Enhancing Virtual Ride Quality Subjective Assessment Using FTire

2024 Zero Prototypes Summit

May 15th-16th, 2024 – Udine, Italy

Presented by: Tony Yardley, Multimatic
Michael Caradonna, Multimatic

Acknowledgements

Cosin

Benjamin Rieff	Cosin Scientific Software
Dino Berki	Cosin Scientific Software

Michelin

Gary Swingle	Michelin – Co-Author
Mathew Pearson	Michelin – Co-Author
Yongkang Huang	Michelin
Shi Fang	Michelin

Multimatic

Behzad Danaei	Multimatic
Aiden Wagner	Multimatic
Peter Gibbons	Multimatic

Industry Leaders in Tire Design, Analysis, and Manufacturing

Globally recognized expertise in tire modeling

Michelin Developed Models

Commercial Tire Models

cosin scientific software

TameTire
Powered by Michelin

MFSwift

CDTire

MFTyre

Multimatic – The Company

Multimatic is a supplier that delivers manufactured products and engineering services to the global automotive industry at any volume level. Headquartered in Toronto, Canada with facilities in North America, Europe and Asia.

Low Volume Production → **High Volume Production**

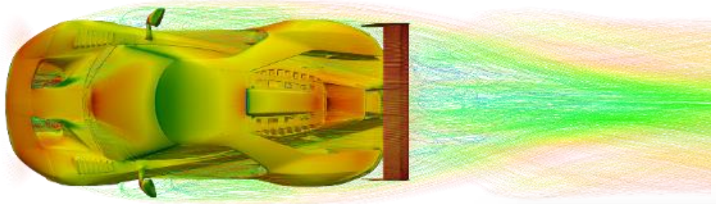
Suspension Products

Structural Products

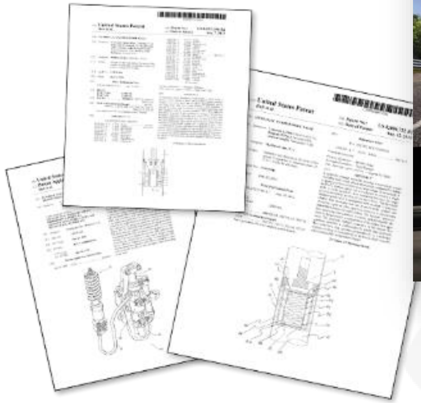
Mechanism Products

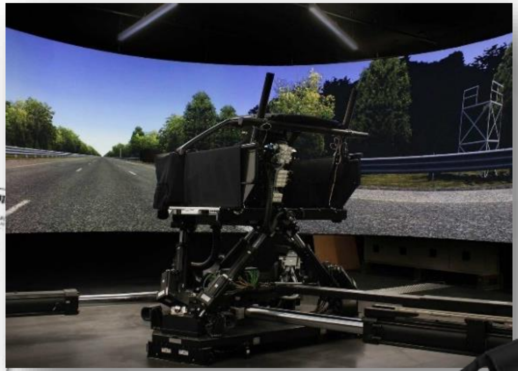
Multimatic Engineering

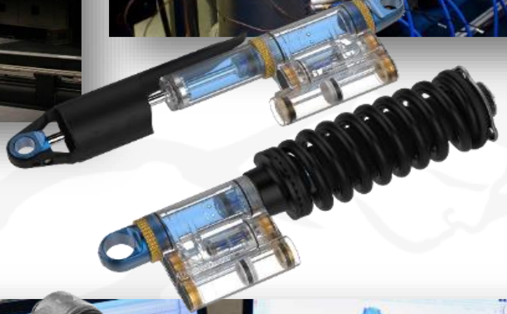
Multimatic Engineering delivers integrated design, analysis, prototyping, testing, validation and R&D activities for products ranging from individual components to complete vehicles



Research and Development

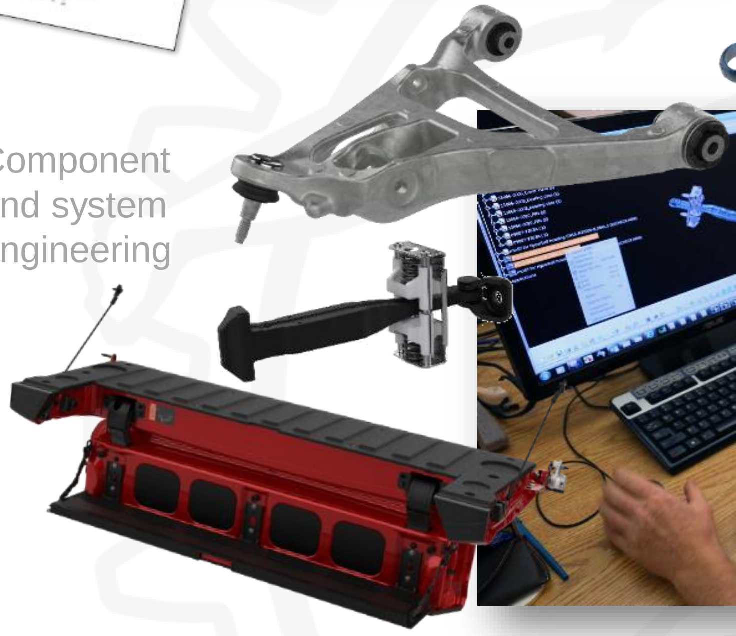




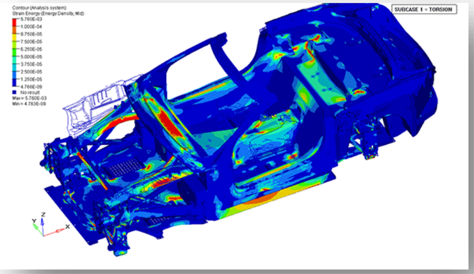


Vehicle Dynamics

Component and system engineering



Advanced simulation



Project Scope

Take the Michelin Pilot Sport Cup 2 R developed bespoke for the Mustang GTD

Use cosin's recommended measurement set to capture the tire in the test lab

Populate an FTire model and correlate the lab performance

In parallel, develop a VI-CarRealTime model of the new Ford GTD super-car

Measure the on-road vertical dynamics of the Vehicle/Tire combination

Present here, the comparison of simulation and on-road vertical dynamics

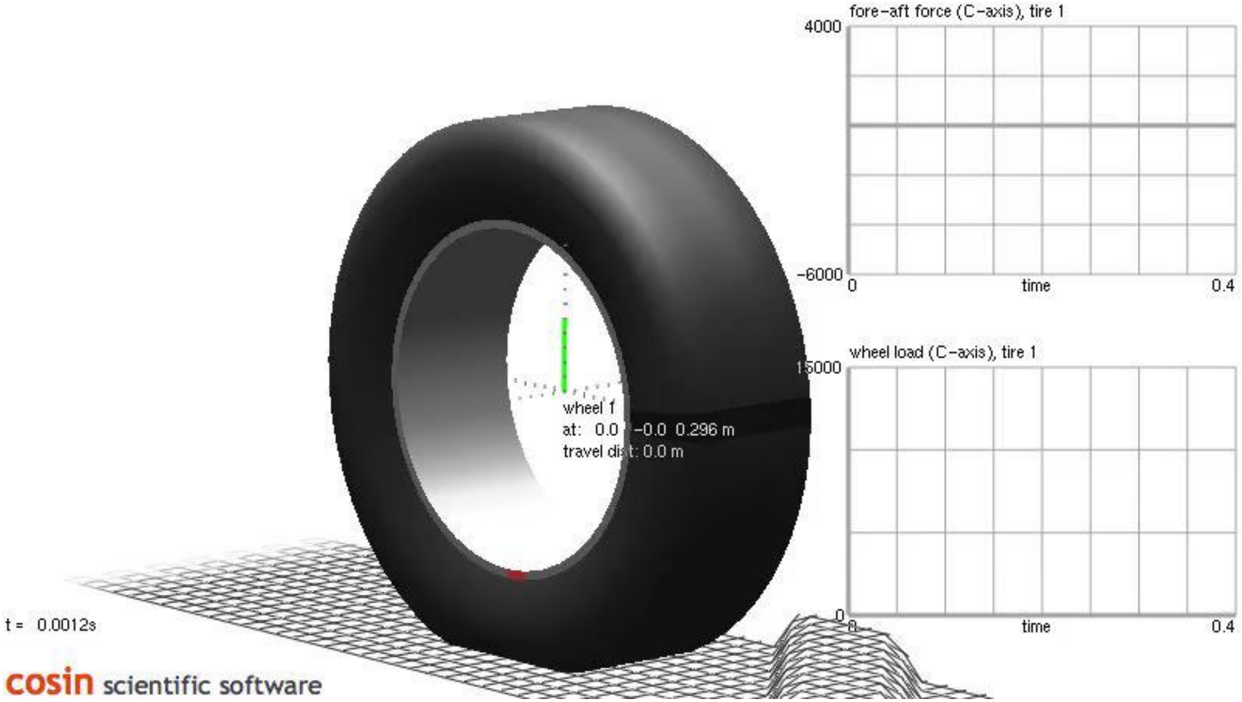
Tire Simulation Models

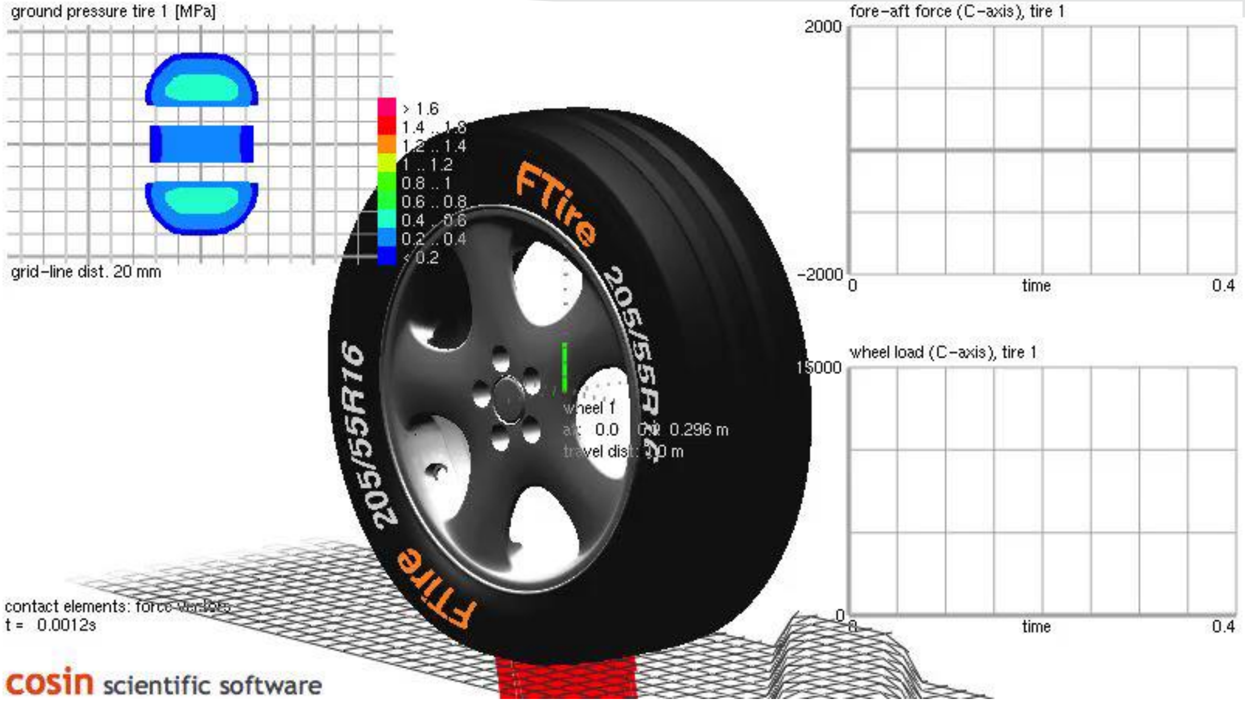
Approximation (MF) Models

one single contact point

Physical Model - FTire

many hundreds contact points,





Videos at www.cosin.eu/showcase/tireroad-contact/

Slow rolling over curbstone

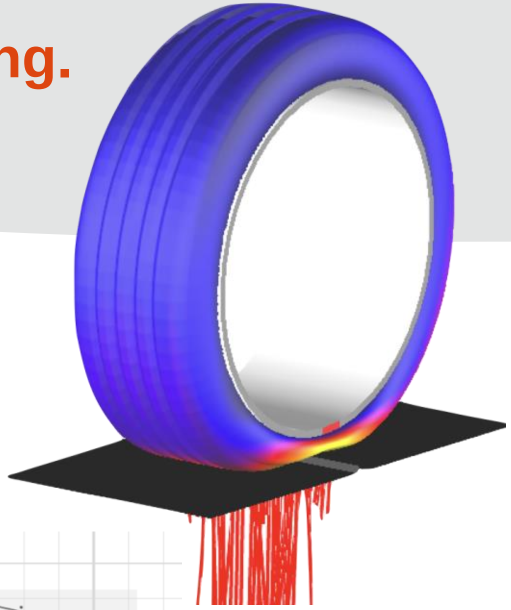
cosin scientific software

Simulating Real Tire Dynamics

MICHELIN Multimatic

Core mechanical model:

Structural Dynamics Modelling.



1. Tire structure

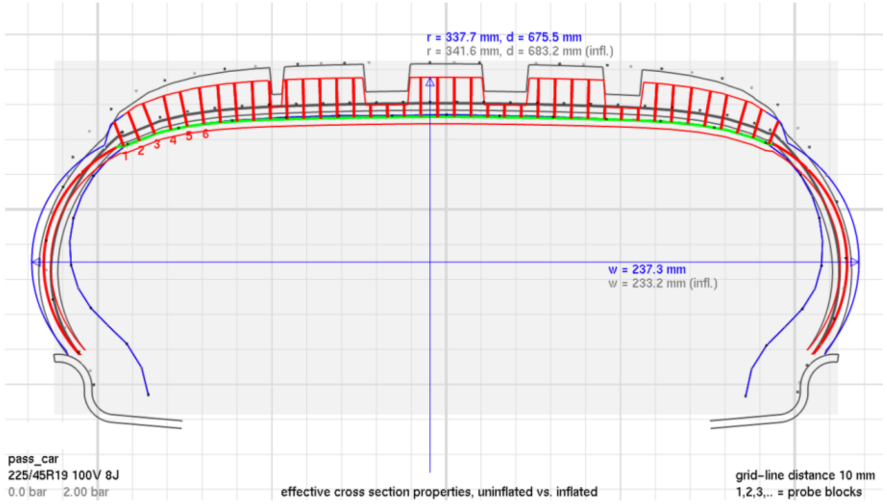
consisting of bead, carcass, belt: sub-divided into 60 .. 360 (or more) belt segments
connected to each other and to the rim by

- non-linear stiffness and damping
- pressure-dependent
- distributed stiffness and damping elements

2. Tread

consisting of 1000 .. 10000 (or more) contact elements
connected to belt segments, sticking / sliding on road surface

- non-linear non-linear rubber stiffness and damping
- friction coefficient dependent on
    - sliding velocity
    - ground pressure
    - temperature



Data-generation workflow

Internal Michelin

Measurement

Smithers/Calspan

Michelin FEA Chain

Virtual

Michelin Material Characterization

Tydex convertor

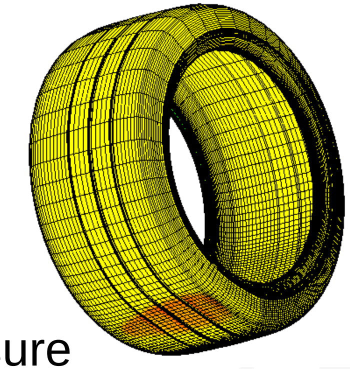
Raw data → **FTire format**

Format conversion by 3rd party

Measurements/Results

Mass & Inertia

Tire mass
Tire axial moment of inertia Iyy (If not specified, will be estimated)
Rim Iyy
Tire polar moment if inertia Ixx/Izz (Optional)
Rim Ixx/Izz (Optional)



Geometry

Mounted/Inflated profile
Footprints

Rmax

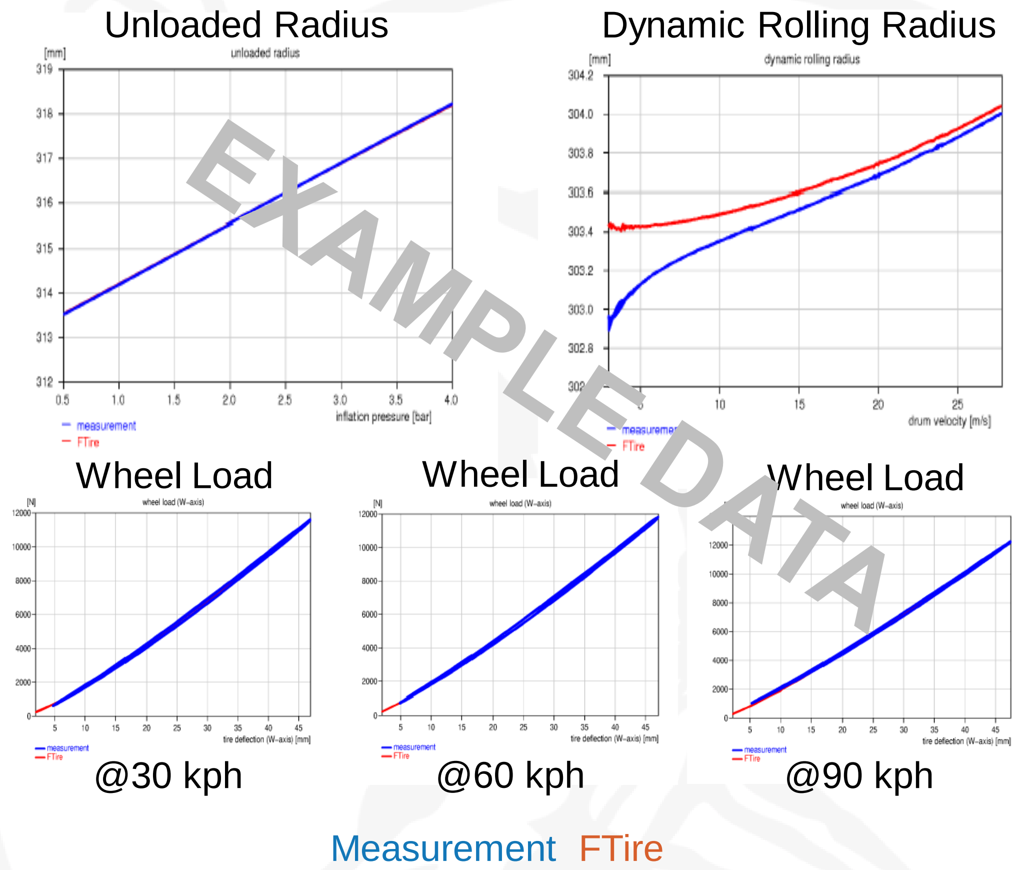
Unloaded radius v.s. inflation pressure

Rdyn

load fixed (50% LI), slowly apply speed variation

Vdyn

Speed fixed, apply sinusoidal load condition
Measure curves at several speed



Measurements/Results

Vertical Stiffness

On flat surface

With/Without camber

On cleat

Oblique

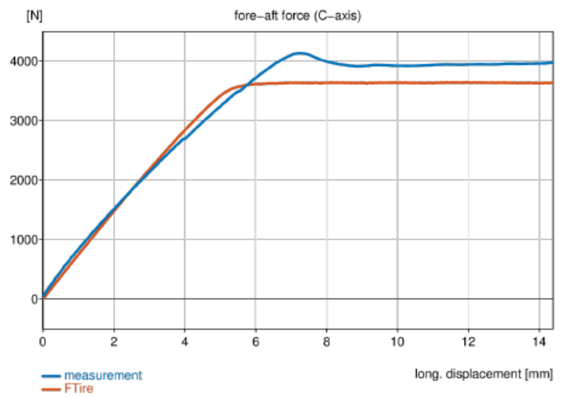
Pure lateral slip & Pure longitudinal slip (no combined slip)

3 load conditions - stationary

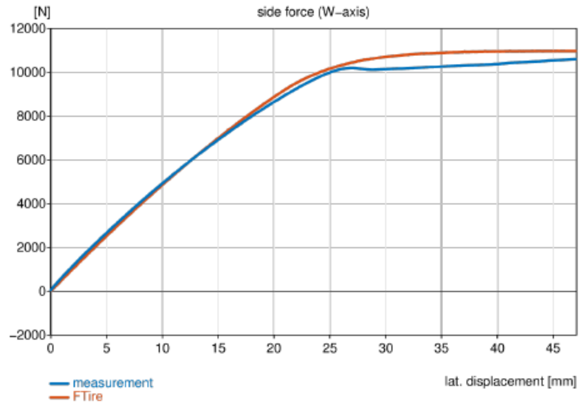
Pure lateral slip: no camber/ positive camber / negative camber

Note that standard format requires 6 forces & moments signal; actual signal used is Fx, Fy, Fz and Mz.

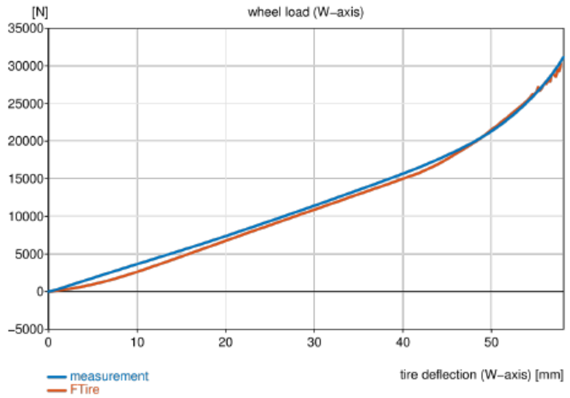
Longitudinal Stiffness



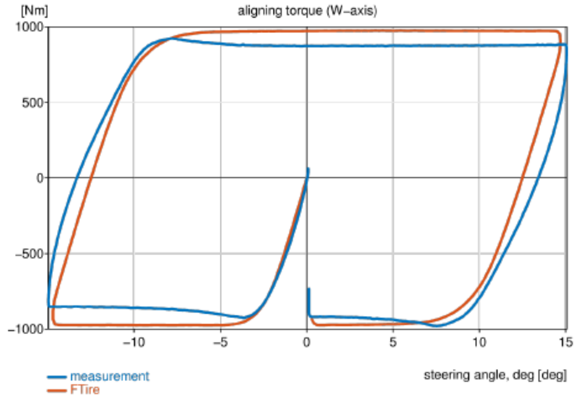
Lateral Stiffness



Bottoming: “pinching”



Torsional Stiffness



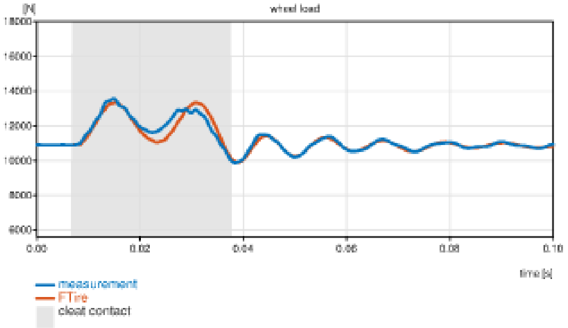
Measurement FTire

Measurements/Results

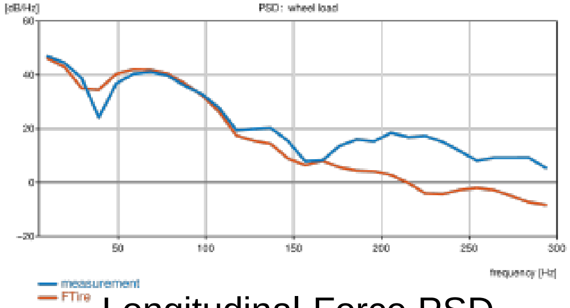
Dynamic cleat test

Transversal / oblique cleat
10x20 mm unless special requirement by customer → consider lab capacity!
Standard condition: 3 load X 3 speed (30, 60, 90 kph)
→ At 2kph or other low speed is not required in standard condition

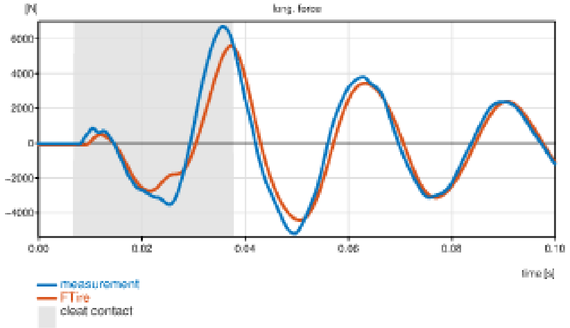
Wheel Load



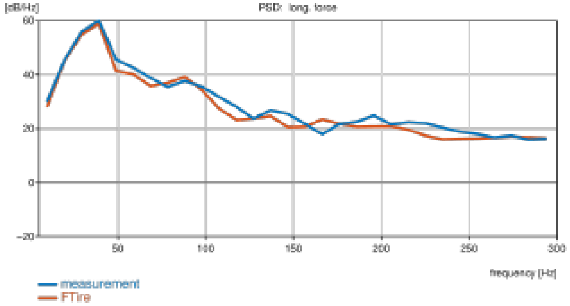
Wheel Load PSD



Longitudinal Force



Longitudinal Force PSD



Measurement

FTire

Measurements/Results

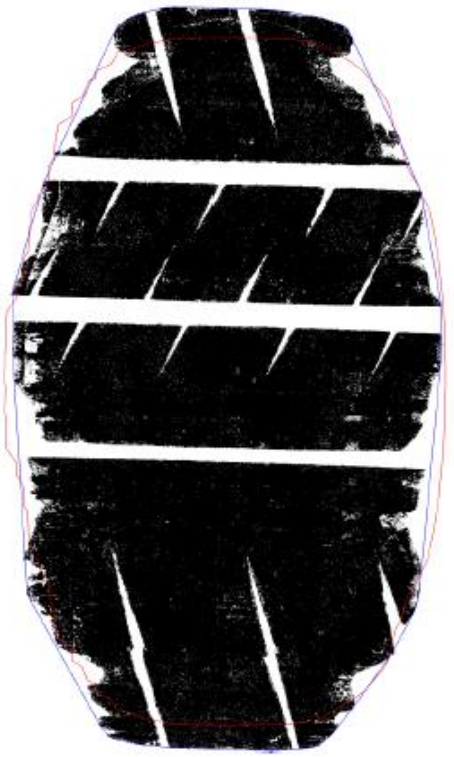
Contact Patch Model

Good correlation for static tire with limited camber

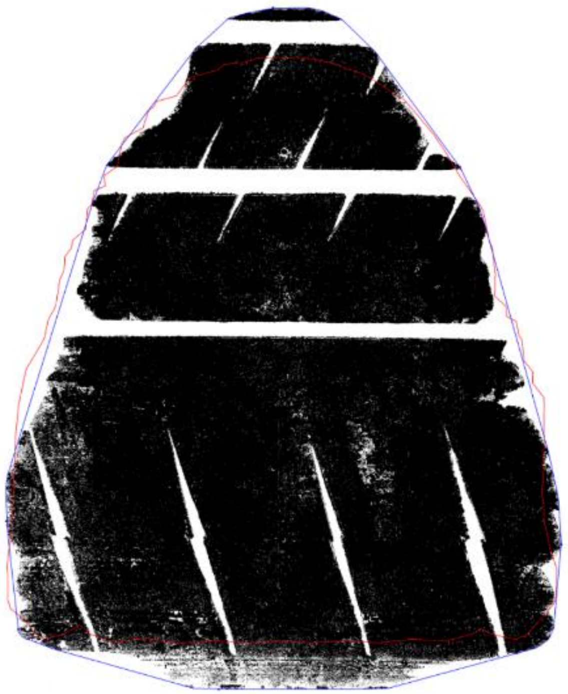
Fitting becomes more challenging with camber and speed, especially at lower loads

Measurement

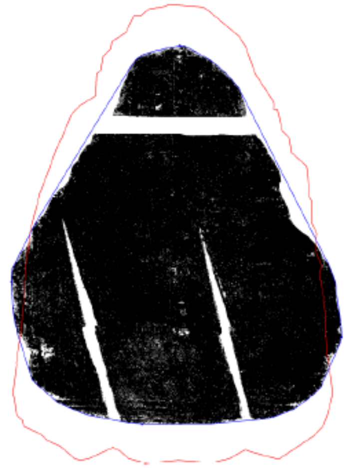
FTire



Fz = 11.18 kN, Camber Angle = 0.00 deg, 2.3 bar



Fz = 11.18 kN, Camber Angle = 6.00 deg, 2.3 bar



Fz = 3.73 kN, Camber Angle = 0.00 deg, 2.3 bar

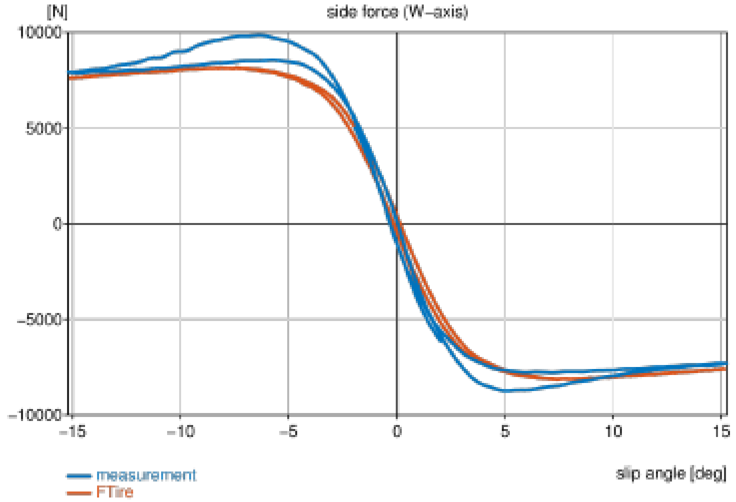
Measurements/Results

Side Force Generation / Aligning Moment & Fore-Aft Force for Rolling Tire

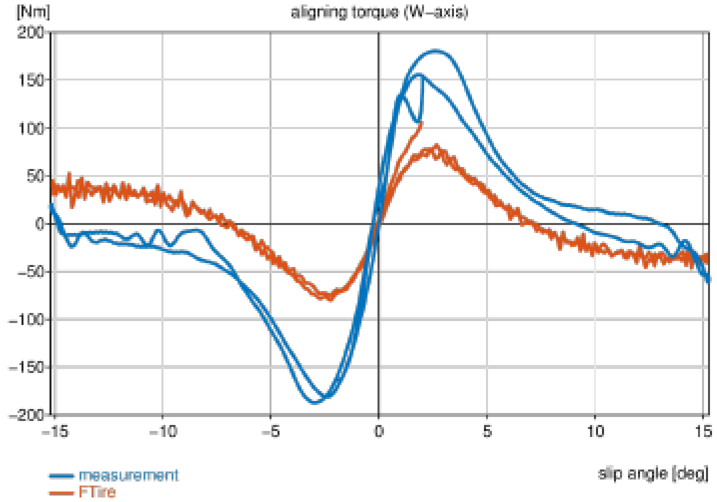
Side force generation as a function of slip can be fit, but a trade off exists for maintaining frequency response and NVH characteristics with an accurate aligning moment

Oscillation in the model around high braking forces (right hand plot)

Side Force



Aligning Torque



Fore-Aft force

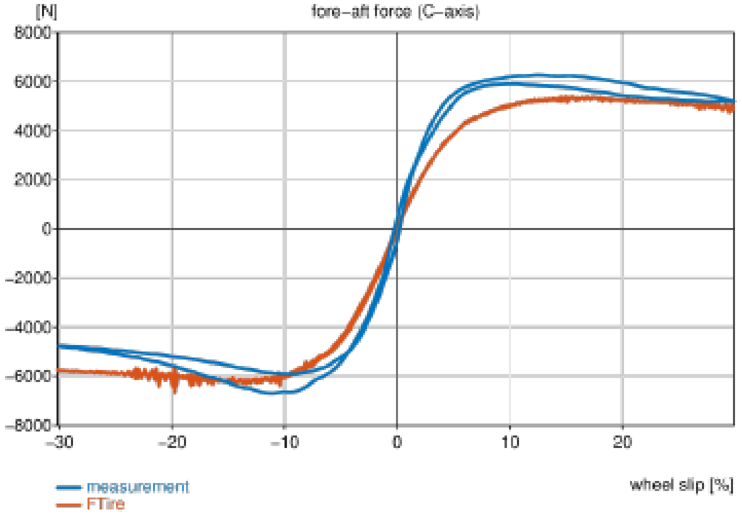


Fig. 10.22: slip angle sweep (drum diam. 9999 m, 59.85 km/h), Fz=5.58 kN, 2.3 bar, camber angle=0 deg

Measurement FTire

Full Vehicle Testing

Another of Multimatic's Niche vehicles …

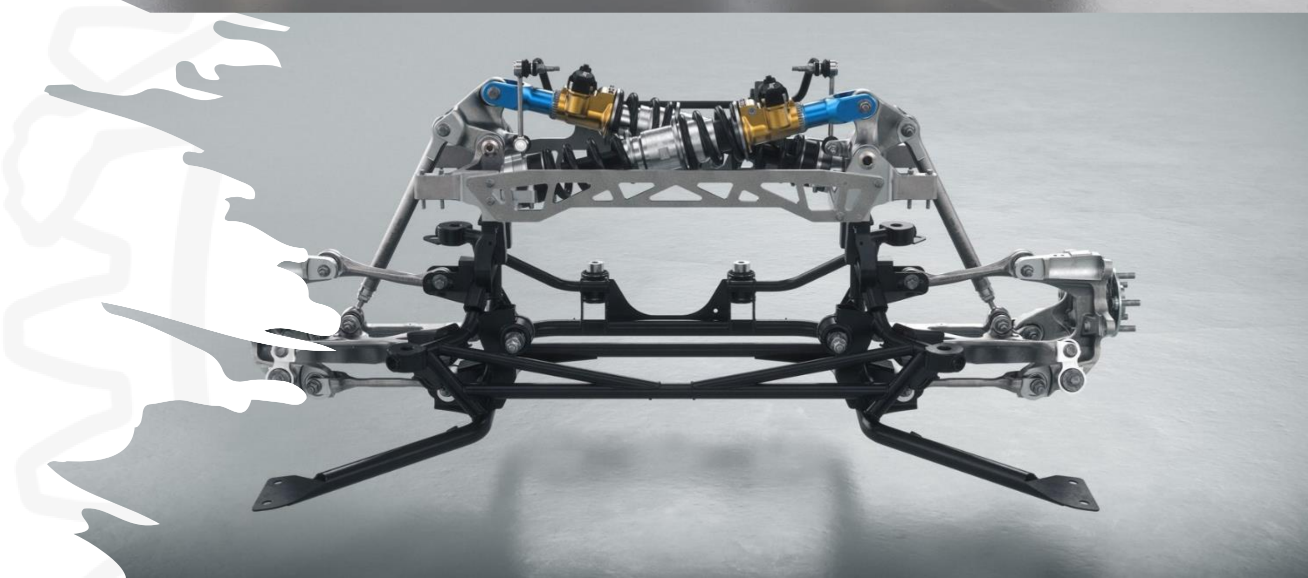
Ford Mustang GTD Prototype

In-board rear suspension

Multimatic's ASV (Adaptive Spool Valve),
DHR (Dual - Height Rate)

Front Tire 325/30R20

Rear Tire 345/30R20



Tires

MICHELIN

PILOT SPORT CUP 2 R

BESPOKE DEVELOPLMENT TIRES FOR THE MUSTANG GTD

FRONT: 325/30ZR20

REAR: 345/30ZR20

Exceptional track performance made to last.

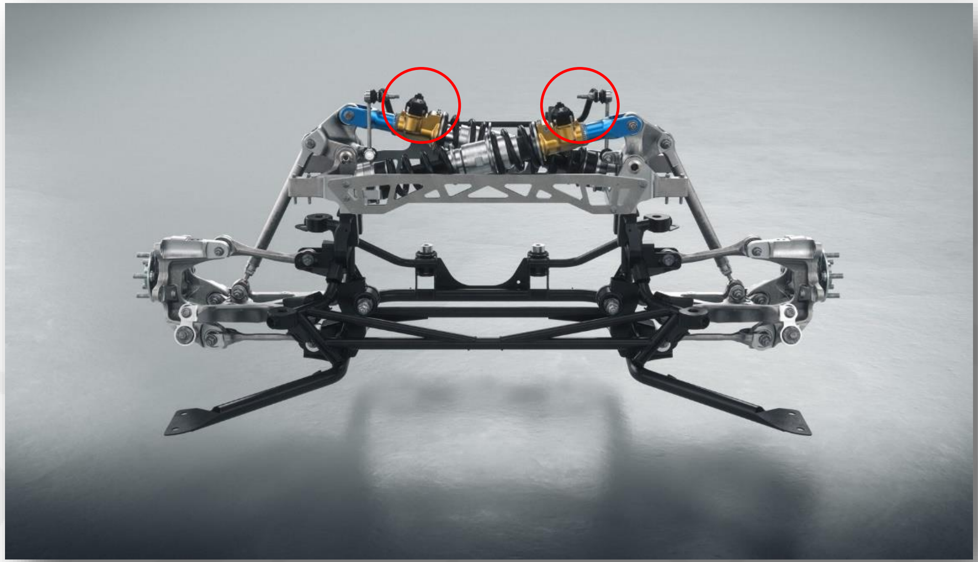
MICHELIN Pilot Sport Cup 2 R track tires are designed for ultra-high performance for sports and hypersport cars, with sensational times.

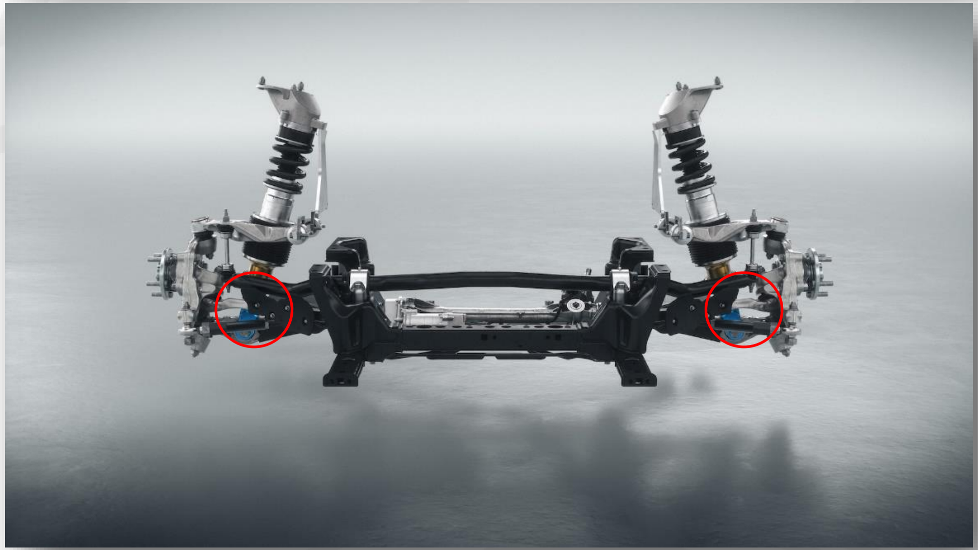
- MICHELIN Semi-Slick high performance track tires, road approved
- Developed to be a Nürburgring laptime weapon
- In the dry, extreme lateral grip and driving precision
- Virtual sizing study along with multiple design evolution loops in partnership with Multimatic Mustang GTD Development

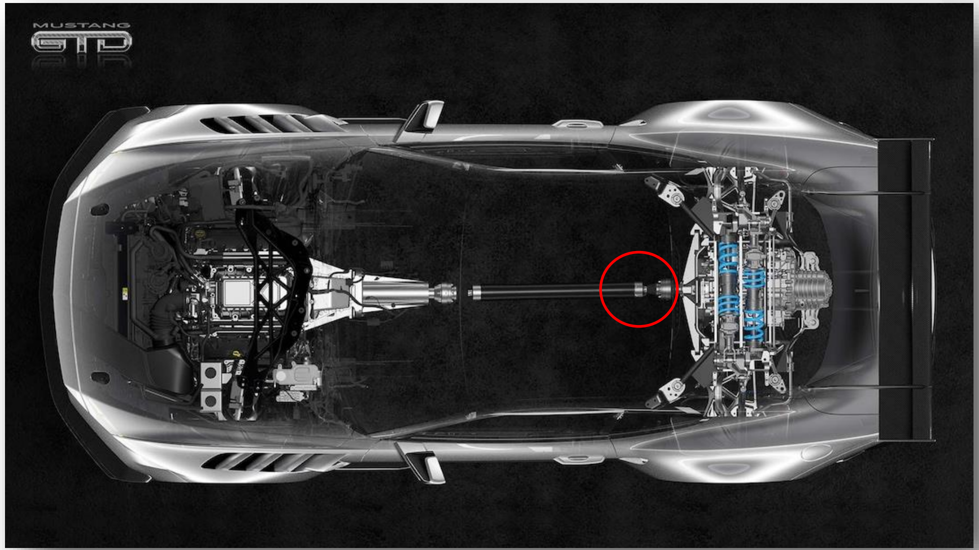
Logging Setup

4x 1000 Hz 3 axis accelerometers mounted on the damper

1x 200 Hz 3 axis accelerometer & 3 axis gyro

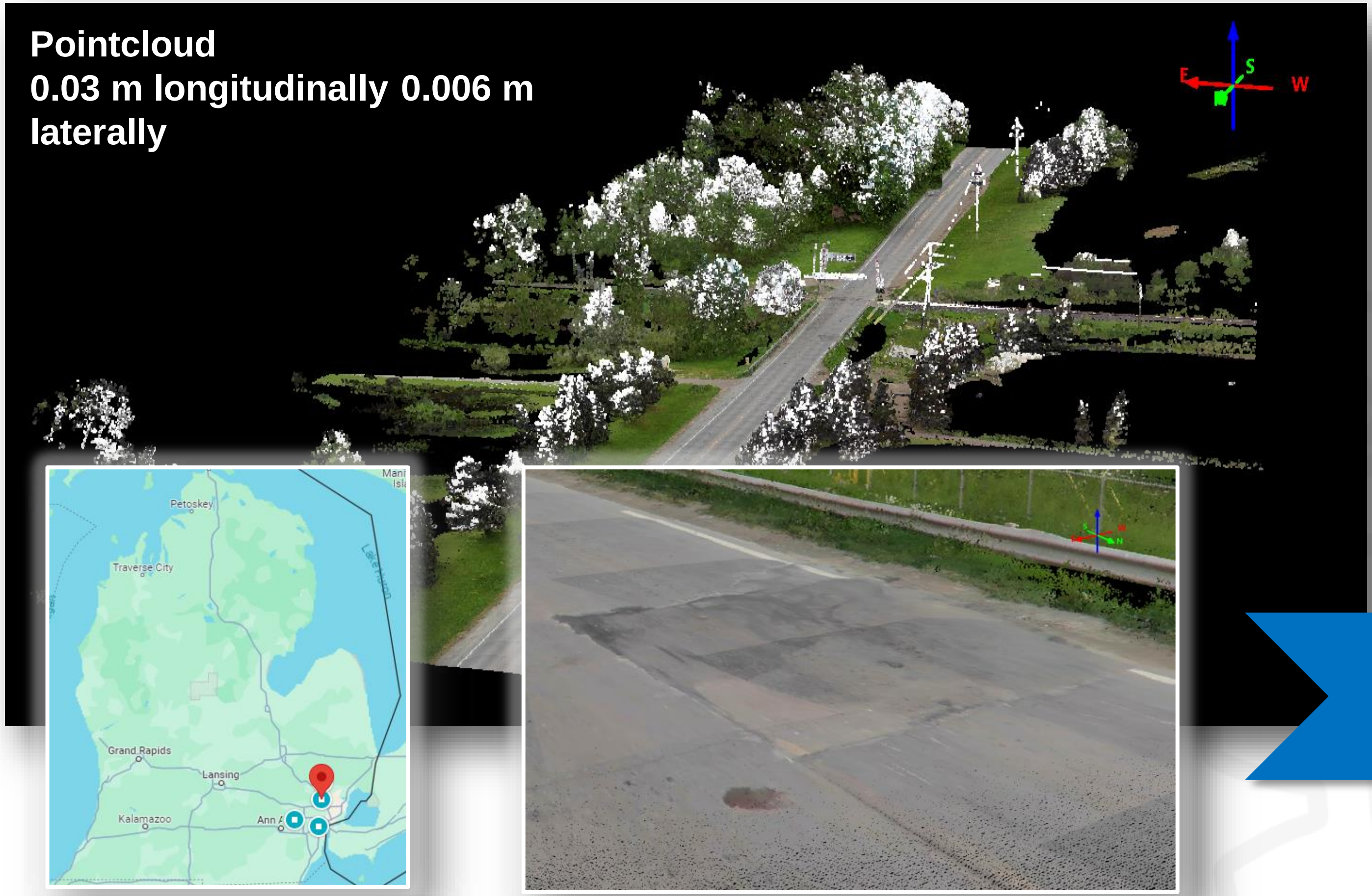


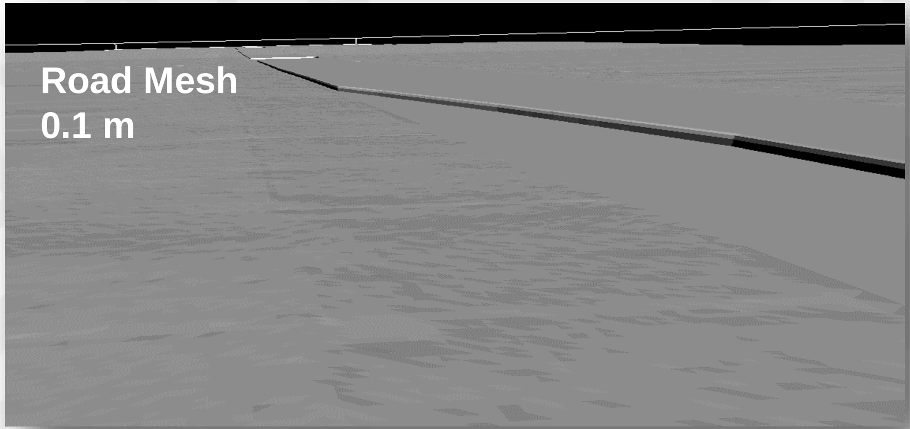


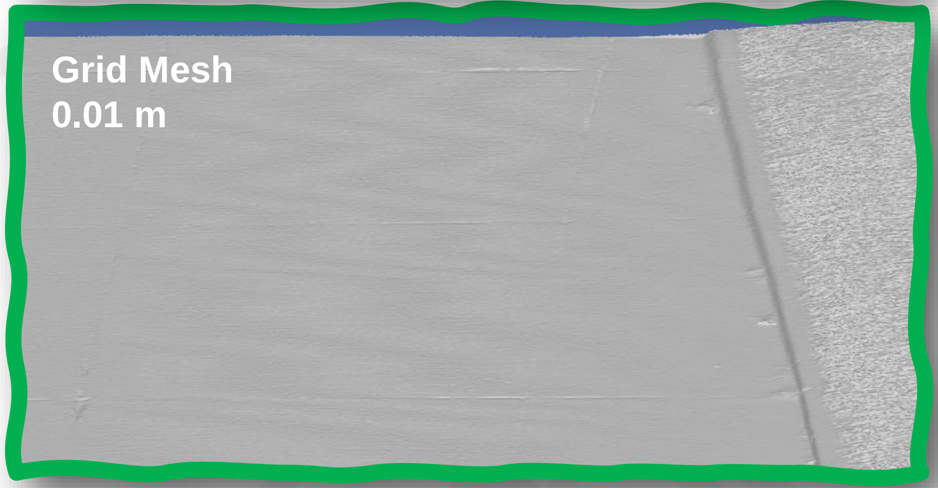


Laser Scanned Point Clouds

VI-Grade’s GridMesh road surface generation process with a resolution of 0.01m

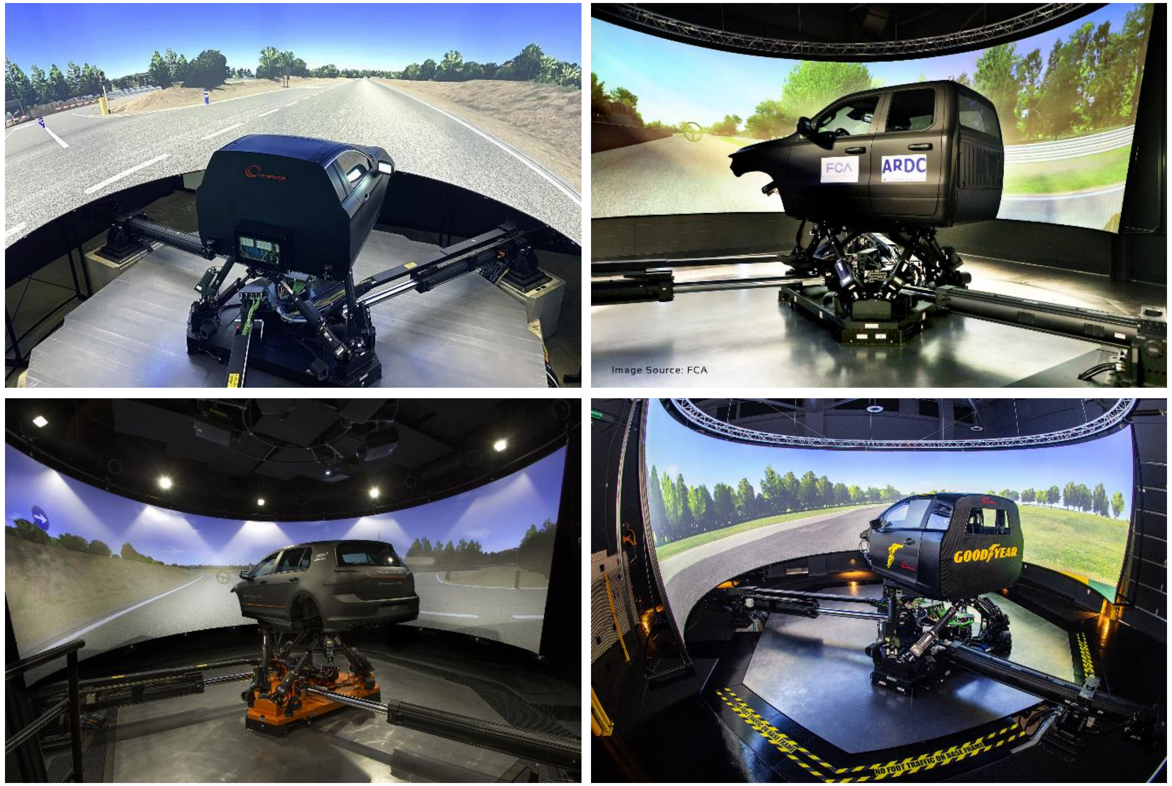




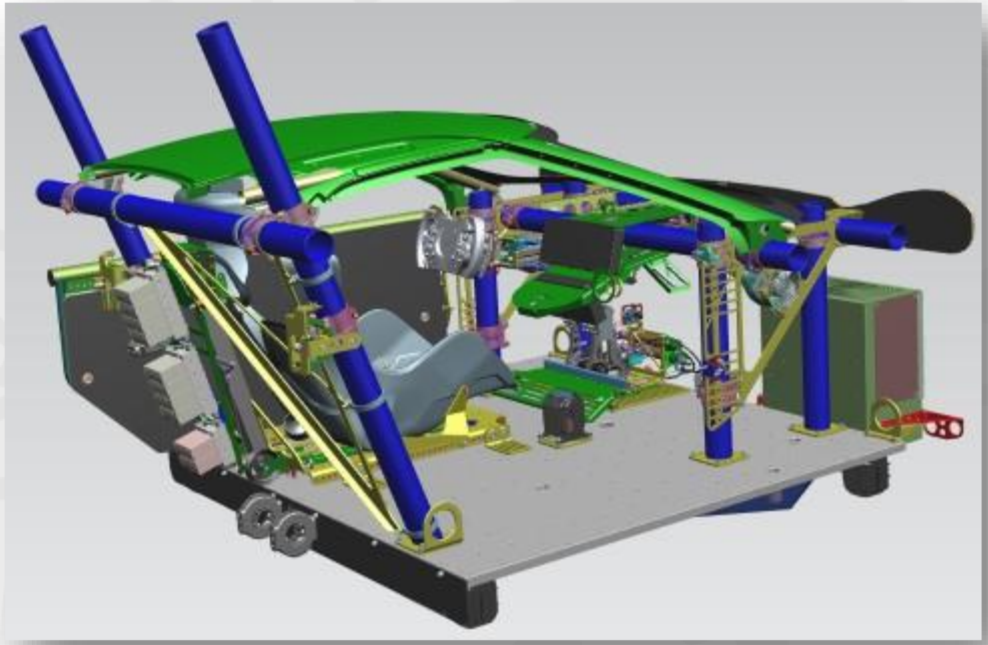


DiM 250 – Modular Cockpit

Due to the wide range of projects and vehicles Multimatic is involved with, **a fully reconfigurable cockpit** have been designed and built.



Example of road car shell from OEMs, tire manufacturers, etc.



Ford GT (Racecar)

Multimatic's modular cockpit

FTire Realtime Simulation

Running on Multimatic & VI-Grade's DiM 250 in Novi Michigan

2 Socket – 16 core CPU, 3.5 GHz Clock

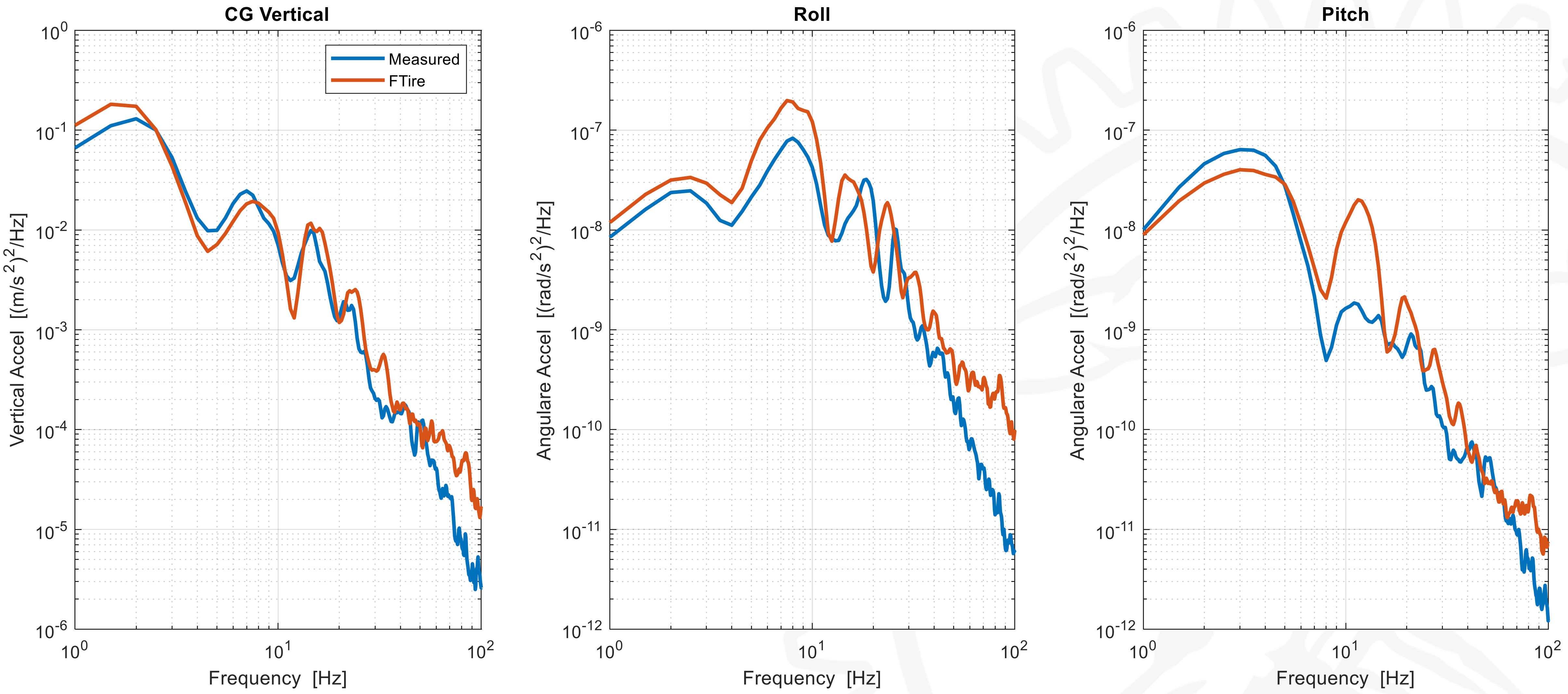
1 millisecond time-step, as normal

Main requirement is one dedicated core per tire

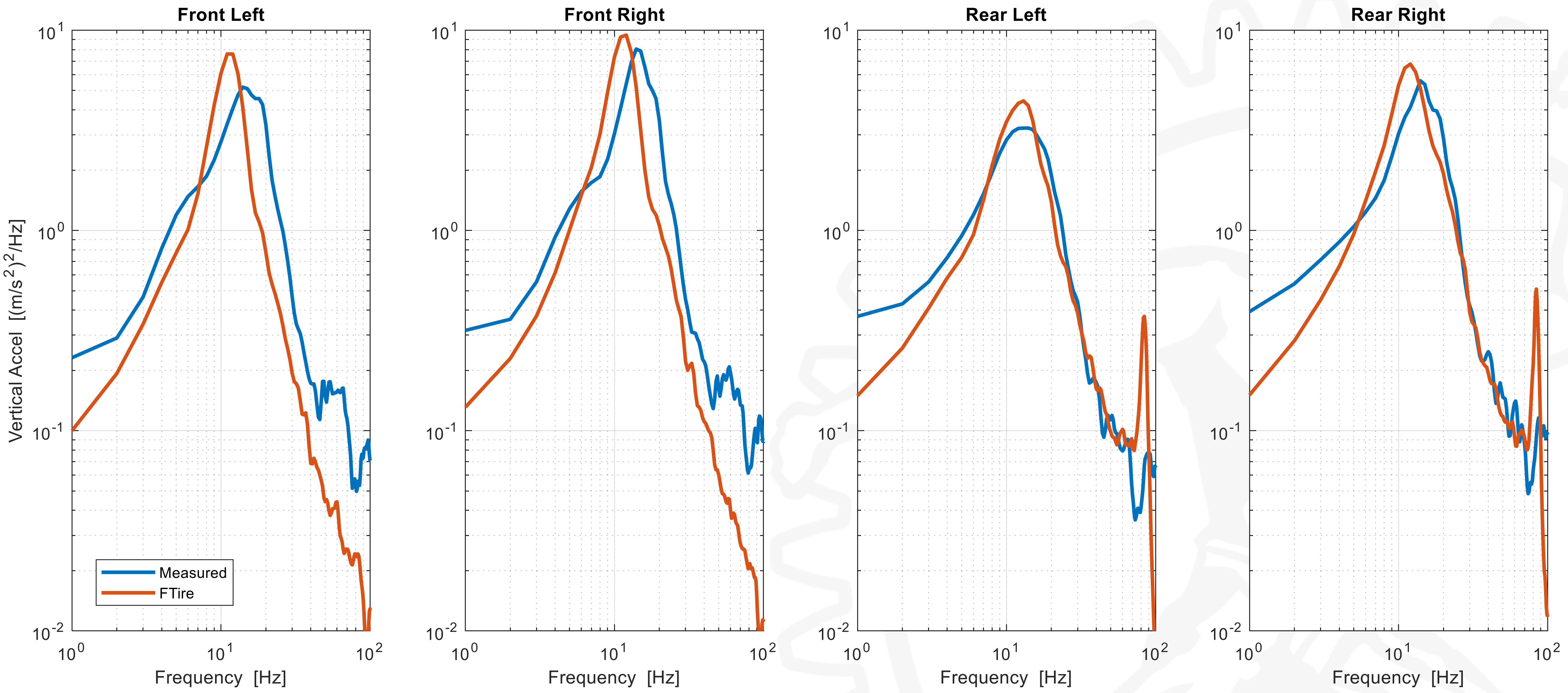
Running FTire in Realtime mode (mode 0)

Reducing the number of tire states from 30 to 15

Body Accelerations



Hub Vertical Accelerations



Next Steps and Future Developments

Development of an FTire model that accurately represents limit handling characteristics with thermal properties

Version 1 - Tradeoff in NVH behaviors acceptable

Version 2 – No tradeoff in NVH characteristics while maintaining limit characteristics

Correlation of FTire contact patch model with Michelin FE tools

Correlation of suspension properties – 4 post test

More vehicle instrumentation – direct hub accelerations, load-cells in the damper load-paths

Greater variety of test surfaces – dependent on tire enveloping behavior

Close the loop on subjective evaluation with the next and final tire submission

Q & A