

Multi-domain physical modelling to enable whole vehicle optimisation

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Claytex Services Limited

- Based in Leamington Spa, UK
 - Office in Cape Town, South Africa
 - Established in 1998
- Experts in Systems Engineering, Modelling and Simulation
- Business Activities
 - Engineering consultancy
 - Software sales and support
 - Dassault Systemes Partner
 - Modelica library developers
 - FMI tool developers
 - Training services
 - Dassault Systemes Certified Education Partner
- Global customer base
 - Europe, USA, India, South Korea, Japan

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CATIA

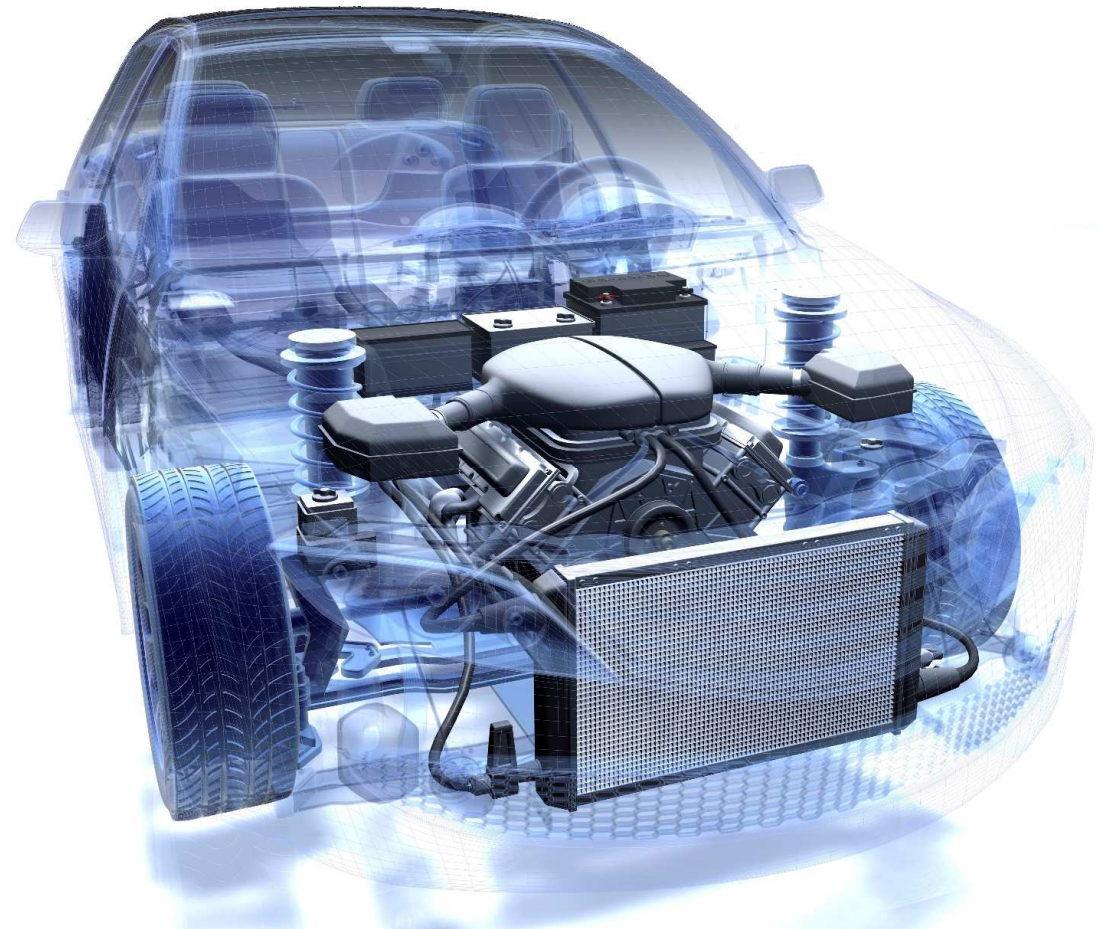
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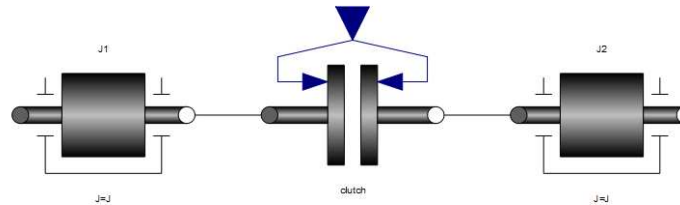
Multi-domain physical modelling to enable whole vehicle optimisation

- Multi-domain physical modelling
 - 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
 - Need to use predictive models and not just functional ones
- Whole vehicle optimisation
 - Consider all vehicle systems and how they interact with each other and the occupants



Functional and Predictive models

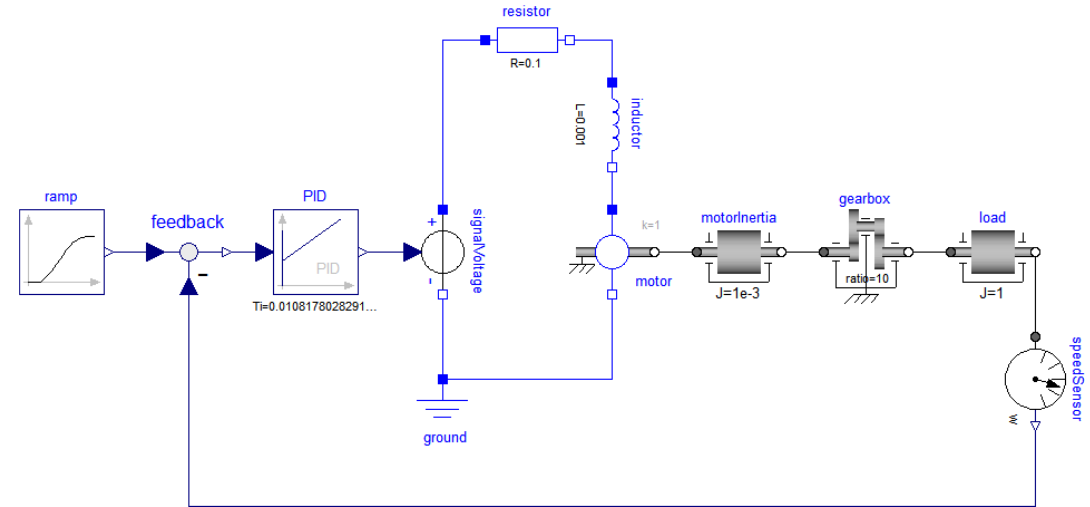
- A Functional model is one that captures the key function of the model
- A Predictive model allows us to predict the behaviour and explore it's characteristics



- The clutch is there to make sure the two inertias rotate at the same speed when engaged
- Functional model
 - Would reduce the relative speed across the clutch in a predefined manner
 - The controlling parameter would be the engagement time
- Predictive model
 - Would include a model for friction and the torque transfer would be a function of the clutch clamp load, relative speed, temperature, ...
 - The parameters would include the geometry and friction characteristics
 - The engagement time could be predicted under different operating scenarios

Multi-domain physical modelling

- Modelica
 - Open source, generic modelling language
 - Designed from the beginning to support a component orientated, physical modelling methodology
 - Developed by an independent, international organisation called the Modelica Association
 - Formed in 1996
- Dymola
 - Modelling and Simulation tool that uses Modelica
 - Extensive range of libraries built using Modelica covering all aspects of automotive products
 - Part of CATIA from Dassault Systemes and also available on the 3DEXPERIENCE platform



MODELICA

 Dymola

 CATIA

Modelling approach

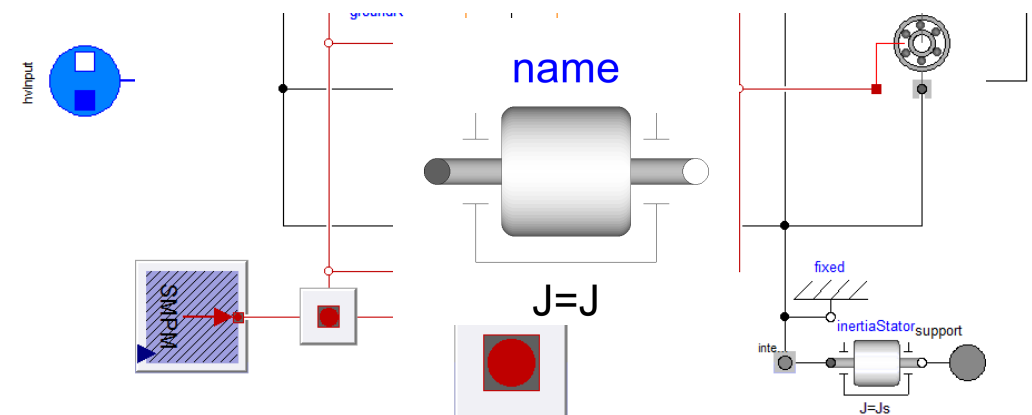
- Modelica models are built from components that are defined from 1st principles
 - Modelica uses an equation based approach
- The components are combined to define devices
 - Physical connections between components
- From devices and components we create subsystems
 - Often using templates that make it easy to swap the model fidelity
- From subsystems we create the whole vehicle model
 - Model architecture can be defined independently to promote reuse of subsystem models



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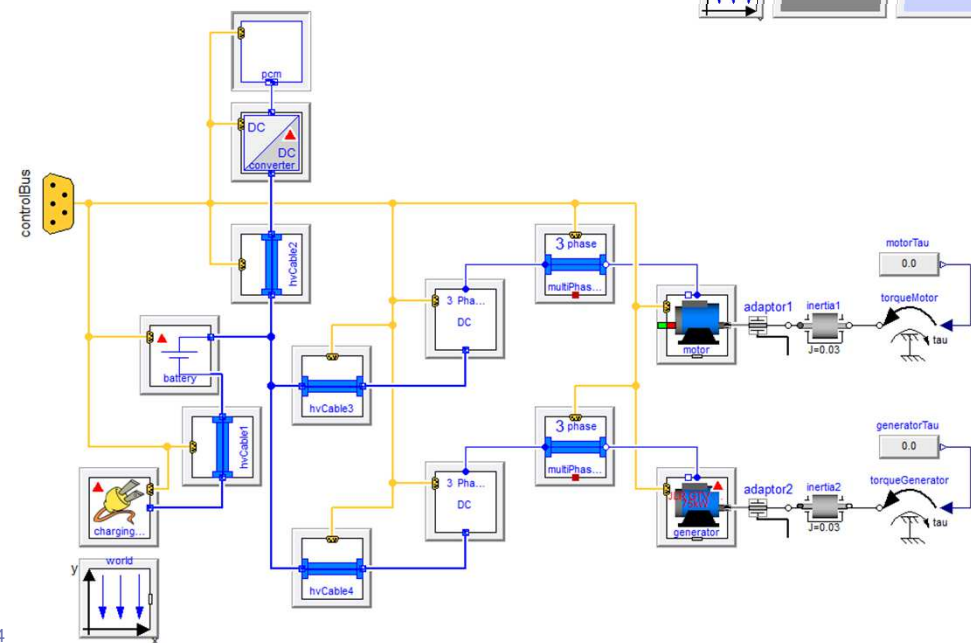
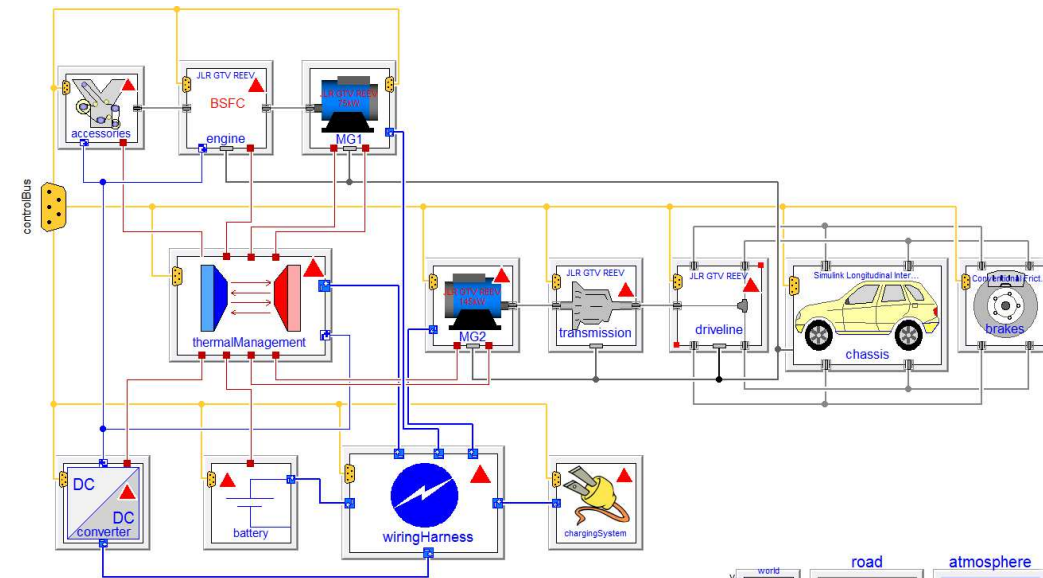
model Inertia
  extends Interfaces.Rigid;
  parameter SI.Inertia J=1 "Moment of Inertia";
  SI.AngularVelocity w "Angular velocity";
  SI.AngularAcceleration a "Angular acceleration";
equation
  w = der(phi);
  a = der(w);
  flange_a.tau + flange_b.tau = J * a;
end Inertia;

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Model Reuse

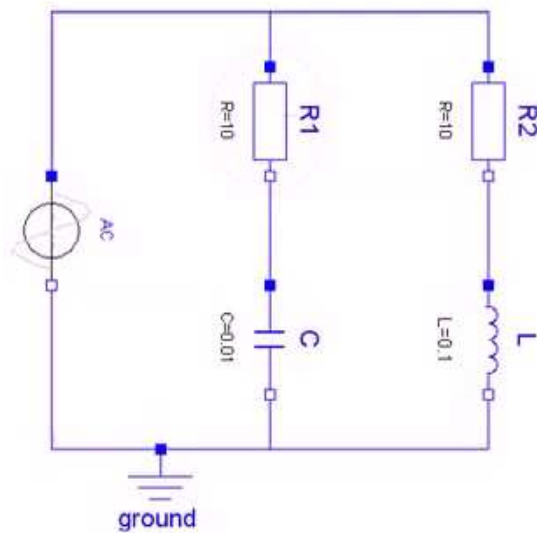
- A physical modelling approach allows a high degree of model reuse
 - Same subsystem model, different types of analysis e.g. forward dynamic or inverse dynamic
 - Reuse the models in different system architectures
- Dymola supports plug-and-play changes in the subsystems to make it easy to configure the model for different tasks
 - Easily swap the power electronics between power balance and detailed switching models without changing any other parts



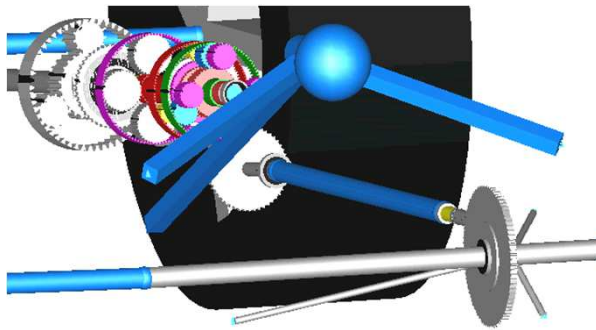
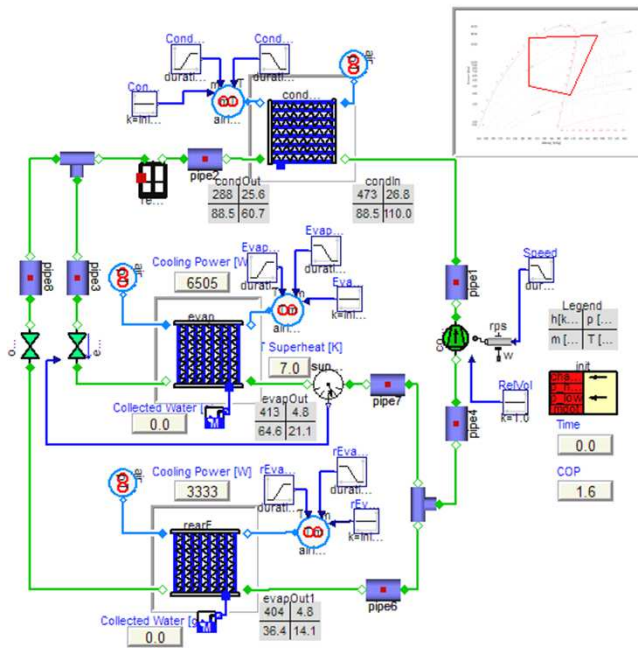
Symbolic Manipulation

- The model equations are automatically transformed into the required solution for simulation
- Advanced mathematical techniques are used to reduce the size of the problem without removing detail from the model

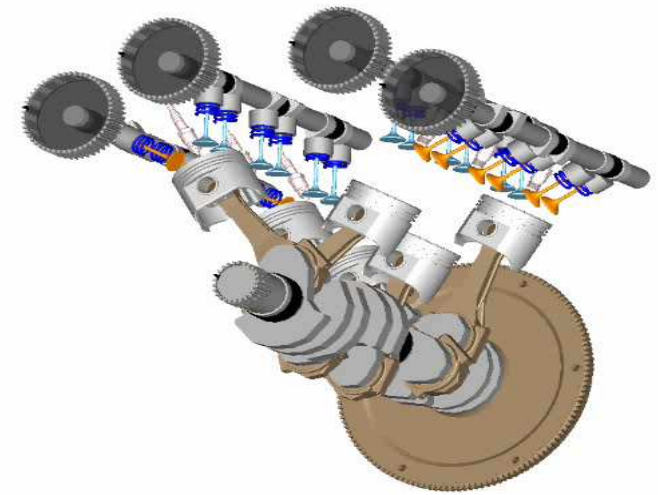
DAE:



Automotive Application Libraries

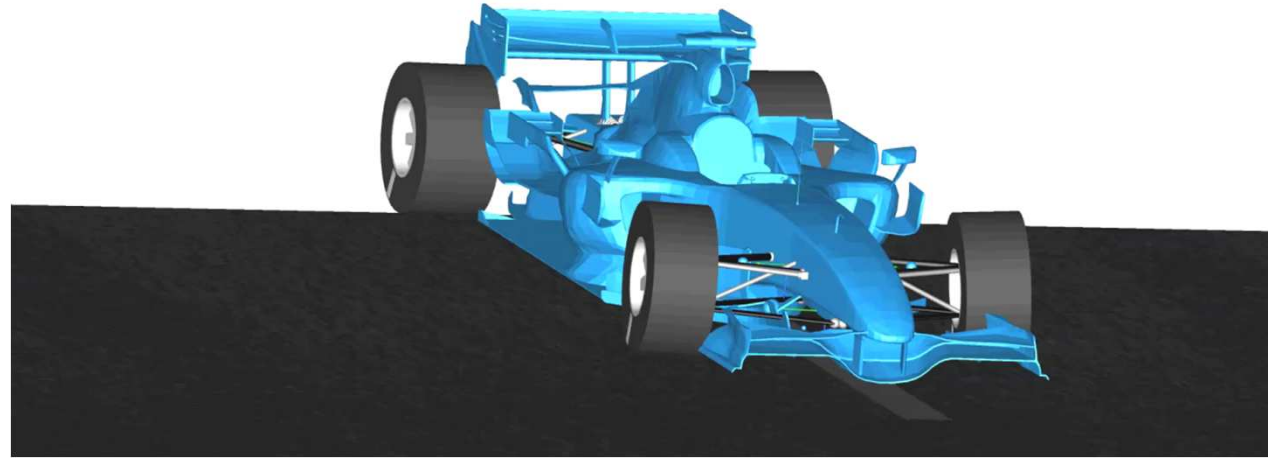


- Air Conditioning
- Belts
- Batteries
- Engines
- E-Drives
- FlexBody
- Fuel Cell
- Heat Exchanger
- Human Comfort
- Hydraulics
- Liquid Cooling
- Pneumatics
- Powertrain Dynamics
- Simulator
- Smart Electric Drives
- SystemID
- TIL Suite
- Vapor Cycle
- Vehicle Dynamics
- VDLMotorsports
- XMLReader



Formula 1 2014 Powertrains

- Dymola is used by F1 teams, NASCAR and IndyCar
- Using Dymola it was possible for the teams to simulate the 2014 powertrain as part of a complete vehicle model
 - Engine performance and efficiency
 - MGU-H and MGU-K strategies
 - Thermal management of all systems
 - Impact on vehicle dynamics of higher torque output
- Why is Dymola popular in Motorsport?
 - Extensive range of application libraries
 - Based on Modelica which means the models are open and extendible
 - Powerful modelling language to implement new ideas from first principles and explore the behaviour
 - The same model can be shared across the team and deployed for different applications
 - Desktop, HiL, SiL, DiL, trackside, ...



Benefits of physical modelling

- Models are built from first principles and are therefore predictive
- Powerful concepts for defining system architecture and then plugging in models of different fidelity to suit each analysis
- Modelling activities can start in the concept phase
 - Functional models can be used together with Predictive models for sizing studies and to make sure targets are compatible
- Dymola uses a component orientated approach based on Modelica
- Modelica is an open modelling language designed for modelling multi-domain systems
- The extensive range of libraries available for Dymola can model the whole vehicle
 - Provide an open and extendible base to start modelling your vehicle or subsystem
- Using Dymola and Modelica we can create models that include all the vehicle systems and we can optimise the behaviour of the whole system



Thank you

For more information visit our stand C2-15

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