynamics state estimator for onboard automotive applications and performance analysis – Vehicle System Dynamics – Under Review

SMART IDEAS TO GET TIRE PARAMETERS

1. GETTING TIRE DATA

2. CHARACTERIZING MULTIPHYSICS



3. MODELLING MULTIPHYSICS

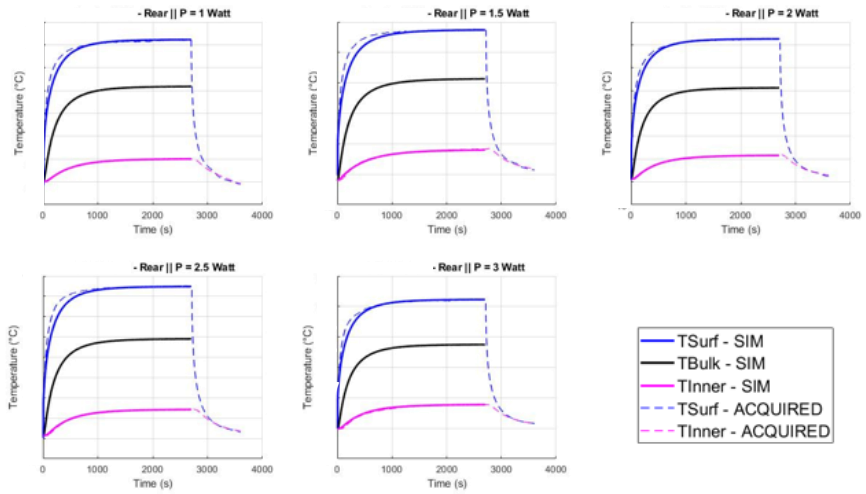
4. CALIBRATION AND VALIDATION

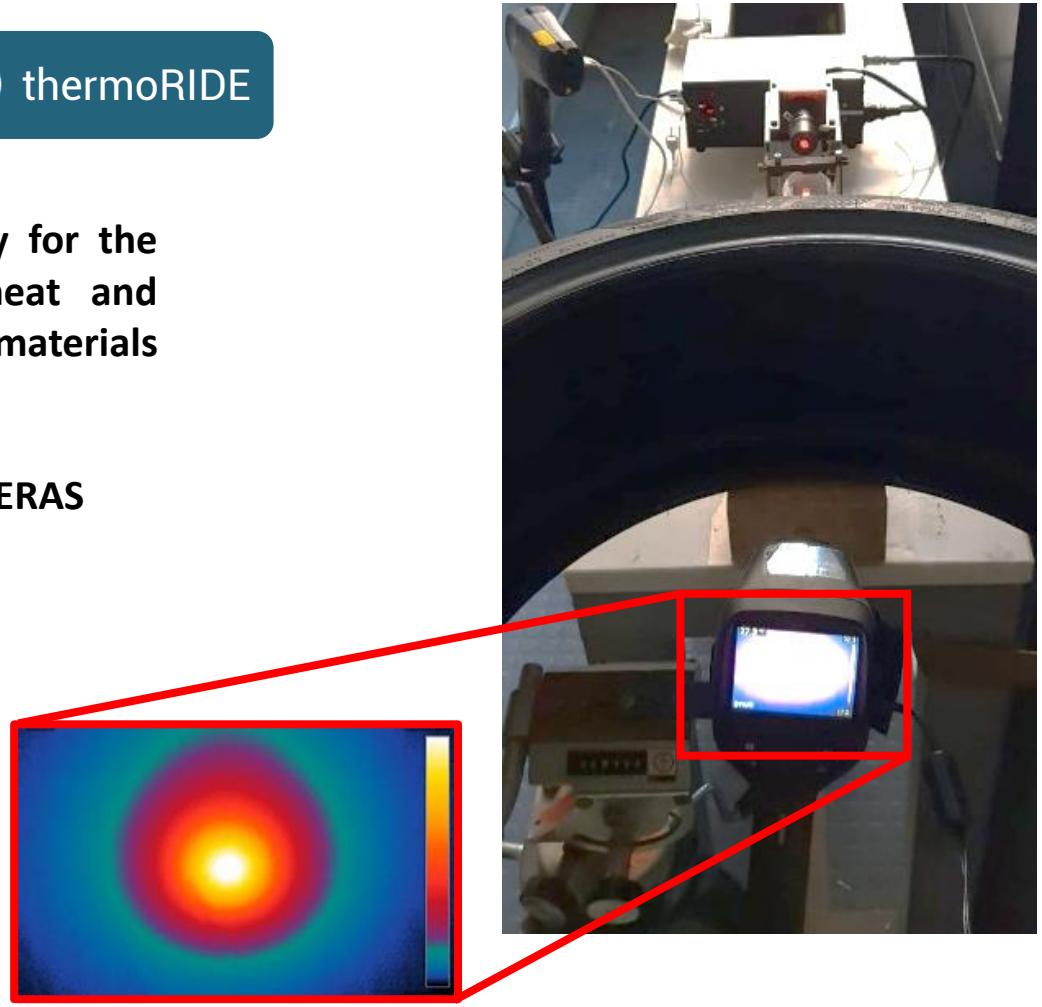
5. TIRE DIGITAL TWIN

thermal parameters ⇨ thermoRIDE

Innovative laser-based nondestructive methodology for the identification of thermal conductivity, specific heat and density characteristics vs temperature, of the materials constituting inner tire layers

- **ADOPTION OF HIGH-RESOLUTION THERMAL CAMERAS**
- **PORTABLE EXPERIMENTAL SETUP**
- **ANY TIRE SIZE AND BRAND**





* for further info:
C Allouis, F Farroni, A Sakhnevych, F Timpone – Tire thermal characterization: test procedure and model parameters evaluation – Proceedings of the World Congress on engineering 2016

SMART IDEAS TO GET TIRE PARAMETERS

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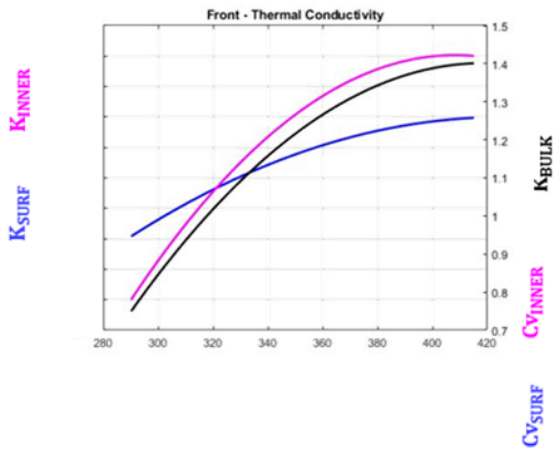

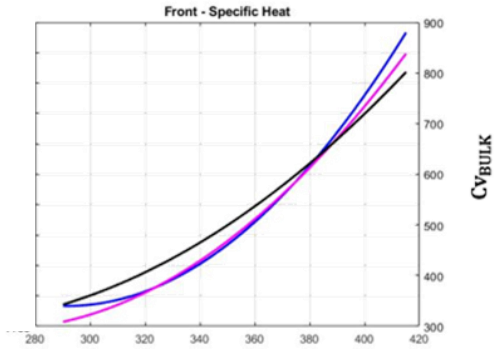

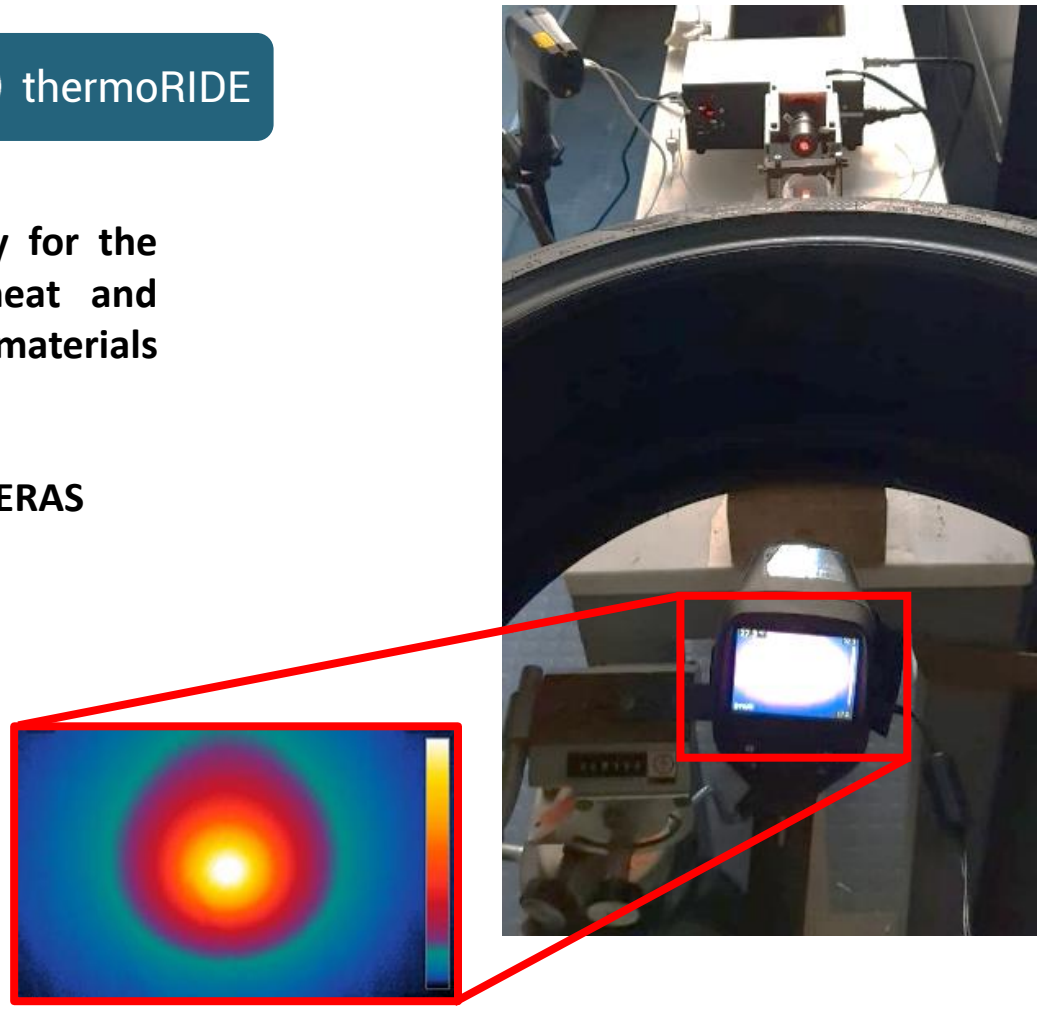

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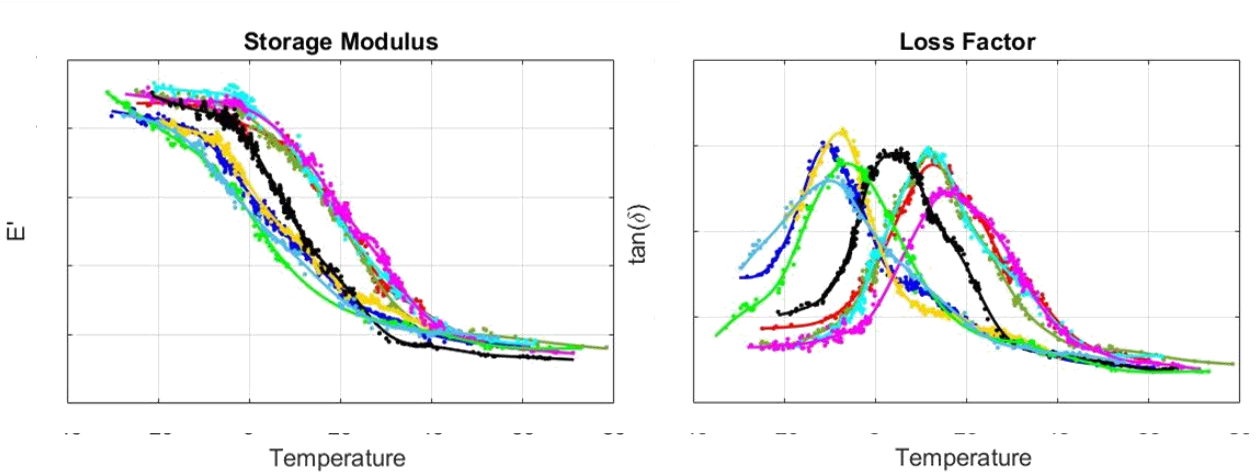
viscoelastic parameters ⇨ weaRIDE, VESevo

In the last year a new hardware has been developed and launched: VESevo tire compounds characterization device

- **NONDESTRUCTIVE TIRE VISCOELASTIC TESTING**
- **PORTABLE, FAST AND EASY TO USE**
- **LIVE TRACK DATA FOR DEVELOPING RACING STRATEGIES**
- **OBJECTIVE DATA FOR PHYSICAL GRIP AND WEAR MODELS**



SMART IDEAS TO GET TIRE PARAMETERS

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5. TIRE DIGITAL TWIN

viscoelastic parameters

weaRIDE

VESevo

QUALITY CHECK

COMPOUNDS CHARACTERIZATION

CURING EFFECTS

BRAND NEW TIRES:

WORKING TIRES:

CORRELATION WITH VEHICLE DATA ENERGY

PROGRESSIVE WEAR EFFECTS

RUN DISTANCE

SMART IDEAS TO GET TIRE PARAMETERS

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viscoelastic parameters

weaRIDE

VESevo

TyrePlex

VESevo Gun Is Helping Teams Master 2021 F1 Tyres

Le mystérieux pistolet qui aide les écuries F1 à maîtriser les pneus

Les équipes de F1 ont utilisé un "pistolet" italien novateur lors des essais de Bahreïn dans ce qui pourrait être une nouvelle tendance pour maîtriser les pneus 2021.

The mysterious gun helping teams master F1's 2021 tyres

Formula 1 teams have been spotted using an innovative Italian 'gun' in testing in what could be the latest move to get on top of the new 2021 tyres.

¿Qué es ese extraño 'martillo' para los neumáticos de F1?

The tech gun helping teams to master F1's 2021 tyres

Uitgelegd: F1-teams gebruiken mysterieus pistool voor bandenanalyse

Diese "Pistole" soll die Reifenanalyse in der Formel 1 revolutionieren

A titokzatos pisztoly, ami segíthet az F1-es csapatoknak megérteni a 2021-es gumikat

UK TIME NEWS

Read the World Today.

Tech gun helps teams master 2021 F1 tires

F1 takımları lastik analizi için gizemli bir çözüm kullanıyor: VESevo Tabancası

MOTORSPORT TOTAL.COM

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Diese "Pistole" soll die Reifenanalyse in der Formel 1 revolutionieren

Der technische Fortschritt in der Formel 1 geht immer weiter, ein italienisches Start-up könnte nun das heikle Thema Reifen revolutionieren

タイヤを理解するためのカギ？ F1テストに登場した秘密兵器"銃"の正体

SMART IDEAS TO GET TIRE PARAMETERS

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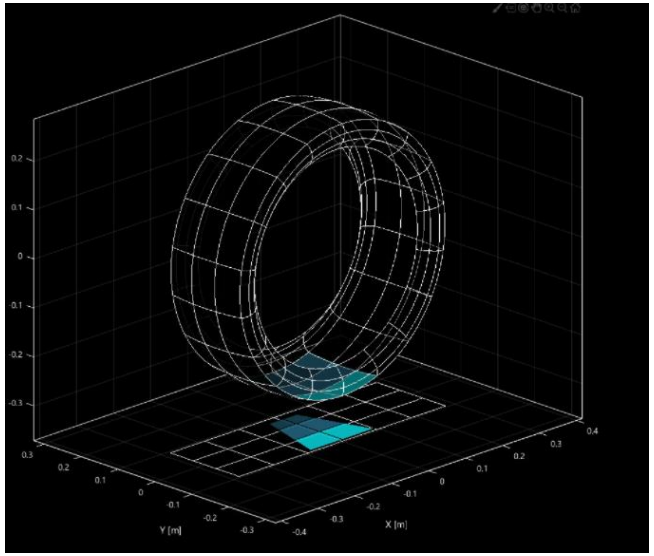
footprint analysis

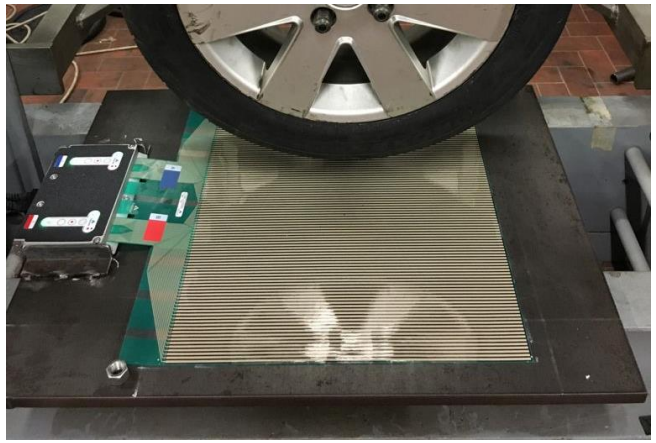
- thermoRIDE
- threedeeRIDE
- weaRIDE

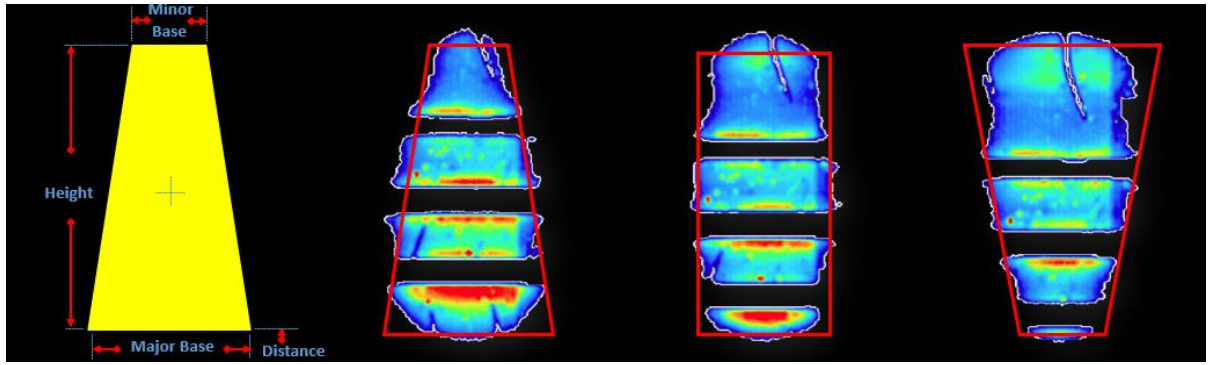
Tekscan bench now available @ Tire Lab

Hydraulic press allows to vary vertical load, inclination angle and inflation pressure, acquiring shape and pressure distribution

- **TEST ON CAR, MOTORBIKE AND LIGHT TRUCK TIRES**
- **PROPRIETARY TOOL FOR FOOTPRINTS "VIRTUALIZATION"**
- **DATA USED FOR THERMAL, WEAR AND MULTICONTACT MODELS**



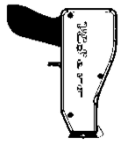




SMART IDEAS TO GET TIRE PARAMETERS

1. GETTING TIRE DATA

2. CHARACTERIZING MULTIPHYSICS



3. MODELLING MULTIPHYSICS

4. CALIBRATION AND VALIDATION

5. TIRE DIGITAL TWIN

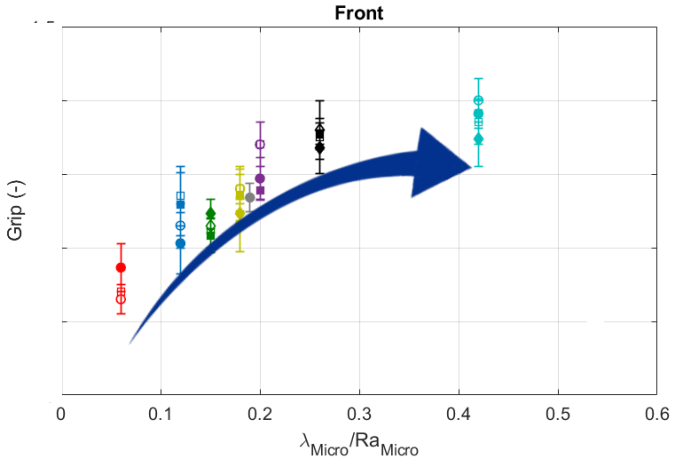
road roughness

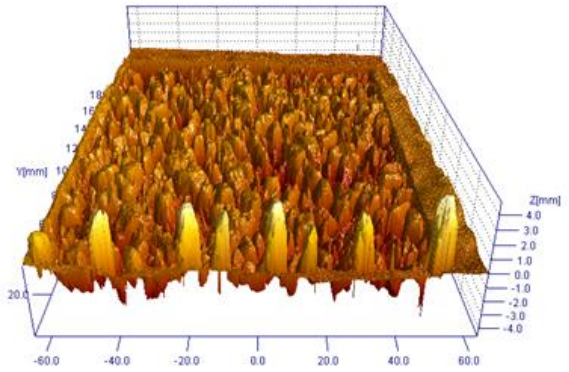
adheRIDE

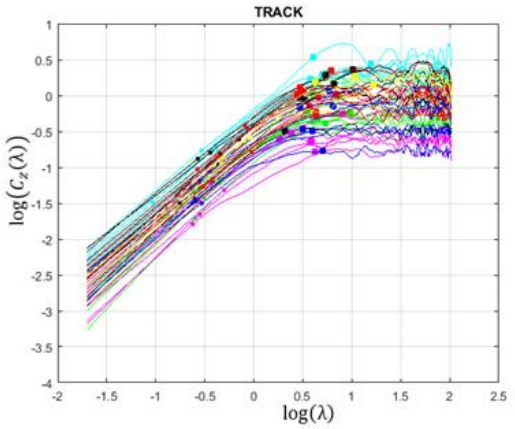
weaRIDE

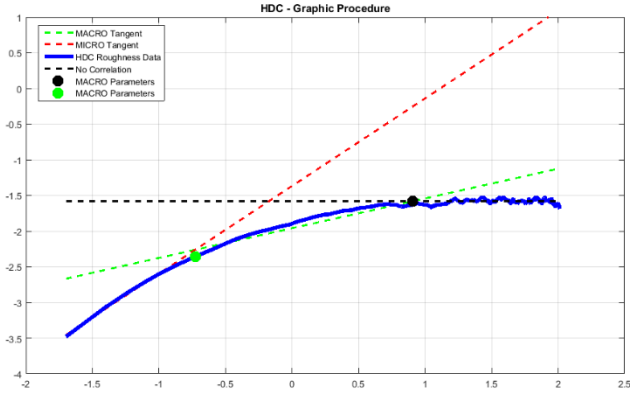
Scientific activities in the field of polymers science and road analysis brought to the development of tools for the identification of roughness parameters of tarmac profiles, useful for:

- **CORRELATION WITH TIRES FRICTION PERFORMANCES**
- **REPRODUCE TIRE SENSITIVITY TO DIFFERENT TRACKS**
- **THE PARAMETERIZATION OF PHYSICAL WEAR MODELS**









RIDEsuite: MODULARITY, PHYSICS & REALTIME

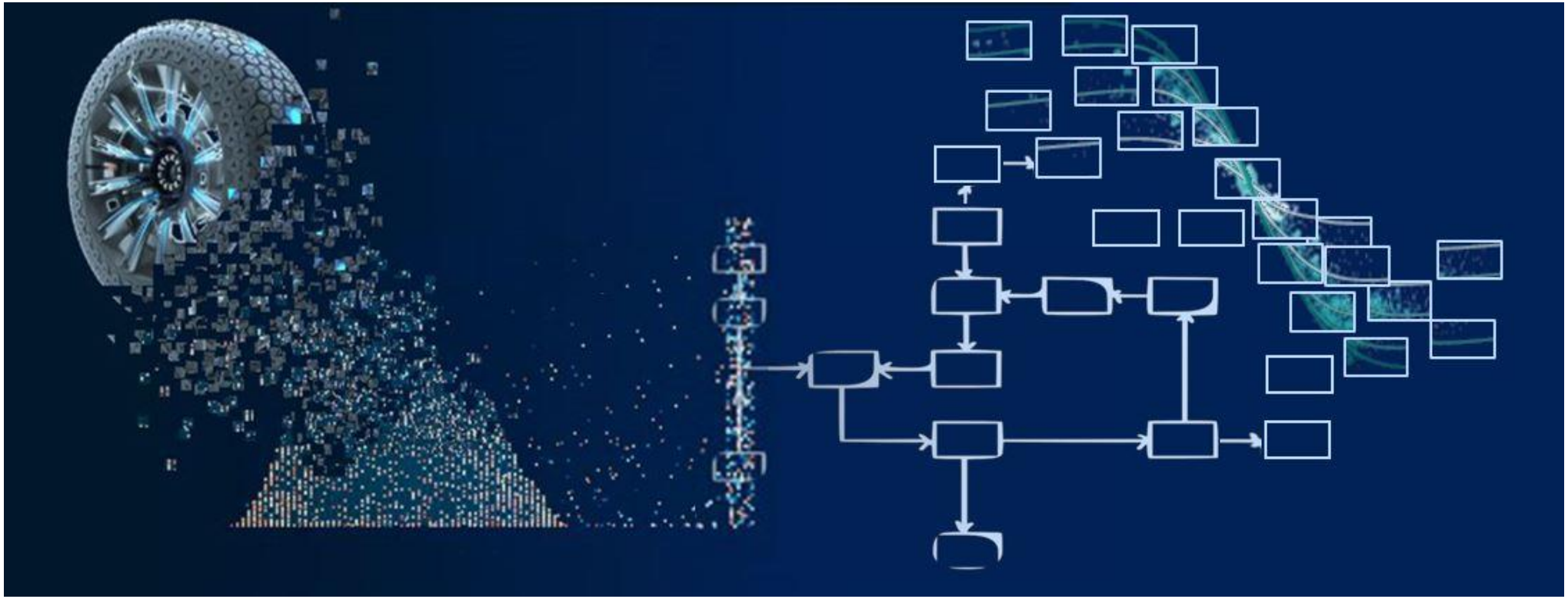
1. GETTING TIRE DATA

2. CHARACTERIZING MULTIPHYSICS

3. MODELLING MULTIPHYSICS

4. CALIBRATION AND VALIDATION

5. TIRE DIGITAL TWIN



Once obtained the physical parameters of the modules to activate in the RIDEsuite platform, it's time for implementing such data in the physical models

Each user can create his own tire physical model, selecting the modules deputed to analyze and reproduce different physical effects and phenomena: thermodynamics, road roughness interaction, viscoelasticity, wear…

Final aim: replicating tire multiphysical complexity, in real-time

RIDEsuite: MODULARITY, PHYSICS & REALTIME

1. GETTING TIRE DATA

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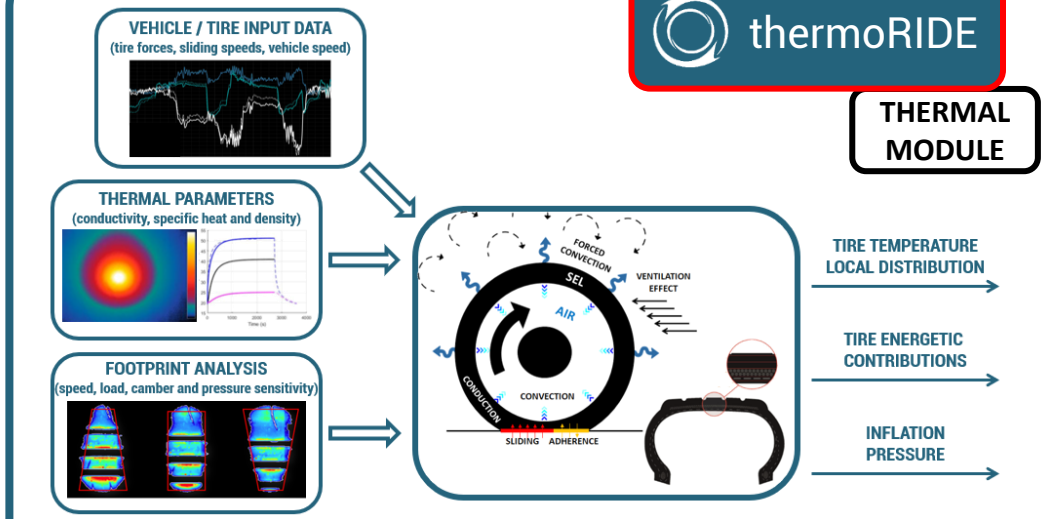
3. MODELLING MULTIPHYSICS

4. CALIBRATION AND VALIDATION

5. TIRE DIGITAL TWIN

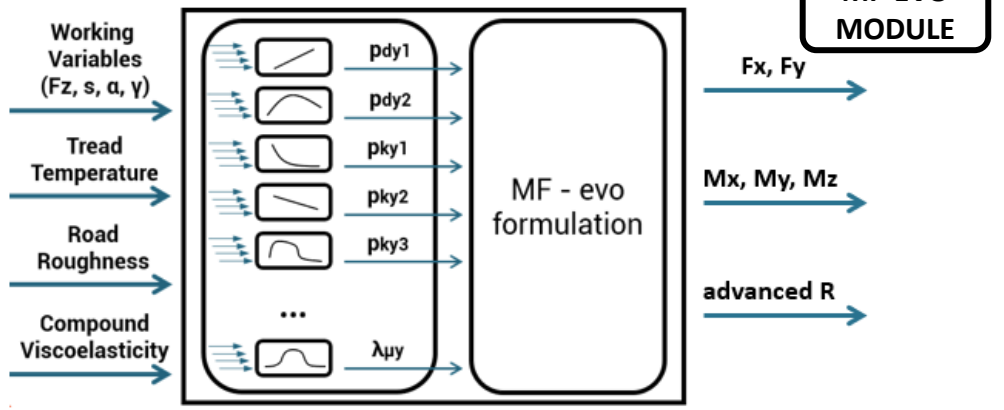
thermoRIDE

THERMAL MODULE



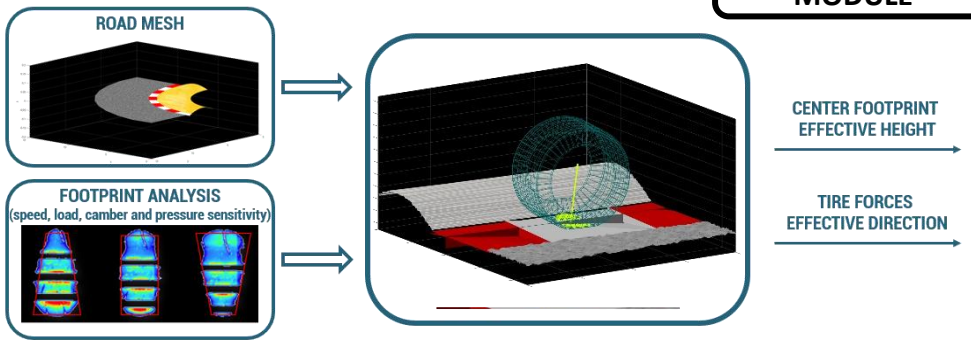
adheRIDE

MF-EVO MODULE



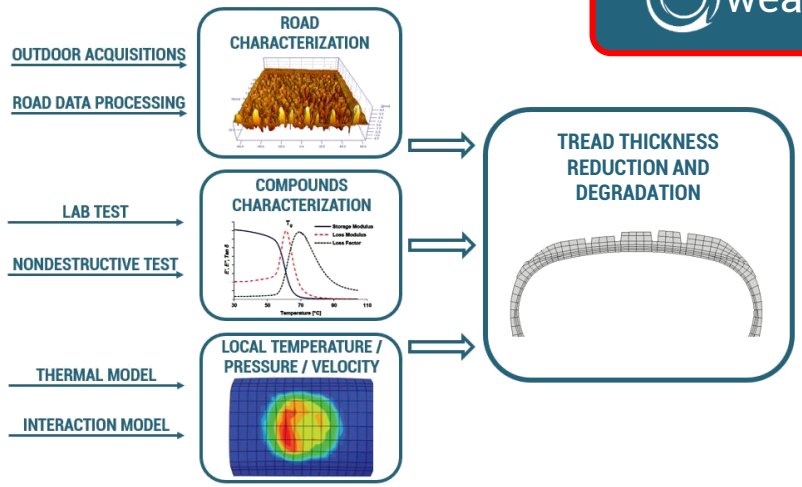
threedeeRIDE

MULTICONTACT MODULE



weaRIDE

WEAR MODULE



BACK TO THE TESTING GROUND

1. GETTING TIRE DATA

2. CHARACTERIZING MULTIPHYSICS

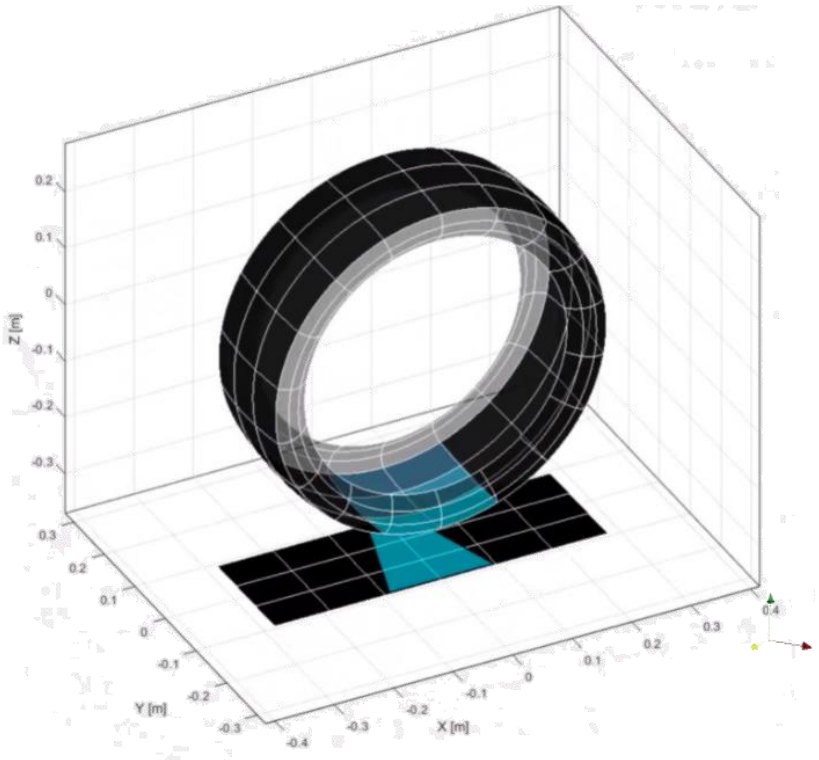
3. MODELLING MULTIPHYSICS

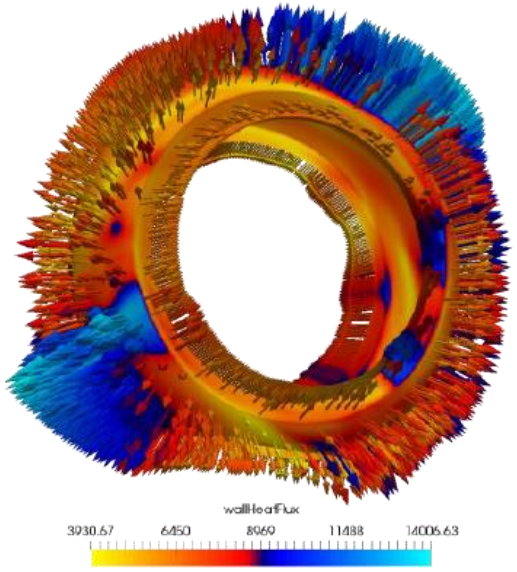
4. CALIBRATION AND VALIDATION

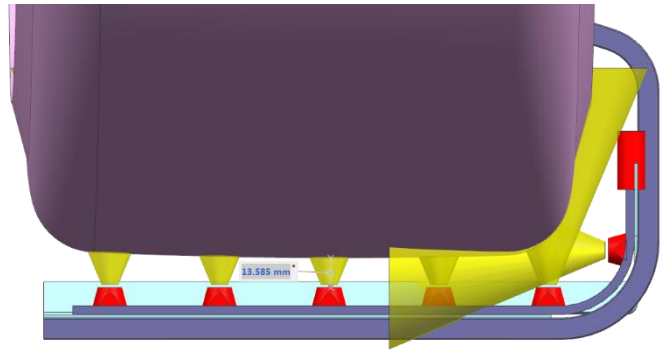
5. TIRE DIGITAL TWIN

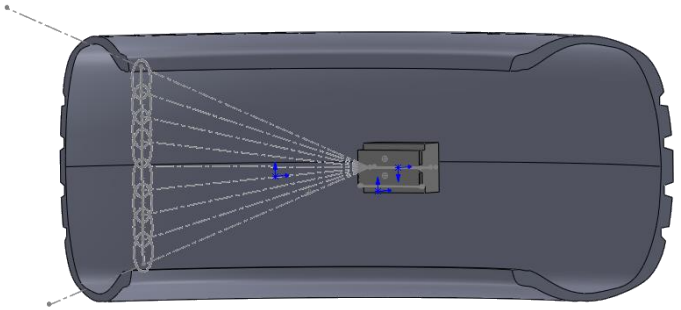
Once implemented the physical parameters, the data collected in specific track experimental sessions are used for the calibration of the effects requiring a dedicated effort:

- **footprint dynamic shape**
- **aero design acting on tire convection**
- **strain energy loss (SEL) evaluation**
- **wear/viscoelasticity correlations**
- **…**









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1. GETTING TIRE DATA

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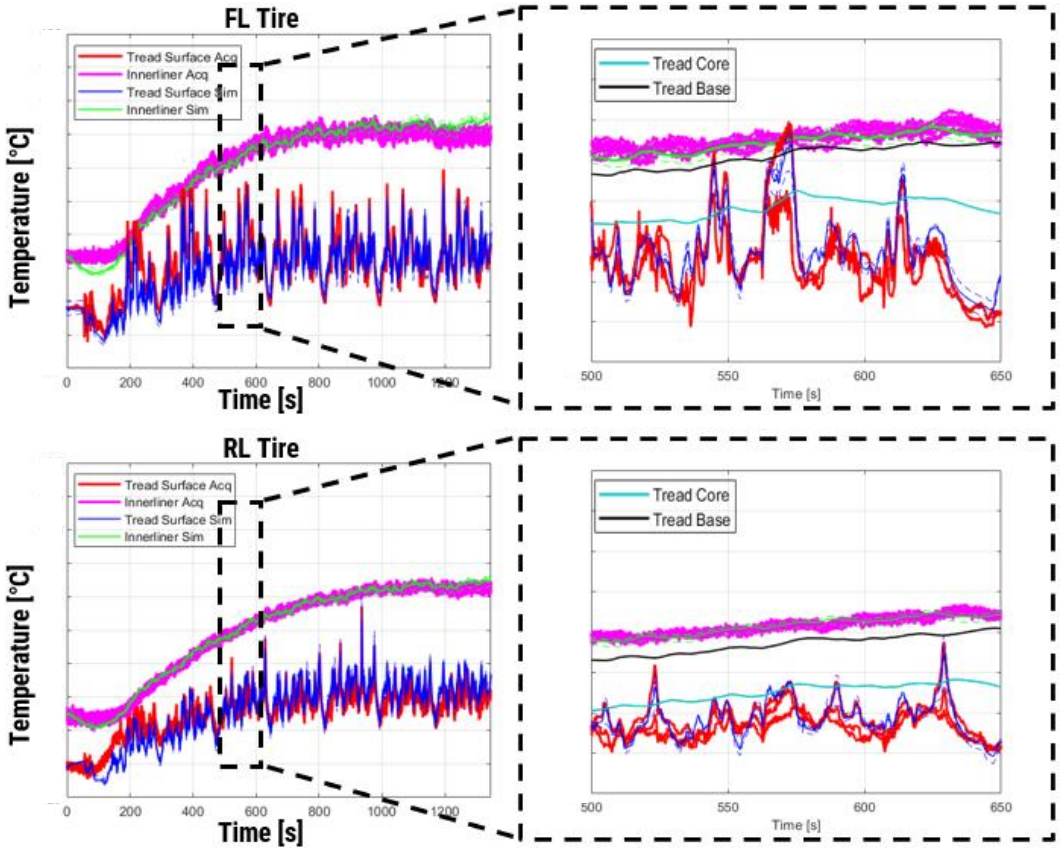
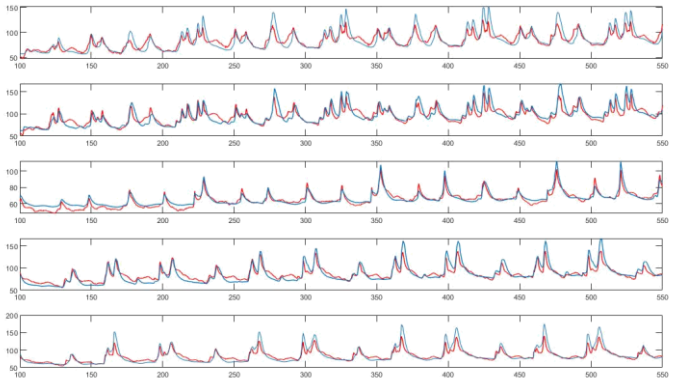
5. TIRE DIGITAL TWIN

Finally, the results from the models are validated in outdoor runs by means of the data acquired with proper instrumentation

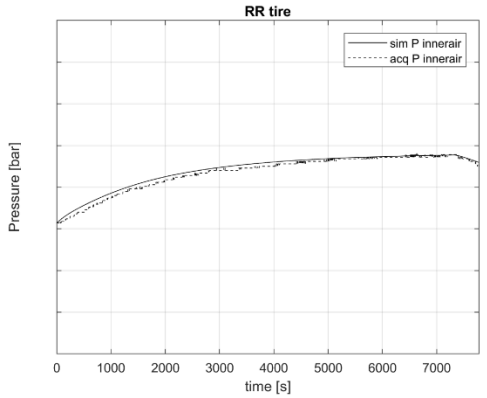
thermoRIDE



high-performance vehicle



thermoRIDE bike



inflation pressure

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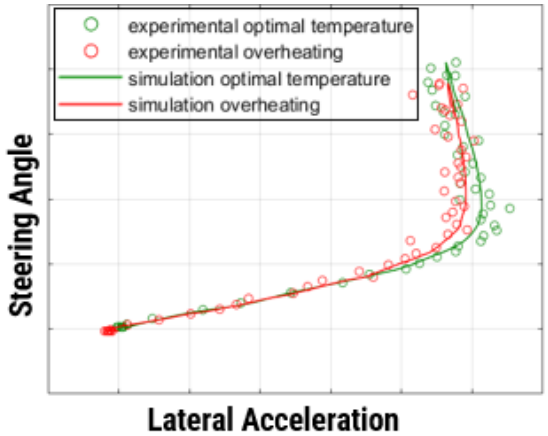
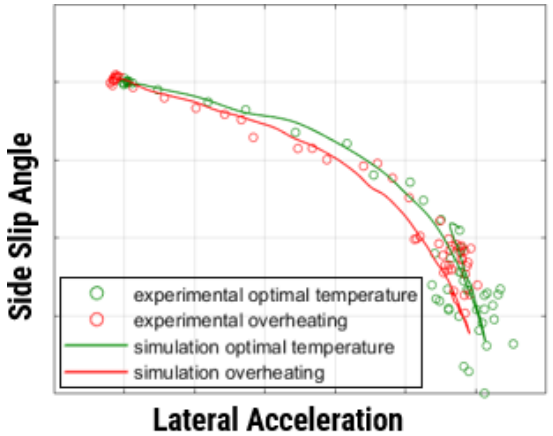
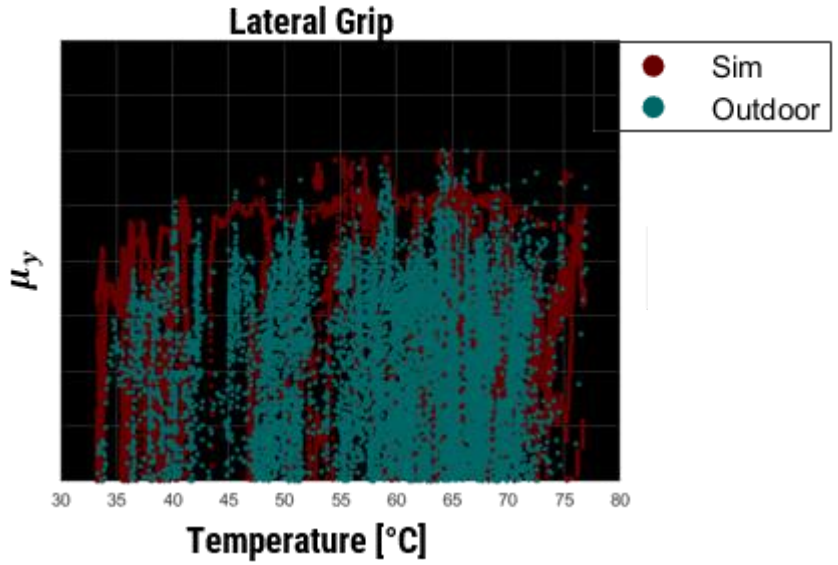
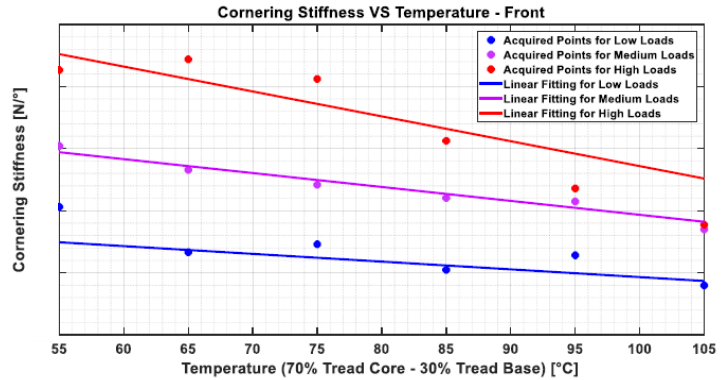
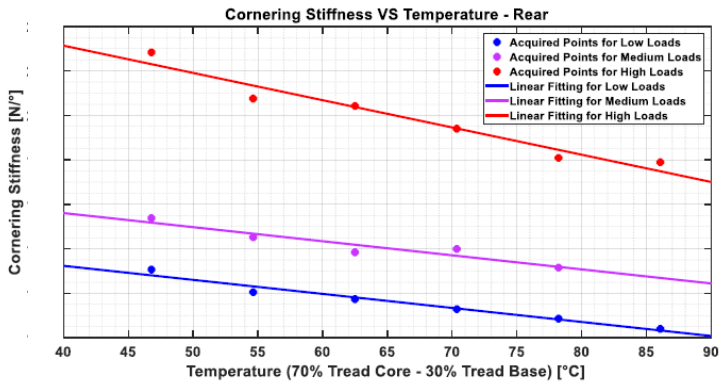
adheRIDE











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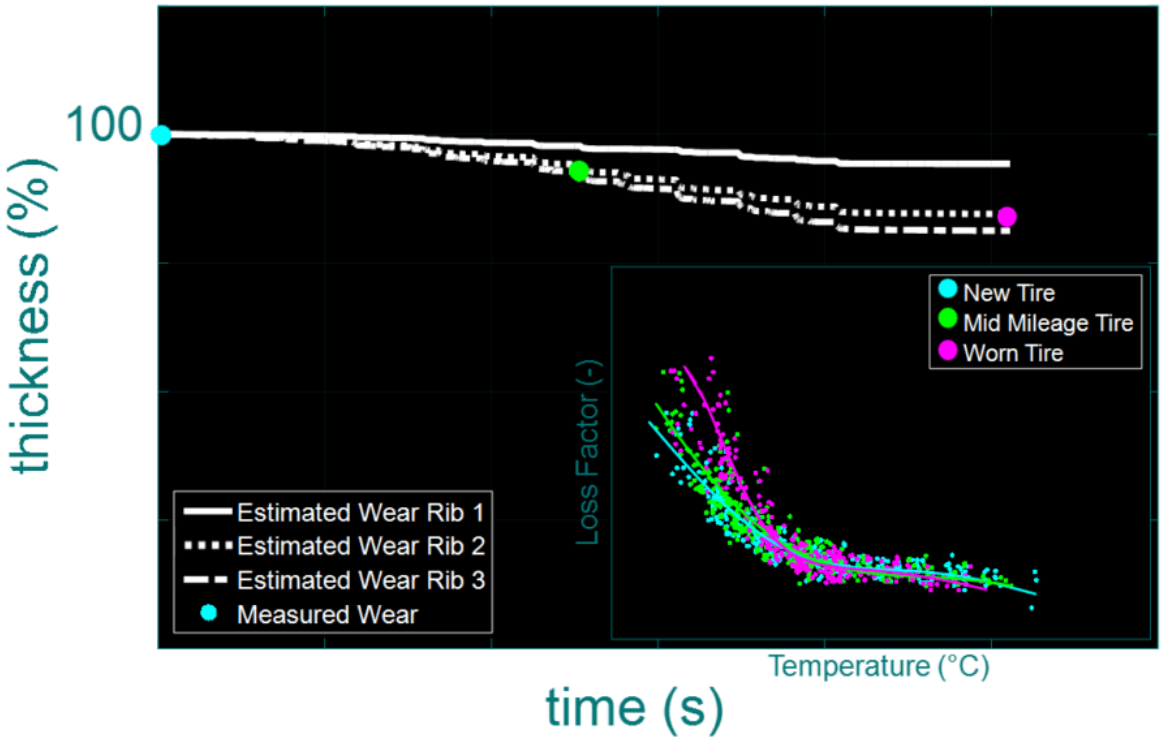
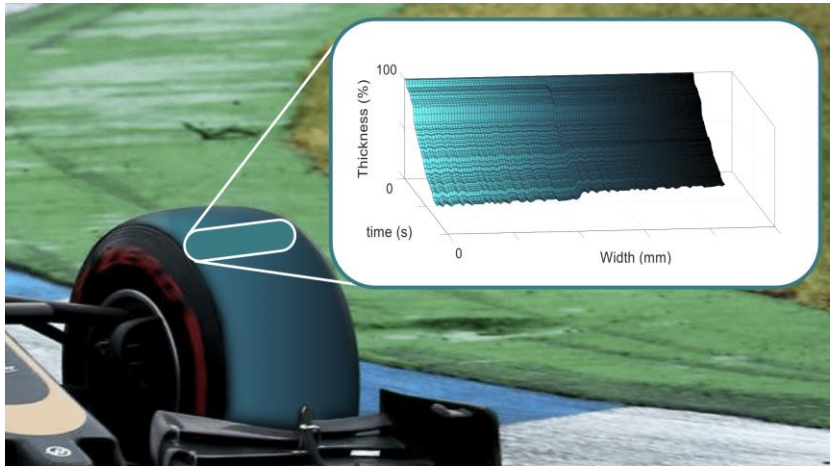
weaRIDE





BACK TO THE TESTING GROUND

1. GETTING TIRE DATA

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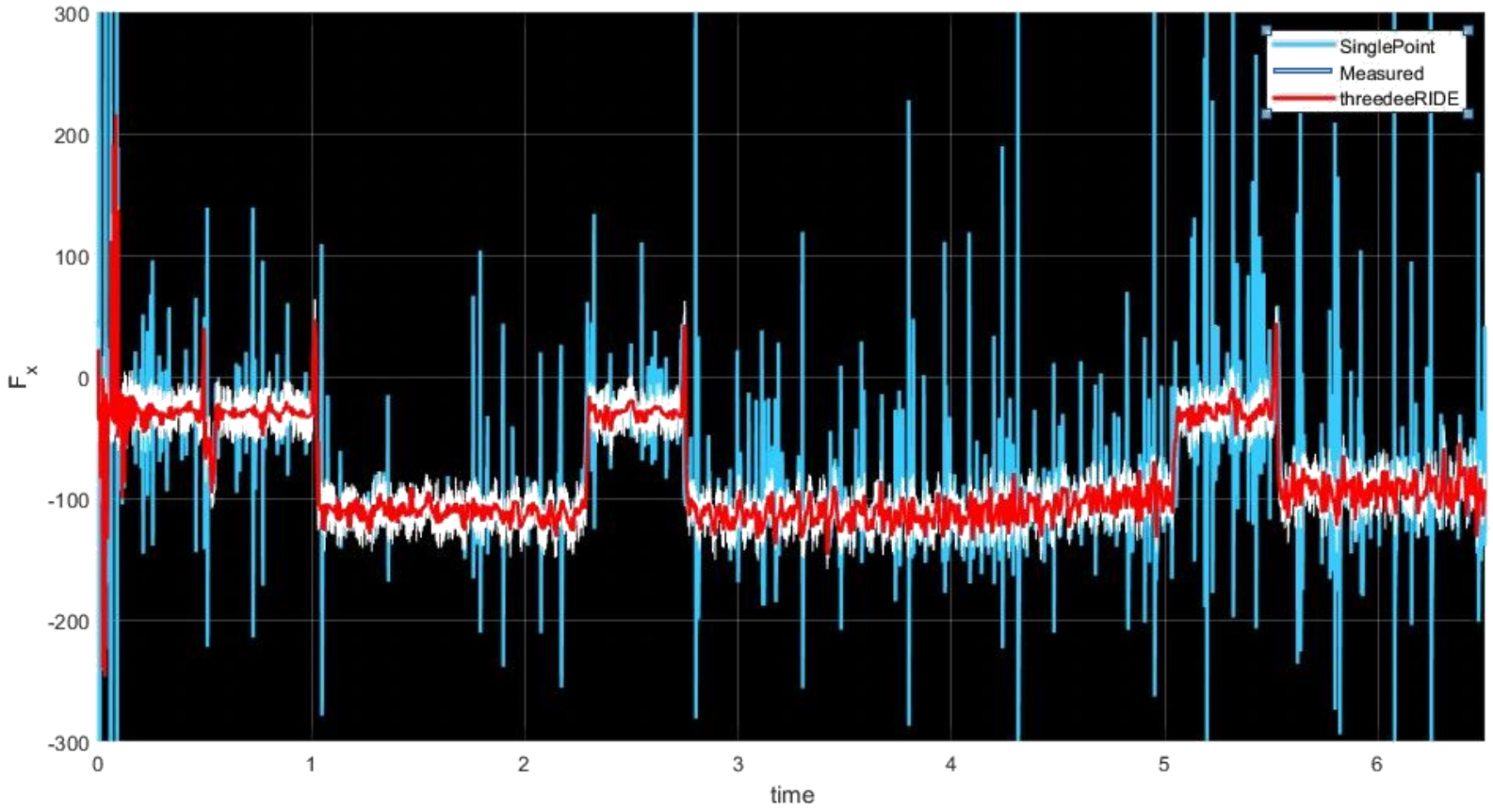
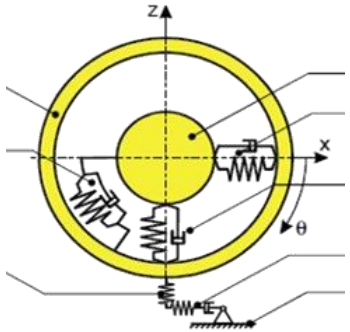
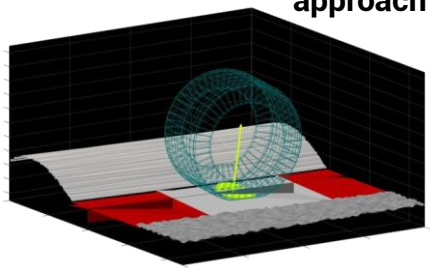
threedeeRIDE





conventional single-point contact

multi-contact threedeeRIDE approach



TIRE DIGITAL TWIN - SCENARIOS OF USE

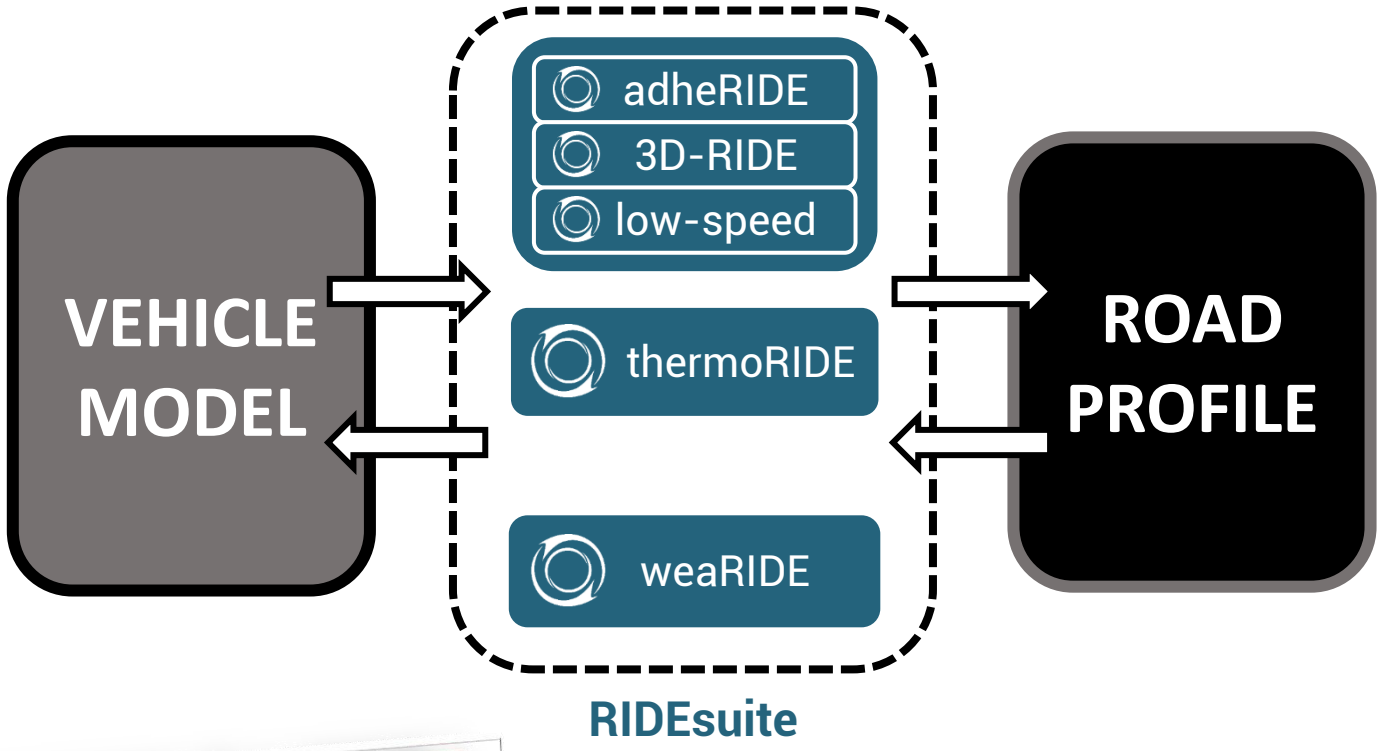
1. GETTING TIRE DATA

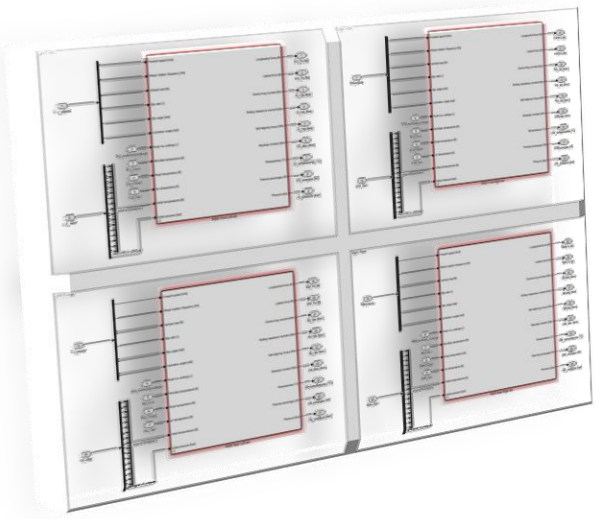
2. CHARACTERIZING MULTIPHYSICS

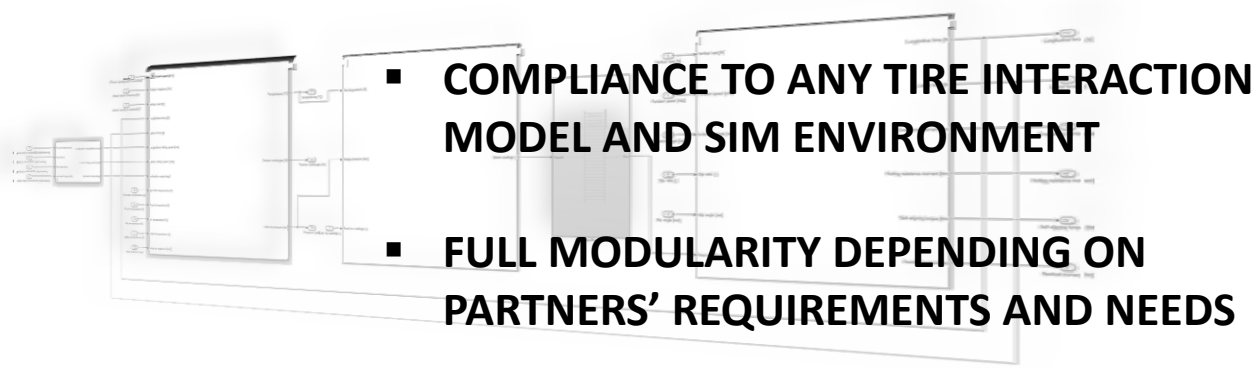
3. MODELLING MULTIPHYSICS

4. CALIBRATION AND VALIDATION

5. TIRE DIGITAL TWIN







- **COMPLIANCE TO ANY TIRE INTERACTION MODEL AND SIM ENVIRONMENT**
- **FULL MODULARITY DEPENDING ON PARTNERS' REQUIREMENTS AND NEEDS**

TIRE DIGITAL TWIN - STAND ALONE

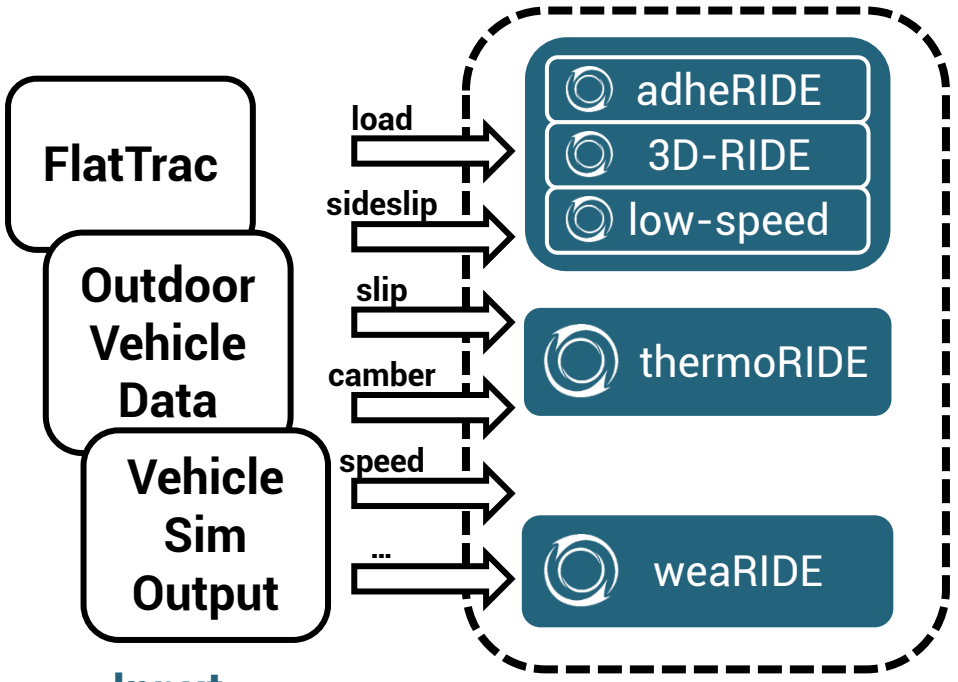
1. GETTING TIRE DATA

2. CHARACTERIZING MULTIPHYSICS

3. MODELLING MULTIPHYSICS

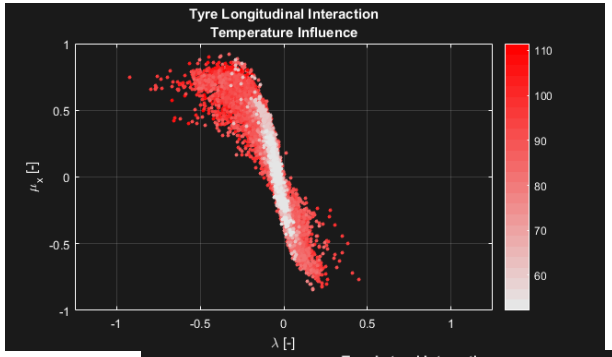
4. CALIBRATION AND VALIDATION

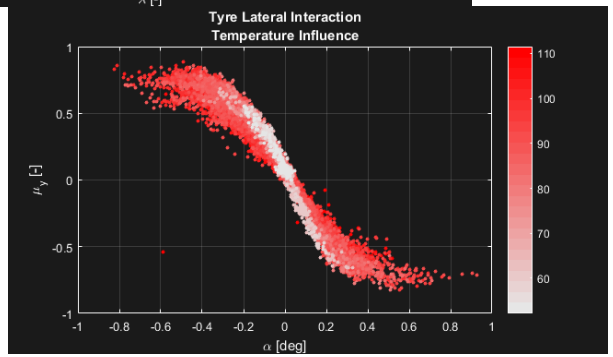
5. TIRE DIGITAL TWIN



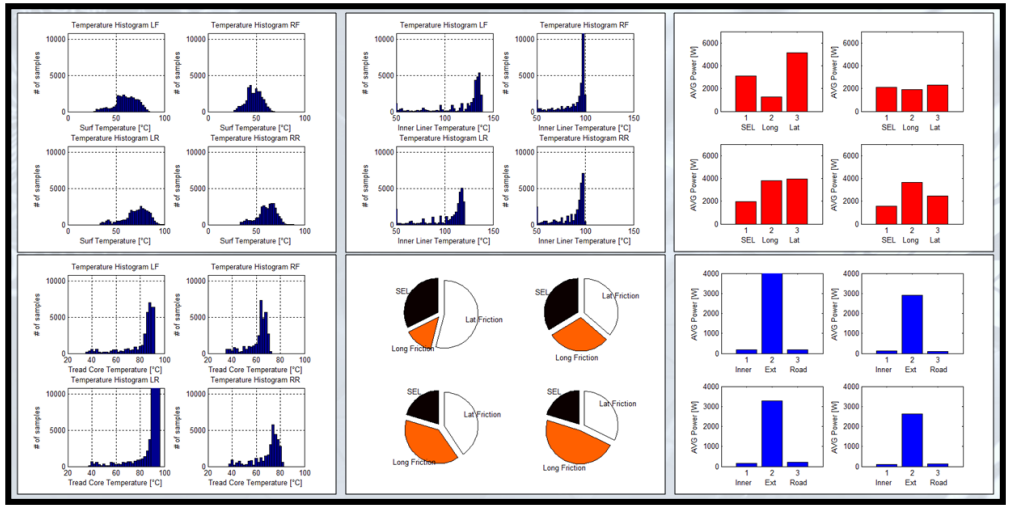
Input Acquisition

RIDEsuite





WARM-UP / HEAT EXCHANGE / THERMODYNAMIC OPTIMIZATION ANALYSIS



ANALYSIS ON TIRE DEPENDENCIES FROM INNER TEMPERATURE / WEAR / ROAD ROUGHNESS / TREAD VISCOELASTICITY

TIRE DIGITAL TWIN - "OFFLINE" SIMULATIONS

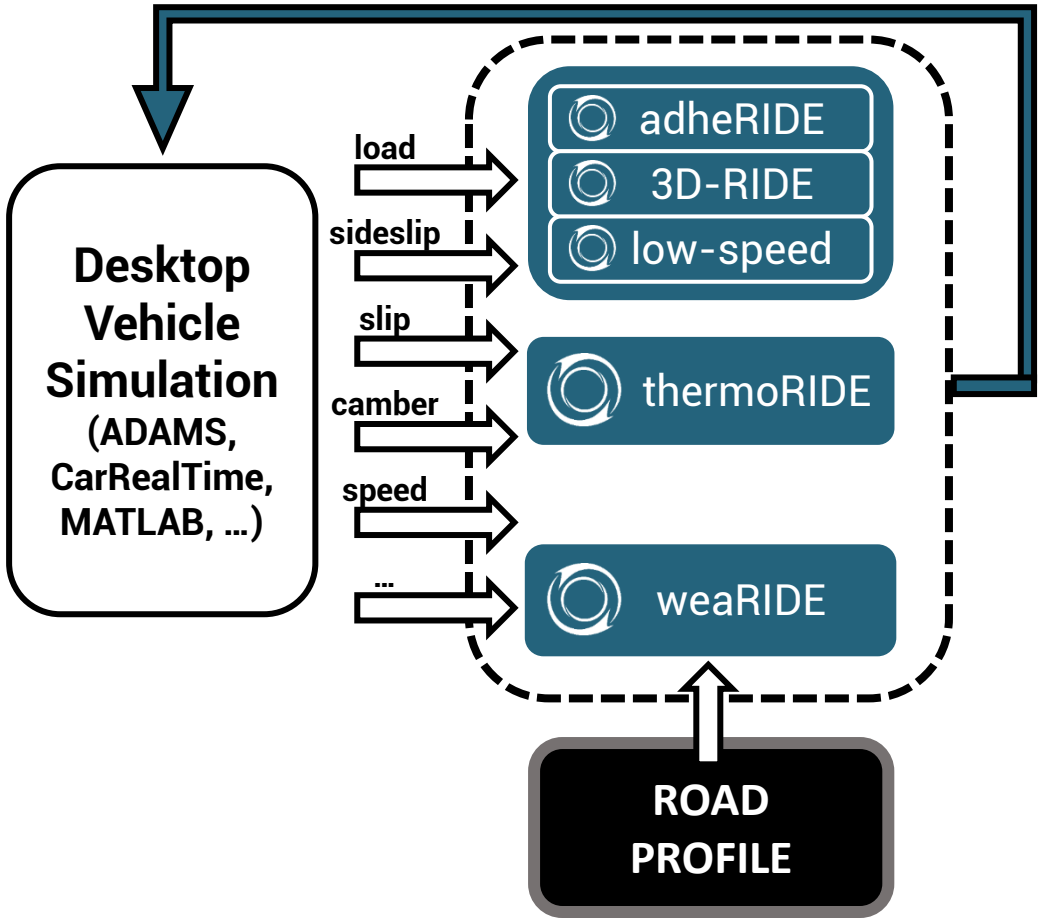
1. GETTING TIRE DATA

2. CHARACTERIZING MULTIPHYSICS

3. MODELLING MULTIPHYSICS

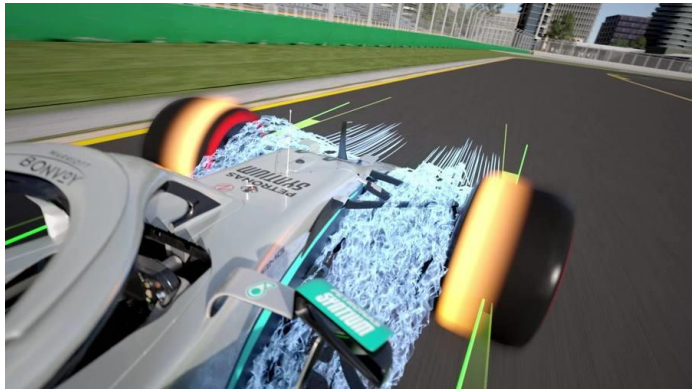
4. CALIBRATION AND VALIDATION

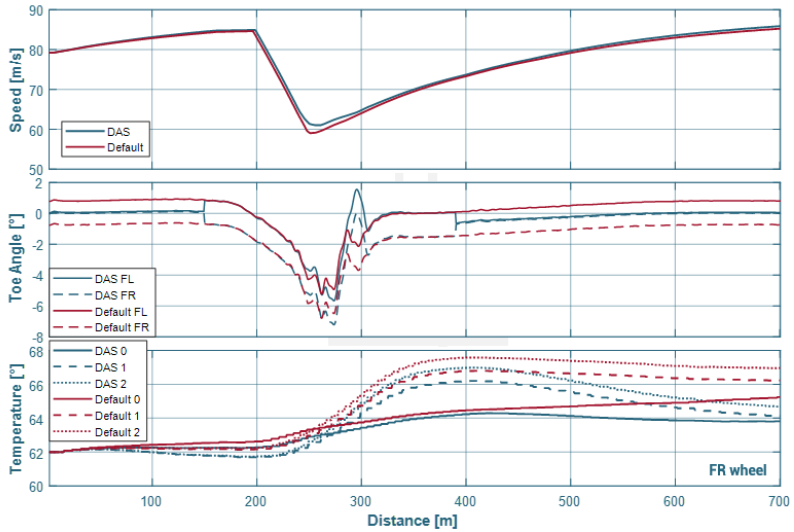
5. TIRE DIGITAL TWIN



Forces
Moments
Temperatures
Tread Wear
…

CASE STUDY: MERCEDES' DAS 2020

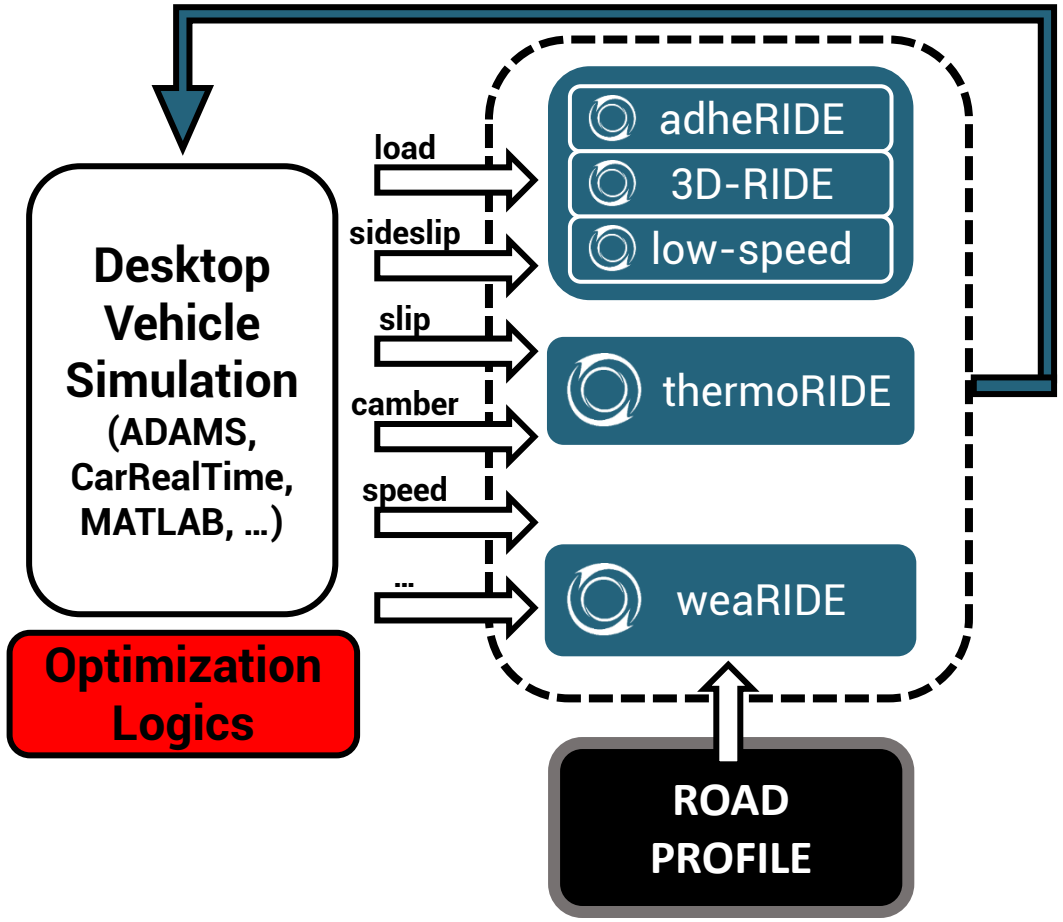




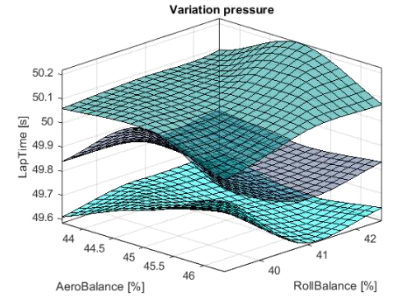
- **DYNAMIC SIMULATIONS FOR CAR / BIKE / TRUCK**
- **TIRES IN THE SIMULATION LOOP ACCOUNTING FOR THERMAL / WEAR / ROAD MESH / SPEED PHENOMENA**

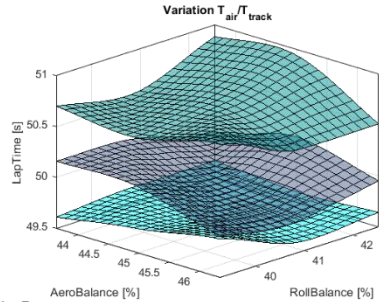
TIRE DIGITAL TWIN – LAPTIME OPTIMIZATION

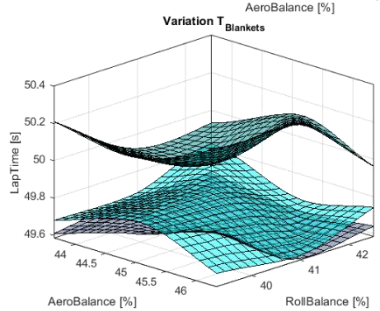
1. GETTING TIRE DATA
2. CHARACTERIZING MULTIPHYSICS
3. MODELLING MULTIPHYSICS
4. CALIBRATION AND VALIDATION
5. TIRE DIGITAL TWIN



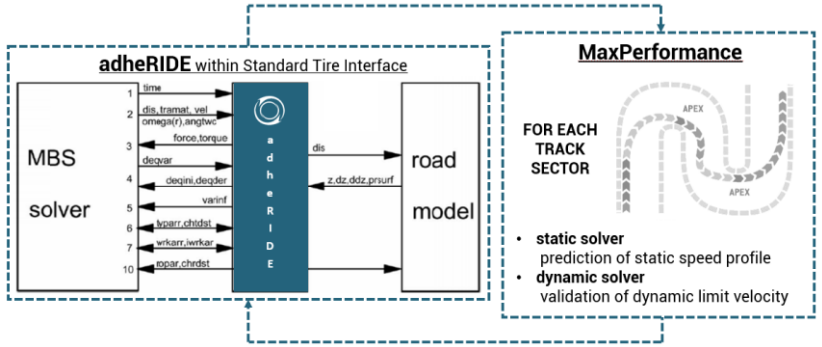
Forces
Moments
Temperatures
Tread Wear
…







- **ADVANCED SETUP OPTIMIZATION (INFLATION PRESSURE / BLANKETS TEMPERATURE / …)**
- **GRIP&STIFFNESS VARIATIONS WITH TEMPERATURE IN THE ITERATIVE OPTIMIZATION ALGORITHMS**



TIRE DIGITAL TWIN – REALTIME PLATFORMS

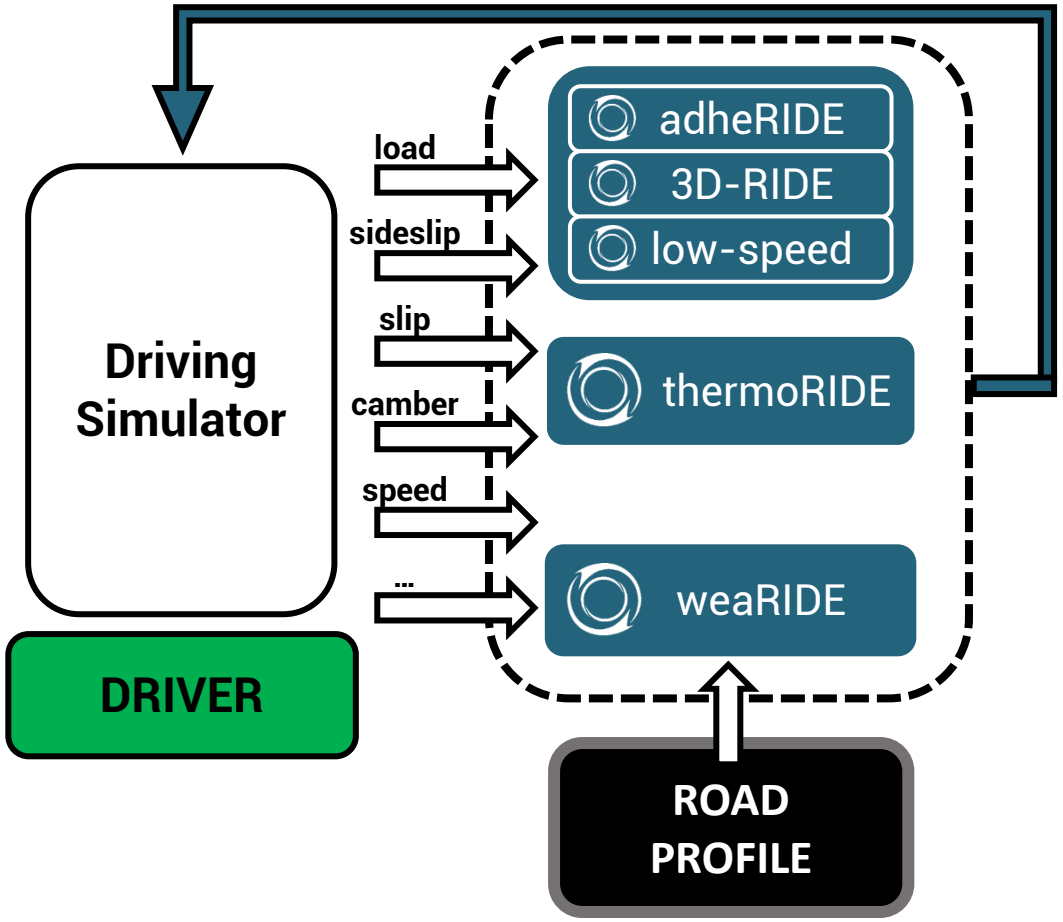
1. GETTING TIRE DATA

2. CHARACTERIZING MULTIPHYSICS

3. MODELLING MULTIPHYSICS

4. CALIBRATION AND VALIDATION

5. TIRE DIGITAL TWIN

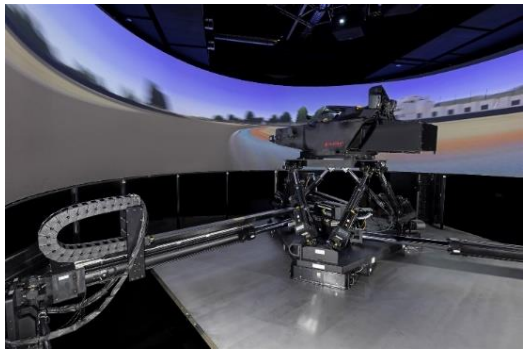


Forces
Moments
Temperatures
Tread Wear
...

- PHYSICAL MODELS OPTIMIZED FOR REALTIME
- ENHANCED FEELINGS FOR SUBJECTIVE ANALYSIS
- MULTICONTACT AND "LOW SPEED" RIDE MODELS

some of the RT users adopting RIDEsuite...

LUXURY AND RACING CAR MANUFACTURERS



MOTORSPORT TEAMS

PASSENGER AND GT VEHICLE MANUFACTURERS

WHAT NEXT?

TECHNICAL TARGETS

- RIDEsuite21 RELEASED IN JUNE 2021
- RIDEtool FEATURED IN RIDEsuite21
- adheLAB READY FOR THE MARKET

STRATEGIC TARGETS

- ENTERING NORTH AMERICAN AND JAPANESE MARKETS
- 3 NEW PHDs AND 6 RESOURCES TO HIRE IN 2021/22
- TIRE-CENTERED CONTROL: LAUNCH OF A NEW BUSINESS BRENCH

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Università degli Studi di Napoli "Federico II"

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