Modern Engineering Simulation Environments

"Maximizing the value of your CAE investments"

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Produced by
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Today's manufacturing industries are under continuous pressure to deliver more innovative, competitive products faster. As product complexity increases, the use of Computer-Aided Engineering (CAE) is also increasing because simulation of both components and complete systems is required to understand and validate product behavior and make informed design decisions more quickly. Engineers need to predict and validate product behavior as early as possible in the development cycle. They also need to collaborate among multifunctional teams spread around the world. This paper presents the challenges that companies face in selecting and deploying suitable modern, productive CAE environments across relevant CAE user organizations to achieve collaborative business benefits, defines the key necessary elements of such environments, and describes how Siemens PLM's NX CAE responds to those needs.

1. Introduction

Today's complex global marketplace is challenging enterprises to become more innovative in order to maintain their competitiveness. Companies are continuously seeking new and better ways of addressing their markets with innovative products that capture the imagination of their customers while also meeting increasingly strict regulations. Companies have realized that enabling their designers and engineers to more quickly and thoroughly understand the functional behavior of what they are designing is a key component in successfully developing innovative, competitive products on time. To do that, companies need Computer-Aided Engineering (CAE) environments that empower their analysts and make their CAE organization more agile and productive.

Klaus Oesterschulze, Siemens Industry Group CIO said that complexity is today's biggest challenge. The amount of digital information increases tenfold every five years and that is slowing down progress. As companies struggle with complexity, noted Oesterschulze, they're not building, creating, and innovating. They're just managing. To succeed, this has to change!

The old paradigm of designing products and testing physical prototypes is too slow to keep up with today's pressure from both increasing product complexity and the need for faster time to market. To meet these challenges, companies are turning more and more to CAE. Increasing product complexity is placing demands on having better CAE tools, environments, processes and management of relevant engineering information within the overall enterprise. The reality is that today, and for the foreseeable future, most implementations of CAE solutions include applications from multiple technology suppliers. These applications need to be integrated with one another to support end-to-end CAE processes and the multi-discipline analyses required to fully simulate and validate complex products. Without improvements in CAE tools and management, additional resources will need to be committed to maintain and facilitate effective combined use of siloed simulation tools (so-called "best of breed" point solutions).

As the ongoing debate of "integrated, from a single supplier" vs. "best of breed" from multiple suppliers continues, analysts and their management need a common environment where seamless integration of their preferred suite of tools is available regardless of the supplier of the components. Additionally, companies want to simplify their CAE environments by using applications and solutions built on common technologies or having a common and seamless user interaction paradigm while working from a common CAE structured geometric model.

This paper describes the key challenges facing CAE end users and their managers, the need for and characteristics of a modern, effective CAE environment, and describes how Siemens PLM's NX CAE addresses those needs.

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2. CAE Today

Over the past four decades CAE has been progressing along the seven steps toward more fully realized enterprise payback as presented in Figure 1.

Step 1 has always been the fundamental requirement for any practical use of CAE. While CAE maturity varies across industries, the leading industries adopting CAE such as aerospace, automotive, and turbo or heavy machinery currently find themselves somewhere within Steps 4 to 7 with lingering problems resulting from steps 2 to 3.

Of course the needs of industrial companies are not static. As users and their management develop familiarity with, and effective use of, any current generation of CAE, they find functional limitations and gain insight as to the additional functionality they need. Because of this continuing evolution, the relative importance of solvers, pre- and post-processing, communication and collaboration, data management, and simulation process capture, management, and re-use has shifted over time. CAE is evolving from being a set of "black box tools" for highly-specialized individuals toward a group productivity environment that delivers strategic competitive advantages to the business by supporting simulation-driven design. This shift has occurred by overcoming the step-by-step obstacles as outlined in Figure 1 and has sharpened and redefined what the most important needs now are and even who gets to define those needs.

Users and companies in major "CAE-leading" industries have also broadened their view of what constitutes an effective CAE solution, from just the core simulation solvers that provide accurate enough simulations and insight required to make product development decisions towards viewing the broader toolset, user environment, as well as the training and capabilities of people using CAE, managing the relevant data needed for and produced by simulations, and capturing and re-using repeatable CAE processes.

This awareness of what is needed for group and enterprise effectiveness of CAE can be described by the four major areas of a total CAE solution represented by the "pinwheel" shown in Figure 2.

Although all areas of a total CAE solution are important to leveraging CAE for maximum business benefit, the key to achieving Steps 2 through 5 of Figure 1 lies in fully recognizing and fulfilling all of the requirements for a modern CAE working environment. The ideal environment represents the bridge between users, solvers, and reporting results for decision making as well as a bridge to Simulation Data Management (SDM) and Simulation Process Management (SPM) and even a foundation for Knowledge-Based Engineering (KBE).

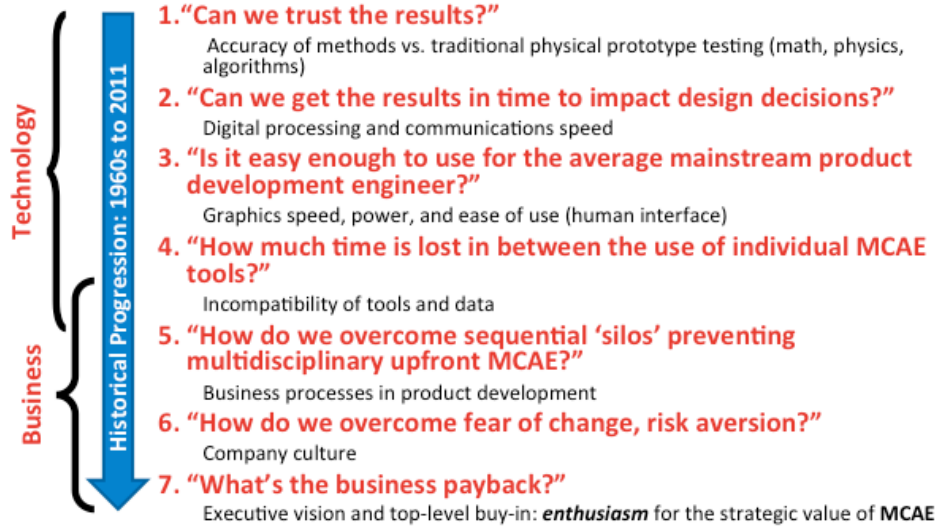

Figure 1—The Seven Steps of CAE Progress to Full Business Payback
(Courtesy of Dennis Nagy)

3. Key Requirements of CAE Environments

The key requirements for a modern, robust CAE environment can be summarized into the following major areas and sub-categories:

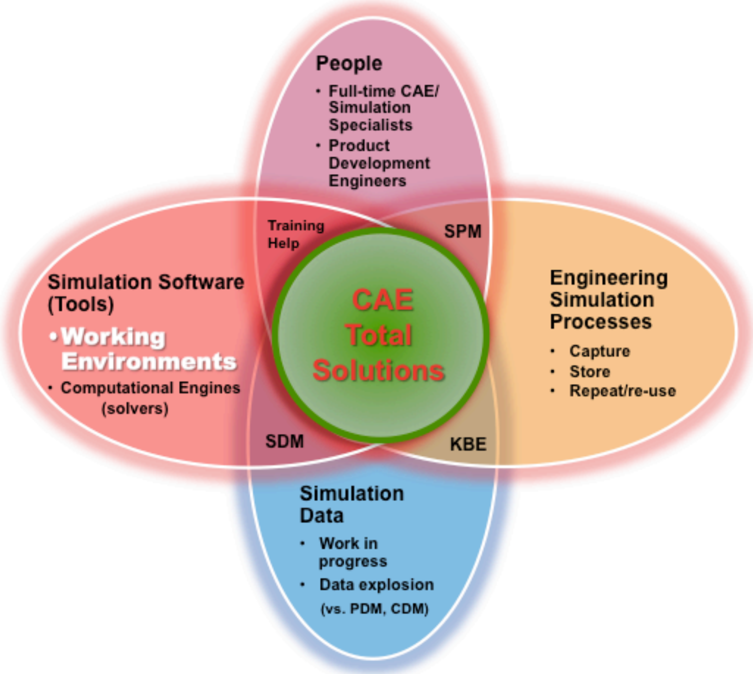

Figure 2—The CAE Total Solutions Pinwheel

3.1 Technology for Individual Users

These technology components are important for each CAE user regardless of the structure of their engineering organization and how they may or may not work with their colleagues.

3.1.1 Geometry

Performing any 2D or 3D simulations and analyses requires a CAE-usable definition of the physical objects (parts, components, subsystems, and total systems) to be simulated. A modern CAE environment needs to be able to easily import geometry from any major outside sources such as CAD systems, modify it (de-feature to remove unnecessary details) and otherwise clean it up (remove imperfections that can invalidate simulation results). This includes the means to create native geometry within the CAE environment (for example, extracting the fluid domain geometry for a CFD simulation from the CAD geometry of the design). It is important to free CAE analysts from dependence on the CAD operators to prepare their model inputs.

Similarly, material information, boundary conditions and loads need to be imported or created relevant to the underlying geometry. Such information is often dependent on the physics of simulation being done. The key requirement is that, in a modern system, this information should be related to the underlying geometry, not the particular discretization or solver being chosen (see below).

3.1.2 Pre-Processing

Most CAE simulation methods require some kind of discretization of the geometry into a mesh and the application of boundary conditions, loads and actions to the discrete representation before conducting a simulation. The meshing and the details of what is needed and how it can be created are often dependent on the targeted solver (structural or solid mechanics or dynamics, including nonlinear behavior; fracture, fatigue and failure; fluid dynamics including multiphase steady-state and transient flow, combustion, and chemical reactions; electromagnetics; or motion of flexible linkages) and the corresponding specific solvers to be used.

The key requirement is that the meshes and related information should be seamlessly tied to their underlying common geometry model so that any geometry changes easily result in correspondingly correct mesh modifications. Also, since meshing is often related to the particular solvers being used, a comprehensive choice of meshing tools must be available within the common CAE environment, including a common, intuitive way of providing all necessary model preparation information for each solver, including 1D, 2D and 3D models, working with legacy (mesh-only) models, and extracting and meshing fluid domains from solid models.

3.1.3 Simulation Execution

Simulation execution is a critical area—no simulation, no useful results and insight! The software tools and modules (solvers) used to conduct the simulations may be part of the CAE environment (imbedded, developed and delivered by the solution vendor) but more frequently they are separate software tools or systems from one or more vendors and are chosen by the experienced users as “best of breed” for the particular simulation. This situation is not likely to dramatically change any time soon. The key requirement here is that a comprehensive variety of best-of-breed solvers should be easily accessible from within the common CAE environment. Further, the common CAE environment should provide the ability to manage and track any types of simulations to assign them to available computer hardware resources (local, clusters, networks, grids, clouds).

3.1.4 Results Post-Processing and Visualization

Post-processing and visualization is where CAE users find insights and conclusions leading to design changes and eventually validation of a suitable design. There are a number of related activities here that a modern CAE environment must support, including but not limited to:

- Accessing and comparing results between different simulations (even from different solvers) and different design alternatives.
- Advanced visualization (manipulable 3D) to support rapid human insight.
- Comparison between simulation results and laboratory or field test measurements, for validation.
- Portrayal of evolving results during an ongoing iterative and/or transient simulation.

3.1.5 Multi-Level Simulation Modeling and Execution

In most industries, the products being developed consist of a hierarchy of components, subsystems, and complete systems. A modern CAE environment needs to facilitate the building up and management of both subsystem and system models from individual components, including performing relevant simulations (e.g. structural behavior, flow, mechanism assembly motion, controls) at each level (that is, how the product under analysis is broken into manageable subsystems) and fidelity (the degree of granularity used in the physics-based simulation).

Concepts such as super elements and sub-structuring in finite-element-based structural simulation are the most common examples of how such multi-level simulations have been done for decades, albeit in a very complicated and solver-specific way. Modern CAE environments must provide for much more intuitive, solver-independent means for creating, managing, and simulating such multi-level configurations.

3.1.6 Ease of Use, Learning and Retention

As CAE solution suppliers have significantly reduced the time consumed by the actual solver runs, they and the users realized that the next very significant obstacle to overall simulation process time reduction ("time to insight") is the difficulty of learning and using multiple simulation environments, especially when they are not being used regularly by any one engineer.

A widespread result was the specialization of individual users in the details and peculiarities of one solver environment and their resistance to changing to newer or better environments. A modern CAE environment thus needs to facilitate individual users' abilities to "learn once, apply often" to a variety of solvers and physics as their specific work assignments require, using journaling (automatically capturing and tracking user commands and screen picks in a file) and developing templates for later use in similar CAE tasks.

3.1.7 Programmable Extensions

Since different users have different needs, and no vendor can anticipate all of them, it is critical that any modern CAE environment have the ability for users to tailor modifications and extensions to the standard "off the shelf" environment. Such tailoring can be used to capture workflows, extend or customize particular commands and menus, or collapse commonly needed multiple-step sequences into one step.

3.2 Technology Requirements for CAE Group Collaboration

Companies are striving to make substantial improvements to the productivity, accuracy, efficiency, reliability, responsiveness, affordability, and accessibility of their CAE environment and tools. However, CAE strategies that have been focused on achieving incremental improvements from slightly better solvers, tighter point-to-point integrations, higher performance computing, cheaper licenses, and fewer tools may have reached a point of diminishing business returns. Making the individual analyst work slightly faster to produce slightly better results, does not offer the now-necessary performance breakthroughs or breakout improvements to keep up with the complexity-related demands of the marketplace, let alone pull away from the competitive pack. Different, more effective CAE strategies and supporting CAE environments are needed.

Critical requirements for technology-enabled collaboration have emerged as the strategic importance of simulation and the corresponding number of CAE engineers has grown. Experience in managing groups of CAE engineers has led CAE management to better understand that a comprehensive common CAE environment will not only dramatically increase individual analyst productivity and efficiency (up to an order of magnitude) but will also provide a solid foundation for group synergy and effectiveness (potentially another order of magnitude).

These requirements become even more important as the engineering function becomes geographically dispersed in major global companies. For example, automotive CAE teams from India, Detroit, Stuttgart, and Sao Paulo, working on the same engine design need to interact and collaborate over corporate intranets and multiple time zones. They need a common CAE working environment, using common CAE tools within that environment, across multiple interacting disciplines (e.g. structural behavior, flow, assembly motion, controls), and the connectivity to exchange models and results easily around the world if necessary. Such an environment enables global-savvy management to add or re-allocate experienced CAE engineers (who are in very short supply) on major projects from wherever they may be physically located, without impacting completion schedules.

3.2.1 Leveraging Individual Technology Requirements for Group Synergy

The technology factors discussed in Section 3.1 that help improve the productivity and effectiveness of individual CAE engineers, become significantly more powerful when implemented for entire groups of CAE engineers. In other words, without any additional technology features, a modern robust CAE environment creates significantly more business value when intelligently managed and used by groups of engineers. However, there are additional technologies that are required to really maximize the group collaboration potential of a common CAE environment. The following sections summarize two of these technologies.

3.2.2 Capturing Repeatable CAE Processes and Best Practices for Use by Others

A modern CAE environment should allow the CAE engineer or manager to capture, fine-tune, standardize, and re-use simulation process templates on subsequent simulations and projects to dramatically decrease modeling and set-up work. Further, there should be a wizard-like creation capability to enable such repeatable "best-practice" processes to be deployed to other (perhaps less CAE-savvy) engineering groups where such simulations are nevertheless heavily required.

This particular requirement is a key enabler for CAE management to leverage re-use and deployment of best-practice procedures and templates on current and future projects, providing them with better organizational flexibility, responsiveness, robustness, resiliency, reliability, and cost effectiveness. It results in an organization that that can more easily expand or contract and collaborate globally 24/7 to fill the elastic volume and extreme variety of workload that has become the new norm of CAE computing groups.

3.2.3 Driving Co-Simulation Processes from the CAE Environment

In many medium- to large-engineering organizations, different groups are responsible for different physics (e.g., structural, thermal, kinematic, electromagnetic) and/or understanding them at different levels of fidelity. Multi-physics and mechatronics behaviors of modern product designs require the product development engineers to better understand how these behaviors functionally interact in the actual in-service use of the products they are developing and analyzing.

More and more needs have arisen for executing so-called co-simulations in parallel, where each type of solver is exchanging solution information with the other(s) as they move forward together in a transient (time-dependent) simulation. Common examples include fluid-structure interaction (co-simulation with FEA-based solid mechanics and computational fluid dynamics) and controls-activated mechanical linkage assemblies (an example of mechatronics). The ability to set up and run such co-simulations from within a common CAE environment is a key enabler to allowing structural and flow or controls engineering groups to collaborate with each other using their own solver tools of choice.

3.3 Other Requirements of Robust Modern CAE Environments

When selecting an enterprise-wide common CAE environment, companies need to consider business factors in addition to the technical requirements outlined above. Although this paper is not intended to be a cookbook for selecting a CAE environment solution, it is relevant to touch upon some of the key business factors:

Vendor track record: does the vendor have a heritage of past technology-based successes in the CAE environment marketplace, in light of the broader "total solution" perspective shown in Figure 2?

Vendor CAE vision and product development roadmap: does the vendor articulate a compelling vision of how they will synergistically work with their customers and prospects to stay ahead of evolving enterprise user needs and do their product roadmap and their release plans support that vision?

Vendor company culture: does the vendor have an open, supportive culture towards its customers, i.e., do they "sit on the same side of the table" with their customers, working together to determine strategic CAE needs and craft win-win solutions?

4. Siemens PLM NX CAE

In 2007, Siemens AG purchased UGS and it became Siemens PLM Software (Siemens PLM), a business unit of the Siemens Industry Automation Division. The Siemens PLM Software CAE suite has a long, strong history as show in Figure 3.

Siemens' modern CAE environment is named NX CAE. The heritage and track record of NX CAE reflects a commitment and success to CAE dating over forty years from the founding of CAE provider SDRC. It includes the 2003 acquisition of NASTRAN source code (the leading finite element structural analysis solution at that time) and key personnel from MSC.Software. Siemens PLM has, in parallel, developed a solid customer-focused technology roadmap and invested significantly in realizing important developments founded on their forty-year heritage. Figure 3 summarizes Siemens PLM's view of their history in CAE. One of their strategic themes is that NX CAE is "Built on a great heritage, built for a great future."

Although Siemens is perhaps best known for its NX product development environment and Teamcenter for product and process knowledge management, CIMdata believes that NX CAE is also a modern, highly capable "stand-alone" CAE environment. This section summarizes our evaluation of how NX CAE addresses the various requirements identified in Section 3.

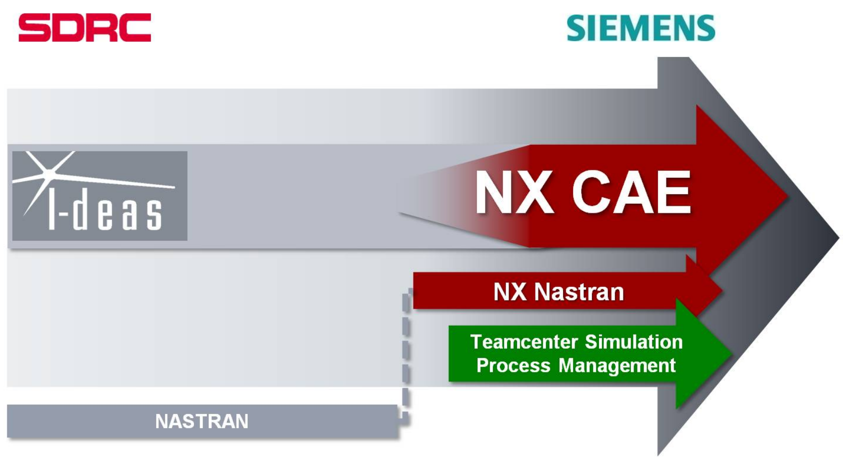

Figure 3—Siemens PLM NX CAE

4.1 Geometry

NX CAE's use of Siemens' Synchronous Technology (ST) to enable CAE analysts to create and/or modify geometry is one of its most important capabilities. NX CAE includes the same geometry engine for creating and manipulating design models as is used in NX CAD. ST allows product design models, including imported designs, to be modified without the need to understand its original design history or intent. ST is fully embedded in the NX CAE GUI and data environment and does not require a separate license of NX CAD or use of NX CAD anywhere within the same company. This enables NX CAE analysts to both create simulation-suited geometry from scratch or import and further modify geometry from SolidWorks, CATIA V4 and V5, Pro/ENGINEER, JT, IGES, STEP, and many other sources. The CAE analyst can defeature and clean-up geometry without the need to wait on CAD operators to implement geometry changes or fixes. The result is a single digital model that can be leveraged across all types of simulations.

This provides a relatively easy-to-use toolset in which the CAE analyst can directly modify geometry without the need to know the original design's part feature history. Ease-of-use is important because dedicated analysts often do not have the expertise or time to be proficient in advanced CAD tools.

If the CAE user or group happens to also be in an NX CAD enterprise environment, additional benefits accrue. Even without NX CAD, NX CAE is a strong geometry environment when measured against the needs and requirements summarized earlier.

4.2 Meshing and Simulation Model Preparation

NX CAE supports several options for meshing and model preparation. For example, in the structural analysis domain, it offers the ability to

- Build models with 1D, 2D, and 3D elements
- Handle thin-walled parts, mid-surface extraction and meshing
- Automatically create tetrahedral and hexahedral mesh models tied to the underlying geometric model
- Build and manipulate large assemblies through multi-level modeling where teams can work on different parts of an assembly concurrently and the system integrator can assemble supplier-delivered models, typically resulting in a five to ten times faster process

- Apply complex loads and boundary conditions
- Work with advanced materials such as laminated composites
- Target input for multiple solvers

4.3 Simulation Execution--Open, Immersive Solver Environments

NX CAE incorporates a broad collection of solvers. It includes NX NASTRAN for both structural and thermal FEA as well as solvers for other physics domains (e.g. multi-body dynamics, NX Flow, NX Thermal, and NX Space Systems Thermal) and optimization. It is important to note that NX CAE is not "just" a CAE environment for NX NASTRAN but rather primarily enables open use of most leading solvers. In the structural analysis domain, for example, MSC.NASTRAN, ANSYS, Abaqus, and LS-Dyna are supported and accessible from NX CAE. Leveraging a common NX CAE environment produces even faster "time to insight" when multidisciplinary simulation processes are conducted completely within NX CAE.

4.4 Co-Simulation

Co-simulation with other third-party environments, such as with Matlab and Simulink from The MathWorks is enabled for mechatronics simulations. The complete co-simulation process can be developed and driven from within NX CAE.

4.5 Process Capture and Wizard-Deployment

NX CAE has programming tools (called NX Open) for, among other very useful applications, capturing repeatable "best-practice" simulation processes and creating deployable wizards based on them. For example, wizards have been created to allow less CAE-experienced engineers to efficiently perform automotive exhaust manifold flow analyses across a wide range of manifold design variations. Using a wizard within NX CAE, users can extract the flow volume from the manifold tubing, create the CFD mesh, apply the appropriate boundary conditions, and solve for the flow variables.

4.6 Simulation Data and Process Management (SDM, SPM)

Although NX CAE is not an SDM or SPM environment, it is built to work with any SDM and/or SPM system. Siemens PLM's Teamcenter Simulation Process Management is particularly developed to manage NX CAE and other CAE data. Users also can work with NX CAE in a "managed" mode, whereby they can perform various operations such as navigating the Teamcenter database, opening files and saving results directly into Teamcenter from within the NX CAE environment.

More information on NX CAE, including case studies and metrics, is available directly from Siemens PLM Software at: http://www.siemens.com/plm/nxcae

5. Some Experiences of Siemens PLM NX CAE Customers

Siemens PLM NX CAE customers interviewed by CIMdata confirmed and reinforced the observations stated above. They have stated that NX CAE is a very useful environment for both individual analysts and broader simulation-centric corporate groups (many of which are geographically dispersed). The ability to work with various native geometries, create geometries from legacy meshes, and/or create and modify geometry directly within NX CAE are widely seen by users as its strengths.

An example of a leading NX CAE customer, ATK is a major diversified aerospace company headquartered in Minneapolis. They have four major divisions—Aerospace Systems, Armament Systems, Missile Products, and Security and Sporting. They employ over 18,000 people in over 60 different facilities around the world.

CIMdata spoke with Mr. Nathan Christensen, Senior Manager, Engineering Tools & Analysis, and. Mr. Ramesh Krishnan, Senior Staff Engineer, CAE/HPC Tools & Processes, at ATK Aerospace Systems Headquarters in Utah. ATK Aerospace is the world's top producer of solid rocket propulsion systems.

Mr. Christensen leads an Aerospace Systems-based group responsible for technical software (introduction, standardization, deployment, training, support, hardware evaluation, and custom development) used throughout the corporation. ATK has made long-term commitments to the use of Siemens PLM solutions, including NX CAE.

ATK's history of acquiring many smaller companies has led to a wide variety of legacy CAE tools within the various facilities. Mr. Christensen emphasized the goal of moving the widely-scattered CAE engineers (>200) onto the common NX CAE platform for the synergistic benefits that would create. His strong support of NX CAE as ATK's target common CAE environment derives from the benefits they have obtained over many years from the NX CAE heritage shown in Fig. 3.

DHI.DCW GROUP COMPANY LIMITED located in the northeast of China is another strong user of NX CAE. CIMdata received comments from Director Li Chunting, involved in managing CAE for DHI.DCW. He stated that DHI.DCW, after evaluating many other CAE environments, chose NX CAE because of its efficient geometry-based FEA pre- and post-processing, its integration with other Siemens PLM tools, and its strong support of the NASTRAN solver.

A further important factor that emerged from the various interviews is the responsiveness a CAE environment vendor to the prioritized needs of its customers. No CAE environment today is complete and perfect, and none will ever be so, because users' needs and expectations continually grow with advancements in relevant technology and their resulting realization of what is possible but not yet doable.

In the area of robust CAE environments as synergistic groupware, this positive ongoing relationship with a key software vendor is even more important. Nathan Christensen of ATK expressed it well: "One of our best vendor partnerships is with Siemens PLM. They have a great vision of where they are taking NX CAE and they work closely with ATK to insure that our needs are prioritized in their development plans to achieve that vision."

6. Summary and Concluding Comments

Maximizing the overall value of CAE to the global enterprise and new product development and introduction programs requires integrated, multi-discipline CAE solutions and processes based on common geometry, loads, and material data with tools and processes that also provide more freedom and flexibility for CAE specialists. Additionally, for a CAE group to function at a performance level that is greater than the sum of its parts requires a common unified CAE environment that supports multiple solvers with embedded integrations and a single GUI. It needs to liberate CAE analysts from CAD dependencies and provide a global collaboration platform that enables analysts to parse out modeling, computing, and post-processing among many members of a globally distributed group. It also needs to have tight multilevel integrations between CAE applications and support knowledge capture and a consistent, unified open CAE environment and user interface.

CIMdata believes that Siemens PLM NX CAE delivers highly competitive CAE solutions and technology in a modern, robust environment. It meets the needs of users to be significantly more productive in their individual work tasks. In particular, the rich geometry creation and manipulation capabilities of Synchronous Technology enables the CAE analyst to create, cleanup and modify the geometry needed to support simulation driven design.

CIMdata also believes that Siemens PLM's overall vision, investments, and resulting technology development roadmap for NX CAE addresses the needs of CAE managers to forge a cohesive team capable of achieving significantly more useful results than just a collection of commonly-managed individuals, each with their own particular expertise and best practices. NX CAE delivers this by supporting teams that flexibly work together in a common, open, synergistic software environment.

While no CAE solution provides all of the applications and functionality required to support the full evolution of the CAE strategic environment, it should provide a foundational platform upon which additional CAE solutions can be integrated as needs dictate. CIMdata believes that Siemens PLM's NX CAE is a good example of such a platform and that companies should include Siemens PLM NX CAE when evaluating their CAE needs.

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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