IPG CARMAKER AT JAGUAR LAND ROVER

IPG APPLY AND INNOVATE 2016

History and Background

Current Modelling landscape

Future plans

Use cases

- Vehicle Dynamics
- Predictive Energy Optimisation
- Off Road Capability
- Active Cruise Control
- Stability Control Systems

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IPG CARMAKER AT JAGUAR LAND ROVER

Our Business

Jaguar Landover have expanded considerably in the last few years and plans to continue into the future.

- 11 vehicle lines.
- 3 UK vehicle assembly plants, with 2 UK design and engineering sites.
- Almost 38,000 people globally – headcount has doubled over the last few years.
- Plants in China, India and Brazil.
- Employs over 9,000 engineers and designers.
- Sales network in 153 countries.
- 150 awards won in 2015/16.

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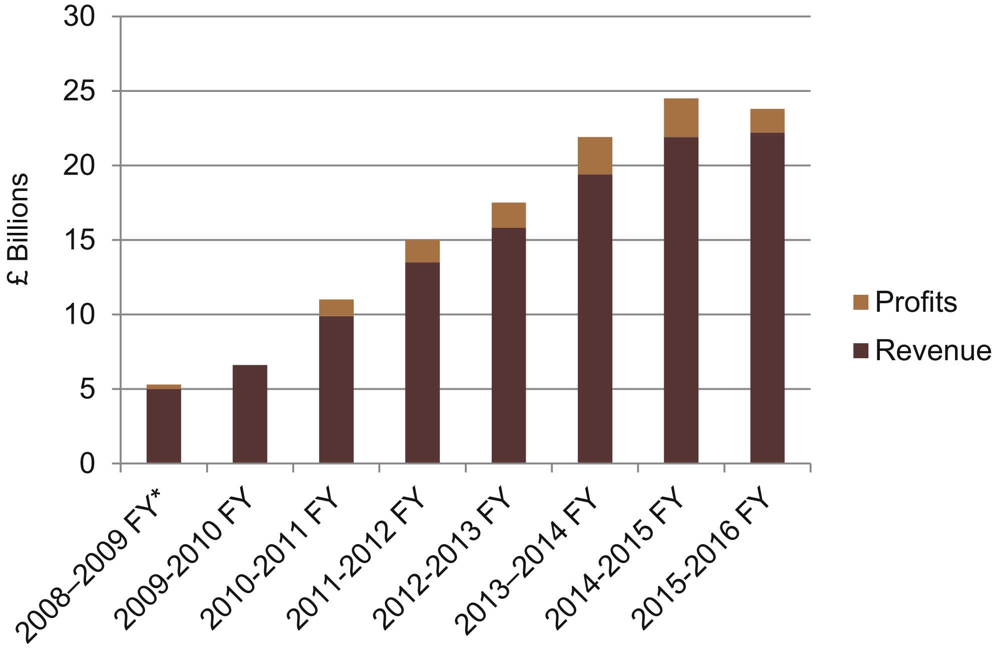
Financial Results

2016 – 2017 financial year investment in product creation and capital expenditure will be over £3 billion to:

- develop new products in new and existing segments
- deliver new powertrains and technologies
- increase our manufacturing capacity.



*10 months from Ford sale

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Product Lineup

XJ

The XJ is a dramatic combination of beauty, luxury and power

XF

Sleek, dynamic, daring, XF is a fusion of sports car styling with outstanding comfort

XE

The most advanced, efficient and refined sports saloon that Jaguar has ever produced

F–TYPE

Powerful, agile and distinctive, F-TYPE is a true Jaguar sports car

F–PACE

The all-new Jaguar F-PACE: a performance crossover from Jaguar for those who love driving

Defender

The icon. The epitome of toughness, ruggedness, strength and capability

Discovery

Versatile and capable enough for your greatest adventures

Discovery Sport

The first in a new generation of Land Rover SUV design

Range Rover Evoque

Distinctive and individual, a true Range Rover in compact form

Range Rover Sport

The most agile and dynamic Land Rover

Range Rover

The pinnacle of refined capability

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The Road Ahead

Expanding into and defining new product segments

Driving innovative technologies

50 new product actions over the next 5 years

More than £3 billion investment in 2015/16

International expansion

Continue sustained, profitable growth

What does this mean for Product Development and Simulation?

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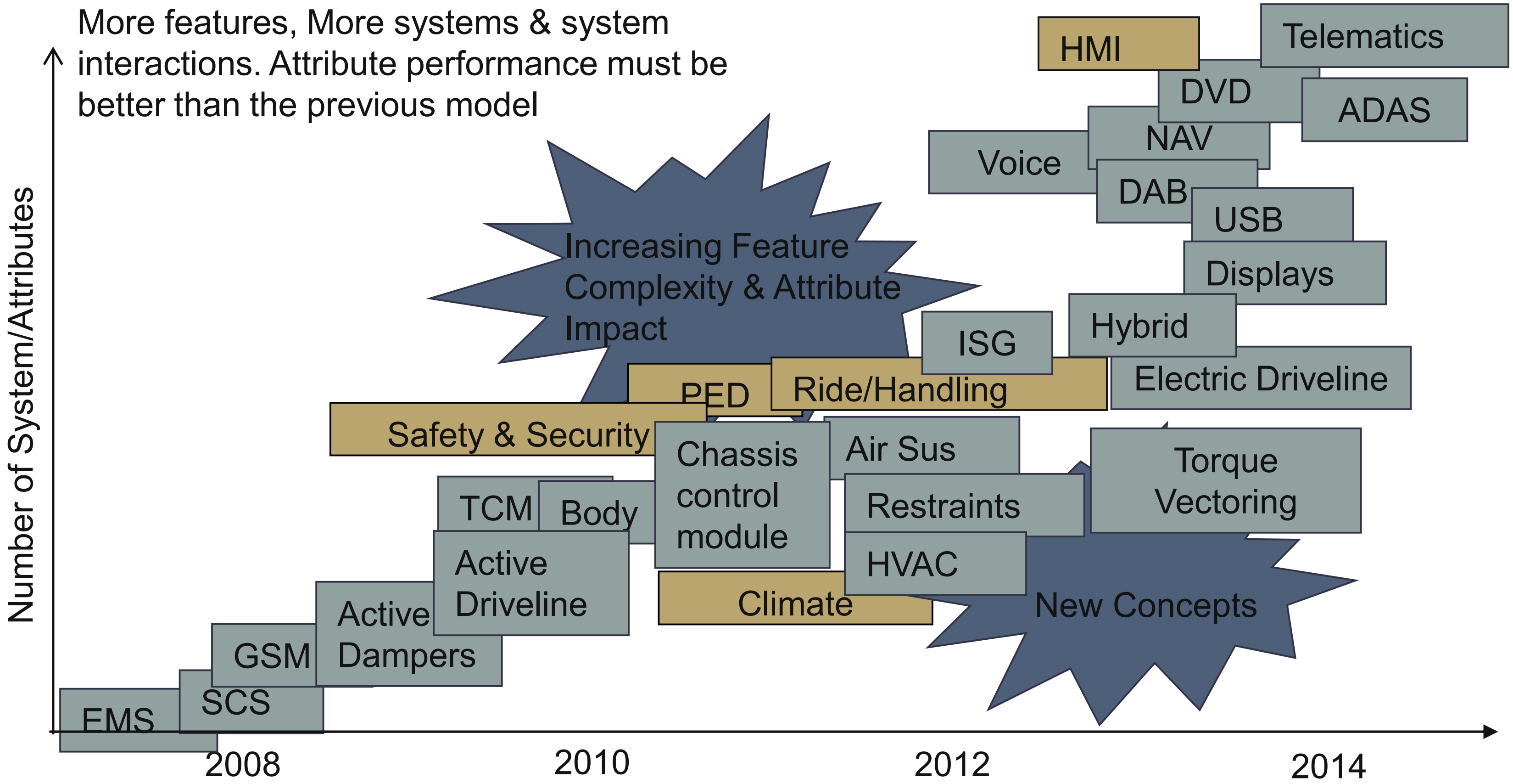
Complexity



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Complexity

JLR parted from Ford in 2007 having inherited much of their tool chain and process. Since then we have been working hard to centralise on an appropriate set of simulation tools and converge on an organisation structure to allow us to deliver our objectives **efficiently**.

We must work in a way that can be **scaled** to keep up with the growing challenge.

- 50 product actions in 5 years
- Massively increased Systems Complexity
- 100 ECUs. More than 100 Million lines of code per car
- 100s New Leading Edge Technologies
- 18 Customer attributes: e.g. Ride, Handling, Performance & Economy
- 10,000 Requirements 100,000 Test Cases

- 172 Global Markets
- 5 Functions: Body, Chassis, Powertrain, Electrical, Vehicle
- Derivitisation / Customisation
- 1000s New Parts. 55 Major Systems.1,200 features
- New complex error states

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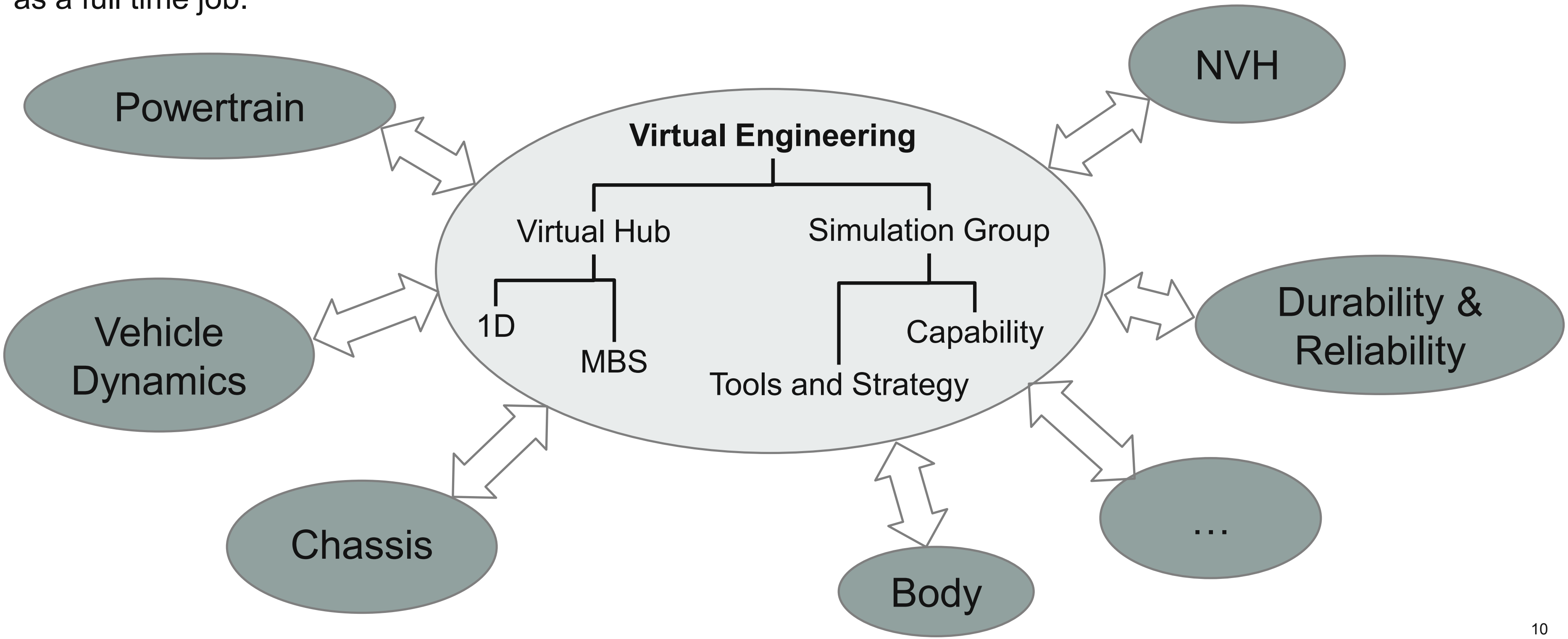
Organisation

JLR has a central “Virtual Engineering” organisation.
Those working to align, coordinate and ensure that our virtual engineering is efficient and capable, are doing it as a full time job.



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Organisation

Virtual Engineering Department – Virtual Hub

In order to cope with the increasing volume of model build activity, the Virtual Hub department was created. Initially to centrally build MBS models for the rest of the business.

Before	After
• 2 MBS codes	• 1 MBS code (SIMPACK)
• Models built by different departments. Sometimes shared informally, sometimes duplicated	• Models delivered to programme timing
• No model standard	• Model standard
• Programme gateways signed off with different models	• Programme gateways signed off with the same model
• Specific models for specific load-cases	• One configurable model suitable for all load-cases.

Having engineers dedicated full time to model build and users across the business engaged in the model standard and capability enhancement has increased accuracy and capability enormously.

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CarMaker Model Build

The following year, a “1D team” was added to the Virtual Hub.

One early task was to “Productionise” supply of CarMaker models as Virtual Prototypes. With this source of high quality models available to programme timing, more departments started to adopt CarMaker into their standard working practices.

Original users

Vehicle Dynamics, Stability Control Systems,

Chassis electronics, Chassis research

Additional users

Automated driving & driver assistance systems,

software integration testing, Energy management,

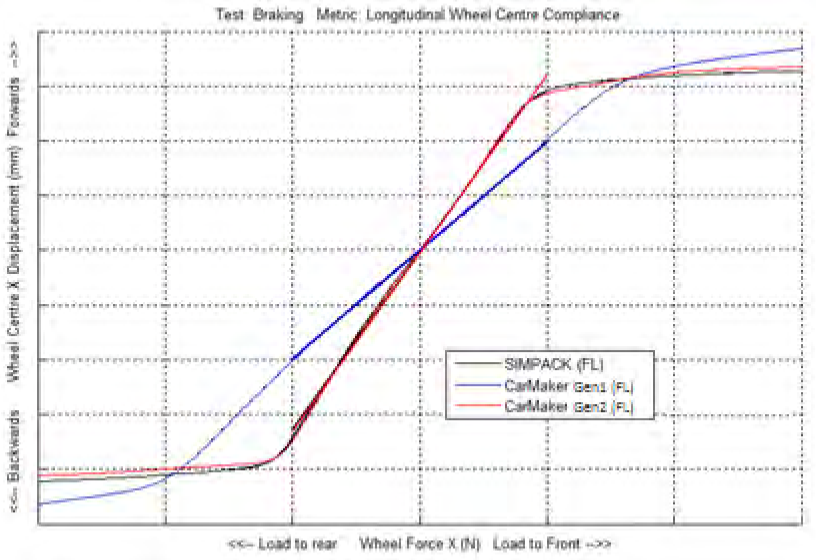
Performance Economy and Drivability, Hybrids,

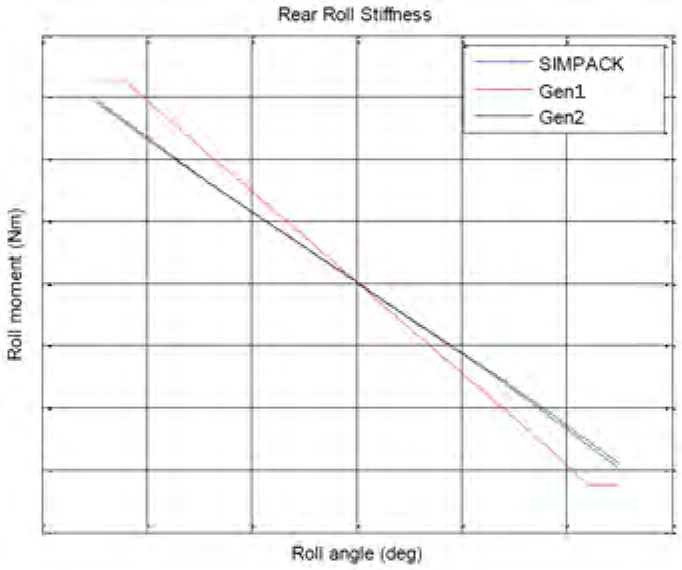
Off road Capability

CarMaker Model Build

A great deal of effort went into "Productionising" our CarMaker dataset creation process.

Each CarMaker vehicle is based off and verified against an MBS model





Datasets are delivered to agreed timing aligned to programme gateways.

The same model is used in many departments across the business

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Through senior engagement between IPG and JLR, some very positive changes have been realised which have been instrumental in achieving what we have done with CarMaker.

Increased visibility of the IPG Roadmap, fixed release dates & Compatibility with other key software versions

- Enabling us to plan for version migration and update our models.
- All departments must use a consistent version so we must be mindful of the requirements of all departments and plan accordingly

Software development freezes and increased Beta testing. IPG test their software using JLR models

- Minimises the internal verification and feedback loop. We can deploy new versions right away

This improved 2-way communication has been extremely valuable to JLR and we have now aligned on a single version business wide (5.1.1) which is compatible with our chosen Mathworks and dSPACE releases.

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IPG CARMAKER AT JAGUAR LAND ROVER
Modelling Landscape

Jaguar Land Rover now employs two tools for modelling driving dynamics.

Our preference is always to standardise on a minimal set of tools wherever possible. A large user base will benefit from:

- Development of best practices and standardised ways of working
- Significant internal knowledge base
- Greater collaboration with the software supplier when requesting enhancements and new features
- Enabling of the central model build regime
- Greater collaboration between departments

The challenge is to select the best toolset for the business as a whole.

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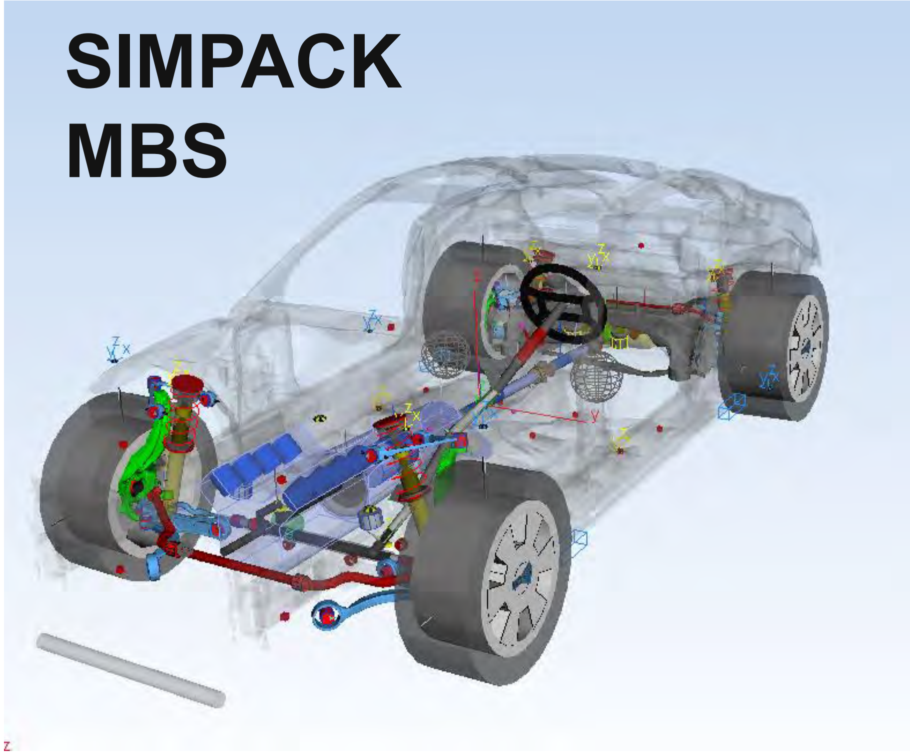
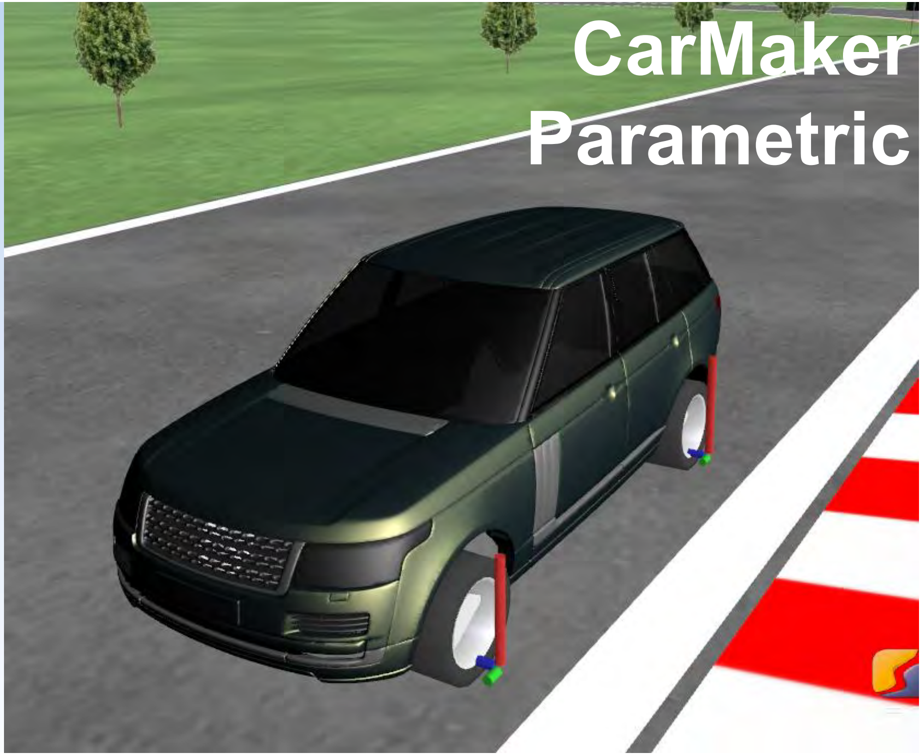
Modelling Landscape





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Modelling Landscape

MBS Model

Component level changes e.g.

- Bush rate
- Hard point location
- Etc.

Large computational overhead. Representative vehicle behaviour up-to structure borne noise (150Hz).

Typically used for suspension design and integration, loads estimation, ride analysis, packaging envelopes, durability analysis & abuse loadcases, NVH, steering analysis, …

Parametric Model

System & some component level changes. Eg:

- Camber gain
- Axle lateral stiffness
- Springs, bars and damper codes
- Etc

Little computational overhead. Useful for lower frequency vehicle behaviour and handling.

Typically used for control system development, SiL and HiL testing, lap time simulation, target setting, ADAS, Prototyping of concepts, Driving Simulator subjective assessments, …

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Future Plans

JLR has an aggressive objective to remove early prototypes. This is in part due to the time, expense and man power associated with physical testing and in part due to additional opportunities presented by CAE for design robustness.

There are several advantages to using CAE rather than a physical prototype.

- The Model may be more up to date of the production intent than the test mule.
- Model is more flexible
- Parameter sweeps and design optimisation are far more practical
- Repeatability & Control of noise factors

The consequence is that detailed models are required earlier in the development cycle and that more is expected of those models.

For our CarMaker models, this means that more of the systems which interact with each other and impact the vehicle behaviour must be included in the simulations.

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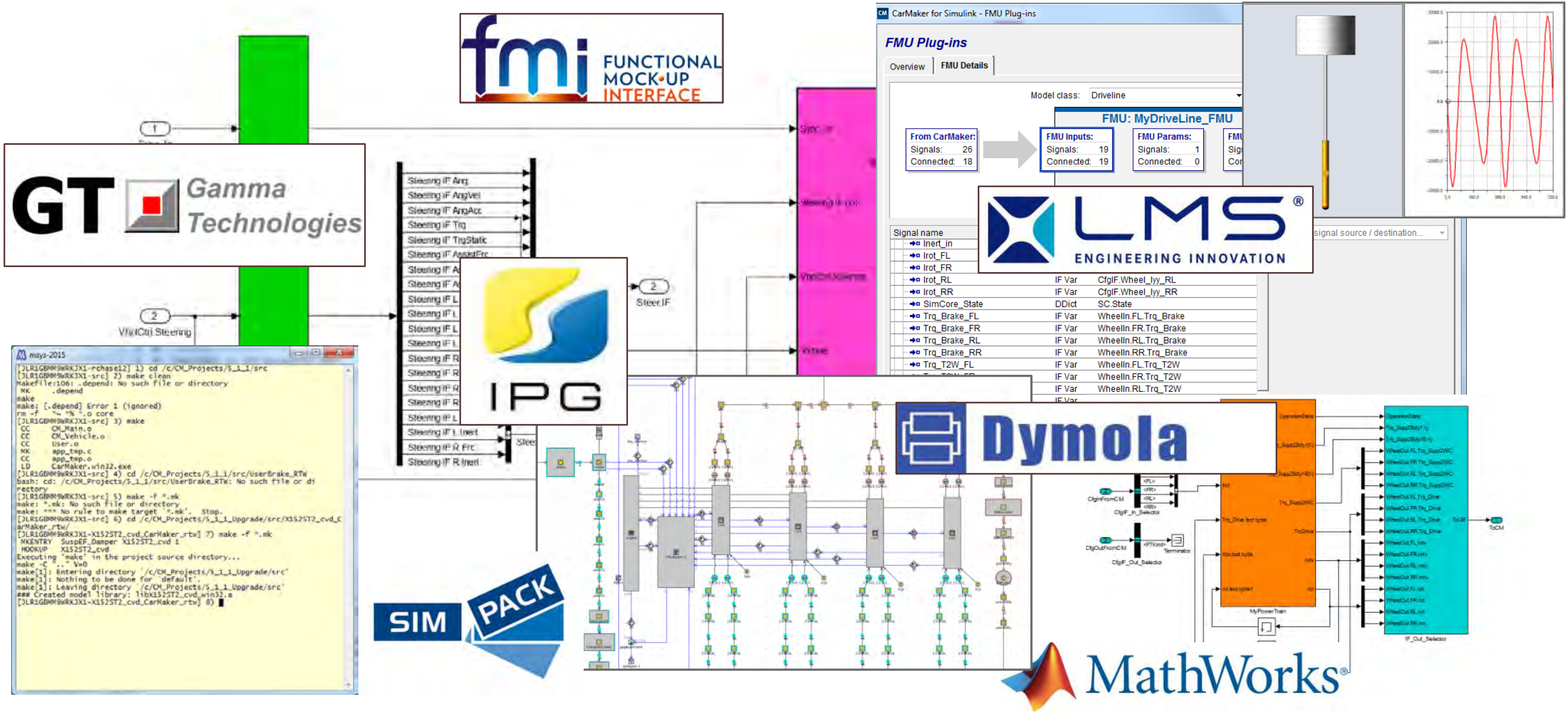
Model Integration



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Model Integration

Initially, all CarMaker models that the Virtual Hub released were “passive” datasets only. Integration of additional systems through the Simulink, FMI or Plugin interface was performed by the end user.

For some time now, the Virtual Hub have been providing a growing number of “Plugins” in order to fill capability gaps and make our Simulations more representative.

Like the passive model build, this is relatively simple for a one off case. Delivering an efficient validated repeatable production process in which we capture accurate system interaction behaviour and maintain real-time performance and extendibility is a far more complex proposition.

Integration methods and model coupling technology are currently our **top priority** and we are investing a lot of effort into understanding and validating the available methods with our production intent models.

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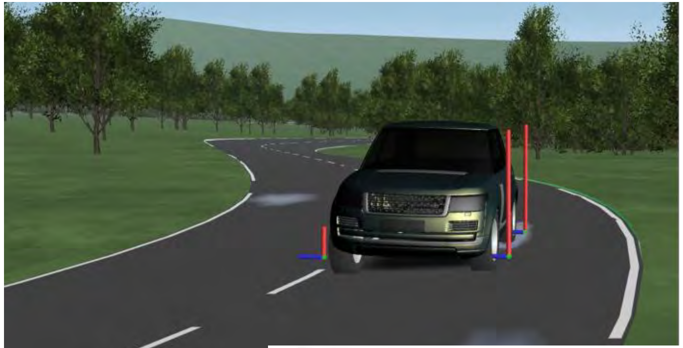
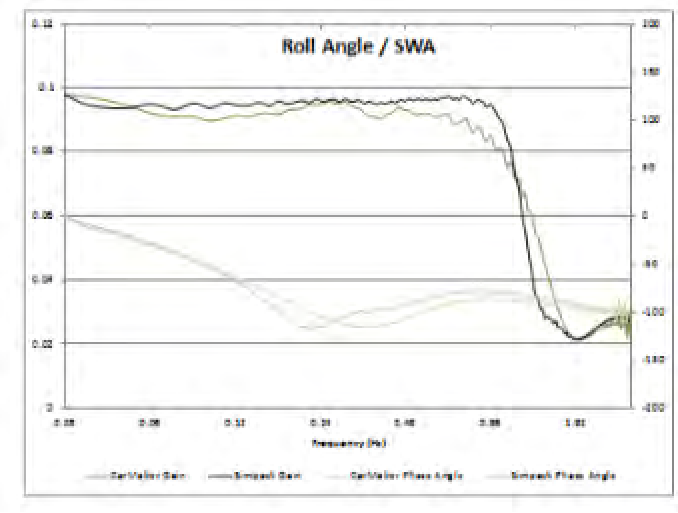
Vehicle Dynamics





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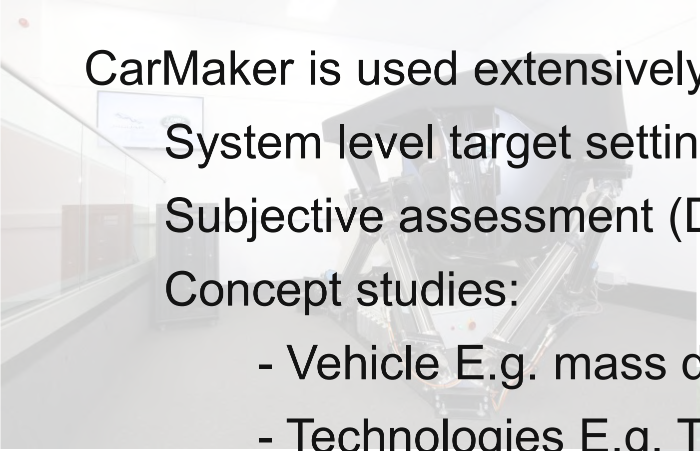
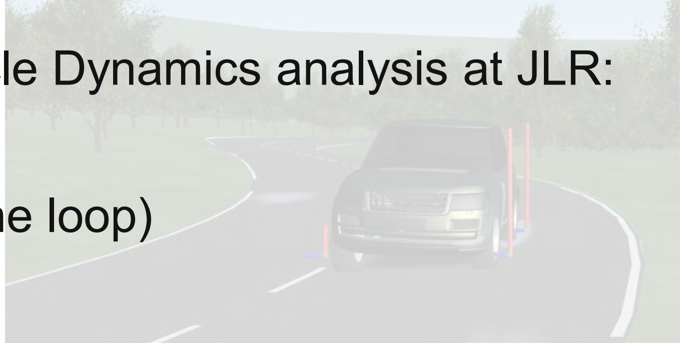
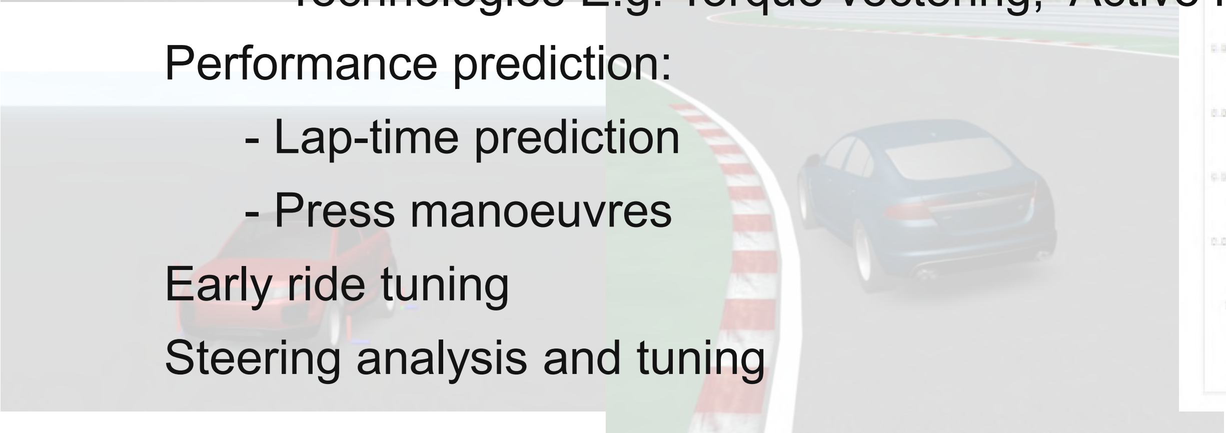
Vehicle Dynamics

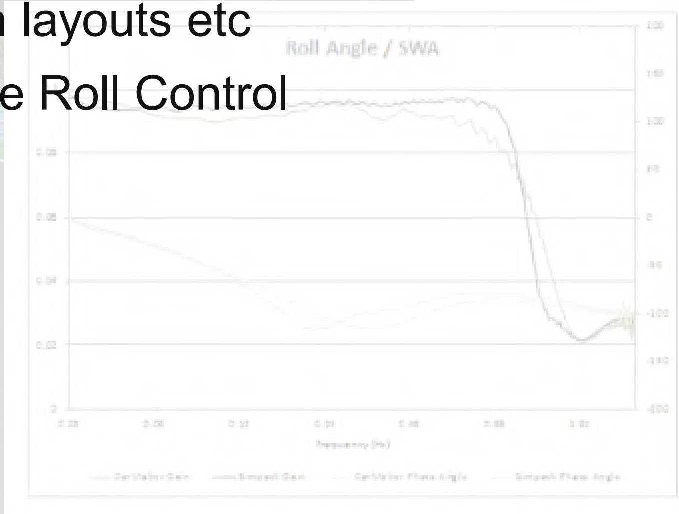




CarMaker is used extensively for Vehicle Dynamics analysis at JLR:

- System level target setting
- Subjective assessment (Driver in the loop)
- Concept studies:
  - Vehicle E.g. mass distribution, suspension layouts etc
  - Technologies E.g. Torque vectoring, Active Roll Control
- Performance prediction:
  - Lap-time prediction
  - Press manoeuvres
- Early ride tuning
- Steering analysis and tuning





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Predictive Energy Optimisation (PEO)

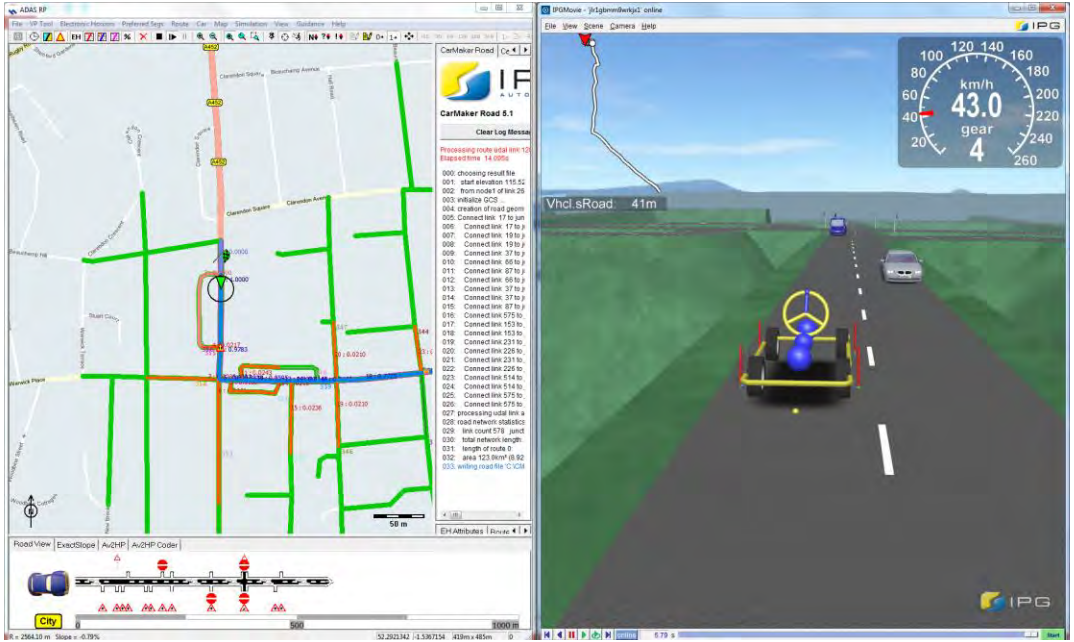
CarMaker used with ADASRP from HERE & in-house powertrain model to simulate repeatable “Real World Drive-cycles”

- Corners, gradients, traffic, junctions, speed limits, traffic lights, different drivers, …

Closed loop simulation of Powertrain supervisory control / satellite navigation interaction

Optimisation and validation of the control strategy

Sensitivity analysis – Ensure the control strategy is robust to varying traffic density and other noise factors



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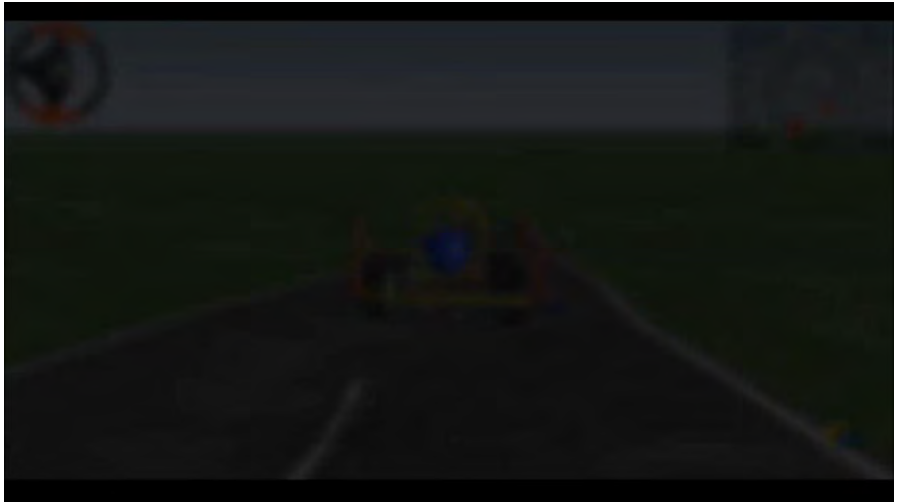
Off Road Capability (ORC)

Off road feature and system concept development. Implementation of non deformable off road surfaces and empirically based tyre/surface models



Scanned articulation surface

Deformable surface modelled using empirically measured data

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Adaptive Cruise Control (ACC)

Automated functional test of ACC using IPG TestManager

At each software update, a number of tests are automatically run (shear in, sheer out, multiple button press etc) to verify that the software still meets requirements.

Integration testing with other control systems (E.g ABS)

Tests performed at MiL and SiL level

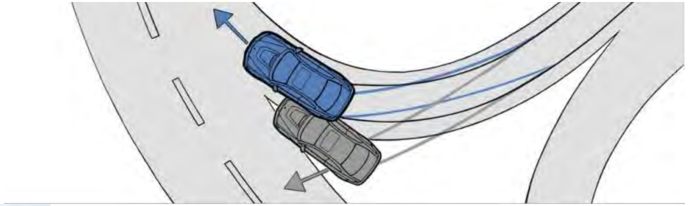
Stability Control Systems

Stability Control System

– Use brake and powertrain torque modulation to manipulate the dynamic state of a vehicle.

– A stable target is defined relative to a simple vehicle model

– Deviation from that target triggers an SCS response designed to either return that vehicle to target or change state in a stable manner.



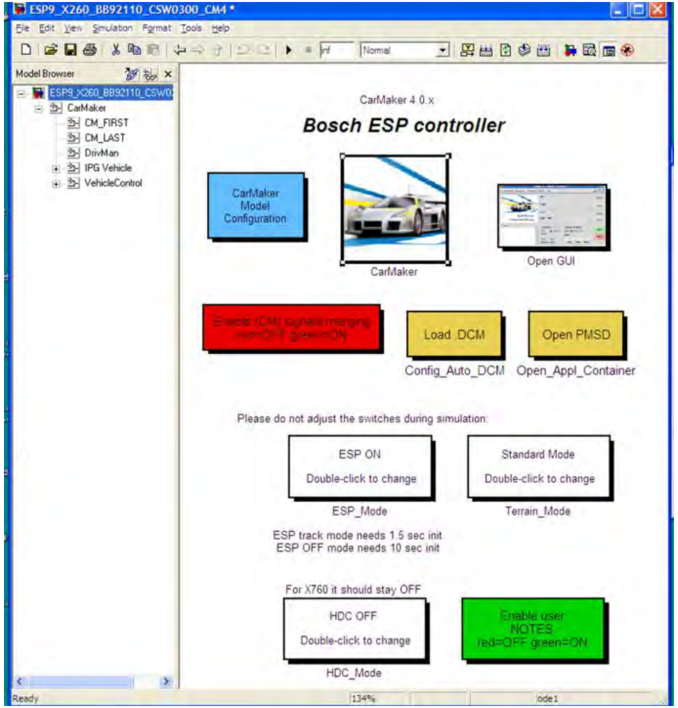
Stability Control Systems

Stability Control System Models

– S-function in SIMULINK environment

– Integrated into IPG Carmaker environment with corresponding vehicle model

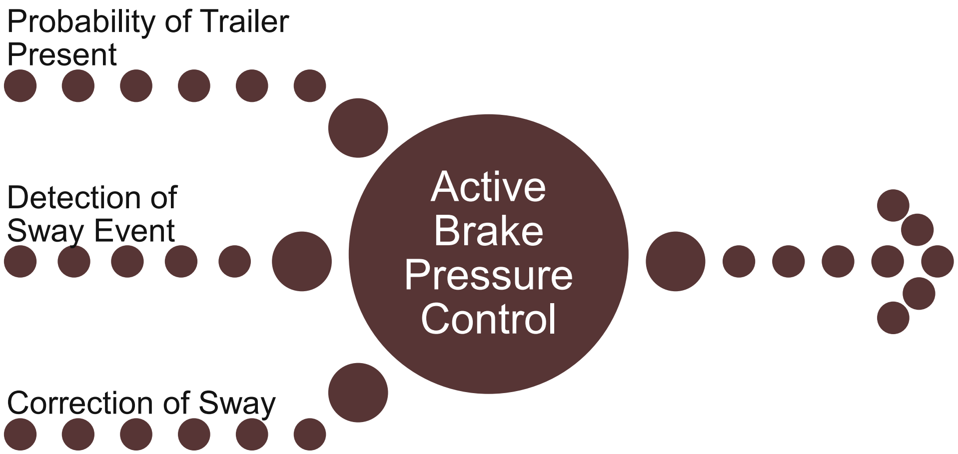
– JLR internal functions can be prototyped and evaluated



Stability Control Systems

Example Function : Trailer Sway Mitigation

– Trailer Stability Mitigation (TSM) is a function to prevent unstable oscillations and trailer sway in Vehicle-Trailer system



Stability Control Systems

Benefits of Performing TSM Calibration & Validation Testing in CAE

– Safety
  - Reduced risk exposure for engineers

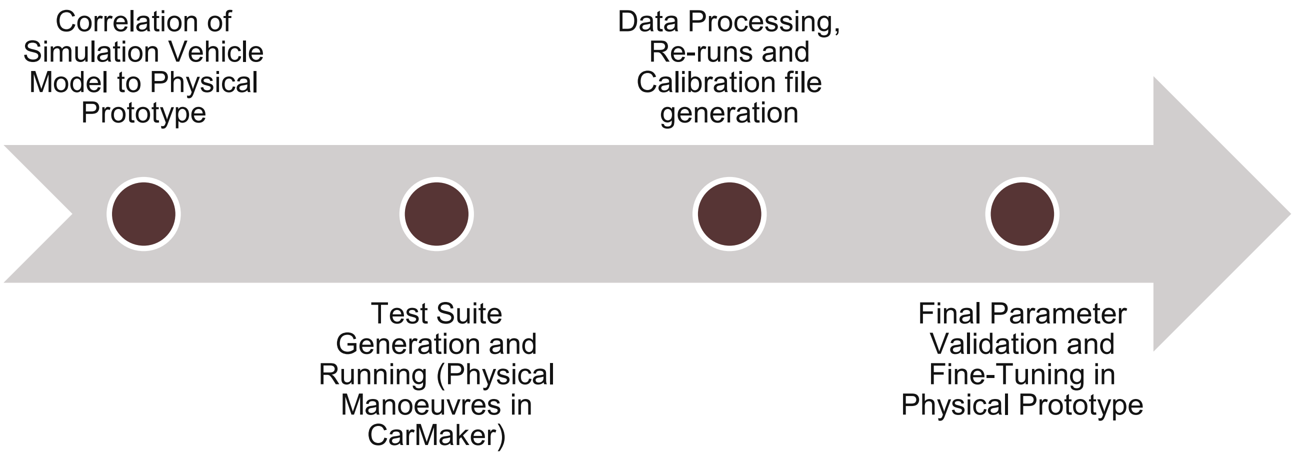
– Efficiency
  - Swapping & loading trailers to different masses and nose weights is both quicker & easier in CAE

– Practicality
  - More different trailer type/configuration & loading conditions considered than with physical tests
  - Trailer behaviour (yaw rate, path deviation..) easier to measure

– Repeatability

Stability Control Systems

Process of Performing TSM Testing in CAE



Stability Control Systems

THANK YOU

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