Thinking simulation data management and CAE process design much further than before

A modern SDM system can break through the limits of systems engineering. SCALE.sdm offers everything that the modern product development process needs.

Simulation and calculation require enormous CPU power. Our picture shows an Nvidia Data Center
Picture: Nvidia

Many experts see the future of product development in system-oriented product development, in particular in model-based systems engineering (MBSE). Surprisingly, only little can be found in the literature about the associated data and model management. So to which backbone can the demanding task of data and model logistics be assigned? To the PLM system? Certainly not – its functionality for managing and controlling CAE artifacts is not sufficient. The domain of PLM systems is concentrated on MCAD data management and consistency, on configuration management and the synchronization of BOMs, such as the engineering bill of material (EBOM) with those for manufacturing (MBOM). Engineering is also linked to resource planning (to the ERP system) via the PLM system.

Systems engineering, with its idea of a modified V-model from software design, requires other support, such as context-related access to details from the specifications as well as simulation and test data. Only a modern simulation data management system (SDM system) is able to provide the necessary capabilities.

But why is the focus on functional validation so important in systems engineering? Systems engineering is about putting system limits to the test and shifting them if necessary, by running through a large number of scenarios and feedback loops. Only an SDM system can efficiently handle this sheer volume of analyses and thus keep the engineer's workload within tolerable limits.

Complete digital representation of the actual calculation process

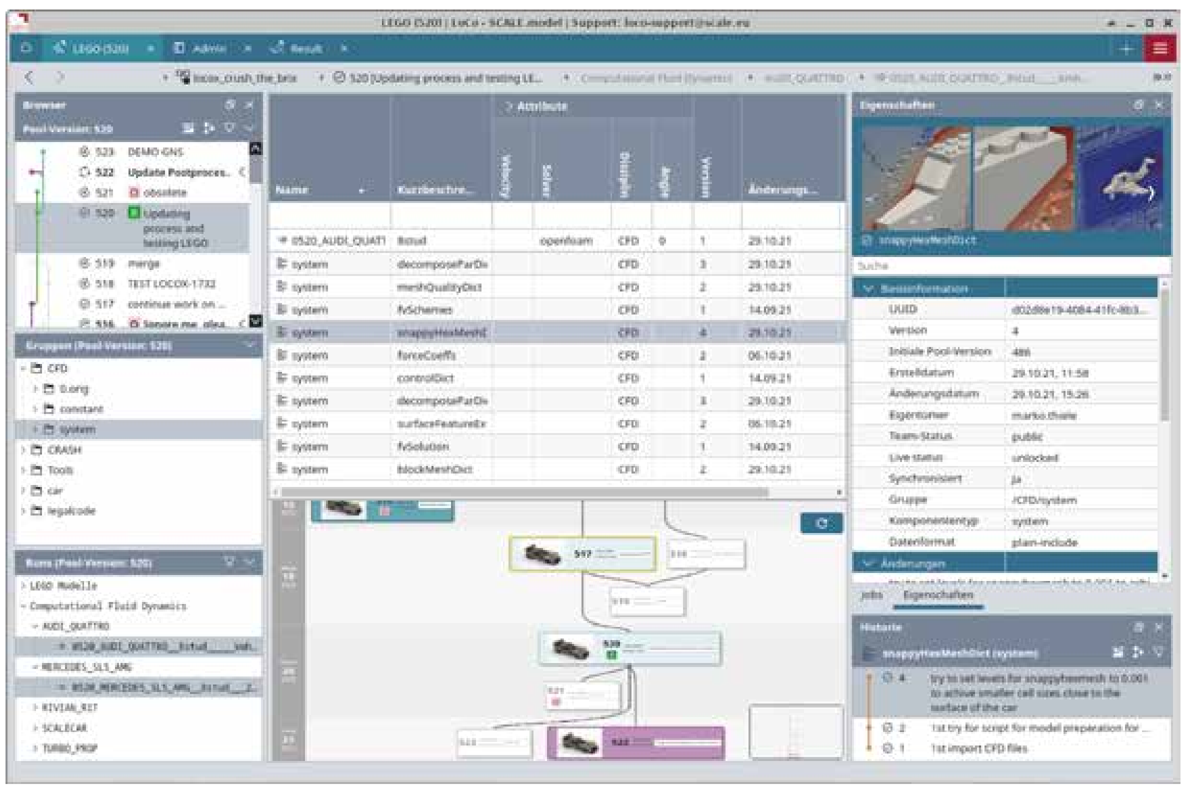
SCALE.sdm divided into the modules SCALE.model, SCALE.result and SCALE.project is an innovative CAx software suite for end-to-end data and data process management. The individual software modules can be used as standalone modules or in combinations, as required by the client for specific use cases.

Data management for pre-processing of a simulation project is performed via the desktop client SCALE.model. Information on product structure, model variants, model data and version control of the selected objects is clearly displayed for the simulation engineer in the GUI in various segments. The user can navigate through the different project statuses – keyword: traceability and versioning. In this way, it is possible for the user to see with which parameter set and which assembly structure a job has been started – incidentally also by any colleagues to whose project data the user has access. "For each simulation object, the respective history can be traced back exactly. This is very important for the daily business. Simulation engineers want to track exactly who from the team has worked on what and when," explains Marko Thiele, Product Manager SCALE.model with SCALE GmbH in Ingolstadt, Germany.

The simulation jobs are controlled via scripts, which are also managed in the SDM system. These scripts specify, for example, how the partial models are combined to form an overall model. "For each partial model, there are so-called includes related to CAE models of different assemblies, which can be processed in different CAE tools. Access to them is transparent for the user directly from the SCALE.sdm desktop client, because all the access and authorization issues as well as the upload and download are controlled in the background. If something is changed in such a submodel, a new version of it is automatically created – at the project level and at the level of the affected individual components that have been connected," says Mr Thiele. The result is an exactly traceable virtual image of the simulation process, mapped by SCALE.model. Let's take the cross-project management of virtual crash barriers as an example: At large automotive OEMs, it is common to identify an expert to take care of the maintenance of such crash simulation components across vehicle series. The simulation engineer can load the data into their crash analysis, whereby a kind of 'recipe' is given to the load case – for example: 'Take a suitable barrier for this ODB load case ...' –, i.e. an action instruction for a crash simulation with an offside-deformable barrier (ODB). A different barrier type is accessed in a different load case via corresponding attributes. SCALE.model also takes into account that the barriers are automatically placed at the correct position by proceeding in the same way for positioning parameters. Mr Thiele explains: "In this way, many load cases can be defined in no time at all, to which the correct components and positions are assigned on the basis of recipes. The load cases with all their data can then be sent to an HPC cluster or to the cloud, and it is always possible to see where the solver is currently located in its processing."

Autonomous driving. Incidentally, such a systematic approach could also be applied to environmental scenarios for the analysis of autonomous driving vehicles. The parameters selected in SCALE.model can be used to control the environmental influences, such as traffic volume or weather conditions.

It is also interesting that parameter sets can be combined in a file via SCALE.model and these can also be generated via tools that generate random sampling. Automated computational jobs are then sent to the cluster and can be evaluated in SCALE.result later, either stochastically or with meta-models such as neural networks. This process is also of great interest for systematic systems engineering. Mr Thiele is noticeably proud of how this is solved in the SDM system, because you won't find anything else like it on the market.



SCALE.model in action

SCALE.model sits and fits well, but also offers a bit of give, like a tailor-made suit

Simulation processes provide impressive evidence of the ability to bring innovations to market, and thus also of the competitiveness of manufacturing companies. They are carefully designed and must be comprehensively supported by an SDM system. For this reason, SCALE offers two types of customizing in pre-processing: "Plug-ins can be implemented if a client requires a special functionality that is not offered in the standard version. More often, however, special tools are integrated by means of configuration, such as solvers developed in-house," Mr Thiele says. And there is a lot to do here, because there are a large number of pre-processing tools or solvers, all of which have their particular strengths and need to be inte-grated on a customer-specific basis. What is important here, as Mr Thiele emphasizes, is that the open system architecture of SCALE.sdm supports this. This gives the user the opportunity to make adjustments on their own. Some clients take great advantage of this by contracting employees internally or even external companies to provide corresponding services.

Crash of a Lego Porsche – SCALE.model lets rip and plays to its strengths

Just how crafty the SCALE developers are can also be seen in the example of the internal project for crash simulation of a Porsche 911 GT3 RS from Lego Technic. Here, we only can outline this exciting project from the perspective of pre-processing. The reader should therefore keep in mind that SCALE.sdm with all its modules allows the entire CAE process to be supported in teamwork. Teams from SCALE and the DYNAmore group have been involved, as the complete project description shows (1).

One of the major challenges in working collaboratively on a computational model is that, in a conventional data management system, only one person can work on the same data set at a given time. However, there are several approaches that allow for more efficiency in this regard by parallelizing work steps. The most user-friendly is to implement a system that allows real-time editing of the same files by multiple team members. This has already been implemented for text editors such as Google Docs as a cloud application.

Since this is not possible for simulation models because the pre-processing tools do not support it, another approach is to split the model to be analyzed into multiple files, with the rule of thumb that the larger the team, the more important it becomes to split the model into smaller and smaller packages. Incidentally, this is a common practice in real automotive projects. When applied consistently, this approach leads to configurations where each part of a vehicle assembly is stored in its own file. As a result, up to several thousand files have to be processed simultaneously in the SDM system. This poses a particular challenge for the user interface and the underlying mechanisms, such as for the synchronization of data. The creation of such a worst-case scenario was incentive enough for the developers of SCALE.sdm to create the Lego examples.

Geometry definition and import. The most commonly used format for describing Lego models is LDraw (1). In this format, only transformation information, color and reference to a Lego brick are found in the standardized LDraw brick library.

Within SCALE.model, Lego bricks are managed in a common library pool that contains a meshed model in initial position for each Lego brick. For the transformation of the Lego models into the solver format a script was written, which translates the LDraw file for the solver and places the individual Lego bricks from the library pool transformed again and again into the correct positions in the model. To ensure effective collaboration, the large Lego models were imported and a (nested) structure for subassemblies was defined. This allows team members to work on one subassembly while others are working on another. In the background, the SDM system always keeps track of who is working on which parts of the model, so users do not have to manually merge the versions of the model parts they have been working on later.

Meshing. The main work in this project was meshing. Each Lego brick was meshed as both a 2-mm and a 1-mm version. These versions are stored in a central location in SCALE.model so that it is easy to create simulations with both mesh resolutions. Together with the Lego brick models of the used solver LS-DYNA, the CAD data and the cleaned geometry were stored in SCALE.model as ANSA DB files (ANSA from Beta-CAE: commercial preprocessor).

The original CAD data for each Lego brick from the LDraw library are mostly in the form of a simple triangulation of the individual elements. These can be converted to STL or OBJ files and imported into the ANSA or Altair Hypermesh preprocessor. However, these meshes are not suitable for performing simulations, so tetrahedral volume meshes with a target edge length of 1 mm und 2 mm were chosen.

A disadvantage of using volume elements is that it leads to models with a very large number of elements. The number can be reduced by using hexahedral elements. For the final model, where bricks like #41239 are used 29 times throughout the model (see figure), this saves more than 800 000 elements in the final simulation. The resulting full Porsche model contained more than 2 700 bricks, each treated as a separate part. For the version with the bricks meshed with a target element size of 1 mm, this model contained the astonishing number of around 19.5 million elements. This is more than double the usual model size for integrated simulations of full-vehicle crashes used in real-world virtual product development at OEMs!

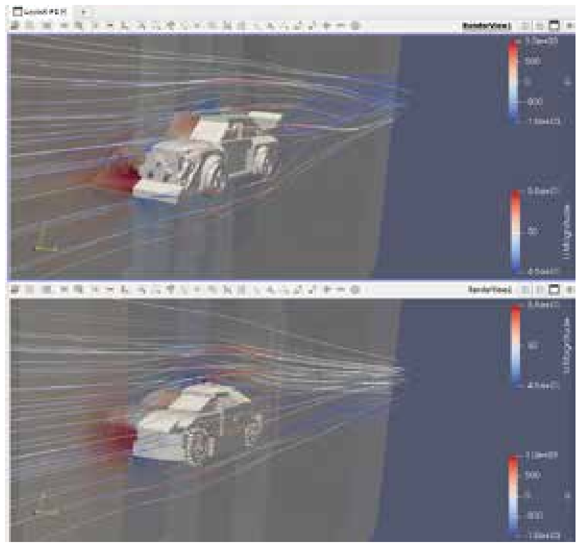
Since many details of the bricks are lost when the 2-mm version is used – such as the contact situation of the individual Lego bricks, which is, however, crucial for the overall behavior of the model – it seemed advisable to use the 1-mm version.

The average runtime on a high-performance cluster (HPC) with 192 CPUs for the simulation was 22 hours for 120 ms of simulated crash.

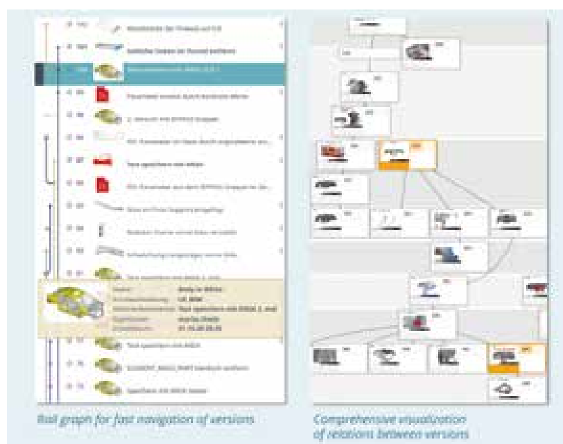
Other files needed for the final simulation, such as a master file with all control cards, barrier models, guide blocks (placed under the vehicle to make sure it goes straight) and files with material cards are also managed in SCALE.model.

In addition to the crash shown on YouTube (2) with a 40 percent offset ODB barrier, load cases were also created for a rigid front wall, a 50 percent and 25 percent offset barrier (both relative to the centerline of the vehicle), crashes with a 30° impact angle, and various speeds.

"SCALE.model has the ability to use attributes defined on components and parameter values to automatically link them to specific simulations. This makes it possible to create a large number of different variations of a virtual product without having to relate all components (files, includes) individually to each load case," says Mr Thiele. Referring to the example with the Lego Porsche, this means that when a change is made to a Lego brick, this change is automatically applied to all defined use cases and the transmission of orders for many load cases to evaluate an overall status of a simulation project is effortless.



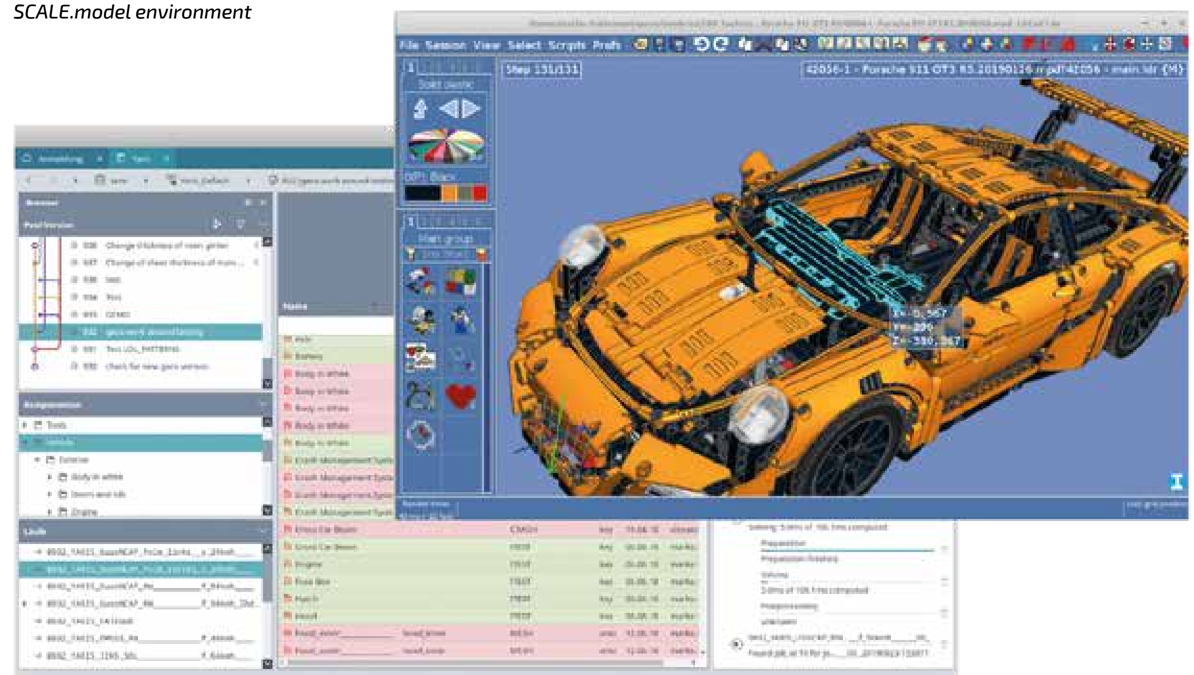
Computational fluid dynamics simulation of a Lego car



In SCALE.model, simulation models can be displayed in the form of version trees, which function like a kind of 'family tree'. This results in a clarity that is very much appreciated. Models for crash simulation consist of up to several hundred files in partly very different version statuses (components for steering wheel, seat, gearshift lever, scripts for the automation of simulation runs and others). The components are processed worldwide, including by suppliers. Each model component has its own history, which can be traced back precisely via SCALE.sdm

Source: SCALE 2019

Modeling with CAD data of a Lego Porsche 911 GT3 within the SCALE.model environment



Marko Thiele, Product Manager SCALE.model

Dr Martin Liebscher, Product Manager SCALE.result

Gordon Geißler, Product Manager SCALE.project

Dr Heiner Müllerschön, Managing Director of SCALE

SCALE.result provides new insights in the results

Once the simulation is completed, the results are either transferred from the computing cluster to the user's workstation, or they can be retrieved via SCALE.result. SCALE.result, as part of the SCALE.sdm suite, is a server-based post-processing management system with central data storage and web interface as well as an additional SDM desktop client. "Especially test engineers working at the test bench, for example, don't want to install another fat client in their PC, so we decided to also offer a web interface where nothing has to be downloaded. The user interface represents a kind of workspace for the test or simulation engineer: Everyone can configure their own views and data filters in the sense of customizing. The results can be delivered in a multimedia display, so that a before-and-after comparison is very intuitive," explains Dr Martin Liebscher, Product Manager with SCALE.result. The reports can also be formatted according to the user's own preferences or company specifications.

Simulation and test data for direct comparison can be uploaded directly or imported from other systems via interfaces. Documents, images, videos, or 2D graphics like curves can also be inserted or made available for display in combination with external applications in the SDM Desktop Client. "The analysis of more extensive data series from parameter studies or robustness analyses, for experiment planning or evaluation, respectively, are supported by a separate data analysis module," says Dr Liebscher, pointing out that various technologies, partly based on machine learning techniques, are available for nonlinear prediction, response surface visualization or outlier detection. The central configuration of views and displayed data allows access as needed, even for different disciplines.

SCALE to become AWS partner

SCALE GmbH has been a partner of the cloud provider Amazon Web Services (AWS) since the beginning of 2022. "With the AWS partnership and the certification of our software products for AWS, SCALE.sdm will be efficiently and professionally available in the Amazon cloud for our clients," says Dr Heiner Müllerschön, Managing Director of SCALE.

A key advantage of operating SCALE.sdm in the cloud is the scalability and high availability of the system modules. Added to this is the standardized, fully automated deployment, which enables uncomplicated provisioning of the system. AWS provides an environment for outstandingly scalable and secure deployment of SCALE.sdm at low cost. In addition, AWS applications developed specifically for data analytics are also available and can be used in combination with SCALE.sdm for advanced analysis. Examples include Amazon Quicksight as a business intelligence system especially for data analytics and Amazon SageMaker as a machine learning platform.

aws.amazon.com/de/big-data/datalakes-and-analytics

In the sense of an open system or for individual customization, own add-ons can be added to SCALE.result. For instance, third-party tools have been developed by Fraunhofer SCAI or Sidact to track down outliers reflecting unusual behavior in simulations. No data has to be downloaded for such analysis, rather this is already done on the server.

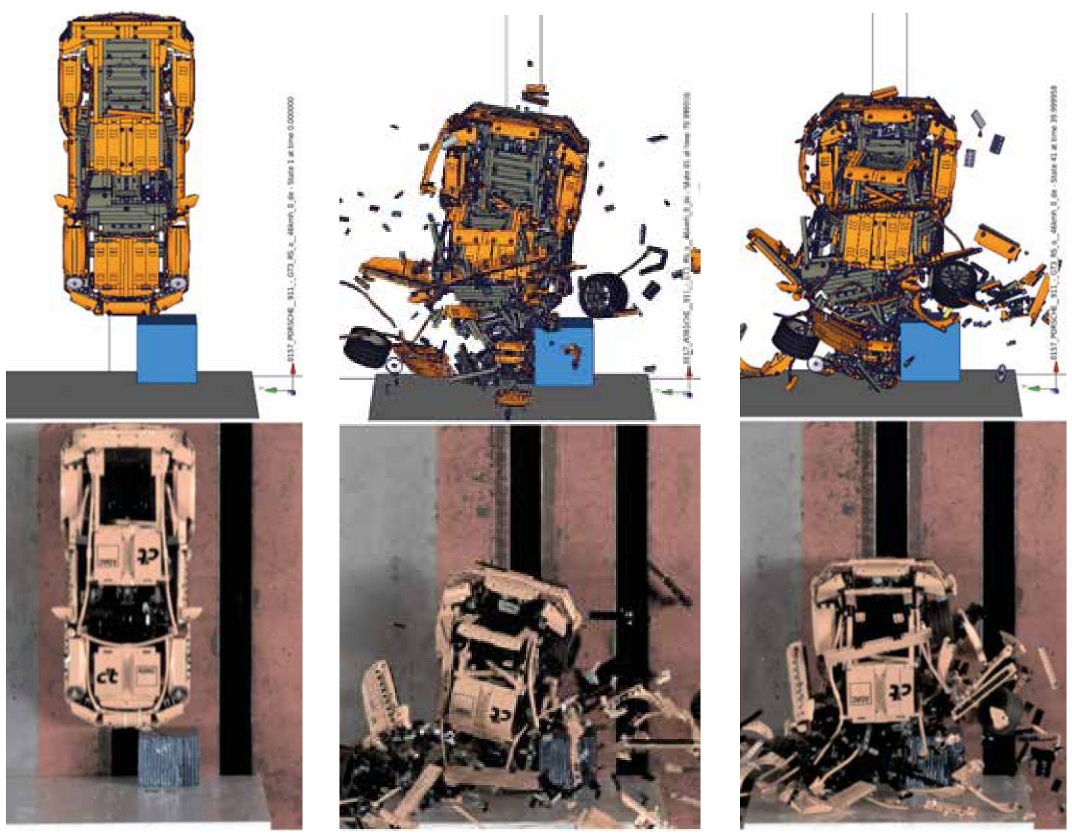
The ball is in user's half of the pitch

How can SCALE.sdm be quickly put into productive operation? This is not an easy question to answer. Sometimes, SDM systems are introduced over a period of years. What is the reason for this? "This is quite understandable, because with the introduction of such process support, the previously lived CAE methodology must also be adapted. Another challenge is that there is an incredible number of CAE tools that have to be integrated depending on the client. It is amazing how many disciplines can be mapped with LS-DYNA alone," Dr Liebscher explains.

Thus the client's agenda is packed full – in the sense of standardization, which should go hand in hand with the implementation. This requires a lot of coordination work in the specialist departments. "For example, it is necessary to agree on designation conventions between simulation and testing so that key results, curves, images, or videos can be clearly referenced. Cross-departmental designations and numbering conventions must be found for car doors, for barriers, and much more. This coordination and standardization takes a lot of time in a corporate group," Mr Thiele adds.

After all, there are hundreds of engineers who have to interact with each other, just to come up with a generally accepted numbering convention for element and part IDs. The coordination work becomes even more demanding when it comes to conventions for the parameterization of processes, i.e. when scripts are to run automatically. "First of all, a dialog has to be initiated between the specialist departments," Mr Thiele points out.

SCALE has a lot of experience in recognizing the current initial situation and can then provide suitable recommendations for action for rapid, efficient implementation. For this purpose, there is a consultant team at SCALE speaking 'the language' of the respective client, slipping into the role of mediator. "Many engineers pulling together – only this brings any really big effect!" says Dr Liebscher emphatically.



Crash data of a Lego Porsche 911 GT3 captured by videos of physical testing compared with simulation data (read also text)

SCALE.project as door opener for systems engineering

Back to the question of how simulation data management can be embedded in systems engineering. The first step is to systematically link requirements management with post-processing. This leads us to SCALE.project. There, requirements (e.g. in the form of colored limit values including their descriptions) for simulation projects are defined and centrally managed, e. g. with regard to still permissible limit values. SCALE.project allows status monitoring and documentation with regard to result evaluation by manual input or by automatically transferred test and simulation data from SCALE.result. By integrating SCALE.result we move, expressed in the nomenclature of systems engineering, on the validation side of the V-model. "SCALE.result represents the working level of the engineer in validating a load case or component against project requirements, while SCALE.project refers to the level above: That of technical management, whose interest may be to question whether, for example, a particular function is fully validated across domains," explains Gordon Geissler, product manager for SCALE.project.

Link to PLM

At this point, the only thing missing in our argumentation is how the PLM system fits into it all. The PLM system is used to manage MCAD data. The PLM system can also be used to manage the networking of references for CAD data in the sense of pre-processing. SCALE and its partner GNS Systems integrate tools such as ANSA, which also interface with PLM systems. If you want to write the results of the simulation back into the PLM system, then you would do this via SCALE.project. (bv)

Intentional or malfunction?

The ViPrIA research project funded by the German BMBF is concerned with the development of assistance systems based on machine learning approaches to support computational engineers (3). With the help of intelligent assistance functions, they are to be supported in complex decisions during the development process and relieved of routine tasks.

Under the lead of SCALE, the project partners have developed a module that automatically detects so-called outliers. For this purpose, large quantities of simulation data are scanned, and unexpected behavior that the expert might overlook in the flood of data is displayed.

If there are anomalies in an analysis compared to other simulations, an alarm is sounded. Of course, it is still possible that the result is in line with the norm and that the deviation is intentional, for example because it is down to an innovation. In order for such analyses to be triggered quickly, it is necessary that the data is available on site in an organized and structured manner. This is ensured by SCALE.sdm. This project supports cloud computing approaches because third-party tools can be methodically integrated to lift still-hidden knowledge from the data. In addition to SCALE, project partners are the Fraunhofer Institute SCAI, Sidact (both from Sankt Augustin), Audi, Porsche and Volkswagen.

www.scale.eu/de/aktuelles/forschungsprojekte/vipria

References

(1) Gerlinger, T. et al., „On the Setup and Simulation of Large Scale LEGO Models built with LS-DYNA and LoCo", 12th European LS-DYNA Conference 2019, Koblenz

(2) youtu.be/dCPWPj4JHqg

(3) www.scai.fraunhofer.de/en/business-research-areas/numerical-data-driven-prediction/projects/ViPrIA.html