

IGNITE

Ricardo Software Multi-Domain System Simulation Software

Ricardo Software Product's Workshop
January 17th, 2013 - Torino, Italy

Detroit Room
9:15 – 10:45 am



Agenda

- Introduction [5 min]
- Product Overview [25 min]
 - Application
 - Functionality
 - Key Features
- Development Status and Timing [5 min]
- Live Product Demo (development prototype) [25 min]
- Future Product Expansion [10 min]
- Questions & Open Discussion [20 min]

- Ricardo Software is currently developing a new complex system simulation software tool: **“IGNITE”**

Ricardo Software

Powertrain design at your fingertips



1D Gas dynamics



3D Powertrain CFD



Advanced Crankshaft Dynamics



1D Valvetrain and Multibody Dynamics



Advanced FEA Workflow and Simulation



3D Piston Dynamics



2D Ring Pack Dynamics



2D Shaft, Gear and Bearing Simulation



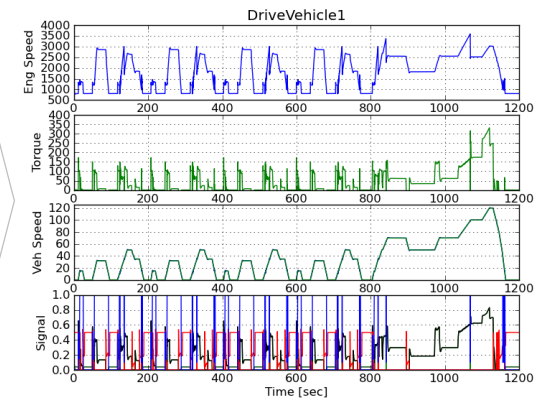
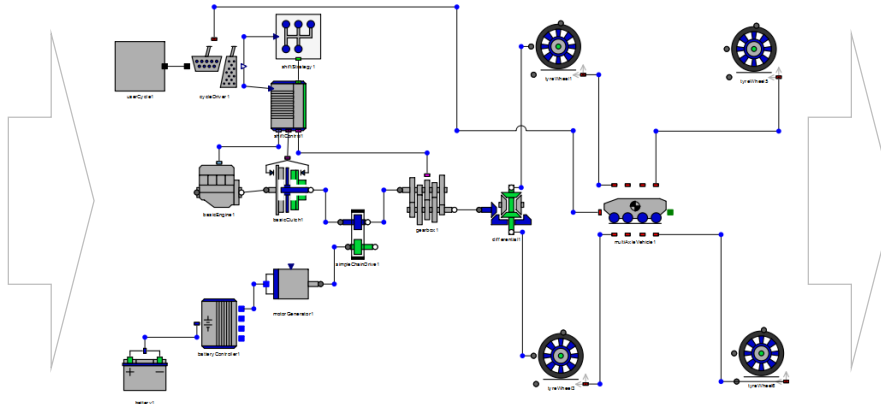
Multi-domain, Complex System Simulation

IGNITE **PRODUCT OVERVIEW**



Application

- Initial focus: **vehicle powertrain** modeling and simulation



– Systems-level modeling of:

- Driver
- Engine
- Transmission
- Driveline
- Vehicle
- Wheel & Tire
- Hybrid-electric systems
- Vehicle control systems
- Vehicle thermal systems
- Powertrain accessories

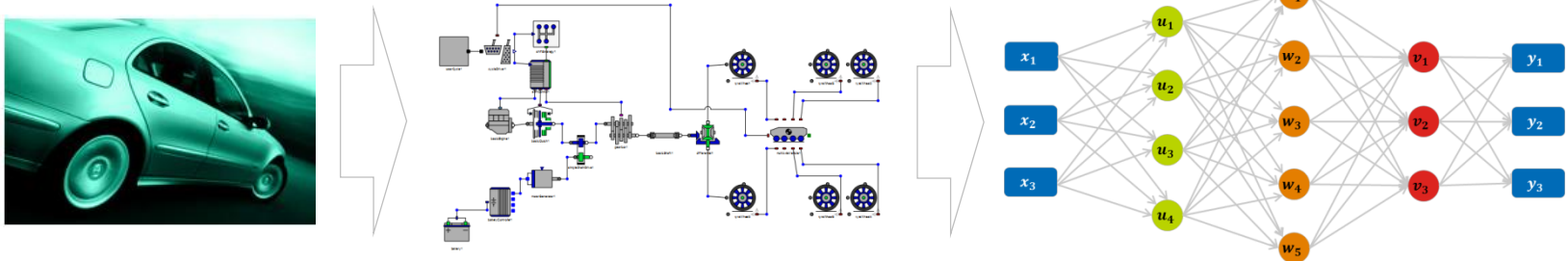
– Drive cycle simulation

- Vehicle performance prediction
- Fuel consumption prediction
- Energy flow analysis and efficiency
- Vehicle architecture design
- Hybrid system architecture design
- Component selection and sizing
- Powertrain integration analysis

- Library objects allows users to build models of complex systems 'one element at a time', across multiple engineering disciplines



- Quantify complex interactions and inter-dependencies between system elements and parameters



- Predict system performance over operational duty cycles
- Perform trade-off studies, sensitivity analyses, design space exploration, and system optimization
- Virtually test thousands of system design iterations prior to prototyping and hardware development!**

Functionality – Vehicle Modeling

- **Conventional vehicle** modeling (*high-level*)
 - Basic engine
 - Torque, fuel and emissions source
 - Cycle driver (throttle) driven
 - Manual transmission
 - Clutch and gearbox, with clutch/shift controller
 - Automatic transmission
 - Torque converter and gearbox, with shift and lock-up controllers
 - Multi-Axle vehicle
 - 2-degree of freedom longitudinal dynamics
 - Translational force balances
 - Pitch about the CoG; axle normal force calculation
 - Tire interface model(s)
 - Longitudinal dynamics
 - Multiple models: Simple, Table-based, Physical, Magic
 - Driveline
 - Differential: open, locked, torque-biased
 - Flexible shafts: stiffness and damping
 - Rotational inertias

Functionality – Vehicle Modeling (con't)

- **Hybrid vehicle** modeling (*high-level*)
 - **Motor-generator**
 - Mechanical-to-electrical and/or electrical-to-mechanical energy/power conversion
 - Multiple models: Scalar and/or table-based inputs, with efficiencies
 - **Battery**
 - Voltage (potential) source, with rated capacity
 - State of charge integration
 - Simple thermal modeling
 - **Batter / Bus controller**
 - Multiple electrical connections
 - Electrical load balancing
 - Battery terminal voltage demand
 - **Hybrid vehicle controller**
 - Extension of cycle driver
 - High-level parallel and series hybrid vehicle control
 - High-level electrical vehicle control
 - SOC bandwidth control
 - Motor/generator demand / duty control

Functionality - Simulation

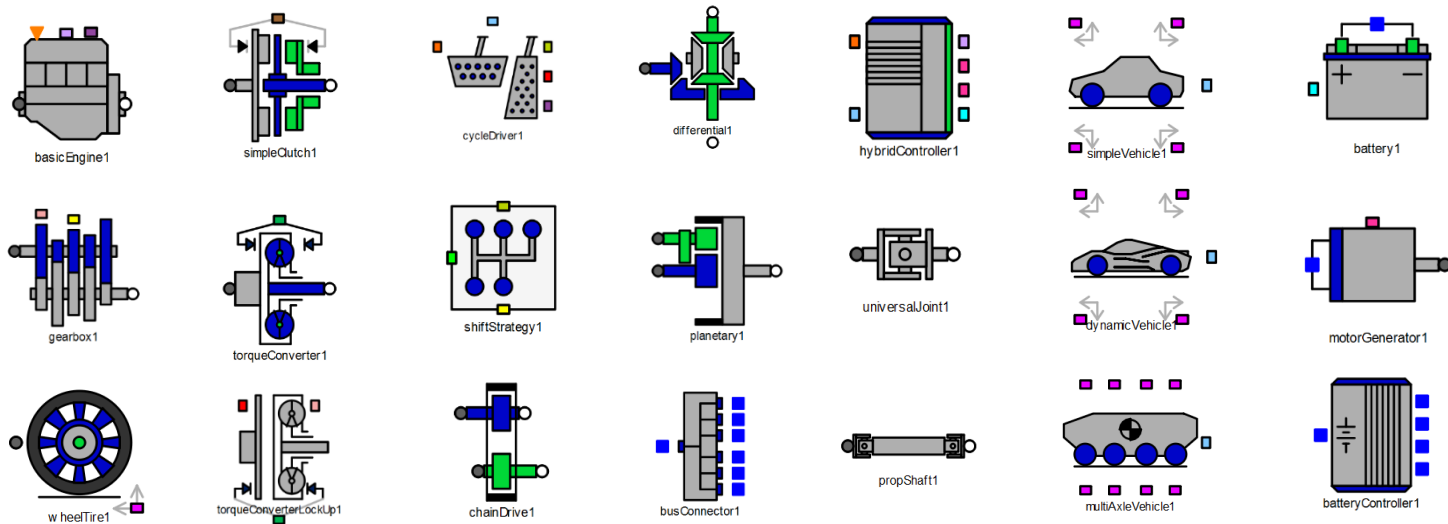
- Time-based **drive cycle simulation**
 - Cycle driver (PID controller)
 - Standard and user-defined drive cycles (external table inputs)
- Time-based, steady-state, **operating point simulation**
 - WOT acceleration
 - Constant operating point
- Vehicle **fuel economy prediction**
 - Instantaneous fuel rate at each time-step
 - Cycle-average fuel economy (MPG integrated over simulation)
- System and component **operating cycle prediction**
 - Object duty / operating point prediction
 - Engine operating points
 - Gear shift cycling
 - Energy flow auditing

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KEY FEATURES



- Complete vehicle modeling from a single library.....
 - Conventional, hybrid and electric vehicle systems



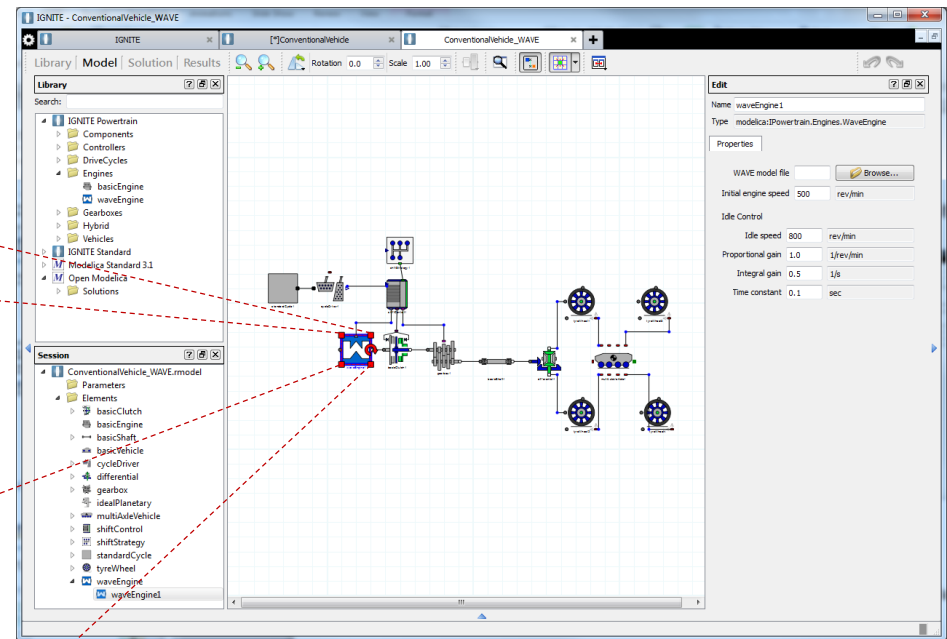
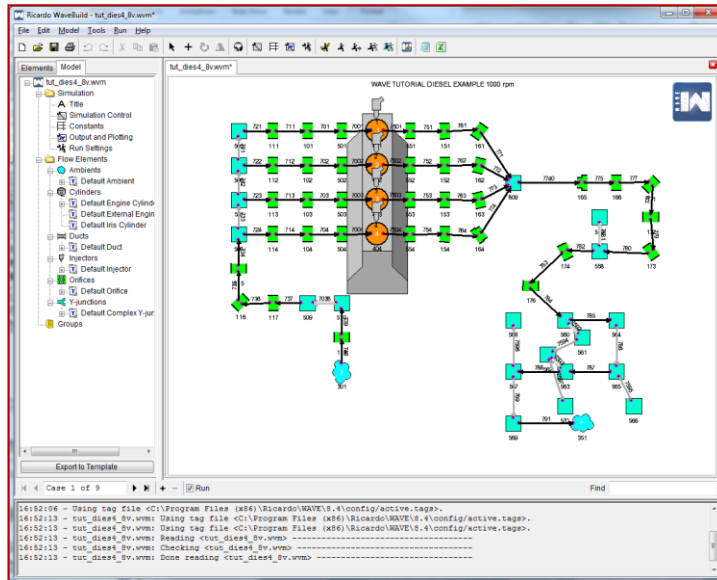
- Allows users to build complex vehicle models 'one object at a time'
- Flexible components, multiple configuration options, supports M&S activities across multiple phases of design and analysis
- **Leveraged from existing internal Ricardo technology, built on world-class powertrain systems domain expertise!**

*** full library not pictured

Seamless Integration with Ricardo Software tools

- Couple (co-sim) IGNITE models with other Ricardo Software Suite tools
 - e.g.: WAVE, WAVE-RT, VALDYN, etc...

WAVE 1-D engine model



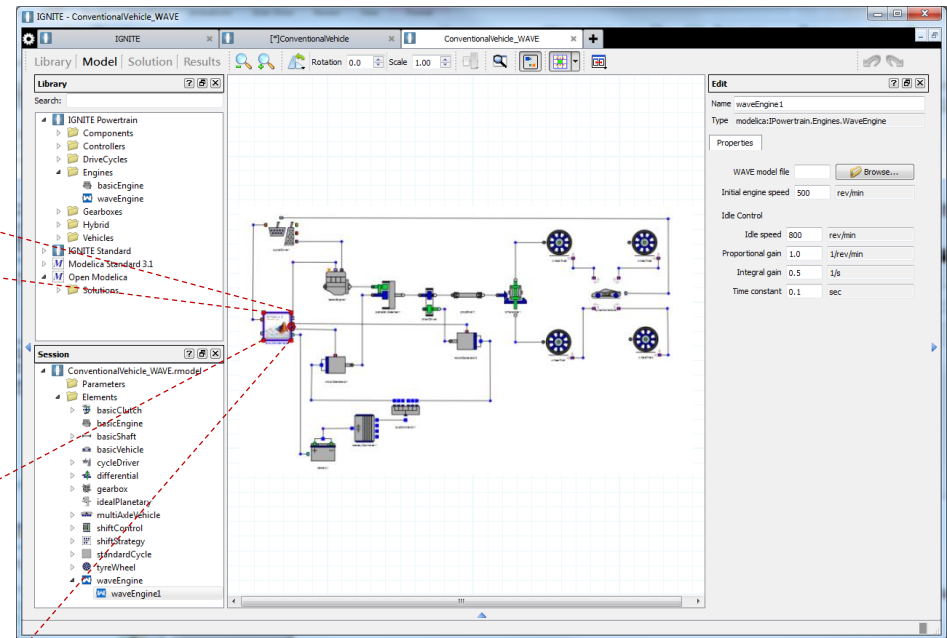
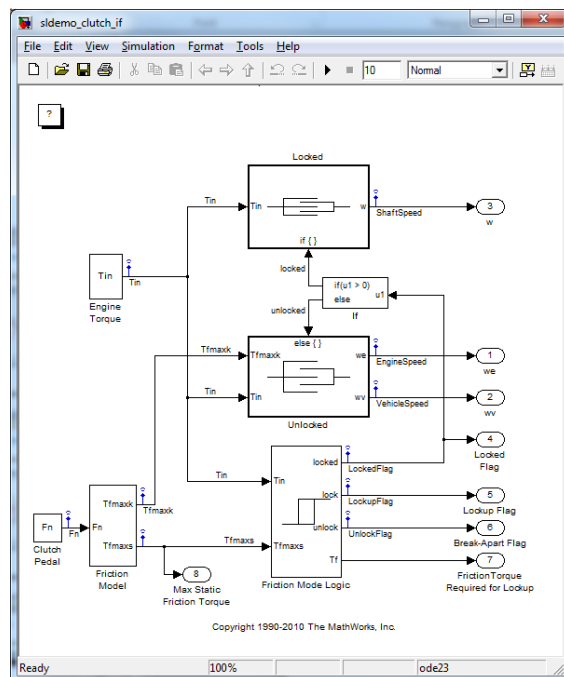
IGNITE 1-D Driveline / Vehicle model

- **Flexible powertrain modeling development and integration!**

Co-Simulation with MATLAB/Simulink

- Couple and co-simulate IGNITE models with MATLAB/Simulink

MATLAB/Simulink controller model

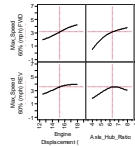


IGNITE Hybrid Vehicle model

- Flexible controls modeling development and integration!

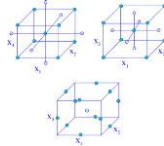
- Built-in toolbox of powerful, multivariate analysis, '[decision making](#)' tools
- Quantify system inter-dependencies and complex interactions

Trade-off / Sensitivity analysis



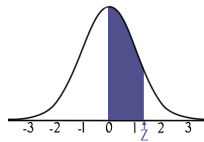
- Perform large multi-case parametric studies
- Quantify and identify complex system interactions and sensitivities

Design Space Exploration (DoE)



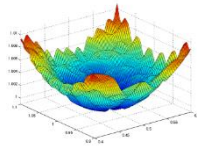
- Intelligently explore system design space
- Facilitates efficient frontier prediction

Reliability & Robustness



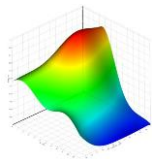
- Perform response and reliability studies
- Quantify the probability of meeting system performance objectives and requirements

Optimization



- Optimize the system for specific objectives and constraints
- Identify the optimum set of inputs to achieve desired system behavior

Response Surface Modeling



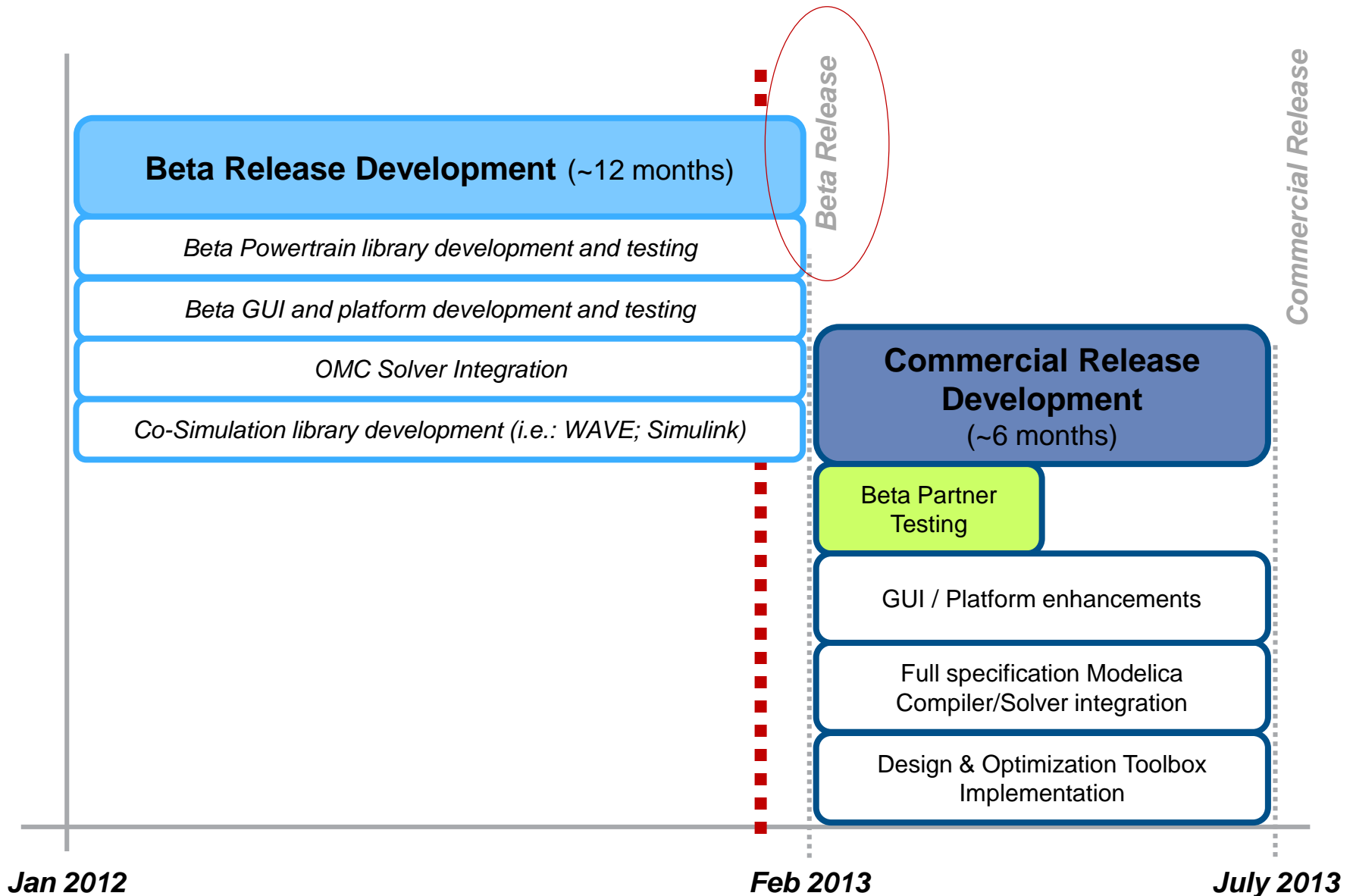
- Create accurate and reliable surrogate models of complex systems
- Provides model abstraction and run-time reduction with minimal reduction of accuracy

- Modelica platform provides easy library extensibility
- If the current Ricardo libraries are lacking any specific modeling objects or capabilities, the user has multiple options for filling the gap
 - User-developed library objects
 - 3rd party, commercially available, libraries (Modelica compatible)
 - Open source Modelica libraries (i.e.: Modelica Standard Library 3.1)
- With Modelica it is easy for engineers, with domain expertise, to develop their own library objects
 - Example: a transmission engineer can develop his own detailed transmission objects
- There numerous available 3rd party Modelica libraries, across multiple domains, than can be used to supplement the Ricardo Powertrain library.
 - Thermal systems
 - Hydraulic
 - etc...

IGNITE **STATUS & TIMING**



IGNITE Development Status and Timing



BETA vs. Commercial Release Functionality Comparison

Attributes / Features / Functionality	Beta (2013.1b1) [Jan/Feb 2013]	Commercial (2013.2) [July 2013]
Basic IGNITE Powertrain library	X	
Open Modelica compiler/solver	X	
Basic Post-Processing in Results Mode <i>(simple, time-based, 2-D XY line graphs)</i>	X	
Full Spec Modelica Compiler/Solver <i>(ability to execute full Modelica specification)</i>		X
Design/Optimization toolbox <i>(DOE, MonteCarlo, RSM, Optimization, post-processing)</i>		X
Enhanced IGNITE Powertrain library <i>(expandable connectors, block connectors)</i>		X

IGNITE LIVE DEMO



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FUTURE PRODUCT EXPANSION



Future Product Expansion

- Library-based software tool = scalability!
- Powertrain library subsystem expansion
 - Vehicle thermal / powertrain cooling
 - Waste heat recovery systems
 - Detailed transmissions
 - etc...
- Library domain expansion
 - Development of component libraries in non-vehicle domains



(Clean Energy)



(Power Gen)



(Agricultural)



(Marine)



(Rail)

- Leverage Ricardo Technical Consulting
- Potential partnerships with domain-specific technology providers
- Compatibility with 3rd party Modelica-based libraries

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QUESTIONS & OPEN DISCUSSION



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Appendix – Additional Presentation Material

IGNITE **POWERTRAIN LIBRARY**

IGNITE Powertrain Library – ‘Beta Release’ Components

Engines

- Basic Engine
- Turbo Lag
- WAVE Engine

Hybrid & Electric

- Battery
- Motor / Generator
- Battery Controller

Controllers

- Cycle Driver
- Transmission Shift Strategy
- Shift/Clutch Controller
- Torque Converter Lock-Up Strategy
- Hybrid Vehicle Controller
- Electric Vehicle Controller

Couplings & Clutches

- Torque Converter
- Basic Clutch
- Basic Shaft

Gears & Transmissions

- Gearbox
- Differential
- Simple Chain Drive

Vehicles & Tires

- Basic Vehicle
- Multi-Axle Vehicle
- Wheel & Tire

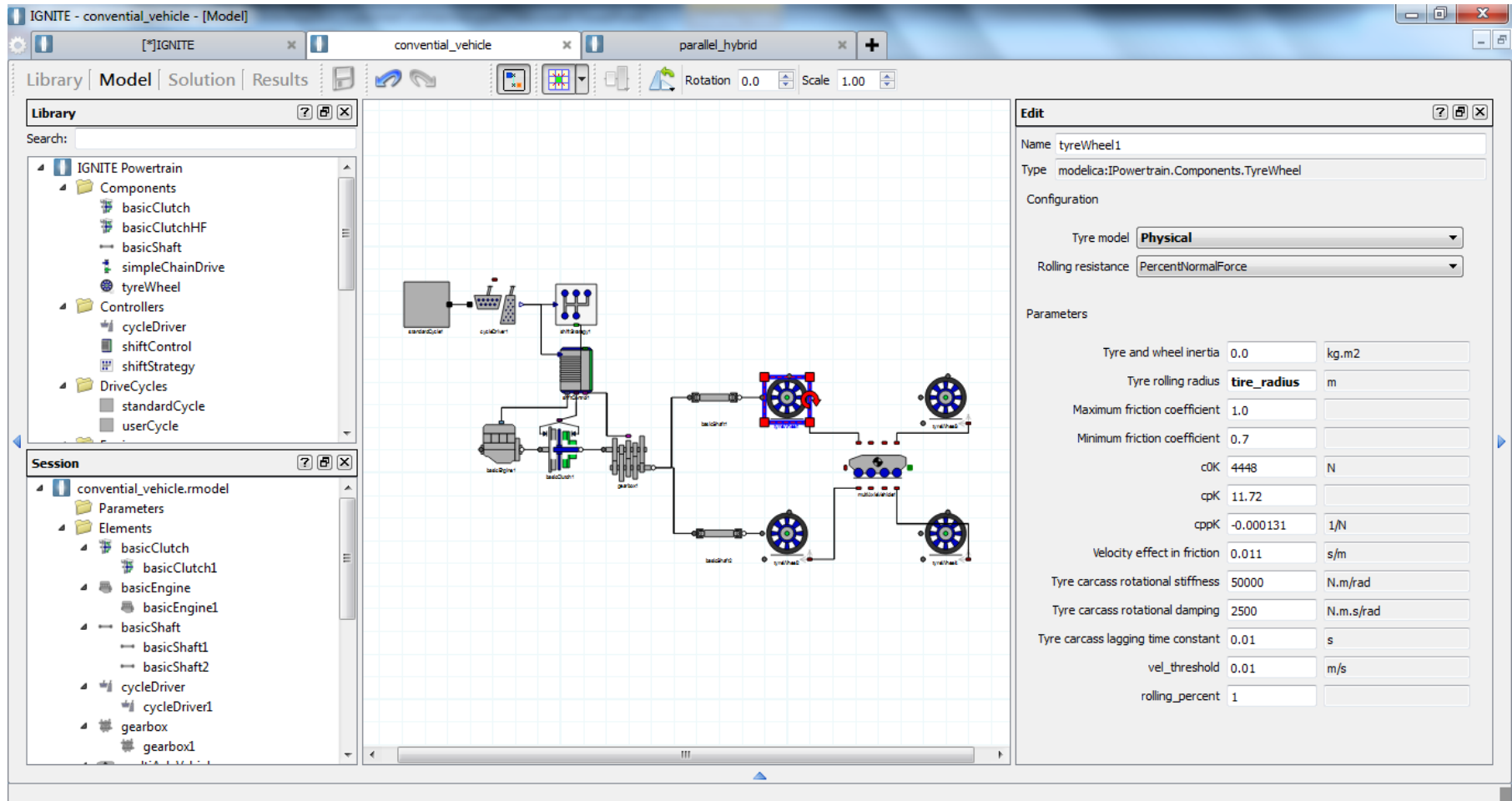
Accessories

- Alternator
- Centrifugal Pump
- Positive Disp. Pump
- Cooling Fan

IGNITE **SCREEN SHOTS**

IGNITE Model Screen Shots

- Conventional vehicle, front wheel drive w/ manual transmission (GUI + model)



IGNITE - convential_vehicle - [Model]

Library | Model | Solution | Results

Rotation 0.0 Scale 1.00

Library

Search:

- IGNITE Powertrain
 - Components
 - basicClutch
 - basicClutchHF
 - basicShaft
 - simpleChainDrive
 - tyreWheel
 - Controllers
 - cycleDriver
 - shiftControl
 - shiftStrategy
 - DriveCycles
 - standardCycle
 - userCycle

Session

- convential_vehicle.model
 - Parameters
 - Elements
 - basicClutch
 - basicClutch1
 - basicEngine
 - basicEngine1
 - basicShaft
 - basicShaft1
 - basicShaft2
 - cycleDriver
 - cycleDriver1
 - gearbox
 - gearbox1

Edit

Name: tyreWheel1

Type: modelica:IPowertrain.Components.TyreWheel

Configuration

Tyre model: **Physical**

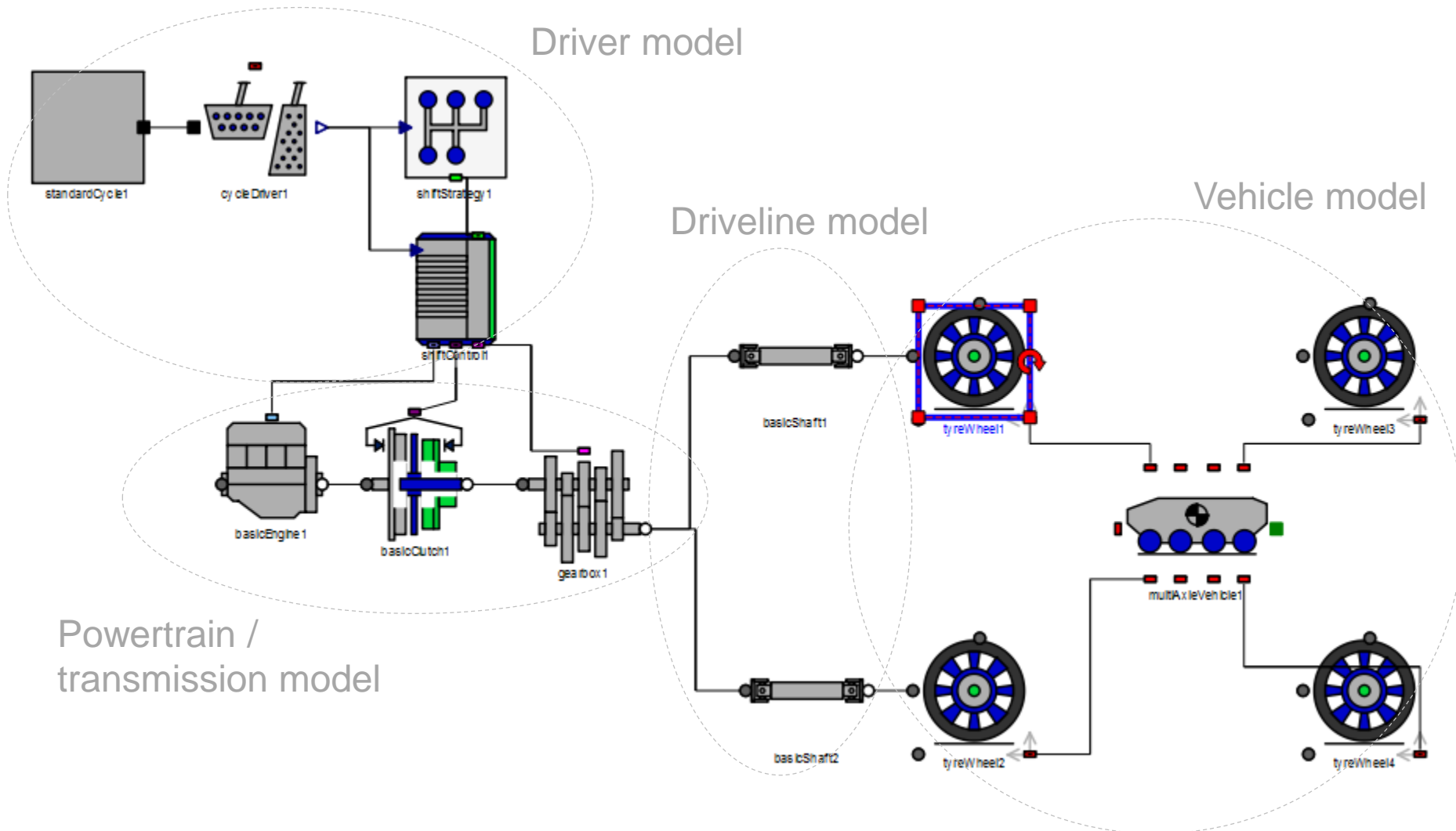
Rolling resistance: **PercentNormalForce**

Parameters

Tyre and wheel inertia	0.0	kg.m2
Tyre rolling radius	tyre_radius	m
Maximum friction coefficient	1.0	
Minimum friction coefficient	0.7	
cOK	4448	N
cpK	11.72	
cppK	-0.000131	1/N
Velocity effect in friction	0.011	s/m
Tyre carcass rotational stiffness	50000	N.m/rad
Tyre carcass rotational damping	2500	N.m.s/rad
Tyre carcass lagging time constant	0.01	s
vel_threshold	0.01	m/s
rolling_percent	1	

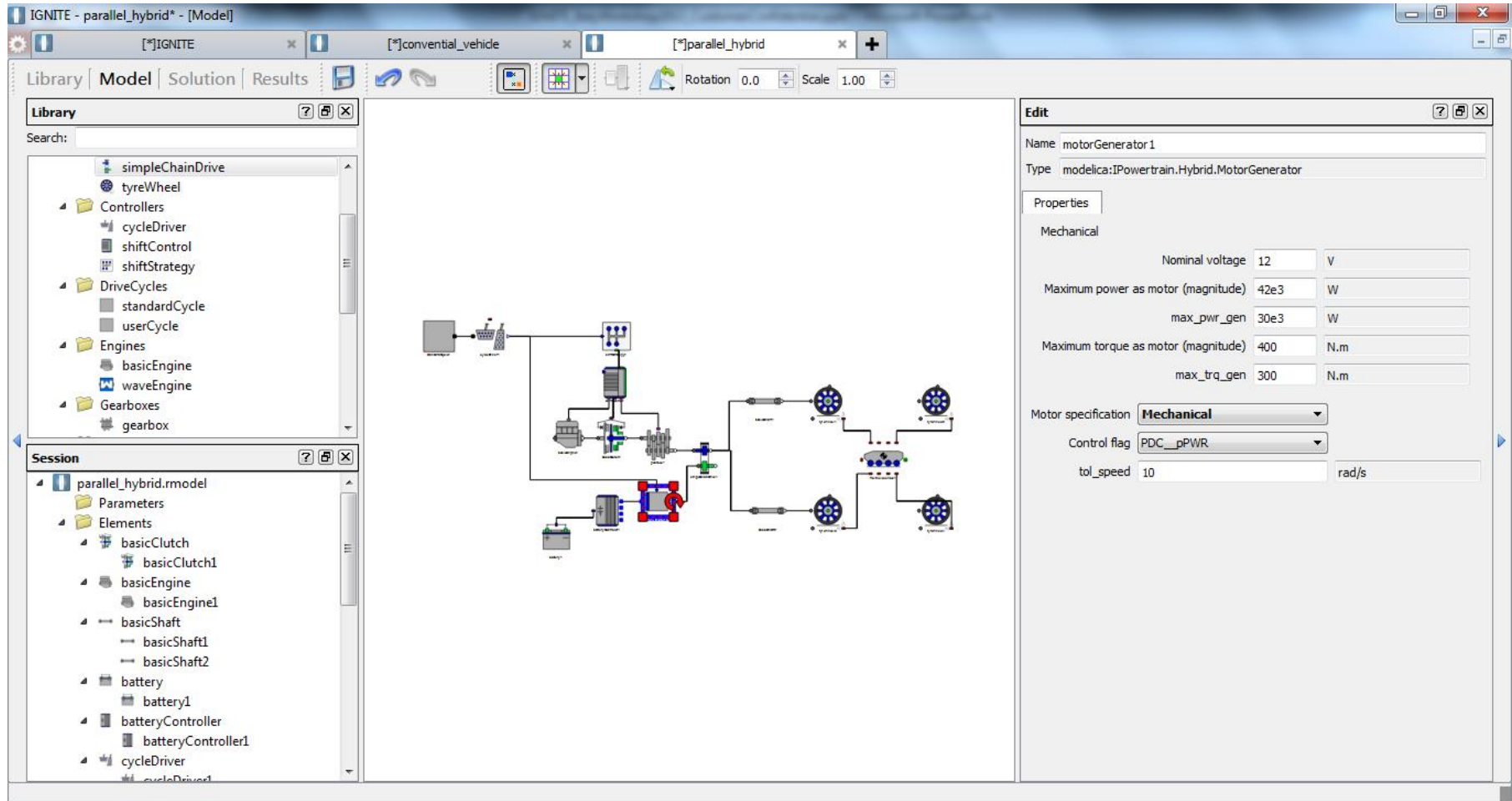
IGNITE Model Screen Shots

- Conventional vehicle, front wheel drive w/ manual transmission (model only)



IGNITE Model Screen Shots

- Hybrid (parallel) vehicle, front wheel drive w/ manual transmission (GUI + model)



The screenshot displays the IGNITE software interface for a parallel hybrid vehicle model. The main window shows a schematic diagram of the vehicle's powertrain, including a battery, a basicEngine, a basicClutch, a basicShaft, and a basicGearbox, connected to a front-wheel drive system with four wheels.

Library Panel:

- Search:
- simpleChainDrive
- tyreWheel
- Controllers
 - cycleDriver
 - shiftControl
 - shiftStrategy
- DriveCycles
 - standardCycle
 - userCycle
- Engines
 - basicEngine
 - waveEngine
- Gearboxes
 - gearbox

Session Panel:

- parallel_hybrid.rmodel
 - Parameters
 - Elements
 - basicClutch
 - basicClutch1
 - basicEngine
 - basicEngine1
 - basicShaft
 - basicShaft1
 - basicShaft2
 - battery
 - battery1
 - batteryController
 - batteryController1
 - cycleDriver
 - cycleDriver1

Edit Panel:

Name: motorGenerator1
 Type: modelica:Powertrain.Hybrid.MotorGenerator

Properties

Mechanical

Nominal voltage	12	V
Maximum power as motor (magnitude)	42e3	W
max_pwr_gen	30e3	W
Maximum torque as motor (magnitude)	400	N.m
max_trq_gen	300	N.m

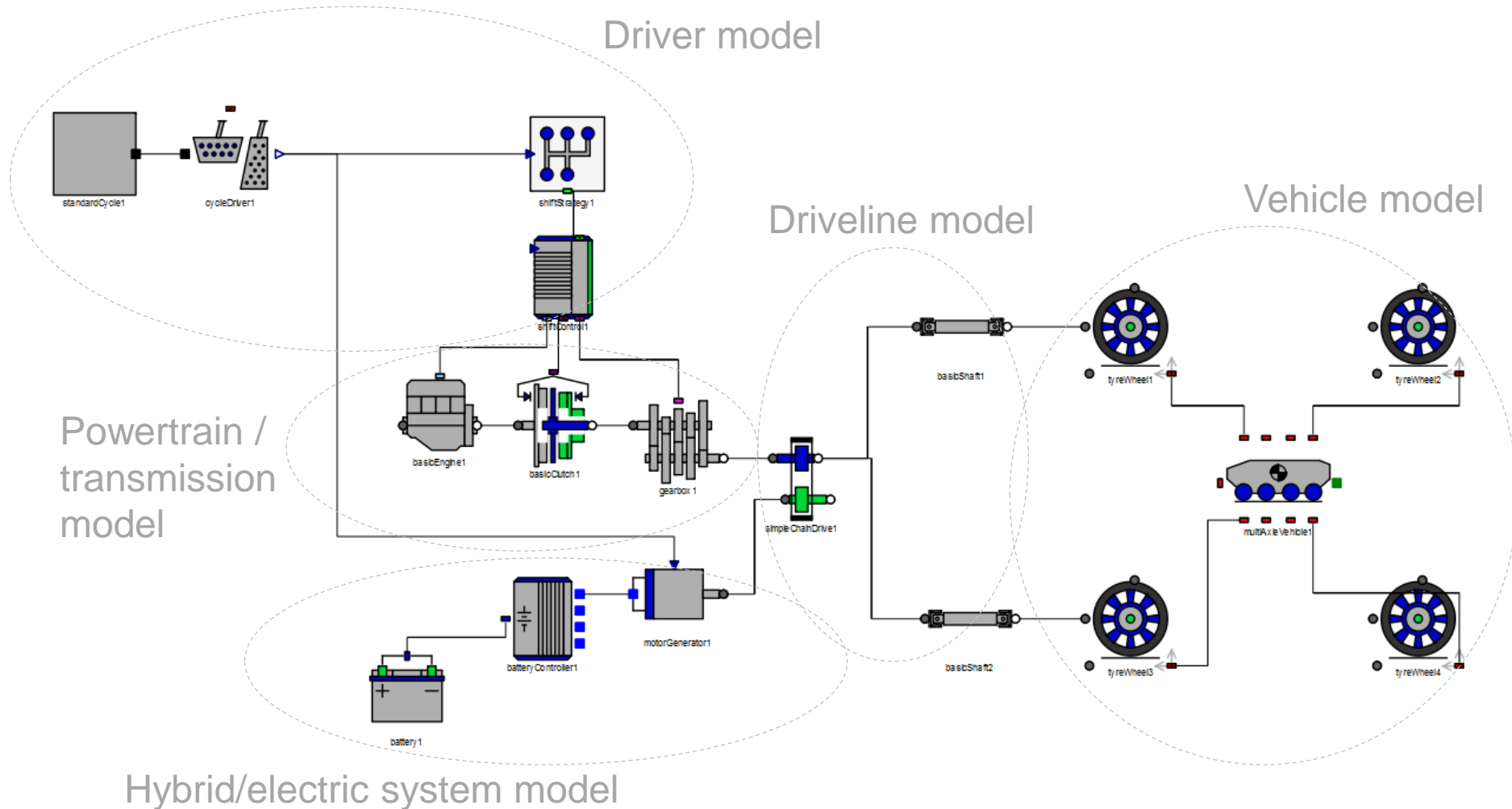
Motor specification **Mechanical**

Control flag: PDC_pPWR

tol_speed: 10 rad/s

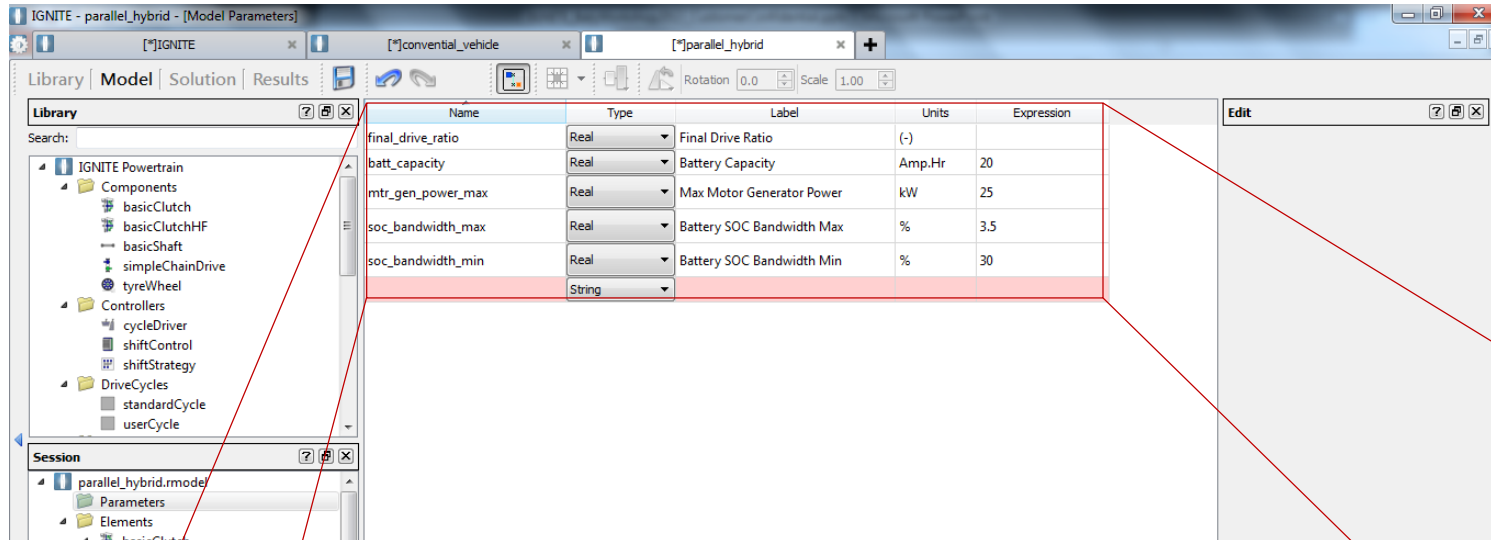
IGNITE Model Screen Shots

- Hybrid (parallel) vehicle, front wheel drive w/ manual transmission (model only)



IGNITE Parameters Table Screen Shot

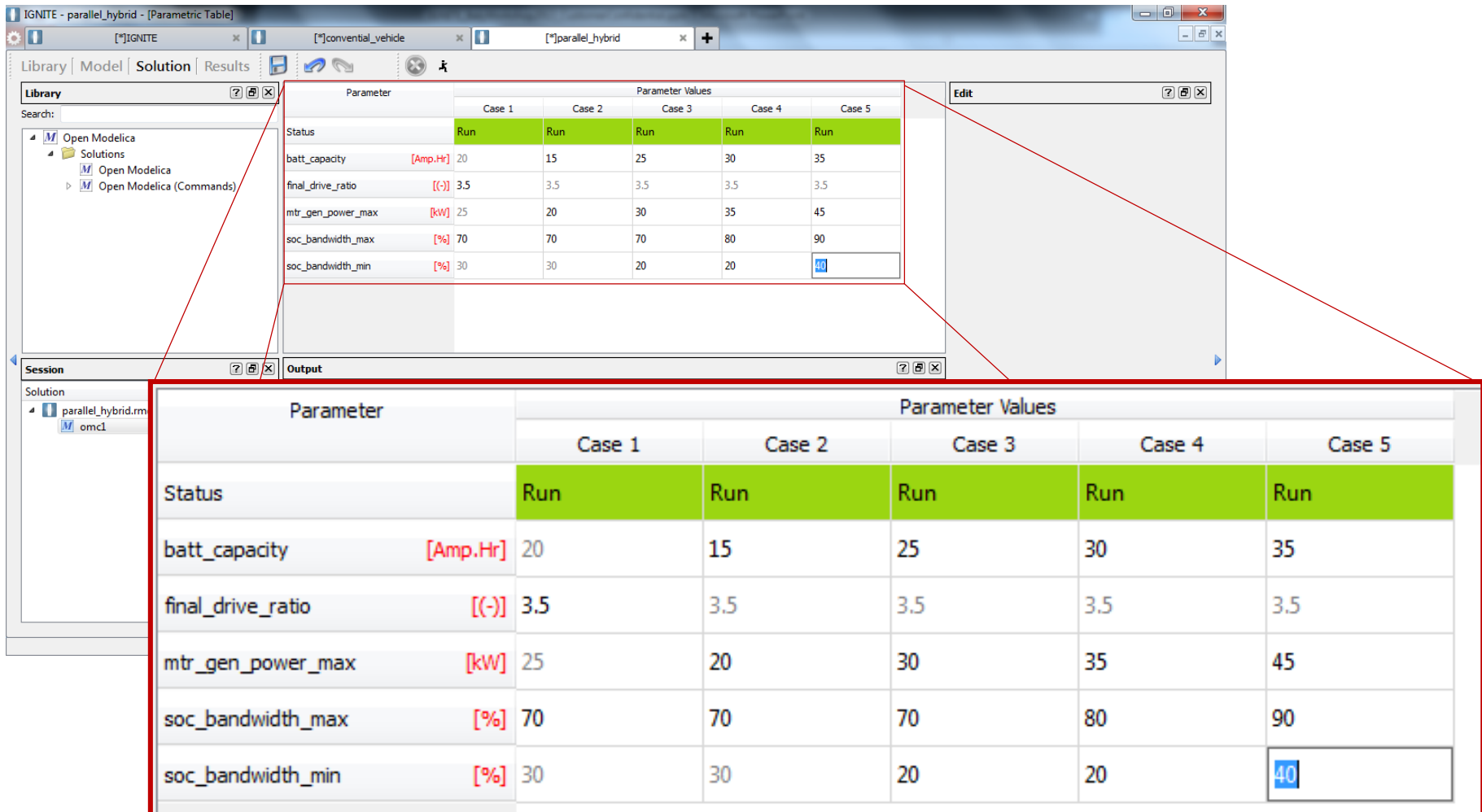
- Parameters table allows users to create and assign input parameters
- Quickly and easily parameterize complex models



Name	Type	Label	Units	Expression
final_drive_ratio	Real	Final Drive Ratio	(-)	
batt_capacity	Real	Battery Capacity	Amp.Hr	20
mtr_gen_power_max	Real	Max Motor Generator Power	kW	25
soc_bandwidth_max	Real	Battery SOC Bandwidth Max	%	3.5
soc_bandwidth_min	Real	Battery SOC Bandwidth Min	%	30
	String			

IGNITE Solution Cases Table Screen Shot

- The solution cases table auto-populates with all user-created parameters
- Quickly and easily setup, and execute, multi-case parametric studies

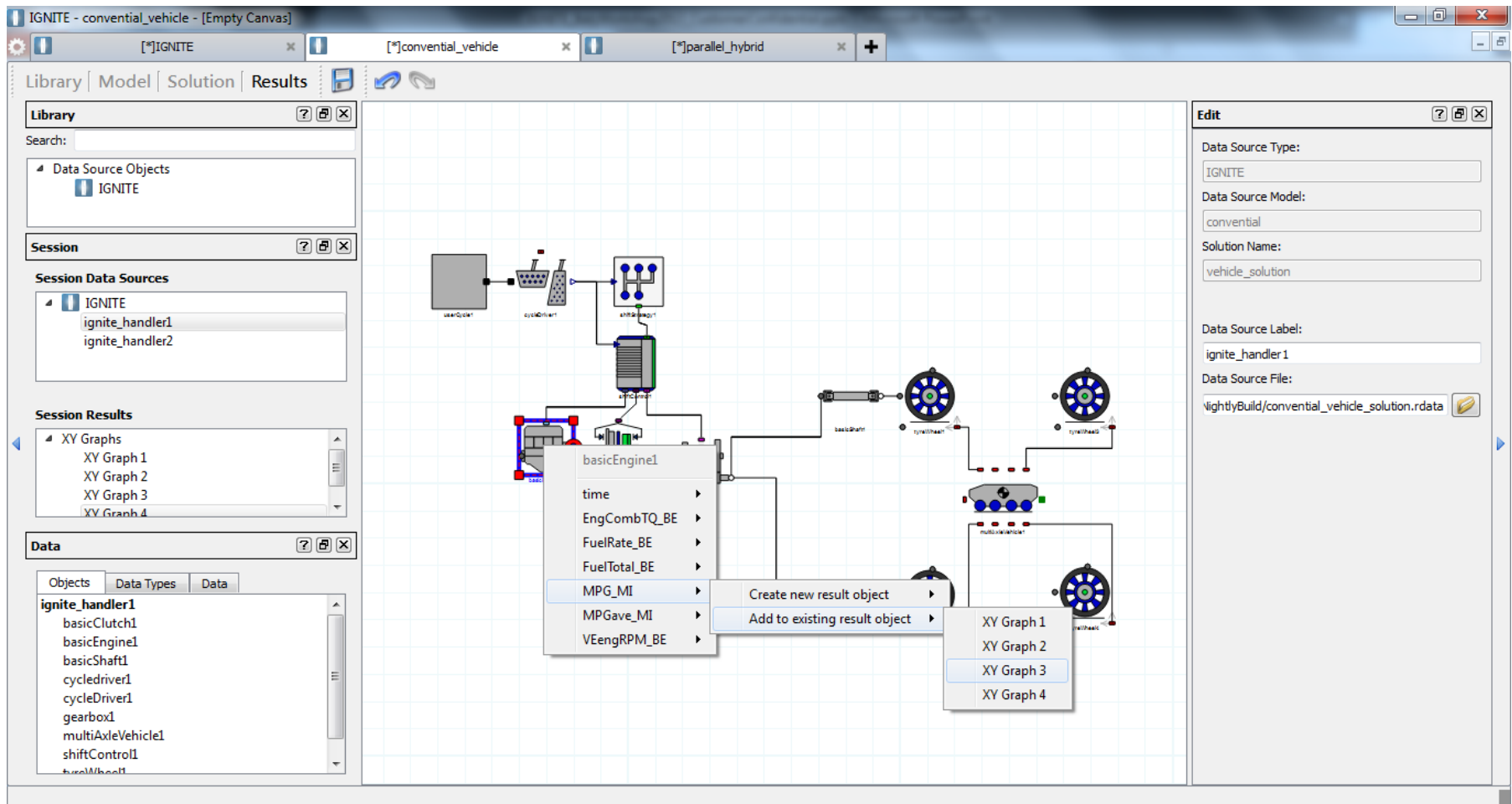


The screenshot displays the IGNITE software interface for a parametric study titled 'parallel_hybrid'. The main window shows a table with parameters and their values across five cases. A red box highlights the table, which is also shown in a larger, detailed view at the bottom of the screenshot.

Parameter	Parameter Values				
	Case 1	Case 2	Case 3	Case 4	Case 5
Status	Run	Run	Run	Run	Run
batt_capacity [Amp.Hr]	20	15	25	30	35
final_drive_ratio [(-)]	3.5	3.5	3.5	3.5	3.5
mtr_gen_power_max [kW]	25	20	30	35	45
soc_bandwidth_max [%]	70	70	70	80	90
soc_bandwidth_min [%]	30	30	20	20	40

IGNITE Post-Processing Screen Shots

- Results mode displays a read-only version of the network mode
- Quickly graph parameters and variables directly from network objects



IGNITE - conventional_vehicle - [Empty Canvas]

Library | Model | Solution | Results

Library

Search:

▲ Data Source Objects

IGNITE

Session

Session Data Sources

IGNITE

ignite_handler1

ignite_handler2

Session Results

▲ XY Graphs

XY Graph 1

XY Graph 2

XY Graph 3

XY Graph 4

Data

Objects | Data Types | Data

ignite_handler1

basicClutch1

basicEngine1

basicShaft1

cycledriver1

cycleDriver1

gearbox1

multiAxleVehicle1

shiftControl1

tyreWheel1

basicEngine1

time

EngCombTQ_BE

FuelRate_BE

FuelTotal_BE

MPG_MI

MPGave_MI

VEengRPM_BE

Create new result object

Add to existing result object

XY Graph 1

XY Graph 2

XY Graph 3

XY Graph 4

Edit

Data Source Type:

IGNITE

Data Source Model:

conventional

Solution Name:

vehicle_solution

Data Source Label:

ignite_handler1

Data Source File:

\lightlyBuild\conventional_vehicle_solution.rdata

IGNITE Post-Processing Screen Shots

- Quickly visualize and examine simulation results
- Customize appearance of results objects (graphs, plots, etc...)

