Development of behavioral models of chassis control algorithms to enhance model-based development:

Rear Wheel Steering use case

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PUBLIC

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PROJECT MANAGEMENT

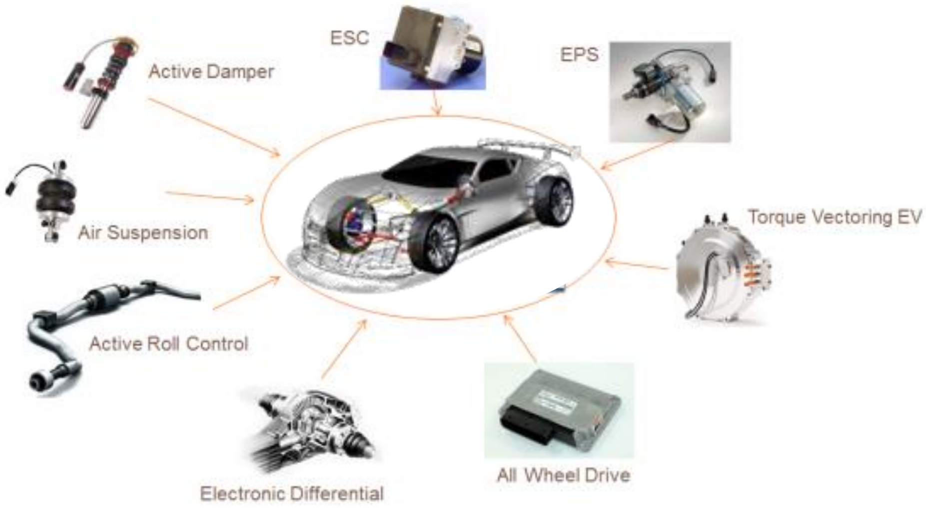
KNOW-HOW IN ALL VEHICLE FUNCTIONALITIES

ENGINEERING, TESTING & HOMOLOGATION

CONTENTS

ACTIVE SYSTEMS INTEGRATION STRATEGY

THE "NEW" SCENARIO



THE CHALLENGES

Models for most the chassis control systems not available in the early development stages

1. Difficult to plan a comprehensive strategy for target cascading, with active & passive chassis

2. Limitation in the adoption of digital twins of benchmark vehicles.

INTRODUCTION

ACTIVE SYSTEMS INTEGRATION STRATEGY

THE CHALLENGES

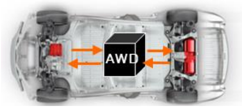
Models for most the chassis control systems not available in the early development stages

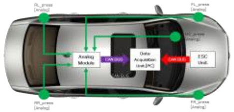
1. Difficult to plan a comprehensive strategy for target cascading, with active & passive chassis

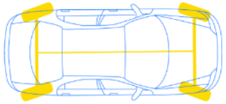
2. Limitation in the adoption of digital twins of benchmark vehicles.

THE SOLUTION

Develop *behavioral* models of the most widely adopted chassis control systems







Purpose: adoption in the early stages of vehicle development and for digital twins

Joint R&D activity since 2017

INTRODUCTION

PROJECT CASE OBJECTIVES

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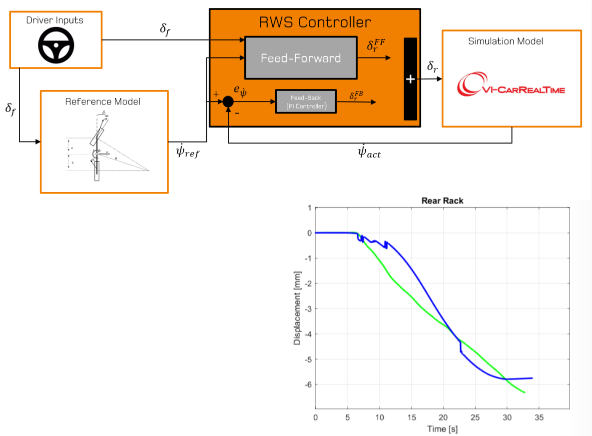
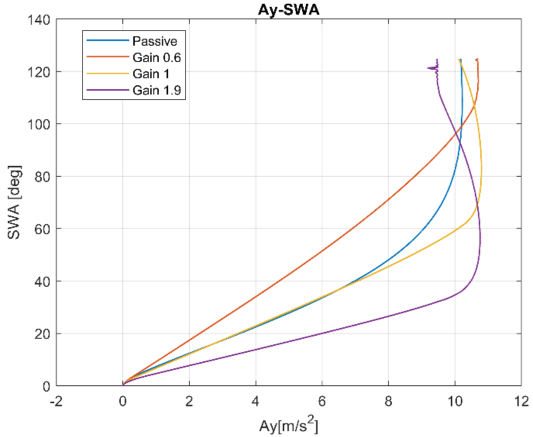


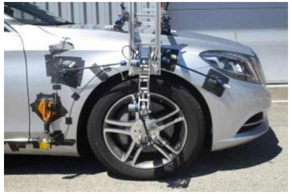


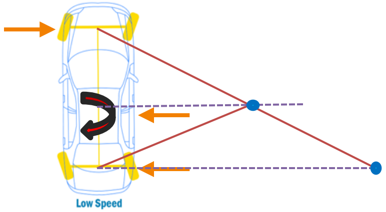
To develop a digital twin of one benchmark vehicle, that can be used as a digital reference in the Driving Simulator.

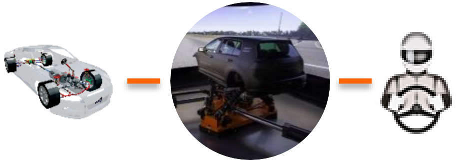
To generate a rear wheel steering logic representative of the application in the benchmark vehicle.

To make the RWS logic highly tunable for application in target cascading.

Activities	Outcome
Benchmark Vehicle Testing	Data for model building and validation
Passive model generation & Concept logic development	RWS logic integrated in the digital twin model of the competitor
Integration to DS	Validated model of the benchmark vehicle







Contents

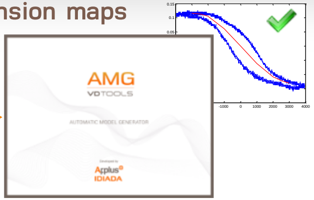
Model generation & validation

Passive model generation

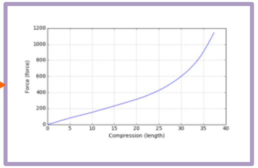
Suspension + Steering K&C Data

Kinematic curves and suspension/steering mechanical properties

Suspension maps



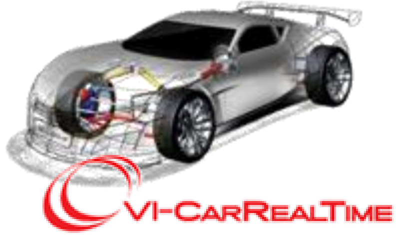
Component specs.



Tyre model

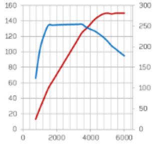
Self-developed tyre model from tyre trailer

Vi-CarRealTime Full Vehicle Model



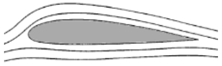
Powertrain Data

Engine curves and transmission ratios obtained from database and vehicle testing



Brake System Data

From reference data and vehicle testing.



Aerodynamics

Data from reference site.

Mass and inertia properties

From dedicated test bench

$$\begin{Bmatrix} J_{xx} & J_{xy} & J_{xz} \\ J_{yx} & J_{yy} & J_{yz} \\ J_{zx} & J_{zy} & J_{zz} \end{Bmatrix}$$

Model generation & validation

Advanced testing for RWS characterisation

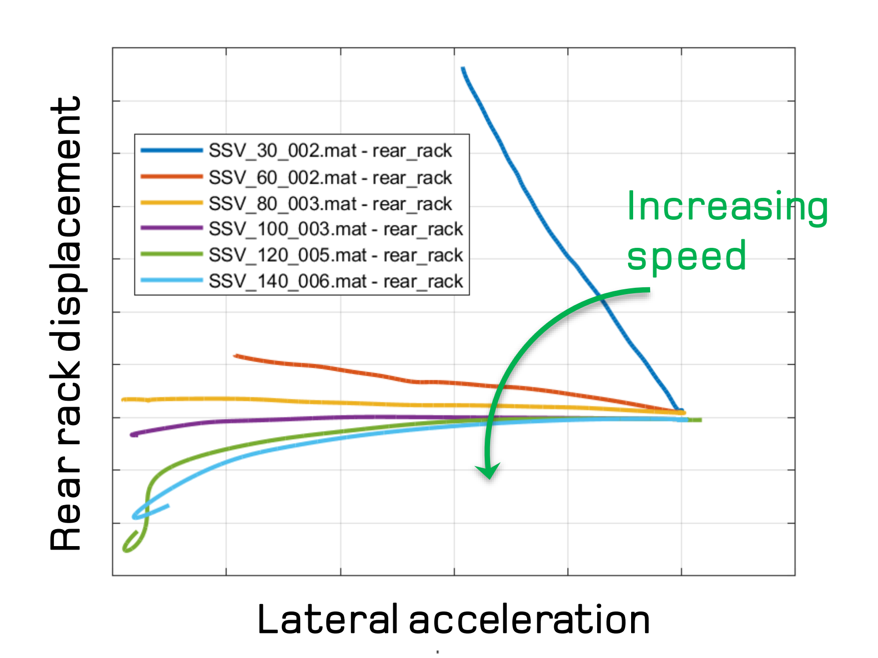
Manoeuvres

1. ISO manoeuvres (wide range of speeds).
2. Close-loop driving (e.g. Dry Handling sub-limit and at the limit)

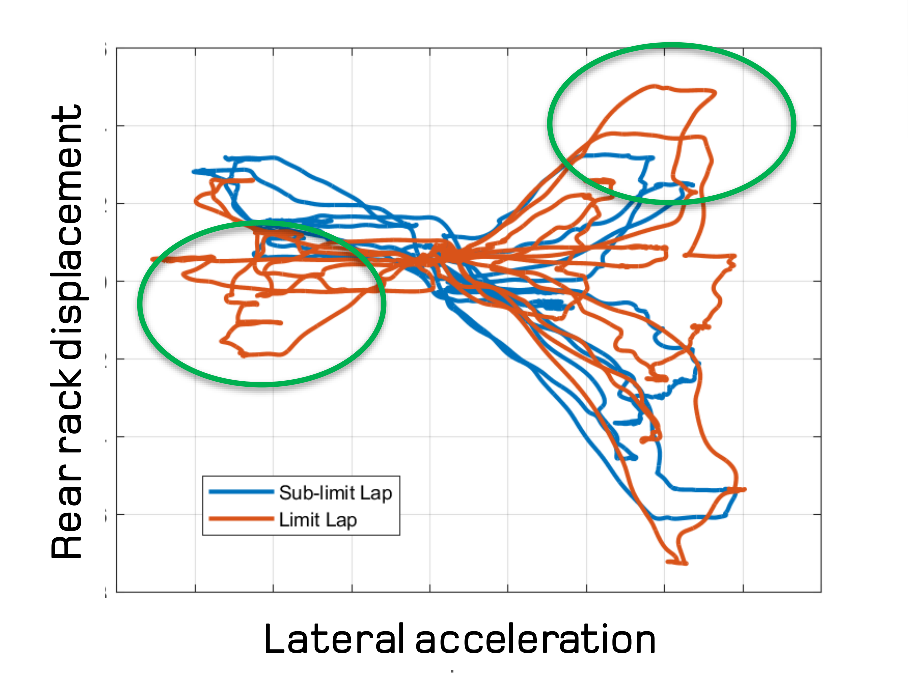
Instrumentation

1. Measure complete vehicle behaviour.
2. Apply additional sensors to the specific actuator under investigation (rear rack displacement)

Analysis of Steady-state cornering



Analysis of Dry Handling laps



Model generation & validation

Active model generation & validation

Modify Control Logic

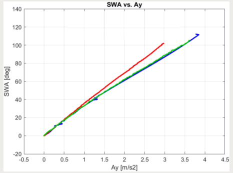
State of the art on RWS systems

&

Analysis of testing data

Passive vehicle + Initial RWS logic

Offline simulations: comparison Simulation Vs Testing



No

Correlation meets objective correlation requirements?

Yes

Driving Simulator sessions: comparison Virtual Vs Physical driving

No

Correlation meets objective & subjective correlation requirements?

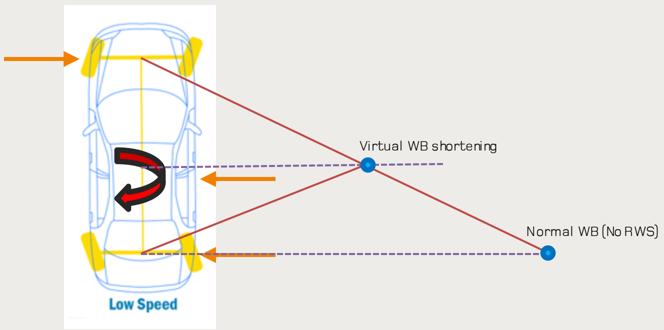
Yes

Final Control Logic and Correlated Model

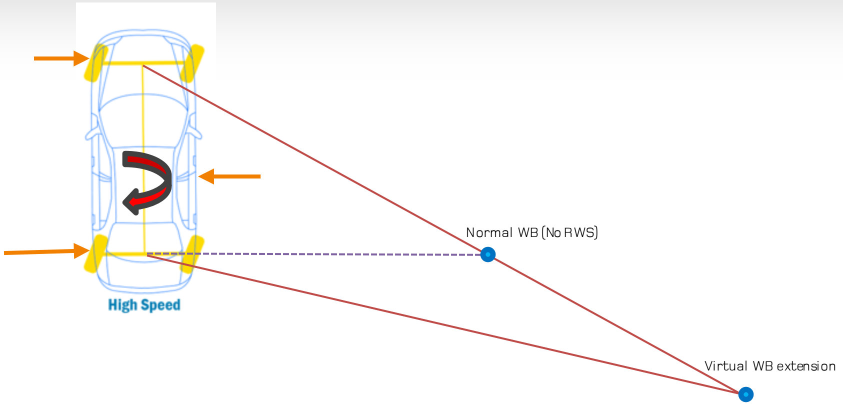
Contents

Basic objectives of Rear Wheel Steering

- Improve vehicle performance in terms of steering maneuverability and handling/stability.
- Higher agility at low speeds and stability at higher speeds.



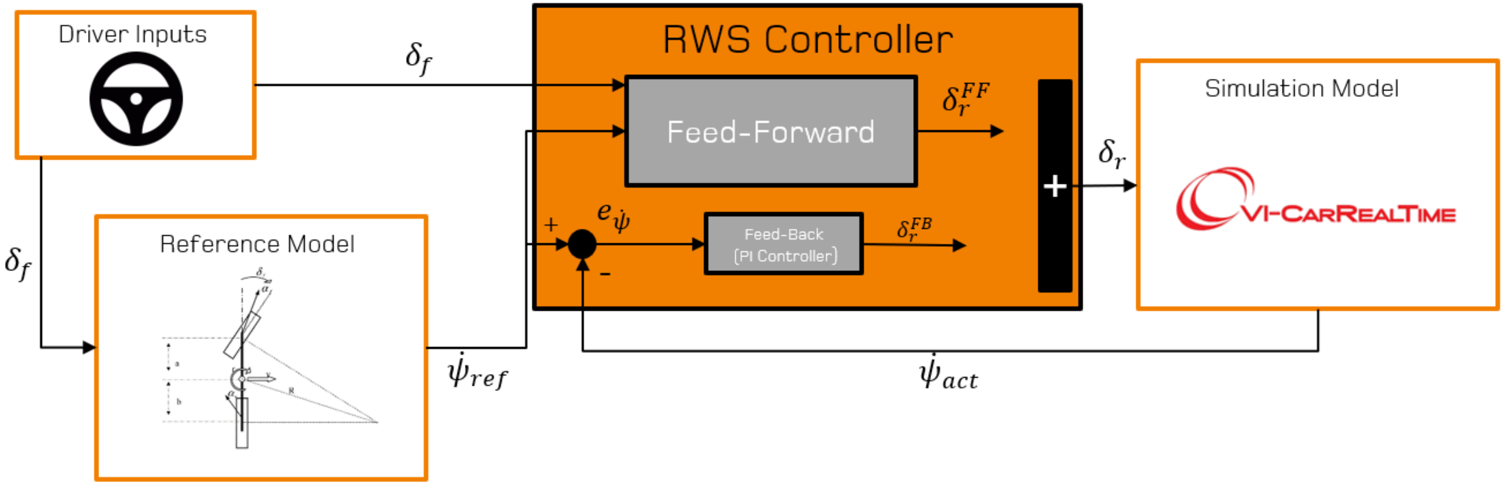
Steering in the opposite direction $\delta > 0; \delta_r < 0$ increases yaw and inhibits lateral acceleration, which is desirable at lower speeds. It also helps to reduce turning radius.



Steering in the same direction $\delta > 0; \delta_r > 0$ allows lateral acceleration to build up more quickly, since the lateral forces on the rear axle are built up faster. This reduces necessary slip angle of the rear axle, reflected in a lower $\dot{\varphi}$

Logic Development

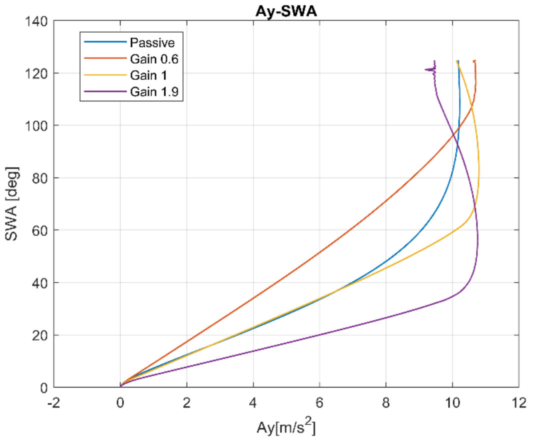
- **Feed-Forward**: applies control actions in advance, according to a yaw rate reference
- **Feed-Back**: compensates for model variations provides error correction, robustness and adaptability.

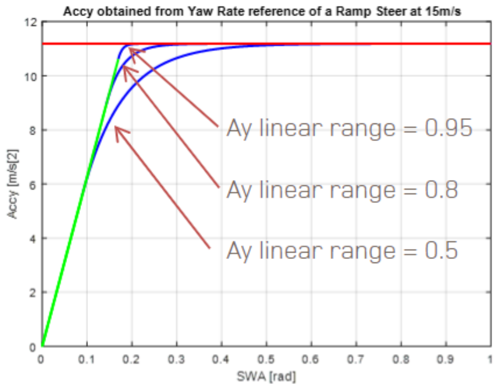


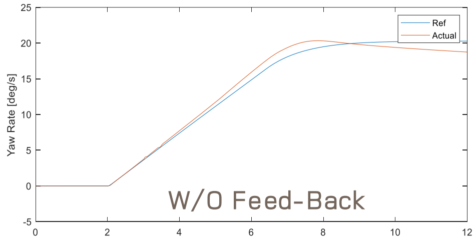
Main Parameters for logic tuning

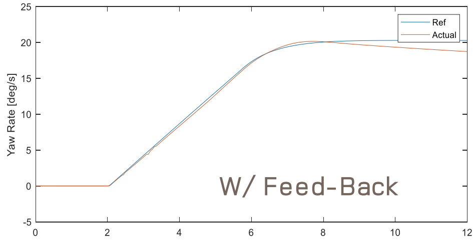
The reference generator provide adaptability to a very wide range of vehicles through its parameters.

Feed-forward Reference Yaw Rate Gain	Feed-forward Ay Linear Range	Feed-back PI parameters









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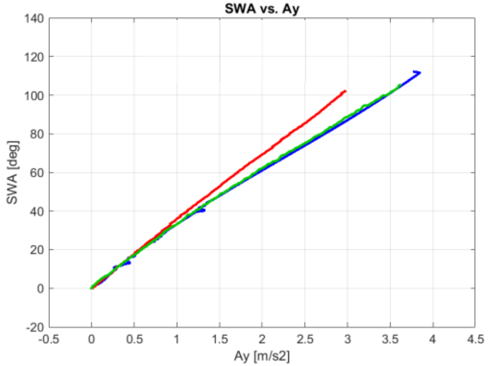
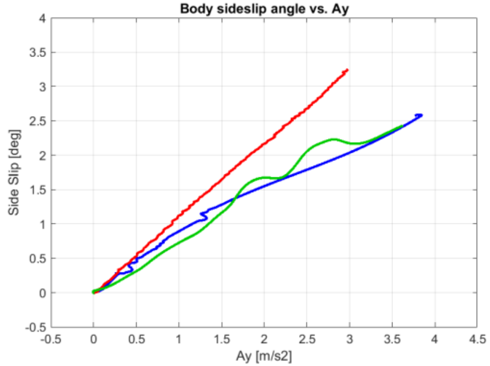
RESULTS

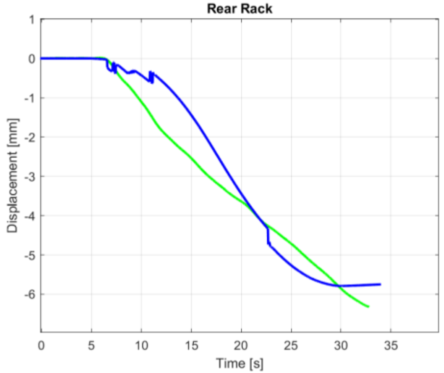
MODEL CORRELATION

MEASUREMENT – SIMULATION PASSIVE – SIMULATION ACTIVE

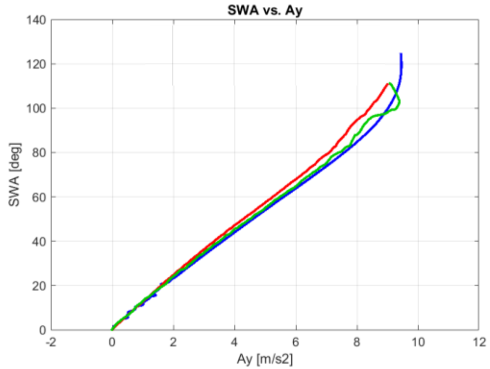
STEADY-STATE CORNERING CONST. SPEED

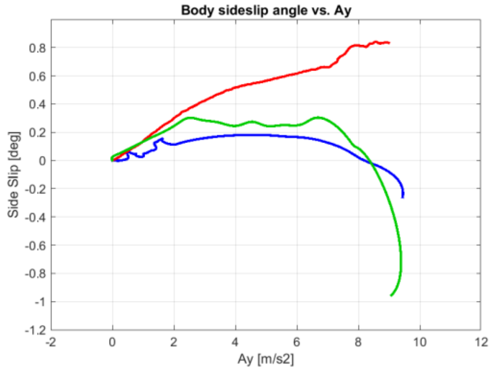


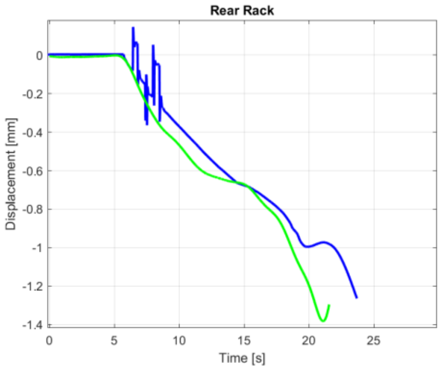




30 km/h





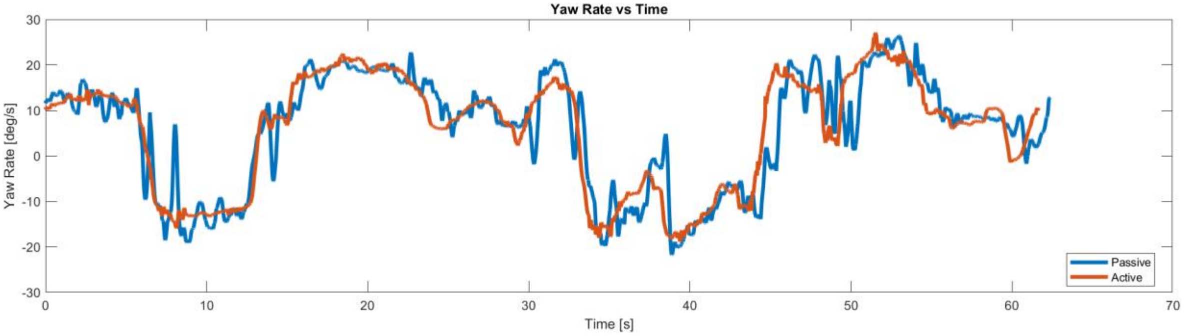


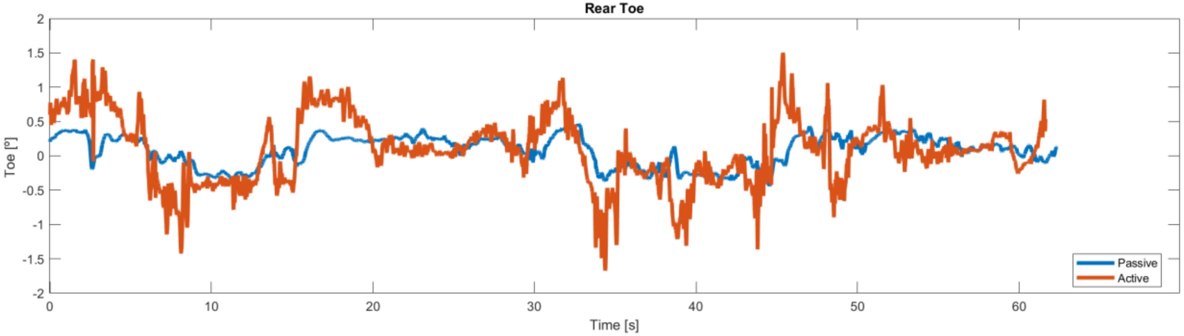
60 km/h

Results

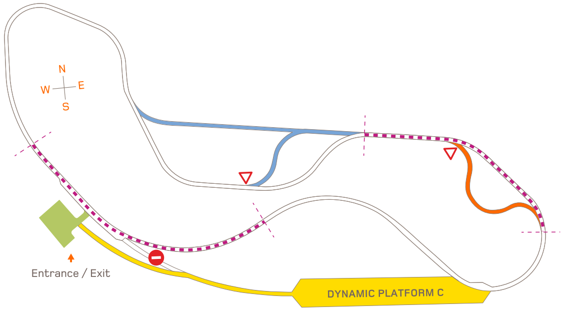
RWS effectiveness

Simulation Active – Simulation Passive





Dry Handling lap on DiM250



Conclusions & Next Steps

Conclusions

The digital twin of the competitor has been generated and correlated.

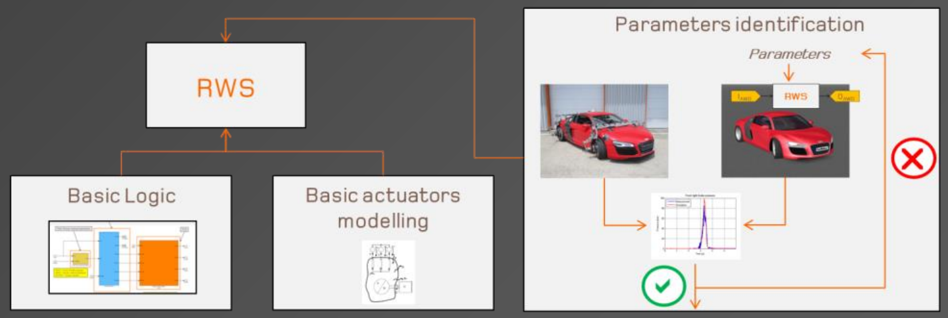
This model includes the complete RWS logic.

Such logic has been used for both benchmarking and early-stages development of new Nissan products.

Next steps

To expand further the library of chassis control systems

To develop a more systematic and automated parameter tuning is being developed to adapt more rapidly the existing logics to new vehicle models.



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