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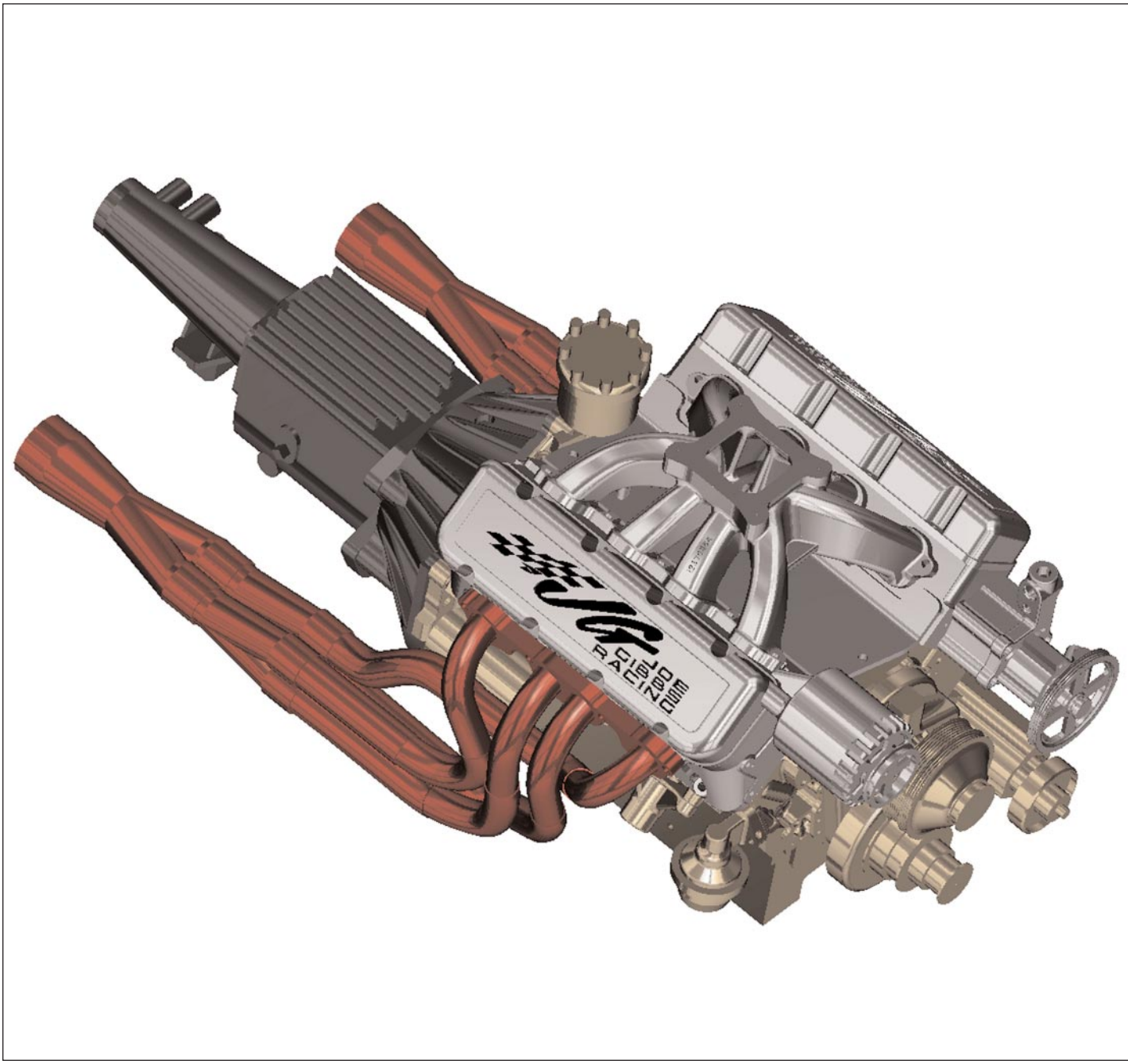
Best Practices for Implementing Digital Simulation and Analysis: *Five Lessons from Savvy Automotive Powertrain Program Managers*



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Tel. 978.774.1102
Fax 978.774.4841

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Best Practices for Implementing Digital Simulation and Analysis: *Five Lessons from Savvy Automotive Powertrain Program Managers*

March 31, 2005

By Bruce Jenkins, Senior Analyst

The world's best auto makers rely on digital simulation and analysis in powertrain development to deliver hot-selling, better-quality products faster and more efficiently than rivals. But CAE has been around a long time, and all use it – what separates the best from the rest? To find out, we interviewed program managers, engineering executives and discipline leads at top firms around the world. From hours of interviews we distilled five best practices that leading powertrain organizations are pursuing to use simulation and analysis to break through the critical business constraints their companies face today:

Manage simulation data and processes Practitioners singled out the dearth of commercially available "PDM for CAE" as their biggest unmet need today. To attack it, map CAE data flows to discover what tools need closer integration. Seek out solution providers competent and willing to help integrate tools and craft data management environments that put simulation data in meaningful context. Most important, analyze work processes to identify how and where CAE discipline specialists can be involved earlier in development cycles for greater program impact.

Optimize simulation/test tradeoffs Use simulation to refine designs, explore alternatives and detect failure modes; use physical test for final validation only – that's the goal of auto makers in all geographies. Companies we studied in Europe and Japan appear closer than North American firms to realizing this goal. But awareness of CAE's potential to reduce prototype counts and shorten schedules is being leveraged by advocates in U.S. firms to weaken entrenched biases toward empirical approaches and strengthen trust in analytical methods.

Manage people factors Involving analysts earlier in product development means culture change – among management and analysts alike. Recruit change agents from senior analysts respected by their peers, and from business-unit executives who understand the business impact of better simulation deployment and usage.

Qualify and select solution providers Unlike CAD and PDM decisions, CAE purchases are controlled by the analysis groups. Technical criteria are paramount in selecting point solutions. But in seeking CAE data management, tool integration and process

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optimization, factor in solution providers' services competence, stability and longevity, and change-management experience as well.

Rationalize the make/buy decision The wealth of commercial off-the-shelf (COTS) solutions developed or adapted for auto makers has let most dispense almost entirely with in-house software development. Most auto makers develop custom routines for 1D functional simulation, but even these are coded using standard commercial toolkits and modeling environments.

BUSINESS DRIVERS AND CONSTRAINTS

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 program schedules, interviewees told us:

> *"…[there are two major constraints on product development]…first is quality but a close second is cost…" – Japanese automotive OEM*

A single physical prototype can cost up to $500,000 to produce, and as many as 60 prototypes may be required to develop a new car model – the value of using simulation and analysis to drive down prototype counts is evident.

> *"…if we reduce the number of physical prototypes or overall development time, that's sufficient to justify the use of simulation…if you can save some prototypes, you can save a lot of money and time…" – German automotive OEM*

> *"…simulation is a tool to reduce the number of physical prototypes and to reduce part count for the final product…" – Japanese automotive OEM*

Equally critical is product quality. Here, the value of simulation and analysis lies in its power to help detect and correct failure modes before product ships. According to the Automotive Industry Action Group, a typical recall now takes 250 days to complete, at an average cost to the auto maker of $1 million per day. Given the industry's history of recalls, physical test-based processes are clearly failing to find the failure modes – something more is needed.

US Auto Recall Statistics: 1993 - 2004

Year	Number of recalls	Number of vehicles involved
1993	221	8,408,950
1994	247	6,202,883
1995	265	18,121,565
1996	304	17,826,392
1997	265	14,712,658
1998	365	17,146,878
1999	396	19,376,291
2000	541	24,646,743
2001	454	13,626,263
2002	434	18,435,586
2003	528	19,098,101
2004*	462	14,353,883
*As of Sept. 30, 2004		

Source: Detroit News; Associated Press; NHTSA

How and when CAE is used varies widely among the companies we studied in the U.S., Germany and Japan. We found that in Germany and Japan, simulation and analysis are seen as powerful means for design exploration and discovery, and are brought to bear early and pervasively throughout product development.

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> *"…[simulation] is absolutely important. Our [product development] processes are based on simulation…in the first half of the development process you have a very close interaction between simulation and design. The product is built between those two groups, and all variants are calculated in close cooperation between design engineers and simulation engineers…" – German automotive OEM*

This is less frequently the case in the U.S., where automotive engineering culture tends to be dominated by physical test, and there remains a fair amount of institutional distrust of, or at least discomfort with, analysis results. In this environment, CAE is used more for late-stage design validation than for exploration and guidance early in design. The result, according to a senior engineering executive at one U.S. OEM, is that "we do way too many physical tests, but because they are not well planned or well informed, they still miss the failure modes." Yet as this remark shows, there is strong awareness in U.S. firms of the potential of simulation and analysis to have greater impact and value if it was deployed and applied more effectively.

But maximizing CAE's impact involves far more than simply buying the best technology and handing it off to an analyst or discipline lead. Contemporary best practice also focuses on making more efficient use of existing resources – both engineering staff and tool investments.

> *"…constraints boil down to expertise and cultural issues…" – U.S. Tier 1 supplier*

No one we interviewed named software budgets as a constraint on product development's ability to contribute to corporate business objectives – all identified time, human resources, and culture issues as limiting factors.

Culture and psychology can be big obstacles to improving work processes. One U.S. executive remarked that "people in simulation want to do a perfect job because it's their nature, but there isn't the time, so they miss impacting the product development cycle." Another impediment to making use of analysis results earlier in design lies in program management shortcomings:

> *"…[the] biggest issue is having a design process where the level of decisions that have to be made is clearly defined and understood. Everybody involved in a program that has been underway for a while has some intuitive feel for where they want to get to. But early on, when you make decisions based on analysis, you may be making only a partial decision based on data available at that time. If it could be more clearly articulated where you go at each step of the program, it would be easier to make decisions based on the necessarily incomplete data available at any given step…" – U.S. automotive OEM*

One solution lies in making more use of system-level simulation tools:

> *"…the [CAE] tool may be powerful, but can it be partitioned to make the partial decisions needed early, using incomplete models? I only need a portion of the model or a certain level of detail to make a decision now, and then more complete definition of the product to make a more complete decision later. Some CAE tools have the ability to work with coarse concept models, then refine that as you go – for example the AVL system-level tools for predicting engine loads, oil paths, etc.…" – U.S. automotive OEM*

Another best practice we found in both Europe and Japan is to locate design, simulation, and test departments close to one another – in one case, all three occupied the same floor of a building.

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In all, our research found that increasing CAE's business impact depends on five tightly focused best-practice areas:

- Manage simulation data and processes
- Optimize simulation/test tradeoffs
- Manage people factors
- Qualify and select solution providers
- Rationalize the make/buy decision

MANAGE SIMULATION DATA AND PROCESSES

Most companies we studied named CAE data management as the biggest unsolved technological problem constraining the value available from simulation and analysis today. Best practice centers on better managing and automating the flow of data between disparate simulation/analysis tools, and between CAE and CAD. It's also about developing ways to capture, archive and retrieve simulation models, input conditions and results, together with related assumptions and conclusions.

> *"…currently the systems to share simulation data, and the libraries of correlations with test data, are in transition…the goal is to make them Web-enabled and searchable…[but] right now the systems are in Excel, Word, and scanned paper documents…" – Japanese automotive OEM*

A related problem is the need for better data integration among CAE tools for different disciplines, and also between CAD and CAE:

> *"…a major constraint is how well the CAE tools integrate with one another and with the CAD tools…[even where vendors have integrated their software with one another] you may have trouble getting CAD geometry into the CAE mesh, then getting CAE results back to the CAD model…in the CAD-to-CAE links, there's a lot of manual intervention in the meshing process…" – U.S. automotive OEM*

Best practice here is about finding – or developing – tools and processes to better manage and automate the flow of data between different simulation and analysis tools as well as between CAE and CAD. Where technological solutions are not yet available, best practice is to develop workarounds:

> *"…we would like to do analysis on incomplete models to make early decisions….[the] problem is that CAD tools are not structured to output an incomplete model…so to do early CAE you often use a surrogate from past work…something close enough…but it could be better…" – U.S. automotive OEM*

Best practice also involves understanding and optimizing program-level work processes that impact use of simulation:

> *"…[there are] bottlenecks in data movement….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*

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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…" – German automotive OEM

"…my constraints are the number of people and the number of hours in the day…my people resource are my biggest constraint…" – U.S. automotive OEM

Another problem that better CAE data/process management can address is limited availability of people and time. Our research found that a key constraint on getting more value from simulation is the availability of trained professionals and time, not a shortage of software tools or budget. Best practice for overcoming these constraints is to use knowledge capture, data/process management and open tools to make more efficient use of existing investments in staff and technologies. While no one we interviewed has yet achieved this goal, all are striving for it.

Ultimately, the aim of CAE work process improvement is to reengineer program workflows to bring simulation to bear early in product development. When simulation is done late in the cycle, after the bulk of engineering decisions have been made, its impact on product development is much diminished – design changes can only be cost-justified if analysis identifies serious design deficiencies or failure modes.

OPTIMIZE SIMULATION/TEST TRADEOFFS

"…the most important metric [for gauging simulation's value] is how many revisions to the design have to be made after the first [physical] prototype. The goal is to be successful in the first pass – the prototype validates the design…" – Japanese automotive OEM

"…[simulation] is used from the very beginning…our goal is to make sure that, on the basis of simulations, no significant problems occur during the [physical] test phase…" – German automotive OEM

In Europe and Japan we found high confidence that simulation provides a trustworthy assessment of product performance. The goal is to find all problems digitally, before the first physical test.

"…in former times we had the discussion whether simulation or test would be the better choice to do different things…there was a competitive situation between simulation and test…today there's no need for discussions like that…everybody knows you can do certain things on the basis of simulation…" – German automotive OEM

This is the goal at U.S. companies as well:

"…there's clearly an ongoing effort over the last ten years to displace physical test with CAE…" – U.S. Tier 1 supplier

But progress appears less advanced:

"…[the U.S. auto industry is] clearly in a transition. There's a desire to do as little physical testing for discovery as possible, and only do test as final validation, but we're not there yet…" – U.S. automotive OEM

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One reason, we found, is that in U.S. companies, people at all levels – both engineers and program managers – remain wedded to inductive reasoning, i.e., physical test, and distrustful of deductive (analytical) methods.

> *"…[how early in product development] analysis tools [are] used…depends on how well the tool is believed for a particular problem…correlation is the word typically used…" – U.S. automotive OEM*

One senior engineering executive at a U.S. OEM told us, "We do way too many physical tests, but because they are not well planned or well informed, they still miss the failure modes." The good news is that, as this executive noted, this is increasingly being recognized as far from best practice, and the pressure of competition is beginning to drive changes in the culture. Ultimately this should lead to wider recognition that, beyond being a cheaper, faster substitute for physical test, simulation is a powerful tool for exploration and discovery of phenomena that would be cost- and time-prohibitive to find through physical test, if not impossible:

> *"…simulation is very important to discover and learn about new phenomena that can't always be seen at the testing phase…" – Japanese automotive OEM*

MANAGE PEOPLE FACTORS

Much of the challenge in optimizing use of simulation and analysis has to do with organizational, cultural and people issues. Our research found that best practice focuses on two objectives:

- Garner executive sponsorship
- Create incentives for discipline leads, analysts and engineers to take ownership

Garner executive sponsorship

> *"…what will it take [to tie simulation more closely to design, test, measurement and manufacturing]? In many organizations change is required, to break down the traditional barriers between these groups, where historically they have been defensive about their roles. This change needs to be driven from the upper level of organizations – it will not be as effective from a program manager level…" – Automotive engineering services firm*

How to drive change in the way U.S. companies deploy and use simulation is a conflicted subject, we found. Many feel that change will only occur if driven by management. But one cause of the problem – the relative independence of the analysis groups, who stand on the authority of their expertise to continue maintaining the status quo – makes it difficult to effect change.

> *"…more accountability for quality of work needs to be developed, where predicted results are suspect or later turn out to be incorrect – verification and validation efforts need to occur more regularly to build/rebuild credibility. This will reduce the independence and help bridge the gap…" – Automotive engineering services firm*

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Nonetheless, the consensus seems to be that executive sponsorship is necessary though not sufficient to change cultures and work habits so that simulation is used earlier and more pervasively in product development.

> *"…change has to be driven from the top down. It boils down to a leadership issue. If the leader lays out what the vision and plan are, and gets everybody on board, then [change can happen]. But they have to get all the interested parties together and explain why they've got to do things differently. They may have to do skip-level meetings, going down several layers in the organization…they've got to engage passionately in communicating why…" – Automotive engineering services firm*

In Europe and Japan we found less evidence of these cultural impediments to optimal use of simulation and analysis:

> *"…all German auto industry executives are aware that the [product development] process would not work without simulation…" – German automotive OEM*

What is the best way to get executive sponsorship? Align simulation/analysis with key business drivers and ongoing company-wide initiatives and budgets – such as Six Sigma, Lean Design, quality and efficiency programs that directly impact:

- New-product cycle time
- Product development costs
- Product quality improvement, warranty cost/recall reduction
- Product differentiation, consumer appeal

Create incentives for discipline leads, analysts and engineers to take ownership

> *"…in early phases of product development you don't have 100% information…geometry may not all be defined…you certainly don't know all the loads…if you set the expectations correctly, [that] simulation is only directional at this phase and then you will get closer to the exact answer as you refine…it will go better…instead people get into this go/no go mindset…" – Automotive engineering services firm*

While it is generally understood that simulation can provide a richer and more complete picture of product performance, there are unavoidable complexities that require analysts to be more comfortable doing analysis with partial information. We found that in some cases, analysts even want to see physical test data to see what "fudge factors" to put into their model to ensure correlation with test results. It's critical to tackle issues such as these head-on in order to fully understand what incentives will actually motivate the changes that need to be implemented.

One solution is to enlist "champions" who are currently using simulation and create incentives that enable them to focus their efforts to implement the change from the user level up. This can ensure a smoother transition and greater adoption of the technology.

Best practices also include deploying knowledge-capture tools and process templates that aid designers in performing first-pass analyses. This has the added benefit of raising the value of designers' engagement in product development and having simulation data and

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analysis to refer back to throughout the process. Best practices also focus on reengineering program workflows to engage discipline specialists earlier in design.

QUALIFY AND SELECT SOLUTION PROVIDERS

Unlike CAD and PDM purchase decisions made by corporate committees with heavy IT involvement, analysts call the shots in simulation/analysis tool purchases.

> *"…the CAE groups decide which tools to use...it's not driven by the IT people...the discipline needs drive [the CAE] decisions…" – German automotive OEM*

> *"…the engineers make the CAE tool choices. CAD is different – the decision for the CAD tool comes from above…" – Japanese automotive OEM*

Nonetheless, it's important that simulation/analysis purchase decisions be grounded in not only technical but also business criteria. Current best practice is to separate these two variables: evaluate one set of solution providers on their ability to deliver the latest solver or mesher, and evaluate another set on their ability to help tie disparate tools together, streamline work processes, secure and shepherd corporate knowledge assets, and provide change-management expertise and support.

Technical evaluation criteria

- Functionality of solvers
- Functionality of meshers, gridders, other tools for problem setup and results execution

> *"…we do not really have restrictions on what we can do, given the variety of software we have. 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…" – German automotive OEM*

Current best practice is to treat point solution providers somewhat opportunistically, evaluating technologies and adopting them as they become proven. Of course, practitioners will often be asked to make the case that the value of the tool exceeds the cost of implementing it.

Business evaluation criteria

- Competence as an integrator of diverse functionality
- Commitment to providing help with process change, people/cultural issues
- Commitment to providing:
    - Simulation data management framework
    - Process automation tools
    - Knowledge capture tools

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- Openness to integrating internally developed codes
- Attractiveness as long-term partner

RATIONALIZE THE MAKE/BUY DECISION

> *"…for analysis experts we are almost 100% COTS, but for design engineers some in-house software applications are still used because of historical reasons. These in-house applications will be changed to COTS in future…" – Japanese automotive OEM*

Rationalizing the make/buy decision is about managing the tradeoffs between commercial off-the-shelf (COTS) software and internally developed tools. Our research found that in contrast to the aerospace and defense industries, auto makers around the world feel that COTS software meets their needs in all but the most specialized circumstances.

> *"…we have some in-house tools…e.g., to do fuel consumption and performance/drivability simulations…[but] I am not a fan of in-house development. It's difficult to make sure that a tool stays in good shape if you have a limited user group…the financial picture is not very good if you have to compete with commercial software products that have a user group 10 to 100 times larger. If there is no comparable tool in the market, it might be a good idea to have it, you might benefit for several years, but generally it's a bad idea…" – German automotive OEM*

Commercial software developers have fielded a wealth of products that target the lucrative opportunities in the auto industry. As a result, auto makers by and large have escaped what they now consider the burden of developing and maintaining in-house tools.

Routines for 1D functional simulation are something of an exception, but even these are increasingly coded using commercial environments designed for this purpose:

> *"…even what I'd call the custom applications have migrated to being coded in Matlab – those are generally very specific applications for camshaft design, aspects of engine/transmission calibration, etc.…" – U.S. automotive OEM*

SIX NEXT STEPS

To put these best practices into action, what can program managers and others do to get started?

Manage simulation data and processes For most organizations this is a new area where best practices are still being developed and validated. One way to start is to assemble a multidisciplinary team – include representatives from the analysis groups, design, test, and program management – to audit current practices, identify gaps and bottlenecks, and develop detailed recommendations for improvement. Seek out a commercial developer with competent foundation technology, and willing to provide support.

Optimize simulation/test tradeoffs Audit three past projects – one highly successful, one typical and one that could have gone better – to gauge whether superior management of the tradeoffs between simulation and test contributed to the success. Use the audit to map

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existing processes for design refinement and validation, and identify opportunities for improvement.

Manage people factors ***Create incentives for discipline leads, analysts, and engineers to take ownership*** – Identify champions of advanced simulation and analysis within your organization. Engage heads of Six Sigma and Lean Design as advocates of best practices. Enlist professionals who enjoy strong peer respect to lead process improvement initiatives. Cultivate corporate and public recognition of these champions. ***Garner executive sponsorship*** – Find an appropriate time and venue to brief VP-level executives on the business impact of the organization's simulation and analysis competencies. Reinforce the need for executive backing at the business-unit level, and enlist assistance in communicating the benefits of the technology and how it contributes directly to business-unit and program objectives.

Qualify and select solution providers In your organization's next procurement cycle, revisit your qualification and selection policies for simulation solutions to ensure they address your requirements not just for superior point functionality but also for simulation data management, tool integration and process optimization. Factor in solution-provider stability, longevity and change management experience.

Rationalize the make/buy decision Make this an agenda item in planning and budgeting. Audit your current expenditures on both commercial software and internally developed tools, and revisit this allocation in each future budget cycle. Benchmark your organization against competitors.

Benchmark your organization against best practice leaders To create change in an organization, a powerful spur to action is to start by benchmarking the organization's maturity level against industry best practices. Using this report as a starting point, compare practices in your organization with those of your most successful rivals. Identify areas where more effective use of simulation and analysis would put you in the lead.

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Best Practices for Implementing Digital Simulation and Analysis in…

- ***Aerospace and Defense***
- ***Aircraft Engines***
- ***Automotive Powertrain***
- ***Consumer Electronics***
- ***Off-Highway***

Five reports that reveal how savvy program managers at the world's leading manufacturers are implementing digital simulation and analysis to create business value.

Digital simulation and analysis is key to making better products more quickly at lower cost. But maximizing the technology's business impact requires far more than just buying the right point functionality and handing it off to the analysis department. Spar Point interviewed program managers and discipline leads at top-ranked manufacturers around the world to find out how they do it – what best practices have they developed to use simulation and analysis to break through the critical business constraints their companies face today?

Each of these concise, industry-focused reports details five best-practice lessons from savvy program managers. Use this exclusive intelligence to benchmark your company against industry best practices – learn where you excel, where to improve and how. And discover key learnings in other industries that you can apply to your own efforts.

For complete product information and details on price and ordering, contact Tom Greaves, Spar Point Research, at email tom.greaves@sparllc.com or phone 978.774.1102.