



Implementing virtual validation
at Jaguar Land Rover

Virtual Revolution

Jaguar Land Rover's motto is to create "experiences customers love, for life". To achieve this goal and continue to provide quality products to its customers while increasing the number of state-of-the-art features, there is a need for smarter software validation. The answer for Jaguar Land Rover is virtual validation, which is used to achieve the company's goals in early development phases.



The increased demand for technologies with complex software functionality and interaction, such as the autonomy functions provided by some advanced driver assistance features, calls for the introduction of new and improved methods for designing and testing the relevant software. This not only increases the need for testing in general, but also the need for testing new functions as early and efficiently as possible in order to reduce the possibility of errors and thereby mitigate the need for costly late fixes. Being smart about software validation helps Jaguar Land Rover save time and money. Additionally, the number of development, verification and validation (V&V) iterations increases, providing customers with a quality vehicle experience. One of the ways Jaguar Land Rover is being smart is by introducing virtualization, i.e., virtual software verification and validation, in order to detect and eliminate errors earlier, and accelerate the vehicle time to market. In particular, it is useful to take virtual ECUs (V-ECUs) as a means of developing and testing applications in an AUTOSAR software architecture and performing functional verification without the need for the physical target ECU. It lets Jaguar Land Rover perform tests before the supplier has completed an ECU build and provide the supplier with earlier feedback since the developers are able to test in parallel to the supplier activity. >>



Initial Challenges and Solutions

Some of the initial challenges encountered while implementing the virtual validation process in the Power Systems (PS) group included modifying the existing software development process (figure 1) and reconfiguring the tool chain to enable V-ECU development and testing. Various activities were undertaken in order to overcome these challenges. Firstly, a forum was set up to allow different departments to interact more closely. The forum included employees from areas such as software V&V, AUTOSAR architecture, hardware-in-the-loop (HIL) testing, and specific system groups. Together, it was possible to devise two flexible approaches for integrating V-ECU development into the existing software development processes: a bottom-up approach to allow for departments with verified legacy software components (SWCs) to quickly combine them and build

an integrated V-ECU, and a top-down approach for those who intend to redesign their V-ECUs for AUTOSAR or other development reasons and for using V-ECUs when developing new features. Both development approaches use the same tool chain (figure 2), and can thus be applied to best suit the needs of the particular feature development

tool for building V-ECUs. Lastly, dSPACE employees and HIL test engineers from Jaguar Land Rover looked into tool chain automation for building the V-ECU and setting it up in the test environment. dSPACE was able to customize the workflow by using Python scripts and provided a one-click solution for V-ECU and ControlDesk® plant model creation.

“Virtual Validation has revolutionized our process.”

Will Suart, Jaguar Land Rover

project. It is also possible to start development with the bottom-up approach and complete it with the top-down approach, if time permits. Secondly, the forum looked into the use of Functional Mock-up Units (FMUs) for importing existing plant and stimulus models to the VEOS® simulation environment for improved V-ECU testing. It also evaluated dSPACE’s Legacy Code Integrator, which generates virtual ECUs from legacy source code, as another

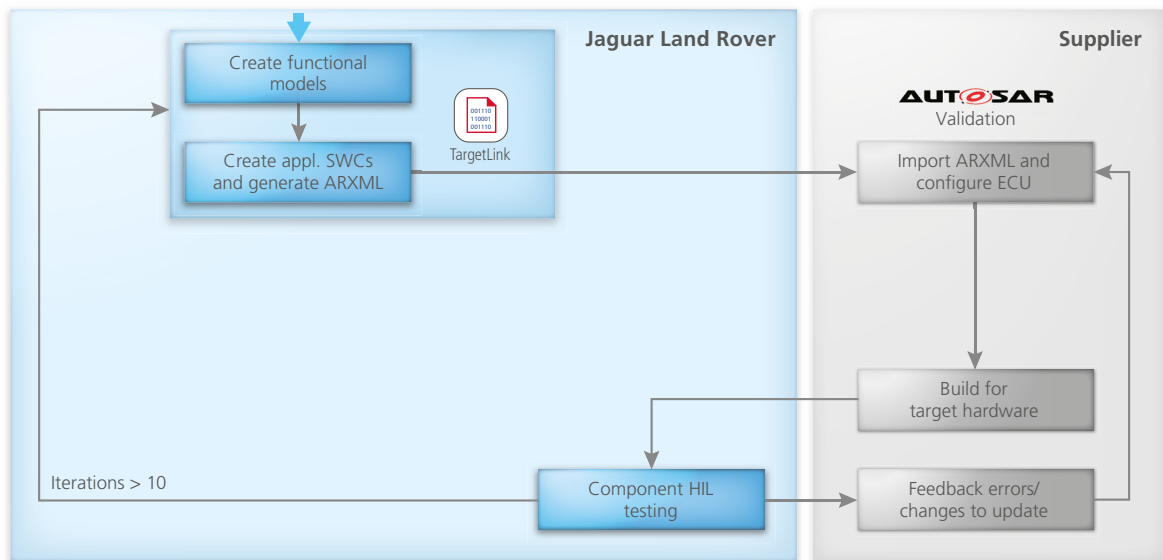
The creation of ControlDesk plant models enabled the software engineers at Jaguar Land Rover to re-use the exact same test setup (previously implemented for HIL testing of the physical ECU) for V-ECU testing.

Using dSPACE Products

In order to effectively implement the V-ECU development and testing process in the PS group, the following dSPACE tools were used extensively:

- 1. TargetLink® (Data Dictionary and production code generator), used

Figure 1: Original Power Systems (PS) development process that required multiple costly iterations before the mature application was ready for use.



Appl. SWCs = application software components ARXML = AUTOSAR XML file

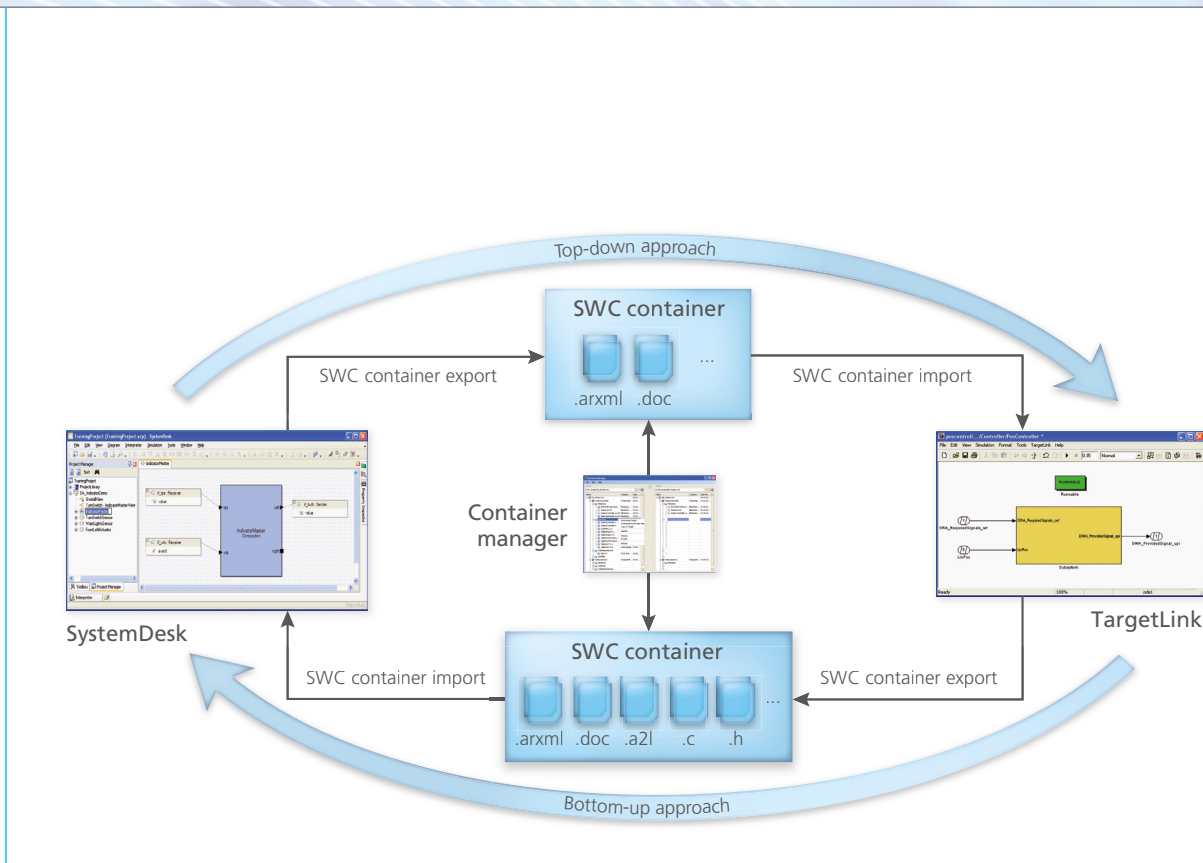


Figure 2: The bottom-up approach, starting the with software components modeled in TargetLink, and the top-down approach, where the architecture is first defined in SystemDesk.

for SWC development and considered a good and industry-standard tool for production code generation.

2. SystemDesk® was introduced to the PS group’s tool chain and proved to be a good system architecture tool, used for modeling AUTOSAR architectures, verifying compliance with AUTOSAR rule sets, SWC integration, and V-ECU generation. SystemDesk was not only a new tool for the PS group, but also introduced new activities for the software development team that were previously performed by suppliers. Therefore, it did have a steep learning curve but the documentation is very helpful and it is now an integral tool for these activities.
3. VEOS was another new tool, introduced to simulate the V-ECUs for testing. The flexibility of the simulation platform plays a central role in increasing quality through virtual testing. Key advantages of VEOS are its ability to interact

with third-party models and the level of simulation control with functions such as PAUSE, STEP, and setting the execution step time.

4. ControlDesk had already been used as the simulation experiment software by the HIL engineers. The ability to use the same tool and share experiments for testing the V-ECU and real ECU was invaluable from both a time and skills viewpoint.

Overall, dSPACE products played a vital role in implementing the virtual validation workflow at Jaguar Land Rover with the products that were already used for AUTOSAR software development and virtual/HIL testing.

Benefits of Virtual Validation

Virtual validation is used to both frontload testing to earlier phases in the development cycle (left-shift) and to increase the overall quality. Using V-ECUs made it possible to

left-shift component-level testing (figure 3). Doing this not only significantly increased the quality and confidence level of the developed software. It also shifted testing to an earlier phase in Jaguar Land Rover’s product development cycle. In terms of AUTOSAR component development, the new virtual validation workflow was particularly beneficial in enabling faster round-trips from the model to the component test platform.

By using the V-ECU development and test process, the PS group was able to save 12 weeks of verification and validation time (figure 4). Additional benefits derived from the virtual validation process include increased error detection capabilities, which in combination with the ability to perform testing earlier, provide an opportunity to perform more extensive HIL testing and robust ECU integration. Increasing the amount and capability of early-stage virtual testing at Jaguar Land Rover, and using the time

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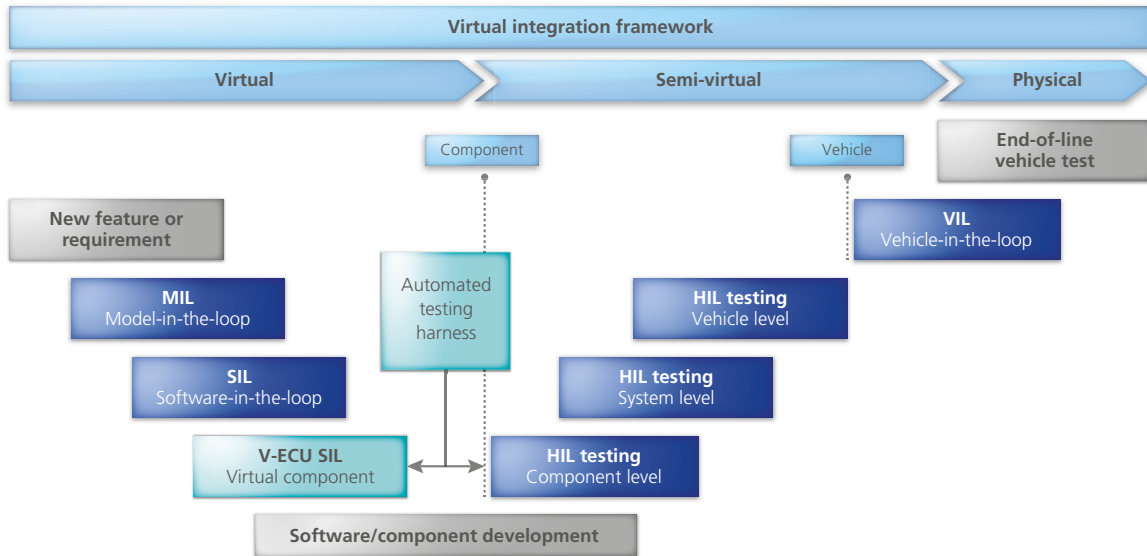


Figure 3: Virtual validation using V-ECUs allows for a left-shift of component testing.

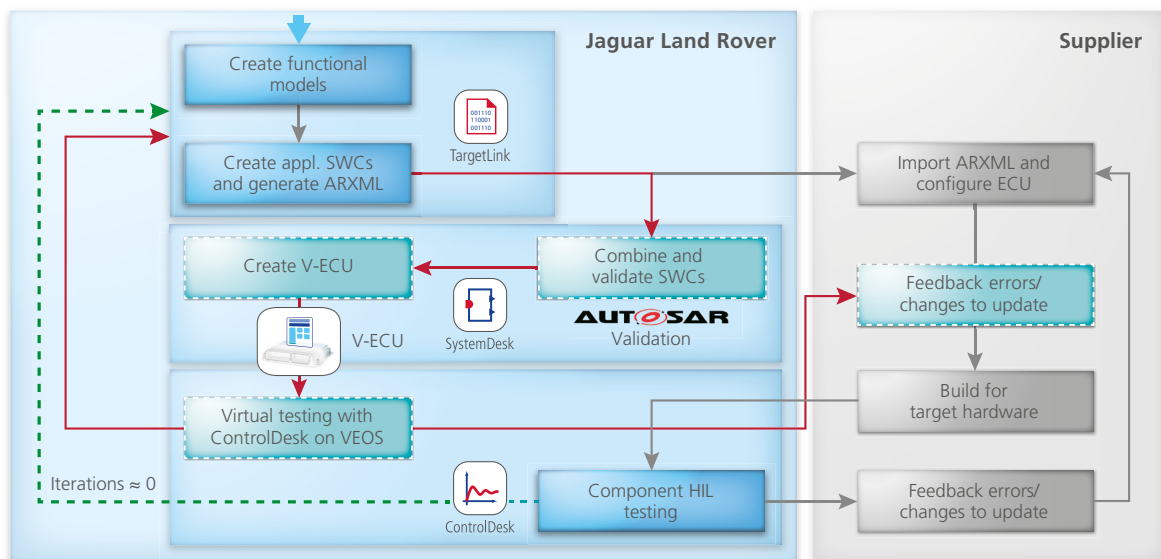
gained to increase robust HIL testing at the component and system levels, provides a visible improvement in quality confidence levels and reduces the overall time to market of the feature software.

The new workflow around the virtual validation process also improved development efficiency, both internally and in the way the Jaguar Land Rover PS group interacts with component suppliers.

Conclusion and Next Steps

Using virtual validation provided Jaguar Land Rover with important insights into changes that need to be implemented in the development process. It also demonstrated the

Figure 4: Modified virtual validation workflow (turquoise boxes and red lines) that increased the testing capability of Jaguar Land Rover. The changes provide increased confidence levels in the correctness of the application before handing it over to the supplier and entail fewer supplier iterations before the product is ready for deployment.



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“dSPACE products played a vital role in implementing our virtual validation workflow.”

Leonardo Poeti, Jaguar Land Rover

flexibility of the tool chain and workflow, which can be adjusted to existing processes at Jaguar Land Rover and its suppliers. Overall, the benefits of implementing virtual validation and supporting a formalized consistent approach to AUTOSAR software development at Jaguar Land Rover are clear. From now on, Jaguar Land Rover plans to extend its virtual validation capabilities in the following ways:

1. Increase the testing capability by using V-ECUs on SCALEXIO® HIL test rigs and MicroAutoBox® II.
2. Build a network of multiple V-ECUs up to the vehicle representation level in order to perform full-system and vehicle-level virtual validation.
3. Integrate multiple V-ECUs and real ECUs in a HIL simulation environment.
4. Seamlessly migrate from virtual to real ECUs in the V&V environment.
5. Reuse existing system architectures for V-ECU generation when adding new features to an existing ECU. ■

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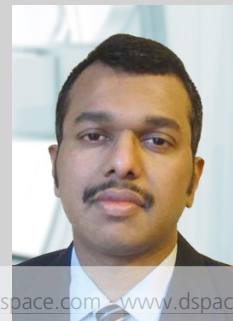
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Why Virtual Validation?

- The new virtual validation workflow enabled faster round-trips. In fact, the Power Systems group was able to save 12 weeks of verification and validation time.
- Using V-ECUs made it possible to left-shift component-level testing to a very early stage of Jaguar Land Rover's product development cycle. This left shift significantly increased the quality and confidence level of the developed software.
- dSPACE was able to customize the workflow by using Python scripts and provide a one-click solution for V-ECU creation.
- Jaguar Land Rover was able to reuse the same test setup for V-ECU testing that was previously implemented for HIL testing of a physical ECU.
- The number of costly iterations was reduced from more than 10 to almost 0.
- Up to 80% of ECU testing was performed with V-ECUs