Real-time tire models for VI-CarRealTime and DiM applications: performance optimization, thermodynamics and innovative multi-physical Magic Formula

Flavio Farroni, Aleksandr Sakhnevych, Francesco Timpone,
Damiano Capra, Gianluca Salvato, Antonio Sorrentino

MEGARIDE
APPLIED VEHICLE RESEARCH

Università degli Studi di Napoli
Federico II

megaride

Mega Ride

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DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

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tire TECHNOLOGY INTERNATIONAL 2018 AWARDS FOR INNOVATION AND EXCELLENCE TIRE TECHNOLOGY OF THE YEAR

MODELS AND TECHNOLOGIES TO OPTIMIZE VEHICLE / ROAD INTERACTION

COMPANY HIGHLIGHTS

- “TIRE TECHNOLOGY OF THE YEAR” @ TIRE TECHNOLOGY EXPO 2018
- GROWING TEAM (x3) AND REVENUES (x10) IN 3 YEARS WITH NO DEBT / NO EQUITY
- EXCLUSIVE INTERACTIONS WITH TIREMAKERS AND MOTORSPORT TEAMS

RESEARCH HIGHLIGHTS

- AWARDED BY “M.I.T. YOUNG INNOVATORS UNDER 35” 2018
- VD RESEARCH GROUP RESOURCES FROM 6 TO 13 PEOPLE IN 3 YEARS
- SUPPORT OF “TYRE LAB” UNIVERSITY FACILITY FOR EXPERIMENTAL ACTIVITIES

GROWTH PATH

"TIRE TECHNOLOGY OF THE YEAR"
@ TIRE TECHNOLOGY EXPO 2018

GROWING TEAM (x3) AND REVENUES (x10)
IN 3 YEARS WITH NO DEBT / NO EQUITY

EXCLUSIVE INTERACTIONS
WITH MOTORSPORT TEAMS

Jun-Dec 2016

Jan-May 2017

Jun-Sep 2017

Oct-Dec 2017

Jan-Jun 2018

Jul-Dec 2018

Jan-Apr 2019


thermoRIDE
Real-Time Tire Thermal Model


adheRIDE
Advanced Pacejka Tire Modelling

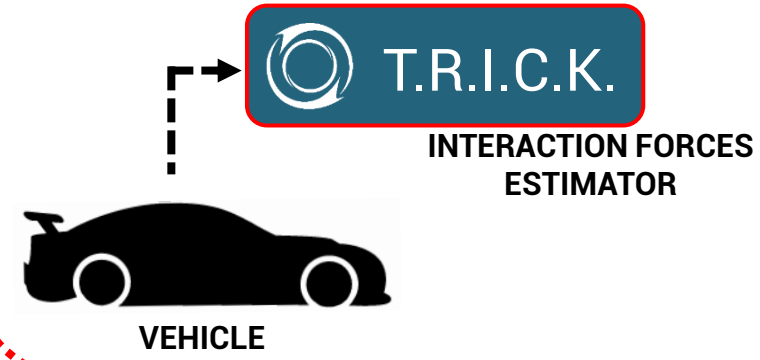

T.R.I.C.K.
Tire-Road Interaction Characterization & Knowledge


TRIP-ID
Tire-Road Interaction Parameters Identificator

A MODULAR PLATFORM FOR TIRE ANALYSIS AND MODELLING

SCENARIO I

vehicle and tires development



T.R.I.C.K.: Tyre/Road Interaction Characterization & Knowledge

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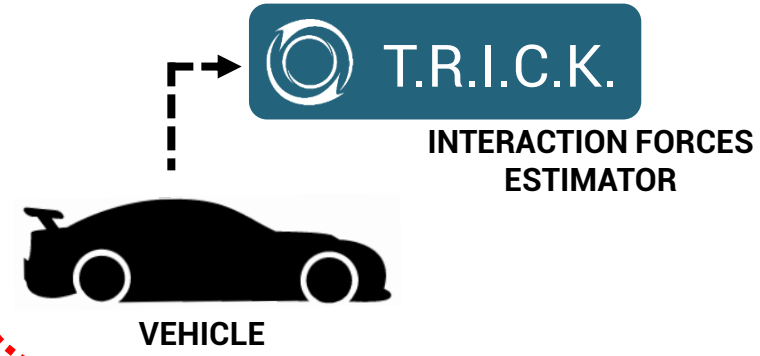
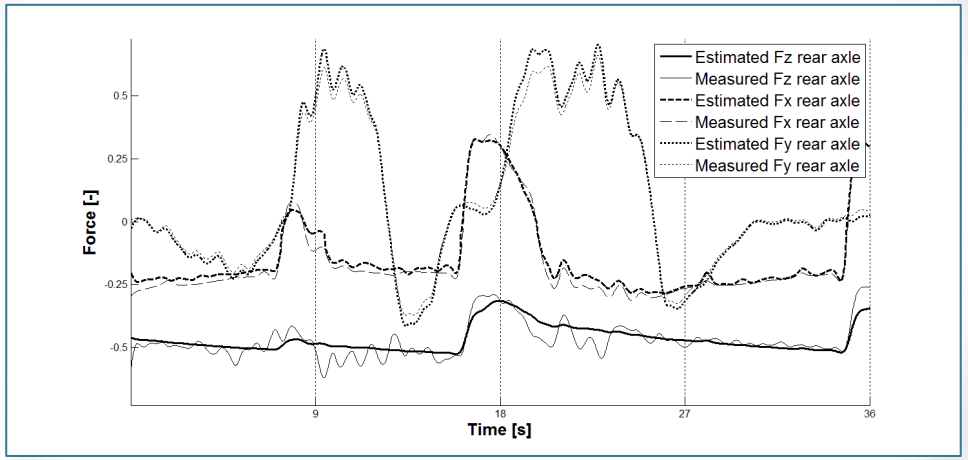
SCENARIO I
vehicle and tires development



T.R.I.C.K.: Tyre/Road Interaction Characterization & Knowledge

- characterize the tires using the vehicle as a "moving lab"

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



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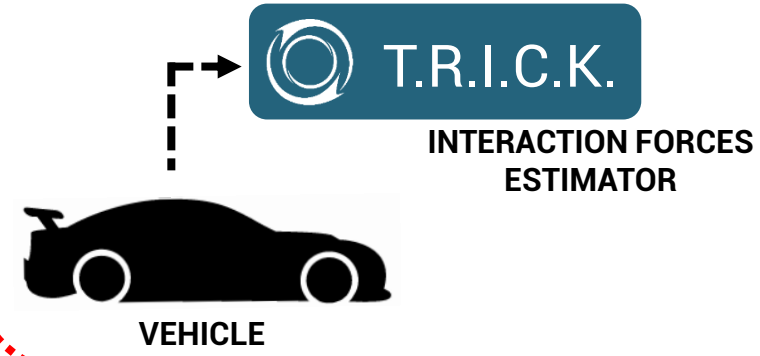
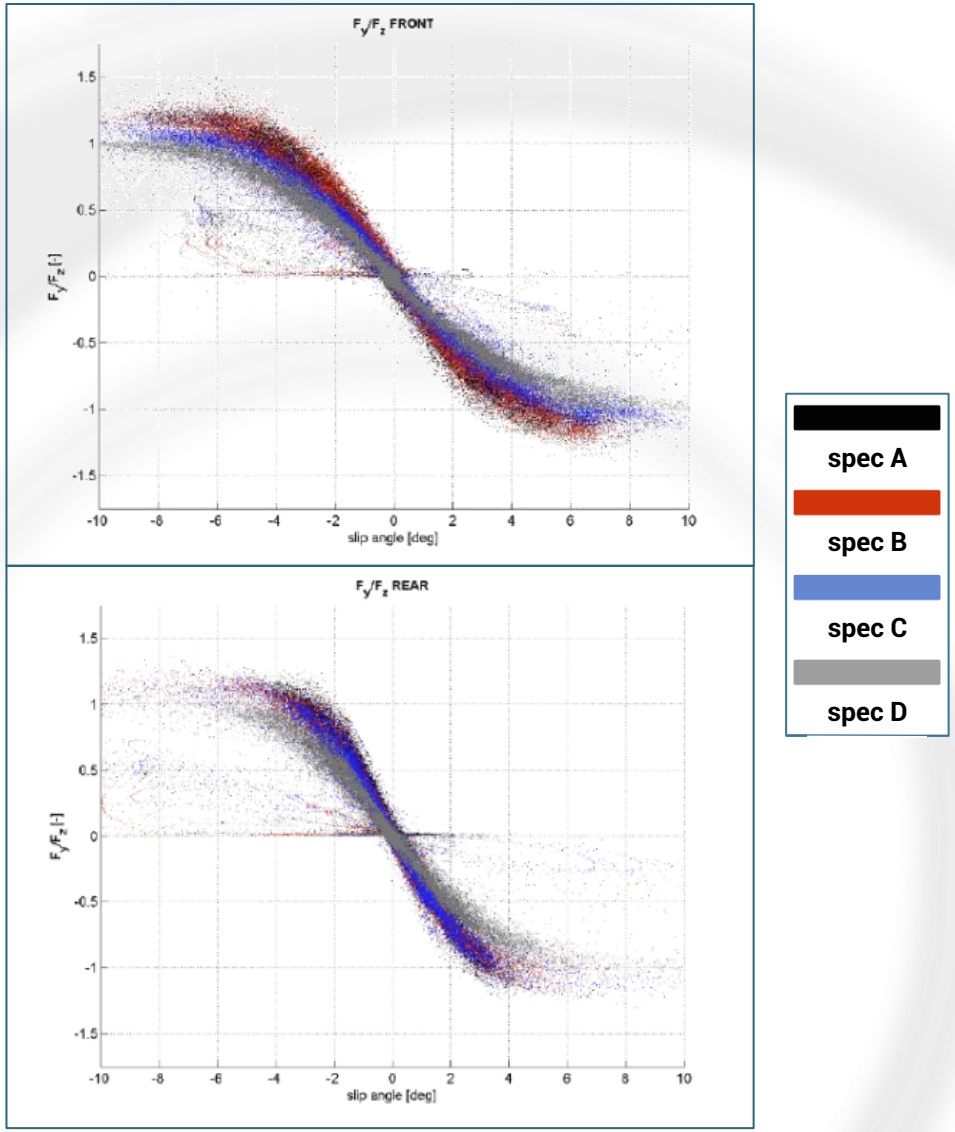
SCENARIO I
vehicle and tires development



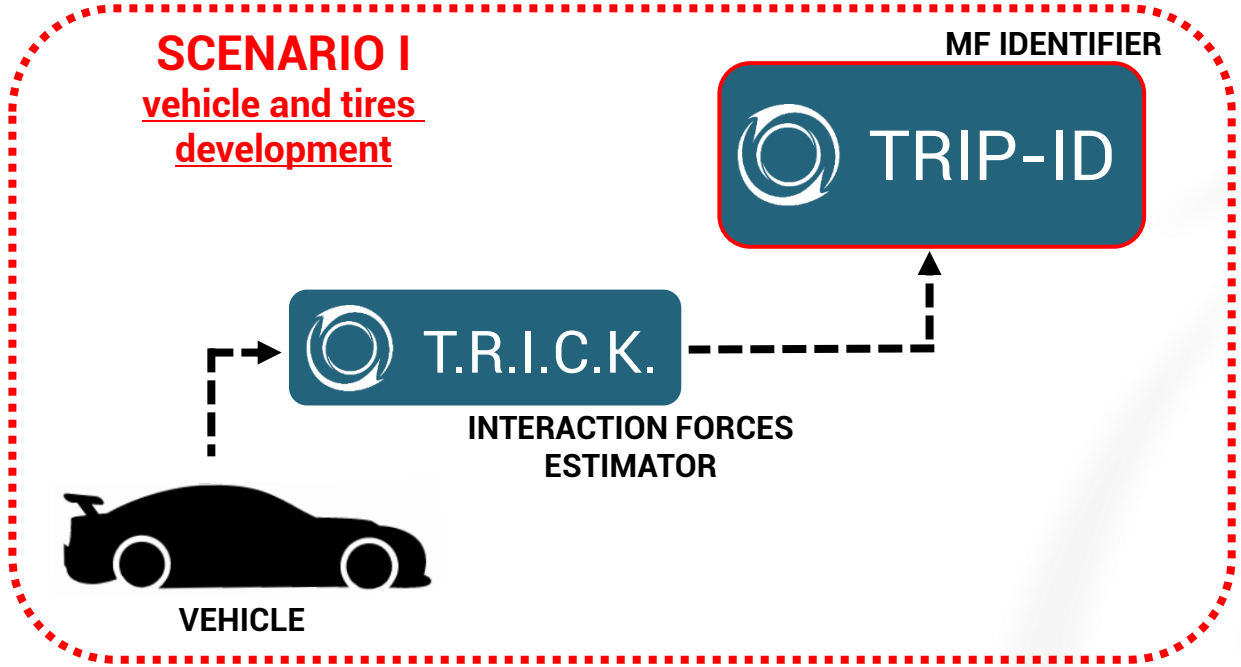
T.R.I.C.K.: Tyre/Road Interaction Characterization & Knowledge

- characterize the tires using the vehicle as a "moving lab"

- objectivize tire and driving performance during testing

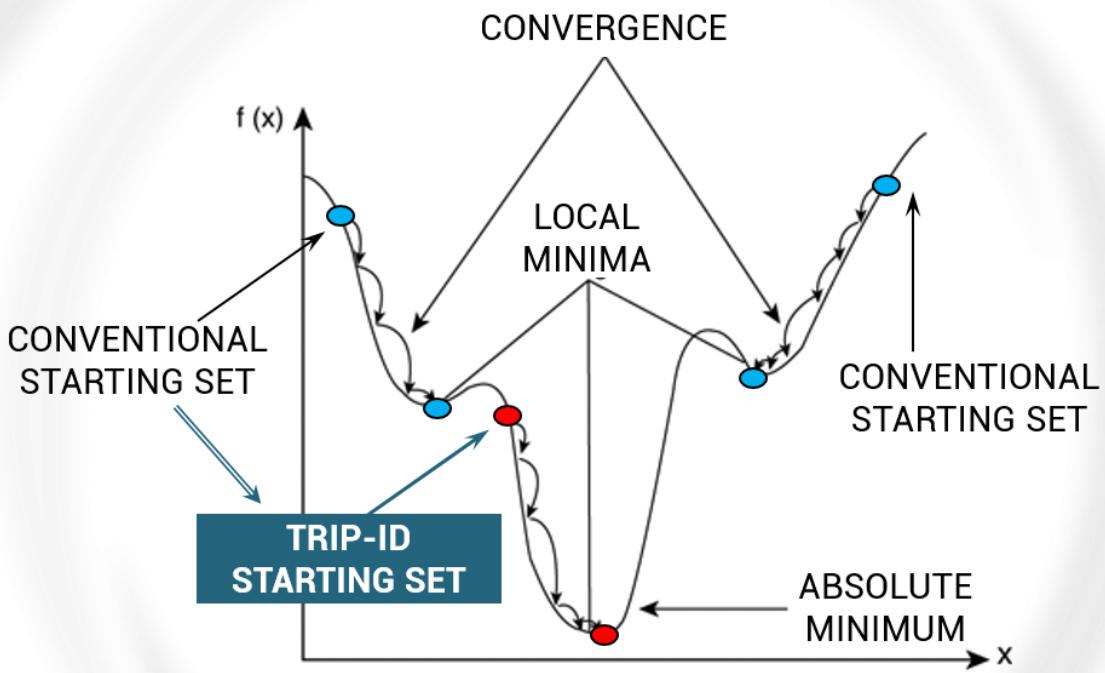


* for further info:
F. Farroni – T.R.I.C.K.: Tire/Road Interaction Characterization & Knowledge – A tool for the evaluation of tire and vehicle performances in outdoor test sessions – Mechanical Systems and Signal Processing – 72-73 808-831 (2016)



TRIP-ID: Tyre/Road Interaction Parameters IDentification

- a tool for multi-variable optimization applied to MF formulation



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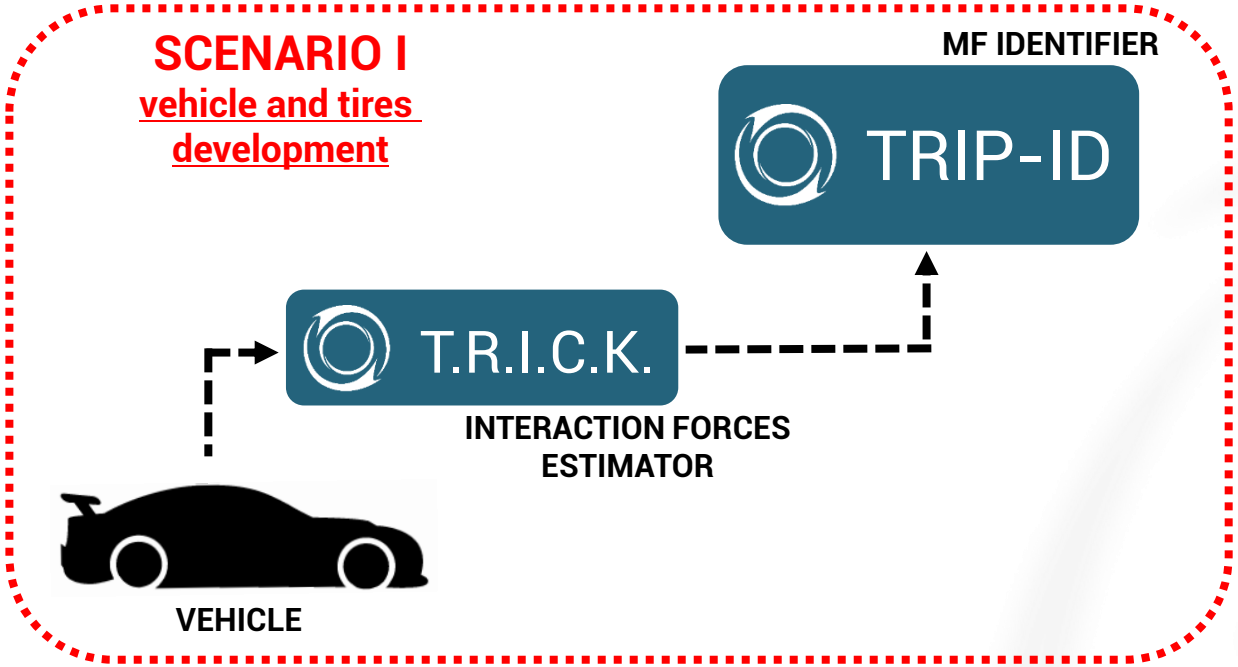

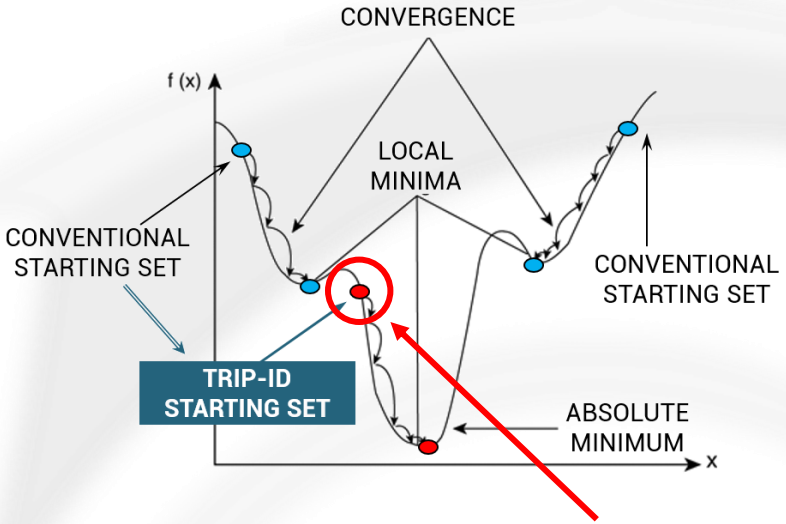

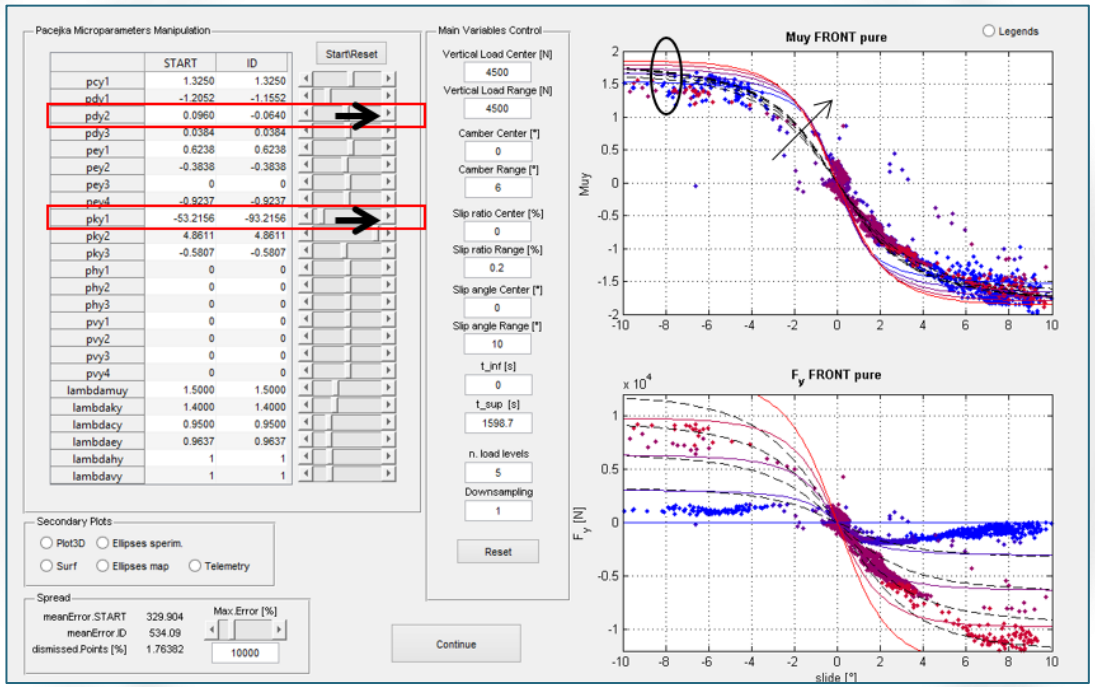

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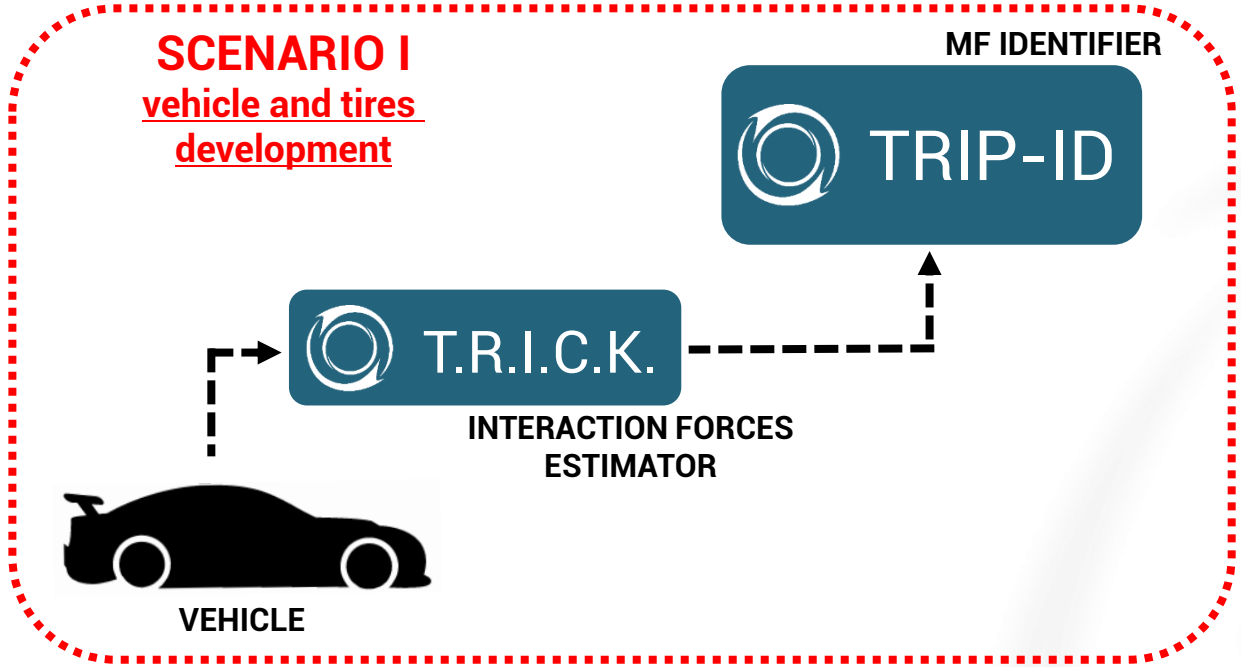
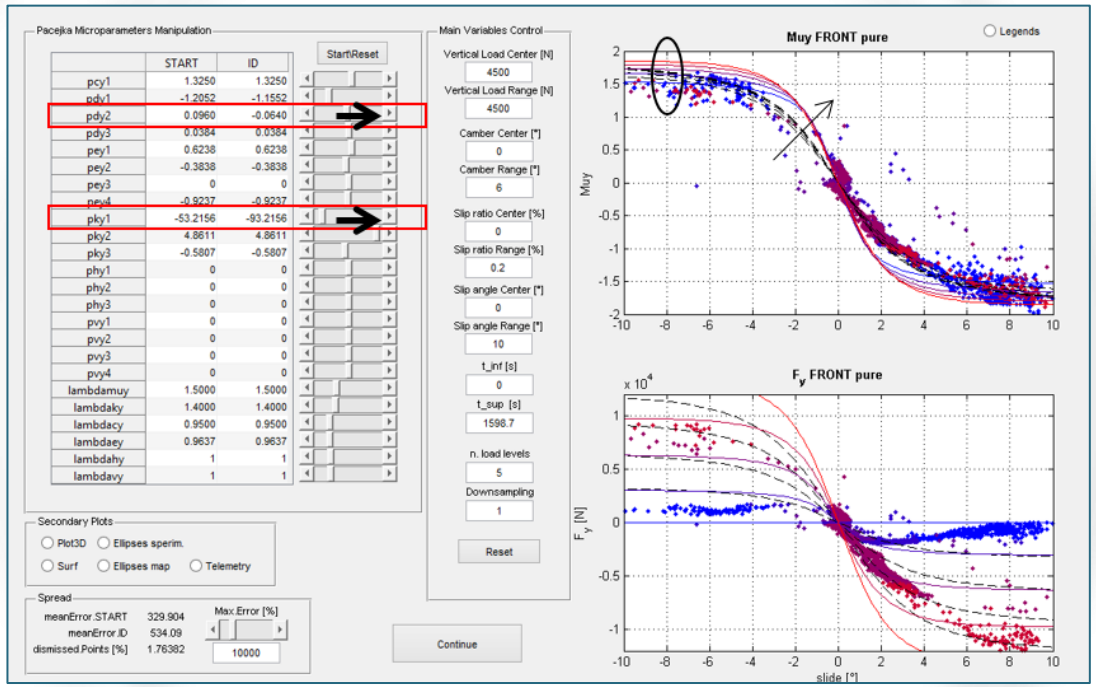


- PACEJKA PLOTTING TOOL
- TIR FILES VALIDATION
- VIRTUAL TIRES DATABASE CREATOR

TRIP-ID: Tyre/Road Interaction Parameters IDentification

- a tool for multi-variable optimization applied to MF formulation



* for further info:
F. Farroni, R. Lamberti, N. Mancinelli, F. Timpone - TRIP-ID: A tool for a smart and interactive identification of Magic Formula tyre model parameters from experimental data acquired on track or test rig - Mechanical Systems and Signal Processing – (2018)

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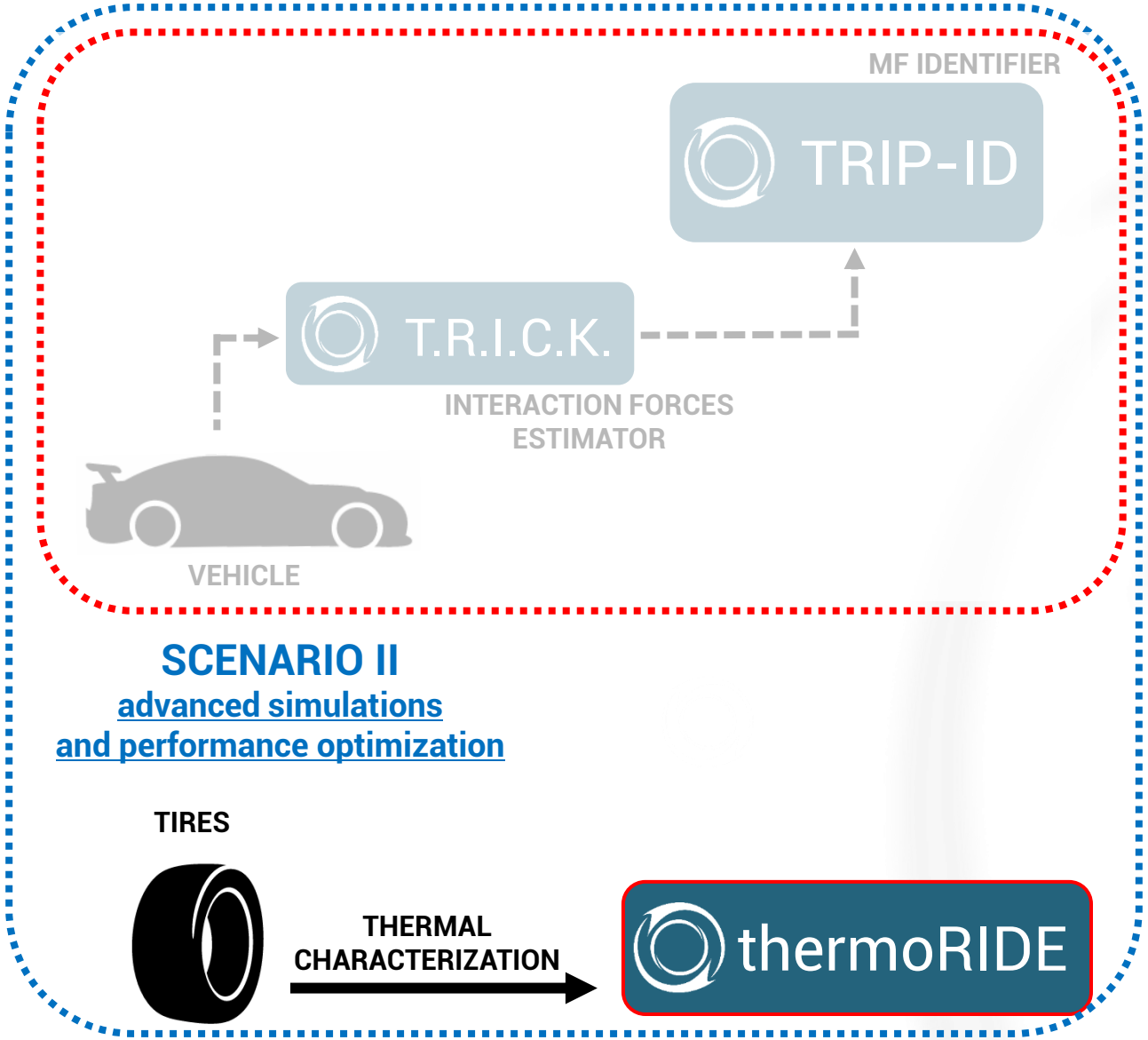
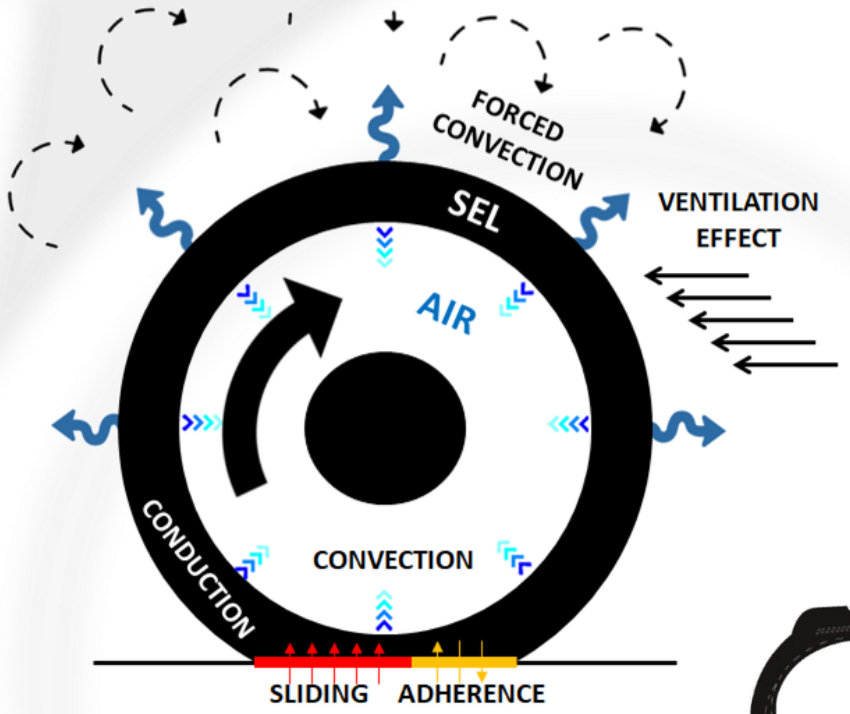


thermoRIDE:

- a real-time physical tire thermal model for performance analysis and simulations



*** exclusive in motoGP for DUCATI CORSE and in Formula E and DTM for Audi Sport**

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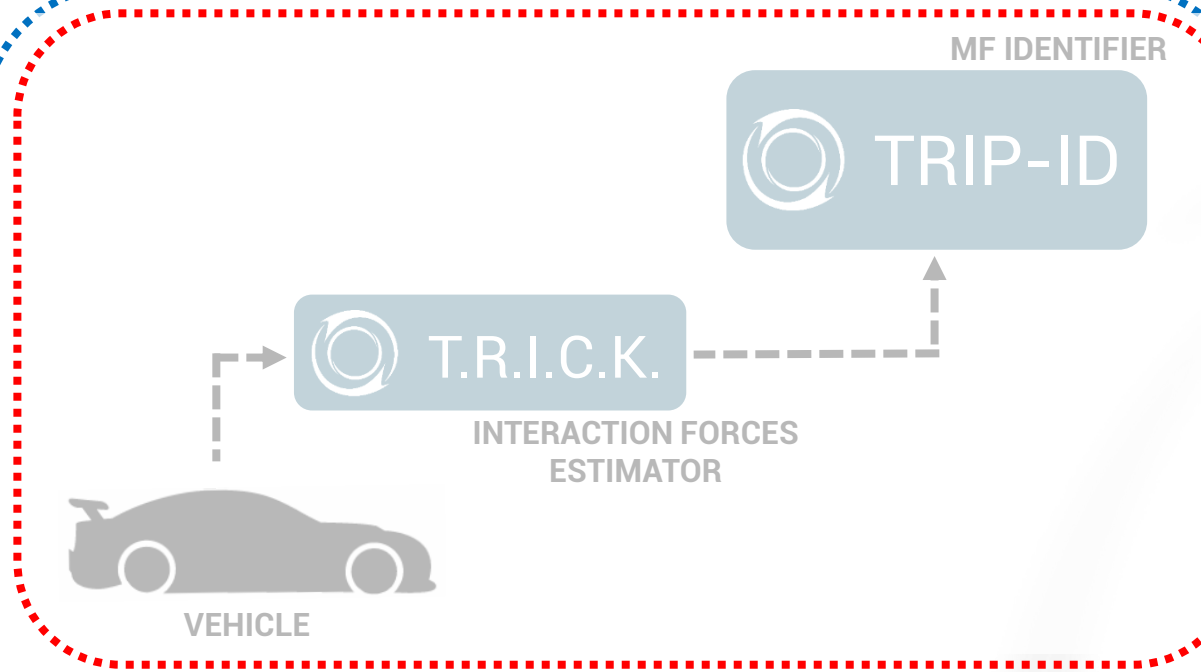


SCENARIO II

advanced simulations
and performance optimization

TIRES

THERMAL CHARACTERIZATION →

thermoRIDE

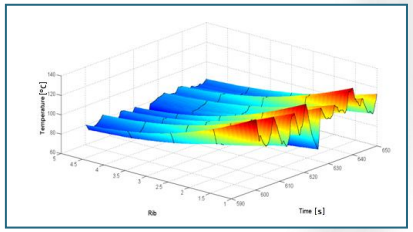
thermoRIDE:

- a real-time physical tire thermal model for performance analysis and simulations

- NONDESTRUCTIVE THERMAL CHARACTERIZATION

- ANY TIRE SIZE AND BRAND

- DISCRETIZATION UP TO 8 DIFFERENT LAYERS 16 DIFFERENT RIBS IN REAL-TIME



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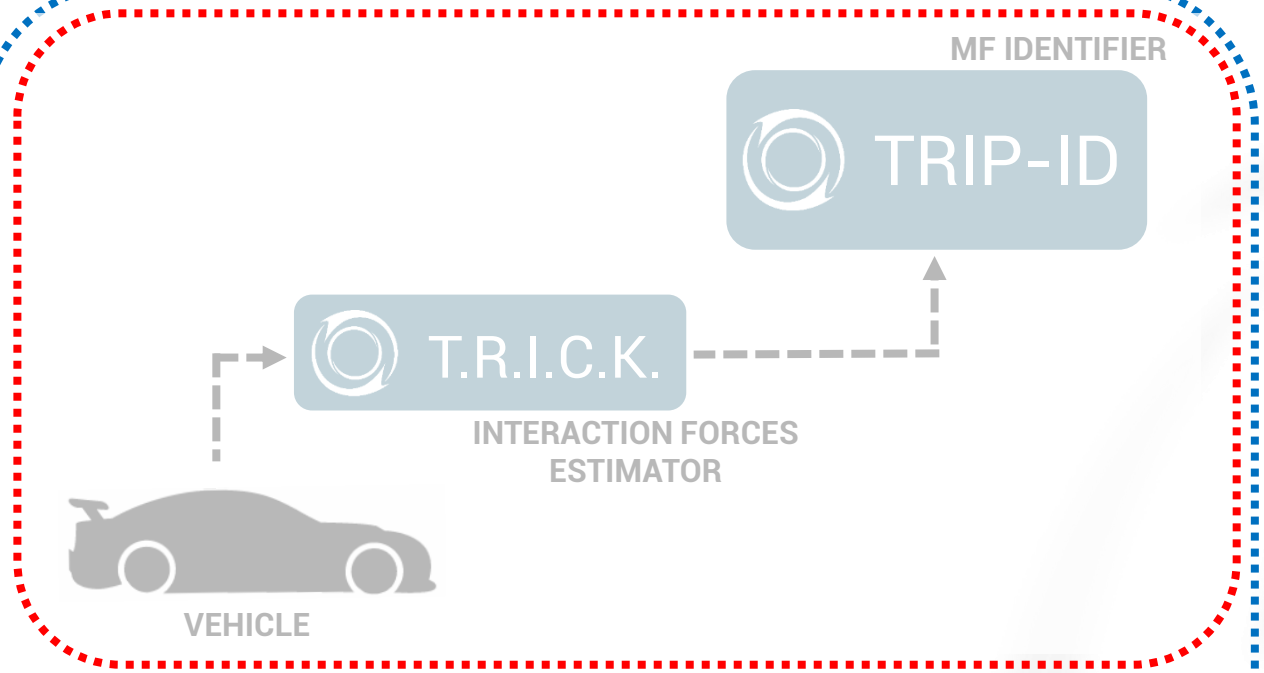

SCENARIO II

advanced simulations
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TIRES

THERMAL CHARACTERIZATION →

thermoRIDE

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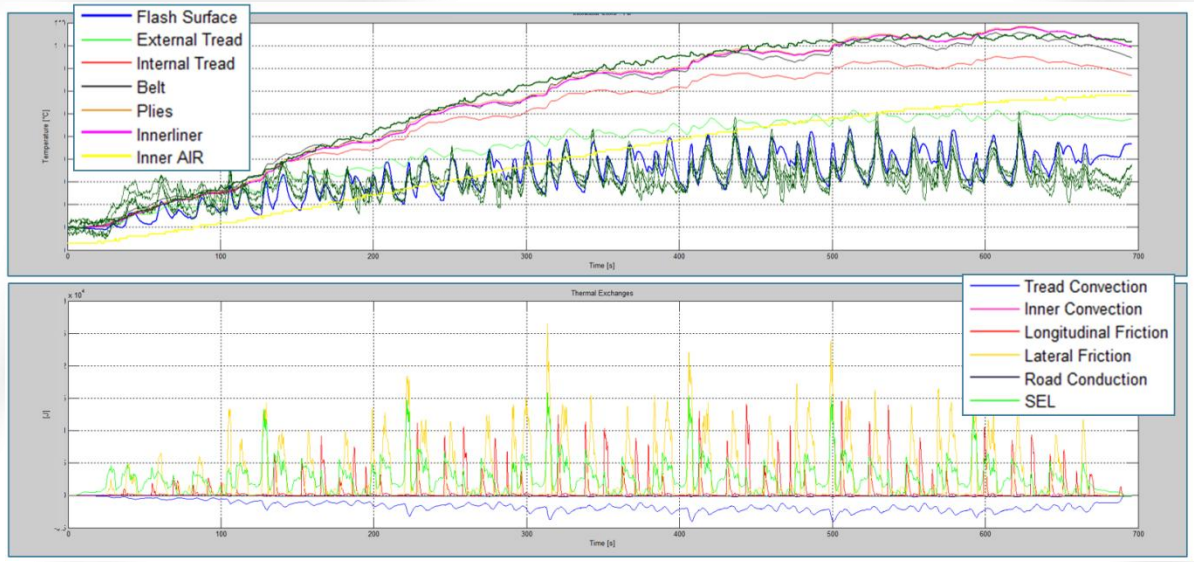

- INNER PRESSURE AND TREAD WEAR EFFECTS

- SPECIFIC ANALYSIS ON HEATING SOURCES AND COOLING CAUSES

* for further info:
F. Farroni, M. Russo, A. Sakhnevych, F. Timpone - TRT EVO: Advances in real-time thermodynamic tire modeling for vehicle dynamics simulations - Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering– (2019)

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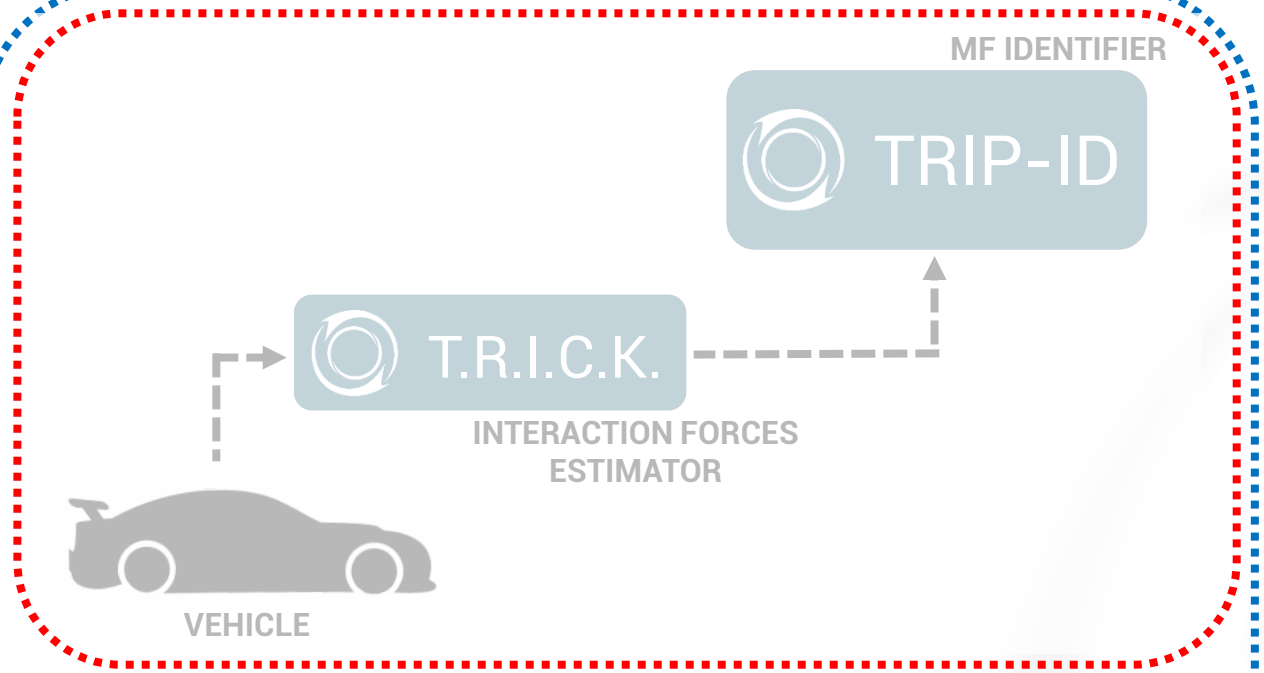

SCENARIO II

advanced simulations
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TIRES

THERMAL CHARACTERIZATION →

thermoRIDE

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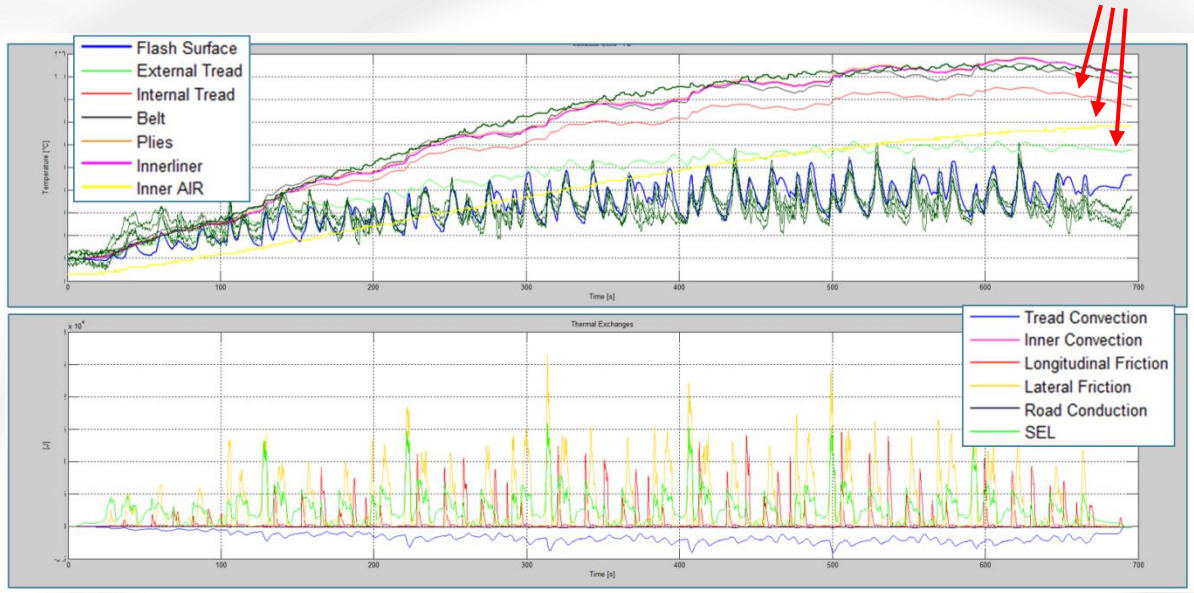

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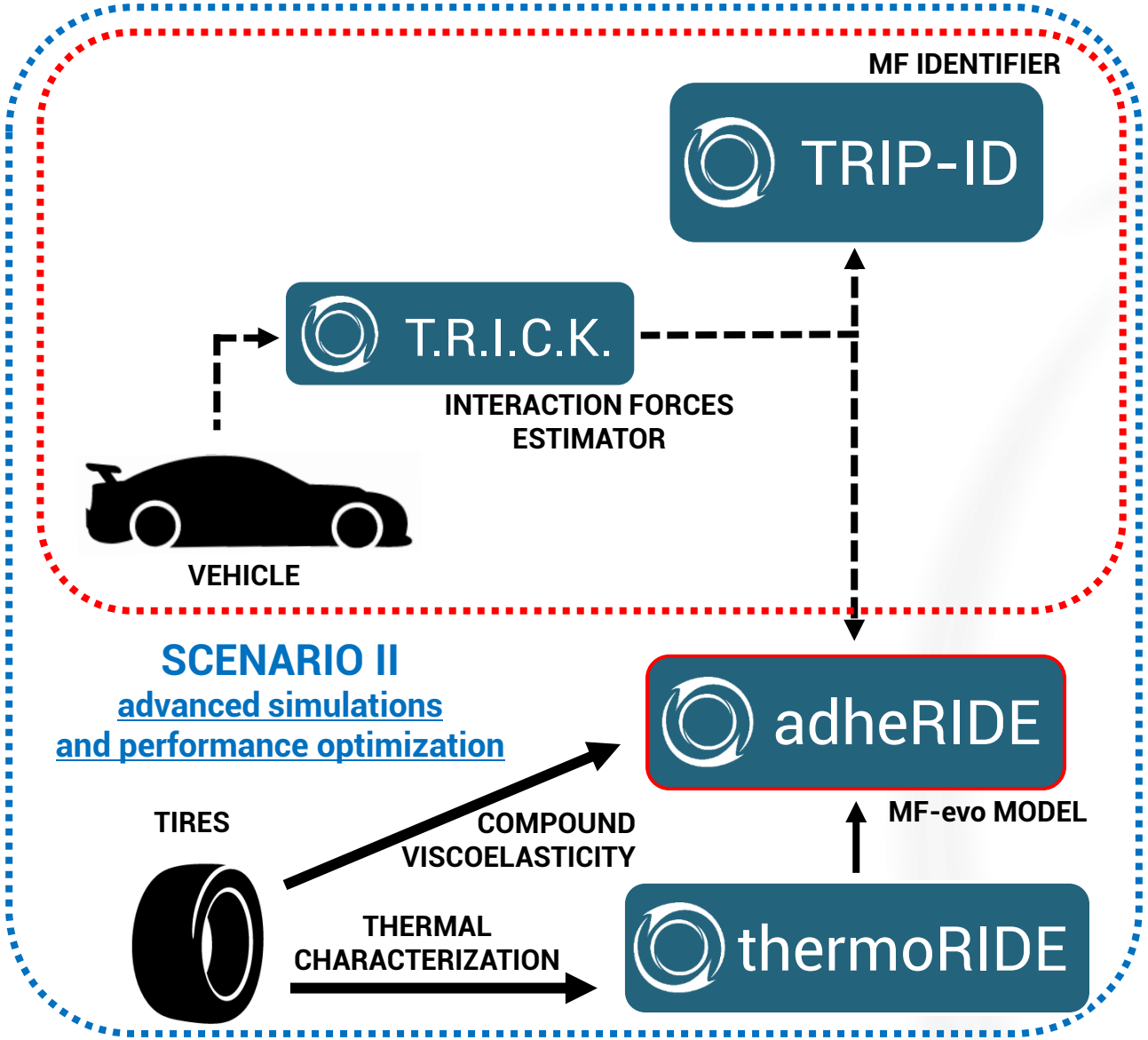
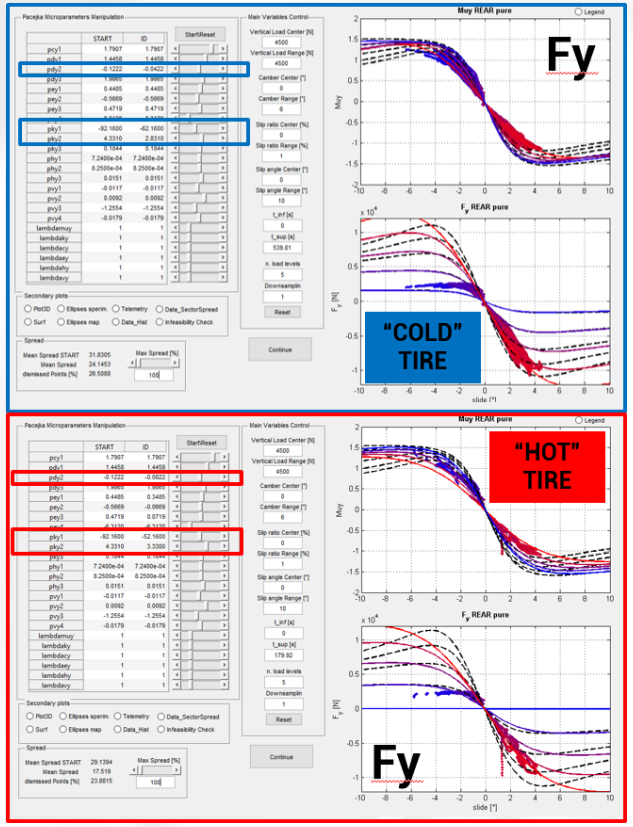
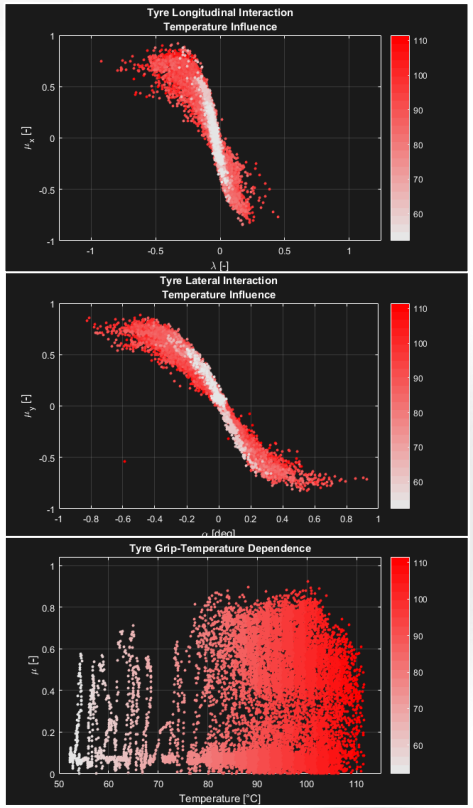


adheRIDE:

- an innovative Pacejka's MF model sensitive to:

- TIRE TEMPERATURE
- COMPOUND VISCOELASTICITY
- ROAD ROUGHNESS





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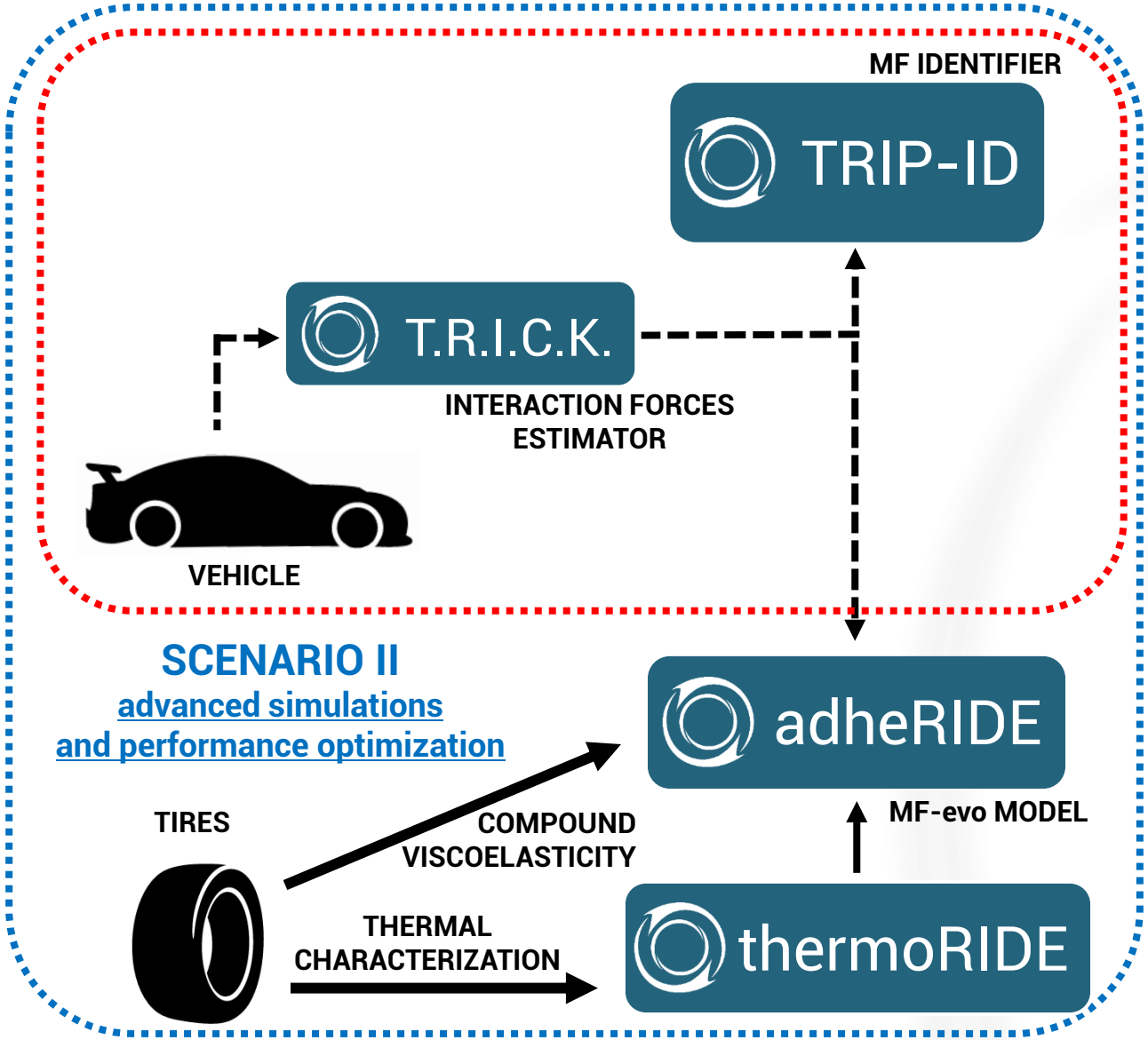

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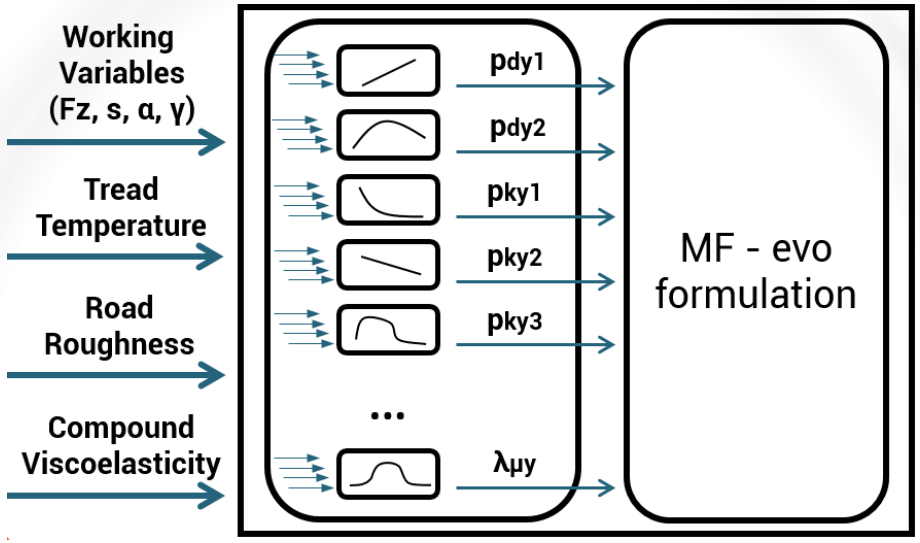

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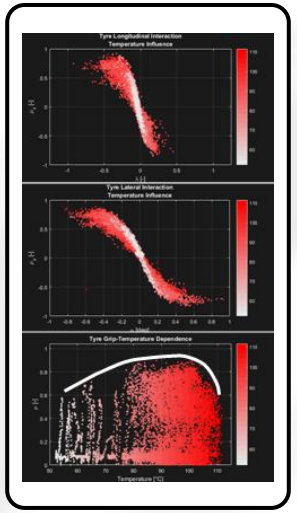
T.R.I.C.K.
FORCES ESTIMATOR

THERMAL MODEL

vehicle

thermoRIDE



ADVANCED GRIP/TEMPERATURE MODELLING

* VI-CARREALTIME
DRIVER-IN-MOTION

REAL-TIME ADVANCED TIRE MODELLING IN THE SIM LOOP

tires

thermodynamic characterizations

viscoelastic characterizations

road

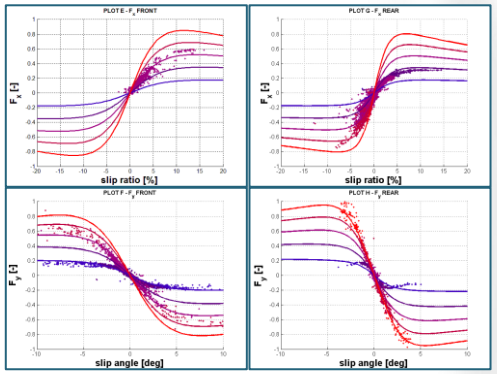
roughness profile PSD

MF IDENTIFIER

TRIP-ID

adheRIDE

MF-evo



Temperature / Wear / Roughness / Compound Sensitivity in MF

* in partnership with VI-GRADE

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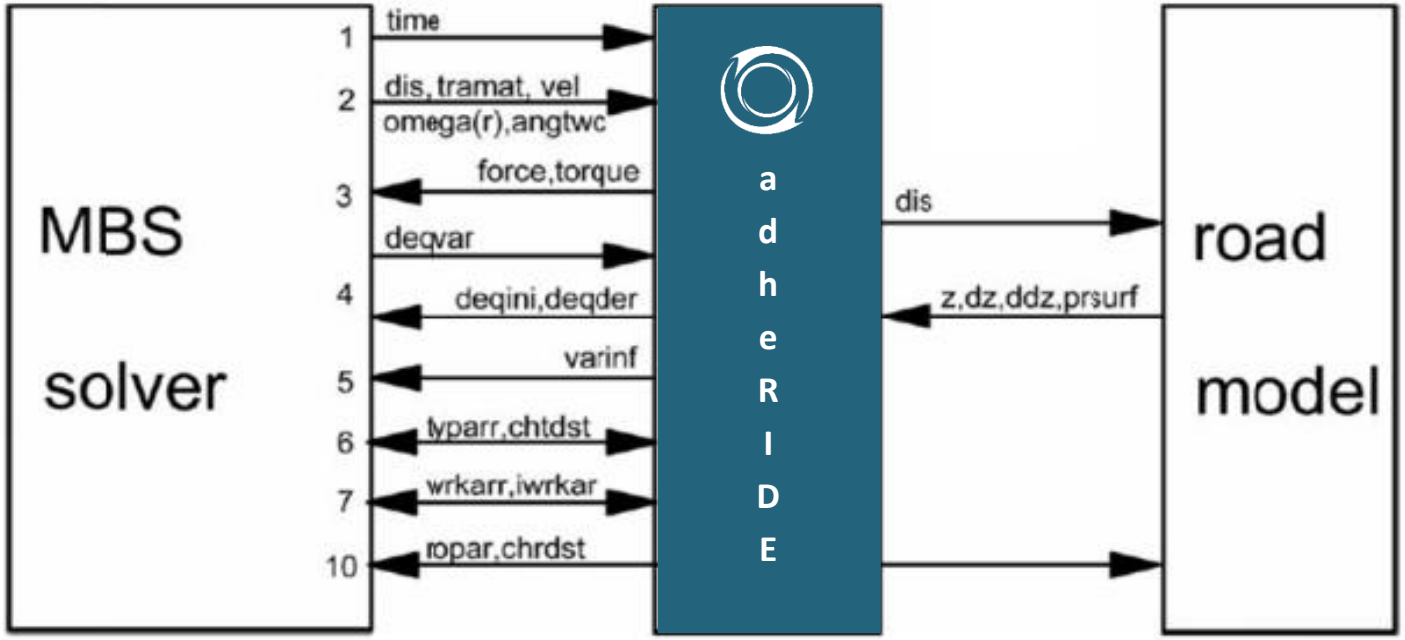
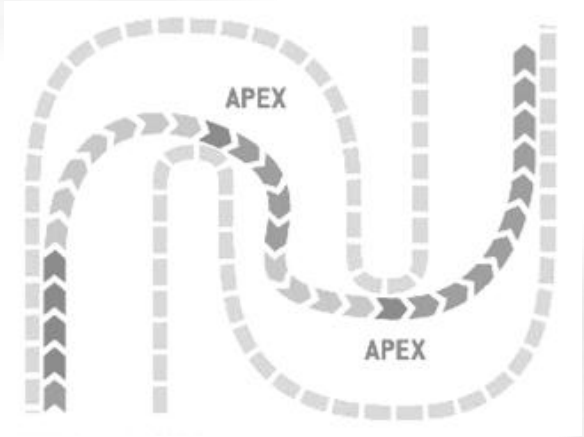
thermoRIDE / adheRIDE & VI-grade MaxPerformance

adheRIDE within Standard Tire Interface



MaxPerformance

FOR EACH TRACK SECTOR



- **static solver**
  prediction of static speed profile
- **dynamic solver**
  validation of dynamic limit velocity

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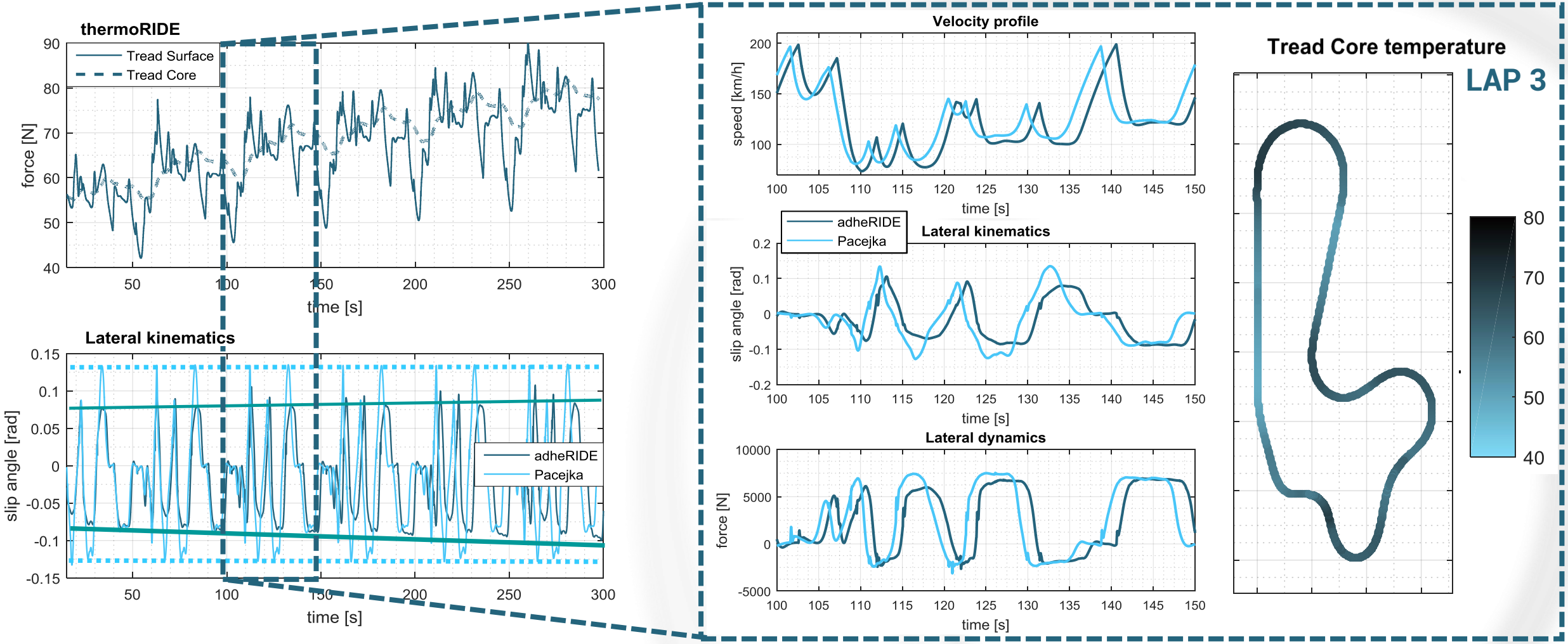
thermoRIDE / adheRIDE & VI-grade MaxPerformance



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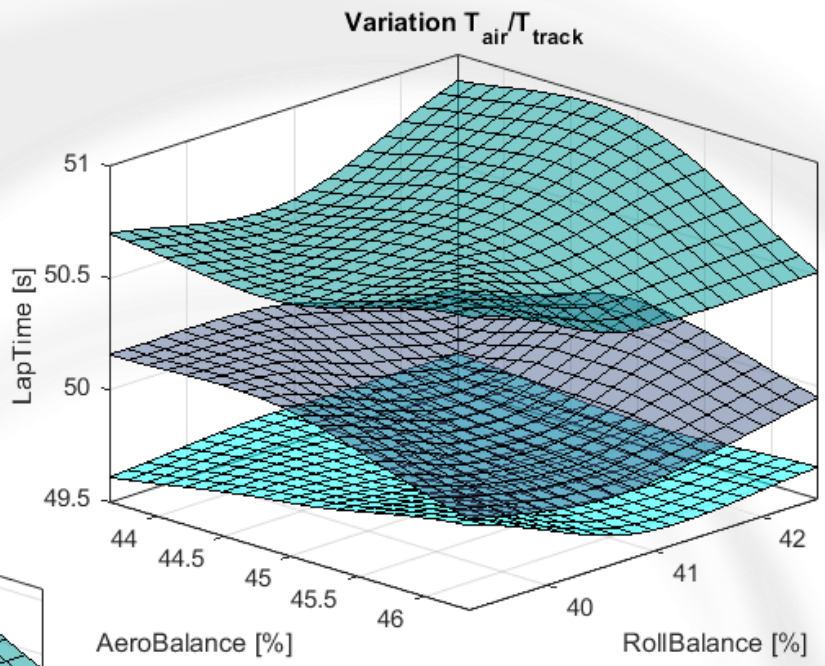
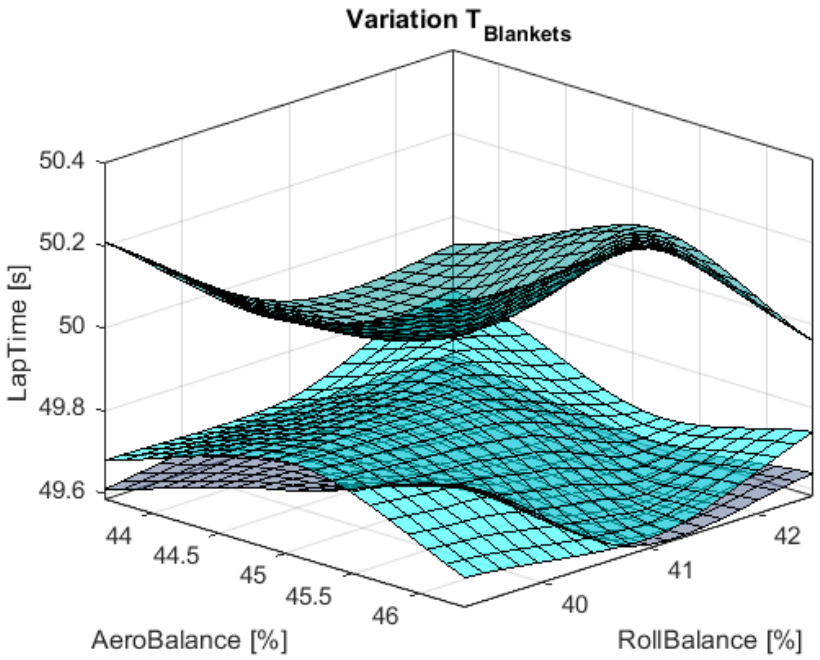
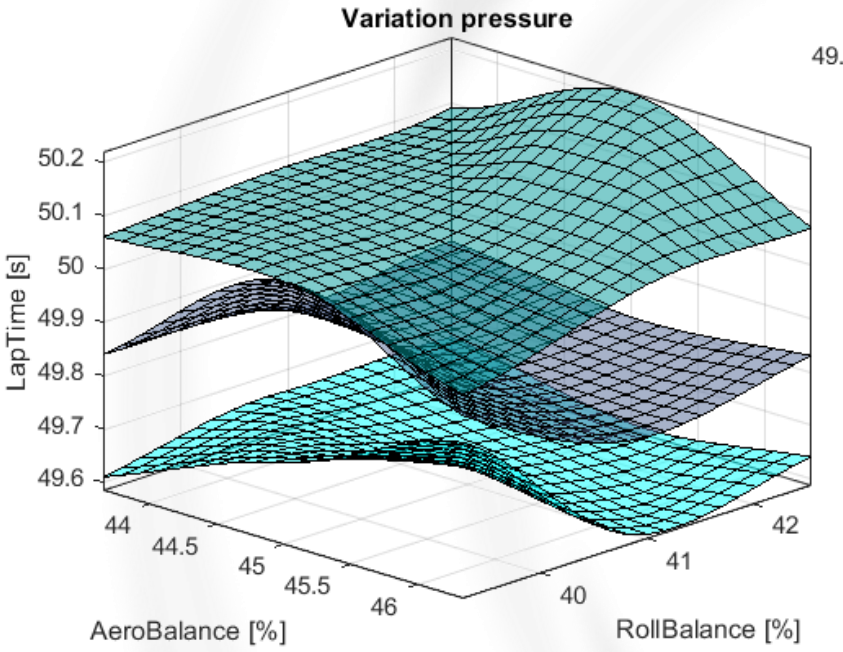
Case study : DOE

How to correct the car setup if conditions are changing?
Case study: 5D DOE with track/air temperature, blankets setting, tire pressure, aero and roll balance







IDENTIFICATION OF THE OPTIMAL VEHICLE SETUP ACCOUNTING FOR PHYSICAL INTERACTION PHENOMENA

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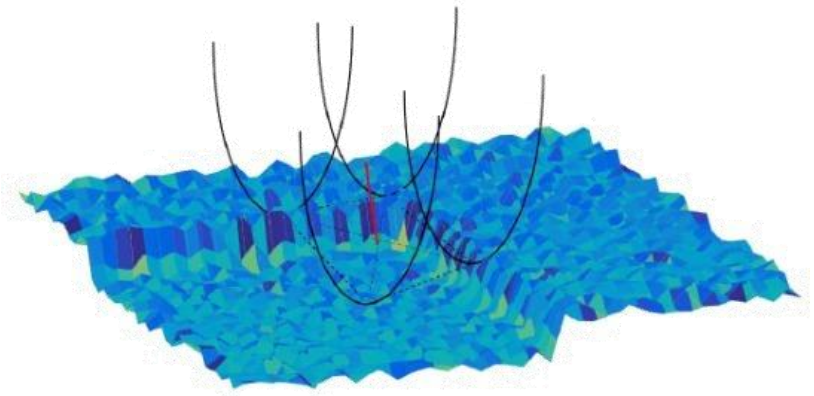
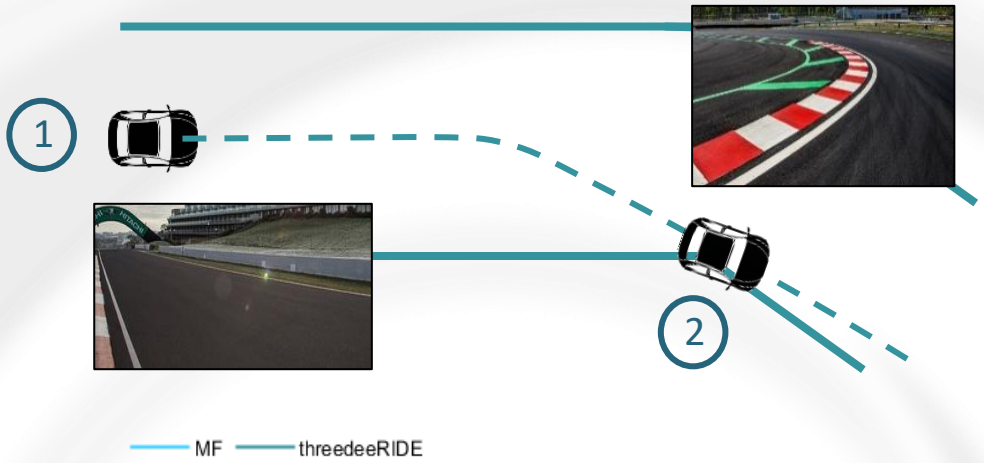
Newborn Model: threedeeRIDE

Cam-based muticontact model

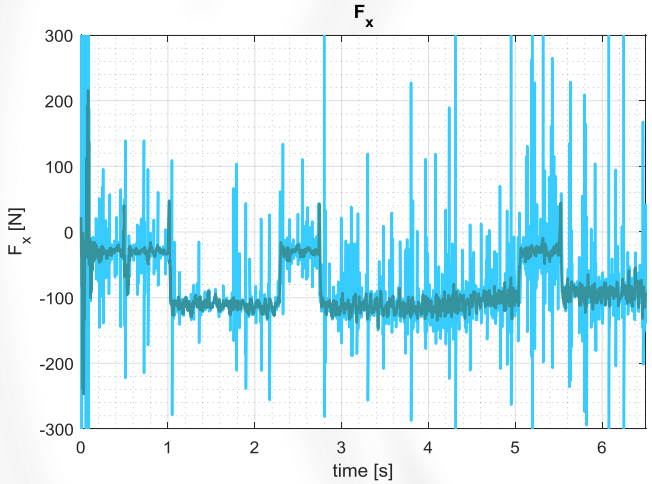
- The cam-based multicontact interaction model is used to correctly model the tire/road interface whenever the tire is encountering soil irregularities



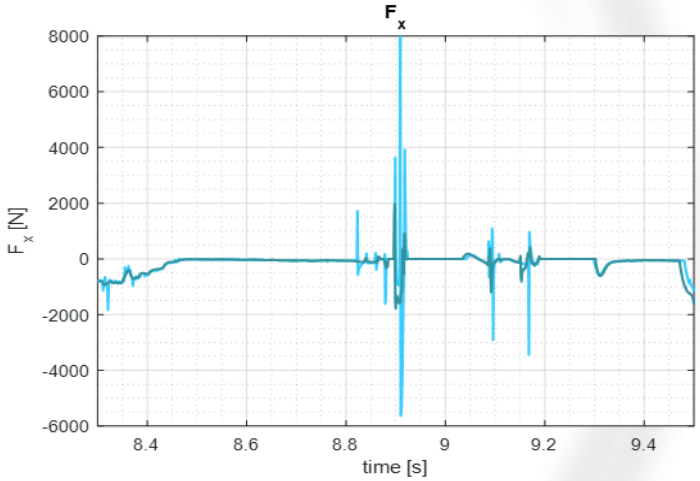
REAL-TIME CAM SHAPE AND CHARACTERISTICS VARIATION WITH:
- VERTICAL LOAD
- INFLATION PRESSURE
- CAMBER ANGLE



1 Uneven road



2 Kerb impact



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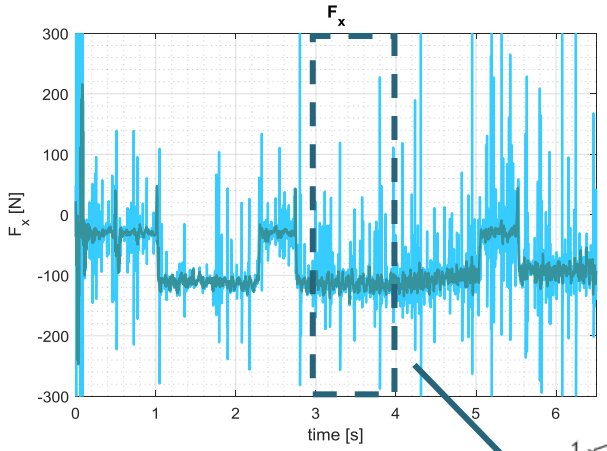
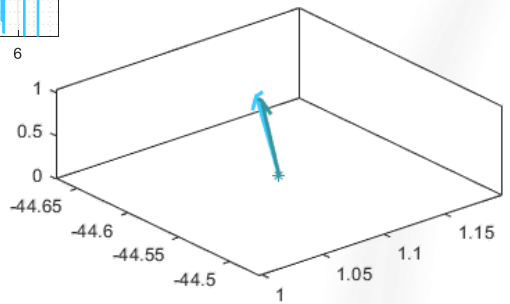
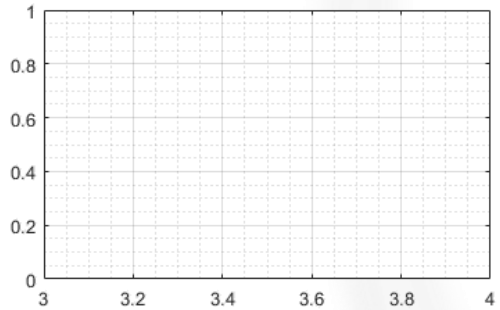
Newborn Model: threedeeRIDE

1







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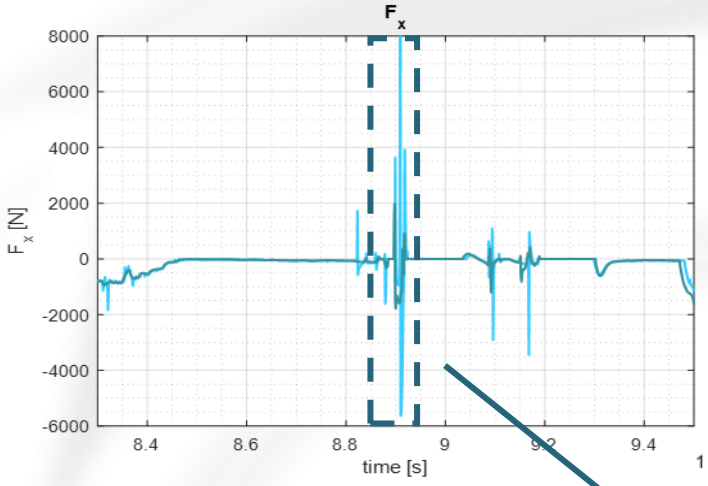

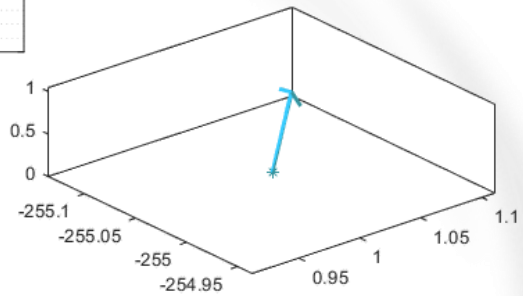

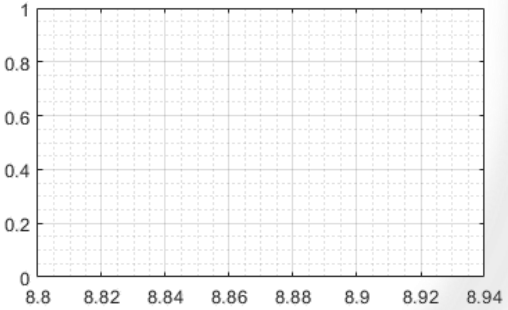

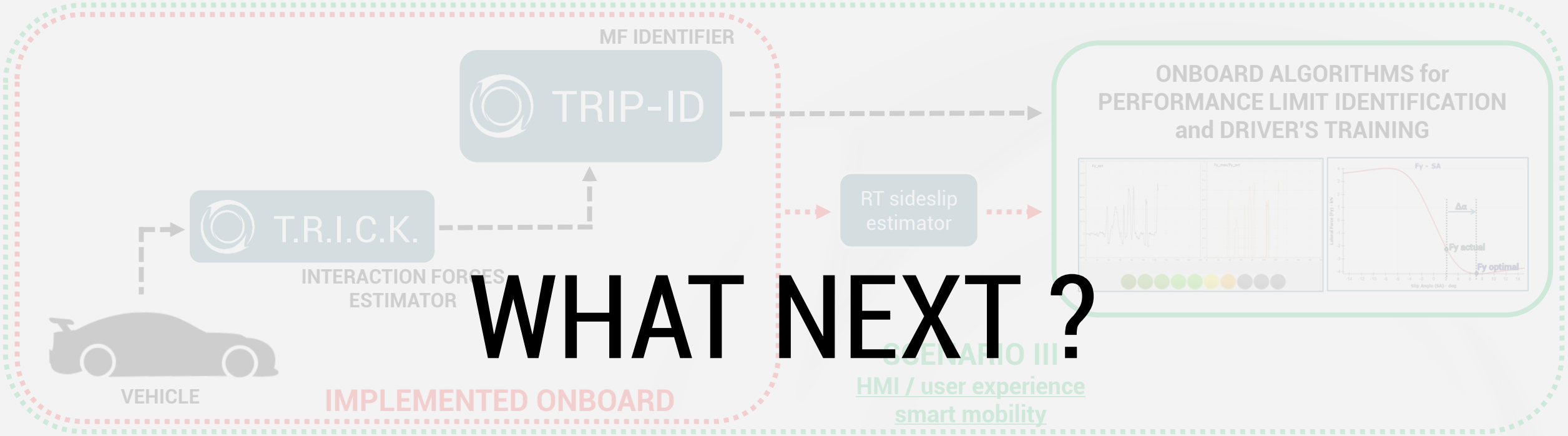

WHAT NEXT ?

- **RACING & MOTORSPORT**:
- evaluation of tire/road available friction for drivers' training activities and driving style optimization
(definition of target slip ratio and sideslip angle for performance optimization and info to the user)

- **SMART MOBILITY**:
- evaluation of tire/road effective friction for V2V AND V2I applications
(tread and soil wear estimation, asphalt predictive manteinance, physical-based safety control algorithms, …)

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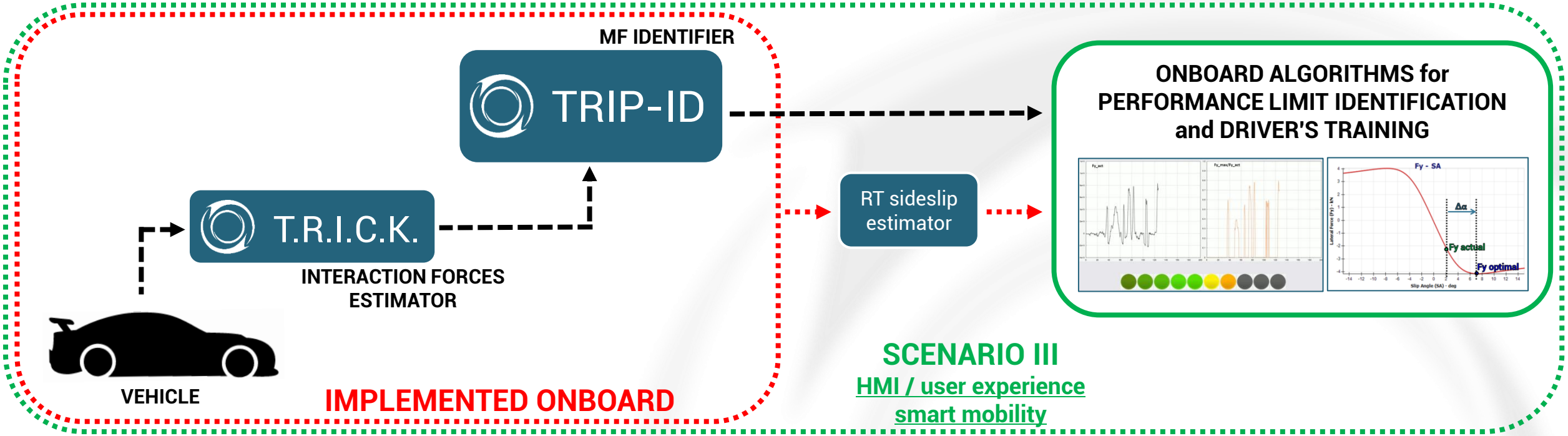

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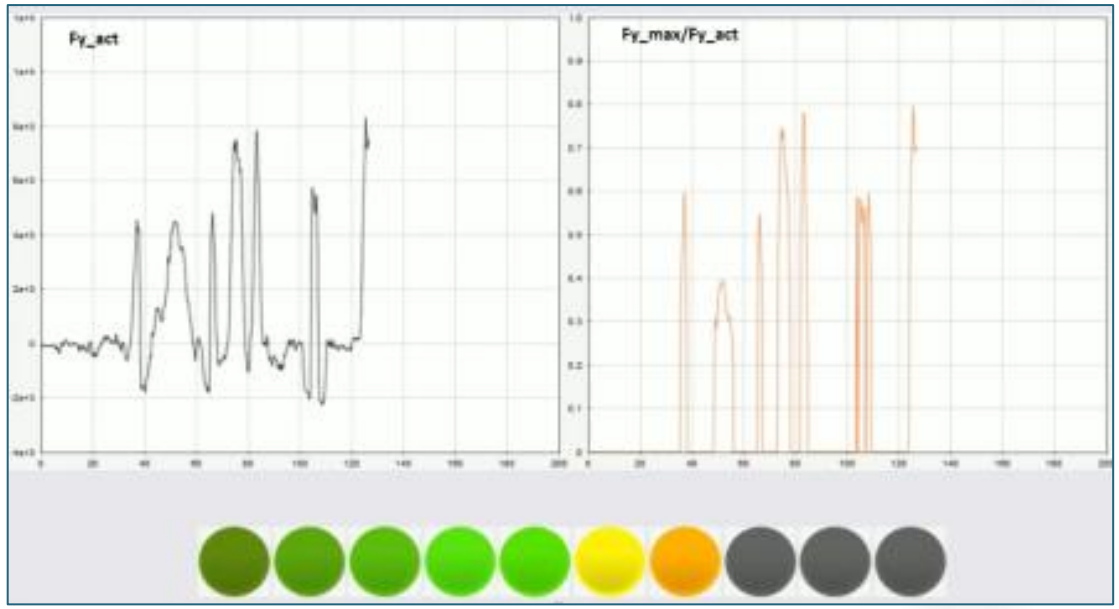
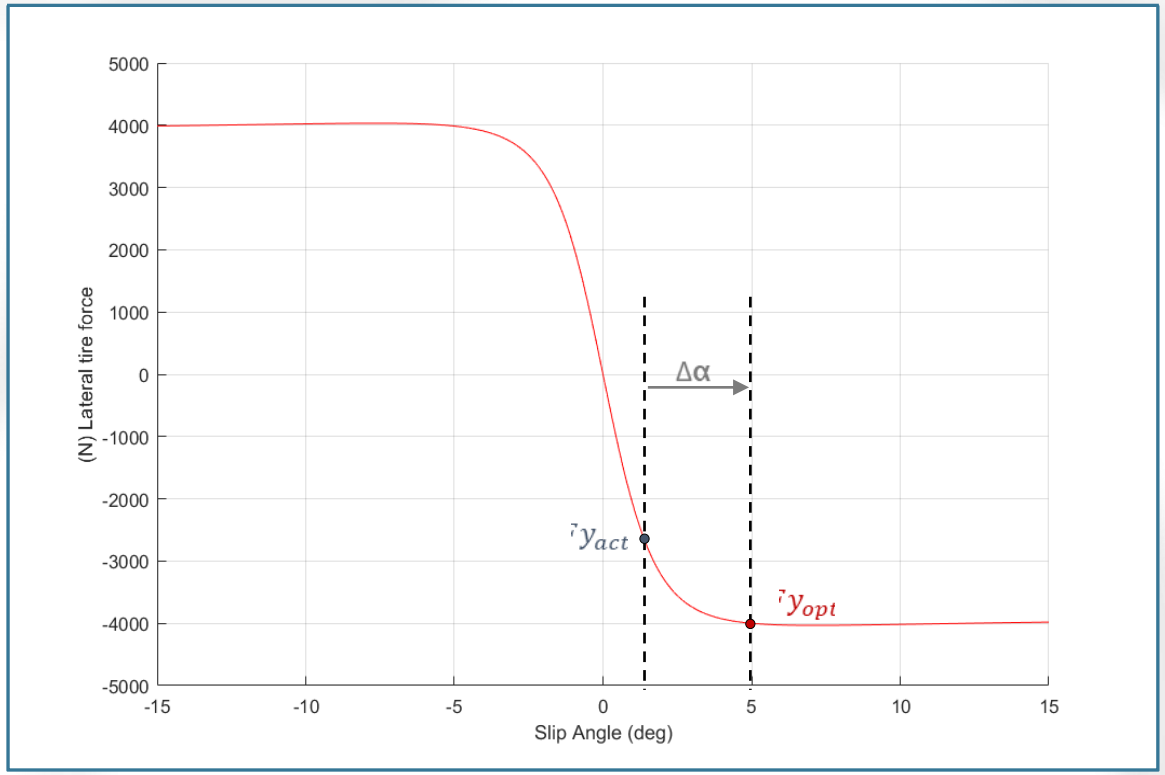
New Scenarios - Onboard Control Logics

ONBOARD MF ID and real-time TRICK in motorsport

Evaluation of tire/road available friction for active controls and drivers' training activities
(definition of target slip ratio and sideslip angle for performance optimization and info to user)





curves referred to the same (s, γ, Fz) working input

performance index = Fy_{act} / Fy_{opt}

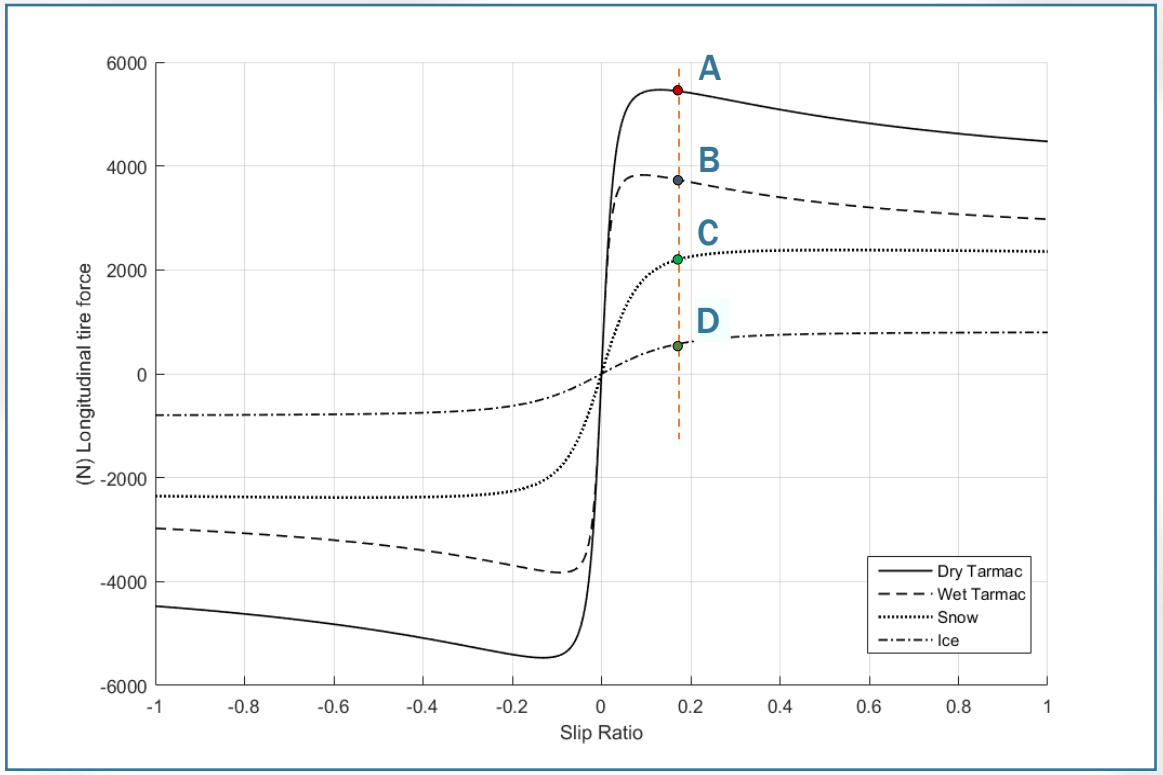
New Scenarios - Onboard Control Logics

ONBOARD MF ID and real-time TRICK in smart mobility

Evaluation of tire/road effective friction for smart mobility applications
(tread and soil wear estimation, asphalt predictive maintenance, physical-based safety control algorithms,…)

A.I., Big Data analysis & Geolocalization-examples:
- several vehicles detected sudden and dramatic friction decrease in small area → **"oil spot" or singularity**
- single vehicles detects sudden and dramatic friction variation in small area → **accident/puncture**
- several vehicles detect progressive and significant friction decrease in medium area → **rain**
- several vehicles detect progressive and dramatic friction decrease in medium area → **ice**
- Several vehicles detect slow friction decrease in big area → **pavement wear**

Single vehicle detects slow friction decrease in big area → **tire tread wear**



curves referred to the same (s, γ, Fz) working input

performance index = Fx_i / Fx_A

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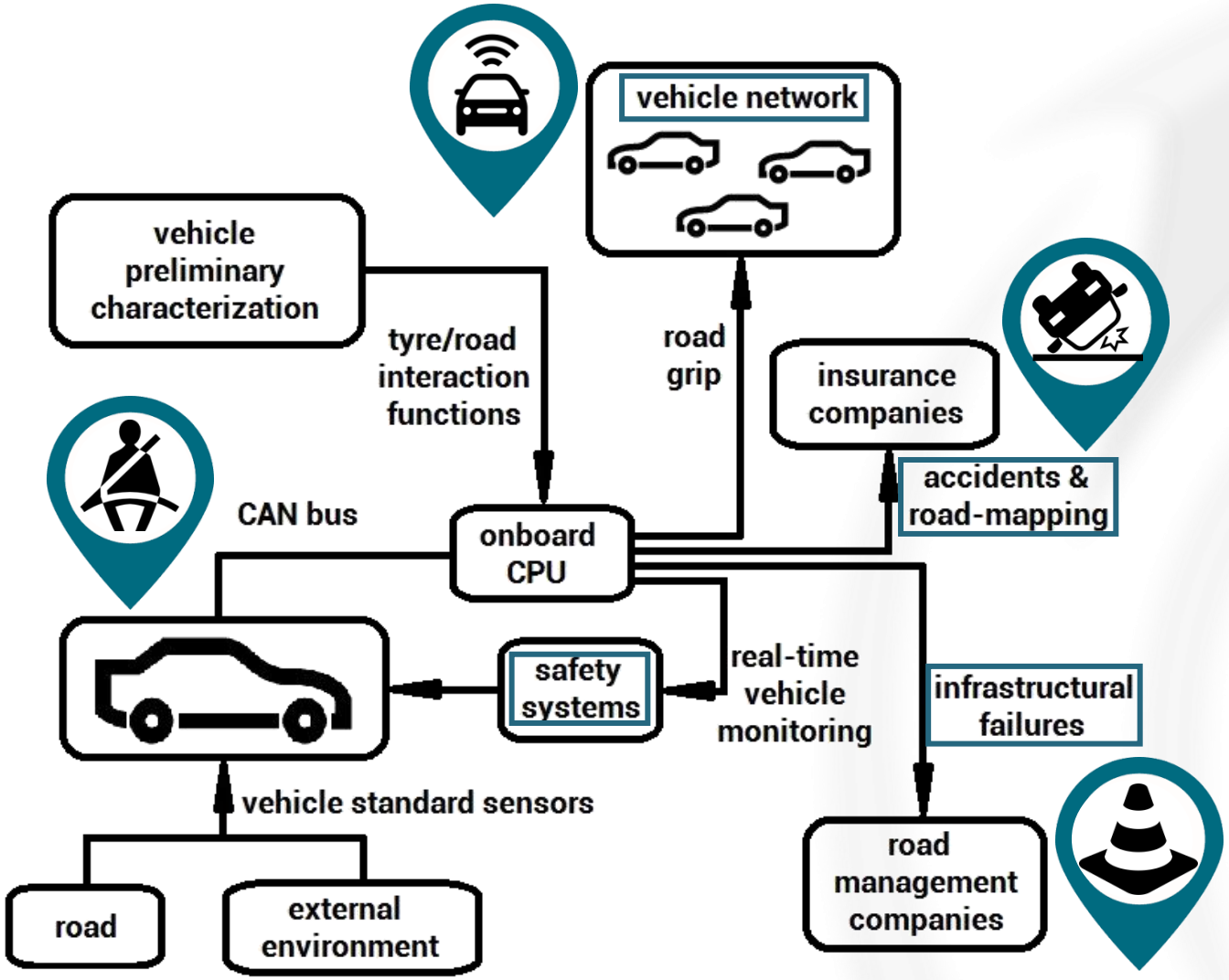
Smart Mobility Platforms



open innovation scenarios:

- UE CONSORTIUMS
- R&D PARTNERSHIPS
- TECHNOLOGICAL JVs

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VEHICLE DYNAMICS INTERNATIONAL AWARDS

DEVELOPMENT TOOL OF THE YEAR

2018: VI-grade – DiM250

2019: MegaRide – Tire Simulation Pack

MIT Technology Review

MIT INNOVATORS UNDER 35 2018

tire TECHNOLOGY INTERNATIONAL 2018 AWARDS

TIRE TECHNOLOGY OF THE YEAR 2018

Harvard Business Review

Borsa Italiana

ECCELLENZE D'IMPRESA 2018

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