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New Tool Chain for Virtual Brake Control System Validation

Validation of brake control systems is becoming increasingly supported by simulations executed on test benches. Performance and test speed are largely determined by the degree of automation of the tool chain used. Elektronische Fahrwerksysteme GmbH (EFS) shows how it has moved to fully automated test execution and the replacement of its entire tool chain in ongoing operation of ESC testing.

MODEL REQUIREMENTS FOR VIRTUAL VALIDATION

As a result of the diversity of functions and derivatives, as well as efforts to increase efficiency of hardware-in-the-loop (HiL) testing for vehicle stability functionalities, test tasks and validation tasks are assigned increasingly to the virtual test drives. The entire working environment of the virtual test drive, in addition to driving dynamics modelling, must also be flexible and highly automatable and fulfil many additional requirements, in order to be capable of handling the fast-growing complexity of virtual validation methods. Here, the development of such requirement validation includes examination and demonstration of how full migration of an existing tool chain for functional brake control system validation, to HiL test rigs in ongoing operation, could be achieved and which motivators were defined by the individual components.

SCOPE ESTIMATE AND POTENTIAL COURSES OF ACTION

The focus on the development starts in 2011 with intensive validation of selected brake control functions, such as the electronic parking brake and central stopping and deceleration management, on HiL test rigs. **FIGURE 1** illustrates the development of the test scope levels. Both staff and test scopes, measured as a number of manoeuvres executable on ESC-HiL, are continually increasing with a slightly exponential character. Test execution, test bench design, and model development, at the start of the review between 2011 and 2014, were heavily characterised by highly specialised function manipulation of the software components to be tested: each test scope for a component is assigned to a single test bench together with an individualised

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braking system, Restbus driving dynamics model adaptations, and a specialised development partner.

Intensive project restructuring started in mid-2013. **FIGURE 1** shows mid-2014 as a reference point in time for the standardisation of required resources and test scope at the time of trade acquisition by a representative (phase 1). During the course of trade setup, the actual employee resource planning deviated significantly for the first time from the staffing requirement curve that was originally anticipated and required at that time. In order to accomplish the upcoming software validation runs, all existing work methods were investigated to leverage immediately accessible optimisation potential. When doing so, the focusing of resources dominated above all by consistent standardisation with uniform driving dynamic models and simulator design, test area structuring as well as the connection to powerful OEM IT infrastructure.

Against the background of the anticipated significant increase in test scopes due to a strongly increasing degree of networking (powertrain, chassis, brake control system, etc.) and functional scope (driver assistance such as distance measurement to the vehicle in front, lane assist, etc.), phase 2 indicated, **FIGURE 1**, that further efficiency gains as a result of further optimisation of the HiL hardware environment were no longer feasible and that instead, new opportunities for action would need to be investigated: Option 1 would be a planning with no change to the tool chain and increase in employees, Option 2 focuses on the adaptation of the simulation tool chain. The tool migration should, however, not exceed the cost advantage of the test resources saved.

DEFINITION AND SPECIFICATION OF A SIMULATION TOOL CHAIN

The essential framework conditions fall into five main categories. The tool chain for validation of brake control systems on a hardware test bench must
- be state-of-the-art and have standardised interfaces
- offer the possibility of certification
- represent a professional tool environment
- be flexible and intuitive to operate
- and enable adherence to Volkswagen-Group standards (control unit communication, test bench automation, etc.).

When measured against these requirements, the existing tool chain proved to not be future proof. It can, however, provide important experience for the definition of a new, future-orientated working environment in which the driving dynamics simulation acts as a core component, but alone does not fulfil all essential requirements. **FIGURE 2** shows the definition of a target tool chain.

The requirements to be tested are maintained in the requirement management tool Doors and can be read out automatically. For example, vehicle-specific parameters shall be maintained in the requirements document and not in the test case definition. As a Group standard, Exam is the tool for test automation for the entire test bench. Odis defines the communication with the control unit. The decisive advantage when choosing software packages lies in their accountability and group-wide visibility. Should errors occur in one of these group tools, they will be quickly detected by a large user group, and handled by a support and development team of adequate capacity. Maintenance is thus not the responsibility of the test execution team.

In addition to automation, it must be possible to execute functional and software tests on the hardware test bench in parallel with development, without having to involve a testing vehicle or prototype. A suitable tool chain should enable intuitive working. Based on the premise of building the tool chain on commercial software and group-wide standard pro-

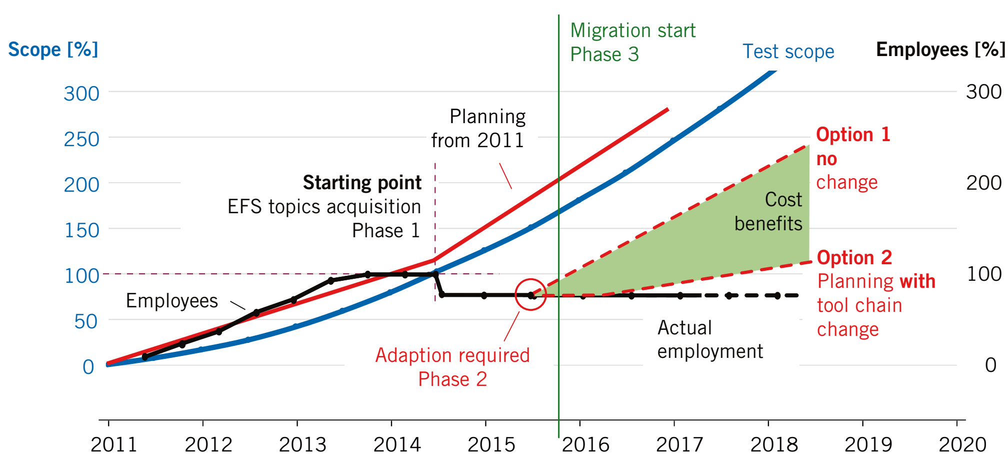

FIGURE 1 Resource planning and test scope development of test scopes from the virtual validation of brake control systems, with key phases: 1) trade setup and topics acquisition by a representative, 2) principle decision on maximum optimisation of the existing tool chain, 3) implementation of the decision on tool chain change (© EFS)

cedures, in the overall chain the question remains as to the optimal simulation tool for driving dynamics calculation. Three market-leading vehicle dynamics simulation representatives were involved in the evaluation process.

Evaluation includes, in addition to catalogue value evaluations, a significant practical phase in which test systems were built using the respective simulation software. Two groups of "experienced employees" and "new employees" were assigned the task of implementing existing and new test scopes for a specific brake control function on the physical test system, with the time available to them and technical support from the manufacturer. The measured variables of time to learn the system, operability, and usability were captured as part of this exercise, within a fixed time frame of undisturbed work, **TABLE 1**. The benchmark was supplemented following intensive cost negotiations regarding financial cost, **TABLE 1**. Costs are classified from 1 to 3 (lowest to highest financial cost). Provider 3 was selected from a functional, technical, and specialist viewpoint. This enabled phase 3 of the project to begin at the end of 2015, **FIGURE 1**.

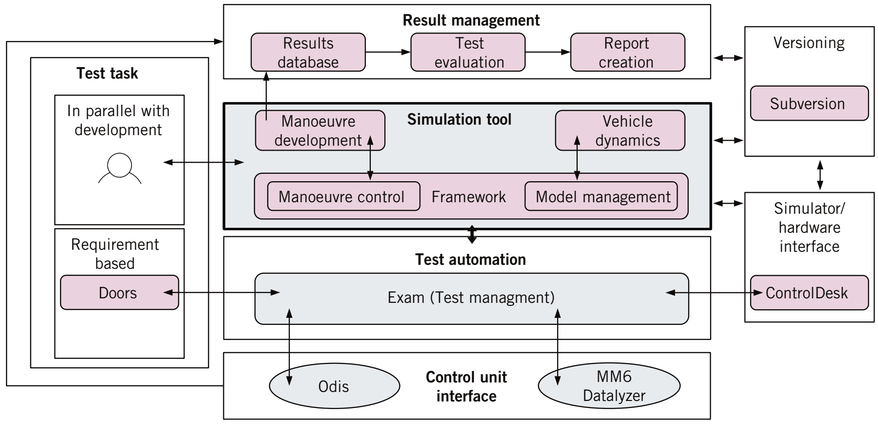

FIGURE 2 Functional requirement and creation of a tool chain for fully automated validation of brake control functions on a hardware-based test bench (© EFS)

Criterion	Provider 1	Provider 2	Provider 3
Test creation effort	100 %	50 %	25 %
Test execution duration	100 %	n.r.	15 %
Test migration effort	100 %	n.r.	35 %
Development phase testing	–	n.r.	+
Tech. Support	–	+	+
Familiarisation time	–	–	+
Operability, usability	–	o	+
Model changes effort	–	n.r.	+
Debugging	–	n.r.	o
Cost from 1 lowest-priced to 3 highest-priced provider			
Licences	2	1	3
Migration expenditure	3	1	1
Internal migration costs	1	2	2
Maintenance per year	3	1	2
Total costs	**2**	**1**	**3**

TABLE 1 Standardised results from evaluation process of three software providers of vehicle dynamics simulation on the actual test scope catalogue of a brake control function (n.r. = not rateable, due to incomplete test bench implementation) (© EFS)

TOOL MIGRATION PROJECT

In order to meet the software release dates planned throughout the year, it was necessary to carry out migration as quickly as possible. To do this, test case migration rate tracking was introduced for all applicable test scopes (test catalogues). All test catalogues had to have a 100-% migration share by 27 April 2016, **FIGURE 3**. Synergy effects and the complete revision of all test cases resulted in reduction in test scopes in half of the test catalogues. This meant that the 100 % mark represented the revised state of the Doors functional software requirements. Over 20 test catalogues were migrated to the new tool chain in this way.

The test team effectively implemented the overall migration in three months. During this time, an additional five complete test executions, including report generation, were added to the old tool chain. Migration of the entire tool chain described here thus constituted a significant additional workload for the team, with operations still ongoing. Additional challenge for the model development team was to create and validate an entirely new kind of vehicle dynamics model, in addition to ongoing support of the existing tool chain.

TESTING RESULTS

In mid-April 2016 the first report of all test cases executed successfully in the new tool chain were generated and submitted. This was at a test bench resource saving of 30 %. The free test benches are available for new test scopes, **FIGURE 4**. The tracking also includes non-running of a test bench, which corresponds to free potential. 100 % here refers to the maximum time that all test benches can run together in eight hours over five working days. With the new tool chain, each test bench is documented as more heavily utilised than previously. **TABLE 2** summarises the main results of this performance test on a test bench setup with three specific function passes of a fully identical test scope in the new and the old tool chains. **TABLE 2** shows a comparison of execution times and measurable experiences of three large test scopes (catalogues 2, 4, and 5).

With the automation of the encoding (vehicle installation condition) and the dataset writing (vehicle parameters, tyre data), and the setting of adjustment chan-

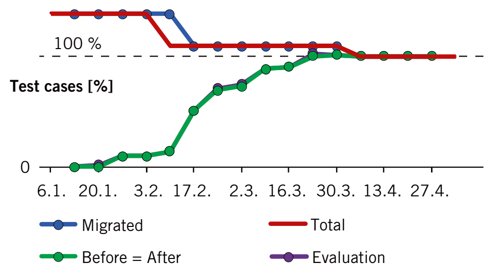

FIGURE 3 Migration tracking of a specific test catalogue for a brake control function with standardisation to target test catalogue requirements (© EFS)

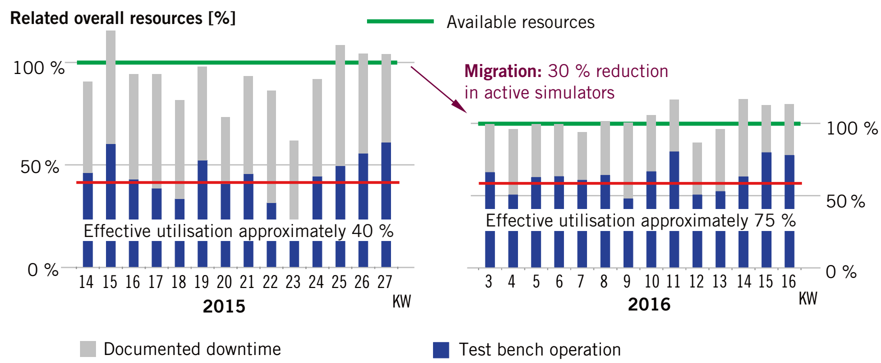

FIGURE 4 Results of tool migration today: reduction in test benches, comprehensive tracking of test bench capacity, approximation to the optimal 85 % test bench capacity limit (© EFS)

nels, the new tool chain made it possible to execute an entire validation of a software version with no test run interruption. The next step is automated sequencing of multiple test catalogues with the aim of uninterrupted execution for overall validation of an entire software baseline on the HiL test bench. After a year of active working with the new tool chain it can be concluded that, in spite of the migration effort, the output increased by a factor of 2.5 from 2016 to 2017.

MIGRATION DIFFICULTIES AND CHALLENGES

During active migration and changeover from the established tool chain to a new one all engineers involved faced many individual challenges to be overcome, which could not have been fully predicted. This included that each test case had to be adapted and largely redefined and that the automation required intelligent error handling. The diversity within the team includes a common understanding of manoeuvre specifications, which can be interpreted independently of individual test experts. This also includes a common knowledge base for all team members.

In addition, the traditional method of working is fundamentally changed, new software and interface adaptations take place during ongoing operation. Here, difficult decisions as to whether necessary adaptations with fixed deadlines should be implemented in the new or old tool chain had to be taken. Courage to implement change and an active risk management brought the large project to its successful conclusion.

SUCCESS FACTORS

The test automation team consisted of experienced employees committed to delivering unambiguous and rigorous implementation specifications and mandatory use of new standards. Tracking the migration speed helped to quickly identify congestion and to implement adaptive support at the relevant bottleneck when migration speed dwindled. Free radicals in the form of flexible employees provided specific help with direct and indirect support and capacity reorganisation.

For the teams involved, the tool migration represented an intensively applied training programme and the tool chain was mandatory for all test experts from day one. The tool manufacturers continuously provided fast and professional support. Finally, it is attributable to the outstanding contribution of the team, who made successful migration possible, that today the potential of the simulation environment ranges far beyond the validation of brake control functions and is able to bring future topics such as highly automated driving into focus.

	Starting point	As of 06/2016
Degree of automation	Low	Exam -> test control
Test cases migrated	100 %	98.4 %
Test bench running time for catalogue 2 I 4 I 5	23:28 h I 22:12 h I 15:59 h	12:04 h I 10:17 h I 8:23 h
Processing time 2 I 4 I 5	40 h I 35 h I 40 h	40 h I 25 h I 30 h
Test creation duration with evaluation	100 %	50 %

TABLE 2 Comparison of execution times and measurable experiences of three large test scopes (catalogues 2, 4, and 5) (© EFS)