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Technology for Optimal Design Engineering

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FOCUS ON: Advanced Materials P.12

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by Jamie J. Gooch

If It Ain't Broke, Improve It

It never fails. Just when I have reached full-blown master guru level with a piece of complicated software, the vendor releases an update intended to make my workflow more efficient. In the long run, I know it will. The run might not even be that long. Still, part of me is reluctant to hit that update button. Whether it's a fear of the unknown, the comfort of complacency or feeling like I don't have enough time to learn one more new thing, I hesitate.

I'm not alone. The more design engineers I talk to, the more I realize how hard it is to escape the status quo. On a personal level, their reasons seem justified. Maybe they're approaching a certain age or point in their career where they'd rather be the technology expert than the amateur. Maybe they blame internal politics for a lack of investment in new technology. Or maybe they think they've got it all figured out — that their work is good enough.

On a higher level, those reasons sound a lot more like excuses for why an organization is falling behind the technology curve. The reticence to try something new applies to all types of new technologies. If it isn't conquered, it can stifle innovation and put an entire organization at a competitive disadvantage.

The technology needed to expand the use of new materials is at a tipping point in many industries.

A Material Matter

Our focus in this issue is a perfect example of a cultural conversion challenge for many organizations: materials. The very essence of the products you engineer — whether end users describe them as cheap, durable, flimsy or light — depends largely on the materials from which they're made. Changing materials is not a decision to be taken lightly. It affects how a product is designed, simulated and tested. It can have a dramatic impact on costs, manufacturing time and techniques, and the greater supply chain. In short, the decision to move away from tried-and-true materials to something new could affect every stage of a product's development and lifecycle.

That's a scary thought for anyone, which is why you should consider it. Being the first to roll out a lighter, stronger, more durable product via the use of new materials is a considerable barrier for your competitors to overcome. For evidence, look no further than the aerospace industry's recent rush to 3D-printed parts, or the automotive industry's move to lighter materials like aluminum and composites. Customer demands and government regulations for fuel economy, plus cost savings associated with consolidating assemblies into fewer parts add up to using materials in new ways and forcing competitors to do the same.

As leading industries blaze the trail in new material uses, the associated technologies to simulate, test and manufacture products using those materials continue to advance. The level of knowledge and technological infrastructure needed to expand the use of new 3D printing materials, and to use composites and high-strength alloys in new ways is reaching a tipping point in many industries.

Lessons Learned

If you're playing catch up on the materials front, you can fast track your education by joining the new public-private partnerships that are part of the National Network for Manufacturing Innovation (NNMI). Several deal with materials, including America Makes, which focuses on 3D printing; the Institute for Advanced Composites Manufacturing Innovation (see page 36 for more information); Lightweight Innovations for Tomorrow, which focuses on lightweight metal manufacturing; and the Flexible Hybrid Electronics Manufacturing Innovation Institute. Each of these institutes receive federal funding via NNMI and are aligned with academia. They share the goal of bringing research to practical industry applications.

Other new material resources include industry trade associations like WorldAutoSteel, The Aluminum Association and the American Composites Manufacturers Association; other government agencies, including NASA and the National Science Foundation's Division of Material Research; and universities. There is a lot of momentum behind the application of new materials.

DE is bringing some of the leaders of that momentum together Oct. 27 for an online discussion of the challenges involved in simulating and manufacturing advanced materials, 3D printing metals and composite parts, and new methods for bonding different materials. *DE* Senior Editor Kenneth Wong will moderate a panel of experts from the Institute for Advanced Composites Manufacturing Innovation, Oak Ridge National Laboratory: Metal Additive Manufacturing, and the Automotive Composites Alliance. Visit deskeng.com/de/newmaterials to register for the webcast. Think of it as your opportunity to break out of the status quo and overcome any reticence to trying new technologies. **DE**

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

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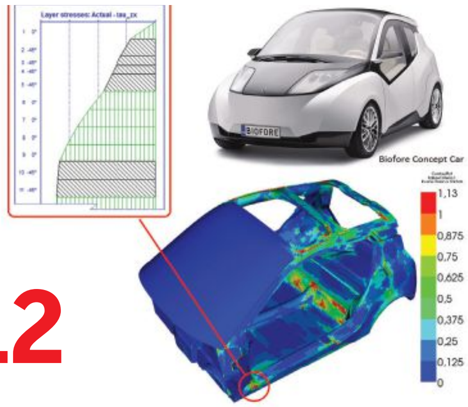

ENGINEERING COMPUTING

DESIGN

ON THE COVER: New materials bring new engineering challenges. Background image courtesy of ESI Group, foreground images courtesy of Dow Automotive, BMW and Stratasys.

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FOCUS ON MATERIALS

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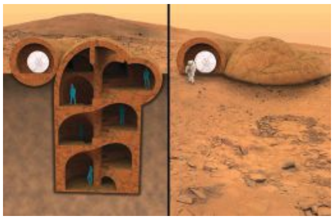

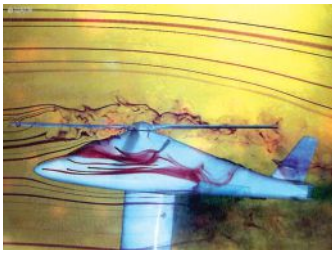

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The HPC Handbook consists of:
- Magazine article excerpts;
- The hpc.deskeng.com website; and
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BPA WORLDWIDE

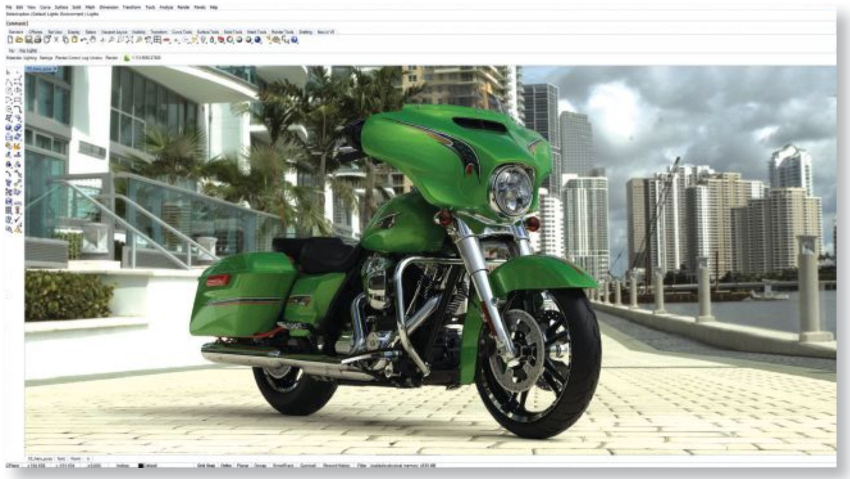
by Kenneth Wong

NVIDIA Launches DesignWorks Suite

At NVIDIA's pre-SIGGRAPH press briefing, the concept of a digital twin took on new meaning. At the reception in the J.W Marriott hotel in downtown Los Angeles, Dr. Steven Parker, NVIDIA's vice president of Professional Graphics, stood before what appeared to be a pair of images of the same object: an 18-volt DeWalt power drill.

"You see two images. One of them is real; one is rendered. Up close and personal at 10-ft.-tall, you might be able to tell, you might not," Parker said. The point of the side-by-side comparison of the photo and the rendered image, he explained, is not to fool the audience, but to show how faithful ray-tracing can be to reality. It gives you assurance that "if you design and expect a product to look [a certain way], you will not be surprised by what it looks like when it's finished," he says.

The digital image is modeled in Autodesk 3dx Max software, rendered in NVIDIA Iray on a Windows workstation powered by Quadro M6000 GPUs, according to an NVIDIA blog post (blogs.nvidia.com/blog/2015/08/11/photorealistic/).



2015 Harley-Davidson Street Glide rendered in Iray for Rhino. *Production data courtesy of the Harley-Davidson Motor Company.*

Real-time Visualization

With the stage set, Dr. Parker introduced NVIDIA DesignWorks. He described it as "a suite of libraries, algorithms and tools to bring this capability to your software. It includes our best technology for rendering, material, display and virtual reality. This is the software we use to build our own products."

On the product's home page, NVIDIA said DesignWorks is "designed specifically for developers creating professional graphics and advanced rendering applications." The collection includes "NVIDIA OptiX for building ray-tracing applications, NVIDIA Material Definition Language (MDL) for sharing materials between applications, and more than 20 other tools for creating, visualizing and sharing digital designs." NVIDIA offers a similar suite for software developers catering the media and entertainment market. The company released NVIDIA GameWorks in March 2014.

For CAD developers, DesignWorks components like Iray SDK (software development kit), MDL SDK, and the vMaterials library offer a chance to bolster the real-time visualization and realistic depiction of manufacturing materials in their modelers. Dassault Systèmes and Autodesk are among software developers that have integrated some of the technologies featured in DesignWorks.

Virtual Reality on the Horizon

DesignWorks VR, a comparatively new offering, anticipates a market for virtual reality-driven design, an area that remains speculative and limited for the present. A segment of the large automotive manufacturers, well-funded research firms, and government agencies deploy such technologies in immersive CAVE environments. But for mainstream 3D software makers, the amount of effort required to integrate gesture-based modeling and stereoscope visuals represents a barrier.

"Gaming, visual effects and design are all in the midst of a revolution — it has to do with physically based rendering," says Parker.

To spare the CPU of the compute burden, CAD software packages traditionally display complex assembly models in bright, exaggerated colors that are easy to render but highly unrealistic. "We affectionately call them clown colors," says Parker. However, the prevalence of GPUs and multi-core CPUs in modern workstations puts more compute capacity at the users' disposal. The technologies bundled in NVIDIA DesignWorks suggest a change is coming. Design software of the near future might display 3D models in ray-traced mode by default.

Automate Lattice Generation

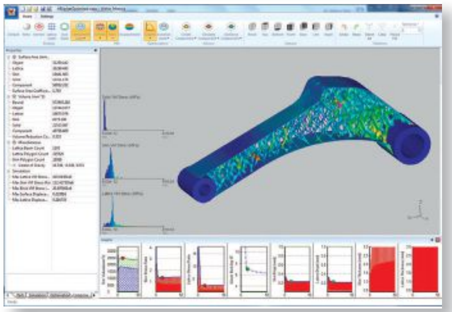
Mechanical parts are usually constructed with circles, lines, rectangles and symmetrical curvatures. Mainstream software in the mechanical design market reflect this with their surfacing and solid modeling tools. In this sense, Autodesk Within is a breakaway from the tradition. Its tools are designed for modeling lattices, the microstructures that prove incredibly difficult to produce with traditional modeling methods.

Autodesk describes Within as "generative design." For those who may be unfamiliar with the term, generative design relies on algorithms and built-in rules to facilitate computer-assisted modeling. In this case, the method is used to generate lattice structures, which are nearly impossible to model manually one bar at a time, one joint at a time.

Within works best when you have a shape with well-defined topology that you want to populate with lattices. Once the shape is imported, you can use Within's lattice library to define the type of microstructure you'd like to apply to your design, define the surfaces that serve as enclosures, then let the software automatically fill the geometric volume with lattices.

Optimize Lattices

The software comes with Nastran solver, so you can run stress and structural analysis on your lattice design to further understand where it's weak, vulnerable and might need reinforcement. The optimization tool is perhaps the best feature of the software. Once you have run a simulation session, you can ask the software to regenerate the design with what is numerically optimized lattice distribution. Some of the answers you get from the software might confirm your intuition. Others might surprise you, leading you to rethink your design in a whole new way. With this approach, you might also stumble on new design options that involve organic, playful shapes, as a consequence of the software's optimization algorithms.



Autodesk Within comes with a Nastran solver, so users can run structural analysis to optimize their lattice design.

In the past, even if you could design lattices, they could not be manufactured using traditional machining. But 3D printing has removed that barrier. For more on Within, see page 50.

VMWorld 2015: NVIDIA's GRID 2.0

Earlier this year, analyst firm IDC published a white paper titled "Driving Business Value with Desktop Virtualization." To the excitement of advocates, IDC estimated, "Every $1.00 invested in migration to CVD (centralized virtual desktop) will yield $4.51 in return for a ROI (return on investment) of 351%."

IDC wrote: "Organizations migrating from a traditional PC environment to CVD face an initial investment of $539 per user, which includes the costs for virtualization software as well as servers, cages, racks, space and installation to support the back end. The combined benefits of the CVD environment — lower annual infrastructure costs, lower staff support costs and lower user productivity costs — will pay for the initial migration in around six to seven months."

If you think PC and workstation vendors are quivering in fear of the trend, you'd be wrong. The paper is, in fact, sponsored by HP. It suggests leading hardware providers know they cannot hope to stem the tide. Many have decided to ride the wave instead.

GRID 2.0: Host 2X the Users

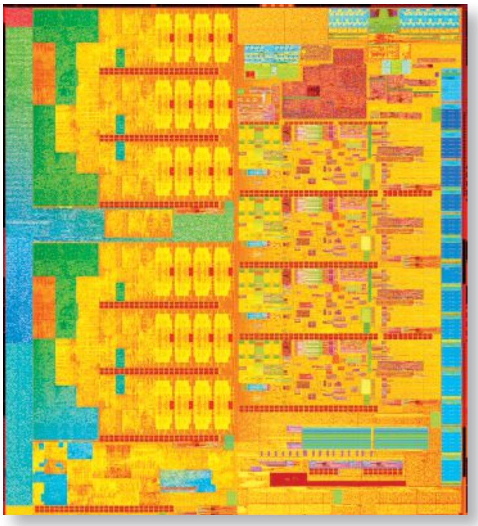
At VMWorld in San Francisco's Moscone Center last month, GPU (graphics processing unit) maker NVIDIA launched Grid 2.0, a GPU-powered virtual desktop infrastructure (VDI) solution for enterprises. Version 2.0 is marked by, among other improvements, the addition of Linux OS support and increased density in capacity. "Linux is big in automotive and manufacturing, especially for analysis," says Will Wade, product manager for GRID at NVIDIA.

According to NVIDIA, GRID 2.0 "doubles user density over the previous version." The hardware can host more virtual machines. "We have run benchmark studies on our (Tesla) M60 cards, supporting up to 32 virtual machines. That doubles the number of users we previously supported with the K2 cards. You now get the same level of performance with twice as many users," says Wade.

With GRID 2.0, NVIDIA began supporting blade servers for the first time. HP, Dell, Lenovo and Cisco are among the vendors offering Grid 2.0 products. Previously, the use of VDI may have been confined to entry-level and mid-range design software users, but Wade said: "We're beginning to see an expansion of usage. Now, with Grid 2.0, you can scale from entry to high-end users."

by Kenneth Wong

The Boundary Between CPUs and GPUs Gets Blurred



The Intel Xeon E3-1200 V4 die. The chipmaker has started integrating Iris Pro graphics into the same chip. *Image courtesy of Intel.*

With the launch of new Xeon E3-1200 V4 processors with integrated Iris Pro graphics, Intel has begun describing its products as more than CPUs. The processor is "a CPU and GPU on the same chip," said Jim Blakley, general manager of Visual Cloud Computing for Intel's Data Center Group.

Iris Pro is a major part of Intel's strategy to drive growth in traditional GPU market segments. (Editor's note: For more details on the GPU market, read *Market Watch* published by JPR, jonpeddie.com.) To speed up graphics-heavy workloads (like ray-traced rendering) and compute-intense workloads (like simulation), engineering and design software users tend to rely on the GPU as a coprocessor to augment the CPU. The GPU's highly parallel nature makes it an attractive device for such applications. However, Intel's CPU with integrated graphics can disrupt the market dynamics, especially for the low-end and mid-range segments.

"Iris Pro graphics is not meant to compete in the high-end GPU market. The performance of Iris Pro is roughly equivalent of a mainstream graphics card," says Blakeley. GPU maker NVIDIA, for instance, offers its NVIDIA Tesla cards to the high-end market, and Quadro cards to the mainstream market, which encompasses CAD software users.

GPUs Not Just for Graphics

In the last four to five years, some researchers and scientists began using the GPU for much more than graphics. In their deployment of high-performance computing (HPC) clusters, they harvest the GPU's parallel processing horsepower to tackle large-scale computing tasks such as pattern recognition, data analysis and weather prediction. To perform such tasks, however, the software has to support NVIDIA's CUDA (compute unified device architecture) parallel processing language. Some CAE software makers have refined their solvers to accelerate on the GPU by adding CUDA support.

Intel's Blakely says software vendors can tap into the additional horsepower in Iris Pro-based CPUs with little or no additional work. "If the application is written to use OpenGL or DirectX, then Iris Pro works without any additional programming effort. NVIDIA also supports OpenGL and DirectX. These are graphics programming APIs (application programming interfaces). If you want to do things that are more compute-oriented, then we support OpenCL programming on the GPU. This is the direct comparison with CUDA. Whereas CUDA is a proprietary NVIDIA programming model, OpenCL is an industry standard" he says.

For highly parallel applications, computer users are expected to continue to rely on the NVIDIA Tesla GPU or its equivalent. However, if software programs can take advantage of Iris Pro's additional horsepower without much effort, it's set to challenge the GPU's dominance in visualization-related tasks like image editing and 3D modeling.

Workstation users may also split their workload on the two GPUs in the same machine. "You can use one of those GPUs for graphics, another for compute-intensive work," says Blakely.

Competition is Good for Engineers

Whereas Intel's Xeon E3-1200 V4 with integrated Iris Pro graphics represents a CPU market leader's penetration of the GPU's territory, NVIDIA's Tegra marked the GPU maker's encroachment of the CPU market. Used in many mobile devices in the market, the NVIDIA Tegra combines an ARM architecture CPU and a GPU into a single system on a chip (SoC).

The boundary between CPU and GPU continues to blur as the two market leaders prepare to move into each other's territories. "Going forward, we'll add substantially better improvement to Iris Pro. We'll be developing more and more GPU features and continuing to increase its performance," says Blakely.

Manufacturing Made Easy

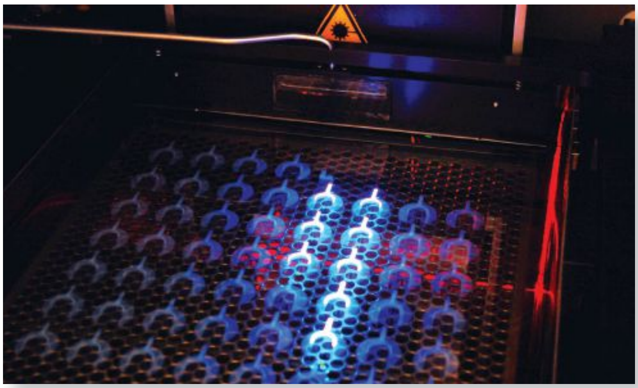
Proto Labs accelerates innovation by turning brilliant concepts into real parts in days.

Proto Labs is a technology-driven company committed to being a solution for getting things done quickly and a catalyst for great ideas. We have three distinct manufacturing services that produce custom parts for designers and engineers around the world. Our proprietary software and automated manufacturing processes allow for rapid prototyping and low- to mid-volume production of plastic, metal and liquid silicone rubber parts through quick-turn injection molding, CNC machining and additive manufacturing.

Product developers can upload their 3D CAD model online and receive an interactive quote with free design analysis and real-time pricing information within hours. The manufacturability analysis helps customers eliminate problems, like sink or internal undercuts, during prototyping so modifications can be made early and often. It's an iterative process that lets designers and engineers avoid product development speed bumps so they can get their product to market as fast as possible.

Additive Manufacturing

Our additive manufacturing service offers three rapid prototyping processes: stereolithography (SL), selective laser sintering (SLS) and direct metal laser sintering (DMLS). Whether small parts with precise geometries or large, highly detailed patterns are needed, additive manufacturing provides another option during early prototyping. Get low quantities of SL, SLS and DMLS prototypes built in as fast as one day.



Stereolithography (above), selective laser sintering and direct metal laser sintering are available via Proto Labs.

In addition to three types of additive manufacturing, Proto Labs also offers CNC machining and injection molding services. ***Images courtesy of Proto Labs.***

CNC Machining

Our CNC machining service can manufacture parts in as fast as the day they were ordered with engineering-grade plastic and metal materials for improved selection, part functionality and cosmetic appearance. We employ both three-axis milling and turning. Our three-axis milling process allows for milling from up to six orthogonal sides of the part to machine as many features as possible. Our turning process includes live tooling to create off-axis holes, flats, slots and grooves. Final milled and turned parts are used as high-quality prototypes, jigs, fixtures, one-offs and in end-use applications.

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For customers who need low-volume production or bridge tooling, our injection molding service can mold 25 to 10,000+ parts from hundreds of thermoplastic, liquid silicone rubber and stainless steel materials, in three weeks or less. We machine our molds in a fraction of the time and cost in comparison to traditional mold manufacturers to produce custom parts across all industries.

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MIT's MultiFab Prints 10 Materials Simultaneously

Researchers have developed a new multi-material AM (additive manufacturing) system that is less expensive than those currently on the market, and is capable of self-monitoring and embedding existing parts into a 3D-printed object. The new design has been dubbed the MultiFab and, according to the research team, it can print in 10 different materials simultaneously.

The system can print at 40 microns and uses 3D scanning as part of its "machine vision" to monitor work in progress. If something has gone awry, the system can make changes during a build to correct the problem.

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RedWorks' Vision for Habitats on Mars

NASA and America Makes challenged teams to devise Martian habitats that could be produced with additive manufacturing (AM) using mainly existing elements found in situ. RedWorks has responded to the challenge with a habitat that spirals down into the planet.

Part of the idea of burrowing into the ground is to take advantage of naturally occurring elements that could contribute to construction. Digging down also gives the habitat an extra layer of natural protection against radiation, which will be an issue for anyone living on Mars.

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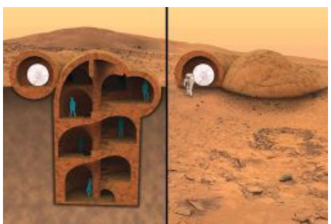

Alcoa to Expand Additive Manufacturing Operations

Alcoa is the latest business to make a serious investment in AM, joining companies such as GE and Ford. Founded over a century ago, Alcoa is largely involved with aluminum manufacturing, and already possesses AM experience. The construction of a new facility in Pennsylvania dedicated to developing AM expands its 3D printing capabilities, and positions the company for a future that increasingly looks to AM.

For Alcoa, the next generation of AM technology is called Ampliforge. This hybrid approach uses 3D design and AM to build a partially complete object. Final production is done through more traditional forms of manufacturing, such as forging. According to Alcoa, the combination of manufacturing approaches leads to stronger parts than those made with just AM alone.

The new Pennsylvania facility is expected to be operational by the first quarter of 2016. The facility will be used for AM research into materials, processes and qualification.

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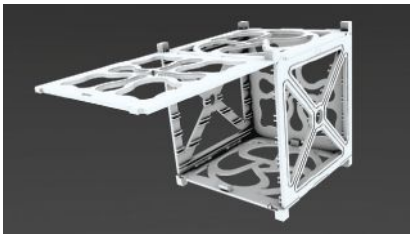
Stratasys' CubeSat Challenge Winners

CubeSats are the next generation vehicle for space research. About the size of a Rubik's Cube, the small satellites are packed full of electronics and released into space. The cost of a producing and launching them is a fraction of that required of larger satellites.



GrabCAD and Stratasys issued a challenge to design the most practical 3D-printed shell for CubeSats. The CubeSat Challenge was open to anyone interested in designing for additive manufacturing, with prize support offered by Stratasys.

The overall winner of the CubeSat Challenge was Paolo Minetola from Italy. Minetola produced a design he named the "FoldSat" consisting of two parts and meant to be produced by Fused Deposition Modeling. Each part of the design consists of three faces. The faces fold up into half a square and are joined to the second half through simple snap mechanisms. Minetola's design also offers an estimated 40% savings in production time.

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Biopen Prints Stem Cells

Researchers at the University of Wollongong in Melbourne are working on a pen that can print regenerative cells onto injured body parts. The team is looking for additional sources of funding, according to their post on Thinkable.

The Biopen is being developed at St. Vincent's Hospital, which has a biofabrication department. It would allow surgeons, for example, to "print" stem cells at an injury site, which would encourage the production of new cells as part of the healing process.

The cells would be delivered via a biopolymer protected by a layer of gel. Cells would multiply at the wound site. A high-powered, ultra-violet light source solidifies the inks and protects the cells.

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Big Workstation Performance Comes in a Small Package

BOXX's APEXX 1 and companion renderPRO 1 rendering solution boast a much smaller footprint than traditional professional workstations.

The push to pack more performance into smaller and lighter mobile devices marches on, yet professional workstations have remained at heavy-weight status, commanding ample desktop space and drawing significant power.

BOXX Technologies is committed to leveraging the latest innovations to meet the needs of its customers, including shrinking the footprint of professional workstations. Joining the BOXX lineup is the APEXX 1, the smallest overclocked liquid workstation built to date, which in concert with a redesigned and size matched rendering companion, delivers a turbocharged workflow for engineering applications like SolidWorks, KeyShot, and Autodesk 3DS Max.

Small Size, Big Performance

With a footprint that is 25% the size of the current offerings in the APEXX line, the APEXX 1 is a mini-ITX form-factor desktop workstation with a uni-body core that is available with overclocked Intel Core i7 processors with up to 8 cores or Intel Xeon processors with up to 18 cores. Despite its compact form factor, the APEXX 1 doesn't skimp on workstation-class features: The system can house a pair of 2.5-in. drives with an optional M.2 PCI-Express SSD for four times the punch of a standard SSD, an NVIDIA Quadro graphics card that can drive four 4K monitors, and the unique BOXX liquid cooling solution designed to ensure long-term workstation stability and performance.

Overclocking and offloading are the keys to BOXX's unique workflow and what sets its workstations apart from the competition. The panning, zooming, and opening and closing of large assemblies common to CAD software are single-threaded tasks, thus they benefit from higher frequency CPUs, not additional cores. On the other hand, performance of multithreaded tasks like simulation and rendering profit immensely from multiple CPU cores, but with the increase of cores comes a drop in frequency, impeding the performance of single-threaded tasks. Typically, professionals have to compromise, but that's not the case with BOXX. The BOXX solution addresses both by pairing overclocked CPUs with the renderPRO desk-side rendering companion and orchestrating a seamless workflow between them.

BOXX has a long history of working with chip makers like Intel to safely leverage overclocking technologies to achieve faster speeds over the base frequency of 3.7 GHz, translating into optimized engineering workflows, greater efficiencies, higher productivity, and a better overall user experience for those multithreaded applications.

"We strive to solve everyday workflow bottlenecks for the creative professional," says Shoaib Mohammad, vice president of Marketing and Business at BOXX. "One of the ways we do that is by eliminating CPU bottlenecks found in single-threaded and multi-threaded applications through professional overclocking. We've continuously set the bar for performance and reliability."

An Optimized Workflow

The APEXX 1's small footprint is matched by the all new renderPRO 1, which allows up to 18 Xeon cores to be stacked on top of one another for space savings. This potent combination delivers unbeatable performance for professional-grade design, rendering and simulation applications without wholly consuming the desktop.

With this setup, BOXX workstations shift computationally intensive tasks for rendering or simulation work to the renderPRO 1 node, which serves as a desktop render farm without the expense and without the computational-intensive workloads being a drain on the core system. The renderPRO 1 functions as a single machine and is configured as a network-connected device, making it accessible to anyone on the network.

To find out more about the streamlined APEXX 1 and BOXX's unique workflow, go to www.boxxtech.com/apexx1.

Simulating Composites: 6 Tips for New Users

Learn from the pros how to design, verify and manufacture composite parts and assemblies.

BY PAMELA J. WATERMAN.

If you've ever doubted that people generally like helping other people, just ask engineers for advice. *DE* did just that, on the topic of what tips to give other engineers working for the first time on a composites-based design project. The floodgates opened: 15 companies shared thousands of words of wisdom on what is clearly a complex but intriguing subject.

Popular for decades in aerospace applications, composites are finding increasing use anywhere that light weight with strength is preferred as an improvement over metal. However, successful composite use involves far more than drop-in replacement. Geometry, material and manufacturing steps must be considered against weight, performance and cost. This complexity has driven dozens of companies to offer software simulation products addressing composite-specific parameters.

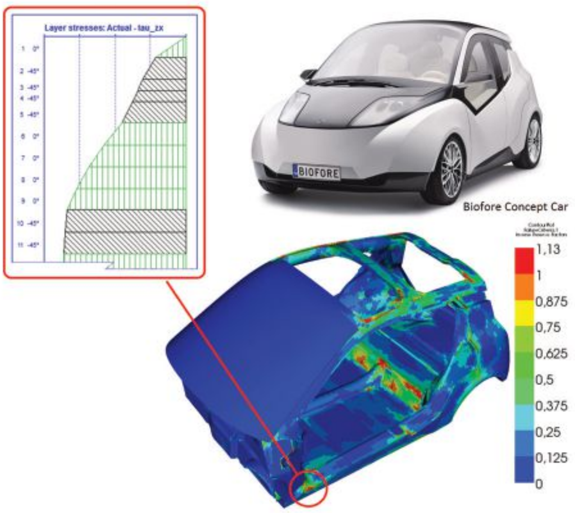
Here's a distillation of the experts' suggestions — what to consider, what to remember, and what not to do when simulating the nuances of composite material behavior.

1. Design with an understanding of the manufacturing methods that could be employed.

Much more than with metals or plastics, composite material behavior depends strongly on the details of both part design and the manufacturing process. Across the board, our experts say that simulations are most useful if tightly coupled and iterated between both stages.

"The best application of composites comes at the beginning of the product design phase, and doesn't simply replace a metal part one-for-one. There are endless combinations of fiber types, matrices, manufacturing methods, laminates and processing conditions (to name a few), and each combination can yield unique behavior. The fabrication method is just as important in the design phase as the design itself," says Angela Schrader, simulation product manager at Autodesk.

This is a sentiment that's echoed throughout the industry. "The number of variables is huge. It's not just the right amount of material in the right place, it's the right material, the right layup and the right configuration that's important," says Richard Mitchell, lead product marketing manager for Structures, ANSYS. He notes two common decisions designers might face: "Should my part have a foam core, and if so, should the number of layers on each side be equal? And, if I have to add connections to other parts, can I build them into my composite, or do I need to build in mountings for bolts?"



During design validation involving composite materials. One should pay attention to the sheer stresses in the out-of-lane directions where allowed stress levels are low. Analysis performed with Componeering's ESAComp analysis software. *Image courtesy of Componeering.*

A positive effect of the tight coupling between product and process is increased manufacturing flexibility. This enables use of design elements such as inserts and undercuts that normally would not be allowed. "Thanks to that flexibility, a single composite part can replace several metallic parts assembled altogether. In that case, cost savings can be significant. The counterpart of that flexibility is the number of manufacturing possibilities," say engineers at ESI Group. They add that this counterpart can be managed with simulation tools that promote creativity and support multiple iterations at minimum cost.

2. Learn the nuances of the materials.

Working with composites is so diffrent from working with metals. You may be simulating a part that will be formed by laying up sheets of fiber-embedded materials or your part might begin as a liquid resin filled with short fibers. Consider how heat curing (typically 300-600°F/150-315°C) will affect the final properties. Be sure to get high quality experimental property data.

"How well do you understand the behavior of your composite material?" is the fundamental question posed by Philippe Hebert, Digimat product manager for the e-Xstream division of MSC Software. "High quality experimental data is a must have," he says. Some problems with composites don't even have counterparts in the world of metals. If resin accumulates in tight corners, the edge becomes very brittle, an example of how microstructure affects mechanical response.

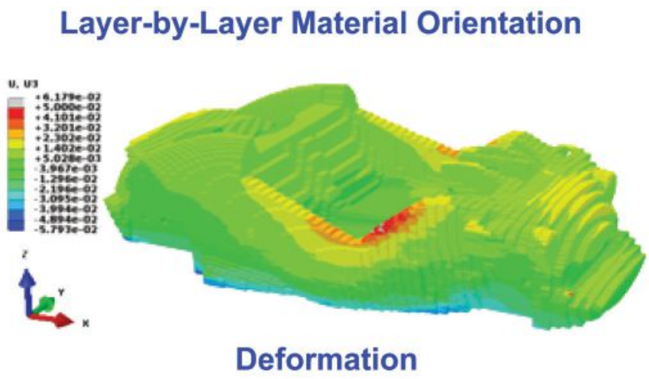
Several years ago Siemens PLM Software acquired the FiberSim solution for composites design, simulation and manufacture. David Leigh Hudson, director of product and market strategy for the Fibersim portfolio, lists several more considerations, such as controlling springback. "Using accurate local fiber orientations," he says, "and not just the theoretical orientations, helps to optimize the use of composite materials by minimizing the weight while satisfying mechanical performances."

In addition to springback, there are other problem areas to consider. "The part normally cures on the outside first," says Bob Yancey, vice president for Aerospace and Composites at Altair, "which can lock in the shape of the structure and cause residual stresses as the interior cures. Residual stresses can cause part warpage after curing, and failure predictions will be inaccurate if they assume composite, fiber and matrix material are at a zero stress state at rest."

Another group that understands composites well is the Composites Innovation Centre (CIC) in Winnepeg, Canada, an organization helping clients design, analyze and test products that benefit from use of composites. For establishing best design practices, "all vertical faces should have a minimum 2° draft," says Alastair Komus, principal engineer at CIC. "If vertical faces in the design are at 90° angles, it makes it very difficult to remove the composite part from the mold without damaging the part and causing extra wear to the tool."

3. Design to criteria that is specific to composite material applications.

When working with materials and elements for aircraft and aerospace vehicles, pay attention to "allowables" — standardized, statistically derived design values (strength properties). Supporting allowables is one of many features inside Hypersizer, the flagship package from Collier Research that helps designers quantify critical failure modes, reduce structural weight, and sequence composite laminates for fabrication. "The software needs to account for the fact that the same ply material behaves differently when formed into a sandwich laminate versus a stiffened panel or a solid," says Craig Collier, president of Collier Research.



Mesh generation of a 3D-printed vehicle using Alphastar simulation tools: GENOA De-Homogenized multi-scale progressive failure analysis (MS-PFA) software and Material Characterization and Qualifications (MCQ) Composites Suite, in conjunction with ABAQUS non-linear simulation software from SIMULIA. ***Image courtesy of Alphastar.***

Olivier Guillermin, director of strategy, specialized engineering at Siemens PLM Software says: "Use accurate and tight safety margins, identified by using nonlinear analysis, in order to reproduce in the most reliable way the real behavior of the composite structures." Experience plus insight from simulations helps allow for geometric nonlinearities and damage modes.

ESRD is a company that has worked with composites for more than 25 years. It is dedicated to quality engineering decision making via verification and validation software. Use of its StressCheck product, combined with the company's Automatic Laminate Builder software, supports estimating interlaminar stresses and strains, necessary for interlaminar failure predictions. Fiber orientations for each ply precisely follow the curvature of the underlying geometry for easy evaluation with StressCheck Fracture and StressCheck Non-Linear Solver modules.

Designers must understand the difference between the physical composite part and the theories formulated to predict its strength, says Barna Szabó, president of ESRD. "Remember to account for the uncertainties associated with numerical simulation," he says. "Error estimation is essential for certifying design."

4. Know what you're trying to predict in your mechanical simulation and set it up accordingly.

Through its Optistruct structural analysis and simulation software, Altair has decades of experience dealing with composites for automotive, aerospace and other lightweight-critical applications. Altair's Yancey says designers should first determine what they are trying to predict, since the appropriate modeling techniques depend on the goal of the analysis.

"If you are just after stiffness and structural response," Yancey says, "you can make simplifying assumptions. If you are looking at failure prediction, there are many options depend-

Resources and Composites-Oriented Software Tools:

Because the label "engineering composite materials" applies to short fiber reinforced plastics (SFRPs), discontinuous fiber composites (DFCs), continuous fiber reinforced composites (CFRPs) and a multitude of sandwiching options, it's no wonder that things get complicated fast. Discussions involve resins and matrices, plies and lay-ups, draping and shrinkage – terms not generally associated with metal part production. (See "Options for Composites Analysis and Simulation," deskeng.com/de/?p=3613)

Here are some groups and sites to help you dig deeper and work more effectively.

Autodesk – detailed definitions of variables/material properties relevant to composites: http://download.autodesk.com/us/algor/userguides/mergedProjects/setting_up_the_analysis/linear/Materials/composite_material_properties.htm

cdmHUB.org – online community offering downloadable software tools for working from the cloud, a cellphone, etc.; working on certification of software for composite analysis. See https://cdmhub.org/resources/948 for initial results.

CGTech – great glossary and explanation of terms: cgtech.com/products/composite-applications/glossary-of-terms/

Composite Agency – CheFEM app quantifies the effects of chemical exposure on various materials including composites: composite-agency.com/product.htm

ESRD – technical briefs on composites verification and validation: http://esrd.com/Services/TechnicalSupport/ResourceLibrary.aspx

JEC Group - subsidiary of CPC, The Center for Promotion of Composites, a non-profit association: jeccomposites.com

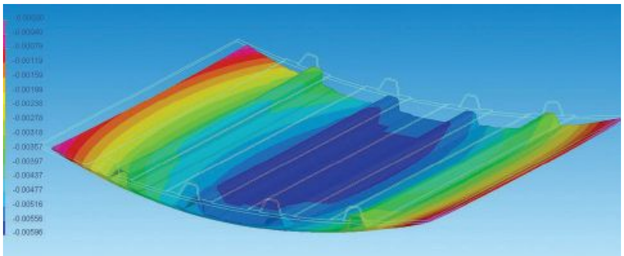
Matweb – material property database: matweb.com/reference/composites.aspx

MSC Software MaterialCenter – a process and data management system linking materials to simulations: mscsoftware.com/product/materialcenter

NAFEMS – courses, conferences, publications, composites working group nafems.org/about/tech/composites/

Society of Manufacturing Engineers – videos, ebooks; joint Composites Conference with Aerodef Manufacturing Conference, Long Beach CA, February 2016: SME.org; aerodefevent.com/composites

– Pamela J. Waterman



A composite aeronautical fuselage panel, showing residual stresses and geometrical deformations, as analyzed with ESI's PAM-DISTORTION software. The result displayed is the deformation of the part observed after curing. *Image courtesy of ESI Group.*

ing on the type of failure, loading conditions, and material configuration." He adds: "Use the right element type. Shell elements are great for in-plane loading but do not accurately capture out-of-plane interlaminar effects. Solid elements more accurately capture (these) effects but can dramatically increase modeling and compute times."

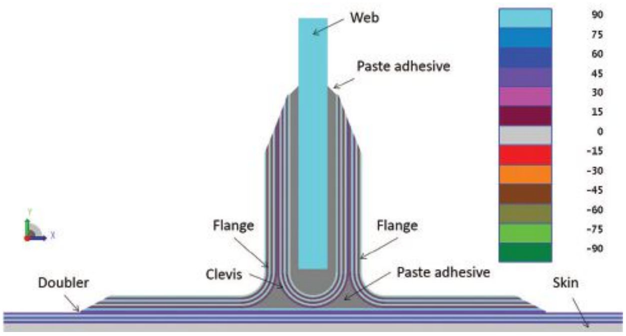
COMSOL is a company known for its multiphysics analysis capabilities. So, it's no surprise that Bjorn Sjodin, COMSOL vice president of Product Management, says that engineers often cannot neglect heat transfer effects within composites because the part they're designing may undergo a thermal cycle or be exposed to the environment. At this point it is necessary to model and simulate the interplay between the structural and thermal problem as they influence each other in ways that are difficult to predict unless a multiphysics approach is adopted.

Tightly coupling your design model with the subsequent meshed model will also produce more accurate and faster results. Having bi-directional capabilities (a one-model, virtual twin approach) saves time and ensures the as-built model meets both the design intent and the structural requirements, says Rani Richardson, senior business experience consultant for Dassault Systèmes' (DS) CATIA division. CATIA software incorporates several composites simulation tools acquired through the 2011 DS purchase of Simulayt.

5. Start small with behavior simulation, verify with test samples then model the larger system.

Experts in other DS divisions offer equally pragmatic points of view on making composites simulation work. "When asked for the time, don't build a watch. Create simple simulations to understand the major aspects and performance of a product. Every simulation does not need to be a complex delamination study, but when possible include the true fiber angles," says Greg Albrechtsen, user experience engagement manager for DS SIMULIA.

EsaComp from Componeering is another tool for composite design and analysis, originally developed for the European Space Agency but expanded to other applications including automotive. There is value in building up your model. "Use simple



Ply-layup configuration of two composite sheets joined at right angles using a "Pi" joint (upside-down Greek letter pi). This structure offers the maximum surface area between the adhesive-coated surfaces. Diagram with labeling shows ideal situation of the joining structure, typical for assembly on an aircraft, for analysis with ESRD's StressCheck software. ***Image courtesy of ESI Group.***

models created with FE software," says Hari Katajisto, engineering consulting at Componeering, "or use dedicated composite design software to decide what are the design drivers. Continue with more detailed models using more accurate material data."

While accurate simulations based on composites generally must include such effects as heat transfer, the first cut of a design can be evaluated in smaller sections to help zero in on behavior. "Engineers typically verify their model by evaluating the thermal stress and displacement in each layer of a few-inches-square sample of the composite structure layup. Handling a smaller model is faster and allows, early in the design process, catching any errors due to modeling choices and parameters and properties used," says COMSOL's Sjodin.

6. Simulate the actual manufacturing process.

Unique to composite manufacturing are such terms as angle, alignment, draping and fiber- or tape-laying. Layers are typically stacked with their fibers oriented at 0°, 45° or 90° to the previous layer. ANSYS' Mitchell describes why precision matters: "If one of my pieces of fabric is not laid correctly and sits a degree or two out of alignment, how does that affect the draping as the material goes around a corner?" And Collier says it's important not only to minimize laps, gaps, bridging and fiber buckling in the design but also to include a statistical viewpoint of these defects in simulations.

Several more companies offer software that simulates the actual manufacturing process, whether that involves laying material by hand or automatically. Anaglyph's Laminate Tools serves first as a pre- and post-processor for FEA (finite element analysis) of composites and then as a generator of ply layout information. Anaglyph's PlyMatch tool offers visual projection technology to accurately guide hand-done ply placements.

To learn more about automated fiber placement and tape-laying equipment, read the interesting overview and watch the video by CGTech (cgtech.com/products/composite-applications/composite-software-overview/). The company's specialized VERICUT Composite Paths for Engineering (VCPe) software lets you view a simulation of the path that will be taken by automated fiber placement and automated tape-laying NC equipment. A third supplier in this area is Spring Technologies; its NCSIMUL Machine Composites software simulates lay-up of fiber ribbons or filament winding, with cutting control for each fiber, layer-by-layer viewing, and measurement of ply thickness, angles and distances.

Anoush Poursartip, director of research at Convergent Manufacturing Technologies (developers of COMPRO pre/post-processing software targeted to composites), sums up the challenge well. "Composites simulation, and composites manufacturing simulation," he notes, "can be an expensive proposition with low ROI if implemented bluntly. Effective composites manufacturing simulation software vendors provide a systems approach, helping designers and manufacturers evaluate their manufacturing facilities, characterize materials, perform the simulation, change workflow and practices to accommodate new methods, and even provide instrumentation and measurement capabilities for in-factory production monitoring." All good reasons to follow up on the tips in this article. **DE**

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INFO ➜ AlphaSTAR: AlphaSTARCorp.com

➜ **Altair:** Altair.com

➜ **Anaglyph:** Anaglyph.co.uk

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➜ **Autodesk:** Autodesk.com

➜ **CGTech:** CGTech.com

➜ **Collier Research:** Hypersizer.com

➜ **Componeering:** ESAComp.com

➜ **Composites Innovation Centre:** CompositesInnovation.ca

➜ **COMSOL:** COMSOL.com

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➜ **Dassault Systèmes:** 3ds.com

➜ **ESI Group:** ESI-Group.com

➜ **ESRD:** ESRD.com

➜ **MSC Software:** MSCSoftware.com

➜ **Siemens PLM Software:** Siemens.com/plm

➜ **Spring Technologies:** Springplm.com

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

Materials: 3D Printing's Medical Miracle

Advances in material science coupled with modified 3D printing processes and new generative design software are ushering in an era of personalized medicine.

BY BETH STACKPOLE

A groundbreaking 3D-printed splint has been credited with restoring a baby's breathing. Cranial implants used to patch missing portions of the skull are being 3D printed to fit a patient's exact anatomy, and 3D-printed biomaterial scaffolds are growing human tissue that will eventually help to regenerate bone and other anatomy.

Such medical miracles are happening at a more frequent pace thanks to major advances in the world of 3D printing, from new and improved bio-compatible materials to the evolution of software and printing processes that promise to make good on the era of personalized medicine.

Well-known materials such as titanium, stainless steel, and a variety of polymers and ceramics have already gotten the FDA stamp of approval for use in 3D printed medical applications where bio-compatibility is crucial, including implants, surgical guides and instrumentation. There is also plenty of R&D in the area of material science, exploring new compounds and formulations that will have a major impact on future 3D printing medical applications.

In the near term, however, much of the emphasis is on modifying and enhancing existing 3D printer technologies to exploit the wide mix of available materials. Companies like Stratasys, 3D Systems, Autodesk, Materialise and EOS, in tandem with a range of other companies and researchers, are devising new printing processes and software that can open doors to new 3D printing medical applications.

"All 3D printing companies are developing completely new materials, but trying to get those approved for medical use is a lengthy and costly process," says Peter Mercelis, Ph.D., director, Applied Technologies, Healthcare, for 3D Systems. "Therefore, the [current] challenge for 3D printing companies is to be able to process well-known, validated materials with completely new manufacturing technology."

Along with a biocompatible rating, Stratasys ULTEM 1010 resin boasts high heat resistance, chemical resistance and tensile strength. ***Image courtesy of Stratasys.***

Mix and Match Materials

For years, commonly used alloys have been used to produce fully dense metallic parts for medical applications using traditional manufacturing processes, but it wasn't until about five years ago that was possible to do the same with 3D printing, Mercelis says. "The Direct Metal Printing (DMP) printers that existed 10 years ago were not powerful enough to process those materials and achieve fully-functional parts," he says. Over the years, 3D Systems, along with other 3D printer manufacturers, have evolved their offerings to incorporate more powerful lasers capable of higher heat intensity, enhanced optical components, and new machine architectures so they can produce metallic parts that can live in the body for long periods of time and don't pose any risk of contamination.

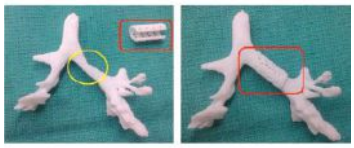
The next phase has been to figure out how to alter the properties of existing materials, creating whole new classes of options that didn't exist before. By tuning the printer hardware and with the introduction of new software, new material combinations and the ability to design and print intricate lattice structures are enabling researchers and practicing physicians to create hip implants, face implants and other structures that are cell friendly, thus can stimulate growth of human tissue.

With its digital materials strategy, Stratasys, for example, now offers over 1,200 materials for use with select PolyJet printer models. Users can combine two or three PolyJet base resins in specific concentrations and structures to create a composite material with the desired properties. Its Fused Deposition Modeling (FDM) printer lines offer three material choices that are FDA approved, including the ULTEM 1010 material, which is high-temp rated so it can withstand the sterilization practices mandated in hospitals, says Scott Rader, general manager for Medical Solutions at Stratasys.

"There really haven't been any fundamental physics hurdles to get over — it's really about looking at the applications and understanding the needs of the customer," Mercelis says. Stratasys delivers a range of bio-compatible materials with various strength, durability, textural and cost properties to support such applications as 3D-printed medical models, surgical tools and implants that can left in the body on a semi-permanent or permanent basis, he says. "When looking at your materials choices, it's important to have a solution for all three use cases," Rader says.

Moving forward, Stratasys is pouring lots of effort into refining its printing practices to take advantage of already known materials to expand the range of medical applications — for example, refining a high-strength plastic that could replace steel used in orthopedic implants. "It's not fundamentally about discovering new materials, it's about learning how to

Oxford Performance Materials' polymer-based cranial implants, made with AM technology from EOS, offer improved patient outcomes with reduced surgical costs. *Image courtesy of Fred Smith Associates.*



A University of Michigan team developed a biodegradable scaffolding and tracheal splint. *Image courtesy of University of Michigan.*

adapt 3D printing processes to make use of known biocompatible materials," says Rader — for instance, modifying 3D printers to be capable of the higher temperatures required to use some of the high-strength plastics.

Researchers and physicians at the University of Michigan are at the forefront of such 3D printing modification efforts. A team there has adapted a biopolymer called polycaprolactone (PCL) for use on a Direct Laser Sintering (DLS) printer from EOS to create a reabsorbable trachea splint used to fix a collapsed bronchus that was preventing a baby from breathing. The team worked with a materials vendor Oxford Performance Materials to adapt PCL into a powdered mix form that could be used with the EOS P100 DLS 3D printer. It also developed software, used in tandem with the Mimics modeling program from Materialise, to design the trachea implant from the patient's own scan data so it was an exact match to the baby's anatomy, explains Dr. Scott Hollister, Ph.D., professor of Biomedical Engineering and Mechanical Engineering and associate professor of Surgery at University of Michigan.

The University of Michigan team has done three more similar procedures and is exploring use of other thermoplastic materials such as PEEK and its polymorphous cousin PEKK, which supports many different applications and a variety of customized materials from the same base molecule. The ma-

4D Printing Human Design Stamps

As we look toward the future, much of the advancement around 3D printed materials will come in the programmability of the materials, not in the materials themselves.

Dan Raviv, a post doctorate associate in MIT's Media Lab, is involved in such research, exploring what he calls the 4D printing of complex self-evolving structures. The idea is to create structures that change shape over time after an environmental interaction — for example, with liquid or electricity — to create a predetermined shape. The impact for medical applications is huge, particularly for implants that can adjust to changing body structures and conditions over time essentially creating pieces that can survive a lifetime inside the body.

"Today, people are 3D printing body parts and putting them in the correct location, but they are static, meaning they don't do anything once they are printed and done," Raviv says. "The concept here is to make structures that alter a bit — like a human design stamp, which deforms to an exact location within the body." — *Beth Stackpole* terials selected for this application all promote cell regeneration, Hollister explains, and can be reabsorbed by the body, ensuring that once human tissue forms, the scaffolding dissolves away.

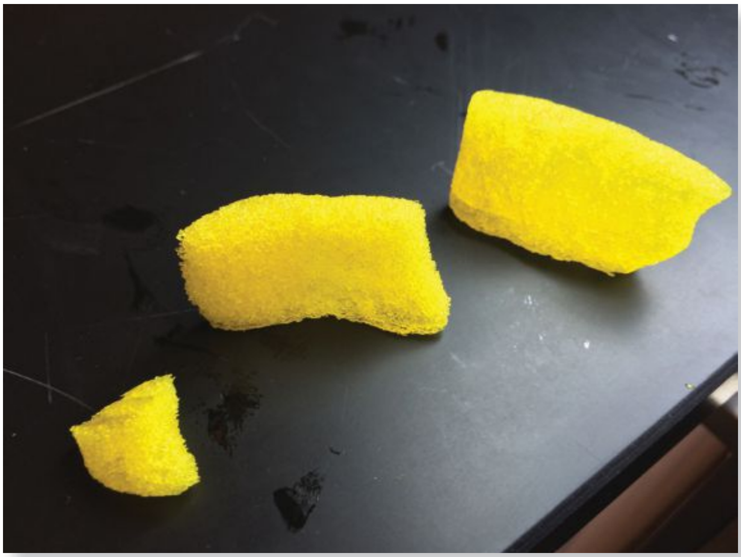
The advent of such materials is making 3D printing invaluable for such regenerative medical applications, Hollister says. "Our anatomy design has complicated shapes and porous structures that can't be built with existing methods like injection molding," he says. "We're just beginning to see 3D printing's impact on enabling the design of implants specifically made for the individual patient."

The University of Michigan team was able to push the envelope because it could modify the EOS DLS printer to work with thermoplastic materials thanks to EOS' open architecture strategy, according to Andy Snow, senior vice president of EOS North America. "They were able to create their own materials to process in our system … because we give people the ability to adjust various parameters in our machine, whether it's the heating platform, thickness or exposure strategies," he says. "That's an important part of taking medical applications to the next level. You have to show flexibility."

In addition to facilitating the design of personalized implants, 3D printing can also be far more cost effective than traditional manufacturing processes like injection molding because it eliminates the amount of secondary processes required. "If you want to put a porous structure on an implant in the traditional way, you have to use foam paste, spread it on and then use a secondary heat treatment process, which can be very expensive," says Snow. "[With 3D printing], you can design the porous structure as part of the CAD file, eliminating the secondary processes and saving time and ultimately, saving costs."

Creating the complex lattice structures used as a basis for implant design has been an on-going challenge that is now starting to be addressed in earnest. In addition to the work being done at University of Michigan and other research facilities, a number of well-known software companies are working on this problem, including Autodesk. Autodesk recently announced Autodesk Within Medical, a generative design software program designed to help biomedical engineers create micro lattice porous structures for custom orthopedic implants. The software, built with an optimization engine, takes input parameters such as desired weight and maximum stress to generate micron-accurate designs that incorporate "variable-density lattice structures and surface skins" that promote fixation of bone and encourage cell growth, officials say. (See page 50 for more information.)

While most of the current implants designed in Within Medical are being printed in metal, Autodesk's bio/nano team is researching the use of other organic materials for use with the software. The team is conducting its research on a modified Autodesk Ember, a high-resolution DLP (Direct Light Processing) printer built on the company's open source Spark 3D printing platform.



Printed on Autodesk's Ember DLP printer, the Zygoma bone is filled with a trabecular lattice and printed with PEG (Polyethylene glycol) material. *Image courtesy of Autodesk.*

One such research initiative involves using the modified Ember 3D printer, Within Medical software, and new biomaterials to design a trabecular lattice structure that is lighter weight than traditional solid titanium implants and predisposed to promote cell growth.

"We are trying to leverage the flexibility of the Ember printing to do 3D printing of materials never done before," says Larry Peck, senior director, Autodesk Bio/Nano Research Group. "We are applying the Within design software to achieve higher resolution on lattice that's amenable to cell growth. By stitching together different technologies, we can come up with solutions we have never had before." **DE**

Beth Stackpole *is a contributing editor to* DE. *You can reach her at beth@deskeng.com.*

INFO ➜ 3D Systems: 3DSystems.com

➜ **Autodesk:** Autodesk.com

➜ **EOS:** EOS.info

➜ **Oxford Performance Materials:** OxfordPM.com

➜ **Materialise:** Materialise.com

➜ **Stratasys:** Stratasys.com

➜ **University of Michigan:** UMich.edu

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Print, Glue and Drive!

BMW's 3D-printed water pump, built from an aluminum alloy powder.
Image courtesy of BMW.

Composites and 3D-printed metal parts are paving the way for part consolidation.

BY KENNETH WONG

A car that's glued together sounds like a preposterous idea, but you may have already used one. The BMW i3, a poster child for the era of mass-produced composite vehicles, is assembled with a combination of welding, bonding and adhesives.

The BMW i3's passenger cell, dubbed the Life Module, is made of carbon fiber reinforced plastics (CFRP). The vehicle's powertrain, chassis, battery and structure making up its Drive Module are made of aluminum. "The CFRP structure requires only a third of the number of body components used in a conventional steel body; the Life Module's basic CFRP structure comprises around 150 CFRP parts in total," reveals BMW. Because of the reduction in parts and the use of advanced adhesives, the carmaker is able to shave off significant production time. "At 20 hours, the total processing time in the body shop and on the assembly line is only half of what would be required in a conventional production process," states BMW. ("A Revolution in Car Making: BMW i Production," September 2013, press.bmwgroup.com.)

Next to the use of composites, BMW is also exploring 3D printing or additive manufacturing (AM) in metal. In April, during the season of the German Touring Car Master, BMW announced that one of its racecars was sporting a powertrain fitted with the 500th water pump wheel made on a 3D printer. "In a race, the high-performance powertrains run up to 70% of the time under full load; in addition, the moving parts in particular have to handle extreme conditions. This is why, back in 2010, the BMW engineering team developed a one-piece, light-metal water pump wheel to replace the previously applied series plastic part," writes BMW.

In the article, Dow Automotive, an adhesive supplier to the BMW i3 project, and NanoSteel, a company breaking into metal-based AM, provide insights into the two cutting-edge approaches.

A Different Kind of Bond

The use of composite materials like CFRP nudges automakers toward bonding and adhesives instead of traditional welding and bolting. BMW writes: "Significant advances in the development of the adhesive mean it is now workable for only 90 seconds after being applied to a component and before adhesion begins. An hour and a half later it has fully hardened and achieved its full strength. This represents a tenfold acceleration of conventional adhesive hardening times."

Ana Wagner, Dow Automotive's global strategic marketing manager, pointed out, "The use of adhesives reduces welded parts, which increases the vehicle's load bearing capacity. It also reduces noise, vibration, and static and dynamic stiffness, leading to increased safety and crash behavior." (For more, read "Forging New Bonds with Composites," Page 32.)

Original equipment manufacturers (OEMs) like BMW tend to have unique specifications with assembly processes that vary from plant to plant. Therefore, Dow Automotive works closely with such customers to address their needs. "Dow Automotive adhesive was customized to accommodate the unique assembly process for the BMW i3. The cure time also was customized to meet the assembly time requirements of vehicle production," says Wagner.

Dow Automotive noted, "Composites are gaining traction in automotive production due to their weight-saving potential, yet they remain difficult to join. Adhesives offer a reliable alternative to traditional mechanical and thermal processes, which cannot be applied to these lightweight materials."

Wagner thinks the use of composites will enable part consolidation among automakers. "Composites can be molded into the desired shape as a single part to replace what used to be three or four parts," she says. The indirect benefits of adhesives include a reduction in CO_2 emissions. Wagner pointed out, "Adhesives enable OEMs to use thinner steel or alternative materials, including aluminum and composites (like carbon fiber), or a mix of these materials for the purposes of lightweighting the vehicle. Lightweighting leads to improved fuel economy and reduced CO_2 emissions."

Dow Automotive products are free of the chemicals regulated by the RoHS guidelines; the company issues written assurance of this to its customers. The company's adhesives comply with the Global Automotive Declarable Substance List (GADSL), an initiative by the automotive industry leaders, parts supplier, and chemical/plastics

The use of industrial adhesives allows automakers to explore bonding options that involve less welding and bolting, thus reducing the vehicle's noise, vibration, and static and dynamic stiffness. *Image courtesy of Dow Automotive.*

The Automotive Adhesive Vocabulary

In the paper detailing the manufacturing of the BMW i3, BMW writes: "At 20 hours, the total processing time in the body shop and on the assembly line is only half of what would be required in a conventional production process." Dow Automotive, an adhesive supplier in the BMW i3 project, stated that its product BETAFORCE "enabled cycle times of about one minute with a flexible open time."

"Cycle time refers to the amount of time needed for a particular manufacturing or assembly process. Faster cycle times enable production efficiencies in terms of more throughput in a given time period. For adhesives, open time refers to how long an adhesive can be on a component before joining the two parts being bonded," says Dow Automotive's Ana Wagner.

industries to be transparent about the use of certain substances throughout the supply chain.

A Different Kind of Print Job

When 3D printing first emerged, it was a rapid prototyping method, a way for engineers and designers to quickly produce physical mockups of their ideas. Printers typically relied on plastic filaments as materials. With 3D printing, it's possible to fabricate and manufacture shapes in complex geometry outside the range of traditional machining. However, the use of structurally inferior materials (compared to metal's durability) limited the parts built with this technology to prototypes — not end-use parts or finished products.

The technology entered a new era when manufacturers began to explore the idea of producing end-use parts with 3D printing. The development of metal-based 3D printing now opens new possibilities. Celebrating the deployment of a 3D-printed water wheel pump in one of its racecars at the German Touring Car Masters event, BMW noted: "[3D printing] allows for the inclusion of design refinements in the six-bladed centrifugal pump wheel, whose implementation would require much greater effort with other production methods." The new part was printed using selective laser melting (SLM) in aluminum alloy powder.

One company betting on the trend is NanoSteel, which, in its own words "designs new steels using conventional steel alloying elements in novel combinations." Last September, NanoSteel entered the AM market with the expansion of its engineered powders business. "By leveraging its uniform metal matrix microstructures in the laser-sintering process, the company was able to build a crack-free, fully dense bulk sample. NanoSteel's initial focus in additive manufacturing supports the market need for on-demand, on-site wear parts while addressing the current challenges in 3D printing of high-hardness parts," the press announcement states.

The company reveals that its technology creates steel powders that are "well suited to the rapid cooling experienced in most AM processes, facilitating the generation of unique mechanical and physical properties." Its materials are currently undergoing validation tests.

"Metals in general are more challenging to print than most plastics. They must be printed with higher power (energy density) to melt the metals, and the process must be tightly controlled to obtain full density, and avoid cracking and oxidation. There are a few stainless steels that are 3D printed today, mainly 316L and 17-4PH, but providing significant wear resistance remains a hurdle. This is where our materials excel and can provide additive manufactured solutions for industries such as oil & gas, tool & die, and agriculture," says Harald Lemke, vice president and general manager of Engineered Powders at NanoSteel.

In April, GE's 3D-printed sensor

housing, dubbed T25, got FAA clearance to take off. In a post on GE Reports, the company explained, "[The T25 is a] piece of silver metal that houses the compressor inlet temperature sensor inside a jet engine … [It's] the first 3D-printed part certified by the FAA to fly inside GE commercial jet engines." More than 400 of the GE90-94B jet engines powering Boeing's 777 fleet are expected to be retrofitted with the T25.

The new part is printed in a cobalt-chrome alloy to protect the temperature sensor's delicate electronics from icing and punishing airflows inside the engine. "Additive manufacturing allows engineers to replace complex assemblies with single parts that are lighter than previous designs, saving weight and boosting a jet engine's fuel efficiency," writes GE.

The trend suggests a need for CAD modelers and simulation software programs to add tools specifically developed to process geometry intended for AM. A sub-segment of the design software market is devoted exclusively to simulating the process of CAM using CAD geometry. A similar repertoire may be in its early development for 3D printing. In the latest release of Autodesk Fusion 360, Autodesk added the ability to automatically generate support structures needed in 3D printing projects. Another company, Materialise, specializes in developing and marketing software for those deploying 3D printing for medical use.

"The true benefit of additive manufacturing is shown when parts are created that could not be made with conventional manufacturing processes. AM gives the designer free complexity, which creates advantages like lightweight matrix structures and internal channels that would not otherwise be possible," says Lemke.

Terry Wohlers, founder and president of the AM industry analyst firm Wohlers Associates, says metal-based 3D printing will likely facilitate part consolidation, but cautioned, "The cost structure will need to improve dramatically, and faster machines will help." **DE**

Kenneth Wong *is* DE's *resident blogger and senior editor. E-mail him at kennethwong@deskeng.com or share your thoughts on this article at deskeng.com/facebook.*

INFO → **BMW:** BMW.com

→ **Dow Automotive:** DowAutomotive.com

→ **GE Reports:** GEReports.com

→ **NanoSteel:** NanoSteelCo.com

→ **Wohlers Associates:** WohlersAssociates.com

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

Managing Your Material Data

Evolving platforms are helping ease the stress of material data management.

BY RANDALL S. NEWTON

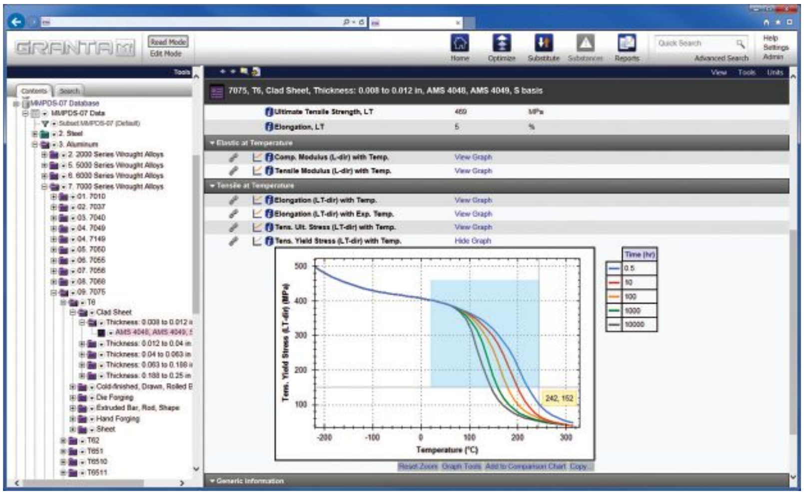
A full understanding of materials is crucial to product development, yet the decision to gather, store and use material data in a modern automated fashion has for the most part eluded the users of mainstream CAD/PLM/SCM technology. All of the software vendors that *DE* spoke with agree that most engineering companies, regardless of size, are still managing materials data using gathering, storage and retrieval methods from 15 years ago.

A modern, comprehensive solution to materials data management must address four key areas:

1. **Research:** materials R&D, testing, characterization, reports, certification and environmental impact.
2. **Design:** decision support data, reference data, purchasing specs, restriction and preference issues.
3. **Production:** materials quality assurance (QA), batch testing, comparison with specs and process improvement.
4. **In-service and end-of-life:** failure reports, empirical knowledge, cost reduction, aging and more.

In addition to the four key areas, material information is highly specialized in a variety of ways. This means more considerations like the following.

- **Range and types of data:** Testing, QA, research, mechanical/thermal/electrical properties, and more, plus various metadata (photos, videos, contextual information).
- **Lifecycle:** Materials information is needed from earliest conceptual to MBOM (manufacturing bill of materials) to mandated ethical and safety regulation reporting.
- **Language:** Materials classes and properties have their own conventions, units, measurements and subtleties.
- **Mathematical models:** Many properties are captured as mathematical models, such as stress/strain properties of an alloy and how they are affected by temperature and loading.



A schematic view of the Granta MI system, similar to that implemented by Lockheed Martin. *Image courtesy of Granta Design.*

- **Complex data management inter-relationships:** Is the material data you need a standard, a company specification, or the subject of a recent simulation?

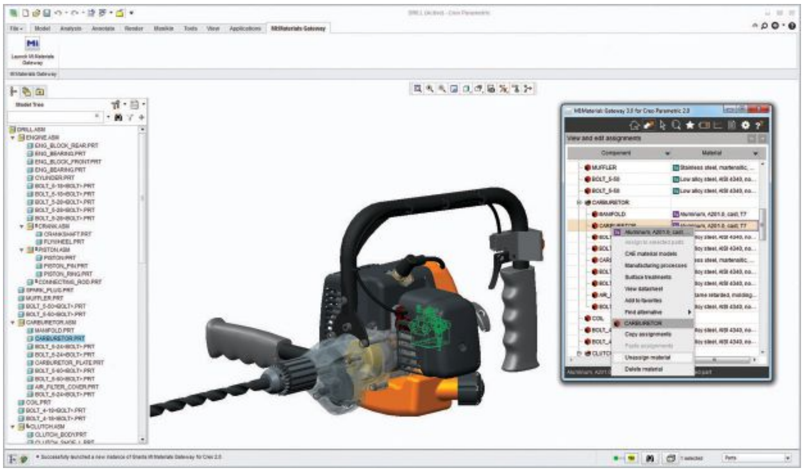
Material data touches both the technical and the business aspects of engineering. If engineering companies are to reap new efficiencies and make new discoveries about how to use materials, they must adopt new processes and build or buy the software to manage what can quickly become a mountain of data. Of the four disruptive IT technologies now on the scene (cloud, analytics, mobile and social), engineering is ripe for an analytics (Big Data) revolution of material data management.

A Material Data Public Challenge

The use of Big Data analysis has solved a variety of challenges in fields as diverse as astrophysics, biology and economics. U.S. Air Force Research Labs hopes to encourage similar breakthroughs in materials science with a public research challenge, now underway. Awards of between $5,000 and $25,000 will be given to researchers who can demonstrate "innovative approaches to solve materials science and engineering problems primarily through the analysis of publicly accessible digital data."

The Materials Science and Engineering Data Challenge is particularly interested in discovery of new materials to meet an application need, and development of a new model describing processing-structure-property relationships for structural (load bearing), functional (electrical, optical or magnetic), or multifunctional material.

Emphasis will be on "use of existing and accessible data sources, novelty of the approach and validation of results." The challenge opened to submissions in July 2015 and closes March 31, 2016.



Accessing materials property data from a corporate materials database (the window on the right) within PTC Creo CAD, through the Granta Materials Gateway. ***Image courtesy of Granta Design.***

MatWeb Online Material Property Data

Since 1996, MatWeb has offered both free and subscription-based access to material data. It now offers more than 110,000 data sheets for a wide variety of metals, plastics, ceramics and composites. Most of the data sheets are supplied by manufacturers and distributors. The online search engine allows combinations of keyword, material category, property ranges and composite ranges. An online weight and moment of inertia calculator is available to assist structural engineering inquires. A hardness converter can provide equivalence to multiple hardness scales.

As part of MatWeb's fee services, data can be exported to the following formats:

- CSV and IQY for Excel
- Text
- SOLIDWORKS/CosmosWorks
- Autodesk Algor
- NEiWorks
- ANSYS
- COMSOL
- SpaceClaim
- ETBX (Engineer's Toolbox)

Granta Design: One Part Database, One Part Specialist System

Granta Design has become an industry leader in software specific to materials data management. Founded as a research spin-out from Cambridge University, the UK-based Granta now excels in two areas: providing a central repository for materials science and engineering data and software for managing the information.

Much of the material information companies need to track is available as free or for-fee datasets. But this information usually needs to be combined with in-house data. An industry survey Granta conducted concluded at least 40% of material test data is used only once and then discarded. For a moderate-sized team, such loss and subsequent retesting could add up to $200,000 in time and resources, says Stephen Warde, vice president of Granta Design.

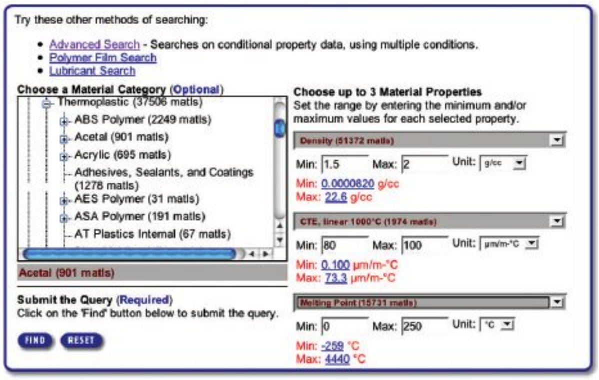
Any plan to tackle materials data management must take account of both the flow of information through the organization and the control of sensitive data. "In many organizations, access to materials data must be restricted to protect intellectual property or to comply with regulations such as ITAR [International Traffic in Arms Regulations]," says Warde.

Granta offers Granta MI, a database system designed to support material science and engineering. It considers the software as an adjunct to any existing PLM system in use. Granta works with the leading CAD and PLM vendors to create plug-ins allowing for simultaneous use of Granta MI and a CAD or PLM system, including Siemens NX CAD and Teamcenter PLM, Dassault Systèmes CATIA CAD and SIMULIA simulation management, and PTC Creo Parametric CAD and Windchill PLM.

Material Management at Lockheed Martin

In 2014, Renae Rippere of Lockheed Martin presented a public briefing in which she shared the results of implementing material data management. An internal audit revealed design teams were using a variety of sources and methods to obtain material data. There was very little data sharing, and there was a strong desire to improve documentation and traceability for previous material choices.

The Missiles and Fire Control division was already using Granta Design's Granta MI for materials information management. A small team of material and process engineers



MatWeb.com provides a variety of online search tools for its database of more than 110,000 materials data sheets. *Image courtesy of MatWeb.com*

were tasked with overseeing expansion of Granta technology into other divisions. The team started by developing a Preferred Materials list, to be linked to the company's use of PTC Creo.

Lockheed Martin expected to gain efficiency from traceability; Rippere said the "best return on investment was the time savings" when engineers searched for material property data. The result was consistent use of a "solid modeling plug-in that provides vetted and consistent information to designers."

From the experience at Lockheed Martin, Rippere noted five keys to successful implementation:

1. Management buy-in.
2. Early involvement of technical staff.
3. Wide availability of one-on-one discussions and demonstrations.
4. A trial discovery period before mandatory use.
5. Starting with a small set of materials (Lockheed Martin started with metals) to enable design teams to become familiar with the process.

Integrating Material Data into PLM

All of the major PLM vendors have modules to manage material data pertinent to sustainability and ethical compliance regulations. But the management of material sciences data for use in design is, generally speaking, a work in progress. Siemens PLM acquired material database technology in 2014 (Material Data Systems from ThinkStep) to beef up its abilities. It is now named "Teamcenter Integrated Materials Management" in their product list.

"Companies are scrambling to get a handle on sourcing of materials," says Teddy West, product manager at Siemens PLM Software. "Designers need to see the material information, as well as the simulation and analysis information, all the way through. Materials touch every aspect of design."

West says there is an important crossover efficiency from uniting materials data management with the central PLM system. "Our research shows 75% of materials come from supply chain components," as opposed to internally developed parts. "We can help companies identify [materials] down to the substance level by gathering information from the supply chain," he says.

West claims installation of Teamcenter Integrated Materials Management is a "trivial" process, but the larger issues of deployment varies widely. "Pulling all the data into Teamcenter can take a while depending on the complexities of the company."

Keys to Developing a Material Data Management Strategy

As *DE* reported earlier this year (see "AutoMatIC Tackles Materials Data Challenge," deskeng.com/de/?p=23595), industry initiatives are underway to support the advancement of material data management. Aerospace and Defense has the Material Data Management Consortium; Automotive has AutoMatIC. Both organizations seek to increase productivity, lower costs, improve product performance, enhance regulatory compliance and deeply integrate material data into simulation and PLM.

For many companies, a thorough assessment of their material data management will reveal the existence of more of those dreaded "data silos" we've been hearing about for as long as PCs have been used for engineering. Whether you do the study internally or in partnership with a software vendor or an industry consortium, the goal should be to develop three balanced legs:

1. Strategies to manage internal material data.
2. Strategies to manage third-party data (from both specialty sources and supply chain sources).
3. Tools to access and use the information for decision support, design, simulation, and regulatory compliance. DE

Randall S. Newton *is Principal Analyst at Consilia Vektor, and a contributing analyst for Jon Peddie Research. He has been part of the engineering software industry, in a variety of roles, since 1985.*

INFO → **Granta Design:** GrantaDesign.com

→ **Lockheed Martin:** LockheedMartin.com

→ **Materials Science and Engineering Data Challenge:** Challenge.gov/challenge/materials-science-and-engineering-data-challenge/

→ **MatWeb:** MatWeb.com

→ **PTC:** PTC.com

→ **Siemens PLM Software:** Siemens.com/plm

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

The Long Life of Materials

A growing waste problem points to the need for product designs that account for environmental impact at every step, from development through disposal.

BY MICHAEL BELFIORE

The Ocean Cleanup's collection stations are powered with solar photovoltaic panels. *Image courtesy of The Ocean Cleanup.*

By some accounts, it's bigger than Texas. Extending to a depth of 3 ft. on the ocean's surface, the Great Pacific Garbage Patch drifts in two main clumps, one between Hawaii and California, the other off the Japanese coast. And it's growing.

Samples taken by researchers turn up bottle caps, toys, fishing lines, buoys and other plastic parts that float, breaking down into ever-smaller pieces that get ingested by sea life and birds. "Plastics are now one of the most common pollutants of ocean waters worldwide," said Charles Moore, merchant marine captain and founder of the Algalita Marine Research and Education Institute, in a *New York Times* editorial last year titled "Choking the Oceans With Plastic." A study he led in 2009 found that particles of plastic outnumbered plankton in the Great Pacific Garbage Patch by six to one. In his editorial, he calls for better-designed products to reduce the amount of garbage being produced.

What Makes a Design Sustainable?

Autodesk is among the companies seeking solutions to the garbage problem. "We want to promote efficiency so we can do more with less, thus requiring fewer extracted resources from the Earth," says Jonathon Rowe, program manager for the Sustainability Solutions Group.

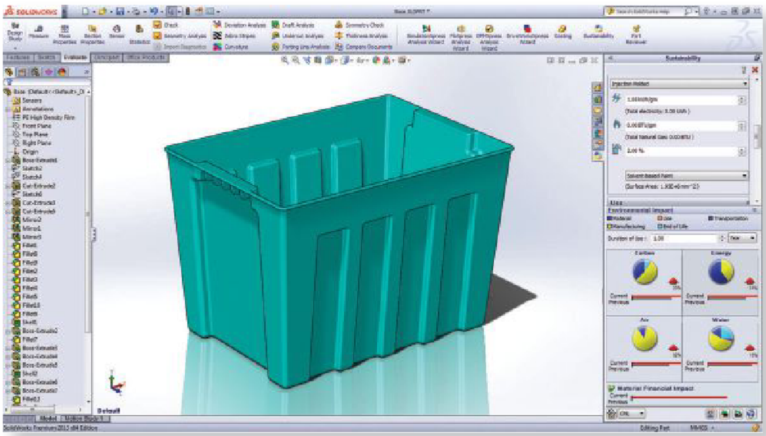
Besides simply reducing the amount of material in products and packaging, sustainable design must also take into account a product's complete lifecycle, including how long it lasts and how it is retired, says Rowe. "Durability extends the useful life of products," he says. This should be a goal of sustainable design. "Design for disassembly and recyclability can channel these materials back into the production stream instead of landfills."

But Rowe cites the energy efficiency of products as the single most important factor when designing for minimal environmental impact. "Materials-related design decisions, while important, should be prioritized after doing everything possible to make the product energy efficient."

In addition to energy consumption, other considerations are carbon impact, water impact and air impact to round out what can be seen as the top four considerations for good sustainable design, says Eric Leafquist, senior product portfolio manager at SOLIDWORKS. "These factors encompass product operation, packaging, product weight, manufacturing location, shipping methods, production methods, etc.," he says.

Using less material, often called lightweighting, is one factor that can improve both environmental impact and overall performance — but not always, cautions Leafquist. Increased use of recycled components, for example, could actually add weight to some products while also reducing overall environmental impact. At the same time, for products such as cars, reduced weight can dramatically lessen environmental impact. "A 10% weight

The proposed array for The Ocean Cleanup with a collection station is pictured. *Image courtesy of The Ocean Cleanup.*



SOLIDWORKS Sustainability provides users an assessment of environmental impact for materials directly within the 3D CAD program. *Image courtesy of SOLIDWORKS.*

reduction in a vehicle can typically lead to a 6% to 7% increase in fuel economy," says Rowe.

Sustainable Design Tools

Autodesk and SOLIDWORKS are among the companies offering tools to assist in designing for sustainability. For example, Autodesk Inventor comes with the Eco Materials Advisor tool, which can rate the materials in design concepts according to such criteria as how much energy is used to produce them, whether they contain potentially harmful chemicals, their impact on water supplies, and how easy it is to recycle them. SOLIDWORKS Sustainability integrates with SOLIDWORKS 3D CAD software to provide a similar picture of the environmental impact of materials in a given design. Such lifecycle assessment tools can help designers make informed decisions about mitigating the environmental impact of their designs while showing them any potential performance tradeoffs.

One area of sustainability that's getting a lot of attention is packaging, according to Prashant Jagtap, president and CEO of product lifecycle assessment software provider Trayak. "When you first get a product, that's the first thing that you open and throw," he says. That added focus has manufacturers focusing their attention on reducing the environmental impact of the waste stream that results. And, of course, much of that packaging may be plastic that can find its way into the oceans.

Among the factors that Tryak's cloud-based software can help designers determine is the extent to which a given design and its packaging will be recyclable or reusable. "Companies are now putting targets on their products," he says. "We help with assessing that." A target may include, for example, what percentage of a product or its packaging can be recycled. Jagtap has observed that the leading companies in their industries are continuing to drive the ongoing move toward sustainability. "I don't see any reduction in terms of investment," he says.

Among his own initiatives, Jagtap and his team are working to make environmental sustainability not just a good idea, but also a way to boost the bottom line. Fortunately, he says, it's not a stretch. "Sustainability," he says, "is also about lean design. Use less material. Use material that lasts longer. Design a product that lasts longer." Such features, Jagtap says, can do more than lessen environmental impact; they can also add value to manufacturers and end users alike.

Other experts echo the idea that sustainable products can benefit design and production. "Environmental impact improvements drive improvements in other areas as well," says Terry Swack, CEO of lifecycle assessment software provider Sustainable Minds. "Our mission is to drive revenue and growth through greener product innovation."

The Future of Sustainability

The environmental impact of products will increasingly become one of the top three considerations for good design, right alongside cost and function, says Leafquist. "Environmental impact, overall product cost and overall function," he says, "form three legs of an overall product triangle that we will hear much more about in the near future."

As awareness grows of the negative impact on our environment of the products that we produce — for example, the growth of the Great Pacific Garbage Patch — we can expect to see a corresponding impact on the regulatory environment, says Leafquist. "Sustainability and compliance issues will likely blur in the future in my opinion," he says.

Algalita Marine Research Institute's Moore says nothing can be done about the garbage already adrift, but a 21-year-old former aerospace engineering student from the Netherlands begs to differ. In 2013, Boyan Slat started a crowd-funded, volunteer-staffed foundation called The Ocean Cleanup tackling the problem of plastic waste in the oceans.

In August, the group completed the latest of a series of surveys of the Great Pacific Garbage Patch to characterize its composition, behavior, depth and other factors, with a view toward engineering a cleanup.

The foundation's plan is to launch a system of booms and processing platforms that Slat says will be able to scoop up plastic down to 0.1 millimeters without harming sea life. The booms will collect and concentrate the plastic, guiding it to the platforms, which will then suck up the smaller particles with a slurry pump and centrifuge. A several-meter-wide conveyor "skirt" on each platform will scoop up the larger pieces. The design for the system calls for 162 solar panels to power each platform.

Computer simulation and scale models have resulted in a boom design that can stand up to most storms, Slat says, while a 40-meter prototype has provided proof of concept. Slat figures a 100-kilometer array could gather up close to half of the plastic in the North Pacific within 10 years, at a cost of $6 per kilogram. The Ocean Cleanup aims to start full-scale operation by 2020, scaling up from smaller versions, and funding itself in part by turning plastic into oil.

In the meantime, however, we would do well to reduce the amount of plastic reaching the oceans in the first place. Filters on storm drains, ordinances banning plastic bags in supermarkets and other ways to stem the tide of garbage are finding traction. But products that are designed for lighter environmental impact from the beginning are an essential part of the solution. **DE**

Michael Belfiore's *book "The Department of Mad Scientists" is the first to go behind the scenes at DARPA, the government agency that gave us the Internet. He writes about disruptive innovation for a variety of publications. Reach him via michaelbelfiore.com.*

INFO ➜ Algalita Marine Research and Education Institute: Algalita.org

➜ **Autodesk:** Autodesk.com

➜ **The Ocean Cleanup:** TheOceanCleanup.com

➜ **SOLIDWORKS:** Solidworks.com

➜ **Sustainable Minds:** SustainableMinds.com

➜ **Trayak:** Trayak.com

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

Focus on Faster Mechanical Simulation

Studies show you can slash the time spent on simulation runs by 6x by upgrading to the latest workstation technology and software.

Introducing the right product in a timely fashion, free of quality issues, remains the secret to success regardless of industry and despite the complexities of today's global competition. Simulation software is increasingly recognized as a critical asset for producing such optimal and reliable product designs. However, many organizations aren't realizing the full benefits of simulation, in part because outdated workstation hardware and software is still too prevalent among engineering teams.

Build a Strong Computing Foundation

Engineering organizations are stuck in a simulation rut for a variety of reasons. Some are saddled with consumer PCs or underpowered workstations that simply don't have the muscle to run large simulations or accommodate high-fidelity multiphysics models effectively. Without an adequate computing foundation, complex simulations can drag on for hours, maybe even days, swallowing up limited processing power, consuming precious development hours and wreaking havoc with project deadlines. As a result, engineering organizations often choose to scale back the number of variations they simulate or reduce the scope of the problem they're exploring, which runs counter to their mission of advancing product designs.

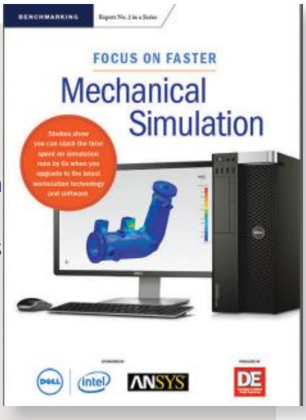
Beyond hardware limitations, there are other factors hindering more widespread use of simulation — even within the same organizations that recognize its potential for design transformation. For some, simulation software remains too costly and difficult to master, limiting its use to pockets within engineering as opposed to being established as an enterprise design tool. In addition, many organizations lack expertise in both simulation software and simulation practices. Some don't have access to on-staff IT personnel who can support the high performance workstations, clusters and servers optimized for the latest simulation software.

Research and Testing

Intel and ANSYS surveyed design engineers to learn more about their use of simulation. The survey showed that 68% of respondents are forced to limit the size and amount of detail in simulation models at least half the time. That might not be surprising when you consider that 18% of respondents are using consumer-based computers to run simulations and 35% are using computing platforms stocked with a single CPU.

Respondents seem to know what they are missing and why. Almost half (47%) said the primary benefit of simulation is producing higher-quality products than their competitors, while 65% cite the time involved in performing simulations as somewhat/very imortant to expanding the use of simulation in their organization. A benchmarking study sponsored by ANSYS, Intel and Dell, provides the answer. It showed that a 4.1x reduction in simulation run times can be achieved by using the latest Dell Precision workstations and ANSYS software, as opposed to an equivalent three-year-old system and software. By employing more of the modern hardware's cores, the results show a 6X reduction in simulation run times can be achieved.

6X Faster Simulations



To learn more about how modern hardware and software can optimize your enigneering team's design process, download "Focus on Faster Mechanical Simulation," the second in a series of benchmarking studies produced by ***Desktop Engineering*** with Intel, Dell and independent software vendor sponsors.

Each benchmarking study pits three-year-old workstations and simulation software against their modern-day equivalents to see how much time can be saved by updating both your hardware and software. In ANSYS' case, the new hardware and latest software completed some mechanical simulations 6X faster.

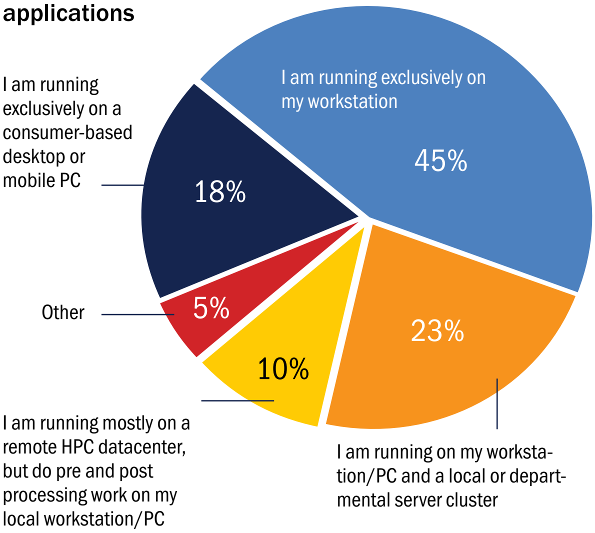
Download "Focus on Faster Mechanical Simulation" here: deskeng.com/de/benchmark2.

Problems Solved

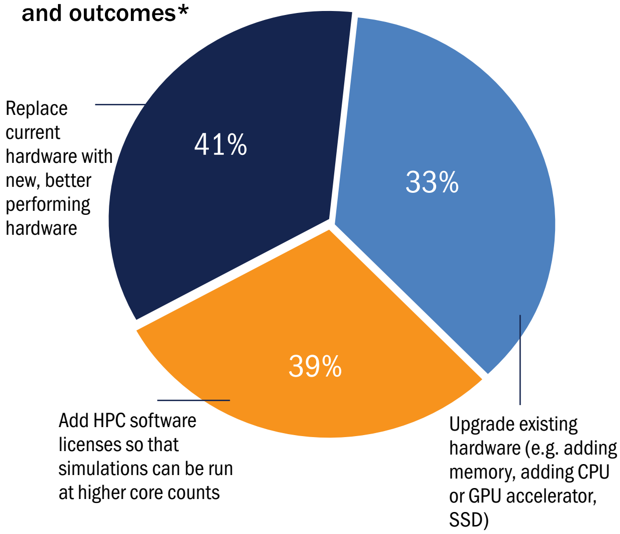
The Survey Says

An HPC/simulation survey sponsored by Intel and ANSYS. It was conducted late last year and includes respondents who are *DE* readers.

Statement that best fits most frequent computing usage scenario for running engineering simulation applications

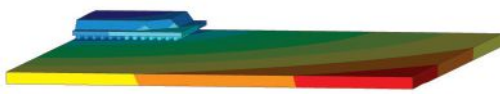


Solutions that could best reduce the turnaround time limitations effecting your simulation models and outcomes*



* Based on respondents who limit the size and amount of detail in simulation models at least half the time. Multiple responses chosen; will not equal 100%.

The Test Model



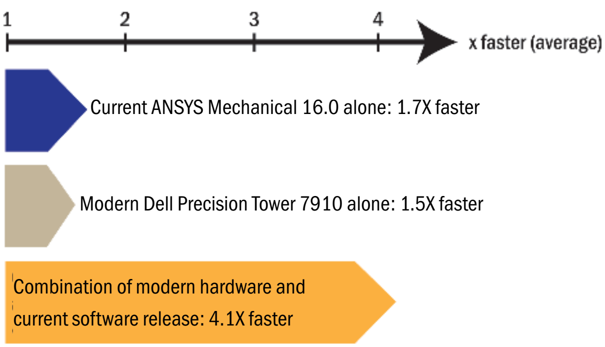
A transient nonlinear structural analysis of an electronic ball grid array.

Model Characteristics: Sparse solver, symmetric matrix, 6 million DOFs

Updating from ANSYS Mechanical 13.0 to ANSYS Mechanical 16.0 resulted in a 1.7X speed boost, while upgrading from a three-year-old Dell workstation to a modern Dell Precision Tower 7910 resulted in a 1.5X speed boost. However, upgrading both the workstation and the software yielded a 4.1X faster solve time on the model above using the same number of cores. When using 16 cores in the modern workstation, the solve time was 6X faster.

Benchmark Results

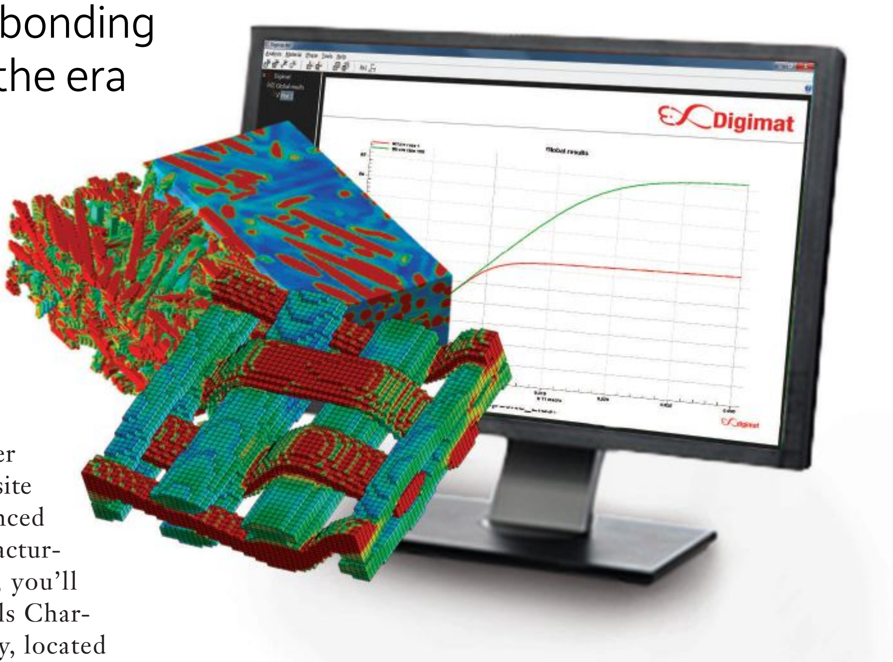
Comparison of three-year-old software and hardware to modern equivalents based on an identical number of computer cores



Forging New Bonds with Composites

Material data and new bonding methods are crucial in the era of composites.

BY KENNETH WONG



Digimat from e-Xtream engineering comes with a database that includes both typical properties for common composite materials and the more accurate, grade-specific values, made available to Digimat by the composite suppliers. ***Image courtesy of MSC Software.***

In the heart of Derbyshire, church steeples, wooded valleys and manor houses preserve the tranquil British countryside depicted in the classics of Jane Austen and Sir Walter Scott. It's an unlikely setting for composite material testing, one of the most advanced areas of exploration in modern manufacturing. Yet, in Darley Dale, Derbyshire, you'll find HBM nCode's Advanced Materials Characterization and Test (AMCT) Facility, located a mere 15-minute walk from St. Helen's Church.

Composite materials are different from traditional materials like metal or plastic. They're engineered to achieve the desired durability, elasticity and resistance. Because they're produced by mixing different material strands, fibers and plies, they're anisotropic and inhomogeneous. In layman's terms, they do not deform, stretch and break in the same way in all directions.

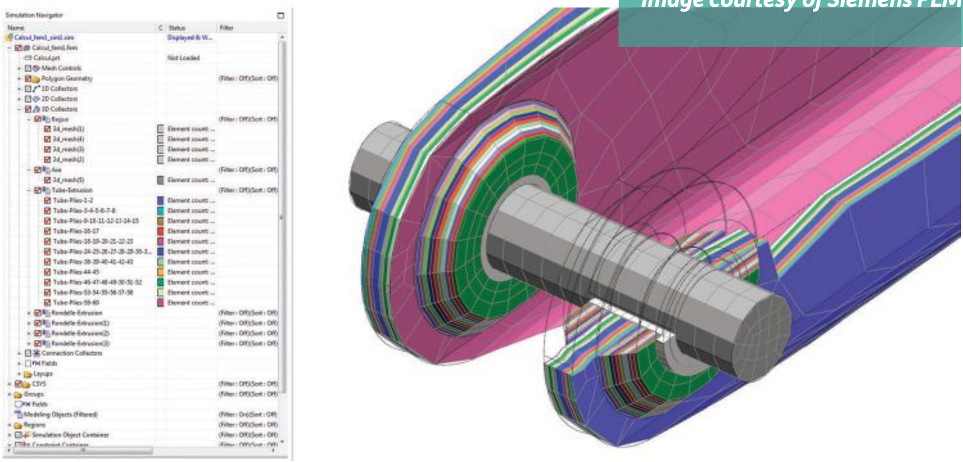
Simulation software relies on material models — numeric equations that express the way the materials react to heat, load, stress and pressure — to make accurate predictions of manufactured parts' mechanical behavior. "With anisotropic composites, simulation-driven design is especially important, because your simulation results completely define the structure and shape of your design. You also need to simulate how you manufacture the material, because how you lay the fibers affects your material's performance," says Ganesh Sethuraman, senior marketing manager at Siemens PLM Software.

Knowledge about composite materials is not readily available in engineering reference books or standard material databases; therefore, testing facilities like nCode's AMCT in Darley Dale play a crucial role. Without their services to ascertain the composites' responses to loads, stresses and pressures, engineers cannot conduct simulation to fully exploit the benefits of the new materials to produce designs of things like lightweight automotive frames and airplane wings.

Finding the Material's Breaking Point

Material testing is usually done by exerting pressure and loads on a sample specimen called a "coupon." The AMCT facility uses "hydraulically loaded strain-control test machines," says Jon Aldred, director of Product Management at HBM nCode. The facility is ISO 9001-certified.

"We do fatigue testing for customers who request



This image shows a partial cutout of a composite tube, composite washers, steel bolt and rings. ***Image courtesy of Siemens PLM Software.***

them. We also do testing to build up our own Premium Material Database, which is included in our software," says Aldred. "When it comes to composites, our primary focus is to understand the effects of stress and strain cycles and how many cycles it takes for the material to break or fail. This is still a very challenging area of composites technology. We spend a lot of time validating and improving on mathematical fatigue models for composites."

With composites, the layout of the fiber strands and plies affect the material's strength and resistance; therefore, unlike steel or metal, composites react differently to stress, load and pressure in different directions. "So we have to test and record their reactions from several angles to accurately characterize them," Aldred says.

nCode's database includes fatigue parameters for more than 90 materials. It's accessible through the nCode Complete Durability System consisting of GlyphWorks and DesignLife for fatigue and durability analysis. CAE software vendors have shown an interest in integrating nCode's database into their software, Aldred says. But currently nCode's Premium Material Database is not part of any other CAE packages.

Material testing facilities characterize the behavior of materials, but do not typically provide design testing services. nCode's AMCT, for example, does not usually perform fatigue-testing services for large structural components or assemblies made of composites. "But we have been involved in such cases in a consultancy role. We can test smaller components but they're considered special projects," says Aldred. A shortage of on-demand service providers in this area suggests many manufacturers must conduct such tests in-house at considerable expense. This is especially true if the part to be tested is large enough to require special rigs and machines.

The Elusive Composite Database

Asking for a database of composite materials is like asking for a chart that lists all the colors producible from a set of primary colors. You can easily list all the primary colors in a table, just as you could with types of metal. In both cases, the number is finite. But the variety of shades you can achieve from color mixing is virtually infinite. Similarly, the variety of composites you can create from weaving and

NASA, Robots and Composites

NASA is using a giant robot named ISAAC (Integrated Structural Assembly of Advanced Composites) to advance the use of composites by researching ways to speed up the development, verification, regulatory approval and design of composites. ISAAC has a robotic arm that picks up huge heads filled with spools of carbon fibers, then deposit the fibers and epoxy to make composite structures that can be studied.

NASA has established a public-private partnership with five organizations to advance knowledge about composite materials that could improve performance on future aircraft. The agency selected the National Institute of Aerospace (NIA) to manage administration of the Advanced Composites Consortium, which is working to improve composite materials research and certification, according to a press release. Included in the consortium are NASA's Advanced Composites Project, managed from the agency's Langley Research Center, the Federal Aviation Administration, General Electric Aviation; Lockheed Martin Aeronautics Company, Boeing Research & Technology, a team from United Technologies Corporation led by subsidiary Pratt & Whitney, and the NIA.

stacking different material fibers in different configurations is virtually infinite.

"There's no one material database for composites," says Siemens' Sethuraman. "In my experience, customers do their own testing to get the data on their composites. That's the knowhow and competitive advantage for some customers."

However, a list of premade composite materials readily available for purchase is not out of the question. Material suppliers usually have the simulation-relevant data (such as resistance, tensile strength and thermal properties), obtained from their own lab tests. Some suppliers are willing to part with it; others treat it as trade secret. However, if a manufacturer has engineered a composite material in-house for a specific purpose, lab testing is the only way to obtain these critical values.

One composite database can be found in the Digimat software suite from e-Xstream engineering, which describes itself as "the material modeling company." In 2012, simulation software developer MSC Software acquired the company.

The Digimat-MX database includes both typical properties for common composite materials (and more accurate, grade-specific values, made available for modeling purposes with Digimat by the composite suppliers themselves). The software also has an interface that lets you add your own custom composite materials to the database. The database is server-based, so it can be centralized and made accessible company-wide.

"Material suppliers use Digimat to understand how the materials they're producing behave, which direction offers better performance, and so on," says Philippe Martiny, the software solution architect at e-Xstream engineering. "Original equipment manufacturers (OEMs) and Tier 1 suppliers from various industries (automotive, aerospace, consumer electronics, etc.) use Digimat to create high-fidelity 3D models to predict how their designs will behave to help them to attain lighter structure design, shorten development cycles and minimize the costly experimental tests."

Digimat is fully interconnected with all of the major simulation tools on the market. It works with not just MSC products but also with other analysis programs, including those from MSC's rivals. Martiny explained: "Some customers use MSC Nastran or any other FE (finite element) software for baseline stress analysis, then access Digimat through the software's simulation environment for better insights into the effects on the materials: For example, what happens when you change the fiber orientation? How many plies do you need?"

Virtual Coupon Testing

The material coupon testing, a process usually conducted in a lab, has been virtualized. MSC recently released its Digimat-VA (stands for Virtual Allowable) software, which lets you "virtually compute the behavior of composite coupons (unnotched, open hole, filled hole) and offers an advanced simulation solution to predict laminate A and B-basis values," according to MSC. The company writes: "It allows engineers to screen, select and compute the allowables of composite materials in less time and at less cost."

"The main purpose of the software is to replace a large part of these costly and lengthy lab tests with simulation," says MSC's Martiny. "The software can basically simulate the loading and testing of these material coupons. You can repeat the tests virtually many times to identify the inherent variability in those materials and use that information to produce reliable designs."

Modeling the Material Making Process

"With composites, you spend a lot of times figuring out the layup [the arrangement of the plies]. That's the work you typically don't have to do with isotropic materials like structural steel," says Siemens' Sethuraman.

Siemens' software portfolio includes Fibersim, a package for composites engineering. The company writes that the software "addresses the entire composites engineering process — from conception, laminate definition and ply creation through simulation, documentation and manufacturing. Fibersim is integrated into the leading commercial 3D CAD systems (CATIA, NX and Creo Parametric) to help you capture a complete digital composite product definition."

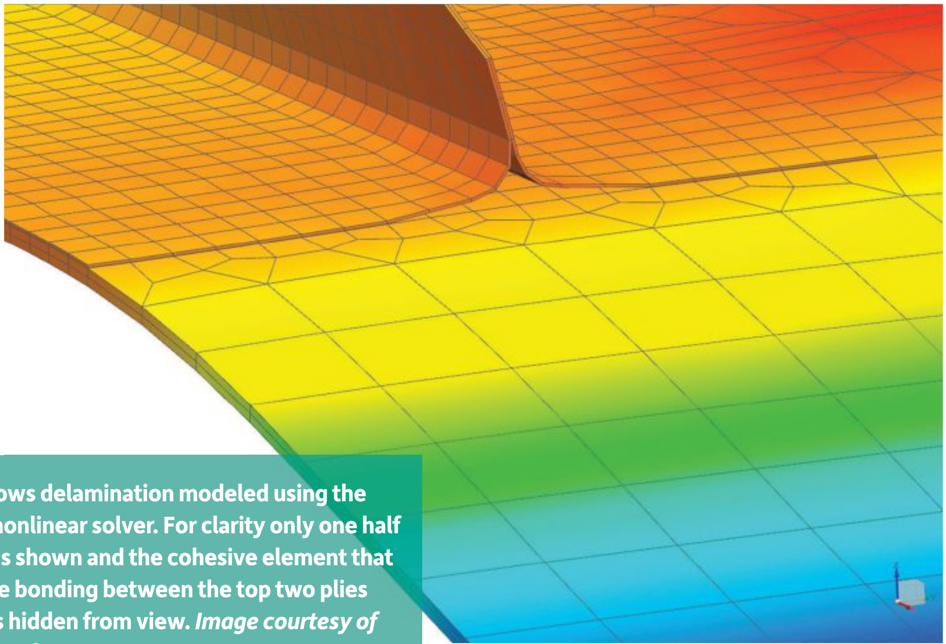
In 2012, the same year MSC acquired e-Xstream engineering, Siemens snatched up LMS, a Belgium-based test and mechatronic simulation software developer. As part of the acquisition, Siemens added the LMS Samcef solver suite to its portfolio. The product can "accurately simulate the behavior of layered composite structures and their progressive degradation including delamination," according to Siemens. It's now integrated with Siemens' NX CAE software. The company points out that the marriage of the two, combined with Fibersim, "creates an ideal integrated environment for the design, analysis and manufacturing of composite structures and components."

Marrying Metal and Composites

The emergence of composites allows manufacturers to dramatically reduce the number of discrete parts in their assemblies. (For more on this, read the story on part consolidation on page 20.) "Composites can be molded into the desired shape as a single part to replace what used to be three or four parts," says Ana Wagner, global strategic marketing manager for Dow Automotive Systems.

Traditionally metal parts are assembled and held together with welds, bolts, rivets and fasteners. But the introduction of composites into the assemblies forces manufacturers to rethink. "Composites cannot be joined together using bolts and rivets. They're much more brittle. You don't want to pierce through them like you would with metal pieces," says Wagner.

Dow Automotive Systems' specialty is the use of adhesives



The image shows delamination modeled using the LMS Samcef nonlinear solver. For clarity only one half of the model is shown and the cohesive element that represents the bonding between the top two plies and the skin is hidden from view. *Image courtesy of Siemens PLM Software.*

to bond composites to composites and also composites to metal. "The special chemical in our adhesives creates a strong bond," Wagner says. According to the company, its BETAFORCE and BETAMATE composite bonding adhesives "are based on a novel polymer technology that allows for consistent mechanical properties over an extremely wide temperature range, providing industry-leading temperature stability."

The use of adhesives "reduces welded parts, which increases the vehicle's load bearing capacity. It also reduces noise, vibration, and static and dynamic stiffness, leading to increased safety and crash behavior," says Wagner. The challenge for advocates of digital prototyping is simulating what MSC's Martiny described as "the load-transferring interface between composites and metal"— the joints. "When you're looking at an assembly where composites and metal parts come together, you also need the extra ingredients to predict the behavior of the interface of the two," he says.

In the case of Dow Automotive Systems customers, that "ingredient" may be the numeric characterization of the adhesive itself, which allows them to run digital simulation on assemblies with glued composite parts. "We [deliver the adhesive's behavior] in a format consistent with our customers' simulation tools. Each customer utilizes a specific software for simulations and we ensure the input provided matches their specific software," says Mansour Mirdamadi, chief engineer at Dow Automotive Systems.

Breaking Out of the Metallic Mindset

Working with composites is a pioneering field, fraught with all the risks associated with experimental applications. While working with the unknown, some users are bound to over-design, observed Siemens' Sethuraman. "They designed to meet a higher factor of safety because they didn't have enough information about the composite materials they were using," he says. That means they may have designed their parts with more material than necessary. While their precaution is understandable, the practice goes against the sole purpose of using composites — to produce smaller, lighter and thinner products.

"Even though companies are now working with stronger, lighter anisotropic composites, they still use traditional design methodologies for metal," says Sethuraman. For example, metallic brackets are usually designed in an L-shape because that's the time-tested form that works well in metal. But the same shape is not necessarily the best for composite brackets. To design with composites appropriately, engineers may need to also learn to break out of the metallic design molds. **DE**

Kenneth Wong *is* Desktop Engineering's *resident blogger and senior editor. E-mail him at kennethwong@deskeng.com or share your thoughts on this article at deskeng.com/facebook.*

INFO → Dow Automotive Systems: DowAutomotive.com

→ **HBM nCode:** nCode.com

→ **MSC Software:** MSCSoftware.com/product/digimat

→ **Siemens PLM Software:** Siemens.com/plm

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

Advancing Composites

IACMI is working to expand accessibility of advanced composite materials in labs and factories nationwide.

BY JESSICA LULKA

As technology advances, engineers keep finding ways to make products that are lighter, faster, cheaper and smarter. These goals can be achieved in a variety of ways, including the use of advanced materials. By using new materials, design teams can meet requirements for sustainability and lightweighting that affect a number of industries. To do so, the materials themselves need to be researched, simulated, tested and manufactured.

To advance research, development and data for composite materials, the Institute for Advanced Composites Manufacturing Innovation (IACMI) was formed as part of the National Network for Manufacturing Innovation (see "Beyond Materials" sidebar) and in partnership with the Department of Energy. IACMI is a group of academic, research and industry giants who are not only helping expand the application of polymer matrix composite materials, but also the adoption of new manufacturing technologies.

The institute officially launched this year, but a lot of its member organizations have been working with the composite industry for decades, says Craig Blue, CEO of IACMI. "There's a small group of people that came together from the Oak Ridge National Laboratory and University of Tennessee," he says. "Through our interactions with industry and the DOE's request for information, [it became clear] they needed capabilities and infrastructure in terms of R&D scale-up, and they wanted it in their backyard."

Beyond the Materials

The IACMI isn't a standalone operation. It's integrated into the National Network for Manufacturing Innovation, a larger federal initiative executed through the U.S. Departments for Energy and Defense.

The NNMI "is intended to create a competitive, effective, and sustainable manufacturing research-to-manufacturing infrastructure for U.S. industry and academia to solve industry-relevant problems," according to its mission statement. This means fostering connections across all manufacturing-related disciplines to increase accessibility to equipment, research and new production methods. In addition to IACMI, the network consists of:

- Digital Manufacturing & Design Innovation Institute — Chicago
- Lightweight Innovations for Tomorrow — Detroit
- PowerAmerica — Raleigh, NC
- America Makes — Youngstown, OH

Also in the works from the NNMI are hubs for flexible hybrid electronics, smart manufacturing and integrated photonics.

For more information, visit manufacturing.gov.

Membership, Projects and Initiatives

The initiative is currently made up of 57 committed private companies, 15 universities and laboratories, 26 consortia members, and 14 additional entities — and that number is growing. Spanning the United States, IACMI is focusing its work in five main areas: vehicles, wind, compressed gas storage, design and simulation, as well as composite materials and processes. Concentrated areas of research are located in Michigan, Colorado, Ohio, Indiana, Kentucky and Tennessee. In these regions, networks of collaboration have been established with local companies, universities, community colleges and research labs.

"The vast majority of projects within the institute will be industry-led projects," says Blue. "Clearly industry knows where there challenges are [with composites], and we're going to work side-by-side with them to address those challenges and let them gain access to research, scientists, engineers and facilities." By having this involvement, it not only gives IACMI a realistic idea of how their work can better help engineers in the field, but also expands the capabilities of companies to integrate composites within products.

Furthermore, the institute is offering a variety of ways for interested organizations to get involved. Not only are there a host of different membership levels, but interested organizations can submit applications for research, design and development projects — from enterprise level (large multi-disciplinary, multi-year projects) to smaller technical initiatives.

Taking Composites to a National Level

To gain optimal resources, accessibility and impact, the IACMI is a national initiative. By having a national footprint and companion technology area expertise, it is able to reach industry where it is most concentrated. Creating collaborations with companies that are located near industry epicenters fosters more direct adoption of research and manufacturing methods.

"Industry does not reside in one location: A lot of the innovation happens in the supply chain and proximity to those companies matters. There's a general movement [where companies are] putting R&D close to their manufacturing. Having one location, while that's good, this initiative is bigger than one location. We're trying to maximize our resources," says Blue.

When forming this more centralized network of manufacturing innovation, IACMI decided that it should "go to where there's existing infrastructure, [because] we don't want to take federal or private funds and reproduce existing capabilities," Blue says. "But we have to have the space where we can do research that's more open and still protects the IP (intellectual property)."

IACMI is working to achieve both technical and industry goals. From a technical viewpoint, the IACMI hopes to:

- Reduce the cost of carbon-fiber reinforced polymers (CFRP) by 25%
- Reduce energy consumption required for production of CRFP by 50%
- Attain 80% composite recyclability into useful products

But IACMI isn't solely focusing on CRFP — it also includes glass-fiber reinforced composites in its research.

By focusing on these technical goals, the institute not only helps produce more effective composites, but it can also ensure there is technology to manufacture these materials quickly, sustainably and at a reduced cost.

In addition to giving industry more direct access to composite data and material, IACMI is also involved in helping grow local economies and manufacturing initiatives. Goals include increasing domestic production capacity and local job growth. According to Blue, IACMI looked to local and state governments to help with economic initiatives and promote economic sustainability.

Extending the Reach of Composites

Integrating composites into a product can yield benefits such as increased strength with lighter weight. But the adoption of these materials for a large-scale manufacturing environment poses two main challenges: time and cost. Even if organizations do have the technology to produce composites, the currently available materials often come at a greater cost in the supply chain and slower production rates, according to Blue.

With current standards, composites are utilized in a handful of consumer products, but are usually used on a small production scale. "Composites are commercial today for typically low-volume applications. And there's a real push to commoditize composites. So we want to look at large platforms," Blue says.

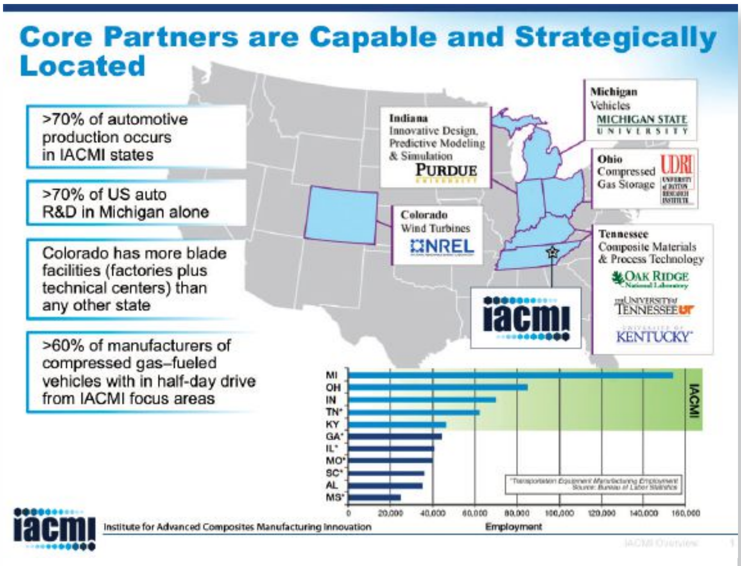
But the availability of low-volume production is serving as a launch pad for the institute. By being able to see what current technologies and applications are available, IACMI can evaluate where innovation and improvements are needed. "Typically when people think of composites, they think of high-end — like aerospace, niche automotive for high-end cars, low volume [production], and we want to enable composites for the consumer vehicle. We want to make sure [the IACMI] can extend the extensive compositing that already goes on," Blue says.

Covering the Entire Design Process

In addition to spanning multiple industries, IACMI isn't specializing in just one area of composite production. To address innovation on several levels, teams are also helping develop both composite-specific simulation software and manufacturing methods to create solutions for the entire design-to-production process.

At Purdue University, researchers are working to create the Composites Virtual Factory HUB (cvfHUB), a portfolio of commercial tools from companies such as Altair, Dassault Systèmes, MSC Software and ESI Group to aid composite design and manufacturing simulation. The Web-based program is being developed to support simulation and validation of composites and processes being used at other IACMI sites. With the cvfHUB, users will eventually be able to use the platform for end-to-end simulation in multiple industries and various levels: from lab-scale to full-scale validation.

Located near IACMI's headquarters in Tennessee, the Composite Materials and Processing Technology area is focusing on materials and processing. Here, local universities and partners are investigating physical material properties and generating production systems for resins, plastics and polymers that are more energy efficient and cost-effective. "Initially, we'll be looking at processing speeds of three minutes, driving it down to within a minute for processing speeds," says Blue. The technology area, led by ORNL with support from the University of Tennessee and the University of Kentucky, currently has systems for spinning, melt spinning, bench and pilot scale heat treatment, compounding, thermoforming and more.



To help industry where it is most prevalent, IACMI established research centers in the top states for automotive, wind and compressed gas. Additional partners are located in close proximity to national research labs and manufacturing centers. *Image courtesy of IACMI.*

Beyond the production of materials, researchers in Tennessee are focusing on increasing recyclability of composite materials. In ensuring these materials have the potential for reuse, it reduces the amount of debris produced while promoting sustainability.

Building a Future

Even with its current member base, Blue says there are plans to grow the number of involved organizations — from industry to state government. In doing so, IACMI can not only increase access to composites and associated research, the institute can also help promote manufacturing initiatives across the nation. This expansive, collaborative institute will not only help organizations gain more knowledge of composite materials and production processes, but also help ensure engineering teams can implement them effectively, efficiently and sustainably. **DE**

Jessica Lulka *is associate editor of* DE. *Send e-mail about this article to DE-Editors@deskeng.com.*

INFO → Department of Energy: Energy.gov

→ IACMI: IACMI.org

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

DE

Technology for Optimal Design Engineering

THE DESIGN ENGINEER'S HIGH–PERFORMANCE COMPUTING HANDBOOK

PUBLISHED IN PARTERNSHIP WITH intel

Your Guide to HPC

The Design Engineer's High-Performance Computing Handbook is a constantly updated resource focused on design engineers' computing needs.

As the world marks the 50th anniversary of Moore's Law, it's difficult not to be amazed and even bewildered by the advances in computing technology. Today we take for granted the computing power now available in cheap, easy-to-use smart phones. Soon, the power of supercomputers will be just as accessible. What will that mean for design engineering?.

"While most organizations don't have access to 36,000 cores today, it won't be long before these extreme core counts are commonplace," said Wim Slagter, product manager, High-Performance Computing (HPC), ANSYS in the February 2015 issue of *DE*. "And even today's users who are running at much lower core counts will see direct benefits through considerably greater efficiencies. The results will be more amazing products delivered to customers much faster than ever."

To achieve those results will require more than just advances in computing hardware. It requires accessibility and affordability. Accessibility is enabled by engineering software that takes advantage of those hardware advances while being so easy to use that they require no special knowledge to do so. Affordability is a relative term based on total cost of ownership vs. return on investment, but there's no disputing the fact that computing prices continue to decrease as computing power increases.

In fact, that's the point Moore was trying to make when he inadvertently laid down the law via what he later called a wild extrapolation: "My real objective was to get the idea across: We have a technology that is going to make electronics cheap," says Moore in a video recalling the impetus of his prediction.

What is the HPC Handbook?

The *Design Engineer's High-Performance Computing Handbook* is a multimedia resource produced by *Desktop Engineering* magazine that will show engineering teams how to determine the best combination of computing hardware and engineering software for their needs. The HPC Handbook is a "living" resource that consists of case studies, videos, surveys, white papers and webinars hosted on hpc.deskeng.com; articles in *Desktop Engineering* magazine; and regularly updated chapters in an expanding electronic handbook. Chapters will include topics such as:

- How to incorporate workstations, in-house clusters/servers and cloud computing into one efficient engineering workflow.
- How to balance workstation components and software preferences to get the most bang for your buck when running specific engineering applications.

Intel Transistor Timeline

Compared to Intel's first microprocessor, the Intel 4004, today's 14nm processors deliver 3,500 times the performance at 90,000 times the efficiency and at 1/60,000th the cost, according to Intel.

1965 Gordon Moore makes a wild extrapolation that would eventually become known as Moore's Law.
1971 Intel's Ted Hoffman invents the first microprocessor, the 4004 with 2,300 transistors.
1979 Intel introduces the 8088 processor with 29,000 transistors.
1981 IBM introduces a PC using the 8088 processor, igniting the personal computing trend.
1982 Intel introduces the 80286 processor with 134,000 transistors.
1985 Intel introduces the 386 processor with 275,000 transistors.
1989 Intel introduces the 486 processr with 1.2 million transistors.
1993 Intel introduces the Intel Pentium processor with 3.1 million transistors.
1995 Intel introduces the Intel Pentium Pro processor with 5.5 million transistors.
1998 Intel introduces the Xeon brand with the Intel Pentium II Xeon processor with 7.5 million transistors.
2001 Intel introduces the Intel Pentium 4 processor with 42 million transistors.
2004 Intel introduces the Intel Pentium 4 processor with HT technology and 125 million transistors.
2012 Intel introduces the Intel Core i5 processor with 1 billion transistors.
2015 Intel introduces the 5th generation Intel Core processor with 1.3 billion transistors.

Source: Intel Corp.

- How parallel software paired with modern processors can improve engineering productivity.
- What virtualization means to the design engineer and why IT wants to deploy it.
- An analysis of professional workstations vs. consumer PCs.
- How to tap into additional computing power when on the go.
- A roundup of the latest workstation hardware.
- Simulation success stories that show how HPC enables simulation-led design in various industries.
- Simulation benchmarking studies.

Why the HPC Handbook?

Design engineers are facing a more disruptive technological landscape today than when the term Moore's Law was coined. The exponential increase in accessible computing power coupled with ubiquitous connectivity has fueled an exponential increase in product complexity. It's no longer enough to design and develop products. Today's engineering teams are designing and developing systems — from self-driving cars to lightweight aircraft to all the connected devices that create the Internet of Things.

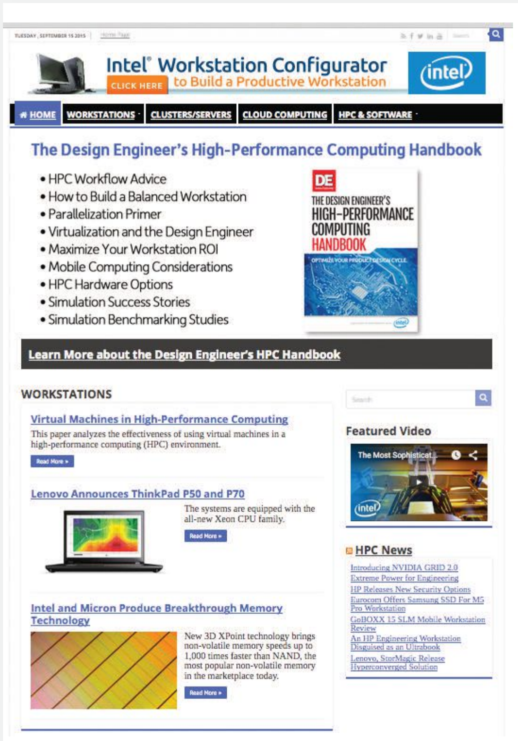
Advances in simulation-led design, optimization technologies and data management is helping design engineering teams innovate more quickly — and powerful, affordable, accessible engineering computing hardware and software makes it all possible. That's why *The Design Engineer's High-Performance Computing Handbook* was created. Design engineering teams need a constantly evolving reference resource that explains what workstation, clusters and cloud-computing can do when used with the latest simulation, visualization and rendering software.

How the HPC Handbook Works

The Design Engineer's High-Performance Computing Handbook is a multimedia resource consisting of magazine article excerpts; the hpc.deskeng.com website that is full of videos, case studies and research; e-newsletters; and regularly released chapters that are free to download. Once you download a chapter, you'll be alerted when new chapters are ready. Each chapter takes a detailed look at a computing topic important to design enigneers. The chapters include pictures, charts, definitions and links to additional information.

The HPC Handbook site is the hub of information for high-performance computing in design engineering. The HPC Handbook is available for download on the site, and the site is constantly updated to include the latest HPC educational resources that are pertinent to design engineering teams. It is divided into sections on Workstations, Clusters/Servers, Cloud Computing and Software, each of which contain the best information available on the Web from *Desktop Engineering* and beyond.

Check it out at hpc.deskeng.com.



CHAPTER 1 EXCERPT

Create a Computing Workflow to Support Simulation-led Design

Determine the right computing options for every stage of design engineering.

You are surrounded by computing power and functionality, so much so that it can be daunting to determine what type of resources to apply to different design engineering tasks. Are tablets, with their modest computing capabilities, useful for anyone on your design engineering team? How should workstations be equipped to best support conceptual designers vs. detailed computer-aided design (CAD) software users vs. simulation analysts vs. rendering and animation experts? Should you set up a cluster of computing resources? Should you burst to the cloud? What about virtual machines? The list of computing questions goes on and on. There are answers to be found, and they're worth uncovering.

Using the right tool for the job not only avoids frustration, it removes precious time from the design cycle, ultimately resulting in faster product development. While every design engineering team may have different computing requirements, they all share the same need you do: to develop better products faster in an increasingly complex product development environment. According to Roland Berger strategy consultants, product complexity doubled between 1997 and 2012 across all industries, even as the average product lifecycle shortened by 24%.

Increasingly, engineering departments are meeting the challenge to produce better products in less time via simulation-led design workflows. For example, GM's PLM Leader Craig Brown said simulation and virtual testing has allowed the auto industry reduce its time to market despite the amazing complexities that have been introduced to automotive design — from lightweight materials to more efficient engines to tens of millions of lines of code. As the name implies, simulation-led design brings simulation further forward in the design cycle to both reduce an organization's reliance on expensive and time-consuming physical testing, and to quickly try many different design approaches to find the optimal ones to pursue.

A simulation-led design strategy requires the right computing environment to support it. As pressure mounts to be faster than the competition, it might be tempting to clamor for an immediate computing hardware investment. Those who hold the purse strings in your organization may even agree. But before long, your engineering workflow may include a patchwork of expensive computing solutions that is a nightmare to maintain, is underutilized and/or won't scale to support future engineering challenges. On the other end of the spectrum, those who hold the purse strings may not understand why the engineering team's computing needs should stray so far afield from the needs of other departments.

The solution is a balanced approach that looks at the big picture, puts the engineering department's importance to the company in context, and wisely invests in the computing needed to support an efficient engineering computing workflow. Such a workflow — when approached systematically rather than in fits and starts, or as a template that sacrifices engineering computing on the altar of enterprise conformity — multiplies your organization's return on investment (ROI).

A systematic approach requires you to:

1. Take an inventory of needs.

2. Match those needs to the best computing resources.

3. Deploy those resources with proper user training.

Learn More

To learn more about creating a computing workflow to support simulation-led design, download Chapter 1 of *The Design Engineer's High-Performance Computing Handbook*. The 16-page chapter also includes a discussion of GPU (graphics processing unit) options, a comparison of high-end and entry-level workstations, mobile computing considerations, a comparison of tablets by operating system, workstation recommendations according to design engineering tasks, definitions of terms and more.

This free resource is available at hpc.deskeng.com/download.

Step 1: Get What You Need

The process of taking an inventory of needs will vary from organization to organization. A small engineering team may get everyone in the same room to get the group's needs out in the open. A large, engineering-centered enterprise may opt to create a planning team or hire a consultant to observe, survey and interview its engineers to reveal the same information. No matter what form the process takes, it's important to differentiate between wants and needs.

"Needs are simply the differences between your current achievements and your desired accomplishments," according to *A Guide to Assessing Needs*, a free resource available via the World Bank's open knowledge initiative that deeply delves into the process of needs assessment. "Needs do not, however, include any mention or discussion of computers, budgets, training courses … executive coaching, leadership, incentives, policy analysis, microfinance strategies, holiday bonuses, reengineering, or any other techniques used to achieve results. Rather, your needs are the basic gaps between current and desired performance."

So this is not the time to say: "I need a new workstation." This is, however, the time to say: "If we're going to meet our deadlines, I need to complete simulation runs faster than the six hours they are averaging."

A thorough needs assessment will likely uncover a number of gaps in your workflow between where you are and where you should be. Some of those gaps can be closed with new hires, training or process improvements, and others can be closed with the right technology.

Step 2: Consider Computing Resources

For those need gaps that can be closed with computing technology, it's important to consider more than just hardware. Hardware is only made useful by software, so the software you're using now, the software you should be using now, and the software you plan to use should help your hardware investments.

A brief outline of the pros and cons associated with different hardware for different stages of the design process can be found in the table below. For a detailed discussion of each solution, please download the first chapter of *The Design Engineer's High-Performance Computing Handbook* at hpc.deskeng.com/download.

Step 3: Deploy

You've analyzed your needs, determined the right hardware for your software and decided on the best configuration for you computing resources. You're done, right? Wrong. Your needs analysis should have determined why a particular computing resource is needed, but that doesn't mean your team will automatically understand how to use those resources effectively, or how to navigate software vendors' licensing requirements, which can quickly become complex.

Even putting something as simple an inexpensive computer tablet in the hands of the engineers on your team is a waste of money and time without proper training. Likewise, an engineer given an upgraded workstation may not fully realize — and therefore not fully utilize — it's capabilities. Many engineering teams drop the ball when it comes to training and support.

Finish strong in the deployment stage to make the most out of your local and remote computing resources.

Pros and Cons of Computing Resources

	Tablets & Ultraportables 	**Workstations** 	**HPC Resources** 
Typical Use Cases	Conceptual design and visualization	Detailed CAD and some simulation and rendering	Intense simulation and rendering, on-demand computing
Pros	More portable than laptops Touchscreen interface Long battery life	Versatile Affordable Power Ease of Setup and Use Expandable/Customizable	Scalability Cost saving potential Flexibility Reduced software maintenance
Cons	Limited functionality Limited processing power Limited onboard storage Limited expandability	Software patches often consist of individual updates Not easily portable Not infinitely scalable	Can be daunting to setup Overcoming security concerns Dependent on connectivity Often dependent on off-site support

Wide-format printers like the Canon ImagePROGRAPH have the performance to print large numbers of documents quickly, enabling collaboration with those who need printed output. *Image courtesy of Canon.*

Using **Large-Format** Printers and Scanners

Integrating printing and scanning into your design workflow takes planning, good equipment and a clear goal in mind.

BY PETER VARHOL

In an era where seemingly every document and detail is digitized and stored for posterity, many engineering plans and drawings are still printed out and maintained in printed form, with comments and changes written directly on the document. While most groups have CAD and similar software, there are still filing drawers full of paper plans and schematics that may be referred to more frequently than their electronic counterparts.

There are good reasons for relying on printed documentation, even today. Documents can easily be shared in meetings. Engineers can make ad hoc changes, mark up designs and write comments. Digital files and storage can be more easily protected against someone who is a partner today, but may be a competitor on a different project tomorrow. Paper documents may also have to be delivered to the customer at different points in time in a project.

However, the documents always have to be maintained electronically. If a document is updated or altered by hand, it is in a single location on a perishable medium. Many documents have to be scanned periodically and versioned so that the most current one is identified and readily available.

Rare is the engineering office that doesn't have a large-format printer and scanner. Large-format is generally defined between 18 and 100 in., so there is a great deal of variation in size, volume and performance. But they all share one thing in common: They are essential in collaborating to produce designs for electronics, consumer products, buildings and more.

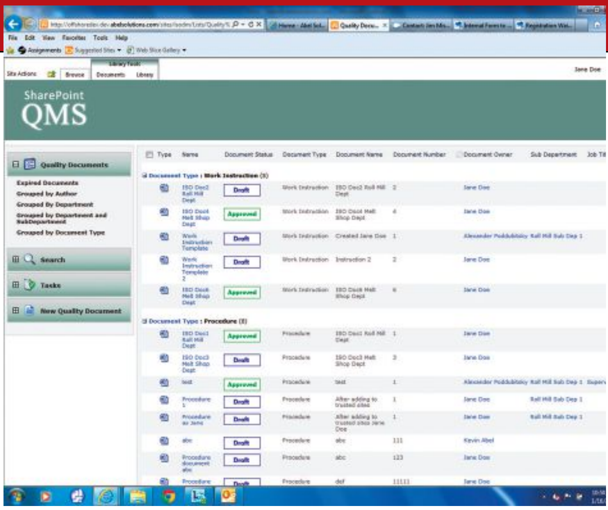
How should these devices be used in the design process? Printing and scanning documents is a way to share information and capture changes and feedback. Given the investment in this equipment, it is essential to set up a system for managing documents. This can typically be more challenging because it encompasses a broad array of possible activities — from storage to workflow to annotation to organization. But printers and scanners work together to distribute and capture changes in information, respectively.

Print to Collaborate

The primary reason to print documents is to communicate and collaborate. Engineering groups almost always need multiple hard copies of drawings, specifications, block diagrams, schematics and similar documents. Often, the number of documents can be in the hundreds or thousands for complex projects.

While many design software packages will let users share engineering drawings and other documents electronically, it may not be feasible to do this with all stakeholders. They may not have licenses for the software, or they may have clients or partners without electronic access to those files.

For large projects, or if you're printing frequently, performance is an important consideration. Fast and dedicated printers will pay for themselves in productivity.



Document management software such as Microsoft SharePoint can help engineering groups organize and version documents so that both originals and scanned copies can easily be identified. *Image courtesy of Microsoft.*

Print at Major Milestones

Whether or not these documents are shared, engineering teams should also print at major milestones, such as critical design reviews and design freeze, so that there is a paper record of the state of the project at that point. This is especially true if the client is requesting deliverables.

If one copy goes to the client, a second copy should be part of the project record. It represents a snapshot of the state of the project at that time, rather than an ongoing status. A snapshot gives project participants an idea of how much work has been done, and how much more needs to be accomplished.

Printing at milestones also provides a convenient look back for engineers to recall why certain decisions were made. While some of that can be done online, the value of a printed copy lets engineers quickly check a detail or comment from a past document. You may also want to print paper copies to store off-site as a disaster preparedness activity. Secure storage services such as Iron Mountain can pick up and store documents to keep a hard copy off-site record.

Scanning for Data Capture

Offices should scan project documents as they change. It's important to capture all changes and annotations as they are made. Many of these are likely to be handwritten on printed copies, especially in the field or by clients or other stakeholders.

With scanned documents, versioning can be problematic. How you manage and store your documents can mean the difference between using the right versions and getting confused by location, version and accuracy of a given document.

The best way to make sure documents and drawings are archived in order and with appropriate dates is to use a document management system or version control system. There are dozens of different commercial document management and versioning systems available, and at least a few free and open source packages. Some, such as Cognidox, are specifically designed for high-tech product development. Others, such as eXo, add social and collaboration features.

In some cases, printers and scanners may already come with document management software. Many groups also use Microsoft SharePoint for document management and other collaboration purposes. Alternatively, do your research and choose a product based on your needs. Among the features you should consider are the ability to categorize and search documents, keep multiple versions of documents and maintain document details such as creator, changes and last change.

For small volumes of work, there are combined printing and scanning solutions that may serve the needs of some groups. However, because only one function can be used at a time, such a solution could create a bottleneck at critical times. It might also be useful as a backup or secondary device on some networks. Also, most of these are at the lower end of the "wide" range, so don't expect them to work with large-format documents.

Additionally, you should plan to archive documents for reference purposes. It's possible that the typical project may have hundreds of scanned documents, each with changes marked on the documents. Saving these documents and making them searchable with a document management system creates a comprehensive project record.

When to Print and Scan

Buying and installing a printer and scanner is only the first part of the story. Knowing when to print and scan is the next part. But managing documents, by purpose, date and summary of changes makes it all work.

Printing is especially important when some project participants don't have software licenses or access to electronic storage where the documents reside. Scanning captures ad hoc comments and handwritten changes, which then have to be incorporated into the design.

To make sure these are captured, scanning and categorizing is required so that the designers can incorporate changes. This means scans have to be put into a document management system and the responsible engineer notified. By using a system that can print, scan and categorize data, engineering and design teams can ensure that their work is available in print and digital formats. **DE**

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INFO ➜ **Canon:** Canon.com

➜ **Cognidox:** Cognidox.com

➜ **eXo:** eXoplatform.com

➜ **Iron Mountain:** IronMountain.com

➜ **Microsoft:** Microsoft.com

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Review: An Impressive Printer

The Epson SureColor T5270 large-format color printer delivers stunning output at an affordable price.

DAVID COHN

The Epson SureColor T5270 large-format color printer with optional scanner is easy to use and rapidly scans, copies and prints onto a wide range of media. ***Image courtesy of Epson America.***

In July 2014, Epson launched its next generation family of large-format color printers — the Epson SureColor T3270, T5270, T7270, T5270D, and T7270D. *DE* got its first look at these new printers at SIGGRAPH 2014 in Vancouver, BC (see "Wowing Them in Vancouver at SIGGRAPH 2014," deskeng.com/de/?p=18757) when product manager Timothy Check demonstrated them for us and graciously printed several samples of drawings and artwork we provided. At that point, we began to make arrangements to do our own hands-on evaluation. It took nearly a year for those efforts to come to fruition, but it was worth the wait.

The five members of the Epson SureColor T-Series represent three widths — 24 in. (T3270), 36 in. (T5270) and 44 in. (T7270) — with the 36- and 44-in. models available as either single- or dual-roll versions. All are suitable for technical drawings, graphic posters and retail signage. List prices for the printers range from $2,995 for the T3270 to $6,995 for the dual-roll T7270D. For our evaluation, Epson sent us the SureColor T5270, a 36-in. wide single-roll printer. While its suggested retail price of $3,995 is already quite affordable, the T5270 is readily available from numerous merchants for $2,945 with free shipping and no sales tax, placing this large-format color printer within reach of even a small engineering firm.

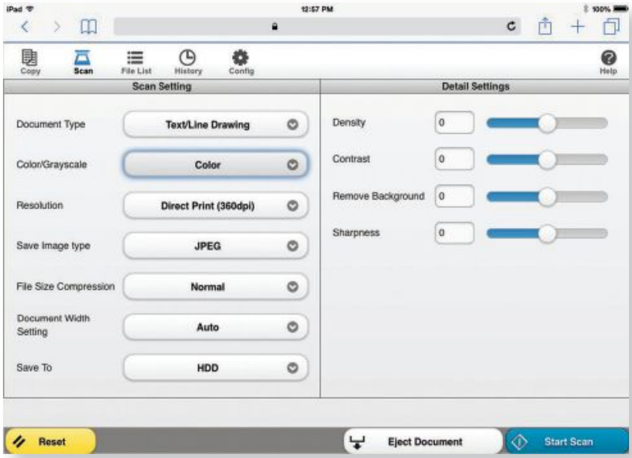
Assembly Required

Rather than ship the T5270 directly to us, Epson sent it to JVH Technical, a dealer based in Bellevue, WA. A JVH representative then delivered the printer and a host of optional accessories to our Bellingham, WA, office and helped us get it up and running.

Setting up the T5270 was not particularly difficult. The printer and stand ship in a palette-mounted carton measuring 70x32x42 in. (LxWxH) and weighing 250 lbs. Unpacking and assembling the stand was relatively simple, but mounting the printer on that stand requires at least two people. All five T-series printers include a paper basket — a cloth sheet that drapes over various support arms and stabilizer brackets — that collects paper from the printer, preventing it from falling to the floor and becoming creased or dirty. The basket can be placed into two different positions to catch a single sheet or up to 20 sheets automatically cut from a roll, enabling unattended print runs.

Epson also sent its optional SureColor Multifunction Module. This $4,200 accessory (available for the 36- and 44-in. models) adds scanning, copying and sharing capabilities. Using Epson's REALOID Image Processing Technology, the scanner's in-line CIS image sensor produces scans and copies at resolutions from 200 to 600 dpi. The scanner ships in three separate boxes (scanner, stand and hard drive). Assembling the stand and mounting the scanner proved to be the most time-consuming part of the process, but was aided by an excellent video on the Epson website. The stand suspends the scanner directly above the printer and a pair of hydraulic struts make it easy to raise the scanner so that you can load paper. The scanner adds an additional 116 lbs., bringing the total weight to more than 300 lbs. The total height of the system reaches 65 in. with the scanner in its raised position.

The scanner also comes with a 320GB internal print server (a component that can also be purchased separately for $400). We did not install that hard drive, however, because Epson also sent us its Adobe PostScript 3 Hardware Module. This $1,200 option includes a 1.6GHz dual-core processor and 320GB hard drive and adds PDF and batch printing capabilities. Because most users will benefit from the ability to manage job queues as well as to save and reprint jobs directly on the printer, an internal hard drive is a must-have regardless of whether you get it as part of the



When connected to a network, you can also control the scanner and printer via a Web browser, even on a tablet. ***Image courtesy of David Cohn.***

scanner, the PostScript module, or as a separate component. Curiously, since we received both the scanner and PostScript module, we ended up with an extra hard drive module — you cannot install both the hard drive and the PostScript module.

Loading roll paper could not have been easier. We simply raised the scanner, opened the roll paper cover, unlocked and removed the roll media adapters, inserted and locked those adapters into the core of the paper roll (no spindle required), inserted and locked the roll into the printer, and then followed the instructions on the printer's display panel. In our case, the printer automatically detected the paper type and quickly indicated that it was ready to print. If the paper type was not detected, it is a simple matter to set the paper type manually and to store custom paper settings.

Finally, we unpacked the ink cartridges, shook them gently, and slid them into a compartment in the front lower-right of the printer. All five T-series printers use the same Epson UltraChrome XD pigmented ink and require a total of five ink cartridges — cyan, yellow, magenta, matte black, and photo black — which are available in three different sizes — 110ml ($70 each), 350ml ($170) and 700ml ($280). The printer ships with all five 110ml cartridges, but nearly half of the ink was consumed during the initial ink charging, a process that took less than 10 minutes (rather than the 25 minutes noted in the manual). The ink yields archival prints that are smudge and water resistant even for short-term outdoor use. Epson guarantees print quality for one year once the ink cartridge has been installed. Typical cartridge shelf life is two years from date of production and you can mix-and-match different sizes for each color. Total assembly and setup time was about 2 and a half hours.

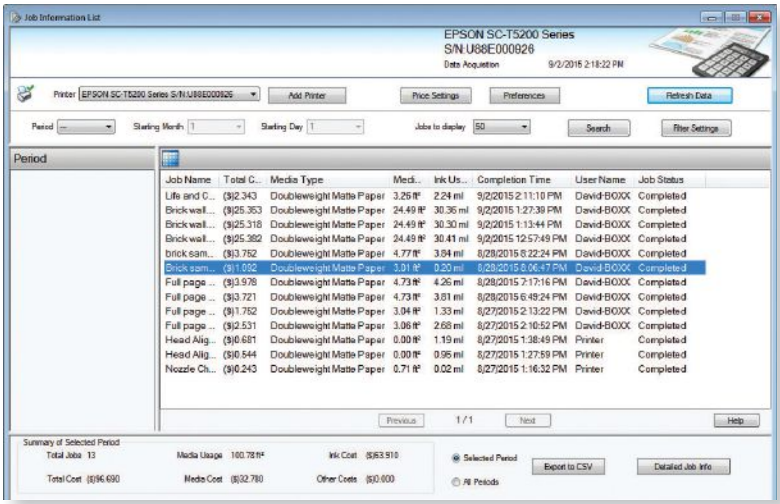
Lots of Paper Choices

The printer does not ship with paper, so be sure to include some as part of your initial purchase. Epson sells a wide range of media and sent us three different types for our review: An 84-ft. roll of double-weight matte paper ($80), a 100-ft. roll of premium semi-matte photo paper ($195), and 10 sheets of 24 x 36 in. enhanced matte poster board ($95). The Epson website lists dozens of other types of media. For example, most typical CAD drawings could be printed on 20# uncoated paper ($22 for a 36 in. x 100 ft. roll). The printer handles rolls with either a 2- or 3-in. core as well as cut-sheets. It accepts media up to 59 ml thick and can use non-Epson media as long as it conforms to the printer's specifications. When printing on roll media or cut sheets, the printer can be placed with its back against a wall, but when printing on poster board, you must raise the integrated poster board supports and ensure that there is adequate space both behind and in front of the printer.

Before using the printer for the first time, the Epson dealer ran a test print to check the alignment of the print head. This proved to be perfect and the printer performed flawlessly throughout our evaluation. Similarly, after installing the scanner, Epson recommends running a calibration and provides a calibration sheet for this process. Like the printer, the scanner worked perfectly right out of the box.

Fast and Easy

The T5270 has a small footprint for a 36-in. wide printer, but at 56x45x30 in. it still commands a fair amount of space. With the optional scanner, you will need two electrical outlets. The printer can connect to a computer via USB, but using its built-in Ethernet port enables the T5270 to be available to anyone on your office network. The printer obtained an IP address within seconds of connecting it to our network. We down-



Once you enter the unit cost for paper and ink, the Job Accounting software shows the cost for each print along with the amount of paper and ink used. ***Image courtesy of David Cohn.***

All scanner and printer functions are accessible using the well-designed control panel. *Image courtesy of Epson America.*

Loading ink cartridges is easy thanks to the front-loading ink bay. *Image courtesy of Epson America.*

loaded the latest drivers from the Epson website and were ready to begin our tests.

All Epson SureColor T-series printers use a PrecisionCore TFP print head with 720 nozzles per color. The print head is permanent for the life of the printer and incorporates variable-size droplet technology (as small as 3.5 picoliters), providing extremely accurate dot placement. Available output resolution ranges from 720x360 dpi up to 2880x1440 dpi. The T5270 can print at up to 115 sq. ft. per hour at 1440 x 720 dpi and at 740 sq. ft. per hour at 720 x 360 dpi. A typical D-size (22 x 34 in.) color CAD drawing takes just 25 seconds to print at 720x360 and less than 3 minutes at 1440x1440 dpi.

All printer and scanner functions can be controlled via the well-designed control panel with a 2.7-in. color LCD. The menu provides easy-to-use controls for scanning and copying, reprinting jobs stored on the optional internal hard drive, loading and adjusting the paper setting, checking ink levels, performing maintenance (such as cleaning nozzles and aligning the print head), and adjusting setup options (such as network and power settings).

The printer was ready to go to work 1.25 minutes after turning it on. When idle for 15 minutes, it goes into sleep mode and after eight hours of inactivity, it shuts itself off (both user-configurable). Once in sleep mode, it takes just over a minute to wake up and go back to work. When printing, the T5270 consumes approximately 60 watts and produces 60dB of sound pressure. This drops to 16 watts (and 37dB) in ready mode and 3 watts or less when in sleep mode, making the printer very energy efficient.

Powerful Software

The printer drivers and utilities, available for both Windows and Mac OS X, proved to be powerful. You can print directly from most Windows or Mac applications as you would to any other printer. With an optional hard disk installed, you can view and control print jobs and reprint jobs stored on the printer. Windows users can print multiple documents to Epson's Layout Manager, arrange them on a virtual page, and then print that sheet. The driver also enables you to set up and manage color profiles.

The optional scanner, which can scan in color at a rate of 6 in. per second, was also incredibly easy to use. Although you can control the scanner from the printer's control panel, we found it easier to open a Web browser on a computer or tablet and control copy, scan, preview and sharing features remotely. Using Copy Center, we were able to make a color copy of a D-size document in 60 seconds and save scanned documents in JPEG or PDF format. You can scan and e-mail a file even without a PC. You can also enable automatic e-mail notifications to alert you when jobs are finished, ink runs low or an error occurs. The printer also has an error status lamp that is easy to see, even across a large room.

Calculating Consumable Costs

The T5270 can print on sheet media as narrow as 8.27 in., on roll media from 10 in. to 36 in. wide, and is capable of borderless printing. The maximum printable length is limited only by the application, operating system and driver used. During our evaluation, we printed full-color posters measuring 36 in. wide and more than 8 ft. in length.

Of course, what you pay for a printer typically pales in comparison to what you will pay for consumables over the life of the printer. Yet calculating typical printing cost is often an exercise in creative estimation. A typical CAD drawing will use a fraction of the ink consumed producing a color photograph, and the Epson SureColor T5270 is adept at both. Using a typical street price of $153 for each 350ml ink cartridge and an ink consumption rate of 1ml per sq. ft. at 100% coverage, we came up with the following costs based on a 24 x 36 in. print:

- **Monochrome CAD drawing:** $0.41 ($0.15 for 20lb. uncoated paper at $22/36 in. x 300 ft. roll and $0.26 for ink based on 10% matte black ink coverage).
- **Color CAD presentation drawing:** $2.80 ($2.41 for double-weight matte paper at $99/36 in. x 82 ft. roll and $0.39 for ink based on 15% CMYK coverage).
- **Color photograph:** $6.52 ($3.90 for premium semi-matte

photo paper at $195/ 36 in. x 100 ft. roll and $2.62 for ink based on 100% CMYK coverage).

Other consumables include replacement cutter blades ($120) and replacement ink maintenance tanks ($63 each), but according to John Harrington at JVH Technical, the self-sharpening T-series rotary cutter lasts almost indefinitely and the ink maintenance tanks last for as many as 10 complete changes of the 350ml ink cartridges, depending on the frequency of head cleanings.

A Versatile Workhorse

Epson backs the printer with a one-year warranty that includes on-site next business day service. You can extend coverage to a second year for $625 or for a total of three years for $1,025. Note that the manual warns that if you do not print for an extended time, the print head nozzles may become clogged. The manual recommends printing at least once a week. While the extended warranty is pricy, you can add the additional coverage at any time during the first year of ownership.

We were impressed when we saw the T7250 demonstrated at SIGGRAPH. Now that we have gotten to use one, we are doubly impressed. The Epson SureColor T5270 rapidly delivers great output with ease, making it a pleasure to use. And with a street price under $3,000, this workhorse wide-format color printer could find a home in many engineering offices. **DE**

David Cohn *is the technical publishing manager at 4D Technologies. He also does consulting and technical writing from Bellingham, WA, and has been benchmarking PCs since 1984. He's a Contributing Editor to* DE *and the author of more than a dozen books. Contact him via e-mail at david@dscohn.com or visit his website at dscohn.com.*

INFO → **Epson:** Epson.com

Epson SureColor T5270 Large-Format Color Printer

- **Price:** $10,095 as tested ($3,995 base price)
- **Size:** (WxHxD): 56x45x30 in. (65 in. high with optional scanner)
- **Weight:** 186 lbs. (302 lbs. with optional scanner)
- **Warranty:** One-year on-site next day business with toll-free phone support Monday through Friday

SYSTEM REQUIREMENTS FOR PRINTER DRIVER:

Operating system:

- **Windows:** Windows XP/Vista/7/8/8.1; Windows Server 2012/2008/2003
- **Mac OS X:** Mac OS X 10.5.8 or later
- **CPU required:** Core 2 Duo 3.05GHz or better
- **Memory required:** 1GB or more of available memory
- **HD space required:** 32GB or more
- **Interface:** USB 2.0 or Ethernet
- **Printer languages:** Epson Precision XD and HPGL/2 and HP-RTL; optional Adobe PostScript 3 module adds support for PS, EPS, PDF, JPEG, TIFF and CALS-G4 file

Product Development for Additive Manufacturing

Autodesk Within aims to make designing for 3D printing easier and more intuitive.

BY RANDALL S. NEWTON

Common design exploration and optimization software tools today rely on simulation and analysis as a step separate from geometry creation. If it were a dance, we'd call it the Engineering Two-Step. First you design a part with CAD then explore options for improvement. Engineering workflows worldwide are based on this iterative dance.

The dance exists because of pre-existing conditions over which the engineer has no control. Such primary factors as material composition or manufacturing method are givens, not subject to modification or optimization. Now, a new set of software tools are coming to market that take advantage of both additive manufacturing and computational design algorithms to bypass the pre-existing conditions of material composition and geometry.

Autodesk Within is the name of a new line of product development software that applies generative design algorithms to additive manufacturing. Originally developed for architectural design, generative design software would work as a parametric engine to find an optimal solution to a specific design challenge. Instead of trying to solve a topology challenge for an architect, Autodesk Within is intended to solve the challenge of designing the most efficient internal structure of an object to be 3D printed. By providing such inputs as desired weight requirements, maximum stress and displacement, Autodesk Within generates designs with variable density lattice structures and surface skins. The company says the resulting components are higher performing and can be considerably lighter in weight than traditional designs. The software is cloud-enabled, so the potentially millions of design iterations do not burden the local CPU.

The technology is currently available in two forms: Autodesk Within is for aerospace, automotive and industrial applications; Autodesk Within Medical is for the design of orthopedic implants. The ability to design lattice structures for additive manufacturing is crucial to both products, but the reasoning for them varies with the application.

Custom Implants

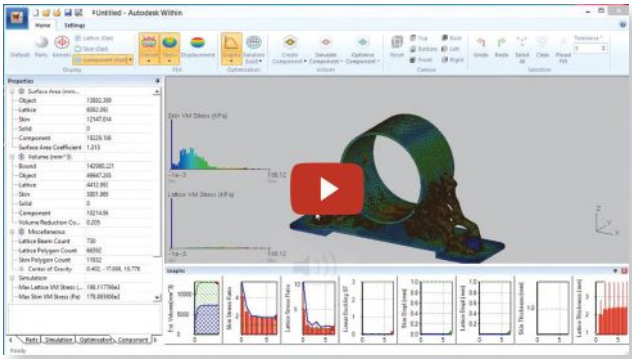
Within Medical allows biomedical engineers to create orthopedic implants with micro-lattice porous structures that help properly connect implants to living bone (osseointegration), and promote development of blood vessels in the surrounding tissue (vascularization) to facilitate healing.

An implant designed using Within Medical for 85% human facial restoration is pictured. *Image courtesy of Autodesk.*

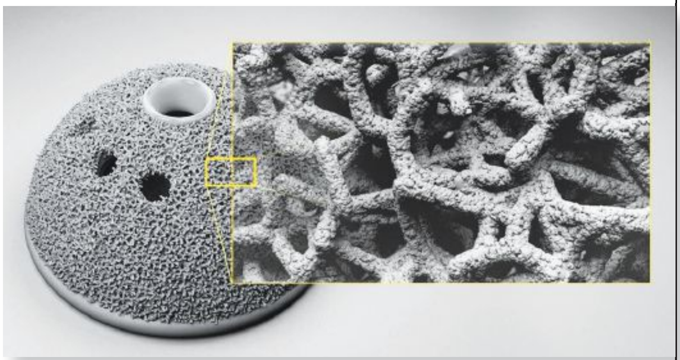
"Because bone ingrowth is vital for many orthopedic surgeries, Within Medical uses various pore size configurations and rough lattice surfaces to help the porous implant integrate properly with the bone," says Mark Davis, senior director of Design Research at Autodesk. "Within Medical designs are also optimized for specific 3D printing processes — such as direct metal laser sintering and electron beam melting — that allow for highly accurate manufacturing."

More than 600 patients are now living with implants designed using Within Medical, including surgical repair of defects or deformities of the skull, hip joint replacement, lumbar vertebral replacement and facial reconstruction.

"Within Medical has contributed enormously to changing the way in which we design and manufacture implants," says Daniel Fiz, CEO of Novax DMA, a company specializing in the R&D and production of innovative medical technologies and an early user of Within Medical. "It is a tool with which both custom made and standardized implants can be designed and developed in a much more biological and intelligent way.



Watch a video overview of Autodesk Within by *DE* Senior Editor Kenneth Wong at deskeng.com/virtual_desktop/?p=10831.



Within Medical helps automatically create structures such as the micro porous trabecular lattice structure in this acetabular hip cup. *Image courtesy of Autodesk.*

As both a surgeon and a designer, I believe this is the most important tool I have ever used, enabling us to make anatomic designs that would be impossible with other software."

Titanium Automotive Roll Hoop

Early Autodesk Within user 3T RPD is a UK-based additive manufacturing production company that consults with manufacturers in a range of industries including aerospace, F1 motorsport and medical devices. For an F1 project 3T RPD co-designed a titanium alloy roll hoop that would be attached to a raised point of the vehicle. Typically roll hoops are heavy to withstand high stresses during a crash. But the weight normally required is not ideal for maintaining a low center of gravity, as needed on this project.

Autodesk Within was used to design a roll hoop with internal lattice structures that could only be fabricated using additive manufacturing, and reduced the weight considerably without compromising design specifications. When installed, only the underside of the hoop's face required a small support structure to be added at final assembly; the remainder of the design was self-supporting. **DE**

Randall S. Newton *is principal analyst at Consilia Vektor, and a contributing analyst for Jon Peddie Research. He has been part of the computer graphics industry, in a variety of roles, since 1985.*

INFO ➜ **3T RPD:** 3TRPD.co.uk

➜ **Altair:** Altair.com

➜ **Autodesk:** Autodesk.com

➜ **Dassault Systèmes:** 3ds.com

➜ **Materialise:** Materialise.com

➜ **Novax DMA:** NovaxDMA.com

➜ **Safran Group:** Safran-Group.com

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Other Optimization Options

There are several engineering software tools on the market that optimize the process of design exploration. But most largely focus on form and function optimization to integrate design and simulation in varying ways. (See "Exploration, Optimization and Iterative Design," deskeng.com/de/?p=23600.)

A new initiative at Dassault Systèmes may bring the next iteration in designing for additive manufacturing. During the Paris Air Show in June, Dassault announced a partnership with Safran Group, an R&D consultancy specializing in aerospace and defense. The partnership seeks to create an "end-to-end digital solution for additive manufacturing" that addresses both upstream material design and downstream manufacturing. The goal is for software to expand Dassault's existing 3DEXPERIENCE platform with software that automates engineering for the additive manufacturing of an engine part, including material science, functional specification, generative design, 3D printing optimization, multi-robotic production and certification.

Altair recently announced new OptiStruct solver capabilities that expand topology optimization support for the use of 3D printing. OptiStruct is a technology for topology, topography, size and shape optimization. It now extends topology optimization to assist in the efficient blending of solid-lattice structures with smooth transitional material volume, according to the company.

Altair is also working with partners like Materialise to enable more efficient data transfer for 3D printing. Lattice structures may contain hundreds of thousands of lattice cells, so conventional STL file transfer can be a bottleneck for the overall process. Software packages like 3-Matic-STL from Materialise focus on improvements of a given lattice component to accommodate the requirements of 3D printing, creating support structures where necessary.

Take Control of Requirements Traceability

Requirements tracking tools address increasingly complex design environments.

BRIAN ALBRIGHT

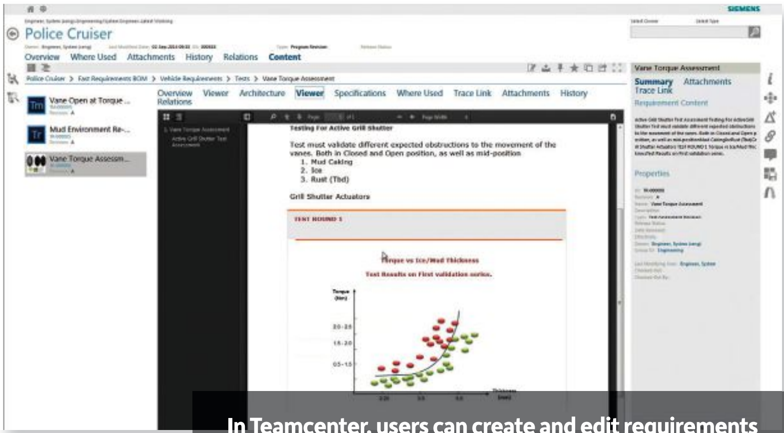
As product design becomes more complex, spanning engineering and including interrelated mechanical, electrical and software requirements, managing those requirements and providing traceability across the design process has become more critical. Designers need a way to ensure their work comports to customer expectations, functional requirements and government regulations. They need visibility into how a change in one component can affect the system. Failing to do so can cause delays, recalls or even complete project failures.

"In the past requirements could be relatively simple because products were relatively simple," says Doug Akers, vice president of ALM solution management at PTC. "You had a purely physical product. As software becomes more pervasive and as products start interacting with the environment and other products, it's no longer so simple. Those requirements live on because you have to be able to reiterate on that design, and take derivatives. The requirements now have a genealogy. Traceability becomes essential; you need to know which specification comes from which version of which requirements within which product family."

In many organizations, engineering and design work was completed in silos, which made this type of traceability difficult or impossible. PLM (product lifecycle management) and ALM (application lifecycle management), for example, were typically managed separately. "So the requirements were kept in one or the other system, or in a stand-alone environment," says Dennis George, Teamcenter marketing manager at Siemens PLM Software. "It's difficult to link requirements in a standalone environment. At a high[er] level, you wouldn't know what the breakdown was for the product or for the software elements."

Requirements for tracking and traceability tools now provide a way for companies to trace requirements forward and backward within the process, and to provide an audit trail. This type of functionality is critical for validation testing. In markets like medical devices and other highly regulated industries, traceability itself is part of the compliance requirement.

"That helps define the regulatory strategy and types of clinical trials you have to do," says Arieh Halpern, director of Life Sciences Industry at Dassault Systèmes. "Transitioning down, you then transfer those product requirements to engineering, and they'll take those and put together an engineering product design spec. Those verification tests can be very simple or can involve thousands of tests if you get into something like a robotic surgical system. Requirements traceability is fundamental to being able to develop the test plan against each of those requirements."



In Teamcenter, users can create and edit requirements specifications containing graphs, images and tables to help ensure the requirement is clearly understood by all stakeholders. *Images courtesy of Siemens PLM Software.*

Traceability Breakdowns

Traceability failures typically occur because of disconnected design processes, or the use of paper documents or spreadsheets to manage requirements. These approaches make it difficult to ensure traceability or revision control.

"That paper document may go from marketing to engineering and be put into a requirements tracking program, but you don't have backward traceability to the initial document," Halpern says. "You [can] lose those initial requirements, and in some cases companies don't even use software to track those requirements in the first place."

Testing requirements could then be developed against what may not be the final release version of the engineering product specification, which means testing won't be 100% accurate or complete. That could warrant a recall.

The volume of the information that has to be tracked also has complicated requirements tracking. Employees can only keep track of so much information or keep so much data on hand. "Up and down the supply chain, traceability becomes essential," Akers says.

With regulatory requirements, both risk and scrutiny are higher. Having a tool to manage that process and provide an audit trail alleviates some of that project risk. "If you are in a regulatory environment and don't have a trace on those requirements, you are far from being OK," Akers says. "You need to have evidence that test results are directly linked to your requirements."

Users can tie requirements to models and test methods that can be simulated and verified to ensure you meet product targets with Teamcenter.

A System-wide View

There are a variety of software approaches to requirements traceability, available as stand-alone or modules, or included as features in PLM or ALM tools. These solutions should provide the ability to trace requirements both forward and backward as they change.

Users should also be able to validate the total system, including both hardware and software that are increasingly interlinked. All of those subsets of requirements should be linked to a master product requirement set.

"You need to make sure you are taking a system view of the product before you decide which of the three disciplines (hardware, software or electrical) will tackle a change," Akers says. "Having that system view that is independent of the implementation is the first key to solving that challenge. It's not the complete solution to the problem, but it helps."

Halpern agrees: "You should be able to keep those early requirements in place and strike them as they change so you are working off of one master document. You can see the changes that have been made, and the features or requirements that have been removed for specific reasons."

Auditing capabilities are also critical for regulatory compliance traceability. "The FDA has been known to close down a product or prevent it from being shipped, or even shut down a whole division until you are in compliance," Halpern says. "That's why it's important to have complete document management."

Traceability also enables impact analysis, allowing you to see how a change to the design or to the requirements can affect the end product.

Tools can help you create workflows across design groups that are uniform and consistent, so when a change is proposed everyone understands what will happen. "An e-mail will tell them what is associated with the change, or if there is a task that must be completed and who needs to sign off on it," Siemens' George says. "All of this needs to be done in tools they are familiar with."

According to Akers, this process is made much easier if traceability is an automatic, secondary element of the primary design activities associated with meeting the requirements. "You can create those relationships automatically," Akers says. "The processes create the traces. The network is the foundation of a solution, not the end point. When I'm writing requirements, I'm deriving that from the neighboring requirements, and those traces should be created as I do the derivation. When I write code, the trace should be attached to the design I'm writing code for. Traces are a byproduct of productive work."

The Human Element is Critical

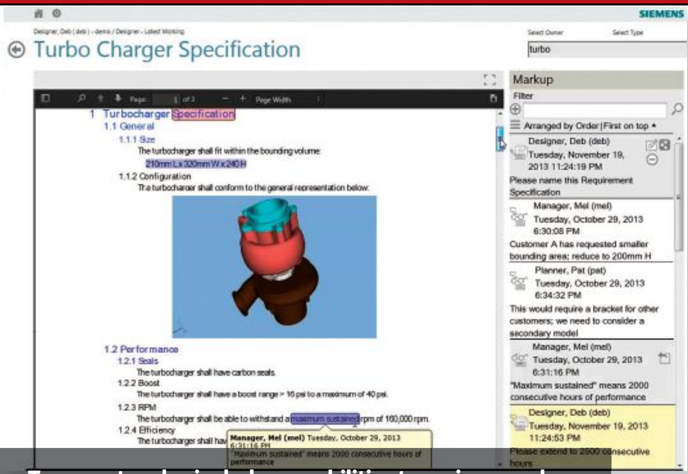
Cultural and operational changes have to accompany the use of requirements tracking solutions for the systems to work effectively. Processes and workflows have to be mapped, and employees need to understand the importance of accurate traces.

"The software really ensures complete traceability forward and backward," Halpern says. "That doesn't mean it's not open to human error; if you mis-enter information or convert a document incorrectly, you'll have errors. But the software tools are still a thousand times better than if you are working from paper."

Companies have to ensure that changes and impact assessments are communicated to the right people, and employees should understand their role in the development process and how they affect requirements compliance. "They have to understand the importance of traceability," Akers says. "It's easy to overlook when you are dealing with different tools and processes."

There also needs to be a clear process to ensure that requirement changes are linked throughout the entire product lifecycle. There can be thousands of changes to a given FDA regulation during the development process, and those changes have to be kept consistent within the development process.

"As you receive requirements, you make sure the appropriate people are responsible for entering the data into the system," George says. "You have to capture the requirements so that they can be linked to the product development process as well as making sure that the mechanism people use in order to get those requirements into the system is one that is familiar to them."



Teamcenter also includes capabilities to review, mark-up and add comment to requirements as they evolve.

New Developments

The industry continues to put new demands on requirements tracking tools. Halpern says customers are asking for CAD or mechanical drawings to be linked to requirements documents, and for the ability to extend that linkage to the parts supply chain.

"You have high-level requirements, but if you get into electrical design you have to make sure that those components adhere to certain specifications," Halpern says. "You have to go out to the supply chain and ensure that the parts meets those standards. This goes all the way down to individual components."

Another emerging need is the ability to propagate change on a massive scale across product families. "If you have to network hundreds of thousands of artifacts and you want to branch all of those traces, how do you do that at scale at the product level?" Akers says. "That spans multiple disciplines."

The emergence of the Internet of Things will create new demands for traceability, while also providing a real-time data feed from the product in the field. Companies are also looking for ways to better link requirements across different design domains. "How do we make sure software requirements are linked and tightly tied to the electronics that turn them, or the mechanical operations associated with them?" George says. "How do you assess potential changes and the effect they have on other domains? That's where the biggest focus is."

These emerging traceability needs should be folded into existing workflows that will make it easier and less disruptive to managing complex requirements. "Customers come to us with a traceability problem, and their misconception is that traceability is hard," Akers says. "It shouldn't be. Process is hard, and engineering products is hard. Traceability is easy if it is a byproduct of natural work." **DE**

Brian Albright *is a freelance journalist based in Columbus, OH. He is the former managing editor of Frontline Solutions magazine, and has been writing about technology topics since the mid-1990s. Send e-mail about this article to DE-Editors@deskeng.com.*

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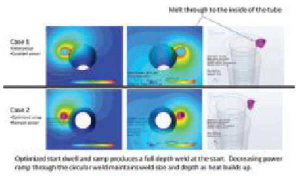
Laser-quick Design

Simulation of laser welding shortens design cycle and optimizes component design at Owens Corning.

BY JOHN KIRKLEY, CD-ADAPCO



It wasn't your everyday assignment. Byron Bemis, senior research associate at Owens Corning, and his team were asked to design a new generation of manufacturing components that could not be made using existing manufacturing processes. Owens Corning is a leading global producer of residential and commercial building materials, including insulation and roofing shingles; glass-fiber reinforcements for products such as cars, boats, wind blades and smartphones; and engineered materials for composite systems. Its Science and Technology Center, where Bemis is located and much of the company's research and development (R&D) takes place, is located in Granville, OH.

With this particular R&D project, Bemis and crew were breaking new ground. To design and fabricate the requested parts, their initial designs called for blind keyhole welding through one sheet metal part and into another. "Developing the welding parameters to make those welds work reliably and robustly took a lot of trial and error," Bemis says. "To accomplish this using physical prototypes meant fabricating the individual component parts and then laser welding them up using a set of pre-determined parameters to see what happens. You continue doing this until you find the right combination."

Bemis adds that one of the most challenging aspects of this project was the necessity to weld close to small features or near corners or edges. If the laser is running too hot or moving too slowly, the feature or edge could melt, ruining the part.

These were small welds, varying in size from millimeter to submillimeter scale, made on very small parts that demanded high-precision fabrication. Bemis says they were running very narrow weld beams — in many cases 50-micron weld spots using up to a kilowatt of laser power on an individual spot.

The materials used were alloys with very high melting points, high molten metal viscosity and surface tension. Geometries were also complicated.

In search of a solution, he spoke with his support engineer at CD-adapco, who had experience in simulating welding.

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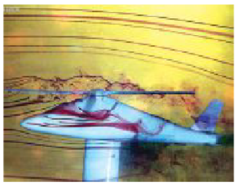
Engineering Techniques for Helicopter Rotor Simulation

Mentor Graphics applications help the Central Aerohydrodynamic Institute gather results for CFD.

BY P.N. SUBBOTINA, T.V. TREBUNSKIKH, MENTOR GRAPHICS; B.S. KRITSKY, SC.D., M.S. MAKHNEV, R.M. MIRGAZOV, PH.D. , TSAGI, ZHUKOVSKY



The Central Aerohydrodynamic Institute (TsAGI) was founded on Dec. 1, 1918, under the initiative and leadership of N.E. Zhukovsky, the father of Russian aviation. It was the first scientific institution to combine basic studies, applied research, structural design, pilot production and testing. Over its distinguished history, TsAGI has developed new aerodynamic configurations, aircraft stability/controllability criteria and strength requirements. It was a pioneer in the theory of flutter, along with many other theories, applications and experimental studies.

Today TsAGI is one of the largest scientific research centers in the world. One of the main areas of TsAGI activity is investigating new configurations of helicopters in general, and helicopter rotors in particular.

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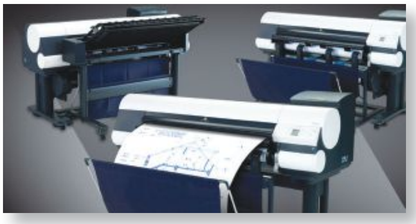
Editor's Picks

by Anthony J. Lockwood

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.



Canon U.S.A. Ships New Large-Format Printers

The portfolio is suited for technical workgroup applications.

The imagePROGRAF iPF850, iPF840 and iPF830 were built with feedback from users in mind. These systems sport a print resultion of 2400 x 1200 dpi and are suited for color and monochrome technical drawings and maps.

These printers have an ink-tank system that lets users replace ink tanks without pausing a print job. The tanks hold 700ml worth of ink, which should get users through most long continuous print runs.

Additionally, the imagePROGRAF iPF850 and the iPF840 are two-roll media systems for automatic routing.

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Eurocom Adds NVIDIA GeForce Graphics Support

The feature is now available for its Scorpius mobile workstation.

The Scorpius unit now supports dual MXM 3.0b NVIDIA GeForce GTX 980M SLI graphics. MXM is an interconnect standard for GPU (graphics processing unit) slots. SLI means "scalable link interface." SLI technology lets you combine GeForce GTX GPUs. It expedites data flows between graphics cards and provides scaled graphics performance. In other words, graphics should appear as vibrant as possible.

It sports a fourth generation Intel Mobile Core i7 4xxx series quad-core CPU, up to 32GB of memory and a 17.3-in. full high-definition 1920 x 1080 display.

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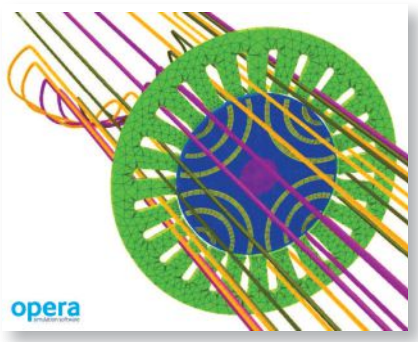

Cobham Updates Opera FEA Software

Enhancements include analysis setup tool for advanced multiphysics simulations.

Opera 18 debuts a new Winding tool that should save users tons of development time. What this tool does is help evaluate the feasibility and efficiency of different coil winding configurations and their impact on rotating electrical machine performance in rich detail before running an FEA job.

The Opera-3d Modeler sees a new drag-and-drop tool that should make preparing data for a sequence of analyses simpler. With this tool, users can add or remove specific analysis stages to an analysis sequence list using drag-and-drop editing with instant visual feedback.

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Lenovo Announces New ThinkPad P Series

Systems offer high-definition displays and latest Xeon processors.

The ThinkPad P50 and ThinkPad P70 are the vanguard of a new series of mobile workstations, according to Lenovo.

Users can load up both systems with as much as 64GB of memory each. They can have 1TB of SSD (solid-state drive) or 2TB hard-disk storage. Each mobile workstation has things users would expect like optical drives, card readers, USB ports and wireless networking. But, because of their Xeon E3-1500M v5 series processor, they also have 40Gbps Thunderbolt 3 USB-C ports (USB 3 operates at 5Gbps).

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Contact Information

Abstracts & papers: papers@lstc.com
Participation, Registration: Marsha Victory, vic@lstc.com

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- **Deadline:** November 30, 2015
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- **Format:** 7″ x 8½″, MS Word template provided

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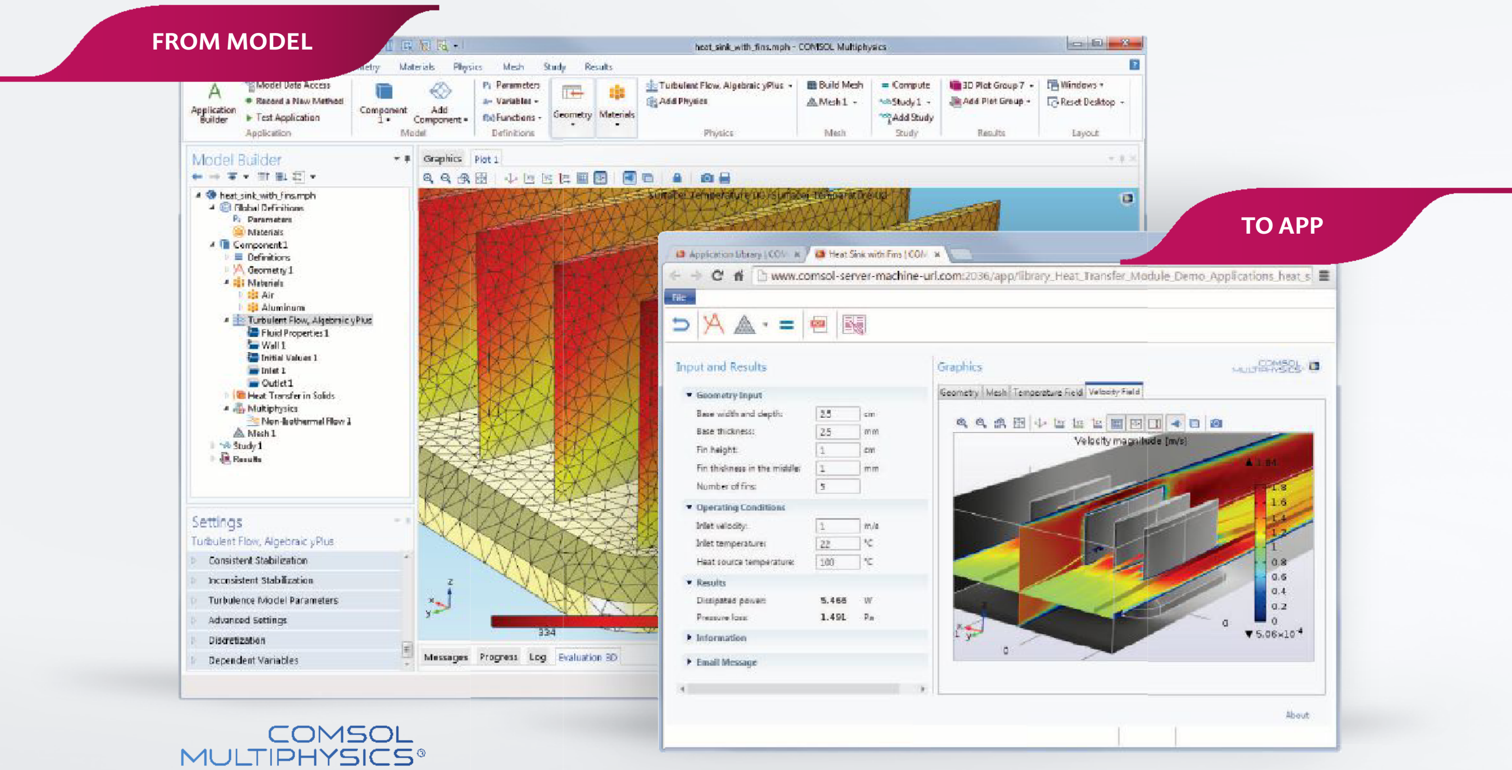

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