Low Carbon Vehicle Event 2016

The UK's Premier Low Carbon Vehicle Event

Virtual Testing of the Full Vehicle System

Mike Dempsey

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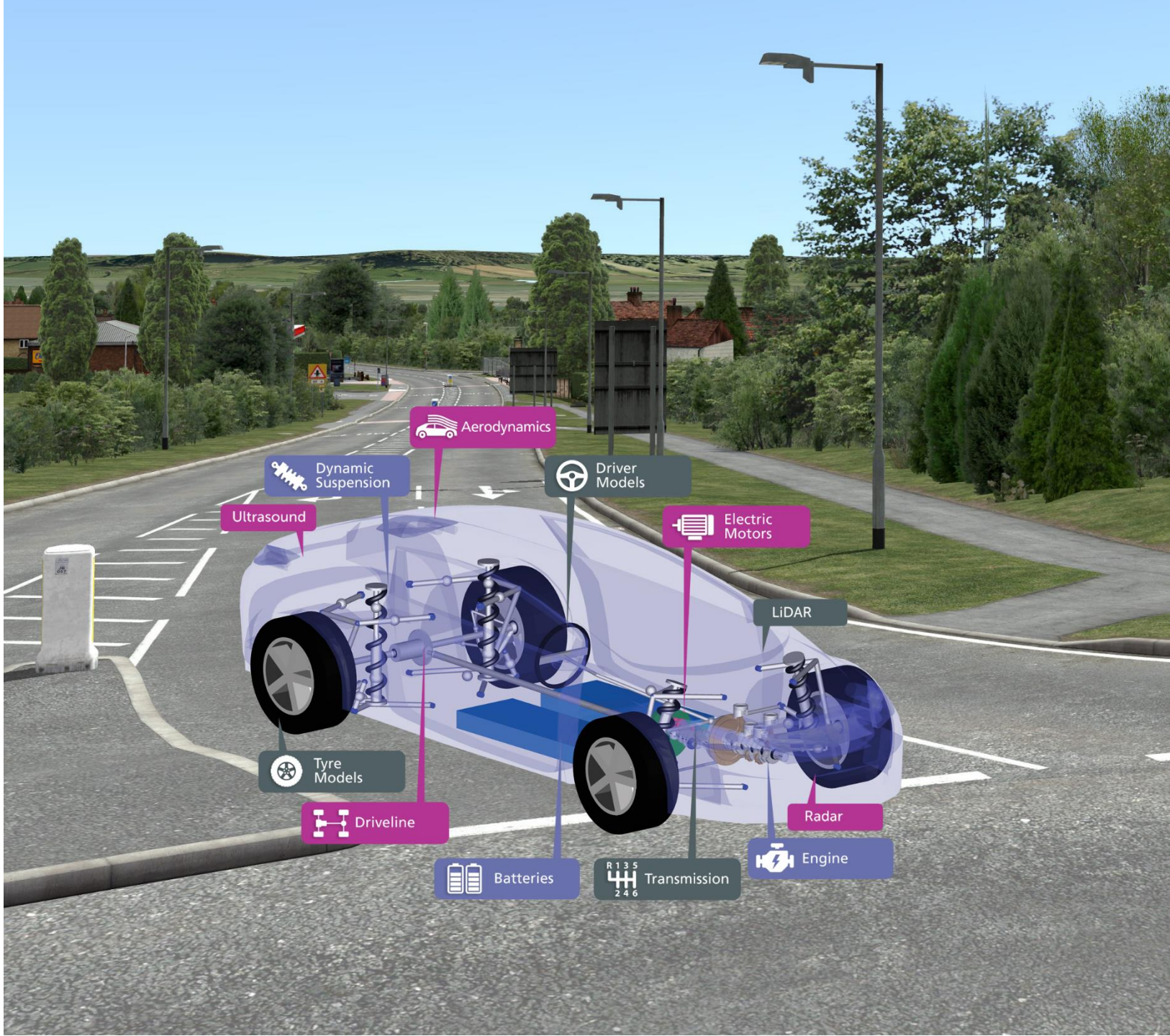


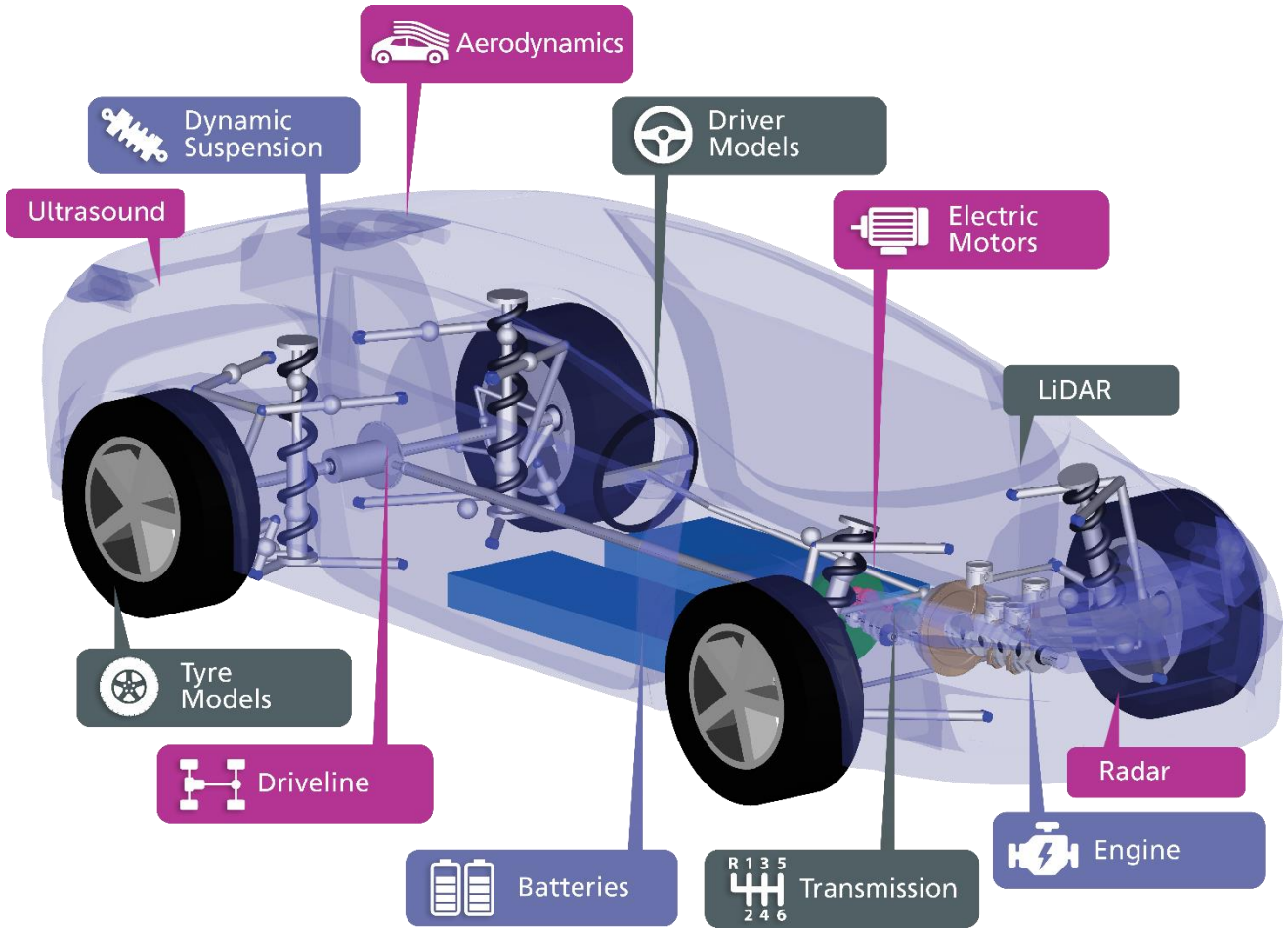
Claytex Services Limited

Software, Consultancy, Training

- Based in Leamington Spa, UK
  - Office in Cape Town, South Africa
- Experts in Systems Engineering, Modelling and Simulation
- Business Activities
  - Engineering consultancy
  - Software sales and support
  - Modelica library developers
  - FMI tool developers
  - Training services
    - Dassault Systemes Certified Education Partner
- Global customer base
  - Europe, USA, India, South Korea, Japan

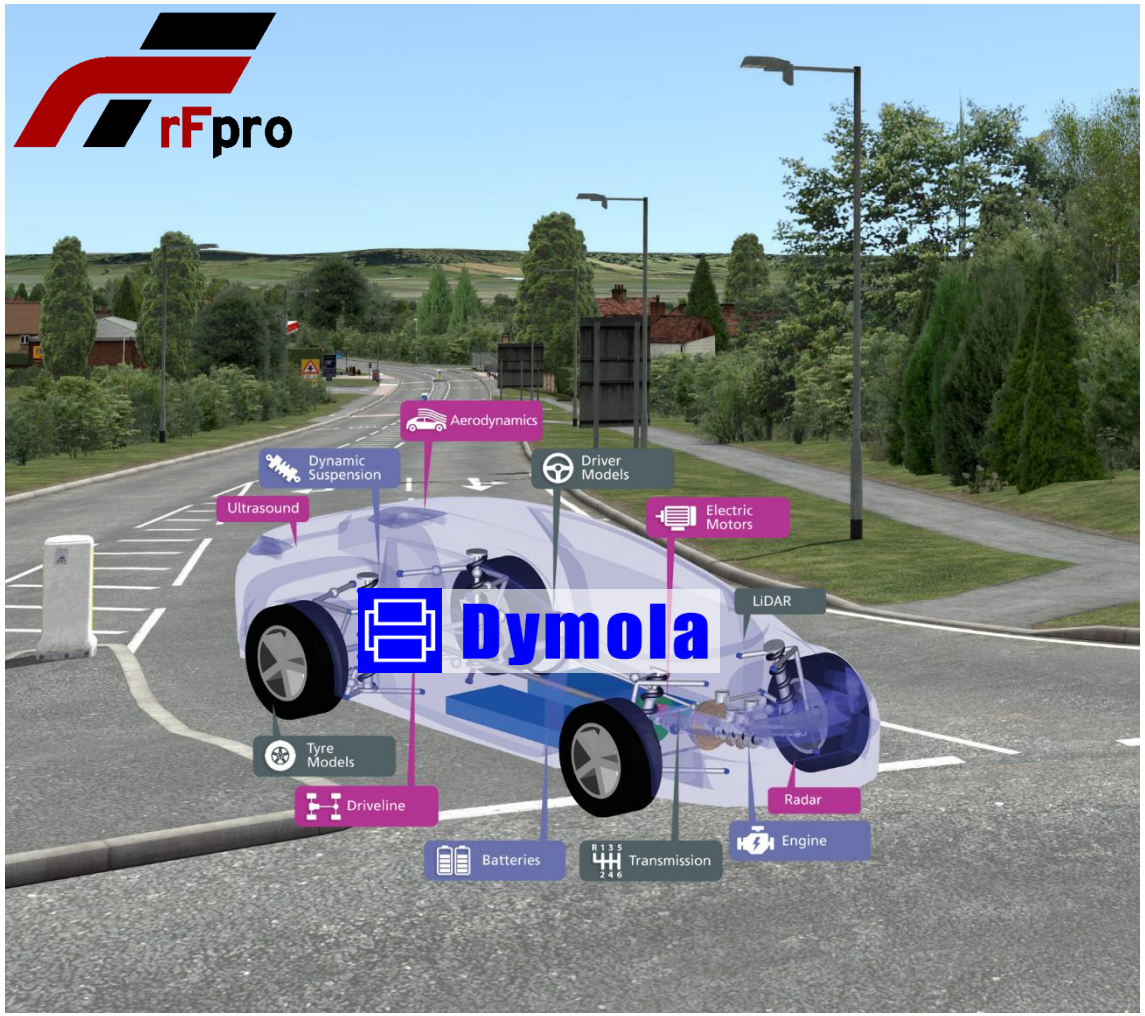
The need for virtual testing and development

- Automotive products are complex systems covering many domains
  - Mechanical, Electrical, Hydraulic, Pneumatic, Thermal, Chemical, Control, Magnetic, …
- No longer sensible to wait for prototypes to verify that all these systems interact in a good way
  - Parts arrive too late in the process to make cost effective changes if they don't work together as intended
- It's not practical, or perhaps even possible, to fully verify and validate control systems using prototypes
  - There are too many scenarios to be considered some of which would be dangerous to the driver and prototype



Virtual testing and development

- Need to simulate the complete vehicle
  - Plant and controller
  - Must use predictive models and not just functional ones to make simulation useful from an early stage of the project
- Need a complete virtual test environment
  - Should provide an immersive environment for both the human driver and vehicle sensors
  - Needs to be flexible to define different driving scenarios
- Our solution:
  - Dymola for the vehicle physics
  - rFpro for the virtual environment
  - SiL and/or HiL for the control systems



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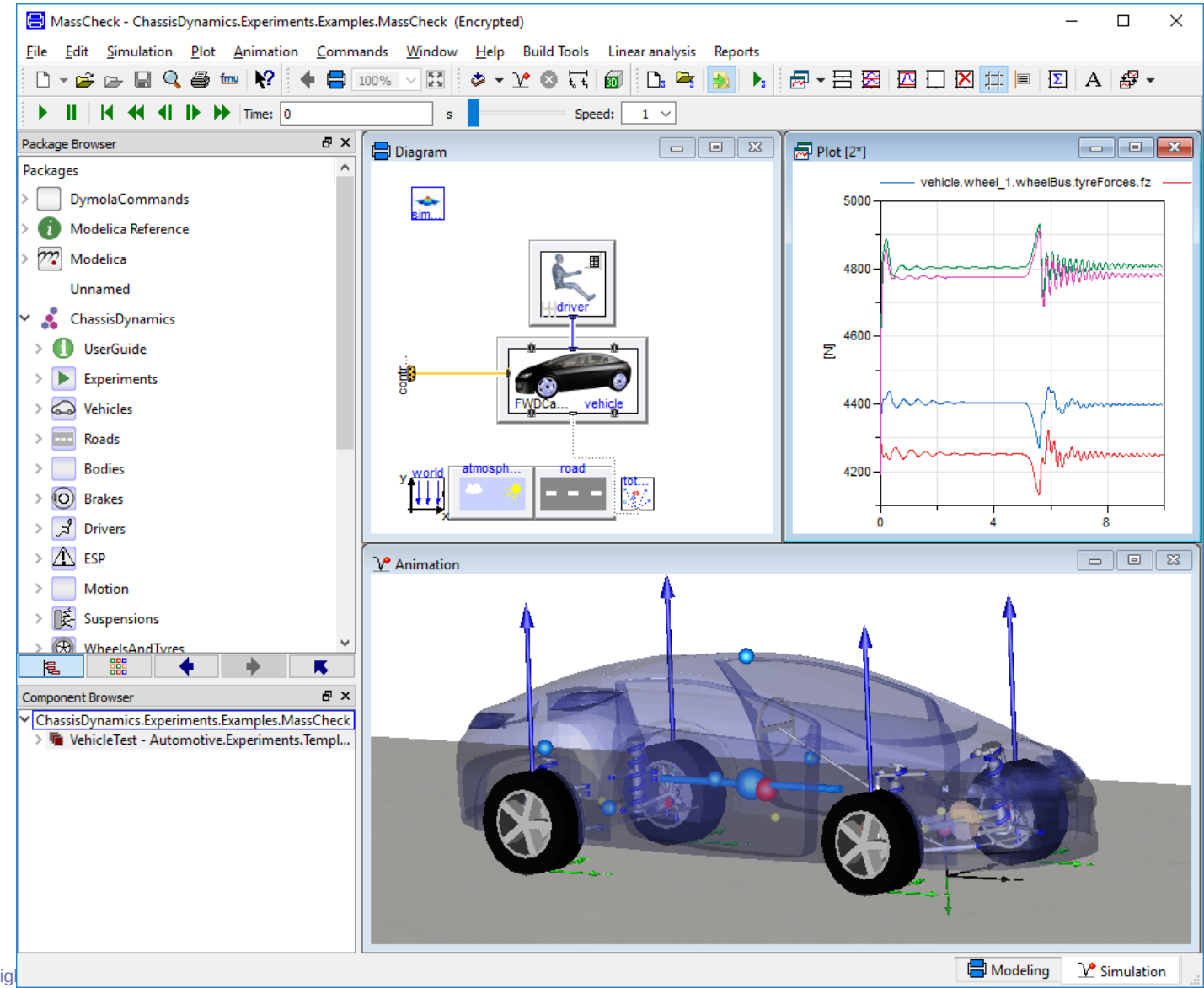
Dymola

- Multi-domain modelling and simulation of complex dynamic systems
  - Mechanical, Electrical, Hydraulic, Pneumatic, ThermoFluids, Thermal, Control
- Component orientated modelling
  - Components represent physical parts: valves, gears, motor
  - Connections between parts describe the physical connection (mechanical, electrical, thermal, signal, etc.)
- Built on open standards of Modelica and FMI
  - Modelica is the modelling language
  - FMI is an open standard for model exchange
- Supports a model based development process

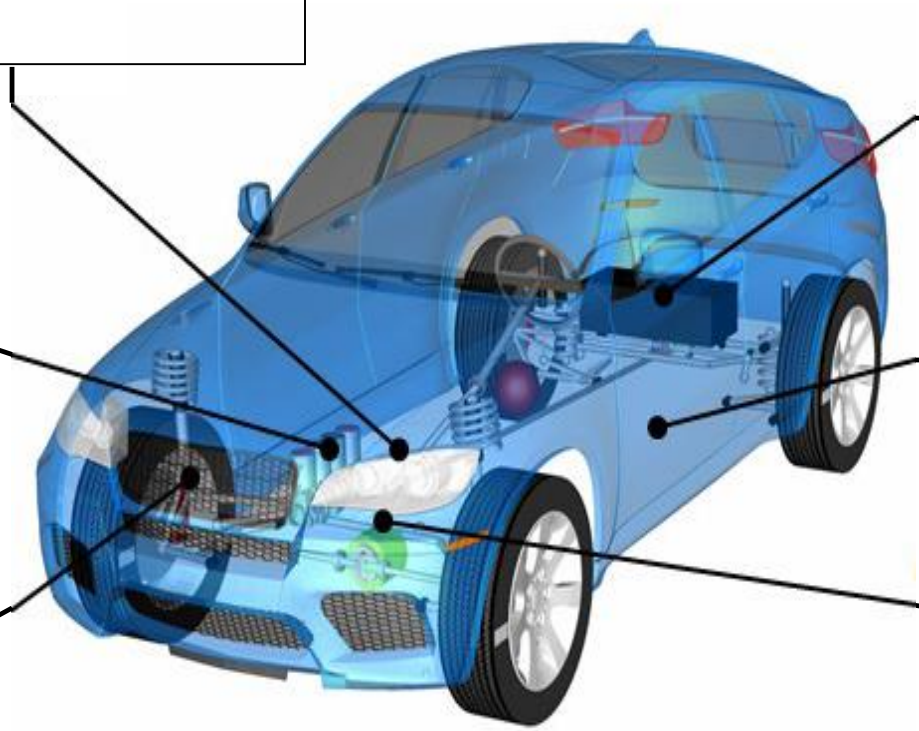


Vehicle Modelling and Simulation

DYMOLA focuses on physical modelling using Modelica and the integration of these models into the design process

- Gearbox and Driveline
  - Mechanics
  - Thermal
  - Hydraulics
  - Electrification
  - Control
  - Cooling

- Engine
  - Air flow
  - Mechanics
  - Cooling system
  - Fuel system
  - Control system
  - Electrification
  - Hydraulics



- Battery
  - Electrical
  - Thermal
  - Cooling
  - Control

- Chassis
  - Mechanics
  - Active systems
  - Control

- Thermal Management
  - Engine Cooling
  - HVAC
  - Battery Cooling
  - Power Electronics Cooling

- Electric Drive
  - Electrical
  - Thermal
  - Control

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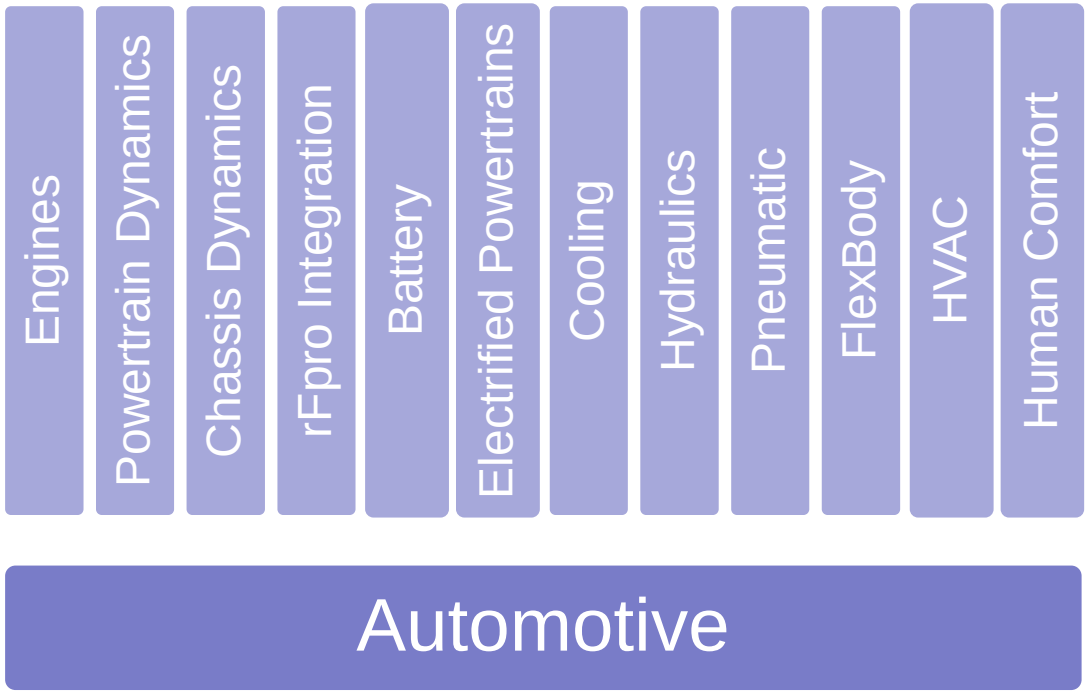
Modelica Libraries for Automotive

- Extensive suite of libraries covering every aspect of the vehicle
- The Automotive Library provides the foundation
  - Defines the model architecture, coordinate systems, etc.
    - Flexible so any vehicle architecture can be created
  - Provides models for performance, fuel economy and energy analysis
- Application focused libraries provide detailed simulation capabilities
  - Engines Library includes 1D thermofluids, MultiBody mechanics, combustion models
  - Chassis Dynamics Library provides MultiBody suspension and tyre models
  - Electrified Powertrains Library provides a motor/generator and power electronics models at a wide range of detail levels
- Many of the models are suitable for real-time simulation



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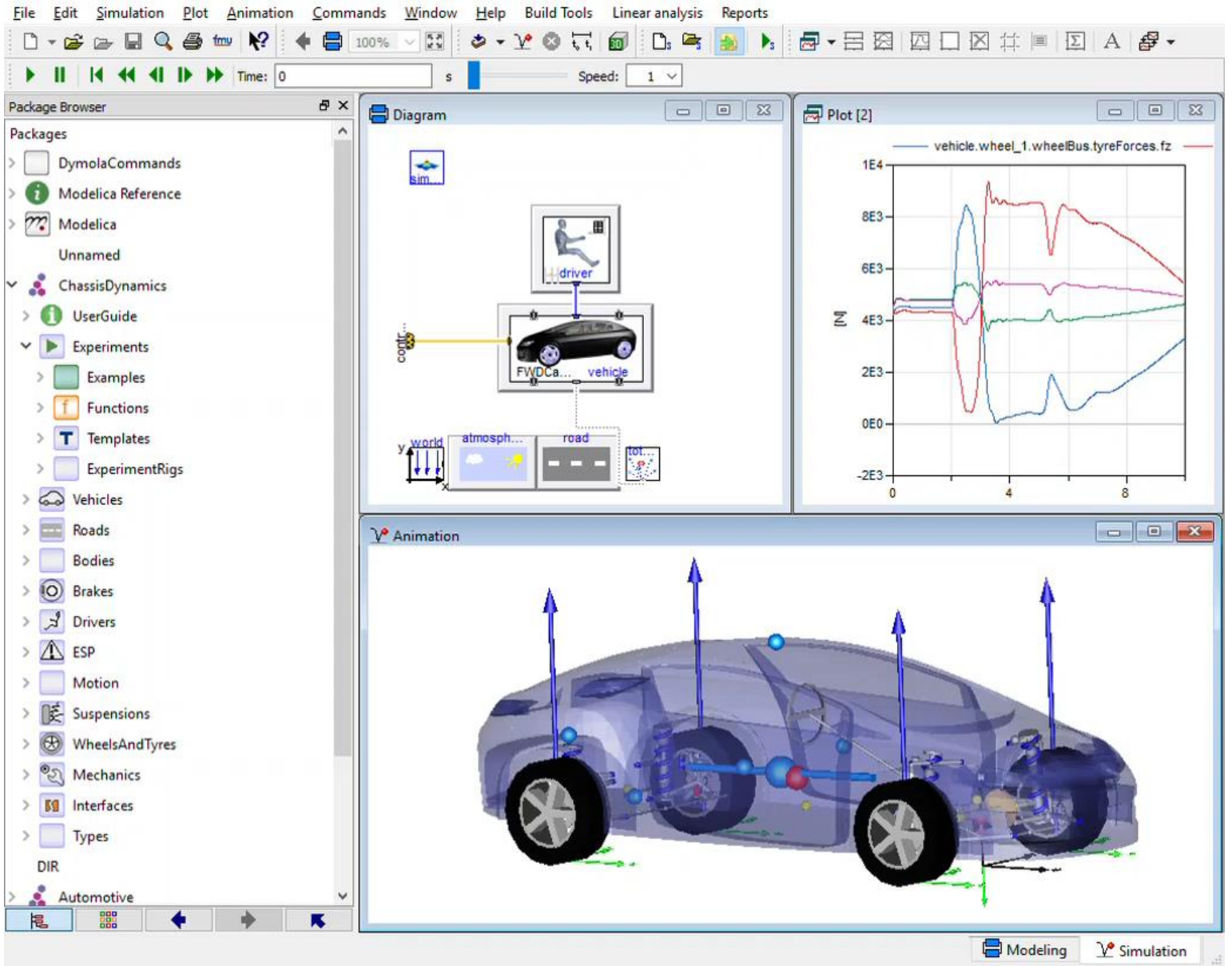
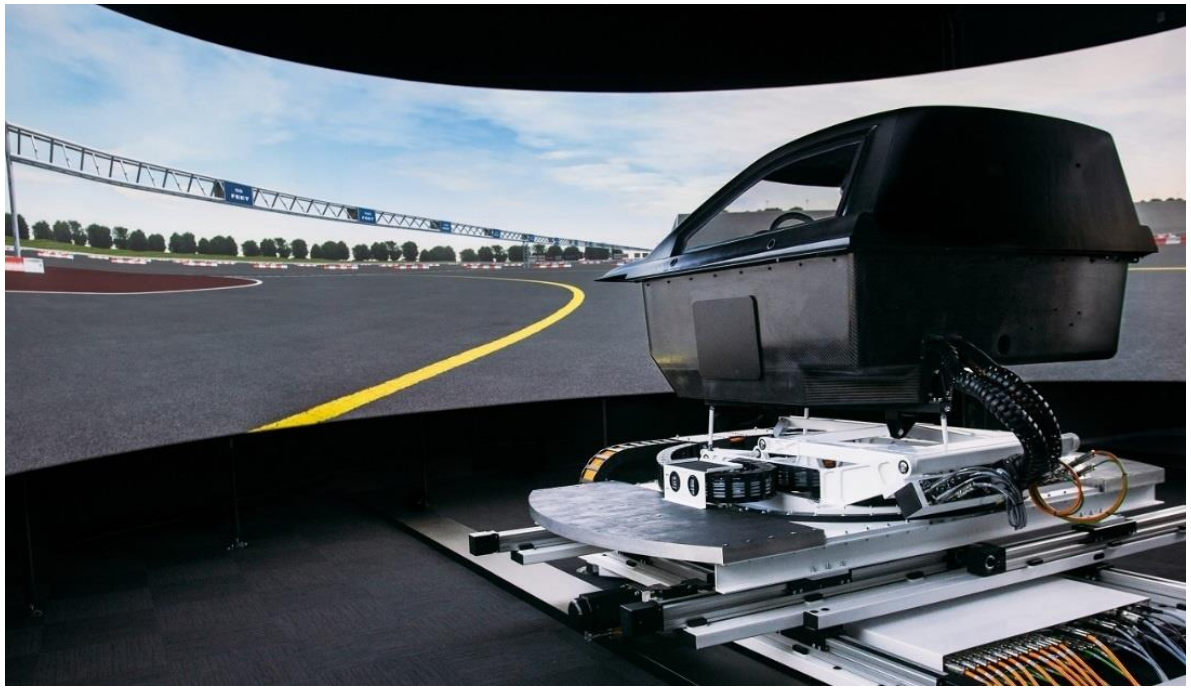
Vehicle Dynamics Simulation

- Full vehicle model including engine, gearbox, driveline, cooling system, suspension
- Visibility of every variable within the model to investigate the behaviour
- Easily define different test scenarios with open and closed loop driver models
  - 3D roads
  - Drive cycles
  - Varying ambient conditions
- Animation aids the understanding of the data traces

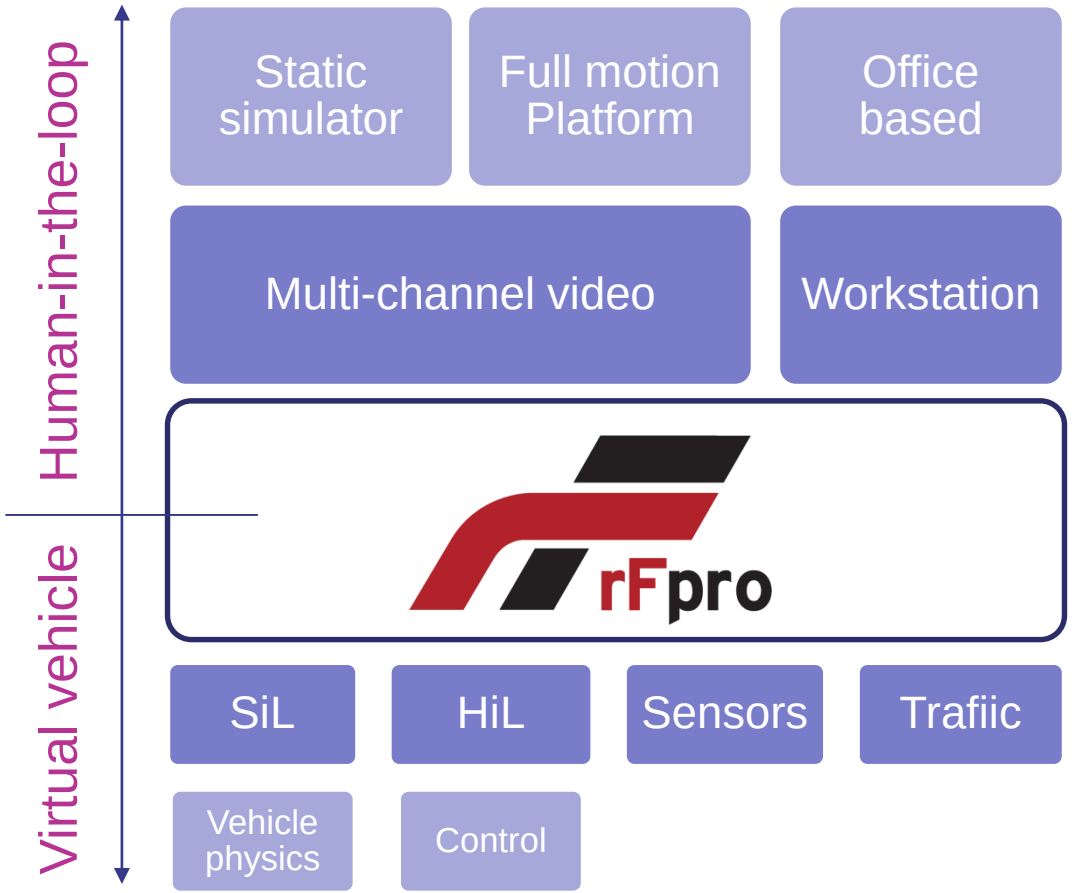


- rFpro provides an environment for vehicle testing and development
- Allows you to reintroduce the human test driver into the model based development process
- Accurate digital track models using LiDAR
  - Extensive library of race tracks, proving grounds and public roads
- Capable of feeding camera, LiDAR, radar and ultrasound sensor models to support ADAS and autonomous vehicle development
- Incorporate traffic simulations to build complex test environments



Virtual Test Environment

- Scaleable from workstation to full DiL simulators
- Modular architecture enables the system to be scaled to suit evolving needs
- Supports SiL and HiL for vehicle physics and controllers
  - Run a mixture of models and real controllers to suit the project requirements
  - SiL environment supports standard calibration tools
  - Wide range of HiL platforms have been integrated
- Dymola models can be easily compiled to run in either SiL or HiL environments

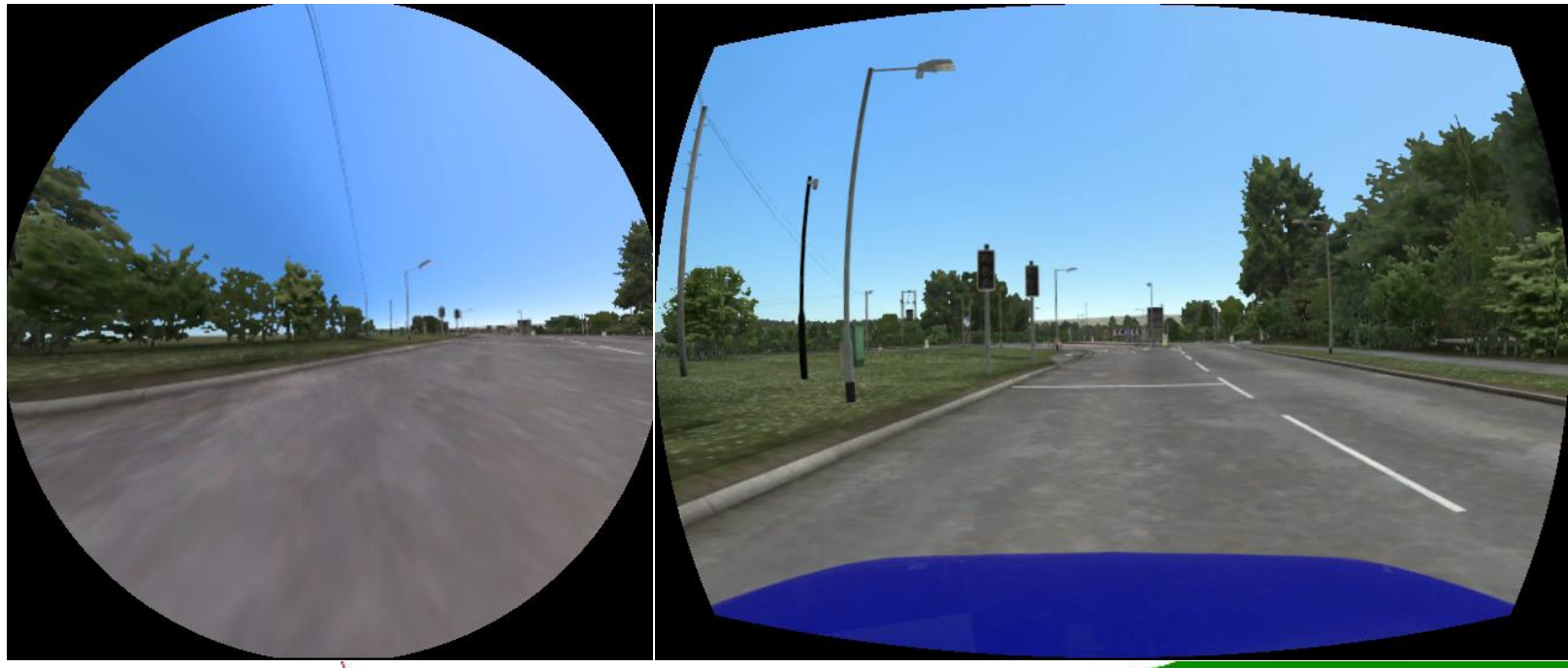


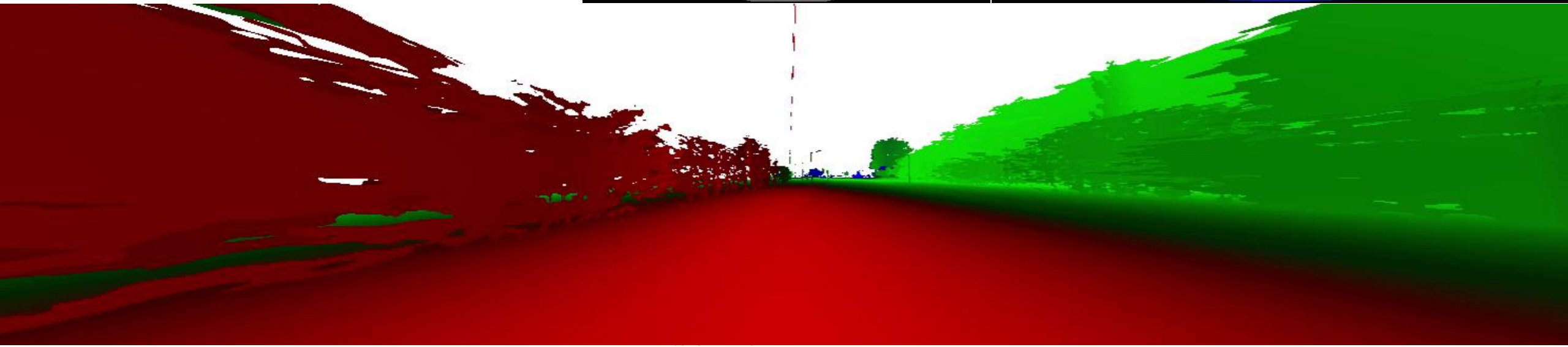
Drivers view

- rFpro using LiDAR scans of public roads
- Dymola providing the vehicle physics and control
- Human driver

Sensor feeds

- Sensors need to be fed with the same high fidelity data as the driver
- Apply lens distortion effects to replicate what the real camera sees
- Each pixel can be interpreted as distance information to feed LiDAR, Radar and Ultrasound sensors





Summary

- Dymola provides a comprehensive suite of automotive focused libraries
  - Built on the Modelica modelling language
  - Application libraries cover every aspect of the vehicle: engine, vehicle dynamics, electrification, hvac, …
- rFpro provides an immersive virtual test environment
  - High fidelity graphics, audio and track data
  - Extensive library of tracks, public roads and proving grounds
  - Define complex scenarios including traffic
- Integration of simulation and virtual test environment accelerates vehicle development

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