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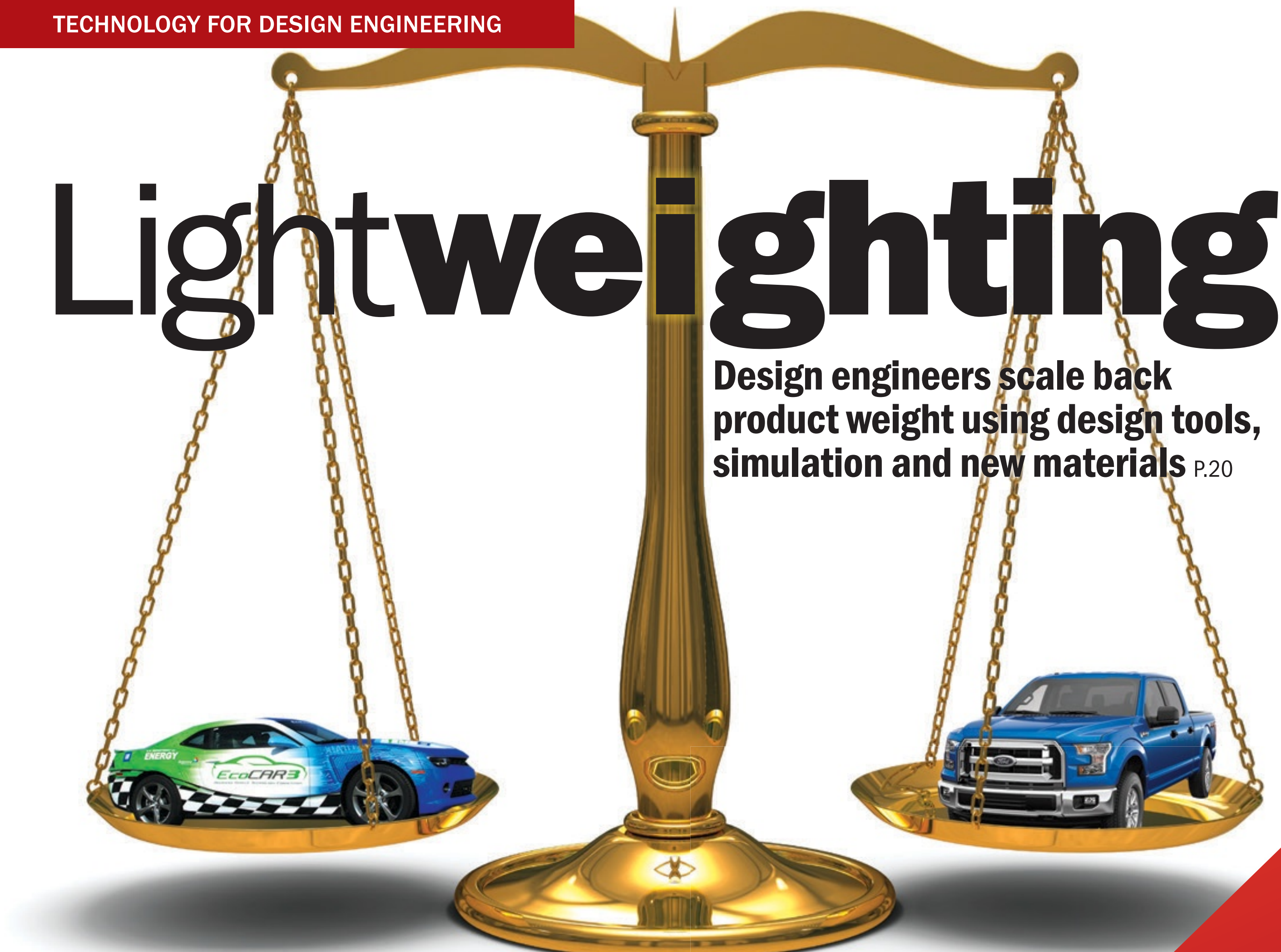


Lightweighting

Design engineers scale back product weight using design tools, simulation and new materials P.20

Enter to Win a Mojo® 3D Print Pack from Stratasys® P. 38

by Jamie J. Gooch

Less Weight is **More**

Despite some recent progress, the majority of Americans are still overweight, and so are the products design engineers create for them. From cars and planes to laptops and phones, thin is in, but dieting isn't easy. Removing weight requires a new mindset, new investments all along the supply chain and the courage to try something different. Advances in material science, optimization software technologies and government mandates in the U.S. and Europe have converged to make lightweighting a top priority for design engineers.

Ford Motor Co. is a prime example. The company intends to shave 700 pounds off the 2015 Ford F-150 pickup truck, and it recently unveiling a concept car that is 25% lighter than a standard sedan.

"Our goal was to investigate how to design and build a mixed-materials, lightweight vehicle that could potentially be produced in high volume, while providing the same level of safety, durability and toughness as our vehicles on the road today," said Matt Zaluzec, Ford technical leader, Global Materials and Manufacturing Research, in a press release.

> **Lightweighting has become a top priority for design engineers.**

The key phrase from Zuluzec is "high volume." Automakers have been investigating and implementing lightweighting for years to increase speeds in race cars, for instance. But high-volume production opens Pandora's box. Are enough high-strength steels and composite materials available? How will different materials be joined together? What changes to the manufacturing line will be needed? Will customers accept a lighter aluminum body "Ford tough" pickup truck? Will a lighter vehicle be safe? Will it cost more? Will service centers invest in the equipment needed to repair the new materials?

A Material Issue

Ford isn't alone in its efforts to optimize its designs to be lighter, or in working through the many ramifications of using new materials. Boeing's 787 Dreamliner consists of more than 50% composites, which the company says equates to a 20% weight savings vs. more conventional aluminum designs. Airbus says the use of composites, titanium and advanced aluminium alloys in its new A350 XWB reduce overall fatigue and corrosion maintenance tasks by 60%. Bombardier is flight testing its CSeries of aircraft that use composites in the wings, empennage and rear fuselage, as well as aluminum lithium in the main fuselage, all of which it says helps the A350 XWB weigh up to 12,000 lbs. less than some similarly sized aircraft.

Not content to let composites and new aluminum alloys push them out of the market, the steel industry is working with manufacturers to incorporate high-strength steels that are lighter than traditional materials.

Where aerospace and automotive lead, many industries are sure to follow, leaving design engineers tasked with catching up.

Design Fundamentals

Changing a product's material requirements equates to many challenges and opportunities for design engineers. Optimization and simulation are the keys to using less materials or replacing tried-and-true traditional materials with lighter weight ones. With the right simulation data, topology optimization software can tell design engineers where material is important, structurally, to a design. That knowledge can open new avenues for design engineers to explore, ultimately resulting in completely different and innovative designs. New materials, when combined with advanced manufacturing techniques such as additive manufacturing, also allow designers to reduce complexity and weight by consolidating parts.

The benefits to lightweighting are as numerous and varied as the design, simulation and testing questions they prompt. Design engineers will have to expand their skill sets yet again to take advantage of the capabilities inherent in new materials.

Some answers to those lightweighting questions may come from two new manufacturing institutes recently announced by the White House: the Lightweight and Modern Metals Manufacturing Innovation Institute, based in the Detroit area; and the Digital Manufacturing and Design Innovation Institute, based in Chicago. Additionally, an Advanced Composites Manufacturing Innovation Institute is also being established.

The institutes are part of the Administration's push to create hubs to bridge the gap between applied research and product development by bringing together companies, universities and other academic and training institutions, and Federal agencies to co-invest in key technology areas. **DE**

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

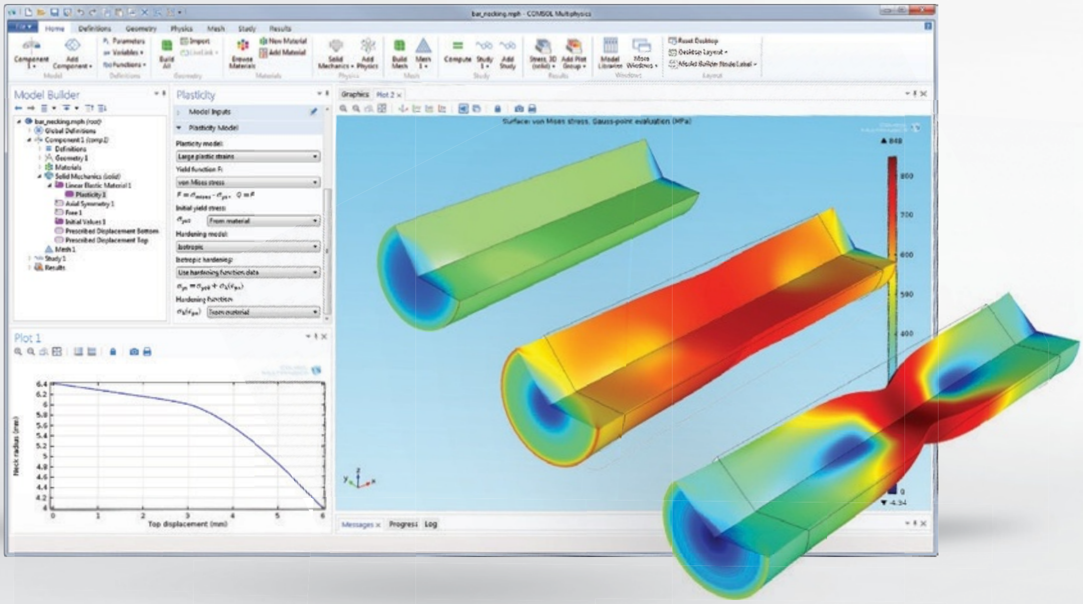

Who will bring
our electrical grid
out of the Dark Ages?

DE October 2014

VOLUME 20/ISSUE 2

ON THE COVER: GM's EcoCar 3 Camaro and the 2015 Ford F-150. *Images courtesy of General Motors and Ford Motor Co.*

LARGE STRAIN PLASTICITY: Simulation results showing von Mises stress and large-scale plastic deformation in a circular bar under uniaxial tension.



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by Kenneth Wong, Beth Stackpole and Jess Lulka

Chromebook as VM Front-end Client Device

Normally, you would think long and hard before you attempt to run a Windows-based CAD program on a Google Chromebook. Though affordably priced (starting at $199), the lightweight notebook has limited local storage capacity and runs the Google Chrome operating system. That presents challenges for those trying to install and run Windows-based design and engineering software titles that demand graphics acceleration, generous hard-disk space, and ample memory.

But what if you use Chromebook only as the front-end client device to access a virtual machine (VM) workstation hosted elsewhere?

That's the setup NVIDIA, VMWare and Google were advocating at VMWorld (San Francisco, Aug. 24-26), a virtualization conference. In a press release, the three jointly announced "a collaborative effort to deliver high-performance virtual desktops and workstation-class graphics to Google Chromebooks." Billed as a technology preview, the virtualization solution lets you use the latest Chromebooks powered by NVIDIA Tegra K1 mobile processors to remotely run Windows programs using VMWare's virtualization software.

"We've noticed Chromebook is very popular among our education users, because of its affordable price," says Victoria Rege, product marketing manager for NVIDIA Grid. "The goal is to show people that Chromebook can be used in enterprises and businesses as well, including manufacturing and construction."

Rege points out that, for some businesses, the Chromebook is a better hardware choice for interns and contractors who don't necessary need a dedicated workstation.

NVIDIA, Google and VMWare join forces to promote the use of Chromebook as the front-end client device for virtual machines.

Chromebook Vs. Workstation

While Chromebook's adoption in education is understandable, its use in manufacturing, construction and professional design is at the present unproven. Most people in these industries rely on workstations to run graphics-heavy programs like AutoCAD, SolidWorks and similar titles. Compared to the touch-driven tablets, however, Chromebook's mouse-and-keyboard input system offers a closer match to CAD programs' current software interface; therefore, Chromebook may offer an easier transition in the virtualized environment as a client device.

In a blog post titled "How, with Google and VMware, We're Unlocking Full Potential of Cloud-Hosted Desktops," NVIDIA wrote, "We're working with VMware and Google to enhance Chromebooks as an endpoint by enabling a new low-latency, high-frame-rate access from the client receiver to NVIDIA Tegra K1-based devices … Tegra K1-based Chromebooks will be the first to fully support these new capabilities." (*Source: blogs.nvidia.com*)

For more on the rise of virtualization and remote desktops, read about NaviSite's Desktop as a Service solutions and OTOY's app-streaming platform at deskeng.com/virtual_desktop.

— K. Wong

Collecting Stories of Design and Innovation across the U.S.

A blue RV is making its way across the U.S., from California to the New York Islands. The vehicle is commandeered by TJ McCue, a writer and 3D enthusiast. The trip's goal is to "[celebrate] the creative process, while illuminating the impact of design through firsthand customer stories, consumer creativity and student innovations," as TJ puts it in his blog on 3DRV.com.

The 3DRV, as the journey is called, is covering more than 100 stops in eight months. The road trip is made possible by Autodesk, NVIDIA, HP and Stratasys, among others. At press time, McCue has met with people developing a 3D printer that'll work in space, an underwater camera that could survive shark bites, and footwear that could double as a cellphone charger. By the end of August, McCue had gulped down his 269th cup of coffee covering 6,209 miles and making 54 stops.

— K. Wong

6 Steps to Workstation Upgrades

With so many options and form factors to choose from, there is no such thing as one-size-fits-all professional workstation. A workstation purpose-built for engineering professionals needs to deliver the right mix of performance tuned to today's 3D modeling and simulation applications with the ability to easily scale to meet future requirements.

So how does this directive translate into actual specs for an optimal workstation configuration? Alex Herrera, a consultant specializing in high-performance graphics and workstations, has laid out a simple set of guidelines that can help engineers discover the best system configuration for their workloads.

1. ISV certification is a must

More than anything else, a professional workstation must be reliable. With ISV certification, engineers are assured they can get their work done without disruption. If your workflow is heavily dependent on CAD modeling or involves simulation software, look for workstations that are certified by your software vendor.

The certification stamp means the workstation OEM and the software provider team have collaborated to put the various system configurations through exhaustive testing at both the system and board level. Through a series of regression tests, each workstation configuration—both hardware and software—is put through its paces and if results match previous benchmarks, the new configuration is deemed reliable and gets certified. Conversely, if errors are detected, the team works together to address bugs until the entire regression suite passes muster.

2. Strike a balance between core speed and core count

The typical multi-stage, multi-iteration CAD workflow or design analysis cycle is a test of workstation performance. Multi-threaded applications like rendering, finite element analysis (FEA) and computational fluid dynamics (CFD) all stand to benefit from modern multi-core CPU technology, which can parallelize tasks across multiple cores.

Yet many common CAD computing tasks—parametric modeling, for example—don't see the same advantages from parallel execution on multiple cores. Instead, they benefit most from an investment in a superscalar CPU core running at the highest possible frequency. The rule of thumb, then, is to balance CPU spending on core speed and number of cores in the way that best meets the needs of your core design tools.

3. Invest in professional GPU power

Despite sharing some core hardware and software technologies, consumer-grade graphics solutions don't hold a candle to professional GPU horsepower when it comes to meeting the needs of design engineers. Professional GPUs are optimized for CAD applications in terms of both performance and accuracy. Equipping a workstation with an uncertified consumer-grade GPU doesn't just limit what you can do—it can lead to a dramatic dip in software performance that will hinder any engineers' productivity.

4. ECC memory is key

Memory errors, while not common, can wreak havoc on an engineer's productivity and cause serious project delays. Beyond providing the largest possible memory configuration, investing in Error Correcting Code (ECC) memory enables your workstation to detect and correct single-bit memory errors.

5. Opt for workstation-class storage technologies

Hard disk drives are fine for consumer or general office applications, but when it comes to the needs of engineering professionals, it's time to turn to higher performance storage options. Solid state drives (SSDs) offer compelling advantages in performance and reliability and are becoming a cost-effective storage alternative. Small engineering organizations that manage their own IT should also consider adding RAID to their storage set-up as way to provide cost-effective data protection as well as a way to provide a potentially significant boost in performance.

6. Put a premium on expandability

The workstation you buy today will be better than systems available 12 to 18 months ago, but it will also likely need to be updated in the future to support new processing requirements. Because of this, ease of expansion is a key selection criteria—choose a workstation that can be easily upgraded mid-life via memory or storage expansion or with a new CPU or GPU in order to maximize the investment.

While there is no hard science to configuring the optimal workstation, these are clear guidelines to ensure you make the right choice. After all, a properly configured workstation is the consummate tool for engineers on the path to creative and innovative design.

Spec Your Ideal Workstation

Deciding on the proper workstation configuration is no easy task, but Intel aims to make it easier. With the online Workstation Configurator, engineers can zero in on the best hardware profile for their particular job and workflow, including guidance on the optimal CPU, memory, video card, and storage configuration.

The tool is easy to use, and results can be output to build the case for a workstation refresh.

Check out the Workstation Configurator at http://www.intel.com/content/www/us/en/workstations/workstation-configurator-tool.html.

A Workstation Checklist

In need of guidance to zero in on the optimal workstation? Consider the following questions to pinpoint a workstation model that will meet both your engineer and budget needs.

❑ **Do I really need a workstation?** Are doing full-blown CAD design or running simulation? Then the answer is "Yes." Workstations are tested, optimized, and certified to run critical engineering applications and offer increased performance and productivity.

❑ **What is the best processor fit?** Buying a system equipped with a processor that's one or two frequencies down from the top-of-line model allows for savings that can be directed toward other, less expensive technologies that can have a greater impact on performance.

❑ **What's the optimum memory configuration?** The rule of thumb is to equip a system with twice as much memory as the largest model you are working with.

❑ **What should I choose for graphics?** If your day-to-day work involves non-linear editing or you handle extremely large graphics models, invest in a system with a top-of-line GPU. A mid-range or entry-level professional graphics card will deliver more than adequate performance for common CAD modeling tasks.

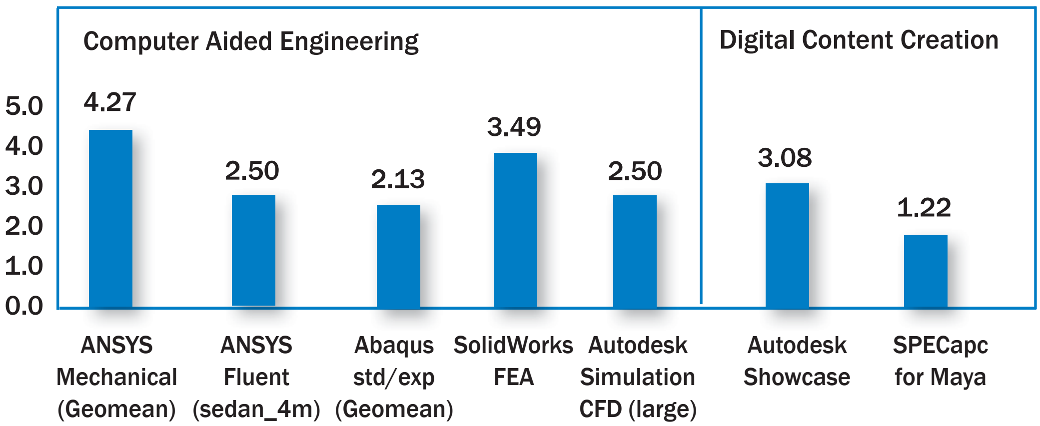
❑ **What kind of storage is appropriate?** Engineering users can greatly benefit from the added performance of solid state disk drives (SSDs), which are a staple of most workstations. They deliver noticeable performance when opening and closing multiple files and working with large data sets.

The Need for Solid State Drives

Everyone talks about the need for speed, but there's more to boosting performance than a faster processor. Solid state drives (SSDs) can radically improve performance of CAD applications. Case in point: In tests, SolidWorks reseller CATI was able to boost the performance of SolidWorks by **47%** by replacing the 7200 RPM hard drive with an SSD. Further optimizing the hard drive configuration saved two hours and 13 minutes on operations—a **56%** improvement.

Retire That Four-Year-Old Workstation

Performance Summary Xeon E5-2687W v3 vs X5690



Refreshing a four-year-old workstation provided a 4X performance increase to some common engineering tasks.

Management says your four-year-old workstation is fine, but sluggish model regeneration and incomplete renderings tell you otherwise. The Intel benchmark above shows significant performance boosts for FEA and CFD simulation as well as photorealistic editing tasks when upgrading from a four-year-old Intel® Xeon® Processor X5690-based system to a workstation outfitted with the latest Intel® Xeon® Processor E5-2687W v3.

Turbo Charge Design with a Dual-Socket Workstation

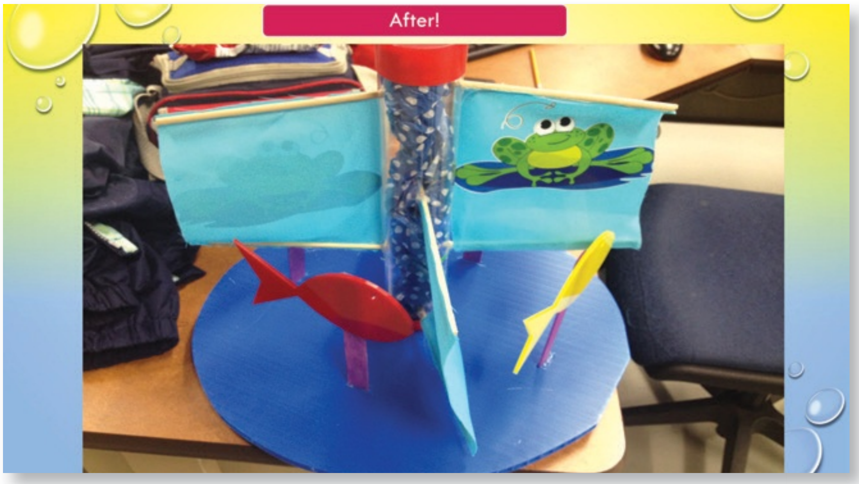
Engineers reliant on simulation or photorealistic imaging software can't afford performance delays from an inadequately-specked workstation. They will see significant performance gains with a workstation based on the most current dual socket Intel® Xeon® Processor E5-2687W v3 compared to a system configured with the latest single socket Intel® Xeon® Processor E5-1680 v3.

by Kenneth Wong, Beth Stackpole and Jess Lulka

Go Go GADgET: Girls Take on Engineering

When you think of summer camp, you usually think of silly songs, lots of new games and running around in the woods exploring. That's not the case at GADgET. Its 16 participants spent part of their summer learning how to use SolidWorks and visiting several manufacturing companies in the Chicago area.

The program aims to provide its all-girl participants, aged 12 to 16, with a window into the engineering and manufacturing world and empower them to pursue science, technology, engineering and manufacturing (STEM) careers.



GADgET camp participant Kayla's Caro-Sail (a twist on the carousel with visual puns), finished and assembled. The fish figures were designed in SolidWorks and cut with machines.

A Growing Interest

Using an acronym for Girls Adventuring in Design, Engineering & Technology, GADgET camp debuted in 2011, running for just one week with an initial grant from the Nuts, Bolts and Thingamajigs Foundation. As interest grew, so did opportunities for participants. The camp ran for two weeks in June this year.

"The kids were so excited, so they learned a lot, but they wanted to do more. It was an interest by the family members and the youth [that brought the two-week camp]," says Antigone Sharris, coordinator, engineering technology at Triton College and camp co-director.

This year, in addition to learning SolidWorks, the girls visited Century Metal Spinning, ACE Metal Crafts and Mars Candy. On their tours, they talked to women who have made careers in the engineering as company owners, heads of marketing, accountants, process engineers and more.

"It's intentionally designed to empower these girls to realize that they can do anything, the diversity of the career pathways, and that the world of manufacturing is not strictly gearhead engineering," Sharris says.

The youth participants also got to show off their skills by making their own products. At ACE Metal Crafts, they helped create the design for a cellphone holder and saw it created on-site. Throughout the session, they then created their own final gadget.

One participant, Kayla, who enjoys theatre, made a "Phantom of the Opera" mask and a carousel (pictured) with the design software. She said her favorite part about being in GADgET was "learning about engineering and the SolidWorks program."

While Kayla was interested in engineering before GADgET, she says visiting and talking with women in the field "was helpful to see what kinds of experiences women have had when they were trying to get themselves involved in the career and field of engineering. They did help to give an idea of what each field of engineering is like." She hopes to pursue a career in the field, but is still figuring out what she specifically wants to do.

Opportunities Abound

Throughout the U.S., almost all major CAD software developers — Autodesk, SolidWorks, Siemens PLM Software and PTC, to name but a few — offer low-cost educational licenses to introduce their brands to aspiring engineers in high schools and universities. The software makers' ongoing partnership with FIRST, a series of national robotic competitions, is another example of their outreach efforts aimed at students who have shown an interest in design, engineering, and robotics.

Programs like City X workshop, Makers' Factory Summer and Spring Break Camps, and Southern Polytechnic State University's 3D Printing and Engineering Camp employ a mix of hands-on 3D modeling, physical prototyping, and 3D printing to attract young people. Triton College's GADgET fills a special need by fostering early STEM education among young women to offset the traditionally male-dominated engineering fields.

Sharris says the biggest reason to support girls in STEM careers is to encourage diversity throughout the design process. She notes that women can bring ideas and insight to how products are manufactured.

— J. Lulka

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 by Kenneth Wong, Beth Stackpole and Jess Lulka

Buying into Mechatronics

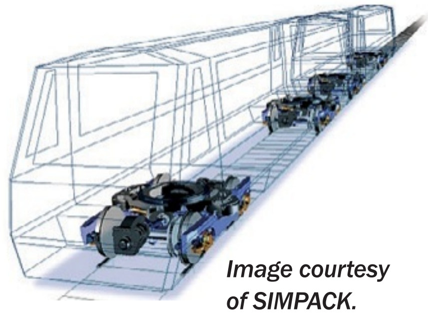
Image courtesy of SIMPACK.

If your end game is to provide tools that provide a soup-to-nuts virtual design experience, you've got to provide real-time simulation of electrical and mechanical controls.

That's exactly what Dassault Systèmes is bringing to the table with its latest acquisition of SIMPACK, based in Munich. SIMPACK, with 130 customers in the energy, automotive and rail industries, including such marquee names as BMW, Jaguar Land Rover and Bombardier, has been a long-time partner of Dassault's, which has similar arrangements with competing multibody simulation offerings.

With the current emphasis on smarter, safer products, there was interest in a higher level of integration between SIMPACK and the rest of the Dassault 3DEXPERIENCE platform and SIMULIA simulation portfolio, according to Steven Levine, senior director of portfolio management for SIMULIA, the simulation software brand at Dassault.

"SIMPACK has done of better job of integrating the vehicle [for simulation]," notes Levine. "They allow designers to go from a logical description to a physical description seamlessly, which is critical when designing a system with a lot of intelligence."

Specifically, Levine says SIMPAK lets engineering teams create the real-time system controls using a higher-performing, dynamic multi-body representation while competing products do so in a more computationally intensive way.

Another advantage of the SIMPACK product compared to competitors is its high-fidelity model representations, Levine says. "They bring a higher level of realism into the model that you couldn't do with other products," he says.

Weaving multi-body simulation capabilities directly into the 3DEXPERIENCE platform is also in keeping with customers' desire to do more robust simulation early on in the design cycle, as opposed to at the end for verification, Levine says.

— B. Stackpole

An Aluminum Diet

It only stands to reason that an aluminum smelter in need of utility vehicles for operations and maintenance would want those vehicles to be made out the same aluminum it manufactures, not steel. However, manufacturing a structurally sound utility transport out of a wholly new material wasn't the only design challenge for Aluminerie Alouette, a Canadian aluminum smelter. The new design also had to accommodate an electric powertrain — a requirement because the smelting process creates such a strong static magnetic field that regular internal combustion engines would have a hard time operating properly within that environment. The third requirement was to create a vehicle design that would allow for easy recycling at the end of the transport's lifecycle.

The design challenge was handed to Services Précicad, a multidisciplinary, product development consulting firm, which had worked with Aluminerie on other projects.

"They thought it would be fun to showcase the material they were producing," explains Stephan Lachevrotiere, Services Précicad's head of design. "Also, by its nature, aluminum is three times lighter than steel. Not having as much of a payload to run around is beneficial for an electric car, giving the batteries a longer lifecycle."

FEA Saves Time

Services Précicad was given a year to come back with the aluminum-based transport design, but was able to develop and deliver the first prototype to the smelter plant in just 10 months. Key to its ability to beat delivery targets was the use of finite element analysis (FEA) as part of an integrated design and analysis process, an approach that substantially cut back development time.

The team used Dassault Systèmes' SolidWorks CAD software to model the vehicle geometry, and then leveraged NX CAE tools from Siemens PLM Software, including NX Nastran and NX Thermal Software for FEA, to do the simulation work. The team said there were no problems integrating the CAD geometry with the FEA meshing tools despite being from competing vendors.

NX's Synchronous Technology feature was tapped to simplify the geometry before creating the FE mesh.

"With this kind of technology, we were able to do things like meshing much faster, and it saved us a lot of hours because we had simplified models for FEA analysis," says Stephane Arsenault, head of Services Précicad's FEA department.

The primary role of the FEA tools was to ensure the aluminum-based vehicle would be as structurally sound as its steel predecessor. Aluminerie Alouette had requested a load-carrying capacity of 1,000 lbs., and the FEA tools were used to explore load conditions like gravity, braking, turning and acceleration. The final design of the vehicle, now called Kargo, weighs only 1,500 lbs. — half the weight of the company's earlier steel-framed vehicles. The Kargo, in its third iteration, can now handle a 1,500-lb. load.

— B. Stackpole

BOXX Takes Virtualization to the XTREME

There's no question that virtualization has taken the data center by storm. Over the years, a growing number of organizations have tapped into virtualization to optimize hardware costs, bolster security, and provide business users with the flexibility to access critical systems and data remotely.

While the general business community has benefitted greatly from virtualization, graphics-intensive users like designers and engineers have remained primarily on the sidelines. Hosting dozens of users on a single physical server in a virtualized environment is a viable option for running office applications or doing simple web browsing, but the approach has been lacking for users of such high-end 3D applications like SolidWorks, Revit, or 3ds Max because of the sacrifices related to performance and productivity.

Despite these obstacles, a virtual desktop infrastructure (VDI) holds great appeal to power users just as it does for their mainstream counterparts. With the right kind of VDI environment, engineering users could benefit from such advantages as remote access to key engineering systems and data to the ability to consolidate data in one centralized, secure place.

Tackling the Performance Problem

BOXX Technologies Inc., recognized for its groundbreaking work in high-performance workstations, is now bringing that expertise to bear on a new VDI approach that tackles the performance problem for high-end graphics users. BOXX's variation on VDI technology, called XTREME Desktop Infrastructure (XDI), employs a number of techniques to deliver optimal performance for graphics-intense applications.

Traditional VDI environments cannot adequately accommodate high-end graphics tasks because they utilize software-remote desktop host applications and software graphics running on the CPU. BOXX XDI, however, is unique, directly assigning one dedicated remote desktop host processor and one physical graphic processing unit (GPU) to each user on the system. Featuring professional GPUs (from either AMD or NVIDIA) running native drivers that are certified for professional applications, XDI systems are able to support almost any professional application by providing the ability to run the specific drivers certified by the ISVs. XDI systems utilize the PCoIP remote desktop protocol and are compatible with VMware Horizon desktop virtualization solutions, allowing them to be used in large enterprise deployments. But because XDI systems utilize a dedicated PCoIP processor per user, VMware Horizon is not required, thereby lowering the overhead, complexity, and cost of a remote workstation solution and making it available to customers who may lack advanced IT resources, but are still in need of a viable solution.

The ABCs of XDI

With BOXX XDI, engineers can easily access a virtual workstation remotely from anywhere with an Internet connection, allowing them to work seamlessly from home or at a client site. An XDI environment also centralizes the large data sets traditionally used by engineering organizations in a server room while "lightweight" pixels are streamed to remote users—an approach that secures sensitive design IP. Finally, XDI users can also take advantage of shared high-speed storage.

BOXX is offering XDI in a variety of configurations. The XDI V8 solution hosts up to eight concurrent power users on a single 2U server within a centralized secure environment, while the XDI V4 configuration provides similar capabilities for up to four concurrent users on a single 1U server. Both feature dual Intel® Xeon® processors (16 cores).

The XDI S1 is BOXX's one-to-one solution, which connects a single user to one physical rack-mounted remote access workstation. Featuring a single Intel Xeon processor (12 cores), XDI S1 is ideal for power users who want the benefits of virtualization, but who don't have a need to host multiple users on one physical server? Users interested in the remote access capability on any of BOXX's other high-performance workstations have the option of converting any BOXX workstation into an XDI solution by adding a PCoIP Remote Workstation card.

Engineers and other power users shouldn't be shut out from the benefits of virtualization. With BOXX's XDI family of solutions, they can finally ride the wave that's transforming the data center while maintaining peak performance and productivity.

For more information visit boxxtech.com/XDI or call 1-877-877- BOXX.

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intel inside XEON

FirstBuild Microfactory Opens in Kentucky

Community members in Louisville, KY, now have access to the FirstBuild Microfactory, which allows consumers

to customize everyday products for their lifestyle needs, design products to solve engineering challenges and fast-track innovation to market.

The facility, created in partnership with GE Appliances, features an electronics prototyping center, laser cutter and hardware components. The products created at the Microfactory will be available online. Some of these products include a water dispenser that can refill itself when placed under a level-sensing dispenser and a dual oven with an ergonomically designed door that allows users to retrieve dishes without reaching into the oven's cavity.

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Sharp Develops Free-Form Display

Sharp has developed the Free-Form Display, a shape that enables new display designs to match a variety of applications.

The device can be shaped to fit specific needs, with the help of IGZO technology and proprietary circuit design methods, the company states. While traditional LCD displays require

a minimum width to account for bezels and drive circuits, the Free-Form display disperses the drive circuit function throughout surrounding pixels. This allows the bezel to be shrunk and design the LCD to whatever shape is necessary.

One possible application of this technology, Sharp states, is a single instrument panel on a car dashboard that combines the speedometer and other gauges and monitors.

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ASD Presents Hybrid Battery At Intersolar North America

The German company Automatic Storage Device (ASD) presented its new hybrid battery for households at Intersolar North America. The device combines stand-alone and grid-tie storage systems. According to the company, this new storage system is inexpensive to produce and supply, costing 20 to 30% less than other lithium-ion batteries on the market.

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Technology, Automotive Companies Form Open Automotive Alliance

Audi, GM, Google, Honda, Hyundai and NVIDIA have created the Open Automotive Alliance (OAA), a collaboration of technology and automotive industry companies working to implement an Android system in cars starting this year. This alliance, a press release states, will focus on creating a platform that fosters innovation, and make car technology safer and more intuitive. The alliance includes a total of 44 companies, including 28 automotive and 16 technology organizations.

At the Google I/O developer conference, the first integration of Android Auto were revealed, and included Google Maps and music streaming service Spotify into an interface suitable for driving. The goal is to create a completely connected car so that once drivers connect their Android phone, they will be able to use applications and services specifically designed for the car and accessible through in-dash display and controls.

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NASA Selects Medigus' micro ScoutCam 1.2 For Robotic Refueling Mission

Medigus Ltd., a medical device company that develops and commercializes micro-cameras, has been selected by the National Aeronautics and Space Administration (NASA) to provide technology for the Visual Inspection Poseable Invertebrate Robot (VIPIR). The company is implementing its micro ScoutCam 1.2 so the device can complete visual inspection and refueling while in space.

As the smallest camera in the world, the company states, the micro ScoutCam is ideal for medical and industrial applications such as cardiology, dentistry, robotics, remote non-destructive testing and micro-drilling inspection.

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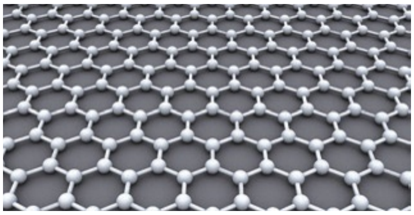
3D Printed Batteries Courtesy of Graphene

A company named Graphene 3D Lab has filed for a provisional patent for, "... materials and methods of 3D printable batteries."

"A 3D printed battery can be incorporated into a 3D printed object



during the building process," said Daniel Stolyarov, CEO of Graphene 3D. "In addition, 3D printed batteries have several advantages over traditional batteries. Their shape, size and specifications can be freely adjusted to fit the particular design of the device. Our batteries are based on graphene and can potentially outperform conventional batteries. Graphene 3D plans to perform live demonstrations of our 3D printed batteries."

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Company Profile: Mcor Technologies

Just like with any narrative, the real stories behind additive manufacturing (AM) are stories about people. It wouldn't be possible to discuss Mcor Technologies without talking about the brothers that co-founded the company in 2004. Conor MacCormack, co-founder and CEO; and Fintan MacCormack, co-founder and CTO.

Both brothers hold engineering degrees and were successful before Mcor Technologies was a passing thought. Conor was part of the team working on the Airbus A380 and Fintan was involved with the semiconductor industry. Each worked with AM systems as part of their jobs, and eventually began to tinker with their own 3D printer. The goal was to build a reasonably priced AM system that didn't require expensive materials.

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Roland DGA Announces Its First 3D Printer

Roland DGA has released its first additive manufacturing (AM) system. The ARM-10 is part of Roland's new monoFab series, which also includes a new milling system, the SRM-20. The ARM-10 uses digital light processing and photopolymer resin to build objects. The SRM-20 is a compact mill that is meant to work alongside its AM brother on the desktop.

"The monoFab series desktop

fabrication tools are the culmination of over 25 years of experience in 3D milling," said Rachel Hammer, 3D product manager for Roland DGA. "By combining the capabilities of these advanced rapid prototyping machines, users can select the best method for their workflow, from concept to production."

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Optomec Launches Aerosol Jet 5X

Optomec is adding its own contribution to printed electronics with the launch

of the Aerosol Jet 5X. The new printer is a five-axis device, offering full object coverage. The new system has been designed specifically to work with 3D printed electronics.

The Aerosol Jet 5X includes interchangeable print heads, giving it a print range of 10 microns to 1mm.

The new system offers two different modes of operation. Sprint mode is the standard mode used for most forms of production, such as printed material evaluation, prototyping and product development. Marathon mode enables low production runs, and high volume needs can also be addressed with additional automated platforms.

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GE Aviation Advances Electron Beam Melting

GE Aviation's branch company located in Italy, Avio Aero. has developed a more powerful method of electron beam melting to build metal blades for jet engines. The beam is generated from a 3 kW laser and is, according to the company, 10 times more powerful than comparable additive manufacturing systems.

The increase in power has allowed Avio Aero to produce blades that are four times thicker than previously possible. A thicker blade means the company requires just 72 hours to build eight stage 7 blades for the low pressure turbine inside the GEnx jet engine. The new process is competitive in both time and money saved when compared to more traditional manufacturing methods.

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It's Time to Go Beyond the Desktop for HPC-Powered Simulation

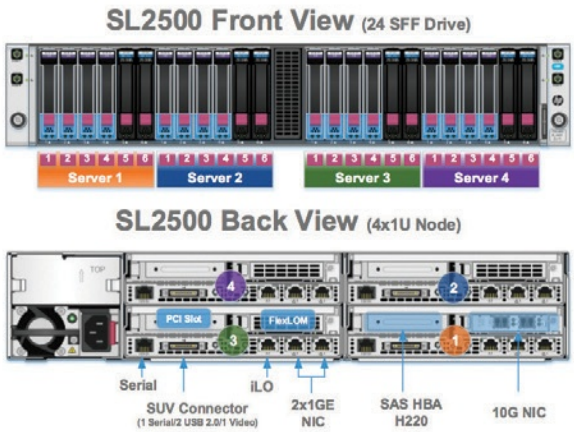
It's no longer just industry giants caught in the web of high-stakes product development. Companies of all sizes, across all sectors are dealing with increasing product complexity at a time when budgets remain tight and there's pressure to get products to market faster, all while deploying fewer resources.

Simulation-led design through the use of computer-aided engineering (CAE) tools has become a key enabler, helping organizations zero in on the right products by designing and testing virtual prototypes in lieu of building costly prototypes. But simulation work is being stymied by the constraints of desktop applications and workstations, which can't deliver the computational horsepower required for these complex modeling efforts.

High performance computing (HPC), a mainstay of industry for decades, provides a robust platform on which engineers can develop and modify product designs, test virtual prototypes, and quickly run through thousands of simulations in real-world conditions. Use of HPC has nearly tripled in the last decade, driven by the advent of new cluster technology, and more affordable industry standard technologies for servers, storage, and networking—in addition to open source HPC software solutions. Yet even within larger firms, CAE users don't always have ready access to HPC resources, which hinders simulation efforts by keeping them "workstation bound," unable to tap enough horsepower to achieve effective results. Small- and mid-sized shops face a greater disadvantage, lagging behind larger organizations in HPC adoption due to the high cost and complexity of traditional HPC solutions.

Specifically, there remains a lack of affordable, packaged HPC solutions tailored to meet the needs of small and mid-sized manufacturing companies. Smaller firms typically have limited IT resources and few, if any, have on-staff experts trained in HPC technology with fluency across the myriad interface tools. Moreover, operating an HPC cluster is a far cry from running applications on a desktop workstation. As a result, most engineering users are not trained nor are comfortable with standard tasks like scheduling and submitting simulation jobs to the cluster or handling day-to-day maintenance and support.

HP ProLiant SL2500 Scalable System
is an ideal starter system for growing modeling and simulation capabilities beyond the workstation.



Out-of-Box HPC

In recognition of the need, the HPC landscape is undergoing a massive transformation that addresses many of these deployment challenges for smaller organizations. From a pure price/performance ratio, there is no better time to add HPC horsepower to a CAE environment. The advent of Intel® multicore processors, the high-speed InfiniBand communications bus, and increasing memory density set the stage for raw horsepower while CAE applications are continuously being fine-tuned to exploit HPC capabilities.

HPC cluster management tools are also evolving to make it easier to setup, maintain, and support the environments without any specialized training. From a user perspective, optional web-based portals simplify interaction with the HPC clusters, allowing engineers to easily submit jobs and optimize workloads from a familiar Windows or Linux client device. For organizations that require robust levels of HPC horsepower during peak periods, cloud service providers are expanding their footprints to support HPC workloads, adding yet another path to HPC for some CAE applications.

In partnership, HP and Intel have launched the "HPC Innovation Initiative," which works with business and technology partners to deliver complete reference architectures, turnkey solutions, and community outreach that make HPC out-of-the-box accessible for small and mid-sized firms. By releasing HPC from its ivory R&D tower, organizations of all sizes can finally leverage HPC-driven simulation to bolster innovation and gain a competitive edge.

To find out more about HP's HPC Innovation Initiative, done in partnership with Intel, go to www.hp.com/go/compete.

Ford Invests Heavily in Lightweighting Efforts

The automaker is trying to outflank the competition in high-volume lightweighting initiatives.

BY BETH STACKPOLE

In the ongoing race to lightweight vehicles and meet more rigorous emissions standards, Ford Motor Co. is out-lapping some of the competition with a pair of high-profile programs intended to advance new materials and manufacturing processes from experimental pilots into high-volume production.

Ford's redesigned 2015 F-150 is due to hit dealer showrooms later this year. It makes liberal use of aluminum throughout the body of the popular full-size pickup, in addition to a new high-strength steel chassis. Together, the innovations drive a dramatic weight loss of up to 700 lbs.

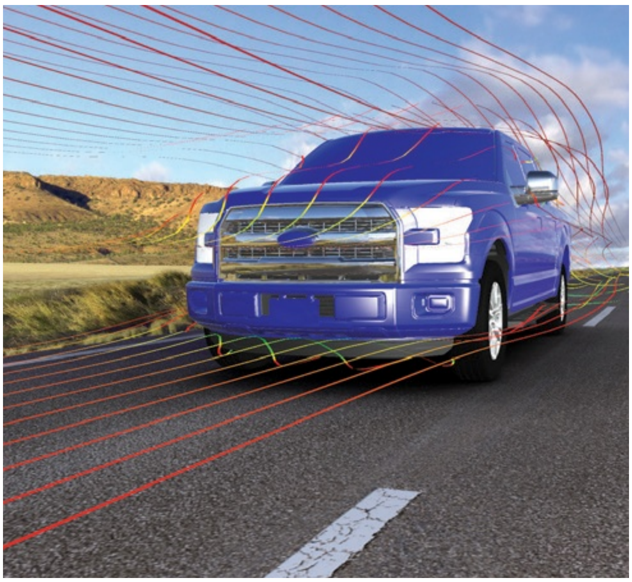
In addition to this effort, Ford is also showing off a Lightweight Concept vehicle. It slashes the weight of a 2013 Fusion to that of a Ford Fiesta — a nearly 25% reduction.

Matt Zaluzec, Ford's senior technical leader for global materials and manufacturing research and a technical advisory board member, notes that lightweighting has always been part of Ford's overall project portfolio to meet government regulations and the Corporate Average Fuel Economy (CAFE) targets set by the U.S. Environmental Protection Agency (EPA).

"As these targets get more challenging, we will continue to refine powertrains to get incremental improvements," he notes. "But lightweighting becomes the big push now."

Like most automotive giants, Ford has stepped up its lightweighting efforts in response to more rigorous government fuel economy mandates. In 2012, the Obama administration put new CAFE standards in place that upped the 29.7 mpg mandate to 35.5 mpg by 2016, and to 54.5 mpg by 2025.

Alternative powertrain systems, like those on electric and hybrid vehicles, have been widely touted as a way for automakers to meet the new government regulations. However, lightweighting, through the introduction of new materials like aluminum or composites, or by consolidating components and reducing the amount of materials



The 2015 Ford F150 undergoing wind tunnel testing and aerodynamic simulation. ***Images courtesy of Ford Motor Co.***

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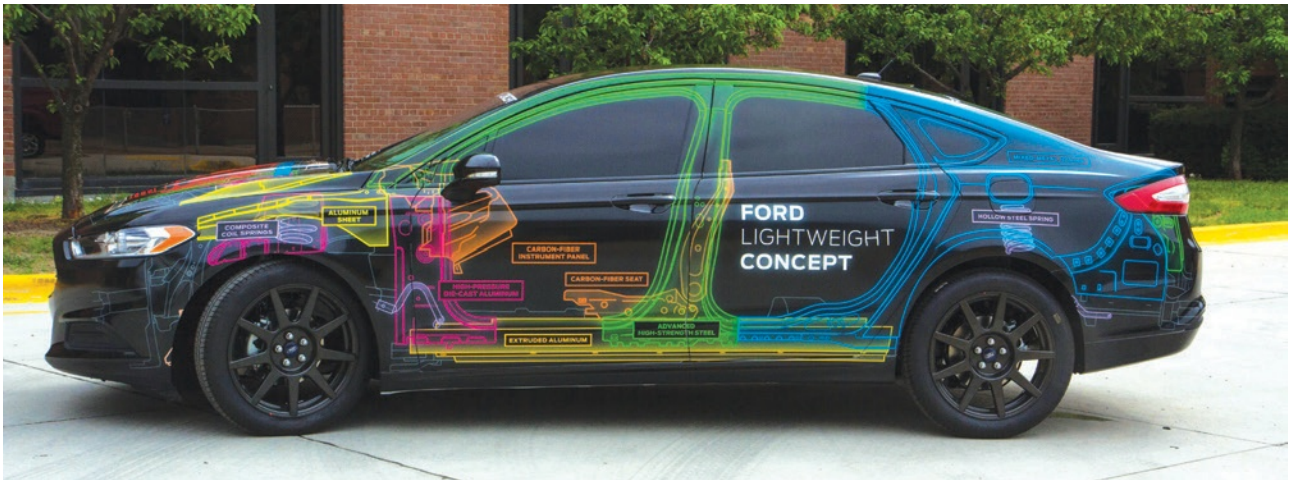


Ford's Lightweight Concept vehicle reduces the weight of a 2013 Fusion to that of a Ford Fiesta — nearly a 25% weight reduction. ***Image courtesy of Ford Motor Co.***

An aluminum front subframe and a chemically laminated windshield are just some of the innovations in Ford's Lightweight Concept vehicle. ***Image courtesy of Ford Motor Co.***

used, is factoring more prominently into automakers' development strategies. Lightweighting also helps manufacturers create balance as additional systems and components are added to new car models to address users' continuing desire for more bells and whistles, from entertainment systems to air bag safety systems.

"The move to alternative powertrain systems has contributed to the emphasis on lightweighting because of the need to offset the added weight of heavy battery packs and electric vehicle/hybrid electric vehicle components and systems," notes Scott Fallon, general manager, automotive at SABIC's Innovative Plastics business, which designed an advanced polycarbonate (PC) glazing solution for the rear window on Ford's Lightweight Concept vehicle. "OEMs are also trying to offset the weight of other content that is being added to vehicles like safety and infotainment systems."

A Combination Approach

With the 2015 F-150 and the Lightweight Concept vehicle, Ford is promoting a holistic, multi-materials strategy that identifies opportunities across the entire vehicle to eliminate weight. "Our goal is to use the right materials in the right location at the right time," Zaluzec explains. "It's a combination of materials and process."

In addition to deploying stamped aluminum across 95% of the F-150's body, the new pickup features a high-strength steel frame, which serves as the backbone of the vehicle. It also makes it 60 lbs. lighter than previous models, according to Ford officials. Replacing the long-proven welded steel construction of the F-150 with lightweight aluminum requires more than an investment in new materials, however. It also requires Ford to investigate next-generation manufacturing processes that can support the production of the aluminum-based truck in high-volume quantities.

"We have been stamping steel for over 100 years, and stamping aluminum for a better part of 25 years," Zaluzec says. "But we have to think beyond stamping to next-generation processes like hydroforming, extruding aluminum, and compression molding of carbon fibers. We have to develop these new manufacturing enablers while simultaneously advancing our engineering and advanced materials development."

Changing manufacturing processes, perfecting new joining strategies, and exploring how to best leverage lightweight materials doesn't come without risk, notes Dave Mason, senior VP, Global Automotive, at Altair, a maker of simulation software. Companies like Ford are making aggressive use of advanced simulation and optimization software in their design processes to minimize that risk; they're helping to expand opportunities for use of lightweight materials and identify potential areas for material removal, he explains, adding: "Ford is doing everything we talk about."

The 2015 F-150 is a huge step forward in terms of lightweighting success. But Ford's Lightweight Concept Car showcases ongoing research in mixed material applications that can be produced in large volumes across the Ford vehicle lineup, while still remaining affordable for consumers. The research vehicle was developed as part of the U.S. Department of Energy's Vehicle Technologies Program, an initiative led by automotive supplier Magna International in cooperation with Ford and other partners to utilize commercially available and demonstrated materials and manufacturing processes to produce a lightweight vehicle.

Magna took the lead on the body structure, closures and chassis, and Ford was responsible for the weight-optimized powertrain, suspension and interior for the concept vehicle — in addition to spearheading validation and testing of the materials and manufacturing processes. Beyond the extensive use of aluminum, the Lightweight Concept vehicle employs strategically placed carbon fiber and magnesium throughout its construction, as well as other advanced materials used in the windows and interior features.

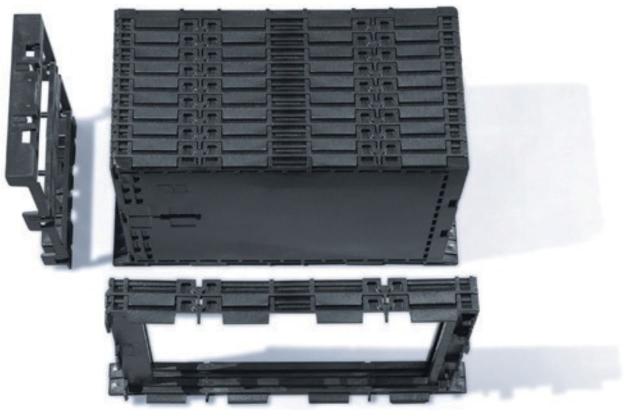
While the use of multi-materials and the corresponding manufacturing processes has been tapped for other vehicle programs, they have only been produced in limited quantities, not in high volume. So says Jeff Conklin, department manager at Cosma International, the division of Magna working with Ford on the Lightweight Concept vehicle.

"That's the biggest challenge here: designing a product that can be built with the processes and products out there today in the industry," Conklin says. "We had to make sure the body in white design could be incorporated in the Ford assembly line, and be assembled in high volume. It couldn't be any hand-applied stuff. This is all robotically done."

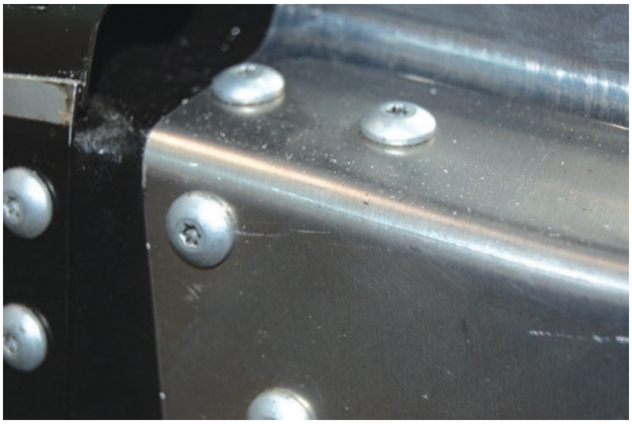
The use of multi-materials throughout the vehicle presented a whole new set of production considerations, Zaluzec admits.

"You're not just bringing in steel or aluminum into a plant, you're bringing steel *and* aluminum in — and they

The kickdown casting used in the Ford Lightweight Concept vehicle reduces weight by incorporating many stampings in the foot pedal region of the body in white structure. *Image courtesy of Cosma International/ Magna International.*



In addition to technology found in the Ford concept vehicle, SABIC's NORYL GFN resin is used to help lightweight the Ford Focus Electric's high-voltage battery pack. *Image courtesy of SABIC*



The joints used in the Lightweight Concept vehicle had to be redesigned to support high-volume vehicle production. *Image courtesy of Cosma International/ Magna International.*

don't join the same way," he explains. "There's a lot of assembly technology required to put together mixed materials."

New joining technologies, specifically those that address galvanic corrosion issues, were part of what Cosma brought to the development effort, Conklin says. The division also adapted its aluminum pressure vacuum die casting process for the project, which Conklin notes was essential in reducing the material thickness of the aluminum compared to traditional casting processes.

SABIC's Innovation Plastics business was another key collaborator on the Lightweight Concept vehicle, responsible for supplying a PC glazing solution that facilitated a 35% weight reduction in the rear window (compared to the same window on a 2013 Ford Fusion production model). The weight savings comes from the lower density of the material, about half that of glass, which is made possible by its ability to be injection molded, says SABIC's Fallon.

"This opens the door to many new design opportunities that glass can not achieve," he explains. "PC allows designers to cost-effectively integrate features that simplify assembly. In addition, integration opportunities made possible through injection molding can mean fewer parts or materials, which can mean less weight."

Beyond weight savings, Fallon says PC glazing offers manufacturers additional advantages in that designs can go beyond the shape and complexity limitations of glass to geometric effects that can result in relatively thin PC surfaces.

"You can create aerodynamic components that minimize drag and reduce fuel demand," Fallon says. "This is significant, because for every 10% increase in aerodynamic efficiency, an increase in fuel economy of 1% to 2% can be achieved."

Having a fundamental understanding of the properties of the materials, along with the manufacturing processes, is critical given there's a balancing act to be mastered — offsetting the costs of the new technologies with part consolidation.

"There's a play when moving from material A to material B with an opportunity to consolidate parts," Zaluzec says. "It becomes a very important part of the design DNA." DE

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

INFO ➜ Altair: Altair.com

➜ **Ford Motor Co.:** Ford.com

➜ **Magna International:** Magna.com

➜ **SABIC:** SABIC-IP.com

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

Keep it Light

Lightweighting is the new directive in product design.

Automotive and aerospace manufacturers were the first to recognize the economic benefits of lighter designs. Planes and cars that weigh less require less fuel to fly and drive. This fuel economy is an attractive proposition to owners and operators because it yields significant savings over time. However, the strategy to keep the products as light as possible must be carefully weighed against passenger safety, industry mandates and manufacturing cost.

Jerad Stack was founder and CEO of Firehole Composites, acquired by Autodesk last year. He joined Autodesk as a Senior Product Line Manager for Advanced Materials after the acquisition. In an interview with DE, Jerad discusses the challenges with lightweighting.

Desktop Engineering: *What is the role of advanced materials in lightweighting?*
Jerad Stack: Advanced materials—specifically, composite materials—have been around for some time. For example, the use of carbon fiber in automotive is not new. But now the manufacturing techniques and cost have gotten to the point where they can be used more widely. With lightweighting, people usually use carbon fiber composites—thin pieces of carbon fiber held together by plastic or epoxy. They're as strong as metallic materials, but significantly lighter. So if you figure out how to build the chassis of your car using this type of material, for example, you could reduce as much as 75% of the chassis' weight.

DE: *Are current digital prototyping software programs capable of replicating the behaviors and characteristics of composite materials?*
JS: Five or ten years ago, they could not. But we have since made great strides in understanding the physics of these materials. Autodesk is making internal investments and acquisitions in this area so you can have as much confidence in simulating them as you do with traditional manufacturing materials.

DE: *What products are applicable to lightweighting projects?*
JS: The first one is our Moldflow product line. Its legacy is in injection molding, and the molding of glass fiber-reinforced plastic composite parts is everyday business. There is more and more interest in the stronger carbon fiber-filled materials because they reduce weight further. With our Moldflow simulation products, orientation of the fibers as a result of the manufacturing process can be calculated, and the effect on form, fit and function can be calculated. The other one is the Simulation Composite product line. The key product is Simulation Composite Analysis. Whether you're designing an airplane wing or the bumper of a car, this allows you to make reliable stiffness and strength predictions.

DE: *What do manufacturers simulate in lightweighting projects?*
JS: It's a little different from what you might with, say, stress analysis of traditional materials. Because composite materials are more advanced, they require different manufacturing techniques. You can't cut them out like sheet metals. So you're trying to find out (1) if you can manufacture the composite materials you need; and (2) how to optimize the manufacturing process. Say you're thinking of using compression molding to produce them. You'd want to know, what are the pressures you need to put on it, and what size mold should you build? Moldflow can help answer these questions. Just like you'd want to find out if a cellphone might shatter when dropped from a certain height, you'd want to find out how many cycles your composite part can operate before it starts to show cracks. They behave very differently, so you need a specialized tool, like our Composite Analysis package.

DE: *Are the composite simulation products preloaded with properties of composite materials?*
JS: Material properties without consideration of the material orientation of the glass or carbon fibers is almost meaningless. The Moldflow products come with a material database of over 9,500 plastics to calculate the actual as manufactured properties, accounting for the fiber orientation. Our Composites Design products include a database of 300 standard composites, and within the product the direction, ply thickness and ply build up can be optimized for optimal strength.

For more on Autodesk composite solutions, visit: simulation.autodesk.com

Lightweight Champions

While no one wants a product to be heavier than necessary, lightweighting has become an obsession in the automotive and aerospace industries.

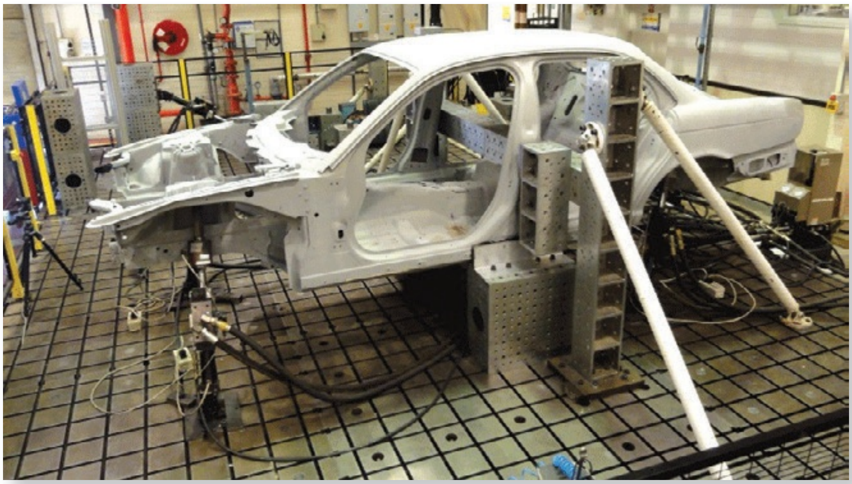
BY MARK CLARKSON

In February, President Obama announced the new Lightweight & Modern Metals Manufacturing Innovation Institute (LM3I), a consortium of universities, material providers and metal manufacturers whose mission is to help U.S. competitiveness and innovation in the areas of advanced lightweight and modern metals manufacturing. Trimming pounds from the nation's cars, trucks and airplanes — thereby saving fuel and reducing pollution — is becoming a national, as well as commercial goal.

One of the simplest ways to trim weight from a product or structure is by substituting new, lighter materials, such as using aluminum in place of steel, for example. But when someone says "new materials," many engineers' minds go immediately to composites.

Composites is a broad term, encompassing everything from fiberglass to metal matrix composites, but we're usually talking about carbon fiber (CF) composites, built from layers of CF cloth impregnated with resin. CF composites are stiff and heat-resistant. They possess an alluringly high strength-to-weight ratio. It's even possible to design the material's physical properties to some degree during production. By varying the number of layers and the relative orientations of the CFs themselves, you can make a composite structure stronger in the directions and locations your application requires.

CF composite use is mainstream in aerospace, where mechanical performance is at an extreme premium. But the aerospace industry has radically different manufacturing concerns than most industries — Boeing might make six or seven 787 Dreamliners this month, but Ford will have built about 65,000 F-150 trucks in that same time. How can composites hope to keep up? Sheet metal parts can be stamped out at the rate of hundreds per minute; CF composite parts can take hours, or even days to cure.



A rig to test adhesive-bonded joints on an aluminum Jaguar body and compare results with predictions from nCode's DesignLife software.

CF composites are also very costly, pound for pound — orders of magnitude more expensive than steel or aluminum. And, while accurate computer simulation is key to timely development of many products, composites (with their weird and varied failure modes) are notoriously difficult to simulate.

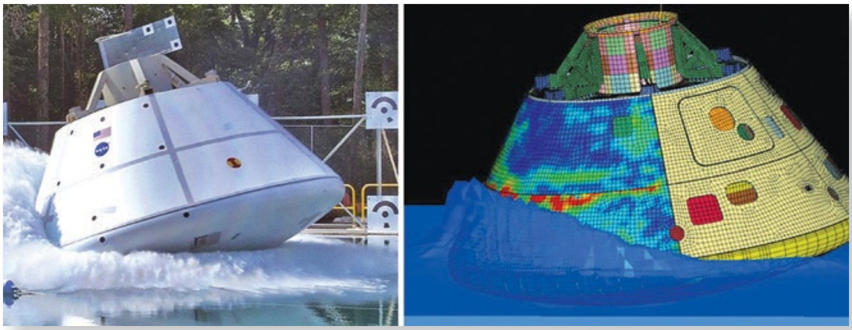
Do we have the maturity of material data and modeling tools to adequately predict CF composites' behavior? Can the cost and manufacturability problems — especially cycle time — be solved anytime soon, or will CF composites remain a novelty?

Siding with Aluminum

If composites aren't quite right for you, how about aluminum? Aluminum is certainly lighter than steel, albeit more expensive. Still, it's much cheaper than CF composites. Unsurprisingly, aluminum is in the vanguard of lightweighting materials.

You've probably heard of Ford's announcement to field an all-aluminum F-150 pickup truck next year (Editor's note: Learn more on page 20). "All-aluminum" is a bit of an overstatement, but the truck will feature an aluminum cab and bed, which in itself is a fairly radical departure for an inherently conserva-

The Orion Ground Test Vehicle at NASA's Kennedy Space Center. The circular heat shield is visible at the base of the vehicle. *Image courtesy of NASA and Collier Research Corp.*



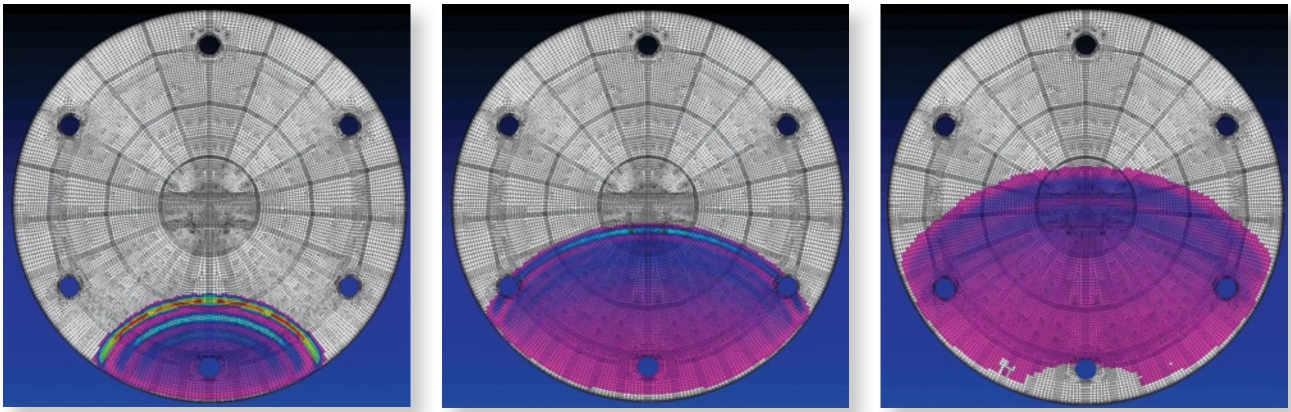
Orion Multi-Purpose Crew Vehicle splashdown test (left) and software simulation of loads on the vehicle (right). *Images courtesy of NASA and Collier Research Corp.*

tive market segment. Altogether, Ford has shaved a third of a ton off the truck's curb weight.

"The Ford F-150 announcement," says John Weritz, The Aluminum Association's VP of Standards and Technology, "is characteristic of where we see that industry going — using aluminum in applications where steel has been used before, to make lighter weight vehicles. That's a bright spot in aluminum's future. When you substitute aluminum for steel, you're saving half the weight."

Aluminum has been slowly gaining ground in the automotive industry for decades. Engines, once almost universally iron, are now almost universally aluminum. Radiators were once copper; they're aluminum now. Aluminum auto bodies are hardly new, dating back to the late 1890s. Some Jaguars and Audis have aluminum bodies, as do Humvees. But while these are somewhat niche vehicles, the Ford F-150 is anything but: It's been the most popular vehicle sold in America for more than three decades.

There is, of course, not just one kind



As the Orion crew module hits the water, high stress moves over the heat shield. The simulation is performed in LS-DYNA, then HyperSizer imports the internal loads at each dynamic millisecond time step. *Image courtesy of NASA and Collier Research. Corp.*

of aluminum; new "recipes" are being developed all the time. Sixty years ago, there were 75 commercial alloys of aluminum. Today, there are more than 500, all of which are pretty hard to weld. This brings us to … steel.

Steely Intent

Steel is still the standard for a number of reasons. We were already working with steel on an industrial scale when Napoleon III's dinner guests were marveling over his aluminum tableware. Steel is well understood; it's easy to work with and it's easy to join. And the steel industry isn't about to roll over and die just yet. New steels, like new aluminums, are being developed all the time. (*Editor's note: See the author's related articles online: deskeng.com/de/competing-with-composites and deskeng.com/de/engineering-the-future-of-steel.*)

If steel is too heavy, what's needed is lighter steel. That translates into stronger steel, and less of it. The new Ford F-150 sits on a frame of high-strength steel employing narrower gauges for a structure that's 60 lbs. lighter, yet stiffer and stronger.

High-strength steels aren't without their own problems, of course. They're more expensive and generally harder to form. Cutting tools used to machine new, ultra-hard steels must themselves be made of expensive, exotic materials.

"You don't get something for nothing," quips Jon Aldred, director of product management at HBM-nCode. "If you're trying to solve weight by going to high-strength steel, be aware that the fatigue behavior of a weld tends to be pretty unaffected by the grade [of steel being welded]. The heating and welding process tends to reduce the strength of that joint. Whether you have a mild steel or a high-strength steel, the strength of that weld is not much different. Without more expensive treatments on top, you don't quite achieve the strength you thought you were going to achieve."

Materials Joining

Aluminum is even more difficult to weld. "Jaguar got around that through the use of adhesives and the use of self-piercing rivets," says Aldred. "We worked with them to simulate that, to assess the durability of these joints, and see where these rivets might be under too much load."

Aluminum-to-aluminum is nowhere near as complicated as it gets, however. "One of the knock-on effects of trying to save weight — of trying to have the material you need in just the right place in the structure — is you may have aluminum at this end, steel at that end, and plastic in the middle," Aldred explains, noting that one needs to consider the joining methodology: Rivets? Glue? Nuts and bolts? How well can your software simulate those joins?

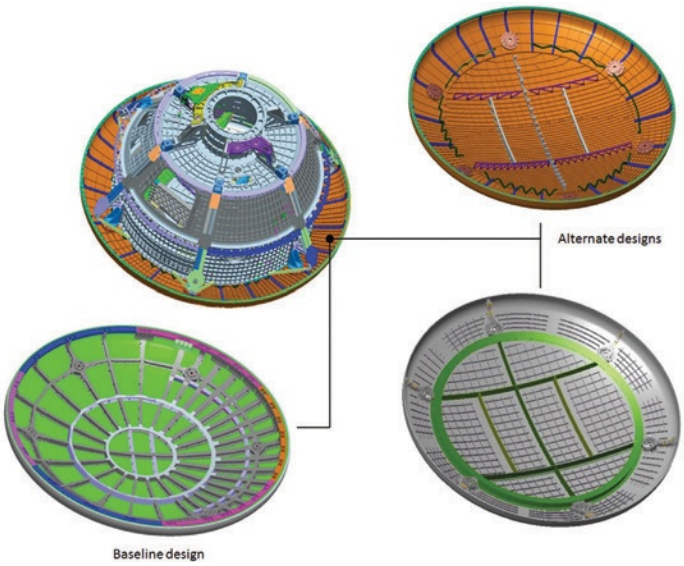
Adding to the problem, says Manish Mehta, senior program manager at the National Center for Manufacturing Sciences (NCMS), "when you have carbon and aluminum hooked up to each other, it creates a galvanic cell. So now you've got to find ways to isolate these joints by creating exotic coatings. These things add cost and processing steps. Which suppliers have the technologies and capabilities for doing it?"

Downstream Consequences

There are many competencies that lightweighting forces on its practitioners, Mehta points out.

"It's not about material substitution alone," he adds. "You hear about aluminum becoming the basis for the new F-150 truck. There are major tooling changes and other domino effects on the industry that are yet to be felt. It completely tips the balance in the entire supply chain — all the way from procurement of raw materials, to processing of raw materials, to getting the supply base ready, to getting the training ready and tuning the production line to Six Sigma or better."

And the new products may cause problems in places you didn't expect. For example, Mehta says, the B pillars on certain vehicles are rumored to be so strong that it "takes a welding torch to extricate a driver from a car crash. There's a movement out there to equip first responders with the right tools to deal with the cars on the road today."



HyperSizer evaluated different structural concepts for the Orion heat shield carrier structure. The baseline composite skin with Titanium I stringers (left image, bottom) was evaluated against alternate metallic grid stiffened designs (right images, top and bottom). ***Image courtesy of NASA and Collier Research Corp.***

Spoiled for Choice

Designers are, as they say, spoiled for choice. In fact, the sheer number of materials available can be a bit daunting. Materials that are stiffness-driven, or dominated by the load in one direction are generally better candidates for CF composites. Structures that are loaded in two or more directions at the same time are probably better candidates for metal. Generally. Probably.

"You can't really always know beforehand what material system is best for your application," admits Craig Collier of Collier Research. "It has a lot to do with shape, and the loading of the structure."

Your preconceived notions, he says, may be wrong: "We've seen that composites do bring down weight in many applications, but not in all applications." He offers as an example his firm's case study on NASA's Orion spacecraft heat shield. When Collier's HyperSizer software was used to explore the different material types, titanium turned out to be substantially lighter than carbon graphite composites.

Remember that new "aluminum" Ford F-150? One of its engine choices — the 2.7L EcoBoost V6 — doesn't have an aluminum block at all; it's cast iron. Then again, it's "new and improved" compacted-graphite-iron (CGI) iron, because even good ol' cast iron isn't holding still these days. **DE**

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INFO → 2015 Ford F-150: Ford.com/trucks/f150/2015

→ The Aluminum Association: Aluminum.org

→ Collier Research Corp.: HyperSizer.com

→ HBM-nCode: nCode.com

→ Lightweight & Modern Metals Manufacturing Innovation Institute (LM3I): Manufacturing.gov/lm3i.html

→ National Center for Manufacturing Sciences: NCMS.org

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Fast Apps

Tomorrow's Technologies, Today

Airbus Group Innovations leverages composites with LMS Samtech Samcef.

One of today's biggest challenges for aircraft manufacturers is reducing fuel consumption and emissions. And one of the best ways to accomplish that is by increasing the structural efficiency and reliability of aircraft and using new, lighter composite materials to minimize weight.

Airbus Group Innovations (formerly EADS Innovation Works) is the corporate research and technology department of Airbus Group. Its primary mission is to develop technology to support industrial innovations within its divisions: Airbus, Airbus Defence and Space (formerly Cassidian and Astrium) and Airbus Helicopters (formerly Eurocopter).

Its secondary objective is to share competencies among these commercial entities to help Airbus Group in an increasingly competitive global environment. Airbus Group Innovations primarily works with Airbus and Airbus Helicopters on its composite analysis research, which requires an innovative and advanced concept for design and deployment in new aircraft programs.

Virtual testing is an essential tool to decrease the number of physical tests on composite components and to support aircraft certification. Siemens PLM Software plays a vital role in this process for Airbus Group Innovations by providing LMS Samtech Samcef software, a finite element analysis (FEA) package dedicated to mechanical and structural virtual prototyping. LMS Samcef is used in numerous industrial fields, for everything from basic to advanced projects.

During the past 20 years, the LMS Samtech software development team has built a strong relationship with Airbus Group Innovations, especially in the area of composite technologies.

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It's Good to be a Lightweight

GM looks to the automotive future by sponsoring the EcoCAR 3 competition.

BY DAVID GEER

EcoCAR 3 is the third installment of the U.S. Department of Energy's (DOE's) Advanced Vehicle Technology Competition (AVTC), described on its website as designed to "help meet the demand for automobile engineers who are thoroughly indoctrinated in advanced vehicle propulsion technology." The AVTC puts vehicle design teams from 16 universities to the test — in this iteration, challenging them to redesign the Chevrolet Camaro into a hybrid-electric car. The 16 teams will each reduce their modified Camaro's environmental impact "while maintaining the muscle and performance expected from this iconic American car."

The four-year competition runs through 2018, with university teams following the EcoCAR Vehicle Development Process (EVDP), which parallels competition sponsor General Motors' VDP in that teams must establish a plan for R&D, analysis and validation of their EcoCAR 3 vehicle design over the four-year period. The undergraduate teams are expected to explore lightweight materials in addition to removing weight from the Chevy Camaro's design as part of the overall competition.

The EcoCAR 3 competition provides each team with a copy of the NX 8.5 CAD package from Siemens PLM Software to perform their solid body modeling for the modified Camaro designs.

Losing Weight

New features of the EcoCAR 3 that set it apart from the previous EcoCAR competitions include an underlying goal to reduce energy consumption and emissions without compromising fuel performance and utility, says Jesse Alley, technical lead, EcoCAR 3 Program, Argonne National Labs. To do that, teams really need to reduce the weight of the vehicle.

When it comes to removing weight from designs, anything goes — within reason, of course.

"Anything is possible as long as you can do it safely," Alley says. "We don't limit specific things: They can create a rear cradle out of magnesium if they can convince GM that it is structurally sound, based on structural and finite element analysis (FEA)."

Judging from past EcoCAR team activity (EcoCAR 2), however, teams use mostly aluminum and carbon fiber whenever they depart from steel, after considering costs, safety and budget.

Typically, teams also self-limit what they attempt. "For the most part, we didn't touch anything structural due to safety," recalls Katherine Bovee, EcoCAR 2 controls team leader for The Ohio State University (OSU) EcoCAR 2 team. But the EcoCAR 2 competition did enable the OSU team to work on lightweighting power trains and body panels, so long as they could make them strong enough. "To maintain vehicle safety, teams are required to use a safety factor of 2 over requirements, meaning two times the required strength," says Bovee.

Simply using smaller designs is an option. Instead of replacing existing materials with a lot of lightweight materials, the Pennsylvania State University (PSU) Advanced Vehicle Team achieved lightweighting by cutting weight out of the designs. "We replaced the stock engine (during EcoCAR 2) with a .75 liter engine. We figured out what was the smallest possible component to power the vehicle, and used a 90 kW peak electric motor while other teams used a 165 kW peak electric motor," says Benjamin Sattler, project manager of PSU's Advanced Vehicle Team.

The Ohio State University EcoCAR 2 team with all 21 awards won. The final award ceremony was in Washington, DC. ***Photographer: Myles Regan.***

The Carbon Fiber Factor

The choice of materials varies among teams in these EcoCAR competitions. Some simply use steel. Other pursue aluminum such as for rear cradles, which can help drop 10 to 20 lbs., Alley says. "The OSU team did that for EcoCAR 2."

A couple of teams in EcoCAR 2 used carbon fiber for battery enclosures. One team used it for structural components. OSU and Ontario's University of Waterloo used carbon fiber for trunks and hoods. "Carbon fiber is probably the most interesting thing that any of the teams use," says Alley.

Teams see opportunities and challenges when working with

Left: Curtiss Stewart and Eric Gallo, members of The Ohio State University EcoCAR 2 team, working on the vehicle's fuel system during the EcoCAR competition. Right: The Ohio State University vehicle participating in the acceleration and braking event in the EcoCAR 2 Competition at the GM Proving Grounds in Milford, MI. *Photographer: Myles Regan.*

lighter materials, he adds. Although carbon fiber is lighter and stronger, it is more expensive and not always suitable for complex designs. Aluminum and steel are more a fit for creating sub-frames, which resemble a bunch of steel tubes that are welded together. Aluminum is an isotropic material that is easy to design with, because it will react consistently under various pressure conditions. By contrast, carbon fiber does not react the same to differing pressure. (*Editor's note: See "FEA & Composites" on page 70 for more information.*)

"How you pull it and how you orient the strands when making parts determines how it will work," says Alley, noting that carbon fiber requires advanced analysis and design techniques to get it to do what team members want. "The teams who are working with carbon fiber are really pushing the limits for an undergraduate design team."

Bovee recalls that her EcoCAR 2 team looked at Kevlar, fiberglass and carbon fiber for light weighting, but ultimately selected carbon fiber for their Malibu's hood. The team considered using Kevlar in the hood to increase its strength, leveraging Kevlar's favorable strength-to-weight ratio.

"A lot of the team members who worked on the carbon fiber hood will stay on for EcoCAR 3, and try to get the Camaro's weight down," she adds, noting that the EcoCAR 3 will be similar to the EcoCAR 2.

"In addition to the composite materials, we have aluminum, magnesium and titanium to consider for the EcoCAR competitions," says Bovee. Aluminum is softer and easier to work with than a block of steel when creating engine mounts

Paul Shoytush (Penn State's GM Mentor), Tim Cleary, Gary Neal, Chris Monaco, Chris Golecki, Benjamin Sattler, Mike Rihl, Nick Wyckoff, Tim Wilson, Issam Salloum pose in front of their EcoCAR entry.

and brackets for inverters, she says. But titanium and magnesium are largely financially out-of-reach for teams in these competitions.

"We looked at getting magnesium rims, but they were too expensive," says Bovee. Using magnesium could have taken off 10 lbs. per rim, adding inertia and favorably affecting fuel economy. "We could have achieved better acceleration and shorter plug-in times, too, since it is a hybrid," she admits.

Likewise, the PSU team had some wishful thinking about design maneuvers that they just couldn't cram in. They wanted to replace the brake rotors on the EcoCAR 2 vehicle with titanium, but there would not have been time to have had the rotors reviewed for safety and to ensure they maintained the thermodynamic qualities necessary in a stock car. "We were able to replace the iron brake hats with aluminum hats, though," says Sattler.

As with most metals, there are a slew of different aluminum alloys a team can use, where the material properties are malleable depending on the heat treatments they apply.

"You have to be careful, though, because the resulting metal will start to deform at different temperatures," Sattler warns. "It will also experience different compressive loadings in a crash event."

For the project, a team can replace steel with aluminum and, if they choose their alloys correctly, they will see the same mechanical properties they need to maintain and have them in a lighter component, he says — but there are trade-offs, such as how much and how well one can machine or weld the resultant metal.

"A great alloy may not be easy to machine," he adds.

While the first order effects of light weighting include increased performance and fuel economy, there are other benefits, Alley says.

"The teams could also improve handling (utility) by making stiffer chassis components that don't bend, while keeping the weight the same by using lighter materials," says Alley. **DE**

David Geer is a freelance technology writer based in Northeast Ohio. Send e-mail about this article to DE-Editors@deskeng.com.

INFO → Argonne National Labs: ANL.gov

→ **EcoCAR 3:** EcoCAR3.org

→ **Siemens PLM Software:** PLM.automation.siemens.com

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3D Printing a Car

A Local Motors demo points to a new way of making cars.

BY BRIAN ALBRIGHT

When attendees arrived at the International Manufacturing Technology Show (IMTS) in Chicago last month, the Local Motors 3D printing demo was a must-see exhibit. The design and manufacturing collective-produced car was printed and milled directly on the show floor over five days using newly designed, large-scale 3D printing equipment. Potentially, this type of printing could not only open up new possibilities for vehicle design and manufacturing, but could also make it possible to produce lighter components and vehicles at a reduced cost.

Taking the prototype out on a test drive.

Local Motors printed the chassis, body, seats and other interior components in several large pieces, then joined them to pre-existing drive components, tires, a steering wheel and other parts. The car, branded "Strati," was then driven off the show floor at the close of the event. The company used carbon fiber composite ABS from SABIC Innovative Plastics to create the car.

The technology to accomplish this grew out of work at Tennessee's Oak Ridge National Laboratory. Oak Ridge initially created the large-scale printing equipment at the behest of Lockheed Martin, using a plastic extruder attached to a robot on an XY gantry system. Oak Ridge then teamed with Cincinnati Inc., an Ohio-based machine tool manufacturer, to commercialize the process.

"Local Motors initiated the concept of printing the car before we'd ever built a machine," says Rick Neff, manager of market development at Cincinnati Inc. "They had seen the prototype gantry at Oak Ridge."

According to James Earle, the engineer who supervised the work on the Strati at Oak Ridge, Local Motors CEO John "Jay" Rogers immediately saw the potential for auto manufacturing when he visited the facility. Local Motors set up a design challenge for its members. "We also issued design rules, which are very different than for traditional auto manufacturing," Earle says.

Designs had to be modified so that they could be easily printable. For example, elements like overhangs, which are difficult to print without generating supports, had to be eliminated.

The winning design for the Strati came from Italian designer Michele Anoe, beating out 205 other entries. Cincinnati Inc. created the 3D printing system — dubbed Big Area Additive Manufacturing, or B.A.A.M., to print the car.

The B.A.A.M. has a build volume of 2x4x0.87 m. "The challenges you find with this type of large system are the same as you would find when printing small parts, but they are literally bigger," Neff says. "People say that complexity is free with 3D printing, but that isn't really the case. The more complex you make the part, the smaller the nozzle you need to extrude the plastics. You sacrifice speed for complexity. If we want to go fast, we need a larger nozzle at higher rates, and you lose complexity."

Neff adds that there is still typically post-processing needed for most printed parts. "We have to machine some areas of the part to provide accuracy or connection points for the drive system or suspension," he says.

Local Motors' Rogers is quick to introduce a broader term to describe the way the Strati is manufactured. "It's direct digital manufacturing to us," he says. "It's not just 3D printing, but became known as that colloquially. It was really driven by the idea of reducing part complexity. We wanted to pit the capability of the computer, design software, printing machine and milling machine vs. the complexity of a car. "

Local Motors created the first prototype Strati at Oak Ridge in May 2014, and it was on the road in June. It took 38 hours to build the first one. The drivetrain, suspension and other mechanical parts come from a Renault Twizy electric car.

Mass Customization

Originally, Local Motors planned to produce the Strati in one piece at IMTS, but the vehicle was actually printed in several parts and then joined together. "We have the space to print it in one piece, but the extruders we're using don't have the material flow rate to keep the thermal mass high enough on the part, and we ran into some deformation problems as the part cools," Earle says. "We had to reduce the size of the parts we're printing to maintain integrity."

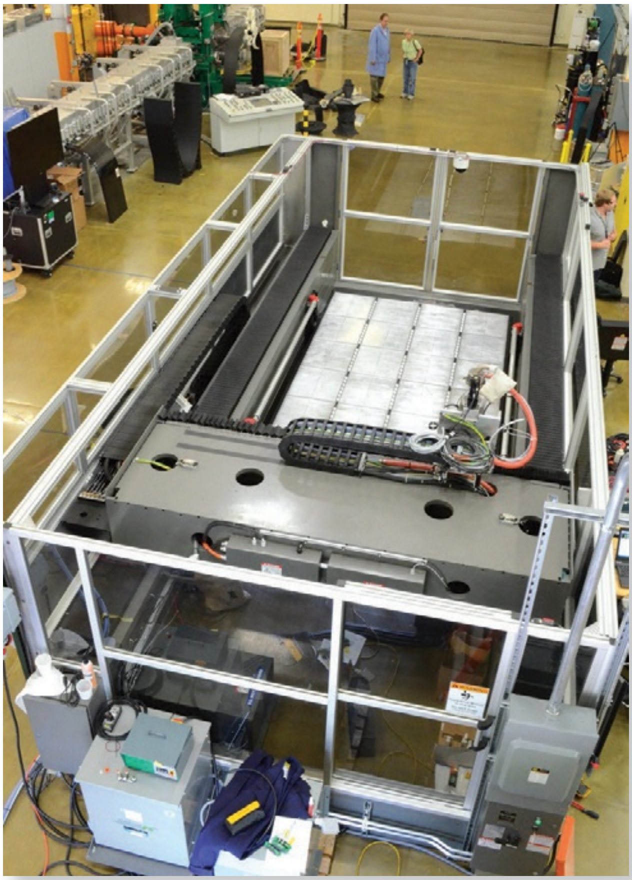
That's a challenge that will eventually be overcome, he adds. Cincinnati Inc. also has the capability to produce much larger and smaller versions of the B.A.A.M.

3D printing an entire car has far-reaching implications on future vehicle designs. For one thing, printing can greatly reduce the complexity of the car by reducing the number of individual components needed.

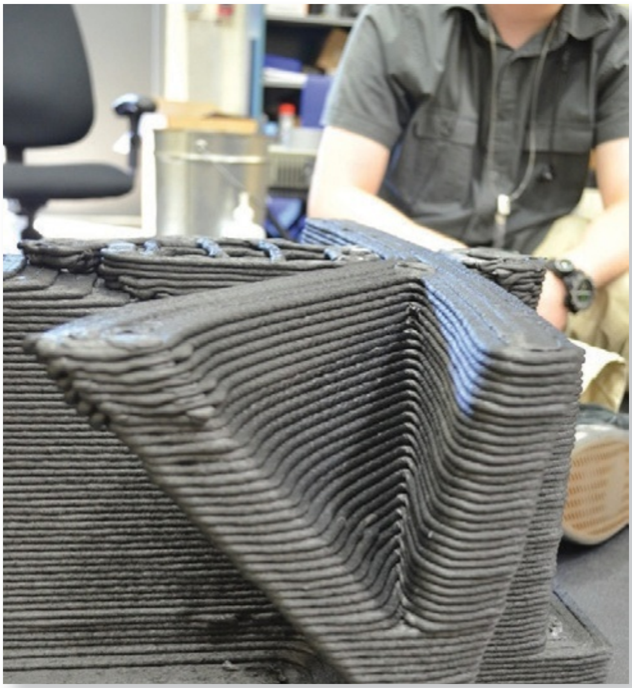
"The world is on a hell-bent path that was accelerated by the internet, says Rogers. "That path leads to virtual design meeting physical manufacturing. Just like electric car was talked about since 1905, and has just become commonly available recently — sometimes takes 100 years for tipping point to happen. I feel a lot like there's a tipping point going on now. You're seeing design for manufacturing, design for additive manufacturing, or direct digital manufacturing ... we're finally, happily, moving past the word prototyping."

Rogers says he hates the word prototyping because it means to the consumer that it's a product they'll never see.

A rendering of the completed Strati.



Cincinnati Inc.'s Big Area Additive Manufacturing, or B.A.A.M. 3D printing system.



A close-up of part of the 3D-printed Strati.

"Designers, especially in CAD, we want people to think 'If you can design it, it can be real.'"

For members of the Local Motors community, the first step toward that reality often begins in Siemens PLM Software's Solid Edge. Almost three years ago, the company introduced a special edition of Solid Edge, dubbed Design1, and made it available to Local Motors for a subscription fee of $19.95 per month.

"That gave us the ability to purchase professional-grade CAD software for basically the cost of a pizza each month," Rogers says. "That was really important to us as a statement that 'This is not beyond you.'"

Karsten Newbury, senior vice president and general manager of Mainstream Engineering Software for Siemens PLM Software, says the company's move to a rental offering is about the "digital enterprise."

"One of the key trends in the consumer world is mass personalization — accelerating the time people can get something real in their hands that is their own," he says. "It's not just about the 3D printed car. It's really about the whole process ... what we call the digital enterprise."

In such an enterprise, if designers don't have to consider the limitations of a traditionally more complex manufacturing model, it opens up all sort of possibilities when it comes to both styling and durability. Eliminating the need for multiple welds, bolts and clips, for example, also eliminates hundreds of points of failure on a vehicle.

"The way we make cars today, there are hundreds of stamped parts that are expensive to make, and they have to be primed and painted and welded," Neff says. "That involves lots of hours of machine time and labor to put them all together. The majority of that work can be done in one piece with 3D printing, and it opens up the possibility for mass customization in the future.

"I don't think Local Motors thinks this will replace GM or Ford anytime soon, but there are people who want to buy a very individualized car," Neff continues. "This can cut many labor hours out of the construction of the car, and make mass customization affordable for the average consumer."

In terms of lightweighting, printing also presents the possibility of reducing weight in non-load bearing components like seats. "You can tailor the material to the application in the car," Earle says. "You have high-strength material for the structure, and lighter weight, less-dense materials for other components. You can greatly reduce the weight of the vehicle by simply changing the material."

Neff cautions that just because the vehicle is printed from lighter weight materials doesn't automatically make it light.

"Carbon reinforced plastic is fairly light, but there is a lot of material in this particular car," he adds. "To meet the new Corporate Average Fuel Economy (CAFE) standards, cars have to be lighter, stronger and more aerodynamic. This would certainly, at a minimum, provide people with a way to prototype cars and test them aerodynamically in a much easier, faster way."

While large-scale vehicle printing is likely a few years away, both the auto and aerospace industries are interested in the technology for creating dies and tooling in a much faster and cheaper manner.

"When airplane manufacturers create parts, they have to get dies made for tooling, and that involves having a large piece of metal CNC-cut to a specific shape," Earle says, referring to the computer numerically controlled process. "That is expensive. In aerospace in particular, they may only make 100 parts off of a wing mold."

With 3D printing, he notes, the same mold can be made for a lot less money, and the turnaround is faster: "It's a few days vs. several months. The other benefit is you don't have to store those molds. You can reprint them later."

For the auto industry, there could be immediate application for cheaper, faster prototyping, in addition to creating small runs of custom vehicles. But if you can print a car that is durable, easier to manufacture, and weighs much less than a traditional model, what are the implications for repairability? If the entire body of the car is made from one piece, what happens when you crash and damage the rear fender?

"Right now, if you have to replace a panel, it can cost several thousand dollars," Earle says. "We'd love to get the technology to the place where we can reprint the entire car for less than the cost of the panel repair." Conversely, different parts could be printed in different materials. A bumper made from a softer, more shock-absorbent material could be popped out and replaced quickly, for example. **DE**

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INFO → **Cincinnati Inc.:** E-Ci.com/baam

→ **Local Motors:** LocalMotors.com

→ **Oak Ridge National Laboratory:** ORNL.gov

→ **SABIC Innovative Plastics:** SABIC-IP.com

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

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The Race is on for Light and Strong Parts

Luxon MX optimizes its motocross bike parts to achieve maximum performance with less weight and more strength.

BY JIM ROMEO

Motocross bikes are built to withstand tremendous stress in demanding conditions. Riders and teams always seek better parts to give them the competitive edge. Well engineered parts offer advantages such as reduced weight, increased toughness to handle the rough-and-tumble environment in which they operate, and afford additional rider safety in an already dangerous sport.

"The market is saturated with products; however, few are designed using advanced tools and practices," says Billy Wight of Luxon MX. The company is an offshoot of Luxon Engineering, a San Diego-based product development and mechanical engineering firm. Luxon MX offers aftermarket parts for the motocross industry.

"The original equipment manufacturer (OEM) components are designed to get the job done with minimal cost," Wight continues. "This opens the door for aftermarket companies designing parts for maximum performance. There are a lot of aftermarket companies making these parts, but none that use the optimization technology we do."

Luxon's first product began with the design of a triple clamp assembly, a bracket that holds the front suspension, steering and handlebars all in place.

"It's a frequently updated component," explains Wight. "It's one of the most notable structural components on the bike, and one of the most highly stressed parts on the bike. In addition to the required strength and stiffness, this part is very important to the handling of the bike."

Billy Wight personally tests all of Luxon's products. ***Images courtesy of Luxon MX.***

Luxon MX sought a more performance-oriented design. Bound by strength requirements, the company sought to reduce weight, maintain stiffness and strength, and ensure an aesthetically pleasing design.

In its design process, the company used HyperWorks, Altair's CAE simulation software platform, to setup and run analysis. It also employed Altair OptiStruct, Altair's tool for optimization-driven structural analysis.

Design optimization applies algorithms to optimize variables that are subject to constraints. Optimization applications are employed by Luxon MX during the product development stage to efficiently drive the design forward.

"The term 'optimization' is often used in engineering as a buzzword, but true optimization involves computerized routines that remove the engineer from the process," says Wight. "Computer routines avoid the designer's intuition and arrive at the true, and often non-intuitive, optimal result."

Luxon began the optimization process before any designing took place.

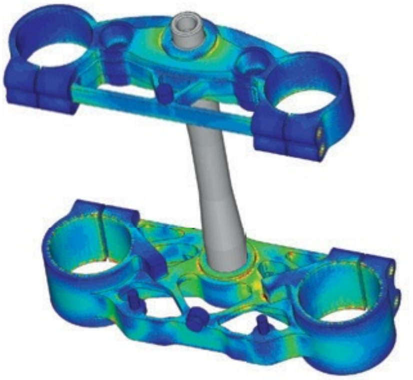
"We do not want to artificially constrain the design with preconceived notions of how the design should take shape," Wight says. "We start with optimization and see where the design wants to go."

Optimization starts with a block of material, the packaging space, as Wight calls it. The optimization software then begins to remove material to leave only the most efficient structure behind.

"Typically with structural components, the goals are high stiffness, high strength or low weight," Wight says.

He adds that Luxon employed a type of optimization called topology optimization, which helps reveal the most efficient material placement within a

Topology optimization results with manufacturing constraints applied.



FEA stress contours of an envelope encompassing all load cases reveal a consistent stress distribution.

The Luxon MX optimized clamp design.

given space. In the case of Luxon's triple clamps, about 64% of the total volume was within the design space. That's the amount of space available for use during the optimization routine. The remainder of that space is required for hard points — bolt locations, component attachments, etc. — and therefore cannot be used as a design variable.

The optimization routine runs the model through all of the loading conditions the components experience, and iterates to achieve the optimization goals. In Luxon's case, 12 different non-linear loading conditions are simulated to accurately represent the real-life loading on the components. The company prepared finite element (FE) models of OEM components, as well as some aftermarket competitors' parts. These models revealed the performance capabilities of the stock and competition products, giving Luxon a baseline on which to set its design goals.

"We want to meet the same stiffness as the stock components, but make them as light as possible while maintaining strength," says Wight. "We must also create a product better than the competition."

Exploring All Options

The optimization routines within the Altair software suite include various options to ensure the results are manufacturable for various processes.

"We always run the first optimization with minimal constraints, to see what the true optimum design looks like," Wight explains. "Once we have the first results, we start adding the appropriate constraints to ensure manufacturability. This allows us to see the compromises we are making in order to choose a particular manufacturing process. There's not one optimized design. There's a different optimized design for each combination of goals and constraints."

Because optimization is determined by the designer's goals, Luxon uses multiple optimization approaches to view and analyze various design options — with consideration given to all the design variables and constraints used to meet the objectives the company sets out to achieve.

The topology optimization results drive the design.

"Using the topology results, we create an initial 3D CAD model for analysis and further optimization," Wight says.

Luxon MX runs an FE analysis on the initial design to determine where it stands in relation to the OEM and competition components. The design is then further optimized using size and shape optimization routines within the Altair software. Finally, the design is evaluated using its FE model to compare its strength, stiffness and weight to that of the OEM and competing companies' parts.

Tests, and More Tests

Once Luxon's engineers are satisfied with the state of the design, they add the finishing touches to the CAD model and submit it for prototyping. The prototypes are then physically tested to validate all performance expectations.

"We prototype it from machined aluminum," says Wight. "We always verify our designs in the real world. Our parts are running on two different bikes right now, as well as being subjected to physical testing on rigs to accurately measure performance metrics."

The results? The final design of the triple clamps is 11.2 % lighter than stock with the same stiffness, and increased strength. The design is also stiffer, lighter and stronger than the competition's products, according to Wight.

"It looks very different from anything else on the market," says Wight. "The optimization leads to a very organic looking structure that is rather unique."

Luxon MX's first triple clamps are expected to be on the market the first quarter of 2015. **DE**

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

INFO → **Altair:** Altair.com

→ **Luxon MX:** LuxonMX.com

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

Keep It Light, **Strong**

Weight optimization is a balancing act to juggle competing objectives.

BY KENNETH WONG

When giving talks at conferences, Pierre Thieffry, ANSYS' product manager, often asks his audience, "Raise your hand! How many of you get your first simulation right?" As he expects, usually no hand goes up. That's the point he's trying to make — nobody does.

"When you do design evaluation, you do one, then another one, then another, and so on," Thieffry says. "So rather than just doing one at a time until you stumble on the right one, why not automate the exploration process?"

That's the principle behind software-driven weight optimization, or lightweighting, as the practice has come to be known among automotive and aerospace manufacturers. It's now possible to delegate a few dozens to hundreds of design variations to a machine, capable of assessing them at a much faster speed than any individual human can.

In theory, you can automatically try out even thousands of design alternatives by varying the thickness, targeted region for trimming, and material. At that scale, however, you'd need to rely on a high-performance computing (HPC) system to be able to process the job in a reasonable timeframe. So in reality, the cost (measured in both time and money) of running these calculations, the need to keep the data manageable, regulatory requirements, and company-approved material choices are bound to exclude some design variants from the exploration pool. Lightweighting is not as simple as shaving off as much material as possible; it's a balancing act.

Inevitable Conflicts

Bob Ryan, president of Red Cedar, part of CD-adapco, points out the competing objectives involved in vehicle lightweighting.

"Consumers want vehicles that have excellent crashworthiness, durability, handling and performance, but also provide good gas mileage," he says. "This requires vehicles that have a good combination of stiffness in the right locations, combined with lower overall mass. It is a balancing act to find the best combination of materials, geometry and part thicknesses to yield the desired vehicle performance."

Matteo Nicolich, enterprise solutions product manager for ESTECO, emphasizes a multidisciplinary approach to lighweighting, noting, "If each discipline is pursuing lightweighting on its own, they have to periodically reconvene with the others to discuss their designs. It's a lot faster for all the disciplines to improve the product as a single system."

Ryan agrees. "What carmakers typically experiment with during lightweighting is geometry, thickness and material," he says. "Your intelligent software will try out various combinations of those variables. They're not infinite; they're confined to, for instance, the types of materials that meet your company standards."

Ryan estimates that, in a typical lightweighting project, the combinations the software must try out "could be between 500 to 1,000." Therefore, a manual approach is impractical. Engineers must rely on optimization software to automate the process.

ANSYS' Thieffry similarly observes, "In lightweighting, you're trying out different shapes, so you definitely need a way to automate the process using design parameters." Adds ESTECO's Nicolich, "You also need a way to mine and explore the data afterward."

ESTECO's modeFrontier comprises an environment to automate the simulation runs and a design space to gain insights from the simulation outcomes.

"In the second phase, you have multiple parties with multiple objectives," Nicolich continues. "modeFrontier lets you analyze the tradeoffs and rank them. That's where all interested parties from multiple disciplines can come together to discuss the options."

Keeping the Data Manageable

The key to prevent a data explosion in optimization is to restrict the archive to only the most promising design variants and their associated parameters.

"Simulation software is now fast enough to recreate a scenario at any given time, so it makes more sense to save the input parameters and design configurations, not the whole simulation result file," says Thieffry, noting it's done usually in gigabyte scale for complex jobs. "You can always rerun the job with the same configuration — that's the smartest way. If you'd like to save the result file, save the one for the design you decide to go with, not for every configuration you tried out. I'm sure the IT guy will like that strategy, too."

But traditional product lifecycle management (PLM) packages may not be the best for optimization data archival.

"A PLM system won't let you evaluate the performances of design variants, or iterate automatically," Nicolich points out, noting that the intermediate steps you go through to get to a lightweight design are not product variants — most of them will never go beyond the computer screen. "They should be managed outside the product lifecycle. Otherwise, you'll clog the PLM system with a huge amount of data."

Lightweighting involves material properties, safety requirements and design parameters used in the simulation runs. The purpose of keeping them is to be able to recreate the same simulation scenario at any given time, and to be able to explain (or defend, as the case may be) a certain option chosen in the final phase. Both the data type and the treatment they require are significantly different from those managed in PLM, such as CAD file versions, approval records, change orders and supplier data.

Even though the optimization software is doing the heavy lifting in searching the space of possible designs, Red Cedar's Ryan says engineers are not off the hook. The optimization software typically yields what Ryan describes as "a small number of design clusters or families, usually numbering less than a dozen, which show the greatest promise of delivering superior performance at lower cost."

It normally takes additional human intelligence, expertise and experience to select the best option.

"There's no one answer to an optimization question," says ANSYS' Thieffry. "You usually end up with a number of good designs that satisfy your criteria. You can't just pick one answer based on the numbers. The optimal shape the computer proposes is numerically optimal, but it's probably not something you can easily manufacture."

Strength in Numbers

Red Cedar's Ryan points out that modern optimization software is changing how lightweighting projects are performed.

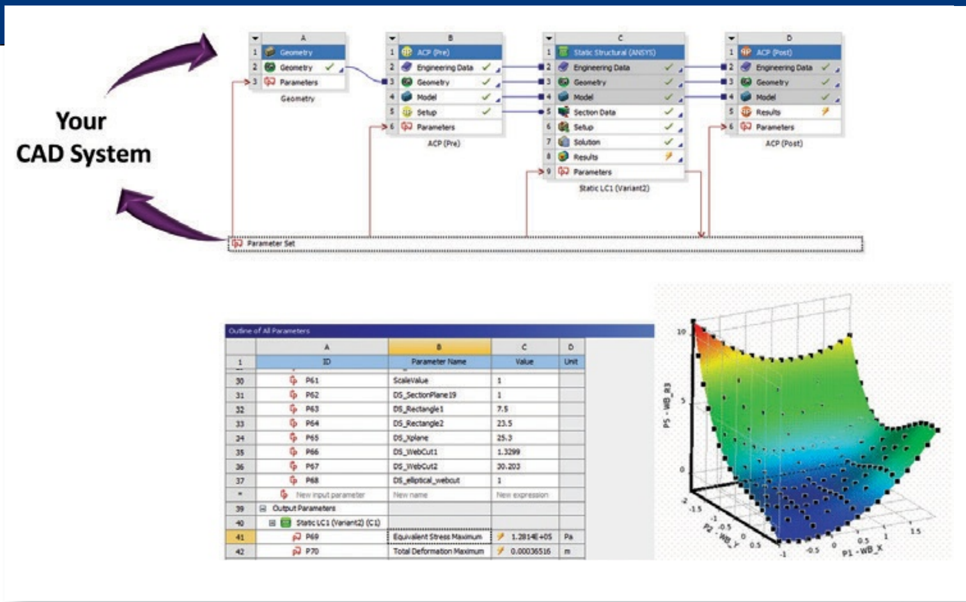
"Traditionally, when engineers did design exploration, they'd simplify the simulation model, screen out seemingly unimportant variables, sample the model, build a response surface [an interactive map showing the design variable changes and the associated consequences], and optimize using that response surface," he explains.

A limited sample pool based on a reduced set of variables was the right approach in the 1990s, in Ryan's view.

"At the time, the software wasn't good enough to accurately regenerate designs that were too far away from the initial design," he says. "We didn't have ubiquitous computing power, and we didn't have efficient design exploration algorithms that could work on any problem.

"But that's no longer the case now," he continues. "With software like Red Cedar's HEEDS, you no longer need to simplify your simulation model or extensively screen out design variables a priori. You can explore your fully validated simulation model directly, without simplification."

Ryan notes that it's common for Red Cedar users to explore 400 to 500 design variables at a time in HEEDS. "If you want to do successful lightweighting today, you have to be able to look at a lot of variables, and a fairly large range of designs," he says.



The number of design variants involved in a lightweighting project is usually too numerous to be executed manually. Shown here is a typical automated workflow in ANSYS Workbench for optimizing composites.

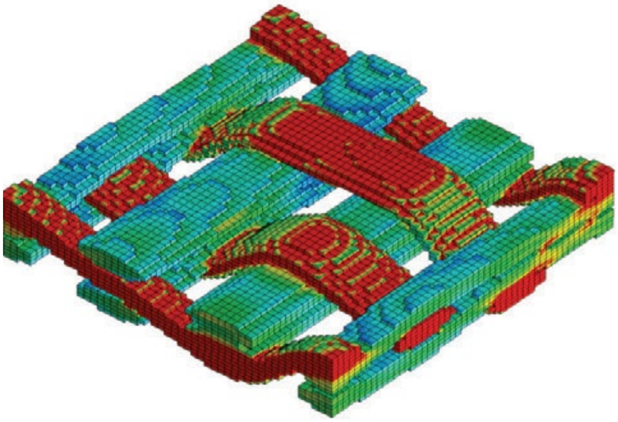
Made in Composites

The long history of traditional manufacturing materials, such as steel and aluminum, gives manufacturers the ability to accurately predict how they'll perform. But in lightweighting, manufacturers turn to advanced materials made of a combination of multiple materials.

Roger Assaker, MSC Software's chief material strategist, says, "Plastic reinforced with chopped glass fiber or continuous carbon fiber-reinforced polymers, for example, have different properties and characteristics than metals. The actual properties of the composites typically varies across the structures and in different directions." Therefore, understanding the nature of composite materials may be the most critical area in the pursuit of lightweighting.

ANSYS' Thieffry notes that if you "pick a standard material, there may be about four or five numeric values to represent its deformation rate, stretching behavior, and so on. But with composite materials, the number is multiplied. Adding the effects of the orientation of the materials [the direction and angle of the ply layout], for instance, is immensely complex mathematically."

Most simulation software comes preloaded with a database of standard manufacturing materials, but for composites, the user



Composite materials commonly used in lightweighting are designed from the ground up, including the direction and pattern of the fiber. Shown here is a close-up of composite materials in MSC Software.

may have to rely on lab tests, public resources and material providers to obtain values representing the quantities of material.

"Currently, the material data available for composites is limited, so the Tier I manufacturers and original equipment manufacturers who are spearheading the lightweighting project would have to test the materials themselves to get accurate data, or work closely with a material supplier to get the data," says Assaker.

Even though the nature of composites offers almost infinite possible varieties, the manufacturer's own choices may be much more limited, Assaker points out.

"Qualifying new materials is kind of expensive, so you want to reuse preapproved materials if possible," he adds.

The switch to advanced materials also requires thinking about other angles — literally. "With composites, the material's properties and resistance to stresses and loads are not the same in all directions," Assaker says, noting that the ply stack's direction, angle and layout all affect its strength differently in each direction.

Treating composites like classic black metals, he says, can lead the engineer to build a part with more materials than necessary, thus compromising the project's lightweighting goal.

"Material is one of the three pillars of MSC Software's strategy," says Assaker, noting that MSC Software's acquisition of e-Xstream engineering, which he founded, is a result of that. "Our Digimat Software lets you model the composite material in detail from the ground up, starting from constituents (polymer/fibers) and underlying microstructure (fiber length, orientation)."

He recommends not just switching to composite throughout the whole design, but identifying the right composites for the chosen regions of the design.

"For example, in some areas of the design, you might want continuous carbon fiber; in others, perhaps a cheaper thermoplastic reinforced with chopped glass fiber is sufficient," Assaker explains. "Digimat will allow you to accurately model all these types of composites, and help you choose the right material and converge to the optimal design."

Designer-driven vs. Expert-driven

Simulation software makers have had good success in promoting their technology to the designers, thereby expanding the market beyond the specialists. Today, simple stress analysis and flow simulation have become an integrated part of CAD software and the conceptual design workflow. But what about lightweighting? Can average designers grasp its intricacies?

MSC's Assaker says he believes they can at least play a role. "Going after the last kilograms or pounds should be the expert's job, because there're too many variables and complexities involved at that point. But topology optimization at the beginning of the design can be done by designers, if they have basic understanding of composite materials," he says. "They can do the first 80% of lightweighting in topology."

One company focusing on simplifying topology optimization is solidThinking, an Altair company. It recently released the latest version of Inspire, which allows designers to investigate structurally efficient concepts quickly. The company refers to Inspire 2014 as a concept development tool, as opposed to Altair OptiStruct, its structural analysis solver for design and optimization.

"With solidThinking Inspire 2014 we focused on enhancing the concept development process by proposing designs that can be rapidly iterated and easily exported to the user's preferred CAD tool," notes Andy Bartels, program manager for solidThinking Inspire in a company press release. "We put a strong emphasis on improving the usability of the software while adding new features like geometry simplification tools for easier model setup and analysis to help users verify their concepts, all directly in the Inspire interface. These new features will allow customers to apply Inspire to a much broader set of design problems."

Automotive and aerospace manufacturers are currently the most aggressive in adopting lightweighting strategies. But there are signs suggesting other industries — consumer goods and electronics, for instance — have begun to experiment too. And the manufacturers' balancing act is crucial in producing smartphones, large-screen TVs and vacuum cleaners that are light enough for us to carry or haul around, but strong enough to survive the inevitable drops and bumps. **DE**

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

INFO → **Altair:** Altair.com

→ **ANSYS:** ANSYS.com

→ **ESTECO:** ESTECO.com

→ **MSC Software:** MSCSoftware.com

→ **Red Cedar Technology:** RedCedarTech.com

→ **solidThinking:** solidThinking.com

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Siemens & Rescale Partnership Brings NX Nastran On Demand to HPC Cloud

CAE is playing an increasingly critical role in the design process, but not every company has access to the kind of scalable computing horsepower needed to run complex FEA simulations and provide timely input during the design process.

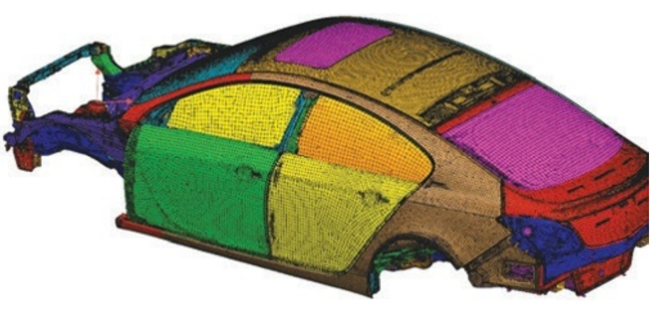
Thanks to a partnership between Siemens PLM Software and Rescale, a cloud simulation platform provider, compute resources will no longer be a bottleneck. The industry leaders have teamed up to offer a joint solution that integrates on-demand, high-performance computing (HPC) hardware with NX Nastran, the leading FEA solver used by manufacturers in automotive, aerospace, machinery, energy and other industries.

The result is an on-demand, dynamically scalable cloud environment that offers NX Nastran through a Software-as-a-Service (SaaS) model. Engineering teams can easily customize HPC resources on an as-needed basis without having to invest in costly in-house IT infrastructure. Those companies with HPC infrastructure already in place gain the flexibility of easily augmenting their existing capabilities with additional HPC capacity on a pay-per-use basis to accommodate peak usage periods.

Improve Product Development

Access to easily scalable, pay-per-use Nastran simulation capabilities can be a game changer for product development efforts. The ability to easily dial up and scale back simulation horsepower lets engineering teams conduct more thorough, and timely, design studies throughout all phases of the design cycle, increasing product quality and bolstering innovation efforts. For instance, large Design of Experiment (DoE), optimizations, and Monte Carlo simulations, which are out of reach for many companies, are now more accessible and affordable on the Rescale platform. A volume pricing model and the ability to simultaneously execute hundreds of individual runs for varying parameters across the design space, compared to the traditional sequential approach, creates a game-changing environment for large and small organizations.

Rescale's intuitive platform and support for a wide range of HPC hardware also ensure companies provide flexibility and efficiency in solving diverse FEA applications. With NX Nastran running on the Rescale on-demand cloud platform, companies can pursue a hybrid model—sizing in-house simulation infrastructure and license counts for a normal workload and leveraging



the cloud for more demanding computations. Alternatively, they can forgo an HPC infrastructure investment completely and run all NX Nastran simulations in the Rescale cloud environment with significant cost savings. Check out this video to see a demonstration of NX Nastran on the Rescale platform. http://goo.gl/CYnK8V.

All Aboard HPC-Driven Simulation

Siemens PLM Software will be showcasing NX Nastran on the Rescale on-demand cloud simulation platform at its upcoming CAE & Test Symposium 2014, to be held October 22-23, aboard the Queen Mary in Long Beach, California. Formally known as the NX CAE Symposium, the gathering is home to two days of presentations, workshops, discussions, and networking events all focused on helping engineers, designers, and analysts gain valuable insights into Siemens' NX CAE and LMS simulation portfolios.

Siemens PLM Software executives will be on hand to detail the company's CAE roadmap and future direction. Prominent CAE customers like General Motors, Cummins, and Jet Propulsion Lab and many others will also present, providing valuable insights and best practices gleaned from their CAE implementations.

A new series of hands-on workshops will also be featured during the symposium. Headlining this part of the event will be a workshop that showcases NX Nastran running on the Rescale on-demand cloud environment, including the different simulation scenarios possible with the new offering.

To learn more about the CAE & Test Symposium 2014 and the new Rescale partnership, go to:
https://www.plm.automation.siemens.com/en_us/about_us/events_webinars/cae-test-symposium/

http://blog.rescale.com/siemens-nx-nastran-now-available-on-rescale-on-demand-cloud-environment/

TABLE OF CONTENTS

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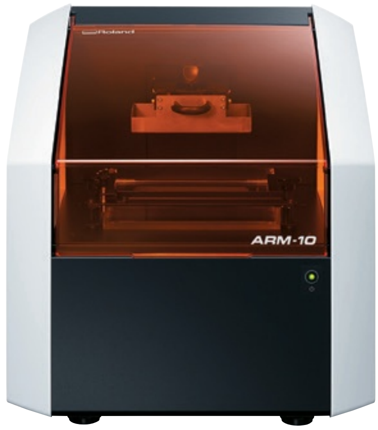
3D Printer Profiles



ProJet 1200

3D Systems' lowest cost ProJet printer is perfect for jewelry casting patterns, dental crown and bridge wax ups, and small, precise prototypes. Page 49

ULTRA® 3SP™

EnvisionTEC's 3SP™ technology allows for the high speed 3D printing of large end-use parts which are stable and durable. Page 52

ProJet 5500X

Simultaneously print and fuse together flexible and rigid material composites in a variety of colors and shades. Page 51

3DP1000™

Take your prints from ordinary to extraordinary with a 74x greater build area than the average ordinary desktop 3D printer. Page 53

SLM® 280HL

The Selective Laser Melting System® has a unique double laser beam technology that increases productivity by 40%. Page 56

3D Printer Profile /// CubePro • *Sponsored by 3D Systems*

3D Printing. Real. Pro.

What's Cool

The CubePro features the largest-in-class build platform with ultra high-resolution in up to three colors in a single build. With prints 2.5 times larger than any other desktop prosumer and hobbyist printer (11.2 x 10.6 x 9.06 in. or 285.4 x 270.4 x 230 mm) with ultra high-resolution settings of 70-micron thin print layers, professional quality printing has never been so large or easy. The CubePro supports a new material for production: nylon, along with strong ABS and compostable PLA plastic.Create functional prototype models or make end-use parts for your engineering applications.

Who's It For

The CubePro is a versatile printer for both the engineer and hobbyist alike.

Materials

CubePro ABS plastic, compostable PLA plastic, and nylon.

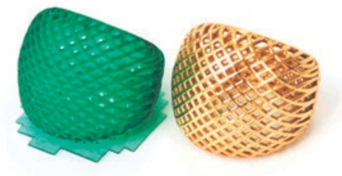
Specs

- **Dimensions:** 22¾ x 22¾ x 23¼ in.
- **Weight:** 80 lb (single-head printer), 82.5 lb (Duo - double-head printer), 85 lb (Trio - triple-head printer)
- **Maximum build size:** 11.2 x 10.6 x 9.06 in. (single-head printer), 9.56 x 10.6 x 9.06 in. (Duo - double-head printer), 7.89 x 10.6 x 9.06 in. (Trio - triple-head printer)
- **Z-axis Resolution:** 100 microns
- **Layer thickness:** 70 microns, 200 microns and 300 microns in fast mode
- **Print Tolerance:** X and Y axis ± 1% dimension or ± 200mm microns, whichever is greater. Z axis ± half the processed z resolution. Shrinkage and warpage can occur on models and is purely geometry dependent
- **Print Speed Extruded Volume:** Maximum 15mm per second and polymer dependent

> "The CubePro far surpasses any desktop 3D printer I have ever used in terms of print quality, setup, and print speeds. The CubePro is designated as a 'ProSumer' printer, which is a fairly bold statement for a printer in this price range. If you're fortunate enough to own one you'll quickly see that it lives up to the name and that the print quality rivals printers costing 3 times as much. Best investment made in 2014."
>
> *— Lyman Connor, Inventor, Engineer T3M Corp.*

For more information visit:
www.cubify.com/en/CubePro

Micro-SLA®, Low-Cost Professional 3D Printer



What's Cool

3D Systems' lowest cost ProJet printer is perfect for jewelry casting patterns, dental crown and bridge wax ups, and small, precise prototypes. It uses micro-SLA technology to print parts with exceptional feature detail right on the desktop. The ProJet 1200 is no bigger than a coffeemaker, and it's just as easy to use. Pop in a $49 material cartridge, and print dozens of rings or hundreds of dental models.

Featuring fast print times, the ProJet 1200 is a workhorse when short cycle times are crucial. Convenient all-in-one material cartridges make it easy to replenish materials, and network-based printing means your whole team can easily access the printer.

Who's It For

Parts made on the ProJet 1200 are castable, so it is ideal for jewelers, dental labs, electronics manufacturers, hobbyists.

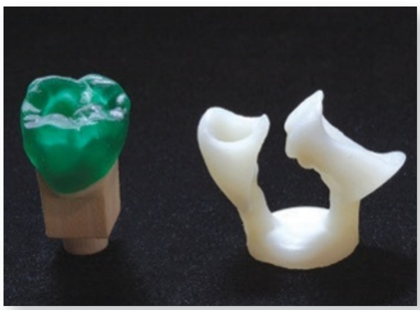
Materials

VisiJet® FTX Green is a durable and rigid material that is tailored for plastic prototyping and casting patterns.

Specs

- **Net Build Volume:** 1.69 x 1.06 x 5.90 in.
- **Native Resolution:** 56 micron (enhanced LED DLP technology provides an effective resolution of 585 DPI)
- **Layer Thickness:** 0.03 mm
- **Vertical Build Speed:** 14 mm/hour (0.55 in./hour)
- **Material:** VisiJet® FTX Green
- **Material Packaging:** All-in-one cartridge with built-in print window
- **File Input:** STL
- **Electrical, Input:** 100-240 VAC, 50/60 Hz, 2.0 A
- **Electrical, Output:** 24 V DC, 3.75 A, 90 W max
- **Dimensions:** 9 x 9 x 14 in
- **Weight:** 20 lbs (9 kg)

> "The ProJet 1200 has the accuracy and reliability to 3D print complete micro-assemblies for scientific testing. Our customers are using it to incorporate passages that are just 50 microns in size. The ProJet 1200 creates each assembly perfectly every time, in just a few hours, saving up to 4-6 weeks that each hand-made micro assembly used to take. This is a perfect printer for detailed work."
>
> *— Drew DaHarb, CADblu*



For more information visit:
www.3dsystems.com/projet1200

3D Printer Profile /// ProJet 4500 • *Sponsored by 3D Systems*

Combine Vibrant Full Color with Durable Plastic Materials

What's Cool

Combine outer beauty with inner toughness and have durable, full-color plastic parts right out of the printer from the ProJet® 4500. It is the industry's only photo-realistic full-color plastic 3D printer. The ProJet 4500 gives you the power to print strong plastic parts, colored pixel by pixel for true-to-life models of your end product. This office-friendly 3D printer is quick and efficient, and features intuitive operation controls, so you can ensure high productivity and cut operating costs.

Who's It For

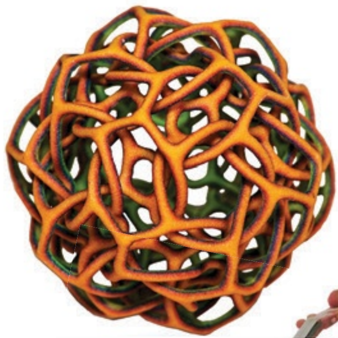
Design, R&D, AEC, marketing and sales teams that need to create vibrant, tough, photo-realistic part models, as well as service bureaus and entrepreneurs who need to print in full color plastic.

Compatible Materials

VisiJet® C4 Spectrum™ plastic material with excellent flexibility and strength for durable concept models, prototypes and more.

Specs

- **Resolution:** 600 x 600 DPI
- **Color:** Continuous CMY
- **Minimum Feature Size:** 0.1 mm
- **Layer Thickness:** 0.1 mm
- **Vertical Build Speed:** 8 mm/hour
- **Prototypes per Build:** 18 models, 75 mm in diameter
- **Net Build Volume:** 8 x 10 x 8 in
- **Build Material:** VisiJet C4 Spectrum
- **Input Data File Formats:** STL, VRML, PLY, ZPR
- **Operating Temperature Range:** 55-75°F
- **Operating Humidity Range:** 20-55% - non-cond.
- **Dimensions:** 64 x 60 x 31.5 in.
- **Weight:** 600 lbs
- **Electrical:** 100-240V, 15-7.5A
- **Certification:** CE, CSA
- **Print3D App:** Remote monitoring and control from tablet, computers and smartphones



“The 3D Systems ProJet 4500 has been a game-changer when it comes to creating professional-level, full-color 3D models. The plastic prints are durable, resilient, and maintain integrity even at super-fine detail, enabling clients to fully interact with the print and thoroughly understand the design at hand. When it comes to medical modelling, we can now better serve our customers by providing a solution encompassing both the level of detail and robustness necessary for laboratory and surgical work. The ProJet 4500 has allowed us to rise to the challenge and create models not possible on any other 3D printer.”

— Steve Cory, President,
Objex Unlimited - Toronto's 3D Printing Studio

For more information visit:
www.3dsystems.com/projet4500

Large, High-Quality Multi-Material Parts in a Single Build

What's Cool

3D Systems' ProJet® 5500X delivers the highest quality, most accurate and toughest multi-material composite parts. The ProJet 5500X simultaneously prints and fuses together flexible and rigid material composites layer by layer at the pixel level in a variety of colors and shades including opaque, clear, black or white and numerous shades of gray.

The ProJet 5500X delivers fast composite material print speeds using breakthrough materials with properties that can be easily varied within a single part. This new VisiJet® Composite family of materials is precisely mixed by the ProJet 5500X print head on-the-fly to achieve superior mechanical properties and custom performance characteristics and comes with a 5-year print head warranty. With so many options, the ProJet 5500X is perfect for a variety of applications, including overmolded parts, multi-material assemblies, rubber-like components, long-lasting living hinges and high-temperature testing.

Who's It For

The ProJet 5500X is ideal for design, R&D, marketing and sales, toolmakers and manufacturing engineers who need to create functional prototypes, test overmolded parts, rapid tooling and end-use parts that feature various material properties, as well as service bureaus and entrepreneurs that need to print in multi-material plastic composites.

Materials

VisiJet® 5500X Composites family, including black, white and clear materials available in rigid or flexible form.

Specs

- **Net Build Volume:** 21 x 15 x 11.8 in.
- **Resolution:** 29µ (0.0011 in) to 32µ (0.0012 in) layers, depending on mode
- **Dimensions:** 67 x 35.4 x 65 in
- **Weight:** 2060 lbs
- **Electrical:** 100 VAC, 50/60 Hz, single-phase, 15 Amps; 115 VAC, 50/60 Hz, single-phase, 15 Amps; 240 VAC, 50/60 Hz, single-phase, 8 Amps

> "The ProJet 5500X brings the benefits of 3D Systems' MultiJet Printing technology to multi-material applications. Print parts with better fidelity, sharper features and that are true-to-CAD, and choose from dozens of material composites made on the fly for your part."
>
> *— Tom Charron, VP of Product Marketing, 3D Systems*

For more information visit:
www.3dsystems.com/projet5500x

3D Printer Profile /// ULTRA® 3SP™ • *Sponsored by EnvisionTEC*

Scan, Spin and Selectively Photocure with the ULTRA® 3SP™

What's Cool

EnvisionTEC's 3SP™ technology allows for the high speed 3D printing of large end-use parts which are stable and durable with excellent surface quality that requires minimal to no post-processing. The surface quality of the printed models show no signs of stair-stepping on the inner and outer surfaces.

Who's It For

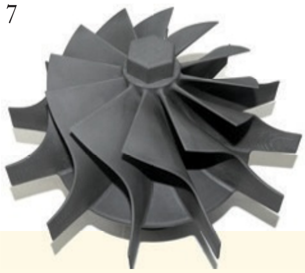
Professional designers and manufacturers across a broad range of applications ranging from aerospace and automotive to sporting goods, electronics and toys.

Compatible Materials

Proprietary high temperature materials for molding, ABS plastic type materials for rigid and stable models and clear materials with superior mechanical properties.

Specs

- **Dimensions:** 28 x 30 x 46 in. with an optional stand measuring 29 x 30 x 25 in.
- **Maximum Build size:** 266 x 175 x 193 mm
- **Resolution in X and Y:** 100 µm (also available in a High Definition model capable of 50µm resolution in X and Y)
- **Dynamic Voxel Resolution in Z:** 25-100 µm (user adjustable and material dependent)
- **Acceptable input format:** STL
- **Network Connectivity:** Yes
- **Power requirements:** 100-127 VAC, 50/60 Hz, single phase, 8A; or 200-240 VAC, 50 Hz, single phase, 4A
- **Workstation OS Compatibility:** Windows 7



“The 3SP™ technology employed by the ULTRA® 3SP™ provides the same high quality results as our flagship DLP process on a larger scale with faster build speeds. The ULTRA® 3SP™ is an excellent solution for anyone who needs to 3D print larger parts quickly without sacrificing resolution or surface quality.”

— Al Siblani, CEO of EnvisionTEC

For more information visit:

http://envisiontec.com/3d-printers/ultra-3sp-family/
http://envisiontec.com/3d-printing-technologies-overview/#3SP

3DP1000™ Large Format 3D Printer

3DP Unlimited™ is the manufacturer of the 3DP1000 large format 3D printer. 3DP Unlimited, a division of PBC Linear®, is a company of skilled mechatronics engineers who embrace rapid advances in technology to innovate, design, and build next-generation equipment for additive manufacturing. 3DP Unlimited is committed to building on industrial strength linear motion components, actuators, and motors while maintaining affordable flexibility with open source control solutions.

What's Cool

- **Big:** 3DP1000 provides a big build area of 1 x 1 x 0.5 m. With 74x greater build area than the average ordinary desktop 3D printer, the 3DP1000 will take your prints from ordinary to extraordinary.
- **Economical:** With base platforms starting under $20,000, 3DP1000 is lowering the cost barrier for entry into large-format 3D printing.
- **Accurate:** For precise prints, the 3DP1000 can print down to 70 micron layer resolutions.
- **Robust:** The 3DP1000 is based on industrial strength linear motion and mechatronics that provide consistent quality performance.

Who's It For

The 3DP1000 is the ideal solution for a wide range of applications in industrial design, rapid prototyping, product development, automotive design, building & naval architecture, custom props, sculptures, stage sets, artistic development, and much, much more.

Materials

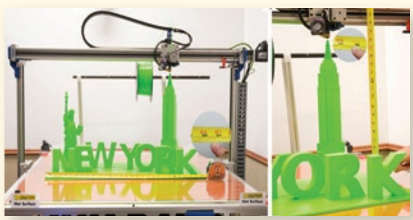
- **Compatibility:** The 3DP1000 printer is capable of printing any material (3 mm diameter) that is created for Fused Filament Fabrication (FFF), including but not limited to PLA (Polylactic Acid), PVA (Polyvinyl alcohol), ABS (Acrylonitrile Butadiene Styrene), PC (Polycarbonate), Nylon, Ninja Flex, and *HIPS (High Impact Polystyrene).*

  Note: Some materials may require increased bed and nozzle temperatures, as well as additional ventilation.
- **Filament Diameter:** 3 mm (0.118 in.)
- **Nozzle Diameter:** 0.4 mm
- **Connectivity to Laptop:** USB

Specs

- **Unit dimensions:** 1.422 m x 1.676 x 1.524 m (56 x 66 x 60 in.)
- **Build area dimensions:** 1 x 1 x 0.5 m (39.3 x 39.3 x 19.6 in.)
- **Layer Resolution:** Down to 70 microns (0.0027 in.) *Note:* Accuracy is dependent upon slice settings, geometry, print speed, filament quality, and a range of other factors. Under average conditions, it is typical to hold layer resolution of 100 microns with a well-tuned and calibrated printer configuration.
- **Input formats:** The 3DP1000 requires gcode for printing. Typical 3D printing software generates gcode from a variety of 3D modeling file types such as STL and OBJ.
- **Power Requirements:** Option 1: 110 V, 15 Amp, 60 Hz; Option 2: 220 V, 13.6 Amp, 60 Hz
- **Workstation OS compatibility:** The 3DP1000 uses open source controls—providing additional flexibility to customers. This flexibility includes the ability to use a broad range of materials and choice of operating software, not limited to a specific manufacturer.

> "3DP Unlimited is a company that has put mechatronic advances to work in building its robust large format 3D printers. With a build area of 1 m x 1 m x 0.5 m, it is critical that 3DP use mechatronic advantages, such as robust linear actuators and controls from PBC Linear, to maintain high performance."
>
> *— Mark Huebner, Market Development Manager, PBC Linear*



For more information visit:

www.3dpunlimited.com

www.3dpunlimited.com/3dp1000-data-sheet

3D Printer Profile /// AM250 • *Sponsored by Renishaw Inc.*

The New Name in Additive Manufacturing

What's Cool

The unique value of this product is that you can build 3D structures with metal for medical and industrial applications from 3D CAD data. Renishaw's laser melting is a pioneering additive manufacturing process capable of producing fully dense metal parts direct from 3D CAD using a high-powered fiber laser. Parts are built from a range of fine metal powders that are fully melted in a tightly controlled atmosphere layer by layer in thicknesses ranging from 20 to 100 microns. Through a digitally driven process, you can manufacture organic or highly complex geometries. It provides an avenue for low volume manufacturing of complex metal parts in specialist materials and functional testing of production quality prototypes.

Who's It For

The technology is already widely employed for the manufacture of custom medical implants, lightweight aerospace and motorsports parts, efficient heat exchangers, and injection molding inserts with conformal cooling channels.

From patient-specific orthopaedic implants to volume production of medical devices featuring hybrid structures and textures, laser melting has the potential to unlock manufacturing capabilities that combine free-form shapes and intricate lattice structures. This improves osseointegration in orthopaedics, leading to much improved patient outcomes. It also allows aerospace and motorsport companies to 'add lightness' to components.

From tooling inserts, featuring conformal cooling, to lightweight structures for aerospace and high technology applications, laser melting gives designers more freedom, resulting in structures and shapes that would otherwise be constrained by conventional processes or the tooling requirements of volume production. Laser melting is complementary to conventional machining technologies and forms part of a manufacturing system including heat treatment, surface post-processing, and directly contributes to reduced lead times, tooling costs and material waste.

Materials

- Aluminum
- Cobalt Chrome
- Inconel
- Stainless Steel
- Titanium

Specs

- **Build Area:** 245 x 245 x 300 mm (360 mm Z axis by request)
- **Build rate:** 5cm³ - 20cm³ per hour
- **Layer thickness:** 20 µm - 100 µm
- **Laser beam diameter:** 70 µm diameter at powder surface
- **Laser options:** 200 W
- **Power supply:** 230 V 1 PH, 16 A

"We're pleased to add this system to our equipment list and expand our capacity to deliver direct metal part manufacturing services. We thoroughly researched our options and selected the Renishaw AM250 due to its reputation for building precision titanium prototypes and parts."

— Alex Fima, CEO, Directed Manufacturing Inc.

For more information visit:
www.renishaw.com

Roland monoFab™ Series ARM-10 Desktop 3D Printer

What's Cool

The included monoFab Player AM software provides 3D printing from STL files and features automatic functions such as healing that corrects gaps in 3D data, simplifies meshes, and generates supports. The simple workflow of Roland's monoFab ARM-10 rapid prototyping 3D printer makes creating 3D models as easy as hitting "print."

Who's It For

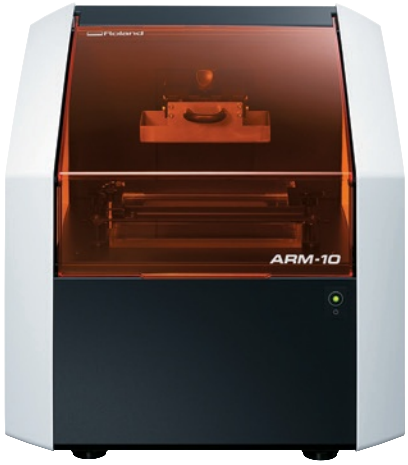
Target audiences include design professionals as well as students.

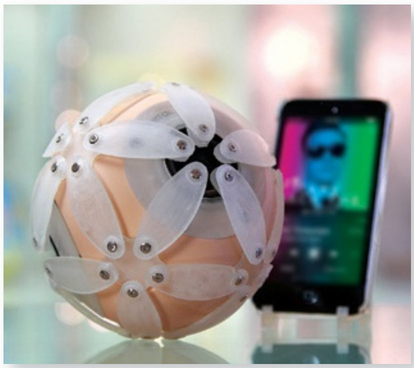
Materials

Roland imageCure™ is a clear, photopolymer liquid resin that when exposed to the ARM-10's UV light becomes hard and semi-transparent.

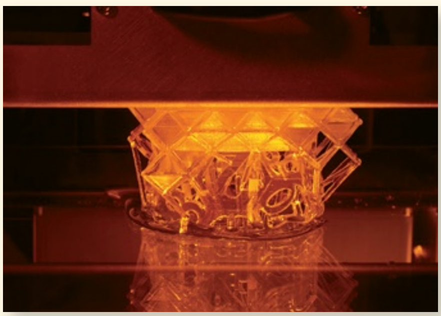
Specs

- **Features:** Digital Light Processing (DLP) layered projection system produces semi-transparent models for concept and form testing; fully enclosed cabinet for safety; easy to use – can be controlled with a single button; easy post-processing: short post curing time, support removal, also finished part may be polished and painted.
- **Dimensions:** 17 x 14.4 x 17.8 in.
- **Build Area:** 5.11 x 2.75 x 2.75 in.
- **Build Resolution, XY:** .0079 in. (0.2 mm)
- **Build Resolution, Z Axis:** .0004 in. (0.01 mm)
- **Material:** imageCure™ photopolymer resin; semi-transparent
- **Software:** monoFab Player AM included, which features automatic support building, healing and mesh simplification, simulation of resin volume, ability to change scale, duplicate, rotate; has a preview layer function
- **Support:** Roland OnSupport delivers the latest firmware and software to your desktop
- **Interface:** USB
- **Operating System Compatibility:** Windows 7/8/8.1





> "The monoFab series desktop fabrication tools are the culmination of over twenty-five years of experience in Roland 3D milling. By combining the capabilities of these advanced rapid prototyping machines, users can select the best method for their workflow, from concept to production. Now, designers have greater opportunities to turn their ideas into reality."
>
> *— Rachel Hammer, 3D Product Manager, Roland DGA*



For more information visit:
rolanddga.com/products/3d/arm10/

3D Printer Profile /// SLM® 280HL • *Sponsored by SLM Solutions*

Flexible, Fast and Safe Through Design, Prototype & Production

What's Cool

The Selective Laser Melting System® 280HL provides a 280 x 280 x 350 mm build chamber with unique double laser beam technology that increases productivity by 40%. The system is equipped with a 400W fiber laser with the option to add an additional 400W laser, or you may exchange for 1000W fiber lasers.

Together with a patented bi-directional loader, safe filter system, and highly efficient protective gas management, the SLM® 280HL is defining the industry gold standard for achieving greater safety, speed, and quality. Options for an automated and continuous transport of metal powder provides best-in-class operator safety by eliminating time consuming manual fills and powder handling. Additionally, the bi-directional loader feeds powder in the forward and reverse motion—saving 35% of auxiliary cycle time.

Open software architecture and system parameters allows you to make modifications according to your specific design and production needs. You gain greater control and flexibility of the laser and build characteristics (laser power, laser/scan speed, powder layer thickness, hatch pattern and spacing). The system is equipped with Materialise, the leading software for additive manufacturing, to process CAD/STL-data files. Additional options offer the ability for monitoring, auditing and quality assessment to exercise optimal quality control in production.

Materials

The SLM 280 covers a wide range of metals such as Stainless Steels, Tool Steels, Cobalt Chrome, Inconel, Aluminum and Titanium. You may use metal materials from SLM Solutions or another material provider without any risk to the machine warranty. Further available options will also increase the versatility and usability of the system.

Specs

- **Build Chamber Volume in mm (x/y/z):** 280 x 280 x 350
- **Length, z-axis in mm:** 360
- **Laser Power:** 400/1000W or 2x 400W YLR-Fiber-Laser
- **Build Speed:** 20 – 35 ccm/h
- **Practical Layer Thickness:** 20 – 75 / 100 µm
- **Min. Wall Thickness:** 200 µm
- **Operational Beam Focus:** 80 – 150 / 700 µm
- **Scan Speed:** 15 m/s
- **Inert Gas Consumption in Operation:** Ar/N2, 2.5 – 3.0 L/min
- **Inert Gas Consumption Venting:** Ar/N2, 1700 L @ 100 L/min
- **Compressed Air Requirement:** SO 8573-1, 18 L/min @ 1.5 bar
- **Dimensions in mm (B x H x D):** 1800 x 1900 (2400) x 1020
- **Weight:** ca. 1000 kg
- **E-Connection / Consumption:** 208 or 480 Volt 3NPE, 32 A, 60 Hz, 8 KW/h

“From design and prototype to part production, our inclusive systems give companies the chance to optimize their production in a more efficient and independent way. All standard parameters are provided and totally transparent so the user can make modifications as desired. An open architecture—quite powerful and different than competitive offerings today.”

— James Fendrick, VP-North America
SLM Solutions NA, Inc.

For more information visit:
www.slm-solutions.com

First Color, Multi-Material 3D Printer

What's Cool

The only 3D printer for color and advanced multi-material combinations. A game-changer for product design, engineering and manufacturing processes, the Objet®500 Connex3™ Color Multi-material 3D Printer features a unique triple-jetting technology that combines droplets of three base materials to produce parts with virtually unlimited combinations of rigid, flexible, and transparent color materials as well as color digital materials—all in a single print run.

The ability to achieve the characteristics of an assembled part without assembly or painting is a significant time-saver. It helps product manufacturers validate designs and make good decisions earlier before committing to anufacturing, and bring products to market faster.

Who's It For

- Design Engineers
- Product Designers
- Animators
- Entertainment Design Studios
- Service Bureaus
- Internal Rapid Prototyping Departments
- R&D Departments
- Education Research Institutes/Universities

Compatible Materials

Model Materials:

- Rigid Opaque: Vero family including color
- Rubber-like: Tango family including black and translucent
- Transparent: VeroClear™ including color
- Simulated Polypropylene: Endur™ & Durus™
- Biocompatible
- High Temperature

Digital Materials:

- Digital ABS and Digital ABS2 in ivory and green
- Hundreds of vibrant, repeatable colors in opaque and translucent
- Rubber-like blends in a range of Shore A values
- Polypropylene materials with improved heat resistance

Support Material:

- SUP705

Specs

- **Build Size:** 490 x 390 x 200 mm (19.3 x 15.4 x 7.9 in.)
- **Layer Thickness:** Horizontal build layers down to 16-microns (0.0006 in.)
- **Workstation Compatibility:** Windows® 7 64-bit or Windows® 8 64-bit
- **Network Connectivity:** LAN – TCP/IP
- **Size and Weight:** 1400 x 1260 x 1100 mm (55.1 x 49.6 x 43.3 in.) 430 kg (948 lbs)
- **Material Cabinet:** 330 x 1170 x 640 mm (13 x 46.1 x 26.2 in.) 76 kg (168 lbs)
- **Power Requirements:** 110–240 VAC 50/60 Hz; 1.5 KW single phase
- **Regulatory Compliance:** CE, FCC
- **Special Facility Requirements:** Temperature 18°C-25°C (64°F-77°F); relative

> “Stratasys' goal is to help our customers revolutionize their design and manufacturing processes. The Objet500 Connex3 Color Multi-material 3D Printer will transform the way our customers design, engineer and manufacture new products. We will continue to push the envelope of what's possible in a 3D world.”
>
> *— David Reis, CEO Stratasys*

For more information visit:
www.stratasys.com/3d-printers/design-series/precision/objet500-connex3

3D Printing's New Plastics, Ceramics, Composites and More

Material choices continue to expand for industrial and prototyping applications.

BY PAMELA J. WATERMAN

There was a time when a big year in 3D printing saw the announcement of three or four new materials across the five or six major players. With fundamental patents recently expiring, and general interest growing, materials development for both professional/consumer systems (open source) and industrial systems (classic equipment companies) is at a record pace.

In fact, the 3D printing materials market is predicted to be worth more than $600 million by 2025 (*Source: MarketResearchReports.biz, "3D Printing Materials 2014-2025: Status, Opportunities and Market Forecasts"*).

With so much going on, *DE* is compiling a two-part update. This article highlights the extensive variety of newer non-metal options, while our November issue will focus on the increasing variety of metal-based materials.

Swirled ceramic artwork 3D-printed with Tethon3D powder, then glazed and fired. Tethon3D specializes in converting standard ceramic powders into 3D-printable ceramic powders that are highly receptive to glazing. ***Image courtesy of Tethon3D.***

Where to Begin?

Powders, pellets, pastes, liquids and filaments — these are the vocabulary words that give form and substance to most non-metal 3D printing materials. Within each category, the base chemistry may be nylon, ceramic, acrylonitrile butadiene styrene (ABS) plastic, polylactic acid (PLA), photo-curable resin or more. The results may be flexible, clear, colored, recyclable, fire-retardant, wax-like, glow-in-the-dark or reinforced. (Spoiler alert: Read on to learn about long-awaited options for 3D printing with carbon fiber, carbon nanotubes and graphene, from MarkForged, Arevo Labs and Graphene 3D Lab.)

Resins

As a nod to the origins of 3D printing, we start with photocurable resins, the kind first used by 3D Systems in its groundbreaking 355nm-laser-based stereolithography (SL) equipment. Envisiontec and others apply digital light processing (DLP) light sources to solidify similar types of resins.

Ultraviolet light (UV)-sensitive resins also work in Stratasys PolyJet systems (including the Connex digital material system) and 3D Systems' ProJet MultiJet Printing systems, both of which "jet" and cure fine droplets from ink-jet-type printer heads. Keep in mind that not all

Classic chess rook piece 3D-printed in the improved (finer detail, less clouding) Black MS UV-curable SL resin from MadeSolid. The company also produces extrusion filament. *Image courtesy of MadeSolid.*

resins work in all systems, and many systems require use of the company's proprietary materials (although some work-arounds exist).

In March, Envisiontec announced EPIC, a dark green wax-based casting material; resulting parts display the crisp edges of the company's polyisocyanurate (PIC) material with the good burn-out properties of its EC-500. Additional resins for Envisiontec systems are now available from DeltaMed, a supplier that was bought in April by Groupe Gorgé, the French manufacturer that now owns Prodways. Prodways offers three systems based on its MOVINGLight Digital Light Processing (DLP) technology — including the K20 Producer system, which can cure highly viscous ceramic pastes.

Addressing the newer 365nm operational wavelength of today's LED and DLP systems, the Somos line from Royal DSM now includes ProtoGen Clear 365nm, featuring excellent transparency, accuracy and high temperature resistance (characteristics very similar to those of Somos ProtoGen SL materials). The company also markets 355/365nm versions of the durable PerFORM tooling composite with improved viscosity and faster build-times.

Both patent-expiration and crowd-sourcing have inspired a new world of photopolymer-resin-based 3D printing systems such as FormLabs Form1, Old World Labs (OWL) Nano, B9Creations B9Creator, FSL3D Pegasus Touch, DWSLab XFAB, Uncia 3D, MAKEX M-One, Hardcotton Elemental, Stalactite 102 and Peachy Printer. Although perhaps initially more oriented toward prosumer and professional (rather than industrial) applications, these systems are important to track. They are driving the development of equipment and resins geared to a wide range of system types, end uses and budgets.

In support of these efforts, independently crafted materials have been mushrooming. Some online sources provide a great deal of information about the relevant chemistry, properties and applications. Some offer lively insights to their team's backgrounds and efforts; others seem very, very private. Check out these manufacturers and their materials: MakerJuice (UV resins for many consumer systems, plus pigments), Spot-A Materials (hard-tough, general-purpose, low-viscosity and elastic resins), Bucktown Polymers (UV, visible light and infrared, or IR, polymer resins), 3D Ink (orange and clear resins) and MadeSolid (lower-viscosity MS Resin, durable orange or yellow MS Tough Resin and no-ash MS FireCast Resin).

Other Liquid/Semi-liquid Materials

Options keep coming for jetted photopolymers, used by Stratasys and its Solidscape systems as well as 3D Systems. The big news this year from Stratasys was the expanded palette of colors and flexibilities for the Objet500 Connex3 Multi-material 3D printer; Stratasys also introduced VeroGlaze dental material and the flexible, polypropylene-like Endur material, for the appropriate Objet systems.

Blended colors and materials are now available in a new line of 3D Systems VisiJet 5500X materials, which can be mixed together two materials at a time in the company's ProJet 5500X system. By combining multiple materials in a single build, the system creates parts with composites that combine black rubber-like, white rigid ABS-like and clear polycarbonate-like materials.

Powders

Instead of liquid resins, two more major 3D printing technologies — sintering and ink-jet — use powdered materials in very different ways. Each category is then subdivided, the former according to power source (UV laser or light source) and the latter by binder and material types.

For almost two decades, 3D Systems and EOS have dominated the world of thermoplastic laser-sintering; last year EOS introduced two new materials, the rubber-like PrimePart ST and the flame-retardant PrimePart FR (a flame-retardant polyamide 12). Over time, though, other independent companies such as CRP Technology, Taulman3D, Arkema and Advanced Laser Materials (ALM) have joined the field, introducing dozens of material options. For example, ALM, now a division of EOS, specializes in custom LS thermoplastics such as carbon composites, optimized to meet new additive manufacturing (AM) material requirements.

Traditionally, adding carbon fibers to dry powders forms parts whose stiffness is good in the X direction, less in the Y direction, and a 40% to 60% loss in the Z direction. ALM has developed a process that compounds carbon fibers and resins into pellets that are then ground into a powder for LS. The resulting material, though containing shorter fibers, displays stiffness values of just 10% variation among X, Y and Z directions. These new isotropic materials based on polyetherketoneketone (PEKK) and Polyamide 11 (PA11), have been developed for the next generation of the Boeing 777Xs. The Lotus F1 design team is currently using them.

Current projects include the development of PEKK materials that process at lower temperatures than the currently available polyetheretherketone (PEEK), resulting in a more recyclable product to save processing time and to lower the cost.

In the ink-jet realm, 3D Systems now offers a powdered plastic material, VisiJet C4 Spectrum, that runs on the new full color ProJet 4500 plastic printer. This is the first new material for any printer in this family in about 15 years, producing more durable parts than those made of the classic plaster-like gypsum.

Tethon 3D is a small company with an artistic slant, and eight years of experience with ceramic materials for 3D printing. Specially formulated Tethonite ceramic (clay) powders are available as earthenware, stoneware and porcelain formulations. Along with liquid binders, they are optimized for use on any powder-based ink-jet 3D printer. Tethon 3D also sells thousands of glazes that work specifically with their powders. (Emerging Objects, a creative architectural firm, continues to develop diverse new materials for 3D Systems equipment based on

Good to Know: Support for 3D Printing

- Tired of painting printed parts or working with off-the-shelf dyes? Check out a new option for coloring 3D-printed parts from Prototype Asia (prototype.asia): They blend custom dyes based on a customer's sample, shipping from Singapore in 5Kg amounts per color.

- A simple material design guide is available at iMaterialise.com, with sample-parts kits for sale.

- An in-depth, 10-year market/technology report on plastics materials has been compiled by SmarTech Markets Publishing (SmarTechPublishing.com/reports — $3,995 license).

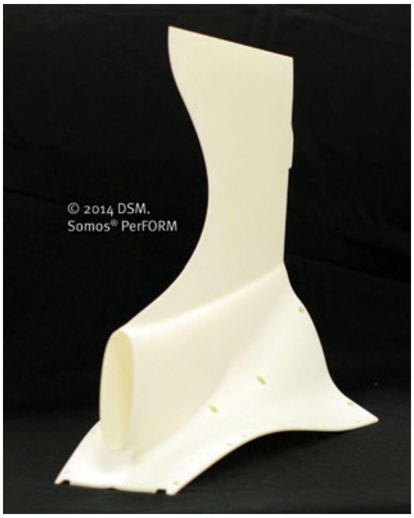
- RJ Lee Group offers a good checklist for medical-applications material screening: "How to Select Polymeric Materials for Medical Devices Produced Using Additive Manufacturing" (RJLG.com/2014/07/17/polymeric-materials-for-medical-devices-additive-manufacturing).

— PJW

Flexible, colorful shoes made on an extrusion printer with Fenner Drives' NinjaFlex filament, available in eight colors plus semi-transparent. ***Image courtesy of Fenner Drives.***

Samples of woodFill, bronzeFill and glowFill filaments from ColorFabb, for extrusion 3D printing systems. ***Image courtesy of ColorFabb.***

Artistic cylinder design 3D-printed with the improved (finer detail, less clouding) Black MS SL resin from MadeSolid. The company also produces extrusion filament. ***Image courtesy of MadeSolid.***



Prototype racecar part made with DSM Somos PerFORM nano-particle-filled SL resin. The stiffness and heat resistance make it well suited for motor-sports wind tunnel testing of parts that will later be made from carbon fiber composites. PerFORM can also be used for non-load-bearing end-parts on the same type of cars. *Image courtesy of DSM Somos.*

cement, salt, wood and paper, but does not currently offer them for sale.)

Filament

Much less expensive than UV resins, and seemingly infinitely adaptable, are materials for filament-based printers. Whether loaded into traditional Fused Deposition Modeling (FDM) systems from Stratasys or fed to any one of the 50-plus variations based on the RepRap open-source system, filament is very popular product; an entire sub-genre has even emerged of make-your-own-filament equipment suppliers.

Obviously, Stratasys offers dozens of FDM filaments. But over the years, enterprising businesses such as Bolson Materials have also developed substitute materials — and the EEPROM ID chips that allow many Stratasys systems to operate with non-OEM material cartridges. Bolson offers custom color-matching, as well as a Monster Green glow-in-the-dark ABS, and is working on compatible materials for the Stratasys uPrint systems.

Also this year, Taulman3D, a two-year-old manufacturer, commercialized its high-strength, low-temperature t-glase (tee-glass) filament for 3D printers that run low-temperature PLA filament.

ColorFabb, a Dutch filament producer founded last year, offers a PLA blended with polyhydroxyalkanoate (PHA), a bio-polyester, for added strength; the material is available in 29 solid or transparent colors plus custom colors. The company recently announced the availability of glow-in-the-dark glowFill, PLA Bronze, bambooFill and woodFill, and sells pellet sources of PLA/PHA, PLA, XT-CoPolyester and woodFill to users with extruders for DIY filaments.

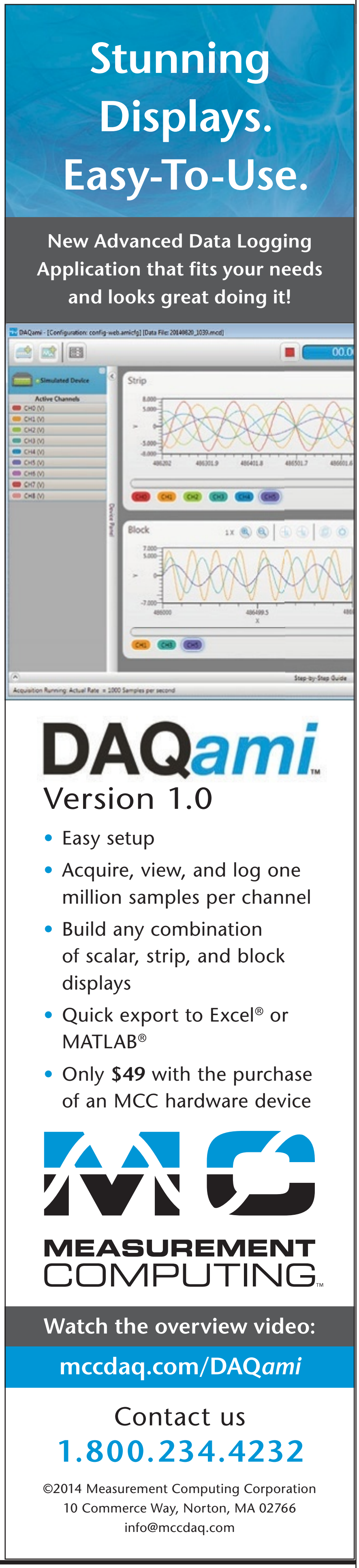
And a year ago, Fenner Drives, a 103-year-old U.S. company traditionally making belts and bushings, introduced the NinjaFlex line of polyurethane filament. It now offers the flexible thermoplastic elastomer material in nine colors — with more to come.

Lighter, Stronger Material

Perhaps the biggest news for 2014 has been announcements by three companies addressing the industry desire for lighter, stronger 3D-printed parts through use of carbon fibers, carbon nano-tubes and other strong filler materials.

MarkForged is one of the first to pull this off. The company has just started delivering its Mark One, a dual-extruder filament-based system that creates parts a user can selectively reinforce with continuous-fiber carbon or fiberglass. The system currently runs four proprietary materials: classic PLA, nylon FFF that works well as a base material, patent-pending carbon fiber CFF (20x stiffer than ABS and stronger than 6061-T6 aluminum by weight), and fiberglass CFF (where strength is important, but stiffness and weight are less critical).

In May, a Silicon Valley start-up named Arevo Labs announced the availability of carbon-fiber and nano-tube (graphene) reinforced filament materials. The chopped fibers, encapsulated in high-performance polymers such as PEEK and Ultem, will enable creating parts that are light, strong



An example of an automotive, aerodynamic wing "footing," 3D-printed in layers of nylon and continuous-strand carbon fiber. The company says that parts made with its continuous-carbon-fiber approach are up to 20 times stiffer and five times stronger than ABS plastic, and have a higher strength-to-weight ratio than 6061T6 aluminum. *Image courtesy of MarkForged.*

and high temperature- and chemical-resistant. These materials will be usable on any filament-type system once outfitted with a high-temp Arevo Labs printhead (soon to be available), as well as on Arevo Labs' own optimized systems.

Also this year, newly formed Graphene 3D Lab has been working to produce graphene-infused filament in partnership with Lomiko Metals as the source for graphite. The initial goal is to use this material along with conventional polymers to produce 3D-printed functional electronic devices.

Choose Wisely

Not all materials work on all systems. Quality is really important, and things can get complicated fast. Whatever the initial structure and chemistry of the raw material, the physical properties of a final part still depend on the sum total of the approach, equipment, material, operational settings and CAD file manipulation. But, developments that today seem really out-there may be mainstream next year: Work is underway on materials derived from, or composited with, straw, clay, potatoes, beeswax, soybeans, seaweed, silk and linen, for example.

For users inclined to roll their own, filament extruders are now available from Ewe Industries, FilaFab and Legacy (open-source). And who knows what materials will accompany Autodesk's Spark resin-based system announced in May?

With so many choices, it pays to ask system manufacturers, service bureaus and material providers to explain all the pros and cons. **DE**

Contributing Editor Pamela Waterman, DE's simulation expert, is an electrical engineer and freelance technical writer based in Arizona. You can send her e-mail to DE-Editors@deskeng.com.

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→ **Advanced Laser Materials:** ALM-LLC.com
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→ **FSL3D:** FSL3D.com
→ **Graphene 3D Lab:** Graphene3DLab.com
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→ **Hardcotton:** Hardcotton.com.au
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→ **Lomiko Metals:** Lomiko.com
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→ **MakerJuice:** MakerJuice.com
→ **MAKEX:** MAKEX.com/mone
→ **MarkForged:** MarkForged.com
→ **Old World Labs:** OldWorldLabs.com
→ **Peachy Printer:** PeachyPrinter.com
→ **Prodways:** Prodways.com/en/
→ **Royal DSM/Somos:** DSM.com/somos
→ **Spot-a-Materials:** SpotAMaterials.com
→ **Stalactite 102:** Bit.ly/1tUk31b
→ **Stratasys:** Stratasys.com
→ **Taulman3D:** Taulman3D.com
→ **Tethon3D:** Tethon3D.com
→ **Uncia 3D:** Uncia3D.com

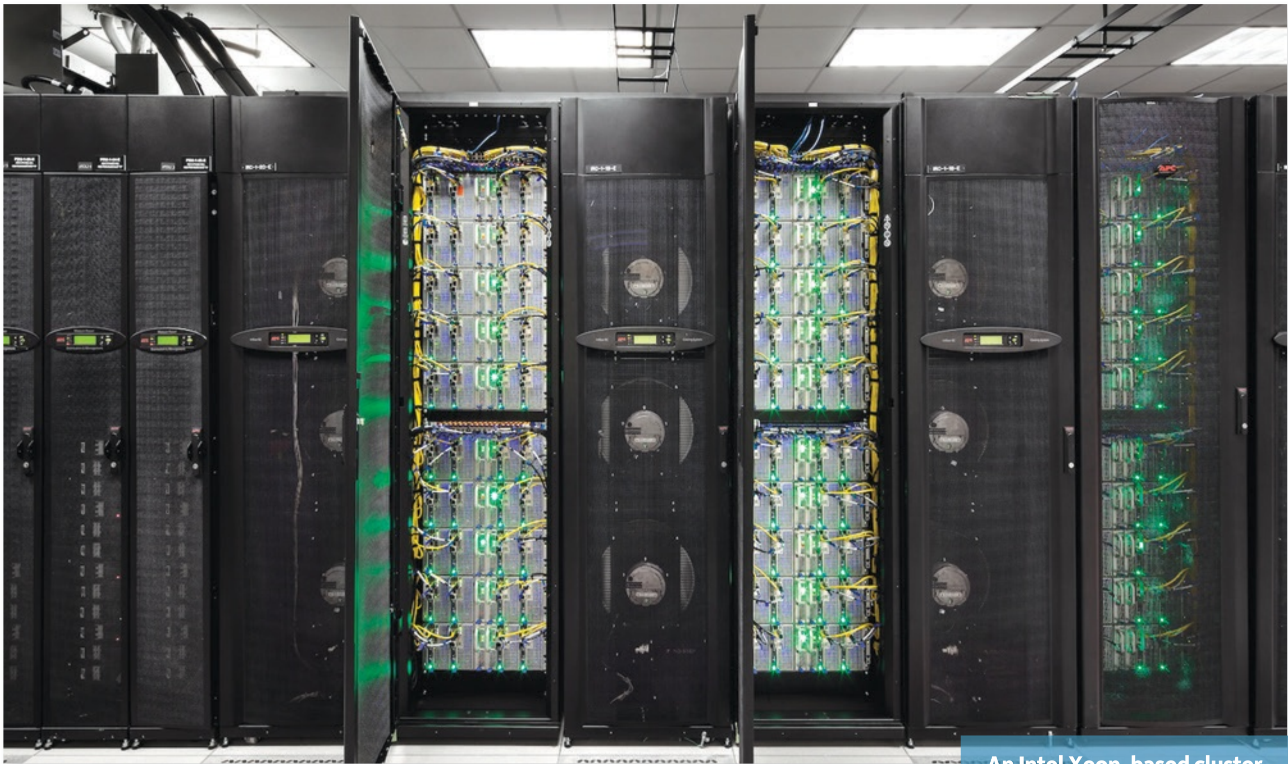
For more information on this topic, visit deskeng.com.

HPC Options, Part 5

Workstation, Cluster or Cloud?

Engineers have to navigate among many alternatives to find the right approach to their high-performance computing tasks.

BY PETER VARHOL



An Intel Xeon-based cluster.

Even in the last few years, high-performance engineering computation (HPC) was a relatively straightforward proposition: You got the fastest workstations you could afford, with multiple cores and a lot of memory. You ran parts of your work locally, or ran an analysis at low fidelity. For final work, you sent your job to a cluster for the best balance of turnaround time and fidelity of results.

Because of all the available options today, though, setting up an HPC platform can become an expensive and time-consuming process. In many cases, the best workstations are powerful enough to take on an increasing share of the CAD, analysis and rendering workload. And their flexibility is such that engineers can often gain more insight into their designs at an earlier stage in the design process than in the past.

But server clusters are still the workhorse of engineering groups; enterprises with one or more good-sized groups have likely invested in cluster technology. To fully utilize what in many cases is existing hardware and licenses, engineering groups are likely to keep feeding important jobs to a cluster if available.

Send in the Cloud?

The cloud is increasingly becoming the wild card in the design process. There is the potential to rent time with your favorite CAD or analysis tool, and perform your work faster and less expensively than if the software and hardware were on-premises.

The economics are compelling, and often a cloud solution can be both powerful and flexible. For software vendors, it makes it possible to reach more potential users with a greater variety of solutions.

That said, the cloud has issues that make it less than an ideal alternative for every situation, at least at this point in time. There are a couple of different strategies of leveraging the cloud in engineering work.

One is to rent cloud time for all computations beyond the desktop, forgoing an on-premises cluster. But configuring a CAD or analysis software package for cloud execution involves challenges. The software and payload have to be configured as a virtual machine (VM), and sent off to the cloud as a single file. If the intent is to run it on multiple machines in the cloud, users have to manually set up communications among the VMs to share processing power and data. For many, the uncertainty of success and the amount of work involved can be a deterrent.

Licensing may also be an issue. First, unless you own enough licenses, you may not be able to run your job on the optimum number of servers. Second, even connecting to the licensing server from the cloud could be problematic. According to Silvina Grad-Frelich, HPC marketing director at MathWorks, accessing a licensing server from within a cloud environment requires special configurations. She says the company is currently testing a beta solution.

Organizations dependent upon their intellectual property are also concerned about the security of computation and data storage in the cloud. If the cloud environment or network connection could be compromised, new designs or simulation data could be stolen or held hostage. There is still significant distrust in letting cutting-edge designs outside of the firewall. Rob Winding, an engineer at consultancy Design Solutions, notes that the best designs are kept under lock and key: "The check-out and check-in processes for designs tend to be pretty rigorous, in part for security."

All of these potential problems are solvable, but they can be technically difficult. An increasing number of design and analysis software vendors are building partnerships with the major cloud providers or launching their own services, enabling their software to work far more seamlessly with that particular cloud. While it may not be the preferred cloud provider for the organization, there are a growing number of tools vendors working with cloud partners to give engineers options for using only the computing resources that they need.

Start with the Workstation

For either CAD or analysis and simulation, the fastest modern workstations offer the best choice for convenience. A designer or engineer can kick off a job at any time, providing a short turnaround time for new ideas. Using a virtualization product like Parallels, engineers can assign memory and cores to that job — giving them some control over how long it takes, while also letting them do other work on the same computer. Engineering groups can also use Parallels to tie together multiple workstations, and use their excess capacity to drive analyses that can make use of multiple cores and systems.

But there are a couple of limitations. First, working in this fashion requires a very high-performance and most modern (and expensive) workstation. A mid-range model from two or three years ago isn't going to be a lot of help. Second, even a state-of-the-art workstation with top-line graphics and lots of cores and memory won't suffice for some final work. Some very high-fidelity designs and simulations require more time or horsepower than a workstation can contribute.

That doesn't mean that the workstation isn't useful, though. In cases involving simpler designs, workstations and small workstation clusters could reasonably be used from inception to final design. When designs are more complex, workstations can be used to model individual components and smaller subsystems of larger designs. Connecting them into small, ad hoc clusters can increase the processing power available.

Inside the HP Z820 workstation.

Relying on the Cluster

A compute cluster is an expensive investment for many small engineering organizations. In addition to the hardware, it requires skilled IT personnel to manage and maintain. But for many mid-sized and larger organizations, they remain the core of the analysis and simulation operation. They are much more powerful than individual workstations, yet still keep the data and designs inside the firewall.

The cluster isn't going to go away anytime soon, but it is changing. Rather than multiple expensive servers, clusters can range from small groups of workstations to a number of interconnected systems with at least 32 cores each. The flexibility of configuration and the ability to serve many different computing needs makes a cluster an important tool for mid-sized and larger engineering organizations. As long as the horsepower can remain fully utilized by multiple groups and projects, clusters of some type will carry the bulk of the rendering, analysis and simulation work for many engineers.

The Inevitability of the Cloud

Ultimately, it is likely that much more engineering design and computation will occur in the cloud. For organizations with only occasional HPC needs, the cloud is enticing. While most license prices will likely remain high for a while, available supply will likely push down prices for occasional use in the future.

It's difficult technically now, because most commercial software packages weren't developed for remote execution and virtualization. Retrofitting them to the cloud poses technical challenges. Those problems are on their way to being addressed, though, and in not too many years engineers may not know whether they are dispatching to local clusters or remote data centers.

However, engineering organizations remain wary of cloud security. In many cases, the intellectual property inherent in new designs can be worth a great deal of money, and companies can be reluctant to use public computing resources.

In response to these concerns, cloud providers are working to better secure both servers and data transfers between the data center and customer. This includes au-

Weigh Your HPC Options

Other articles in this series are available on deskeng.com:

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3 Consider CAE in the Cloud
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4 Solving the Mystery of the Invisible Desktops
Mobility and intellectual property security and increased bandwidth nudge users toward virtual machines: deskeng.com/de/?p=18847

Look for additional coverage in *Desktop Engineering's* November issue, which will focus on high-performance computing and the future of mobile, including a look at the latest processors from Intel and AMD.


A view of some of Google's Cloud servers.

tomatic encryption, and in some cases, dedicated VPN connections between the organization and data center.

Is There a 'Best' Solution?

CAD is still largely an individual engineering activity, performed on workstations. However, in some cases complex drawings, especially complete designs, are rendered on servers or supercomputers. In some cases, this handoff can slow down the design process — to the dismay of engineers waiting in a queue.

Analysis and simulation are performed less often on the desktop, primarily because of the computing horsepower involved, and because many engineers don't have the latest and fastest workstations.

But there are more ways to offload some of that processing onto workstations. An increasing amount of simulation is occurring on HPC workstations, and workstation clusters. It allows for a higher level of interactivity than other platforms, as engineers are able to examine results, change a few variables, and kick off a new run immediately, rather than having to schedule an entirely new job. The fidelity likely wouldn't be as good as on a dedicated cluster, but the turnaround time for different types of analyses can make it a valuable resource.

While there is a lot of interest in cloud computing today, the technology, products and design initiatives are still evolving. But for at least occasional computational jobs, the cloud represents a lot of horsepower for relatively little money.

Anyone looking for a single and definitive solution today is doomed to disappointment. However, those engineers who remain flexible will see the trends working in their way over the next several years. The server cluster may be de-emphasized as the workhorse for serious engineering computing, but will remain an important solution for the foreseeable future. Faster workstations, workstation-based clusters, and cloud solutions are starting to fill in the gaps, resulting in more iterative design solutions. **DE**

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The Value of a Consultant

Help with compliance in an ever-changing regulatory environment.

BY JIM ROMEO

Automotive recalls have been in the headlines this year. In fact, more calls have been recalled this year than ever before. But automakers and suppliers aren't the only ones catching mistakes, some of which have resulted in fatalaties.

A visit to the portal Recalls.gov will give you a jumping-off point to various government sites on recalls of boats, tires, consumer and automotive products, and more, as well as food and other industry non-conformance. Drill down further into the site, and you'll see the price that companies pay after the product is well underway and the damage is done.

For example, the U.S. Consumer Product Safety Commission (CPSC) reported that a floor-cleaning device manufacturer must pay a $725,000 civil penalty for a defect in floor cleaners that were overheating. The company received many complaints from consumers, but did not report it to the CPSC as required by law.

Building the Best

For the engineering design community, there is a persistent drive to build the best products. Doing so, however, means being compliant with a growing load of regulatory compliance, which includes safety as well as security measures from various agencies. Professional societies and non-profit consortiums also serve to self-regulate various industry standards. For example, ISO, ASTM and IEEE are all recognizable industry associations whose members agree to establish standards and comply with the same. This brings into question, however, the value of a consultant. Just where is the value in the services of a consultant in the design process, and what is at the crux of the value they provide?

David Rothkopf is president of MEDIcept, a firm specializing in providing regulatory and validation assistance to medical device clients, as well as others within the design community. Founded in 1996, MEDIcept helps clients gain a better understanding of design controls — FDA/ISO regulatory requirements, for example, and how to be compliant to those regulations.

"We review the product and design to understand the regulatory approval strategy, and then facilitate validations and standards testing," he explains. "We have all been in the medical business for a minimum of 15 years, and many of us are engineers. We understand how an engineer thinks and speaks, and we know the regulatory requirements. The mesh of those two items is fairly unique in this industry."

Rothkopf notes that many clients are start-ups, because staffs at these new companies typically do not have years of medical experience, "and they commonly need their hands held through the process. Since we have been around for many years, we understand the client's specific needs. From there, we simply execute."

The sequence of events in a design is important, but often overlooked. In other words, the steps and processes of product design and development may proceed without regard for various regulatory measures that influence specific facets of the design. This highlights the importance of a thorough check for requirements and compliance before the product development moves too far forward.

Rothkopf recalls how one new client developed a medical device, but the team had not designed it using design controls — nor had it been reviewed by the U.S. Food & Drug Administration (FDA). "Yet they wanted to 'get it into

Toy Injuries

Year	All Ages	Younger Than 15	12 or Younger	Younger Than 5
2008	235,300	172,700	164,400	82,300
2009	250,100	185,900	177,800	90,600
2010	251,700	181,500	172,000	89,200
2011	262,300	193,200	184,100	92,200
2012	265,000	192,000	181,600	89,600

Estimated emergency department-treated injuries associated with toys.

Source: NEISS, U.S. Consumer Product Safety Commission/EPHA. Estimates are rounded to the nearest 100.

Nursery Product Injuries

Year	Injuries
2010	81,700
2011	74,100
2012	77,900
2010-2012 Average	77,900

Estimated emergency department-treated injuries to children younger than age five associated with nursery products.

Source: NEISS, U.S. Consumer Product Safety Commission (CPSC).

a human,'" he says. "It took a little time, but we were able to educate them on the specific documents the FDA would want to see, and how to submit an application to the FDA for review."

Other Facets of Design Risk

It's not just pure safety issues that concern a designer. Nowadays, it's also security.

For example, Deloitte's Cyber Risk Services practice helps organizations address cyber risks, including regulatory requirements, to their products.

"We help clients understand the cyber threat landscape as it relates to business risk, and assist them in developing practical cyber risk programs," says Sean Peasley, principal of Deloitte & Touche LLP in Costa Mesa, CA. "This can include assessing risks, evaluating compliance standards, assisting in the development of cyber risk programs, designing and implementing security controls, testing product security, educating the workforce, and extending the reach of cyber risk compliance out to key third parties. We help clients address identified compliance issues, interact with regulatory authorities, and respond to inquiries, investigations and other regulatory actions."

As Peasley explains, if a medical device company gets a letter from the FDA saying that the agency is aware of a security flaw and wants more information on how the flaw is being addressed, "we'll help them assess the risk, respond to the inquiries, and assist in developing a methodology and framework to both correct the current problem and help avoid similar ones in the future.

"Compliance is an indispensable part of the overall risk program, but Deloitte's approach is distinct because it also considers the potential motivations of various threat actors, and helps organizations proactively consider the potential attack surfaces that surround each product," Peasley continues. "This is important because it helps manufacturers become more confident in bringing innovation to market."

It is, however, a significant shift in how many organizations have traditionally approached cyber threats, he says.

"Historically, engineering design organizations focused compliance on meeting sector standards at an enterprise security level," Peasley explains. "The shift to Internet-connected devices requires a vastly different approach to product development. We help companies identify product security considerations earlier in the development lifecycle, helping reduce instances in which flaws are identified in the testing phase — or worse, once the product has been released. Integration of threat awareness early in the process has the potential to not only better protect the public, but also to lower overall production costs."

Peasley says that organizations still don't have the internal resources to approach cyber threats in a truly holistic way. In general, product designers have that role because they can create functional, useful products — not because they understand security risks or are expected to know how a device could be exploited. Deloitte specialists bring a depth and breadth of knowledge about both products and the threat landscape, he says.

"Understanding risk is not about building up a fortress around the product; it's about understanding the motive of the actor and anticipating how they are going to try to exploit the system for gain," he adds. "If you're only focused on how to prevent someone from hacking a device, it's easy to miss real intention, and therefore, the real danger. That actor probably isn't just looking for the data on one device — they could use the attack to mask or execute a much more dangerous breach of your intellectual property, which the network may not be set up to detect. It's a completely different mindset that we bring to our assessments."

An Ounce of Prevention ...

A prevailing problem is that designers are quick to jump onto the drawing board, but do not realize that there are regulatory bodies that have standards to allow or disallow products and product features to be used. As Rothkopf notes, it's an issue that affects industries from medical to automobile and aerospace.

"They are regulated industries for a reason: Poor designs can and have killed," he points out. "Design must be built from the beginning to meet specific documented requirements and validations. When they don't like this client, there is a huge delay and extra costs associated with the project that could have been avoided."

But the biggest problem, as Rothkopf sees it, is that manufacturers don't ask about design impact early enough: "They go along merrily and then get popped in the end when they didn't design the product to a specific regulation or standard." **DE**

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

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FEA & Composites

PART 1

The challenge of composites is to predict the resulting stiffness and strength of the design. It is no longer as straightforward as working with steel or aluminum.

BY TONY ABBEY

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

Throughout industry, many designs use composite structures or components for increased structural strength and stiffness-to-weight ratios, simpler manufacturing processes or more innovative design capabilities.

The nature of the composite system used can range from cheap and freely available glass fiber reinforced systems to exotic and specifically tailored carbon, Kevlar or even metal/matrix systems. Many forms of manufacturing process are available. The design variations available within composites are immense; ply thickness, orientation and property can all be varied to tune the structural response.

Designs may include thick composite sections with large numbers of plies and regions of significant ply drop-off. The shape of the structure may imply changes in draping angle or layup thickness, and it may be important to model this accurately. Tee joints may be loaded in tension, and through-thickness effects then become very important for strength prediction. There are potentially large amounts of stress or strain data from a multi-ply layup structure — and many failure theories to assess strength.

Decisions are needed on the type of idealization, level of detail required and definition of failure. A rational approach is needed to use the finite element analysis (FEA) results to design and verify the structure.

Material Types

Materials usually fall into one of three categories, as Fig. 1 shows:

- **Isotropic.** The same material properties occur in all directions. Steel is a typical example.
- **Anisotropic.** Different material properties occur in all directions. A chunk of volcanic rock is a typical example.
- **3D Orthotropic.** A special case of anisotropy, with distinct material directionality in three directions. Composite systems fall into this category.

In a carbon fiber and resin system, for example, the "along-the-fiber" (longitudinal) axis, "transverse-to-fiber" (transverse) axis and "through-fiber-thickness" (through) axes are different. In thick sections, edges, joints etc., through thickness and edge effects can dominate — giving a 3D stress state needing 3D solids or thick shells in FEA idealization.

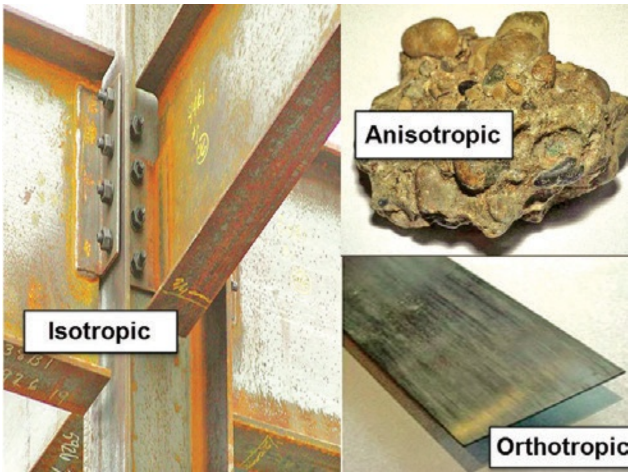

FIG. 1: Material types.

2D Orthotropic is a further simplification where the through thickness axis direction is ignored. This is the usual starting point for what we call Classical Laminate Theory (CLT), the foundation of most FE solutions. Thin shells are used for this type of idealization.

The Composite System

A composite is a system that consists of fibers in a resin or similar medium (called the matrix). The composite is usually shown in a macro-level schematic, as in Fig. 2. In reality, of course, the fibers are very small in diameter and scattered through the matrix, and interaction is much more subtle.

The fibers in isolation can have incredibly strong and stiff properties, but it is important to consider both the fibers and the matrix as a system at micro-level to assess the material stiffness and strength. Fibers will have microscopic dislocation, cracking or kinks and not be perfectly aligned — the weaker matrix forms a stabilizer. Fig. 3 shows the strengths achieved in testing for the different loading directions: X is longitudinal; Y is transverse. Notice tension (Xt, Yt) and compression (Xc, Yc) are different.

A pre-impregnated sheet (pre-preg) has well-defined fiber and transverse fiber properties; through thickness effects for thin skin type structures can often be ignored. Sheets can be laid up individually forming a ply, or overlaid in a stack called a laminate (or layup or stackup). If loading is applied in the fiber direction for a single ply, high full strength can be achieved.

In practice, though, loading is usually "off-axis" and strength is drastically reduced — as shown in an FEA result in Fig. 4. A range of loading angles from longitudinal to transverse are applied to a single-ply.

With load in the transverse direction in tension, the matrix forms the weak link and will fail. For other loading angles, the interaction among longitudinal, transverse and shear strengths becomes more complex. The ply stress state has to be calculated, and then effective strength assessed. This requires a failure criterion that includes longitudinal, transverse, shear and interaction terms. The most popular failure criterion is probably Tsai-Wu, which was used here to predict failing load in the single ply.

Laminates

In practice, plies are rarely used individually; multiple plies are stacked in a laminate to tailor the performance of the composite. Plies can also be woven cloth, which will have aggregate properties very different from unidirectional. In FEA usage, though, it is still considered a single ply. A laminate can have plies of both unidirectional and woven material.

Tuning the material, layup orientation, thickness and stacking order is key to optimum design. There are many more variables available than in an isotropic material. A classic example is in a pressure vessel, where the ratio of hoop-to-axial stresses is 2:1. In a steel vessel, we just have to accept the overdesign in the axial direction (all similar structures, from pipes to sausages, always split along their length). However, with a composite, we can tune the strength in the axial and hoop directions to match, giving a much more efficient structure. Composite pressure vessels are very common.

The shorthand used to describe plies in a laminate is angle1/angle2/angle3/etc. Extensions to this are:

- [0/90/45/-45/s] indicates a symmetric layup: [0/90/45/-45/-45/45/90/0]
- [0/90/45/-45s] (or over bar) indicates a symmetric layup through the last ply center surface: [0/90/45/-45/45/90/0]
- [0/90/45/-45/as] indicates an asymmetric layup: [0/90/45/-45/45/-45/0/90]
- [45/-45]6 indicates a repeat of 45/-45 six times in a layup : [45/-45/ 45/-45/ 45/-45/ 45/-45/ 45/-45/ 45/-45/]

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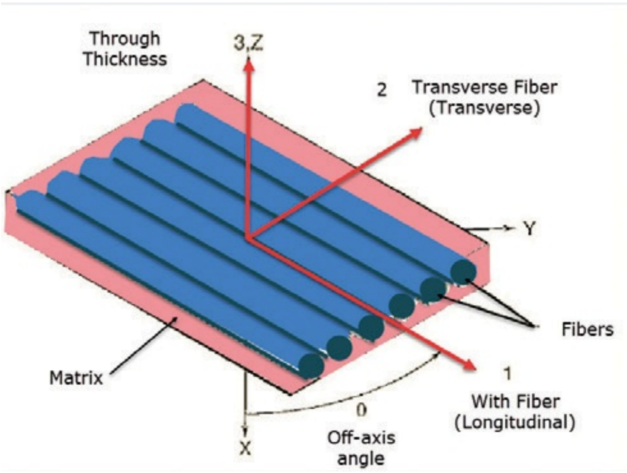

FIG. 2: Fiber and matrix schematic.

Strength	Value (MPa)	PSI*1E3	Stiffness	Value (GPa)	PSI*1E6
Xt	1830	265.4	E1	142	20.60
Xc	1096	159.0	E2	10	1.45
Yt	57	8.3	G12	6.4	0.93
Yc	84	12.2	nu12	0.21	0.21
S12	89	12.9			
S23	89	12.9			

FIG. 3: Typical material properties.

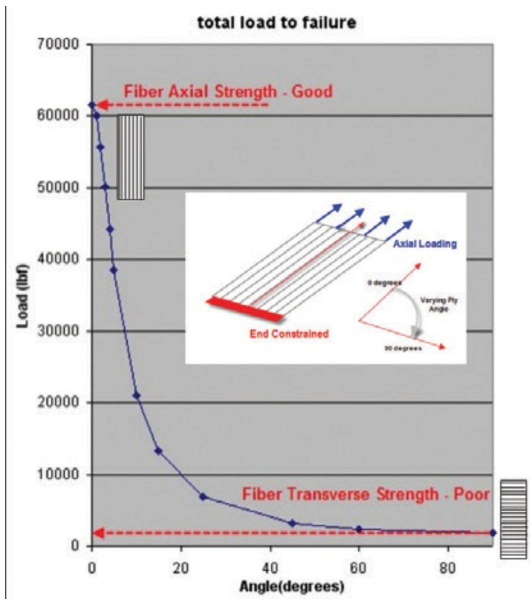

FIG. 4: Single ply off axis strength.

Compound definitions are used such as: [[0/90]4/[55/-55]3]s

A fabric or woven material is sometimes shown as (30/60) or (0/90) or (+45/-45) or (+-45)

Mixed materials may be defined as (a) and (b): [45(a)/-45(a)/0(b)]s

If the single ply is replaced by a [0/90/45/-45/s] laminate of the same total thickness, the maximum strength is reduced, as shown in Fig. 5. However, the strength at any loading angle is now predictable. This type of configuration represents a type of pseudo isotropic material. It is a conservative design, as opposed to special laminates tailored for more extreme loading cases.

In the November issue of *DE*, we will discuss how to calculate the laminate stiffness and strength terms that allow prediction of this behavior.

Failure Prediction

The simplest approach to FEA failure is to assume that as soon as a composite strength value is exceeded by the stress level present in any ply, the structure has failed, or at least is not fit for further service. This approach is called First Ply Failure mode. In November, we will review more advanced failure modeling.

The Tsai-Wu failure criterion was mentioned earlier, and is similar in concept to the Von Mises criterion for isotropic material. However, multiple directional failure modes must now be included. Important features include:

- directional material strengths (longitudinal, transverse, shear);
- tensile/compressive distinction; and
- directional stress interactions.

Criteria such as Tsai-Wu fit a continuous failure curve, as shown in Fig. 6. A Failure Index (FI) of 1.0 indicates the ply has just failed. Greater than 1.0 is bad news, and less than 1.0 is safe. No completely reliable failure theory has emerged, and specific material testing data is required in safety critical cases. More advanced criteria based on individual failure modes, rather than a continuous curve fit, is a topic for another day.

It is not possible to scale a design by using the FI directly, as it is a quadratic term. Most solvers give the option to convert the FI to an alternative linear form called the Strength Ratio (SR). This can be used directly to resize designs and assess safety margins.

Practical Considerations

Thin shell element models use CLT to idealize 2D orthotropic materials where through thickness effects are ignored. This works well for thin skins, webs and flanges, but is not suitable for thick sections, joints, edges or any other case where through thickness effects are important. In these cases we need a full 3D orthotropic representation. This is done via solid 3D elements or special thick shell elements.

Two stress systems often dominate in 3D scenarios: direct through thickness stress and interlaminar shear stress. Both cause ply delamination and peeling, as well as matrix cracking. It is important to assess whether a component should be repre-

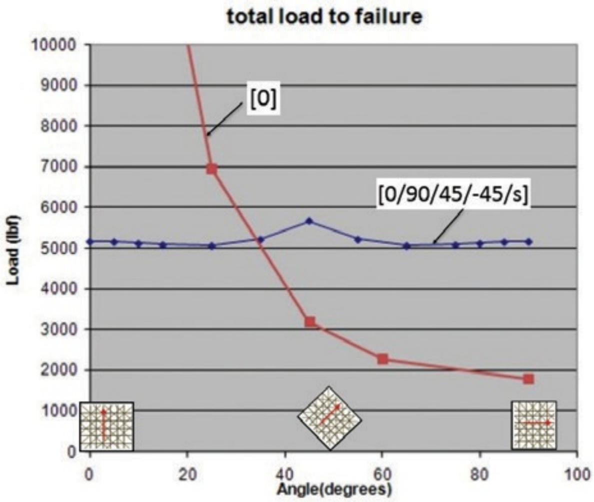

FIG. 5: Off axis strength, single ply and pseudo isotropic laminate.

sented by a 3D solid, as the 2D shells will completely miss the 3D effects and give incorrect results.

The definition of a composite element property requires the laminate present at that spot on the structure. With a complex structure, such as in Fig. 7, it can become tedious (and error-prone) to map overlays of plies. The strategy for tracking this data needs to be planned well in advance, either using a spreadsheet as here, or more specialized tools that mimic the "natural" process of laying up plies over a structure and building laminates.

If a structure has significant curvature, particularly of conical form, ply draping may be important. Consider trying to drape a glass-reinforced plastic (GRP, or Fiberglass) cloth over a dome shape. It will scrunch up as we go around the dome, and we will have to cut darts to achieve a smooth drape. The resultant flat ply pattern will be complex, and the drape angles will change over the dome surface. In an FEA model it may be important to capture these effects, and software is available to predict this.

However, it is vital that the analyst, designer and production engineer all work together to ensure the as-designed, the as-built and the analyzed structure are one and the same! These tools are very powerful, and should be used across disciplines to avoid analyzing a totally unrepresentative model.

Assessing Results

The quantity of data from a composite FEA can be immense. Each ply will have three directional stresses, with failure criteria, and there will be many plies in a laminate. The structure may have many different layups across regions. Various stress sorting and filtering schemes are available in the solver and post processor. Become familiar with these tools, as you'll spend far more time assessing local behavior than in isotropic materials. The use of contour plots and specific ply mapping tools is essential.

One logical approach to assessing strength results in thin shell structures would be as follows:

1. Plot overall SR as a contour plot (this is preferable to

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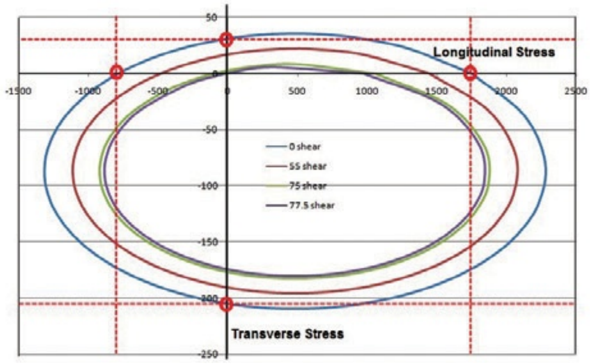

FIG. 6: **Tsai-Wu failure envelope for various shear stress states.**

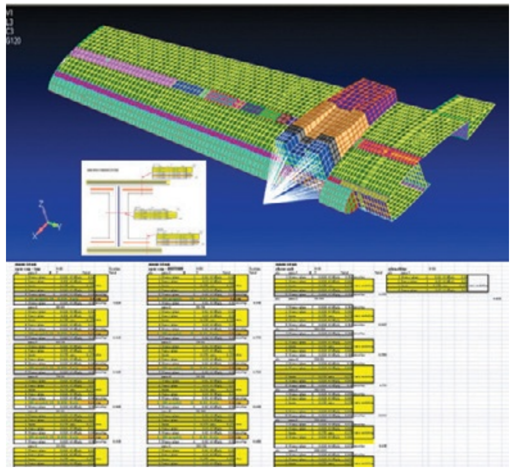

FIG. 7: **Laminates in a complex structure.**

FI, as it scales linearly). Use this to assess where the "hot spots" are in a structure.

2. Identify the hot spots, and put the elements in these zones into separate groups for visualization.

3. For each zone, identify which ply is most critical in the laminate (that is, what triggered the critical SR). This is usually available as a direct output quantity. If it is not, you will have to create a filtering method or a macro to find it — it is a critical step.

4. Having identified the critical ply, the component stresses are plotted in turn to understand the driving failure mechanism (fiber tensile failure, matrix transverse or shear failure, etc.). Based on that information, evaluate possible design changes.

5. Another option is to assess the local hot spot laminate results in detail and conduct "what if" scenarios to understand design changes. Third-party ply stress calculators are available, or contact the author for a simple free educational spreadsheet tool.

The use of composite brings many advantages to the designer. However, with this comes increased complexity. There may be poor evidence of test data for specific composite materials under compressive and shear loadings in particular. In this case, failure theories need to be used conservatively.

More input data, more analysis and more output data all translate into taking a logical approach toward model construction and results interpretation. This has to be planned in advance, and will require developing strong skills in the tools required.

Next month, we will delve into the theory behind composites a little more deeply, and explore some of the most recent innovations in FEA methods. DE

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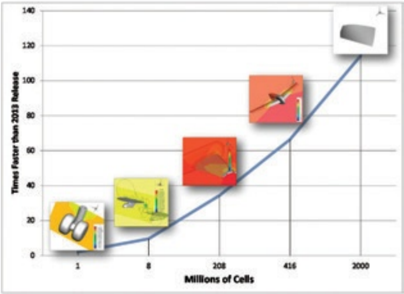
by Anthony J. Lockwood

Editor's Picks

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



Tecplot Inc. Launches Tecplot 360 EX With SZL Technology

The application can visualize a billion cell CFD solution on a workstation.

Tecplot 360 EX with SZL (subzone loading) technology potentially enables you to load and analyze data on your desktop or laptop engineering workstation that you currently believe can only be executed on some HPC (high-performance computing) setup with memory utilization.

To give you an idea of what we're talking about here, examples of the memory utilization improvements in Tecplot 360 EX with SZL technology include post-processing a 2 billion cell data set on a typical laptop with 8GB RAM and loading a 408M cell model with less than 5GB of RAM on an engineering laptop.

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National Instruments Ships LabVIEW 2014

New capabilities enable users to acquire, analyze and visualize data anywhere.

LabVIEW 2014 is built around a number of upgrades intended to help you quickly acquire, analyze and visualize data sets to make informed decisions. Among these features is a technology called DataFinder Federation. This technology provides a methodology for quickly searching for, acquiring and analyzing data across a local drive, network or anywhere in the world you have it.

Version 2014 also offers new built-in algorithms for a richer deployment of analysis including .m files to NI Linux Real-Time and vision functions to FPGAs (field-programmable gate arrays).

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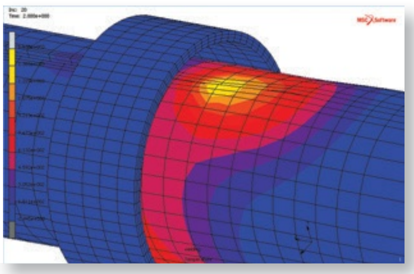

New Version of Marc Nonlinear FEA Program Available

The updated application has an added crack propagation function.

Marc 2014 enhances your ability to perform accurate crack propagation studies with a new high-cycle fatigue capability. Similarly, the application has an improved method for scaling crack growth along a crack front and between separate cracks.

MSC also says it upgraded how you implement a friction model, which also improves convergence and the accuracy of the contact solutions.

For electromagnetics, Marc 2014 debuts a new circuit approach that lets you apply either current or voltages to your system under study.

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Materialise Releases Version 9.0 of 3-maticSTL

Software helps simplify, modify and texture designs for analysis, rapid prototyping.

Materialise reports that 3-maticSTL version 9.0 sees improvements in its design, remeshing, texturing and lightweight structure functionalities, and that most of these changes were inspired by user feedback. For design, there's a new render with ruler capability that, compared to earlier versions, allows for faster model manipulation and visualization. A new rib pattern functionality can create a clean rib structure that conforms to the 3D model automatically. Also added is an Edit Curve feature that lets you adjust an existing curve's shape without making you redraw the curve.

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Autodesk Adds NEi Nastran to Lineup

In-CAD or alongside, Autodesk Nastran supports better/sooner design decisions.

BY PAMELA J. WATERMAN

Since 2008, Autodesk has invested in simulation software, adding the capabilities of Moldflow, Algor, CFdesign and Firehole Composites to its product line. Each addition added one more function — molding techniques, structural mechanics, computational fluid dynamics and composites analysis — to the company's toolbox. Now Autodesk has made another strategic move, tapping into the power of industry-standard Nastran solver code. With Autodesk's launch of Autodesk Nastran 2015 and Autodesk Nastran In-CAD 2015, the company completes its May acquisition of NEi Software and strengthens its support of digital prototyping across the product cycle.

"To get the masses to do simulation and push multiphysics into the design space, you have to have 'environmentally friendly' materials," says Derrek Cooper, director, Autodesk Simulation products. "The software must address how to go from CAD to a mesh, how to handle large, complex models, and how to see an entire assembly simulated."

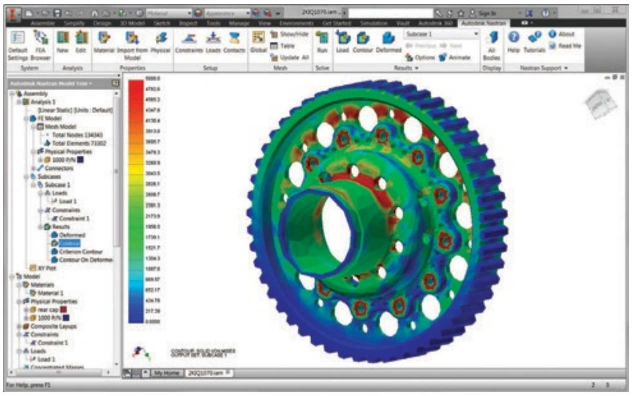
By adding NEi Nastran to Autodesk's simulation flow, users have another way to do those tasks, with a better way to access Nastran's well-known capabilities in the up-front design space.

Two Autodesk Nastran Options

Two versions of the simulation product are available. For experienced Nastran engineers, Autodesk Nastran 2015 offers a higher level of simulation sophistication in a stand-alone, scalable package that can run on a desktop and/or take advantage of cloud resources as needed. For designers, the new Autodesk Nastran In-CAD 2015 package lets them do more complex analyses with different physics than before. Interestingly, Autodesk will support the existing Nastran SolidWorks In-CAD package, and may even develop other CAD-centric offerings, such as a Nastran In-CAD for Creo from PTC.

Mitch Muncy, formerly of NEi Software and now Autodesk Simulation Nastran product manager, says the new Autodesk products have embedded non-linear analysis capabilities such as buckling, normal modes, assembly modeling with contacts, transient response, random response, frequency response, impact analysis and drop test, all set up according to the familiar Nastran structure.

All the previous capabilities are still there but now you can do a linear analysis both ways (your choice of solver, SimMech or Nastran is a click in the drop-down menu) and compare the results. A new editor helps users create the required "card deck" format for input to a Nastran simulation, and a real-time solver and output log tool ships with the software. Muncy also notes



The new Nastran In-CAD works within both Autodesk Inventor and SolidWorks. *Image courtesy of Autodesk.*

that while people had gotten the impression it was necessary to simplify analysis to bring it into CAD, Autodesk Nastran In-CAD instead elevates CAD users to let them do advanced analysis in a familiar environment, he says.

Autodesk's Simulation Strategy

Looking to the future the company continues to expand beyond CAD into CAE, Autodesk discussed the six elements of its simulation strategy, which will particularly address customer needs for working with smart machines, advanced materials and additive manufacturing:

1. **Open** – multi-CAD, multi-CAE.
2. **Integrated** – more multi-physics capabilities will be supported, plus all Autodesk tools work with each other, with PLM (product lifecycle management) tools and with visualization tools.
3. **Purpose-built** – tools are available for the designer, engineer and analyst.
4. **Optimizing** – supporting parametric experiments has be come a critical aspect of efficient design.
5. **Flexibility** – this will become more and more important for licensing models, supporting day-by-day cloud usage.
6. **Advanced** – composites, foams, blended materials and nanomaterials must all have accurate and validated material properties as input for analysis. DE

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