Simulation-based Development Process for Motorsport and Series Production

AUTHORS

Dipl.-Ing. Kai Fritzsche
is Consultant Performance LMP1 at Porsche in Weissach (Germany).

Dipl.-Ing. (FH) Florian Strecker
is Special Consultant Driving Dynamics, Calculation & System Dynamics at Porsche in Weissach (Germany).

Dr.-Ing. Malte Huneke
is Head of Performance LMP1 at Porsche in Weissach (Germany).

The Porsche development centre in Weissach (Germany) is home to both of the vehicle series production development as well as the motor racing application and development departments. We can see clear parallels when we look at the tasks and challenges involved in the development of road vehicles and racing cars. Both areas only have short development periods and limited resources available. These overlaps suggest there ought to be close collaboration in the areas of method and tool development.

RETURNING TO THE TOP TIER AT LE MANS

In addition to making a major commitment to GT and road racing vehicles, Porsche Motorsport has been participating in the LeMans-Prototype-1 (LMP1) class of the FIA WEC racing series with the Porsche 919 Hybrid since 2014. The WEC includes nine races per year: eight 6 h races and the 24 Hours of Le Mans. The manufacturer vehicles in the LMP1 category are hybrid vehicles for which the regulations allow a great degree of technical freedom. The 919 Hybrid, **FIGURE 1**, has an electric motor at the front axle, giving it a temporary all-wheel drive with an additional power of 300 kW. However, there are upper limits on the amount of electric and fossil-fuel energy released per lap. To ensure racing success, the focus is therefore on developing overall vehicle efficiency.

VEHICLE DEVELOPMENT 2.0

Systems are becoming increasingly complex both in road vehicles and racing cars. Due to the growing influence of software on vehicles in both fields, the issue of software development and application is gaining importance. However, this does not eliminate the need for comprehensive hardware development. Chassis and drive control systems help tap into all the potential offered by the overall system.

In the LMP1 racing car, new software versions can also be developed and introduced between races. In contrast to hardware development, this brings improvements to the vehicle without involving major lead times. For road vehicles, it is also already technically feasible to retrospectively load new software versions into the customer vehicle. However, new functions can only be tested using model-based variant studies due to the high number of vehicle, model and software variants.

SIMULATION AS AN EXCHANGE PLATFORM

One of the core competencies at Porsche during vehicle development is objective evaluation of vehicle dynamics. Although commercial software packages are available for this task, Porsche prefers to use tools developed in-house for simulation of vehicle dynamics and objectification of vehicle handling. All models and programs developed in-house are provided centrally for motorsport and series production applications. In areas where competition is less relevant, it makes more sense from a strategic perspective to use commercially available products.

An enhancement for tools developed in-house that is particularly helpful in motorsport is the use of a driving simulator with a motion platform. Simulator specific hardware and software are not regarded as core competencies and are therefore procured from a system supplier (VI-grade). However, the same vehicle model developed in-house and used in the remaining simulation tools is used as the vehicle model and integrated into the simulator environment. The use of the simulation models can therefore also be extended to the area of subjective evaluation by the driver. The driver is essentially serving as an evaluation tool, whereby subjective impressions are used in addition to objective key figures in order to evaluate handling. The vehicle model delivers reproducible, deterministic behaviour in a safe but still sufficiently realistic environment. This permits rapid development and meaningful preliminary synchronisation of connected functions that are relevant for handling. A positive side effect of using the same vehicle model for this type of application is the increase in model quality across the model's entire application area. Evaluating lap times on the driving simulator is particularly useful for issues relating to vehicle stability limits. In contrast to offline simulation, a human driver cannot tap into the entire theoretical potential of a vehicle. Vehicle handling close to the individual stability limit has a significant influence on the lap times a human driver can achieve. On the other hand, there are questions that are better answered through offline simulation. The influence of changed driving resistance on lap times can be evaluated with greater accuracy through offline simulations as the variance of a human driver does not apply in this case.

In-house development of tools has several advantages.

- Models and evaluation software serve as an executable knowledge database and communication platform for all users, allowing for a lively exchange between all the departments involved as well as between motorsport and series production developers. Customised integration into the processes ensures that they can be used efficiently and with ease.
- In-house development significantly improves understanding of both tools and vehicle handling. It provides the opportunity for quantitative evaluation and creation of objective and authoritative key figures.
- Using methods, models and evaluation programs jointly across projects and departments automatically creates the need for close collaboration and communication and therefore ensures a constant exchange of knowledge between the different areas in the development centre. It also results in common metrics and a common language for describing driving physics. In addition, tool extensions and improvements will benefit all users, **FIGURE 2**.

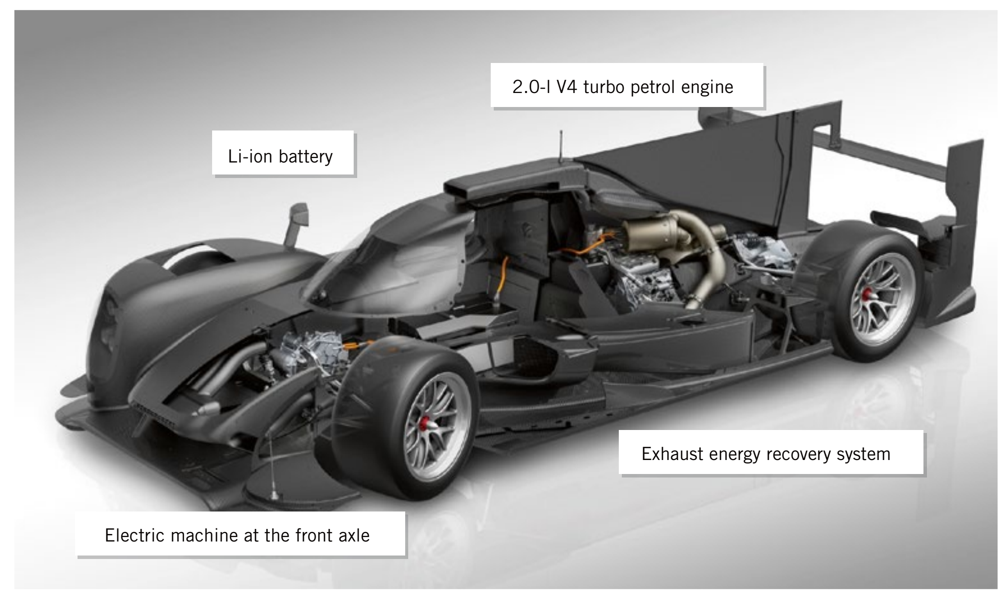

FIGURE 1 Technical details of Porsche 919 Hybrid (© Porsche)

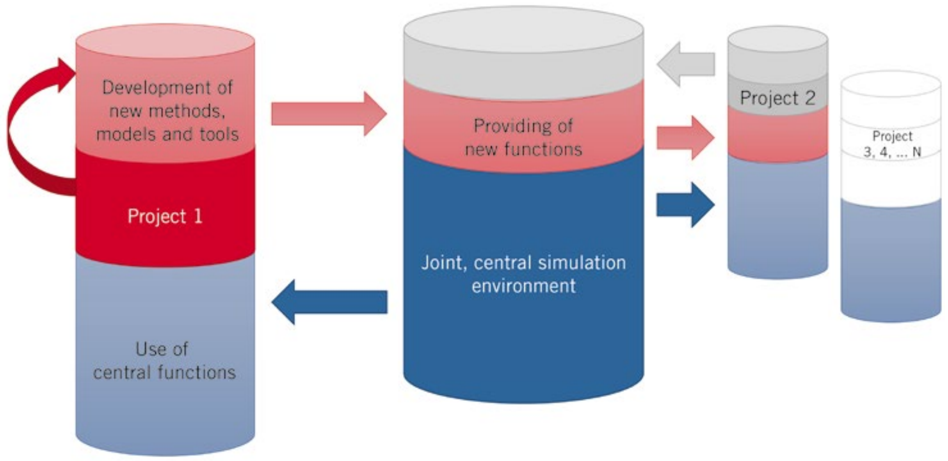

FIGURE 2 Central simulation environment as project platform (© Porsche)

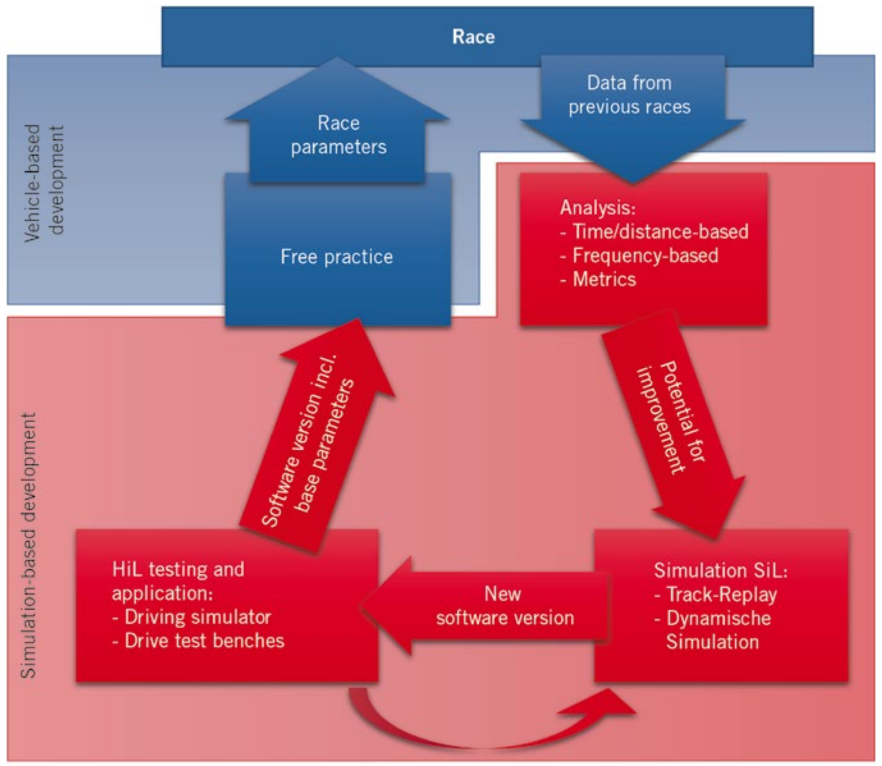

FIGURE 3 Steps during the software development process between races (© Porsche)

- In-house models and evaluation tools make it possible to work in a very quick, flexible and efficient way and to quickly adapt to new requirements, different vehicle concepts and new systems.

Generally speaking, simulation permits a high level of test coverage and thorough screening of new system approaches prior to setting up actual prototypes.

The key factors for good integration into development activities include a sensible choice of model complexity and an established catalogue of objective test criteria and key figures that make it possible to compare measurement and simulation.

WHEN ONE RACE ENDS, ANOTHER BEGINS

The preparation for each LMP1 race can be seen as an individual development process. Hardware changes between races are only possible to a limited extent, but it is possible to develop and introduce new software functions, **FIGURE 3**. This is why similar steps are followed as during the series production process between the races, but within a shorter period of time. In the case of functional software updates, the steps are as follows:

- Analyse the previous race as well as the upcoming race from the previous season to identify potential for improvement for the next race.
- Develop potential for improvement identified in the simulation. To that end, the control system software is linked to various simulation environments as software-in-the-loop. On the one hand, recorded track data can be loaded into the software to analyse direct changes to the previous version based on track data. On the other hand, the software can be linked to the dynamic simulation model to evaluate variants in the closed control loop based on individual manoeuvres or lap time simulations.
- Test the newly developed software version on various levels. New functions are always tested on the hardware-in-the-loop test bench. This ensures that the functionality is also provided on the target hardware in the compiled state. In addition, innovations are tested on the driving simulator as part of the race preparations. This ensures that the desired influences on handling are working correctly in the closed control loop. As a side effect, the test on the driving simulator in a realistic environment also checks the functional robustness. The driving simulator also makes it possible to develop the application of the software based on the data gathered and subjective driver evaluation in rapid iteration steps. Updates, which to a large extent are directly linked to the hardware, will continue to be released on drive test benches as well as during test drives on the test track where necessary

BOOST STRATEGY ON THE DRIVING SIMULATOR

The 2016 season race in Mexico is a concrete example of the process and the integration of the development tools as part of the race preparations. The WEC was held in Mexico for the first time in 2016, which meant that none of the competitors had any experience on the race track. This made the importance of the simulation tools more evident than in other races.

A key issue as part of the race preparation is the development of the boost strategy. It defines the permitted amount of electrical energy and the power level for the boost in each sector of the track. However, the entire amount of energy that can be released for each lap is limited; in Mexico it was limited to 3.92 MJ. The additional power of 300 kW could therefore be applied for a duration of 13.07 s per lap. With a lap time of roughly 1:26 minutes, this corresponds to 15.2 percent of the lap. It is always the goal of strategic energy distribution to minimise the lap time. However, since the powerful temporary all-wheel drive also influences handling, the influence on driving dynamics must also be considered.

The development of the boost strategy for a new track begins with the optimisation of the energy distribution using the vehicle model. The necessary prerequisites for these lap time evaluations on the track typically involve high-quality measurement data that can be used to derive the vehicle trajectory.

As an alternative, a driving line can be recorded with a factory driver on the driving simulator, **FIGURE 4**, due to the highly precise track models. This driving line is then used as a basis for the first simulations to prepare for the race and therefore also to optimise the boost strategy. A first iteration variant of the boost strategy is available as the result of the optimisation. It is then used as a starting point for another session in the driving simulator. The goal of the session is to fine-tune the boost strategy in terms of vehicle balance and driving quality. This is done on the basis of a subjective evaluation by one or more factory drivers in the simulator. Furthermore, variants are developed that, for example, include a strategy for the start of the race or different strategies to provide assistance with a passing manoeuvre. As the original variant is used as a basis for comparison, all variants generated on the driving simulator are evaluated once more during an offline simulation. At the end of the process, relative lap time differences compared to the original variant without any driver influence are available.

The result of this race preparation process is a high-quality base strategy. The time available during free practice can be used effectively to fine-tune the remaining unknown variables. This may include the response to weather conditions, the interaction between tyres and asphalt or the response to traffic conditions. Although the driving simulator is not typically used as a driver training tool, it has a positive side effect on new tracks in particular as the drivers are familiar with the track layout and have already driven the vehicle virtually on the new track. The **FIGURE 5** illustrates the lap times from the flying laps by the three LMP1 manufacturers in the first session of the 6 h of Mexico race (collective test) in ascending order.

The results show that, thanks to the procedure described above, the lap times by the Porsche vehicle were already more consistent and faster during the first free practice than those of the competitors.

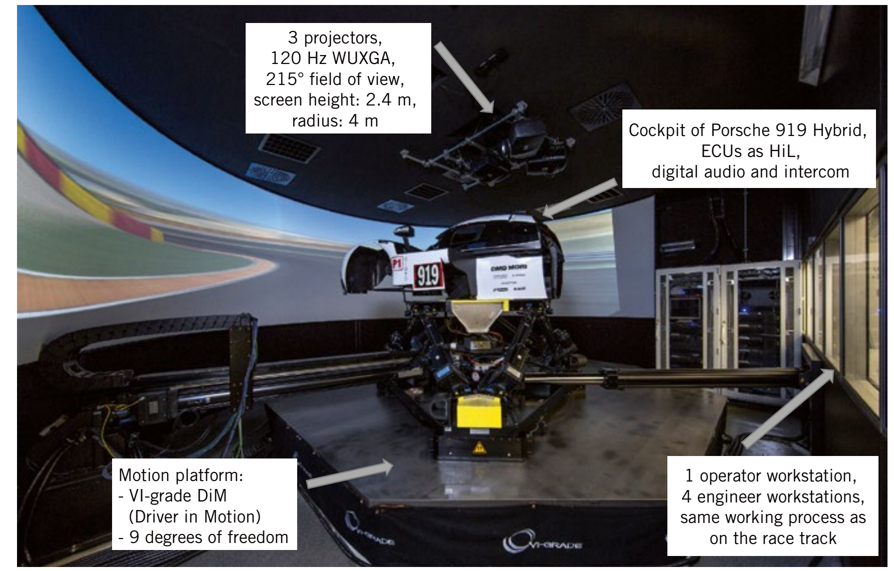

FIGURE 4 Profile of the Porsche LMP1 Team driving simulator with 3 projectors, cockpit, motion platform and (© Porsche)

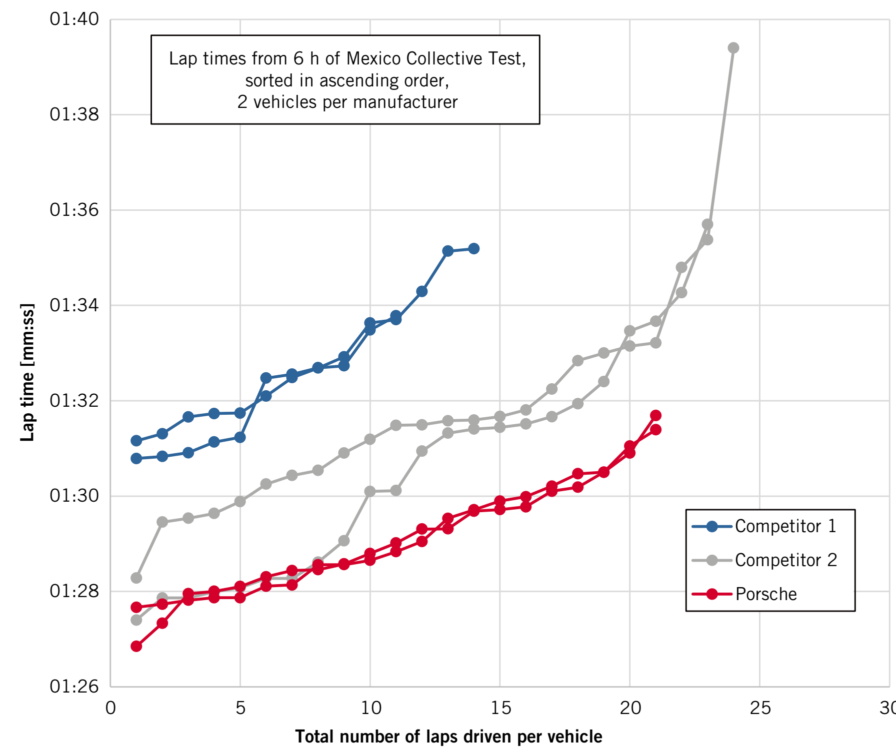

FIGURE 5 Lap times from the 6 h of Mexico 2016 Collective Test (© Porsche)