IGNITE

Ricardo Software Multi-Domain System Simulation Software

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

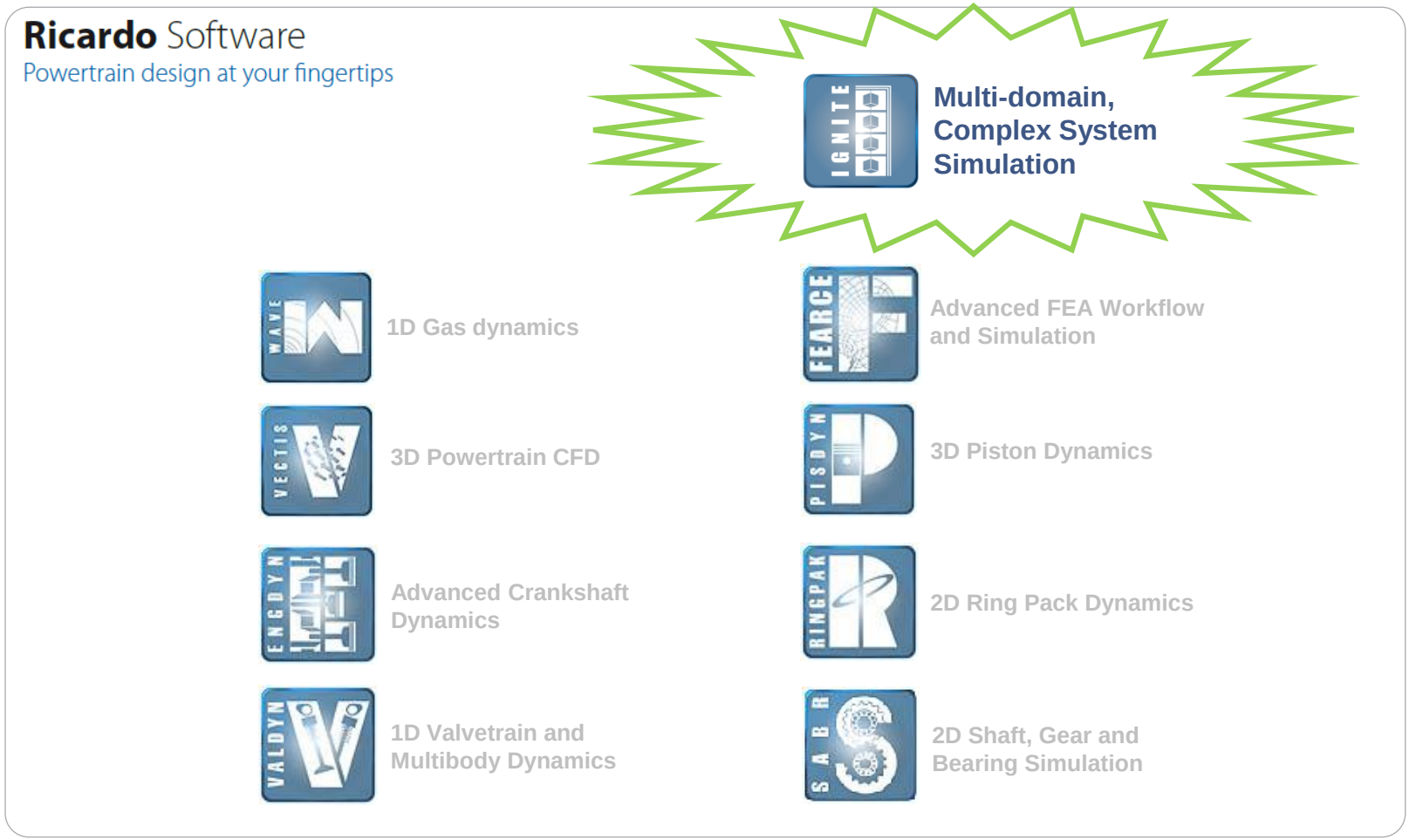
Detroit Room
9:15 – 10:45 am

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]

Introduction

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



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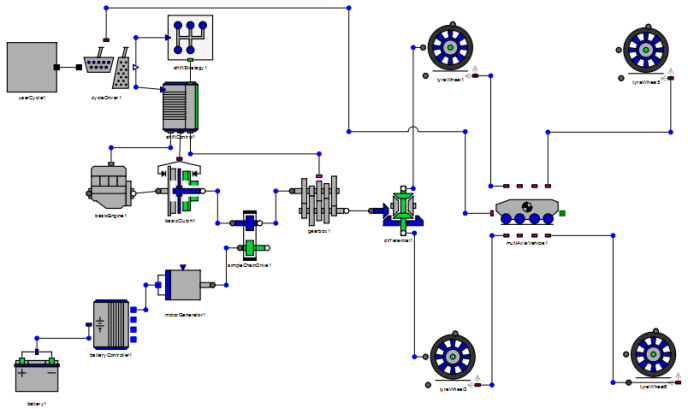
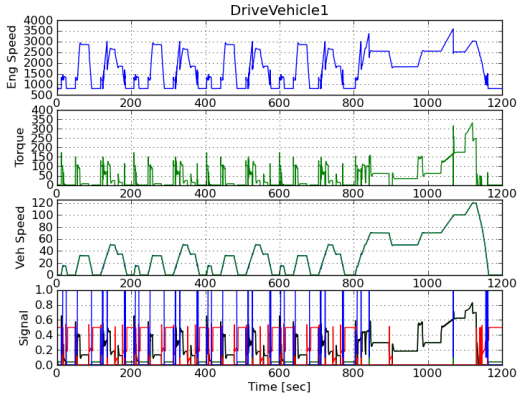
PRODUCT OVERVIEW

Application

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



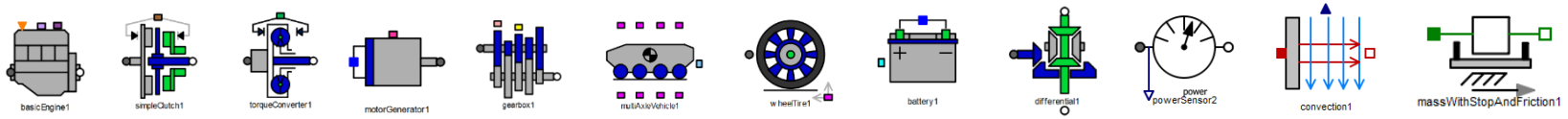


- Systems-level modeling of:
  - Driver
  - Engine
  - Transmission
  - Driveline
  - Vehicle
  - Wheel & Tire
  - Hybrid-electric systems
  - Vehicle control systems
  - Vehicle thermal systems
  - Powertrain accessories

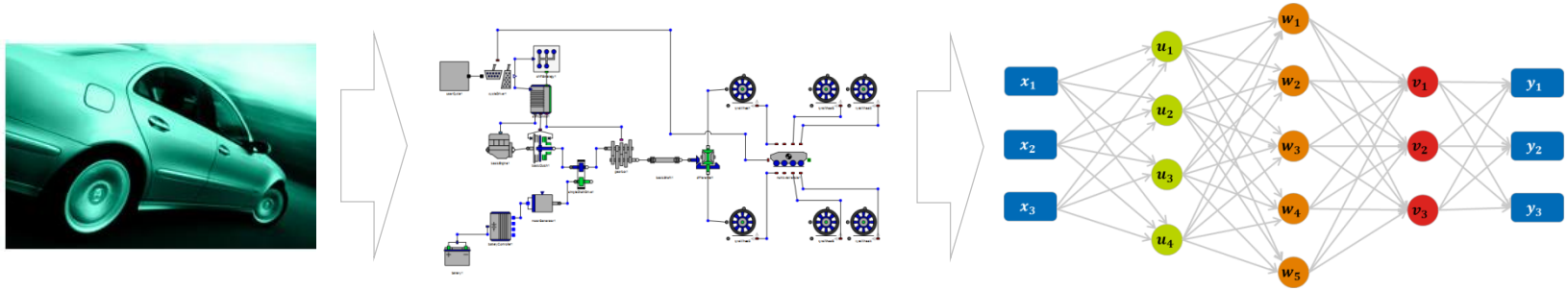
- Drive cycle simulation
- Vehicle performance prediction
- Fuel consumption prediction
- Energy flow analysis and efficiency
- Vehicle architecture design
- Hybrid system architecture design
- Component selection and sizing
- Powertrain integration analysis

Functionality

- 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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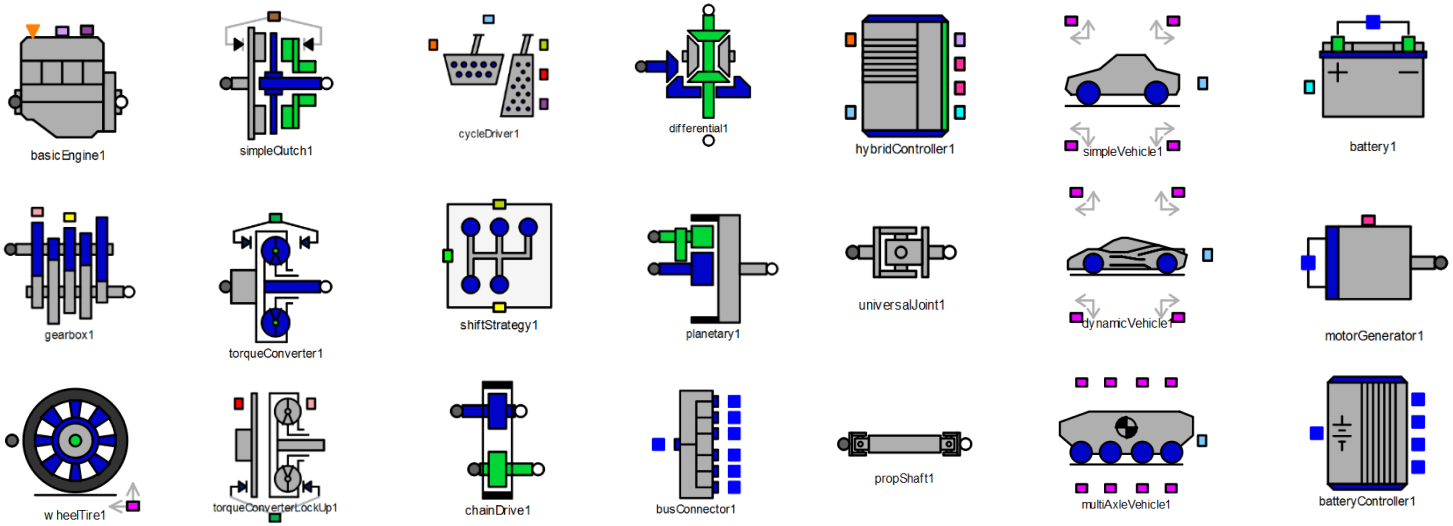
KEY FEATURES

Ricardo IGNITE Powertrain Library

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



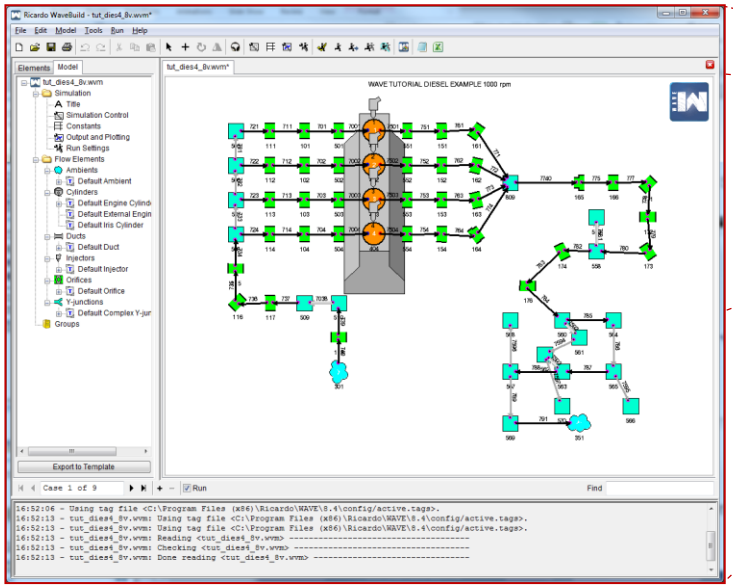
- Allows users to build complex vehicle models ‘one object at a time’
- Flexible components, multiple configuration options, supports M&S activities across multiple phases of design and analysis
- **Leveraged from existing internal Ricardo technology, built on world-class powertrain systems domain expertise!**

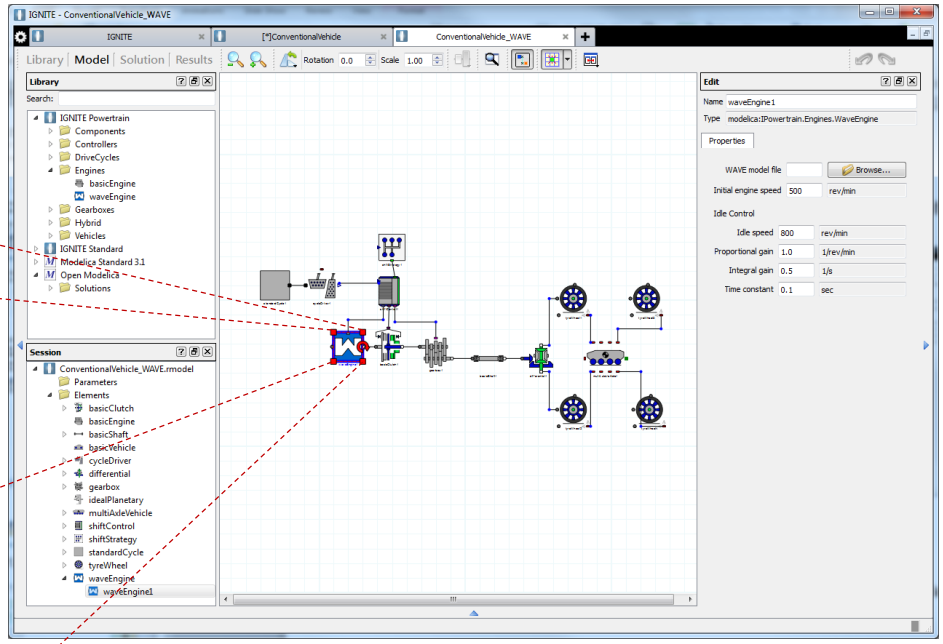
**** full library not pictured*

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





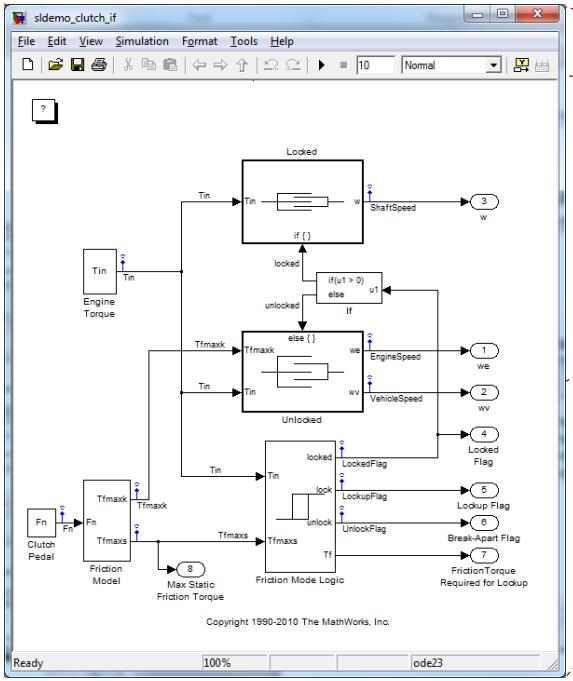
IGNITE 1-D Driveline / Vehicle model

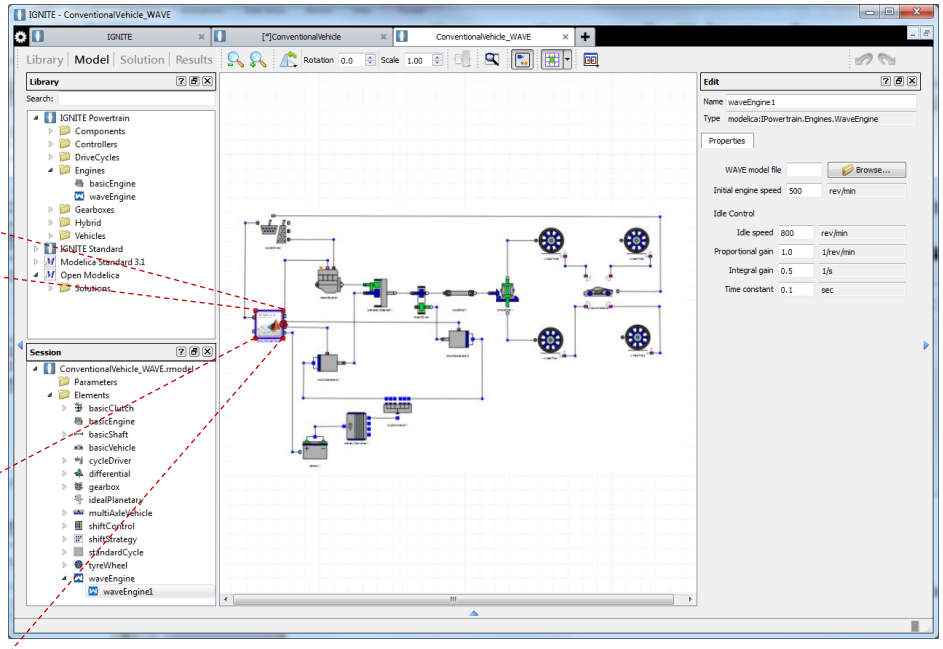
- **Flexible powertrain modeling development and integration!**

Co-Simulation with MATLAB/Simulink

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

MATLAB/Simulink controller model





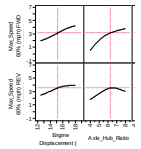
IGNITE Hybrid Vehicle model

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

Design & Optimization Toolbox

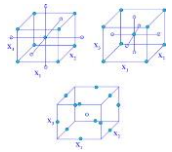
- Built-in toolbox of powerful, multivariate analysis, 'decision making' tools
- Quantify system inter-dependencies and complex interactions

Trade-off / Sensitivity analysis



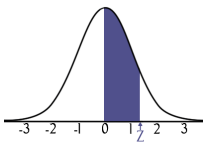
- Perform large multi-case parametric studies
- Quantify and identify complex system interactions and sensitivities

Design Space Exploration (DoE)



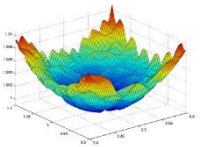
- Intelligently explore system design space
- Facilitates efficient frontier prediction

Reliability & Robustness



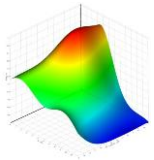
- Perform response and reliability studies
- Quantify the probability of meeting system performance objectives and requirements

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

Library Extensibility

- 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…

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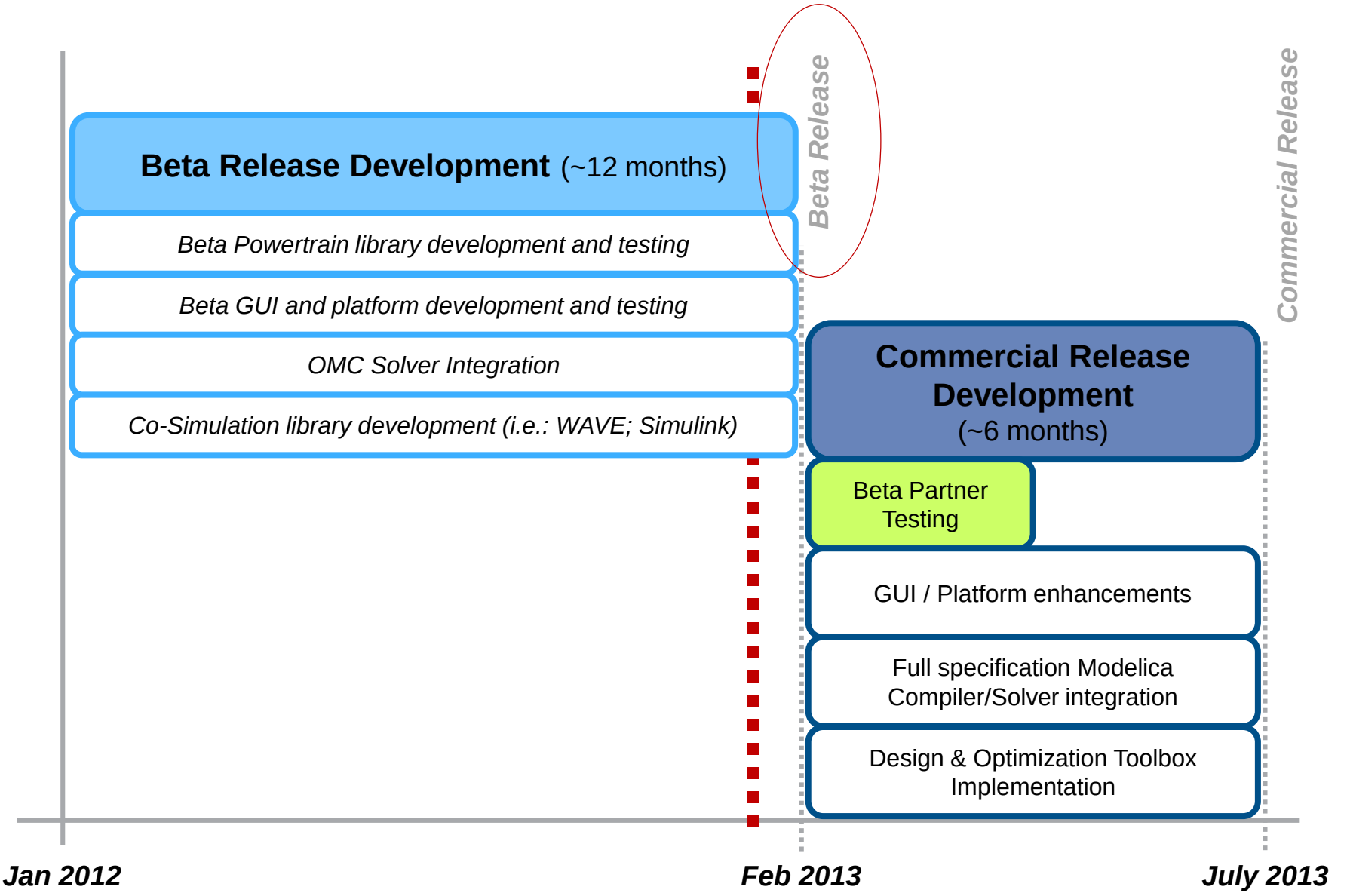
STATUS & TIMING

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 *(simple, time-based, 2-D XY line graphs)*	X	
Full Spec Modelica Compiler/Solver *(ability to execute full Modelica specification)*		X
Design/Optimization toolbox *(DOE, MonteCarlo, RSM, Optimization, post-processing)*		X
Enhanced IGNITE Powertrain library *(expandable connectors, block connectors)*		X

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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

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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

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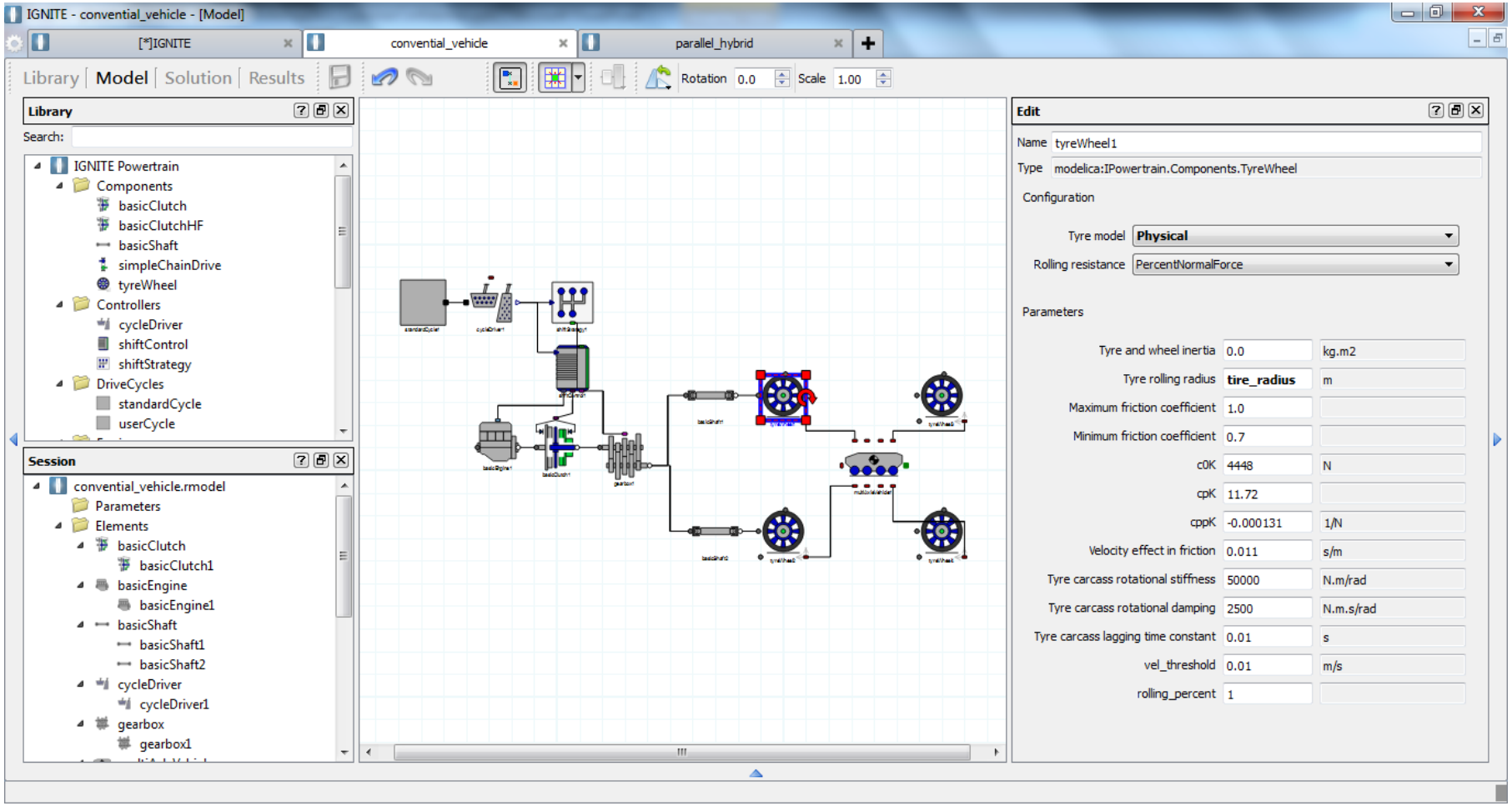
SCREEN SHOTS

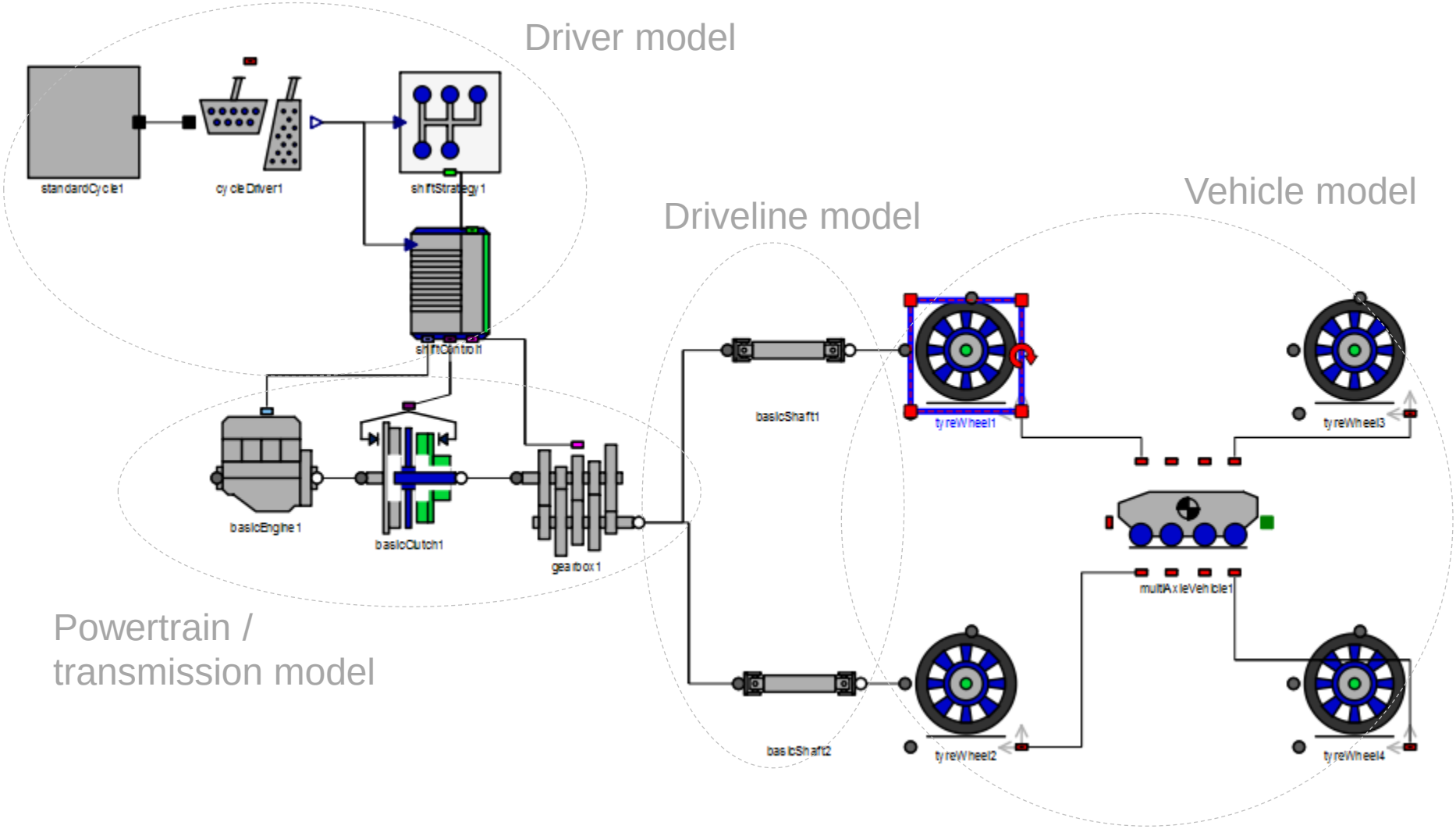
IGNITE Model Screen Shots

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



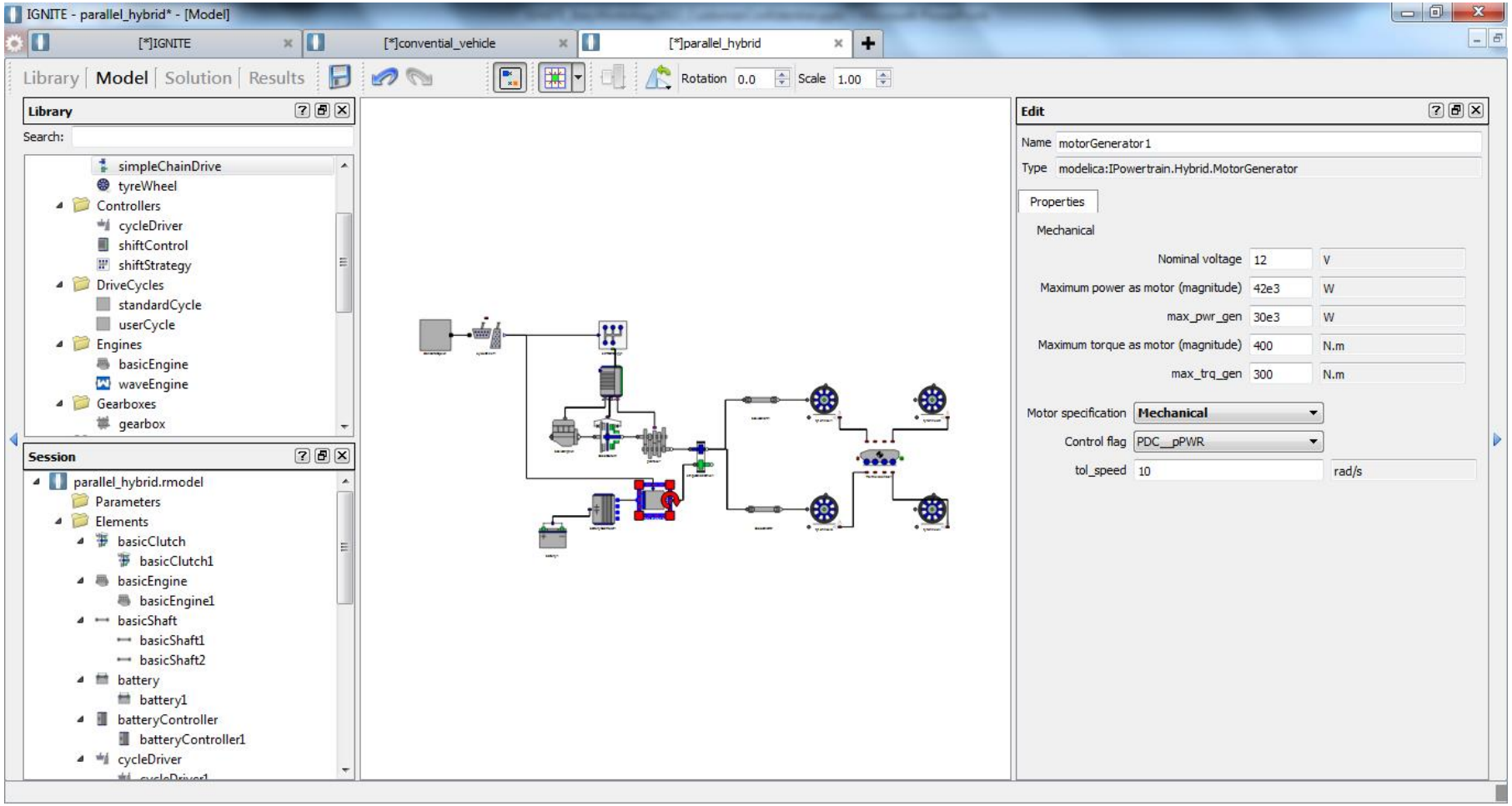
IGNITE Model Screen Shots

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



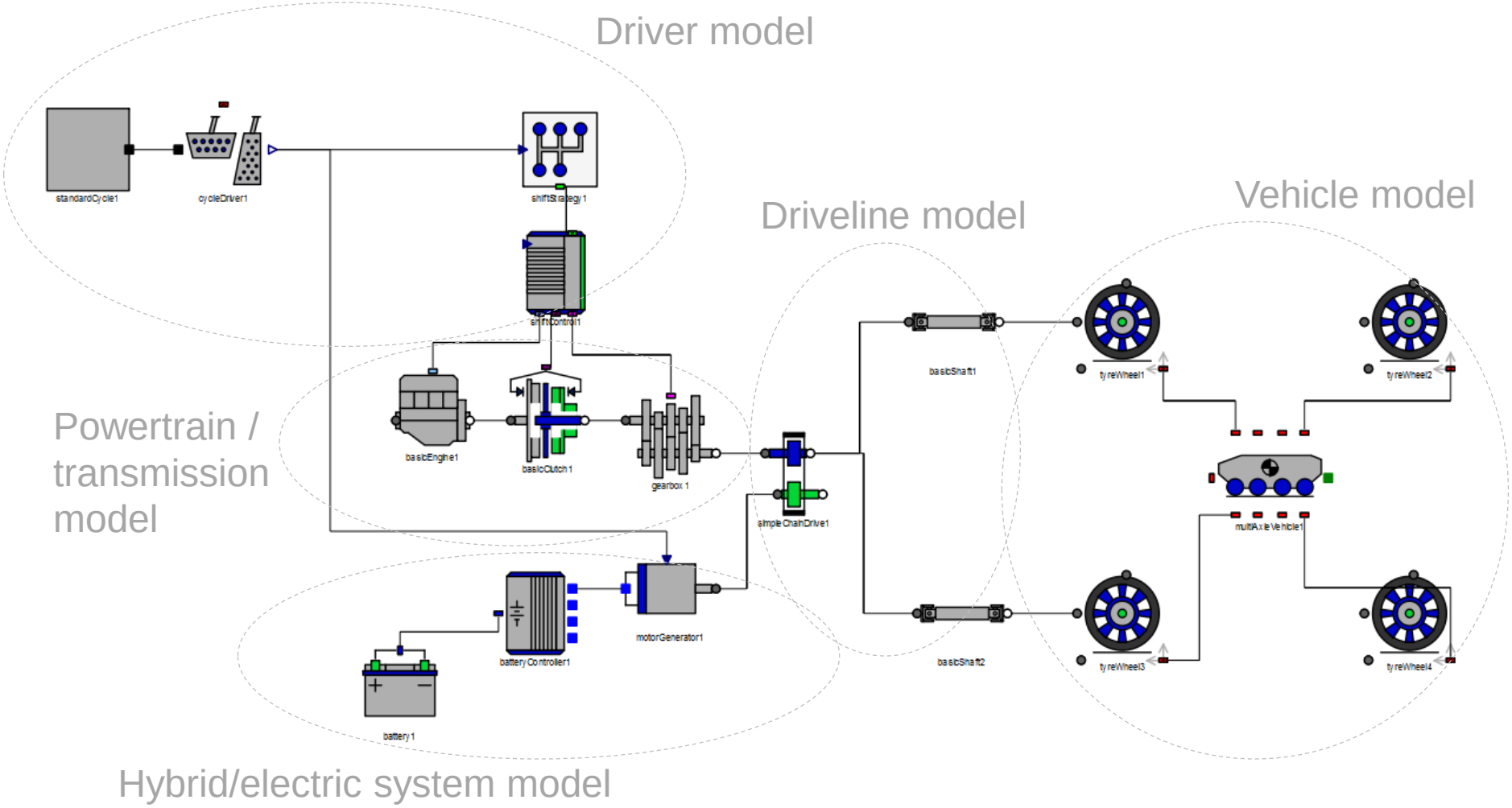
IGNITE Model Screen Shots

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



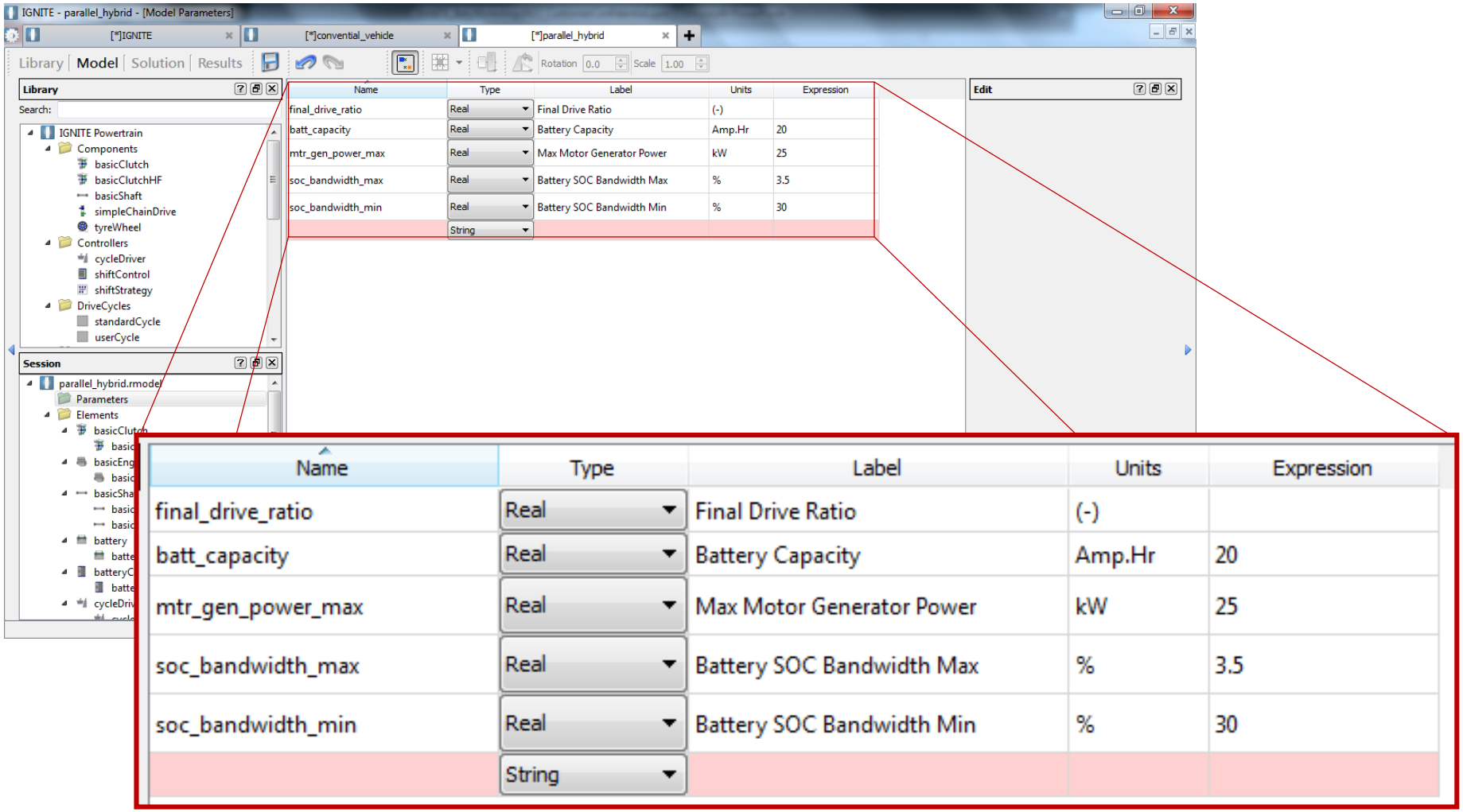
IGNITE Model Screen Shots

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



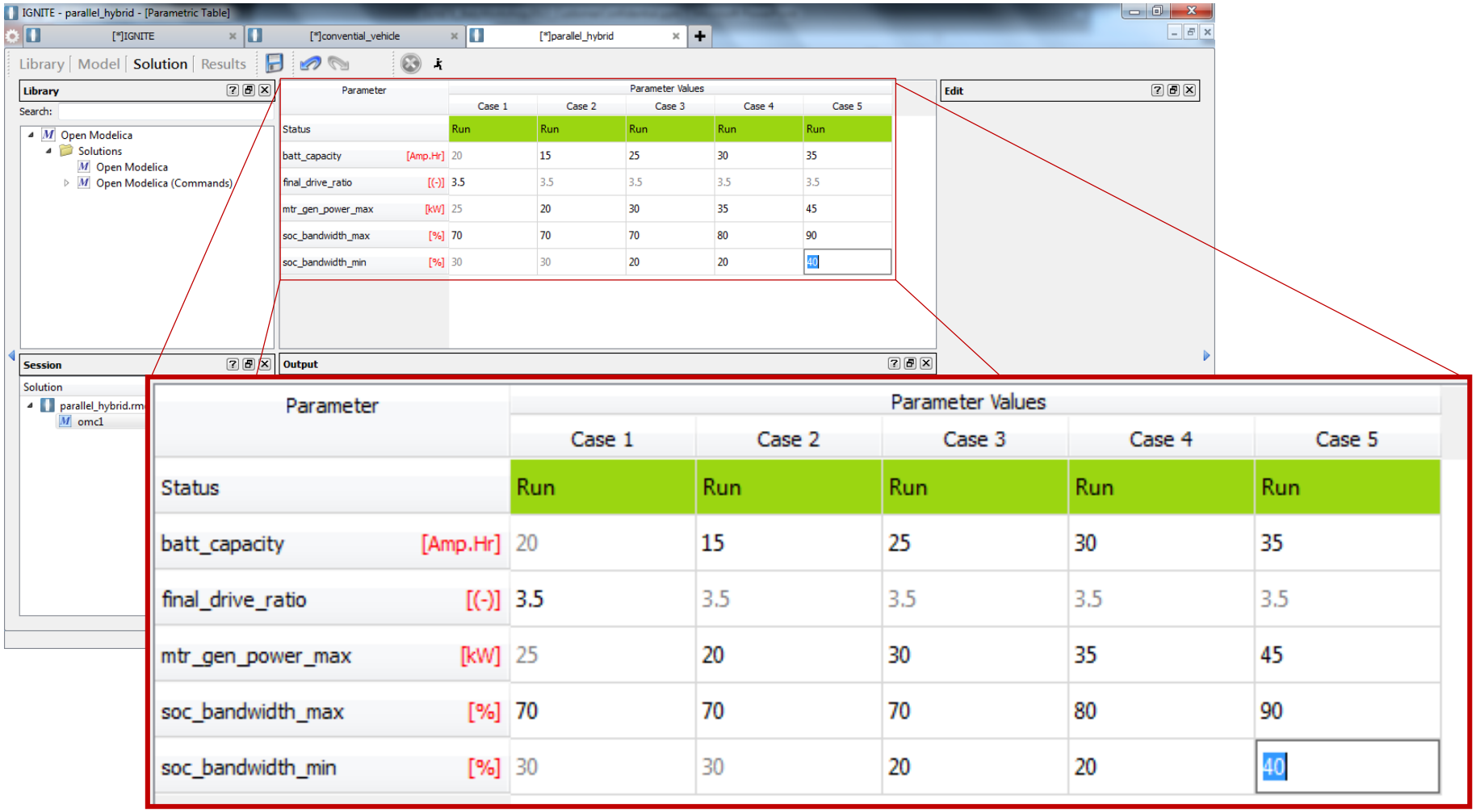
IGNITE Parameters Table Screen Shot

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



IGNITE Solution Cases Table Screen Shot

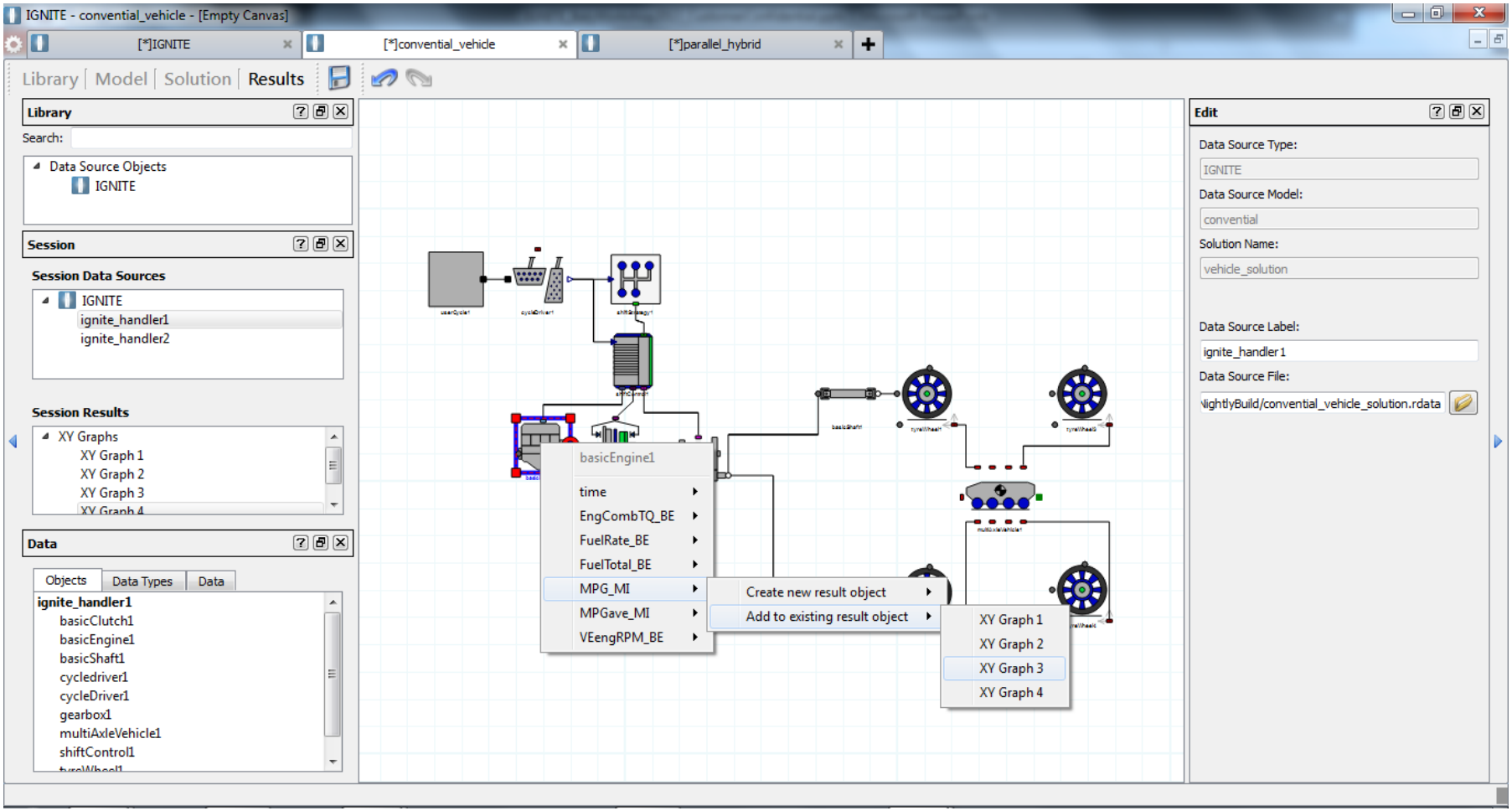
- The solution cases table auto-populates with all user-created parameters
- Quickly and easily setup, and execute, multi-case parametric studies



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 Post-Processing Screen Shots

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