Ora Research LLC
P.O. Box 61334
Raleigh, NC 27661
USA
tel. +1 617 875 9598
www.oraresearch.com

Strengthening Simulation's Business Impact: New Strategies in Off-Highway Equipment

December 31, 2009

By Bruce Jenkins, Principal Analyst, Ora Research LLC

Executive Summary

Some of the world's best off-highway equipment manufacturers are 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, and better able to innovate and meet new emissions and fuel economy targets. Nevertheless, these companies still experience program-gating constraints on getting the value they need from these technologies and the work processes that employ them. What are they doing about it? To find out, we interviewed experts at industry leaders around the world. We investigated business drivers for investing in simulation, current state of industry practice, constraints on maximizing simulation's value, and new strategies for overcoming these constraints.

This report summarizes our findings:

DISCLOSURE & DISCLAIMER: Research for this publication was funded in part by Siemens PLM Software, Inc.

Ora Research LLC
P.O. Box 61334
Raleigh, NC 27661
USA
tel. +1 617 875 9598
www.oraresearch.com

This report offers a practical, action-oriented analysis of new directions and emerging best practices for getting more value than ever before from digital simulation and analysis. Program managers, discipline leads and practitioners will find first-hand advice and lessons of experience for planning new and ongoing investments in simulation technology, and for managing these tools to exploit their organizations' simulation competencies to the fullest.

Digital Simulation and Analysis Investments: Business Drivers

What business goals are best-practice leaders seeking through more effective use of simulation and analysis?

Reducing emissions, improving fuel economy Increasingly central in today's environment is compliance with both regulatory mandates and customer preferences for greener and more fuel-efficient products. What new challenges does this pose for product development organizations?

> *"The industry's focus is on a different aspect of 'green' now than five years ago. Tier 4 [U.S. Environmental Protection Agency's Clean Air Nonroad Diesel Tier 4 Rule, issued May 2004[1]] was all about reducing pollutants. But now we're starting to worry about CO_2, and that in turn involves energy issues: we're realizing our products have to become more energy-efficient. That fits with sustainable-development priorities. And it's a good scenario for competitive advantage – for both us and our competitors to come up with hybrids and other technologies that are more energy-friendly, beyond the Tier 4 pollution issues. That's what's driving our business today." – Off-highway manufacturer B, source B*

What role does simulation and analysis play in meeting those business objectives?

> *"We firmly believe that CAE, or what we call virtual product development, is still our advantage, because it just takes too much time to build physical prototypes and test them. CAE also helps us achieve sustainable development by minimizing prototypes that end up as scrap – building this big iron machine just to test and throw away is not very eco-friendly.*
>
> *"So we are looking at the value of CAE through two lenses – advancing green technologies, and strengthening our competitive advantage. With both, there's a feeling among product development management that virtual prototyping and simulation are keys to achieving these goals within the time frames we have." – Off-highway manufacturer B, source B*

Maximizing time in market, reducing development costs Equally critical are the business goals of maximizing a product's time-in-market, performance, quality, reliability and

[1] "EPA has adopted a comprehensive national program to reduce emissions from future nonroad diesel engines by integrating engine and fuel controls as a system to gain the greatest emission reductions…" – *Clean Air Nonroad Diesel – Tier 4 Final Rule,* U.S. Environmental Protection Agency, May 2004. http://www.epa.gov/nonroad-diesel/2004fr.htm

safety, while controlling development costs. 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, while improving and advancing product functionality.

> *"…[to shorten development cycles] we 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*

Simulation and analysis technology offers the potential for lower development costs and faster program 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.

Simulation: Current State of Practice in the Off-Highway Industry

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?

Focused on physical prototype reduction… 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.

> *"…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…Savings come from reducing prototype counts [through virtual prototyping], reducing iterative loops in development by getting it right the first time, and 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*

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.

> *"Using analysis-led design approaches to minimize physical testing by simulating instead – that's one of our primary goals, because building prototypes and running hardware tests account for a great portion of our development costs." – Off-highway manufacturer C*

More, finding and fixing design flaws late in the development cycle can cost 10 to 100 times what it costs to make changes early.

> *"Off-highway manufacturers are ahead of the automotive industry: We promote analysis-led design from the top down, and it is prevalent throughout the company. The culture here is that you never rely on physical test only; everything has to be analyzed at some level. Our culture is very analytically led – that's been an initiative for five to ten years. What sparked that was the fact that analysis is a better way to capture failure modes and prevent repeat failures than physical test, plus the cost savings from reduced engine testing. We are so cost-focused, and the cost avoidance potential of analysis is not in eliminating test, but rather eliminating re-test. That's where the money is saved, by using analysis to be able to put forward the best prototype for test, and only running the test*

Ora Research LLC
P.O. Box 61334
Raleigh, NC 27661
USA
tel. +1 617 875 9598
www.oraresearch.com

> *once, instead of using the test as the sorting mechanism. That's our value to the company." – Off-highway manufacturer C*

Beyond this, another big return for off-highway manufacturers supplanting test with simulation lies in shorter product development cycles – faster time to market yields longer time *in* market.

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

…but working to achieve still more: advance from physically led to virtually led development processes based on whole-product performance modeling

The focus today is on achieving the ability to bring virtual prototyping and simulation to bear at the earliest stages of product development for whole-product performance characterization, then continue using them throughout product development and refinement into detail design.

In this respect, we found that maturity of simulation/analysis implementation and usage in the off-highway industry varies widely from one company to another. This is in marked contrast to some other industries we have investigated – for example, in the aerospace/defense and aircraft engine industries, all major participants appear to cluster near the leading edge of simulation 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.

> *"We have to strike a balance between analyzing quickly and conservatively at the component level (when the product has not been modeled completely), versus achieving the best optimized system possible. To do that, we heavily front-load our analysis activity. We seek the best balance between being conservative and efficient, versus being analysis-led. A risk is if the analysis is thorough but too late – 'Well, too bad you had to produce your engine six months ago.'" – Off-highway manufacturer C*

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.

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.

Ora Research LLC
P.O. Box 61334
Raleigh, NC 27661
USA
tel. +1 617 875 9598
www.oraresearch.com

But moving up this curve 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. 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.

Constraints on Maximizing Simulation's Value

What constrains off-highway product development organizations from achieving the goals laid out above? We found that constraints fall into two primary categories: (1) technology constraints and (2) organizational and work-process constraints.

Technology constraints

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

CAD-CAE gaps A perennial constraint has been the technological gaps that exist between product definition geometry on one hand, and simulation models on the other – and the resulting penalties in time and, sometimes, accuracy exacted by the need to prepare geometric and functional models for input to analysis.

"Closer integration of analysis tools with CAD? We've been working on that for a couple of decades. Part of the problem is that we don't have standard nomenclature or a good data concept for this task. The way it still works is that our analysts will go and get a CAD model from a designer, or from multiple designers. They will mix that data into their systems model, then come back and report to the designer how healthy his design is. In that problem-solving, consultative type of work, first we worry about such things as whether the analyst is working on a part model that's now out of date; those are integration issues. But a lot of the time we're still in a situation where, with structures, the analyst will have to take a design and de-feature it, or add features to it, before he can do the simulation work. So we're still in a state of having CAD and CAE interfaced, but not integrated." – Off-highway manufacturer B, source B

Cross-discipline analysis gaps Similar barriers impede sharing of results between analysis tools in different disciplines:

"Hard-coding to integrate different CAE tools was the approach for the last five to ten years. Getting away from that is one of my goals. My group writes the procedures for how engineers and designers throughout the company do things. We make components, so the parts over which we have design control – engine blocks, crankshafts, engine heads – we develop procedures and a philosophy for, down to the command level. We follow that up by developing standardized macros for everyone to use – files to preprocess geometry, and then files to post-process the results. Now our goal is, first, to move those routines into a more user-friendly commercial software platform; and, second, to move up to doing system-level analyses – for example, analyses of gasket sealing. This needs to be done in a system-level environment – the disciplines involved include structural, thermal and more. Sealing can become a complex multi-physics problem." – Off-highway manufacturer C

"A lot of times, simulation goes on before we even make a CAD model. We have our own system-level simulation tool that we've developed over the years. People will pass around the input file for this tool, and each person will put in a little of his own information.

Ora Research LLC
P.O. Box 61334
Raleigh, NC 27661
USA
tel. +1 617 875 9598
www.oraresearch.com

We use standard concepts and nomenclature – 'pins' and so forth – so it turns out that everyone is sharing the data at its lowest-detailed level. The result is a machine model. One machine group will have its particular representation of an engine, while another machine group may have its own model of the same engine at a different level of detail. But when you want to compare the two models, it's difficult because we don't have a single, standard model of that engine – because, in turn, we don't have a standard nomenclature for that engine. Take a transmission – it could be modeled just as a torque speed curve. But you may want a higher-fidelity model, so you go to a deeper level of detail in the model. To really share this data and collaborate across groups, you need a plug-and-play model based on some standards." – Off-highway manufacturer B, source B

Need for better simulation data/process management Another chief constraint is the need for robust, capable simulation-specific data management and process management tools. Indeed, many name simulation data and process management as the biggest technological challenge constraining the value available from simulation and analysis today.

"We have standards for drawings and models – IGES and so forth. What's needed now is a similar standard for the simulation space. We all agree what 'pressure' is, but what do we mean by 'digging dirt'? Describe that to me in terms that we can put into a database. If you can't model the application, you can't do this work; but you can't model the application with these kinds of tools unless there's nomenclature and a schema for sharing this information: can everybody read a model like they can read a drawing? I think that's the next horizon for the software vendors: don't just throw us a database. CAD designers think about parts and assembles, whereas in the CAE world, we think about systems and subsystems. If we're going to share CAE data, someone has to come up with those kinds of standards – not just a version of a PDM system." – Off-highway manufacturer B, source B

A related constraint is gaps in capability to manage test data efficiently when using it as input to analyses:

"What's getting in the way of our being better able to optimize at the system level rather than just the component level? Time is the biggest constraint. There's enough power in the tools to get where we need. But there are so many inputs required – that's where the problem is. The tools can give us a physics model that has 6800 inputs, and if you were God, and you got them all correct, you could get them to calculate. That is, the challenge is having the input parameters, which are typically test derivatives – measured temperature changes to be sure you have the responses of your metals right, your heat transfer coefficients and so on. The biggest barrier is identifying and categorizing your inputs, and how they change with time and temperature, and how nonlinear they are." – Off-highway manufacturer C

Need for simulation knowledge capture and reuse Better ability to capture and then reuse simulation knowledge is emerging as a key to helping manufacturers overcome the twin constraints examined earlier in this report – not enough trained, knowledgeable analysis professionals, and not enough time in the schedule to do all the analysis you want. One practitioner explains the challenges in off-highway product development:

"One of our primary philosophies is comparative analysis – asking what worked in the past, then making use of that knowledge by compare the new design with the old one. We know we're not perfect or omniscient – 'we're not God,' I like to say – so we have to use God to help us where we can – meaning, retrieve and reuse what's worked in the past." – Off-highway manufacturer C

Ora Research LLC
P.O. Box 61334
Raleigh, NC 27661
USA
tel. +1 617 875 9598
www.oraresearch.com

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.

> *"…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*

Organizational and work-process constraints

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 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.

> *"I think the issue is that we're increasing our capabilities, and our tools continue to improve, but I don't yet know if the industry has figured out how to build analysis deeply into the overall workflow of developing product. Simulation grew up trying to solve tough problems – to better understand why there was a failure, or to evaluate a design once it's almost done to see whether it's going to have good performance. So usually these simulation tools and their users behave as 'consultants' – they're brought in to solve the tough problems. What needs to happen now, to change this? Engineering organizations are good at releasing drawings and checking them, but now we need a better concept of how to release models as we develop them – so that, if we later have to change the design, we actually change the model. We need to make all these processes part of the same discipline. I believe that's key to letting us embed simulation more deeply into how we develop product." – Off-highway manufacturer B, source B*

Overcoming Constraints: New Directions, Emerging Best Practices

Fortunately, our research identified significant progress now being made on all these fronts.

Overcoming technology constraints

Toolset integration: CAD-CAE We found substantial progress in efforts to narrow the gaps between design and simulation models. Best practice in overcoming toolset gaps is about finding tools and processes to better manage and automate the flow of data between CAE and CAD, as well as between different simulation and analysis tools.

Ora Research LLC
P.O. Box 61334
Raleigh, NC 27661
USA
tel. +1 617 875 9598
www.oraresearch.com

> *"In our new toolset, when a CAD model is updated, the CAE software will look at the new version of the CAD file, and do the best job it can of identifying all the changes and updating the mesh. That's important. In those hurdles – getting CAD to talk to analysis, and also getting analysis tools to talk to each other – we know what stands in the way, and the tools we have are getting there." – Off-highway manufacturer C*

Best practice also involves understanding and optimizing collaborative work processes that impact use of simulation.

> *"Another technological advance that is helping us integrate data and work processes is all the new visualization and collaboration tools. It's easier today than ever before for an analyst and a designer to have a web session and show each other what they're doing. Years ago, you were lucky to be able to give the designer a color stress contour plot. Today we're giving them much better collaboration tools, even including video and animations. This visualization technology is a great help, in letting us share data without the data getting all buried together in a database." – Off-highway manufacturer B, source B*

Toolset integration: cross-discipline analysis Similarly, we found substantial progress in integrating the tools used in the various analysis disciplines:

> *"One ting we like that's coming from some tool providers is the ability to have one environment in which the multiphysics capabilities are linked to one another. For example, conjugant heat transfer has the potential to remove iteration time, since the CFD results don't have to be manually translated into the finite element code. That kind of environment lets us eliminate a lot of manual bookkeeping. Likewise, such a single environment could also include combustion analysis that would give us inputs for the combustion chamber, then also thermal and fluid analyses. All that under one roof will be very helpful. In the past, when each analyst worked standalone, then handed off the results to another analyst, you would get hung up on each other's data. Now, multiphysics will let us iterate quickly. If you make a structural change to a model, that model is now linked not only to your FE model but also your CFD model and maybe also your combustion model. That enables you to set up and run automated case studies. That is the biggest vision I have for the value of multiphysics technology, and it's something we are going to." – Off-highway manufacturer C*

Implementing simulation data/process management Practitioners we interviewed repeatedly described new initiatives to break through the two most frequently cited constraints on getting more value from simulation and analysis: (1) availability of trained, knowledgeable professionals and (2) time in the program schedule to do all the analysis they would like. Best-practice initiatives aimed at overcoming these constraints focus on tying existing design tools, preprocessors and solvers more closely together, and on using data/process management and knowledge capture technologies and methods 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.

Ora Research LLC
P.O. Box 61334
Raleigh, NC 27661
USA
tel. +1 617 875 9598
www.oraresearch.com

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.

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.

> *"What's good is we have a lot of smart people doing these simulations, and they usually figure out how to get this data into the system. But how they have collaborated has been by staying tightly in their own groups. So these databases are the new frontier in getting CAE ingrained into the product development process – instead of just using it to fix problems. You don't test quality into a product; you've got to design it in, up front." – Off-highway manufacturer B, source B*

Overall, we found that practitioner priorities are focused on capabilities to:

- Automate data exchange between analysis disciplines, and between geometry modelers and mesh generators
- Ensure that CAD-CAE data exchange capabilities are multi-CAD – partner/supplier collaboration requires this
- Readily re-run or update analyses months or years later
- Ensure that design changes trigger re-analysis; ensure analysts receive correct inputs from modified design; ensure re-analysis results feed back to design

Implementing simulation knowledge capture and reuse We also found cases where manufacturers are working to implement technologies that automate the capture, classification, storage, retrieval and re-use of knowledge. The goal is a greatly enhanced capability to capture, archive and retrieve simulation models, input conditions and results, together with related assumptions and conclusions. Beyond simply securing information, it involves the collateral activities of classifying data and putting it in meaningful context, so that subsequent consumers will find the information both meaningful and trustworthy – transforming an organization's "implicit knowledge" into "explicit knowledge."

Most often, best practice is to seek 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.

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. However, to be practical, knowledge-capture technology must not impose too great a burden on those tasked with building the knowledge bases. Success lies not just in the ability to build tools, but the ways users can capture knowledge – for example, selecting technology that lets users build one single application to capture knowledge and automate an activity that currently takes four separate applications to execute. Best practice involves capturing what users do, then building that into a repeatable automation tool.

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

Ora Research LLC
P.O. Box 61334
Raleigh, NC 27661
USA
tel. +1 617 875 9598
www.oraresearch.com

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.

Overcoming organizational and work-process constraints

Of course, with even the most optimal technology implementations, much of the progress in optimizing simulation usage and maximizing its impact has to do with organizational considerations and people factors.

Organizational design issues One question is how best to deploy analysts in relation to specific programs: in centralized analysis groups, or embedded in specific product programs?

> *"There's always going to be the challenge that analysts make up a small set of people who are highly skilled, and it's a perennial problem for management to keep the analysis groups properly staffed. The universities are helping with that somewhat, but not enough. Likewise, we don't know in advance exactly how many we will need, or where to keep them placed. Product groups always debate whether they want to have analysts embedded in their design teams or, instead, organize the analysts in centers of excellence, and let the design teams come to them. But the latter creates a problem: design teams don't always come to the analysts when they should. Embedding them in the design teams is probably the better way, but then that risks thinning out the expertise available organization-wide; too, the analysts tend to start chasing small fires, and also they may not spend enough time keeping current in the technologies. On the other hand, I believe that when you focus people too tightly in their analysis groups, you can get them stuck there. You want people to be upwardly mobile." – Off-highway manufacturer B, source B*

Ultimately, the aim of simulation 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.

People factors Much of the challenge in optimizing use of simulation and analysis has to do with organizational, cultural and people 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 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*

Ora Research LLC
P.O. Box 61334
Raleigh, NC 27661
USA
tel. +1 617 875 9598
www.oraresearch.com

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.

Next Steps

To drive change in an organization, a powerful call to action can be to benchmark 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.

One way to begin 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 recommendations for improvement. First review the

Ora Research LLC
P.O. Box 61334
Raleigh, NC 27661
USA
tel. +1 617 875 9598
www.oraresearch.com

constraints identified by practitioners in this paper. Determine which of these is most severely gating progress in your organization today:

Technology constraints
- *CAD-CAE gaps*
- *Cross-discipline analysis gaps*
- *Need for better simulation data/process management*
- *Need for simulation knowledge capture and reuse*

Organizational and work-process constraints
- *Human resource constraints*
- *Methods development, work-process integration requirements*

Then investigate sources of solutions for both classes of constraints.

Technology solutions

Unlike CAD and PDM purchase decisions made by corporate committees with heavy IT involvement, analysts call the shots in simulation/analysis tool purchases. Nonetheless, it's important that simulation/analysis purchase decisions be grounded in not only technical but also business criteria.

> *"…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*

Criteria for qualifying and selecting a solution provider, conditioned on what constraints you need to address first, include:

- *Functionality of solvers*
- *Functionality of meshers, gridders, other tools for problem setup and results execution*
- *Competence as integrator of diverse functionality – multi-CAD, multi-CAE, other product lifecycle functionality from requirements capture through manufacturing into service, support and sustainment*
- *Commitment to providing help with process change, people/cultural issues*
- *Commitment to providing:*
  - *Simulation data management framework*
  - *Process automation tools*
  - *Knowledge capture tools*
- *Reliability as long-term partner*

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.

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.

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

Ora Research LLC
P.O. Box 61334
Raleigh, NC 27661
USA
tel. +1 617 875 9598
www.oraresearch.com

simply echoes functionality that is commercially available. Benchmark your organization against competitors.

Organizational and work-process solutions

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 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.

Attract 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 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 timely compliance with government mandates and customer preferences for greener, more sustainable products.