Virtualisation of Durability Studies For The New Era Of Vehicle Propulsion

Presented By

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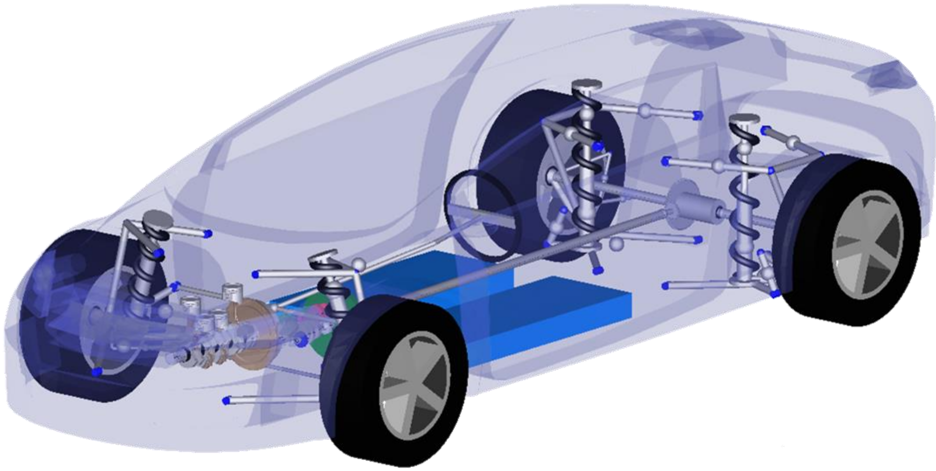
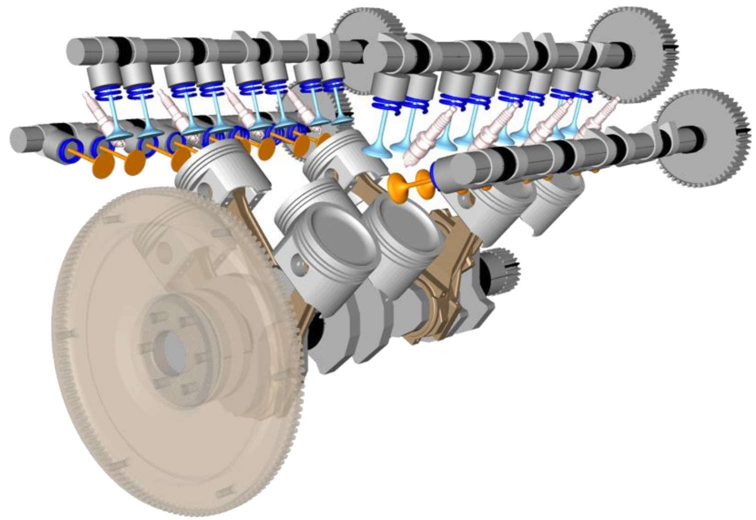
Who is Claytex?

- Engineering Consultancy
- Software Training
- Modelica Library Developers
- FMI Tool Developer
- Virtual test environments for ADAS and Autonomous Vehicles with rFpro
- Software Distributor
  - Dassault Systemes
  - rFpro
- Head office in the UK, offices in USA (NC & MI) and South Africa
- Acquired by TECHNIA January 2022





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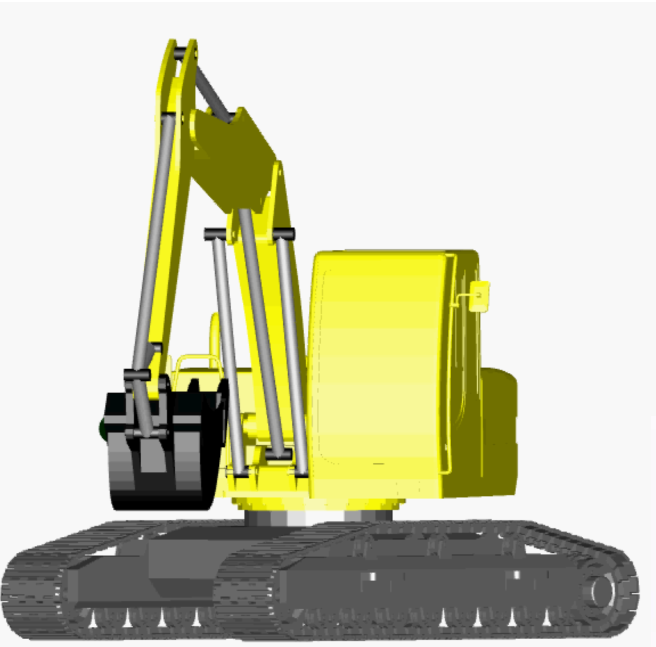
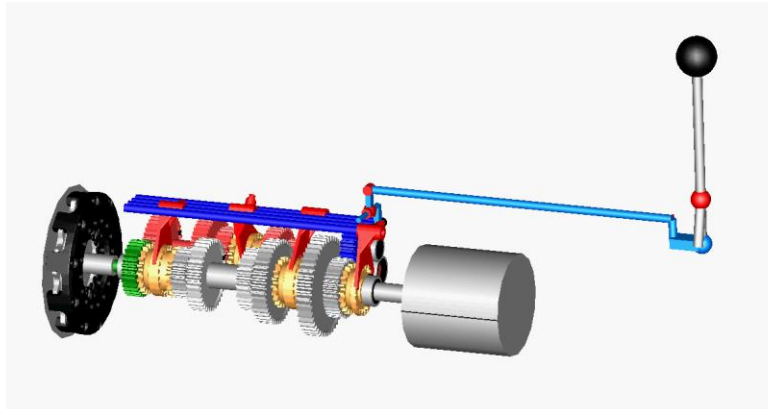
What we do





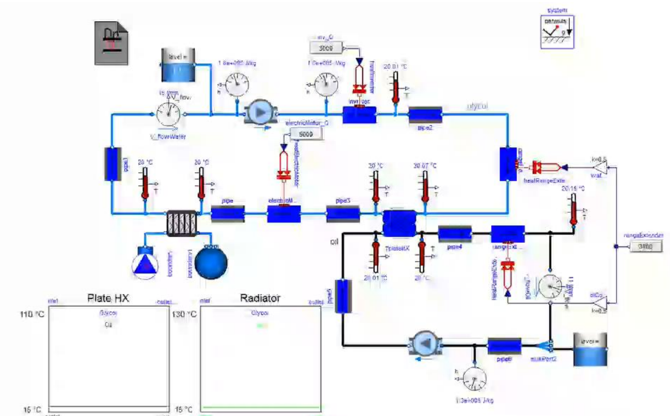
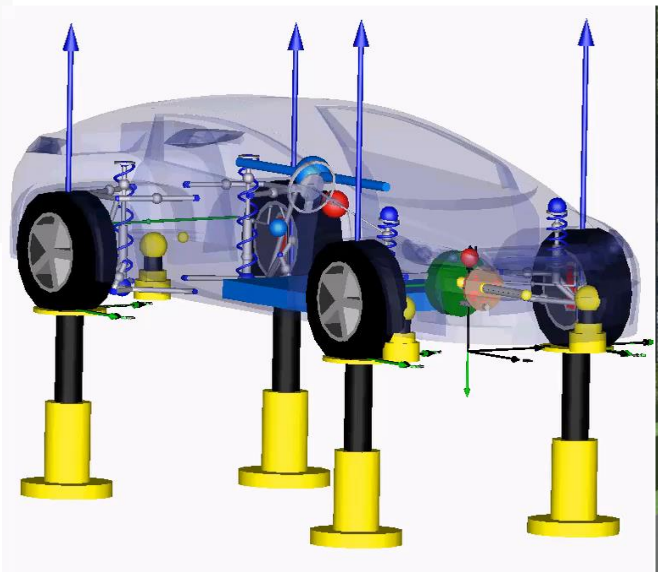
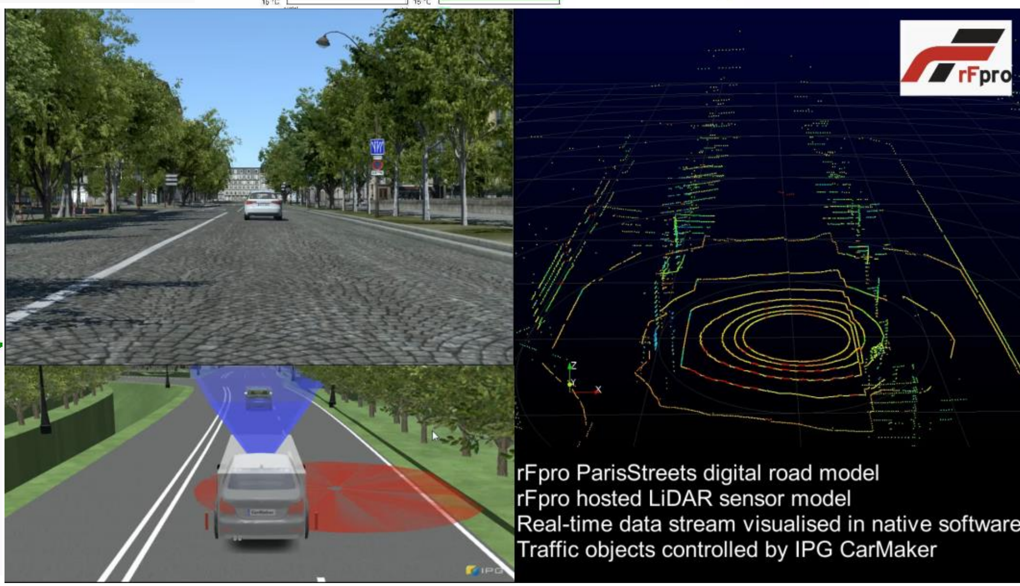


Plate HX
Radiator




rFpro
rFpro ParisStreets digital road model
rFpro hosted LiDAR sensor model
Real-time data stream visualised in native software
Traffic objects controlled by IPG CarMaker

The Durability Problem

- Evaluating durability has been an enduring problem since the start of vehicle production
- The closer to release that physical durability testing, the more accurate the results
  - The earlier the testing the larger the differences to the final release
  - The later the testing the higher the cost to remedy any problems
- Changes to interdependent systems impacting loads
- Radical vehicle change reduces knowledge carryover
- 100k’s miles to run a full cycle
  - Months to complete
  - Fuel and track usage costly
  - Heavy environmental impact
  - Multiple vehicle variants

Project Outline

What:

- International vehicle manufacturer
- Recreate dynamic powertrain durability study virtually
- Validate against logged data
- Process data to output to durability analysis program
- Allow enhancement, modification and expansion
- Back to back ICE vs Electric

How:

- Based on VeSyMA Suite in Dymola
- Virtualise every test
- Make each test adaptable
- Include protection against failures
- Automate library generation for new vehicle
- Run multiple simulations simultaneously

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Vehicle Systems Modelling and Analysis (VeSyMA)

VeSyMA

- Driver-in-the-Loop
- Engines
- Fluids
- Kinematics
- Motorbike
- Motorsports
- Powertrain
- Suspensions
- Terrain Server
- UAV Dynamics

Fluid Power

FlexBody

- Suite of Modelica libraries for **Vehicle Systems Modelling and Analysis**
- Models a variety of different vehicle layouts and types
- Application specific extensions provide detailed models across many areas
- Compatible with many other libraries including the Electrified Powertrains and Battery libraries
- Compare ICE vs Electric vehicles using same templates and sub-systems
- Built on the VehicleInterfaces open standard model architecture
- Open and modifiable

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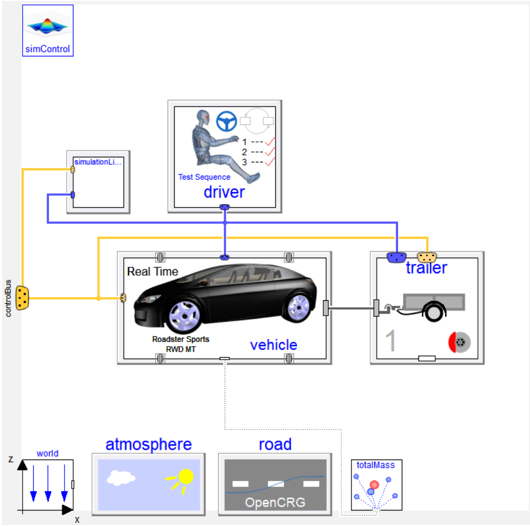
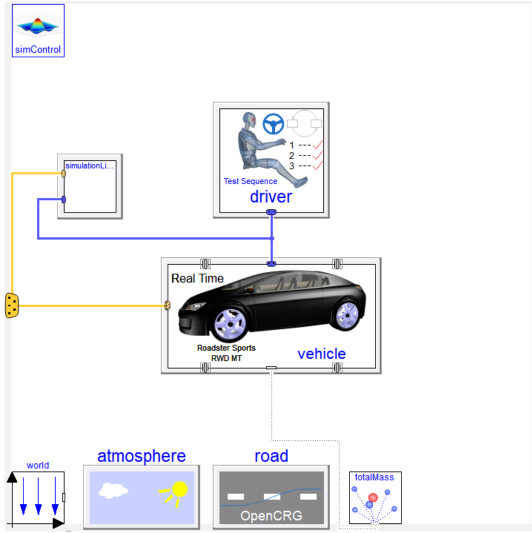
Experiment Breakdown





- The experiments follow the VeSyMA vehicle experiment templates.
- The experiments contain separate models for the:
  - **Driver** – Controls the vehicle
  - **Vehicle** – All physics of the vehicle
  - **Trailer** (optional) – All physics of the trailer
  - **Road** – Road surface and driving line
  - **Atmosphere** – Environment parameters
  - **Simulation Limits** – Stops simulation if limits are exceeded
- Each element, while self-contained is dependent on the other elements and elements like driver react to changes in the vehicle.
- 2 layouts used for all tests (with or without a trailer).

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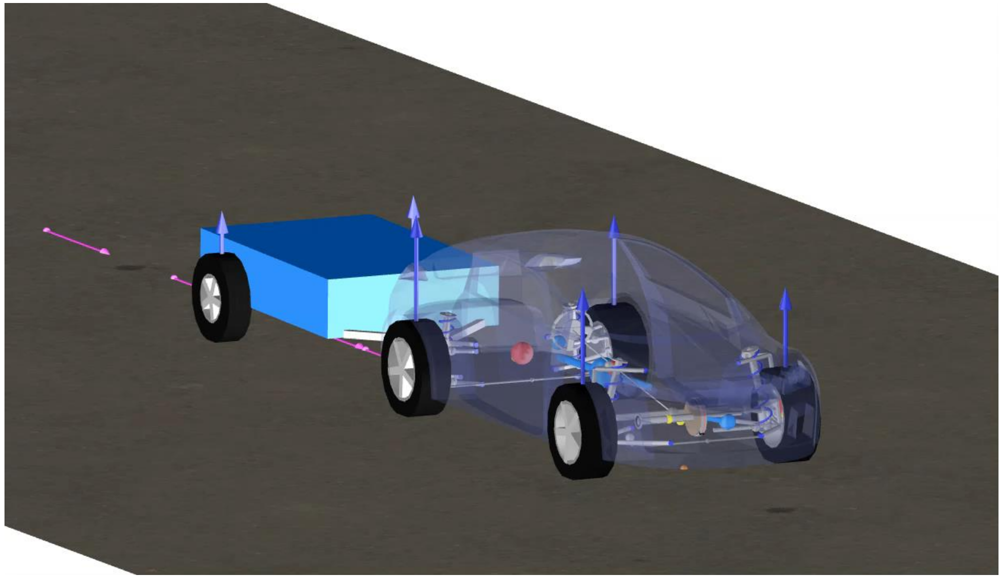
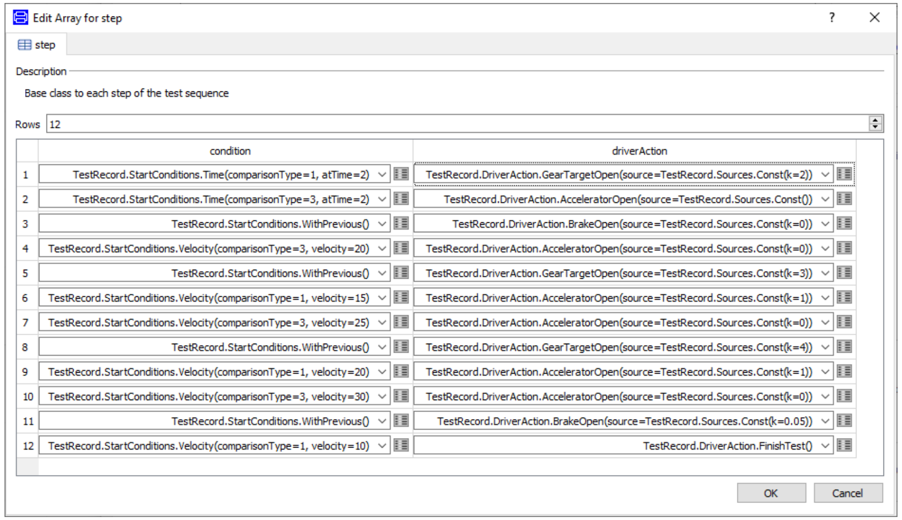
Driver Tasks Define Experiment

- Closed loop driver
  - Longitudinal and lateral control
  - Reversing with trailer
  - Gear/clutch control
- Conventional vehicle controls
- Not vehicle specific
- Test specification converted to sequence of tasks containing:
  - Condition (e.g. position, speed, gear, etc)
  - Action (e.g. accelerator position, target speed, gear)
- For example:
  - At mile marker 3 change into 3rd gear
  - When vehicle speed drops below 30mph, change to 2nd and accelerate at WOT to 50mph
- Driver terminates test when all steps complete





Edit Array for step

step

Description

Base class to each step of the test sequence

Rows 12

	condition	driverAction
1	TestRecord.StartConditions.Time(comparisonType=1, atTime=2)	TestRecord.DriverAction.GearTargetOpen(source=TestRecord.Sources.Const(k=2))
2	TestRecord.StartConditions.Time(comparisonType=3, atTime=2)	TestRecord.DriverAction.AcceleratorOpen(source=TestRecord.Sources.Const())
3	TestRecord.StartConditions.WithPrevious()	TestRecord.DriverAction.BrakeOpen(source=TestRecord.Sources.Const(k=0))
4	TestRecord.StartConditions.Velocity(comparisonType=3, velocity=20)	TestRecord.DriverAction.AcceleratorOpen(source=TestRecord.Sources.Const(k=0))
5	TestRecord.StartConditions.WithPrevious()	TestRecord.DriverAction.GearTargetOpen(source=TestRecord.Sources.Const(k=3))
6	TestRecord.StartConditions.Velocity(comparisonType=1, velocity=15)	TestRecord.DriverAction.AcceleratorOpen(source=TestRecord.Sources.Const(k=1))
7	TestRecord.StartConditions.Velocity(comparisonType=3, velocity=25)	TestRecord.DriverAction.AcceleratorOpen(source=TestRecord.Sources.Const(k=0))
8	TestRecord.StartConditions.WithPrevious()	TestRecord.DriverAction.GearTargetOpen(source=TestRecord.Sources.Const(k=4))
9	TestRecord.StartConditions.Velocity(comparisonType=1, velocity=20)	TestRecord.DriverAction.AcceleratorOpen(source=TestRecord.Sources.Const(k=1))
10	TestRecord.StartConditions.Velocity(comparisonType=3, velocity=30)	TestRecord.DriverAction.AcceleratorOpen(source=TestRecord.Sources.Const(k=0))
11	TestRecord.StartConditions.WithPrevious()	TestRecord.DriverAction.BrakeOpen(source=TestRecord.Sources.Const(k=0.05))
12	TestRecord.StartConditions.Velocity(comparisonType=1, velocity=10)	TestRecord.DriverAction.FinishTest()

OK Cancel

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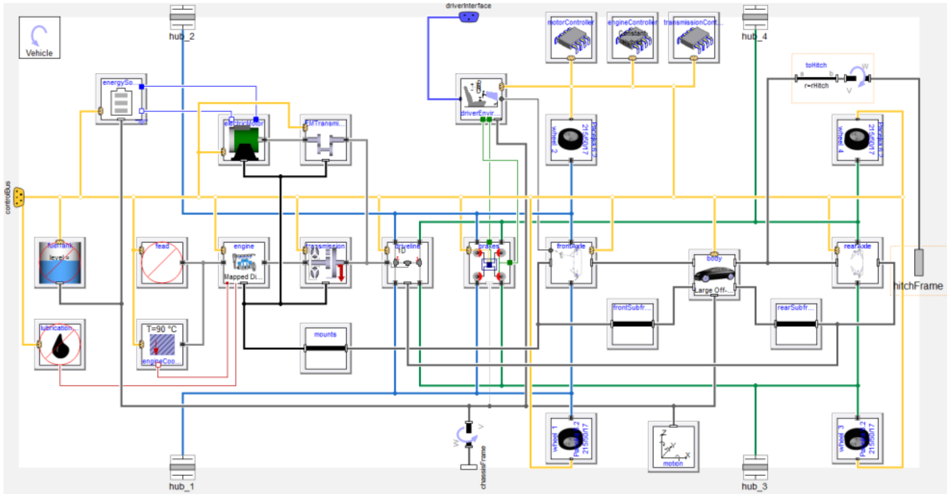
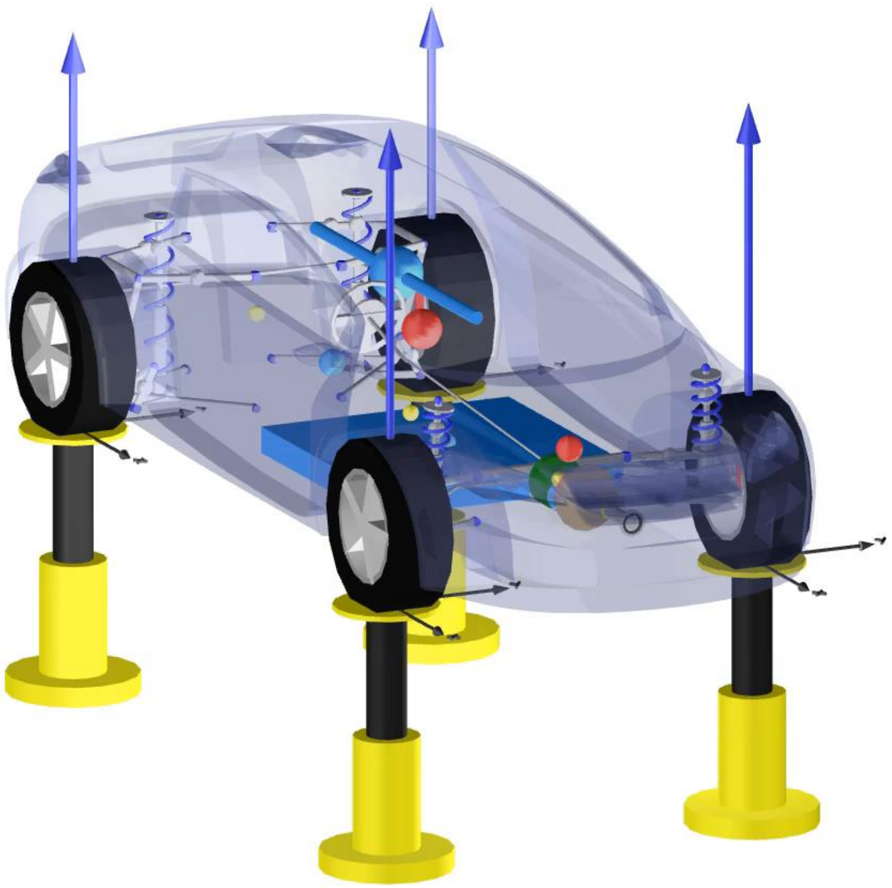
Vehicles Models

- Based on VeSyMA templates
- Replaceable sub-systems
- Separate vehicle/sub-system orientations
- Allows mixed fidelities
- Import FMUs as controllers
- Mixed media system simulation
  - Multibody
  - Thermal
  - Fluid
  - Electrical

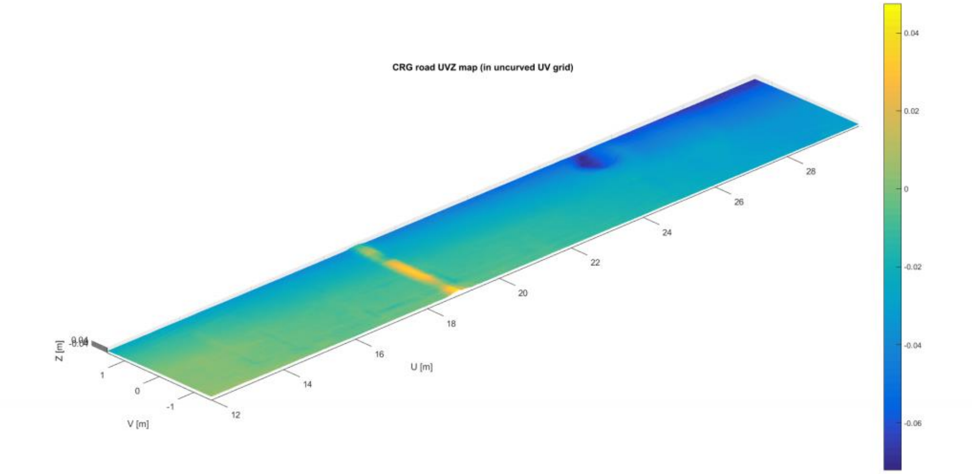


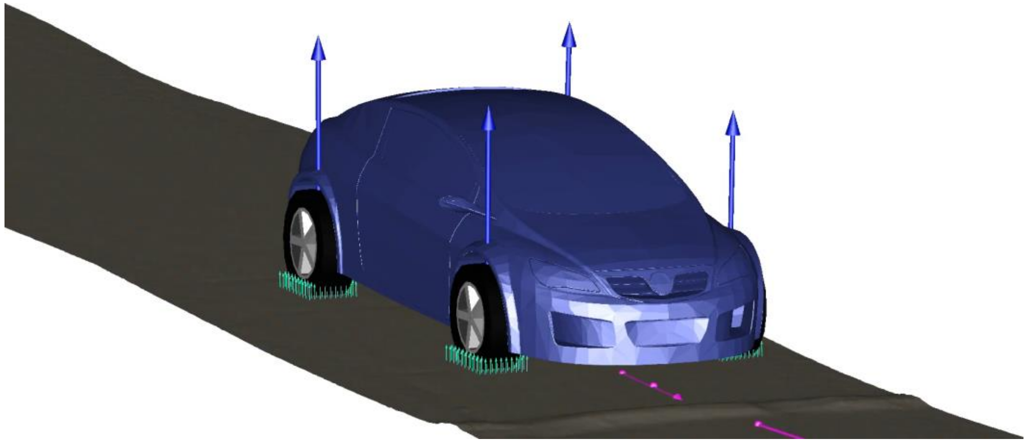


Source of Road Data

Roads virtualised in 3 ways:

- Lidar scanned road models are used for the “surface events”
  - e.g. potholes, speedbump
- High speed circuits created from measured GPS data
  - e.g. race tracks, high speed bowl
- Manually generated surfaces from facility specifications
  - e.g. gradients, banked circuits
- Same vehicle model
  - Multiple tyre contact models for efficiency
  - Non-scanned roughness defined by ISO standard





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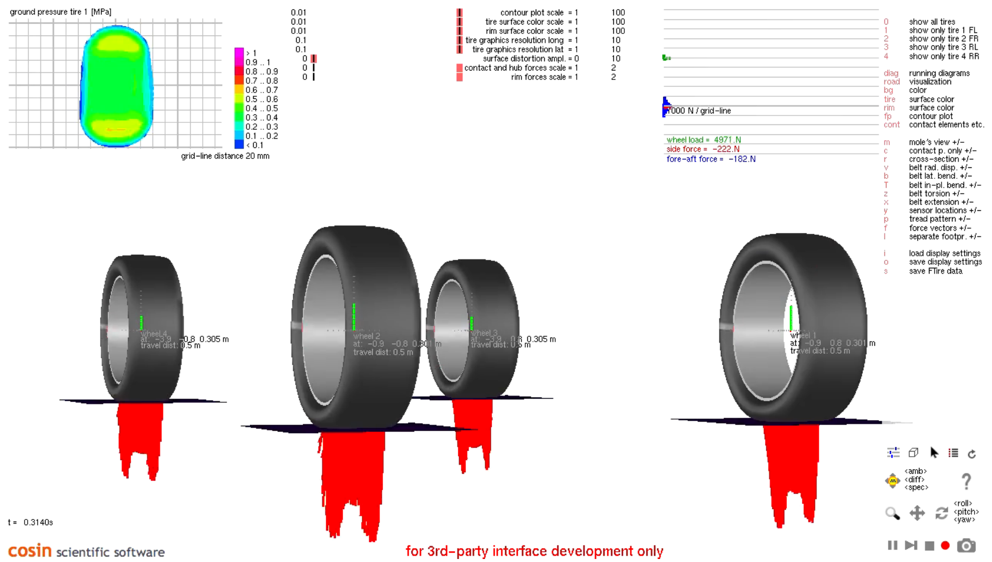
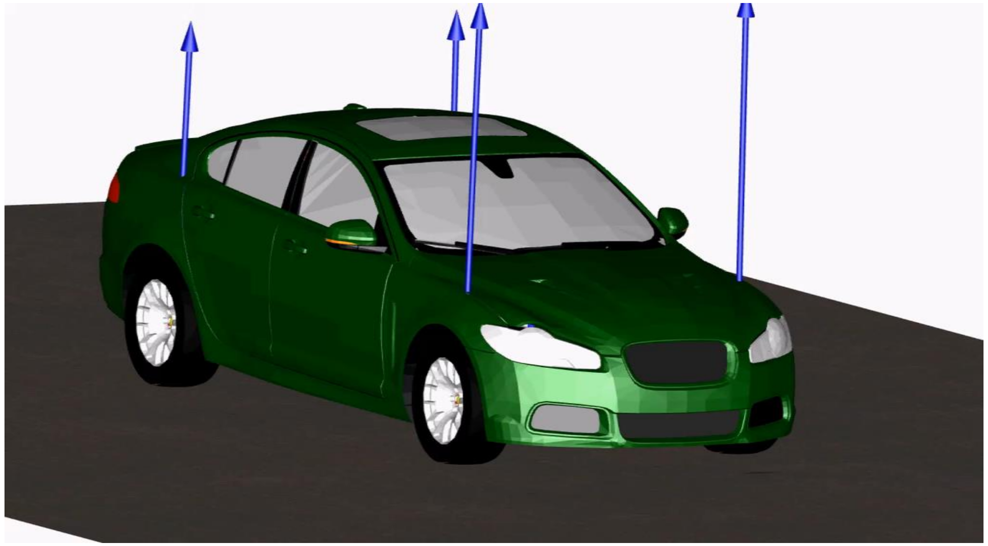
Alternate Contact Models and Road Data

- FTire – High fidelity tyre and surface models





- Library of Lidar scanned surfaces in rFpro
  - Millbrook proving ground
  - IDIADA proving ground
  - Nürburgring
  - Race tracks
  - Public road surfaces

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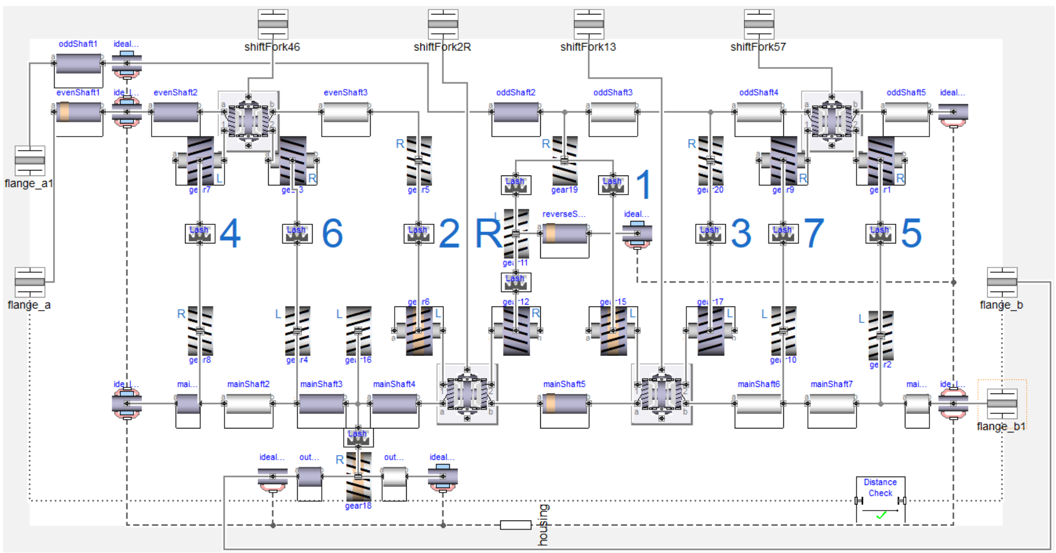
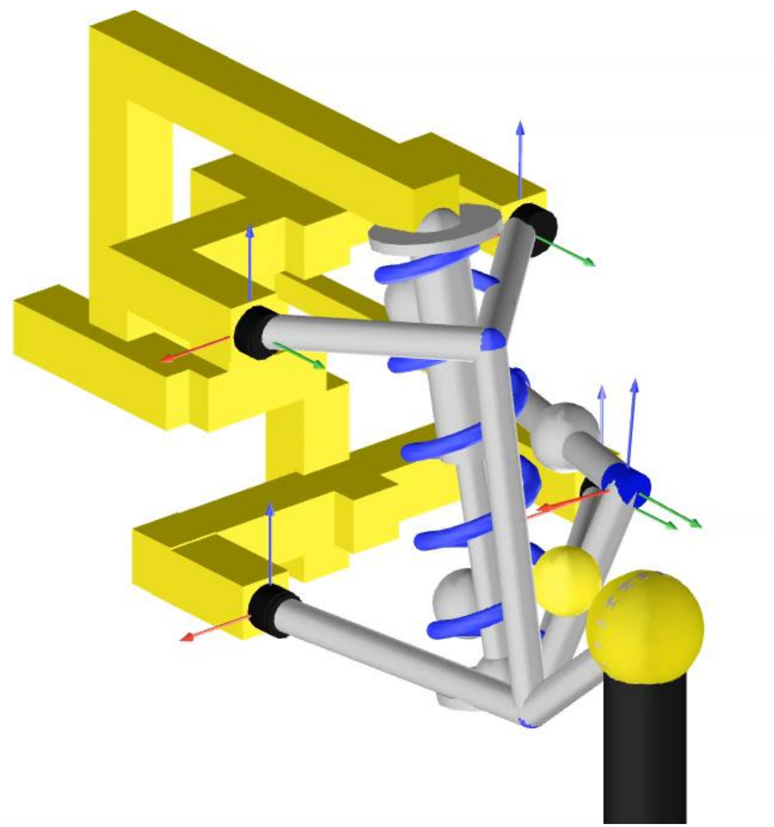
Incremental Development and Failure Modelling

- Fidelity of models match availability of data and development stage
  - Simple/Ideal/Table in early development
  - Higher fidelity when design is refined
- Subsystems developed independently
- Each subsystem has higher fidelity options

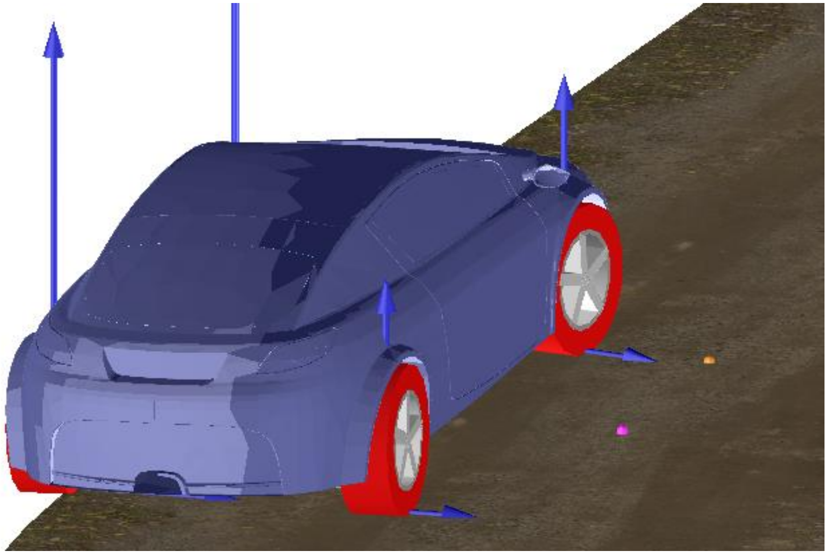
- Degraded/failed components can also be modelled
- Evaluate effect of degraded components to accelerate failures

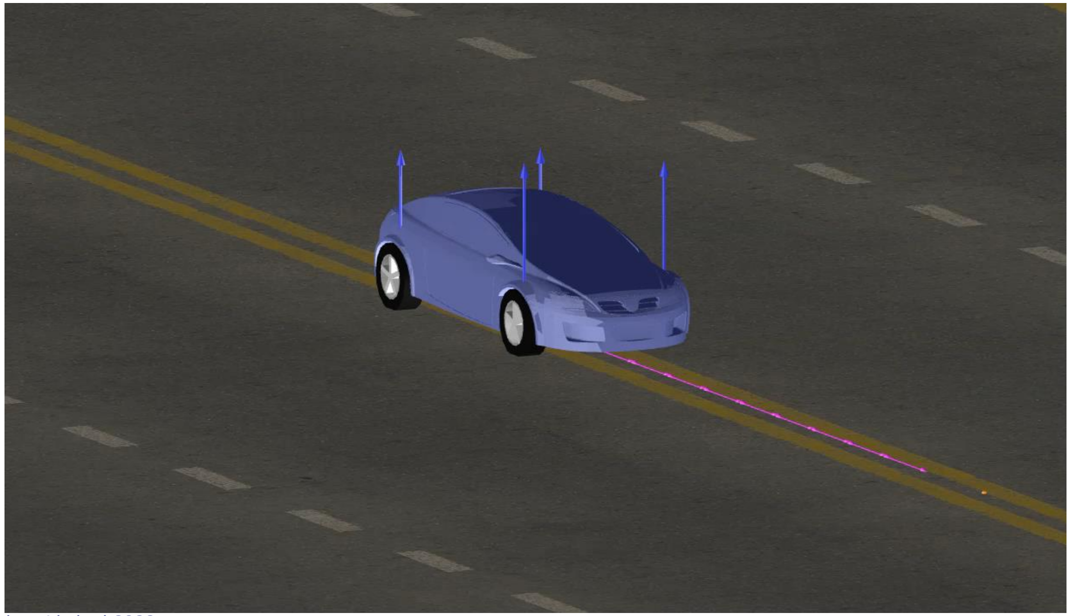




Test Validation

- Each test contains automatic checks
- Dynamically checks if test is valid, for example:
  - Vehicle off course
  - Engine Stall
  - Battery out of charge
  - Trailer Jackknife
- Stops test if invalid
- Feedback provided
- Results able to be interrogated separately
- Opportunity to rerun individual tests and replace data
- If vehicle change required all tests inherit single change





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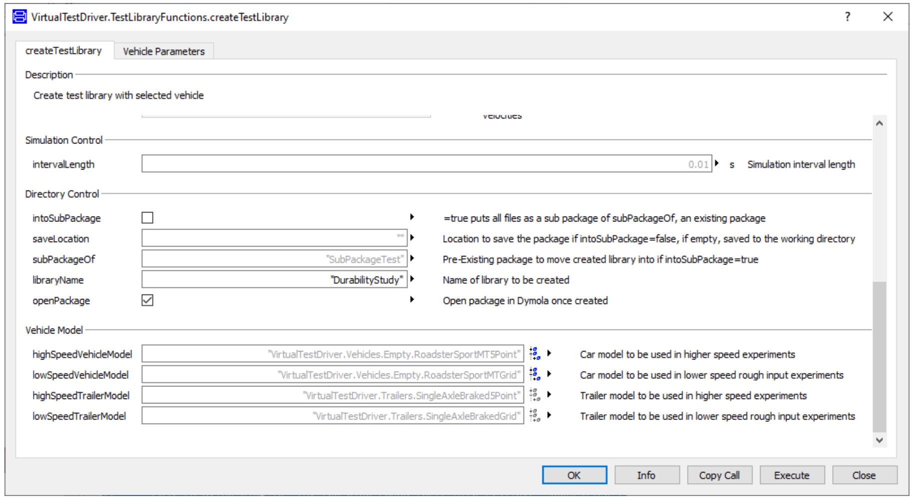
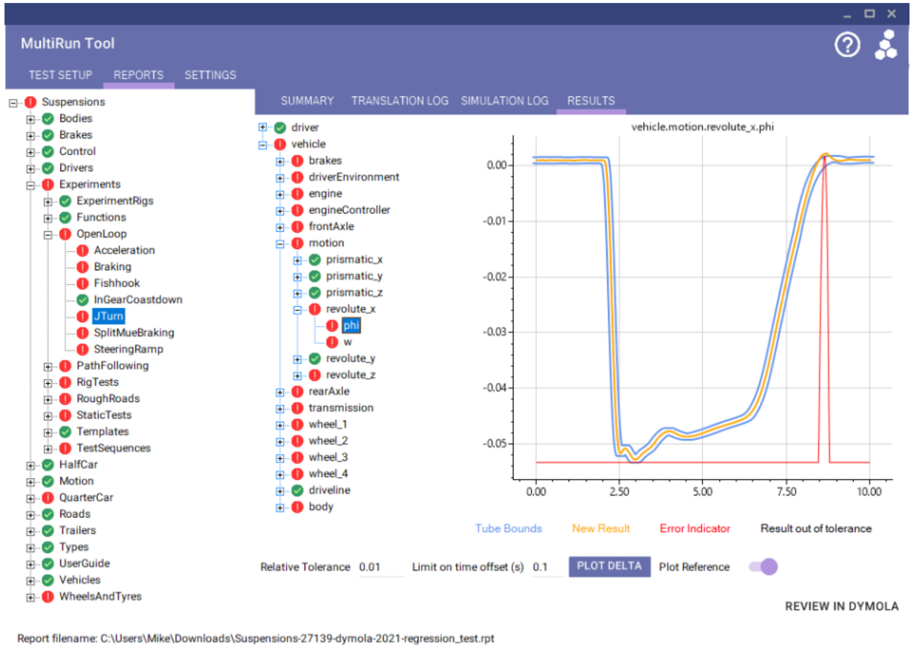
Simulating Vehicle Durability

- Function to create virtualised durability study:
  - Pre testing vehicle evaluation:
    - Shift speeds
    - Maximum speeds
    - Max lateral acceleration
  - Results from evaluation parameterise tests
  - Generate library of tests using chosen vehicle
- Run multiple simulations simultaneously
- Run using GUI external to Dymola
- Repeatable and consistent results
- Repeating simulations with representative variation to eliminate data spikes

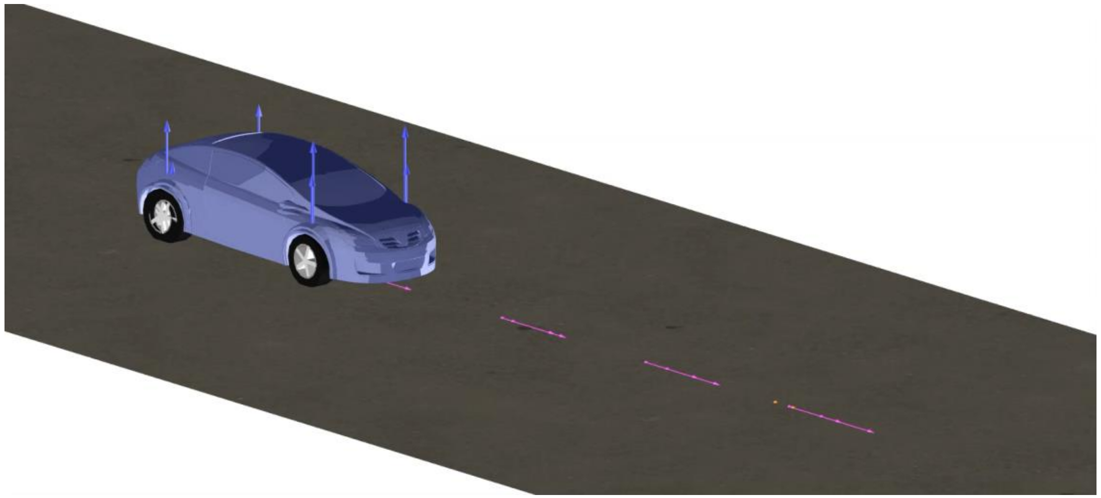




Post Processing The Data

- Simulation data is like measured
- Exported as raw data
- Replication of data to account for number of cycles required
- Python-Dymola interface used to
  - Extract relevant data
  - Process it into correct format
  - Output to required file type
- File imported into degradation analysis software

- Simulation results validated against measured data
- Back to back comparisons ICE vs Electric



Thank You For Listening

Any Questions?

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