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DE

Desktop Engineering®

TECHNOLOGY FOR DESIGN ENGINEERING

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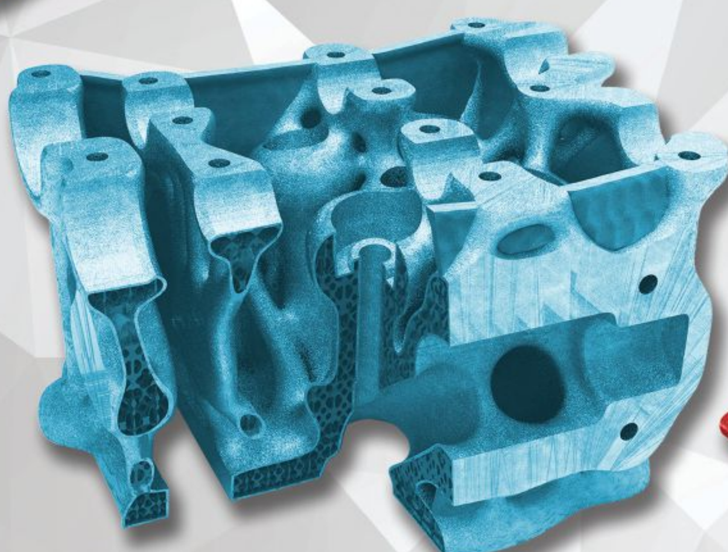

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by Jamie J. Gooch

What's the Computer Think?

I grew up watching reruns of the "Jetsons," "Lost in Space" and the original "Star Trek." Maybe it was because the shows were already old ("Lost in Space" wasn't even in color) or because I was watching them around the same time I was getting my first taste of BASIC programming — but I took for granted that having a meaningful conversation with a computer was in my not-too-distant future.

Fast forward 30-some years and I can indeed ask a computer for its opinion, but while Apples' Siri, Microsoft's Cortana and Google Now's voice assistants are useful, they're not capable of scintillating conversation. They are much more powerful versions of the BASIC programming If-Then statement. If I ask about movie show times, then they display the show times for theaters near me. If I ask how to optimize a design, the results aren't as useful. It's not like they're thinking.

What will massive computing power learn from design data?

But that is changing as machine learning algorithms become more sophisticated and massive computer power becomes more accessible. Via deep learning, computers have taught themselves to read Chinese, identify cats by watching YouTube videos and — particularly disturbing to me — write articles that make sense. (*Editor's note: This article was written the old-fashioned way.*)

Automated Design Optimization

Many of the advancements in artificial intelligence stem from the fact that computers can quickly process massive amounts of data. For example, 1,000 computers were connected and fed 10 million YouTube stills for three days to identify and learn cat faces. So what? Google didn't tell the computers to learn cat faces; the computers decided that on their own. That experiment took place two years ago. Google is now using the same type of technology to enable computers to "read" massive amounts of text online in order to deduce the meaning of words. That scintillating conversation with your phone may take place sooner than you think.

Cool? Yes. Scary? Maybe. But what does it have to do with design? In this issue's special focus on lightweighting, you can see a number of examples of software that suggest design ideas that people probably would not have thought of themselves. Design engineers supply the design data and constraints, and the software suggests different, optimized ways to meet those parameters.

The optimization algorithms still depend on the information being provided by the design engineer. But what if the software could come up with that information on its own? What if the data being fed to computers wasn't YouTube stills or words, but 3D parts catalogs, your previous models and data captured from real-world products similar to what is being designed? What would massive computing power be able to glean from such data?

"We're developing a system that learns the same way we do … and the outcome is a tool that works in a lifelike manner and supports the way we solve problems naturally," said Autodesk CTO Jeff Kowalski during the Autodesk University 2014 keynote last month in Las Vegas. "We need to stop telling the computer what to do and instead tell the computer what we want to achieve."

Kowalski admitted that this idea — part of what Autodesk calls generative design — is not new, but the computing power to make it a reality is finally here. From the many real-world computing examples I heard a few months ago in New Orleans at the Supercomputing 2014 conference, I don't doubt it.

"The biggest change has been the ability to work with much richer data," said Autodesk CEO Carl Bass in his AU 2014 keynote. "Data that better captures the complexity of the real world."

Automated Manufacturing

To be clear, there is no product commercially available right now that can learn what makes a good design and suggest a 3D model of it. Even if that technology is eventually created, such a design might be impossible to manufacture via traditional means. That's where 3D printing comes in.

Considered together, the democratization of high-performance computing, design and simulation optimization technologies, and advances expected in additive manufacturing and industrial automation paint an amazing picture of the future. But what is the role of the design engineer in such a future? The current levels of automation in manufacturing didn't cause the massive unemployment that many predicted, but it is often cited as a reason for stagnant wages.

Will some design engineers be replaced by technology? Only time will tell. One thing is certain: If tomorrow's technology can autonomously design and produce optimized parts, it will certainly be able to write an article about the process. I hope to be retired by then. **DE**

Jamie Gooch *is the editorial director of* Desktop Engineering. *Contact him at de-editors@deskeng.com.*

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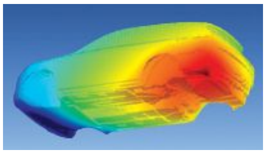

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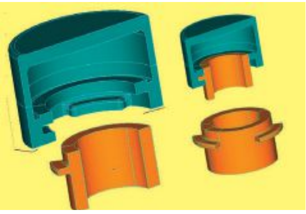

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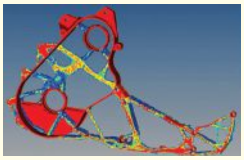

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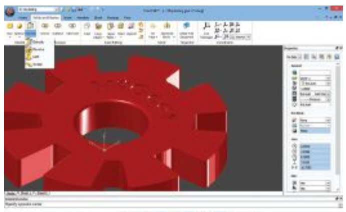

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Mark Curran
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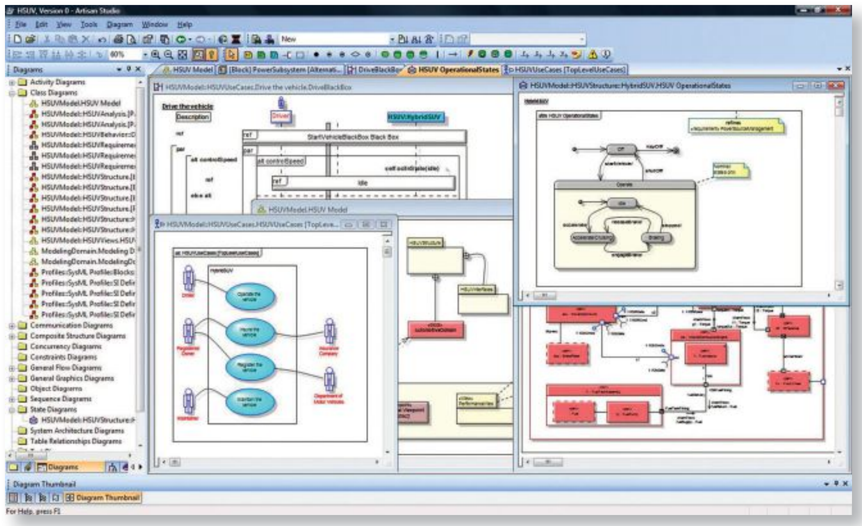
PTC Parlays Series of Acquisitions into Systems Engineering Payoff

PTC has spent the last several years in acquisition mode, amassing technology to help it build out a compelling systems engineering story. The fruits of that strategy are now ready for prime time as the firm just announced its first integrated solution built on that technology platform.

The PTC Systems Engineering Solution is a packaged offering that ties together the Integrity Application Lifecycle Management (ALM) products with Atego, a suite of system-architectural modeling and Model-Based Systems Engineering (MBSE) solutions. As an integrated portfolio of products, the PTC Systems Engineering Solution is designed to help companies across industries develop the next generation of "smarter, connected" products, as PTC likes to say, which require a significantly higher level of cross-disciplinary collaboration.



PTC's Systems Engineering Solution integrates the Integrity Application Lifecycle Management (ALM) products with Atego's model-based systems engineering solution. ***Image Courtesy of PTC.***

Integration Tools

While aerospace and defense have been at the systems engineering discipline for decades, mainstream industries like consumer electronics are now starting to follow suit. As products from home thermostats to cars maintain a deeper reliance on embedded software and a higher degree of variability, there's a requirement for an integrated development platform that ties together system requirements, system modeling, and validation, according to John Wylie, PTC's vice president of Systems Engineering Solution Management.

"The world is getting more complicated for our customers and it elevates the way they need to handle things more systematically at a systems level," he says. This new offering, an evolution of the individual products PTC has marketed for the last year or so, is designed to help companies understand their customers' needs and architect the system design before having specifics on the detailed design work. "This comes before and after traditional PLM (product lifecycle management)," he explains. "It's about making sure market requirements are met, that the virtual prototype is validated, and that testing is performed and the results meet the needs of the customer."

The PTC Systems Engineering Solution includes:

- PTC Integrity for system requirements and validation;
- Atego Asset Library for collaborative asset management and reuse;
- Atego Modeler for collaborative, scalable architectural modeling and model-based systems and product line engineering; and
- Atego Process Director for process authoring and deployment, including out-of-the-box systems engineering best practices.

Saving Time, Costs

The components are intended to help organizations design products with a collaborative MSBE approach, which PTC, citing analyst research, says aids in delivering 23% more projects on time at 62% lower cost than alternative approaches. The PTC Systems Engineering Solution supports requirements engineering, including the ability to capture and communicate the voice of the customer; system design; and trade-off analysis of design options.

The platform also fosters the reuse of system artifacts through capabilities such as modular design, product line modeling, and requirement, model and test reuse. To facilitate the validation workflow, the platform has capabilities for model verification, test management, traceability and governance.

—B. Stackpole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Perfection takes time.
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by Kenneth Wong & Beth Stackpole

Autodesk Develops Generative Design, Gives Away Education Licenses

Autodesk CTO Jeff Kowalski thinks it's time to infuse some life into our dead designs. As he took the stage at Autodesk University (Las Vegas, December 2-4), he said, "As wonderful as our creations are, they're more dead than they are alive. We've been forging a path that's divergent from Nature … Through technology, we've actually been working in opposition to our provenance … So at Autodesk, we're starting to look at technology and design itself through the lens of Nature, a complete inversion of the traditional perspective — looking at the natural world through the lens of technology."

How might engineering software mimic Nature? It might have to become much more autonomous. Kowalski envisions employing machine-learning algorithms to develop a system that "learns the same way we do, by referencing mechanical engineering codes, building codes and part catalogs, even by observing real-world examples; and the outcome is a tool that works in a lifelike manner." Such a tool fundamentally changes the way we interact with our hardware and software. "We have to stop telling computers what to do. Instead, start telling them what we want to achieve," Kowalski said.

The Autodesk research project codenamed Dreamcatcher represents the company's vision for Generative Design, driven by algorithms that can identify the best structure and topology.

Generative Design

To Autodesk, mimicking Nature's iterative approach means coming up with optimization algorithms. Autodesk calls it Generative Design. Kowalski said, "[It] starts with your goal. Then it explores all the possible permutations of the solution through successive generations, until the best one is found."

It's not a new process, but one that was previously confined to enterprises and researchers with access to data centers, because "the computation would have taken too long," he added. But now, on-demand high-performance computing (HPC), remote hardware and virtualization make it possible for average designers to "evolve millions of individual options in parallel."

The nomenclature similarity between Autodesk's Generative Design and rival Bentley Systems' Generative Component (GC) deserves some clarification. Kowalski insists they're different software species. "GC is closer to what [Autodesk is] going for with DesignScript, which largely targets those in architecture," he explained in a Q&A session with the press. "Generative Design is meant to be applied much more generally, including manufacturing, architecture and construction."

Generative Design, Kowalski said, would automate three types of optimization: topology, lattice-based structures and strut/beam structures. "The algorithms we're using underneath haven't been seen in our market so far," he says. Yes, the software could remove materials to shave off weight, just like other topology optimization software programs do, but "we can also grow the structure computationally," Kowalski said in his keynote.

Generative Design is currently a research project, dubbed Dreamcatcher. It's described as "a goal-directed design (GDD) system that enables designers to input specific design objectives, including functional requirements, material type, manufacturability, performance criteria and cost restrictions … a new workflow: a fusion of the designer, artificial intelligence and the cloud."

Free Software for Schools, Students, and Teachers

One of the largest rounds of applause during the keynote came when Autodesk CEO Carl Bass announced, "Autodesk is making all of its software available for free to any student, teacher, or school, anywhere in the world." The move is philanthropic, but it also comes with a huge strategic benefit: brand loyalty cultivation. "In the long term, the key to all our success is finding well-trained, young people," Bass said.

Autodesk education licensing contributes about $2 million USD to the corporate balance sheet, Bass revealed in the press Q&A. According to Autodesk's financial disclosures, revenues for the third quarter of fiscal year 2015 rounds out at U.S. $618 million, an increase of 11% compared to the same quarter last year. In that context, $2 million seems like a negligible sum; yet, the free software distributed will certainly give Autodesk a significant advantage over its competitors in introducing its software titles to aspiring engineers and designers.

Autodesk's major rivals — Dassault Systèmes, Siemens PLM Software and PTC — offer discounted education licensing, with some free offerings and occasional in-kind donations. But none has gone so far as to declare its software free for the entire education community. If they choose to match Autodesk's $0 education licensing, it'll be a boon for all educators and students.

For more on news from AU 2014, including details about Autodesk's plan for an open-source 3D printer and software, visit deskeng.com/virtual_desktop/?p=9625.

— K. Wong

Time to Re-engineer Licensing?

One of the conversation topics at Siemens CAE & Test Symposium (October 22-23, Long Beach, CA) was Computer-Aided Engineering (CAE) in the cloud. The inevitable question came up: Do current software licensing methods impede cloud-driven CAE?

Keith Meintjes, CIMdata's practice manager for simulation and analysis, sums up the evolution of simulation licensing: "In the old days, they were licensed per mainframe computer, with unlimited simultaneous users. Then, along came Unix workstations and PCs. Software was licensed by end user machine or, for server-based software, by named user. Then, along came serious workstations that were 100x more powerful than normal desktops. Licensing was by CPU power. Then came multiprocessor Cray [systems]. Licensing started to be per CPU or parallel thread."

The pay-per-core licensing model has its critics. However, many enterprise users have learned to get their money's worth by investing in enough hardware (computing cores) to get a justifiable speedup from the software.

New Technology Demands

But the prohibitive cost discourages those who want to pursue optimization or Design of Experiment (DOE) studies, which involve simulating multiple variations of a design on high-performance computing (HPC) hardware with hundreds of cores. For example, should a user be expected to purchase 25 licenses of a simulation software to simulate the crash worthiness of a new vehicle with 25 airbag deployment variations? A typical CAE license would let such a user run the simulation one variation at a time, but not all 25 in parallel — not unless the user pays for 24 more licenses.

Monica Schnitger, founder and president of analyst firm Schnitger Corporation, points out, "Buyers feel gouged when they want to run a complex simulation on multiple CPUs (theirs or someone else's) but need to have that many licenses in their agreements."

Meintjes says, "I counsel our solution-provider clients that pricing based on perceived customer value is toxic in terms of developing a long-term relationship. Some of them listen, many don't."

If existing CAE software vendors cannot accommodate DOE studies at a reasonable cost, users may migrate to start-ups that operate with a business model to cater to DOE champions.

One such vendor is San Francisco-headquartered Rescale, which offers its computing infrastructure and job-management software as an on-demand bundle. Rescale has also struck up partnerships with existing CAE vendors — including Siemens PLM Software, ANSYS, Autodesk, Dassault Systèmes SIMULIA, and CD-adapco — to negotiate and acquire additional licenses where needed.

Jim Rusk, a senior VP from Siemens' digital factory division, says, "Our partnership with Rescale lets people use NX Nastran in a HPC environment to facilitate DOE-type work, so you can vary a set of parameters over a design to see what the design should look like. If the customer lets us know they're trying to do DOE, we have some approaches that let them accomplish that without paying for hundreds of licenses."

Schnitger ponders on a few CAE providers' policies. "Autodesk and CD-adapco — which price by the job — may be on to something," she says. Meintjes points to Altair's HPC business model as another DOE-friendly example.

"Most solution providers are pursuing added features for leading-edge users rather than a broader customer base," Meintjes says. "This runs counter to the desire of most end users to have simulation be democratized and pervasive."

—K. Wong

HP, Autodesk Team on 3D Printing

Two important tech players are teaming up, and could have a big impact on the 3D printing space. HP says it will integrate Autodesk's Spark Platform into its upcoming Multi Jet Fusion 3D Printers.

According to the announcement, the combination of the two technologies will allow users to "access a rich palette of sophisticated tools such as constraint-based design to create and produce output with many types of materials and properties at once."

HP has touted Multi Jet as being able to print 10 times faster than other 3D technologies. Spark is an open software solution that could provide a unified platform for all types of 3D printers, from consumer up to large industrial systems.

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Royal Mail Teams with iMakr to Pilot Custom 3D Printing Service

Traditional post is another potential casualty of the digital age. With the convenience of email and the vast array of available social media services, unless you need to ship something, most people would never consider sending a letter by snail mail.

With hopes of turning its fortunes around, the United Kingdom's mail service, the Royal Mail, has moved on the idea of on-site 3D printing, and launched a pilot program with the assistance of partner iMakr.

The pilot program kicked off in London in December. Customers can choose from a small range of items from the Royal Mail store, each of which can be further customized for each customer. The Royal Mail will also accept customer designs, which can either be printed on-site or sent to iMakr for processing.

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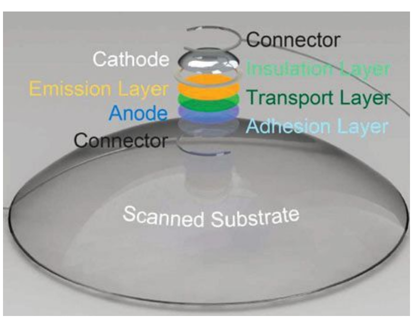
Princeton Builds Quantum Dot LED 3D Printer

A group of researchers at Princeton are the latest to apply additive manufacturing (AM) to technical problems. The team was experimenting with ways of manufacturing quantum dot LEDs, and decided to build a new AM system specifically designed for the task. After six months of work and $20,000 the team is in possession of the first system that can build quantum dot LEDs composed of up to five different materials.



The ability to mix materials to produce an LED works in similar fashion as Stratasys' PolyJet systems, though at a much smaller level. Big technology firms are looking at quantum dot LEDs as the next evolution of display technology. Individual dots can be turned off and on to save power, and the image created by this type of LED is crisper than anything available today. Quantum dot LEDs are also less prone to wear and tear than other types of LEDs, leading to longer product lifecycles.

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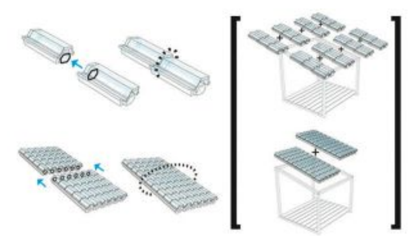
Raise the 3D Printed Roof

The 3D printing processes some groups have used to print a building can also be environmentally friendly, using local materials to provide shelter for homeless people around the world. What can top that? Roofing, literally. Resilient Modular Systems (RMS) is a startup that is looking to additive manufacturing (AM) to help solve roofing issues in the poorer sections of the world.

In many parts of the world, roofing is constructed from cheap, easily replaceable materials such as corrugated iron. Not only do roofs made from these sorts of materials leak, they are inadequate for insulation, making them nearly useless for regulating temperature inside a dwelling. A corrugated iron roof



will also rust through in about two years, leading to wasted resources.

RMS has an idea to change all that by offering inexpensive roofing to people around the world. Based on the appearance of terracotta tiles, the roofing tiles are manufactured from recycled plastic. Plastic tiles last longer than corrugated metal, and make it possible to replace or repair in small areas, rather than requiring a whole new roof.

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First 3D Print in Space

Made In Space is the company responsible for the printer currently onboard the International Space Station. The 3D printer is a Fused Deposition Modeling-type system, with plastic as its primary material. 3D designs and instructions are provided by a laptop. The first item printed in space was a replacement faceplate for the printer's extruder, customized with the Made in Space and NASA logos.

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The Finish Line Just Got Closer

Molding or shaping plastics into usable forms is not new technology, however, the way plastics are being produced and brought to us is becoming faster every day. The injection molding process begins with an idea that is conveyed into sketches, then into 3D CAD models. During the planning stages, this is the moment where bottlenecks can occur because getting quotes from manufacturers can take up valuable time. The Instant Online Quoting & Project Management System developed by ICOMold® presents injection molding and CNC manufactured parts customers with instant quotes to streamline the quoting and budgeting step in your project.

Unlearning What You Have Learned

The days are over of sending your file to a third party, waiting several days (or weeks) then repeating that process when your design needs to be tweaked. Three-dimensional computer aided design models, as you know, are more complex than just computer drawings or hand-drawn sketches. They contain mathematical (vector-based) information regarding angles, curves, weight, and material thickness. Within the paradigm of computer-aided technology, calculating a quote for a even a simple CAD model isn't as easy as throwing a number off of the top of one's head, and it's compounded exponentially for large or complex injection molds, parts and CNC milled parts.

ICOMold's® Instant Quoting System analyzes your .STP CAD file once uploaded and processed by ICO's servers. Then, as you change part quantities, materials, colors, number of mold cavities, family mold and shipping options, the quote on your screen updates instantly. CNC machined parts can also be quoted instantly in the new system. The Instant Online Quoting System also has the capability to allow you to view your uploaded parts in real time. ICO Viewer™ displays your part and allows you to manipulate it in three-dimensional space, zoom in and out, display the dimensions of the part, and calculate approximate measurements between chosen points to mention some of the features.

CAD Engineers and project managers now have the ability to better manage their project's budget and minimize the impact of lost time by having the cost of their project instantly, rather than waiting for days for a quote. Once your unconfirmed quote is submitted, your project is a step closer to deployment.

Nothing Beats the Human Touch

An instant quote is usually pretty accurate with the cost of your project, but the one thing that any automated system lacks is the human touch. That's where ICOMold's® project management engineers analyze your project for moldability and other technical nuances that even the most advanced computer logic and algorithms simply cannot catch. Most times, a project is green-lighted immediately after moldability analysis because the part design is moldable or millable. However, there are some designs that may not be viable due to the aforementioned technical nuances. This is when your project management engineer will reach out to inform you of a design flaw or a minor change that can get your project back on track or possibly alter the cost of the project. Once the project managers have confirmed your quote, they will send a firm quote back to you for your approval.

Simple Project Management

If your project has mulitple pieces for an assembly, you may opt to choose a family mold for production of those parts. If you have multiple projects, all of your uploaded projects appear on your personal online project management site. All of your confirmed, unconfirmed, and launched projects remain in the Instant Quoting and Project Management System for you to access at any time. Also, notes about projects and email communication between you and project managers are also handled inside the system, and are kept organized by project.

To learn more about ICOMold's® Instant Online Quoting and Project Management System, go to www.icomold.com/icoquote.

3 Approaches to Lightweighting

Get a close-up look at optimizing mass with solidThinking, netfabb and Autodesk design tools.

BY PAMELA J. WATERMAN

In the world of astronomy, 2015 is the International Year of Light, a year dedicated to education about generating, controlling and detecting photons. In the world of engineering, it appears 2015 will be the International Year of Lightweighting, with efforts dedicated to generating, evaluating and identifying the lightest and best mechanical designs — fast. Like the view you get with a powerful telescope, the insight you gain from lightweighting software is exciting stuff.

For traditional automotive and aerospace applications, the goal of lightweighting is to reduce energy consumption, but in many other industries, the benefits can go even further. Lighter designs save on raw material quantities and/or use alternative materials, come in at a reasonable cost, maintain or increase the desired strength and may improve such behavior as internal cooling.

The concept and goal of lightweighting is good in so many ways that dozens of software products now incorporate it in the design workflow. *Desktop Engineering* spoke to three such companies whose software products (different yet complementary) are representative of the many resources now available in this field: solidThinking, netfabb and Autodesk.

Design Guidance, Pre-CAD

It makes sense that the better the initial concept design, the easier it is for the mechanical engineer to make that design practical and manufacturable; also, the easier it is for an analyst (who may also be the engineer) to fine-tune that model for the best possible operation.

What if there was a way, even before you drafted a CAD model, to zero in on the best general shape, size and structure of a part? What if you could have the confidence that this part had already been optimized such that the minimum amount of material had been used to support specified, real-world loads? Only then would you invest time in generating detailed CAD geometry with exact dimensions and the requisite manufacturing necessities of fillets and chamfered edges. That's the premise behind Inspire, the concept design package dedicated to lightweighting from solidThinking, an Altair company.

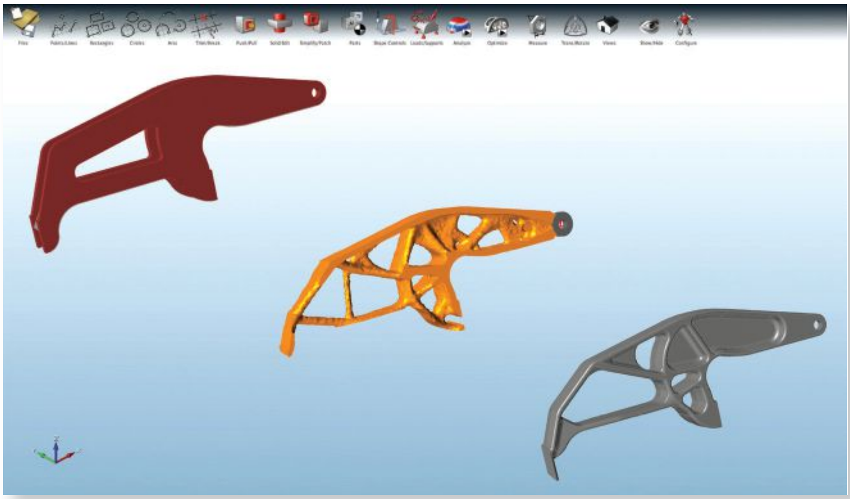
"We position Inspire as a concept design tool, not a detailed CAD tool," says Jason Napolitano, solidThinking executive vice president of Global Sales. "You use it for the very first designs. Once you have the load patterns defined, you bring that model into the CAD program and validate it with FEA (finite element analysis)." Inspire fits into the workflow at the beginning, supporting a process to investigate structural concepts that either maximize stiffness or minimize mass.

Built on Siemens PLM Software's Parasolid 3D modeling kernel and the Altair OptiStruct optimization engine, Inspire continually works to remove unnecessary material through the progression of one design concept to the next. "OptiStruct has been a great technology for 20 years," says Napolitano, "but it was reserved for high-end CAE use. We saw a need in the design community and created an interface that was meaningful."

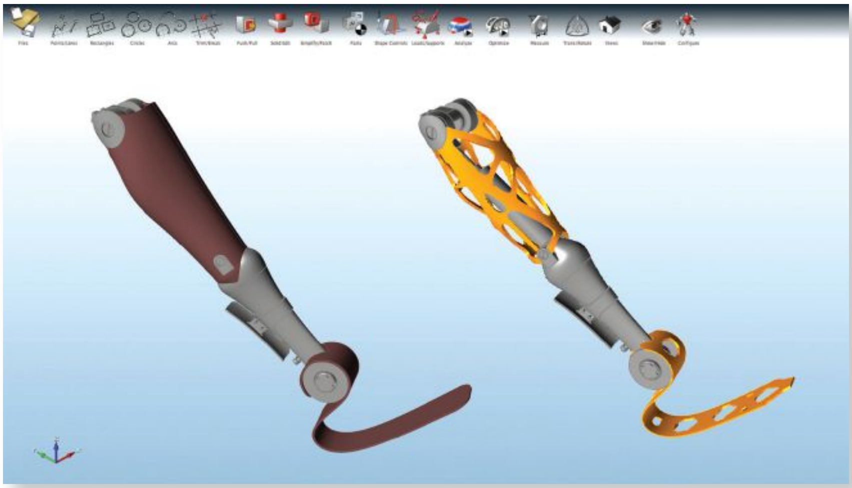
Now in its fourth major release, Inspire 2014 takes users through importing an existing CAD file or defining a maximum blank "package space." Jaideep Bangal, solidThinking senior application engineer, explains this with an example: "Imagine designing the mounting bracket for an automotive engine in the cramped space under a hood. The designer knows how much space he or she has; that becomes the starting point — the design space." You can't use more than that volume, but you can find ways to use less.

Inspire removes any features (e.g., fillets and small holes) that have little effect on the part behavior and guides the users' placement of loads on surfaces such as on an axis or unsupported edge. Users then specify a variety of constraints: e.g., a pin can rotate but can't slide in or out, an area of a part is clamped, or the load pattern cannot trigger a modal frequency. New features include constraining a part so that it can only move or deflect by a certain distance, the ability to create concentrated mass parts and an option to do some quick FEA.

Changing the values of a given load case and rerunning Inspire automatically updates the material geometry. Many visualization options let users see which regions of a part are in tension or compression, where areas of high stress are



Workflow for pile driver bracket redesigned with solidThinking Inspire software for reduced weight. *Image courtesy solidThinking.*



Redesign of a trunnion (shaft) mounting bracket using solidThinking Inspire software for reduced weight. Rectangular areas define the "package space" or design volume for working with the part. *Image courtesy solidThinking.*

located, and how much the part deflects. Once the optimal (and sometimes organic) shape is established, invoking the "fit" function overlays smooth geometric boundaries, creating a file that can be saved and exported to any CAD system.

Inspire 2014 gives you an answer independent of manufacturing processes, though you can define shape controls that produce a design appropriate for stamping, forging or even additive manufacturing. Planned capabilities include generating cost comparisons of material use versus each design. As with its previous versions, the software runs on both PCs and Macs. *(Editor's note: For an example of how one manufacturer uses Inspire,* *see page 18.)*

What's Inside Really Matters

With the increased emphasis on minimizing part weight, it seems logical that another approach is to restructure a normally solid part as a shell with a honeycomb-like interior. This can produce an extraordinary material reduction that translates directly into weight savings, but the process requires two distinct steps: efficiently generating the internal design geometry and building the part with a 3D printer. Given today's broad marketplace of 3D printers, the latter task can be accomplished by one of perhaps a hundred hardware systems (depending on required accuracy, material, durability, etc.) However, the former task — designing the airy structure — requires software such as netfabb's Selective Space Structures (3S) package.

Tailoring the properties of parts for optimal performance opens a world of possibilities because 3D printing enables new ways to use existing materials. Spinal implants, innovative furniture, automotive parts and structural aircraft components can be made strong and light, saving on total mass and sometimes adding a function like improved air-cooling or flexibility.

netfabb's tag-line for 3S reads "from solids to structures in seconds." To generate a volume structure, 3S breaks down the solid into box-shaped fragments or voxels, where the smallest voxel is a unit cell. These are usually built from a combination of nodes, bars and faces, producing shapes that look something like 3D versions of the letters Z, M, O and X, or snowflakes, soccer balls and stylized children's game jacks. You also have the option to import an STL file and use that to establish a unit cell, and each bar can be designated as hollow to save even more on weight.

"The process is fairly automated," says Ulf Lindhe, netfabb business development manager. "We have two types of structures: volume structures where you fill a volume with structures and surface structures where you wrap one layer of cells onto a surface." Voxels can be edited and divided into groups, and each group can comprise different styles of unit cells for different regions of a single structure. Sizes and proportions are all user-defined.

The level of detail possible within the confines of a part is amazing. A 3D printed part with a netfabb 3S internal structure may contain millions of unit cells. It has essentially been built with a

Cylinder head (before and after) redesign using netfabb Selective Space Structures software and 3D-printed for lightweighting. The original solid part weighed 5.1 kg while the additive design weighs just 1.9 kg. The cooling effectiveness of the cylinder head internal volume is greatly increased, too, since the "honeycomb" structure increased the functional internal surface area from 823 cm3 to 10,223 cm3. *Image courtesy netfabb.*

new material. As such, Lindhe recommends that customers verify each structure type with testing and calculations; no FEA is done in 3S. Due to the typical size of a complex 3S-enhanced part, netfabb recommends outputting to a slice file for direct 3D printing.

After lightweighting an engine block with 3S, netfabb's parent company, FIT Production, found the functional (cooling) surface had increased from 823 cm3 to 10,223 cm3, while the weight went from 5.1 kg to just 1.9 kg, a decrease of 62%. *(Editor's note: For more examples of lightweighting via 3D printing, see page 22 and 30.)*

Fast Design-Space Model Validation

It's clearly not enough to just create variations on a concept design and eyeball the pros and cons of each change. Vikram Vedantham, Autodesk business line manager for manufacturing industry strategy and marketing, says what's needed are ways to validate concept models without analyst support. Autodesk already offers high-level feedback tools to designers concerned with airflow effects (via Autodesk FlowDesign) and with plastic-part manufacturability (via Autodesk Simulation DFM). Now, Autodesk Simulation Mechanical 2014 is bringing the insight of linear static stress analysis to the first-cut-design level through the addition of Parametric Design Studies.

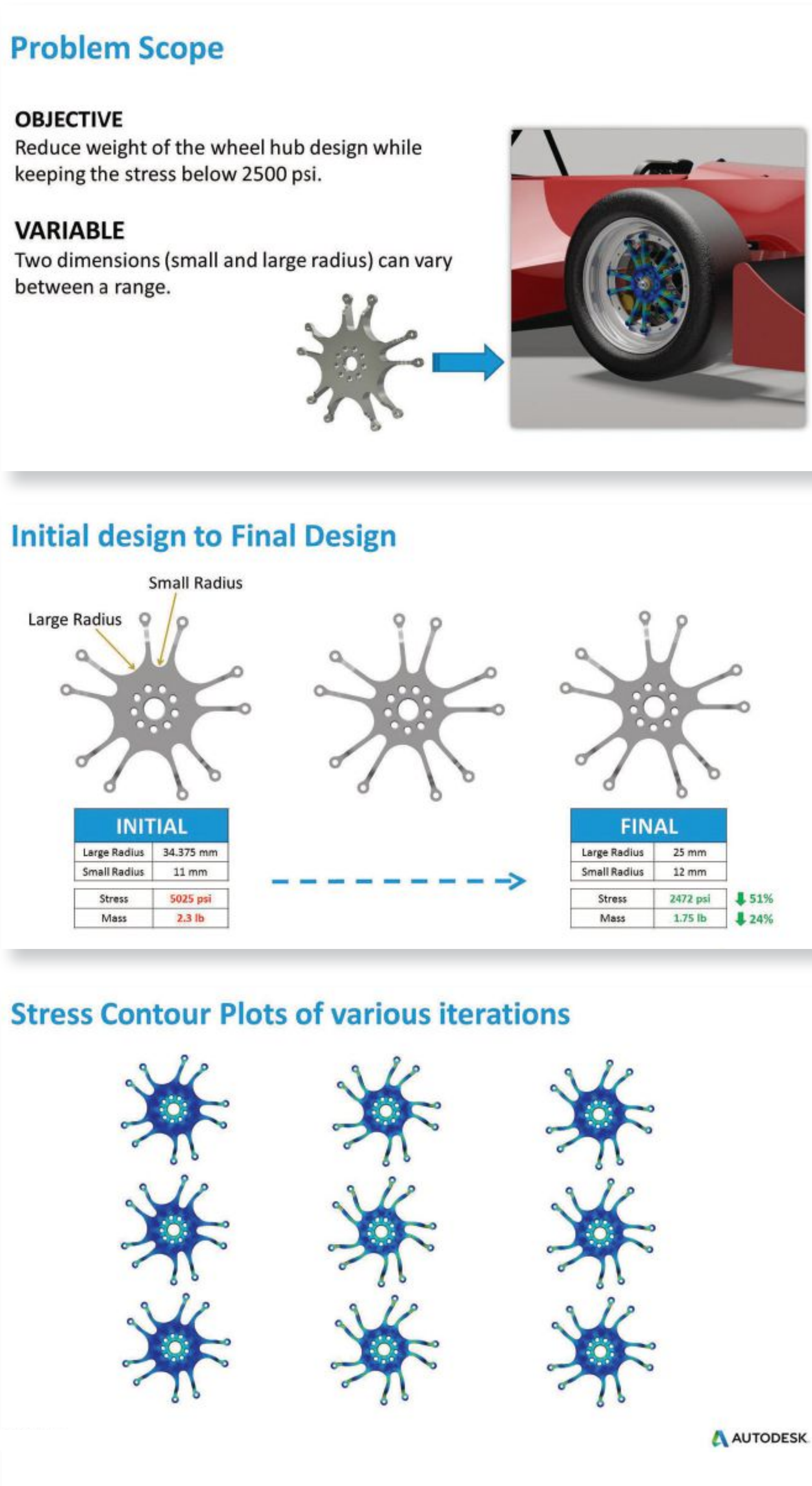
"If you look at Simulation Mechanical today and the way that it interacts with Autodesk Inventor," says Vedantham, "we're getting closer and closer to seamless integration. If a user wants to optimize their design, they know what variables and constraints they want to work with. They have the ability to now pull the parametric geometry (the dimensions), specify which ones they want to alter, and work their way toward a more optimized design. Simulation Mechanical works in conjunction with Inventor whether you're making changes based on stresses or displacements or changes in material."

Ease of use is critical within Simulation Mechanical. Derrek Cooper, Autodesk director of product management, Digital Simulation, notes that two releases ago, the company introduced the Parametric Design Study editor to make the process appealing to design engineers rather than analysts. "Optimization is not new, and it can be topological, material-based or process-based," Cooper says. "The challenge is: How do we make this more accessible and more mainstream?"

The ease of the Autodesk design optimization workflow starts with users bringing a model, whether a single part or an assembly, from Inventor into Simulation Mechanical. As with any FEA job, users first mesh the geometry then assign loads and boundary conditions and run the simulation.

Once the first analysis has been performed, clicking on the Design Studies button opens a window showing all the parameters in the model, including dimensions and material types and their current values. Users can select one, two or more parameters to be evaluated, designating a "design space." Via the ribbon at the bottom of the window, they set upper and lower limits for the highlighted parameter values as well as the number of values to step through in each range then run an automated, methodical evaluation of each data set.

For example, on a part containing curved sections of two different radii, users could choose to vary one radius over a small range at three different values, while defining a larger range for the second radius covering four different values. Twelve possible scenarios would then be analyzed. Users can filter the results to see just the geometries that generate certain conditions, e.g., stress values of 20 psi or less. If activated, a built-in comparison table highlights the best design based on



Design optimization workflow done with the Parametric Design Study tool in Autodesk Simulation Mechanical software. The goal was to reduce the weight of an automotive wheel hub while also reducing stress. Users quickly see the results of various changes in the geometric parameters. *Images courtesy Autodesk.*

combined user criteria for weight, stress and deformation reduction.

Because material choice can also be evaluated as a Parametric Design Study variable, users interested in an environmental footprint can tap the knowledge base found in the Autodesk Inventor Eco Materials Advisor. The basic Advisor version includes a sample database and eco analysis capabilities; the full version, available for purchase from the Advisor's developer, Granta Design, adds a database of 3,000 materials, more in-depth analysis and support for larger assemblies.

Users can bring the improved CAD design back into Inventor and send all data to an Excel spreadsheet or other program for further review. A good Parametric Design Study example is found on Autodesk Simulation TV, at http://goo.gl/B7AqaU. *(Editor's note: For another take on democratizing simulation, see page 48.)*

More Tools Coming

The next stages of design and analysis software will support many more automated tools that conduct Design of Experiments (DOE) and include evaluation of organic shapes and even more diversity of materials. Within the automotive industry alone, the need to meet fuel efficiency requirements slated for 2025 is pushing for grand improvements. "Lightweighting is a key element of optimization," says Autodesk's Vedantham, "and it's going to grow exponentially in the next three years." **DE**

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In Search of the Perfect Snowmobile Design

Polaris uses optimization software to achieve lightweight designs and reduce time to market.

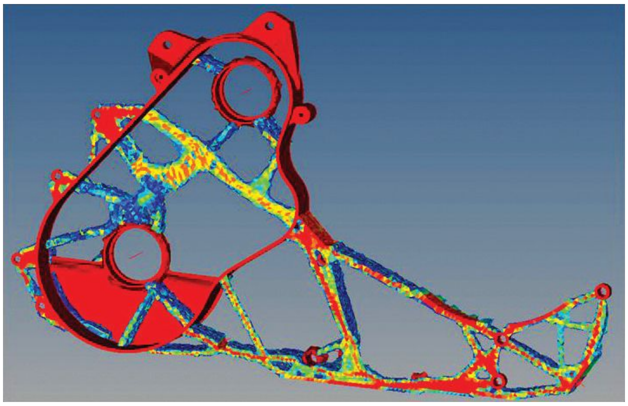
BY BETH STACKPOLE

For snowmobilers, there's nothing like the thrill of freshly fallen snow. The same could be said for Polaris, a leading snowmobile manufacturer that is blazing new trails with optimization technology to get lighter, high-performance sleds out to market well ahead of its competition.

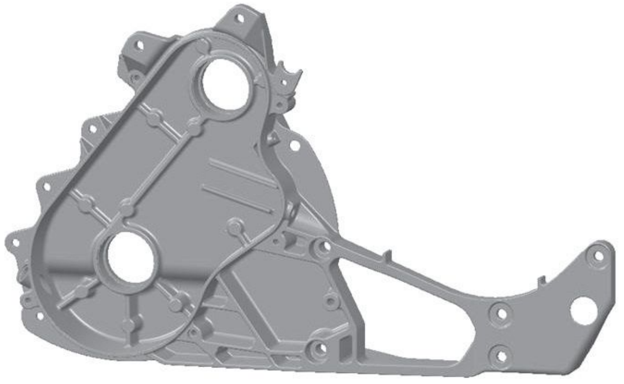
Identifying opportunities for alternative materials and lighter weight components isn't exactly a novel development charter for Polaris or any other manufacturer of high-performance equipment, be it a car or a recreational vehicle. While streamlining designs to be more lightweight without sacrificing structural integrity has always been the goal, there have been numerous obstacles along the way, including a need for hours of specialized simulation work and dozens of protracted design iterations.

"The biggest challenge for us in terms of lightweighting is that this is a very fast-paced industry, not only because of product timelines, but because it's a very seasonal business," says Luc Wilson, senior design engineer for Polaris' Snowmobile group. Going at the problem the old-fashioned way means Polaris engineers create a model of a design, run it through finite element analysis (FEA) tools to identify areas of low stress, redesign those areas to reduce material composition, do another round of FEA and repeat the process many times, before landing on the optimal design.

"Depending on the level of complexity, we go through a couple of dozen iterations," Wilson says. "The process is just too time consuming and resource consuming."



By optimizing the chain case and bulkhead, Polaris was able to save 0.2 pounds and increase stiffness.



This new design removes several joint structure and fasteners, creating a single part chain case.

Eliminating the Guesswork

In 2012, Polaris engineers got a lead on technology that could help break the lightweighting design bottleneck. Optimization technology, employed early in the development cycle, showed potential for helping the team zero in on possible areas for material reduction or shape redesign well before putting 3D models through their paces with FEA simulation as part of the validation process. The team began experimenting with Altair's OptiStruct topology optimization solver, and later with the more user-friendly solidThinking Inspire concept generation tool, to arrive at lightweight designs faster.

Enlisting optimization methods upfront eliminates a lot of the guesswork when developing new snowmobile concepts, says Wilson. That's important when you're trying to finesse next-generation snowmobile platforms against a rigorous time-to-market schedule — typically three to four years from concept to production.

"Knowing where to add materials and where you can reduce material definitely streamlines the process from design to first prototype," he says. "By taking a bunch of those iterations out of the timeline, you can be more efficient with the time you have."

Polaris' first experiment with optimization came a couple of years back in the early planning stages for its AXYS 2015 snowmobile platform, the first trail performance models to undergo a major weight reduction effort. Polaris' goal for the AXYS platform was to offer an extremely lightweight vehicle that didn't compromise ride and handling or durability — a design approach that encompassed everything from reducing the number of parts to substituting steel components with lighter weight aluminum structures where and when it made sense.

OptiStruct's first target for weight loss was the snowmobile chassis. The team created an amorphous design space or package, as it is called in OptiStruct, to which it applied the appropriate load conditions. The software's topology analysis capabilities identified possible areas for material reduction. The process yielded a new, lighter design that combined the central chain case and bulkhead side casting into a single assembly, eliminating a joint structure and fasteners. By reducing the number of parts and through other design modifications, the optimization exercise shaved 0.2 pound off the weight of the 2014 multi-piece snowmobile assembly while increasing stiffness — a combination key to accelerating performance of the new AXYS 2015 platform.

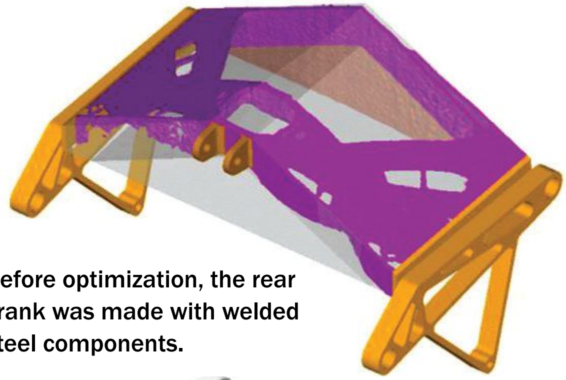
"OptiStruct generated a structure that we probably wouldn't have thought of using traditional methods," Wilson says. "We might have gotten there eventually, but it wouldn't have been obvious and it would have required more costly prototypes."

The rear crank assembly was another area where optimization technology made its mark. The suspension structure, originally made out of heavy, welded steel components, was recast in lightweight aluminum with a forged center piece and extruded side pieces thanks to an optimization-inspired design alternative that trimmed 2.7 pounds off the original assembly. Based on those successes, the Polaris team moved forward to leverage OptiStruct and solidThinking Inspire in several other key areas, including the "X brace" for the rear chassis, which ended up as a "K" to allow for more room for fuel, and in the chain case's lower sprocket, which was revamped to eliminate a series of holes while still achieving a weight savings of 0.64 pound, Wilson says.

In total, Polaris was able to eliminate over 30 pounds from the AXYS 2015 platform compared to the previous generation Polaris Pro-Ride platform. By optimizing and getting the design right early in the process, Polaris' engineering team also minimized the likelihood of major issues popping up during the validation stage. "When you're doing more iterations the old way, you may or may not get a design that works the way you wanted it to by the first validation season," he explains. "The sooner you have things locked down and finalized, the more likely the rest of the process is smooth sailing."

Not a Magic Bullet

One way Polaris is promoting the use of optimization is by taking advantage of more accessible tools like Altair's solidThinking Inspire, which has a look and feel similiar to familiar CAD applications, Wilson says. "Inspire makes it even easier and takes even more time out of the process because it can be picked up easily by someone who doesn't have a huge background in CAE or FEA," he explains. "Inspire helps design engineers and [CAD] designers pick up and explore and put a different perspective on what they are trying to achieve."



Before optimization, the rear crank was made with welded steel components.

The new design for the rear crank is 2.7 pounds lighter and made from aluminum.

While optimization provides a much-needed boost to the design cycle, Wilson cautions that the tools are not a panacea, and they still require a lot of engineering know-how and finesse in order to zero in on the optimal lightweight design. For example, the optimization tool doesn't specify which material to use nor does it output a fully featured design. "It doesn't give you a fully baked solution — a lot of time, the shapes are organic and you have to figure out how to take that shape and make it manufacturable," Wilson says. "Also, if you start with incorrect loads or your constraints aren't correct, you may come up with a solution, but it might not be accurate or correct."

Wilson also stresses that optimization is not a replacement for FEA, but rather can have a significant impact in the upfront process by identifying an optimized structure that can be further validated with FEA analysis. To avoid over-reliance on the optimization results, Wilson suggests conducting peer reviews to provide a sanity check as design alternatives are identified by the tool.

"Now that optimization has proven itself to be effective, we will start to apply it to more areas of the vehicle and try to expand our knowledge to other Polaris groups that can benefit from the technology," Wilson says. **DE**

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Optimize by Land & Sea

Topology optimization goes under the hood and sets sail.

BY KENNETH WONG

In the last decade, automakers and their suppliers began losing weight at a dramatic pace, through a diet of carefully selected optimization software. The strategy is driven in part by the direct correlation between fuel economy and the consumers' personal economy. A lighter car that yields better mileage per gallon is generally more appealing to a buyer. Another motivation to shed every ounce of excess materials from the design comes from stricter environmental standards and regulatory requirements.

For Voith Turbo, which manufactures hydrodynamic drives, coupling and braking systems, lightweight products are part of its vision to balance economic, ecological and social factors. On its homepage, the company states, "Sustainability is a cross-functional responsibility shared by our Corporate Board of Management, Group Divisions and Corporate Departments."

The quest for lighter design has long been a proponent of the division that produces planetary gear systems, or gears that revolve around a central gear (the system's metaphorical Sun). But when engineers adopted SIMULIA Tosca Structure, an optimization software package that bears the same name as a Puccini opera, the weight reduction turned dramatic — more than 30%.

The Limits of Manual Optimization

The planet carrier is a component in Voith Turbo's automatic transmission system. Its rounded, disc-like shape was consistent with how such a part traditionally looks. To optimize it, Voith Turbo previously employed "a manual process," says Bernd Wöhrle from the Technical Calculations Bus Drive Systems division.

"The planet carrier was designed in a traditional way based on its function and in accordance with the other existing planet carriers," Wöhrle says. "The component has been constantly optimized in different details for better and more efficient manufacturability. With the manual optimization process, we could only study minimal design changes/improvements based on existing design, because it was time consuming, and involved extensive prototype testing. It took huge efforts to get minimal improvements."

To conduct design analysis, Voith Turbo uses Abaqus, part of Dassault Systèmes' SIMULIA product family. In April 2013, when Dassault Systèmes acquired FE-DESIGN GmbH, the latter's Tosca product line (comprising Tosca Structure and Tosca Fluid) became part of Dassault Systèmes' simulation software portfolio.

The Tosca software titles are developed for structural and flow optimization. According to FE-DESIGN, Tosca Structure is suitable for designing "lightweight, rigid and durable components and systems.

Does That Look Right?

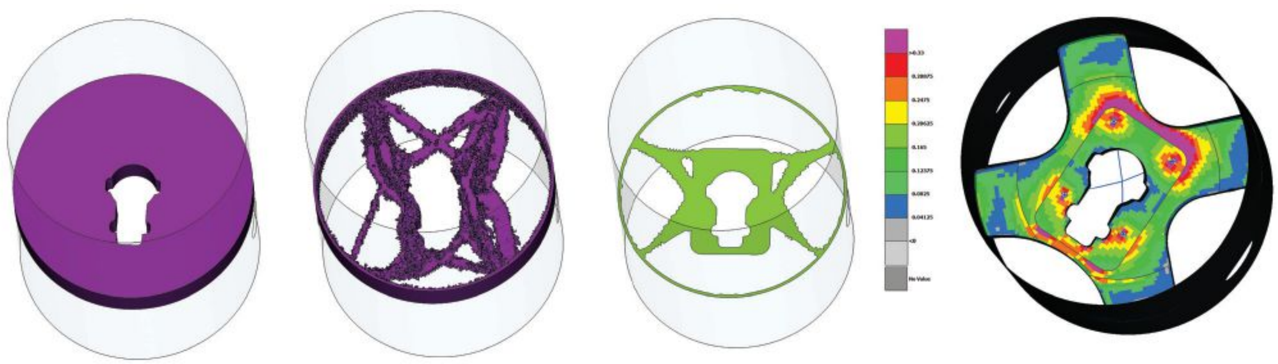
The software-driven optimization started with the CAD model of the planet carrier. The engineers created the finite element analysis (FEA) and imported it into Tosca Structure to define the optimization task — including the design space, the region in which they'd like the optimization algorithm to find the perfect topology. They excluded critical joints and connecting features from the design space. This ensured the new design would not alter how the component fit into the larger assembly. They also placed further restrictions to satisfy the manufacturing requirements. Perhaps most critical of all, the functional stiffness of the planet carrier must guarantee bearing durability and equal load on the tooth flanks.

In most cases, a design proposed by the optimization software contains jagged surfaces and organic features not feasible for manufacturing. Due to Tosca Structure's available set of manufacturing constraints, the optimization results came close to the final manufacturing design. Thus the engineers only needed to perform minor refinements in their CAD system to fit their existing manufacturing processes.

When the project began, Voith Turbo's aim was to "improve the performance of the planet carrier component with the aim to reduce its weight using topology optimization," says Wöhrle. He and his engineers might not have anticipated the optimal shape proposed by Tosca Structure's built-in algorithm. After running iterative simulations and design assessments, Tosca Structure proposed a component that weighed one-third less than the original design.

But can the new design withstand the stresses and loads the planet carrier is expected to bear in day-to-day operations? "We became convinced because all doubts were eventually eliminated on the test bench," Wöhrle says. "The analytic procedure guided us to a complete redesign with a performance which exceeded our expectations by far."

The evolution of Voith Turbo's planet carrier component, from the original design, to mesh model, to optimized shape. ***Image courtesy of Dassault Systèmes and Voith Turbo.***



iXent used Tosca Structure to optimize the Alegre 3 racing boat gearbox. Its design space was transformed into a topology result with crude meshes that were then refined, then turned into a form suitable for verification in FEA.

The experience with the planet carrier prompted Wöhrle and his colleagues to start looking for weight-reduction opportunities in other components, and to start using Tosca at the beginning of the design cycle whenever possible.

Wöhrle says SIMULIA Tosca Structure gave the planet carrier "vast improvements in terms of weight and manufacturability. Within a shorter development time, one gets an efficient redesign."

Sailing Faster with Composites

The weight advantage that comes with composite design is a more recent discovery for automakers, but the secret has been with watercraft engineers for a long time, according to Thomas Hahn, managing director of the engineering firm iXent.

"The boat building industry has mastered composite design for 30 years," he says. "They were among the first using this material in a successful manner. The challenge in automotive is to mass-produce parts (hundreds or thousands a day), compared to yachting industry, where most high-tech yachts are one-off designs."

The role of composites is not restricted to the boat's hull and outer shell. Every part, from rigging to gearbox, is fair game for weight-reduction, thus a candidate for composite infusion.

Winch specialist Jon Williams enlisted the engineering firm iXent to design the stiffest and lightest possible support for Alegre 3, a 72-ft. IRC Mini-Maxi racing boat designed by Mark Mills and built by Longitud Cero Composites.

"These supports are used to secure a gear box which typically powers a winch on deck or a hydraulic pump and gets driven by one or several driveshaft under deck," iXent's Hahn says. "The required power for this task is generated by the human force of up to eight crew members operating the so-called 'coffee grinders' at several positions on the boat."

iXent turned to Dassault Systèmes' Tosca Structure to identify the initial topology in the concept phase. The software, Hahn says, "supports us in an early phase of projects by calculating a proposal of a 3D structure, which is optimized with respect to weight and stiffness or other physical targets. This approach is quite useful on the path to creative and innovative ideas and solutions — sufficient flexibility and openness in the design envelope and the customer's vision provided. One of the very strong aspects of this approach is that multiple load cases can be incorporated simultaneously into such a study — an important fact since it is very difficult also for experienced engineers to visualize and determine load paths when several load cases come in play."

Batman Onboard

The FEA model gave iXent engineers guidance on the design space — the cylindrical region that serves as the basis for topology variation. In Tosca Structure's open environment, iXent was able to use simulation data not only from Dassault Systèmes' Abaqus, but also from competing software like MSC Nastran. "Topology optimization is a first step in the design of a product. The results will give the experienced engineer additional input and clarity about the feasibility of the concept chosen and will help in the choice of the manufacturing method and the detailing work later on," says Hahn. The software-proposed optimal shape reminded engineers of the Bat signal used by the Caped Crusader, so it became known internally as "Batman."

After smoothing the topology results with the built-in smoothing module, iXent engineers imported the geometry into CATIA software for further detailing. The next steps, Hahn says, were "Adding manufactural (draft angles, etc.) and also functional aspects (layer orientation, thickness and stacking sequences) to the CAD model … Some iterative analysis has to be done to ensure to use the minimum laminate scantling for the loads defined."

The resulting gearbox is 17% lighter than the usual design of such a component in a racing yacht, iXent revealed.

"Our original component for the race yacht is already lighter than similar parts in a car, which are usually made out of isotropic material," says Hanh. "In that respect, the 17% weight saving is much more significant than a 30% saving in an automotive part." **DE**

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3D Printing **Takes Off**

Aerospace companies turn to additive manufacturing to make lighter parts at a lower cost.

BY BRIAN ALBRIGHT

The pressure is on aerospace companies to reduce the weight of their planes while ensuring safety and quality. Manufacturers are increasingly turning to new materials and technologies to lighten the load, including rapidly evolving 3D printing and additive manufacturing solutions.

When Airbus Group Innovations partnered with EOS to compare rapid investment casting and direct metal laser sintering for the production of an Airbus A320 nacelle hinge bracket, they found that using direct metal laser sintering (DMLS) to build the hinge out of titanium could reduce the weight per plane by as much as 10 kg because of the lattice structure used in the hinge. The additive manufacturing process also used less total energy, reduced material consumption by 25%, and even reduced CO_2 emissions by nearly 40% over the lifecycle of the hinges.

The SuperDraco engine chamber is manufactured from Inconel using direct metal laser sintering (DMLS). The thruster will power the launch escape system on SpaceX's Dragon Spacecraft. ***Image courtesy of SpaceX.***

"The door hinge had a bulky design, and it was a low-volume manufacturing item for multiple locations on the plane," says Drew Snow, senior vice president at EOS North America. "Using the lattice structure, we could maintain mechanical integrity while reducing weight. And it's a design that can only be manufactured additively."

3D printing was initially seen as a way for aerospace, automotive and other manufacturers to create rapid prototypes or molds. Now, new additive manufacturing techniques and materials are making it possible to create lightweight end-use parts. While many

Dyna-Empire Turns to Creo to Reduce Component Weight

Designing lighter-weight airplane parts is one thing; manufacturing them presents several challenges and 3D printing is not the only solution. When one major aerospace original equipment manufacturer (OEM) redesigned the braces used to support the passenger cabin floor on its planes, they did so by designing in pockets and curves, and specifying that the parts be built in titanium.

The company selected Dyna-Empire, a Long Island-based aerospace company, to manufacture the parts, but the redesign presented several challenges. The curves and surfaces on the titanium part would require complex computer numerically controlled (CNC) programming, for example. Additionally, titanium milling tools are expensive, and the metal can quickly wear them down. Complicating the project, there were 25 different configurations of the brace for different parts of the plane.

"It was taking us hours to make one piece, and we were spending hundreds of dollars in tools per piece," says manufacturing engineer Colin Crossley.

Using the CAM functionality in PTC Creo, Crossley and his team were able to program the CNC machines while also utilizing new milling approaches that minimized tool wear.

Using Creo also allowed Crossley to program faster. "Instead of two hours, it would take me 15 minutes," Crossley says. "That gave me more time to try new things, and improve my cycle times and tool life."

Before, the company was only getting one part per tool; now they can cut 14 parts with one tool, saving thousands of dollars. Throughput has also increased from two pieces per shift to six.

of these parts are for interior areas of planes that are not subject to extreme stresses, printed parts are working their way into vehicle bodies, as well as being incorporated into jet and rocket engines.

Printed parts can reduce weight, cost and complexity. “Anything that helps on the assembly side is going to be worth the implementation process, because the return on investment is through the roof,” says Chris Holshouser, senior manager, Vertical Solutions, Stratasys.

Lighter Parts at Lower Cost

The expansion of additive techniques into end-use components is enabled, in part, by the addition of techniques like electron-beam melting, and the increase of available materials like titanium, ceramic, resin and thermoplastics to generate production-grade aerospace parts.

“The printing technique and the materials are very tightly coupled advancements,” says Tom Charron, vice president of Product Marketing at 3D Systems. “That’s why companies like 3D Systems develop the materials and printers together. It’s not like injection molding, where you can put lots of different plastics into a mold. Printers have engineered material specifically for what they are doing, as a general rule.”

Additive manufacturing can reduce costs by eliminating tooling and production expenses, provide additional manufacturing flexibility by reducing tooling required for injection molding or casting, and most importantly, provide lighter weight components. A printed part can be made with a hollow or latticed interior structure that reduces the amount of required material, and cuts down weight while maintaining strength and durability. Manufacturers can also create more complex geometries.

“Mass customization is also a big driver of 3D printing,” Charron says. “There is no cost difference between printing one or one thousand different pieces. Every one costs the same.”

Companies across the aerospace industry have launched 3D printing projects, and many have already incorporated these parts into aircraft. At GE Aviation, engineers are testing cobalt-chromium alloys (traditionally used for joint replacements and dental implants) to use for printing nozzles and other jet engine components. GE has been able to print the nozzle using direct metal laser melting, and created a nozzle that is 25% lighter and five times more durable than the current nozzle (which is made from 20 different components). The process can take up to 120 hours and requires a massive amount of computing power to monitor construction of the part.

Honeywell has its own 3D printing program under development.

Boeing has produced thousands of 3D-printed parts, including 30 components in the Dreamliner.

These printing efforts aren't always targeted at lightweighting. In early 2014, BAE Systems produced and certified the first replacement part for the BAE 146 regional jet using additive manufacturing, a plastic window breather pipe. The pipes were previously injection molded, but the tooling for the pipes was no longer available. New tooling would have taken several months and nearly $25,000 to develop. The printed parts cost 60% less than manufactured parts. (The company has also produced some 3D printed parts for the Tornado GR4 fighter jet.)

BAE's experience points to one of the major advantages of additive manufacturing: the elimination of tooling and molds that can add months or even years to a production schedule.

"If you look at the whole process, it may take several seconds to injection mold a part that takes an hour to print, but you have to consider the two and a half months it took to make the tooling for injection molding, and you don't have to store that tooling," Charron says. "If you make a design change, it doesn't cost you anything, because you don't have to change the tooling."

Additive manufacturing also has other advantages over machining or molding. "It's hard in machining to add material back if there is a problem," Stratasys' Holshouser says. "With additive, you can take action to save a long build-time part."

Unitization Reduces Weight

In many cases, printed parts can be produced in one or two pieces, greatly simplifying the assembly process and reducing weight by eliminating rivets and adhesives. "Unitizing an assembly into one component saves labor, and that's an important benefit," Holshouser says. "There are limitations to that, but the design freedom you get with respect to additive lets you make extremely complex parts without incurring a lot of cost."

New materials have also helped with lightweighting. PEEK and PEKK high-temperature, high-performance polymers, for example, can be used to replace other heavier materials.

According to Snow, the fiber optic single-model diode pump laser that EOS is using in its direct metal sintering solutions allows these systems to work with other types of metals. "We can work with traditional alloys now like Titanium 64. We can do super alloys, and the sky is the limit on stainless steel, so it has opened up a whole new plethora of materials," he says. "That has been a key innovation."

Holshouser says that there are now thermoplastic resin systems that can compete on specific strength with aluminum. "People don't realize the capabilities and benefits of thermoplastics, and what you can do with them now," Holshouser says. "There are ways to tailor thermoplastics to control conductivity or thermal passages. You can't get that with metals. Thermoplastics are more tunable."

3D printing companies have also gotten better at meeting tighter tolerances with a wider variety of materials. "We've gotten much better at controlling those tolerances and predicting how the material will react within the powder bed," Holshouser says. "Before, we could process materials but not in a repeatable manner. You have to have that predictability for manufacturing."

And because the technology can generate higher quality parts with these new materials, printing applications have moved into some of the most extreme applications in aerospace. NASA and Aerojet Rocketdyne recently conducted hot-fire tests on 3D-printed injector and thrust chamber assemblies using copper alloy materials, confirming the printed parts could potentially be used

New Techniques, Materials Curb Weight

Researchers at Harvard and MIT both published research last year that could point the way toward lighter, stiffer materials that will help manufacturers reduce product weight while maintaining durability.

At Harvard, researchers were able to use fiber-reinforced epoxy-based thermosetting resins and 3D extrusion printing to create cellular composite materials that mimic balsa wood. The technique could be used to replace the sandwich panels in massive turbine blades for wind farms. The team was able to 3D print honeycombs with fiber-reinforced cell walls that are much stiffer than other composites.

Using the resins, manufacturers could create materials with more precise fabrication control, and that are lighter and stiffer than balsa. By controlling the direction that the fillers (silicon carbide and carbon fibers) in the material are deposited, the researchers can control the strength of the materials. The technique results in cellular composites that are as stiff as wood and 10 to 20 times stiffer than commercial 3D printing polymers, and twice as strong as printed polymer composites.

Harvard School of Engineering and Applied Sciences (SEAS) and the Wyss Institute for Biologically Inspired Engineering published their research in *Advanced Materials* (onlinelibrary.wiley.com/doi/10.1002/adma.201401804/abstract).

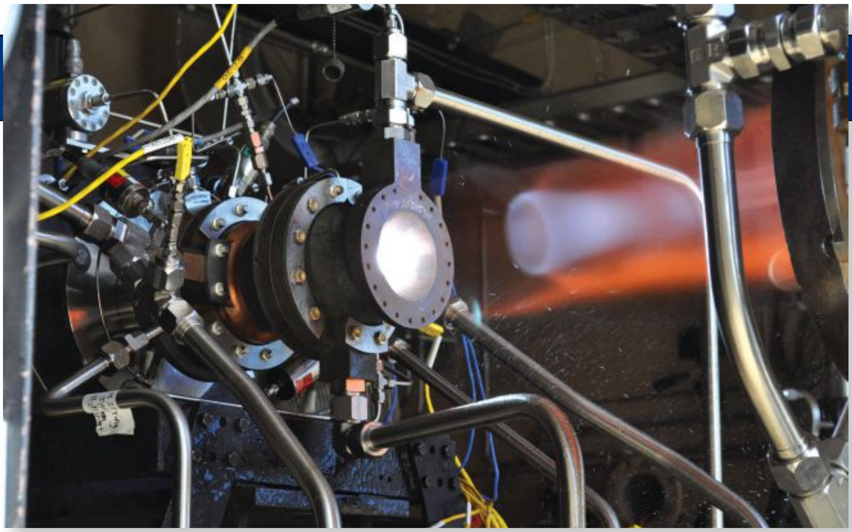
Engineers at MIT and Lawrence Livermore National Laboratory (LLNL) also turned to honeycomb-like design to produce very strong structures that are also lightweight. The designs uses microlattices with nanoscale features that can be produced via projection microstereolithography, combined with nanoscale coating and postprocessing.

In fact, even using a very light material like aerogel, the researchers were able to produce a mechanical stiffness that compared to that of solid rubber, and that was 400 times stronger than a material of similar density. The samples could withstand a load of more than 160,000 times their own weight, according to the researchers.

The research was published in *Science* in June 2014 (sciencemag.org/content/344/6190/1373).

in space launches. NASA also tested printed injectors in August 2014 that could be used on the RS-25 engine for the planned Space Launch System (SLS) rocket. Those injectors can be printed and assembled using just two parts, compared to the 160 components needed for traditionally manufactured injectors.

In January 2014, SpaceX launched a Falcon 9 rocket with a 3D-printed main oxidizer valve body in one of the craft's nine Merlin 1D engines. The valve is now qualified to fly interchangeably with cast parts on all Falcon 9 flights. SpaceX also tested a printed SuperDraco engine chamber, which could be used on the Dragon Version 2 vehicle's launch escape system.



Rocket engine parts made by 3D manufacturing in copper alloy undergo hot-fire testing at NASA Glenn with Aerojet Rocketdyne. *Image courtesy of NASA.*

Innovations Move Tech Forward

To move from prototyping to end-use parts, 3D printer companies have had to modify their equipment and approaches to the manufacturing floor.

3D Systems, for example, in its new ProX 400 direct metal 3D printer, has separated the pre- and post-processing steps from the actual printing. "That way you are purely printing, and as soon as the part is done it can be moved out of the printer and into a separate depowdering unit that does the post-processing," Charron says. "You can use the print volume more efficiently that way and increase throughput."

3D Systems also developed a high-speed, continuous fab-grade printer for high-volume, customized printing of plastics that moves the print beds at high speeds beneath print heads.

Throughput and production efficiency will be critical for expanding additive manufacturing in aerospace. "People have applications that they want to adapt to additive, but it can be cost prohibitive because of the speed of the technology," says Snow at EOS. "We're trying to bring the ROI (return on investment) for the customer into place via innovations that increase productivity of the technology. We're looking at new ways of delivering the laser beam to the powder bed, and at multi-laser solutions to better meet the needs of the applications for production."

Those multi-laser systems would use multiple lasers with multiple fields in a single build envelope to increase throughput. "That would be most beneficial for larger part applications where a single laser solution takes a long time to complete a build," Snow says.

Design Challenges

For aerospace companies that want to use 3D printing to reduce weight or costs, the biggest challenges may not come from the technology or materials, but from the design side.

To successfully print a part, these companies need engineers that can design for additive manufacturing, and software that can fully leverage the technology. "Engineers don't know how to design for it," Holshouser says. "It wasn't available to them before. We can create internal lattices with our solutions, for example, but you need a CAD expert to go in and create these structures in the design. The disruptive nature of additive is further along than the know-how available to utilize it."

Conventional design of a steel bracket (left) and the EOS titanium bracket created via additive manufacturing (right). ***Image courtesy of Airbus Group Innovations.***

"Adoption of additive for end use manufacturing on a large scale will require a rethinking of how parts are designed," Charron says. "Today every engineer out there is used to designing for the manufacturing processes. The software works the same way. Now you can design things in ways that are very different."

That will require a large-scale education effort within aerospace and across engineering schools. "That's our biggest challenge, showing engineers how to design with additive in mind," Snow says. "We're making some headway as the industry brings awareness of the design rules of additive and what is possible, and more and more college curriculums have the technology."

"There are pioneers who are starting to think differently and take advantage of additive manufacturing, but I think most companies have not seriously thought about changing how they do production to take advantage of the technology," Charron says. "That will be a huge part of the way the industry moves forward over the next five or 10 years." **DE**

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NASA's Weight Loss Plan for Future Missions

The US space agency explores composite materials as the foundation for propulsion systems.

BY KENNETH WONG

On March 26, 2014, a wide-bodied Super Guppy aircraft from NASA landed at the Redstone Army Airfield near Huntsville, AL, with a special passenger. When the aircraft's hinged nose opened, a cryogenic fuel tank measuring 18 ft. in diameter emerged. The cargo was in transit, destined for a series of tests at NASA's Marshall Space Flight Center nearby. Though it's intended to fuel space missions, the tank was built by The Boeing Co., a manufacturer more closely associated with air travel.

Boeing, known around the world for its jetliners, also happens to be the prime contractor for designing, developing and manufacturing NASA launch vehicle components. The company's Space Launch System (SLS) division attests to its aspiration to be a major player in the space exploration business. In 2011, NASA awarded Boeing a $24 million contract to develop and manufacture two cryogenic fuel tanks. The delivery in March marked the first of the two. It was manufactured in Boeing's Developmental Center in Tukwila, WA. What distinguishes this tank from the others is the construction materials — composites.

The project was part of the space agency's efforts to identify new technologies for future missions. For its part, Boeing relies on software-based simulation — conducted in products such as MSC Patran and Nastran — to test and refine the tank's design.

Michael Gazarik, NASA's director of the space technology program, spelled out the objectives. "The goal of this particular technology demonstration effort is to achieve a 30% weight savings and a 25% cost savings from traditional metallic tanks," he said. John Vickers, project manager at NASA's Marshall Space Flight Center, described the project as "one of the largest composite propellant tanks ever built."

Dan Rivera, Boeing's program manager, said, "To design the tank, we use new materials. We process the tank by automated fiber placement. The benefit of that is, we can lay down the material quickly, which provides a low-cost operation and a lightweight tank."

To accomplish the ambitious weight reduction goal, engineers turned to software-driven optimization. In a paper titled

NASA's Super Guppy airplane lands at the Redstone Army Airfield near Huntsville, AL, on March 26. *Image courtesy of NASA/MSFC/Emmett Given.*

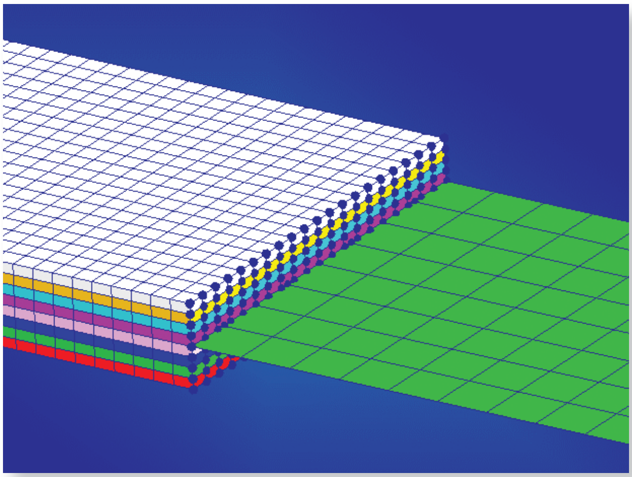
"Cryogenic Tank Structure Sizing with Structural Optimization Method," NASA authors wrote: "Structural optimization methods in MSC Nastran are used to size substructures and to reduce the weight of a composite sandwich cryogenic tank for future launch vehicles … In this study, a simple procedure is introduced to create a new starting point based on design variable values from previous optimization analyses. Optimization analysis using this new starting point can produce a lower weight design."

Learning to Slice, Glue and Chill

MSC Software products can simulate and optimize composite ply layup, analyze laminate stresses and strains and identify potential failures. According to MSC, they're widely used in designing aircraft panels, floors, doors, heat shields, wing structures, rudder, helicopter fuselage, rotor blades and ballistic protection.

"In this project, solid elements were used to model the critical joints in the composite tank," says Hanson Chang, an MSC Software application engineer who helped Boeing engi-

One of the largest composite rocket propellant tanks ever manufactured is prepared for transport on NASA's Super Guppy airplane. *Image courtesy of The Boeing Co.*



An MSC Software interface shows glued contact between solid elements and shell elements with the contact footprint (blue spheres) plotted. *Image courtesy of MSC Software.*

neers build the Nastran finite element models. "Solid elements simulating composite layers allow the engineers to assess the peel stress and interlaminar shear stress in the composite layup under mechanical and cryogenic loading environments."

With composites, the orientation of the materials — specifically, the layout and direction of the plies — also affect the durability, strength and shearing behavior of the products built. To design the cryogenic fuel tank, Boeing used a mix of solid and shell elements to get the best results.

"In areas away from the critical joints, shell composite elements were used instead of solid elements to minimize the model size," Hanson said. "The shell composite element edges are connected to solid element faces using the glued contact technology in MSC Nastran. Additional techniques such as modeling only a slice of the tank by applying axisymmetric boundary conditions were also used. These modeling techniques helped to reduce the model size so design trade studies could be performed quickly to explore different tank joint configurations."

Weight-reduction for Space Missions

Because space travel is associated with weightlessness, it may sound paradoxical to hear about NASA's desire to use composites to reduce weight in its launch vehicles. But weight has a direct impact on the volume of fuel required in space travel. "The Space Technology Mission Director pushes us to develop technologies that make NASA missions more affordable, more capable, and more reliable," NASA's Vickers said.

Boeing's Rivera remarked, "Being able to prove that we can design and build and contain liquid hydrogen only using composite is a significant breakthrough."

In October 2014, Vickers and Rivera headed out to Orlando for the Composites and Advanced Materials Expo (CAMX). During the conference, in a ballroom inside the Orange County Convention Center, just an hour's drive west from Cape Canaveral at the Kennedy Space Center, Vickers and Rivera accepted the Combined Strength Award for Composites Excellence for the Composite Cryogenic Technology Demonstration.

"This is one of NASA's major technology accomplishments for 2014," said Gazarik. "This is the type of technology that can improve competitiveness for the entire U.S. launch industry, not to mention other industries that want to replace heavy metal components with lightweight composites. These tests, and others we have conducted this year on landing technologies for Mars vehicles, show how technology development is the key to driving exploration." **DE**

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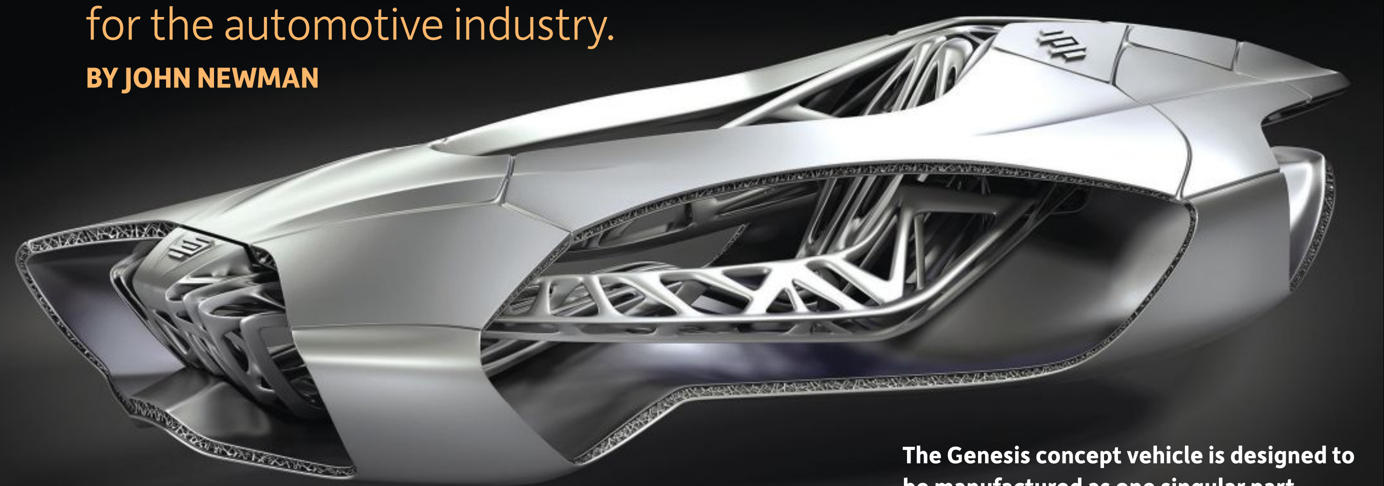
3D Printing Advances Design

EDAG's Genesis project investigates additive manufacturing for the automotive industry.

BY JOHN NEWMAN



The Genesis concept vehicle is designed to be manufactured as one singular part.

Additive manufacturing (AM), or 3D printing, is bringing about a revolution. As the technology matures, the value in AM continues to move past rapid prototyping to full-scale production of end-use parts. Some companies have already embraced the revolution and begun to shift the focus of research and production facilities in accordance. GE is one of the leaders in this area, and has invested heavily in AM, including the construction of new plants devoted to advanced manufacturing, and plans for a dedicated research facility in Pennsylvania.

The revolution doesn't start with manufacturing. It starts with design. Old ways of thinking about how a part or product must be designed to account for traditional forms of manufacturing will be replaced by a new design freedom. Complex parts designed with traditional manufacturing methods in mind were often broken down into multiple pieces. Each piece required its own pre and post-production process, followed by final assembly into a completed part. The same part built with AM can often be designed and manufactured as a single piece, reducing material waste, production costs and time to market.

Designing the Future

Two of the industries set to profit the most from the coming revolution are aerospace and automotive. While GE Aviation is one of the leaders in aerospace, EDAG, a design and engineering firm based in Germany, is devising a path to the future for automotive AM with its Genesis project. The project represents the results of a think tank that included experts from Fraunhofer, Laser Zentrum Nord and the DMRC Paderborn. The goal of the project was to examine the state of AM and predict how the technology will impact automotive design and production.

The findings were published in an EDAG white paper titled, "EDAG Insights: Additive Manufacturing," and are summarized in the following passage from that paper.

"Additive manufacturing enables parts to be designed so that they are load-specific, multifunctional and bionic, while ensuring ideal wall thickness and outstanding material properties. Working directly from data models, tool-free, highly flexible production is possible. Weldable metals and plastics developed to be suitable for specific applications will pave the way to future applications."

EDAG's group of experts are certain that new methods of designing for AM will evolve, as more designers embrace the freedom of design possible with 3D printing. This includes new and improved tools for design. Most CAD programs are still rooted in the old engineering and design philosophies developed for tool-based, traditional manufacturing methods. As more companies embrace AM for production, new tools will need to be developed to fully leverage the flexibility of 3D printing.

Proof of Concept

It is, of course, easy to call for innovation, or to wait for the present to catch up to your vision for the future. Rather than stand on the sidelines, EDAG has stepped up to its own challenge and developed a proof-of-concept model. The ultimate aim of project Genesis was to design a vehicle using new design philosophies and manufacturing techniques. In this case, EDAG's team looked to nature for inspiration. The firm refers to this as bionics (it has also been labeled biomimicry), and it is the process of applying biological principles to design philosophy.

After some debate, the team settled on the humble turtle to act is its muse. A turtle's shell has evolved to act as armor while still being light enough to allow for mobility. A cross section of a turtle's shell reveals a system of delicate interior bone structures that offer durability while reducing the overall weight of the shell. The question soon became whether an automobile could be designed and constructed using a turtle's shell as a model.

"At the very beginning, we had to justify our decision to take a ponderous turtle as the basis of an idea for a car," said Johannes Barckmann, chief designer and bionics innovator at EDAG, in a blog post. "Under water, turtles are skilled swimmers, but on land they are not the fastest of creatures. But what really persuaded us to take the turtle's shell as the inspiration for Genesis was the simple fact that what we are talking about here is a kind of passenger safety that nature has perfected over the course of millions of years. No engineer could come up with an idea like that!"

Less Weight via Part Consolidation

Basing the design on the structure of a turtle's shell offered a chance for significant lightweighting. Earlier testing by EDAG and Laser Zentrum Nord had shown that AM can reduce the overall weight of a part even if that part wasn't originally designed to be built with 3D printing. A joint effort at building a lighter multi-functional housing part for an electric vehicle resulted in a weight reduction of 1000 g. Project Genesis took that idea forward by applying AM design principles from the ground up to develop an entire vehicle body to be built in one part.

With a design in place, it then fell to EDAG to determine which AM process and material would best fit its needs. The think tank evaluated Fused Deposition Modeling (FDM), selective laser melting, stereolithography and selective laser sintering based criteria that included component size, ecological performance, structural relevance, tolerance and production costs. While it might be assumed that FDM would lose out in such a head-to-head competition with metal AM processes, EDAG's team found that FDM may well be the AM process best positioned for large-scale 3D printing, both now and in the future.

EDAG suggests that, in the future, FDM thermoplastics might be "boosted" with carbon fiber during the production process to increase strength and durability. The think tank also concluded that FDM was well suited for building lightweight structures that minimize internal support to reduce weight. Like the turtle shell, FDM parts can be strengthened by a complex honeycomb-like internal architecture, in place of parts that have been manufactured using traditional methods that are completely solid, heavier and more expensive to produce.

The resulting Genesis concept vehicle is part FDM shell, part artistic sculpture. It proposes that AM will be a major factor in the future of automotive manufacturing, and provides a glimpse into one way to create lightweight, yet robust, parts of all sizes while keeping material costs low. The project also highlights the idea that weight and material savings begin in design. DE

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EDAG'S LIGHT COCOON PREMIERES AT GENEVA MOTOR SHOW 2015

Following the success of the EDAG GENESIS, engineering specialists at EDAG have expanded their vision of a bionically inspired body structure via additive manufacturing.

The EDAG Light Cocoon concept study is "an unprecedented projection of the ultimate in future lightweight construction," according to the company. The vehicle structure is combined with a weatherproof textile outer skin panel that is backlit to illuminate the skeleton-like, organic structure.

"We are pursuing the vision of sustainability — as demonstrated by nature: lightweight, efficient and without any waste," explains EDAG's head designer, Johannes Barckmann, in a press statement. "The result: the EDAG Light Cocoon presents a stable, branch-like load bearing structure from the 3D printer, which only uses material where it is absolutely necessary."

EDAG says its simulation experts carried out static and dynamic calculations for the basis of the topologically optimized ideal structure. The EDAG designers took a leaf as their inspiration for the lightweight outer skin.

"The Jack Wolfskin material supports maximum lightweight design requirements with minimum weight," says EDAG CTO Jörg Ohlsen of the outer skin. "To give you a comparison: this extremely strong material is four times lighter than standard copier paper. Combined with the topologically optimized, additively manufactured structure, it offers enormous potential and stimulus for the ultimate lightweight construction of the future."

Fast App

Robust Racecar Design

ANSYS software is instrumental in designing the HIT racing team's lightweight vehicle.

BY HAO YUZHOU

The Harbin Institute of Technology (HIT) racing team is very familiar with the use of simulation for automotive design. The team has participated in Formula Student Germany and Formula Student Japan; it received second prize for Formula Student China in 2013. ANSYS software has been instrumental in designing many aspects of the team's lightweight vehicle, including the carbon-fiber monocoque, aerodynamics and the intake system. Of the 58 members on the team, 30 use ANSYS tools to achieve their individual design goals by employing ANSYS Mechanical, ANSYS Fluent, ANSYS Composite PrepPost, ANSYS DesignXplorer and ANSYS LS-DYNA.

The team overcame design challenges using parametric simulation and optimization. The students perform parameterization using ANSYS DesignXplorer to create a faster car that is also powerful, lightweight and reliable. Multiphysics capabilities accessed through ANSYS Workbench allowed HIT team members to develop models that closely matched real-world conditions.

The HIT team used ANSYS Composite PrepPost to simulate the stiffness of the vehicle's monocoque to reduce the weight of the layered composite body. Team members combined experiments with ANSYS simulation to develop the composites material. The intuitive interface of Composite PrepPost efficiently defined the materials, plies and stacking sequences; it also offered a wide choice of state-of-the-art failure criteria. ANSYS solvers provided the foundation for accurate results, and data from physical testing was consistent with the analyses. The software helped the team to improve the stiffness of the chassis and reduce local stress concentrations. The final monocoque weighed 18.4 kg (40.6 lbs), which is 2.6 kg (5.7 lbs) lighter than the previous version. The team also achieved a 14% improvement in the stiffness-to-weight ratio.

The air intake for the vehicle was designed with the help of fluid–structure interaction (FSI) that combined Fluent with ANSYS Mechanical software. The intake system for the engine experiences negative pressure during operation. By collecting manifold pressure sensor data, the HIT team found that the peak negative pressure is 0.7 bar in the intake manifold. This level of negative pressure can change the shape of the air intake system, which influences the flow field inside the manifold and can even destroy the structure of the air intake.

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How to Set Realistic Boundary Conditions

When applying boundaries, a variety of methods can be used to ensure accuracy.

BY TONY ABBEY

Editor's Note: Tony Abbey teaches live NAFEMS FEA classes in the US, Europe and Asia. He also teaches NAFEMS e-learning classes globally. Contact tony.abbey@nafems.org for details.

One of the most difficult aspects of setting up an FEA (finite element analysis) model to simulate the real world is applying realistic boundary conditions. This means understanding how the structure is loaded by external forces and how it is constrained from moving globally in space. Sometimes the distinction between whether a structure should be fixed to the ground or loaded externally can become a little blurred. It is up to the analyst to decide how to deal with this.

An example structure is shown in Fig. 1. It is a two-part assembly. The top fitting latches onto the lower fitting using a bayonet type connection, by pushing down and rotating through 60 degrees. A seal runs around the entire mating face, but is not shown here. The bayonet connection leaves three pairs of latches in contact under an internal pressure loading. The assembly has a plane of symmetry, and this is used to advantage in the FEA model, as shown in the figure. The run time is reduced by a factor of four with a half model.

A typical latch mesh is shown in Fig. 2. On the top fitting, there is a stress concentration at the inner fillet radius and this is the subject of investigation. The line of nodes used to check the stresses is shown in the inset in Fig. 2.

Checking Stress Levels

If a linear static analysis is used initially to check stress levels then there are three ways of doing this. Fig. 3 shows how the latch can be loaded and the top fitting assumed held remotely (3a), the latch can be clamped by a constraint to ground and the load applied to the top fitting remotely (3b), or a glued contact can be used to join the latch and mating inner component (3c).

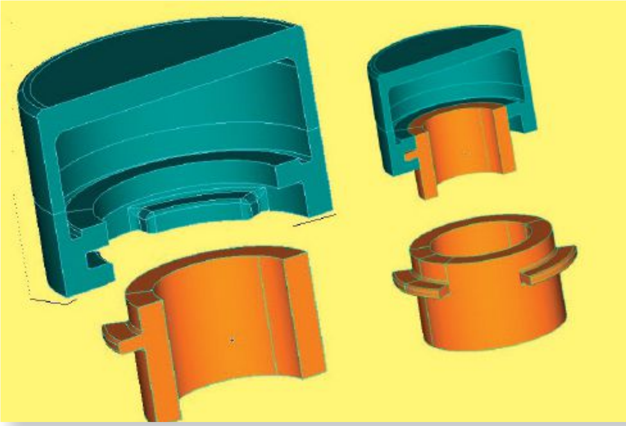

FIG 1: Two part assembly showing contacting latches.

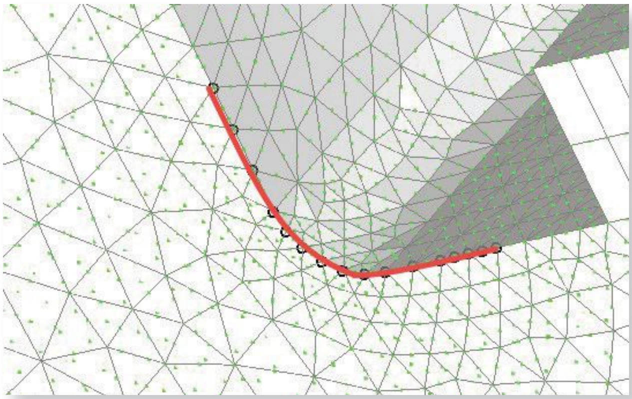

FIG 2: Mesh detail in latch and key nodes.

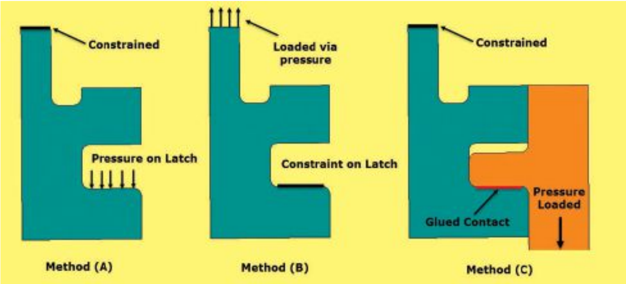

FIG 3: Latch loading and constraint methods.

The motivation for making these linear assumptions about the bearing loading path and associated stress distribution is that a linear analysis will usually be much faster and easier to run. There is always a risk in running a nonlinear analysis in that convergence is never guaranteed and may be difficult to achieve. A 'quick-look' equivalent linear analysis is always worth trying.

Applying equivalent pressure to the latch face as in Fig. 3a is considered a "soft" loading. The idealization provides no stiffening, however an assumption has to be made about the pressure footprint. Here it is assumed to be evenly distributed right up to the edge of the latch contacting faces. The result is shown in Fig. 4a and is a classical stress concentration distribution. The mesh density is adequate as shown by a separate mesh convergence study.

Traditionally, clamping the latch as in Fig. 3b is considered a "hard" load path. The idealization represents a latch face that is bonded to an infinitely stiff mating surface. At the edge of any constraint run out like this a stress singularity is created. The FEA model assumes a jump from infinitely stiff to flexible over a single element width. This is like an extreme example of a stiff material 'digging in' at its edges into a soft material. The line of high stresses, representing the singularity, is shown in Fig. 4b. However, what is surprising here is that the stiffening effect of the constraint does reduce the level of the stress concentration compared to a "soft" pressure distribution as shown in Fig. 4a. The stress plot around the fillet is shown in figure 5 for both soft pressure, hard clamping and also glued contact.

The soft pressure distribution (3a) and glued contact (3c) give very similar stress distribution results. There are two idealization observations here: the pressure footprint for the glued contact is similar to the soft pressure. The stiffening effect of the inner glued latch does not seem to affect the stress distribution significantly. The singularity caused by the harsh constraint (3b) is shown in Fig. 5 and dominates the result. The constraint also seems to reduce the stress concentration significantly, presumably by altering the effective load path to be more favorable to the fillet region.

It seems that the constrained method is a poor idealization for this geometry; it gives a spurious singularity, which is adjacent to the fillet radius and is effecting the distribution. There is also a slight tendency for the glued contact to give a spurious stress raiser at the edge of the contact. A contact run out is often a source of mild singularity. Similarly, the general contact method (in a sub-

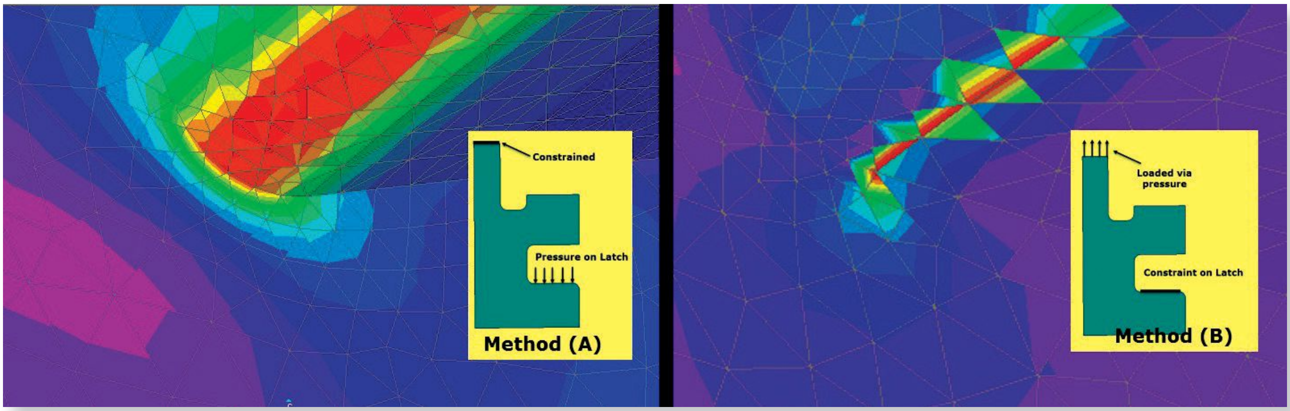

FIG 4: **Stress contours for pressure and constraint.**

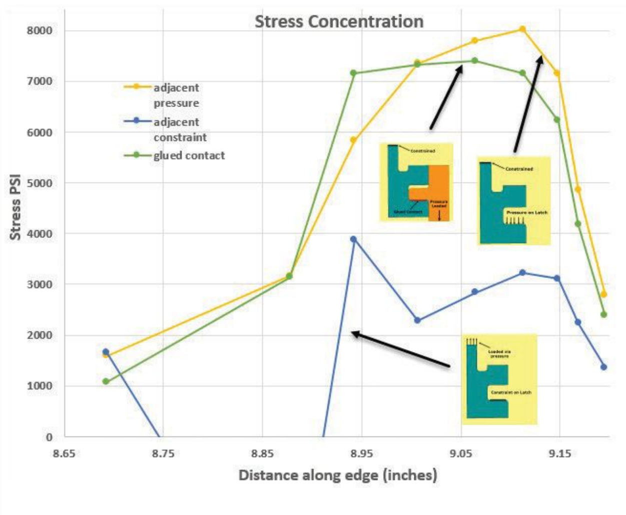

FIG 5: **Stress variation around fillet for cases 3a, 3b, 3c.**

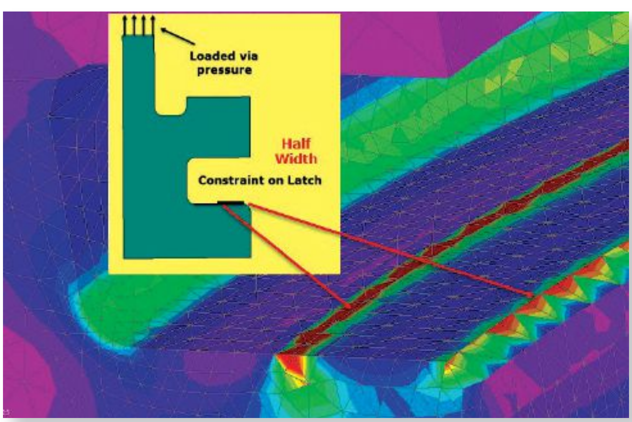

FIG 6: **Attempting to move the constraint edge singularity away from the fillet.**

sequent nonlinear analysis) also gave a slight stress raiser at the contact edge, and also a reduction in peak stress distribution over the soft pressure. A soft pressure distribution is therefore recommended. This may be surprising, as a general contact surface model would traditionally be assumed to be the most realistic idealization. However, it shares the tendency of glued contact to give a spurious edge effect and there may be concerns that this affects the peak stress.

An alternative approach to method 3b is to apply the constraint with a separation from the fillet edge. The line of singularity is now moved away from the fillet toe to the new latch mating edge. This leaves the fillet radius freer to develop a reasonable stress distribution. The region of stress singularity is still present, but is now away from the fillet radius, as shown in Fig. 6. To compare the peak stress value, it is necessary to run a similar pressure distribution footprint. A new general contact analysis result is also compared. The three new methods are shown in Fig. 7, with a graph of the stress distribution.

Fig. 7 shows that the singularity is moved away from the fillet toe in the constraint method and the general contact method. However, as before, the constraint method is over constraining the latch feature and so the fillet region does not develop the full peak stress value. The contact method also appears to constrain the solution compared to the "free" pressure loading method. The stress has increased in all cases due to the bigger offset of the line of action.

Offsetting the contact footprint would be a reasonable approach because in hand stress calculations we would always assume the line of action was conservatively offset, rather than through the mid line of the latch. The actual bearing contact footprint is really an unknown in many situations. Without some test evidence it is difficult to assess if the general contact surface method gives an accurate representation. In this particular case, the offset moment is the dominant factor in the peak stress at the fillet radius and it is therefore important that a conservative approach is taken.

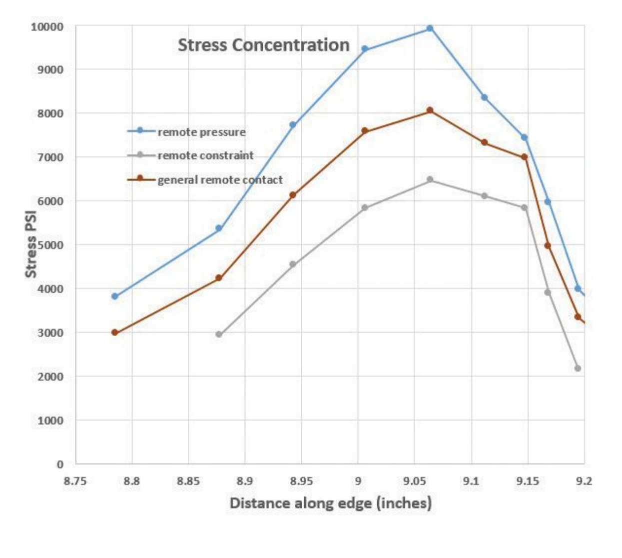

FIG 7: Distribution of stress, offset contact region assumed.

2015 NAFEMS e-Learning Events

NAFEMS has announced its 2015 e-learning course program. Over the past five years, NAFEMS says its e-learning has been used by 3,200 online attendees worldwide.

The two-hour weekly live online sessions are led by industry-recognized tutors. They combine theory and real case studies that are intended to engage and teach those involved in analysis and simulation. Designed to fit engineers' and simulation analysts' busy schedules, attendance at all of the live classes is not required because the classes are recorded and made available to study whenever it's most convenient. Notes from the course tutors are also available to download and save.

The 2015 course program kicks off this month:

- CFD for Structural Designers and Analysts, January 21
- Advanced Dynamic FE Analysis, January 29
- Structural Optimization in FE Analysis, February 3
- Fluid Dynamics Review for CFD, February 11
- Composite FE Analysis, February 26
- Practical CFD, March 11
- Non-Linear FE Analysis, March 17
- Elements of Turbulence Modeling, April 8
- Practical Modelling of Joints and Connections, April 16
- Basic FE Analysis, April 21
- Basic Dynamic FE Analysis, May 7
- Fatigue & Fracture Mechanics in FE Analysis, May 26

For more information, visit nafems.org/e-learning/

Don't Be Misled

The "hard" constraint method of applying a boundary condition is seen to be misleading in this case for two reasons:

1. The edge of the constraint is a singularity and influences the fillet toe directly by giving unrealistic local stresses.

2. The constraint over-stiffens the latch flange and reduces the peak stress from that expected by cantilever action of the latch flange.

The general contact and glued contact methods rely on a realistic bearing footprint, hence load line action. The peak stresses seen in the fillet are reduced from the equivalent 'free' pressure distribution, suggesting that the line of load action is closer to the fillet toe in these methods. Without test evidence, it is difficult to assess whether this conservatism is warranted.

Hand calculations, based on bending stresses at the weld toe (distance 8.88 in.), with assumed stress concentration factor at this position, show stresses at this point are close to the indicated stresses. However the peak stress is at a distance of 9.06 in., the center of the fillet in all cases.

Method	Label	Peak P1 Stress
Overall Press	3A	8020.539
Adjacent Constraint	3B	3214.853
Glued Contact	3C	7396.921
General Contact		7432.468

Peak stress values at fillet.

In summary a "free" equivalent pressure distribution with a conservatively assumed line of loading action is probably the safest assumption to make in this case.

In my next article, we will discuss how to apply equivalent pressure distributions throughout a structure to achieve balance, avoid any direct constraint boundary modeling, and rigid body motion. DE

Tony Abbey *is a consultant analyst with his own company, FETraining. He also works as training manager for NAFEMS, responsible for developing and implementing training classes, including a wide range of e-learning classes. Specific classes on Structural Optimization are available.*

MODO 801 Gets More Refined

The visualization software now has streamlined Snapping, updated UV mapping and Nodal Shading features.

BY MARK CLARKSON

MODO 801 render of a hot rod designed by Scott Robertson.

I've been using MODO since version 302, way back in 2008 (when it was spelled 'modo.') Since then, it's grown from a neat but bare bones polygon modeler to a robust modeling and animation package that supports complex assemblies, dynamics, particle effects and long, wavy hair.

What's New ... and Relevant?

Admittedly, as a program matures, new features can grow increasingly obscure for particular users. I always struggle to decide what's relevant. Someone's excited about 801's improved tools for styling long hair, but it's probably not this magazine's readership. If you've been anxiously awaiting support for rounded edges in material baking then good news, it's here. If you haven't, then it's hard to get too worked up about it.

So, what new features does MODO 801 have to offer that might be of interest to the majority of design engineers? Here's what stood out to me.

It's a Snap

Sometimes, the big improvements can be easy to overlook at first. MODO's new snapping tools are a good case in point. Snapping's not especially sexy, and Snapping worked fine in 701. But MODO's Snapping has been completely rebuilt and streamlined considerably.

Now, instead of selecting Vertex Mode or Polygon Mode, you click on a Snapping feature — vertex, polygon, pivot, etc. — to turn it on or off. You can have any number of Snapping features enabled at once, so you can snap to the grid, straight lines and object vertices at the same time.

Snapping is now context sensitive. You can select different snapping features to be active globally, in item mode, or in component mode. One set of snapping rules applies if you're working with polygons, but another set applies when you switch to item mode. You can save combinations of features as Snapping presets. You might find one combination of features useful when tracing architectural drawings, but another combination better for building complex mechanisms. Save each as a preset, to be selected later from a drop-down box.

801 adds a lot of new Snapping features. You can now snap to instances, to the intersection between objects, and to the corner or center of a bounding box.

While some new features I'll use rarely, if ever, I use Snapping constantly so the rebuild is much appreciated.

Nodal Shading

Arguably the most visible addition in 801 is MODO's new Nodal Shading system. Nodal Shading doesn't replace MODO's existing layer-based Shader Tree; it exists sort of at a right angle to it. The (entirely optional) nodal system feeds into the Shader Tree.

Nodal Shading setup takes place in MODO's Schematic Editor, which was previously reserved for setting up particle systems or rigging assemblies.

To create a texture you use a channel from one node (e.g. x location, or red, green values) to drive a channel on another node (e.g. y location or blue values.) You can hook red to red, red to blue, or red to specular value or bump amplitude.

You can hook up any number of nodes. You can use a single node to drive different values on the same texture, or different

A comparison of the Snapping settings in MODO 701 (left) and MODO 801 (right). 801 Has significantly streamlined the Snapping interface.

values on altogether different textures. You can perform basic math on channels, multiplying or blending them together. You can even apply logical constraints.

If you're already familiar with MODO's Schematic Editor, you'll feel at home pretty quickly. If not, it will take you a while to find your bearings. But remember, the Shader Tree is unaltered. For many, though, creating complex textures through the new nodal interface will feel more comfortable, or at least more familiar, than MODO's somewhat idiosyncratic Shader Tree.

Improved UV Mapping

UV (ultraviolet) mapping is my personal Kryptonite. MODO's UV tools are as good as any I've used, but I still fight with UV mapping. Fortunately, 801 addresses one of my pet peeves — the difficulty of getting symmetrical meshes to produce symmetrical UV maps. There are now some new tool options that enforce symmetry, making my mapping jobs a lot easier.

801 also has the ability to merge separate UV maps into a single map, as well as some new unwrapping methods. These are always welcome as one of the challenges of UV mapping is finding the best method of unwrapping a particular part or model.

Animating with the Spacing Chart

801 includes a new method of laying out animations using a Spacing Chart. Instead of worrying about timing up front, animations with the Spacing Chart are built around poses. To a traditional animator, these poses would be running or jumping; to a designer they might be a car suspension articulating, or desk drawers opening and closing. Once you've created and ordered all the poses you need, you then adjust the animation's timing by playing with the spacing between poses.

It's a different way of approaching animation.

Onscreen Controls

MODO has a cool feature that's not new to 801; it's been around for a few versions, but I haven't really given it much thought before now. It's shown off perfectly in one of the showcase pieces that comes with 801 — a sample scene that lets you play around with a concept hot rod designed by Scott Robertson. Load it up and you're presented with a cool car sitting out on the salt flats somewhere. You can play with the geometry, materials and lighting as much as you'd like.

Hovering in space near the car itself are three balls labeled 'roof line,' 'salt painting' and 'render passes.' Floating above it in the sky are two thumbnails images. All five of these objects are active; click on the ball labeled 'render passes' and you can choose the camera view, the time of day, or the color of the car's paint. Click on the thumbnails, or the other balls, and MODO will take you to a web page and play a video or audio file.

You can, similarly, create controls for different parts of your assembly — maybe a slider that steers the front wheels, or opens the trunk. The full extent of this capability is a bit obscure but at a minimum, in combination with render passes, it's very powerful.

I finally understand just how very useful this kind of capability could be in a collaborative environment, allowing people to safely look at different lighting, paint, camera views and so on, without having to understand much about the models or the application.

Shatter, Bubbles and More

There are, of course, lots of other goodies scattered throughout the new release. The new Shatter command will break up a mesh into whatever size chunks you desire so that MODO's dynamics system can make your objects explode, or drop and shatter on the floor. The new thin film and iridescent materials let you create realistic soap bubbles and oil films. OpencolorIO color management helps to tie MODO together with other Foundry applications, such as the 3D painting tool, MARI.

GL Measures allow you to display information about models and assemblies — measurements, distances, meters and bar graphics and simple text — directly in the viewport.

MODO does a reasonably good job of reading many standard file formats including STL, OBJ and SolidWorks parts and assemblies. Still, if your work includes importing and exporting a lot of meshes to and from CAD applications, you'll probably want to look into the Power Translators plug-in, which facilitates importing and exporting standard CAD file types.

Want to see how well MODO integrates into your workflow? You can download a free 30-day trial version at thefoundry.co.uk/products/modo/trial/. **DE**

Contributing Editor **Mark Clarkson** *is* DE's *expert in visualization, computer animation, and graphics. His newest book is Photoshop Elements by Example. Visit him on the web at MarkClarkson.com or send e-mail about this article to DE-Editors@deskeng.com.*

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For more information on this topic, visit deskeng.com.

Lenovo ThinkStation P300 Provides Power in a New Package

Desktop Engineering tests the first entry-level offering in Lenovo's new P Series workstation lineup.

DAVID COHN

Lenovo made several major announcements in August at SIGGRAPH 2014, including the launch of an entirely new ThinkStation P Series. But the first system in this new series — the entry-level P300 — was actually unveiled in May, and both tower and small form factor models began shipping in June. Although as of this writing other models in the new P Series have not been released, we recently received a Lenovo ThinkStation P300 tower and put it through its paces to see how it would perform under common design enigneering workloads.

With its new chassis design, the P300 marks the first entry-level system in Lenovo's new ThinkStation workstation series.

The Lenovo ThinkStation P300 tower boasts an entirely new design that delivers a great deal of flexibility. Measuring 6.9 x 16.9 x 14.8 in. (W x D x H) and weighing just 20.5 pounds, the P300 is smaller than the entry-level S30 that we assume it will eventually replace (see *DE* November 2012: deskeng.com/de/?p=2959) One reason for the reduction in both size and weight is the replacement of the removable front handle. Instead, the new P Series chassis features an extended lip in the front and back for easy carrying, with the front lip incorporating a red touch point, something that will become more prominent in other P Series workstations Lenovo will release in the months to come.

The front panel of the P300 also features a new FLEX Module that gives users the option to add only the components they need, allowing customized configurations that incorporate ultra-slim optical drives, 29-in-1 card readers, iEEE 1394 Firewire and eSATA. In our evaluation unit, the FLEX Module contained a standard 5.25 in. DVD+/-RW optical drive while a second 5.25 in. drive bay remained empty and the third bay contained a single-slot SD card-reader, two USB 3.0 ports, headphone and microphone jacks, a hard drive activity indicator, and a round power button and adjacent power indicator. The rest of the front panel below the FLEX Module consists of a perforated metal screen that sports the ThinkStation logo.

The rear panel provides a 9-pin serial port, four USB 3.0 ports, a pair of USB 2.0 ports, an RJ45 network jack, audio jacks for line-in, line-out and microphone. There is a 15-pin VGA port as well as a pair of DisplayPort connectors for those models lacking discrete graphic cards, but our system came with an NVIDIA Quadro K4000 graphic processing unit (GPU). There are also knock-out panels for PS/2 keyboard and mouse connectors and an additional serial port available on some models.

After removing two non-captive thumb screws, we removed the left side-panel by pressing a round button and revealed a well-organized interior with easy access to all components. The single CPU socket in our evaluation unit housed a 3.6GHz quad-core Intel Xeon E3-1276 v3 processor, but Lenovo offers a choice of 16 different CPUs, ranging from the Core i3-4350 at the entry-level to the 3.7GHz Xeon E3-1281 v3. The Intel Xeon E3-1276 v3 CPU has an 8MB cache, a maximum turbo speed of 4.0GHz, support for PCIe 3.0, and a thermal design power (TDP) rating of 84 watts. It also includes Intel HD Graphic P4600 and adds $370 to the P300 base price. CPU cooling is provided by a large heat sink and a dedicated cooling fan.

Four memory sockets adjacent to the CPU support up to 32GB of memory. Although the base configuration comes with just 4GB of 1600MHz RAM, our evaluation unit came with 8GB, installed as a single 1600MHz ECC uDIMM, adding $380 more to the base price.

The motherboard also provides a total of four expansion slots: two full-length PCIe 3.0 x16 slots (one of which is only x4 electrically), a full-length PCI card slot and a half-length PCIe x1 card slot. One of the x16 slots in our evaluation unit was filled with the aforementioned NVIDIA Quadro K4000, a high-end graphics accelerator with 3GB of discrete GDDR5 memory and 768 CUDA cores. The K4000 provides its own dual-link DVI-I connector and two DisplayPorts. Although its 80 watt power consumption requires an auxiliary power connection, it occupies just a single slot, so three others remain available for future expansion. Since receiving our evaluation unit, Lenovo has started offering the newer NVIDIA Quadro K4200 GPU as its top-level video adapter, as well as other NVIDIA NVS and Quadro boards.

The Lenovo P300 provides two 3.5-in. internal drive bays with quick-release acoustic dampening rails as well as space for an internal mSATA solid-state drive. Our evaluation unit came with a 3.5-in. 1TB Seagate hybrid hard drive. Other options include standard SATA drives up to 4TB and solid state drives up to 512GB capacity.

Power is provided by a 450 watt 92% efficient power supply. In spite of fans on the CPU, graphics board, and power supply, and additional fans behind the front grill and rear panel, the ThinkStation P300 was virtually silent after its fast initial startup.

Excellent Entry-Level Performance

We have always been somewhat amazed at Lenovo's ability to combine and configure quality components for optimum performance, and the ThinkStation P300 continues that tradition. Thanks to the NVIDIA Quadro K4000 GPU, the P300 yielded excellent scores on the SPECviewperf benchmark, ranking at or near the top for single-socket workstations with standard-clocked CPUs.

On the SPECapc SolidWorks benchmark, the P300 delivered the best scores to date for a single-socket workstation. On the multi-threaded AutoCAD rendering test, however, on which systems with more CPU cores have a decided advantage, the ThinkStation P300 lagged behind other quad-core systems we've tested recently, requiring an average of 64.08 seconds to complete the rendering.

We also ran the new SPECwpc workstation performance benchmark. Because we have only had the opportunity to run this test on a handful of systems and the results vary widely, we still cannot make any meaningful comparisons, but in general the P300 lagged a bit behind the other systems we have tested thus far.

Single-Socket Workstations Compared

		Lenovo P300 one 3.6GHz Intel Xeon E3-1276 v3 quad-core CPU, NVIDIA Quadro K4000, 8GB RAM	Digital Storm Slade PRO one 3.4GHz Intel Xeon E3-2687W v2 eight-core CPU, NVIDIA Quadro K4000, 32GB RAM	HP Z1 G2 one 3.6GHz Intel Xeon E3-1280 v3 quad-core CPU, NVIDIA Quadro K4100M, 16GB RAM	HP Z230 one 3.4GHz Intel Xeon E3-1245 v3 quad-core CPU, NVIDIA Quadro K2000, 8GB RAM	Lenovo E32 SSF one 3.4GHz Intel Xeon E3-1240 v3 quad-core CPU, NVIDIA Quadro K600, 8GB RAM	BOXX 3DBOXX W4150 XTREME one 3.5GHz Intel Core i7-4770K quad-core CPU over-clocked to 4.3GHz, NVIDIA Quadro K4000, 16GB RAM
Price as tested		$2,072	$5,804	$5,918	$2,706	$1,479	$4,273
Date tested		11/9/14	5/10/14	5/3/14	11/24/13	11/10/13	7/31/13
Operating System		Windows 7	Windows 7	Windows 7	Windows 7	Windows 7	Windows 7
SPECviewperf 12	higher						
catia-04		38.19	34.81	42.23	n/a	n/a	n/a
creo-01		34.31	33.15	30.82	n/a	n/a	n/a
energy-01		0.65	0.60	1.74	n/a	n/a	n/a
maya-04		32.31	31.28	33.79	n/a	n/a	n/a
medical-01		12.38	10.75	10.34	n/a	n/a	n/a
showcase-01		22.64	20.65	21.12	n/a	n/a	n/a
snx-02		36.79	34.12	40.37	n/a	n/a	n/a
sw-03		69.37	50.78	38.66	n/a	n/a	n/a
SPECviewperf 11	higher						
catia-03		67.84	69.41	63.80	46.17	25.14	72.37
ensight-04		48.80	47.76	61.56	29.32	15.47	49.20
lightwave-01		88.54	76.90	82.76	87.98	75.52	100.78
maya-03		132.59	101.12	128.09	92.05	51.32	131.31
pro-5		21.34	16.29	17.18	20.25	15.61	24.74
sw-02		72.05	63.66	67.75	57.32	41.99	78.27
tcvis-02		55.66	54.26	58.99	38.78	23.74	55.73
snx-01		53.24	52.98	65.58	34.09	19.56	53.95
SPECapc SolidWorks 2013	higher						
Graphics Composite		6.29	5.37	5.67	4.38	3.14	5.25
RealView Graphics Composite		6.88	5.90	6.16	4.69	3.09	5.38
Shadows Composite		6.89	5.85	6.13	4.68	2.96	5.36
Ambient Occlusion Composite		9.65	9.46	8.48	5.81	2.90	5.63
Shaded Mode Composite		6.17	5.30	5.55	4.75	3.25	5.12
Shaded with Edges Mode Composite		6.41	5.45	5.79	4.04	3.02	5.38
RealView Disabled Composite		4.39	3.70	4.08	3.35	3.31	4.74
CPU Composite	ratio	4.18	3.70	3.12	4.15	4.27	4.07
Autodesk Render Test	lower						
Time	seconds	64.08	38.25	45.00	49.00	48.66	42.00

Numbers in blue indicate best recorded results. Numbers in red indicate worst recorded results.

Lenovo pre-loaded Windows 7 Professional 64-bit. Windows 8.1 Pro 64-bit is also available. Like other Lenovo workstations, the new ThinkStation P300 comes with a three year on-site warranty. A 104-key USB keyboard and USB optical wheel mouse come standard, with other keyboard and pointing devices available. The system is independent software vendor (ISV) certified for applications from Adobe, Autodesk, Dassault Systèmes, PTC, Avid and Siemens.

With a starting price of just $729, the Lenovo ThinkStation P300 tower provides power and stability in an affordable, entry-level ISV-certified tower workstation perfectly suited for CAD. While its base price includes just 4GB of memory and integrated Intel graphics, our evaluation unit — which included 8GB of ECC memory, a more robust CPU, a high-end NVIDIA GPU, and a 1TB hybrid hard drive — cost just $2,072, making the new Lenovo ThinkStation P300 a well-designed, powerful workstation at a very affordable price. **DE**

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INFO ➜ Lenovo: Lenovo.com

Lenovo ThinkStation P300

- **Price:** $2,072 as tested ($729 base price)
- **Size:** 6.9 x16.9 x14.8 in. (WxHxD) small form factor desktop/mini-tower
- **Weight:** 20.5 pounds
- **CPU:** 3.6GHz Intel Xeon quad-core E3-1276 v3
- **Memory:** 8GB DDR3 ECC at 1600MHz
- **Graphics:** NVIDIA Quadro K4000
- **Hard Disk:** 1TB Seagate 3.5-in. hybrid SSHD
- **Floppy:** None
- **Optical:** 16X DVD+/-RW
- **Audio:** Integrated HD audio (front panel: microphone, headphone; rear-panel: line-in, line-out, microphone)
- **Network:** Integrated gigabit Ethernet, one RJ45 port
- **Modem:** None
- **Other:** Six USB 3.0 (2 front/4 rear), two USB 2.0 ports (2 rear), one 9-pin serial, one 15-pin VGA and two DisplayPorts (for integrated Intel HD graphics), SD card reader
- **Keyboard:** 104-key Lenovo USB keyboard
- **Pointing device:** Lenovo USB optical wheel mouse
- **Power Supply:** 450 watts, 92%
- **Warranty:** Three years parts and labor

Volvo Drives NVH Simulation Forward

Volvo Cars has long recognized the importance of leveraging noise, vibration and harshness simulation software to improve its vehicles.

BY FRANK J. OHLHORST

One of the most important customer-facing elements of any new vehicle is NVH (noise, vibration and harshness). NVH directly impacts the customer experience and helps identify the quotient of quality put into the design and construction of a new automobile.

NVH is such an important part of new vehicle design that today's auto manufacturers invest millions of dollars into engineering solutions to simulate NVH before moving a vehicle into production. Swedish auto manufacturer Volvo Car Corporation is no exception. Volvo Cars has made significant investments into both HPC (high-performance computing) hardware and CAE software to support its engineering teams' quest to master NVH.

Volvo Cars' Andrzej Pietrzyk, advanced engineering leader, Body and Vehicle NVH CAE, says his group uses several different products to focus on their core tasks of supporting new product development.

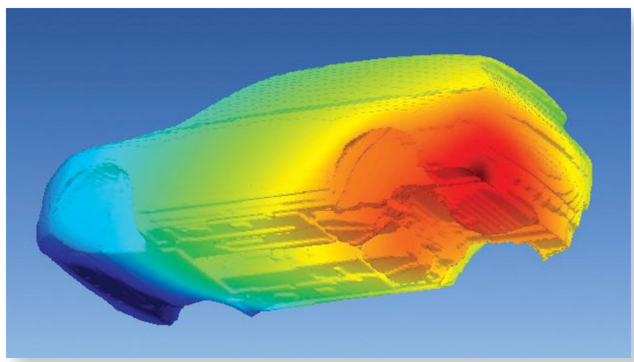
"In NVH CAE, the focus of MSC Software products is on body NVH, so the typical analyses are evaluating the dynamic stiffness, vibration transfer functions, noise transfer functions and acoustic transfer functions," he says.

Volvo Cars has adopted several modules from MSC, including Nastran, 2013.1 and 2014.0, MSC Actran v14.1, v15.0, MSC Adams, and MSC Marc and other modules. Naturally, running all of those modules takes some serious computing power, explains Pietrzyk.

HPC for NVH

"Currently, we have a set of multi-node servers, typically using state-of-the-art processors, lots of memory and large advanced disk systems," he says. "We run on 50 nodes, each equipped with double Intel Xeon E5 8-core CPUs, 256GB memory and 5TB fast disk systems."

The goal at Volvo Cars is to be able to perform simulations as quickly as possible, allowing the engineers to delve deeper into the various vehicle designs to determine how changes impact NVH. With simulation processing time a major concern, Volvo Cars has sought out applications that can leverage HPC technology, leading to ongoing selection of MSC's platforms and modules.



Pressure distribution around a car body due to a sound source at the exhaust orifice is pictured.
Image courtesy of Volvo.

Pietrzyk says some typical solution sequences used by his group involve MSC Nastran ACMS, a product that can divide workloads across multiple domains using distributed memory parallel processing.

"For those applications, we can cut the solution time by a factor of 4-5 by running on several hosts simultaneously," he says. "In applications involving the SOL 108 (a select solution sequence in Nastran) procedure, the scaling is linear, meaning that adding more hosts results in the corresponding reduction of the solution time. Running on 16 hosts instead of one leads to the solution time being cut by a factor of 16."

While that proves to be an impressive gain, Pietrzyk explains that additional performance gains will be realized down the road, thanks to innovations in both HPC systems and CAE software solutions.

The Hardware-Software Gap

Yet, leveraging those additional possibilities remains a challenge. Hardware improvements seem to be outpacing software improvements.

"We are concerned with the growing gap between the development direction of the computing hardware and the algorithms

The Power of Three

Volvo Cars is developing a lightweight 3-cylinder engine in Sweden that will require the same high standards for NVH as its other engines.

"We have come a long way in the last few years at Volvo," says Dr. Peter Mertens, senior vice president, Research & Development at Volvo Car Group. "The development program for the new 3-cylinder engine is very advanced, and we have already begun prototype testing of the unit."

The company says the move to include a 3-cylinder engine is the next step in Volvo's strategy of downsizing. Applying new technology and analysis techniques enables more power and better fuel economy from smaller displacement internal combustion engines than ever before, according to the company.

used in the software," Pietrzyk says. "On the hardware side, the development goes into offering massively parallel solutions, with literary hundreds of cores sharing memory, and unlimited possibilities to extend the number of nodes (distributed memory). On the software side, we do not see the corresponding development toward massively parallel processing. We see bottlenecks in the bandwidth of memory access for systems with many cores and in effective utilization of distributed memory solutions."

Pietrzyk currently uses 16-core machines, which he says are not being used efficiently, so moving to even higher numbers of cores becomes an issue. Some algorithms do not scale well over DMP (distributed memory parallel), or are limited in the number of DMP hosts that can be used by a single analysis, he says. For many using CAE, a viable alternative may be to use GP-based GPUs (GPGPUs) to speed up computations. However, Pietrzyk currently discounts that alternative for NVH CAE. "The use of GPGPUs for speeding up computations has been considered, but we haven't seen much effect in our types of simulations yet," he says.

Nevertheless, Volvo Cars has made some great strides applying HPC and MSC's products to the NVH problem.

"The primary issue we use MSC products for at NVH CAE is the study of the vibro-acoustic response of the car body," Pietrzyk says. "The aim is to provide suggestions to the design team on how to resolve the NVH issues. Those issues relate to structure-borne sound transmissions at relatively low frequencies, which could be caused by insufficient stiffness at some attachment points or too high levels of NTFs (noise transfer functions) or VTFs (vibration transfer functions) at some receiver positions."

Pietrzyk says his team recently started looking at airborne issues and incorporating advanced acoustic models. They are working toward supporting the Audio group with simulations concerning the behavior of the loudspeakers when built in into the flexible body.

"Ultimately, our goal is to enable auralization, or the ability to listen to the sound in a yet non-existing car," he says. "That requires looking at transfer functions from sources outside of the vehicle to the response points inside, as well as looking at exterior noise, both intentional (like different warning signals, e.g. signal horn, alarm siren) and unwanted, such as the pass-by noise."

According to Pietrzyk, accomplishing those goals means looking at their traditional MSC Nastran, which recently enriched its acoustics offering, and the newly acquired MSC Actran, which is a dedicated tool for modelling and solving vibro-acoustic problems.

"We are looking for a long-term solution for our needs, and MSC's products, Nastran, Actran, and Adams form a tool that addresses a broad field of applications within NVH CAE group," Piertzyk says. "We hope that those pieces of software will be further integrated with each other, thus simplifying their use and enhancing productivity.

"We are always looking at possibilities to extend the range of problems covered by the simulation and to improve the accuracy of simulations," Pietrzyk adds. DE

Frank Ohlhorst *is chief analyst and freelance writer at Ohlhorst.net. Send e-mail about this article to DE-Editors@deskeng.com.*

INFO → **MSC Software:** MSCsoftware.com

→ **Volvo Cars:** VolvoCars.com

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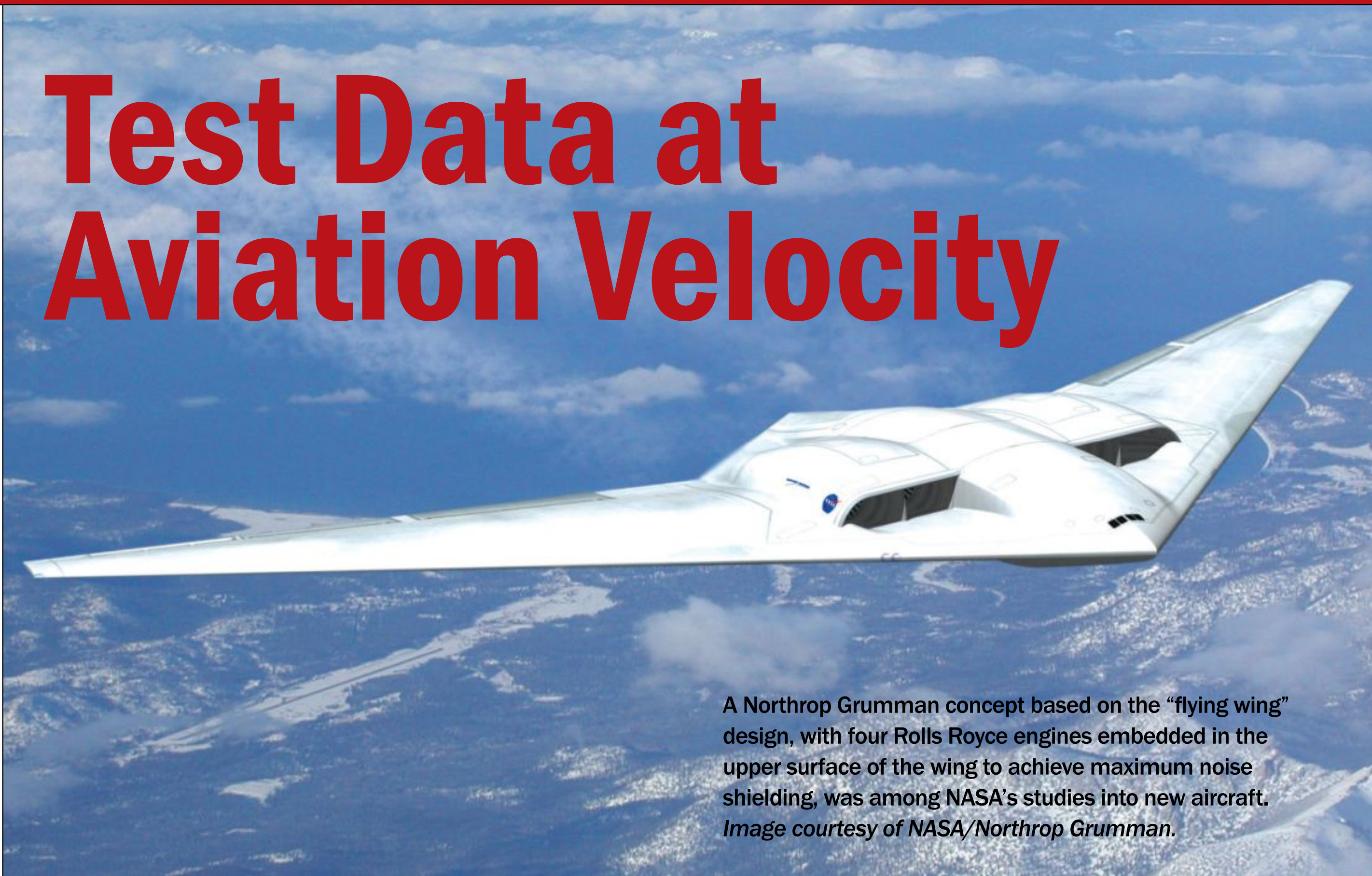
Test Data at Aviation Velocity



A Northrop Grumman concept based on the "flying wing" design, with four Rolls Royce engines embedded in the upper surface of the wing to achieve maximum noise shielding, was among NASA's studies into new aircraft. *Image courtesy of NASA/Northrop Grumman.*

One of the top challenges engineering teams in the aerospace industry face is coordinating data and designs across the globe.

BY JIM ROMEO

United Technologies' Aerospace Systems facility in Troy, OH plans to supply wheels and carbon brakes for Taiwan-based China Airlines. Its equipment will be used in China Airlines' first A350-900 aircraft in 2016.

It's an example of how, in aerospace design and production, the distance between vendor and customer can be any length — next door to thousands of miles away. Capitalizing on dispersed knowledge workers with specialized design and engineering skills, products in the aerospace industry are designed and produced from the best suppliers all over the globe.

The design process includes knowledge workers who are more collaborative than ever. This necessitates advanced applications to coordinate all the necessary steps in the design, testing and production process chain, giving way to advancements in software and database applications that the distributed team can access.

Test Results in Real Time

The swift and accurate completion of mechanical testing is critical, with results being analyzed by others on the team. Its scope ranges from characterizing material properties to validating final products. Ensuring safety is testing's core mission, but testing also plays an important role in contributing to cost-effective design, and technological evolution and superiority.

Various paths in the design process are contingent upon test results. For example, trials and performance data may be the driving factor as to how a design engineer may proceed in developing a plan to extend the life of existing systems and improve the maintenance schedule of equipment. Test and performance data is also used to promptly receive the results of test data to understand the impact of system modifications; in fact, test data may be the driver of a go or no-go design decision.

Additionally, test information and data is used to avoid over-designing and creating complicated designs that adversely impact operational performance, and increase weight and subsequent cost. For these reasons, the speed of data access and data availability is key.

Testing and evaluation is used by independent sources to conduct an objective assessment of components and systems. Vendors and contractors with capable facilities,

ANSYS, Stanford and Honeywell Collaborate on Fuel-Efficient Aircraft Engines

Engineers from Stanford University, Honeywell International and ANSYS are working together with simulation software to create more energy-efficient aircraft engines at lower costs, according to a press announcement.

As demand grows for increased gas turbine efficiency, engine manufacturers are challenged with creating designs that operate at higher temperatures. But that becomes a significant challenge as temperatures approach the melting point of some engine component material. One established method for maintaining turbine blade temperatures at acceptable levels is to employ “film-cooling,” a technique in which cooler, compressor discharge air is detoured around the combustor then ejected from precisely machined holes placed over the surface of the turbine airfoil. Excessive use of compressor air for turbine film cooling can, however, reduce engine efficiency.

Historically, film-cooling-hole-placement on turbine airfoils has been optimized by elaborate experiments, sometimes necessitating engine testing. For decades, research engineers have been developing computer simulations of film cooling geometries with the ambition of reducing — if not eliminating — the need for expensive, time-consuming rig testing.

Stanford, with support from Honeywell and ANSYS, is performing a new type of testing with 3D magnetic resonance velocimetry to measure the velocity and concentration field in a test section. These methods measure the turbulent interaction of crossflow jets with the main flow. These data sets provide a benchmark against which ANSYS turbulence models and computational methods can be compared. The objective is to develop validated models, methods and best practices for prediction of film cooling.

“Our combined efforts are aimed at validating the turbulent mixing models in these tools over entire complex flow fields, something that has never been done before,” said John K. Eaton in a press statement. Eaton is the Charles Lee Powell Foundation professor in Stanford’s School of Engineering. “Conducting this testing over a wide range of film cooling conditions provides a comprehensive test of the predictive capability.”

MIT and NASA engineers test a 1/11th scale model version of the D8 airliner concept in the 14-by-22-ft. Subsonic Wind Tunnel at NASA's Langley Research Center. *Image courtesy of NASA Langley/Kathy Barnstorff.*

equipment and skills provide such testing.

The real-time access of performance testing data is a significant advantage to a dispersed design team. Because teams collaborate virtually, often across different time zones, data must be shared efficiently. One entity's progress in design project may depend on ready access to performance and test data.

Bringing Data Together

This demand has driven firms like Intertek to develop products that address the need for data sharing and collaboration.

The company recently introduced eReporting Pro. This software enables inspection data and reports to be promptly available after their completion. Traditionally, data reporting for performance testing and evaluation takes time to complete, then put into the proper discernible format, and made available. eReporting Pro allows the report data to be aggregated while at the customer's worksite. Accurate reports are generated in real time as they are completed, according to the company.

Intertek's user interface is tablet-friendly. Data may be entered locally on the floor of the test site and the results sent while at the customer's facility.

Airbus, which has about 52,000 people at 16 sites in France, Germany, the UK, and Spain, has followed suit with another vendor. The company relies on partnerships with major companies around the world and has a network of 1,500 suppliers in 30 countries. Airbus manufactures the A380, the largest passenger jet in the world. It consistently captures around 50% of all commercial airliner orders, and it has about 6,700 aircraft in service. To expedite and improve their time-to-market, it recently deployed Oracle Secure Global Desktop for access to secure test flight performance data, available in real time.

Such reports are valuable in making supply chain decisions promptly. Specifc parts, components, material and composites are specified with regard to weight, cost, tem-

Performance Testing For All

Dassault Systèmes has developed a collaborative test platform called Test To Perform. This application focuses on key needs for today's aerospace design teams and demonstrates a solution to the growing demand for accurate and real-time test data. Stakeholders participate virtually to access critical test and performance data for successful project management and design accomplishment.

In contemporary engineering design, data silos are everywhere, and are often not linked, causing disjointed and awkward communication between teams. United Technologies may design and fabricate components in Ohio for China Airlines customers in Taiwan or other Asian locations. However, communicating between all players, in real time, may be a challenge. Companies have vendors, suppliers and cross-functional teams located in distant geographical locations. In addition, many subject matter experts may be sole participants contracted for their expertise and working from a remote location. All are key players in the complex and sophisticated designs of today's globally competitive aerospace market.

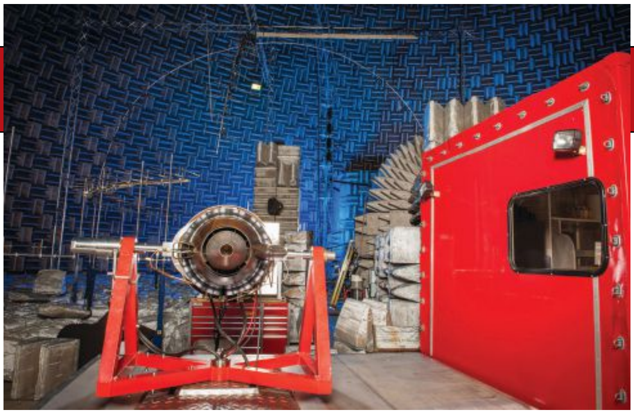
Material, equipment and system testing is commonly contracted to companies and organization with specific test equipment and competencies that allow things like fuel tanks, lighting susceptibility, shock testing and other requirements to be accomplished. However, a firm may be located anywhere — and sometimes near a project facility where other designers are not located. Thus, the test facility may have easier access to the material and equipment being tested, but the rest of the design team may not.

The disparity of design professionals has been a longstanding challenge to design team harmony. With significant disparity, design projects may not progress as well as they could or as quickly as they should.

Dassault's Test to Perform was developed to address these concerns and integrate test teams with engineering and program management professionals. It helps break down the "silo effect" and provide accessible, real-time visibility for all. It also provides an audit trail of what was tested when and how. Through Dassault's visual capabilities, digital mockups may be viewed and used by the team.

For example, design professionals are able to simulate actual cockpit conditions and ultimately govern the test process using a lean model. This subsequently improves efficiency, keeps programs and projects on budget and schedule, and delays costly back tracking.

Test To Perform is a specific solution that enables sharing services and collaboration among engineering teams. This, in turn, unifies communication among cross-functional groups involved in the design process, and can lead to a more efficient and cost-effective design process.



The aero-acoustic propulsion lab at the NASA Glenn Research Facility in Cleveland includes an anechoic testing environment for engine component research and development that is 65 ft. high and 130 ft. in diameter. ***Image courtesy of NASA.***

perature, tensile strength and other parameters, based on performance test data. Designers validate their designs with the performance test data.

National Technical Systems Inc. (NTS), a provider of test and engineering services, offers similar solutions. An enhanced version of NTS' LabInsight web application was developed to meet customer demands for secure access to reports and other important data used in the engineering design process.

The portal was created in compliance with ITAR (International Traffic in Arms Regulations) to enable sensitive data access. "NTS was the first testing and engineering services company to create a secure, online customer portal six years ago and it has evolved to become a valuable tool for our customers," said Jason Youmazzo, director, Customer Experience.

"Much like the banking industry, the airline industry and other service providers that communicate regularly with customers through web-based applications, our LabInsight application will deliver 99% of all our work-related information to our customers," Youmazzo added. "Our focus ... is to provide instantaneous access for our customers to all data, project reports, project status, testing progress and video; in short, everything that we do for them. We know from our customers that this provides tremendous value when we are running tests and saves an incredible amount of time, while creating a seamless collaborative effort." **DE**

Jim Romeo *is a freelance writer based in Chesapeake, VA. Send e-mail about this article to DE-Editors@deskeng.com.*

INFO ➜ Dassault Systèmes: 3DS.com

➜ **Intertek:** Intertek.com

➜ **NASA:** NASA.gov

➜ **National Technical Systems, Inc.:** NTS.com

➜ **Oracle:** Oracle.com

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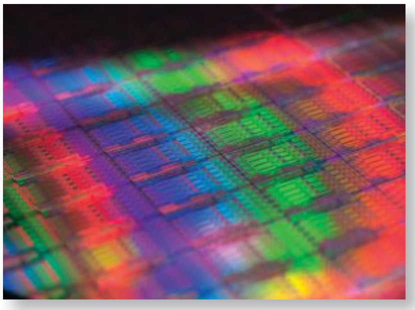
by Anthony J. Lockwood

Editor's Picks

Each week, Tony Lockwood combs through dozens of new products to bring you the ones he thinks will help you do your job better, smarter and faster. Here are Lockwood's most recent musings about the products that have really grabbed his attention.



New Xeon Processors Accelerate Data Centers

Intel technology supports greater performance and virtualization.

With up to 18 cores per socket and 45MB of last-level cache, the Intel Xeon E5-2600 v3 family delivers up to 50% more cores and cache compared to the previous processor generation. It also has something called Intel Advanced Vector Extensions 2 (Intel AVX2). This extension doubles the width of vector integer instructions to 256 bits per clock cycle for integer-sensitive workloads and, according to Intel, delivers up to 1.9 times higher performance compared to earlier generations. The processors also support up to 70% more virtual machines per server.

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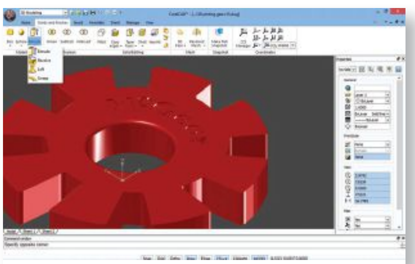

CorelCAD 2015 Released

Parametric and in-text editing tools are now included in the platform.

A notable capability introduced in the Windows edition of CorelCAD 2015 is parametric drawing constraints. This functionality lets you apply dimensional constraints to ensure 2D designs meet exact proportion, angle and size requirements. You can also use geometric constraints to control dependencies and relationships between objects.

Corel also enhanced CorelCAD's customizable Windows ribbon user interface. It has new contextual ribbon options for selecting and using various tools, such as its in-place text editing tools.

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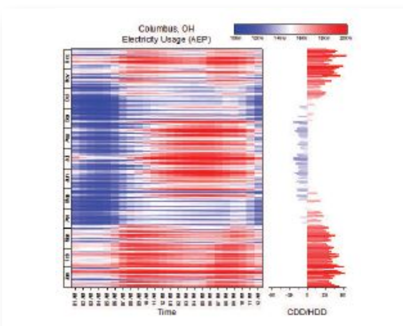

Data Analysis, Graphing and Presentation Suite Improved

Updated Origin platform offers new graphs and analysis functions.

The 2015 release of Origin and OriginPro introduces more than 100 new features and upgrades compared to its immediate predecessor, including several ease-of-use enhancements recommended by users. The Origin 2015 version of the Project Explorer feature for helping you organize projects sees a number of improvements, including a new find and search functionality that enables users to locate a string anywhere in a project.

New analysis and statistics capabilities in Origin 2015 include repeated measure ANOVA tools that support unequal sample sizes.

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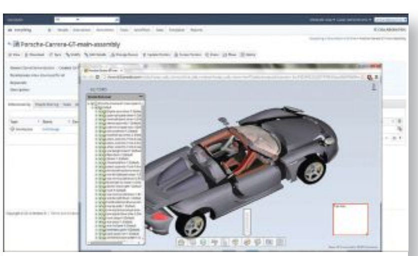

Document Management, Sharing Merge in the Cloud

Product Document Management system adds file vaulting functionality.

Kenesto reflects a personal cloud paradigm throughout its features. Its user interface offers a customizable dashboard that provides you with ready access to documents and information. You can drag and drop documents from your desktop directly to Kenesto. You can also edit Microsoft Word, PowerPoint or Excel documents in the cloud.

Kenesto's new vaulting feature merges the document check-in and check-out functionality with the ability to synchronize documents between your desktop device and Kenesto.

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Commentary

by Svante Littmarck

Modeling and Simulation for **Everyone**

Scientists like Newton, Maxwell and others have given us the mathematical models, the "laws of science," that make it possible to accurately predict how physical objects and systems will develop in space and time given certain boundary conditions and initial conditions. Applied mathematicians have invented numerical methods that can generate numbers and graphics to accurately describe how such objects and systems would develop in space and time.

This makes it possible for us to simulate, modify parameters and ultimately make a better — if not the best — design.

The physics, the math, the computational tools and the engineering community are all in place to achieve wonders using simulation. Sending exploration vehicles to the surface of Mars that report back to Earth, creating communication devices like cell phones and GPS are just two examples.

> **Computational tools are so complicated to use that there are very few engineers trained to do it ...**

Many breakthrough technological innovations have seen daylight in the last several decades. But many areas that would benefit greatly remain almost untouched by the powerful computational tools available today. Why is this?

The Obstacles

It is a fact that current computational tools are so complicated to use that there are very few engineers trained to do it — at least compared to the number of potential beneficiaries.

The setup of mathematical models needs to be done by a mathematician or a physicist. Model simplifications are necessary in order to save computational time, memory and solution data management. Negligible phenomena should be ignored. The phenomena that should be ignored depend on the application and what is to be achieved. This requires a modeling expert.

Once the model is set up, solving the equations numerically means replacing the continuous differential equations, space and time, with discretized difference equations and points in space and time. The discretization must be done in such a way that the solution to the difference equation converges to the solution of the differential equation. Otherwise, it has no physical meaning. Additionally, in order to obtain an accurate solution, the discretization must be fine enough. There are theories for good default numerical solver settings for many physics areas, but they are not all the same. It sometimes takes a numerical analysis expert to define the solver settings.

As a result, the typical user of a simulation package is someone who holds a Ph.D. or an M.Sc. and has several years of experience in modeling and simulation. The user also underwent thorough training to use the specific package. He or she typically works as a scientist in a big organization's research & development department. It is up to that person to employ his or her expertise to create and validate the model and the simulation.

This all means that a small group of people is servicing a much larger group of people working in product development, design or production. Simulation models are oftentimes so complicated that the person who implemented the model is the only one who can safely provide the input data needed to get useful output. Hence, we have a bottleneck.

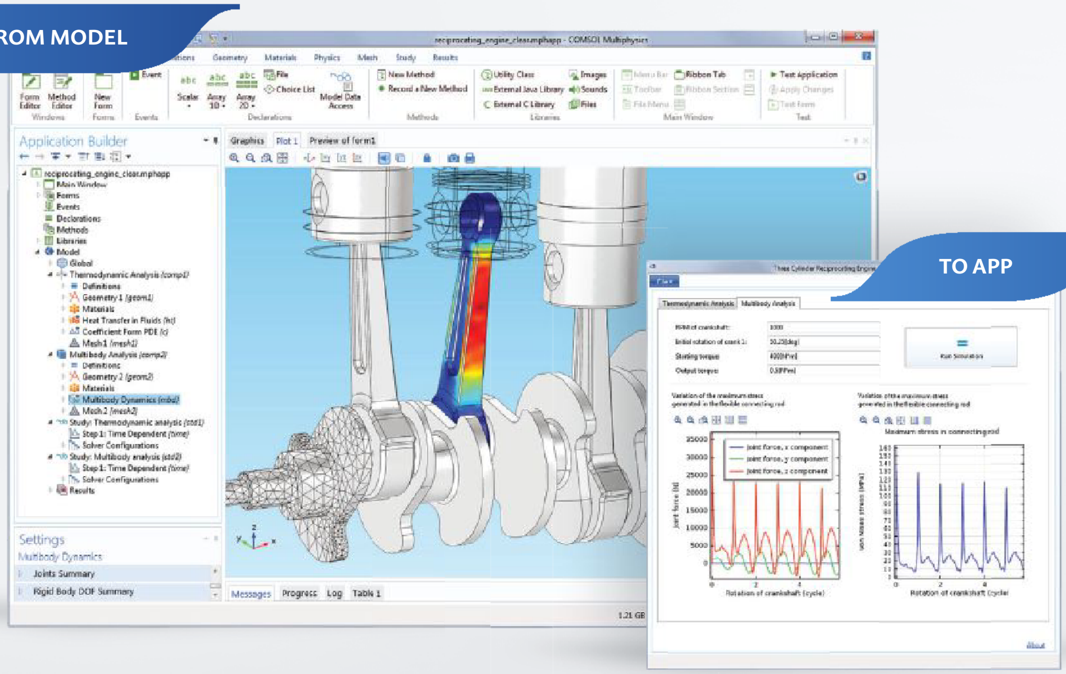
The Solution

In order to make it possible for this small group to service a much larger group, there is an obvious solution: Create a simulation package that makes it possible for the simulation expert to build an intuitive and specific user interface for his or her otherwise general model — a ready-to-use application. The application should include user documentation, checks for "input within bounds," and predefined reports at the click of a button. A simulation application with these capabilities makes it possible for a user to avoid accidental input errors while keeping the focus on relevant output details. The application can then be shared with a larger group of users.

Making this happen is easy compared to the achievements listed in the beginning of this article. It is happening as you read this.

The spread of such applications will be immediate. No design engineer will want to be left behind. No company can afford to let their competitor get an advantage through earlier adoption. Eventually consumers will be running simulation applications to make better purchase decisions. **DE**

Svante Littmarck *is co-founder and CEO of the COMSOL Group and the president and CEO of COMSOL, Inc. He can be reached via comsol.com.*



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