VEHICLE, TIRE AND ROAD DIGITALIZATION: METHODS AND PRACTICES TOWARDS ZERO PROTOTYPES

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Flavio Farroni - MegaRide & UniNa

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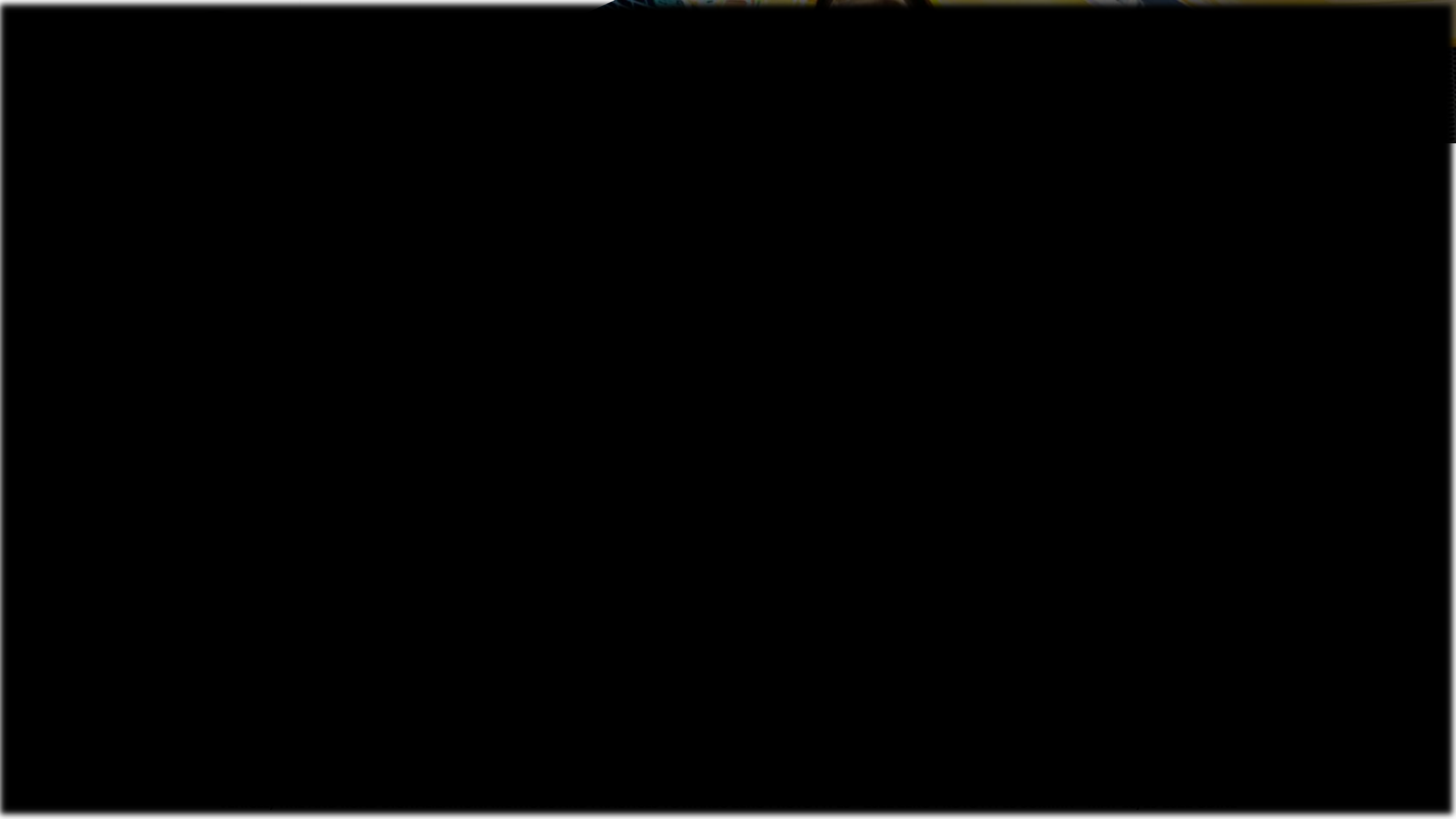
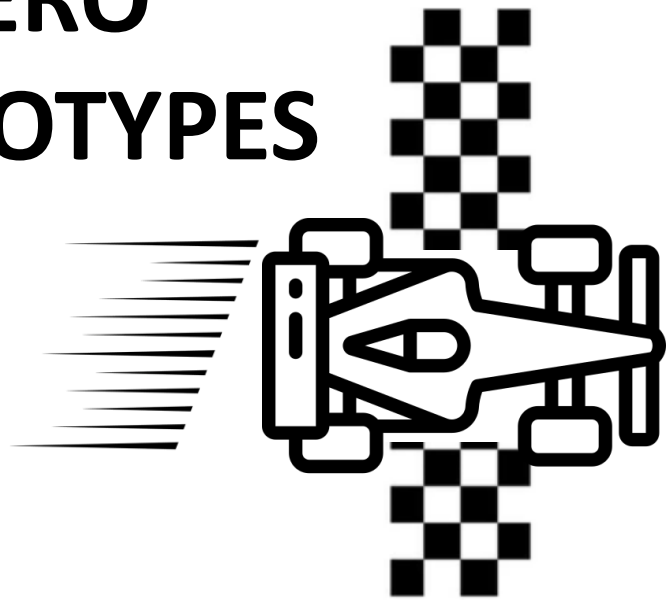


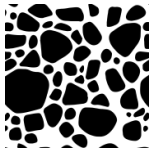
ZERO PROTOTYPES



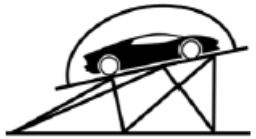
STANDARDIZING DIGITALIZATION PROCESS

VEHICLE

TIRES

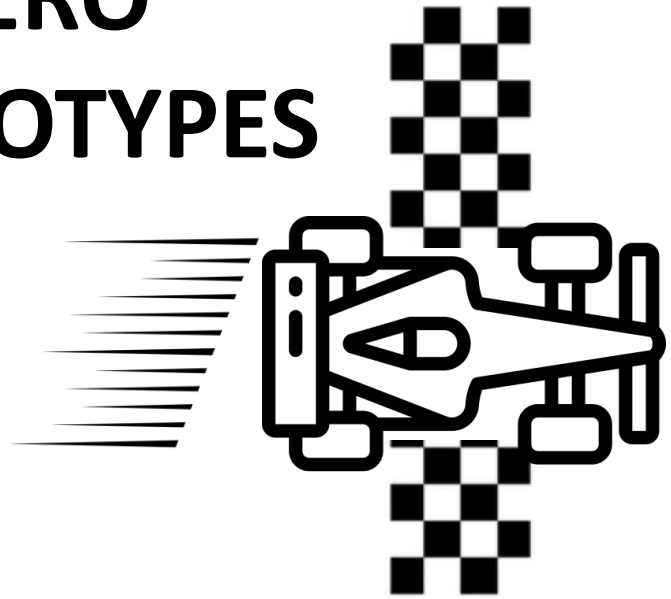


ROAD



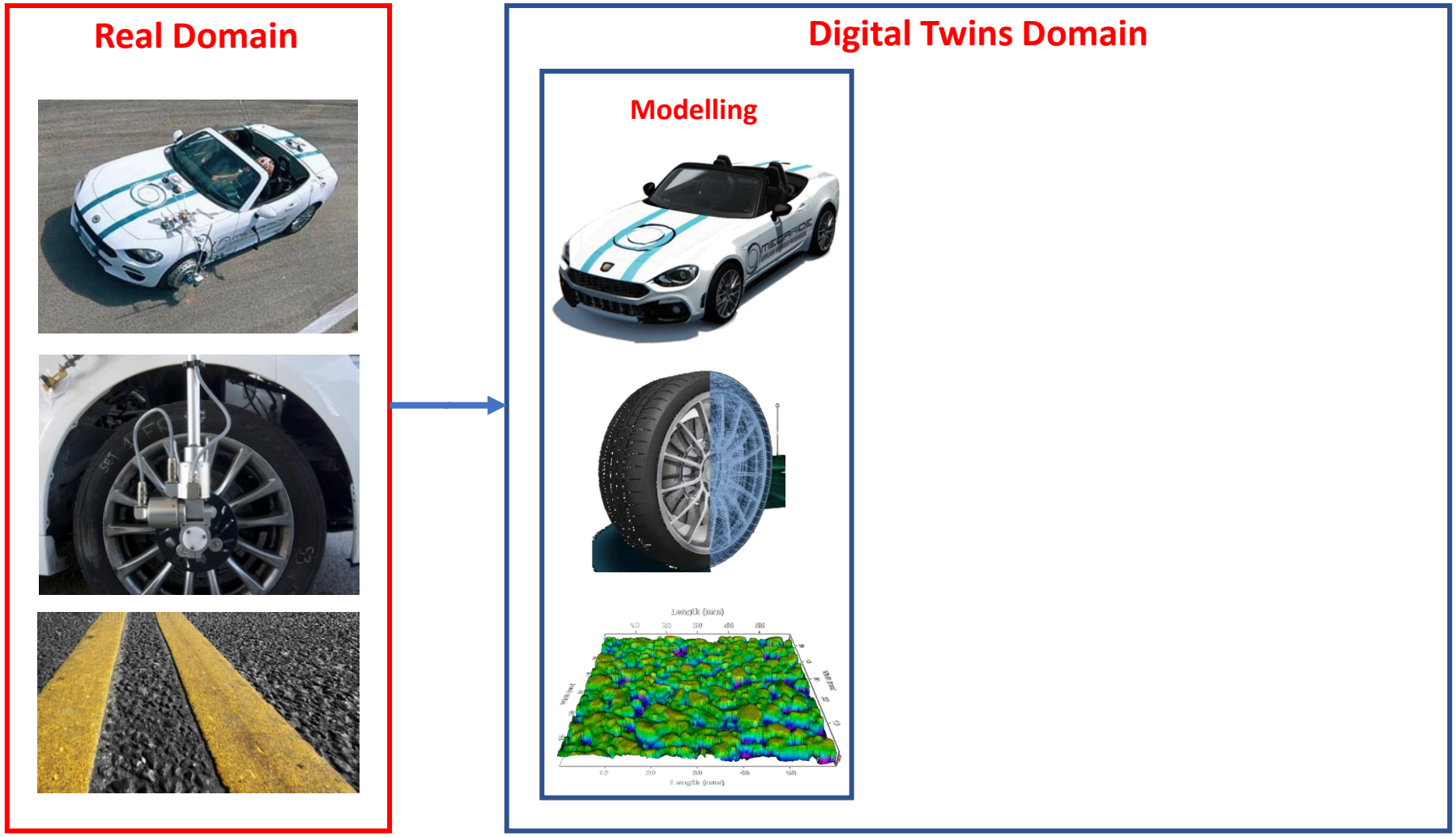
SIMULATOR

ZERO PROTOTYPES



Digital Twins Critical Components

- **Vehicle Model**
  - VI-CarRealTime
  - Others
- **Tire Model**
  - MegaRide
  - CDTire
  - Ftire
  - MF
  - …
- **Road Model**
  - Laser Scan Data
    - VI-GridMesh
    - CRG
    - …



Digital Twins Integration & Validation

- Vehicle Model

Functional validation vs. measured test data

- Tire Model

Functional validations on tire test rigs and on road measurements

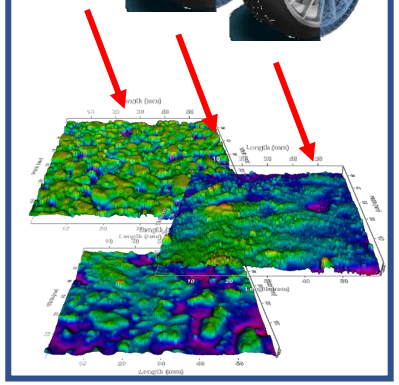
- Road Model

Functional validation, depending on measurement accuracy and tire model

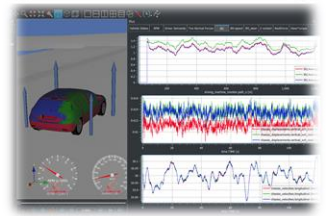
Real Domain

Digital Twins Domain

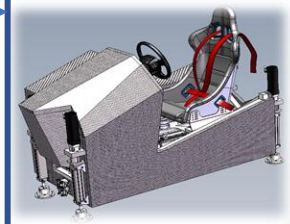
Modelling



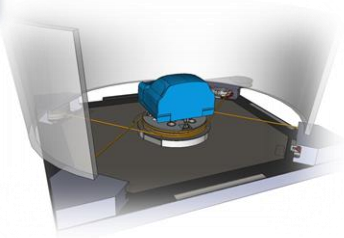
Zero Prototypes Testing



Multibody off-line Simulation



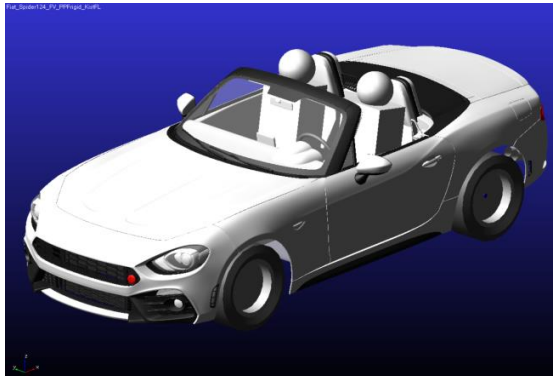
NVH and Full Spectrum Simulator

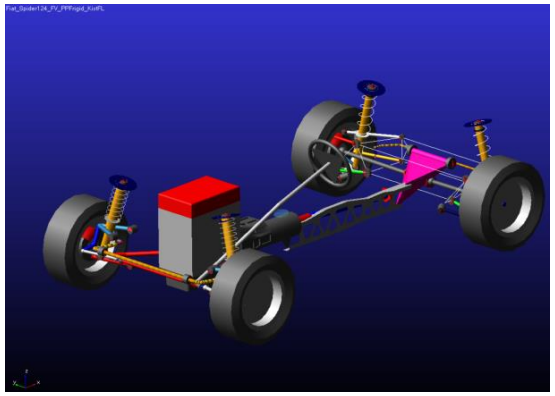


DiM

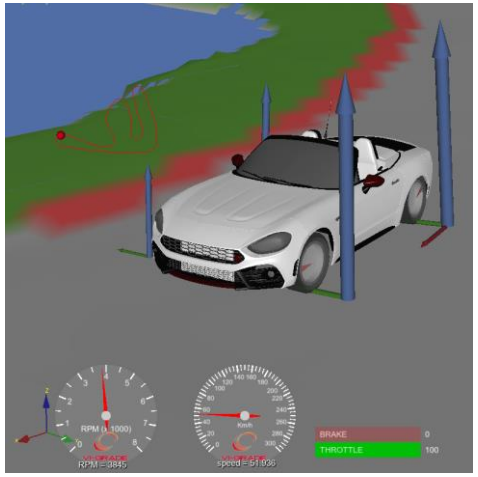
Vehicle Model Implementation

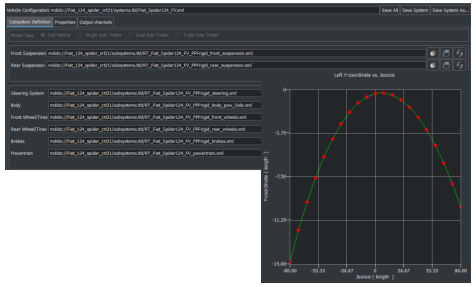
Full MBS model





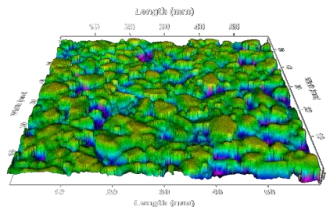
VI-CRT model for DiMs and offline sim



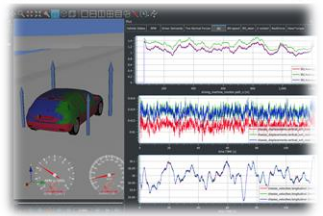


Digital Twins Domain

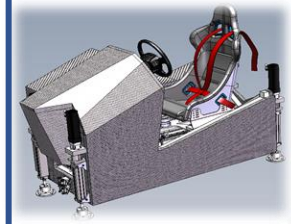
Modelling



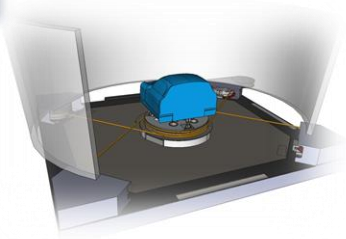
Zero Prototypes Testing



Multibody off-line Simulation

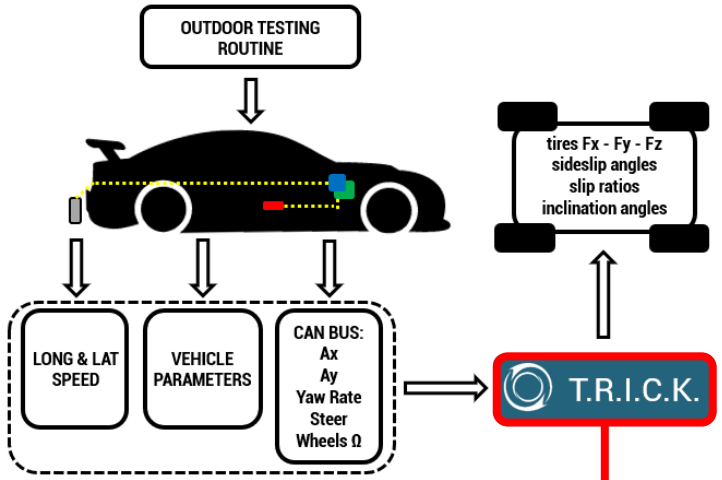


NVH and Full Spectrum Simulator

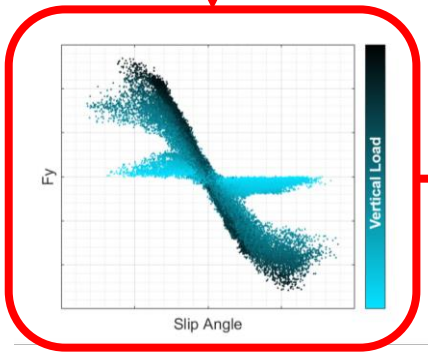


DiM

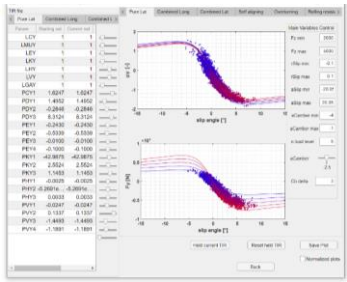
Tire Model Implementation



FROM TRACK DATA TO TIRE CHARACTERIZATION

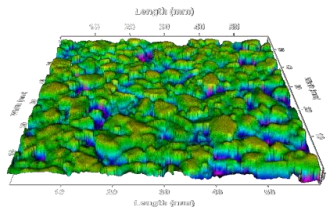


MULTI-PHYSICAL TIRE PARAMETERS IDENTIFICATION

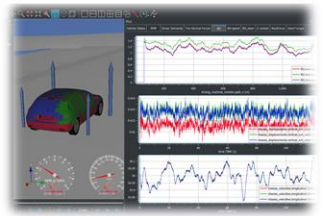


Digital Twins Domain

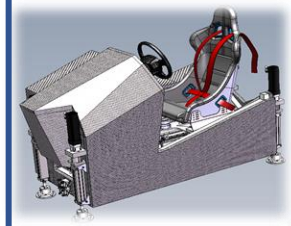
Modelling



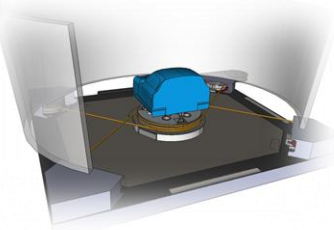
Zero Prototypes testing



Multibody off-line Simulation



NVH and Full Spectrum Simulator



DiM

Road Model Implementation

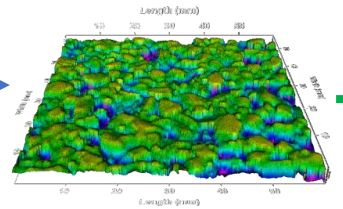
Laser + Camera Scanning

Existing .las data

Data Cleaning

Digital Twins Domain

Modelling



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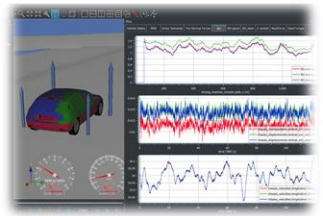
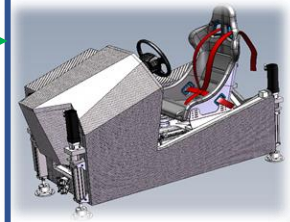


Multibody off-line Simulation



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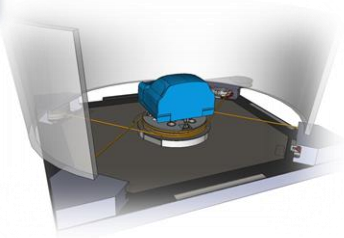
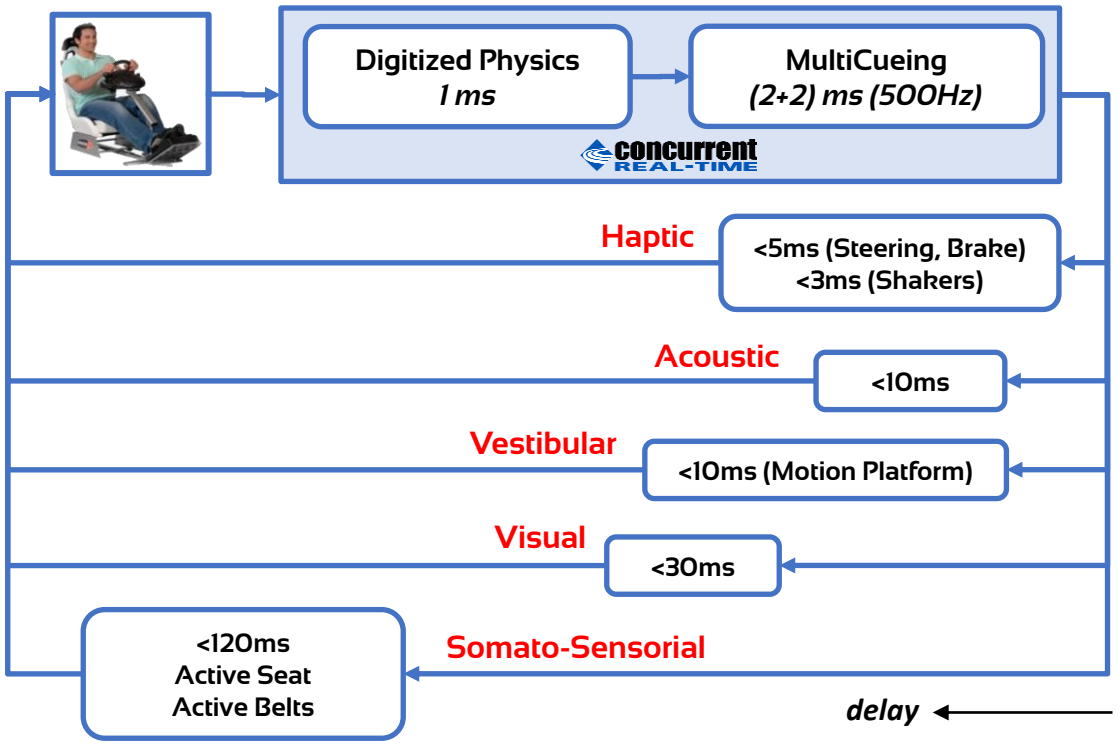


DiM

Digital Twins Components

- Road ☑
- Tire ☑
- Vehicle ☑



Different sensory modalities can be misaligned over time because they work at different speed

Different sensory modalities **suffer the effect of our motor state**, for example of preparation for action or excessive motion compensation

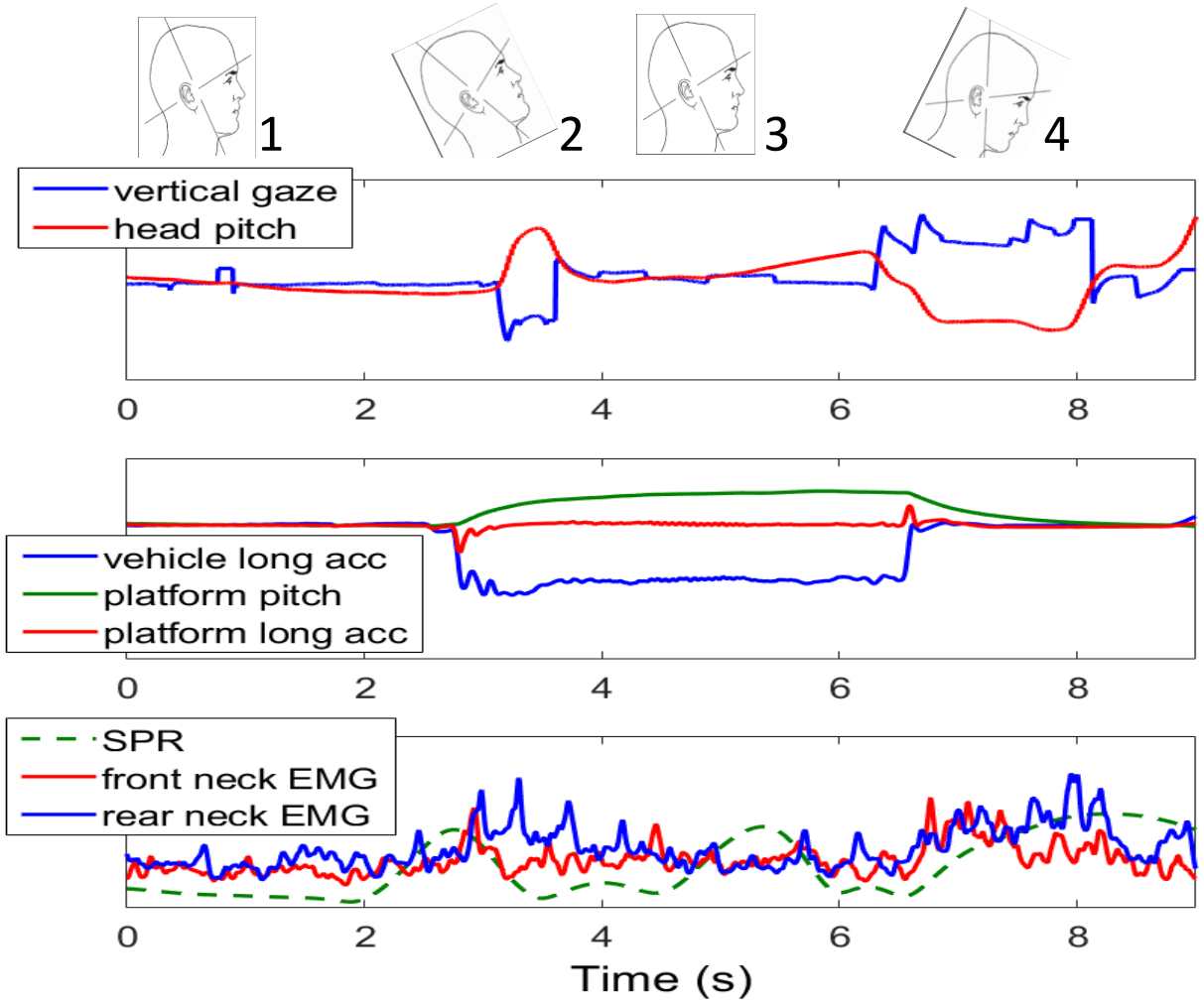
The current predominant hypothesis is that **the motor system plays a crucial role in estimating time and can act as a "harmonizer" of sensory timing**

Uni-sensory temporal estimates, as well as multisensory temporal integration, **is one of the domains in which there is the greatest variability** between individuals

- **How does the driver get it all?**

Conflictual Sensory Signals

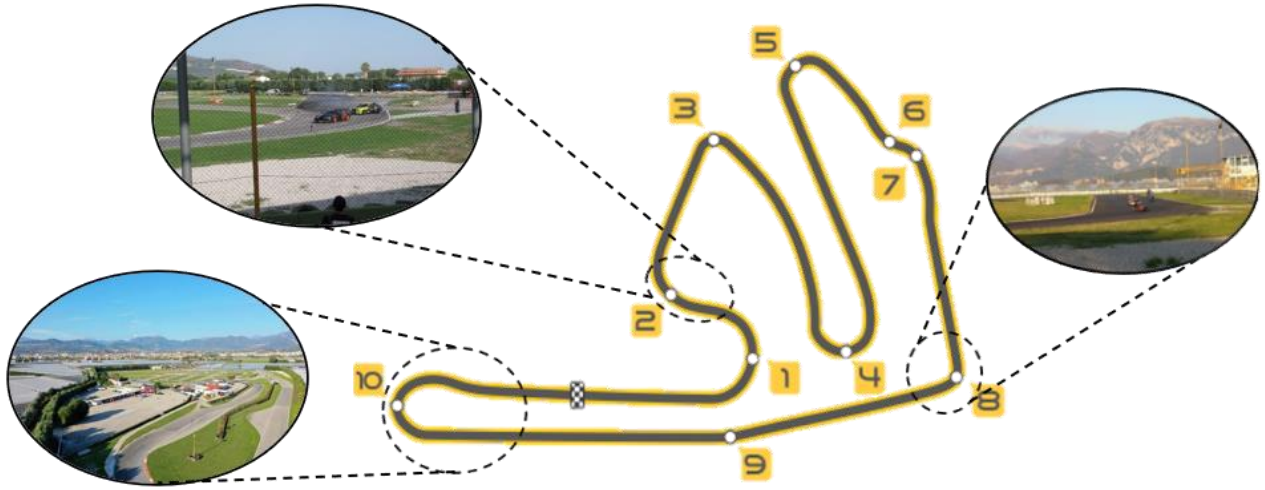
Conflict!



1. Head horizontal, no long acc
2. Beginning of braking, head pointing up
3. Stable braking, head horizontal
4. End of braking, head pointing down

MEASURED CHANNELS, NON-EXPERT SIM DRIVERS ⇨ BIOFEEDBACK TO CORRECT?

The "Seaside Racing" Project: Overview



Partners

VI-GRADE, AlmaTec software technology, MEGARIDE, BeCAE & TEST, Calspan, KISTLER measure. analyze. innovate.

Onboard Equipment

- **2 S-Motion Sideslip Sensors**
- **Wheel Dyno Hub**
- **IR tire tread**
- **IR inner liner**
- **OXTS IMU**
- **16 accelerometers**
- **CAN BUS reading hub**
- **2 high resolution GPS**

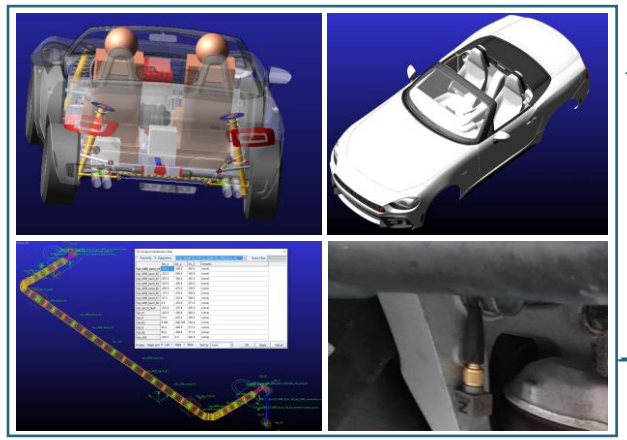
Track

Name: Circuito del Sele
Length: 1664 meters
Corners: 10 (3 left, 7 right)
Longest straight length: about 400 meters

Vehicle

- **FIAT 124 SPIDER (RWD)**

The "Seaside Racing" Project: Structure



CHASSIS & SUSPENSIONS

TIRE

VEHICLE

TRICK TOOL

MF STD ID

MF STANDARD IDENTIFICATION

THERMAL CHARACTERIZATION (conductivity, specific heat and density)

TIRE THERMAL MODEL ID

thermoRIDE MODEL CALIBRATION

MF EVO ID

MF EVO IDENTIFICATION

3D RIDE ID

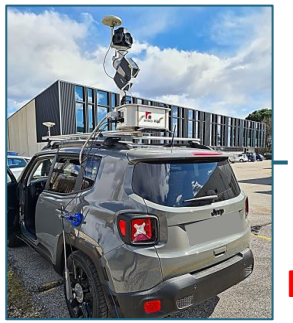
STRUCTURAL CHARACTERIZATION (tire geometric profile and contact patch parameterization)

threedeeRIDE model

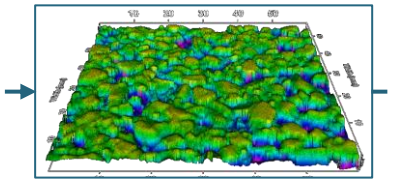
VISCOELASTIC CHARACTERIZATION (storage modulus and loss factor evaluation)

TIRE WEAR MODEL ID

weaRIDE MODEL CALIBRATION



ROAD



VI CRT offline simulations

DiL application

The "Seaside Racing" Project: Target

- Optimization of the Road Texture Geometrical Resolution
  - Related to Tire Modelling and Contact Multiphysics
- Deepen Knowledge of Tire Ride and Wear Effects on Driving Perception
- Correlation among Road Geometrical, Frictional and Acoustic Features
  - Application of Model-based and Statistical Methodologies
- Implementation on Driving Simulators
  - Optimization of Multisensorial Experience for best Digital Twin
  - Harmonized Haptical, Acoustic and Vestibular Perception

Road Data - Acquisition and Processing

- Laser scan + integrated photogrammetry
- 3 cameras + 2 laser
- Millimeters resolution

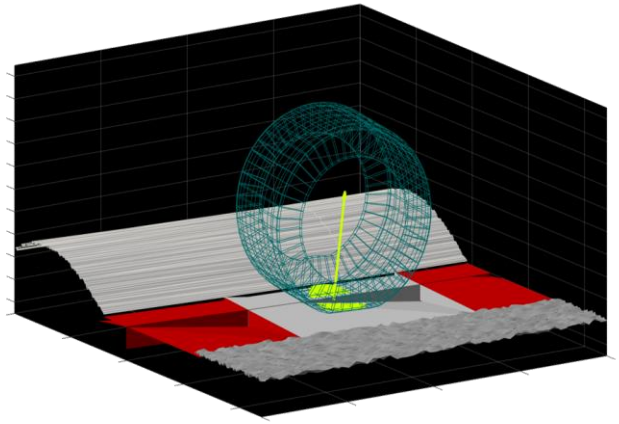
- Objective: clean and filter road point cloud to generate a VI-GridMesh functional to match simulation data with measured data and driver feeling

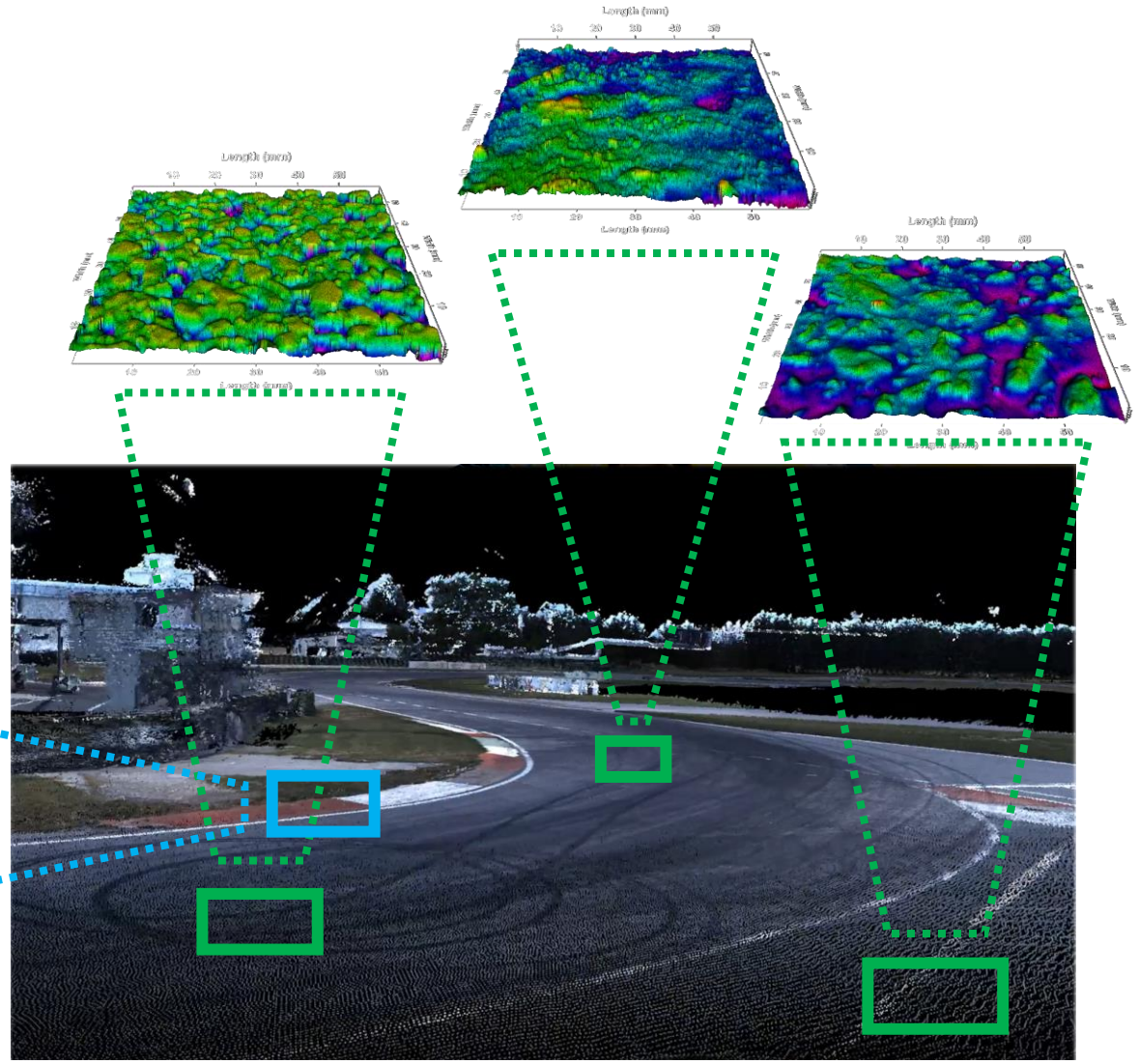
- Proprietary algorithms with user paremeters taking into account:
  - Original cloud density
  - Road slope
  - Capability to distinguish real roughness and scanner noise

- Correlation between measured roughness and algorithm parameters

Road Data - Next Level

- Definition of the Optimal Geometrical Resolution
  (AMES 9400HD Laser Texture Scanner)
- Local & real-time footprint modelling
  (threedeeRIDE RIDEsuite module)
- Functional correlation between geometrical, frictional, acoustic features

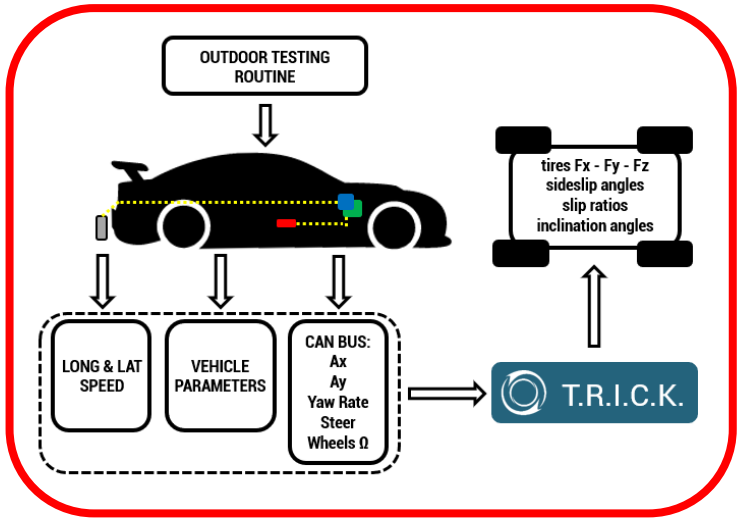




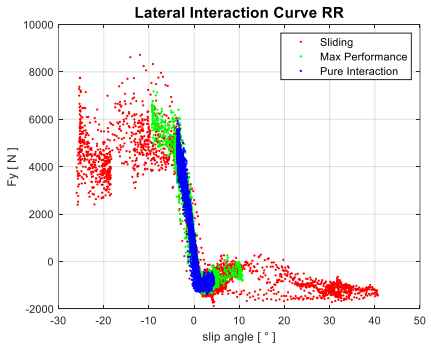
in cooperation with

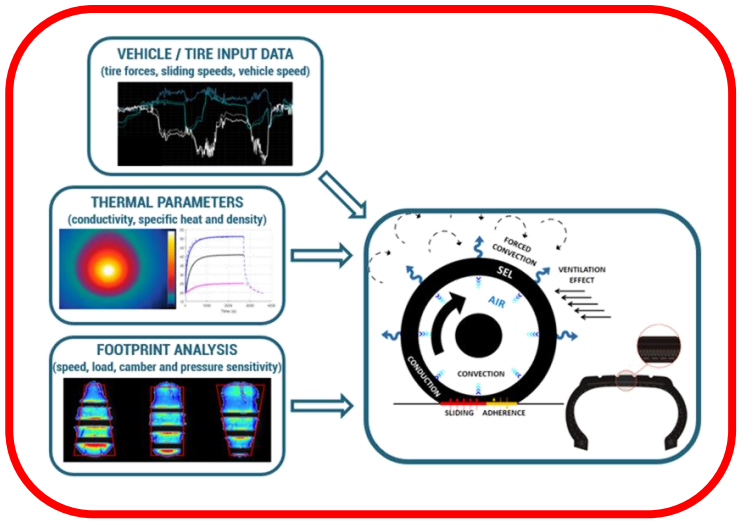
DROMO
Applied Italian Circuit Design

Tire Model - Standardizing Parameterization

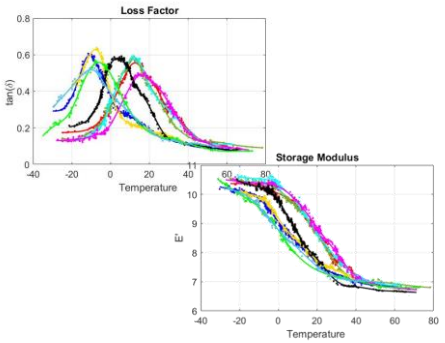


KINEMATICS & DYNAMICS

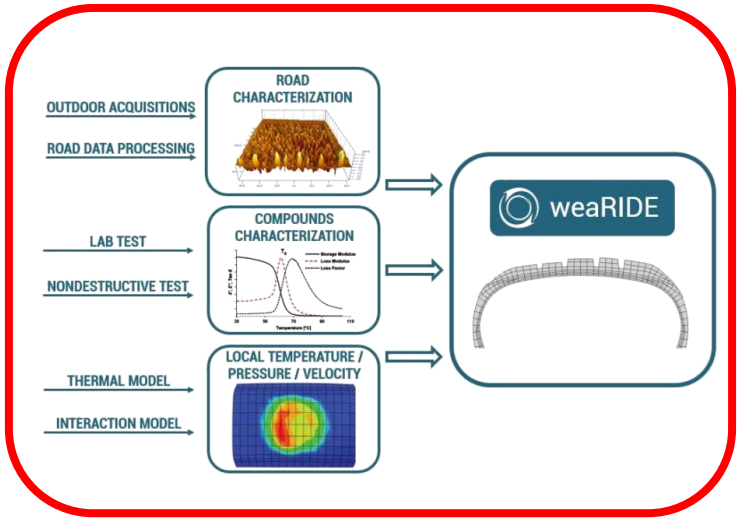




TEMPERATURE & ENERGIES

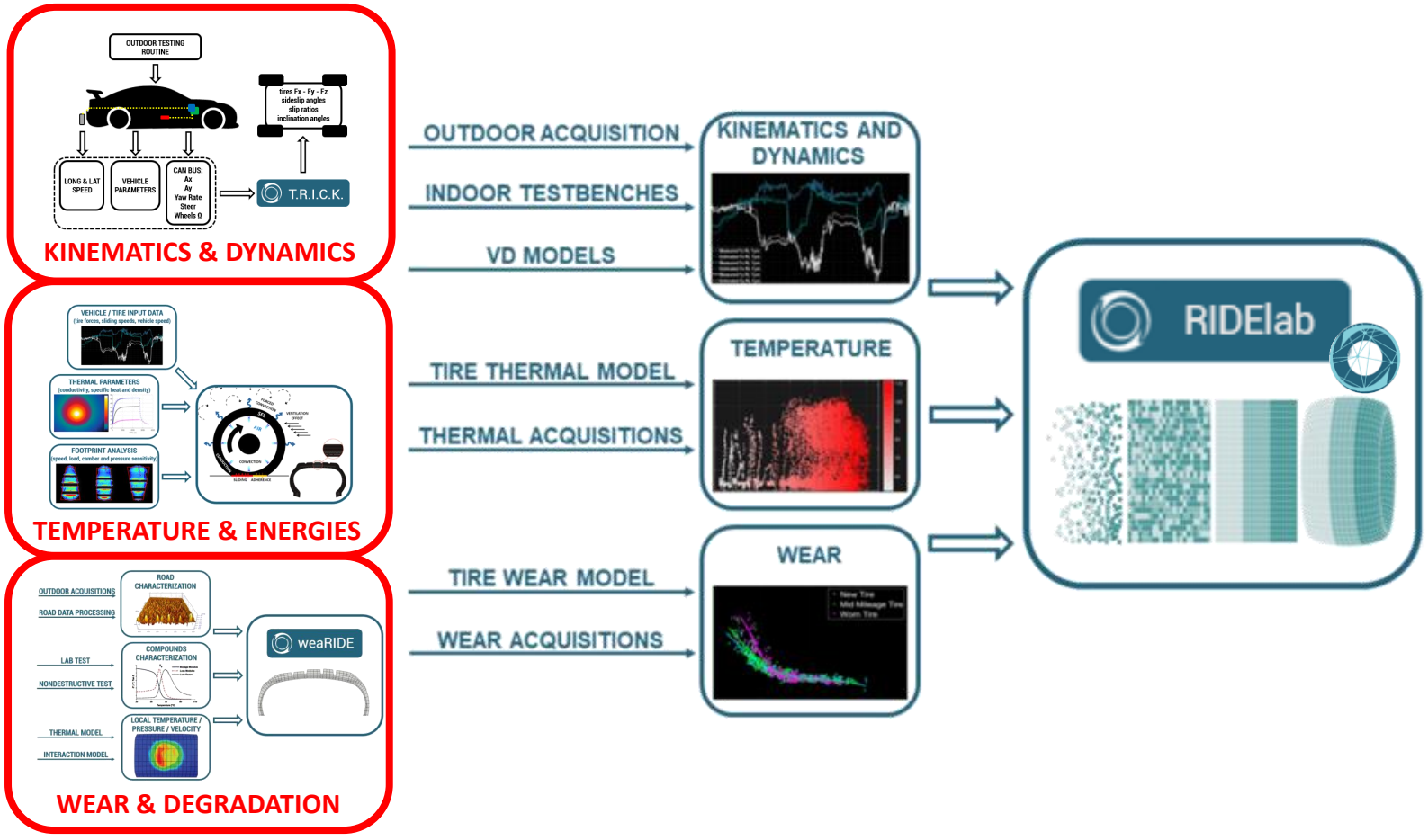


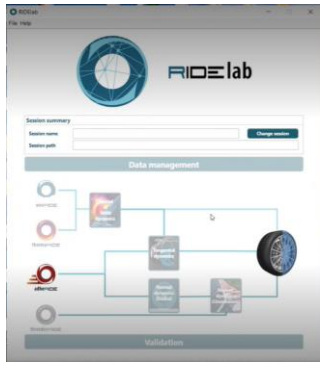
VESevo

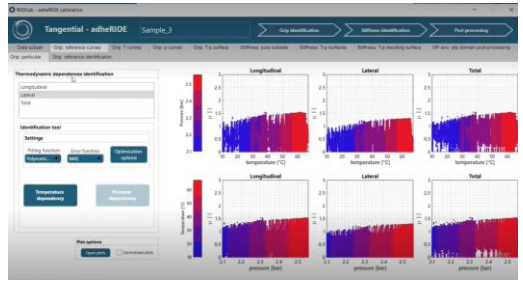


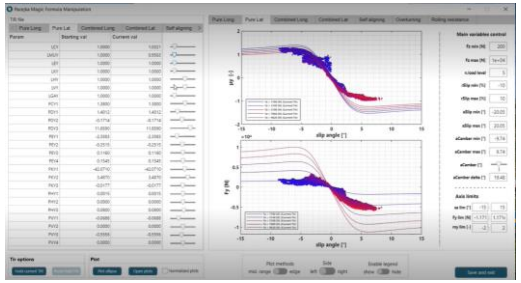
WEAR & DEGRADATION

Tire Model - A Modular Platform for Contact MultiPhysics

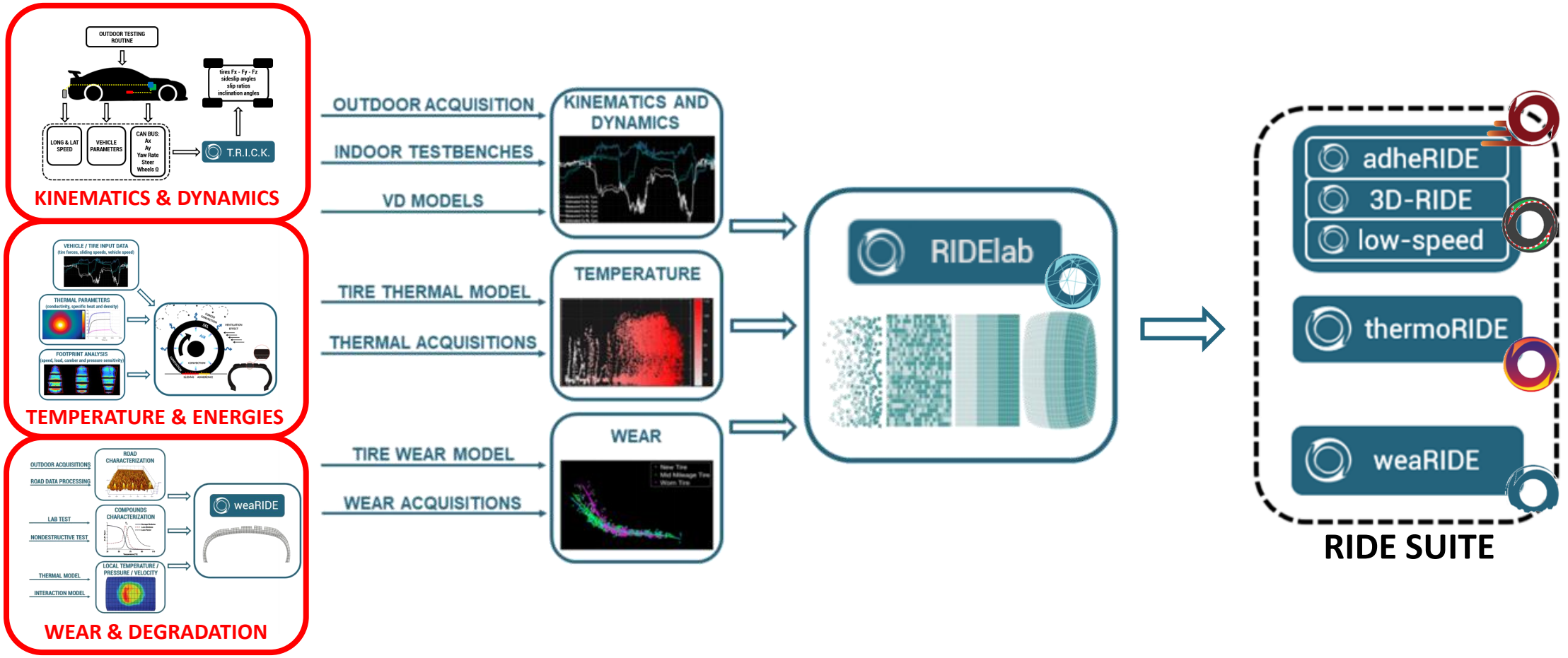




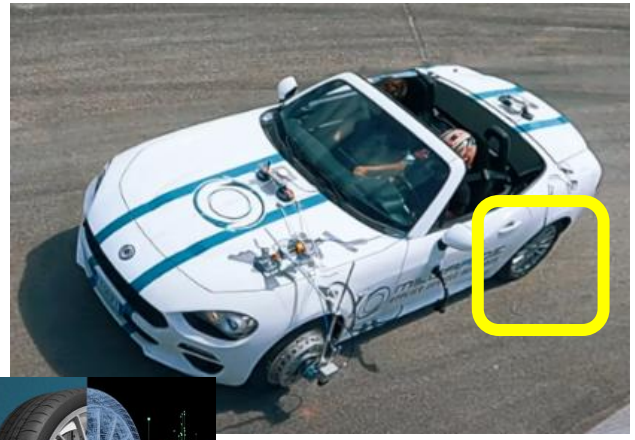




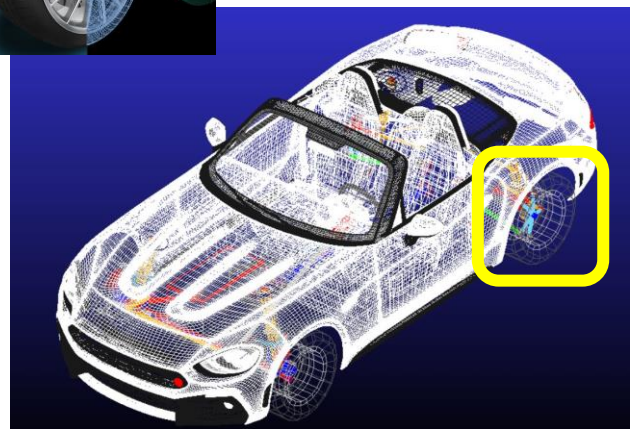
Tire Model - A Modular Platform for Contact MultiPhysics

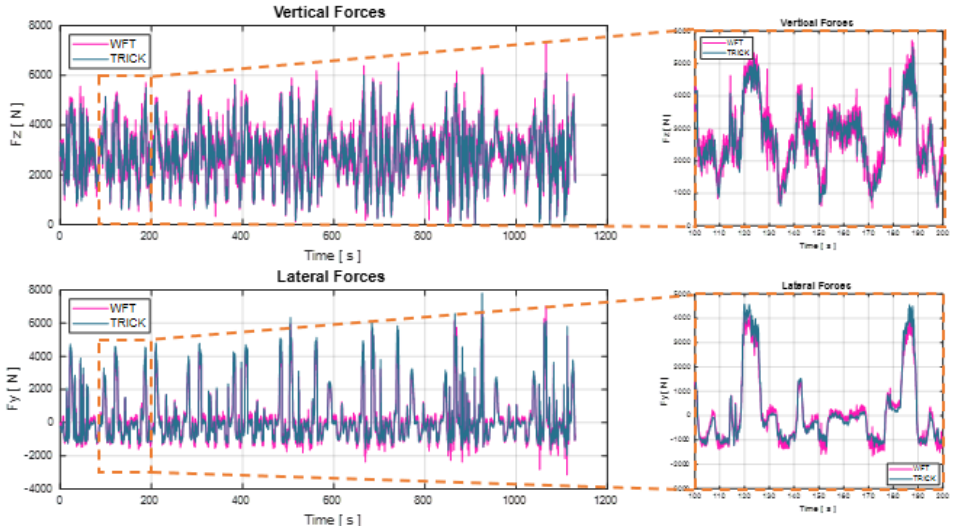


Tires MultiPhysics - getting interaction data

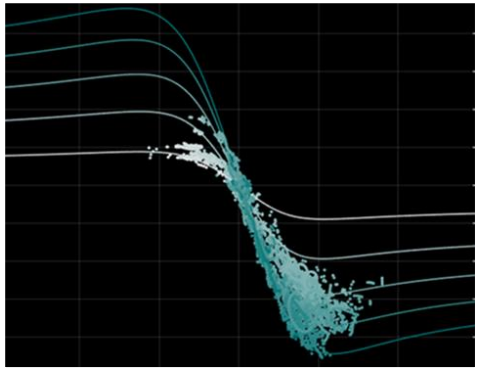


REAL vs DIGITAL

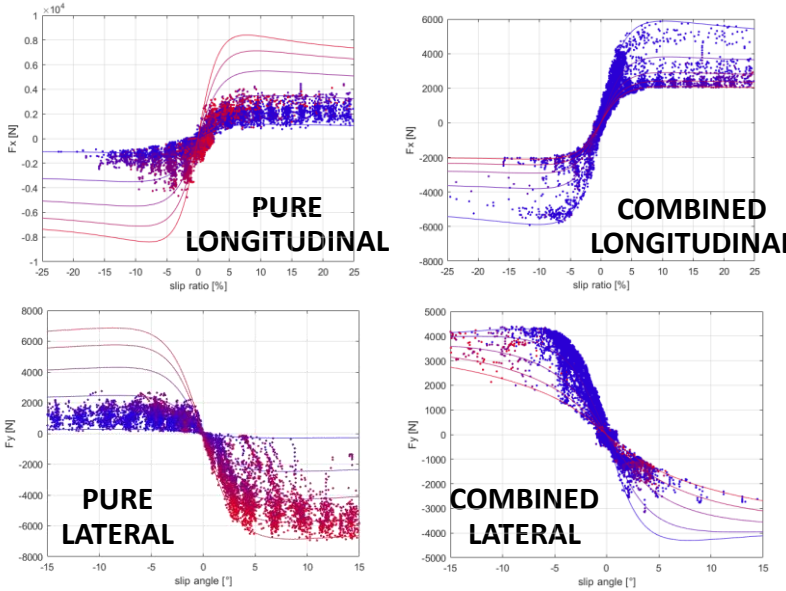




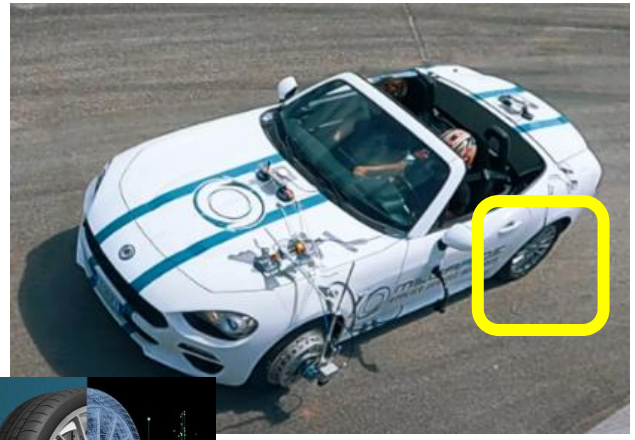
FORCES EVALUATION BY T.R.I.C.K. vs DYNO HUBS



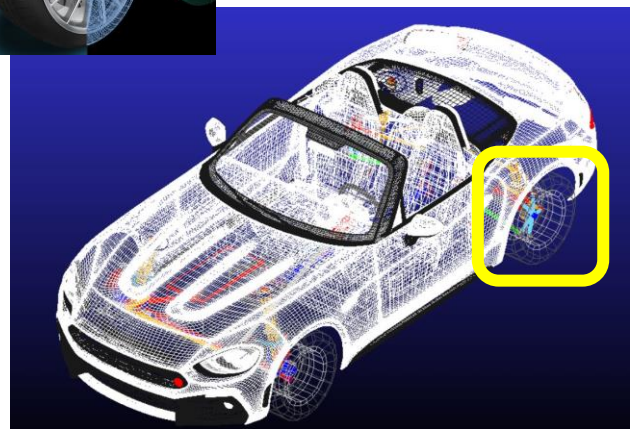
BASELINE MF IDENTIFICATION

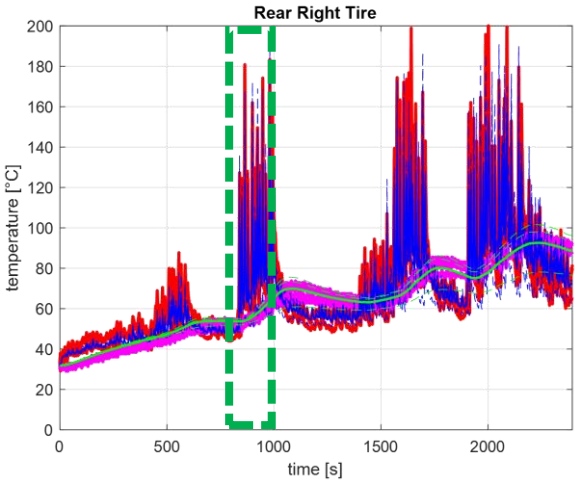


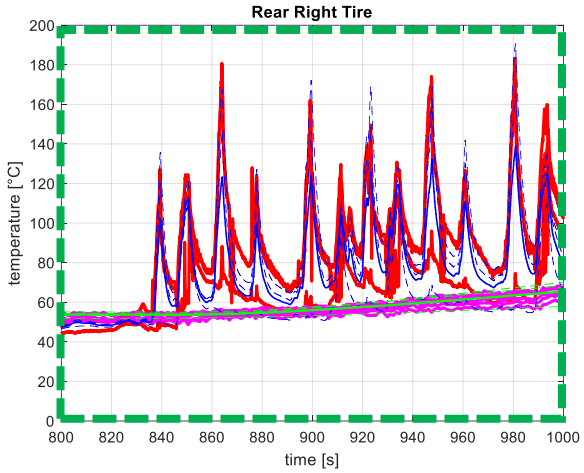
Tires MultiPhysics - thermodynamic validation

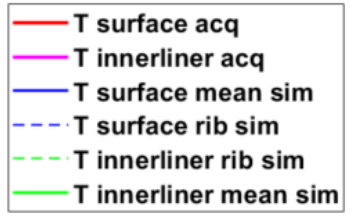


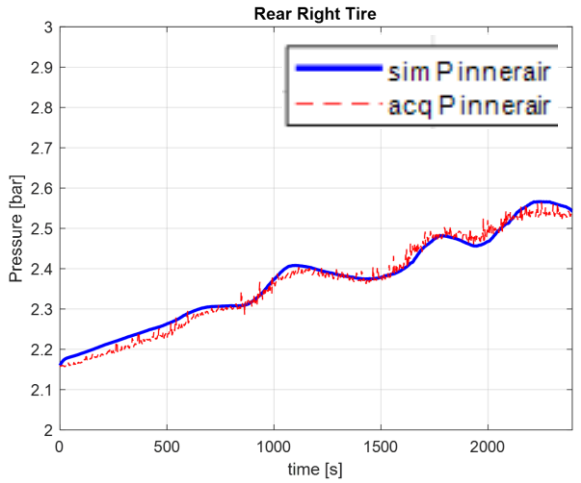
REAL vs DIGITAL

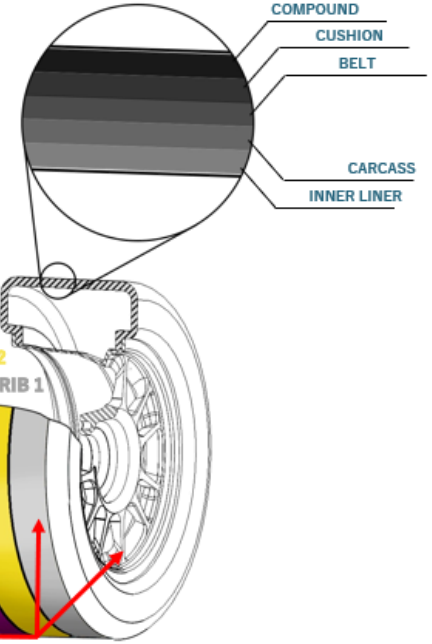




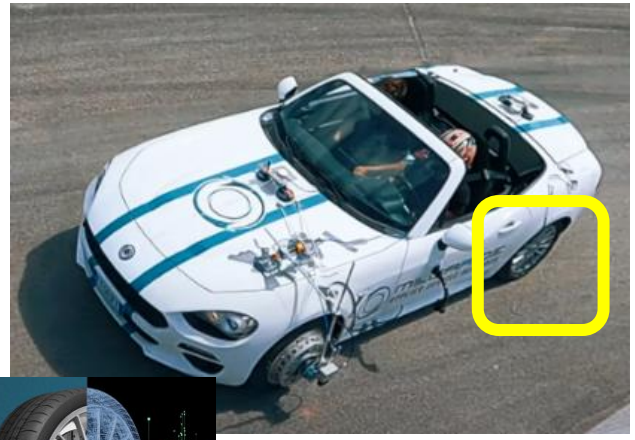




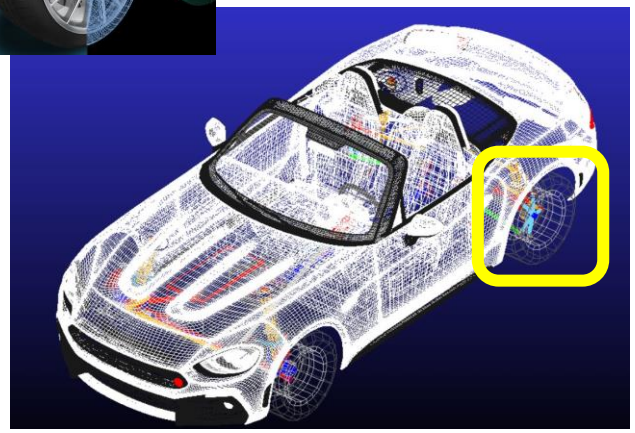


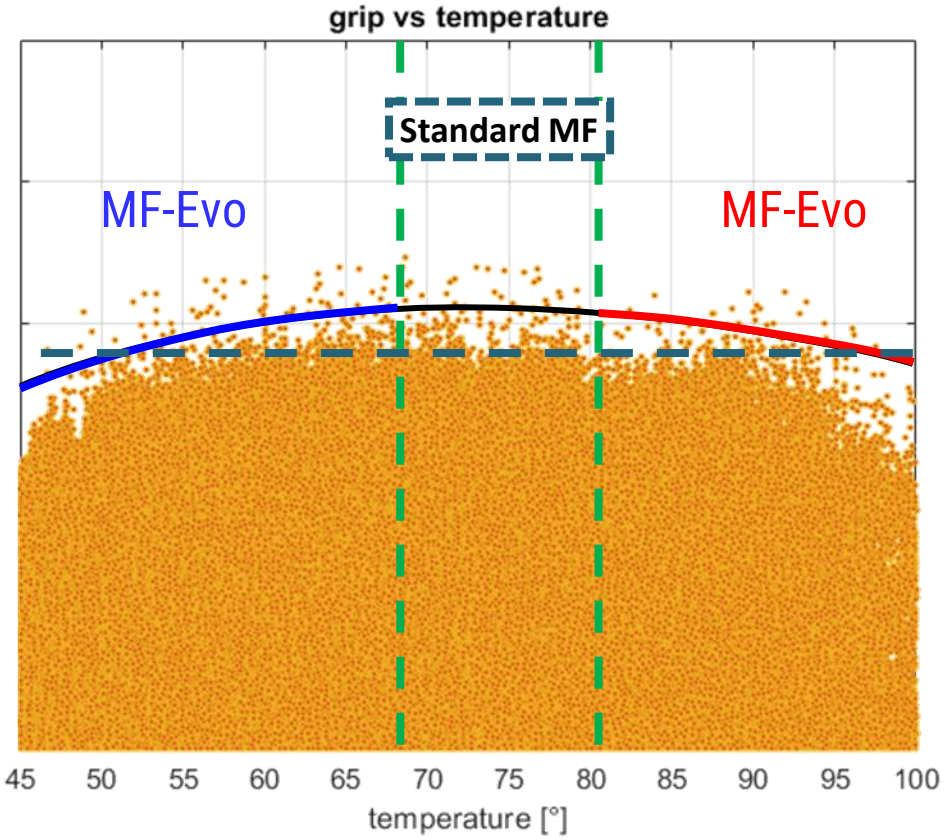


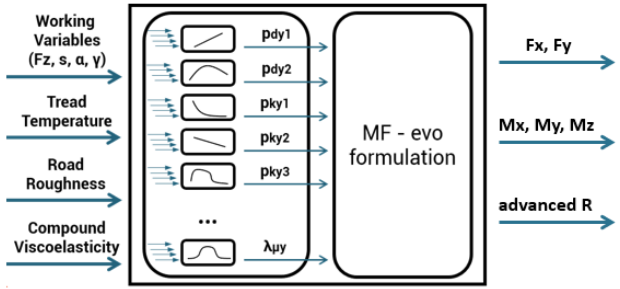
Tires MultiPhysics - temperature and pressure variabilities

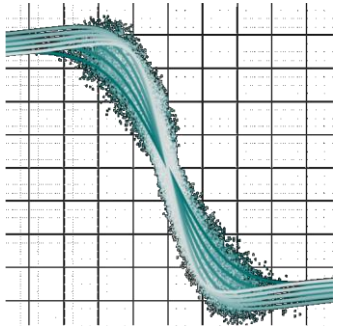


REAL vs DIGITAL



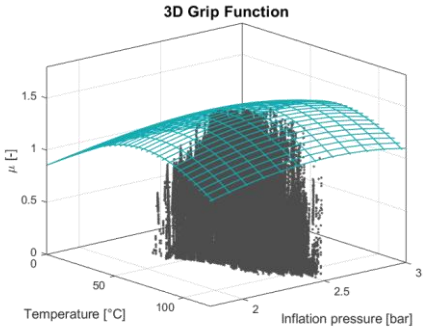




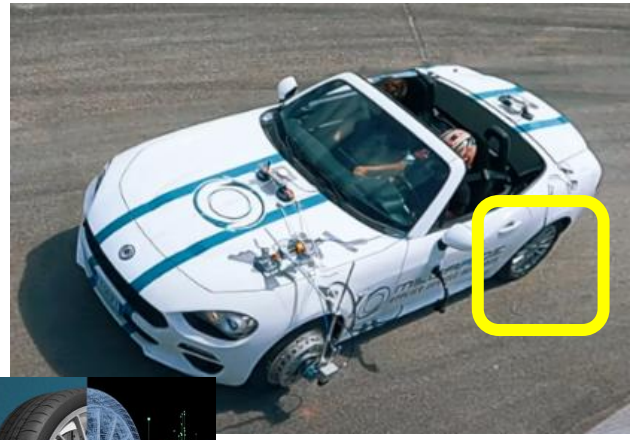


CORNERING AND BRAKING STIFFNESSES VS PRESSURE AND TEMPERATURE

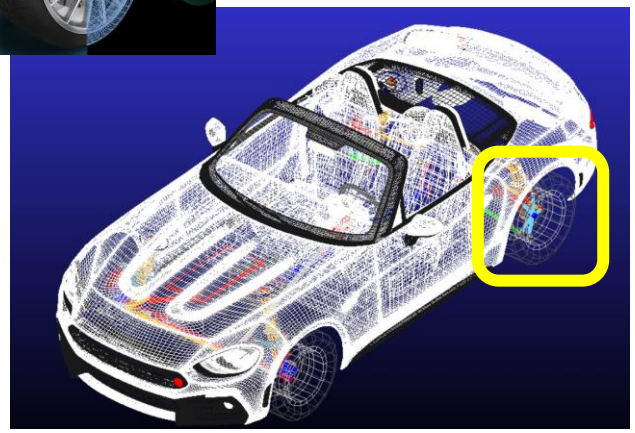
GRIP AND LOAD SENSITIVITIES VS PRESSURE AND TEMPERATURE

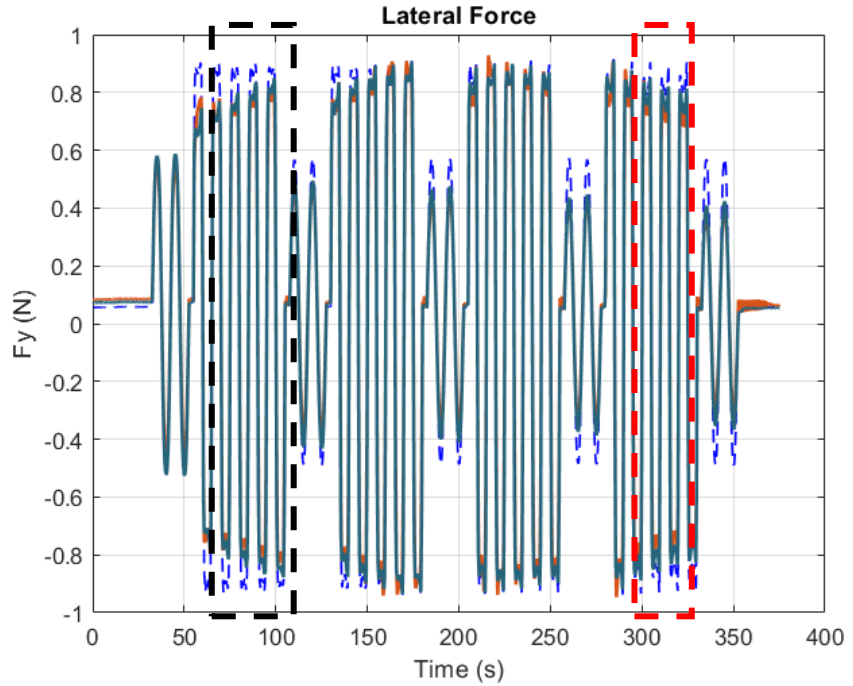


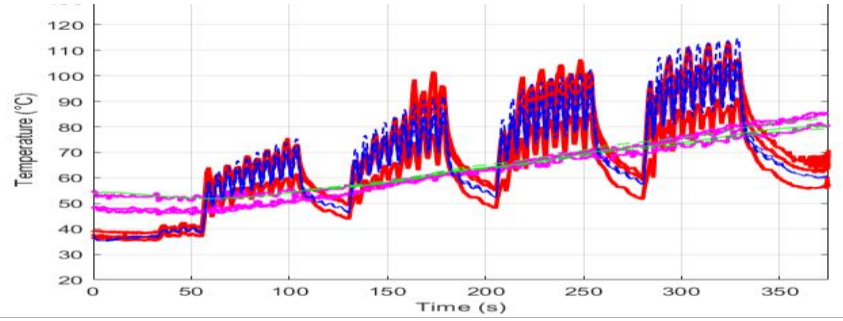
Tires MultiPhysics - the key role of thermodynamics and wear

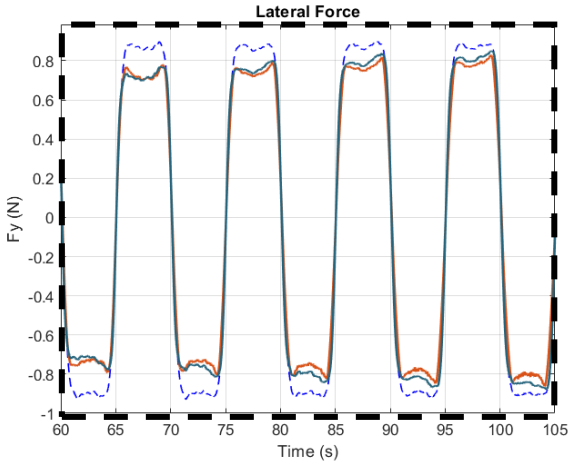


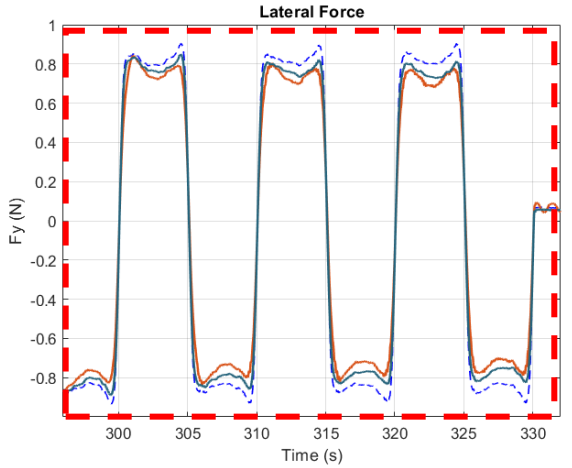
REAL vs DIGITAL





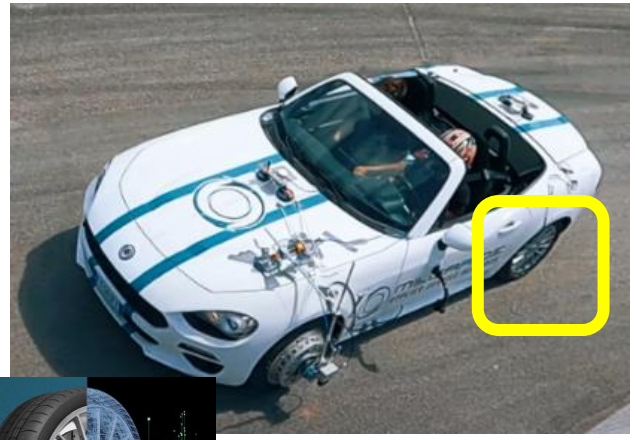




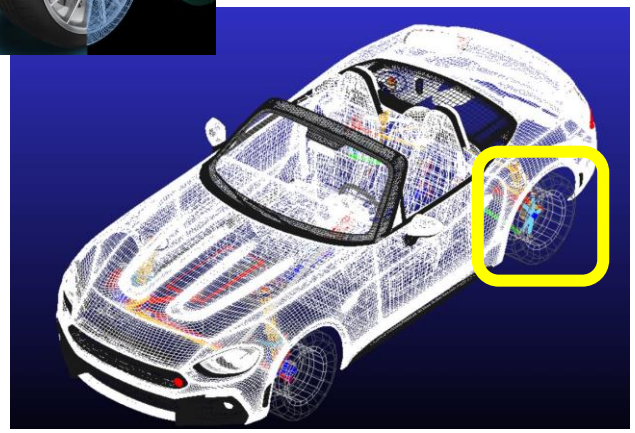


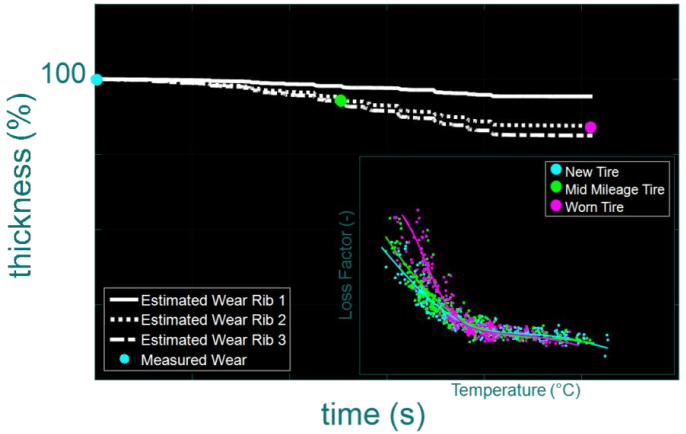
Tires MultiPhysics - wear and degradation

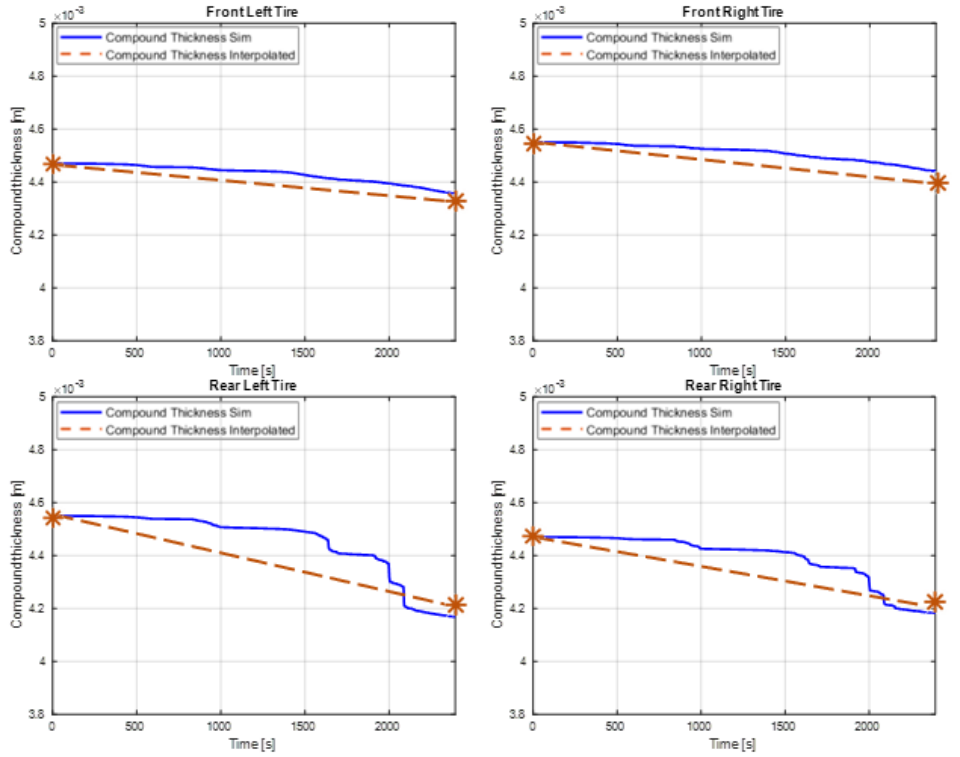
tires: TOYO PROXES R888R



REAL vs DIGITAL







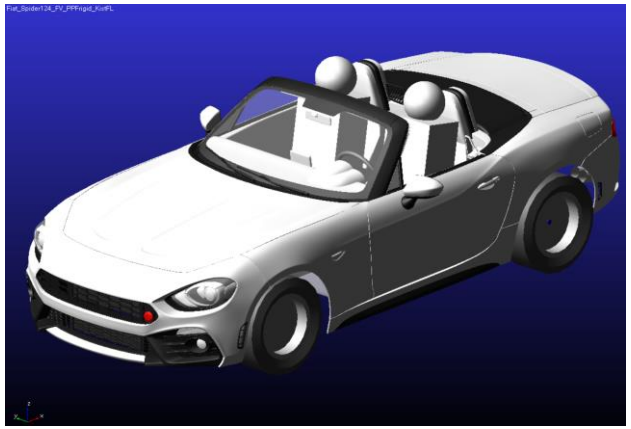
✱ Average acquired values

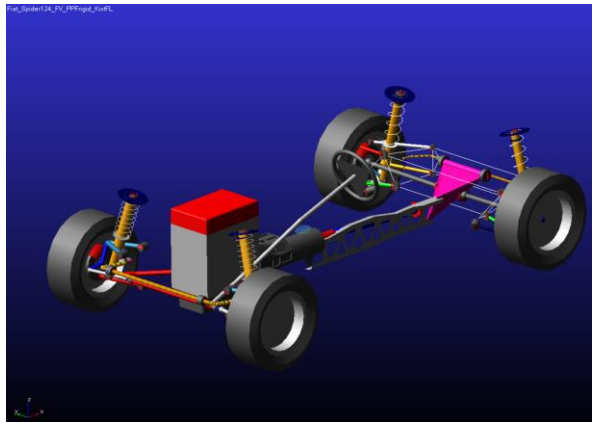
Continuous simulated tread wear

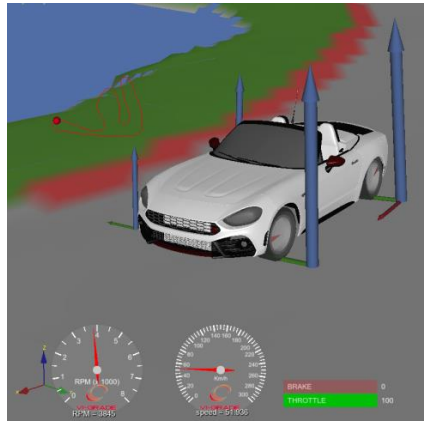
Vehicle Model - Chassis and Suspensions

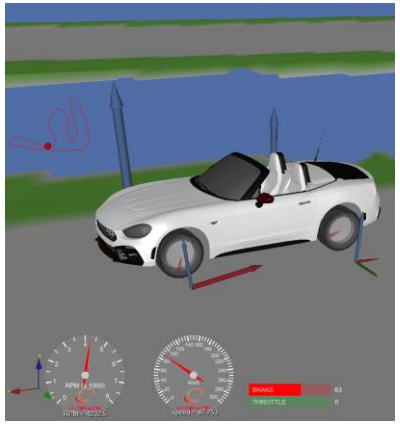
- MegaRide testcar (Fiat 124 Spider) with same setup at Sele's track

Detailed ADAMS\Car model → VI-CRT model for DiMs and offline sim

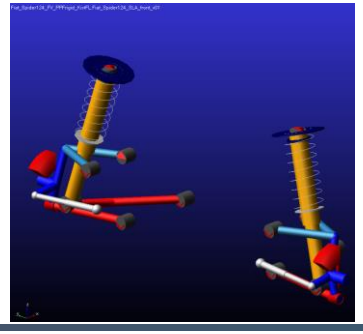




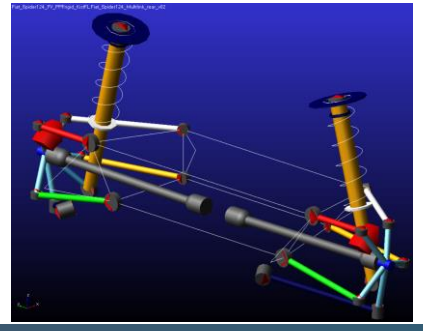




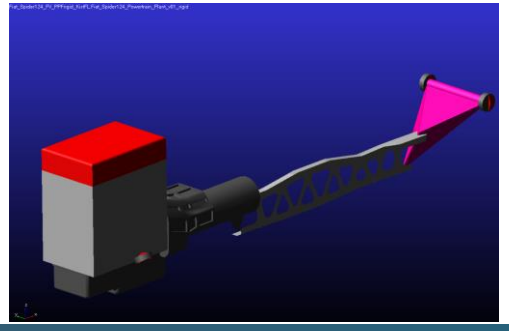
SLA front susp

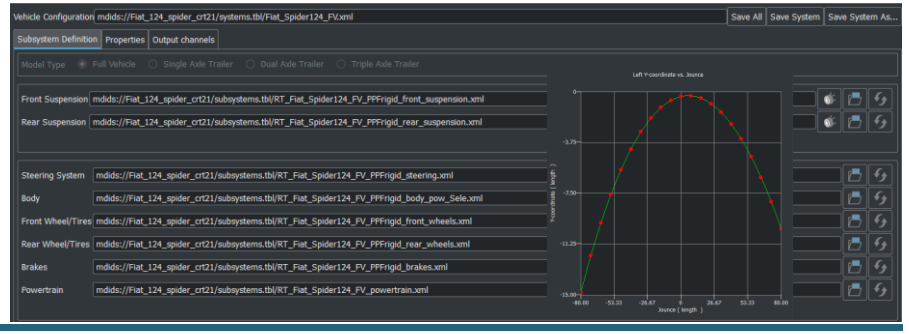


Multi-link rear susp

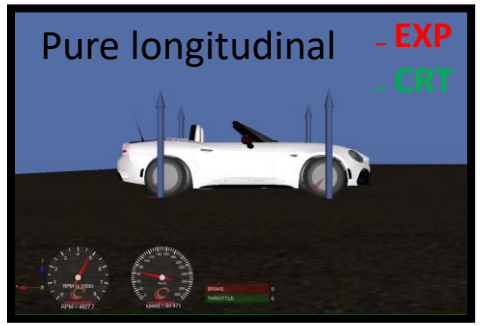


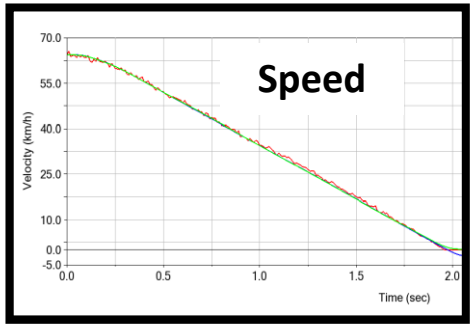
Power-Plant-Frame and mounts

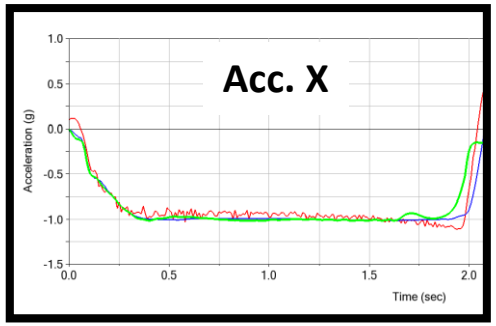


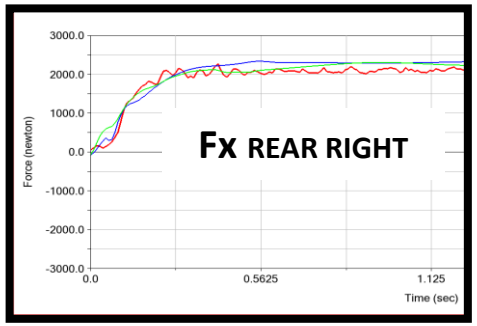


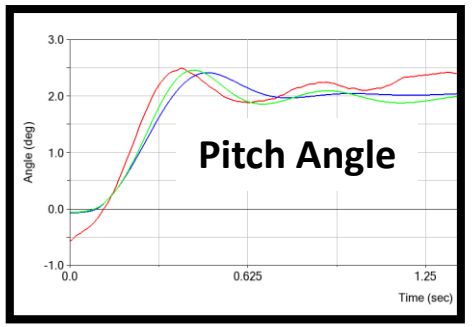
Vehicle Model - preliminary offline validation on flat road: pure slip tests

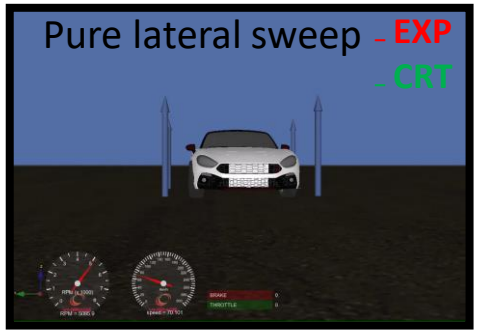


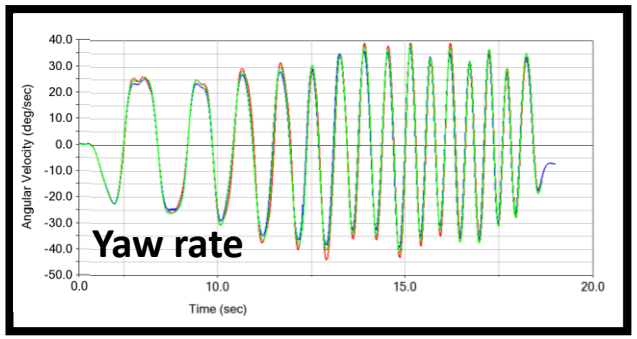


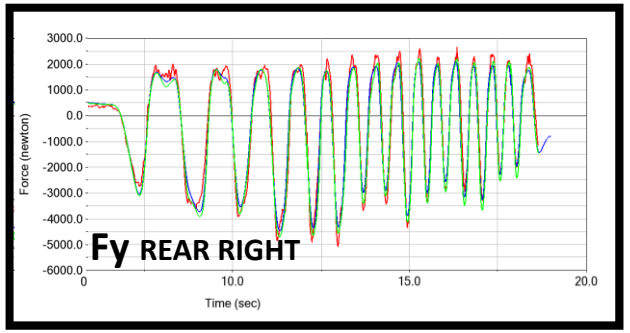


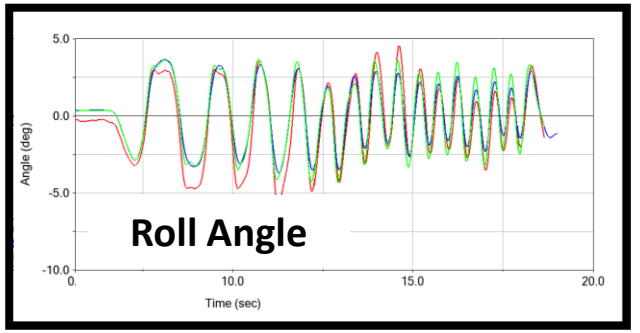


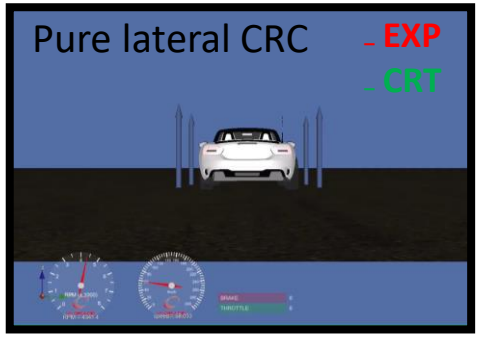


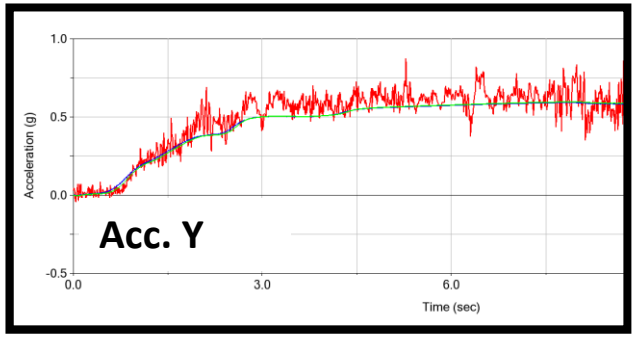


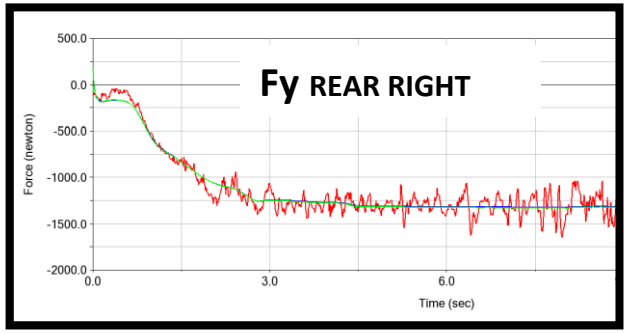


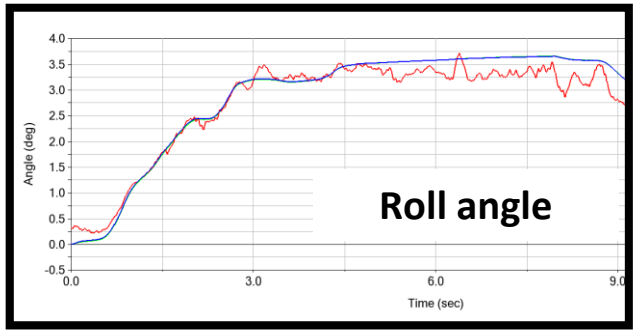








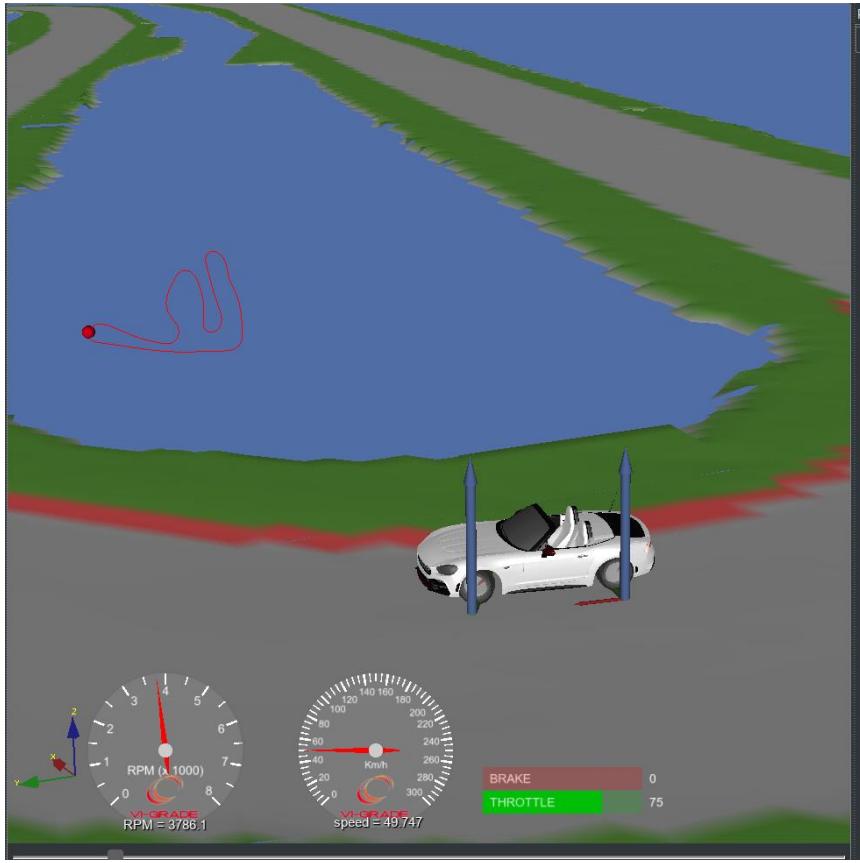


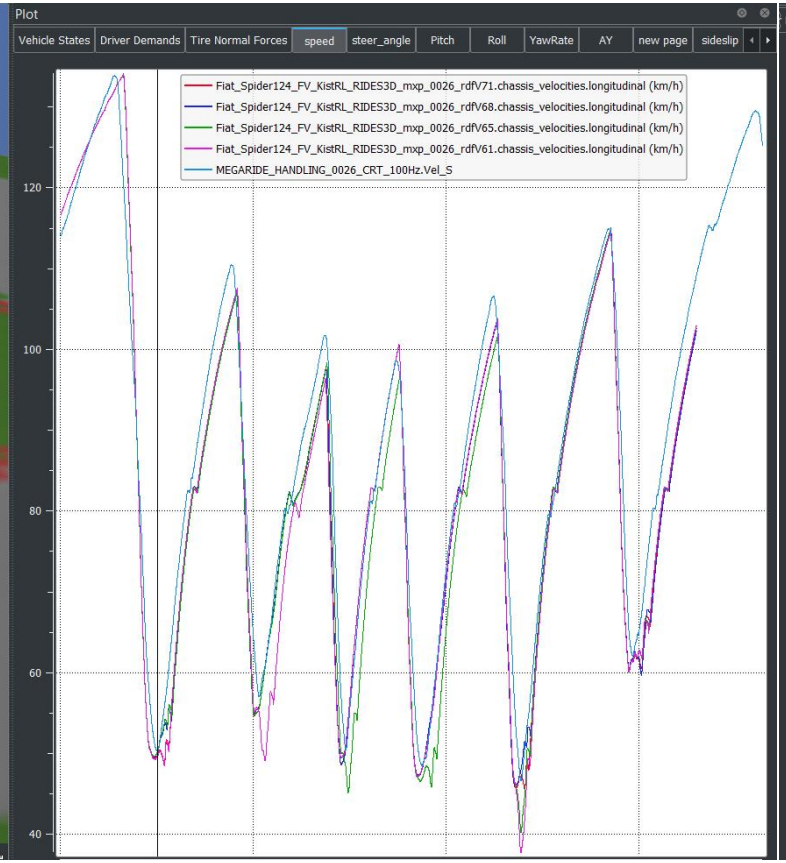


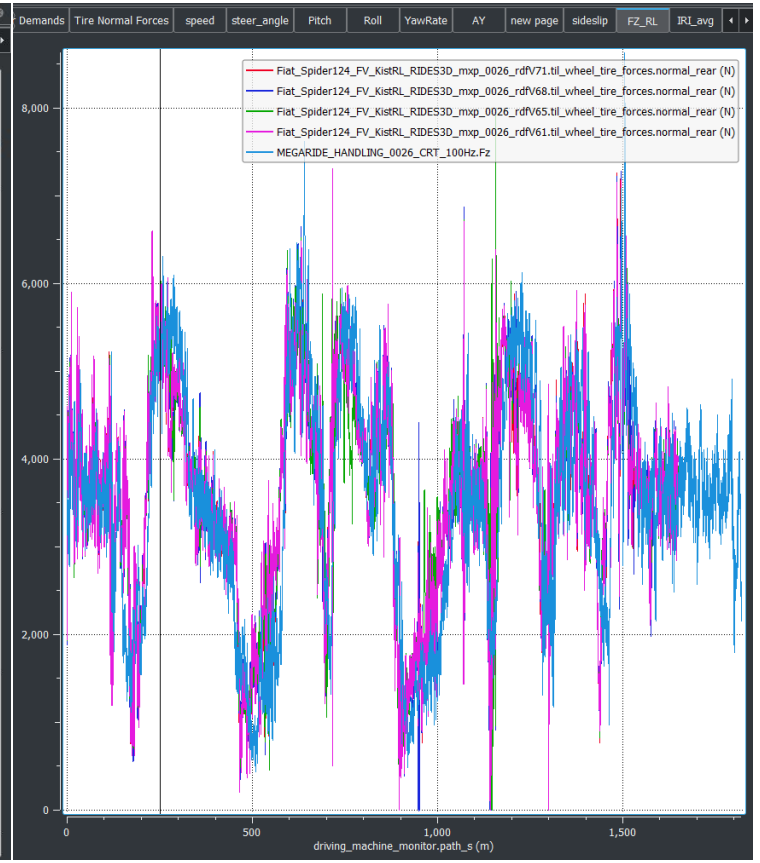
Vehicle Model - preliminary offline validation on rough road: max-performance event

GPS driver path measured during track test session

Comparison of different level of road discretization on performance and tire force (hub dyno on rear left wheel)



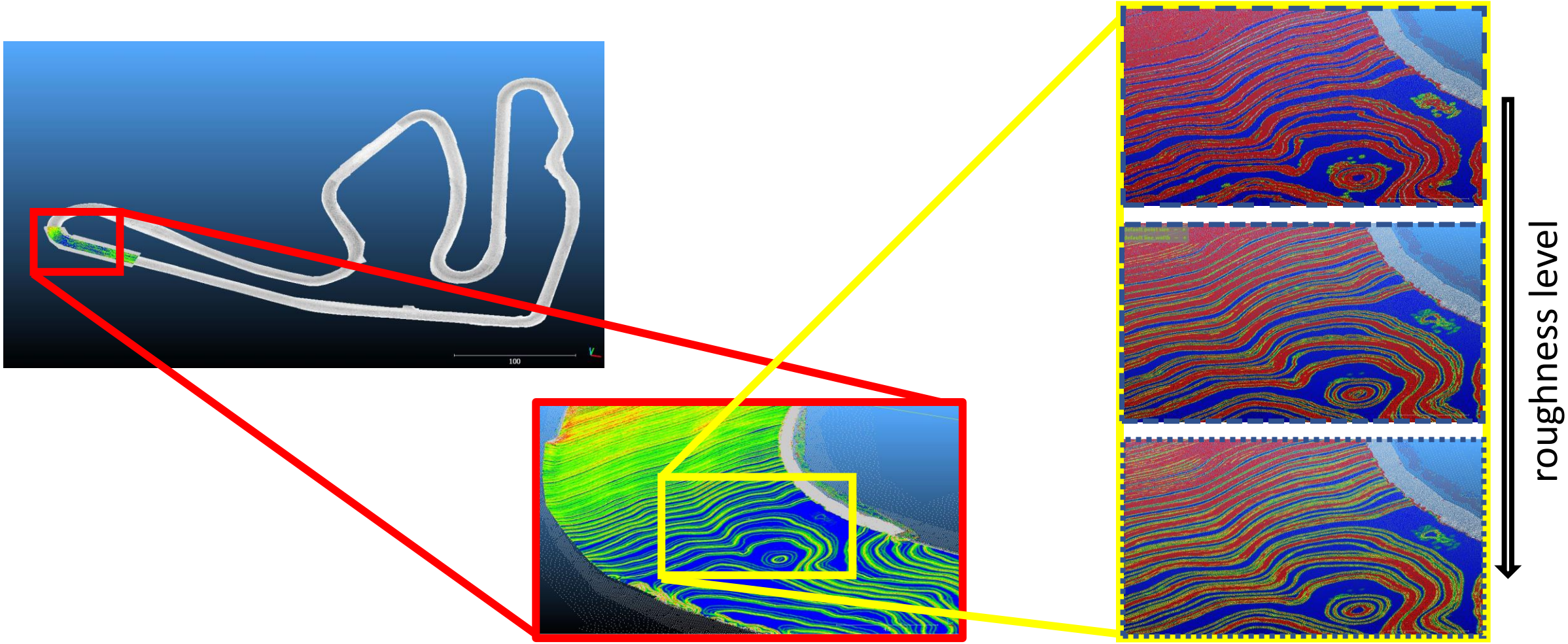




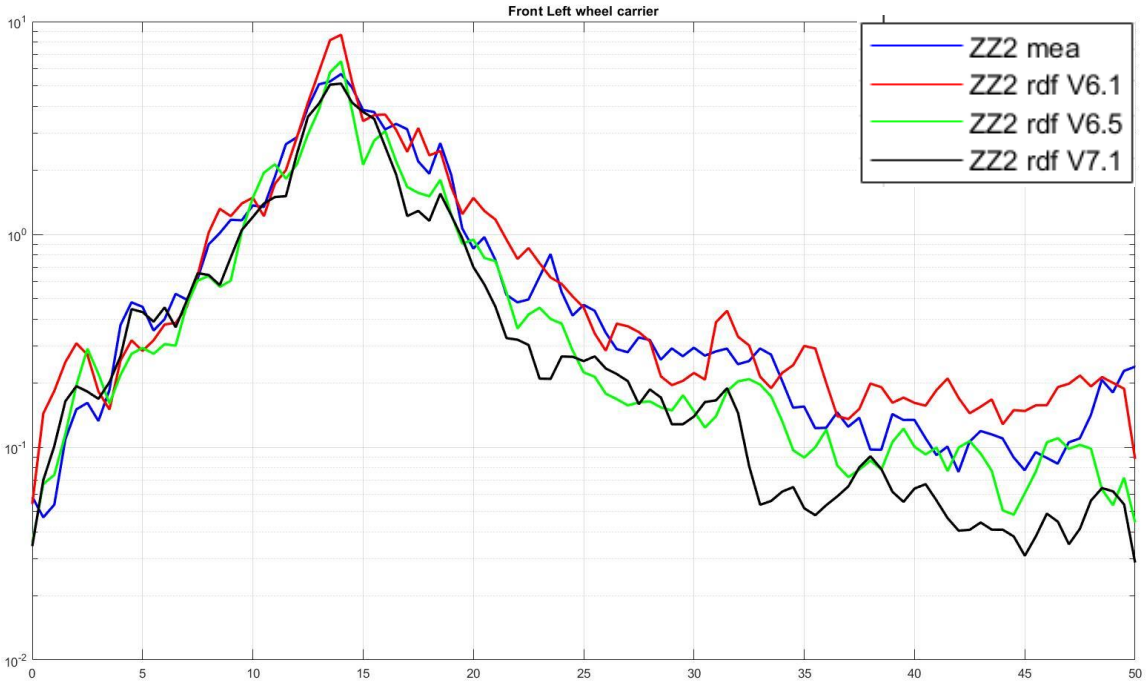
Towards zero prototypes scenario - DiMs test sessions (vehicle + tire + road)

- DiM 150: model tuning conceived as a chassis tuning session with a list of setup changes
  - front springs
  - front ARB and roll balance
  - front and rear dampers
  - bumpstop clearence
- DiM 400: tire and road tuning starting from modified chassis setup, subjective evaluation of tire heating and wear effects, additional fine tuning of chassis parameters
- Compact FSS: further vibration tuning

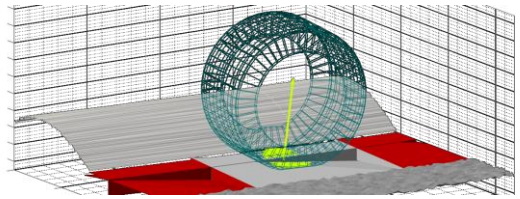
Towards zero prototypes scenario: changing road roughness representation

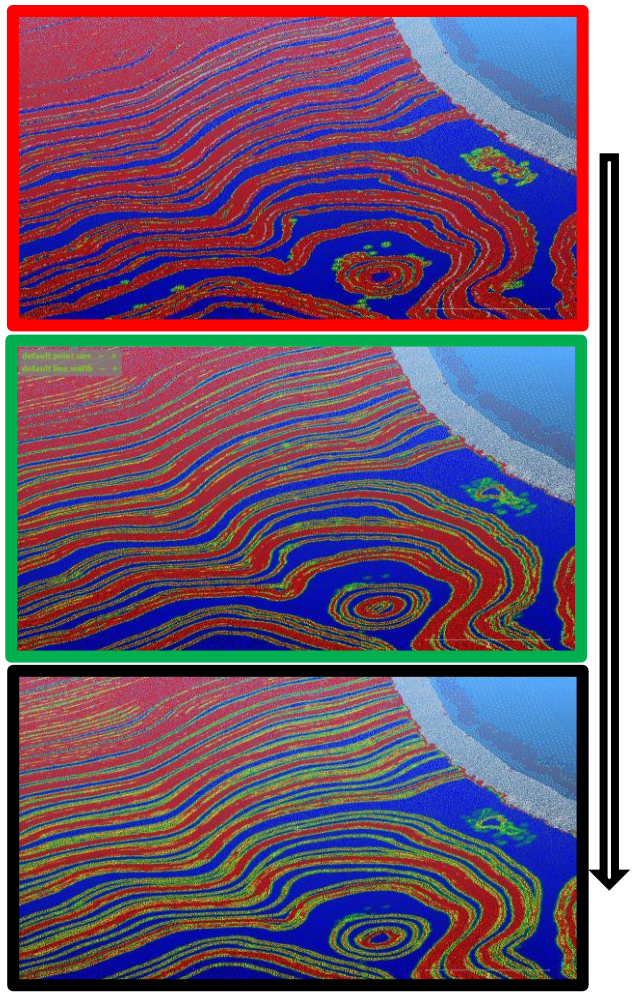


Towards zero prototypes scenario: effect of road roughness on hub acceleration PSD

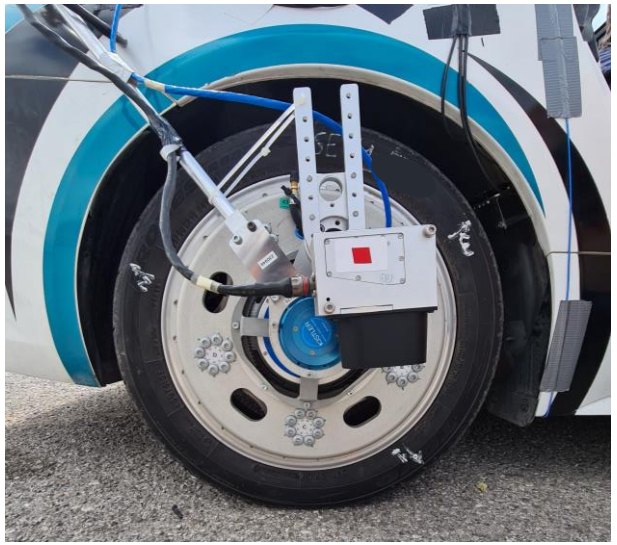


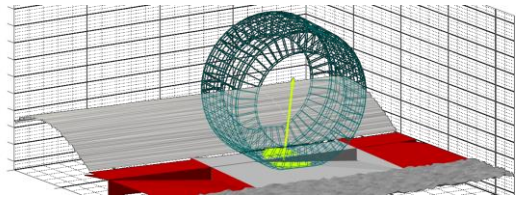
Simulations carried out with MegaRide multi-contact threedeeRIDE module active



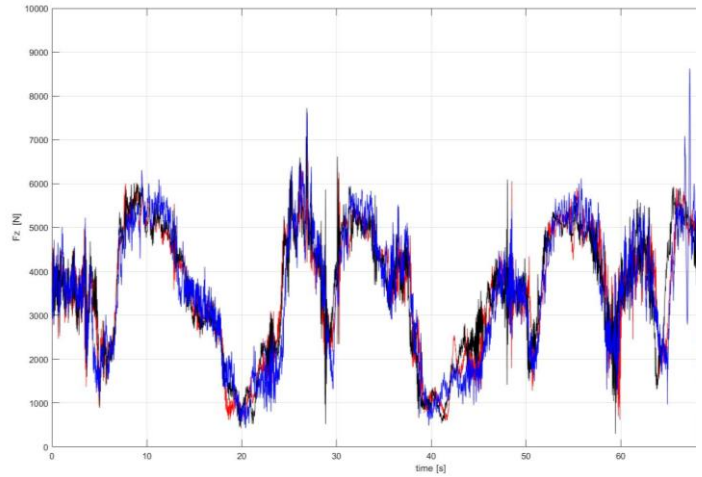


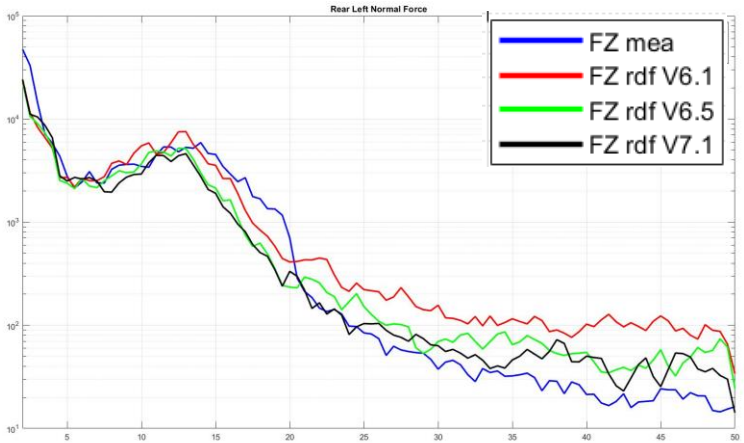
Towards zero prototypes scenario: effect of road roughness on hub force PSD

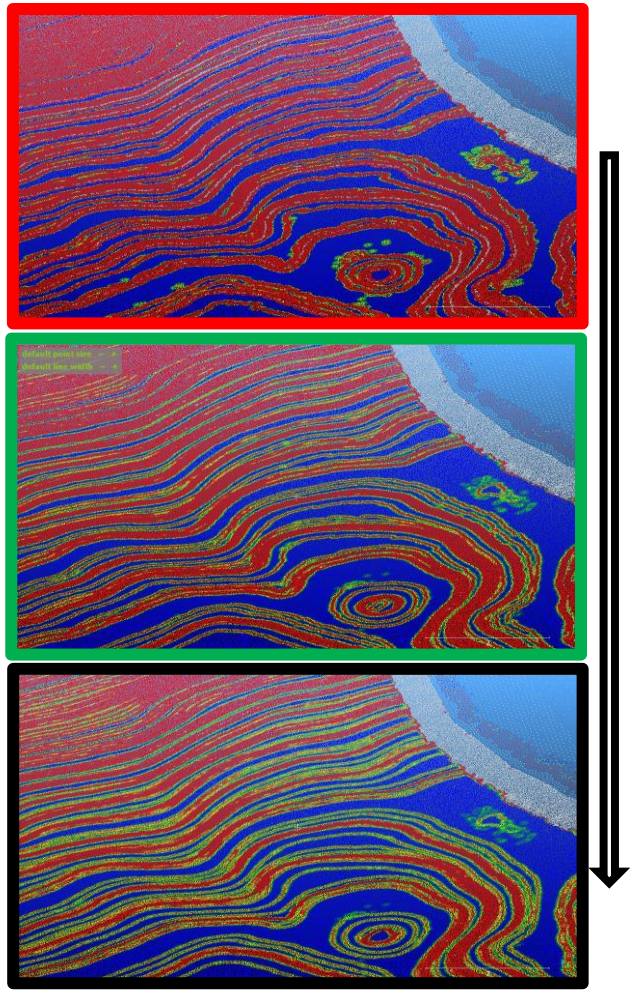




Simulations carried out with MegaRide multi-contact threedeeRIDE module active







Towards zero prototypes scenario: driver's subjective evaluation

- Starting setup from offline validation: "good level of perception before grip loss, poor feeling after"
- After tuning at simulator: "95% of real feeling is caught; well developed roll, pitch and yaw"
- Regarding road perception: "too sharp at beginning, more realistic later, too smooth at the end" (the driver didn't know what changes have been made to road profile)
- Regarding tire degradation with temperature: "very good perception of vehicle behavior change from cold tires to overheated; perception is enhanced after model and chassis tuning"

Subjective evaluations are well aligned to objective results from tests!

Where next?
Seaside Racing 2nd edition!

More Partners

New Targets:

- Objectivizing the driver's **steering feel** concept
- Tire contact phenomena on **deformable soil**
- Advances in tire **multiphysics** in **ride** dynamics
- What's the actual difference **between a pro and a rookie** driver?

More Tracks & Vehicles

- **Fiat 124 spider**
- **Skoda Fabia Rally2 evo**







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