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Digital Engineering

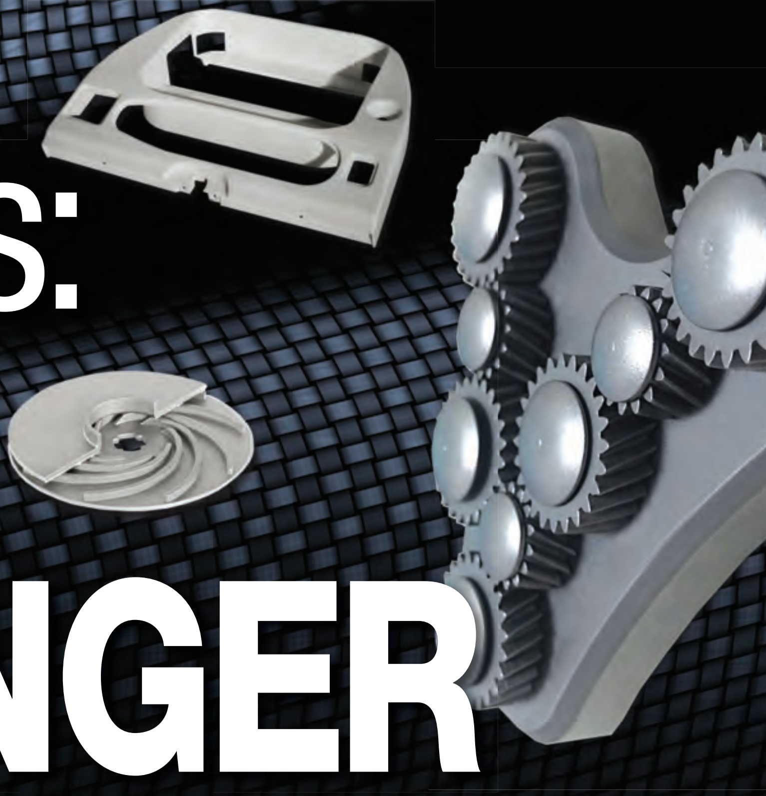
October 2018

Metal 3D Printing

Solid Edge 2019 Review

IIoT Platforms

FOCUS ON: Materials



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by Jamie J. Gooch

Additive Manufacturing Invades IMTS

I WAS ONE of the 125,350+ attendees walking the 1,424,232 sq. ft. of exhibit space at the International Manufacturing Trade Show (IMTS) in Chicago last month, trying to see all the new technologies on display from the 2,563 companies there. It was an impossible task.

IMTS occupied all five levels of McCormick Place's four buildings. Even just focusing on CAD-CAM software, digitalization and additive manufacturing (AM) sent us running back and forth among the buildings. I didn't see everything I would have liked, but I did come back with some important takeaways.

From Prototype to Production

"I think it's fantastic that here, at the largest manufacturing show in America, we're talking about 3D and additive," said Stephen Nigro, president of HP's 3D printing business, as he introduced the company's Metal Jet technology at IMTS. "What we plan to do is take metal 3D printing from a specialized production technology today, to mass production."

There is no doubt that additive manufacturing has moved beyond the incredible benefits it adds to prototyping and tooling, and into production. However, significant challenges remain before it can earn the mass production moniker.

"GE and HP validated the market," said 3D Systems' Vyomesh "VJ" Joshi, speaking of the tech giants' entry into industrial-scale additive manufacturing during a press conference at IMTS. Joshi, who spent 32 years at HP, said the key to advancing AM in industry is building platforms.

The word "platform" was used by multiple vendors to describe how they are approaching the top challenges of industrial AM, namely scalability, quality, repeatability, speed and cost.

Platforms combine some or all of the AM process—file preparation, 3D printing, materials management, parts management and post-processing—into one system, often in components that can be added for scalability.

For example, 3D Systems' Figure 4 is marketed in a Standalone configuration, a Modular configuration with an automated material feed system and separate post-processing units, or the Production line consisting of a control cell, print engine cells and post-processing cells—plus the software to manage it all.

Safety and Automation

While Figure 4 uses UV-curable materials, material handling is even more important when it comes to fine metal powders or off-gassing from sintering that operators should not be exposed to—not to mention fire hazards. Many AM equipment vendors are containing their processes to avoid exposure issues.

For example, at IMTS AddUp showed off its Flex Care System, a controlled atmosphere solution to protect operators and buildings from risks involved in the industrial use of metal additive manufacturing machines. The containers can incorporate machines, sifters, inerted vacuum cleaner, a trolley for loading/unloading and powder storage for new and recycled materials. The containers can also be connected for scalability.

Velo3D launched its Sapphire hardware, Flow print-preparation software and Intelligent Fusion technology at IMTS after four years of development. Pam Waterman covered Velo3D for *DE* (rapidreadytech.com/?p=12913), including its material handling, writing that after the print module is loaded from a transfer cart into the machine: "The module is then locked in place and unsealed, to start printing automatically. After printing, the module is sealed again, undocked and moved out to the ready-to-unpack stage."

Sensors, Data and Simulation

Velo3D and other vendors also realize the importance of software and real-time data collection to AM quality and repeatability. For example, Additive Industries' MetalFAB1 system is integrated with its Additive World Platform, allowing customers to store, share and analyze relevant data. EOS launched its EOS M 300 Series at IMTS, touting its scalability, productivity and flexibility. Its EOSTATE monitoring suite captures production- and quality-relevant data in real time, and its upcoming EOSCONNECT software will enable that data to be used by third-party enterprise systems. Formalloy's X-series laser metal deposition system uses scanning technology to monitor build quality and accuracy in real-time, and then autocorrect errors.

What the ramping up of industrial 3D printing toward mass production scale means to design engineers, is that design for additive manufacturing (DfAM) is quickly becoming a must-have skill. Soon, the production data showing which optimizations were most successful and why will be readily available—allowing you to simulate specific product designs on specific machines to enable first-time-right prints. "Allowing you" is the key phrase there. If you don't know DfAM, you won't be able to take advantage of the data, software or hardware—and your company won't fully realize the benefits of industrial AM. **DE**

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

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TECHNOLOGY FOR OPTIMAL ENGINEERING DESIGN

INSIDE

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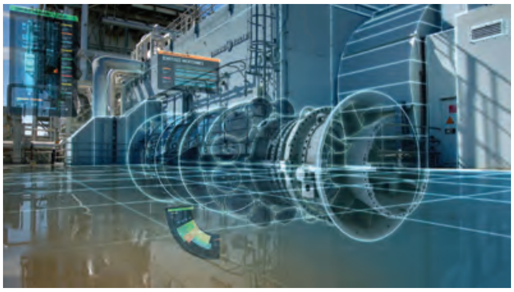
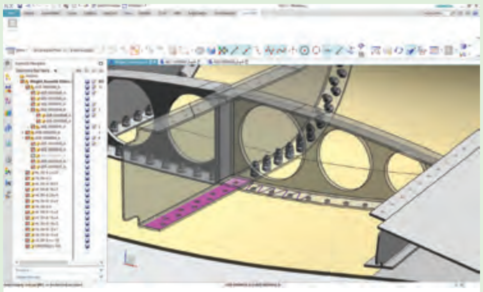
ON THE COVER: Courtesy of 3D Systems, HP, XJet and gettyimages/iLexx.

COVER STORY

FEATURES





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Expanding Material Markets

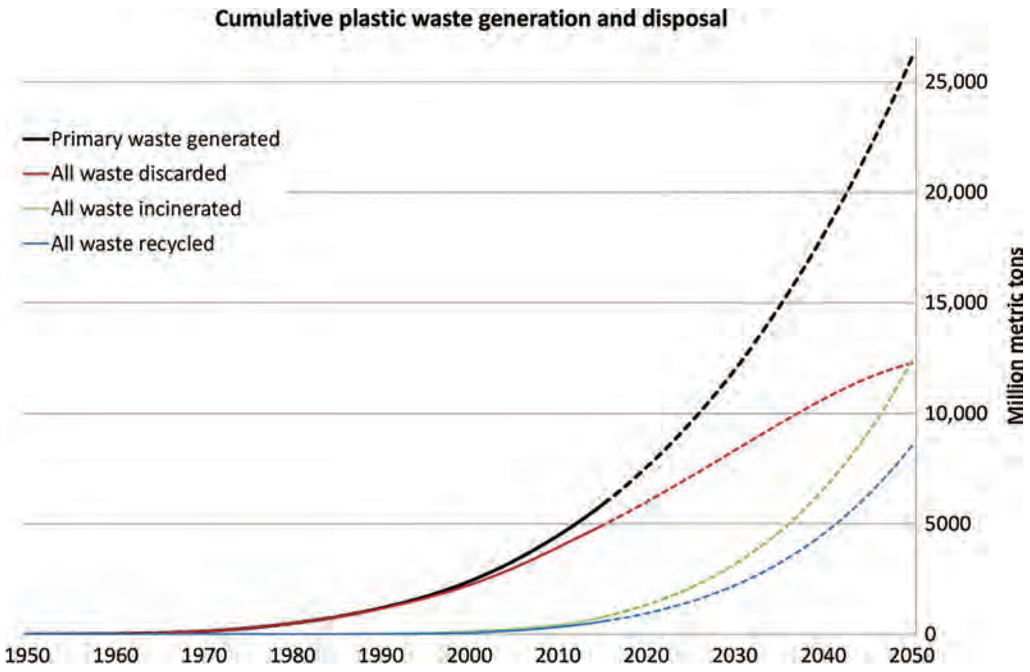
8.4% The high strength steel market is projected to grow from $27.32 billion in 2018 to $40.85 billion by 2023, at a CAGR of 8.4% between 2018 and 2023.
— High Strength Steel Market: Global Forecast until 2023, Markets and Markets, April 2018

13.45% The carbon fiber market was valued at $2,859.26 million in 2017 and is expected to reach $6,096.95 million by 2023, registering a CAGR of 13.45% between 2018 and 2023.
— "Global Carbon Fiber Market Industry Trend and Forecast," Mordor Intelligence via Orbis Research, May 8, 2018

20% The global 3D printing materials market, in terms of value, is projected to reach $1,400 million in 2022, at a CAGR of 20% till 2022.
— "3D Printing Materials Market," MarketsandMarkets, January 2017

22% The biocompatible 3D printing materials market size is estimated to be $308.1 million in 2018 and is projected to reach $832.7 million by 2023, at a CAGR of 22% between 2018 and 2023.
— Biocompatible 3D Printing Materials Market, MarketsandMarkets, Sept. 7, 2018

Expanding Plastic Waste



Solid lines show historical data from 1950 to 2015. Dashed lines show projections of historical trends to 2050.

12,000 Mt

As of 2015, about 6,300 metric tons of plastic waste had been generated, around 9% of which had been recycled, 12% was incinerated and 79% accumulated in landfills or as litter. If current trends continue, roughly 12,000 Mt of plastic waste will be in landfills or in the natural environment by 2050.
— "Production, use, and fate of all plastics ever made," Science Advances, July 19, 2017

Watching Weight

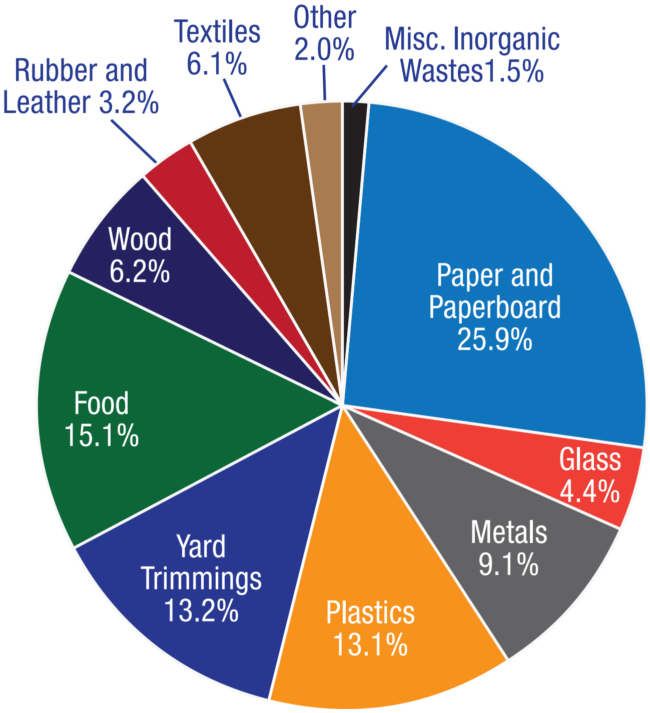
40% Glass Bubbles S32HS, a material technology from 3M, is expected to help original equipment makers achieve up to a 40% weight reduction of composite parts, at a density below 1.0 g/cc, while still enabling a class A paintable finish.

— 3M press release, May 7, 2017

600 lbs. A typical automobile has more than $3,000 worth of chemistry, including more than 330 pounds of plastics and polymer composites and over 270 pounds of rubber, textiles, and coatings.

— "Making the future of mobility," Deloite Insights, April 19, 2018

262.4 Million Tons



Construction and demolition data is not included in the U.S. municipal solid waste data shown above.

— "Facts and Figures about Materials, Waste and Recycling," EPA, 2015

| CONSULTANT'S CORNER |

SIMULATION 101

by Donald Maloy

A Beginner's Guide to Simulation, Part 1

ARMED WITH A WORKSTATION LAPTOP and a fresh cup of coffee, you're ready for the challenge of learning simulation. Maybe your boss promoted you to engineering lead, or you've been curious about how to improve a design you whipped up or you want to be more marketable to employers. Whatever the reason, you're starting the journey toward becoming a simulation analyst. Where do you begin?

First, it's important to understand what simulation is and how it works. Simulation is a system of equations or algorithms used to model real-world behavior. Physics and engineering-based equations provide the foundations to describe a specific analysis. The two main types are:

- finite element analysis (FEA) and
- computational fluid dynamics (CFD).

FEA is primarily used to describe behavior in solid objects, whereas CFD is used for fluids and/or gases. The two core areas are divided mainly due to the mathematical efficiencies they use to approach a given problem. Each core area can be broken down into studies that we will discuss in a future article.

How Do I Start?

Whenever I hear this question, an elephant comes to mind. "Start with small bites," is generally my response. Joking aside, slicing this large task into small, manageable bites is the preferred method. Begin with software selection. Simulation software falls into two categories: embedded and standalone.

Almost all large, mainstream engineering software packages—including PTC Creo, Dassault Systèmes SOLIDWORKS, Autodesk Inventor and Siemens NX—have integrated FEA and CFD tools built into their CAD interface. The capabilities of the embedded tools vary by vendor and tend to be based on the segment of the market that they serve. An obvious advantage of embedded simulation software is ease of use from being familiar with the software. The ability to quickly make design changes based on analysis results increases productivity.

Standalone vendors are generally focused more on the niche market within the analyst community where specific requirements of an analysis are outside the scope or capability of embedded tools. Most simulation analysts start out with the tool their employer uses based on their needs.

Vendor Software Training

Once you've got a simulation tool, how do you use it? Simulation software vendors have developed training curriculums offered direct from the company or through authorized resellers of the software. In some instances, independent engineering consulting firms specializing in FEA and CFD offer this training.

The training tends to be focused more on the software's capabilities and how to navigate the interface. Courses are separated into several classes that delve into specific aspects of the software's capabilities. One example would be a two-day course based on the nonlinear analysis section of a tool. This type of training becomes vital to your growth as a simulation analyst because you will learn the limitations of the vendor's simulation tool. Plus, course instructors tend to have real-world experience as simulation analysts and often come from a mechanical design background.

Simulation Analyst Training

Engineers craving a more in-depth understanding of simulation after vendor training often join the simulation analyst community. NAFEMS, a vendor-neutral simulation organization, provides training courses tailored to bridge the gap that exists between vendor-based training and a formal university engineering education.

Started in the late 1970s, NAFEMS was originally established by the UK government to develop standards and accuracy methods for simulation software. Today, it has expanded globally, providing software vendors and engineering companies with peer-reviewed publications and professional development curriculum. NAFEMS also offers e-learning courses and an independently assessed professional simulation engineer (PSE) certification for those who wish to gain recognition for their level of competency in the areas of FEA and CFD.

Primed with the resources and fundamentals of how to get started, now it's time to sign up for a training course and dive into simulation. Stay tuned for future articles on software selection and approaching simulation studies from a CAD user perspective. DE

Donald Maloy *is a consultant analyst based in the greater Boston area. He also works as a certified simulation and mechanical design instructor for a software reseller. Contact him via de-editors@digitaleng.news.*

Simulate Additive Manufacturing

Increase additive manufacturing efficiencies and lower production costs with upfront simulation.

FALLING PRICES on printer hardware and a plethora of new materials and design tools have catapulted additive manufacturing (AM) from a part-time prototyping resource into a full-scale production method. Yet as companies engage in more widespread use of the technology, they are actively trying to formulate new design for AM (DfAM) practices to address longstanding challenges and to capitalize on the design freedom AM affords.

The overall 3D printing segment is enjoying explosive growth, but metal AM in particular is a rising star: Research firm Wohlers Associates estimates that 1,768 metal AM systems were sold in 2017, a leap from 983 units in 2016. Laser sintering is the most common metal AM process, and research shows the automotive, aerospace, and biomedical industries are leveraging the technology to successfully produce prototypes, tooling and end-use parts.

Companies are flocking to metal AM for a variety of reasons. The technology, coupled with topology optimization software, provides a real opportunity to consolidate parts and deliver improved functionality thanks to greater design freedom. Unlike traditional forging or casting methods, metal AM offers a greater opportunity to produce organic designs that are more lightweight, thus saving on material costs. The production method also unleashes mass customization and on-demand business models simply not possible or practical with conventional manufacturing. At the same time, metal AM provides an opportunity to more seamlessly sync manufacturing with design processes via emerging concepts like the digital thread.

Trial and Expensive Errors

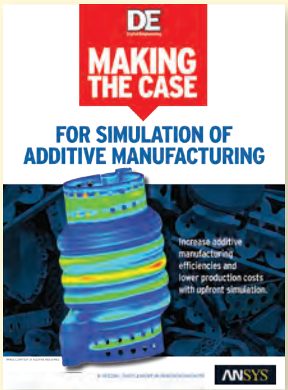
While there's growing recognition of metal AM's value as a full-scale production method, challenges abound, especially as they relate to DfAM practices, which are still fairly nascent. Most companies don't have on-staff expertise versed in metal AM technologies and materials let alone significant knowledge of design best practices in newer areas like building lattice structures, varying material properties to achieve outcomes, or proper orientation of parts to ensure a successful and efficient build.

"What's shifted in the last year or so is that as companies go deeper, they realize a lot can go wrong," explains Brent Stucker, director, additive manufacturing at ANSYS. "They are wasting massive amounts of money on trial and error, and they need help."

The cost of running an AM printer, on average, is estimated to be around $100 per hour, and a single build can take upwards of 20 hours—or closer to 80 hours for highly complex parts. That's $2,000 to $8,000 wasted every time a part fails and has to be reprinted.

Make Your Case

TAKE a moment to download the "Making the Case for Simulation of Additive Manufacturing" paper to learn how you can use simulation to determine the outcome of additive manufacturing processes before wasting time, effort and expensive materials.



This 11-page report from *Digital Engineering* is sponsored by ANSYS. It provides examples of real-world uses of metal additive manufacturing (AM) by various industries, shows how companies can integrate AM into their existing product design and development workflows, explains how companies are already saving costs by simulating AM processes, and more.

FREE DOWNLOAD: digitaleng.news/de/AMsimulation

Simulation Helps Solve Challenges

Rather than learning from expensive trial-and-error processes, simulation—and specifically simulation of additive manufacturing processes—is a much more efficient and cost effective way to optimize use of metal AM technology. AM simulation tools and DfAM practices working in concert can help companies avoid the high costs associated with outputting parts that don't meet quality specifications or that deform on production.

Learn more: digitaleng.news/de/AMsimulation

OPTIMIZE Composite Orientation

New advancements help better predict material, product performance.

BY BRIAN ALBRIGHT

IN MAY 2018, the Institute for Advanced Composites Manufacturing Innovation (IACMI), announced the completion of the first phase of an IACMI project led by DuPont, Fibrtec and Purdue University to create a new carbon fiber composite manufacturing process that would provide better fabric formability characteristics.

The project's goal was to improve performance and reduce the cost of creating these composites. Integral to the initiative was the development of simulation tools that helped predict material performance and behavior in manufacturing and in the finished part. The Purdue Composites Manufacturing and Simulation Center handled that leg of the work.

The resulting process and the improved simulation models were able to reduce time and material waste as a result. "Carbon fiber is very expensive, and, as such, limiting the amount of waste that goes into the creation of any given part is essential," says DuPont's Lee Silverman, who is the project lead. "Traditionally, using woven cloth, you take a rectangular piece and cut the required shapes out of it. You end up throwing away a lot of carbon fiber. This program relies on near-net shaping, where we use a robotic system to only lay down the carbon fiber tow in the shapes required. We eliminate all that wasted material."

The new process also eliminates the complicated weaving process required for some carbon fiber manufacturing.

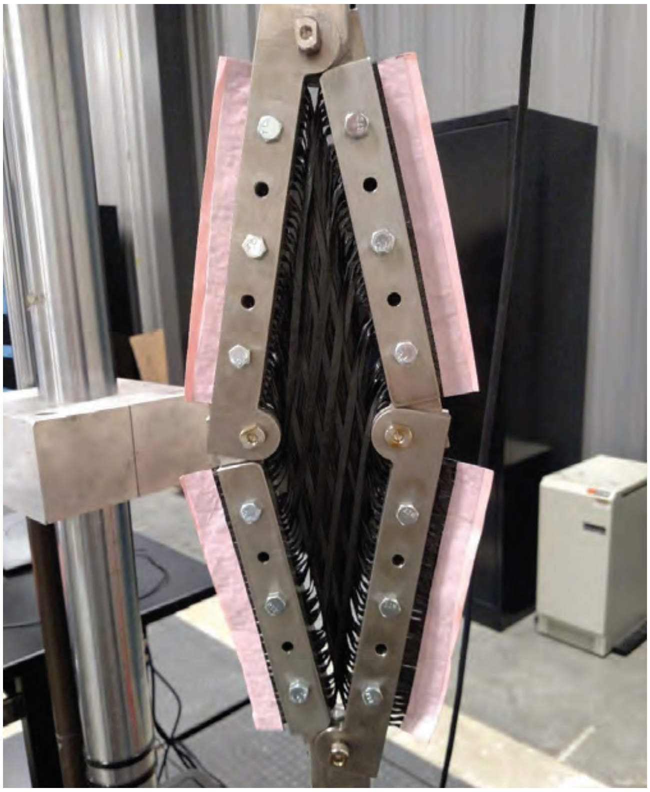
The simulation models developed as part of the project could help bridge what is characterized as a "disconnect" between the design phase and how the part is actually manufactured when it comes to composites, says Michael Bogdanor, director of the Composites Design Studio in the Purdue Composites Manufacturing and Simulation Center. "Designers will design for a perfect part with ideal orientation states," Bogdanor says. "As you go through the forming process, especially with complex curvatures, the fibers are going to move. There's going to be shearing and orientation angle changes that happen. That's not a defect; it's just the way the geometry behaves."

At Purdue, Bogdanor says the focus is on manufacturing-informed performance. How does manufacturing affect fiber orientation? That information can be used to optimize the design.

Simulation is increasingly important when considering

A cover made from Fibrtec's Fibrflex prepreg (left) and an image showing the drapability of Fibrflex over the cover mold. *Images courtesy of Fibrtec.*

composite design, but it has only been within the past few years that tools have been available to help with this process. Without the ability to successfully simulate the performance of these composite materials, it can be difficult or impossible for engineers to create accurate performance predictions about part shrink, warp behavior or material strength.



DuPont's Rapid Fabric Formation technology deploying Fibrflex at high shear angles. *Image courtesy of the Institute for Advanced Composites Manufacturing Innovation.*

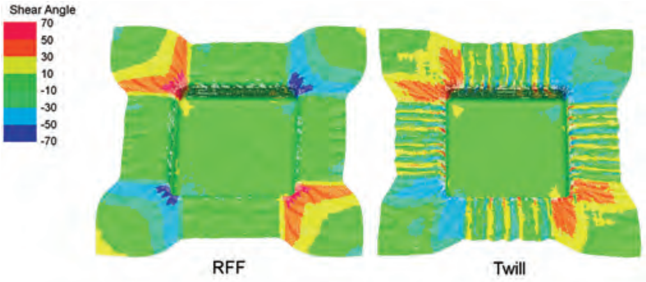
Composite Challenges

Having the right material properties on hand and successfully using them in a simulation can be challenging, because different companies offer different formulations of these materials. "The challenge comes when the material properties are missing," says Srikar Vallury, engineering manager at Moldex3D (CoreTech System). "You need to them to be characterized through testing."

It can also be difficult to move from individual material constituents to composite-level predictions. "If you want to characterize composites at a global level, there are too many variables like fiber orientation, type of resin," says Flavio Souza, co-founder, president and CTO of MultiMechanics. "The approach we've proposed is a bottom-up approach to characterize individual constituents and then make a prediction at the component level to reduce the amount of physical testing required to qualify a composite material."

"Another challenge for processes like compression molding, is that in reality this is a single-state process in which the material compresses," Vallury says. "Simulation has to divide this into a two-phase process, where the solid mechanics drive the initial phase, and fluid dynamics drive the second phase."

Moldex3D addressed this issue through integration with



A comparison between the forming characteristics of the RFF vs. a 2x2 Twill. The RFF shears to conform to the geometry, but this is localized to the regions where the complex geometry exists. The Twill exhibits more widespread shearing behavior coming from wrinkles that form due to the shear locking of the material. *Image courtesy of Purdue University.*

LS-DYNA, where the draping analysis is first conducted via LS-DYNA, and then the integration allows for a streamlined approach to simulating the entire compression molding process. The Moldex3D Multi-component Molding (MCM) module supports the orthotropic material settings of the part insert by reading the draping analysis data from LS-DYNA.

Moldex3D also incorporated a simulated resin transfer modeling process capability in its solution. It is also working on approaches for predicting fiber orientation in long fiber composites or in highly filled systems.

At MultiMechanics, Souza says the company uses tool multiscaling at the part level and microstructural level to accurately capture resins and fiber behavior, how they interact and how events at the microstructural level affect composite properties.

"Fibers have a wide distribution of strength, and the average is not sufficient to capture the physics of the fibers in a material," Souza says. "How do you characterize the resin? You can find elastic properties for the resin, but those materials are very temperature- and time-dependent."

In addition, fiber clustering can affect the strength of the composite, as does resin distribution. "Differential temperature across the part or changes in the environment can affect the curing process and the properties of the resin," Souza says. "That can have a big impact on part failure."

Simulation Drives New Process

The IACMI/DuPont project generated a new material using Fibrtec's flexible coated tow (Fibrflex) with DuPont's Rapid Fabric Formation (RFF) technology and a proprietary DuPont polyamide resin. The coated tow material is a partially impregnated carbon fiber/polyamide composite tow. The carbon fiber is not fully wetted with the polyamide, so the tow is more flexible than a fully impregnated material. The RFF process allows rapid manufacturing of fabrics with tows in varying orientations without the need to lift the tow during processing.

"The Fibrflex remains flexible after it is impregnated with the resin," says Robert Davies, CEO at Fibrtec. "We coat the outer one-third of fibers, leaving the inner one-third unsaturated so that the tow remains flexible and saturation of the inner fiber takes place when it's consolidated."

This approach can help reduce the cost of manufacturing carbon-fiber reinforced polymer (CFRP) composites using a "near net shape process" such as automated fiber placement on a less-expensive carbon fiber/polymer tow-preg, according to IACMI. The coated tows can be easily manipulated, so the material can be more easily draped and conform during molding without shear locking. This could reduce carbon fiber waste by up to 30%, and create fiber preforms that predictably deform during compression. This first "resulted in better than expected outcomes with embodied energy being reduced by more than 40% using this processing scheme," according to an announcement about the project.

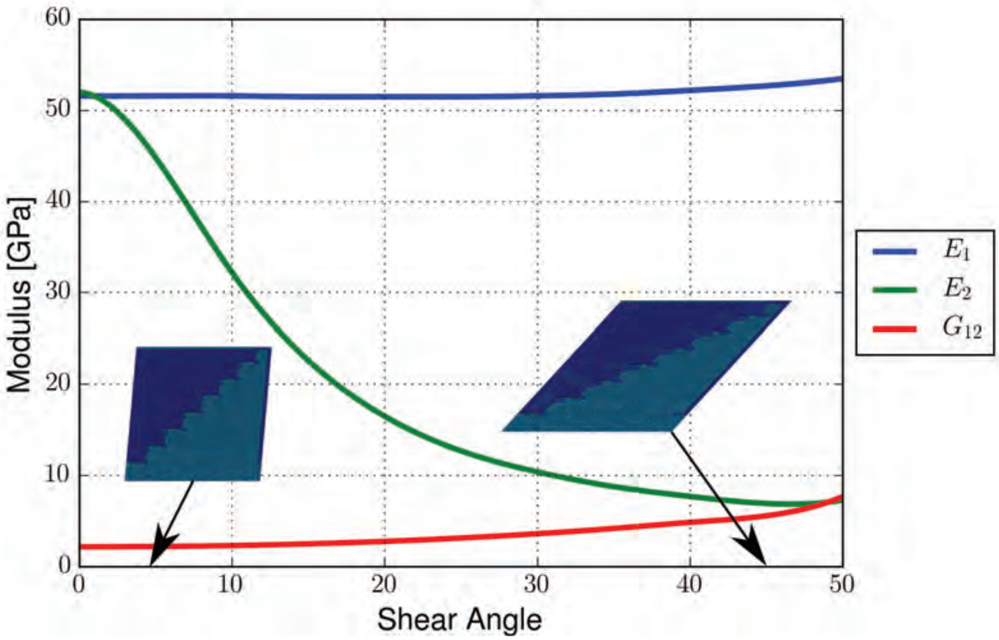
The Purdue team's contribution was to test the material and create new simulation models that could be used to predict performance. "As we create different geometries of RFF fabric, how does that impact drapability and mechanical performance?" Bogdanor asks. "How does the material behave in the drapability analysis, and how does that validate against the actual manufacturing process?"

At Purdue, Bogdanor says the aim is to leverage simulation tools to anticipate those issues and do so without creating a large number of experimental cases to explore the design space. "As we go through the prototype phase, volume is something we're working up to, so we want to be able to identify the right targets for manufacturing and set ourselves on the right foot," he says. "We can use simulation to look at different cases, do sensitivity studies and parametric analysis, and see where we can get the most bang for our buck out of the physical experimental work."

According to Davies, Purdue helped determine the mechanical properties of the material with different fiber volume fractures. "You can change the amount of resin-to-fiber. As your fiber content goes up and resin goes down, that's a typically more difficult carbon fiber composite to work with. We characterized the material so we could apply that to the design of parts, and that is what Mike needed to input into the simulation programs," Davies says.

That process involved creating test panels from the coated tow and RFF fabric and doing mechanical testing, which allowed the team to create the underlying model structure for different unit cells to represent the material system. The first cell was an unconsolidated state where the fabric is formable and drapable to model the shear behavior of the fabric. "Then we compared our RFF structure that doesn't have interlocking tows to a more traditional interwoven fabric," Bogdanor says. "We could do studies to show where you get a difference in properties that can be used to inform the draping studies."

The second cell looked at mechanical properties and the



The impact on mechanical properties is shown as the RFF undergoes shearing, something that can be predicted with simulation and directly applied to part performance prediction and design. The local, as-manufactured material properties can vary quite a bit from the nominal properties. By mapping material properties based on forming-induced fiber orientation, it provides a clearer picture of the way that the part will perform. *Image courtesy of Purdue University.*

effects of topology on the mechanical behavior.

"We're using micromechanical modeling and multiscale modeling to create a unit cell structure that hasn't been explored too much," Bogdanor says. "If you look at most fabric generation software, they only support interwoven textiles. There's not a lot of support for structures that aren't interwoven."

Purdue was able to use this work and create mesoscale models for investigating different material parameters and how they affect performance. "We're also looking at the material as it undergoes shearing, and how that can change the structure of the unit cell and mechanical properties," Bogdanor says. "We can use those models to predict performance."

Better Tools Needed for Interactions

With improved composite simulation, engineers can successfully complete more designs with less need for physical model trials. This can accelerate time to market and reduce overall costs to produce a new design or part. Having better simulation tools can also help manufacturers and designers optimize material for specific applications.

The DuPont-led IACMI project has advanced to phase 2, which will involve making an industrially relevant part that would benefit from the new process. The automotive market can benefit from this technology as it reduces cost through reduced scrap and better predictability through the modeling and simulation outcomes.

One of simulation's advantages is understanding where composites add additional savings, and where they do not contribute. For example, Purdue's simulation process identified that the initial part the team considered would actually not benefit from the use of carbon fiber instead of aluminum. "Because the part was so thick, it would have been a challenge to process in terms of molding and consolidation," DuPont's Silverman says. Therefore, the team has identified alternate components where the true value of the technology can be demonstrated. There are other opportunities to optimize the use of composites, and according to Silverman the team gained a tremendous amount of insight in the first phase. This has allowed them to narrow down the targets to those components with the most impact.

"The real heart of that understanding came out of Purdue doing that simulation work, and understanding the loading cases so that we could get a good design without having to make the part," Silverman adds. "That's the benefit I've realized out of this program ... the ability to absolutely understand what the part needs to look like and how it will respond before you make it. That saves time and money."

Fibrtec's Davies echoes those sentiments about the value of simulation when it comes to composites. "One of the things I've learned is how much simulation can help potential customers of ours with these types of materials in the future," Davies says. "It opened my eyes to how important that piece of the puzzle is, especially if you want to go after high-volume markets like automotive." **DE**

Brian Albright *is a freelance journalist based in Cleveland, 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 ➜ DuPont: DuPont.com

➜ **Fibrtec:** Fibrtec.com

➜ **IACMI:** IACMI.org

➜ **Moldex3D:** Moldex3d.com

➜ **MultiMechanics:** MultiMechanics.com

➜ **Purdue Composites Manufacturing and Simulation Center:** Purdue.edu/cmsc

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Sticking Up for Lightweighting

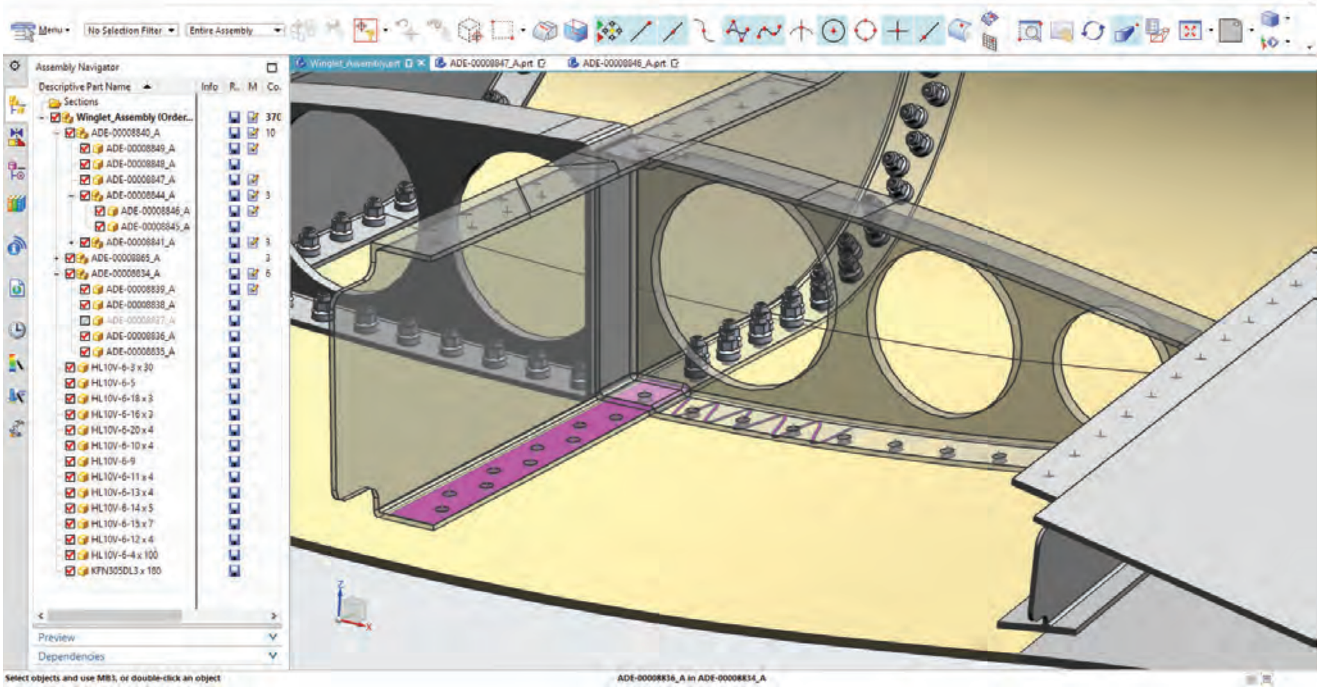
Use of adhesive-bonded structures increases as lightweighting continues.

BY KENNETH WONG

HOW WOULD YOU LIKE to drive or ride in a car that's glued together? Chances are, you may already be doing so. On Sept. 8, 2014, *The Wall Street Journal* informed its readers, "Super Glues Are the Secret to Making Cars Lighter."

3M, the company best known for its yellow Post-it notes, is a major player in the business of automotive adhesives. In the section of its site dedicated to automotive lightweighting, it writes, "Did you know that some of today's vehicles contain more than 500 linear feet of adhesive? This is nearly 15 times more adhesive than was used in a vehicle in 2001. There is no question when it comes to lightweight vehicle design, new materials need new methods for joining them together ... Adhesives are playing a larger role in ensuring that engineers can put these materials together without the worry of corrosion, different melting points, or thermal expansion."

In August, just as the Global Automotive Lightweight Materials Summit was underway (Aug. 21-23 in Detroit), the organizers published an interview with conference speaker Jeff McGarry, engineering group manager, ME Body in White Dispense Technologies, General Motors. McGarry's



Siemens PLM Software's Syncrofit allows the ability to specify the areas bonded with adhesives. The information can be transferred to NX CAD and simulation software for further analysis. *Images courtesy of Siemens PLM.*

team oversees the equipment and processes involved in the application of adhesives and sealers in the body shop.

"One of the biggest challenges with the increased use of adhesives is in process verification," says McGarry. "Verification of adhesive wet-out within the joint can only be completed by destructive evaluation. Destructive evaluation is costly and time-consuming."

If this is the case, could digital simulation technologies play a role in verifying the strength and performance of adhesive-bonded joints and structures? We pose the question to some simulation software makers.

Path to Multimaterial Lightweight Vehicles

Six years ago, manufacturing giant Siemens acquired Vistagy, known for its composite design software Fibersim. With this acquisition, John O'Connor, a Vistagy veteran, became Siemens PLM Software's director of Aerospace Product and Market Strategy.

"The interest in adhesives came from not only weight reduction but also cost reduction," he explains. "Mechanically fastened aerospace assemblies are expensive to manufacture. There's a lot of manual touch labor involved in drilling holes [and] installing fasteners, and the process is injury-prone." By comparison, "composites are pieces of material essentially glued together."

"The move to using adhesives is a byproduct of moving to the use of many different materials in a vehicle," explains Tod Dalrymple, SIMULIA R&D applications director, AM & Materials Applications, Dassault Systèmes. "It is not the adhesives that are directly the driver of the weight savings, but the move to lighter weight materials, which is enabled by the use of adhesives," adds Shawn Freeman, Structures R&D lead customer projects director, Dassault Systèmes.

The move toward multimaterial vehicles is evident in the current research projects and industry conference talks. In 2015, SAE International published "The Multi Material Lightweight Vehicle Project: PT-170" (sae.org). "The aluminum-intensive structure, combined with carbon fiber, magnesium and titanium, results in full vehicle mass reduction of a C/D class family sedan to that of a subcompact B-car (two vehicle segments lighter)," the authors note.

In 2017, at the Automotive Composites Conference Exhibition (ACCE), Dr. Patrick Blanchard, global technical leader, Composites, Ford Motor Company, delivered a keynote titled "Completing the transition From Metallic to Multi-Material Automotive Solutions."

One consequence of this trend is the increased use of adhesives. The incorporation of aluminum, magnesium and composites into traditional steel structures forces automakers to rethink how they fasten and join parts. "You would not want to spot-weld steel to aluminum. You cannot spot-weld composites to aluminum," Dalrymple points out.

Glued and Screwed

The adoption of adhesives doesn't mean the imminent death of traditional fasteners. Screw-less, bolt-less assemblies are becoming more common in smaller consumer electronics, such as smartphones, mobile tablets and connected monitoring devices. But in larger aerospace and automotive projects, fasteners will likely be used in conjunction with adhesives, leading to parts that are both glued and screwed, so to speak.

The 3M Magnet Bonding Adhesive AU-205 is one example of how design engineers are using adhesives. It is designed to provide electric motor design and manufacturing engineers with a means to bond permanent magnets to rotors and stators in high-efficiency permanent magnet electric motors. *Image courtesy of 3M via Business Wire.*

"Our consensus here is that [adhesives] do not eliminate the need for other fasteners in structural assemblies," Freeman notes. "It can reduce the number of fasteners, often resulting in a change from spot welds to rivets, or even bolted connections. For non-structural assemblies, the need for spot welds and other fasteners can be significantly reduced and eliminated in some cases."

One problem associated with traditional fasteners is the potential cracks that develop from cyclical loading and fatigue in the material around holes and bolts. The use of adhesive reduces this risk, but introduces other issues related to scenarios where bonded surfaces may become detached. "If the adhesive joints are not well-protected, you can have debonding. Or an impact to the area of the joint can cause debonding. Also, tight process control in application of the adhesive becomes critical to ensure its strength." says O'Connor.

Bonded in Pixels

Testing the strength of assembly joints can be done both physically (inside a testing lab) and digitally (inside finite element software programs). Design and simulation software vendors—Dassault Systèmes, Siemens PLM Software and their rivals—have been adding new enhancements to keep up with the evolving practices of the industries they serve.

The key, according to Freeman, is "knowing the proper way to model the connection properties and behaviors—and validating your model." For simulation software developers, that involves obtaining the proper material characterizations from adhesive suppliers (such as 3M) and material database merchants (such as GRANTA).

In aerospace, Dassault Systèmes is well-known for its flagship CAD products from CATIA and for its 3DEXPERIENCE platform. The company's SIMULIA brand represents its simulation software portfolio. "We provide technologies and options for discrete fasteners (e.g., spot welds and bolts) and adhesion over large areas (e.g., cohesive contact and cohesive elements)," says Harry Harkness, SIMULIA R&D technology senior director, Dassault Systèmes. "Some situations call for discrete and continuous interface options to be used together."

Simulation workflow often starts with simple representations, then progresses to detailed digital models of the behaviors of the assemblies. Therefore, one may "start with a simplistic representation of connections, such as permanent bond over entire interface, to get initial perspectives on the system, and then incrementally refine connection details for subsequent investigations," suggests Harkness.

"For virtual testing, Dassault Systèmes offers a wide range of modeling approaches that already cover spot welds, rivets, bolts, adhesives [and] combinations," says Laurent Petit, SIMULIA R&D applications manager, Dassault Systèmes. "There are also tools that allow the user to capture various design criteria using the 'knowledgeware' toolbox. Plugging these rules to our parametric and topology optimizers could lead to very powerful AI tools that would minimize the weight of an entire vehicle while automatically deciding which technology to use in each local situation."

Well-defined Joints

Siemens PLM Software, best known for its NX software, design and simulation package, offers Syncrofit, a program for managing complex assemblies and joints. "Syncrofit was developed as a joining tool. It is a design engineer's solution and operates inside of NX. It also runs inside of Dassault's CATIA product. The software allows you to specify the method of joining. That includes mechanically fastened joints, welded joints and adhesive-bonded joints. It also lets you incorporate lots of other information about the joints, like the expected loads or finish requirements. That allows you to calculate and predict the behavior of the joints in service over time," explains O'Connor.

Syncrofit itself doesn't come with a solver, but the software communicates with Simcenter 3D from Siemens' Simcenter portfolio. In these products, engineers and designers can simulate and test the various joints and structures in 3D models.

"To simulate the bonded area—the faying surface, as it is called—you specify the characteristics of the adhesive involved, such as thickness and coverage. That information can be communicated to Simcenter 3D," says O'Connor. "Adhesives usually don't behave in a linear fashion, like steel or metal, so you need more sophisticated simulation methods, like those available in Simcenter 3D."

"We now have the capability to define adhesively bonded joints to simulate and predict how they perform in service. But the technology is evolving. You have lots of new adhesives developed for different types of applications. The ability to get the right properties to run the simulation in CAE tools is critical, so we work with material vendors to help our customers gather those properties," adds O'Connor.

See Where it Sticks

The composite-related weight reduction statistics from 3M are quite tantalizing. The adhesive maker reveals, "Components made of carbon-fiber reinforced plastic (CFRP) are up to 40% lighter than steel components, while aluminum is around 20% lighter. Modern and highly filled thermoplastics reduce weight by up to 30%."

Freeman notices the pervasiveness of adhesives use now, compared to 20 years ago. "There have always been low volume uses of non-traditional materials among the original equipment manufacturers, but now we see a lot more flexibility in material selection even for the large volume vehicles," he says.

But it would be a mistake to get too aggressive with adhesives. In products that are designed to be disposable with a limited lifespan (for example, smartwatches), it may not matter. In aerospace and automotive projects, where the aircraft and vehicles are expected to go through numerous repair and maintenance cycles throughout their long lifespans, the inseparable bonds could prove costly, if used unwisely.

"When an assembly needs to be repaired, it's one thing to remove the bolts and fasteners to disassemble it, but quite another to debond a glued part," O'Connor points out. "While there are lots of advantages to adhesive-bonded parts, there are also questions about where it's appropriate to use them, and where it's not. Understanding this balance is important for best utilizing the ongoing innovations in adhesive technologies." **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 → Global Automotive Lightweight Materials Summit: global-automotive-lightweight-materials-detroit.com

→ **3M's Adhesives:** 3M.com/adhesives

→ **Dassault Systèmes:** 3DS.com

→ **Automotive Composites Conference Exhibition:** speautomotive.com/acce-conference

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Simulation Evolves for CAD Veterans

Advancing the use of simulation in the conceptual design phase often runs into roadblocks because the key players are more familiar with geometry modeling, less so with simulation software.

For simulation to expand beyond a small pool of expert analysts and become more mainstream, it must be more accessible. FEA (finite element analysis), CFD (computational fluid dynamics), and other simulation software developers have explored various ways to make their products more appealing to CAD users.
But how successful are their initiatives?

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Advanced Materials Challenge Durability Testing

The emergence of composites and new material options lead engineers to rely on new testing methods and simulation.

BY RANDALL S. NEWTON

BASIC MATERIALS HAVE RADICALLY transformed in recent years, as advances in chemistry and physics offer lighter yet stronger, resistant yet breathable, and many other feature combinations once thought impossible. A variety of resins, polymers, fibers and composite materials make materials specification an adventure in possibilities. A biomechanical engineer can design a new knee, but it takes a biomaterials engineer to find the right materials that can replace bone and cartilage. A computer scientist can design circuits for a high-speed CPU, but a materials engineer creates the semiconductor base.

Spending on research into advanced materials is increasing, according to Stewart Bland, Ph.D., of *Materials Today*. Research papers published on the subject increased 140% between 2004 and 2014. A recent survey from ASM International on materials-related technologies identified several materials categories "expected to have significant impact" in the near future, including new materials for high performance, energy and additive manufacturing.

Materials are the final frontier in the rollout of digital engineering processes. Factors like weight and color are trivial compared to the need to deeply understand durability—and to translate it into digital data. Basic and applied materials scientists are tasked with creating mind-boggling new materials and formulating testing processes that simultaneously prove suitability and provide the data to bring materials into the digital engineering chain. The increased use of 3D printers for final production is also creating new demands for materials data. Manufacturers need to validate new materials in simulations. Durability testing providers have become the gatekeepers in this process of bringing materials into the product design and development process.

Fatigue Challenges

Many manufacturers use test results provided by materials vendors, but certain disciplines, including aerospace and defense, must conduct their own rigorous testing. BAE Systems is a lead contractor for the F-35 fighter jet, also known as the joint combat aircraft (JCA). It operates a specific Structural and Dynamic Test Facility (S&DT) in Brough, UK, to create quantitative data to prove airframes meet their structural design specifications over the operational lifetime. The S&DT team has created a complex test rig with more than 3,800 data acquisition channels, managed by various nCode software products and related equipment from HBM Prenscia. The system conducts static and fatigue tests. A typical test routine generating gigabytes of data is delivered to engineers in the UK and North America in less than two hours.

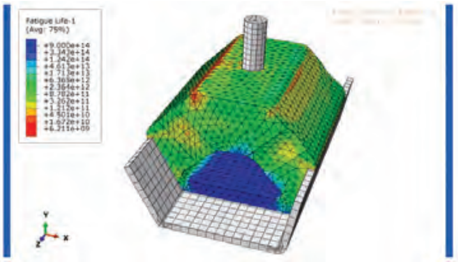
nCode software is also used in the Turbocharger Research Institute at the University of Huddersfield, UK. "We find their expertise in fatigue and durability is particularly useful as turbochargers present engineers with many complex fatigue challenges," says John Allport, institute director. "Aluminium impeller durability is driven by high-speed centrifugal forces; creep is an issue for aluminium compressor housings, and thermomechanical fatigue is an issue for turbine housings."

New Materials for 3D Printing

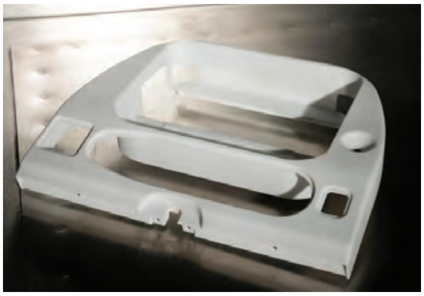
The 3D printing industry is moving from being a source for prototypes to a source for part production. Prototyping materials are generally not engineered for real-world use, so the challenge is to create specialized, durable materials suitable for final production. "In many instances, choosing production-grade materials is more cost effective than only serving prototyping needs," says Scott Cost, director of SLS product management at 3D Systems. "Parts last longer without failing and that durability over time saves money and effort."

End-use production parts have different requirements from jigs and fixtures, so 3D Systems has engineered a variety of production-grade SLS materials to suit the broader market. "End-use interior parts need to have flexibility, durability and impact resistance while assembly jigs and fixtures need strength and rigidity," notes Cost. "We have spent the last two years developing new materials designed to satisfy our customers' de-

Materials used in the F-35 fighter jet are subjected to continuous testing on long-term durability; results data are sent daily to engineers. *Image courtesy of HBM Prenscia.*



Endurica specializes in FEA of elastomers, compressing test cycles and eliminating the production of physical prototypes for every design iteration. *Image courtesy of Endurica.*



3D Systems' SLS production-grade nylon material DuraForm FR1200 is FAR 25.853 compliant, the flame retardant standard for aerospace. *Image courtesy of 3D Systems.*

mands for elongation, flexibility, impact strength, rigidity, temperature resistance or flame retardancy."

The first two production-grade select laser sintering (SLS) materials released by 3D Systems were an aluminum-filled nylon and a true black production-grade nylon 11 material, which requires minimal post-processing (no coatings). The company recently certified—in cooperation with Emirates Airlines—an SLS nylon that meets FAR 25.853 aerospace standards for interior flame retardancy, has a UL rating for consumer good use and carries Form 1 certification for aircraft use. The certification process took almost 12 months.

At the International Manufacturing Technology Show in Chicago last month, Stratasys showed off its Fortus 380mc Carbon Fiber Edition, an industrial system available for $70,000. The material used in the 3D printer, Stratasys Nylon 12CF, is 35% chopped carbon fiber by weight. The company says it has the highest stiffness-to-weight ratio of any filament 3D-printed part.

"In addition to tools and jigs, customers are using it for end-use connectors and brackets, replacing aluminum in many case" says Stratasys Senior VP of Sales Pat Carey.

Top 10 Time Savers

1. Don't use uncorrelated test bogeys.
2. Don't run worst case all the time.
3. Use the right test rig.
4. Collect lots of data to understand customer usage.
5. Create an equivalent damage test.
6. Reproduce only damaging cycle loads.
7. Reduce complicated loading to simplified loading.
8. Turn up the loading—within reason.
9. Use finite element modeling to understand what loads are important.
10. Understand the uncertainty of testing only one part.

— Source: nCode

Making Predictions

Predicting noise, vibration and harshness (NVH) fatigue is a key element of product engineering today. Endurica has emerged as a recognized vendor in the durability simulation software market. The competition is not other software vendors but traditional "build and break" testing methods, says William Mars, Endurica president. "Build and break is a plan for business failure. The advent of simulation has fueled a new 'right the first time' movement that empowers the engineer to very rapidly investigate and understand how alternative materials, alternative geometries or alternative duty cycles impact durability."

The Endurica CL solver for finite element analysis (FEA) uses rubber fracture mechanics principles and critical plane analysis to calculate fatigue lifetimes for every element in a simulation model. The resulting data gives engineers a clear view of the complete lifetime of a product or material without time-consuming and expensive physical prototypes.

The combination of new materials and market pressures is pushing research into advancing the state of durability testing. The University of Manitoba (UM) has conducted several studies they refer to as "test tailoring," in which specific materials are matched with specific CAE processes. The goal is to reduce the time of conventional durability testing without altering failure mechanisms.

In one test, UM researchers matched an aluminum alloy to the design of a cantilever beam and tested it in a simulation written in ANSYS Parametric Design Language. The simulation could do random vibration analysis and harmonic response analysis, but was not written to do unit acceleration displacements and strains while performing harmonic analysis. So the research team achieved acceleration displacement through "coupled degrees of freedom" to excite the base. The results were then passed to nCode's DesignLife solver, which could complete the test problem. The team concluded "good agreements have been found between the numerical results from the computer-aided model and the experimental results." **DE**

Randall S. Newton *is principal analyst at Consilia Vektor, covering engineering and emerging digital ledger technologies. He has been part of the computer graphics industry in a variety of roles since 1985.*

INFO ➜ ANSYS: ANSYS.com

➜ **HBM nCode:** ncode.com

➜ **BAE Systems:** BAEsystems.com

➜ **3D Systems:** 3Dsystems.com

➜ **Stratasys:** Stratasys.com

➜ **University of Manitoba:** Umanitoba.ca

Take Uncertainty Out of Engineering Simulation

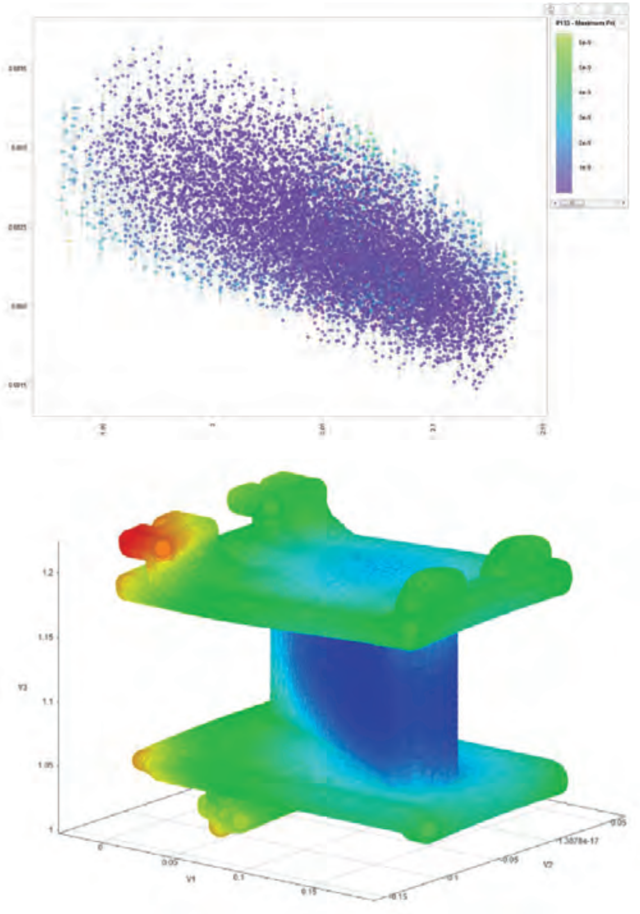
The SmartUQ uncertainty quantification and analytics platform allows simulation to overcome ambiguities for better informed decision making.

Simulation has become an indispensable tool, allowing engineers to model product designs and predict behavior while in the digital world, which speeds iteration and identifies problems well before building costly prototypes. Yet the exercise is a form of deterministic analysis, failing to consider real-world variability and the uncertainties surrounding the simulation and test process. Without taking such variability into account, engineers run the risk of conducting simulations that are missing key information or worse, are off the mark, leading to ineffective decision making.

If uncertainties can be quantified at the start of simulation, it's a completely different ball game. Uncertainty Quantification (UQ) is the science of characterizing and reducing uncertainties in both computational and real-world applications, a tool for determining how likely certain outcomes are if aspects of the system are not completely known. While the models and methodologies (which combine mathematics, statistics and engineering) are used throughout academia, the practice has not been incorporated into professional engineering workflows because of the lack of commercial, off-the-shelf software.

Enter SmartUQ, the first commercial software for industrial-scale UQ analytics designed to bring real-world variability and probabilistic behavior problem solving to engineering and systems analysis workflows. By augmenting traditional simulation packages with the SmartUQ platform, engineering teams can quantify every uncertainty, helping to accelerate design cycles, maximize high-impact insights, and improve overall design work.

While simulation software has brought a lot to the table, the transition from designing products in the physical world to doing so as part of a continuous digital workflow creates challenges by introducing ambiguities into the process. "As we transition into the digital age, we have to be concerned about the uncertainties that come with the process of going from a hands-on approach to a digital approach," explains Dr. Mark Andrews, SmartUQ's UQ Technology Steward. "When you introduce a physics-based model, you have to make sure the software represents the physics correctly with model validation. You have to ensure the math is coded correctly and works as expected — if you don't, the analysis won't make a lot of sense and you'll end up with something that's faulty."



SmartUQ can be applied to engineering problems across a host of industries, including defense, semiconductors, medical devices and turbomachinery. *Images courtesy of SmartUQ.*

An Error Bar on Simulation

So what is uncertainty in the context of product design and simulation? Uncertainty is an inherent part of all aspects of engineering modeling and design. Uncertain material properties and measurement errors are common examples. In simulation and testing, boundary conditions, system parameters, and computational and numerical errors found in systems and models are just a few instances where uncertainty rears its head.

Using physics-based simulation in conjunction with UQ's advanced statistical and machine learning modeling makes the probabilistic analysis of complex systems more manageable. Common approaches like Monte Carlo-based methods require generating and evaluating large numbers of system variation, which becomes prohibitive for large-scale problem solving. In addition, while most analysis tools provide some level of model validation and testing, they aren't equipped to handle the complexity of large-scale problems, which can result in failure to converge or missing data that puts simulation integrity at risk.

Tools like SmartUQ bring UQ methodologies within reach, providing a layer of context and knowledge that effectively places an error bar on simulation, identifying potential problems or incomplete models that could lead to poor design choices down the road. SmartUQ offers a range of training and consulting services that can help engineering teams augment their existing workflows with UQ practices. In addition to UQ assessment and deployment services, SmartUQ works with firms to integrate UQ processes in accordance with government regulatory guidelines, including compliance mandates from the Department of Defense (DoD), Federal Aviation Agency (FAA), and the Food and Drug Administration (FDA).

SmartUQ can be applied to engineering problems across a host of industries, including defense, semiconductors, medical devices and turbomachinery. In aerospace, for example, simulation models can help quantify, trace and analyze the impact of uncertainty such as shifting routes, environmental concerns and volatile fuel prices on design choices. Oil and gas companies are leveraging UQ to make equipment designs more reliable and to get a handle on the sensitivity to stochastic inputs like weather or wave loading. And in the automotive and off-road sectors, UQ helps rapidly explore the design space, trace uncertainty through vehicle systems to get probabilistic performance estimates, and accurately calibrate models to test data.

SmartUQ can be used alongside other simulation tools. In addition to simulation workflows, SmartUQ is being used in Six Sigma manufacturing applications and as a way to address uncertainty in digital twin scenarios.

Uncertainty is a reality of the engineering and design process. Yet by understanding the uncertainties associated with simulation of complex systems, engineers can reduce the time and expense of test and verification cycles while enabling more confidence in high-impact decision making.

Interested in learning more? Check out SmartUQ's free whitepapers at smartuq.com/resources/whitepaper.

SMARTUQ®
Quantify Every Uncertainty™

Under the Covers

SmartUQ, a powerful uncertainty quantification and analytics platforms, includes a range of functionality that empowers high-impact decision making to improve design cycles. It is currently in Version 5.0. Core capabilities include:

Design of Experiments and Data Sampling: A number of data sampling techniques and a comprehensive library of advanced DOE (design of experiments) generators for both simulation and physical experiments. One of the highlights here is a subsampling tool for Big Data applications and Adaptive Design, which maximizes sampling efficiency by using already gathered data to select additional data points.

Emulation (a.k.a., statistical prediction): In lieu of expensive Monte Carlo sampling and hours-long wait-times for analytic calculations, SmartUQ employs emulators or statistical predictive models to predict the behavior of complex black-box computational and physical systems. This approach enables extremely fast uncertainty propagation, sensitivity analysis, optimization and statistical calibration, and design space exploration.

Statistical Calibration: This tool quickly and automatically determines model calibration parameters even with limited simulation and test data. It provides model discrepancy measurements to identify opportunities for improvement and provides metrics for model validation. As a result, the tool is critical for decreasing design cycles by limiting the number of tests required to understand complex systems.

Sensitivity Analysis: This set of features helps rapidly determine which factors have a relatively low or high impact on the design space, allowing engineers to focus efforts appropriately.

Uncertainty Propagation: The heart of the system, this set of features helps engineers determine whether system outputs will meet requirements, what the extreme probabilities really are, and which inputs have the most significant effect on output distributions.

Optimization: Using adaptive sampling techniques and analytical models, this feature enables rapid search area reduction with multiple objectives as well as the ability to run through very large numbers of input parameters. It's another tool for shortening test cycles.

Inverse Analysis: This capability, which determines the probability distribution of an input results in a set of outputs from a system, helps verify hard-to-measure system properties.

Metal AM Market **HEATS UP**

From new cold spray deposition methods to innovations in extrusion processes, advances in metal 3D printing address long-standing limitations related to cost, safety and time to print.

BY BETH STACKPOLE

DECADES AGO, THE ONLY COMPANIES privy to computational horsepower had the deep pockets and technical expertise to run mammoth mainframes, until the PC revolution and subsequent rise of the internet democratized scalable computing. It's a similar trajectory with metal 3D printing—what was once the province of a select few engineers and manufacturers is slowly giving rise to more mainstream deployment thanks to innovative technologies designed to address long-standing limitations surrounding cost and performance.

For decades, powder-based sintering processes have dominated the metal 3D printing landscape, most significantly direct metal laser sintering (DMLS), which spreads layers of metal powder across a surface using a laser to sinter the material in a series of very thin layers. Although DMLS gained traction in the aerospace and medical sectors, the slow speeds and high costs limit usage to specific, very high-end applications, including lightweighting parts and creating highly customized medical implants.

In recent years, with early patents now expired, a host of startups are trying to reinvent metal 3D printing. They're introducing technologies and using more mainstream materials to aim to bring down the costs, accelerate time to print, and most significantly, establish metal 3D printing technology as a viable alternative to traditional machining and casting methods for early prototyping and production applications.

"As the market grows, startups and others are seeking new ways to process metals by AM," says Terry Wohlers, president of Wohlers Associates, a consultancy and research firm specializing in 3D printing. The *Wohlers Report 2018* estimates that 1,768 metal AM systems were sold in 2017 compared to 983 systems in 2016. "Speed and cost are two of the biggest challenges faced by the makers of metal powder bed fusion systems."

HP Metal Jet was launched last month at the 2018 International Manufacturing Technology Show. HP says it provides up to 50 times more productivity at a significantly lower cost than other metal 3D printing methods Inset: A Volkswagen gearshift knob created by HP Metal Jet. *Images courtesy of HP.*

The combination of patents expiring and highly visible success stories like GE's effort to lightweight and consolidate parts on its LEAP jet engine fuel nozzle have set the wheels in motion for further advances in metal 3D printing, according to Larry Lyons, vice president of Products at Desktop Metal, a prominent newcomer in the field. It's also making the technology a viable alternative for companies with mid-range manufacturing needs, where cost targets are more stringent.

"The bar for displacing traditional manufacturing with additive is much higher in cost-sensitive industries," Lyons explains. "Being able to adapt the technology to focus on speed and use more commonly used powders than traditional sintering processes … enables us to make the technology more affordable and accessible, getting into the hands of more engineers."

Raising the Metals Bar

Desktop Metal has two systems—the Studio designed as an office-friendly unit touted as up to 10 times less expensive than comparable laser-based systems for engineers doing realistic prototypes or limited runs of end-use parts, and the Production System, slated for delivery next year, which targets traditional manufacturing processes with claims of competitive speed and cost-per-part targets.

The Production System will use a single-pass jetting (SPJ) bidirectional process that combines all the necessary steps for printing into a single action. SPJ employs 32,000 jets and powder spreaders to spread powder and print in a single pass across the build area so there is no wasted motion. SPJ deposits the metal powder and jets droplets of a binding agent to form high-resolution layers, adding agents that help supports fall off easily after sintering, another critical step in reducing time to print. Desktop Metal claims the Production System can produce over 500 parts in the time it takes a laser-based printer to output about a dozen. The system also uses low-cost MIM powder, which greatly impacts cost.

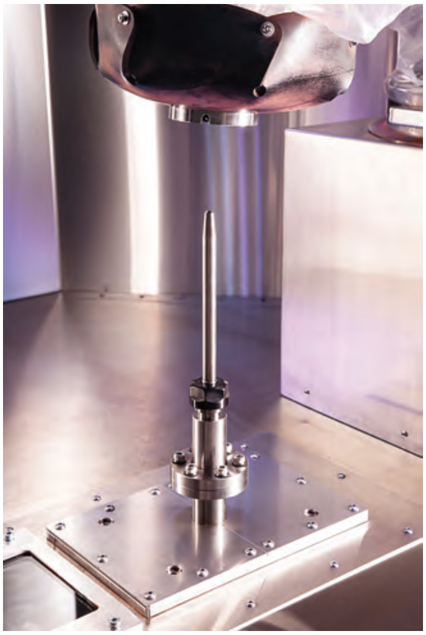
"When you combine the speed increases with lower raw materials costs, you end up with parts that start to cost more like what it would be with traditional manufacturing processes like machining or casting," Lyons says, adding that the printer's sweet spot will be for complex geometric parts on the middle end of production needs.

One of Desktop Metal's competitor's, Markforged, says its Metal X 3D printer is up to 10x less expensive than alternative metal additive manufacturing technologies. Its Atomic Diffusion Additive Manufacturing (ATOM) process prints metal powder bound in a plastic matrix, to help eliminate safety risks associated with traditional metal 3D printing powders.

addLEAP is a Swedish startup working on another disruptive metal extrusion print technology. Its patent-pending Layered Encased Additive Process (LEAP) combines injection molding technology and additive capabilities, creating a thin mold or "skin" in a polymer material and filling in the mold with metal compounds in parallel, layer by layer. Its other differentiator is CODE, or continuous debind, which performs the binding process continuously and simultaneously, eliminating the cumbersome step of removing binder materials from the printed object—a major headache in traditional metal 3D printing, says Mats Moosberg, president and founder of the company.

"Working out of a powder bed is a health hazard—you have to wear a body suit to be safe," he says, explaining that with the addLEAP approach, engineers deal with powder in a water-based binder, which is safer than working with loose powder. In addition, traditional metal 3D printing technologies incur a lot of powder waste and there are challenges removing binder material from the object in a safe way. addLEAP was designed to eliminate that complexity

Desktop Metal's Studio System claims to be up to 10 times cheaper than comparable laser-based 3D printers. ***Image courtesy of Desktop Metal.***



The cold spray deposition method relies on a rocket nozzle that accelerates air up to three times the speed of sound, eliminating the need for a heat source. ***Image courtesy of SPEE3D.***

and manual labor, while its fused deposition modeling-style skin molds ensure isotropic parts, he explains. addLEAP is still in the early stages of development with proof of concepts slated for next year and launch planned for sometime in 2020.

In addition to advances in metal extrusion/binding 3D printing technologies, there are some new alternatives on the horizon. Borrowing from cold spray technologies used in the military for years, some companies have refined the approach to achieve significantly faster speeds than traditional approaches by eliminating the need for heat source. Titomic, an Australian company, uses the Titomic Kinetic Fusion process, which sprays titanium powder particles at supersonic speeds, employing kinetic energy, not thermal energy, to fuse them into solids.

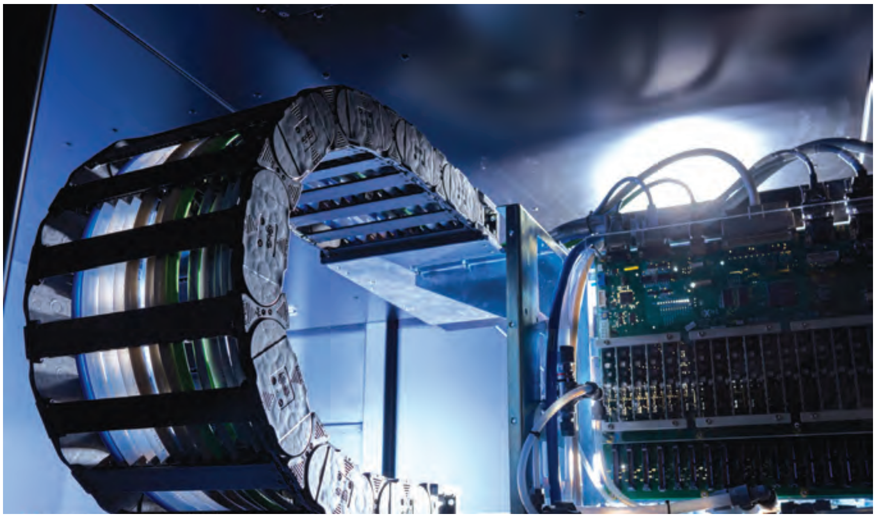
SPEE3D, another Australia-based company, is also hanging its hat on supersonic deposition technology to achieve the speed, cost and repeatability intended to rival casting processes. Unlike other metal 3D printing technologies aimed at creating highly detailed parts, SPEE3D aims to make cast aluminum and copper parts—think brackets, pulleys, even heat sinks used in electronics applications. The LightSPEE3D printer's supersonic gas jets achieve speeds three times the speed of sound, and the kinetic energy of the metal particles helps them deform and stick to the substrate, according to the company. A six-axis KUKA robotic arm, which is incorporated in the printer, allows for greater range of motion and aids in faster build times, notes Byron Kennedy, SPEE3D's co-founder and CEO.

"Our advantage is speed—in a traditional powder bed printer, you use a laser to melt the powder and you go from solid to liquid to solid, and that just takes time because there is physics involved," he explains. "No doubt you can make stunning parts, but it's slow." At speeds from 100 times to 1,000 times faster than what's possible today and with the ability to print medium-sized parts, the LightSPEE3D is positioned as an alternative to casting and molding processes, Kennedy says.

XJet, founded in 2005 in Rehovot, Israel, is pushing the boundaries of traditional metal 3D printing with another alternative technology. Its NanoParticle Jetting (NPJ) liquid dispersion methodology, which supports metals and ceramic materials, uses 24 print heads with 512 nozzles each to jet liquid suspensions of solid nanoparticles into ultra-thin layers, eliminating the use of traditional metal powders. In addition, the printer maintains a high temperature in the build volume, which evaporates the liquid, and a bonding agent is applied to form green parts that are then sintered. The stochastic nanoparticles ensure outstanding high-density part properties, making the technology a fit for producing highly detailed and custom parts, says Dror Danai, XJet's chief business officer.

XJet's ability to simultaneously jet a build and support materials means there is no need to plan for supports in the design stage, saving time and money; at the same time, the soluble supports are easily removed, Danai explains. "By using two different materials for the build and support structures, we can create anything that the design engineer can imagine," he claims. "Moreover, the beauty is that this material is easily removed so it minimizes post-processing."

All of these technologies have a place in the engineering workflow, depending upon the application and use



XJet's NanoParticle Jetting (NPJ) employs 24 print heads with 512 nozzles for liquid dispersions of metal and ceramics to produce highly-detailed parts. *Image courtesy of XJet.*

case, notes Cullen Hilkene, CEO of 3Diligent, a digital manufacturing service provider. The new cold-spray 3D printing technologies lend themselves to quick production of replacement parts while nanoparticle technologies deliver advantages for highly detailed parts and geometries. Regardless of which technology, having multiple metal 3D printing choices is a boon for engineers looking for opportunities to stretch their design wings and find new ways to cost-effectively create complex parts.

"There is a real diaspora of different technologies and tools to solve different problems and we'll continue to see more and more," Hilkene says. "Engineers will need to get familiar with the different strengths and limitations of different technologies or work with companies that can guide them." DE

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

INFO → **3Diligent:** 3Diligent.com

→ **addLEAP:** addLEAP.se

→ **Desktop Metal:** DesktopMetal.com

→ **Markforged:** Markforged.com

→ **SPEED3D:** SPEE3D.com

→ **Titomic:** Titomic.com

→ **Wohler's Associates:** WohlersAssociates.com

→ **XJet:** XJet.com

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

Siemens Solid Edge 2019: *Honing Its Edge*

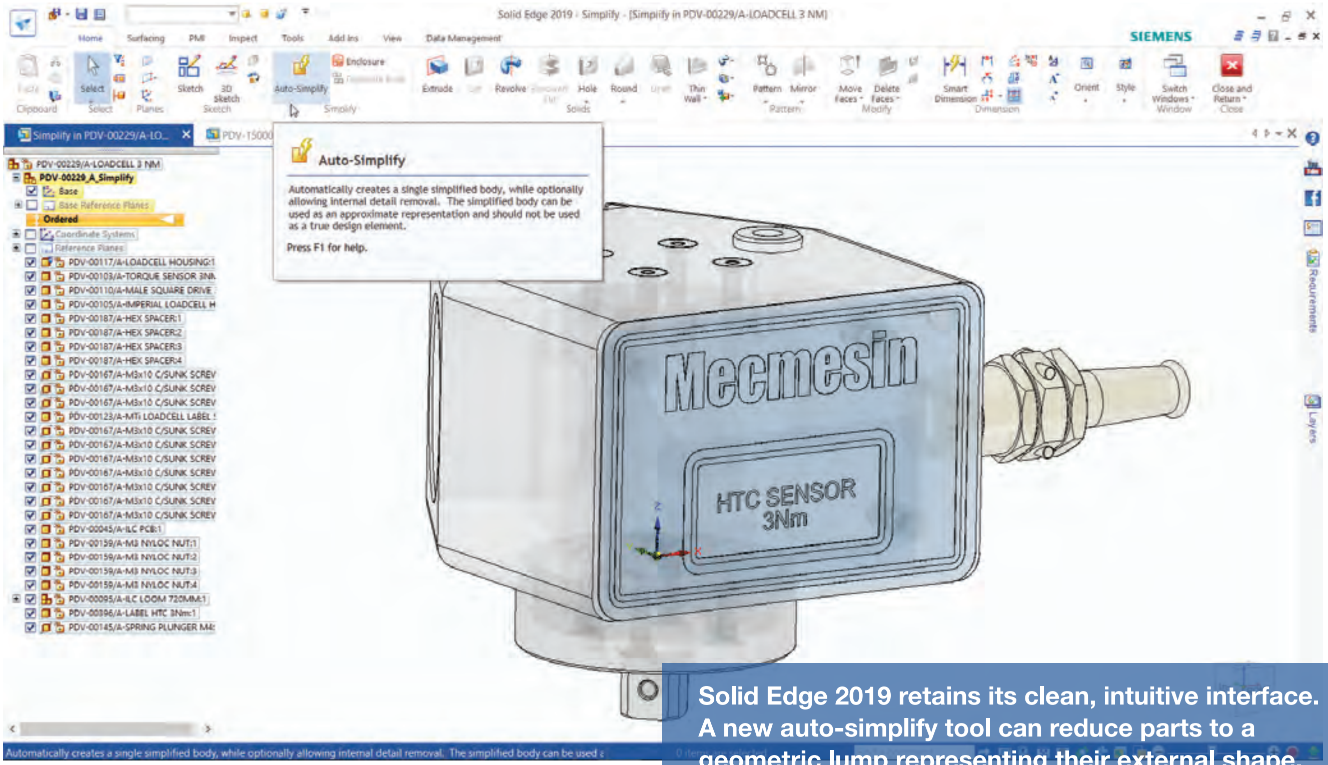
Siemens' latest update plus a host of add-ons make Solid Edge 2019 a significant release.

BY DAVID COHN

SIEMENS PLM SOFTWARE recently released the latest updates to Solid Edge, its mainstream engineering and design software aimed at small and medium-sized businesses. Solid Edge 2019 represents a broad expansion of the company's product development software portfolio, thanks to newly integrated capabilities, many the result of recent corporate acquisitions.

In particular, the new release integrates electrical tools for wiring, harness and printed circuit board (PCB) design. Solid Edge 2019 also incorporates improvements in additive and subtractive manufacturing, and modular plant design, and includes access to the Solid Edge Portal, a secure online service providing CAD management, viewing and collaboration capabilities for controlled project documentation and CAD file sharing.

Solid Edge 2019 (also referred to as ST10) is the program's 30th release. Originally developed and released by Intergraph in 1996 using the ACIS geometric modeling kernel, the software was purchased by UGS in 1998, at which time the modeling kernel was switched to Parasolid. In 2007, UGS was acquired



Solid Edge 2019 retains its clean, intuitive interface. A new auto-simplify tool can reduce parts to a geometric lump representing their external shape. ***Images courtesy of Siemens PLM Software.***

by the Automation and Drives Division of Siemens AG and the company name was changed to Siemens PLM Software.

A Well-designed Interface

Solid Edge offers a clean interface. When you first install the software, you can select an interface theme, which essentially determines how much assistance the software provides as you use various commands. You can change this at any time from the Quick Access Toolbar.

The basic user interface consists of an Application menu and Quick Access toolbar. Below this, a ribbon extends across the screen and organizes commands into tabs and panels. Along the left side, a scrollable window called the PromptBar displays prompts and messages related to the current command while the PathFinder organizes all the active document elements into a hierarchical view. When working in the part environment, this shows the feature tree, while in the assembly environment, PathFinder displays the components making up the assembly. A tabbed document interface fills most of the screen, with a Command Finder and view control tools along the bottom edge. There is also a Quick View cube in the lower-right corner of the document window that you can use to quickly reorient the model.

You can begin an ordered model by creating a two-dimensional (2D) sketch and then adding features (lofts, revolves, sweeps and more) as you would when using a typical solid modeler, with each step recorded in the feature tree. You can use shape handles to manipulate the model, use a steering wheel to create and edit geometry, or press and drag the right mouse button to display a radial menu where you can select various tools. The cursor's appearance changes as you use various commands and some commands also bring up a command bar, which displays command options and data entry fields for the command in progress.

You also can use direct modeling to modify geometry without regard to existing—or in the case of imported models, the lack of—parametric data. Direct modeling changes made to an ordered model are appended to the feature tree, just like any other ordered feature.

But Solid Edge also combines direct modeling with dimension-driven design—Siemens calls this Synchronous Technology (ST)—enabling parametric features to be applied directly to solid features without having to rely on 2D sketch geometry. When preparing to make synchronous edits, tools in the Design Intent panel help preserve or alter the design intent. For example, when selecting and dragging the face of a symmetric part, toggle off the symmetric design intent to alter just that face.

Improvements to Core Tools

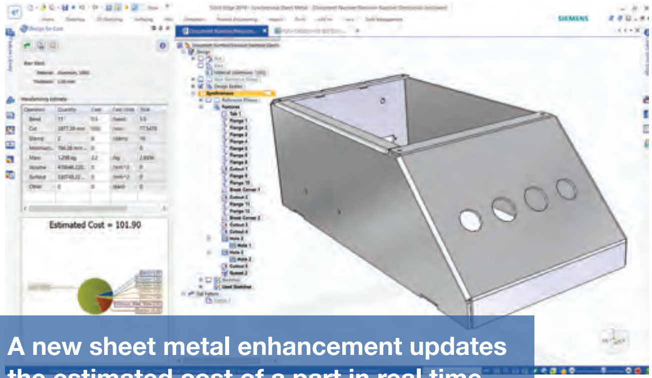
Solid Edge 2019 introduces some exciting new features. For example, you can automatically simplify assemblies to speed the design process and protect intellectual property. Auto-simplify results in a part or assembly being converted into a solid geometric lump that represents the part or assembly's external shape. Within the assembly, you can then easily switch to and from the simplified representation.

Solid Edge 2019 can also calculate the volume of any enclosed container based on an intersecting plane, such as the surface of liquid in a container. A goal seek function can then find the surface level based on a given volume.

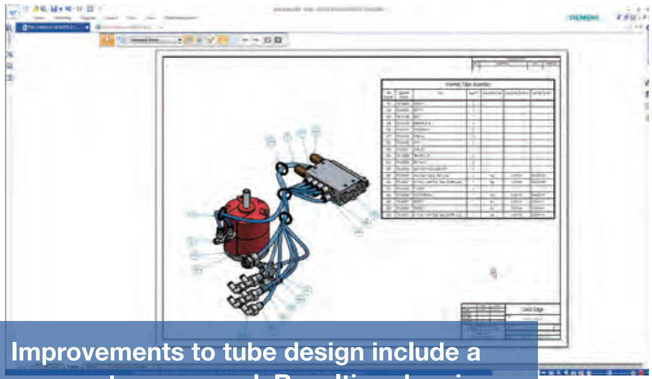
Solid Edge has long had some of the best sheet metal tools. Solid Edge 2019 now enables users to estimate the manufacturing and material cost of a sheet metal part in real time. Cost estimate data comes from Siemens' suppliers as well as information you supply. As you make choices and adds bends, cuts, stamps and so on, there is immediate feedback on how decisions will likely influence the cost, and one can automatically generate cost estimate reports.

Solid Edge 2019 brings enhancements to tube design, allowing the placement of the same tube subassembly multiple times using different paths. A new Route command lets one quickly adjust the tube path so that it passes through specific fittings or clips, yet parts lists continue to show the correct number of occurrences of each tube even though they have physically different paths.

New for generative design is the ability to apply multiple



A new sheet metal enhancement updates the estimated cost of a part in real time as you make changes to the model.



Improvements to tube design include a new route command. Resulting drawings include an accurate bill of materials.

You can now apply multiple loads in a single generative design study and create optimized designs that can be manufactured using standard machining.

load cases within the same study, so that opposing forces can be used to optimize the design. New controls allow for changing the distribution of material, while other enhancements allow the creation of an optimized design that can still be manufactured using regular subtractive machining. Parts can also be optimized to meet a given factor of safety. In addition, when working with mesh data, Solid Edge can now recognize planar and cylindrical faces, enabling users to add features and create assembly relationships.

Lastly, views can now be broken at any angle beyond just horizontal or vertical, further enhancing the creation of 2D production-ready drawings. And improvements have been made to the KeyShot renderer.

Lots of Add-ons

In addition to the new features and functions in Solid Edge itself, Siemens also announced multiple add-ons for electrical design, simulation, manufacturing, technical documentation and data management.

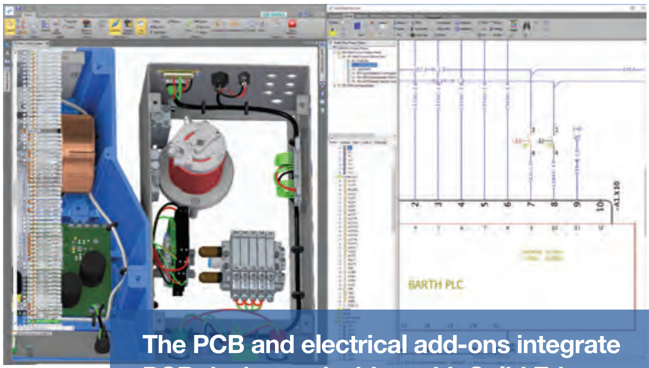
For example, Solid Edge adds new tools for wiring, harness design and electrical routing. Solid Edge Wiring Design provides design simulation tools for the rapid creation of wiring diagrams and verification of electrical systems. The harness design tools allow for the creation of nonscaled and full-size form board designs. Electric circuits can be analyzed and validated. Qualitative analysis gives the ability to check a circuit's correctness, while numerical analysis can be used to indicate dynamically any voltage drop or load issues.

Users can run the wiring and SOLIDWORKS 3D modeling environments in cross-connected mode (even across a network), so that physical changes made to the 3D model, such as wire lengths, are reflected in the harness design. When selecting a wire, harness or connector in one environment, it highlights in the other, and any changes made in either environment transfer across.

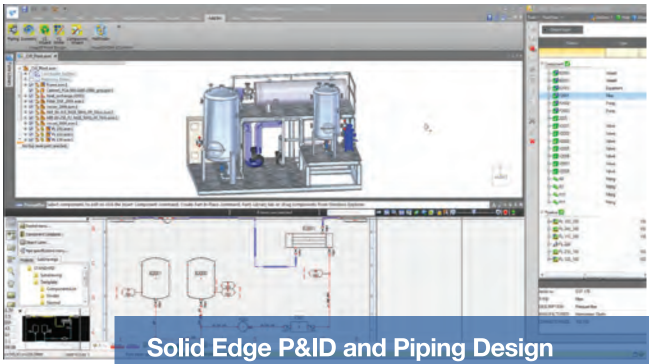
Solid Edge PCB Design enables designers to create 2D and three-dimensional (3D) views of printed circuit boards (PCB) and related components. After creating a PCB outline and determining the location of mounting holes in Solid Edge, the data can be imported into PCB Design for initial placement of components with fixed locations, such as connectors and taller components that may cause conflicts. Engineers can then complete the electrical design of the PCB. A collaboration file is then created and read back into Solid Edge, creating an associative link, so that changes made in either Solid Edge or the add-on are automatically reflected.

The Structural, Thermal and Flow Simulation add-on expands upon the program's structural and flow simulation capabilities. In addition to static studies for stress, strain, buckling, vibration and steady-state heat transfer, you can now study the effects of heat moving through parts over time, also known as transient heat transfer. This allows designers to see temperature changes over time to assess things like heating and cooling performance. Flow simulation also can be used to analyze the behavior of fluid moving, sloshing and flowing within a container.

Solid Edge 2019 adds an entirely new add-on for plant design. Solid Edge P&ID Design provides 2D flow diagram and symbol support for creation of P&ID drawings with support for ANSI/ISA (American National Standards Institute/Industry Standard Architecture), DIN (Deutsches Institut für Normung



The PCB and electrical add-ons integrate PCB design and wiring with Solid Edge models. Changes made in one environment automatically update in the other.



Solid Edge P&ID and Piping Design facilitate the creation of flow diagrams and fully automated isometric plant drawings.

e.V., which stands for German Institute for Standardization) and EN ISO (International Standards Organization) standards. Solid Edge Piping Design then provides automated 3D piping design with comprehensive 3D part libraries and fully automated isometric drawing output for plant design.

Solid Edge CAM Pro (previously called CAM Express) provides a computer numerically controlled programming interface that maintains associativity with the Solid Edge 3D model. The latest version handles product and manufacturing information with feature-based tolerance data.

There are also new add-ons for Requirements Management, which provide role and credential-based authentication and allow users to track key design tasks and improvements to the Solid Edge Technical Publication add-on, which provides an integration between Solid Edge and QuadriSpace's technical documentation software.

Finally, rounding things out, Siemens offers data management tools and cloud collaboration capabilities, including improvements to the integration between Solid Edge and Siemens' Teamcenter PLM system. An interesting final piece is the browser-based Solid Edge Portal, which allows users to view, share and mark up CAD files from any device. The portal also includes explode and sectioning tools, and Solid Edge users get 5GB of space on the portal for free.

Pick Your Level

Solid Edge is available in four levels. Solid Edge Design and Drafting provides 2D drafting, basic 3D part and assembly design, automated 2D drawings, synchronous technology (intelligent direct modeling) and design automation. This entry-level also includes a standard parts library, animation, mesh data import and basic motion simulation.

Solid Edge Foundation provides more complete 3D part and assembly design and adds sheet metal design, frame and weldment design, surface modeling, plastic part design, jig and fixture design and conceptual assembly layout. It also includes data migration for SOLIDWORKS, Inventor and Pro/E and Creo, as well as more complete motion simulation.

Solid Edge Classic adds CAM, gear, pulley, shaft, spring, beam and column design, extensions to the parts library, 3D scanning, generative design, photorealistic rendering, and basic stress and vibration simulation.

Finally, Solid Edge Premium incorporates everything in the lower cost packages and adds wire harness design, piping and tubing design, more complete stress and vibration simulation, and buckling simulation, thermal simulation and optimization.

You can download a free 45-day trial or stream the trial on a web browser, thus avoiding having to download any files. With all its improved core features, plus multiple add-ons, Solid Edge 2019 is a pretty significant release. **DE**

David Cohn *is the senior content manager at 4D Technologies. He also does consulting and technical writing from his home in Bellingham, WA. He is a Contributing Editor to Digital Engineering and is the author of more than a dozen books. You can contact him via email at david@dscohn.com or visit his website at dscohn.com.*

INFO ➜ Siemens PLM Software: Siemens.com/PLM

Solid Edge 2019

PRICING

- **Solid Edge Design and Drafting:** $100/month or $900/year
  – **or perpetual license:*** $2,117 (+$476/year maintenance)
- **Solid Edge Foundation:** $230/month or $2,220/year
  – **or perpetual license:*** $4,239 (+$1,375/year maintenance)
- **Solid Edge Classic:** $290/month or $2,760/year
  – **or perpetual license:*** $5,830 (+$1,591/year maintenance)
- **Solid Edge Premium:** $420/month or $3,940/year
  – **or perpetual license:*** 8,376 (+$2,262/year maintenance)

** Price is for a node-locked license. A floating license is slightly higher.*

SYSTEM REQUIREMENTS

- **OS:** Windows 10 Enterprise or Professional (64-bit only) version 1709 or later; software can be installed on Windows 8.1 Pro or Enterprise (64-bit only) or Windows 7 Enterprise, Ultimate, or Professional (64-bit only) with Service Pack 1
- **Memory:** 4GB minimum, 8GB or more recommended
- **Disk Space:** 6.5GB required for installation
- **Display:** 65K color minimum (TrueColor recommended; 1280x1024 or higher resolution

Jostling for the Best Position in a Peloton

CFD and wind tunnel test reveal aerodynamically advantageous positions in a group cycling race.

BY KENNETH WONG

IN 2017, VIDEOS OF THE ITALIAN CYCLIST Michael Guerra riding his bike in the Superman pose went viral on YouTube. Guerra rode the bike in a horizontal position, with his legs fully stretched out behind him and his back facing the sky. It was the same iconic pose of the DC Comics superhero in flight. (Hence, the name "Superman pose.") Many in the professional cycling sector wondered: Does this position offer an unfair aerodynamic advantage?

Researchers from Eindhoven University of Technology (The Netherlands) and KU Leuven (Belgium) ran wind tunnel tests on the mockup of a peloton in race. ***Images courtesy of Professor Bert Blocken and ANSYS.***

The community seemed to think one of the best people to settle this question was Professor Bert Blocken of Eindhoven University of Technology (The Netherlands) and KU Leuven (Belgium). Blocken's previous research proved that a cyclist being followed by a vehicle could benefit from the aerodynamic push. The advantage, he revealed, was significant enough to alter the outcome of a race. (For more, read "Can a Vehicle Following a Cyclist Change the Outcome of Tour de France?," Virtual Desktop, *DE*, June 29, 2015; https://bit.ly/2uVhtjD)

Eventually, queries about the YouTube clip began to fill Blocken's inbox. The Superman pose, Blocken's computational fluid dynamics (CFD) tests proved, is indeed a highly advantageous position for drag reduction, but he called the pose "dangerous and irresponsible."

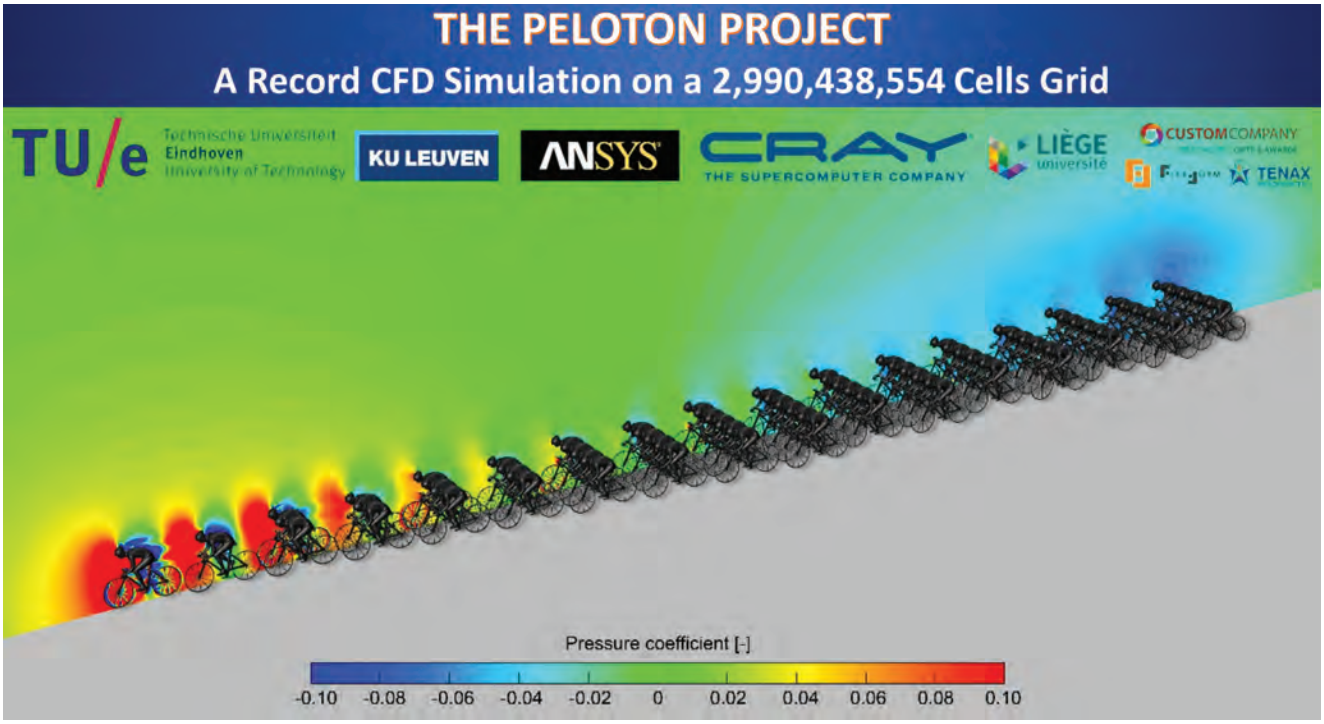
"Professional and recreational cyclists are counter-advised to ever attempt this and the International Cycling Union should ban of this type of position by means of its rules. Cycling is already dangerous enough as it is, and cyclist safety should always be the top priority," he wrote in a public LinkedIn response.

This year, Blocken and his team decided to examine the relative advantages offered by different positions in a cycling peloton—the platoon or group formation. His findings confirm some things experienced cyclists instinctively knew, reveal some they may not and raise questions about the accuracy of some widely cited statistics.

Group Behavior

In an article from San Francisco-based interactive museum Exploratorium (exploratorium.edu), the museum's senior scientist Paul Doherty wrote, "Cyclists who are part of the group can save up to 40% in energy expenditures over a cyclist who is not drafting with the group. To be effective drafting, a cyclist needs to be as close as possible to the bicycle in front of him. Many professional cyclists get within inches of the bicycle in front of them. The shorter the distance the larger the decrease in wind resistance."

Because the riders in the front protect those in the back from wind resistance, riders in pelotons develop sophisticated strategies to jostle for the best aerodynamic positions within the pack in different stages of the race. Riding in the middle of the group—the belly of the peloton, as it were—offers protection from wind resistance, but this advantage is offset by the fact that riders closer to the front are in a better position to react to opportunities. Furthermore, leading riders are also less likely to be hampered by collisions.



CFD test reveals the best positions (judged in wind resistance and drag) in a peloton ride.

With support from simulation software developer ANSYS and supercomputer maker Cray, Blocken decided to simulate the aerodynamic interactions of a large cycling pack, involving 121 riders. It was "the largest numerical simulation ever done in the sport industry and cycling discipline," according to the announcement from ANSYS ("The Peloton Project: Where to position leaders and sprinters? How much energy will they save?" June 20, 2018).

Blocken created a virtual peloton in 3D software and ran CFD simulations to understand how airflow, wind resistance and other factors affect the riders occupying different positions. To verify his findings, he also ran wind tunnel tests on a physical mockup, comprising 121 quarter-scale Neolith sculptures of cyclists.

According to his findings, the best position is in the core of the peloton close to its head, rows 12 to 14. His model also revealed, according to Blocken, "the drag experienced by the athletes in this position is 10 to 20 times less than for an isolated cyclist." Reactions from the cycling research community are 98% positive, Blocken estimated. The remaining 2% falls into the extreme spectrums, from "this is nothing new; we knew this already," to "we do not believe these results," Blocken reveals.

Surprises

Some of the common beliefs about drag reduction in peloton rides can be traced back to "old tests in wind tunnels with up to four riders in line, where it was noticed that riders 3 and 4 have about 50% of the resistance of a lone rider," Blocken explained. He believes extrapolating these numbers to the subsequent rows (fifth, sixth, seventh riders, all the way to the entire peloton) might be the origin of the suspiciously high percentages of drag reductions often cited in cycling literature.

"When you are Number 3 in a line of three or four cyclists, you are much less sheltered than when you have several rows (say, 10 or 15 rows) of tightly packed cyclists riding in front of you," Blocken pointed out.

To get a better picture, he used a virtual peloton with 121 cyclists spread across 17 rows. His wind tunnel test was also based on the same configuration. Blocken investigated "different pelotons—a dense one and a sparse one. These peloton configurations are based on aerial photographs of actual pelotons," he said.

Blocken noticed that key riders tend to ride at the edges of the peloton triangle. "We have now shown that these positions still have a very large air resistance, and they should move just one position more to the core," he said.

Could cyclists experientially figure out the drag differences by riding in various positions—by feeling the wind? Would they arrive at the same conclusion shown in Blocken's research?

Blocken is a cyclist himself, with 15 years of experience in different types of races and pelotons. He pointed out, "As a rider, it is very difficult to estimate your air resistance. You do not feel the differences between 40%, 50% or 60%. Between 100% and 60%, sure, but not in the much smaller percentage ranges."

Number Crunching

Processing the peloton simulation means running CFD equations on a 3D model with 3 billion cells. Per peloton, it took 54 hours to run on the Cray XC-40 supercomputer. "Each node has 128GB of memory. The number of nodes utilized per job is 13,824 / 36 = 384 nodes. Total memory used is 49,152GB. Each peloton case took about 54 hours to run, a large part of which was used for writing output files," recalled Blocken.

In a real race, peloton riders with varying heights, sizes and body types are involved, but to account for all these differences in the CFD model or the wind tunnel test would have been impractical. "There is an infinite number of possible combinations of cyclist sizes and distances in between, but evidently we cannot do an infinite number of simulations and an infinite number of wind tunnel tests," said Blocken.

Therefore, there remains a wide range of possible research to follow his initial findings. Blocken reasoned, "We did not investigate cross wind. That is for a follow-up study ... We did not consider cross-wind situations and pelotons going through bends in the road, as then the peloton can have a very different configuration. That is for follow-up research in the coming year."

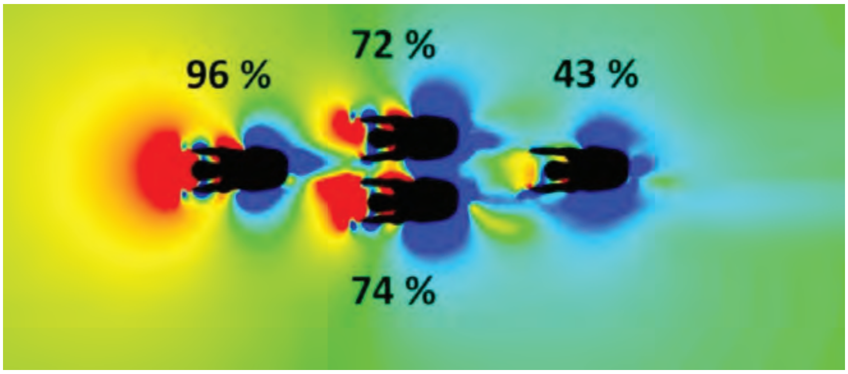
Winning Strategy

Conventional wisdom suggests that, in a peloton race, you can take shelter from the wind by riding behind other riders, then breaking out at the critical moment to overtake the competition. Blocken's findings may give cyclists new ways to refine this basic strategy.

"For the first time, we provided a digital map of what positions have what air resistance. This shows that key riders should not be riding at the outer edges of the peloton anymore," said Blocken. "Second, the mathematical models used by some teams for deciding when to attempt breakaways should be adjusted: The large number of 50%-70% air resistance needs to be decreased by about 5%-10% (or slightly more, depending on the number of bends in the race). This will lead to very different moments when the breakaway should happen."

Thanks to aerodynamics and physics, in the belly of a peloton, even an average cyclist might feel they are keeping up with the professionals. "Though the peloton is cruising at around 54 km/h, if you're in the belly of it, it feels like you are merely cycling at about 17 km/h. That is a very low speed that most amateurs can attain," Blocken explained.

But a cyclist shouldn't feel too secure in this false sense of performance. "This doesn't mean that you and I would be able to ride along with a professional cycling peloton from start to finish," cautioned Blocken. You could cruise along "maybe for a few kilometers, when the peloton is tightly packed and on a flat, straight road. But as soon as it goes through bends, you get this spike in the air resistance and you'll need the skills, training, and power of a professional cyclist to be able to catch up," he pointed out. This phenomenon demonstrates how much skill and effort it takes to successfully break away from a peloton to launch an attack or a sprint, Blocken noted.



CFD tests reveal how cyclists in the back aerodynamically benefit from the shelter provided by the front rider.

Knowing the most advantageous aerodynamic position doesn't automatically guarantee a victory. Other decisions—when to break out of the group for an attack, how to react when adjacent riders move in or out and how to react to the turns and obstacles on the route—still affect race performance. The athlete's determination, skills, stamina and instincts matter just as much as the position he or she occupies in the peloton.

Blocken's latest work with the peloton was published in the *Journal of Wind Engineering and Industrial Aerodynamics*, Vol. 179, August 2018, Elsevier, in Open Access: www.sciencedirect.com/science/article/pii/S0167610518303751.

Resource:
"Can a vehicle following a cyclist change the outcome of Tour de France?"
digitaleng.news/virtual_desktop/2015/06/can-a-vehicle-following-a-cyclist-change-the-outcome-of-tour-de-france

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 → ANSYS: ANSYS.com

→ **Bert Blocken:** Urbanphysics.net

→ **Cray:** Cray.com

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

Xi MTower PCIe Workstation: An Overclocked Performance Champ

@Xi updates its top-of-the-line workstation.

BY DAVID COHN

IT HAS BEEN SEVERAL YEARS since we last reviewed a system from @Xi Computer Corporation. Recently, the California-based company shipped us the latest version of its Xi MTower PCIe. Despite retaining the same name as the system we reviewed several years ago (see *DE*, February 2015 here: digitaleng.news/de/?p=22421), the workstation we received was all new, from its Fractal Design case to its 8th-generation Intel Core i7 Coffee Lake CPU.

Our evaluation unit came housed in a large Fractal Design Define S black tower measuring 9.17x20.94x19.31-in. (WxDxH). The total system weight was 30.75 lbs. A round power button is centered in the top front edge of the case, with a reset switch, microphone and headphone jacks to its left and a pair of USB 3.0 jacks to the right. The rear two-thirds of the case's top consists of a ventilation port, below which the radiator for the liquid cooling system is visible, while the monolithic front panel sports only a large @Xi logo—there are no accessible drive bays in the front of the system.

The rear panel provides a USB 3.1 Gen2 Type-A port, a USB 3.1 Gen2 Type-C port, a DisplayPort and HDMI port for the integrated Intel CPU-based graphics, a pair of USB 2.0 ports, two additional USB 3.1 ports, RJ-45 jack for the integrated gigabit ethernet, an optical S/PDIF out port and five audio jacks, including line-in/side speaker out, front speaker out, microphone, center/sub-woofer out and rear speaker out. The NVIDIA graphics card in our evaluation unit provided four DisplayPorts.

Extensive Options List

Prices for the latest generation of Xi MTower PCIe workstations start at $999 for a system based on a 2.8GHz 6-core Intel Core i5-8400 CPU, 8GB of RAM, an NVIDIA GT710 graphics board, a 1TB 7200rpm hard drive, mouse and keyboard, running Windows 10 Home and housed in a CM-N200 tower case with a 600-watt power supply. (Note: the online price of $1,099 includes a monitor that we removed when calculating our system price.)

As we have come to expect, however, everything about this workstation is customizable. We counted more than three dozen chassis options, including towers, cubes and rack-mount systems. The Fractal Design case with sound dampening materials that housed our evaluation unit added $39 to the base price.

FAR LEFT: The interior of the @Xi MTower PCIe workstation offers lots of room for expansion. LEFT: The new @Xi MTower PCIe workstation came housed in a large Fractal Design case with a monolithic front panel. *Photos by David Cohn*.

Loosening a pair of captive thumb-screws and removing the left side panel of the case revealed an expansive interior. Our evaluation unit was based on an ASUS PRIME ZS370-A motherboard rather than the base configuration's MSI motherboard. Here again, @Xi offers more than 10 motherboard choices, with the ASUS motherboard in our evaluation unit adding $119. That motherboard has four memory sockets and our system included 32GB of memory installed as four 8GB 3600MHz DDR4 DIMMs, which added $589 to the price. @Xi offers the system with up to 128GB of RAM.

@Xi also offers a choice of 14 different Intel CPUs with additional options for over-clocking. Our evaluation unit included an Intel Core i7-8700K. Although that CPU in a standard 3.7Ghz configuration with air cooling would add $249 to the system, the CPU in our unit had all six of its cores over-clocked to 5.0GHz and cooled using a Corsair H105 liquid CPU cooler with dual-fan radiator, an option that increased the system cost by $1,099. (Note that @Xi charges less for slower over-clocking.) The i7-8700K CPU has a 12MB cache, a TDP rating of 95 watts and includes Intel UHD Graphics 630.

The motherboard also provides ample expansion, with three PCIe x16 slots and four PCIe x1 slots. Though the base configuration does include a discrete graphics board, @Xi offers a wide range of NVIDIA graphics boards and the system we received came with an NVIDIA Quadro P4000 GPU, which added $759. That high-end GPU has 1,792 compute unified device architecture cores and includes 8GB of dedicated GDDR5 memory. With a 256-bit interface, it delivers a bandwidth of up to 243GB/second. Its 105-watt consumption requires an auxiliary six-pin power connector. The MTower system we received also included an 850-watt Gold Certified 80 Plus Rosewill Photon power supply, which added $95 to the cost.

Although the case includes three full-size drive bays, accessed by removing the right side panel, none were used in the system we received. @Xi offers more than 35 different primary hard drive choices, including SATA drives ranging from 1TB to 4TB and solid-state drives (SSDs) from 250GB to 4TB. But rather than the standard 1TB SATA drive included in the base configuration, our system came with a 500GB Samsung 970 EVO M.2 PCIe SSD, adding $199 to the price. If that's not enough storage, @Xi also offers nearly 50 choices for adding a second hard drive, including drives of up to 10TB.

Although our MTower system did not include an optical drive or any other accessories, @Xi again offers lots of options, including more powerful hard drive controllers, RAID arrays, optical drives, VR headsets, sound cards, external speakers, networking options and more.

Award-Winning Performance

With its over-clocked six-core CPU and high-end NVIDIA graphics board, we expected the new Xi MTower PCIe workstation to perform very well, and it definitely lived up to those expectations. On the SPECviewperf benchmark, only systems equipped with the more powerful NVIDIA Quadro P5000 GPU did better, and the @Xi system even beat those workstations on one of the

Workstations Compared

Workstations Compared	@Xi Mtower PCIe one 3.7GHz Intel Core i7-8700K 6-core CPU over-clocked to 5.0GHz, NVIDIA Quadro P4000, 32GB RAM, 500GB SSD	HP Z2 Small Form Factor G4 one 3.8GHz Intel Xeon E-2174G quad-core CPU, NVIDIA Quadro P1000, 32GB RAM, 256GB Z Turbo SSD, 1TB SATA HD	Origin PC M-Class one 3.7GHz Intel Core i7-8700K 6-core CPU over-clocked to 4.9GHz, NVIDIA Quadro P5000, 64GB RAM, 512GB SSD, 3TB SATA HD	Velocity Micro ProMagix HD80A one 3.5GHz AMD Ryzen Threadripper 1920X 12-core CPU, NVIDIA Quadro P5000, 32GB RAM, 512GB SSD, 4TB SATA HD	BOXX APEXX S3 one 3.70GHz Intel Core i7-8700K 6-core CPU over-clocked to 4.8GHz, NVIDIA Quadro P4000, 32GB RAM, 512GB SSD	Lenovo ThinkStation P320 Tiny one 2.90GHz Intel Core i7-7700T quad-core CPU, NVIDIA Quadro P600, 16GB RAM, 512GB SSD
Price as tested	$4,056	$1,949	$5,385	$6,603	$4,549	$1,479
Date tested	6/4/18	8/26/18	5/18/18	4/26/18	11/30/17	9/8/17
Operating System	Windows 10 Home	Windows 10 Pro	Windows 10 Home	Windows 10 Home	Windows 10 Pro	Windows 10 Pro
SPECviewperf 12 (higher is better)						
3dsmax-05	140.25	60.53	150.40	143.38	140.20	30.87
catia-04	164.72	62.60	206.44	159.73	170.48	40.37
creo-01	147.00	66.38	169.24	96.93	148.65	41.63
energy-01	12.70	4.46	18.64	18.58	12.62	0.41
maya-04	135.10	53.41	134.99	114.39	120.80	37.07
medical-01	56.16	18.03	79.37	76.94	56.17	12.24
showcase-01	82.86	24.96	103.99	102.04	82.78	16.32
snx-02	161.81	59.36	218.72	201.65	159.37	36.04
sw-03	197.24	103.80	212.00	167.42	196.79	63.53
SPECapc SOLIDWORKS 2015 (higher is better)						
Graphics Composite	6.04	4.17	5.86	3.38	6.25	2.59
Shaded Graphics Sub-Composite	4.13	3.13	3.91	2.22	4.53	1.99
Shaded w/Edges Graphics Sub-Composite	5.23	4.05	4.95	2.70	5.55	2.46
Shaded using RealView Sub-Composite	4.59	3.46	4.38	2.43	5.51	2.17
Shaded w/Edges using RealView Sub-Composite	5.17	3.92	4.92	2.73	5.93	2.60
Shaded using RealView and Shadows Sub-Composite	5.26	3.87	5.02	2.80	5.82	2.25
Shaded with Edges using RealView and Shadows Graphics Sub-Composite	5.45	4.08	5.21	2.90	6.22	2.55
Shaded using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	13.75	6.03	14.60	9.22	10.77	3.97
Shaded with Edges using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	13.63	6.75	13.94	8.46	11.93	4.49
Wireframe Graphics Sub-Composite	4.77	3.89	4.58	2.99	4.67	2.05
CPU Composite	4.10	2.53	3.87	4.25	4.27	1.67
SPECwpc v2.0 (higher is better)						
Media and Entertainment	4.70	2.42	4.93	5.03	4.91	1.44
Product Development	4.32	2.24	4.88	5.26	4.65	1.36
Life Sciences	4.88	2.25	5.65	7.32	5.24	1.39
Financial Services	6.31	3.56	6.14	10.37	6.07	1.70
Energy	4.95	2.40	7.48	5.76	4.91	1.10
General Operations	1.73	1.11	1.91	1.55	2.33	0.86
Time						
Autodesk Render Test (in seconds, lower is better)	24.00	45.10	28.80	34.30	33.40	109.90

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

Viewperf datasets.

On the SPECapc SOLIDWORKS benchmark, the @Xi workstation also scored near the top on every aspect of this test, and again turned in the best score we've ever recorded on one portion of the test. And on our AutoCAD rendering test, which clearly shows the advantage of fast CPUs with multiple cores, the Xi MTower PCIe workstation averaged just 24 seconds to complete our test rendering, nearly 5 seconds faster than any other workstation we have received.

We also ran the demanding SPECwpc workstation performance benchmarks. Here again, the Xi MTower PCIe performed extremely well, delivering results consistently near the top of the field and again recording the top scores in several of the individual test components. Despite a total of six fans (front and rear case fans, two radiator fans, plus fans in the GPU and power supply), the system remained nearly silent throughout most of our testing. But heavy compute loads during some tests caused sound levels to reach 73dB.

@Xi pre-loaded Windows 10 Professional 64-bit, a $59 upgrade from the copy of Windows 10 Home supplied as part of the base configuration. Our system also included a 104-key Logitech MK120 USB keyboard and USB mouse, but again, @Xi offers lots of other input options.

Like many other system integrators, the standard warranty only covers system parts for one year, although @Xi does include three years of coverage for labor and lifetime tech support. Longer warranties of up to five years are available for an additional cost. Once we tallied up all the high-end components, our evaluation unit priced out at $3,957 ($4,056 after adding $99 to reflect a full three-year parts warranty).

Although that price represents a significant markup compared to the cost to build a similar system, it's possible to fall short of the extreme CPU over-clocking achieved by the folks at @Xi. When considering the fact that it matched and, in some cases, outperformed other over-clocked workstations costing considerably more, this new Xi MTower PCIe workstation delivers a great price/performance proposition. **DE**

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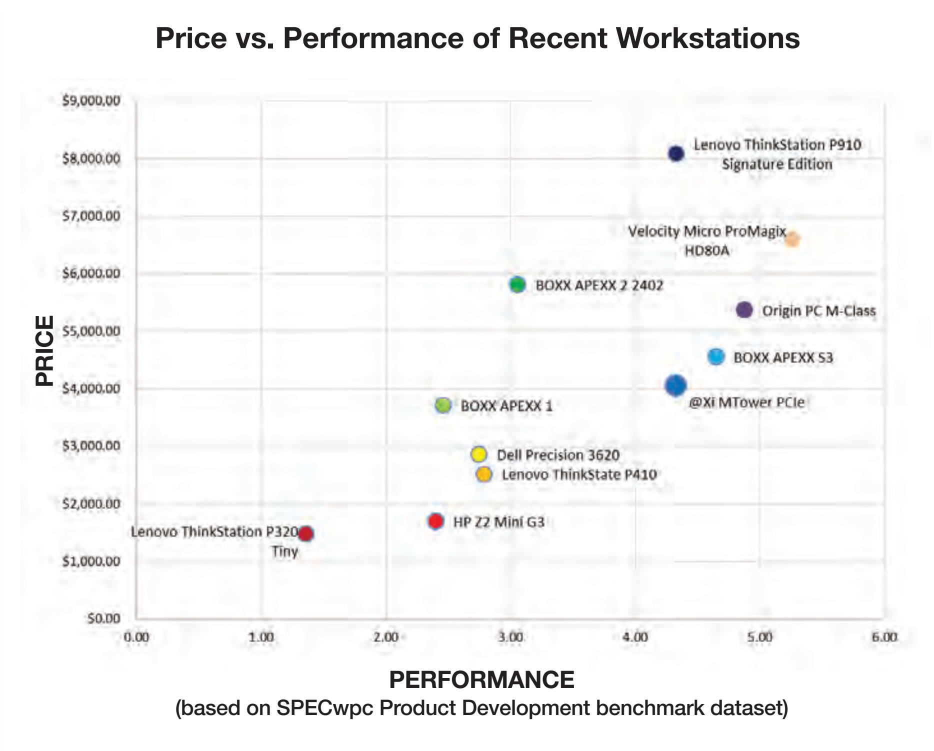


Price/Performance chart based on SPECwpc Product Development benchmark dataset.

INFO ➔ @Xi Computer: XIcomputer.com

@Xi MTower PCIe

- **Price:** $4,056 as tested ($999 base price)
- **Size:** 9.17x20.94x19.31-in. (WxDxH) tower
- **Weight:** 30.75 lbs.
- **CPU:** 3.7GHz Intel Core i7-8700K 6-core, over-clocked to 5.0GHz
- **Memory:** 32GB DDR4 at 3600MHz
- **Graphics:** NVIDIA Quadro P4000 w/8GB memory and 1,792 CUDA cores
- **Hard Disk:** 500GB Samsung 970 EVO M.2 PCIe 3.0 SSD
- **Optical:** None
- **Audio:** Integrated audio (front panel: microphone, headphone; rear-panel: line-in/side speaker, front speaker, microphone, center/sub-woofer, rear speaker and S/PDIF out)
- **Network:** Integrated Gigabit Ethernet (10/100/1000 NIC) with one RJ-45 port
- **Modem:** None
- **Other:** Six USB 3.0 (2 front/4 rear), one USB 3.1 Type-C, two USB 2.0 ports (rear), DisplayPort and HDMI port (for Intel CPU graphics)
- **Keyboard:** Logitech USB keyboard
- **Pointing device:** Logitech USB mouse

ITAR Compliance in the Age of On-Demand HPC

How to stay within ITAR's rigid boundaries while straddling the cloud's blurred borders.

BY KENNETH WONG

IN 2011, AMAZON WEB SERVICES (AWS) launched AWS GovCloud, described as "a new AWS Region designed to allow U.S. government agencies and contractors to move more sensitive workloads into the cloud." This was a necessary step for the cloud giant to cater to clients who must work in ITAR-compliant IT setups.

Born in the heat of the Cold War, International Traffic in Arms Regulations (ITAR) governs the transfer of sensitive defense and military technologies to non-U.S. persons. Items under the ITAR jurisdiction, as defined by the U.S. Munitions List, include launch vehicles, aircraft, nuclear weapons, chemical agents, submersibles and more. The rules stipulate that a U.S. person who wants to transfer technical data related to such items much first obtain authorization in a review process that involves the Department of Defense (DoD), the Directorate of Defense Trade Controls (DDTC) and the Bureau of Industry and Security in the Commerce Department, among others.

ITAR's intent and guidelines are publicly available at the DDTC's site at pmddtc.state.gov, but deciding what constitutes a violation gets complicated in the age of globally dispersed teams working on cloud-hosted infrastructures, on-demand software and browser-based file sharing systems. For instance, is uploading files to a server overseas considered a "transfer"? Can 3D CAD files for a DoD project be hosted and shared in a cloud server located outside the U.S.? Can engineers work on such a project with virtual machines (VM) hosted on a high-performance computing (HPC) server outside the U.S.?

Ordinary engineering firms and design shops may have neither the time nor the expertise to wade through the ITAR jungle. Their safest bet to ensure compliance may be to work with cloud service providers that are ITAR compliant.

Growing ITAR Queries

On the community forum of virtualization software provider VMware (communities.vmware.com), a user asks, "I need to implement a segregated VMware infrastructure to host VMs subjected to ITAR regulations, effectively ensuring that people of non-U.S.-approved nationalities can access this infrastructure. Does anyone have any clarity of what is needed to meet these requirements?" The five-year-old post remains unanswered.

With its cloud-straddling Fusion 360 products, Autodesk has convinced many CAD users that the online collaborative design environment is a much better approach than isolated desktops. One user asks on Autodesk's online forum (forums.autodesk.com), "Is there an option for the Fusion A360 Enterprise subscription for an ITAR-certified cloud?" Phil Eichmiller, Autodesk software QA engineer, responds, "The short answer is no, not currently."

Servers on U.S. Soil Only?

The common impression is that you could run afoul of ITAR, perhaps unwittingly, by working with software-as-a-service (SaaS) or cloud-hosted products. This may have stemmed from the notion that, when you work with cloud providers, you can't control where and how the physical data is stored; therefore, you're not in a position to comply with ITAR's non-transfer guideline. Since manufacturing data in modern times is largely digital, the question comes down to the location of the physical servers on which the digital files are stored.

According to FileCloud, an enterprise file sharing and syncing service provider, you don't necessarily need to rule out cloud offerings to remain ITAR compliant. "The State Department maintains that technical data can be stored on servers outside the U.S., provided … the ITAR license exemption conditions are met, and adequate measures are taken to obviate non-U.S. individuals from accessing technical data."

In most cases, the measure typically involves ensuring that any data sent to a server beyond U.S. borders, or that is potentially accessible by a foreign person within or outside the U.S., has to

AWS launches Cloud.gov to cater to government agencies with specific ITAR requirements. *Image courtesy of AWS.*

be properly encrypted," writes Gabriel Lando, the author of FileCloud's company blog.

Rescale, an on-demand HPC provider that caters to heavy simulation users, prides itself on security leadership in cloud simulation. The company states that it is registered with the U.S. DDTC, and its products are ITAR compliant.

"Companies subject to ITAR export regulations, such as many of Rescale's customers in the aerospace industry, must control unintended exports by restricting access to protected data to U.S. persons and restricting physical location of that data to the U.S. Rescale works with partners to provide an end-to-end environment physically located in the U.S. and where access is limited to U.S. persons, thereby allowing qualified companies to transmit, process and store protected articles and data subject to ITAR restrictions," the company writes.

Browser-based CAD

John McEleney, Jon Hirschtick and their colleagues at Onshape are veterans of the CAD world. In the mid-1990s, most of them had a hand in launching SOLIDWORKS, the first Windows PC-based CAD program. They have since moved on from SOLIDWORKS. Not quite ready to fade away, they got together to do what many CAD vendors said couldn't be done—run CAD from a browser. Three years after the launch of Onshape, the first SaaS CAD program, many other CAD vendors—including their former company SOLIDWORKS—are working to develop some kind of cloud-hosted solution.

"The important requirement for people who want to be ITAR compliant is to know and control where the data is," says McEleney, cofounder of Onshape. "We have ways to manage the client's data to ensure it stays within the U.S."

Onshape lets you run the CAD program from a standard browser, and work with design files saved and shared in a secure cloud. Technically, you could choose to disregard the cloud-hosted repository and use complicated workarounds to save files locally, but it proves cumbersome since it goes against Onshape's basic tenet and architecture.

Enterprise Control

In May, Onshape launched a new offering for its lineup: Onshape Enterprise. Onshape Standard and Professional cost $1,500 and $2,100 per user per year, respectively. Onshape Enterprise starts at a $20,000 minimum configuration.

Enterprise clients get their own domain URL. They can have a mix of full users with more privileges ($3,000 per user per year) and light users with limited rights and access ($300 per user per year), to reach the $20,000 minimum required for an Enterprise account. This mix allows a firm to have, for example, a pool of designated design engineers and project overseers with full rights, as well as a set of reviewers and sales staff with limited rights. The Enterprise version comes with project activity reports, centralized IP control, real-time analytics and other functions. It also has application protocol interfaces that allow integration with data from other product lifecycle management and product data management systems.

McEleney sees ITAR's importance, but also thinks it needs some reform to "recognize the power of the cloud and be put into the modern context." To him, a system like Onshape with strict digital history of file ownership and revision records is much more secure than some of the ITAR-compliant facilities where people habitually pass around files on USB drives, he reasons.

"Many of our larger customers love our product, but want some tools to manage it at the enterprise level. So the launch of Onshape Enterprise reflects the customers' interest to take advan-

SaaS CAD company Onshape released Onshape Enterprise to attract larger customers. Shown here is the software with a report of design release activities. *Image courtesy of Onshape.*

tage of the cloud," says McEleney.

The Enterprise setup brings Onshape one step closer to servicing the more IP-sensitive clients, such as military contractors working on DoD projects. Onshape says it is working toward ITAR compliance.

Order From the Cloud

With the rise of on-demand manufacturing, small design shops and even large enterprises now frequently turn to service providers like Xometry, Protolabs, Plethora, Stratasys Direct and Fictiv to produce their prototypes and parts. The convenience comes from the ability to upload the CAD files to the provider through a browser and obtain a quick job quote.

Perhaps to attract IP-sensitive projects, some of the service providers have registered with the DDTC. "Being ITAR registered tells our customers Protolabs is committed to physical security and logical access controls throughout the entire manufacturing process," says Jacob Heilman, director of Legal and Compliance, Protolabs.

"Protolabs' IT infrastructure was created to be ITAR compliant from the start ... Our online upload system incorporates strong encryption, CAD files are stored on-site on Protolabs' servers and all parts are manufactured in ITAR-controlled facilities," Heilman adds.

Who's Responsible for What?

On its page for GovCloud, AWS states, "Because AWS GovCloud is physically and logically accessible by U.S. persons only, government agencies can now manage more heavily regulated data in AWS while remaining compliant with strict federal requirements." AWS counts the Department of Veterans Affairs, the Department of Justice and Defense Digital Service among its customers.

Because AWS is one of the largest cloud infrastructure providers, its compliance is bound to have a downstream impact on the fate and fortunes of other companies that have their cloud offerings on AWS hardware. On AWS's website, the company spells out the shared burden of ITAR between it and its customers: "AWS is responsible for the logical and physical compliance of the cloud infrastructure and core services we offer. Customers are responsible for their own on-premises IT infrastructure, applications and systems."

The complexity of ITAR is such that it has spawned a thriving industry for consulting firms that help companies become compliant. ECS, which stands for Export Compliance Solutions & Consulting, is one such business.

"Even though cloud computing is a rapidly advancing technology at present, with more and more businesses routinely using Dropbox, Google Drive and similar online services, this has been—and still is—a confusing regulatory area for which State and Commerce have provided very limited guidance until recently," the company writes on its blog. "We're glad that appears to be changing now."

Whereas regulation changes seem slow and sluggish, technology is evolving at a furious pace, raising more questions for which only a few to date have good answers. One of the controlled items in the ITAR list is military training equipment and training. Does that mean those developing virtual reality and augmented reality training programs for the military need to be ITAR compliant? If so, what does it mean for the HPC server (which may be virtualized) where the virtual 3D environment data (which is usually a replica of some real-world terrain) lives? The answer is to be found somewhere in the murky borders between the virtual world and the regulatory hallways. **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 → FileCloud's blog: GetFileCloud.com/blog

→ **Onshape:** Onshape.com

→ **Rescale:** Rescale.com

→ **Directorate of Defense Trade Controls:** pmddtc.state.gov

→ **ECS:** Exportcompliancesolutions.com

→ **Protolabs:** Protolabs.com

For more information on this topic, visit digitaleng.news

Developing the Internet of Things

Engineers are creating more use cases for the industrial internet of things; but what roadblocks do they still need to consider?

BY TOM KEVAN

Image courtesy of Getty Images/ metamorworks.

HYPE OF THE INTERNET OF THINGS (IoT) often gives the illusion that all elements associated with the technology have transitioned from concept to tangible physical form. Although that is true in some instances, in others, the assumption is a bit premature. Given the current state of the technology, a fair question would be: Is this the case with IoT development platforms? Are these design environments on the market yet? What comprises an IoT development platform?

Before seeking answers to these questions, remember that the diversity of the IoT is staggering, and blanket solutions remain rare commodities. As with many things pertaining to the IoT, answers are not cut and dry.

Obstacles Abound

At this point in the IoT evolution, designing products for the new connected world remains daunting. As recently as 2016, Jeff Voas, a computer scientist at the National Institute of Standards and Technology, said, "There is no formal, analytic or even descriptive set of building blocks that govern the operation, trustworthiness and lifecycle of IoT components." Things have improved since then, but finding the right tools and development environments to create IoT products can be challenging.

Numerous issues contribute to this dilemma. Topping the list is the technology's complexity and scope. Forging links from sensors to enterprise systems requires development teams to work with embedded systems, multifaceted connectivity technology, real-time data and assorted power supplies. Furthermore, system architecture, multidiscipline collaboration and systems integration have become essential elements of success.

The obstacles, however, go beyond these factors. For one, the technology is still in its early days. As a result, developers have few standards to guide them. This means the market lacks all of the necessary terms and definitions required to fully understand and express the intricate facets of the IoT. All of these factors have converged to hamper the introduction of end-to-end development platforms.

Add to these challenges the fact that the IoT is not a monolithic infrastructure. Instead, this web of connectivity has assumed two personas: systems tailored for the industrial market and products engineered for consumer and enterprise applications.

A broad spectrum of factors differentiates these two segments. As a result, the composition of development platforms serving the industrial sector differs from those tailored for the consumer/enterprise market.

What Makes IIoT Development Different?

In developing IoT products for the industrial arena, designers must contend with unique challenges. These issues go a long way toward defining the development platforms currently available to engineers. To understand the platforms, engineers first must examine the issues they face.

Primary challenges are volume, variety and velocity of asset data. "It's important to first draw a distinction between the IoT and the IIoT [Industrial IoT]," says Darren Haas, senior vice president, Platform Cloud Engineering, GE Digital. "The IIoT is asset intensive, with billions of pieces of connected equipment from across the industrial ecosystem. The amount of data generated by those assets is unparalleled, all generating huge quantities of operational data. The volume, variety and velocity of asset data is vastly different than consumer-grade data. Hence, developing for the IIoT is quite different than developing for the enterprise or consumer IoT."

Key to today's IIoT development platforms is their ability to manage huge volumes and complexities of industrial data. In addition, these platforms must support the broad range of industrial communications protocols to source data into the platform. Without this support, developers would have to build custom connectors using a software development kit, adding more time and risk to development processes.

In another area, industrial modeling and persistence are also somewhat different than those found in the consumer/enterprise sectors. Industrial environments have to rapidly create many different types of data that must be brought together and modeled to deliver value to apps.

Lastly, IIoT development platforms must serve a different set of users. "Within an industrial environment, there are many different stakeholders that need access to apps that contain aggregated asset and system data," says Rob Patterson, vice president of strategic marketing, Technology Platforms for PTC. "One app will not satisfy the needs of the masses. An IIoT platform needs to enable rapid iteration of unique applications for individual users."

IIoT Data Handling

To successfully create a scalable industrial product, designers need a development platform built to manage the huge volumes and complexities of industrial data generated by equipment and systems from all types of manufacturers and vintages. Beyond the types of data defined by proprietary systems and communication protocols, there are two fundamental types of data—batch and streaming—and the platform's data ingestion function must be designed and built to account for these options.

Managing data entails not only acquiring input from the assets, but also processing it into a usable form. This

> **"Product design processes need to change. Product designers cannot simply design and deploy products the same way and then ex post facto add sensors and read the results."**
>
> —Peter Sutton, PTC

means determining what data is needed, defining what the data means and deciding how to tag it so that it can be evaluated by analytics to uncover insight.

Part of this process requires the platform to have adequate memory, judging how and where data is stored. "In some cases, assets may generate terabytes of data in a single cycle—like an aircraft engine in a single transcontinental flight. In other cases, it may need to be preserved for three years—in cases like food and beverage manufacturing, for example, or kept in country because of data governance restrictions," says Haas. "Retrieving, tagging and preparing the data for analysis is handled at the platform layer, freeing up the application developer to focus more on the advanced analytics."

Modeling for the IIoT

IIoT platforms should support various modeling approaches, beyond the basic level. Interoperability with different CAD systems is also essential. The platform should provide the means to integrate data with other tools, including CAD solutions so users can make better design decisions.

More critical to the platform, though, are the mathematical models. "These are largely data-driven models that are not visual, but rather abstract representations of asset behaviors and performance," says Haas. "So, if the design drawings represent the intent of the design engineer, the asset models represent how the asset actually behaves once it's deployed and operated in the real world. Bringing the two types of models together is one of the many capabilities of a digital twin, and critical to a successful IIoT platform."

Success of these models depends on collecting the right data. "The platform should deliver the correct data streams in a form the CAD modeling system can use," says Peter Sutton, senior director of CAD marketing for PTC. "Our customers tell us that getting data isn't the problem. Getting meaningful information out is certainly the problem."

Related to this issue is the sensing strategy. This is important because the CAD model serves an expanded purpose in the world of the IoT. The model, digital by nature, is a critical place where the real-time data from the product appears — the point where the physical and digital worlds converge. For the right data to appear, sensors must be integrated into the detailed design process from the start, so the sensors are a strategic lever instead of an afterthought.

Industrial Analytics

After modeling, the next step in extracting value from data is analytics. When considering an IoT development platform, look for an environment that provides analysis capabilities that go beyond conventional tools.

"Traditional reporting and visualization approaches are not well suited for IoT data analysis," says Patterson.

"They are difficult and time-consuming to adapt and use for high volumes of complex IoT data in new and varying formats. A good platform should use sophisticated artificial intelligence and machine learning to deliver reliable, actionable insights in real time."

This approach promises to provide the ability to detect changes in behavior and operating conditions in real time, minimize time to resolution, and optimize performance outcomes using prescriptive and simulative analytics that diagnose problems and generate recommendations.

Changing the Design Process

The call for CAD tools that understand the IIoT, the increasing role of artificial intelligence and machine learning, and the gravitation toward new sensing strategies all combine to create a demand for a new design process for the industrial sector.

Ideally, the new design methodology will begin with the stakeholders defining the whole product, its subsystems, interfaces and desired data streams. Engineering will sit side by side with marketing, service, packaging, operations, sales and finance.

"Product design processes need to change," says Sutton. "Product designers cannot simply design and deploy products the same way and then ex post facto add sensors and read the results. Product design now becomes a team sport, meaning more stakeholders than ever must be present—and from the first moments of product design. They will be the ones deciding the IoT strategy for the whole product and the customized data streams needed to support that strategy."

To meet the demand for a new design process and provide the tools to help it become a reality, the market has begun to see the introduction of development platforms tailored to meet the IIoT's unique requirements. Users can further customize these platforms by adding tailored modules that serve industry (e.g., oil and gas) and task (e.g., asset management) functions. This overall trend has been in the works for some time, driven by startups and industry leaders. That said, the question becomes: Can designers expect the introduction of similar development platforms in the consumer and enterprise sectors?

A Horse of a Different Color

Before this can happen, there are numerous hurdles to overcome. The diversity of operating parameters and application demands in the consumer and enterprise sectors hinder the development and use of a single, end-to-end development platform.

"Most IIoT products are very similar in use case and data profile," says Todd Zielinski, senior director of Electrical Engineering at the Bresslergroup, a Philadelphia-based IoT product development lab. "The IoT, however, isn't a one-size-fits-all endeavor. You need different tools for different applications, which is regularly the case for purpose-built hardware. To take advantage of differences in hardware, processors and vendor capabilities, there is still a need for different environments and libraries."

This is particularly true of mobile products, ranging from smartphones and tablets to smartwatches and fitness devices. "In the case of mobile applications, there are specialized development environments needed to support Android and iOS applications, along with developer portals, testing programs to see if they are supported on required versions of mobile platforms, and authorization-and-approval processes to be delivered through appropriate platform online app stores," says Zielinski.

Digital Supply Chain Distribution

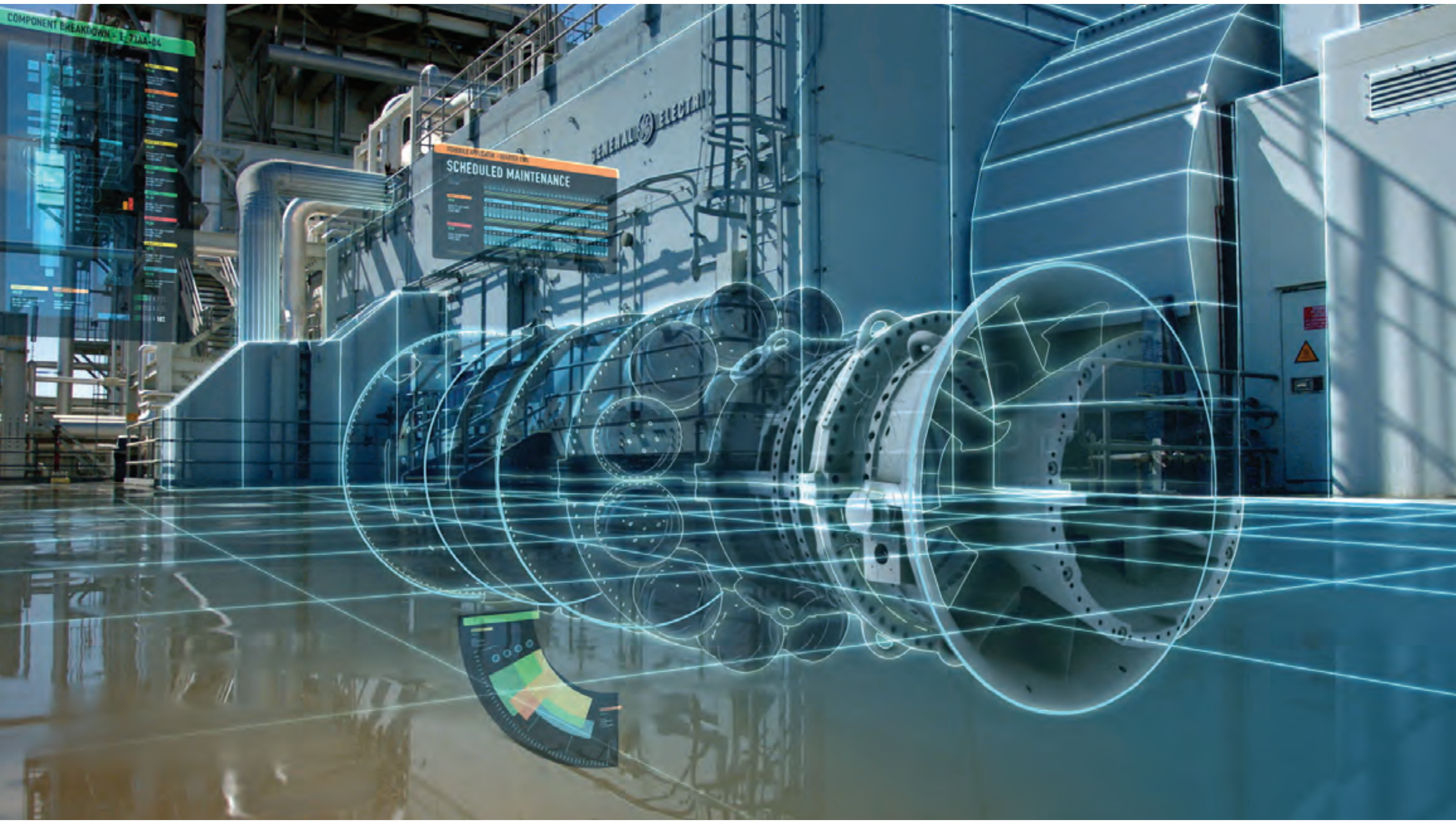
Identify3D, a software provider for intellectual property (IP) protection, manufacturing repeatability and traceability, demonstrated its Digital Supply Chain Solution at Siemens' booth during last month's International Manufacturing Technology Show 2018 in Chicago.

Every time data moves throughout the supply chain, it creates cybersecurity vulnerabilities that could result in theft, malicious or accidental alteration, or misplacement of data. Identify3D helps enterprises curb these risks by securing intellectual property while assuring manufacturing repeatability and traceability. It offers an advanced digital supply chain solution to facilitate secured data distribution related to the manufacturing of parts and ensuring exact authorized specifications are met. With this "secure container" approach, users can simultaneously send protected data to hundreds of machines, enabling a decentralized manufacturing process where components are produced at the time and place of demand.

"The digital container has everything needed to manufacture a product," says Joe Inkenbrandt, co-founder and CEO of Identify3D. "It enables security, repeatability, standardization and traceability. It can help manufacturers enable the digital twin."

Identify3D Protect creates a secure container while Identify3D Manage enables distribution and licensing policies for data usage within the container. In production, Identify3D Enforce allows applications and devices to access data based on a defined licensing policy.

—J. Gooch



The IIoT is asset intensive, with billions of pieces of connected equipment from across the industrial ecosystem generating huge quantities of operational data. Development platforms tailored to accommodate these factors have become available, leveraging analysis tools like the digital twin, which brings together data from the digital and physical worlds to provide enhanced insight. ***Image courtesy of GE Digital.***

Diversity Demands a Bigger Toolkit

Many consumer and enterprise IoT products derive their intelligence from embedded systems. Unfortunately, this technology is by definition a fragmented market, where tradeoffs are the rule, not the exception. These markets sport a broad variety of communications technologies, processors and operating systems and many of these require specialized development tools.

For example, there are numerous flavors of processors for every application. To deploy these, developers often turn to common development environments from companies like Keil, IAR Systems and others supported under the auspices of the GNU Compiler Collection.

Common integrated development environments (IDEs), like Visual Studio Code, make the coding process easier, but eventually designers must use JTAG/SWD debugger support through one of the standard embedded IDEs to see the low-level effects in hardware and manage the memory map of the application.

In addition, support for an embedded operating system depends on the particular platform being used. Whatever OS the development team chooses will affect the IP that the OS needs access to for the application. Many silicon vendors have begun to adopt FreeRTOS or mbed.

Embedded operating systems also generally have additional tools to monitor battery life or process efficiency. These tools are available in the open source domain or from third-party vendors. In the memory protection used for heavier IoT devices, more common coding tools can be used, but the operating system tends more to support embedded Linux flavors, such as Yocto, or Android for particular applications where the user interface is paramount.

Start Testing Early

In addition to the challenges posed by use case and data-profile diversity, modeling, simulation and prototyping of products for the consumer and enterprise sectors pose their own challenges.

"Modeling and simulation with IoT device development can be difficult because of the varied connection methodologies, routing during actual deployment and platform differences," says Bresslergroup's Zielinski. "The earlier you can test out the key functionality and connectivity of an IoT device, the better. Evaluation systems and modules can be extremely useful in quickly testing a concept for a minimum viable product, but the closer you can get to the actual product architecture the better. Trying your prospective development environment out as soon as possible will help show where potential issues will be encountered in getting to a working prototype."

The Value of Analytics

Another resource that eases the designer's job is analytics. These tools define the issues that arise when it's time to make design tradeoffs.

"Common analytics include operating system latency, power usage, code coverage, compliance metric and tools to do unit testing of connectivity stacks," says Zielinski. "Benchmarks can be difficult to compare in this space, in that most IoT devices' performance are not dictated by total data processed, but by efficiency of battery life and how they deliver value for performance. A simple device that consumes little battery power and communicates accurate data appropriately and reliably is usually the best device for this application. Benchmarks should reflect this attitude, in power used per cycle, efficient memory usage for communications and reliability of code."

Automating the Development Process

Whether talking about the IIoT or the IoT, automation has increasingly proven to be critical to the success of product development platforms. These platforms should streamline as many development steps as possible to enable scaling.

This process relies heavily on the use of artificial intelligence and machine learning, as well as new approaches to tools and environments. For example, for applications to run successfully across different form factors—whether on the edge or in the cloud—many developers have turned to containerization strategies for development and deployment, which allows more flexibility to where applications can run.

These developments are just the beginning of IoT development platforms' evolution. For years to come, the only certainty in this area will be change. DE

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INFO→ Bresslergroup: BresslerGroup.com

→ **GE Digital:** GE.com/digital

→ **Identify3D:** Identify3D.com

→ **PTC:** PTC.com

→ **Siemens:** Siemens.com

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Next-Gen Engineers

The ASM Materials Foundation Undergraduate Design Competition

Awarding Material Design

BY JIM ROMEO

ASM INTERNATIONAL, formerly known as the American Society for Metals, is a professional organization for materials scientists and engineers. In 1952, the society established the ASM Materials Education Foundation, a 501(c)(3), nonprofit supporting organization, to encourage education and scholarships. The organization has been devoted to promoting applied science careers for students and teachers for 65 years.

The ASM Materials Education Foundation provides advancement of scientific and engineering knowledge through its support of education and research. Each year, the foundation sponsors an undergraduate design competition that centers on the use of materials and metallurgical design and engineering applications in a competitive forum. The submissions are judged and winners are selected and awarded with monetary sums for each prize level.

Carrie Wilson is the executive director of the ASM Materials Education Foundation. We spoke to her to gain insight into their competition.

Digital Engineering: Can you provide an overview of the ASM Materials Education Foundation Undergraduate Design Competition, how it came to be and the intent of the program? Who will be participating or who has participated? How many participants have you had or are you expecting? Any demographics on participants?

Carrie Wilson: The program was started in 2007 by the ASM Action in Education Committee, which acknowledged that design is the most critical component in materials engineering education. The competition was developed to encourage strengthening of design curricula in materials science engineering departments. Recognizing the diversity of these curricula, they allowed for projects that address the design of a material, design of a process or the selection of materials in product design. The awards are selected by a subcommittee of industry and national laboratory representatives.

Each year the foundation receives up to eight team entries and selects three winners. Participant teams are undergraduate students, usually completing the entry as part of a capstone project in their department, and can be from any undergraduate university engineering program (e.g., materials science and engineering, metallurgy, metallurgical engineering, ceramic engineering, polymer engineering and manufacturing engineering or related programs, including but not limited to mechanical, chemical, electrical or bioengineering). Interdisciplinary teams with members from various engineering and science disciplines are encouraged to submit entries. **DE**

Winners of the 2017 undergrad design competition. *Image courtesy of ASM International.*

Jim Romeo *is a freelance writer focused on business and technology topics. Contact him vis JimRomeo.net.*

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.*

Requirements, Product Record and Quality Linked

Requirements management capabilities said to foster collaboration.

Arena Requirements Management expands the Arena platform's support for NPIs by providing the ability to better document, analyze, trace, prioritize and control requirement changes through the process. Apply Arena Requirements Management to new product development activities from the concept stage through manufacturing or to work done on future iterations of an existing product as well. One data source, one product record and one management system foster multi-team collaboration.

MORE ➔ digitaleng.news/de/?p=46283

Fourth-Generation HP Z2 Lineup Launches

Pro-level HP EliteDesk 800 Workstation Edition G4 launches simultaneously.

The HP Z2 G4 lineup includes the HP Z2 Mini, HP Z2 Small Form Factor (SFF) and HP Z2 Tower workstation. They include built-in security services, Thunderbolt connectivity, and graphics and processing oomph. Boost graphics, add on devices and expand them so that they're the right fit for you.

A new fourth-generation desktop was also launched; it's CAD-certified; and VR-ready out of the box. It has five bays, four full-height slots, three M.2 slots and many ports.

MORE ➔ digitaleng.news/de/?p=46160

Mills Expand and Flex for User Needs

Tormach unveils its next generation of CNC machines.

Tormach reports its new 770M and 1100M series mills combine years' worth of upgrades, optimizations and user feedback. Of note is that these modular units are built to provide a flexible workstation to handle various jobs and materials.

They're designed to get you up and cutting quickly while offering expandability to take on varied challenges. Optional accessories include things like an automatic tool changer, a fourth axis and a chucker lathe.

MORE ➔ digitaleng.news/de/?p=46078

Custom Open Hardware Platforms

Family of servers and storage solutions handles analytics, AI and virtualization.

Equus Compute Solutions announced its WHITEBOX OPEN family of open-hardware server platforms. Open hardware means you can access your hardware documentation and discover what the hardware can do. Turn on capabilities you didn't know it had or modify it in ways that fit your workflow. Just like with open source software. No more wondering if the software development kits have given all the information you need. Models range from a 1U four-bay unit to a 24-bay 2U unit.

MORE ➔ digitaleng.news/de/?p=45959

LS-PrePost® an Advanced Pre- and Post-processor

LS-PrePost® is an advanced pre- and post-processor developed for LS-DYNA®. It is fully multi-platform with support for Windows, Linux and Mac OSX. LS-PrePost is based on the OpenGL rendering engine with a design that is both efficient and intuitive. It is delivered with LS-DYNA without additional cost and may be installed on multiple platforms. License keys are not needed.

Geometry and Meshing Includes

- A geometry engine which allows the creation and modification of curves, surfaces, and solid objects. Also included are tools to heal and simplify the geometry model
- An automatic surface meshing tool
- An automatic 3-Dimension(3D) tetrahedron meshing module
- Various methods to create a mesh by dragging, spinning, offsetting, and sweeping
- The construction of middle surface shells from 3D Solids

Pre- and Post-Processing Capabilities

- Complete LS-DYNA Keyword management
- Tools to create and modify LS-DYNA entities
- General model setup for NVH (Noise, Vibration and Harshness), Implicit, and Thermal Analyses
- Tools to measure FEA data like distance, area, angle, volume, etc.
- Section cuts for better visualization in complicated models
- Comprehensive time history plotting for the d3plot, ASCII history, and BINOUT databases
- Time history plotting for user defined data
- Particle and Discrete element visualization
- CFD model and result visualization

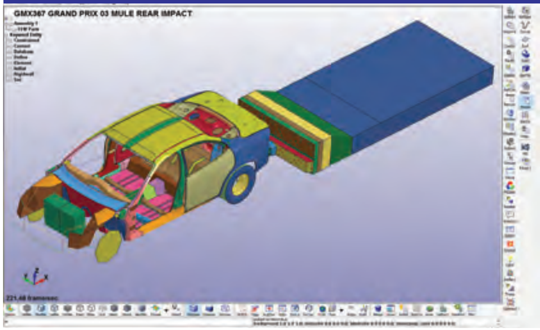
Other General Functions

- Tools to display, reverse, and auto reverse the normal vector directions of Shells, Segments, Thick Shells, and Cohesive Elements
- Printing of High Definition pictures in a choice of formats
- Movie creation for animation sequences
- Commands, Macros and a Scripting Command Language (SCL) for automated Pre- and Post-Processing

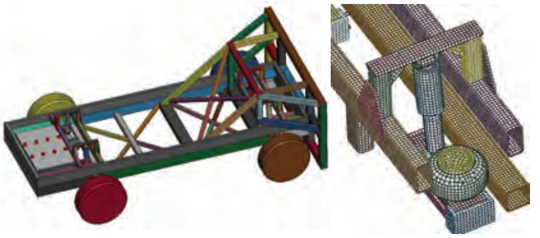
Applications

- Airbag folding
- Comprehensive model checking including contact initial penetration check
- Dummy positioning
- Metal forming process setup
- Seatbelt fitting

LS-PrePost Pre- and Post-Processing



LS-DYNA Geometry and Meshing



ICFD Post-Processing