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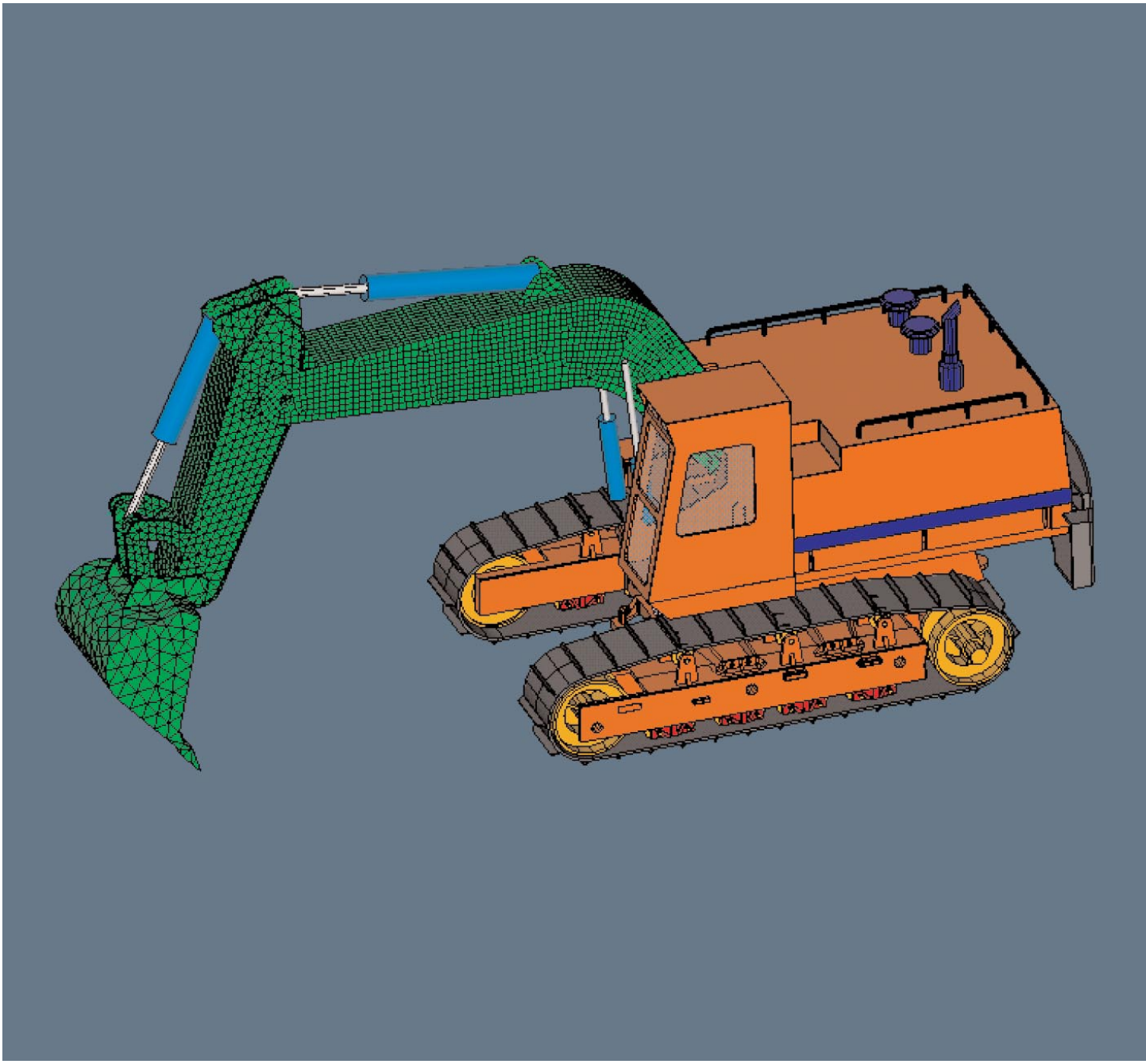
Best Practices for Implementing Digital Simulation and Analysis: *Five Lessons from Savvy Off-Highway Program Managers*



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Best Practices for Implementing Digital Simulation and Analysis: *Five Lessons from Savvy Off-Highway Program Managers*

March 28, 2005

By Bruce Jenkins, Senior Analyst

Some of the world's best off-highway manufacturers are in the midst of driving their product development methodology toward an analysis-led, right-first-time, zero-prototypes process. Digital simulation is helping these companies move beyond traditional test-centric development – "design, build, test, break, fix, break, fix, sell" – to become leaner, faster, better able to innovate and meet new efficiency and environmental targets. 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, then distilled five best practices for achieving an analysis-driven development process that makes it possible to "sell the first physical prototype":

Manage simulation data and processes Practitioners identified the need for better CAE toolset integration and simulation data management as key challenges in moving analysis usage to the center of product development. To address these challenges, procure or co-develop tools for simulation data management and knowledge capture. Identify technology and techniques that make it easier to capture, archive and retrieve simulation models, input conditions, assumptions, results and conclusions.

Manage people factors Involving analysts earlier in product development means culture change – among management and analysts alike. Incent analysts to embrace new methods by ensuring they understand how change will benefit the company; bolster participation and adoption by implementing tools that facilitate the new processes. Garner executive sponsorship by ensuring executives understand simulation's power to impact business metrics – time-in-market, quality, reliability, regulatory compliance, other critical business metrics. Use simulation to provide marketing collateral for pre-selling forthcoming models.

Rationalize the make/buy decision Use commercial off-the-shelf software whenever it will suffice. Invest in internal software development in special cases to encapsulate proprietary know-how that confers competitive advantage.

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 best-practice leaders. Today's business pressures mean engineering is being asked to become leaner, faster, and better able to meet increasingly stringent efficiency and

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emissions requirements. Simulation advocates are using these pressures to help drive change in product development from traditional test-based methods, with their penalties in both cost and time of prototype fabrication and testing, to analysis-led processes that are faster and cheaper as well as more powerful routes to exploration, discovery and innovation.

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

BUSINESS DRIVERS AND CONSTRAINTS

Off-highway vehicles and equipment for construction, mining and agriculture are a mainstay of the U.S. and worldwide economy. Manufacturers are increasingly facing pressure to improve on compliance with environmental regulations, product cost, product quality/reliability, product safety, and product performance while speeding up development schedules and lowering development costs.

> *"…[to shorten development cycles] we will have to move from physical test to much more electronic test – that is, computer simulation. We want to sell the first physical prototype…" – Off-highway manufacturer A*

Developing a new off-highway product can take two years or more and cost tens of millions of dollars. Simulation and analysis is key to shortening development schedules by as much as half, improving and advancing product functionality, and complying with increasingly stringent environmental requirements.

> *"…We spend a lot of money building prototypes, and there's a huge value in learning how not to have to spend all that money in development. That's the value-add we're going to drive for in the future. Savings come from reducing prototype counts, reducing iterative loops in development by getting it right the first time, reducing the cost of remaking parts, the costs of servicing and paying warranty and fixing. There are orders-of-magnitude increases in costs, the further down the cycle you go with mistakes…" – Off-highway manufacturer B, source A*

Simulation and analysis technology offers the potential for lower program development costs and faster development schedules by substantially reducing errors and rework late in the design cycle. The results – faster time to market and longer time in market – substantially increase the profitability of any new product program. Properly deployed, simulation and analysis also enable manufacturers to produce machinery that is more fuel-efficient and cleaner, complying with emissions regulations and contributing to a better environment.

> *"…Emissions regulations created an opportunity for us. Early on, we wondered how to get emission levels down. The approach chosen by our competitors was exhaust gas recirculation. We were getting ready to do that, but then stepped back and said, 'Why don't we take a new approach with the [new] engine' – a very smart engine developed as a systems solution. Our technology and simulation capability were essential to this development. Now we have a product like no other out there because it's not only cleaner, it's more reliable. [Simulation was key to] improving performance at the same*

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time as exceeding green emissions standards…" – Off-highway manufacturer B, source B

Against this background, we interviewed experts at the industry's leaders to find out how they do it. What best practices have they developed for using simulation and analysis to achieve the business objectives that they and all manufacturers face – shorten program schedules, improve engineering productivity, and reduce development costs? Participants asked not to be identified, but were pleased to share their insights and lessons of experience.

Maximizing the technology's business impact, we found, is more subtle than simply buying today's best point functionality and handing it off to the analyst or discipline lead. Instead, contemporary best practices focus on making fundamental changes in the product development process.

"…Dr. Toyoda characterizes the U.S. process as quick-draw, slow-bullet…It's kind of excruciating for our hell-bent mentality in the West to spend a lot of time up front, but with [our new initiative], doing the simulation and analysis up front before you finalize anything is definitely a big value proposition…" – Off-highway manufacturer B, source A

What we found was that bringing simulation and analysis to bear early and pervasively is the focus of intensive initiatives at the off-highway industry's best-practice leaders today. The aim of these initiatives is to utilize these techniques at the earliest stages of product development for whole-product performance characterization, then continue using them throughout product development and refinement into detail design.

"…If you…get more time in market, you make a huge amount more money…" – Off-highway manufacturer B, source A

A key objective is to reduce and ultimately eliminate iterative design-refinement loops involving expensive physical prototypes. Reducing physical prototype counts can trim hundreds of thousands of dollars from development costs. More, finding and fixing design flaws late in the development cycle can cost 10 to 100 times what it costs to make changes early. Beyond this, the greatest returns for off-highway manufacturers lie in accelerating the development cycle – faster time to market yields longer time *in* market.

In all this, we found that success depends on tight focus on five best-practice areas:

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

MANAGE SIMULATION DATA AND PROCESSES

Fully deploying simulation and analysis is a fundamental change from the off-highway industry's traditional approach to developing new products – an iterative process that involves

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building a series of physical prototypes, testing them, and making changes late into the design process to react to problems found at each testing stage.

> *"…If you set a date earlier and get more time in market, you make a huge amount more money. So the U.S. cowboy mentality is to fix the date at three years instead of five years. But if you don't change the process, that just leads to shortcuts and quality problems. The issue becomes that you need a new [product development] process in order to execute that business strategy…" – Off-highway manufacturer B, source A*

The principal constraints on getting more value from simulation and analysis are availability of trained professionals and time, not a shortage of software licenses or budget. We found that a key best practice being pursued to overcome these constraints is to tie these tools more closely together, using knowledge capture and simulation data management aids to increase work throughput.

> *"…[Integration is] part of our vision, to address common data management, common tools, common structure…" – Off-highway manufacturer B, source A*

Best practice here focuses on capturing a company's knowledge, methods and work processes in the form of design rules, and embed these rules in its simulation, analysis and CAD tools. Also key is better managing the flow of data between different simulation and analysis tools, and between simulation/analysis tools and CAD tools. It's also about being able to capture, archive and retrieve simulation models, input conditions and results, together with related assumptions and conclusions.

Indeed, 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 – though how to best accomplish this is far from settled. One organization is developing its own data 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.

MANAGE PEOPLE FACTORS

Much of the challenge in optimizing the use of simulation and analysis and maximizing its impact has to do with organizational issues. The entire design process must be re-engineered to allow for adequate time and resources at the front end to develop the models, run the simulations and correct problems while the design is still "cast in bits" rather than in hard tooled parts. Our research found that best practice focuses on two objectives:

- Create incentives for discipline leads, analysts, engineers to take ownership of the new tools and work processes
- Garner executive sponsorship

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

Alienating the head structural analyst by forcing him or her to use a tool he/she doesn't like or trust is not the best way to get a front-end loader out on schedule. What should program

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managers do to get discipline leads, analysts and engineers to take ownership of the new work processes?

> *"…the engineers [feel they] already have too much workload to take on this analysis too…what you're trying to do is eliminate test and re-design. But test is usually built into the future plan, so in effect engineers are often pressured to push analysis off that way…" – Off-highway manufacturer B, source B*

The answer lies in best practices for knowledge capture and change management. Engineers and the rest of the team are motivated to produce the best designs possible. They want to do more – analyze more designs or analyze a design more thoroughly than otherwise possible. They want to be in more control of their own environment and work situation. The concerns that need to be overcome include questions about the impact of this new approach on the company and their own jobs, the abilities and limitations of the tools, and questions about the commitment of the company to the tools in question (am I going to have to learn something else next project?). Adequately explaining benefits to the company and demonstrating executive commitment in terms of formal training and time for engineers to explore the capabilities of the tools on the first project will address some of these concerns. Including engineers and analysts on the selection team and implementation team will also help give people ownership in the change process.

> *"…First, the engineer has to understand why it's good for [the company] for him to change. Second, you have to change the process to get him to use the tool and use it consistently. So change the process, then hand him the tool and say, 'We just happen to have this really neat tool that will help facilitate your process.' And then he will keep using it…" – Off-highway manufacturer B, source A*

Garner executive sponsorship

Equally critical to a successful process change management program is executive sponsorship. Of course the executive team controls the purse strings, but more importantly they set the tone and direction within organizations. Middle managers, engineers and others sense when an executive team is paying lip service to an initiative. Getting genuine support from the top will make it easier to gain support from all within the organization. In addition, the payback from moving to a simulation-based product design process may not be obvious in the short term. Commitment and staying power are necessary to weather the inevitable bumps in the road when an organization is learning how to most effectively utilize these techniques.

How to get it: Ensure that the executive team understands the potential to significantly impact key metrics that they focus on – time to market, time *in* market, quality, reliability, repair frequency and cost, regulatory compliance, product cost, and product performance. Tie it to other ongoing quality and efficiency initiatives and budgets such as Six Sigma.

Another best practice is to use simulation to generate functional product models and performance data that marketing can use early on to present to customers, dealers, and others to solicit feedback or begin the selling process. Also, there seems to be great potential in exposing customers to the fact that simulation is being used extensively, particularly with new products. If done right it can add credibility to claims of reliability and performance that would otherwise only be backed up later in the life cycle by a track record of experience in the field.

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RATIONALIZE THE MAKE/BUY DECISION

Rationalizing the make/buy decision encompasses two key issues:

- Can the organization add unique value by using proprietary codes and algorithms?
- When are point solutions appropriate vs. an integrated solution? Is it possible to have the best of both worlds?

One organization we interviewed uses custom in-house-developed tools for its whole-product and systems-level performance analysis, because it believes this software embodies critical know-how and intellectual capital that gives the company a competitive edge. This organization uses commercial off-the-shelf (COTS) software for all its structural analysis and electrical analysis, because it believes these are commodity capabilities more than adequately provided by COTS offerings.

> *"…In performance software, we have a tool we developed…a full-systems simulation tool. It can model the entire machine, lets us see how it works, how fuel-efficient it is, how much it can dig…And we have lots of specialty applications focused on particular design processes for systems or subsystems…" – Off-highway manufacturer B, source B*

One best practice we identified is a hybrid approach of capturing a company's proprietary knowledge, methods and work processes in design rules, then embedding these rules in the commercial solutions for simulation, analysis and CAD in use at the company. For example, when a designer creating a CAD model chooses a fastener, design rules can automatically call an analysis routine to check that the fastener has adequate strength.

OPTIMIZE SIMULATION/TEST TRADEOFFS

The relationship between digital simulation and physical test can be used as a lever to drive change in how each is used in product development. We found that best-practice leaders are pursuing a goal of carrying out as much design exploration and refinement as possible with simulation/analysis, and driving physical test toward a role of final design validation only. Indeed one organization boasts of selling the first article produced.

> *"…on a truck [project], we used a lot of simulation to develop it…we were able to make numerous design changes to major structures well before any iron was poured. Simulation was the only way to develop a machine like that…" – Off-highway manufacturer B, source B*

Key elements of this are to:

- Use simulation/analysis early in a program, when designs have not been detailed to the point where physical test is possible.

  "…doing the 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…" – Off-highway manufacturer B, source A

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- Use simulation/analysis to drive the role of physical test away from discovery and refinement to final validation.
- Align simulation/analysis with corporate initiatives to drive time and cost out of product development.

  "…[our goal is] to transform the process for developing product to a more up-front-loaded, analysis-driven, build-it-right-the-first-time, zero-prototypes process…" – Off-highway manufacturer B, source A

QUALIFY AND SELECT SOLUTION PROVIDERS

For companies with long development cycles and product service lives, simulation/analysis purchase decisions need to 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

Technical evaluation criteria

Simulation and analysis software tools comprise (1) engineering analysis programs called solvers, and (2) programs used to create the data for input to solvers, and to interpret the results that solvers generate. Technical evaluation criteria focus on the functionality of these two classes of tool.

- Solvers – can they predict the physics?
- Meshers, gridders, other tools for problem setup and results interpretation – can they speed up the process?

Current best practice is to treat point solution providers somewhat opportunistically, evaluating technologies and adopting them as they become proven. The art is being able to incorporate these into the next project without betting the company's future – not a difficult challenge for companies that have made the right business evaluation.

Business evaluation criteria

- Attractiveness as long-term partner
- Premium on stability and relationship
- Commitment to providing help with process change, human/cultural issues
- Openness to integrating internally developed codes
- Commitment to providing:
  - Knowledge capture tools
  - Process automation tools
  - Simulation data management framework

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- Software license models geared to make large multi-seat purchases attractive. While price is generally not an obstacle to utilizing these tools, lowering R&D cost is always seen as a positive factor.

  "…At the prices we can negotiate, [software tools'] direct cost is not significant…But of course any time I cut R&D costs, that's straight to the bottom line, so we won't turn that down…" – Off-highway manufacturer B, source A

In the off-highway industry, the answer is to choose a solution provider best able to help a company increase its permeability to new technologies and code streams – without requiring prohibitive new investments in integration, support and personnel.

> *"…if you get into the mode of picking point solutions, you're going to be changing your solutions every few years. 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…" – Off-highway manufacturer B, source A*

Another key business criterion is staying power. With service lifetimes of off-highway equipment spanning years and often decades, the solution providers most likely to maintain business continuity on this time scale are the ones that best-practice leaders choose to partner with. Manufacturers in some respects bet the company on those relationships: these are the companies that help with the essentials of tool integration, process definition, data management, knowledge capture.

SIX NEXT STEPS

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

Benchmark simulation/analysis maturity levels 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. In the off-highway industry, our research indicates that maturity of simulation/analysis implementation and usage varies widely from company to company. This is in marked contrast to some other industries studied by Spar Point. For example, in both aircraft engines and aerospace/defense, all major industry participants appear to cluster near the leading edge of simulation/analysis best practice.

For off-highway manufacturers, the pinnacle of best practice is the ability to simulate and analyze not just components or subsystems but critical aspects of whole-product performance. Off-highway leaders we interviewed view this as key to bringing simulation to bear in the earliest stages of product development, transforming the role of physical test from exploration to validation, and ultimately becoming able to optimize and prove out a product design wholly digitally before creating any physical prototypes. At the industry's best-practice leaders, structural analysis of components is a commodity capability. It is done with commercial off-the-shelf software, and much of the work is outsourced – some even to university students. This is not seen as increasing project risk, because the task of creating finite element meshes is labor-intensive but requires little understanding of the total product. More, it frees capable and experienced people to concentrate on system- and product-level performance analysis – the highest-payback activities.

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Just below this maturity level are companies that are advanced users of all the applicable simulation/analysis tools – CFD (computational fluid dynamics) and thermal/cooling codes to improve engine performance and reduce emissions, kinematics analysis to model product motion and performance, durability/fatigue tools to predict and engineer product life, NVH (noise, vibration, harshness) and of course structural simulation. For these companies, the goal now is to achieve a level of toolset integration that enables whole-product simulation.

Behind this are companies whose product development processes remain heavily reliant on physical prototyping and test.

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 program management, the analysis and simulation groups, and the IT department – to audit current practices, benchmark them against industry best practices, identify gaps and bottlenecks, and develop detailed recommendations for improvement.

Manage people factors ***Create incentives for discipline leads, analysts, and engineers to take ownership of the new tools and work processes –*** Identify champions of advanced simulation and analysis within your organization. Ensure that they are adequately trained and have an opportunity to explore the capabilities and limitations of tools selected so that they will have confidence in the tool and trust the results. 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 your CEO and senior management team on the business impact of your organization's simulation and analysis competencies. Reinforce management awareness of how the technology contributes directly to board-level objectives such as faster time to market, longer time in market, higher product quality, lower incidence of repair/lower cost to repair, lower product cost, and better compliance with government regulations such as emissions control.

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. Ensure that your internally developed tools embody knowledge and expertise that give you a competitive advantage rather than simply echoes functionality that is commercially available. Benchmark your organization against competitors.

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 success. Use the audit to map existing processes for design refinement and validation, and identify opportunities for improvement.

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 and longevity.

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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.

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