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Digital Engineering

April 2020

CAD to 3D Printing Connection

Peerless MEDIA, LLC

By Brian Albright

Keep Your Distance

THE ONGOING CORONAVIRUS CRISIS IS HAVING A SIGNIFICANT IMPACT on the global economy in general, and in the tech sector specifically. That's particularly true if you happen to be trying to plan your upcoming business travel to any number of industry trade shows and conferences. At the same time, the threat of a pandemic has highlighted the potential for technology to help organizations cope with a potential crisis.

As I write this, the upcoming NVIDIA GTC conference in Silicon Valley has been changed to an online-only event. The Additive World conference for industrial 3D printing in The Netherlands has likewise morphed into a virtual event. Both ARBURG and ModuleWorks also cancelled tech conferences in Germany. Dell World is now online, and other events like Google I/O, Facebook's F8 event and the Mobile World Conference are cancelled.

This trend isn't limited to technology conferences with large international contingents, either. Conferences are folding up across the board, from the South by Southwest music festival in Texas, to the UNICEF Ball, the HIMSS conference, book conferences in Italy and France, and concerts around the globe that will leave fans of everyone from Green Day to the Boston Symphony Orchestra holding useless tickets.

According to PredictHQ, just the economic losses from the major tech conferences have surpassed $1 billion. For the conferences that are going to have a live event, company travel restrictions (and in some cases, travel bans involving specific geographies) are going to severely reduce attendance.

As a journalist, I can take these cancellations in stride; while there's plenty of value in seeing new technology in person and making one-on-one connections that aren't possible in other venues, I can still keep up with new announcements remotely if necessary. I can set up virtual meetings, and attend online conference sessions and webinars. Technology has given me options that weren't available when I began working in the magazine industry more than 20 years ago.

A New Way to Work

I thought a lot about this while attending the recent 3DEXPERIENCE World conference in Nashville in February. Formerly SOLIDWORKS World, the rebranded conference was organized around the 3DEXPERIENCE Platform from Dassault Systèmes, which encompasses SOLIDWORKS, along with SIMULIA, CATIA and other products. The solutions can be accessed virtually via the 3DEXPERIENCE Works portfolio, which also includes social collaboration apps, simulation and manufacturing capabilities.

Although Dassault has been promoting this concept for a few years now, the SOLIDWORKS user base has been slow to shift from traditional licensing to the cloud-based model. And Dassault isn't alone in this challenge. Although major companies in the design and simulation space like PTC, Autodesk and Siemens have rolled out new cloud-based solutions and alternative licensing models, most engineers have not yet made the switch.

Attendance at the Nashville event roughly matched the 2019 conference, but was short of last year's projections (which were based, at least partly, on getting users of other Dassault products to attend this previously SOLIDWORKS-focused event). The exhibit floor was also a bit smaller.

Some of those attendance issues were likely related to the coronavirus, and as I've seen more announcements issued about cancelled or greatly scaled-back events, the potential benefits of these cloud-based solutions can be viewed under a new light.

These solutions are often discussed in the context of improving collaboration, reducing licensing complexity or increasing productivity. But the value of these remote tools is more apparent when you consider their ability to let your team work from anywhere. If your engineers in China or Italy are prevented from going to the office or a client site because of open-ended travel restrictions, design and simulation work can theoretically continue unabated.

That's not to downplay the very real hurdles that software vendors have faced in rolling out these solutions. There are technical problems that have yet to be ironed out. There are workflows and processes that don't necessarily map to the cloud. There are system integrations that are not quite as seamless as they ought to be. But these platforms can provide a new way to approach design and collaboration that may be increasingly important in the future. DE

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INSIDE

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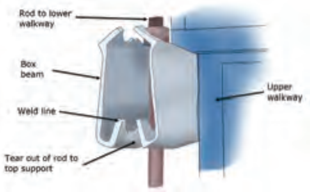
ON THE COVER: Getty Images

FEATURES continued



REVIEW

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Rapid Growth for 3D Printing

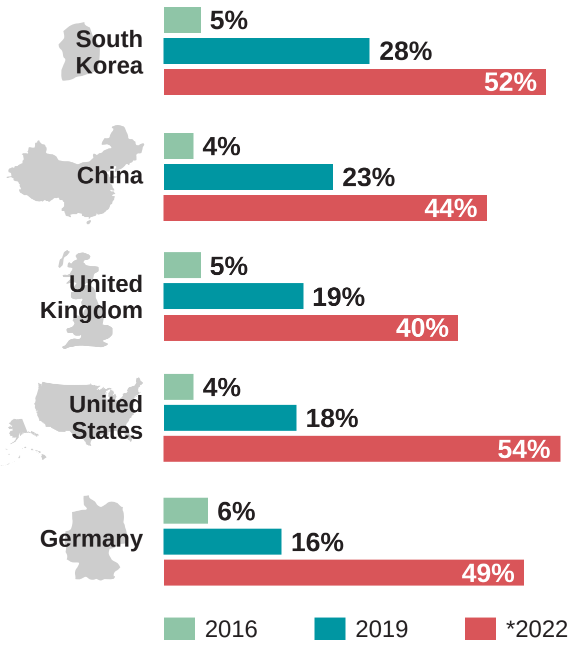
The global 3D printing market was valued at **$11.58 billion** in 2019, and is expected to expand at a compound annual growth rate (CAGR) of **more than 14%** through 2027. Globally, **1.42 million units** of 3D printers were shipped in 2018; this number is expected to reach **8.04 million** units by 2027. The industrial printers segment made up the largest market share of **77%** in 2019 and is anticipated to continue its dominance over the forecast period.

The functional parts segment is expected to register a significant **CAGR of 14.9%** from 2020 to 2027 in line with the increasing demand for designing and building functional parts.

The metals segment is also expected to expand at the highest **CAGR of above 19%** over the forecast period.

Source: Grand View Research, February 2020

Use of AM for Making End Products



*Numbers indicate projected growth.

Source: EY, "Global 3D Printing Report 2019"

$14 BILLION

The size of the global 3D printing materials market by **2024**. According to new research from Global Market Insights, the global 3D printing materials market reached **$590 million** in **2015**, and is expected to register a CAGR of **20%** through 2024.

Source: Global Market Insights, 2019

$10.4 BILLION

The size of the global additive manufacturing market in **2019**.

Source: SmarTech Analysis, "Annual Additive Manufacturing Summary," January 2020

$100 MILLION

Estimated amount of investment in 3D printed composite industry, according to IDTechEx.

Source: IDTechEx, "3D Printing Composites, 2020-2030," February 2020

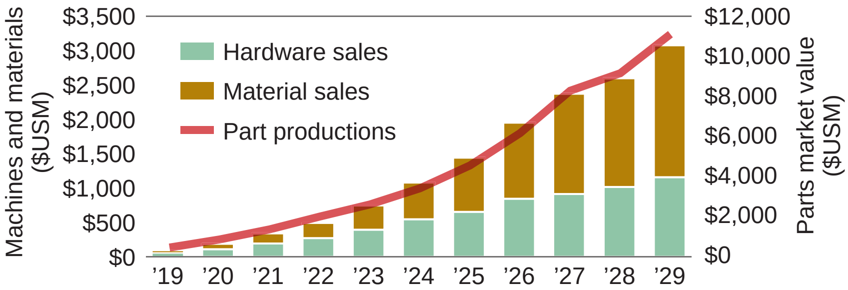
$530 MILLION

Estimated annual revenue for additive manufacturing of silicone carbide parts by **2029**. The overall silicon carbide market will experience a CAGR between **15%** and **17%** through **2025**.

Source: SmarTech Analysis, January 2020

Global Bound Metal AM Opportunities

($USM) by category 2019-2029

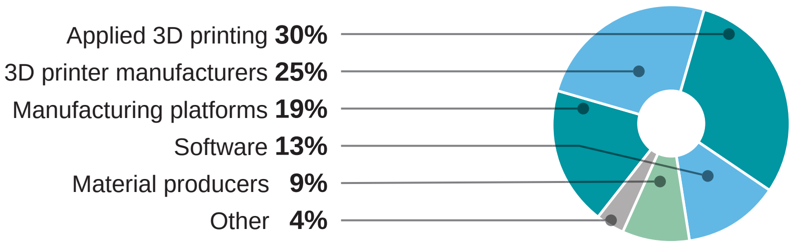


Growth rates for bound metal deposition technologies will range from **30%** to **35%** through **2029**. Over the same period, the overall metal additive manufacturing hardware market is expected to grow **20%** annually.

Source: SmarTech Analysis, December 2019

Venture Capital Investment in the 3D Printing Industry

Number of 3D printing investments by category



Source: 3D Hubs

A study conducted by Essentium revealed a significant increase in the use of large-scale additive manufacturing (AM). According to the study, the number of manufacturers using 3D printing for full-scale production doubled between **2018** and **2019 (40% in 2019; 21% in 2018)**. Two-thirds of companies reported they have more than doubled their use of industrial-scale AM in their manufacturing, and **47%** are now using the technology for runs of thousands of printed parts, a jump of **17%** compared to **2018**.

While reduced manufacturing costs is a key driver for many manufacturers **(58%)**, the increased adoption of AM at scale is also fueled by manufacturers' need to improve customer response time: **61%** of respondents are adopting the technology to reduce lead times, **59%** will benefit from mass customization, **59%** want to increase speed-to-part production, and **51%** want to achieve high part performance.

Source: Essentium, November 2019

CAASE20

CAASE 2020 Preview: Boosting Diversity in Computer Science and Engineering

Harvey Mudd College's President Dr. Maria Klawe discusses minority recruitment for STEM

BY KENNETH WONG

Dr. Maria Klawe, president of Harvey Mudd College, thinks academia's usual "Prove to me you belong here" attitude for computer science and engineering majors is detrimental to diversity.

"The first year or two are what's known as weed-out courses. They're supposedly designed to identify the students who have the intellectual muscle to figure things out," says Klawe. That attitude is a legacy of "a time when we didn't need nearly as many technically skilled talents," she adds. "We now do, and we will need more in the future."

This survival-of-the-fittest approach, Klawe points out, discourages women and people of color to go into specialized areas. "Think of two different approaches," Klawe says. "One instructor says, 'This is a technically challenging course; everyone will have difficulties; but everyone who works hard will do fine.' Another says, 'This is a technically challenging course, and you'll find out if you belong in this field or not.' The second way has been the cultural tradition. This has a disproportionate impact on underrepresented groups in engineering."

The Harvey Mudd Difference

At Harvey Mudd, women account for 50% of the student body, and they represent 50% in nearly every major, Klawe estimates. Furthermore, about 50% of the graduates in computer science, engineering and physics are women, Klawe verifies.

Dr. Maria Klawe
Image courtesy of CAASE20/NAFEMS.

By contrast, the national average for women in computer science is only about 14% to 18%, according to the resource portal ComputerScience.org. The portal also lists the top 20 schools with the most women graduates in computer science. Harvey Mudd is #10 on the latest list for 2018.

"Women and men have no difference in their ability to understand technically challenging concepts," Klawe observes. "But how you teach influences how they learn." Figuring that out has been transformational for Harvey Mudd, she adds.

Students today, Klawe says, are "more motivated by learning what they think will be important in tackling climate change or affordable healthcare, for example, than by learning abstract concepts."

Her recent conversation with DeepMind, a leading AI technology firm, reinforces this notion. "The company has works aimed at theoretical advances in machine learning, and works to apply machine learning for social good," Klawe recalls. "They said women's participation in the social good projects far outweighs their participation in theoretical works."

Chances for Diversity in Automotive

According to the 2015 study titled, "Women at the wheel: Recruitment, retention, and advancement of women in the automotive industry" by Deloitte and Automotive News, "While women represent 47% of the total U.S. labor force, they comprise less than a third (24%) of the automotive workforce."

The automotive industry is now facing challenges in transforming itself to be less fossil fuel-reliant and more environment-friendly. Leading car makers are all developing hybrid models with this in mind. "Think about promoting these types of projects in recruitment to attract more women and increase diversity," Klawe advises.

When building project teams, Klawe

suggests managers should avoid putting a single woman in a team. "In discussions, it often feels very isolated for the lone woman on the team," she points out. "In addition, providing female role models is incredibly important." To her, these measures are part of the strategy to increase diversity in engineering.

At CAASE, Klawe is scheduled to give a talk titled, "Increasing diversity in the STEM workforce might be easier than you think."

To register for the conference and learn more about Klawe, please visit the CAASE20 website (bit.ly/2xheztg). DE

CAASE20 Themes Address Simulation Opportunities, Challenges

The CAASE20 conference is built around four key themes, each of which will be addressed through in-depth presentations and training sessions. This year's themes include:

Theme 1: Simulation-Driven Design
As manufacturing techniques and product lifecycle management processes develop and grow, the use of Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), Multibody Simulation (MBS) and all of the associated technologies is increasing exponentially. As a result, your community is expanding and evolving with the technology into a truly cross-industry, multi-skilled, global society, with its own unique perspectives, problems and solutions.

Theme 2: Implementing Simulation Governance
As companies drive toward virtual product development and complete digital descriptions of their products and manufacturing systems, simulation becomes increasingly important. A company's actual capability to do simulation successfully so that it is repeatable, reliable and robust, can become an important factor in quality, cost and time to market, as well as overall competitiveness.

Theme 3: Advancing Manufacturing Processes & Additive Manufacturing
Are you interested in simulation's role in advancing the digital factory and manufacturing processes? Relatively new processes, such as additive manufacturing/3D printing, promise benefits of lightweighting through generatively designed parts that place materials only where needed and internal lattice structures with varying densities; reduced part complexity via consolidation; and even on-the-fly material property customization. But, like any manufacturing process, simulation methodologies and best practices need to be implemented before 3D printing can reach its full industrial manufacturing potential.

Theme 4: Addressing Business Strategies, Challenges & Advanced Technologies
The use of simulation realized 10%-15% annual growth for more than 30 years. This cumulative growth now means that simulation is a significant portion of the engineering software market and a driver for future growth. This has resulted in increased focus and investment in simulation by major PLM software vendors.

This growth is coupled with increasing awareness by end user companies that simulation is the key enabler to increased competitiveness; therefore, the changing role of simulation is more about its role in business than the changes in technology. The business drivers bring an opportunity for unprecedented growth in the use of simulation, as well as a new set of business challenges associated with this increased demand.

DESIGN

Autodesk Unveils People-Centered Subscription Plan

BY BETH STACKPOLE

Out with the old and in with the new. Autodesk, which has currently migrated 1.8 million users away from traditional perpetual licensing to a subscription plan, is ditching serial numbers for a named user format as part of a strategy to deliver a more relevant user experience, according to Carl White, Autodesk's vice president of business models and pricing.

According to Autodesk, named-user plans provide direct visibility into usage by both product and version, allowing organizations to optimize their licensing costs.

"By sharing usage information with customers, we can help them make their business investments with us more optimized," White says. "Instead of putting their finger in the air and saying, 'We are going to need three more licenses this year,' they can make decisions based on knowledge and facts."

Starting May 7, 2021, all Autodesk subscriptions with multi-user access and all maintenance plans will be retired and no renewals will be possible. At the same time, Autodesk will no longer offer new one-year subscriptions with multi-user access after May 7, 2020, and the last version of Design & Creation Suites will be released in April with no renewals on these programs. Shops can also trade in their multi-user licenses and get two single named-user replacements, White says.

In addition, a new Premium offering, aimed at larger businesses seeking advanced administrative tools, includes detailed reporting, single sign-on (SSO) capabilities, and 24x7 voice support. Reports cover product usage with specific product details. DE

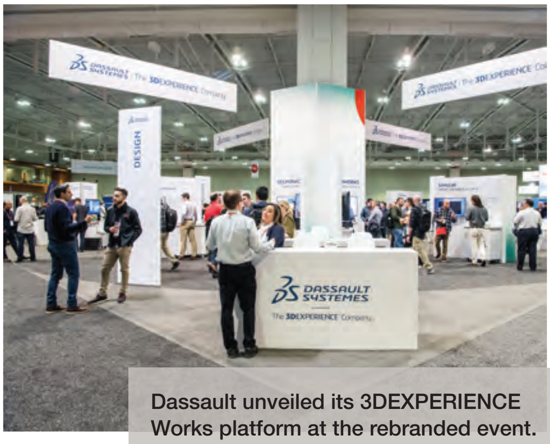
ROAD TRIP

Dassault Rolls out 3DExperience Works

Rebranded 3DEXPERIENCE World Show Emphasized Web-based, Platform Approach to Design

BY BRIAN ALBRIGHT

In February, Dassault Systèmes held its 3DEXPERIENCE World 2020 conference (formerly SolidWorks World) in Nashville. The rebranded conference marked a continuation of the company's efforts to consolidate its software offerings around the 3DEXPERIENCE Works brand.



Dassault unveiled its 3DEXPERIENCE Works platform at the rebranded event.

The company launched the 3DEXPERIENCE Works offering, promoting it as a way to create a fully connected experience for SolidWorks users. "We are all here together to dream and to turn our dreams into reality," said SolidWorks CEO Gian Paolo Bassi, touting the benefits of 3DEXPERIENCE Works and its compass-based navigation interface. "Everyone will discover and navigate the 3DEXPERIENCE universe using this compass to understand the past and navigate the future online."

Prior to the event, Dassault Systèmes announced its strategic direction for the company, including the company's goal to create a virtual twin experience of the human body and to focus heavily on the healthcare and life sciences sectors, as well as manufacturing and smart cities.

The 3DEXPERIENCE Works rollout includes three varieties: standard, professional and premium. Each includes SolidWorks applications that are installed from, licensed from and updated in the 3DEXPERIENCE platform. According to the company, SolidWorks users will have the same desktop applications they are used to, but can also benefit from the digital platform via improved collaboration, embedded data management, automatic software updates and flexible access to all project data in a central location.

SolidWorks CEO Gian Paolo Bassi addresses the crowd at 3DEXPERIENCE World. *Images courtesy of Dassault Systèmes.*

The solution also includes 3D Creator and 3D Sculptor. Users can also access other 3DEXPERIENCE applications in an on-demand environment as they need them.

"Customers want to do more than just design. They want to have a lifelike experience of the products they make. This requires better design, simulation, governance, management and manufacturing and, most importantly, collaboration with the entire value chain. We want to provide customers with more options that make sense for their business, which is why we've made it easy for them to take advantage of and explore 3DEXPERIENCE Works," said Bassi. "With our new commercial offers, SolidWorks users have access to the powerful desktop applications that they know and love, with huge additional value.

The Magic Wheelchair organization creates themed chairs (like this *Star Wars*-themed chair) for physically challenged children using the 3DEXPERIENCE platform.

On the 3DEXPERIENCE platform, everything and everyone involved in the concept, design, simulate, manufacture, sell and service processes are connected and integrated in one continuous loop. Of course, our SolidWorks customers can continue to buy the standalone SolidWorks desktop version if they prefer, but our new customer-centric option will free up time to think, create and get things done. We are also planning similar offers for education and startups, to bring value to them too."

Dassault has reconfigured its solutions in a roles-based framework, and has defined several hundred different roles, each with specific application capabilities. Soon all of its applications will be web-enabled and available via subscription. The company has been touting this model for a while, even as traditional SolidWorks users have been hesitant to migrate in that direction.

That's why the company was quick to demonstrate how traditional SolidWorks fits into the various flavors of 3DEXPERIENCE Works.

On day two, a panel of SolidWorks executives walked attendees through an imaginary use case for the integrated platform. The demo included using the 3DSwYm social application to share ideas, and the lifecycle management services inside SolidWorks to keep stakeholders up to date on project progress.

Xometry and Dassault also announced that engineers using Dassault Systèmes' SolidWorks and CATIA applications will have automatic and immediate access to Xometry price quotes on MAKE Marketplace for manufacturing parts, without leaving the design environment. Xometry is the first named member of Dassault's Prime Partner program.

Hackathon Lends a Helping Hand

The conference included entrants in the company's first 3DEXPERIENCE World Hackathon. Dassault invited five teams to use its software tools to improve the design and manufacturability of a prosthetic hand created by the Ellen Meadows Prosthetic Hand Foundation. The organization distributes free prosthetics globally for recipients who have been affected by forearm amputations.

David Randle, senior strategy and business development manager at SolidWorks, discovered the hand foundation via a team-building exercise on assembling hands. "The hand was originally designed decades ago," he says. "We could deliver a better version of this hand; it's what our portfolio was built for."

The five teams in the hackathon included six members: Dassault employees, students and customers. "None of the members were co-located geographically," he says. "They used the 3DEXPERIENCE platform to collaborate."

Foundation founder Michael Mendonça named Team 3 as the winner. The Foundation has distributed 55,000 hands.

Besides the Hackathon, Dassault helps the organization via a pilot program with four FabLabs to help boost distribution efforts. DE

Rescale and Partners Host HPC Event in San Francisco

BY KENNETH WONG

In the early morning hours of Wednesday February 11, Big Compute 20 got underway. On the upper level of the SFJAZZ performance venue, executives, researchers and software developers mingled over cookies and coffee as they waited for the keynote. Later, Joris Poort, CEO of Rescale, took to the 350-seat stage to open the event, dedicated to exploring the use of high-performance computing (HPC) in various sectors.

"Think about the innovation that was promised to us in science fiction, in popular movies like 'Back to the Future.' What among these have come true?" asked Poort. The time-traveling car and the hoverboard have not yet come true but others, such as "real-time videoconferencing and ubiquitous communication" have become part of our lives, he pointed out.

"Not only have we delivered that; we've got much more. Social media, the gig economy, services like Uber,

ROAD TRIP

Big Compute 20: Tackling the Big Issues for a Better Future

Twitter and Airbnb have truly connected us and changed our lives," he noted.

Misplaced Priorities in Innovation?

But there's also the nagging feeling that, as engineers, we may have misallocated our talent and priorities. In the 2012 November/December MIT Technology Review, former astronaut Buzz Aldrin penned an article titled, "The Imperative to Explore." His stern face on the cover called out, with bold letters: "You promised me Mars colony; instead, I got Facebook."

Poort urged attendees to turn their attention to big issues. "If you look at the U.S. in the last ten years, life expectancy has been going down. This is a real challenge we need to overcome. And sustainability and climate change—even with the impending doom of climate change, we have yet to deliver the innovations to fix this challenge. These are fundamental to the future," said Poort.

According to a study published in November 2019 by the Journal of the American Medical Association, "Between 1959 and 2016, U.S. life expectancy increased from 69.9 years to 78.9 years but declined for three consecutive years after 2014."

Neither human intellect nor data is lacking to tackle these issues, according to Poort, who says the real challenge, is Big Compute. "This is why we founded the company Rescale 10 years ago."

Big Compute vs. HPC

The terms, as defined by Poort, clarify what he sees as the type of computing jobs that demand Big Compute.

"Loosely coupled problems, the kind that you can chop up into pieces and solve on individual processors, are what hyperscale computing services are built to address," he reasoned. On the other hand, "there are classes of problems that we cannot chop up into pieces to solve. Individual processors have to make the calculation, and communicate with one another as they start solving these algorithms. From fluid dynamics and aerodynamics to finite element analysis and structural crash simulation ... they depend on physics, and physics scales differently," he added.

Two years ago, at its premier user gathering called Rescale Night in San Francisco, the company began using the term Big Compute. Microsoft, one of the sponsors of the event, defines the term more broadly, as "large-scale workloads that require a large number of cores, often numbering in the hundreds or thousands" in its online page for Microsoft Azure.

Don't Write Off the Combustion Engine

Big Compute 20 speakers included Walt Hearn, VP of ANSYS; Nidhi Chappell, head of Product, Microsoft Azure; Bill Margo, Intel fellow and chief technologist, HPC; Kelly Senecal, founder of Convergent Science and more.

If given access to infinite computing power, Convergent Science's Senecal would like to reinvent the internal combustion engine. "The greenest engine possible—an engine we can hug and feel good about," said Senecal.

As more consumers begin to view hybrid and electric as greener alternatives, the combustion engine suffers from bad PR. In an article from The Economist, August 2017, the author said the combustion engine "had a good run. But the end is in sight for the machine that changed the world." The title is more blunt. It screamed, "The death of the internal combustion engine."

"Ninety-nine percent of the vehicles on the road are powered by internal combustion engines," Senecal estimated, noting that writing off the technology might be impractical.

The key to reinventing the combustion engine is to find the perfect flame—to simulate and refine the thermal behavior inside the engine.

"The engine has hundreds of variables—spark timing, fuel injection, airflow, geometric parameters—too many to name. We need to find the optimal [configuration]. This is where infinite computing can help us," said Senecal.

Senecal plans to use a combination of machine learning and CFD (computational fluid dynamics) to generate hundreds of design options for a greener combustion engine.

Big Compute ran for two days. The event was sponsored by ANSYS, Microsoft, Intel and Siemens, among others. DE

Rescale CEO Joris Poort opened the Big Compute 20 Conference.

Trailblazing the **Path to Design** for Additive Manufacturing

Increased use of AM means the CAD model may well be used for countless variations of a product or part.

BY RANDALL S. NEWTON

Today's engineering design tools were created in an era where one CAD model defined a singular part or product that a specific manufacturing process could generate. The rise of additive manufacturing (AM) means the CAD model may well be used for many variations of a product or part.

Yet design tools still follow the single product and single process paradigm—even though the move from graphics to physical instantiation can take place on several 3D printing devices in addition to more traditional build processes.

The tension between past and future is apparent in the stereolithography (STL) file format. STL was created in 1987 as a way to move data from CAD to the 3D printer. STL joined other text-based neutral file formats in engineering software, such as DXF, PostScript, IGES and HPGL. The common element in all these 1980s formats its ability to transfer graphical engineering data from CAD to another device, generally the pen plotter or the laser printer.

At present, all of these formats are either buried inside modern interfaces or abandoned as outdated—except for STL. Despite various efforts, STL remains the lingua franca for moving design data to 3D printing.

Each CAD vendor and each 3D printing manufacturer must deal with STL, even though it only delivers triangulation of the CAD model, and strips out any data regarding color or material. Not every 3D printer can build from an STL file.

A sub-industry has evolved, creating software tools to either bypass STL or to restructure CAD data for contemporary buildability. *Digital Engineering* talked to several vendors about the need for next-generation CAD that streamlines the workflow for additive manufacturing processes.

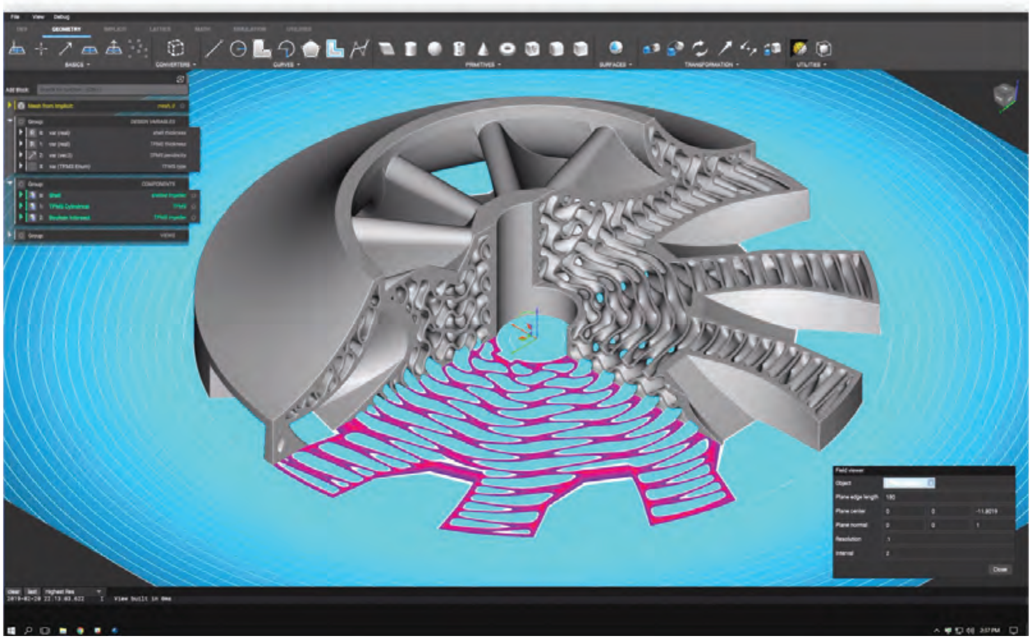
Tools for the Manufacturing Engineer

"CAD companies support designers in what they do best, designing," notes Manuel Michiels, market innovation manager at Materialise. "We have seen many excellent applications emerge from CAD solutions that have truly revolutionized design thinking for additive manufacturing."

Yet, Michiels notes, "we cannot expect designers to be true AM experts." The full potential of AM, Michiels says, "requires a skillful manufacturing engineer with an in-depth understanding of the AM process, materials, part tolerances and part behavior" as well as the use of dedicated software tools that "allow the manufacturing engineer to increase productivity and efficiency in the AM production process."

The intention is to allow and to simplify "unique design and production benefits that allow for mass customization," Michiels says. Materialise is a 3D printing services consultancy and a software vendor. Michiels says the company's goal is to "automate the design modifications and build preparations throughout the digital factory, allowing mass customization at the same cost as mass manufacturing."

Designing for additive manufacturing (DfAM) is just too complex to leave it to intuition, says Brent Stucker, director of additive manufacturing for ANSYS. "Additive [manufacturing] is so complex even a person with a career in it gets surprised quite often. The only way to handle the complexity is with CAE," he says.



The nTopology nTop Platform combines CAD with generative design to streamline designing parts for additive manufacturing. *Image courtesy of nTopology.*

ANSYS offers Additive Suite to help with typical DfAM issues, but it stands apart from integration with any particular CAD product.

New Tools for DfAM

CAD was created when product engineering was a deterministic, draw-test-repeat process. Now, many CAD companies are investing in various new DfAM technologies. Traditionally, DfAM software explores how to optimize a specific design to be manufactured. The new generation of DfAM tools help create more efficient AM-buildable parts at the design stage.

Most of these new products—or existing CAD program features—offer a variation on generative design, which turns deterministic design into an iterative process. Generative design enables exploration of virtually unlimited design options, from topology optimization to matching a specific 3D printer's build envelope and support requirements.

Generative design crunches the numbers to autonomously arrive at optimal designs from a set of system design requirements. The engineer can specify requirements and goals, and the software produces a suggested design. The engineer then tweaks the design or the parameters and runs it again. This means the CAD tool becomes a more intelligent assistant in the design process.

In an era where it becomes possible to manufacture previous "unbuildable" parts, generative design can provide novel design alternatives that surpass existing paradigms. (For background on generative design, see digitalengineering247.com/r/19122)

All leading CAD vendors have incorporated generative design or related DfAM technology in some fashion. For instance, PTC made news when it acquired Frustum in late 2018 for $75 million.

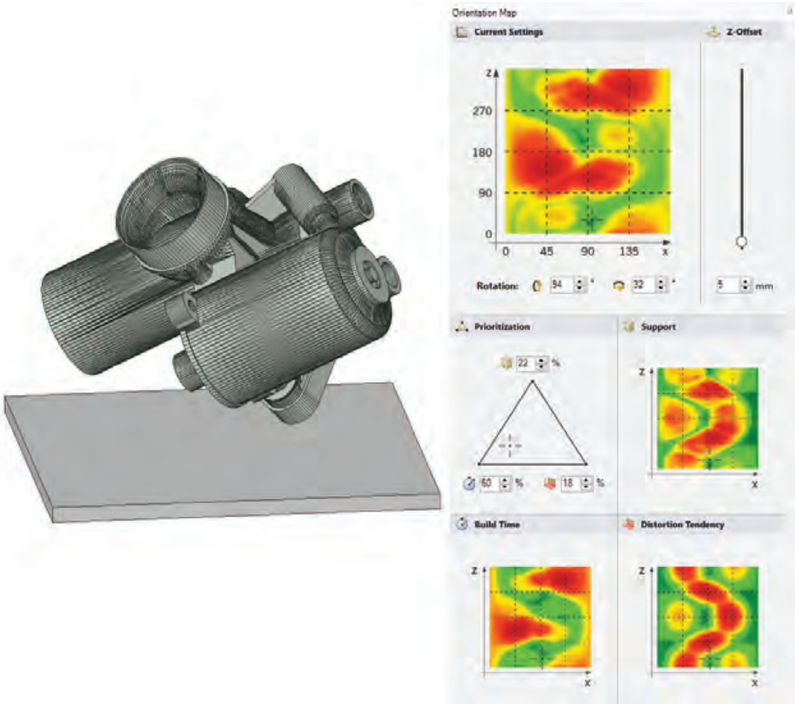
There is confusion in the engineering marketplace regarding generative design, says Jesse Coors-Blankenship, a co-founder of Frustum and now a senior vice president of technology at PTC. He believes many confuse generative design with topology optimization.

"Topology optimization is a foundational technology upon which generative design is built, and it's been around for decades," said Coors-Blankenship in an interview published on the PTC website (bit.ly/2wzdigZ). Topology optimization converges on a single solution based on functional objective. Generative design differs in that it considers many possible solutions based on functional and non-engineering requirements before offering a solution.

"Generative design utilizes topology optimization to explore all the possible permutations of a solution, continuously iterating and learning from the process," Coors-Blankenship added. "It's a way of designing for the next generation of CAD and it is changing the way engineers think about design."

Though Frustum was snapped up by PTC, there are other startups working on related ways to automate DfAM.

nTopology nTop Platform (nTopology.com/ntop-platform) offers a new approach to expressing shape and



ANSYS Additive Suite is a stand-alone module for preparing models for additive manufacturing. *Image courtesy of ANSYS.*

substance. The product allows explicit and computer-assisted (generative) computational modeling but does not rely on the boundary representation (B-rep) technology common in today's CAD programs.

Instead, the nTop Platform uses implicit modeling, which defines an object as a series of implicit functions returning a value in 3D space. Thus, the tool outlines not only the surface of a solid, but it also defines every part of the interior, which the company claims makes it more suitable as a design platform for additive manufacturing.

"Current [CAD] systems assume that the interior of the object is homogeneous, in which case the boundary alone does provide us with enough information to fully describe the object," said nTopology chief technologist George Allen in a company white paper (bit.ly/37Hbxep). "However, given the capabilities of modern 3D printers, the assumption of homogeneity is no longer valid—if it ever was."

nTopology claims the size of today's B-rep models is a major bottleneck to production. Allen cites a test design for a heat exchanger created first with a typical B-rep CAD program and then again with nTopology. The exchanger has a gyroid lattice structure with 10,000 cells. The B-rep model is 1.5 GB in size; nTopology says a model of this size takes an average of six days to generate on a typical workstation. The company says the same object created in nTopology takes up 1.3 MB of disk space and can be generated in 2 minutes. nTopology claims this size advantage reaps benefits during design and in model preparation for 3D printing, especially when using a slicing function.

ParaMatters CogniCAD uses generative technology aided by a built-in finite element analysis (FEA) engine and AI-assisted topology optimization. Dr. Michael Bogomolny, CEO and founder of ParaMatters, says the AI used in CogniCAD is not the same as what many people think of when they hear "AI."

In generative design, AI is a tool for human augmentation, whereas in science fiction AI is seen as a tool for human imitation. Bogomolny believes AI as augmentation will move from geometry to physics and into all design criteria including aesthetics, manufacturing processes and materials selection.

"In mechanical design, we have the privilege of having very accurate physical models described by differential equations, which are solved by FEA," says Bogomolny. The data from a generation of CAD models analyzed by CAE can now be the source for training design software. "The generative design, which we do at ParaMatters is a combination of FEA and optimization algorithms, which converge to extremely effective designs, fully automated and valid."

Dyndrite offers its Accelerated Computation Engine (ACE), which uses graphics processing unit (GPU) technology. Dyndrite says GPU computing access can reduce model modification recalculation from hours to seconds. Python scripting is available to automate model prep. The offering also gives attention to two issues specific to DfAM: calculating support structures and the use of slicing. The user may select truss, tree, column, block/ribbon, or extrude milling offsets or cones as support structures. Dyndrite then automates design of the supports and factors in the specific 3D printer system.

Dyndrite says its ACE uses a memory-efficient streaming architecture suitable for very large datasets, 10 GB or larger. For slicing the model as part of prepping an AM job, Dyndrite can output directly to a variety of machine-specific formats. Tasks can be divided between CPU threads and a GPU, offering the potential for extreme speed increases.

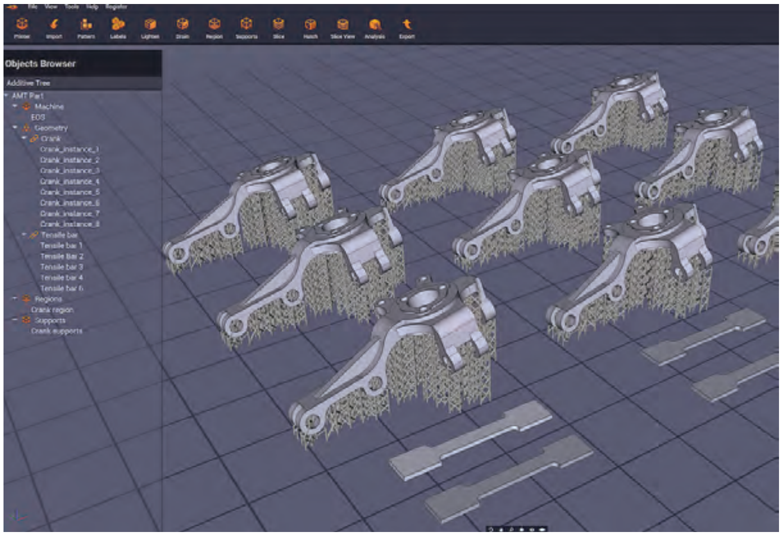
Established Vendors Keeping Up

In addition to the new products from startups, a variety of new DfAM technologies are available from established vendors. Hexagon's MSC division recently released Apex Generative Design, which combines new generative design technology with elements from its existing products, MSC

Simufact (metal) and MSC Digimat (polymer) for build process simulation. In use, the designer specifies boundary conditions and design objectives. MSC Apex Generative Design then produces multiple lightweight design candidates, all of which explore design space possibilities with the best combinations of stress distribution and weight minimization.

MSC says that without the generative design engine and the built-in manufacturing knowledge, engineers would have to move data back and forth between multiple CAD and CAE tools to accomplish the same goal.

Generally, engineers only use such manual methods to devise one or two alternatives because of the time involved. Apex Generative Design evaluates thousands of alternatives before suggesting options to the user.



Dyndrite uses CPU and graphics processing unit (GPU) computational power to streamline model preparation for additive manufacturing. *Image courtesy of Dyndrite.*

Design tools for additive manufacturing "are different from traditional CAD," says Mark Rushton, the senior product portfolio manager for additive manufacturing at Dassault Systèmes SolidWorks. "CAD systems can create any geometry; it becomes about knowing the additive manufacturing properties."

Dassault's next-generation CAD tool xDesign, for example, has a build design library with details of leading 3D printers. "Choose the printer, and the build envelope is displayed," says Rushton. The build envelope design library, created in consultation with noted 3D printing analyst Terry Wohlers, is now available to SolidWorks 2020 users.

There are many tools available from all the leading CAD vendors, Rushton notes, but the problem is the connections. The designer is not usually the person running the 3D printer. CAD tools need to help users preserve "tribal knowledge," which Rushton says doesn't always make it back to the designer. "We want to connect every part of the business."

For a few years Autodesk has been acquiring promising technology to assemble a DfAM portfolio. Pieces of it are now in Netfabb, and others in Fusion 360, says Sualp Ozel, Autodesk's senior product manager for additive manufacturing. A Manufacturing Extension is available for Fusion that automates doing print prep for powder bed fusion 3D printers from Renishaw and EOS. New tech will be coming soon to Fusion that extends DfAM to filament, SLA, DLP and composite 3D printing.

Autodesk is also working on being able to design at the voxel level. Autodesk Volumetric Kernel will be able to design "architected materials," which Ozel says gives control over geometry, color and material on a microscopic level, based on capabilities of the 3D printer.

Siemens has introduced a process-oriented service it calls the AM Network, to improve collaboration between engineers and procurement.

Closer to CAD, a separate module is available for NX that uses technology from Materialise Magics to simplify the process of creating lattices, support structures, 3D nesting, build tray preparation and related design essential to the AM process. DE

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MORE INFO

- **ANSYS:** ANSYS.com
- **Autodesk:** Autodesk.com
- **Dassault Systèmes:** 3DS.com
- **Dyndrite:** Dyndrite.com
- **Materialise:** Materialise.com
- **MSC Software/Hexagon:** HexagonMI.com
- **nTopology:** nTopology.com
- **ParaMatters:** ParaMatters.com
- **PTC:** PTC.com
- **Siemens:** Siemens.com

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Bridging CAD to Additive Manufacturing

Plug-ins and new formats help preserve model integrity in the roundtrip journey.

BY KENNETH WONG

Advanced CAD users have lamented that some complex surfaces and shapes they could model with their software could not be manufactured due to the limitations of production technologies. However, the advances in additive manufacturing (AM) or 3D printing flipped the situation. Many CAD users found out their software couldn't digitally model the complex shapes AM hardware is itching to print.

Classic parametric modelers were developed to produce geometry suited for machine shops. But AM is capable of so much more. It can produce lattice fills, membrane-like structures and swirling geometry—nicknamed alien topology by some—the kind few will attempt to fabricate using machining.

To fill the gap, some AM hardware makers, such as Desktop Metal and 3D Systems, developed their own software. CAD vendors simultaneously sought out acquisitions and partnerships.

In late 2018, PTC paid $70 million to buy Frustum, a startup with generative design technology. Frustum could let PTC users "create complex geometries optimized for additive manufacturing and deliver better products faster," points out Jesse Coors-Blankenship, founder of Frustum and senior VP of technology at PTC.

Furthermore, he notes, "With generative, engineers can take advantage of advanced manufacturing techniques and embrace additive manufacturing."

In 2017, manufacturing and design software maker Siemens struck up a partnership with Materialise, an AM software developer. The goal is to integrate "AM technology from Materialise into Siemens' NX software, streamlining the design-to-manufacturing process for the rapidly growing universe of products being produced using AM," the press announcement stated.

These mergers and alliances are indicators of design and manufacturing software jointly tackling AM challenges that each sector is unequipped to tackle on its own.

Print Simulation is Complex

CAD developers are generally not in the best position to write full-fledged AM software—particularly, print preparation software. Their coders do not thoroughly know what happens to materials when they go through the printing process.

"You could use the empirical approach. You can print out a few specimens, measure the shrinkage and warpage in the results, then calibrate the production runs based on this knowledge," says Maoz Barkai, product manager for 3DXpert, 3D Systems.

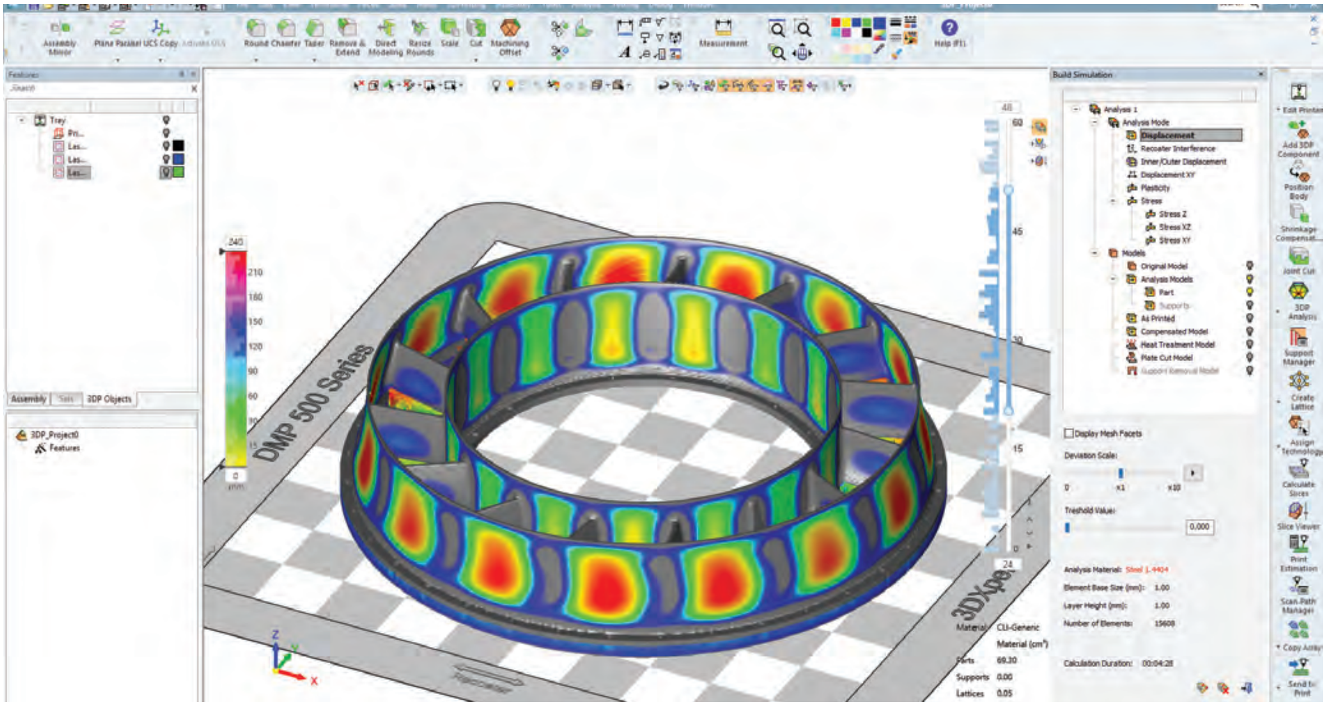
But a better tactic is a computer simulation-driven approach. "You simulate what will happen in the print process, down to the micron level," he says. This allows the design engineer to understand the inevitable warpage and shrinkage that occurs in the print process, so they can then adjust the geometry to compensate for these effects in advance.

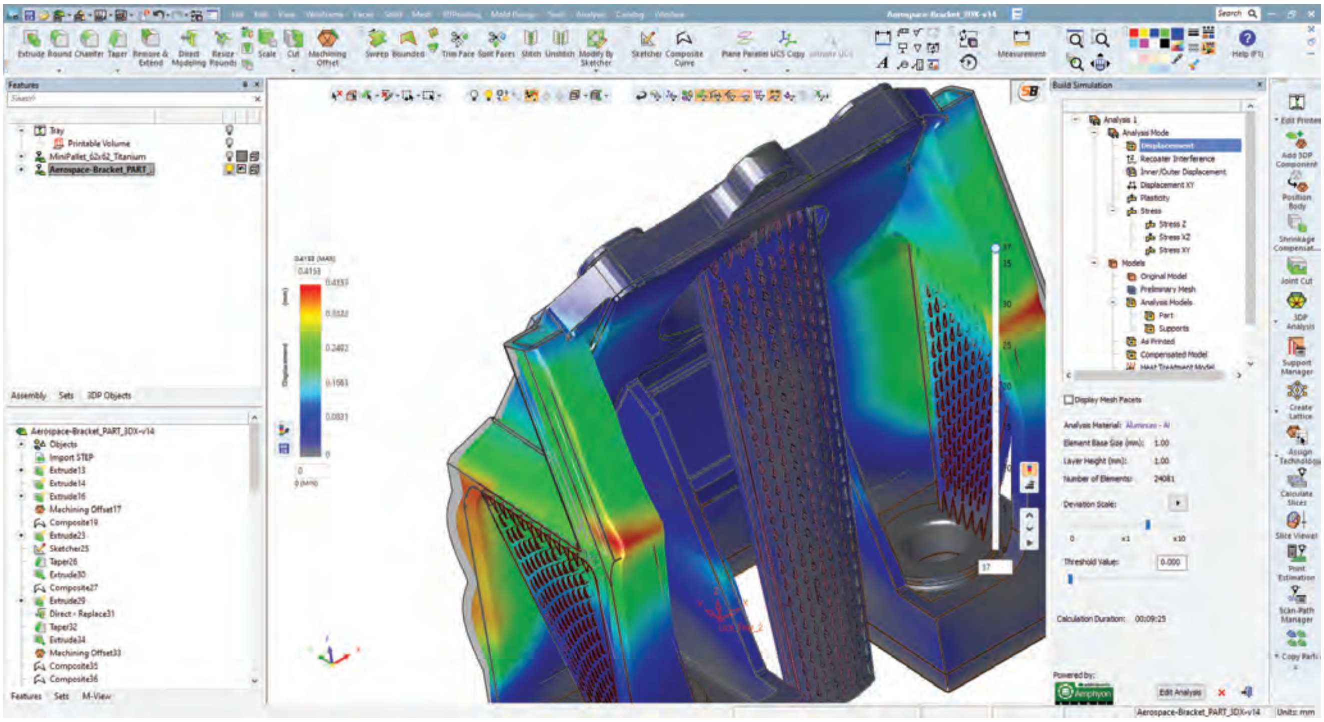
"There are more things you can do with plastic printing to compensate for the anticipated morphing or to fix it post-printing, but metal is much less forgiving," Barkai says. "The harder the metal, the less forgiving it is. So printing in titanium, for example, gives you less room to work with than aluminum."

3DXpert uses the Amphyon simulation kernel, developed by Additive Works. The same kernel is also used by Altair in its AM-targeted products. Described as "end-to-end fault prediction," 3DXpert allows users to analyze and determine part orientation for the print job, design lattice fills and add support structures.

The software keeps the original CAD file's "B-rep data (solids and surfaces) without downgrading to mesh [and] maintain data integrity, including analytic geometry, part topology and color-coding," according to 3D Systems.

At SolidWorks World in February 2018, 3D printer maker Desktop Metal introduced its generative design software, dubbed Live Parts. It was a software borne out of necessity. The hardware maker felt existing modeling tools didn't meet





The ability to simulate what happens to the part during the print process, as shown here in examples from 3DXpert, prevents print job failures. *Images courtesy of 3D Systems.*

the design needs of its hardware users, and was prompted to develop its own offering.

"We feel it's important that such tools are integrated into the manufacturing processes. You have to design a part that not only looks good but is also be a good candidate for 3D printing," says Andy Roberts, VP of software for Desktop Metal.

As the name suggests, Desktop Metal focuses primarily on metal-based 3D printing. In addition to Live Parts, the company also offers Fabricate, model-preparation software and Fab Flow, print job management software for fabrication shops.

"We spent quite a bit of time developing software that lets you simulate what happens in the print process and the sintering process. We are integrating both design rules and manufacturing rules in Live Parts, so you can force the software to generate parts that need no internal support or reduce supports to only what's absolutely necessary based on orientation," notes Roberts.

Scaling a part to account for distortion in printing isn't as simple as enlarging a part uniformly by a certain factor. "The Z-direction shrinkage is subject to gravity and material compression," notes Roberts. "You also need to deal with creating supports that can be removed."

Desktop Metal developed a patented technology to create easily removable support structures. "The ceramic-like connections turn to dust when you sinter the part, so they can be removed like puzzle pieces by hand afterwards," explains Roberts.

Multiphysics Phenomena

With some print processes, the simulation software may need to account for more than one type of physics to accurately mimic what happens to the materials. "The simplest example is the combined heat transfer and structural analysis," notes Bjorn Sjodin, VP of product management, COMSOL.

Using COMSOL software's Application Builder function, UK-based The Manufacturing Technology Centre developed an app to simulate shaped metal deposition.

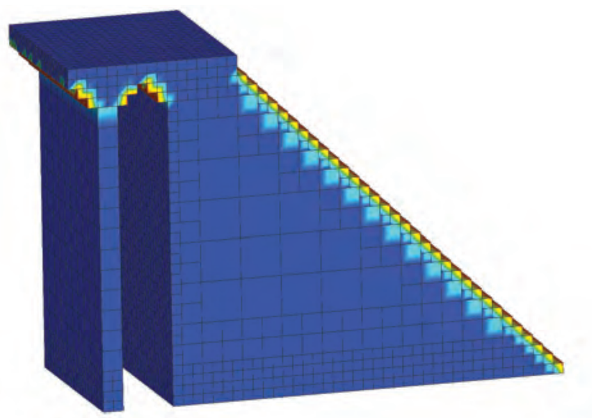
According to Borja Lazaro Toralles, MTC's technology manager, the process involves "molten metal […] deposited layer-by-layer on a surface, allowing for use of multiple materials on one part. However, due to the intense heat of the metal, the final piece can deform during printing."

"The solidification of molten metal may include fluid flow, heat transfer and maybe even transport of chemical species," Sjodin points out. Multiphysics simulation also may be required to recreate the behaviors of DC or AC electric currents, magnetic fields or microwaves in AM, he adds.

COMSOL Multiphysics 5.5, released in November 2019, includes improvements to export smooth geometry from topology optimization results.

"Such smooth geometry output from COMSOL can then be used in CAD software or dedicated software tools for preparing for AM," Sjodin points out.

The software also includes a metal processing module for analyzing metallurgical phase transformations in materials such as steel and cast iron. "I believe this product will also be of interest to AM in some cases since such phase transformation also occurs in AM in unexpected manners," says Sjodin.



Hexagon's Simufact Additive 2020 uses adaptive meshing technology to retain the original's CAD model in fine details shown here. *Image courtesy of Hexagon.*

CAD Geometry vs. Print Geometry

CAD geometry is the shape of the desired part. By contrast, print geometry is the geometry destined to be produced in a 3D printing machine. The two often have slight or significant differences. For example, the CAD geometry of a bracket is different from the print geometry, which involves the shape of the bracket and the support structures necessary to keep it propped up during the print process.

The transformation from CAD geometry to print geometry usually occurs during the simulation phase or the print prep phase. This is where the manufacturing engineer adjusts the geometry to account for the anticipated distortion and adds the required support structures.

"It is more important to have detailed information on the build job, which can be different from the CAD geometry," says Manuel Michiels, market innovation manager at Materialise. "You want to simulate the behavior of the machine and hence the machine input, including things like support geometries and the real process parameters. These are required in order to simulate the creation of the parts accurately."

Materialise offers Magics software, a model preparation and STL editor for AM. Despite shortcomings, the STL format remains a robust format for common types of AM jobs, Michiels points out.

"It's capable of describing any type of geometry. It's straightforward to correct geometries into watertight geometries and currently offers compatibilities with most other software solutions," he says.

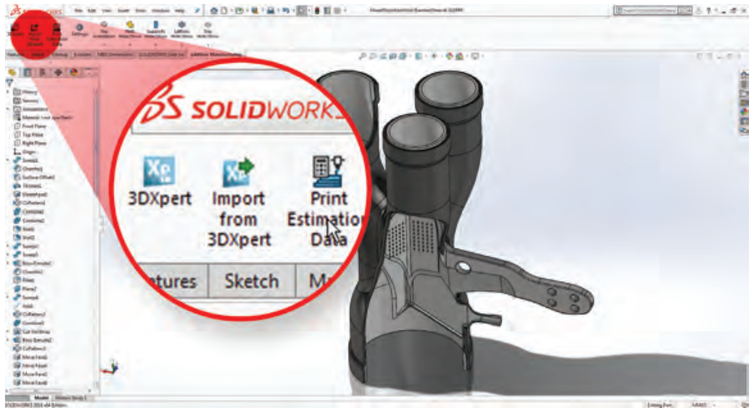
To augment STL's capabilities, Magics software also retains the color information and uses parametric data—things the file format cannot do.

The Journey of the Part

The typical path from CAD geometry to printed part goes as follows: "It starts with CAD, then build planning (e.g., Materialise), and then simulation (e.g., Simufact Additive). In this workflow, the value of using CAD data would be lost because the build planning software is generally only able to export models in STL. There is a need to develop enhanced 3D data formats, which can maintain fidelity of the original CAD," outlines Jeff Robertson, technical business development at Simufact, part of Hexagon.

STL, which stands for stereolithography, uses triangles to depict geometry. Therefore, converting the mathematically precise CAD geometry into STL means using approximations for rounded corners, fine details and complex surfaces. Furthermore, it cannot describe colors. Recently, 3MF, managed by the 3MF Consortium, emerged as a new format to compete with STL.

"There are meshing techniques like voxel meshing that can automatically mesh any geometry fast and reliably without any user interaction. Also, smaller features can be represented well with approaches like volume fraction consideration and adaptive meshing, made as available in Simufact Additive," notes Robertson. "It is also possible to export distortion-compensated geometries in generic CAD formats so they can be fed back into the digital workflow without losing feature information of the part."



3D Systems' AM analysis and print preparation software 3DXpert for SolidWorks allows users to bring the modified part back into the CAD program. *Image courtesy of 3D Systems.*

STL's Challenger

Materialise's Michiels believes a tight link between AM software and CAD formats would be a blessing. "We are taking appropriate actions to also allow our customers to get the best out of both worlds. This started many years ago by describing lattice structures in a parametric way instead of in STL," he says.

Simufact's Robertson points out, "In extreme use cases where an STL file has 25 million facets or more, the file structure becomes unfeasible. Of course, STL will always be challenging to utilize in a production environment because it is generally undesirable to manage STLs within product lifecycle management (PLM) systems."

A common file format to move the geometry from CAD to print without data loss still remains elusive, but, Robertson argues, "result-driven formats are an important consideration for additive workflows. It seems that formats like HDF5 or VMAP have the potential to become standards for data exchange in simulation."

One advantage in the newer 3MF is the format's inherent ability to understand and treat different segments of the geometry based on purpose, such as marking certain segments as lattice fills and others as support structures.

"Supports are identified explicitly in the 3MF core spec. A lattice structure is identifiable because it's defined by its own extension to the core spec. Any part of a printable object could be identified separately in 3MF because of the concept of parts in the core spec. A 3MF file is not a single blob. It's a collection of parts and relationships between them," explains Bob Olson, PR for 3MF Consortium.

Back to the Beginning

As a result of the links and bridges, at least for some, the journey that begins in CAD can have a happy ending—back in CAD. "With SolidWorks users, they can export a part to 3D Systems' 3DXpert, create their lattice, then bring it back into SolidWorks," says Barkai.

This is an important step in many lightweighting projects, where lattice structures offer the most efficient way to reduce a part's weight without compromising its strength.

"The lattice configuration changes based on the orientation on the print tray. It would be very hard to design the lattice without this information," Barkai says. This information is usually unavailable at the CAD design phase, as it needs to be ascertained and determined through print process analysis.

In mid-February, during 3DEXPERIENCE World, hosted by SolidWorks' parent company Dassault Systèmes, 3D Systems released an update to its plug-in, 3DXpert for SolidWorks.

With more than 3 million customers worldwide, the SolidWorks CAD user base represents a formidable force. Plugging into this crowd goes a long way to expand the pool of designers with parts destined for production in 3D Systems hardware. This SolidWorks-3DXpert connection, solidified and maintained with application programming interface exchanges and corporate handshakes, symbolize the collective desire in engineering: better bridges between CAD and AM. **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.*

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- **Additive Works:** Additive.Works
- **Desktop Metal:** DesktopMetal.com
- **Hexagon/Simufact:** Simufact.com
- **Materialise:** Materialise.com
- **PTC:** PTC.com
- **SolidWorks:** SolidWorks.com
- **3D Systems:** 3DSystems.com
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In Pursuit of Predictable 3D Metal Printing

Simulation software offers promise in the desire for repeatable, standardized 3D metal prints.

BY TOM KEVAN

Metal additive manufacturing (AM) stands poised to expand its footprint in the manufacturing sector, transitioning from a proven prototyping tool and small-lot fabrication process to mainstream part production. But there's a catch.

Today's AM technology isn't predictable and repeatable enough to be cost-effective for companies that want to use AM to mass-produce parts. Currently, engineers must go through an iterative process of trying different printing parameters before they can identify the combination that will enable them to build parts that meet the necessary quality standards.

Technologists specializing in this area readily admit that reliance on trial-and-error makes 3D printing metal parts time-consuming and costly and hamstrings the technology with high failure rates.

"By some estimates, it takes companies five or more attempts to 3D print a qualified part from their additive manufacturing design models," says Aaron Frankel, vice president of the additive manufacturing software program for Siemens Digital Industries Software.

"This high failure rate not only compromises the economic feasibility of additive, but it also thwarts efforts to employ the technology in high-volume production. This is particularly true of 3D metal printing," he says.

The market, however, may have a solution. A growing variety of modeling and simulation tools aim to give engineers and designers the means to analyze the behavior of a part under a range of build conditions and provide the insight required to make "first-time-right printings" a reality (Fig. 1).

Fig. 1: Multi-scale simulation of additive manufacturing processes promises to open the door for mass production of metal parts by delivering high precision and repeatable quality. *Image courtesy of Siemens Digital Industries Software.*

These tools provide an environment in which engineers can model and simulate multiple physical aspects, such as heat transfer and phase changes, as well as track the evolution of material properties throughout the build. In other words, the software supplies multi-scale, multiphysics capabilities that support the complex interaction of multiple algorithms and processes.

Consider Powder-Bed Systems

To understand the dynamic forces with which engineers and designers must contend, look at AM part manufacturing within the context

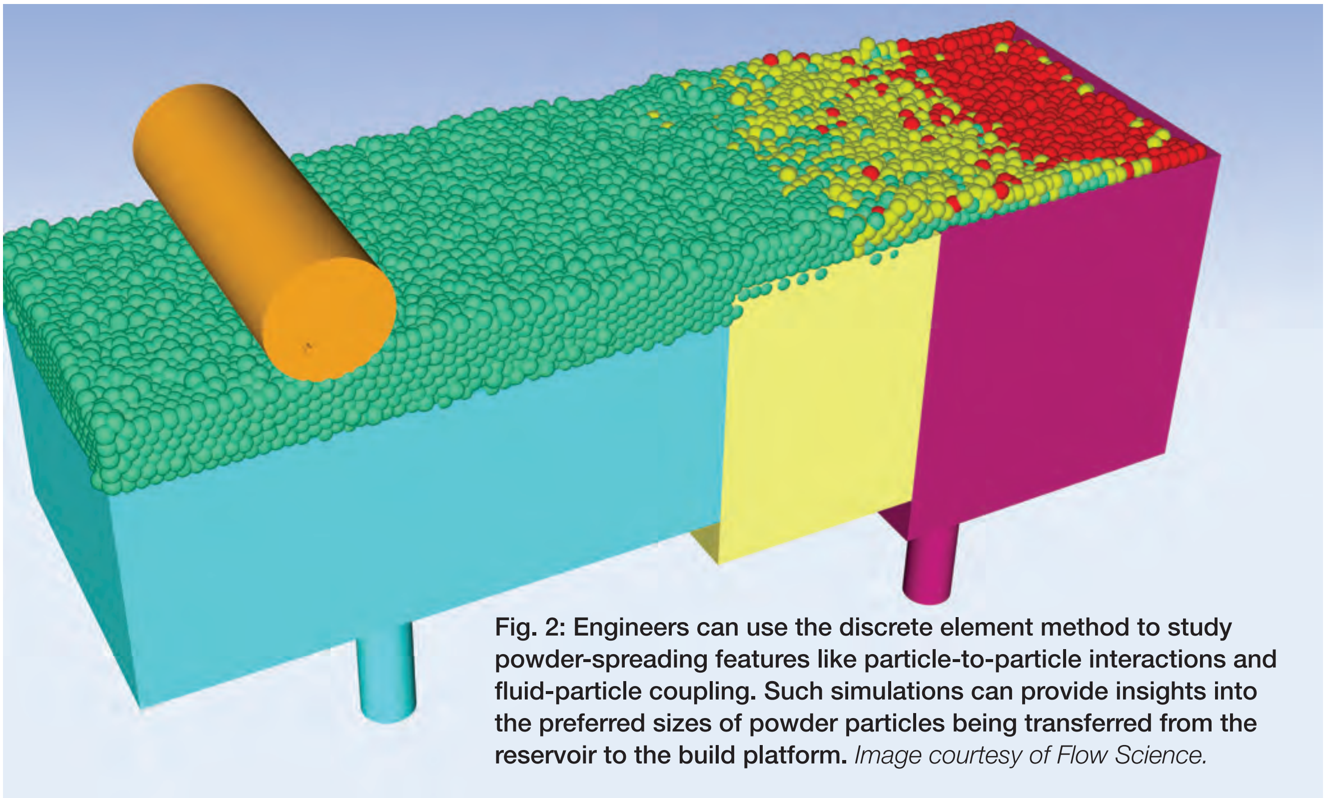

Fig. 2: Engineers can use the discrete element method to study powder-spreading features like particle-to-particle interactions and fluid-particle coupling. Such simulations can provide insights into the preferred sizes of powder particles being transferred from the reservoir to the build platform. *Image courtesy of Flow Science.*

of laser powder-bed fusion (LPBF) technology, one of the most common metal AM systems on the market today. These platforms owe their market presence to the technology's superior ability to create geometrically complex parts.

In a typical LPBF process, a laser beam scans across a thin layer of metallic powders, fusing the desired cross-section of the geometry to the plate. After the initial exposure, the machine lowers the plate and applies the next layer of powder. The printer repeats these steps until the part is complete.

This process may be conceptually simple, but many dynamic and transient physical phenomena come into play, driven by the extremely high heating and cooling rates that occur.

For example, with these systems, the temperature of the melt pool determines the pool's dynamics and stability. If the temperature falls within an unfavorable range, the build process can create conditions like partial vaporization of metallic powders, flow of molten metal, powder ejection and redistribution, rapid solidification and non-equilibrium phase transition.

These complex interactions can result in a product with a rough surface, significant porosity, residual stress and unfavorable phase and grain structures, with the consequent impact on properties. It is therefore important to understand the mechanisms responsible for defect formation.

Visibility Through Simulation

Almost all process conditions have an effect on the final as-built material quality. From the initial process conditions of powder humidity and size distribution, to the applied process parameters—such as powder thickness and laser power and speed—all of the factors play a role in defining the material's microstructure.

Layer by layer, the heat source remelts the material several times, which intensifies the local thermal gradients' history. Depending on the local evolution of the melt pool and the solidified microstructure, micro-defects such as hot cracking or porosities can occur. The evolution of those defects, combined with the part's overall thermal history, lead to high residual stresses, distortions and various unexpected behaviors during printing.

To achieve the required visibility to mitigate or control these factors, engineers have turned to a special class of simulation. The challenge with the technology, however, becomes fitting simulation in the complete AM numerical chain within an acceptable cost for end users.

The most common solution is to simplify the physics that model the complete printing process. This promises to let engineers accurately predict the overall distortions and residual stresses arising during the building process, assess the print job's manufacturability, and ensure topological part compliance with the initial design.

"It would probably be too ambitious to create a unique numerical model that simulates all of the physics to be considered, especially for an industrial application," says Pierre-Adrien Pires, additive manufacturing domain leader at ESI Group. "The reasonable approach is to split our focus on several modeling scales, from the micro scale at melt pool size to the macro scale, where the complete part, its supports and the base plate are to be modeled."

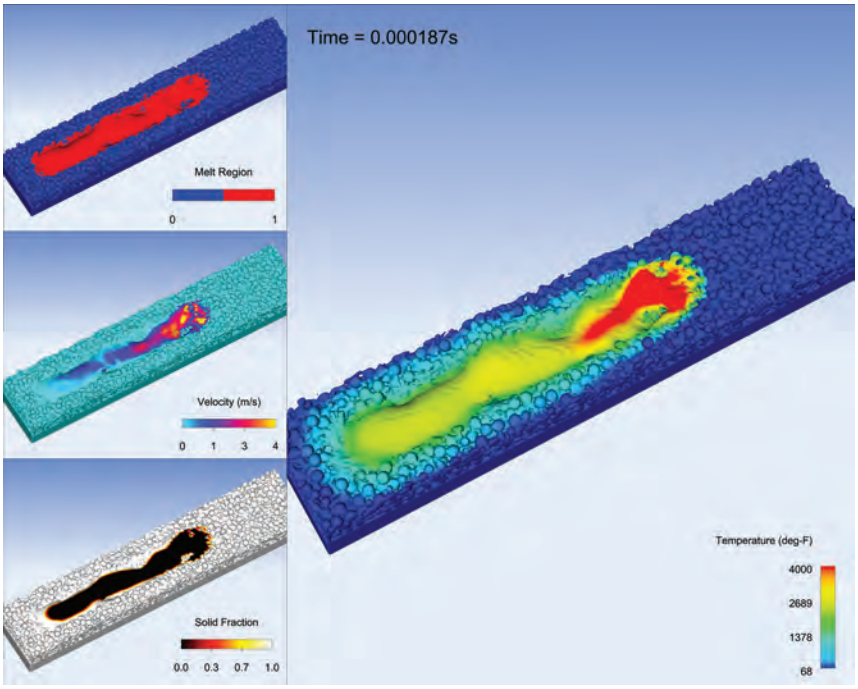

Fig. 3: This melt pool analysis of a powder bed allows the engineer to analyze the effects of temperature, velocity, solid fraction, temperature gradients and solidus velocity variations. *Image courtesy of Flow Science.*

Starting Small

Simulating powder-bed build processes begins on the microscopic level. In this phase, engineers create micro-scale models of each particle, treating the particles as discrete entities. The goal here is to mitigate or avoid the effects of the microscopic defects.

For example, polycrystalline metallic alloys consist of individual crystallites, commonly referred to as grains. These grains are connected via grain boundaries, which are often formed through recrystallization and grain growth during metal part fabrication and heat treatment.

After the metal build process, most grains are connected through highly misoriented and equiaxed grain boundaries. Misoriented boundaries can influence the metal's mechanical properties, such as high- and low-cycle fatigue lives, yield strength and creep. Equiaxed grain boundaries, on the other hand, can be susceptible to stress corrosion cracking, which can be undesirable in oil and gas, power generation, medical implant and aircraft engine applications.

Other types of grain boundaries, such as coincidence site lattice boundaries and low-angle boundaries, exhibit improved properties compared with equiaxed grain boundaries. The improved properties can include increased resistance to stress corrosion cracking by inhibiting intergranular cracking due to a disrupted network of the grain boundaries.

With this information, engineers can attempt to control grain structure, but this is not an easy task. "Grain structure control is challenging for metal AM," says Rashid Miraj, director of technical operations at AlphaSTAR. "Grain structure optimization requires control of grain morphology, with

AM Process Simulation Software Buyer's Checklist

When choosing additive manufacturing (AM) process simulation software, cost probably will not be the deciding factor. In fact, industry leaders contend that the software pays for itself in no time.

"The simulation investment typically breaks even within two to three build failures," says Brent Stucker, director of additive manufacturing at ANSYS. "Implementing simulation can help users avoid wasting time and money on materials, design and development."

Functionality will help you decide on a simulation platform. Following is a list of features buyers should strongly consider.

The simulation tool should:

- maintain validated material databases;
- support multi-scale progressive failure analysis;
- support multi-physics analysis;
- assess material and process parameter sensitivities to build outcomes;
- generate accurate meshes for work pieces and supports;
- predict transient temperature and material states;
- support orientation optimization;
- predict transient temperature and material states;
- predict damage/failure initiation and damage/failure propagation;
- provide for post-processing steps simulation and production assistance features; (part orientation assistance, topological supports generation and part compensation);
- provide workflows that smoothly connect different stages of the product cycle and establish a complete virtual thread;
- support optimized builds to improve manufacturability; and
- ultimately predict in-service qualification of printed parts and in-service life, strength and durability.

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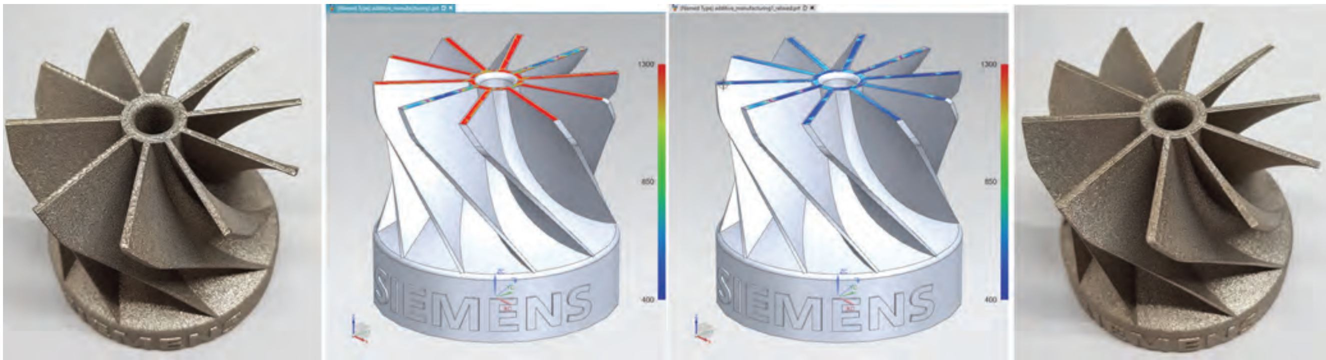

Fig. 4: Meso-scale, physics-based simulation of powder-bed fusion manufactured parts aims to identify overheating and enable the engineer to adjust process parameters to achieve improved part quality. The impeller on the left is printed using the original file and shows evidence of local overheating, highlighted in red. The part on the right is printed using the optimized file, which shows no evidence of local overheating. *Image courtesy of Siemens Digital Industries Software.*

grain size refinement, which can improve the mechanical properties of additive manufactured components. Here, influences of temperature gradient, solidification velocity and alloy composition on grain morphology come into play."

In addition to grain structure issues, micro-scale analysis looks at the spreading (Fig. 2) and packing of the powder for different powder size distributions and roller speeds, directions (clockwise vs. counterclockwise) and configurations.

To do this, engineers use the discrete element modeling (DEM) method, which has become the main tool for computationally studying the micro-scale spreading process.

Research has shown that powder bed quality stands out as one of the main factors that influences manufactured part quality. One way to achieve optimum conditions is by simulating powder spreading, characterizing the interactions of individual metal powders with the substrate and container wall. This includes calculating the friction coefficients between the powders and boundaries.

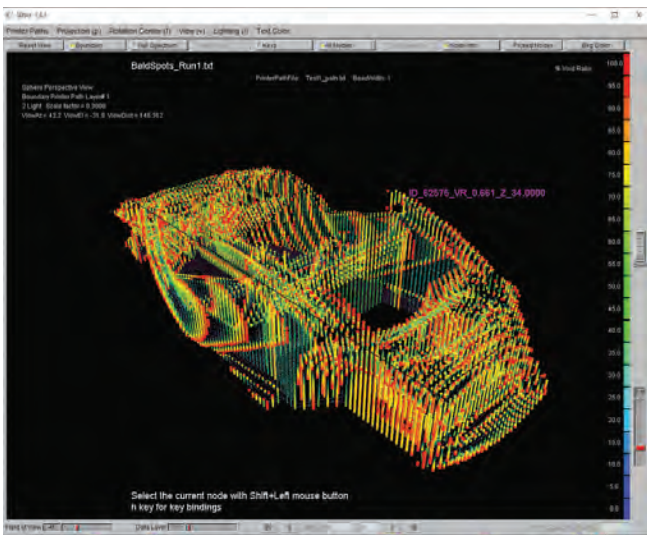

Fig. 5: The screen shows macro-scale analysis in which the simulation identifies voids in the part. *Image courtesy of AlphaSTAR.*

AM technology developers have demonstrated that improving the powder bed density and homogeneity decreases melting defects like denudation and porosity and improves part quality. Therefore, engineers must understand the spreading process to accurately predict powder-bed quality.

Powder packing density also plays a critical role in the quality of the powder bed. This parameter directly affects powder thermal conductivity and consequently the temperature distribution in the melt pool. Engineers can model and simulate mechanical contact interactions between deformable particles using DEM software.

"Micro-scale simulations provide insights into the origin of defects such as porosity, lack of fusion, balling and surface roughness," says Allyce Jackman, a CFD engineer at Flow Science. "These defects affect microstructure and part-scale structural integrity by compromising material strength. Porosity—which arises because of air being trapped within the material during melting—decreases the strength of the material in its solidified state. Lack of fusion, uneven surface roughness and balling defects make it difficult to evenly deposit subsequent layers, which leads to non-uniformity and reduced structural integrity in the overall part."

The Intermediate Step

The next simulation chain segment occurs on the meso scale. Here, the simulation focuses on the laser's interaction with the powder bed and on subsequent melting and solidification. At this scale, software tools simulate material deposition issues like powder-bed fusion, hydrodynamics in the melt pool and thermal stress (Fig. 3).

Meso-scale simulation helps engineers identify structural problems within the part. This level of simulation excels at analyzing the deposition path of a part to identify issues with the melt pool.

"It's important to understand how the layer-by-layer 3D printing of a part can be affected by overheating, distortion, warping and re-coater collisions," says Frankel. "Layer-by-layer simulation of the build process, however, is just one aspect of meso-level analysis. Engineers also need to be able to predict and correct defects caused by local overheating along each layer at the toolpath's fusion point with the melt pool (Fig. 4)."

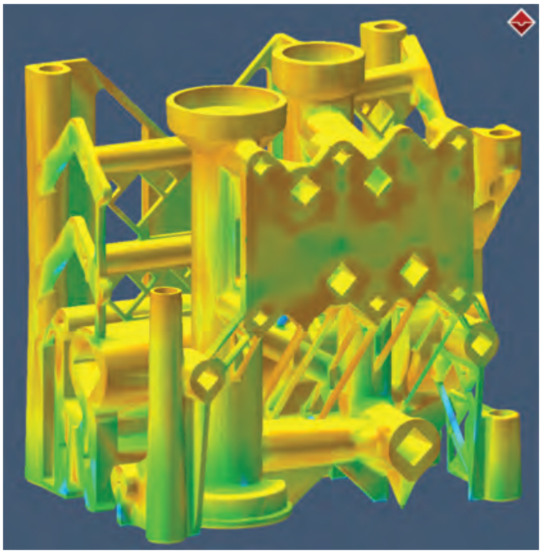

Fig. 6: Multi-scale, multiphysics simulation can be used to predict distortion and residual stress in a part and guide the production engineer in how to compensate for these factors and ensure a quality part the first time. *Image courtesy of Simufact.*

Looking at the bigger picture, meso-scale simulation examines the overall metallurgical properties of the build. Results depend on alloy composition, temperature distribution, deposition patterns and residual materials.

Because of their inherent qualities, meso-scale models interact with the micro and macro simulations of the powder-bed build. To help with this process, multi-scale, multiphysics simulation platforms use metallurgical tools and databases from established metal-based manufacturing tools to help generate results.

Simulation With a Wide Lens

Macro-scale simulation examines features such as part construction, distortions and stress buildup, and often rely on finite element analysis to provide insights into the build process (Fig. 5). Unlike the micro- and meso-scale simulations, this form of analysis ignores details of laser-particle interactions and fluid flow in the fusion zone, focusing instead on factors like temperature distribution, heat transfer and mechanical response.

Designers using macro-scale simulations can optimize the build orientation and subject the part to virtual service loads—environmental and structural—to ensure that it meets specification and performance requirements. These simulations also address factors like fatigue, aging and other degradation factors to assess as-is behavior and determine whether the virtual part will still meet specification later in its lifecycle.

Because the elements analyzed at this scale are larger in size, engineers can run the simulations fairly quickly. The simulations also promise precision. "Thermomechanical macro-scale models have proven to deliver high accuracy," says Patrick Mehmert, product manager at Simufact. "Distortions and stresses can be predicted, and manufacturing risks like re-coater crashes or cracks can be identified."

Simulations Pay It Forward

The simulations of each scale contribute valuable design and manufacturing information. Their contributions, however, extend beyond isolated scale concerns.

For example, micro- and meso-scale simulations provide engineers with information about process settings—such as laser power, scan speeds and scan patterns—which allows engineers to optimize melt pool dynamics and process stability. Once the process parameters are optimized, engineers can use the settings as input parameters for macro-scale simulations, like thermal stresses and distortions, to better understand the build quality.

"Optimizing the process parameters at the micro- and meso-scales ensures that the melt pool is of excellent quality," says Paree Allu, senior CFD engineer at Flow Science. "This in turn paves the way for a good structural build." DE

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MORE INFO

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- **ESI Group:** ESI-group.com
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Materials Take a Giant Leap Forward in 3D Printing

3D printing expands deeper into developing areas of innovation, including biotechnology.

BY JIM ROMEO

Recently, researchers at Carnegie Mellon vaulted 3D printing into unprecedented heights in biotechnology: they were able to use a 3D printer to actually print functional organs and devised a method to rebuild parts of the human heart.

Recently, researchers at Carnegie Mellon vaulted 3D printing into unprecedented heights in biotechnology: they were able to use a 3D printer to actually print functional organs and devised a method to rebuild parts of the human heart.

The researchers were able to print (or "bioprint") parts of the heart using a process called FRESH printing, that combines print with a gelled collagen substance to create what they refer to as "unprecedented complexity and construct components of the human heart spanning from small blood vessels to valves to beating ventricles."

The scale of possibility of 3D printing is increasing daily, as new materials are used with advanced printers to create products that change lives, and change our world.

"Materials play a central role in the continuing growth of 3D printing," says Edwin Hortelano, PhD, vice president, materials R&D, 3D Systems. "In fact, for 3D Systems, every solution we develop begins with the customer's application and then the material best suited to accomplish that. The properties of the parts that result from a 3D

Skateboard printed from recycled materials by students of Michigan Technological University.

Xerox is using commercial, off-the-shelf alloys, already familiar to manufacturers.
Image courtesy of Xerox.

printing process are largely defined by the materials selected. There are currently many 3D printing materials available, but the real opportunity for innovation exists in the continuing efforts to expand the properties that can be achieved."

Dave Veisz is vice president of engineering at MakerBot. He says that 3D printing offers much more design freedom than traditional subtractive manufacturing processes. "Parts can have internal voids and variable cross-sections, which are advantageous for weight savings," he says. "Also, many complex parts can be combined into a single part without any fasteners. This has benefited industries like aerospace where it is easy to justify the cost of 3D printing to get better strength-to-weight ratios. Medical is also an arena where mass customization and part complexity lend [themselves] to 3D printing due to the required customization."

Metals and Metallic Alloys

Feedstocks aren't just resin based. Metallic products are gaining ground, and are now able to be printed with delicate operations. Kevin Lewis is the business lead for 3D printing at Xerox in Webster, NY. When companies print with metals, he points out that most 3D printers are using metal powders. These require post-process steps such as depowdering, debinding and sintering, steps that can be time-consuming and costly.

Xerox is forging a different path, focusing on liquid metal technology. "We use commercial, off-the-shelf alloys that manufacturers are already used to using in their current workflows," says Lewis. "Parts are denser, faster to make and cheaper compared to those made with metal powders, and manufacturers can make parts from start to finish in hours instead of days without sacrificing quality or strength.

"Throughout the industry, the technology continues to change and improve. We are seeing numerous new materials being introduced and automation being used to improve labor-intensive steps, which is resulting in further integration of additive manufacturing processes into manufacturing workflows," Lewis adds.

MakerBot's Veisz envisions 3D printing using more economical practices in the future, driving capability of fabricated objects—but at a lower per-unit cost. He feels that in the future the per-unit cost will continue to decrease for 3D printing tech-

Products made from recycled materials provide a direct economic incentive to recycle and help the environment. *Image courtesy of Michigan Technological University.*

nologies as the machines scale up in volume. He also says this will continue to make the ROI for 3D printing more attractive at higher volumes. This is despite the present scenario where volumes that justify production via 3D printing are somewhat low.

"Material development is also accelerating as all of the large global chemical and materials companies are focusing more effort into materials for various 3D printing processes," Veisz adds. "Many of these are use-case focused."

Veisz says that industries affected are those where mass customization is beneficial, such as medical orthopedics and prosthetics. He also sees much demand in the buildup of a library of spare parts for industries such as defense and transportation.

"Product companies are able to justify launching a product using 3D printing in order to come to market quickly and test the waters before committing to expensive tooling," says Veisz. "This democratizes manufacturing for companies that otherwise would not afford to purchase high-volume tooling. Therefore, I would expect a sharp rise in smaller companies putting out hardware products faster, lowering the bar of entry to shipping hardware."

Recycled Materials

Joshua Pearce is the Richard Witte Professor of Materials Science and Engineering at Michigan Technological University in Houghton, MI. An important niche that's not always at the forefront of conversation when materials are discussed is the use of waste as a feedstock for 3D printing.

"I think the most interesting current area of 3D printing materials is direct 3D printing of waste materials—both pure plastics and composites made with other wastes," explains Pearce. "We have been working with an American industrial 3D printer manufacturer, re:3D, that makes the Gigabot X to directly 3D print from waste. There is a lot of potential from this approach and such fused particle systems have barely begun to be commercialized—so there is a lot of room for growth. Needless to say, it is super eco-friendly."

Pearce says there's a very important and emergent use of feedstock from recycled materials. This could open up many new possibilities.

"One of my students turned a bunch of shredded plastic directly into a skateboard deck for his electric skateboard," he says. "This saved him a ton of money and got him a product that was customized for his interests. 3D printing is already taking off and the distributed recycling technology is right behind it. Recycling will be something you do for yourself. Then everyday people will have a direct economic incentive to recycle rather than simply rely on goodwill to protect the environment."

Consider the Printer

The type of printer greatly influences how material is used and what it produces. James Lynch is engineering director of Design Partners, a firm that designs and produces products for customers like Samsung, Honeywell, Panasonic and Google. They are able to fabricate products using different and innovative materials.

The firm uses three types of printers. Stratasys Objet printers operate with a UV-curable plastic simulant, and Lynch calls them their workhorses, saying they require very little setup and produce very accurate parts.

"The real benefit of these machines is they allow us to design and digitally iterate up to the very end of our day and we can send parts to be printed overnight ready for review in the morning," Lynch says. "The ability to produce real parts

There are currently many 3D printing materials available, but the real opportunity for innovation exists in the continuing efforts to expand the properties that can be achieved. *Image courtesy of Michigan Technological University.*

overnight means we can iterate, design and react quickly to changes, and our clients really appreciate that."

Design Partners also uses ultra-high resolution DLP (Digital Light Projection) printers to produce high-quality surface finish models with a variety of materials—from plastic simulants, to clear parts, to ceramic filled resins, with high temperature resistance.

"We use this when we are pushing the boundaries of surface finishes and textures," Lynch says. "Humans are sensory beings, and we believe in designing products that engage the senses in multiple ways—like through the desirable tactility of a textural pattern, or how light beautifully emits through a translucent surface.

3D printing these concepts allows Design Partners to test and validate ideas at a fast pace, creating a new experience for people, Lynch explains.

The company also uses a Fused Deposition Modeling (FDM) printer, which Lynch likens to a hot-glue gun. It heats and then accurately extrudes real plastics like ABS, polypropylene and Nylon.

"These parts can be incredibly tough and can be very useful for testing how real plastics will ultimately behave in mass production. We also have an extensive list of external suppliers who give us access to the full gamut of new and emerging print technologies," he says.

Into the Future

The full gamut of new and emergent print technologies with 3D printing continues to transform science each day. The better way of technology and innovation has already found a straight path into science and engineering with 3D printing. And the best is yet to come.

As for Carnegie Mellon and its ability to print components of the human heart, the remarkable technology of bioprinted hearts prevails. Although the human heart was used for proof of concept, FRESH printing of collagen and other soft biomaterials is a platform that has the potential to build advanced scaffolds for a wide range of tissues and organ systems.

Such achievements are bellwether milestones for the possibilities of next-generation 3D printing with multimaterials.

"We now have the ability to build constructs that recapitulate key structural, mechanical and biological properties of native tissues," says Adam Feinberg, chief technology officer and co-founder, FluidForm, and principal investigator for the Regenerative Biomaterials and Therapeutics Group at Carnegie Mellon, where the research was done. "There are still many challenges to overcome to get us to bioengineered 3D organs, but this research represents a major step forward." **DE**

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MORE INFO

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- **MakerBot:** MakerBot.com
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Pedal to the Metal

Digital simulation and modeling allowed VinFast to launch a car company from scratch in less than two years.

BY BRIAN ALBRIGHT

The automotive industry is consistently under pressure to accelerate design cycles that better meet shifting demand. But for most companies, the launch of a new vehicle requires years of development and validation. However, a new Vietnamese auto startup may point the way to more rapid development.

Miss Vietnam Tran Tieu Vy, the VinFast executive team, and soccer star David Beckham at the Paris Motor Show in 2018. *All images courtesy of VinFast.*

Armed with massive amounts of capital and advanced simulation technology, VinFast didn't just quickly launch a new vehicle—they literally built the entire company from scratch, and went from design to completion of their inaugural vehicles and factory in less than two years.

VinFast is Vietnam's first volume car manufacturer, and it debuted its first two models in June 2018 at the Paris Motor Show. The company is a subsidiary of Vingroup, the largest private company in the country. When VinFast launched, Vingroup operated in the real estate, retail and healthcare sectors as well.

"Our chairman [Pham Nhat Vuong] has spent his career looking at what he felt was best for Vietnam and its people," says David Lyon, director of design at VinFast. "He believes that Vietnam needs a manufacturing base to have a strong middle class."

Vuong also famously lacks patience, which made traditional automotive startup scenarios unappealing. "He wanted to do this in two years, starting with nothing," Lyon says.

Digital Design

To accomplish this unprecedented timeline, VinFast took an almost entirely digital approach to designing its vehicles and its factory. The company partnered with Siemens Digital Industries Software (and other Siemens divisions) to turn

Above: VinFast Director of Design David Lyon. Inset: The VinFast LUX SA2.0.

the company's plans into reality.

VinFast leveraged Siemens' product lifecycle management (PLM) software, including the Tecnomatix portfolio with Manufacturing Operations Management (MOM), and Siemens Opcenter, to facilitate lean manufacturing across all production phases. Additional Siemens products helped drive the factory's automation systems.

According to the original announcement from Siemens and VinFast, this holistic approach "increased speed and flexibility in development, ensured high global standards in production, optimized the manufacturing process and made the entire plant future-proof for further expansions and new business models."

"Using the combined power of both product lifecycle management and manufacturing operations management technology is a key part of our digitalization journey," said Jason Buxton, chief information officer at VinFast, when the company was launched. "To drive innovation within the automotive industry, it is essential to have the right technology in place."

VinFast leveraged Siemens design tools such as the Xcelerator portfolio and Totally Integrated Automation portal, which facilitates a link between design and manufacturing, so modular manufacturing operations can respond to inputs accordingly.

The company created digital twins with Xcelerator, which combined simulations, test data and performance analytics. This helped reduce reliance on physical prototypes and accelerated the company's ability to iterate and improve the design. Actual vehicle performance data can be collected, analyzed and fed back into the development cycle.

VinFast used Teamcenter to help engineers collaborate throughout the design and production phases, and to ensure that the physical production lines could flex dynamically based on the virtual designs and commands.

Siemens Opcenter software also supported high production speed and quality through its support of closed-loop manufacturing.

"The key to this all going well is digital infrastructure and digital backbone that allow us to model everything virtually before it really happens," Lyon says. "One thing about doing it this fast—it took us about half the time it takes for an [original equipment manufacturer] that's been around for 100 years to put a car on the road. There's a lot of risk here. That risk is uncomfortable, but it meant we had to rely heavily on the digital tools."

The elimination of the traditional clay modeling step also helped accelerate development, according to Lyon.

"All of our engineering requirements and the assemblies live in the virtual world," he says. "We worked with digital sculptures."

VinFast leveraged partnerships with leading suppliers and designers to accelerate the development process.

Leveraging Partnerships

Rather than start the design from scratch, Vingroup turned to outside companies to help launch the brand. The cars were designed with aid from Pininfarina (an Italian design studio), BMW and contract manufacturer Magna Steyr.

Vingroup's chairman decided that part of the design process would be to put the initial concepts online, and then have a contest in which the Vietnamese public could chime in with their own preferences.

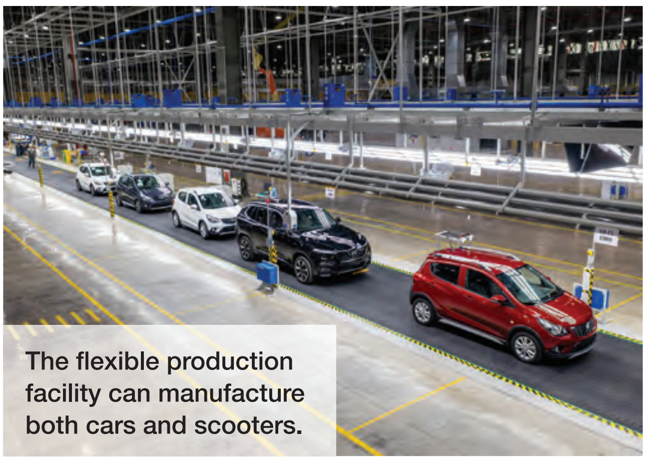
"This would be crazy in any other setting," Lyon says. "We had 60,000 people voting, and we knew we had a winner on our hands. By November 2017, there was not a lot of second-guessing and we were able to move forward.

"The key element we focused on was that we wanted to work with the best ... the only way to pull this off was to get the best partners. We weren't going to spend years building an internal team to create standards," Lyon adds.

When talking to potential partners and suppliers, VinFast was frequently asked for specifications, but they had none. "We told them there is no team here creating specifications. You tell us what we should have and we'll implement it," Lyon says.

Lyon, who previously worked for General Motors, says the company asked potential partners to ignore all of the "dumb and unnecessary steps" that other OEMs usually asked their suppliers to follow. "We just asked them, 'What would it take to do it in this time frame?'" Lyon says. "One by one, after a lot of internal discussions, they came to the table with plans that were able to meet that timing if it all went well."

Surprisingly, everything went well. By December 2017, VinFast had an agreement with BMW to license the vehicle architecture and technology from them. "Before that, we didn't even know what the underlying vehicle architecture was going to be," Lyon says. "But in January we had our first model review. By March 2018, we were able to make all of our choices virtually without creating full dress models."



The flexible production facility can manufacture both cars and scooters.

Over the next several months, the company worked with suppliers and partners to create perfectly manufacturable surfaces that could be produced with cut tools. By October 2018, they were able to unveil the first models at the Paris Motor Show.

At the Paris event, the company launched its LUX A2.0 sedan and LUX SA2.0 mid-size luxury SUV. In 2019, the company added the LUXV8 SUV and Fadil city car to the line. The company also offers three models of electric scooter.

VinFast also needed a production facility. Part of the plant site was literally underwater during vehicle development. They broke ground in September 2017.

"One thing that Vingroup really knows how to do is build things quickly," Lyon says. "We now have 4,750 employees, and we can do everything there from manufacturing the body and the engine, to the paint shop, and all subassemblies. We can make 250,000 cars and 250,000 scooters per year."

In March 2019, the plant rolled out its first test vehicles. "We were all very concerned about this first build, and whether or not it was going to work. It had to be right the first time," Lyon says. "We didn't have time for do-overs. The first one rolled off the line, our chairman got into it, pushed the start button and drove it around the plant. We put a lot of trust in our digital tools, and they didn't let us down."

The Hai Phong, Vietnam, facility leverages Siemens

Vingroup rapidly designed and constructed a flexible manufacturing facility even as the new vehicles were being created.

automation equipment, and was designed based on a flexible production model. It is capable of making not only the sedan and SUV models, but also e-scooters, compact cars and electric busses. According to Lyon, the facility can be easily scaled up and down to meet demand.

"VinFast and their new production site are a great example of how the automotive industry is driving the digital transformation of manufacturing," said Bernd Mangler, senior vice president, automotive solutions at Siemens Digital Industries, in a press release. "We are proud that we contributed with our offerings to create the virtual and real production lines including the technology for continuous optimizations along the entire lifecycle of the equipment—and of course, all had to happen in record speed."

Deliveries of the first VinFast vehicles began in September 2019, far ahead of schedule. In January, the company reported it has already received 17,000 vehicle orders and 50,000 orders for electric motorcycles. With the success of the auto firm, Vingroup has jettisoned its retail and agriculture businesses and scrapped plans for an airline to focus on VinFast and its Vsmart smartphone brand.

VinFast chairman Vuong also hopes to launch the brand in the U.S. in 2021, and has pledged as much as $2 billion of his personal fortune to help make that happen. DE

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→ MORE INFO

- **Siemens:** SW.Siemens.com
- **VinFast:** VinFastMedia.com/en

For more information on this topic, visit DigitalEngineering247.com.

The VinFast LUX A2.0 was rapidly designed and produced thanks to advanced simulation technology.

No One-Size-Fits-All Optimal System

Software use and workload should determine IT manager workstation selection.

BY KENNETH WONG

The best workstation for someone is not necessarily the most expensive system with the fastest CPU, the most powerful graphics processing unit (GPU) and the biggest memory capacity. From the IT manager's perspective, it's a system that's best suited for the user's daily expected computing tasks.

Shown here is the GoBOXX SLM mobile workstation used by NCC engineers who need to view CAD files. *Image courtesy of BOXX.*

Someone who uses AutoCAD and SolidWorks heavily but rarely renders ray-traced scenes, for example, has very different CPU, GPU and memory needs from one who uses 3D Studio Max to animate characters or run computational fluid dynamics (CFD) simulations routinely. This type of usage-based configuration is the key to cutting costs and boosting productivity in an IT manager's strategy.

For further insight into this, *Digital Engineering* spoke to real-world IT managers and CAD users so they could explain how they configure their systems based on what they do.

Tiered System

IT managers who need to distribute finite computing resources among teams and fleets tend to divide computer users into three types: casual users, normal users and power users. These profiles serve as guidance for physical or virtual workstation configuration.

Lenovo is a supplier to the engineering and construction firm JE Dunn. Shown here is the Lenovo ThinkPad P53. *Image courtesy of Lenovo.*

Michael Ferraro, mechanical engineering team leader, NCC Automated Systems, classifies his engineers as viewers, editors and beasts.

"Viewers generally float into CAD models to check progress, pull dimensions and then move on. They generally use [the system] a few hours a week. Editors are either in mechanical engineering or application engineering positions. As such, they generally live in the CAD program 30 to 40+ hours a week. The beasts are those who not only work in the program 40+ hours a week, but also do renderings for customers and social media posts," he explains.

For mobility, viewers get BOXX GoBOXX SLM 17 mobile workstations. "It allows them to more easily host meetings and design reviews," says Ferraro. "The editors and beasts all get dedicated towers, APEXX S3, for better performance. And then we just give faster GPUs and more RAM for our beast [users]."

At JE Dunn, Jason Bowne, VP of IT, separates his users primarily into building information modeling (BIM) users and normal users.

"Normal users get a standard laptop that is pretty powerful, has a discrete graphics card so they can do some work in apps that require discrete graphics," explains Bowne. "BIM users get a big laptop with a strong GPU, fast processors, lots of RAM and lots of SSD [solid-state] drive space [for storage]."

But according to Bowne, the outliers are the estimators and travelers. "Estimators would get less than a BIM machine but more than a standard, and travelers need smaller and ultraportable machines," he says.

BIM is an architectural modeling program that usually comes with rendering and simulation features. Autodesk Revit is one of the industry standard BIM programs.

"BIM folks push the laptops to the limit with Revit, AR/VR and more. Standard users need a solid laptop with lots of connections and good performance, just not the level of BIM users," adds Bowne.

"Estimators need a bigger screen and a [numeric keypad], but they don't necessarily need the power of a BIM machine. They travel more, so we're testing them with a lighter laptop. Travelers work while on the road or in a plane. They run regular office apps [and] review drawings in Bluebeam [project tracking software], so nothing too demanding," Bowne says.

JE Dunn relies on Lenovo systems. For workers at construction sites, engineers use Citrix apps for remote work. "We have also been testing … [virtual desktop infrastructure] sessions for BIM users so they can access Revit models on a virtual station from a jobsite and not be burdened with trying to work natively on a laptop or downloading large model over really slow network connections," explains Bowne.

Riding the AR/VR Wave

Mike McArdle, chief product officer at Lucid Dream VR, relies on Dell for the systems his workforce needs. The firm functions more like a video game studio than an architectural or industrial design firm, McArdle explains.

The company uses Autodesk Maya as its primary 3D modeling software, but also works with client assets delivered in AutoCAD, Revit or Rhino formats. Teams use Unity or Unreal Engine 4 to render content for virtual reality (VR) in real time.

"Generally, when we are dealing with very high polygon-count 3D assets, or very high bitrate in 6K or 8K 360 video assets, the CPU and GPU become very important," notes McArdle. "That leads to our decision to use the Dell Precision workstations because the Intel Xeon Gold 6134 CPU and Radeon Pro WX 9100 are optimized for the type of parallel processing needed for the intense workloads we need."

Because CAD modeling operations are mostly sequential, CAD users tend to benefit from faster CPUs. By contrast, simulation software users and visualization artists see better performance from the parallel processing power of GPUs. For Lucid Dream VR, however, the requirements are at both ends.

"When it comes to running a high-end VR simulation, the GPU is arguably the single most important factor."

—Mike McArdle,
Lucid Dream VR

"When it comes to running a high-end VR simulation, the GPU is arguably the single most important factor. But when we are developing the simulation, we use a wide variety of assets, from video to 2D to 3D models, which all need to be optimized, compressed and prepared for the real-time engine, and that requires a fast, multi-core CPU," says McArdle.

The firm has investigated remote collaboration using solutions from Adobe and Autodesk, but McArdle says, "most of our team works onsite and is in the office 90% of the time, so remote collaboration is not as relevant for our workflow."

Corporal Willy's Personal Machine

As a long-time SolidWorks user, Richard "Corporal Willy" Williams is a familiar face in the CAD community. Though retired, he's still flexing his engineering muscles, firing up CAD software in pursuit of personal projects. At press time, he was in the middle of designing a guitar-playing stool, with guitar-shaped holes along the support pillars.

The Williams household juggles eight computers from HP, Dell and Xi Computer, with RAM sizes ranging from 16GB to 24GB. Williams and his son, an IT manager, account for most of the computer usage. Williams characterizes his son and himself as "somewhere between intermediate and heavy professional users."

"One of the biggest problems for CAD users are the graphics cards [GPUs]," notes Williams. "The most powerful graphics cards cost as much as a higher end computer. I have an older NVIDIA Quadro Card in a system with dual Xeon CPUs, but it's old … to do a render, it takes time and patience."

When purchasing a new system, he encourages CAD users to pick a dual Xeon CPU machine with the most available high-speed RAM memory, but he also admits he's often reluctant to upgrade to newer systems. One word sums up his upgrade weariness: compatibility.

"When you get a newer computer with the newest OS… [you might find that] many of your existing software and older drivers don't work with the newest system," he explains. A newer system offers more horsepower in the latest CPUs and GPUs, but upgrading drivers and fine-tuning the system take time.

Cool Tech to Attract Talent

Investing in best-in-class systems doesn't just benefit the current workforce but also the future engineers, as Bowne sees it.

"Now, many in the next generation of workforce are actually making decision to join a company based on the technology they get," he says. "They don't want to be strapped down to an old, underperforming laptop running Windows 7. They want new up-to-date technology, and the agility to work remotely with integration and syncing across [a] laptop, phone and tablet."

This attitude explains JE Dunn's thinking behind acquiring laptops and towers. The next-gen engineers are the type who may choose to work from home, on the go or in a cubicle; therefore, to accommodate them, both mobile and stationary systems are needed. 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.*

→ MORE INFO

- **BOXX:** BOXX.com
- **Dell:** Dell.com
- **E J Dunn:** JEDunn.com
- **HP:** HP.com
- **Lenovo:** Lenovo.com
- **Lucid Dream VR:** LucidDreamVR.com
- **NCC Automated Systems:** NCCAS.com
- **Xi:** XiComputer.com

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Smart Scanning

For those versed in reverse engineering, here's how to stay afloat in the sea of available hardware and software solutions.

BY KIP HANSON

Traditionally, reverse engineering was once a colossal pain in the neck. Capturing the dimensions of a machined, cast or injection-molded component often entailed hundreds of measurements on a surface plate or coordinate measuring machine (CMM), followed by hours of tedious CAD work. And larger objects like aircraft fuselage or automobile interiors? You may have cut them into smaller sections, measured each one and digitally stitched it all together again, but it was probably easier to just start from scratch.

The good news is that all of this tedium is now obsolete. A range of easy-to-use and cost-effective scanning systems have hit the market in recent years, making the capture of dimensional data on practically any object about as tricky as snapping a family photo. Plus, a host of software tools are now available that can turn scanned data into accurate 3D models within hours or even minutes.

Armed for Success

One provider is FARO Technologies Inc., which offers numerous solutions for anyone wishing to reverse engineer a product. Perhaps the most challenging aspect of these systems, however, is deciding which one is best for your use case.

Proper system selection depends on the desired accuracy and resolution, speed requirements, the size of the objects being scanned and the available budget, says Ken Steffey, product manager for the FaroArm/ScanArm and Laser Line Probe portfolio.

"Scanning a machined part, for example, might require accuracy to within a few thousandths of an inch, whereas a car bumper or chassis component probably needs far less than that," he says. "The advantage of our articulated arm technology is that you can get very dense point data on small parts and part features, then use a looser, faster scan for larger or less critical components."

FARO's ScanArm has significant reach, he adds, able to measure objects several meters or more across. It can also accommodate hard probes and touch-trigger probes like those used on CMMs, as well as several noncontact options.

One possible option, laser line scanning, works on the principle of using a camera to view a line of laser light that's

Laser and structured light scanners are often used to model objects with fine details, as in this Luke Skywalker replication project. *Image courtesy of nPower.*

Handheld scanners offer a cost-effective way to scan many objects quickly and easily. *Image courtesy of Thor3D.*

made to traverse the target workpiece. And just as one can determine a cellphone's position by measuring the distance to nearby towers, so too can point data be collected by triangulating the camera's relative viewpoints.

"The challenge with any method of non-contact scanning is that it's never as accurate as hard probing on a traditional CMM," Steffey says. "This is why we give customers the option of different probes or scanning heads, so as to cover as wide a range of applications as possible. The desire to cover a diverse application space is also why we recently introduced color scanning capabilities, which broadens the scope of materials and surfaces that can be scanned—dark and shiny plastics, for instance, and reflective surfaces."

Then There's Thor

For designers who don't need the capabilities—and admittedly higher cost—of the FaroArm or similar metrology solutions, there is an alternative. Anna Zevelyov, CEO and co-founder of scanning provider Thor3D, explains that the company brought the first wireless, handheld 3D scanner to the market in 2015, and continues to expand its offerings.

"The goal of our product is a little different than that of a FaroArm," Zevelyov says. "Not everybody needs the high accuracy and repeatability of a high-end scanner, or has the budget for it. Most of our customers want the ability to take a device into the field, or into places where an arm cannot fit. A handheld scanner like our Calibry does both, and thanks to its large field of view, [it] scans even large objects such as tractors and airplanes very quickly."

Thor3D's handheld scanners are adept at detecting sharp edges, black or shiny objects, and tiny details such as fur and human hair, artifacts that are traditionally very difficult to scan, she adds.

Archaeologists often use handheld scanners to document dig sites. A museum could use one to digitize a T-rex skeleton. A 3D printing or plastic-injection molding house might choose to scan a cape-clad Chris Hemsworth, shrink the resulting model to 1/10th scale, and use it to manufacture the next Thor: Ragnarok figure.

Connecting the Dots

The other piece of the scanning equation is software. FARO offers several scan-to-CAD tools, among them is the recently acquired RevEng Capture, to address "a variety of reverse engineering and design challenges across a range of industries," according to the company.

Thor3D, on the other hand, bundles Cyborg3D MeshTo-CAD with its Calibry scanner, software that Zevelyov says is needed to process the massive data sets acquired by any 3D scanner into usable files for further CAD processing.

Industrial CT scanners can see where other scanning technologies cannot, giving designers a view deep inside a variety of workpieces. *Image courtesy of Exact Metrology.*

Hard probes and touch probes provide more accurate results than non-contact scanners, but at the expense of speed. *Image courtesy of FARO.*

David Gill, president of nPower Software, a division of IntegrityWare Inc., notes that his company's software works with a range of scanning equipment, handheld or otherwise.

"Scan data is often bumpy and irregular, with gaps in one area or too much information in another," he says. "Our software smooths surfaces, matches contours and turns what would otherwise be non-intelligent bundles of points into clean meshes that can then be imported into any CAD system."

High-quality data is vital to most reverse engineering adventures, but so are modest file sizes. Today's scanners are so effective at gathering 3D information that the resultant files are typically massive, with gigabytes of data and millions of polygons; even with a powerful computer, it can take a great deal of time to process this amount of information. This is particularly true with organic shapes, which, thanks to advanced CAD software and 3D printing, are easier than ever before to produce, but generate truly massive files, Gill points out.

Phone a Friend

All of this advanced technology is good news to any would-be reverse engineer, but what about those folks who only have an occasional requirement and don't want to invest time and money into a 3D scanning system?

Even for companies ready and willing to buy a 3D scanner, it should be clear by now that there is no one-size-fits-all solution, and that choosing between the dozens of companies and equipment options will be no easy task. Now what?

You may want to give Steve Young a call. As president of Exact Metrology Inc., he and his team provide a range of reverse engineering, dimensional inspection and 3D scanning services, as well as computed tomography technology able to image an entire workpiece—inside and out—in a single operation.

Sending parts out for scanning—at least initially—allows companies to thoroughly "kick the tires" before investing in their own equipment, a crucial step given the increasingly broad array of systems available.

"It's easy to make a mistake. I just got off the phone with a gentleman who was having problems with a piece of equipment that he bought last month," says Young. "Unfortunately, he didn't do his homework and ended up with the wrong system. If he'd asked us to scan some parts for him or at least called us before cutting a purchase order, we could have steered him in the right direction."

Exact Metrology also sells or rents scanning equipment, giving customers a chance to try it out before committing to a hardware purchase.

"Our offerings include Leica long-range scanning systems and portable CMMs, Hexagon measuring arms and laser scanners, Artec handheld scanners, and reverse-engineering software from Geomagic and PolyWorks," he says. "And since we also use these products in-house for our service offerings, we're in a somewhat unique position, in that we can evaluate everything first-hand and select the hardware and software that we feel will best benefit our customers." **DE**

Kip Hanson *writes about all things manufacturing. You can reach him at kip@kahmco.net*

→ MORE INFO

- **Exact Metrology:** ExactMetrology.com
- **FARO Technologies:** FARO.com
- **nPower:** nPowerSoftware.com
- **Thor3D:** Thor3DScanner.com

For more information on this topic, visit DigitalEngineering247.com.

When Free Body Diagrams Go Wrong

Sometimes a potential simulation solution isn't immediately apparent. Using finite element analysis can provide insight into a real-life free body diagram example.

BY TONY ABBEY

Free body diagrams are used in structural analysis to try and reduce the problem to its simplest description. Where does the load get applied and where does the load get reacted? Free body diagrams can be created for the overall assembly and for each component in that assembly—hence tracking the load path.

This seems like a straightforward procedure—yet it is surprisingly easy to get things very wrong!

Many years ago, I worked in a stress office where my colleague was checking the strength of a helicopter control circuit run. This was long before the days of fly-by-wire, so it was an assembly of cranks, pulleys and pushrods, all supported by brackets.

The load case in question was where two helicopter pilots have different views on which direction to fly. Each one pushes hard on their rudder pedal (or strictly speaking, an anti-torque pedal), but in an opposing sense.

The loads were high (a braced leg can impart a lot of force) and my colleague chased these through the structure. He was very surprised to find that a lot of the brackets and other fittings were significantly below the normal strength margin of safety.

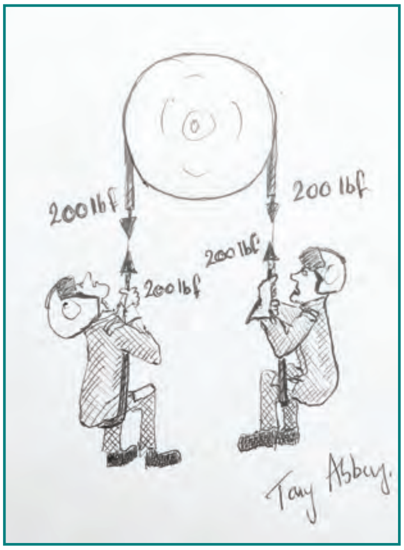

Fig. 1: Two men on a rope—or opposing pilot forces! *Illustration created by Tony Abbey.*

The helicopter was a derivative of earlier designs and the designers were highly experienced. Eventually he finished the stress report, ready for delivery to the prime contractor. I remember then seeing him suddenly slump, head into hands, over his desk.

He had just done a final sanity check and discovered a big mistake—each pilot's input was 200 lbs. force, so he had added this up and assumed 400 lbs. force in the circuit. But of course, it doesn't work like that!

Fig. 1 shows the correct assumption with a "two men on a rope" analogy we happily supplied, having the benefit of hindsight. Once the control circuit loads were halved, the structure was shown to be slightly over-designed. Thus, all the detailed work in his report, justifying the loads where he could, and making design recommendations where he couldn't, went into the trash can.

My friend was a highly experienced and very good stress man. So, of course we made his life a misery for the next few months by mentioning "two men on a rope" at every opportunity!

EDITOR'S NOTE: Tony Abbey provides live e-Learning courses, FEA consulting and mentoring. Contact tony@fetraining.com for details or visit his website at www.fetraining.net.

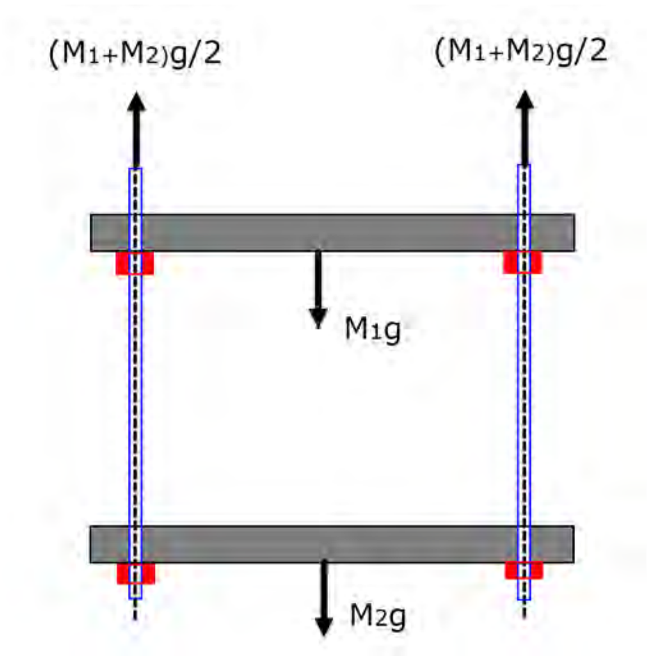

Fig. 2: Schematic of walkways, rods and nuts, showing free body forces. *Image sourced from Structure magazine (bit.ly/37XWiOj).*

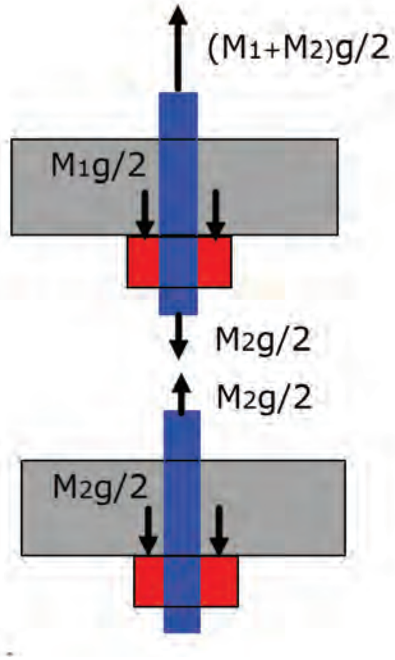

Fig. 3: Free body diagram of each walkway and supporting nut region.

The Hyatt Regency Walkway Collapse

About two years after this event, another free body diagram mistake went unspotted and had horrific consequences. The Hyatt Regency Hotel in Kansas City, MO, had a central open internal area flanked by walkways. The walkways were suspended by threaded tie rods and retained by nuts. During a dance at the hotel, the walkways collapsed into the central area, killing 114 people.

The official report found several significant errors in the structural calculations. The most critical error was in assessing a change to the design of the tie rods and how they attached to the floor beams. The initial design intent was for threaded rods to pass through the upper and lower walkways. The walkways were connected to the rods via nuts. The layout is shown schematically in Fig. 2, with the corresponding free body loads.

(For more information on this incident, see "Collapse of the Kansas City Hyatt Regency Walkways," which appeared

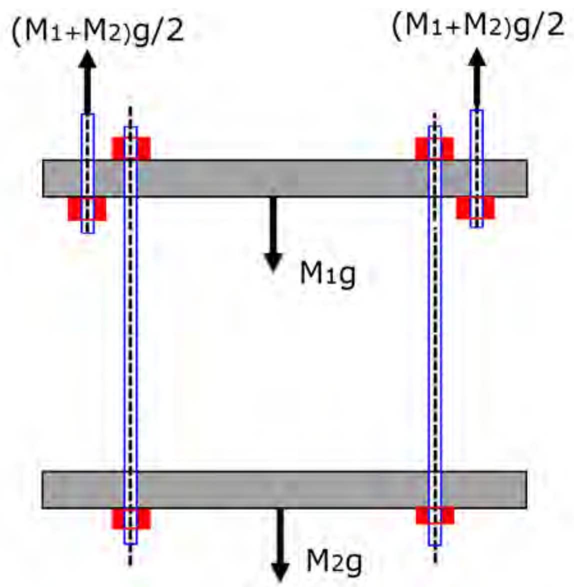

Fig. 4: Free body diagram of revised and installed configuration.

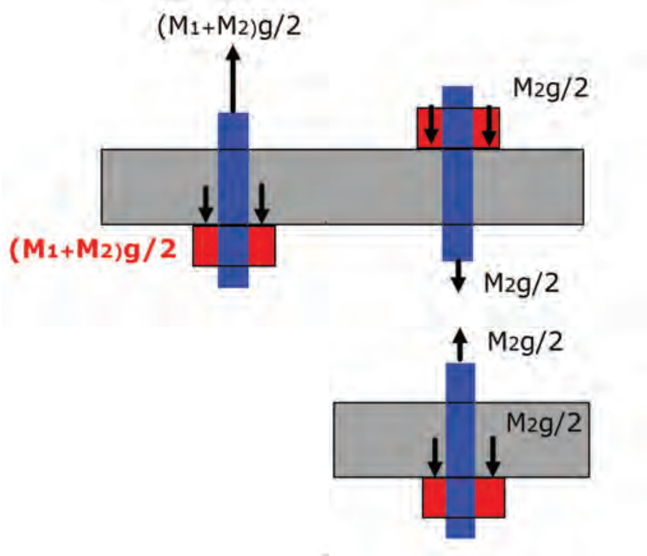

Fig. 5: Free body diagram of connections in installed configuration.

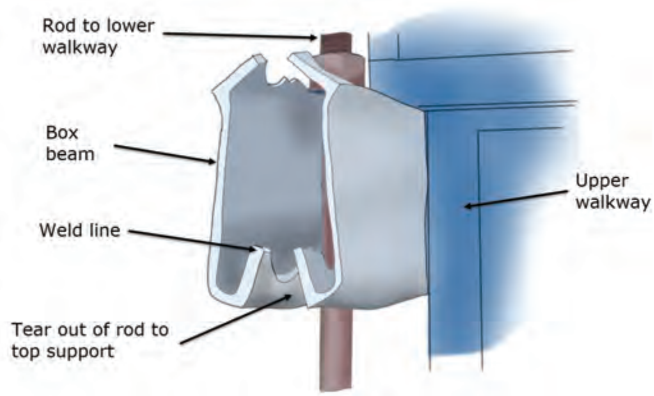

Fig. 6: A failed box beam support under the walkway.

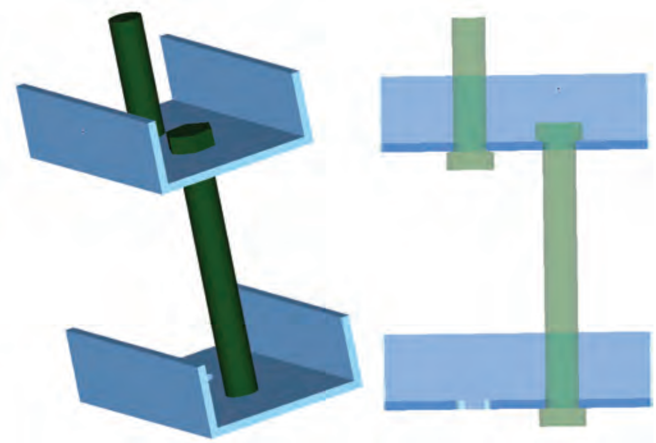

Fig. 7: Geometry used in FEA model of installed configuration.

in the July 1982 issue of *Civil Engineering ASCE*, and can be accessed at bit.ly/2vx5yfq.)

The lower walkway load is transferred via nuts into the lower section of the rods. The upper walkway load is transferred via nuts into the upper section of the rod. A more detailed free body diagram in Fig. 3 shows the load transfer at each walkway.

Fig. 3 is a schematic intended to show the load balance. In practice, there were a pair of rods front and back, so the forces are applied to each rod and nut pair as shown. The key elements of the design are that each rod accumulates load at the lower walkway and the upper walkway, and the load on each nut is equal.

The installed assembly deviated from this design—how and why this was allowed to occur was the basis of much controversy. It was decided that the single rod concept was not practical. The full length of each rod would need to be threaded to allow lower and upper nuts to be installed.

The revised installation is shown in Fig. 4.

At first glance, the free body diagram seems to show a very similar load path. The walkway loading is accumulated at each rod station. The axial load distribution going up each—now separate—rod section remains the same.

The only obvious difference is the offset moment introduced between the two rods at the upper walkway. When I first studied the literature on this accident, I assumed that this moment was the deciding factor. In fact, it is a secondary factor, so I have ignored the offset in the free body diagrams. This was also done in the accident report. The offset was around 4 inches in the installation.

If we look at the joint free body diagrams, as shown in Fig. 5, then we can see the real issue: the nut under the upper walkway takes twice the load as seen previously.

In Fig. 5, the nut now carries the weight of the upper walkway, but also sees the weight of the lower walkway. This is the point that was likely missed in assessing the strength of the installation. In fact, the safety margins used were already too low, even in the original configuration. The modified installation was doomed because of this. The actual failure mode was bursting of the nuts out of the box beams used to support the walkways, as shown in Fig. 6.

The main bearing load from the nut was reacted across a weld line at the bottom flange of the box beam. This failed, allowing the nut to burst through at the weld line and to subsequently tear through the top flange of the box beam.

It is worth carefully studying Fig. 5. It took me a few hand-drawn figures to convince myself why the upper walkway support nut sees double the load in the revision.

FEA Simulation

I set up an FEA model to investigate the response of a similar configuration to the modified installation. The geometry is shown in Fig. 7.

Channels were used instead of the box beams. The rod length is shortened to keep the mesh size down. Only one side of the walkway support is modeled. A guided (sliding) constraint on the end faces of the channel represents the presence of material adjacent to the modeled section.

A pressure load is applied in a downwards direction to each of the box beam bases, to represent the distributed loading transferred from the walkways. The upper rod is fixed at its top face to represent the suspension from the structure above the walkways. A spurious bolt hole is present in the lower channel, but this does not affect the results. Contact is set up between the channel flanges and the bolt shanks and nuts.

A static analysis with so-called "linear contact" is run. There are eight iterations to convergence. Linear contact excludes any simulation of plasticity or geometric nonlinearity due to configuration changes—other than contact opening and closing and small relative movement.

The mesh generated and the deflected shape are shown in Fig. 8.

The top and bottom flange show bending action longitudinally and transversely across the channel bottom flange. No attempt has been made to simulate the buckling and rupture of the weld line in these regions. Fig. 9 shows further investigation of the stress state.

The channel flanges are clearly the highest stressed region. The bolts (rods) are not critically loaded. The von Mises stress plot (right) shows double the stress in the critical nut region of the upper channel compared to the lower. The stress concentration in the upper surface of both flanges due to bending across the bolt hole is shown by the longitudinal tension stress in the left plot. A corresponding compressive state was found on the bottom surfaces (not shown). Plotting transverse stresses showed a similar stress concentration response due to transverse bending.

A comparison was made against a model of the original design. This is shown in Fig. 10.

The figure clearly now shows nearly identical stress states at the upper and lower channel flanges. As expected, both nuts are exerting the same bearing load into their respective channel sections.

The local bending stresses are again present as shown by the transverse top surface stresses with the corresponding stress concentration around the bolt hole. The longitudinal stress state is a similar pattern, oriented through 90°. As before, corresponding compressive stresses are found on the lower surfaces of both flanges.

Conclusion

The Kansas City design variation, as installed, presents a tricky free body diagram and resultant load path definition. Like a lot of puzzles, you either see the solution straightaway—or you don't.

What is interesting here is that the FEA almost gives too much information. It took a while to work out the best way to plot the stresses, even though I knew what the conclusion was! Bending, due to the offset between the rods, really dominates, and the resultant stress distribution is complicated. It is overlaid onto the bidirectional bending of the flange locally around each nut location. This latter effect is seen in the straight-through rod as well.

For me, the clearest indication from FEA of the double loading in the offset rod configuration comes from comparison with the FEA model of the straight-through rod. The hand calculations ignore the bending effect, which is helpful to understand the "double loading," but I suggest the offset bending was also probably a dominant factor in practice. DE

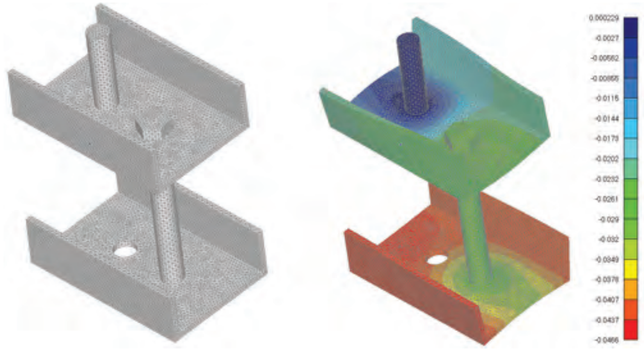

Fig. 8: Mesh (left) and deformed shape (right).

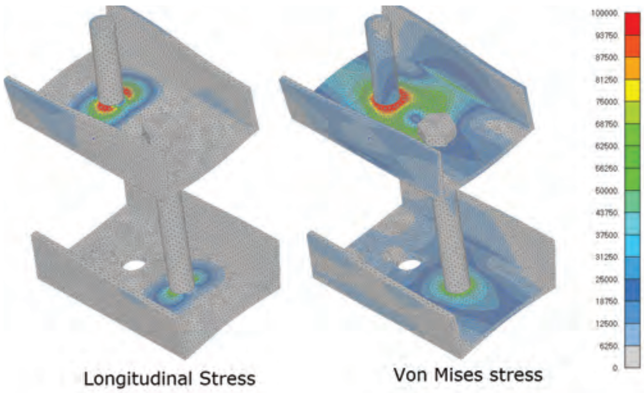

Fig. 9: Longitudinal stress (left) and von Mises stress (right).

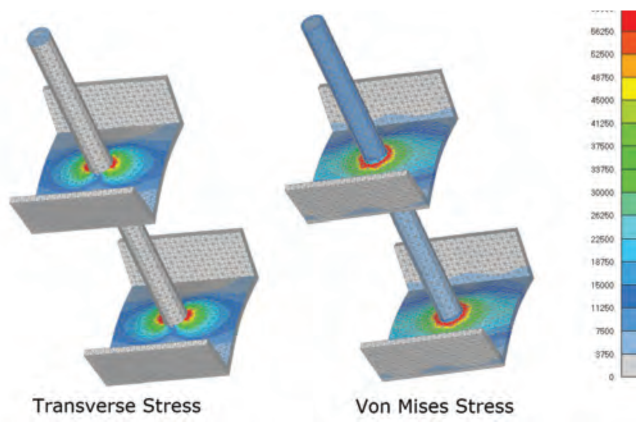

Fig. 10: FEA model of original design; transverse stress (left), von Mises stress (right).

Dell Precision 7540: Mobile Workstation Put Through Paces

This new 15-in. mobile workstation is a price and performance leader.

BY DAVID COHN

We were quite impressed with the pair of Dell entry-level mobile workstations we reviewed earlier this year (see *DE*, September 2019; digitalengineering247.com/r/23068). When the company sent us one of its premium 7000-series systems, we were happy to put it through its paces.

The new Dell Precision 7540 is a 15-in. mobile workstation featuring a 9th-generation Intel processor. Depending on the configuration, the 7540 can house three hard drives and up to 128GB of memory. With a starting price of just $1,269, the base configuration includes a 2.5GHz Intel Core i5-9400H four-core CPU, integrated Intel ultra-high definition (UHD) graphics, 8GB of RAM, a 2.5-in. 500GB 7200rpm SATA hard drive and a 1920x1080 display, but that's just the starting point.

Unlike the thin, dark gray case of the 3000-series systems we recently reviewed, the Dell Precision 7540 comes housed in a silver-colored case measuring 14.86x9.89x1.12-in. (WxDxH), noticeably thicker than the 3540 and 3541 we tested in September. At 6.2 lbs., plus an additional 1.36 lbs. for the larger (6.0x2.94x0.88-in.) 180-watt power supply, the Precision 7540 also outweighs those systems by several pounds.

Well-Designed

Lifting the lid reveals a 15.6-in. display with a webcam centered in the top edge of the bezel, flanked by a pair of microphones and a camera status light. The webcam and microphone are optional—their inclusion depends on the specific display configuration—but even the base model comes with a camera and microphone. Our evaluation unit also included an infrared camera and a privacy shutter.

The larger size of the Precision 7540 compared with the 3000-series means that there is much room for expansion. The right side provides a headphone jack, two USB 3.1 Gen 1 ports (one power-enabled) and a security lock slot. The left side hosts two Thunderbolt 3 USB Type-C ports, an SD card reader and an optional SmartCard reader.

There are also ports on the rear of the 7540, including an RJ-45 network jack, a mini DisplayPort, an HDMI port and a round power adapter port. The bottom only includes a fan vent and a pair of speakers for the built-in MaxAudio Pro by Waves sound system. A Qualcomm dual-band wireless adapter with Bluetooth 4.2 comes standard on the base configuration, but the system we received substituted a more powerful Intel Wi-Fi 6 AX2000 dual-band adapter with Bluetooth 5.0.

The new Dell Precision 7540 15.6-in. mobile workstation is a great choice for serious design, engineering and virtual reality on the go. *Image courtesy of David Cohn.*

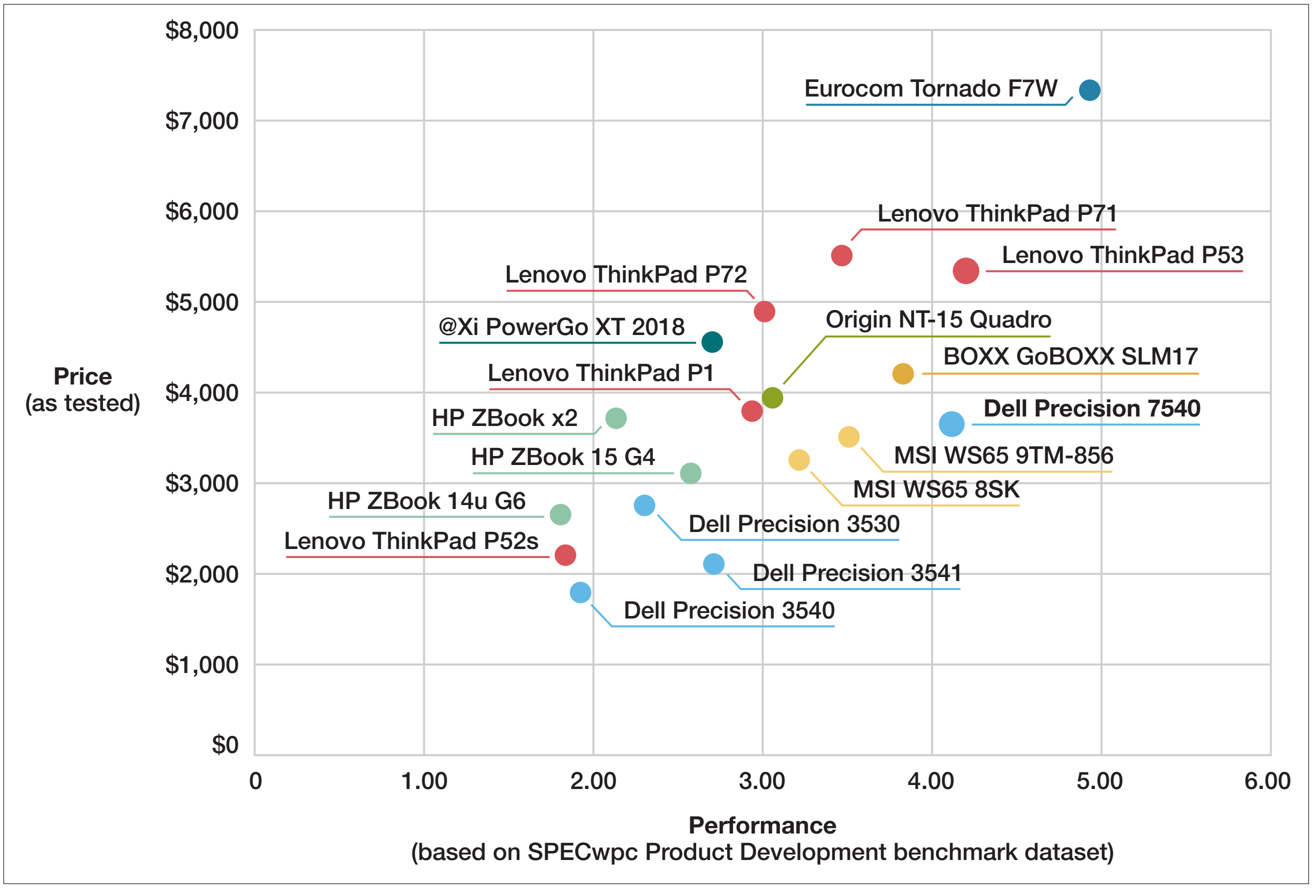

Fig. 2: Graphic performance of recent mobile workstations, based on the SPECviewperf 13 geomean results.

Lots of Options

The extra thickness of the 7000-series means that you can pack more components inside the chassis. CPU options range from the 2.5GHz quad-core processor in the base unit to the 2.4GHz Intel Core i9-9980H 8-core Coffee Lake CPU included in our evaluation unit. This processor contains a 16MB cache, a 5GHz maximum turbo speed and integrated Intel UHD graphics 630.

Dell also offers the 7540 with a choice of a six-core 2.8GHz Intel Xeon E 2276M processor or an eight-core 2.4GHz Xeon E 2286M CPU (which increase the price by $290 or $514, respectively).

Dell has a choice of discrete graphics cards, including an AMD Radeon Pro WX 3200 with 4GB of GDDR5 memory (a $56 option), or a choice of five different NVIDIA Quadro GPUs, ranging from the T1000 ($215) to one of three RTX GPUs including the high-end RTX 5000 ($2,346).

Our evaluation Precision 7540 came with an NVIDIA Quadro RTX 3000 graphics board with 6GB of GDDR6 memory. This virtual reality (VR)-ready GPU provides 1920 compute unified device architecture (CUDA) cores, 30 RT cores and 240 Tensor cores, backed by a 192-bit interface, enabling it to deliver a bandwidth of 336GB/second while consuming a maximum 80 watts.

Dell also offers a choice of nine different display configurations, ranging from a 1920x1080 in-plane switching (IPS) anti-glare panel with a carbon fiber cover supporting 42% of the Adobe color gamut to the 3840x2160 IPS anti-glare premium panel with aluminum cover and 100% Adobe color gamut included in our evaluation unit, a $340 option that also included an infrared camera.

The Precision 7540 can support up to 128GB of RAM, and 666MHz and 3200MHz memory modules are available. Our evaluation unit came with 32GB of 2666MHz memory, installed using four 8GB modules ($419). Systems based on Xeon processors can also be equipped with 2666MHz error-correcting code (ECC) memory.

Storage options are also abundant, and the 7540 can support up to three M.2 PCIe solid-state drives (SSDs) or two M.2 drives and one 2.5-in. SATA drive. Solid-state options range from 256GB to 2TB, whereas Dell offers 2.5-in. drives ranging from 500GB to 2TB, so you could configure a system with 6GB of onboard storage. The mobile workstation we received came with a 512GB M.2 NVMe PCIe Class 50 Hynix drive, which added $419. Systems equipped with two M.2 drives can also be configured as a redundant array of independent disks.

Although a four-cell 64 watt-hour (WHr) battery comes standard, the inclusion of the UHD display panel and RTX graphics in our evaluation unit meant that we also received a six-cell 97WHr Lithium-ion battery with ExpressCharge. That battery kept our Precision 7540 running for 7 hours and 51 minutes. A long-lifecycle Lithium Polymer version of

Mobile Workstations Compared	Dell Precision 7540 15.6-in. mobile workstation (2.40GHz Intel Core i9-9980H 8-core CPU, NVIDIA Quadro RTX 3000, 32GB RAM, 512GBB NVMe PCIe SSD)	Lenovo ThinkPad P53 15.6-in. mobile workstation (2.80GHz Intel Xeon E-2276M 6-core CPU, NVIDIA Quadro RTX 5000, 64GB RAM, 1TB NVMe PCIe SSD)	BOXX GoBOXX SLM17 17.0-in. mobile workstation (2.30GHz Intel Core i9-9880H 8-core CPU, NVIDIA Quadro RTX 3000, 32GB RAM, 512GB NVMe PCIe SSD)	HP ZBook 14u G6 14.0-in. mobile workstation (1.90GHz Intel Core i7-8665U 4-core CPU, AMD Radeon Pro WX3200, 32GB RAM, 512GB NVMe PCIe SSD)	MSI WS65 9TM-856 15.6-in. 2.60GHz Intel Core i7-9750H 6-core CPU, NVIDIA Quadro RTX 5000, 32GB RAM, 512GB NVMe PCIe SSD	Dell Precision 3541 15.6-in. 2.60GHz Intel Core i7-9750H 6-core CPU, NVIDIA Quadro P620, 16GB RAM, 512GB NVMe PCIe SSD
Price as tested	$3,646.00	$5,338.00	$4,200.00	$2,649.00	$3,499	$2,0687
Date tested	**10/25/2019**	10/24/2019	10/23/2019	8/8/19	7/12/19	7/3/19
Operating System	Windows 10 Pro 64	Windows 10 Pro 64	Windows 10 Pro 64	Windows 10 Pro 64	Windows 10 Pro 64	Windows 10 Pro 64
SPECviewperf 13.0 (higher is better)						
3dsmax-06	155.08	181.47	148.65	36.42	169.52	47.53
catia-05	209.89	269.51	200.15	35.60	213.02	53.63
creo-02	187.29	255.96	185.52	34.17	210.09	52.16
energy-02	31.69	38.63	29.94	2.61	39.87	8.25
maya-05	183.66	261.90	187.67	34.17	206.74	56.88
medical-02	63.63	85.31	63.59	9.73	80.88	12.63
showcase-02	78.72	63.79	79.50	13.93	92.57	21.87
snx-03	217.45	223.64	218.39	52.78	288.08	71.37
sw-04	130.57	88.51	123.98	46.04	123.16	60.95
SPECapc SolidWorks 2015 (higher is better)						
Graphics Composite	4.27	5.47	5.03	2.27	3.73	4.16
Shaded Graphics Sub-Composite	2.55	3.53	3.01	1.39	2.23	2.69
Shaded w/Edges Graphics Sub-Composite	3.37	4.38	3.89	2.06	2.96	3.51
Shaded using RealView Sub-Composite	3.08	4.05	3.57	1.63	2.63	3.05
Shaded w/Edges using RealView Sub-Composite	3.83	4.73	4.35	2.98	3.12	3.50
Shaded using RealView and Shadows Sub-Composite	3.42	4.59	4.11	1.45	3.04	3.48
Shaded with Edges using RealView and Shadows Graphics Sub-Composite	3.92	4.71	4.56	2.47	3.30	3.66
Shaded using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	11.30	15.06	13.54	3.01	10.06	10.13
Shaded with Edges using RealView and Shadows and Ambient Occlusion Graphics Sub-Composite	11.13	14.58	13.35	4.58	9.59	9.73
Wireframe Graphics Sub-Composite	3.91	3.92	4.34	2.76	3.50	3.69
CPU Composite	3.76	5.32	5.33	1.85	2.71	4.17
SPEC Workstation v3 (higher is better)						
Media and Entertainment	1.88	2.07	1.98	0.8	1.82	1.37
Product Development	1.91	2.24	2.07	1.04	2.01	1.57
Life Sciences	1.67	1.77	1.99	0.87	1.97	1.00
Financial Services	1.75	1.69	2.16	0.70	1.49	1.41
Energy	1.36	1.37	1.32	0.54	1.28	0.95
General Operations	1.72	1.89	1.79	1.13	1.75	1.67
GPU Compute	3.20	3.31	3.09	0.60	3.41	1.00
Time						
AutoCAD Render Test (in seconds, lower is better)	34.80	49.20	45.90	140.40	43.80	59.70
Battery Life (in hours:minutes, higher is better)	7:51	5:30	8:37	5:30	6.07	15:28

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

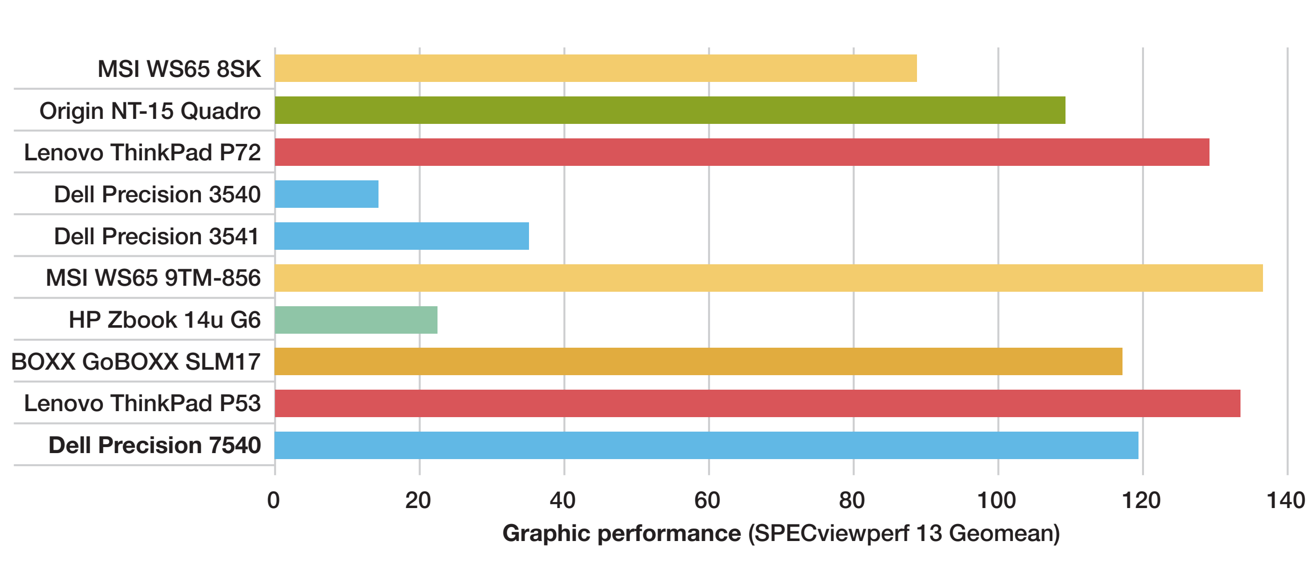

Fig. 3: Price/performance chart of recent mobile workstations, based on the SPECwpc Product Development benchmark.

this battery with a three-year warranty is also available.

Great Performance

The Dell Precision 7540 mobile workstation remained cool and nearly silent throughout our testing, with fan noise barely audible even under heavy compute loads. As expected, on the SPECviewperf test, which evaluates pure graphics performance, the Precision 7540 scored at—or near—the top on every dataset, losing only to systems equipped with the even more powerful NVIDIA Quadro RTX 5000 GPU. Scores for the SPECapc SolidWorks benchmark were equally impressive.

This Dell system also delivered excellent results on the very demanding SPEC workstation performance benchmarks. Although its CPU and graphics scores placed it near the top among systems we have tested recently, its storage subsystem score was the lowest we have recorded since we began using the latest version of this benchmark. The Dell Precision 7540 also completed our AutoCAD rendering test in less than 35 seconds, the best result we have recently recorded for any mobile workstation.

Windows 10 Pro came preloaded. Systems based on a Xeon CPU include Windows 10 Pro for Workstations, which adds $154 to the price. Ubuntu Linux and Windows 10 Home are also available.

All Dell Precision workstations come with a three-year warranty with on-site service after remote diagnosis. As configured, the Dell Precision 7540 priced out at $3,646, making it a price/performance leader. Though it is a bit larger and heavier than some mobile workstations, it delivered the best performance of any system we have tested under $4,000. Simply put, the Dell Precision 7540 is a great choice for serious design, engineering and VR on the go. **DE**

David Cohn *is the senior content manager at 4D Technologies. He also does consulting and technical writing from his home in Bellingham, WA, and has been benchmarking PCs since 1984. He's a contributing editor to Digital Engineering and 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.*

MORE INFO

Dell: Dell.com

Dell Precision 7540

- **Price:** $3,646 as tested ($1,269 base price)
- **Size:** 14.86x9.89x0.1.12-in. (WxDxH) notebook
- **Weight:** 6.2 lbs. plus 1.36-lb. power supply
- **CPU:** 2.4GHz Intel Core i9-9980H eight-core w/16MB Smart Cache
- **Memory:** 32GB (4x8GB DDR4-2666MHz non-error-correcting code SDRAM)
- **Graphics:** NVIDIA Quadro RTX 3000 w/6GB GDDR6 memory
- **LCD:** 15.6-in. UHD 3840x2160 anti-glare IPS non-touch
- **Storage:** 512GB M.2 PCIe NVMe Class 50 SSD
- **Audio:** MaxAudio Pro by Waves with built-in speakers, built-in microphone array
- **Network:** Intel Wi-Fi 6 AX2000 2x2 .11ax 1600MHz plus Bluetooth 5.0
- **Other:** Three USB 3.1 Gen 1 (one with PowerShare), two USB Type-C/Thunderbolt 3, HDMI, mini DisplayPort, headphone jack, microSD card reader, SmartCard reader, RJ-45 LAN port, integrated 720p IR webcam, fingerprint reader
- **Keyboard:** Integrated 103-key full-size backlit keyboard with numeric keypad
- **Pointing device:** Gesture-enabled multi-touch touchpad with three buttons and pointing stick with three buttons

For more information on this topic, visit DigitalEngineering247.com.

EDITOR'S PICKS

Each week, DE's editors comb through dozens of new products to bring you the ones we think will help you do your job better, smarter and faster. Here are our most recent musings about the products that have really grabbed our attention.

3D CAD Viewer for Real-Time Collaboration

Online, shared viewing in real time enables team to discuss and manage the data.

ZWSOFT introduces CADbro 2020, which it says is an easy-to-use 3D CAD view for all members of the organization who need to collaborate on CAD data. There are also tools for bill of materials development, annotation, and query and analysis. A premium version provides tools for editing the 3D data.

After logging into CADbro 2020, users can invite project members to join an online collaboration, or they can view the CAD data asynchronously.

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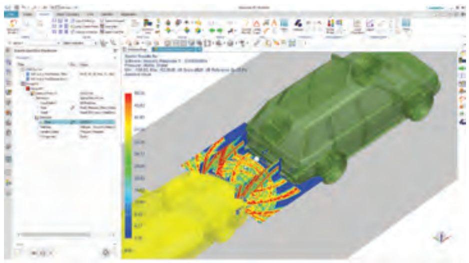
Creating Faster CAE Processes

Siemens Simcenter update targets collaborative multiphysics simulation.



Siemens unveils Simcenter 3D 2020.1 a unified work environment for collaborative multiphysics simulation and design space exploration. Each quarterly update enhances portions of this unified portfolio, to keep improving without being disruptive.

Siemens wants Simcenter to be an open analysis environment compatible with a wide range of tools and services. There is also new on-demand access to Simcenter 3D on the Cloud, in conjunction with Rescale.

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Use Simulation Data to Create Testing Environments

Vortex Studio users can publish and connect simulations with the Unreal Engine.

CM Labs releases Vortex Studio 2019c, the current update to this suite of real-time simulation visualization software. The highlight of the update is support for Epic Games Unreal Engine for simulator development.

Users can publish and connect simulations with Unreal Engine, a popular choice for developing enterprise virtual reality environments for applications including virtual prototyping, driver-in-the-loop testing, operator training and simulation-based AI training.

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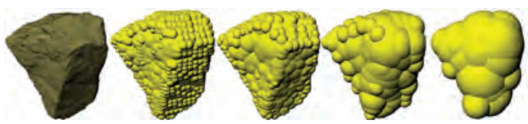
Automate Analysis of Complicated Discrete Loads

Altair EDEM 2020 software is made for bulk and granular material simulation.

Altair introduces EDEM 2020, the first update since acquisition of the discrete element analysis software for bulk and granular material simulation. There are new tools to automate various setup procedures, and there is new support for GPU-based computation.



EDEM can simulate any size and shape of material using the computationally efficient and well-validated multi-sphere method. EDEM 2020 is now available for upgrade directly from Altair.

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Students' Imagination Surges Full Speed Ahead in Indy Autonomous Challenge

BY JIM ROMEO

The Indy Autonomous Challenge (IAC) is a two-year, $1 million prize competition among universities that will culminate in a head-to-head, high-speed autonomous vehicle race, Oct. 23, 2021, around the Indianapolis Motor Speedway's (IMS') famed 2.5-mile oval. The Speedway also plays host annually to the Indianapolis 500, the largest single-day sporting event in the world.

By building on the success and impact of the DARPA Grand Challenge—the 2004-05 defense research initiative that helped create the modern autonomous vehicle industry—as well as IMS' roots dating back to 1909 as a proving ground for the nascent automotive industry, the IAC invites college-level students from across the globe to envision, innovate and demonstrate the next generation of automated vehicle software that may advance the commercialization of full autonomous vehicles, boost existing advanced driver-assistance systems (ADAS) and inspire the next generation of STEM talent.

Matt Peak is the managing director of Energy Systems Network and helps run the Indy Autonomous Challenge.

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

Matt Peak: The Challenge consists of five rounds. Teams submit a short white paper during the first round, and in the second round, teams must demonstrate vehicular automation by sharing a short video of an existing vehicle or by participating in Purdue University's self-driving go-kart competition at IMS. The Indy Autonomous Challenge's simulation sponsor ANSYS will supply its industry-leading VRXPERIENCE Driving Simulator powered by SCANeRTM and its SCADE software development suite to teams for their use in developing autonomous vehicle software.

The competition ends with an autonomous vehicle race. *Image courtesy of IAC.*

ESN and ANSYS will co-host "hackathons" to familiarize teams with the simulator's full potential, and ANSYS will award $150,000 in prizes to top finishers of a simulated race during the third round. The fourth round enables teams to test their actual vehicles at IMS in advance of the head-to-head race around the oval, which will award $1 million, $250,000 and $50,000 to the first, second and third finishers, respectively.

***DE:* Can you tell us about some of the designs?**

Peak: The Indy Autonomous Challenge taps into inducement prize competitions' long track record of focusing minds and leveraging competing teams' and other third-party contributions to overcome complex challenges. In particular, it is inspired and advised by innovators who competed in the Defense Advanced Research Projects Agency (DARPA) Grand Challenge, which put forth a $1 million award in 2004 that created the modern automated vehicle industry.

***DE:* Can you provide some examples of what the event has produced?**

Peak: The IAC is challenging university students around the world to imagine, invent and prove a new generation of automated vehicle software that can help speed the commercialization of full autonomous vehicles and enhance existing ADAS in people-driven cars that can save lives today, while inspiring the next generation of STEM talent.

***DE:* Does Energy Systems Network have a stance on adopting an innovation that is linked to the program?**

Peak: Every year, approximately 40,000 people lose their lives due to on-road accidents. Fully 94% of those deaths are caused by human factors. Automated vehicle technologies such as lane-keeping assist and automatic emergency braking, among others, can play a valuable role in helping human drivers avoid accidents and save tens of thousands of lives every year. The Indy Autonomous Challenge is aiming to advance those state-of-the-art technologies, so that they can be deployed in more vehicles today. The notion is that if automated vehicle technologies and software can help self-driving race cars avoid each other while maneuvering at 200 miles per hour, then they'll surely be able to help drivers avoid unexpected obstacles on the road at 65 miles per hour. DE

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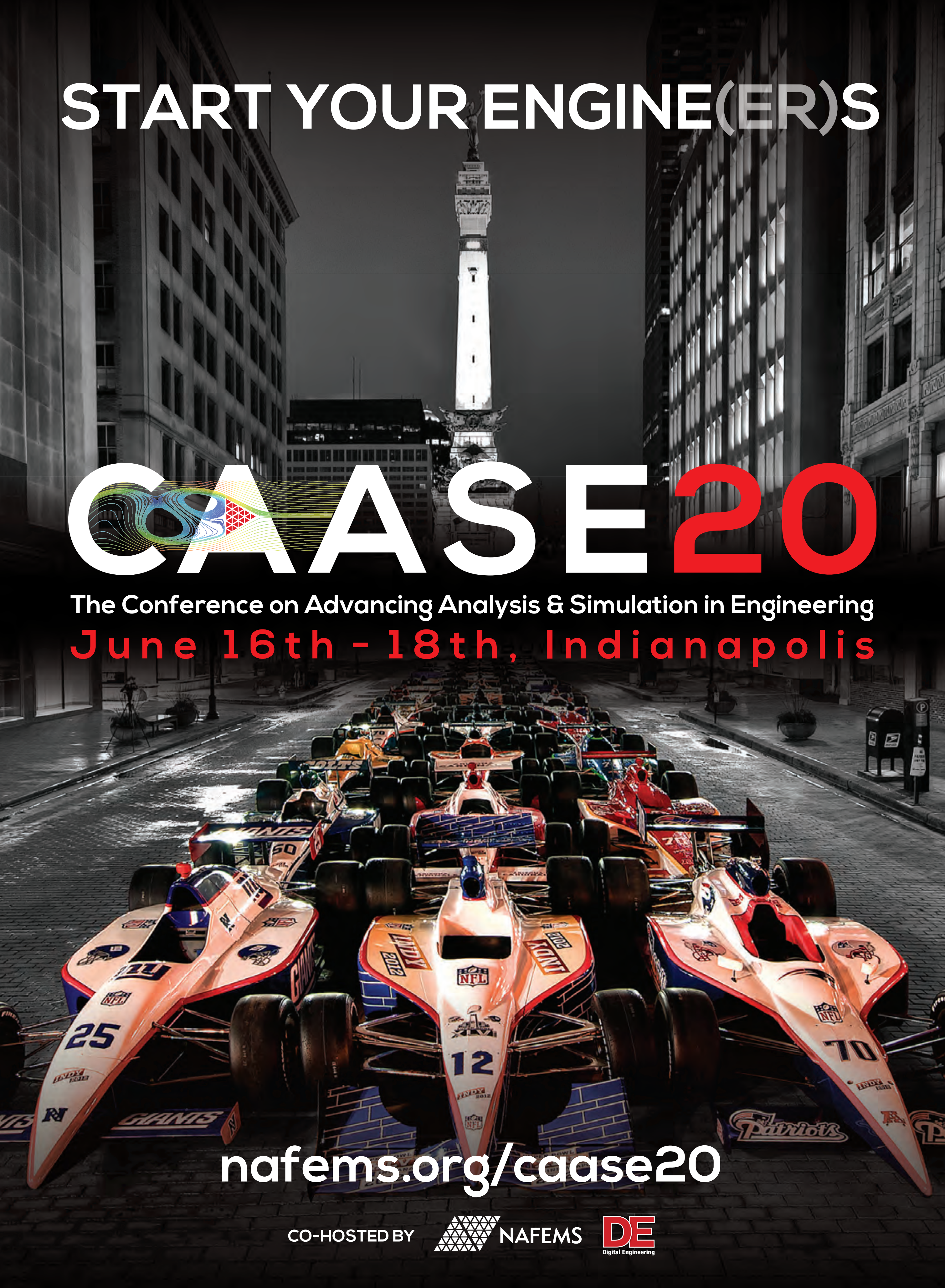
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