NAFEMS

What is
simulation data management?

THE INTERNATIONAL ASSOCIATION FOR THE ENGINEERING ANALYSIS COMMUNITY

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Simulation is key to digital product development, manufacturing, and lifecycle management. “Simulation” also known as “Computer Aided Engineering (CAE)” or “Analysis” is the use of computer tools, which are based on fundamental physical laws, to evaluate aspects of product performance.

Companies everywhere want to take advantage of simulations in order to develop better products faster and cheaper. They want to extend simulations early, during product concept and architecture development, and they want to replace physical testing for product validation as much as possible. However, they struggle to manage their simulation data, which is increasing in size and complexity by orders of magnitude as more numerous and more detailed simulations are performed.

The effective management of simulation data and process information is increasingly important as simulation becomes a core business practice and organizations rely on simulation results as the basis for business decisions. “Simulation Data Management (SDM)” is a technology which uses database solutions to enable users to manage structures of simulation and process data across the complete product lifecycle. SDM artifacts can be data, models, processes, documents and metadata relevant to modeling, simulation, and analysis.

Characteristics of simulation data

An often-asked question is, “We already have a product data management system for our (CAD) data, why not just use it for our simulation (CAE) data?” It is convenient to understand the requirements to manage simulation data through a comparison with other data and processes managed in the PLM environment. Simulation poses some unique challenges for both data and process.

Simulation generates huge amounts of data that has a short lifecycle of days or weeks. The majority of simulation data is created in iterative learning cycles or is temporary reference data that might be deleted once the product functional performance has been assessed and design decisions have been made.

Complexity and size of data
Simulation has many data types, and requires significant extensions to a standard PLM data model to represent simulation objects, data sets and process records. Simulation comprises many physics domains, and each domain may require a different solver and a different representation of the product geometry. A single part, for example, an automobile windshield, may have dozens of different representations in the simulation models that include it. Indeed, some representations are abstractions that contain no explicit information on the geometry.

Simulation data forms can be quite complex, and often involve the time history of multiple field values (scalars, vectors and tensors) on discrete locations of the model.

Large file sizes bring another dimension of complexity to Simulation Data Management. CAE results files may be orders of magnitude larger than, for example, CAD component geometry files.

Size, complexity, and the work-in-process (WIP) nature of simulation data are special aspects that need to be addressed.

Distributed data
Strategies for SDM must face the issue that the data is often distributed. Very large files may be generated on remote HPC systems and large files may be generated on local clusters or high-end desktop computers. It may not be feasible, or desirable, to move all simulation data into a single physical repository. Indeed, many large analysis output files may be deleted after a relatively short period of time. SDM enables the key results of many experiments to be consolidated into a single enterprise database.

Visualization and collaboration
The size, complexity and data structure issues noted above bring particular challenges for simulation data visualization and collaboration.

Highly compressed representations of simulation results, which comprehend complex field data across a wide range of physics, can be effective for collaboration in a simulation environment.

Process and context
Engineering simulation typically involves a complex sequence of steps, the result of which is an assessment of the design and or product performance. The context and the process are key to the value of simulation data. SDM involves tracking the "how" and the "why" of data as it is created. A simulation model should be traceable to the design information used to generate it, and a simulation result should be traceable to the input data and to the application software version used to generate it. This process and context information is the core feature of an SDM, and it enables reuse of data and processes.

Business processes and rules
Simulation process requirements may be very different than those of other functions. Examples are change control, and data authority for creation and deletion.

Enterprise access
The number of groups across the enterprise that need to access simulation data is significantly fewer than those interested in other product data, such as CAD. However, managing access control, security, and access to software licenses across a range of computing resources can be an extreme challenge.
During the simulation lifecycle there are three distinct phases with different goals and objectives.

Process, context, and metadata capture

The simulation process may vary from a complex chain of events and interactions to a simple job submission. The process may be manual, semi-automated, or fully automated. The process (user for manual processes) knows the information that is required such as the identity of every piece of data used together with their respective relationships along with what software tools were used. It is highly suggested that whenever possible that the simulation information should be extracted from the process automatically as it is run, to avoid errors and lack of validity associated with manual entry of this information. Automated capture of the simulation information from the process is key to unlocking the value of managed simulation data.

It is also important that the process and context information (metadata) be robust. It is desirable, for example, to preserve the link between the input file and a lightweight report when deleting a large results file.

Simulation lifecycle

Data gathering and model preparation
This first phase involves creating product configurations and bills of materials, and then building and detailing the simulation models. Access to a wide range of product design information is required, including product requirements, geometry, connections (welds and bolts), material properties, loads, etc. For example, specialists at Automotive OEMs often do this phase as a service, and they heavily utilize the enterprise PDM system. There is also a need for simulation-specific libraries containing occupant models, multi-body dynamics subsystems, and the like. SDM is not just for the automotive and aerospace industries; SDM can be utilized over a range of simulation activities which are utilized in the chemical, pharmaceutical, and consumer goods industries.

Active work-in-process. During this phase the analysis work is ongoing and may be exploratory in nature and the large analysis output files created may be temporary. Indeed most of the output data created in this phase will be deleted shortly after creation but which simulation models and results data will need to be retained is not known a-priori. Simulation Data Management in this phase should be as transparent as possible to the user and be integrated with the simulation processes. The capture of key results, process and context information in this phase adds significant value.

This phase includes recommendations and decisions made during product development, and continues through final design release and start of production.

Sustain to end of lifecycle
"Final" simulation information is retained to support manufacturing, product changes, and customer field issues during the remainder of the product's life cycle. This information is also for reuse – it may form the basis to investigate new products or product improvements.

This stage includes the archiving of simulation data to retain a record of the information used in the decision making process. Effectively, this re-quires context and process information as well as the data. Requirements for compliance, regulations, and legal discovery must be met.

SDM system functionality

An SDM system must have basic functionality, and should manage the process and context information necessary for simulation data. At a minimum, it should provide:

- User management, system access, and security
- User roles, groups, and permissions
- Base data management functions: versions, groups, status, and change control
- Automatic and manually generated metadata that allows data objects to be unambiguously identified and classified.
- Relationships and links that allow the association of data objects for example, parent child relationships that establish the provenance and pedigree of data objects.
- Search capabilities based on file context, content, metadata, and relationships.

Additional functionality may include:

- Work flows that allow handoff of work: For example, document approval.
- Process templates that describe tasks and then automate metadata creation.
- Lightweight visualization and collaboration tools that interface to multiple data formats.
- The ability to embed or integrate with simulation processes
- The ability to integrate in the PLM environment: PDM, CAT, requirements, materials, etc.
- Capability to create and manage configurations and bills of material.
- Integration in the CAE environment, particularly for pre- and post-processing, and job submission to compute clusters and HPCs, so that data management and metadata collection are as unobtrusive and automatic as possible.

Process management and automation

The base functionality that an SDM system must provide is the management of simulation data, and information describing its context.

Process automation options run the entire gamut: at one extreme, the SDM contains no process definitions, but is used as an external store by automation tools, perhaps through an API. This simplest conceptual approach is akin to a shared electronic filing cabinet, an extension of the common Unix shared drive. The primary means of accessing information is by a (perhaps configurable) hierarchy of attributes. This system does not control the processes that create the data, be they manual or automated. It should provide a means for processes to populate and update data, and to capture metadata.

At the other extreme, process definitions and automations are completely encapsulated in the SDM, which cannot manage data created or modified outside the system. "Vertical applications", which automate specific tasks, are at this extreme.

Most SDM implementations are between these extremes – they enable some degree of process definition and automation, and they are able to bank external data and metadata.

Process automation may yield large benefits, but may be expensive to implement. The cost to implement and maintain customizations must be carefully weighed against the ongoing and projected benefits.

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Often, in an organization there are a lot more diverse tools used in CAE/simulation compared to CAD/PDM. So rapid deployment approaches in smaller groups to begin with that does not require the entire CAE/simulation organization to come up with a unified strategy may have to be considered as part of a deployment strategy (bottom-up approach).

PLM integration

The choice of an SDM strategy should be carefully weighed against the requirements for customization, configuration, and integration with other systems. This includes not only initial costs, but provision of the skills needed to maintain and further develop the system.

The SDM strategy should not be developed and deployed without considering its part in the total PLM strategy. An SDM system will need integration not only with simulation applications, but also with elements of the PLM ecosystem, for example:

- CAD and other design data
- Material properties
- Test data
- Product performance requirements
- Product configurations and Bills of Materials
- Workflows for change management

An SDM system should enhance end-user productivity while also providing broader benefits like improved information for decision-making. Dictates to use systems that reduce end user productivity will likely fail.

SDM capability delivered as part of the native data authoring tools (CAE pre, post-processors or simulation tools) can reduce the barriers to adoption and provides a bottom-up approach to implementing SDM.

Business case. The business case for SDM can be made by efficiency gains within the simulation function, particularly where simulation processes are repetitive and applied to similar product definitions such as in the automotive industry. Some companies have realized large enterprise-level gains in product development time, quality, and cost.

Please refer to the NAFEMS Business Value from Simulation Process and Data Management white paper which addresses both the benefits derived from the core data management system and the additional gains achievable through process automation.

Further resources

The following are recommended:

- NAFEMS publication "Simulation Data Management Survey Report" (order reference R0102 from NAFEMS)
- NAFEMS publication "Business Value from Simulation Process and Data Management" (order reference R0104 from NAFEMS)
- NAFEMS working group on Simulation Data Management
- NAFEMS SDM Conferences
- CIMdata / CPDA website
- Vendor websites

Glossary

CAD Computer-aided design

CAE Computer-aided engineering (simulation)

CAT Computer-aided test

DMU Digital mock-up

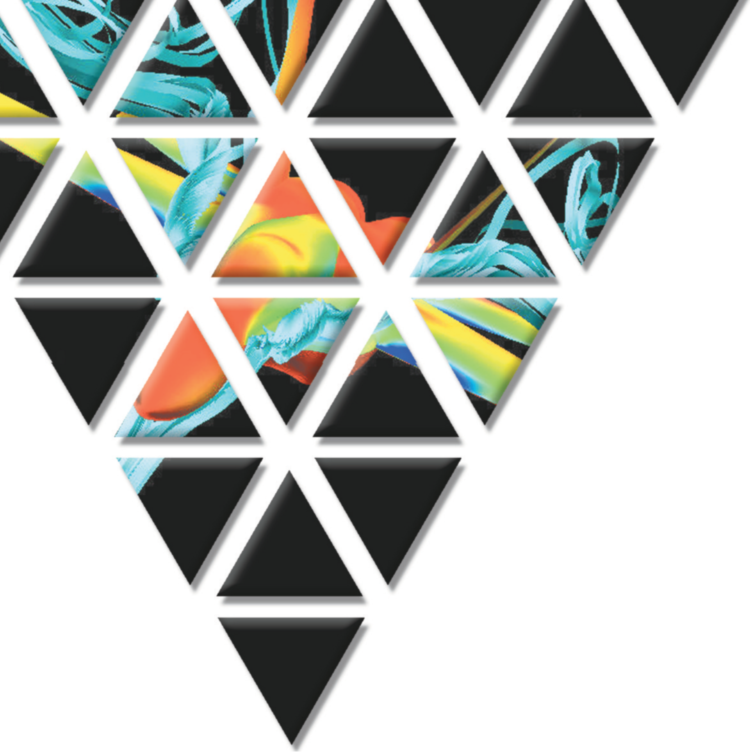
PDM Product Data Management

OEM Original Equipment Manufacturer

PLM Product Lifecycle Management

WIP Work In Process

HPC High Performance Computing



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