Assuring Confidence in Simulation Results through Simulation Data Management

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The first Simulation Data Management solution built on a commercial SDM platform was implemented to assure the quality of simulation results for multi-million $ business decisions. Back in the year 2000, BMW had taken a lead in developing crash simulation methods that were sufficiently accurate to replace physical testing. Dr Holzner asserted that an information system was needed to assure the quality of results and provide appropriate governance for a product development process that used simulation-based experimentation. The two key SDM capabilities deployed were the automated recording of the Audit Trail and the management of digital complexity, providing confidence that the simulation was run on the correct data files.

This SDM solution was implemented to support a simulation process that was already defined and validated to assure the quality of results. However, the last fifteen years has seen dramatic advances in product technology, for example the usage of new materials especially Carbon Fibre Reinforced Plastic (CFRP), see figure 1, in passenger cars and commercial aircraft, as well as in simulation technology. Simulation Data Management platforms have not just kept up, but have been used as the platforms for process and technique development, verification and validation.

Figure 1: BMW's revolutionary i8 Hybrid CFRP sports car, 6000 simulations on the SDM platform

Assuring Simulation Quality in the Face of Extreme Digital Complexity

Clearly an SDM solution can't make value judgments about the quality of work, it's just a sophisticated database. What SDM can do is to assure that the right data is used. This is no trivial task when 400 engineers are performing experiments on 50 virtual vehicle prototypes, ref 1. There is wide recognition that manual management of files in folder structures and shared drives is no longer up to the task of tracking data-sets of many hundreds of mesh files through simulations for a hundred design iterations.

Digital complexity has expanded beyond geometry data to materials definitions, fastening methods as well as thickness and residual stress distributions from the sheet metal stamping process. The proliferation of material types in use in a passenger car; pressed, cast and extruded aluminium, hot and cold formed steel and now glass- and carbon-fiber reinforced composites, requires each meshed component to be associated with the correct material model file. These new structural materials have led to an ever widening range of fastening methods, 64 at the last count, ref 2, to add these further layers of complexity to the file management problem. This scale of the problem is not limited to Automotive and Aerospace OEMs. Christophe LeMaitre cited the 2000 analyses necessary to assure the quality and fitness for purpose of a set of car seats in his presentation of Faurecia's Simulation and Test Data Management systems, ref 3. Steve Howell of Abercus, in an article in the April edition of this magazine, described how an SPDM solution for CFD assured quality and saved the engineers time by setting up individual simulations, launching runs and then collating the CFD predictions in the SDM database. He explained that SDM enhanced the success of applying CFD on an HPC because of the large numbers of simulations needed, hundreds to thousands, for probabilistic explosion assessments for the oil and gas industry, ref 4. It's interesting that both Faurecia and Abercus developed their own SDM solutions in-house to save engineers time managing a large number of similar simulations.

File system privileges are simply inadequate to assure confidence in today's simulation environments, especially where method development is proceeding in parallel with product development. A cautionary tale concerns a simulation run to refine a material model for vehicle engineering. This promising novel approach proved not to be representative of the material behaviour. Unfortunately the material file, which had the same name as the standard material model, was left on a shared drive and used for every subsequent product simulation. The company then complained to their FEA supplier that their code was giving erroneous results. It took a week for an expert engineer to find the cause of the problem and identify that it was a rogue file. During which time all the HPC runs on products incorporating this material were compromised. Fit-for-purpose version and configuration control has long been a necessity for the simulation domain and it's not deliverable without an appropriate information system.

Beyond Version Control

File version control incorporating an approval workflow and the replication of files are basic capabilities of any fit-for-purpose SDM solution. But the challenges of Simulation Governance extend way beyond file management which, though a serious and visible issue, is actually the simplest to solve. Simulation is a multi-stage engineering process. It needs to be planned methodically, ref 5. Consistent modelling and discretisation decisions need to be made. All this meta-data, together with the relevant data sets for each iteration, need to be recorded with the minimum overhead on the analyst. Sylvain Castellani of Peugeot-

Citroen commented that an SDM solution was being implemented to replace their existing content manager to address the number one question that engineering managers ask simulation engineers: "How did you validate this simulation result for that vehicle program", ref 6.

The capability of an SDM solution to capture meta-data and then to provide interactive, web browser access to the audit trail of any set of results is invaluable for generating confidence in simulation results. This is especially valuable when the work is being done remotely, which otherwise can require as much as one supervisor for three remote engineers. SDM can provide a project supervisor with a dashboard showing how simulations are progressing. He can directly access information on Work In Progress (WIP), reassuring him on project progress or flagging up areas of concern.

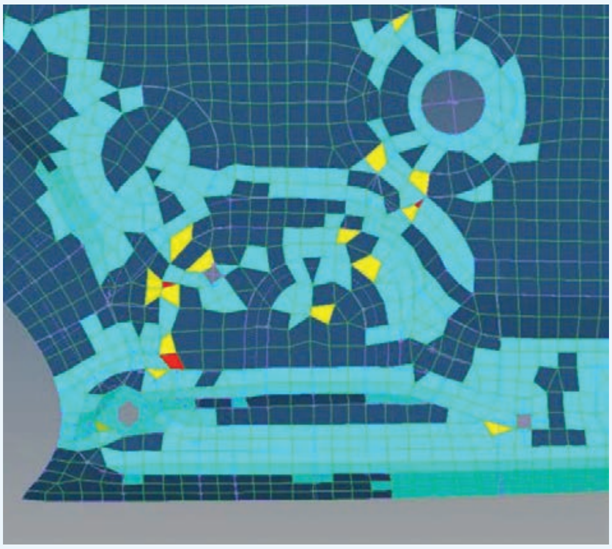

Figure 2: Plot showing element distortions to characterise mesh quality

As well as capturing metadata, SDM can be used to launch programmatic quality checks, display quality plots for review and then store them with approved mesh files. Thorsten Pohl of GM Europe described how the mesh management functions of TeamCenter had been extended to provide interactive access to quantitative and visual Quality Criteria of Finite Element meshes of automotive CAD models, see figure 2, ref 7. The aim of this project was to save time and money by eliminating re-meshing of already meshed parts when a further analysis was to be performed on a different site. Analysts were reticent to use meshes created elsewhere until they could readily see quantitative quality indicators and be assured of the quality of the mesh.

Verification, Validation, Industrialisation

For simulation to come of age as an industrial process in a particular domain, processes need to be captured, documented, refined, verified and validated. This is particularly important when testing is impractical, such as in nuclear industries or for large scale CFD, or where new product architectures, such as the CFRP i8, are being developed. Dr Dirschmidt described BMW's stepwise Validation strategy in his keynote to the NAFEMS 2015 World Congress ref 8, see figure 3.

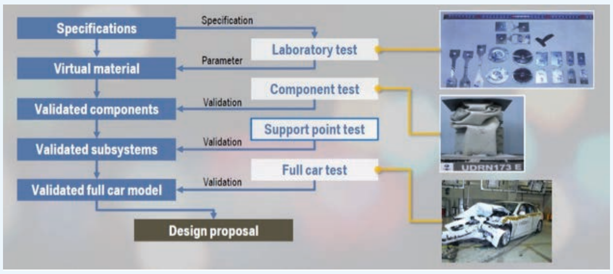

Figure 3: Interaction of testing and simulation for method validation at BMW

Other technical domains have already encountered the need to move from heroic individual efforts by a few specialists to repeatable, defined and managed processes to assure the quality of results. In particular, process improvement in Software Engineering, Systems Engineering and Integrated Product Development have been addressed by an approach called the Capability Maturity Model (CMM), originally developed at Carnegie-Mellon University's Software Engineering Institute. CMM was sponsored by the US Department of Defense, which wished to achieve more reliable and fit-for-purpose weapons system, but has found widespread civilian use. This has been refined over two decades into CMMI, see figure 4, and a wealth of know-how, guides, case studies and checklists are available, ref 9. Dr Joe Luxmore of Siemens PLM proposed an SPDM-specific 5 stage maturity model for SPDM in his paper to the NAFEMS UK conference, ref 10.

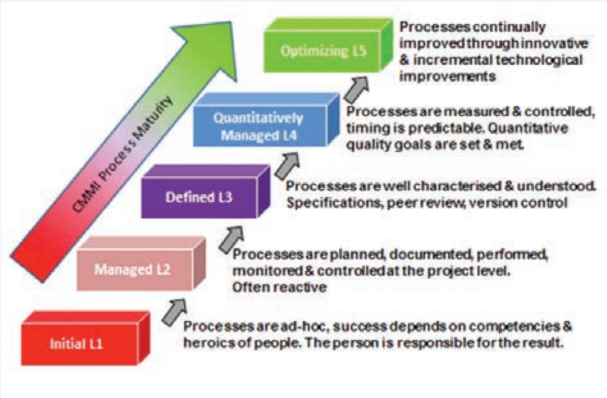

Figure 4: The Capability Maturity Model (CMMI) approach to delivering assured results

Being at level 1 as a Simulation group is not in itself "bad", the majority of clinical consultants are there also and we rely on them for our health. It's a function of the difficulty of the tasks performed and the duration of the learning process to become a competent practitioner. Here, programs like NAFEMS Professional Simulation Engineer(PSE) accreditation are valuable since the practitioner is relied upon for the validity of the result. The implementation of Best Practice processes such as "How to plan a CFD analysis", ref 5, and the NAFEMS Quality Systems Supplement (QSS008) ref 11 combined with appropriate SDM technology provide a route for simulation groups to move to Level 2 and beyond. Level 3 requires formal version control which can't realistically be achieved using file system permissions but in the 21st century it would be aberrant to embark on such a global process improvement initiative without an information system to underpin it.

A recent SDM project in the nuclear industry addresses the issues of Verification and Validation. Chetwynd & Nurbhai of the UK AWE described a custom implementation of NAFEMS QSS001 process implemented as a workflow in their PLM system, ref 12. The workflow they had developed enables engineers to record assumptions, approximations and decisions, provides version and configuration control of documents and a link to the archived results. It replaces a paper document which required 17 ink signatures. Best Practice processes and xLM technology have been combined to build a system to record the process steps, approvals and information gathered to verify the codes and validate the results. AWE typically deals with unique problems which can't be tested, such as risks in transporting nuclear weapons, so a rigorous digital verification and validation process and formal version control of key data-files are essential components of their Governance approach. .

Verification is a subject where SDM is ideally placed to help. The test data-sets, test conditions and expected results can all be stored in the SDM together with documents describing the mathematical basis for the methods. This information can then be accessed by anyone concerned about the verification of the code. Subsequently, verification tests of new software versions or models can be run with just a few mouse clicks and compared with previous results. And without the risk of leaving in-development methods on a production server! SDM is therefore a good platform for methods development. The progress of the validity of the method under development can be tracked and displayed in a dashboard.

Supporting Method Development

Dr Ferdinand Dirschmid presented the advanced simulation methods developed on the BMW SDM platform for the functional development of the BMW i8 hybrid sports car. The i8 is the first example of a new product architecture with a Carbon Fibre Reinforced Plastic Body In White (BIW), ref 8, which is produced in a new, entirely automated, CFRP body shop, with front and rear aluminium structures for energy absorption. He commented that SDM has been essential to enable the timely development and validation of new simulation techniques, a new product architecture and a first new product. He described a systematic process of progressive validation of material models, components and sub-systems. This rigorous methodological approach culminated in the successful validation of the crash simulations of the i8 see figure 5.

Figure 5: Validation of simulation models of side test crash simulation of the i8

BMW's achieved and planned simulation engineering throughput gains were presented at NWC13 after their move to an SDM2.0 configurable SDM solution set, ref 1. BMW's measurement of simulation program data and prediction of future process performance for the 50 or so virtual vehicles under development is indicative of Level 5 Capability Maturity. It's perhaps un-surprising that process rigor and early adoption of information systems go together.

McCoy described Ford's use of an integrated SDM environment, VDSS, to develop and deploy a suite of simulations for Roll-Over testing of safety systems, ref 13. Once these simulation processes had been verified and validated in the USA, they were rolled out globally within the SDM solution. McCoy reported that the global rollout had been accelerated by the SDM environment since the training times for analysts to become proficient were reduced by 50% since they could easily browse all aspects of the process approach as well as previous data- and result-sets.

Conclusion

In conclusion, SDM solutions are not just systems of record to support regulatory compliance. They are structured information and process management environments which enable organisations to gain better control of their simulation processes and data thus providing greater assurance in results delivered. SDM can also support process and method development and provide the necessary infrastructure for attaining the higher levels of Capability Maturity.

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NAFEMS SDM Bibliography

These presentations are now accessible to NAFEMS members through the NAFEMS SDM bibliography on the SDMWG web-page which contains some 200 papers. I would like to thank the staff members from these organisations who took the time to present their SDM projects and lessons learnt.

About the Author

Mark Norris is an SDM consultant with extensive experience of SDM, PLM and mechanical simulation. He advises companies on the evaluation, selection and deployment of advanced engineering IT solutions, especially SDM. He joined the Stress Office of Hawker Siddeley Aviation as an apprentice when the digital calculation capacity consisted of four HP35 calculators. He applied a method incorporating finite elements on an ICL mainframe for computing stress intensity factors in bonded fuselage structures and successfully validated the method against test results. He was awarded the postgraduate N.E.Rowe medal of the RAeS in 1980 for his paper describing this work. He can be reached by email @ Mark.Norris@theSDMconsultancy.com