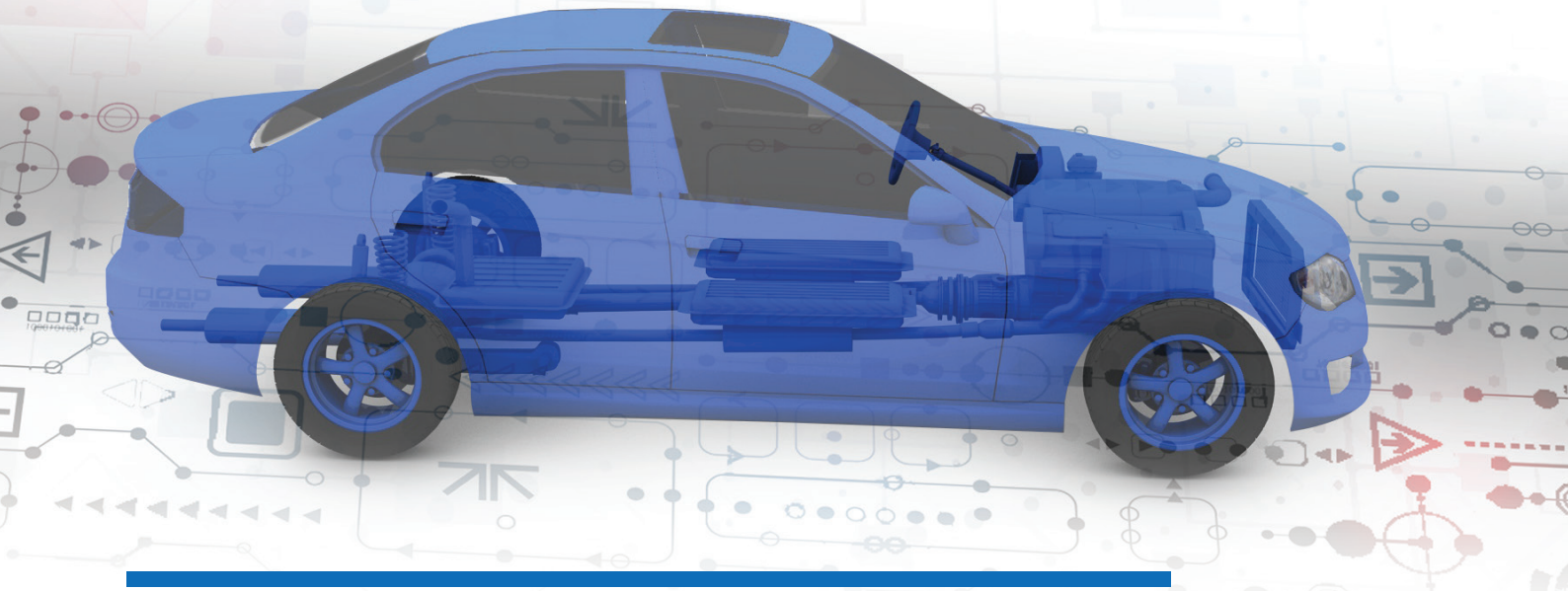
Ricardo Software Case Study



An emerging technology:

Optimizing drive-cycle waste-heat recovery systems using the Functional Mock-Up Interface

In a recent collaboration, Ricardo Software worked alongside Volkswagen AG Research (VWAG) to develop new methods for design and optimization of waste-heat recovery systems in future vehicles.

Opportunity: Increase fuel economy and reduce CO_2 emissions

For vehicle manufacturers, there is an opportunity to optimize waste-heat recovery systems for the benefit of recovering exhaust gas and converting it into usable mechanical and electrical energy. This application represents an emerging automotive technology for improving fuel efficiency and reducing CO_2 emissions. Successful simulation of waste-heat recovery systems requires modeling and capturing the complex interactions between multiple vehicle sub-systems, and as a result often requires the use of multiple CAE software tools. This approach can be cumbersome, costly, inefficient, and error-prone.

Problem and solution: Integrated multi-domain modeling using IGNITE and the Functional Mock-Up Interface (FMI)

In order to achieve the level of fidelity and sub-system dynamics required for accurate waste-heat recovery system optimization, the FMI was used to combine three domain-specific models in IGNITE, resulting in a single integrated model.

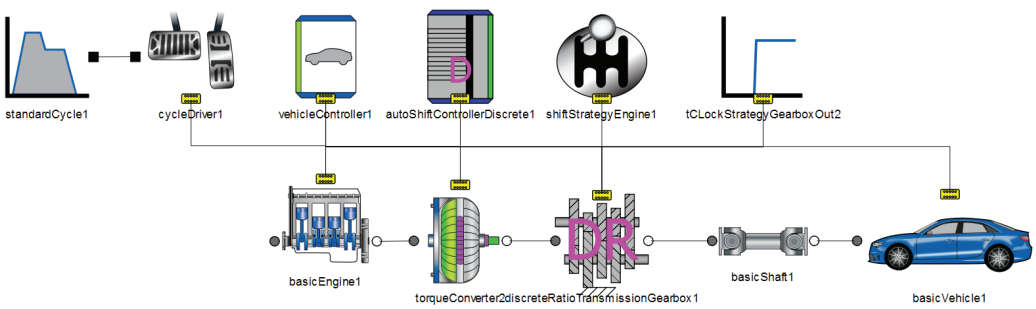


Figure 1

TLK-Thermo GmbH

VOLKSWAGEN AKTIENGESELLSCHAFT

First, IGNITE was used to construct a full system-level vehicle model needed to confirm boundary conditions and overall vehicle performance (**Figure 1**). This initial concept-level model included a map-based engine model, physics-based plant models of the transmission and driveline, and a longitudinal dynamics capable vehicle. It also included drive-cycle-specific vehicle controllers for driver behavior, transmission, shift, and engine strategies.

IGNITE was designed with dynamic model fidelity in mind and, as a result, users can seamlessly transition from high-level concept components to fully detailed physical plant models. For this application, VWAG Research required more advanced transient engine exhaust gas boundary conditions to accurately model waste-heat recovery system performance. Using the industry standard FMI, engineers rapidly added new and more comprehensive sub-system models, including a transient 1D gas dynamics engine exported from Ricardo Software's WAVE-RT toolset using the FMI standard (**Figure 2**).

With a transient engine integrated directly within the vehicle model, the next step was to add a detailed waste-heat recovery sub-system model. Using TLK-Thermo's TIL-Suite library, VWAG Research built a physics-based model of an organic Rankine system, which included physical models for the pump, evaporator, and expander and condenser operation. Similar to WAVE-RT, the TLK model was imported, using FMI standards, directly into the IGNITE environment and combined with the engine and vehicle models (**Figure 3**).

The integration available between the sub-system models and native models in IGNITE provides a robust method for creating a single integrated model in which parameters, variables, and data signals can be easily exchanged between sub-systems during simulation.

Results: Dynamic model fidelity delivers advanced analysis

By combining flexible modeling fidelity with the multi-domain integration capabilities of the FMI, IGNITE provided VWAG Research engineers with a flexible and efficient approach to advanced systems simulation and optimization.

The results of this multi-domain approach present an opportunity for manufacturers to increase the overall fuel efficiency of their vehicles by using recaptured energy to power auxiliary electrical systems or provide mechanical power-back onto the crank shaft. VWAG Research, a leader in advancements for fuel economy and engine design, is harnessing various technologies to explore the realms of possibility. Using IGNITE's integrated platform, VWAG Research engineers are better equipped to control key parameters and attributes of the system and components, explore dynamics and interdependencies, and rapidly perform "what-if" analyses that impact design.

IGNITE represents a step forward in vehicle simulation, offering comprehensive libraries, variable component fidelity, and integration of Ricardo's proprietary technology.

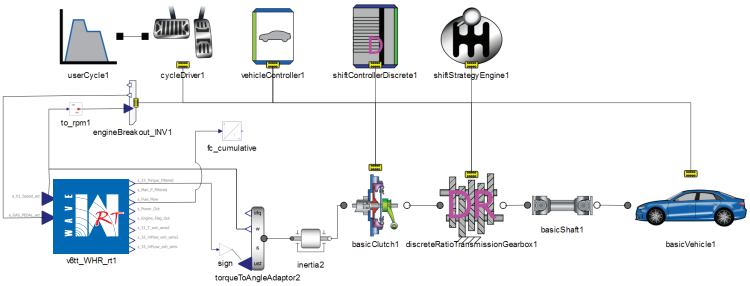


Figure 2

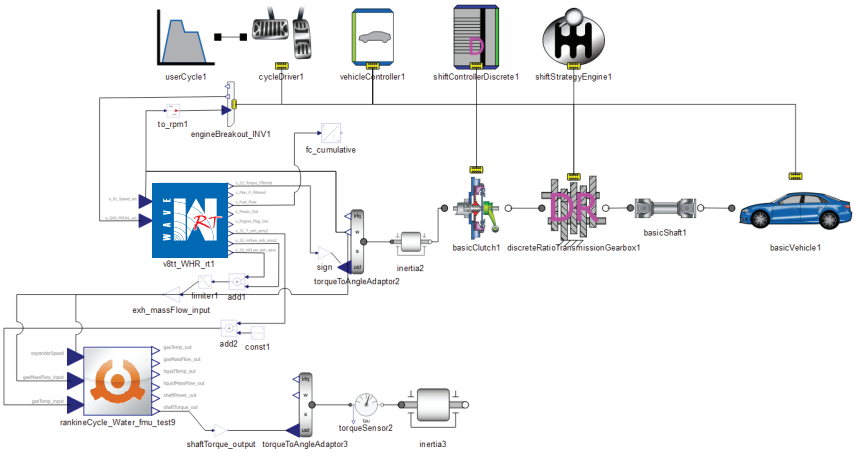


Figure 3

Find out more about IGNITE

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