OSU at EcoCar 2 –
hybrid power takes first place

Model-Based Winning

The Ohio State University drove home first-place honors in the EcoCAR 2 advanced vehicle technology competition finale for delivering a re-engineered plug-in hybrid that impressed judges across the board. During the three-year project, the students used state-of-the-art industry tools to redesign a 2013 Chevrolet Malibu, implementing vehicle energy storage, electric drive and ethanol-(E85)-fueled engine technology.

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"Using one's own concept to give a production vehicle such a reduction in fuel consumption and emissions – while retaining full performance – is an incredible result. And on top of that, it was students who accomplished this as part of their studies," said Santhosh Jogi, Director of Technology at dSPACE Inc. "Earning first place in the overall standings of the EcoCAR 2 competition was more than deserved. And we are, of course, proud that tools from dSPACE have played such a decisive role in the development process."
"In addition," Jogi continued, "we also awarded the team with the 1st place dSPACE Embedded Success Award for fully embracing the concepts behind product development, the model-based development process and tool use, and combining them effectively."

Competition for the Makers of Tomorrow

"Placing first overall was a big deal," said M.J. Yatsko, EcoCAR 3 Co-Team Leader and EcoCAR 2 HIL Development Leader. "The whole three-year EcoCAR 2 competition with 15 North American university teams, sponsored by the U.S. Department of Energy (DOE), General Motors (GM) and several other institutions and companies, gave us students an up-close feel of the current and future challenges in the automotive industry."
One of the main underlying goals of the EcoCAR 2 competition was for teams to come up with creative ways to further optimize the energy efficiency and environmental compatibility of the 2013 Chevrolet Malibu – an already established production vehicle. Each team was given three years to envision, develop, and implement their vehicle designs, without compromising performance, safety, and consumer acceptability features. Throughout the competition, each team was required to put their vehicles through the same level of industry testing used by GM for their production vehicles.
With their plug-in hybrid vehicle design, the OSU team achieved an impressive 50 miles per gallon (4.7 l/100 km) gas equivalent, while using 315 watt-hours per mile (196 watt-hours per kilometer) of electricity and were able to significantly reduce their vehicle's emission levels.

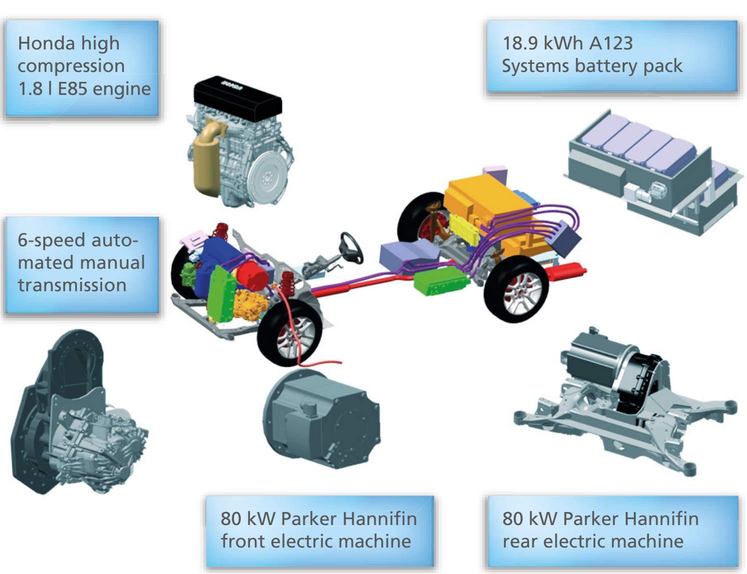
In the Heart of EcoCAR 2

"For the vehicle architecture we chose a plug-in hybrid concept," explained Jason Ward, Project Manager of the OSU team. "There are many sources for power: the front axle is powered by a Honda 1.8-liter ethanol combustion engine with a 6-speed automated manual transmission. Additional torque is provided by an 80 kW electric motor which is coupled with the transmission via a belt. The rear axle is driven by an additional 80 kW electric drive."
Andrew Huster, Electrical Team Leader, presented the key advantages: "The various drive components can be combined flexibly to set up drive modes as combustion engines, hybrid drives, and purely electric drives. According to the particular drive mode, the battery pack can be recharged, maintained by energy recovery or discharged during operation." The OSU team performed extensive tests to ensure smooth transitions from one mode to another.
The plug-in hybrid controller has a hierarchic architecture. A dSPACE MicroAutoBox® II acts as the central supervisory control system. Below the supervisory level, connected via CAN bus interfaces, are the low-level controllers for the engine, battery, brakes, transmission, electric motors, etc. The architecture allows easy expandability, is fault tolerant, and makes it easier to try out various controller variants.

HIL Tests with dSPACE Simulator

In the first year of the competition, the OSU students focused on the vehicle architecture and vehicle subsystems. In addition to performing SIL tests (primarily with their own

Figure 1: The vehicle architecture – flexible power on both axles.



"dSPACE tools were a significant contribution towards making our team reach the milestones and specification targets for EcoCAR 2. With the dSPACE tools, we were able to test the control code easily, while designing and creating the mechanical/electrical subsystems at the same time."

Matthew Yard, former OSU EcoCAR 2 Team Leader

developed SIL simulator), they also carried out intensive HIL tests with hardware and software from dSPACE. The second year involved the actual completion of a prototype vehicle and the integration of components. Finally, in the third year of the competition, accompanied by numerous road tests, the car was further optimized by using the constructed tool chain to achieve the desired fuel consumption, emissions, performance, and driveability goals defined in the team's Vehicle Technical Specification (VTS).

During the HIL testing phase, the OSU team worked with four different HIL configurations, utilizing a dSPACE Simulator Mid-Size to develop and validate subsystem-to-system functions. This included thoroughly checking each of the controllers that they implemented themselves. The team utilized these HIL configurations with closed-loop dynamic plant models to test functional behavior, failure detection and mitigation, communication between controllers, and many other component and vehicle-level features. The four HIL configurations were:

- *Case 1:* Validating the main controller, implemented on a dSPACE MicroAutoBox II. Simulation models from various manufacturers were used.

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Figure 2: ControlDesk® Next Generation was used for HIL tests with a dSPACE Simulator and for controller applications on the dSPACE MicroAutoBox II.

Figure 3: Ohio State's Katherine Bovee shows U.S. DOE's Michael Knotek their vehicle.

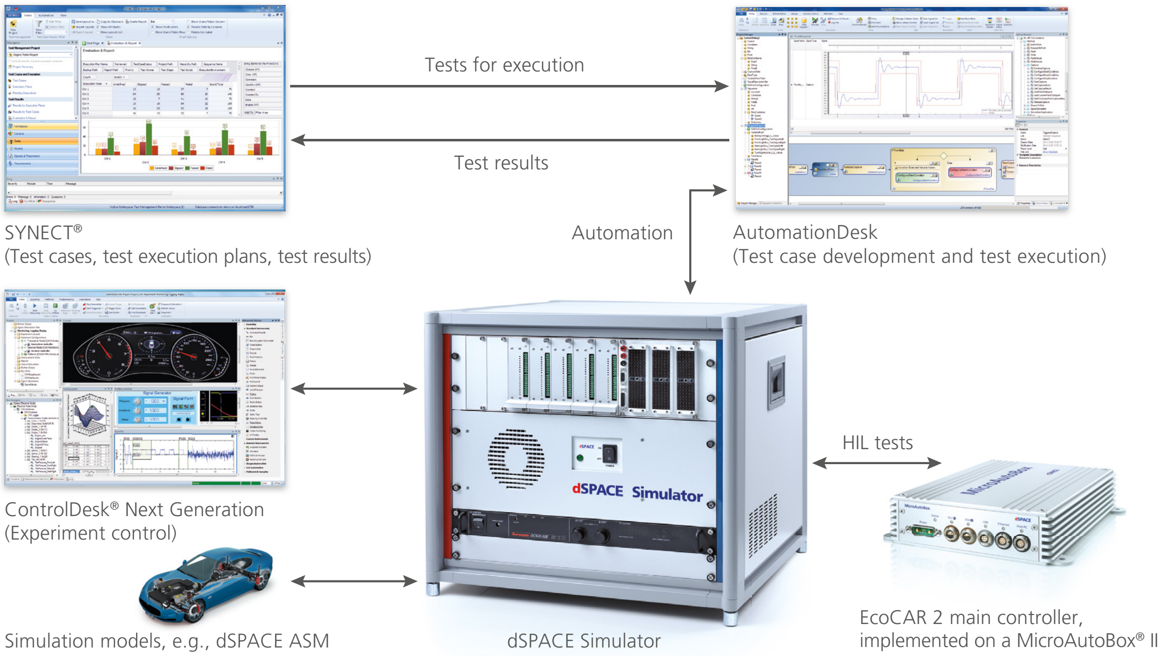

Figure 4: A comprehensive dSPACE tool chain with SYNECT as the central data management software.

- *Case 2:* Validating the combustion engine control, with dSPACE Automotive Simulation Models (ASM) as the simulation model and with their own development ECU.
- *Case 3:* Validating the transmission control, with dSPACE ASMs as the simulation model and a 128-pin Woodward MotoTron as the controller.
- *Case 4:* Validating the CAN communication of the entire controller network, developed by the OSU team.

"Initially, our team performed the tests manually, but it quickly became clear that 'more' was needed to reach the safety of the control code," said Amanda Hyde, former OSU EcoCAR 2 Fault Diagnosis Team Leader. "Extensive, automated regression testing was necessary for each new version of the code, considering the full controller functionality. The solution was to build a powerful tool chain with dSPACE SYNECT®, dSPACE AutomationDesk and the dSPACE Simulator. This automation gave our team a crucial time advantage for in-vehicle tests. Altogether, a total of 74% of our HIL tests were automated."

AutomationDesk – Test Authoring and Automation

The test cases and scripts were implemented in AutomationDesk through its graphical programming environment. Utilizing AutomationDesk's integrated debugger and the ability to insert breakpoints and investigate tests step-by-step ensured fast error-finding and resulted in reliable test sequences. Overall, the team used 76 automated tests that were covered by only 16 test scripts, due to skillful test grouping and parameterization.

"dSPACE SYNECT was a great help for our regression tests in the third year of the competition. It let us focus more on the in-vehicle tests and on the overall optimization of the vehicle, while providing a central tool for managing our development data and test runs."

Amanda Hyde, former OSU EcoCAR 2 Fault Diagnosis Team Leader

SYNECT – Superior Data Management for Automated Tests

SYNECT, the data management software from dSPACE, played a key role in the area of automated testing. First, the OSU team loaded the list of requirements from the "Control and Validation Requirements Document" into SYNECT. To define the tests, the students imported parameterized test sequences from AutomationDesk. The defined test cases, linked to the requirements for optimal traceability, were then processed comfortably step-by-step in SYNECT via the test execution plans. With the specially-configured test reports, it was easy to trace the success of the tests during the development period. Changes in the requirements, the associated test cases, and AutomationDesk automation scripts could be updated at any time with a few clicks in SYNECT. ■

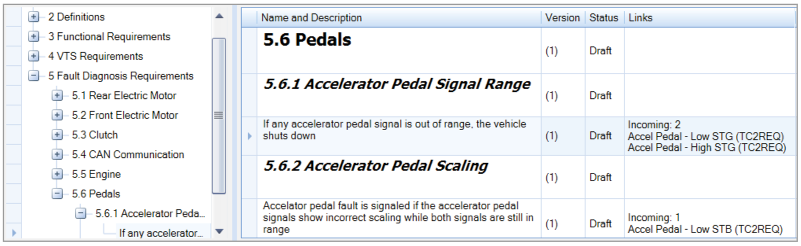

Figure 5: List of requirements in SYNECT, with linked test cases.

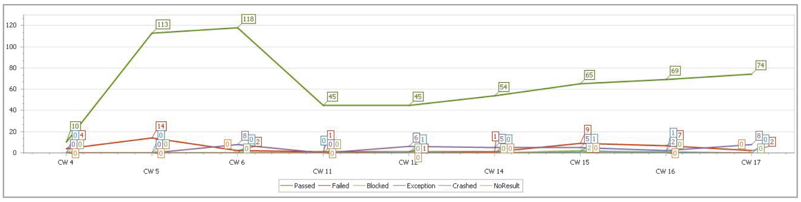

Figure 6: Clear trace of the test progress in SYNECT.

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Conclusion and Outlook

"With the high achievement goals, right from the beginning, and the significant complexity of the plug-in hybrid, our team could not have achieved success without a highly efficient development process and professional tools," concluded Matthew Yard, former OSU EcoCAR 2 Team Leader. The OSU team succeeded in optimally managing time and resources to achieve its goals. In a short amount of time, the students became accustomed to the development process and tools and gained confident control of the dSPACE tool chain, which consisted of a dSPACE Simulator, MicroAutoBox II, SYNECT, AutomationDesk, and ControlDesk Next Generation. While the EcoCAR 2 competition is over, the OSU team is now in full swing with the next advanced vehicle technology competition – EcoCAR 3. In this competition, students have four years to optimize a 2016 Chevrolet Camaro and the bar for requirements has been set even higher with added criteria for costs and the degree of innovation. The OSU team, with its new team members, continues to impress and already won the first year of this new competition. dSPACE congratulates the Ohio State University team for their outstanding performance and wishes them future success!

Figure 7: The smile of champions – The Ohio State University EcoCAR 2 team received first-place honors for their plug-in hybrid concept.