SPAR POINT
RESEARCH

Enabling
Digital Simulation and Analysis

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Background & Methodology

This report series documents Spar Point's research into best practices across a range of discrete manufacturing industries for implementing digital simulation and analysis and maximizing its business impact.

Industries studied included aerospace and defense, aircraft engines, automotive powertrain, consumer electronics, medical devices and off-highway equipment.

Primary research consisted of in-depth interviews with some two dozen program managers, discipline leads, analysts, engineers and others employed by manufacturing enterprises in North America, Europe and Asia. All interviews were conducted by Spar Point senior analysts in person or by telephone.

Interviewees reported using many different CAE software products from a variety of vendors including but not limited to ABAQUS, AMEsim, ANSYS, CFD++, CFX, COSMOSWorks, Elfini, EXCITE, Femap, FEMLAB (now COMSOL Multiphysics), Flowmaster, Fluent, Hypermesh, I-DEAS CAE, LS-DYNA, MATLAB, Moldflow, MSC.Adams, MSC.Nastran, MSC.Patran, NPSS, NX Nastran, Simulink, STAR-CD, Valvedyn, Vectis and WAVE.

Companies studied were generally selected on the basis of their recognition and standing in their respective industries. Interviewees were selected based on their positions in their respective companies and their knowledge of how digital simulation and analysis is being used in their organizations to improve product development, with particular attention to initiatives aimed at increasing the efficiency, effectiveness and impact of CAE usage.

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December 1, 2007

By Bruce Jenkins, President of Research, Spar Point Research LLC

Digital simulation and analysis is increasingly critical for manufacturing enterprises to meet program objectives for schedule, budget and quality – the complexity, performance and efficiency demanded of today's products simply can't be achieved any other way. Companies are working not just to use CAE on more projects, but to make its use pervasive throughout product development. This extends from early concept design, where good decision-making has the greatest leverage on lifecycle costs, all the way through manufacturing engineering where simulation helps shorten production ramp-up, control unit costs, and boost fit and finish.

What business goals are best-practice leaders seeking through more effective use of simulation and analysis? Better product quality, lower development and production costs, and shorter schedules are key. For example, in the auto industry, a single physical prototype can cost up to $500,000 to produce, and as many as 60 may be required to develop a new car model – the value of using simulation and analysis to drive down prototype counts is evident. Equally critical is product quality. According to the Automotive Industry Action Group, a typical auto recall now takes 250 days to complete, at an average cost to the manufacturer of $1 million per day. The value of simulation and analysis is clear in its power to find and fix failure modes before products ship.

In this report – based on Spar Point's research in digital simulation best practices at aerospace/defense, aircraft engine, automotive powertrain, consumer electronics, medical device and off-highway equipment manufacturers – you'll discover eight functional enablers that are key to helping these industries achieve their goal of deploying digital simulation pervasively through the product lifecycle:

- Scalability and consistency
- Intelligent model generation
- Industrial-strength productivity
- Multi-physics, multi-disciplinary
- Open integration
- Visualization and collaboration
- Reusable processes and knowledge
- Simulation process management

Scalability and consistency

Business need What drives the requirement for scalability and consistency in digital simulation and analysis? Manufacturers tell us it's the need to make people in all parts of the organization and all phases of product development more productive with their tools, and to minimize the need for continual training and retraining on different tools. This is the payback

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when the same simulation toolset can be used for a wider range of simulations by different people throughout the organization, and at varying levels of fidelity.

Our research found a push by more and more manufacturers to deploy simulation earlier and more pervasively than in the past. For example, a manager at a leading off-highway equipment maker says his company is working hard “to transform the process for developing product to a more up-front-loaded, analysis-driven, build-it-right-the-first-time, zero-prototypes process.”

Likewise, an engineering manager at a major manufacturer of medical diagnostic equipment explains: “[Simulation] tools are readily available” to users in his organization, but still are not as widely used as he’d like. Why? Shortages in staffing levels, he says, together with constraints on “engineers’ time and schedule. And what goes hand in hand with schedule constraint is limited opportunity to mentor junior users of the tools.” To address the problem, this manager says, “part of the role of my team is to try to increase the awareness [of simulation in the organization], mentor people, and be a mechanism for knowledge transfer and growth in these areas.”

Indeed, wide variations in skill levels among different classes of user is a common problem. A manager at a surgical instrument manufacturer describes how his company too is working to make simulation more pervasive, and what’s still needed to get there: “…we are trying to bring in CAE earlier in the product development cycle. It is not always available to all who need it, because of their skill levels. But generally the organization is working to bring CAE in earlier and use it throughout the process, and they are doing a pretty good job of that. It is a goal of the organization to use these tools early to find good designs.”

At the other end of the scale, the increasing fidelity demanded of performance simulation is driving problem size and complexity to levels of sophistication not even conceivable just five years ago. This not only challenges the world’s most advanced computers but often requires software vendors to re-architect their applications to be able to cope.

Enabling functionality Ability to leverage consistent and scalable applications will enable expert users to effectively support and mentor the extended product development team. Using simulation earlier and more pervasively throughout product development not only saves time through fewer iteration cycles; it also fosters collaboration at all levels, breaking down barriers and promoting trust, information re-use, better-quality simulations and higher product quality.

At the same time, the CAE industry originally evolved to service a small niche of elite engineers, and these specialists still exist to solve the world’s most challenging problems. This makes performance a key issue: if tools that are suitable for occasional users cannot satisfy the needs of the “high end,” then this means there is no platform scalability.

Productivity is key; tools are increasingly used at all levels – from infrequent non-specialists to advanced users requiring advanced tools for mission-critical analysis work. The ability to define common workflows and best-practice tools will enable new team members to more rapidly assimilate into specialist teams while empowering occasional users to safely use company-specific best practices.

Questions for decision makers In evaluating solutions and providers, managers need to understand how well tools can be optimized for multiple user communities within the

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organization. How easy is it to get started and become productive? Do the tools provide the leverage required to increase the effectiveness of product development and eliminate process bottlenecks? Can a single toolset satisfy the needs of new users and advanced specialists alike? Are there technical capabilities to help advanced specialists mentor new users, monitor their work, and encapsulate expertise so non-specialists can make use of it? Finally, do the tools scale up effectively to handle ever-increasing problem size and complexity?

Intelligent model generation

Business need Manufacturing companies invest millions of dollars in developing and documenting product designs, yet many simulation processes don't leverage these investments. In the absence of tools for intelligent model generation, valuable CAE experts spend inordinate amounts of their time re-creating geometry – time that would be better spent executing simulations and interpreting results.

Worse, simulation models based on snapshots of the continuously evolving design model risk becoming outdated before analysis results are even delivered. The upshot? Design managers who can't hold up the program waiting for simulation results are forced to move ahead with scant information and risk expensive changes late in the program – or else make "safe" design decisions that too often stifle innovation and add cost.

Why the emphasis on up-front analysis? At a major off-highway equipment manufacturer, a manager describes the need this way: "Doing simulation and analysis up front before you finalize anything is definitely a big value proposition. I'm spending all my time working in the one-dollar-to-change region of the product development cycle, up front. You don't have a lot committed there except some engineers' time." This is the time when manufacturers have only incomplete product performance information, but must make decisions that drive big product lifecycle costs.

Ability to derive simulation models automatically on an as-needed basis from the current design state will help simulation deliver more impact both early in product development, when its impact can be greatest, and then throughout the cycle.

Enabling functionality What are the barriers that the right technology will help manufacturers overcome? One is incomplete information about the product. As a U.S. auto maker told us, "We would like to do analysis on incomplete models to make early decisions." The problem? "CAD tools are not structured to output an incomplete model, so to do early CAE you often use a surrogate from past work." While analysts can usually find "something close enough," the situation "could be better."

Another barrier is inflexible, non-intelligent, point-to-point CAD model import. Most simulation tools can work with specific CAD input formats. However, the ability to access, create, revise and repair geometry is a core differentiator among simulation vendors – this is a key driver of user productivity in a multi-CAD world. It helps enable companies to apply lean methodologies to analysis workflows and thus dramatically reduce overall development cycle time.

A clear demonstration comes from a recent benchmark at an American aircraft engine manufacturer. In a final presentation to management, the company reported, "We saved two

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weeks of translation effort, and a further four weeks from geometry healing and associative FEM on a single model." With 26 models involved in the project, this adds up to six-figure dollar savings per iteration.

Questions for decision makers Decision makers need to consider the barriers to moving simulation up-front – how well can their system create and change geometry? Then, throughout all of product development, what about advanced analysis requirements such as rapid geometry cleanup and repair, feature suppression and modification, and topology evaluation/abstraction, automation and control? Finally, what about change management and customization to re-use knowledge and best practices in more automated validation applications?

Industrial-strength productivity

Business need Even manufacturers that can buy all the digital simulation tools they need still face constraints on getting more value from them. "We do not really have restrictions on what we can do [in simulation and analysis] given the variety of software we have," a German auto maker reported to us, for example. "But that does not mean we would not like to have software that gives better performance than today – better in speed of execution, model size, runs well on cheap computers…" We also heard about needs for closer, more automated linkages between simulation and other data and processes.

Enabling functionality Decision makers need to ask what is the largest problem solved in its class by each solution being considered. As the German auto maker notes, model size is one key factor. For example, in automotive powertrain analysts. NVH models of an engine or drive system can regularly exceed 10 MDOF, with some models reaching 80 to 90 MDOF. FEA models with 5 million elements and upwards of 8 million nodes (~25.5 MDOF) are not uncommon. Indeed, in the CFD and crash worlds, these are considered small.

At the same time, it is clearly not enough to be able to solve massive problems if you cannot create the right input to the solver or view the results in time to respond. In many cases, engineers spend over 80% of their time building analysis models. But new tools are emerging that promise to dramatically change this: see "Intelligent Model Generation" above. Other enablers of industrial-strength productivity include the ability to tie simulation processes and results into a corporate PDM backbone, to collaborate across multiple sites, and to standardize and automate work processes – see "Reusable Processes and Knowledge" and "Simulation Process Management" below.

Questions for decision makers Decision makers must bear in mind that in-depth analysis toolsets are required to support a highly distributed, collaborative model creation environment. Managers need to understand the capabilities of analysis toolsets – not only to build the types of models they are required to work on, but also to enable fast, easy access to results and model management. How easy is it to collaborate with multiple sites across the world? What automation exists to support common settings for solutions (often solver- and solution-dependent), visible model organization, standards and best practices?

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Multi-physics, multi-disciplinary

Business need Often the results of one simulation activity are used as input to others. This drives the need for better integration and coupling of simulation solutions. Today many customer implementations have only loose coupling of solutions, if any. Manual processes for retrieving results from one analysis discipline and re-entering them into another are all too common – this can exact a heavy toll on accuracy, efficiency and, ultimately, program schedules and product quality.

Growing product complexity and performance demands, together with ever increasing schedule pressure, make both multi-physics and multi-disciplinary simulation more important than ever before. A prime example is the aerospace/defense industry, where simulation is especially critical “at the systems level, where interactions may not be obvious,” as one major contractor told us.

Another aerospace/defense contractor explains why: “If you look at the complexity of our product, just go back to earlier versions of [a fighter aircraft] that’s been in production for nearly 25 years. In its infancy in the 1970s, it was a much less complicated product. The amount of simulation required was minimal compared with today, where many complex subsystems are interoperating and multiple sensors are collecting loads of information.” Because of this, “you have to rely on simulation tools to validate performance. We’re constantly pushing the edge of the envelope in simulating physics.”

Enabling functionality *Multi-physics* has come to refer to any simulation that involves highly coupled systems, for example tightly integrating fluid mechanics with finite elements for coupled thermal-flow analysis of an electronics enclosure. It goes without saying that the more coupled the physical phenomena, the greater the need to use a coupled solution.

Multi-disciplinary simulation commonly refers to the less coupled, but no less important, case where several disciplines are combined. For example, a simulation of an aircraft flap system to ensure a smooth flight transition may involve kinematics and rigid-body dynamics to look at loads in the system, a CFD analysis to calculate pressures, a structural analysis to estimate stresses, and a durability analysis to estimate the life of key components.

Questions for decision makers Besides ensuring that solution providers can deliver the capabilities described above, decision makers need to ensure that vendors are pursuing a two-pronged development strategy:

- Continuing to add capabilities aimed at the most advanced simulation practitioners.
- Making core solver technology available integrated with a suite of modeling, meshing, and results display and analysis tools.

Decision makers should identify their internal needs for multi-physics simulation – which applications need this ability the most? They should also identify opportunities for multi-disciplinary simulation, and exploit these opportunities by working with vendors that can support the use of common models and data to avoid needless translation and rework.

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Open integration

Business need Consolidation of engineering software tools, and of solution providers, is a key cross-industry focus for many manufacturers. However, for digital simulation, large OEMs find they simply must have a multitude of software tools – auto makers have to use several dozen, while major aerospace companies use literally hundreds. Because of the requirement to transfer data from tool to tool, how well toolsets are – or can be – integrated is a key determinant of process efficiency. As one aircraft engine maker summed up for us, what's needed – but not always readily available – are "tools at each phase that we [can] connect."

Likewise in the auto industry, "how well the CAE tools integrate with one another and with the CAD tools" is a big factor in qualifying simulation solutions, a major U.S. auto maker reports. Indeed, even when CAD and CAE vendors have "integrated" their software with each other's, "you may have trouble getting CAD geometry into the CAE mesh, then getting CAE results back to the CAD model," this company told us. "In the CAD-to-CAE links, there's a lot of manual intervention in the meshing process."

Likewise, "we always need better tools that can work faster and better together," a corporate Six Sigma master at an aerospace/defense company told us. "That's what I do for a living – make tools work together at a system level, able to cycle through faster and more accurately, and bring higher fidelity further and further up to the front end of the design process."

The need is not to be locked into a closed solution set, but instead to implement open simulation solutions that can readily be integrated with other commercial solvers and internally developed codes, as well as with collateral design and manufacturing applications. The benefits are clear – better tool integration yields more efficient and accurate work processes and data flows, while greater tool freedom-of-choice gives companies more control over technology costs as well as training and maintenance expenses.

Other aerospace/defense companies report much the same thing. "From a DFSS [Design for Six Sigma] perspective," said one, "the industry and we do a lot around performance modeling, cost modeling, defect modeling and other things – but are they all integrated together so you're trading off across these spaces?"

Enabling functionality Many manufacturers we interviewed believe the answer is to find a solution provider best able to help companies increase their permeability to new technologies and code streams – without requiring prohibitive new investments in integration, support or personnel. "If you get into the mode of picking point solutions, you're going to be changing your solutions every few years," one maker of off-highway equipment told us. "You don't want to do that. It's way too costly. Your models don't work anymore. We have to pick the best partner for the future, and stick with them. We'll make so much money from this strategy that it won't be worth our time to chase the best point solution at any given time."

The cost of integrating legacy applications with commercial simulation environments has traditionally been prohibitive. However, new applications that leverage SOA (service-oriented architectures), and those based on XML, can offer significantly lower integration costs, and provide an economical way to maintain investments in unique intellectual property.

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Questions for decision makers Decision-makers need to understand the range of applications in daily use and the teams using them. What does it cost to maintain their user interface? Where do they get data from?

More specifically, decision makers need to understand how well systems under consideration can access various data formats – STEP, IGES, STL, Parasolid, ACIS, Pro/ENGINEER, CATIA V4 and V5, SolidWorks, DXF, DGN, ANSYS, ABAQUS, Nastran, RecurDyn, MSC.Adams, more. They should also evaluate how well these systems are positioned to leverage SOA capabilities for integration and information exchange with other applications and data repositories.

Then they should ask: Is it possible to automate data flows and thus reduce the risk of errors while speeding up throughput? Should the point tools be integrated into a broader process? If so, what solution and service providers are best equipped to help with this?

Visualization and collaboration

Business need There is much discussion in the marketplace today about the value of 3D visualization to extend product development information throughout the extended enterprise. A common estimate is that for every author of information, there are 10 consumers. In fact many believe the ratio may be as high as 1:20. But even so, manufacturers we studied have only begun to scratch the surface in realizing all the value available from 3D visualization technologies in making simulation a more valuable tool throughout product development and across supply, delivery and support value-chains.

Most of the world's best-in-class manufacturers use 3D visualization throughout their business processes; the same is true of top engineering/construction firms that build and maintain the world's physical infrastructure. Just one example – a leading Japanese consumer electronics manufacturer told us, "Simulation and analysis has recently become important as a tool for visualization, in addition to performance analysis." The company explains that "higher-quality simulation enables all members of the design team to make decisions using the reference 3D model."

The power of 3D visual communication is intuitively obvious – instead of 2D technical drawings, specialized reports, or pages of numerical output requiring special expertise to interpret, 3D data can be easily comprehended by stakeholders far beyond the specialists who authored it. Moreover, 3D visualization models can be augmented with information targeted to specific stakeholders; design review tools make it easy for anyone to manipulate and interrogate 3D visual data without knowledge of the tool that authored it. Too, deliverables generated by visualization tools can have much smaller file sizes than the corresponding source – lightweight files are readily transmitted over modest Internet and other network connections, and easy to work with on commonly available computers.

Enabling functionality What's needed in the simulation domain? A common viewing platform will streamline CAE data sharing, making digital simulation results available to unprecedented numbers of users beyond the core analysis group. Such a common platform will also reduce complexity of the IT infrastructure that manufacturers must maintain, by minimizing the number of viewing solutions that simulation users need and use. All this will

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reduce costs and, more importantly, broaden the audience that can benefit from simulation and analysis.

Questions for decision makers Decision-makers need to ask how much time simulation users spend filtering, clarifying, collating and publishing analysis results. What tools will make it easier to translate simulation results into high-fidelity, easy-to-understand visual presentations? Next, can these deliverables be readily distributed for comments, markup and suggestions by the wider product development team? Finally, what tools will best help upper management use simulation results to check that designs in progress are meeting product requirement definitions?

Reusable processes and knowledge

Business need Manufacturers tell us their biggest constraints on getting more value from simulation and analysis are people and schedule – too few trained, knowledgeable professionals, and too little time. As a program manager at a major aerospace defense contractor told us, "The only constraints [on CAE usage] are getting simulations set up and knowing how to do them" – she termed this "a matter of corporate knowledge."

A manager at an aircraft engine maker details why better knowledge capture is needed. "When someone runs an analysis, and a couple of years later wants to redo or update that analysis, we find it very hard to pull together all the data from that analysis. Or when something changes in the design, how do you make sure that analysis is re-run when the inputs are changed? It's an extension of PDM into all the associated analysis areas."

Enabling functionality What's the answer? We found many cases where manufacturers are seeking to implement technologies that automate the capture, classification, storage, retrieval and re-use of knowledge. For example, at a Japanese consumer electronics manufacturer, "one of the goals of the simulation group is to standardize the storage of know-how," an engineering executive told us – a big advance over "today's simulation data management tools, [which] are cobbled together from in-house systems – spreadsheets, documents, databases, etc."

A Japanese auto maker describes similar needs, and what it's doing about them. "Currently the systems to share simulation data, and the libraries of correlations with test data, are in transition," a program manager told us. "The goal is to make them Web-enabled and searchable…right now the systems are in Excel, Word, and scanned paper documents."

Technologies that support these initiatives to capture knowledge in standardized, easily accessible ways will make it easier for anyone in the organization to understand, trust and reuse others' data and processes.

A related benefit of these activities is securing corporate knowledge assets against generational turnover in the workforce. "One objective [of our project to capture know-how] is to transfer knowledge to younger engineers," the consumer electronics company told us. "The Japanese engineering workforce is graying. However, design engineers are very busy and the product lifecycles are very short – both of which make it difficult to transfer simulation know-how."

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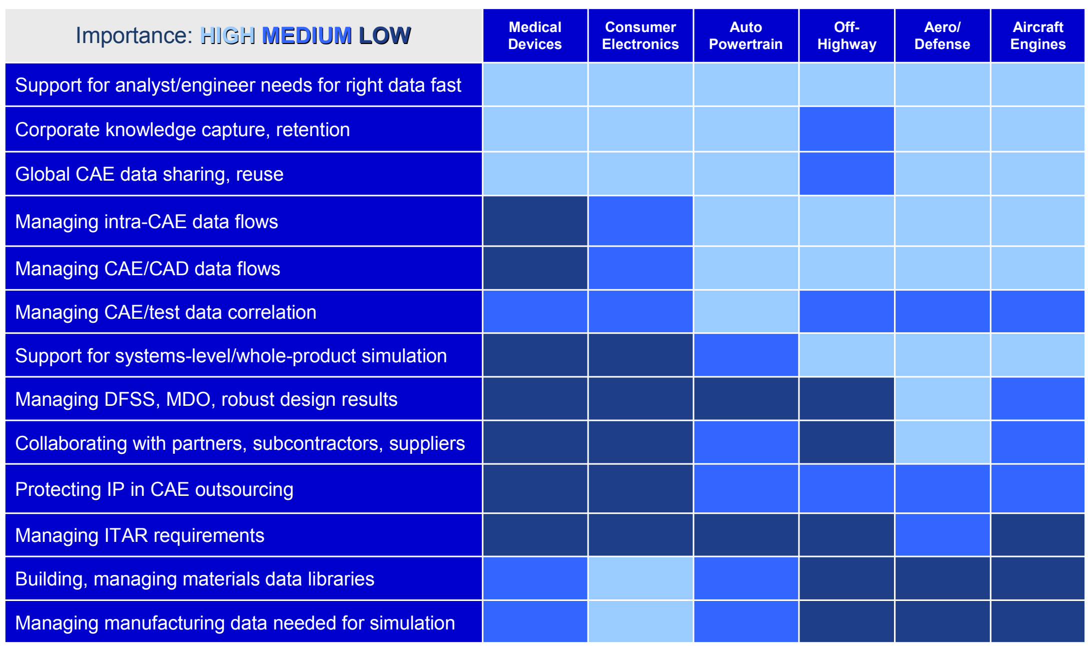
The resulting capabilities will empower experts to capture, manage and reuse best practices throughout a given product development cycle as well as across different projects and programs. Making these best practices and key project learnings readily available for re-use through data mining will powerfully support organizations' continuous-improvement initiatives. Product quality is improved because performance data can then be delivered in time to positively impact design decisions.

Questions for decision makers Managers evaluating technologies should look at how solutions gather process and application know-how. How easy is it to capture and manage knowledge? Is corporate value driven through team efficiency, or instead via entire engineering, design, simulation and manufacturing processes that can be streamlined and automated with best practices? Has the solution provider established a track record of longevity in the marketplace, and reliable delivery on its promises?

Simulation process management



Simulation Process/Data/Workflow Management: Industry Requirements

[For more on research summarized in this chart, see "Simulation Data Management: Rationalizing the Decision," Spar Point Research White Paper, July 2006, www.sparllc.com]

Business need Closely related to the business drivers for reusable processes and knowledge are those for simulation process management. Simulation results needed by concurrent and downstream project functions are too often unavailable, outdated, or captive to error-prone manual methods of dissemination and re-entry, practitioners told us over and over. Also needed are ways to capture and share best-practice work processes beyond the project where they originated.

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These needs arise across all the industries we studied. "We need to be handling analysis data much better than we are" – that's how a manager at an aircraft engine maker put it. "Tools having an ability to hide or encrypt some portions of the simulation activity and not others is important" in order more easily to work with suppliers, subcontractors and joint-venture partners. A manager at another jet engine company reiterated this need, pointing to the importance of version and configuration control for simulation data, just as for design data: "Sometimes we'll contract out the engineering of pieces of the engine," he said. "In that work there are requirements to share the right version of analysis data."

Likewise, an engineering manager at a maker of medical diagnostic equipment observes: "[What constrains] the product development cycle? We do an extremely good job of expediting schedules and getting things done quickly. But what gets lost in the process is global data sharing."

The auto industry has its own version of these challenges. "[There are] bottlenecks in data movement," an engineering manager at a German auto maker told us. "In some areas it's demanding…e.g., with body-in-white, spot welds are something you have to look at very carefully…is design aware of how the positions of the welds might influence the behavior of the overall structure, or will they adjust and finalize spot weld positions during the production process definition? You have to make sure that you get the correct data for simulation."

Another valuable objective is to help product development make better use of knowledge gained in manufacturing. "One of the constraints on the use of more simulation is to find better ways to integrate fabrication experience," an executive at a Japanese consumer electronics manufacturer explained. "The product development process has manufacturing process dependencies which are not readily addressed by today's simulation processes. Nor do today's PDM systems help manage these dependencies."

Indeed, process automation and toolset integration appears to be more important in some respects than the functionality of any given point solution. All the experts we interviewed stressed the need for integration – the value in eliminating work and errors associated with different data formats is clear.

One organization we studied is developing its own data/process management environment, and plans to integrate both its COTS and internally developed applications into this environment in order to standardize data handling across the organization. But most believe that working with commercial solution developers is the optimal way to implement these capabilities. "Global data sharing, including across different sites…is something we are working on" with a commercial PDM provider, a manager at a diagnostic equipment manufacturer told us. "Making that process more efficient and robust and less error-prone [by eliminating] manual intervention is a big opportunity for us." Inadequate capability for "data sharing and global collaboration is the biggest hit to productivity" in simulation activities because users too often "get data that's out of date, out of synch…That's why we are moving to a true global data vaulting tool" – something that should also aid "knowledge retention."

Enabling functionality Practitioners identified insufficient focus on managing CAE data, processes and workflows as possibly their biggest single constraint on getting greater value from their digital simulation investments. We found that a key best practice being pursued to overcome these constraints is to implement solutions that have three key capabilities:

- Ability to tie simulation applications more closely together

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- Process automation tools to accelerate work throughput

- Ability to capture, archive and retrieve simulation models, input conditions and results, together with related assumptions and conclusions

The focus is on technologies that enable a company's knowledge, methods and work processes to be captured in reusable process wizards and other tools that encapsulate knowledge and automate its application. Also key is technology to better manage the flow of data between different simulation and analysis tools, and between simulation/analysis tools and CAD applications.

Questions for decision makers What should decision-makers look for? Individual analysts and engineers reported pragmatic needs for solutions that let them work faster and with higher confidence. Key requirements include:

- Ability to have confidence that analysis was based on current, correct CAD configuration
- Ability to easily retrieve data from one CAE discipline for use as input to another discipline
- Ability to easily retrieve past analysis models, processes and results for re-execution or updating months or years later

Balanced against these user-level requirements, what enterprise requirements should decision makers seek? Most manufacturers told us they would ask whether the solution under consideration makes it possible to embed simulation data and process management in the context of the following functions:

- Configuration management, product structure management?
    - To coordinate CAD geometry and CAE models and processes. This is needed for two kinds of new-product development work processes:
        - CAD-led
        - FEM-led
    - To coordinate simulation models and results with corresponding matrices of product variants, such as in automotive and commercial vehicle development
- Change management, workflow management?
    - To ensure geometry changes trigger timely re-analysis
    - To ensure analysis results are fed back to product development, and acted on
- Requirements management?
    - To ensure system-level performance targets adhere to program requirements
    - To ensure adherence is maintained as system-level targets are "cascaded" down to component-level performance targets
- Project/program management?
    - To enable controlled data sharing as determined by partner trust levels
    - To achieve ITAR compliance
    - To ensure schedule adherence
- Document management?
    - To associate simulation data with, or incorporate it into, documents such as those mandated by regulatory agencies
- Management reporting?

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Next steps

To help their companies advance the goal of deploying digital simulation early and pervasively throughout the product lifecycle, what questions should decision makers ask?

To begin with, they should look at the overall architecture of the solution environment being considered – first, is it proven to work? Then, is it built on infrastructure technologies that are familiar to the customer's internal support organization? Better, is it built on an infrastructure that's already installed and supported? Best of all, is it part of an existing installed infrastructure that is already generating or managing volumes of structured product data that simulation users will be able to leverage? This all helps customers gauge how well the long-term support costs are understood, and whether the technologies can be implemented as an extension of existing installed capability rather than a new, additional infrastructure.

Decision makers should then ask: Does the technology under consideration have, or is it open to, all the enabling capabilities identified in this report:

- Scalability and consistency?
- Intelligent model generation?
- Industrial-strength productivity?
- Multi-physics, multi-disciplinary?
- Open integration?
- Visualization and collaboration?
- Reusable processes and knowledge?
- Simulation process management?

Finally, decision makers need to consider the business issues: Does the vendor have a major market presence and market share in its field? Has it demonstrated a long-term commitment to, and expertise in, digital simulation? Will the vendor be compatible as a long-term partner?

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