White paper

Mastering Development Requirements of Modern Vehicles

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Content

1. Introduction

Mastering the complexity caused by development of modern vehicles is crucial. The main reason for the steady increase of complexity is the growing portion of software in vehicles. In the past, vehicles differed from each other especially in terms of hardware components, but today, software is becoming the key distinguishing feature and determining factor for vehicle characteristics. This development is known as software-defined vehicle.

Due to the increasing portion of software in vehicles, it is more and more important to significantly shorten development times (time to market). One exemplary cause for this is that vehicle owners expect OTA software updates during the entire product life cycle, enabling bug fixes, improvements and new vehicle functionalities even after multiple years. As a consequence, every vehicle will be unique and change constantly, which is linked to high costs and enormous validation and release efforts.

To be able to master this complexity in the development process, a superordinate simulation level is required. To introduce such a level, the following questions need to be addressed:

Which prior-ranking goals need to be achieved?

- Coverage of all relevant test cases
- Simultaneously considerable shortening of development times

Which features are decisive for such a superordinate simulation level?

- Easy access to all relevant data
- Option to manage and revise the accruing amount of data

To take a closer look at these topics, this white paper uses the development and test environment VIRTO as an example to overcome various challenges of modern vehicle development, regardless of company size and type.

2. Requirements for Virtual Vehicle Development

For scalability and cost efficiency reasons, current development aims at virtualizing as many areas of testing as possible. In this context, tests for individual software modules in simulation are often performed in an isolated way. In many cases, their integration only takes place later on in the physical vehicle.

Virtual prototypes which evolve during the development and utilization cycle play a key role here: They can map validated representations of physical vehicles and include models of all relevant (sub)systems of their real-world counterparts, see fig. 01. Therefore, they represent the basis for agile development and validation in between defined quality gates as well as for management and validation of OTA updates during the entire life cycle.

Fig. 01: The virtual prototype and its components

As the complexity of simulation and the vehicle itself is increasing, more and more staff has specialized to cover specific fields of simulation, while, in the past, individuals were responsible for the entire simulation process. As all involved parties need a common work progress status, it is crucial that required models and data are available across departments and the entire company at all times. Another premise for the correct setup of virtual prototypes is the availability of component data to parameterize simulation models. Furthermore, data about the function software in the vehicle including calibration data, data to describe scenarios as well as measurement data from sensors and about the vehicle's driving status are needed.

An option to save, compare and analyze simulation result data as well as potential test data to improve the software is essential, too. In addition, all data need to be traceable. Developers with no simulation skills, e.g. from the field of software development, should be able to use simulation as well – in the best case without noticing it, for example when simulation is triggered automatically in the background.

Based on a detailed analysis of current development processes and focusing on the mentioned requirements, IPG Automotive invested a great deal of expertise to design a suitable development platform. The main goal was to close gaps in the development process and to thus enable a continuous testing process. It was hence vital to consider all imaginable problem areas as well as to be able to flexibly adapt the platform to existing development processes. The decades of industry expertise and the constant exchange with experts from the field on the use of a corresponding platform in every-day work defined the following basic premises.

A suitable development and test environment must essentially cover three fundamental areas of test driving. The first area is the simulation setup, the so-called build process. It includes the generation of virtual vehicle fleets enabling to test them in test drives. The challenge here is that vehicle data and parameters, simulation models as well as software need to be integrated safely, reliably and at predefined points in time.

The development and test environment VIRTO was designed based on this concept to present a solution for all named challenges. With the modular concept it is possible to close individual gaps in the development process in a targeted manner. VIRTO is an optimal foundation for the build process as vehicles are already checked and evaluated regarding basic functions from the beginning. The second area covers the actual simulation with selected scenarios as well as components. Tests can either be performed on dedicated computing clusters such as HPC or in the cloud at defined points in time. The third area, which at the same time is the key function of VIRTO, focuses on process chain automation

3. Basic Concepts of the App Suite

VIRTO offers a new and intuitive access to virtual vehicle development that benefits all company types and sizes. As a modular app suite, VIRTO provides a collection of individual tools that can be used independently from each other or as a complete toolbox, see fig. 02. In a consistent development environment, this enables seamless data and workflow management for fully traceable simulation.

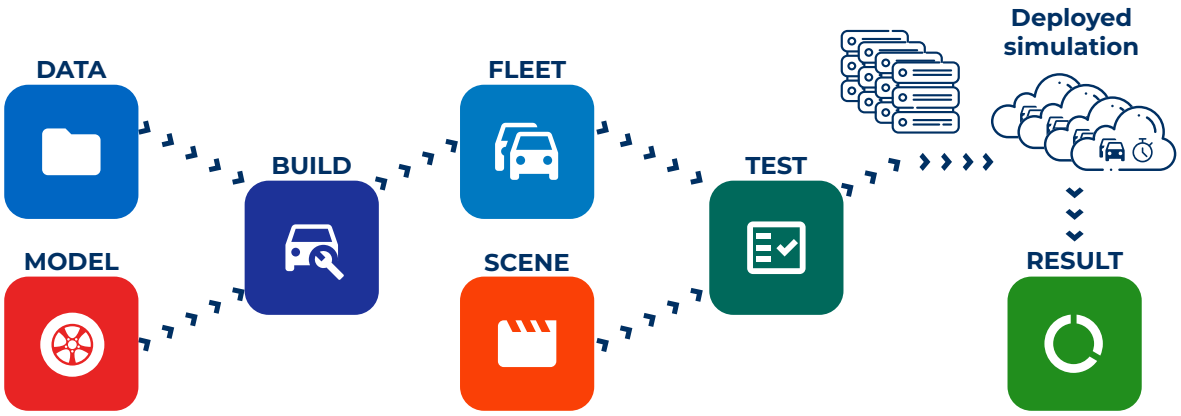


Fig. 02: Application overview of the development and test environment VIRTO

The software infrastructure is divided into seven applications which reduces the complexity that use of simulation can entail. At the same time, it simplifies the management of parameter data, vehicle software, test results and vehicle models. The applications are web-based and connected to a central entity such as the cloud. They are modular and oriented towards the workflows of development processes to ensure a seamless solution from the output data to the visualization of test results.

In a shared development environment, developers from different fields of expertise can collaborate seamlessly. The generation of valid virtual prototypes is covered as well as the management of complex simulation scenarios. The environment is created in a way that it can be adapted for seamless integration into existing processes. The resulting toolkit offers users the option to optimize their individual development work. Since the tool environment can also be used for individual components, integration into existing tool landscapes according to requirements is possible.

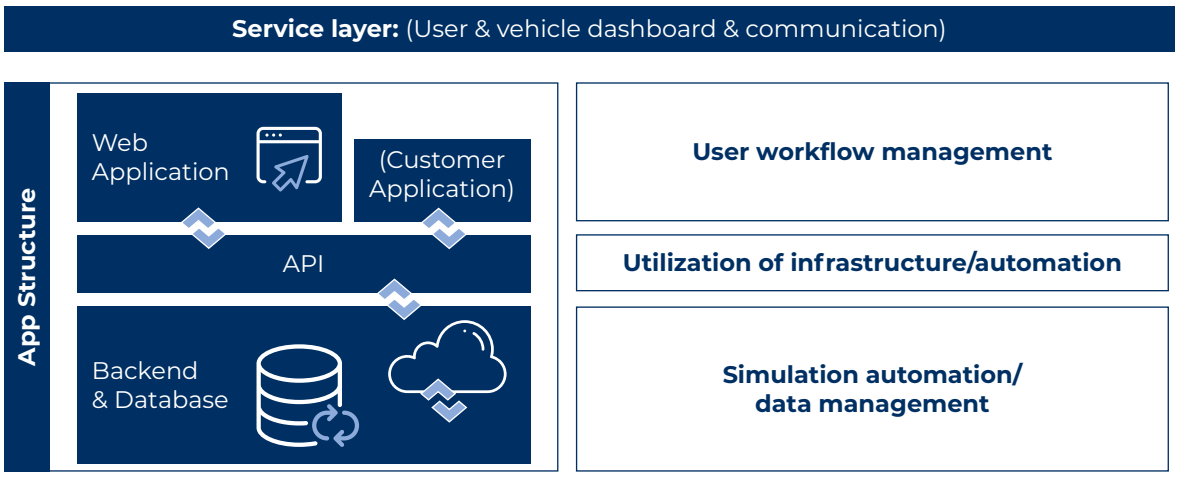


Fig. 03: Overview of architecture: Frontend – REST API – database/backend

Every VIRTO application is set up modularly, see fig. 03, footed on a level consisting of a backend logic and connected structure-free databases. The access to this level is ensured with a defined and expandable REST (representational state transfer) API as an interface. This enables a high degree of application and data access automation while a micro-service architecture and container orchestration ensure a use that is as efficient as possible. Moreover, a web-based user interface provides protected end points combined with a documented access as well as various dashboard configuration options and thus ensures secure user access. In this way, any user-defined work process can be represented individually.

4. VIRTO Components

Fig. 04: VIRTO landing page with an overview of all applications

VIRTO fundamentally changes conventional development processes. The workflow always begins on the landing page, see fig. 04. Here, all required applications to optimally navigate the world of virtual test driving can be configured freely and are available in one location. Work can be carried out locally or in the cloud.

The first component VIRTO.FLEET is the basis for a virtual vehicle fleet in which simulation models are easy to access for all involved parties and any configuration of the virtual vehicle derivatives can be managed, see fig. 05. The virtual vehicle fleet is quality checked, traceable and versioned.

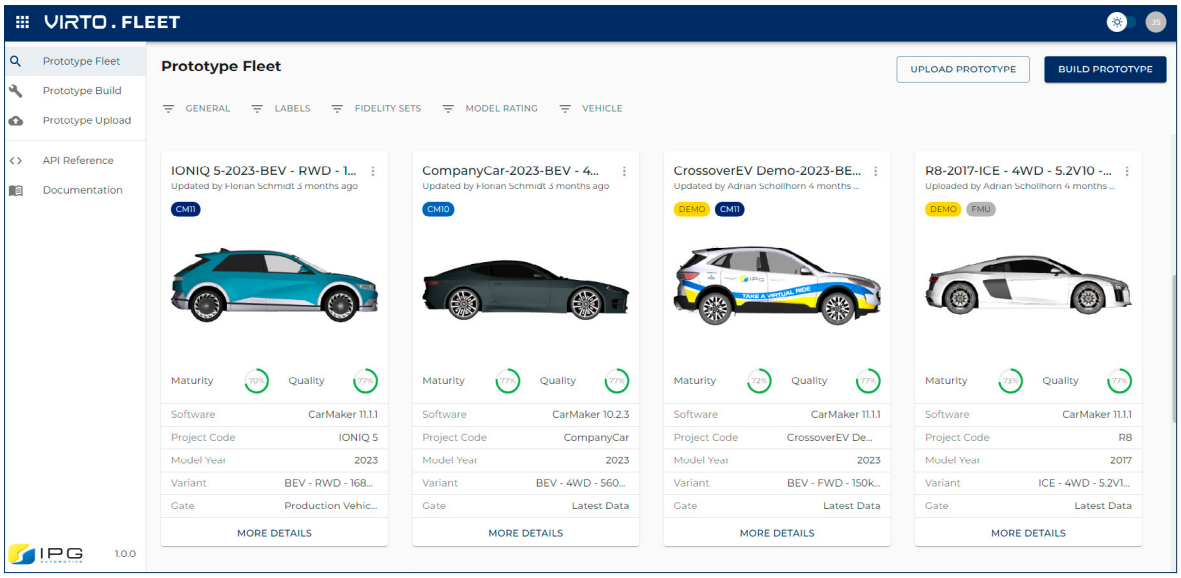


Fig. 05: User interface VIRTO.FLEET

VIRTO.BUILD enables the fully automated setup of these virtual vehicles in any configuration, see fig. 06. The possibility to create, evaluate and validate vehicles in a traceable manner regarding data and software significantly reduces the effort usually involved in this process.

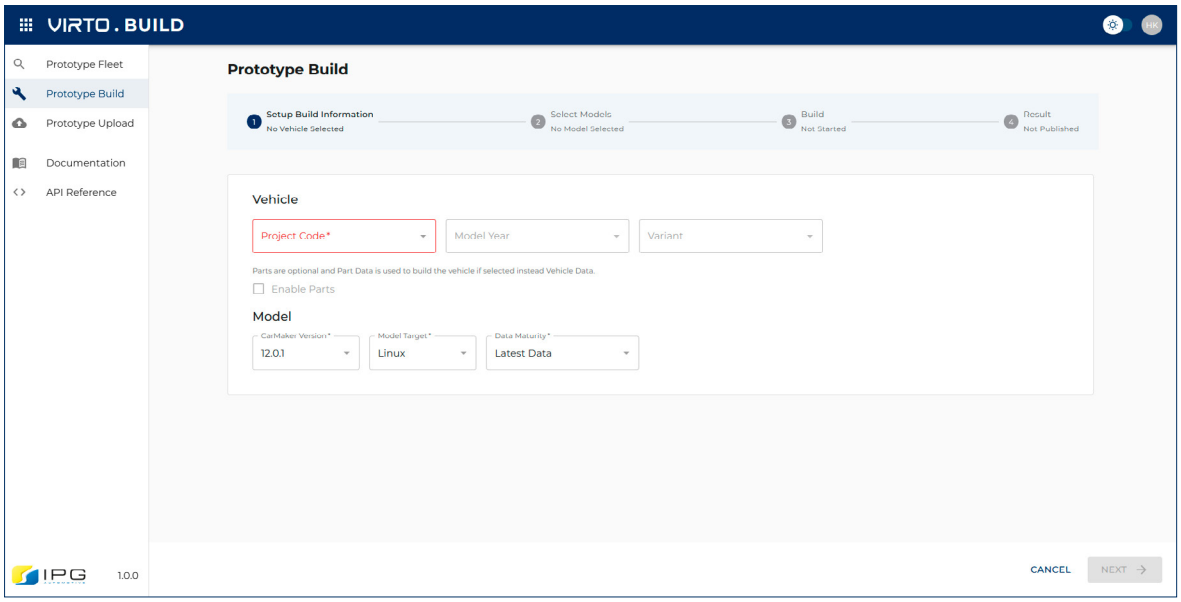


Fig. 06: User interface VIRTO.BUILD

The app VIRTO.DATA is the foundation to manage and provide all parameter data required to build a virtual vehicle, see fig. 07. It ensures robust engineering and enables a quality-assured, maturity- and version-controlled management of technology data. The application is a central source for vehicle data and enables the setup of a complete virtual vehicle fleet.

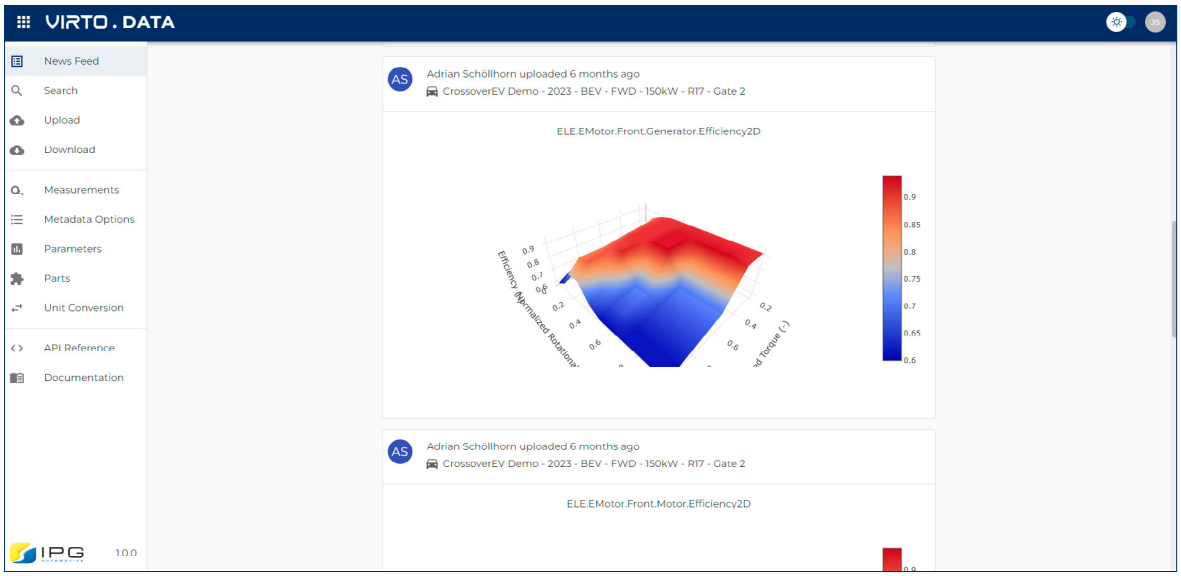


Fig. 07: User interface VIRTO.DATA

VIRTO.MODEL however is used for the central, quality- and maturity-checked and version-controlled management of ECU software and simulation models, see fig. 08. This guarantees a simple as well as open integration of vehicle software and the usage of the right software at the right time.

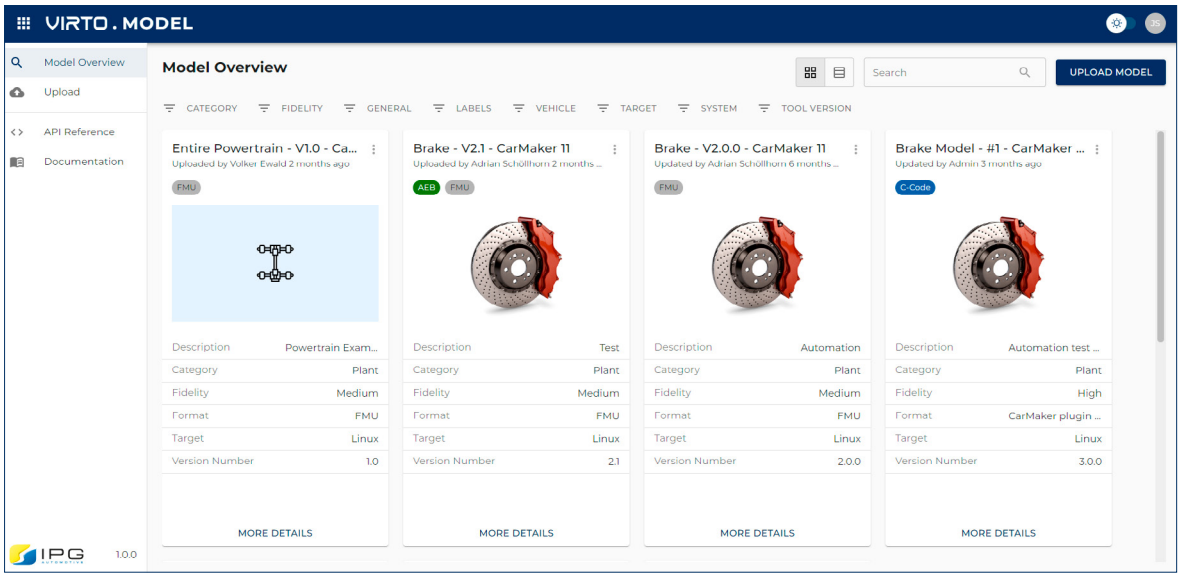


Fig. 08: User interface VIRTO.MODEL

VIRTO.SCENE offers a versioned scenario database that serves to save and manage all test scenarios with their components, see fig. 09. It reduces unnecessary duplication of effort and ensures robust, easy to create and accessible virtual detection events. Furthermore, this database can be searched freely.

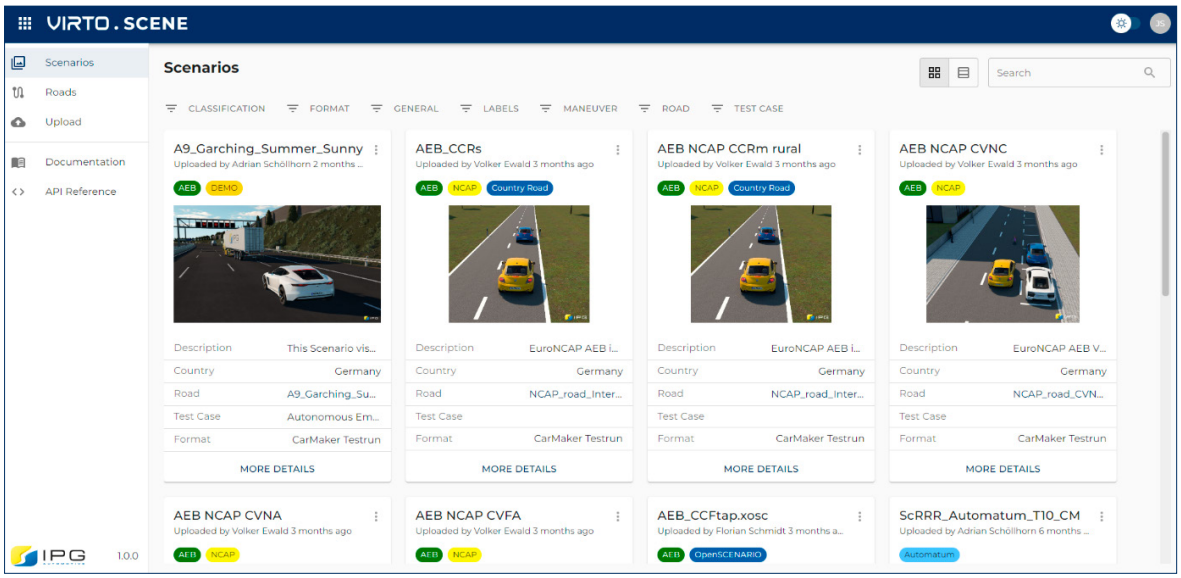


Fig. 09: User interface VIRTO.SCENE

The application VIRTO.TEST allows to plan, manage and perform virtual test campaigns in a cloud-based environment, see fig. 10. It accelerates the continuous integration and deployment (CI/CD) process known from software development as well as the automation of virtual vehicle development.

VIRTO.TEST thus significantly contributes to reducing the effort and costs for robust and reliable simulation results. Intelligent scheduling combines scenarios and models, and distributes them to the simulation toolchain and required resources via an automatable process.

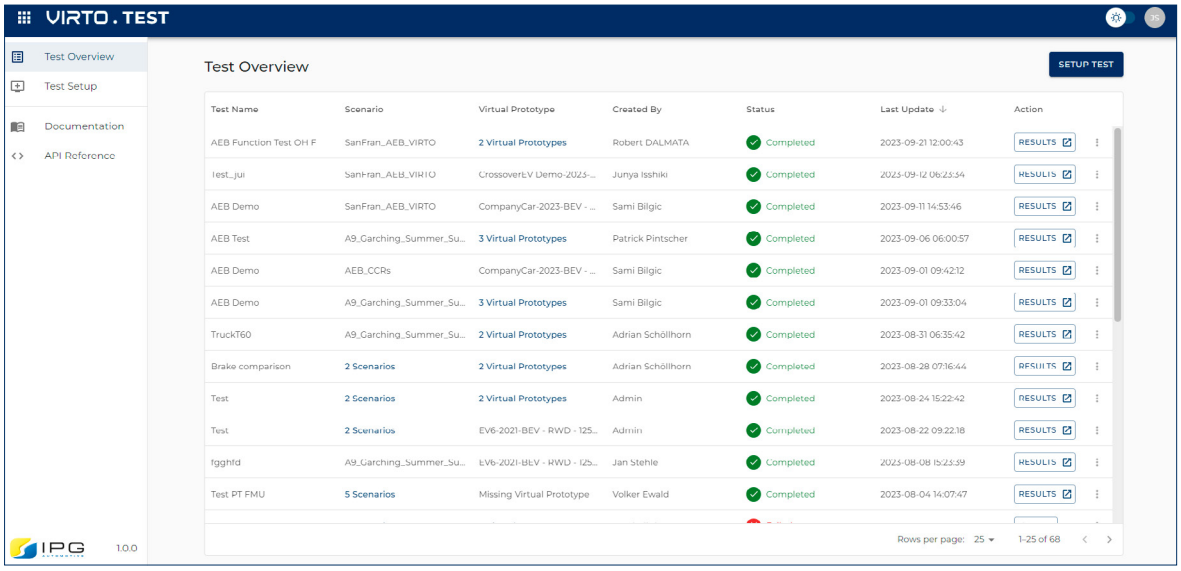


Fig. 10: User interface VIRTO.TEST

Finally, with VIRTO.RESULT, test results can be saved and managed, see fig. 11. Result transparency also reduces duplication of work and costs at this level. The application allows to analyze results either in form of plots or as 3D animations of the test drive in the visualization tool Movie NX. The evaluation of key performance indicators is also possible on individual user dashboards.

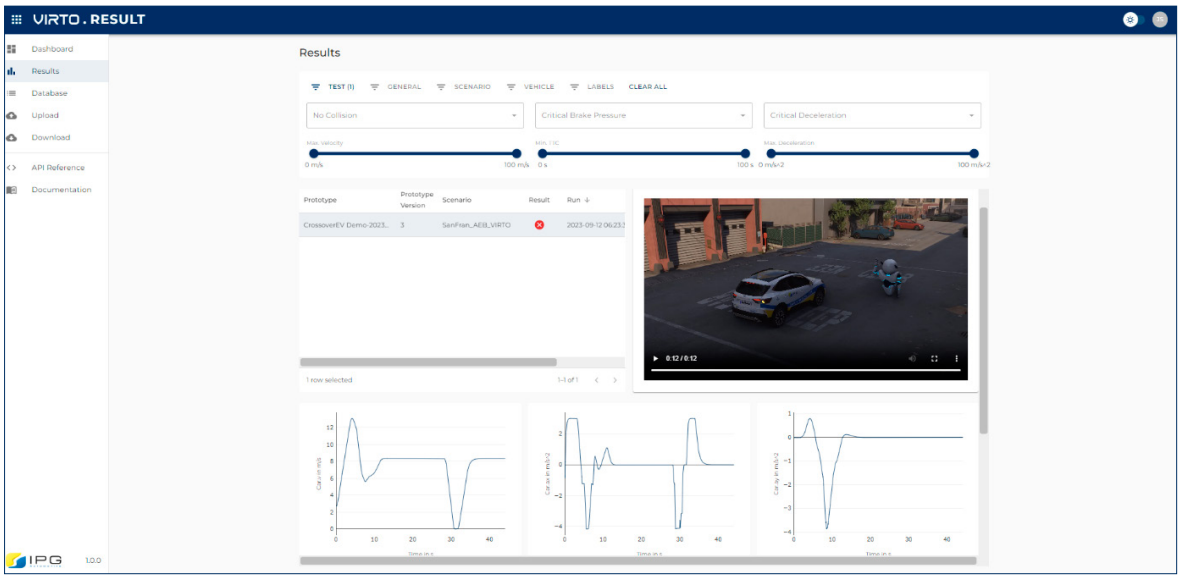


Fig. 11: User interface VIRTO.RESULT

5. Optimization of Existing Development Processes

The variety of included applications enables VIRTO to significantly optimize already existing conventional work processes in vehicle development.

In the following, possible application examples are provided.

Application 1: Increasing simulation validity

Missing data in the vehicle development process are oftentimes replaced with individual assumptions or estimations when simulation methods are in use. This is caused by the laborious data acquisition process for simulation which is in general more time consuming than the actual execution and evaluation of tests. Not only the physical, also the virtual vehicle – the aforementioned virtual prototype – runs through a complex development process until it reaches series production maturity. It is therefore important to continuously track and manage the current development statues, especially when the system development needs to be supported or accelerated using simulation. It is particularly interesting to know which information on every data point used in simulation is known.

Here, VIRTO offers support with the application VIRTO.DATA. In this database, all data which are directly or indirectly required to build simulations are collected. These data mainly differ from the know CAD data in their description of system and component characteristics and less in their geometry. This results in the necessity for a new database solution that makes the great variety of data manageable

VIRTO.DATA transforms the often practiced pull principle, for which required data must be requested explicitly, into a push principle. Data suppliers provide the required data at defined points in time. The resulting data source is called golden source. Data stored here always have a known uniform creator: Together with the data, the responsible person and recording modalities are documented. At the time of recording, the measurement method as well as the measurement equipment can impact the precision of data and thus their validity.

It is not about recording the most precise data, it is much more important to communicate the according precision transparently. New versions and data statuses can thus trigger new analyses and simulations in order for involved persons to be able to work with the latest status of the respective system. This ensures a high transparency during the entire development process.

Application 2: Shared use and exchange of simulation models

During the development process, different divisions create numerous simulation models. They serve to model systems or components that validate their characteristics development at an early point in time. Simulation models are either developed and provided in-house or by suppliers. Oftentimes, the build of replacement models to emulate peripheral systems that have already been generated by other divisions with the same goal leads to an additional effort. The usual process frequently prevents the exchange of such models inside organizations. Furthermore, divisions usually trust their own models more than they trust models from external sources.

VIRTO with its applications VIRTO.MODEL and VIRTO.FLEET can act as a valuable multiplier by offering a central storage for a multitude of models. They can include mechanical or hydraulic subsystem models as well as models for ECU code. A fleet of complete vehicles, consisting of different sub-models, enables a large user base to use vehicle models for targeted testing without having to deal with complex modeling and parameterization. In connection with the application VIRTO.BUILD, this vehicle fleet can be updated constantly as soon as new parameter data or models are available as the model setup takes place automatically.

This enables an easy access to a central, automatically managed model repository which results in considerable synergies for virtual vehicle development.

Application 3: Control of model quality

The use of simulation models requires a certain trust in the performance and validity of the respective simulation. Generally, this trust is based on long-term experience in the application and construction as well as verification and validation of model behavior. The more application areas of models grow and diversify, the more effort is involved in ensuring and controlling model quality.

This is where VIRTO's application VIRTO.BUILD comes into play. It ensures the automated setup of a virtual vehicle according to predefined standards. The relevant data are checked regarding their actuality, conformity and plausibility and the resulting vehicle behavior is verified and validated in automated tests. Directly afterwards, the application provides information about which data and submodels have been contributed by which person for the respective milestone. Maturity, level of detail and quality are transparently visualized with evaluation formulas, helping to identify for which purpose the respective virtual vehicle is suited. This transparency lays the foundation for trust in virtual vehicle development.

Application 4: Reducing simulation complexity

When executing simulations, the exact representation of the real-world behavior is rarely necessary. The assumption that basic models are generally less complex is oftentimes an error of judgement which frequently results in misconceptions and confusion. To be able to identify which level of detail can be left out and which one has a direct impact on the demanded evaluation, extensive system knowledge is required.

The modular interaction of the different applications in VIRTO can thus be of great help. VIRTO.DATA provides valuable insights into the according stage of development and increases trust in the basis for parameter data. By contrast, VIRTO.MODEL contributes documented and verified submodels of various levels of detail from the different areas of expertise, while VIRTO.BUILD takes care of the automated setup with predefined configurations that are based on tried and tested simulation methodology. With the fleet of different vehicle models divided into use cases, VIRTO.FLEET allows to search for a suitable simulation model for the according use case.

VIRTO hence offers a generic access to simulation and allows all user groups to benefit from the many advantages.

Application 5: Establishing a superordinate workflow

The previously described applications focus on generating results and knowledge from the performed simulations. Especially with the pressure of an ever more extensive test catalog as well as lower availability of physical prototype vehicles, an enormous effort inside organizations is required to be able to perform simulations in the first place. VIRTO is therefore not only limited to the management and provision of simulation artifacts, it also aims at harmonizing and simplifying work with simulation.

The applications VIRTO.TEST and VIRTO.RESULT are the cornerstones to deduce actions from the simulation results. Simulations can be assembled individually in VIRTO.TEST with the vehicles build in VIRTO.FLEET and the scenarios from VIRTO.SCENE. The execution of simulation on suitable IT infrastructures such as cloud or HPC computers is managed in VIRTO.TEST. This approach allows for insights into result generation at any time.

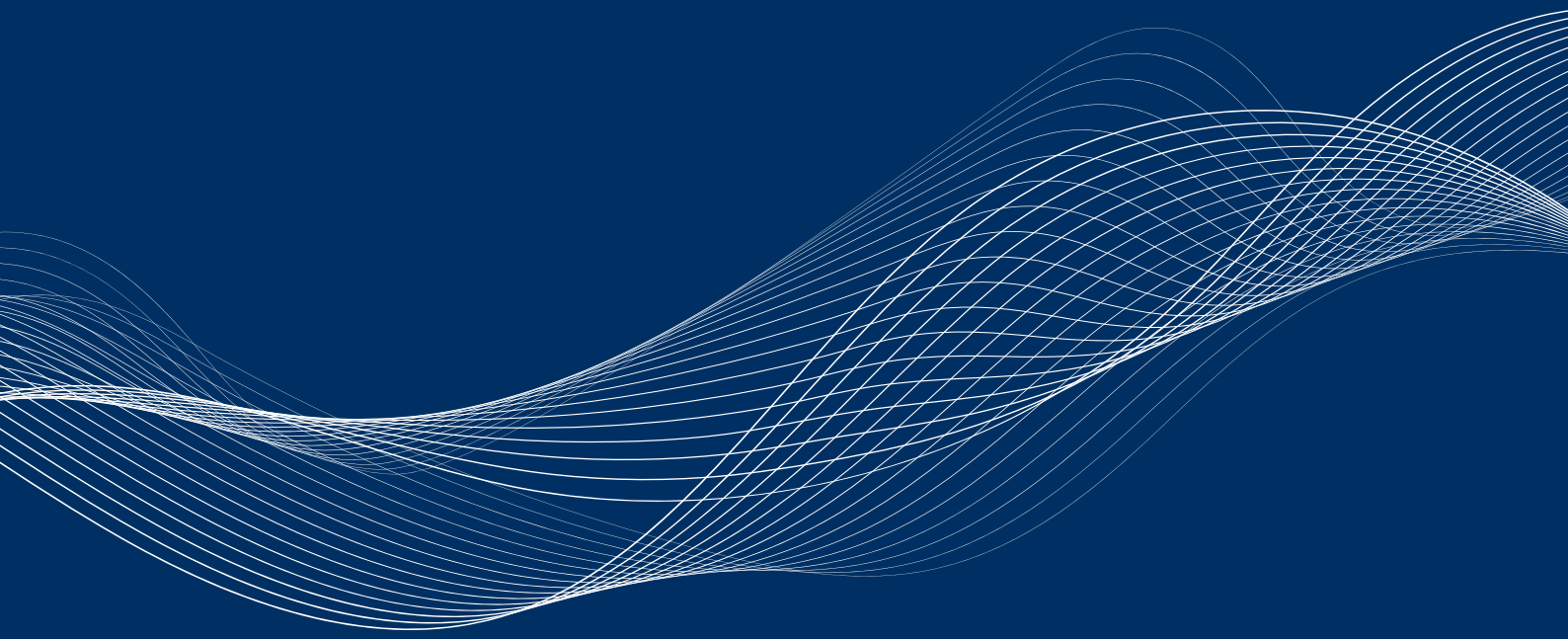
The results are saved and visualized in the application VIRTO.RESULT. This seamlessness also has the great advantage of traceability, as the results show which initial data were used for simulation. VIRTO therefore contributes significantly to scalability and enables system developers to focus on innovation.

6. Summary

Now that software has become the key distinguishing feature in vehicles, holistic solutions are required to master the associated complexity. The primary goal is to cover all relevant test cases and, at the same time, to significantly shorten development times. In addition to an easy access to all data, it is decisive that this level provides the possibility to manage and revise the accruing amount of data.

The development and test environment VIRTO described in this white paper was developed specifically to meet these requirements. As a modular app suite, it unites individual tools that can be used independently or as a complete toolbox. It is geared towards established workflows to close gaps in the development process and to create a seamless solution, from input data to test result visualization. The broad range of applications allows to significantly optimize existing work processes while the seamless development environment ensures smooth data and workflow management for fully traceable simulation..

As a global leader in virtual test driving technology, IPG Automotive develops innovative simulation solutions for vehicle development. Designed for seamless use, the software and hardware products can be applied throughout the entire development process.
IPG Automotive is an expert in the field of virtual development methods for the application areas of Autonomous Vehicles, ADAS, Powertrain, and Vehicle Dynamics. Together with its international clients and partners, the company is pioneering simulation technology that is increasing the efficiency of development processes.



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