Simulation Lifecycle Management

"More than data management for simulation"

July 2011

A CIMdata Report

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As product complexity increases, manufacturing industries are under continuous pressure to deliver innovative, competitive products faster. To do this, they are increasing the use of simulation and analysis (S&A) to better understand and validate product behavior, and to make more informed design decisions. Managing this expanding S&A environment (the analysis tools, data and processes) is more and more important—and it needs to be integrated with the enterprise's overall product development environment. This paper presents the challenges that companies face in deploying modern, productive simulation lifecycle management (SLM) environments, defines the key necessary elements of such environments, indicates the benefits that SLM can deliver, and describes how Dassault Systèmes SIMULIA SLM product suite responds to those needs.

1. Introduction

In today's highly competitive global market, delivering right-to-market products faster is critical to a company's success. The increasing complexity of a product, often a combination of mechanical, electronic, and software components, adds to the difficulty of doing this. Old ways of developing products simply do not meet the needs for innovative and faster development lifecycles.

To help design and perfect today's more complex products, simulation and analysis (S&A) is becoming increasingly important to manufacturing enterprises of all sizes. Broader, deeper, and more effective simulation is needed to properly analyze the complex products being designed and developed and validate that they meet functional and regulatory requirements. S&A tools and methodologies must be used more effectively throughout the product development process to improve designs and reduce the cost of prototyping and physical testing. This is driving increased investments in simulation.

Simulation has significantly expanded over the past several years. Wikipedia defines simulation as, "the imitation of some real thing, state of affairs, or process. The act of simulating something generally entails representing certain key characteristics or behaviors of a selected physical or abstract system." For years, simulation in product development was primarily limited to finite element or computational fluid dynamics analyses. Today, simulation encompasses a much broader range of technologies and functions. Companies now need to, and can, perform multi-physics and multi-discipline simulations to enable them to make better and earlier design decisions.

Because of the increased need for and importance of simulation, companies now recognize that S&A information is valuable intellectual property (IP) that needs to be captured, shared, and leveraged throughout the product lifecycle. New approaches are transforming product-related S&A into a visible and accessible component of the product development process, across the full product lifecycle and across extended enterprises; not just maintaining them as a domain for specialists. The result is that the impacts on a company's operations and success are much broader than previous S&A-related initiatives. We call this approach to managing S&A information and processes, and integrating them within the full product lifecycle, Simulation Lifecycle Management (SLM). SLM is the enterprise's gateway to simulation tools, processes, and data. By serving as that gateway, SLM offers excellent potential to provide solid benefits to companies over the coming years, and to significantly improve the value of S&A to the overall product development process within the enterprise.

This paper provides a perspective on SLM: the pressures that motivate its use; SLM's role; its value and future; and how Dassault Systèmes is developing and delivering advanced SLM solutions for the PLM market.

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2. Business Challenges

In today's market, competition can come at any time from anywhere. Manufacturing companies everywhere are developing products not just for their "home" market, but to

be sold and serviced worldwide. This global market is demanding that companies design, develop, deliver, and support products that are tailored to localized needs. These market demands continue to require companies to deliver products with increased performance and higher quality at acceptable prices. This demand drives innovation; which increases the integration of systems and complexity of the products.

To compete, companies must analyze and simulate their designs to validate that they meet or exceed all areas of functionality and performance while complying with all applicable regulatory issues. They need to compress their product development and validation processes so that they can bring these more complex products to market faster.

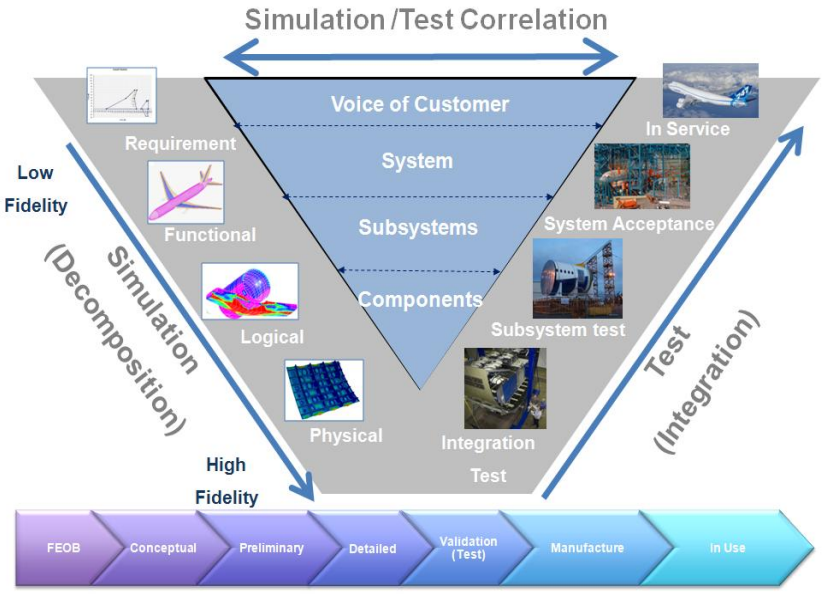

Figure 1—Simulation Across Multiple Domains and Disciplines

A key factor in delivering right-to-market products in the shortest possible time is improving how companies analyze, simulate, and test new designs and products to validate that the designs meet both customer and functional requirements and applicable standards. Historically, this has been accomplished by using a combination of different, non-integrated analysis tools and testing physical prototypes. Such processes have added significant time and costs to the overall product development process.

Companies are recognizing that S&A information (models, test sets, results, and other related data) generated during the design, deployment, and execution of simulation methods is valuable IP that needs to be captured, shared, and leveraged throughout a product's lifecycle. As a result, investments in simulation and analysis offer an outstanding opportunity to significantly improve the overall product development process. New approaches are being developed and implemented in companies worldwide that much more effectively integrate S&A activities into the enterprise and enable capturing and reusing knowledge gained in this critical area.

Simulation and analysis has not, by and large, been well integrated into the broader enterprise. Investments in S&A have typically been for the development or acquisition of focused technologies that allowed specialists to more precisely analyze alternative product designs for improving performance, validating compliance, and other design purposes. However, S&A has generally been treated as something of a "black hole" within the overall product development organization. Previous investments have not focused on linking S&A more effectively into the overall product development process to satisfy the needs of the broader enterprise.

2.1 Simulation is Pervasive Across the Product Lifecycle

Simulation has significantly expanded over the past several years. For years, simulation in product development was primarily considered or limited to component-level finite element or computational fluid dynamics analyses. Today, simulation encompasses a much broader range of technologies used to predict design behavior and enable design decisions throughout the product development lifecycle. For instance:

- *Front End of Business (FEOB):* Simulations are used to predict solutions, to proactively communicate options to potential customers and to capture business.
- *Conceptual Design:* High level, lower fidelity systems simulations are performed to ensure that design systems meet market requirements.
- *Detailed Design:* Component-level higher fidelity simulations are performed to meet physical requirements.
- *Validation:* Simulations are correlated with physical test data at all system levels.

As a design matures, from concept through detailed design, simulations are progressively performed to help make

product design decisions that meet defined requirements, functional descriptions, system behavior, and engineering and physical specifications. Further, each simulation may address different levels or disciplines of the system being analyzed. During the lifecycle, the scope of performed simulations will vary from the full system to a sub-system and to an individual component. The fidelity of the simulations also varies depending on when and how the results are being used.

As companies develop more complex products they are expanding the use of S&A so that they can conduct more complete and broader multi-physics analyses. They need to consolidate and harmonize the multiple types of solutions being used so that data and geometry re-entry are reduced and to ensure that multi-physics and multi-body interactions are correctly simulated and analyzed. Product complexity drives the need for more complete simulations and analyses. For example:

- Coupled thermal and flow; e.g., electronics cooling simulations
- Coupled structural and flow; e.g., airflow over a windmill blade changes the shape of the blade and hence the stiffness
- Impact of control systems that drive mechanical systems; e.g., computer-driven hydraulic systems

Today simulation covers a much broader scope of product development. Multiple product characteristics and domains need to be simulated and analyzed to gain a complete understanding of the product's design and performance. Other technical areas of simulation include kinematics, sound, and thermal. Beyond specific technical domains, the need for full system simulation is becoming more critical. Automobile companies want to conduct full car crash simulations so that they can fully understand and predict how each area of the vehicle will react. This enables them to design for safety while reducing the size and cost of individual car components.

Other types of simulations are used to predict and model how multiple systems will interact. This is particularly important for understanding how mechanical and electronic sub-systems will perform when connected to one another. Simulations are being used to illustrate how human interaction with a product occurs—testing functionality and ease of use. And cost is being included in simulations to better understand the impact of changes in design options.

As a result, simulations are becoming more multi-physics and multi-discipline. These more complex simulation scenarios help designers and engineers more easily "see" the impact of one area on another, e.g., changing the size of an enclosure on the thermal flow and heat over electronics. However, each discipline requires different degrees of simulation fidelity and different types and levels of inputs. Furthermore, these multi-disciplinary simulations are typically performed by different individuals in different organizations, thus creating the need for a common collaborative enterprise simulation system.

2.2 Growth of Simulation Data and Methods

The pervasive use and accelerated adoption of simulation is being aided by three critical factors:

1. The core simulation applications continue to grow and mature. Across multiple simulation domains, and ever greater complexity of simulation models, the technology today is very robust and mature, and has gained the confidence of manufacturers as a means to predict performance.
2. As companies' confidence has grown in the core simulation technology, adoption has expanded from the traditional use in detailed design and validation, to more predictive roles across the product lifecycle.
3. Today's high performance computing systems enable users to build far more detailed and accurate models than even a few years ago, and run through a wider variety of design alternatives, resulting in more robust designs.

As the success of engineering simulation grows, it has created a real challenge for the engineering and information technology (IT) organizations responsible for the protection and storage of this enterprise asset. As the design processes' reliance on simulation grows, the engineering analysts are challenged to effectively manage the associative data they require while at the same time, corporations look to effectively protect, manage, and maintain these data volumes. Meanwhile, the average data volumes generated and stored by engineering communities within medium to large manufacturers is increasing dramatically and projected to reach multiple petabytes (1 petabyte = 1,000 terabytes) by 2012. Further, because most of this content is unmanaged, the quality of the data is suspect—estimates show that each S&A user will develop 25 to 48 thousand files, of which 20% to 30% will be duplicates, and over half will not have been touched in the past few years.

2.3 Simulation and Test Within the Enterprise

Although engineering simulation and analysis has increasingly become an indispensable part of product

development, it continues to be relatively disconnected and ineffectively used by the rest of the organization. Thus, many companies are failing to get the full potential value from simulation. There are several factors preventing maximum benefit, for example:

- Simulations are often performed to validate a design rather than to support the evolution of a design.
- Simulations are performed by a few experts and the results are not available to designers as they evaluate design options.
- The design and simulation process may be out of sync, and the lack of associativity between the state of the design and a simulation causes confusion.
- Inconsistent quality and accuracy: the results of simulations do not always match physical tests (although this is continually being improved).
- Cultural, operational, and organizational differences exist across the design and analysis groups.

In many companies, S&A is handled in a serial manner, in which concept engineering creates a design and then passes it to simulation specialists, who then enter (or most likely re-enter) the design data in a form needed to run their simulation applications. This process is time consuming, and while the simulation specialists perform their analyses, the concept designers continue to work—which results in designs being developed or modified without the benefit of appropriate simulation and analysis to determine what changes should be made. The design then must be re-worked, adding time and cost to the overall process.

Most companies have no formal system in place for properly archiving and managing this valuable intellectual capital; nor do most of them have mechanisms in place to capture and leverage "best practice" processes developed by their best simulation and analysis experts. When others need the resulting information at a later time, they must spend considerable time checking with colleagues and looking through obscure files and information, perhaps coming up with nothing or maybe retrieving the wrong version. Worse yet, critical information is often inaccessible when originators leave the company or are otherwise unavailable.

In addition, the processes used to develop the analysis may not be defined or remembered, even by the individuals who initially developed them, so repeatability of analyses is frequently not possible and comparing results may be questionable. The knowledge of what processes work best is often lost entirely. The impact of not managing analysis data and related information on work processes can be significant. Without this information, no audit trail exists to document how or why the work was performed. Additionally, procedures are not recorded for reuse on subsequent similar projects, forcing engineers and analysts to waste time re-inventing the same process over and over. Without complete and accurate capture of the simulation test data and methods used, the results may be called into question or not be usable, and simulations will lack repeatability.

As products move into validation lifecycles phases, virtual simulations performed in the earlier phases of design are now being validated through physical testing. Test data management tools tend to be specific to post-processing raw test data and localized to a department or a type of test. Investments in these tools have traditionally focused on device or hardware acquisition and maintenance, and raw data collection and preparation and correction. This results in a very capable and efficient test capability applicable to the particular needs of the test community, but one that is not targeted at the broader enterprise consumption of test data outside of the test lab. A significant opportunity exists to increase the value of both testing and simulation, and can be realized when the data and methods are maintained in a common platform.

Companies need to create environments in which the knowledge of the S&A and test specialists are captured and made available to others who need that information. Further, simulation, analysis, and test functionality needs to be incorporated into the conceptual design process such that design engineers can perform preliminary simulation to determine the validity of their design concepts before detailed design commences.

2.4 Preserving Simulation Knowledge

Complicating these issues we find that aging and changing workforces are forcing many industries to face a generational transition. Simulation skills and expertise, developed over many years (and a valuable competitive edge), are (1) being lost due to the aging of the workforce, and/or (2) going offshore due to outsourcing or design partnering. The "gurus" who have experience in an enterprise's S&A processes will not be around forever and their knowledge and expertise will leave with them unless it is captured and used as a corporate resource. It is critical that companies capture this knowledge and distribute it so that others are able to reuse it and pass it on to the next generation of engineers and designers. The cost of losing this knowledge is considerable and has significant impacts on the ability of a company to maintain and deliver innovative products in a timely manner.

The increasing importance of S&A to the success of a business is driving the need to better manage S&A—the people, processes, data, and technologies involved. A new more systematic, integrated, transparent, and collaborative approach to simulation is necessary to break this negative paradigm. This need has led to the emergence of SLM.

3. SLM Defined

To bring simulation data and processes into the enterprise lifecycle, leading-edge companies are implementing programs to get their simulation data under control and to better manage their simulation processes and knowledge. These companies seek to include the analysis of intellectual property as part of their product lifecycle management (PLM) implementation. However, bringing simulation into the enterprise is much more than managing simulation data. As traditional PLM routinely captures the form and fit of product designs through digital mockup (DMU), simulation lifecycle management compliments PLM by associating behavioral simulation data and processes with the DMU; in essence offering behavioral-digital mockup (B-DMU). In doing so, this then provides a single source of truth for all design and S&A information and processes.

Therefore, a major objective of SLM is to transform simulation from a specialty operation to an enterprise product development enabler that spans many segments of the product lifecycle. To do this, SLM should provide technology in four foundational areas:

- Simulation and test data management
- Simulation and test process management
- Decision support
- Enterprise collaboration

Figure 2—Four Components of SLM

3.1 Simulation and Test Data Management

Simulation and test data management allows companies to formally manage the data used and generated by simulations and tests; making all content searchable, traceable, and associated with enterprise business data and practices. It manages the data used as part of simulation including geometry, simulation representations (e.g., meshes and models), input and output parameters, test conditions and options, supporting references and tools, and the results of the simulations executed.

A key capability of SLM is the ability to associate simulation information and processes to the product design information and structures. Simulation inputs, results, and processes used can be linked to specific components and assemblies of a product and to specific versions of the product and its bill of materials (BOM). This also enables simulation information to be associated with product requirements so that validation of those requirements can be tracked. By associating simulation data to enterprise data, SLM becomes part of an enterprise's single, logical information backbone for CAD, CAM, requirements, design, manufacturing, and simulation. Users have one logical source to find and access all product related information regardless of their task or work domain.

SLM also provides an architecture tailored to manage the unique challenges of simulation and test data in a way that is seamless to the analysts. This includes managing and minimizing file transfers over the network to provide users with access to simulation data regardless of its size or geographic location. Data produced and consumed is also automatically revisioned, dynamically attributed, and access controlled. This allows SLM to capture a clear history of the simulation evolution and ownership back to its origin.

Simulation data management is similar functionally to PDM but designed specifically for S&A needs. It enables users to more easily and quickly find the simulation information they need. They can query for simulation inputs and results and the status of simulation

processes. Companies, and users, can associate simulation-related attributes, e.g., the input for a specific parameter, and later search for and retrieve simulations with those attributes. SLM systems support the ability to dynamically assign attributes as needed as well as supporting pre-defined attributes.

SLM enables engineers performing both virtual and physical testing to work on the same data management platform from anywhere in the world—from the specification phase to production—and maintain traceability between all the phases of the complete product development. It provides a uniform data model that can handle both the simulation and test data in a consistent manner, integrated into the product development environment. The intention is not to displace the applications dedicated to test data collection and preparation, but rather to connect them to the primary design and engineering information systems of the company, usually PLM, where decision makers can have access to the information at any time in the product development process for making a better and fast decision.

Because SLM is part of a simulation enterprise backbone, engineering knowledge, whether in work or legacy, simulation or test, is accessible and searchable in this single framework. The general engineering community has less concern about the source of the data (virtual versus physical) and is more concerned with the quality of the data—the knowledge imparted by the data, and the reuse of the data to support further analysis and decision making. SLM brings all forms of validation data to the larger community in a manner that encourages trust, confidence, and collaboration.

3.2 Simulation and Test Process Management

Equally important to managing data, SLM manages the simulation processes—what will be done, when, by whom, and where the results will be delivered for both use and to archive. SLM manages the execution of integrated simulations and supporting tools. SLM solutions should take an agnostic approach to simulation integration, as these tools may be provided by multiple suppliers or developed within the organization. Thus SLM can support applications from multiple disciplines, e.g., FEA, CFD, kinematics, cost, and mathematical models, allowing the full scope of simulation to be addressed. With proper integration, SLM can assign a simulation to the appropriate computing systems (local, distributed or HPC) and the behavior (user interactive or batch), thus providing the basis for a range of flexible simulation processes:

- Ad-hoc: Dynamic process that involves a high degree of user interaction.
- Best Practice: A process with documented methods driven by analyst interaction.
- Guided Practice: Domain-focused template methods to guide the user through a best practice; may be a combination of interactive and automated steps.
- Fully Automated: A fully automated template-driven process; complete with automatic in-process data management.

Once started, the SLM environment ensures that the processes proceed correctly by managing the execution order of the activities and the in-process data transfer (both files and parameters) between activities. This also establishes traceable links between simulation data, activities, and processes, that can display up-to-date status to understand how downstream work is affected by enterprise change. As the enterprise community evolves the design, these downstream simulation activities and data impacted by this change can be displayed in real-time.

By supporting the capture of the complete range of simulation processes, SLM allows organizations to distribute and evolve simulation knowledge for maximum reuse and efficiency. For this purpose, templates can be created by simulation experts and then used by non-simulation engineers, thus expanding the number of workers able to conduct simulation activities and leverage simulation results.

3.3 Decision Support

Fundamentally, organizations perform simulations to validate decision making based on functional, logical, and physical requirements. SLM provides capabilities to capture and present simulation information and results to enable these design decisions. SLM's support of simulation reviews enables organizations to quickly access and visibly associate simulation information with its design definition, so that simulation results can be interpreted to make collaborative design decisions. To enable design performance and quality decisions, SLM provides the ability to explore multiple design options through the application of multi-run design exploration methods, such as design of experiments, optimization, and design for Six Sigma. This information, which may represent hundreds of design alternatives, can then be used to collaborate with colleagues, partners, or customers. What was a discussion regarding a single design now transitions into a discussion about design options and tradeoffs based on requirements.

3.4 Centralized, Secure Enterprise Collaboration

SLM enables simulation collaboration both within an enterprise and across its value chain. Since all simulation activities are managed by the SLM system, it provides a secure environment for simulation. User simulation roles and responsibilities can be defined and the system will ensure that each worker has access to his or her needed data and can only perform those actions for which they are authorized.

SLM enables companies to capture unique company S&A best practices and make these practices usable when appropriate, by "less expert" individuals throughout the product lifecycle. Experts develop the best practices, and SLM provides a mechanism to save both these practices and the results of the simulation analyses. Once best practices are captured, they are made available to be used by anyone in the organization capable of gaining value from them.

SLM has evolved from just managing simulation results files (essentially providing S&A data vaulting) to being a process- and context-driven management environment. With SLM, simulation is no longer decoupled from the product lifecycle. Simulation data and processes can be linked with requirements, parts, the BOM and other elements in the PLM process. Verification and validation of the design becomes more than a check in a box. Approvals have more substance than just a signature. Users can navigate to the exact simulation results that drove the design decision. SLM helps make it straightforward to see the genesis of the design—why certain designs were selected in favor of others. This exposure of simulation to the enterprise PLM provides a critical bridge between design and engineering.

4. Benefits of SLM

Because of its broad scope in the product lifecycle and the potential to touch a wide range of disciplines, SLM can be a fundamental component of a company's strategy for PLM, an overall enterprise-based initiative to tackle product and product-related process improvement. This transforms product-related simulation into a visible and accessible component of the product development process across the full product lifecycle and across extended enterprises; not just a domain for specialists.

The ability to more broadly use simulation capabilities and enable non-experts to benefit from expert practices offers many important benefits, including:

- Eliminating barriers between various groups
- Enabling improved assessment of risks
- Enabling more informed decisions
- Providing a more collaborative engineering enterprise
- Improving traceability of design validation
- Increasing the speed of product design activities

The most profound impact of SLM is that the approach can be an enabler for simulation-driven design in which analysis becomes a fundamental part of product development from early conceptual stages to performance optimization and detailed design. This elevates simulation from a design validation tool to a decision-support solution in developing innovative product designs that may not otherwise be intuitively obvious or practical to study in any other way.

Having a central role for SLM in product development opens the way to a number of positive impacts on the financial health of organizations that embrace SLM capabilities. People in non-analysis areas can see, use, and react to simulation results to help them make better design and product decisions faster. Benefits can accrue from SLM in two broad categories: business value enhancements and product development cost savings. Opportunities for business value enhancement can be identified in several areas:

- Improved design quality, by supporting the use of S&A technologies and capabilities much more broadly across the product lifecycle, early in the cycle as well as downstream to support production, maintenance and service, and other areas.
- Improved product designs and faster development by expanding the number and types of people who can use simulation and analysis technologies, processes, and knowledge.
- Promotion of innovation and enabling continuous improvement by capturing, continuously refining, and applying knowledge to designs.
- Increased revenue through increased efficiency and improvements in bidding.
- Decreased time-to-market by integrating simulation and analysis earlier in the development process.
- Increased numbers of new products per year by enabling faster development of products.
- Ensured repeatability of analyses across multiple design iterations and compliance with standards and regulations.

Product development cost savings are much more direct and easily measured. Experience with SLM users shows that these savings can be estimated for many areas, some of which are:

- Reduced costs by up to 90% in executing simulations through lower efforts for data acquisition, model creation, pre-processing, solving, post-processing, reporting, and simulation data and process management.
- Reduced cost for managing third-party analyses through better management and coordination of their work.
- Increased analysis model reuse which can reduce cost by up to 60%.
- Reduced costs of up to 40% through lower numbers of and costs for prototypes and tests.
- Lower simulation technology budgets by up to 40% through consolidation of simulation tools and techniques.
- Lower re-work costs due to performing analyses earlier in the lifecycle and providing results earlier to designers.

5. SLM Deployment

Implementing an effective SLM environment has the same issues and needs as implementing PLM, ERP, and other solutions that can have a major impact on business, operations, and performance. The key to success is a full understanding of a company's business requirements as they pertain to S&A. Once these requirements are defined, they can be evaluated against possible solutions as part of the SLM selection process. Factors that need to be considered include:

- Simulation content management
- Simulation integration and execution management
- Simulation process management
- Design exploration and test data correlation
- Multi-disciplinary optimization

The situation in most companies today is that simulation data resides in files that are largely unmanaged and spread across organizational file systems. The first step of an SLM deployment is to get this data under control. This means storing simulation-related files in a managed repository and adding version control and traceability. Once the simulation data is under control, management of simulation activities can be implemented. This requires integrating simulation and test applications. SLM manages these processes, preserves best practices, makes them easy to find and ensures that users are working with the latest and correct version of the process. As processes continue to mature they may be automated to further improve simulation efficiency. Once automated, design exploration problems can be formulated and execution performed.

An SLM solution should be designed with an appropriate architecture, one that is capable of meeting the integration, deployment, and maintenance demands of a broad and constantly changing set of IT environments. It should be built on an open, flexible data model that supports the full scope of simulation information needed. It needs to incorporate or support the S&A technologies the company requires, either as part of the selected solution suite or via integrations with third party and in-house developed applications. Factors to consider are:

- The simulation data management needed both for work-in-process and at the enterprise level; including support for suppliers, partners, and customers.
- Internal and external collaboration, both real-time and asynchronous.
- The level of integration required within the S&A organizations. This includes the type of decision support needed relative to S&A information.
- The impact of deploying an SLM solution on current and planned IT infrastructure.

When evaluating potential SLM solution providers, questions to ask include:

- What simulation and analysis expertise and domain experience do they have? Do they understand and have experience with the types of simulations and analyses that you will need to perform? Do they understand how that must be done for your products?
- What PLM expertise does the supplier have? Do they understand the interrelationships among functions and processes of a complete PLM environment? Do they have personnel with domain expertise in each of the major PLM domains who also understand the interactions needed with simulation and analysis relative to their domains?
- What process expertise and experience do they have for both S&A and PLM? Can they help you with your process definition? Can they help you define and implement any needed cultural and organizational change plans? Do they have appropriate partners that can augment their staff and expertise?
- Do they have a flexible and open architecture and data model? Can this architecture fit into your current technology environment without undue cost and disruption? Will it support

technology and solutions provided by other (and competing) S&A solution providers? How well does it support your overall PLM strategy? What standards does it support?

- How do they plan to implement their solution for your needs? What products will be used and what capabilities will be supported?
- Who are their references and the contacts within those references? What other companies have implemented their SLM solution in a manner similar to your needs?

SLM will have a major impact on your business and you need to take the steps necessary to ensure that you effectively select the supplier of your SLM solution and the manner in which it will be implemented.

6. Dassault Systèmes SLM Solution

Dassault Systèmes has for many years recognized the importance of simulation and analysis as a key component of product development. Dassault Systèmes has a history in simulation and they continue to develop their domain expertise across the SIMULIA product suite. After the acquisition of Abaqus, Dassault Systèmes created SIMULIA as a separate division and brand with equal status to their other brands. They have applied their deep understanding of simulation to creating a comprehensive SLM solution.

Over the past several years Dassault Systèmes had made significant investments in S&A both with internal developments and with acquisitions. But Dassault Systèmes has done more than just improve their S&A applications (e.g., pre and post processors and solvers); they have applied their knowledge and expertise in the simulation and analysis domain to develop a comprehensive SLM solution suite. While similar to PLM and PDM solutions (and a part of an overall PLM environment), the SLM solution is designed and tailored to support the CAE specialist and S&A process and data.

Based on Dassault Systèmes' V6 platform technology, their SLM solution is designed to enable a company to define and manage simulation methods, models, and procedures (scenarios). They can automate standard simulation processes, deploy them across their organization, distribute workloads across computing resources, and manage the simulation results to improve collaborative decision making.

SIMULIA SLM is designed to simplify capturing and deploying approved simulation methods and best practices, providing guidance and improved confidence in the use of simulation results for product design decision making. It can help improve quality by providing traceability into simulation history and associated data. It also provides access to the right information needed for simulation through storage, search, and retrieval with functionality dedicated specifically to simulation scenarios and data that helps reduce the cost and time to prepare and execute simulations.

Components of Dassault Systèmes' SIMULIA SLM solution include:

- Scenario Definition
- Execution Engine
- Live Simulation Review
- Isight
- Add-on Components

Built on ENOVIA V6 data management technology and expertise, SIMULIA Scenario Definition enables a company to access current design models, define simulation scenarios, manage simulation data and results, and collaborate on performance-based decision making.

Through Scenario Definition, users are able to access workspaces to create and edit simulation scenarios. Experts can create company-specific templates using their simulation best practices and methods. These templates can be shared for regular use by a wide range of users. Companies can define standard practices and have the SLM environment manage them to improve repeatability and reliability of simulations.

The product enables each simulation to be configured with a set of attributes, activities, and applications required to complete the simulation.

Additional capabilities are provided by Isight and the Execution Engine modules.

Isight, a component of Dassault Systèmes' SLM solution, provides engineers with a suite of visual tools for creating simulation process flows—consisting of a variety of applications including commercial CAD and CAE software, internally developed programs, and Excel spreadsheets—to automate the exploration of design alternatives and the identification of optimal performance parameters.

Isight is designed to enable users to automate simulation process flows and leverage advanced techniques such as design of experiments, optimization, approximations, and design for Six Sigma to thoroughly explore the design space. Interactive post-processing tools allow engineers to explore the design space from multiple points of view.

Isight supports the integration of customer-proprietary applications. It also includes a module for integration of

Dymola models that are used for modeling and simulating the dynamic behavior of integrated and complex systems. It also provides a capability for users to overlay results from several analyses, customize charts, and deploy carpet plots to show the interactive behavior of two independent variables.

Most companies use a variety of analysis and simulation tools. Add-on Components is an extension to the standard Isight library of components that provides interfaces to Abaqus FEA software, major third-party simulation applications, and a range of design exploration and optimization algorithms. Additionally, the framework supports the integration of Add-on Components developed by customers and partners using publicly documented APIs. These components enable a company to integrate and run models or simulation applications (third-party or in-house-developed) directly within Isight.

Product performance data, as predicted by virtual testing, needs to be available to those who make mission-critical design decisions. Often, these people do not have access to, or knowledge of, the IP authoring tools used to create and view simulation data. To address this problem, Dassault Systèmes provides Live Simulation Review.

Live Simulation Review is an extension of Dassault Systèmes' 3DLive product's capabilities for 3D search and navigation with simulation-focused functionality, such as the ability to identify and navigate to all simulations performed on a given part or assembly. It enables collaborators to access simulation data, execute simulation templates, and review simulation results, and supports collaborative decision making during the product development process.

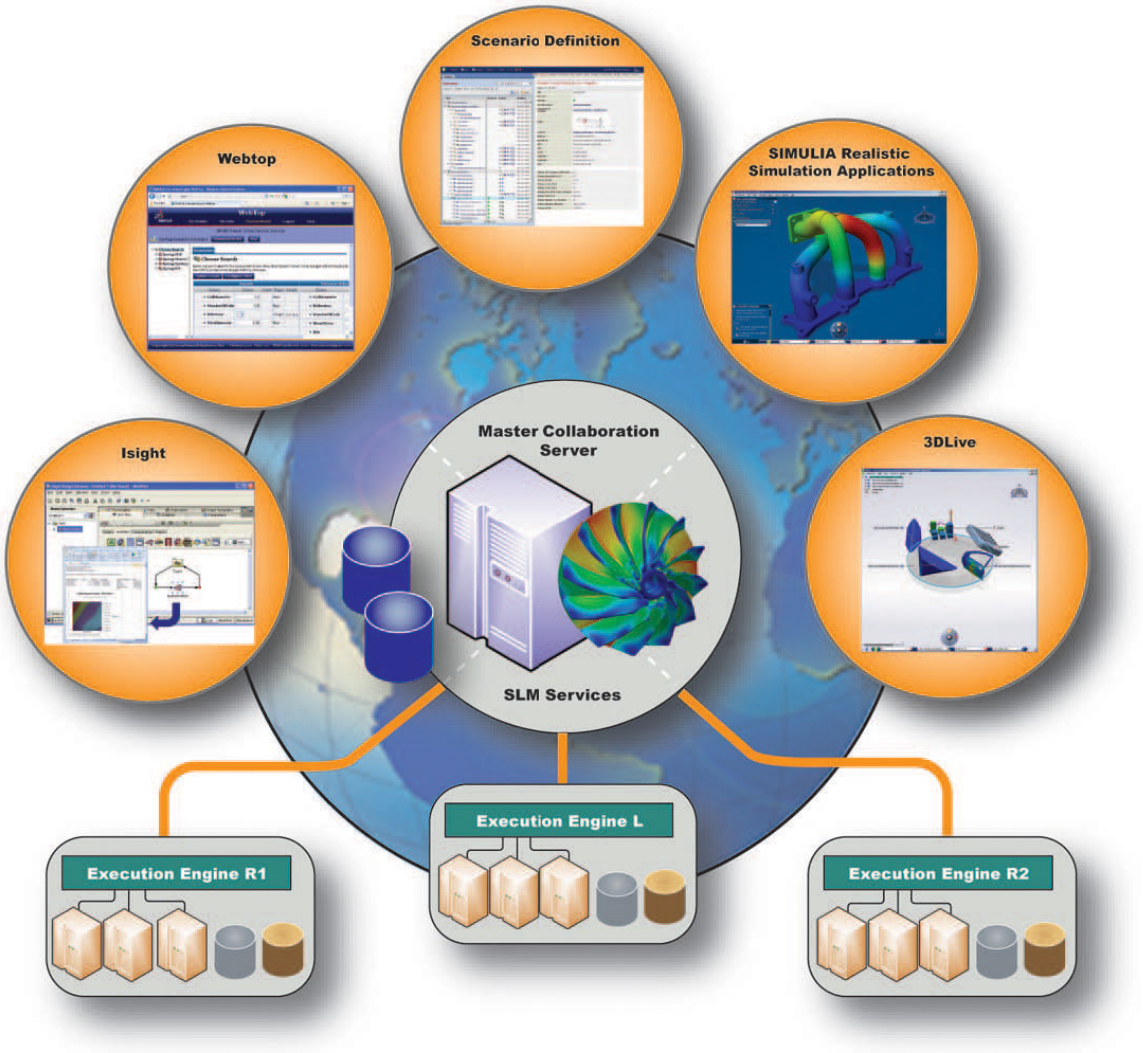

Figure 3—SIMULIA Execution Engine

Live Simulation Review helps collaborators and infrequent simulators explore simulation IP and execute simulation templates to explore product performance during all phases of the design process.

Another SLM component is the SIMULIA Execution Engine (formerly Fiper), which provides for distributed and parallel simulation process flows to help utilize a company's existing hardware and software investments (see Figure 3, above). The Execution Engine enables users, administrators, and IT organizations to control where simulations are executed and the processes by which they are run.

Companies are able to automate the execution of complex multidisciplinary design processes and leverage the most effective computing resources available at the time of execution. It also supports hot restart in the event of an unplanned application control system (ACS) shutdown (crash) or loss of network activity.

Dassault Systèmes' SLM solution is designed to support the full scope of S&A activities, data, and processes and to be a single source of truth for S&A information shared and used by CAE specialists, designers, engineers, quality personnel, management, and others.

It provides a large breadth of S&A solutions designed to work together and enable a company to perform simple, part level simulations through complex, multi-discipline full system simulations. It supports all the S&A solutions provided by Dassault Systèmes but also has an architecture designed to let a company integrate and use technologies and solutions developed in house or provided by other S&A providers.

Dassault Systèmes' solution addresses the four key SLM factors:

- Simulation and test data management
- Simulation and test process management
- Decision support
- Enterprise collaboration

By making S&A information available across the enterprise, Dassault Systèmes' SLM solution helps companies make better design decisions faster, while validating design conformance to functional and regulatory requirements.

7. Customer Case Study

CIMdata interviewed Frank Popielas, Manager of Advanced Engineering in the Power Technologies Group of Dana Holding Corporation, about their need for SLM, how they are deploying it, and the benefits they are achieving.

Dana is a major user of S&A. Many of their products have become almost commodities and they have to be very efficient in their design and development to maintain their competitive position. They do not run a centralized organization but have globally dispersed teams to better enable them to maintain closer contact with their customers.

Dana has been a long time user of Abaqus. They have evolved from doing basic structural and crash analyses to performing much more complex and complete simulations. While they continue to conduct component testing, they also are simulating sub-systems, complete systems, and global models. This has changed their needs for managing simulation technologies and processes.

Historically, S&A was performed by individuals who did all aspects from data preparation to execution to analysis. These individuals were responsible for their work-in-process and generally maintained both their inputs and results on local hard drives that they individually managed. This made collaborating and coordinating on larger projects difficult, as the different individuals did not know or could not easily find information they needed that was located on other individual's hard drives. Another problem was that the S&A analysts frequently did not know design changes had been made and thus they were conducting simulations with outdated information. Too often, analyses had to be redone to match the modified designs.

To improve their competitiveness, Dana needed to get the full leverage and advantage of using common technologies, sharing design and model information, common processes, and sharing the output and results of simulations.

Therefore, Dana has transitioned from having individuals who did all aspects of CAE to using large, globally dispersed S&A teams in which different individuals and groups are responsible for different S&A functions and work within an SLM environment. Separate teams are responsible for:

- Developing models and pre-processing
- Performing test setup
- Execution of simulations
- Post-processing the data

To make this change, Dana needed an SLM environment that would provide them the ability to manage end-to-end S&A processes, and the data and tools used within those processes. They needed a solution that supported their current simulation tools but also provided the flexibility to bring in other tools as required or as their simulation needs changed. They wanted to be able to automate the S&A processes as much as possible and ensure that analysis inputs and results were linked to the defining design models

so as to maintain configuration management across design and simulation.

Dana selected Dassault Systèmes' SIMULIA SLM solution. SIMULIA SLM has enabled Dana to create an environment that supports their globally dispersed S&A teams and to enable those teams and individuals to collaborate more quickly and effectively.

Mr. Popielas stated that Dana has achieved significant benefits from using SIMULIA SLM. Their simulation data is now accessible to the analyst community as well as to personnel in other areas who need to work with, or make decisions on, simulation results. They have been able to automate S&A processes and have reduced or eliminated non-value-added effort and time by their analysts.

He also said the quality of simulations has improved. Analysts are following consistent standards for simulation based on the types of simulation being conducted. There are standard templates and processes which are either executed automatically by the SLM system or that guide an individual through their assigned tasks. This has reduced time and errors. Input data is linked to the CAD models ensuring that the simulations are conducted against the current version of a design.

The SLM system provides up-to-date status information on simulation processes and results and notifies individuals and groups when results are available or when they need to perform an action. This has improved decision making while reducing the overall simulation process times. The SLM system is also being used to automate reporting and documentation of results.

One of the major benefits is that the consistency of simulation work across Dana has improved—reducing time and errors and enabling Dana to use its S&A personnel in a more flexible manner.

Mr. Popielas indicated that Dana has had a good working experience with Dassault Systèmes, who understood their problems and issues and were able to tailor the solution to meet those needs. He indicated that Dassault Systèmes' open approach to supporting multiple technologies (not just those they sell), was important in enabling Dana to use the applications that best meet their needs. He also stated that Dassault Systèmes has a good, dedicated SLM team that has been responsive to Dana's questions and requests for support and solution enhancements. He indicated that the architecture and technology provided fit into the Dana IT landscape relatively well.

8. Summary and Concluding Remarks

Product complexity continues to increase and simulation and analysis is becoming a key factor for developing timely, right-to-market products. Broader, deeper, and more effective simulations are needed to properly analyze the complex products being designed and developed and to validate that they meet functional and regulatory requirements.

The increasing use of simulation drives issues that must be addressed, including:

- Managing the data and processes used during simulation and test.
- Associating simulation and test content and processes with other enterprise PLM functions such as design, requirements, and programs.
- Improving simulation and analysis capabilities across multiple disciplines.
- Ensuring that the right simulations are performed.
- Linking simulation and test data and results to product configurations.
- Executing simulations on the most appropriate computing resources.
- Analyzing and reporting simulation results in ways that facilitate informed decision making.
- Making simulation information available to decision makers and users who are not analysis specialists.

Managing all of these factors throughout the simulation process and lifecycle requires more than just data management capabilities. Simulation Lifecycle Management is the answer.

Dassault Systèms is addressing these needs with their SIMULIA SLM program. They have developed a comprehensive SLM suite that provides not only the simulation technologies, but manages the S&A processes and information of a company in concert with their other product lifecycle information and processes. The solution also supports use of third party applications, including those from their competitors, so that companies may use the tools that best fit their needs.

Companies that have a need for managing their simulation and analysis processes and environment should consider Dassault Systèmes' SIMULIA SLM solution.

About CIMdata

CIMdata, a leading independent worldwide firm, provides strategic management consulting to maximize an enterprise's ability to design and deliver innovative products and services through the application of Product Lifecycle Management (PLM) solutions. Since its founding more than twenty-five years ago, CIMdata has delivered world-class knowledge, expertise, and best-practice methods on PLM solutions. These solutions incorporate both business processes and a wide-ranging set of PLM enabling technologies.

CIMdata works with both industrial organizations and suppliers of technologies and services seeking competitive advantage in the global economy. CIMdata helps industrial organizations establish effective PLM strategies, assists in the identification of requirements and selection of PLM technologies, helps organizations optimize their operational structure and processes to implement solutions, and assists in the deployment of these solutions. For PLM solution suppliers, CIMdata helps define business and market strategies, delivers worldwide market information and analyses, provides education and support for internal sales and marketing teams, as well as overall support at all stages of business and product programs to make them optimally effective in their markets.

In addition to consulting, CIMdata conducts research, provides PLM-focused subscription services, and produces several commercial publications. The company also provides industry education through PLM certification programs, seminars, and conferences worldwide. CIMdata serves clients around the world from offices in North America, Europe, and Asia Pacific.

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