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May 2017

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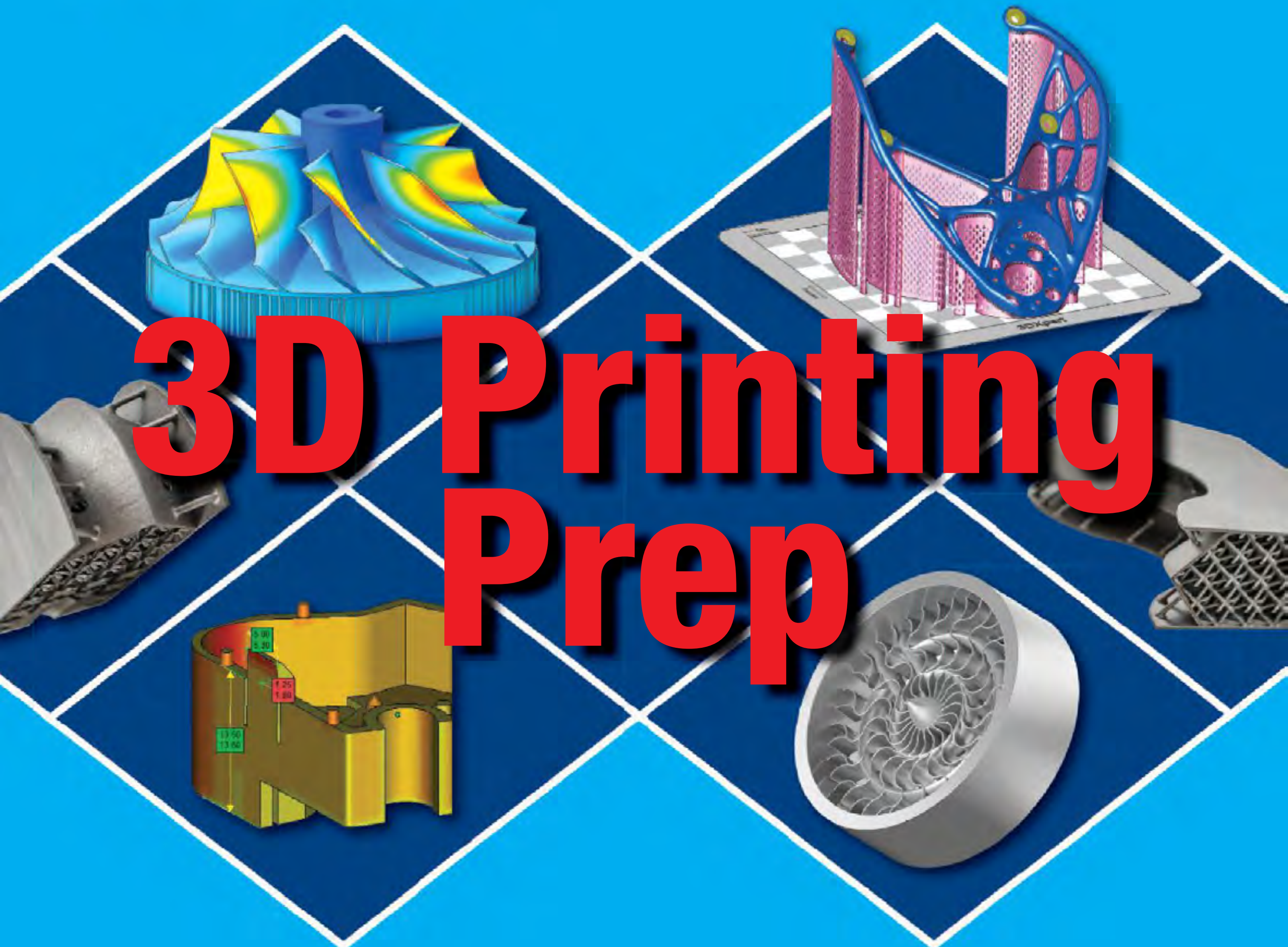
3D Printing Prep



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by Jamie J. Gooch

Big Business Gets Additive Manufacturing

OVER THE YEARS, we've covered a number of firsts in 3D printing. The first commercial use of the term 3D printer (1996), the first working 3D printed kidney (2000), the first self-replicating 3D printer kit (2004), the first 3D printed prototype car body (2010), the first general consumer-focused 3D printer (2012) and the first 3D printer in space (2014), to name a few. But now the firsts are breaking out of R&D labs and being made by big businesses.

Boeing, with the help of Norsk Titanium, just received Federal Aviation Administration (FAA) approval to use 3D printed parts in its 787 Dreamliner. It's the first time a plane will use 3D-printed metals as structural components. Adidas and Carbon worked together using Carbon's Digital Light Synthesis technology to create the Futurecraft 4D midsole. Adidas released more than 300 of the new 3D printed shoes last month and plans to produce more than 5,000 this year and 100,000+ by the end of 2018. Caterpillar recently opened a 3D Printing & Innovation Accelerator and announced a partnership with FIT AG, known for creating the Netfabb 3D printing software company that it sold to Autodesk. Ford is the first automaker to pilot the Stratasys Infinite Build 3D printer, which is capable of very large builds. GE Additive, which calls itself the world's leading digital industrial company, has invested about $1.5 billion in manufacturing and additive technologies at GE's Global Research Center. It wants to grow its new additive business to $1 billion by 2020 and sell 10,000 additive machines over the next 10 years. Google Ventures and BMW iVentures are among the investors in Desktop Metal, a start-up developing the first desktop 3D printers that can create metal parts.

The Business Case for Industrial 3D Printing

The list goes on and on. What they all have in common is combining the manufacturing and supply chain experience of big businesses with the technology and expertise of additive manufacturing providers. Whether working directly with, investing in, or simply purchasing 3D printing technology vendors outright, it's clear that big business is ready to fully embrace 3D printing.

The momentum of "digitalization"—connecting all phases of a product lifecycle throughout and beyond the enterprise via a digital thread—can only further the adoption of industrial 3D printing/additive manufacturing. It's a huge undertaking for any enterprise, and direct digital manufacturing is only part of it. In the past, some wrote off 3D printing as a solution in search of a problem. Now, some of the challenges of digitalization—such as mass customization, connected automation and realizing the benefits of topology optimization—are big problems 3D printing can help solve.

The benefits to industrial 3D printing, given the right circumstances, are well documented. The time and cost savings, coupled with less tangible notions of "free" design complexity and fewer manufacturing constraints, make 3D printing a no-brainer for sectors that specialize in short-run production of custom parts. But beyond expensive aerospace and racecar parts, or custom medical and dental applications lies mass market manufacturing. The extent to which 3D printing can penetrate those markets depends largely on how much faster it can get, how much larger build volumes become and how many engineers know how to design for a future that melds additive and subtractive technologies.

Designing for Additive Manufacturing

As we've noted in the past (digitaleng.news/de/designing-for-the-future-of-manufacturing), design engineers need new tools and thought processes to design and simulate for additive manufacturing. Everything from material options (see page 26) to model prep (see page 18) to post-processing follows traditional manufacturing process rules, requirements and tribal knowledge developed over generations. Rapid prototyping & manufacturing service providers can help fill the knowledge gap (see page 22) and design software vendors are making great strides in providing better tools for 3D printing. Still, for 3D printing to reach the levels being forecast by industry analysts (see page 8), the comfort level of design engineers, old and young, is just as important as an acceptance of its benefits by CEOs or its ability to meet technical challenges. DE

Jamie Gooch *is editorial director of* DE. *Contact him via jgooch@digitaleng.news.*

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INSIDE

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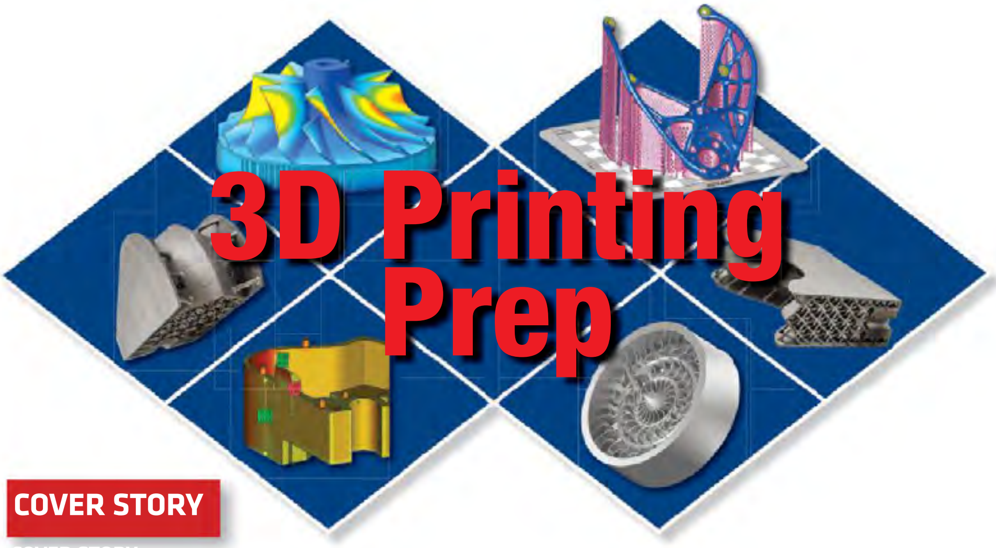

COVER STORY

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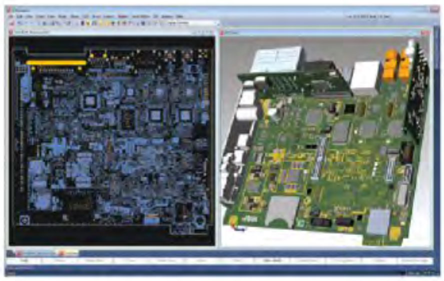

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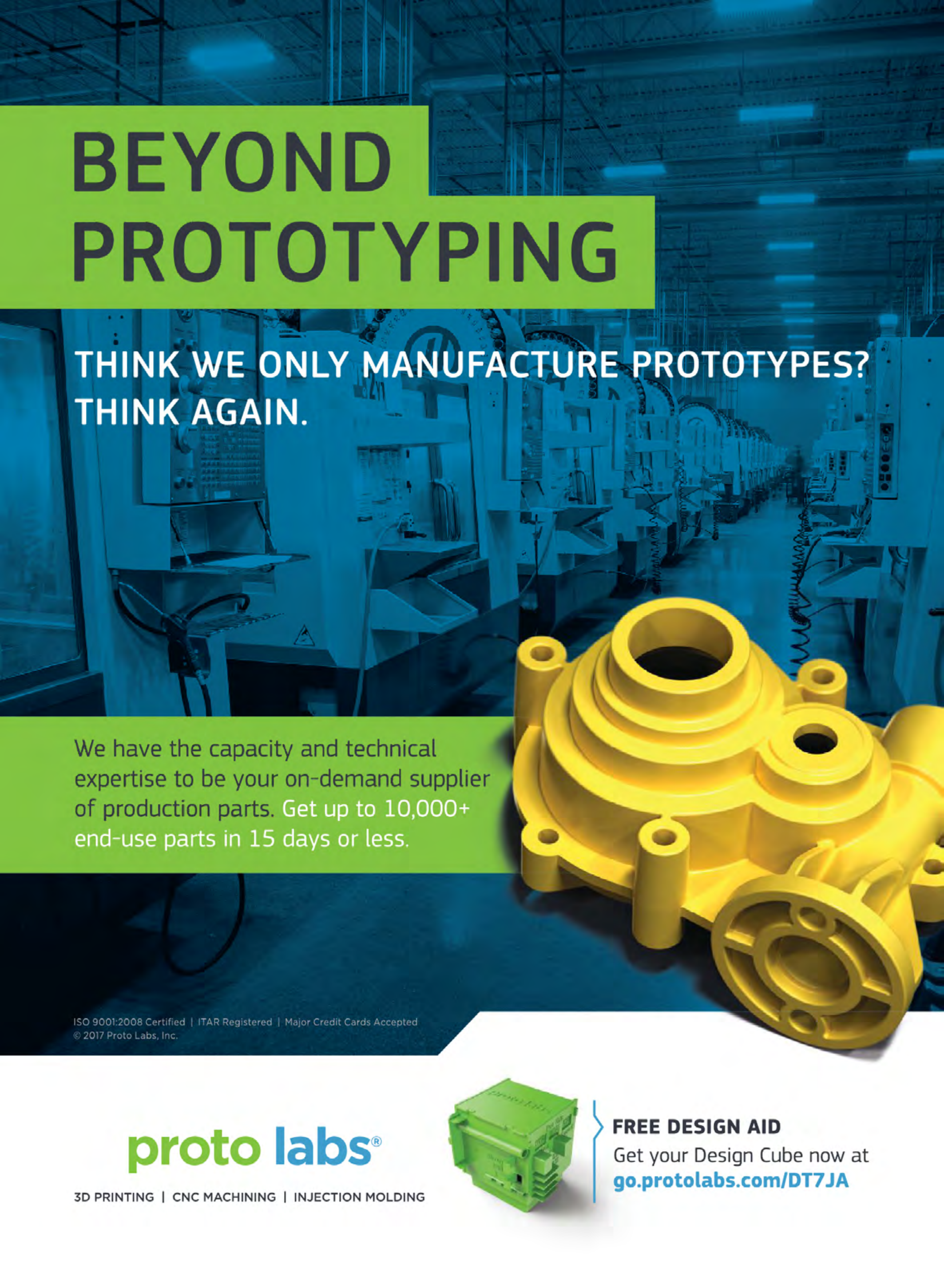
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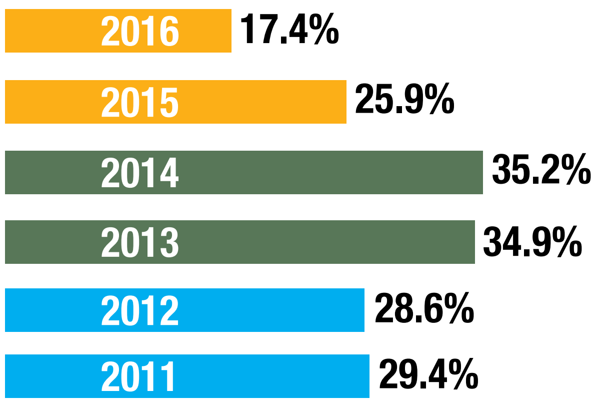
3D Printing Market Snapshot

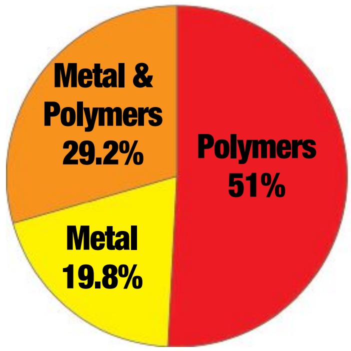
Industry Growth



The additive manufacturing industry grew by 17.4% in worldwide revenues in 2016, reaching $6.063 billion, down from 25.9% growth the year before.

— Wohlers Associates

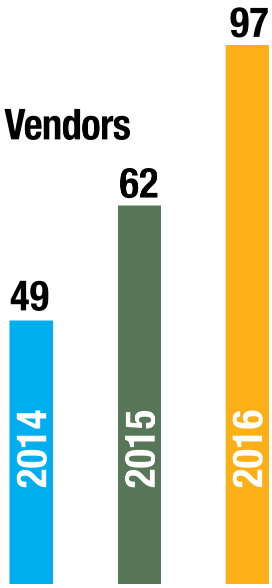
Materials Offered by Service Providers



Nearly half of the 3D printing/ additive manufacturing service providers surveyed in 2016 offered metal printing.

— Wohlers Report 2017

Vendors



Number of companies producing and selling additive manufacturing equipment.

— Wohlers Report 2017

3D Printing Saves Time and Money

$3 million: What Boeing could save, per jet, now that it's using 3D-printed titanium parts in the construction of its 787 Dreamliner.

— Source: Norsk Titanium AS

$1.39: What it cost for U.S. Navy repairmen to 3D print one of many cooling fans, which would otherwise cost $375 each.

— Source: U.S. Navy

$3-5 billion: The amount GE expects to reduce in manufacturing costs over the next 10 years via additive manufacturing.

— Source: GE

75 hours: The time it took U.S. Army researchers to print and post-process a grenade launcher barrel and receiver, vs. months via conventional methods.

— Source: U.S. Army

4 hours: The time it takes for the Honda division McLaren Formula 1 Racing team to 3D print their car's hydraulic line bracket vs. two weeks for traditional manufacturing.

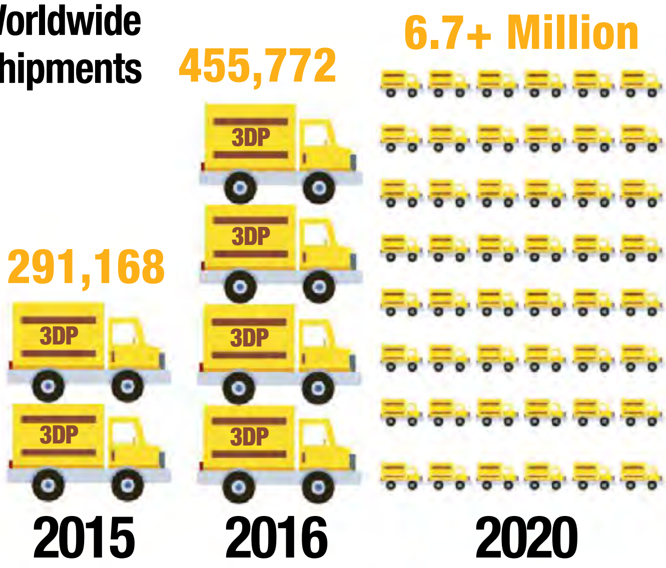
— Source: Stratasys

75%: The lead time savings seen by Bell Helicopters when using additive manufacturing on a de-fog nozzle in its 429 and 412 helicopters vs. traditional manufacturing and tooling.

— Source: Bell Helicopters

3D Printing: A Look Ahead

Worldwide Shipments

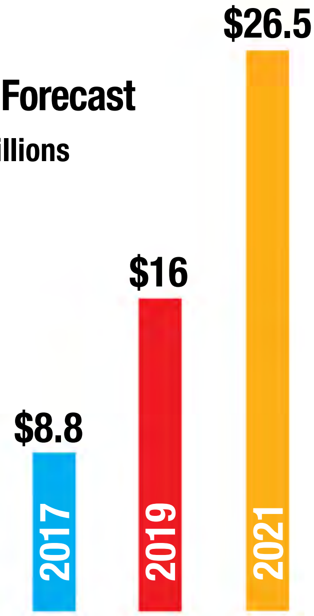


Worldwide shipments of 3D printers were projected to reach 455,772 units in 2016, more than doubling the 219,168 units shipped in 2015, but dwarfed by the more than 6.7 million units expected to be shipped in 2020.

— *"Forecast: 3D Printers, Worldwide, 2016," Gartner, October 2016*

Market Forecast

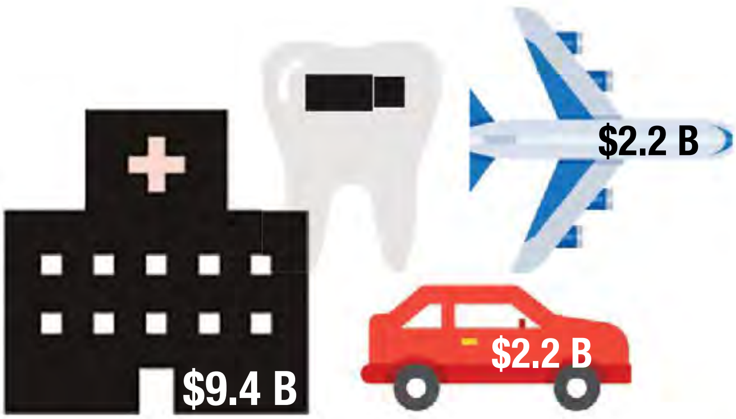
In Billions



About 20% to 25% of the $26.5 billion market forecast for 2021 is expected to be the result of metal additive manufacturing.

— *"Additive Manufacturing, the Next Industrial Revolution," Oerlikon, December 2016*

3D Printing Value in Key Industries, 2022



By 2022, 3D printing in medicine is expected to account for 9.4 billion in market value, revenues of $4.3 billion will be seen in the dental market, $2.7 billion in aerospace and $2.7 billion in automotive.

— *"Additive Manufacturing: Review of Opportunities in Key Industries 2017," SmarTech Publishing, January 2017.*

Metal or Plastic?

The market for polymers and plastics for 3D printing will reach **$3.2** billion by **2022**.

— *"Opportunities in Polymer and Plastic 3D Printing - 2017, " SmarTech Publishing, March 2017*

The primary market for metal additive manufacturing, including systems and powder materials, will grow to over **$6.6** billion by **2026**.

— *"Additive Manufacturing with Metal Powders 2017," SmarTech Publishing, March 2017*

Enterprise 3D Printing, 2020

End-Use Parts 65%

Manufacturing Aids 75%

Prototyping will remain the primary enterprise use for 3D printers through 2020.

— *"Forecast: 3D Printers, Worldwide, 2016," Gartner, October 2016*

ROAD TRIP

Engineering Conference News

A New Design Renaissance

BY JAMIE J. GOOCH

DASSAULT SYSTÈMES embarked on 3DEXPERIENCE in 2012 as a way to bring the end user's experience into the design loop across its portfolio of products.

The big design engineering software players acknowledge that disruptive change is coming to product design, development and manufacturing, but they all have different approaches to take advantage of that disruption.

Bernard Charlès, CEO of Dassault Systèmes, summed up his company's approach when he addressed attendees at the Design in the Age of Experience conference in Milan, Italy April 4-5: "Since we announced 3DEXPERIENCE on Feb. 9, 2012 in a one-page document after my board meeting, I said: 'I'm going to invest all resources that we have—all cash, all talents, all our ecosystem'—not to do more of the past, because the world is sick of doing more of the past."

The conference focused on what Dassault Systèmes defines as the four pillars of the 3DEXPERIENCE:

1. Designing experience by reducing the distance between the real and the virtual experience to zero.
2. Design is the business plan because it allows you to reinvent the way you interact with your customers.
3. Design is tribes because it must be collaborative and include social elements.
4. Design is science-driven that is inspired by the beauty of nature.

During the conference, a number of Dassault Systèmes customers took the stage to discuss designing for experience. Attendees were also able to visit the 3DEXPERIENCE Playground, a gallery of demonstrations divided among the four pillars that leaned heavily toward experiencing design in virtual and augmented reality. Other exhibits included a topology optimized open source robot that helps people understand the virtual twin concept, and the new 3DPrinting Marketplace by Dassault Systèmes that is now in beta.

"The marketplace is very strategic, very strategic," Charlès told assembled press and analysts. "We will offer much more than 3D printing. We are doing it step by step. We can compute taxes real-time across the globe. It changes the supply chain completely because you basically trade IP and work. It's a very different model. We are taking it very seriously."

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Engineering the Future with Parts Management

BY RANDALL NEWTON

IF A TEAM of engineering students from Ryerson University in Toronto has anything to say about it, the first Hyperloop transit systems to go into commercial use will be built with off-the-shelf aircraft landing gear for "take-off" and "landing" in the vacuum environment envisioned by Elon Musk and others as a "fifth mode of transport."

The team assumed the task of designing the Hyperloop wheel system as part of a SpaceX Hyperloop competition. The wheels had to be capable of supporting 180mph start and stops, and be available for emergency service. The rest of the time, while the Hyperloop capsule travels at 700mph through a tube, the wheels must be retracted.

As explained by Graeme Klim at the recent CADENAS Industry Forum in Augsburg, Germany, the Ryerson team saw specific advantages in saving manufacturing time and costs by specifying existing aircraft parts. They used Aerospace Industries Association (AIA) specs, and searched through a library of 3D CAD models from landing gear assemblies that met National Aeronautics Standards. Their search—powered by CADENAS technology—helped the team to quickly identify a suitable wheel system already on the market from IHS Markit. The landing gear they chose had eight subassemblies, 42 custom designed parts, 162 standard parts and 204 total parts.

Klim estimates the team saved 58% of the time it would have taken to design a similar gear without access to the PARTsolutions database. "Our use of AIA/NAS parts accelerated design times," says Klim. "Using it lets innovators focus on key design components, rather than creating standards parts."

The Ryerson University team was one of many at the CADENAS Industry Forum who gathered in Augsburg March 15-16 to learn—from each other and from the company—the latest in design and engineering efficiency through better use and management of parts data.

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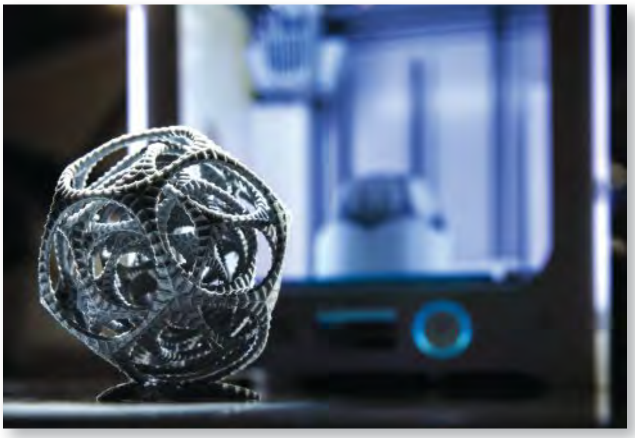

Siemens Puts Simulation on the Path of Predictive Analysis

BY RANDALL NEWTON

IN MARCH, the STAR Global conference convened in Berlin, and Siemens PLM Software outlined how it was integrating CD-adapco, the simulation software provider it acquired in 2016.

The former CD-adapco product line in Siemens PLM Software will become part of the emerging Simcenter portfolio. As explained by Dr. Jan Leuridan, head of Simulation and Testing, Simcenter will do for simulation data what Siemens Teamcenter does for design and engineering data. "[Simcenter] will manage STAR data with complete lifecycle traceability, from project requirements to product design, to simulation, to results," he said.

It should be no surprise that one of the billionaire companies in PLM (by annual revenue) would buy a company like CD-adapco. The lead product, STAR-CCM+ is used by 14 of the 15 largest automotive companies, by all top 10 suppliers in aerospace, and by nine of the 10 largest manufacturers in the energy and marine sectors. Siemens paid $970 million to add the CD-adapco line to the Siemens PLM portfolio, which also included the HEEDS line of multidisciplinary design exploration and optimization tools, from CD-adapco's acquisition of Red Cedar Technology in 2013.

Leuridan says the driver of business transformation today is digitalization. Siemens PLM Software says its role in the process is to help customers transform into digital enterprises, by focusing on three product issues:

1. Changing the way products come to life, with new technologies such as generative design, predictive simulation and intelligent models;
2. changing the way products are realized, with new technologies such as machine learning, additive manufacturing and robotics; and
3. changing the way products evolve, through use of cloud technology, knowledge automation and big data analytics.

Jan Leurida, head of Simulation and Testing, Siemens PLM Software.

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Aras Outlines its Platform Approach to PLM

BY JAMIE J. GOOCH

DIGITAL transformation is coming faster than previous product design and development shakeups.

"We had literally decades to get used to the rollout of 2D CAD and then 3D CAD," said Aras CEO Peter Schroer during his ACE 2017 keynote in March. "What that means is—as we software vendors were bringing you new technology in CAD, specifically—you had time to build control systems. CAD allows you to go faster, you need better control systems to make sure you don't get out of control. What happened is the acceleration from what was purely mechanical … to electronics, the software, systems of systems … the timescale has been very short."

That quickly increasing complexity is driving the need for improved controls. It's driving the need for a digital thread that works in both directions as well as digital twins for specific products, which in turn results in Big Data needed to enable the digital transformation.

What Schroer called a "lightbulb moment" was when industry analysts Gartner, IDC and CIMdata made statements about PLM not being an application anymore, but something that should be thought of as a platform.

"A platform: I like that, so let's make that the next stage of the Aras journey," he said.

Aras defines a PLM platform as an open, resilient, flexible suite of applications so that it has the ability to support customer data and processes over a long time (decades, in many cases), have a reasonable cost, and be able to support change. "As you think about platform, none of you should be thinking about 'How do I replace 100 IT systems … all at one time,'" Schroer said from the stage in Nashville. "We tried that 20 years ago ... It's too big, you can't do it all at once. As we think about our platform here, we have to think about doing something that is iterative. I think the digital transformation is very much a journey. It's steps. It's got to be iterative."

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| ABBEY'S ANALYSIS |

SIMULATION

by Tony Abbey

When Button Clicking Ends in Tears

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

OVERSIMPLIFICATION OF analysis decisions can lead us astray in finite element analysis. Sometimes the user interface fails to impart the correct level of importance to the options we select. Below are where menu "quick choices" can lead to trouble.

Fatigue

Setting up data for fatigue analysis can be quite complicated, with many steps along the way. (See "Conduct Fatigue Analysis Using FEA," digitaleng.news/de/conduct-fatigue-analysis-using-fea for an overview of fatigue.)

Several of the questions posed by a user interface may almost seem like a general user survey. These may include the following:

- Is the material high- or low-strength steel?
- What is the surface finish?
- Is the stress state bending, axial or shear?

In fact, the answers to these questions directly influence the final fatigue life calculation. Initial fatigue life data, described on an S-N or e-N curve, will probably relate to smooth polished axial test specimens as a datum point. To develop a similitude between this "perfect" fatigue life and the actual component you are dealing with, correction factors are applied. For example, the first two are interlinked and a typical fatigue life correction factor could be as low as 0.1 for an untreated forged high tensile steel. This has a big effect on the resultant fatigue life. If we compound a full set of factors, we can easily have fatigue life reduced by three or more. Knowledge of the reason behind each question is vital: The tendency to treat the questions as part of a general survey should be avoided.

It is critical that the software tool is designed to emhasize the importance of these questions. For example, failing to apply a "typical" correction factor should prompt a warning that this is unusual. A list of typical values with background information should be easily accessible to the user. "Typical" values should also have a caveat. However, it is better to work with generic values rather than no correction terms, which will give hopelessly optimistic fatigue lives.

Frequency Response Analysis

Data setup for dynamic analysis can be tricky because it needs some very careful tuning to yield the best results. One good example of this is in frequency response analysis. A previous article ("Practical Frequency Response Analysis," digitaleng.news/de/practical-frequency-response-analysis) gave an overview of this type of solution.

What's important in this type of analysis is to define exactly where we want the frequency response calculation points to be made across the frequency range. In essence, this means we need to know the natural frequencies of our system and the frequency range of interest. There should be user controls to define both the spread of calculation points around each natural frequency and between adjacent natural frequencies. In addition, the lead into the first natural frequency needs to be carefully defined. Usually there are quite a few ways to achieve this that are already built into the FEA Solver. However, it is difficult to design a user interface that easily explains to the user what the usage and implications of each are. Sometimes there may be no route between resonant frequencies and frequency response analysis, as in the case of a direct solution method. It is always unclear to me what an inexperienced user is supposed to do in a case like that.

> Understand how oversimplification can create challenges in finite element analysis.

It is very easy to miss any, or all, of the peak responses without taking some care. The implications of missing a peak response can result in underpredicting any type of response by up to 30% to 40%. It really becomes a bit of a lottery how non-conservative the answer will be. If you are doing a random response analysis on the back of the frequency response analysis, the shape of the overall response curve is important. In this case the RMS responses could be either conservative or non-conservative; a more sophisticated lottery!

Again, in this case it is incumbent upon the software designer to provide clear generic guidelines that will tend to give conservative results. If the user does not provide a table of natural frequencies, or the preprocessor is unable to extract them from previous normal modes analysis, there should be a huge caveat.

Nonlinear Analysis

In nonlinear analysis, we may want to apply a load that tracks the deformation (that is, changing configuration) of the component under the loading. This is known as a follower force and was described in "Moving into the Nonlinear World with FEA" (digitaleng.news/de/moving-into-the-nonlinear-world-with-fea).

In some user interfaces, this can be a three-step process to set up. The user obviously must request a nonlinear analysis, usually with a further option to select geometric nonlinear analysis specifically. Usually, the option to calculate follower forces is an additional selection.

That would seem to be all, but in fact there is another wrinkle. If a distributed force has been applied, via geometry or mesh, this can be interpreted by the solver as a vector, and be updated as the mesh distorts. However, if a nodal force is applied, there is usually no way this is captured as a vector, and therefore any mesh configuration change will be ignored. This all represents a tricky setup, and the user interface should be guiding the user. Caveats must be provided to keep the user out of trouble.

Be Sensitive to Simplicity

I have stressed the importance of the software developer's role in providing guidance and caveats. However, in the final analysis (to use a dreadful pun) it is up to us to make sure the analysis works. If you're not sure of the implications of any of the options you are selecting, it is a good idea to run sensitivity analyses to see what happens in extreme cases. I am often faced with this when doing fatigue analysis: I never know which of the mean-stress correction methods is really most appropriate, so I end up running all of them—and I choose the most conservative.

So, be cautious, be safe—and check out those buttons! DE

Tony Abbey works as training manager for NAFEMS, responsible for developing and implementing training classes, including a wide range of e-learning classes. Check out the range of courses available: www.nafems.org/e-learning.

| CONSULTANT'S CORNER |

EDUCATION

by Monica Schnitger

Stand Behind STEM/STEAM Programming

I AM LUCKY. I get to attend a lot of events that showcase design and engineering technology—tools to make our jobs more efficient. Nearly every event today includes a STEM component, projects that showcase a commitment to science, technology, engineering and math education. If you've seen FIRST Robotics or a Science Olympiad, you've seen STEM in action.

Participants in these programs start young: Elementary school kids build machines and other cool stuff in the FIRST LEGO League, or try to catch and catalog bugs at a local playground during a Science Olympiad "Don't Bug Me Day." These projects build on the natural curiosity of children while teaching the scientific method, engineering, physics and biology, and let kids try on careers at an early age.

As students progress to middle and high school, the projects become more complex. At a FIRST Robotics competition, you'll see industrial scale robots race one another along an obstacle course, throw basketballs and climb poles to get to the platform at the top. By the time their competition ends, these students know how to look at a problem, formulate possible solutions and investigate those possibilities to find what can realistically be accomplished with the materials and time allowed—and they're not hamstrung by what didn't work before; they're willing to explore a much wider solution set than more experienced (and jaded) engineers might consider.

The Good and the Bad

The good part: These kids are sought by universities. MIT professor Woodie Flowers, one of the founders of FIRST, once told me participating in FIRST improves a youth's odds of getting into a top-tier college. These students already have critical thinking, teamwork, design and manufacturing skills. They may already know how to use Creo, Inventor, Onshape or SOLIDWORKS CAD products because those companies sponsor FIRST teams. These kids have a head start on the practical side of engineering—whether they go on to study robotics or not.

The bad part: We then take all of the creativity these kids have, their curiosity, their "why not try this?" and stomp it out of them. Corporations like things to be done a certain way; their customers expect generation 2 of a product to be only slightly different from generation 1. Senior engineers and designers have seen and tried many things, and in the interest of saving time and trouble, steer these young engineers toward what has worked in the past and will, therefore, work again. These are important and necessary, but can coexist alongside the creativity of newcomers.

Major industrial companies are pairing junior and senior engineers to strike the right balance of experience and naiveté. Juniors ask questions that seniors perhaps haven't considered in decades; seniors steer the project and provide guidance that keeps things moving forward. When done well, these partnerships yield two benefits: a junior who grows more quickly than he or she would without this mentoring, and a re-energized senior engineer.

There's also the tried and true: Move new employees around the parts of the company to see what they learn. My first job in a shipyard had me rotate through the departments. I learned so much—what impact a decision in one department has on another, why yard workers thought office workers were nuts (there was a real lack of communication) where inefficiencies manifested—that really helped when I started my formal job. Yes, I wasn't all that productive while I was a temp in each department, but I was probably far more effective in the Hull Drawing Room when I finally landed there.

Even the youngest engineers come with all of their prior learning and experiences. Let's not hire these terrifically creative and skilled workers, and then waste their talents.

If you can, get involved. STEM (or STEAM, which adds Arts) programs always need adult mentors. The two mentioned are Science Olympiad (soinc.org) and FIRST (firstinspires.org/robotics/frc). DE

Monica Schnitger *is president of Schnitger Corp. (schnitger-corp.com). Send email about this commentary to de-editors@digitaleng.news.*

BRIEFINGS

Deep Dive into Metal AM Material Properties

Researchers at the University of Pittsburgh have been working with ANSYS to create a simulation technique that can evaluate the effects of additive manufacturing (AM) on the microstructure and material properties of parts produced for high-temperature applications. Up to this point, the only way to certify the quality of these parts has been to perform comprehensive physical tests.

Using metal AM, manufacturers can build subsystems in layers, reducing the part count to a few components. This in turn will reduce the materials, fabrication processes and labor required to produce the subsystems.

What manufacturers need is a quick and inexpensive way of determining how the interactions between the laser or electron beam and the metal powder used in the AM process affect the part's final state.

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3D Printing Prosthetics

Ambionics was launched by Ben Ryan of the UK, confronting the need for a "training" prosthetics for the under-two-years-old age group. Inspired by his own son's needs, Ryan—a psychologist/teacher, not an engineer—designed and developed a novel, pint-sized hydraulic prosthetic that uses a double-acting helical bellow to allow opening and closing a thumb. He tested the lower-arm concept in foam then 3D-printed it on a Stratasys Connex system.

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3DHEART: 3D Printing Surgical Planning Models for Tiny Patients

Imagine doing open-heart surgery. Then imagine doing it on a heart that is maybe the size of a small lemon, structured with its major components in all the wrong places (hardly textbook). And the operating room clock is ticking.

Help is available in the form of full-color, full-scale 3D-printed models surgeons can hold and analyze for pre-surgical planning. Through a new program called Project 3DHEART, over the next two years physicians around the country will be participating in a clinical trial to quantify the benefits of using such models, both health-wise and economically.

Project 3DHEART, which stands for 3D Hearts Enabling A Randomized Trial, is a single-blind clinical trial that continues and formalizes work begun on a case-by-case basis several years ago. It is the first to study the use of patient-specific 3D-printed models in pre-operative planning for pediatric heart surgery, with the focus on congenital heart patients requiring complex two-ventricle repair.

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3D Printing Metals: Why Support Designs Matter

Support structures for laser-melt, powdered metal additive manufacturing parts are almost a misnomer. You could say supports provide a certain amount of anti-gravity assurance in 3D printing, but mostly they serve as solid paths for heat transfer. Why is heat transfer so important?

The service bureau of Robert Smith, CEO of Qualified Rapid Products, helps customers design and print metal parts on either a Concept Laser Mlab R system or an EOS m280. Qualified Rapid Products also operates two furnaces (large and small), which they use for stress relief, solution annealing (with a quench step) and age hardening. His team insists on designing its own support structures.

Recently Smith began writing a series of well-illustrated blog posts explaining why this factor is so critical. In this feature, he poses the question: "What would happen if you exposed a layer of loose powder-bed metal with no solid directly beneath it?" Smith explains that not only do supports provide something to "weld" against, they hold the part down (to prevent edge-curling) and draw away the heat.

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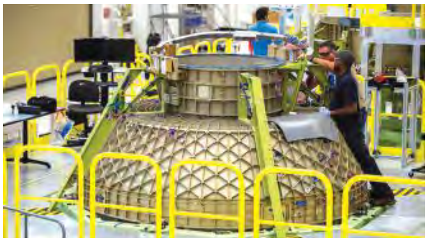
Boeing Starliner to Fly with Printed Parts



When Boeing's proposed CST-100 Starliner space taxis take flight, they will be ferrying more than just astronauts and space tourists into the stratosphere. The vehicles will include roughly 600 3D-printed parts. Boeing has contracted for the parts with Oxford Performance Materials, which received a $10 million investment from advanced materials provider Hexcel.

NASA awarded a $4.2 billion contract to Boeing to build three Starliner capsules, and Oxford has shipped the parts made of PEKK (polyetherketoneketone) material.

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3D Printing Prep Gets *into Shape*

Preparing models for 3D printing is no longer heavy lifting, but it's still not as simple as it looks.

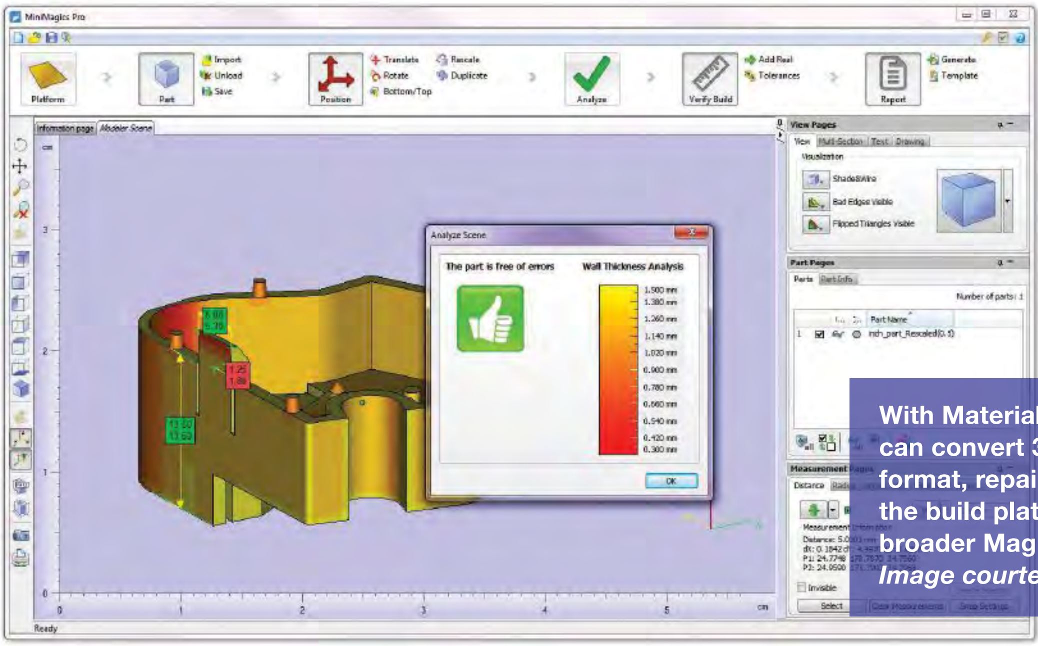
BY BETH STACKPOLE

NOT MANY OF US SWEAT ABOUT hitting the print button to output a document, but for those assembling presentations or other complex materials, there are copious formatting and file tweaks that need attention to ensure the final product is up to snuff.

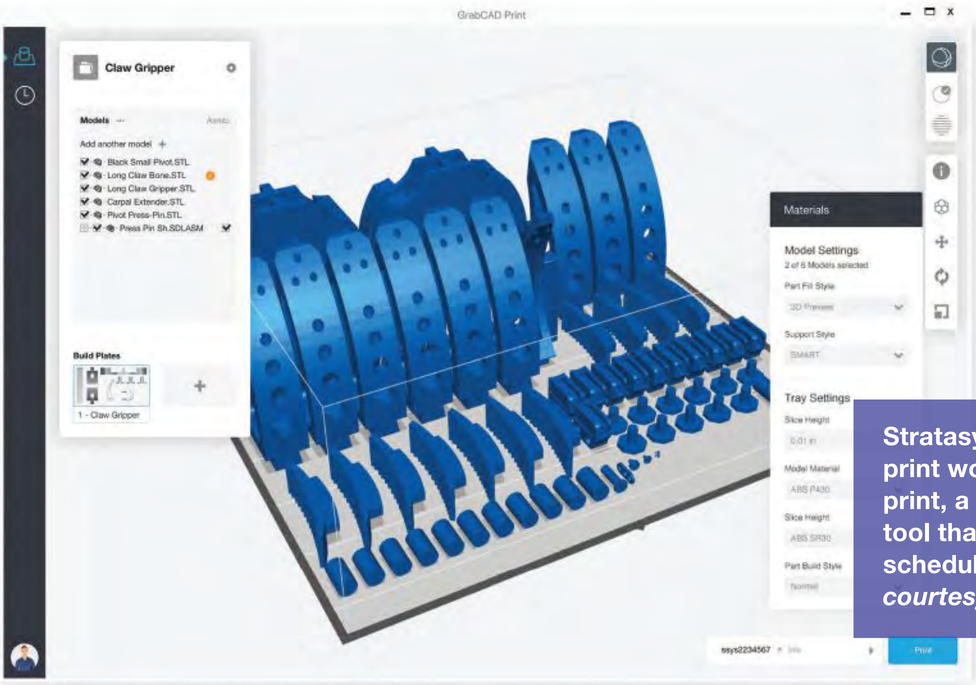
It's a similar situation in the world of additive manufacturing (AM). Despite the ease-of-use promises from a recent spate of office-style 3D printers, design teams that have spent years muscling through trial and error AM practices know there's a ton of upfront model preparation and hands-on pre- and post-processing work required to ensure a successful build.

"It often comes across that 3D printing is as simple as pressing a button, but that's not even remotely the case—there's a great deal of work required to get a model in the shape it needs to be," says Terry Wohlers, president of Wohlers Associates, an independent consulting firm specializing in AM and 3D printing. "There's a perception that 3D printing is easy among people who've never done it, but people who are close to the machines and operate them have an appreciation for what it takes."

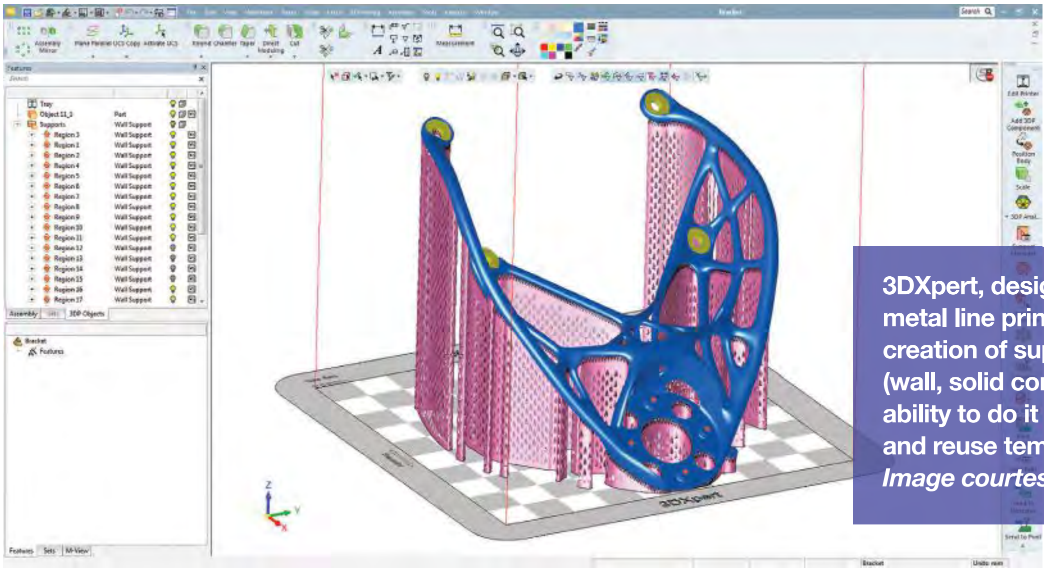
The challenges surrounding 3D model prep vary depending on the type of 3D printing method—fused deposition modeling (FDM) with thermoplastics materials, for example, or direct metal laser sintering (DMLS), which uses powdered metals. With FDM and some other 3D printing methods, 3D models can run into trouble with edges that are not fully watertight (meaning adjacent surfaces around the perimeter aren't meshed properly so the volume isn't fully closed). DMLS and other metal-based AM methods can introduce their own set of design challenges to ensure there are no structures in place that trap loose powder materials upon printing. Proper orientation of the 3D model on the build envelope, nesting models properly



With Materialise Magics, users can convert 3D models to STL format, repair errors and prepare the build platform as part of the broader Magics 3D Print Suite. *Image courtesy of Materialise.*



Stratasys aims to change the 3D print workflow with GrabCAD print, a software-as-a-service tool that unifies job preparation, scheduling and monitoring. ***Image courtesy of Stratasys.***



3DXpert, designed for 3D Systems' metal line printers, enables easy creation of supports of any type (wall, solid cone and skirts) with the ability to do it manually or define and reuse templates for automation. ***Image courtesy of 3D Systems.***

to optimize a print build, and issues related to designing around support structures or powder drains are other factors to consider when prepping 3D models for 3D printing.

Most of these issues are typically addressed in the post-design process, often using additional editing software and file healing tools and involving multiple, disconnected steps, notes Jose Coronado, product management manager, CAD, at PTC. In a typical scenario, for example, a user would create a solid model in their CAD system and perform a conversion to create a triangulated model while potentially introducing lattice structures to reduce weight. From there, there is additional software required to slice the final model and create an STL file, the standard format most 3D printers understand.

"In this scenario, there are three different systems and the original part is no longer a solid model," Coronado explains, adding that if you bring in topology optimization or finite element analysis (FEA) to validate and optimize the design, you might end up with five disparate programs. "For users with CAD and PLM systems, going through four or five systems to finally print a part makes it difficult to adhere to corporate processes," Coronado says. Even worse, changing from solid to mesh can sacrifice precision or lose PMI (product and manufacturing information) that is needed downstream, he adds.

Vendors Heed the Call

As 3D printing gains traction as a method for prototyping and limited run production, CAD vendors like PTC and other specialty tool providers are adding capabilities that make it easier to prepare 3D models for 3D printing. PTC, for example, offers the AM extension for Creo, which executes critical steps in the CAD platform while also adhering to solid geometry standards (boundary representation or BREP geometry). The module has a feature called "tray assembly" that serves as a repository for AM-related data like positions, colors and materials to promote

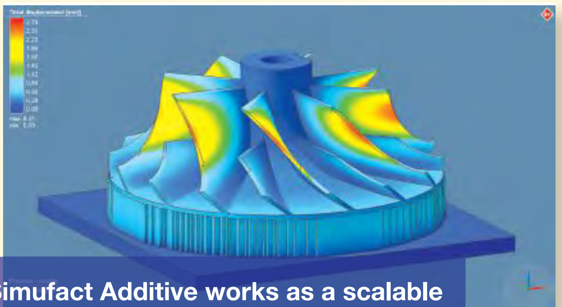
Simufact Brings Simulation to Metal-Based AM

Tools that ease 3D printing model prep are being buttressed by another category of simulation software used to optimize the process in the digital world, in the hopes of reducing the cost and time of trial-by-error 3D printing.

Although packages like Materialise Magics and others help prepare the 3D model for 3D printing, Simufact, an MSC software company, picks up where they left off. The Simufact Additive module, part of the firm's manufacturing simulation suite, is billed as a scalable process simulation environment to ensure "first-time-right" optimization of metal additive manufacturing processes, according to Patrick Mehmert, product manager for additive manufacturing for the firm.

It's not uncommon to encounter issues with distortion and stresses, he says, which can result in parts being printed out of tolerance and possibly broken. "It's much better to simulate the process before so you can detect the problems before you go to the machine," he explains. "Producing production parts can cost hundreds, even thousands of dollars and you typically need three to five trial runs before settling on the part."

To ensure parts are 3D printed accurately the first time, Simufact Additive helps calculate the deformation of the final part, which can be used to minimize residual stress as well as optimize the build-up orientation and support structure. The software is for use with Powder Bed Fusion processes, including Selective Laser Melting, EOS' Direct Metal Laser Sintering (DMLS), Concept Laser's Laser CUSING and ARCAM's Electron Beam Melting (EBM).



Simufact Additive works as a scalable process simulation environment for "right first time" optimization of laser powder bed fusion processes. ***Image courtesy of Simufact.***

reuse and maintain file consistency along with lattice capabilities for creating lightweight designs that aren't part of the initial solid without any compromise to stress or displacement. Finally, there are connectivity functions that ensure a bidirectional exchange of data between the CAD package and the 3D printer in real time to minimize the pain of file conversions, Coronado says.

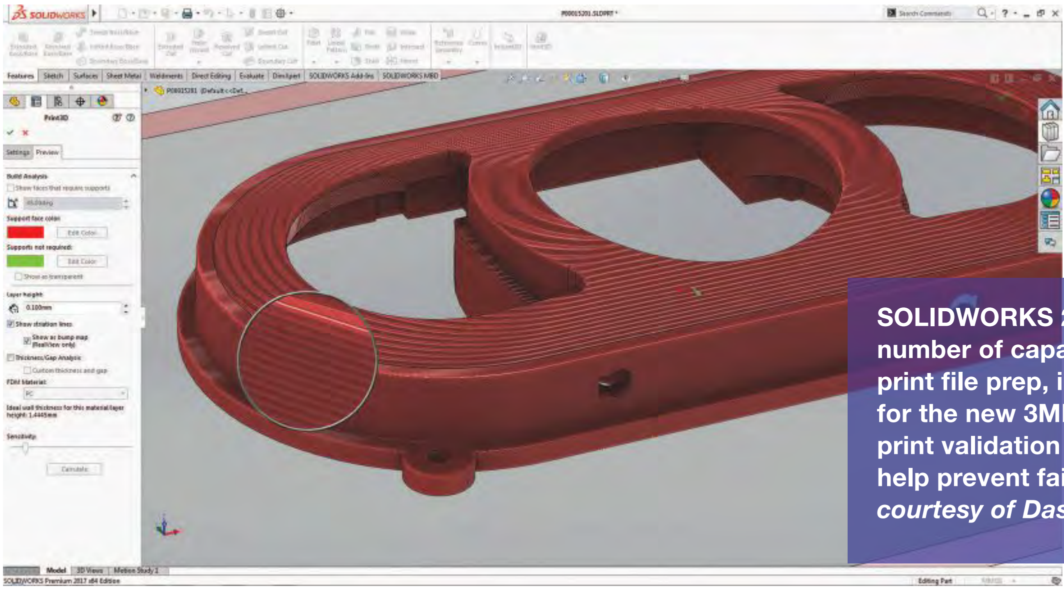
Autodesk, as part of a major investment in 3D printing and AM technology, is easing the 3D model preparation burden through its Netfabb 2017 suite, an industrial-grade portfolio that spans model preparation, manufacturing simulation and design optimization used to create internal lattice structures for lightweighting parts. Netfabb enables engineers to import, analyze and repair models from a variety of CAD formats and identify areas that require supports. Netfabb can also be used to semi-automatically generate support structures and modify models so they are optimized for production, including the ability to adjust wall thicknesses and smooth rough areas—common pain points for 3D printing model prep, according to Duann Scott, Autodesk's additive manufacturing strategist.

Another key capability of Netfabb is the ability to build repair scripts. "This is helpful for advanced engineers who want to help inexperienced engineers via access to a script," Scott says. "There's a black art in 3D manufacturing and this helps make that knowledge available to others."

For its part, SOLIDWORKS 2017 also ushers in capabilities for facilitating 3D printing and 3D model prep. The Print3D option, which enables engineers to evaluate the build orientation of a part and export a SOLIDWORKS file to STL or the newer, high-fidelity and extensible 3D manufacturing format (3MF), has been enhanced with additional capabilities. Specifically, the tool has new analysis capabilities for determining support structure material as well as a thickness/gap analysis check, which flags small features or gaps that could possibility fail, particularly when creating a scaled down version of a part, says Mark Rushton, product portfolio management at Dassault Systèmes.

In addition to melding specific 3D print functionality into CAD programs, vendors are also focused on building bridges between CAD and 3D printing environments so that engineers can move seamlessly between the two. SpaceClaim's STL Prep for 3D printing modules lets users work directly with STL files to shell and scale models or to split models to add features as needed as well as clean up common bad geometry issues related to wall thickness, watertight models and self-intersecting triangles, officials report. The module does so by leveraging all of the solid creation and direct editing tools familiar to SpaceClaim users. "Ideally, you want to go back and forth between solid models and STL files, but there's not a one-to-one relationship," says John Graham, product marketing manager at SpaceClaim, now owned by ANSYS. "This is the next best thing."

Some industry players are addressing the CAD-to-3D printing integration challenge through partnerships like the one between Siemens PLM Software and Materialise, which



SOLIDWORKS 2017 includes a number of capabilities to ease 3D print file prep, including support for the new 3MF format and a print validation feature used to help prevent failed builds. ***Image courtesy of Dassault Systèmes.***

markets Magics, long considered a standard for 3D printing model preparation. Earlier this year, the two companies showcased a technology demonstration to integrate some of Magics' capabilities, particularly in the areas of lattice structure and support creation and nesting of models in the build platform, into Siemens NX CAD program to create a seamless experience for users, according to Bryan Crutchfield, Materialise's vice president and general manager for North America.

3D printer manufacturers are also turning to the CAD world to ease 3D model preparation. Although Stratasys has offered the Insight software for years to prepare STL files for output on its Fortus FDM printers along with Catalyst for its uPrint and Dimension offerings, the company saw an opportunity to make a universal tool that worked across printer families. In addition, it wanted to make this part of the process more accessible to engineers and laymen who didn't necessarily have the know-how or the inclination to learn Insight or who didn't require its more advanced feature set, optimized for customized tooling use cases, says Allen Kreeme, head of application engineering for Stratasys.

Leveraging its GradCAD acquisition, the new GrabCAD Print lets users prepare, schedule and monitor 3D printing jobs across the Stratasys printer line with a simpler drag-and-drop interface and working with most native CAD formats. GradCAD Print, built on the open, cloud-based GrabCAD platform, is designed to streamline the design-to-3D print workflow by eliminating or minimizing the need to export files to the STL format, Kreeme explains. "Our goal with GrabCAD Print is to get to hit the most number of installed, office-friendly machines because that's where people need the most help cleaning files," he explains.

3D Systems is also looking to streamline and simplify the experience for users of its plastic and metal-based 3D printers. 3DXpert, the system for the metals-based offerings, is an integrated platform that covers the entire metal additive manufacturing process, eliminating the need to have multiple solutions to import part data, optimize lattice creations, calculate the scan path and arrange the build platform, according to Maoz Barkai, product manager for the software. The software also eliminates the need for working with STL or other mesh models, enabling users to prepare a part for printing using history-based parametric features. "When creating supports using CAD geometry, there's no reason not to build it like you would in any other CAD system," he explains. 3D Sprint, 3D Systems' software for its plastic printers, also provides an array of analysis and repair tools and is focused on ease of use with the aim for push-button 3D printing, notes Scott Green, director of product management software for 3D Systems.

Although great progress is being made on the tool front, it's actually the in-the-trenches experience and sharing of tribal knowledge that will advance 3D printing and make model preparation challenges a thing of the past. Wohlers suggests that companies start documenting design guidelines and 3D model preparation best practices in addition to leveraging the new genre of tools that facilitate and optimize important workflows. "Individuals have years of trial-and-error experience in their heads and increasingly they need to document this information so it can be passed on to others," Wohlers explains. "The tools still have room for development and so does the talent—it's just a matter of time." **DE**

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

INFO ➜ 3D Systems: 3DSystems.com

➜ **ANSYS:** ANSYS.com

➜ **Autodesk:** Autodesk.com

➜ **Materialise:** materialise.com

➜ **PTC:** PTC.com

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

➜ **Stratasys:** Stratasys.com

➜ **Wohlers Associates:** WohlersAssociates.com

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3D Printing Help is at Hand

From rapid prototyping to manufacturing, service providers fill the knowledge gap and help design engineers meet peak production needs.

BY GIORGIO MAGISTRELLI

RAPID PROTOTYPING & MANUFACTURING (RP&M) technologies, also known as solid freeform fabrication, desktop manufacturing, direct digital manufacturing, layered manufacturing or additive manufacturing (AM) are used to physically create a design via a number of different processes that add and bond materials in layers to form manufactured objects.

RP&M technologies allow for manufacturing objects with geometric intricacy, reducing construction of many complex objects to a manageable, straightforward, relatively fast process. Moreover, in some RP&M techniques, different materials can be jointly utilized following a controlled methodology at any location in a piece.

Remember though, that RP&M describes a variety of processes, aiming at quickly creating three-dimensional physical parts from virtual 3D computer models using automated machines. The parts are directly manufactured from a 3D CAD model and can match it very closely (within the precision limits of the chosen process). It is therefore different from traditional fabrication, only possible using computers and software both to generate the 3D CAD model data, as well as to control the mechanical systems of the machines that build the parts.

Though RP&M processes are different, the basic operating principles are very similar. The basic AM process includes the following eight steps:

1. Construct the CAD model.
2. Convert the CAD model to STL format.
3. Check and fix STL file.
4. Generate support structures if needed.
5. Slice the STL file to form layers.
6. Produce physical model.
7. Remove support structures.
8. Post-process the physical model.

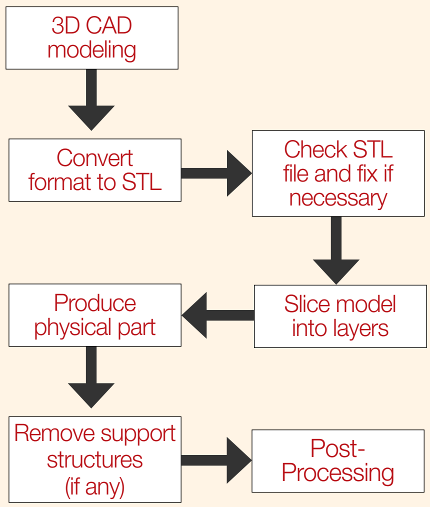
However, notwithstanding that one of the advantages of RP&M is related to design without limitation, AM often represents an unexplored opportunity due to the difficulty in using all the characteristics of (AM) technologies. The main causes are:

- sometimes engineers and designers work with conventional technologies limitations in mind;
- there is often a generation gap, and it is easier for young designers to embrace RP&M oriented design; and
- design rules for rapid prototyping and AM are specific for each process and sometimes for each material, requiring, for example, an in-depth knowledge of the minimum wall thickness and/or the minimal diameter of an internal channel of the final design.

AM Services and Materials: Where The Real Money Is

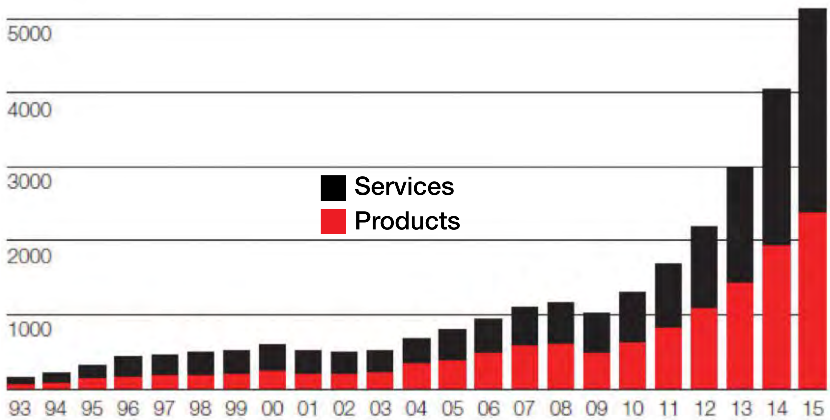
AM is constantly evolving and adjusting itself to new developments, whereas AM

The AM Process Sequence



—Source: Frank W. Liou. Rapid Prototyping and Engineering (Boca Raton, FL, CRC Press, 2008).

Revenues Are Adding Up



Revenues for AM products and services in the past six years, in millions of U.S. dollars, according to Oerlikon, a global technology group.

actors and companies in all emerging sectors are facing—or taking advantage of—sector consolidations and corporate mergers. The evolution of the technology and the extended number of applications are leading to a steady growth of materials availability; in parallel, service centers are growing worldwide—providing clients with multiple technologies and processes available in the same location and for diverse additively manufactured parts.

In fact, AM services income grew in the past six years reaching $2.8 billion, according to a December 2016 fact sheet published by Oerlikon (oerlikon.com/am/dist/media/project/Oerlikon-AM-Factsheet_I.pdf). The support available to design engineers represents a further opportunity for business development—both for providers and end users.

PolyJet technology is capable of creating multiple materials and colors in a single print. *Image courtesy of Stratasys.*

Stratasys Direct Manufacturing serves customers in a number of industries, including the energy sector, which is turning to its stereolithography, laser sintering, direct metal laser sintering and CNC machining services for applications such as rotors and stators. *Image courtesy of Stratasys Direct Manufacturing.*

Rapid Prototyping Services Worldwide

As you take advantage of rapid prototyping, numerous service platforms offer design engineers the support required to translate CAD files into 3D manufactured objects, as well as provide the required services to fill the existing knowledge gap. *Digital Engineering* contacted some service providers that offered an overview of the market situation, trends and technical services to support digital designers.

As presented by Scott McGowan, vice president of marketing at Stratasys Direct Manufacturing, the company's platform "provides a very consultative sales process," whereby account managers and project engineers engage with customers about the project, its application and use, which leads to "decisions about the technology and materials best suited and tailored for the customer's business needs." Such a consultative approach has allowed Stratasys Direct Manufacturing to "advance the technology's capabilities one application at a time."

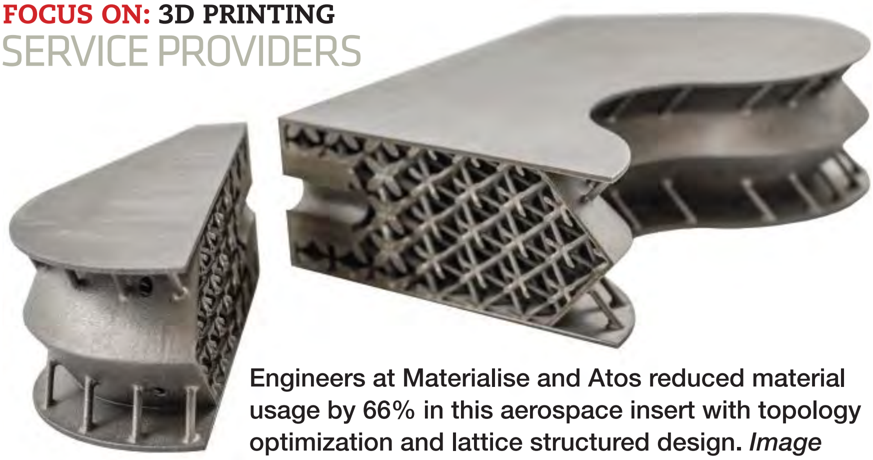
Being aware of the knowledge gap among digital engineers when it comes to rapid prototyping and AM, McGowan says "a professional services team provides advanced consultative services to further support the integration of 3D printing tailored to unique business needs and hosts training events at both company's facilities and customer sites." Training encompasses a range of topics including technologies, designing for AM, applications optimized for 3D printing and AM of production components.

Lack of knowledge is also seen by Stratasys Direct Manufacturing as a challenge for wider adoption of RP&M because "3D printing solves unique problems that are more difficult in a traditional manufacturing environment," McGowan says, and it is the "best series of technologies for projects with requirements that include lower quantities, complex designs, speed to market or a bridge to tooling."

In terms of customers' categories, top industries for Stratasys Direct Manufacturing include: aerospace (commercial and military); medical (devices and equipment); industrial equipment, and energy and consumer products. Its typical customer titles include mechanical and design engineers, as well as C-level and upper-level managers, who have witnessed the effect that 3D printing is having or recognize its potential. They are passing down the desire to assess and integrate this technology into their product development and production portfolios. Customers are located throughout the United States, Canada and Brazil.

Stratasys Direct Manufacturing sees "a lot of growth opportunities in additive metals and production components," McGowan says. "As companies learn more about what has been done with success, they are more apt to consider ways to adapt their operations to incorporate 3D printing [and foresee] less focus on new technologies and more on materials and properties that offer new applications for existing technologies."

According to Pieter Vos, marketing director of Materialise Manufacturing, the company's in-house design and engineering team supports clients by "answering to the design questions that arise at each stage of 3D printing adoption and of the product development cycle." Specifically, the company's 3DP Academy workshops are half-day or full-day events aimed at "increasing the internal knowledge on



Engineers at Materialise and Atos reduced material usage by 66% in this aerospace insert with topology optimization and lattice structured design. *Image courtesy of Materialise.*

Additive manufacturing provided the design flexibility needed for HOYA's Vision Simulator, which enables the end-user to experience the vision they will have with their new HOYA lenses. *Image courtesy of Materialise.*

3D printing within a company" on various subjects from the strengths and weaknesses of different technologies and materials, to specific customer cases. Last year the "Materialise Metal Tour" organized a series of 3DP Academy sessions across Europe, exclusively focusing on Metal 3D Printing gaining a widespread interest.

For Materialise, a key role is played by "co-creation," which bridges the existing knowledge gap while merging customers' experience and knowledge of their market with the company's expertise in AM. For example, the design and engineering team worked together with Atos to re-engineer an aerospace part in titanium and made it just one-third of the initial weight.

Materialise's customer base consists primarily of designers and process engineers in production units. As a business division, Materialise Manufacturing focuses on Europe, while i.materialise is a business-to-consumer platform that addresses individual designers around the globe.

While over the years, the possibilities for 3D printing have significantly increased with innovations in material, processes and applications, "the industry is now in transition and the next achievement will be to enhance series production and larger-volume end-use production," says Vos. Moreover, he adds that another challenge for AM service providers is to "highlight the product development benefits that 3D printing is already bringing to businesses—from lighter parts to shorter lead times to more nimble product development cycles—and thereby encourage wider adoption of 3D printing," as well as "changing the design mindset, once a business has recognized the advantages of 3D printing."

Complexity is not a cost driver for AM and parts can be designed in ways that would not have been possible with conventional manufacturing, but "designing or redesigning for 3D printing requires a new design approach," Vos says, as happened when Materialise partnered with HOYA, resulting in a virtual reality simulator that allowed customers to experience lenses before purchasing them.

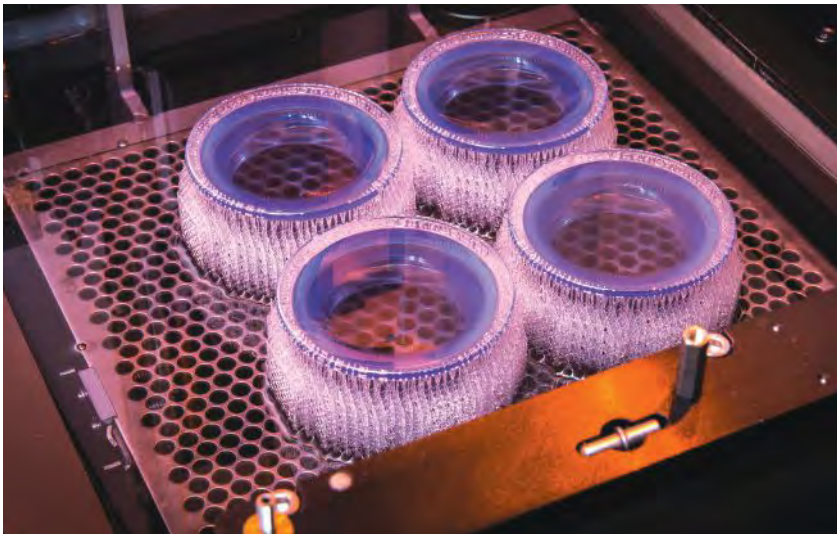
Proto Labs has seen double-digit revenue growth since entering 3D printing in 2014 when the company acquired Fineline Prototyping, followed by another acquisition in 2015 of German-based Alphaform. "What's pretty unique about our business is that we really are a technology-agnostic provider, meaning our production equipment is quite broad as it seeks to satisfy the particular project need of each and every customer," says Abby Christensen, advertising and promotions specialist at Proto Labs. "In fact, Proto Labs offers stereolithography (SL), selective laser sintering (SLS) and direct metal laser sintering (DMLS) services while PolyJet will soon be introduced as well as the new Multi Jet Fusion technology of HP."

Furthermore, CNC machining and injection molding services—both of which have been fully digitized—are also offered to "provide parts really fast (for example, cutting an aluminium tool and having upwards of 10,000 parts made in 15 days or less)," Christensen says, adding that all three services will continue to expand in the coming years.

In-house applications engineers at Proto Labs support customers—many of whom are design engineers—in optimizing parts and products for 3D printing, while also offering free webinars on metal 3D printing technology and end-use production for both metal and plastic parts.

Proto Labs customers include Fortune 100 multinationals, startups and entrepreneurs: "Although headquartered in Minnesota, Proto Labs is a global company with eight manufacturing facilities and tens of thousands of customers worldwide, coming from a multitude of industries, especially from key sectors as medical devices, consumer products, electronics, automotive, and aerospace," Christensen says.

Challenges for a wider AM adoption, in addition to the existing knowledge gap, are related to "limited pro-



Proto Labs offers stereolithography (pictured), selective laser sintering and direct metal laser sintering as well as support services in its new 77,000 sq.-ft. facility in Cary, NC. *Image courtesy of Proto Labs.*

Direct metal laser sintering enables the creation of complex internal channels. *Image courtesy of Proto Labs.*

duction quantities in the hundreds," Christensen says. "If, or when, that increases to larger volumes, there would be added value to the technology."

Dr. Tracy Albers, president and chief technology officer at rp+m, says the company "offers a complete customer service, as to understand design, applications, technologies and materials, which best suit their needs as a whole, and at the same providing the needed knowledge and translating design and ideas in manufactured prototypes."

Based 95% in the United States and Canada, the company's clients mainly work in the aerospace, defense, automotive and heavy industry sectors, with additional possible future applications in the medical sector.

One of the most relevant challenges in terms of rapid prototyping and manufacturing adoption is related to the "lack of material availability, in comparison with what is available for traditional subtractive manufacturing," Albers says, as well as the need to "help customers to totally understand the full range of opportunities represented by AM technologies." It is also for these reasons that Albers remains "conservatively bullish" for the adoption of RP&M technologies on a wider scale considering the "need to extend the knowledge of which AM applications could be more effective than subtractive ones," while aerospace and defense will continue to investigate opportunities to further incorporate design freedom and functionality of parts that are currently subtractively manufactured.

Anyshape, led by CEO Roger Cocle, "supports its customers by redesigning prototypes to ease the fabricability of the part, to decrease printing cost, to ensure proper anchoring of the part and to allow subsequent positioning during machining operation, while at the same time varying printing parameters to improve surface roughness or the material properties, to increase productivity, or to minimize the risk of crash" and for some complex parts "topology optimization or simulation to improve the printability are made internally and results or options are proposed to customers and partners."

Specifically concerning rapid prototyping, the company's multi-jet printing (MJP) systems can rapidly manufacture parts with high accuracy in high-performing plastic. MJP is the process designed to produce prototypes, mock-ups, patterns for silicon molds as well as end-use parts, while ABS-like materials offer robustness, endurance, stability, thermal resistance, sealing features and biocompatibility.

Anyshape clients are "among the main large companies in our geographical area in the sectors of aerospace, tooling and transportation and their design departments," Cocle says, as well as smaller ones "for which the design/redesign for AM printability is made without delaying their projects."

Also, for Anyshape the challenges for a wider adoption of RP&M are related to the limitation in the range of available materials, though Cocle says the company does not hesitate to qualify a new material when required by a client. "Price and timing are the key drivers," he says. "AM must be a fast track process, including the machining and post-treatment or finishing treatment, which nowadays can represent a challenge for those clients who require a ready-to-use part."

In the next five years, the market will continue to grow at a high rate as presently observed, but the ambition of Anyshape will be to "develop the AM benefits as much as possible for technological industrial companies across Europe." **DE**

Giorgio Magistrelli, *L.L.M, is a management consultant specifically focused on the regulatory and business aspects of Additive Manufacturing in mature and emerging markets. Contact him about this article via de-editors@digitaleng.news.*

INFO → **Any-Shape:** any-shape.com

→ **Proto Labs:** protolabs.com

→ **Materialise:** materialise.com

→ **iMaterialise:** i.materialise.com

→ **RP+M:** rpplusm.com

→ **Stratasys:** Stratasys.com

For more information on this topic, visit digitaleng.news.

Material Supplier	Specific Material Types	Selected Examples
3D Systems	ABS/PP, ABS/PP-like, ABS-like, Acrylic, Aluminum, Cobalt, Gypsum, Nickel, PA, PA-Glass, PC, PP-like, Rubber-like, Steel, Titanium, Wax-like	Accura ClearVue, NextDent, VisiJet M5-Black
3DCeram	Alumina, Zirconia	Alumina (3DCeram), Zirconia (ZrO2/MgOPSZ)
3DXTech	ABS, ABS-Carbon, ASA, HIPS, PA, PA-Carbon, PC, PEEK-Carbon, PEI, PETG-Carbon, PETG-Glass, PLA, PLA-Carbon	3DXMax, Firewire Carbon Reinforced PEEK Filament, iOn Nylon Filament
Additive Metal Alloys	Aluminum, Cobalt, Nickel, Steel, Titanium	AM 155, AM 625, AM Co75
Addwii	Gypsum	CMYK Full Color
Allied Photopolymers	ABS-like	KZ-1860-CL, KZ-1862-ICE, KZ-1870-WH
ALM	PA, PA-Carbon, PA-Glass, PA-Metal, PA-Mineral, PS	FR-106, PA-650, PS-200
AP&C	Titanium	Cp-Ti, Ti-6Al-4V
Apium	PEEK, POM-C, Cobalt, Titanium	PEEK 450 Natural, POM-C ESD White
Arcam	Cobalt, Titanium	Arcam ASTM F75 CoCr Alloy, Arcam Grade 2 Titanium, Arcam Ti6Al4Vm
Arevo Labs	PAEK, PAEK-Carbon, PARA-Glass, PEEK, PEEK-Carbon	Katevo, PEEK F1, Quantevo
Argyle / Bolson Materials	ABS, BS/PC	ABS (P400), ABS B31 (M-TYPE), ABSmax
Arkema	PA	Orgasol Invent Smooth, Rilsan Invent Black, Rilsan Invent Natural
Asiga	ABS/PP-like, Wax-like	Plas, PlasCLEAR, SuperCAST
BigRep	PETG, PLA, PVA	PETG Filament, PLA Filament, PRO HT
Carbon	Resin	CE220, EPU 40, RPU 80
CMET	Epoxy, Silicone-like	HS-680, TSR-510, TSR-884B
Concept Laser	Aluminum, Bronze, Cobalt, Gold, Nickel, Silver, Steel, Titanium	CL 100NB (Inconel 718), CL 42TI (Commercially Pure Titanium), Remanium star CL
Cookson Gold	Gold, Platinum, Silver	18K 3N Yellow Gold, 950 Pt/Ru (Platinum), Brillante Sterling Silver
CRP Technology	PA, PA-Carbon, PA-Glass, PS	Windform EL, Windform GT, Windform XT 2.0
Diamond Plastics	—	Laser HDPE HX 17, Laser PP CP 22
D-MEC	Epoxy, Oxycetane Resin	SCR11120, SCR751, SCR950
Dreve	—	PLASTCure Cast 100, PLASTCure Clear 100, PLASTCure Flex 100
DSM	PA, TPC	Arnitel ID 2045, Novamid ID 1070
DSM Somos	ABS-like, ABS/PBT-like, PP-like	Somos 14120, Somos NanoTool, Somos ProtoTherm 12110
DWS Systems	ABS-like, Gypsum-like, PP-like, Rubber-like, Wax-like	AB 001 (White), GM08B (Black), TEMPORIS
EnvisionTEC	ABS-like, Gypsum-like, PA, PBT, PC, PE, PEEK, PEI, PEKK, PET, PP, PP-like, Silicone-like, Wax-like	ABS Flex M Series, Ortho Tough M, PolyPro MAX 3SP
EOS	Aluminum, Bronze, Cobalt, Nickel, PA, PA-Carbon, PA-Glass, PA-Metal, PEEK, PS, Silicate, Steel, Titanium, TPE	EOS Titanium Ti64ELI, PA 1102 Black, PrimePart Plus PA 2221
Evonik	PA, PEEK	VESTAKEEP AM 9000, VestoSint Z2611
ExcelTec	PA	Innov'PA 1350_Etx, Innov'PA 1550_Xs, Innov'PA 3450_GBx
ExOne	Carbon-Metal Composite, Chromite, Cobalt, Glass, Iron, Nickel, Refractory Metal, Steel, ircon	316 Stainless Steel, FS 001 ExOne silica sand, Tungsten Carbide
Fabrisonic	Aluminum, Copper, Gold, Refractory Metal, Silver, Steel, Titanium	Aluminum 1100-H18, Pure Copper (99.9), Stainless Steel 309
H.C. Starck	Cobalt, Nickel, Steel	AMPERSINT 0032 CoCrMo, AMPERSINT 0168 Ni-SA, AMPERSINT 1556 FeNiCoMo (18Ni300)

Material Supplier	Specific Material Types	Selected Examples
Hoeganaes Corporation	Titanium	AncorTi Ti6Al4V Grade 23, AncorTi Ti6Al4V Grade 5
HP	PA	HP 3D High Reusability PA 12
Hunan Farsoon	PA-Carbon, PA-Glass, PA-Mineral	FS3250MF, FS3400CF
Kevvox	ABS-like, PP-like	Beige (LC 120), Dental Stone, Castable
Lehmann&Voss&Co.	PP, TPU	LUVOSINT 65-8824, LUVOSINT X92A-1, LUVOSINT X92A-2
Lithoz	Alumina, Zirconia	LithaCon 3Y 610 Purple (ZrO2), LithaLox HP 500 (Al2O3)
LPW	Aluminum, Cermet, Cobalt, Copper, Nickel, Steel, Titanium	LPW 316 (316L), LPW AlSi12, LPW WC CoCr
Mcor	Paper	Letter, A4
MarkForged	PA, PA-Aramid, PA-Carbon, PA-Glass	Carbon Fiber FFF, Kevlar FFF, Nylon FFF
Material Technology Innovations (Mti)	Cobalt, Steel	MTI C01 (CoCr), MTI S01, MTI S10
Molecule Digital	—	Jg - Flexible, Pr - Rigid, Ss - Super Stretch
NanoSteel	Steel	BLDRmetal J-10, BLDRmetal J-11
NextDent	—	NextDent C&B, NextDent Model Ortho, NextDent SG
Oerlikon Metco	Cobalt, Nickel, Steel	MetcoAdd 718A, MetcoAdd 75A, MetcoAdd 78A
Optomec	Aluminum, Carbon-Metal Composite, Cobalt, Copper, Nickel, Refractory Metal, Steel, Titanium	Composite CrC, Aluminum 4047, Stainless Steel 420
OSAKA Titanium Technologies	Titanium	TILOP64-150, TILOP64-45
Oxford Performance Materials	PEEK, PEKK	OXPEKK OXFAB
Praxair	Cobalt, Nickel, Steel, Titanium	Fe-271 (316 Stainless Steel), Ni-914 (Pure Nickel), Ti-201 (Ti Aluminide)
Prodways	PA, PA-Carbon, PA-Glass, PA-Mineral, PU	PA11-GF 3450, PA12-GFX 2550, PLASTCure Model 200
Push Plastic	ABS, PC/PBT, PRTG, PLA	Push Plastic PC/PBT, Push Plastic PLA, Push Plastic Premium ABS
Renishaw	Aluminum, Cobalt, Nickel, Steel, Titanium	CoCr-0404, Renishaw Inconel 718, Ti6Al4V ELI-0406
Rize	—	Rizium One
Sandvik	Cobalt, Copper, Nickel, Steel	430L (Sandvik), F75 (Sandvik), IN625 (Sandvik)
Sino-Euro Materials Technologies	Nickel, Titanium	Superalloy EP741NP (0-45 microns), Superalloy Inconel 718 (45-105 microns), Ti6AI-4V (45-105 microns)
Sinterit	PA	Sinterit PA12
Sintratec	PA	Polyamide 12
SLM Solutions	Aluminum, Cobalt, Nickel, Steel, Titanium	SLM Solutions Inconel 625, Pure Titanium, CoCr ASTM F75
Solidscape	—	3Z LabCAST, 3Z Model
Solvay	PA	TECHNYL XP 1501/F, TECHNYL XP 1537/A
Stratasys	ABS, ABS/PP, ABS-like, Acrylic, ASA, PA, PC, PEI, PP-like, PPS, Rubber-like, Wax-like	Tango Plus, VeroClear RGD810, ULTEM
Structo	ABS-like, PP-like	Structomer META, Structomer PROTO+
Taulman 3D	PA, PA/TPE, PE, PETG	Alloy 910, BluPrint, T-Lyne
Tekna	Refractory metal	TEKMAT Mo-45, TEKMAT Ta-75, TEKMAT W-25
United States Metal Powders	Aluminum	AM 2024, AM AlSi12, AM F357
Valimet	Aluminum	AM-103, AM-205, AM-7075
voxeljet	PMMA, Silicate	PMMA - Polypor B, PMMA - Polypor C, Silica Sand - Inorganic Binder
Xi'an Bright Laser Technologies	Aluminum, Nickel, Steel, Titanium	BLT-G09 (17-4PH), BLT-S22 (HX), BLT-T08 (TA15)
ZRapid Tech	PA, Resin	PA-RP125, ZR60, ZR90

The information in the table above is courtesy of Senvol, a provider of data for additive manufacturing. One data product Senvol provides is the Senvol Database, which is a comprehensive database for industrial additive manufacturing machines and materials. For more information on any of the above materials, visit the Senvol Database – which is online and free to use – at senvol.com.

SENVOL®

Consumer Convenience, Professional Printing

The Ultimaker 3 is a "prosumer" 3D printer up to the rigors of professional design engineering work.

BY JAMIE J. GOOCH

WHEN Ultimaker released its Ultimaker 3 in October last year, the company described it as a "next-generation professional 3D printer." Ultimaker has a good reputation among the Maker crowd, so we were eager to see if the Ultimaker 3 would stand up to the demands of professional design engineers.

The Ultimaker 3 is offered with a 8.5x8.5x7.9-in. build volume. For those who need bigger prints, the company also offers the taller Ultimaker 3 Extended, which provides an extra 3.94 in. (100 mm) of building space. We reviewed the Ultimaker 3, which features dual extrusion for 3D printing with two different materials or materials of different colors; smart material detection via near-field communication (NFC) technology; active bed leveling; integrated Wi-Fi capabilities in addition to USB and Ethernet connections; and a built-in camera for remote monitoring of print output. Other than the dimensions, the two printers have the same specifications.

Unbox and Print

Unlike some early 3D printers aimed at hobbyists, the Ultimaker 3 is shipped fully assembled with everything you need to begin 3D printing, including a power supply and cable, spool holder, glass plate, two 350-gram spools of filament (PLA and PVA), USB and Ethernet cables, two swappable 0.4 AA (general purpose) print cores and a swappable 0.4 BB (intended for PVA support material) print core. The company even throws in an empty USB stick, a glue stick, grease, hex wrenches, a test print, and a calibration card and XY calibration sheet. "Throws in" is a poor choice of words. The components are carefully packaged in a way that reminded us of unboxing an Apple product. In addition to the hardware, its Cura 3D (version 2.3) print preparation software and Ultimaker app for iOS and Android are free to download.

The white 3D printer would be at home in any modern office. It has frosted glass sides that allow the glow from the printer's light (a necessity for the onboard camera) to shine through for a suitably futuristic aesthetic. With a footprint of less than 14x20 in., it takes up less space than many inkjet printers.

Following the included quick-start guide, we removed some bubble wrap and tape, attached the spool holder to the back, slid the glass build plate into place, plugged the power cord into a standard 120-volt outlet and hit the power button. After a few seconds the Ultimaker 3's onscreen display lit up with the company's logo and walked us through snapping in the print cores, loading the filament and connecting the printer to our Wi-Fi network. Because the Ultimaker filament contains NFC tags, the printer was able to automatically detect when we loaded the PVA and PLA materials. Once connected to Wi-Fi, we updated the printer's firmware and were ready to print. All totalled, unboxing through initial setup took less than an hour and was accomplished via a scroll wheel and the printer's on-screen menus.

We found the scroll wheel to be touchy, sometimes making it difficult to select the option we wanted on the first try. At times, after accidentally clicking an incorrect menu item, we wished there were a "back" or "cancel" option on the screen. Sometimes this option existed, but other times it did not. Once we installed the app and Cura software, we found the click wheel to be a handy secondary interface at times, but was not our first choice.

DUAL EXTRUSION print cores in the Ultimaker 3 are easy to quickly swap for different material combinations. *Image courtesy of Ultimaker.*

THIS TEST MODEL took 4 hours and 3 minutes to print at high quality without supports. It measures 3.94x3.94x0.93 in. *Model courtesy of ctrlV.*

Print Speed and Quality

Without bothering to calibrate the 3D printer, we started melting plastic. We threw job after job at it—multiple small models in the same build, large models, fast drafts and high quality prints—intending to test the 24/7 type of use the printer might see in a small design engineering shop. The 3D printer's self-leveling bed can only be fully appreciated if you've used a 3D printer without one. Before a print, the Ultimaker 3 quickly checked level by touching the hot end to the bed, adjusting itself as needed and then cleared the nozzle. Soon it was humming along on a print, emitting less noise than our inkjet printer.

For the most part, we accepted the Cura 3D slicing software's recommended settings based on the printer, model, material and output quality layer heights (draft 0.2mm; fast 0.15mm; normal 0.1mm and high 0.06mm); chose an infill percentage and whether we wanted supports. More fine control of various aspects of the 3D printer are available (fan speed adjustments, hot-end and bed temperatures, infill types, Z-hop adjustments and many more), but are behind a clean interface that is welcoming to beginners. Of course, the printer can be used with other 3D printing software as well.

We were quickly able to test the printer's 24/7 operation because a model roughly 5x5x4 in. at a high quality 0.06mm layer height without supports took 29 hours to complete. With PVA supports suggested by Cura, that same model would have taken more than three and a half days to print. The good news, the 0.06 mm resolution looked great (the normal 0.1mm layer height would be acceptable for many prototypes) and the printer had no hiccups printing day and night. We could check the progress via the built-in camera's video feed over our phone or the Cura desktop software. The bad news, as with any 3D printer, you will be balancing time vs. resolution and tweaking default settings to get the support and quality you need in an acceptable time frame.

After days of near continuous use, we used up the included Ultimaker PLA material. We also tested non-Ultimaker PLA and ABS materials with the Ultimaker 3. This meant we had to manually select the type of material, rather than the printer gathering that info via NFC. It took just a few seconds to do so, making it difficult to recommend the higher cost ($49.95 for 750g of PLA) of Ultimaker's smart spools. The off-brand PLA filament ($15 for 1kg of PLA) worked perfectly, but we had some trouble getting the off-brand ABS to adhere to the print bed. Though admittedly, we didn't try workarounds like taping off the build plate or tweaking its temperature. All told, we went through more than 3 lbs. of material, running the 3D printer with very few breaks. Other than the non-Ultimaker ABS adhesion issue, the only failed prints happened when the 3D printer ran out of material.

Value and Verdict

For professional design engineers who need to spend more time creating innovative products and less time tweaking 3D printer settings to get a good prototype, the $3,495 Ultimaker 3 offers push-button 3D printing conveniences. Some, such as its dual extrusion and self-leveling capabilities, offer more value than others, such as the NFC material identification. For design engineers who want to invest the time to learn to be as efficient as possible with their 3D prints, Ultimaker offers a plethora of self-help guides, videos and active user forums. The Ultimaker 3 is a good example of the evolution of desktop 3D printers into something easy enough for a first-timer to use without reading a manual, but powerful enough for many professional prototyping applications. **DE**

Jamie Gooch *is editorial director of* Digital Engineering. *Contact him via jgooch@digitaleng.news.*

INFO → Ultimaker: Ultimaker.com

Ultimaker 3

- **Ultimaker 3 (reviewed, 8.5x8.5x7.9-in. build volume):** $3495
- **Ultimaker 3 Extended (8.5x8.5x11.8-in. build volume):** $4295
- **Size/Weight:** 13.5x19.9x23.1-in. (with tube and spools)/23.38 lbs.
- **Layer resolution:** 0.40 mm nozzle: 200 to 20 microns
- **Build plate:** 68˚F to 212˚F heated glass build plate
- **Print technology:** Fused filament fabrication
- **Print head:** Dual extrusion print head
- **Build speed:** up to 16 mm³/s
- **Print head travel speed:** 30 to 300 mm/s
- **XYZ accuracy:** 12.5, 12.5, 2.5 micron
- **Nozzle diameter/temperature:** 0.4 mm/180 ˚C to 280 ˚C
- **Nozzle/build plate heat up time:** < 2 minutes/< 4 minutes
- **Operating sound:** 50 dBA
- **Materials:** Nylon, PLA, CPE, PVA, ABS, Polycarbonate, TPU 95A

Complexity, Competition Require a New PLM Approach

Legacy IT and CAD lack readiness to drive digital transformation.

Mounting product complexity necessitates sophisticated product development platforms to foster innovation and streamline collaboration. Yet, the reality is, most traditional product lifecycle management (PLM) and product data management (PDM) systems lack the capabilities to help engineering organizations meet their objectives and accelerate time to market.

The proliferation of sensors and software, driven by demand for smart, connected products and the Internet of Things (IoT), has raised the stakes for manufacturers. Purely mechanical designs are becoming rare, as manufacturers now need to incorporate electronics and software, as well as integrate products into system designs, or into systems of systems. In addition to product complexity, manufacturers face heightened global competition, both from their traditional ranks and from new tech-savvy disruptors, which have the potential to undermine their businesses. At the same time, increased activity on the regulatory front has put pressure on manufacturers to maintain visibility on product configuration throughout the entire lifecycle.

Legacy PLM and PDM applications and related processes were designed for a simpler era and are being stretched by current-day product development processes and requirements. These systems are not adequately equipped to coordinate global collaboration among engineers in different disciplines spanning mechanical, software and electrical/electronics. They also lack capabilities for managing configurations and facilitating processes that span the entire product lifecycle, especially field maintenance and support, which is an increasingly important element of smart, connected products. The ability to collect data from products—for example, monitoring of aero engines to facilitate predictive maintenance services—or deliver key capabilities through in-service software updates is becoming a prerequisite for next-generation products.

The growing reliance on partners and suppliers for the design of critical product components also tests the capacity of existing PDM and PLM systems. Here again, existing PDM and PLM systems are often hamstrung with closed proprietary architectures and limited capacity for integration with other enterprise systems, not to mention high costs due to their traditional licensing paradigms.

Free Download to Learn More

"Making the Case for an Open PLM Platform" is a 10-page paper produced by *Digital Engineering* in partnership with Aras. It explains the need for a new way to manage engineering data and business processes, defines the four key functions of a PLM platform, provides real-world examples of the benefits of PLM platform adoption and shows you how to implement a PLM platform.

Download "Making the Case for an Open PLM Platform" here: digitaleng.news/de/PLMplatform

Fragmented IT Architectures Require an Open PLM Platform

Existing PDM systems have largely remained focused on 3D computer-aided design (CAD) data management, aiding in some of the more technical documentation and workflow aspects of engineering, but not making the leap to address broader business-related concerns. This has resulted in disconnected processes. The full vision of PLM has also struggled to get off the ground. Traditional PLM typically requires complex customizations that prevent systems from being easily upgraded, and the heavily customized data models and workflows make it extremely difficult to implement user-driven changes. For the same reasons, it becomes hard to keep the PLM system current with continually shifting market and user requirements, or to implement ongoing vendor upgrades and enhancements.

These limitations have affected the perceived benefits of PLM, which has been criticized for taking too long to implement, being almost impossible to upgrade and too narrowly focused. Legacy PDM/PLM systems have also taken a hit for their inability to accommodate the tools and processes that come into play as companies embark on partnerships and acquisitions.

Without the enterprise tools to deal effectively with product complexity, engineers are forced to circumvent PDM/PLM systems and use whatever tools and manual processes are on hand. Instead of diligently working from the same shared systems, engineers come to rely on email, phone calls, meetings and thousands of Excel spreadsheet to collaborate on designs and manage product-related data. This leads to poor visibility of critical information and undocumented workflows, requiring engineers to spend more time putting out fires, issuing workarounds and fixing problems, undermining their ability to innovate and maintain a competitive edge.

Open PLM Platform Enables Digital Thread

As digital transformation promises to disrupt more and more industries, companies are looking for a way to manage what is becoming an entirely digital thread, from the first conception of an idea for a product, through the enterprise, to the customer and back again. The potential business benefits of this transformation are massive: more efficient product design and development, new revenue streams based on services and predictive maintenance and rock solid compliance and regulatory tracking, just to name a few. The combination of customer demand for smart, connected products; the data those products can collect and access to nearly unlimited computer processing power to analyze that data is accelerating digital transformation faster than many businesses can handle with their current data management processes.

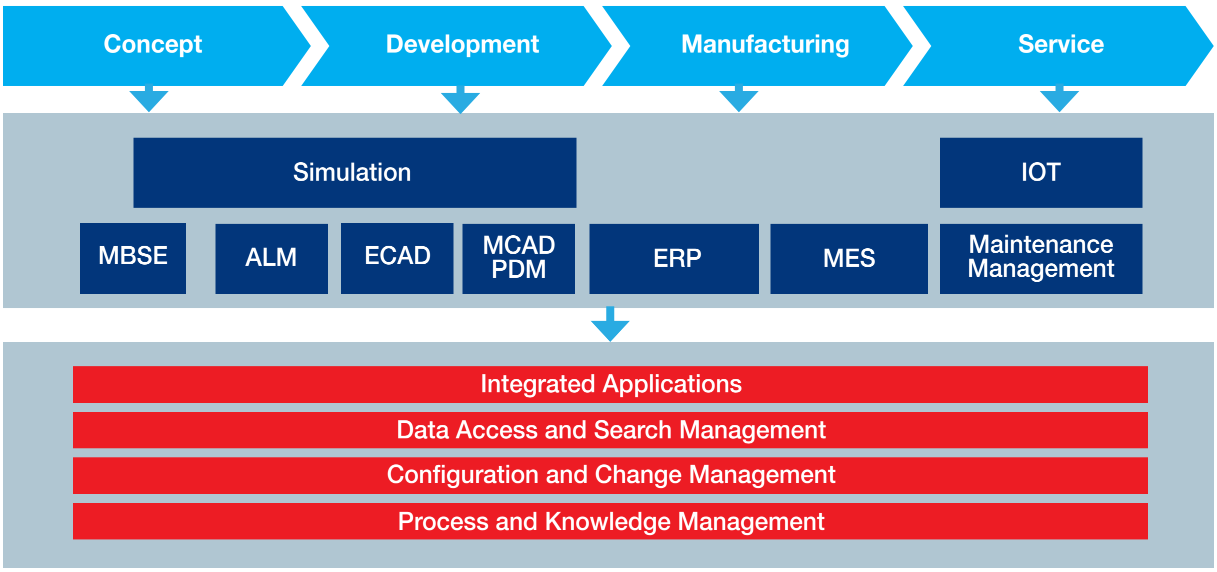
Rather than go through the costly and painful disruption of replacing existing PDM/PLM systems, a platform PLM approach promises the best of both worlds. A PLM platform encompasses a mix of integrated technologies that deliver end-to-end lifecycle management at the enterprise level along with cross-functional collaboration capabilities and through-life configuration management. Integrating existing PDM/PLM systems into a PLM platform approach is a way to protect legacy investments, maximizing the utility of those components without draining productivity or curtailing innovation.

Unlike legacy PDM/PLM systems, a PLM platform supports extended data and process integration across the extended enterprise, beyond the engineering department to other areas of the business. PLM platforms reduce or eliminate integration challenges, help reduce the costs and resources required to support technology upgrades and new capabilities and deliver greater flexibility managing intellectual assets and processes throughout the entire product lifecycle.

MORE → digitaleng.news/de/PLMplatform

THE ARAS PLM PLATFORM

Aras Innovator embraces the PLM platform approach with an open, resilient technology that is flexible, scalable and upgradable to meet the evolving needs of an extended enterprise. The Aras PLM Platform layers applications; data access and search management; configuration and change management; as well as process and knowledge management on top of existing processes.



Dealing with Stress Concentrations and Singularities

It's good know the stress peaks and distribution of high stresses, but it's better to know when they are meaningful.

BY TONY ABBEY

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

LOCAL DESIGN FEATURES, under applied loading, often result in an increase in local stress. Often the stress levels will dominate any strength analysis we carry out using finite element analysis (FEA). A theme occurring throughout my *DE* articles has been the requirement for these stresses to be as accurate as possible. In this article, I take a closer look and review the background to the accuracy objective. Do the local stresses really matter from a physical and compliance point of view?

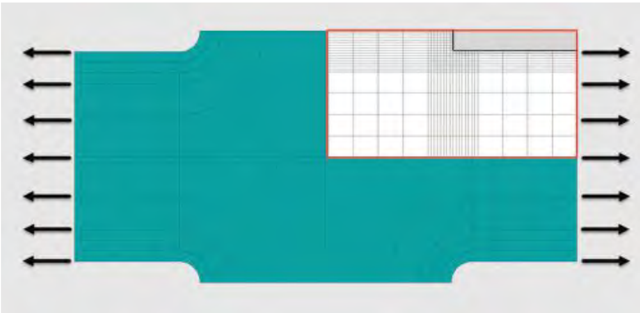


FIG. 1: Typical geometry of a shoulder fillet.

Are the Stresses Real or Imagined?

In some circumstances, the stress levels that we predict from FEA are not physically meaningful. The stress distribution and high levels of stress locally can be described as an FEA "artifact." The most common examples of where this can happen are the following:

- applying a point load;
- creating abrupt local transitions in local loading;
- constraining a model at a point;
- creating abrupt transitions in local constraints;
- abrupt transition between materials; and
- sharp re-entrant corners.

In this article, I'm focusing on the last example. We will use a typical shoulder feature as shown in Fig. 1. This represents a transition between widths of a component. It is assumed that the FEA model ignores the fillet radius and represents this as a right angle. A typical mesh, using quarter symmetry, is shown in the inset in Fig. 1. What stress will be calculated in the FEA, and is it realistic?

Fig. 2 shows the stress variation for a model with eight elements along each local edge adjacent to the right angle. A peak stress of 100,450 psi occurs. Notice how localized this stress peak stress region is. The average stress across

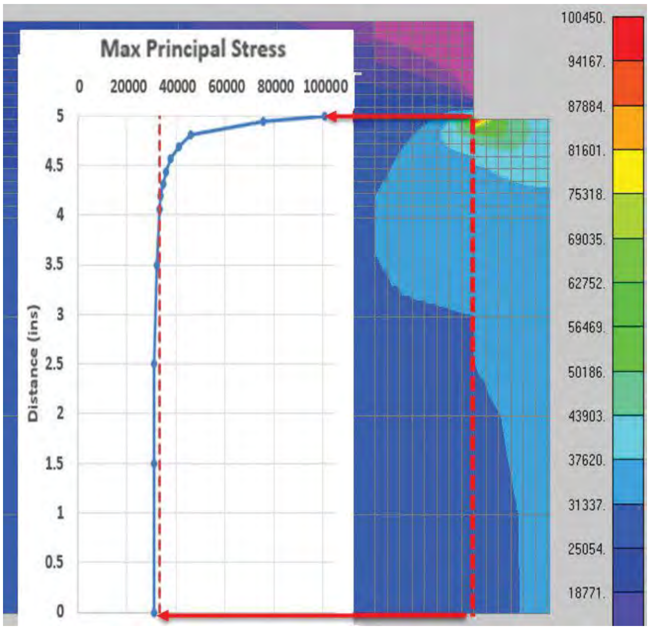


FIG. 2: Stress variation across shoulder with eight elements on edge.

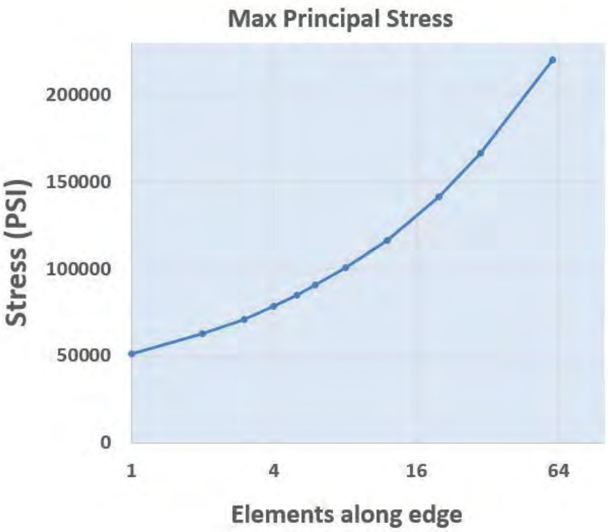


FIG. 3: Convergence study for the right angle model.

the bulk of the section is around 31,000 psi. The peak stress can be quoted as a stress concentration factor, Kt. Kt is defined as the ratio of peak stress to nominal stress. The nominal stress is defined as the applied load divided by the narrow cross-sectional area. It is important to realize that the nominal stress is not a "real" stress. It is an effective baseline stress, which ignores the influence of any local stress-raising feature. In this case the nominal stress is calculated as 33,335 psi, giving a Kt of 3.01.

Fig. 3 shows the peak stresses in the corner for a range of mesh sizes, from one element on edge to 60 elements on edge. The element edge axis is plotted on a log scale. The value of peak stress is totally dependent on the level of mesh density around this region. At 60 elements on edge, the peak stress is 220,213 psi and the Kt value is 6.61. The average stress distribution in the bulk of the cross-section remains the same. It is only the very local peak stress (and hence stress gradient) that is increasing. There is no sign of any convergence, as shown in the log-linear scales of the plot. Essentially, we will get an infinite stress as the number of elements increases to infinity.

This is a warning sign that our FEA model is not physically meaningful. An FEA model should always converge to a stress level. We have stumbled into a stress singularity. Classical elasticity theory can also be used to solve simple geometric problems like this. In fact, the handbooks of Kt values for standard geometries are based on this type of calculation. It turns out that these solutions also result in conflicting assumptions at the corner of the feature, where theoretically the stresses go off to infinity. In the limit, at very small load levels, stresses will exceed yield. This is obviously completely fictitious. By de-featuring the fillet radius, we have removed any possibility of getting an accurate prediction for what the peak stress would be in this region.

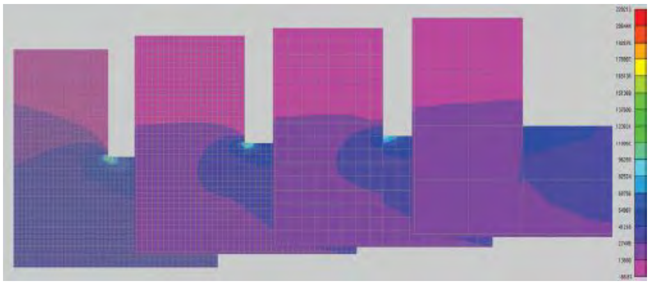


FIG. 4: Stress distributions for the right angle model.

Fig. 4 shows that this is very much a localized problem. The stress contours have been fixed at the maximum stress 220,213 psi, across all of the results for mesh size of 2, 8, 20 and 60 elements on edge.

Modeling the Fillet

The filet region with 1.0-in. radius is now modeled. The quarter symmetry mesh is shown in Fig. 5.

A series of analyses are carried out with increasing mesh density. The geometry is divided up into sectors so that careful control of the mesh and element shape is possible. One challenge of a good mesh convergence study is to keep the element shapes consistent. An arbitrary mesh will give changing aspect ratios, internal angles, etc. in the local elements and distort convergence trends.

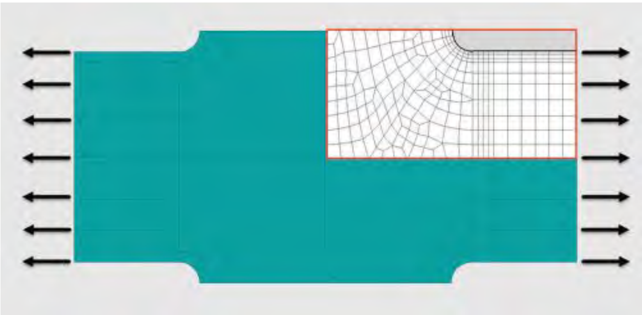


FIG. 5: Geometry and mesh of filleted model.

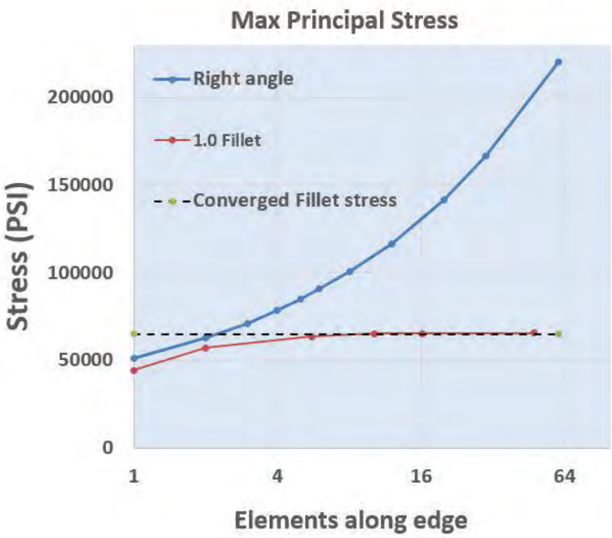


FIG. 6: Convergence study for the filleted model.

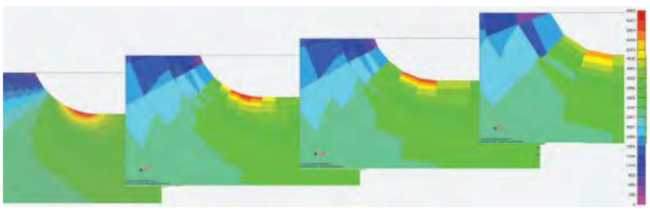


FIG. 7: Stress distributions for the filleted model.

Fig. 6 shows the results of the study. The curve labeled "1.0 Fillet" shows that the stress peak converges to a value of 65,600 psi at around 10 elements per edge, where the edge is defined as a 45° arc of the fillet. This allows broadly the same x-axis to be used for both the filleted and right angle model. A line is drawn on the graph to indicate the converged stress result. The converged Kt value is 1.97. The right angle model results are overlaid and labeled as such. As before, there is no convergence for this model.

The stress patterns for increasing mesh density are shown in Fig. 7, with a common contour range, set to the peak value of 65,600 psi. The convergence to the peak value can be seen across the plots. The location of the peak value also migrates around the fillet arc slightly. The coarser meshes are unable to give sufficient fidelity to locate its position accurately. Again, the area is extremely localized.

Reconciling Right Angle and Filleted Models

It is sometimes held to be true that a de-featured model such as the right angle model can give reasonable stress results if the element size can be tuned to a characteristic length. In Fig. 6, the right angle study intersects the converged solution at two elements per edge. We could argue that around two elements per edge on the right angle model would give the "correct" stress to match the filleted model converged results. I really don't buy into this approach as it takes a lot of data fitting to get a similitude between the actual mesh and defeatured mesh results. The only merit would be where a particular range of components is regularly analyzed and careful correlation can be made. The de-featured tuned mesh can then be used as a surrogate. A 2D study could save a lot of expensive fine mesh 3D modeling.

However, in a general case, the actual stress concentration peak is unknown, and there is not much alternative to doing a convergence study. One of the trends in commercial FEA meshers has been for default mesh density to increase. This means that a typical edge count of two is now perhaps eight. In turn, this means that a sharp corner like ours will see 100,000 psi rather than a "comfortable" 65,600 psi. Neither value has any merit, but these types of stress predictions are often used. Over the course of 10 years, a typical mesh may be at a 32 count and give 175,000 psi. This will perhaps serve to make the need for accurate modeling more obvious as the spurious high stresses are increasingly unacceptable in design.

To some extent we have had a "serendipity" effect for many years. A poorly detailed feature with an inadequate mesh has given stress levels that seem, by intuition, to be of the right order.

Does Stress Concentration Accuracy Matter That Much?

If we assume that including the geometric feature is important, so that at least we can get some order of accuracy, then the next question is how accurate do we have to be? The answer depends on the type of failure we are trying to predict and the behavior of the material.

For a strength analysis on a ductile material, traditionally only nominal stresses were calculated and reserve factors or margins of safety on limit load were based on this. The justification was always that very localized peak stress regions would yield and self-relieve. The conclusion for an FEA result, following on from the hand calculation approach, should perhaps be similar; we can ignore the localized stress and deal with nominal stresses. In the case of the fillet feature discussed here that would mean using 33,335 psi as found in the main body of the shoulder. However, with FEA, we can raise our game, and with a little extra effort get a converged stress concentration result. Now we can see a stress representation that was impossible in hand calculations. We should get reasonable accuracy via a stress convergence study and then we can decide what engineering assessment to make of that stress level. If we subsequently choose to ignore local stress concentrations, we do so on the basis of knowing their value and distribution.

If we are concerned about ultimate loading, then we can take a different approach. Hand calculations use form factors and other methods to correlate test results with simple elastic calculations. In FEA we can use nonlinear analysis to investigate further what a nonlinear relationship is. It is very difficult to model failure, but we can move toward ultimate loads. In this case, we need a very fine mesh model to track the growth of plasticity and the development of geometrically nonlinear internal forces. Good mesh convergence on a linear analysis would be a first stage in this type of analysis.

For a strength analysis on a brittle material, we need to have very accurate mesh convergence proven. There is no demonstrable margin between yield and ultimate failure. Therefore, the peak stress at the stress concentration will dictate the final failure margin. We also should not be de-featuring in this case.

For a fatigue analysis, we also need to have very accurate stresses. The stresses will be directly used in a high cycle fatigue calculation and converted to equivalent strains in a low cycle fatigue calculation. As an example, assume that the shoulder is loaded with a fully reversed cyclic loading with a stress amplitude of 65,600 psi (converged mesh value) at the stress concentration region. Assuming a medium strength steel and no environmental corrections, the life would be 221,000 cycles. If the very coarse mesh of two elements per arc is used, then the peak stress is 57,800 psi and the life would be over 1 million cycles. A medium accuracy mesh of six elements per arc gives a peak stress of 63,700 psi, resulting in a life of 315,000 cycles. It is clear that the fatigue life is very sensitive to the accuracy of the stress calculation.

The effect of a stress concentration on fatigue life is actually subtler than this. Low strength steels are not as fatigue sensitive as the stress concentration factor, Kt, would suggest. From experimental evidence a reduced factor Kf (fatigue notch factor) is used to better correlate with test. However, we have to start with an accurate estimate of Kt (or the stress gradient at the peak). The reduction in effectiveness follows as part of the fatigue life calculation.

There is a strong temptation to either de-feature or mesh poorly at geometric stress raisers. Many failure predictions do require accurate stresses with evidence of a good convergence study. Even in the case of ductile materials being assessed against limit loading, it is useful to know the stress peaks and distribution of high stresses—even if subsequent engineering judgment can discount them. **DE**

Tony Abbey *works as training manager for NAFEMS, responsible for developing and implementing training classes, including a wide range of e-learning classes. Check out the range of courses available: nafems.org/e-learning.*

Engineering the WOW Factor into Sales

Positioning virtual products in real spaces gives manufacturers an advantage.

BY KENNETH WONG

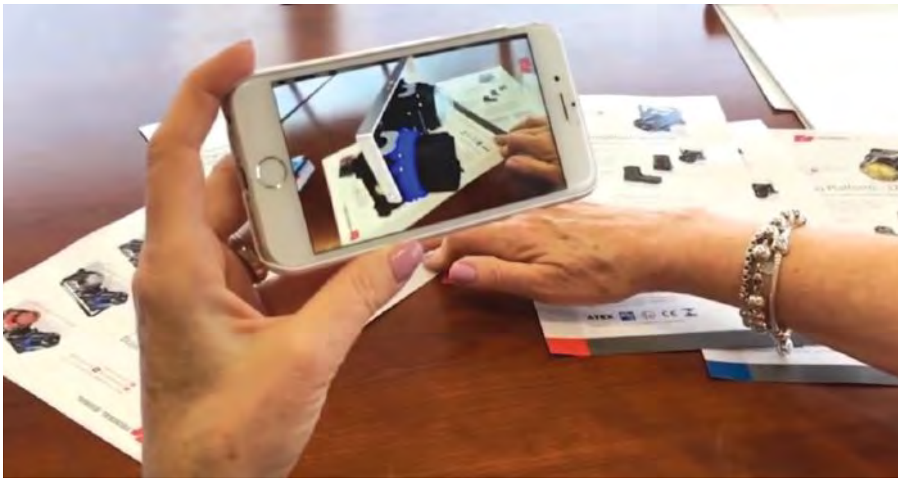
ON THE ROAD, when negotiating the distances between their vehicles and others, drivers get a helpful reminder from the safety warning "objects in the mirror are closer than they appear." In speedy e-commerce, where many products are marketed and sold on the basis of the way they look on a webpage, some consumers might benefit from the warning "objects in the digital catalog are larger than they appear."

Nirmal Chudgar, head of products for Federal Signal, discovered this when he decided to take a look at an industrial speaker, one of the biggest revenue generators in his employer's portfolio. "I'd always seen the picture of it. It seemed like a 6-in. speaker to me," he recalls. "But when the box was finally delivered to my office, it was much bigger than I'd imagined it."

Chudgar was looking at the image of the speaker in isolation on a webpage. If he had seen a photo of it sitting next to a standard tool chest or a lightbulb, he could have better judged its dimensions.

Jean-Francois Chianetta has had a similar experience while shopping online. A published review proclaims it was the biggest of its kind. But the digital photo didn't convey its scale. That's when Chianetta got the idea to develop an application to "visualize 3D models in the real world," as he put it. It eventually led to the launch of his new company, Augment, in October 2011.

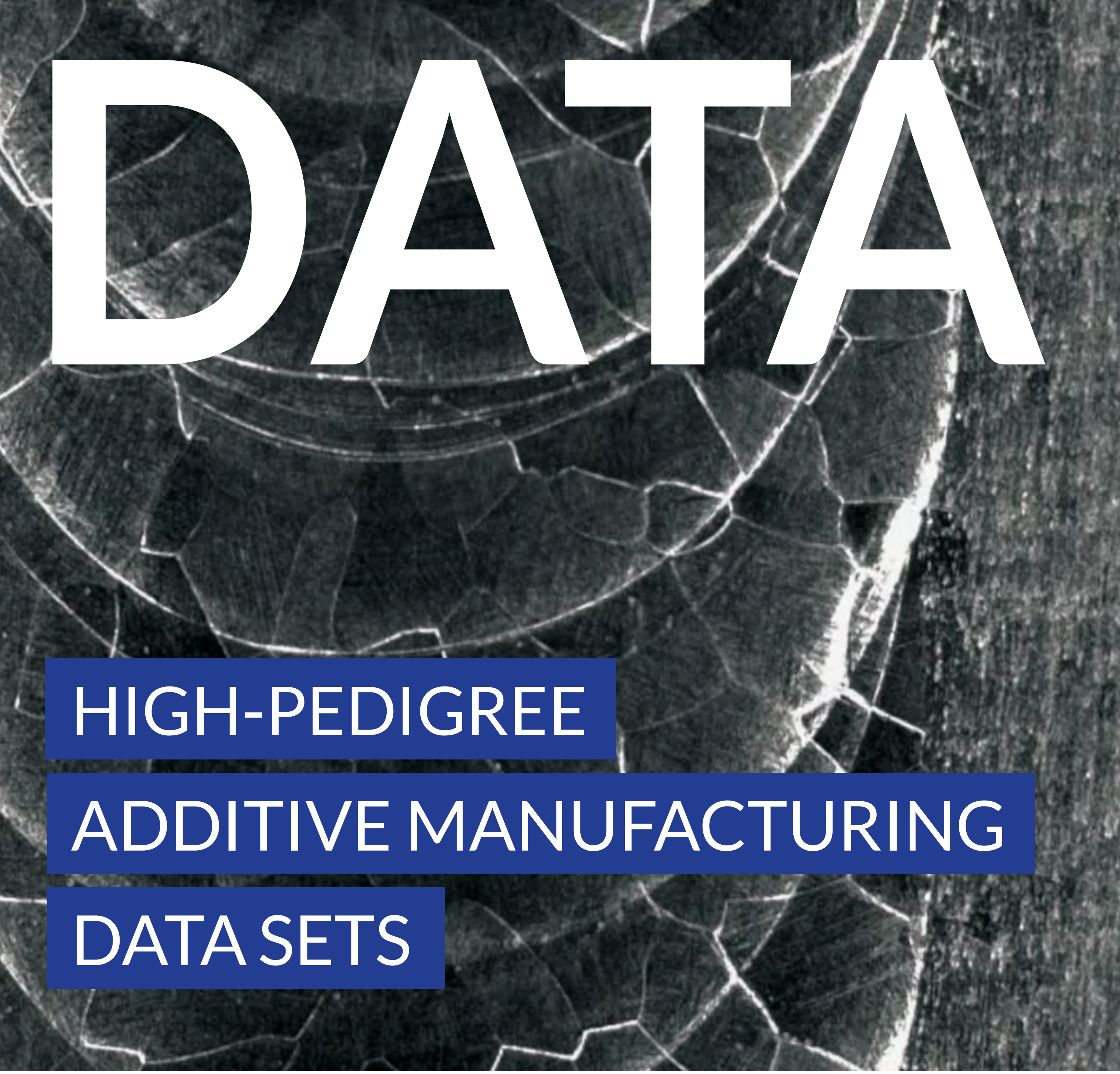
Today, Federal Signal is a client of Augment. Chudgar's sales people use Augment's technology to let clients see and experience products before the transaction. For the client, it's a chance to visualize the product in the real environment. They can, for example, understand how Federal Signal's industrial alarm systems—a combination of flashing lights, beacons and sirens—would fit into their factories and plants. For the sales reps, it's a way to impress the client with the "wow factor"—something a photo, catalog or mockup won't deliver.



With Augment's mobile app, Federal Signal customers can point their mobile device to the AR code-embedded brochure to inspect a product as if it were sitting before them in true-life scale. *Image courtesy of Federal Signal.*

AR Triggered by Printed Catalogs

Having studied mechanical engineering in Belgium and Canada, Chianetta began working as a software engineer for Coventor, which caters to semiconductor developers. The job allowed him to explore the intersection of mechanical design, 3D modeling, microelectromechanical systems (MEMS) and user interfaces. Those insights and knowledge found their way into the technology of Augment.



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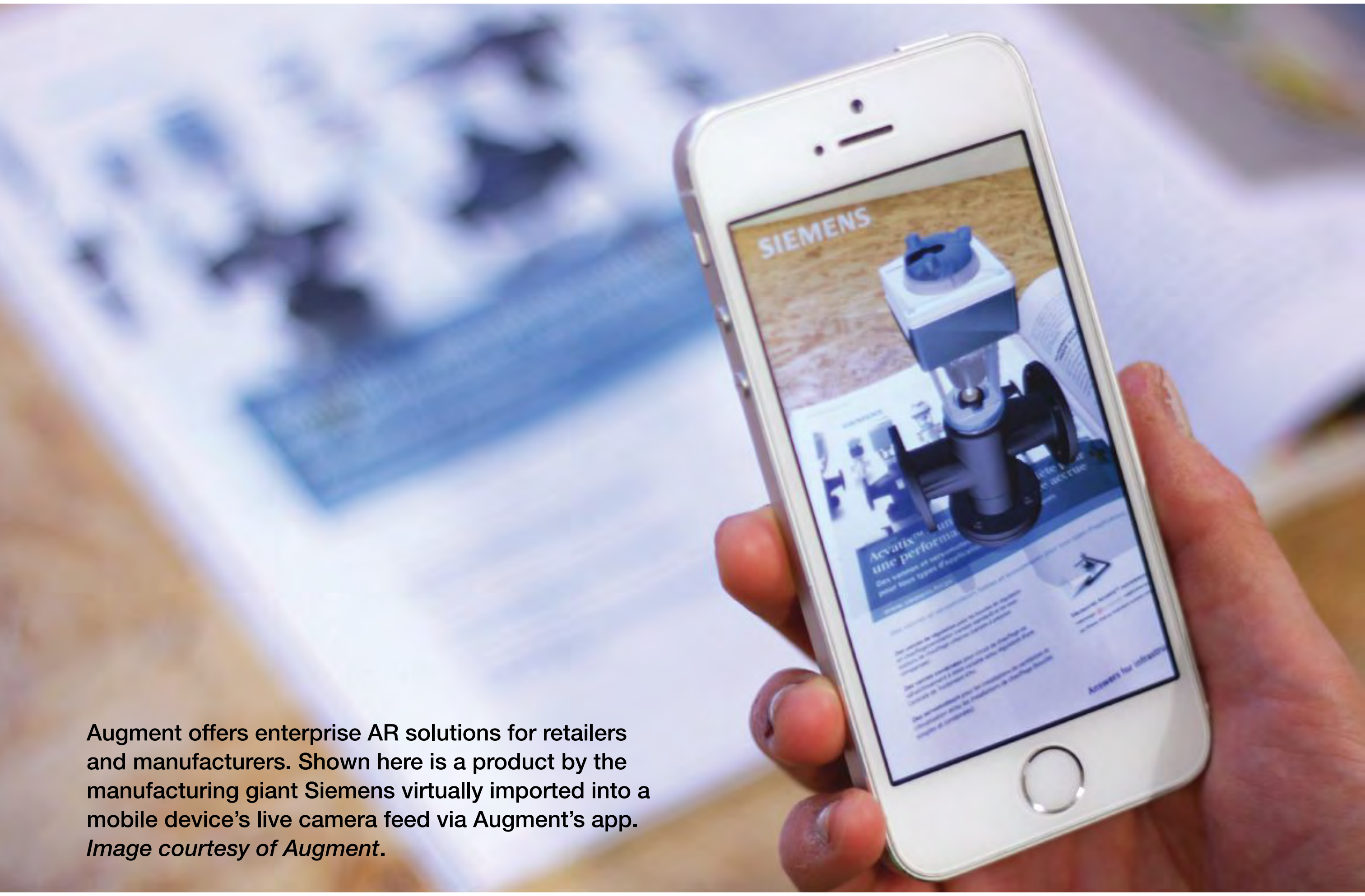


Augment offers enterprise AR solutions for retailers and manufacturers. Shown here is a product by the manufacturing giant Siemens virtually imported into a mobile device's live camera feed via Augment's app. *Image courtesy of Augment*.

Augment targets two segments in particular: manufacturing and retail. It operates with 40 employees from 14 countries, and has 200 clients in 36 countries. It offers a software developer kit (SDK), a desktop program and a mobile app. The desktop program allows you to apply materials to your 3D CAD model, apply animation triggers, refine it and upload it to the cloud. The Augment mobile app can interpret a marker—a paper printed with a computer code—as a 3D model. Therefore, you can use the app to point at a marker to virtually import a 3D model into the live camera view.

With this technology, you can "make your brochures and catalogs interactive ... [and] let customers unlock your entire inventory of products to try at home through a scan of your 2D marketing collateral," Augment explains on its website.

A Memorable "Wow Factor"

Some view augmented reality (AR) apps as an offshoot of the videogame market; good enough for entertainment but not for serious business. Others stay away from what they view as early phase technology with room for improvement. But Chudgar thinks being an early adopter gives Federal Signal an advantage.

"Popular technologies don't always get adopted early in the industrial market," Chudgar explains. "So this gives us the 'wow factor.'"

When Federal Signal employees visit clients, they still bring catalogs and brochures, but when viewed with the Augment mobile app, the predesignated markers in those brochures come alive. They become 3D models that can be rotated, reoriented, inspected from different angles and distances—and even positioned roughly in the spot where they might be installed after purchase.

"Our products in the latest Global Series, for instance, are industrial size beacons and speakers. They're meant for hazardous environments, like oil refineries. A lot of them get installed in places with risk of explosions," Chudgar says. With a simple photo, "[the client will] remember that the product is bright, or loud, but it doesn't make the same impression," he says. "[Augmented reality] gives the client another reason to remember the product."

What Happened After You Left

When it comes to recordkeeping and analytics, the cloud offers a much better paper trail than traditional paperwork. The mobile app collects viewing data in a way that's unobtrusive. After a client visit, the sales rep doesn't have to pester a prospective client with another email or a phone call to inquire if he or she has had a chance to look at the brochure and discuss it with the purchasing manager. The mobile app offers analytics that reveal what happens to the AR code-embedded brochure after the sales call.

"We can actually track who is viewing [the 3D model], and how often, so we can tell if the demo is popular or not," Chudgar says. The analytics function is part of a supplementary package that Augment offers.

Often, Federal Signal wants to give its top-tier clients a sneak peek or preview of its upcoming products still under development, and the Augment mobile app is the perfect delivery vehicle. For a start, the product only exists as a 3D model because it hasn't been built. Further, previewing it inside a mobile app works well as an intellectual property protection measure. Unlike a detailed CAD model, the low-resolution, lightweight model inside an AR app cannot easily be exported and used to reverse-engineer a product.

Chudgar says that, with the Augment app, he feels comfortable showing the products still in R&D even at crowded tradeshows. "I can do it without any of our competitors walking by and discovering what the new product looks like," he says. A mockup or a prototype displayed on a table, on the other hand, would be accessible to everyone at a tradeshow, including Federal Signal's competitors.

Quest for Interoperability

This year, at CES, 28 technology firms came together to form and launch the Virtual Reality Industry Forum (VRIF), a nonprofit organization to advance the widespread availability of high-quality audiovisual VR experiences for the benefit of consumers.

"The primary stated goal of the forum is to allow end-to-end interoperability. People who joined this forum understand this market won't really take off unless there's good interoperability and it's a high quality experience for the consumer," says Rob Koenen, the principal of TNO, a Dutch research and development organization, and a member company of the VRIF. "But the market is still nascent, so there are still lots of proprietary solutions. VR360 [immersive VR experiences that allow you to look around and navigate virtual environments] is possible today, but not necessarily efficient. But standards for this are emerging now."

AR and VR are sibling visualization technologies. Many hardware and software makers who cater to the visualization market are developing applications for both AR and VR. In AR, digital content is seamlessly blended into the real world surroundings. In VR, digital content is usually delivered as an immersive experience.

The Handoff

Federal Signal uses SOLIDWORKS, a mechanical CAD software package, to design its products. AR programs typically do not display 3D models in native CAD formats due to compatibility issues and large file sizes. CAD models are intended as faithful representations of the products to be manufactured, down to the nuts, bolts, rounded edges and holes. The level of geometric details is overkill for AR visualization, so a conversion process is needed to prepare the CAD models for AR applications. Such conversions are partially automated in some AR content publishing programs, but they are seldom fully automated.

Chudgar says his company contracted Augment for some conversion and rendering services. He wants AR vendors to offer much simpler conversion and publishing tools. "Businesses usually don't have a budget for AR," he says. "It's an add-on, so not every company can spend a few more thousands for file format conversion or rendering. The more DIY, the better it is."

The AR Race

The transition from CAD to AR/VR content will gradually improve as more CAD software developers invest in the development or acquisition of AR/VR technologies. SolidWorks, the company behind the SOLIDWORKS CAD software, has already added AR functions to its free file viewer eDrawings, available for mobile devices. Dassault Systemes, the parent company of SolidWorks, acquired RTT (Realtime Technology) in 2013. The transaction made RTT's AR product line part of the Dassault Systemes portfolio. RTT has since been rebranded as 3DEXCITE. PTC, another CAD software maker, acquired the AR firm Vuforia in 2015 as part of its strategy to enable the creation of digital twins.

Chudgar thinks AR is not just an effective tool for sales and marketing, but also for engineering and product development. "What's important is getting the full perspective," he says. "If the engineers look at a virtual car mockup in isolation, they can't tell how big or small it is, but with a house behind it, it gives a much better perspective." **DE**

Kenneth Wong *is DE's resident blogger and senior editor. Email him at de-editors@digitaleng.news or share your thoughts on this article at digitaleng.news/facebook.*

INFO ➜ **Augment:** augment.com

➜ **Federal Signal:** fedsig.com

➜ **RTT/3DEXCITE:** 3dexcite.com

➜ **SOLIDWORKS eDrawings:** edrawingsviewer.com

➜ **Virtual Reality Industry Forum:** vr-if.org

➜ **Vuforia:** vuforia.com

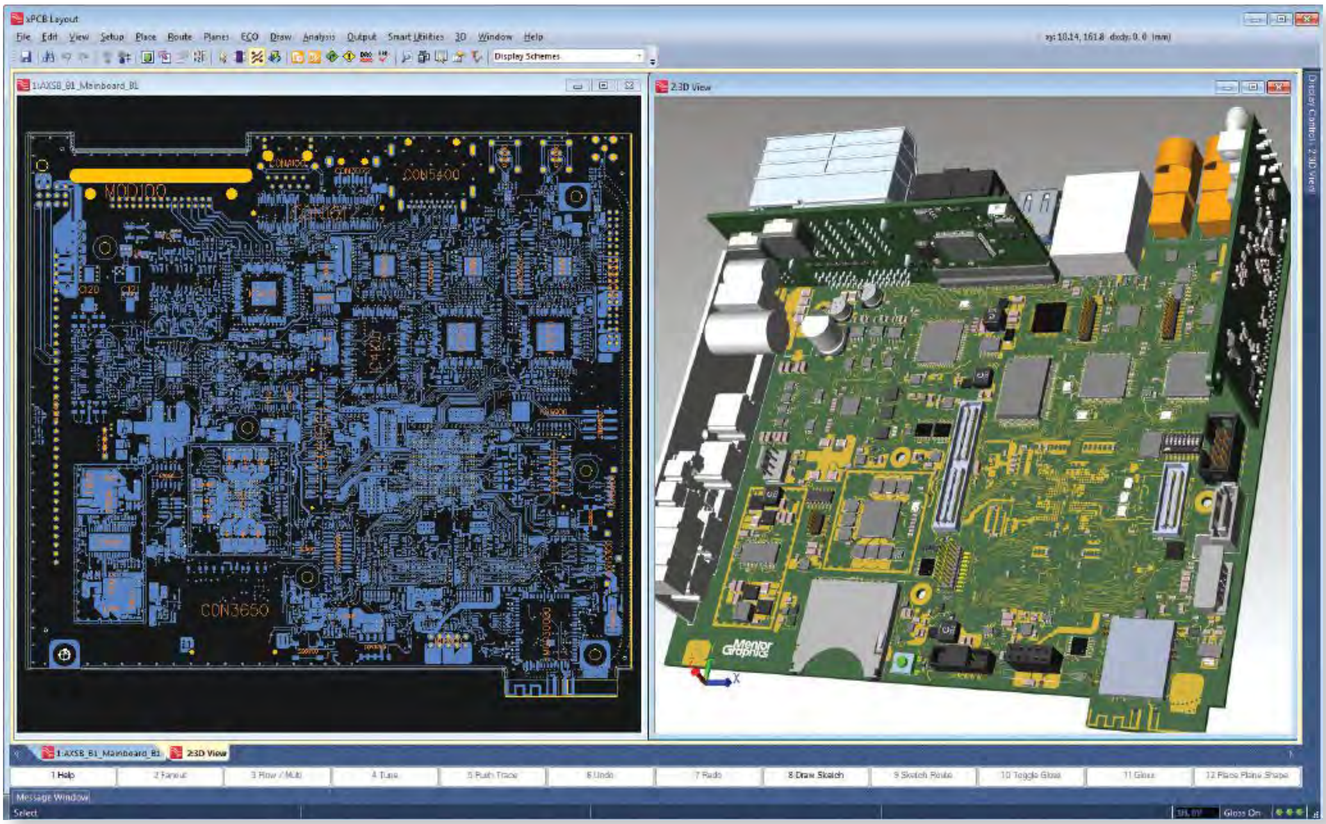
For more information on this topic, visit digitaleng.news

Bridge Building in Progress

The IoT demands a stronger link between electrical and mechanical design disciplines.

BY KENNETH WONG

DAVID WIENS QUIPS that electrical-mechanical design collaboration is sometimes facilitated by "a voice-driven mouse"—one engineer standing over another's shoulder, issuing instructions about the changes needed. Regarding efficiency, Wiens thinks this method is just as bad as swapping electrical CAD (ECAD) and mechanical CAD (MCAD) files by email.



A co-working environment with visibility into changes in MCAD and ECAD design, as exemplified by the solution shown here from Mentor Graphics (recently acquired by Siemens PLM Software), lets mechanical and electrical engineers efficiently collaborate with each other. ***Image courtesy of Mentor Graphics*****.**

Notable Recent MCAD-ECAD Mergers, Acquisitions and Partnerships

- **Siemens PLM** Software acquires ECAD developer Mentor Graphics (April 2017)

- **Dassault Systèmes** acquires electromagnetic and electronic simulation software maker CST (July 2016)

- **SOLIDWORKS** partners with ECAD developer Altium to develop SOLIDWORKS PCB, an interoperability solution (February 2016).

Wiens is the Xpedition product marketing manager for ECAD developer Mentor Graphics, recently acquired by Siemens PLM Software, a division of the manufacturing giant Siemens AG. Historically a CAD and product lifecycle management (PLM) provider, Siemens PLM Software is bringing an ECAD developer on board in recognition of the growing importance of the electronics in connected devices and IoT commerce.

Dassault Systèmes, a rival of Siemens PLM in CAD and PLM, recently acquired the electromagnetic and electronic simulation software maker CST. SOLIDWORKS, the division of Dassault Systèmes responsible for the popular SOLIDWORKS MCAD software, struck up a partnership with ECAD maker Altium to develop an MCAD-ECAD interoperability solution, dubbed SOLIDWORKS PCB.

Due to the distinctly different types of geometry each discipline must create, a single modeling package for MCAD and ECAD is unlikely. So the best approach may be to "enable dynamic/concurrent visualization of changes made in ECAD and MCAD environments," says Wiens.

Bridge Building

Previously, ECAD meant 2D schematics of printed circuit board (PCB) designs. But today, many ECAD modeling programs have 3D modeling features. These tools are necessary because circuitry and board designs have evolved to include bendable, flexible PCBs and PCB stacks that are difficult (or, some might say, impossible) to represent in 2D drawings. However, many standard 3D mechanical modeling features like surfacing tools, spline tools, sheet metal tools and subdivision modeling tools would be irrelevant to the electrical design discipline. Although they are necessary to produce the smooth surfaces and aesthetically pleasing shapes preferred by industrial designers, they are of little or no use to PCB designers. Therefore, a single consolidated modeling package for both disciplines seems ill-advised. What the two disciplines need is a bridge—a 3D visual environment where MCAD and ECAD models can come together for collision and clash detections.

"Naturally, users prefer to work in their own respective ECAD and MCAD software. However, there are strong reasons for the design to be fully available and also interoperable for other downstream processes and use cases, be that for supplier work-in-progress or final manufacture," says Annalise Suzuki, director of technology and engagement, Elysium. Elysium develops interoperability solutions for digital design and product lifecycle management (PLM) markets. Its products focus on translating, repairing and ensuring product data quality for 3D CAD/CAM and CAE models.

"ECAD and MCAD are very different systems and work to integrate them is still in progress. This will be challenging; in addition to software integration there are the issues between two completely separate teams/cultures/architectures," says Alexander Christ, technical expert, Elysium.

"Today's ECAD and MCAD engineers/designers typically prefer to work in their own respective environments, mostly because there have not been any other alternatives," says Linda Mazzitelli, PTC's segment solution director for PLM. "These collaborative design environments currently rely on the exchange of a data file between them to ensure alignment.

Once a CAD and PLM company, PTC transformed itself in the last decade into an IoT technology provider. A milestone in its metamorphosis was the 2014 acquisition of ThingWorx, which offers a platform to develop applications for connected devices. Prior to that, in 2011 PTC acquired MKS, which provides software lifecycle management solutions.

PTC also offers the PTC Creo MCAD-ECAD Collaboration Extension, a module based on the company's own proprietary technology. The add-on component allows MCAD and ECAD users to see each other's updates at the geometry level.

"Mentor Graphics and Siemens PLM currently leverage 3D information between each other," says Joe Bohman, senior VP of lifecycle collaboration software, Siemens PLM Software. "We will continue to enhance the customer business process between mechanical and electrical so that cross-domain decisions can be made quickly and easily."

The Impact of IoT

Traditionally, MCAD and ECAD users collaborate by setting up clear boundaries: While working on the housing or shape of the product, the MCAD user leaves sufficient room for the anticipated electronics, circuitry and PCBs in the design. The ECAD users design their components within the prescribed specification so the completed work can fit snugly into the housing. This approach may still work with larger assemblies (household appliances, for example).

However, with connected devices for the IoT era, the interdependencies between the outer shape and inner electronics make the traditional approach inefficient. In a mobile tablet or a smart watch, for example, any changes made to the outer shape is bound to alter the location and orientation of the inner circuitry, battery and PCB layout. Conversely, even slight repositioning of the inner components would need to be accommodated by modifications in the housing; hence, the need for an MCAD-ECAD co-working environment.

"Mechanical drives electrical most of the time," notes Christ. "In long-term projects, it is assumed that electrical will make last-minute changes due to the faster evolution of electronics ... Mechanical designers are limited by the material properties of the structural ingredients, hence the shape is determined by performance requirements leading to specific material, and/or design constraints that are hard to change. The challenge is to allow for last-minute electrical changes. More cables, more sensors, changing size of sensors, motors, actuators, etc."

The design collaboration, or problem solving, usually occurs at the interfaces of the ECAD and MCAD envelopes, says Suzuki. "MCAD and industrial modelers are increasingly bidirectional and are helped by interoperability and healing solutions that resolve issues over inexact geometry and data transfer," she observes.

"Most times the form is first proposed by the mechanical team," says Wiens. "But that doesn't diminish the contribution of the ECAD team to the decision, since they must determine the function within the form, considering options for layer stack-ups, IC packaging, rigid/flex, embedded devices ... Regardless of who starts first, there is inevitably iteration to reach the optimal solution."

In most cases, MCAD defines the board size, shape, holes, slots, keep out areas and electro-mechanical component locations, Mazzitelli says, that is, anything that needs to interact with the outside world/enclosure and overall product structure. "Negotiations do occur regarding those predefined items in order to fit everything within the confines of that footprint; however, as long as there is flexibility regarding the mechanical constraints, they are often easily resolved," she says.

Beyond Electromechanical

System simulation has traditionally been defined by the needs of the OEMs (original equipment manufacturers). Therefore, by and large, its protocols and processes are manufacturing-centric. However, with the likes of Google and Apple dipping their toes into manufacturing with self-driving car concepts, system simulation may take on new flavors.

"Depending on the industry you are dealing with, processes, systems and expertise may vary," says Christ. "Think about building a car. An established automotive OEM like Ford integrating ICT (information and communication technology) into their cars for connectivity and communications will take one approach. With high expertise in ICT but less experience in engineering, someone like Apple building and developing a connected car will take a different approach."

CAD and PLM vendors' expansion of their portfolios, often by acquisition, suggests they recognize the need to be able to offer a comprehensive collection of tools to address the convergence of modeling (electrical and mechanical), simulation, software development and even sensor-collected data from connected devices.

"IoT is all about collaboration and communication in an interdisciplinary environment. Besides ECAD and MCAD for modeling and simulation, you need to integrate solutions from ICT," says Christ. "We need to start developing interoperability solutions that extend our ECAD/MCAD systems that we are using today with functionalities that allow the development, simulation and validation of all these upcoming challenges."

"Siemens PLM and Mentor Graphics jointly view software-in-the-loop as a key to enabling our customers to quickly get to market with first-time production of products that combine electrical, software and mechanical," says Bohman. "Of course IoT will have many products that will fit this profile. We see our combination as enabling simulation of these products as a need based on the increase in product complexity and the rapid expansion of IoT."

"Some ECAD and MCAD vendors provide hardware and system simulation products. However, at least on the ECAD side, they are not yet at the stage where they incorporate IoT as a part of those," says Mazzitelli. "Creo has a lead in enabling digital twin emulation, but ECAD currently remains behind in this area."

With a portfolio that addresses IoT apps development, software development and electromechanical collaboration, PTC continues to champion the "digital twin" concept—connecting digital prototypes to real-world products with sensor-collected field data. (For more information, read "Driving Toward Digital Twins," digitaleng.news/de/driving-toward-digital-twins, or watch the on-demand webcast "Breathing Life into Digital Twins," digitaleng.news/de/category/resources/webcasts). **DE**

Kenneth Wong *is DE's resident blogger and senior editor. Email him at de-editors@digitaleng.news or share your thoughts on this article at digitaleng.news/facebook.*

INFO ➜ Siemens PLM Software/Mentor Graphics: plm.automation.siemens.com

➜ **PTC:** ptc.com

➜ **Dassault Systèmes:** 3ds.com

➜ **Elysium:** Elysiuminc.com

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The SMB Case for Simulation

Small companies have more affordable simulation and computing options than ever to help them benefit via faster time to market.

BY BRIAN ALBRIGHT

DESIGNERS AND ENGINEERS are under increasing pressure to deliver better designs faster to bring products to market at an accelerated pace. Many firms have begun implementing design exploration and optimization processes earlier in the process that rely on more frequent simulation.

That transition has been enabled by the availability of lower-cost high-performance computing hardware, cloud-based HPC and simulation services, more powerful workstations, easier to use simulation tools and simulation functionality that is embedded in some CAD programs. By performing simulations during the design process, the designs are improved and there is less of a bottleneck caused by a shortage of simulation experts and analysts.

In the testing phase, simulation has also helped drive down the cost and time required for prototyping and physical testing. "Companies are spending more money to do a lot of virtual testing and advanced product design and development before testing," says Akbar Farahani, vice president of global engineering at Engineering Technology Associates (ETA) in Detroit. The company provides product design and development services for the automotive and ground transportation industry. "That's because of the confidence people have in the virtual testing to reduce the cost of product design and prototyping."

However, smaller and mid-sized firms often can't afford computational fluid dynamics, computing clusters, high-performance computing (HPC) systems and the other tools necessary to perform rapid simulations. For companies that design lower-cost consumer goods, the business case for simulation may be unclear because prototypes and physical testing are relatively inexpensive.

Accelerating Development

Other benefits to simulation, however, go beyond prototyping/testing cost. The viability of lower cost items, particularly consumer goods, is often driven by time to market. Long delays can adversely affect competitive advantage and make it difficult to recoup development costs.

Design optimization and innovation then become of paramount importance. Advanced simulation can help reduce the time and cost of trials and experiments. It also makes it easier to optimize and troubleshoot designs without the time or cost associated with physical prototypes.

Using simulation in advance of physical testing, designers can render, visualize, analyze and discard various designs or iterations before any prototypes need to be built. Smaller companies can take advantage of third-party simulation/testing services that can help them with this process without the expense of investing in new hardware or software.

This can generate significant cost savings and provide a faster time to market for new products.

"There's no substitute for testing, but it can be more expensive and more time-consuming than running a simulation," says Gary Delserro, president of Delserro Engineering Solutions. "If you study and understand how to design the product right the first time, it will reduce that test time and cost.

"If you test something and it fails, you might spend a week setting it up and a week testing it, and then you have to go back and do a failure analysis," Delserro adds. "You can spend three or four weeks on a program like that. If you had done some accurate simulation up front, you could have found that problem in less than a week, so you'd have significant time savings."

Ultimately that can result in faster product development. According to Farahani, ETA has created a software and services package the company calls its Accelerated Concept to Product Process that includes design, development and CAE analysis that can reduce both cost and development time. "It's an extensive process, and applies our expertise and knowledge to every aspect of cost reduction for the customer," says Farahani.

Simulation also makes it easier to build up a knowledge store based on the results of those virtual tests that can guide future designs.

Simulation for Designers

In the past, simulation created bottlenecks because multiple designers were handing their work to a small number of analysts for validation. If there was a flaw in the design, the turnaround time could run into weeks to correct the issue and then have another analysis run.

Software companies are making it easier for engineers and designers to manage simulations earlier in the process, and do

ETA's Accelerated Concept to Product Process includes design, development and CAE analysis that can reduce both cost and development time. *Image courtesy of ETA.*

so with easier to use tools. There are simulation tools integrated into CAD packages, simulation apps, engineer-friendly wizards and smart templates, and industry-specific solutions. SOLIDWORKS, Autodesk, Siemens and PTC, for example, have all gone this route.

There are also custom app-building tools that analysts can use to create interfaces for designers on an ad hoc basis. Smaller companies can benefit from new pricing schemes offered by these providers, including tiered pricing and subscription-based cloud offerings.

There are other options as well. ANSYS, for example, offers a startup program for smaller companies that provides low-cost or free access to its simulation tools. SimScale offers a similar program with a low monthly subscription fee for eligible small businesses that includes support from a company consultant and training.

With lower cost tools and services that are created with designers in mind, smaller firms can leverage simulation to validate their designs. This can provide a return on investment, even for relatively inexpensive products, because the time savings can add so much value to the process.

Getting Started

Effectively using simulation—either internally or via a third-party service provider—requires some preparation. Designers should understand the engineering problem they are trying to solve and should have enough expertise to interpret the simulation results.

If you are working with a testing/simulation company, make sure to fully vet the company prior to signing a contract. Many of these companies specialize in particular industries or product categories (aviation, automotive, plastics, consumer electronics and so on), so they should have experience with the types of products you need tested as well as the proper certifications. "Be careful that the company you work with has a track record in your industry and check their references," Delserro says. "If you haven't got any experience in simulation, it can be worth it to have someone who knows what they are doing to handle those first projects."

Designers also need to have the right data available in order to successfully complete these simulations or take their projects to third-party providers. "The challenge is always to request the right information," Farahani says.

Without that data, it will be difficult to validate the results of the simulation and move forward with a viable design.

Having the correct materials information and specifications is another stumbling block, particularly when it comes to composites and other materials that have comparatively little available testing data. "The new materials are very difficult to work with in terms of simulation because the confidence is still not 100% there," Farahani says. "The computer doesn't have any understanding of what that material behavior is, especially with composite and other variations. Defining that and providing that in the virtual environment is a challenge. You have to have the right material characteristics to do better simulations."

Simulation and modeling solution vendors are striving to extend the reach of their products to smaller companies and less expensive classes of products. The advantage to using simulation in advance of, and in conjunction with, physical testing lies in lower costs and a faster development process—critical advantages in today's faster paced and highly competitive markets. **DE**

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

INFO → **ANSYS:** ANSYS.com

→ **Autodesk:** Autodesk.com

→ **Delserro Engineering Solutions:** desolutions.com

→ **Engineering Technology Associates (ETA):** ETA.com

→ **PTC:** PTC.com

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

→ **SOLIDWORKS:** SolidWorks.com

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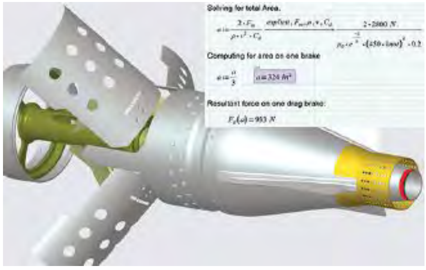
EDITOR'S PICKS

*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.*



PTC Mathcad Prime 4.0 Released

Calculation capabilities boosted; data in shared worksheets made more secure.

PTC Mathcad Prime version 4.0 offers major features such as mathematical notations, units intelligence and plotting, and graphing.

Sharing worksheets sees a couple of new functions improving data protection. One lets you set areas of your worksheet so that people can see what's going on in them but edit nothing. A second new feature collapses data from view entirely and locks it down from view from all except authorized users.

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NVIDIA Quadro GP100 Released

GPU engineered for design, simulation, photorealism and virtual reality.

NVIDIA rolled out its new range of Quadro GPUs (graphics processing units) that are built around NVIDIA's new high-performance Pascal microarchitecture.

The Quadro GP100 basically brings HPC (high-performance computing) graphics horsepower to desktop workstations. It offers double-precision performance with 16GB of second-generation high-bandwidth memory (HBM2) and a 717GB per second memory bandwidth.

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Siemens Releases STAR-CCM+ Version 12.02

Adaptive gridding, ray-tracing features debuted to enhance simulations.

The new ray-tracing capability in STAR-CCM+ version 12.02 lets you add photorealistic renderings to your design and simulation results.

The new models for analyzing electrochemical reactions introduced in STAR-CCM+ v12.02's incorporate multi-component gas/liquid species and solid ions models. These should enable you to create a spot-on virtual model of your product's real-world physical and performance characteristics—a digital twin.

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AMD Ryzen 7 Processors Launched

User-controllable overclocked eight-core processors based on new AMD architecture.

Collectively called the Ryzen 7 series, these processors have eight cores and support 16 threads. They are the first processors based on AMD's new high-throughput, low-power Zen architecture.

The Ryzen 7 processor family has three members: the 1700, the 1700X and the 1800X. They offer base clock speeds of 3GHz, 3.4GHz and 3.6GHz, respectively. They also can hit turbo speeds when needed from 3.7GHz to 4GHz.

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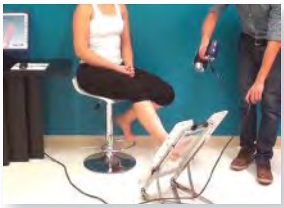
FAST APPS
Engineering Case Studies

Transforming Ankle Foot Orthosis (Afo) with 3D Printing

With the help of large-format 3D printing technology via 3D Platform and research conducted by students at Gonzaga University, patients may soon be able to count on 3D printed orthotics.



Prosthetics and orthotics are necessary for many patients, but the current manufacturing process of these medical devices is time-consuming and costly for both patients and hospitals. Thanks to the large format 3D printing technology enabled by 3D Platform and research efforts by students at Gonzaga University, patients soon can expect high-quality 3D printed orthotics that are affordable and produced within an optimized time frame.

Traditional Ankle Foot Orthosis Costly

An ankle foot orthosis (AFO), is a brace that is designed to treat foot and ankle disorders in children. AFO provides a stable base of support for a child's lower extremities, thus allowing a child to develop the process of walking and balancing. The current process of fabricating an AFO consists of several heavily involved steps including scanning, molding, vacuum heat forming, and form and fitting. This process normally takes as many as four weeks and costs as much as $2,000 for most patients.

Seeing the need to improve the process of designing and constructing ankle foot orthosis (AFO) to cut time and cost, in late 2015, a group of students at the Gonzaga University started to research and develop a 3D-printed rapid prototyping process for fabricating AFO. The goal was to "create a simple, easily 3D printed AFO with the best composition and geometry to meet strength and comfort requirements for patients."

3D Printing a High-Quality, Affordable AFO

Gonzaga University researchers used a 3D scanner to collect a patient's ankle and foot measurement data, then a 3D model is designed for 3D printing the AFO. In addition to 3D printing the AFO design, researchers also tested several types of 3D printing materials (including polylactic acid or PLA, polypropylene, carbon fiber PLA, PETG, nylon) to help determine optimal materials for 3D-printed AFOs.

"We want to 3D print large braces (up to 18 in.), and we need to print with a variety of materials as we research the best design for the braces," says McKenzie Horner, one of the researchers at Gonzaga University. "3D Platform helped solve the problem by providing a versatile large-format 3D printer that helps us with our materials research and AFO printing."

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A Spacewalk on Mars with 3D Printed Technology

High-precision, low-weight and strength attributes can help determine the success of a mission to Mars. 3D printing solutions can meet all these requirements.

The Mars rover Ares 2 is a four-wheeled space rover capable of independently exploring the surface of the Red Planet. It was constructed by a group of students from Warsaw's University of Technology who were a part of a Student Astronomical Study Group. The vehicle has competed with other prototypes created by some of the largest technological universities in the world.

Students from the Warsaw University of Technology have been using Zortrax's M200 3D printers to design and print the necessary components for their space rover. They printed out such fundamental parts as the rover's wheels and a housing for its ultrasonic sensor. Using Zortrax's Z-ULTRAT printing materials resulted in a significantly reduced weight of the final project, a factor of great importance when considering the costs of an entire space mission. Components such as the rover's gripper, which traditionally weighed 33 grams, had its weight reduced down to 10 grams after it was printed using 3D printing technology.

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AD INDEX

Next-Gen Engineers

Student Design Competition Profile: Digital Manufacturing Challenge

Getting Digital About Manufacturing

BY JIM ROMEO

EACH YEAR SME conducts a Digital Manufacturing Challenge that follows a specific theme. Using 3D prototyping, entrants are invited to follow the theme, its rules and guidelines, and submit designs.

In the most recent challenge, the SME description stated: "Student designers and engineers are invited to figure out how to help us get around better. More specifically, contestants are challenged to consider how our inherent human physical mobility and/or performance may be restored, enhanced or given new capabilities whether on land, in/on the sea, in the air or in space. Such 'performance mobility' may be represented by a functional item, subsystem or system."

Entrants are typically college and university engineering students who focus on the challenge and submit an entry. Arif Sirinterlikci, Ph.D., CMfgE, is the engineering department head and director of Engineering Laboratories at Robert Morris University. He is also a professor of Industrial and Manufacturing Engineering at the University. He helps coordinate the theme, the contest and judges, and the applicants' entries. We spoke to him for his insight into the world that the digital manufacturing challenge unveils.

***Digital Engineering*:** Can you provide an overview of the 3D Digital Manufacturing Challenge, how it came to be and the intent of the program?

Dr. Arif Sirinterlikci: This was done as a means to engage students so the concepts of AM (additive manufacturing) could be highlighted in a fashion that would not have IP (intellectual property) issues. This would also train the incoming workforce on how to apply these technologies more effectively and thus advance the industry as a whole.

***DE*:** Who will be participating?

Sirinterlikci: The target is to have students submitting the entries. Getting them to open their minds and consider the options that DDM (direct-digital manufacturing) enables can lead to more than great entries—it can lead to advanced engineers. Cross-functional teams of up to four students each are encouraged to promote teamwork and enable more challenging concepts to develop.

***DE*:** Why mobility?

Sirinterlikci: We have had a number of themes over the years and our judges always try to come up with something that will help society and advance the technology. Mobility has the potential to meet unique applications that many of us may not be aware of and that DDM could help greatly.

***DE*:** What becomes of the designs presented, or what do you anticipate will become of them?

Sirinterlikci: The winner will be presented their award at the RAPID conference; some mention of the additional contestants may be given but due to time restrictions the focus is on the contest winners. They will also be invited to present a webinar on their entry. The other contestants may get publicity in our magazine, but nothing specific is defined to date. If possible, some or all of the winning entry may be built by a RAPID exhibitor.

***DE*:** What is the best way to stimulate STEM career pursuits and get students engaged with manufacturing design?

Sirinterlikci: As with anything, "make it easy" would be nice, but you also have to make it fun. These students get to use a lot of their creativity and develop things that couldn't have been done before. In addition to developing students, we anticipate faculty will annually integrate this competition into their course work—perhaps even as part of a capstone project, making it an integral part of their curriculum.

In 2016's competition, students from the University of Massachusetts at Lowell won with their inspector drone to be used as a means of inspecting bridges.

***DE*:** Do you have any corporate sponsors for the event?

Sirinterlikci: We are beginning to entertain sponsors, but have wanted to ensure this was a neutral and contestant-focused competition. As more contests are appearing we are evaluating sponsors to enlarge the promotion, give a larger prize to the winners and hopefully help these amazing students find future employment.

***DE*:** Anything else you'd like to tell us about the event?

Sirinterlikci: The ability of these students to compete is only the tip of the iceberg. Their ability to share their learning with other students expands what can be achieved. The visibility they receive will hopefully give great minds a chance to find employment with support for these technologies. We are not changing the masses overnight, but we are making a continual impact. Hopefully we will all see advanced technologies as a result of these creative and brilliant minds as they apply what they have learned in the industry. **DE**

Jim Romeo *is a freelance writer based in Chesapeake, VA. Send e-mail about this article to de-editors@digitaleng.news.*